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ALL ABOUT

CABLE-TV DESCRAMBLING

Learn the theory behind cable-TV signal-scrambling techniques by investigating a descrambling circuit.

FRED MEANS

IT IS ESTIMATED THAT BY THE END OF THIS decade, almost ninety percent of all households will be wired for cable television. One reason for cable TV's popularity is the excellent reception of local television broadcasts that it provides. Another reason is that several premium (pay) channels—that cannot be received without cable service—are offered. To prevent unauthorized persons (or non-subscribers) from viewing those premium channels, the signals are often *scrambled*. That is, the video signals are processed so that they can't be viewed on a normal TV—even one that is wired for cable—unless some device is used to decode or descramble them.

There are several techniques that cable-TV companies are now using to scramble their signals. In this article, we'll take a look at one of the more popular methods used today: the *inband gated-sync* method. We will explain the theory behind inband gated-sync scrambling/descrambling; and to further help you to understand and become familiar with the theory, we'll discuss a descrambling circuit that you can experiment with.

WARNING

The legality of the use of privately owned or built devices to receive or decode cable TV broadcasts is currently a subject of much controversy, debate, and litigation.

In certain instances, the TV cable companies and the FCC have taken the position that receiving and decoding cable-TV broadcasts without paying for them is "theft of service."

This article merely explains how one decoding device functions and is constructed. Prior to your using such a device, however, you are advised to obtain independent advice as to the propriety of such use based upon your individual circumstances and jurisdiction.

How is a signal scrambled?

Before we can understand what a scrambled signal is, we have to take a look at a normal signal. Such a normal signal contains horizontal- and vertical-synchronizing pulses that are sent during the horizontal- and vertical-blanking intervals respectively. (During those blanking intervals, the picture tube's electron beam is cut off as it retraces horizontally or vertically.) Those synchronizing pulses are among the most important parts of a standard TV signal. They are picked up by synchronizing circuits in the television set and are used to stablize the picture.

Figure 1-a shows part of a normal, demodulated, television signal that you would see, for example, after the TV's video-detector stage. The horizontal-blanking pulse can be seen in its proper place in the signal. (The vertical-blanking interval—when the electron beam snaps back to the top left corner of the screen to begin a new picture field—is not shown.)

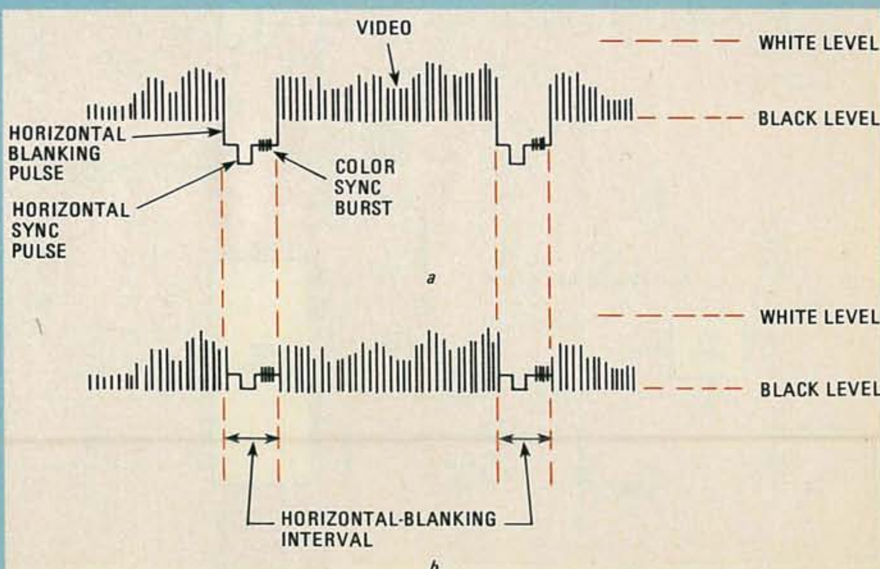

FIG. 1—THE INBAND GATED-SYNC scrambling method moves the horizontal-blanking pulse of a normal signal (*a*) into the video portion of the signal (*b*).

Now we can explain how the inband gated-sync scrambling method works. In that scrambling method, the level of the horizontal-sync and colorburst information is changed so that it is the same as that of the video information, as shown in Fig. 1-b. (The suppressed information is still within the signal's 6-MHz bandwidth, thus the word "inband." The "gated-sync" portion of the term means that during the horizontal-blanking interval, a gating signal is used to change the level of the signal.)

Because of the change (about 6 dB) in the level of the horizontal-blanking pulse, the TV's horizontal- and color-synchronization circuits do not pick up the pulses they need for synchronization. Therefore, the picture that you see is not stable—it is out of horizontal sync and the picture's color is also poor. The audio is not affected, though. Unlike many of the over-the-air scrambling schemes, the audio is not scrambled in the inband gated-sync method; it is simply passed through.

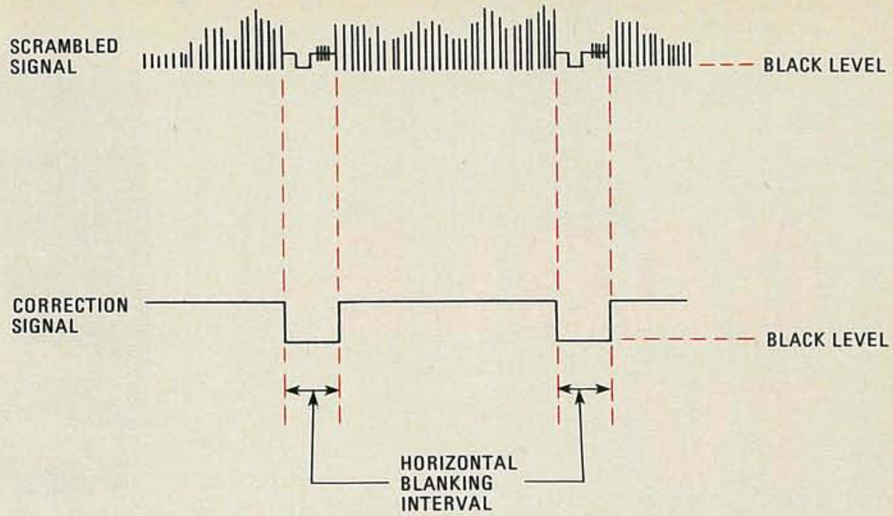

FIG. 2—WE CAN DECODE A SCRAMBLED SIGNAL by adding a correction signal to it, thus restoring the horizontal-blanking pulse to its proper location.

Descrambling the signal

We can see that to descramble the signal, it will be necessary to place the horizontal-blanking and -sync pulses back into their proper location. But first we must locate the hidden pulses. In the inband gated-sync signal, the horizontal-sync pulses are modulated on the sound carrier of the video signal. And because the sound carrier is 4.5 MHz above the picture carrier, we know where to look for the hidden sync pulses. For example, channel 3, whose picture carrier is at 61.25 MHz, has its sound carrier at 65.50 MHz. Therefore, if you wanted to decode signals from a cable system that used channel 3 as its output, you would have to look for the horizontal-sync pulses at 65.50 MHz. However, for a cable system that has its output on channel 2 (55.25 MHz), the horizontal-sync pulses are on 59.75 MHz, and so on.

Once we extract the horizontal-sync pulses, they can be used, along with the aid of some time-delaying circuits, to create a correction signal. The correction signal can then be added to the input signal to put the horizontal-blanking and -sync pulses back where they are supposed to be. What we want to do is to add a small DC voltage to the input signal *but only during its video portion*, not during

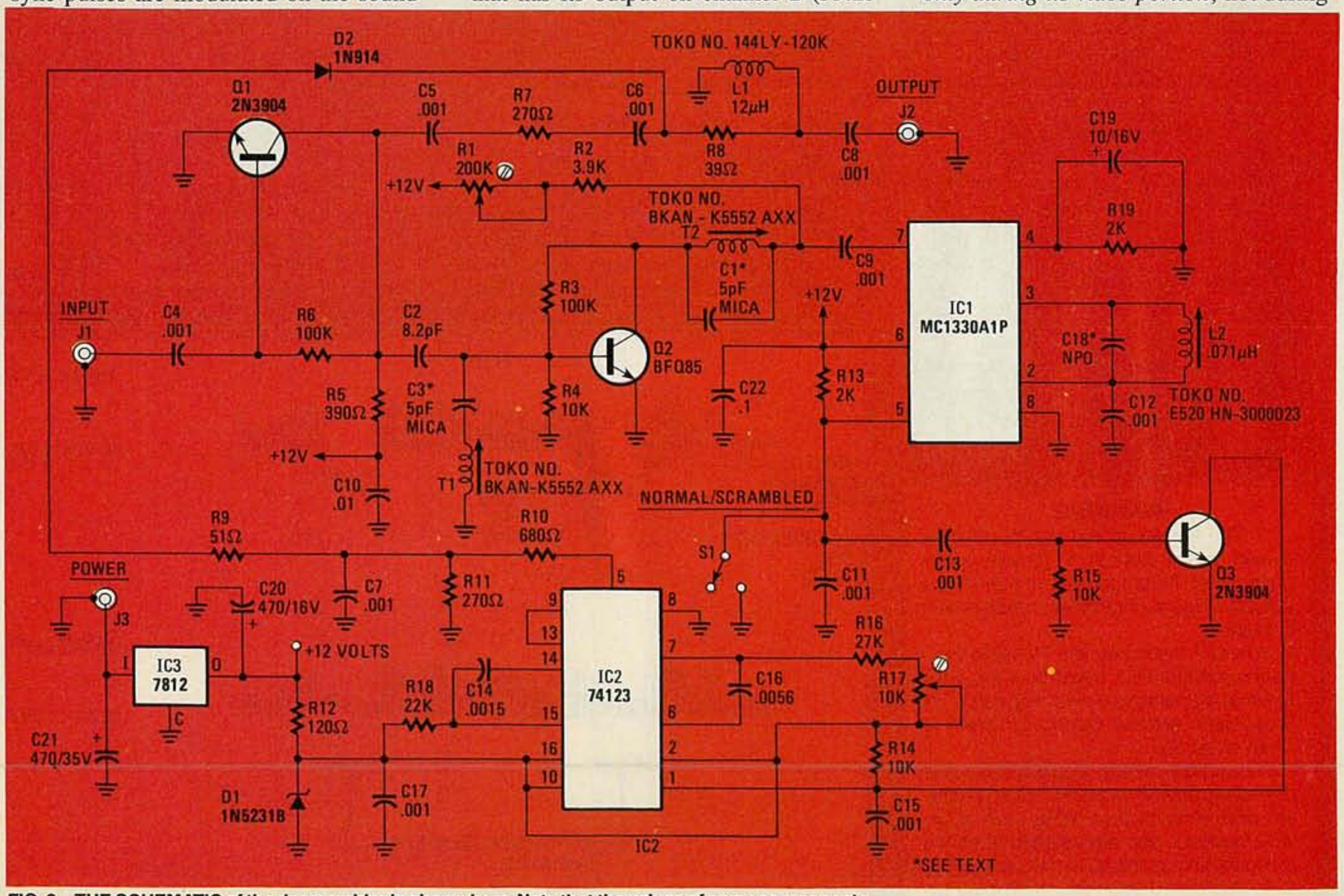

FIG. 3—THE SCHEMATIC of the descrambler is shown here. Note that the values of some components should be changed for operation at different frequencies. The descrambler can be used even with cable-ready sets. See the text for information.

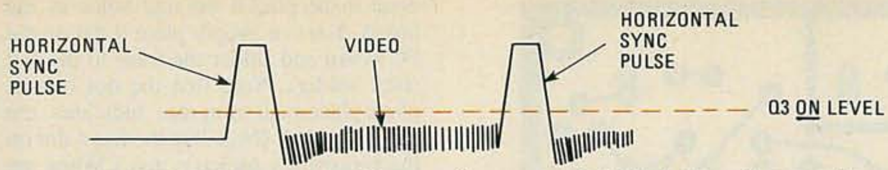

FIG. 4—THE OUTPUT OF IC1 (pin 5) should have a minimum amount of video between the sync pulses.

the blanking interval. That process is shown in Fig. 2. The result of the descrambling process should be the original waveform shown in Fig. 1-a.

Circuit description

The schematic of a circuit that will do what we want is shown in Fig. 3. First we'll look at the power supply. The circuit can be powered by an AC adapter that has an output from 14 to 18 volts DC at 100 mA. The 7812 regulator, IC3, provides 12 volts DC to the rest of the circuit. The input and output of the regulator are filtered by capacitors C20 and C21. Zener diode D1 is used to provide +5 volts for IC2, a 74123 dual retriggerable monostable multivibrator.

Transistor Q1 provides a small amount of gain to the input signal—that compensates for any losses caused by the descrambling circuit. Transistor Q2, a BFQ85, is also used as an amplifier. But it will amplify only signals of a certain frequency. That frequency is determined by the setting of two tuned circuits. The first tuned circuit is made up of T1 and C3. Its resonant frequency will be set to shunt the video portion of the input signal to ground, while letting the audio portion of the signal through. The other tuned circuit is made up of T2 and C1. That is set to pass only the audio portion of the input signal. Potentiometer R1 can be used to vary the level of the signal at the output of the tuned circuit. Adjustment may be necessary because the inputs to the decoder from different cable-TV systems often are at different voltage levels.

After being amplified by Q2 and passed through the C1-T2 filter, the signal is fed into IC1, an MC1330A1P low-level video detector. (That signal contains the audio information of the input signal—where the sync pulses are hidden.) The tuned circuit (L2 and C18) associated with IC1 is also tuned to the frequency of the audio carrier of the input signal. That is, 65.50 MHz for channel-3 operation, 59.75 MHz for channel-2 operation. So, if operation on channel 3 is required, the value of C18 must be 68 pF. Operation on channel-2 requires C18's value to be 82 pF.

By changing the resonant frequency of the tuned circuits, the descrambler can be used at other frequencies than those of channel 2 or 3. For example, if your TV is "cable-ready" you would want to descramble the output of the tuner section. The output of the tuner is usually at 45.75 MHz (video carrier). The audio carrier is therefore located at 50.25 MHz. The tuned circuits could be adjusted for those frequencies by changing capacitors C1 and C3 to 10 pF, and changing the value of C18 to 130 pF.

The output of IC1 (pin 5) is the demodulated horizontal-sync pulses, as shown in Fig. 4. Most of the video on pin 5 of IC1 should be filtered by C13 and the input of Q3 (provided that the video is below the level that is needed to turn Q3 on). However, there will still be a small amount of video present between the horizontal-sync pulses. That video has to be reduced—which can be done by fine-tuning L2. (The result of too much video at pin 5 is false triggering of IC2. That shows up as streaking horizontal lines across the picture.)

When watching non-scrambled signals, we do not need the sync pulses from pin 5 of IC1. Therefore switch S1 is provided to shunt the sync pulses to ground. When the switch is open, however, the sync signals are sent to transistor Q3, which is used as a buffer. From there, the horizontal-sync signals are sent to IC2, a 74123 dual monostable multivibrator.

We use IC2 to form the horizontal-blanking interval from the demodulated sync signals. (The horizontal-sync pulses from IC1 are not the proper pulse width that we need.) The two R-C timing circuits associated with IC2 (at pins 6 and 7 and at pins 14 and 15) determine the pulse width of the output. Potentiometer R17 can be adjusted to "fine tune" the output for the pulse width that is needed—11 microseconds.

Once the proper pulse width is obtained for horizontal blanking, the signal from pin 5 of IC2 is fed to a voltage divider made up of R10 and R11. (The value shown for R11 works well when the input signal's level is between 50 to 70 millivolts. However, because different cable systems have different signal levels, it may be necessary to increase or decrease the value of R11.) From the voltage divider, the signal is fed to diode D2, where it is used to raise the DC level of the input signal—but as we mentioned before, only during the video portion of the signal.

During vertical blanking and horizontal blanking, no DC level is added to the signal. In effect, by increasing the DC level on the video—and only during the video—we are returning (with the help of the DC-restoration circuit in the TV) the horizontal-blanking pulse and colorburst information to their proper location on the composite-video signal.

Building the circuit

For those of you who want to experiment with the circuit we have been describing, we have included foil patterns for a double-sided board in Figs. 5 and 6. Although a double-sided printed-circuit board is used, plated-through holes are not necessary. That's because there are only seven connections that need to be

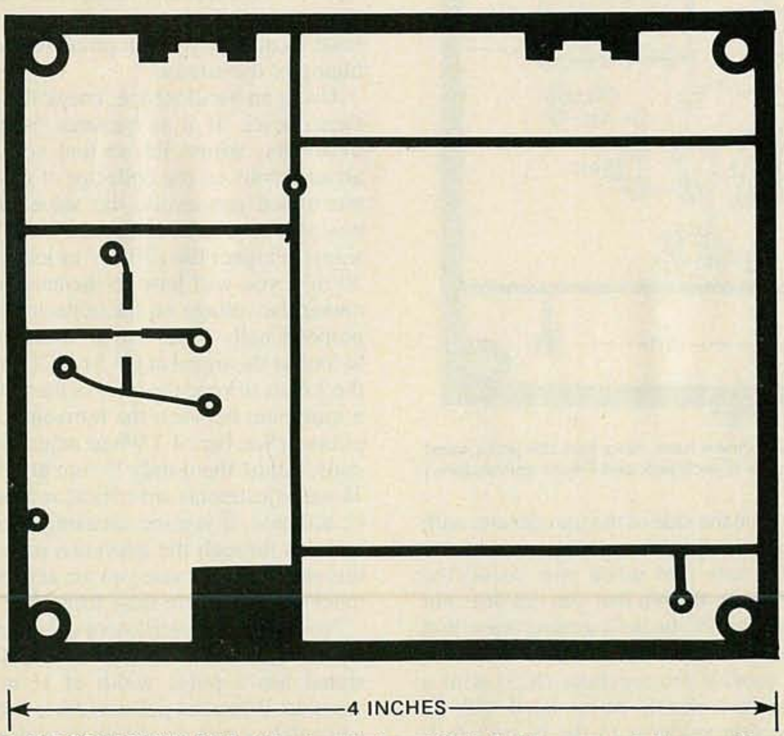

FIG. 5—THE COMPONENT SIDE of the decoder board. Note that there are only 7 connections to be made on this side of the double-sided board, so plated-through holes are not necessary.

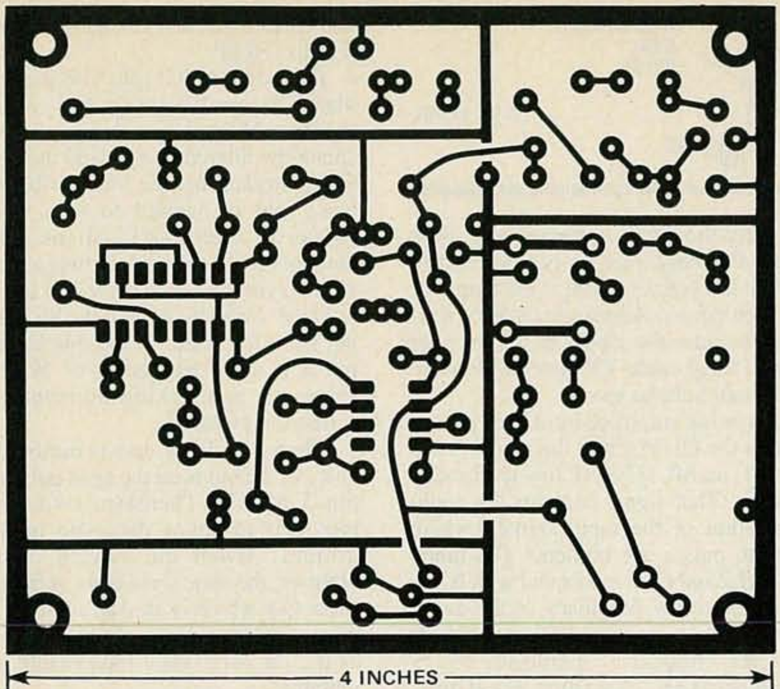

FIG. 6—THE FOIL SIDE of the decoder board is shown here.

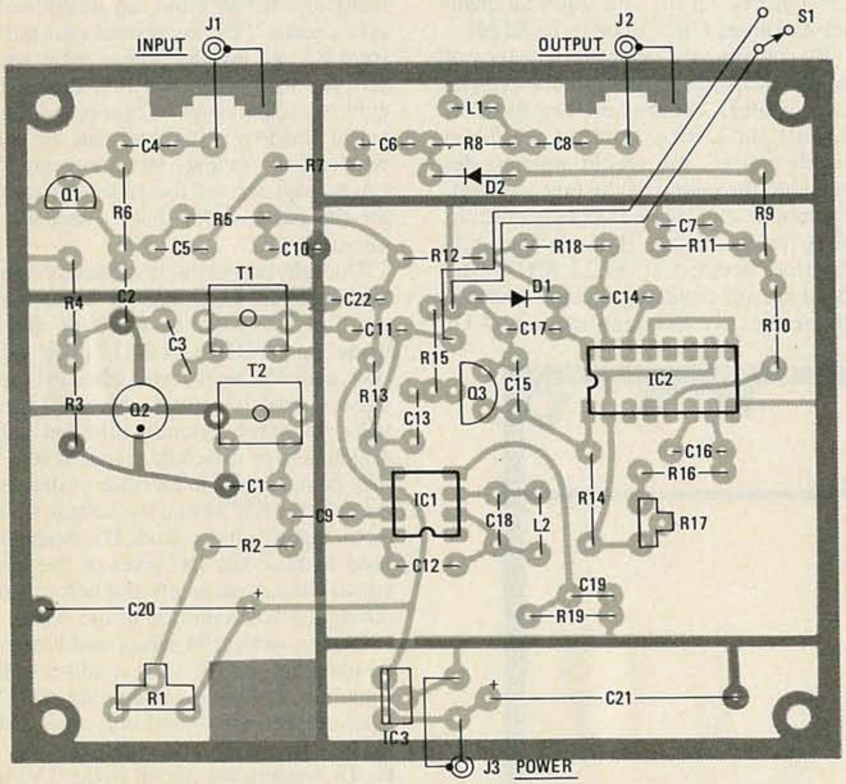

FIG. 7—PARTS-PLACEMENT and off-board connections are shown here. Note that the jacks used depend on your power source and RF connections. (We used a ⅛-inch jack and F-type connectors.)

soldered on both sides. Figure 7 is a parts-placement diagram for the board. Mount the components as close to the PC board as possible. When installing the electrolytic capacitors (C19, C20, and C21), be careful to check for proper polarity. The same holds true for the two diodes.

Transformers T1 and T2 must be modified so that they will fit into the holes on the PC board. That is, one of the pins—the one on the side of the transformer with the part number— on each has to be cut off. Be sure that when you install the transformer, the pin that you cut does not contact the PC-board's ground trace that runs under it.

To provide the regulator (IC3) with a heat sink, it should be mounted with its flat portion soldered to the board's foil. The leads of transistor Q2 (BFQ85) do not need to be placed through holes in the board. You can simply place it flat on the PC board and solder the leads to the foil (tack solder). Note that the dot on the parts-placement diagram indicates the collector lead. (Note that there is a dot on the transistor's package, too.) When we assembled our prototype, we mounted it in a plastic box and used an ⅛-inch jack for the input from the AC adapter, and F-type connectors for the signal input and output. The connectors that you use in your setup depend on what type of plug your AC adapter has, and what type of RF connectors you need to connect to your TV and cable converter.

Checkout and alignment

Do not hook up this device unless you are properly authorized to do so. As we continue, we will presume that you have received the proper authorization.

The first step is to plug the output from the AC adapter into J3. Using a voltmeter, check for +12 volts at the positive side of C20. Then check that you have +5 volts at pin 16 of IC2.

The next step is to tune to a scrambled station and connect the circuit between a cable-TV converter and your television. (Jack J1 is the input jack, and J2 is the jack for output to your TV.) Make sure that switch S1 is in the open position (not shorting the output of IC1 to ground). Then adjust potentiometers R1 and R17 to approximately the "12 o'clock" position. To set the coils in their approximate location, turn the slugs counterclockwise until the top of the slug is even with the top of the coil. Then turn the slugs clockwise as follows: T1, 2½ turns; T2 and L2, 3 turns. With those adjustments in their approximate locations, you can go on to the fine tuning of the circuit.

Using an oscilloscope, check the input signal level. If it is between 50 to 70 millivolts, adjust R1 so that you have about 4 volts on the collector of Q2. (As mentioned previously, the value of R11 may also have to be changed.) If the input signal is higher than 70 mV or lower than 50 mV, you will have to increase or decrease the voltage on the collector of Q2 proportionally. Next use an oscilloscope to look at the signal at pin 5 of IC1. Adjust the 3 coils to keep the level of the video to a minimum between the horizontal-sync pulses. (See Fig. 4.) When adjusting the coils, adjust them only ¼ turn at a time. Those adjustments are critical and have to be accurate. If you see streaking horizontal lines through the television picture at this point, it's because you are getting too much video and are false firing IC2.

Now, using an oscilloscope, look at the signal at pin 5 of IC2. Adjust R17 until the signal has a pulse width of 11 microseconds. When the pulse width is correct, you will be correctly gating the video sig-

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CABLE DESCRAMBLING

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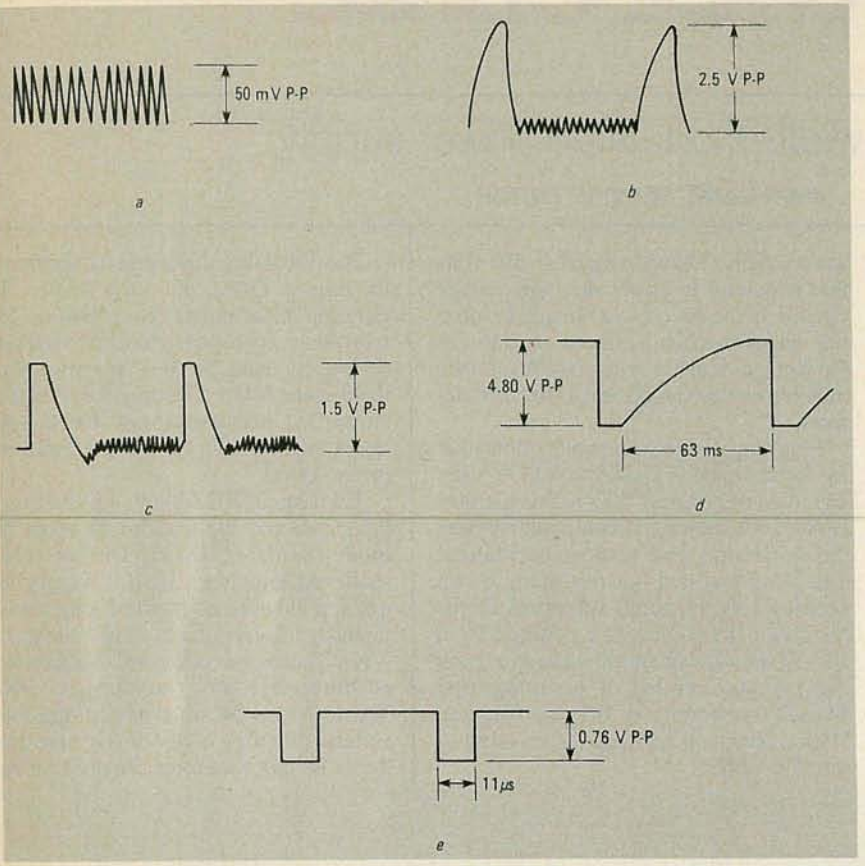

WHEN TESTING THE DECODER, look for the following signals: The input should look something like what's shown in *a*. The signal in *b* should be seen on pin 5 of IC1. The signals in *c* and *d* should be seen at the base and collector of Q3 respectively. The waveform shown in *e* should be seen at the junction of R10 and R11.

nal to return the horizontal-blanking pulse (which contains the horizontal sync and colorburst information) back into its proper location. The scrambled video should be clear.

Once the circuit is working properly on one scrambled channel, you will have to switch to other scrambled channels to see if the circuit is tracking properly. If it isn't (and some channels are not being properly descrambled), some minor, final touch-up adjustments will have to be made.

Remember that switch S1 has to be open to view a scrambled channel, and must be closed to view a non-scrambled channel. Unless you modify the circuit with a bypass-switch arrangement, it will be necessary to leave this circuit on whenever you watch TV. **R-E**

CABLE-TV DESCRAMBLING

A few comments about the Cable-TV Descrambling article published in your February 1984 issue. First, in order to obtain the correction signal shown in Fig. 8-e, the 680-ohm resistor, R10, should be connected to pin 12 instead of pin 5 of IC2. The foil pattern must be modified.

Secondly, one of the multivibrators of IC2 delays the correction signal. Changing R18 to a 100-kilohm trimmer potentiometer allows one to adjust the proper delay.

Finally, for those who have difficulty finding the inductors T1, T2, and L2, the following seems to work fine: Replace T1, T2, and L2 with 0.1-μH fixed inductors: Replace C1, C3, and C18 with 100, pF trimmer capacitors.

SENCER YERALAN
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IRKSOME PRACTICES

I find two things done by most of the electronics, computer, and mechanic/science magazines most irksome. The first is demonstrated on page 86 of the May 1984 issue of **Radio-Electronics,** and relates to the use of the letters