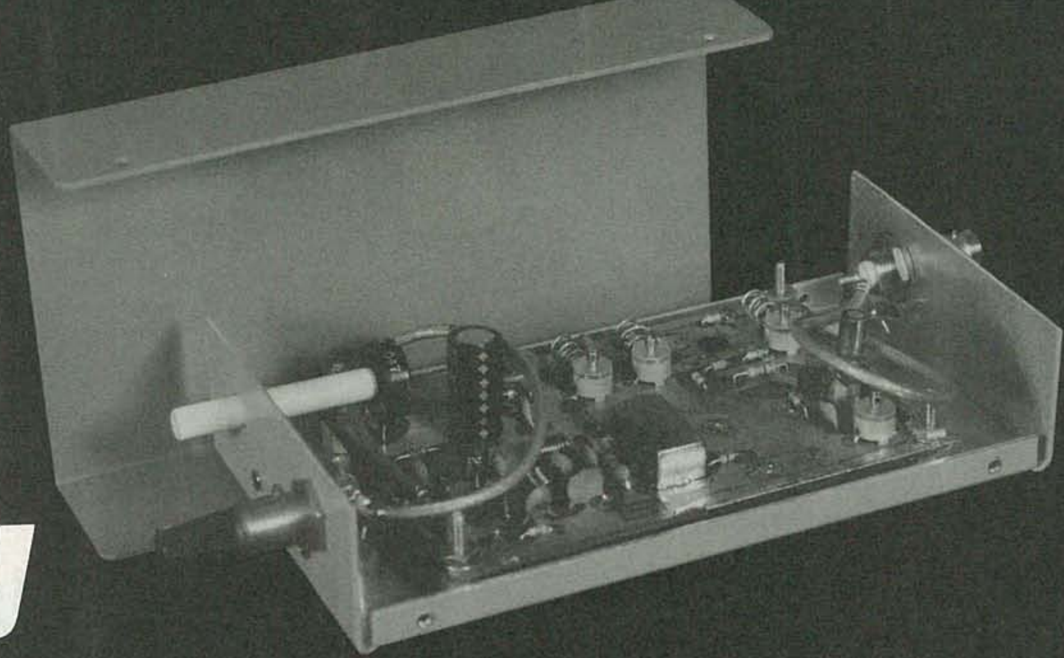
Receive amateur TV signals on a standard TV with our low-noise downconverter.



ATV Downconverter

WILLIAM SHEETS and RUDOLF F. GRAF

YOU CAN RECEIVE AMATEUR TV SIGNALS on a standard TV receiver with our inexpensive ATV downconverter. The downconverter converts the 420–450 MHz ATV band, which is several channels below the lower limit of the UHF band, to channel 3 or 4 for viewing on virtually any TV. The downconverter has a low-noise preamplifier stage and a double-balanced passive mixer for good performance and a wide dynamic range. That is necessary with today's crowded UHF bands. The converter draws about 27 milliamperes from a 13.2-volt DC source, so it can be used in portable and mobile applications. An extra IF stage gives an overall gain of about 25 dB.

Circuitry

Figure 1 is a block diagram of the downconverter. It consists of three active stages and a passive diode double-balanced mixer. The input signal is first filtered so that only signals centered around 430 MHz are fed to Q1, an RF amplifier with a 20-dB gain and a noise figure of 1.5 dB. Q1 is an NEC 25137 gallium-arsenide field-effect transistor, or GaAsFET. The amplified signal in the 420–450 MHz range is fed to a double-tuned bandpass filter. The overall bandwidth of the RF stage is about 12 MHz, which is sufficient to cover the most frequently used part of the ATV band (426–439 MHz) without retuning. For operation over the entire 420–450 MHz band, you may have to repeak the filters to tune in weak signals.

The amplified signals are mixed by a diode double-balanced mixer with an oscillator signal (generated by Q2) that is nominally 60–70 MHz lower than the received frequency. A 2-dB pad is used between the oscillator and mixer to reduce interaction. The IF output from the mixer is fed to a low-pass filter that cuts off at about 100 MHz. That reduces UHF signal feedthrough. Amplifier Q3 boosts the IF signal at 60 or 66 MHz (channel 3 or 4) by about +15 dB. The output of Q3 is fed to the TV receiver being used as an IF amplifier.

Figure 2 shows the schematic of the downconverter. The input signal from J1 is applied to a tap on L1, the input (antenna) coil. L1 is nominally a 3-turn coil and the tap is at ¾ turn so that the voltage applied from J1 is stepped up four times. Capacitor C1 tunes L1 to resonance, and is also connected to gate 1 of Q1.

Capacitors C3 and C4 provide

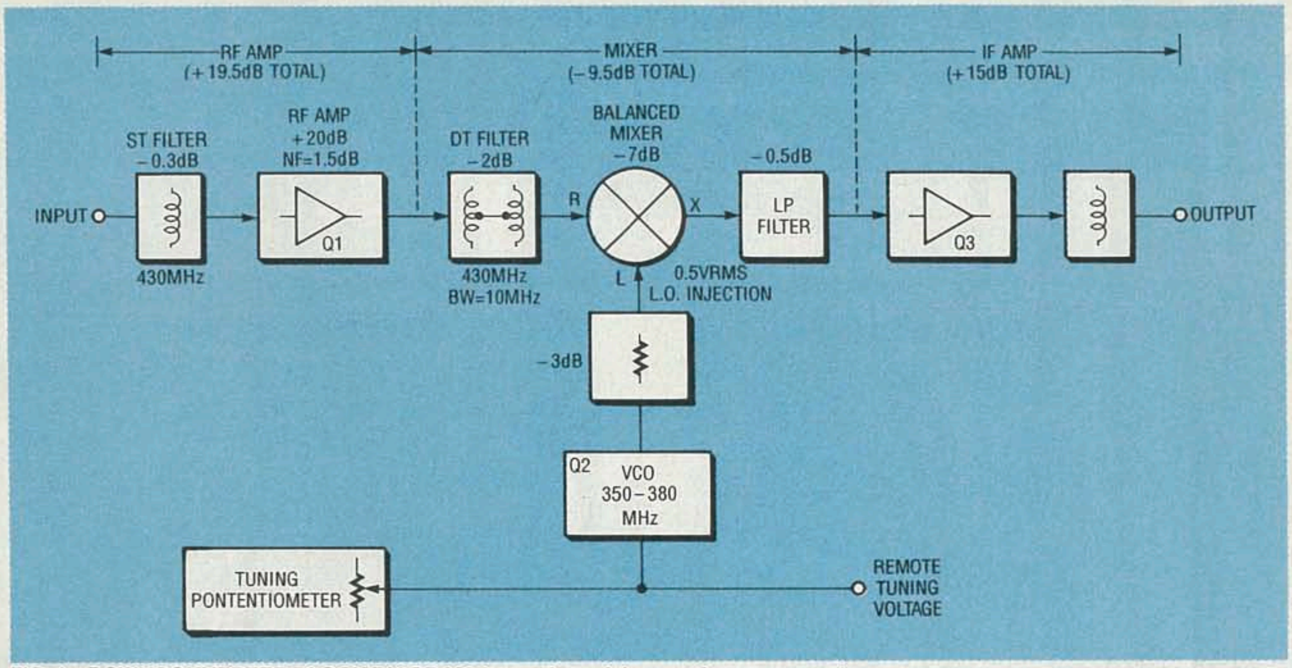


FIG. 1—DOWNCONVERTER BLOCK DIAGRAM. It consists of three active stages and a passive diode double-balanced mixer.

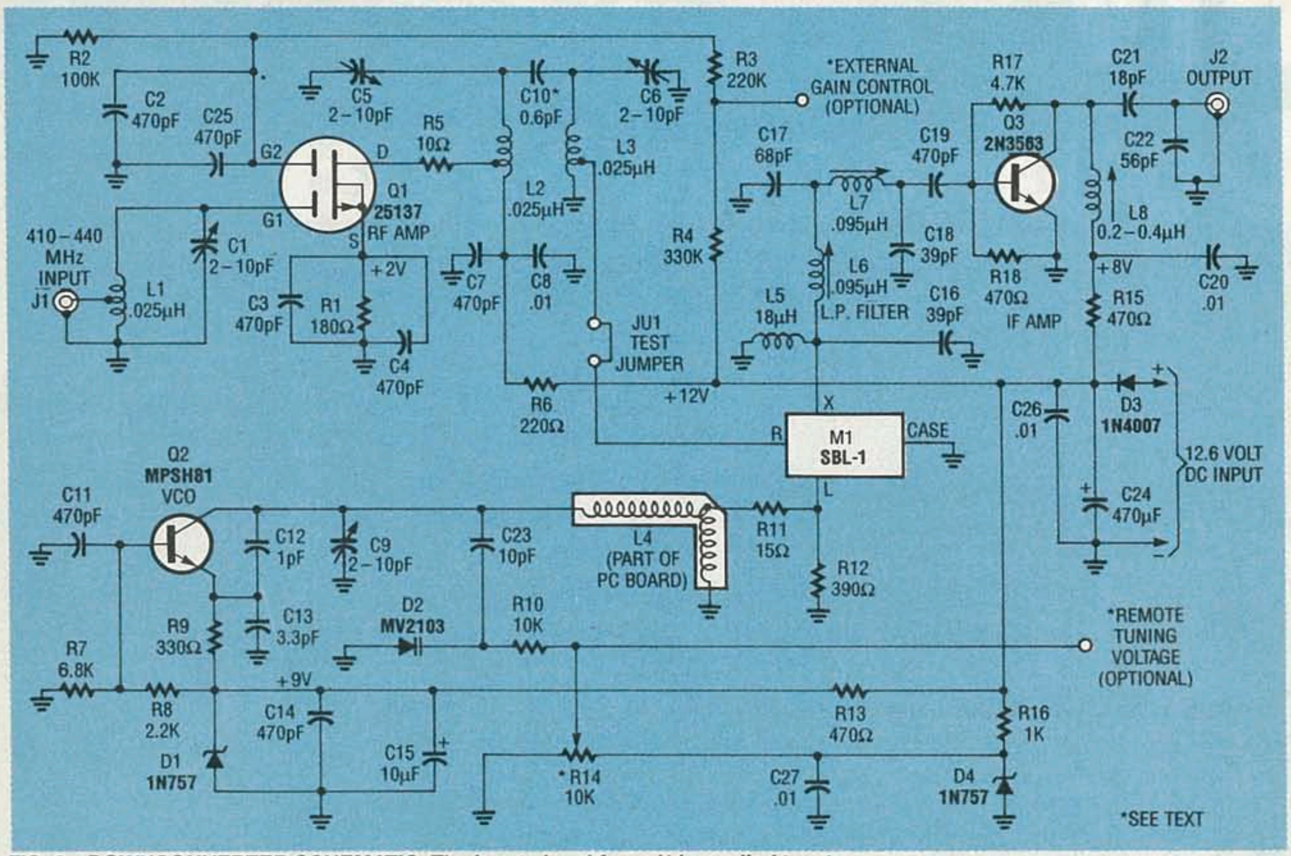
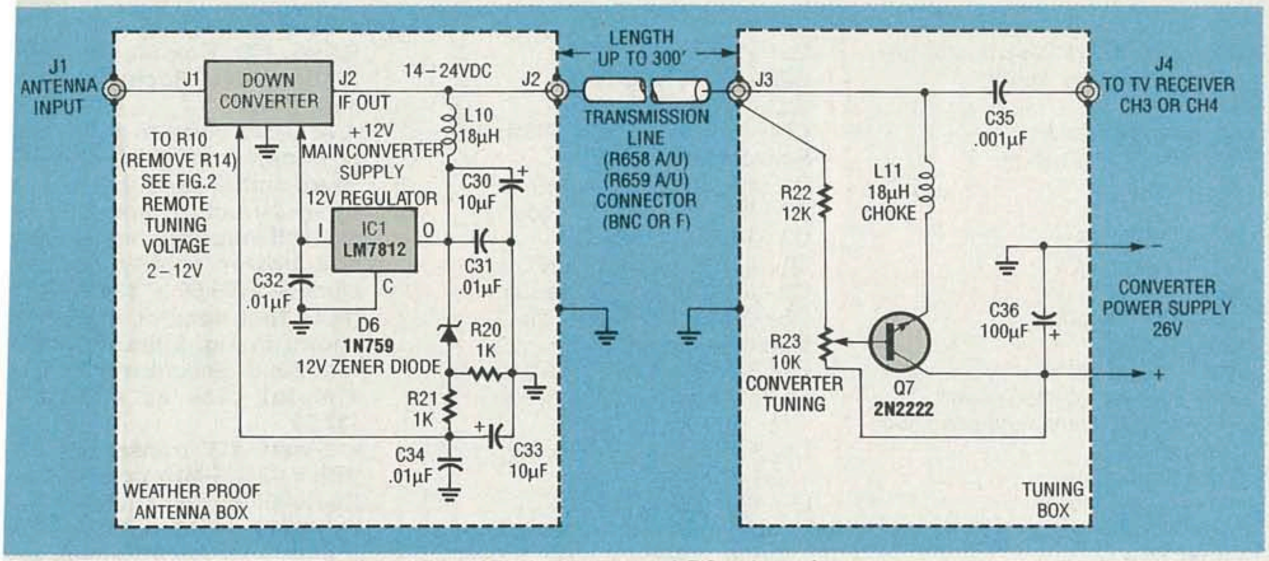


FIG. 2—DOWNCONVERTER SCHEMATIC. The input signal from J1 is applied to a tap on L1. Capacitor C1 tunes L1 to resonance and passes the signal to Q1, an NEC 25137 GaAsFET.

RF bypassing for the source of Q1, and R1 provides self-bias for Q1. Gate 2 of Q1 is biased by network R2, R3 and R4. An external gain-control signal (which is usually not required) can be applied to the junction of R3 and R4 if it becomes necessary to reduce the gain of the converter on very strong signals. A DC voltage of +6 volts will cause full gain, and −6 volts will cause nearly a −40-dB reduction in gain. The voltage can be derived from an AGC circuit, if necessary, but a potentiometer can also be used. Capacitor C2 provides RF



IG. 3—THE DOWNCONVERTER can be supplied with an external DC voltage for emote-control tuning.

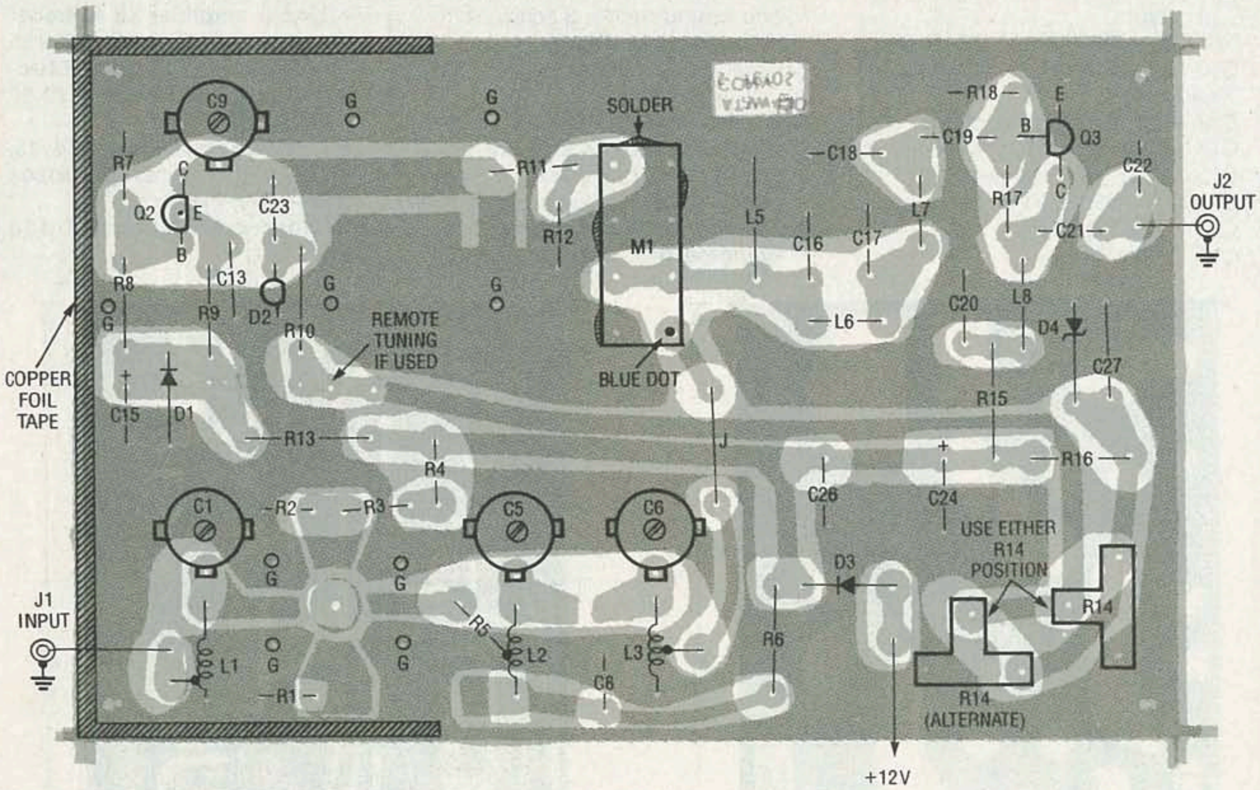


FIG. 4—PARTS-PLACEMENT DIAGRAM. This layout must be followed exactly to duplicate the performance of the downconverter. Some components mount on the solder side of the board as shown in Fig. 6.

grounding for gate 2 of Q1, and R5 reduces any UHF parasitic oscillations. The drain of Q1 is connected to a tap on L2, which is part of the bandpass filter network. Capacitors C7 and C8 provide RF grounding for the cold end of L2. DC bias is fed through R6. Under normal conditions, the drain pin of Q1 will be at +10 to +11 volts DC.

Capacitor C10 couples the signal from the first tuned circuit (C5-L2) to the second tuned circuit (C6-L3). The value of C10 is very small (0.6 pF); it determines the degree of coupling between L2 and L3. It is made from a small piece of PC board material and is mounted on the bottom of the main board. A signal from a tap on L3 is fed via test jumper JU1 to mixer M1. The local oscillator (L.O.) signal from Q2 is also fed to the mixer.

Transistor Q2 is the local oscillator, for which R13, D1, C14, and C16 provide a stabilized 9 volts DC. Because Q2 is a PNP transistor, it allows the collector to be DC grounded, which is an advantage in this type of oscillator circuit. Resistors R7 and R8 provide base bias for Q2, C11 provides a solid RF ground

PARTS LIST

All resistors are ⅛-watt, 5%, unless otherwise noted.
R1—180 ohms
R2—100,000 ohms
R3, R4—220,000 ohms
R5—10 ohms
R6—220 ohms
R7—6800 ohms
R8—2200 ohms
R9—330 ohms
R10—10,000 ohms
R11—15 ohms
R12—390 ohms
R13, R15—470 ohms, ¼-watt
R14—10,000 ohms, potentiometer with shaft
R16—1000 ohms
R17—4700 ohms
R18—470 ohms

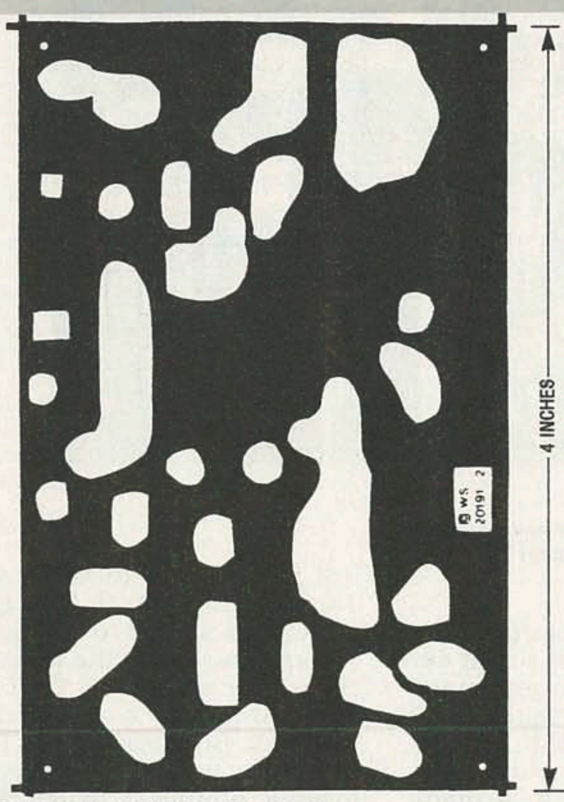
Capacitors
C1, C5, C6, C9—2–10 pF trimmer
C2–C4, C7, C11, C14, C25—470 pF, chip
C8, C20, C26, C27—0.01 µF, disc
C10—0.6 pF (must be handmade, see text)
C12—1 pF, NPO disc or chip
C13—3.3 pF, NPO disc or chip
C15—10 µF, 16 volts, electrolytic
C16, C18—39 pF, NPO disc
C17—68 pF, NPO disc
C19—470 pF, disc
C21—18 pF, NPO disc
C22—56 pF, NPO disc
C23—10 pF, NPO disc
C24—470 µF, 16 volts, electrolytic

Semiconductors
D1, D4—1N757A Zener diode
D2—MV2103 varactor diode
D3—1N4007 diode
Q1—25137 GaAsFET (NEC)
Q2—MPSH81 NPN transistor
Q3—2N3563 NPN transistor

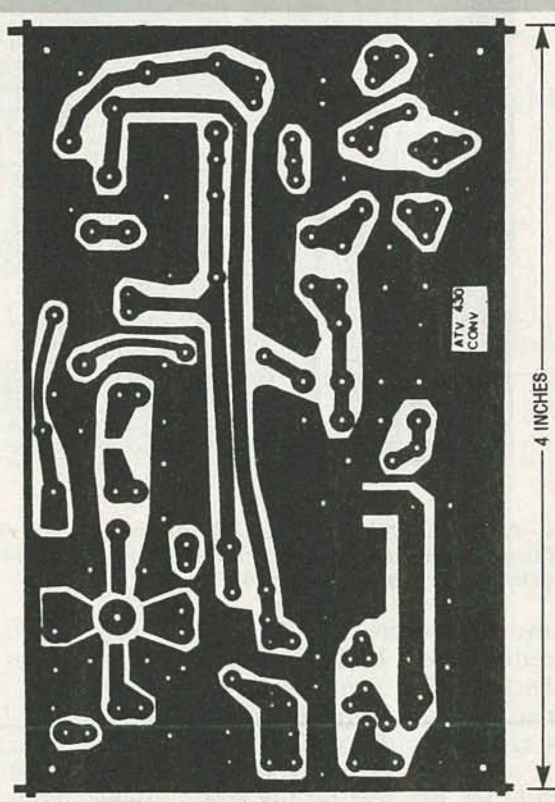
Other components
L1–L3—3 turns of 20 AWG tinned wire (approx. 0.025 µH, see Fig. 5)
L4—part of PC board etching, see text
L5—18 µH RF choke
L6, L7—8 turns of 22 AWG enameled wire wound on No. 8 screw (approx. 0.095 µH, see Fig. 5)
L8—9½ turns of 22 AWG enameled wire wound on No. 8 screw, with ferrite slug (see Fig. 5)
M1—MCL SBL-1 mixer
J1, J2—F connector
Miscellaneous: PC board, 3/16-inch copper-foil tape, coaxial cable, project case, 12.6-volt DC power supply, solder, etc.

Note: The following items are available from North Country Radio, P.O. Box 53, Wykagyl Station, New Rochelle, New York 10804:
- **A kit of parts to build the downconverter (includes PC board and all parts that mount on it, J1 and J2, and wire to wind all inductors (metal case and power supply not included)—$59.50 + $3.50 S&H (Note that none of the parts shown in Fig. 3 are included with the downconverter kit.)**
- **Metal case as shown—$12.50**
- **2-watt ATV transmitter kit with a 439.25-MHz crystal (see Radio-Electronics, June and July 1989)—$110 + $3.50 S&H**
- **A 0.5-watt, 9-volt transmitter kit with a 439.25-MHz crystal—$112 + $3.50 S&H**
- **Linear amplifier kit to boost the output of ATV transmitter to 15 watts (see Radio-Electronics, August 1992)—$79.50 + $3.50 S&H**
- **Crystals for channels 14, 15, 16, 17, or 18 (for test purposes only)—$7.50 each**

New York residents must add sales tax.



COMPONENT SIDE FOIL PATTERN.



SOLDER SIDE FOIL PATTERN.

for the base of Q2, and R9 provides emitter bias. Nominal current through Q2 is about 5 to 6 milliamperes. Capacitors C12 and C13 provide a feedback network for Q2.

Components C9 and L4 (a length of microstrip line etched on the PC board), together with

3 and varactor diode D2, m a circuit that can be tuned . the bias on D2 over the ige of 350 to 390 MHz, de- nding on the setting of C9. ierefore, Q2 will oscillate over at frequency range, because sitive feedback is provided by .2 and C13, and Q2 acts as a ounded-base amplifier. Os- llator output is taken through 17 and R12 to mixer M1. The vel at terminal L of the mixer is oout 0.3 volt RMS. Resistor 11 is connected to a tap on L4, hich also provides bias return or the collector of Q2, because is at DC ground.

The output from mixer M1 at i0 to 70 MHz (the difference fre- quency between received signal and L.O. frequency) appears at nixer terminal X. There is about a 7-dB loss in the mixer. Coil L5 provides a DC return for the mixer IF port. A low-pass fil- ter made up of C16, L6, C17, L7, and C18 eliminates any remain- ing UHF signal components ap- pearing at terminal X. Tran- sistor Q3 is an IF amplifier stage, which is biased by R13, R14, and R15 to a V_{CE} of 8 volts and a collector current of about 8 mA. Tuned circuit L8, C21, and C22 can be tuned to either channel 3 or 4. The signal from the low-pass filter is coupled to Q3's base via C19. Transistor Q3 provides about a 15-dB gain; its output signal appears at J2. Power for the downconverter is supplied through D3, which protects against reverse volt- ages, and C24 and C26, which bypass RF and noise.

Resistor R10 couples DC bias to D2 supplied from tuning-po- tentiometer R14. Components R16, D4, and C25 provide 9- volts DC for that purpose. If de- sired, R10 can be supplied with external DC for remote-control tuning, or to allow the down- converter to be mounted close to the antenna. That is commonly done to reduce transmission- line losses between the antenna and converter—losses run high at 450 MHz unless very expen- sive transmission line, such as ½-inch hard line, is used. If you are planning on remote-control- ling the converter, install R14 so it's easy to move.

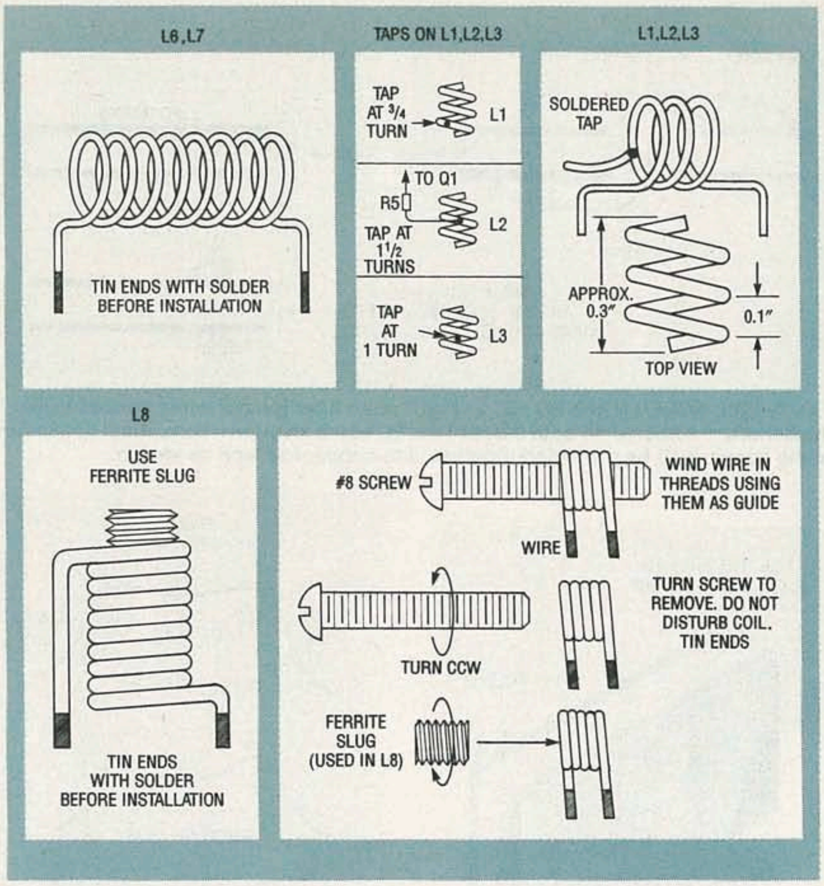


FIG. 5—COILS L1, L2, AND L3 are three turns each of 20 AWG tinned wire wound around a No. 8 screw and stretched to 0.3 inch. The lead from J1 has its center conductor soldered to L1 at ¾ turn from the grounded end. Resistor R5 is soldered 1½ turns from the end of L2 that connects to R6, C7, and C8. Coil L3 is tapped at 1 turn from the grounded end. Coils L6 and L7 are 8 turns each of 22 AWG enamelled wire wound on a No. 8 screw. Coil L8 is 9½ turns of 22 AWG enamelled wire wound on a No. 8 screw with a ferrite tuning slug added.

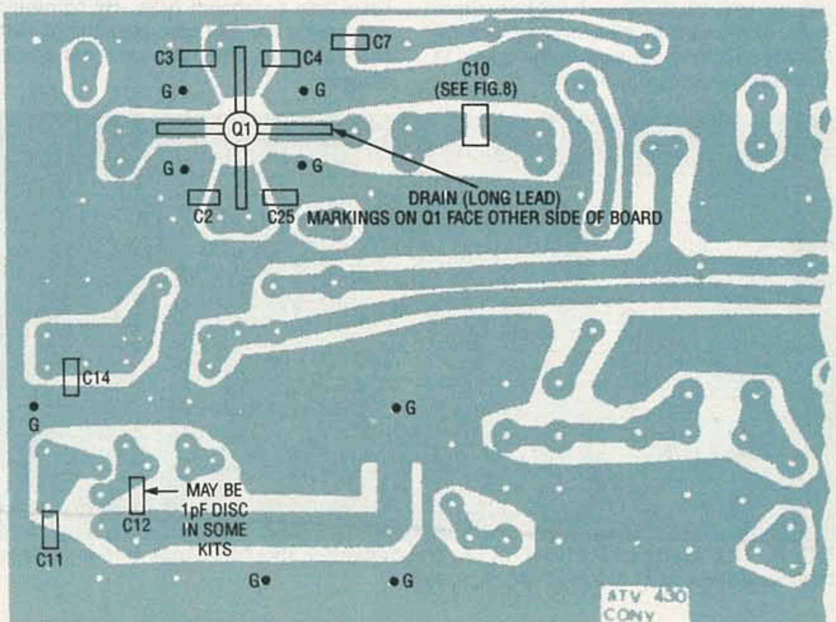


FIG. 6—ALL CHIP CAPACITORS, C10 (see Fig. 8), and Q1 mount on the solder side of the board. The markings on Q1 face the component side of the board.

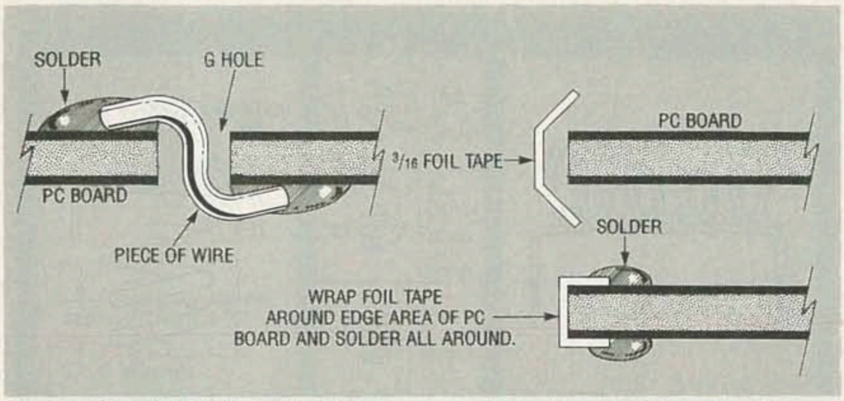


FIG. 7—ALL HOLES MARKED "G" in Fig. 4 must have jumper wires passed through them that are soldered on both sides of the PC board as shown here. Also, both sides of the board must be grounded together with copper-foil tape as shown.

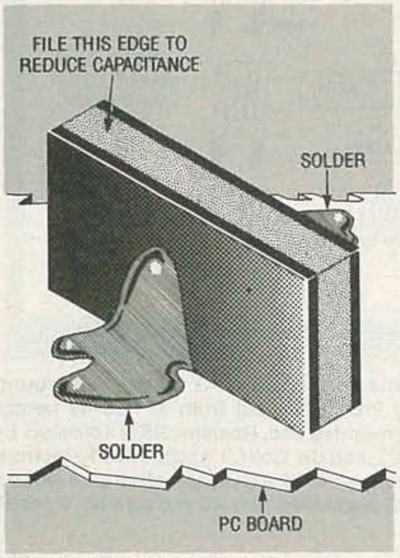


FIG. 8—TO MAKE C10, take a small square of G-10, 0.062-inch PC board material and trim it to a 3/16-inch square. Install it on the solder side of the board in the location shown in Fig. 6.

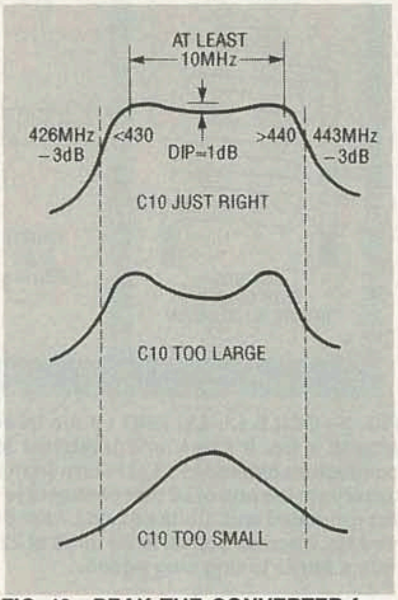


FIG. 10—PEAK THE CONVERTER for a response as shown here. By trimming C10 with a file you can experiment with the coupling and resultant bandpass shape.

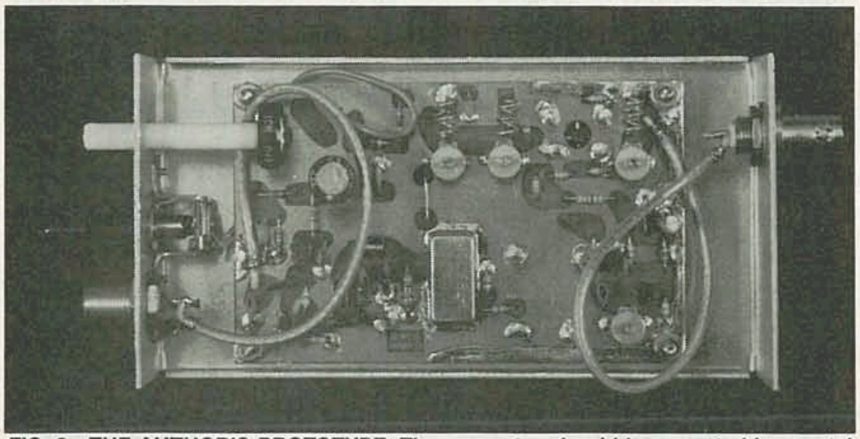


FIG. 9—THE AUTHOR'S PROTOTYPE. The converter should be mounted in a metal box, weatherproof if outdoor use is intended.

Figure 3 shows how J2 can be connected to a long coaxial transmission line that runs to the ATV receiver station. The cable is isolated from ground and can therefore carry a DC voltage. The DC voltage is impressed on the cable as follows: A nominal 26-volt power source at the ATV receiver station is connected to Q7, a 2N2222 NPN transistor used as an emitter-follower. Resistors R22 and R23 produce a variable voltage of 14 to 26 volts at the base of Q7, whose emitter will follow the voltage. Power is supplied to the cable through L11, and by varying potentiometer R23, the voltage applied via R22 to the cable at J3 can be adjusted between 14 and 24 volts. Capacitor C35 prevents any DC voltage from appearing at J4.

The DC voltage is taken off the cable via the 18μH RF choke L10. Capacitors C30 and C31 remove noise from the DC voltage and provide an RF ground. Positive voltage is fed to the downconverter via the cable's center conductor and the outer shield serves as the negative supply lead; it is grounded to the case and ground foil.

The DC input is fed to D6, a 12-volt Zener diode (a 1N759 can be used). Capacitors C33 and C34 filter any noise from the voltage which will be 12 volts less than the voltage on the coaxial transmission line (+14 to +24 volts), or +2 to +12 volts DC. That is fed to R10, which feeds the tuning voltage to the downconverter varactor. By varying the DC voltage on the transmission line between +14 and +24 volts, not only can the downconverter be powered, but it can be remotely tuned to a desired frequency as well.

Note that the components shown in Fig. 3 are not part of the downconverter board, and they are used only if remote operation is required.

Construction

The PC board material (G-10, 0.062 inch thick glass epoxy) and layout must be followed exactly to duplicate the performance of the downconverter. The stray capacitance, coupling between elements, and L4 are all integrated into the design of the board. Any layout deviations can change those specifications. The foil patterns are

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TV DOWNCONVERTER

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vided for you to make your 1 board, and the parts-place- nt diagram is shown in Fig.

'irst install resistors R1–R13, d R15–R17. Next, install all pacitors except the chip ca- citors and C10. Install mixer , and then wind and install ils L1, L2, L3, L5, L6, L7, L8. Coils L1, L2, and L3 are three rns each of 20 AWG tinned re wound around a No. 8 rew as a form (see Fig. 5) and en stretched to a length of 0.3 ch with the turn spacing enly maintained. All three of ose coils must be tapped as lown in Fig. 5. The lead from 1 (which can be coaxial 50- m line) has its center conduc- r soldered to L1 at ¾ turn from e grounded end. Resistor R5 soldered 1½ turns from the d of L2 that connects to R6, 7, and C8. Coil L3 is tapped at turn from the grounded end. Coils L6 and L7 are 8 turns ach of 22 AWG enamelled wire ound on a No. 8 screw. The crew is removed after winding he coil. Coil L8 is 9½ turns of 2 AWG enamelled wire, wound he same way as L6 and L7. However, after winding, the No. 8 screw is removed and a ferrite uning slug is screwed into the winding as shown in Fig. 5. RF choke L5 is installed as if were a resistor.

Install Q2, Q3, D1, D2, and D3. Now install the chip capacitors. Chip capacitors require special installation procedures—and they all mount on the solder side of the PC board. Figure 6 shows where all of the chip capacitors, C10 (which we'll get to in a moment), and Q1 are mounted on the solder side of the board. As for the chip capacitors, first tin the area on the PC board where a chip is to be installed. Then hold the chip in place with the tip of a small screwdriver or tweezers and tack solder one side. After it's tacked in place, fully solder both sides of the chip.

Now install Q1, whose long lead is the drain. Make sure you use a grounded iron and work in a static-free area. Treat Q1 as you would a delicate CMOS IC. The tuning potentiometer (R14) can be mounted in different positions for added flexibility; it can be mounted off the board for remote tuning purposes.

Make sure all holes marked "G" in Fig. 4 have jumper wires passed through them and soldered on both sides of the PC board as shown in Fig. 7. Also, both sides of the board must be grounded together with copper foil tape, also as shown in Fig. 7. Once the tape is in place, solder both sides.

Next make capacitor C10. Take a small square of G-10, 0.062 material (the same as the PC board material) and trim it to a 3/16-inch square. Install it on the solder side of the board as shown in Fig. 8. Connect coaxial 50-ohm cables to J1 and J2, and DC power leads to D3 and ground. Set trimmer capacitors C1, C5, and C6 to about 20% of maximum, and set C9 to about 80% of maximum. If you use R14, it can be set halfway. If R14 is not used, R10 should be temporarily connected to a supply of about +8 volts. Figure 9 shows the author's prototype.

Tune up

Tuning consists of peaking the tuned circuits for best reception. Using a frequency counter connected across R12, adjust C9 for a nominal frequency of 370 to 375 MHz. If installed, R14 should vary that by about ±15 MHz. If R14 is not installed, 0 to +12 volts applied to R10 should do the same. The oscillator might stop if less than 2 volts is applied to R10—which is acceptable as long as you can obtain a frequency range of 30 MHz.

Connect the converter to a TV set tuned to channel 3 and to an external antenna for ATV reception. Find a signal and peak L1, L2, and L3 for the best picture. You can also use an RF signal generator tuned to 435 MHz if no on-the-air signal is available. As a last resort, you can also peak L1, L2, and L3 on noise.

It is also possible to experimentally peak the converter on UHF channels 14, 15, or 16 if no other signals are available. Set C9 for a L.O. frequency of around 410 to 420 MHz. Note: This is only to see if everything works if there's no other way to obtain an ATV signal and you have no access to a signal generator. You will later have to repeak the converter to 420 to 450 MHz.

If a sweep generator is available, simply peak the converter for a response as shown in Fig. 10. By trimming C10 (use a file on the edge of it) you can also experiment with the coupling and resultant bandpass shape. You can also do this with a calibrated RF signal generator and a receiver and/or RF voltmeter, but this will take more time.

The converter should be mounted in a weatherproof metal box, if outdoor use is intended. A metal box reduces stray signal pickup, and also protects the converter from damage.

If you will be remote-tuning the converter (as was shown in Fig. 3), the converter should be mounted right at the antenna or very close to it. That permits a short cable from J1 to the antenna, reducing signal losses. The converter can then be mounted as far as 300 feet from the TV monitor. **R-E**

DRAWING BOARD

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case, you should trim the level because the circuits we'll be building expect a 1-volt signal.

The only other thing to notice here—there just isn't much to the circuit at all—is that the video signal being fed to the base of the transistor is related to both positive voltage and ground through R1 and R2. The circuit is going to run on a regulated 5-volt supply; it must be steady because the level of the supply voltage is going to have an effect on the level of the video. Wire up the circuit shown in Fig. 4 and get the video source in place. When we get together next time we'll start designing some kind of circuit to screw up the signal. **R-E**