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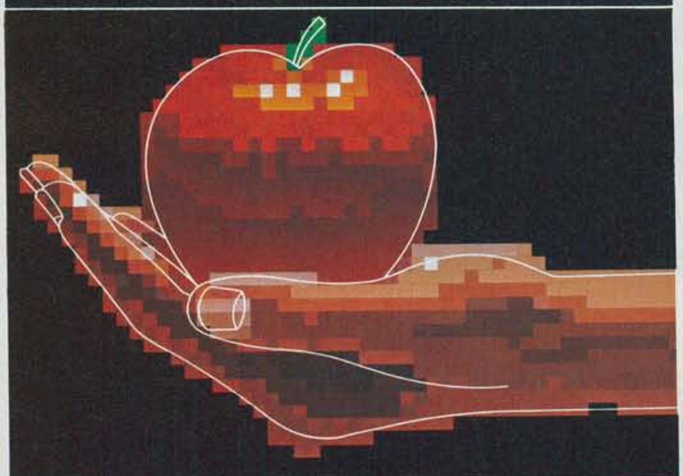
POLISH YOUR APPLE WITH A LUMINANCE BOARD



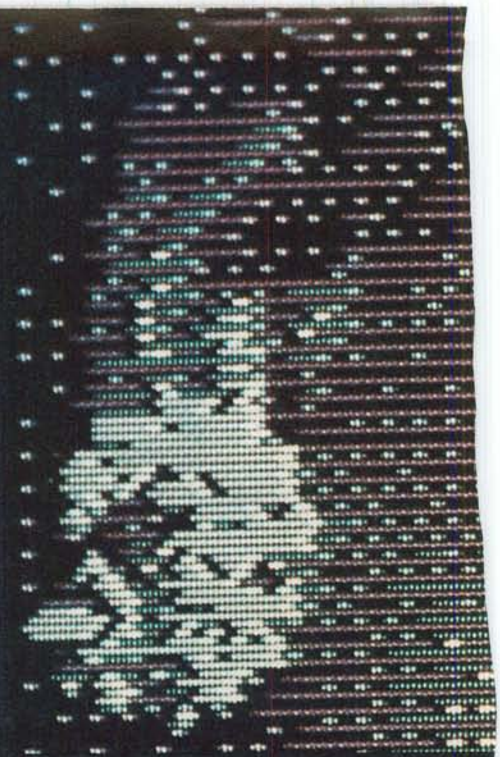
A low-cost plug-in board turns an Apple II computer into a graphics giant with 240 color choices

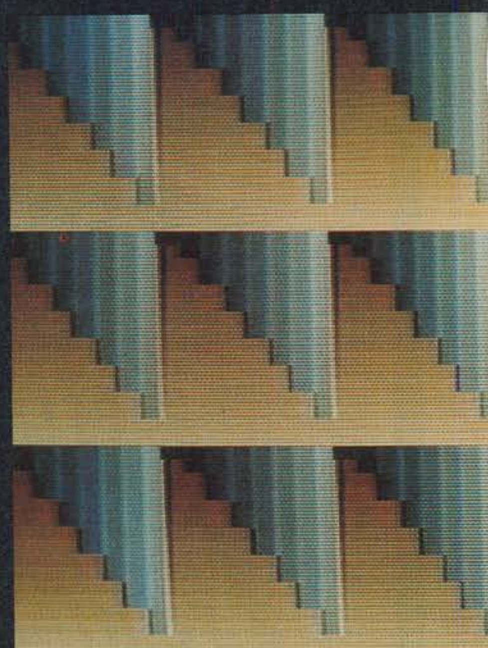
By Ray Dahlby

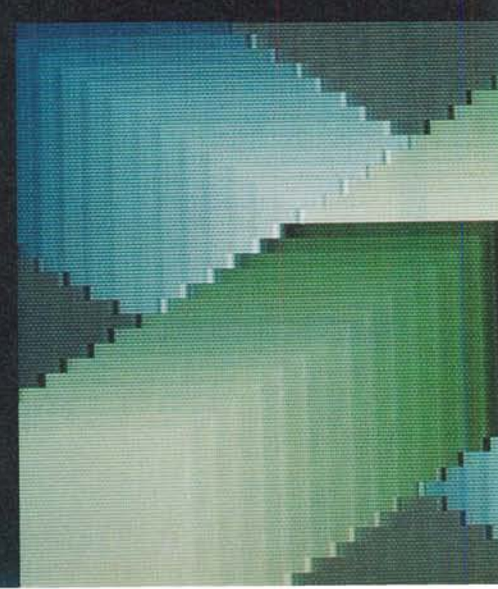
ENHANCING the utility of his/her computer is among the most fruitful accomplishments that a computerist can achieve. It separates the appliance operator from the innovative enthusiast. An Apple II microcomputer, for example, can produce the dramatic displays shown at right by simply plugging in an under-$100 hardware board (assembled in about an hour with the plans presented here) and running some software.

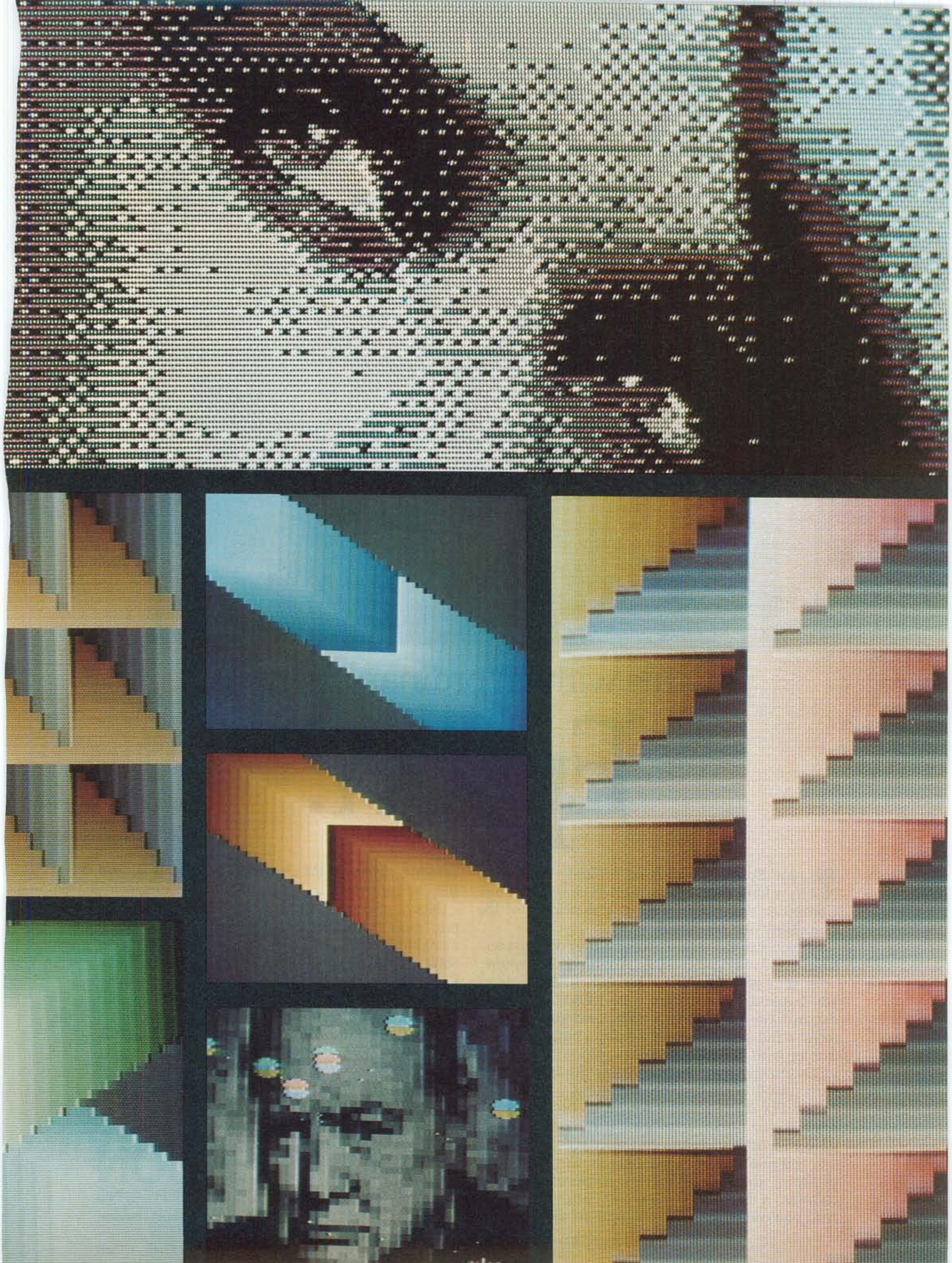
This accessory luminance board enables an Apple II to block-shade text with one of 16 brightness levels for 240 low-resolution colors in place of the normal 16 colors, and simultaneously display bar graphs with high resolution. In addition to luminance control, the circuit adds a video interrupt mechanism for synchronous video-screen page flipping and screen splits. This makes it possible to expand the Apple's mixed text and graphics mode so that text can be displayed above or below the graphics.

Using the board you can even display part of page-1 hi-res graphics with part of the graphics on page 2, or you









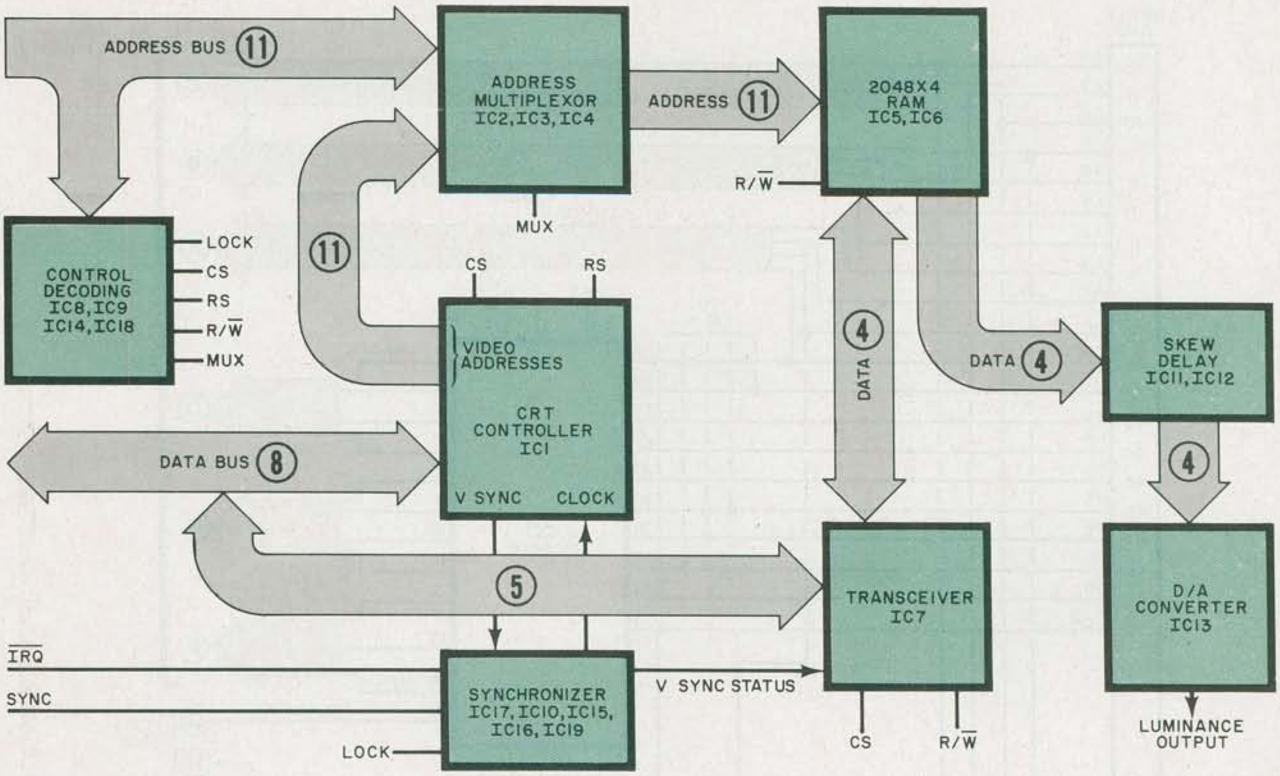
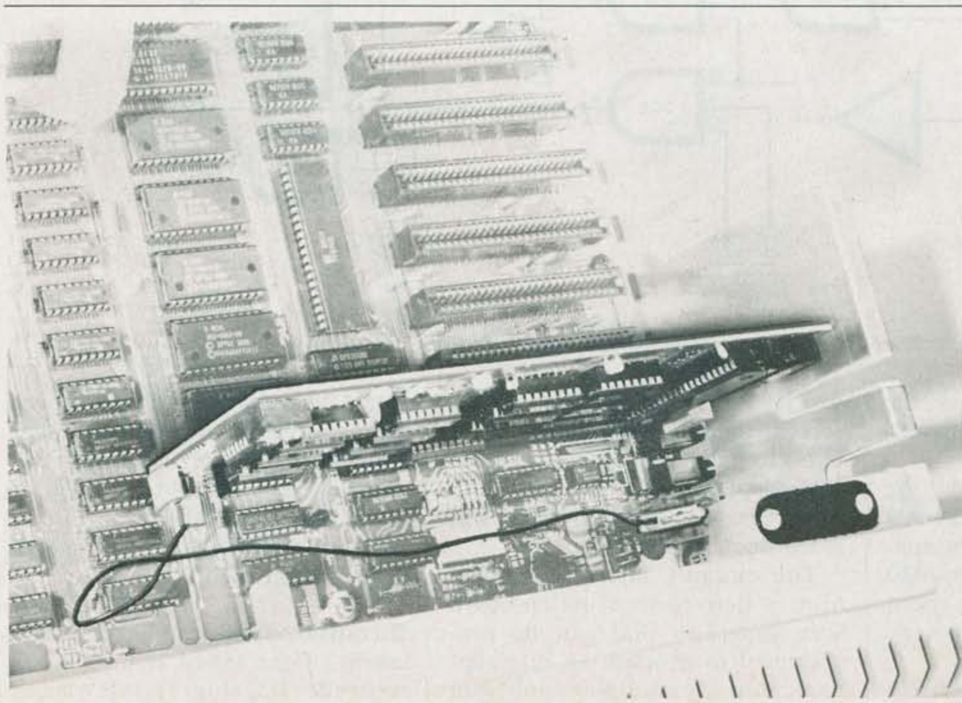


Fig. 1. The most important element of the system is the 6845 CRT controller.

can display them simultaneously for a double-resolution graphics display of 560 x 192 pixels. All of this is accomplished without complex modifications to existing Apple equipment and without losing the normal display modes. The card plugs into slot 7 as shown in the photo below.

The luminance component of a television signal contains brightness information about the image being viewed. Similarly, to add luminance capabilities to a computer, brightness information must be added to its video output. The circuit card supplies this information from a 2048 × 4-bit RAM memory. Data is mapped to overlay the Apple's screen in a 40 × 48 array of pixels. Data written to each



The accessory luminance board plugs into slot 7 on the Apple bus.

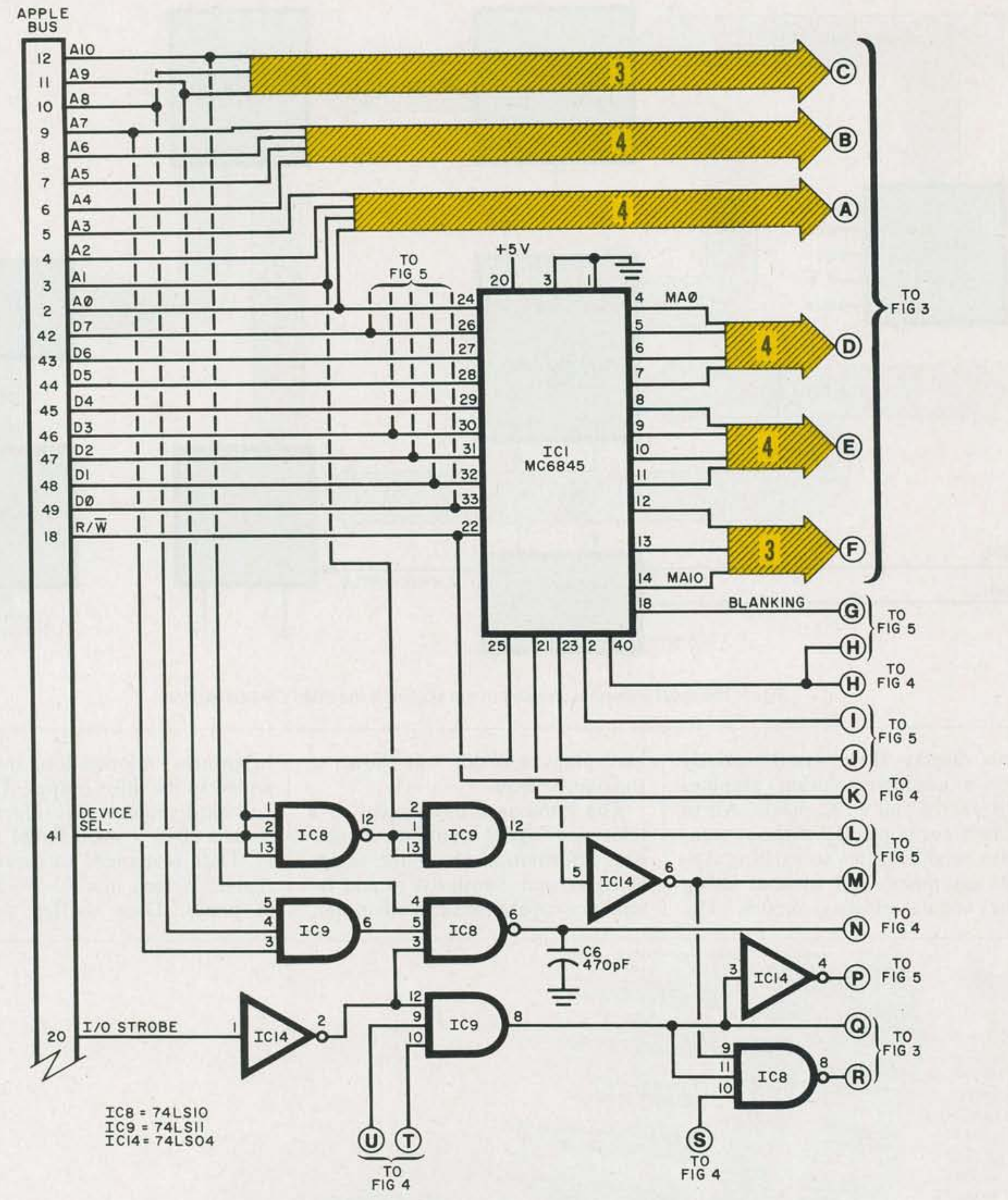


Fig. 2. The 6845 synchronously regenerates the video RAM addressing.

memory location determines the brightness level of the corresponding pixel.

Since 16 tone levels rival the quality of photographic film, 4 bits was considered adequate. The spatial resolution of 40 × 48 or 1920 pixels was chosen for high-speed animation and memory-size reduction.

Each luminance pixel precisely overlays a 7 × 4 dot area of the screen, adding luminance attributes to one block of low-res or an equivalent area of hi-res. Two luminance pixels stacked vertically will shade one text character.

The circuit's interrupt mechanism is derived from its on-board scan generator and can be programmed to produce an interrupt request on any multiple of four scan lines. This feature allows smooth animation plus synchronous page flipping. The 60-Hz interrupts can also be used as a real-time clock. A block diagram is shown in Fig. 1, with the complete schematic shown in Figs. 2 through 5.

Circuit Operation. The central element of the board is 6845 CRT controller *IC1* (Fig. 1). It is used to

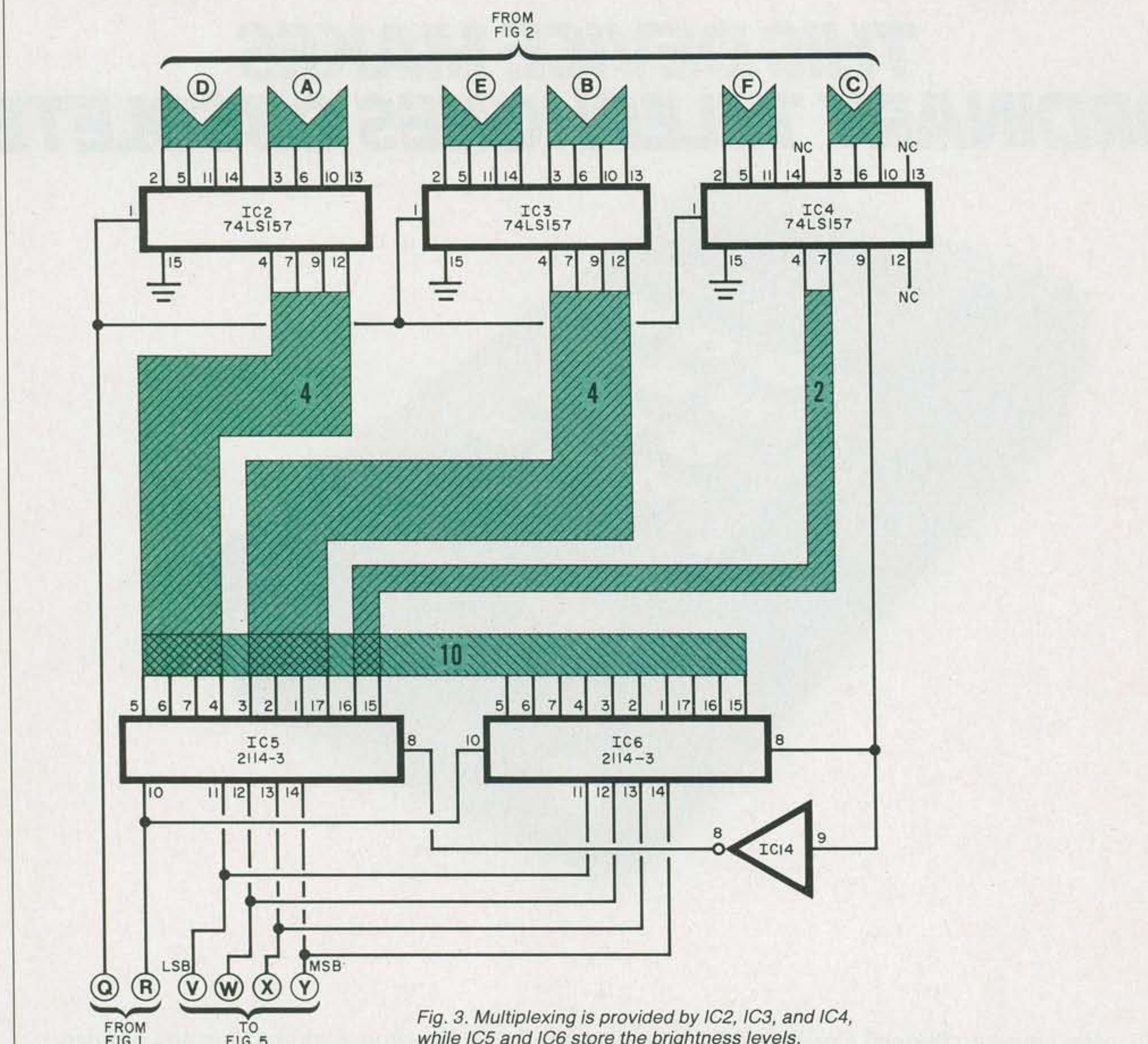


Fig. 3. Multiplexing is provided by IC2, IC3, and IC4, while IC5 and IC6 store the brightness levels.

synchronously regenerate the video RAM addressing not available on the Apple bus. This IC is programmed for the Apple video timing, then phase locked to the sync pulse on pin 19 of slot 7.

The circuit then runs in step with the Apple video, providing addressing for the on-board 2K × 4 luminance RAMs *IC5* and *IC6*, which store the brightness level of each luminance pixel. The RAMs can be read from, or written to, transparently by the Apple during phase 2 of the processor clock. This removes the "glitches" that are common to many 80-column plug-in boards. Address multiplexing is taken care of by *IC2*, *IC3*, and *IC4* (Fig. 3).

During phase 1 of the processor clock, contents of the luminance RAM addressed by *IC1* are fed to *IC12* (Fig. 5) which in turn drives the four-bit D/A comprised of elements of *IC13* and its associated resistor/ladder network. This converts the digital data into a 16-level analog signal. The output of this network, preset by *R11*, is coupled to the Apple baseband video output.

In *IC17* (Fig. 4) and its associated circuit the vertical sync signal is extracted from the composite signal that appears on pin 19 of slot 7. The resulting output provides a reference for the phase locking. The remainder of the phase-lock circuit is formed from *IC10*, *IC15A*, *IC16*, and elements of *IC19* in Fig. 4, and a portion of *IC12* of Fig. 5.

TABLE I
SWITCH POSITIONS

Revision	S1	S2	S3	S4
0-6	On	Off	*	On
7	Off	On		Off
8 and up	On	Off		Off
Future	Off	On		On

*S3 enable interrupts and is independent of revision number.

Construction. The circuit can be built on any Apple prototyping board using wire wrap or, alternatively, on a pc board such as that shown in Fig. 6. Since some elements of the circuit operate at 7 MHz, take care when using the point-to-point wiring technique.

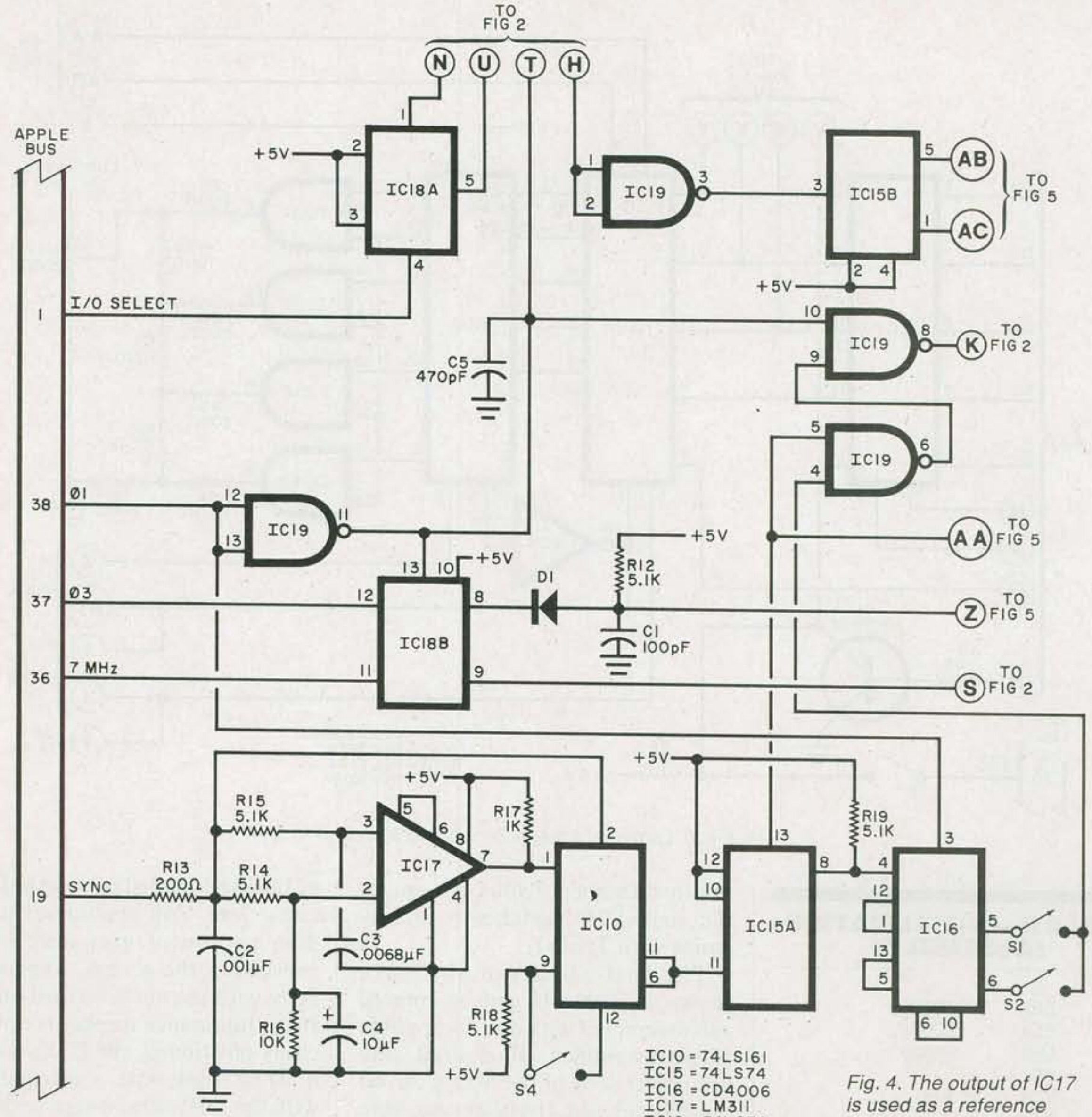


Fig. 4. The output of IC17 is used as a reference for the phase-lock loop.

PARTS LIST

C1—100-pF ceramic disc capacitor
C2—0.001-μF capacitor
C3—0.0068-μF capacitor
C4—10-μF, 15-V electrolytic
C5, C6—470-pF ceramic disc capacitor
C7 through C11—0.1-μF ceramic disc capacitor
D1—1N914 diode
IC1—MC6845 CRT controller
IC2 through IC4—74LS157 quad 2-input data selector
IC5, IC6—2114-3 1024 x 4 static RAM
IC7—74LS245 octal bus transceiver
IC8—74LS10 triple 3-input NAND
IC9—74LS11 triple 3-input AND
IC10—74LS161 4-bit binary counter
IC11, IC12—74LS174 hex D flip-flop
IC13—74LS08 quad 2-input AND
IC14—74LS04 hex inverter
IC15, IC18—74LS74 hex D flip-flop
IC16—CD4006 shift register
IC17—LM311N comparator
IC19—74LS00 quad 2-input NAND
Q1—2N3904
The following are ¼-W, 5% resistors unless otherwise noted:
R1, R16—10 kilohms
R2, R12, R14, R15, R18, R19—5.1 kilohms
R3 through R7, R13—200 ohms
R8, R9, R10—100 ohms
R11—200-ohm trimmer potentiometer (Bourns 3386W or equiv.)
R17—1 kilohm
S1 through S4—4-position DIP spst switch
Misc.—Sockets, 6" to 8" length of insulated lead, small alligator clip.

Note: The following is available from Ray Dahlby Electronics, Box 7600, Vancouver, B.C. V6B 4X9, Canada: Printed-circuit board, $29.95; sub-interpreter diskette, $10 check or money order in U.S. funds.

The use of sockets is recommended for the ICs, and caution must be observed with static-sensitive MOS devices *IC1*, *IC5*, *IC6*, and *IC16*.

After all components are installed (Fig. 7), carefully check all connections. A miniature DIP switch can be used for the four switches called for in the circuit. Attach a short length (6" to 8") of insulated lead to the luminance output (top of *R11*), and terminate the lead with a small alligator clip.

The Apple II has undergone several revisions in video timing to accommodate new TV receivers. This circuit handles these timing changes via the four DIP switches on the board. After determining the

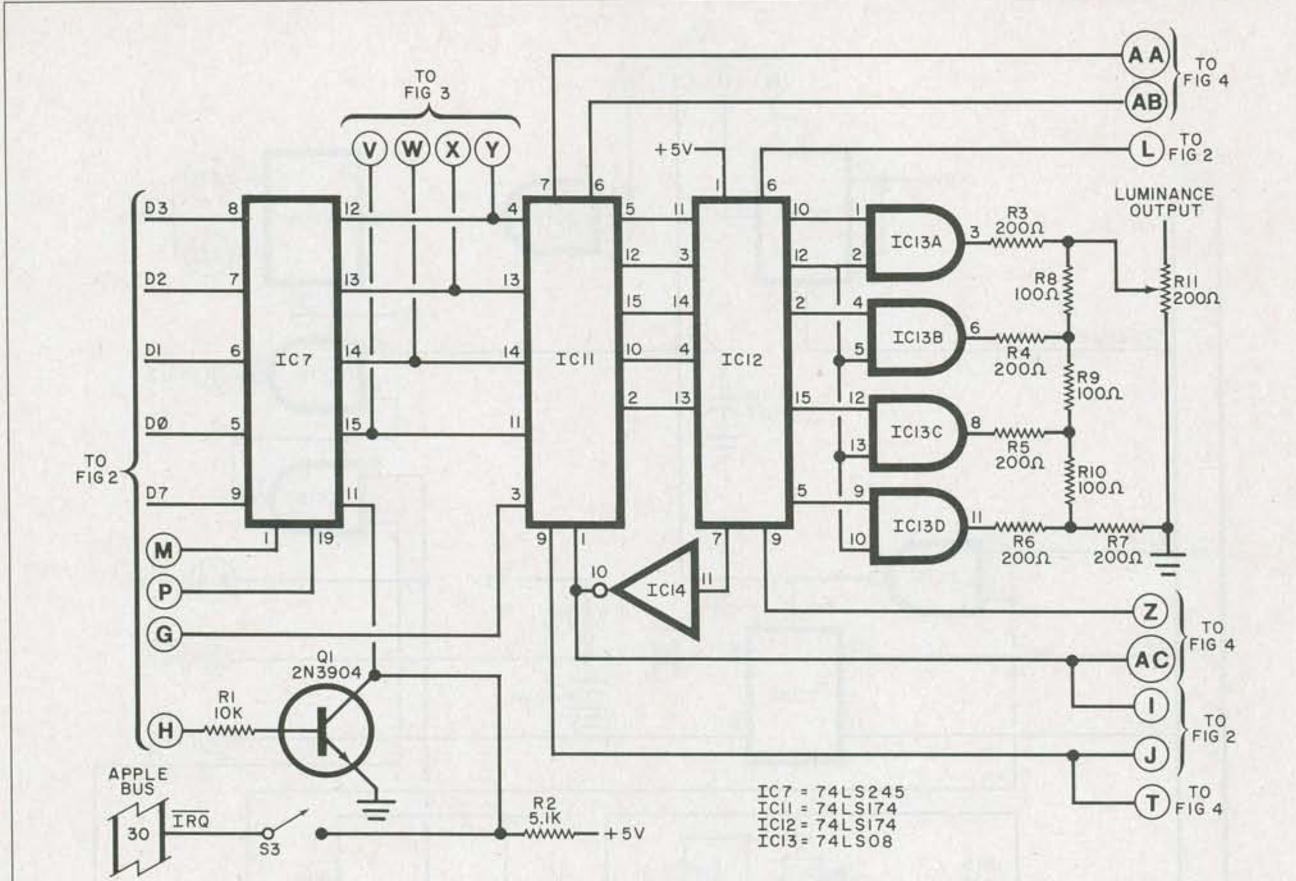


Fig. 5. Luminance output is obtained from D/A IC13.

TABLE II—INITIALIZATION (ASSEMBLY)

```
RS      EQU   $C0F0
LOCK    EQU   $C0F2
        ORG   $0300
        SEI
        LDX   #00
INIT    STX   RS
        LDA   TABLE, X
        STA   RS+1
        INX
        CPX   #16
        BNE   INIT
        JSR   WAIT
        BIT   LOCK
        RTS
WAIT    LDX   #01
        LDY   #255
HERE    DEX
        BNE   HERE
        DEY
        BNE   HERE
        RTS
TABLE   DFB   64,40,48,08,63,06
              48,53,00,03,32,00
              00,00,00,00
```

(HEX OBJECT CODE)

```
78, A2, 00, 8E, F0, C0, BD, 23, 03, 8D, F1,
C0, E8, E0, 10, D0, F2, 20, 18, 03, 2C, F2,
C0, 60, A2, 01, A0, FF, CA, D0, FD, 88, D0,
FA, 60, 40, 28, 30, 08, 3F, 06, 30, 35, 00,
03, 20, 00, 00, 00, 00, 00
```

revision number of your system, set the four DIP switches in accordance with Table I.

The initialization software shown in Table II can be entered and assembled with any compatible editor/assembler. If desired, the hex object code of the listing can be directly entered. In either case, save the object code on disk.

With the Apple II power turned off, connect the luminance lead alligator clip to the center connector of the video output connector at the rear of the motherboard. Install the Syncard in slot 7.

If you are using a video modulator that gets its video from the four-pin connector in the Apple, it will have to be modified. In the case of an M&R Supr-Mod, cut the brown lead coming from the modulator and patch the video from the rear of the Apple to the auxiliary input of the Supr-Mod. Rotate the modulator level control full clockwise and re-install it. Even without the board, the modulator will work normally. Other r-f modulators should be similar.

With the initialization program of Listing 1 loaded in the computer, CALL 768. You should see a random pattern of gray-scale blocks overlaying the screen, aligned exactly with the normal video output. If the luminance display is not precisely positioned, the DIP switches must be reset. After experimenting with the DIP switches (note that *S3* is always off), re-run the initialization routine.

When the board is running, adjust luminance control *R11*, and the video output level of the Apple for a good picture without tearing. There will be a loss of vertical sync until the Syncard is initialized. If desired, this can be avoided by tem-

TABLE III PROGRAM PARAMETERS

$C0F0	6845 register select*
$C0F1	6845 data register*
$C0F2	Lock
$CFFF	Disable access to luminance RAM
$C700	Enable access to luminance RAM
$C800-$CF7F	Luminance RAM

*See 6845 data sheet.

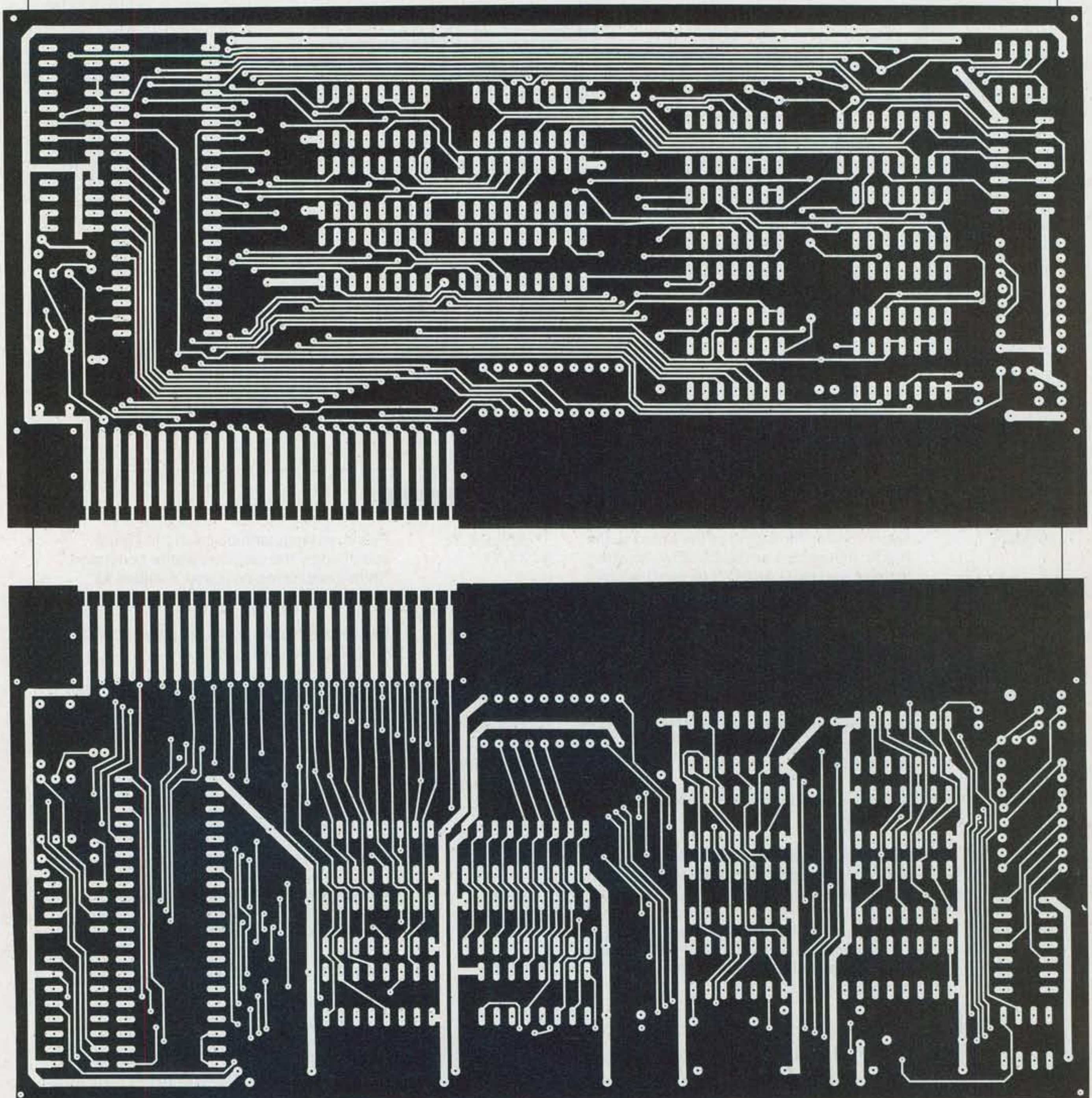


Fig. 6. Foil patterns for the double-sided printed circuit board.

porarily disconnecting the alligator clip from the video connector (the board will not deliver an output when this is done).

Programming. With the luminance board running, a machine-language programmer can start experimenting immediately. Program parameters are shown in Table III.

The gray-scale RAM is located in $C800 to $CFFF. By writing values between 0 and 15 into this area,

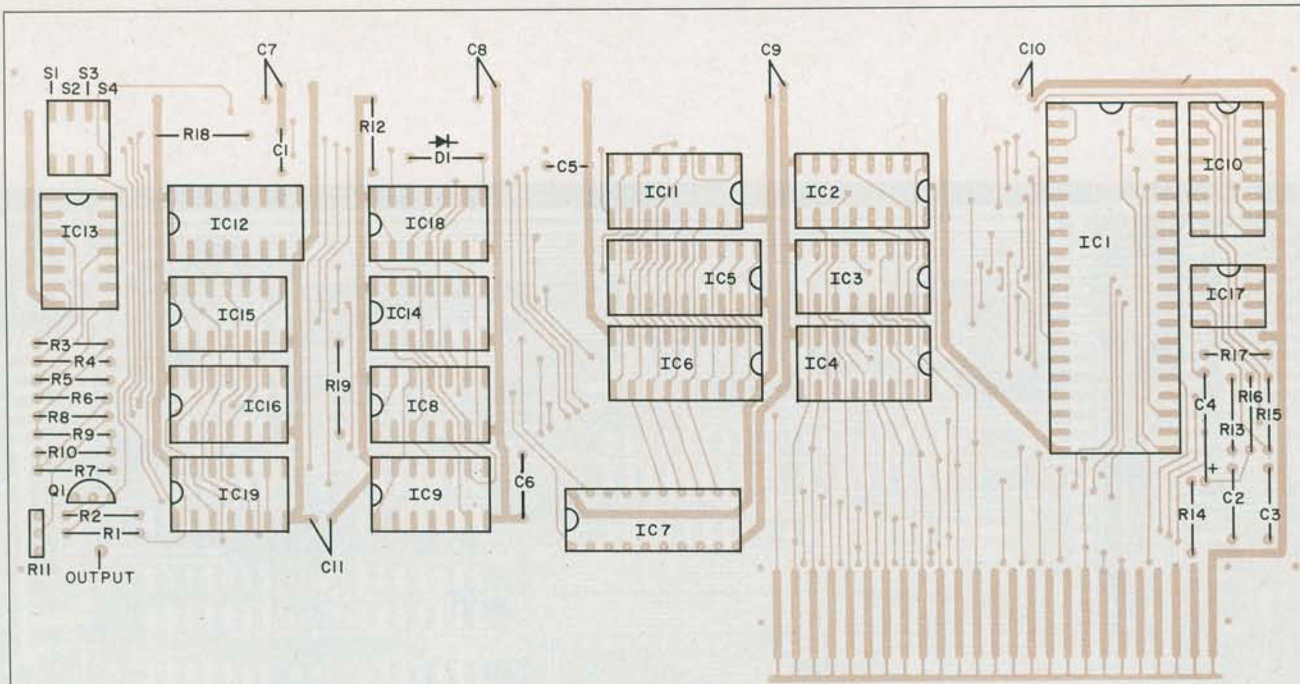


Fig. 7. Component layout for the printed circuit board.

TABLE IV—SPECIAL COMMANDS

&LOCK	Synchronizes the timing of the board to the Apple. It executes an &NOSHOW, so after locking, you must &SHOW to see the luminance screen.
&SHOW &NOSHOW	Switches the luminance display on and off. Does not alter the content of the luminance RAM.
&CLR,X	Clears the luminance screen to the shade indicated by the expression after the comma. (0-15)
&SHADE,X	Sets the shade for the &PLT and &FILL commands.
&PLT,X,Y	Plots a pixel of the shade specified by the last &SHADE command. Same screen coordinates as lo-res
&RTN,X,Y	Used to return the shade of the indicated X,Y location. Like the "SCRN" function of Applesoft except the value is returned through location 255 ($FF)
&FILL,X,Y, X1,Y1	Fills a rectangular block with the shade specified by the previous shade command. Same restrictions on X and Y values as lo-res.
&MOSAIC,1 &MOSAIC,2	Converts a picture on hi-res page 1 or 2 to a 40 x 48 grey scale mosaic.
&S1 (text1) &S2 (text2) &S3 (lo-res 1) &S4 (lo-res 2) &S5 (hi-res 1) &S6 (hi-res 2)	Synchronous screen switches used for flipping pages.
&I1,X	Split screen into text and hi-res 1
&I2,X	Split screen into text and hi-res 2
&I3,X	Split screen into hi-res 1 and hi-res 2
&SEI	Sets the interrupt disable flag
&CLI	Resets the interrupt disable flag

pixels can be set to the desired brightness level. The screen is linearly mapped with $C800 at the upper left corner. The high bit of each location in the luminance RAM indicates vertical synchronization status. This signal can be used to flip pages synchronously with the video frame rate.

If you don't use machine language, a special operating system has been written for the Apple that forms a subset of Applesoft BASIC. Twenty special commands have been added, as shown in Table IV. This sub-interpreter is too lengthy to be listed here, so it is being made available on diskette from the source shown in the Parts List. The floppy diskette also contains demonstrations.

When the sub-interpreter is run, it installs itself just below DOS, and it resets Hi-Mem so that BASIC programs will not overwrite it. Three demonstration programs and pictures of the results accompany this article to show what can be done with the luminance board and the sub-interpreter.

The result of "polishing" your Apple with these low-cost additions will clearly expand the utility of your computer, providing you with astounding video results and a new challenge. ◇