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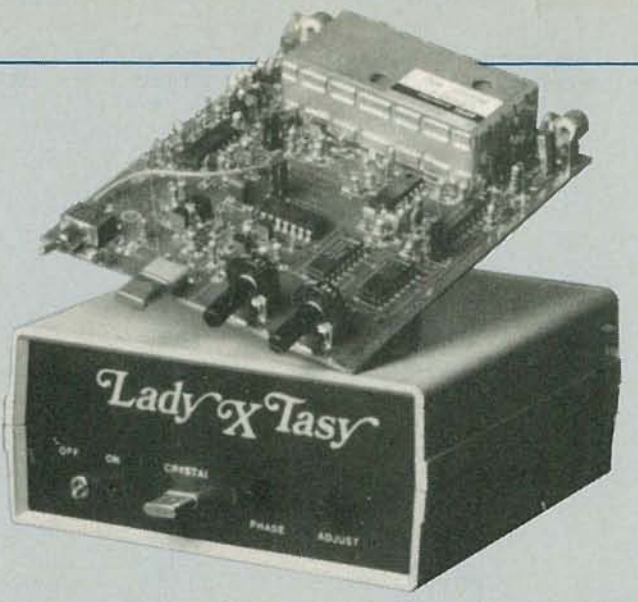
Satellite-TV Descrambler



VICTOR J. TERRIO, JR. and JAMES PERODI

Learn about one of the more popular satellite-TV scrambling systems, and how it can be decoded.

IF YOU HAVE BEEN WAITING FOR AN EASY-to-build satellite decoder, your wait is over. Here is a relatively simple unit that can be built in just a few evenings. In the process, it can teach you about some of the technology behind satellite-TV scrambling

Before you get too excited, we should tell you that the unit will *not* decode HBO, Showtime, or any of the other services that use the *VideoCipher II* system. Instead, it decodes the *Telease-Maast* system. That medium-security system is used by two adult-oriented direct-broadcast systems, as well as by a few sports-programming services.

Next, heed this important warning: **The use of an unauthorized descrambler may constitute a violation of federal or local laws. It is up to the user to determine what the requirements for use are, and to meet them fully before using the unit.** The details presented in this article are for informational purposes only.

Design philosophy

The decoder represents the latest version of a series of decoders that have been developed over the last five years. We took the best features of previous designs and combined them with the latest technical advancements to achieve the unit described here. The unit offers a number of convenience features, including front-panel-mount phase-control adjustments and crystal socket.

The unit is designed to accept baseband audio and video inputs; outputs of that type are available from just about any satellite-TV receiver. The unit as described in this article features an RF modulator. It is an easy matter to eliminate that modulator and bring out baseband audio and video outputs for connection to a VCR, etc. If applicable, that modification is recommended. It will be fully described later on.

The *Telease-Maast* system

The *Telease-Maast*, or Telease system is a medium security system that uses analog audio and video scrambling. By contrast, to the high-security *Videocipher II* system uses analog video scrambling and *digital* audio scrambling.

That's not to say that a *Telease*-encoded signal is simple to descramble. In the *Telease* system the video is inverted, its level is reduced to one half of normal, and it is modulated by a 94-kHz sinewave. The audio is modulated by a 15.67 kHz sinewave before being placed on the usual 6.8-MHz subcarrier. To further complicate matters, no attempt is made to precisely control the frequency of the scrambling oscillator at the uplink and no reference signal is transmitted with the scrambled signal. Finally, 94 kHz is nearly 6 times the TV horizontal-scan frequency (15.734 kHz), but not exactly. If the scrambling sinewave is not completely cancelled, the 6th harmonic of the horizontal frequency (94.4 kHz) can beat with the sinewave to generate an annoying 400-Hz interference signal.

Descrambling *Telease*

A block diagram of the descrambler circuit is shown in Fig. 1. Circuit details for that unit are shown in the schematic of Fig. 2. Refer to both of those figures as we describe the operation of the circuit.

Transistors Q1 through Q4 form a balanced differential video amplifier. The baseband video input jack, J1, is connected to the inputs of Q1 and Q2. The signals at the collector of Q3 and the emitter of Q4 are inverted with respect to each other, and are also 180° out of phase. Those signals are fed to the inputs (pins 1 and 4) of IC3, an MC1496 balanced demodulator. That IC removes the 94-kHz carrier from the video signal. The outputs of IC3 appear at pins 6 and 12; the outputs differ in phase by 180°.

The outputs of IC3 are fed to IC1-a, ¼ of a TL084CN quad biFET op-amp. That amp takes the outputs of the balanced demodulator and uses them to develop an error voltage that in turn is used to control operation of the *V*oltage *C*ontrolled *O*scillator (VCO).

The VCO, which consists of XTAL1, varactor diode D2, and Q9, is part of a *P*hase-*L*ocked *L*oop (PLL). The other stages of the PLL consist of a divide-by-16 counter, a divide-by-4 counter, and a 94-kHz bandpass filter. The PLL accurately tracks the scrambling sinewave frequency and allows the decoder to generate the reference signal needed for descrambling. The output of the VCO, taken from Q9, is fed to Q8 and then Q7 for amplification and buffering. It is then fed to pin 1 of IC5, a 4024 7-stage binary ripple counter that is set up as a divide-by-16 counter. The output of that stage (pin 6) is then fed to IC4, a 4027 dual J-K flip-flop that is set up as a divide-by-4 counter. Three outputs are taken from IC4. One, taken from pins 6 and 15 and labeled CLOCK1 in Fig. 1, is fed to a 94-kHz bandpass filter built around IC1-b. The output of that filter serves as a reference signal for IC3.

The second output, taken from pins 1 and 11 and labeled CLOCK2, is fed to another 94-kHz bandpass filter, which is built around IC1-c. The output of that filter is the correction signal used to remove the scrambling sinewave. It is fed to the cancel- and phase-adjust stage, which consists of R70, R65, R39, R47, R49, C10, and C11. That stage is used to adjust the phase of the correction signal for proper cancellation of the scrambling signal.

The actual cancellation of the scrambling signal takes place in the clamper-amp and adder stage. In that stage, which consists of transistors Q5 and Q6 the scrambled video, which is taken from the output of the differential amp, is summed with the correcting sinewave to yield an unscrambled video signal.

The third output of IC4, taken from

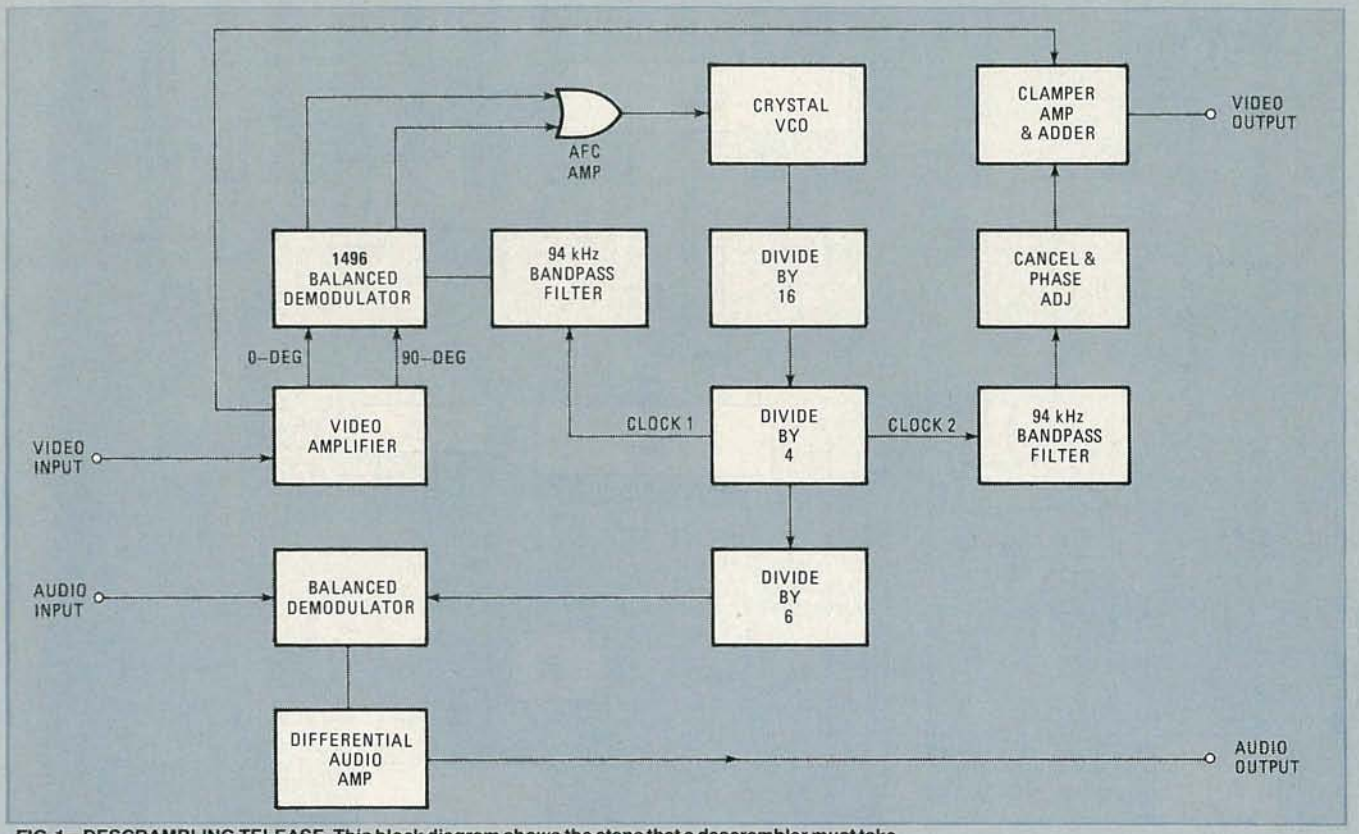


FIG. 1—DESCRAMBLING TELEASE. This block diagram shows the steps that a descrambler must take to decode that medium-security system.

pins 2 and 10, is fed to IC6, a divide-by-2-through-10 synchronous counter configured as a divide-by-6 counter. The output of that IC is used as a reference signal by IC2, a second MC1496 balanced demodulator. That demodulator removes the 15.67-kHz scrambling sinewave from the audio and passes the audio to a differential audio amplifier, which is the last of the four op-amps of IC1-d. The output of that amp is fed either to an audio output or to the RF modulator, if it is used.

Building the unit

The first step in building the descrambler is to obtain the board. An appropriate double-sided PC pattern is shown in PC Service, found elsewhere in this issue. Otherwise, a board can be purchased from the supplier mentioned in the Parts List.

A parts-placement diagram for the board is shown in Fig. 3. Note that the version shown includes an RF modulator. If you have a VCR, TV, etc. that can accept direct audio and video inputs, the RF modulator and its associated components (D1, C1, and R46) can be deleted. If that is done, the audio and video inputs to the modulator can be brought out to the rear panel of the case and terminated with standard phono plugs. If your TV, VCR, or other equipment can accept direct audio and video inputs that is the recommended approach as it will yield superior picture and sound.

Building the unit is a fairly straightforward procedure, although a few things bear special mention. Before mounting S1, trim the lead nearest the outer edge of the board so that it does not make contact with the board when the switch is mounted. Connect the lead stub to the appropriate pad in the center of the PC board with a jumper as indicated in Fig. 3. The unused pad beneath the switch becomes the ground connection for the external power supply (more on that in a moment).

The crystal socket should be accessible from the front panel so that you can switch between services easily. There are a number of ways to accomplish that. One is to use a panel-mounted socket and to make the connections to the PC board with short jumpers. Another is to mount a PC-mounted socket on Y-shaped PC-mount tie points, creating a 90° crystal socket.

As mentioned, the PC board is double-sided. If you buy the board from the supplier mentioned in the Parts List, it will be provided with plated-through holes. Otherwise, you should solder all component leads on both sides of the board and you must also install feedthroughs at all unused pads. Use short, uninsulated pieces of wire for that and be sure to solder them on both sides of the board. Clipped resistor, capacitor, etc. leads are ideal for use as feedthroughs.

Three components, C17, R74, and R75, are installed on the solder side of the board. One end of R74 shares a mounting hole with the base of Q5; one end of R75 shares a mounting hole with Q6. The other end of both resistors is tack-soldered to the ground plane. One end of C17 connects to the junction of C8/R43; it shares its mounting hole with either of those components. The other end of the capacitor is connected to the ground plane. You likely will need to extend the lead length of the capacitor with a jumper to make that connection.

The unit requires ±5 volts, and +12 volts if the optional RF modulator is used. Most aftermarket computer power supplies are capable of supplying the needed voltages and current levels.

Note that the components are tightly spaced in some regions of the board. Because of that, some of the resistors must be mounted vertically.

For easiest construction, if used, mount the RF modulator last. Otherwise you might run into difficulty when mounting the surrounding components. Note that the output channel is selected by the

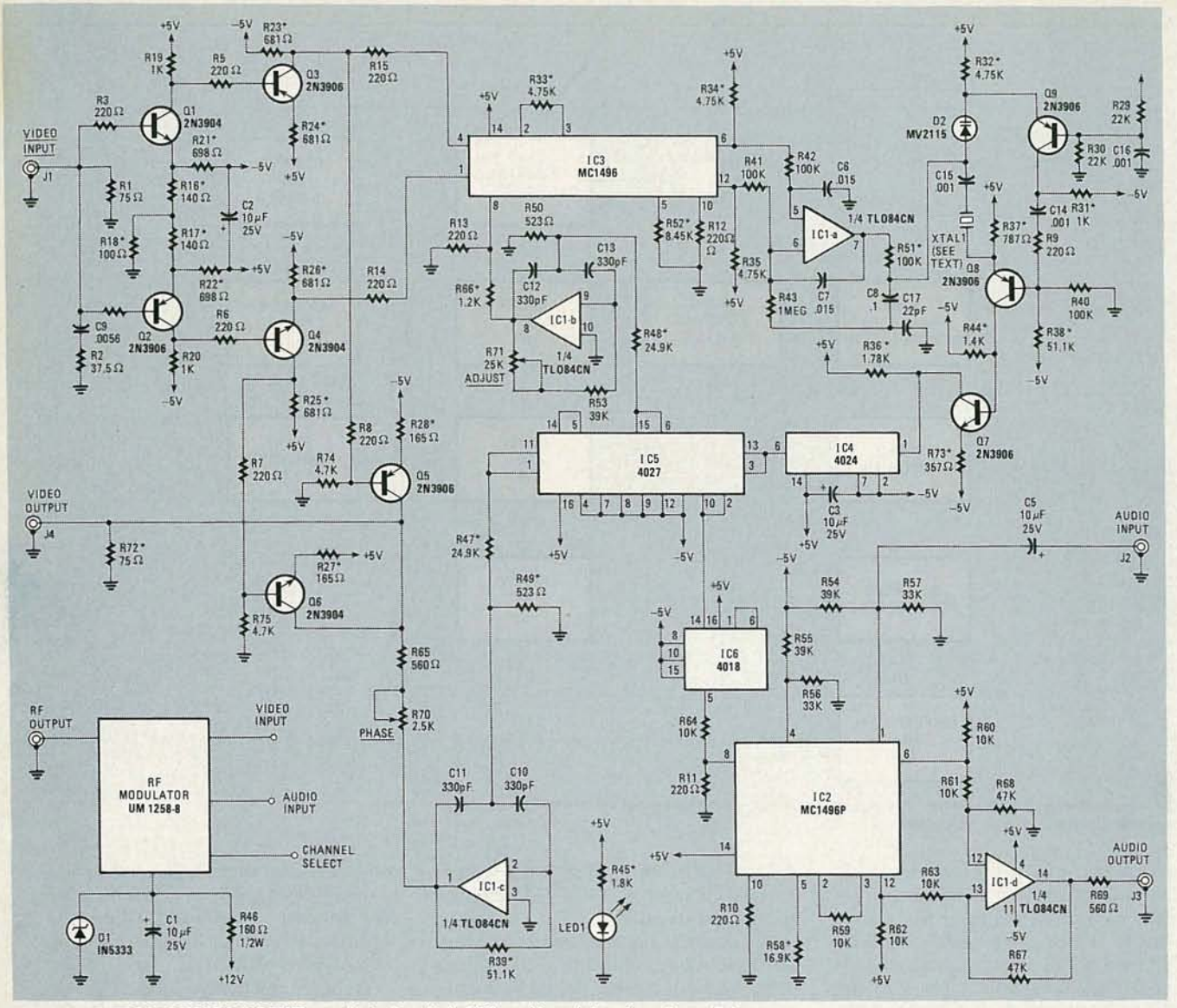


FIG. 2—THE DESCRAMBLER CIRCUIT uses just a handful of IC's and transistors to restore a Telease-encoded signal to normal.

CHANNEL SELECT lead. For a Channel 3 output, that lead should be grounded; otherwise, clip the lead. Finally, be sure to solder all four of the modulator's mounting lugs to the ground plane.

Note that many of the resistors are 1% precision types. Do not substitute 5% units for them.

Checkout

Before you test or use the unit, read the following notice:

It may be unlawful to operate a descrambler to decode certain satellite transmissions without authorization. It is up to the user to determine what the requirements are for legal use of the decoder and to meet them.

Once you have obtained the needed authorizations, if any, you may proceed with the testing.

Plug in the power pack and switch S1 to the on position. LED1 should light up. Check the power-supply voltages at the following locations: B, +5; Y, −5; R, +12, and cathode side of D3 (if RF modulator is used), +6. All voltages should be within 5% of the given values. Assuming that all voltages are correct, plug an appropriate crystal into the socket and monitor the unit for signs of overheating. If none of the transistors or IC's become hot, you can proceed.

Actually, we've gotten a little ahead of ourselves. Let's backtrack and say a few words about selecting and obtaining the crystal.

Table 1 lists the required crystal frequencies to decode some of the satellite services that use the Telease system. Note that the crystal's resonant frequency must be within 150 Hz of the listed center frequency for acceptable picture locking.

Crystals can be obtained from several sources. Among those are JAN Crystals (2400 Crystal, Fort Myers, FL 06017) and B&D Crystal Company (1727 West Galbraith Rd., Cincinnati, OH 45239). Further, crystals are available from a source mentioned in the Parts List. However, due to Federal law, it is illegal to supply a descrambler in assembled or kit form with a crystal. Thus, the kit supplier will not honor orders for crystals.

Once you have selected and obtained the proper crystal, and obtained any required authorization, it is time to do the final checkout.

Connect the baseband-video and the audio outputs of your satellite receiver to the appropriate inputs on the descrambler. If using the RF modulator, connect the modulator's output to the VHF terminals on your TV set. Be sure to use only the highest grade shielded cable and to terminate that cable with a 75-ohm-to-300-ohm matching transformer. If using direct video outputs, connect the video and audio outputs of the descrambler to the ap-

PARTS LIST

All resistors ¼ watt, 5% unless otherwise noted
R1—75 ohms
R2—37.5 ohms
R3–R15—220 ohms
R16, R17—140 ohms, 1%
R18—100 ohms, 1%
R19, R20—1000 ohms
R21, R22—698 ohms, 1%
R23–26—681 ohms, 1%
R27, R28—165 ohms, 1%
R29, R30—22,000 ohms
R31—1000 ohms 1%
R32–R35—4750 ohms, 1%
R36—1780 ohms, 1%
R37—787 ohms, 1%
R38, R39—51,100 ohms, 1%
R40–R42—100,000 ohms
R43—1 megohm
R44—1400 ohms, 1%
R45—1800 ohms, 1%
R46—160 ohms, ½ watt
R47, R48—24,900 ohms, 1%
R49, R50—523 ohms, 1%
R51—100,000 ohms, 1%
R52—8450 ohms, 1%
R53–R55—39,000 ohms
R56, R57—33,000 ohms
R58—16,900 ohms, 1%
R59–R64—10,000 ohms
R65, R69—560 ohms
R66—1200 ohms, 1%
R67, R68—47,000 ohms
R70—2500 ohms, potentiometer, PC mount
R71—25,000 ohms, potentiometer, PC mount
R72—75 ohms, 1%
R73—357 ohms, 1%
R74, R75—4700 ohms
Capacitors
C1–C5—10 µF, 25 volts
C6, C7—.015 µF
C8—0.1 µF
C9—.0056 µF
C10–C13—330 pF
C14–C16—.001 µF
C17—22pF
Semiconductors
IC1—TL084CN quad BiFET op-amp (Texas Instruments)
IC2, IC3—MC1496P balanced modulator (Motorola)
IC4—4024B CMOS 7-stage binary ripple counter
IC5—4027B CMOS dual J-K flip-flop
IC6—4018B CMOS divide-by-2-through-10 counter
Q1, Q4, Q6, Q7—2N3904 NPN transistor
Q2, Q3, Q5, Q8, Q9—2N3906 PNP transistor
D1—1N5333 6-volt Zener diode
D2—MV2115 Varactor diode
LED1—green LED
Other components
S1—SPDT toggle switch
J1, J2—phono jacks, PC mount
Miscellaneous: PC board, regulated power supply (+5 volts, 0.9 amps, −5 volts, 0.1 amps, +12 volts, 0.3 amps), RF modulator (optional, Astec UM-1285-8 or equivalent), crystal socket (see text), additional phono jacks (optional, for direct video/audio version), cabinet, wire, solder, hardware, etc.

Note: The following are available from Pilgrim Video Products, 33 Grasshopper La, Marshfeld MA 02050: Complete kit including PC board, RF modulator, case, power supply, and all parts except the crystal, $109.95; basic kit, including PC board, power supply, and all components except the crystal, but minus the modulator and case, $69.95; PC board alone, $24.95; Assembled and tested unit, minus the crystal, $189.95. Other components and kit configurations are available; contact the supplier for more information. Please add $2.50 for postage and handling. All MA residents must add 5% for sales tax.

Crystals are available from Blackbeard, P.O. Box 737, Prudential Center Station, Boston, MA 02199 for $22.00 each. Be sure to specify frequencies desired. All MA residents must add 5% for sales tax.

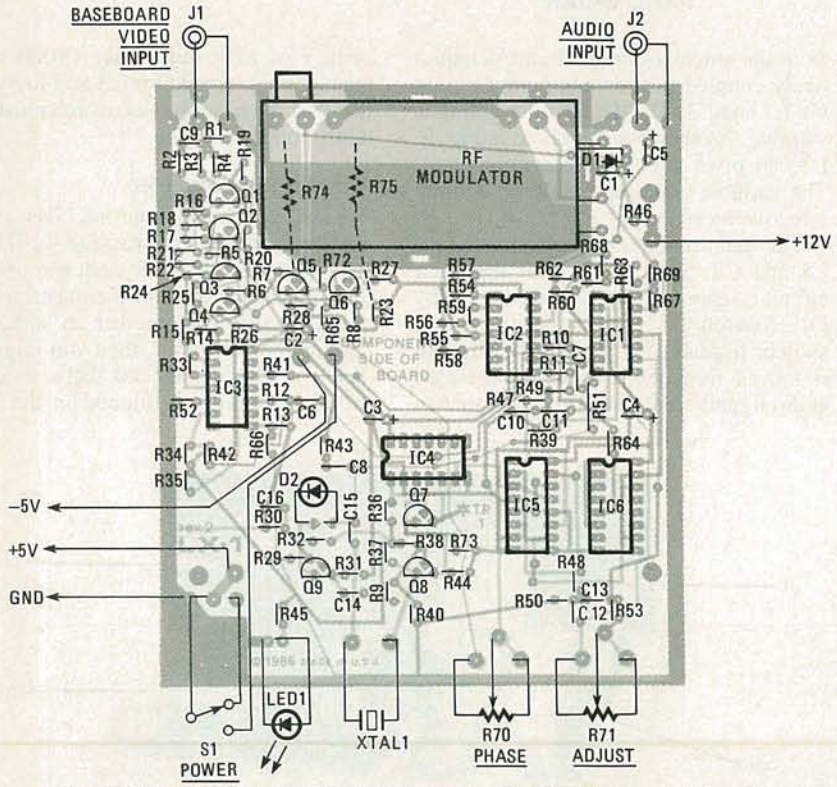
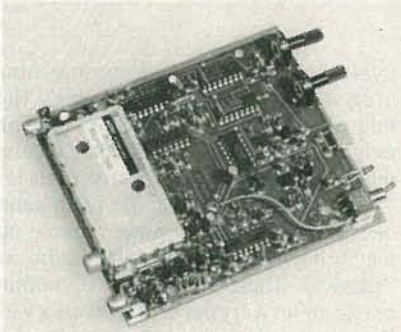


FIG. 3—FOLLOW THIS PARTS-PLACEMENT DIAGRAM when building the decoder. The patterns for the double-sided PC board are provided in PC Service.



THE COMPLETED DESCRAMBLER board is shown here.

TABLE 1—CRYSTAL FREQUENCIES

Service	Frequency (MHz)
Italian Soccer	6.052167
Portuguese Soccer	6.056800
Fantasy Channel	6.020412
American Triple Ecstasy	6.028440
Wrestle/Mania	6.025140

propriate inputs on your TV-set, monitor, or VCR.

Turn the unit on, using S1. You should now be receiving clear audio. Adjust potentiometers R70 and R71 until the picture locks in. That's all there is to it. If you run into trouble, go back over your work looking for things like cold solder joints, solder bridges, or out-of-place components. If you've satisfied yourself that all is as it should be, your crystal may be off frequency. Remember, one that is off by as little as 150 Hz will cause the unit to fail to function. Obtain a different one and try again. **R-E**