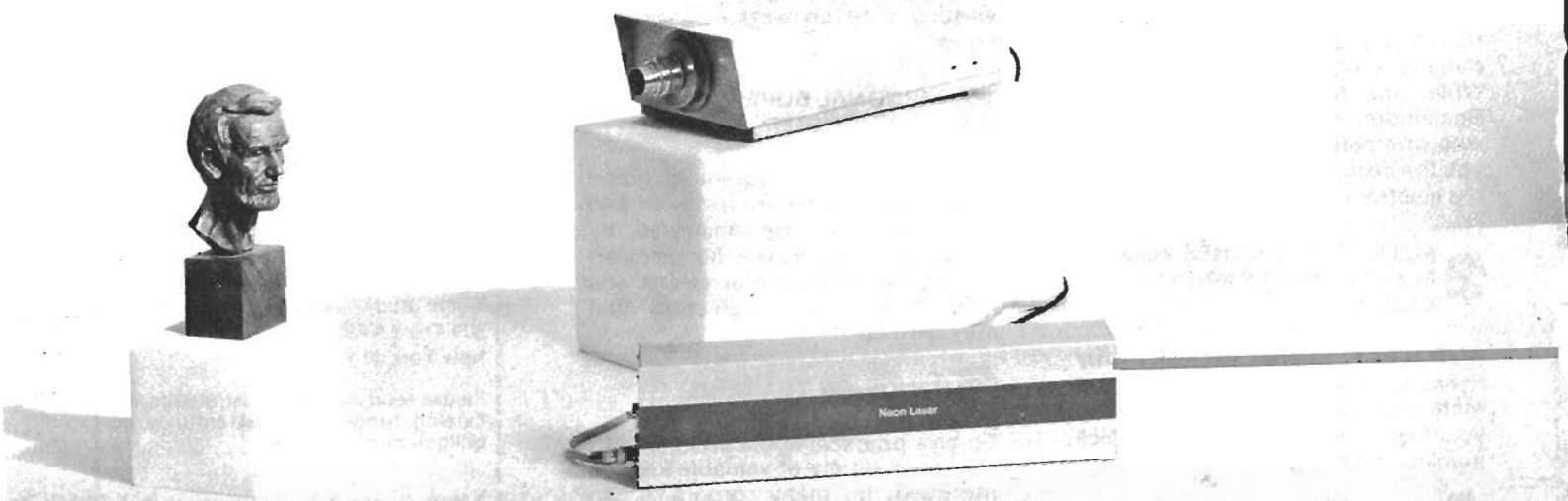
Popular Electronics

NOVEMBER 1974



EVER since we published construction plans for the world's first hobbyist/experimenter's laser in December of 1969, POPULAR ELECTRONICS has kept readers abreast of laser developments. For example, in January 1970, we gave details on how to use the laser for making three-dimensional holograms. Then, in May 1970, we published plans for assembling a laser voice communicator (which, incidentally, was featured for several weeks in the Smithsonian Institution).

Now, we have another breakthrough—plans for building the world's first experimenter's laser video (TV) system for a moderate $150. (The TV camera and receiver are extra items.)

THE POPULAR ELECTRONICS laser TV system gives you an advance look at a communication system of the future. There are two key devices in the system. One is the composite laser tube/video modulator "transmitter" that works in conjunction with a low-cost TV camera. The other is the detector/r-f modulator "receiver" that feeds an ordinary TV receiver. (See box on Class-1 requirements.)

The helium-neon laser tube used in the system employs the latest aluminum cathode design. The tube is used in conjunction with solid-state modulation and detection circuits.

With the laser TV system, you can expect a range up to 50 ft without special optics. For extended range, you can use a telescope and/or a converging lens. More about range later in the article.

Overall System. The block diagram of the overall laser TV system is shown in Fig. 1. The video (or audio, not both simultaneously) output signal from the TV camera is typically on the order of 1 volt peak-to-peak. This signal is fed to the laser modulator, which is designed to provide a gain of 2 mA/volt. Hence, the 1-volt p-p video output signal from the camera, after passing through the modulator, is converted to a 2-mA p-p signal that current-drives the laser tube.

The gain of the laser tube is about 0.1 mW/mA, while the laser detector has a gain of 1.25 mA/mW. The r-f oscillator in the detector is tunable over a 60- to 72-MHz range to permit the system to operate on TV channel 3 or channel 4, whichever is not in use in your area.

The output of the r-f modulator is an amplitude-modulated (AM) signal that is adjustable from 0 to 5 mV rms. This signal can be fed into an ordinary TV receiver through its vhf antenna terminals by means of 300-ohm twin-lead cable.

Laser/Modulator Circuit. In the laser/modulator power supply, shown schematically in Fig. 2, *T1*, *C5-C8*, and *D9-D14* are arranged in a voltage doubler configuration that serves as the main high-voltage supply. This supply delivers about 1700 volts to the laser tube. Diodes *D1-D8* and capacitors *C1-C4* form two more voltage doublers that are "stacked" on top of the main high-voltage supply for ionizing the gas in the laser tube. As soon as ionization is complete, current starts to flow through the laser tube. However, the values of *C1-C4* are too low to support the 5-mA tube current. So, the starting voltage collapses and only the main sustaining voltage remains.

Transformer *T2* and its associated rectifiers (*D15-D18*) and filter capacitors (*C9-C14*) make up

ANOTHER

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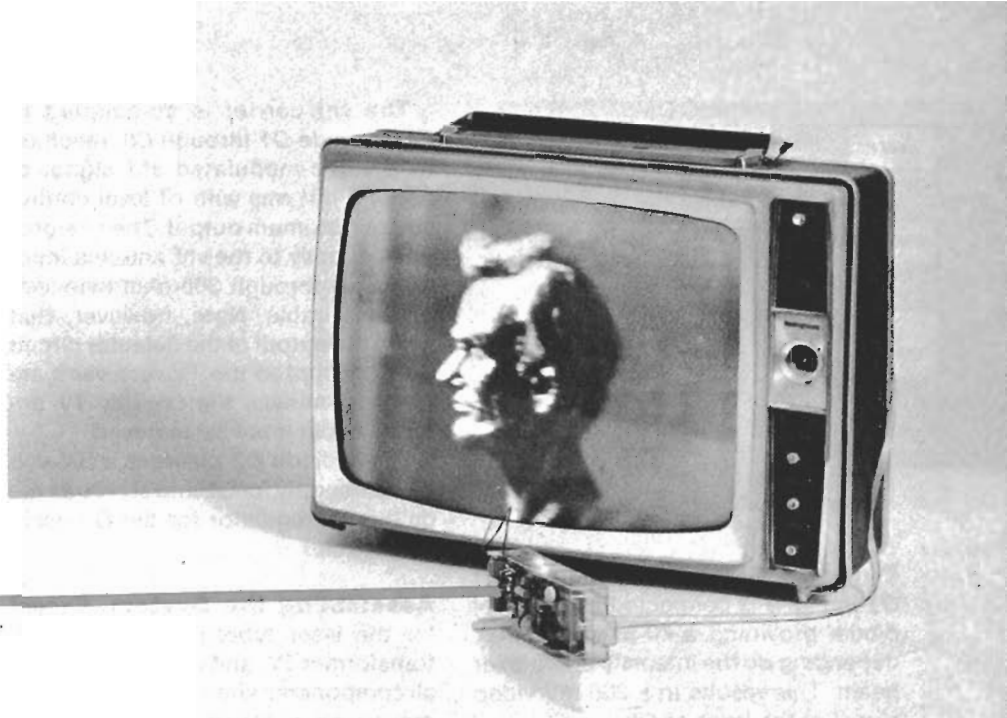


BUILD A

Laser TV System

BY GIANCARLO PUNIS
AND JOSEPH O'DONNELL

Now you can transmit and receive black and white TV pictures over a substantial distance with a license-free laser beam video link

the low-voltage supply that delivers the +20- and −20-volt lines for the low-voltage portions of the modulator.

High-impedance amplifier *Q1* preamplifies low-level microphone signals of about 0.1 volt p-p to the 1-volt p-p level required to drive *Q2* to obtain the full 15-percent modulation. (See Fig. 3 for the modulator schematic diagram.) The high-level 1-volt p-p video input at *J2* and the collector of *Q1* are both ac-coupled to the base of *Q2* and, therefore, to each other. Hence, when using either of the *J1* (audio) or *J2* (video) inputs, it will be necessary to disconnect the unused input. This is important to prevent interference between the two signals as well as to prevent loading *Q1*'s collector.

Transistors *Q2*-*Q4* each provide some gain at the lower frequencies and one stage each of high-frequency boost, starting at about 250 kHz and ending at about 1 MHz. The boost characteristics are achieved by the RC networks used as emitter loads for the transistors. In addition, there are two broadly tuned traps consisting of *C24*/*L1*/*R16* and *C25*/*L2*/*R22* centered at 160 kHz and 330 kHz.

The frequency response of the laser tube only is shown in Fig. 4A. The strong peak at 170 kHz would cause severe overshoots and ringing on the fast edges of TV sync pulses or any sharp white-to-black transitions. In addition, the −3-dB bandwidth is only 250 kHz wide, with correspondingly poor picture resolution. So, to smooth out the frequency response and to extend it beyond 500 kHz, the modulator combines boost circuitry and traps to yield the compensating response shown in Fig. 4B. Combining the A and B response curves, the overall laser tube/modulator system has the frequency response characteristic shown in Fig. 4C, which is adequate for most applications.

The frequency-compensated signal is coupled to *Q5*, which acts as a current source for both the dc bias (trimmed to 5 mA by *R33*) and the ac signal currents for the laser tube. Except for a small amount of current through *R27* and *R28*, the current sourced by *Q5* also flows through *Q6* and *Q7*, ballast resistor *R26*, and the laser tube. Each rated at 300 volts, *Q6* and *Q7* are cascaded to act as one transistor with a 600-volt break-down rating.

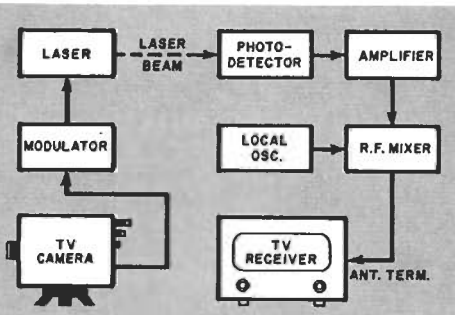


Fig. 1. Block shows the basic arrangement of the laser video link.

Detector Circuit. Phototransistor *Q1* in Fig. 5 is connected as a photodiode, providing a 40-μA p-p signal, depending on the intensity of the laser beam. This results in a 200-mV video signal at the base of *Q2*.

Transistor *Q3* is a Hartley oscillator stage, whose operating frequency is determined by *L1* (printed on the circuit board as part of the conductor pattern), *C7*, and *C8*. Capacitor *C7* is adjustable to permit the circuit to operate on either the TV channel 3 or channel 4 frequency.

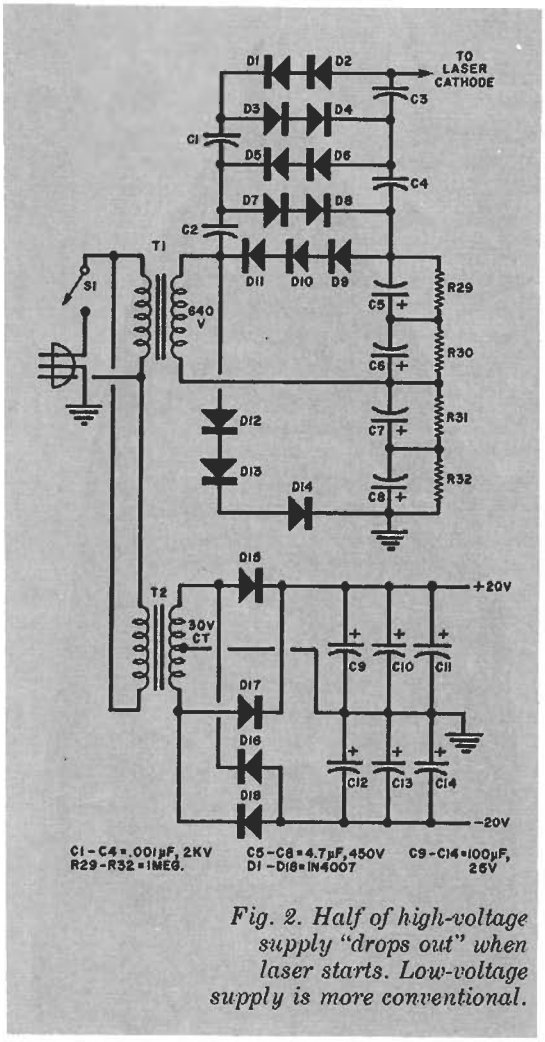


Fig. 2. Half of high-voltage supply "drops out" when laser starts. Low-voltage supply is more conventional.

The vhf carrier is ac-coupled to mixer diode *D1* through *C6*, resulting in a video-modulated vhf signal of about 5 mV rms with r-f level control set for maximum output. The r-f signal goes directly to the vhf antenna input terminals through 300-ohm twin-lead antenna cable. Note, however, that when the output of the detector circuit is connected to the TV receiver's antenna terminals, the regular TV antenna cable must be removed.

Zener diode *D2* provides a 3.6-volt dc bias supply for *Q2* and serves as the dc supply regulator for the *Q3* oscillator circuit.

Assembling the System. Except for the laser tube, jacks *J1* and *J2*, transformer *T1*, and power switch *S1*, all components shown in Figs. 2 and 3 mount on a single printed circuit board. The actual-size etching and drilling guide and components placement diagram for the laser/modulator system are shown in Fig. 6. To permit the etching and drilling guide to be reproduced without reduction, it is shown in two parts. The left edge of the lower portion butts against the right edge of the upper portion, with the ground bus (heavy black areas) aligned.

When wiring the circuit board according to the diagram in Fig. 6, take care to properly orient the components. Pay particular attention to electrolytic capacitor polarities, transistor basing, and *T2*'s lead routing. Bear in mind that *T2* and the laser tube mount on the *foil* side of the board. Also, all resistors (except *R26* and *R29-R32*) and *L1* and *L2* mount on-end. The rest of the components mount on the board in the conventional manner. Note that only *C5-C8* are axial-lead capacitors, designed to mount flat on the board, while all other electrolytic capacitors are upright types.

Potentially lethal voltages are developed in the laser circuit. Consequently, it is imperative that the entire assembly be mounted inside a rugged — preferably metal — enclosure. Use only nylon screws when mounting anything inside the enclosure to prevent access to any high-voltage points in the circuit once the system is assembled. Select an enclosure that is large enough to accommodate the laser tube, pc board assembly, and transformer *T1*. Mount closed-circuit miniature phone jack *J1*, BNC jack *J2*, and power switch *S1* on the rear wall of the enclosure. In another hole on this wall should be the three-conductor power cord, held in place with a plastic strain relief. (Or line the hole with a rubber grommet, pass the line cord through, and tie a knot in the cord.)

The exit hole for the laser beam must be drilled through the enclosure's front wall, directly in line with the beam's travel. Use a ¼-in. (6.35-mm) diameter drill bit. If possible, mount a tubular flange with a ferrous outer ring as a bezel over the hole. The ferrous ring is a convenience feature that supports the various lenses that come mounted in circular magnets in the event you decide to perform other experiments using the laser.

Solder push-on connectors to one end of a red and a black 3-in. (7.72-cm) or less pieces of 5-kV test-lead cable. Shrink tubing over the connections. Then solder the free end of the red cable to point A and the black cable to point C on the foil side of the pc board.

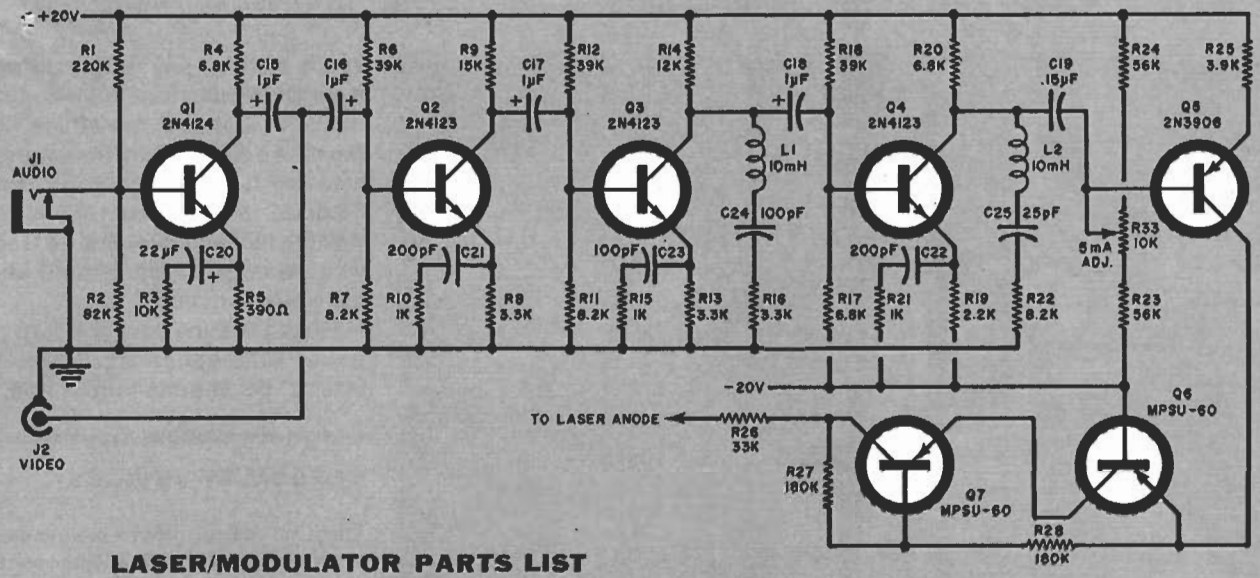
Drill ⅛-in. (3.27-mm) holes through the donuts marked X on the pc board. Mount a tube mounting clamp at each hole location. Orient the laser tube so that its pin-connector end is toward *T2* and the anode pin on the narrow neck points toward the red cable. Set the tube down in the clamps and anchor it in place with rubber hold downs. Caution: Do not mount or handle the laser tube by its narrow necks.

Slip the red cable connector onto the anode pin of the laser tube. Then locate the cathode pin on the opposite side of the tube from the anode pin, and slip the black cable's connector onto it.

Solder 10-in. (25.4-cm) long pieces of hookup wire, preferably color coded for easy identification, to the remaining holes in the pc board. Slip 1-in. (2.54-cm) long pieces of heat-shrinkable tubing over the wires connected to the *T1* secondary points. Then mount the board in the enclosure with nylon screws and insulated spacers.

Mount *T1* on the floor of the enclosure. Then locate the leads with the shrinkable tubing on them. Route these leads along the component side of the board, and connect and solder them to *T1*'s secondary winding, trimming as necessary. Shrink the tubing tightly over the connections. Complete the wiring, referring to Figs. 2, 3, and 6.

Assembling the detector is a very simple, straightforward process. Except for phototransistor *Q1* (Fig. 5), output connector, and power switch,



LASER/MODULATOR PARTS LIST

C1-C4—0.001-μF, 2-kV ceramic disc capacitor
C5-C8—4.7-μF, 450-volt axial-lead electrolytic capacitor
C9-C14—100-μF, 25-volt upright electrolytic capacitor
C15-C18—1-μF, 50-volt upright electrolytic capacitor
C19—0.15-μF disc capacitor
C20—22-μF, 10-volt upright electrolytic capacitor
C21, C22—200-pF, 100-volt disc capacitor
C23, C24—100-pF, 100-volt disc capacitor
C25—25-pF, 100-volt disc capacitor
D1-D18—1000-PIV, 1-A rectifier (1N4007 or similar)
J1—Miniature shorting-type phone jack
J2—BNC jack
L1, L2—10-mH choke
Q1—2N4124 transistor
Q2-Q4—2N4123 transistor
Q5—2N3906 transistor
Q6, Q7—MPSU-60 transistor (Motorola)
R1—220,000-ohm
R2—82,000-ohm
R3—10,000-ohm
R4, R17, R20—6800-ohm
R5—390-ohm
R6, R12, R18—39,000-ohm
R7, R11, R22—8200-ohm
R8, R13, R16—3300-ohm
R9—15,000-ohm
R10, R15, R21—1000-ohm
R14—12,000-ohm
R19—2200-ohm
R23, R24—56,000-ohm
R25—3900-ohm
R27, R28—180,000-ohm
R29-R32—1-megohm
} All resistors ½-watt, 10%
R26—33,000-ohm, 2-watt resistor
R33—10,000-ohm upright pc trimmer potentiometer
S1—Spst switch
T1—640-volt, 25-mA power transformer
T2—Dual 15-volt, 25-mA power transformer
Misc.—Metal enclosure; printed circuit board; laser tube No. PE719; mounting clamps for laser tube mounting; 5-kV test-lead cable; three-conductor line cord; pin connectors (2) for anode and cathode cables; heat-shrinkable tubing; rubber grommet or plastic cable clamp/strain relief; nylon mounting hardware and insulated spacers; 1000—ohm, ½-watt resistor (for transmitter checkout); hookup wire; solder; etc.
Note: The following items are available from Metrologic Instruments, Inc., 143 Harding Ave., Bellmawr, NJ 08030: No. PE719 laser tube ($96); No. PE640 640-volt power transformer ($7); No. PE101 etched and drilled transmitter pc board ($6); No. PE201 etched and drilled detector/modulator pc board ($3); No. PE669 complete kit of transmitter parts, including laser tube, pc board, transformers, metal housing, etc. ($124.50); No. PE301 complete kit of detector/modulator parts, including housing ($25); No. PE500 complete kits of transmitter and detector/modulator parts (not including TV camera) ($148). All prices postpaid. Canadian readers can order from Merlan Scientific, Ltd., 825 Lake Shore Rd., Port Credit, Ontario, Canada.

Fig. 3. Frequency response of video amplifier is "tailored" to improve laser tube's response. Resulting video modulates laser beam.

CAUTION

Never look into the laser beam proper or directly into its reflection.

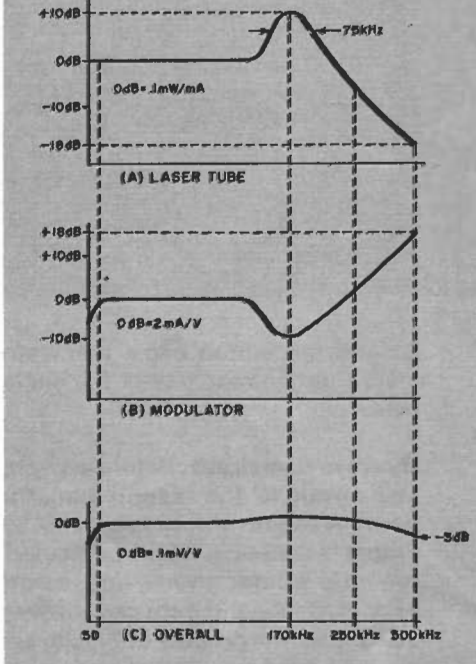
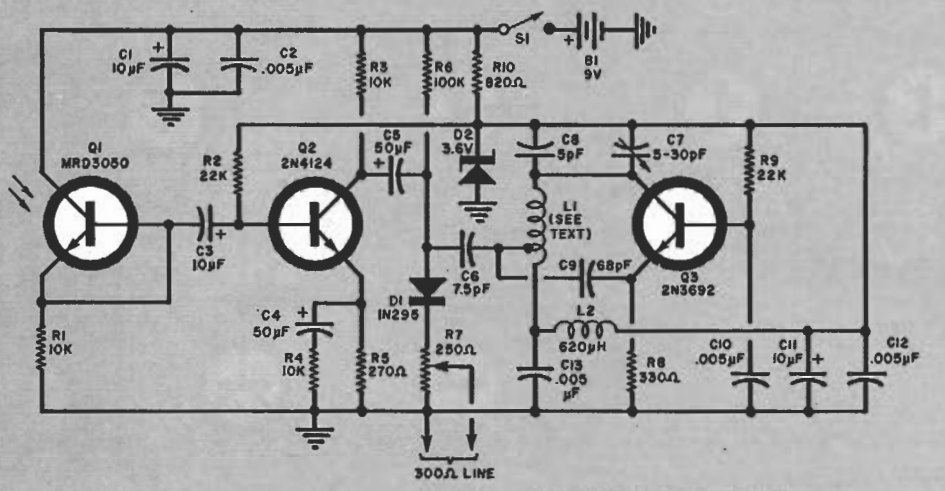


Fig. 4. Response curves of laser tube (A) and modulator (B) combine to provide flat overall system response (C).

everything mounts on a small pc board. The actual-size etching and drilling guide and components placement diagram for the detector are shown in Fig. 7. Note that coil *L1* is part of the printed wiring.

The on-board components mount in the conventional manner. Just be sure to properly polarize the electrolytic capacitors and transistors. Transistor *Q1* mounts in a hole on one wall of the metal enclosure, its lens "looking" to the outside world. The phototransistor can be held in place with a bead of clear epoxy or plastic glue.

Install the battery on the floor of the enclosure, under the pc board assembly, in a battery clip. And power switch



DETECTOR/R-F MODULATOR PARTS LIST

B1—9-volt battery
C1, C3, C11—10-μF, 10-volt electrolytic capacitor
C2, C10, C12, C13—0.005-μF disc capacitor
C4, C5—50-μF, 10-volt electrolytic capacitor
C6—7.5-pF silver-mica capacitor
C7—5-30-pF miniature ceramic trimmer capacitor
C8—5-pF silver-mica capacitor
C9—68-pF silver-mica capacitor
D1—1N295 diode
D2—3.6-volt zener diode (1N747 or similar)
L1—R-f coil (etched on pc board)
L2—620-μH choke
Q1—MRD-3050 phototransistor (Motorola)
Q2—2N4124 transistor
Q3—2N3692 transistor
R1, R3, R4—10,000-ohm
R2, R9—22,000-ohm
R5—270-ohm
R6—100,000-ohm
R8—330-ohm
R10—820-ohm
(All resistors ½-watt, 10%)
R7—250-ohm vertical pc-type trimmer potentiometer
S1—Spst switch (optional)
Misc.—Chassis box; printed-circuit board; battery clip; output cable connector (optional); 300-ohm twin-lead cable; hookup wire; spacers (2); hardware; etc.
(Note: For kit information, see Laser/Modulator Parts List.)

Fig. 5. Photodetector modulates oscillator on channel 3 or 4 to generate signal that goes via 300-ohm line to television receiver's antenna terminals.

S1 and the output cable connector mount on the rear wall of the enclosure.

System Checkout. Before applying any power to the laser/modulator, double check all components for proper installation. Check particularly for cold solder joints and solder bridges. If everything checks out okay, disconnect the primary of *T1*, *Q6*, and the laser tube from the circuit.

Temporarily connect a 1000-ohm, ½-watt resistor between *Q5*'s collector and the −20-volt bus. Turn on the power. Now, using a high-impedance multimeter (a 20,000-ohms/volt VOM will do), check to verify that +20 and −20 volts dc is available from the power supply. Because of the temporary collector load, *Q5*'s collector will be at about −15 volts. Adjust *R33* for a reading of exactly 5 volts across the temporarily installed 1000-ohm resistor. Alternatively, insert a milliammeter in series with the resistor and adjust *R33* for a reading of exactly 5 mA. Turn off the power and disconnect the line cord from the ac receptacle.

Wire *T1* into the circuit. Before applying power, remember that potentially lethal voltages are present at the negative end of *C5* and the cathode (black) lead. Keep the latter well away from ground and the low-voltage circuits. The starting voltage at the top of *C3* can be checked, but the meter has a loading effect on the circuit. So, do not expect to read more than about 3.5 kV when making measurements on the 5-kV range with a 20,000-ohms/volt meter. Turn off the power, and remove the plug from the ac receptacle. After power is removed, *do not touch any part of the circuit for about five minutes* until the high-voltage charges on the capacitors dissipate.

When the circuit is safe to handle again, remove the temporary resistor from *Q5*'s collector circuit and reconnect *Q6*. Connect the anode lead to the tube and a 0-10-mA meter in series with the tube's cathode pin and the cathode (black) lead. Make certain that the milliammeter and its leads are well separated from ground and the low-voltage circuits.

Plug in the line cord and turn on the power. After a short lag, the gas in the laser tube should ionize and glow

CLASS-1 TV DEVICES

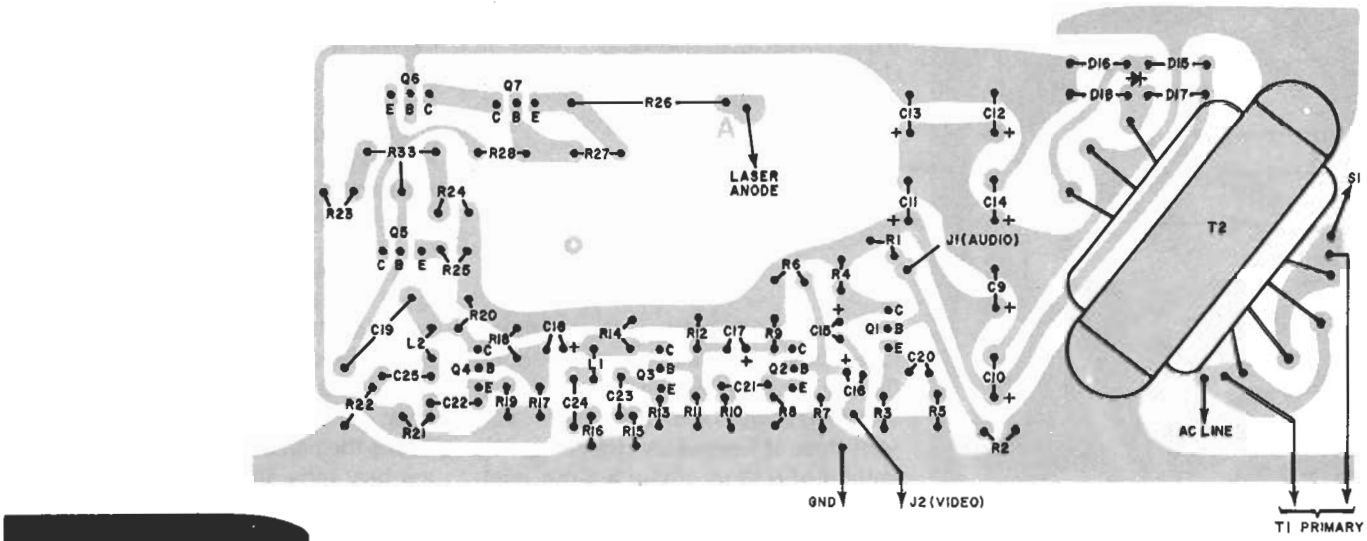
There has recently been a proliferation of electronic games designed to be used with a conventional TV receiver. These so-called "Class-1" devices apply a modulated low-level r-f carrier signal directly to the receiver's antenna terminals. Because they might produce interference, the FCC has placed restrictions on the manufacture, sale, and use of Class-1 devices, of which the laser detector/r-f modulator in this article is one.

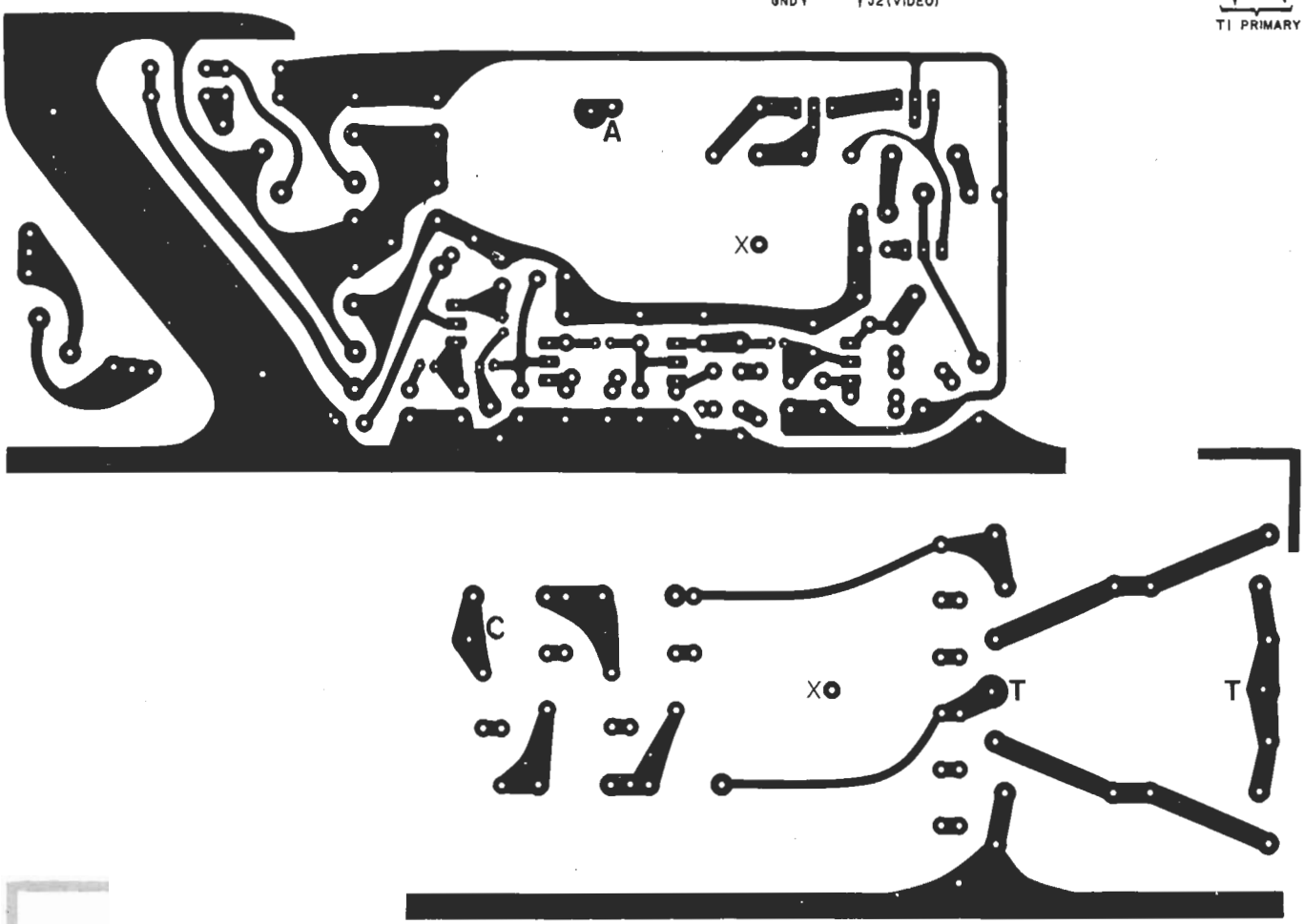
Class-1 TV device requirements are:

1. They must operate on a channel allocated for vhf or uhf broadcast TV.
2. They must transmit the r-f signal to the TV receiver by wire or cable.
3. The r-f output level must be less than 6 mV rms into a 300-ohm output.
4. A transfer switch with 60 dB of isolation must be used for switching the antenna terminals between the TV antenna and the Class-1 device.
5. The peak envelope power of any spurious emission at frequencies 3 MHz or more from either edge of the standard TV channel being used must be 30 dB or more below the peak envelope power of the in-band signal.
6. Radiated EMI from the device must be less than 15 μV/meter at 2.6 ft. (0.79 m) from the detector modulator.
7. The device must be formally type approved by the FCC. In the case of a kit-form Class-1 device, only the manufacturer of the kit is required to obtain type approval.

The above list of regulations applies only to the detector/r-f modulator portion of the laser TV system. No specific restrictions are placed on the laser transmitter. With regard to the isolating switch, the laser TV system has none, but removing the TV receiver's antenna will satisfy the requirement. (Bear in mind that it is illegal to have the detector's output cable and the TV antenna hooked up to the TV receiver at the same time.)

The detector/r-f modulator has been type approved by the FCC. However, it is strongly urged that if you build your own instead of buying the kit from Metrologic, you faithfully follow the pc layout and assembly instructions presented in this article.





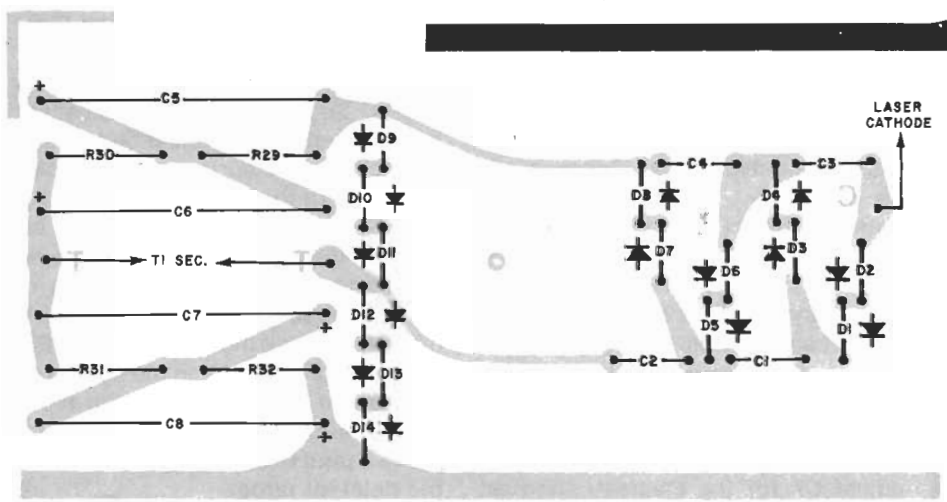


Fig. 6. Actual-size etching and drilling guide for power supply and modulator is shown in two parts (center). The component-placement guides are shown above (top) and below (left) their respective etching guides.

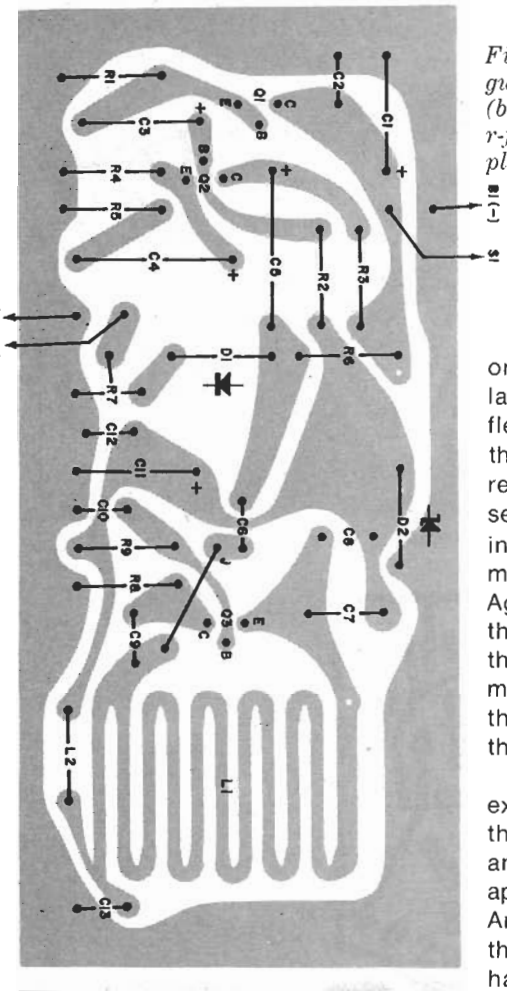


Fig. 7. Actual-size etching guide for detector/modulator (bottom) features printed r-f oscillator coil. Component-placement guide is at left.

orange. (Caution: Never look into the laser beam or directly into the reflected beam.) The milliammeter at this time should indicate a 5-mA current flow. If necessary, touch up the setting of *R33* to obtain a 5-mA reading. Then turn off the power and remove the line cord from the ac line. Again, do not touch the assembly until the high-voltage charges have bled off the electrolytic capacitors. Then remove the milliammeter and reconnect the black cable to the cathode pin on the laser tube.

Reapply power to the system. Now, exercising extreme caution, measure the collector-emitter voltages on *Q6* and *Q7*. Both transistors should have approximately the same voltage drop. An unequal drop indicates that something is wrong, meaning that you will have to troubleshoot the circuit.

Since the detector employs only a low-voltage battery supply, it is safer to work on than the laser/modulator. The emitter of *Q1* should be at 0 volt with no light entering the phototransistor through its lens. With the laser beam impinging on the sensitive surface of *Q1*, the emitter will be at about 2 volts. (Note: A 20,000-ohms/volt meter will load this down to about 1.6 volts.)

Connect the r-f output line to the antenna terminals of a conventional TV receiver, after first removing the TV antenna cable. Adjust *C7* for operation on either channel 3 or channel 4, whichever is not in use in your area. Now, modulating the laser with a TV camera, an oscilloscope should reveal the composite video signal at the emitter of *Q1* at a level of about 220 mV p-p. (Almost any type of oscilloscope can be used here.) The waveform at the cathode of *D1* will be the video-modulated r-f signal operating at about a 5-mV p-p level. It may be necessary to adjust *R6* to obtain the correct signal level.

If you do not have access to a scope, set potentiometer *R7* to the middle of its range. Set the TV receiver to the unused channel 3 or 4. Very slowly adjust *C7* for the clearest, sharpest picture on the screen of the TV receiver, while video-modulating the laser. Then adjust pot *R7*, and the TV receiver's brightness and contrast controls for the best picture quality. Also, if the TV camera does not have a wide agc light range, its lens should be adjusted as well for best picture.

Setup and Use. In setting up the laser TV system, bear in mind that adequate light must be on the subject to be televised. Avoid subjects (pictures) that have very bright and very dark contrasts close to each other. Focus the camera carefully, and select the best lens opening for the subject to be televised.

When mounting the laser/modulator and receiver, use solid supports to obviate vibrations and shifts that might cause the laser beam to miss the phototransistor in the detector and result in transmission drop-outs.

The uncollimated beam from the laser has a 1-milliradian divergence characteristic that causes the spot to spread to about 1 meter in diameter at 1000 meters. So, if you plan on long-distance transmission of the laser beam, you must use collimation to keep the beam as narrow as possible. The collimator is simply a telescope used backwards, with the laser beam fed into the eye-piece and exiting through the large end of the telescope. You can use either a reflecting or a refracting telescope.

The greater the power of the telescope used, the greater the range you can expect and the tighter the laser beam. However, with increasing range, optical alignment becomes a critical factor. So use a solid mount for the telescope.

Range can also be increased with a light-gathering lens at the detector end. This is comparable to using a high-gain antenna for radio waves. You can buy lightweight plastic Fresnel lenses measuring up to 11 in. (27.94 cm) square at very reasonable prices. Such lenses make excellent light gatherers. They must be focused on the sensitive surface of the phototransistor in the detector.

Long-distance alignment can be simplified in several ways. Use a rigid mounting system and some form of vernier positioner (for fine adjustment) for aiming the laser. Perform the alignment at night when the bright red laser beam is easier to see. For night setups, a bicycle safety reflector will prove useful in following the beam to the detector target. ◈