

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.