

Apple[®] II

Apple IIe Technical Reference Manual



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Manual
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Manual









Apple II Apple IIe

Apple IIe Technical Reference





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About This Manual

This is the reference manual for the Apple® IIe personal computer. It contains detailed descriptions of all of the hardware and firmware that make up the Apple IIe and provides the technical information that peripheral-card designers and programmers need.

This manual contains a lot of information about the way the Apple IIe works, but it doesn't tell you how to use the Apple IIe. For this, you should read the other Apple IIe manuals, especially the following:

- □ Apple IIe Owner's Guide
- □ Applesoft Tutorial

This manual is designed to answer the question "What's inside the box?" It describes the internal operation of the Apple IIe as completely as possible in a single volume.

Contents of this manual

The material in this manual is presented roughly in order of increasing intimacy with the hardware; the farther you go in the manual, the more technical the material becomes. The main subject areas are

- □ introduction: preface and Chapter 1
- □ use of built-in features: Chapters 2 and 3
- □ how the memory is organized: Chapter 4
- □ information for programmers: Chapters 5 and 6
- □ hardware implementation: Chapter 7
- □ additional information: appendixes, glossary, and bibliography

Chapter 1 identifies the main parts of the Apple IIe and tells where in the manual each part is described.

Chapters 2 and 3 describe the built-in input and output features of the Apple IIe. This part of the manual includes information you need for low-level programming on the Apple IIe. Chapter 2 describes the built-in I/O features, and Chapter 3 tells you how to use the firmware that supports them.

Chapter 4 describes the way the Apple IIe's memory space is organized, including the allocation of programmable memory for the video display buffers.

Chapter 5 is a user manual for the Monitor that is included in the built-in firmware. The Monitor is a system program that you can use for program debugging at the machine level.

Chapter 6 describes the programmable features of the peripheralcard connectors and gives guidelines for their use. It also describes interrupt programming on the Apple IIe.

Chapter 7 is a description of the hardware that implements the features described in the earlier chapters. This information is included primarily for programmers and peripheral-card designers, but it will also help you if you just want to understand more about the way the Apple IIe works.

Additional reference information appears in the appendixes:

Appendix A is the manufacturer's description of the Apple IIe's microprocessor.

Appendix B is a directory of the built-in I/O subroutines, including their functions and starting addresses.

Appendix C describes differences among Apple II family members.

Appendix D describes some of the operating systems and languages supported by Apple Computer for the Apple IIe.

Appendix E contains conversion tables of interest to programmers.

Appendix F contains additional copies of some of the tables that appear in the body of the manual. The ones you will need to refer to often are duplicated here for easy reference.

Appendix G contains information about using Apple IIe 80-column text cards with the Apple IIe and high-level languages.

Appendix H discusses programming on the Apple IIe with the Apple Super Serial Card.

Appendix I describes the international keyboards and character sets. This appendix also contains schematic diagrams of the international circuit boards.

Appendix J contains the source listing of the Monitor firmware. You can refer to it to find out more about the operation of the Monitor subroutines listed in Appendix B.

Following Appendix J is a glossary defining many of the technical terms used in this manual. Some terms that describe the use of the Apple IIe are defined in the glossaries of the other manuals listed earlier.

Following the glossary is a selected bibliography of sources of additional information.

The Apple IIe family

Changes have been made in the Apple IIe since the original version was introduced. The first change resulted in a version called the *enhanced Apple IIe*. The latest version is called the *extended keyboard Apple IIe*. These versions are all described in this manual. Where there are differences between the original Apple IIe, the enhanced IIe, and the extended keyboard IIe, they will be called out in the manual. Otherwise, the three machines operate identically.

Identifying your Apple Ile

You can tell whether you have an enhanced or an original Apple IIe when you start up your computer: an original IIe will display "Apple] [" at the top of the monitor screen, while the enhanced Apple IIe will display "Apple //e". The extended keyboard Apple IIe is easily identified by the numeric keypad built into the keyboard.

The original Apple lie

The original Apple IIe is the oldest member of the IIe family. It has the following features:

- □ the 6502 microprocessor
- □ 64K of RAM
- 40-column display (unless an optional 80-column text card is installed)

The enhanced Apple lie

The enhanced Apple IIe includes the following changes from the original Apple IIe:

- ☐ The 65C02 microprocessor, which is an improved version of the 6502 microprocessor found in the original Apple IIe. The 65C02 uses less power, has 27 new **opcodes**, and runs at the same speed as the 6502. (See Chapter 7 and Appendix A.)
- □ A new video ROM containing the same MouseText characters found in the Apple IIc. (See Chapter 2.)
- □ New Monitor ROMs (the CD and EF ROMs) containing the enhanced Apple IIe firmware. (See Chapter 5.)
- □ The identification byte at \$FBC0 has been changed. In the original Apple IIe it is \$EA (decimal 234); in the enhanced Apple IIe it is \$E0 (decimal 224).
- □ Recent models of the enhanced He include the Extended 80-Column Text Card as a standard accessory, thus increasing the available RAM in the enhanced He from 64K to 128K.

The enhanced Apple IIe includes a number of improved features in addition to the changes listed above. The following sections describe the improved features of the enhanced IIe.

Startup drives

You can use startup (boot) devices other than a Disk II® to start up ProDOS® on the enhanced Apple IIe.

Apple II Pascal versions 1.3 and later may start up from slots 4, 5, or 6 on a Disk II, ProFile™, or other Apple II disk drive. Apple II Pascal versions 1.0 through 1.2 must start up from a Disk II in slot 6.

DOS 3.3 may be started from a Disk II in any slot.

Opcode is short for operation code and is used to describe the basic instructions performed by the central processing unit of a computer.

When you turn on your Apple IIe, it searches for a disk drive controller to start up from, beginning with slot 7 and working down toward slot 1. As soon as a disk controller card is found, the Apple IIe will try to load and execute the operating system found on the disk. If the drive is not a Disk II, the operating system of the startup volume must be either ProDOS or Apple II Pascal (version 1.3 or later). If it is a Disk II, the startup volume may be any Apple II operating system.

Video firmware

Tł	ne enhanced Apple IIe has improved 80-column firmware:
	The enhanced Apple IIe now supports lowercase input.
	Escape Control-E passes most control characters to the screen
	Escape Control-D traps most control characters before they get to the screen.
	Escape R was removed because uppercase characters are no

Video enhancements

longer required by Applesoft.

Both 80-column Pascal and 80-column mode Applesoft output are faster than before, and scrolling is smoother. 40-column Pascal performance is unchanged.

In the original Apple IIe, characters echoed to COUT1 during 80-column operation were printed in every other column; the enhanced Apple IIe firmware now prints the characters in each column.

Applesoft 80-column support

The following Applesoft routines now work in 80-column mode:		
	HTAB	
	TAB	
	SPC	
	comma tabbing in PRINT statements	

Applesoft lowercase support

Applesoft now lets you do all your programming in lowercase. When you list your programs, all Applesoft keywords and variable names are automatically in uppercase characters; literal strings and the contents of DATA and REM statements are unchanged.

Apple II Pascal

Apple II Pascal (version 1.2 and later) can now use a ProFile hard disk through the Pascal ProFile Manager.

To find out more, see the *Pascal ProFile Manager* manual.

The Pascal 1.1 firmware no longer supports the control character that switches from 80-column to 40-column operation. This control character is no longer supported because it can put Pascal into a condition where the exact memory configuration is not known.

System Monitor enhancements

Enhancements to the Apple IIe's built-in Monitor (described in Chapter 5 in this manual) include the following:

- □ lowercase input
- □ ASCII input mode
- □ Monitor Search command
- □ the Mini-Assembler

Interrupt handling

Interrupt-handler support in the enhanced Apple IIe firmware now handles any Apple IIe memory configuration.

The extended keyboard Apple IIe

The extended keyboard Apple IIe includes the following changes from the enhanced Apple IIe:

- ☐ The new keyboard contains a built-in 18-key numeric keypad.
- ☐ The Extended 80-Column Text Card is a standard feature. The card is shipped installed in the auxiliary slot.
- One 128K ROM IC replaces the two 64K Monitor ROM ICs (the CD and EF ROMs).
- ☐ Two 64Kx4 RAM ICs replace the eight 64Kx1 RAM ICs.
- ☐ The single-wire Shift-key mod is standard.

RAM upgrade

Both the original Apple IIe and the enhanced Apple IIe are 64K machines, expandable to 128K through the use of auxiliary memory cards like the Extended 80-Column Text Card. The extended keyboard Apple IIe has 64K of main memory, mounted on the circuit board. However, because the Extended 80-Column Text Card is now a standard feature, providing 64K of auxiliary memory, the extended keyboard IIe comes "pre-expanded" to 128K of RAM.

The eight 64Kx1 RAM ICs on the original and enhanced Apple IIe circuit boards have been replaced by two 64Kx4 ICs on the extended keyboard IIe circuit board. This means that the extended keyboard Apple IIe has two RAM ICs instead of eight like the original and enhanced IIe's. Pin-out diagrams for both RAM IC configurations are provided in Chapter 7.

Single-wire Shift-key mod

The single-wire Shift-key mod is an option jumper point on the circuit board that lets the extended keyboard Apple IIe detect the Shift key with the mouse active. From a practical standpoint, the single-wire Shift-key mod allows mouse-based programs to use "Shift-click" control sequences on the extended keyboard IIe.

The single-wire Shift-key mod option jumper is labeled X6 on the circuit board.

Symbols used in this manual

Special text in this manual is set off in several different ways, as shown in these examples.

Warning

Important warnings appear like this. These flag potential danger to the Apple IIe, its software, or you.

Important

Text set off in a box like this is less urgent or threatening than text placed inside a Warning box, but still of a critical nature.

Extended keyboard lie

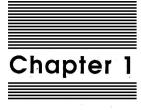
Text set off like this defines the differences in features or operation between the three versions of the Apple IIe.

Definitions, cross-references, and other short Items appear in marginal glosses like this. By the way: Information that is useful but incidental to the text is set off like this. You may want to skip over such information and return to it later.

Terms that are defined in a marginal gloss or in the glossary appear in **boldface**.

Words that appear on the screen are shown in a monospaced font: It looks like this.

Preface: About This Manual



Introduction

This first chapter introduces you to the Apple IIe itself. It shows you what the inside looks like, identifies the main components that make up the machine, and tells you where to find information about each

Removing the cover

Remove the cover of the Apple IIe by pulling up on the back edge until the fasteners on either side pop loose, then move the cover an inch or so toward the rear of the machine to free the front of the cover, as shown in Figure 1-1. What you will see is shown in Figure 1-2.

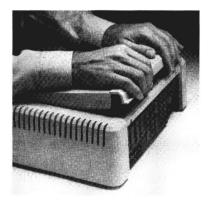


Figure 1-1 Removing the cover



Figure 1-2
Apple Ile with the cover off

Warning

There is a red LED (light-emitting diode) inside the Apple IIe, in the left rear corner of the circuit board. If the LED is on, it means that the power is on and you must turn it off before you insert or remove anything. To avoid damaging the Apple IIe, don't even think of changing anything inside it without first turning off the power.

The keyboard

ASCII stands for *American* Standard Code for Information Interchange. The keyboard is the primary input device for the Apple IIe. As shown in Figure 1-3 it has a normal typewriter layout, uppercase and lowercase, with all of the special characters in the **ASCII** character set. The keyboard is fully integrated into the machine; its operation is described in the first part of Chapter 2. Firmware subroutines for reading the keyboard are described in Chapter 3.

Extended keyboard lie

The extended keyboard lle keyboard is laid out differently from the original and enhanced lle keyboards, and includes an 18key numeric keypad. The extended keyboard lle keyboard is shown in Figure 1-4.



Figure 1-3 Original and enhanced lie keyboard



Figure 1-4
Extended keyboard lie keyboard

The speaker

The Apple IIe has a small loudspeaker in the bottom of the case. The speaker enables Apple IIe programs to produce a variety of sounds that make the programs more useful and interesting. The way programs control the speaker is described in Chapter 2.

The power supply

The power supply is inside the flat metal box along the left side of the interior of the Apple IIe. It provides power for the main board and for any peripheral cards installed in the Apple IIe.

The power supply produces four voltages: +5V, -5V, +12V, and -12V. It is a high-efficiency switching supply; it includes special circuits that protect it and the rest of the Apple IIe against short circuits and other mishaps. Complete specifications of the Apple IIe power supply appear in Chapter 7.

Warning

The power switch and the socket for the power cord are mounted directly on the back of the power supply's metal case. This mounting ensures that all the circuits that carry dangerous voltages are inside the power supply. Do not defeat this design feature by attempting to open the power supply.

The circuit board

All the electronic parts of the Apple IIe are attached to the circuit board, which is mounted flat in the bottom of the case.

Figure 1-5 shows the main integrated circuits (ICs) in the original and enhanced Apple IIe's. They are the central processing unit (CPU), the keyboard encoder, the keyboard read-only memory (ROM), the two interpreter ROMs, the video ROM, and the custom integrated circuits: the Input Output Unit (IOU), the Memory Management Unit (MMU), and the Programmed Array Logic (PAL) device.

Extended keyboard lle

The extended keyboard lie circuit board layout is much the same as that shown in Figure 1-5. However, the two Interpreter ROMs (CD ROM and EF ROM) have been replaced by a single ROM, and the eight RAM ICs have been replaced by two RAM ICs.

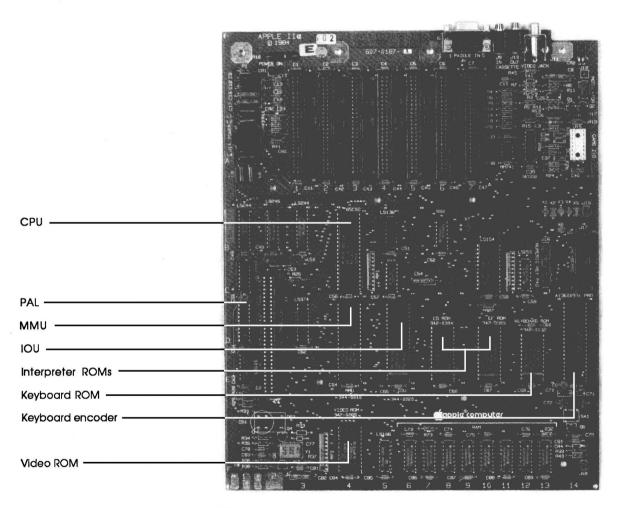


Figure 1-5 Circuit board

The CPU used by both the enhanced IIe and the extended keyboard IIe is the 65C02 microprocessor. The 65C02 is an 8-bit microprocessor with a 16-bit address bus. The 65C02 runs at 1.02 MHz and performs up to 500,000 8-bit operations per second. The specifications for the 65C02 are given in Appendix A.

The original version of the Apple IIe uses the 6502 microprocessor. You can tell which version of Apple IIe you have by starting up your machine. An original Apple IIe displays "Apple] [" at the top of the screen during startup, while the enhanced and the extended keyboard Apple IIe's display "Apple //e". This manual will call out specific areas where the three versions of the Apple IIe differ.

Original lle

The original IIe uses the 6502 microprocessor. The 6502 is very similar to the 65C02, except that it lacks ten instructions and two addressing modes found in the 65C02. In addition, the 6502 is an NMOS device, which means its power consumption is higher than the CMOS 65C02. Except for these differences, and some minor differences in the number of clock cycles required for execution of some instructions, the 6502 and 65C02 are identical.

The keyboard is decoded by an AY-3600-PRO or 9600-PRO integrated circuit and a read-only memory (ROM). These devices are described in Chapter 7.

The interpreter ROMs (or ROM, in the case of the extended keyboard IIe) are integrated circuits that contain the Applesoft BASIC interpreter. The ROMs are described in Chapter 7. The Applesoft language is described in the Applesoft Tutorial and the Applesoft BASIC Programmer's Reference Manual.

Two of the large ICs are custom-made for the Apple IIe: the MMU and the IOU. The MMU IC contains most of the logic that controls memory addressing in the Apple IIe. The organization of the memory is described in Chapter 4; the circuitry in the MMU itself is described in Chapter 7.

The IOU IC contains most of the logic that controls the built-in input/output features of the Apple IIe. These features are described in Chapter 2 and Chapter 3; the IOU circuits are described in Chapter 7.

Connectors on the circuit board

The seven slots lined up along the back of the Apple IIe circuit board are the expansion slots, sometimes called *peripheral slots*. (See Figure 1-6.) These slots make it possible to attach additional hardware to the Apple IIe. Chapter 6 tells you how your programs deal with the devices that plug into these slots; Chapter 7 describes the circuitry for the slots themselves.

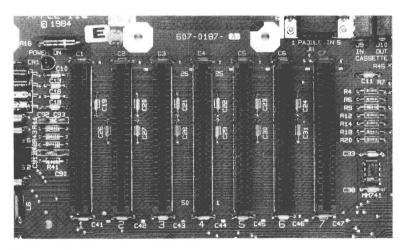


Figure 1-6 Expansion slots

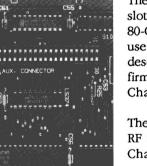


Figure 1-7 Auxiliary slot

The large slot next to the left side of the circuit board is the auxiliary slot (Figure 1-7). If your Apple IIe has an auxiliary memory card or 80-Column Text Card, it will be installed in this slot. The Apple IIe use this slot for the Extended 80-Column Text Card. Chapter 2 describes the 80-column display feature. The hardware and firmware interfaces to either type of card are described in Chapter 7.

There are also smaller connectors for game I/O and for an internal RF (radio frequency) modulator. These connectors are described in Chapter 7.

Connectors on the back panel

The back of the Apple IIe has two miniature phone jacks for connecting a cassette recorder: an RCA-type jack for a video monitor, and a 9-pin D-type miniature connector for the hand controls, as shown in Figure 1-8. In addition to these, there are spaces for additional connectors used with the peripheral cards installed in the Apple IIe. The installation manuals for the peripheral cards contain instructions for installing the peripheral connectors.

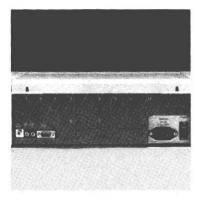


Figure 1-8
Back panel connectors

Chapter 2

Built-in I/O Devices

This chapter describes the input and output (I/O) devices built into the Apple IIe in terms of their functions and the way they are used by programs. The built-in I/O devices are

- □ the keyboard
- □ the video-display generator
- □ the speaker
- □ the cassette input and output
- □ the game input and output

For descriptions of the built-in I/O hardware, refer to Chapter 7.

At the lowest level, programs use the built-in I/O devices by reading and writing to dedicated memory locations. This chapter lists these locations for each I/O device. It also gives the locations of the internal soft switches that select the different display modes of the Apple IIe.

Built-in I/O firmware routines are described in Chapter 3.

❖ Built-in I/O routines: This method of input and output—loading and storing directly to specific locations in memory—is not the only method you can use. For many of your programs, it may be more convenient to call the built-in I/O routines stored in the Apple IIe's firmware.

The keyboard

The primary built-in input device for the Apple IIe is the keyboard. The original and enhanced IIe keyboards have 63 keys, while the extended keyboard IIe keyboard has 81 keys. Both keyboard types have automatic repeat, which means that if you press any key longer than you would during normal typing, the character code for that key will be sent continuously until you release the key. Both keyboard types also allow you to hold down any number of keys and still press another key; this is known as *N-key rollover*.

The keyboard layout shown in Figure 2-1 is for the original and enhanced IIe keyboards. The keyboard layout shown in Figure 2-2 is for the extended keyboard IIe keyboard.

Apple IIe's manufactured for sale outside the United States have a slightly different standard keyboard arrangement and include provisions for switching between different character sets. These differences are described in Appendix I.

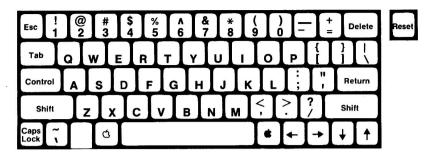


Figure 2-1 Original and enhanced lle keyboard

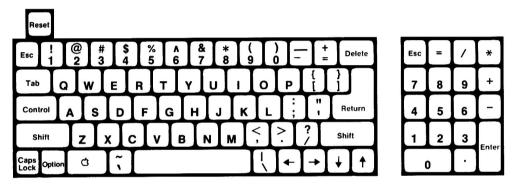


Figure 2-2
Extended keyboard lie keyboard

In addition to the keys normally used for typing characters, there are four cursor-control keys with arrows: left, right, down, and up. The cursor-control keys can be read the same as other keys; their codes are \$08, \$15, \$0A, and \$0B. (See Table 2-2.)

Three special keys—Control, Shift, and Caps Lock—change the codes generated by the other keys. The Control key is similar to the ASCII CTRL key.

Three other keys have special functions: the Reset key, and two keys marked with apples, one outlined (Open Apple) and one solid (Solid Apple). Pressing the Reset key with the Control key depressed resets the Apple IIe, as described in Chapter 4. The Apple keys are connected to the one-bit game inputs, described later in this chapter.

Extended keyboard lle

On the extended keyboard lie the Solid Apple key is labeled *Option;* the Solid Apple and Option keys are functionally identical. Also note that manuals accompanying products with the Solid Apple labeled as *Option* may refer to the Open Apple key as simply the *Apple key*.

See Chapter 7 for a complete description of the electrical interface to the keyboard.

The electrical interface between the Apple IIe and the keyboard is a ribbon cable with a 26-pin connector. This cable carries the keyboard signals to the encoding circuitry on the main board.

Reading the keyboard

The keyboard encoder and ROM generate all 128 ASCII codes, so all the special character codes in the ASCII character set are available from the keyboard. Machine-language programs obtain character codes from the keyboard by reading a byte from the keyboard-data location shown in Table 2-1.

Table 2-1 Keyboard memory locations

Location		
Hex	Decimal	Description
\$C000 \$C010	49152 –16384 49168 –16368	Keyboard data and strobe Any-key-down flag and clear-strobe switch

Hexadecimal refers to the base-16 number system, which uses the digits 0 through 9 and the six letters A through F to represent values from 10 to 15. Your programs can get the code for the last key pressed by reading the keyboard-data location. Table 2-1 gives this location in three different forms: the **hexadecimal** value used in assembly language, indicated by a preceding dollar sign (\$); the decimal value used in Applesoft BASIC; and the complementary decimal value used in Apple Integer BASIC. (Integer BASIC requires that values greater than 32,767 be written as the number obtained by subtracting 65,536 from the value. These are the decimal numbers shown as negative in tables in this manual; refer to the *Apple II BASIC Programming Manual*.) The low-order seven bits of the byte at the keyboard location contain the character code; the high-order bit of this byte is the strobe bit, described below.

Your program can find out whether any key is down, except the Reset, Control, Shift, Caps Lock, Open Apple, and Solid Apple (or Option, on the extended keyboard IIe) keys, by reading from location 49152 (hexadecimal \$C000 or complementary decimal –16384). The high-order bit (bit 7) of the byte you read at this location is called *any-key-down*; it is 1 if a key is down, and 0 if no key is down. The value of this bit is 128; if a BASIC program gets this information with a PEEK, the value is 128 or greater if any key is down, and less than 128 if no key is down.

The Open Apple and Solid Apple keys are connected to switches 0 and 1 of the game I/O connector inputs. If OA is pressed, switch 0 is "pressed," and if Solid Apple is pressed, switch 1 is "pressed."

Extended keyboard lie

On the extended keyboard lle, the Shift key is connected to switch 2 of the game I/O ports via the X6 jumper (single-wire Shift-key mod jumper).

The strobe bit is the high-order bit of the keyboard-data byte. After any key has been pressed, the strobe bit is high. It remains high until you reset it by reading or writing at the clear-strobe location. This location is a combination flag and switch; the flag tells whether any key is down, and the switch clears the strobe bit. The switch function of this memory location is called a *soft switch* because it is controlled by software. In this case, it doesn't matter whether the program reads or writes, and it doesn't matter what data the program writes: the only action that occurs is the resetting of the keyboard strobe. Similar soft switches, described later, are used for controlling other functions in the Apple IIe.

Important

Any time you read the any-key-down flag, you also clear the keyboard strobe. If your program needs to read both the flag and the strobe, it must read the strobe bit first.

After the keyboard strobe has been cleared, it remains low until another key is pressed. Even after you have cleared the strobe, you can still read the character code at the keyboard location. The data byte has a different value, because the high-order bit is no longer set, but the ASCII code in the seven low-order bits is the same until another key is pressed. Table 2-2 shows the ASCII codes for most of the keys on the keyboard of the Apple IIe.

There are several special-function keys that do not generate ASCII codes. For example, you cannot read the Control, Shift, and Caps Lock keys directly, but pressing one of these keys alters the character codes produced by the other keys.

Extended keyboard lie

As a result of the single-wire Shift-key mod, the Shift key can be read directly in the extended keyboard lie.

The reset routine is described in Chapter 4.

Another key that doesn't generate a code is Reset, located at the upper-right corner of the keyboard; it is connected directly to the Apple IIe's circuits. Pressing Reset with Control depressed normally causes the system to stop whatever program it's running and restart itself. This restarting process is called the *reset routine*.

Two more special keys are the Apple keys, Open Apple and Solid Apple, located on either side of the Space bar. These keys are connected to the one-bit game inputs, which are described later in this chapter in the section "Switch Inputs." Pressing them in combination with the Control and Reset keys causes the built-in firmware to perform special reset and self-test cycles, described with the reset routine in Chapter 4.

Extended keyboard lie

The Open Apple and Option keys are both located on the left side of the Space bar on the extended keyboard IIe. See Figure 2-2 for a diagram of the keyboard layout for the extended keyboard IIe.

Table 2-2 Keys and ASCII codes

	Normal		Control		Shift		Both	
Key	Code	Char	Code	Char	Code	Char	Code	Char
Delete	7 F	DEL	7F	DEL	7 F	DEL	7F	DEL
Left Arrow	08	BS	08	BS	08	BS	08	BS
Tab	09	HT	09	HT	09	HT	09	HT
Down Arrow	0 A	LF	0A	LF	0 A	LF	0A	LF
Up Arrow	ОВ	VT	0B	VT	0B	VT	0B	VT
Return	0D	CR	0D	CR	0D	CR	0D	CR
Right Arrow	15	NAK	15	NAK	15	NAK	15	NAK
Escape	1B	ESC	1B	ESC	1B	ESC	1B	ESC
Space	20	SP	20	SP	20	SP	20	SP
1 11	27	•	27	ť	22	**	22	**
, <	2C	,	2C	,	3C	<	3C	<

Table 2-2 (continued) Keys and ASCII codes

	Nor	mal	Cor	ntrol	Sh	Shift		Both	
Key	Code	Char	Code	Char	Code	Char	Code	Char	
	2D	-	1F	US	5F	-	1F	US	
. >	2E		2E		3E	>	3E	>	
/ ?	2F	/	2F	/	3F	?	3F	?	
0)	30	0	30	0	29)	29)	
1!	31	1	31	1	21	!	21	1	
2@	32	2	00	NUL	40	@	00	NUL	
3 #	33	3	33	3	23	#	23	#	
4 \$	34	4	34	4	24	\$	24	\$	
5 %	35	5	35	5	25	%	25	%	
6 ^	36	6	1E	RS	5E	٨	1 E	RS	
7 &	37	7	37	7	26	&	26	&	
8 *	38	8	38	8	2A	•	2A	•	
9(39	9	39	9	28	(28	(
; :	3B	;	3B	;	3A		3A	:	
, . = +	3D	, =	3D	=	2B	+	2B	+	
11	5B	1	1B	ESC	7B	{	1B	ESC	
\ \	5C	Ĭ	1C	FS	7C	ì	1C	FS	
1}	5D]	1D	GS	7D	}	1D	GS	
` ~	60		60		7E	~	7E	~	
A	61	a	01	SOH	41	A	01	SOH	
В	62	b	02	STX	42	В	02	STX	
C	63	С	03	ETX	43	С	03	ETX	
D	64	d	04	EOT	44	D	04	EOT	
E	65	e	05	ENQ	45	E	05	ENQ	
F	66	f	06	ACK	46	F	06	ACK	
G	67	g	07	BEL	47	G	07	BEL	
Н	68	h	08	BS	48	Н	08	BS	
I	69	i	09	HT	49	I	09	HT	
Ĵ	6A	- j	0A	LF	4A	Ĵ	0 A	LF	
K	6B	k	0B	VT	4B	K	0B	VT	
L	6C	1	0C	FF	4C	L	0C	FF	
M	6D	m	0D	CR	4D	M	0D	CR	
N	6E	n	0E	SO	4E	N	0E	SO	
O	6F	0	0F	SI	4F	Ö	0F	SI	
P	70	p	10	DLE	50	P	10	DLE	
Q	70 71	ч Р	11	DC1	51	Q	11	DC1	
R	72	r	12	DC2	52	R	12	DC1	
S	73	S	13	DC2 DC3	53	S	13	DC3	
	75 74		14	DC3 DC4	55 54	T	14		
T		t						DC4	
U	75	u	15	NAK	55	U	15	NAK	

Table 2-2 (continued) Keys and ASCII codes

,	Nor	Normal		Control		Shift		Both	
Key	Code	Char	Code	Char	Code	Char	Code	Char	
v	76	v	16	SYN	56	V	16	SYN	
W	77	w	17	ETB	57	W	17	ETB	
X	78	x	18	CAN	58	$\mathbf{X}^{'}$	18	CAN	
Y	79	У	19	EM	59	Y	19	EM	
Z	7 A	z	1A	SUB	5A	Z	1A	SUB	

Note: Codes are shown here in hexadecimal; to find the decimal equivalents, refer to Table E-3.

Extended keyboard lie

The ASCII codes generated by the numeric keypad on the extended keyboard lie are the same as those for the corresponding characters on the main keyboard. See Table 2-2.

The video display generator

The primary output device of the Apple IIe is the video display. You can use any ordinary video monitor, either color or black-and-white, to display video information from the Apple IIe. An ordinary monitor is one that accepts composite video compatible with the standard set by the NTSC (National Television Standards Committee). If you use Apple IIe color graphics with a monochrome (single-color) monitor, the display will appear as that color (black, for example) and various patterns made up of shades of that color.

If you are using only 40-column text and graphics modes, you can use a television set for your video display. If the TV set has an input connector for composite video, you can connect it directly to your Apple IIe; if it does not, you'll need to attach a radio frequency (RF) video modulator between the Apple IIe and the television set.

Important

With the 80-column text card installed, the Apple IIe can produce an 80-column text display. However, if you use an ordinary color or black-and-white television set, 80-column text will be too blurry to read. For a clear 80-column display, you must use a high-resolution video monitor with a bandwidth of 14 MHz or greater.

The specifications for the video display are summarized in Table 2-3.

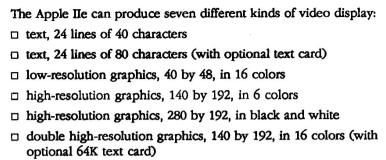
Original lie

Note that MouseText characters are not included in the original version of the Apple IIe.

For a full description of the video signal and the connections to the Molex-type pins, refer to the section "Video Output Signals" in Chapter 7. The video signal produced by the Apple IIe is NTSC-compatible composite color video. It is available at three places: the RCA-type phono jack on the back of the Apple IIe, the single Molex-type pin on the main circuit board near the back on the right side, and one of the group of four Molex-type pins in the same area on the main board. Use the RCA-type phono jack to connect a video monitor or an external video modulator; use the Molex pins to connect the type of video modulator that fits inside the Apple IIe case.

Table 2-3
Video display specifications

Display modes	40-column text; map: Figure 2-3 80-column text; map: Figure 2-4 Low-resolution color graphics; map: Figure 2-8 High-resolution color graphics; map: Figure 2-9 Double high-res color graphics; map: Figure 2-10
Text capacity	24 lines by 80 columns (character positions)
Character set	96 ASCII characters (uppercase and lowercase)
Display formats	Normal, inverse, flashing, MouseText (Table 2-4)
Low-resolution graphics	16 colors (Table 2-5), 40 horizontal by 48 vertical; map: Figure 2-8
High-resolution graphics	6 colors (Table 2-6), 140 horizontal by 192 vertical (restricted) Black-and-white: 280 horizontal by 192 vertical; map: Figure 2-9
Double high-resolution graphics	16 colors (Table 2-7), 140 horizontal by 192 vertical (no restrictions) Black-and-white: 560 horizontal by 192 vertical; map: Figure 2-10



□ double high-resolution graphics, 560 by 192, in black and white (with optional 64K text card)

The 2 text modes can display all 96 ASCII characters: uppercase and lowercase letters, numbers, and symbols. The enhanced and extended keyboard Apple IIe's can also display MouseText characters.

Any of the graphics displays can have four lines of text at the bottom of the screen. The text may be either 40-column or 80-column, except that double high-resolution graphics may only have 80-column text at the bottom of the screen. Graphics displays with text at the bottom are called *mixed-mode displays*.

The low-resolution graphics display is an array of colored blocks, 40 wide by 48 high, in any of 16 colors. In mixed mode, the four lines of text replace the bottom eight rows of blocks, leaving 40 rows of 40 blocks each.

The high-resolution graphics display is an array of dots, 280 wide by 192 high. There are six colors available in high-resolution displays, but a given dot can use only four of the six colors. If color is used, the display is 140 dots wide by 192 high. In mixed mode, the 4 lines of text replace the bottom 32 rows of dots, leaving 160 rows of 280 dots each.

The double high-resolution graphics display uses main and auxiliary memory to display an array of dots, 560 wide by 192 high. All the dots are visible in black and white. If color is used, the display is 140 dots wide by 192 high with 16 colors available. In mixed mode, the 4 lines of text replace the bottom 32 rows of dots, leaving 160 rows of 560 (or 140) dots each. In mixed mode, the text lines can be 80 columns wide only.

Text modes

The text characters displayed include the uppercase and lowercase letters, the ten digits, punctuation marks, and special characters. Each character is displayed in an area of the screen that is seven dots wide by eight dots high. The characters are formed by a dot matrix five dots wide, leaving two blank columns of dots between characters in a row, except for MouseText characters, some of which are seven dots wide. Except for lowercase letters with descenders and some MouseText characters, the characters are only seven dots high, leaving one blank line of dots between rows of characters.

The normal display has white (or other single color) dots on a black background. Characters can also be displayed as black dots on a white background; this is called *inverse format*.

Text character sets

The Apple IIe can display either of two text character sets: the primary set or an alternate set. The forms of the characters in the wo sets are actually the same, but the available display formats are different. The display formats are						
normal, with white dots on a black screen						
inverse, with black dots on a white screen						
flashing, alternating between normal and inverse						
With the primary character set, the Apple IIe can display uppercase characters in all three formats: normal, inverse, and flashing. Lowercase letters can only be displayed in normal format. The primary character set is compatible with most software written for the Apple II and Apple II Plus models, which can display text in clashing format but don't have lowercase characters.						
The alternate character set displays characters in either normal or nverse format. In normal format, you can get						
uppercase letters						
lowercase letters						
numbers						
special characters						
n inverse format, you can get						
MouseText characters (on the enhanced and extended keyboard						

- □ uppercase letters
- □ lowercase letters
- □ numbers
- □ special characters

The MouseText characters that replace the alternate uppercase inverse characters in the range of \$40-\$5F in the original Apple IIe are inverse characters, but they don't look like it because of the way they have been constructed.

You select the character set by means of the alternate-text soft switch, ALTCHAR, described later in the section "Display Mode Switching." Table 2-4 shows the character codes in hexadecimal for the Apple IIe primary and alternate character sets in normal, inverse, and flashing formats.

Each character on the screen is stored as one byte of display data. The low-order six bits make up the ASCII code of the character being displayed. The remaining two (high-order) bits select inverse or flashing format and uppercase or lowercase characters. In the primary character set, bit 7 selects inverse or normal format and bit 6 controls character flashing. In the alternate character set, bit 6 selects between uppercase and lowercase, according to the ASCII character codes, and flashing format is not available.

Table 2-4Display character sets

	Primary charact	er set	Alternate character set		
Hex values	Character type	Format	Character type	Format	
\$00-\$1F	Uppercase letters	Inverse	Uppercase letters	Inverse	
\$20-\$3F	Special characters	Inverse	Special characters	Inverse	
\$40-\$5F	Uppercase letters	Flashing	MouseText	Inverse	
\$60-\$7F	Special characters	Flashing	Lowercase letters	Inverse	
\$80-\$9F	Uppercase letters	Normal	Uppercase letters	Normal	
\$A0-\$BF	Special characters	Normal	Special characters	Normal	
\$C0-\$DF	Uppercase letters	Normal	Uppercase letters	Normal	
\$E0-\$FF	Lowercase letters	Normal	Lowercase letters	Norma	

Note: To identify particular characters and values, refer to Table 2-2.

Original Ile

In the alternate character set of the original Apple IIe, characters in the range \$40-\$5F are uppercase inverse.

40-column versus 80-column text

The Apple IIe has two modes of text display: 40-column and 80-column. (The 80-column display mode described in this manual is the one you get with the Apple IIe 80-Column Text Card or other auxiliary-memory card installed in the auxiliary slot.) The number of dots in each character does not change, but the characters in 80-column mode are only half as wide as the characters in 40-column mode. Compare Figure 2-3 and Figure 2-4. On an ordinary color or black-and-white television set, the narrow characters in the 80-column display blur together; you must use the 40-column mode to display text on a television set.

Graphics modes

The Apple IIe can produce video graphics in three different modes. All the graphics modes treat the screen as a rectangular array of spots. Normally, your programs will use the features of some high-level language to draw graphics dots, lines, and shapes in these arrays; this section describes the way the resulting graphics data are stored in the Apple IIe's memory.

Low-resolution graphics

In the low-resolution graphics mode, the Apple IIe displays an array of 48 rows by 40 columns of colored blocks. Each block can be any one of sixteen colors, including black and white. On a black-and-white monitor or television set, these colors appear as black, white, and three shades of gray. There are no blank dots between blocks; adjacent blocks of the same color merge to make a larger shape.

Data for the low-resolution graphics display is stored in the same part of memory as the data for the 40-column text display. Each byte contains data for two low-resolution graphics blocks. The two blocks are displayed one atop the other in a display space the same size as a 40-column text character, seven dots wide by eight dots high.

```
10 REM APPLESOFT CHARACTER DEMO
20 TEXT: HOME
30 PRINT: PRINT "Applesoft Character Demo"
40 PRINT: PRINT "Which character r set--"
50 PRINT: INPUT "Primary (P) or Alternate (A) ?"; A$
```

1LIST 0,100

60 IF LEN (A\$) < 1 THEN 50

65 LET A\$ = LEFT\$ (A\$,1)

70 IF A\$ = "P" THEN POKE 49166,

80 IF A\$ = "A" THEN POKE 49167,

90 PRINT: PRINT "...printing the e same line, first"

100 PRINT " in NORMAL, then INVE
 RSE ,then FLASH:": PRINT
]

Figure 2-3 40-column text display

```
10 REM APPLESOFT CHARACTER DEMO
20 TEXT : HOME
30 PRINT : PRINT "Applesoft Character Demo"
40 PRINT : PRINT "Which character set--"
50 PRINT : INPUT "Primary (P) or Alternate (A) ?"; A$
60 IF LEN (A$) < 1 THEN 50
70 LET A$ = LEFT$ (A$,1)
80 IF A$ = "P" THEN POKE 49166,0
90 IF A$ = "A" THEN POKE 49167,0
100 PRINT : PRINT "...printing the same line, first"
150 PRINT " in NORMAL, then INVERSE , then FLASH:": PRINT
160 NORMAL : GOSUB 1000
170 INVERSE: GOSUB 1000
180 FLASH : GOSUB 1000
190 NORMAL: PRINT: PRINT: PRINT "Press any key to repeat." GET A$
1000 PRINT: PRINT "SAMPLE TEXT: Now is the time--12:00"
1100 RETURN
1
```

Figure 2-4 80-column text display

]LIST 0,1100

Table 2-5 Low-resolution graphics colors

Nibble	e value	
Dec	Hex	Color
0 1 2 3 4 5 6	\$00 \$01 \$02 \$03 \$04 \$05 \$06	Black Magenta Dark blue Purple Dark green Gray Medium blue
7 8 9 10 11 12 13 14 15	\$07 \$08 \$09 \$0A \$0B \$0C \$0D \$0E	Light blue Brown Orange Gray 2 Pink Light green Yellow Aquamarine White

Note: Colors may vary, depending upon the controls on the monitor or TV set.

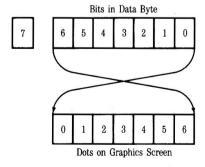


Figure 2-5 High-resolution display bits

Half a byte—four bits, or one nibble—is assigned to each graphics block. Each nibble can have a value from 0 to 15, and this value determines which one of 16 colors appears on the screen. The colors and their corresponding nibble values are shown in Table 2-5. In each byte, the low-order nibble sets the color for the top block of the pair, and the high-order nibble sets the color for the bottom block. Thus, a byte containing the hexadecimal value \$D8 produces a brown block atop a yellow block on the screen.

As explained later in the section "Video Display Pages," the text display and the low-resolution graphics display use the same area in memory. Most programs that generate text and graphics clear this part of memory when they change display modes, but it is possible to store data as text and display it as graphics, or vice-versa. All you have to do is change the mode switch, described later in this chapter in the section "Display Mode Switching," without changing the display data. This usually produces meaningless jumbles on the display, but some programs have used this technique to good advantage for producing complex low-resolution graphics displays quickly.

High-resolution graphics

In the high-resolution graphics mode, the Apple IIe displays an array of colored dots in 192 rows and 280 columns. The colors available are black, white, purple, green, orange, and blue, although the colors of the individual dots are limited, as described later in this section. Adjacent dots of the same color merge to form a larger colored area.

Data for the high-resolution graphics displays are stored in either of two 8192-byte areas in memory. These areas are called *high-resolution Page 1* and *Page 2*; think of them as buffers where you can put data to be displayed. Normally, your programs will use the features of some high-level language to draw graphics dots, lines, and shapes to display; this section describes the way the resulting graphics data are stored in the Apple IIe's memory.

The Apple IIe high-resolution graphics display is bit-mapped: each dot on the screen corresponds to a bit in the Apple IIe's memory. The seven low-order bits of each display byte control a row of seven adjacent dots on the screen, and forty adjacent bytes in memory control a row of 280 (7 times 40) dots. The least significant bit of each byte is displayed as the leftmost dot in a row of seven, followed by the second-least significant bit, and so on, as shown in Figure 2-5. The eighth bit (the most significant) of each byte is not displayed; it selects one of two color sets, as described later.

On a black-and-white monitor, there is a simple correspondence between bits in memory and dots on the screen. A dot is white if the bit controlling it is on (1), and the dot is black if the bit is off (0). On a black-and-white television set, pairs of dots blur together; alternating black and white dots merge to a continuous gray.

On an NTSC color monitor or a color television set, a dot whose controlling bit is off (0) is black. If the bit is on, the dot will be white or a color, depending on its position, the dots on either side, and the setting of the high-order bit of the byte.

Call the left-most column of dots column zero, and assume (for the moment) that the high-order bits of all the data bytes are off (0). If the bits that control dots in even-numbered columns (0, 2, 4, and so forth) are on, the dots are purple; if the bits that control odd-numbered columns are on, the dots are green—but only if the dots on both sides of a given dot are black. If two adjacent dots are both on, they are both white.

You select the other two colors, blue and orange, by turning the high-order bit (bit 7) of a data byte on (1). The colored dots controlled by a byte with the high-order bit on are either blue or orange: the dots in even-numbered columns are blue, and the dots in odd-numbered columns are orange—again, only if the dots on both sides are black. Within each horizontal line of seven dots controlled by a single byte, you can have black, white, and one pair of colors. To change the color of any dot to one of the other pair of colors, you must change the high-order bit of its byte, which affects the colors of all seven dots controlled by the byte.

For more details about the way the Apple IIe produces color on a TV set, see the section "Video Display Modes" in Chapter 7. In other words, high-resolution graphics displayed on a color monitor or television set are made up of colored dots, according to the following rules:

- □ Dots in even columns can be black, purple, or blue.
- □ Dots in odd columns can be black, green, or orange.
- ☐ If adjacent dots in a row are both on, they are both white.
- ☐ The colors in each row of seven dots controlled by a single byte are either purple and green, or blue and orange, depending on whether the high-order bit is off (0) or on (1).

These rules are summarized in Table 2-6. The blacks and whites are numbered to remind you that the high-order bit is different.

Table 2-6High-resolution graphics colors

Bits 0-6	Bit 7 off	Bit 7 on
Adjacent columns off	Black 1	Black 2
Even columns on	Purple	Blue
Odd columns on	Green	Orange
Adjacent columns on	White 1	White 2

Note: Colors may vary depending upon the controls on the monitor or television set.

For information about the way NTSC color television works, see the magazine articles listed in the bibliography. The peculiar behavior of the high-resolution colors reflects the way NTSC color television works. The dots that make up the Apple IIe video signal are spaced to coincide with the frequency of the color subcarrier used in the NTSC system. Alternating black and white dots at this spacing cause a color monitor or TV set to produce color, but two or more white dots together do not. Effective horizontal resolution with color is 140 dots per line (280 divided by 2).

Double high-resolution graphics

In the double high-resolution graphics mode, the Apple IIe displays an array of colored dots 560 columns wide and 192 rows deep. There are 16 colors available for use with double high-resolution graphics (see Table 2-7).

Double high-resolution graphics is a bit-mapping of the low-order seven bits of the bytes in the main-memory and auxiliary-memory pages at \$2000-\$3FFF. The bytes in the main-memory and auxiliary-memory pages are interleaved in exactly the same manner as the characters in 80-column text: of each pair of identical addresses, the auxiliary-memory byte is displayed first, and the main-memory byte is displayed second. Horizontal resolution is 560 dots when displayed on a monochrome monitor.

Unlike high-resolution color, double high-resolution color has no restrictions on which colors can be adjacent. Color is determined by any four adjacent dots along a line. Think of a four-dot-wide window moving across the screen: at any given time, the color displayed will correspond to the four-bit value from Table 2-7 that corresponds to the window's position (Figure 2-10). Effective horizontal resolution with color is 140 (560 divided by 4) dots per line.

To use Table 2-7, divide the display column number by four, and use the remainder to find the correct column in the table: ab0 is a byte residing in auxiliary memory corresponding to a remainder of zero (byte 0, 4, 8, and so on); mb1 is a byte residing in main memory corresponding to a remainder of one (byte 1, 5, 9, and so on); and similarly for ab3 and mb4.

Table 2-7Double high-resolution graphics colors

Color	ab0	mb1	ab2	mb3	Repeated bit pattern
Black	\$00	\$00	\$00	\$00	0000
Magenta	\$08	\$11	\$22	\$44	0001
Brown	\$44	\$08	\$11	\$22	0010
Orange	\$4C	\$19	\$33	\$66	0011
Dark green	\$22	\$44	\$08	\$11	0100
Gray 1	\$2A	\$55	\$2A	\$55	0101
Green	\$66	\$4C	\$19	\$33	0110
Yellow	\$6E	\$5D	\$3B	\$77	0111
Dark blue	\$11	\$22	\$44	\$08	1000
Purple	\$19	\$33	\$66	\$4C	1001
Gray 2	\$55	\$2A	\$55	\$2A	1010
Pink	\$5D	\$3B	\$77	\$6E	1011
Medium blue	\$33	\$66	\$4C	\$19	1100
Light blue	\$3B	\$77	\$6E	\$5D	1101
Aqua	\$77	\$6E	\$5D	\$3B	1110
White	\$ 7F	\$7F	\$7F	\$7F	1111

Video display pages

The Apple IIe generates its video displays using data stored in specific areas in memory. These areas, called *display pages*, serve as buffers where your programs can put data to be displayed. Each byte in a display buffer controls an object at a certain location on the display. In text mode, the object is a single character; in low-resolution graphics, the object is two stacked colored blocks; and in high-resolution and double high-resolution modes, it is a line of seven adjacent dots.

The 40-column-text and low-resolution-graphics modes use two display pages of 1024 bytes each. These are called *text Page 1* and *text Page 2*, and they are located at 1024–2047 (hexadecimal \$0400–\$07FF) and 2048–3071 (\$0800–\$0BFF) in main memory. Normally, only Page 1 is used, but you can put text or graphics data into Page 2 and switch displays instantly. Either page can be displayed as 40-column text, low-resolution graphics, or mixed mode (four rows of text at the bottom of a graphics display).

The 80-column text mode displays twice as much data as the 40-column mode—1920 bytes—but it cannot switch pages. The 80-column text display uses a combination page made up of text Page 1 in main memory plus another page in auxiliary memory located on the 80-column text card. This additional memory is *not* the same as text Page 2—in fact, it occupies the same address space as text Page 1, and there is a special soft switch that enables you to store data into it. (See the next section, "Display Mode Switching.") The built-in firmware I/O routines, described in Chapter 3, take care of this extra addressing automatically; that is one reason to use those routines for all your normal text output.

The high-resolution graphics mode also has two display pages, but each page is 8192 bytes long. In the 40-column text and low-resolution graphics modes each byte controls a display area seven dots wide by eight dots high. In high-resolution graphics mode each byte controls an area seven dots wide by one dot high. Thus, a high-resolution display requires eight times as much data storage, as shown in Table 2-8.

The double high-resolution graphics mode uses high-resolution Page 1 in both main and auxiliary memory. Each byte in those pages of memory controls a display area seven dots wide by one dot high. This gives you 560 dots per line in black and white, and 140 dots per line in color. A double high-resolution display requires twice the total memory as high-resolution graphics, and 16 times as much as a low-resolution display.

Table 2-8Video display page locations

		Lowest	address	Highest	address
Display mode	Display page	Hex	Dec	Hex	Dec
40-column text, low-resolution graphics	1 2*	\$0400 \$0800	1024 2048	\$07FF \$0BFF	2047 3071
80-column text	1 2*	\$0400 \$0800	1024 2048	\$07FF \$0BFF	2047 3071
High-resolution graphics	1 2	\$2000 \$4000	8192 16384	\$3FFF \$5FFF	16383 24575
Double high- resolution graphics	1† 2†	\$2000 \$4000	8192 16384	\$3FFF \$5FFF	16383 24575

^{*} This is not supported by firmware; for instructions on how to switch pages, refer to the next section, "Display Mode Switching."

Display mode switching

You select the display mode that is appropriate for your application by reading or writing to a reserved memory location called a *soft switch*. In the Apple IIe, most soft switches have three memory locations reserved for them: one for turning the switch on, one for turning it off, and one for reading the current state of the switch.

Table 2-9 shows the reserved locations for the soft switches that control the display modes. For example, to switch from mixed-mode to full-screen graphics in an assembly-language program, you could use the instruction

STA \$C052

To do this in a BASIC program, you could use the instruction

POKE 49234,0

Some of the soft switches in Table 2-9 must be read, some must be written to, and for some you can use either action. When writing to a soft switch, it doesn't matter what value you write; the action occurs when you address the location, and the value is ignored.

[†] See the section "Double High-Resolution Graphics" earlier in this chapter.

Table 2-9Display soft switches

Name	Action	Hex	Function
ALTCHAR	w	\$C00E	Off: display text using primary character set
ALTCHAR	W	\$C00F	On: display text using alternate character set
RDALTCHAR	R7	\$C01E	Read ALTCHAR switch (1 = on)
80COL	W	\$C00C	Off: display 40 columns
80COL	W	\$C00D	On: display 80 columns
RD80COL	R7	\$C01F	Read 80COL switch (1 = on)
80STORE	W	\$C000	Off: cause PAGE2 on to select auxiliary RAM
80STORE	W	\$C001	On: allow PAGE2 to switch main RAM areas
RD80STORE	R7	\$C018	Read 80STORE switch (1 = on)
PAGE2	R/W	\$C054	Off: select Page 1
PAGE2	R/W	\$C055	On: select Page 2 or, if 80STORE on, Page 1 in auxiliary memory
RDPAGE2	R7	\$C01C	Read PAGE2 switch (1 = on)
TEXT	R/W	\$C050	Off: display graphics or, if MIXED on, mixed
TEXT	R/W	\$C051	On: display text
RDTEXT	R7	\$C01A	Read TEXT switch (1 = on)
MIXED	R/W	\$C052	Off: display only text or only graphics
MIXED	R/W	\$C053	On: if TEXT off, display text and graphics
RDMIXED	R7	\$C01B	Read MIXED switch (1 = on)
HIRES	R/W	\$C056	Off: if TEXT off, display low-resolution graphics

Table 2-9 (continued) Display soft switches

Name	Action	Hex	Function
HIRES	R/W	\$C057	On: if TEXT off, display high-resolution or, if DHIRES on, double high-resolution graphics
RDHIRES	R7	\$C01D	Read HIRES switch (1 = on)
IOUDIS	W	\$C07E	On: disable IOU access for addresses \$C058 to \$C05F; enable access to DHIRES switch*
IOUDIS	W	\$C07F	Off: enable IOU access for addresses \$C058 to \$C05F; disable access to DHIRES switch*
RDIOUDIS	R7	\$C07E	Read IOUDIS switch (1 = off)†
DHIRES	R/W	\$C05E	On: if IOUDIS on, turn on double high resolution
DHIRES	R/W	\$C05F	Off: if IOUDIS on, turn off double high resolution
RDDHIRES	R7	\$C07F	Read DHIRES switch (1 = on)†
VBL	R7	\$C091	Vertical blanking

Note: W means write anything to the location, R means read the location, R/W means read or write, and R7 means read the location and check bit 7.

^{*} The firmware normally leaves IOUDIS on. See also †.

[†] Reading or writing any address in the range \$C070-\$C07F also triggers the paddle timer and resets VBLINT (Chapter 7).

By the way: You may not need to deal with these functions by reading and writing directly to the memory locations in Table 2-9. Many of the functions shown here are selected automatically if you use the display routines in the various high-level languages on the Apple IIe.

Any time you read a soft switch, you get a byte of data. However, the only information the byte contains is the state of the switch, and this occupies only one bit—bit 7, the high-order bit. The other bits in the byte are unpredictable. If you are programming in machine language, the switch setting is the sign bit; as soon as you read the byte, you can do a Branch Plus if the switch is off, or Branch Minus if the switch if on.

If you read a soft switch from a BASIC program, you get a value between 0 and 255. Bit 7 has a value of 128, so if the switch is on, the value will be equal to or greater than 128; if the switch is off, the value will be less than 128.

Addressing display pages directly

Before you decide to use the display pages directly, consider the alternatives. Most high-level languages enable you to write statements that control the text and graphics displays. Similarly, if you are programming in assembly language, you may be able to use the display features of the built-in I/O firmware. You should store directly into display memory only if the existing programs can't meet your requirements.

The display memory maps are shown in Figures 2-6, 2-7, 2-8, 2-9, and 2-10. All the different display modes use the same basic addressing scheme: characters or graphics bytes are stored as rows of 40 contiguous bytes, but the rows themselves are not stored at locations corresponding to their locations on the display. Instead, the display address is transformed so that three rows that are eight rows apart on the display are grouped together and stored in the first 120 locations of each block of 128 bytes (\$80 hexadecimal). By folding the display data into memory this way, the Apple IIe, like the Apple II, stores all 960 characters of displayed text within 1K bytes of memory.

The high-resolution graphics display is stored in much the same way as text, but there are eight times as many bytes to store, because eight rows of dots occupy the same space on the display as one row of characters. The subset consisting of all the first rows from the groups of eight is stored in the first 1024 bytes of the high-resolution display page. The subset consisting of all the second rows from the groups of eight is stored in the second 1024 bytes, and so on for a total of 8 times 1024, or 8192 bytes. In other words, each block of 1024 bytes in the high-resolution display page contains one row of dots out of every group of eight rows. The individual rows are stored in sets of three 40-byte rows, the same way as the text display.

For a full description of the way the Apple lle handles its display memory, refer to the section "Display Memory Addressing" in Chapter 7.

All of the display modes except 80-column mode and double high-resolution graphics mode can use either of two display pages. The display maps show addresses for each mode's Page 1 only. To obtain addresses for text or low-resolution graphics Page 2, add 1024 (\$400); to obtain addresses for high-resolution Page 2, add 8192 (\$2000).

The 80-column display and double high resolution graphics mode work a little differently. Half of the data is stored in the normal text Page-1 memory, and the other half is stored in memory on the 80-column text card using the same addresses. The display circuitry fetches bytes from these two memory areas simultaneously and displays them sequentially: first the byte from the 80-column text card memory, then the byte from the main memory. The main memory stores the characters in the odd columns of the display, and the 80-column text card memory stores the characters in the even columns.

For more details about the way the displays are generated, see Chapter 7. To store display data on the 80-column text card, first turn on the 80STORE soft switch by writing to location 49153 (hexadecimal \$C001 or complementary –16383). With 80STORE on, the page-select switch, PAGE2, selects between the portion of the 80-column display stored in Page 1 of main memory and the portion stored in the 80-column text card memory. To select the 80-column text card, turn the PAGE2 soft switch on by reading or writing at location 49237.

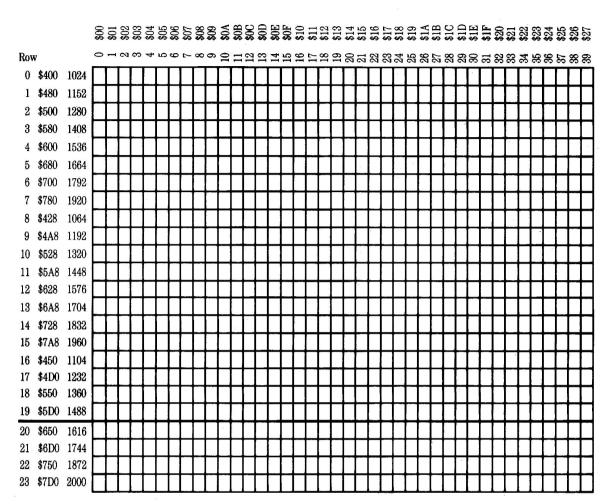


Figure 2-6 Map of 40-column text display

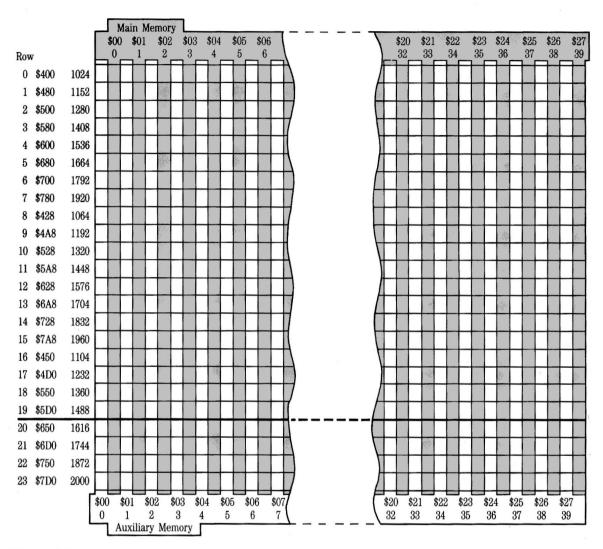


Figure 2-7 Map of 80-column text display

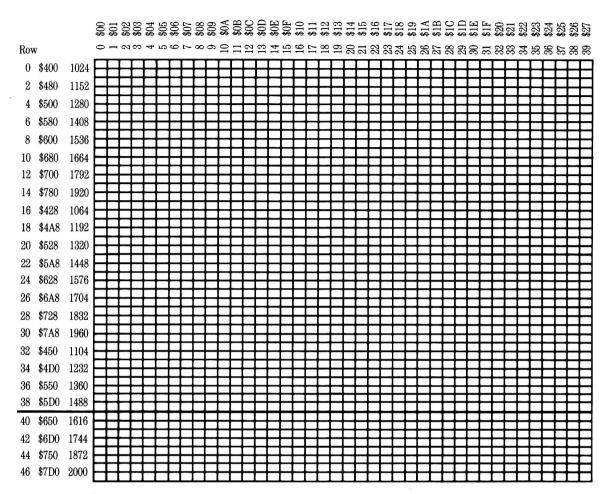


Figure 2-8
Map of low-resolution graphics display

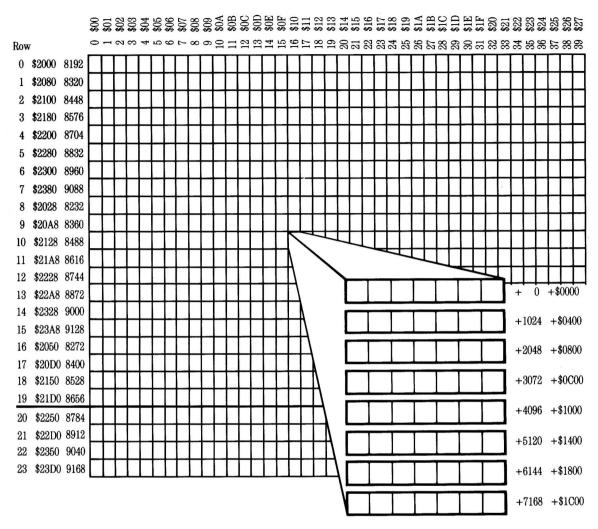


Figure 2-9
Map of high-resolution graphics display

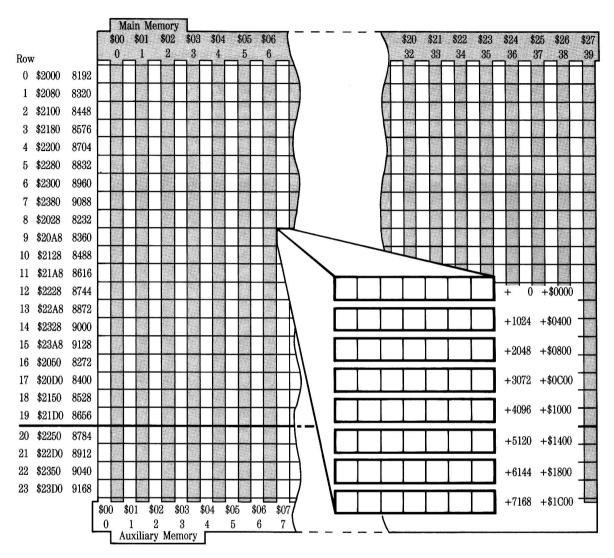


Figure 2-10
Map of double high-resolution graphics display

Secondary inputs and outputs

In addition to the primary I/O devices—the keyboard and display—there are several secondary input and output devices in the Apple IIe. These devices are

- □ the speaker (output)
- cassette input and output
- annunciator outputs
- □ strobe output
- switch inputs
- □ analog (hand control) inputs

These devices are similar in operation to the soft switches described in the preceding section: you control them by reading or writing to dedicated memory locations. Action takes place any time your program reads or writes to one of these locations; information written is ignored.

Important

Some of these devices toggle—change state—each time they are accessed. If you write using an indexed store operation, the Apple Ile's microprocessor activates the address bus twice during successive clock cycles, causing a device that toggles each time it is addressed to end up back in its original state. For this reason, you should read, rather than write, to such devices.

The speaker

Electrical specifications of the speaker circuit appear in Chapter 7. The Apple IIe has a small speaker mounted toward the front of the bottom plate. The speaker is connected to a soft switch that toggles; it has two states, off and on, and it changes from one to the other each time it is accessed. (At low frequencies, less than 400 Hz or so, the speaker clicks only on every other access.)

If you switch the speaker once, it emits a click; to make longer sounds, you access the speaker repeatedly. You should always use a read operation to toggle the speaker. If you write to this soft switch, it switches twice in rapid succession. The resulting pulse is so short that the speaker doesn't have time to respond; it doesn't make a sound.

The soft switch for the speaker uses memory location 49200 (hexadecimal \$C030). From Integer BASIC, use the complementary address –16336. You can make various tones and buzzes with the speaker by using combinations of timing loops in your program. There is also a routine in the built-in firmware to make a beep through the speaker. This routine is named BELL1.

BELL1 is described in Appendix B.

Cassette input and output

There are two miniature phone jacks on the back panel of the Apple IIe. You can use a pair of standard cables with miniature phone plugs to connect an ordinary cassette tape recorder to the Apple IIe and save programs and data on audio cassettes.

The phone jack marked with a picture of an arrow pointing toward a cassette is the output jack. It's connected to a toggled soft switch, like the speaker switch described above. The signal at the phone jack switches from 0 to 25 millivolts or from 25 millivolts to 0 each time you access the soft switch.

Detailed electrical specifications for the cassette input and output are given in Chapter 7.

If you connect a cable from this jack to the microphone input of a cassette tape recorder and switch the recorder to record mode, the signal changes you produce by accessing this soft switch will be recorded on the tape. The cassette output switch uses memory location 49184 (hexadecimal \$C020; complementary value –16352). Like the speaker, this output will toggle twice if you write to it, so you should only use read operations to control the cassette output.

The standard method for writing computer data on audio tapes uses tones with two different pitches to represent the binary states zero and one. To store data, you convert the data into a stream of bits and convert the bits into the appropriate tones. To save you the trouble of actually programming the tones, and to ensure consistency among all Apple II cassette tapes, there is a built-in routine named WRITE for producing cassette data output.

WRITE is described in Appendix B.

The phone jack marked with a picture of an arrow coming from a cassette is the input jack. It accepts a cable from the cassette recorder's earphone jack. The signal from the cassette is one volt (peak-to-peak) audio. Each time the instantaneous value of this audio signal changes from positive to negative, or vice versa, the state of the cassette input circuit changes from zero to one or vice versa. You can read the state of this circuit at memory location 49248 (hexadecimal \$C060, or complementary decimal -16288).

When you read this location, you get a byte, but only the high-order bit (bit 7) is valid. If you are programming in machine language, this is the sign bit, so you can perform a Branch Plus or Branch Minus immediately after reading this byte. BASIC is too slow to keep up with the audio tones used for data recording on tape, but you don't need to write the program: there is a built-in routine named READ for reading data from a cassette.

READ is described in Appendix B.

The hand control connector signals

Several inputs and outputs are available on a 9-pin D-type miniature connector on the back of the Apple IIe: three one-bit inputs, or switches, and four analog inputs. These signals are also available on the 16-pin IC connector on the main circuit board, along with four one-bit outputs and a data strobe. You can access all of these signals from your programs.

Ordinarily, you connect a pair of hand controls to the 9-pin connector. The rotary controls use two analog inputs, and the push-buttons use two one-bit inputs. However, you can also use these inputs and outputs for many other jobs. For example, two analog inputs can be used with a two-axis joystick. Table 7-19 shows the connector pin numbers.

Complete electrical specifications of these inputs and outputs are given in Chapter 7.

Annunciator outputs

For electrical specifications of the annunciator outputs, refer to Chapter 7.

The four one-bit outputs are called *annunciators*. Each annunciator can be used to turn a lamp, a relay, or some similar electronic device on and off.

Each annunciator is controlled by a soft switch, and each switch uses a pair of memory locations. These memory locations are shown in Table 2-10. Any reference to the first location of a pair turns the corresponding annunciator off; a reference to the second location turns the annunciator on. There is no way to read the state of an annunciator.

Table 2-10
Annunciator memory locations

Annunciator		ator	Addres	Address		
No.	Pin*	State	Decimal	Hex		
0	15	Off	49240 -16296	\$C058		
		On	49241 -16295	\$C059		
1	14	Off	49242 -16294	\$C05A		
		On	49243 -16293	\$C05B		
2	13	Off	49244 -16292	\$C05C		
		On	49245 -16291	\$C05D		
3	12	Off	49246 -16290	\$C05E		
		On	49247 -16289	\$C05F		

^{*} Pin numbers given are for the 16-pin IC connector on the circuit board.

Strobe output

The strobe output is normally at +5 volts, but it drops to zero for about half a microsecond any time its dedicated memory location is accessed. You can use this signal to control functions such as data latching in external devices. If you use this signal, remember that memory is addressed twice by a write; if you need only a single pulse, use a read operation to activate the strobe. The memory location for the strobe signal is 49216 (hexadecimal \$C040 or complementary -16320).

Switch inputs

The three one-bit inputs can be connected to the output of another electronic device or to a pushbutton. When you read a byte from one of these locations, only the high-order bit—bit 7—is valid information; the rest of the byte is undefined. From machine language, you can do a Branch Plus or Branch Minus on the state of bit 7. From BASIC, you read the switch with a PEEK and compare the value with 128. If the value is 128 or greater, the switch is on.

The memory locations for these switches are 49249 through 49251 (hexadecimal \$C061 through \$C063, or complementary –16287 through –16285), as shown in Table 2-12. Switch 0 and switch 1 are permanently connected to the Open Apple and Solid Apple (or Option, on the extended keyboard IIe) keys on the keyboard; these are the ones normally connected to the buttons on the hand controls. Some software for the older models of the Apple II uses the third switch, switch 2, as a way of detecting the Shift key. This technique requires a hardware modification known as the single-wire Shift-key mod.

You should be sure that you really need the Shift-key mod before you go ahead and do it. It probably is not worth it unless you have a program that requires the Shift-key mod that you cannot either replace or modify to work without it.

Extended keyboard lie

The extended keyboard lie already has the single-wire Shift-key mod hardwired on the logic board.

Warnina

If you make the Shift-key modification and connect a joystick or other hand control that uses switch 2, you must be careful never to close the switch and press Shift at the same time: doing so produces a short circuit that causes the power supply to turn off. When this happens, any programs or data in the computer's internal memory are lost.

♦ Shift-key mod: To perform this modification on your Apple IIe, all you have to do is solder across the broken diamond labeled X6 on the main circuit board. Remember to turn off the power before changing anything inside the Apple IIe. Also remember that changes such as this are at your own risk and may void your warranty.

Analog inputs

Refer to the section "Game I/O Signals" in Chapter 7 for details.

The four analog inputs are designed for use with 150K ohm variable resistors or potentiometers. The variable resistance is connected between the +5V supply and each input, so that it makes up part of a timing circuit. The circuit changes state when its time constant has elapsed, and the time constant varies as the resistance varies. Your program can measure this time by counting in a loop until the circuit changes state, or times out.

Before a program can read the analog inputs, it must first reset the timing circuits. Accessing memory location 49264 (hexadecimal \$C070 or complementary –16272) does this. As soon as you reset the timing circuits, the high bits of the bytes at locations 49252 through 49255 (hexadecimal \$C064 through \$C067 or complementary –16284 through –16281) are set to 1. If you PEEK at them from BASIC, the values will be 128 or greater. Within about 3 milliseconds, these bits will change back to 0—byte values less than 128—and remain there until you reset the timing circuits again. The exact time each of the four bits remains high is directly proportional to the resistance connected to the corresponding input. If these inputs are open—no resistances are connected—the corresponding bits may remain high indefinitely.

PREAD is described in Appendix B.

To read the analog inputs from machine language, you can use a program loop that resets the timers and then increments a counter until the bit at the appropriate memory location changes to 0, or you can use the built-in routine named PREAD. High-level languages, such as BASIC, also include convenient means of reading the analog inputs: refer to your language manuals.

Summary of secondary I/O locations

Table 2-11 shows the memory locations for all of the built-in I/O devices except the keyboard and display. As explained earlier, some soft switches should only be accessed by means of read operations; those switches are marked.

Table 2-11 Secondary I/O memory locations

	Address	5		
Function	Decimal	Hex	Access	
Speaker	49200 –16336	\$C030	Read only	
Cassette out	49184 -16352	\$C020	Read only	
Cassette in	49248 -16288	\$C060	Read only	
Annunciator 0 on	49241 -16295	\$C059	-	
Annunciator 0 off	49240 -16296	\$C058		
Annunciator 1 on	49243 -16293	\$C05B		
Annunciator 1 off	49242 -16294	\$C05A		
Annunciator 2 on	49245 -16291	\$C05D		
Annunciator 2 off	49244 -16292	\$C05C		
Annunciator 3 on	49247 -16289	\$C05F		
Annunciator 3 off	49246 -16290	\$C05E		
Strobe output	49216 -16320	\$C040	Read only	
Switch input 0 (4)	49249 -16287	\$C061	Read only	
Switch input 1 ()	49250 -16286	\$C062	Read only	
Switch input 2	49251 -16285	\$C063	Read only	
Analog input reset	49264 -16272	\$C070		
Analog input 0	49252 -16284	\$C064	Read only	
Analog input 1	49253 -16283	\$C065	Read only	
Analog input 2	49254 -16282	\$C066	Read only	
Analog input 3	49255 -16281	\$C067	Read only	

Note: For connector identification and pin numbers, refer to Tables 7-18 and 7-19.

Chapter 3

Built-in I/O Firmware The **Monitor**, or System Monitor, is a computer program that is used to operate the computer at the machine-language level.

Almost every program on the Apple IIe takes input from the keyboard and sends output to the display. The **Monitor** and the Applesoft and Integer BASICs do this by means of standard I/O subroutines that are built into the Apple IIe's firmware. Many application programs also use the standard I/O subroutines, but Pascal programs do not; Pascal has its own I/O subroutines.

This chapter describes the features of these subroutines as they are used by the Monitor and by the BASIC interpreters, and tells you how to use the standard subroutines in your assembly-language programs.

Important

High-level languages already include convenient methods for handling most of the functions described in this chapter. You should not need to use the standard I/O subroutines in your programs unless you are programming in assembly language.

Table 3-1
Monitor firmware routines

Location0	Name	Description
\$C305	BASICIN	With 80-column firmware active, displays solid, blinking cursor; accepts character from keyboard
\$C307	BASICOUT	Displays a character on the screen; used when the 80-column firmware is active (Chapter 3)
\$FC9C	CLREOL	Clears to end of line from current cursor position
\$FC9E	CLEOLZ	Clears to end of line using contents of Y register as cursor position
\$FC42	CLREOP	Clears to bottom of window
\$F832	CLRSCR	Clears the low-resolution screen
\$F836	CLRTOP	Clears top 40 lines of low-resolution screen
\$FDED	COUT	Calls output routine whose address is stored in CSW (normally COUT1, Chapter 3)
\$FDF0	COUT1	Displays a character on the screen (Chapter 3)

Table 3-1 (continued) Monitor firmware routines

Location0	Name	Description
\$FD8E	CROUT	Generates a carriage return character
\$FD8B	CROUT1	Clears to end of line, then generates a carriage return character
\$FD6A	GETLN	Displays the prompt character; accepts a string of characters by means of RDKEY
\$F819	HLINE	Draws a horizontal line of blocks
\$FC58	HOME	Clears the window and puts cursor in upper-left corner of window
\$FD1B	KEYIN	With 80-column firmware inactive, displays checkerboard cursor; accepts character from keyboard
\$F800	PLOT	Plots a single low-resolution block on the screen
\$F94A	PRBL2	Sends 1 to 256 blank spaces to the output device
\$FDDA	PRBYTE	Prints a hexadecimal byte
\$FF2D	PRERR	Sends ERR and Control-G to the output device
\$FDE3	PRHEX	Prints 4 bits as a hexadecimal number
\$F941	PRNTAX	Prints contents of A and X in hexadecimal
\$FD0C	RDKEY	Displays blinking cursor; goes to standard input routine, normally KEYIN or BASICIN
\$F871	SCRN	Reads color value of a low-resolution block
\$F864	SETCOL	Sets the color for plotting in low resolution
\$FC24	VTABZ	Sets cursor vertical position
\$F828	VLINE	Draws a vertical line of low-resolution blocks

AUXMOVE and XFER are described in the section "Auxiliary-Memory Subroutines" in Chapter 4.

The standard I/O subroutines listed in Table 3-1 are fully described in this chapter. The Apple IIe firmware also contains many other subroutines that you might find useful. Those subroutines are described in Appendix B. Two of the built-in subroutines, AUXMOVE and XFER, can help you use the optional auxiliary memory.

Using the I/O subroutines

Before you use the standard I/O subroutines, you should understand a little about the way they are used. The Apple IIe firmware operates differently when an option such as an 80-column text card is used. This section describes general situations that affect the operation of the standard I/O subroutines. Specific instances are described in the sections devoted to the individual subroutines.

Apple II compatibility

Compared with older Apple II models, the Apple IIe has some additional keyboard and display features. To run programs that were written for the older models, you can make the Apple IIe resemble an Apple II Plus by turning those features off. The features that you can turn off and on to put the Apple IIe into and out of Apple II mode are listed in Table 3-2.

Table 3-2 Apple II mode

	Apple lie	Apple II mode
Keyboard	Uppercase and lowercase	Uppercase only
Display characters	Inverse and normal only	Flashing, inverse, and normal
Display size	40-column; also 80-column with optional card	40-column only

If the Apple IIe does not have an 80-column text card installed in the auxiliary slot, it is almost in Apple II mode as soon as you turn it on or reset it. One exception is the keyboard, which is both uppercase and lowercase.

Original Ile

On an original Apple IIe, statements in Integer BASIC, Applesoft, and DOS 3.3 commands must be typed in uppercase letters. To be compatible with older software, you should switch the Apple IIe keyboard to uppercase by pressing Caps Lock.

Another feature on the Apple IIe that differs from the Apple II is the displayed character set. An Apple II displays only uppercase characters, but it displays them in three ways: normal, inverse, and flashing. The Apple IIe can display uppercase characters all three ways, and it can display lowercase characters in the normal way. This combination is called the *primary character set*. When the Apple IIe is first turned on or reset, it displays the primary character set.

The primary and alternate character sets are described in Chapter 2 in the section "Text Character Sets."

The Apple IIe has another character set, called the *alternate* character set, that displays a full set of normal and inverse characters, with the inverse uppercase characters between \$40 and \$5F replaced on enhanced Apple IIe's with MouseText characters.

Original lie

In the original Apple IIe, uppercase inverse characters appear in place of the MouseText characters of the enhanced Apple IIe and the Apple IIc.

The ALTCHAR soft switch is described in Chapter 2.

You can switch character sets at any time by means of the ALTCHAR soft switch.

The 80-column firmware

There are a few features that are normally available only with the 80-column display. These features are identified in Table 3-3b and Table 3-6. The firmware that supports these features is built into the Apple IIe, but it is normally active only if an 80-column text card is installed in the auxiliary slot.

When you turn on power or reset the Apple IIe, the 80-column firmware is inactive and the Apple IIe displays the primary character set, even if an 80-column text card is installed. When you activate the 80-column firmware, it switches to the alternate character set.

The built-in 80-column firmware is implemented as if it were installed in expansion slot 3. Programs written for an Apple II or Apple II Plus with an 80-column text card installed in slot 3 usually will run properly on a Apple IIe with an 80-column text card in the auxiliary slot.

See the section "Switching I/O Memory" in Chapter 6 for details.

If the Apple IIe has an 80-column text card and you want to use the 80-column display, you can activate the built-in firmware from BASIC by typing PR#3.

To activate the 80-column firmware from the Monitor, press 3, then Control-P. Notice that this is the same procedure you use to activate a card in expansion slot 3. Any card installed in the auxiliary slot takes precedence over a card installed in expansion slot 3.

Important

Even though you activated the 80-column firmware by typing PR#3, you should never deactivate it by typing PR#0, because that just disconnects the firmware, leaving several soft switches still set for 80-column operation. Instead, press the sequence Escape-Q (see Table 3-6).

SLOTC3ROM is described in Chapter 6 in the section "Switching I/O Memory."

interrupts, see Chapter 6.

If there is no 80-column text card or other auxiliary memory card in your Apple IIe, you can still activate the 80-column firmware and use it with a 40-column display. First, set the SLOTC3ROM soft switch located at \$C00A (49162). Then type PR#3 to transfer control to the firmware.

For more information about

When the 80-column firmware is active without a card in the auxiliary slot, it does not work quite the same as it does with a card. The functions that clear the display (CLREOL, CLEOLZ, CLREOP, and HOME) work as if the firmware were inactive: they always clear to the current color. In addition, interrupts are supported only with a card installed in the auxiliary slot.

Warning

If you do not have an interface card in either the auxiliary slot or slot 3, don't try to activate the firmware with PR#3. Typing PR#3 with no card installed transfers control to the empty connector, with unpredictable results.

Programs activate the 80-column firmware by transferring control to address \$C300. If there is no card in the auxiliary slot, you must set the SLOTC3ROM soft switch first. To deactivate the 80-column firmware from a program, write a Control-U character via subroutine COUT.

The old monitor

Apple II's and Apple II Pluses used a version of the System Monitor different from the one the Apple IIe uses. It had the same standard I/O subroutines, but a few of the features were different; for example, there were no arrow keys for cursor motion. If you start the Apple IIe with a DOS or BASIC disk that loads Integer BASIC into the bank-switched area in RAM, the old Monitor (sometimes called the Autostart Monitor) is also loaded with it. When you type INT from Applesoft to activate Integer BASIC, you also activate this copy of the old Monitor, which remains active until you either type FP to switch back to Applesoft, which uses the new Monitor in ROM, or type PR#3 to activate the 80-column firmware. Part of the firmware's initialization procedure checks to see which version of the Monitor is in RAM. If it finds the old Monitor, it replaces it with a copy of the new Monitor from ROM. After the firmware has copied the new Monitor into RAM, it remains there until the next time you start up the system.

The standard I/O links

When you call one of the character I/O subroutines (COUT and RDKEY), the first thing that happens is an indirect jump to an address stored in programmable memory. Memory locations used for transferring control to other subroutines are sometimes called *vectors;* in this manual, the locations used for transferring control to the I/O subroutines are called **I/O links.** In a Apple IIe running without a disk operating system, each I/O link is normally the address of the body of the subroutine (COUT1 or KEYIN). If a disk operating system is running, one or both of these links hold the addresses of the corresponding DOS or ProDOS I/O routines instead. (DOS and ProDOS maintain their own links to the standard I/O subroutines.)

By calling the I/O subroutines that jump to the link addresses instead of calling the standard subroutines directly, you ensure that your program will work properly in conjunction with other software, such as DOS or a printer driver, that changes one or both of the I/O links.

For the purposes of this chapter, we shall assume that the I/O links contain the addresses of the standard I/O subroutines—COUT1 and KEYIN if the 80-column firmware is off, and BASICOUT and BASICIN if it is on.

For more information about the I/O links, see the section "Changing the Standard I/O Links" in Chapter 6.

Standard output features

The standard output routine is named COUT, pronounced "C-out," which stands for *character out*. COUT normally calls COUT1, which sends one character to the display, advances the cursor position, and scrolls the display when necessary. COUT1 restricts its use of the display to an active area called the *text window*, described below.

COUT output subroutine

Your program makes a subroutine call to COUT at memory location \$FDED with a character in the accumulator. COUT then passes control via the output link CSW to the current output subroutine, normally COUT1 (or BASICOUT), which takes the character in the accumulator and writes it out. If the accumulator contains an uppercase or lowercase letter, a number, or a special character, COUT1 displays it; if the accumulator contains a control character, COUT1 either performs one of the special functions described below or ignores the character.

Each time you send a character to COUT1, it displays the character at the current cursor position, replacing whatever was there, and then advances the cursor position one space to the right. If the cursor position is already at the right edge of the window, COUT1 moves it to the leftmost position on the next line down. If this would move the cursor position past the end of the last line in the window, COUT1 scrolls the display up one line and sets the cursor position at the left end of the new bottom line.

The cursor position is controlled by the values in memory locations 36 and 37 (hexadecimal \$24 and \$25). These locations are named CH, for cursor horizontal, and CV, for cursor vertical. COUT1 does not display a cursor, but the input routines described below do, and they use this cursor position. If some other routine displays a cursor, it will not necessarily put it in the cursor position used by COUT1.

Control characters with COUT1 and BASICOUT

COUT1 and BASICOUT do not display control characters. Instead, the control characters listed in Tables 3-3a and 3-3b are used to initiate some action by the firmware. Other control characters are ignored. Most of the functions listed here can also be invoked from the keyboard, either by typing the control character listed or by using the appropriate escape code, as described in the section "Escape Codes With KEYIN and BASICIN" later in this chapter. The stop-list function, described separately, can only be invoked from the keyboard.

Table 3-3a Control characters, 80-column firmware off

Control character	ASCII name	Apple lle name	Action taken by COUT1
Control-G	BEL	Bell	Produces a 1000 Hz tone for 0.1 second
Control-H	BS	Backspace	Moves cursor position one space to the left; from left edge of window, moves to right end of line above
Control-J	LF	Line feed	Moves cursor position down to next line in window, scrolls if needed
Control-M	CR	Return	Moves cursor position to left end of next line in window, scrolls if needed

Table 3-3b Control characters, 80-column firmware on

Control character	ASCII name	Apple IIe name	Action taken by BASICOUT
Control-G	BEL	Bell	Produces a 1000 Hz tone for 0.1 second
Control-H	BS	Backspace	Moves cursor position one space to the left, from left edge of window, moves to right end of line above

Table 3-3b (continued) Control characters, 80-column firmware on

Control character	ASCII name	Apple lie name	Action taken by BASICOUT
Control-J	LF	Line feed	Moves cursor position down to next line in window; scrolls if needed
Control-K*	VT	Clear EOS	Clears from cursor position to the end of the screen
Control-L*	FF	Home and clear	Moves cursor position to upper-left corner of window and clears window
Control-M	CR	Return	Moves cursor position to left end of next line in window, scrolls if needed
Control-N*	SO	Normal	Sets display format normal
Control-O*	SI	Inverse	Sets display format inverse
Control-Q*	DC1	40-column	Sets display to 40-column
Control-R*	DC2	80-column	Sets display to 80-column
Control-S†	DC3	Stop-list	Stops listing characters on the display until another key is pressed
Control-U*	NAK	Quit	Deactivates 80-column video firmware
Control-V*	SYN	Scroll	Scrolls the display down one line, leaving the cursor in the current position
Control-W*	ETB	Scroll-up	Scrolls the display up one line, leaving the cursor in the current position
Control-X	CAN	Disable MouseText	Disables MouseText character display; use inverse uppercase

Table 3-3b (continued) Control characters, 80-column firmware on

Control character	ASCII name	Apple lle name	Action taken by BASICOUT	
Control-Y*	ЕМ	Home	Moves cursor position to upper-left corner of window (but doesn't clear)	
Control-Z*	SUB	Clear line	Clears the line the cursor position is on	
Control-[ESC	Enable MouseText	Maps inverse uppercase characters to MouseText characters	
Control-*	FS	Forward space	Moves cursor position one space to the right, from right edge of window, moves it to left end of line below	
Control-]*	GS	Clear EOL	Clears from the current cursor position to the end of the line (that is, to the right edge of the window)	
Control	US	Up	Moves cursor up a line, no scroll	
* Doesn't work from the keyboard				

[†] Only works from the keyboard

The stop-list feature

When you are using any program that displays text via COUT1 (or BASICOUT), you can make it stop updating the display by holding down Control and pressing S. Whenever COUT1 gets a carriage return from the program, it checks to see if you have pressed Control-S. If you have, COUT1 stops and waits for you to press another key. When you want COUT1 to resume, press another key; COUT1 will send the carriage return it got earlier to the display, then continue normally. The character code of the key you pressed to resume displaying is ignored unless you pressed Control-C. COUT1 passes Control-C back to the program; if it is a BASIC program, this enables you to terminate the program while in stop-list mode.

The text window

After starting up the computer or after a reset, the firmware uses the entire display. However, you can restrict video activity to any rectangular portion of the display you wish. The active portion of the display is called the *text window*. COUT1 or BASICOUT puts characters into the window only; when it reaches the end of the last line in the window, it scrolls only the contents of the window.

You can set the top, bottom, left side, and width of the text window by storing the appropriate values into four locations in memory. This enables your programs to control the placement of text in the display and to protect other portions of the screen from being written over by new text.

Memory location 32 (hexadecimal \$20) contains the number of the leftmost column in the text window. This number is normally 0, the number of the leftmost column in the display. In a 40-column display, the maximum value for this number is 39 (hexadecimal \$27); in an 80-column display, the maximum value is 79 (hexadecimal \$4F).

Memory location 33 (hexadecimal \$21) holds the width of the text window. For a 40-column display, it is normally 40 (hexadecimal \$28); for an 80-column display, it is normally 80 (hexadecimal \$50).

Original Ile

COUT1 truncates the column width to an even value on the original Apple IIe.

Warning

On an original Apple IIe, be careful not to let the sum of the window width and the leftmost position in the window exceed the width of the display you are using (40 or 80). If this happens, it is possible for COUT1 to put characters into memory locations outside the display page, possibly into your current program or data space.

Memory location 34 (hexadecimal \$22) contains the number of the top line of the text window. This is normally 0, the topmost line in the display. Its maximum value is 23 (hexadecimal \$17).

Memory location 35 (hexadecimal \$23) contains the number of the bottom line of the screen, plus 1. It is normally 24 (hexadecimal \$18) for the bottom line of the display. Its minimum value is 1.

After you have changed the text window boundaries, nothing is affected until you send a character to the screen.

Warning

Any time you change the boundaries of the text window, you should make sure that the current cursor position (stored at CH and CV) is inside the new window. If it is outside, it is possible for COUT1 to put characters into memory locations outside the display page, possibly destroying programs or data.

Table 3-4 summarizes the memory locations and the possible values for the window parameters.

Table 3-4
Text window memory locations

			Mini		Normal values			Maximum values				
Window	Loc	ation		mum lue	40	col.	80	col.	40	col.	80	col.
Window parameter	Dec	Hex	Dec	Hex	Dec	Hex	Dec	Hex	Dec	Hex	Dec	Hex
Left edge	32	\$20	00	\$00	00	\$00	00	\$00	39	\$27	79	\$4F
Width	33	\$21	00	\$00	40	\$28	80	\$50	40	\$28	80	\$50
Top edge	34	\$22	00	\$00	00	\$00	00	\$00	23	\$17	23	\$17
Bottom edge	35	\$23	01	\$01	24	\$18	24	\$18	24	\$18	24	\$18

Table 3-5
Text format control values

Mask	value	
Dec	Hex	Display format
255	\$FF	Normal, uppercase, and lowercase
127	\$7F	Flashing, uppercase, and symbols
63	\$3F	Inverse, uppercase, and lowercase

Note: These mask values apply only to the primary character set (see text).

Inverse and flashing text

Subroutine COUT1 can display text in normal format, inverse format, or, with some restrictions, flashing format. The display format for any character in the display depends on two things: the character set being used at the moment, and the setting of the two high-order bits of the character's byte in the display memory.

As it sends your text characters to the display, COUT1 sets the high-order bits according to the value stored at memory location 50 (hexadecimal \$32). If that value is 255 (hexadecimal \$FF), COUT1 sets the characters to display in normal format; if the value is 63 (hexadecimal \$3F), COUT1 sets the characters to inverse format. If the value is 127 (hexadecimal \$7F) and if you have selected the primary character set, the characters will be displayed in flashing format. Note that flashing format is not available in the alternate character set.

To control the display format of the characters, routine COUT1 uses the value at location 50 as a logical mask to force the setting of the two high-order bits of each character byte it puts into the display page. It does this by performing the logical AND function on the data byte and the mask byte. The result byte contains a 0 in any bit that was 0 in the mask. BASICOUT, used when the 80-column firmware is active, changes only the high-order bit of the data.

Important

If the 80-column firmware is inactive and you store a mask value at location 50 with zeros in its low-order bits, COUT1 will mask out those bits in your text. As a result, some characters will be transformed into other characters. You should set the mask to the values given in Table 3-5 only.

Switching between character sets is described in the section "Display Mode Switching" in Chapter 2.

If you set the mask value at location 50 to 127 (hexadecimal \$7F), the high-order bit of each result byte will be 0, and the characters will be displayed either as lowercase or as flashing, depending on which character set you have selected. Refer to the tables of display character sets in Chapter 2. In the primary character set, the next-highest bit, bit 6, selects flashing format with uppercase characters. With the primary character set you can display lowercase characters in normal format and uppercase characters in normal, inverse, and flashing formats. In the alternate character set, bit 6 selects lowercase or special characters. With the alternate character set you can display uppercase and lowercase characters in normal and inverse formats.

Original lie

On the original Apple IIe, the MouseText characters are replaced by uppercase inverse characters.

Standard input features

The Apple IIe's firmware includes two different subroutines for reading from the keyboard. One subroutine is named RDKEY, which stands for *read key*. It calls the standard character input subroutine KEYIN (or BASICIN when the 80-column firmware in active), which accepts one character at a time from the keyboard.

For more information on GETLN, see the section "Editing With GETLN" later in this chapter.

The other subroutine is named GETLN, which stands for *get line*. By making repeated calls to RDKEY, GETLN accepts a sequence of characters terminated with a carriage return. GETLN also provides on-screen editing features.

RDKEY input subroutine

A program gets a character from the keyboard by making a subroutine call to RDKEY at memory location \$FDOC. RDKEY sets the character at the cursor position to flash, then passes control via the input link KSW to the current input subroutine, which is normally KEYIN or BASICIN.

RDKEY displays a cursor at the current cursor position, which is immediately to the right of whatever character you last sent to the display (normally by using the COUT routine, described earlier). The cursor displayed by RDKEY is a flashing version of whatever character happens to be at that position on the screen. It is usually a space, so the cursor appears as a blinking rectangle.

KEYIN input subroutine

KEYIN is the standard input subroutine when the 80-column firmware is inactive; BASICIN is used when the 80-column firmware is active. When called, the subroutine waits until the user presses a key, then returns with the key code in the accumulator.

If the 80-column firmware is inactive, KEYIN displays a cursor by alternately storing a checkerboard block in the cursor location, then storing the original character, then the checkerboard again. If the firmware is active, BASICIN displays a steady inverse space (rectangle), unless you are in escape mode, when it displays a plus sign (+) in inverse format.

KEYIN also generates a random number. While it is waiting for the user to press a key, KEYIN repeatedly increments the 16-bit number in memory locations 78 and 79 (hexadecimal \$4E and \$4F). This number keeps increasing from 0 to 65535, then starts over again at 0. The value of this number changes so rapidly that there is no way to predict what it will be after a key is pressed. A program that reads from the keyboard can use this value as a random number or as a seed for a random-number routine.

When the user presses a key, KEYIN accepts the character, stops displaying the cursor, and returns to the calling program with the character in the accumulator.

Escape mode is described in the next section, "Escape Codes."

Escape codes with KEYIN and BASICIN

KEYIN has special functions that you invoke by typing escape codes on the keyboard. An escape code is obtained by pressing Escape, releasing it, and then pressing some other key. See Table 3-6; the notation in the table means press Escape, release it, then press the key that follows.

Table 3-6 includes three sets of cursor-control keys. The first set consists of Escape followed by A, B, C, or D. The letter keys can be either uppercase or lowercase. These keys are the standard cursormotion keys on older Apple II models; they are present on the Apple IIe primarily for compatability with programs written for old machines.

Cursor motion in escape mode

The second and third sets of cursor-control keys are listed together because they activate escape mode. In escape mode, you can keep using the cursor-motion keys without pressing Escape again. This enables you to perform repeated cursor moves by holding down the appropriate key.

When the 80-column firmware is active, you can tell when BASICIN is in escape mode: it displays a plus sign in inverse format as the cursor. You leave escape mode by typing any key other than a cursor-motion key.

The escape codes with the directional arrow keys are the standard cursor-motion keys on the Apple IIe. The escape codes with the I, J, K, and M keys are the standard cursor-motion keys on the Apple II Plus, and are present on the Apple IIe for compatability with the Apple II Plus. On the Apple IIe, the escape codes with the I, J, K, and M keys function with either uppercase or lowercase letters.

Table 3-6 Escape codes

Escape code	Function
Escape @	Clears window and homes cursor (places it in upper-left corner of screen), then exits from escape mode
Escape A or a	Moves cursor right one line; exits from escape mode
Escape B or b	Moves cursor left one line; exits from escape mode

Table 3-6 (continued) Escape codes

Escape code	Function
Escape C or c	Moves cursor down one line; exits from escape mode
Escape D or d	Moves cursor up one line; exits from escape mode
Escape E or e	Clears to end of line; exits from escape mode
Escape F or f	Clears to bottom of window; exits from escape mode
Escape I or i or Escape Up Arrow	Moves the cursor up one line; remains in escape mode (see text)
Escape J or j or Escape Left Arrow	Moves the cursor left one space; remains in escape mode (see text)
Escape K or k or Escape Right Arrow	Moves the cursor right one space; remains in escape mode (see text)
Escape M or m or Escape Down Arrow	Moves the cursor down one line; remains in escape mode (see text)
Escape 4	If 80-column firmware is active, switches to 40-column mode; sets links to BASICIN and BASICOUT; restores normal window size; exits from escape mode
Escape 8	If 80-column firmware is active, switches to 80-column mode; sets links to BASICIN and BASICOUT; restores normal window size; exits from escape mode
Escape Control-D	Disables control characters; only carriage return, line feed, BELL, and backspace have an effect when printed
Escape Control-E	Reactivates control characters
Escape Control-Q	If 80-column firmware is active, deactivates 80-column firmware; sets links to KEYIN and COUT1; restores normal window size; exits from escape mode

GETLN input subroutine

Programs often need strings of characters as input. While it is possible to call RDKEY repeatedly to get several characters from the keyboard, there is a more powerful subroutine you can use. This routine is named GETLN, which stands for *get line*, and it starts at location \$FD6A. Using repeated calls to RDKEY, GETLN accepts characters from the standard input subroutine—usually KEYIN—and puts them into the input buffer located in the memory page from \$200 to \$2FF. GETLN also provides the user with onscreen editing and control features, described in the next section, "Editing With GETLN."

The first thing GETLN does when you call it is display a prompting character, called simply a **prompt.** The prompt indicates to the user that the program is waiting for input. Different programs use different prompt characters, helping to remind the user which program is requesting the input. For example, an INPUT statement in a BASIC program displays a question mark (?) as a prompt. The prompt characters used by the different programs on the Apple IIe are shown in Table 3-7.

GETLN uses the character stored at memory location 51 (hexadecimal \$33) as the prompt character. In an assembly-language program, you can change the prompt to any character you wish. In BASIC, changing the prompt character has no effect, because both BASIC interpreters and the Monitor restore it each time they request input from the user.

As you type the character string, GETLN sends each character to the standard output routine—normally COUT1—which displays it at the previous cursor position and puts the cursor at the next available position on the display, usually immediately to the right. As the cursor travels across the display, it indicates the position where the next character will be displayed.

GETLN stores the characters in its buffer, starting at memory location \$200 and using the X register to index the buffer. GETLN continues to accept and display characters until you press Return; then it clears the remainder of the line the cursor is on, stores the carriage-return code in the buffer, sends the carriage-return code to the display, and returns to the calling program.

Table 3-7
Prompt characters

Prompt character	Program requesting input
?	User's BASIC program (INPUT statement)
]	Applesoft BASIC (Appendix D)
>	Integer BASIC (Appendix D)
*	Firmware Monitor (Chapter 5)

The maximum line length that GETLN can handle is 255 characters. If the user types more than this, GETLN sends a backslash (\) and a carriage return to the display, cancels the line it has accepted so far, and starts over. To warn the user that the line is getting full, GETLN sounds a bell (tone) at every keypress after the 248th.

Important

In the Apple II and the Apple II Plus, the GETLN routine converts all inputs to uppercase. GETLN in the Apple IIe does not do this, even in Apple II mode. To get uppercase input for BASIC, use Caps Lock.

Editing with GETLN

Subroutine GETLN provides the standard on-screen editing features used by the BASIC interpreters and the Monitor. For an introduction to editing with these features, refer to the *Applesoft Tutorial*. Any program that uses GETLN for reading the keyboard has these features.

Cancel line

Any time you are typing a line, pressing Control-X causes GETLN to cancel the line. GETLN displays a backslash (\) and issues a carriage return, then displays the prompt and waits for you to type a new line. GETLN takes the same action when you type more than 255 characters, as described earlier.

Backspace

When you press Left Arrow, GETLN moves its buffer pointer back one space, effectively deleting the last character in its buffer. It also sends a backspace character to routine COUT, which moves the display position and the cursor back one space. If you type another character now, it will replace the character you backspaced over, both on the display and in the line buffer. Each time you press Left Arrow, it moves the cursor left and deletes another character, until you reach the beginning of the line. If you then press Left Arrow one more time, you have cancelled the line, and GETLN issues a carriage return and displays the prompt.

Retype

Right Arrow has a function complementary to the backspace function. When you press Right Arrow, GETLN picks up the character at the display position just as if it had been typed on the keyboard. You can use this procedure to pick up characters that you have just deleted by backspacing across them. You can use the backspace and retype functions with the cursor-motion functions to edit data on the display. (See the earlier section "Cursor Motion in Escape Mode.")

Monitor firmware support

Table 3-8 summarizes the addresses and functions of the video display support routines the Monitor provides. These routines are described in the subsections that follow.

Table 3-8 Video firmware routines

Location	Name	Description
\$C307	BASICOUT	Displays a character on the screen when 80-column firmware is active
\$FC9C	CLREOL	Clears to end of line from current cursor position
\$FC9E	CLEOLZ	Clears to end of line using contents of Y register as cursor position
\$FC42	CLREOP	Clears to bottom of window
\$F832	CLRSCR	Clears the low-resolution screen
\$F836	CLRTOP	Clears top 40 lines of low-resolution screen
\$FDED	COUT	Calls output routine whose address is stored in CSW (normally COUT1, Chapter 3)
\$FDF0	COUT1	Displays a character on the screen (Chapter 3)
\$FD8E	CROUT	Generates a carriage return character
\$FD8B	CROUT1	Clears to end of line, then generates a carriage return character

Table 3-8 (continued) Video firmware routines

Location	Name	Description
\$F819	HLINE	Draws a horizontal line of blocks
\$FC58	HOME	Clears the window and puts cursor in upper-left corner of window
\$F800	PLOT	Plots a single low-resolution block on the screen
\$F94A	PRBL2	Sends 1 to 256 blank spaces to the output device whose address is in CSW
\$FDDA	PRBYTE	Prints a hexadecimal byte
\$FF2D	PRERR	Sends ERR and Control-G to the output device whose output routine address is in CSW
\$FDE3	PRHEX	Prints 4 bits as a hexadecimal number
\$F941	PRNTAX	Prints contents of A and X in hexadecimal
\$F871	SCRN	Reads color value of a low-resolution block on the screen
\$F864	SETCOL	Sets the color for plotting in low resolution
\$FC24	VTABZ	Sets cursor vertical position (Setting CV at location \$25 does not change vertical positon until a carriage return.)
\$F828	VLINE	Draws a vertical line of low-resolution blocks

BASICOUT, \$C307

BASICOUT is essentially the same as COUT1—BASICOUT is used instead of COUT1 when the 80-column firmware is active.
BASICOUT displays the character in the accumulator on the display screen at the current cursor position and advances the cursor. It places the character using the setting of the inverse mask (location \$32). BASICOUT handles control characters; see Table 3-3b. When it returns control to the calling program, all registers are intact.

CLREOL, \$FC9C

CLREOL clears a text line from the cursor position to the right edge of the window. This routine destroys the contents of A and Y.

CLEOLZ, \$FC9E

CLEOLZ clears a text line to the right edge of the window, starting at the location given by base address BASL, which is indexed by the contents of the Y register. This routine destroys the contents of A and Y.

CLREOP, \$FC42

CLREOP clears the text window from the cursor position to the bottom of the window. This routine destroys the contents of A and Y.

CLRSCR, \$F832

CLRSCR clears the low-resolution graphics display to black. If you call this routine while the video display is in text mode, it fills the screen with inverse-mode at-sign (@) characters. This routine destroys the contents of A and Y.

CLRTOP, \$F836

CLRTOP is the same as CLRSCR, except that it clears only the top 40 rows of the low-resolution display.

COUT, SFDED

COUT calls the current character output subroutine. (See the section "COUT Output Subroutine" earlier in this chapter.) The character to be sent to the output device should be in the accumulator. COUT calls the subroutine whose address is stored in CSW (locations \$36 and \$37), which is usually the standard character output subroutine COUT1 (or BASICOUT).

COUT1, \$FDF0

COUT1 displays the character in the accumulator on the display screen at the current cursor position and advances the cursor. It places the character using the setting of the inverse mask (location \$32). It handles these control characters: carriage return, line feed, backspace, and bell. When it returns control to the calling program, all registers are intact.

See the section "Control Characters With COUT1 and BASICOUT" earlier in this chapter for more information on COUT1.

CROUT, \$FD8E

CROUT sends a carriage return to the current output device.

CROUT1, \$FD8B

CROUT1 clears the screen from the current cursor position to the edge of the text window, then calls CROUT.

HLINE, \$F819

HLINE draws a horizontal line of blocks of the color set by SETCOL on the low-resolution graphics display. Call HLINE with the vertical coordinate of the line in the accumulator, the leftmost horizontal coordinate in the Y register, and the rightmost horizontal coordinate in location \$2C. HLINE returns with A and Y scrambled and X intact.

HOME, \$FC58

HOME clears the display and puts the cursor in the upper-left corner of the screen.

PLOT, \$F800

PLOT puts a single block of the color value set by SETCOL on the low-resolution display screen. Call PLOT with the vertical coordinate of the line in the accumulator, and its horizontal position in the Y register. PLOT returns with the accumulator scrambled, but X and Y intact.

PRBL2, \$F94A

PRBL2 sends from 1 to 256 blanks to the standard output device. Upon entry, the X register should contain the number of blanks to send. If X = \$00, then PRBLANK will send 256 blanks.

PRBYTE, \$FDDA

PRBYTE sends the contents of the accumulator in hexadecimal to the current output device. The contents of the accumulator are scrambled.

PRERR, \$FF2D

PRERR sends the word ERR, followed by a bell character, to the standard output device. On return, the accumulator is scrambled.

PRHEX, \$FDE3

PRHEX prints the lower nibble of the byte in the accumulator as a single hexadecimal digit. On return, the contents of the accumulator are scrambled.

PRNTAX, \$F941

PRNTAX prints the contents of the A and X registers as a four-digit hexadecimal value. The accumulator contains the first byte printed, taband the X register contains the second. On return, the contents of the accumulator are scrambled.

SCRN, \$F871

SCRN returns the color value of a single block on the low-resolution display. Call it with the vertical position of the block in the accumulator and the horizontal position in the Y register. The block's color is returned in the accumulator. No other registers are changed.

SETCOL, \$F864

SETCOL sets the color used for plotting in low-resolution graphics to the value passed in the acumulator. The colors and their values are listed in Table 2-6.

VTABZ, \$FC24

VTABZ sets the cursor vertical position. Unlike setting the position at location \$25, change of cursor position doesn't wait until a carriage return character has been sent.

VLINE, \$F828

VLINE draws a vertical line of blocks of the color set by SETCOL on the low-resolution display. Call VLINE with the horizontal coordinate of the line in the Y register, the top vertical coordinate in the accumulator, and the bottom vertical coordinate in location \$2D. VLINE returns with the accumulator scrambled

I/O firmware support

Apple IIe video firmware conforms to the I/O firmware protocol of Apple II Pascal 1.1. However, it does not support windows other than the full 80-by-24 window in 80-column mode, and the full 40-by-24 window in 40-column mode. The video protocol table is shown in Table 3-9.

Table 3-9 Slot 3 firmware protocol table

Address	Value	Description
\$C30B \$C30C \$C30D \$C30E \$C30F	\$01 \$88	Generic signature byte of firmware cards. 80-column card device signature. \$C3ii is entry point of initialization routine (PINIT). \$C3rr is entry point of read routine (PREAD). \$C3ww is entry point of write routine (PWRITE). \$C3ss is entry point of the status routine

PINIT, \$C30D

PINI	T doe	s the	foll	owing:

- □ sets a full 80-column window
- □ sets 80STORE (\$C001)
- □ sets 80COL (\$C00D)
- □ switches on ALTCHAR (\$C00F)
- □ clears the screen; places cursor in upper-left corner
- □ displays the cursor

PREAD, \$C30E

PREAD reads a character from the keyboard and places it in the accumulator with the high bit cleared. It also puts a zero in the X register to indicate IORESULT = GOOD.

PWRITE, \$C30F

PWRITE should be called after placing a character in the accumulator with its high bit cleared. PWRITE does the following:

- □ It turns the cursor off.
- ☐ If the character in the accumulator is not a control character, it turns the high bit on for normal display or off for inverse display, displays it at the current cursor position, and advances the cursor. If the character at the end of a line, PWRITE does carriage return but not line feed. (See Table 3-10 for control character functions.)

When PWRITE has completed this, it

- □ turns the cursor back on (if it was not intentionally turned off)
- □ puts a zero in the X register (IORESULT = GOOD) and returns to the calling program

Table 3-10
Pascal video control functions

Control-	Hex	Function performed
E or e	\$05	Turns cursor on (enables cursor display)
F or f	\$06	Turns cursor off (disables cursor display)
G or g	\$07	Sounds bell (beeps)
H or h	\$08	Moves cursor left one column. If cursor was at beginning of line, moves it to end of preceding line
J or j	\$0A	Moves cursor down one row; scrolls if needed
K or k	\$0B	Clears to end of screen
L or l	\$0C	Clears screen; moves cursor to upper-left of screen
M or m	\$0D	Moves cursor to column 0
N or n	\$0E	Displays subsequent characters in normal video (Characters already on display are unaffected.)
O or o	\$ 0F	Displays subsequent characters in inverse video (Characters already on display are unaffected.)
V or v	\$ 16	Scrolls screen up one line; clears bottom line
W or w	\$17	Scrolls screen down one line; clears top line
Y or y	\$19	Moves cursor to upper-left (home) position on screen
Z or z	\$1A	Clears entire line that cursor is on
l or \	\$1C	Moves cursor right one column; if at end of line, does Control-M
} or]	\$1D	Clears to end of the line the cursor is on, including current cursor position; does not move cursor
^ or 6	\$1E	GOTOxy: initiates a GOTOxy sequence; interprets the next two characters as x+32 and y+32, respectively
-	\$1F	If not at top of screen, moves cursor up one line

PSTATUS, \$C310

A program that calls PSTATUS must first put a request code in the accumulator: either a 0, meaning "Ready for output?" or a 1, meaning "Is there any input?" PSTATUS returns with the reply in the carry bit: 0 (No) or 1 (Yes).

PSTATUS returns with a 0 in the X register (IORESULT = GOOD), unless the request was not 0 or 1; then PSTATUS returns with a 3 in the X register (IORESULT = ILLEGAL OPERATION).

Chapter 4

Memory Organization

For information about these shared address spaces, see the section "Bank-Switched Memory" in this chapter and the sections "Other Uses of I/O Memory Space" and "Expansion ROM Space" in Chapter 6.

For details of the built-in I/O feature, refer to the descriptions in Chapters 2 and 3.

For information about I/O operations with peripheral cards, refer to Chapter 6.

The Apple IIe's microprocessor can address 65,536 (64K) locations in memory. All of the Apple IIe's RAM, ROM, and I/O devices are allocated locations in this 64K address range. Because each device or function requires a certain block of memory, there are more devices and functions than there are legal addresses, which means that the legal addresses must be shared. This sharing is accomplished through a technique called *bank-switching*, which is explained under the "Bank-Switched Memory" and "Auxiliary Memory and Firmware" sections in this chapter.

All input and output in the Apple IIe is *memory mapped*. This means that all devices connected to the Apple IIe appear to be a set of memory locations to the computer. In this chapter, the I/O memory spaces are described simply as blocks of memory.

Programmers often refer to the Apple IIe's memory in 256-byte blocks called **pages**. One reason for this is that a one-byte address counter or index register can specify one of 256 different locations. Thus, *page 0* consists of memory locations from 0 to 255 (hexadecimal \$00 to \$FF), inclusive; *page 1* consists of locations 256 to 511 (hexadecimal \$0100 to \$01FF). Note that the page number is the high-order part of the hexadecimal address. Don't confuse this kind of page with the display buffers in the Apple IIe, which are sometimes referred to as *Page 1* and *Page 2*.

Main memory map

The map of the main memory address space in Figure 4-1 shows the functions of the major areas of memory. For more details on the I/O space from 48K to 52K (\$C000 through \$CFFF), refer to Chapter 2 and Chapter 6; the bank-switched memory in the memory space from 52K to 64K (\$D000 through \$FFFF) is described in the section "Bank-Switched Memory" later in this chapter.

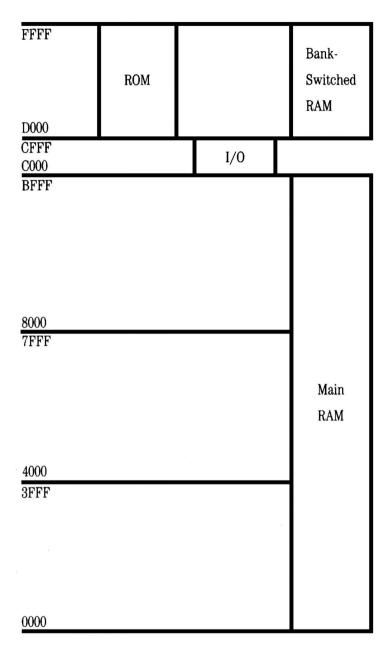


Figure 4-1 System memory map

RAM memory allocation

As Figure 4-1 shows, the largest portion of the Apple IIe's memory space is allocated to programmable storage (RAM). Figure 4-2 shows the areas allocated to RAM. The main RAM memory extends from location 0 to location 49151 (hex \$BFFF), and occupies pages 0 through 191 (hexadecimal \$BF). There is also RAM storage in the bank-switched space from 53248 to 65535 (hexadecimal \$D000 to \$FFFF), described in the section "Bank-Switched Memory" later in this chapter, and auxiliary RAM, described in the section "Auxiliary Memory and Firmware" later in this chapter.

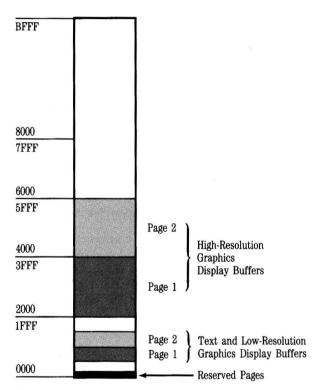


Figure 4-2 RAM allocation map

Reserved memory pages

Most of the Apple IIe's RAM is available for storing your programs and data. However, a few RAM pages are reserved for the use of the Monitor firmware and the BASIC interpreters. The reserved pages are described in the following sections.

Important

The system does not prevent your using these pages, but if you do use them, you must be careful not to disturb the system data they contain, or you will cause the system to malfunction.

Page zero

Several of the 65C02 microprocessor's addressing modes require the use of addresses in *page zero*, also called **zero page**. The Monitor, the BASIC interpreters, DOS 3.3, and ProDOS all make extensive use of page zero.

To use indirect addressing in your assembly-language programs, you must store base addresses in page zero. At the same time, you must avoid interfering with the other programs that use page zero—the Monitor, the BASIC interpreters, and the disk operating systems. One way to avoid conflicts is to use only those page-zero locations not already used by other programs. Tables 4-1 through 4-5 show the locations in page zero used by the Monitor, Applesoft BASIC, Integer BASIC, DOS 3.3, and ProDOS.

As you can see from the tables, page zero is pretty well used up, except for a few bytes here and there. It's hard to find more than one or two bytes that aren't used by BASIC, ProDOS, the Monitor, or DOS. Rather than trying to squeeze your data into an unused corner, you may prefer a safer alternative: save the contents of part of page zero, use that part, then restore the previous contents before you pass control to another program.

The 65C02 stack

The 65C02 microprocessor uses page 1 as the **stack**—the place where subroutine return addresses are stored—in last-in, first-out sequence. Many programs also use the stack for temporary storage of the registers (via push and pull operations). You can do the same, but you should use it sparingly. The stack pointer is eight bits long, so the stack can hold only 256 bytes of information at a time. When you store the 257th byte in the stack, the stack pointer repeats itself, or wraps around, so that the new byte replaces the first byte stored, which is now lost. This writing over old data is called *stack overflow*, and when it happens, the program continues to run normally until the lost information is needed, whereupon the program terminates catastrophically.

The input buffer

The GETLN input routine, which is used by the Monitor and the BASIC interpreters, uses page 2 as its keyboard-input buffer. The size of this buffer sets the maximum size of input strings. (Applesoft uses only the first 237 bytes, although it permits you to type in 256 characters.) If you know that you won't be typing any long input strings, you can store temporary data at the upper end of page 2.

Link-address storage

The Monitor, ProDOS, and DOS 3.3 all use the upper part of page 3 for link addresses or vectors.

BASIC programs sometimes need short machine-language routines. These routines are usually stored in the lower part of page 3.

The display buffers

The primary text and low-resolution-graphics display buffer occupies memory pages 4 through 7 (locations 1024 through 2047, hexadecimal \$0400 through \$07FF). This entire 1024-byte area is called *text Page 1*, and it is not usable for program and data storage. There are 64 locations in this area that are not displayed on the screen; these locations are reserved for use by the peripheral cards.

For more information about links, see the section "Changing the Standard I/O Links" in Chapter 6.

See Chapter 6 for information on the memory locations that are reserved for peripheral cards. Text Page 2, the alternate text and low-resolution-graphics display buffer, occupies memory pages 8 through 11 (locations 2048 through 3071, hexadecimal \$0800 through \$0BFF). Most programs do not use Page 2 for displays, so they can use this area for program or data storage.

The primary high-resolution-graphics display buffer, called *high-resolution Page 1*, occupies memory pages 32 through 63 (locations 8192 through 16383, hexadecimal \$2000 through \$3FFF). If your program doesn't use high-resolution graphics, this area is usable for programs or data.

High-resolution Page 2 occupies memory pages 64 through 95 (locations 16384 through 24575, hexadecimal \$4000 through \$5FFF). Most programs use this area for program or data storage.

The primary double high-resolution-graphics display buffer, called double high-resolution Page 1, occupies memory pages 32 through 63 (locations 8192 through 16383, hexadecimal \$2000 through \$3FFF) in both main and auxiliary memory. If your program doesn't use high-resolution or double high-resolution graphics, this area of main memory is usable for programs or data.

Table 4-1 Monitor zero-page use

High nibble	Low nibble of address															
of address	\$0	\$1	\$1 \$2 \$3 \$4 \$5 \$6 \$7 \$8 \$9 \$A								\$В	B \$C \$D \$E \$				
\$00																
\$10																• 1
\$20	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
\$30	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
\$40	•	•	•	•	•	•	•	•	•	•					•	•
\$50	•	•	•	•	•	•										
\$60																
\$70																
\$80																
\$90																
\$A0																
\$B0																
\$C0																
\$D0																
\$E0																
\$FO																

Byte used in original Apple IIe ROMs, now free

For more information about the display buffers, see the section "Video Display Pages" in Chapter 2.

Table 4-2 Applesoft zero-page use

High nibble	Low nibble of address															
of address	\$0	\$1	\$2	\$3	\$4	\$5	\$6	\$7	\$8	\$9	\$A	\$В	\$C	\$D	\$E	\$F
\$00	•	•	•	•	•	•					•	•	•	•	•	•
\$10	•	•	•	•	•	•	•	•	•	•	•	•	•	•		
\$20							•	•					•	•		•
\$30	•		•	•									•	•	•	•
\$40																
\$50	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
\$60	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
\$70	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
\$80	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
\$90	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
\$A0	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
\$B0	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
\$C0	•	•	•	•	•	•	•	•	•	•	•	•	•	•		
\$D0	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•
\$E0	•	•	•	•	•	•	•	•	•	•	•					
\$F0	•	•	•	•	•	•	•	•	•	•						•

Table 4-3Integer BASIC zero-page use

High nibble	Low nibble of address															
of address	\$0	\$1	\$2	\$3	\$4	\$5	\$6	\$7	\$8	\$9	\$A	\$В	\$C	\$D	\$E	\$F
\$00														•		
\$10																
\$20																
\$30																
\$40											•	•	•	•		
\$50						•	•	•	•	•	•	•	•	•	•	•
\$60	•	•	•	•	,•	•	•	•	•	•	•	•	•	•	•	•
\$70	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
\$80	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
\$90	•	•	,•	•	•	٠	•	•	•	•	•	•	•	•	•	•
\$A0	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
\$B0	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
\$C0	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
\$D0	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
\$E0																
\$F0															•	•

Table 4-4 DOS 3.3 zero-page use

High nibble						Low	/ nik	ble	of (add	ress					
of address	\$0	\$1	\$2	\$3	\$4	\$5	\$6	\$7	\$8	\$9	\$A	\$В	\$C	\$D	\$E	\$F
\$00																
\$10																
\$20							•	•			•	•	•	•	•	•
\$30						•	•	•	•	•					•	•
\$40	•	•	•	•	•	•	•	•	•		•	•	•	•		
\$50																
\$60								•	•	•	•					•
\$70	•															
\$80																
\$90																
\$A0																•
\$B0	•															
\$C0											•	•	•	•		
\$D0									•							
\$E0																
\$F0																

Table 4-5ProDOS MLI and disk-driver zero-page use

High nibble						Low	nik	ble	of (add	ress					
of address	\$0	\$1	\$2	\$3	\$4	\$5	\$6	\$7	\$8	\$9	\$A	\$B	\$C	\$D	\$E	\$F
\$00	•	•														
\$10																
\$20																
\$30											•	•	•	•	•	•
\$40	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
\$50																
\$60																
\$70																
\$80																
\$90																
\$A0																
\$B0																
\$C0																
\$D0																
\$E0																
\$F0																

Bank-switched memory

The memory address space from 52K to 64K (hexadecimal \$D000 through \$FFFF) is doubly allocated: it is used for both ROM and RAM. The 12K bytes of ROM (read-only memory) in this address space contain the Monitor and the Applesoft BASIC interpreter. Alternatively, there are 16K bytes of RAM in this space. The RAM is normally used for storing either the Integer BASIC interpreter or part of the Pascal Operating System (purchased separately).

You may be wondering why this part of memory has such a split personality. Some of the reasons are historical: the Apple IIe is able to run software written for the Apple II and Apple II Plus because it uses this part of memory in the same way they do. It's convenient to have the Applesoft interpreter in ROM, but the Apple IIe, like an Apple II with a language card, is also able to use that address space for other things when Applesoft is not needed.

You may also be wondering how 16K bytes of RAM are mapped into only 12K bytes of address space. The usual answer is that it's done with mirrors, and that isn't a bad analogy: the 4K-byte address space from 52K to 56K (hexadecimal \$D000 through \$DFFF) is used twice.

Switching different blocks of memory into the same address space is called *bank switching*. There are actually two examples of bank switching going on here: first, the entire address space from 52K to 64K (\$D000 through \$FFFF) is switched between ROM and RAM, and second, the address space from 52K to 56K (\$D000 to \$DFFF) is switched between two different blocks of RAM.

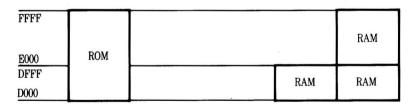


Figure 4-3 Bank-switched memory map

Setting bank switches

You switch banks of memory in the same way you switch other functions in the Apple IIe: by using soft switches. Read operations to these soft switches do three things: select either RAM or ROM in this memory space; enable or inhibit writing to the RAM; and select the first or second 4K-byte bank of RAM in the address space \$D000 to \$DFFF.

Warning

Do not use these switches without careful planning. Careless switching between RAM and ROM is almost certain to have catastrophic effects on your program.

Table 4-6 shows the addresses of the soft switches for enabling all combinations of reading and writing in this memory space. All of the hexadecimal values of the addresses are of the form \$C08x. Notice that several addresses perform the same function: this is because the functions are activated by single address bits. For example, any address of the form \$C08x with a 1 in the low-order bit enables the RAM for writing. Similarly, bit 3 of the address selects which 4K block of RAM to use for the address space \$D000-\$DFFF; if bit 3 is 0, the first bank of RAM is used, and if bit 3 is 1, the second bank is used.

When RAM is not enabled for reading, the ROM in this address space is enabled. Even when RAM is not enabled for reading, it can still be written to if it is write-enabled.

When you turn power on or reset the Apple IIe, it initializes the bank switches for reading the ROM and writing the RAM, using the second bank of RAM. Note that this is different from the reset on the Apple II Plus, which didn't affect the bank-switched memory (the language card). On the Apple IIe, you can't use the reset vector to return control to a program in bank-switched memory, as you could on the Apple II Plus.

Reset with Integer BASIC: When you are using Integer BASIC on the Apple IIe, reset works correctly, restarting BASIC with your program intact. This happens because the reset vector transfers control to DOS, and DOS resets the switches for the current version of BASIC.

Table 4-6
Bank select switches

Name	Action	Hex	Function
	R	\$C080	Read RAM; no write; use \$D000 bank 2.
	RR	\$C081	Read ROM; write RAM; use \$D000 bank 2.
	R	\$C082	Read ROM; no write; use \$D000 bank 2.
	RR	\$C083	Read and write RAM; use \$D000 bank 2.
	R	\$C088	Read RAM; no write; use \$D000 bank 1.
	RR	\$C089	Read ROM; write RAM; use \$D000 bank 1.
	R	\$C08A	Read ROM; no write; use \$D000 bank 1.
	RR	\$C08B	Read and write RAM; use \$D000 bank 1.
RDBNK2	R7	\$C011	Read whether \$D000 bank 2 (1) or bank 1 (0).
RDLCRAM	R7	\$C012	Reading RAM (1) or ROM (0).
ALTZP	W	\$C008	Off: use main bank, page 0 and page 1.
ALTZP	W	\$C009	On: use auxiliary bank, page 0 and page 1.
RDALTZP	R7	\$C016	Read whether auxiliary (1) or main (0) bank.

Note: R means read the location, W means write anything to the location, R/W means read or write, and R7 means read the location and then check bit 7.

Reading and writing to RAM banks: You can't read one RAM bank and write to the other; if you select either RAM bank for reading, you get that one for writing as well.

♦ Reading RAM and ROM: You can't read from ROM in part of the bank-switched memory and read from RAM in the rest: specifically, you can't read the Monitor in ROM while reading bank-switched RAM. If you want to use the Monitor firmware with a program in bank-switched RAM, copy the Monitor from ROM (locations \$F800 through \$FFCB) into bank-switched RAM. You can't do this from Pascal or ProDOS.

To see how to use these switches, look at the following section of an assembly-language program:

ΑD	83	C0	LDA	\$C083	*SELECT 2ND 4K BANK & READ/WRITE
ΑD	83	C0	LDA	\$C083	*BY TWO CONSECUTIVE READS
A9	D0		LDA	#\$D0	*SET UP
85	01		STA	BEGIN	*NEW
Α9	FF		LDA	#\$FF	*MAIN-MEMORY
85	02		STA	END	*POINTERS
20	97	C9	JSR	RAMTST	*FOR 12K BANK
AD	8B	C0	LDA	\$C08B	*SELECT 1ST 4K BANK
20	97	C9	JSR	RAMTST	*USE ABOVE POINTERS
AD	83	CO	LDA	\$C088	*SELECT 1ST BANK & WRITE PROTECT
Α9	80		LDA	#\$80	
E6	10		INC	TSTNUM	
20	58	C9	JSR	WPTSINIT	
	80	C0			*SELECT 2ND BANK & WRITE PROTECT
E6	10		INC	TSTNUM	
	01		LDA	#PAT12K	
20	58	C9	JSR	WPTSINIT	
	8B				*SELECT 1ST BANK & READ/WRITE
	8B	C0		• 0.000	*BY TWO CONSECUTIVE READS
	0E				*FLAG RAM IN READ/WRITE
	10			TSTNUM	ž
	80		LDA	#PAT4K	
20	58	C9	JSR	WPTSINIT	

The LDA instruction, which performs a read operation to the specified memory location, is used for setting the soft switches. The unusual sequence of two consecutive LDA instructions performs the two consecutive reads that write-enable this area of RAM; in this case, the data that are read are not used.

Reading bank switches

You can read which language card bank is currently switched in by reading the soft switch at \$C011. You can find out whether the language card or ROM is switched in by reading \$C012. The only way that you can find out whether the language card RAM is writeenabled or not is by trying to write some data to the card's RAM space.

Auxiliary memory and firmware

By installing an optional card in the auxiliary slot, you can add more memory to the Apple IIe. One such card is the Apple IIe 80-Column Text Card, which has 1K bytes of additional RAM for expanding the text display from 40 columns to 80 columns.

Another 80-column text card, the Apple IIe Extended 80-Column Text Card, has 64K of additional RAM. A 1K-byte area of this memory serves the same purpose as the memory on the 80-Column Text Card: expanding the text display to 80 columns. The other 63K bytes can be used as auxiliary program and data storage. If you use only 40-column displays, the entire 64K bytes is available for programs and data. The Extended 80-Column Text Card is installed in the extended keyboard IIe and shipped with later models of the enhanced IIe.

Warning

Do not attempt to use the auxiliary memory from a BASIC program. The BASIC interpreter uses several areas in main RAM, including the stack and the zero page. If you switch to auxiliary memory in these areas, the BASIC interpreter fails and you must reset the system and start over.

As you can see by studying the memory map in Figure 4-4, the auxiliary memory is broken into two large sections and one small one. The largest section is switched into the memory address space from 512 to 49151 (\$0200 through \$BFFF). This space includes the display buffer pages: as described in the section "Text Modes" in Chapter 2, space in auxiliary memory is used for one half of the 80-column text display. You can switch to the auxiliary memory for this entire memory space, or you can switch just the display pages: see the next section, "Memory Mode Switching."

❖ Soft switches: If the only reason you are using auxiliary memory is for the 80-column display, note that you can store into the display page in auxiliary memory by using the 80STORE and PAGE2 soft switches described in the section "Display Mode Switching" in Chapter 2.

The other large section of auxiliary memory is switched into the memory address space from 52K to 64K (\$D000 through \$FFFF). This memory space and the switches that control it are described earlier in this chapter in the section "Bank-Switched Memory." If you use the auxiliary RAM in this space, the soft switches have the same effect on the auxiliary RAM that they do on the main RAM: the bank switching is independent of the auxiliary-RAM switching.

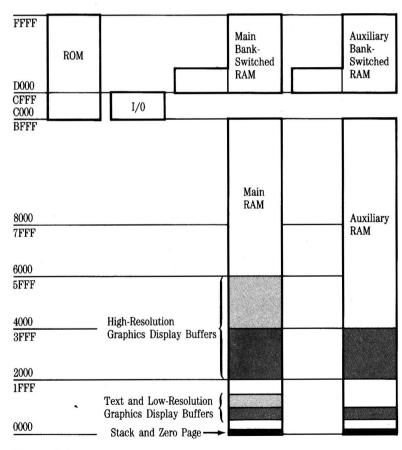


Figure 4-4 Memory map with auxilliary memory

* Bank switches: Note that the soft switches for the bank-switched memory, described in the previous section, do not change when you switch to auxiliary RAM. In particular, if ROM is enabled in the bank-switched memory space before you switch to auxiliary memory, the ROM will still be enabled after you switch. Any time you switch the bank-switched section of auxiliary memory in and out, you must also make sure that the bank switches are set properly.

When you switch in the auxiliary RAM in the bank-switched space, you also switch the first two pages, from 0 to 511 (\$0000 through \$01FF). This part of memory contains page zero, which is used for important data and base addresses, and page one, which is the 65C02 stack. The stack and zero page are switched this way so that system software running in the bank-switched memory space can maintain its own stack and zero page while it manipulates the 48K address space (from \$0200 to \$BFFF) in either main memory or auxiliary memory.

Memory mode switching

Switching the 48K section of memory is performed by two soft switches: the switch named RAMRD selects main or auxiliary memory for reading, and the one named RAMWRT selects main or auxiliary memory for writing. As shown in Table 4-7, each switch has a pair of memory locations dedicated to it, one to select main memory, and the other to select auxiliary memory. Enabling the read and write functions independently makes it possible for a program whose instructions are being fetched from one memory space to store data into the other memory space.

Warnina

Do not use these switches without careful planning. Careless switching between main and auxiliary memories is almost certain to have catastrophic effects on the operation of the Apple IIe. For example, if you switch to auxiliary memory with no card in the slot, the program that is running will stop and you will have to reset the Apple IIe and start over.

Writing to the soft switch at location \$C003 turns RAMRD on and enables auxiliary memory for reading; writing to location \$C002 turns RAMRD off and enables main memory for reading. Writing to the soft switch at location \$C005 turns RAMWRT on and enables the auxiliary memory for writing; writing to location \$C004 turns RAMWRT off and enables main memory for writing. By setting these switches independently, you can use any of the four combinations of reading and writing in main or auxiliary memory.

Auxiliary memory corresponding to text Page 1 and high-resolution graphics Page 1 can be used as part of the address space from \$0200 to \$BFFF by using RAMRD and RAMWRT as described above. These areas in auxiliary RAM can also be controlled separately by using the switches described in the section "Display Mode Switching" in Chapter 2. Those switches are named 80STORE, PAGE2, and HIRES.

As shown in Table 4-7, the 80STORE switch functions as an enabling switch: with it on, the PAGE2 switch selects main memory or auxiliary memory. With the HIRES switch off, the memory space switched by PAGE2 is the text Page 1, from \$0400 to \$07FF; with HIRES on, PAGE2 switches both text Page 1 and high-resolution graphics Page 1, from \$2000 to \$3FFF.

If you are using both the auxiliary-RAM control switches and the auxiliary-display-page control switches, the display-page control switches take priority: if 80STORE is off, RAMRD and RAMWRT work for the entire memory space from \$0200 to \$BFFF, but if 80STORE is on, RAMRD and RAMWRT have no effect on the display page. Specifically, if 80STORE is on and HIRES is off, PAGE2 controls text Page 1 regardless of the settings of RAMRD and RAMWRT. Likewise, if 80STORE and HIRES are both on, PAGE2 controls both text Page 1 and high-resolution graphics Page 1, again regardless of RAMRD and RAMWRT.

The next section, "Auxiliary-Memory Subroutines," describes firmware that you can call to help you switch between main and auxiliary memory.

A single soft switch named ALTZP (for *alternate zero page*) switches the bank-switched memory and the associated stack and zero page area between main and auxiliary memory. As shown in Table 4-7, writing to location \$C009 turns ALTZP on and selects auxiliary-memory stack and zero page; writing to the soft switch at location \$C008 turns ALTZP off and selects main-memory stack and zero page for both reading and writing.

Table 4-7Auxiliary-memory select switches

		L	ocation	
Name	Function	Hex	Decimal	Notes
RAMRD	Read auxiliary memory	\$C003	49155 -16381	Write
	Read main memory	\$C002	49154 -16382	Write
	Read RAMRD switch	\$C013	49171 -16365	Read
RAMWRT	Write auxiliary memory	\$C005	49157 -16379	Write
	Write main memory	\$C004	49156 -16380	Write
	Read RAMWRT switch	\$C014	49172 -16354	Read
80STORE	On: access display page	\$C001	49153 -16383	Write
	Off: use RAMRD, RAMWRT	\$C000	49152 -16384	Write
	Read 80STORE switch	\$C018	49176 -16360	Read
PAGE2	Page 2 on (aux. memory)	\$C055	49237 -16299	*
	Page 2 off (main memory)	\$C054	49236 -16300	•
	Read PAGE2 switch	\$C01C	49180 -16356	Read
HIRES	On: access high-res pages	\$C057	49239 -16297	†
	Off: use RAMRD, RAMWRT	\$C056	49238 -16298	†
	Read HIRES switch	\$C01D	49181 -16355	Read
ALTZP	Aux. stack & zero page	\$C009	49161 -16373	Write
	Main stack & zero page	\$C008	49160 -16374	Write
	Read ALTZP switch	\$C016	49174 -16352	Read

^{*} When 80STORE is on, the PAGE2 switch selects main or auxiliary display memory.

When these switches are on, auxiliary memory is being used; when they are off, main memory is being used.

There are three more locations associated with the auxiliary-memory switches. The high-order bits of the bytes you read at these locations tell you the settings of the three soft switches described above. The byte you read at location \$C013 has its high bit set to 1 if RAMRD is on (auxiliary memory is read-enabled), or 0 if RAMRD is off (the 48K block of main memory is read-enabled). The byte at location \$C014 has its high bit set to 1 if RAMWRT is on (auxiliary memory is write-enabled), or 0 if RAMWRT is off (the 48K block of main memory is write-enabled). The byte at location \$C016 has its high bit set to 1 if ALTZP is on (the bank-switched area, stack, and zero page in the auxiliary memory are selected), or 0 if ALTZP is off (these areas in main memory are selected).

[†] When 80STORE is on, the HIRES switch enables you to use the PAGE2 switch to switch between the high-resolution Page 1 area in main memory or auxiliary memory.

❖ Sharing memory: In order to have enough memory locations for all of the soft switches and remain compatible with the Apple II and Apple II Plus, the soft switches listed in Table 4-7 share their memory locations with the keyboard functions listed in Table 2-1. The operations—read or write—shown in Table 4-7 for controlling the auxiliary memory are just the ones that are not used for reading the keyboard and clearing the strobe.

Auxiliary-memory subroutines

If you want to write assembly-language programs that use auxiliary memory but you don't want to manage the auxiliary memory yourself, you can use the built-in auxiliary-memory subroutines. These subroutines make it possible to use the auxiliary memory without having to manipulate the soft switches described in the previous section.

Important

The subroutines described below make it easier to use auxiliary memory, but they do not protect you from errors. You still have to plan your use of auxiliary memory to avoid catastrophic effects on your program.

You use these built-in subroutines the same way you use the I/O subroutines described in Chapter 3: by making subroutine calls to their starting locations. Those locations are shown in Table 4-8.

Table 4-848K RAM transfer routines

Name	Action	Hex	Function
AUXMOVE	JSR	\$C311	Moves data blocks between main and auxiliary 48K memory
XFER	ЈМР	\$C314	Transfers program control between main and auxiliary 48K memory

Moving data to auxiliary memory

In your assembly-language programs, you can use the built-in subroutine named AUXMOVE to copy blocks of data from main memory to auxiliary memory or from auxiliary memory to main memory. Before calling this routine, you must put the data addresses into byte pairs in page zero and set the carry bit to select the direction of the move—main to auxiliary or auxiliary to main.

Warning

Don't try to use AUXMOVE to copy data in page zero or page one (the 65C02 stack) or in the bank-switched memory (\$D000-\$FFFF). AUXMOVE uses page zero all during the copy, so it can't handle moves in the memory space switched by ALTZP.

The pairs of bytes you use for passing addresses to this subroutine are called A1, A2, and A4, and they are used for parameter passing by several of the Apple IIe's built-in routines. The addresses of these byte pairs are shown in Table 4-9.

Table 4-9Parameters for AUXMOVE routine

Name	Location	Parameter passed
Carry		1 = Move from main to auxiliary memory
•		0 = Move from auxiliary to main memory
A1L	\$3C	Source starting address, low-order byte
A1H	\$3D	Source starting address, high-order byte
A2L	\$3E	Source ending address, low-order byte
A2H	\$3F	Source ending address, high-order byte
A4L	\$42	Destination starting address, low-order byte
A4H	\$43	Destination starting address, high-order byte

Note: The X, Y, and A registers are preserved by AUXMOVE.

Put the addresses of the first and last bytes of the block of memory you want to copy into A1 and A2. Put the starting address of the block of memory you want to copy the data to into A4.

The AUXMOVE routine uses the carry bit to select the direction to copy the data. To copy data from main memory to auxiliary memory, set the carry bit; to copy data from auxiliary memory to main memory, clear the carry bit.

When you make the subroutine call to AUXMOVE, the subroutine copies the block of data as specified by the A byte pairs and the carry bit. When it is finished, the accumulator and the X and Y registers are just as they were when you called AUXMOVE.

Transferring control to auxiliary memory

You can use the built-in routine named XFER to transfer control to and from program segments in auxiliary memory. You must set up three parameters before using XFER: the address of the routine you are transferring to, the direction of the transfer (main to auxiliary or auxiliary to main), and which page zero and stack you want to use.

Table 4-10Parameters for XFER routine

Name or location	Parameter passed
Carry	1 = Transfer from main to auxiliary memory 0 = Transfer from auxiliary to main memory
Overflow	1 = Use page zero and stack in auxiliary memory0 = Use page zero and stack in main memory
\$03ED	Program starting address, low-order byte
\$03EE	Program starting address, high-order byte

Note: The X, Y, and A parameters are preserved by XFER.

Put the transfer address into the two bytes at locations \$03ED and \$03EE, with the low-order byte first, as usual. The direction of the transfer is controlled by the carry bit: set the carry bit to transfer to a program in auxiliary memory; clear the carry bit to transfer to a program in main memory. Use the overflow bit to select which page zero and stack you want to use: clear the overflow bit to use the main memory; set the overflow bit to use the auxiliary memory.

After you have set up the parameters, pass control to the XFER routine by a jump instruction, rather than a subroutine call. XFER saves the accumulator and the transfer address on the current stack, then sets up the soft switches for the parameters you have selected and jumps to the new program.

Warning

It is the programmer's responsibility to save the current stack pointer at \$0100 in auxiliary memory and the alternate stack pointer at \$0101 in auxiliary memory before calling XFER and to restore them after regaining control. Failure to do so will cause program errors.

The reset routine

To put the Apple IIe into a known state when it has just been turned on or after a program has malfunctioned, there is a procedure called the *reset routine*. The reset routine is built into the Apple IIe's firn.ware, and it is initiated any time you turn power on or press Reset while holding down Control. The reset routine puts the Apple IIe into its normal operating mode and restarts the resident program.

When you initiate a reset, hardware in the Apple IIe sets the memory-controlling soft switches to normal: main board RAM and ROM are enabled, and, if there is an 80-column text card in the auxiliary slot, expansion slot 3 is allocated to the built-in 80-column firmware. Auxiliary RAM is disabled and the bank-switched memory space is set up to read from ROM and write to RAM, using the second bank at \$D000.

The reset routine sets the display-controlling soft switches to display 40-column text Page 1 using the primary character set, then sets the window equal to the full 40-column display, puts the cursor at the bottom of the screen, and sets the display format to normal.

The reset routine sets the keyboard and display as the standard input and output devices by loading the standard I/O links. It turns annunciators 0 and 1 off and annunciators 2 and 3 on, clears the keyboard strobe, turns off any active peripheral-card ROM, and outputs a bell (tone).

The Apple IIe has three types of reset: power-on reset, also called **cold-start** reset; **warm-start** reset; and forced cold-start reset. The procedure described above is the same for any type of reset. What happens next depends on the reset vector. The reset routine checks the reset vector to determine whether it is valid or not, as described later in this chapter in the section "The Reset Vector." If the reset was caused by turning the power on, the vector will not be valid, and the reset routine will perform the cold-start procedure. If the vector is valid, the routine will perform the warm-start procedure.

For information about the I/O links, see the section "Changing the Standard I/O Links" in Chapter 6.

For more information about peripheral-card ROM, see the section "Peripheral-Card ROM Space" in Chapter 6.

The cold-start procedure

If the reset vector is not valid, either the Apple IIe has just been turned on or something has caused memory contents to be changed. The reset routine clears the display and puts the string "Apple //e" ("Apple] [" on an original IIe) at the top of the display. It loads the reset vector and the validity-check byte as described below, then starts checking the expansion slots to see if there is a disk drive controller card in one of them, starting with slot 7 and working down.

If the reset routine finds a controller card, it initiates the startup (bootstrap) routine that resides in the controller card's firmware. The startup routine then loads DOS or ProDOS from the disk in drive 1. When the operating system has been loaded, it displays other messages on the screen. If there is no disk in the disk drive, the drive motor just keeps spinning until you press Control-Reset.

If the reset routine doesn't find a controller card, or if you press Control-Reset again before the startup procedure has been completed, the reset routine will continue without using the disk, and pass control to the built-in Applesoft interpreter.

The warm-start procedure

Whenever you press Control-Reset when the Apple IIe has already completed a cold-start reset, the reset vector is still valid and it is not necessary to reinitialize the entire system. The reset routine simply uses the vector to transfer control to the resident program, which is normally the built-in Applesoft interpreter. If the resident program is indeed Applesoft, your Applesoft program and variables are still intact. If you are using DOS, it is the resident program and it restarts either Applesoft or Integer BASIC, whichever you were using when you pressed Control-Reset.

Important

A program in bank-switched RAM cannot use the reset vector to regain control after a reset, because the Apple IIe hardware enables ROM in the bank-switched memory space. If you are using Integer BASIC, which is in the bank-switched RAM, you are also using DOS, and it is DOS that controls the reset vector and restarts BASIC.

For more information about ProDOS and the startup procedure, see the *ProDOS*Technical Reference Manual.

Forced cold start

If a program has loaded the reset vector to point to the beginning of the program, as described in the next section, pressing Control-Reset causes a warm-start reset that uses the vector to transfer control to that program. If you want to stop such a program without turning the power off and on, you can force a cold-start reset by holding down Open Apple and Control, then pressing and releasing Reset.

Unconditional restart: When you want to stop a program unconditionally—for example, to start up the Apple IIe with some other program—you should use the forced cold-start reset, Open Apple-Control-Reset, instead of turning the power off and on.

Whenever you press Control-Reset, firmware in the Apple IIe always checks to see whether either Apple key is down. If the Solid Apple key (or Option key, in the extended keyboard IIe) is down, with or without the Open Apple key, the firmware performs the self-test described later in this chapter. If only the Open Apple key is down, the firmware starts a forced cold-start reset. First, it destroys the program or data in memory by writing two bytes of arbitrary data into each page of main RAM. The two bytes that get written over in page 3 are the ones that contain the reset vector. The reset routine then performs a normal cold-start reset.

The reset vector

When you reset the Apple IIe, the reset routine transfers control to the resident program by means of an address stored in page 3 of main RAM. This address is called a *vector* because it directs program control to a specified destination. There are several other vector addresses stored in page 3, as shown in Table 4-11, including the interrupt vectors described in the section "Interrupts on the Enhanced Apple IIe" in Chapter 6, and the ProDOS and DOS vectors described in the *ProDOS Technical Reference Manual* and the *Apple II DOS Programmer's Manual*.

The cold-start reset routine stores the starting address of the built-in Applesoft interpreter, low-order byte first, in the reset vector address at locations 1010 and 1011 (hexadecimal \$03F2 and \$03F3). It then stores a validity-check byte, also called the *power-up byte*, at location 1012 (hexadecimal \$03F4). The validity-check byte is computed by performing an exclusive-OR of the second byte of the vector with the constant 165 (hexadecimal \$A5). Each time you reset the Apple IIe, the reset routine uses this byte to determine whether the reset vector is still valid.

You can change the reset vector so that the reset routine will transfer control to your program instead of to the Applesoft interpreter. For this to work, you must also change the validity-check byte to the exclusive-OR of the high-order byte of your new reset vector with the constant 165 (\$A5). If you fail to do this, then the next time you reset the Apple IIe the reset routine will determine that the reset vector is invalid and perform a cold-start reset, eventually transferring control to the disk startup routine or to Applesoft.

The reset routine has a subroutine that generates the validity-check byte for the current reset vector. You can use this subroutine by doing a subroutine call to location –1169 (hexadecimal \$FB6F). When your program finishes, it can return the Apple IIe to normal operation by restoring the original reset vector and again calling the subroutine to fix up the validity-check byte.

Table 4-11Page 3 vectors

A	W.
Vector address	Vector function
\$3F0\$3F1	Address of the subroutine that handles BRK requests (normally \$59, \$FA)
\$3F2\$3F3	Reset vector (see text)
\$3F4	Power-up byte (see text)
\$3F5\$3F6\$3F7	Jump instruction to the subroutine that handles Applesoft & commands (normally \$4C, \$58, \$FF)
\$3F8\$3F9\$3FA	Jump instruction to the subroutine that handles user Control-Y commands
\$3FB\$3FC\$3FD	Jump instruction to the subroutine that handles nonmaskable interrupts
\$3FE\$3FF	Interrupt vector (address of the subroutine that handles interrupt requests

Automatic self-test

If you reset the Apple IIe by holding down Solid Apple and Control while pressing and releasing Reset, the reset routine will start running the built-in self-test. Successfully running this test assures you that the Apple IIe is operational.

Warning

The self-test routine tests the Apple Ile's programmable memory by writing and then reading it. All programs and data in programmable memory when you run the self-test are destroyed.

The self-test takes several seconds to run. The screen will display some patterns in low-resolution mode that will change rapidly just before the self-test finishes. If the test finishes normally, the Apple IIe displays System OK and waits for you to restart the system.

If you have been running a program, some soft switches might be on when you run the self-test. If this happens, the self-test will display a message such as

IOU FLAG ES: 1

Turn the power off for several seconds, then turn it back on and run the self-test again. If it still fails, there is really something wrong; to get it corrected, contact your authorized Apple dealer for service.

Chapter 5

Using the Monitor

The starting addresses for all of the standard subroutines are listed in Appendix B. The System Monitor is a set of subroutines in the Apple IIe firmware. The Monitor provides a standard interface to the built-in I/O devices described in Chapter 2. The I/O subroutines described in Chapter 3 are part of the System Monitor.

ProDOS, DOS 3.3, and the BASIC interpreters use these subroutines by direct calls to their starting locations, as described for the I/O subroutines in Chapter 3.

If you wish, you can call the standard subroutines from your programs in the same fashion.

You can perform most of the Monitor functions directly from the keyboard. This chapter tells you how to use the Monitor to

	,
	look at one or more memory locations
	change the contents of any location
	write programs in machine language to be executed directly by the Apple IIe's microprocessor
	save blocks of data and programs onto cassette tape and read them back in again
	move and compare blocks of memory
	search for data bytes and ASCII characters in memory
	invoke other programs from the Monitor
П	invoke the Mini-Assembler

Invoking the Monitor

The System Monitor starts at memory location \$FF69 (decimal 65385 or -151). To invoke the Monitor, you make a CALL statement to this location from the keyboard or from a BASIC program. When the Monitor is running, its prompt character, an asterisk (*), appears on the left side of the display screen, followed by a blinking cursor.

To use the Monitor, you type commands at the keyboard. When you have finished using the Monitor, you return to the BASIC language you were previously using by pressing Control-Reset, by pressing Control-C then Return, or by typing 3D0G (3D-zero-G), which executes the resident program—usually Applesoft—whose address is stored in a jump instruction at location \$3D0.

Syntax of Monitor commands

To give a command to the Monitor, you type a line on the keyboard, then press Return. The Monitor accepts the line using the standard I/O subroutine GETLN, described in Chapter 3. A Monitor command can be up to 255 character in length, ending with a carriage return.

A Monitor command can include three kinds of information: addresses, data values, and command characters. You type addresses and data values in hexadecimal notation. Hexadecimal notation uses the ten decimal digits (0–9) and the first six letters (A–F) to represent the sixteen values from 0 to 15. A pair of hexadecimal digits represent values from 0 to 255, corresponding to a byte; and a group of four hexadecimal digits can represent values from 0 to 65,536, corresponding to a word. Any address in the Apple IIe can be represented by four hexadecimal digits.

When the command you type calls for an address, the Monitor accepts any group of hexadecimal digits. If there are fewer than four digits in the group, it adds leading zeros; if there are more than four hexadecimal digits, the Monitor uses only the last four digits. It follows a similar procedure when the command syntax calls for two-digit data values.

Each command you type consists of one command character, usually the first letter of the command name. When the command is a letter, it can be either uppercase or lowercase. The Monitor recognizes 23 different command characters. Some of them are punctuation marks, some are letters, and some are control characters.

Note: Although the Monitor recognizes and interprets control characters typed on an input line, they do not appear on the screen.

This chapter contains many examples of the use of Monitor commands. In the examples, the commands and values you type are shown in a normal typeface and the responses of the Monitor are in a computer typeface. Of course, when you perform the examples, all of the characters that appear on the display screen will be in the same typeface. Some of the data values displayed by your Apple IIe may differ from the values printed in these examples, because they are variables stored in programmable memory.

See "Summary of Monitor Commands" at the end of this chapter.

Monitor memory commands

When you use the Monitor to examine and change the contents of memory, it keeps track of the address of the last location whose value you inquired about and the address of the location that is next to have its value changed. These are called the *last opened location* and the *next changeable location*.

Examining memory contents

When you type the address of a memory location and press Return, the Monitor responds with the address you typed, a dash, a space, and the value stored at that location, like this:

```
*E000 20 33 AA
```

Each time the Monitor displays the value stored at a location, it saves the address of that location as the last opened location and as the next changeable location.

Memory dump

When you type a period (.) followed by an address and then press Return, the Monitor displays a memory dump: the data values stored at all the memory locations from the one following the last opened location to the location whose address you typed following the period. The Monitor saves the last location displayed as both the last opened location and the next changeable location. The amount of data displayed by the Monitor depends on how much larger than the last opened location the address after the period is; here are some examples:

```
*20

0020- 00

*.2B

0021- 28 00 18 0F 0C 00 00

0028- A8 06 D0 07
```

```
*300
0300- 99

*.315
0301- B9 00 08 0A 0A 0A 99
0308- 00 08 C8 D0 F4 A6 2B A9
0310- 09 85 27 AD CC 03

*.32A

0316- 85 41
0318- 84 40 8A 4A 4A 4A 4A 09
0320- C0 85 3F A9 5D 85 3E 20
0328- 43 03 20
```

When the Monitor performs a memory dump, it starts at the location immediately following the last opened location and displays that address and the data value stored there. It then displays the values of successive locations up to and including the location whose address you typed, but only up to eight values on a line. When it reaches a location whose address is a multiple of eight—that is, one that ends with an 8 or a 0—it displays that address as the beginning of a new line, then continues displaying more values.

After the Monitor has displayed the value at the location whose address you specified in the command, it stops the memory dump and sets that location as both the last opened location and the next changeable location. If the address specified on the input line is less than the address of the last opened location, the Monitor displays only the address and value of the location following the last opened location.

You can combine the two commands, opening a location and dumping memory, by simply concatenating them: type the first address, a period, and the second address. This combination of two addresses separated by a period is called a *memory range*.

*300.32F

```
0300- 99 B9 00 08 0A 0A 0A 99
0308- 00 08 C8 D0 F4 A6 2B A9
0310- 09 85 27 AD CC 03 85 41
0318- 84 40 8A 4A 4A 4A 4A 09
0320- C0 85 3F A9 5D 85 3E 20
0328- 43 03 20 46 03 A5 3D 4D
```

*30.40

```
0030- AA 00 FF AA 05 C2 05 C2
0038- 1B FD D0 03 3C 00 40 00
0040- 30
```

*E015.E025

```
E016- 4C ED FD
E018- A9 20 C5 24 B0 0C A9 8D
E020- A0 07 20 ED FD A9 *
```

Pressing Return by itself causes the Monitor to display one line of a memory dump; that is, a memory dump from the location following the last opened location to the next multiple-of-eight boundary. The Monitor saves the address of the last location displayed as the last opened location and the next changeable location.

*5

0005- 00

*Return

00 00

*Return

0008- 00 00 00 00 00 00 00 00

*32

0032- FF

*Return

AA 00 C2 05 C2

*Return

0038- 1B FD D0 03 3C 00 3F 00

*

Changing memory contents

The preceding section showed you how to display the values stored in the Apple IIe's memory; this section shows you how to change those values. You can change any location in RAM—programmable memory—and you can also change the soft switches and output devices by changing the locations assigned to them.

Warnina

Use these commands carefully. If you change the zero-page locations used by Applesoft, ProDOS, or DOS, you may lose programs or data stored in memory.

Changing one byte

The previous commands keep track of the next changeable location; these commands make use of it. In the next example, you open location 0, then type a colon (:) followed by a value:

```
*0
0000- 00
*:5F
```

The contents of the next changeable location have just been changed to the value you typed, as you can see by examining that location:

```
*0
0000- 5F
*
```

You can also combine opening and changing into one operation by typing an address followed by a colon and a value. In the example, you type the address again to verify the change:

```
*302:42
*302
0302- 42
*
```

When you change the contents of a location, the value that was contained in that location disappears, never to be seen again. The new value will remain until you replace it with another value.

Changing consecutive locations

You don't have to type a separate command with an address, a colon, a value, and Return for each location you want to change. You can change the values of up to 85 consecutive locations at a time (or even more, if you omit leading zeros from the values) by typing only the initial address and colon followed by all the values separated by spaces, and ending with Return. The Monitor will duly store the consecutive values in consecutive locations, starting at the location whose address you typed. After it has processed the string of values, it takes the location following the last changed location as the next changeable location. Thus, you can continue changing consecutive locations without typing an address on the next input line by typing another colon and more values. In these examples, you first change some locations, then examine them to verify the changes:

```
*300:69 01 20 ED FD 4C 0 3

*300

0300- 69

*Return

01 20 ED FD 4C 00 03

*10:0 1 2 3

*:4 5 6 7

*10.17

0010- 00 01 02 03 04 05 06 07

*
```

ASCII input mode

The enhanced Apple IIe has an ASCII input mode that lets you enter ASCII characters just as you can their hexadecimal ASCII equivalents by preceding the literal character with an apostrophe ('). This means that 'A is the same as \$C1 and 'B is the same as \$C2 to the Monitor. The ASCII value for *any* character following an apostrophe is used by the Monitor.

Each character to be placed in memory should be delimited by a leading apostrophe (') and a trailing space. The only exception to this rule is that the last character in the line is followed with a return character instead of a space. The following example would enter the string "Hooray for sushi!" at \$0300 in memory.

*300:'H 'o 'o 'r 'a 'y ' 'f 'o 'r ' 's 'u 's 'h 'i "!

Important

ASCII input mode sets the high bit of the code for a character that you enter. So 'A will equal \$C1, not \$41.

Original Ile

The original Apple IIe does not have an ASCII input mode.

Moving data in memory

You can copy a block of data stored in a range of memory locations from one area in memory to another by using the Monitor's MOVE command. To move a range of memory, you must tell the Monitor both where the data is now situated in memory (the source locations) and where you want the copy to go (the destination locations). You give this information to the Monitor by means of three addresses: the address of the first location in the destination and the addresses of the first and last locations in the source. You specify the starting and ending addresses of the source range by separating them with a period. You separate the destination address from the range addresses with a less-than character (<), which you may think of as an arrow pointing in the direction of the move. Finally, you tell the Monitor that this is a MOVE command by typing the letter M (in either lowercase or uppercase). The format of the complete MOVE command looks like this:

{destination} < {start} . {end} M

When you type the actual command, the words in braces should be replaced by hexadecimal addresses, and the braces and spaces should be omitted.

Here are some examples of Monitor commands, including some memory moves. First, you examine the values stored in one range of memory, then store several values in another range of memory; the actual MOVE commands end with the letter M.

```
* 0.F
```

*300:A9 8D 20 ED FD A9 45 20 DA FD 4C 00 03

*300.30C

```
0300- A9 8D 20 ED FD A9 45 20 0308- DA FD 4C 00 03
```

*0<300.30CM

*0.C

0000- A9 8D 20 ED FD A9 45 20 0008- DA FD 4C 00 03

*310<8.AM

*310.312

0310- DA FD 4C

*2<7.9M

*0.C

0000- A9 8D 20 DA FD A9 45 20 0008- DA FD 4C 00 03

The Monitor moves a copy of the data stored in the source range of locations to the destination locations. The values in the source range are left undisturbed. The Monitor remembers the last location in the source range as the last opened location, and the first location in the source range as the next changeable location. If the second address in the source range specification is less than the first, then only one value (that of the first location in the range) will be moved.

If the destination address of the MOVE command is inside the source range of addresses, then strange (and sometimes wonderful) things happen: the locations between the beginning of the source range and the destination address are treated as a subrange and the values in this subrange are replicated throughout the source range.

See the section "Special Tricks With the Monitor" later in this chapter for an interesting application of this feature.

Comparing data in memory

You can use the VERIFY command to compare two ranges of memory using the same format you use to move a range of memory from one place to another. In fact, the VERIFY command can be used immediately after a MOVE command to make sure that the move was successful.

The VERIFY command, like the MOVE command, needs a range and a destination. The syntax of the VERIFY command is

```
{destination} < {start} . {end} V
```

The Monitor compares the values in the source locations with the values in the locations beginning at the destination address. If any values don't match, the Monitor displays the address at which the discrepancy was found and the two values that differ. In the example, you store data values in the range of locations from 0 to \$D, copy them to locations starting at \$300 with the MOVE command, and then compare them using the VERIFY command. When you use the VERIFY command after you change the value at location 6 to \$E4, it detects the change.

```
*0:D7 F2 E9 F4 F4 E5 EE A0 E2 F9 A0 C3 C4 C5
```

- *300<0.DM
- *300<0.DV
- *6:E4
- *300<0.DV

0006-E4 (EE)

*

If the VERIFY command finds a discrepancy, it displays the address of the location in the source range whose value differs from its counterpart in the destination range. If there is no discrepancy, VERIFY displays nothing. The VERIFY command leaves the values in both ranges unchanged. The last opened location is the last location in the source range, and the next changeable location is the first location in the source range, just as in the MOVE command. If the ending address of the range is less than the starting address, the values of only the first locations in the ranges will be compared. Like the MOVE command, the VERIFY command also does unusual things if the destination address is within the source range.

See the section "Special Tricks With the Monitor" later in this chapter.

Searching for bytes in memory

The SEARCH command lets you search for one or two bytes (either hexadecimal values or ASCII characters) in a range of memory. You must type in the ASCII string (or hexadecimal number or numbers) in reverse of the order that they appear in memory. Think of the SEARCH command as looking for items in a last-in, first-out queue.

The syntax of the SEARCH command is

{value or ASCII\<{start}.{end} S

If the byte (or two-byte sequence) that you specify is in the specified memory range, the Monitor will return with a list of the addresses where that byte (or byte sequence) occurs. If the byte (or byte sequence) is not in the range, the Monitor just displays the prompt

The following example looks for the character string "LO" in memory between \$0300 and \$03FF:

- *'O'L<300.3FFS
- High bit set: Remember that ASCII input mode sets the highorder bit of each character that you enter.

The next example searches for the two-byte sequence \$FF11.

*11FF<300.3FFS

You can't search for a two-byte sequence with a high byte of 0. The Monitor ignores the high byte and searches for the low byte only. The sequence 00FF is seen by the Monitor SEARCH command as FF.

Original Ile

The Monitor in the original Apple lle does not recognize the SEARCH command.

Examining and changing registers

The microprocessor's register contents change continuously whenever the Apple IIe is running any sort of program, such as the Monitor. The Monitor lets you see what the register contents were when you invoked the Monitor or a program that you were debugging stopped at a break (BRK). The Monitor also lets you set 65C02 register values before you execute a program with the GO command.

When you call the Monitor, it stores the contents of the microprocessor's registers in memory. The registers are stored in the order A, X, Y, P (processor status register), and S (stack pointer), starting at location \$45 (decimal 69). When you give the Monitor a GO command, the Monitor loads the registers from these five locations before it executes the first instruction in your program.

Pressing Control-E and then Return invokes the Monitor's EXAMINE command, which displays the stored register values and sets the location containing the contents of the A register as the next changeable location. After using the EXAMINE command, you can change the values in these locations by typing a colon and then typing the new values separated by spaces. In the following example, you display the registers, change the first two, and then display them again to verify the change.

```
*Control-E
```

A=OA X=FF Y=D8 P=B0 S=F8

*:B0 02

*Control-E

A=B0 X=02 Y=D8 P=B0 S=F8

Monitor cassette tape commands

The Apple IIe has two jacks for connecting an audio cassette tape recorder. With a recorder connected, you can use the Monitor commands described later in this section to save the contents of a range of memory onto a standard cassette and recall it for later use.

Saving data on tape

The Monitor's WRITE command saves the contents of up to 65,536 memory locations on cassette tape. To save a range of memory on tape, give the Monitor the starting and ending addresses of the range, followed by the letter W (for WRITE), like this:

(start) . (end) W

Don't press Return yet: first, put the tape recorder in record mode and let the tape run for a second, then press Return. The Monitor will write a ten-second tone onto the tape and then write the data. The tone acts as a leader: later, when the Monitor reads the tape, the leader enables the Monitor to get in step with the signal from the tape. When the Monitor is finished writing the range you specified, it will sound a bell (beep) and display a prompt. You should rewind the tape and label it with the memory range that's on the tape and what it's supposed to be.

Here's a small example you can save and use later to try out the READ command. Remember that you must start the cassette recorder in record mode before you press Return after typing the WRITE command.

```
*0.FF FF AD 30 C0 88 D0 04 C6 01 F0 08 CA
D0 F6 A6 00 4C 02 00 60
```

```
*0.14
```

```
0000- FF FF AD 30 CO 88 DO 04
0008- C6 01 F0 08 CA DO F6 A6
0010- 00 4C 02 00 60
```

*0.14W

It takes about 35 seconds total to save the values of 40% memory locations preceded by the ten-second leader onto tape. This works out to an average data transfer rate of about 1350 bits per second.

The WRITE command writes one extra value on the tape after it has written the values in the memory range. This extra value is the checksum, which is the eight-bit partial sum of all values in the range. When the Monitor reads the tape, it uses this value to determine if the data has been written and read correctly. (See the next section.)

Reading data from tape

Once you've saved a memory range onto tape with the Monitor's WRITE command, you can read that memory range back into the computer by using the Monitor's READ command. The data values you've stored on the tape need not be read back into the same memory range from whence they came; you can tell the Monitor to put those values into any memory range in the computer's memory, provided that it's the same size as the range you saved.

The format of the READ command is the same as that of the WRITE command, except that the command letter is R:

```
{start} . {end} R
```

Once again, after typing the command, don't press Return. Instead, start the tape recorder in play mode and wait a few seconds. Although the WRITE command puts a ten-second leader tone on the beginning of the tape, the READ command needs only three seconds of this leader to lock on to the signal from the tape. You should let a few seconds of tape go by before you press Return to allow the tape recorder's output to settle down to a steady tone.

This example has two parts. First, you set a range of memory to zero, verify the contents of memory, and then type the READ command (but don't press Return).

Now start the cassette running in play mode, wait a few seconds, and press Return. After the Monitor sounds the bell (beep) and displays the prompt, examine the range of memory to see that the values from the tape were read correctly.

```
*0.14

0000- FF FF AD 30 CO 88 DO 04

0008- C6 01 FO 08 CA DO F6 A6

0010- 00 4C 02 00 60
```

After the Monitor has read all the data values on the tape, it reads the checksum value. It computes the checksum on the data it read and compares it to the checksum from the tape. If the two checksums differ, the Monitor sends a beep to the speaker and displays ERR. This warns you that there was a problem reading the tape and that the values stored in memory aren't the values that were recorded on the tape. If the two checksums match, the Monitor will just send out a beep and display a prompt.

Miscellaneous Monitor commands

These Monitor commands enable you to change the video display format from normal to inverse and back, and to assign input and output to accessories in expansion slots.

Inverse and normal display

You can control the setting of the inverse-normal mask location used by the COUT subroutine (described in Chapter 3) from the Monitor so that all of the Monitor's output will be in inverse format. The INVERSE command, I, sets the mask such that all subsequent inputs and outputs are displayed in inverse format. To switch the Monitor's output back to normal format, use the NORMAL command, N.

```
*0.F

0000- 0A 0B 0C 0D 0E 0F D0 04

0008- C6 01 F0 08 CA D0 F6 A6

*I

*0.F

0000- 0A 0B 0C 0D 0E 0F D0 04

0008- C6 01 F0 08 CA D0 F6 A6

*N

*0.F

0000- 0A 0B 0C 0D 0E 0F D0 04

0008- C6 01 F0 08 CA D0 F6 A6
```

Back to BASIC

Use the BASIC command, Control-B, to leave the Monitor and enter the BASIC that was active when you entered the Monitor. Normally, this is Applesoft BASIC, unless you deliberately switched to Integer BASIC. Any program or variables that you had previously in BASIC will be lost. If you want to reenter BASIC with your previous program and variables intact, use the CONTINUE BASIC command, Control-C.

If you are using DOS 3.3 or ProDOS, press Control-Reset or type 3D0G to return to the language you were using, with your program and variables intact.

That's a number, not a letter: If you use 3DOG, make sure that the third character you type is a zero, not a letter O. The letter G is the Monitor's GO command, described in the section "Machine-Language Programs" later in this chapter.

Redirecting input and output

The PRINTER command, activated by Control-P, diverts all output normally destined for the screen to an interface card in a specified expansion slot, from 1 to 7. There must be an interface card in the specified slot, or you will lose control of the computer and your program and variables may be lost. The format of the command is

{slot number} Control-P

A PRINTER command to slot number 0 will switch the stream of output characters back to the Apple IIe's video display.

Warning

Don't give the PRINTER command with slot number 0 to deactivate the 80-column firmware, even though you used this command to activate it in slot 3. The command works, but it just disconnects the firmware, leaving some of the soft switches set for 80-column display.

In much the same way that the PRINTER command switches the output stream, the KEYBOARD command substitutes the interface card in a specified expansion slot for the Apple IIe's normal input device, the keyboard. The format for the KEYBOARD command is

{slot number} Control-K

A slot number of 0 for the KEYBOARD command directs the Monitor to accept input from the Apple IIe's built-in keyboard.

The PRINTER and KEYBOARD commands are the exact equivalents of the BASIC commands PR# and IN#.

Hexadecimal arithmetic

The Monitor will also perform one-byte hexadecimal addition and subtraction. Just type a line in one of these formats:

```
{value} + {value} {value} - {value}
```

The Apple IIe performs the arithmetic and displays the result, as shown in these examples:

```
*20+13
```

=33

*4A-C

=3E

 $\star FF+4 =$

03

*3-4

=FF

.

Special tricks with the Monitor

This section describes some more complex ways of using the Monitor commands.

Multiple commands

You can put as many Monitor commands on a single line as you like, as long as you separate them with spaces and the total number of characters in the line is less than 254. Adjacent single-letter commands such as L, S, I, and N need not be separated by spaces.

You can freely intermix all the commands except the STORE (:) command. Since the Monitor takes all values following a colon and places them in consecutive memory locations, the last value in a STORE must be followed by a letter command before another address is encountered. You can use the NORMAL command as the required letter command in such cases; it usually has no effect and can be used anywhere.

In the following example, you display a range of memory, change it, and display it again, all with one line of commands:

```
*300.307 300:18 69 1 N 300.302
0300- 00 00 00 00 00 00 00 00
0300- 18 69 01
```

If the Monitor encounters a character in the input line that it does not recognize as either a hexadecimal digit or a valid command character, it executes all the commands on the input line up to that character, then grinds to a halt with a noisy beep and ignores the remainder of the input line.

Filling memory

The MOVE command can be used to replicate a pattern of values throughout a range of memory. To do this, first store the pattern in the first locations in the range.

```
*300:11 22 33
```

Remember the number of values in the pattern: in this case, it is three. Use the number to compute addresses for the MOVE command, like this:

```
{start+number} < {start} . {end-number} M
```

This MOVE command will first replicate the pattern at the locations immediately following the original pattern, then replicate that pattern following itself, and so on until it fills the entire range.

```
*303<300.32DM
```

```
*300.32F
```

```
0300- 11 22 33 11 22 33 11 22 0308- 33 11 22 33 11 22 33 11 0310- 22 33 11 22 33 11 22 33 0318- 11 22 33 11 22 33 11 0328- 22 33 11 22 33 11 22 33
```

You can do a similar trick with the VERIFY command to check whether a pattern repeats itself through memory. This is especially useful to verify that a given range of memory locations all contain the same value. In this example, you first fill the memory range from \$0300 to \$0320 with zeros and verify it, then change one location and verify again, to see the VERIFY command detect the discrepancy:

```
*301<300.31FM

*301<300.31FV

*304:02

*301<300.31FV
```

0303-00 (02) 0304-02 (00)

Repeating commands

You can create a command line that repeats one or more commands over and over. You do this by beginning the part of the command line that you want to repeat with a letter command, such as N, and ending it with the sequence 34:n, where n is a hexadecimal number that specifies the position in the line of the command where you want to start repeating; for the first character in the line, n=0. The value for n must be followed with a space in order for the loop to work properly.

This trick takes advantage of the fact that the Monitor uses an index register to step through the input buffer, starting at location \$0200. Each time the Monitor executes a command, it stores the value of the index at location \$34; when that command is finished, the Monitor reloads the index register with the value at location \$34. By making the last command change the value at location \$34, you change this index so that the Monitor picks up the next command character from an earlier point in the buffer.

The only way to stop a loop like this is to press Control-Reset; that is how this example ends.

```
*N 300 302 34:0

0300- 11

0302- 33

0300- 11

0302- 33

0300- 11

0302- 33

0300- 11

0302- 33

0300- 11

0302- 33

0300- 11

0302- 33

0300- 11

0302- 33
```

Creating your own commands

The USER command, Control-Y, forces the Monitor to jump to memory location \$03F8. You can put a JMP instruction there that jumps to your own machine-language program. Your program can then examine the Monitor's registers and pointers or the input buffer itself to obtain its data. For example, here is a program that displays everything on the input line after the Control-Y. The program starts at location \$0300; the command line that starts with \$03F8 stores a jump to \$0300 at location \$03F8.

```
*300:A4 34 B9 00 02 20 ED FD C8 C9 8D D0 F5 4C 69 FF

*378:4C 00 03

*Control-Y THIS IS A TEST

THIS IS A TEST
```

Machine-language programs

The main reason to program in machine language is to get more speed. A program in machine language can run much faster than the same program written in high-level languages such as BASIC or Pascal, but the machine-language version usually takes a lot longer to write. There are other reasons to use machine language: you might want your program to do something that isn't included in your high-level language, or you might just enjoy the challenge of using machine language to work directly on the bits and bytes.

♦ Boning up on machine language: If you have never used machine language before, you'll need to learn the 65C02 instructions listed in Appendix A. To become proficient at programming in machine language, you'll have to spend some time at it and study at least one of the books on 6502 programming listed in the bibliography. With the books and Appendix A, you'll have the needed information to program the 65C02.

You can get a hexadecimal dump of your program, move it around in memory, or save it on tape and recall it using the commands described in the previous sections. The Monitor commands in this section are intended specifically for you to use in creating, writing, and debugging machine-language programs.

Running a program

The Monitor command you use to start execution of your machine-language program is the GO command. When you type an address and the letter G, the Apple IIe starts executing machine language instructions starting at the specified location. If you just type G, execution starts at the last opened location. The Monitor treats this program as a subroutine: it should end with an RTS (return from subroutine) instruction to transfer control back to the Monitor.

The Monitor has some special features that make it easier for you to write and debug machine-language programs, but before you get into that, here is a small machine-language program that you can run using only the simple Monitor commands already described. The program in the example merely displays the letters A through Z you store it starting at location \$0300, examine it to be sure you typed it correctly, then type 300G to start it running.

*300:A9 C1 20 ED FD 18 69 1 C9 DB D0 F6 60

*300.30C

0300- A9 C1 20 ED FD 18 69 01 0308- C9 DB D0 F6 60

*300G ABCDEFGHIJKLMNOPQRSTUVWXYZ

*

Disassembled programs

Machine-language code in hexadecimal isn't the easiest thing in the world to read and understand. To make this job a little easier, machine-language programs are usually written in assembly language and converted into machine-language code by programs called **assemblers**.

Since programs that translate assembly language into machine language are called assemblers, a program like the Monitor's LIST command that translates machine language into assembly language is called a **disassembler**.

The Monitor's LIST command displays machine-language code in assembly-language form. Instead of unformatted hexadecimal gibberish, the LIST command displays each instruction on a separate line, with a three-letter instruction name, or **mnemonic**, and a formatted hexadecimal operand. The LIST command also converts the relative addresses used in branch instructions to absolute addresses.

The word **mnemonic** comes from the same root as *memory* and refers to short acronyms that are easier to remember than the hexadecimal operation codes themselves: for example, for *clear carry* you write CLC instead of \$18.

The Monitor LIST command has the format

{location} L

The LIST command starts at the specified location and displays as much memory as it takes to make up a screenful (20 lines) of instructions, as shown in the following example:

*300L						
0300-	A9	C1		LDA	#\$C1	
0302-	20	ED	FD	JSR	\$FDE	D
0306-	18			CLC		
0306-	69	01		ADC	#\$01	
0308-	C9	DB		CMP	#\$DE	3
030A-	DO	F6		BNE	\$030	2
030C-	60			RTS		
030D-	00			BRK		
030E-	00			BRK		
030F-	00			BRK		
0310-	00			BRK		
0311-	00			BRK		
0312-	00			BRK		
0313-	00			BRK		
0314-	00			BRK		
0316-	00			BRK		
0316-	00			BRK		
0317-	00			BRK		
0318-	00			BRK		
0319-	00			BRK		
*						

The first seven lines of this example are the assembly-language form of the program you typed in the previous example. The rest of the lines are BRK instructions only if this part of memory has zeros in it: other values will be disassembled as other instructions.

The Monitor saves the address that you specify in the LIST command, but not as the last opened location used by the other commands. Instead, the Monitor saves this address as the program counter, which it uses only to point to locations within programs. Whenever the Monitor performs a LIST command, it sets the program counter to point to the location immediately following the last location displayed on the screen, so that if you type another LIST command it will display another screenful of instructions, starting where the previous display left off.

The Mini-Assembler

Without an assembler, you have to write your machine-language program, take the hexadecimal values for the opcodes and operands, and store them in memory using the commands covered in the previous sections. That is exactly what you did when you ran the previous examples.

The Monitor includes an assembler called the *Mini-Assembler* that lets you enter machine-language programs directly from the keyboard of your Apple. ASCII characters can be entered in Mini-Assembler programs, exactly as you enter them in the Monitor. Note that the Mini-Assembler doesn't accept labels; you must use actual values and addresses.

Starting the Mini-Assembler

To start the Mini-Assembler first invoke the Monitor by typing CALL -151 and pressing Return, and then from the Monitor, type! followed by Return. The Monitor prompt character then changes from * to!.

When you finish using the Mini-Assembler, press Return from a blank line to return to the Monitor.

Restrictions

The Mini-Assembler supports only the subset of 65C02 instructions that are found on the 6502.

Original lle

Before you can use the Mini-Assembler on the original Apple IIe, you have to be running Integer BASIC. When you start up the computer using DOS or either BASIC, the Apple IIe loads the Integer BASIC interpreter from the file named INTBASIC into the bank-switched RAM. Here's how to start the Mini-Assembler on an original Apple IIe:

- Start Integer BASIC from DOS 3.3 by typing INT and pressing Return.
- 2. After the Integer prompt character (>) and a cursor appear, enter the Monitor by typing CALL -151 and pressing Return.
- Now start the Mini-Assembler by typing F666G and pressing Return.

Using the Mini-Assembler

The Mini-Assembler saves one address, that of the program counter. Before you start to type a program, you must set the program counter to point to the location where you want the Mini-Assembler to store your program. Do this by typing the address followed by a colon.

After the colon, type the mnemonic for the first instruction in your program, followed by a space and the operand of the instruction. Now press Return. The Mini-Assembler converts the line you typed into hexadecimal, stores it in memory beginning at the location of the program counter, and then disassembles it again and displays the disassembled line. It then displays a prompt on the next line.

Now the Mini-Assembler is ready to accept the second instruction in your program. To tell it that you want the next instruction to follow the first, don't type an address or a colon: just type a space and the next instruction's mnemonic and operand, then press Return. The Mini-Assembler assembles that line and waits for another.

Formats for operands are listed in Table 5-1.

!300:LDX #02					
0300-	A2 02	LDX	#\$02		
! LDA \$	60,X				
0302-	B5 00	LDA	\$00,X		
! STA \$	510,X				
0304	95 10	STA	\$10,X		
! DEX					
0306-	CA	DEX			
! STA \$	C030				
0307-	8D 30 C0	STA	\$C030		
! BPL \$	302				
030A-	10 F6	BPL	\$0302		
! BRK					
030C- !	00	BRK	je.		

If the line you type has an error in it, the Mini-Assembler beeps loudly and displays a caret (^) under or near the offending character in the input line. Most common errors are the result of typographical mistakes: misspelled mnemonics, missing parentheses, and so forth. The Mini-Assembler also rejects the input line if you forget the space before or after a mnemonic or include an extraneous character in a hexadecimal value or address. If the destination address of a branch instruction is out of the range of the branch (more than 127 locations distant from the address of the instruction), the Mini-Assembler flags this as an error.

There are several different ways to leave the Mini-Assembler and reenter the Monitor. On an enhanced Apple IIe only, simply press Return at a blank line.

Original Ile

On an original Apple IIe, type the Monitor command \$FF69G.

On any Apple IIe, you can press Control-Reset, which forces a warm restart of BASIC, then type CALL -151.

Your assembly-language program is now stored in memory. You can display it with the LIST command:

*3001					
0300-	A2	02		LDX	#\$02
0302-	B5	00		LDA	\$00,X
0304-	95	10		STA	\$10,X
0306-	CA			DEX	
0307-	8D	30	C0	STA	\$C030
030A-	10	F6		BPL	\$0302
030C-	00			BRK	
030D-	00			BRK	
030E-	00			BRK	
030F-	00			BRK	
0310-	00			BRK	
0311-	00			BRK	
0312-	00			BRK	
0313-	00			BRK	
0314-	00			BRK	
0316-	00			BRK	
0316-	00			BRK	
0317-	00			BRK	
0318-	00			BRK	
0319-	00			BRK	
*					

The Mini-Assembler

See Appendix A for more Information about 65C02 (and 6502) instructions.

Table 5-1Mini-Assembler address formats

Addressing mode	Format
Accumulator	•
Implied	•
Immediate	#\${value}
Absolute	\${address}
Zero page	\${address}
Indexed zero page	\${address},X \${address},Y
Indexed absolute	\${address},X \${address},Y
Relative Indexed indirect	\${address} (\${address},X)
Indirect indexed	(\${address}),Y
Absolute indirect	(\${address})

These instructions have no operands.

Mini-Assembler instruction formats

The Apple Mini-Assembler recognizes 56 mnemonics and 13 addressing formats. These constitute the 6502 subset of the 65002 instruction set. The mnemonics are standard, as used in the *Synertek Programming Manual* (Apple part number A2L0003), but the addressing formats are somewhat different. Table 5-1 shows the Apple standard address-mode formats for 6502 assembly language.

An address consists of one or more hexadecimal digits. The Mini-Assembler interprets addresses the same way the Monitor does: if an address has fewer than four digits, the Mini-Assembler adds leading zeros; if the address has more than four digits, then it uses only the last four.

Dollar signs: In this manual, dollar signs (\$) in addresses signify that the addresses are in hexadecimal notation. They are ignored by the Mini-Assembler and may be omitted when typing programs.

There is no syntactical distinction between the absolute and zero-page addressing modes. If you give an instruction to the Mini-Assembler that can be used in both absolute and zero-page mode, the Mini-Assembler assembles that instruction in absolute mode if the operand for that instruction is greater than \$FF, and it assembles it in zero-page mode if the operand is less than \$0100.

Instructions in accumulator mode and implied addressing mode need no operands.

Branch instructions, which use the relative addressing mode, require the target address of the branch. The Mini-Assembler calculates the relative distance to use in the instruction automatically. If the target address is more than 127 locations distant from the instruction, the Mini-Assembler sounds a bell (beep), displays a caret (^) under the target address, and does not assemble the line.

If you give the Mini-Assembler the mnemonic for an instruction and an operand, and the addressing mode of the operand cannot be used with the instruction you entered, the Mini-Assembler will not accept the line.

Summary of Monitor commands

Here is a summary of the Monitor commands, showing the syntax for each one.

Examining memory

{adrs} Examines the value contained in one

location.

{adrs1}.{adrs2} Displays the values contained in all

locations between {adrs1} and {adrs2}.

Return Displays the values in up to eight locations

following the last opened location.

Changing the contents of memory

{adrs}:{val} {val} Stores the values in consecutive memory

locations starting at {adrs}.

:{val}{val}... Stores values in memory starting at the next

changeable location.

Moving and comparing

{dest}<{start}.{end}M Copies the values in the range

{start}.{end} into the range beginning at

 $\{dest\}.$

{dest}<{start}.{end}V Compares the values in the range

(start). (end) to those in the range

beginning at {dest}.

The Examine command

Control-E

Displays the locations where the contents

of the 65C02's registers are stored and

opens them for changing.

The Search command

{val}<{start}.{end}S

Displays the address of the first

occurrence of {val} in the specified range

beginning at {start}.

Cassette tape commands

{start}.{end}W

Writes the values in the memory range

(start).(end) onto tape, preceded by a

ten-second leader.

{start}.{end}R

Reads values from tape, storing them in memory beginning at {start} and stopping at {end}. Prints ERR if an error

occurs.

Miscellaneous Monitor commands

I

Sets inverse display mode.

N

Sets normal display mode.

Control-B

Enters the language currently active

(usually Applesoft).

Control-C

Returns to the language currently active

(usually Applesoft).

 $\{val\}+\{val\}$

Adds the two values and prints the

hexadecimal result.

 $\{val\}-\{val\}$

Subtracts the second value from the first

and prints the result.

{slot} Control-P

Diverts output to the device whose

interface card is in slot number (slot). If

{slot}=0, accepts input from the

keyboard.

Control-Y

Jumps to the machine-language

subroutine at location \$3F8.

Running and listing programs

{adrs}G

Transfers control to the machine language

program beginning at {adrs}.

{adrs}L

Disassembles and displays 20 instructions, starting at {adrs}.

Subsequent LIST commands display 20

more instructions.

The Mini-Assembler

Original Ile

The Mini-Assembler is available on an original Apple IIe only when Integer BASIC is active. See the earlier section "The Mini-Assembler."

F666G	Invokes the Mini-Assembler on the original Apple IIe.
!	Invokes the Mini-Assembler on the enhanced Apple IIe.
\${command}	Executes a Monitor command from the Mini-Assembler on the original Apple IIe.
\$FF69g	Leaves the Mini-Assembler on the original Apple IIe.
Return	Leaves the Mini-Assembler on the enhanced Apple IIe.

Chapter 6

Programming for Peripheral Cards

The seven expansion slots on the Apple IIe's main circuit board are used for installing circuit cards containing the hardware and firmware needed to interface peripheral devices to the Apple IIe. These slots are not simple I/O ports; peripheral cards can access the Apple IIe's data, address, and control lines via these slots. The expansion slots are numbered from 1 to 7, and certain signals, described below, are used to select a specific slot.

Apple II and II Plus

The Apple II and Apple II Plus have an eighth expansion slot: slot number 0. On those models, slot 0 is normally used for a language card or a ROM card; the functions of the Apple II Language Card are built into the main circuit board of the Apple IIe.

Interrupt support on the enhanced Apple IIe requires that special attention be paid to cards designed to be in slot 3. A description of what you need to watch for is given at the end of this chapter.

Original Ile

The interrupt support built into the enhanced (and extended keyboard) Apple IIe is an enhanced and expanded version of the interrupt support in the original Apple IIe.

Peripheral-card memory spaces

Because the Apple IIe's microprocessor does all of its I/O through memory locations, portions of the Apple IIe's memory space have been allocated for the exclusive use of the cards in the expansion slots. In addition to the memory locations used for actual I/O, there are memory spaces available for programmable memory (RAM) in the main memory and for read-only memory (ROM or PROM) on the peripheral cards themselves.

The memory spaces allocated for the peripheral cards are described below. Those memory spaces are used for small dedicated programs such as I/O drivers. Peripheral cards that contain their own driver routines in firmware like this are called *intelligent peripherals*. They make it possible for you to add peripheral hardware to your Apple IIe without having to change your programs, provided that your programs follow normal practice for data input and output.

Table 6-1 Peripheral-card I/O memory locations enabled by DEVICE SELECT'

Slot	Locations
1	\$C090-\$C09F
2	\$COAO-\$COAF
3	\$C0B0-\$C0BF
4	\$C0C0-\$C0CF
5	\$C0D0-\$C0DF
6	\$C0E0-\$C0EF
7	\$C0F0-\$C0FF

Signals for which the active state is low are marked with a prime (*).

Table 6-2
Peripheral-card ROM
memory locations
enabled by I/O SELECT'

Slot	Locations
1	\$C100-\$C1FF
2	\$C200-\$C2FF
3	\$C300-\$C3FF
4	\$C400-\$C4FF
5	\$C500-\$C5FF
6	\$C600-\$C6FF
7	\$C700-\$C7FF

See the section "I/O Programming Suggestions" later in this chapter.

Peripheral-card I/O space

Each expansion slot has the exclusive use of 16 memory locations for data input and output in the memory space beginning at location \$C090. Slot 1 uses locations \$C090 through \$C09F, slot 2 uses locations \$C0A0 through \$C0AF, and so on through location \$C0FF, as shown in Table 6-1.

These memory locations are used for different I/O functions, depending on the design of each peripheral card. Whenever the Apple IIe addresses one of the 16 I/O locations allocated to a particular slot, the signal on pin 41 of that slot, named DEVICE SELECT', switches to the active (low) state. This signal can be used to enable logic on the peripheral card that uses the 4 low-order address lines to determine which of its 16 I/O locations is being accessed.

Peripheral-card ROM space

One 256-byte page of memory space is allocated to each accessory card. This space is normally used for read-only memory (ROM or PROM) on the card with driver programs that control the operation of the peripheral device connected to the card.

The page of memory allocated to each expansion slot begins at location \$Cn00, where n is the slot number, as shown in Table 6-2 and Figure 6-3. Whenever the Apple IIe addresses one of the 256 ROM memory locations allocated to a particular slot, the signal on pin 1 of that slot, named I/O SELECT', switches to the active (low) state. This signal enables the ROM or PROM devices on the card, and the eight low-order address lines determine which of the 256 memory locations is being accessed.

Expansion ROM space

In addition to the small areas of ROM memory allocated to each expansion slot, peripheral cards can use the 2K-byte memory space from \$C800 to \$CFFF for larger programs in ROM or PROM. This memory space is called *expansion ROM space*. (See the memory map in Figure 6-3.) Besides being larger, the expansion ROM memory space is always at the same locations regardless of which slot is occupied by the card, making programs that occupy this memory space easier to write.

This memory space is available to any peripheral card that needs it. More than one peripheral card can have expansion ROM on it, but only one of them can be active at a time.

Each peripheral card that uses expansion ROM must have a circuit on it to enable the ROM. The circuit does this by a two-stage process: first, it sets a flip-flop when the I/O SELECT' signal, pin 1 on the slot, becomes active (low); second, it enables the expansion ROM devices when the I/O STROBE' signal, pin 20 on the slot, becomes active (low). Figure 6-1 shows a typical ROM-enable circuit.

The I/O SELECT' signal on a particular slot becomes active whenever the Apple IIe's microprocessor addresses a location in the 256-byte ROM address space allocated to that slot. The I/O STROBE' signal on all of the expansion slots becomes active (low) when the microprocessor addresses a location in the expansion-ROM memory space, \$C800-\$CFFF. The I/O STROBE' signal is used to enable the expansion-ROM devices on a peripheral card. (See Figure 6-1.)

Important

If there is an 80-column text card installed in the auxiliary slot, some of the functions normally associated with slot 3 are performed by the 80-column text card and the built-in 80-column firmware. With the 80-column text card installed, the I/O STROBE' signal is not available on slot 3, so firmware in expansion ROM on a card in slot 3 will not run.

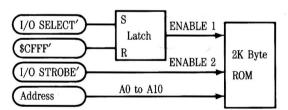


Figure 6-1 Expansion ROM enable circuit

A program on a peripheral card can get exclusive use of the expansion ROM memory space by referring to location \$CFFF in its initialization phase. This location is special: all peripheral cards that use expansion ROM must recognize a reference to \$CFFF as a signal to reset their ROM-enable flip-flops and disable their expansion ROMs. Of course, doing so also disables the expansion ROM on the card that is about to use it, but the next instruction in the initialization code sets the flip-flop in the expansion-ROM enable circuit on the card.

A card that needs to use the expansion ROM space must first insert its slot address (\$Cn) in \$07F8 before it refers to \$CFFF. This allows interrupting devices to reenable the card's expansion ROM after interrupt handling is finished. Once its slot address has been inserted in \$07F8, the peripheral card has exclusive use of the expansion memory space and its program can jump directly into the expansion ROM.

As described earlier, the expansion-ROM disable circuit resets the enable flip-flop whenever the 65C02 addresses location \$CFFF. To do this, the peripheral card must detect the presence of \$CFFF on the address bus. You can use the I/O STROBE' signal for part of the address decoding, since it is active for addresses from \$C800 through \$CFFF. If you can afford to sacrifice some ROM space, you can simplify the address decoding even further and save circuitry on the card. For example, if you give up the last 256 bytes of expansion ROM space, your disable circuit only needs to detect addresses of the form \$CFxx, and you can use the minimal disable-decoding circuitry shown in Figure 6-2.

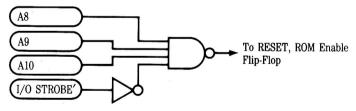


Figure 6-2 ROM disable address decoding

Important

Applesoft addresses two locations in the \$CFxx space, thereby resetting the enable flip-flop. If your peripheral device is going to be used with Applesoft programs, you must either use the full address decoding or else enable the expansion ROM each time it is needed.

Peripheral-card RAM space

There are 56 bytes of main memory allocated to the peripheral cards, eight bytes per card, as shown in Table 6-3. These 56 locations are actually in the RAM memory reserved for the text and low-resolution graphics displays, but these particular locations are not displayed on the screen and their contents are not changed by the built-in output routine COUT1. Programs in ROM on peripheral cards use these locations for temporary data storage.

Table 6-3
Peripheral-card RAM memory locations

Base	Slot number						
address	1	2	3*	4	5	6	7
\$0478	\$0479	\$047A	\$047B*	\$047C	\$047D	\$047E	\$047F
\$04F8	\$04F9	\$04FA	\$04FB*	\$04FC	\$04FD	\$04FE	\$04FF
\$0578	\$0579	\$057A	\$057B*	\$057C	\$057D	\$057E	\$057F
\$05F8	\$05F9	\$05FA	\$05FB*	\$05FC	\$05FD	\$05FE	\$05FF
\$0678	\$0679	\$067A	\$067B*	\$067C	\$067D	\$067E	\$067F
\$06F8	\$06F9	\$06FA	\$06FB*	\$06FC	\$06FD	\$06FE	\$06FF
\$0778	\$0779	\$077A	\$077B*	\$077C	\$077D	\$077E	\$077F
\$07F8	\$07F9	\$07FA	\$07FB*	\$07FC	\$07FD	\$07FE	\$07FF

^{*} If there is a card in the auxiliary slot, it takes over these locations.

A program on a peripheral card can use the eight base addresses shown in the table to access the eight RAM locations allocated for its use, as shown in the next section, "I/O Programming Suggestions."

Warning

The Apple lle firmware sets the value of \$04FB to \$FF on a reset, even if there is no 80-column card installed.

I/O programming suggestions

A program in ROM on a peripheral card should work no matter which slot the card occupies. If the program includes a jump to an absolute location in one of the 256-byte memory spaces, then the card will work only when it is plugged into the slot that uses that memory space. If you are writing the program for a peripheral card that will be used by many people, you should avoid placing such a restriction on the use of the card.

Important

To function properly no matter which slot a peripheral card is installed in, the program in the card's 256-byte memory space must not make any absolute references to itself. Instead of using jump instructions, you should force conditions on branch instructions, which use relative addressing.

The first thing a peripheral card used as an I/O device must do when called is to save the contents of the Apple IIe's microprocessor's registers. (Peripheral cards not being used as I/O devices do not need to save the registers.) The device should save the register's contents on the stack, and restore them just before returning control to the calling program. If there is RAM on the peripheral card, the information may be stored there.

Most single-character I/O is done via the microprocessor's accumulator. A character being output through your subroutine will be in the accumulator with its high bit set when your subroutine is called. Likewise, if your subroutine is performing character input, it must leave the character in the accumulator with its high bit set when it returns to the calling program.

Finding the slot number with ROM switched in

The memory addresses used by a program on a peripheral card differ depending on which expansion slot the card is installed in. Before it can refer to any of those addresses, the program must somehow determine the correct slot number. One way to do this is to execute a JSR (jump to subroutine) to a location with an RTS (return from subroutine) instruction in it, and then derive the slot number from the return address saved on the stack, as shown in the following example.

```
PHP ; save status

SEI ; inhibit interrupts

JSR KNOWNRTS ; ->a known RTS instruction
; ...that you set up

TSX ; get high byte of the

LDA $0100,X ; ...return address from stack

AND #$0F ; low-order digit is slot no.

PLP ; restore status
```

The slot number can now be used in addressing the memory allocated to the peripheral card, as shown in the next section.

I/O addressing

Once your peripheral-card program has the slot number, the card can use the number to address the I/O locations allocated to the slot. Table 6-4 shows how these locations are related to 16 base addresses starting with \$C080. Notice that the difference between the base address and the desired I/O location has the form \$n0, where n is the slot number. Starting with the slot number in the accumulator, the following example computes this difference by four left shifts, then loads it into an index register and uses the base address to specify one of 16 I/O locations.

```
ASL ; get n into
ASL ;
ASL ;
ASL ;
...high-order nybble
TAX ; ...of index register
LDA $C080,X ; load from first I/O location
```

Selecting your target: You must make sure that you get an appropriate value into the index register when you address I/O locations this way. For example, starting with 1 in the accumulator, the instructions in the above example perform an LDA from location \$C090, the first I/O location allocated to slot 1. If the value in the accumulator had been 0, the LDA would have accessed location \$C080, thereby setting the soft switch that selects the second bank of RAM at location \$D000 and enables it for reading.

See the section "Setting Bank Switches" in Chapter 4 for more information.

Table 6-4Peripheral-card I/O base addresses

Base		, (Connecto	r number		2	
address	1	2	3	4	5	6	7
\$C080	\$C090	\$C0A0	\$C0B0	\$C0C0	\$C0D0	\$C0E0	\$C0F0
\$C081	\$C091	\$C0A1	\$C0B1	\$C0C1	\$C0D1	\$C0E1	\$C0F1
\$C082	\$C092	\$C0A2	\$C0B2	\$C0C2	\$C0D2	\$C0E2	\$C0F2
\$C083	\$C093	\$C0A3	\$C0B3	\$C0C3	\$C0D3	\$C0E3	\$C0F3
\$C084	\$C094	\$C0A4	\$C0B4	\$C0C4	\$C0D4	\$C0E4	\$C0F4
\$C085	\$C095	\$C0A5	\$C0B5	\$C0C5	\$C0D5	\$C0E5	\$C0F5
\$C086	\$C096	\$C0A6	\$C0B6	\$C0C6	\$C0D6	\$C0E6	\$C0F6
\$C087	\$C097	\$C0A7	\$C0B7	\$C0C7	\$C0D7	\$C0E7	\$C0F7
\$C088	\$C098	\$C0A8	\$C0B8	\$C0C8	\$C0D8	\$C0E8	\$C0F8
\$C089	\$C099	\$C0A9	\$C0B9	\$C0C9	\$C0D9	\$C0E9	\$C0F9

Table 6-4 (continued)
Peripheral-card I/O base addresses

Dave		C	Connector	number			
Base address	1	2	3	4	5	6	7
							100
\$C08A	\$C09A	\$COAA	\$COBA	\$COCA	\$C0DA	\$C0EA	\$C0FA
\$C08B	\$C09B	\$COAB	\$COBB	\$C0CB	\$CODB	\$C0EB	\$C0FB
\$C08C	\$C09C	\$COAC	\$C0BC	\$COCC	\$CODC	\$C0EC	\$C0FC
\$C08D	\$C09D	\$C0AD	\$C0BD	\$C0CD	\$C0DD	\$C0ED	\$C0FD
\$C08E	\$C09E	\$COAE	\$COBE	\$COCE	\$CODE	\$COEE	\$C0FE
\$C08F	\$C09F	\$COAF	\$COBF	\$COCF	\$CODF	\$COEF	\$C0FF

RAM addressing

A program on a peripheral card can use the eight base addresses shown in Table 6-3 to access the eight RAM locations allocated for its use. The program does this by putting its slot number into the Y index register and using indexed addressing mode with the base addresses. The base addresses can be defined as constants because they are the same no matter which slot the peripheral card occupies.

If you start with the correct slot number in the accumulator (by using the example shown earlier), then the following example uses all eight RAM locations allocated to the slot:

TAY	
LDA	\$0478,Y
STA	\$04F8,Y
LDA	\$0578,Y
STA	\$05F8,Y
LDA	\$0678,Y
STA	\$06F8,Y
LDA	\$0778,Y
STA	\$07F8,Y

Warning

You must be very careful when you have your peripheral-card program store data at the base-address locations themselves since they are temporary storage locations; the RAM at those locations is used by the disk operating system. Always store the first byte of the ROM location of the expansion slot that is currently active (\$Cn) in location \$7F8, and the first byte of the ROM location of the slot holding the controller card for the startup disk drive in location \$5F8.

See "The Standard I/O Links" in Chapter 3.

COUT1 and BASICOUT are described in Chapter 3.

KEYIN and BASICIN are described in Chapter 3.

Changing the standard I/O links

There are two pairs of locations in the Apple IIe that are used for controlling character input and output. They are called the I/O links. In an Apple IIe running without a disk operating system, the I/O links normally contain the starting addresses of the standard input and output routines—KEYIN and COUT1 if the 80-column firmware is not active, BASICIN and BASICOUT if the 80-column is active. If a disk operating system is running, one or both of the links will hold the addresses of the operating system input and output routines.

The link at locations \$36 and \$37 (decimal 54 and 55) is called CSW, for *character output switch*. Individually, location \$36 is called CSWL (CSW Low) and location \$37 is called CSWH (CSW High). CSW holds the starting address of the subroutine the Apple IIe is currently using for single-character output. This address is normally \$FDF0, the address of routine COUT1, or \$C307, the address of BASICOUT.

When you issue a PR#n from BASIC or an n Control-P from the Monitor, the Apple IIe changes this link address to the first address in the ROM memory space allocated to slot number n. That address has the form \$Cn00. Subsequent calls for character output are thus transferred to the program on the peripheral card. That program can use the instruction sequences given above to find its slot number and use the I/O and RAM locations allocated to it. When it is finished, the program can execute an RTS (return from subroutine) instruction to return control to the calling program, or jump to the output routine COUT1 at location \$FDF0 to display the output character (which must be in the accumulator) on the screen, then let COUT1 return to the calling program.

A similar link at locations \$38 and \$39 (decimal 56 and 57) is called KSW, for *keyboard input switch*. Individually, location \$38 is called KSWL (KSW low) and location \$39 is called KSWH (KSW high). KSW holds the starting address of the routine currently being used for single-character input. This address is normally \$FD1B, the starting address of KEYIN, or \$C305, the address of BASICIN.

When you issue an IN#n command from BASIC or an n Control-K from the Monitor, the Apple IIe changes this link address to \$Cn00, the beginning of the ROM memory space that is allocated to slot number n. Subsequent calls for character input are thus transferred to the program on the accessory card. That program can use the instruction sequences given above to find its slot number and use the I/O and RAM locations allocated to it. The program should put the input character, with its high bit set, into the accumulator and execute an RTS instruction to return control to the program that requested input.

When a disk operating system (ProDOS or DOS 3.3) is running, one or both of the standard I/O links hold addresses of the operating system's input and output routines. The operating system has internal locations that hold the addresses of the character input and output routines that are currently active.

Important

See the *ProDOS Technical* Reference Manual for more about using link addresses.

Refer to the section on input and output link registers in the DOS Programmer's Manual and the ProDOS Technical Reference Manual for further details.

If a program that is running with ProDOS or DOS 3.3 changes the standard link addresses, either directly or via IN# and PR# commands, the operating system is disconnected.

To avoid disconnecting the operating system each time a BASIC program initiates I/O to a slot, it should use either an IN# or a PR# command from inside a PRINT statement that starts with a Control-D character. For assembly-language programs, there is a DOS 3.3 subroutine call to use when changing the link addresses. After changing CSW or KSW, the program calls this subroutine at location \$03EA (decimal 1002). The subroutine transfers the link address to a location inside the operating system and then restores the operating system address in the standard link location.

Other uses of I/O memory space

The portion of memory space from location \$C000 through \$CFFF (decimal 49152 through 53247) is normally allocated to I/O and program memory on the peripheral cards, but there are two other functions that also use this memory space: the built-in self-test firmware and the 80-column display firmware. The soft switches that control the allocation of this memory space are described in the next section.

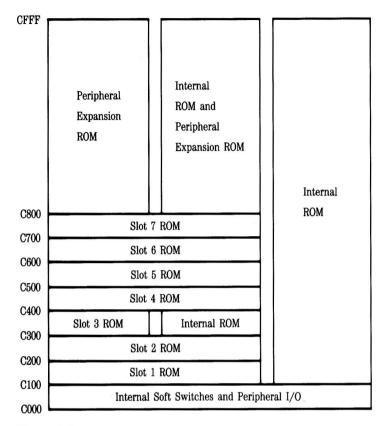


Figure 6-3 I/O memory map

Switching I/O memory

The built-in firmware uses two soft switches to control the allocation of the I/O memory space from \$C000 to \$CFFF. The locations of these soft switches, SLOTCXROM and SLOTC3ROM, are given in Table 6-5.

Note: Like the display switches described in Chapter 2, these soft switches share their locations with the keyboard data and strobe functions. The switches are activated only by writing, and the states can be determined only by reading, as indicated in Table 6-5.

Table 6-5 I/O memory switches

		Location			
Name	Function	Hex	Decimal	Notes	
SLOTC3ROM	Slot ROM at \$C300	\$C00B	49163 –16373	Write	
	Internal ROM at \$C300	\$C00A	49162 –16374	Write	
	Read SLOTC3ROM switch	\$C017	49175 –16361	Read	
SLOTCXROM	Slot ROM at \$Cx00	\$C006	49159 –16377	Write	
	Internal ROM at \$Cx00	\$C007	49158 –16378	Write	
	Read SLOTCXROM switch	\$C015	49173 –16363	Read	

When SLOTC3ROM is on, the 256-byte ROM area at \$C300 is available to a peripheral card in slot 3, which is the slot normally used for a terminal interface. If a card is installed in the auxiliary slot when you turn on the power or reset the Apple IIe, the SLOT3ROM switch is turned off. Turning SLOTC3ROM off disables peripheral-card ROM in slot 3 and enables the built-in 80-column firmware, as shown in Figure 6-3. The 80-column firmware is assigned to slot-3 address space because slot 3 is normally used with a terminal interface, so the built-in firmware will work with programs that use slot 3 this way.

The bus and I/O signals are always available to a peripheral card in slot 3, even when the 80-column hardware and firmware are operating. Thus it is always possible to use this slot for any I/O peripheral that does *not* have built-in firmware.

When SLOTCXROM is active (high), the I/O memory space from \$C100 to \$C7FF is allocated to the expansion slots, as described previously. Setting SLOTCXROM inactive (low) disables the peripheral-card ROM and selects built-in ROM in all of the I/O memory space except the part from \$C000 to \$C0FF (used for soft switches and data I/O), as shown in Figure 6-3. In addition to the 80-column firmware at \$C300 and \$C800, the built-in ROM includes firmware that performs the self-test of the Apple IIe's hardware.

♦ Note: Setting SLOTCXROM low enables built-in ROM in all of the I/O memory space (except the soft-switch area), including the \$C300 space, which contains the 80-column firmware.

Developing cards for slot 3

Original Ile

In the original Apple IIe firmware, the internal slot 3 firmware was always switched in if there was an 80-column card (either 1K or 64K) in the auxiliary slot. This means that peripheral cards with their own ROM were effectively switched out of slot 3 when the system was turned on.

With the enhanced Apple IIe Monitor ROM, the rules are different. A peripheral card in slot 3 is now switched in when the system is started up or when Reset is pressed *if* the card's ROM has the following ID bytes:

C305 = 38C307 = 18

The enhanced Apple IIe firmware requires that interrupt code be present in the \$C3 page (either external or internal). A peripheral card in slot 3 must have the following code to support interrupts. After this segment, the code continues execution in the internal ROM at \$C400.

\$C3F4:IRQDONE	STA	\$C081	;Read ROM, write RAM
	JMP	\$FC7A	;Jump to \$F8 ROM
	IRQ		
	BIT	\$CO15	;slot or internal ROM
	STA	\$0007	:force in internal ROM

When programming for cards in slot 3:

- ☐ You must support the AUXMOVE and XFER routines at \$C311 and \$C314.
- Don't use unpublished entry points into the internal \$Cn00 firmware, because there is no guarantee that they will stay the same.
- ☐ If your peripheral card is a character I/O device, you must follow the Pascal 1.1 firmware protocol, described in the next section.

For more information about the \$C300 firmware, see the Monitor ROM listing in Appendix J of this manual. Especially note the portion from \$C300 through \$C420.

Pascal 1.1 firmware protocol

The Pascal 1.1 firmware protocol was originally developed to be used with Apple Pascal 1.1 programs. The protocol is followed by all succeeding versions of Apple II Pascal, and can be used by programmers using other languages as well.

The Pascal 1.1 firmware protocol provides Apple IIe programmers with

- □ a standard way to uniquely identify new peripheral cards
- a standard way to address the firmware routines in peripheral cards

Table 6-6Peripheral-card device-class assignments

accignine inc				
Device class				
Reserved				
Printer				
Joystick or other X-Y				
input device				
Serial or parallel I/O				
card				
Modem				
Sound or speech device				
Clock				
Mass storage device				
80-column card				
Network or bus interface				
Special purpose (none				
of the above)				
Reserved for future				
expansion				

Device identification

The Pascal 1.1 firmware protocol uses four bytes near the beginning of the peripheral card's firmware to identify the peripheral card.

Address	Value
\$Cs05	\$38 (like the old Apple II Serial Interface Card)
\$Cs07	\$18 (like the old Apple II Serial Interface Card)
\$Cs0B	\$01 (the generic signature of new cards)
\$Cs0C	\$ci (the device signature)

The first hexadecimal digit, c, of the device signature byte identifies the device class; and the second hexadecimal digit, i, of the device signature byte is a unique identifier for the card, used by some manufacturers for their cards. Table 6-6 shows the device-class assignments.

For example, the Apple II Super Serial Card has a device signature of \$31: the 3 signifies that it is a serial or parallel I/O card, and the 1 is the low-order digit supplied by Apple Technical Support.

Although version 1.1 of Pascal ignores the device signature, applications programs can use them to identify specific devices.

I/O routine entry points

Indirect calls to the firmware in a peripheral card are done through a branch table in the card's firmware. The branch table of I/O routine entry points is located near the beginning of the Cs00 address space (s being the slot number where the peripheral card is installed).

The branch table locations that Pascal 1.1 firmware protocol uses are as follows:

Address	Contains
\$Cs0D	Initialization routine offset (required)
\$Cs0E	Read routine offset (required)
\$Cs0F	Write routine offset (required)
\$Cs10	Status routine offset (required)
\$Cs11	\$00 if optional offsets follow; nonzero if not
\$Cs12	Control routine offset (optional)
\$Cs13	Interrupt handling routine offset (optional)

Notice that \$Cs11 contains \$00 only if the control and interrupt handling routines are supported by the firmware. (For example, the SSC does not support these two routines, and so location \$Cs11 contains a nonzero firmware instruction.) Apple II Pascal 1.0 and 1.1 do not support control and interrupt requests, but such requests are implemented in Pascal 1.2 and later versions and in ProDOS.

Table 6-7 gives the entry point addresses and the contents of the 65C02 registers on entry to and on exit from Pascal 1.1 I/O routines.

Table 6-7
I/O routine offsets and registers under Pascal 1.1 protocol

Address	Offset for	X register	Y register	A register
\$Cs0D	Initialization On entry On exit	\$Cs Error code	\$s0 (unchanged)	(unchanged)
\$Cs0E	Read On entry On exit	\$Cs Error code	\$s0 (unchanged)	Character read
\$Cs0F	Write On entry On exit	\$Cs Error code	\$s0 (unchanged)	Char. to write (unchanged)
\$Cs10	Status On entry On exit	\$Cs Error code	\$s0 (changed)	Request (0 or 1) (unchanged)

Interrupts on the enhanced Apple IIe

The original Apple IIe offered little firmware support for interrupts. The enhanced Apple IIe's firmware provides improved interrupt support, very much like the Apple IIc's interrupt support. Neither machine disables interrupts for extended periods.

Interrupts work on enhanced Apple IIe systems with an installed 80-column text card (either 1K or 64K) or a peripheral card with interrupt-handling ROM in slot 3. Interrupts are easiest to use with ProDOS and Pascal 1.2 because they have interrupt support built in. DOS 3.3 has no built-in interrupt support.

The new interrupt handler operates like the Apple IIc interrupt handler, using the same memory locations and operating protocols. The main purpose of the interrupt handler is to support interrupts in *any* memory configuration. This is done by saving the machine's state at the time of the interrupt, placing the Apple in a standard memory configuration before calling your program's interrupt handler, then restoring the original state when your program's interrupt handler is finished.

For more about interrupt support in ProDOS, see the *ProDOS*Technical Reference Manual.

For information about interrupt handling with Apple Pascal 1.2, see the *Device and Interrupt Support Tools Manual*, which is part of the Apple II Device Support Tools package (A2W0014).

What is an interrupt?

An **interrupt** is a hardware signal that tells the computer to stop what it is currently doing and devote its attention to a more important task. Print spooling and mouse handling are examples of interrupt use, things that don't take up all the time available to the system, but that should be taken care of promptly to be most useful.

For example, the Apple IIe mouse can send an interrupt to the computer every time it moves. If you handle that interrupt promptly, the mouse pointer's movement on the screen will be smooth instead of jerky and uneven.

Interrupt priority is handled by a daisy-chain arrangement using two pins, INT IN and INT OUT, on each peripheral-card slot. As described in Chapter 7, each peripheral card breaks the chain when it makes an interrupt request. On peripheral cards that don't use interrupts, these pins should be connected together.

The daisy chain gives priority to the peripheral card in slot 7: if this card opens the connection between INT IN and INT OUT, or if there is no card in this slot, interrupt requests from cards in slots 1 through 6 can't get through. Similarly, slot 6 controls interrupt requests (IRQ) from slots 1 through 5, and so on down the line.

When the IRQ' line on the Apple IIe's microprocessor is activated (pulled low), the microprocessor transfers control through the vector in locations \$FFFE-\$FFFF. This vector is the address of the Monitor's interrupt handler, which determines whether the request is due to an external IRQ or a BRK instruction and transfers control to the appropriate routine via the vectors stored in memory page 3. The BRK vector is in locations \$03F0-\$03F1 and ProDOS uses the IRQ vector in locations \$03FE-\$03FF. (See Table 4-11.) The Monitor normally stores the address of its reset routine in the IRQ vector; you should substitute the address of your program's interrupt-handling routine.

Apple Pascal doesn't use the BRK vector at \$03F0-\$03F1, but it does use the IRQ vector at \$03FE-\$03FF.

Interrupts on Apple IIe series computers

The interrupt handler built into the enhanced Apple IIe's firmware saves the contents of the accumulator on the stack. (The original Apple IIe saves the contents of the accumulator at location \$45.) DOS 3.3, as well as the Monitor, rely on the integrity of location \$45, so this change lets both DOS 3.3 and the Monitor continue to work with active interrupts on the enhanced Apple IIe.

Original Ile

Since the built-in interrupt handler on the original Apple IIe uses location \$45 to save the contents of the accumulator, the operating system falls when an interrupt occurs under DOS 3.3 on the original Apple IIe.

If you want to write programs that use interrupts while running on the original Apple IIe, Apple II Plus, or Apple II, you must use either ProDOS or Apple II Pascal 1.2 (or later versions). Both these operating systems give you full interrupt support, even though these versions of the Apple II don't include interrupt support in their firmware. (Versions of Pascal before 1.2 do not work with interrupts enabled on an original Apple IIe.)

Some other manufacturer's hardware, such as coprocessor cards, don't work properly in an interrupting environment. If you are trying to develop an application and encounter this problem, check with the manufacturer of the card to see if a later version of the hardware or its software will operate properly with interrupts active. You may not be able to use interrupts if an interrupt-tolerant version isn't available.

Interrupts are effective only if they are enabled most of the time. Interrupts that occur while interrupts are disabled will not be serviced.

Pascal, DOS 3.3, and ProDOS turn off interrupts while performing disk operations because of the critical timing of disk read and write operations. Some peripheral cards used in the Apple IIe disable interrupts while reading and writing.

Original lie

Although the enhanced Apple IIe firmware never disables interrupts during screen handling, the original Apple IIe periodically turns interrupts off while doing 80-column screen operations. The effect is most noticeable while the screen is scrolling.

Important

Don't use PR#6 to restart your Apple IIe while running ProDOS with interrupts enabled since PR#6 doesn't disable interrupts. If you try it, ProDOS will fail as it starts up since its interrupt handlers aren't yet set up. If you have to restart, use Control-Reset or make sure that your program disables interrupts before it ends.

Rules of the interrupt handler

Unlike the Apple IIc, the enhanced Apple IIe's interrupt-handling firmware is not always switched in. Here are the reasons why this is so and the implications that necessarily follow.

There is *no* part of memory in the Apple IIe that is always switched in. Thus, there is no location for an interrupt handler that works for all memory configurations. However, the \$C3 page of firmware is present on all systems that have 80-column text cards in their auxiliary slots, so it was selected as the starting location of the built-in interrupt-handling routine.

There are two factors that determine if the \$C3 firmware is switched in and therefore whether or not interrupts will be usable:

- ☐ Is there an 80-column text card in the auxiliary slot?
- ☐ If not, is there a peripheral card in slot 3 with built-in ROM with bytes \$C305 = \$38 and \$C307 = \$18?

The Apple IIe's memory is switched according to the following rules at both powerup and reset:

- ☐ If there is a ROM card in slot 3, but no text card in the auxiliary slot, the firmware on the ROM card is switched in. This is necessary for Pascal to work.
- ☐ If there is a text card in the auxiliary slot, but no ROM card in slot 3, the internal \$C3 firmware is switched in.
- ☐ If there is both a text card in the auxiliary slot and a ROM card in slot 3, the firmware on the ROM card is switched in.

Important

See the section "Developing Cards for Slot 3" earlier in this chapter.

These rules mean that systems without 80-column text cards in the auxiliary slot do not have their internal \$C3 firmware switched in. Such systems cannot handle interrupts or breaks (the software equivalent of interrupts). An application program must swap in the \$C3 firmware both on initialization and after reset to make interrupts function properly on such a machine configuration. (ProDOS versions 1.1 and later do this for you during startup.)

Another implication of the decision to have interrupt code in the \$C3 page affects the shared \$C800 space in the Apple IIe. When the \$C3 page is referenced, the IIe hardware automatically switches in its own \$C800 space. When the interrupt handler finishes, it restores the \$C800 space to the original owner using MSLOT (\$07F8). This means that it is very important for a peripheral card to place its slot address in MSLOT to support interrupts while code is being executed in its \$C800 space.

Interrupt handling on the 65C02 and 6502

There are three possible conditions that will allow interrupts on the 65C02 and 6502:

- ☐ The IRQ line on the microprocessor is pulled low after a CLI instruction has been used (interrupts are not masked). This is the standard technique that devices use when they need immediate attention.
- ☐ The microprocessor executes a break instruction (BRK = opcode \$00).
- A nonmaskable interrupt (NMI) occurs. The microprocessor services this interrupt whether or not the CLI instruction has been used. An NMI is completely independent of the interrupts discussed in this manual.

The microprocessor saves the current program counter and status byte on the stack when an interrupt occurs and then jumps to the routine whose address is stored in \$FFFE and \$FFFF. The sequence of operations performed by the microprocessor is as follows:

- 1. It finishes executing the current instruction if an IRQ is encountered. (If a BRK instruction is encountered, the current instruction is already finished.)
- 2. It pushes the high byte of the program counter onto the stack.
- 3. It pushes the low byte of the program counter onto the stack.
- 4. It pushes the processor status byte onto the stack.
- 5. It executes a JMP (\$FFFE) instruction.

The interrupt vector at \$FFFE

Three separate regions of memory contain address \$FFFE in an Apple IIe with an Extended 80-Column Text Card: the built-in ROM, the bank-switched memory in main RAM, and the bank-switched memory in auxiliary RAM. The vector at \$FFFE in the ROM points to the built-in interrupt handling routine. You must copy the ROM's interrupt vector to the other banks yourself if you plan to use interrupts with the bank-switched memory switched in.

The built-in interrupt handler

The enhanced Apple IIe's built-in interrupt handler records the computer's current memory configuration, then sets the computer's memory configuration to a standard state so that your program's interrupt handler always begins running in the same memory configuration.

Next the built-in interrupt handler checks to see if the interrupt was caused by a break instruction, and handles it as just described under "Interrupt Handling on the 65C02 and 6502." If it was not a break, it passes control to the interrupt-handling routine whose address is stored at \$3FE and \$3FF of main memory. Normally, that would be the operating system's interrupt handler, unless you have installed one of your own.

After your program's interrupt handler returns (with an RTI), the built-in interrupt handler restores the memory configuration, and then does another RTI to return to where it was when the interrupt occurred. Table 6-8 illustrates this entire process. Each of these steps is explained later in this chapter.

Interrupt-handler installation is described in the *ProDOS*Technical Reference Manual and the *Device and Interrupt Support Tools Manual*, which is part of the Apple II Device Support Tools package (A2W0014).

Table 6-8 Interrupt-handling sequence

Interrupted	Draganas	Built in handler	User's handler
program	Processor	Built-in handler	user's nanaier
Program-	►Push address Push status		
	JMP (\$FFFE)→	Save old and set new memory configuration	
		If BRK, then go to break handler (\$FA47)————————————————————————————————————	
		Our interrupt?	
		NO: Push address Push status JMP (\$3FE)—	►Handle interrupt
			•••
		YES: Handle it	
		Restore memory configuration	—RTI
Program→	Pull status < − −Pull address	–RTI	

Saving the Apple Ile's memory configuration

The built-in interrupt handler saves the Apple IIe's memory configuration and then sets it to a known state according to these rules:

- ☐ Text Page 1 is switched in (PAGE2 off) so that main screen holes are accessible if 80STORE and PAGE2 are on.
- □ Main memory is switched in for reading (RAMRD off).
- □ Main memory is switched in for writing (RAMWRT off).
- □ \$D000-\$FFFF ROM is switched in for reading (RDLCRAM off).
- ☐ Main stack and zero page are switched in (ALTZP off).
- ☐ The auxiliary stack pointer is preserved, and the main stack pointer is restored. (See the next section, "Managing Main and Auxiliary Stacks.")

Important

Because main memory is switched in, all memory addresses used later in this chapter are in main memory unless otherwise specified.

Managing main and auxiliary stacks

Apple has adopted a convention that allows the Apple IIe to be run with two separate stack pointers since the Apple IIe with an Extended 80-Column Text Card has two stack pages. Two bytes in the auxiliary stack page are used as storage for inactive stack pointers: \$0100 for the main stack pointer when the auxiliary stack is active, and \$0101 for the auxiliary stack pointer when the main stack is active.

When a program using interrupts switches in the auxiliary stack for the first time, it must place the value of the main stack pointer at \$0100 (in the auxiliary stack) and initialize the auxiliary stack pointer to \$FF (the top of the stack). When it subsequently switches from one stack to the other, it must save the current stack pointer before loading the pointer for the other stack.

The current stack pointer is stored at \$0101, and the main stack pointer is retrieved from \$0100 when an interrupt occurs while the auxiliary stack is switched in. *Then* the main stack is switched in. The stack pointer is restored to its original value after the interrupt has been handled.

Important

The built-in XFER routine does not support this procedure. If you are using XFER to swap stacks, you must use code like the following to set up the stack pointers and stack.

```
* This example transfers control from a code segment running * using the main stack to one running using the aux stack.
```

					The state of the s	
	XFERALT	PHP			;preserve interrupt status in A	
2		PLA				
3		SEI			;disable interrupts	
4		TSX			;save main stack pointer at \$100	
5		STA	SETALTZP		; and swap zero pages	
6		STX	\$100			
7		LDX	\$101		; now restore aux stack pointer	
8		TXS				
9		PHA			;and interrupt status	
10		PLP				
11		LDA	#DESTL		; set destination address	
12		STA	\$3ED			
13		LDA	#DESTH			
14		STA	\$3EE			
15		SEC/	'CLC		;set direction of transfer	
16		BIT	RTS		;V=1 for alt zero page(RTS=\$60)	
17		JMP	XFER		;do transfer	
		To t	ransfer contro	ol the other	direction, change the following lin	ıes
5			\$101			
6		LDX	\$100			
7		STA	SETSTDZP			
16		CLV			;V=0 for main zp	
					•	

The user's interrupt handler at \$3FE

If your program has an interrupt handler, it must place the entry address of that handler at \$03FE. After it sets the machine to a standard state, the IIe's internal interrupt handler transfers control to the routine whose address is in the vector at \$03FE.

It is very important for a peripheral card to place its slot address in MSLOT to support interrupts whenever it is executing code in its \$C800 space. Whenever the \$C3 page is referenced, the IIe automatically switches in its own \$C800 ROM space. When the interrupt handler finishes, it restores the \$C800 space to the original owner using MSLOT (\$07F8).

Warning

Be careful to install interrupt handlers according to the rules of the operating system that you are using. Placing the address of your program's interrupt handler at \$03FE disconnects the operating system's interrupt handler. The \$03FE interrupt handler must do these things:

- 1. Verify that the interrupt came from the expected source.
- 2. Handle the interrupt as desired.
- 3. Clear the appropriate interrupt soft switch.
- 4. Return with an RTI.

Here are some things to remember if you are dealing with programs that must run in an interrupt environment:

- ☐ There is no guaranteed maximum response time for interrupts because the system may be doing a disk operation that lasts for several seconds.
- □ Once the built-in interrupt handler is called, it takes *at least* 150 to 200 microseconds for it to call your interrupt-handling routine. After your routine returns, it takes 40 to 140 microseconds to restore memory and return to the interrupted program.
- □ If memory is in the standard state when the interrupt occurs, the total overhead for interrupt processing is about 150 microseconds less than if memory is in the worst state. (The worst state is one that requires the most work to set up for: 80STORE and PAGE2 on; auxiliary memory switched in for reading and writing; bank-switched memory page 2 in the auxiliary bank switched in for reading and writing; and internal \$Cn00 ROM switched in).
- □ Interrupt overhead will be greater if your interrupt handler is installed through an operating system's interrupt dispatcher. The length of delay depends on the operating system, and on whether the operating system dispatches the interrupt to other routines before calling yours.

Table 6-9BRK handler information

Information	Location
Program counter (low byte)	\$3A
Program counter (high byte)	\$3B
Encoded memory state	\$44
Accumulator	\$45
X register	\$46
Y register	\$47
Status register	\$48

Handling break instructions

The 65C02 treats a break instruction (BRK, opcode \$00) just like a hardware interrupt. After the interrupt handler sets the memory configuration, it checks to see if the interrupt was caused by a break (bit 4 of the status byte is set) and, if it was, jumps to a break-handling routine. This routine saves the state of the computer at the time of the break as shown in Table 6-9.

Finally the break routine jumps to the routine whose address is stored at \$3F0 and \$3F1.

The encoded memory state in location \$44 is interpreted as shown in Table 6-10.

Table 6-10Memory configuration information

Bit 7 = 1	if auxiliary zero page and auxiliary stack are switched in
Bit $6 = 1$	if 80STORE and PAGE2 both on
Bit 5 = 1	if auxiliary RAM switched in for reading
Bit 4 = 1	if auxiliary RAM switched in for writing
Bit 3 = 1	if bank-switched RAM being read
Bit 2 = 1	if bank-switched \$D000 Page 1 switched in and RAMREAD set
Bit 1 = 1	if bank-switched \$D000 Page 2 switched in and RAMREAD set
Bit 0 = 1	if internal Cs ROM was switched in (IIe only)

Interrupt differences: Apple IIe versus Apple IIc

If you are writing software for both the Apple IIe and the Apple IIc, you should know that there are several important differences between the interrupts on the enhanced Apple IIe and those on the Apple IIc. They are the following:

- □ In the Apple IIc ROM, \$FFFE points to \$C803; in the Apple IIe ROM, to \$C3FA. To ensure that the proper interrupt vectors are placed into the Language Card RAM space, always copy them to the RAM from the ROM. (When you initialize built-in devices on the IIc, these vectors are automatically updated).
- □ There is no shared \$C800 ROM in the Apple IIc. Peripheral cards share this space in the Apple IIe. Thus it is crucial that the slot address of the peripheral card using the \$C800 space is stored in MSLOT (\$07F8). When the interrupt handler goes to the internal \$C3 space, the IIe hardware switches in its own \$C800 space. When the interrupt handler finishes, it restores the \$C800 space to the slot whose address is in MSLOT.
- □ The Apple IIc \$C800 space is always switched in. The enhanced Apple IIe's interrupt handler preserves the state of the \$C800-space switch and then switches in the slot I/O space. This means that when restoring the state of the system using the value placed in location \$44, break-handling routines must restore one more value on the Apple IIe than on the Apple IIc.

Chapter 7

Hardware Implementation

Most of this manual describes functions—what the Apple IIe does. This chapter, on the other hand, describes objects—the pieces of hardware the Apple IIe uses to carry out its functions. If you are designing a piece of peripheral hardware to attach to the Apple IIe, or if you just want to know more about how the Apple IIe is built, you should study this chapter.

Extended keyboard lie

Because the extended keyboard lie uses several new components and includes the Extended 80-Column Text Card as a standard feature, its schematic diagram is slightly different from that of the original and enhanced lie's. The schematic for the extended keyboard lie is provided in Figure 7-16a-d at the end of this chapter. If you have an extended keyboard lie you should refer to this schematic whenever the text refers to the schematic for the original and the enhanced lie's (Figure 7-15a-d).

Table 7-1Summary of environmental specifications

Operating temperature	10° to 40° C (50° to 104° F)
Relative humidity	10% to 90%

95 to 127 VAC

Line voltage

Environmental specifications

The Apple IIe is quite sturdy when used in the way it was intended. Table 7-1 defines the conditions under which the Apple IIe is designed to function properly.

You should treat the Apple IIe with the same kind of care as any other electrical appliance. You should protect it from physical violence, such as hammer blows or defenestration. You should protect the mechanical keyboard and the electrical connectors inside the case from spilled liquids, especially those with dissolved contaminants, such as coffee and cola drinks.

In normal operation, enough air flows through the slots in the case to keep the insides from getting too hot, although some of the parts inside the Apple IIe normally get rather warm to the touch. If you manage to overheat your Apple IIe, by blocking the ventilation slots in the top and bottom for example, the first symptom will be erratic operation. The memory devices in the Apple IIe are sensitive to heat: when they get too hot, they occasionally change a bit of data. The exact result depends on what kind of program you are running and on just which bit of memory is affected.

The power supply

The power supply in the Apple IIe operates on normal household AC power and provides enough low-voltage electrical power for the built-in electronics plus a full complement of peripheral cards, including disk controller cards and communications interfaces. The basic specifications of the power supply are listed in Table 7-2.

The Apple IIe's power cord should be plugged into a three-wire 110-to 120-volt outlet. You must connect the Apple IIe to a grounded outlet or to a good earth ground. In addition, the line voltage must be in the range given in Table 7-2. If you try to operate the Apple IIe from a power source with more than 127 volts AC, you will damage the power supply.

Table 7-2Power supply specifications

Line voltage	97 to 127VAC
Maximum power consumption	60W continuous 80W intermittent*
Supply voltages	+5V ±3% +11.8V ±6% -5.2V ±10% -12V ±10%
Maximum supply currents	+5V: 2.5A +12V: 1.5A continuous, 2.5A intermittent* -5V: 250mA -12V: 250mA
Maximum case temperature	40° C (104° F)

Intermittent operation: The Apple IIe can safely operate for up to 20 minutes at the higher load if followed by at least 10 minutes at normal load.

The Apple IIe uses a custom-designed switching-type power supply. It is small and lightweight, and it generates less heat than other types of power supplies do.

The Apple IIe's power supply works by converting the AC line voltage to DC and using this DC voltage to power a variable-frequency oscillator. The oscillator drives a small transformer with many separate windings to produce the different voltages required. A circuit compares the voltage of the +5-volt supply with a reference voltage and feeds an error signal back to the oscillator circuit. The oscillator circuit uses the error signal to control the frequency of its oscillation and keep the output voltages in their normal ranges.

The power supply includes circuitry to protect itself and the other electronic parts of the Apple IIe by turning off all four supply voltages whenever it detects one of the following malfunctions:

- □ any supply voltage short-circuited to ground
- □ the power-supply cable disconnected
- □ any supply voltage outside the normal range

Any time one of these malfunctions occurs, the protection circuit stops the oscillator, and all the output voltages drop to zero. After about half a second, the oscillator starts up again. If the malfunction is still occurring, the protection circuit stops the oscillator again. The power supply will continue to start and stop this way until the malfunction is corrected or the power is turned off.

Warning

If you think the power supply is broken, do not attempt to repair it yourself. The power supply is in a sealed enclosure because some of its circuits are connected directly to the power line. Special equipment is needed to repair the power supply safely, so see your authorized Apple dealer for service.

The power connector

The cable from the power supply is connected to the main circuit board by a six-pin connector with a strain-relief catch. The connector pins are identified in Table 7-3 and Figure 7-15d (or Figure 7-16d for the extended keyboard IIe).

Table 7-3Power connector signal specifications

Pin	Signal	Description
1,2 3 4 5	Ground +5V +12V -12V -5V	Common electrical ground +5V from power supply +12V from power supply -12V from power supply -5V from power supply

The 65C02 microprocessor

The enhanced Apple IIe uses a 65C02 microprocessor as its central processing unit (CPU). The 65C02 in the Apple IIe runs at a clock rate of 1.023 MHz and performs up to 500,000 eight-bit operations per second. You should not use the clock rate as a criterion for comparing different types of microprocessors. The 65C02 has a simpler instruction cycle than most other microprocessors and it uses instruction pipelining for faster processing. The speed of the 65C02 with a 1MHz clock is equivalent to other types of microprocessors with clock rates up to 2.5MHz.

See Appendix A for a description of the 65C02's instruction set and electrical characteristics.

The 65C02 has a 16-bit address bus, giving it an address space of 64K (2 to the 16th power, or 65,536) bytes. The Apple IIe uses special techniques to address outside of this range: see the sections "Bank-Switched Memory" and "Auxiliary Memory and Firmware" in Chapter 4 and the section "Switching I/O Memory" in Chapter 6.

Table 7-4 65C02 microprocessor specifications

Туре	65C02
Register complement	8-bit accumulator (A) 8-bit index registers (X,Y) 8-bit stack pointer (S) 8-bit processor status (P) 16-bit program counter (PC)
Data bus	8 bits wide
Address bus	16 bits wide
Address range	65,536 (64K)
Interrupts	IRQ (maskable) NMI (nonmaskable) BRK (programmed)
Operating voltage	+5V (± 5%)
Power dissipation	5 mW (at 1 MHz)

65C02 timing

The operation of the Apple IIe is controlled by a set of synchronous timing signals, sometimes called *clock signals*. In electronics, the word *clock* is used to identify signals that control the timing of circuit operations. The Apple IIe doesn't contain the kind of clock you tell time by, although its internal timing is accurate enough that a program running on the Apple IIe can simulate such a clock.

The frequency of the oscillator that generates the master timing signal is 14.31818 MHz. Circuitry in the Apple IIe uses this clock signal, named 14M, to produce all the other timing signals. These timing signals perform two major tasks: controlling the computing functions, and generating the video display. The timing signals directly involved with the operation of the 65C02 (and 6502 on the original version of the Apple IIe) are described in this section. Other timing signals are described in this chapter in the sections "RAM Addressing," "Video Display Modes," and "The Expansion Slots."

The main 65C02 timing signals are listed in Table 7-5, and their relationships are diagrammed in Figure 7-1. The 65C02 clock signals are Ø1 and Ø0, complementary signals at a frequency of 1.02273 MHz. The Apple IIe signal named Ø0 is equivalent to the signal called Ø2 in the hardware manual. (It isn't identical: it's a few nanoseconds early.)

The operations of the 65C02 are related to the clock signals in a simple way: address during Ø1, data during Ø0. The 65C02 puts an address on the address bus during Ø1. This address is valid not later than 140 nanoseconds after Ø1 goes high and remains valid through all of Ø0. The 65C02 reads or writes data during Ø0. If the 65C02 is writing, the read/write signal is low during Ø0 and the 65C02 puts data on the data bus. The data is valid not later than 75 nanoseconds after Ø0 goes high. If the 65C02 is reading, the read/write signal remains high. Data on the data bus must be valid no later than 50 nanoseconds before the end of Ø0.

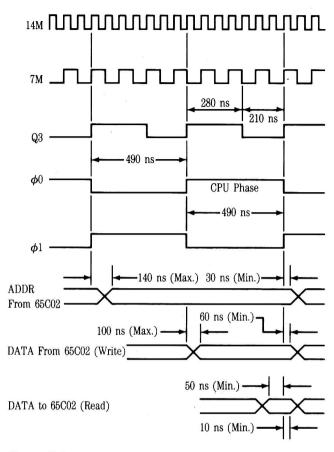


Figure 7-1 65C02 timing signals

Table 7-5 65C02 timing signal descriptions

Signal	Description	
14M	Master oscillator, 14.318 MHz; also 80-column dot cloc	
VID7M	Intermediate timing signal and 40-column dot clock	
Q3	Intermediate timing signal, 2.045 MHz with asymmetrical duty cycle	
ø0	Phase 0 of 65C02 clock, 1.0227 MHz; complement of ø1	

The custom integrated circuits

Most of the circuitry that controls memory and I/O addressing in the Apple IIe is in three custom integrated circuits called the Management Unit (MMU), the Input/Output Unit (IOU), and the Programmed Array Logic device (PAL). The soft switches used for controlling the various I/O and addressing modes of the Apple IIe are addressable flags inside the MMU and the IOU. The functions of these two devices are not as independent as their names suggest; working together, they generate all of the addressing signals. For example, the MMU generates the address signals for the CPU, while the IOU generates similar address signals for the video display.

The Memory Management Unit

The circuitry inside the Memory Management Unit (MMU) implements these soft switches, which are described in the indicated chapters in this manual:

- ☐ Page 2 display (PAGE2): Chapter 2
- □ high-resolution mode (HIRES): Chapter 2
- □ store to 80-column card (80STORE): Chapter 2
- □ select bank 2: Chapter 4
- □ enable bank-switched RAM: Chapter 4
- □ read auxiliary memory (RAMRD): Chapter 4
- □ write auxiliary memory (RAMWRT): Chapter 4
- □ auxiliary stack and zero page (ALTZP): Chapter 4
- □ slot ROM for connector #3 (SLOTC3ROM): Chapter 6
- □ slot ROM in I/O space (SLOTCXROM): Chapter 6

The 64K dynamic RAMs used in the Apple IIe use a multiplexed address, as described later in this chapter in the section "Dynamic-RAM Timing." The MMU generates this multiplexed address for memory reading and writing by the 65C02 CPU. The pinouts and signal descriptions of the MMU are shown in Figure 7-2 and Table 7-6.

			1
GND	1	\bigcup_{40}	A1
A0	2	39	A2
$\phi 0$	3	38	A3
$\mathbf{Q}3$	4	37	A4
PRAS'	5	36	A5
RA0	6	35	A6
RA1	7	34	A7
RA2	8	33	A8
RA3	9	32	A9
RA4	10	31	A10
RA5	11	30	A11
RA6	12	29	A12
RA7	13	28	A13
R/W'	14	27	A14
INH'	15	26	A15
DMA'	16	25	+5V
EN80'	17	24	Cxxx
KBD'	18	23	RAMEN'
ROMEN2'	19	22	R/W′ 245
ROMEN1'	20	21	MD7

Figure 7-2 MMU pinouts

Table 7-6 MMU signal descriptions

Pin	Signal	Description
1	GND	Power and signal common
2	A0	65C02 address input
3	ø0	Clock phase 0 input
4	Q3	Timing signal input
5	PRAS'	Memory row-address strobe
6-13	RAO-RA7	Multiplexed address output
14	R/W'	65C02 read-write control signal
15	INH'	Inhibits main memory (tied to +5V)
16	DMA'	Controls data bus for DMA transfers
17	EN80'	Enables auxiliary RAM
18	KBD'	Enables keyboard data bits 0-6
19	ROMEN2'	Enables ROM (tied to ROMEN1')
20	ROMEN1'	Enables ROM (tied to ROMEN2')
21	MD7	State of MMU flags on data bus bit 7
22	RW' 245	Controls 74LS245 data-bus buffer
23	RAMEN'	Enables main RAM
24	Cxxx	Enables peripheral-card memory
25	+5V	Power
26–40	A15-A1	65C02 address input

The Input/Output Unit

The circuitry inside the Input/Output Unit (IOU) implements the following soft switches, all described in Chapter 2 in this manual:

- □ Page 2 display (PAGE2)
- □ high-resolution mode (HIRES)
- □ text mode (TEXT)
- □ mixed mode (MIXED)
- □ 80-column display (80COL)
- □ text display mode select (ALTCHAR)
- □ any-key-down
- □ annunciators
- □ vertical blanking (VBL)

	, ·		
GND	1	40	H0
GR	2	39	SYNC'
SEGA	3	38	WNDW'
SEGB	4	37	CLRGAT'
VC	5	36	RA10'
80VID'	6	35	RA9'
CASSO	7	34	VID6
SPKR	8	33	VID7
MD7	9	32	KSTRB
AN0	10	31	AKD
AN1	11	30	C0xx
AN2	12	29	A6
AN3	13	28	+5V
R/W'	14	27	Q 3
RESET'	15	26	$\phi 0$
(n.c.)	16	25	PRAS'
RA0	17	24	RA7
RA1	18	23	RA6
RA2	19	22	RA5
RA3	20	21	RA4
			l.

Figure 7-3 IOU pinouts

The 64K dynamic RAMs used in the Apple IIe require a multiplexed address, as described later in this chapter in the section "Dynamic-RAM Timing." The IOU generates this multiplexed address for the data transfers required for display and memory refresh during clock phase 1. The way this address is generated is described later in this chapter in the section "Display Address Mapping." The pinouts and signal descriptions for the IOU are shown in Figure 7-3 and Table 7-7.

Table 7-7IOU signal descriptions

Pin	Signal	Description
1	GND	Power and signal common
2	GR	Graphics mode enable
3	SEGA	In text mode, works with VC (see pin 5) and SEGB to determine character row address
4	SEGB	In text mode, works with VC (see pin 5) and SEGA; in graphics mode, selects high resolution when low, low resolution when high
5	VC	Display vertical counter bit: in text mode, SEGA, SEGB, and VC determine which of the eight rows of a character's dot pattern to display; in low resolution, selects upper or lower block defined by a byte
6	80VID ′	80-column video enable
7	CASSO	Cassette output signal
8	SPKR	Speaker output signal
9	MD7	Internal IOU flags for data bus (bit 7)3
10-13	AN0-AN3	Annunciator outputs
14	R/W'	65C02 read-write control signal
15	RESET'	Power on and reset output
16		(Nothing is connected to this pin.)
17–24	RA0-RA7	Video refresh multiplexed RAM address (phase 1)

Table 7-7 (continued) IOU signal descriptions

Pin	Signal	Description
25	PRAS'	Row-address strobe (phase 0)
26	ø0	Master clock phase 0
27	Q3	Intermediate timing signal
28	+5V	Power
29	A6	Address bit 6 from 65C02
30	C0xx	I/O address enable
31	AKD	Any-key-down signal
32	KSTRB	Keyboard strobe signal
33,34	VIDD7,VIDD6	Video display data bits
35,36	RA9',RA10'	Video display control bits
37	CLRGAT'	Color-burst gate (enable)
38	WNDW'	Display blanking signal
39	SYNC'	Display synchronization signal
40	Н0	Display horizontal timing signal (low bit of character counter)

The PAL device

A Programmed Array Logic device, type PAL 16R8, generates several timing and control signals in the Apple IIe. These signals are listed in Table 7-8. The PAL pinouts are given in Figure 7-4.

Table 7-8PAL signal descriptions

Pin	Signal	Description
1	14M	14.31818 MHz master timing signal
2	7M	7.15909 MHz timing signal
3	3.58M	3.579545 MHz timing signal
4	Н0	Horizontal video timing signal
5	VID7	Video data bit 7
6	SEGB	Video timing signal
7	GR	Video display graphics-mode enable
8	RAMEN'	RAM enable (CAS enable)
9	80VID'	Enable 80-column display mode

+5V 14M 20 2 19 PRAS' 7M 3.58M3 18 (n.c.) PCAS' 4 17 H0VID7 5 16 Q36 15 $\phi 0$ SEGB 7 14 GR $\phi 1$ VID7M RAMEN' 8 13 80VID' 9 12 LDPS' GND 10 11 **ENTMG**

Figure 7-4 PAL pinouts

Table 7-8 (continued) PAL signal descriptions

Pin	Signal	Description
10	GND	Power and signal common
11	ENTMG	Enable master timing
12	LDPS'	Video shift-register load enable
13	VID7M	Video dot clock, 7 or 14 MHz
14	==1	Phase 1 system clock
15	ØO	Phase 0 system clock
16	Q3	Intermediate timing and strobe signal
17	PCAS'	RAM column-address strobe
18	N.C.	(This pin is not used.)
19	PRAS'	RAM row-address strobe
20	+5V	Power

Memory addressing

The Apple IIe's microprocessor can address 65,536 locations. Apple IIe uses this entire address space, and then some: some areas in memory are used for more than one function. The following sections describe the memory devices used in the Apple IIe and the way they are addressed. Input and output also use portions of the memory address space; refer to the section "Peripheral-Card Memory Spaces" in Chapter 6 for information.

A12	2	27	+5V
A7	3	26	+5V
A6	4	25	A8
A5	5	24	A9
A4	6	23	A11
A3	7	22	ROMENx'
A2	8	21	A10
A1	9	20	CE'
A 0	10	19	MD7
MD0	11	18	MD6
MD1	12	17	MD5

16

15

MD4

MD3

Figure 7-5 2364 ROM pinouts

13

ROM addressing

In the original and the enhanced Apple IIe's, the following programs are permanently stored in two type 2364 8K by seven-bit ROMs (read-only memory):

- ☐ Applesoft editor and interpreter
- □ System Monitor
- □ 80-column display firmware
- □ self-test routines

These two ROMs are enabled by two signals named ROMEN1 and ROMEN2. The ROM enabled by ROMEN1, sometimes called the *Diagnostics ROM*, occupies the memory address space from \$C100 to \$DFFF. The address space from \$C300 to \$C3FF and from \$C800 to \$CFFF contains the 80-column display firmware. Those address spaces are normally assigned to ROM on a peripheral card in slot 3.

MD2

GND

For a discussion of the way the 80-column firmware overrides the peripheral card, see the section "Other Uses of I/O Memory Space" in Chapter 6. The pinouts of the 2364 ROMs are given in Figure 7-5.

Extended keyboard lie

	7		
NC	1	28	VCC
A12	2	27	CS1
A7	3	26	A13
A6	4	25	A8
A5	5	24	A9
A4	6	23	A11
A3	7	22	ŌĒ
A2	8	21	A10
A1	9	20	$\overline{ ext{CE}}$
A0	10	19	MD7
MD0	11	18	MD6
MD1	12	17	MD5
MD2	13	16	MD4
GND	14	15	MD3
		1/2	

Figure 7-6 23128 ROM pinouts

4.77		O_{ij}	. 637
Α7	1	24	+5V
A6	2	23	A8
A5	3	22	A9
A4	4	21	+5V
A3	5	20	KBD'
A2	6	19	GND
A 1	7	18	ENKBD'
A 0	8	17	(n.c.)
MD0	9	16	MD6
MD1	10	15	MD5
MD2	11	14	MD4
GND	12	13	MD3

Figure 7-7 2316 ROM pinouts

The extended keyboard lie has the same programs stored in ROM as the original and enhanced lie's do. However, the extended keyboard lie uses a single 23128 IC (128K ROM) instead of the two 2364 ICs used in the original and the enhanced lie. This new ROM IC is enabled by the ROMEN signal, which is a logical AND of the ROMEN1 and ROMEN2 signals. The pinout diagram for the 23128 ROM is given in Figure 7-6.

Two other portions of the Diagnostics ROM, addressed from \$C100 to \$C2FF and from \$C400 to \$C7FF, contain the built-in self-test routines. These address spaces are normally assigned to the peripheral cards; when the self-test programs are running, the peripheral cards are disabled.

The remainder of the Diagnostics ROM, addressed from \$D000 to \$DFFF, contains part of the Applesoft BASIC interpreter.

The ROM enabled by ROMEN2, sometimes called the Monitor ROM, occupies the memory address space from \$E000 to \$FFFF. This ROM contains the rest of the Applesoft interpreter, in the address space from \$E000 to \$EFFF, and the Monitor subroutines, from \$F000 to \$FFFF.

The other ROMs in the Apple IIe are a type 2316 ROM used for the keyboard character decoder and a type 2333 ROM used for character sets for the video display. This 2333 ROM is rather large because it includes a section of straight-through bit-mapping for the graphics modes. This way, graphics display video can pass through the same circuits as text without additional switching circuitry. The 2316's pinout is given in Figure 7-7, and the 2333's pinout is given in Figure 7-8.

RAM addressing

The RAM (programmable memory) in the Apple IIe is used to store both programs (along with their associated data) and the video display. The RAM in both the original and the enhanced IIe consists of eight 64Kx1 RAM ICs (Figure 7-9). The RAM in the extended keyboard IIe consists of two 64Kx4 RAM ICs (Figure 7-10).

VID4	1	24	+5V
VID3	2	23	VID5
VID2	3	22	RA9
VID1	4	21	GR
VID0	5	20	WNDW'
VC	6	19	RA10
SEGB	7	18	ENVID'
SEGA	8	17	D7
D0	9	16	D6
D1	10	15	D5
D2	11	14	D4
GND	12	13	D3

Figure 7-8 2333 ROM pinouts

+5V	1	O 16	GND
MDx	2	15	CAS'
R/W'	3	14	MDx
RAS'	4	13	RA1
RA7	5	12	RA4
RA5	6	11	RA3
RA6	7	10	RA2
+5V	8	9	RA0

Figure 7-9 64Kx1 RAM pinouts

19			
$\overline{\text{OE}}$	1	18	VSS
I/01	2 3	17	I/04
I/02		16	CAS
WRITE	4	15	I/03
RAS	5	14	A0
A6	6	13	A1
A5	7	12	A2
A4	8	11	A3
VCC	9	10	A7

Figure 7-10 64Kx4 RAM pinouts

The areas in RAM that are used for the display are accessed both by the 65C02 microprocessor and by the video display circuits. In some computers, this dual access results in addressing conflicts (cycle stealing) that can cause temporary dropouts in the video display. This problem does not occur in the Apple IIe, thanks to the way the microprocessor and the video circuits share the memory.

The memory circuits in the Apple IIe take advantage of the two-phase system clock described earlier in this chapter in the section "65C02 Timing" to interleave the microprocessor memory accesses and the display memory accesses so that they never interfere with each other. The microprocessor reads or writes to RAM only during Ø0, and the display circuits read data only during Ø1.

Dynamic-RAM refreshment

The image on a video display is not permanent; it fades rapidly and must be refreshed periodically. To refresh the video display, the Apple IIe reads the data in the active display page and sends it to the display. To prevent visible flicker in the display, and to conform to standard practice for broadcast video, the Apple IIe refreshes the display 60 times per second.

The dynamic RAM devices used in the Apple IIe also need a kind of refresh, because the data is stored in the form of electric charges, which diminish with time and must be replenished every so often. The Apple IIe is designed so that refreshing the display also refreshes the dynamic RAMs. The next few paragraphs explain how this is done.

The job of refreshing the dynamic RAM devices is minimized by the structure of the devices themselves. The individual data cells in each RAM device are arranged in a rectangular array of rows and columns. When the device is addressed, the part of the address that specifies a row is presented first, followed by the address of the column. Splitting information into parts that follow each other in time is called *multiplexing*. Because only half of the address is needed at one time, multiplexing the address reduces the number of pins needed for connecting the RAMs.

Different manufacturers' 64K RAMs have cell arrays of either 128 rows by 512 columns or 256 rows by 256 columns. Only the row portion of the address is used in refreshing the RAMs.

Table 7-9
RAM address multiplexing

Mux'd address	Row address	Column address
RA0	A0	A9
RA1	A0 A1	A6
RA2	A2	A10
RA3	A3	A11
RA4	A4	A12
RA5	A5	A13
RA6	A 7	A14
RA7	A8	A15

Now consider how the display is refreshed. As described later in this chapter in the section "The Video Counters," the display circuitry generates a sequence of 8,192 memory addresses in high-resolution mode; in text and low-resolution modes, this sequence is the 1,024 display-page addresses repeated eight times. The display address cycles through this sequence 60 times a second, or once every 17 milliseconds. The way the low-order address lines are assigned to the RAMs, the row address cycles through all 256 possible values once every two milliseconds. (See Figure 7-11.) This more than satisfies the refresh requirements of the dynamic RAMs.

Dynamic-RAM timing

The Apple IIe's microprocessor clock runs at a moderate speed, about 1.023 MHz, but the interleaving of CPU and display cycles means that the RAM is being accessed at a 2 MHz rate, or a cycle time of just under 500 nanoseconds. Data for the CPU is strobed by the falling edge of Ø0, and display data is strobed by the falling edge of Ø1, as shown in Figure 7-11.

The RAM timing looks complicated because the RAM address is multiplexed, as described in the previous section. The MMU takes care of multiplexing the address for the CPU cycle, and the IOU performs the same function for the display cycle. The multiplexed address is sent to the RAM ICs over the lines labeled RAO-RA7. Along with the other timing signals, the PAL device generates two signals that control the RAM addressing: row-address strobe (RAS) and column-address strobe (CAS).

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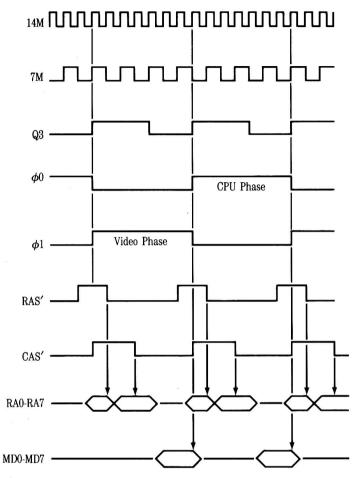


Figure 7-11 RAM timing signals

Table 7-10RAM timing signal descriptions

Signal	Description
ø0	Clock phase 0 (CPU phase)
ø1	Clock phase 1 (display phase)
RAS	Row-address strobe
CAS	Column-address strobe
Q3	Alternate RAM/column-address strobe
RAO-RA7	Multiplexed address bus
MD0-MD7	Internal data bus

The video display

The Apple IIe produces a video signal that creates a display on a standard video monitor or, if you add an RF modulator, on a black-and-white or color television set. The video signal is a composite made up of the data that is being displayed plus the horizontal and vertical synchronization signals that the video monitor uses to arrange the lines of display data on the screen.

Video standards: Apple IIe's manufactured for sale in the U.S. generate a video signal that is compatible with the standards set by the NTSC (National Television Standards Committee). Apple IIe's manufactured for sale in European countries generate video that is a modified NTSC signal.

The display portion of the video signal is a time-varying voltage generated from a stream of data bits, where a 1 corresponds to a voltage that generates a bright dot, and a 0 to a dark dot. The display bit stream is generated in bursts that correspond to the horizontal lines of dots on the video screen. The signal named WNDW' is low during these bursts.

During the time intervals between bursts of data, nothing is displayed on the screen. During these intervals, called the *blanking intervals*, the display is blank and the WNDW' signal is high. The synchronization signals, called *sync* for short, are produced by making the signal named SYNC' low during portions of the blanking intervals. The sync pulses are at a voltage equivalent to blacker-than-black video and don't show on the screen.

The video counters

The address and timing signals that control the generation of the video display are all derived from a chain of counters inside the IOU. Only a few of these counter signals are accessible from outside the IOU, but they are all important in understanding the operation of the display generation process, particularly the display-memory addressing described in the next section.

The horizontal counter is made up of seven stages: H0, H1, H2, H3, H4, H5, and HPE'. The input to the horizontal counter is the 1 MHz signal that controls the reading of data being displayed. The complete cycle of the horizontal counter consists of 65 states. The six bits H0 through H5 count normally from 0 to 63, then start over at 0. Whenever this happens, HPE' forces another count with H0 through H5 held at 0, thus extending the total count to 65.

The IOU uses the 40 horizontal count values from 25 through 64 in generating the low-order part of the display data address, as described later in this chapter in the section "Display Address Mapping." The IOU uses the count values from 0 to 24 to generate the horizontal blanking, the horizontal sync pulse, and the colorburst gate.

When the horizontal count gets to 65, it signals the end of a line by triggering the vertical counter. The vertical counter has nine stages: VA, VB, VC, V0, V1, V2, V3, V4, and V5. When the vertical count reaches 262, the IOU resets it and starts counting again from zero. Only the first 192 scanning lines are actually displayed; the IOU uses the vertical counts from 192 to 261 to generate the vertical blanking and sync pulse. Nothing is displayed during the vertical blanking interval. (The vertical line count is 262 rather than the standard 262.5 because, unlike normal television, the Apple IIe's video display is not interlaced.)

* Smooth animation: Animation displays sometimes have an erratic flicker caused by changing the display data at the same time it is being displayed. You can avoid this on the Apple IIe by reading the vertical-blanking signal (VBL) at location \$C019 and changing display data while VBL is low only (data value less than 128).

Display memory addressing

As described in Chapter 2 in the section "Addressing Display Pages Directly," data bytes are not stored in memory in the same sequence in which they appear on the display. You can get an idea of the way the display data is stored by using the Monitor to set the display to graphics mode, then storing data starting at the beginning of the display page at hexadecimal \$400 and watching the effect on the display. If you do this, you should use the graphics display instead of text to avoid confusion: the text display is also used for Monitor input and output.

If you want your program to display data by storing it directly into the display memory, you must first transform the display coordinates into the appropriate memory addresses, as shown in the section "Video Display Pages" in Chapter 2. The descriptions that follow will help you understand how this address transformation is done and why it is necessary. They will not (alas!) eliminate that necessity.

The address transformation that folds three rows of forty display bytes into 128 contiguous memory locations is the same for all display modes, so it is described first. The differences among the different display modes are then described in the section "Video Display Modes."

Display address mapping

Consider the simplest display on the Apple IIe, the 40-column text mode. To address 40 columns requires 6 bits, and to address 24 rows requires another 5 bits, for a total of 11 address bits. Addressing the display this way would involve 2048 (2 to the eleventh power) bytes of memory to display a mere 960 characters. The 80-column text mode would require 4096 bytes to display 1920 characters. The leftover chunks of memory that were not displayed could be used for storing other data, but not easily, because they would not be contiguous.

Instead of using the horizontal and vertical counts to address memory directly, the circuitry inside the IOU transforms them into the new address signals described below. The transformed display address must meet the following criteria:

- □ map the 960 bytes of 40-column text into only 1024 bytes
- $\hfill\Box$ scan the low-order address to refresh the dynamic RAMs
- □ continue to refresh the RAMs during video blanking

The transformation involves only horizontal counts H3, H4, and H5, and vertical counts V3 and V4. Vertical count bits VA, VB, and VC address the lines making up the characters, and are not involved in the address transformation. The remaining low-order count bits, H0, H1, H2, V0, V1, and V2 are used directly, and are not involved in the transformation.

The requirements of the RAM refreshing are discussed earlier in this chapter in the section "Dynamic-RAM Refreshment."

The IOU performs an addition that reduces the five significant count bits to four new signals called S0, S1, S2, and S3, where S stands for sum. Figure 7-12 is a diagram showing the addition in binary form, with V3 appearing as the carry in and H5 appearing as its complement H5'. A constant value of 1 appears as the low-order bit of the addend. The carry bit generated with the sum is not used.

If this transformation seems obscure, try it with actual values. For example, for the upper-left corner of the display, the vertical count is 0 and the horizontal count is 24: H0, H1, H2, and H5 are 0's, and H3, and H4 are 1's. The value of the sum is 0, so the memory location for the first character on the display is the first location in the display page, as you might expect.

Horizontal bits H0, H1, and H2 and sum bits S0, S1, and S2 make up the transformed horizontal address (A0 through A6 in Table 7-12). As the horizontal count increases from 24 to 63, the value of the sum (S3 S2 S1 S0) increases from 0 to 4 and the transformed address goes from 0 to 39, relative to the beginning of the display page.

The low-order three bits of the vertical row counter are V0, V1, and V2. These bits control address bits A7, A8, and A9, as shown in Table 7-12, so that rows 0 through 7 start on 127-byte boundaries. When the vertical row counter reaches 8, then V0, V1, and V2 are 0 again, and V3 changes to 1. If you do the addition in Table 7-11 with H equal to 24 (the horizontal count for the first column displayed) and V equal to 8, the sum is 5 and the horizontal address is 40: the first character in row 8 is stored in the memory location 40 bytes from the beginning of the display page.

Figure 7-12 shows how groups of 3 40-character rows are stored in blocks of 120 contiguous bytes starting on 127-byte address boundaries. This diagram is another way of describing the display mapping shown in Figure 2-6. Notice that the 3 rows in each block of 120 bytes are not adjacent on the display.

Table 7-11Display address transformation

H5'	V3 H5′	H4 V4	V3 Carry in H3 Augend 1 Addend
S3	S2	S1	S0 Sum

	128 Bytes —			
	← 40 Bytes ← ►	← 40 Bytes ← →	40 Bytes	8 Bytes
\$400	row 0	row 8	row 16	*
\$480	row 1	row 9	row 17	*
\$500	row 2	row 10	row 18	*
\$580	row 3	row 11	row 19	*
\$600	row 4	row 12	row 20	*
\$680	row 5	row 13	row 21	*
\$700	row 6	row 14	row 22	*
\$780	row 7	row 15	row 23	*

Figure 7-12

40-column text display memory (memory locations marked with an asterisk * are reserved for use by peripheral I/O firmware: refer to the section "Peripheral-Card RAM Space" in Chapter 6)

Table 7-12 shows how the signals from the video counters are assigned to the address lines. H0, H1, and H2 are horizontal-count bits, and V0, V1, and V2 are vertical-count bits. S0, S1, S2 and S3 are the folded address bits described above. Address bits marked with an asterisk (*) are different for different modes: see Table 7-13 and the four subsections under "Video Display Modes."

Table 7-12Display memory addressing

Memory address bit	Display address bit	Memory address bit	Display address bit
A0	Н0	A8	V1
A1	H1	A9	V2
A2	H2	A10	*
A3	SO	A11	*
A4	S1	A12	•
A5	S2	A13	•
A6	S3	A14	*
A7	V0	A15	GND

^{*} For these address bits, see text and Table 7-13.

Table 7-13Memory address bits for display modes

	Display mo	des	
Address bit	Text and low resolution	High resolution and double high resolution	
A10	80STORE+PAGE2'	VA	16
A11	80STORE'.PAGE2	VB	
A12	0	VC	
A13	0	80STORE+PAGE2'	
A14	0	80STOREv'.PAGE2	

Note: Period (.) means logical AND; prime (') means logical NOT.

Video display modes

The different display modes all use the address-mapping scheme described in the preceding section, but they use different-sized memory areas in different locations. The next four sections describe the addressing schemes and the methods of generating the actual video signals for the different display modes.

Text displays

The text and low-resolution graphics pages begin at memory locations \$0400 and \$0800. Table 7-13 shows how the display-mode signals control the address bits to produce these addresses. Address bits A10 and A11 are controlled by the settings of PG2 and 80STORE, which are set by the display-page and 80-column-video soft switches. Address bits A12, A13, and A14 are set to 0. Notice that 80STORE active inhibits PG2: there is only one display page in 80-column mode.

The bit patterns used for generating the different characters are stored in a 32K ROM. The low-order six bits of each data byte reach the character generator ROM directly, via the video data bus VID0-VID5. The two high-order bits are modified by the IOU to select between the primary and alternate character sets and are sent to the character generator ROM on lines RA9 and RA10.

The data for each row of characters are read eight times, once for each of the eight lines of dots making up the row of characters. The data bits are sent to the character generator ROM along with VA, VB, and VC, the low-order bits from the vertical counter. For each character being displayed, the character generator ROM puts out one of eight stored bit patterns selected by the three-bit number made up of VA, VB, and VC.

The bit patterns from the character generator ROM are loaded into the 74166 parallel-to-serial shift register and output as a serial bit stream that goes to the video output circuit. The shift register is controlled by signals named LDPS' (for load parallel-to-serial shifter) and VID7M (for video 7 MHz). In 40-column mode, LDPS' strobes the output of the character generator ROM into the shift register once each microsecond, and bits are sent to the screen at a 7 MHz rate.

The addressing for the 80-column display is exactly the same as for the 40-column display: the 40 columns of display memory on the 80-column card are addressed in parallel with the 40 columns in main memory. The data from these two memories reach the video data bus (lines VID0-VID7) via separate 74LS374 three-state buffers. These buffers are loaded simultaneously, but their outputs are sent to the character generator ROM alternately by Ø0 and Ø1. In 80-column mode, LDPS' loads data from the character generator ROM into the shift register twice during each microsecond, once during Ø0 and once during Ø1, and bits are sent to the screen at a 14 MHz rate. Figures 7-13a and 7-13b show the video timing signals.

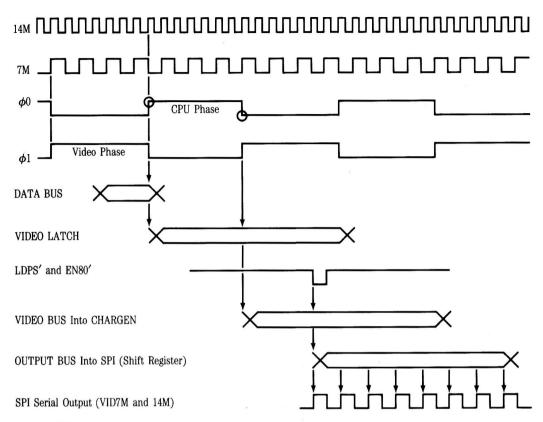


Figure 7-13a 7 MHz video timing signals

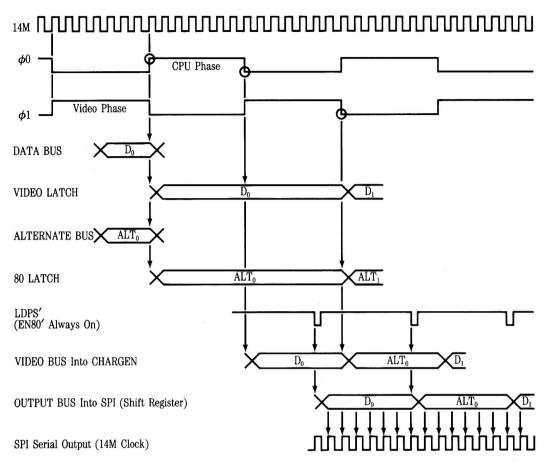


Figure 7-13b 14 MHz video timing signals

Low-resolution display

In the graphics modes, VA and VB are not used by the character generator, so the IOU uses lines SEGA and SEGB to transmit H0 and HIRES', as shown in Table 7-14.

Table 7-14Character-generator control signals

Display mode	SEGA	SEGB	SEGC
Text	VA	VB	VC
Graphics	H0	HIRES'	VC

The low-resolution graphics display uses VC to divide the eight display lines corresponding to a row of characters into two groups of four lines each. Each row of data bytes is addressed eight times, the same as in text mode, but each byte is interpreted as two nibbles. Each nibble selects one of 16 colors. During the upper four of the eight display lines, VC is low and the low-order nibble determines the color. During the lower four display lines, VC is high and the high-order nibble determines the color.

The bit patterns that produce the low-resolution colors are read from the character-generator ROM in the same way the bit patterns for characters are produced in text mode. The 74166 parallel-to-serial shift register converts the bit patterns to a serial bit stream for the video circuits.

The video signal generated by the Apple IIe includes a short burst of 3.58 MHz signal that is used by an NTSC color monitor or color TV set to generate a reference 3.58 MHz color signal. The Apple IIe's video signal produces color by interacting with this 3.58 MHz signal inside the monitor or TV set. Different bit patterns produce different colors by changing the duty cycles and delays of the bit stream relative to the 3.58 MHz color signal. To produce the small delays required for so many different colors, the shift register runs at 14 MHz and shifts out 14 bits during each cycle of the 1 MHz data clock. To generate a stream of fourteen bits from each eight-bit pattern read from the ROM, the output of the shift register is connected back to the register's serial input to repeat the same eight bits; the last two bits are ignored the second time around.

Each bit pattern is output for the same amount of time as a character: 0.98 microseconds. Because that is exactly enough time for three and a half cycles of the 3.58 MHz color signal, the phase relationship between the bit patterns and the signal changes by a half cycle for each successive pattern. To compensate for this, the character generator ROM puts out one of two different bit patterns for each nibble, depending on the state of H0, the low-order bit of the horizontal counter.

High-resolution display

The high-resolution graphics pages begin at memory locations \$2000 and \$4000 (decimal 8192 and 16384). These page addresses are selected by address bits A13 and A14. In high-resolution mode, these address bits are controlled by PG2 and 80STORE, the signals controlled by the display-page (PAGE2) and 80-column-video (80COL) soft switches. As in text mode, 80STORE inhibits addressing of the second page because there is only one page of 80-column text available for mixed mode.

In high-resolution graphics mode, the display data are still stored in blocks like the one shown in Figure 7-12, but there are eight of these blocks. As Tables 7-12 and 7-13 show, vertical counts VA, VB, and VC are used for address bits A10, A11, and A12, which address eight blocks of 1024 bytes each. Remember that in the display, VA, VB, and VC count adjacent horizontal lines in groups of eight. This addressing scheme maps each of those lines into a different 1024-byte block. It might help to think of it as a kind of eight-way multiplexer: it's as if eight text displays were combined to produce a single high-resolution display, with each text display providing one line of dots in turn, instead of a row of characters.

The high-resolution bit patterns are produced by the character-generator ROM. In this mode, the bit patterns simply reproduce the eight bits of display data. The low-order six bits of data reach the ROM via the video data bus VID0–VID5. The IOU sends the other two data bits to the ROM via RA9 and RA10.

The high-resolution colors described in Chapter 2 are produced by the interaction between the video signal the bit patterns generate and the 3.58 MHz color signal generated inside the monitor or TV set. The high-resolution bit patterns are always shifted out at 7 MHz, so each dot corresponds to a half-cycle of the 3.58 MHz color signal. Any part of the video signal that produces a single white dot between two black dots, or vice versa, is effectively a short burst of 3.58 MHz and is therefore displayed as color. In other words, a bit pattern consisting of alternating 1's and 0's gets displayed as a line of color. The high-resolution graphics subroutines produce the appropriate bit patterns by masking the data bits with alternating 1's and 0's.

To produce different colors, the bit patterns must have different phase relationships to the 3.58 MHz color signal. If alternating 1's and 0's produce a certain color, say green, then reversing the pattern to 0's and 1's will produce the complementary color, purple. As in the low-resolution mode, each bit pattern corresponds to three and a half cycles of the color signal, so the phase relationship between the data bits and the color signal changes by a half cycle for each successive byte of data. Here, however, the bit patterns produced by the hardware are the same for adjacent bytes; the color compensation is performed by the high-resolution software, which uses different color masks for data being displayed in even and odd columns.

To produce other colors, bit patterns must have other timing relationships to the 3.58 MHz color signal. In high-resolution mode, the Apple IIe produces two more colors by delaying the output of the shift register by half a dot (70 ns), depending on the high-order bit of the data byte being displayed. (The high-order bit doesn't actually get displayed as a dot, because at 7 MHz there is only time to shift out seven of the eight bits.)

As each byte of data is sent from the character generator to the shift register, high-order data bit D7 is also sent to the PAL device. If D7 is off, the PAL device transmits shift-register timing signals LDPS' and VID7M normally. If D7 is on, the PAL device delays LDPS' and VID7M by 70 nanoseconds, the time corresponding to half a dot. The bit pattern that formerly produced green now produces orange; the pattern for purple now produces blue.

A note about timing. For 80-column text, the shift register is clocked at twice normal speed. When 80-column text is used with graphics in mixed mode, the PAL device controls shift-register timing signals LDPS' and VID7M so that the graphics portion of the display works correctly even when the text window is in 80-column mode.

Double high-resolution display

Double high-resolution graphics mode displays two bytes in the time normally required for one, but uses high-resolution graphics Page 1 in both main and auxiliary memory instead of text or low-resolution Page 1.

Note: There is a second pair of pages, high-resolution Page 2, which can be used to display a second double high-resolution page. Double high-resolution graphics mode displays each pair of data bytes as 14 adjacent dots, seven from each byte. The high-order bit (color-select bit) of each byte is ignored. The auxiliary-memory byte is displayed first, so data from auxiliary memory appears in columns 0–6, 14–20, and so on, up to columns 547–552. Data from main memory appears in columns 7–13, 21–27, and so on, up to 553–559.

As in 80-column text, there are twice as many dots across the display screen, so the dots are only half as wide. On a TV set or low-bandwidth monitor (less than 14 MHz), single dots will be dimmer than normal.

Note: Except for some expensive RGB-type monitors, any video monitor with a bandwidth as high as 14 MHz will be a monochrome monitor. Monochrome means one color: a monochrome video monitor can have a screen color of white, green, orange, or any other single color.

The main memory and auxiliary memory are connected to the address bus in parallel, so both are activated during the display cycle. The rising edge of Ø0 clocks a byte of main memory data into the video latch, and a byte of auxiliary memory data into the 80 latch.

ø1 enables output from the (auxiliary) 80 latch, and ø0 enables output from the (main) video latch. Output from both latches goes to CHARGEN, where GR and SEGB' select high-resolution graphics. LDPS operates at 2 MHz in this mode, alternately gating the auxiliary byte and main byte into the parallel-to-serial shift register. VID7M is active (kept true) for double high-resolution display mode, so when it is ANDed with 14M, the result is still 14M. The 14M serial clock signal gate shift register then outputs to VID, the video display hybrid circuit, for output to the display device.

Video output signals

The stream of video data generated by the display circuits described above goes to a linear summing circuit built around transistor Q1 where it is mixed with the sync signals and the color burst. Resistors R3, R5, R7, R10, R13, and R15 adjust the signals to the proper amplitudes, and a tank circuit (L3 and C32) resonant at 3.58 MHz conditions the color burst.

The resulting video signal is an NTSC-compatible composite-video signal that can be displayed on a standard video monitor. The signal is similar to the EIA (Electronic Industries Association) standard positive composite video (see Table 7-15). This signal is available in two places in the Apple IIe:

- □ At the phono jack on the back of the Apple IIe. The sleeve of this jack is connected to ground and the tip is connected to the video output through a resistor network that attenuates it to about 1 volt and matches its impedance to 75 ohms.
- □ At the internal video connector on the Apple IIe circuit board near the RCA jack, J13 in Figure 7-15c. It is made up of four Molex-type pins, 0.25 inches tall, on 0.10-inch centers. This connector carries the video signal, ground, and two power supplies, as shown in Table 7-15.

Table 7-15 Internal video connector signals

Pin	Signal	Description
1	GROUND	System common ground.
2	VIDEO	NTSC-compatible positive composite video. White level is about 2.0 volts, black level is about 0.75 volts, and sync level is 0.0 volts. This output is not protected against short-circuits.
3	-5V	–5 volt power supply.
4	+12V	+12 volt power supply.

Built-in I/O circuits

The use of the Apple IIe's built-in I/O features is described in Chapter 2. This section describes the hardware implementation of all of those features except the video display described in the previous sections.

The IOU (Input/Output Unit) directly generates the output signals for the speaker, the cassette interface, and the annunciators. The other I/O features are handled by smaller ICs, as described later in this section.

The addresses of the built-in I/O features are described in Chapter 2 and listed in Tables 2-1, 2-10, and 2-11. All of the built-in I/O features except the displays use memory locations between \$C000 and \$C070 (decimal 49152 and 49264). The I/O address decoding is performed by three ICs: a 74LS138, a 74LS154, and a 74LS251.

The 74LS138 decodes address lines A8, A9, A10, and A11 to select address pages on 256-byte boundaries starting at \$C000 (decimal 49152). When it detects addresses between \$C000 and \$C0FF, it enables the IOU and the 74LS154. The 74LS154 in turn decodes address lines A4, A5, A6, and A7 to select 16-byte address areas between \$C000 and \$C0FF. Addresses between \$C060 and \$C06F enable the 74LS251 that multiplexes the hand control switches and paddles; addresses between \$C070 and \$C07F reset the NE558 quadruple timer that interfaces to the hand controls, as described later in the section "Game I/O Signals."

The keyboard

The Apple IIe's keyboard is a matrix of keyswitches connected to an AY-3600-type keyboard decoder via a ribbon cable and a 26-pin connector. The AY-3600 scans the array of keys over and over to detect any keys pressed. The scanning rate is set by the external resistor-capacitor network made up of C70 and R32. The debounce time is also set externally, by C71.

The AY-3600's outputs include five bits of key code plus separate lines for Control, Shift, any-key-down, and keyboard strobe. The any-key-down and keyboard-strobe lines are connected to the IOU, which addresses them as soft switches. The key-code lines, along with Control and Shift, are inputs to a separate 2316 ROM. The ROM translates them to the character codes that are enabled onto the data bus by signals named KBD' and ENKBD'. The KBD' signal is enabled by the MMU whenever a program reads location \$C000, as described in the section "Reading the Keyboard" in Chapter 2.

Table 7-16Keyboard connector signals

Pin	Signal	Description
1,2,4,6,8,10, 23,25,12,22	Y0-Y9	Y-direction key-matrix connections
3	+5	+5 volt supply
5,7,9,15	n.c.	
11	LCNTL'	Line from Control key

Table 7-16 (continued)
Keyboard connector signals

Pin	Signal	Description
13	GND	System common ground
14,18,16,20, 21,19,26,17	X0-X7	X-direction key-matrix connections
24	LSHFT'	Line from Shift key

Connecting a keypad

There is a smaller connector wired in parallel with the keyboard connector in the original and the enhanced IIe. You can connect a ten-key numeric pad to the Apple IIe via this connector.

Extended keyboard lie

The extended keyboard lie has a numeric keypad built into the keyboard.

Table 7-17 Keypad connector signals

Pin	Signal	Description
1,2,5,3,4,6	Y0-Y5	Y-direction key-matrix connections
9,11,10,8	n.c. X4–X7	X-direction key-matrix connections

Cassette I/O

The two miniature phone jacks on the back of the Apple IIe are used to connect an audio cassette recorder for saving programs. The output signal to the cassette recorder comes from a pin on the IOU via resistor network R6 and R9, which attenuates the signal to a level appropriate for the recorder's microphone input. Input from the recorder is amplified and conditioned by a type 741 operational amplifier and sent to one of the inputs of the 74LS251 input multiplexer.

The signal specifications for cassette I/O are

- ☐ Input: 1 volt (nominal) from recorder earphone or monitor output. Input impedance is 12K ohms.
- Output: 25 millivolts to recorder microphone input. Output impedance is 100 ohms.

Table 7-18Speaker connector signals

Pin	Signal	Speaker signal. This line will deliver about 0.5 watt into an 8-ohm speaker.	
1	SPKR		
2	+5	+5V power supply. Note that the speaker is not connected to system ground.	

The speaker

The Apple IIe's built-in loudspeaker is controlled by a single bit of output from the IOU (Input Output Unit). The signal from the IOU is AC coupled to Q5, an MPSA13 Darlington transistor amplifier. The speaker connector is a Molex KK100 connector, J18 in Figure 7-15b, with two square pins 0.25 inches tall and on 0.10-inch centers.

A light-emitting diode is connected in parallel across the speaker pins such that, when the speaker is not connected, the diode glows whenever the speaker signal is on. This diode is used as a diagnostic indicator during assembly and testing of the Apple IIe.

Game I/O signals

Several I/O signals that are individually controlled via soft switches are collectively referred to as the game signals. Even though they are normally used for hand controls, these signals can be used for other simple I/O applications. There are five output signals: the four annunciators, numbered A0 through A3, and one strobe output. There are three one-bit inputs, called *switches* and numbered SW0 through SW2, and four analog inputs, called *paddles* and numbered PDL0 through PDL3.

The annunciator outputs are driven directly by the IOU (Input Output Unit). These outputs can drive one **TTL** (**transistortransistor logic**) load each; for heavier loads, you must use a transistor or a TTL buffer on these outputs. These signals are only available on the 16-pin internal connector. (See Table 7-19.)

The strobe output is a pulse transmitted any time a program reads or writes to location \$C040. The strobe pin is connected to one output of the 74LS154 address decoder. This TTL signal is normally high; it goes low during Ø0 of the instruction cycle that addresses location \$C040. This signal is only available on the 16-pin internal connector. (See Table 7-19.)

The game inputs are multiplexed along with the cassette input signal by a 74LS251 eight-input multiplexer enabled by the C06X' signal from the 74LS154 I/O address decoder. Depending on the low-order address, the appropriate game input is connected to bit 7 of the data bus.

The switch inputs are standard low-power Schottky TTL inputs. To use them, connect each one to 560-ohm pull-down resistors connected to the ground and through single-pole, momentary-contact pushbutton switches to the +5 volt supply.

The hand-control inputs are connected to the timing inputs of an NE558 quadruple 555-type analog timer. Addressing \$C07X sends a signal from the 74LS154 that resets all four timers and causes their outputs to go to 1 (high). A variable resistance of up to 150K ohms connected between one of these inputs and the +5V supply controls the charging time of one of four 0.022-microfarad capacitors. When the voltage on the capacitor passes a certain threshold, the output of the NE558 changes back to 0 (low). Programs can determine the setting of a variable resistor by resetting the timers and then counting time until the selected timer-input changes from high to low. The resulting count is proportional to the resistance.

The game I/O signals are all available on a 16-pin DIP socket labeled GAME I/O on the main circuit board inside the case. The switches and the paddles are also available on a D-type miniature connector on the back of the Apple IIe; see J8 and J15 in Figure 7-15d (Figure 7-16d for the extended keyboard IIe).

Table 7-19
Game I/O connector signals

Internal connector pin	Back-panel connector pin	Signal	Description
1	2	+5V	+5V power supply. Total current drain from this pin must not exceed 100mA.
2,3,4	7,1,6	PB0-PB2	Switch inputs. These are standard 74LS inputs.
5	_	STROBE'	Strobe output. This line goes low during øo of a read or write instruction to location \$C040.
6,10, 7,11	5,8,4,9	PDL0-PDL3	Hand control inputs. Each of these should be connected to a 150K-ohm variable resistor connected to +5V.

Table 7-19 (continued)
Game I/O connector signals

Internal connector	Back-panel connector			
pin	pin	Signal	Description	
8	3	GND	System ground.	
15,14, 13,12	_	ANO-AN3	Annunciators. These are standard 74LS TTL outputs and must be buffered to drive other than TTL inputs.	
9,16	,	n.c.	Nothing is connected to these pins.	

Expanding the Apple Ile

The main circuit board of the Apple IIe has eight empty card connectors or slots on it. These slots make it possible to add features to the Apple IIe by plugging in peripheral cards with additional hardware. This section describes the hardware that supports them, including all of the signals available on the expansion slots.

Chapter 6 describes the standards for programming peripheral cards for the Apple IIe.

The expansion slots

The seven connectors lined up across the back part of the Apple IIe's main circuit card are the expansion slots, also called peripheral slots or simply slots, numbered from 1 to 7. They are 50-pin PC-card edge connectors with pins on 0.10-inch centers. A PC card plugged into one of these connectors has access to all of the signals necessary to perform input and output and to execute programs in RAM or ROM on the card. These signals are described briefly in Table 7-20. The following paragraphs describe the signals in general and mention a few points that are often overlooked. For further details, refer to the schematic diagram in Figures 7-15a-d (Figure 7-16a-d for the extended keyboard IIe).

The peripheral address bus

The microprocessor's address bus is buffered by two 74LS244 octal three-state buffers. These buffers, along with a buffer in the microprocessor's R/W' line, are enabled by a signal derived from the DMA' daisy chain on the expansion slots. Pulling the peripheral line DMA' low disables the address and R/W' buffers so that peripheral DMA circuitry can control the address bus. The DMA address and R/W' signals supplied by a peripheral card must be stable all during ø0 of the instruction cycle, as shown in Figure 7-14.

Another signal that can be used to disable normal operation of the Apple IIe is INH'. Pulling INH' low disables all of the memory in the Apple IIe except the part in the I/O space from \$C000 to \$CFFF. A peripheral card that uses either INH' or DMA' must observe proper timing; in order to disable RAM and ROM cleanly, the disabling signal must be stable all during Ø0 of the instruction cycle (refer to the timing diagram in Figure 7-14).

The peripheral devices should use I/O SELECT' and DEVICE SELECT' as enables. Most peripheral ICs require their enable signals to be present for a certain length of time before data is strobed into or out of the device. Remember that I/O SELECT' and DEVICE SELECT' are only asserted during Ø0 high.

The peripheral data bus

The Apple IIe has two versions of the microprocessor data bus: an internal bus, MD0-MD7, connected directly to the microprocessor; and an external bus, D0-D7, driven by a 74LS245 octal bidirectional bus buffer. The 65C02 is fabricated with MOS circuitry, so it can drive capacitive loads of up to about 130 pF. If peripheral cards are installed in all seven slots, the loading on the data bus can be as high as 500 pF, so the 74LS245 drives the data bus for the peripheral cards. The same argument applies if you use MOS devices on peripheral cards: they don't have enough drive for the fully loaded bus, so you should add buffers.

Loading and driving rules

Table 7-20 shows the drive requirements and loading limits for each pin on the expansion slots. The address bus, the data bus, and the R/W' line should be driven by three-state buffers. Remember that there is considerable distributed capacitance on these buses and that you should plan on tolerating the added load of up to six additional peripheral cards. MOS devices such as PIAs and ACIAs cannot switch such heavy capacitive loads. Connecting such devices directly to the bus will lead to possible timing and level errors.

Interrupt and DMA daisy chains

The interrupt requests (IRQ' and NMI') and the direct-memory access (DMA') signal are available at all seven expansion slots. A peripheral card requests an interrupt or a DMA transfer by pulling the appropriate output line low (active). If two peripheral cards request an interrupt or a DMA transfer at the same time, they will contend for the data and address busses. To prevent this, two pairs of pins on each connector are wired as a priority daisy chain. The daisy-chain pins for interrupts are INT IN and INT OUT, and the pins for DMA are DMA IN and DMA OUT, as shown for J1–J7 in Figure 7-15d (Figure 7-16d for the extended keyboard IIe).

Each daisy chain works like this: the output from each connector goes to the input of the next higher numbered one. For these signals to be useful for cards in lower numbered connectors, all of the higher numbered connectors must have cards in them, and all of those cards must connect DMA IN to DMA OUT and INT IN to INT OUT. Whenever a peripheral card uses pin DMA', it must do so only if its DMA IN line is active, and it must disable its DMA OUT line while it is using DMA'. The INT IN and INT OUT lines must be used the same way: enable the card's interrupt circuits with INT IN, and disable INT OUT whenever IRQ' or NMI' is being used.

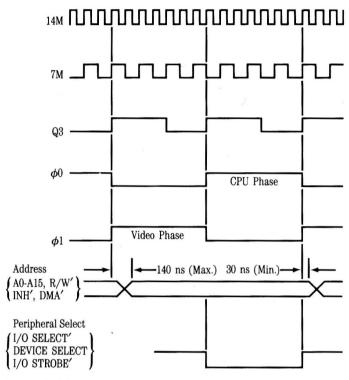


Figure 7-14 Peripheral-signal timing

Table 7-20 Expansion slot signals

Pin	Signal	Description
1	I/O SELECT	Normally high; goes low during Ø0 when the 65C02 addresses location \$CnXX, where n is the connector number. This line can drive 10 LS TTL loads.*
2–17	A0-A15	Three-state address bus. The address becomes valid during Ø1 and remains valid during Ø0. Each address line can drive 5 LS TTL loads.*
18	R/W'	Three-state read/write line. Valid at the same time as the address bus; high during a read cycle, low during a write cycle. It can drive 2 LS TTL loads.*

Table 7-20 (continued) Expansion slot signals

Pin	Signal	Description
19	SYNC'	Composite horizontal and vertical sync,on expansion slot 7 <i>only</i> . This line can drive 2 LS TTL loads.*
20	I/O STROBE'	Normally high; goes low during Ø0 when the 65C02 addresses a location between \$C800 and \$CFFF. This line can drive 4 LS TTL loads.
21	RDY	Input to the 65C02. Pulling this line low during Ø1 halts the 65C02 with the address bus holding the address of the location currently being fetched. This line has a 3300 ohm pullup resistor to +5V.
22	DMA'	Input to the address bus buffers. Pulling this line low during ø1 disconnects the 65C02 from the address bus. This line has a 3300 ohm pullup resistor to +5V.
23	INT OUT	Interrupt priority daisy-chain output. Usually connected to pin 28 (INT IN).†
24	DMA OUT	DMA priority daisy-chain output. Usually connected to pin 22 (DMA IN).
25	+5V	+5-volt power supply. A total of 500mA is available for all peripheral cards.
26	GND	System common ground.
27	DMA IN	DMA priority daisy-chain input. Usually connected to pin 24 (DMA OUT).
28	INT IN	Interrupt priority daisy-chain input. Usually connected to pin 23 (INT OUT).
29	NMI'	Nonmaskable interrupt to 65C02. Pulling this line low starts an interrupt cycle with the interrupt-handling routine at location \$03FB. This line has a 3300 ohm pullup resistor to +5V.

Table 7-20 (continued) Expansion slot signals

Pin	Signal	Description
30	IRQ'	Interrupt request to 65C02. Pulling this line low starts an interrupt cycle only if the interrupt-disable (I) flag in the 65C02 is not set. Uses the interrupt-handling routine at location \$03FE. This line has a 3300 ohm pullup resistor to +5V.
31	RES'	Pulling this line low initiates a reset routine, as described in Chapter 4.
32	INH'	Pulling this line low during ø1 inhibits (disables) the memory on the main circuit board. This line has a 3300 ohm pullup resistor to +5V.
33	-12V	-12 volt power supply. A total of 200mA is available for all peripheral cards.
34	-5V	-5 volt power supply. A total of 200mA is available for all peripheral cards.
35	3.58M	3.58 MHz color reference signal, on slot 7 <i>only</i> . This line can drive 2 LS TTL loads.*
36	7M	System 7 MHz clock. This line can drive 2 LS TTL loads.*
37	Q3	System 2 MHz asymmetrical clock. This line can drive 2 LS TTL loads.*
38	ø1	65C02 phase 1 clock. This line can drive 2 LS TTL loads.*
39	μPSYNC	The 65C02 signals an operand fetch by driving this line high during the first read cycle of each instruction.
40	ø0	65C02 phase 0 clock. This line can drive 2 LS TTL loads.*
41	DEVICE SELECT'	Normally high; goes low during Ø0 when the 65C02 addresses location \$C0nX, where n is the connector number plus 8. This line can drive 10 LS TTL loads.*

Table 7-20 (continued) Expansion slot signals

Pin	Signal	Description
42-49	D0-D7	Three-state buffered bi-directional data bus. Data becomes valid during Ø0 hi and remains valid until Ø0 goes low. Each data line can drive one LS TTL load.*
50	+12V	+12 volt power supply. A total of 250mA is available for all peripheral cards.

^{*} Loading limits are for each card.

The auxiliary slot

The large connector at the left side of the Apple IIe's main circuit card is the auxiliary slot. It is a 60-pin PC-card edge connector with pins on 0.10-inch centers. A PC card plugged into this connector has access to all of the signals used in producing the video display. These signals are described briefly in Table 7-21. For further details, refer to the schematic diagram in Figure 7-15a-d (Figure 7-16a-d for the extended keyboard IIe).

Many of the internal signals that are not available on the expansion slots are on the auxiliary slot. By using both kinds of connectors, manufacturing and repair personnel can gain access to most of the signals needed for diagnosing problems in the Apple IIe.

Important

In the extended keyboard lie, the auxiliary slot is already occupied by the Extended 80-Column Text Card.

80-column display signals

The additional memory needed for producing an 80-column text display is on the 80-column text card, along with the buffers that transfer the data to the video data bus, as described earlier in this chapter in the section "Text Displays." The signals that control the 80-column text data include the system clocks Ø0 and Ø1, the multiplexed RAM address RAO-RA7, the RAM address-strobe signals PRAS' and PCAS', and the auxiliary-RAM enable signals, EN80' and R/W80.

[†] On slot 7 only, this pin can be connected to the graphics-mode signal GR: see text for details.

The EN80' enable signal is controlled by the 80STORE soft switch described in Chapter 4. Data is sent to the auxiliary memory via the internal data bus MD0–MD7; the data is transferred to the video generator via the video data bus VID0–VID7.

Table 7-21Auxiliary slot signals

Pin	Signal	Description
1	3.58M	3.58 MHz video color reference signal. This line can drive two LS TTL loads.
2	VID7M	Clocks the video dots out of the 74166 parallel-to-serial shift register. This line can drive two LS TTL loads.
3	SYNC'	Video horizontal and vertical sync signal. This line can drive two LS TTL loads.
4	PRAS'	Multiplexed RAM row-address strobe. This line can drive two LS TTL loads.
5	VC	Third low-order vertical-counter bit. This line can drive two LS TTL loads.
6	C07X'	Hand-control reset signal. This line can drive two LS TTL loads.
7	WNDW'	Video nonblank window. This line can drive two LS TTL loads.
8	SEGA	First low-order vertical counter bit. This line can drive two LS TTL loads.
51,10,49, 48,13,14, 46,9	RAO-RA7	Multiplexed RAM-address bus. This line can drive two LS TTL loads.
11,12	ROMEN1, ROMEN2	Enable signals for the ROMs on main circuit board.
44,43,40, 39,21,20, 17,16	MD0-MD7	Internal (unbuffered) data bus. This line can drive two LS TTL loads.

Table 7-21 (continued) Auxiliary slot signals

Pin	Signal	Description
45,42,41, 38,22,19, 18,15	VID0-VID7	Video data bus. This three-state bus carries video data to the character generator.
23	ø0	65C02 clock phase 0. This line can drive two LS TTL loads.
24	CLRGAT'	Color-burst gating signal. This line can drive two LS TTL loads.
25	80VID ′	Enables 80-column display timing. This line can drive two LS TTL loads.
26	EN80'	Enable for auxiliary RAM. This line can drive two LS TTL loads.
27	ALTVID'	Alternative video output to the video summing amplifier.
28	SEROUT'	Video serial output from 74166 parallel-to-serial shift register.
29	ENVID'	Normally low; driving this line high disables the character generator such that the video dots from the shift register are all high (white), and alternative video can be sent out via ALTVID. This line has a 1000 ohm pulldown resistor to ground.
30	+5	+5 volt power supply.
31	GND	System common ground.
32	14M	14.3 MHz master clock signal. This line can drive two LS TTL loads.
33	PCAS'	Multiplexed column-address strobe. This line can drive two LS TTL loads.
34	LDPS'	Strobe to video parallel-to-serial shift register. This signal goes low to load the contents of the video data bus into the shift register. This line can drive two LS TTL loads.

Table 7-21 (continued) Auxiliary slot signals

Pin	Signal	Description	
35	R/W80	Read/write signal for RAM on the card in this slot. This line can drive two LS TTL loads.	
36	ø1	65C02 clock phase 1. This line can drive two LS TTL loads.	
37	CASEN'	Column-address enable. This signal is disabled (held high) during accesses to memory on the card in this slot. This line can drive two LS TTL loads.	
47	Н0	Low-order horizontal byte counter. This line can drive two LS TTL loads.	
50	AN3	Output of annunciator number 3. This line can drive two LS TTL loads.	
52	R/W'	65C02 read/write signal. This line can drive two LS TTL loads.	
53	Q3	2 MHz asymmetrical clock. This line can drive two LS TTL loads.	
54	SEGB	Second low-order vertical-counter bit. This line can drive two LS TTL loads.	
55	FRCTXT'	Normally high; pulling this line low enables 14MHz video output even when GR is active.	
56,57	RA9',RA10'	Character-generator control signals from the IOU. This line can drive two LS TTL loads.	
58	GR	Graphics-mode enable signal. This line can drive two LS TTL loads.	
59	7M	7 MHz timing signal. This line can drive two LS TTL loads.	
60	ENTMG'	Normally low; pulling this line high disables the master timing from the PAL device. This line has a 1000 ohm pulldown resistor to ground.	

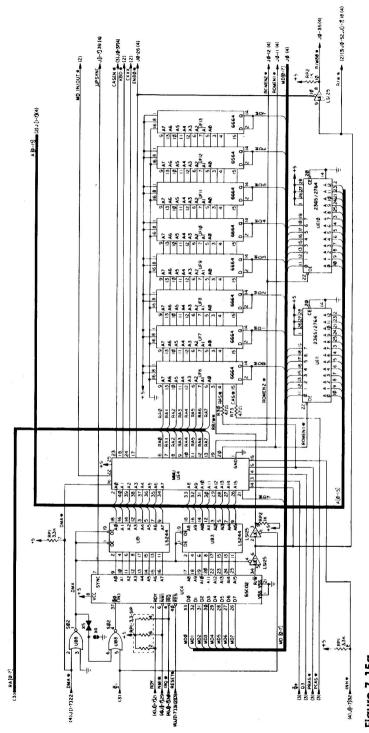


Figure 7-15a Original and enhanced lle schematic diagram, part 1

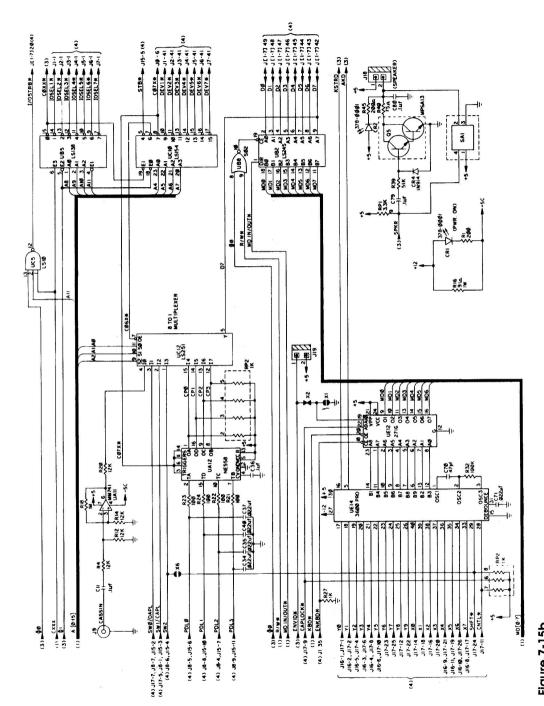


Figure 7-15b Original and enhanced lle schematic diagram, part 2

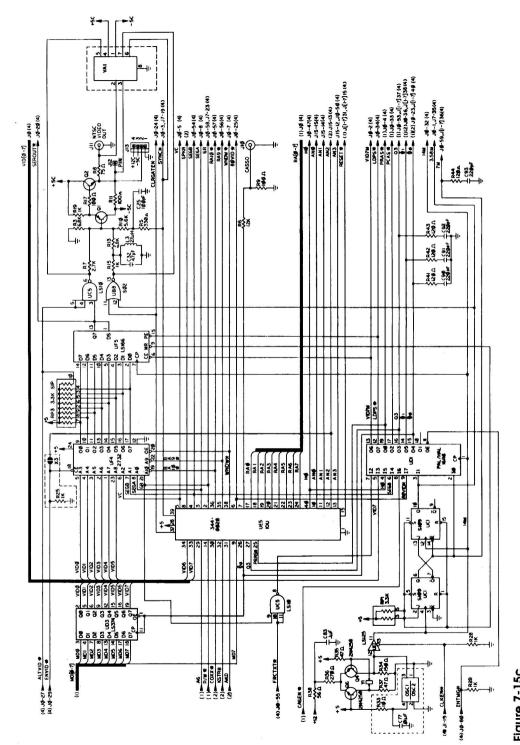


Figure 7-15c Original and enhanced lle schematic diagram, part 3

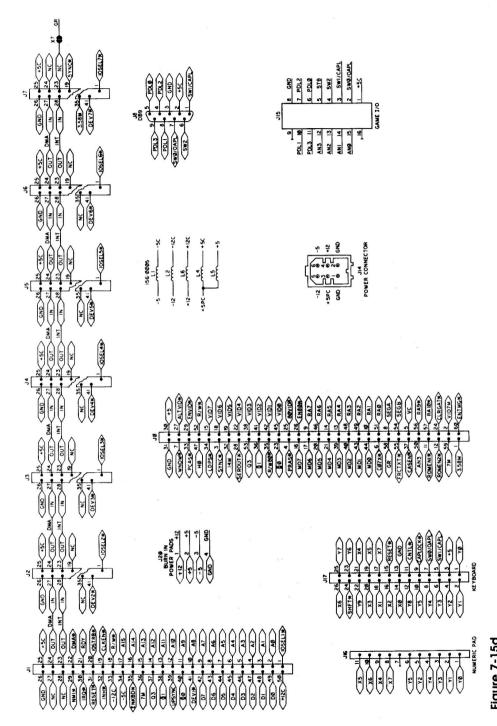


Figure 7-15d Original and enhanced lle schematic diagram, part 4

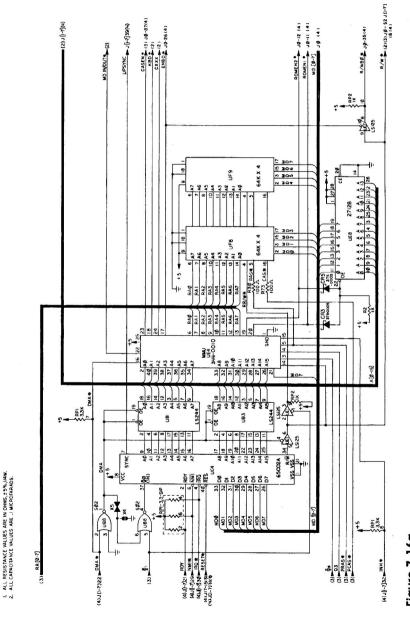


Figure 7-16a Extended keyboard lle schematic diagram, part 1

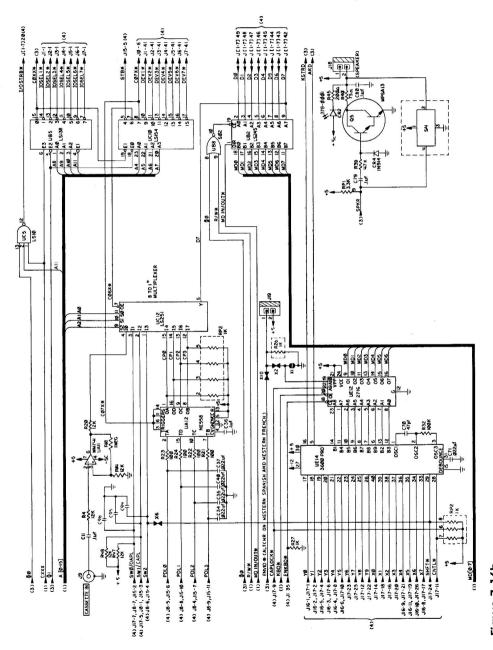


Figure 7-16b Extended keyboard lle schematic diagram, part 2

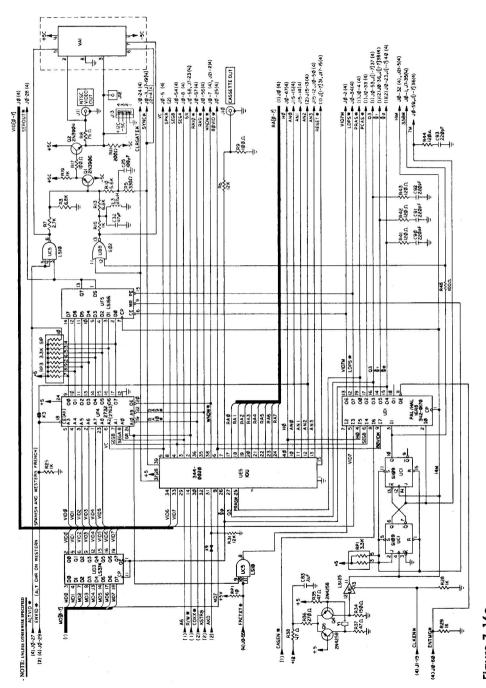


Figure 7-16c Extended keyboard lle schematic diagram, part 3

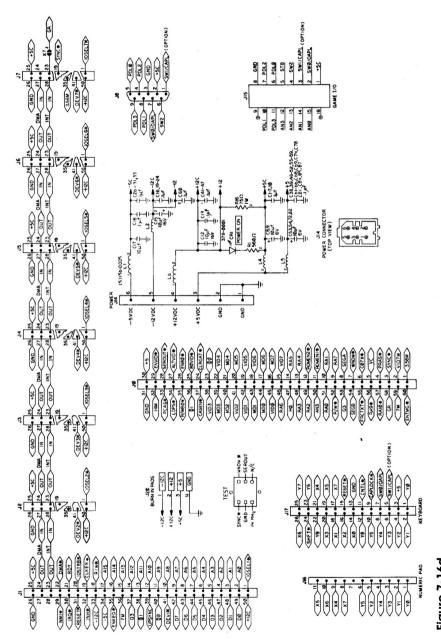


Figure 7-16d Extended keyboard lle schematic diagram, part 4



The 65C02 Microprocessor

This appendix contains a description of the differences between the 6502 and the 65C02 microprocessors. It also contains the data sheet for the 65C02 microprocessor.

The 6502 microprocessor was used in the original Apple IIe, Apple II Plus, and Apple II. The 65C02 is a 6502 that uses less power and has ten new instructions and two new addressing modes. The 65C02 is used in the enhanced and extended keyboard Apple IIe's, as well as in the Apple IIc.

In the data sheet tables, execution times are specified in number of cycles. One cycle time for the Apple IIe equals 0.978 microseconds, giving a system clock rate of about 1.02 MHz.

Note: If you want to write programs that execute on all computers in the Apple II series, use only those 65C02 instructions that are also present on the 6502.

Differences between 6502 and 65C02

The data sheet lists the instructions and addressing modes of the 65C02. This section supplements that information by listing those instructions whose execution times or results differ in the 6502 and the 65C02.

Different cycle times

A few instructions on the 65C02 operate in different numbers of cycles than their 65C02 equivalents. These instructions are listed in Table A-1.

Table A-1
Cycle time differences

Instruction/mode	Opcode	6502 cycles	65C02 cycles	
ASL Absolute, X	1E	7	6	
DEC Absolute, X	DE	7	6	
INC Absolute, X	FE	7	6	
JMP (Absolute)	6C	5	6	
LSR Absolute, X	5E	7	6	
ROL Absolute, X	3E	7	6	
ROR Absolute, X	7E	7	6	

Different instruction results

It is important to note that the BIT instruction when used in immediate mode (opcode \$89) leaves processor status register bits 7 (N) and 6 (V) unchanged on the 65C02. On the 6502, all modes of the BIT instruction have the same effect on the status register: the value of memory bit 7 is placed in status bit 7, and memory bit 6 is placed in status bit 6.

Also note that if the JMP indirect instruction (code \$6C) references an indirect address location that spans a page boundary, the 65C02 fetches the high-order byte of the effective address from the first byte of the next page, while the 6502 fetches it from the first byte of the current page. For example, JMP (\$02FF) gets ADL from location \$02FF on both processors. But on the 65C02, ADH comes from \$0300; on the 6502, ADH comes from \$0200.

Data sheet

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GENERAL DESCRIPTION

The NCR CMOS 6502 is an 8-bit microprocessor which is software compatible with the NMOS 6502. The NCR65C02 hardware interfaces with all 6500 peripherals. The enhancements include ten additional instructions, expanded operational codes and two new addressing modes. This microprocessor has all of the advantages of CMOS technology: low power consumption, increased noise immunity and higher reliability. The CMOS 6502 is a low power high performance microprocessor with applications in the consumer, business, automotive and communications market.

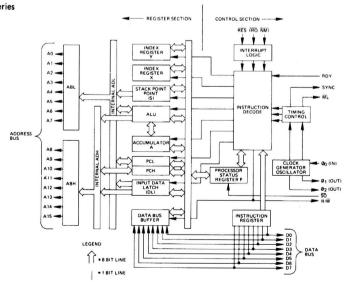
FEATURES

- Enhanced software performance including 27 additional OP codes encompassing ten new instructions and two additional addressing modes.
- 66 microprocessor instructions.
- 15 addressing modes.
- 178 operational codes.
- 1MHz, 2MHz operation.
- Operates at frequencies as low as 200 Hz for even lower power consumption (pseudo-static: stop during \$\mathcal{Q}_2\$ high).
- Compatible with NMOS 6500 series microprocessors.
- 64 K-byte addressable memory.
- Interrupt capability.
- Lower power consumption.
 4mA @ 1MHz.
- +5 volt power supply.
- 8-bit bidirectional data bus.
- Bus Compatible with M6800.
- Non-maskable interrupt.
- 40 pin dual-in-line packaging.
- 8-bit parallel processing
- · Decimal and binary arithmetic.
- · Pipeline architecture.
- Programmable stack pointer.
- Variable length stack.
- Optional internal pullups for (RDY, IRQ, SO, NMI and RES)
- Specifications are subject to change without notice.

PIN CONFIGURATION



NCR65C02 BLOCK DIAGRAM



ABSOLUTE MAXIMUM RATINGS:

 $(V_{DD} = 5.0 \text{ V} \pm 5\%, V_{SS} = 0 \text{ V}, T_{A} = 0^{\circ} \text{ to} + 70^{\circ}\text{C})$

RATING	SYMBOL	VALUE	UNIT
SUPPLY VOLTAGE	V _{DD}	-0.3 to +7.0	V
INPUT VOLTAGE	VIN	-0.3 to +7.0	V
OPERATING TEMP.	TA	0 to + 70	°C
STORAGE TEMP.	T _{STG}	-55 to + 150	°C

PIN FUNCTION

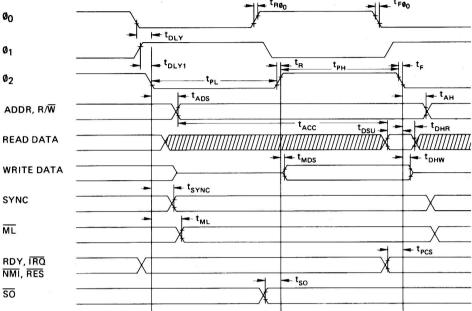
PIN	FUNCTION
A0 - A15	Address Bus
D0 - D7	Data Bus
RQ *	Interrupt Request
RDY *	Ready
ML	Memory Lock
NMI *	Non-Maskable Interrupt
SYNC	Synchronize
RES *	Reset
SO *	Set Overflow
NC	No Connection
R/W	Read/Write
/DD	Power Supply (+5V)
VSS	Internal Logic Ground
ØO	Clock Input
01, 02	Clock Output

^{*}This pin has an optional internal pullup for a No Connect condition.

■ DC CHARACTERISTICS

	SYMBOL	MIN.	TYP.	MAX	UNIT
Input High Voltage					
Ø ₀ (IN)	VIH	V _{SS} + 2.4	-	V_{DD}	V
Input High Voltage					
RES, NMI, RDY, IRQ, Data, S.O.		V _{SS} + 2.0	-	_	٧
Input Low Voltage					
Ø ₀ (IN)	VIL	V _{SS} -0.3	_	V _{SS} + 0.4	٧
RES, NMI, RDY, IRQ, Data, S.O.		-	-	V _{SS} + 0.8	V
Input Leakage Current					
$(V_{IN} = 0 \text{ to } 5.25V, V_{DD} = 5.25V)$	IIN				
With pullups		-30	-	+30	μΑ
Without pullups		-	_	+1.0	μΑ
Three State (Off State) Input Current					
$(V_{IN} = 0.4 \text{ to } 2.4V, V_{CC} = 5.25V)$					
Data Lines	ITSI	-	-	10	μΑ
Output High Voltage					
$(I_{OH} = -100 \ \mu Adc, \ V_{DD} = 4.75V$					
SYNC, Data, A0-A15, R/W)	V _{OH}	V _{SS} + 2.4	_	_	V
Out Low Voltage					
$(I_{OL} = 1.6 \text{mAdc}, V_{DD} = 4.75 \text{V}$					
SYNC, Data, A0-A15, R/W)	VOL	_	-	V _{SS} + 0.4	V
Supply Current f = 1MHz	IDD	_	_	4	mA
Supply Current f = 2MHz	I _{DD}		-	8	mA
Capacitance	С				pF
$(V_{IN} = 0, T_A = 25^{\circ}C, f = 1MHz)$	_			_	
Logic	GN	_	_	5	
Data		-	_	10	
A0-A15, R/W, SYNC	Cout	_	-	10	
Ø _O (IN)	CØ ₀ (IN)	_	_	10	

TIMING DIAGRAM



Note: All timing is referenced from a high voltage of 2.0 volts and a low voltage of 0.8 volts.

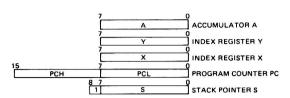
NEW INSTRUCTION MNEMONICS

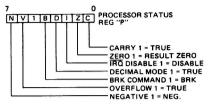
HEX	MNEMONIC	DESCRIPTION
80	BRA	Branch relative always [Relative]
3A	DEA	Decrement accumulator [Accum]
1A	INA	Increment accumulator [Accum]
DA	PHX	Push X on stack [Implied]
5A	PHY	Push Y on stack [Implied]
FA	PLX	Pull X from stack [Implied]
7A	PLY	Pull Y from stack [Implied]
9C	STZ	Store zero [Absolute]
9E	STZ	Store zero [ABS, X]
64	STZ	Store zero [Zero page]
74	STZ	Store zero [ZPG,X]
1C	TRB	Test and reset memory bits with accumulator [Absolute]
14	TRB	Test and reset memory bits with accumulator [Zero page]
oc	TSB	Test and set memory bits with accumulator [Absolute]
04	TSB	Test and set memory bits with accumulator [Zero page]

ADDITIONAL INSTRUCTION ADDRESSING MODES

MNEMONIC	DESCRIPTION
ADC	Add memory to accumulator with carry [(ZPG)]
AND	"AND" memory with accumulator [(ZPG)]
BIT	Test memory bits with accumulator [ABS, X]
BIT	Test memory bits with accumulator [ZPG, X]
CMP	Compare memory and accumulator [(ZPG)]
EOR	"Exclusive Or" memory with accumulator [(ZPG)]
JMP	Jump (New addressing mode) [ABS(IND,X)]
LDA	Load accumulator with memory [(ZPG)]
ORA	"OR" memory with accumulator [(ZPG)]
SBC	Subtract memory from accumulator with borrow [(ZPG)]
STA	Store accumulator in memory [(ZPG)]
	ADC AND BIT BIT CMP EOR JMP LDA ORA SBC

MICROPROCESSOR PROGRAMMING MODEL





FUNCTIONAL DESCRIPTION

Timing Control

The timing control unit keeps track of the instruction cycle being monitored. The unit is set to zero each time an instruction fetch is executed and is advanced at the beginning of each phase one clock pulse for as many cycles as is required to complete the instruction. Each data transfer which takes place between the registers depends upon decoding the contents of both the instruction register and the timing control unit.

Program Counter

The 16-bit program counter provides the addresses which step the microprocessor through sequential instructions in a program.

Each time the microprocessor fetches an instruction from program memory, the lower byte of the program counter (PCL) is placed on the low-order bits of the address bus and the higher byte of the program counter (PCH) is placed on the high-order 8 bits. The counter is incremented each time an instruction or data is fetched from program memory.

Instruction Register and Decode

Instructions fetched from memory are gated onto the internal data bus. These instructions are latched into the instruction register, then decoded, along with timing and interrupt signals, to generate control signals for the various registers.

Arithmetic and Logic Unit (ALU)

All arithmetic and logic operations take place in the ALU including incrementing and decrementing internal registers (except the program counter). The ALU has no internal memory and is used only to perform logical and transient numerical operations.

Accumulator

The accumulator is a general purpose 8-bit register that stores the results of most arithmetic and logic operations, and in addition, the accumulator usually contains one of the two data words used in these operations.

Index Registers

There are two 8-bit index registers (X and Y), which may be used to count program steps or to provide an index value to be used in generating an effective address.

When executing an instruction which specifies indexed addressing, the CPU fetches the op code and the base address, and modifies the address by adding the index register to it prior to performing the desired operation. Pre- or post-indexing of indirect addresses is possible (see addressing modes).

Stack Pointer

The stack pointer is an 8-bit register used to control the addressing of the variable-length stack on page one. The stack pointer is automatically incremented and decremented under control of the microprocessor to perform stack manipulations under direction of either the program or interrupts ($\overline{\text{NMI}}$ and $\overline{\text{IRO}}$). The stack allows simple implementation of nested subroutines and multiple level interrupts. The stack pointer should be initialized before any interrupts or stack operations occur.

Processor Status Register

The 8-bit processor status register contains seven status flags. Some of the flags are controlled by the program others may be controlled both by the program and the CPU. The 6500 instruction set contains a number of conditional branch instructions which are designed to allow testing of these flags (see microprocessor programming model).

■ AC CHARACTERISTICS V_{DD} = 5.0V ± 5%, T_A = 0°C to 70°C, Load = 1 TTL + 130 pF

		1N	MHZ	2N	lHZ	3N	НZ	
Parameter	Symbol	Min	Max	Min	Max	Min	Max	Unit
Delay Time, Ø ₀ (IN) to Ø ₂ (OUT)	t _{DLY}	_	60	-	60	20	60	nS
Delay Time, Ø1 (OUT) to Ø2 (OUT)	t _{DLY1}	-20	20	-20	20	-20	20	nS
Cycle Time	tcyc	1.0	5000*	0.50	5000*	0.33	5000*	μς
Clock Pulse Width Low	tpL	460	_	220	-	160	-	nS
Clock Pulse Width High	t _{PH}	460	-	220	_	160	-	nS
Fall Time, Rise Time	t _F , t _R	_	25	-	25	_	25	nS
Address Hold Time	t _{AH}	20	-	20		0	-	nS
Address Setup Time	t _{ADS}	_	225	-	140	_	110	nS
Access Time	tACC	650	-	310	-	170	_	n\$
Read Data Hold Time	t _{DHR}	10	-	10	-	10	-	nS
Read Data Setup Time	tosu	100	-	60	_	60	_	nS
Write Data Delay Time	t _{MDS}	_	30	-	30	-	30	nS
Write Data Hold Time	t _{DHW}	20	-	20	_	15	-	nS
SO Setup Time	t _{so}	100	-	100	-	100	-	nS
Processor Control Setup Time**	t _{PCS}	200	-	150	_	150	_	nS
SYNC Setup Time	tsync	-	225	_	140	-	100	nS
ML Setup Time	t _{ML}	-	225	_	140	_	100	nS
Input Clock Rise/Fall Time	t _{FØo} ,t _{RØo}	-	25	-	25	_	25	nS

^{*}NCR65C02 can be held static with Ø 2 high.

• MICROPROCESSOR OPERATIONAL ENHANCEMENTS

Function	NMOS 6502 Microprocessor	NCR65C02	Microproc	essor
Indexed addressing across page boundary.	Extra read of invalid address.	Extra read of last	instruction	n byte.
Execution of invalid op codes.	Some terminate only by reset. Results	All are NOPs (rese	erved for fu	uture use).
*	are undefined.	Op Code	Bytes	Cycles
		X2	2	2
		X3, X7, XB, XF	1	1
		44	2	3
		54, D4, F4	2	4
		5C	3	8
		DC, FC	3	.4
Jump indirect, operand = XXFF.	Page address does not increment.	Page address incr additional cycle.	ements an	d adds one
Read/modify/write instructions at effective address.	One read and two write cycles.	Two read and one	write cyc	le.
Decimal flag.	Indeterminate after reset.	Initialized to bina reset and interrup		D=0) after
Flags after decimal operation.	Invalid N, V and Z flags.	Valid flag adds	one additi	onal cycle.
Interrupt after fetch of BRK instruction.	Interrupt vector is loaded, BRK vector is ignored.	BRK is executed, executed.	then inter	rupt is

MICROPROCESSOR HARDWARE ENHANCEMENTS

Function	NMOS 6502	NCR65C02
Assertion of Ready RDY during write operations.	Ignored.	Stops processor during 02.
Unused input-only pins (IRQ, NMI, RDY, RES, SO).	Must be connected to low impedance signal to avoid noise problems.	Connected internally by a high- resistance to V _{DD} (approximately 250 K ohm.)

^{**}This parameter must only be met to guarantee that the signal will be recognized at the current clock cycle.

ADDRESSING MODES

Fifteen addressing modes are available to the user of the NCR65C02 microprocessor. The addressing modes are described in the following paragraphs:

Implied Addressing [Implied]

In the implied addressing mode, the address containing the operand is implicitly stated in the operation code of the instruction

Accumulator Addressing [Accum]

This form of addressing is represented with a one byte instruction and implies an operation on the accumulator

Immediate Addressing [Immediate]

With immediate addressing, the operand is contained in the second byte of the instruction; no further memory addressing is required.

Absolute Addressing [Absolute]

For absolute addressing, the second byte of the instruction specifies the eight low-order bits of the effective address, while the third byte specifies the eight high-order bits. Therefore, this addressing mode allows access to the total 64K bytes of addressable memory.

Zero Page Addressing [Zero Page]

Zero page addressing allows shorter code and execution times by only fetching the second byte of the instruction and assuming a zero high address byte. The careful use of zero page addressing can result in significant increase in code efficiency.

Absolute Indexed Addressing [ABS, X or ABS, Y]

Absolute indexed addressing is used in conjunction with X or Y index register and is referred to as "Absolute, X," and "Absolute, Y." The effective address is formed by adding the contents of X or Y to the address contained in the second and third bytes of the instruction. This mode allows the index register to contain the index or count value and the instruction to contain the base address. This type of indexing allows any location referencing and the index to modify multiple fields, resulting in reduced coding and execution time.

Zero Page Indexed Addressing [ZPG, X or ZPG, Y]

Zero page absolute addressing is used in conjunction with the index register and is referred to as "Zero Page, X" or "Zero Page, Y." The effective address is calculated by adding the second byte to the contents of the index register. Since this is a form of "Zero Page" addressing, the content of the second byte references a location in page zero. Additionally, due to the "Zero Page" addressing nature of this mode, no carry is added to the highorder eight bits of memory, and crossing of page boundaries does not occur.

Relative Addressing [Relative]

Relative addressing is used only with branch instructions;

it establishes a destination for the conditional branch. The second byte of the instruction becomes the operand which is an "Offset" added to the contents of the program counter when the counter is set at the next instruction. The range of the offset is -128 to +127 bytes from the next instruction.

Zero Page Indexed Indirect Addressing [(IND, X)]

With zero page indexed indirect addressing (usually referred to as indirect X) the second byte of the instruction is added to the contents of the X index register; the carry is discarded. The result of this addition points to a memory location on page zero whose contents is the low-order eight bits of the effective address. The next memory location in page zero contains the high-order eight bits of the effective address. Both memory locations specifying the high- and low-order bytes of the effective address must be in page zero.

*Absolute Indexed Indirect Addressing [ABS(IND, X)] (Jump Instruction Only)

With absolute indexed indirect addressing the contents of the second and third instruction bytes are added to the X register. The result of this addition, points to a memory location containing the lower-order eight bits of the effective address. The next memory location contains the higher-order eight bits of the effective address.

Indirect Indexed Addressing [(IND), Y]

This form of addressing is usually referred to as Indirect, Y. The second byte of the instruction points to a memory location in page zero. The contents of this memory location are added to the contents of the Y index register, the result being the low-order eight bits of the effective address. The carry from this addition is added to the contents of the next page zero memory location, the result being the high-order eight bits of the effective address.

*Zero Page Indirect Addressing [(ZPG)]

In the zero page indirect addressing mode, the second byte of the instruction points to a memory location on page zero containing the low-order byte of the effective address. The next location on page zero contains the high-order byte of the effective address.

Absolute Indirect Addressing [(ABS)]

(Jump Instruction Only)

The second byte of the instruction contains the low-order eight bits of a memory location. The high-order eight bits of that memory location is contained in the third byte of the instruction. The contents of the fully specified memory location is the low-order byte of the effective address. The next memory location contains the high-order byte of the effective address which is loaded into the 16 bit program counter.

NOTE: * = New Address Modes

SIGNAL DESCRIPTION

Address Bus (A0-A15)

A0-A15 forms a 16-bit address bus for memory and I/O exchanges on the data bus. The output of each address line is TTL compatible, capable of driving one standard TTL load and 130oF.

Clocks (00, 01, and 02)

00 is a TTL level input that is used to generate the internal clocks in the 6502. Two full level output clocks are generated by the 6502. The 02 clock output is in phase with 00. The 01 output pin is 180° out of phase with 00. (See timing diagram.)

Data Bus (D0-D7)

The data lines (D0-D7) constitute an 8-bit bidirectional data bus used for data exchanges to and from the device and peripherals. The outputs are three-state buffers capable of driving one TTL load and 130 pF.

Interrupt Request (IRQ)

This TTL compatible input requests that an interrupt sequence begin within the microprocessor. The \overline{IRO} is sampled during θ_2 operation; if the interrupt flag in the processor status register is zero, the current instruction is completed and the interrupt sequence begins during θ_1 . The program counter and processor status register are stored in the stack. The microprocessor will then set the interrupt mask flag high so that no further \overline{IROs} may occur. At the end of this cycle, the program counter low will be loaded from address FFFE, and program counter high from location FFFF, transferring program control to the memory vector located at these addresses. The RDY signal must be in the high state for any interrupt to be recognized. A 3K ohm external resistor should be used for proper wire OR operation.

Memory Lock (ML)

In a multiprocessor system, the $\overline{\text{ML}}$ output indicates the need to defer the rearbitration of the next bus cycle to ensure the integrity of read-modify-write instructions. $\overline{\text{ML}}$ goes low during ASL, DEC, INC, LSR, ROL, ROR, TRB, TSB memory referencing instructions. This signal is low for the modify and write cycles.

Non-Maskable Interrupt (NMI)

A negative-going edge on this input requests that a non-maskable interrupt sequence be generated within the microprocessor. The NMI is sampled during 02; the current instruction is completed and the interrupt sequence begins during 01. The program counter is loaded with the interrupt vector from locations FFFA (low byte) and FFFB (high byte), thereby transferring program control to the non-maskable interrupt routine.

Note: Since this interrupt is non-maskable, another $\overline{\text{NMI}}$ can occur before the first is finished. Care should be taken when using $\overline{\text{NMI}}$ to avoid this.

Ready (RDY)

This input allows the user to single-cycle the microprocessor on all cycles including write cycles. A negative transition to the low state, during or coincident with phase one (Ø1), will halt the microprocessor with the output address lines reflecting the current address being fetched. This condition will remain through a subsequent phase two (Ø2) in which the ready signal is low. This feature allows microprocessor interfacing with low-speed memory as well as direct memory access (DMA).

Reset (RES)

This input is used to reset the microprocessor. Reset must be held low for at least two clock cycles after VDD reaches operating voltage from a power down. A positive transistion on this pin will then cause an initialization sequence to begin. Likewise, after the system has been operating, a low on this line of at least two cycles will cease microprocessing activity, followed by initialization after the positive edge on RES.

When a positive edge is detected, there is an initialization sequence lasting six clock cycles. Then the interrupt mask flag is set, the decimal mode is cleared, and the program counter is loaded with the restart vector from locations FFFC (low byte) and FFFD (high byte). This is the start location for program control. This input should be high in normal operation.

Read/Write (R/W)

This signal is normally in the high state indicating that the microprocessor is reading data from memory or I/O bus. In the low state the data bus has valid data from the microprocessor to be stored at the addressed memory location.

Set Overflow (SO)

A negative transition on this line sets the overflow bit in the status code register. The signal is sampled on the trailing edge of \emptyset_1 .

Synchronize (SYNC)

This output line is provided to identify those cycles during which the microprocessor is doing an OP CODE fetch. The SYNC line goes high during Ø1 of an OP CODE fetch and stays high for the remainder of that cycle. If the RDY line is pulled low during the Ø1 clock pulse in which SYNC went high, the processor will stop in its current state and will remain in the state until the RDY line goes high. In this manner, the SYNC signal can be used to control RDY to cause single instruction execution.

■ INSTRUCTION SET — ALPHABETICAL SEQUENCE

	Add Memory to Accumulator with Carry	LDX	Load Index X with Memory
AND	"AND" Memory with Accumulator	LDY	Load Index Y with Memory
		LSR	Shift One Bit Right
BCC	Branch on Carry Clear	NOP	No Operation
BCS	Branch on Carry Set	ORA	"OR" Memory with Accumulator
BEQ	Branch on Result Zero	PHA	Push Accumulator on Stack
BIT	Test Memory Bits with Accumulator	PHP	Push Processor Status on Stack
BMI	Branch on Result Minus	* PHX	Push Index X on Stack
BNE	Branch on Result not Zero	* PHY	Push Index Y on Stack
BPL	Branch on Result Plus	PLA	Pull Accumulator from Stack
*BRA	Branch Always	PLP	Pull Processor Status from Stack
BRK	Force Break	* PLX	Pull Index X from Stack
BVC	Branch on Overflow Clear	* PLY	Pull Index Y from Stack
BVS	Branch on Overflow Set	ROL	Rotate One Bit Left
CLC	Clear Carry Flag	ROR	Rotate One Bit Right
CLD	Clear Decimal Mode	RTI	Return from Interrupt
CLI	Clear Interrupt Disable Bit	RTS	Return from Subroutine
CLV	Clear Overflow Flag	SBC	Subtract Memory from Accumulator with Borro
CMP	Compare Memory and Accumulator	SEC	Set Carry Flag
CPX	Compare Memory and Index X	SED	Set Decimal Mode
CPY	Compare Memory and Index Y	ŠEI	Set Interrupt Disable Bit
* DEA	Decrement Accumulator	STA	Store Accumulator in Memory
DEC	Decrement by One	STX	Store Index X in Memory
DEX	Decrement Index X by One	STY	Store Index Y in Memory
DEY	Decrement Index Y by One	* STZ	Store Zero in Memory
EOR	"Exclusive-or" Memory with Accumulator	TAX	Transfer Accumulator to Index X
* INA	Increment Accumulator	TAY	Transfer Accumulator to Index Y
INC	Increment by One	* TRB	Test and Reset Memory Bits with Accumulator
INX	Increment Index X by One	* TSB	Test and Set Memory Bits with Accumulator
INY	Increment Index Y by One	TSX	Transfer Stack Pointer to Index X
JMP	Jump to New Location	TXA	Transfer Index X to Accumulator
JSR	Jump to New Location Saving Return Address	TXS	Transfer Index X to Stack Pointer
LDA	Load Accumulator with Memory	TYA	Transfer Index Y to Accumulator
	The state of the s		

Note: * = New Instruction

MICROPROCESSOR OP CODE TABLE

											,						
S D	0	1	2	3	4	5	6	7	8	9	А	В	С	D	E	F	
0	BRK	ORA ind, X			TSB* zpg	ORA zpg	ASL zpg		PHP	ORA imm	ASL A		TSB* abs	ORA abs	ASL abs		0
1	BPL rel	ORA ind, Y	ORA*† (zpg)		TRB*	ORA zpg, X	ASL zpg, X		CLC	ORA abs, Y	INA*		TRB* abs	ORA abs, X	ASL abs, X		1
2	JSR abs	AND ind, X			BIT zpg	AND zpg	ROL zpg		PLP	AND imm	ROL A		BIT abs	AND abs	ROL abs		2
3	BMI rel	AND ind, Y	AND*†		BIT* zpg, X	AND zpg, X	ROL zpg, X		SEC	AND abs, Y	DEA*		BIT*† abs, X	AND abs, X	ROL abs, X		3
4	RTI	EOR ind, X				EOR zpg	LSR zpg		PHA	EOR imm	LSR A		JMP abs	EOR abs	LSR abs		4
5	BVC rel	EOR ind, Y	EOR*†			EOR zpg, X	LSR zpg, X		CLI	EOR abs, Y	PHY*			EOR abs, X	LSR abs, X		5
6	RTS	ADC ind, X			STZ* zpg	ADC zpg	ROR zpg		PLA	ADC imm	ROR A		JMP (abs)	ADC abs	ROR abs		6
7	BVS rel	ADC ind, Y	ADC*†		STZ* zpg, X	ADC zpg, X	ROR zpg, X		SEI	ADC abs, Y	PLY*		JMP*† abs (ind, X)	ADC abs, X	ROR abs, X		7
8	BRA*	STA ind, X			STY zpg	STA zpg	STX zpg		DEY	BIT*	TXA		STY abs	STA abs	STX abs		8
9	BCC rel	STA ind, Y	STA*† (zpg)		STY zpg, X	STA zpg, X	STX zpg, Y		TYA	STA abs, Y	TXS		STZ* abs	STA abs, X	STZ* abs, X		9
Α	LDY	LDA ind, X	LDX imm		LDY	LDA zpg	LDX zpg		TAY	LDA imm	TAX		LDY abs	LDA abs	LDX abs		Α
В	BCS rel	LDA ind, Y	LDA*†		LDY zpg, X	LDA zpg, X	LDX ₂pg, Y		CLV	LDA abs, Y	TSX		LDY abs, X	LDA abs, X	LDX abs, Y		В
С	CPY imm	CMP ind, X			CPY zpg	CMP zpg	DEC zpg		INY	CMP imm	DEX		CPY abs	CMP abs	DEC abs		С
D	BNE rel	CMP ind, Y	CMP+†			CMP zpg, X	DEC zpg, X		CLD	CMP abs, Y	PHX*			CMP abs, X	DEC abs, X		D
E	CPX imm	SBC ind, X			CPX zpg	SBC zpg	INC zpg		INX	SBC	NOP		CPX abs	SBC abs	INC abs		E
F	BEQ rel	SBC ind, Y	SBC*†			SBC zpg, X	INC zpg, X		SED	SBC abs, Y	PLX*			SBC abs, X	INC abs, X		F
	0	1	2	3	4	5	6	7	8	9	Α	В	С	D	E	F	

Note: * = New OP Codes Note: † = New Address Modes

• OPERATIONAL CODES, EXECUTION TIME, AND MEMORY REQUIREMENTS

			DIA			SO	Z	'ER	O E	ACI	CUN		IM-	ь	(IN			ND: Y). -	ZPG.	, x	ZPO	G, \	YA	BS.	×	AB	S, Y		LA IVE		ABS) (AE IND	3S , X)	(Z	PG		ST	AT	US	_	DES	_	
MNE	OPERATION		OP	0	ОР	, n	, .	ρ,	, ,	OP	n	0	Pn	#	ОР	,	ОР	2	# 0	OP n	#	ОР	,	#0	P	,	ОР	n #	OF		#OF	, ,	# (DP.		ОР	_	,	7 (N	5 5	4 B	3 : D	1 2	읝	MNE
ADC	A+M+C+A (1,3)	69	2 2	6D	4		5 3			Ħ	T	T					5			1 2		П	7	D 4	3	79	4 3		П		П		1						v .			z		ADC
AND		1)	29	2 2	OE	6	3 2 3 0	6 5	2	0A	2	1	8	П	21	6 2	31	5	2	35 4 16 6	4 2 5 2		П	1	E E	3	39	4 3		П	1	Ш		1		32	1	2	N				ž		AND ASL
BCC	Branch if C=0 (2)			2	П								П						- [Ш			90	2	2			1			П		100			4	0.00		BCC
		2)	-+	+	-	╁	+	$^{+}$	Н	_	H	t	+	Н	\dashv	+	╁	+	Н	+	+	-	Н	+	+	H	-	+		2		Н	Н	+	+	H	Н	Н	low.					-	BEQ
BIT	AAM (4	4,5)	89	2 2	2C	4	3 2	4 3	2		Ш			П	-			1	:	34 4	4 2			3	c 4	3							4					H	M7*			Ė	Z		BIT
		2) 2)				П		-			П								П		1									2 2			П									e U			BMI
		2)		1	L	Ц	1	4	1		Ц	Ļ	1	Ц		1	L	L	Ц	\downarrow	\perp		Ц	1	4	Ц		Ц	10	2	2	Ц	Ц	1	1	L	L	Ц			v	v	i s	-+	BPL
	Branch Always (: Break	2)				П	П					1	0 7	١,١					П				П						80	2	2		П				П	П		× 2	,	*			BRA BRK
BVC	Branch if V=0	2)				П						ľ	1	ľ					П		l		П		1				50	2	2		П			1	П					÷			BVC
CLC		2)		ı		П			1		П	1	8 2	1		1							П						74	2	2	П	П												BVS
CLD				+	T	П	1	1	T	Т	Ħ	D	8 2	1		1	T	1	Ħ	1	+	T	П	T	T	Т		Т	T	П	T	T	П	1	Ť	T	T	П					9.3		CLD
CLV	0 * I					П	1				П	5 B	8 2 8 2	1									П				1			П			П	Ì				П				. 1			CLV
CMP	A - M (1)	C9 E0	2 2	CE	4	3 0	25	3 2		П	1	1	ľ	C1	6 2	D	1 5	2	D5	4 2		П	C	D	3	D9	4 3	3				Н			D2	5		N			i,	. z	С	CMP
	X - M Y - M				CC						++	+	+	Н	-	+	+	+	H	+	+	+	H	+	+	+	-	Н	+	Н	+	+	Н	+	+	╁	+	Н	2 2			19	. z		CPX
DEA	A - 1 + A		CU	1			-			3A	2	1							П				П										Ш						N				. z		DEA
	M-1+M { X-1+X	1)			CE	6	3 0	6	5 2			c	A	١,					П	D6	6 2			10	DE	5 3		П		$\ \ $			П			1			2 2				Z		DEC
DEY	Y - 1 * Y				L	\sqcup	1	1	1		Ц	8	A 2	1		Ц	1	\perp	Ц		\perp	L	Ц	Ц	1	1	L	Ц	1	Ц	1	1	Ц	\sqcup	\downarrow	\perp	\perp	Ц	7	1 1	7	ij.	. Z		DEY
EOR INA	A V M + A A + 1 + A		49	2	40	4	3 4	15			2	,			41	6	2 5	5	2	55	4 2			5	iD 4	1 3	59	4 3	3					-		52	5		22				Z		EOR
INC	M + 1 * M {	1)		1	EE	6	3 6	6								П			П	F6	6 2		П	F	E	3							П					П	N		- 6	ij.	. 2		INC
INX	X + 1 • X Y + 1 • Y			1	1			-				E	8 2	1					П				П										П			1			2 2	3 3	- 61	39	. Z		INX
JMP	Jump to new loc			+		3		1	+	t	Ħ	1	1	1		H	t	†	Ħ		†	+	Ħ	\dagger	1	+		H	+	Ħ	6	c 6	3	7C	6 3	;	+	H				-			JMP
	Jump Subroutine M + A	1)	Ag	2 3	20 A	6		45	3 2		П	П			A1	6	2 8	1/5	2	B5	4 2			۱	30	4 3	89	4	3				П			R	5	١,	N		- 21		 . z		JSR LDA
LDX	M + X	1)	A2	2 2	AE	4	3	46	3 2								Τ	1	П	- 1	П	86	4	2			BE	4					Н			-	1	П	N	20.0	- 5	į.	. z		LDX
LSR		1)	AU	2 2	AC						2	+	+	+	H	Н	+	+		84 56			+	-	-	4 3 6 3		H	+	+	+	+	₩	-	+	╁	+	╁	0				. Z	\rightarrow	LDY
NOP	PC + 1 + PC							- 1		1			A 2	1				L	П					Ш	- 1			Ш					11		П						-	1			NOP
PHA	A V M + A (A + M _s S - 1 + S	11	09	2 3	00	4	3 1	05	3 2			4	8 3	1	01	6	2 1	1 5	2	15	4 2	1			1 D	4 3	19	4 :	3				П			13	2 5	2	N		1		. Z		ORA PHA
PHP	P+M, S-1+S			Ц	L	Ц	Ц		1		Ц	0	8 3	1		Ц	1	\perp	Ш	\sqcup	Ц	L	L	Ц		\perp	L	Ц	1	\perp	Ц	1	Ц		Ц	L	\perp	L			i	į.			PHP
PHX	X + M ₅ S - 1 + S Y + M ₅ S - 1 + S										П		A	1			3		П					П	-1			П				-							-						PHX
PLA	S+1+S M, +A							- 1		-	Ш	E	8 4	1		П			П					П				П			П		П		Ш				N				Z		PLA
PLP	S + 1 * S M, * P S + 1 * S M, * X						П				Ш		8 4 A 4			П	1		П									П	ı										2 2	٧.	1	D	1 Z		PLP
PLY	S+1+S M,+Y			\dagger	t	T	1	1	†	t	H	7	A		_	H	†	†	Ħ		\dagger	t	+	tt	7	+	T	Ħ	+	\dagger		Ť	H		Ħ	Ť	+	t	N		- 5	rs.	Z		PLY
ROL	-6-6-	(1)									2					П				36 76						6 3 6 3		П							П				N				. Z		ROL
RTI	Return from Inter.				1		ĬĬ.		1			4	10 6			П				, ,	١,	1		П		,		П							П					V	1	D		q	RTI
	Return from Subr.	1,3)	EC	3	2 6 7	1	1	-	2 -	+	\mathbb{H}	+	50 E	1	E +		1	1 5	1	F5	4	+	+	H.		4 2	50	4	1	+	Н	+	H	H	H	+	2 5	-	NI.		- 2	la.		\rightarrow	SBC
SEC	1 + C	1,31	ca		- CL	1	3	-5	3			1	88	2 1		°	-	1	1		1.			11	. 0	13	"	1	3						П		4 5	1		٠.		in in		1	SEC
SED												F	8 2	2 1							П			11											П				-			1	,		SED
STA	A + M			Ц	80	4	3	85	3	1		Щ				6	2 9	1 6	2	95	4:				9D	5 3	99	5	3	\perp	Ш				Ц	9	2 5	2	Ŀ		-	ä			STA
	X + M Y + M				88	4 4 4	3	86	3 3	?						П				94	1		6 4	2			Γ				П				lĺ			1	-		-	15			STX
STZ	00 • M			П	90	4	3	64	3	2						П				74	4	2			9E	5 3				1					П				1						STZ
TAX	A • X A • Y			П			П			1			A S			П	1				Ш			11											\prod		1		N				. Z		TAX
TRB	Ā ^ M + M	4)		11		6					T	Ħ	T	Ť	T	H	†	+	H		H	t	+	Ħ	T	+	t	H	†	+	tt	+	†		††	1	+	t	Ĺ		-	76	. z	-	TRB
	AVM+M	4)				6						۱.	BA :	, .		П								П														l	1					.	TSB TSX
TXA	X + A			П			П					8	A S	2 1		П		1			П			11											П				N				. 2		TXA
TXS			 	Н	+	+	H	4	+	+	+	_	A 2	-	1	H	+	+	+		H	+	+	H	_	Н	+	\mathbb{H}	4	+	H	+	+	\vdash	H	+	+	+	Ŀ			100		-	TXS
TYA	TTA		1	Ш		\perp	Ш			L		Ц	8	2 1	L	Ц		\perp	L		Ц	L	\perp	П		Ш			Ц		Ц	_[\perp	L	Ш			1	N			Č.	. z		TYA

Notes:

- tes:

 1. Add 1 to "n" if page boundary is crossed.

 2. Add 1 to "n" if branch occurs to same page.

 Add 2 to "n" if branch occurs to different page.

 3. Add 1 to "n" if decimal mode.
- 4. V bit equals memory bit 6 prior to execution.
- X Index X
 - Index Y
 - Accumulator
- M Memory per effective address Ms Memory per stack pointer
- + Add Subtract
- Λ And
- V Or ¥ Exclusive or
- n No. Cycles # No. Bytes
- M₆ Memory bit 6 M₇ Memory bit 7

<sup>No bit equals memory bit 7 prior to execution.

No bit equals memory bit 7 prior to execution.

No bit equals memory bit 7 prior to execution.

No bit equals memory bit 7 prior to execution.

No bit equals memory bit 7 prior to execution.

No bit equals memory bit 7 prior to execution.

No bit equals memory bit 7 prior to execution.</sup>

Appendix B

Directory of Built-in Subroutines

Here is a list of useful subroutines in the Apple IIe's Monitor. To use these subroutines from machine-language programs, store data into the specified memory locations or microprocessor registers as required by the subroutine and execute a JSR to the subroutine's starting address. After the subroutine performs its function, it returns with the 65C02's registers changed as described.

Warning

Do not jump into the middle of Monitor subroutines. Although the starting addresses are the same for all models of the Apple II, the actual code is different.

BASICIN Read the keyboard

\$C305

When the 80-column firmware is active, BASICIN is used instead of KEYIN. BASICIN operates like KEYIN except that it displays a solid, nonblinking cursor instead of a blinking checkerboard cursor.

BASICOUT Output to screen

\$C307

When the 80-column firmware is active, BASICOUT is used instead of COUT1. BASICOUT displays the character in the accumulator on the Apple IIe's screen at the current output cursor position and advances the output cursor. It places the character using the setting of the Normal/Inverse location. It handles control codes; see Table 3-3b. BASICOUT returns with all registers intact.

BELL Output a bell character

\$FF3A

BELL writes a bell (Control-G) character to the current output device. It leaves the accumulator holding \$87.

BELL1 Sends a beep to the speaker

\$FBDD

BELL1 generates a 1-kHz tone in the Apple IIe's speaker for 0.1 second. It scrambles the A and X registers.

CLREOL Clear to end of line

\$FC9C

CLREOL clears a text line from the cursor position to the right edge of the window. CLREOL destroys the contents of A and Y.

CLEOLZ Clear to end of line

\$FC9E

CLEOLZ clears a text line to the right edge of the window, starting at the location given by base address BASL, which is indexed by the contents of the Y register. CLEOLZ destroys the contents of A and Y.

CLREOP Clear to end of window

\$FC42

CLREOP clears the text window from the cursor position to the bottom of the window. CLREOP destroys the contents of A and Y.

CLRSCR Clear the low-resolution screen

\$F832

CLRSCR clears the low-resolution graphics display to black. If you call CLRSCR while the video display is in text mode, it fills the screen with inverse-mode at-sign (@) characters. CLRSCR destroys the contents of A and Y.

CLRTOP · Clear the low-resolution screen

\$F836

CLRTOP is the same as CLRSCR (above), except that it clears only the top 40 rows of the low-resolution display.

COUT Output a character

\$FDED

COUT calls the current character output subroutine. The character to be output should be in the accumulator. COUT calls the subroutine whose address is stored in CSW (locations \$36 and \$37), which is usually one of the standard character output subroutines, COUT1 or BASICOUT.

COUT1 Output to screen

\$FDF0

COUT1 displays the character in the accumulator on the Apple IIe's screen at the current output cursor position and advances the output cursor. It places the character using the setting of the Normal/Inverse location. It handles the codes for carriage return, linefeed, backspace, and bell. It returns with all registers intact.

CROUT Generate a carriage return character \$FD8E

CROUT sends a carriage return character to the current output device.

CROUT1 Generate carriage return, clear rest of line \$FD8B CROUT1 clears the screen from the current cursor position to the edge of the text window, then calls CROUT.

GETLN Get an input line with prompt \$FD6A

GETLN is the standard input subroutine for entire lines of characters, as described in Chapter 3. Your program calls GETLN with the prompt character in location \$33; GETLN returns with the input line in the input buffer (beginning at location \$0200) and the X register holding the length of the input line.

GETLNZ Get an input line

\$FD67

GETLNZ is an alternate entry point for GETLN that sends a carriage return to the standard output, then continues into GETLN.

GETLN1 Get an input line, no prompt

\$FD6F

\$F819

GETLN1 is an alternate entry point for GETLN that does not issue a prompt before it accepts the input line. If, however, the user cancels the input line, either with too many backspaces or with a Control-X, then GETLN1 will issue the contents of location \$33 as a prompt when it gets another line.

HLINE Draw a horizontal line of blocks

HLINE draws a horizontal line of blocks of the color set by SETCOL on the low-resolution graphics display. Call HLINE with the vertical coordinate of the line in the accumulator, the leftmost horizontal coordinate in the Y register, and the rightmost horizontal coordinate in location \$2C. HLINE returns with A and Y scrambled X intact.

HOME Home cursor and clear

\$FC58

HOME clears the display and puts the cursor in the home position: the upper-left corner of the screen.

IOREST Restore all registers

\$FF3F

IOREST loads the 65C02's internal registers with the contents of memory locations \$45 through \$49.

IOSAVE Save all registers

\$FF4A

IOSAVE stores the contents of the 65C02's internal registers in locations \$45 through \$49 in the order A, X, Y, P, S. The contents of A and X are changed and the decimal mode is cleared.

KEYIN Read the keyboard

\$FD1B

KEYIN is the keyboard input subroutine. It reads the Apple IIe's keyboard, waits for a keypress, and randomizes the random number seed at \$4E-\$4F. When a key is pressed, KEYIN removes the blinking cursor from the display and returns with the keycode in the accumulator. KEYIN is described in Chapter 3.

MOVE Move a block of memory

\$FE2C

MOVE copies the contents of memory from one range of locations to another. This subroutine is the same as the MOVE command in the Monitor, except that it takes its arguments from pairs of locations in memory, low-byte first. The destination address must be in A4 (\$42-\$43), the starting source address in A1 (\$3C-\$3D), and the ending source address in A2 (\$3E-3F) when your program calls MOVE. Register Y must contain \$00 when your program calls MOVE.

NEXTCOL Increment color by 3

\$F85F

NEXTCOL adds 3 to the current color (set by SETCOL) used for low-resolution graphics.

PLOT Plot on the low-resolution screen

\$F800

PLOT puts a single block of the color value set by SETCOL on the low-resolution display screen. The block's vertical position is passed in the accumulator, its horizontal position in the Y register. PLOT returns with the accumulator scrambled, but X and Y intact.

PRBLNK Print three spaces

PRBLNK outputs three blank spaces to the standard output device. On return, the accumulator usually contains \$A0, the X register contains 0.

PRBL2 Print many blank spaces

\$F94A

\$F948

PRBL2 outputs from 1 to 256 blanks to the standard output device. Upon entry, the X register should contain the number of blanks to be output. If X=\$00, then PRBL2 will output 256 blanks.

PRBYTE Print a hexadecimal byte

\$FDDA

PRBYTE outputs the contents of the accumulator in hexadecimal on the current output device. The contents of the accumulator are scrambled.

PREAD Read a hand control

\$FB1E

PREAD returns a number that represents the position of a hand control. You pass the number of the hand control in the X register. If this number is not valid (not equal to 0, 1, 2, or 3), strange things may happen. PREAD returns with a number from \$00 to \$FF in the Y register. The accumulator is scrambled.

PRERR Print ERR

\$FF2D

PRERR sends the word ERR, followed by a bell character, to the standard output device. On return, the accumulator is scrambled.

PRHEX Print a hexadecimal digit

\$FDE3

PRHEX prints the lower nibble of the accumulator as a single hexadecimal digit. On return, the contents of the accumulator are scrambled.

PRNTAX Print A and X in hexadecimal

\$F941

PRNTAX prints the contents of the A and X registers as a four-digit hexadecimal value. The accumulator contains the first byte output, the X register contains the second. On return, the contents of the accumulator are scrambled.

RDCHAR Get an input character or escape code \$FD35

RDCHAR is an alternate input subroutine that gets characters from the standard input subroutine, and also interprets the escape codes listed in Chapter 3.

RDKEY Get an input character

\$FD0C

RDKEY is the character input subroutine. It places a blinking cursor on the display at the cursor position and jumps to the subroutine whose address is stored in KSW (locations \$38 and \$39), usually the standard input subroutine KEYIN, which returns with a character in the accumulator.

READ Read a record from a cassette

\$FEFD

READ reads a series of tones at the cassette input port, converts them to data bytes, and stores the data in a specified range of memory locations. Before calling READ, the address of the first byte must be in A1 (\$3C-\$3D) and the address of the last byte must be in A2 (\$3E-\$3F).

READ keeps a running exclusive-OR of the data bytes in CHKSUM (\$2E). When the last memory location has been filled, READ reads one more byte and compares it with CHKSUM. If they are equal, READ sends out a beep and returns; if not, it sends the word ERR through COUT, sends the beep, and returns.

SCRN Read the low-resolution graphics screen \$F871

SCRN returns the color value of a single block on the low-resolution graphics display. Call it with the vertical position of the block in the accumulator and the horizontal position in the Y register. Call it as you would call PLOT (above). The color of the block will be returned in the accumulator. No other registers are changed.

SETCOL Set low-resolution graphics color

SETCOL sets the color used for plotting in low-resolution graphics to the value passed in the accumulator. The colors and their values are listed in Table 2-6.

SETINV Set inverse mode

\$FE80

\$F864

SETINV sets the dislay format to inverse. COUT1 will then display all output characters as black dots on a white background. The Y register is set to \$3F, all others are unchanged.

SETNORM Set normal mode

\$FE84

SETNORM sets the display format to normal. COUT1 will then display all output characters as white dots on a black background. On return, the Y register is set to \$FF, all others are unchanged.

VERIFY Compare two blocks of memory

VERIFY compares the contents of one range of memory to another. This subroutine is the same as the VERIFY command in the Monitor, except it takes its arguments from pairs of locations in memory, low-byte first. The destination address must be in A4 (\$42–\$43), the starting source address in A1 (\$3C–\$3D), and the ending source address in A2 (\$3E–\$3F) when your program calls VERIFY.

\$FE36

VLINE Draw a vertical line of blocks \$F828

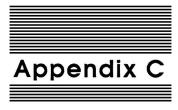
VLINE draws a vertical line of blocks of the color set by SETCOL on the low-resolution display. You should call VLINE with the horizontal coordinate of the line in the Y register, the top vertical coordinate in the accumulator, and the bottom vertical coordinate in location \$2D. VLINE will return with the accumulator scrambled.

WAIT Delay \$FCA8

WAIT delays for a specific amount of time, then returns to the program that called it. The amount of delay is specified by the contents of the accumulator. The delay is 1/2(26+27A+5A^2) microseconds, where A is the contents of the accumulator. WAIT returns with the accumulator zeroed and the X and Y registers undisturbed.

WRITE Write a record on a cassette \$FECD

WRITE converts the data in a range of memory to a series of tones at the cassette output port. Before calling WRITE, the address of the first data byte must be in A1 (\$3C-\$3D) and the address of the last byte must be in A2 (\$3E-\$3F). The subroutine writes a ten-second continuous tone as a header, then writes the data followed by a one-byte checksum.



Apple II Family Differences

This appendix lists the differences among the Apple II Plus, the original, enhanced, and extended keyboard Apple IIe's, and the Apple IIc.

If you're trying to write software to run on more than one version of the Apple II, this appendix will help you avoid unexpected problems of incompatibility.

The differences are listed here in approximately the order you are likely to encounter them: obvious differences first, technical details later. Each entry in the list includes references to the chapters in this manual where the item is described.

Keyboard

The Apple IIe and Apple IIc have a 63-key uppercase and lowercase keyboard. The keyboard includes fully operational Shift and Caps Lock keys. It also includes four directional arrow keys for moving the cursor. Chapter 2 includes a description of the keyboard. The cursor-motion keys are described in Chapter 3.

The extended keyboard IIe keyboard includes an 18-key numeric keypad, for a total of 81 keys.

Apple keys

The keyboards for the original and enhanced Apple IIe's and the Apple IIc have two keys marked with the Apple logo. These keys, called the *Open Apple key* and *Solid Apple key*, are used with the Reset key to select special reset functions. They are connected to the buttons on the hand controls, so they can be used for special functions in programs.

On the extended keyboard IIe, the Solid Apple key is replaced by the *Option key* and the Open Apple key is simply referred to as the *Apple key*.

The Apple II and the Apple II Plus do not have Apple keys.

Character sets

The Apple IIe and Apple IIc can display the full ASCII character set, uppercase and lowercase. For compatibility with older Apple II's, the standard display character set includes flashing uppercase instead of inverse-format lowercase; you can also switch to an alternate character set with inverse lowercase and uppercase but no flashing. Chapter 2 includes a description of the display character sets. Chapter 3 tells you how to switch display formats.

The Apple IIc and the enhanced and extended keyboard Apple IIe include a set of "graphic" text characters, called *MouseText characters*, that replace some of the inverse uppercase characters in the alternate character set of the original Apple IIe. MouseText characters are described in Chapter 2.

80-column display

With the addition of an 80-column text card, the Apple IIe can display 80 columns of text. The 80-column display is completely compatible with both graphics modes—you can even use it in mixed mode. (If you prefer, you can use an old-style 80-column card in an expansion slot instead.) Chapter 2 includes a description of the 80-column display.

The Extended 80-Column Text Card is a standard accessory in the enhanced IIe, and comes installed in the extended keyboard IIe. The Apple IIc has a built-in Extended 80-Column Text Card.

Escape codes and control characters

On the Apple IIe and Apple IIc, the display features mentioned above (and many others not mentioned) can be controlled from the keyboard by escape sequences and from programs by control characters. Chapter 3 includes descriptions of those escape codes and control characters.

Built-in Language Card

The 16K bytes of RAM you add to the Apple II Plus by installing the Language Card is built into the Apple IIe and Apple IIc, giving the Apple IIe a standard memory size of 64K bytes. (The Apple IIc has a built-in Extended 80-Column Text Card as well, giving it a standard memory size of 128K bytes.) In the Apple IIe, this 16K-byte block of memory is called the *bank-switched memory*. It's described in Chapter 4.

Auxiliary memory

By installing the Apple IIe Extended 80-Column Text Card, you can add an alternate 64K bytes of RAM to the Apple IIe. Chapter 4 tells you how to use the additional memory. (The Extended 80-Column Text Card also provides the 80-column display option.)

The Extended 80-Column Text Card is a standard accessory in the enhanced IIe, and comes installed in the extended keyboard IIe.

The Apple IIc has a built-in Extended 80-Column Text Card.

Auxiliary slot

In addition to the expansion slots on the Apple II Plus, the Apple IIe has a special slot that is used either for the 80-Column Text Card or for the Extended 80-Column Text Card. This slot is identified in Chapter 1 and described in Chapter 7.

The Apple IIc has the functions of the auxiliary slot built in.

Back panel and connectors

The Apple IIe has a metal back panel with space for several D-type connectors. Each peripheral card you add comes with a connector that you install in the back panel. Chapter 1 includes a description of the back panel; for details, see the installation instructions supplied with the peripheral cards.

The Apple IIc back panel has seven built-in connectors.

Soft switches

The display and memory features of the Apple IIe and the Apple IIc are controlled by soft switches like the ones on the Apple II Plus. On the Apple IIe and the Apple IIc, programs can also read the settings of the soft switches. Chapter 2 describes the soft switches that control the display features, and Chapter 4 describes the soft switches that control the memory features.

Built-in self-test

The Apple IIe has built-in firmware that includes a self-test routine. The self-test is intended primarily for testing during manufacturing, but you can run it to be sure the Apple IIe is working correctly. The self-test is described in Chapter 4.

The Apple IIc also has built-in diagnostics.

Forced reset

Some programs on the Apple II Plus take control of the reset function to keep users from stopping the machine and copying the program. The Apple IIe and Apple IIc have a forced reset that writes over the program in memory. By using the forced reset, you can restart the Apple IIe (or Apple IIc) without turning power off and on and causing unnecessary stress on the circuits. The forced reset is described in Chapter 4.

Interrupt handling

Even though most application programs don't use interrupts, the Apple IIe (and Apple IIc) provide for interrupt-driven programs. For example, the 80-column firmware periodically enables interrupts while it is clearing the display (normally a long time to have interrupts locked out). Interrupts are discussed in Chapter 6.

Vertical sync for animators

Programs with animation on the Apple IIe and Apple IIc can stay in step with the display and avoid flickering objects in their displays. Chapter 7 includes a description of the video generation and the vertical sync.

Signature byte

A program can find out whether it's running on an Apple IIe, Apple III, (in emulation mode), or older model Apple II by reading the byte at location \$FBB3 in the System Monitor. In the Apple IIe Monitor, this byte's value is \$06; in the Autostart Monitor (the standard Monitor on the Apple II Plus), its value is \$EA. (If you start up with DOS and switch to Integer BASIC, the Autostart Monitor is active and the value at location \$FBB3 is \$EA, even on an Apple IIe.) Obviously, there are lots of other locations that have different values in the different versions of the Monitor; location \$FBB3 was chosen because it will have the value \$06 even in future revisions of the Apple IIe Monitor.

Hardware implementation

The hardware implementation of the Apple IIe is radically different from the Apple II and Apple II Plus. Three of the more important differences are

- □ the custom ICs: the IOU and MMU
- the video hardware, which uses ROM to generate both text and graphics
- ☐ the peripheral data bus, which is fully buffered

These features are described in Chapter 7.

For more information about the Apple IIc Apple IIc, see the Apple IIc

Technical Reference.

The Apple IIc

shares some of the custom ICs of the Apple IIe

has some new ones all its own

lacks the slots of the Apple IIe, replacing some of them with built-

in I/O ports

Appendix D

Operating Systems and Languages

This appendix is an overview of the characteristics of operating systems and languages when run on the Apple IIe. It is not intended to be a full account. For more information, refer to the manuals that are provided with each product.

Operating systems

This section discusses the operating systems that can be used with the Apple IIe.

ProDOS

ProDOS is the preferred disk operating system for the Apple IIe. It supports interrupts, startup from drives other than a Disk II, and all other hardware and firmware features of the Apple IIe.

DOS 3.3

The Apple IIe works with DOS 3.3. The Apple IIe can also access DOS 3.2 disks by using the BASICS disk. However, neither version of DOS takes full advantage of the features of the Apple IIe. DOS support is provided only for the sake of Apple II series compatibility.

Pascal operating system

The Apple II Pascal operating system was developed from the UCSD Pascal system from the University of California at San Diego. While it shares many characteristics of that system, it has been extended by Apple in several areas.

Pascal versions 1.2 and later support interrupts and all the hardware and firmware features of the Apple IIe.

The Apple II Pascal system uses a disk format different from either ProDOS or DOS 3.3.

CP/M

CP/M is an operating system developed by Digital Research that runs on either the Intel 8080 or Zilog Z80 microprocessors. This means that a coprocessor peripheral card, available from several manufacturers for the Apple IIe, is required to run CP/M. Several versions of CP/M from 1.4 through 3.0 and later can be run on an Apple IIe with an appropriate coprocessor card.

Languages

This section discusses special techniques to use, and characteristics to be aware of, when using Apple programming languages with the Apple IIe.

Assembly language

Programs written in assembly language have the potential of extracting the most speed and efficiency from your Apple IIe, but they also require the most effort on your part.

An aid for assembly-language programming is the *ProDOS* Assembler Tools manual (A2W0013).

Applesoft BASIC

The focus of the chapters in this manual is assembly language, and so most addresses and values are given in hexadecimal notation. Appendix E in this manual includes tables to help you convert from hexidecimal to the decimal notation you will need for BASIC.

In BASIC, use a PEEK to read a location (instead of the LDA used in assembly language), and a POKE (instead of STA) to write to a location. If you read a hardware address from a BASIC program, you get a value between 0 and 255. Bit 7 holds a place value of 128, so if a soft switch is on, its value will be equal to or greater than 128; if the switch is off, the value will be less than 128.

Integer BASIC

Integer BASIC is not included in the Apple IIe firmware. If you want to run it on your Apple IIe, you must use DOS 3.3 to load it in to the system. ProDOS does not support Integer BASIC.

Pascal language

The Pascal language works on the Apple IIe under versions 1.1 and later of the Pascal Operating System. However, for best performance, use Pascal 1.2 or a later version.

Fortran

Fortran works under version 1.1 of the Pascal Operating System, which does not detect or use certain Apple IIe features, such as auxiliary memory. Therefore, Fortran does not take advantage of these features.

Appendix E

Conversion Tables

This appendix briefly discusses bits and bytes and what they can represent. It also contains conversion tables for hexadecimal to decimal and negative decimal, for low-resolution display dot patterns, display color values, and a number of eight-bit codes.

These tables are intended for convenient reference. This appendix is not intended as a tutorial for the materials discussed. The brief section introductions are for orientation only.

Bits and bytes

This section discusses the relationships between bit values and their position within a byte. The following are some rules of thumb regarding the 65C02 and 6502:

- □ A bit is a binary digit; it can be either a 0 or a 1.
- ☐ A bit can be used to represent any two-way choice. Some choices that a bit can represent in the Apple IIe are listed in Table E-1.

Table E-1 What a bit can represent

Context	Representing	0 =	1 =
Binary number	Place value	0	1 x that power of 2
Logic	Condition	False	True
Any switch	Position	Off	On
Any switch	Position	Clear*	Set
Serial transfer	Beginning	Start	Carrier (no information yet)

Table E-1 (continued) What a bit can represent

Context	Representing	0 =	1 =
Serial transfer	Data	0 value	1 value
Serial transfer	Parity	SPACE	MARK
Serial transfer	End		Stop bit(s)
Serial transfer	Communication state	BREAK	Carrier
P reg. bit N	Neg. result?	No	Yes
P reg. bit V	Overflow?	No	Yes
P reg. bit B	BRK command?	No	Yes
P reg. bit D	Decimal mode?	No	Yes
P reg. bit I	IRQ interrupts	Enabled	Disabled (masked out)
P reg. bit Z	Zero result?	No	Yes
P reg. bit C	Carry required?	No	Yes

^{*} Sometimes ambiguously termed reset

- ☐ Bits can also be combined in groups of any size to represent numbers. Most of the commonly used sizes are multiples of four bits.
- ☐ Four bits are a **nibble** (sometimes spelled *nybble*).
- ☐ One nibble can represent any of 16 values. Each of these values is assigned a number from 0 through 9 and (because our decimal system has only 10 of the 16 digits we need) A through F.
- ☐ Eight bits (two nibbles) make a **byte** (Figure E-1 and Table E-2).
- ☐ One byte can represent any of 16 x 16 (or 256) values. The value can be specified by exactly two hexadecimal digits.

High Nibble Low Nibble MSB LSB 7 6 5 4 3 2 1 \$80 \$01 \$40 \$20 \$10 \$08 \$04 \$02 Hexadecimal 128 64 32 16 8 4 2 1 Decimal

Figure E-1
Bits, nibbles, and bytes

Table E-2
Values represented
by a nibble

Binary	Hex	Dec
0000	\$00	0
0001	\$01	1
0010	\$02	2
0011	\$03	3
0100	\$04	4
0101	\$05	5
0110	\$06	6
0111	\$07	7
1000	\$08	8
1001	\$09	9
1010	\$0A	10
1011	\$0B	11
1100	\$0C	12
1101	\$0D	13
1110	\$0E	14
1111	\$OF	15

- □ Bits within a byte are numbered from bit 0 on the right to bit 7 on the left.
- ☐ The bit number is the same as the power of two that it represents, in a manner completely analogous to the digits in a decimal number.
- ☐ One memory position in the Apple IIe contains one eight-bit byte of data.
- ☐ How byte values are interpreted depends on whether the byte is an instruction in a language, part or all of an address, an ASCII code, or some other form of data. Tables E-6 through E-13 list some of the ways bytes are commonly interpreted.
- ☐ Two bytes make a **word**. The 16 bits of a word can represent any one of 256 x 256 (or 65.536) different values.
- ☐ The 65C02 uses a 16-bit word to represent memory locations. It can therefore distinguish among 65,536 (64K) locations at any given time.
- □ A memory location is one byte of a 256-byte page. The low-order byte of an address specifies this byte. The high-order byte specifies the memory page the byte is on.

Hexadecimal and decimal

Use Table E-3 for conversion of hexadecimal and decimal numbers.

Table E-3Hexadecimal/decimal conversion

Digit	\$x000	\$0x00	\$00x0	\$000x	
F	61440	3840	240	15	
E	57344	3584	224	14	
D	53248	3328	208	13	
C	49152	3072	192	12	
В	45056	2816	176	11	
A	40960	2560	160	10	
9	36864	2304	144	9	
8	32768	2048	128	8	
7	28672	1792	112	7	
6	24576	1536	96	6	
5	20480	1280	80	5	
4	16384	1024	64	4	
3	12288	768	48	3	
2	8192	512	32	2	
1	4096	256	16	1	

To convert a hexadecimal number to a decimal number, find the decimal numbers corresponding to the positions of each hexadecimal digit. Write them down and add them up.

For example:

```
$3C = ? $FD47 = ?

$30 = 48 $F000 = 61440.

$0C = 12 $ D00 = 3328

$40 = 64

$3C = 60 $7 = 7

$FD47 = 64839
```

To convert a decimal number to hexadecimal, subtract from the decimal number the largest decimal entry in the table that is less than the number. Write down the hexadecimal digit (noting its place value) also. Now subtract the largest decimal number in the table that is less than the decimal remainder, and write down the next hexadecimal digit. Continue until you have zero left. Add up the hexadecimal numbers.

For example:

Hexadecimal and negative decimal

If a number is larger than decimal 32,767, Applesoft BASIC allows and Integer BASIC requires that you use the negative-decimal equivalent of the number. Table E-4 is set up to make it easy for you to convert a hexadecimal number directly to a negative decimal number.

Table E-4Hexadecimal to negative decimal conversion

Digit	\$x000	\$\$0x00	\$\$00x0	\$\$000x	
F	0	0	0	-1	
E	-4096	-256	-16	-2	
D	-8192	-512	-32	-3	
C	-12288	-768	-48	-4	
В	-16384	-1024	-64	- 5	
A	-20480	-1280	 80	- 6	
9	-24576	-1536	-96	- 7	
8	-28672	-1792	-112	- 8	
7		-2048	-128	- 9	
6		-2304	-144	-10	
5		-2560	-160	-11	
4		-2816	-176	-12	
3		-3072	-192	-13	
2		-3328	-208	-14	
1		-3584	-224	-15	
0		-3840	-240	-16	

To perform this conversion, write down the four decimal numbers corresponding to the four hexadecimal digits (zeros included). Then add their values. The resulting number is the desired negativ decimal number.

For example:

```
$C010 = - ?
$C000: -12288
$ 000: - 3840
$ 10: - 224
$ 0: - 16
$C010 -16368
```

To convert a negative-decimal number to a positive decimal number, add it to 65,536. (This addition ends up looking like subtraction.)

For example:

```
-151 = + ?
65536 + (-151) = 65536 - 151 = 65385
```

To convert a negative-decimal number to a hexadecimal number, first convert it to a positive decimal number, then use Table E-3.

Graphics bits and pieces

Table E-5 is a quick guide to the hexadecimal values corresponding to seven-bit high-resolution patterns on the display screen. Since the bits are displayed in reverse order, it takes some calculation to determine these values. Table E-5 should make it easy.

Table E-5Hexadecimal values for high-resolution dot patterns

	Bits in Data Byte							
7	6	5	4	3	2	1	0	
		_						
	\langle						7	
	0	1	2	3	4	5	6	
Dots on Graphics Screen								
Fianna I	F 0							

Figure E-2Bit ordering in graphics displays

x0000000 \$00 \$80 x0100000 \$02	\$82 \$C2

x0000001 \$40 \$C0 x0100001 \$42	
x0000001 \$40 \$C0 x0100001 \$42 x0000010 \$20 \$A0 x0100010 \$22	
	\$A2
x0000011 \$60 \$E0 x0100011 \$62	\$E2
x0000100 \$10 \$90 x0100100 \$12	\$92
x0000101 \$50 \$D0 x0100101 \$52	\$D2
x0000110 \$30 \$B0 x0100110 \$32	\$B2
x0000111 \$70 \$F0 x0100111 \$72	\$F2
x0001000 \$08 \$88 x0101000 \$0A	\$8A
x0001001 \$48 \$C8 x0101001 \$4A	\$CA
x0001010 \$28 \$A8 x0101010 \$2A	\$AA
x0001011 \$68 \$E8 x0101011 \$6A	\$EA
x0001100 \$18 \$98 x0101100 \$1A	\$9A
x0001101 \$58 \$D8 x0101101 \$5A	\$DA
x0001110 \$38 \$B8 x0101110 \$3A	\$BA
x0001111 \$78 \$F8 x0101111 \$7A	\$FA
x0010000 \$04 \$84 x0110000 \$06	\$86
x0010001 \$44 \$C4 x0110001 \$46	\$C6
x0010010 \$24 \$A4 x0110010 \$26	\$A6
x0010011 \$64 \$E4 x0110011 \$66	\$E6
x0010100 \$14 \$94 x0110100 \$16	\$96
x0010101 \$54 \$D4 x0110101 \$56	\$D6
x0010110 \$34 \$B4 x0110110 \$36	\$B6
x0010111 \$74 \$F4 x0110111 \$76	\$F6
x0011000 \$0C \$8C x0111000 \$0E	\$8E
x0011001 \$4C \$CC x0111001 \$4E	\$CE
x0011010 \$2C \$AC x0111010 \$2E	\$AE
x0011011 \$6C \$EC x0111011 \$6E	\$EE
x0011100 \$1C \$9C x0111100 \$1E	\$9E
x0011101 \$5C \$DC x0111101 \$5E	\$DE
x0011110 \$3C \$BC x0111110 \$3E	\$BE
x0011111 \$7C \$FC x0111111 \$7E	\$FE

The x represents bit 7. Zeros represent bits that are off; ones, bits that are on. Use the first hexadecimal value if bit 7 is to be off, and the second if it is to be on.

For example, to get bit pattern 00101110, use \$3A; for 10101110, use \$BA.

Table E-5 (continued) Hexadecimal values for high-resolution dot patterns

Bit pattern	x=0	x=1	Bit pattern	x=0	x=1
x1000000	\$01	\$81	x1100000	\$03	\$83
x1000001	\$41	\$C1	x1100001	\$43	\$C3
x1000010	\$21	\$A1	x1100010	\$23	\$A3
x1000011	\$61	\$E1	x1100011	\$63	\$E3
x1000100	\$11	\$91	x1100100	\$13	\$93
x1000101	\$51	\$D1	x1100101	\$53	\$D3
x1000110	\$31	\$B1	x1100110	\$33	\$B3
x1000111	\$71	\$F1	x1100111	\$73	\$F3
x1001000	\$09	\$89	x1101000	\$0B	\$8B
x1001001	\$49	\$C9	x1101001	\$4B	\$CB
x1001010	\$29	\$A9	x1101010	\$2B	\$AB
x1001011	\$69	\$E9	x1101011	\$6B	\$EB
x1001100	\$19	\$99	x1101100	\$1B	\$9B
x1001101	\$59	\$D9	x1101101	\$5B	\$DB
x1001110	\$39	\$B9	x1101110	\$3B	\$BB
x1001111	\$79	\$F9	x1101111	\$7B	\$FB
x1010000	\$05	\$85	x1110000	\$07	\$87
x1010001	\$45	\$C5	x1110001	\$47	\$C7
x1010010	\$25	\$A5	x1110010	\$27	\$A 7
x1010011	\$65	\$E5	x1110011	\$67	\$E7
x1010100	\$15	\$95	x1110100	\$17	\$97
x1010101	\$55	\$D5	x1110101	\$57	\$D7
x1010110	\$35	\$B5	x1110110	\$37	\$ B7
x1010111	\$75	\$F5	x1110111	\$77	\$F7
x1011000	\$0D	\$8D	x1111000	\$OF	\$8F
x1011001	\$4D	\$CD	x1111001	\$4F	\$CF
x1011010	\$2D	\$AD	x1111010	\$2F	\$AF
x1011011	\$6D	\$ED	x1111011	\$6F	\$EF
x1011100	\$1D	\$9D	x1111100	\$1F	\$9F
x1011101	\$5D	\$DD	x1111101	\$5F	\$DF
x1011110	\$3D	\$BD	x1111110	\$3F	\$BF
x1011111	\$7D	\$FD	x1111111	\$7F	\$FF

Eight-bit code conversions

Tables E-5 through E-12 show the entire ASCII character set twice: once with the high bit off, and once with it on. Here is how to interpret these tables.

- ☐ The *Binary* column has the eight-bit code for each ASCII character.
- ☐ The first 128 ASCII entries represent seven-bit ASCII codes plus a high-order bit of 0 (SPACE parity or Pascal)—for example, 010010000 for the letter *H*.
- □ The last 128 ASCII entries (from 128 through 255) represent seven-bit ASCII codes plus a high-order bit of 1 (MARK parity or BASIC)—for example, 11001000 for the letter *H*.
- □ A transmitted or received ASCII character will take whichever form is appropriate if odd or even parity is selected—for example, 11001000 for an odd-parity H, 01001000 for an even-parity H.
- ☐ The ASCII Char column gives the ASCII character name.
- ☐ The *Interpretation* column spells out the meaning of special symbols and abbreviations, where necessary.
- ☐ The What to Type column indicates what keystrokes generate the ASCII character (where it is not obvious).

The columns marked *Pri* and *Alt* indicate what displayed character results from each code when using the primary or alternate display character set, respectively. Boldface is used for inverse characters; italic is used for flashing characters.

Note that the values \$40 through \$5F (and \$C0 through \$DF) in the alternate character set are displayed as MouseText characters if MouseText is turned on.

Note: The primary and alternate displayed character sets in Tables E-6 through E-13 are the result of firmware mapping. The character generator ROM actually contains only one character set. The firmware mapping procedure is described in the section "Inverse and Flashing Text" in Chapter 3.

The MouseText characters are shown in Table E-8.

Table E-6 Control characters, high bit off

Binary	Dec	Hex	ASCII char	Interpretation	What to type	Pri	Alt
0000000	0	\$00	NUL	Blank (null)	Control-@	@	@
0000001	1	\$01	SOH	Start of header	Control-A	A	A
0000010	2	\$02	STX	Start of text	Control-B	В	В
0000011	3	\$03	ETX	End of text	Control-C	C	C
0000100	4	\$04	EOT	End of transm	Control-D	D	D
0000101	5	\$05	ENQ	Enquiry	Control-E	E	E
0000110	6	\$06	ACK	Acknowledge	Control-F	F	F
0000111	7	\$07	BEL	Bell	Control-G	G	G
0001000	8	\$08	BS	Backspace	Control-H or Left Arrow	H	Н
0001001	9	\$09	HT	Horizontal tab	Control-I or Tab	I	1
0001010	10	\$0 A	LF	Line feed	Control-J or Down Arrow	J	J
0001011	11	\$0B	VT	Vertical tab	Control-K or Up Arrow	K	K
0001100	12	\$0C	FF	Form feed	Control-L	L	L
0001101	13	\$0D	CR	Carriage return	Control-M or Return	M	M
0001110	14	\$0E	SO	Shift out	Control-N	\mathbf{N}	N
0001111	15	\$0F	SI	Shift in	Control-O	0	O
0010000	16	\$10	DLE	Data link escape	Control-P	P	P
0010001	17	\$11	DC1	Device control 1	Control-Q	Q	Q
0010010	18	\$12	DC2	Device control 2	Control-R	R	R
0010011	19	\$13	DC3	Device control 3	Control-S	S	S
0010100	20	\$14	DC4	Device control 4	Control-T	T	T
0010101	21	\$15	NAK	Neg. acknowledge	Control-U or Right Arrow	U	U
0010110	22	\$16	SYN	Synchronization	Control-V	\mathbf{v}	\mathbf{v}
0010111	23	\$17	ETB	End of text blk.	Control-W	\mathbf{w}	W
0011000	24	\$18	CAN	Cancel	Control-X	\mathbf{x}	\mathbf{x}
0011001	25	\$19	EM	End of medium	Control-Y	Y	Y
0011010	26	\$1A	SUB	Substitute	Control-Z	\mathbf{z}	Z
0011011	27	\$1B	ESC	Escape	Control-[or Escape	1	I
0011100	28	\$1C	FS	File separator	Control-\	1	\
0011101	29	\$1D	GS	Group separator	Control-]]]
0011110	30	\$1E	RS	Record separator	Control-^	^	۸
0011111	31	\$1F	US	Unit separator	Control	_	=

Table E-7 Special characters, high bit off

Binary	Dec	Hex	ASCII char	Interpretation	What to type	Pri	Alf
0100000	32	\$20	SP	Space	Space bar		
0100001	33	\$21	!	-	- 2	1	!
0100010	34	\$22	"			н	**
0100011	35	\$23	#			#	#
0100100	36	\$24	\$			\$	\$
0100101	37	\$25	%			%	%
0100110	38	\$26	&x			&	&
0100111	39	\$27	1	Apostrophe			,
0101000	40	\$28	(((
0101001	41	\$29)))
0101010	42	\$2A	•				•
0101011	43	\$2B	+			+	+
0101100	44	\$2C	,	Comma		,	,
0101101	45	\$2D	-	Hyphen		-	-
0101110	46	\$2E	•	Period		•	
0101111	47	\$2 F	/			/	/
0110000	48	\$30	0			0	0
0110001	49	\$31	1			1	1
0110010	50	\$32	2			2	2
0110011	51	\$33	3			3	3
0110100	52	\$34	4			4	4
0110101	53	\$35	5			5	5
0110110	54	\$36	6			6	6
0110111	55	\$37	7			7	7
0111000	56	\$38	8			8	8
0111001	57	\$39	9			9	9
0111010	58	\$3A	:			:	:
0111011	59	\$3B	;			;	;
0111100	60	\$3C	<			<	<
0111101	61	\$3D	=			-	-
0111110	62	\$3E	>			>	>
0111111	63	\$3F	?			?	?

Table E-8Uppercase characters, high bit off

Binary	Dec	Hex	ASCII char	Interpretation	What to type	Pri	Alt
1000000	64	\$40	@			@	É
1000001	65	\$41	A			\boldsymbol{A}	Ć
1000010	66	\$42	В			$\boldsymbol{\mathit{B}}$	
1000011	67	\$43	С			C	X
1000100	68	\$44	D			D	~
1000101	69	\$45	E			$\boldsymbol{\mathit{E}}$	\checkmark
1000110	70	\$46	F			F	
1000111	71	\$47	G			\boldsymbol{G}	=
1001000	72	\$48	H			H	\leftarrow
1001001	73	\$49	I			I	
1001010	74	\$4A	J			J	\downarrow
1001011	75	\$4B	K			K	<u>↑</u>
1001100	76	\$4C	L			\boldsymbol{L}	_
1001101	77	\$4D	M	4		M	ل
1001110	78	\$4E	N			N	
1001111	79	\$4F	0			0	+ + + +
1010000	80	\$50	P			\boldsymbol{P}	.
1010001	81	\$51	Q			Q	₩.
1010010	82	\$52	R			R	+
1010011	83	\$53	S			S	
1010100	84	\$54	T			T	Ļ
1010101	85	\$55	U			$\boldsymbol{\mathit{U}}$	\rightarrow
1010110	86	\$56	V			V	**
1010111	87	\$57	\mathbf{w}			W	**
1011000	88	\$58	X			\boldsymbol{X}	
1011001	89	\$59	Y			Y	\neg
1011010	90	\$5A	Z			\boldsymbol{Z}	- 1
1011011	91	\$5B	[Opening bracket		· [•
1011100	92	\$5C	١	Reverse slant		\	_
1011101	93	\$5D]	Closing bracket]	#
1011110	94	\$5E	٨	Caret		٨	$\mathbf{\Xi}$
1011111	95	\$5F		Underline			I I

Table E-9 Lowercase characters, high bit off

Binary	Dec	Нех	ASCII char	Interpretation	What to type	Pri	Alt
1100000	96	\$60		Grave accent			•
1100001	97	\$61	a			1	a
1100010	98	\$62	b			n	b
1100011	99	\$63	С			#	C
1100100	100	\$64	d			\$	d
1100101	101	\$65	e			%	e
1100110	102	\$66	f			ε	f
1100111	103	\$67	g			,	g
1101000	104	\$68	h			(h
1101001	105	\$69	i)	i
1101010	106	\$6A	j			*	j
1101011	107	\$6B	k			+	k
1101100	108	\$6C	1			,	1
1101101	109	\$6D	m			_	m
1101110	110	\$6E	n			•	n
1101111	111	\$6F	0			/	O
1110000	112	\$70	p ·			0	p
1110001	113	\$71	q			1	\mathbf{q}
1110010	114	\$72	r			2	r
1110011	115	\$73	S			3	S
1110100	116	\$74	t			4	t
1110101	117	\$75	u			5	u
1110110	118	\$76	v			6	V =
1110111	119	\$77	w			7	\mathbf{w}
1111000	120	\$78	x	¥.		- 8	x
1111001	121	\$79	у			9	y
1111010	122	\$7A	z			:	Z
1111011	123	\$7B	{	Opening brace		;	{
1111100	124	\$7C	1	Vertical line		<	1
1111101	125	\$7D	}	Closing brace		=	}
1111110	126	\$7E	\	Overline (tilde)		>	~
1111111	127	\$7F	DEL	Delete/rubout		?	DEI

Table E-10 Control characters, high bit on

Binary	Dec	Hex	ASCII char	Interpretation	What to type	Pri	Alt
10000000	128	\$80	NUL	Blank (null)	Control-@	@	@
10000001	129	\$81	SOH	Start of header	Control-A	A	Α
10000010	130	\$82	STX	Start of text	Control-B	В	В
10000011	131	\$83	ETX	End of text	Control-C	С	C
10000100	132	\$84	EOT	End of transm.	Control-D	D	D
10000101	133	\$85	ENQ	Enquiry	Control-E	E	E
10000110	134	\$86	ACK	Acknowledge	Control-F	F	F
10000111	135	\$87	BEL	Bell	Control-G	G	G
10001000	136	\$88	BS	Backspace	Control-H	H	Н
					or Left Arrow		
10001001	137	\$89	HT	Horizontal tab	Control-I	I	I
					or Tab		
10001010	138	\$8A	LF	Line feed	Control-J	J	J
					or Down Arrow		
10001011	139	\$8B	VT	Vertical tab	Control-K	K	K
					or Up Arrow		
10001100	140	\$8C	FF	Form feed	Control-L	L	L
10001101	141	\$8D	CR	Carriage return	Control-M	M	M
	0.7			E CONTRACTOR OF THE CONTRACTOR	or Return		
10001110	142	\$8E	SO	Shift out	Control-N	N	N
10001111	143	\$8F	SI	Shift in	Control-O	0	0
10010000	144	\$90	DLE	Data link escape	Control-P	P	P
10010001	145	\$91	DC1	Device control 1	Control-Q	Q	Q
10010010	146	\$92	DC2	Device control 2	Control-R	R	R
10010011	147	\$93	DC3	Device control 3	Control-S	S	S
10010100	148	\$94	DC4	Device control 4	Control-T	T	T
10010101	149	\$95	NAK	Neg. acknowledge	Control-U	U	U
					or Right Arrow		
10010110	150	\$ 96	SYN	Synchronization	Control-V	V	V
10010111	151	\$97	ETB	End of text blk.	Control-W	W	W
10011000	152	\$98	CAN	Cancel	Control-X	\mathbf{X}	X
10011001	153	\$99	EM	End of medium	Control-Y	Y	Y
10011010	154	\$9A	SUB	Substitute	Control-Z	Z	Z
10011011	155	\$9B	ESC	Escape	Control-[[[
					or Escape		
10011100	156	\$9C	FS	File separator	Control-\	\	\
10011101	157	\$9D	GS	Group separator	Control-]	j]
10011110	158	\$9E	RS	Record separator	Control-^	٨	٨
10011111	159	\$9F	US	Unit separator	Control		

Table E-11 Special characters, high bit on

10100000	Binary	Dec	Hex	ASCII char	Interpretation	What to type	Pri	Alt
10100001	10100000	160	\$A0	SP	Space	Space bar		
10100011 163 \$A3 # # # # # # # # 10100100 164 \$A4 \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$	10100001	161	\$A1		•	•	1	!
10100100 164 \$A4 \$ \$ \$ \$ \$ \$ \$ \$ \$ % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % %	10100010	162	\$A2	H .			*	**
10100101 165 \$A5 % <t< td=""><td>10100011</td><td>163</td><td>\$A3</td><td>#</td><td></td><td></td><td>#</td><td>#</td></t<>	10100011	163	\$A3	#			#	#
10100101 165 \$A5 % <t< td=""><td>10100100</td><td>164</td><td>\$A4</td><td>\$</td><td></td><td></td><td>\$</td><td>\$</td></t<>	10100100	164	\$A4	\$			\$	\$
10100111 167 \$A7 Apostrophe (<td>10100101</td> <td>165</td> <td>\$A5</td> <td></td> <td></td> <td></td> <td>%</td> <td></td>	10100101	165	\$A5				%	
10101000 168 \$A8 () () ((<t< td=""><td>10100110</td><td>166</td><td>\$A6</td><td>&:</td><td></td><td></td><td>&</td><td>&</td></t<>	10100110	166	\$A6	& :			&	&
10101000 168 \$A8 () <t< td=""><td>10100111</td><td>167</td><td>\$A7</td><td>!</td><td>Apostrophe</td><td></td><td>1</td><td>ŧ</td></t<>	10100111	167	\$A 7	!	Apostrophe		1	ŧ
10101010 170 \$AA * <t< td=""><td>10101000</td><td>168</td><td>\$A8</td><td>(</td><td>•</td><td></td><td>(</td><td>(</td></t<>	10101000	168	\$A8	(•		((
10101010	10101001	169	\$A9)	en ())
10101100 172 \$AC , Comma ,	10101010	170	\$AA	•		N.	•	•
10101101 173 \$AD - Hyphen - - - - 10101111 174 \$AE <	10101011	171	\$AB	+			+	+
10101110 174 \$AE . <t< td=""><td>10101100</td><td>172</td><td>\$AC</td><td>,</td><td>Comma</td><td></td><td>,</td><td>,</td></t<>	10101100	172	\$AC	,	Comma		,	,
10101111 175 \$AF / <t< td=""><td>10101101</td><td>173</td><td>\$AD</td><td></td><td>Hyphen</td><td></td><td>-</td><td>-</td></t<>	10101101	173	\$AD		Hyphen		-	-
10110000 176 \$B0 0 0 10110001 177 \$B1 1 1 10110010 178 \$B2 2 2 10110011 179 \$B3 3 3 10110100 180 \$B4 4 4 4 10110101 181 \$B5 5 5 5 10110110 182 \$B6 6 6 6 1011011 183 \$B7 7 7 7 10111000 184 \$B8 8 8 8 10111011 185 \$B9 9 9 9 10111010 186 \$BA : : : 10111011 187 \$BB ; ; ; 10111101 189 \$BD = = = 10111101 189 \$BD = = = 10111110 190 \$BE > > >	10101110	174	\$AE	•:	Period			
10110001 177 \$B1 1 <t< td=""><td>10101111</td><td>175</td><td>\$AF</td><td>/</td><td></td><td></td><td>/</td><td>/</td></t<>	10101111	175	\$AF	/			/	/
10110010 178 \$B2 2 2 10110011 179 \$B3 3 3 10110100 180 \$B4 4 4 4 10110101 181 \$B5 5 5 5 10110110 182 \$B6 6 6 6 10110111 183 \$B7 7 7 7 10111000 184 \$B8 8 8 8 10111001 185 \$B9 9 9 9 10111010 186 \$BA : : : 10111011 187 \$BB ; ; ; 10111101 189 \$BC <	10110000	176	\$ B0	0			0	0
10110011 179 \$B3 3 10110100 180 \$B4 4 10110101 181 \$B5 5 10110110 182 \$B6 6 10110111 183 \$B7 7 7 10111000 184 \$B8 8 8 10111001 185 \$B9 9 9 10111010 186 \$BA : : : 10111011 187 \$BB ; ; ; 10111100 188 \$BC <	10110001	177	\$ B1	1			1	1
10110100 180 \$B4 4 4 4 10110101 181 \$B5 5 5 5 5 5 10110110 182 \$B6 10 10 10 1 10	10110010	178	\$B2	2			2	2
10110100 180 \$B4 4 4 4 4 10110101 181 \$B5 5 5 5 5 10110110 182 \$B6 6 6 6 6 6 6 10110111 183 \$B7 7 7 7 7 7 7 7 7 7 7 10111000 184 \$B8 10111011 <t< td=""><td>10110011</td><td>179</td><td>\$B3</td><td>3</td><td></td><td></td><td>3</td><td>3</td></t<>	10110011	179	\$B3	3			3	3
10110110 182 \$B6 6 6 6 10110111 183 \$B7 7 7 7 10111000 184 \$B8 8 8 8 10111001 185 \$B9 9 9 9 10111010 186 \$BA : : : 10111011 187 \$BB ; ; ; 10111100 188 \$BC <	10110100	180	\$B4	4				
10110111 183 \$B7 7 7 10111000 184 \$B8 8 8 10111001 185 \$B9 9 9 10111010 186 \$BA : : : 10111011 187 \$BB ; ; ; 10111100 188 \$BC <	10110101	181	\$B5					5
10111000 184 \$B8 8 10111001 185 \$B9 9 10111010 186 \$BA : : 10111011 187 \$BB ; ; ; 10111100 188 \$BC <	10110110	182	\$ B6	6			6	6
10111001 185 \$B9 9 9 9 10111010 186 \$BA :<	10110111	183	\$B7	7			7	
10111010 186 \$BA : : : : 1 10111011 187 \$BB ;<	10111000	18 4	\$B8				8	8
10111010 186 \$BA : : : : : : 10111011 187 \$BB ; <td>10111001</td> <td>185</td> <td></td> <td>9</td> <td></td> <td></td> <td>9</td> <td>9</td>	10111001	185		9			9	9
10111100 188 \$BC <	10111010	186	\$BA	:			:	:
10111101 189 \$BD = = = 10111110 190 \$BE > >	10111011			;			;	;
10111110 190 \$BE > >	10111100			<				
	10111101	189	\$BD	=			=	=
10111111 191 \$BF ? ?				>			>	>
	10111111	191	\$BF	?			?	?

Table E-12 Uppercase characters, high bit on

Binary	Dec	Hex	ASCII ch	ar Interpretation	What to type	Pri	Alt
11000000	192	\$C0	@			@	@
11000001	193	\$C1	A			Α	Α
11000010	194	\$C2	В			В	В
11000011	195	\$C3	С			С	C
11000100	196	\$C4	D			D	D
11000101	197	\$C5	E			E	E
11000110	198	\$C6	F			F	F
11000111	199	\$C7	G			G	G
11001000	200	\$C8	H			H	H
11001001	201	\$C9	I			I	I
11001010	202	\$CA	J			J	J
11001011	203	\$CB	K			K	K
11001100	204	\$CC	L			L	L
11001101	205	\$CD	M			M	M
11001110	206	\$CE	N			N	N
11001111	207	\$CF	0			0	0
11010000	208	\$D0	P			P	P
11010001	209	\$ D1	Q			Q	Q
11010010	210	\$D2	R			R	R
11010011	211	\$D3	S			S	S
11010100	212	\$D4	T			T	T
11010101	213	\$D5	U		96	U	U
11010110	214	\$D6	V			V	V
11010111	215	\$ D7	\mathbf{w}			W	W
11011000	216	\$D8	X			X	\mathbf{X}
11011001	217	\$D9	Y			Y	Y
11011010	218	\$DA	Z			Z	Z
11011011	219	\$DB	[Opening bracket		[[
11011100	220	\$DC	\	Reverse slant		\	1
11011101	221	\$DD]	Closing bracket]]
11011110	222	\$DE	٨	Caret		٨	^
11011111	223	\$DF	_	Underline		_	_

Table E-13 Lowercase characters, high bit on

Binary	Dec	Нех	ASCII cho	ar Interpretation	What to type	Pri	Alt
11100000	224	\$E0		Grave accent		K *	~
11100001	225	\$E1	a			a	a
11100010	226	\$E2	b			b	b
11100011	227	\$E3	С			С	С
11100100	228	\$E4	d			d	d
11100101	229	\$E5	e			e	e
11100110	230	\$E6	f			f	f
11100111	231	\$E7	g			g	g
11101000	232	\$E8	h			h	h
11101001	233	\$E9	i			i	i
11101010	234	\$EA	j			j	j
11101011	235	\$EB	k			k	\mathbf{k}
11101100	236	\$EC	1			1	1
11101101	237	\$ED	m			m	m
11101110	238	\$EE	n			n	n
11101111	239	\$EF	0			0	O
11110000	240	\$F0	р			p	p
11110001	241	\$F1	q			q	q
11110010	242	\$F2	r			r	r
11110011	243	\$F3	s			S	s
11110100	244	\$F4	t			t	t
11110101	245	\$F5	u			u	u
11110110	246	\$F6	v			v	v
11110111	247	\$ F7	\mathbf{w}			\mathbf{w}	\mathbf{w}
11111000	248	\$F8	x			X	x
11111001	249	\$F9	y			y	y
11111010	250	\$FA	z			Z	Z
11111011	251	\$FB	{	Opening brace		{	{
11111100	252	\$FC	L	Vertical line		1	I
11111101	253	\$FD	}	Closing brace		}	}
11111110	254	\$FE	~	Overline (tilde)		~	~
11111111	255	\$FF	DEL	Delete/rubout	DELETE	DEL	DEL



Frequently Used Tables

This appendix contains copies of the tables you will need to refer to frequently; for example, ASCII codes and soft-switch location. The original table number is given in a footnote to the table.

Table F-1*
Keys and ASCII codes

	Nor	mal	Cor	ntrol	Sh	ift	Bot	h
Key	Code	Char	Code	Char	Code	Char	Code	Char
Delete	7F	DEL	7 F	DEL	7F	DEL	7F	DEL
Left Arrow	08	BS	08	BS	08	BS	08	BS
Tab	09	HT	09	HT	09	HT	09	HT
Down Arrow	0A	LF	0 A	LF	0 A	LF	0A	LF
Up Arrow	0B	VT	ОВ	VT	0B	VT	$\mathbf{0B}$	VT
Return	0D	CR	0D	CR	0D	CR	0D	CR
Right Arrow	15	NAK	15	NAK	15	NAK	15	NAK
Escape	1B	ESC	1B	ESC	1B	ESC	1B	ESC
Space	20	SP	20	SP	20	SP	20	SP
t û	27	•	27	•	22	**	22	**
, <	2C	,	2C	,	3C	<	3C	<
	2D	_	1F	US	5F	_	1F	US
. >	2E		2E		3E	>	3E	>
/ ?	2F	/	2F	/	3F	?	3F	?
0)	30	0	30	0	29)	29)
1!	31	1	31	1	21	!	21	!
2@	32	2	00	NUL	40	@	00	NUL
3 #	33	3	33	3	23	#	23	#
4 \$	34	4	34	4	24	\$	24	\$

Table F-1 (continued)*
Keys and ASCII codes

	Nor	mal	Cor	ntrol	Sh	ift Both		h
Key	Code	Char	Code	Char	Code	Char	Code	Char
5 %	35	5	35	5	25	%	25	%
6 ^	36	6	1E	RS	5E	٨	1E	RS
7 &	37	7	37	7	26	&x	26	&
8 *	38	8	38	8	2A	*	2A	•
9 (39	9	39	9	28	(28	(
; :	3B	;	3B	;	3A	:	3A	:
= +	3D	=	3D	=	2B	+	2B	+
[{	5B	[-	1B	ESC	7B	{	1B	ESC
\ 1	5C	1	1C	FS	7C		1C	FS
1 }	5D	1	1D	GS	7D	}	1D	GS
`~	60	•	60	`	7E	~	7E	~
A	61	a	01	SOH	41	A	01	SOF
В	62	b	02	STX	42	В	02	STX
C	63	С	03	ETX	43	С	03	ETX
D	64	d	04	EOT	44	D	04	EOT
E	65	e	05	ENQ	45	E	05	ENÇ
F	66	f	06	ACK	46	F	06	ACK
G	67	g	07	BEL	47	G	07	BEL
Н	68	h	08	BS	48	Н	08	BS
I	69	i	09	HT	49	I	09	HT
J	6A	j	0A	LF	4A	J	0 A	LF
K	6В	k	ОВ	VT	4B	K	0B	VT
L	6C	1	0C	FF	4C	L	0C	FF
M	6D	m	0D	CR	4D	M	0D	CR
N	6E	n	0E	SO	4E	N	0E	SO
O	6F	О	OF	SI	4F	0	OF	SI
P	70	p	10	DLE	50	P	10	DLE
Q	71	q	11	DC1	51	Q	11	DC1
R	72	r	12	DC2	52	R	12	DC2
S	73	s	13	DC3	53	S	13	DC3
T	74	t	14	DC4	54	T	14	DC4
U	75	u	15	NAK	55	Ū	15	NAK
v	76	v	16	SYN	56	v	16	SYN
W	77	w	17	ETB	57	W	17	ETB
X	78	x	18	CAN	58	X	18	CAN
Y	79	y	19	EM	59	Y	19	EM
Ž	7 A	z	1A	SUB	5A	Ž	1A	SUB

^{*} Table 2-2

Note: Codes are shown here in hexadecimal; to find the decimal equivalents, refer to Table E-3.

Table F-2*Keyboard memory locations

Location		
Hex	Decimal	Description
\$C000 \$C010		Keyboard data and strobe Any-key-down flag and clear-strobe switch

^{*} Table 2-1

Table F-3* Video display specifications

Display modes	40-column text; map: Figure 2-3 80-column text; map: Figure 2-4 Low-resolution color graphics; map: Figure 2-8 High-resolution color graphics; map: Figure 2-9 Double high-res color graphics; map: Figure 2-10
Text capacity	24 lines by 80 columns (character positions)
Character set	96 ASCII characters (uppercase and lowercase)
Display formats	Normal, inverse, flashing, MouseText (Table 2-4)
Low-resolution graphics	16 colors (Table 2-5), 40 horizontal by 48 vertical; map: Figure 2-8
High-resolution graphics	6 colors (Table 2-6), 140 horizontal by 192 vertical (restricted) Black-and-white: 280 horizontal by 192 vertical; map: Figure 2-9
Double high-resolution graphics	16 colors (Table 2-7), 140 horizontal by 192 vertical (no restrictions) Black-and-white: 560 horizontal by 192 vertical; map: Figure 2-10

[•] Table 2-3

Table F-4*Double high-resolution graphics colors

Color	ab0	mb1	ab2	mb3	Repeated bit pattern
		<u> </u>		. 3	E con acceptance
Black	\$00	\$00	\$00	\$00	0000
Magenta	\$08	\$11	\$22	\$44	0001
Brown	\$44	\$08	\$11	\$22	0010
Orange	\$4C	\$19	\$33	\$66	0011
Dark green	\$22	\$44	\$08	\$11	0100
Gray 1	\$2A	\$55	\$2A	\$55	0101
Green	\$66	\$4C	\$19	\$33	0110
Yellow	\$6E	\$5D	\$3B	\$77	0111
Dark blue	\$11	\$22	\$44	\$08	1000
Purple	\$19	\$33	\$66	\$4C	1001
Gray 2	\$55	\$2A	\$55	\$2A	1010
Pink	\$5D	\$3B	\$77	\$6E	1011
Medium blue	\$33	\$66	\$4C	\$19	1100
Light blue	\$3B	\$77	\$6E	\$5D	1101
Aqua	\$77	\$6E	\$5D	\$3B	1110
White	\$7F	\$7F	\$7F	\$7F	1111

[•] Table 2-7

Table F-5* Video display page locations

		Lowest	address	Highest address		
Display mode	Display page	Hex	Dec	Hex	Dec 2047 3071 2047 3071 16383	
40-column text, low-resolution graphics	1 2†	\$0400 \$0800	1024 2048	\$07FF \$0BFF		
80-column text	1 2†	\$0400 \$0800	1024 2048	\$07FF \$0BFF		
High-resolution graphics	1 2	\$2000 \$4000	8192 16384	\$3FFF \$5FFF	16383 24575	
Double high- resolution graphics	1 ‡ 2 ‡	\$2000 \$4000	8192 16384	\$3FFF \$5FFF	16383 24575	

[•] Table 2-8

[†] This is not supported by firmware; for instructions on how to switch pages, refer to the section "Display Mode Switching" in Chapter 2. ‡ See the section "Double High-Resolution Graphics" in Chapter 2.

Table F-6*
Display soft switches

Name	Action	Hex	Function
ALTCHAR	W	\$C00E	Off: display text using primary character set
ALTCHAR	W	\$C00F	On: display text using alternate character set
RDALTCHAR	R7	\$C01E	Read ALTCHAR switch (1 = on)
80COL	W	\$C00C	Off: display 40 columns
80COL	W	\$C00D	On: display 80 columns
RD80COL	R7	\$C01F	Read 80COL switch (1 = on)
80STORE	W	\$C000	Off: cause PAGE2 on to select auxiliary RAM
80STORE	W	\$C001	On: allow PAGE2 to switch main RAM areas
RD80STORE	R7	\$C018	Read 80STORE switch (1 = on)
PAGE2	R/W	\$C054	Off: select Page 1
PAGE2	R/W	\$C055	On: select Page 2 or, if 80STORE on, Page 1 in auxiliary memory
RDPAGE2	R7	\$C01C	Read PAGE2 switch (1 = on)
TEXT	R/W	\$C050	Off: display graphics or, if MIXED on, mixed
TEXT	R/W	\$C051	On: display text
RDTEXT	R7	\$C01A	Read TEXT switch (1 = on)
MIXED	R/W	\$C052	Off: display only text or only graphics
MIXED	R/W	\$C053	On: if TEXT off, display text and graphics
RDMIXED	R7	\$C01B	Read MIXED switch (1 = on)
HIRES	R/W	\$C056	Off: if TEXT off, display low-resolution graphics

Table F-6* (continued) Display soft switches

Name	Action	Hex	Function
HIRES	R/W	\$C057	On: if TEXT off, display high-resolution or, if DHIRES on, double high-resolution graphics
RDHIRES	R7	\$C01D	Read HIRES switch (1 = on)
IOUDIS	W	\$C07E	On: disable IOU access for addresses \$C058 to \$C05F; enable access to DHIRES switch [†]
IOUDIS	W	\$C07F	Off: enable IOU access for addresses \$C058 to \$C05F; disable access to DHIRES switch [†]
RDIOUDIS	R7	\$C07E	Read IOUDIS switch $(1 = off)^{\ddagger}$
DHIRES	R/W	\$C05E	On: if IOUDIS on, turn on double high-resolution
DHIRES	R/W	\$C05F	Off: if IOUDIS on, turn off double high resolution
RDDHIRES	R7	\$C07F	Read DHIRES switch (1 = on) [‡]
VBL	R7	\$C019	Vertical blanking

^{*} Table 2-9

Note: W means write anything to the location, R means read the location, R/W means read or write, and R7 means read the location and check bit 7.

Table F-7*
Monitor firmware routines

Location0	Name	Description
\$C305	BASICIN	With 80-column firmware active, displays solid, blinking cursor; accepts character from keyboard
\$C307	BASICOUT	Displays a character on the screen; used when the 80-column firmware is active (Chapter 3)

[†] The firmware normally leaves IOUDIS on. See also †.

[‡] Reading or writing any address in the range \$C070-\$C07F also triggers the paddle timer and resets VBLINT (Chapter 7).

Table F-7° (continued) Monitor firmware routines

Location0	Name	Description
\$FC9C	CLREOL	Clears to end of line from current cursor position
\$FC9E	CLEOLZ	Clears to end of line using contents of Y register as cursor position
\$FC42	CLREOP	Clears to bottom of window
\$F832	CLRSCR	Clears the low-resolution screen
\$F836	CLRTOP	Clears top 40 lines of low-resolution screen
\$FDED	COUT	Calls output routine whose address is stored in CSW (normally COUT1, Chapter 3).
\$FDF0	COUT1	Displays a character on the screen (Chapter 3)
\$FD8E	CROUT	Generates a carriage return character
\$FD8B	CROUT1	Clears to end of line, then generates a carriage return character
\$FD6A	GETLN	Displays the prompt character; accepts a string of characters by means of RDKEY
\$F819	HLINE	Draws a horizontal line of blocks
\$FC58	HOME	Clears the window and puts cursor in upper-left corner of window
\$FD1B	KEYIN	With 80-column firmware inactive, displays checkerboard cursor, accepts character from keyboard
\$F800	PLOT	Plots a single low-resolution block on the screen
\$F94A	PRBL2	Sends 1 to 256 blank spaces to the output device
\$FDDA	PRBYTE	Prints a hexadecimal byte
\$FF2D	PRERR	Sends ERR and Control-G to the output device

Table F-7° (continued)
Monitor firmware routines

Location0	Name	Description
\$FDE3	PRHEX	Prints 4 bits as a hexadecimal number
\$F941	PRNTAX	Prints contents of A and X in hexadecimal
\$FD0C	RDKEY	Displays blinking cursor; goes to standard input routine, normally KEYIN or BASICIN
\$F871	SCRN	Reads color value of a low-resolution block
\$F864	SETCOL	Sets the color for plotting in low resolution
\$FC24	VTABZ	Sets cursor vertical position
\$F828	VLINE	Draws a vertical line of low-resolution blocks

^{*} Table 3-1

Table F-8a°
Control characters, 80-column firmware off

Control character	ASCII name	Apple lie name	Action taken by COUT1
Control-G	BEL	Bell	Produces a 1000 Hz tone for 0.1 second
Control-H	BS	Backspace	Moves cursor position one space to the left; from left edge of window, moves to right end of line above
Control-J	LF	Line feed	Moves cursor position down to next line in window, scrolls if needed
Control-M	CR	Return	Moves cursor position to left end of next line in window, scrolls if needed

^{*} Table 3-3a

Table F-8b°
Control characters, 80-column firmware on

Control character	ASCII name	Apple lie name	Action taken by BASICOUT
Control-G	BEL	Bell	Produces a 1000 Hz tone for 0.1 second
Control-H	BS	Backspace	Moves cursor position one space to the left; from left edge of window, moves to right end of line above
Control-J	LF	Line feed	Moves cursor position down to next line in window; scrolls if needed
Control-K†	VT	Clear EOS	Clears from cursor position to the end of the screen
Control-L†	FF	Home and clear	Moves cursor position to upper-left corner of window and clears window
Control-M	CR	Return	Moves cursor position to left end of next line in window, scrolls if needed
Control-N†	SO	Normal	Sets display format normal
Control-O†	SI	Inverse	Sets display format inverse
Control-Q†	DC1	40-column	Sets display to 40-column
Control-R†	DC2	80-column	Sets display to 80-column
Control-S‡	DC3	Stop-list	Stops listing characters on the display until another key is pressed
Control-U†	NAK	Quit	Deactivates 80-column video firmware
Control-V†	SYN	Scroll	Scrolls the display down one line, leaving the cursor in the current position
Control-W†	ETB	Scroll-up	Scrolls the display up one line, leaving the cursor in
/ Used Tables			the current position

Table F-8b* (continued)
Control characters, 80-column firmware on

Control character	ASCII name	Apple lie name	Action taken by BASICOUT
Control-X	CAN	Disable MouseText	Disables MouseText character display; use inverse uppercase
Control-Y†	EM	Home	Moves cursor position to upper-left corner of window (but doesn't clear)
Control-Z†	SUB	Clear line	Clears the line the cursor position is on
Control-[ESC	Enable MouseText	Maps inverse uppercase characters to MouseText characters
Control-\†	FS	Forward space	Moves cursor position one space to the right, from right edge of window, moves it to left end of line below
Control-]†	GS	Clear EOL	Clears from the current cursor position to the end of the line (that is, to the right edge of the window)
Control * Table 3-3b † Doesn't work	US from the l	Up keyboard	Moves cursor up a line, no scroll

Table F-9*
Text format control values

Mask value				
Dec	Hex	Display format		
255	\$FF	Normal, uppercase, and lowercase		
127	\$7F	Flashing, uppercase, and symbols		
63	\$3F	Inverse, uppercase, and lowercase		
Note.		e mask values apply primary character set		

(see text).

‡ Only works from the keyboard.

Escapo codos		
Escape code	Function	
Escape @	Clears window and homes cursor (places it in upper-left corner of screen), then exits from escape mode	
Escape A or a	Moves cursor right one line; exits from escape mode	
Escape B or b	Moves cursor left one line; exits from escape mode	

Table F-10*
Escape codes

Table F-10* (continued) Escape codes

Escape code	Function
Escape C or c	Moves cursor down one line; exits from escape mode
Escape D or d	Moves cursor up one line; exits from escape mode
Escape E or e	Clears to end of line; exits from escape mode
Escape F or f	Clears to bottom of window; exits from escape mode
Escape I or i or Escape Up Arrow	Moves the cursor up one line; remains in escape mode (see text)
Escape J or j or Escape Left Arrow	Moves the cursor left one space; remains in escape mode (see text)
Escape K or k or Escape Right Arrow	Moves the cursor right one space; remains in escape mode (see text)
Escape M or m or Escape Down Arrow	Moves the cursor down one line; remains in escape mode (see text)
Escape 4	If 80-column firmware is active, switches to 40-column mode; sets links to BASICIN and BASICOUT; restores normal window size; exits from escape mode
Escape 8	If 80-column firmware is active, switches to 80-column mode; sets links to BASICIN and BASICOUT; restores normal window size; exits from escape mode
Escape Control-D	Disables control characters; only carriage return, line feed, BELL, and backspace have an effect when printed
Escape Control-E	Reactivates control characters
Escape Control-Q	If 80-column firmware is active, deactivates 80-column firmware; sets links to KEYIN and COUT1; restores normal window size; exits from escape
• Table 3-6	mode

Table F-11*
Pascal video control functions

Control-	Hex	Function performed	
E or e	\$05	Turns cursor on (enables cursor display)	
F or f	\$06	Turns cursor off (disables cursor display)	
G or g	\$07	Sounds bell (beeps)	
H or h	\$08	Moves cursor left one column. If cursor was at beginning of line, moves it to end of preceding line	
J or j	\$0 A	Moves cursor down one row; scrolls if needed	
K or k	\$0B	Clears to end of screen	
L or l	\$0C	Clears screen; moves cursor to upper-left of screen	
M or m	\$0D	Moves cursor to column 0	
N or n	\$0E	Displays subsequent characters in normal video (Characters already on display are unaffected.)	
O or o	\$0F	Displays subsequent characters in inverse video (Characters already on display are unaffected.)	
V or v	\$16	Scrolls screen up one line; clears bottom line	
W or w	\$ 17	Scrolls screen down one line; clears top line	
Y or y	\$19	Moves cursor to upper-left (home) position on screen	
Z or z	\$1A	Clears entire line that cursor is on	
l or \	\$1C	Moves cursor right one column; if at end of line, does Control-M	
} or]	\$1D	Clears to end of the line the cursor is on, including current cursor position; does not move cursor	
^ or 6	\$1E	GOTOxy: initiates a GOTOxy sequence; interprets the next two characters as x+32 and y+32, respectively	
-	\$1F	If not at top of screen, moves cursor up one line	

^{*} Table 3-10

Table F-12*
Bank select switches

Name	Action	Hex	Function
	R	\$C080	Read RAM; no write; use \$D000 bank 2.
	RR	\$C081	Read ROM; write RAM; use \$D000 bank 2.
	R	\$C082	Read ROM; no write; use \$D000 bank 2.
	RR	\$C083	Read and write RAM; use \$D000 bank 2.
	R	\$C088	Read RAM; no write; use \$D000 bank 1.
	RR	\$C089	Read ROM; write RAM; use \$D000 bank 1.
	R	\$C08A	Read ROM; no write; use \$D000 bank 1.
	RR	\$C08B	Read and write RAM; use \$D000 bank 1.
RDBNK2	R7	\$C011	Read whether \$D000 bank 2 (1) or bank 1 (0).
RDLCRAM	R7	\$C012	Reading RAM (1) or ROM (0).
ALTZP	W	\$C008	Off: use main bank, page 0 and page 1.
ALTZP	W	\$C009	On: use auxiliary bank, page 0 and page 1.
RDALTZP	R7	\$C016	Read whether auxiliary (1) or main (0) bank.

^{*} Table 4-6

Note: R means read the location, W means write anything to the location, R/W means read or write, and R7 means read the location and then check bit 7.

Table F-13*
Auxiliary-memory select switches

			ocation	
Name	Function	Hex	Decimal	Notes
RAMRD	Read auxiliary memory	\$C003	49155 –16381	Write
	Read main memory	\$C002	49154 –16382	Write
	Read RAMRD switch	\$C013	49171 –16365	Read
RAMWRT	Write auxiliary memory Write main memory Read RAMWRT switch	\$C005 \$C004 \$C014	49157 –16379 49156 –16380 49172 –16354	Write Write Read
80STORE	On: access display page	\$C001	49153 –16383	Write
	Off: use RAMRD, RAMWRT	\$C000	49152 –16384	Write
	Read 80STORE switch	\$C018	49176 –16360	Read
PAGE2	Page 2 on (aux. memory) Page 2 off (main memory) Read PAGE2 switch	\$C055 \$C054 \$C01C	49237 -16299 49236 -16300 49180 -16356	† † Read
HIRES	On: access high-res pages	\$C057	49239 –16297	‡
	Off: use RAMRD, RAMWRT	\$C056	49238 –16298	‡
	Read HIRES switch	\$C01D	49181 –16355	Read
ALTZP	Aux. stack & zero page	\$C009	49161 –16373	Write
	Main stack & zero page	\$C008	49160 –16374	Write
	Read ALTZP switch	\$C016	49174 –16352	Read

^{*} Table 4-7

Table F-14*
48K RAM transfer routines

Name	Action	Hex	Function
AUXMOVE	JSR	\$C311	Moves data blocks between main and auxiliary 48K memory
XFER	JMP	\$C314	Transfers program control between main and auxiliary 48K memory

^{*} Table 4-8

[†] When 80STORE is on, the PAGE2 switch selects main or auxiliary display memory.

[‡] When 80STORE is on, the HIRES switch enables you to use the PAGE2 switch to switch between the high-resolution Page 1 area in main memory or auxiliary memory.

Table F-15*
I/O memory switches

		Location		
Name	Function	Hex	Decimal	Notes
SLOTC3ROM	Slot ROM at \$C300	\$C00B	49163 –16373	Write
	Internal ROM at \$C300	\$C00A	49162 –16374	Write
	Read SLOTC3ROM switch	\$C017	49175 –16361	Read
SLOTCXROM	Slot ROM at \$Cx00	\$C006	49159 –16377	Write
	Internal ROM at \$Cx00	\$C007	49158 –16378	Write
	Read SLOTCXROM switch	\$C015	49173 –16363	Read

[•] Table 6-5

Table F-16*
I/O routine offsets and registers under Pascal 1.1 protocol

Address	Offset for	X register	Y register	A register
\$Cs0D	Initialization On entry On exit	\$Cs Error code	\$s0 (unchanged)	(unchanged)
\$Cs0E	Read On entry On exit	\$Cs Error code	\$s0 (unchanged)	Character read
\$Cs0F	Write On entry On exit	\$Cs Error code	\$s0 (unchanged)	Char. to write (unchanged)
\$Cs10	Status On entry On exit	\$Cs Error code	\$s0 (changed)	Request (0 or 1) (unchanged)

^{*} Table 6-7

Appendix G

Using an 80-Column Text Card

This appendix explains how to use 80-column text cards with high-level languages. Information about using 80-column text cards with assembly-language programs through the Apple IIe Monitor firmware is found in Chapter 3 of this manual. The information in this appendix applies to the Apple IIe 80-Column Text Card and the Apple IIe Extended 80-Column Text Card.

If you are using Applesoft, ProDOS, or DOS you can choose to leave the 80-column text card inactive after installing it. You will want to do this when running software that does not take advantage of the 80-column display capability.

The startup procedure for displaying 80 columns of text on your Apple IIe depends on which operating system you plan to use. Starting up the system with Apple II Pascal or CP/M is very easy; the operating system does it for you. The procedures for starting up with ProDOS or DOS 3.3 are slightly more complicated, but not difficult.

Starting up with Pascal or CP/M

Pascal programmers don't have to activate the text card because Pascal does it for them. If you use the Pascal language or the CP/M operating system, displaying 80 columns of text is automatic once you've installed the card. Simply start up your system with any Pascal or CP/M startup disk.

- CP/M: Control Program for Microprocessors is a trademark of Digital Research. To use the CP/M operating system with your Apple IIe, make sure the SOFTCARD by Microsoft or the Z-Engine by Advanced Logic Systems is correctly installed before you start up the computer.
- Coprocessor cards and interrupts: Some coprocessor cards that were designed for use in the Apple II Plus may not work with an Apple IIe without some modification. There could be problems if you want to use interrupts on the Apple IIe. If you are having problems with a coprocessor card, check with the card's manufacturer for their recommendations.

Refer to the operating system reference manual for your version of Apple Pascal for more information.

When using Apple II Pascal 1.1, you'll probably want to run the program SETUP to make the Up Arrow and Down Arrow keys functional. SETUP is a self-documenting program on the Pascal disk APPLE3. Pascal versions 1.2 and later are already configured to use the Up Arrow and Down Arrow keys.

Starting up with ProDOS or DOS 3.3

ProDOS and DOS 3.3 both look for a startup program on the startup (boot) disk as soon as the operating system has been loaded and begins executing. If the operating system finds the program, named STARTUP on a ProDOS disk and usually HELLO on a DOS 3.3 disk, it will execute the program.

You can write a customized startup program that will set up the 80-column text card in any state you need. Just be sure it is on your startup disk and has the startup filename.

Here is a sample Applesoft startup program that works with both ProDOS and DOS 3.3:

- 10 HOME: D\$=CHR\$ (4)
- 20 PRINT D\$; "PR#3"
- 30 END

You can do whatever you wish with the program from line 20 on. Note that the screen will have switched to 80-column text mode after line 20.

By the way: If you arrange to have the card active automatically, you will still, of course, be able to switch into 40-column mode.

Using the GET Command

The presence of an active 80-column text card in the IIe requires that BASIC programmers use some alternative to Applesoft's INPUT command if their programs are to be userproof. Applesoft programmers should use either the GET command or the RDKEY or GETLN subroutines.

This is because the escape sequences used to switch back and forth between modes or to deactivate the card sometimes make it necessary to accept escape sequences in INPUT mode when using an 80-column card. Because the program accepts escape sequences typed from the keyboard, your program will not be userproof against accidental sequences typed in response to an INPUT command.

To get around this problem, you can use the GET command instead. The program does not read escape sequences typed from the keyboard in response to a GET command. This means that your users can err in their responses without endangering the display.

When to switch modes versus when to deactivate

When using BASIC, deactivate the text card whenever a previous (BASIC) program has left the card active (leaving a solid cursor on the screen) or whenever you want to send output to a peripheral device.

Switch back and forth between 40-column and 80-column displays for visual appeal. For full use of the control characters described later, your card must be active, although it can display in either 40-column or 80-column mode.

Original lle

Tabbing in Applesoft: You must switch to a 40-column display to use Applesoft comma tabbing or the HTAB command.

Display features with the text card

With an active 80-column card you can issue BASIC and PRODOS commands in lowercase characters. You can also issue commands in lowercase from the keyboard, that is, in immediate mode. This is particularly convenient because REM statements and data within quotation marks remain in lowercase as they were typed.

If you are using DOS 3.3, you must issue commands in uppercase whether or not your card is active.

INVERSE, FLASH, NORMAL, HOME

There are several commands you can give your computer from Applesoft BASIC to affect the appearance of text on the screen. All of these features are described in the *Applesoft BASIC Programmer's Reference Manual*.

- □ INVERSE tells the computer to display black characters on a white background instead of the normal display of white characters on a black background. This command is normally only available for uppercase characters, but with an active 80-column text card it is available for uppercase and lowercase characters.
- ☐ FLASH causes subsequently printed characters to blink quickly between inverse and normal characters. You can turn off the FLASH command by typing the NORMAL command. The FLASH command is normally available only with uppercase characters; it is not available at all while the card is active.
- □ NORMAL tells the computer to turn off the INVERSE or FLASH command and to display subsequently printed characters normally. It works the same way with the card active or inactive.
- □ HOME clears the screen and returns the cursor to the upper-left corner of the screen. Both the NORMAL HOME and INVERSE HOME commands are available while the card is active, but INVERSE HOME works a little differently when the card is active.
- By the way: The FLASH and INVERSE commands can be used to highlight important screen messages within a BASIC program.

Important

If you are using the FLASH command (which means the 80-column text card is inactive) and then type PR#3 to activate the card, the screen turns white as the cursor goes to the HOME position. Whatever you type appears in black characters on the white screen. If you list or run an Applesoft BASIC program, some of the characters will appear as MouseText characters. To avoid this, remember to use the NORMAL or INVERSE command before you exit the program.

Tabbing with the original Apple Ile

You cannot use conventional 40-column tabbing in BASIC with the original model Apple IIe with an 80-column display. You do not have to turn off your card, but you must switch out of 80-column mode to use the HTAB command or to use comma tabbing.

When an original Apple IIe is displaying 80-column text, you should use the POKE 1403 command for horizontal tabbing in the right half of the screen instead of the HTAB command.

Comma tabbing with the original Apple IIe

In BASIC you can use commas in PRINT statements to instruct the computer to display all or part of your output in columns. This is known as *comma tabbing*. You can use this method of tabbing as long as the screen is displaying 40 columns (that is, with the card inactive or after issuing the Escape 4 command to switch to 40-column mode). You cannot use this method of tabbing with an 80-column display. If you try to do so, characters will be placed in memory outside the screen area and may change programs or data in memory.

HTAB and POKE 1403

The VTAB (vertical tab) and HTAB (horizontal tab) statements can be used to place the cursor at a specific location on the screen before printing characters. The largest value you can use with the VTAB statement is 24; the largest for HTAB is 255. The VTAB command works just the same in an 80-column display as it does in a 40-column display.

On the original Apple IIe, the HTAB command causes the cursor to wrap around to the next line after it reaches the 40th column, so you cannot use this command to position the cursor in the last 40 columns while the screen is displaying 80 columns.

POKE 1403 is specifically designed to solve this problem. Using the POKE 1403 command allows you to tab horizontally across the extra 40 columns provided by the 80-column text card.

If you want to tab past column 40 while the card is active and the screen is displaying 80 columns, use the following, where n is a number from 0 to 79:

POKE 1403, n

When you use the HTAB command, HTAB 1 places the cursor at the leftmost position on the screen. When you use the POKE 1403 command, "POKE 1403,0" places the cursor at the leftmost position on the screen.

Using control characters with the card

Using BASIC with an active 80-column text card increases the number of functions you can perform with control characters. Originally control-character commands were so named because they were given from the keyboard by pressing the Control key in conjunction with another key. You can perform the same functions from your programs by using an equivalent control-character code. Commands based on these two-key combinations are called *control-character commands* even when they must be issued from a program.

Control characters and their functions

Table G-1 lists the control-character commands supported by BASIC with an 80-column card. The table includes the corresponding command code, its function, and whether a given command can be executed from the keyboard as well as from a program.

Table G-1 Control characters, 80-column firmware on

Control character	ASCII name	Apple lie name	Action taken by BASICOUT
Control-G	BEL	Bell	Produces a 1000 Hz tone for 0.1 second
Control-H	BS	Backspace	Moves cursor position one space to the left; from left edge of window, moves to right end of line above
Control-J	LF	Line feed	Moves cursor position down to next line in window; scrolls if needed
Control-K*	VT	Clear EOS	Clears from cursor position to the end of the screen
Control-L*	FF	Home and clear	Moves cursor position to upper-left corner of window and clears window
Control-M	CR	Return	Moves cursor position to left end of next line in window, scrolls if needed
Control-N*	SO	Normal	Sets display format normal
Control-O*	SI	Inverse	Sets display format inverse
Control-Q*	DC1	40-column	Sets display to 40-column
Control-R*	DC2	80-column	Sets display to 80-column
Control-S†	DC3	Stop-list	Stops listing characters on the display until another key is pressed
Control-U*	NAK	Quit	Deactivates 80-column video firmware
Control-V*	SYN	Scroll	Scrolls the display down one line, leaving the cursor in the current position

Table G-1 (continued)
Control characters, 80-column firmware on

Control character	ASCII name	Apple lie name	Action taken by BASICOUT	
Control-W*	ЕТВ	Scroll-up	Scrolls the display up one line, leaving the cursor in the current position	
Control-X	CAN	Disable MouseText	Disables MouseText character display; use inverse uppercase	
Control-Y*	ЕМ	Home	Moves cursor position to upper-left corner of window (but doesn't clear)	
Control-Z*	SUB	Clear line	Clears the line the cursor position is on	
Control-[ESC	Enable MouseText	Maps inverse uppercase characters to MouseText characters	
Control-*	FS	Forward space	Moves cursor position one space to the right, from right edge of window, moves it to left end of line below	
Control-]*	GS	Clear EOL	Clears from the current cursor position to the end of the line (that is, to the right edge of the window)	
Control	US	Up	Moves cursor up a line, no scroll	
Doesn't work from the keyboard				

[†] Only works from the keyboard

How to use control-character codes in programs

To issue a control-character command from a program, use the ASCII decimal code that corresponds to the control character. (See Table G-1.)

The following example shows how to use ASCII decimal codes in an Applesoft BASIC program. Type

```
HOME [?] NEW

10 PRINT CHR$(15): PRINT "MAKE HAY"

20 PRINT CHR$(14): PRINT "WHILE THE SUN SHINES"
RUN
```

(CHR\$ is the Applesoft BASIC command that signifies that a control-character function is to be performed.)

You will get

```
]NEW
]10 PRINT CHR$(15): PRINT "MAKE HAY"
]20 PRINT CHR$(14): PRINT "WHILE THE SUN SHINES"
]RUN
MAKE HAY
WHILE THE SUN SHINES
]
```

The ASCII decimal codes for inverse video (Control-O) and normal video (Control-N) are 15 and 14. When the PRINT statements in the example are executed, the display switches to inverse and prints MAKE HAY, then switches back to a normal display and prints WHILE THE SUN SHINES.

A word of caution to Pascal programmers

Avoid writing Control-U or Control-Q to the console from a Pascal program. Either one puts the system into a state that will eventually cause Pascal to crash.

You can't send control characters from the keyboard to the 80-column firmware when using Pascal. The only exceptions to this rule are Control-M (CR) and Control-G (BEL).

See Chapter 3 in this manual for a description of controlcharacter functions.

Appendix H

Programming With the Super Serial Card

For more information about the installation and operation of the SSC, see the Super Serial Card manual.

This appendix briefly tells how to use the Apple II Super Serial Card (SSC) from programs and how to find the SSC through software, and describes the commands supported by the SSC.

The SCC is one of the most common serial interface cards used with the Apple IIe, and the Apple IIc's serial ports operate very much like the Super Serial Card. This similarity should make it easier for you to write programs for both the Apple IIe and Apple IIc.

Locating the card

The Pascal 1.1 firmware protocol is described in Chapter 6.

Locations \$Cs05, \$Cs07, \$Cs0B, and \$Cs0C (where s is the number of the slot where the SSC is installed) contain the identification bytes for the Super Serial Card. The identification byte's values are

\$Cs05	\$38
\$Cs07	\$18
\$Cs0B	\$01
\$Cs0C	\$31

Operating modes

The Super Serial Card has two main operating modes: printer mode and communications mode. There is nothing you can do from software to change from one mode to the other because they are set by the position of the jumper block.

Note to software developers: If you are writing software that depends on the SSC being in a given operating mode, make sure that your documentation tells the user to set up the SSC in the proper way.

In printer mode, the SSC is set to send data to a printer, local terminal, or other serial device. In communications mode, the SSC is set to operate with a modem. From communications mode, the SSC can enter a special mode called *terminal mode*. In terminal mode the Apple IIe acts like an unintelligent terminal.

Operating commands

For each of the operating modes, you can control many aspects of data transmission such as baud rate, data format, and line feed generation.

Your program can change these aspects by sending control codes as commands to the card. All commands are preceded by a command character and followed by a carriage return character (\$0D).

The command character is usually Control-I in printer mode and Control-A in communications mode and terminal mode. In the command examples in the following sections, Control-I is used unless the command being described is available only in communications mode or terminal mode. A carriage return character is represented by its ASCII symbol, CR.

There are three types of command formats:

- ☐ A number, represented by n, followed by an uppercase letter with no space between the characters (for example, 4D to set data format 4).
- ☐ An uppercase letter by itself (for example, R to reset the SSC).
- ☐ An uppercase letter followed by a space and then either E to enable or D to disable a feature (for example, L D to disable automatic insertion of line feed characters).

The allowable range of n is given in each command description that follows

The choice of enable or disable is indicated with E/D. The underscore character (_) before the E/D in commands that allow enable/disable is to remind you that a space is required there.

The SSC checks only numbers and the first letters of commands and options. (All such letters must be uppercase.) Further letters, which you can add to assist your memory, have no effect on the SSC. For example, XOFF Enable is the same as X E. The SSC ignores invalid commands.

Important

The spaces in command examples are there for clarity; generally you will not use spaces in a command string. Where a space is required in a command string, an underscore (_) character will appear in the text as a reminder.

The command character

The normal command character is Control-I (ASCII \$09) in printer mode, or Control-A (ASCII \$01) in communications mode. If you want to change the command character from Control-I to Controlsomething else, send Control-I Control-something else. For example, to change the command character to Control-W, send Control-I Control-W. To change back, send Control-W Control-I. No return character is required after either of these commands.

Here is how to do this in BASIC and Pascal:

Applesoft BASIC:

PRINT CHR\$ (9); "new command character"

Pascal:

WRITELN (CHR(9), 'new command character');

You can send the command character itself through the SSC by sending it twice in a row: Control-I Control-I; no return character is required after this command. This special command allows you to transmit the command character without affecting the operation of the SSC, and without having to change to another command character and then back again later.

Baud rate, nB

You can use this command to override the physical settings of switches SW1-1 through SW1-4 on the SSC. For example, to change the baud rate to 135, send Control-I 4B CR to the SSC.

Table H-1 Baud rate selections

n	SSC baud rate	n	SSC baud rate	
0	Use SW1-1 to SW1-4	8	1200	
1	50	9	1800	
2	75	10	2400	
3	109.92 (110)	11	3600	
4	134.58 (135)	12	4800	
5	150	13	7200	
6	300	14	9600	
7	600	15	19200	

8 1 7 1 6 1 5 1 8 2 * 2 7

Stop bits

Data format selections Data bits

Table H-2

n

0

1

2

3

4

5

6

7

6

2

Table H-3 Parity selections

n Parity to use		
0,2,4, or 6	None (default value)	
1	Odd parity (odd total number of ones)	
3	Even parity (even total number of ones)	
5	MARK parity (parity bit always 1)	
7	SPACE parity (parity bit always 0)	

Data format, nD

You can override the settings of switch SW2-1 with this command. The table below shows how many data and stop bits correspond to each value of n. For example, Control-I 2D CR makes the SSC transmit each character in the form one start bit (always transmitted), six data bits, and one stop bit.

Parity, nP

You can use this command to set the parity that you want to use for data transmission and reception. There are five parity options available, described in Table H-3.

For example, the command string Control-I 1P CR makes the SSC transmit and check for odd parity. Odd parity means that the high bit of every character is 0 if there is an odd number of 1 bits in that character, or 1 if there is an even number of 1 bits in the character, making the total number of 1 bits in the character always odd. This is an easy (but not foolproof) way to check data for transmission errors. Parity errors are recorded in a status byte.

^{* 1} with parity options 4 through 7

^{† 11/2} with parity options 0 through 3

Table H-4 Time delay selections

n	Time delay
0	None
1	32 milliseconds
2	250 milliseconds
	(1/4 second)
3	2 seconds

Set time delay, nC, nL, and nF

Some printers can't keep up with the Apple IIe when they are doing certain operations. You may need to change default settings on the SSC to give a printer the time it needs.

The nC command overrides the setting of switch SW2-2 on the SSC. That switch provides two choices: either no delay or a 250 millisecond delay after the SSC sends a carriage return character.

The nL command allows time after a line feed character for a printer platen to turn so that the paper is vertically positioned to receive the next line.

The nF command allows time after a form feed character for the printer platen to move the paper form to the top of the next page (typically a longer time than a line feed).

Consult the user manual for a given printer to find out how much time it takes to move its print head and platen so that you can determine an appropriate set of values for these three delays. The idea is to have at least enough time for the printer parts to move the required distance, but not so much time that overall printing speed is slowed down drastically. Many printers require no delays because they have a buffer built in to keep accepting characters even while they are doing form feeds and so on.

A typical setup for a *very* slow printer would be Control-I 2C CR, Control-I 2L CR, Control-I 3F CR; that is, the SSC waits 250 milliseconds after transmitting carriage returns, 250 milliseconds after transmitting line feeds, and 2 seconds after transmitting form feed characters.

Echo characters to the screen, E_E/D

For the Apple IIe, as for most computers, displaying (echoing) a character on the video screen during communications is a separate step from receiving it from the keyboard, though we tend to think if these as one step, as on a typewriter. For example, if you send Control-A E_D CR, the SSC does not forward incoming characters to the Apple IIe screen. This can be used to hide someone's password entered at a terminal, or to avoid double display of characters.

This command is used in communications mode only.

Automatic carriage return, C

Sending Control-I C CR to the SSC causes it to generate a carriage return character (ASCII CR) whenever the column count exceeds the current printer line-width limit. This command is used in printer mode only.

Important

Once this option is on, only clearing the high-order bit at location \$578+s (where s is the slot the SSC is in) can turn this option back off. This option is normally off.

Automatic line feed, L_E/D

You can use this command to have the SSC automatically generate and transmit a line feed character after each carriage return character. This overides the setting of switch SW2-5. For example, send Control-I L_E CR to your printer to print listings or double-spaced manuscripts for editing.

Mask line feed in, M_E/D

If you send Control-I M_E CR to the SSC, it will ignore any incoming line feed character that immediately follows a carriage return character.

Reset card, R

Sending Control-I R CR to the SSC has the same effect as sending a PR#0 and an IN#0 to a BASIC program and then resetting the SSC. This command cancels all previous commands to the SSC and puts the physical switch settings back into force.

Specify screen slot, S

In communications mode, you can specify the slot number of the device where you want text or listings displayed with this command. (Normally this is slot 0, the Apple IIe video screen.) This allows chaining of the SSC to another card slot, such as an 80-column text card. For the firmware in the SSC to pass on information to the firmware in the other card, the other card must have an output entry point within its \$Cs00 space; this is the case for all currently available 80-column cards for the Apple IIe.

For example, let's say you have the SSC in slot 2 with a remote terminal connected to it, and an 80-column card in slot 3. Send Control-A 3S CR to cause the data from the remote terminal to be chained through the card in slot 3, so that it is displayed on the Apple IIe in 80-column format. (Not available in Pascal.)

Translate lowercase characters, nT

The Apple IIe Monitor translates all incoming lowercase characters into uppercase ones before sending them to the video screen or to a BASIC program. The nT command has four options, which are shown in Table H-5.

Table H-5
Lowercase character display options

n Action

- O Change all lowercase characters to uppercase ones before passing them to a BASIC program or to the video screen. This is the way the Apple IIe monitor handles lowercase.
- Pass along all lowercase characters unchanged. The appearance of the lowercase characters on the Apple II screen is undefined (garbage).
- 2 Display lowercase characters as uppercase inverse characters (that is, as black characters on a white background).
- 3 Pass lowercase characters to programs unchanged, but display lowercase as uppercase, and uppercase as inverse uppercase (that is, as black characters on a white background).

Suppress control characters, Z

If you issue the Z command described here, all further commands are ignored; this is useful if the data you are transmitting, such as graphics data, contains bit patterns that the SSC can mistake for control characters.

Sending Control-I Z CR to the SSC prevents it from recognizing any further control characters (and hence commands) whether coming from the keyboard or contained in a stream of characters sent to the SSC.

Important

The only way to reinstate command recognition after the Z command is to either reinitialize the SSC, or clear the high-order bit at location \$5F8+s (where s is the number of the slot in which the SSC is installed).

Find keyboard, F_E/D

You can use this command to make the SSC ignore keyboard input.

For example, you can include Control-I F_D CR in a program, followed by a routine that retrieves data through the SSC, followed by Control-I F_E CR to turn the keyboard back on.

XOFF recognition, X_E/D

Sending Control-I X_E CR to the SSC causes it to look for any XOFF (\$13) character coming from a device attached to the SSC, and to respond to it by halting transmission of characters until the SSC receives an XON (\$11) from the device, signaling the SCC to continue transmission. In printer mode, this function is normally turned off.

Important

In printer mode, full-duplex communication may not work with XOFF recognition turned on, so be careful.

Tab in BASIC, T E/D

In printer mode only, if you send Control-I T_E CR to the SSC, the BASIC horizontal position counter is left equal to the column count. All tabs work, including back-tabs. Tabs beyond column 40 require a POKE to location 36. Commas only work as far as column 40, and BASIC programs will be listed in 40-column format.

Note that this use of tabbing is specific to the SSC—it doesn't go through the 80-column firmware.

Terminal mode

From communications mode, the SSC can enter terminal mode and make the Apple IIe act like an unintelligent terminal. This is useful for connecting the Apple IIe to a computer timesharing service, or for conversing with another Apple II.

Entering terminal mode, T

Send Control-A T CR to enter terminal mode. This causes the Apple IIe to function as a full-duplex unintelligent terminal. You can use this command together with the Echo command to simulate the half-duplex terminal mode of the old Apple II Communications Card.

♦ By the way: If you enter terminal mode and don't see what you type echoed on the Apple video screen, probably the modem link has not yet been established, or you need to use the Echo Enable command (Control-A E_E CR).

Transmitting a break, B

Sending Control-A B CR causes the SSC to transmit a 233-millisecond break signal, recognized by most time-sharing systems as a signoff.

Special characters, S_E/D

If you send Control-A S_D CR, the SSC will treat the Escape key like any other key.

Quitting terminal mode, Q

Send Control-A Q CR to the SSC to exit from terminal mode.

SSC error codes

The SSC uses I/O scratchpad address \$678+s (s is the number of the slot that the SSC is in) to record status after a read operation. The firmware calls this byte STSBYTE. Table H-6 lists the bit definitions of this byte.

Table H-6
STSBYTE bit definitions

Bit	"1" means	"0" means
0	Parity error occurred	No parity error occurred
1	Framing error occurred	No framing error occurred
2	Overrun occurred	No overrun occurred
3	Carrier lost	Carrier present
5	Error occurred	No error occurred

The terms parity, framing error, and overrun are defined in the glossary.

Bits 0, 1, and 2 are the same as the corresponding three bits of the ACIA Status Register of the SSC. Bit 3 indicates whether or not the Data Carrier Detect (DCD) signal went false at any time during the receive operation. Bit 5 is set if any of the other bits are set, as an overall error indicator. If bit 5 is the only bit set, an unrecognized command was detected. If all bits are 0, no error occurred.

These error codes begin with the number 32 to avoid conflicting with previously defined and documented system error codes.

In BASIC, you can check this status byte via a PEEK \$678+s (s is the SSC slot), and reset it with a POKE command at the same location.

In Pascal, the IORESULT function returns the error code value.

By the way: Any character—including the carriage return at the end of a WRITELN statement—will cause posting of a new value in IORESULT.

Table H-7 shows the possible combinations of error bits corresponding to these decimal error codes.

Table H-7
Error codes and bits

Error code*	Carrier lost	Overrun	Framing error	Parity erro	
0		No	o error		
32		Illegal command			
33	No	No	No	Yes	
34	No	No	Yes	No	
35	No	No	Yes	Yes	
36	No	Yes	No	No	
37	No	Yes	No	Yes	
38	No	Yes	Yes	No	
39	No	Yes	Yes	Yes	
40	Yes	No	No	No	
41	Yes	No	No	Yes	
42	Yes	No	Yes	No	
43	Yes	No	Yes	Yes	
44	Yes	Yes	No	No	
45	Yes	Yes	No	Yes	
46	Yes	Yes	Yes	No	
47	Yes	Yes	Yes	Yes	

^{*} Result of PEEK \$678+s in BASIC or IORESULT in Pascal

The ACIA

The Asynchronous Communication Interface Adapter (ACIA) chip is the heart of the Super Serial Card. It takes the 1.8432 MHz signal generated by the crystal oscillator on the SSC and divides it down to one of the 15 baud rates that it supports. The ACIA also handles all incoming and outgoing signals of the RS232-C serial protocol that the ACIA supports.

The ACIA registers control hardware handshaking and select the baud rate, data format, and parity. The ACIA also performs parallel to serial and serial to parallel data conversion, and buffers data transfers.

SSC firmware memory use

Table H-8 is an overall map of the locations that the SSC uses, both in the Apple IIe and in the SSC's own firmware address space.

Table H-8 Memory use map

Address	Name of area	Contents
\$0000-\$00FF	Page zero	Monitor pointers, I/O hooks, and temporary storage.
\$04xx-\$07xx	Peripheral slot RAM	Locations (8 per slot) in Apple IIe pages \$04 through \$07. SSC uses all 8 of them.
\$C0(8+s)0-\$C0(8+s)F	Peripheral card I/O space	Locations (16 per slot) for general I/O. SSC uses 6 bytes.
\$Cs00-\$CsFF	Peripheral card ROM space	One 256-byte page reserved for card in slot s; first page of SSC firmware.
\$C800-\$CFFF	Expansion ROM	Eight 256-byte pages reserved for 2K ROM or PROM. SSC maps its firmware onto \$C800-\$CEFF.

Zero-page locations

Table H-9 Zero-page locations used by the SSC

Address	Name	Description
\$24*	СН	Monitor pointer to current position
4- 1	011	of cursor on screen
\$26	SLOT16	Usually (slot x 16); that is, \$s0
\$27	CHARACTER	Input or output character
\$28*	BASL	Monitor pointer to current screen line
\$2A	ZPTMP1	Temporary storage (various uses)
\$2B	ZPTMP2	Temporary storage (various uses)
\$35	ZPTEMP	Temporary storage (various uses)
\$36*	CSWL	BASIC output hook (not for Pascal)
\$37*	CSWH	High byte of CSW
\$38*	KSWL	BASIC input hook (not for Pascal)
\$39*	KSWH	High byte of KSW
\$4E*	RNDL	Random number location, updated when looking for a keypress (not used when initialized by Pascal)

^{*} Not used when Pascal initializes SSC

Peripheral-card I/O space

There are 16 bytes of I/O space allocated to each slot in the Apple IIe. Each set begins at address \$C080 + (slot x 16); for example, if the SSC is in slot 3, its group of bytes extends from \$C0B0 to \$C0BF. Table H-10 interprets the six bytes the SSC uses.

Table H-10
Address register bits interpretation

Address	Register	Bits	Interpretation	
\$C081+s0	DIPSW1	0	SW1-6 is OFF when 1, ON when 0.	
	(SW1-x)	1	SW1-5 is OFF when 1, ON when 0.	
		4–7	Same as above for SW1-4 through SW1-1.	

Table H-10 (continued) Address register bits interpretation

Address	Reaister	Bits	Interpretation
\$C082+s0	DIPSW2	0	Clear To Send (CTS) is true when 0.
	(SW2-x)	1–3	Same as above for SW2-5 through SW2-3.
		5,7	Same as above for SW2-2 and SW-2-1.
\$C088+s0	TDREG	0–7	ACIA transmit register (write).
	RDREG	0-7	ACIA receive register (read).
\$C089+s0	STATUS		ACIA status/reset register.
		0 1	Parity error detected when 1. Framing error detected when 1.
		2	Overrun detected when 1.
		3	ACIA receive register full when 1.
		4	ACIA transmit register empty when 1.
		5	Data Carrier Detect (DCD) true when 0.
		6	Data Set Ready (DSR) true when 0.
		7	Interrupt (IRQ) has occurred when 1.
\$C08A+s0	COMMAND		ACIA command register
		0	(read/write). Data Terminal Ready (DTR): enable (1) or disable (0)
		1	receiver and all interrupts. When 1, allow STATUS bit 3 to
		2–3	cause interrupt. Control transmit interrupt, Request To Send (RTS) level,
		4	and transmitter. When 0, normal mode for
			receiver; when 1, echo mode (but bits 2 and 3 must be 0).
		5–7	Control parity.

Table H-10 (continued)
Address register bits interpretation

Address	Register	Bits	Interpretation
\$C08B+s0	CONTROL	-	ACIA control register (read/write).
		0–3	Baud rate: \$00 = 16 times external clock; see Table H-1.
		4	When 1, use baud rate generator; when 0, use external clock (not supported).
		5–6	Number of data bits: 8 (bit 5 and 6 = 0) 7 (5 = 1, 6 = 0), 6 (5 = 0, 6 = 1) or 5 (bit 5 and 6 both = 1).
		7	Number of stop bits: 1 if bit 7= 0; if bit 7 = 1, then 1-1/2 (with 5 data bits, no parity), 1 (8 data plus parity), or 2

Scratchpad RAM locations

The SSC uses the scratchpad RAM locations listed in Table H-11.

Table H-11 Scratchpad RAM locations used by the SSC

Address	Field name	Bit	Interpretation
\$0478+s	DELAYFLG	0-1 2-3 4-5 6-7	Form feed delay selection. Line feed delay selection. Carriage return delay selection. Translate option.
\$04F8+s	PARAMETE	0-7	Accumulator for firmware's command processor.
\$0578+s	STATEFLG	0-2 3-5 6 7	Command mode when not 0. Slot to chain to (communications mode). Set to 1 after lowercase input character. Terminal mode when 1 (communications mode). Enable CR generation when 1 (printer mode).

Table H-11 (continued) Scratchpad RAM locations used by the SSC

Address	Field name	Bit	Interpretation
\$05F8+s	CMDBYTE	0–6 7	Printer mode default is Control-I; communications mode default is Control-A. Set to 1 to Zap control commands.
\$0678+s	STSBYTE		Status and IORESULT byte.
\$06F8+s	CHNBYTE	0–2 3–7	Current screen slot (communication mode); when slot = 0, chaining is enabled. \$Cs00 space entry point (communications mode).
	PWDBYTE	0–7	Current printer width; for listing compensation, auto-CR (printer mode).
\$0778+s	BUFBYTE	0–6 7	One-byte input buffer (communications mode); used in conjunction with XOFF recognition. Set to 1 when buffer full (communications mode).
	COLBYTE	0–7	Current-column counter for tabbing and so forth (printer mode).
\$07F8+s	MISCFLG	0	Generate line feed after CR when 1.
		1 2 3 4 5 6	Printer mode when 0; communications mode when 1. Keyboard input enabled when 1. Control-S (XOFF), Control-R, and Control-T input checking when 1. Pascal operating system when 1; BASIC when 0 Discard line feed input when 1. Enable lowercase and special-character generation when 1
		6 7	(communications mode). Tabbing option on when 1 (printer mode). Echo output to Apple IIe screen when 1.

Appendix |

International Versions

International versions of the Apple IIe have two sets of keyboard characters their users may choose between. One set, known as the USA character set, is the standard Apple IIe character set described in Chapter 2 of this manual. The other set, known as the alternate character set, is a special set of characters designed to meet the needs of various international users. This appendix describes the layout of the various international keyboards when the alternate character set has been selected. A layout drawing and a table of character codes generated by the keyboard are provided for each version described in this appendix. You should note, however, that only the ASCII codes that are different from those in the USA set are defined in the tables; where a keyboard does not generate any different codes, no table is provided. Figure I-1 is a schematic diagram of the international circuit board.

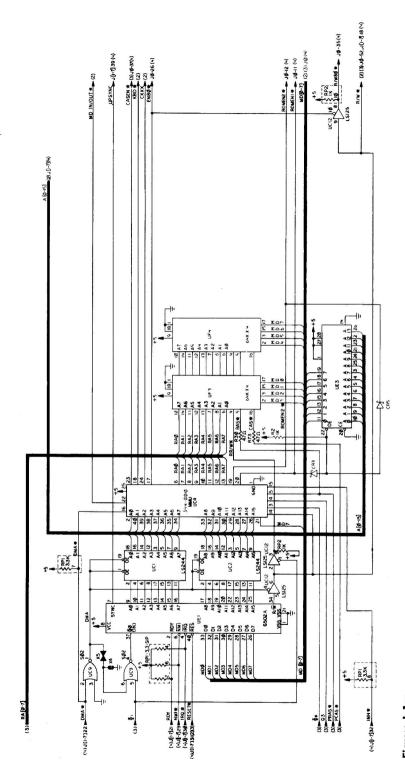


Figure 1-1a International IIe schematic diagram, part 1

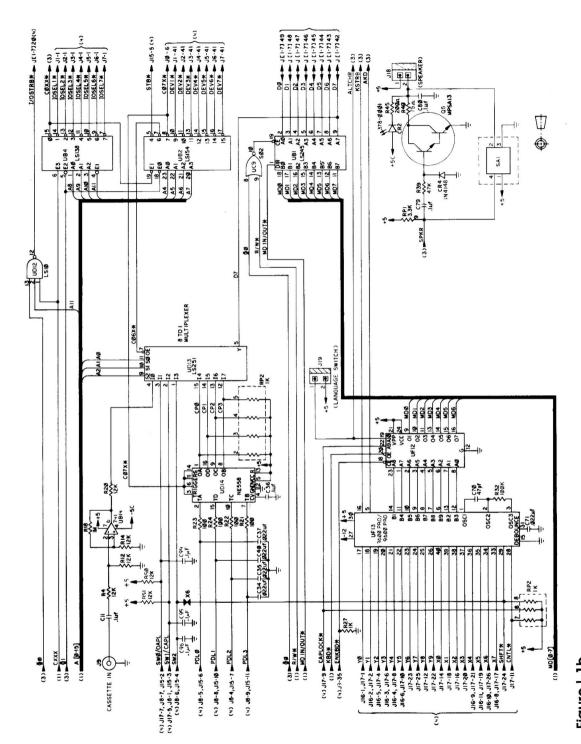


Figure I-1b International Ile schematic diagram, part 2

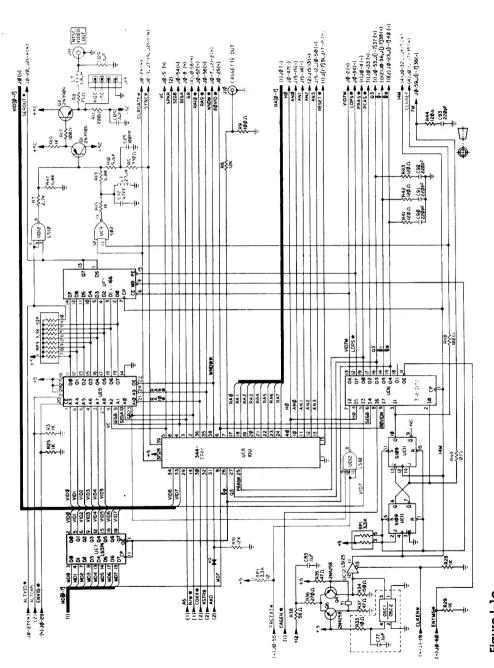


Figure 1-1c international lie schematic diagram, part 3

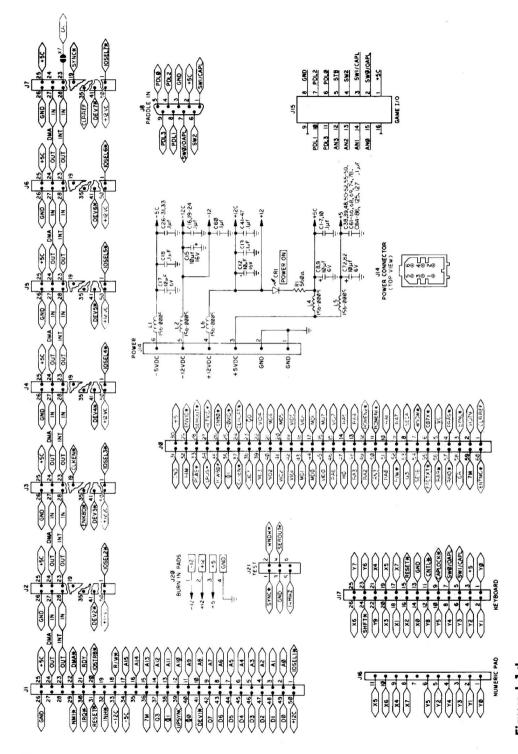


Figure I-1d International Ile schematic diagram, part 4

The English keyboard

Figure I-2 shows the English keyboard layout. The English character set generates only one character that is different from the USA character set: the & character replaces the # character.

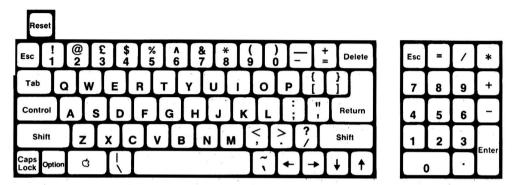


Figure 1-2 English keyboard

Table I-1 English keyboard ASCII codes

	Nor	mal	Cor	ntrol	Sh	ift	Bot	h
Key	Code	Char	Code	Char	Code	Char	Code	Char
3£	33	3	33	3	23	£	23	#

The French keyboard

The French keyboard layout is shown in Figure I-3. Table I-2 lists the ASCII codes for the French character set that are different from those in the USA character set.

On the French keyboard, the Caps Lock key affects all keys. Pressing the Shift key while the Caps Lock key is engaged "unshifts" to lowercase, but only so long as the Shift key is held down.

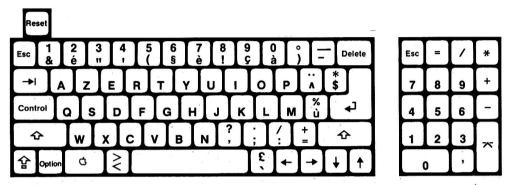


Figure 1-3 French keyboard

Table I-2
French keyboard ASCII codes

	Nore	mal	Cor	ntrol	Sh	ift	Во	th
Key	Code	Char	Code	Char	Code	Char	Code	Char
&1	26	&	26	&	31	1	31	1
é2	7B	е	7B	e	32	2	32	2
"3	22	**	22	Ħ	33	3	33	3
'4	27	•	27	•	34	4	34	4
(5	28	(28	(35	5	35	5
\$ 6	5D	S	1D	GS	36	6	1D	GS
è7	7D	è	7D	è	37	7	37	7
!8	21	!	21	!	38	8	38	8
ç9	5C	ç	1C	FS	39	9	39	FS
à0	40	à	00	NUL	30	0	00	NUL
)°	29)	1B	ESC	5B	٥	1B	ESC
۸~	5E	^	1E	RS	7E	~	1E	RS
\$*	24	\$	24	\$	2A		2A	*
ù%	7C	ù	7C	\$ ù	25	%	25	%
£	60	`	60	•	23	£	23	£
,?	2C	,	2C	,	3F	?	3F	?
;.	3B	;	3B	•	2E		2E	
:/	3A	:	3A	:	2 F	/	2F	/

The Canadian keyboard

The Canadian keyboard layout is shown in Figure I-4. Table I-3 lists the ASCII codes for the Canadian character set that are different from those in the USA character set.



Figure 1-4 Canadian keyboard

Table I-3 Canadian keyboard ASCII codes

	Nor	mal	Cor	ntrol	Sh	ift	Во	th
Key	Code	Char	Code	Char	Code	Char	Code	Char
2°	32	2	00	NUL	5B	o	00	NUL
3£	33	3	33	3	23	£	23	£
6 §	36	6	1E	RS	5D	S	1E	RS
àé	40	à	7F	DEL	7D	é	7 F	DEL
ù^	7C	ù	7C	ù	5E	٨	5E	٨
èç	7B	è	1C	FS	5C	ç	1C	FS
"/	7E	**	7E	H	2F	/	2F	/

The German keyboard

The German keyboard layout is shown in Figure I-5. Table I-4 lists the ASCII codes for the German character set that are different from those in the USA character set.



Figure 1-5 German keyboard

Table I-4 German keyboard ASCII codes

	Nori	mal	Cor	ntrol	Sh	nift	Во	th
Key	Code	Char	Code	Char	Code	Char	Code	Char
2°	32	2	32	2	22	•	22	٥
3§	33	3	00	NUL	40	S	00	NUL
6&	36	6	36	6	26	&x	26	&
7/	37	7	37	7	2F	/	2F	/
8(38	8	38	8	28	(28	(
9)	39	9	39	9	29)	29)
0=	30	0	30	0	3D	=	3D	=
ß?	7E	ß	7 E	ß	3F	?	3F	?
Ü	7D	Ü	1D	GS	5D	Ü	1D	GS
+*	2B	+	2B	+	2A	•	2A	*
Ö	7C	Ö	1C	FS	5C	Ö	1C	FS
Ä	7B	Ä	1B	ESC	5B	Ä	1B	ESC
#^	23	#	1E	RS	5E	~	1E	RS
<>	3C	<	3C	<	3E	>	3E	>
,;	2C	,	2C	,	3B	;	3B	;
.:	2E		2E		3A	:	3A	:

The Italian keyboard

The Italian keyboard layout is shown in Figure I-6. Table I-5 lists the ASCII codes for the Italian character set that are different from those in the USA character set.

On the Italian keyboard, the Caps Lock key affects all keys. Pressing the Shift key while the Caps Lock key is engaged "unshifts" to lowercase, but only so long as the Shift key is held down.



Figure 1-6 Italian keyboard

Table I-5 Italian keyboard ASCII codes

	Nor	mal	Cor	ntrol	Sh	ift	Bot	th
Key	Code	Char	Code	Char	Code	Char	Code	Chai
&1	26	&	26	&	31	1	31	1
"2	22	"	22	Ħ	32	2	32	2
'3	27	•	27	•	33	3	33	3
(4	28	(28	(34	4	34	4
ç5	5C	ç	1C	FS	35	5	1C	FS
è6	7D	é	7D	é	36	6	36	6
)7	29)	29)	37	7	37	7
£8	23	£	23	£	38	8	38	8
à9	7B	à	7B	à	39	9	39	9
é0	5D	é	1D	GS	30	0	1D	GS
ì۸	7E	ì	1E	RS	5E	٨	1E	RS
\$*	24	\$	24	\$	2A	•	2A	
ù%	60	ù	60	ù	25	%	25	%
§°	40	S	00	NUL	5B	0	1B	ESC
<>	3C	<	3C	<	3E	>	3E	>
,?	2C	,	2C	,	3F	?	3F	?
;.	3B	;	3B	;	2E		2E	
:/	3A	:	3A	:	2F	/	2F	/
ò!	7C	ò	7C	ò	21	1	21	1

The Western Spanish keyboard

The Western Spanish keyboard layout is shown in Figure I-7. Table I-6 lists the ASCII codes for the Spanish character set that are different from those in the USA character set.

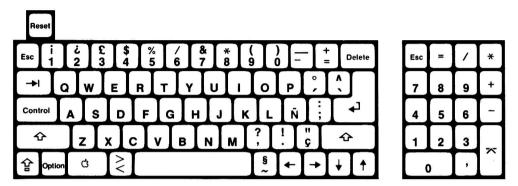


Figure 1-7 Western Spanish keyboard

Table 1-6 Western Spanish keyboard ASCII codes

	Nori	mal	Cor	ntrol	Sh	iff -	Во	th
Key	Code	Char	Code	Char	Code	Char	Code	Char
1;	31	1	31	1	5B	i	5B	ī
2¿	32	2	32	2	5D	ė	5D	į
3£	33	3	33	3	23	£	23	£
6/	36	6	36	6	2F	/	2F	/
-0	27	•	27		7B	•	7B	0
~§	7E	~	7F	DEL	40	S	7 F	DEL
Ñ	7C	ñ	1C	FS	5C	Ñ	1C	FS
,?	2C	•	2C		3F	?	3F	?
.1	2E		2E		21	!	21	!
ç"	7D	Ç	1D	GS	22	"	1D	GS
<>	3C	<	1E	RS	3E	>	1E	RS

The Swedish keyboard

The Swedish keyboard layout is shown in Figure I-8. Table I-7 lists the ASCII codes for the Swedish character set that are different from those in the USA character set.



Figure 1-8 Swedish keyboard

Table 1-7Swedish keyboard ASCII codes

	Non	mal	Cor	ntrol	Sh	ift	Во	th
Key	Code	Char	Code	Char	Code	Char	Code	Char
2"	22	11	32	2	22	"	32	2
6&	36	6	36	6	26	&x	26	&
7/	37	7	37	7	2F	/	2F	/
8(38	8	38	8	28	(28	(
0=	30	0	30	0	3D	=	3D	=
+?	2B	+	2B	+	3F	?	3F	?
^	27	,	27	-	60	•	60	`
åÅ	7D	å	1D	GS	5D	Å	1D	GS
~^	7E	~	1E	RS	5E	^	1E	RS
@*	40	@	00	NUL	2A	*	00	NUL
öÖ	7C	Ö	1C	FS	5C	Ö	1C	FS
āÄ	7B	ā	1B	ESC	5B	Ä	1B	ESC
,;	2C	,	2C	,	3B	;	3B	;
.:	2E		2E		3A	:	3A	:
	2D	_	1F	US	5F	_	1F	US
<>	3C	<	3C	<	3E	>	3E	>

Certification

In countries where it is applicable, the following product safety certification supplements the USA FCC Class B notice printed on the inside front cover of this manual.

Product safety

This product is designed to meet the requirements of IEC 380, Safety of Electrically Energized Office Machines.

Grounding notice

This product is intended to be electrically grounded. This product is equipped with a power supply plug having a third prong called a ground prong. This plug will only fit into a grounding-type AC outlet. This is a safety feature.

If you are unable to insert the power supply plug into the outlet, contact a licensed electrician to replace the outlet and, if necessary, install a ground.

Do not defeat the purpose of the grounding-type plug.

Power supply specifications

The basic specifications for the international version of the Apple IIe are provided in Table I-8.

Table 1-8 International power supply specifications

Line voltage 170 to 270 VAC, 50Hz

Max. input power 70W consumption

Supply voltages +12 VDC @ 2.5 A

-12 VDC @ .25 A +5 VDC @ 2.5 A -5 VDC @ .25 A

Appendix J

Monitor Firmware Listing

3 ;>127 if main RAM read enabled	1717		7017.	1717	1214:	9 :>127 if not vertical blanking	7617.			Olf>127 if alt char set switched in		F :>12/ if 80 column video enabled	Todagle enesker	_	switches in text page		switches in text page		F :annunciator 3			2 ;closed-apple key		C I I OI I DESCRIPTION	••	B ; swap in LC bank 1			••		ar 100 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	BI FRVEXSLON SOU FROMS+3383 ; FR ROM ID	F8ORG+\$51B ;normal input	F80RG+\$5F0 :normal output						;used for doing PR#	sed for doing PB#				serolling window left	The second second	scrolling window width	scrolling window top	[tmottod wobain partions.	יפרוסדווופ אדוומסא ספרסייידי	cursor norizontal	;cursor vertical	:GBASL,GBASH	nothing to current line of text			; pointer used for scroll					to income and dispersion.	tengen tor mnemonics		.>197=normal /197=ingeneral	esiacii (1717, 1817)	theed by monicor upsuit	:input buffer index for mini	THE OUT THE THEFT TO MITH	:for restoring Y	
U \$C013	•				1 \$C018				2102¢ 0	ALTCHARSET FOIL SCOLE			11 80030		On \$0054	DI COOLE			SCOSE			u \$c062				U \$C08B			59 * MONITOR EQUATES:		.000	FOU FROM					- CO	POOR		0 n	1 1	10000	101	5 \$20	_		_	-	-		-	-	2	2		U BASL+I		U BAS2L+1			G \$2F			2	-	٠.	-	-		-	
RDRAMRD EQU	TOUR DOGS	PDATTZP FOII	TOTA MORCOGA	DEUM EU	RDSUCOL EQU	RDVBLBAR EOU	DOTTON TOTAL	יייי דעיי	RDPAGEZ EQU	HARSET		RDSOVID EQU	TOT	2	TXTPAGE1 EQU	TOG CASTATATO	CAUCE C		AN3 EOU			NI EQU				LCBANK1 EQU			ONITOR		. moroun	EKSTON	IN EQU	L1 EOU			2010000	ENOT MOE		0 EQU			20	ORG	TET DS		MUDMDI'H DS	TOP DS			Sa	DS	DS					2H EOU			ORG					20 20		V DS			
37 RDR						43 RDV	A.A. DD.T.		45 RDP	46 AT.T		4/ RD8	dads 87		TXI 65	EVE OR	141	51 CLRANZ	52 CLRAN3		23 BUING	54 BUTNI		TON CO		57 LCB	* 85	. 00	29 * M	* 09	200	61 F8V	62 KEYIN	63 COUT1	64 MONZ	* 59	1	7	* /9	020T 89	69 1.001	200	2 :	7.1	72 WNDIET	1		74 WNDTOP	75 UNDRIN			77 CV	78	79 RAST	000		81 BAS2L	82 BAS2H	+ 00	83.	84	DE TENOTE	O) PEN	98	STAWFIC	ANT /O	88 PRUMPI	89 YSAV	100	90 SAVYI	
C013	100	6016	2100	1100	C018	6100	4100	2100	2102	COLE		COIF	0030	200	C054	3000	con	COSD	COSP	1700	1900	C062	1802	1000	5000	C08B					2000	FBB3	FD1B	PDFO	PP69					0000	1000	-		0020	1000	1000	0001	1000	1000	1000	0001	1000	0002	0000	2000	6700	0005	002B			002F	1000	1000	0002	1000	1000	1000	000	1000	0001	
:0000	.0000	.0000	. 0000	:0000	:0000	:0000	.0000	.0000	:0000	0000		:0000	.0000	.0000	:0000	.0000	.0000	:0000	:0000	.0000	0000	:0000	.0000	.0000	:0000	:0000	.0000	.0000	:0000	0000		:0000	:0000	:0000	.0000	.0000	.0000	.0000	:0000	:0000	.0000	. 0000	.0000	0020:	.0000		0021:	0022:	0003.		. 4700	0025:	0026:	0028	0050	002A:	002A:	002C:	.0000	0070	002F:	.4000	0021:	0030:	0033	0032:	0033;	0034:		0035:	_
0000 1 TEST EQU 0 :REAL VERSION		2 LIST ON ; DO LISTING AND SYMBOL TABLES	NO GCE	4 IROTEST EQU	00	6 PROBG POIL \$1800		CIORG EQU	8 C30RG EQU \$2300		COURCE	10 ELSE	20000	11 FBURG EQU	C100 12 C10RG EOU SC100		C30RC EQU	14 C80RG	1.5	1177	16 MSB ON	17 INCLUDE ROHATES	电影电影电影电影电影电影电影电影电影电影电影电影电影电影电影电影电影	+ 6	× 2	3 * Apple //e Video Firmware	•		5 * RICK AURICCHIO 08/81	6 4 PERDNING DUILITAMS 1984		×	8 * (C) 1981.1984 APPLE COMPUTER INC.	* ALL RICHTS	*			17 *	0006 13 GOODFB EQU 6 ;F8 ROM VERSION	* 71	15 * HADNIADE POSTADE.	TUNDANDE :	× 97	COOO 17 KBD EOU SCOOO :Read keyboard	OCCUPATION TO TO BE TO BE	ום הדעם חרות בתם שרתתם	C001 19 SET80COL EQU \$C001 ; Enable 80 column store	20 RDMAINRAM FOIL SCOOP	COOOS HOU PARAMETER	ZI KUCAKUKAM EQU SCOUS	22 WRMAINRAM EOU \$C004	23 WRCARDRAM EOU \$C005	SETSTOTCXBOM FOIL SCOOL	SECULIARIZABILI COOL	SEITNICARUM EUU SCOO!	26 SETSTDZP EQU \$C008		28 SETTUTCREM FOIL SCOOL	SELLINICARON EQU SCOOK	29 SETSLOTC3ROM	30 CLRSOVID FOU \$COOC	ממשט המיים מיים מיים מיים	31 SETSUVID EQU \$COOD	COOF 32 CLRALTCHAR EOU SCOOE : Normal Apple II char set	toood not delicate to to	33 SETALICHAR EQU SCOOF	CO10 34 KBDSTRB EQU \$CO10 ;Clear keyboard strobe	35 DAI CRAY POIL SCOIL	35 KULCBNKZ EQU \$CUII	CO12 36 RDLCRAM EOU SCO12 :>127 if LC is read enabled	71000 000 10000000000000000000000000000

;hook for output routine		; hook for input routine			; Monitor temps for MOVE				; A3 NOT USED			machine state on breaks		;random number seed			2 9 9 mg 4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	input burier	rermanent data in screennoies	Note: these screenholes are only used by	the 80 column firmware if an 80 column card		If the 80 column card is not	trashed on RESET.		success of these routines rely on the	fact that if 80 column store is on (as it	normally is during 80 column operation), that	itched in. Do not call the	video page 2 is switched in!!		:=\$Cn ;n=slot using \$C800	TAST CH used by widen firmmare	video firmware operating mode	;80 column CH	;80 column CV	;character to be printed/read	;GOTOXY X-coord (pascal only)		tast past (pascal only)		; last BASH (pascal only)			active	active			Print control characters	print ctrl chars.
2	CSWL+1	2	KSWL+1	\$30	2	A11.+1	2	A2L+1	2	2	A4L+1	_	\$4E	2	RNDL+1		0000	2500	gara in	Screen	in firm	d or if	Te. If	MOD WITH	1	s of the	if 80 cc	s during	l is swi	ware if		\$7F8	547843	S4F8+3	\$578+3	\$5F8+3	\$678+3	\$6F8+3	\$778+3	21/0+3	\$7F8+3	\$7 F8+3	0170		BASIC				Print	Don't
DS	EQU	DS	EQU	ORG	DS	EQU	DS	EQU	DS	DS	_		ORG	DS	EOU	DEND	1104	בלה	anenc	: thes	80 001	pterte	the firmware.	on the	, , ,	sacces	that	ally i	page	video firmware		EQU	FOIL	FOU	EQU	EOU	EQU					н Еди	2007	C HOIDE	0	1	0-			- ·····
CSWL	CSWH	KSML	KSWH		AIL	AIH	A2L	A2H		A4L	A4H	MACSTAT		RNDL	RNDH		* 0	100	* Ferm	* Nore	* + +	* 1s d	* + 10	*	*	* The	* fact	* norm	* text	* vide	*	MSLOT	OTPCH	MODE	OURCH	OURCV	CHAR	XCOORD	TEMPI	ULDBASE	TEMP2	OLDBASH	* 0 0 0 1 0	Tewa *	*	* 1	* 0.	* -1:	* *	:
91	92	93	96	95	96	97	86	66	100	101	102	103	104	105	106	107	108	6		112	113	114	115	1 1	117	118	119	120	121	122	123	124	126	127	128	129	130	131	132	133	134	135	136	138	139	140	141	142	143	144
0005	0037	0005	0039	0030	0000	003D	0005	003F	0005	0000	0043	1000	004E	0005	004F		0000	0070														07F8	0.678	04FB	0578	OSFB	067B	06FB	0778	9//0	OVEB	07 FB								
0036:	0038:	0038:	003A:	003C:	003C:	003E:	003E:	:0500	:0700	0042:	: 4400	: 7700	004E:	004E:	00200	:0000	:0000	:0000	.0000	0000	0000	0000	0000	.0000	. 0000	0000	:0000	:0000	:0000	:0000	:0000	:0000	.0000	.0000	:0000	:0000	:0000	:0000	:0000	:0000	:0000	:0000	:0000	.0000	0000	:0000	:0000	:0000	:0000	:0000

0 *	*	- Print control characte	* Don't print next ctrl char	0	- ·········	0		- Mouse text	*] - Mouse text active		EQU \$40	LZ EQU	EQU \$10	TL EQU	EQU	FQU	M.MOUSE EQU \$01	;	rascal mode bics		BASIC a	* l Pascal active	- *************************************	* ·I····· -	*		Cursor always	*l Cursor always off	- GOTOXY	- GOTOXY	· - Normal	- Inverse Vic	PASCAL 1.1	- PASCAL 1.0	- Mouse text	* = Mouse cext active	M DASCAT POLITICAL	FOII \$10 : Don't n	800 808	EQU \$04 ; PASCAL	M.PASI.0 EQU \$02 ;PASCAL 1.0 MODE	*	* F8 ROM entries	•	K EGU		EZ EQU	TSTROM EQU F8ORG+\$B7		NAME IS REFLIST.U	RETINCIPE FOIL *	2
145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	191	162	163	104	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	101	183	184	185	186	187	188	189	190	191	192	193	194	18	FILE	- ~	•
											0040	0020	0010	8000	0007	0005	0001																				0800	0010	8000	0004	0005				FA47	FC74	FC/A	F887	ECCL	OBJECT	0013	,
.0	:0	:0		:0	:0	:0	:0	0:	:0	:.		0:	0:	0:	:0	:0	:0					 C			0:	0:	0:	0:	:0	:0	:0		:0	:0						0:	.0	0:	.0	:0	:0	:0	:0	:.		NEXI		
0000	:0000	0000	:0000	0000	: 0000	:0000	:0000	0000	0000	0000	0000	:0000	:0000	0000	:0000	:0000	:0000	000	0000	0000	:0000	:0000	:0000	:0000	:0000	:0000	:0000	:0000	:0000	:0000	:0000	0000	:0000	:0000	:0000	0000	0000	0000	:0000	:0000	:0000	:0000	:0000	:0000	:0000	:0000	:0000	:0000	:0000	.00.00	10013	,

ADDRESS 1 \$FB ROM. 8 routines 1. om disabled This makes \$CPFF with the	ssary.	NETOLINFO TETTAL SCNOO ROM E trail SCNOO ROM NO column routine of spacched to a In all cases return wagh F.RETURN.	: ESC F IS CLR TO END OF PACE (carry set)
MINI EQU F80RG+\$6C5 ; RETURN ADDRESS MINI EQU F80RG+\$4F0 * BASIC FUNCTION HOOK: * \$6100 is called by the patched \$F8 ROM. * It provides an extension to \$F8 routines * that do not work in 80 columns. * Before jumping here, the \$F8 rom disabled * slot I/0 and enabled ROM I/0. This makes * the entire space from \$C100 - \$CFFF with * exception of the \$C300 page available. **	On exit slot I/O is restored if necessary INPUT: Y=FUNCTION AS FOLLOWS: 1 = KEYIN 2 = Fix escape char 3 = BASCALC 4 = VTAB or VTABZ 5 = HOWE 6 = SCROLL 7 = CLREOLL 8 = CLREOLC C = SETWIN D = MILI ASSEMbler D = MILI ASSEMbler D = MILI ASSEMbler D = MILI ASSEMBLE	E = set 4U columns on FRPO INFU Stack has PHP for status of internal SCNOO ROM Note: If 80 Vid is on and the MODE byte is valid, state call will be dispatched to an 80 column routine by 8.FUNGO. Otherwise it will be dispatched to a 40 column routine by 8.OLDFUNG. In all cases return to the Autostart ROM is done through F.RETURN. FUNC JMP DISPATCH ;figure out what to do	CH CV VTABZ X.CLREOLZ #\$00 WNDBTM CLEOP1
3 PUNCEXIT 4 MINI 5 * 6 * BASIC 7 * \$6100 9 * It pro 10 * that d 11 * 11 * 11 * Before 11 * Before 11 * Sefore 11 * The sefore 12 * The sefore 13 * The sefore 14 * The sefore 15 * The sefore 16 * The sefore 17 * The sefore 18 * The sefore 19 * The sefore 10 * The sefore 10 * The sefore 11 * The sefore 12 * The sefore 13 * The sefore 14 * The sefore 15 * The sefore 16 * The sefore 17 * The sefore 18 * The sefore 19 * The sefore 10 * The sefore 11 * The sefore 12 * The sefore 13 * The sefore 14 * The sefore 15 * The sefore 16 * The sefore 16 * The sefore 17 * The sefore 18	* * * * * * * * * * * * * * * * * *	* * * * * * * * * * * *	P.CLREOP
PCC5		C2	CE C1 C107
		13	25 25 25 00 00 23 70
00000000000000000000000000000000000000		C100: C100: C100: C100: C100: C100: C100: C100: C100: C100:	C103:14 C105:145 C107:148 C108:20 C108:20 C108:20 C108:20 C108:20 C101:68 C111:69 C111:69

;=>always to VTABZ

F.HOME

C14D

; (ALWAYS TAKEN)

C107

CE

C168:			=======================================	*			
C168:			112	*	404	nd of 1the	Clear to end of line mains V = BAS21.
C16B:			113	*	Was	was set up by t	the SF8 ROM
C168:			114	*			
C16B:A4	2A		115		LZ LD	B.CLREOLZ LDY BASZL	:get Y
4C	90	23	116		JMP	X.GSEOLZ	clear to end of line
C170:			117	*			
C170:4C	14	သ	118		P JMP		CLEAR TO EOS
C173:4C	9	C2	119		D JAP		
C176:4C	80	C5	120			B. RESETX	MUST BE IN BFUNC PAGE
C179:4C	F2	C2	121	B. RDKEY	JMD	B. RDKEYX	
C17C:			122				
C17C:20	90	ဗ	123	B. HOME	JSR	X.FF	HOME & CLEAR
C17F:AD	7B	05	124		LDA	OURCH	
C182:85	54		125		STA	СН	;COPY CH/CV FOR CALLER
C184:8D	7B	90	126		STA	OLDCH	REMEMBER WHAT WE SET
C187:4C	PE	CD	127		JMP.	VTAB	;calc base & return
C18A:			128	*		9	
C18A:			129	*	ete P	Complete PR# or IN# call.	0
C18A:			130	*	#0 an	d it was ac	if PR#O and it was active (B.QUII). Complete call
C18A:			131	* 1f	activ	inactive (F.OUIT).	
C18A:			132				
C18A:		C18A	133	B.QUIT	EQU	*	
C18A:B4	8		134		LDY	roco,x	;was it PR#0/IN#0?
C18C:F0	OF	C19D	135		BEO	NOTO	;=>no, not slot 0
C18E:C0	18		136		CPY	#KEY IN	;was it IN#0?
C190:F0	OE	C1 A0	137		BEO	180	;=>yes, update high byte
C192:20	80	CD	138		JSR	DULT	quit the firmware
C195:B4	00		139	F.QUIT	LDY	roco, x	;get low byte into Y
C197:F0	04	C19D	140		BEO	NOTO	inot slot 0, firmware inactive
C199:A9	FD		141	F8HOOK	LDA	# <key in<="" td=""><td>set high byte to \$FD</td></key>	set high byte to \$FD
C19B:95	01		142		STA	LOC1, X	
C19D:B5	01		143	NOTO	LDA	LOC1, X	;restore accumulator
C19F:60			144		RTS		
C1 A0:			145				
C1 A0: A5	37		146	ISO	LDA	CSWH	;1s \$C3 in output hook?
C1 A2:C9	S		147		CMP	# <basicin< td=""><td></td></basicin<>	
C1 A4: D0	F3	C199	148		BNE	F8HOOK	;=>no, set to \$FD0C
C1A6:4C	32	C8	149		JMP	C3IN	;else set to \$C305, exit A=\$C3
C1 A9:			150				
C1 A9: A4	54		151	F. RDKEY		СН	;else do normal 40 cursor
CIAB: B1	28		152		LDA	(BASL),Y	grab the character
C1AD:48			153		PHA		
C1AE:29	3F		154		AND	#\$3F	set screen to flash
C1B0:09	40		155		ORA	075#	
C1 B2:91	28		156		STA	(BASL),Y	; and display it
C1B4:68			157	F. NOCUR	PLA		
C1B5:60			158		RTS		;return (A=char)
C186:			159				
C186:A8			160	F.BASCALC TAY	ILC TA	¥	;restore Y
	28		161		LDA	BASL	restore A
	BA	CA	162		JSR	BASCALC	
C1 BC: 90	4C	C20A	163		BCC	F. RETURN	;BASCALC always returns BCC!
C1 BE:			164	*			

;do mini-assembler;X=0. Set mode to 0, and counter;so not CR on new line

JSR MINI TXA STA YSAV RTS

;and go to open spaces

#\$8F DOMN

STA LDA AND TXA

C103:88
C103:88
C105:10 P5 C10
C105:10 70 C8
C105:10 70 C8
C105:10 F6
C105:10 F7
C105:10

make it a length; ;get old Y into A get old acc

#\$03 LENGTH BAS2L

print the character

; AND RETURN

175 BHI F.ETURN: RETURN : RETURN the 176 BHI P.RETURN : PAINT THE 178 BHI P.RETURN : AND RETURN 180 * Do displaced mnemonic stuff 181 *

B.ESCFIX2 F.RETURN ; RETURN: CHAR IN AC

DEY BPL BMI

;YES, TRANSLATE IT

167 B.ESCPIXI LDF #4-1
168 B.ESCFIXZ EQU*
170 BNB B.ESCFIXY : 1
171 LDA ESCUT,Y : Y
172 B.ESCPIXI 3 EQU *
174 BPL B.ESCFIXI

C18E: C18E 1
C18E:20 14 CE 1
C1C1:A0 03 C1C3 1
C1C3:D9 EE C2 1
C1C5:D9 AE C2 1
C1C5:D9 AE C3 C1C5
C1C5:D9 AE C3 C1C5
C1C5:D9 AE C3 C1C5
C1C6:D1 C1C5

IS IT? ->NAW

upshift lowercase; SCAN FOR A MATCH

JSR UPSHPT

165 B.ESCFIX EQU *

194 * Pick an 80 column character for the monitor 195 *

C201

C201

C1172:14 C1117:14 C11

CIF2

CIF1:60 CIF2: CIF2: CIF2:

C243: 273 * does an RTS, it returns to F.RETURN, which restores C243: 274 * the INTCXROM status and returns. 275 * the INTCXROM status and returns. 275 * pre-	277 *		280 * C244 281 F.TABLE EOU	282 DFB	285 DFB		286 DFB #>B.RESET-1;(9) 40/80 column reset 287 DFR #>F.CIREOP-1:(4) 40 column clear and of nage	288 DFB	289 DFB	290 DFB		293 DFB	C250: 0000 204 *	295 IABLEN EUU	8	298 DFB	-		302 DFB	303 DFB	C257:72 304 DFB #>B.SETWND-1;(18) 40/80 column VTAB	306 DFB	307 DFB #	C25B:D5 308 DFB #>MNNDX-1 ;(IC) calc mnemonic index	250	2C 1F CO 311	C267 312 BPL B.KEYINI	C261:2U /4 C8 313 JSR BIN ; get a keystroke	315 *	316 B.KEYINI TAY		C269148 318 PHA :restore A	320 PHA	81	C26D: 322 * C26D:68 323 NEW.CUR PLA ; Ret last cursor	324 CMP #\$FF	C2/U:FU U4 C2/6 325 BEQ NEW.CURI ;=/yes, get old char
C20A: 219 * EXIT. EITHER EXIT WITH OR WITHOUT C20A: 221 * ENABLING I/O SPACE.	C20A 223 F.RETURN EQU *	C210 225 F.RET2 BMI F.RET1	C20D:4C C5 FE 226 JMP FUNCEXIT ;=>EXIT & ENABLE I/O C210:4C C8 FE 227 F.RETI JMP FUNCEXIT+3 ;EXIT DISABLED			232 DISPATCH DEY	C214:30 BA C100 233 BMI F.80UT ; code 0 = 80 column output	A5 CIBE 235	236 DEY	9A C1B6 237	C21C:88 238 DEY DEY C21D:30 3 - FFFIN	240 DEY	30 E2 C204 241	7777. 270 # 270 # 270	C222: 244 * First push address of generic feturn foutine	C2	246 PHA	C225:A9 U9 24/ LDA #>F-RETURN-1	246 *		C228: 251 * valid for video firmware. Use old routines.	D FB 04	254 AND #M.PASCAL+	OD C23C 255 BNE GETFUNC		00 258	259 PHA	CSETUP	262 PLA	83	264 *	C23C: 265 * Now push address of routine	19 CI	268 PHA	C22F:B9 44 C2 269 LDA F.TABLE,Y		C243: 272 * RTS goes to routine on stack. When the routine

LDA #\$FF ;no, get checkerboard BNE NEW.CUR1 1.1.	BNE WAITERY BUE WAITERY BUE RANH EOR RANH F\$40 BNE NEW-CUR BPLA TA KBD FLA TA KBD TA KBD TA KBD TA KBD TO CH TA KBD TO CH TO C	S 2 . E
NEW.CUR1 NEW.CUR2 * * * Now less * until s * waltkey!	WALTKEY * WALTKEY * B.SETWN SKPSHFT SKPSHFT * * HANDL	* IF TI * (AL) * DEPI * AFTI
326 327 327 328 330 331 334 335 335 337	333 7 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3	371 372 373 374 375 376 377 378
. C278	C2 8 B C2 C2 D C2 C2 D C2 C4 C2 C2 O C2 C2 O C2 C2 O C2 C2 O C2 C2 O C2 O	88 8
FF 02 24 28 28 4E		
900888841	807870000 8841884000 0008700	8
C272:A9 C274:D0 C276:68 C277:48 C278:48 C278:44 C278:9:A4 C279:A4 C270: C270: C270: C270: C270: C270: C270:	C27 P: 10 C28 1: 45 C28 1: 45 C28 1: 45 C28 1: 45 C28 1: 45 C29 1: 68 C29 1: 68 C28 1: 68 C38 1:	C285:AD 5D C288:AD 5F C288: C288: C288: C288: C288: C288: C288:

| RPL NODIAGS :="> NODIAGS | SPL NOTIAGS | SPL NOTIAGE | S

C2D1

C2D1

C2D0:38 C2D1: C2D1:85 3D

C2D3:48

GORETNI ;=>ROM or no card, leave \$C3 slot SETINTG3ROM ;card, enable internal ROM SETSLOTC3ROM ; swap in slot 3 TSTROMCRD ; ROM or no card plugged in?

STA JSR BNE STA RTS

CZED C2E2

414 RESETRET EQU *

C2K2:
C2E2:
C2E3:

DFB \$88,\$95,\$8A,\$8B

C2EE:88 95 8A 8B

C2F2:

(BASL),Y RN80VID.

423 B. RDKEYX LDY CH

LDA (BASL),Y BIT RDBOVID. BMI GORETNI JMP INVERT

GORETNI

425 426 427

C2ED.

C2F2:A4 24 C2F4:B1 28 C2F6:2C 1F C0 C2F9:3O F2 C2E C2F8:4C 26 CE

;else display cursor, exit ;=>don't display cursor. get cursor position; and character; 80 columns?

overflow'

FAIL 2, C300

DS C3ORG-*,0 IFNE *-C3ORG

DS

428 429 430 431 432 433

0000

0002

C2FE: C2FE: C2FE: C300:

ZSPAREC2 EQU C30RG-*

C2C3 C2E2

C2014B.110 03 - C2 C20314D 14 C2 C20511 14 C2 C20511 C2051 C2051 C2051 C2051 C2051 C2051 C2051 C2051 B0 C20C143 00 C20C143 BF

; DUMPR INDEX		(AlL), Y ; GET A BYTE (A4L), Y ; MOVE IT		NXTAI	.	ı .i	#	H	1	= =	MOVELOOP :=>MORE TO MOVE		RESTORE ORIGINAL FLAGS:	COATE GAGIO. MAGNIANGE		=>IT WAS OFF	WRCARDRAM			GET ORIGI	MOVERET ;=>II WAS OFF	KLCAKUKAM *	v agomega.		; AND AC		ANNANANANANANANANANANANANANANANANANANA	TRANSFER CONTROL CROSSBANK	\$03ED=TRANSFER ADDR	RY SET=XFER TO CARD	CLR-XFER TO	CLR=USE STD	SET=USE ALT ZP/STK	SORE IN DEST BANK	NOTHING	ENTERED VIA JMP, NOT JSR			SAUR AC ON CHREENT STACK	The state of the s	COPY DESTINATION ADDRESS TO THE OTHER RANK SO THAT WE HAVE IT	THE POST OF THE POST OF
* 4		55	A4L	TXN	All	A2L	AIH	A2H	All	C01	MO		191	9		C03	WR	*	RD	2	2 8	₹.					VEFD	TRA	\$03	CARRY		VFLAG	anon.	80 S	NOT	ENT	*		*		INAT	
* MOVESTRT EQU LDY	* MOVELOOP EQU	LDA	INC	BNE	LDA	CMP	LDA	SBC	INC	BNE	BCC		FORE OF	4 80	PLA	BPL	STA	EQU	STA	PLA	BPL	SIA POII		TAY	PLA	RTS		TION		••		••		VOLATIE.	87		*****		FOU		OPY DESTINA	JEN Des
* MOVEST	* MOVEL(NXTAI						C01	*	* RES	k				C03				TAGANOM	MOVEN				* NAME	* FIIN	* INPUT	*	*	* .	*	* VOI.	* CALLS	* NOTE	****	*	XFER	*	* COP	5
162 163 164	165	167 168	169	170	172	173	174	175	176	177	179	180	181	182	184	185	186	187	188	189	26	191	103	194	195	196	197	2 6	200	201	202	203	204	206	207	208	209	210	211	213	214	417
C391	C393			C39D						C3AB	C393			9	3	C3B6	00	C386	9		C3BF	CO	1900																C3C3			
00		3C 42	42	02	3 5	3E	30	3F	30	37	E6			2		03	05		02	5	60																					
C391: C391: C391:A0	C393:	C393:B1 C395:91	C397:E6	C399:D0	C39D: A5	C39F:C5	C3A1:A5	C3A3:E5	C3A5:E6	C3A7:D0	C3AB:90	C3AD:	C3AD:	C3AD:	C3R0.68	C3B1:10	C383:8D	C3B6:	C3B6:8D	C3B9:68	C3BA:10	C3BC:8D	C387.68	C3C0: A8	C3C1:68	C3C2:60	6363:	6363	c3c3:	c3c3:	c3c3:	c3c3:	C3C3:		C3C3:	C3C3:	c3c3:	c3c3:	C3C3:	C3C4:	C3C4:	. 1000
																																										-

;look for a key		rorre fled dela-			*************************************		IRQ \$C800 PROTOCOL				* CALLS : NOTHING	*****		: SLOT NUMBER		kick out other \$C8 ROMs		*************************************				CE END	A4=DESTINATION START	1	CLK=CARD>MAIN			**************************************			; SAVE AC	; AND Y		SAVE STA	; MEMORY FLAGS	IKI		FOR CROSSBANK MOVE:			RAM ; SET FOR MAIN	; TO CARD	RT ;=>(ALWAYS TAKEN)		day don has. Well	; TO MAIN
KBD PNOTRDY		#3	2		****		Δ.	NONE	NONE	NOTHING	NOTHING	**	•	# <cn00< td=""><td>MSLOT</td><td>SCFFF</td><td></td><td>****</td><td>MOVE</td><td>PERFORM</td><td>A1=SOURCE</td><td>A2=SOURCE</td><td>A4=DEST</td><td>CARRY S</td><td></td><td>NONE</td><td>NOTHING</td><td>NOTHING TAXXXXX</td><td></td><td>*</td><td></td><td></td><td></td><td>RDRAMRD</td><td>Tai bee and</td><td>KUKANI</td><td></td><td>POR CRO</td><td></td><td>MOVEC2M</td><td>RDMA I NRAM</td><td>WRCARDRAM</td><td>MOVESTRT</td><td></td><td>LIDWA TANDAM</td><td>RDCARDRAM</td></cn00<>	MSLOT	SCFFF		****	MOVE	PERFORM	A1=SOURCE	A2=SOURCE	A4=DEST	CARRY S		NONE	NOTHING	NOTHING TAXXXXX		*				RDRAMRD	Tai bee and	KUKANI		POR CRO		MOVEC2M	RDMA I NRAM	WRCARDRAM	MOVESTRT		LIDWA TANDAM	RDCARDRAM
BIT	SEC	IDV		RTS	****	••	FUNCTION:		OUTPUT :	1176		*	103	Ě	STX	LDX	RTS	****		FUNCTION:		••					VOLALILE:	****		EQU	PHA	TYA	PHA	LDA	PHA	ייייי	LHA	PLACS		BCC	STA	STA	BCS		OT P	STA
		PCTFPP			****	* NAME	* FUNCT	* INPUT	* OUTPUT	A VOLA	* CALLS	*	00440	20190					* NAME	* FUNCI	* INPUT	*	* -	* +	K +	* OUTPUT	+ VOLAI	******	*	MOVE							*	* SET						*	MOVECZM	
108 109	110	112	114	115	116	117	118	119	120	171	771	123	125	126	127	128	129	130	131	132	133	134	135	136	13/	138	139	141	141	143	144	145	146	/4/	148	14	151	152	153	154	155	156	157	158	150	161
CO C368													4367		07	CF														C376				00	ç					C38B	8	ဗ	C391		2000	
9 %	orde one	03												C	F8	मुन																2000		13	7.								90		Š	
C362:2C C365:10	C367:38 C368:60	C369:	C36B:18	C36C:60	C36D:	C36D:	C36D:	C36D:	C36D:	Coon:	C36D:	C36D:	C36D.	C36D: A2	C36F:8E	C372:AE	C375:60	C376:	c376:	c376:	C376:	C376:	c376:	C376:	6376:	6376:	.9763	6376	0376:	C376:	C376:48	C377:98	C378:48	C3/9:AD	C3/C:48	C3/D:AD	7381.	381:	C381:	C381:90	C383:8D	C386:8D	C389:BO	C38B:	C365:	C38E:8D

7 sec ;C=1 if internal slot space 8 bmi irqintcx 9 clc	inx inx inx inx inx inx bha shoo,x and \$510,x and \$510,x ind ind release2 and festo bed ire2 ind release2 and \$520 bed ire2 by ire3 by ire4 by	
7 8 9 10 11 12 13 13	116 117 118 119 119 119 119 1117 1117 1117	59
C401:38 C402:30 01 C405 C403:48 C403:48 C403:48 C403:48 C403:8A	C4008 E8 C4002 E8 C4002 E8 C4002 E8 C4002 E8 C4012 B9 C4112 B0 0 01 C4112 B1 00 C4112 B1 00 C4212 B1 00 C4212 B1 00 C4212 B1 00 C4212 B1 00 C4213 B1 00 C431 C1 C0 C431 B1 00 C431 C1 C0 C431 B1 C0 C441 C1 C0 C441 C1 C0 C441 C1 C0 C441 C1 C0 C451 C1	C45F:30 UC C46D C461:85 44 C463:68
* IN CASE WE DO A SWAP: * LLDA \$03ED ; SET XFERADDR LO PHA ; SAVE ON CURRENT STACK LDA \$03EE ; GET XFERADDR HI PHA ; SAVE IT TOO * SWITCH TO APPROPRIATE BANK:	RECZH ROZARDS STA ROZARDS STA ROZARDS STA RECARDS STA MECANDS STA MECHONE ** This is where the ** This is the main e ** Indianoler This set ** Indian	**************************************
216 217 218 219 220 221 222 223	2020 20 20 20 20 20 20 20 20 20 20 20 20	4 0 0
C3C4: C3C4:Ah ED 03 C3C7:48 C3C8:Ah EE 03 C3C8:48 C3CC:	Carcing Carc	C400: C400 C400: C400

;A stored where RTS address would go ;Go to normal break routine stuff ;Save state of machine on stack ;Save major ;Save major ;It returns to icquee ;Estus Gor user's RTI ;Estus Gor user's RTI ;Estus Gor user's RTI ;Off to the user rus here smabled with a LDA fromin abbed; it still is abbed; it still is imabled with a LDA fromin abbed; it still is smabled with a LDA fromin abbed; it still is imabled to a machine state ;Grenabled (2 dass); it still will be eas an INC because some of the switches are read and before the write. ; imast be an INC abs, x since both the 6502 and ads before the write. ; imast be lail ; is main ZP ; Get all stack pointer ; is and if ince table of switch addresses ; is and if ince table deck ; G = 1 if internal alot space ; RTI opcode ; RTI opcode ; RTI opcode ; RTI opcode ; All if internal alot space ; All if internal alot space ; All if internal alot space ; All setalotcaron ; STA setalotcaron	teay bla teax bla	65 teax 66 teax 66 teax 66 teax 66 teax 67 teax 68 teax 68 teax 68 teax 68 teax 68 teax 69 teax 69 teax 60 tea	C4AC:9A 114 txs ; Restore stack pointer C4AD:8A 115 txa ; Make return address on stack point to code on stack C4AE:69 3 116 adc #3 ; C = 0 from earlier adc c4ABO:AA 117 tack	118	00 01 120 1878 01 122 148 00 01 123 858 124 pla 125 pla 127 rrs	C4C1:83 88 8 129 trqtble dfb >lcbankl,>lcbankl,>lcbankl C4C1:83 88 8 129 trqtble dfb >lcbankl,>lcbankl C4C4:65 53 130 dfb >lcbankl,>lcbankl C4C7: 21	C6001 6 * In the event of any failure, the diagnostic is halted. A message C6001 8 * is written to excreen memory indicating the source of the failure. C6001 9 * When RMA fails the message is composed of "RMA ZP" (Indicating failure C6001 10 * detected in the first page of RMA) or "RAM ("easting the other 63.75K), C6001 11 * foilowed by a binary representation of the failing bits set to "I". C6001 12 * For example, "MAM 0 1 1 0 0 0 0" indicates that bits 5 and 6 were C6001 13 * detected as failing. To represent auxiliary memory, a "*" symbol is C6001 14 * printed preceeding the message.		C6001: 00009 28 IOUIDIX equ 809 C6001: 0001 29 MICHIX equ 801 C6001: C588 30 SCREXW equ 858
				A stored where RTS address would go	41 41	iOff to the user run here anabled with a LDA romin was write protected, it still is rite enabled, it still is rite enabled (2 ldas), it still will be ses an IMC because some of the switches are read run may be an IMC abs, x since both the 6502 and adds before the write.	1000 1000 1000 100 100 100 100 100 100	ifit the switch. no race ckubbs; jet next bit to check ;C = 1 if internal alot space ;Restore the registers ;Rari opcode ;Rii opcode	cerron ;Ad 1 if internal slot space ;STA setslotexton

, x	;all 256 filled yet? ;branch if not	; bump page #		coont to page 1 again	save ACC in Y for now		3 raps address				select primary \$DUOU space	;Plus carry =+\$10	; branch always taken		200	fill this page with the pattern		×	(302),y MEMERROR : if any bits are different give notif		; keep x in the range $0-4$:all 256 filled vet?				a ; change ACC for next pass				; branch if not		;save acc		STI	sull test byte	;check memory
ntbl,x (\$02),y mem6	mem5	1		801			\$0083		-		\$5008			\$01		00\$#		_				memB		тешА		mem7					meml				SWCHTSTI		\$000
clc adc sta dex bpl		inc	aug	inc		lda	lda	and	cmp	bne	Ida	adc	pue			Lya 1dy	clc	adc	eor hne	lda	dex	Pp1			inc	pue	ror	bol	eor	dec	bpl		TAX	JSR	BNE	ASI.	CMP
87 mem.5 88 89 90 91	93 mem6 94	95	2	86	99 mem7	001	101	103	104	105	106	108	60	110 mem8	111 mem9	113	114 memA	115	110	118	119	120	121 memB	123	124	125	126	128	129	130 memC			133	134	135	137	138
C667	6 2592	5 4530				Ξ,	2 2	1 2		0 8890	= =	3 =	C68A 10	=:	= =	==	= :	= :	C6CC 11			C69E 12	12	C68F 12		C670 12	12	C6AD 12			ce38 13		13	13	C6BE 13	1 =	13
53	F2			01		83 CO	83 C0	10		6	88 60	0.F		01	60	00		B4 C7					5				19 00	3						8D C9	6	30	00 00
C65C:18 C65D:7D B4 (C660:91 02 C662:CA C663:10 02 C665:A2 04	C667:C8 C668:D0	C66A:E6 01	2000	C66E:E6	C670:A8	C671:AD 83 C0	C674:AD	C679:29	C67B:C9	C67D:D0 09	C6/F:AD 8B	C684:69 OF	C686:D0 02	C688:A5 01	C68A:83	C68D: A0 00	C68F:18	C690:7D B4	C695:00 35	C697:B1 02	C699:CA	C69A:10 02		C69F: DO EE	C6A1:E6 01	C6A3:D0 CB	C6A6:2C 19	C6A9:10 02	C6AB:49 A5	C6AD:C6 04	C6AF:10		C681:AA	C6B2:20 8D C9	C6B5:D0 07	C684:0A	C688:CD 00 0C
sta \$C050 * Test Zero-Page, then all of memory. Report errors when encountered. * Accumulator can be anything on entry. All registers used, but no stack. * Addresses between \$C000 and \$CPFP are mapped to main \$D000 bank. * Auxillary 64K is also tested if present.		;fill zero page with a pattern		Latter and the made	atter att bytes titted,			K ; branch if memory falled	:loop until all 256 bytes rested		AR ; use RDVBLBAR for a little randomness		;use a different pattern now		; branch always		;which bits are bad?	;indicate zero page failure	S				;do RAM \$100-\$FFFF five times	touth appear of the fore-	save ACC in Y for now	;anticipate not \$C000 range		get page address	Lest 101 500 507 Talige	:branch if not		;select primary \$D000 space	OlSta varies and.	the cally right			restore pattern to ACC; fill this page with the pattern
sta \$CO50 Test Zero-Page, th Accumulator can be Addresses between Auxillary 64K is a	0# \$\$#		\$00,x	7	102	ntbl,y	\$00°x	2PEKKUK	202	. 6	RDVBLBAR	Zp3		zpl	TSTMEM		×,00\$		BADBITS	501	\$02	\$03	**	\$04	•	\$0083	\$0083	\$01 #cp0	# SCO	mem3	\$C08B	\$C08B	#S#	7mom	\$01	\$03	00\$#
sta t Zero- umulato resses illary	G 1dy	clc	sta	inx	olo olo	adc	cmp	pue	bne	ror	bit	bp1	dey	bpl	bmi		OR eor	clc		equ stx	stx	stx	1dx	4 no	tav	sta	sta	Ida	CIED	bne	lda	lda	Ida	hne	1da	sta	tya 1dy
34	40 TSTZPG	42 zpl	44	45	47 252		67	200	52	53	54	55	57 zp3	28	29		61 ZPERROR	62	63		99	29	89	70 mem 77		72	73	75	76		78	79	81	82		84 mem4	86
C600:8D 50 C0 C603: C603: C603:	C603:A0 04 C605:A2 00	i	C608:79 B4 C7 C608:95 00	C60D:E8			00	C618:00 10 C628	C619:D0 F5 C610		19 CO	C61F:10 02 C623		E1	C626:30 06 C62E		C628:55 00		C62B:4C CD C6	10 98			C634:A2 04				83	C641:A5 01	02 62:53 00		88	_	C651:69 OF		01	C657:85 03	C65A:A0 00

y print "Mell" or "Iol" ;branch forever	set switches of the IOU/MMU to march Accumularo	>	;branch if setting switch to 0-state y ;else get index to set switch to l	IOSPACE-1,x ;set switch	;branch always taken		v now verify the settings inst made				thranch sluave	×	;branch always	restore original value	; and IOU/MMU index	try next pattern;				indicate switch error				clear screen for success message		
screen,y bswtchl hangy				IOSPACI	swtst2	\$5030	RSWTBL.v		8	SWISTS TOSPACE.x	Swerr swret4	IOSPACE,x	SWEST 4	æ		#1 swret?		BIGLOOP	swistl	0#	#IOUIDX+1	\$80	SWCHTST #\$A0	\$400.4	\$500,7	\$700,y
12 sta dey bpl bmi	ST 1dy			sta	bne	1dx	-		rol	bcc	bcc		bcc	rol	iny	sbc	dey	bne	bne	1dx	cpy		bne 1da	ldy sta	sta	sta
193 bswtch2 194 195 196 hangy	198 SWCHTST 199 swtstl 200 swtst2		203	205 swtst3 206	207	209 click	211 swtst4 212	213	215	216	218	220 swtst5	222	223 * 224 swtst6	225	227	229	230	232	233 * 234 swerr	235	237 BIGLOOP	238 239 blp2	240 241 blp3	242 243	244 245
C72E.99 B8 05 C731:88 C732:10 F2 C726 C734:30 FE C734	C736:A0 01 C738:A9 7F C73A:6A	B9 C7	C/40:90 03 C/45 C742:BE C9 C7	C745:9D FF BF C748:C8	C749:D0 EF C73A	C748:AE 30 C0	D9 C7	C768		C758:90 07 C761 C75A:1E 00 C0	C75D:90 17 C776 C75F:80 EE C74F	ö	0 E7	C768:2A	C769:C8	C768:E9 01 C760:B0 CB C73A		C770:D0 0B C77D	2	C776:A2 00	C778:C0 0A	₹ .	C77F:D0 B5 C736 C781:A9 A0	C783:A0 00 C785:99 00 04	C788:99 00 05 C78B:99 00 06	C78E:99 00 07 C791:C8
;=>not 128K ;=>not 128K	is wap in all zero page is and test it! indicate main ram failure is abew bit pattern in x for now idetermine if primary or auxillary RAM	with V-FLG; branch if primary bank	try to clear video screen	>	Y.						. toot for custch took foilire	;branch 1f 1t was a switch	;branch if ZP ok	mark aux report with an asterisks				;message is either "RAM" or "RAM ZP"	prince ores		;bits are printed as ascii 0 or 1	K		thang forever and ever		;branch if MMU in error ;else indicate IOU error
SWCHTST := Not 128K \$800 ; look for shadowing SWCHTST := Not 128K	TSTZPG TSTZPG RDRAMRD		> 9	#6 IOSPACE-2.v	IOSPACE+6,y		CITS CONTRACT TXTPAGE	\$400, y \$500.v	\$600.y	\$700,y	chrs toot for outtob toot foilure	BADSWICH ;branch if it was a switch	main	#5 #\$AA ;mark aux report with an asterisks	badprim	iness,y erreanly		badprim ;message is either "RAM" or "RAM ZP"		æ	\$58 ;bits are printed as ascii 0 or 1	a screen-2,y		bbits2 hangx :hang forever and ever	>	λ,
ST	SIA SELACIZE Jmp TSTZPG MEMERROR sec BADBITS tax Ida RDRAMRD	clv bpl bbitsl	bit setv bbitsl 1da #\$AO	152 1dy #6 153 clrsts sta IOSPACE-2.v	sta	dey	sta	clrs sta		sta	bne clrs	beq BADSWTCH	bcs badmain	ldy #5 badmain lda #\$AA	byc badprim	17. badprim lda rmess.y 174 badprim acrees.y 175 cta acrees.7	dey	bpl badprim	016#	180 1sr a 181 tax	1da #\$58	sta	185 dey 186 dey	bne bbits2 hangx beq hangx	BADSWTCH 1dy #2 bswtch1 1da smess.y	bcc 1da

versions of these values for its own use.	DIFFERS FROM		set up OURCV		CET IT	IS IT THE SAME?	=>YES, USE OUR OWN	update our cursor	cursor horizontal must not		le is, then put cursor	י זבור בחצב מו אדוותמא		; exit with Y = CH		Ellog Too Mile	CES DOW	They cannot use the SC3 entry points	the \$C8 space, causing	possible conflict with other \$C8 users.	These routines are only called by the \$C100-\$C2FF space.		·*	a PR#3. 80 columns will not	simply by turning on the 80VID flag.	load V stuffed by SF8 ROM		skip SEC		signal an input:	save the char		save X		BASIC IN/OUT	;=>input a character	KEAL VERSION				ints is the place where characters printed using the	CSW hook are actually printed (or executed if they are			Setup user cursor GET CHARACTER	1S IT C/R?	=>don't wait. OURCH ok	non c watch course on
versions of these values	WHAT WE I AST DITT THERE.	the continues.	CV	OURCV	CH	OLDCH ;	cs2	OURCH	WNDWDTH ;		Cea		-	OURCH		dr. keen one TIIO	dant and autout he the 650 DOM shile	hey cannot use	hat switches in	conflict with o	tines are only		ry points will	initialized using a PR#3.	ly by turning o	SAVVI	11.00	*	Ĩ- *		CHAR	•			*	BINPUT	0	ON, A, V	INCLUDE BPRINT		ne place where	are actually pr	control characters).	dimenso.	CHAR	#880	NOWALT	170400
* *	*	*	CSETUP	t STA				-	CS2	oro cro			-	95 CS3 LDY	S RTS	. ,		* is on-	*	*	*	*	*	* first	* work	A ROLL I.DV	1000			BIN	STA				C8BASIC		TEST		,			* *	t control c		D BPKINI JSK	CMP	BNE	
79	8.18	82		0.5		90	385F	05		90	2860	2002	05	78 05 9	96	16	96	100	101	102	103	104	105	106	107			C873	C874		06 114	116	117		C87C	_	0000	23	24	- `					800	2	C8A0	
C850:	C850:	C850:	C850:A5 25	C852:8D FB	9.0			C85C:8C 7B	C85F:A5 21	C861:18	C865:ED /B	C867.40 00		C86C:AC 7B	C86F:60	:020	.020.	0870:	C870:	C870:	C870:	C870:	C870:	C870:	C870:	C870.44 35		C873:BO FE		C874:38	C875:8D 7B	C879:48	C87A:8A	C87B:48		C87C:BO 5E	:0000	C87E:	C8/E:	2007		C87E:	2075.		C881:40 7B			

hese values for its own use. URSOR IF II DIFFERS FROM		2 =	LDX	KBD NOWAIT	; IS KEY PRESSED? ; NO
PUT THERE:	93	12	CPX	#\$93	; IS IT CTL-S?
nounce and a	C88F: DO OF C8AU	13	BNE	NOWALT	;NO, IGNORE IT
RCV.	C894:AE 00 C0	15 KBDWAIT		KBD	; WAIT FOR NEXT KEYPRESS
	C897:10 FB C894	16	BPL	KBDWAIT	
DCH ; IS IT THE SAME?	83	17	CPX	#\$83	; IF CTL-C, LEAVE IT
	C89B:FU U3 C8AU	8 9	BEQ	NOWALT	IN THE KBD BUFFER
	C690:2C 10 C0	61	119	KBUSIKB	CLEAR OTHER CHARACTER
DWDTH ; cursor horizontal must not	C8AU:29 /F	20 NOWALT	AND	#4/F	drop possible hi bit
	C844.10 06. 1940	17	JE O	07¢#	
Ach ; it it is, then put cutsor 3 .at left edge of window	2	23	ISB	CTLCHARO	sexecute CTL if M.CTL ok
	8	24	IMP	CTLON	: *>enable ctl chrs
RCH		25 *			
RCH ; exit with $Y = CH$	C8AC:	NOT	A CTL C	CHAR. PRINT IT.	T IT.
		27 *			
	C8AC: C8AC	28 BPNCTL		*	
are used when characters are	C8AC:AD 7B 06	59		CHAR	;get char (all 8 bits)
put by the \$F8 ROM while 80VID	C8AF:20 38 CE		JSR	STORCHAR	;and display it
cannot use the \$C3 entry points	C8B2:	31 *			
switches in the \$C8 space, causing	C882:		THE CU	* BUMP THE CURSOR HORIZONTAL:	ZONTAL:
lict with other \$C8 users.	C8B2:	33 *			
s are only called by the \$C100-\$C2FF space.	C8B2:C8	34	IN		; bump it
		35	STY	OURCH	; are we past the
sints will only work if the card was		36	CPY	WNDWDTH	; end of the line?
[zed using a PR#3. 80 columns will not	C8B8:90 03 C8BD	37	BCC	CLION	;=>NO, NO PROBLEM
y turning on the 80VID flag.	C8BA:20 51 CB	38	JSR	X.CR	;YES, DO C/R
	C8BD:	39 *			
VYI ;load Y stuffed by \$F8 ROM	C88D:	40 × M CL	, 18 Se	t by RDCH	40 * M.CTL is set by KDCHAR and cleared here, atter each
;signal an output	C8BD:		creri	* character is displayed.	• pa
;skip SEC		× 74			
		43 CIFON	LUA.	MODE	senable printing of control chars
	C8C0:29 F/	44	AND	#255-M.CTL	
AR ;save the char	C8C2:8D FB 04	42		MODE	
; save Y	C8C5:AD /B 05	46 BIORET		OURCH	get newest cursor position
	CSCS:2C IF CO	/ 5		KD8UVID	IN SO-MODE?
;save X	C8CB:10.02 C8CF	8 7	BPL	SETALL	;* >no, set other cursors
FIG/MI CISAG.	2000:83	SO SETATI	STA	2 7	יאווו מו נס ס יסו מס כסימווווס
TOO AT OTHER	7871.80	51	CTA	OI DCH	CMITTAS BUT GRANAMAG.
	C8D4:58	S2 CRTPECS		10000	· RESTORE
A U	000450	53			The state of the s
RPRINT	C8D6:568	54	PI.A		X AND Y
THE PARTY OF THE P	C8D7: A8	55	TAY		
off point bottoing anothogonaly cooks con	C808:40 78 06	9 5	I.DA	CHAR	
tace where characters printed using the	C8D8:60	57	RTS	CHAIN	RETHEN TO BASTC
strongly princed (or executed in the) are	CBDC:	25	INCLI	INCLUDE BINPUT	
	CSDC	*			
ETHP : setup user cursor	CBDC:	2 * BASI	fundt:	entry po	* BASIC input entry point called by entry point in the
	C8DC:	3 * \$C3	pace.	This is	* \$C3 space. This is the way things normally happen.
SD :IS IT C/R?	C8DC:	* 7			
-	C8DC: A4 24	S BINPUT	LDY	CH	

LDA CHAR		•	JSR INVERT	GETKEY:	CHAR	INVERT	TAY ;preserve acc.			be returned. If M.CTL is set, however, escape functions	are enabled, and CTL-U causes the character under the	cursor to be picked up from the screen.	M.CTL is set whenever a character is requested using	RDCHAR in the SF8 ROM.		LDA MODE ; is escape mode enabled?	#M.CTL		#580	NOTACR	MODE	AND #255-M.CTL :else end of line		*	CPY #\$9B ;ESCAPE KEY?	ESCAPING		an escape sequence. Check for control-u.		CPY #\$95 ;is it control-U?	BNE BIORET ;no, return to caller	OURCH	JSR PICK ; and pick up the char	ORA #\$80 ;always pick as normal	CHAR	BNE BIORET ;=>(always) return to caller			pressed is one of the following, it is executed.	Otherwise it is ignored.		- home & clear	- clear to end of line	- clear to end of screen	- move cursor up	- move cursor left	- move cursor right	- move cursor down	- enter 40 column mode	enter 80 column mode	disable the printing of control	- enable the printing of control characters	
			B.INPUT						ou be	be re	are e			RDCHA										NOTACR				* Not a										Start	press	Other		9	H	Œ	I	ר	×	Σ	4	80	CTL-D-	CTL-E-	CIL
9	7	8		0	_	7	13	* *	* 51	* 9	*		* 6	*	*	7	~	4	5	9	7	8	6		_	2	*			9	7	8	6	0	_	7	* ·	* .	*	• •	*	*	*	*	*	*	*	* 7	*	*	* .	* *	٠ -
•		~	•	10	=	12	-	-	-	16	17	18	19	20	21	22	23	24	25	26	27	28	29	ĕ	31	32	33	m	35	36	37	38	39	40	41	42	43	77	45	46	47	48	49	.50	21	52	53	54	57	28	59	9 5	0
90						CE										04		C8C5		9060	04		90	9060		C918					C8C5		CE		90	C8C5																	
7.B	28	20	56	38	78	56										FB		CB	80	08		F7	FB		9B					95	B7		77		7.8	¥																	
C8DE: AD	C8E1:91	C8E3:20	C8E6:20	C8E9:20	C8EC:8D	C8EF:20	C8F2:A8	C8F3:	C8F3:	C8F3:	C8F3:	C8F3:	C8F3:	C8F3:	C8F3:	C8F3:AD	C8F6:29	C8F8:FO	CSFA:CO	C8FC: D0	C8FE: AD	C901:29	C903:8D	:9060	03:9063	C908:F0	C90A:	C90A:	C90A:	C90A:C0	C90C:D0	C90E: AC	C911:20	C914:09	C916:8D	C919:DO	C91B:	C91B:	C91B:	C91B:	C91B:	C91B:	C91B:	C91B:	C91B:	C918:	C91B:	C91B:	C91B:	C91B:	C91B:	C91B:	C91B:

	OFF	*		GET ESCA	; REPLACE	DROP HI RIT	I-MU	AB,Y	-		TRY EM ALL	=>MAIDE II 3 A	*	GET CHAR TO	; DROP HI BIT	; EXECUTE			••	**	: but char here	• ••	;was it	ou<=:	do the	7	TE		;was it CTL-E for	=>no	save new mode	PUT		;was it CTL-D for	;=>no, exit escape	;disable	;=> exit	4			should not be exited after execution of		4		SOC : G: FORMFEED
	MSB	PING EQU					LDY	CMP	BEQ			IWG		LDA		JSR	LDA	BMI	BPL				CPY	BNE	JSK					BNE					BNE	ORA	BNE	table			scape mode	e charact			DFB
*												*										_	_	_			_					ESC			_		4	k *	*	*	*	*			
63	9	9	99	67	9	70	7.1	72	73	7 1	. ,	7 7	78	79	80	8	83	83	20 0	0 0	8	88	8	8 8	7 6	, 6	76	95	8	90	6	100	101	102	103				108	100	110	Ξ			114
		C918	CE	83	CE	S C		60	c935		C928	Chat	6935	63		CA	60	C918	C8E6	7700		04	1												0960		C95D						0.000	C96B	
			B 1	38	5.	77	10	7C	05	í				6B	7 F	90	6 B	60	A2			FB	=	0.8	40		_							_											
C91B:	C918:	C91B:	C91B:20	1E:20	21:20	07:47	C929: AO	C92B:D9	2E:F0	30:88	31:10	33:30	35:	35:89	C938:29	C93A:20	3D: B9	40:30	42:10	: 55	44 : A8	C945:AD	C948:C0	94A:D0	4C:20	51 . 8n	C954:4C	C957:	27:00	59:D0	15n:8n	960:4C	C963:	963:00	965:D0	60: 296	00:69	108:	. B9	C968:	C96B:	C96B:	C96B:	96B:	C96B:0C
	18: 63 *	63 * 64	63 * MSB 64 MSB C918 65 ESCAPING EQU	63 * MSB OFF 64 MSB OFF C91B 65 ESCAPING EQU * 20 B1 CE 66 JSR ESCON	63 * MSB OFF 64 MSB OFF C91B 65 ESCAPING EQU * 20 B1 CE 66 JSR ESCON ; ESCAPE C 20 3B C8 67 JSR GFIKEY ; GET ESCA	63 * MSB OFF 64 MSB OFF 64 MSB OFF 70 BI CE 66 JSR ESCON 70 CA CE 67 JSR CETYEY 70 CA CE 68 JSR ESCOPF 70 CA CE 68 JSR ESCOPF	63 * MSB OFF 64 MSB OFF C918 65 ESCAPING EQU * . ESCAPE C 20 38 C8 67 JSR ESCON ; ESCAPE C 20 38 C8 57 JSR ESCOPF ; ESPLACE 20 14 CE 69 JSR UPSCAPF ; ESPLACE 20 14 CE 69 JSR UPSCAPF ; ESPLACE 20 27 70 AND 457F ; MAD HIDD HID	63 * MSB OFF 64 MSB OFF 65 ESCAPING EQU * : ESCAPE C 10 B1 CE 66 ESCAPING EQU * : ESCAPE C 10 B2 C8 67 JSR CFTKEY : GET ESCA 10 C4 CE 68 JSR LESCOPF : EFPLACE 10 14 CE 69 JSR LESCOPF : UPSHIFT 129 7F 70 AND \$\$77F : UPSHIFT 129 7F 70 LDY \$\$ESCUMP-1; COUNTVILLE	63 * MSB OFF 64 MSB OFF C918 65 ESCAPING EQU* 20 B1 CE 66 JSR ESCON ; ESCAPE C 20 3B C8 67 JSR ESCOPF ; EFF ESCA 20 14 CE 69 JSR .UPSHFT ; upshift 29 7F 70 AND #57F ; DOUNT/IN A0 10 71 ESCC CMP ESCAND-1; COUNT/IN	64 MSB OFF C918 65 ESCAPING EQU * 185CAPE C D0 31 CE 66 STRYEY GET ESCAP D0 C4 CE 68 JSR ESCOPF REPLACE D1 4 CE 69 JSR USCOPF REPLACE D1 4 CE 70 AND \$77 USPHIFT MO 10 71 LDY \$ESCUNI-1; COUNT/ISP D1 72 CAP ESCAPING EQU * 18 TS AND P MO 7C 97 72 CAP ESCAPING ISP TS AND P MO 7C 97 72 ESC CAP ESCAPING IS TS AND P MO 7C 97 72 ESC CAP ESCAPING ISP TS AND P MO 7C 97 72 ESC CAP ESCAPING ISP TS AND P MO 7C 97 72 ESCAPING ESCAPING ISP TS AND P MO 7C 97 72 ESCAPING ESCAPING ISP TS AND P MO 7C 97 72 ESCAPING ESCAPING ISP TS AND P MO 7C 97 72 ESCAPING ESCAPING ISP TS AND P MO 7C 97 72 ESCAPING ESCAPING ESCAPING ISP TS AND P MO 7C 97 72 ESCAPING ESCAPING ESCAPING ISP TS AND P MO 7C 97 72 ESCAPING ESCA	63 * MSB OFF 64 MSB OFF 65 ESCAPING EQU * 10 B1 CE 66 ESCAPING EQU * 66 ESCAPING EQU * 10 B1 CB 67 ESCAPING EQU * 10 B1 CB 68 ESCAPING EQU * 10 B1 CB 69 ESCAPING EQU * 11 CB 69 ESCAPING EQU * 11 CB 69 ESCAPING EQU * 12 ESCAPING EQU * 13 ESCAPING EQU * 14 CB 64 ESCAPING EQU * 15 ESCAPING EQU * 16 ESCAPING EQU * 17 ESCAPING EQU * 18 ESCAPING EQU *	C918 65 ESCAPING EQU *	63 * MSB OFF	63 * MSB OFF C918 65 ESCAPING EQU * C918 65 ESCAPING EQU * C8	63 * MSB OFF	63 * MSB OFF	63 * MEB OFF	64 MSB OFF	64 MSB OFF	63 * MEB OFF 10 12 12 13 13 13 14 14 15 15 15 15 15 15	63 * MSB OFF	63 * MSB OFF 64 MSB OFF 65 ESCAPING EQU * 66 JSR ESCON ; ESCAPE C C C C C C C C C C C C C C C C C C C	63 * MSB OFF	63 * MEB OFF 10	64 MSB OFF	63 * MSB OFF	64 MSB OFF	63 * MEB OFF	63 * MSB OFF	C918 63 * MSB OFF	C918 63 *	63 * MBB OFF	C918 63 *	C918 63 *	C918 64 MSB OFF	C918 64 MSB OFF	C918 63 * MSB OFF	C918 64 MSB OFF	Color Colo	Col	C918 64 MSB OFF	64	Coll	C918 64 MSB OFF	C918 64 MSB OFF

		****		****			HOOK ALIGNMENT		GET OUTPUT CHARACTER	:=>USE STANDARD WRITE	*****		****		xt	KKKKKKKKKK		O+M.MOUSE	ys	ad an avs.			save version ID				THERE?		discard ID byte	; IORESULT='NO DEVICE'				get version ID	ave.	80 STOKE	AND 80 VIDEO	window and cursor		fix OLDBASL/H. display cursor, exit	factor factor			Character always returned with high bit clear.		*****		ZP STUFF	KEYSTROKE	HI BIT	THE CHAR
OFF	INCLUDE PASCAL	*************************************	OUTPUT HOOK:	********************************		*-C80KG-\$1	2, C9AA			JPWRITE :=>USE	*************		***************************************	PASCAL INITIALIZATION:	printing of mouse text	化环状状状 化环状状 化环状状状 化环状状状状状状状状状状状状状状状状状状状状	*	CAL+I	PINIT2 :=>always	#W DACCATAN MOTOR	WILL FASCALTINOUSE	*	save v		CARD'S PLUGGED IN:		TESTCARD ; IS IT THERE?	PIGOOD ;=>YES		#9 ; IORESU			*				SEIGHVID ; AND S		HOME	St. :fix C	****	III:		always returned wi		**********************		; SETUP	Y ; GET A	; DROP	CHAR ; SAVE T
MSB	INCL	*********	* PASCAL 1.0	*******	DS	IFNE	FAIL	FIN	rd A	JMP	**********	*	*****	* PASCAL INIT	* Disable pri	****	PINITI.0 EQU	LDA		PINIT EQU	*	PINIT? ROII		*	* SEE IF THE	*	JSR	BEQ	PLA	LDX	RIS		PIGOOD EQU	PLA	STA	STA	SIA	TSE	ISE	IMP	********	* PASCAL, TNPIIT:	*	* Character	*	*********	PREAD EQU	JSR	JSR	AND	STA
170	56	-	7	e.	4	Λ,	9 1	1	∞	6	10	Ξ	12	13	14	15	91	17	18	7 6	21	33	23	24	25	26	27	28	29	30	31	32	33	34	3	3.0	30	300	40	4	42	73	44	45	94	47	48	64	20	51	25
					0005	0000			90	3							C9B0		C986	CARA		CORE					CA	0262					0262			_	3 8	3 8	3 5	S S	5						6906		83 83		90
										26							1	83	05	6	0						8	04		60							00		8	4	:										7B
C9A8:	C9A8:	C9A8:	C9A8:	C9A8:	C9A8:	C9AA:	so e	C9AA:	C9AA:AD	C9AD:4C	C9B0:	C9B0:	C9B0:	C9B0:	C9B0:	C9B0:	C980:	C9B0: A9	C982:D0	C984:	CORF.	. 986	C9B6:48	C987:	C987:	C9B7:	C9B7:20	C9BA:FO	C9BC:68	C9BD: A2	C9BF:60	:0060	:0060	C9C0:68	C9C1:8D	C9C4:8D	08:7363	C9CB: 8D	C9100.50	2903:40	C9D6:	C9D6:	c9D6:	: 9060	:9060	: 9060	:9060	C9D6:20	C9D9:20	C9DC:29	C9DE:8D

## 18 ## 18 ## 19	yer test pattern vertee ANN RAM read AUX RAM tread AUX RAM tand this byte innd this 18 Noff thas \$500 been updated? icheck in main diags. in \$Cl page in \$Cl page
18: 88: 18: 18: 18: 18: 18: 18: 18: 18:	get ; write ; read ; test ; and ; has ; chec [X in §
DPB \$08 DPB \$10A DPB \$11D DPB \$11P+\$80 DPB \$	TA #SEE : gee' TA MCABDRAM : written # MCADDRAM : written # MCABDRAM : written # MCABDRAM : written # MCABDRAM : written # MCADDRAM : w
DPB DPPB DPPB DPPB DPPB DPPB DPPB DPPB	
* ESCTAB ESCNUM * * Tack CSTAUX	XSTAUX B * * ESCOUT A ESCOUT A
1116 1117 1118 1119 1119 1119 1119 1119 1119	158 159 160 161 162 163 164 165 165 168
C97C	CB CD C9
	CB 000 000 000 000 000 000 000 000 000 0
C96 E108 C97 E108 C98	C992: A9 C994: 8D C997: 8D C990: 8D C990: C90: C943: 6O C944: C944: C944

	;YES, RETURN CN IN X ;RESTORE CHAR	OUTPUT: to be executed, control characters must have igh bits cleared. All other characters are ed regardless of their high bits.	s ', don't OTOXY?	inow check for control char; = fat control = fat control get horizontal position check for inverse inverse, go store it	;now store it (erasing cursor);1NC CH; (c);1NC CH; (d);1NC CH; (d);1NC CH; (e);1NC CH; (e)	;save BASL for pascal ;display new cursor ;return with no error	;turn off cursor;get character;MAKE BINAKY;dolug X?;->yes, set it
#0 MODE #M.PASI.0 PREADRET2	# <cnuu J * CHAR</cnuu 	KiS PASCAL OUTPUT: Note: to be executed, control their high bits cleared. All displayed regardless of their	* #\$7F PSETUP #M.GOXY MODE GETX	PRTS PCTL OURCH INVFLG PWR1 #\$80	STORIT OURCH WNDWDTH DOBASL #0 OURCH X.LF	ASI. LDA BASL STA OLDBASL LDA BASH LDA BASH STA OLDBASH LITERT JSR PASINV T LDX #\$0 S RTS HANDLE GOTOXY STUFF:	#32 XCOORD PSETX
LDX LDA AND BEO	* PREADRET2 EQU * LDA CH	KIS PASCAL OUTPUT: Note: to be e: their high bit: displayed rega		TXA BIT BEQ LDY BIT BPL ORA		DOBASI, LDA BASIL STA OLDBASIL LDA BASH STA OLDBASH PRITERET JSR PASINV PRET LDX #\$0 PRET RS #TS ** HANDLE GOTOXY STU	JSR TXA SEC SBC BIT BMI
	PREA	4 * * * *	* PWRITE		PWR1	DOBASL PWRITE PRET PRTS * HAN	* GETX
53 54 55	588 29	62 64 65 65	68 69 70 71 72 74	75 77 77 78 79 80	82 84 85 85 87 88 88	90 92 93 94 95 96 98	99 100 101 102 103 104 106
04 C9EC	C9EC 06		C9F0 CE 04 CA2F	CA CA53 05 CA0C	CE 05 CAIF 05 CB	07 CE	CE 06 CA6B
	E #		7F D4 08 FB 32	2E 50 78 32 02 80		28 78 29 FB 11F 00	1F 20 FB 30
C9E1:A2 C9E3:AD C9E6:29 C9E8:F0	C9EA: AZ C3 C9EC: C9EC: C9EC:	C9F0: C9F0: C9F0: C9F0: C9F0:	C9FO: C9FO: C9FO:29 C9F2:AA C9F3:20 C9F6:A9 C9F8:2C	C9FD:8A C9FE:2C CAO1:FO CAO3:AC CAO6:24 CAO8:10 CAO8:10	CAOC:20 CAOF:C8 CA10:8C CA13:C4 CA15:90 CA17:A9 CA19:8D	CAIF: A5 CA21:80 CA24: A5 CA26: 80 CA29: 20 CA29: 20 CA26: A2 CA26: A2	CAZF: CAZF:20 CA32:8A CA33:38 CA34:E9 CA36:2C CA39:30

d do the GOTOXY		A CV		XCOORD	OURCH ;set cursor			A MODE	DOBASE	R PASINV :turn off cursor		#S1E	STARTXY	CTLCHAR : EXECUTE IT IF POSSIBLE	IF DUBABL ;=/update babk/n, cursor, exit	IE GOTOXY SEQUENCE:		* =	#M.GOXY		MODE	XCOORD :set X	PWRITERET	E SUBS1	*		NA BASZL ;GET OPCODE AGAIN			SR A second times times to the second many	A	 V	#\$20 ; 2) XXXYYY01 =>	; 3) XXXXXXIO =>	IE MNNDX2 ; 4) XXXXYIOU => UOIUUXXX	- 0000000000000000000000000000000000000	TE MNNDX1	S		3, then test for a	If none found, test for 80 column card, also return with BNF.		*	TSTROM	<pre>IESTCARD ;=>no KOM, check for 80 column card</pre>
* Set Y and		GELY STA	JSR	LDA	STA	LDA	AND	STA	NO 4	PCTL JSR	TXA	CMP	BEO	JSR	JAC *	* START THE		STARTXY EOU	LDA	ORA	STA	PSETX STA		INC	DOMN EQU	TAX	LDA	CPX	BEO	MNNDX1 LSR	I.SR	MNNDX2 LSR		DEY	INV	MNNDX3 DEV		RTS	*	* Switch in slot	* If none found,	*	TSTROMCRD EQU	JSR	BNE
107		100	Ξ	112	113	114	115	110	110		120	121	122	123	125	126	127		129	130	131			27		7	n <	ŧν	9	_ 0	0 0			12	13			17	18	13	20			24	52
		c ₀	CA	90	05		04	04	CALF	CE			CA61	CA.	¥5			CA61		90	04	90	CA		CA71				CA85	0	COWO				CA/E		CA7A						CA89	F8	CANO
	9	25	BA	FB	7B	F7	E :	2 5	3	14		1.8	90	9 5	1				08	FB	F 2	4 8	29				47 C	8 A	0.8	9	8		20		FA		F2							B7	02
CA3B:	CASE.	CA3E:85	CA40:20	CA43:AD	CA46:8D	CA49: A9	CA4B:2D	CA4E:8D	CA51: DO	CA53:20	CA56:8A	CA57:C9	CA59:F0	CA5B:20	CA5E:40	CA61:	CA61:	CA61:	CA61:A9	CA63:0D	CA66:8D	CA68:8D	CA6E:4C	CA71:	CA71:	CA71: AA	CA/2:A5	CA76:E0	CA78:F0	CA7A:4A	CA7D:4A	CA7E:4A	CA7F:09	CA81:88	CA82:D0	CA85.88	CA86:D0	CA88:60	CA89:	CA89:	CA89:	CA89:	CA89:	CA89:20	CASC: DO

7 B 7 B 7 B 113 110 110 110 110 110 110 110 110 110			* NAME * INDUT * OUTPUT * OUTPUT * OUTPUT * OUTPUT * OUTPUT * NAME * NAM	CLU C CLV C C CLV C C C C	CTLCHARO Execute CTL AC-CHAR "MCS" if no "MCS" if no "MCHING MANY THINGS "ALMAY THINGS "AC-CHAR "AC-C	char if M.CTJ excuted ***********************************
	CAFA CAF7		* CTLCHARX EQU SEC BCS	BEQ EQU SEC BCS	CTLGO * CTLRET	;=>then go do them ;SAY 'NOT CTL' ;=>DONE
CAFA:AD 7B (07 CAFD	131 (CTLG00	LDA	TEMP1	get address back

E								va idora contu manana	TDEO DISCRA	SSTING	DE IN 'N'	r.1	FLAGS			CAM		'C' FLAGS			4	DE	2		SEQ/BNE																			
INY ;make BNE for return RTS	CARD		CARD AVAILABLE	£4		化拉水烷化拉拉水烷化拉水烷烷烷烷烷烷烷烷烷烷烷烷烷烷烷烷烷烷烷烷烷烷烷烷烷烷烷		wadano dadwaran		USEFUL CHAR FOR TESTING	REMEMBER VIDEO MODE IN	STOP	AND 'C'	PAGEZ	SET TO A '*'	GET IT BACK FROM RAM	RESTORE ORIG CHAR	RESTORE 'N' AND 'C		RESTORE PAGE1	M 10000 KI WATO	. =>STAY IN SUCUL MUDE		WAS CHAR VALID?	RETURN RESULT AS BEQ/BNE																			
	TESTCARD	NONE NONE	I.F	BNE' IF NOT	AC, Y	***	•	* 1	A A	#\$88	RD80COL	SET80COL		TXTPAGEZ	\$0400	\$0400	\$0400		STAY2	TXTPAGE1		STAYBU		#\$88							A	#\$03	#804	BASH	813	BSCI.C2	#S7F	BASL	A	٧	BASL	BASL		
INY	* NAME :	* INPUT :	* OUTPUT :	*	* VOLATILE:	****	*	TESTCAKD EUU	ASI	LDA	BIT	STA	PHP	STA	STA	LDA	STY	PLP	BCS		STAY EQU	STA	STAYSO EOU		RTS	*	* Do the	BASCALC	BACCATO POIT		LSR	AND	ORA	STA	PLA AND	BCC	ADC	BSCLC2 STA		ASL	ORA	STA	* KTS	
26 27 28	30 23	32	33	34	35	36	37	200	40	41	42	43	44	45	40	48	67	20	51		2 2	4 2	26	57	58		9		5 5	63	9	65	99	67	80	2	7	72	73	74	75	76	78	2
							0000	CASO	3		60	8		8 8	90	90	04		CAB2	00	CAB2	CAB/	CAB7					monitor ROM	4040	and o						CACO								
									2	88	18	0		25	3 8	00	00		03	24	6	5 6		88				TOE				03	04	29	8	20	7.	28			58	28		
CA8F:C8 CA8F:60 CA90:	CA90:	CA90:	CA90:	CA90:	CA90:	CA90:	CA90:	CA90:	CA93:04	CA94:A9	CA96:2C	CA99:8D	CA9C:08	CA9D:8D	CAAO: AC	CAA6: AD	CAA9:8C	CAAC:28	CAAD: BO	CAAF:8D	CAB2:	CAB2:30	CAR7:	CAB7:C9	CAB9:60	CABA:	CABA:	normal	CABA.	CABA:48	CABB: 4A	CABC:29	CABE:09	CAC0:85	CAC2:68	CAC5:90	CAC7:69	CAC9:85	CACB:0A	CACC: 0A	CACD:05	CACF:85	CAD1:60	. 2000

							BACK UP CH	BACK IN TO BELOW IINE	HOTAL OF TO	E 1701	; NOW DO REV LINEFEED				TURN:			BACK UP CH TO	DEGINATE OF LINE	ARE WE IN BASIC:	avolu											;set base for OURCV					SOME CH	Santa mun picum sings	NO COOD	TANCE CARD ABOUTUDE	N N				SEED.		; are we at top?		;=>yes, stay there
;	T#	WALIL		EXECUTE BACKSPACE:	1	*	OURCH	CANDUNE	Ollben	OURCH	X.US	*			EXECUTE CARRIAGE RETURN:		* =	0#	CORCH	MODE	A.CRREI	Y• FŁ			ME:		*	WNDTOP	CV	0#	OURCH	VTAB		EXECUTE FURWARD SPACE:	*		OURCH	UNINCE	HADWDIN V	A CP	A.C.	*			TARCHTE PROFICE LINERED.	APROP PTM	WNDTOP	CV	X.USRET
PLA	286	RTS		TE BA		EQU	DEC	PPL	CTA	DEC	JSR	EQU	RIS		TE CA		EQU	LDA	ATC	LDA	TEG	FOIL			EXECUTE HOME:		EQU	LDA	STA	LDA	STA	JMP		TE FO	1102	0	I NC	Y O	E CE	100	460	FOIL		CTA	TE DE	2	LDA	CMP	BCS
			*	* EXECU	*	X.BS						BSDONE		*	* EXECU	*	X.CR					TAGGO		*	* EXECU	*	X.EM							* EXECU	. 4	A.F.3					*	Y. FSRET		*	* PYRCII	*	X.US		
187	88	190	191	192			195	190	100	199	200	201	202	203	204	202	206	207	907	209	210	212	213	214	215	216	217	218	219	220	221	222	573	477	200	077	177	977	677	230	232	233	234	235	236	237	238	239	240
	2000	Cean				CB40	05	CROO	90	05	CB	CB50					CB51		2 2	04	CBOE	CB CBS#	3				CBSF				05	CD			0.700	CBBB	0.5	0	0200	0 60	9	CB78							CB9D
;	1 6	0					78	5 5	78	78	19							9 5	9 6	F 5	5 8	8						22	25	00	7B	FE				;	7 8	9 :	77	3 5	10						22	25	1E
CB3A:68	CB3B:E9	CB3F:50	CB40:	CB40:	CB40:	CB40:	CB40:CE	CB43:10	CB47.87	CB4A:CE	CB4D:20	CB50:	CB50:60	CB51:	CB51:	CB51:	CB51:	CB51:A9	CB33:80	CB56:AD	CB39:30	CBSB:20	CRSE.60	CBSF:	CRSF	CBSF:	CB5F:	C85F: A5	CB61:85	CB63: A9	CB65:8D	CB68:4C	CB6B:	CB6B:	CBOB:	CBOB	CB6B:EE	CB6E: AD	CB/1:C3	CB/3:90	CB/3:20	CB78.	09.020	CB79.00	.620	CB79:	CB79:A5	CB7B:C5	CB7D:B0
_																																																_	_

CB36

45 * 4		CBBD:00 298	98 DFB	
EQU * LDA MODE BPL X.SO3 AND #255-M.VMO LDY #255) ***
LDA MODE BPL X.SO1 AND #255-M.VMO LDY #255		CBBF:4C		4
#255-M.VMO	SET MODE BIT			# <x.ff-\$80< td=""></x.ff-\$80<>
-	don't set mode for BASIC DE :SET 'NORMAL'	CBC1 : CB	302 DFB	# <x.so=58001 :so<="" td=""></x.so=58001>
				*
BNE STUFFING (ALWAYS)	ALWAYS)			0
House mountains in mine			306 DFB	****
53 * EXECUTE "INVERSE VIDEO" 54 *		CBC6:4C	107 DFB	# <x.dc2-\$8001; dc2<="" td=""></x.dc2-\$8001;>
* FOII *			309 DEB	0 0
LDA MODE ; SF	SET MODE BIT			# <x.nak-s8< td=""></x.nak-s8<>
X.SI1	don't set mode for BASIC			790
#M. VMODE	;SET 'INVERSE'		_	*
			313 DFB	-
60 SIUFFINA SIA MODE ; SE	SEL MODE	CBCD:4B	314 DFB	# <x.em=\$8001 ;em<="" td=""></x.em=\$8001>
7				- 40
				-
•				-
***	; ENQ		319 DFB	
784	1; ACK	+B	320 DFB	# <x.us-\$8001 ;="" td="" us<=""></x.us-\$8001>
#>X.BELL-I	BEL	CBD4:	28 INC	INCLUDE SUBS2
DFB #>X.BS-1 ;BS	185	CBD4:	* -	
#\W TE-1	al.	CBD4:	2 * SCROLLIT	* SCROLLIT scrolls the screen either up or down, depending
#>X.VT-1	LA	CBD4:	4 * or odd ed	5 * on the value of X. It scrolls within windows with even 4 * or odd addes for both 40 and 80 columns. If can earall
-	Da.	CBD4:	5 * windows do	* windows down to I characters wide.
-	CR	CBD4:	* 9	
#>X.SO-1	80	CBD4:A0 00	7 SCROLLDN LDY #0	Y #0 ;direction = down
#>X.SI-1	1s	CBD6:F0 15 CBED	8 BEQ	TITTO
0	DLE	CBD8:	* 6	
#>X.DC1-1	;001	CBD8:	10 * EXECUTE LINEFEED:	INEFEED:
# >X • DC2-1	DC2			
DFB U DC3	DC3	CBD8: CBD8	12 X.LF EQU	* :
WAY WAY	. 114.	CBD8:E6 25	13 INC	CA
#>SCBOILDN-	NAS.	CBDA: A5 25	Te CE	CV SEE IF OFF BOILD
	EL SI	CRDE-CS 23	TATE CMP	
-		9247 50 00 1247	17	V 1 20
#>X.EM-1	W2:	03 08	18 140	
#>X.SUB-1	SUB	CBE6:	*	and a
-		CBE6: CBE6	20 X.LF2 EQU	*
#>X.FS-1	*FS	CRE6:CE FB 05	21 DEC	OURCV ; back up to bottom
#>X.GS-1	59:	CBE9:C6 25	22 DEC	CV ; and fall into scroll
0	8	CBEB:	23 *	
DFB #>X.US-1 ;1	sn:	CBEB: A0 01	24 SCROLLUP LDY #1	
92 x		CBED:8A	25 SCROLLIT TX.	A ;save X
	8001 ; ENQ	CBEF:8C 7B 07	27 STY	TEMPI :save direction

22244 22244 22244 22244 22244 22244 2224 2224 2224 2224 2224 2224 2224 2224 2224 2224 2224 2224 2234 2234 2344

CBB114C FE CDB411
CBB411
CBB110
CBB110
CBB110
CBB110
CBB110
CBB110
CBB110
CBB110
CBB110
CBB111
CBB1111
CBB11111

CB9E

CBB9

CB8F 04 CB96

CB84 04 CB8B

LDA (BASL),Y STA (BASZL),Y		86 BCS	•	88 SIA (BASZL),Y	90 90	91 BMI	92 *	SCRLDN DEX	94 CPX WNDTOP			Of DOLLES FLE SPUT SCALUS OIL SCACK	STA WNDWDTH	JSR	JSR VTAB	PLA	TAX		105 *	106 * EXECUTE CLR TO EOS:		X.VT JSR X.GS	109 LDA CV ;SAVE CV		112 X.VTI.OOP JSR VTABZ		X.VTNEXT INC CV		116 CMP WNDBTM	117 BCC X.VTLOOP	PLA	STA CV	120 JMP VTAB ;return via VTAB (blech)	122 * EVECITE OFFAB:	122 * EAGUALE CLEAN.		125	TV. X TML	*	128 * EXECUTE CLEAR LINE	4	130 A.Sub LDY #U ;start at left	131 BEU A-63EULZ 132 *	133 * EXECUTE CLEAR TO EOL:		135 X.GS LDY OURCH ;get CH
28 2A	21 52		CC59:B1 28	CC3B:91 ZA	0058:10 89 0059	C :		CC62:CA		CC65:10 CE CC35	cc67:	87: 700	CC69:85 21		CC6E:20 FE CD	CC71:68	CC72:AA	0573:60	CC74:	CC74:			CC//:A5 25	CC/9:48	Ċ	CC7F:20 96 CC	25		23		CC8A:68	25	CCSD:4C FE CD			0600 :0600	20 SF CE		:9630	:9600	3600:	CC96: NO 00	c	CC9A:	CC9A:	CC9A:AC 7B 05
iget width of screen window isave original width	;in 40 or ou columns; ;=>40, determine starting line	; make sure this is enabled	; divide by 2 for 80 column index	; and save	test oddity of fight edge	:V=O if left edge even	:=>check right edge	; V=l if left edge odd	;restore WNDLFT	;get oddity of right edge	;C=1 if right edge even	יונ מתח דבורי ממת ר מפו	if right edge odd, need one less	save window width	;N=1 if 80 columns	; save N,Z,V	;assume scroll from top	;up or down?	dn<=:	down, start scrolling at bottom	;really need one less		get current line	carcurate base with window width	current line is destination					;test direction	; ">do the downer	;do next line	done yet:	, - yup, all none	get hase for new current line	set width for scroll	get status for scroll	:N=1 if 80 columns	;=>only do 40 columns	;scroll aux page first (even bytes)	itest Y	il I=U, only scroll one byce				odd left edge, skip this byte
WNDWDTH	GETSTI	SET80COL	¥	TO LOWIT	A	:	CHKRT	SEVI	¥	WNDWDTH	A	CETCT	10170	WNDWDTH	RDSOVID		WNDTOP		SETDBAS	WNDBIM			WTABA	ATABA	BASL	BAS2L	BASH	BAS2H		TEMP1	SCRLDN		WNDBIM	SCALLE	VTARZ	WNDWDTH			SKPRT	TXTPAGE2	1000		_		SCRLEVEN	SKPLFT
LDA	BPL	STA	LSR	T A	1.SR	CLV	BCC	BIT	ROL	EOR	LSR	0 0	DEX	STX	LDA	PHP	LDX	TAA	BNE	CDX	DEX		S TXA	400	LDA		LDA	STA		LDA	BEQ	IN	CPA			LDY	PLP	PHP	BPL	LDA	TAA	DEQ.	STA	DEY	BNE	BVS
288	31	32	33	2.4	36	37	38	39	40 CHKRT	41	42	77	45	46 GETST	47	48 GETST1	64	20	51	52		54 *	55 SETUBAS	* 22	58 SCRLIN	59	09	61	62 *	63	94	65	99	68 SPTSBC		70	7.1	72	73	74	75	77 CCBIETEN INA		42	80	81 SCRLFT
CBF2:A5 21 CBF4:48	10	CBFA:8D 01 CO	CBFD:4A	CBFE:AA		CC02: B8	CC03:90 03 CC08	CC05:2C 06 CB		CC09:45 21	CC08:4A	3 3	5	CC11:86 21	CC13:AD 1F CO		CC17:A6 22		CC1A: DO 03 CC1F		CCIE:CA	CC1F:	CC1 F:8A	20	CC23:A5 28			CC29:85 2B		78 07	CC2E: FO 32 CC62		CC31:E4 23	*	CC36:20 03 CE	21	CC3B:28	cc3c:08		CC3F: AD 55 CO	CC42:98	000			F9	CC4C:70 04 CC52

	mask blank	make it a blank		;=>yes do quick clear							screen for 40 to 80			;save X	;set horizontal counter		;set (inverse) blank			to and of line for 80 columns		X dues.	אַכּינּע אָנייּי.	talla orallik		save for refr edge check	;count=WNDWDTH-Y-1		;save on counter	tary on by 2 tot natt pages		"restore original ob	got starting nage	20ml 0			;iff WNDLFT odd, starting byte odd	;get blank	ting page	;else do page 2		now do page 1		;all done		;forward 2 columns	;next ch	;not done yet	restore X	good exic condition	, מווח וברתויי
	FSBO	#\$20	RD80VID	CLR80	(BASL),Y		HIGMONA	CLR40			oĘ	screen conversion		BAS2L	#\$D8	#20	INVFLG	#\$A0	CLR2	nd of line		RAS21.	11000				The state of the s	WINDWITH			4		WNDLFT	A	CLRO	CLRO			CLR1	TXTPAGE2	(BASL),Y	TXTPAGE1		CLR3	(BASL),Y			CLR2	BASZL		
:	AND	ORA PA	BIT	BMI	STA	IN	CPY	PCC	RTS			Con		STX	LDX	LDY	LDA	AND	JMP.			XTS	PUA		LYA	E S	SEC	200	3 2	1 50	TAV T	PLA	FOR	ROR	BCS	BPL	IN	PLA	BCS	BIT	STA	BIT	INX	BE0	STA	INY	INX	BNE	YOT	RTS	MAC
***************************************	A.GSEOLZ LDA				CLR40					ĸ	* Clear	* scree	*	CLRHALF						* *	*	CLRRO	0															CLR0		CLR2					CLRI				CLR3		
	135	138	139	140	141	142	143	144	145	140	147	148	149	150	151	152	153	154	155	156	158	159	160	161	101	701	163	104	166	167	169	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	188	200
			00	CCBD				CCA8											ပ္ပ																CCD2	CCD2			CCEO	00		00		CCE6				CCD5			
6	20	20			28			3						2A			32		02			2 A						17					20	ì	03	01			0.8			24		90	28			EF.	7.A		
34.4000	CC9D: A5	CCA1:09	CCA3:2C	CCA6:30	CCA8:91	CCAA:C8	CCAB: C4	CCAD: 90	CCAF: 60	CCBU:	CCBO:	CCBO:	CCBO:	CCB0:86	CCB2: A2	CCB4: A0	CCB6: A5	CCB8:29	CCBA:4C	CCBD:	CRD.	CCBD:86	CCBE-48	0000	2003 - 78	2000	CCC2:38	CCCS:ES	CCC 300	0000	4+ 1000	04:63	CCCA:45	CCCC: 6A	CCCD: BO	CCCF:10	CCD1:C8	CCD2:68	CCD3:B0	CCD5:2C	CCD8:91	CCDA:2C	CCDD:E8	CCDE: FO	CCE0:91	CCE2:C8	CCE3:E8	CCE4:DO	CCE6: Ab	CCE0:30	2000

8.:		;don't convert if Pascal	Pages	; set top of window (0 or 3		;=>no, no convert needed	else convert 80 to 40	,-/atways set new window					•••	· · ·		;=>no, no convert needed	;else convert 40 to 80		;get cursor	since new window left = (:=>yes, CH is ok	;else if CH is too big,	set it to 39	H) men eves.		esed.		; in 80 columns?	;=>no, set forty column wi	,	set 80 column window	;=/always branch	;set 40 column window	;assume normal window	;text or mixed?	;=>text, all ok		;set new top			OFF				;to disable mouse chars	NO	
* EXECUTE '40COL MODE':		MODE	myir's Pascal				SCKN64			80 column mode							SCRN48		OURCH			_			X.DCIC				BASCALC		D040			SELLOP	FULL40	-				WNDTOP	ro		* EXECUTE MOUSE TEXT				SMOUSE	242 * EXECUTE MOUSE TEXT ON	
UTE '		LDA	PTS	JSR	BIT	BPL	No.	2		80 col		EQU	JSR	BNE	BIT	BMI	JSR			CIC	ADC	BIL	BMI	CMP	20.			LDA	JSR	BIT	BPL		JSR	BEO	JSR	LDA	BIT	BMI	LDA	STA	TS RT		UTE M		FF LD	ORA	BNE	UTE M	
O * EXEC	* *	193	BMI X DCIRTS	95 X.DCIA JSR	9	_	ю г		* -	201 * Set	202 *	203 X.DC2	. .	· ·	۰.		mo i	* 500	210 X.DC18		7 7	~ .	.	•	۰.	717 718 X DC1C				2		*	25 D080	*	B D040	229 SETTOP	0	_	2	233 D040A	234 X.DCIRTS RTS	*	5 * EXEC	× .	238 MOUSEOFF LDA	a	240	2 * EXEC	
190				19			198		200	20		-					208	50	21	211	212				A 216	17	219	220	221	222	.4	224		227	228	22		A 231	23	23	23	235	236	737	23			24	
	4000	04	7	CO	0	CD09	(I)					CCFC	CA	CD3C	00	6000	CD		0.5			3	CDIA		CDIA	50	5		CA	00	CDZE		CD	CD31	CD		00	CD3A							90		CD49		
		AD FB	30 4D	CCEF: 20 31 CD	CCF2:2C 1F CO	CCF5:10 12	CCF/:20 91 CD	00 06:					CCFC: 20 90 CA	DO 38	CD01:2C 1F CO	CD04:30 03	CD06:20 C4 CD		CD09:AD 7B 05	18	CD0D:65 20	2C 1F	30 06	CD14:C9 28		CD18:A9 2/	CDID-85 24	CD1F: A5 25	CD21:20 BA CA	CD24:2C IF CO	CD27:10 05	. :	CD29:20 71 CD	CDZC: FU U3	:20 6D	CD31:A9 00	CD33:2C 1A CO	CD36:30 02	CD38: A9 14	CD3A:85 22	09:					0 60	50 00:		
CCEA:	CCEA:	CCEA: AD	CCED:30	CCEF	CCF2	CCFS	120	CCFA	CCFC	CCFC:	CCFC:	CCFC:	CCFC	CCFF: DO	CDOI	CD04	90GO	CD00	CD09	CD0C:18	CDOD	CDOF	CD12:30	CDI4	CDIP	CDIS: A9	010	CDIF	CD21	CD24	CD27	CD29:	CD29	CDZC:	CD2E:20	CD31	CD33	CD36	CD38	CD3A	CD3C: 60	CD3D:	CD3D:	CD3D:	CD3D: AD	CD40:09	CD42:D0	CD44:	,
	; with high bit of invflg	О	30 ;=>yes do quick clear 51.) v		HIGH	0,			If of screen for 40 to 80	non			set horizontal counter		TG ;set (inverse) blank				f line for 80 columns			;and blank	;get count for CH	; save for lett edge check	:count=WNDWDIH-Y-I	HLO.	.diw CH hw 2 for half name	ary on by 1 tot hakes		restore original ch				the cand maintain the Talling bit.	; get blank		AGE2 ;else do page 2		AGE1 ;now do page 1		; all done		; forward 2 columns				good exit condition	;and return	
INVFLG	\$\$80	RD80VID	(RASI.) V			CLR40			tht half of screen for 40 to 80	nversion		BAS2L	#\$D8	#20	INVFLG	#\$A0			end of line for 80 columns		BASZL					MUDMDIH		4			WNDLFT			CLRU		CLR1	TXTPAGE2	(BASL),Y	TXTPAGE1		CLR3	(BASL),Y			CLR2	BAS2L			
INVFLG		RD80VID	STA (RASI.) V	IN		BCC CLR40	KIS		ear right half of screen for 40 to 80	reen conversion		STX BAS2L	#\$D8	#20	INVFLG	AND #\$AO			ear to end of line for 80 columns		STX BAS2L							4			WNDLFT				PLA	BCS CLR1	BIT TXTPAGE2	(BASL),Y	TXTPAGE1		BEQ CLR3	STA (BASL),Y			BNE CLR2	LDX BAS2L	SEC ; good exit condition		
X.GSEOLZ LDA INVFLG	AND #\$80	BIT RD80VID	CLR40 STA (RASI.) V	INI	CPY	BCC			/ * Clear right half of screen for 40 to 80	* screen conversion		STX BAS2L	LDX #\$D8	LDY #20	LDA INVFLG	AND	JMP	* •	7 * Clear to end of line for 80 columns		STX BAS2L	PHA	TYA	PHA	SEC	SBC WNDWDTH	AVT	A ST	TAY	PLA	EOR WNDLFT	ROR	BCS	BPL CLRU	CLRO PLA	BCS CLR1	CLR2 BIT TXTPAGE2	STA (BASL),Y	BIT TXTPAGE1	INX	BEQ CLR3	CLRI STA (BASL),Y	IN	INX	BNE CLR2	CLR3 LDX BAS2L	SEC	KIS *	
X.GSEOLZ LDA INVFLG	\$\$80	139 BIT RD80VID	140 BMI CLR80	INI	143 CPY	144 BCC		1400	14/ * Clear right half of screen for 40 to 80	148 * screen conversion		CLRHALF STX BAS2L	LDX #\$D8	LDY #20	LDA INVFLG	AND	JME	156 *	157 * Clear to end of line for 80 columns		CLR80 STX BAS2L	PHA		PHA	SEC	MUDMDIH	AVT.	A ST	TAY	PLA	EOR WNDLFT	171 ROR	172 BCS	174 EPL CLRU	CLRO PLA	176 BCS CLRI	CLR2 BIT TXTPAGE2	STA (BASL),Y	BIT TXTPAGE1	180 INX	181 BEQ CLR3	CLRI STA (BASL),Y	IN	184 INX	185 BNE CLR2	CLR3 LDX BAS2L	SEC		
136 X.GSEOLZ LDA INVFLG	137 AND #\$80	139 BIT RD80VID	CCBD 140 BMI CLR80	142 INY	143 CPY	CCA8 144 BCC		404	147 * Clear right half of screen for 40 to 80	148 * screen conversion	* 671	150 CLRHALF STX BAS2L	151 LDX #\$D8	152 LDY #20	LDA INVFLG	154 AND	CC 155 JMP	* 951	157 * Clear to end of line for 80 columns	158 *	STX BAS2L	PHA	TYA	PHA	163 SEC	SBC WNDWDTH	AVT	A ST	TAY	PLA	EOR WNDLFT	171 ROR	CCD2 172 BCS	BPL CLRU	CLRO PLA	CEO 176 BCS CLR1	CO 177 CLR2 BIT TXTPAGE2	178 STA (BASL),Y	CO 179 BIT TXTPAGE1	180 INX	BEQ CLR3	182 CLRI STA (BASL),Y	IN	I 84	BNE CLR2	186 CLR3 LDX BAS2L	SEC	KIS *	

;in 80 columns?;;=>no, set forty column window

CCEA:

;set top of window (0 or 20);set we in 80 columns?;are we in convert needed;alse convert 80 to 40;">always set new window

;is there an 80 column card?;=>no, can't do this ;=>no, can't do this ;=>no, no convert needed ;else convert 40 to 80

SE ;clear mouse bit ;to enable mouse chars.	ONLY VALID IN BASIC ifgnore if pascal force 40 column window ido stuff used by PR#0 ;set output hook ;set input hook	SETCOUT1 LDA # <cout1 #="" ;set="" gsm4="" hook="" lda="" output="" sta="">COUT1 STA GSM2 STA CSW1 STA CSW1 ***********************************</cout1>	FULL40 EQU * LDA #40 ;set window width to 40 LDA #40 ;=>(always taken) ***********************************	set full 80 column window
A MODE D #255-M.MOUSE A MODE ;to S	* MODE SKRTS SKRTS OUT OUT SETCOUT \$<	## COUTI ; set ou CSMH SOUTI CSWL CSWL CSWL SET FULL 40COL WIN NONE NONE ACCOL WIN ACC	* #40 ;set wil #80 ;set wil #80 ;set wil #80 ;set vil #80 ;set wil #80 ;set wil #80 }set set set set set set set set set set	#80 WNDWDTH #24 WNDBTM #0 WNDTOP WNDLFT
** MOUSEON LDA AND SMOUSE STA * * EXECUTE 'Q	X.NAK EQU EDA BHI JSR JSR JSR SETKEYIN LDA STA LDA STA LDA STA	SETCOUTI LDA STA LDA STA LDA STA STA STA STA STA STA STA STA STA ST	FULL40 EQU LDA BNE ** ************* * NAME : : * FUNCTION: : * INPUT : : * VOLTPUT : * * VOLATILE: * ***********************************	SAVWDTH STA SAVWDTH STA LDA STA LDA STA STA STA STA
244 244 245 247 244 244 244 244 244	CD4D 2510 252 254 254 255 254 255 255 257 257 257 257 257 257 257 257		CD60 278 279 CD73 280 281 282 283 284 285 285 286 286 286	290 291 293 293 294 295 295
FB 04 FE FB 04	FB 04 11A 22E CD 28 CC 64 CD FD 11B 38	37 36 36	02 8	50 21 18 23 00 22 20
CD44: CD44:AD CD47:29 CD49:8D CD40:CD4C:60 CD4D: CD4D:	CD4D1: CD4D1: CD4D1:AD CD5D1:20 CD5D1:20 CD5B1:20 CD5B1:40 CD5B1:40 CD5B1:40 CD5P1:40 CD5P1:40 CD5P1:40 CD6D1:4	CD66:85 CD66:85 CD66:85 CD66:85 CD66:80 CD60:	CD6D: CD6D:A9 CD6P:D0 CD71:	CD71:A9 CD73:85 CD75:A9 CD77:85 CD79:A9 CD78:85

RTS is used by $PR\#0$ to turn off everything	Samueloo 08 at an areas.		; switch to 40 columns	CHAR ;don't use lower case	; DESTROY THE	; MODE BYTE		CODMA CODMA CONTRACT CONTRACT AND A SAME CODE	t 6	d.		;save X		;start at bottom of screen		; calc base for line		start at right of screen	1 index	;div by 2 for 80 column index			even column, do page	.get 80	iger on	:get 40			;do next 40 byte	; do next line	:=>done	;at top yet?	Of sar ROSTORE for 40 columns				;save X		bottom of sc	;set base for current line		start at lett	;enable		; save char
ed by PF	*	QUITZ	X.DC1A	CLRALTCHAR	# SFF	MODE		CODM'S	t he set	All reg				#23	SET80COL		BASCALC	#39	BAS2L		A	SCR3	IXIFAGEZ	(BACT) V	TYTPACE!	BASZL	(BASL),Y		SCR2		SCR4	WNDTOP	CLEROCOL	CLR80VID	SCRNRET				#23	140040	BASCALC	0#	SETSUCOL	RAC21	-
RTS Is us	EQU	BPL	JSR	STA	LDA	STA	RIS		P mis	ne.		TXA	PHA	LDX	STA	TXA	JSR	LDY	STY	TY.	LSR	BCS	114	177	RIT	LDY	STA	DEY	BPL	DEX	BMI	CPX	STA	STA	JM,		TXA	PHA	LDX	IXA	J.SK	LDY	STA	N A	PHA
드	QUIT			QUIT2				* CCDNG/	* WNDTO	* be done.	*	SCRN84				SCRI			SCR2				6000	200									74.75				SCRN48			SCRS				SCRO	
297 298 299 300	301	303	304	305	306	307	308	309	315	312	313	314	315	316	317	318	319	320	321	322	323	324	323	227	328	329	330	331	332	333	334	335	337	338	339	340	341	342	343	344	340	346	347	240	350
	CD80	CD88	22	8		90									8		CA					CDA/	3		5				CD9E		CDBB	8000	5	8 8	CD						CA		8		
	1	03	EF	0E	FF	FB								17	01		BA	27	2A		9	6	2	0	9 7	2 4	28		EA	į	04	22	3 8						17				0 0	27	47
CD7F:60 CD80: CD80: CD80:	CD80:	CD83:10	CD85:20	CD88:8D	CD8B: A9	CD8D:8D	09:060	CD91:	. 1600	CD91:	CD91:	CD91:8A	CD92:48	CD93:A2	CD95:8D	CD98:84	CD99:20	CD9C: AO	CD9E:84	CDA0:98	CDA1:4A	CDA2: B0	CDA4:20	CDA/: Ao	CDAA: 51	CDAD: A4	CDAF:91	CDB1:88	CDB2:10	CDB4:CA	CDB5:30	CDB7:E4	CDEB-8D	CDBE:8D	CDC1:4C	CDC4:	CDC4:8A	CDC5:48	CDC6: A2	CDC8:8A	CDC9:20	CDCC: AO	CDCE:8D	CDD1:81	CDD5:48

; *>cursor off, don't invert	;save AC	: AND Y		;GET CH	GET CHARACTER	; FLIP INVERSE/NORMAL	; ONTO SCREEN	; RESTORE Y	; AND AC			********************		CHAR ON SCREEN		TION	SCREEN			*********************			; SAVE AC	; NORMAL OR INVERSE?	;=>NORMAL	;inverse it		;=>do it!!	; RESTORE AC		******************		RECOM SCREEN	NOIL	TER		*************	***************************************	sectionary confice of the	.80 columns?	=>no do text shift	. For a SOCHODE for 80 columns	positi	divide CH by two	;C=1 if char in main RAM	get low bit into carry	;=>store in main memory	;else switch in page 2		;divide position by 2	;and use carry as	; page indicator
INVX				OURCH	PICK	#\$80	STORIT					*******	STORCHAR	STORE A CH	AC=CHAR	Y=CH POSITION	CHAR ON SC	NOTHING	SCREENIT	*******		*		INVFLG	STOR2	#\$7F	*	STORIT			*****	PICK	GET A CHAR FROM	Y=CH POSITION	AC=CHARACTER	NOTHING	SCREENIT	***	A (1374)	pheny, i	PICKS	CETBOCOT	BAS21.		WNDLFT	A	PICK1	TXTPAGE2			4	
BNE	PHA	TA	PHA	LDY	JSR	EOR	JSR	PLA	TAY	PLA	RTS	****			••	••	••			***		EQU	PHA	BIT	BMI	AND	EQU	JSR	PLA	RTS	***	••	ION:			I.LE:	:	*	2	RIT	RPI	A TO	A L	Y	EOR	ROR	BCS	LDA	IN	TYA	LSR	TAY
	INVERT										INVX	******	* NAME	* FUNCTION:	* INPUT	*	* OUTPUT	* VOLATILE:	* CALLS	******	*	STORCHAR EQU					STOR2				****	* NAME	* FUNCTION:	* INPUT	* OUTPUT	* VOLATILE:	* CALLS	*		FICK										PICK1		
20	21	22	23	24	25	56	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	77	45	46	47	48	64	20	21	25	53	54	55	\$:	25	200	200	20 5	5 6	70	20	65	99	67	99	69	70	71	72	73
CE37				05	CE		CE															CE38			CE3F		CE3F	CE												ç		1000	3				CE5A	ဗ				
Ξ				78	77	80	70																	32	02	7.		70											6	97	10	1 2	24	i	20		04	55				
CE24:D0	CE26:48	CE27:98	CE28:48	CE29:AC	CE2C:20	CE2F:49	CE31:20	CE34:68	CE35: A8	CE36:68	CE37:60	CE38:	CE38:	CE38:	CE38:	CE38:	CE38:	CE38:	CE38:	CE38:	CE38:	CE38:	CE38:48	CE39:24	CE3B:30	CE3D:29	CE3F:	CE3F:20	CE42:68	CE43:60	CE44:	CE44:	CE44:	CE44:	CE44:	CE44:	CE44:	CE44:	CE44:	CE44: B1	01.0740	0549.10	CE4B: OD	CE 50:98	CE51:45	CE53:6A	CE54: BO	CE56: AD	CE59:C8	CE5A:98	CESB:4A	CESC: A8

:div 2 for 80 column index		SCR7 ; save on pagel			;now save character		El ;flip pagel	BAS2L ;restore 40 column index	move to	;at right yet?	;=>no, do next	en	;else do next	•	WNDTOP ; at top yet?		OVID		;restore X					:cob	C ;calc hase address	••	۵	w width ok	;else divide width by 2	; prepare	ppw:		; and exit		#\$El ;is it lowercase?		FT2				********************	INVERT	CHAR AT CH/	Unless Pascal and M.CURSOR=1		CHAR AT CH/CV INVERTED	NOTHING	PICK, STORCHAR	*************************************		MODE ; check pascal cursor flag	
¥.	LSR A			TAY		_													PLA	TAX	RTS			_		_			LSR A				RIS	3	CMP #\$				RTS		*****	· IN			: NOT	••		: PIC	*****		LDA MC	
				SCR7	- 7			2000										SCRNRET				*	VTAB		VTABZ					VTAB40			VTABX		UPSHFT				UPSHFT2	*	******	* NAME	* FUNCTION:	*	* INPUT	* OUTPUT	* VOLATILE:	* CALLS	****		PASINV	
35.1	352	353	354	355	326	357	328	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	53		7 "	4	. 7	9	7	00	6	10	11	12	13	14	15	16	17	18	
		CDDD	00				00				CDD1	ည		CDF5		CDC8	00	ຕ						05	CA		8	CEOE								CELE	CRIR														90	
		03	25			28	24	2A		28	E6	80		90	22	D3	00	E					25	FB	BA	20	1.5	01			58	28		1	EI	20 2	0	DF													£ .	
80.900	CDD7:4A	CDD8:BO	CDDA:8D	CDDD: A8	CDDE: 68	CDDF:91	CDE1:8D	CDE4: A4	CDE6:C8	CDE7:C0	CDE9:90	CDEB:20	CDEE: CA	CDEF:30	CDF1:E4	CDF3:B0	CDF5:8D	CDF8:20	CDFB:68	CDFC: AA	CDFD:60	CDFE:	CDFE: A5	CE00:8D	CE03:20	CE06:A5	CE08:2C	CEOB:10	CEOD: 4A	CEOE: 18	CEOF:65	CE11:85	CE13:60	CE14:	CE14:C9	CE10:90	CE IA: BO	CE1C:29	CE1E:60	CEIF:	CE1F:	CEIF:	CEIF:	CE1F:	CEIF:	CEIF:	CELF:	CEIF:	CEIF:	CELF:	CEIF: AD	000.0000

																																															_
(BASI),Y ;get that char IXTPACEI ;flip to page l BASI.	,oury allow mouse teat if alternate character set					*****									*****		ıar	if high bit set	:=>not mouse text	is mouse text enabled?	use carry as flag	store char	need to save it too		ALTCHARSET ; only do mouse text if	alt char set switched in	do mouse shift	is it in proper range?	=>yes, leave it	else shift it back		:sums:	=>no, 40 columns	force 8USTURE for 8U columns	SHILLER CHAIACLEL	nosition	C=1 of char in main RAM		main RAM	else flip in main RAM	do this for odd left bytes		ride it by 2		acc	screen	to page 1
get that char;	if alte					*******			store	of char	LION	(CK)			******		;save char	if high	:=>not m	: is mous	;use car	; and restore	ineed to		f ;only d	;alt cha	snow op:	its it i	;=>yes,	else sh		;80 columns?	,=>no, 4	; torce 8USTUR	, save su		.C=1 1f		:=>yes.	;else fl	;do this	:get pos	;and divide it		;restore acc	;save to screen	flip to
(BASL),Y TXTPAGE1 BAS2L	PICK4	F\$20	075#			****************************	STORIT	STORE CHAR	AC=char for store	Z=high bit of char	Y-CH POSITION	AC=CHAR (PICK)	NOTHING	NOTHING	******************			#SFF	STORE	MODE	A			STORE1	ALTCHARSET	STORE1	075#	HEX60	STORE	4\$40		RDSOVID	STOR40	SETRUCOL	1634		WNDLFT	A	STORE2	TXTPAGE2			A			(BASL),Y	TXTPAGE1 BAS2L
LDA	BPL	BCS	ORA	RIS		***	••	ON:		••	••		LE:	••	***		PHA	AND	BMI	LDA	ROR	PLA	PHA	တ္ထ	BIT	BPL	EOR	BIT	BEO	EOR		BIT	BPL	SIA		Y	FOR	SP	BCS	LDA	INY	TYA	LSR	TAY	PLA	STA	LDA LDA
PICK2				PICK4	*	******	* NAME	* FUNCTION:	* INPUT	*	*	* OUTPUT	* VOLATILE:	* CALLS	******	*	STORIT														*	STORE										STORE2			STORIT2		
75 75 76		8 3	81	82	83	84	85	86	87	88	89	9	91	92	6	94	95	96	46	86	66	001	101	102	103	104	105	901	107	108	601	110	111	711	117	115	9	117	118	119	120	121	122	123	124	125	126 127
8 8		CE6F																		90					ဗ	CE8B		S	CE8B			ರ		3					CEAO	00							පි
28 24 24			40	100																FB				_		_				40				10	2.4		20		90	55				8 10			2A
CE5D:B1 CE5F:2C CE62:A4	CE67:10	CE6B:BO	CE6D:09	CE6F: 60	CE70:	CE70:	CE70:	CE70:	CE70:	CE70:	CE70:	CE70:	CE70:	CE70:	CE70:	CE70:	CE70:48	CE71:29	CE73:30	CE75: AD	CE78:6A	CE79:68	CE7A:48	CE7B:90	CE7D:2C	CE80:10	CE82:49	CE84:2C	CE87:F0	CE89:49	CE8B:	CE8B:2C	CESE: 10	CE90:80	78.7040	CE96.98	CE97:45	CE99:4A	CE9A: B0	CE9C:AD	CE9F:C8	CEA0:98	CEA1:4A	CEA2: A8	CEA3:68	CEA4:91	CEA6: AD CEA9: A4

CED4 183 PSETUP EQU 184 188 180 1.0A 184 185 186 1.0A 185 187 186 1.0A 186 187 186 1.0A 186 187	:0000	:0000	:0000	:0000	S	s s	S	S	:0000	:0000	.0000	: 0000	0000		:0000	.0000	:0000	0000	:0000	:0000	:0000	:0000	:0000	:0000	:0000	:0000	0000	:0000	:0000	.0000	F800:	F800:	F800:	F800:	F800:	F800.	F800:	F800:	F800:	F800:	F800:	F800:	F800:	F800.	-
20 71 CD D4 183 PSETUP BOU * 85 32 186 STA INVFLG 86 32 186 STA INVFLG 86 32 186 STA INVFLG 87 187 LD D4 4255 88 32 186 STA INVFLG 88 188 LD MDDE 89 192 * LD MDDE 89 28 LD MDDE 89 28 LD MDDE 89 28 LD MDDE 89 28 LD MDDE 89 29 SETUPRET EQU * 80 28 LD STA BAEL 80 20 STA BAEL 80 8 STA BAEL 80 STA		ENTERIN TOUCH	OCCUP MINDOR	IORMAL MODE			INVERSE			ASE ADDRESS			's cursor vertical	1t up		***	oo firmuara (c	card is switched	F8 ROM to the	state of the			C switched in?	nothing ck SF8 RAM	match?	ROM is there	bank 2, RAM write enabled	in 2: p were right	write	see if LC is	otected (read RAM)		rite enabled	icate write protect	, write RAM	nice	KUM to KAM	t later		te.	it			Aug	
20 71 CED4 183 # 2 * 4 * 4 * 5 * 5 * 5 * 6 * 5 * 5 * 6 * 6 * 5 * 6 * 6		1 1110 400	isti rutt	; ASSUME N						SET UP B.			get user	; and set		*	on the vide	language	opies the	stores the			is the L	ves. chec	does it r	;=> assum	; indicate	=>ves. we	;no, bank	;write to	write		;=>yes, wi	;else tudi	; read ROM,	twice is	inow copy	:hooks set		get a byt	;and move		apen twen.	· finish co	THITSH CO
20 71 CED4 183 # 2 * 4 * 4 * 5 * 5 * 5 * 6 * 5 * 5 * 6 * 6 * 5 * 6 * 6		* 6	#255	INVFLG	MODE	#M.VMODE	INVFLG		* 1	OLDBASL	BASL	RASH	OURCV	CV		***	called who	d. If the	ding, it co	ard and res	ard.		RDLCRAM	#GOODF8	F8VERSION	ROMOK	#3	BANK2	#\$B	F8VERSION	FRUERSTON	#GOODF8	WRTENBL		\$0081	\$0081	#SES	CSWH	CSWL	(CSWL),Y	(CSWL),Y	CHOAVEON	7LION	CMO	
20 71 CD	*		1880		LDA	AND	LSR	*	PSETUPRET EQI	LDA	STA	STA	LDA	STA	RTS	***********	* COPYROM 1s	* initialized	* in for read	* language Ca	* language Ca	*	COPYROM BIT	LDA	CMP	BEQ	LDX	BMI			BIT	CMP	BEQ			LIS	LDA	STA			STA	RNF	TNC	RME	THE
### 19 10 10 10 10 10 10 10	182	183	185	186	188	189	191	192		194	195	190	198	199			203	204	205	506	207			211	212	213	214	216	217	218	219	221	222			577	227	228			231	232	234	235	100
8 8 9 8 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9		5			70	7000	t day						05										9245	0630	FB	CF36	5	CF09			CO ##	2	CF17	,	8 8	3						CE25	0170	CF25	
CED4: CED7: CED7: CED7: CED7: CED8:		7	FF																																										
	CED4:	CED4:	CED7: A9	CED9:85	CEDB: AD	CEDE:29	CEE2:46	CEE4:	CEE4:	CEE4:AD	CEE/:85	CEES: ALL	CEEE: AD	CEF1:85	CEF3:60	CEF4:	CEF4:	CEF4:	CEF4:	CEF4:	CEP4:	CEF4:	CEF4:2C	CEF9: A9	CEFB:CD	CEFE: FO	CF00: A2	CF05:30	CF07:A2	CF09:8D	CFOC: 2C	CF12:C9	CF14:F0	CF16:E8	CF1/:2C	CFIA:2C	CF1F: A9	CF21:85	CF23:84	CF25:B1	CF27:91	CF29:C8	CF2C: E6	CF2E: DO	-

;left edge of text window ;vidth of text window ;top of text window ;bottom+1 of text window ;cursor horizontal position ;cursor vertical position ;lo-res graphics base addr.

> EQU EQU EQU EQU EQU EQU EQU

00000 00001 00021 00022 00023 00024 00025 00026

text base address;

;vector for autost from disk

* Zero Page Equates

COND ASSM/RRA0981

0001

F800 2000

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1977
14 * JOHN A
15 * R. AURICCHIO SEP 1981
16 * E. BEERRINK
17 *

* MONITOR II

* APPLE II

\$F800 \$C100 \$C300 \$C800

F800 C100 C300 C800

8 C10RG 9 C30RG 110 C80RG 111 12 F80RG 13 C10RG 14 C30RG 15 C80RG

For setting PR# hooks;

\$1800 \$2000 \$2100 \$2300 \$2800

SET THEM HIBITS

On, A, V

3 IRQTEST

1000

EQU EQU MSB MSB DO EQU EQU

1 TEST

0000

;NMI vector ;Maskable interrupt vector	first line of text screen	;current user of \$C8 space						;enable slots 1-7	;swap out slots for firmware																				COO - F - COL	COOKSTATA ; INC entry in aca page	מייים מיים מייים מייים מייים מייים מייים מייים מייים מייים מייים מ	29	10	AA				:Y-COORD/2		CALC BASE ADR IN GBASL, H	; MASK \$0F IF EVEN
\$03FB \$03FE	\$0400	\$07F8	TEST	0000	\$0000		\$0000	\$000\$	\$000	\$0010	\$CUIF	90050	SC050	\$0051	\$0052	\$0053	\$0034	\$005	\$0057	\$0058	\$0029	SC05B	\$C05C	\$C05D	\$C05E	\$000s	\$000\$	\$000	20.0000	30RC+\$1		C30RG+\$267	C30RG+\$2D1	C3ORG+\$2AA	SCFFF	\$E000	\$E003	V		GBASCALC	#\$0F
EQU		EQU			FIN		EQU :	4 EQU	EQU !			000					FOIL					FOIL			EQU			EQU (FOIL			_	EQU (EOU			LSR		JSR (
NMI	LINEI	96 MSLOT			100 104DK	*		104 SLOTCXROM EQU \$C006		KBDSTRB	10/ RDSUVID	CDVD	TXTCLR	TXTSET	MIXCLR		LOWSCK	LORES	HIRES	SETANO	_	CLRANI	SETAN2	CLRAN2	124 SETAN3 F	TAPEIN	PADDL.0	PTRIG	129 *	X		2	XREAD	135 WRITE2 F	CLRROM	138 BASIC F	139 BASIC2 F	PLOT		143	
03FB 03FE	0400	07 F8	0000	0	0000		0000	9000	2000	0100	COLF	0030	0020	C051	C052	C053	2004	CO 26	C057	C058	6502	CO 5 B	C05C	C05D	C05E	2090	C064	0200	4460	C47C	,	C567	C5D1	C5AA	CFFF	E000	E003				
		F800: 0		F800:		F800:					F800:					F800:					F800:				F800: C				F800:					F800: C		F800: E	F800: E	F800:4A	!	F802:20 47 F8	F806:A9 OF
temp base for scrolling;	;temp for lo-res graphics	;temp for mnemonic decoding	temp for mnemonic decoding	; color mask for lo-res gr.	temp for opcode decode	temp for tape read csum	temp for opcode decode	;color for lo-res graphics	; Monitor mode	;normal/inverse(/flash)	prompt character	town for V register	character output hook		;character input hook		temp for program counter	:A1-A5 are Monitor temps							the section of the se	juacitue state for oreak	;Acc after break (destroys A5H)	X reg after break	Y reg after break	SP after break	; random counter low	;random counter high		;CONTROL-U character	;input buffer for GETLN			; vectors here after break	;vector for warm start	HIS MUST = EOR #\$A5 OF SOFTEV+1	Articoli a ball vector; Applesoft USR function vector
\$29 \$2A	\$28 \$20	\$2C	\$2D	SZE	\$2E	\$2F	\$2F	\$30	\$31	\$32	224	533	\$36	\$37	\$38	459	338	\$3C	330	\$3E	53F	541	342	543	244	345	545	346	7 4 7	648	34E	34 F		362	30200		ırs	303F0	\$03F2	03F4	03F8
EQU	EQU	FOIL	EOU	FQU	EOU	EQU	EQU .	EQU	EOU	EQU	FOIL	FOIL	EQU	EQU	EQU	EQU.	FOIL	FOU	EQU	EQU	EQU	EOU	EQU	EQU	EQU	EQU	EQU	EQU	EQU .	FOU	EQU ;	EOU ;		EQU	EQU \$		3 vector		EQU \$		
BASH BAS2L	40 BASZH 41 H2	LMNEM V2	RMNEM	MASK	47 FORMAT	LASTIN	LENGTH	COLOR	MODE	INVFLG	VSAV	YSAVI	CSWL	CSWH	58 KSWL	KSWH	PCH	AIL	AlH	A2L	AZH A31	67 A3H	A4L	A4H	A5L	A5H	ACC	XREG	YREG	SPNT	RNDL	RNDH	*	PICK *	IN	*	85 * Page 3	BRKV		AMPREDUP	91 USRADR
F800: 0029 F800: 002A																																		000: 000:	000: 0200	:00:	7800:				F800: 03F8

MASK \$FO IF ODD	; DATA	; XOR COLOR	; AND MASK	; XOR DATA	; TO DAIA		; PLOT SQUARE	; DONE?	; YES, RETURN	; NO, INCR INDEX (X-COORD)	PLOT NEXT SQUARE	NEXT Y-COORD	; SAVE ON STACK	; PLOT SQUARE		DONE?	, wo, too, .		; MAX Y, FULL SCRN CLR	; ALWAYS TAKEN		STORE AS BOTTOM COORD	FOR VLINE CALLS	RICHTMOST X-COORD (COLUMN)	TOP COORD FOR VLINE CALLS	DRAW VIINE	NEXT LEFTMOST X-COORD	LOOP UNTIL DONE.		FOR INPUT GODEFGH			GENERATE GBASH=000001FG	OOOgdadan 134go day.	AND GBASL-HDEDECOO									: INCREMENT COLOR BY 3	
RTMASK #\$E0 MASK	(GBASL),Y	COLOR	MASK	(GBASL),Y	(GBASL),		PLOT	H2	RTS1		PLOTI	#SO1		PLOT		V2	TOTAL		#\$2F	CLRSC2	#\$27	V2		#\$27	00100	VILTNE		CLRSC3				#\$03	# \$0¢	GBASH	910#	GBCALC	#\$7F	GBASL	A	A	GBASL	GBASL		COLOR	
BCC ADC STA	LDA	EOR	AND	EOR	RTS		JSR	CPY	BCS	IN	JSR	ADC A	PHA	JSR	PLA	CMP	RTS		LDY	BNE	LDY	STY	į	F F	LDA	ISB	DEY	BPL	RIS	PHA	LSR	AND	ORA	SIA	A PLA	BCC	ADC	STA	ASL	ASF	ORA	STA	KIS	LDA	
RTMASK	PLOT					*	HL I NE	HL INE!				VLINEZ	VLINE				RTS1	*	CLRSCR			CLRSC2			CLRSC3				*	GBASCALC PHA								GBCALC					*	NXTCOL	
146 147 148	149	150	151	152	154	155	156	157	158	159	160	162	163	164	165	166	168	169	170	171	172	173	174	175	177	178	179	180	181	183	184	185	186	187	188	190	191	192	193	194	195	196	100	199	
F80C							F8		F831		F8	roic		F8		7000	1070			F838						82		F83C								F856									
02 E0 2E	26	30	2E	26	97		8	2C	11		OE Pe			00		20			2 F			2D			3 6			F6						17	0							26		30	
F808:90 F80A:69 F80C:85	F80E: B1	F810:45	F812:25	F814:51	F816:91	F819:	F819:20	F81C:C4	F81E: B0	F820:08	F821:20	F826:69	F828:48	F829:20	F82C:68	F82D:C5	F831:60	F832:	F832: A0	F834:D0	F836: AO	F838:84	F83A:	F83A: A0	F83C: A9	F840:20	F843:88	F844:10	F846:60	F847:48	F848:4A	F849:29	F84B:09	F84D:85	F84F:58	F852:90	F854:69	F856:85	F858:0A	F859:0A	F85A:05	F85C:85	FROE: DO	F85F: A5	
																									4																				

P87F-29 OF P881-60 P882: P882-A6 3A P886-20 96 FD P886-20 96 FD P886-20 96 FD P886-21 3A P886-31 3A

F87F

F878:28 F879:90 04 F878:4A F87C:4A F870:4A

F8

F872:08 F873:20 47 F F876:B1 26

F871: F871:4A F870:60

P861:18 P862:69 03 P864:29 0F P866:85 30 P868:0A P869:0A P869:0A P866:05 30 P86E:05 30

F8A9

P89B:4A P89C:4A P89C:4A P89D:8D 62 F9 P8A3:D0 04 F8 P8A3:D0 04 P8 P8A3:A9 00 P8A3:A9 00 P8A3:A9 00 P8A4A P8A4A B9 6 F9

F8AF: F8AF: F8AF: F8AF: F8AF:

F8A5

F892:6A

F893:B0 10 F895:C9 A2 F897:F0 0C

F88E:A8 F88F:4A F890:90 09

	^			
3	ತ	ĸ.	5	4

TAX STY BAS2L ;aad Y in scrolling temp LDY #\$10 ;call = finish mnemonics ** Test slot 3 for a card containing ROM. ** If there is one, we'll not switch in our internal ** alor 3 fireware (for 80 columns). ** On entry Y has a high value like \$F2, so the ** ROM/bus is read a bunch of times ** ROM/bus is swap internal ROM ** INTCKOM sand return there ** NOP
TAX STY BAS21. LDX #\$10 JPE GOTOCX slot 3 for a ci sere is one, we' stry bas a high uns is read a bi STA SLOTOXROP ILDX #2 DEX CHP CLREDL, X CHP CLC, Y JSR PRENTE LDA #501 LDA
TAK STA JUDY SILO SI
254 255 257 258 259 259 250 250 250 250 250 250 250 250 250 250
255 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
PRAF: AA PRBD: 84 2A PRBD: 84 2A PRBD: 84 10 PRBD: 10 PRBD: 10 PRBD: 10 PRBD: 10 PRBD: 10 PRBD: 10 PRBD: 10 PRD: 10 PR

;PCL, PCH+OFFSET+1 TO A,Y

;+1 TO Y,X

PRNTYX

OUTPUT TARGET ADR

PRBYTE

PRBYTE

;HANDLE REL ADR MODE ;SPECIAL (PRINT TARGET, ; NOT OFFSET)

PRADR2 PRBYTE FORMAT #\$E8 (PCL),Y PRADR4

PRADRI

CNT FOR 6 FORMAT BITS

; OUTPUT 3 BLANKS

; IF X=3 THEN ADDR.

PRMNI
PREJIM
LENCTH
LENCTH
#\$00

#\$03

PRADR5
PRADR5
COUT
COUT
COUT
COUT

; PCL+LENGTH(OR DISPL)+1 TO A ; CARRY INTO Y (PCH)

PCL RTS2 XXXXXXYO INSTRS THEN LEFT HALF BYTE THEN RIGHT HALF BYTE

:TEST DISPLACEMENT SIGN : (FOR REL BRANCH) :EXTEND NEG BY DECR PCH

;0=1 BYTE, 1=2 BYTE, ; 2=3 BYTE

> LENGTH PCH PCADJ4

LOOP UNTIL COUNT=0

#\$03 #\$A0 COUT PRBL2

;BLANK COUNT ;LOAD A SPACE ;OUTPUT A BLANK

	ERR : INM : INM : ABS : ABS : IMPLIED : ACCUMULATOR : (2PAG, X) : (2PAG, X) : ZPAG, X : ABS, X : ABS, X : ABS, X : (ABS) : ZPAG, X	RELA
\$00 \$80 \$04 \$04 \$04 \$22 \$44 \$34 \$90 \$90 \$90 \$90 \$90 \$90 \$90 \$90 \$90 \$90	INSTR'S 1005	\$90 9AC 9AC 9AC 9AA 9AA 9AA 9AA 9AA 9AA 9BB 9BB 9BB 9BB
DPB DPB DPB DPB DPB DPB DPB DPB DPB DPB	TZZXXXY01 I TZZ DFB DFB DFB DFB DFB DFB DFB DFB	DF8 1 0 PF8 1 0 PF8 1 0 PF8 2 0 PF8 2 0 PF8 2 0 PF8 1
416 417 418 419 420 422 424 424 427 426 430 430	· · · · Ē	448 449 CHARI 451 452 454 455 455 455 460 460 460 461 461 463 465 466 466 466 467 466
444444444444444	<i>ববববববববববব</i>	<u> </u>
F996:0D F997:80 F997:80 F998:04 F998:22 F998:22 F990:44 F990:44 F990:44 F990:33 F997:80 F997:80 F997:31 F994:37 F944:87	F946: F946: F946: F947:21 F943:81 F948:81 F948:81 F948:00 F948:00 F948:91 F948:91 F948:91 F948:91	9983:90 9985:49 9986:46 9986:47 9986:43 9988:48 9988:48 9988:40 9986:10 9987:11 9962:11 9962:11 9963:98
F996 F998 F999 F999 F996 F996 F996 F997 F997 F998 F998 F998 F998	66666666666666	888888888888888888888888888888888888888

```
        P962:
        362 ;
        (K=INDEX)

        P962:
        364 FMT1
        PR

        P962:04
        364 FMT1
        DFB $20

        P963:20
        365 FMT1
        DFB $20

        P964:34
        36 DFB $20

        P965:30
        367 DFB $30

        P966:00
        36 DFB $30

        P966:00
        370 DFB $30

        P966:00
        371 DFB $30

        P968:04
        371 DFB $30

        P968:04
        371 DFB $30

        P968:05
        373 DFB $30

        P968:06
        374 DFB $30

        P968:07
        373 DFB $30

        P968:08
        374 DFB $30

        P97:09
        373 DFB $30

        P97:00
        374 DFB $30

        P97:00
        373 DFB $30

        P97:00
        374 DFB $30

        P97:00
        374 DFB $30

        P97:00
        377 DFB $30

        P97:00
        378 DFB $30

        P97:00
        378 DFB $30

        P97:00
        378 DFB $30

        P97:00
        378 DFB $30

        P97:30
        384 DFB $30

        P97:30
        384 DFB $30
```

	; (A) FORMAT	; (B) FORMAT ; (C) FORMAT
\$AA \$BB \$BB \$5.54	\$72 \$72 \$72 \$84 \$88 \$00 \$00 \$74 \$74	\$37 \$44 \$44 \$68 \$32 \$32 \$50 \$50 \$1A \$1A \$1A \$25 \$25 \$25 \$25 \$25 \$25 \$25 \$25 \$25 \$25
0 PPB	DFB DFB DFB DFB DFB DFB DFB	DFB
524 525 MNEMR 526 MNEMR 527 528 528 529 531 531 531 534 534 534 544 544 544 546 550	552 554 554 558 558 560 560 561	563 564 564 565 565 569 569 570 571 572 573 574 575
F9FF: AO FAO1: B6 FAO1: B6 FAO2: 54 FAO3: 48 FAO5: 55 FAO5: 56 FAO5: 56 FAO5: 56 FAO5: 56 FAO5: 56 FAO6: 94 FAO7: 88 FAO8: 44	FALC: 72 FALC: 72 FALD: F2 FALS: 84 FAZO: 00 FAZO: 00 FAZO: AA FAZO: AA FAZO: AA FAZO: AA FAZO: AA	FAZ6:74 FAZ6:74 FAZ7:72 FAZ7:68 FAZ9:68 FAZ7:82 FAZC:82 FAZC:9
; (A) FORMAT ABOVE	; (B) FORMAT ; (C) FORMAT	; (D) FORMAT ; (E) FORMAT
\$84 \$110 \$910 \$910 \$910 \$910 \$910 \$910 \$910	\$24 \$24 \$24 \$AE \$AE \$AB \$AB \$29 \$7C	\$150 \$150 \$150 \$150 \$150 \$150 \$150 \$150
DFB	DFB DFB DFB DFB DFB DFB DFB	DPB DPB DPB DPB DPB DPB DPB DPB DPB DPB
6 4 7 0 7 0 7 0 7 0 7 0 7 0 7 0 7 0 7 0 7	\$ 499 \$ 500 \$ 501 \$ 504 \$ 504 \$ 506 \$ 506 \$ 506 \$ 506 \$ 507	508 509 510 511 512 513 514 516 517 520 520 521 523
P9C9:8A P9CA:1D P9CC:823 P9CC:823 P9CC:823 P9CC:812 P9CC:812 P9D2:129 P9D3:129 P9D3:129 P9D5:48 P9D6:19 P9D6:1	F9E5: 09 F9E6: 24 F9E8: 24 F9E8: AE F9E9: AE F9EA: AB F9EC: 29 F9EC: 29	F9EE:00 F9FC:15 F9FC:15 F9FC:9C F9FC:9C F9FC:29 F9FC:53 F9FC:53 F9FC:13 F9FC:13 F9FC:13 F9FC:13 F9FC:13

FA34:72 FA35:72	577 578	i i	DFB \$	\$72 \$72			631 632		SOFTEV+1 NOFIX	; YES SO REENTER SYSTEM
FA36:88 FA37:CR	580	a 2		\$88	; (D) FORMAT	FA9B:A0 03 FA9D:8C F2 03	633 FIXSEV 634	STY S	#3 SOFTEV	; NO SO POINT AT WARM START
FA38:C4	581	5 A		20,			635	JMP	BASIC	: AND DO THE COLD START
FA39:CA	582	מ		SCA.		FAA3:6C F2 03			(SOFTEV)	SOFT ENTRY VECTOR
FA3A:26	583	ה ה		\$26		FAAD:	63/ XXXXXX			
FA3C:44	585	מ מ		\$48 \$44		FAA9: FAA9			AFFLE11 *	SET PAGE 3 VECTORS
FA3D:44	586	2 2		775		12 05	640		*5	2000
FA3E: A2	587	ŭ		\$A2	; (E) FORMAT	FAAB: BD FC FA	641 SETPLP		PWRCON-1,X	; WITH CNTRL B ADRS
FA3F:C8	588	10		\$C8		FAAE:9D EF 03	642	STA	BRKV-1,X	
FA40:	589	A COLITAIN	104	, , , ,		FABI:CA FAR2:DO F7 FAAR	643	DEX	0 10445	
	591				thew ind entry	. 8	549	LDA	#SC8	. 10AD HT STOT +1
FA40:85 45		OLDIRQ ST	STA \$	\$45	(should never be used)	FAB6:86 00	949	STX	1000	SETPG3 MUST RETURN X=0
45	593			\$45	for those who save A to \$45	FAB8:85 01	647	STA	1001	; SET PTR H
FA44:4C FA C3	294		JMP N	NEWIRO ;	;go to interrupt handler	FABA:	* 849			
						FABA:	946 * Chec	k 3 II	bytes inste	649 * Check 3 ID bytes instead of 4. Allows devices
FA47:8D 06 CO		NEWBREAK		RETSLOTCXRC	SETSLOTCXROM ; force in slots	FABA:	650 * othe	r that	Disk II's t	650 * other than Disk II's to be bootable.
32			STA A	YCC :	;save accumulator	FABA:	651 *			
FA4C:							652 SLOOP			;Y is byte ptr
		BREAK PL					653	DEC	Loci	
FA4D:20 4C FF	009	ñ	JSR S	SAVI	SAVE REG'S ON BREAK	FABE: AS 01	654	LDA	Loci	. AP 1 AOP 01 OF SPH
PAS1.85 24	703	1.5		100	1 INCLUDING FU		656	100	2000	, Al LASI SLOI IEI!
	803	6 4		7		TR 07	657	STA	METOT	; IES AND II CAN'I BE A DISK
FA54:85 3B	604	LS		PCH		FAC7: B1 00	658 NXTRYT		(1.0CO), v	· FETCH A SLOT RVTE
FA56:6C FO 03	605	Š	JAP ((BRKV)	BRKV WRITTEN OVER BY DISK BOOT	FAC9: D9 01 FB	659		DISKID-1,Y	
	909					FACC: DO EC FABA	099	BNE	SLOOP	; NO, SO NEXT SLOT DOWN
82	607	OLDBRK JS		INSDS1	;PRINT USER PC	FACE:88	199	DEY		
DA	809	JS		RGDSP1	; AND REGS		662	DEY		; YES, SO CHECK NEXT BYTE
FA5F:4C 65 FF				MON	GO TO MONITOR (NO PASS GO, NO \$200!)	FADO:10 F5 FAC7	663	BPL	NXTBYT	; UNTIL 3 BYTES CHECKED
FA62:D8		RESET CL	CED	Machina	DO THIS FIRST THIS TIME	FAD2:6C 00 00	664	AMS	(LOCO)	; GO BOOT
FAC 3.20 04 FE	110	3 5		THIE		EADS:	. 600	a Cia		
	613	15	ISR S	SETVID		FAD6:EA	666	NOP		
8	614	SI		SETKRD		FAD7:	* 899			
28		INITAN LD		SETANO	: ANO = TTL LO	FAD7:20 8E FD	669 REGDSP	JSR	CROUT	DISPLAY USER REG CONTENTS
SA	919	11		SETANI	; ANI = TTL LO		670 RGDSP1		\$\$45	WITH LABELS
	617	L	LDY #	6#	;CODE=INIT/RRA0981		671	STA	A3L	
	618	Sr		COTOCX	;DO APPLEZE INIT/RRA0981		672	LDA	00\$#	
	619	NC			;/RRA0981	FAE0:85 41	673	STA	А3Н	
FA7B: AD FF CF	620	LD		CLRROM	; TURN OFF EXTNSN ROM		919	LDX	#\$FB	
10	621	18		KBDSTRB	; CLEAR KEYBOARD	FAE4: A9 A0	675 RDSP1	LDA	#\$A0	
		NEWMON CL	CLD			FAE6:20 ED FD	979	JSR	COUT	
FA82:20 3A FF	623	JS		BELL	; CAUSES DELAY IF KEY BOUNCES		219	LDA	RTBL-251,X	
13	624	E.		SOFTEV+1	; IS RESET HI		678	JSR	COUT	
8	625	EC		#\$A5	A FUNNY COMPLEMENT OF THE	FAEF: A9 BD	679	LDA	#\$BD	
0	626	5		PWREDUP	; PWR UP BYTE ???	FAFI:20 ED FD	089	JSR	COUT	
1 6		NA .		PWRUP	; NO SO PWRUP	FAF4:B3 4A	189	LDA	ACC+5,X	
F2 03		3 8		SOFTEV	; YES SEE IF COLD START	FAF6:20 DA FD	789	JSR	PRBYTE	
FA92: DO UF FAA3	630	A0 I	INA #	NOF LX	HAS BEEN DONE YET?	FAFA:30 FR FAFA	684	RMT	phepi	
	200	77		034	. DOES SUFI ENIKI VECIUR FULNI AL BASILI		100	Ting	KUSFI	

PB6F: 31 * PB6F: PB6F: PB6F: PB6F: PB72: PB72: PB72: PB72: PB72: PB72: PB72: PB72: PB72: PB82:	0F F894 43 BNE 110 C0 44 BNT 100 C0 45 RDMAIT LDY FB F888 46 BPT 83 47 CPY 03 F894 49 BEQ 10 C0 49 BIT FD F8 50 NOMAIT JMP FD F8 55 SCOLD SEC	2C FC 53 ESCNOW 48 FA 54 ESCNOW 97 FB 56 21 FD 57 CE FB97 59 CA FB97 61 CA FB	E6 FB97 63 BRQ E8 FB98 64 BNE C006 65 SETSLOTCKROM C007 67 SETSLOTCKROM E0U C015 68 RNCKROM E0U C015 69 ** 70 VERSION DPB 71 ** FBB4 72 GOTOCK E0U 15 C0	PBB7:08 74 PHP PBB7:08
OLDBRK \$00,\$E0,\$45 \$20,\$FF,\$00,\$FF \$03,\$FF,\$30 **Apple 1 \$C4,\$C2,\$C1 \$FF,\$G3 \$FF,\$G3	SCI, SDB, SDB, RECISTER NAMES FOR RECOSP: SDO, SDB, ; LAXYPS' FTRIGGER PADDLES \$900 ; LNIT COUNT ; COMPENSATE FOR 1ST COUNT RADDLO, X; COUNT Y-REG EVERY 12 USEC. RTSZD :EXIT AT 255 MAX	; CLR STATUS POR DI ; CLR STATUS POR DI ; INIT VIDEO MODE ; SET FOR TEXT MODI ; FULL SCREEN WIND		\$1.7 ; VAB TO ROW 23 .V ; VTABS TO ROW IN A-REC .TAB : CLEAR THE SCRN 99 CITLE-1,Y ;GET A CHAR .INE1+14,Y ;PUT IT AT TOP CENTER OF SCREEN
				-0
RTS DW DPB DFB DFB ASC EQU DFB DFB	DFB LDA LDY NOP NOP LDA LDA LDA INY			LDA STA JMP I JSR LDY LDA LDA STA BNE RTS
685 * 686 * 687 PWRCON 688 DISKID 699 DISKID 691 692 693 694 695			9 SETGR 10 111 12 13 SETWND 14 15 16 17 17	20 21 TABV 23 * 24 APPLEII 25 STITLE 27 27 30
PARC: 60 PARD: 6 PARD: 6 PARD: 8 PARD: 8 PARD: 9 PA	11 D8 D9 D9 D0 D3 D0 D3 C0 D3 C0 D3 C0 D3 C0 D0	56 C0 56 C0 57 C0 60 60 60 60 60 60 60 60 60 60 60 60 60	FR46.3 O CO FR46.2 O 36 F8 FR49.3 O 14 FR49.3 O 14 FR49.3 O CO FR40.3 O CO FR51.3 O C FR53.3 O C FR53.3 O C FR53.3 O C FR53.3 O C FR53.3 O C	FB59;49 17 FB5B14C 22 FC FB60;0 SFC FB60;0 SFC FB63;340 09 FB65;89 09 FF FB68;89 02 04 FB65;00 F7 FB65 FB66;00 F7

; USE CHAR AS INDEX
; DTRANEATE LIAR TO CRAD
; DO THE CURSOR MOTION
; DET LIAM, LIAM, ARROWS/RRAO981
; STHIS AN 'N'?
; N' OR GREATER - DO IT!
; ELSS THAN '1'?
; YES, SO DO OLD WAY
; DO NORAL
; GO DO IT

; INSURE CARRY SET

DO AS BEFORE

;GT CURENT STATE/RRA0981;SAVE COMBANK STATE/RRA0981;SAVE ROMB ON/RRA0981;=>OFF TO GXSPACE/RRA0981

TINTCXROM

FOR IDCHECK/RRA0981

;/RRA0981

/RRA0981

;/RRA0981 ;/RRA0981 ;/RRA0981

;CALC BASE ADDR IN BASL,H;FOR GIVEN LINE NO.

;//e ROM rev ID byte

CHECK FOR A PAUSE (CONTROL-S).
ONLY WHEN I HAVE A CR
NOT SO, DO REGULAR
; IS KEY PRESSED?
'NO.
'YES - IS IT CTRL-S?
'NOPE - IGNORE
CLEAR FROBE
HAIT FOR KEYPRESS
'HAIT FOR KEYPRESS
; IS IT CONTROL-C?
'YES, SO LEAVE IT
CLI

; ROUTINE TO CALCULATE THE 'FUNNY ; COMPLEMENT' FOR THE RESET VECTOR

in 80 columns; =>not 80 columns; Print a character; through video firmware

#\$0 GOTOCX3 RD80VID

NEWVWI

FC4F

;/RRA0981 ;CODE=CLREOP/RRA0981 ;DO 40/80 /RRA0981

#\$A GOTOCX1

160 161 162

FC42:A0 0A FC44:D0 E3 FC46:

FC42:

EQU

#\$FD CLREOL RTS3

get masked character; and set up for vidwait; print the character

restore Acc

VIDWAIT

BPL LDY BEQ TYA PHA JSR PLA LDY RTS

PC46:2C 1F CO PC49:10 04 PC4 PC48:40 08 PC5 PC45:98 PC50:48 PC50:48 PC51:20 78 PB PC55:46 35 PC55:46 35 PC57:60

YSAVI

;/RRA0981 ;CODE=HOME/RRA0981 ;do 40/80

* #5 GOTOCX

EQU JMP

| 163 NEWUW | 164 | 165 NEWUW | 166 NEWUW | 166 NEWUW | 173 | 173 | 173 | 174 NEWUW | 175 NEWUW | 175

FC58:A0 05 FC5A:4C B4 FB FC5D:

PC58:

NOP NOP NOP NOP

ESC. 40.7

ESC.-A OR B CHECK
A. ADVANCE
B. B. BACKSPACE
ESC.-OR D CHECK
C. DOWN
C. DOWN
ESC.-C OR D CHECK
C. DOWN
E. B. COU
ESC.-C OR P CHECK
E. CLEAR TO END P LINE
E. ELSE NOT F. RETURN

#\$FD ADVANCE

FCZ6:98
FCZ1:A0 04
FCZ9:00 89
FCZB:EA
FCZB:EA
FCZB:EA
FCZ0:69 FD

BS #\$FD

145 147 147 148 150 151 151 153 154 155 155 157 157 158 158

;temporarily save Acc
;and Y
;this is VTABZ call
;=> always perform call

#\$4 GOTOCX

LDA STA TYA LDY BNE

FC22:A5 25 FC24:85 28

GET CURSOR V INDEX

; NO, SET BASE ADDR ;DECR CURSOR V. (BACK TO BOTTOM)

;/RRA0981

192 SCROLL

PC70

138 *

FC22:

OFF SCREEN?

#\$00 CH CV CV WNDBTM VTABZ

;(RET CURSOR H=0) :INCR CURSOR V. (DOWN 1 LINE)

CURSOR TO LEFT OF INDEX

						ą												ne state																		V				le le					
;CODE=SCROLL/RRA0981 ;DO 40/80 /RRA0981	Jump here to swap out ROMs for interrupt handlers in peripheral cards		SETSLOTCXROM ; switch in slots	iand jump to user	IRODONE (\$C3F4) jumps here after interrupt	because this cannot be done from \$Cn00 space		;Fix \$C800 space	;restore MSLOT	;valid Cn?		; Deselect all \$C800			do \$Cn00 reference	;fix zp location	×	; and restore the machine state		;don't mask controls	;apply inverse mask	;go back to COUT!	PROBC+S49C-* () *-24	to the control of	d CLREOLZ (\$38 and \$18)	slot test at \$FBB7.		;say it is EOL	'BCC' opcode;	;say it is EOLZ	;save Y in temp	;code=CLREOL	do it	code o=crkgorg		senter with count in A	delav is:		;13+11*A+5*A*A cycles	;@ 1.023 usec per cycle				TINCE 2-RUTE AA	; AND Al
#6 GOTOCX1	here to swap out ROMs interrupt handlers in		SETSLOTCXB	(SOFE)	C3F4) 1umps	is cannot b			MSLOT	#\$C1	IRONOSLI	SCFFF	2.5	SI	Y.(0\$)	\$1		IROFIX		DOCOUT2	INVFLG	COUTZI	PROBC+5490	2	S CLREOL an	v slot test			06\$		BAS2L	47	GOTOCXZ	CAUCACO	6010032			#\$01	WAIT3		#\$01	WAIT2		177	NXTAI
LDY BNE	* Jump here	*	IRQUSER STA	*	* IRODONE (\$	* because th	*	IRQDONE2 PLA	STA	CMP	BCC	STA	LDX	STA	LDA	STX	IRONOSLI STA	JMP		DOCOUT1 BCC		DOCOUTZ JMP	SU	*	* Note: bytes CLREOL and CLREOLZ	* are used by	*	CLREOL SEC	DFB	CLREOLZ CLC	STY	LDY	BCS	INI	PNE PNE	WATT SEC	2		BNE	PLA	SBC	BNE	* RTS	NYT A 4	
193 194 195	196 197	198	199	201	202	203	204	205	206	207	208	209	211	212	213	214	215	216			219	220	222	223	224	225	226	227	228		230	231	737	237	235	236	237		239	240	241	242	243	576	246
FC29			8 8	50					07		FC8F	CF					8	C4		PC99	1	FD	0000										FDID	alua	FDID				FCAA			FCA9			FCBA
06 B5			90	2						CI		FF	3 5	5 6	00	01	07	70	1	05	32	F									2A	6	8	75				01	FC		01	F6		67	02
FC70: A0 FC72: DO FC74:	FC74: FC74:	FC74:	FC74:8D	FC7A:	FC7A:	FC7A:	FC7A:	FC7A:68	FC7B:8D	FC7E:C9	FC80:90	FC82:8D	FC87: A6	FC89:85	FC8B:B1	FC8D:86	FC8F:8D	FC92:4C	FC95:	FC95:90	FC97:25	FC99:4C	FC9C:	FC9C:	FC9C:	FC9C:	FC9C:	FC9C:38	FC9D:90	FC9E:18	FC9F:84	FCAI: AO	FCA3: BO	FCA5: C0	FCA6: DO	FCA8:38	FCA9:48	FCAA:E9	FCAC: DO	FCAE: 68	FCAF: E9	FCB1:D0	FCB3:60	FCR4 - PA	FCB6:D0 02

,														slots,	h the	es the							ction			ction					lu																			ing	
	:INCR 2-BYTE Al.	; AND COMPARE TO A2	; (CARRY SET IF >=)							SETINICXROM ;force internal ROM	header	;force slots and return		to be able	1/0	d in. Inis stuff switches	cances.	SETSIOTCXROM . Force old to BOM	tab to the error	;to print a caret """	; print it	; and beep	; and go get next instruction		SETSLOTCXROM ; force slot ROM	;disassemble the instruction	;calculate new PC	; and update PC			entry point GETINSTI is hard-coded in	irmware.	01 m 4 m 4 m 5 m 5 m 4 m 5 m 5 m 5 m 5 m 5	: ndmord_ruru naxe	the section of the care				;get character	; point to next char	;is it lowercase?	:=>nope	;lowercase?	:=\nobe	;else upshift			;code=RDKEY	;allow \$FD10 entry	if enter here, do nothing	display cursor
A4H	AlL	A2L	AlH	A2H	AlL	RTS4B	AlH			SETINICXR	XHEADER	RETCXI	:	sassembler	it cannot make calls to the	Internal Rom Switched in.	sucii Tills	SPTSLOTCX	PRBL2	#\$DE	COUT	BELL	GETINSTI		SETSLOTCX	INSTDSP	PCADJ	PCH	PCL		entry poin	of the Video firmware.	404		PROMPT CETT N2	SETTNICXE	DOINST		IN,Y		#\$E1	UPMONZ	#SFB	UPMONZ	#\$DF			#\$B	RDKEYO	RDKEY 1	COTOCX
INC	LDA	CMP	LDA	SBC	INC	BNE	INC	KIS		STA	JSR	JAP	:	e d1	not	N IBL	11 10	STA	JSR	LDA	JSR	JSR	JMP		STA	JSR	JSR	STY	STA	i	The		100	משיי	SIA	STA	Æ		LDA	IN	CMP	BCC	CMP	BCS	AND	RTS		LDY	BNE	E	JSR
	NXTAI							KIS4B	*	HEADR			k +	FOT.	TI Cal		0 HOV : *	FRR3						*	DISLIN					*	* NOTE:	* BFUNC	AGT ITONITED	CELLING				*	UPMON							UPMONZ	*	RDKEY		FD10	RDKEYO
247	248	249	250	251	252	253	254	522	256	257	258	657	260	197	797	267	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	780	281	707	283	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300
						FCC8			,	8	S	F.E.						00	F9		FD	FF	FC		00	F8	F9								LE C	9 9	CF		02			FD0B		FDOB					FD13	FD	FB
43	30	3E	30	3F	30	02	30			0	19	S						90	4 A	DE	ED	3A	FO		90	2	23	38	34				7	2 5	53	07	8		8		El	90	FB	02	DF			08	03	1 28	B4
FCB8:E6	FCBA: A5	FCBC:C5	FCBE: A5	FCC0: E5	FCC2:E6	FCC4: D0	FCC6:E6	FCC8:00	FCC9:	FCC9:8D	FCCC: 20	FCCF:4C	FCD2:	FCDZ:	FCDZ:	FCD2:	PCD2:	FCD2:8D	FCD5:20	FCD8:A9	FCDA:20	FCDD:20	FCE0:4C	FCE3:	FCE3:8D	FCE6:20	FCE9:20	FCEC:84	FCEE:85	FCF0:	FCF0:	FCFO	FCFO: A9	FCFO. A	FCF2:85	PCF7:80	PCFA:4C	FCFD:	FCFD: B9	FD00:C8	FD01:C9	FD03:90	FD05:C9	FD07:B0	FD09:29	FD0B:60	PD0C:	FDOC: AO	FDOE: DO	FD10:4C	FD13:20

OUTPUT PROMPT CHAR	INTT INPUT INDEX	O OF DAAGOVAR ITTO	WILL BACKSFACE 10 0	USE SCREEN CHAR	; FOR CONTROL-U	do 40 column pick	-= Nico 644 it	2 (2.6)	; ADD TO INPUT BUFFER			;CLR TO EOL IF CR		;(ALWAYS)		:PRINT CR, Al IN HEX				:PRINT '-'			A HOTATO OF WOO.	. WOD 8=7	(Po gou .							. OILT BI ANK	while to the	; OUTPUT BYTE IN HEX		; NOT DONE YET. GO CHECK MOD 8	; DONE.		DETERMINE IF MONITOR MODE IS	; EXAMINE, ADD OR SUBTRACT				FORM 2'S COMPLEMENT FOR SUBTRACT.	
PROMPT	COUT #SO1	- N 1440	GEILING	#\$95	ADDINE	RDBOVID	PICVETY	T INC.	IN,X	#\$8D	NOTCR	CLREOL	#\$8D	COUT		AIH	AlL	CKOOL	#SOO	#SAD	COUT		AIL	A21	AIH	А2н			#\$07	DATAOUT	FKAI	TITO	(AIL),Y	PRBYTE	NXTAI	MOD8CHK			A	хам	< <	A	ADD	#SFF	All
LDA	JSR	TXA		CMP	BNE	RIT	PMT	NOP	STA	CMP	BNE	JSR	LDA	BNE		LDY	LDX	100	J.SK	LDA	JMP		LDA	S T	TPA	STA			AND	BNE	JSK T T		LDA	JSR	JSR	BCC	RTS		LSR	BCC F	LSK	I SK	BCC	EOR	ADC
354 GETLN	355	357 BCKSPC	359 MYTCUAR	361	362	363	365	366	367 ADDINP	368	369	370	371 CROUT	372	373 *	374 PRA1	375	3/0 PRIA2	378	379	380	381 *	382 XAM8	367	385	386	387 MO		388	389	390 XAM	391 DALACO	393	394	395			398 *	399 XAMPM	400	101	402	404	405	406 ADD
			KD6/		FD84		Ph3n	200			FD47			FDED																FDB6						FDAD				FDB3			FDD1		
33	ED FD		ă	95		1F C0	,		00 02	80		9C FC				30	30	05 50		AD AD	ED FD		30	30	3 5	3.5	30	A AIL		i	92 FD	PD PD		DA FD	BA FC	E8			į	EA		7			30
FD6A:A5 33	FD6C:20	FD71:8A	FD74:CA	FD78:C9 95	FD7A:D0 08	FD/C:B1 28	PD 01.30 BA	FD83:EA	FD84:9D 00 02	FD87:C9 8D	FD89: DO	FD8B:20	FD8E:A9 8D	FD90:D0 5B	FD92:	FD92:A4 3D	FD94: A6	F 090:20	FD99:20 40	FD9E: A9 AD	FDAO:4C ED FD	FDA3:	FDA3: A5 3C	FDA3:09 07	FDA9.45 3D	FDAB:85 3F	FDAD: A5 3C	D8CHK LDA	FDAF:29 07	FDB1: DO 03	FDB3:20 92	FDB0: A9	FDBB: B1 3C	FDBD:20 DA FD	FDC0:20 BA FC	FDC3:90	FDC5:60	FDC6:	FDC6:4A		FDC9:4A	FDCA:4A	FDCD: 90 02	FDCF:49 FF	FDD1:65
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	NI-X3X M3SN OI OS:		; RDKEY/RRA0981	;/RRA0981		GET A KEY	TINIA TOO	;=>always		rmware that escapes are allowed.	ed by RDCHAR which is called by	of MSLOT is set by all cards	ace.		;<128 means escape allowed	;now read the key		.000	; / RRAU981 : HANDLE ESC FINCTION.	:Flag RDCHAR and read key	, ESC'?	; YES, DON'T RETURN.		H Figure 1	do 80 column of ch	restore Y	and save new character			echo typed char				CHECK FOR EDIT KEYS	; - BACKSPACE		: - CONTROL-X		; MARGIN?	; YES, SOUND BELL	; ADVANCE INPUT INDEX		:BACKSLASH AFTER CANCELLED LINE		; ourpur 'ck'
			>				1			ideo firmware that escapes are allowed.	is called by RDCHAR which is called by	igh bit of MSLOT is set by all cards	C800 space.						_	ž					×		×	Auto-Start Monitor ROM 27-AUG-84					×		٠.							TCHAR			
ac	(KSML)		#3	400		RDKEY	#1	GOTOCX2 ;		the video firmware that escapes are allowed.	utine is called by RDCHAR which is called by	The high bit of MSLOT is set by all cards	the C800 space.			RDKEY	JP.		RDESC	NEWRDKEY	#\$9B	ESC	S	400	COTOCX	CH	IN,X	Auto-Start Monitor ROM 27-AUG-84		COUT	or or	÷ 9	N.X	#\$88	BCKSPC ;	#898	CANCEL :	#SF8	NOTCRI	BELL	NATIONAL DE		#SDC	COUT	CROUT
NOP	NOP (KSWL)	+ 1100	LDY #3	NOP		EQU *	#1			ag to the video firmware that escapes are allowed.	is routine is called by RDCHAR which is called by	TLN. The high bit of MSLOT is set by all cards	at use the C800 space.			RDKEY	NOP		_	JSR NEWROKEY	CMP #\$9B	ESC	RTS	400	COTOCX	CH	×	Auto-Start Monitor ROM 27-AUG-84		JSR COUT	AON MON	NOR		#\$88	BCKSPC ;	#898	CANCEL :		NOTCRI	JSR BELL	LINX		LDA #SDC	JSR COUT	JSR CROUT
	(KSML)	+ 1100 01000	LDY #3	NOP	*	RDKEY	Thy #1	BNE GOTOCX2 ;	314 *	315 * Flag to the video firmware that escapes are allowed.	* This rout	317 * GETLN. The high bit of MSLOT is set by all cards	318 * that use the C800 space.	*	NEWRDKEY LSR MSLOT	JMP RDKEY	322 NOP		RDESC	RDCHAR JSR NEWRDKEY	CMP #\$9B	BEQ ESC	329 RTS	DICKETY INV #SE	TONE IN LDI FOR	LDY CH	IN,X	*#03 AUTOST2 Auto-Start Monitor ROM 27-AUG-84		NOTCR JSR COUT				CMP #\$88	BEQ BCKSPC ;	CMP #\$98	BEQ CANCEL ;	#SF8	BCC NOTCRI	JSR BELL	NATIONAL DE	BNE.	CANCEL LDA #SDC	JSR COUT	CROUT

	;MOVE (A1) THRU (A2) TO (A4)	; WITH (AA) ; WITH (AA)		HOVE AI (2 BYTES) TO FP	; DISASSEMBLE 20 INSTRUCTION; ; ADJUST PC AFTER EACH INSTRUC	;NEXT OF 20 INSTRUCTIONS ;IF USER SPECIFIED AN ADDRESS; COPY II FROM AI TO PC.	SET FOR INVERSE VID ; VIA COUT! ; SET FOR NORMAL VID
LT2	(AlL),Y (A4L),Y NXTA4 MOVE	(AIL),Y (A4L),Y VFYOK PRA1 (AIL),Y PRBYTE	#\$AO COUT #\$A8 COUT (A4L),Y PRBYTE #\$A9	COUT NXTA4 VFY A1PC	INSTDSP PCADJ PCL PCH	#\$01 LIST2 AIPCRTS AIL,X PCL.X	Alpclp #\$3F SETIFLG #\$FF INVFLG
DEX BPL RTS	LDA STA JSR BCC RTS	LDA CMP BEQ JSR LDA JSR	JSR LDA JSR LDA JSR	JSR JSR BCC RTS JSR LDA	PHA JSR JSR STA STY PLA SEC	SBC BNE RTS TXA BEQ LDA STA	DEX BPL S RTS LDY BNE # LDY R STY RTS
461 462 463	464 × 465 MOVE 467 468 469	470 * 471 VFY 472 473 474 475	477 478 479 480 481 482	485 VFYOK 486 487 488 * 489 LIST 490	491 LIST2 492 493 494 495 496	498 499 501 * 502 AIPC 503 AIPCLP 505	506 BEX 507 BPL 508 APPCRTS RTS 509 * LDY 510 SETINO LDY 511 SETINORAL LDY 512 SETINORAL LDY 513 SETIFIC STY 514 RTS
FE22	FE2C	FE58	0 0 0	FE36	m a	FE63	FE78
F7	3C 42 B4 FC F7		A0 ED FD A8 ED FD 42 DA FD		53 F9 3A 38	01 EF 07 3C 3A	F9 3F 32 32
FE28:CA FE29:10 F7 FE28:60	FE2C:B1 3C FE2E:91 42 FE30:20 B4 FE33:90 F7 FE35:60	FE36: FE36:B1 FE38:D1 FE3A:F0 FE3C:20 FE3F:B1 FE41:20	FE44:A9 FE46:20 FE49:A9 FE4B:20 FE4E:B1 FE50:20	FE55:20 ED FE58:20 B4 FE58:90 D9 FE5D:60 FE5E: FE5E: FE5E: FE5E: FE5E: FE6E: A9 14	FE63:48 FE64:20 FE67:20 FE66:85 FE6C:84 FE6E:68	FR70:E9 01 FR72:D0 EF FR74:60 FR75:8 FR76:F0 07 FR78:B5 3C	FE7C:CA FE7D:10 F9 FE7D:10 F9 FE8O: FE8O: FE8O:00 02 FE8A:AO FF FE8O:84 32 FE8O:84 32
; PRINT '=', THEN RESULT	; (DESTROYS A-REG)	; PRINT HEX DIGIT IN A-REG; LSBITS ONLY.	; VECTOR TO USER OUTPUT ROUTINE ;save original character ;is it a control? [1] ;=>mask if not; return to COUTZ]	;save original character ;save yrsinal character ;save masked character ;get original char ;new entry to vidwait	N	KEEP IN STORE MODE ,Y ;STORE AS LOW BYTE AT (A3) ;INCR A3, RETURN.	: SAVE CONVERTED ':', '+',
#\$BD ;PRINT '-', THEN RESULT COUT	; PRINT BYTE AS 2 HEX DIGITS A ; (DESTROYS A-REG) A A A A	PRHEXZ #\$0P ;PRINT HEX DIGIT IN A-REG #\$50 ;LSBITS ONLY. #\$8A COUT	(CSWL) ;VECTOR TO USER OUTPUT ROUTINE :save original character #\$AD its it a control? DOCOUT1 :=>mask if not: return to COUTZ1	isave original character isave Y isave masked character isave masked character iser original char inew entry to vidwalt	z ,	MODE ;KEEP IN STORE MODE A2L (A3L),Y ;STORE AS LOW BYTE AT (A3) A3L RTS ;INCR A3, RETURN. A3H	YSAV ;SAVE CONVERTED ':' '+'. IN-1, Y ; '-', 'AS MODE MODE #501 #501 A44, X ; A4 AND A5 A51, X
	***	#\$0F #\$0F #\$BA COUT #\$06	G E		N	MODE (A3L),Y (A3L) RTS5 A3H	LDY YSAV LDA IN-1, Y STA MODE STA MODE LDX #801 LDA A21, X STA A41, X STA A51, X
#\$BD COUT	PRBYTE PHA LSR A LSR A LSR A LSR A	JSR PRHEXZ PRHEX AND \$50F PRHEXZ ORA \$50 CMP \$58A BCC COUT ACC COUT	(CSWL) #\$AO DOCOUT1	COUTZ PHA COUTZI STY YSAVI PLA PLA JMP NEWW NOP	BL1 DEC YSAV BLANK DEX XAMB BLANK SET SET MOZ CMP \$ \$BM BME XAMPM	MODE (A3L),Y (A3L) RTS5 A3H	SETMODE LDM YSAV LDM IN-1,Y SETMOZ STA MODE * LT LDM #501 LT2 LDM A21,X STA A51,X STA A51,X

550 * a two byte pair with a high byte of 0. A list of all 570 * adresses containing the specified pattern is displayed. 571 * 1. * 1. * 1. * 1. * 1. * 1. * 1. *		60TOCX ;get internal ROM switched in BLI ;HANDLE CR AS BLANK ; THEN POP STACK ; AND RETTRN TO HON HONZ ; (ALMAYS) SETINTCXROM ;set internal ROM XKRAD ;do tape read SETSLOTCKNRD; restore all critical and charters all critical and charters are considered.	SR SI	DIGG ::tt was a digit \$55.00 :check for quote (') RTS6 :chope, return char \$70.07 :ches get next char
byte poes con the byte poes con the boundary of the byte poes con the byte poes contraction the byte poes con the byte poes con the byte poes con the byte poes con the byte poes contraction th		LDY # JSR G JSR B PLA BNE M STA S STA S STA S STA S STA S	BREQ B BNE P ASC " JSR U CMP # RTS	BCS D CMP # BNE R LDA \$ LDX # TINY BNE N LDA # CMP # CMP # CMP # LDA # LDA # LDA # LDA # LDA # LDA #
569 * a two by 570 * adresses 571 * 572 SEARCH LL 573 LL 574 BE	СН1	585 * 11	597 BB	609 LOOKASC RC 610 LOOKASC RC 611 RC 612 LL 613 LL 613 LC 614 CC 614 CC 614 RC 616 CC 616 RC 616 RC 616 RC 616 RC 616 RC 619 RC 619 RC 621 LL 622 LL 622 LL 622 LL 622 LC
FED7: FED7: FED7: FED7:A0 01 FED9:A5 43 FED8:A5 43 FED8:D1 34		00 B4 FB 00 FE 00 FE 00 C0 00 C0	5 5	FF18:10 GD FF8A FF110:29 A0 FF110:00 28 FF21:19 00 02 FF24:22 07 FF26:09 B0 FF26:09 B0 FF26:09 B0 FF20:00 70 FF20:00
; DO 'IN#AREG'	;DO 'PR\$AREG';SET INPUT/OUTPUT VECTORS	1 STY LOCO,X issue low byte of hook STA LOCI,X issue acc LDV \$5E code=FRE/IN# X4 JHP GOTOCX perform call NOP (FEADER OF CALL) (FEADER OF C	JAP (PCL) ; AND GO! RTS REGIST ; GO DISPLAY REGISTERS RTS RTS RTS RTS RTS RTS RTS RTS RTS R	TCX2 RTS :simply return NOP R JMP USRADR ;JUMP TO CONTROL-Y VECTOR IN RAM TTE LDA #\$40 TQ STA SETINTCXROM; set internal ROM TQ STA SETINTCXROM; set stock beep BEQ RD2 ;=>alwise set slots, beep BEQ RD2 ;=>always set slots, beep HHILADRALADR2 in which aNRIC ADR2 and LL precedes HH In memory. If HH is 0, or omitted (LL/ADR1.ADR2), then the single byte LL is searched for. You cannot search for
#\$00 A2L #KSWL #KEYIN IOPRT	#\$00 A2L #CSWL #COUTI A2L \$\$0F IOPKTI \$<10ADR	LOCO,X LOCI,X #\$E GOTOCX 0 ECT CKSU BASIC A1PC RESTORE	JMP (PCL) ; ACE RTS ACE RTS ; REZ RTS ; Return here from GOTOCX WIE: This address is h video firmware TCXI STA SETSLOTCXROM	#\$40 SETINTCS WRITE2 RD2 alled wi DR2 in If HH i
STA A: LDX #1 LDY #1 BNE I	***	STY LC STA LC LDY #8 LDY #8 NOP NOP ->CORREC JMP B4 JMP B4 JSR A1 JSR A1 JSR A1	JMP (PC) JMP REG RTS NOP RTS This add firmware	TCX2 RTS NOP TO JMP 198AI TT
Q H		S CX4 S E E E E E E E E E E E E E E E E E E	E: ar	X2 R N J J J ARCH LL(AD) memo
* SETKED INPORT INPR		GOTOCX4 * CKSUMF1 * XBASIC BASCONT	TR * * * * * * * * * * * * * * * * * * *	***** *****
515 516 517 518 518 520		531 532 533 534 535 536 537 540 541 542 543	543 544 544 545 549 549 550 551 553	555 556 557 558 559 561 561 563 564 564 565 567 568
FE89: FE89:A9 00 FE88:85 3E FE8D:A2 38 FE8F:A0 18 FE9:D0 08 FE9B	FE93:49 00 FE93:49 00 FE93:48 3E FE99:40 F0 FE99:40 F0 FE99:20 07 FE93:40 04 FEA3:40 00	00 01 00 03 03 37 37	PERSECT 3A 00 PERSET 4C D7 PA PEC21 60 PEC31 FRC460 PEC51 FRC51 FR	P8 07 07 2C 2C

;LEAVE X=SFF IF DIG ;IF MODE IS ZERO, · THEN CODY A2 TO A1 AND A3		;CLEAR A2 ;get char, upshift, INY ;INY now done in UPMON	; BR IF HEX DIGIT ; check for ASCII input	; DISPATCH TO SURROUTHE, BY ; PUSHING THE HI-ORDER SUBR ADDR, ; THEN THE LO-ORDER SUBR ADDR ; OWNO THE STACK, ; (CLEARING THE MODE, SAVE THE OLD ; MODE IN A-REC),	8		; N GET NUMERA UIDEO) ; I (SET INVEREN UIDEO) ; L (DISASSEMBLE 20 INSTRS) ; W (WAITE TO TARE) ; G (EXECUTE PROGRAM) ; R (READ FROM TAFE) ; ' (ADBORY PILL) ; ' (ADDRESS DELLMITER) ; 'CR' (END OF INPUT)
NXTBIT NODE NXTBS2		#\$00 # A2L # A2H				% % % % % % % % % % % % % % % % % % %	
DEX BPL S LDA BNE		STX STX STX STX NOP EOR	CMP BCC ADC CMP			DFB DFB DFB DFB DFB DFB	DFB DFB DFB DFB DFB DFB DFB
677 678 679 NXTBAS 680	682 683 684 NXTBS2 685 686	688 GETNUM 689 690 691 NXTCHR 692 693	694 695 696 697 698	700 TOSUB 701 702 703 704 705 ZMODE	706 707 708 * 709 CHRTBL 710 711	714 715 716 717 719 720	722 724 724 725 726 727 729
FF90 FFA2	FF98 FFAD		FF8A				
F8 31 35		00 3E 3F FD FC BO	2	FE E3 FF 000	31		
FF95:CA FF96:10 FF98:A5 FF9A:D0		700040	FFB3:C9 OA FFB5:90 D3 FFB7:69 88 FFB9:C9 FA FFBB:4C 1B			FFD1:C4 FFD2:EC FFD3:A9 FFD4:BB FFD5:A6 FFD6:A4 FFD6:A4	FFD9:07 FFD4:02 FFD8:05 FFDC:FO FFDC:FO FFDC:EB FFDC:EB FFDC:EB FFDC:EB
HAKE A JOYFUL NOISE, THEN RETURN.	R CONTENTS	ints			. *	Y AGAIN. UBROUTINE NB	
; MAKE A JOYFUL N	RESTORE 6502 REGISTER CONTENTS; USED BY DEBUG SOFTWARE	;SAVE 6502 REGISTER CONTENTS ; FOR DEBUG SOFTWARE		;SFT SCREEN MODE ; AND INIT KEB/SCREEN ; AS I/O DEVS.	HUST SET HEX MODE! FWEEPER. READ A LINE OF INPUT CLEAR MONITOR MODE, SCAN IDX GET ITH, NOW-HEX GARR IN A-REG.	; X-REG-O IF NO HEX INPUT ;COMMAND NOT FOUND, BEEP & TRY AGAIN, ;FING COMMAND GHAR IN TABLE ;NOT THIS THE ;COT IT! CALL CORRESPONDING SUBROUTINE ;FROCESS NEXT ENTRY ON HIS LINE	; SHIFT INTO A2
	Sí		TATUS	J			E JH
COUT #\$87 COUT	STATUS A5H XREG YREG	A5H XREG YREG	SP	SETNORM INIT SETVID SETKBD	BELL #\$AA PROMPT GETLNZ ZMODE GETNUM YSAV	#\$17 MON CHRTBL,Y CHRSRCH TOSUB YSAV NXIITM	#\$03 A A A A A A A A A A A A A A A A A A A
	RESTORE LDA STATUS PHA LDA A5H RESTRI LDX XREG LDY YREG PTO	RTS6 RTS * SAVE STA A5H SAVI STX XREC PHP	PLA PLA STA ST STX SP CLD RTS	* OLDRST JSR SETNORM JSR INIT JSR SETVID JSR SETVED	MON CLD MONZ LDA #\$AL MONZ LDA #\$AL STA PROMPT JSR GETLIZ JSR GETLIZ JSR CETLIZ STY YSAV	CHRSRCH DEY BMI MON CMP CHRSBL,Y BNE CHRSRCH JSR TOGUS LDY YSAV	E JH

	FFE2:99	731		DFB	66\$	BLANK	~	C4E		
	FFE3:	732	*					CAE		
	FFE3:	733	* .	of 1	ow order mo	nitor	Table of low order monitor routine dispatch	C4E		
e050	FFE3:	734	*	addresses.	High byte always \$FE	alwaye	B SFE	C4EI		H
	FFE3:	735						C4FC		
	FFE3:82	736	SUBTBL	DFB	>BASCONT-1	<u>ي</u>	(BASIC warm start)	C4F2	C4F2:F0 01	C4F5
410	FFE4:C9	737		DFB	>USR-1	_	(not used)	C4F4:E8		
	FFE5:BE	738	~	DFB	>REGZ-1	_	(open and display registers)	CAF		
	FFE6:F0	739		DFB	MINI-I	ī	assembler	C4F	C4F7:A2 03	
	FFE7:35	740	•	DFB	>VFY-1	۰.	(memory verify)	C4F9:88		
	FFE8:8C	741		DFB	>INPRT-1	, ×	(IN#SLOT)	C4F/	C4FA:86 3D	_
	FFE9:D6	742	•	DFB	>SEARCH-1	search	search for pattern	C4FC	C4 FC : CA	
	FFEA:96	743	_	DFB	>OUTPRI-1	, P	(PR#SLOT)	C4FI	C4FD:10 C9	C4C8
	FFEB: AF	744		DFB	>XBASIC-1	. B	(BASIC cold start)	C4F1	C4FF:60	
	FFEC:17	745		DFB	>SETMODE-1	1	(subtraction)	C200:	:	
	FFED: 17	146		DFB	>SETMODE-1	+	(addition)	CF3A:	::	CF3A
	FFEE: 2B	747		DFB	>MOVE-1	¥.	(memory move)	CF3A:	;;	
	FPEF: 1 P	748	•	DFB	>LT-1		(delin for move.vfy)	CF3A:	::	
	FFF0:83	749		DFB	>SETNORM-1	N.	(set normal video)	CF3A:	::	
	FFF1:7F	750	_	DFB	>SETINV-1	1:	(set inverse video)	CF34	CF3A:E9 81	
	FFF2:5D	751		DFB	>LIST-1	.1.	(disassemble 20 instrs)	CF30	CF3C:4A	
	PPF3:CC	752	. ~	DFB	WRITE-1		(write to tape)	CF31	CF3D: DO 14	CF53
	FFF4:85	753		DFB	>60-1	9:	(execute program)	CF31	CF3F: A4 3F	
	PFF5:FC	754		DFB	>READ-1	2:	(read from tape)	CF4]	CF41:A6 3E	
	FFF6:17	755		DFB	>SETMODE-1	-:	(memory fill)	CF43	CF43:D0 01	CF46
	FFF7:17	756	٠,٢	DFB	>SETMODE-1		(address delimiter)	CF4	CF45:88	
	PPP8:FS	757	_	DFB	>CRMON-1		'CR' (end of input)	CF46	CF46:CA	
	FFF9:03	758	~	DFB	>BLANK-1	; BLANK		CF47	CF47:8A	
	FFFA:	759	*					CF48		
		760	_	D.	IWI	-NON:	NON-MASKABLE INTERRUPT VECTOR	CF4		٠.
	FFFC:62 FA	761		M	RESET	RESE	RESET VECTOR	CF41		
	FFFE:FA C3	762	~	M	IRQ	; INTE	INTERRUPT REQUEST VECTOR	CF41	CF4D:10 01	CF50
	:0000	19		INCL	INCLUDE MINI			CF41	CF4F:C8	
	:0000							CF5		
	:0000	. •	2 * Apple	a //e	* Apple //e Mini Assembler	oler		CFS		
	:0000	. , .	* +				- 6	CF33:1	CF53:D0 40	CF9
	:0000		105 * *	nnemon	Got mnemonic, check address mode	address	mode		: :	
	.0000:	0070		000	SUL STUDIOES	~			: :	
			*	ON O	COURTAIC	•		CFS	CF55:A4 2F	
	C4C8:20 13 FF		8 AMODI	JSR	NNBL	get ne	get next non-blank	CF5		3D 00
	34	•		STY	YSAV	; save Y	*	CF5	CF5A:91 3A	_
	C4CD:DD B4 F9	10		CMP	CHARI, X			CFS	CF5C:88	
	C4D0:D0 13 C	C4E5 11	_	BNE	AMOD2			CF51	CF5D:10 F8	CF57
	C4D2:20 13 FF	12	7	JSR	NNBL	;get n	;get next non-blank	CF5F:		
	C4D5:DD BA F9	-	~	CMP	CHAR2,X			CF5F:	:	
	C4D8:F0 0D C	C4E7 14	4	BEO	AMOD3			CF5F:		
	BA F9	_	S	LDA	CHAR2,X	;done yet?	yet?	CF51		F9
	07	C4E6 16	9	BEO	AMOD4			CF6		FC
	A4			CMP	# \$A4	;1f "S	if "S" then done	CF6		PC
	03	C4E6 18	œ,	BEO	AMOD4			CF6	CF68:4C E3	
	C4E3:A4 34	19	6	LDY	YSAV	restore Y	re Y	Cr68:	:	
	C4E5:18	7	20 AMOD2	CLC				CF6B:		
	C4E6:88	.7	AMOD4	DEY				CF6B:	::	

22 AMOD3 ROL ASL ;shift bit into format
24 AROD6
25 1.0R 48.00
26 1.0R AMOD5
27 REQ AMOD5
28 AMOD5 STX ARM
30 1.0X 48.03
31 AMOD6 STX AIH
32 AMOD6 STX AIH
33 AMOD6 STX AIH
34 REL
35 AMOD6 STX AIH
36 A Calculate offset byte for relative addresses
41 REL
42 A SRE
44 A SRE
44 A SRE
45 BRE
46 BRE
48 RELI DX A2L
48 RELI DX A2L
49 RELI DX A2L
49 RELI DX A2L
40 A SRE
50 CCC
51 SBC RAS
51 SCC
52 STA A1H
52 AMOD6 STX AIH
53 AMOD6 STX AIH
54 A SRE
55 CCC
56 BRE
56 CCC
57 A SRE
56 CCC
57 A SRE
56 CCC
57 A SRE
57 A SRE
58 A SRE
58 A SRE
59 A SRE
50 CCC
50 A SRE
50 CCC
50 A SRE
50 CCC
51 SBC RAS
51 SCC
52 STA A2L
53 SCC
54 SRE
55 CCC
56 A SRE
56 CCC
57 SCC
58 CCC
5

CF50

CF95

print blanks to make ProDOS work

CF57

C4FA C4F5 C4C8

CF3A

CF53 CF46

CFC2:09 C2 CFC4:90 D1 CF9 CFC6: CFC6: CFC6: CFC6: CFC6:04 CFC7:04		05 C8 C4 44 20 35 80 80	
;get opcode ; idecemine mnemonic index ; determine mnemonic index ; X = index ; X = index ; get right half of index ; dess if match entry? ; =>try next opcode ; get left half of index ; dess if the half of index ; get left half of index		or with	** Read a line of input. If prefaced with "", decode ** memonic. If "g's do monitor command. Otherwise parse ** hex address before decoding mnemonic. ** bolust JSR ZMODE ;clear mode ** LDA \$200
A1H INSDS2 MNEMR,X A4L NXTOP MNEML,X	NXTOP ASL FORMAT #\$9D REL FORMAT	AlH GETOP A5L YSAVI GETOP :he erro	ERR3 te of in the series of the series before \$200 bolin \$50 bolin \$580 boli
LDA JSR LDA CMP LDA LDA	BNE LDA CPY CMP	DEC BNE INC DEC DEC DEC LO E E E E E E E E E E E E E E E E E E	TAX JMP ddress ddress ddress ddress JSR KTS KTS BBNE BNE RTS JSR LDA JSR STA NA DS DS DS DS DS DS DS DS DS DS DS DS DS
GETOP			
76 77 79 80 81 82 83	88 88 89 90 91	92 93 94 95 96 97 98 99 100 101 102 103	103 104 105 106 107 108 109 110 111 111 111 111 111 111 111 111
3D 8E F8 00 FA 42 13 CP8B	CF8B CF3A CF55		D2 PC C7 FP 00 02 00 02 01 CF88 01 CF88 01 CF88 03 FP 03 FP 13 FF
			C7 000 000 000 000 000 000 000 000 000 0
CF6B: CF6B:A5 CF6D:20 CF70:AA CF71:BD CF74:C5 CF76:D0 CF78:BD	CF711.00 CF711.00 CF711.00 CF811.00 CF811.00 CF811.00 CF811.00 CF811.00	CF8B:C6 CF8P:E6 CF91:C6 CF93:P0 CF95: CF95: CF95: CF95: CF95: CF95: CF95: CF95: CF95: CF95: CF95: CF95: CF95: CF95:	CF981.AA CF991.CB9C1.CB9

byte for making CTOD checksum ok

get next opcode

;update format
;update position
;get next character
;isi t a ";";
;=>yas, skip comment
;is it carriage return

CFFC CFBO

get our format

index into address mode tables ido this elsewhere iget format

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CF97



accumulator: The register in the 65C02 microprocessor where most computations are performed.

ACIA: Acronym for Asynchronous Communications Interface Adapter. A single chip that converts data from parallel to serial form and vice versa. An ACIA handles serial transmission and reception and RS-232-C signals under the control of its internal registers, which can be set and changed by firmware or software.

acronym: A word formed from the initial letters of a name or phrase, such as ROM (from read-only memory).

address: A number that specifies the location of a single byte of memory. Addresses can be given as decimal integers or as hexadecimal integers. A 64K system has addresses ranging from 0 to 65535 (in decimal) or from \$0000 to \$FFFF (in hexadecimal).

algorithm: A step-by-step procedure for solving a problem or accomplishing a task.

American Simplified Keyboard: See Dvorak keyboard.

analog: Varying smoothly and continuously over a range, rather than changing in discrete jumps. For example, a conventional 12-hour clock face is an analog device that shows the time of day by the continuously changing position of the clock's hands. Compare digital.

analog data: Data in the form of continuously variable quantities. Compare digital data.

analog signal: A signal that varies continuously over time, rather than being sent and received in discrete intervals. Compare digital signal.

analog-to-digital converter (ADC): A device that converts quantities from analog to digital form. For example, computer hand controls convert the position of the control dial (an analog quantity) into a discrete number (a digital quantity) that changes stepwise even when the dial is turned smoothly.

AND: A logical operator that produces a true result if both its operands are true, and a false result if either or both of its operands are false. Compare **OR**, **NOT**, **exclusive OR**.

ANSI: Acronym for *American National Standards Institute*, which sets standards for many technical fields and is the most common standard for computer terminals.

Apple I: The first Apple computer. It was built in a garage in California by Steve Jobs and Steve Wozniak.

Applesoft BASIC: The Apple II dialect of the BASIC programming language. An interpreter for creating and executing Applesoft BASIC programs is built into the firmware of computers in the Apple II family. See also **BASIC**, **Integer BASIC**.

Apple III: An Apple computer; part of the Apple II family. The Apple III offered a built-in disk drive and built-in RS-232-C (serial) port. Its memory was expandable to 256K.

Apple II: A family of computers, including the original Apple II, the Apple II Plus, the Apple IIe, the Apple IIc, and the Apple IIGS. The original Apple II used Integer BASIC instead of Applesoft BASIC, and it required a keyboard command (PR#6) in order to start up from a disk.

Apple IIc: A transportable personal computer in the Apple II family, with a disk drive and 80-column display capability built in.

Apple IIe: A personal computer in the Apple II family with seven expansion slots and an auxiliary memory slot that allow the user to enhance the computer's capabilities with peripheral and auxiliary cards. The Apple IIe has been improved and enhanced over the years.

Apple IIe 80-Column Text Card: A peripheral card that plugs into the Apple IIe's auxiliary memory slot and allows the computer to display either 40 or 80 characters per line.

Apple He Extended 80-Column Text Card: A peripheral card that plugs into the Apple He's auxiliary memory slot and allows the computer to display either 40 or 80 characters per line while extending the computer's memory capacity by 64K.

Apple IIGS: A powerful new member of the Apple II family. The Apple IIGS uses a 16-bit microprocessor and has 256K of RAM. It has slots like the Apple IIe and ports like the Apple IIc, and contains a 15-voice custom sound chip.

Apple II Pascal: A software system for the Apple II family that lets you create and execute programs written in the Pascal programming language. Apple II Pascal was adapted by Apple Computer from the University of California, San Diego, Pascal Operating System (UCSD Pascal).

Apple II Plus: A personal computer in the Apple II family with expansion slots that allow the user to enhance the computer's capabilities with peripheral and auxiliary cards.

application program: A program written for some specific purpose, such as word processing data base management, graphics, or telecommunication. Compare system program.

argument: A value on which a function or statement operates; it can be a number or a variable. For example, in the BASIC statement VTAB 10, the number 10 is the argument. Compare operand.

arithmetic expression: A combination of numbers and arithmetic operators (such as 3 + 5) that indicates some operation to be carried out.

arithmetic operator: An operator, such as +, that combines numeric values to produce a numeric result. Compare logical operator, relational operator.

ASCII: Acronym for *American Standard Code* for *Information Interchange*; pronounced "ASK-ee." A code in which the numbers from 0 to 127 stand for text characters. ASCII code is used for representing text inside a computer and for transmitting text between computers or between a computer and a peripheral device. Compare **EBCDIC.**

assembler: A language translator that converts a program written in assembly language into an equivalent program in machine language. The opposite of a **disassembler.**

assembly language: A low-level programming language in which individual machine-language instructions are written in a symbolic form that's easier to understand than machine language itself. Each assembly-language instruction produces one machine-language instruction. See also machine language.

asynchronous: Not synchronized by a mutual timing signal or clock. Compare **synchronous.**

asynchronous transmission: A method of data transmission in which the receiving and sending devices don't share a common timer, and no timing data is transmitted. Each information character is individually synchronized, usually by the use of start and stop bits. The time interval between characters isn't necessarily fixed. Compare synchronous transmission.

auxiliary slot: The special expansion slot inside the Apple IIe used for the Apple IIe 80-Column Text Card or Extended 80-Column Text Card, and also for the RGB monitor card. The slot is labeled "AUX. CONNECTOR" on the circuit board.

base address: In indexed addressing, the fixed component of an address.

BASIC: Acronym for *Beginners All-purpose Symbolic Instruction Code*. BASIC is a high-level programming language designed to be easy to learn. Two versions of BASIC are available from Apple Computer for use with all Apple II–family systems: Applesoft BASIC (built into the firmware) and Integer BASIC.

baud: A unit of data transmission speed: the number of discrete signal state changes per second. Often, but not always, equivalent to *bits per second*. Compare **bit rate**.

binary: Characterized by having two different components, or by having only two alternatives or values available; sometimes used synonymously with **binary system.**

binary digit: The smallest unit of information in the binary number system; a 0 or a 1. Also called a **bit.**

binary operator: An operator that combines two operands to produce a result. For example, + is a binary arithmetic operator; < is a binary relational operator; OR is a binary logical operator. Compare unary operator.

binary system: The representation of numbers in the base-2 system, using only the two digits 0 and 1. For example, the numbers 0, 1, 2, 3, and 4 become 0, 1, 10, 11, and 100 in binary notation. The binary system is commonly used in computers because the values 0 and 1 can easily be represented in a variety of ways, such as the presence or absence of current, positive or negative voltage, or a white or black dot on the display screen. A single binary digit—a 0 or a 1—is called a bit. Compare decimal, hexadecimal.

bit: A contraction of binary digit. The smallest unit of information that a computer can hold. The value of a bit (1 or 0) represents a simple two-way choice, such as yes or no, on or off, positive or negative, something or nothing. See also binary system.

bit rate: The speed at which bits are transmitted, usually expressed as *bits per second*, or *bps*. Compare **baud.**

bits per second: See bit rate.

board: See printed-circuit board.

body: In BASIC, the statements or instructions that make up a part of a program, such as a loop or a subroutine.

boot: Another way to say start up. A computer boots by loading a program into memory from an external storage medium such as a disk. Starting up is often accomplished by first loading a small program, which then reads a larger program into memory. The program is said to "pull itself up by its own bootstraps"—hence the term bootstrapping or booting.

boot disk: See startup disk.

bootstrap: See boot.

bps: See bit rate.

branch: (v) To pass program control to a line or statement other than the next in sequence. (n) A statement that performs a branch. See **conditional branch, unconditional branch.**

BREAK: A SPACE (0) signal, sent over a communication line, of long enough duration to interrupt the sender. This signal is often used to end a session with a time-sharing service. BREAK is also used in BASIC to stop execution of a program. It's generated by pressing Control-C.

BRK: A "software interrupt." An instruction that causes the 6502 or 65C02 microprocessor to halt. Pronounced "break."

buffer: A "holding area" of the computer's memory where information can be stored by one program or device and then read at a different rate by another; for example, a print buffer. In editing functions, an area in memory where deleted (cut) or copied data is held. In some applications, this area is called the *Clipboard*.

bug: An error in a program that causes it not to work as intended. The expression reportedly comes from the early days of computing when an itinerant moth shorted a connection and caused a breakdown in a room-size computer.

bus: A group of wires or circuits that transmit related information from one part of a computer system to another. In a network, a line of cable with connectors linking devices together. A bus network has a beginning and an end. (It's not in a closed circle or T shape.)

byte: A unit of information consisting of a fixed number of bits. On Apple II systems, one byte consists of a series of eight bits, and a byte can represent any value between 0 and 255. The sequence represents an instruction, letter, number, punctuation mark, or other character. See also kilobyte, megabyte.

cable: An insulated bundle of wires with connectors on the ends; the number of wires varies with the type of connection. Examples are serial cables, disk drive cables, and AppleTalk cables.

call: (v) To request the execution of a subroutine, function, or procedure. (n) A request from the keyboard or from a procedure to execute a named procedure. See **procedure.**

carriage return: An ASCII character (decimal 13) that ordinarily causes a printer or display device to place the next character on the left margin.

carrier: The background signal on a communication channel that is modified to carry information. Under RS-232-C rules, the carrier signal is equivalent to a continuous MARK (1) signal; a transition to 0 then represents a start bit.

carry flag: A status bit in the 6502 or 65C02 microprocessor, used as a ninth bit with the eight accumulator bits in addition, subtraction, rotation, and shift operations.

central processing unit (CPU): The "brain" of the computer; the microprocessor that performs the actual computations in machine language. See **microprocessor.**

character: Any symbol that has a widely understood meaning and thus can convey information. Some characters—such as letters, numbers, and punctuation—can be displayed on the monitor screen and printed on a printer. Compare **control character.**

character code: A number used to represent a character for processing by a computer system.

character set: The entire set of characters that can be either shown on a monitor or used to code computer instructions. In a printer, the entire set of characters that the printer is capable of printing.

Clear To Send: An RS-232-C signal from a DCE to a DTE that is normally kept false until the DCE makes it true, indicating that all circuits are ready to transfer data out. See Data Communication Equipment, Data Terminal Equipment.

code: (1) A number or symbol used to represent some piece of information. (2) The statements or instructions that make up a program.

cold start: The process of starting up the Apple II when the power is first turned on (or as if the power had just been turned on) by loading the operating system into main memory, and then loading and running a program. Compare **warm start.**

column: A vertical arrangement of graphics points or character positions on the display.

command: An instruction that causes the computer to perform some action. A command can be typed from a keyboard, selected from a menu with a hand-held device (such as a mouse), or embedded in a program.

compiler: A language translator that converts a program written in a high-level programming language (source code) into an equivalent program in some lower-level language such as machine language (object code) for later execution. Compare interpreter.

composite video: A video signal that includes both display information and the synchronization (and other) signals needed to display it. See RGB monitor.

computer: An electronic device that performs predefined (programmed) computations at high speed and with great accuracy. A machine that is used to store, transfer, and transform information.

computer language: See programming language.

conditional branch: A branch whose execution depends on the truth of a condition or the value of an expression. Compare unconditional branch.

configuration: (1) The total combination of hardware components—CPU, video display device, keyboard, and peripheral devices—that make up a computer system. (2) The software settings that allow various hardware components of a computer system to communicate with each other.

connector: A plug, socket, jack, or port.

constant: In a program, a symbol that represents a fixed, unchanging value. Compare **variable**.

control character: A nonprinting character that controls or modifies the way information is printed or displayed. In the Apple II family, control characters have ASCII values between 0 and 31, and are typed from a keyboard by holding down the Control key while pressing some other key. In the Macintosh family, the Command key performs a similar function.

control code: One or more nonprinting characters—included in a text file—whose function is to change the way a printer prints the text. For example, a program may use certain control codes to turn boldface printing on and off. See control character.

control key: A general term for a key that controls the operation of other keys; for example, Apple, Caps Lock, Control, Option, and Shift. When you hold down or engage a control key while pressing another key, the combination makes that other key behave differently. Also called a modifier key.

Control key: A specific key on Apple II–family keyboards that produces **control characters** when used in combination with other keys.

controller card: A peripheral card that connects a device such as a printer or disk drive to a computer's main logic board and controls the operation of the device.

Control-Reset: A combination keystroke on Apple II–family computers that usually causes an Applesoft BASIC program or command to stop immediately. If a program disables the Control-Reset feature, you need to turn the computer off to get the program to stop.

copy protect: To make a disk uncopyable. Software publishers frequently try to copy protect their disks to prevent them from being illegally duplicated by software pirates. Compare **write protect.**

CPU: See central processing unit.

crash: To cease to operate unexpectedly, possibly destroying information in the process.

current input device: The source, such as the keyboard or a modem, from which a program is currently receiving its input.

current output device: The destination, such as the display screen or a printer, currently receiving a program's output.

cursor: A symbol displayed on the screen marking where the user's next action will take effect or where the next character typed from the keyboard will appear.

DAC: See digital-to-analog converter.

data: Information, especially information used or operated on by a program. The smallest unit of information a computer can understand is a bit.

data bits: The bits in a communication transfer that contain information. Compare start bit, stop bit.

Data Carrier Detect (DCD): An RS-232-C signal from a DCE (such as a modem) to a DTE (such as an Apple IIe) indicating that a communication connection has been established. See Data Communication Equipment, Data Terminal Equipment.

Data Communication Equipment (DCE): As defined by the RS-232-C standard, any device that transmits or receives information. Usually this device is a modem.

data set: A device that modulates, demodulates, and controls signals transferred between business machines and communication facilities. A form of modem.

Data Set Ready (DSR): An RS-232-C signal from a DCE to a DTE indicating that the DCE has established a connection. See Data Communication Equipment, Data Terminal Equipment.

Data Terminal Equipment (DTE): As defined by the RS-232-C standard, any device that generates or absorbs information, thus acting as an endpoint of a communication connection. A computer might serve as a DTE.

Data Terminal Ready (DTR): An RS-232-C signal from a DTE to a DCE indicating a readiness to transmit or receive data. See Data Communication Equipment, Data Terminal Equipment.

DCD: See Data Carrier Detect.

DCE: See Data Communication Equipment.

debug: A colloquial term that means to locate and correct an error or the cause of a problem or malfunction in a computer program. Compare **troubleshoot.** See also **bug.**

decimal: The common form of number representation used in everyday life, in which numbers are expressed in in the base-10 system, using the ten digits 0 through 9. Compare **binary**, **hexadecimal**.

default: A preset response to a question or prompt. The default is automatically used by the computer if you don't supply a different response. Default values prevent a program from stalling or crashing if no value is supplied by the user.

deferred execution: The execution of a BASIC program instruction that is part of a complete program. The program instruction is executed only when the complete program is run. You defer execution of the instruction by preceding it with a program line number. The complete program executes consecutive instructions in numerical order. Compare immediate execution.

Delete key: A key on the upper-right corner of the Apple IIe and IIc keyboards that erases the character immediately preceding (to the left of) the cursor. Similar to the Macintosh Backspace key.

delimiter: A character that is used for punctuation to mark the beginning or end of a sequence of characters, and which therefore is not considered part of the sequence itself. For example, Applesoft BASIC uses the double quotation mark (") as a delimiter for string constants: the string "DOG" consists of the three characters *D*, *O*, and *G*, and does not include the quotation marks.

demodulate: To recover the information being transmitted by a modulated signal. For example, a conventional radio receiver demodulates an incoming broadcast signal to convert it into the sound emitted by the radio's speaker. Compare modulate.

device: Frequently used as a short form of **peripheral device.**

device driver: A program that manages the transfer of information between the computer and a peripheral device.

device handler: See device driver.

digit: (1) One of the characters 0 through 9, used to express numbers in decimal form. (2) One of the characters used to express numbers in some other form, such as 0 and 1 in binary or 0 through 9 and A through F in hexadecimal.

digital: Represented in a discrete (noncontinuous) form, such as numerical digits or integers. For example, contemporary digital clocks show the time as a digital display (such as 2:57) instead of using the positions of a pair of hands on a clock face. Compare analog.

digital data: Data that can be represented by digits—that is, data that are discrete rather than continuously variable. Compare analog data.

digital signal: A signal that is sent and received in discrete intervals. A signal that does not vary continuously over time. Compare analog signal.

digital-to-analog converter: A device that converts quantities from digital to analog form.

DIP: See dual in-line package.

DIP switches: A bank of tiny switches, each of which can be moved manually one way or the other to represent one of two values (usually on and off). See **dual in-line package.**

disassembler: A language translator that converts a machine-language program into an equivalent program in assembly language, which is easier for programmers to understand. The opposite of an assembler.

disk: An information-storage medium consisting of a flat, circular, magnetic surface on which information can be recorded in the form of small magnetized spots, in a manner similar to the way sounds are recorded on tape. See floppy disk, hard disk.

disk-based: See disk-resident.

disk controller card: A peripheral card that provides the connection between one or two disk drives and the computer. This connection, or interface, is built into both the Apple IIc and Macintosh-family computers.

disk drive: The device that holds a disk, retrieves information from it, and saves information to it.

disk envelope: A removable, protective paper sleeve used when handling or storing a 5.25-inch disk. It must be removed before you insert the disk in a disk drive. Compare disk jacket.

disk jacket: A permanent, protective covering for a disk. 5.25-inch disks have flexible, paper or plastic jackets; 3.5-inch disks have hard plastic jackets. The disk is never removed from the jacket. Compare **disk envelope.**

Disk Operating System (DOS): An optional software system for the Apple II family of computers that enables the computer to control and communicate with one or more disk drives. The acronym *DOS* rhymes with *boss*.

disk-resident: An adjective describing a program that does not remain in memory. The computer retrieves all or part of the program from the disk, as needed. Sometimes called *disk-based*. Compare **memory-resident**.

Disk II drive: An older type of disk drive made and sold by Apple Computer for use with the Apple II, II Plus, and IIe. It uses 5.25-inch disks.

display: (1) A general term to describe what you see on the screen of your display device when you're using a computer; from the verb form, which means "to place into view." (2) Short for a display device.

display color: The color currently being used to draw high-resolution or low-resolution graphics on the display screen.

display device: A device that displays information, such as a television set or video monitor.

display screen: The screen of the monitor; the area where you view text and pictures when using the computer.

DOS 3.2: An early Apple II operating system. DOS stands for **Disk Operating System**; 3.2 is the version number. Disks formatted using DOS 3.2 have 13 sectors per track.

DOS 3.3: An operating system used by the Apple II family of computers. DOS stands for **Disk Operating System;** 3.3 is the version number. Disks formatted with DOS 3.3 have 16 sectors per track.

drive: See disk drive.

DSR: See Data Set Ready.

DTE: See Data Terminal Equipment.

DTR: See Data Terminal Ready.

dual in-line package (DIP): An integrated circuit packaged in a narrow rectangular box with a row of metal pins along each side. DIP switches on the box allow you to change settings. For example, ImageWriter printer DIP switches control functions such as line feed, form length, and baud setting.

Dvorak keyboard: An alternate keyboard layout, also known as the *American Simplified Keyboard*, which increases typing speed because the keys most often used are in the positions easiest to reach. Compare **QWERTY keyboard**.

EBCDIC: Acronym for *Extended Binary-Coded Decimal Interchange Code;* pronounced "EB-si-dik." A code used by IBM that represents each letter, number, special character, and control character as an 8-bit binary number. EBCDIC has a character set of 256 8-bit characters. Compare **ASCII.**

effective address: In machine-language programming, the address of the memory location on which a particular instruction operates, which may be arrived at by indexed addressing or some other addressing method.

80-column text card: A peripheral card that allows the Apple II, Apple II Plus, and Apple IIe to display text in either 40 columns or 80 columns.

80/40-column switch: A switch that controls the maximum number of columns or characters across the screen. A television can legibly display a maximum of 40 characters across the screen, whereas a video monitor can display 80 characters.

embedded: Contained within. For example, the string 'HUMPTY DUMPTY' is said to contain an embedded space.

emulate: To operate in a way identical to a different system. For example, the Apple II 2780/3780 Protocol Emulator and the Apple II 3270 BSC Protocol Emulator, together with the Apple Communications Protocol Card (ACPC), allow the Apple II, Apple II Plus, or Apple IIe to emulate the operations of IBM 3278 and 3277 terminals and 3274 and 3271 control units.

end-of-command mark: A punctuation mark used to separate commands sent to a peripheral device such as a printer or plotter. Also called a command terminator.

end-of-line character: A character that indicates that the preceding text constitutes a full line.

error code: A number or other symbol representing a type of error.

error message: A message displayed or printed to tell you of an error or problem in the execution of a program or in your communication with the system. An error message is often accompanied by a beep.

ESCAPE character: An ASCII character that, with many programs and devices, allows you to perform special functions when used in combination keypresses.

escape code: A sequence of characters that begins with an ESCAPE character and constitutes a complete command. Usually synonymous with **escape sequence.**

Escape key: A key on Apple II–family computers that generates the ESCAPE character. The Escape key is labeled *Esc.* In many applications, pressing Escape allows you to return to a previous **menu** or to stop a procedure.

escape mode: A state of the Apple IIe and IIc entered by pressing the Escape key and certain other keys. The other keys take on special meanings for positioning the cursor and controlling the display of text on the screen.

escape sequence: A sequence of keystrokes, beginning with the Escape key. In **escape mode**, escape sequences are used for positioning the cursor and controlling the display of text on the screen. Escape sequences are also used as codes to control printers.

Esc key: See Escape key.

even/odd parity check: In data transmission, a check that tests whether the number of 1 bits in a group of binary digits is even (even parity check) or odd (odd parity check).

even parity: In data transmission, the use of an extra bit set to 0 or 1 as necessary to make the total number of 1 bits an even number; used as a means of error checking. Compare MARK parity, odd parity.

exclusive OR: A logical operator that produces a true result if one of its operands is true and the other false, and a false result if its operands are both true or both false. Compare OR, AND, and NOT.

execute: To perform the actions specified by a program command or sequence of commands.

expansion slot: A connector into which you can install a peripheral card. Sometimes called a *peripheral slot*. See also **auxiliary slot**.

expression: A formula in a program that defines a calculation to be performed.

FIFO: Acronym for "first in, first out" order, as in a queue.

file: Any named, ordered collection of information stored on a disk. Application programs and operating systems on disks are files. You make a file when you create text or graphics, give the material a name, and save it to disk.

firmware: Programs stored permanently in read-only memory (ROM). Such programs (for example, the Applesoft Interpreter and the Monitor program) are built into the computer at the factory. They can be executed at any time but cannot be modified or erased from main memory. Compare hardware, software.

fixed-point: A method of representing numbers inside the computer in which the decimal point (more correctly, the binary point) is considered to occur at a fixed position within the number. Typically, the point is considered to lie at the right end of the number so that the number is interpreted as an **integer.** Compare **floating-point.**

flag: A variable whose value (usually 1 or 0, standing for *true* or *false*) indicates whether some condition holds or whether some event has occurred. A flag is used to control the program's actions at some later time.

floating-point: A method of representing numbers inside the computer in which the decimal point (more correctly, the binary point) is permitted to "float" to different positions within the number. Some of the bits within the number itself are used to keep track of the point's position. Compare fixed-point.

floppy disk: A **disk** made of flexible plastic, as compared to a **hard disk**, which is made of metal. The term *floppy* is now usually applied only to disks with thin, flexible **disk jackets**, such as 5.25-inch disks. With 3.5-inch disks, the disk itself is flexible, but the jacket is made of hard plastic; thus, 3.5-inch disks aren't particularly "floppy."

format: (n) (1) The form in which information is organized or presented. (2) The general shape and appearance of a printed page, including page size, character width and spacing, line spacing, and so on. (v) To divide a disk into tracks and sectors where information can be stored. Blank disks must be formatted before you can save information on them for the first time; same as initialize.

form feed: An ASCII character (decimal 12) that causes a printer or other paper-handling device to advance to the top of the next page.

Fortran: Short for *Formula Translator*. A high-level programming language especially suitable for applications requiring extensive numerical calculations, such as in mathematics, engineering, and the sciences.

framing error: In serial data transfer, the absence of the expected stop bit(s) at the end of a received character.

frequency: In alternating current (AC) signals, the number of complete cycles transmitted per second. Frequency is usually expressed in hertz (cycles per second), kilohertz (kilocycles per second), or megahertz (megacycles per second). In acoustics, frequency of vibration determines musical pitch.

full duplex: A four-wire communication circuit or protocol that allows two-way data transmission between two points at the same time. Compare **half duplex.**

function: A preprogrammed calculation that can be carried out on request from any point in a program. A function takes in one or more arguments and returns a single value. It can therefore be embedded in an expression.

game I/O connector: A 16-pin connector inside the Apple II, II Plus, and IIe, originally designed for connecting hand controls to the computer, but also used for connecting some other peripheral devices. Compare hand control connector.

graph: A pictorial representation of data.

graphics: (1) Information presented in the form of pictures or images. (2) The display of pictures or images on a computer's display screen. Compare **text.**

half duplex: A two-wire communication circuit or protocol designed for data transmission in either direction but not both directions simultaneously. Compare full duplex.

hand control connector: A 9-pin connector on the back panel of the Apple IIe and IIc computers, used for connecting hand controls to the computer. Compare game I/O connector.

hand controls: Peripheral devices, with rotating dials and push buttons. Hand controls are used to control game-playing programs, but they can also be used in other applications.

hang: To cease operation because either an expected condition is not satisfied or an infinite loop is occurring. A computer that's hanging is called a *hung system*. Compare **crash**.

hard disk: A disk made of metal and sealed into a drive or cartridge. A hard disk can store very large amounts of information compared to a floppy disk.

hard disk drive: A device that holds a hard disk, retrieves information from it, and saves information to it. Hard disks made for microprocessors are permanently sealed into the drives.

hardware: In computer terminology, the machinery that makes up a computer system. Compare firmware, software.

hertz: The unit of frequency of vibration or oscillation, defined as the number of cycles per second. Named for the physicist Heinrich Hertz and abbreviated Hz. The 6502 microprocessor used in the Apple II systems operates at a clock frequency of about 1 million hertz, or 1 megahertz (MHz). The 68000 microprocessor used in the Macintosh operates at 7.8336 MHz.

hexadecimal: The representation of numbers in the base-16 system, using the ten digits 0 through 9 and the six letters A through F. For example, the decimal numbers 0, 1, 2, 3, 4, ... 8, 9, 10, 11, ... 15, 16, 17 would be shown in hexadecimal notation as 00, 01, 02, 03, 04, ... 08, 09, 0A, 0B, ... 0F, 10, 11. Hexadecimal numbers are easier for people to read and understand than are binary numbers, and they can be converted easily and directly to binary form. Each hexadecimal digit corresponds to a sequence of four binary digits, or bits. Hexadecimal numbers are usually preceded by a dollar sign (\$).

high ASCII characters: ASCII characters with decimal values of 128 to 255. Called *high ASCII* because their high bit (first binary digit) is set to 1 (for *on*) rather than 0 (for *off*).

high-level language: A programming language that is relatively easy for people to understand. A single statement in a high-level language typically corresponds to several instructions of machine language. High-level languages available from Apple Computer include BASIC, Pascal, Instant Pascal, Logo, Pilot, SuperPILOT, and Fortran. Compare low-level language.

high-order byte: The more significant half of a memory address or other two-byte quantity. In the 6502 microprocessor used in the Apple II family of computers, the **low-order byte** of an address is usually stored first, and the high-order byte second. In the 68000 microprocessors used in the Macintosh family, the high-order byte is stored first.

high-resolution graphics: The display of graphics on a screen as a six-color array of points, 280 columns wide and 192 rows high. When a text window is in use, the visible high-resolution graphics display is 280 by 160 points.

hold time: In computer circuits, the amount of time a signal must remain valid after some related signal has been turned off. Compare **setup time**.

Hz: See hertz.

IC: See integrated circuit.

immediate execution: The execution of a program statement as soon as it is typed. In BASIC, immediate execution occurs when the line is typed without a line number; immediate execution allows you to try out nearly every statement immediately to see how it works. Compare deferred execution.

implement: To put into practical effect, as to *implement* a plan. For example, a language translator implements a particular language.

IN#: This command designates the source of subsequent input characters. It can be used to designate a device in a slot or a machine-language routine as the source of input.

index: (1) A number used to identify a member of a list or table by its sequential position. (2) A list or table whose entries are identified by sequential position. (3) In machine-language programming, the variable component of an indexed address, contained in an index register and added to the base address to form the effective address.

indexed addressing: A method used in machine-language programming to specify memory addresses. See also **memory location.**

index register: A register in a computer processor that holds an index for use in indexed addressing. The 6502 microprocessor used in the Apple II family of computers has two index registers, called the **X register** and the **Y register**. The 68000 microprocessor used in Macintosh-family computers has 16 registers that can be used as index registers.

index variable: A variable whose value changes on each pass through a loop. Often called control variable or *loop variable*.

infinite loop: A section of a program that will repeat the same sequence of actions indefinitely.

initialize: (1) To set to an initial state or value in preparation for some computation. (2) To prepare a blank disk to receive information by organizing its surface into tracks and sectors; same as format.

initialized disk: A disk that has been organized into tracks and sectors by the computer and is therefore ready to store information.

input: Information transferred into a computer from some external source, such as the keyboard, a disk drive, or a modem.

input/output (I/O): The process by which information is transferred between the computer's memory and its keyboard or peripheral devices.

input routine: A machine-language routine; the standard input routine reads characters from the keyboard. A different input routine might, for example, read them from an external terminal.

instruction: A unit of a machine-language or assembly-language program corresponding to a single action for the computer's processor to perform.

integer: A whole number in fixed-point form. Compare **real number.**

Integer BASIC: A version of the BASIC programming language used by the Apple II family of computers. Integer BASIC is older than Applesoft BASIC and is capable of processing numbers in integer (fixed-point) form only. Many games are written in Integer BASIC because its instructions can be executed very quickly. Compare Applesoft BASIC.

integrated circuit: An electronic circuit—including components and interconnections—entirely contained in a single piece of semiconducting material, usually silicon. Often referred to as an *IC* or a *chip*.

interface: (1) The point at which independent systems or diverse groups interact. The devices, rules, or conventions by which one component of a system communicates with another. Also, the point of communication between a person and a computer. (2) The part of a program that defines constants, variables, and data structures, rather than procedures.

interface card: A peripheral card that implements a particular interface (such as a parallel or serial interface) by which the computer can communicate with a peripheral device such as a printer or modem.

interpreter: A language translator that reads a program instruction by instruction and immediately translates each instruction for the computer to carry out. Compare **compiler.**

interrupt: A temporary suspension in the execution of a program that allows the computer to perform some other task, typically in response to a signal from a peripheral device or other source external to the computer.

inverse video: The display of text on the computer's display screen in the form of dark dots on a light (or other single phosphor color) background, instead of the usual light dots on a dark background.

I/O: See input/output.

I/O device: Input/output device. A device that transfers information into or out of a computer. See input, output, peripheral device.

I/O link: A fixed location that contains the address of an input/output subroutine in the computer's Monitor program.

IWM: "Integrated Woz Machine"; the custom chip that controls Apple's 3.5-inch disk drives.

joystick: A peripheral device with a lever, typically used to move creatures and objects in game programs; a joystick can also used in applications such as computer-aided design and graphics programs.

K: See kilobyte.

keyboard: The set of keys, similar to a typewriter keyboard, used for entering information into the computer.

keyboard input connector: The connector inside the Apple II family of computers by which the keyboard is connected to the computer.

keyword: A special word or sequence of characters that identifies a particular type of statement or command, such as *RUN*, *BRUN*, or *PRINT*.

kilobyte (K): A unit of measurement consisting of 1024 (2¹⁰) **bytes.** In this usage, *kilo* (from the Greek, meaning a thousand) stands for 1024. Thus, 64K memory equals 65,536 bytes. See also **megabyte.**

KSW: The symbolic name of the location in the computer's memory where the standard input link (namely, to the keyboard) is stored. KSW stands for *keyboard switch*.

language: See programming language.

language card: A peripheral card that, when placed in slot 0 of a 48K Apple II or Apple II Plus, gives the computer a total of 64K of memory. If you have an Apple II or Apple II Plus, you need a language card or the equivalent to use ProDOS.

language translator: A system program that reads another program written in a particular programming language and either executes it directly or converts it into some other language (such as machine language) for later execution. See interpreter, compiler, assembler.

leading zero: A zero occurring at the beginning of a decimal number, deleted by most computing programs.

least significant bit: The rightmost bit of a binary number. The least significant bit contributes the smallest quantity to the value of the number. Compare **most significant bit.**

LIFO: Acronym for "first in, last out" order, as in a stack.

line: See program line.

line feed: An ASCII character (decimal 10) that ordinarily causes a printer or video display to advance to the next line.

line number: A number identifying a program line in an Applesoft BASIC program.

line width: The number of characters that fit on a line on the screen or on a page.

list: To display on a monitor, or print on a printer, the contents of memory or of a file.

load: To transfer information from a peripheral storage medium (such as a disk) into main memory for use—for example, to transfer a program into memory for execution.

location: See memory location.

logic: (1) In microcomputers, a mathematical treatment of formal logic using a set of symbols to represent quantities and relationships that can be translated into switching circuits, or gates. AND, OR, and NOT are examples of logical gates. Each gate has two states, open or closed, allowing the application of binary numbers for solving problems. (2) The systematic scheme that defines the interactions of signals in the design of an automatic data processing system.

logical operator: An operator, such as AND, that combines logical values to produce a logical result, such as true or false; sometimes called a *Boolean operator*. Compare arithmetic operator, relational operator.

logic board: See main logic board.

loop: A section of a program that is executed repeatedly until a limit or condition is met, such as an index variable's reaching a specified ending value.

loop variable: See index variable.

low-level language: A programming language that is relatively close to the form the computer's processor can execute directly. One statement in a low-level language corresponds to a single machine-language instruction. Examples are 6502 machine language, 6502 assembly language, and 68000 machine and assembly languages. Compare high-level language.

low-order byte: The less significant half of a memory address or other two-byte quantity. In the 6502 microprocessor used in the Apple II family of computers, the low-order byte of an address is usually stored first, and the **high-order byte** second. The opposite is true for Macintosh computers.

low-power Schottky (LS): A type of transistor-transistor logic (TTL) integrated circuit having lower power and higher speed than a conventional TTL integrated circuit; named for Walter Schottky (1886–1956), a semiconductor physicist.

low-resolution graphics: The display of graphics on a display screen as a 16-color array of blocks, 40 columns wide and 48 rows high. For example, on a Macintosh when the text window is in use, the visible low-resolution graphics display is 40 by 40 plotting points—that is, 40 by 40 pixels. See high-resolution graphics.

LS: See low-power Schottky.

machine language: The form in which instructions to a computer are stored in memory for direct execution by the computer's processor. Each model of computer processor (such as the 6502 microprocessor used in the Apple II family of computers) has its own form of machine language.

mainframe computer: A central processing unit or computer that is larger and more powerful than a minicomputer or a personal computer (microcomputer). Frequently called simply a mainframe for short. The Apple Access II program and MacTerminal make it possible to communicate with mainframe computers over telecommunications media.

main logic board: A large circuit board that holds RAM, ROM, the microprocessor, custom-integrated circuits, and other components that make the computer a computer.

main memory: The part of a computer's memory whose contents are directly accessible to the microprocessor; usually synonymous with random-access memory (RAM). Programs are loaded into main memory, and that's where the computer keeps information while you're working. Sometimes simply called *memory*. See also readonly memory, read-write memory.

MARK parity: A bit of value 1 appended to a binary number for transmission. The receiving device checks for errors by looking for this value on each character. Compare even parity, odd parity.

megabyte: A unit of measurement equal to 1024 kilobytes, or 1,048,576 bytes; abbreviated Mb. See kilobyte.

memory: A hardware component of a computer system that can store information for later retrieval. See main memory, random-access memory, read-only memory, read-write memory.

memory location: A unit of main memory that is identified by an address and can hold a single item of information of a fixed size. In the Apple II family of computers, a memory location holds one byte, or eight bits, of information.

memory-resident: (1) Stored permanently in memory as firmware (ROM). (2) Held continually in memory even while not in use. DOS is a memory-resident program.

menu: A list of choices presented by a program, from which you can select an action.

MHz: Megahertz; one million hertz. See hertz.

microcomputer: A computer, such as any of the Apple II or Macintosh computers, whose processor is a **microprocessor**.

microprocessor: A computer processor contained in a single integrated circuit, such as the 6502 or 65C02 microprocessor used in the Apple II family of computers and the 68000 microprocessor used in the Macintosh family. The microprocessor is the central processing unit (CPU) of the microcomputer.

microsecond: One millionth of a second. Abbreviated us.

millisecond: One thousandth of a second. Abbreviated ms.

mode: A state of a computer or system that determines its behavior. A manner of operating.

modem: Short for *MOdulator/DEModulator*. A peripheral device that links your computer to other computers and information services using the telephone lines.

modifier key: A key (Apple, Caps Lock, Control, Option, Shift) that generates no keyboard events of its own, but changes the meaning of other keys or mouse actions. Also called a *control key*.

modulate: To modify or alter a signal so as to transmit information. For example, conventional broadcast radio transmits sound by modulating the amplitude (amplitude modulation, or AM) or the frequency (frequency modulation, or FM) of a carrier signal.

monitor: See video monitor.

Monitor program: A system program built into the firmware of some computers, used for directly inspecting or changing the contents of main memory and for operating the computer at the machine-language level. The Monitor program activates the disk drive when you turn on the computer.

most significant bit: The leftmost bit of a binary number. The most significant bit contributes the largest quantity to the value of the number. For example, in the binary number 10110 (decimal value 22), the leftmost bit has the decimal value 16 (2⁴). Compare least significant bit.

mouse: A small device you move around on a flat surface next to your computer. The mouse controls a pointer on the screen whose movements correspond to those of the mouse. You use the pointer to select menu items, to move data, and to draw with in graphics programs.

mouse button: The button on the top of the mouse. In general, pressing the mouse button initiates some action on whatever is under the pointer, and releasing the button confirms the action.

nanosecond: One billionth of a second. Abbreviated ns.

nested loop: A loop contained within the body of another loop and executed repeatedly during each pass through the outer loop. See **loop.**

nested subroutine call: A call to a subroutine from within the body of another subroutine.

nibble: A unit of data equal to half a byte, or four bits. A nibble can hold any value from 0 to 15.

NOT: A unary logical operator that produces a true result if its operand is false, and a false result if its operand is true. Compare **AND**, **OR**, **exclusive OR**.

NTSC: (1) Abbreviation for *National Television Standards Committee*. The committee that defined the standard format used for transmitting broadcast video signals in the United States. (2) The standard video format defined by the NTSC.

object code: See object program.

object program: The translated form of a program produced by a language translator such as a compiler or assembler. Also called *object code*. Compare **source program.**

odd parity: In data transmission, the use of an extra bit set to 0 or 1 as necessary to make the total number of 1 bits an odd number; used as a means of error checking. Compare **even parity, MARK parity.**

opcode: See operation code.

Open Apple: A **control key** on the Apple II–family keyboards; on later keyboards, simply called the *Apple key*.

operand: A value to which an operator is applied. The value on which an operation code operates. Compare **argument.**

operating system: A program that organizes the actions of the parts of the computer and its peripheral devices.

operation code: The part of a machine-language instruction that specifies the operation to be performed. Often called *opcode*.

operator: A symbol or sequence of characters, such as + or AND, specifying an operation to be performed on one or more values (the operands) to produce a result. See arithmetic operator, relational operator, logical operator, unary operator, binary operator.

option: (1) Something chosen or available as a choice; for instance, items in a menu. (2) An argument whose provision is optional.

OR: A logical operator that produces a true result if either or both of its operands are true, and a false result if both of its operands are false. Compare **exclusive OR**, **AND**, **NOT**.

output: Information transferred from a computer to some external destination, such as the display screen, a disk drive, a printer, or a modem.

output routine: A machine-language routine that performs the sending of characters. The standard output routine sends characters to the screen. A different output routine might, for example, send them to a printer.

overflow: The condition that exists when an attempt is made to put more data into a given memory area than it can hold; for example, a computational result that exceeds the allowed range.

override: To modify or cancel an instruction by issuing another one.

overrun: A condition that occurs when the processor does not retrieve a received character from the receive data register of the Asynchronous Communications Interface Adapter (ACIA) before the subsequent character arrives. The ACIA automatically sets bit 2 (OVR) of its status register; subsequent characters are lost. The receive data register contains the last valid data word received.

page: (1) A screenful of information on a video display. In the Apple II family of computers, a page consists of 24 lines of 40 or 80 characters each. (2) An area of main memory containing text or graphical information being displayed on the screen. (3) A segment of main memory 256 bytes long and beginning at an address that is an even multiple of 256.

page zero: See zero page.

parallel interface: An interface in which several bits of information (typically eight bits, or one byte) are transmitted simultaneously over different wires or channels. Compare serial interface.

parity: Sameness of level or count, usually the count of 1 bits in each character, used for error checking in data transmission. See even parity, MARK parity, odd parity, parity bit.

Pascal: A high-level programming language with statements that resemble English phrases. Pascal was designed to teach programming as a systematic approach to problem solving. Named after the philosopher and mathematician Blaise Pascal.

pass: A single execution of a loop.

PC board: See printed-circuit board.

peek: To read information directly from a location in the computer's memory.

peripheral: (adj) At or outside the boundaries of the computer itself, either physically (as a peripheral device) or in a logical sense (as a peripheral card). (n) Short for *peripheral device*.

peripheral bus: The **bus** used for transmitting information between the computer and peripheral devices connected to the computer's expansion slots or ports.

peripheral card: A removable printed-circuit board that plugs into one of the computer's expansion slots. Peripheral cards allow the computer to use peripheral devices or to perform some subsidiary or peripheral function.

peripheral device: A piece of hardware—such as a video monitor, disk drive, printer, or modem—used in conjunction with a computer and under the computer's control. Peripheral devices are often (but not necessarily) physically separate from the computer and connected to it by wires, cables, or some other form of interface. They often require peripheral cards.

peripheral slot: See expansion slot.

phase: (1) A stage in a periodic process. A point in a cycle. For example, the 6502 microprocessor uses a clock cycle consisting of two phases called Φ 0 and Φ 1. (2) The relationship between two periodic signals or processes.

PILOT: Acronym for *Programmed Inquiry*, *Learning*, *Or Teaching*. A high-level programming language designed for teachers and used to create computer-aided instruction (CAI) lessons that include color graphics, sound effects, lesson text, and answer checking. SuperPILOT is an enhanced version of the original Apple II PILOT programming language.

pipelining: A feature of a processor that enables it to begin fetching the next instruction before it has finished executing the current instruction. All else being equal, processors with this feature run faster than those without it.

pixel: Short for *picture element*. A point on the graphics screen; the visual representation of a bit on the screen (white if the bit is 0, black if it's 1). Also, a location in video memory that maps to a point on the graphics screen when the viewing window includes that location.

plotting vector: A code representing a single step in drawing a shape on the high-resolution graphics screen. The plotting vector specifies whether to plot a point at the current screen position, and in what direction to move (up, down, left, or right) before processing the next vector.

pointer: An item of information consisting of the memory address of some other item. For example, Applesoft BASIC maintains internal pointers to the most recently stored variable, the most recently typed program line, and the most recently read data item, among other things. The 6502 uses one of its internal registers as a pointer to the top of the stack.

point of call: The point in a program from which a subroutine or function is called.

poke: To store information directly into a location in the computer's memory.

pop: To remove the top entry from a **stack**, moving the stack pointer to the entry below it. Synonymous with *pull*. Compare **push**.

power supply: A circuit that draws electrical power from a power outlet and converts it to the kind of power the computer can use.

power supply case: The metal case inside most Apple II and Macintosh computers that houses the power supply. The Apple IIc uses an external power supply case.

PR#: An Applesoft BASIC command that sends output to a slot or a machine-language program. It specifies an output routine in the ROM on a peripheral card or in a machine-language routine in RAM by changing the address of the standard output routine used by the computer.

precedence: The order in which operators are applied in evaluating an expression. Precedence varies from language to language, but usually resembles the precedence rules of algebra.

printed-circuit board: A hardware component of a computer or other electronic device, consisting of a flat, rectangular piece of rigid material, commonly Fiberglas, to which integrated circuits and other electronic components are connected.

procedure: In the Pascal and Logo programming languages, a set of instructions that work as a unit; approximately equivalent to the term **subroutine** in BASIC.

processor: The hardware component of a computer that performs the actual computation by directly executing instructions represented in machine language and stored in main memory. See **microprocessor.**

ProDOS: An Apple II operating system designed to support hard disk drives like the ProFile, as well as floppy disk storage devices. ProDOS stands for *Professional Disk Operating System*. Compare **DOS.**

ProDOS command: Any one of the 28 commands recognized by ProDOS.

program: (n) A set of instructions describing actions for a computer to perform in order to accomplish some task, conforming to the rules and conventions of a particular programming language. (v) To write a program.

program line: The basic unit of an Applesoft BASIC program, consisting of one or more statements separated by colons (:).

programming language: A set of symbols and associated rules or conventions for writing programs. BASIC, Logo, and Pascal are programming languages.

prompt: A message on the screen that tells you of some need for response or action. A prompt usually takes the form of a symbol, a message, a dialog box, or a menu of choices.

prompt character: A text character displayed on the screen, usually just to the left of a cursor, where your next action is expected. The prompt character often identifies the program or component of the system that's prompting you. For example, Applesoft BASIC uses a square bracket prompt character (]); Integer BASIC, an angle bracket (>); and the System Monitor program, an asterisk (*).

prompt line: A specific area on the display reserved for prompts.

protocol: A formal set of rules for sending and receiving data on a communication line.

push: To add an entry to the top of a **stack**, moving the stack pointer to point to it. Compare **pop.**

queue: A list in which entries are added at one end and removed at the other, causing entries to be removed in first-in, first-out (FIFO) order. Compare stack.

QWERTY keyboard: The standard layout of keys on a typewriter keyboard; its name is formed from the first six letters on the top row of letter keys. Compare **Dvorak keyboard.**

radio-frequency (RF) modulator: A device that makes your television set work as a monitor.

RAM: See random-access memory.

random-access memory (RAM): Memory in which information can be referred to in an arbitrary or random order. As an analogy, a book is a random-access storage device in that it can be opened and read at any point. RAM usually means the part of memory available for programs from a disk; the programs and other data are lost when the computer is turned off. A computer with 512K RAM has 512 kilobytes available to the user. (Technically, the read-only memory (ROM) is also random access, and what's called RAM should correctly be termed read-write memory.) Compare read-only memory, read-write memory.

random-access text file: A text file that is partitioned into an unlimited number of uniform-length compartments called *records*. When you open a random-access text file for the first time, you must specify its record length. No record is placed in the file until written to. Each record can be individually read from or written to—hence, *random-access*.

raster: The pattern of parallel lines making up the image on a video display screen. The image is produced by controlling the brightness of successive points on the individual lines of the raster.

read: To transfer information into the computer's memory from outside the computer (such as a disk drive or modem) or into the computer's processor from a source external to the processor (such as the keyboard or main memory).

read-only memory (ROM): Memory whose contents can be read, but not changed; used for storing firmware. Information is placed into read-only memory once, during manufacture; it then remains there permanently, even when the computer's power is turned off. Compare random-access memory, read-write memory.

read-write memory: Memory whose contents can be both read and changed (or written to). The information contained in read-write memory is erased when the computer's power is turned off and is permanently lost unless it has been saved on a disk or other storage device. Compare random-access memory, read-only memory.

real number: In computer usage, a number that may include a fractional part; represented inside the computer in **floating-point** form. Because a real number is of infinite precision, this representation is usually approximate. Compare **integer.**

register: A location in a processor or other chip where an item of information is held and modified under program control.

relational operator: An operator, such as >, that operates on numeric values to produce a logical result. Compare arithmetic operator, logical operator.

reserved word: A word or sequence of characters reserved by a programming language for some special use and therefore unavailable as a variable name in a program.

resident: See memory-resident, disk-resident.

return address: The point in a program to which control returns on completion of a subroutine or function.

RF modulator: See radio-frequency modulator.

RGB monitor: A type of color monitor that receives separate signals for each color (red, green, and blue). See **composite video**.

ROM: See read-only memory.

routine: A part of a program that accomplishes some task subordinate to the overall task of the program.

row: A horizontal arrangement of character cells or graphics **pixels** on the screen.

RS-232 cable: Any cable that is wired in accordance with the RS-232 standard, which is the common serial data communication interface standard.

run: (1) To execute a program. When a program runs, the computer performs the instructions. (2) To load a program into main memory from a peripheral storage medium, such as a disk, and execute it.

save: To store information by transferring the information from main memory to a disk. Work not saved disappears when you turn off the computer or when the power is interrupted.

screen: See display screen.

scroll: To move all the text on the screen upward or downward, and, in some cases, sideways. See **viewport, window.**

serial interface: An interface in which information is transmitted sequentially, a bit at a time, over a single wire or channel. Compare parallel interface.

setup time: The amount of time a signal must be valid in advance of some event. Compare **hold** time.

silicon (Si): A solid, crystalline chemical element from which integrated circuits are made. Silicon is a *semiconductor*; that is, it conducts electricity better than insulators, but not as well as metallic conductors. Silicon should not be confused with silica—that is, silicon dioxide, such as quartz, opal, or sand—or with silicone, any of a group of organic compounds containing silicon.

simple variable: A variable that is not an element of an array.

6502: The microprocessor used in the Apple II, in the Apple II Plus, and in early models of the Apple IIe.

65C02: The microprocessor used in the enhanced Apple IIe, the extended keyboard IIe, and the Apple IIc.

68000: The microprocessor used in the Macintosh and Macintosh Plus.

slot: A narrow socket inside the computer where you can install peripheral cards. Also called an **expansion slot.**

soft switch: Also called a software switch; a means of changing some feature of the computer from within a program. For example, **DIP** switch settings on ImageWriter printers can be overridden with soft switches. Specifically, a soft switch is a location in memory that produces some special effect whenever its contents are read or written.

software: A collective term for **programs**, the instructions that tell the computer what to do. They're usually stored on disks. Compare **hardware**, **firmware**.

source code: See source program.

source program: The form of a program given to a language translator, such as a compiler or assembler, for conversion into another form; sometimes called *source code*. Compare **object program.**

space character: A text character whose printed representation is a blank space, typed from the keyboard by pressing the Space bar.

stack: A list in which entries are added (pushed) or removed (popped) at one end only (the top of the stack), causing them to be removed in last-in, first-out (LIFO) order. Compare queue.

standard instruction: An instruction automatically present when no superseding instruction has been received.

starting value: The value assigned to the index variable on the first pass through a loop.

start up: To get the system running. Starting up is the process of first reading the operating system program from the disk, and then running an application program.

startup disk: A disk with all the necessary program files—such as the Finder and System files contained in the System folder in Macintosh—to set the computer into operation. In Apple II, sometimes called a *boot disk*.

statement: A unit of a program in a high-level language that specifies an action for the computer to perform. A statement typically corresponds to several instructions of machine language.

step value: The amount by which the index variable changes on each pass through a loop.

string: An item of information consisting of a sequence of text characters.

strobe: A signal whose change is used to trigger some action.

subroutine: A part of a program that can be executed on request from another point in the program and that returns control, on completion, to the point of the request.

synchronous: A mode of data transmission in which a constant time interval exists between transmission of successive bits, characters, or events. Compare **asynchronous**.

synchronous transmission: A transmission process that uses a clocking signal to ensure an integral number of unit (time) intervals between any two characters. Compare asynchronous transmission.

syntax: (1) The rules governing the structure of statements or instructions in a programming language. (2) A representation of a command that specifies all the possible forms the command can take.

system: A coordinated collection of interrelated and interacting parts organized to perform some function or achieve some purpose—for example, a computer system comprising a processor, keyboard, monitor, and disk drive.

system configuration: See configuration.

system program: A program that makes the resources and capabilities of the computer available for general purposes, such as an operating system or a language translator. Compare application program.

system software: The component of a computer system that supports application programs by managing system resources such as memory and I/O devices.

TAB: An ASCII character that commands a device such as a printer to start printing at a preset location (called a *tab stop*). There are two such characters: horizontal tab (hex 09) and vertical tab (hex 0B). TAB works like the tabs on a typewriter.

television set: A display device capable of receiving broadcast video signals (such as commercial television broadcasts) by means of an antenna. Can be used in combination with a radio-frequency modulator as a display device for the Apple II family of computers. Compare **video monitor.**

text: (1) Information presented in the form of readable characters. (2) The display of characters on a display screen. Compare **graphics.**

text window: An area on the video display screen within which text is displayed and scrolled.

traces: Electrical paths that connect the components on a circuit board.

transistor-transistor logic (TTL): (1) A family of integrated circuits having bipolar circuit logic; TTLs are used in computers and related devices. (2) A standard for interconnecting such circuits, which defines the voltages used to represent logical zeros and ones.

troubleshoot: To locate and correct the cause of a problem or malfunction, especially in hardware. Compare **debug.**

TTL: See transistor-transistor logic. turnkey disk: See startup disk. **unary operator:** An operator that applies to a single operand. For example, the minus sign (-) in a negative number such as -6 is a unary arithmetic operator. Compare **binary operator.**

unconditional branch: A branch that does not depend on the truth of any condition. Compare conditional branch.

value: An item of information that can be stored in a variable, such as a number or a string.

variable: (1) A location in the computer's memory where a value can be stored. (2) The symbol used in a program to represent such a location. Compare **constant.**

vector: (1) The starting address of a program segment, when used as a common point for transferring control from other programs. (2) A memory location used to hold a vector, or the address of such a location.

video: (1) A medium for transmitting information in the form of images to be displayed on the screen of a cathode-ray tube. (2) Information organized or transmitted in video form.

video monitor: A display device that can receive video signals by direct connection only, and that cannot receive broadcast signals such as commercial television. Can be connected directly to the computer as a display device. Compare television set.

viewport: All or part of the display screen used by an application program to display a portion of the information (such as a document, picture, or worksheet) on which a program is working. Compare **window**.

volume: A general term referring to a storage device; a source of or a destination for information. A volume has a name and a volume directory with the same name. Its information is organized into files.

warm start: The process of transferring control back to the operating system in response to a failure in an application program. Compare cold start.

window: The portion of a collection of information (such as a document, picture, or worksheet) that is visible in a viewport on the display screen. Compare viewport.

word: A group of bits that is treated as a unit; the number of bits in a word is a characteristic of each particular computer.

write: To transfer information from the computer to a destination external to the computer (such as a disk drive, printer, or modem) or from the computer's processor to a destination external to the processor (such as main memory).

write-enable notch: The square cutout on one edge of a 5.25-inch disk's jacket. If there is no write-enable notch, or if it is covered with a write-protect tab, the disk drive can read information from the disk, but cannot write on it.

write protect: To protect the information on a 5.25-inch disk by covering the write-enable notch with a write-protect tab, preventing the disk drive from writing any new information onto the disk. Compare copy protect.

write-protect tab: (1) A small adhesive sticker used to write protect a 5.25-inch disk by covering the write-enable notch. (2) The small plastic tab in the corner of a 3.5-inch disk jacket. You lock (write protect) the disk by sliding the tab toward the edge of the disk; you unlock the disk by sliding the tab back so that it covers the rectangular hole.

X register: One of the two index registers in the 6502 microprocessor.

Y register: One of the two index registers in the 6502 microprocessor.

zero page: The first page (256 bytes) of memory in the Apple II family of computers, also called *page zero*. Since the high-order byte of any address in this page is zero, only the low-order byte is needed to specify a zero-page address; this makes zero-page locations more efficient to address, in both time and space, than locations in any other page of memory.

Bibliography

- Addendum to the Design Guidelines. Cupertino, Calif.: Apple Computer, Inc., 1984.
- Applesoft BASIC Programmer's Reference Manual, Volumes 1 and 2. For the Apple II, IIe, and IIc. Reading, Mass.: Addison-Wesley, 1982, 1985. ISBN 0-201-17722-6.
- Applesoft Tutorial. Reading, Mass.: Addison-Wesley, 1983, 1985. ISBN 0-201-17724-2.
- Apple II Monitors Peeled. Cupertino, Calif.: Apple Computer, Inc., 1978. Currently not updated for Apple IIe and IIc, but a good introduction to Apple II series input/output procedures; also useful for historical background.
- Apple IIe Design Guidelines. Cupertino, Calif.: Apple Computer, Inc., 1982.
- "Characteristics of Television Systems." C.C.I.R. Report, Rep. 624 (1970–1974), pp. 22–52.
- "Colorimetric Standards in Colour Television." C.C.I.R. Report, Rep. 476-1 (1970–1974), pp. 21–22.
- Leventhal, Lance. 6502 Assembly Language Programming. Berkeley, Calif.: Osborne/McGraw-Hill, 1979.
- Sims, H. V. Principles of PAL Colour Television and Related Systems. London, England: Newnes-Butterworth, 1969. ISBN-0-592-05970-7.
- Synertek Hardware manual. Santa Clara, Calif.: Synertek Incorporated, 1976. Does not contain instructions new to 65C02, but is the only currently available manufacturer's hardware manual for 6500-series microcomputers.
- Synertek Programming manual. Santa Clara, Calif.: Synertek Incorporated, 1976. The only currently available manufacturer's programming manual for 6500-series microcomputers.

- "Video-Frequency Characteristics of a Television System to Be Used for the International Exchange of Programmes Between Countries That Have Adopted 625-Line Colour or Monochrome Systems." C.C.I.R., Recommendation 472-1 (1970–1971), pp. 53–54.
- Watson, Allen, III. "A Simplified Theory of Video Graphics, Part I." *Byte*, Vol. 5, No. 11 (November, 1980).
- __. "A Simplified Theory of Video Graphics, Part II." *Byte,* Vol. 5, No. 12 (December, 1980).
- __. "More Colors for Your Apple." Byte, Vol. 4, No. 6 (June, 1979).
- ___. "True Sixteen-Color Hi-Res." Apple Orchard, Vol. 5, No. 1 (January, 1984).
- Wozniak, Steve. "System Description: The Apple II." *Byte*, Vol. 2, No. 5 (May, 1977).
- __. "SWEET16: The 6502 Dream Machine." *Byte,* Vol. 2, No. 10 (October, 1977).

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The Official Publication from Apple Computer, Inc.

Written and produced by the people at Apple Computer, this is the definitive, up-to-date reference manual for the Apple® IIe computer. It was written for professional programmers, designers of peripheral equipment, and advanced home users. The first printing of this manual described the internal operation of the original and enhanced Apple IIe computers. The manual has now been revised to cover the new 128K Apple IIe with extended keyboard.

The *Apple IIe Technical Reference Manual* provides detailed descriptions of all of the Apple IIe's hardware and firmware, including input/output features (such as Mousetext), memory organization, and the use of the monitor firmware. Appendixes offer complete reference information to the 6502 and 65C02 instruction sets and built-in I/O subroutines, a complete source listing of the monitor firmware, and more. Anyone who needs technical information on the internal workings of the original, the enhanced, or the extended-keyboard Apple IIe will find this book an indispensable guide to one of the world's most popular computers.

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