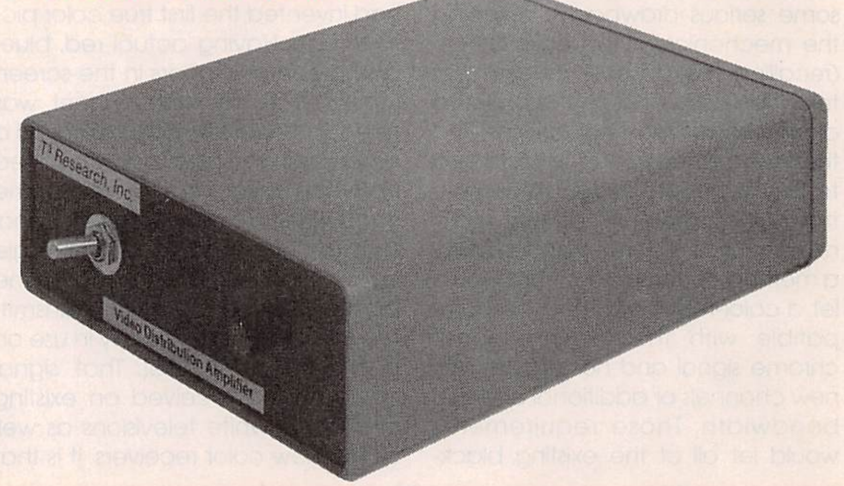
TOD T. TEMPLIN

BUILD AN S-VIDEO DISTRIBUTION AMPLIFIER



Connect up to four S-video devices to one source with this easy-to-build unit!

Whether you are a true videophile or just an avid electronics enthusiast, you are probably aware of the fact that almost all new video devices—including such things as Digital-Satellite Receivers (DSS), Digital Video-Discs players (DVD), Digital-Video Camcorders (DVC), Hi-8 and Super-VHS video-cassette recorders, and Laser-Disc players—come equipped with S-video signal connectors. The "S" stands for "separated," meaning that the video signal has been split into two separate channels—one for the luminance or basic black-and-white picture, and one for the chrominance or color information. If your monitor or television supports S-video inputs, then it is capable of displaying signals from those devices. The resulting display will be higher in resolution and truer in color fidelity than the video signals available at either the composite video output, or worse yet, the RF-modulated output of the device. If you have S-video capability but aren't using it, you might be missing half of the picture—at least in terms of resolution—not to mention the full capabilities of the equipment that you paid top dollar for.

It has been the author's experience that each of the above-listed devices has but a single S-video output jack. Imagine the difficulty in such a situation of wanting to record the S-video signal from a DSS receiver simultaneously on two separate S-VHS recorders and to display the picture on an S-video monitor. With only one output available on the DSS receiver, the only way to do that task would be to use the composite output from the DSS unit for one recorder. The monitor would then have to be hooked up to the video pass-through connector of the second recorder.

Problems such as that are a thing of the past with the Video Distribution Amplifier described here. This device is also handy to send S-video to a monitor in a second room, dubbing S-VHS or Hi-8 video tapes to multiple recorders, connecting various components together in a home theater, or at any time that multiple S-video signals are required. The design includes adjustments to compensate for losses of signal strength or high frequencies that might occur in long cable runs.

A Short History of Color TV. To really understand why S-video is the better choice for connecting video components together, you need to understand the differences between S-video and composite video. To do that, a brief and somewhat simplified review of television history is in order. Not everyone today remembers, but in the beginning, television was monochrome (black and white). That original television signal was comprised of the horizontal and vertical synchronizing pulses plus the monochrome signal.

In the late 1940s, CBS laboratories proposed a color system that used a sequential-scanning scheme. The CBS method broke down a color picture into separate red, green, and blue layers. The separate layers were transmitted in order, one after the other, and displayed sequentially on a monochrome screen. To reconstruct the color image, a motor-driven synchronized rotating "color wheel" that had red, green, and blue filters was placed in front of the monochrome picture tube. The color wheel rotated at 1800 rpm, blending the three sequential images into a full-color picture.

The CBS engineers proposed transmitting 750 horizontal lines with a 3-to-1 interlace. That resolution meant that the three-color layers had to be sent at a rate of $1/180$ second per field in order to make a single color frame at $^1/_{60}$ second. With a rate of 60 complete color frames per second, the resulting video signal would need a video-channel bandwidth of 25 MHz. Such a signal would need a new set of wide-bandwidth television channels. For experimental purposes, the FCC established and allocated the UHF television band that is still in use today.

The CBS system produced separate full-bandwidth RGB signals, and displayed 720 active horizontal lines with nearly 1000 lines of resolution. Compare that with the 480 display lines and 335 lines of resolution of a standard TV signal; in essence, CBS was showing a viable high-definition color-television system with World War II-era equipment.

Unfortunately, the CBS system had some serious drawbacks, including the mechanics of the color wheel (recalling the days of mechanical television of the 1920s), the expense of new transmission equipment, and the fact that everyone would need to buy a new television to receive the color picture. What was really needed was a signal standard and a method of transmission that would let a color-television signal be compatible with the existing monochrome signal and not require any new channels or additional channel bandwidth. Those requirements would let all of the existing black-and-white televisions already in use continue to be viewed while offering an orderly and less expensive transition to color broadcasting.

Enter the engineers from RCA laboratories. They had two tricks up their sleeve that CBS didn't have. First (and most importantly), they had invented the first true color picture tube. Having actual red, blue, and green phosphors in the screen meant that no color wheel was needed. Secondly, they proposed a broadcast standard that combined both the color and monochrome signals into a single complex signal that could be carried by a single coaxial cable. What's more, the proposed signal could be transmitted by equipment already in use on a 6-MHz TV channel. That signal could still be received on existing black and white televisions as well as the new color receivers. It is that system that was eventually selected by the National Television Standards Committee (NTSC), adopted by the FCC, and is still in use today. Although it is scheduled to be phased out by the end of the next decade as a part of the transition to digital TV, NTSC color TV will probably be with us for years to come.

If you are interested in a more detailed description of the history and development of color TV, an excellent article on the subject was published in the July 1995 issue of our sister publication, **Popular Electronics**.

Anatomy of a Color-TV Signal. Let's look at how the NTSC signal is put together. Color-television signals are made up of three main pieces of information (red, green, and blue images). Monochrome television, in contrast, only needs brightness infor-

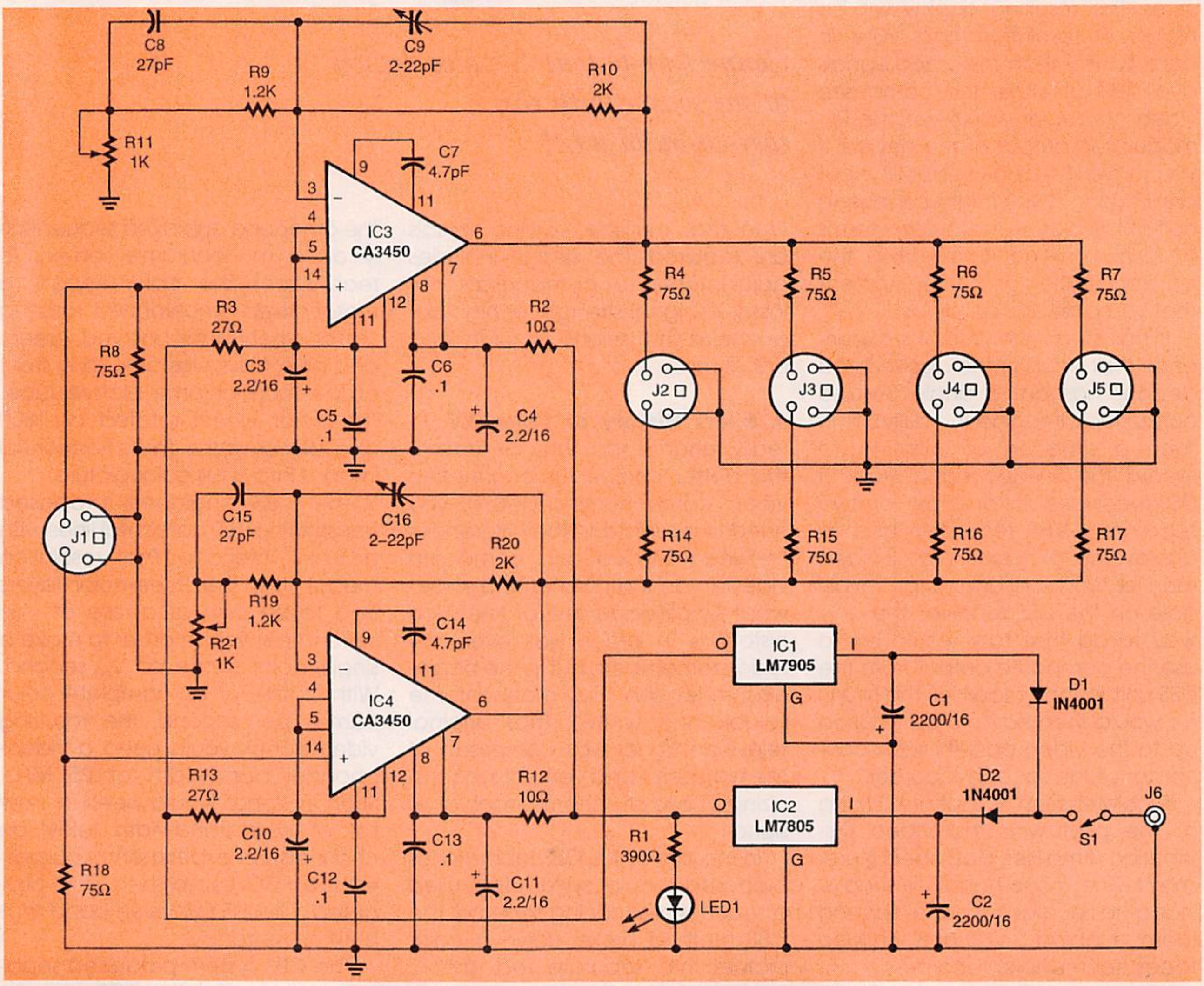


Fig. 1. The Video Distribution Amplifier lets you connect up to four S-video devices to a single S-video source.

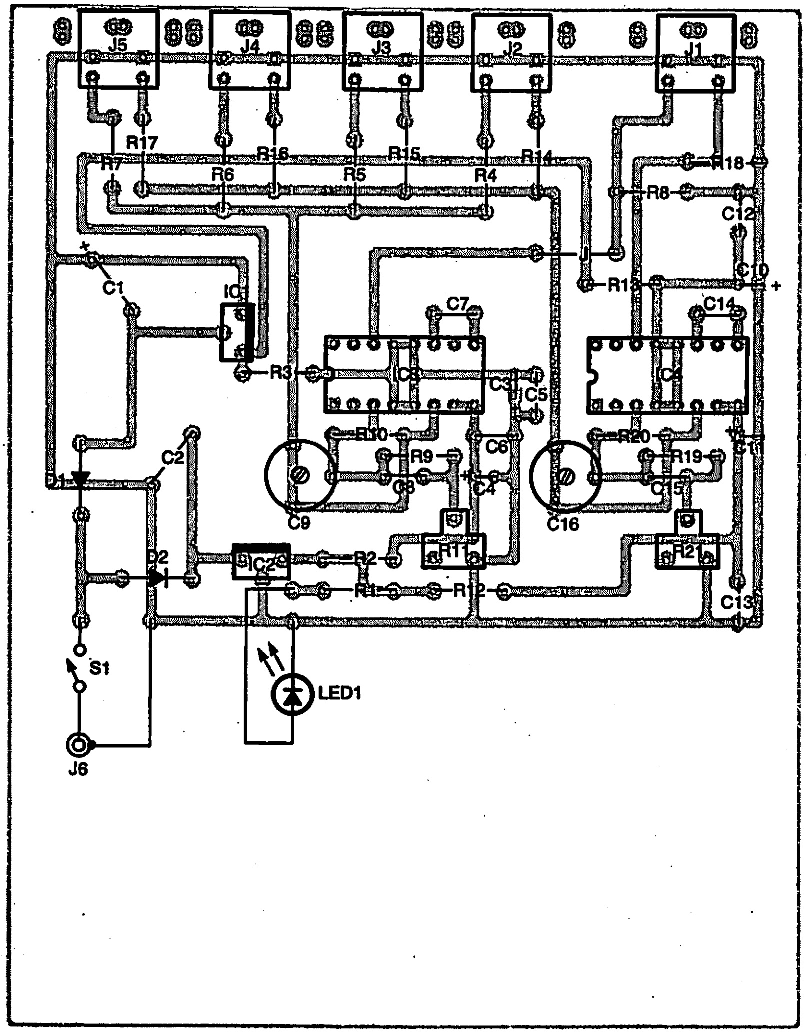


Fig. 2. Use this parts-placement diagram when building the Video Distribution Amplifier board. Don't forget the jumper wire near R13.

mation. An encoding process is used to send the red, green, and blue information simultaneously on a single coaxial cable or to transmit it on a single TV channel. In a color television or monitor, a decoding process is then used to separate the complex signal back into the three separate signals. The process must also be done so that monochrome displays can produce a monochrome picture from the color information.

To accomplish that feat, four techniques are used: matrixing, bandwidth limiting, two-phase modulation, and frequency interleaving. We'll look at each technique and show you how the picture quality is affected.

The first technique, matrixing, is the process of mixing the red, green, and blue outputs of a color camera (or other RGB source) in a linear cross-mixing circuit. The output of that circuit produces three new signals called M, I, and Q. Each new signal is a different linear combination of the original red, green, and blue signals.

The M signal, also called the *luminance* signal, is made by simply adding 30% red, 59% green, and 11% blue together to make white. That particular combination, when displayed on a monochrome TV, looks nearly as good as if the original signal had come from a monochrome camera.

The I and Q signals are called the *chrominance* signals. Those signals represent how the color information in a scene differs from the M (luminance) signal. The I and Q signals are required by a color receiver to decode the color information in a picture. Sometimes called *difference* signals, the I signal is made by adding 60% red, -28% green, and -32% blue. The Q signal is made by adding 21% red, -52% green and 31% blue. The negative values, needed for the math to come out right, are created by passing the signal through a simple phase inverter. The relationships between the signal percentages are chosen so that when red, green, and blue are added to produce white, the values of I and Q add to become zero. For example, if a color camera were used to shoot a black and white photograph, the I and Q signals both would have values of zero, while the M signal would have a value representing the brightness of the photograph. Even a color receiver that is presented with values of zero for I and Q would produce a monochrome picture from the M value signals. A monochrome receiver, having no way to recover the I and Q from a color signal, for the most part ignores them.

The apparent resolution of a television picture depends on the bandwidth of the signal—the greater the resolution, the greater the needed bandwidth. Television produces an apparent resolution of about 80 horizontal picture elements (lines) for every 1 MHz of bandwidth. A television channel is 6 MHz wide, but 1.25 MHz is lost in the vestigal sideband—a sacrifice to the RF carrier that carries the video signal. That leaves 4.75 MHz of bandwidth to carry all of the picture and audio signals. Of that, the picture signal is allowed 4.2 MHz, or about 335 lines of resolution per picture height. But from a subjective point of view, the human eye is not as sensitive to color details in a picture as it is to luminance detail. That biological tidbit lets the bandwidth of the chroma signal be limited so that the majority of the bandwidth goes to the luminance signal. Moreover, the eye is even less sensitive to detail in the green/blue part of the color spectrum than the orange/yellow part. So the I signal (mostly orange/yellow) is passed through a low-pass filter, limiting its bandwidth to 1.5 MHz. The Q signal (mostly green/magenta) is low-pass filtered to

0.5 MHz.

Now that we have the three signals, we need to combine them into one composite signal that can be broadcast or carried down a single coaxial wire. Not only that, but the decoding circuit in the television receiver must be able to separate out the individual signals from the composite signal without too much interference.

The electronics are technically complex, but basically the I and Q signals are modulated onto two subcarriers of the same frequency that are 90° out of phase with each other. Having two signals at the same frequency but out of phase by 90° is called *quadrature modulation*. The frequency of the subcarriers is 3.579545 MHz (we'll use the common abbreviated value of 3.58 MHz for the rest of the discussion). The subcarriers are 3.58 MHz *above* the main video carrier, but because the subcarrier modulators used are of the double-balanced type, their carriers are suppressed, leaving only the sidebands in the composite signal. The 3.58-MHz value was chosen

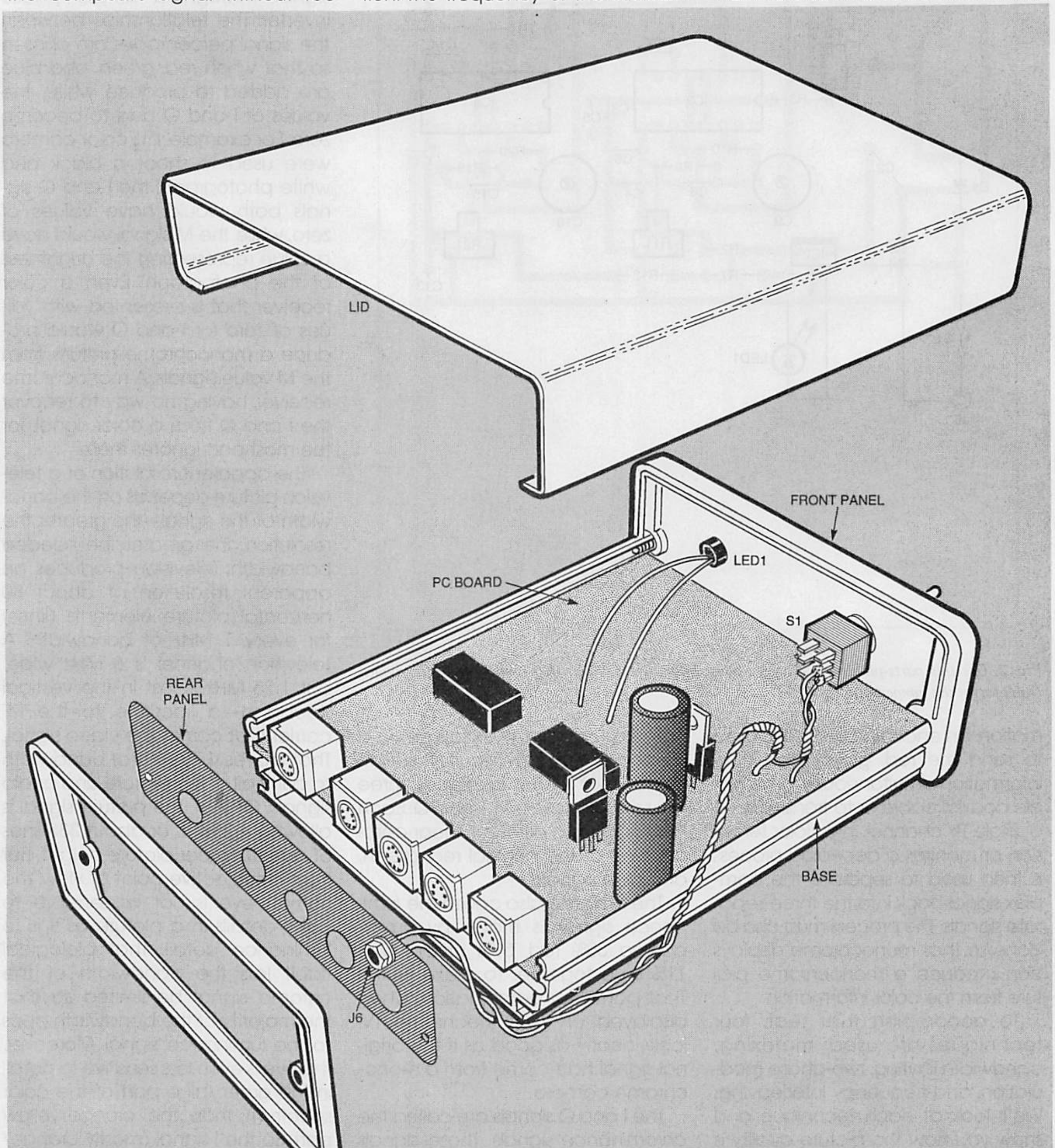


Fig. 3. The Video Distribution Amplifier fits neatly into an all-metal case.

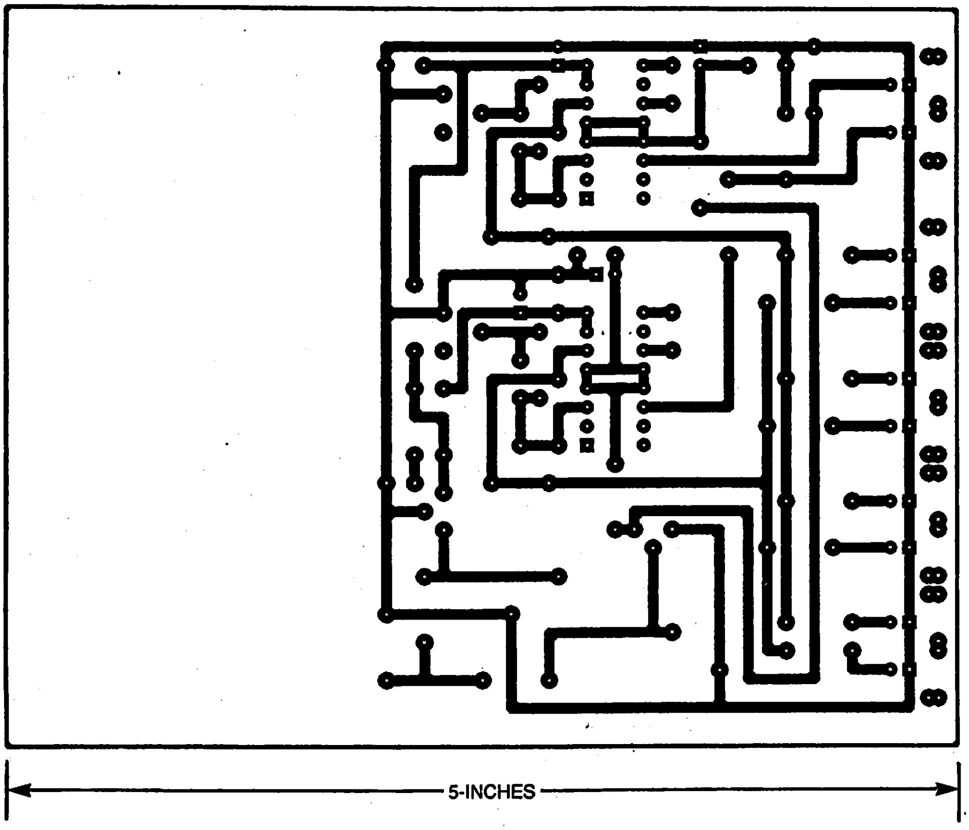


Fig. A. Here's the foil pattern for the Video Distribution Amplifier. A single-sided layout is both easy to build and helps prevent cross-talk between the two amplifier channels.

because it is an odd multiple of one half of the horizontal scan rate (455 × ½ × 15,734). The resulting relationship between the energy of the luminance signal and the energy of the chromanance signal has a tendency to concentrate at alternating points of the combined signal spectrum. That interleaving of the signals reduces the interference between luminance and chrominance signals. As an added bonus, the positioning makes it somewhat easier to separate the two signals in the decoding process. In the real world, however, the interleaving of the two signals causes intermodulation, resulting in the undesirable NTSC picture artifact known as *dot crawl.* In addition, non-linearities in the chroma-processing circuits (during both encoding and decoding) can cause distortions know as *differential phase* and *differential gain.*

To decode the chrominance signal at the receiver or monitor, a 3.58-MHz oscillator must be synchronized in both frequency and phase with the original signal. Synchronizing information, consisting of a 3.58-MHz burst that is 8 cycles long, is added to each horizontal line just after the end of the horizontal-sync pulse. That reference is known as the *color burst.*

A Better Picture? We have been using the NTSC system for almost 50 years. Modern televisions equipped with digital-comb filters as well as very stable and linear circuitry do produce very acceptable color pictures. But what if we had a simple way to eliminate some of the compromises made to transmit the NTSC signal? Doing that would greatly improve the picture resolution and reduce the undesirable artifacts resulting from the encoding/decoding process.

Well, there is a way—it is called the Y/C or Separated Video connection, and it is just that. Two separate signal paths are used to send video between components. One cable carries only the luminance signal, while a second cable carries only the chrominance signal. The signals are never combined, so no interleaving distortion occurs, and no low-pass filtering is required to keep the signals within a 4.2-MHz bandwidth. The S-video input on a television or monitor bypasses much of the video-processing circuitry, such as the comb filter. The result is a higher-resolution picture from devices like Hi-8, S-VHS, DSS, DVD, DVC, computer-graphic cards and laser discs, where the signals originate separately as Y and C and are not combined as they would be if they were to be broadcast over the airwaves.

Circuit Description. The Video-Distribution Amplifier uses two identical amplifier circuits that share a common power supply. Refer to the schematic diagram in Fig. 1 during the following discussion of the circuit.

Alternating current from a wall-mounted transformer is applied to J6, with S1 turning the unit on and off. A simple half-wave rectifier circuit consisting of D1 and D2 is used to change the AC power to DC. Since the circuit needs a split-type power supply, that method makes creating the proper voltages easy and does not require a center-tapped transformer. Capacitors C1 and C2 smooth out the large amounts of resulting ripple; hence the reason for their extremely high value. The direct-current voltage is regulated by IC1 and IC2. The positive voltage supply has an LED connected to it to act as a power-on indicator. The current flowing through LED1 is limited by R1.

Since both amplifier circuits are the same, one for the luminance and one for the chromlance, only one will be described; the other behaves in the same way. The S-VHS signal is input via J1 to IC3. The op-amp chosen for IC3 is specifically designed to be a high-speed

PARTS LIST FOR THE S-VIDEO-DISTRIBUTION AMPLIFIER

SEMICONDUCTORS

IC1—LM7905 5-volt negative voltage regulator, integrated circuit
IC2—LM7805 5-volt positive voltage regulator, integrated circuit
IC3, IC4—CA3450 video-line driver op-amp, integrated circuit
D1, D2—1N4001 silicon diode
LED1—Light-emitting diode, red

RESISTORS

(All resistors are ¼-watt, 5% units, unless otherwise noted.)
R1—390-ohm
R2, R12—10-ohm
R3, R13—27-ohm
R4–R8, R14–R18—75-ohm
R9, R19—1200-ohm
R10, R20—2000-ohm
R11, R21—1000-ohm potentiometer

CAPACITORS

C1, C2—2200-µF, 16-WVDC, electrolytic
C3, C4, C10, C11—2.2-µF, 16-WVDC, electrolytic
C5, C6, C12, C13—0.1-µF, polyester film
C7, C14—4.7-pF, polyester film
C8, C15—27-pF, ceramic disc
C9, C16—2-22-pF trimmer

ADDITIONAL PARTS AND MATERIALS

J1–J5—Mini-DIN jack, 4-pin
J6—Power jack, center-pin
S1—Single-pole, single-throw toggle switch
IC sockets, enclosure, 9-volt 300-mA AC wall-mount transformer, wire, hardware, etc.

Note: The following items are available from T3 Research, Inc., 5329 N. Navajo Ave., Glendale, WI 53217-5036: Etched PC board, $12.00; Metal case, $16.00; Complete kit of all parts, PC board, case, and wall-mount transformer, $69.00. Please include $3.00 for shipping by priority mail. Wisconsin residents must add appropriate sales tax. MasterCard and Visa credit cards are accepted for purchases.

video driver with a large signal range. It has a bandwidth of about 200 MHz, an output impedance of less than 4 ohms, and is capable of delivering a drive current of up to 75 mA.

Video signals are normally, by convention, 1 volt from the tip of the sync pulse to the peak of the white level when fed across an impedance of 75 ohms. That means that both the source impedance and the load impedance of the amplifier's input must also be 75 ohms. To insure proper impedance matching between the amplifier's output and the amplifier's load, the shielded cable used to carry the output signal must also have a 75-ohm impedance. Since the circuit needs to have unity gain from the input to the output, the actual gain of IC3 must be set to 2. The reason for amplifying the video signal has to do with impedance matching. The output impedance of the Video Distribution Amplifier is set by R4–R7. The input impedance of the device that the Video Distribution Amplifier is driving has a 75-ohm resistor between its input and ground, resulting in a divider network between the two devices. For practical purposes, the output impedance of IC3 can be considered to be zero ohms. Thus, any device connected to any of the four outputs will only see a 75-ohm source resistance to ground. That eliminates any interaction between devices that are connected to the output of the Video Distribution Amplifier. Even if one or more outputs are shorted, there is little effect on the other outputs. In addition, the unused outputs can be left open with no adverse effects on the outputs being used.

To insure a good low-frequency response, the Video Distribution Amplifier was designed with direct coupling; that is, there are no coupling capacitors in the signal path. That is important when working with video signals because the sync pulses, as well as the video itself, are DC referenced. The input signal is sent directly to the non-inverting input of IC3. The input impedance of the circuit is set by R8 to 75 ohms. The feedback resistor combination of R9, R10, and R11 from the output (pin 6) to the inverting input (pin 3) sets the gain of IC3 to 2. The value of R11, the gain pot, was chosen so that the overall gain of the circuit can be adjusted slightly above and below unity. The high-frequency response of the circuit is set by C8 and C9. Adjusting C9 allows either boosting or cutting of the high frequencies. Normally, C9 is adjusted for a flat frequency response. If a long cable run is needed, C9 can be set to provide some high frequency boost to overcome the natural tendency of shielded cable to roll off the high frequencies. In practice, C9 provides a gently sloped boost/cut action starting at about 2 MHz and reaches a maximum of about 1.5 dB at 10 MHz. Internal phase compensation for IC3 is set by C7. As mentioned previously, the 75-ohm output impedance is set by R4–R7 for each of the four outputs.

Construction. Because of the very high frequencies involved, a properly designed printed-circuit board is required. A foil pattern has been included if you wish to etch your own board. Alternatively, a PC board can be purchased from the source given in the Parts List.

If you use the foil pattern or purchase a board from the source mentioned in the Parts List, use the parts-placement drawing in Fig. 2 for locating the various components. Mount the components as close as possible to the surface of the PC board. Double-check the polarities of the diodes and the electrolytic capacitors before soldering them in place. It is also a good idea to use sockets for IC3 and IC4.

Inspect the completed board for any mistakes or errors. There is one jumper wire near R13. The completed board should be mounted in a metal chassis in order to shield it from any possible stay RF pickup. Drill appropriate holes for J1–J6, S1, and LED1. Suggested locations are shown in Fig. 3. Once everything is wired up, you're ready to test and align the Video Distribution Amplifier.

Alignment and Use. If you have a signal generator capable of providing a calibrated video-multiburst pattern, connect it to the amplifier. Using an oscilloscope, set the gain (R11 and R21) for unity and the frequency response (C9 and C16) for a flat response on each circuit. Of course, that type of test gear is rarely found on a hobbyist's workbench. As an alternative, simply set the gain pot to a position of about

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o'clock and set the trimmer capacitor to half mesh of the plates. Another way to set up the amplifier is to patch it in and out of a signal feeding a monitor. Watching the monitor, make adjustments until you cannot see any change in the brightness or color intensity of the picture.

At this point, the Video Distribution Amplifier is ready to go. Simply connect any S-video source to J1 and up to four S-video inputs to J2–J5. Turn on the power, and you're ready to enjoy the benefits of S-video picture quality.

Until digital-television transmission and digital connections between our home-satellite receivers, videodisc players, video recorders, computers, and television displays becomes a reality, the S-video connection is the state-of-the-art method to connect those devices together. However, one can't help but wonder—had CBS Labs developed a color picture tube, might we have spent the last 50 years watching high-definition television? Ω