September 1998

Application Note 42038

Benchmarking the Performance of the ML6440

INTRODUCTION

The ML6440 is a multi-standard 8-bit adaptive digital input comb filter. The 8-bit composite video input can be either NTSC or PAL at CCIR 601 or Square Pixel rates. The chip contains both multi-delay lines for combing and band- splitting filters for notching, along with decision and adaptation logic. This adaptive logic causes the device to switch between combing and notching on a pixel-by-pixel basis. The decision to switch is influenced by the characteristics of the video over the preceding 60 horizontal lines.

The ML6440 contains all the circuitry necessary to produce high-quality, 8-bit, Y and C (Luma and Chroma) signals from 8-bit composite video input. Internal compensation circuits provide filtered and buffered (75Ω) outputs with optimal video resolution while suppressing cross-color (rainbow), cross-luminance (dot crawl), and other corrupting artifacts that reduce picture quality along with reducing video compression efficiency.

EVALUATION KIT AVAILABLE

The ML 6440 EVAL KIT is a combination of hardware and software. As received the hardware is set up as a complete NTSC S-Video processor. A composite video input produces separate Y and C outputs. User-changeable presets on the board allow the board to process PAL input. Other presets activate the serial port. This gives the software complete control of the internal register, thus providing overrides of the EVAL Board's many possible presets. This same software controls the registers in other chips on the board. Use of the EVAL Board is not mandatory, but it certainly helps to shorten the time necessary to understand the separation algorithms. All the oscilloscope traces shown in this paper were taken using the EVAL Kit. (See Figure 1, also refer to the Evaluation Board section of this document).

THE Y/C SEPARATION ALGORITHM

In the early days of color television receivers, the usual method of separating composite video into Y and C was the notch filter. Base-band video passed through a filter about 1MHz wide centered at the color subcarrier frequency. Since color information is contained in the sidebands of the color sub carrier, the output of the filter contained most of the color signal. The video without these frequencies contained most of the Luma signal. There were problems with this method. Fine detail was lost from the picture and rain- bows appeared on some edges. Solid color areas often had herringbone patterns. As the technology improved, comb filters, usually in the form of delay lines, replaced notch filters. This method of Y/C separation depended on the fact that the color bursts on adjacent lines of video are of opposite phase . Adding adjacent lines caused the color bursts to disappear. If the adjacent lines also had the same colors on them, the colors also added to zero, leaving only the Y signal. Subtracting the same two lines left only the color information. This was the Chroma signal. With PAL every other line would be used instead of adjacent ones. The rainbows went away, but other problems were created. Edges suffered from artifacts such as hanging dots or dot crawl. A notch filter would have processed the edge better.

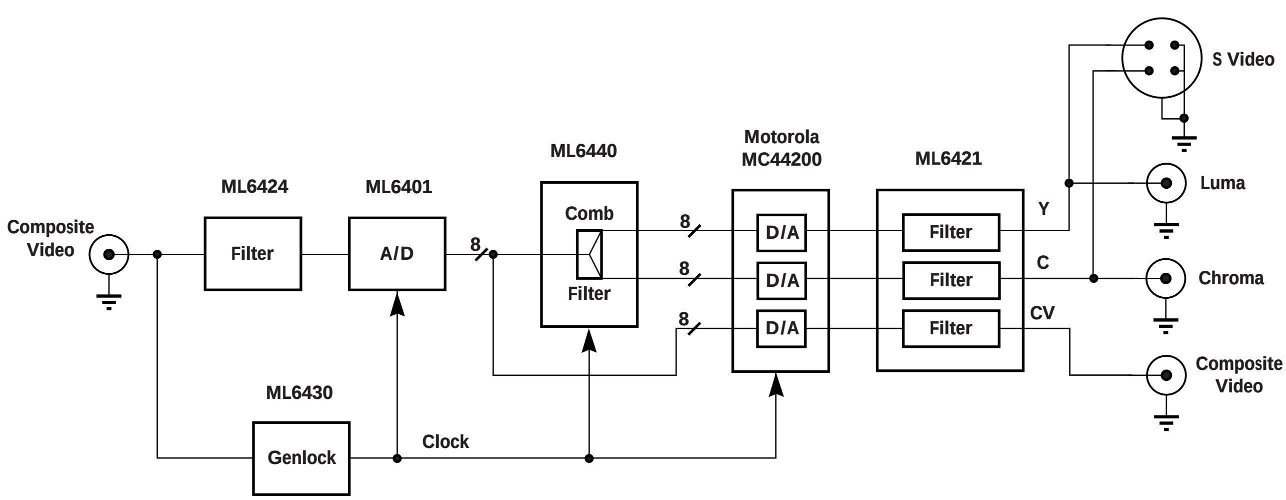

Figure 1. ML 6440 Eval Kit Block Diagram

INTRODUCTION (Continued)

The obvious solution is to have both a notch filter and a comb filter. Circuits then look at the signal and make decisions as to whether to notch or comb. If an area of constant or slowly changing color is encountered, combing is called for. If an edge is detected by a change in color and / or texture, then notching will produce the best picture. This describes the adaptive decision logic used in the ML6440. Having the output of both a comb filter and a notch filter available and being able to switch between them on a pixel-by-pixel basis enables optimal separation of Y and C.

Y/C SEPARATION

Adaptive systems, especially those with self-adjusting thresholds, can be difficult to verify. Those systems that have been optimized for live video, like the ML6440, can be very difficult. Rather than trying to verify each state in the system, a better understanding may be gained by forcing the system into a known state and examining its operation on standard video test signals. The two signals chosen are the two most commonly used in system evaluation: color bars and multiburst.

Figure 2 shows the system operating on composite video. Trace 1 is the input, standard NTSC color bars. Trace 2 shows the Luma, the Y output. Trace 3 shows the Chroma, the C output. Several points should be noted. First, the outputs, traces 2 and 3, are delayed about 2 microseconds from the input. This is the processing time needed for separation of Y and C from composite video. Second, the traces are the same for forced combing or forced notching. By changing the presets on pins 10 and 11 of the ML6440, we can force the chip to do only notching or only combing or we can allow the chip to adapt to the input signal. Third, the separation is complete. No cross-color or cross-luma distortion is present. Good combs and good notches are equally efficient when separating simple test signals such as color bars.

Figure 3 shows multi-burst input with forced combing. Trace 1 is again input. Trace 2, Y out. Trace 3, C out. The delay is again apparent. The separation is again complete. The separation algorithm determines that the only color information in this multi burst is the color burst itself. Since there is no change in video from line to line, combing produces the best separation. The envelope of the Y output shows the frequency response of the system. There are 12 sine wave bursts. The first is 1 MHz. In each succeeding burst the frequency increases by 1 MHz. The last burst is 12 MHz. It should be noted that magnitude is linear on an oscilloscope. The log magnitude display of a network analyzer produces the more commonly seen frequency response curves. It should also be noted that multi-burst and its counter part, zone plates are the only way to obtain frequency response information from a digital comb filter. Zone plates were not used here since they add the complication of the monitor response along with only showing luma response, no color frequency response information can be obtained from Zone plates. Note that frequencies above 6-7MHz were filtered out by the anti alias filter before the A/D.

Figure 4 again shows multi-burst as input on trace 1. This time, forced notching is applied. The ML6440 must be forced to notch this signal since the decision algorithm, noting that there is no line-to-line difference on the preceding lines, would comb as in figure 3. Had the preceding lines been different line to line, then the ML6440 would be notching as in figure 4. It should be noted that there is no color information in the Luma output. There is Luma in the Chroma output. This needs to be examined more closely. Figure 5 shows the important part of figure 4, with an expanded oscilloscope time base. First, notice that the color burst has been completely removed from trace 2, the Y output signal. This is because the notch is centered at the color burst frequency. (Had the ML6440 been setup for PAL and feed PAL multiburst, this would also be true.) Moving from left to right, most of the 2T pulses appear in the Luma. Only the higher frequency components appear in the chroma, trace 3. This trace also shows the color bandwidth. The 3 MHz and the 4 MHz bursts are of equal amplitude. The 2MHz and the 5 MHz bursts are half that amplitude, or down 6 dB. A PAL signal would have produced a comparable display. Above 4 MHz, the gain increases again in the Luma, trace 2, so that any sharp edge information can be processed correctly. The adequacy of this notch filter can not be determined since it is difficult to produce a test signal containing only edges. Even if such a signal could be produced, triggering an oscilloscope would be even more difficult. Live video can show the answer. Feeding the ML6440 with composite video derived from a laser disk or DVD player set up to repeat 10 to 20 frames of a complex scene will produce the absolute best test signal. Unfortunately this kind of test signal can not be seen on an oscilloscope; it must be seen and evaluated by a human being. At this time, recorded live video is the only test signal for complete evaluation of comb filters.

CONCLUSION

In this Application Note, the ML6440 EVAL Board has been used to produce oscilloscope traces which aid in understanding the adaptive algorithms used to separate the Y from the C of composite video. The limitations of common test signals have been pointed out. An alternative using live video has been described. With this information, the superior Y, C separation possible with the ML6440 can be understood and demonstrated where it is most important, in live video.

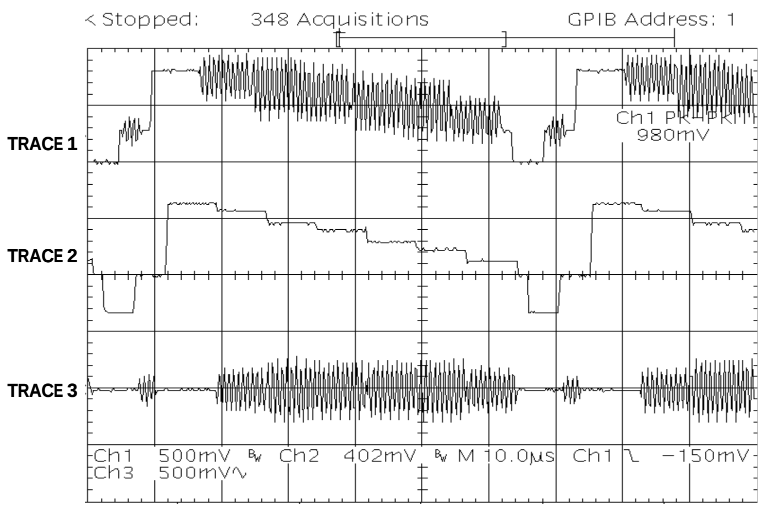

Figure 2. Comb or Notch

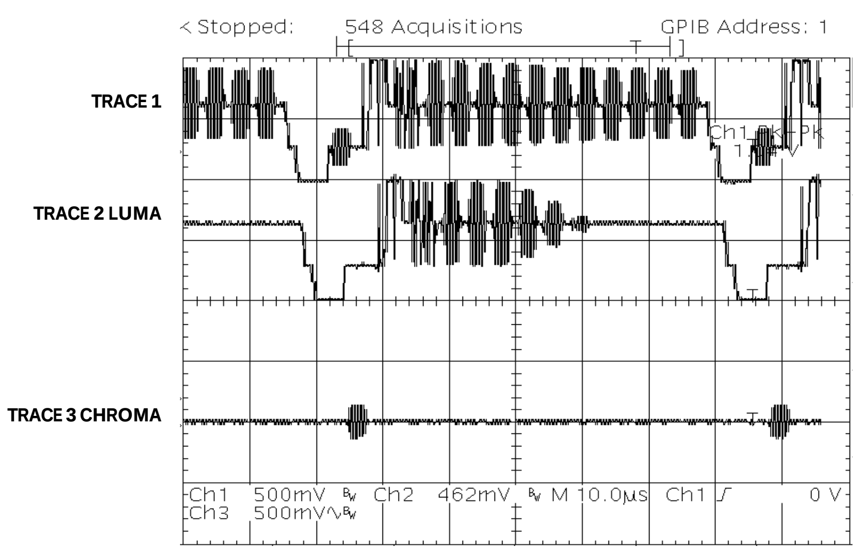

Figure 3. Forced Comb Filter

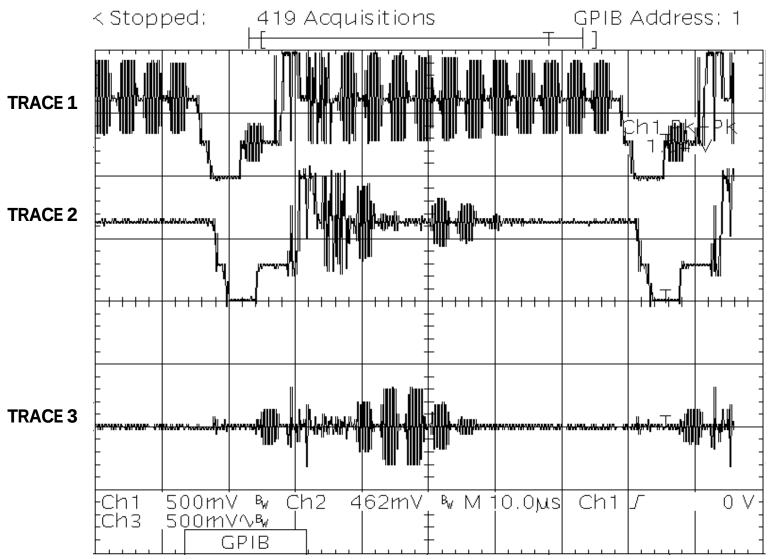

Figure 4. Forced Notch Filter

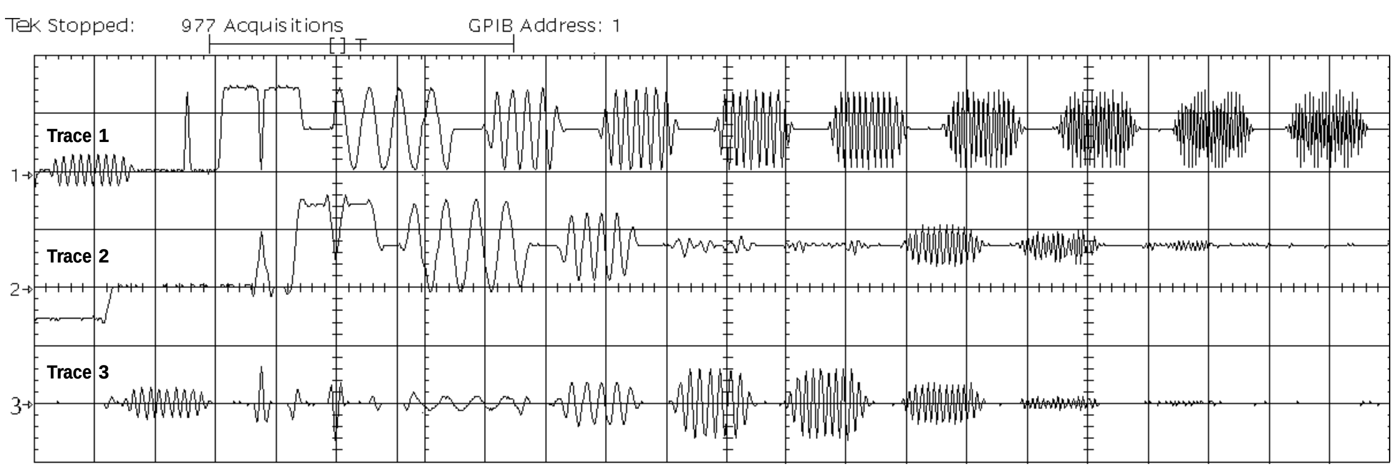

Figure 5. Forced Notch Filter - Expanded Time Base

ML6440 EVALUATION BOARD

The ML6440 evaluation board contains five different Micro Linear IC's. The board can be used to demonstrate the major features of each IC separately, as well as the same ICs functioning in a complex system. The five ICs and their functions are:

- ML6401 — 8-Bit 20 MSPS A/D Converter used to sample composite video, CV, either NTSC or PAL.
- ML6421 — Triple, Phase and (sin x)/x Equalized, Low-Pass Video Filters used as reconstruction filters and cable drivers.
- ML6424 — CCIR601 Video Low-Pass Filter and line driver used as an anti-alias filter
- ML6430 — Genlocking Sync Generator used to generate clocks for the A/D converter and the three D/A converters.
- ML6440 — Adaptive Digital Comb Filter used to separate either NTSC or PAL composite video into Y (luma) and C (chroma).

The ML6440 evaluation board requires one input, composite video, and produces four outputs: Y, C, CV, and an audio sampling clock. The board is preset for NTSC and CCIR601 sampling. NTSC square pixel, PAL CCIR601, or PAL square pixel sampling require only a quick change in presets on the board. More options are available by programming registers inside the ICs through the serial port on the board via a parallel port on a PC. National Instruments' LabWindows software is supplied to accomplish that. The board requires a 5V, 1A supply for power.

EVALUATION KIT CONTENTS

The ML6440 evaluation kit contains the following items:

1. ML6440 User's Guide
2. ML6401 Data Sheet
3. ML6421 Data Sheet
4. ML6424 Data Sheet
5. ML6430 Data Sheet
6. ML6440 Data Sheet
7. MC44200 Motorola pinout Sheet (see Figure 18)
8. 74ACT04 pinout Sheet (see Figure 17)
9. 3.5″ Floppy diskette with LabWindows software for register control of the ML6430 and the ML6440, and Gerber files for circuit board layout (Figures 15-15c).
10. Fully functional ML6440 Evaluation Board

THEORY OF OPERATION

The video board can best be understood by starting with the block diagram, Figure 1. On the left of this diagram is the input. The signal is composite video, either NTSC or PAL. It is coupled to the ML6424, precision video low-pass filter with an input clamp and an adjustable cut-off frequency. Its major function is to act as an anti-aliasing filter. Its output feeds the ML6401, an 8-bit video A/D converter. From the outputs of the ML6401, the composite video, now on an 8-bit digital bus, splits into two paths.

The shorter path takes the signal to one set of inputs on the MC44200, a triple 8-bit D to A converter. The signal, now analog again, feeds one input on the ML6421, a triple low pass reconstruction filter with (sin x)/x correction. The output of this filter is connected to the CV, composite video, output connector, also called the 'Comb Bypassed' output. The purpose of this path is to show the simplest signal processing. Filter effects and system delays can be evaluated apart from any processing complications.

The longer path leads the 8-bit digital signal from the ML6401 to the ML6440, a multi-standard 8-bit adaptive digital comb filter. Here, under preset or serial bus control, the signal is separated into two 8-bit busses, one containing the chrominance and the other the luminance part of the incoming composite video signal. Each of these goes to one of the other two sets of inputs on the MC44200. The chrominance and luminance signals now pass through the other two sections of the ML6421 reconstruction filter and terminate at the output LUMA and CHROMA connectors on the right side of the block diagram. Since luma and chroma together are called S-Video, these two signals are passed to an S-Video connector for ease of evaluation.

Going back to the left side of the block diagram: the input composite video is also coupled into the ML6430, the adaptive genlock. Here, under the control of either a set of 4 presets or a PC through the serial port, a system timing clock and 10 timing signals are available. These timing signals are all locked to the composite video input signal. The timing clock is used to control the ML6401 A/D converter, the ML6440 comb filter, and the MC44200 D to A converter. This completes the signal and control lines on this evaluation board.

Most video parts have several modes of operation. Using the parts in a circuit such as on this board limits the available choices. For a detailed discussion of all modes refer to the individual data sheet for each part. What follows is an explanation of the choices pertinent to each part's functioning on this video board.

The ML6424: the Mode pin is set high so that the sync tip is clamped inside the chip and the signal is AC coupled to the chip. The Gain pin is also tied high for X2 gain. For internal consistency the Range pin is left floating.

THEORY OF OPERATION (Continued)

ML6401: References generated inside the chip could be used to set the signal input limits. However, this board allows adjustable limits to be set so that non-standard signals can pass through the shorter processing path.

ML6440: All options noted in the data sheet for this part are available on the board and through the serial port. This part requires a clocked reset pulse. After V_{CC} is applied to the IC and to the RESET signal (Pin 6), the RESET signal must go low for at least 1µs before returning to V_{CC}. The rise and fall times are not critical.

In most applications a microprocessor will be used to provide timing and control signals. It can provide the reset pulse, preset registers in the genlock chip, and set the appropriate comb filter modes. This Evaluation Board does not have a controller, so the reset timing signal is provided by the circuit encompassing D4, D5, R32 and C32.

MC44200: This D to A converter is normally run with fixed gain. On this board the gain is adjustable enabling many different input signals.

ML6421: The only option possible with this part is the Range pin. It is tied high so that the output of the D/A converter can go as close to ground as needed.

ML6430: All composite video options are available either through presets or the serial port. No VGA options are possible on this circuit board.

Since the board is laid out very much like the block diagram, these descriptions enable signal tracing and observation on the board.

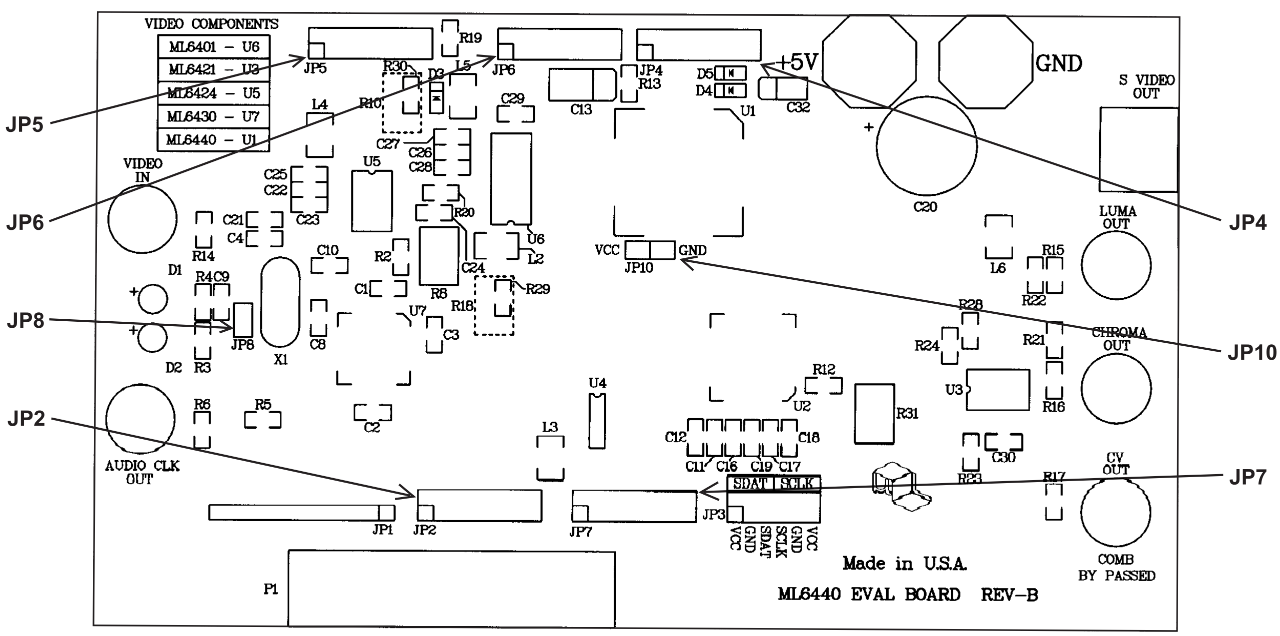

Figure 6. Location of Jumpers

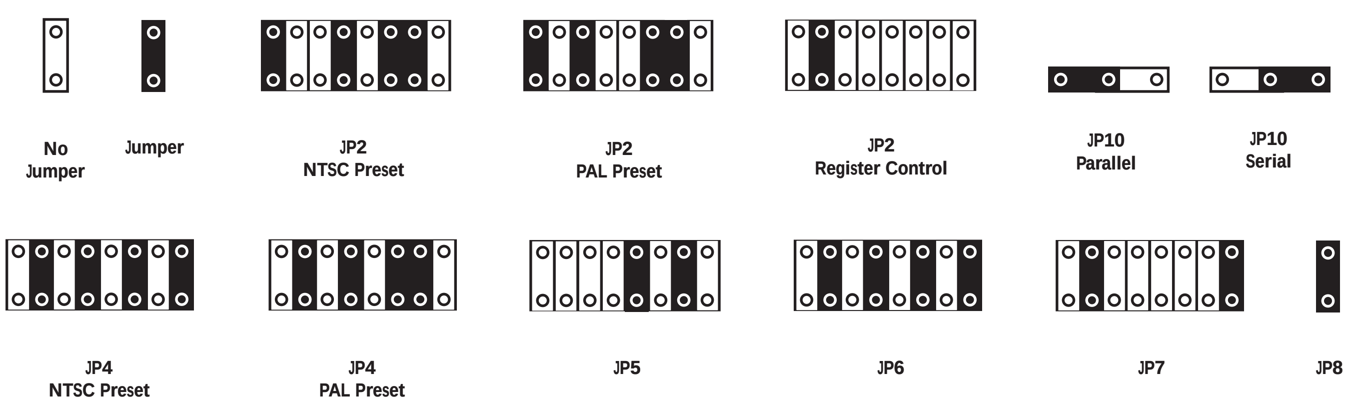

Figure 6a. Jumper Configurations

USING THE EVALUATION BOARD

The Evaluation Kit Circuit Board is preset for NTSC CCIR601 before shipping. Figures 6 and 6a show that preset. In Europe the preset can be changed to PAL CCIR601. For all possible presets see the ML6430 Product Data Sheet and ML6440 Product Data Sheets.

To place the circuit board in operation, the positive terminal of a 5V power supply capable of supplying 0.75A should be connected to the banana jack labeled 5V. The power supply return should be connected to the banana jack labeled GND. On applying power D1, the signal absent lamp, will light. Applying a composite video signal, CV, color bars to the input BNC connector, labeled VIDEO IN, will cause D1 to extinguish and D2, the Signal locked lamp, to light. At this point all of the signals shown in Figures 7 and 9 for NTSC, or Figures 8 and 9 for PAL will be available at header JP1 on the lower edge of the evaluation board. To make the other signals called out in the data sheet available at JP1 requires access to the internal registers of the ML6430. Performance verification for the ML6430 consists of applying noisy composite video signals to VIDEO IN and noting the effect on the output signals at header JP1.

The shorter path through the board consists of the ML6424 anti-aliasing filter, the ML6401 8-bit A/D converter, the MC44200, 8-bit D to A converter, and the ML6421 triple reconstruction filter. The output of this path can be seen at the BNC connector labeled CV Comb Bypassed. It should be noted that this signal is a replica of the input composite video but delayed by about 0.8μs due to signal processing through the board. This short path performance verification is shown in Figures 10 and 11.

Performance verification of the longer path involves two steps. First, one line of the input composite video should be displayed on an oscilloscope and compared to the signals at the two BNCs labeled LUMA and CHROMA. This comparison can be seen in Figure 12. It should be noted that the luma trace contains no color information and that the chroma trace contains only color information. Figure 13 shows the delay between CV in and luma out. Second, a standard color monitor with both a CV and an S-video or Y/C input capable of being switched between these inputs, needs to be connected to the input CV and to the output S-Video or Y/C. The usual loop through and 75Ω terminating connections should be made. By switching back and forth between CV and S-Video or Y/C the effects of the comb filter on removing artifacts will be noted.

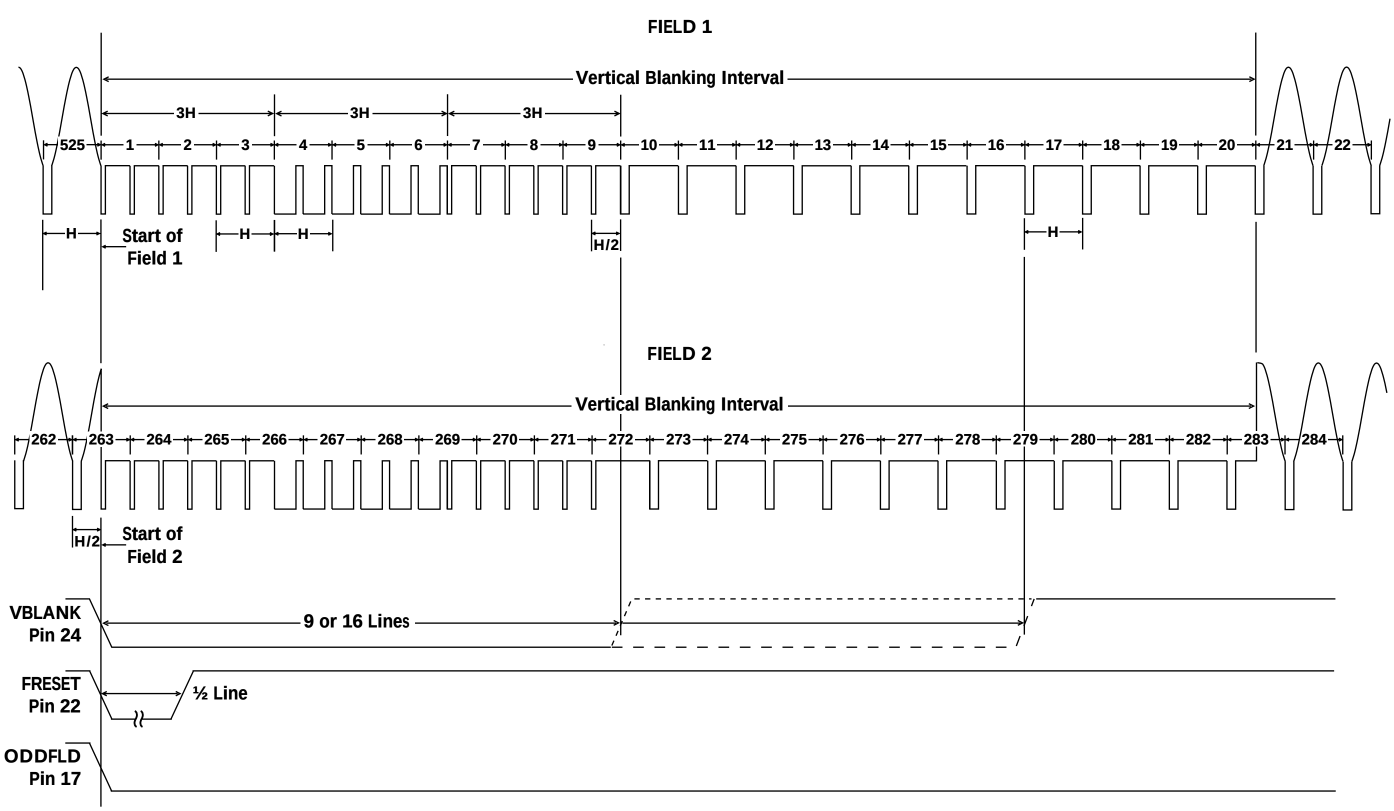

Figure 7. NTSC field Rate Waveforms

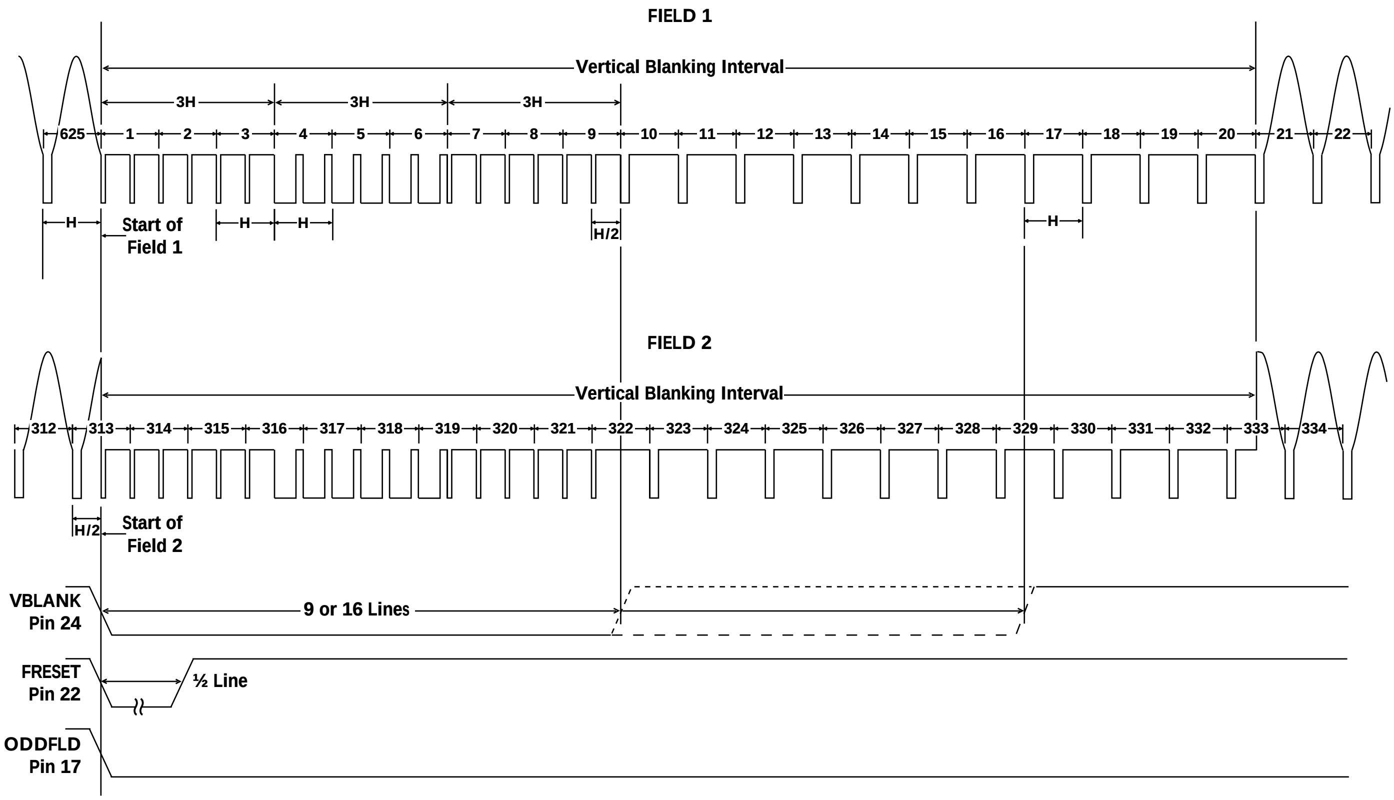

Figure 8. PAL Field Rate Waveforms

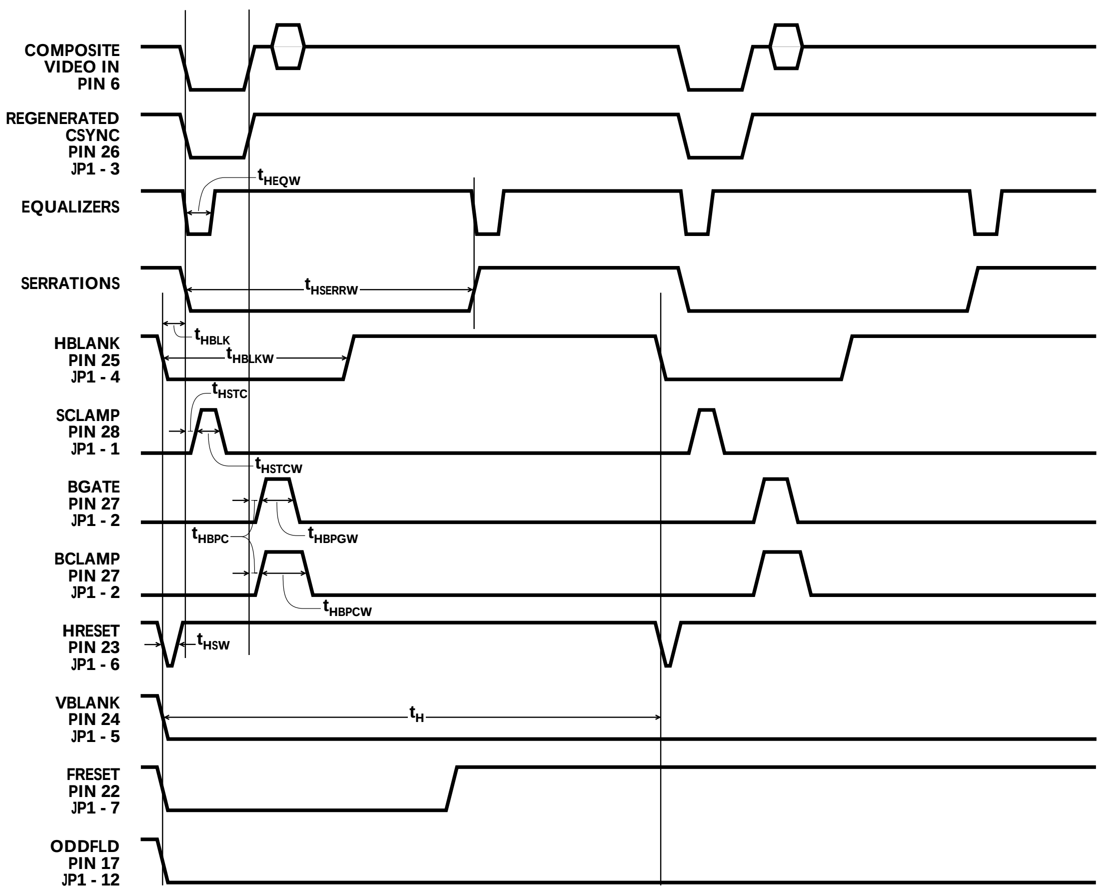

Figure 9. Line Rate Waveforms

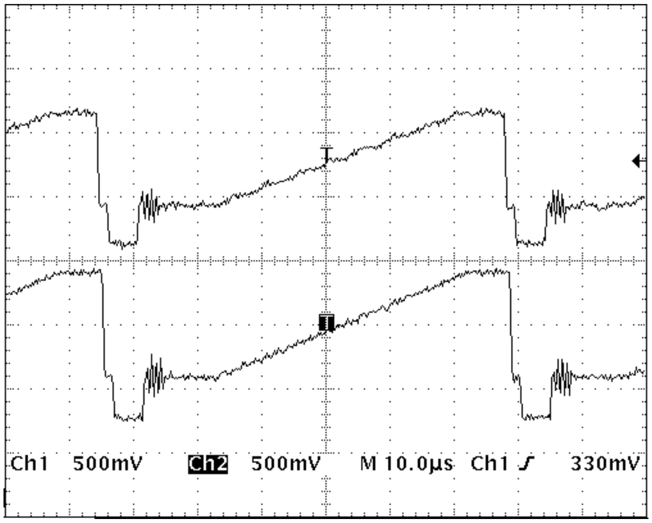

Figure 10. CV Through Shorter Path

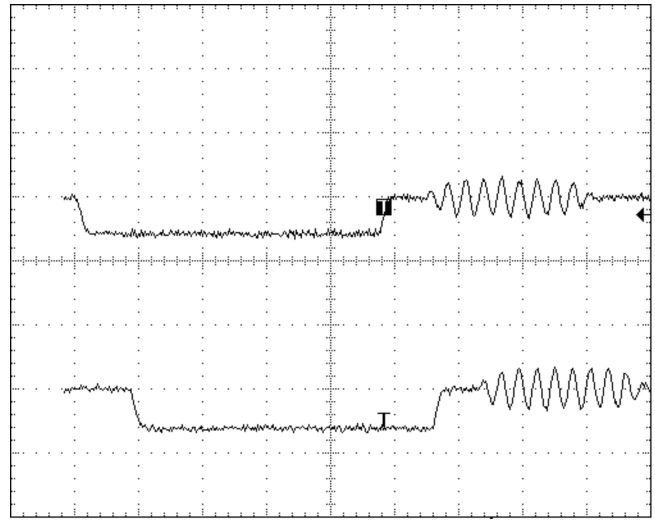

Figure 11. Detail of 0.8µs Delay

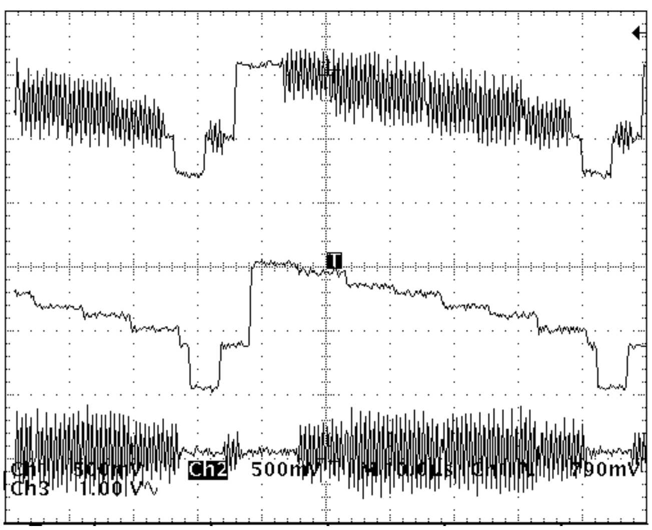

Figure 12. CV In, Luma and Chroma Out

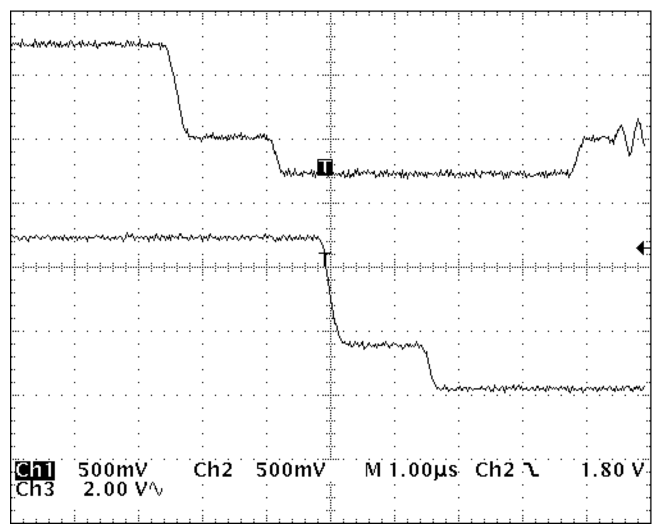

Figure 13. Detail of 2.5µs Delay

INTERNAL REGISTER CONTROL

Although full control of all of the ML6430 and ML6440 features is possible through the serial port, only a limited number of the ML6430 features can be shown in this Video Evaluation Kit. For a full explanation of the ML6430 consult its Data sheet. To demonstrate the control available connect a printer cable from the parallel port (either LPT1 or LPT2) of a PC, running DOS or WINDOWS, to P1 on the Video Evaluation Board. JP2 and JP10 should be configured as shown in Figure 6a. All other connections are as they were in the full preset mode. The software is loaded in the usual manner, typing VIDEO and pressing "Enter/Return". After a short time the instrument control panel appears on the screen (Figure 14).

Use a mouse to click on applicable choices, or use the Tab, arrow(s), and "Enter/Return" keys to access all available function modifications. To leave the program press the Escape key. See Table 1 for a list of choices with comments.

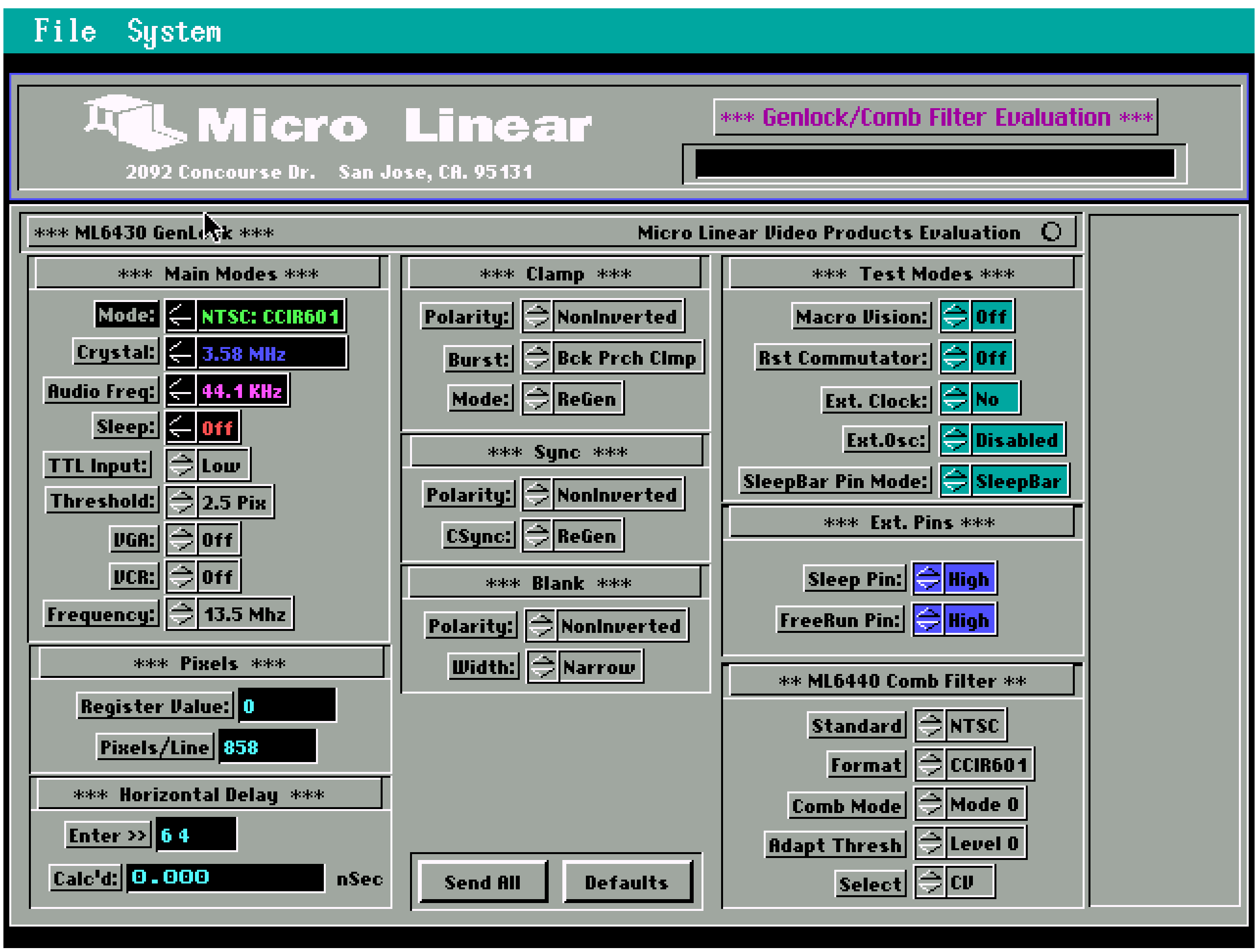

Figure 14. Control Panel

MAIN MODES	
HORIZONTAL DELAY	
CLAMP	
Mode	Sets IC for PAL or NTSC
Crystal	Sets IC to crystal frequency
Audio Freq	Sets audio clock frequency
Sleep	Turns IC on or off
TTL	Not available, board hardwired for composite video
Threshold	Sets Out of Lock threshold
VGA	Forces IC into VGA mode
VCR	Forces IC into VCR mode
Frequency	Sets the clock output to 1X or 4XPixel Clock
Enter	Decimal value in Delay register
PIXELS	
Register Value	Decimal value of binary number in Pixel register
Pixels/Line	Number of pixels per line
Calc'd	Delay in seconds
Burst	Sets IC to produce Burst Gate clamp or Back Porch clamp
Mode	Derives clamp from raw or regenerated sync
SYNC	
Polarity	Normal or inverted
CSync	Regenerated or raw sync
BLANK	
Polarity	Normal or inverted
Width	Narrow or wide
TEST MODES	
Macro Vision	No control: hardwired board
RST Commutator	No control: hardwired board
Ext. Clock	No control: hardwired board
Ext. Osc	No control: hardwired board
SleepBar Pin Mode	No control: hardwired board
EXT. PINS	
Sleep Pin	No control: hardwired board
FreeRun Pin	No control: hardwired board
ML6440 COMB FILTER	
Standard	PAL or NTSC
Format	Square pixel or CCIR601
Comb Mode	Modes 0, 1, 2, or 3
Adapt Thresh	Level 0 through 7
Select	Y+C or CV
Send All	Send change to board
Defaults	Resets all registers to their default values

Table 1. Genlock/Comb Filter Evaluation Control Panel (Figure 14) Explanations

EVALUATION BOARD TEST

The following test equipment is required. Refer also to the Parts List at the end of this document.

1 ea. Power Supply	5 Volts, 1Amp
1 ea. Signal Source	Composite NTSC and PAL
1 ea. Oscilloscope	Video Compatible
1 ea. Video Monitor	NTSC and PAL Compatible. Switchable between CV and S Video Inputs

Use the following test procedure to verify functionality:

1. Verify all presets. See Figures 6 and 6a.
2. Adjust R8 for maximum bandwidth, fully counter-clockwise until a clicking sound is heard.
3. Connect the 5 Volt power supply to the ML6440 Eval Board observing polarity marked on the board.
4. Connect the Signal Source to J1.
5. Use the Oscilloscope to verify that all output signals are available at JP1 as listed in the Evaluation Kit User's Guide, Figures 7, 8, and 9.
6. Verify that a 13.5MHz square wave is present on JP1 pin 9, and similarly, a 27MHz square wave on pin 10.
7. With J5 terminated in 75Ω, adjust R31, the gain control on the MC44200, D/A converter, so that the signal amplitude across that termination matches the signal amplitude at J1.
8. Connect the S-Video output of the board to the S-Video input on the Monitor. Do the same with the CV output from the board.
9. Using CV as a reference, adjust R10 and R18 for maximum color purity, minimum artifacts, and total absence of rain, as viewed on the monitor set to S-Video. The two controls, R10 and R18, interact strongly. Optimization may take several minutes.
10. When a satisfactory image is attained, seal the adjustment screws on R8, R10, R18, and R31.
11. Reset the presets for serial port control. See Figures 6 and 6a. Connect a printer cable from the PC's parallel port (select either LPT1 or LPT2 from the File menu in the Labwindows control panel) running the LabWindows Register Control Software to the EVAL Board. As in step 5, verify that all control options work by observing the signals on JP1.
12. Observing the S-Video on the monitor, verify the ML6440 control options.
13. Return all presets to their original positions.
14. Turn off signal source and power source.
15. Remove power and the signal source connections from the board. Disconnect the monitor.

LABWINDOWS SOFTWARE INCLUDED ON THE 3.5” FLOPPY DISK

December 2,1997, Video Evaluation Software file list:

Gerber Files

VID_GBR.EXE - Self-extracting zip file.

NOTE: Copy VID_GBR.EXE to the hard drive and then type VID_GBR.EXE and press Enter to extract the Gerber files.

Demo Program

VIDEO.EXE - Demo Executable.

VIDEO.UIR - Graphical User Interface Resource File. Required to run VIDEO.EXE.

VIDEO.H - #Include file for VIDEO.UIR. NOT required to run. Used for compiling source code only.

VIDEO.C - Source code for VIDEO.EXE.

Port Driver

VBUS.C - Source code for Port Driver.

VBUS.H - #Include file for Port Driver.

VBUS.LWI - LabWindows 2.3a specific file.

VBUS.FP - LabWIndows 2.3a specific file.

VBUS.LBW - LabWIndows 2.3a specific file.

VBUS.OBJ - Compiled module for Port Driver. May be linked into other programs.

VID_GBR.exe Compressed Gerber files to expand copy to hardware then execute.

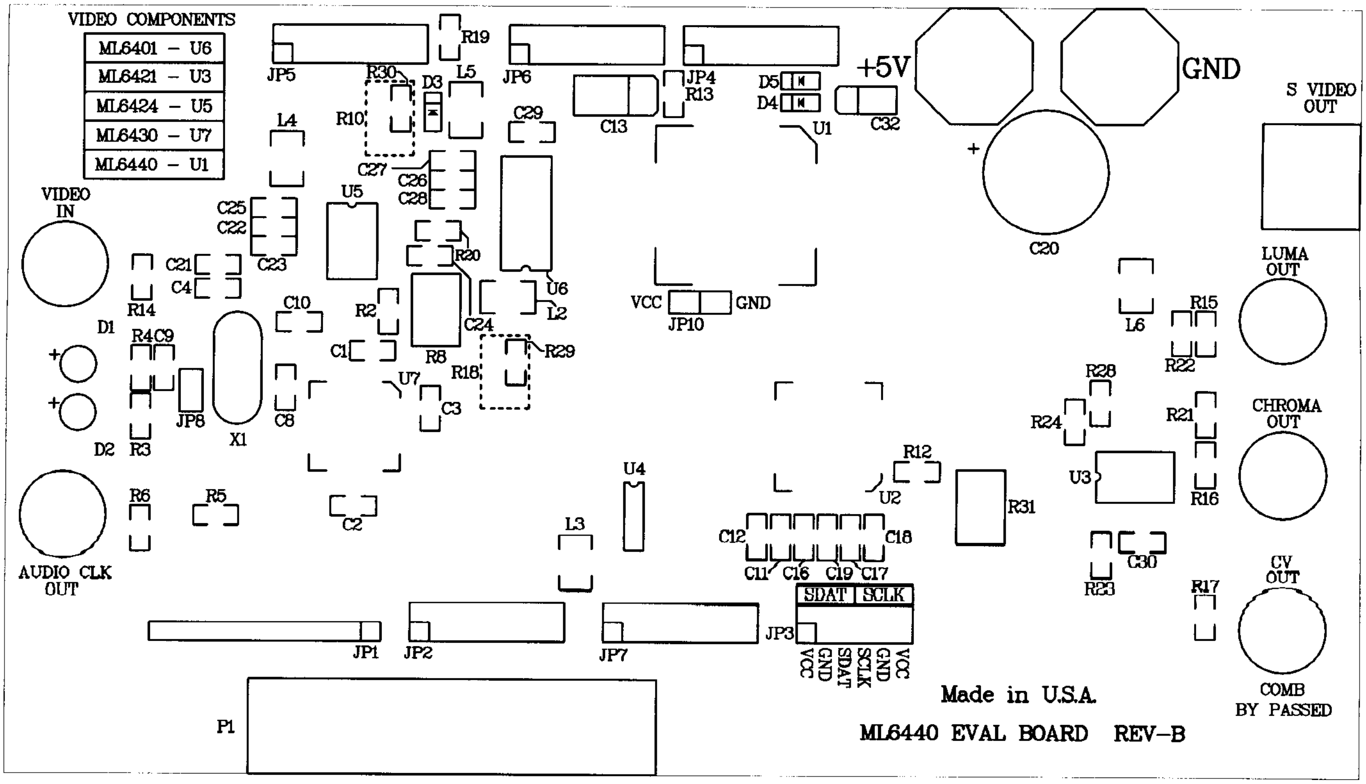

Figure 15. Top Silk

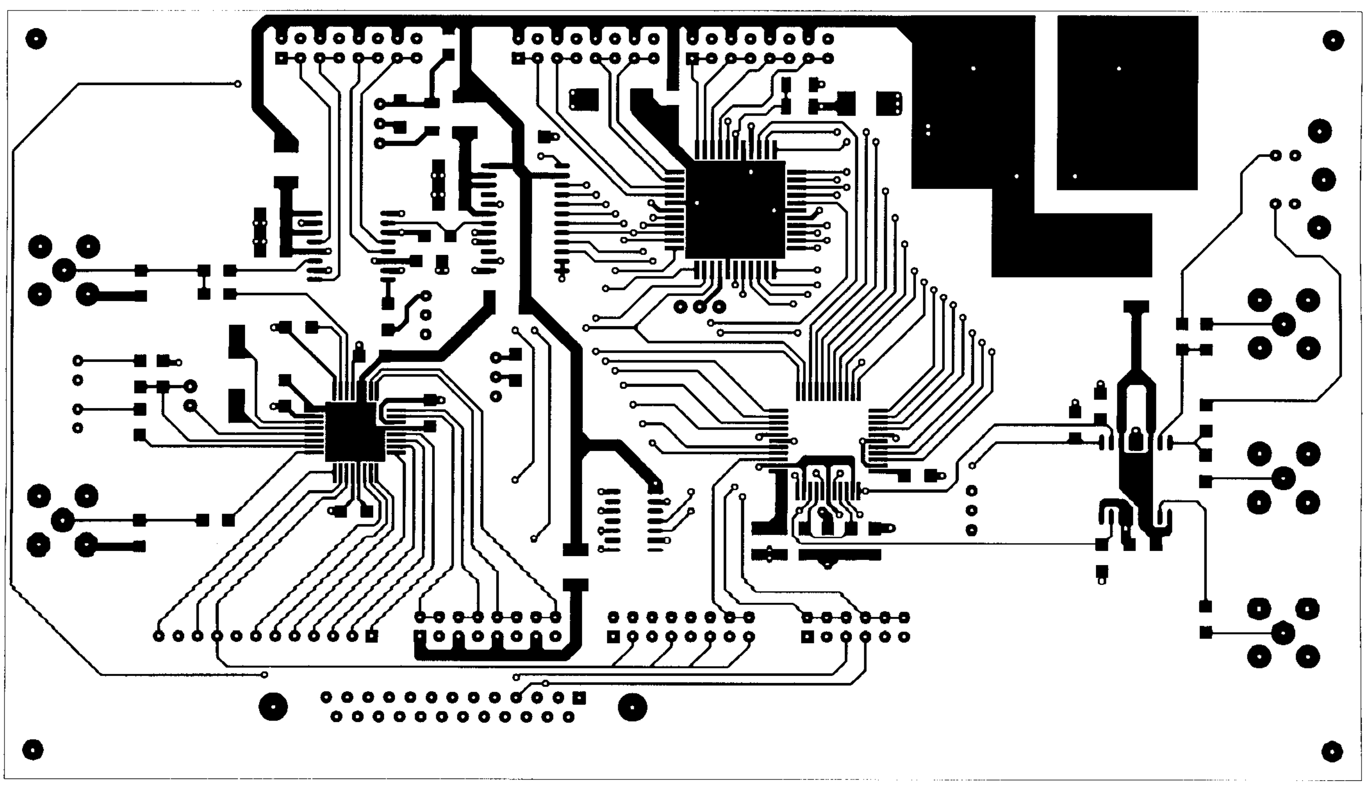

Figure 15a. Top Layer

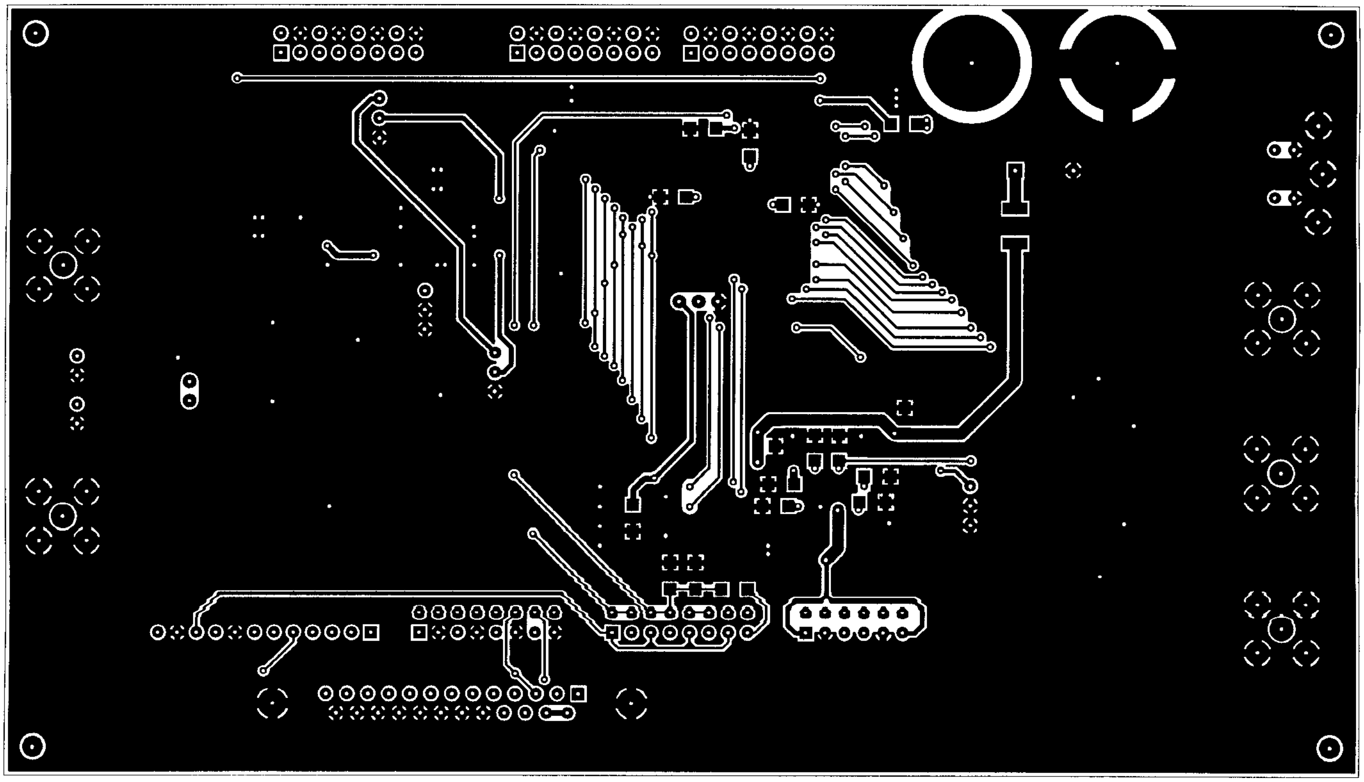

Figure 15b. Bottom Layer

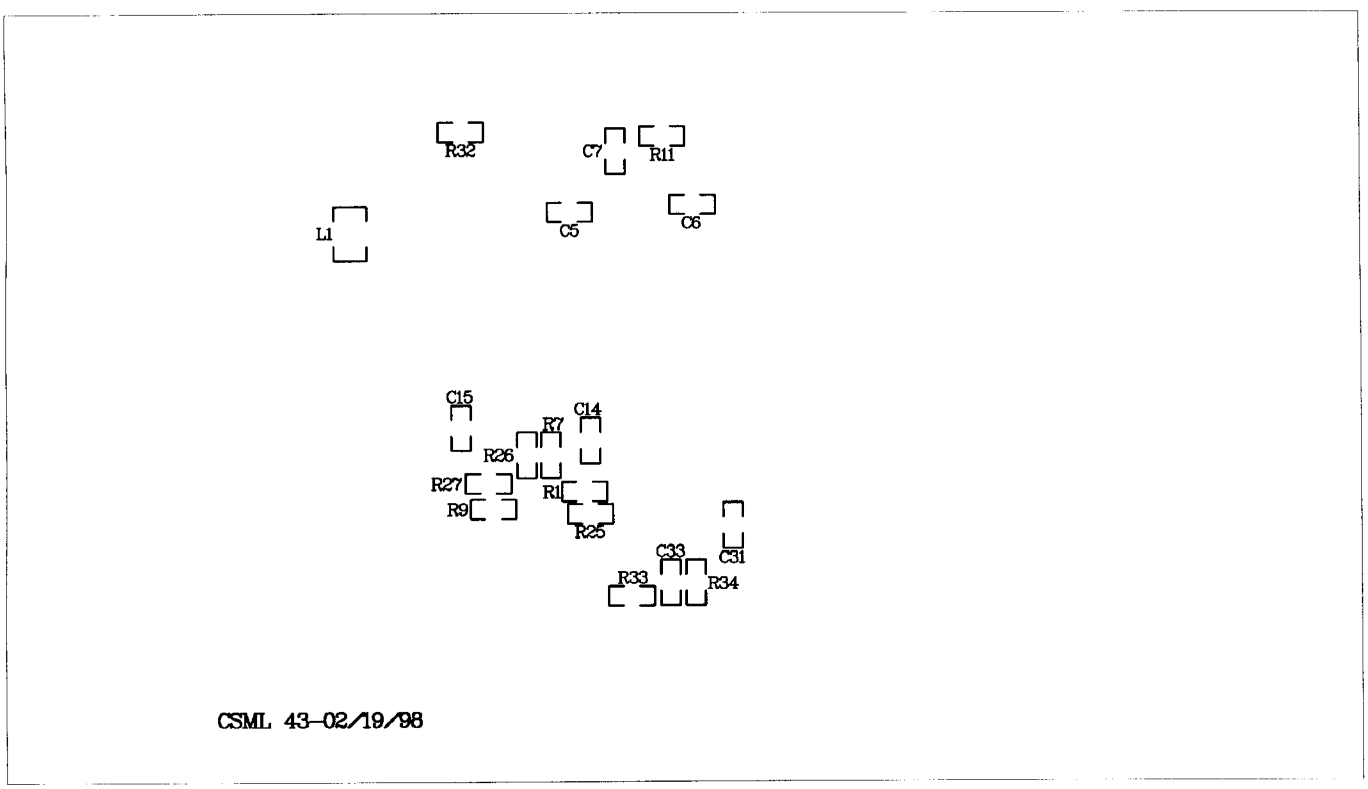

Figure 15c. Bottom Silk

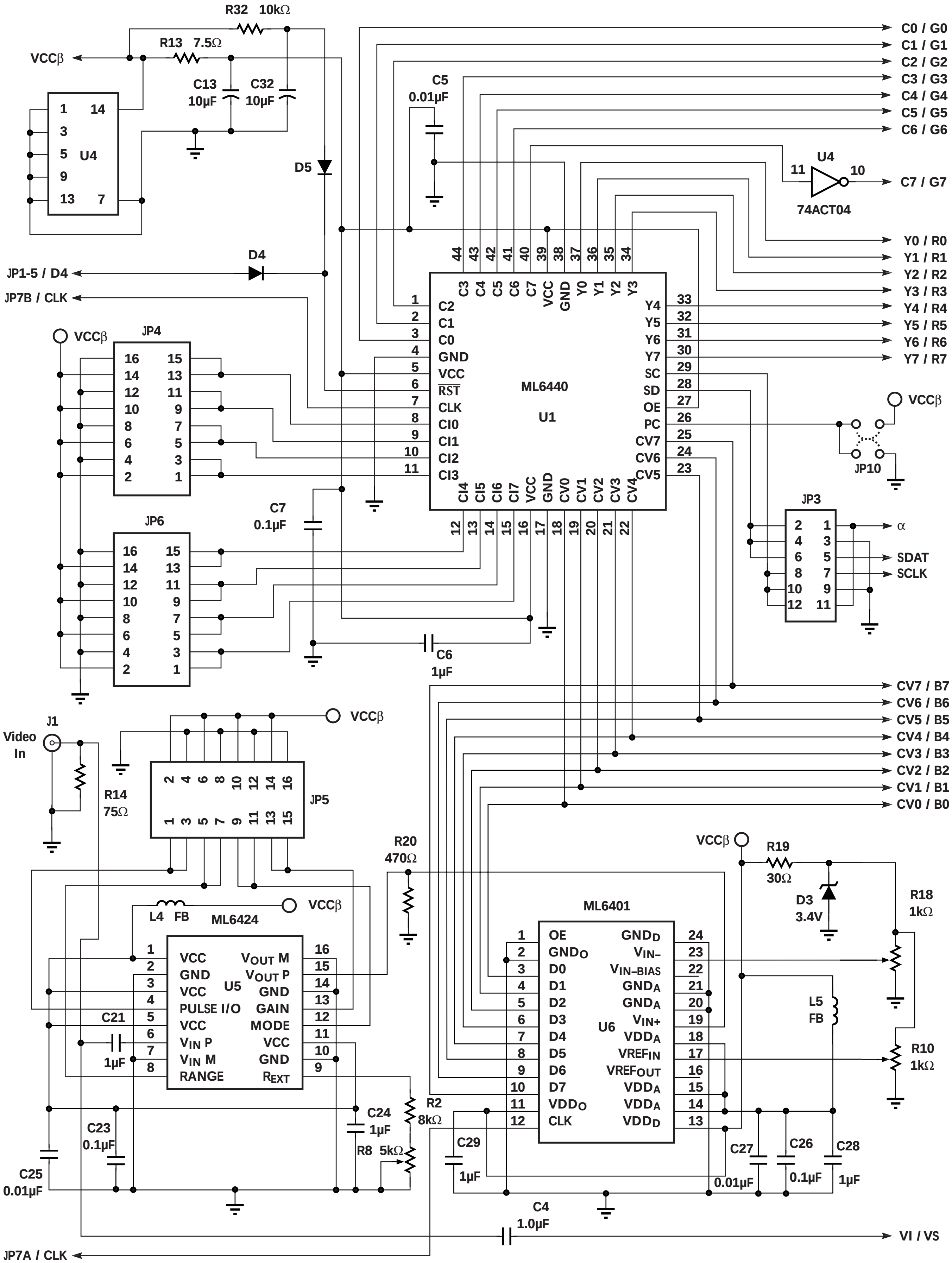

Figure 16. Evaluation Board Schematic, Sheet 1 ot 3

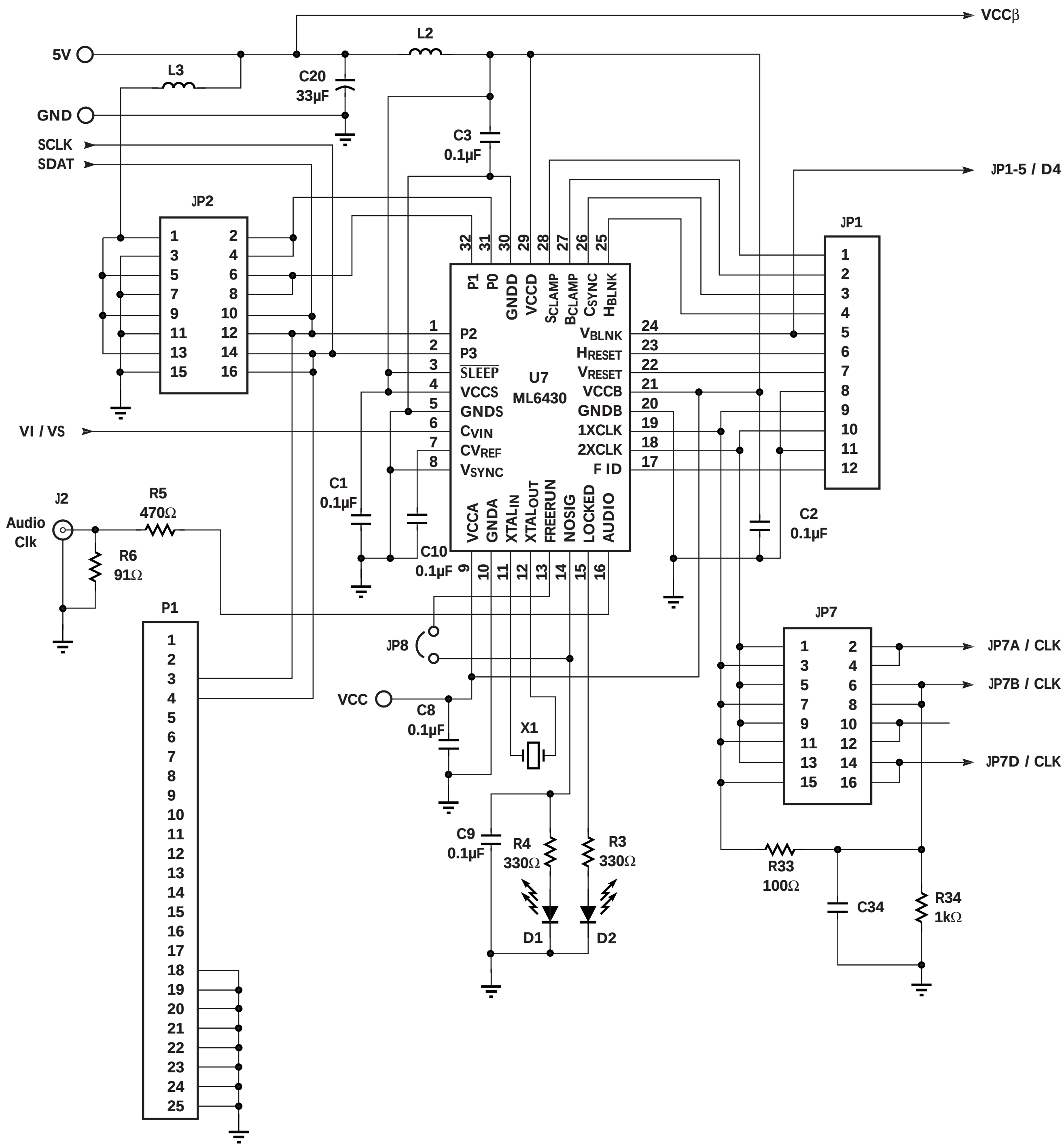

Figure 16a. Evaluation Board Schematic, Sheet 2 of 3

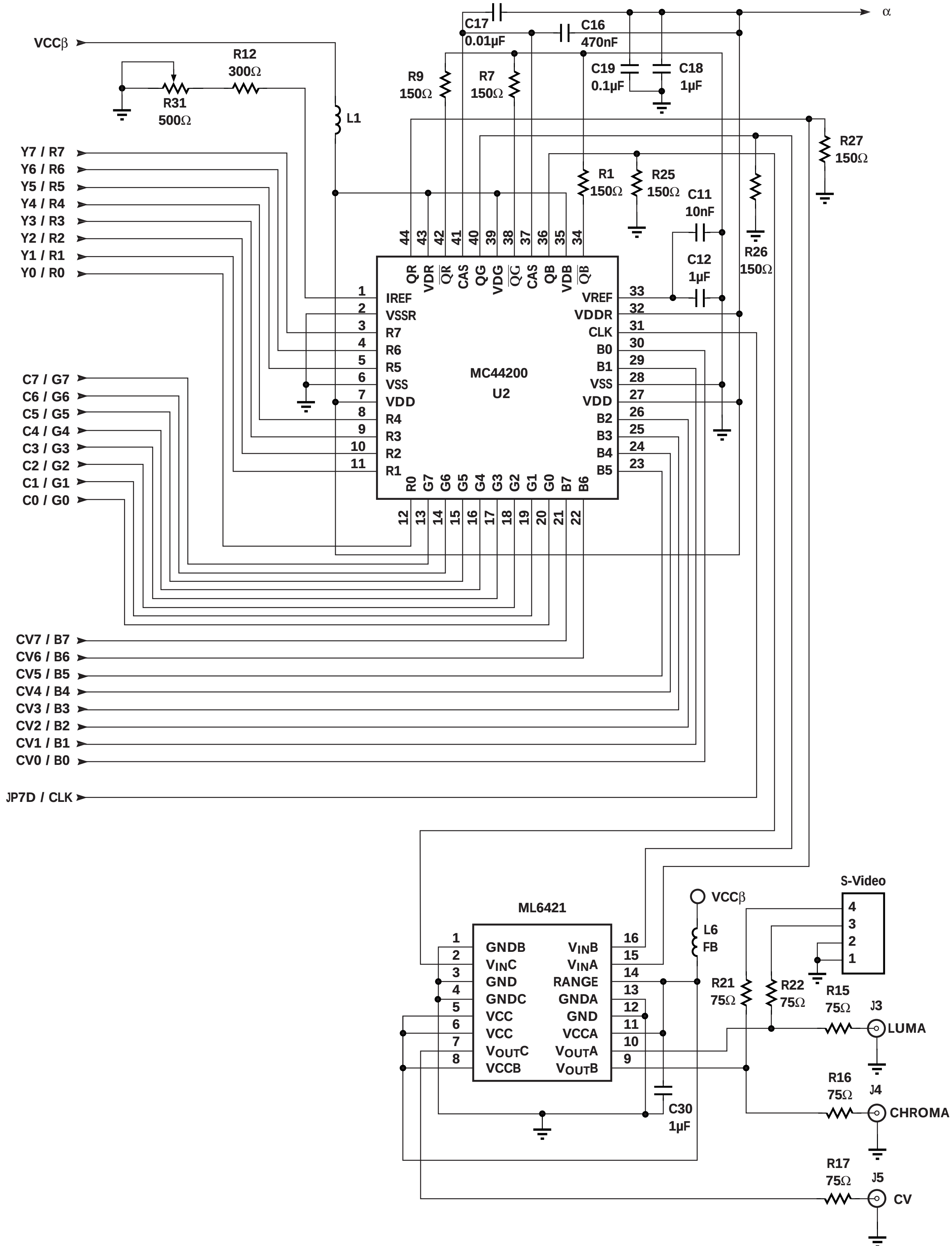

Figure 16b. Evaluation Board Schematic, Sheet 3 of 3

PARTS LIST

QTY	DESCRIPTION	VENDOR/PART (note 3)	DESIGNATION
Resistors (note 1)			
6	150Ω, 5%, 1206	Any	R1, R7, R9, R25, R26, R27
1	8.25kΩ, 5%, 1206	Any	R2
2	330Ω, 5%, 1206	Any	R3, R4
2	470Ω, 5%, 1206	Any	R5, R20
1	91Ω, 5%, 1206	Any	R6
1	5kΩ, 5%, Trimpot	Beckman, Type 66WR	R8
2	1kΩ, 5%, Trimpot	Beckman, Type 66WR	R10, R18
1	300Ω, 5%, 1206	Any	R12
1	7.5Ω, 5%, 1206	Any	R13
6	75Ω, 5%, 1206	Any	R14, R15, R16, R17, R21, R22
1	30Ω, 5%, 1206	Any	R19
1	500Ω, 5%, Trimpot	Beckman, Type 66WR	R31
1	10kΩ, %5, 1206	Digi-Key / P10KECT	R32
1	100Ω, %5, 1206	Any	R33
1	1kΩ, %5, 1206	Any	R34
Capacitors (note 2)			
10	0.1μF, 1206	Digi-Key / PCS4104BCT	C1, C2, C3, C7, C8, C9, C10, C19, C23, C26
8	1.0μF, 1206	Digi-Key / PCT3105CT	C4, C6, C12, C18, C21, C24, C28, C29, C30
5	0.01μF, 1206	Digi-Key / PCF1024CT	C5, C11, C17, C25, C27
1	10μF, polarized, C pkg.	Digi-Key / PCS2106BCT	C13
1	0.47μF, 25V, 1206	Digi-Key / PCT5474CT	C16
1	100pF, 1206	Kemet / C1026C101J5GACTIR	C34
Diodes			
2	LEDs,	Digi-Key / P516-ND	D1, D2
1	3.4 V Zener, surface mount	Any	D3
2	1N4148, surface mount	Any	D4, D5
Semiconductors			
1	Comb Filter	Micro Linear / ML6440	U1
1	D/A Converter	Motorola / MC44200	U2
1	Filter	Micro Linear / ML6421	U3
1	Hex Inverter	74ACT04, Any	U4
1	Filter	Micro Linear / ML6424	U5
1	A/D Converter	Micro Linear / ML6401	U6
1	Genlock	Micro Linear / ML6430	U7

PARTS LIST (Continued)

QTY	DESCRIPTION	VENDOR/PART (note 3)	DESIGNATION
Hardware			
5	BNC connector	A-D Electronics / 580-002-00	J1, J2, J3, J4, J5
1	Test point header, 12 pin	Digi-Key WM4010-ND	JP1
5	Jumper header, duel 8 pin	Digi-Key 52012-6-ND	JP2, JP4, JP5, JP6, JP7
1	Jumper header, duel 6 pin	Digi-Key 52012-6-ND	JP3
1	Test point header, 2 pin	Digi-Key WM4010-ND	JP8
6	Ferrite bead	Digi-Key 240-1030-1-ND	L1, L2, L3, L4, L5, L6
2	Banana Plug	Digi-Key 108-0740-001	na
1	DB-25 connector, female, board mounting	Thomas & Betts / SR25RA29B	P1
1	S-Video connector	Digi-Key MD-40 SGK	S-Video
1	3.58 MHz Crystal	Ecliptek / SM-3.579545M	X1

Note 1: Resistors not used: R11, R29, R23, R24, R28, R30
Note 2: Capacitors not used: C14, C15, C20, C22, C31, C32, C33
Note 3: “Vendor / Parts” column does not match Processing Instructions