LM1203,LM1203A,LM1203B,LM1205,LM1207

AN-1013 Video Amplifier Design for Computer Monitors

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Video Amplifier Design for Computer Monitors

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1.0 INTRODUCTION

Tomorrow's monitors will have higher resolution pictures, faster video speeds and fewer parts count, all of which are affected by the monitor video amplifier. This amplifier is usually divided into a preamplifier section and a CRT driver section. The overall monitor performance is affected by the performance of both sections. This note describes some of the characteristics of the video amplifier that must be taken into consideration to design this kind of monitor. It includes design theory and techniques for using video preamplifiers and CRT drivers in computer monitors, as well as a complete design for a video driver amplifier.

2.0 MONITOR VIDEO CHANNEL

2.1 Basic Timing Formats

In the display industry, there are a variety of video resolution formats that are in use. Each was designed to meet the specific need of an application. However, there are several formats that are popular and in wide use within the Personal Computer industry. Some of these are 640 x 480, 800 x 600, 1024 x 768 and 1280 x 1024, which are referred to as VGA, SVGA, XGA and CAD/Workstation. The numbers refer to the amount of active pixels displayed on the screen horizontally and vertically.

Within each of these video resolutions, there are also a variety of timing formats available. These are usually differentiated by the vertical or horizontal refresh rate. The faster the vertical rate, the less flicker is noticeable on the monitor screen. Video formats are now specified by such numbers as 800 x 600, 60 Hz or 800 x 600, 38 kHz. The last set of numbers in each format will refer either to the vertical (Hz) or horizontal (kHz) frequency rate. The exact timing for each of the video formats is really determined by the computer graphics card. The timings will typically be similar, but there will be some variations from manufacturer to manufacturer. Therefore, it is up to the monitor manufacturer to design a monitor that can automatically synchronize to a range of horizontal and vertical frequencies.

A monitor display created by the raster scan method has two parts: an active (visible) part, and a blanked (not visible) part made of horizontal and vertical blanking and retrace intervals. *Figure 1* illustrates this.

Scan size is adjusted so the edges of the visible scan area are at the edges of the monitor bezel. The visible scan time depends on the actual timing of the video format being displayed. For VESA formats (see Appendix A), the visible scan time is approximately 73% of the total scan time. Remember, the 73% is an average of the ratios of the active time to the total time (t_{active}/t_{total}) of several VESA timing formats. Use of the exact value for a particular format will allow calculating the exact pixel clock frequency for that format.

The pixel clock frequency depends on the number of active horizontal pixels, the number of active vertical pixels, and the vertical refresh rate, according to the formula

$$\text{Pixel Clock Frequency} = (\text{Active Horizontal Pixels}) \times (\text{Active Vertical Pixels}) \times (\text{Vertical Refresh Rate}) / (t_{active}/t_{total}) \quad \text{Equation 1}$$

For example, for an 800 x 600, 60 Hz SVGA format, the pixel clock frequency is

$$\text{Pixel Clock Frequency} = (800 \times 600 \times 60)/0.724 = 39.8\ \text{MHz.}$$

The actual time required per pixel is the inverse of the pixel clock frequency. For the above example, this is

$$\text{Pixel Time} = 1/39.8\ \text{MHz} = 25.1\ \text{ns} \quad \text{Equation 2}$$

It is necessary to know this number to define the required performance of the video driver assembly, as will be explained in the next section.

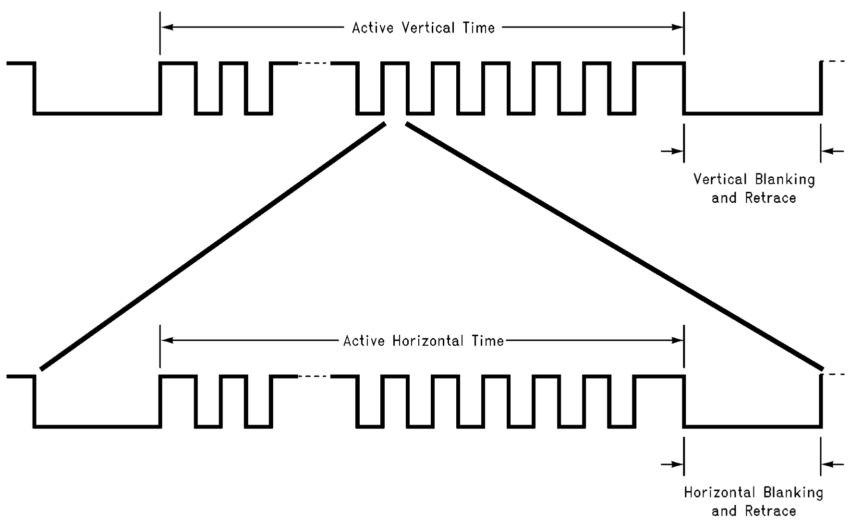

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FIGURE 1. Horizontal and Vertical Timing

3.0 RISE TIME, BANDWIDTH AND PIXEL CLOCK FREQUENCY

3.1 Rise Time of Cascaded Stages

The measured rise and fall time of a system of an amplifier and associated equipment will depend on the rise and fall time of each of its parts. If the system is a video generator, amplifier chain, load and oscilloscope/probe, the measured rise and fall time at the output of the system will be

$$Tmeas = [Tgen^2 + Tamp^2 + Tscope^2]^{1/2} \qquad \text{Equation 3}$$

The rise and fall times for the amplifier by itself can be obtained by removing the known times of the test equipment, as shown below.

$$Tamp = [Tmeas^2 - Tgen^2 - Tscope^2]^{1/2} \qquad \text{Equation 4}$$

The effect of the rise and fall times of the video source is sometimes overlooked. If a measured system rise time is 5 ns, and the generator and oscilloscope rise times are 1 ns each, the actual amplifier rise time is

$$Tamp = [5^2 - 1^2 - 1^2]^{1/2} = 4.8 \text{ ns.}$$

If the generator rise time is 3 ns instead of 1 ns, the actual amplifier rise time is

$$Tamp = [5^2 - 3^2 - 1^2]^{1/2} = 3.9 \text{ ns.}$$

This represents a large change in apparent driver performance at the higher resolution modes, which is actually due to the rise time of the input video signal, and not to the amplifier.

Test equipment performance is a factor which should also be considered. Taking the effects of test equipment into account is important when designers are trying to get switching times down to the lowest possible values. As a general rule, test equipment should be at least three times as fast as the fastest signal to be measured.

3.2 Rise and Fall Time Measurement

When measuring fast transition times, one should avoid using long ground leads from the probe. Using the typical oscilloscope probe, and a 6 to 8 inch ground lead with an alligator clip on the end, to measure rise and fall times will produce misleading results. The ground lead, which is a signal path that is not terminated in its characteristic impedance, should not be more than 2 inches long for 1 ns response time. Keep the connection from the oscilloscope probe ground to the circuit ground plane as short as possible. A good rule to use is ½ inch maximum. Oscilloscope manufacturers' bayonet adapters for probe tips work well. Try looking at a fast rise time signal with a good short ground and one that is too long, and you can see the difference on the oscilloscope screen. See the listed reference "ABC's of Probes" by Tektronix in Appendix A for photographs of these oscilloscope screens.

3.3 Specifying CRT Driver Amplifiers

Video driver amplifiers often have specifications like "80 MHz bandwidth at 50 Vp-p", "120 MHz bandwidth at 10 Vp-p", or "−3 dB bandwidth of 42 MHz at 50 Vp-p". Specifications like these imply that the amplifier can produce a large output signal up to some frequency, and will have reduced response at higher frequencies. This is true, but when these numbers are used in the equation

$$(\text{Bandwidth}) \times (\text{Rise Time}) = 0.35 \qquad \text{Equation 5}$$

they may not produce results that agree with other specifications or measurements. This is because the bandwidth and rise time numbers in the specifications are often not the same as the bandwidth and rise time terms in the equation. This equation applies to a single pole network (see Appendix B), and it should only be used to obtain approximate bandwidth numbers. The terms in the equation refer to the small signal characteristics of a network, and the numbers on a data sheet refer to the large signal performance of the device.

The term "small signal" means that the signal used to measure the bandwidth of the device is small enough that the device is always operating in the linear mode, so any rolloff in response is due only to the high frequency performance of the device, and is not being influenced by any other characteristic of the device, such as slew rate limiting. Improperly applying this equation can produce such incorrect results as indicating the rise time is slower than the specification, or that the device is not suitable for some application.

There is a very easy way to avoid any of this confusion when designing a CRT driver amplifier. This is to not be concerned with any reference at all to bandwidth. Specify only the output signal voltage range and the corresponding rise and fall times. These numbers tell the designer everything he needs to know to design the circuit.

For any mode of operation, a displayed pixel has a certain duration in time, usually specified in nanoseconds. Also, the brightness of the pixel is determined by the amplitude of the CRT drive voltage produced by the video driver. Therefore, the driver should be specified in terms of the peak to peak CRT drive voltage it can produce, and the rise and fall times that it will produce at that voltage level. The concept of bandwidth is not used.

Calculating the pixel clock frequency and pixel time, as described in Section 2.1, is the starting point. One rule of thumb used in the industry is that the CRT driver should have rise and fall times no longer than ⅓ of the pixel time. Additionally, monitor manufacturers typically require the CRT drivers to have a peak to peak swing capability of 50V to adequately drive a CRT. Designers should specify CRT driver components in terms of required rise and fall times at 50 Vp-p for the video mode they are concerned with, and not refer to the confusing "bandwidth" numbers.

3.4 The Relationship Between Bandwidth and Pixel Clock Frequency

3.4.1 General

If the concept of "bandwidth" is not used, as described above, it may still be useful to specify the maximum pixel clock frequency that a particular video amplifier may be used with. This is because this term refers to a real signal in the monitor, that a designer can relate to.

The term bandwidth, as applied to amplifiers in general, refers to the frequency that the small signal frequency response of the amplifier is reduced by 3 dB from the response at low frequencies (see Appendix B). The term "small signal" means that the test is done with a signal amplitude that is small enough that other factors do not affect the frequency response. The amplitude of the amplifier output signal is important. If it is too large during the test, factors other than the small signal response of the amplifier, such as signal clipping or slew rate limiting, will affect the output signal amplitude. It is generally assumed that the frequency response is flat at low frequencies and begins to roll off as the frequency is increased. To measure bandwidth, some low frequency, in the range where the response is flat, will be chosen as the reference frequency, and the amplifier output will be measured at this frequency. The test frequency will then be increased until the amplifier output has dropped by 3 dB. The frequency where this occurs is called the bandwidth of the amplifier. For example, if the low test frequency is 1 MHz, and the output amplitude drops by 3 dB when the frequency is increased to 80 MHz, then the bandwidth of the amplifier is 80 MHz. This is shown in *Figure 2*.

One other factor that can affect the measurement result is the shape of the test signal used. For correct results, the test signal must be a sine wave, at both the input and output of the amplifier.

If the bandwidth of an amplifier is determined by the method described above, and if the amplifier has a one pole low pass frequency response, then the equation (Bandwidth) x (Rise Time) = 0.35 (Equation 5) can be applied to the system. In this equation, bandwidth is described above, and rise time is the time for the amplifier output to change from 10% to 90% of full response when a step change of input voltage is applied. This equation shows how the time response and frequency response of an amplifier are related. It should be remembered, however, that this is the small signal frequency response, and may not be the same as the large signal response.

3.4.2 Bandwidth of Video Amplifiers

As applied to video amplifiers for computer monitor use, the term bandwidth has a slightly different meaning. The definition is the same, except it is the large signal response instead of the small signal response that is involved. The test signals will be near the maximum amplitude signals the amplifiers are intended to supply. For video preamplifiers, the bandwidth is measured with a 4 Vp-p output signal amplitude. For CRT driver amplifiers, bandwidth is usually measured at 40 Vp-p or 50 Vp-p.

This difference in operating conditions from small signal operation has some consequences. One, that is not important for the actual operation of the amplifier, but is important for our understanding of this operation, is that the above equation relating bandwidth and rise time (Equation 5) does not apply. For example, using this equation to predict rise time from the measured or specified large signal bandwidth may not give the correct answer. It is entirely possible for two different amplifiers which have the same large signal bandwidth to have different rise times because they have different circuit topologies. Bandwidth and switching time must be determined by separate tests.

A second effect of large signal operation of an amplifier is that the switching time of the amplifier may not be the same in both directions. Time to switch from black video to white video may be different than time to switch in the other direction, by as much as a factor of two.

3.4.3 Pixel Clock Frequency

Bandwidth, as described above, refers to a physical property of the amplifier. The next paragraphs examine how the amplifier is used.

The video signals being amplified in a monitor will be changing at a high rate. For example, if the video mode is 1280 horizontal pixels by 1024 vertical pixels, and is being refreshed at 72 Hz, the pixel frequency is

(1280) x (1024) x (72) = 94.4 million pixels per second   Equation 6

This is the average rate that the pixels will be displayed. Because pixels on a computer monitor are displayed only during the active video time and are blanked during retrace, the actual pixel clock frequency during the active video time will be higher than the average pixel frequency calculated above.

Continuing the above example, if the combined horizontal and vertical blanking are 10% of the total time, then the pixel frequency is (from Equation 1)

(1280) x (1024) x (72)/(1-0.10) = 104.9 million pixels per second.

This quantity is called the pixel clock frequency. It is the frequency that video pixels are being generated by the video source and are moving through the video amplifier.

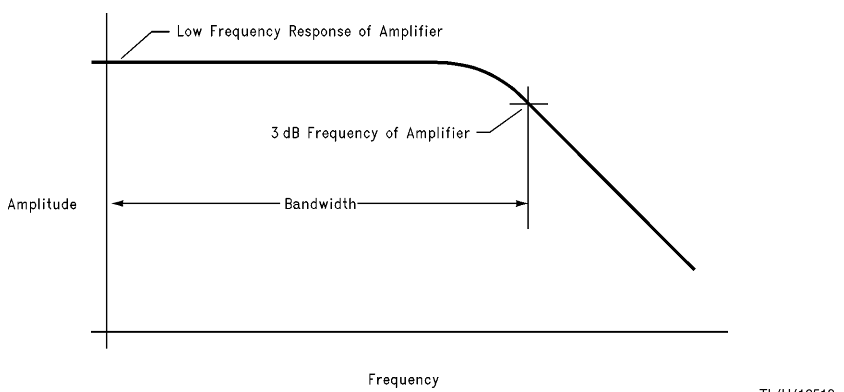

FIGURE 2. Amplifier Bandwidth Definition

There are many different video formats, so the actual pixel clock frequency for any format must be calculated from the number of pixels, refresh rate and blanking time for that format. The pixel clock frequency will be higher than the pixel frequency.

Notice that pixel clock frequency is a characteristic of the signal passing through the amplifier, not of the amplifier itself.

3.4.4 Relation Between Bandwidth and Pixel Clock Frequency

As the above paragraphs show, bandwidth is a property of the amplifier and pixel clock frequency is a property of the signal being amplified.

The amplifier will have some rise and fall time. The assumption can be made that when the amplifier input signal makes a full scale transition, it should not change again before the output has changed by at least 90% of the total amount it is going to change. This will minimize the amount of distortion the amplifier adds to the signal, and, in a monitor, will allow all the displayed pixels to be shown at the correct brightness. The pixel clock frequency controls the rate at which the video signal applied to the amplifier is changing. If one period of the pixel clock lasts just as long as the amplifier's rise/fall time, and if the pixels are alternating black and white, then the amplifier output signal will be alternately changing between the black and white levels as fast as it can. This is shown in *Figure 3*.

In this type of operation, with the amplifier switching as fast as it can, the video signal frequency will be one half of the pixel clock frequency, and will also be at the 3 dB bandwidth frequency of the amplifier. Therefore, one definition of the maximum pixel clock frequency that can be used with a video amplifier is twice the bandwidth of the amplifier.

Several other definitions of maximum pixel clock frequency have been used by monitor designers. It could be said that the high frequency pixel amplitude should not be less than 90% of the low frequency amplitude. The response of an amplifier will be down to 90% of full amplitude at ½ of the 3 dB frequency. Therefore, use of a 90% rule will result in a maximum pixel clock frequency equal to the bandwidth of the amplifier. The "⅓ rule" mentioned at the end of Section 3.3 could also be used.

Other definitions could be used, such as 85% instead of 90%. Use of other definitions will usually result in a maximum pixel clock frequency between 1 and 2 times the bandwidth of the amplifier. Each monitor designer will have to make his own decision on what relationship he wants to use between video amplifier bandwidth and pixel clock frequency, based on the design requirements for the system he is building.

In the above discussions, it is the relationship between the pixel rate and the rise/fall time of the video amplifier that determines how well the amplifier works. The concept of bandwidth is not required to specify or measure monitor operation. A monitor designer would find his work simpler if he thought about monitor operation only in terms of how fast his video amplifier switches in relation to the speed of the video signals it amplifies (this is the rise and fall time), and did not concern himself at all with bandwidth.

4.0 PREAMPLIFIERS

4.1 Interface to the Computer

Most computers have 50Ω or 75Ω video output signals that must be terminated correctly to get the best looking picture. This termination is provided by the video amplifier. The best way is to route the video cable directly to the video amplifier input connector, without connecting its signal or shield wires to other parts of the monitor. Terminating resistors of the correct value are installed next to this connector and connected to it with short leads. This provides the best video signal waveforms and lowest Electromagnetic Interference (EMI). The low level input video signal from the computer is amplified to an intermediate level (typically 2.5V to 4V peak to peak) by the video preamplifier, which also provides other signal processing functions. Integrated circuit technology is used to do this in nearly all modem monitors. Video bandwidth is up to 200 MHz. Among the advanced functions now included are dc controlled gain and offset, blanking, On Screen Display (OSD), and Electrostatic Discharge (ESD) immunity.

Dc control can replace the usual method of calibrating the video amplifier, which is by manually adjusting trimpots. The functions of the monitor can be measured by a computer controlled test system, which adjusts control voltages in the monitor to tune it up to the required operating conditions. Any of the monitor's video functions can be adjusted in this manner. The industry standard preamp, the LM1203, can use dc voltages to control some, but not all, of its functions. The newer LM1205 preamp accepts dc voltages to set all of its controllable functions: contrast, drive level and output

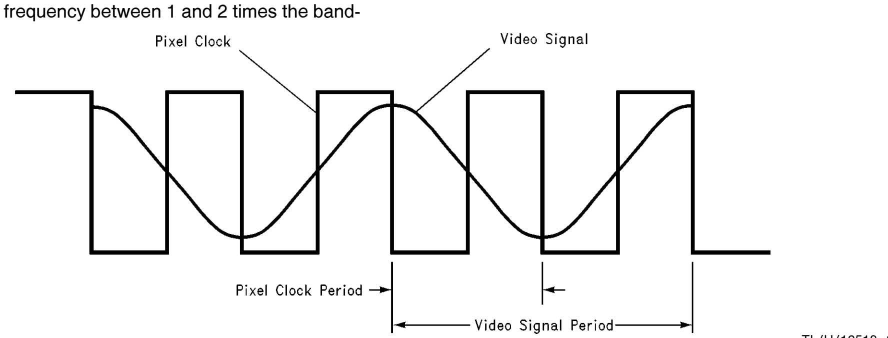

FIGURE 3. Pixel Clock and Video Signal

bias level for the CRT driver. All dc control inputs offer high input impedance and an operating range of 0V to +4V, for easy interface to bus controlled systems.

The OSD function included in the LM1281 preamp allows displaying adjustment information on the screen for monitor functions that are controllable by the monitor user. This design idea is incorporated by many monitor manufacturers to make the monitor easier to use.

ESD protection up to 2 kV is built into modem IC preamps. Protection for these preamps can be increased up to about 15 kV by adding components to the printed circuit board (PCB).

4.2 Preamplifier Control Inputs

In most displays, in order for the 0.7V peak to peak input video signal from the computer—or other source—to become a 50V peak to peak signal at the CRT cathode, it needs to be initially amplified by a preamplifier and then fed to the CRT driver. The preamplifier provides a gain of about 4 to 10 and also includes all the controls for adjusting the video signal to proper operating levels. Some of these controls include contrast, brightness, blanking, individual channel gain, and bias level.

National Semiconductor produces a range of triple-channel video preamplifiers for various application needs. They include the LM1203, LM1203A, LM1203B, LM1205 and LM1207. For detailed information on these devices, please refer to their data sheets.

For the LM1203 series, the contrast is controlled by a 0V to +12V dc signal, output offset is controlled by a 0V to +5V dc signal and variable resistors are used for separate drive controls for each channel. For the LM1205 and LM1207, these functions are all controlled by 0V to +4V dc signals.

4.3 LM1203 RGB Video Amplifier System

The LM1203 is a wideband video amplifier system intended for high resolution RGB color monitor applications. In addition to three matched video amplifiers, it contains three gated differential input black level clamp comparators for brightness control and three matched attenuator circuits for contrast control. Each video amplifier contains a gain set node for setting maximum system gain as well as providing trim capability for color matching. A low impedance output driver is included, which also can be used for gain peaking.

LM1203A and LM1203B versions are available, which provide faster response time, slightly lower output offset, and a built in power down spot killer that will prevent CRT phosphor burn.

4.4 LM1205/LM1207 RGB Video Amplifier System

The LM1205/LM1207 is a very high frequency video amplifier system intended for use in high resolution RGB monitor applications. In addition to the three matched video amplifiers, the LM1205/LM1207 contains three gated single ended input black level clamp comparators for brightness control, three matched dc controlled attenuators for contrast control, and three dc controlled sub-contrast attenuators providing gain trim capability for color balance. All dc control inputs offer high input impedance and an operating range of 0V to 4V. The LM1205/LM1207 also contains a blanking circuit which clamps the video output voltage during blanking to within 0.1V of ground. This feature provides blanking capability at the cathode of the CRT. The LM1205 provides faster response times than the LM1207.

4.5 LM1281 On Screen Display (OSD) RGB Video Amplifier System

The LM1281 is similar to the LM1205, but also has the capability of displaying messages superimposed on the video signal. These messages are used to show the status of various monitor functions. In addition to RGB inputs for normal video, there are also three separate RGB TTL video inputs for OSD, a control input to select normal video or OSD video, and an OSD contrast input. The monitor designer can use this function to allow the monitor user to control the monitor operation from front panel buttons or the computer keyboard.

5.0 OUTPUT DRIVERS

In order to be able to display images on the screen, all color CRT monitors require a CRT driver that can provide a high frequency peak-to-peak swing of as much as 50V at the cathodes of the CRT. The drivers accept the low level video signals from the preamplifiers and provide a further typical inverting gain of 13 to 18. These drivers operate from a power supply voltage of about 80V to achieve these output levels.

National Semiconductor produces a wide range of triple channel CRT amplifiers that are specifically designed to serve this purpose and will simplify monitor designs. The selection of amplifiers has a range of response times which are suitable for low-resolution VGA monitors up to the high-resolution CAD/CAM workstation monitors.

National's CRT amplifiers are based on two basic circuit topologies which are tailored to provide the best performance possible: the open-loop cascode with complementary emitter-follower circuit, and the closed-loop dual-stage complementary design.

National Semiconductor's Triple-Channel CRT Drivers:

- LM2406 Monolithic cascode with complementary emitter-follower output stage
- LM2416 Cascode with complementary emitter-follower output stage
- LM2419 Cascode with complementary emitter-follower output stage
- LM2427 Dual-stage complementary design with feedback

For detailed information on any of the above CRT drivers, refer to their respective data sheets.

5.1 Open Loop Drivers

The simplest open loop driver is a common emitter transistor amplifier, with a 1000Ω collector resistor, operating from an 80V power supply and producing about 50 Vp-p at its output. The voltage gain is fixed and there is no feedback around the amplifier. Variations of the design include emitter followers on the output, a cascode input circuit and different input biasing networks. Advantages of this design are fewer internal components, which produces lower cost, and smaller package size.

5.2 The Cascode Circuit

The cascode configuration is an improvement of the simple common emitter circuit described above. It has a high input impedance, thereby reducing the need for an input buffer stage; low input capacitance, which helps maintain a high frequency response; and fewer internal components. This design is also referred to as an open loop configuration because it has a fixed gain with no feedback applied around the amplifier.

In the cascode circuit (see *Figure 4*), the input NPN transistors Q1 and Q2 act as a low input capacitance, fixed gain amplifier to drive the load resistor R1. R3 is added to provide a dc offset at the input to match the output level characteristics of the preamplifiers.

The output stage emitter followers Q3 and Q4 are used to speed up the output voltage swing and to isolate the impedance of R1 from the capacitance of the output load, making the rise and fall times relatively insensitive to variations in load capacitance.

The gain of the circuit is established by the ratio of resistor R1 to the parallel resistance of R3 and R4, and the switching speed is primarily limited by the time constant established by load resistor R1 and the associated capacitances of D1, Q1, Q3 and Q4. Since these capacitances are usually fixed by the design of the part, increasing the switching speed requires using a lower value of R1, which also increases the power dissipation. Diode D1 is added to provide a forward bias voltage to the output stage to reduce the small-signal crossover distortion. A small resistor, R2, at the base of Q1 is added to prevent oscillations from occurring at high frequencies.

5.3 Cascode With Charge Pump and Emitter Bypass

To further improve the rise and fall times in a cascode circuit, the combination of a charge pump and an emitter bypass capacitor can be added. The charge pump is used to improve the rise times of the cascode circuit. Similar to the active load (described in Section 5.5), the charge pump uses a portion of the input signal to produce a current that helps the collector load resistor pull the output signal in the positive direction to reduce the response time of the amplifier. The charge pump consists of a common-emitter PNP transistor, Q5, with its base capacitively coupled by C1 to the input node of the device *(Figure 5)*.

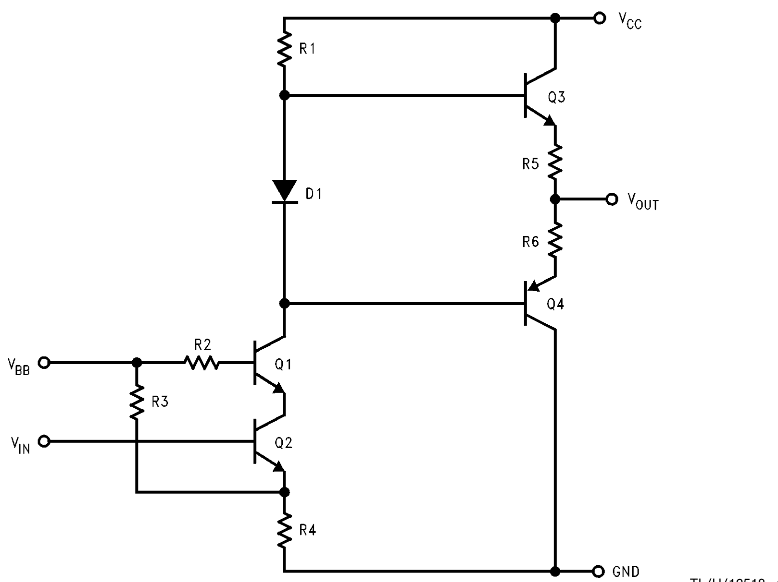

FIGURE 4. Cascode Circuit

The collector is connected to the base of the output transistor Q3, and provides extra current to charge the capacitive load during the output's low to high transitions. During the input signal's high to low transitions, transistor Q5 turns on for a short time and pumps additional current to the base of the output NPN transistor, thereby reducing the amount of time it takes to charge the load capacitance.

The time which Q5 remains on is determined by the time constant established by capacitor C1 and the parallel resistance value of R5 and input impedance of Q5, and it can be approximated by the equation:

$$Q5,\ t_{ON} = C1 \times [(R7 \times (\beta_{Q5}) \times R8)/(R7 + (\beta_{Q5}) \times R8)] \quad \text{Equation 7}$$

The time constant is selected so the current increase occurs for only a few nanoseconds, so transition edges of the signal are sped up, but lower frequency components of the signal are not affected. The additional current charges the output load capacitance faster and results in faster rise times for the output voltage. The use of the charge pump has the advantage of improving rise times and not increasing the power dissipation substantially, since it only dissipates power during the very short transition.

To improve the fall times, an emitter bypass capacitor, C2, is added in parallel with emitter resistor R4. During the input signal's fast low to high transitions, Q2 turns on and additional current is needed to charge C2. This additional increase in current allows the output capacitive load to discharge faster through PNP transistor Q4, and thus causes the output voltage to fall faster. The current needed to discharge the capacitive load can be calculated from

$$I = C_L \times (V_o/t) \quad \text{Equation 8}$$

Another way to view this is that during the high frequency transition, emitter resistor R4 is bypassed and the gain of the circuit becomes very large during that short transition time, which leads to faster fall times.

5.4 Closed Loop Drivers

If the collector load resistor of the open loop amplifier is replaced by a current source, the voltage gain of the stage increases by a large amount. This allows negative feedback to be applied around the amplifier, which can be used to improve and control the response time. The LM2427 uses this design. Advantages include lower power dissipation and faster response time.

Feedback is provided by a resistor built into the driver. An external input resistor is used to set the voltage gain. As will be described later, the input resistor can be replaced with an RC network to control the rise time and overshoot of the output signal (Section 7.4). An RC network can also be connected between the input and output of the device, to provide another method of wave shaping (Section 9.0).

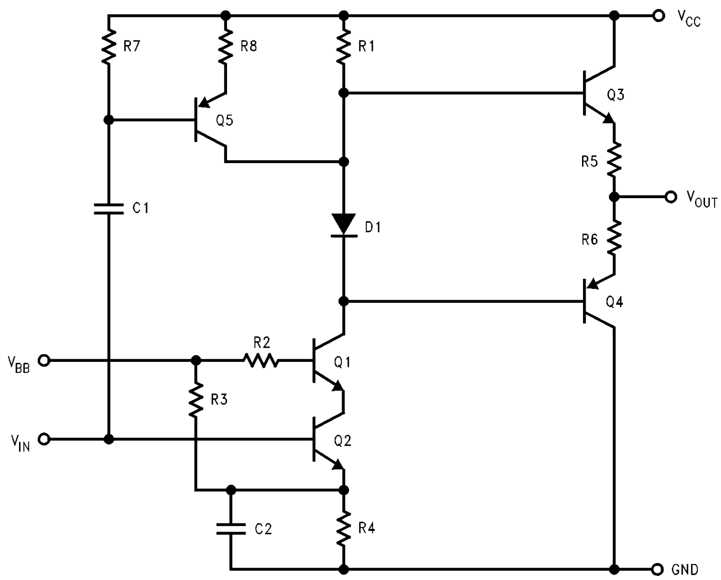

FIGURE 5. Cascode Circuit with Charge Pump and Emitter Bypass Capacitor

5.5 Active Load

The current source used as the collector load in the closed loop design can have the input signal applied to it through a capacitor. This connection is called an active load. The circuit is shown in *Figure 6*.

When the input signal is going negative, the signal coupled to the current source through capacitor C1 causes the current to increase, which helps the output signal rise faster. The response time of the amplifier is improved. The time constant of the circuit is selected so the current increase occurs for only a few nanoseconds, so edges of the signal switch faster, but lower frequency components of the signal are not affected.

5.6 Dual-Stage Complementary with Feedback

The circuit of *Figure 6* uses a two stage amplifier with complementary transistors as the input amplifier, and is also known as the dual stage complementary circuit. Using the dual-stage complementary circuit presents the advantages of having a lower power dissipation than a cascode circuit, and that it allows the monitor designer to shape the output wave to a form that fits the specific application. The closed loop driver can be thought of as an op-amp with a fixed value internal feedback resistor (R2 of *Figure 6*). The gain is set by adding a resistor at the input pin with the following relation: $VA = -R2/R_{IN}$. For the closed loop LM2427, an input resistor, R_{IN}, of 430Ω sets the gain to about −13, fixes the input node at 1.6V, and without any drive signal, the output sits at approximately 50% of the supply voltage (+V).

The input stage consists of matched, common-emitter, lower NPN (Q1) and upper PNP (Q2) transistors. Upper transistor Q2 is biased by resistors R4 and R5. Q1 gets its bias through the feedback resistor R2 and the input biasing current. The bases of Q1 and Q2 are capacitively coupled and, therefore, both transistors are actively driven.

The emitter resistors of Q1 and Q2 are bypassed with small capacitors. This increases the gain of the stages for high frequencies and increases the bandwidth of the amplifier. Emitter followers Q3 and Q4 are used for the output stage and help isolate the input stage from the output load. This minimizes the circuit sensitivity to variations in load capacitance.

Being a transimpedance amplifier (the input signal is a current, the output signal is a voltage), an input network is required to make the device work with a voltage source, such as the typical video preamplifier. The gain of the device is set by the ratio of the feedback resistor R2 and the input resistor R_{IN}. However, the frequency response of the amplifier using a single resistor network at the input may not be desirable. A well designed RC input network will help increase the frequency response of the amplifier and shape the output waveform as desired by the monitor designer. The method of designing this RC network is shown in Section 7.4.

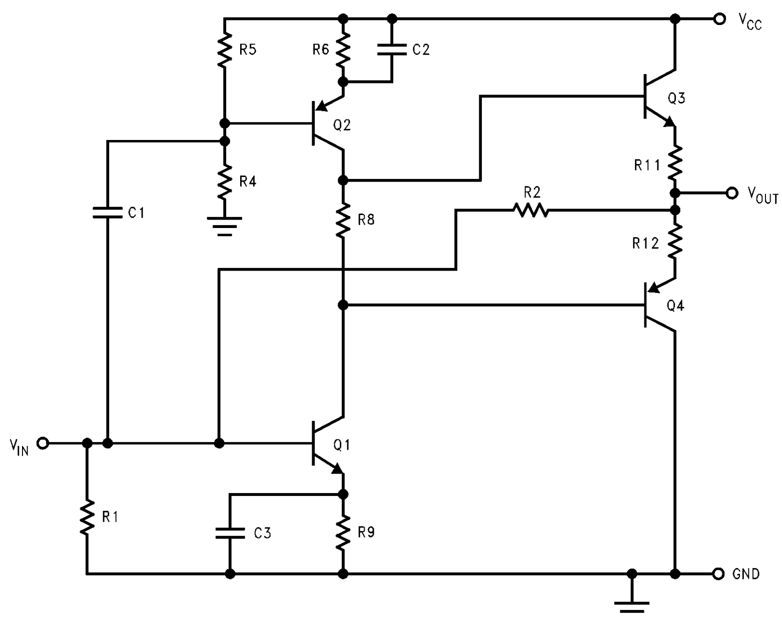

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FIGURE 6. Active Load

5.7 Buffer Amp for Closed Loop Drivers

Because a cascode input stage is not used for a closed loop amplifier, and because a capacitor is connected to the input, the input impedance of this type of CRT driver is low enough that driving it from an IC preamp may not produce rise and fall times that are as good as they could be. A buffer amplifier is usually used between the preamplifier and CRT driver to overcome this problem. The circuit is shown in *Figure 7*.

5.8 Comparison of Features Between Open Loop and Closed Loop CRT Drivers

A CRT driver amplifies the output of a video preamplifier in a computer monitor to a voltage level suitable for driving the color cathodes of the CRT. There are two basic types of CRT drivers: open loop and closed loop. This section provides more detail on how the two types work than the above sections and shows some similarities and differences between them.

5.8.1 Open Loop CRT Driver

The open loop CRT driver is a basic two stage transistor voltage amplifier, made of a cascode amplifier input stage followed by a complementary emitter follower output stage. A cascode amplifier is a two transistor circuit, with the input transistor operating in the common emitter connection, and driving an output transistor which is operating in the common base connection. The cascode amplifier circuit has been used since the eariy days of vacuum tubes, and is used because it minimizes the effects of circuit capacitance at the output of the first stage and achieves a wide bandwidth frequency response. The load for the cascode amplifier is a resistor. The video signal is coupled from this load resistor to the output through the emitter follower stage.

There is a resistor in series with the emitter of the first transistor of the cascode amplifier. The ratio of the first stage output load resistor to the input emitter resistor sets the voltage gain of the CRT driver.

The circuit of the open loop CRT driver is shown in *Figure 4*. A very detailed and complete description of the design of an open loop CRT driver is given in ‘‘Simplify High-Voltage Video-Amplifier Design’’ by Zahid Rahim in the March 18, 1993 issue of Electronic Design magazine.

5.8.2 Closed Loop CRT Driver

The closed loop CRT driver design is based on the open loop design, by making three changes: use a single transistor input stage, replace the load resistor with a current source, and add a feedback resistor from output to input. The circuit is shown in *Figure 6*.

A current source is used for the first stage load instead of a resistor because it provides higher current over the range of output voltages than a resistor does, so it can provide more drive to the output transistors when the output voltage is going from a low level to a high level. This will improve the switching time for transitions in the positive direction. Since better current drive is available, the current bias level can be reduced from the level used for a resistor load, so overall power dissipation is reduced.

Using a current source instead of a resistor for the first stage collector load increases the voltage gain of this stage by a large amount, and the resistor ratio method of setting the gain, as in the open loop driver, will not work. Some other method of setting the gain must be used.

The voltage gain of this circuit is high enough that the overall gain can be set the same way that the gain of an operational amplifier circuit is set. A feedback resistor is connected from the video output to the video input, and a resistor is connected in series with the input. The voltage gain is then the ratio of the feedback resistor to the input resistor. The feedback resistor is included in the driver package, and the input resistor is mounted on the printed circuit board the driver is installed in.

Placing the input resistor outside the driver package allows the monitor designer to connect other components to the resistor to control the pulse response of the driver. Rise time, fall time and overshoot can be adjusted to meet the design requirements of the monitor. This ability to control the pulse response can be a very valuable tool to set the appearance of the displayed picture, and can also allow control of radiated EMI levels from the monitor.

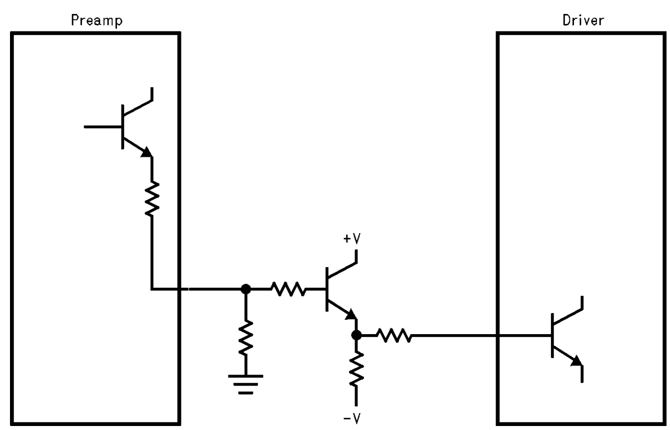

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FIGURE 7. Buffer Amplifier for Closed Loop Drivers

5.8.3 Summary

The above discussions of open loop and closed loop CRT drivers do not give all the details of driver operation, but do cover several important ones, to show the monitor designer how the two types work. The major points, and some others, are summarized in Table I.

The table below shows some differences between the open loop and closed loop types of CRT drivers. There are also some similarities. They are:

- Package size and shape
- Heat sinking is required
- EMI reduction techniques must be used
- Load driving ability − 8 pF to 12 pF CRT
- No short circuit protection (except for monolithic parts)
- Arc protection must be used
- Pcb layout technique is critical to good amplifier performance

5.9 Monolithic CRT Drivers

The LM2406 is both the industry's and National Semiconductor's first commercially available monolithic CRT driver for computer monitors. Traditionally, CRT drivers were manufactured with discrete high speed transistors. Then, chip components were used to package the drivers in hybrid form. Now, the LM2406 makes available a triple channel, 40 MHz full power bandwidth driver in monolithic form. It is designed to meet the performance needs of SVGA (800 x 600) and XGA (1024 x 768) monitor applications, supporting scan frequencies up to 58 kHz/72 Hz. This device is intended to be a cost effective alternative to discrete and hybrid CRT driver solutions, and provide increased ease of manufacturing monitors, increased reliability and reduced electromagnetic interference.

The LM2406 utilizes a new complementary bipolar process called Vertically Integrated PNP High Voltage (VIP 3H). The combination of high voltage capability, high f_t, and high performance PNP transistors make this process ideal for making CRT driver amplifiers. With the use of this high voltage process, problems associated with the use of standard bipolar processes in high speed applications can be overcome.

The monolithic design allows the use of on-chip protection devices, to protect the chip against fault conditions caused by high voltage arcing in the monitor and against temporary short circuits at the outputs. Also, the reduction in the number of components used to assemble the CRT driver and the complete video channel solution increases reliability.

5.10 Coupling to the CRT

Any of the various types of CRT drivers are designed to produce output signals within a certain voltage range. For example, the LM2419's proper output range is +25V to +75V, when it is operated from an 80V power supply. A design should operate the driver in its correct range. However, this voltage range may not be correct for the CRT the driver is being used with. A simple network that can be used to shift the signal to the range required by the CRT is shown in *Figure 8*.

TABLE I. Comparison of Features Between Open Loop and Closed Loop CRT Drivers

Open Loop	Closed Loop
Voltage amplifier—output voltage is proportional to input voltage	Transimpedance amplifier—output voltage is proportional to input current
Fixed voltage gain	Voltage gain set by external resistor
No external control of performance	External components allow external control of gain, bandwidth, switching time and overshoot
No external components required	2 to 9 external components required per channel
Cascode transistor input circuit	Single transistor input circuit
Input offset is +3V to +4V	Input offset is +1.6V
No input buffer amplifier required	Emitter follower input buffer amplifier required
Up to 65 MHz bandwidth—LM2419	Up to 80 MHz bandwidth—LM2427
Two power supply voltages required (+12/+80)	One power supply voltage required (+80)
I_{CC} increases as V_{OUT} decreases	I_{CC} does not increase as V_{OUT} decreases
No smear compensation required	Smear compensation circuit required
Package has staggered pin arrangement	Package has in line pin arrangement with ground or power pins on both sides of all signal pins
One to three ground pins per package	One ground pin per channel Track length and stray capacitance at input pins must be minimized

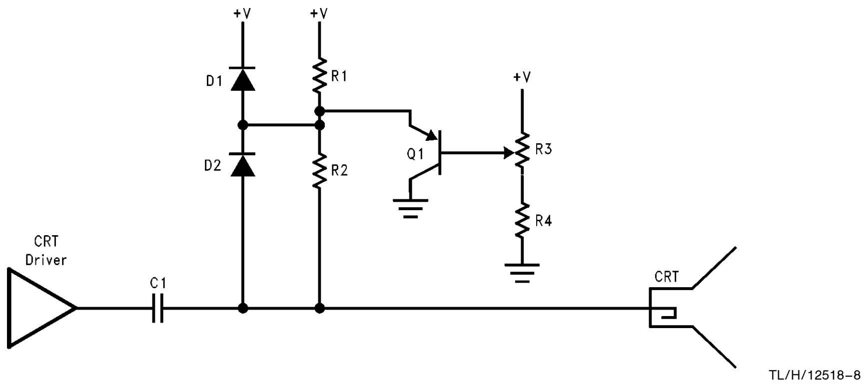

FIGURE 8. Output Level Shift Network

This circuit also performs the black level clamping function, which is adjusting the most positive part of the output signal to a specified voltage level. Resistor voltage divider R3, R4 and Q1 establish a voltage level at Q1 emitter. The video signal is ac coupled to the CRT cathode by C1. C1 and D2 are a diode clamp circuit. When the output signal goes positive, D2 conducts, and C1 will charge so the most positive portion of the signal will be 0.7V more positive than the voltage at Q1 emitter. All other portions of the signal will be more negative than this level at the CRT cathode. This fixes the dc offset of the CRT drive signal. The offset is adjustable by changing the setting of R3. The offsets of the three CRT drive signals are made adjustable by this method so they may be set to different values for each channel to allow color balancing of the displayed picture.

Diode D1 provides part of the CRT driver assembly arc protection by providing a path for arc current from the CRT to flow around the other amplifier components.

The method of coupling to the CRT described above is called ac coupling. Its characteristics are summarized in Table II.

The big advantage of ac coupled cathode drive is the higher voltage that can be used at the cathode. This higher voltage gives higher beam current, resulting in a brighter display. The circuit also provides a wide color cutoff voltage adjustment range for the CRT. However, higher beam current can also mean a larger spot size, which limits the resolution. This circuit also makes the displayed picture sensitive to power supply variations, including any noise which may be present. The dc restoration is done by passive components. It is necessary to have a bias resistor that slowly discharges the capacitance of the cathode, which may cause some tilt in the video signal at the cathode.

If a CRT can be obtained that has a required color cutoff voltage adjustment range that is within the correct output voltage range of the CRT driver, then the ac coupling components can be eliminated and the driver output can be connected directly to the CRT cathode. This is called dc coupling. This condition usually cannot be obtained, because CRT's of this type are not available. However, newer CRT drivers made with the VIP 3H process will have higher operating voltages, and may be able to be used in this manner. The characteristics of dc coupling are summarized in Table III.

TABLE II. Ac Coupling of CRT Drivers

Advantages	Disadvantages
Cathode can be biased at very high voltages, which are different for each cathode.	Black level is sensitive to power supply variations.
Wide color cutoff adjustment range.	Sensitive to noise coupled from the power supply. Larger CRT spot size.

TABLE III. Dc Coupling of CRT Drivers

Advantages	Disadvantages
Black level clamping provides dc restoration for every line.	Maximum cathode voltage is limited by the CRT driver's maximum operating voltage.
Good power supply rejection.	Limited color cutoff adjustment range.
Minimum black level drift (low tilt).	

5.11 Short Circuit Protection

The outputs of CRT drivers are not short circuit protected, except the LM2406, since this would increase the response times the parts can produce. Shorting the output to either ground or V+ will destroy the device. The minimum dc load resistance the devices can drive without damage depends on the device. For the LM2419, it is 1.6 kΩ. Driving the minimum resistance load continuously is not recommended because of power dissipation considerations.

5.12 Power Dissipation

The power dissipated in a CRT driver depends on several factors, including type of CRT driver, supply voltage, and video signal pattern. Power dissipation measurements made on two typical CRT drivers are described in Table IV. The CRT drivers were operated in a monitor with an LM1205 preamplifier, in the 1024 x 768 pixel x 70 Hz mode. The CRT drivers tested are the LM2427, a closed loop CRT driver, and a new prototype open loop CRT driver, similar to the LM2419. Each was operated as it normally would be in a monitor, except the LM2427 was also operated at a lower power supply voltage than normal, to provide a more direct comparison to the prototype. Various video patterns were used.

These measurements show the differences in power dissipation between open loop and closed loop CRT drivers. With open loop CRT drivers, the main effect is an increase in power dissipation as the amount of white area in the picture increases. With closed loop CRT drivers, the power dissipation is fairly constant as the amount of white area changes, but increases a large amount as the number of transitions between brightness levels increases.

5.13 Heat Sinking CRT Drivers

A semiconductor component will dissipate heat as it operates. This heat must be removed from the part or it may get hot enough to fail. For CRT driver amplifiers used in computer monitors, heat is removed from the part by mounting it on a piece of thermally conductive material (a heat sink), such as aluminum. If the heat sink is the proper material, size, shape and color, and if it is installed properly, it will keep the CRT driver cool enough to operate correctly.

A heat sink must be designed to be suitable for the particular monitor it is used in. The heat sink must be adequate to keep the operating temperature of the CRT driver below its maximum rated case temperature, under all possible operating conditions of the monitor. Worst case operating conditions will be when the monitor is displaying a white screen with maximum contrast and minimum brightness settings, and when the room temperature is at its maximum value. Minimum brightness is a worst case condition, instead of maximum brightness, because when the brightness is set high, the monitor Automatic Brightness Limiter may reduce the contrast setting, which will cause the power dissipated in the CRT driver to be reduced.

The thermal resistance of a heat sink is used as a starting point for the heat sink design. For example, if a CRT driver dissipates 13W under maximum drive conditions, if the operating temperature inside the monitor is 50°C, and if the CRT driver maximum case temperature is 90°C, then the required thermal resistance is (90−50)/13 = 3°C per watt. Any heat sink that has a thermal resistance of 3°C per watt or less is acceptable. This thermal resistance must be achieved when the heat sink is mounted in the monitor. Since installing a heat sink in a monitor will increase its thermal resistance, it will be necessary to begin the design by choosing one that has a lower rating than the calculated maximum.

Some things may be done in the monitor design to optimize the heat sink performance. The heat sink should be mounted with its fins in a vertical position, in a location where air flow is not restricted by other monitor parts, such as the EMI shield or the cabinet. It should be located away from other hot components in the monitor. There should be adequate ventilation holes in the cabinet. The heat sink surface should be a flat black color, since this type of surface radiates heat best. Thermal joint compound should be used to mount the CRT driver. If an EMI shield or metal chassis is used in the monitor, the heat sink can be thermally coupled to it, so it can help radiate the heat.

Every monitor design will be different. The best procedure is to measure the actual temperature of the selected heat sink early in the monitor design process, to make sure it is low enough under all operating conditions. This will ensure that an adequate heat sink is designed into the monitor.

5.14 Component Derating

Solid state components have certain maximum voltage and current ratings, and must be operated within these ratings. They will typically be derated so the actual operating voltages and currents do not exceed some percentage of the maximums, such as 80%, to obtain acceptable reliability. A monitor designer must choose devices that have high enough ratings that they will be properiy derated with the monitor power supply voltages available.

Hybrid microcircuit CRT drivers also have maximum ratings that must not be exceeded. A typical open loop CRT driver may have an absolute maximum voltage rating of 85V and

TABLE IV. Power Dissipation in CRT Drivers

Test Pattern	LM2427		Prototype
	Power at $V_{CC} = 70$	Power at $V_{CC} = 80$	Power at $V_{CC} = 70$
Black Flat Field	5.6W	7.2W	1.7W
Text	5.6W	8.0W	3.2W
SMPTE	4.9W	6.8W	6.4W
Typical Windows	4.6W	6.4W	8.8W
Reverse Text	4.9W	6.8W	10.2W
One On/One Off Pixels	8.4W	12W	10.2W
White Flat Field	4.6W	6.0W	10.6W

will be specified to operate at 80V. This does not mean that the derating is only 80/85 = 94%. A hybrid CRT driver of this type would be made with transistors that have maximum voltage ratings of over 100V, and would be tested in production at 100V. Also, samples of each date code would be life tested at maximum rated power and maximum rated case temperature with 80V applied. This establishes the part's reliability at the specified operating conditions. Derating is already built in at the specified operating voltage, and no further derating is required.

6.0 ON SCREEN DISPLAY

Emitter follower buffer amplifiers may be added between the video preamplifier and the CRT driver amplifier, as described in Section 5.7. The On Screen Display (OSD) function can also be added to the connection from the video preamplifier to the CRT driver amplifier. The OSD signal has two components: blanking and video. Blanking is used to replace a section of the normally displayed video with a box, which provides a background for symbology provided by the OSD video signal. Blanking is added at the input to the video assembly, as shown in *Figure 9*.

The blanking signal turns on the transistors connected to the input, which attenuates the input video signal to a low value and provides a black box on the display.

Symbology is added to the black box by connecting an emitter follower to inject the OSD video signal into the green channel, as shown in *Figure 10*.

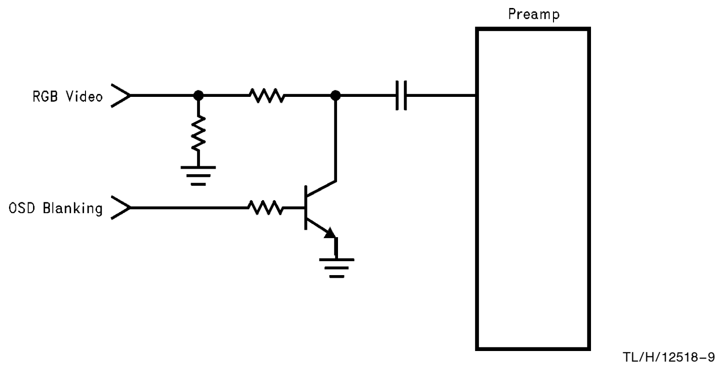

FIGURE 9. On Screen Display Blanking

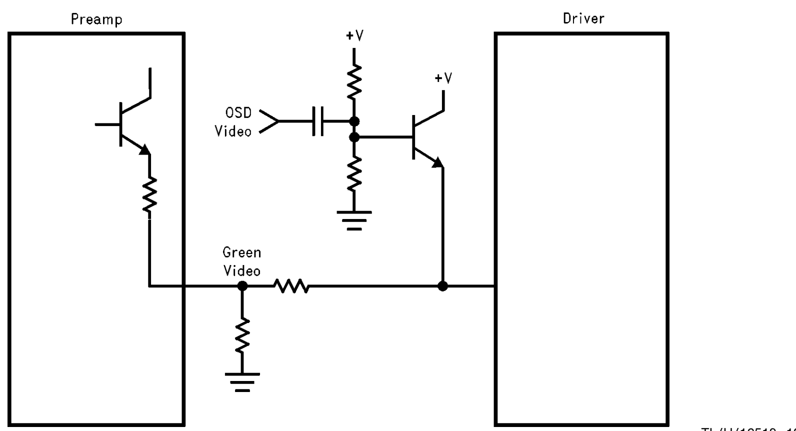

FIGURE 10. On Screen Display Video

The emitter follower is biased so the base voltage is below the lowest normal green video level, so it is turned off and does not affect the normal operation of the green channel. Applying TTL level OSD signals will cause the displayed information to appear as green symbols on a black background. This circuit can be added to all three channels, so full color OSD can be produced.

As described in Section 4.5, the LM1281 preamp has these OSD blanking and video features built in.

7.0 PEAKING METHODS

Peaking networks can be used to speed up the rise and fall times of the video signals that drive a CRT. The word ''peaking'' is used to describe these networks because the frequency response curve of an amplifier using one has a peak at the high frequency end of the curve, just before it begins to roll off. Peaking techniques are good to obtain small improvements in switching speed without adding overshoot, such as from 8 ns to 7 ns. Larger improvements will be accompanied by increased overshoot, so the circuit designer must make a decision on exactly how much peaking/overshoot to use. The way to do this is to increase peaking enough to make the displayed picture look better, but not so much that overshoot becomes visible.

There are several ways this can be done. Some are shunt peaking, series peaking, emitter bypass capacitors, and input resistor bypass networks. Shunt and series peaking involve adding an inductor somewhere in the signal path. The inductor works with other circuit elements to produce the peaked response. An emitter bypass capacitor, placed around the emitter resistor of a common emitter amplifier stage, will increase the gain of the stage at high frequencies. Finally, the input gain setting resistor of a closed loop CRT driver can be bypassed by an RC network to increase the high frequency gain of the stage. Each of these circuits is described below.

7.1 Shunt Peaking

If a small inductor is placed in the right place in a circuit, it will interact with the resistance and capacitance in the circuit to produce faster response times. The circuit is shown below.

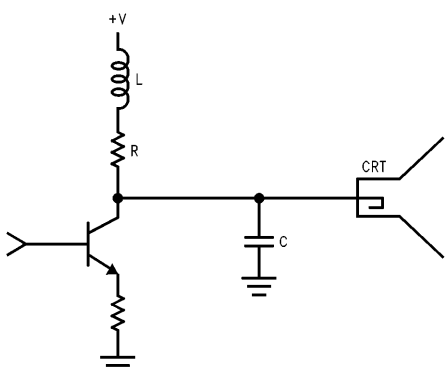

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FIGURE 11. Shunt Peaking

Theory of this circuit is described in ''Vacuum Tube Amplifiers'' by Valley and Wallman. The inductor value is calculated from:

$$L = mR^2C \qquad \text{Equation 9}$$

where R = collector resistor

C = stray + load capacitance.

The value of m used determines the amount of peaking produced. For values of m from 0 up to about 0.25, some improvement in switching speed is obtained without overshoot. For larger values of m, overshoot increases as m increases, as shown in the following table (from ''Vacuum Tube Amplifiers'').

TABLE V. Performance of Shunt Peaking

m	Relative Speed, Referred To An RC Circuit	Overshoot, %
0	1.0	0
0.25	1.4	0
0.414	1.7	3.1
0.5	1.9	6.7
0.6	2.1	11.4

7.2 Series Peaking

An inductor added in series with the signal path can also produce peaking. One place to do this is at the output of the CRT driver amplifier. An example of this is shown on the LM2419 data sheet, and in *Figure 12* below. The inductor works with stray capacitance and the input capacitance of the CRT cathode. Typical values of L that work are 0.1 μH to 0.5 μH. A series inductor may also be added between stages, such as between the video preamplifier and CRT driver amplifier.

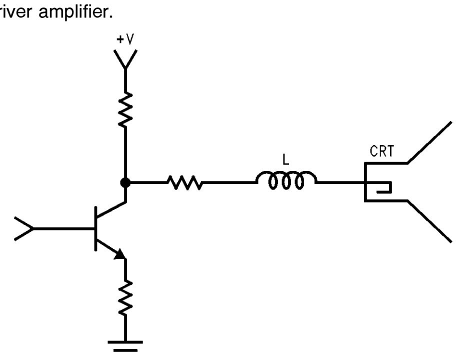

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FIGURE 12. Series Peaking

There are many other types of RLC peaking networks. The simple shunt and series networks described are called two terminal networks. Other, more complicated four terminal networks can be designed that theoretically will produce faster transition times than the simple networks. However, they use more components, and some component values are comparable to stray circuit values, so the predicted gains are difficult to achieve.

7.3 Emitter Bypass

Placing a bypass capacitor in parallel with the emitter resistor of a common emitter amplifier stage, as shown in *Figure 6*, will increase the voltage gain above a certain frequency (which depends on component values). Such a capacitor is included in the LM2427, and can be added externally to the LM1203.

The correct value of capacitance to use can be determined by experiment. It may fall between 10 pF and 100 pF. In practice, a video amplifier assembly should be tested in its intended application, and the bypass capacitor value should be varied until the assembly produces the best looking display. Look at the right hand side of a large, sharp dark to bright transition (dark on left, bright on right). The correct amount of capacitance will cause the edge to become sharper. Too much capacitance will cause the edge to be brighter than the rest of the display. The monitor designer will probably find that adding some resistance in series with the capacitance will improve the results. Both component values should be adjusted until the best picture appearance is obtained.

7.4 Input Resistor Frequency Compensation Network

7.4.1 Introduction

The voltage gain and frequency response of closed loop CRT drivers, such as the LM2427, are determined by some resistors and capacitors connected to it, as described in the data sheet, and shown in *Figure 13* below. Values of these components will be affected by layout of the printed circuit board the part is used in, and by the performance desired by the monitor designer. This section provides some additional information on how to determine these values.

The input gain setting resistor will usually be set to 430Ω. If the part is direct coupled to the preamplifier, a 560Ω resistor will be connected from each input to ground, to bias the output to the correct range. If C1, R2/C2, R3/C3 and R4/C4 are not used, rise and fall times will be very slow, so these components are added to improve the switching times, as described below.

7.4.2 Low Frequency Compensation

A series resistor/capacitor combination (R2/C2) is connected across the 430Ω resistor to adjust switching time. Variable components are used to adjust the circuit for best performance, which is usually defined as best switching time with no overshoot. Each monitor designer must define what is best performance for his own particular application. Use a physically small adjustable resistor and adjustable capacitor, connected to the printed circuit board with very short leads. (See **7.6, Test Board** Section.) Monitor the output waveform with an oscilloscope and adjust the components for the desired performance. Measure the component values, and replace the adjustable components with fixed components of the same value. Recheck switching time to verify that the desired effect is achieved.

7.4.3 Mid Frequency Compensation

A second series connected resistor/capacitor network (R3/C3) can be added in parallel with the 430Ω resistor to further improve the switching time. Use the same adjustment procedure as described above, and install permanent fixed value components.

Approximate values for the first network are R2 = 6.8 kΩ and C2 = 15 pF. Approximate values for the second network are R3 = 68Ω and C3 = 39 pF. The actual values will

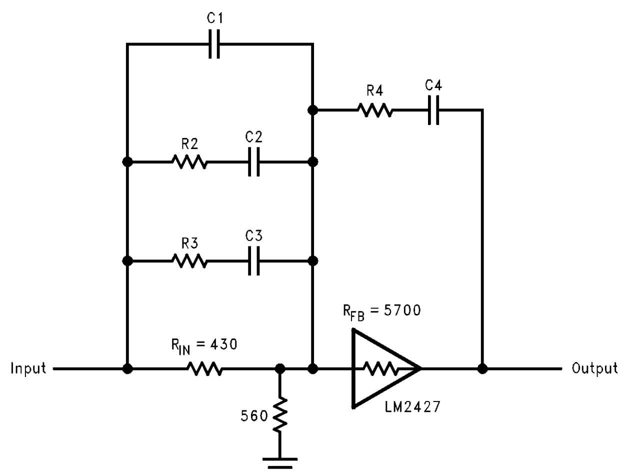

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FIGURE 13. Input Resistor Frequency Compensation Network

depend on the application and will be affected by the factors described in the first paragraph above.

7.4.4 High Frequency Compensation

More improvement in switching time can be obtained by connecting a capacitor (C1) across the 430Ω resistor. Select a capacitor value that provides the best switching time with not too much overshoot. The value will probably be less than 10 pF. The correct amount of overshoot will depend on the application, and is determined by increasing the overshoot to the largest amount possible that will not produce an objectionable picture on the CRT screen.

It is easy to apply so much capacitance in this location that the amplifier will oscillate under some operating conditions. Care must be taken to prevent this from happening.

7.4.5 Smear Compensation

Smear compensation is obtained by connecting a series resistor/capacitor (R4/C4) from input to output of the CRT driver. Use a black box on white field test pattern. Connect a variable resistor and capacitor from input to output and adjust them for minimum smear, as observed on the CRT screen. Measure their values and replace them with fixed value components. The values will be about R4 = 150 kΩ and C4 = 56 pF.

Smear compensation will be optimized for the test pattern used to determine component values. If the monitor designer wants best smear compensation for a different test pattern than a black box, he should use that test pattern to select component values.

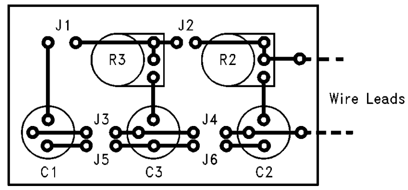
The procedures described above are done separately for each video channel. After all compensation components have been determined, recheck switching time and smear performance to determine if the correction is still acceptable. It may be possible to get slightly more improvement by readjusting the component values.

All component leads and circuit board tracks in these sections of the circuit should be as short as possible, especially the circuit board tracks connected to the driver input pins. On the LM2427, the inputs are like the summing junction of an operational amplifier. They are more sensitive to noise pickup than most circuits, and an important requirement of the circuit board layout is to keep them as short as possible and isolated from other signals. The total circuit board track length connected to each input pin of the LM2427 should be no more than one inch. Also, the stray capacitance to ground from these pins should be as low as possible, to maximize the performance of the amplifier.

7.4.6 Test Board

Artwork for a printed circuit board that can be used to determine the required component values is shown below. The actual board should be as small as possible, to reduce stray reactances.

Component Side View



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C1 = 5 pF–15 pF

C2 = 15 pF–65 pF

C3 = 15 pF–65 pF

R2 = 20000Ω

R3 = 200Ω

FIGURE 14. Frequency Compensation Test Board

This assembly contains the components that must be selected to obtain the desired video amplifier performance. The board can be assembled with all components, or only the ones the monitor designer wants to adjust. Use small components to build the board, so stray reactance is low. The jumpers shown (J1 through J6) allow connecting or disconnecting groups of components.

The assembly is used by connecting it in place of the selected components on the video amplifier, and adjusting the variable resistors and capacitors on it until the amplifier works as desired. Connect the test board across the 430Ω input resistor of the assembly to be calibrated with short wire leads. Monitor the assembly pulse response with an oscilloscope and adjust the test board components for the desired pulse response waveshape. Disconnect the test board from the assembly being calibrated and measure the test board component values. Install resistors and capacitors with these values on the video amplifier.

The monitor designer is encouraged to experiment with different versions of this Test Board and different values of frequency compensation components until he finds a final monitor design that meets his own particular requirements.

7.5 Overshoot and Settling Time

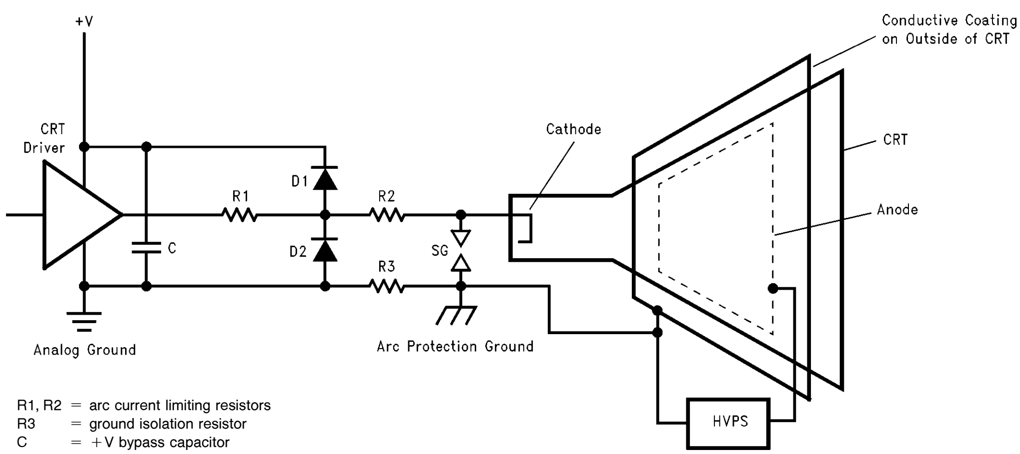
A CRT driver, operated by itself in a proper test fixture, and driven by a fast square wave video input signal, will produce a square wave output signal that has some rise and fall time and some overshoot. If the stray capacitance and inductance are low, these effects will be due only to the device being tested. Some types of drivers will produce no overshoot, and some will produce large amounts. The performance of a part in an actual application will depend on factors such as CRT input capacitance and stray inductance and capacitance in the monitor wiring. Actual performance is what matters, so the monitor designer should not accept or reject any device based on specified data sheet parameters. There are design techniques that can affect parameters such as rise and fall time, to adjust them to the desired values.

Application of a CRT driver involves making a tradeoff between values of rise/fall time and overshoot. As a general rule, any attempt to increase the switching speed of a device will also increase the overshoot on the output signal. For example, the charge pump decreases the output positive transition switching time and the bypass capacitor decreases the output negative transition switching time, and they both add overshoot in the process. In an actual application, some method of controlling overshoot would be used to gain the benefit of the device's faster response time.

A decision must be made on how much overshoot is acceptable. This decision should be made based on use of the part in a real application, and will probably be influenced more by the appearance of the display than on other factors, such as some number of volts or nanoseconds of overshoot. Also, as explained in the section on Electromagnetic Interference, increased overshoot and faster switching times are usually accompanied by generation of higher levels of interference, so the least amount of overshoot and slowest switching times that will meet the other requirements of the monitor operation are the best ones to use.

8.0 ARC PROTECTION

During normal operation of a CRT, arcs can occur between the elements of the tube. These arcs usually last only a short time and are not noticed by the person viewing the CRT. However, they can apply very high voltages to the circuits connected to the CRT, so protection components are included in these circuits to prevent them from being damaged by these voltages. A typical circuit used in computer monitors is shown in *Figure 15* below.



R1, R2 = arc current limiting resistors
R3 = ground isolation resistor
C = +V bypass capacitor
D1, D2 = arc protection diodes
SG = spark gap
HVPS = CRT high voltage power supply

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FIGURE 15. Arc Protection

The CRT driver applies a video signal to the CRT cathode. Other elements in the CRT are charged to a very high voltage with respect to the cathode, so if no protection is used, an arc from one of these elements to the cathode will apply voltages to the CRT driver that can exceed its ratings and damage it. The various protection components are intended to prevent this. They must be applied correctly to achieve this result. The correct application is not obvious by looking at the schematic, so this section is intended to supply more information.

Arcs inside the CRT will cause currents to flow in circuits connected to the CRT. The purpose of the protection components is to shunt these currents around the video amplifier. Since the arc starts within the CRT, the first level of protection is applied where the video amplifier connects to the CRT, which is at the tube socket. There are spark gaps (SG in *Figure 15*) built into the socket which will limit the maximum voltage that appears at the video amplifier terminals. Normally, the spark gaps are a non-conducting open circuit. When an arc voltage exceeds the breakdown voltage of a spark gap, it begins conducting the current caused by the arc. This current comes from energy stored in the capacitance between the anode and other elements inside the CRT, and the conductive coating on the outside of the CRT. The current path is from the anode (or other elements), through the cathode, spark gap and arc protection ground lead to the conductive coating.

Since the breakdown voltage of a spark gap is about 300V, the arc voltage is still large enough to damage the video amplifier. Components R1, R2, D1 and D2 are used to further reduce the arc voltage applied to the CRT driver by providing a path for the arc current to flow around it. R2 is in series with the arc voltage, so will act to attenuate it. If the arc voltage is still more positive than the CRT driver power supply voltage, +V, diode D1 will conduct and steer the arc current through capacitor C into the analog ground, instead of allowing it to flow into the CRT driver. If the voltage is negative, diode D2 will conduct to steer the arc current into the analog ground. The complete path for arc current is from the CRT element capacitance, through R2, D1 and C, or D2, to the analog ground, then through the ground isolation resistor R3 and arc protection ground lead, to the conductive coating.

The physical arrangement of the arc protection components must provide a path for the arc current to flow around the video amplifier semiconductors instead of through them. This is the part of arc protection circuit design that is not obvious from looking at the schematic diagram. In general, the following rules should be followed to obtain the best arc protection circuit performance:

1. Use a ground plane under the CRT socket to connect the ground lead from the CRT conductive coating to all of the spark gap ground leads. This is the arc protection ground plane. It acts as a very wide, low impedance circuit track to keep all of these component ground points at the same potential. All other video amplifier circuits should be physically separated from this plane, so transient arc voltages will not be capacitively coupled to them.
2. Use a ground plane to connect all analog ground points together. Keep this ground plane physically separated from the arc protection ground, except connect the planes together at one point through a low impedance.
3. Locate the spark gaps as close to the tube socket as possible. The total length of the spark gap leads plus pc board tracks from the spark gaps to the CRT cathodes and to the arc protection ground plane should be as short and as wide as possible.
4. Keep the circuit tracks from the CRT driver to the CRT short (no more than 1.5 inches).
5. Arc protection components which conduct arc currents to the arc protection ground (SG, D1 and C, D2) should connect as directly as possible to this ground, and be as isolated as possible from the other components in the video amplifier.
6. Connect the D1 cathode lead to C, not to the CRT driver power pin. If the diode connects to +V at the CRT driver, and there is some pc board track length between this point and C, then C will not be able to conduct transient arc currents around the CRT driver as well as it could, and the transient voltage applied to the CRT driver may be large enough to damage it.
7. Connect the D2 anode lead to the analog ground near the arc protection ground, not at the CRT driver ground pins.
8. The impedance of tracks that shunt arc currents around the video amplifier should be as low as possible. Ensure that the arc currents have a good path to flow around the CRT driver, not through it.
9. Do not omit any of the arc protection components.

The purpose of these general rules is to provide the arc currents with a path around the video amplifier that is better than the path through it. Some compromises must be made among video amplifier performance, arc protection and EMI performance. For best video amplifier rise and fall times, R1, R2 and R3 would be 0Ω and D1 and D2 would not be installed. Also, for lowest EMI, R3 would be 0Ω. To keep EMI low, a ferrite core is used on the wire from the arc protection ground plane to the CRT conductive coating, which will interfere with operation of the arc protection circuit. However, for good protection from CRT arcs, these component values cannot be used. Values for the components must be chosen so the video amplifier performance meets all the requirements for rise and fall times, low EMI and ability to survive CRT arcs. Some typical values are:

R1 = 22Ω
R2 = 33Ω
R3 = 10Ω
D1, D1 = FDH400 (do not use small diodes such as the 1N4148)

Smallest ferrite core that attenuates EMI sufficiently.

9.0 SMEARING/TILT

Smearing is often a problem that is encountered in many monitors. It is the effect that is seen when the image on the screen goes from full black to full white. If smearing is present, the left side of the white image is either darker or brighter, depending on the type of signal tilt present (*Figure 16*). This leads to a nonuniform brightness on the screen.

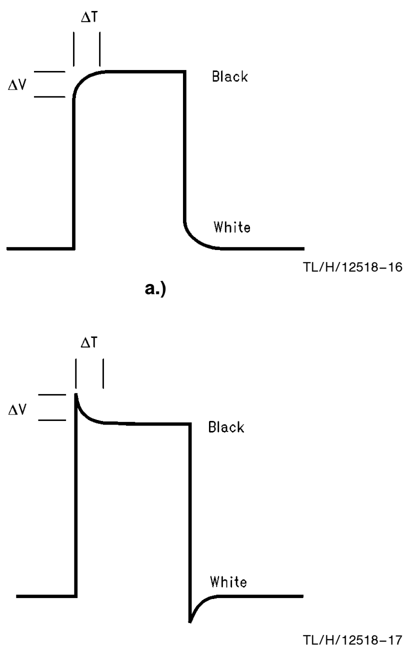

FIGURE 16. Tilt on Video Signal for a.) Dark Smear b.) White Smear

The words tilt and smear are sometimes used interchangeably: smear is the effect seen on the monitor screen due to tilt present on the output video signal. Therefore, in order to reduce smear, the designer must minimize tilt on the video signal.

On CRT drivers using the cascode design, sometimes the tilt problem can be traced to poorly decoupled supply or bias voltages. During the fast transitions of the video signal, the CRT amplifiers will switch on and off accordingly, putting a heavy demand on the power supplies for fast switching current. In the cases where the output swing is large, the power supply transient current may fall short and, therefore, introduce a tilt at the output signal. The fastest solution to this problem is by placing a capacitor as close as possible to the voltage supply (V+) and bias (12V) pins of the CRT driver. The capacitor can be a small high frequency ceramic (0.1 μF) or a larger electrolytic (10 μF–50 μF) or, better still, a combination of both. Tests have indicated that placing a capacitor as close as possible to the bias pins is very important in reducing tilt.

It is also important to use these types of capacitors on the preamp power pins, for the same reason. At least 50 μF should be used, with smaller capacitors connected in parallel.

For a closed loop type of driver, this same tilt problem can be controlled at the input stage. By using the proper RC network, the gain at the frequency of interest can be peaked, thereby compensating for the tilt. An example of an RC network is outlined in Section 7.4.5, and shown in *Figure 13*. This RC feedback network serves the purpose of reducing the gain of the stage at the frequencies of interest. This reduced gain is only effective for a short time, determined by the RC time constant of the network R4/C4 (in *Figure 13*). For a given amplifier output waveshape, as illustrated in *Figure 16*, the following equation can be used to determine the RC values:

$$R4 = [(100-x\%)/x\%] \times (1+A) \times R_g \qquad \text{Equation 10}$$

$$C4 = t/2.2R4 \qquad \text{Equation 11}$$

(For NSC drivers, A is typically 13 to 15)

(For the LM2427, R_{fb} is 5700Ω and R_g is 430Ω)

where x% is the percent of overshoot reduction, A is the gain of the amplifier, and R_g is the output resistance of the signal source plus the input network resistance, if one is used. For example, to reduce an overshoot of 35% that lasts for 18 μS, R4 = 150 kΩ (from equation 10) and C4 = 56 pF (from equation 11).

The values obtained using this method will provide proper compensation. However, the optimum values may change depending on the application.

10.0 ELECTROMAGNETIC INTERFERENCE

From ''Radiated Emissions and CRT Displays'', National Semiconductor Application Note 990: ''Electromagnetic compatibility (EMC) is a vital concern for anyone who produces or uses electronic equipment. As the performance of computer systems continues to improve, designing for EMC will become more challenging. This makes it very important to address EMC right at the start of the product design. Doing this will minimize the product development costs attributable to EMC and avoid unnecessary delays in product release.''

10.1 Use of Ground Planes

Ground planes on printed circuit boards are used to make high speed circuits work better (which means faster switching times and lower distortion). When signal current flows from one point of the circuit to another, the return current also flows in some path. A ground plane allows the return current to flow in a path next to the signal current, which produces the desired faster switching, lower distortion and lower noise. For this reason, it is important to not interrupt the current flow in a ground plane with holes and cutouts for circuit tracks. A solid ground plane keeps signal current loops as small as possible, which also causes the circuit to radiate the smallest possible amount of EMI (Electromagnetic Interference).

For video driver assemblies, the exception to the rule of using as much ground plane as possible is in the high signal amplitude connections from the CRT driver to the CRT.

Since this is a high impedance part of the amplifier, any stray capacitance connected to these lines will degrade circuit performance. To avoid this, remove the ground plane in the area of these tracks. Some assemblies have as much as 20 pF of stray capacitance. Designers should measure the actual capacitance of their video amplifiers, and try to keep stray capacitance much lower than this.

A summary of general rules for ground planes is:

- Use as much area as possible for the ground plane, except near high amplitude output signals. Do not use narrow circuit tracks for ground, instead of a complete plane.
- Use the best ground plane possible from the video input connector to the preamp and from the preamp to the CRT driver. Arrange the ground plane to follow the video signal path.
- For rise and fall times at the CRT cathode of about 8 ns or less, use a double sided pc board, with one side for the ground plane and the other side for circuit tracks. Connect the plane to all points in the circuit that are grounded, except the arc protection ground, which is a separate ground plane.
- Mount components and conductors that carry high frequency signal currents as close to the ground plane as possible. Small components, such as resistors, should be mounted laying flat on the board, not standing on end.
- Any component lead connected to the ground plane should be as short as possible.
- Keep power supply wires close to the ground plane.

10.2 Component Lead Length

The method of getting a video signal from the circuit where it is generated (perhaps a printed circuit board at the bottom of a monitor) to the video driver board at the CRT socket is important. If coax cable is used, it should be terminated in its characteristic impedance, being sure to keep lead wires that are connected to the braid or unshielded parts of the center conductor no longer than about ¼ inch. Unshielded transmission lines should not be used.

The design rules for wiring on and off the video amplifier are:

- Do not place preamp and CRT driver on opposite ends of the pc board, or on separate pc boards.
- Do not cross input and output tracks to CRT driver.
- Do not place CRT driver near edge of board unless it also has short tracks to the CRT socket.
- Do not place closed loop CRT driver compensation RC networks so long tracks connect to the driver inputs.
- Keep signal paths as short as possible.
- A signal path that is not terminated in its characteristic impedance and is expected to carry signals with 1 ns rise and fall times should not be longer than 2 inches.
- If sockets must be used, use spring loaded pin sockets for each component lead, instead of large plastic or ceramic sockets.
- Power voltage and return wires connected to an assembly should be twisted pairs.

10.3 Power Supply Bypassing

Proper power supply bypassing is necessary to make fast switching circuits work as desired. High value electrolytic capacitors should be mounted on the board where the dc power enters the board and at the preamplifier and CRT driver. At least one capacitor should be used for each voltage. Use at least 10 μF for 80V power for a CRT driver. Use at least 50 μF, and as much capacitance as can reasonably fit, for 12V power.

Power connections at integrated circuits must also be bypassed to the ground plane with small capacitors that work well at high frequencies. 12V connections should have a capacitor at each IC power pin, except pins may share a capacitor if the maximum lead length from the pin to the capacitor is ¼ inch. 0.1 μF capacitors are suitable. The noise level at IC power pins should be measured during circuit operation to determine if bypassing is adequate. More than one size capacitor may be required to do a good job of bypassing. For example, 0.1 μF in parallel with 0.01 μF may be required.

10.4 Use of Ferrite Beads

The video amplifier should be designed to make the monitor display meet the design requirements for the monitor. If testing then shows the EMI level of the monitor is too high, it is easy to put ferrite beads in the video path to reduce the EMI. Unfortunately, this also reduces the video amplifier performance that the monitor designer has worked so hard to achieve. There are other places where ferrite beads can be installed so they will reduce EMI without making the picture look bad. They are:

- In series with the G2 and focus leads, near the CRT socket. This reduces radiation of pickup from the color cathodes which are near these leads.
- In series with the dc power leads on the video board and connected to the video board. Any video signal that couples into these wires can be radiated as EMI and should be suppressed.
- Around video and other cables connected to the video amplifier.
- Around any long cables in the monitor.

High frequency, high amplitude video signals can couple from the circuits where they are generated to other nearby circuits, and then be radiated by these circuits as EMI. Installing ferrite beads on the printed circuit board in tracks connected to the video amplifier stages can help reduce this. For example, beads should be installed in the dc power tracks to the preamplifier and CRT driver. They should be located near the video components, and filter capacitors should be connected from the power tracks to ground on both sides of the ferrite beads, as shown in *Figure 17*. This type of construction will maximize the isolation between high frequency signals and other nearby circuits.

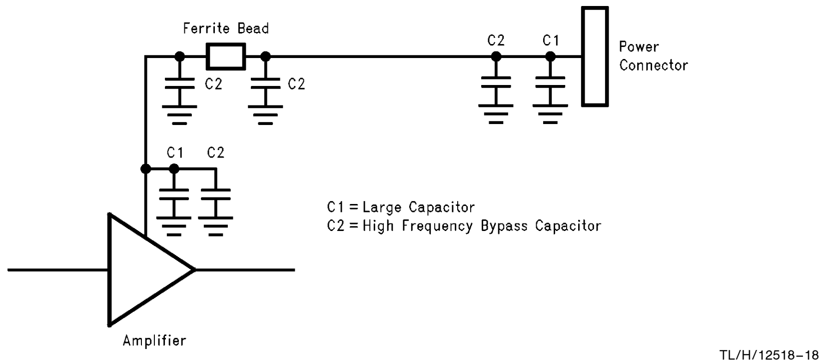

FIGURE 17. Ferrite Bead EMI Filtering

The ferrite bead is located in the end of the track nearest the component. There is a large value capacitor near the component and near the power connector, and high frequency bypass capacitors at the component power pin, at both ends of the ferrite bead and at the power connector.

Ferrite beads must be made from a ferrite material that works at the EMI frequencies of concern, and should fit tightly around the wires they are installed on. If beads are installed by winding several turns of wire through the bead hole, care should be taken to keep the input and output turns separated from each other, so coupling through the inter-turn capacitance does not defeat the purpose of using the bead.

10.5 CRT Driver to CRT Connections

When a monitor is being tested for EMI emissions, it is often found that turning down the contrast causes the emissions to decrease. This means that most of the emissions are coming from the video channel. The highest amplitude signals in this channel, which are probably the ones causing the EMI, are in the circuit between the CRT driver and the CRT. For EMI, this is an especially bad place to have high amplitude signals, since there is no ground plane between the driver and the CRT to help reduce the size of the video signal current loops. Therefore it is necessary to find some other way to make the antennas in the circuit that are doing the radiating work as poorly as possible. One way to do this is to make them as short as possible. This means the CRT driver should be located as close to the CRT socket as it can be, and the printed circuit board tracks between the driver and socket should be as short as they can be. Track length should be no more than 2 inches per channel. These tracks should also be separated from other signal tracks, so the other tracks will not pick up video signals and radiate them.

It was mentioned above that there is no ground plane between the video amplifier and the CRT. This means that the return path for the video signal that flows off the video amplifier assembly to the CRT must be long, and the loop antenna created by this condition is extremely large, compared to the sizes of the other video circuits. If some way to reduce the size of this antenna could be found, EMI levels would be much lower. This has been done during lab experiments by using copper foil to connect the CRT dag coating to the video amplifier ground plane. This can greatly reduce EMI levels, but is difficult to implement in a monitor that is being designed for high volume, low cost production. One possible way to do this would be to extend the dag coating along the neck of the CRT, inside the deflection yoke, to a point near the CRT socket. The video amplifier ground plane could then be connected to this coating by flexible copper fingers that contact the coating when the video amplifier is installed. The radiating loop size could be greatly reduced by doing this, so EMI would be lower. Care must be taken, however, to not surround the CRT neck completely by a conductive coating inside the deflection coil, since this would form a shorted turn in the coil and prevent it from operating properly.

10.6 Minimizing Crosstalk

Crosstalk in a video amplifier is affected both by the hybrid CRT driver layout and pin arrangement, and by the printed circuit board layout. For example, the LM2427 CRT driver pin arrangement has a pin at ac ground potential on both sides of the signal input and output pins. With this type of pin arrangement, the printed circuit board layout method that produces the best isolation between channels is as follows:

1. Use a good ground plane from the video input connector, through the video preamplifier, to the CRT driver. Connect all driver ground pins directly to this ground plane. Keep the connections as short as possible.
2. Use good high frequency bypass capacitors from each driver power pin to the ground pin of the same channel. Locate these capacitors next to the driver so the circuit tracks are as short as possible. Also connect an electrolytic capacitor from the driver +80V power pin to ground, near the driver.
3. Keep components associated with each channel grouped together, and separated from components and signal tracks associated with other circuits. The components connected to the driver input pins should be between the driver and the preamp. The components connected to the driver output pins should be between the driver and the CRT socket.

4. All component leads and circuit board tracks in these sections of the circuit should be as short as possible, especially the circuit board tracks connected to the driver input pins. On the LM2427, the inputs are like the summing junction of an operational amplifier. They are more sensitive to noise pickup than most circuits, and an important requirement of the circuit board layout is to keep them as short as possible and isolated from other signals. The total circuit board track length connected to each input pin of the LM2427 should be no more than one inch. Also, the stray capacitance to ground from these pins should be as low as possible, to maximize the performance of the amplifier.

10.7 Shielding

Keeping EMI from leaving the equipment is done by shielding and filtering. Shields can be placed around strong emitters, such as the high amplitude CRT cathode driver output stage. Shielding effectiveness will be influenced by the thickness and material the shield is made from, and by the size and shape of holes and seams in the shield. Holes and seams in the shield should be provided for cooling air, but must not be too big. The maximum linear dimension of the hole is what matters. It should be no more than 1/20 wavelength of the highest frequency of concern. For an EMI test that goes up to 1000 MHz, this is about 0.5″. If several holes are located close together, shielding effectiveness decreases, so holes should be smaller. If the shield contains long seams, they should be bonded together at points no further apart than the maximum hole size used.

Use a high conductivity material, such as aluminum or copper, to shield electric fields. Use a high permeability material, such as steel or nickel/iron alloys, to shield a magnetic field. If an EMI test installation uses a dipole antenna to pick up radiated EMI, it will be more sensitive to electric fields. If it uses a shielded loop antenna, it will be more sensitive to magnetic fields. The type of shielding that works best will be determined by the type of EMI source and the type of test being done.

Except for video cables, shields of signal cables coming into equipment cabinets should be connected to chassis ground at the point of entry, using a wire of #20 minimum size, no more than 1½″ long. Except for coax cables, shields on the outside of a cable must not be used to carry signal return currents. They are only intended to shield EMI sources. Return paths should be provided by wires inside the cable. Connect the shield to chassis ground at both ends. Noise currents that may flow on the outer surface of the shield may be decreased by putting ferrite cores around the cable. Cores should have the smallest inner diameter that will allow them to fit around the cable. The number and type of cores required will depend on the application, and will probably have to be determined by experiment.

The video cable point of entry to a chassis should be separated from the ac power cable entry by at least 3″.

When a conductor becomes an odd multiple of ¼ wavelength long, it becomes a good antenna, and its shielding/grounding effectiveness becomes zero. If an EMI test shows radiation at some frequency that cannot be reduced by design, shielding or filtering, it might be that some conductor, such as a cable shield or enclosure shield, has a dimension that is ¼ wavelength long at the problem frequency. Changing cable lengths or shield dimensions may cure the problem. Also, connecting another conductor, that is twice as long, in parallel with it, may help.

10.8 Filtering

Switching power supplies typically used in monitors tend to put out several hundred millivolt spikes containing components at very high frequencies which are difficult to filter out. These spikes can get into the video amplifier and cause visible noise in the display. Filtering used to keep this from happening is a combination of electrolytic and high frequency bypass capacitors at the power input connector of the video amplifier and at the power pins of the video IC's.

As mentioned in the section on smearing, there must be at least 50 μF on the +12V power line at the video preamp.

High frequency signals in the video amplifier may be coupled to other signal tracks on the assembly and be radiated as EMI. Filtering can help prevent this from happening. Any signal lead connected to the assembly can have a filter capacitor or inductor connected to it to reduce EMI. One lead which this especially applies to is the G2 voltage lead. This lead connects to the assembly between the red and green cathodes, which both have high amplitude video signals on them, which can be coupled to the G2 lead. A filter capacitor and ferrite bead on this lead can often cause a large reduction in EMI.

All bypass capacitors should have very short leads to the points being bypassed and to the ground plane.

10.9 Minimizing EMI

There are two basic approaches to minimizing EMI: generate as little as possible and keep what is being generated from leaving the equipment.

One way to make the monitor generate as little EMI as possible is to use a video channel that has the slowest rise and fall times and lowest overshoot that will meet the monitor design requirements. The potential for generating EMI increases as the video signal switching times decrease and as its overshoot increases.

Following the previously discussed design rules for ground planes will help reduce the amount of EMI leaving the equipment. A high frequency current flowing in a signal and return path will follow a closed loop, which will act as an antenna and radiate electromagnetic energy. The amount of energy radiated is proportional to the loop area, so making the area as small as possible will keep the radiated energy as low as possible. A ground plane does this by providing a return path that is next to the signal path. Keeping component lead length and printed circuit board track length as short as possible also helps.

EMI measuring antennas are positioned level with or above the unit being tested. An EMI emitter will radiate less energy as it is moved closer to a ground plane, so cables or emitters located on the video output board at the back of the CRT should be located on the lowest part of the board, so they can take advantage of shielding and ground plane effects provided by other parts of the monitor.

11.0 EVALUATION BOARD

11.1 Typical Configurations

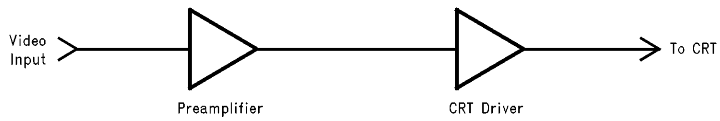

FIGURE 18. Complete Video Channel Solution

Preamplifiers

- Industry Standard Preamp — LM1203
- DC Control of Functions — LM1205
- On Screen Display — LM1281

CRT Driver Amplifiers

- Low Cost Monolithic — LM2406
- Hybrids
  - Open Loop — LM2419
  - Closed Loop — LM2427

11.2 Types of Evaluation Boards Available

TABLE VI. Types of Evaluation Boards Available

Type	T_r/T_f Range ns	Single Sided	Double Sided	OSD	Comments
LM1205/LM2406 Rev 1 3-94	10–12		X	X	Surface Mount Components
LM1205/LM2406 Rev 2 6-94	10–12	X			
LM1217/LM2408 Rev 1 2-95	6–8		X		Narrow Preamp
LM1281/LM2408 Rev 1 4-95	7–9		X	X	OSD Preamp
LM1205/LM2419 Rev 4 2-94	6–8		X	X	Surface Mount Components
LM1205/LM2419 Rev 5 6-94	6–8	X			
LM1281/LM2419 Rev 1 11-94	7–9		X	X	OSD Preamp
LM1205/LM2427 Rev 2 3-94	5–7		X	X	Surface Mount Components
LM1281/LM2427 Rev 1 11-94	6–8		X	X	OSD Preamp

11.3 Evaluation Board Sample

A complete design for a monitor video amplifier using an LM1205 preamplifier and an LM2406 CRT driver amplifier is presented in Appendix D. The amplifier is suitable for mounting on a monitor CRT and performing the complete monitor video amplifier function. It includes the following features:

- accepts RGB video inputs, with H sync or clamp used for back porch clamping
- separate RGB drive controls for color matching
- separate RGB output level shifting adjustments
- contrast control
- arc protection
- G1 and G2 circuits
- dual focus CRT socket, can be replaced with single focus socket
- single sided ground plane board

Information enclosed (in Appendix D) includes:

Figure 19, Schematic Diagram.

Figure 20, Parts List.

Figure 21, Component Arrangement (silkscreen).

Figure 22, Artwork Drawing.

The user is encouraged to modify the assembly as required to adapt it to his particular monitor design. For example, the brightness, G1 and G2 circuits may be replaced with whatever circuits the designer finds will work in his monitor. Peaking inductors may be installed at the outputs of the CRT driver to speed pulse response, if necessary. If a bus control system is used in the monitor, the drive, contrast and cutoff pots may be removed and the analog bus signals may be applied directly to the preamplifier pins.

This design is offered as an example of how a complete video amplifier may be made, using the ideas presented in this application note. It should be studied to see how the design techniques described are actually incorporated in a real printed circuit board. It may also be copied, in whole or in part, into a monitor. Users of this design or microcircuit components are encouraged to contact National Semiconductor Application Engineers to discuss any questions they may have or to obtain more information about our products or designs.

12.0 APPENDICES

APPENDIX A: References

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APPENDIX B: Derivation of (Bandwidth) x (Rise Time) = 0.35

The equation (Bandwidth) x (Rise time) = 0.35 is often used to describe amplifier operation. The derivation of this equation is shown here. Please note an important basic part of this derivation is that it applies only to a one pole, linear system. Since video amplifiers are sometimes not operated under these conditions, this equation may not accurately describe their operation.

For the one pole, linear system, if a step input voltage from zero to V_{IN} is applied, the output voltage, V_{OUT}, is described by

$$V_{OUT} = V_{IN} (1\text{-}e^{-2\pi(BW)t}),$$

where BW = the system bandwidth

t = time.

This is an exponentially changing voltage which starts at zero and approaches V_{OUT} as a limit. The rise time of the system is defined as the time it takes to go from 10% of V_{OUT} to 90% of V_{OUT}. Therefore V_{OUT} = 10% of V_{IN} at $t = t_{10\%}$ and V_{OUT} = 90% of V_{IN} at $t = t_{90\%}$ Rise time is $t_{90\%} - t_{10\%}$, and

$$\text{at } t_{10\%},\ 0.1\ V_{IN} = V_{IN} (1\text{-}e^{-2\pi(BW)t_{10\%}})$$

and

$$\text{at } t_{90\%},\ 0.9\ V_{IN} = V_{IN} (1\text{-}e^{-2\pi(BW)t_{90\%}})$$

Therefore
$$0.1 = (1\text{-}e^{-2\pi(BW)t_{10\%}})$$
$$e^{-2\pi(BW)t_{10\%}} = 0.9$$
$$-2\pi(BW)t_{10\%} = \ln (0.9) = -0.105$$
$$t_{10\%} = 0.105/2\pi(BW)$$

Similarly
$$0.9 = (1\text{-}e^{-2\pi(BW)t_{90\%}})$$
$$e^{-2\pi(BW)t_{90\%}} = 0.1$$
$$-2\pi(BW)t_{90\%} = \ln (0.1) = -2.303$$
$$t_{90\%} = 2.303/2\pi\ (BW)$$

Therefore
$$t_{90\%} - t_{10\%} = 2.303/2\pi\ (BW) - 0.105/2\pi(BW)$$
$$= 2.197/2\pi\ (BW)$$
$$= 0.35/BW$$
$$= \text{Rise Time}$$
$$(\text{Bandwidth}) \times (\text{Rise Time}) = 0.35$$

This is the equation that relates the time domain response of the system to the frequency domain response.

APPENDIX C: Comparison of Hybrid vs Discrete CRT Driver

Purpose

A monitor designer must decide between a discrete component design or a microcircuit design for his video amplifier. There are many factors to consider when making this choice. This appendix describes the advantages and disadvantages of some of these factors, to help the designer make more informed choices.

Cost

The cost of components for the two types of video CRT driver assemblies is compared in the following table. One assembly is made using an integrated circuit video preamplifier and a discrete component CRT driver output stage (the ''Discrete'' model). The other assembly is made using an integrated circuit preamplifier and a hybrid CRT driver output stage (the ''Hybrid'' model). Each assembly contains all the functions of a complete video chain. The Discrete model is made in two parts: a chassis mounted amplifier and a CRT neck board. It is equivalent to an LM2419 hybrid design. The Hybrid model contains all the components on a neck board. Since this comparison is intended to show the difference in component cost between the two designs, only components which are different between the two designs are included in the table.

TABLE VII. Cost Comparison of Discrete and Hybrid CRT Drivers

Component	Price Each	Discrete	Hybrid
Collector Resistor	$0.11	$0.99	
Peaking Inductor	$0.02	$0.06	
Filter Inductor	$0.03	$0.09	$0.03
Filter Capacitor	$0.03	$0.09	$0.03
Decoupling Capacitor	$0.01	$0.03	$0.01
Emitter Follower (NPN/PNP)	$0.22	$0.66	
Crossover Diode	$0.03	$0.09	
Cascode Transistors	$0.17	$0.51	
Input Bias Resistors	$0.002	$0.01	
Emitter Peaking Resistor	$0.002	$0.01	
Emitter Peaking Capacitor	$0.085	$0.26	
3 Channel Hybrid CRT Driver	$4.00		$4.00
Printed Circuit Board	$0.06/sq. in.	$2.16	$1.32
Total		$4.95	$5.39

The component costs used in the above table are based on large quantities. Each monitor manufacturer will have different costs, but they will be similar to those used. The designer should make his own cost estimate, using the complete parts list for his monitor and the actual component costs for his company. When he completes this task, he will know the real component cost for each design.

Two other factors which should be considered are the costs of purchasing and storing components and the cost of assembling the amplifiers.

Since the Discrete design uses more components than the Hybrid design, the Purchasing and Inventory Control functions will be more complicated, and will add to the total video amplifier cost. If a Hybrid design is used, it is possible for the monitor manufacturing company to obtain all the video amplifier semiconductor components from one source, therefore minimizing the problem.

A Discrete video amplifier design will use approximately twice as many components as a Hybrid amplifier, so the time required to build the amplifier in production will be longer. The monitor designer should calculate the assembly cost of each design, based on the labor standards for his company, to see the difference in assembly cost of the two designs. He must also remember that the Discrete design is made with two printed circuit boards, and the Hybrid design is made with one.

Size

The size of a typical Discrete assembly is 4.5″ x 8″ = 36 square inches. This assembly will be mounted on the monitor chassis and connected to a CRT neck board with coax cables. The neck board will be about 3″ x 3″ = 9 square inches, and will contain the CRT socket, arc protection components, and other small components used to connect the CRT to the monitor.

The size of a Hybrid assembly is 4″ x 5.5″ = 22 square inches. The assembly mounts on the CRT and contains all the components required for the video amplifier function and for interfacing the CRT. Cables and connectors for connecting a separate video amplifier and neck board are not required.

Weight

The weight of a typical discrete assembly is about 1 pound. This includes the weight of the amplifier assembly, the neck board, EMI shielding, heat sink and the interconnecting cables.

The weight of a typical hybrid assembly is about ½ pound. This includes the entire amplifier assembly with EMI shield and heat sink.

The video amplifier will need to be shielded to minimize electromagnetic interference (EMI). If the monitor has metal chassis parts, they can be used as part of the EMI shield for the chassis mounted part of a Discrete video amplifier. The neck board will require a separate shield. If the video amplifier is a Hybrid design made as a neck board, it will need a similar type of shield. In this case, the shield can be thermally connected to the CRT driver hybrid microcircuit, and can also be used as the heat sink for the amplifier. This has the advantage of removing the requirement for a separate heavy heat sink, and spreading the heat dissipated over a large volume to eliminate hot spots in the monitor.

Power Required

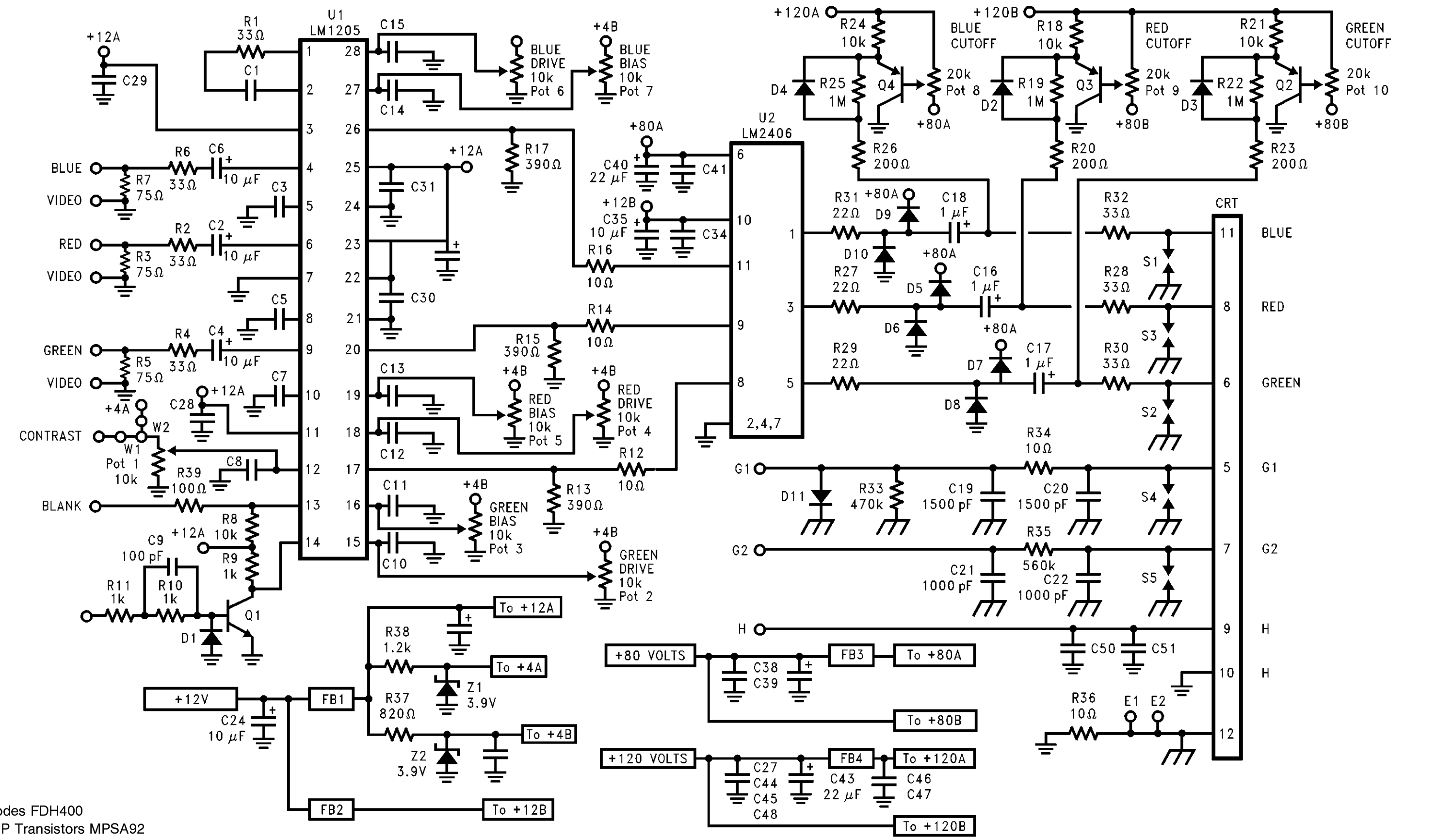
Measurements of the power required by typical Discrete and Hybrid video amplifiers are shown in the following table. The Hybrid amplifier used an open loop CRT driver. A SMPTE test pattern was displayed on a monitor in the 1280 x 1024 pixel mode, at maximum contrast and brightness.

TABLE VIII. Power Comparison of Discrete and Hybrid CRT Driver

Voltage	Power Required	
	Discrete	Hybrid
80	15.8 Watts	8.3 Watts
12	2.4 Watts	2.4 Watts
Total	**18.2 Watts**	**10.7 Watts**

Discrete amplifiers typically use a circuit design similar to the open loop hybrid design. Because of larger stray capacitance in a printed circuit board layout than in a microcircuit, the Discrete design must operate at a higher power level to obtain the same performance.

APPENDIX D: Design for Complete Video Amplifier Evaluation Board



Diodes FDH400
PNP Transistors MPSA92
NPN Transistors 2N2369
Unmarked capacitors 0.1 μF

TL/H/12518–20

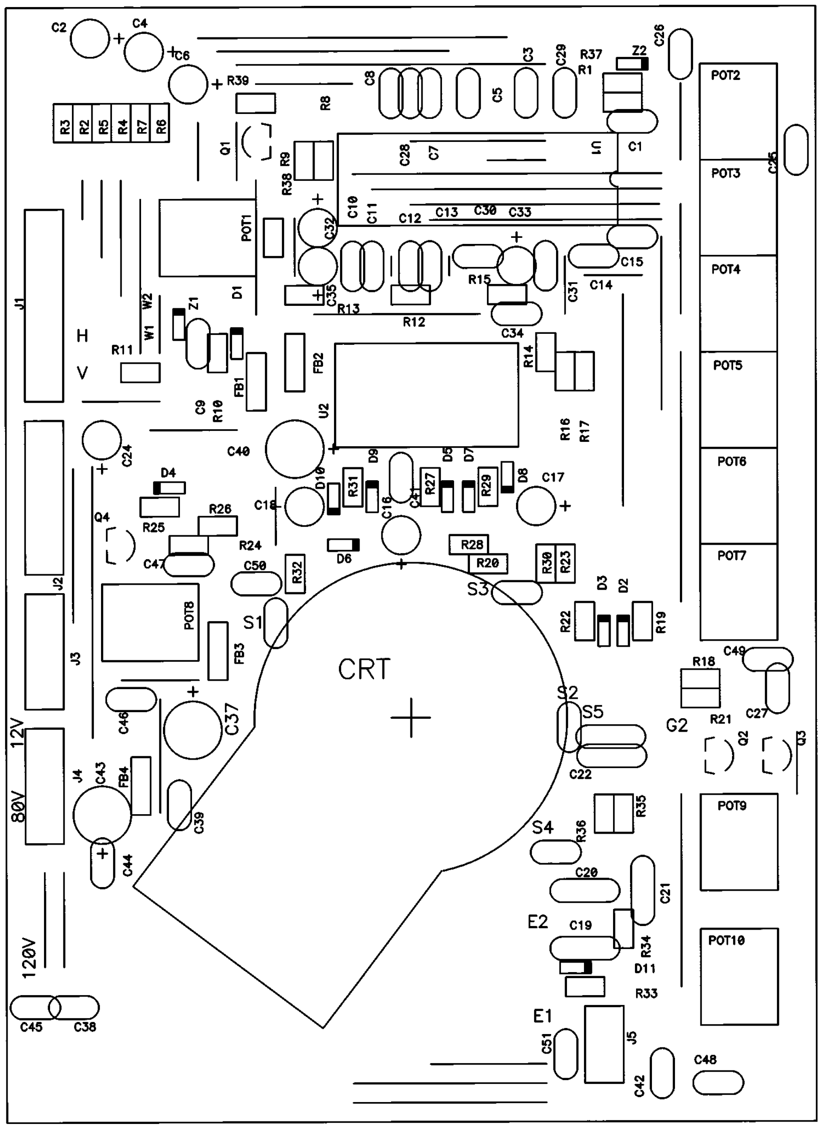
FIGURE 19. Schematic Diagram for Evaluation Board

Parts List for Evaluation Board

RI, R2, R4, R6, R28, R30, R32	33Ω, ¼W
R3, R5, R7	75Ω, ¼W
R8, R10, R18, R21, R24	10 kΩ, ¼W
R9, R11	1 kΩ, ¼W
R12, R14, R16, R34, R36	10Ω, ¼watt
R13, R15, R17	390Ω, ¼W
R19, R22, R25	1 MegΩ, ¼W
R20, R23, R26	200Ω, ¼W
R27, R29, R31	22Ω, ¼W
R33	470 kΩ, ¼W
R35	560 kΩ, ¼W
R37	820Ω, ¼W
R38	1.2 kΩ, ¼W
R39	100Ω, ¼W
C1, C3, C5, C7, C8, C10, C11, C12, C13, C14, C15, C25, C26, C28, C29, C30, C31, C42, C50, C51	0.1 µF, 50V
C2, C4, C6, C24, C32, C35	10 µF, 16V
C9	100 pF, 50V
C16, C17, C18	1 µF, 160V
C19, C20	1500 pF, 1 kV
C21, C22	1000 pF, 2 kV
C27, C34, C38, C39, C41, C44, C45, C46, C47, C48	0.1 µF, 150V
C33	50 µF, 16V
C37, C40, C43	22 µF, 160V
Pot 1–Pot 7	10 kΩ
Pot 8–Pot 10	20 kΩ
D1–D11	FDH400
Q1	2N2369A
Q2, Q3, Q4	MPSA92
U1	LM1205N
U2	LM2406T
Z1, Z2	1N748A
J1	10 Pin Connector
J2	8 Pin Connector
J3, J4	6 Pin Connector
J5	3 Pin Connector
CRT Socket	Hosiden HPS0380-11
E1, E2, G2	Terminal, 0.09 dia. x 0.56 length
S1–S4	230V Spark Gap
S5	1.5 kV Spark Gap
FB1–FB4	Ferrite Bead Fair-Rite 2743021447
Printed Circuit Board	National Semiconductor LM1205—LM2406 Rev 5
Heat Sink	3 °C/watt, use on U2

FIGURE 20. Parts List for Evaluation Board

View from Component Side



TL/H/12518–21

FIGURE 21. Component Arrangement (Silkscreen) for Evaluation Board

View from Component Side

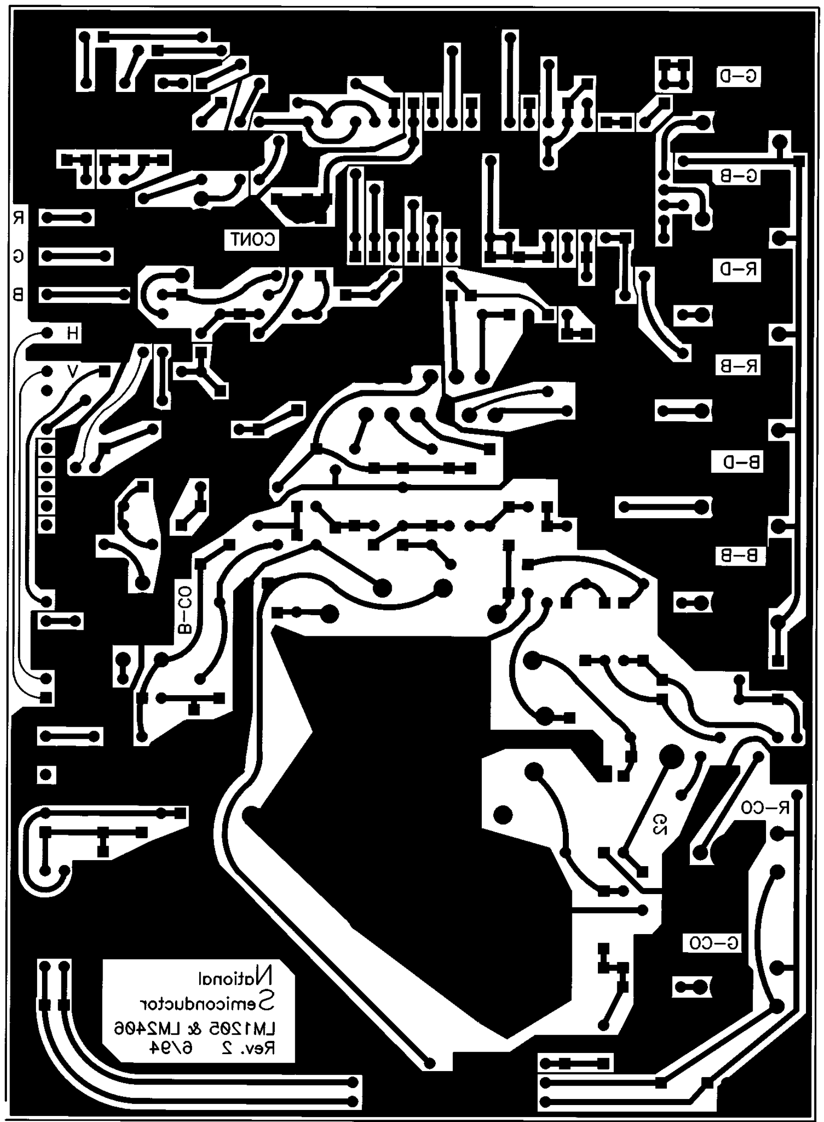


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FIGURE 22. Artwork Drawing for Evaluation Board

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