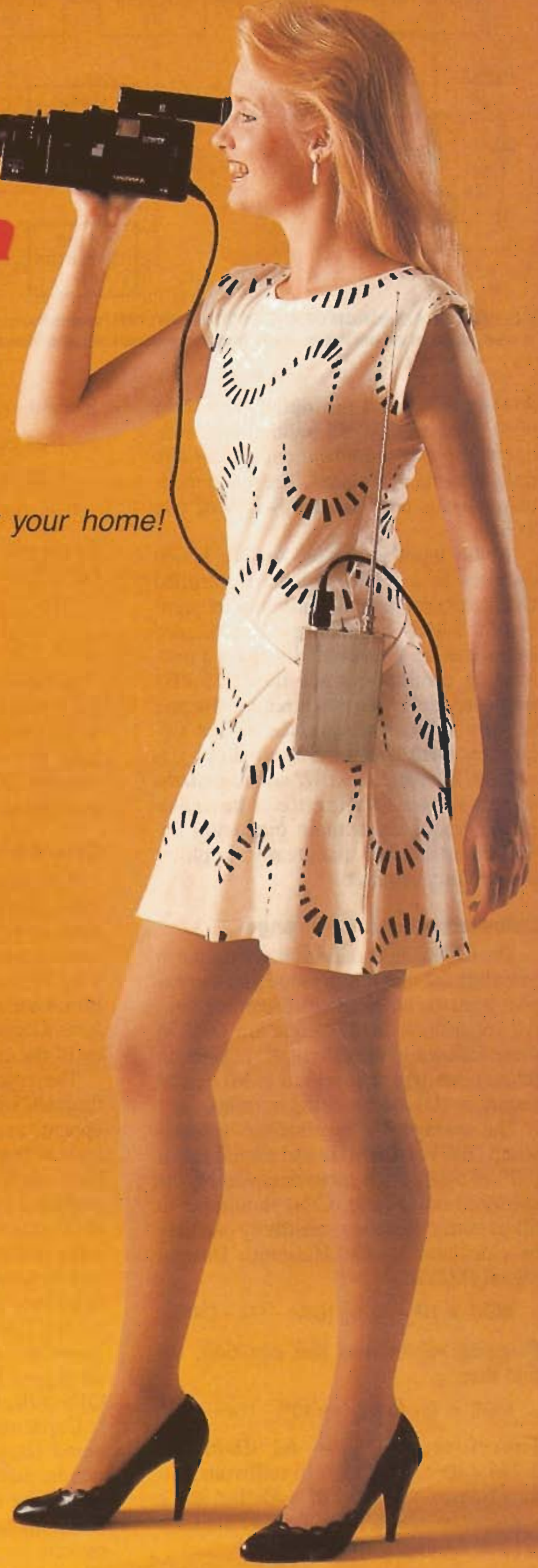
Wireless Video Camera Link



Use this high-performance video-camera link to transmit signals from your video camera to your VCR, or from your VCR to TV's all over your home!

WILLIAM SHEETS AND RUDOLF F. GRAF

IF YOU ACHE TO BE FREE OF THE CUMBERSOME "UMBILICAL cord" that connects your video camera to your VCR, then our high-performance wireless video link is just what you need. Its small size and light weight make it a natural for "wireless" video-camera recording. You'll be able to capture all those shots you're missing because your camera cord is just a little too short, or because it restricts your maneuverability in tight places.

Our wireless link can transmit high-quality audio and video to any UHF TV channel. Low power requirements allow the transmitter to run on AA penlight batteries, and the PC board can be mounted easily in a small metal case, complete with batteries and a short antenna. The transmitter is crystal-controlled and it's easy to build and align. In addition, it uses low-cost, easy-to-get components, and it can be built for well under $100.

Transmitter circuit overview

The block diagram of the wireless video link is shown in Fig. 1. The RF chain is fairly conventional. Its first stage is a crystal-controlled oscillator (Q1) with a frequency of 60 to 65 MHz, which is one-eighth the final output frequency. For example, our prototype used a crystal frequency of 60.40625 MHz, which gives a final output frequency of 483.25 MHz—the video-carrier frequency of UHF channel sixteen.

The oscillator produces a signal of about +6 dBm (4 milliwatts) that drives three stages of frequency doublers. The combined action of those doublers multiplies the input frequency by eight for a final output frequency of (nominally) 500 MHz. Double-tuned circuits are used between each stage to help reduce spurious outputs that might cause unwanted interference.

The video input signal (from your VCR, video camera, etc.) drives a video modulator (Q6 and Q7) that adds the video signal to the +12-volt line supplying power to the final

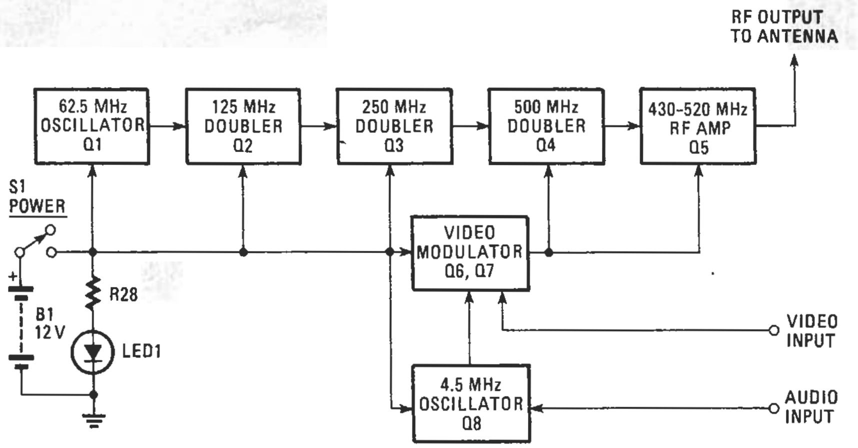


FIG. 1—BLOCK DIAGRAM OF THE TV TRANSMITTER reveals the overall simplicity of the circuit, which is composed of an oscillator, three frequency doublers, and video and audio modulators.

doubler (Q4) and the output amplifier (Q5). That method of modulation is similar to the way a conventional AM-radio transmitter is modulated. The video modulator has a nominal bandwidth of five MHz.

Audio input is applied to Q8, which operates as a VCO (*V*oltage *C*ontrolled *O*scillator) running at a nominal frequency of 4.5 MHz to produce the modulated sound carrier. For simplicity, Q8 is a free-running oscillator, since the ±25-kHz frequency deviation that is required would be very difficult to produce at that frequency with a crystal-controlled oscillator. Besides, most TV sound systems will accept a ±10-kHz error in the sound-carrier frequency without producing undue distortion, and that greatly simplifies the circuitry required.

Calculating maximum range

The following equations may be used to calculate the maximum range you can expect from the wireless video-camera link. All logarithms in this equation (and in those following) are calculated in base 10; frequencies (*f*) are specified in MHz; and distances (D) are specified in miles.

The average TV receiver has a bandwidth (BW) of 4.0 MHz and a noise factor (NF) of 6 dB. For a snow-free picture, the carrier-to-noise ratio (C/N) should be 40 dB or better. Receiver sensitivity can then be calculated as the *M*inimum *D*esired *S*ignal (MDS):

$$MDS = NF + 10 \log (BW) - 174 + C/N$$

Plugging values into that equation, we find that:

$$MDS = 6 + 10 \log (4 \times 10^6) - 174 + 40$$

Therefore, MDS = 62 dBm, or $0.794 \times 10^{-3} \times 273 = 216$ millivolts. So for a transmitter power of +15dBm and 2 isotropic antennas, that allows a *P*ath *L*oss (PL) of 87 dB.

$$PL = 37 + 20 \log (D) + 20 \log (f)$$

Isolating the distance factor we see that:

$$20 \log (D) = PL - 37 - 20 \log (f)$$

$$20 \log (D) = 87 - 37 - (20 \times 2.7)$$

$$\log (D) = -4/20 = -0.2$$

So the maximum range obtainable should be:

$$D = 10^{-0.2}$$

$$D = 0.6 \text{ mile} = 3100 \text{ feet}$$

However, you wouldn't really be able to get a range of 3100 feet because of reflections, loss from "dead spots," terrain loss, and obstacle shielding. However, a distance of several hundred feet is easily possible using a +12V supply.

Detailed circuit description

The complete schematic of the wireless video link is shown in Fig. 2; we'll discuss each stage in detail. Transistor Q1 is a common-base (or Colpitts) oscillator biased by resistors R1, R2, and R3. Inductor L4 and capacitors C3, C4, C5, and C8 form a circuit that is tuned to the frequency of the crystal.

The crystal is series-resonant at some frequency between 60 and 65 MHz, so it appears as a low impedance (50 ohms or less) at that frequency. Therefore Q1 will have sufficient gain as a common-base amplifier only at the resonant frequency of the crystal. Hence the signal developed at the junction of C4 and C5 will be amplified by Q1 only if that signal is at the same frequency as the crystal. At that frequency, Q1, has sufficient gain to oscillate because the ratio of the voltage initially developed between C4 and C5 to that at Q1's collector is greater than unity.

Capacitors C3 and C8 complete the tuned circuit; they also form a voltage divider that feeds the base of Q2 about one volt of the signal from Q1. Transistor Q2 functions as an overdriven amplifier that distorts its input signal and thereby produces harmonics of the input frequency. The second harmonic (120 MHz) is the

PARTS LIST

All resistors ¼-watt, 5% unless otherwise noted.

R1, R5, R11—22,000 ohms
R2, R6, R12, R16—4,700 ohms
R3, R7, R13—220 ohms
R4, R9, R10, R18, R19, R21, R25—100 ohms
R8, R14, R33—10 ohms
R15, R26, R35—100,000 ohms
R17, R28, R30—2200 ohms
R20, R22—470 ohms
R23, R27, R34—10,000 ohms
R24—3300 ohms
R29—82 ohms
R31—1000 ohms, linear taper potentiometer
R32—10,000 ohms, audio taper potentiometer

Capacitors

C1, C6, C15, C32, C38—0.01 µF 50 volts, cermaic disc
C2, C7, C9, C14, C16, C23, C26, C29, C30—470 pF cermaic disc
C3—33 pF, 5%, mica
C4, C19—15 pF, 5%, mica
C5—56 pF, 5%, mica
C8—82 pF, 5%, mica
C10—18 pF, 5%, mica
C11—2 pF, ±1pF, mica
C12—24 pF, 5%, mica
C13—39 pF, 5%, mica
C17—8 pF, 5%, mica
C18, C24—1 pF, ±1pF, mica
C20—12 pF, 5%, mica
C21, C27—47 pF, 5%, mica
C22, C25, C28—1–8 pF, polystyrene trimmer
C31, C33, C39—8.2 µF, 20 volts, tantalum
C34—470 pF, 5%, mica
C35—220 pF, 5%, mica
C36—5–60 pF, polystyrene trimmer
C37—100 pF, 5%, mica

Semiconductors

Q1–Q3, Q6—2N3563
Q4—2N3564
Q5, Q7—2N3866
Q8—MPF102
Q9—2N3565
LED1—standard red LED
D1—1N757 9V Zener
D2—MV2117 varactor
D3—1N4002

Other components

J1—Video camera jack
J2—BNC jack
J3—Coaxial power jack
L1—6.2 µH (see text)
L2, L3—0.074 µH (see text)
L4—0.15 µH (see text)
L5, L6—0.035 µH (see text)
L7, L8, L9—0.018 µH (see text)
L10, L11—5.6 µH
S1—SPST miniature toggle
XTAL—Crystal (see text)

Miscellaneous: Aluminum project case AA-penlight cell battery holders

Note: The following are available from North Country Radio, P. O. Box 53, Wykagl Station, New York 10804: Etched and drilled PC board, ferrite cores for coils L1 and L4, and crystal for Channel 14 or 15, $32.50; Complete set of all parts that mount on PC board, $69.95. In either case, be sure to specify channel.

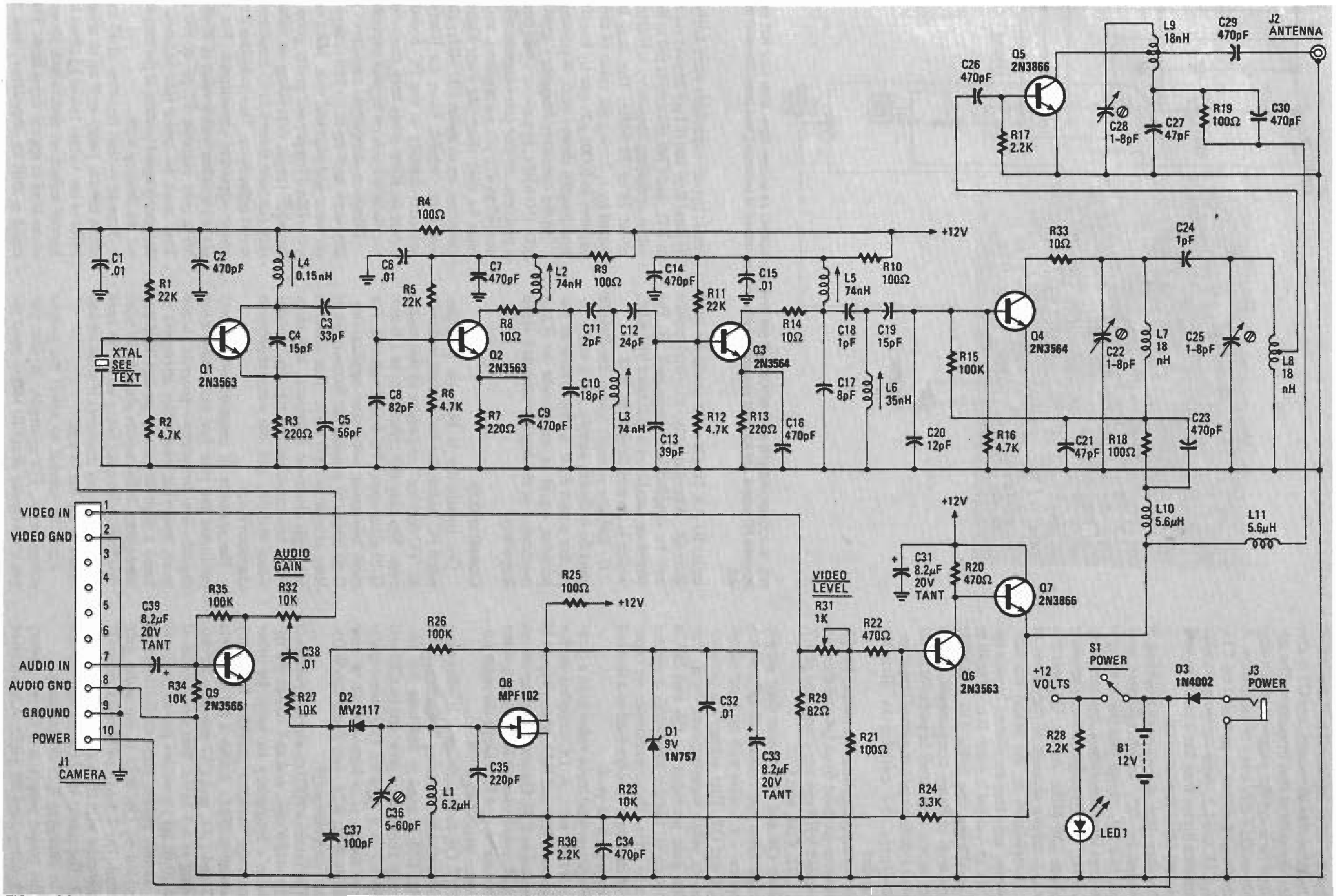


FIG. 2—COMPLETE SCHEMATIC OF THE TV TRANSMITTER is shown here. The circuit is straightforward, but see the text for information on winding coils L1–L9.

frequency we're interested in; L2 and C10 are tuned to that harmonic, and C8 is also series-resonant at that frequency. The additional base current supplied by C8 also improves Q2's efficiency of oscillation. A double-tuned circuit is provided by C11, C12, C13, and L3; those components filter harmonics higher than the second, as well as the 60-MHz fundamental.

Another stage of frequency doubling is provided by Q3, which operates very much like Q2, except that the tuned circuits at its input resonate at approximately 125 MHz, and its output circuits resonate at about 250 MHz. Again, Q4 operates like Q3, taking account of the values of the components in the tuned circuits. However, note that no emitter-bypass capacitor or resistor is used. It is difficult to get good bypassing in the 430–500-MHz range with ordinary components, and it takes only a very small impedance in the emitter to kill the power gain of that stage. Therefore, the emitter is directly grounded.

Power amplification is provided by Q5; it receives its drive from Q4 and the double-tuned VHF circuits composed of L7, L8, C22, C24, and C25.

Both Q4 and Q5 receive their supply voltage from the emitter of Q7, which supplies +4.5 volts with no input signal to Q4 and Q5. That voltage has positive-sync-tip video superimposed on it. The video gain provided by Q6 and Q7 is about eight, and the bandwidth is greater than 10 MHz. Those transistors are capable of driving a 75-ohm load to a level of 10 volts peak-to-peak.

Negative-sync input video from a camera, VCR, etc., is DC-coupled to the junction of R21 and R22. Video bypass is provided by C31. Gain and Q-point are set by R24; potentiometer R31 acts as a video gain control; and R29 keeps the input impedance around 75 ohms.

FET Q8 functions as a Hartley-type VCO with a free-running frequency of 4.5 MHz; C36 is used to fine-tune that frequency. Feedback is provided by C35 and C34; D2 is a varactor (variable-capacitance) diode. It is biased at about nine volts by R25, R26, and Zener diode D1, which also biases Q8.

The varactor (D2) changes capacitance at the audio rate, and that causes the oscillator's frequency to vary. In other words, the varactor provides frequency modulation (FM). Audio is fed to D2 via R27 and C38, and C37 provides RF bypassing at 4.5 MHz. The small value of C38 (0.01 μF) provides pre-emphasis to the audio. Audio pre-amplification is provided by Q9; R32 is the audio gain control. The 4.5-MHz FM signal from Q8 is summed with the video signal through R23. The sound-level carrier may be varied by changing R23 as necessary.

The power supply is a 12-volt battery pack composed of eight AA alkaline cells; 10 AA Ni-Cd cells could be used instead. Alternatively, external power may be coupled in through jack J3. The power-on condition is indicated by LED1, which is current-limited by R28.

If, for any reason, video bandwidth must be reduced, simply add a small capacitor across R24. It should have an impedance equal in magnitude to R24's impedance at the highest intended video frequency.

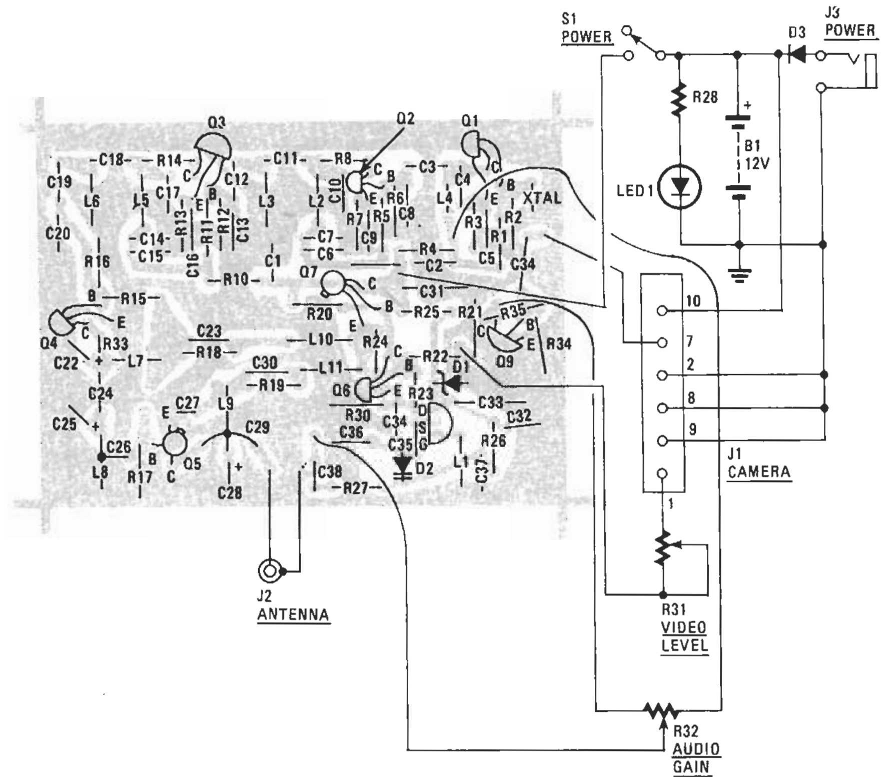


FIG. 3—COMPONENTS ARE MOUNTED ON THE PC BOARD as shown here. Note how R31 dangles from the PC board. We suggest you use a more secure method of mounting that potentiometer than we did.

Construction

Our transmitter is built on a single-sided PC board; the foil pattern is shown in "PC Service" elsewhere in this magazine. You may use either 0.8- or 1.6-mm G-10 glass-epoxy PC-board material. For most low-power, solid-state applications, G-10 epoxy is suitable for frequencies at least as high as 1000 MHz. That material has high electrical resistance, low electrical loss, mechanical rigidity, dimensional stability and low water-absorption characteristics.

The majority of construction projects published the past few years have been digital—low frequency—projects. Since many hobbyists have never attempted to build a high-frequency project like our transmitter, a few words about UHF construction techniques are in order. So bear with us for a few moments if what we say below is old hat to you.

First, be careful to select the proper components. For example, at low frequencies (under about 10 MHz), most ceramic bypass capacitors work fairly well. Typical 0.01 and 0.1 μF bypass capacitors in TTL and CMOS circuits fail to do their job as operating frequency is increased to about 25 or 30 MHz. That may be corrected by reducing the value of those capacitors to 0.001 μF, and by keeping the lead lengths short—zero, if possible.

As the operating frequency approaches 100–150 MHz, bypassing again becomes a problem. At that point even smaller values (47 to 470 pf) are required, and leads must be *very* short. At even higher frequencies, up to about 500 MHz, chip capacitors, which have no leads, are soldered directly to the PC board. The moral is: Keep leads very short—do not use ¼-inch leads on bypass capacitors.

Common electrolytic capacitors generally work well up to 10 MHz, depending on value and physical size. Mica capacitors (DM-15 type) are pretty good up to the VHF range, depending on value, but they can have from 5 to 15 nanohenries of series inductance. That inductance can increase *apparent* capacitance. For example, a capacitor with a value of 47 pF at 30 MHz may measure 82 pF at 150 MHz. That must be taken into account when designing tuned circuits at the frequencies we are dealing with.

Typical ¼-watt resistors of 15 to 1000 ohms behave pretty well up to about 250 MHz or so. Values below 15 ohms tend to appear inductive, and values above 1000 ohms tend to appear capacitive. That can cause a shift in impedance, and, theredered to the PC board. One end of capacitor C26 is mounted in the normal fashion, and the other end hangs from the approximate mid-point of L8's loop. Similarly, C29 is mounted from the board to the mid-point of L9; the lead then continues to the pad near the collector of Q5.

- L10 and L11 are standard 5.6 μH, 10%-tolerance chokes obtainable from the J.W. Miller Corporation, etc. They could also be wound from 36-gauge wire on ½-watt, 1-megohm carbon resistors if desired.

Last, install the transistors, making sure that they are oriented correctly and that their lead length is minimized.

We use a 10-pin camera jack for J1, but feel free to substitute whatever connectors you need. If no sound carrier is needed, R23, R25, CR2 and all other components associated with Q8 and Q9 can be omitted. Doing that will not affect the operation of the video portion of the transmitter. They can be added at a later date should audio transmission become necessary.

We chose not to leave space on the PC board for the audio- (R32) and video-input (R29, R31) components, since those components were unnecessary in our application. We used fixed-value resistors for R31 and R32, but small potentiometers could be mounted to the case and wires run to the PC board. If no gain control is necessary, R32 should be replaced by a fixed 10K resistor, and C38 should be connected directly to the collector of Q8.

Solder the coils to the PC board now, and solder short interconnecting wires from the board to the chassis components. Before applying power, check over your work: Make sure no solder bridges exist and make sure that all polarized components are correctly oriented.

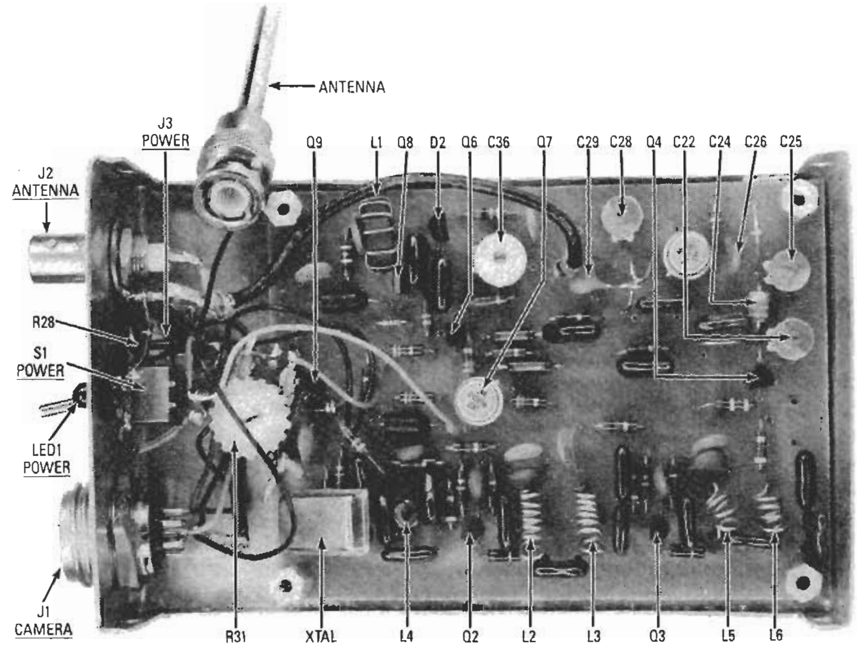


FIG. 4—MOST COMPONENTS ARE STANDARD, but note how C26 and C29 connect to L8 and L9, respectively. Also note the unequal turn-spacing of L2, L3, L5, and L6, which was brought on by tuning those coils. Finally, note the small slug L4 is wound around, and L1's toroidal core.

fore, the resonant frequency, of a tuned circuit. Stray inductive and capacitive reactances cause that shift.

Also, remember that every PC trace has inductance and capacitance. A PC pad may have, depending on size, several pF of capacitance to ground or to another PC pad. A long PC rail may act as an RF transmission line or even as a resonant circuit. It may also appear as an additional turn on a coupling transformer, by which unwanted signals might be radiated to other components or PC traces.

We hope you're not scared by all those cautions. We just want you to be aware of some of the problems involved in RF design and construction. But if you take care to duplicate our prototype exactly, the chances are that you'll have no problem getting your transmitter working. There is no "black magic" involved—only common sense and careful construction. Just be sure to use the same or equivalent parts—be careful!

After you have your components together, check the PC board over for shorts and opens, and make sure that the copper is clean and shiny. Then, referring to the parts-placement diagram in Fig. 3, insert and solder the components, starting with those that have the lowest profile (the resistors and diodes), and working up to the electrolytic and trimmer capacitors. Remember to cut all leads—especially the capacitors' leads—as short as possible. Don't overheat the semiconductors when soldering them to the PC board.

Now you're ready to wind and install the RF coils. Spread the turns of each coil evenly, but don't worry about spacing those turns perfectly, since the coils will be compressed and expanded later when you tune up your transmitter. You can see in the photo (Fig. 4) how our prototype's coils turned out.

- L1 is eight turns of 22-gauge wire wound on a Ferroxcube 768T188 toroid core made from 4C4 ferrite.
- L2 and L3 are seven turns of 22-gauge wire wound on a #26 drill bit. Of course, remove the drill bit after the coil is completed.
- L4 is wound around a standard 10-32 screw thread. The screw should be removed after the coil is completed. Then L4 should be fitted with a ferrite slug. You may be able to find an appropriate slug in an old TV, radio, or CB radio. Best results will be obtained when the slug is taken from a circuit that operates in the 25–100-MHz range, such as a TV IF circuit, or the front end of an FM radio. But it's not really critical, and almost anything should work (provided it's made of ferrite) as a last resort. If necessary, L4's diameter, and number of turns, could be changed to fit the slug you have.
- L5 and L6 are three turns of 22-gauge wire wound on a #26 drill bit.
- L7, L8, and L9 are merely 1.5 cm loops of wire wound on a ⅜-inch form and sol-

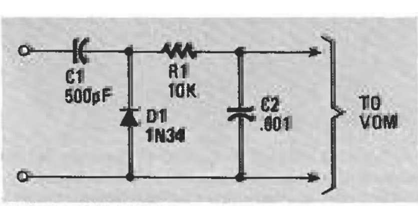


FIG. 5—RF-PROBE may be used with any VOM or DVM that has sensitivity greater than 20K ohms/volt.

Testing and alignment

The following equipment is necessary to align the transmitter:

- VOM or DVM having sensitivity of at least 20,000 ohms/volt
- RF probe
- Video source (VCR or camera)
- TV set or monitor
- 50-ohm dummy load

If an RF probe is not available, you can use the circuit shown in Fig. 5 with your voltmeter. If you have no 50-ohm dummy load, you can use a 51-ohm, ¼-watt resistor. One handy gadget to have is a tuning wand: a plastic rod with a ferrite slug at one end and a brass slug at the other. The inductance of a coil can be increased or decreased by placing the ferrite or the brass slug, respectively, near the coil.

Apply power and check for +12V at R4, R9, R10 and the collector of Q7. Check for +9V at the drain of Q8. Then check for 1.0 to 1.5 volts at the emitters of Q1, Q2, and Q3. Check for +4.5 to

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+ 5.5 volts at the emitter of Q7, and check for + 4.5V at the collectors of Q4 and Q5. The emitter of Q7 may show 4–7 volts—that's OK. Also, Q7 will normally run somewhat warm to the touch.

If all DC voltages check out, you can begin alignment. First, check the voltage at the collector of Q5. As you ground the base of Q6, that voltage should increase to over 10 if the modulator is working.

Next, connect the RF probe to the junction of C3 and C8. Tune L4 until Q1 starts to oscillate, as indicated by a reading of 0.5 to 1.0 volts on the VOM. Now connect the RF probe to the base of Q3 and spread or squeeze the turns of both L2 and L3 to obtain maximum voltage. Now connect the RF probe to the base of Q4 and adjust the turn spacing of L5 and L6 for a maximum voltage. Now, re-adjust L2, L3, and L4 to maximize the voltage reading. Connect the voltmeter to the base of Q5 and adjust trimmers C22 and C25 for maximum reading. Re-adjust L5 and L6.

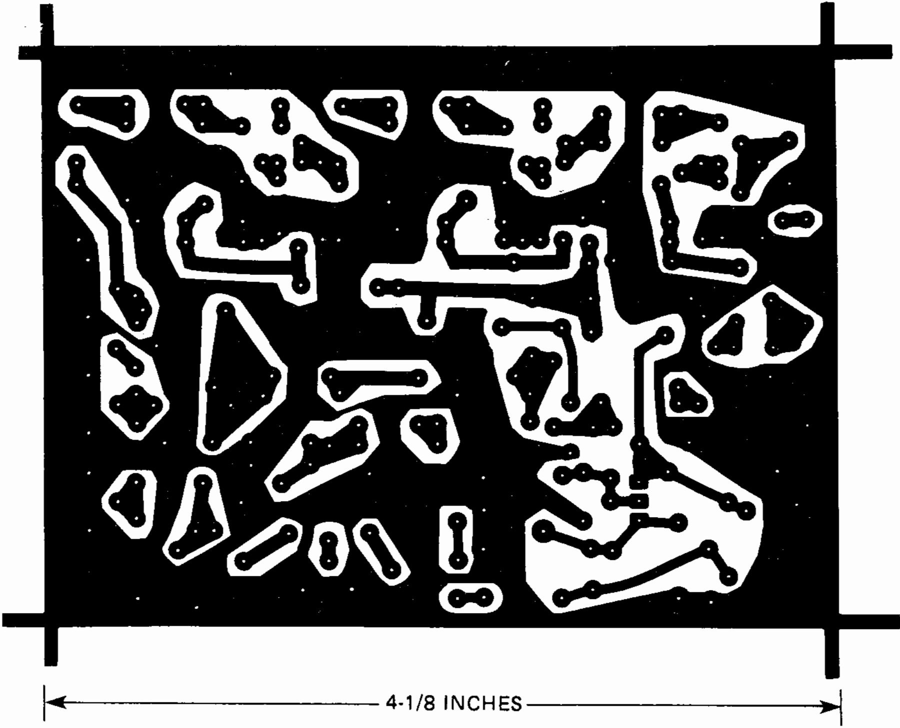
Now connect the dummy load to J2, and connect the RF probe across that load. Adjust C22, C25, C28 and the tap positions on both L8 and L9 until no further increase in output can be observed.

If one stage has no output, the cause may be misalignment of (or circuit trouble in) the preceding stage. It may be necessary in some instances to add or subtract a turn from L2, L3, L5, or L6 if proper adjustment cannot be obtained by adjusting turn spacing. If a coil's turns are spread far apart, and the alignment calls for even more spacing, a turn should be removed. On the other hand, if a coil has to be "crushed" together, add a turn. (But make a new coil rather than splicing on more wire.)

Now tune the TV receiver to the transmitter's output frequency. You should see a blank raster when the transmitter is turned on. Connect a video signal to the input jack (J1) and adjust video level so that a stable picture is obtained. Increase the video level until tearing or rolling develops; that indicates sync-tip compression. Retune the Q4 and Q5 stages for best picture quality without tearing.

Adjust C36 for clearest audio while applying an audio signal to C38. Be careful not to overdeviate or misadjust the 4.5-MHz oscillator frequency. A frequency counter can be helpful for that. Connect it to the emitter of Q7 and adjust C36 for a frequency of 4.500 MHz with no video input (short R21 to ground).

That completes alignment and testing of the wireless video link. A very short antenna (about one inch) connected to a 51 ohm resistor makes a good limited-range antenna. For greater range, a six-inch whip antenna could be used. **R-E**



THE PC BOARD for the wireless video link is shown here.

BUILD THIS

AMATEUR TV TRANSMITTER

Get in the picture with our television transmitter.

WILLIAM SHEETS and RUDOLF F. GRAF

LAST MONTH WE ANALYZED THE TV transmitter circuitry in great detail, describing the function of virtually every transistor, capacitor, inductor, and resistor. Now we'll present the construction techniques in the same detail. They should pose no special problems, but your best bet is to duplicate the author's prototype as closely as possible. That's because when working with ultra-high-frequency RF, such things as PC-board layout, component placement, and especially lead lengths become critical.

Assembly hints

As long as the author's design is exactly duplicated, you shouldn't encounter any *off the wall* UHF problems, so follow these suggestions without compromise:

1. As you assemble this project, use only the parts specified in the Parts List because ultra-high frequency circuits are sensitive to changes in component type and value. Also follow the author's parts placement as closely as possible.

2. Lead lengths should be kept short. Handle the surface-mount components and ferrite beads with extra care. The 1/10-watt resistors and miniature NPO ceramics should have short leads, and close component spacing.

3. Wind your own slug-tuned coils with available materials, rather than using commercial, hard-to-get factory-made types. That gets rid of the coil headaches. If the dimensions are followed, no problems should result. As shown in Fig 1, you'll find that the coils are easy to wind, and the largest ones have only eight or nine turns of wire. In fact, several are only loops or pieces of wire because the inductors required at 420–500 MHz are usually in the 0.01 to 0.1-microhenry range. Complete technical data is compiled in Table 1.

4. Pay particular attention to supply bypassing. We have incorporated a tantalum chip capacitor to guarantee good bypassing. By keeping everything compact, and by using a shielded, double-sided PC board with good RF bypassing, all the possible "horrors" associated with VHF and UHF circuitry can be done away with.

5. The PC board is compact and parts are small, so a small iron with a pointed tip is recommended, especially for soldering the chip capacitors.

6. Use only 0.062-inch thick epoxy-fiberglass PC-board materials. Other materials and thicknesses could be used, but may result in different tuning conditions, and stray capacitances. Don't use paper-base phenolic materials; they're too lossy at UHF frequencies.

7. Transistor Q12 must be heat-sinked because it must dissipate up to 3 watts. The method shown in Fig. 2 has proven adequate if at least 1-ounce copper is used. On the other hand, Q7 is adequately heat-sinked if the metal case is soldered to the PC-board ground plane.

8. Solder as many component leads as possible (that pass through the ground plane) to the top and bottom of the board. In particular, the ground lugs on all trimmer capacitors should be soldered on both sides, and also the resistors that have one side connected to ground. The idea is to ground as much of the ground plane to the ground foil on the component side, in as many places as possible; that's especially important around Q4–Q7.

9. Use chip capacitors where specified. Do not substitute ordinary leaded capacitors.

10. Keep all component leads as short as possible, and as close to the board as possible.

11. Take care to make coils as accurately as possible. While some errors can be tolerated, accurate work will make tuneup easier.

Parts installation

Figure 3 shows the Parts-Placement diagram for the TV transmitter. First install all resistors and then diodes D1 and D3. Don't forget the ferrite beads on R15, R17, R19, and R21. Next install all disc ceramics (0.01 µF and 470 pF), and then the NPO capacitors. Now install potentiometers R22, R32, and R33, soldering the grounded side of R22 and R33 to both sides of the PC board. Install all trimmer capacitors. Note that C18 and C40 are different from the rest. Solder ground tabs of all trimmers to both top and bottom of the PC board. Install transistors Q1 through Q5, and Q8 through Q11, but don't install Q6, Q7, or Q12 yet.

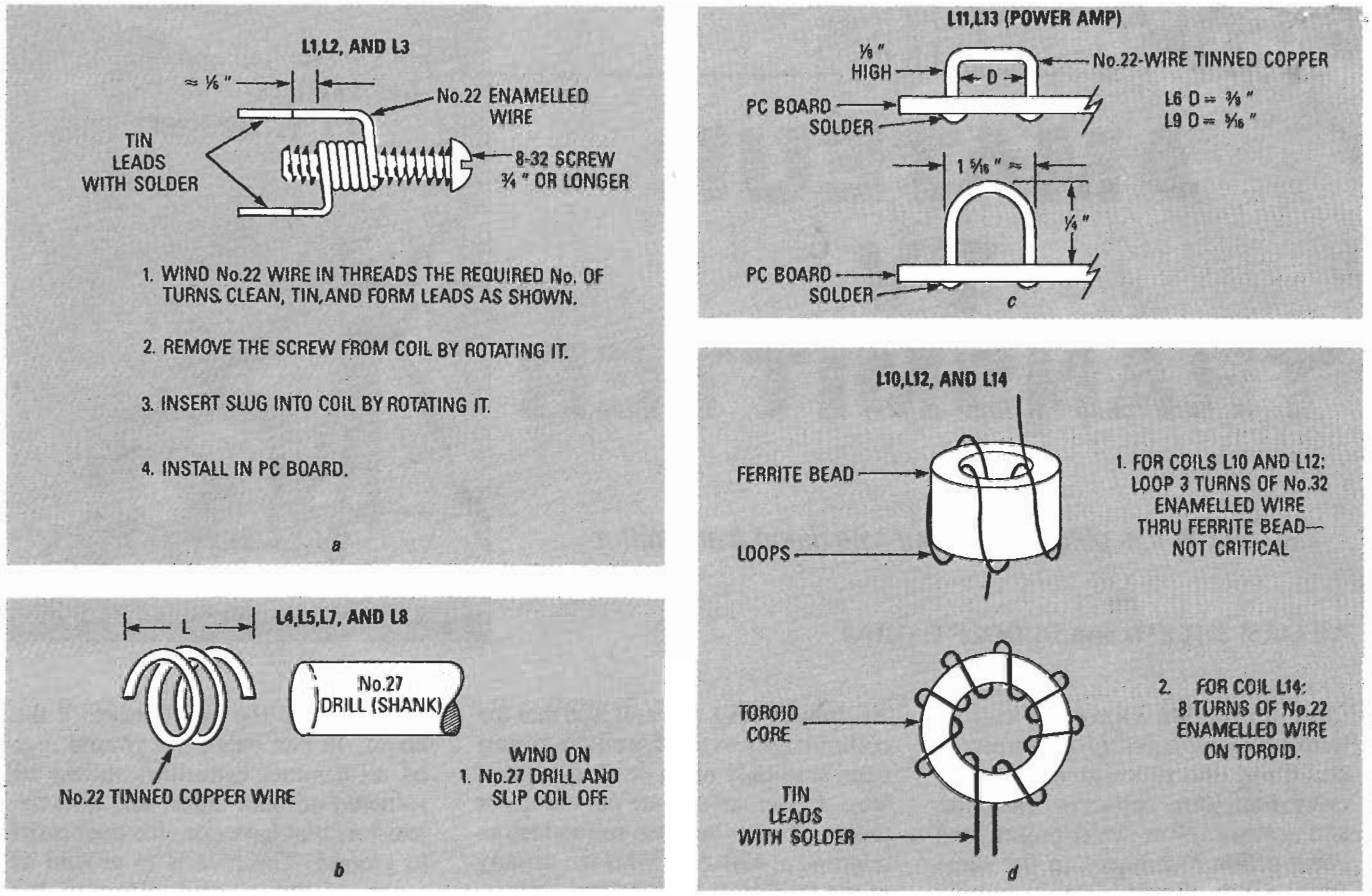


FIG. 1—IF YOU WANT TO CONSTRUCT THE COILS BY HAND, you have to wind them on the threads of a screw *(a)*, the shank of a drill bit *(b)*, using measured bends *(c)*, or around a ferrite bead *(d)*.

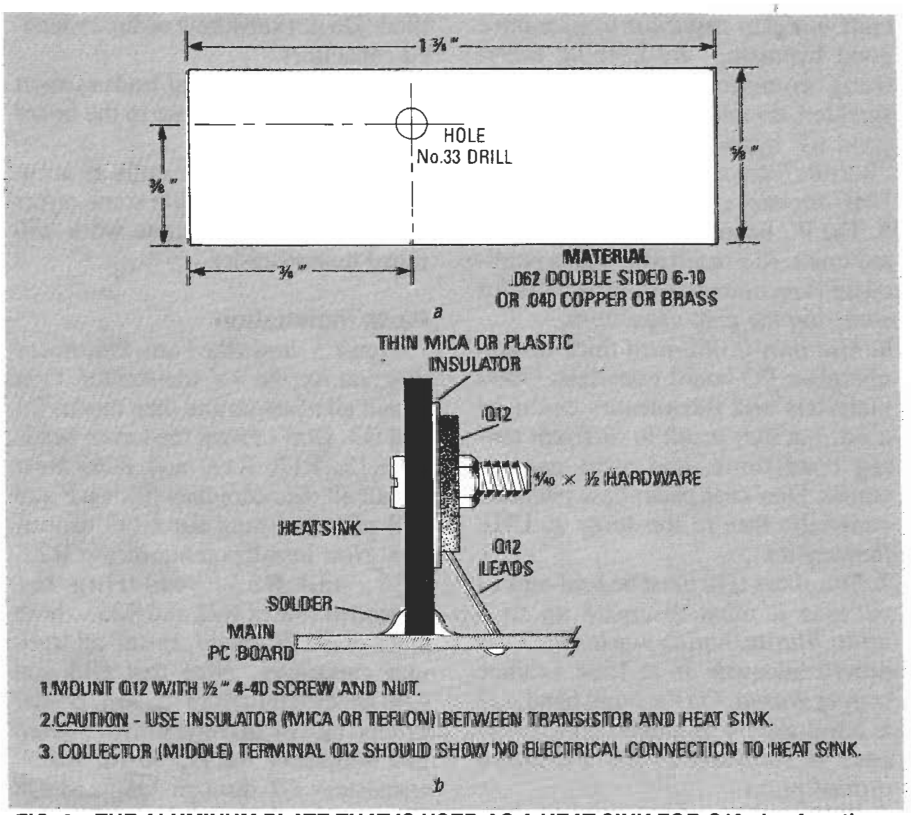


FIG. 2—THE ALUMINUM PLATE THAT IS USED AS A HEAT SINK FOR Q12 also functions as an RF shield for transistors Q6 and Q7.

Wind and install L1 through L9, and L14. If you're building the low-power version, leave out any components associated with Q6 and Q7, except L9; go ahead with the modification shown in Fig. 4, and be sure to omit C22. Install chip capacitors C22, C24, C44, and C20.

Check the PC board for shorts, solder bridges, and trim away any excess foil with a sharp knife (*X-acto* type or equal). Make sure that excess foil on the top side is not touching any component leads that are not intended to be grounded. Slight mis-registration of the top foil during PC fabrication may cause that.

Now install Q12 and its heat sink. Note that the heat sink also serves as an RF shield for Q6 and Q7 (if used). Be sure to solder the heat sink where it butts against the PC board. Note that Q12's case should be insulated from the heat sink. Use a TO-220 insulator (cut to size), or a scrap of mica, mylar, polyethylene, or teflon tape used in plumbing work.

You are now ready to test the main part of the board. If you're constructing the 2-watt version, Q6, Q7, and any associated components will be installed only after the rest of the PC board is tested.

Testing

After checking your work, measure the DC resistance between V_{CC} and ground; it should be greater than 200 ohms. If it's lower than that, check your work again for the cause before proceeding any further.

Next, install the slugs in L1, L2, and L3 if you haven't already done so. The slugs should be initially set fully inside the coils. Set R22, R32, and R33 about halfway between extremes of rotation. Set trimmer C40 and all other trimmer capacitors to half mesh. Final settings will depend on the operating frequency, coil-construction technique, and application.

Apply +12 volts after connecting the negative-supply lead to the PC-board ground plane. Immediately observe power-supply current; if it's over 130 mA, there may be a problem. If anything smokes or gets too hot, immediately remove the power and find the problem before proceeding.

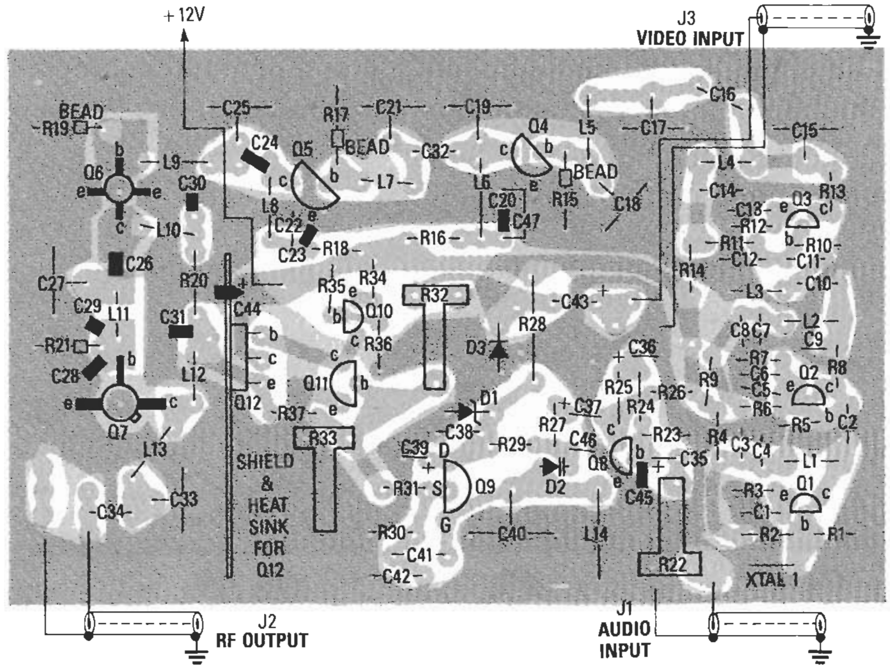


FIG. 3—PARTS PLACEMENT DIAGRAM shows capacitor chips (C20, C23, C24, C26, C28, C29, C30, C31, C45) mounted on the solder side, as is Q6.

If all seems OK, connect a VOM (preferably an analog meter) across R3, and then R7. You should read between 1.5 and 3-volts DC. Next connect the VOM across resistor R12 Q3;you should read 1 volt or less. Now connect the VOM between point A (emitter of Q12) and ground. Verify

TABLE 1—COIL DESCRIPTIONS L1–L14

COIL	FREQ. RANGE MHz	NO. TURNS & LENGTH	WINDING FORM	NOTES
L1	420-450 (HAM TV) 450-500 (VIDEO LINK)	9½ 8½		
L2	420-450 450-500	4½ 3⅓	8-32 SCREW THREAD	NO. 22 ENAMEL WIRE
L3	420-450 450-500	5½ 3½		
L4	ALL	3 TURNS ¼" LONG		
L5	ALL	4 TURNS ¼" LONG	NO. 27 DRILL (0.144" DIA) SPACE TURNS	MADE WITH NO. 22 TINNED COPPER
L7	ALL	1½ TURNS 1/16" LONG		
L8	ALL	2½ TURNS ⅛" LONG		
L6, L9, L11, L13	ALL	PER FIG. 1	NONE (PC BOARD)	
L10, L12	ALL	PER FIG. 1	FERRITE BEAD	NO. 32 ENAMEL WIRE
L14	4.5 MHz (NTSC SOUND SUBCARRIER)	8 TURNS NO. 22 ENAMEL	TOROID	NO. 22 ENAMEL WIRE

NOTE: Due to individual winding technique and normal circuit tolerances, L1, L2, L3 and L14 may require one turn more or less than shown in Table 1. L4, L5, L7 and L8 may have to be squeezed or spread lengthwise. All dimensions are taken from average of several working units. Individual units vary somewhat from given dimensions due to tolerances, winding techniques, and installation.

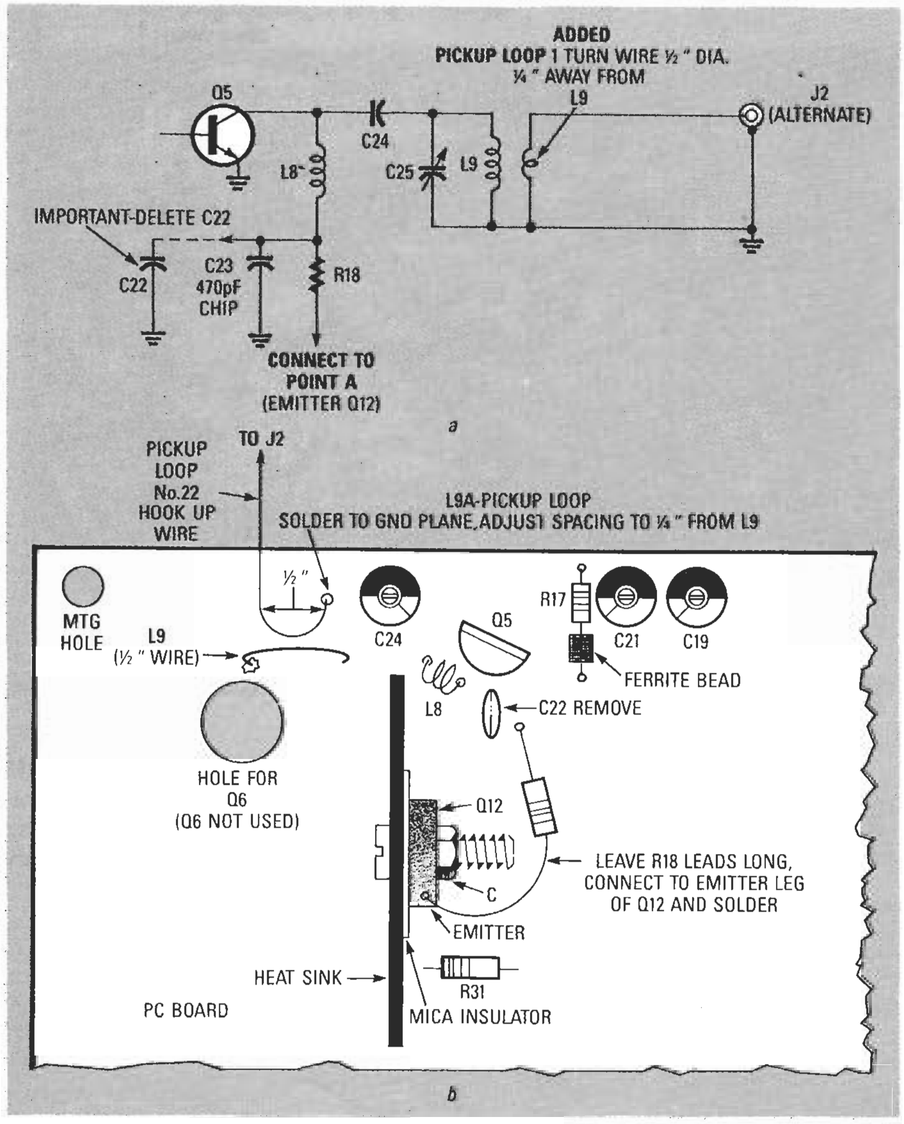


FIG. 4—TO OPERATE THE UNIT AT LOW POWER you should follow schematic *(a)* and assembly modification *(b)*.

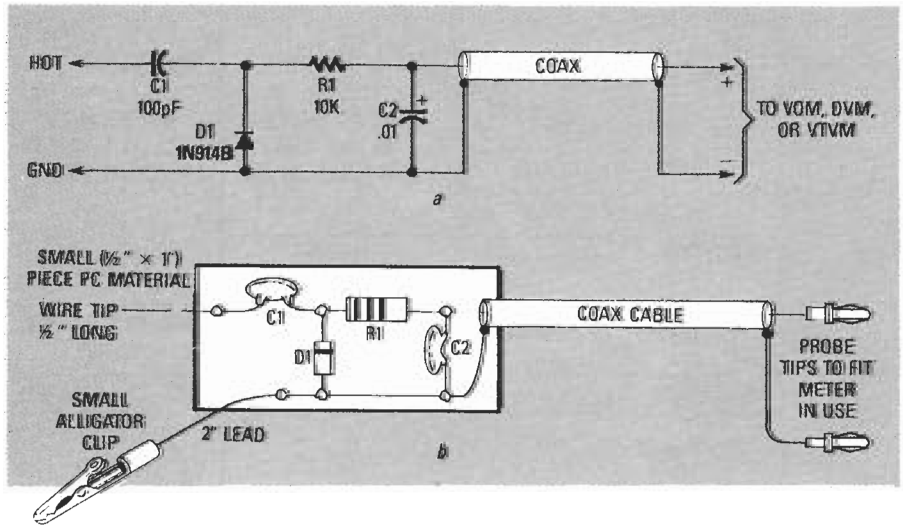


FIG. 5—HERE'S AN RF PROBE YOU CAN BUILD for your DMM, VOM, or scope. It's helpful in adjusting the transmitter for peak power.

that adjusting R33 through its full range will vary the voltage at point-A between less than 5 volts to greater than 11 volts. Set R3 for full voltage (greater than 11 volts) at point A for now.

Measure the voltage at Q8's collector; about 4 to 7 volts is OK. Next measure the voltage across D1; it should be between 8- and 10-volts DC. If it is more or less, that indicates a problem in Q8, Q9, or the associated circuitry. Check for 8- to 10-volts across D2. If it reads 1 volt, D2 is installed backwards or is shorted.

If all is good up to this point, install crystal XTAL1, connect a VOM across R7, and apply power. Tuning the oscillator is done as follows: Slowly back L1's slug out of the winding. You'll find that the voltage across R7 will suddenly increase, then slowly decrease as the slug is tuned. Adjust

PARTS LIST

All resistors are ⅛ or ⅒-watt, 5%.
R1, R5—3900 ohms
R2, R6, R11, R31—15,000 ohms
R3, R7, R15—330 ohms
R4, R9, R12, R14, R16–R19, R35—100 ohms
R8, R13—10 ohms
R10—680 ohms
R20—10 ohms, ¼-watt
R21—22 ohms
R22—100,000-ohms potentiometer
R23—22,000 ohms
R24, R29—100,000 ohms
R25—33,000 ohms
R26—4700 ohms
R28—470 ohms, ¼-watt
R30—2200 ohms
R32, R33—1000-ohm potentiometer
R34—15 ohm
R36—1000 ohms
R37—3300 ohms
Capacitors
C1—56 pF, NPO, ceramic disc
C2, C12—33 pF, NPO, ceramic disc
C3, C7, C19, C22, C38, C47—0.01µF, ceramic disc
C4, C6, C8, C13, C14—470 pF, NPO, ceramic disc
C5—82 pF, NPO, ceramic disc
C9, C11—15 pF, NPO, ceramic disc
C10—2.2 pF, NPO, ceramic disc
C15, C17, C19, C21, C25, C27, C33—2–10-pF, trimmer
C16, C32—1 pf, NPO, ceramic disc
C18—2–18 pF, or 2–20-pF trimmer
C20, C23, C24, C45—470 pF, ceramic chip
C26, C30, C31—100 pF, ceramic chip
C28, C29—22 pF, ceramic chip
C34—5 pF, silver mica
C35–C37—1 µF, 50 volt, electrolytic
C39—10 µF, 16 volt, electrolytic
C40—3–40 pF, trimmer
C41—220 pF, NPO, ceramic disc

C42—470 pF, NPO, ceramic disc
C43—220 µF, 16 volt, electrolytic
C44—10 µF, 16 volt, chip tantalum
C46—100 pF, NPO, ceramic disc
C47—0.01µF, ceramic chip

Semiconductors

Q1, Q2—2N3563, transistor
Q3-Q5—MPS3866, transistor
Q6—MRF559 or MRF627 transistor
Q7—MRF630, transistor
Q8—2N3565, transistor
Q9—MPF102, transistor
Q10—2N3906, transistor
Q11—2N3904, transistor
Q12—MJE180, transistor
D1—1N757A, diode
D2—MV2112, varactor diode
D3—1N914, diode
D4—1N4007, diode

Inductors

L1-L14—See table 1

Other components

XTAL1—52.5-62.5 MHz

Notes: The following kits are available from North Country Radio, PO Box 53, Wykagyl Station, New Rochelle, NY 10804: Low-Power Kit w/ATV crystal for operation on 439.25 MHz, $79.95 plus $2.50 shipping and handling; 2-Watt Kit w/ATV crystal for operation on 439.25 MHz, $104.95 plus $2.50 S/H; extra crystals for CH14, CH15 operation, $6.50 plus $1.50 S/H; PC board only plus Cores, chip capacitors, and D2, (partial kit), $49.95 plus $2.50 S/H; Crystals can be purchased separately from Crystek Corporation, PO Box 06135, Fort Myers, FL 33906. Kits do not include jacks, connectors, batteries, power-supply components, or case.

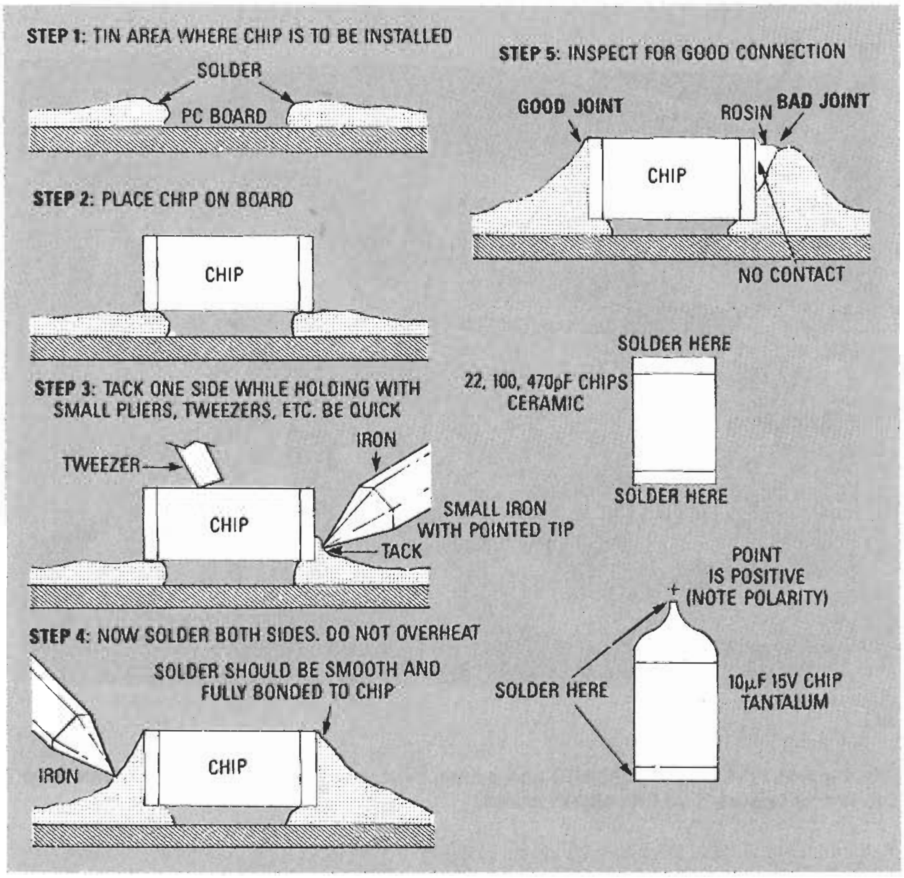


FIG. 6—IF YOU FOLLOW THESE STEPS when soldering the chip components to the PC board, you'll have no problems with them.

the slug for maximum voltage (3 to 5 volts), then back out the slug for about a 10% drop to ensure stable oscillation. As a check, a frequency counter connected to the junction of C2 and C5 should indicate the crystal frequency. An unstable reading indicates that the crystal is not controlling the frequency. If that's the case, try re-adjusting L1.

Here's how to tune the 1st doubler. Connect the VOM across R12, and adjust L2 and L3 for maximum voltage (about 1 to 2 volts). If adjusting the L1 and L2 slugs doesn't peak the voltage, then add or subtract a turn from the coil as required, after first checking C9, C10, C11, and C12 for correct values.

Here's how to tune the 2nd and 3rd doublers. Connect an RF probe to the junction of L9 and R19, or to the junction of C25 and L9 if you're building the low-power version. Figure 5 shows you how to build an RF probe if you don't already have one. Adjust C15, C17, C18, C19, C21, and C25 for a maximum reading. You should be able to obtain at least 1.5 volts of RF energy at the junction of R19 and L9 for the high-power version, and about 2 volts at the junction of C25 and L9 for the low-power version. If everything looks good, that checks out stages Q1 through Q5.

To adjust the RF output for the low-power version connect a 47-ohm resistor to J2A (*A*lternate). Adjust C25 and the position of L9A (*A*lernate) with respect to L9 for maximum output. Don't couple L9A too close to L9—just enough for about 1 volt across the 47-ohm resistor.

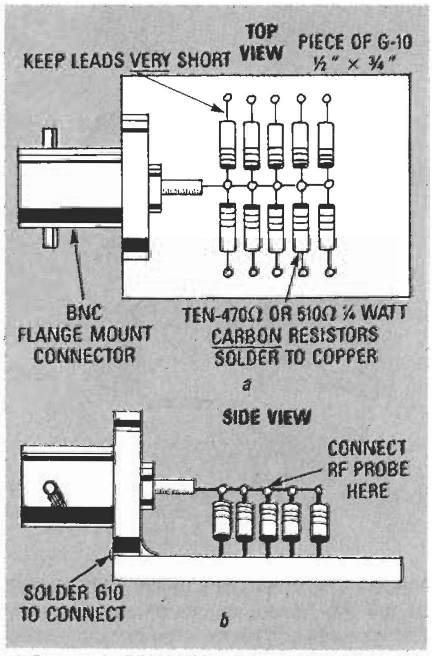


FIG. 7—A DUMMY LOAD SHOULD BE USED while adjusting the power output.

Final assembly

If you're building the 2-watt version, now is the time to install Q6 and Q7, and then L10 through L13. You may now install the chip capacitors C26, C28, C29, C30, and C31, but don't overheat them! Make sure that the PC board is tinned in the areas where chips are installed. The best way to install them is to first tack-solder one side to hold it down, solder the other side, and then go back and

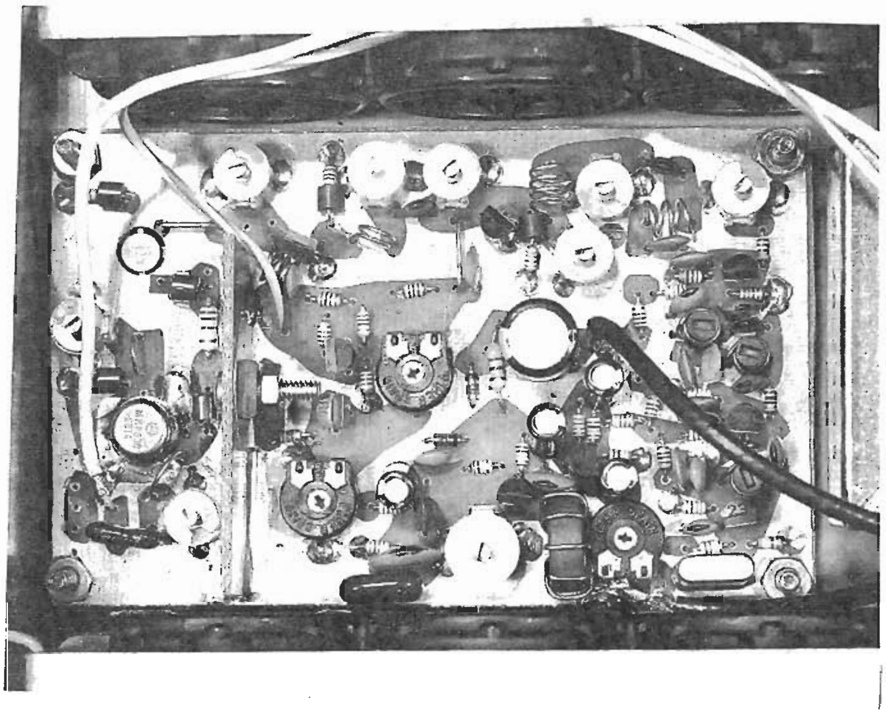


FIG. 8—THE FINISHED PC BOARD has a neat, clean appearance. Sloppy workmanship can not be tolerated on this circuit layout.

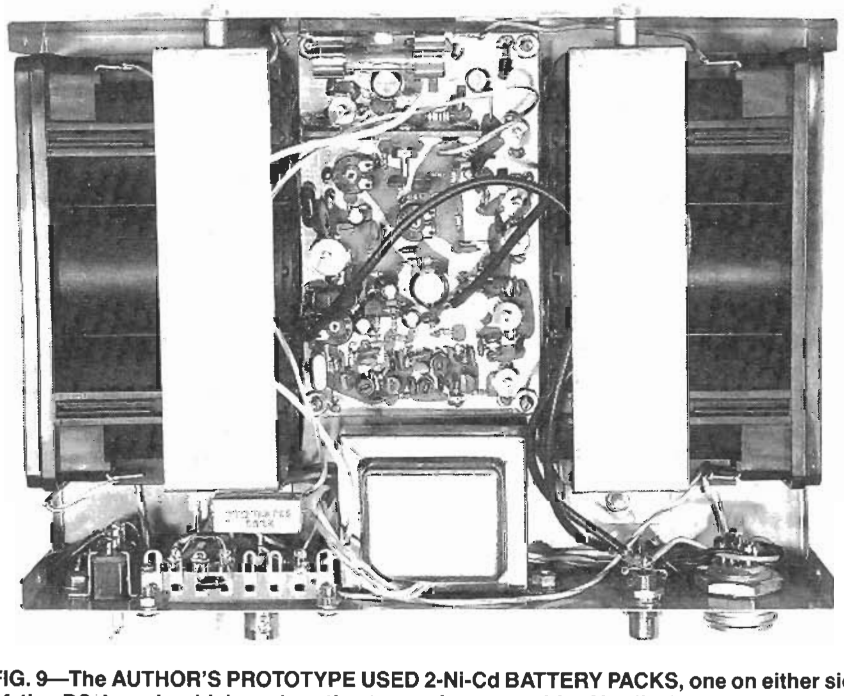


FIG. 9—The AUTHOR'S PROTOTYPE USED 2-Ni-Cd BATTERY PACKS, one on either side of the PC board, which makes the transmitter portable. You'll also notice a power transformer and associated circuitry used for running the transmitter off household AC-line voltage.

resolder the first (tack-soldered) side.

Figure 6 shows you how to solder chip components. Use a 25-watt iron with a pointed tip. Fine-point needle-nose pliers or tweezers should be used to manipulate the chip capacitors.

Finally, install C34 and a suitable length of small-diameter 50-ohm coax to J2. Check all joints for solder bridges. Make sure that the metal case of Q7 is soldered to the ground plane (top side), and connect its leads to the PC-board underside using as little lead length as possible.

Apply power and quickly adjust C25, C27, and C33 for maximum power into a 50-ohm load connected to J2. You can use a 47-ohm, 2-watt carbon resistor, or the dummy load which can be assembled as shown in Fig. 7. An RF probe can be connected to the hot side of the resistors (center conductor of connector) to read the RF voltage, but an RF power meter is nice to have.

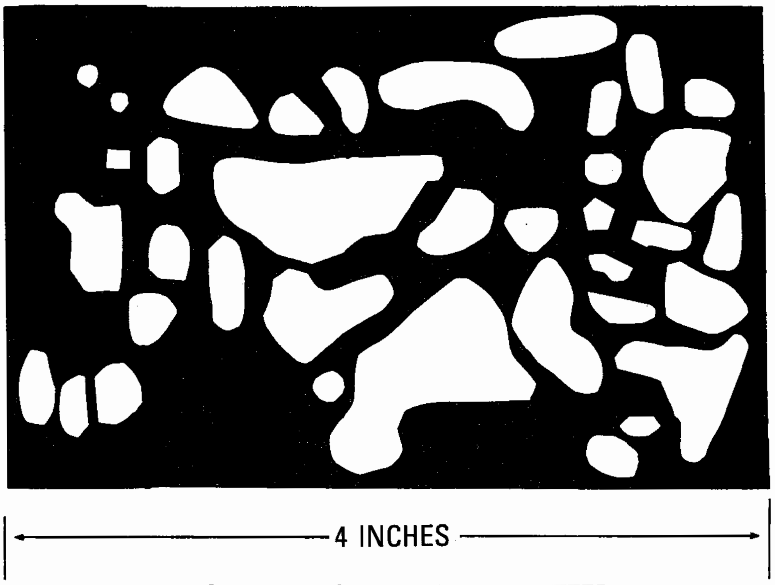
You should get at least 1.5 watts (about 8.5-volts RMS) into the 50-ohm load, which should become warm when operating. Power-supply current will be about 500 mA. Now adjust R33 for an output voltage about half that, or a quarter the power as read on the power meter, if used. Leave the RF load connected as you proceed to the next step.

For either the low- or high-power unit, adjust R33 for about +6 volts at point A (emitter of Q12). Connect a frequency counter to point A, and adjust C40 for exactly 4.500 MHz. Now apply video and audio signals to J3 and J1, respectively. Watch the transmitted image on a TV receiver tuned to the transmitter frequency; adjust the video gain (R32) for best picture contrast and stability, then adjust the audio level (R22) until its level is comparable to a commercial station. Now alternately adjust R32 and R33 for maximum video contrast without seeing any side effects such as instability, audio buzz, or other evidence of clipping. You may also wish to go over all tuning adjustments again for best results. The finished PC board is shown in Fig. 8

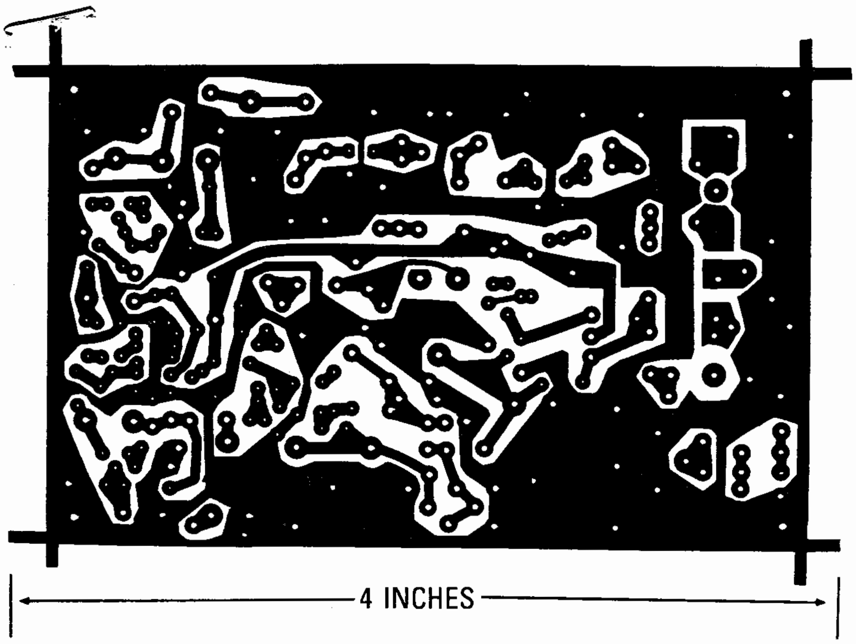
Enclosure

Mount the PC board in a shielded metal-case, as shown in Fig. 9, and connect leads from the board to suitable jacks for J1, J2, or J2A, and J3. Also provide a suitable connector for the 12-volt supply, if desired. The transmitter case can house an AC supply, or batteries for portable operation. Use the right size *Ni-Cd* batteries to handle the 100-mA drain (low power), or 500-mA drain (2-watt unit). Use a BNC-type fitting for the antenna jack, J2.

A suitable antenna would be a 6-inch whip or a center-fed dipole, 12-inches long. For amateur TV, a linear amplifier may be installed between J2 and the antenna for greater power output. For the low-power version, use the 6-inch whip antenna. **R-E**



COMPONENT SIDE OF TV TRANSMITTER.



FOIL SIDE OF TV TRANSMITTER.

MORE PC SERVICE ON PAGE 84