A stereo FM broadcaster

As we found out last month, *Rohm* is an outstanding hacker source for unusual integrated circuits. And one that's super hard to find, since they have not been advertising very much in the trade journals.

Anyway, I finally did get a few samples and data on their BA1404 FM stereo modulator chip. Sadly, I just have not had enough time to fully put it through its paces.

This is a single integrated circuit which could convert two high-quality stereo audio channels into a miniature FM broadcast-band transmitter output. Since the chip needs only three mils from 1.25 volt supply, it is also ideal for new wireless microphones, surveillance devices, and for other low-power broadcast uses. Separation can be 45 dB and a flatpack version is available for miniature applications.

Another intended use is to accept the stereo output of a CD player and broadcast it to an FM car radio, without needing any special add-on connections between the CD player and the receiver. You should also be able to use it for some offbeat applications, such as model rocketry, telemetry, computer data linkups, CB communications, or remote controls. The possibilities boggle the mind. A typical broadcast range is 50 to 100 feet.

Figure 4 shows you one possible schematic. The two audio channels go in by way of a typical FM pre-emphasis network. A 38-kHz crystal oscillator is used to create the L−R stereo multiplexed signal, which is routed to an internal varactor-tuned RF oscillator that operates in the 88- to 108-MHz range. That modulated oscillator signal is then sent to a final isolating RF amplifier, and then gets routed to an antenna. The RF output voltage is somewhere around 600 millivolts.

Cost of the chip is around $1.50, and free engineering evaluation samples are often available on letterhead requests. Several **Radio-Electronics** classified advertisers offer ready-to-go component kits and printed-circuit boards for the circuit.

Be sure to check Rohm's entire product line. They have dozens of unique and oddball integrated circuits available that have outstanding hacker potential.

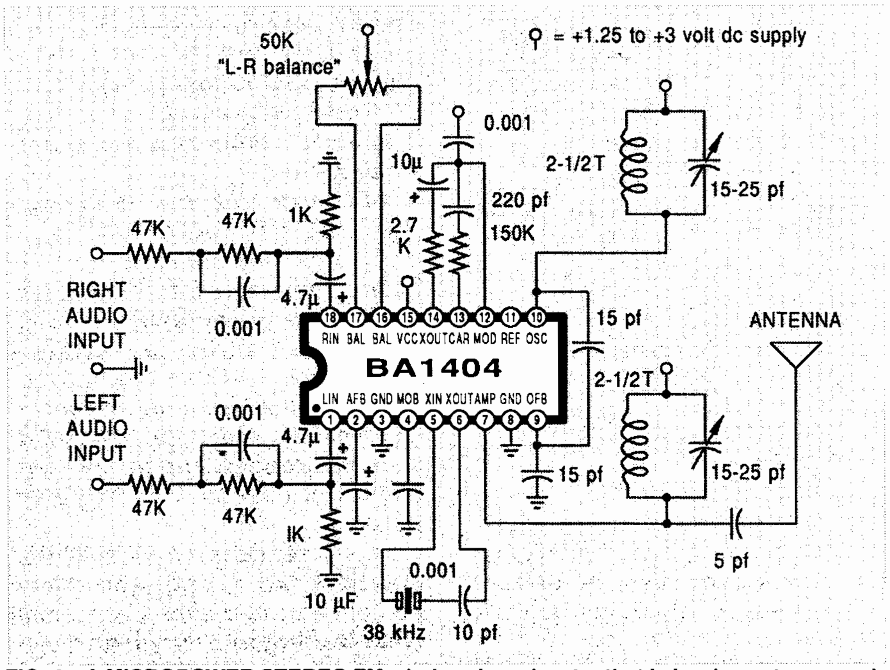


FIG. 4—A MICROPOWER STEREO FM wireless broadcaster that is low in cost, can work off a single AA battery, uses few parts, and offers high audio quality.

WIRELESS STEREO LINK

This great little stereo FM transmitter lets you listen to whatever you want, whenever you want, wherever you want.

WILLIAM SHEETS and RUDOLF F. GRAF

YOU'RE WATCHING THE BEST BOXING match you've seen in years on your cable-television sports channel. The fighters are really slugging it out. Now the dog decides he has to go out and he's not going to wait. What do you do? You connect the television's audio to our FM broadcaster, put on your *Walkman* stereo tuned to a frequency near 88 MHz, and take the dog out without missing a punch.

In this article we'll show you how to build a low-cost, low-power stereo FM transmitter that can broadcast about 100 feet in a typical residential environment. Its signal is received on an unused FM channel, just as if it were any other FM station.

The idea of a radio transmitter for use with a home-audio system is not new. Those who were into electronics in the 1950's will remember the "phono oscillators" that were used to broadcast phonograph records to a nearby AM radio. Today, however, modern-IC devices make it possible to build a high-fidelity stereo FM transmitter that doesn't need much "tweaking" to get it working. Also, all of the necessary parts are available from the source that is listed in the Parts List.

FM transmitter

Whereas the old phono oscillator could only broadcast a mono signal, stereo requires two audio channels—one for left audio and one for right audio. An FM stereo signal has the frequency spectrum shown in Fig. 1. The main channel of the audio baseband (50 Hz to 15 kHz) is the sum of the left- and right-channel (L + R) audio. A monophonic receiver is able to receive that, and everyone is happy. Also, a *stereo difference* channel (L − R) is generated. That channel is the difference between the left and right signals. The (L − R) signal modulates a 38-kHz subcarrier, whose sideband products are transmitted along with the main audio.

The 38-kHz carrier is suppressed in accordance with FCC technical standards for stereo-FM modulation (the reason for that is beyond the scope of this article). But the 38-kHz subcarrier is necessary for reception of the L − R signal, so it must be supplied in some way at the stereo FM receiver. It is reconstructed in the receiver by using a 19-kHz pilot carrier sent along by the transmitter. The 19-kHz pilot carrier represents 10% of the full-modulation amplitude.

A block diagram of our FM stereo transmitter is shown in Fig. 2: The left and right audio inputs are fed into a matrix consisting of two halves of an LM1458 dual operational amplifier. One half of the IC uses a summing configuration to algebraically add the two audio waveforms to create the main-channel audio. It has a gain of −1 for each input, so each input contributes equally to the output of the op-amp. The output is the algebraic sum (L + R) of the left and right chan-

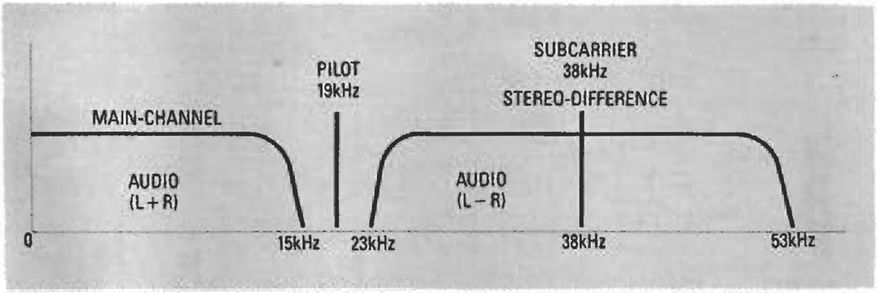


FIG. 1—THE FREQUENCY SPECTRUM of an FM-stereo signal, and the MPX transmitter must duplicate this signal in order for an FM receiver to pick it up.

nels. The other half of the LM1458 is set up to algebraically subtract the two inputs to create the stereo-difference channel. The right input is subtracted from the left input to form the L − R signal. Note that if the inputs are the same, the L − R output would be zero.

The difference (L − R) signal is fed to a balanced modulator, an MC1496 IC. That modulator produces sum and difference frequencies of the audio and subcarrier input. Both the audio input and the subcarrier input are suppressed by the IC—only the sum and difference frequencies appear at the output. A balance control is used to set the correct DC voltage on the IC to achieve maximum 38-kHz subcarrier suppression. (If a 1-kHz audio signal (L − R) and a 38-kHz subcarrier are mixed in that stage, a signal having only 37- and 39-kHz components appears at the (L − R) subcarrier output. If the audio signal is 10 kHz, we have 28- and 48-kHz components in the output.)

The 38-kHz signal is derived from a 76-kHz oscillator and a CD4027 dual flip-flop. One flip-flop divides the frequency by 2, producing a 38-kHz square wave; the other flip-flop divides the 38-kHz square wave by 2 to obtain a 19-kHz square wave. Both the 38- and the 19-kHz square waves are converted to sine waves by passing the signal through a tuned circuit.

The L + R signal, the L − R subcarrier signal, and the 19-kHz pilot signal are fed to a summing amplifier whose output is a composite multiplex (MPX) signal that is fed to a *V*oltage-*C*ontrolled *O*scillator (VCO) operating at the low end of the FM broadcast band. Controls are provided to adjust each component of the MPX signal to its correct level.

To ensure stability, the VCO is powered by a Zener-regulated power source and its output is fed to a buffer-amplifier that isolates the VCO from the antenna-output connector. The antenna should be about 12 inches long, and any piece of wire will do.

Circuit details

The schematic is shown in Fig. 3. The left- and right-audio inputs are connected to J1 and J2. Capacitors C1 and C2 couple audio to R2 and R4 (input resistors for the L + R channel) and R11 and R12 (input resistors for the L − R channel). Resistor R3, connected between R2 and R4, is used to set the ratio of gains for the L and R signals to exactly 1:1. Ideally, if R2 is equal to R4, then R3 is set at the midpoint. Resistor R6 sets the stage gain to about one (unity gain).

The L − R difference amplifier is IC1-b. Resistors R8, R10, and R11 form an adjustable network similar in function to R2, R3, and R4. Signals from the right channel are coupled by R12 and R13. A network made up of resistors R14, R15, and capacitor C3 is used to bias both op-amp sections at half the supply voltage. Since the gain of IC1-b, as seen from the non-invert-

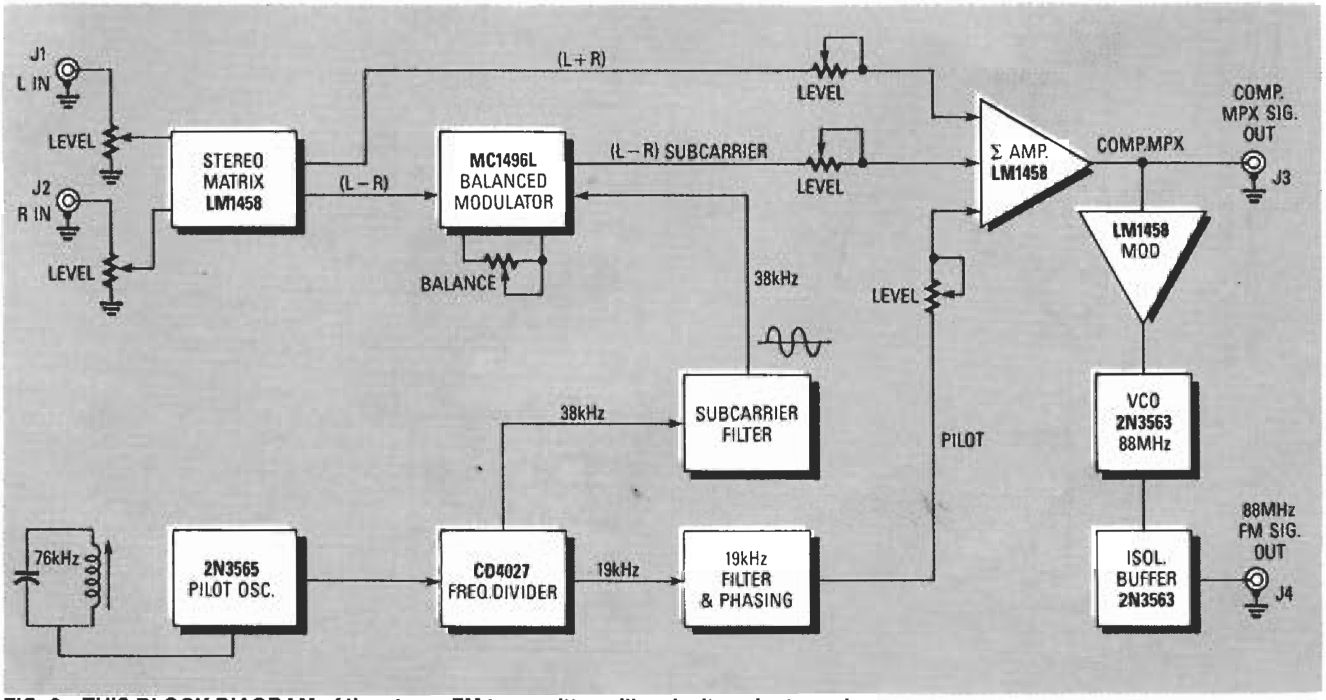


FIG. 2—THIS BLOCK DIAGRAM of the stereo FM transmitter will make it easier to understand how it actually works.

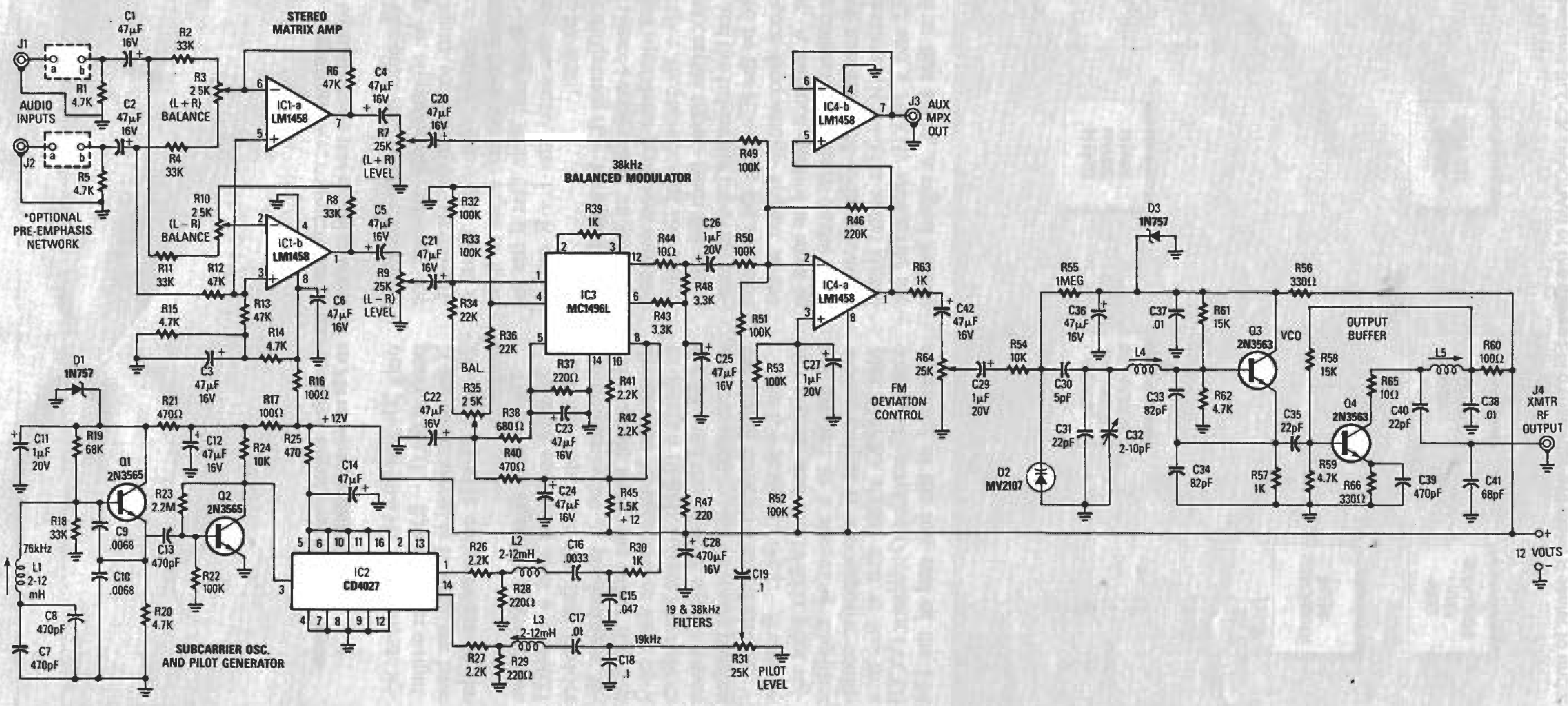


FIG. 3—THIS STEREO FM TRANSMITTER is capable of transmitting a stereo signal up to a hundred feet.

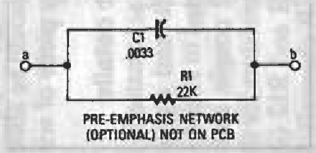


FIG. 4—THIS PRE-EMPHASIS NETWORK can be added to the audio inputs of the MPX transmitter, if necessary.

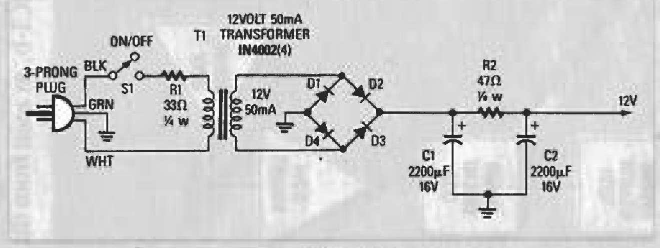


FIG. 5—THIS POWER SUPPLY can be used if you do not want to power the transmitter with batteries.

PARTS LIST— MPX TRANSMITTER

All resistors are ¼-watt, 10% unless otherwise noted

R1, R5, R14, R15, R20, R59—4,700 ohms
R2, R4, R8, R11, R18—33,000 ohms
R3, R7, R9, R10, R31, R35, R64—25,000 ohm potentiometer
R6, R12, R13—47,000 ohms
R16, R17, R60—100 ohms
R19—68,000 ohms
R21, R25, R40—470 ohms
R22, R32, R33, R49–R53—100,000 ohms
R23—2.2 Megohms
R24, R54—10,000 ohms
R26, R27, R41, R42—2,200 ohms
R28, R29, R37, R47—220 ohms
R30, R39, R57, R63—1,000 ohms
R34, R36—22,000 ohms
R38—680 ohms
R43, R48—3,300 ohms
R44, R65—10 ohms
R45—1,500 ohms
R46—220,000 ohms
R55—1 Megohm
R56, R66—330 ohms
R58, R62—15,000 ohms

Capacitors

C1–C6, C12, C14, C20–C25, C36, C42—47 µF, 16 volt radial-lead electrolytic (PC-mounting type)
C7, C8—470 pF (silver mica or NPO)
C9, C10—0.0068 µF, Mylar
C11, C26, C27, C29—1 µF, 20 volt radial-lead electrolytic
C13, C39—470 pF, ceramic 20%
C15—0.047 µF, Mylar 10%
C16—0.0033 µF, Mylar 10%
C17—0.01 µF, Mylar 10%
C18, C19—0.1 µF, Mylar 10%
C30—5 pF, silver mica or NPO
C28—470 µF, 16-volt radial lead electrolytic
C31, C35, C40—22 pF, silver mica or NPO
C32—2–10 pF trimmer capacitor
C33, C34—82 pF, silver mica or NPO
C37, C38—0.01-µF disc
C41—68 pF, silver mica or NPO

Semiconductors

IC1, IC4—LM1458N op-amp
IC2—CD4027 dual JK flip flop
IC3—LM1496N balanced modulator
D1, D3—1N757 9.1 volt Zener diode
D2—MV2107 varactor diode
Q1, Q2—2N3565 NPN transistor
Q3, Q4—2N3563 NPN transistor

Other components

L1–L3—2–12 mH variable inductor (No. Country Radio, P/N 212103)
L4, L5—5-½ turns #22 enameled wire on Cambion blue 8-32 × ¼ slug (see text)
J1–J4—RCA jack
Miscellaneous—1 on/off switch, 1 LED and a 1K resistor for an optional pilot light, 1 cabinet, hardware, shielded wire, power-supply components if needed, components for Fig. 8 if needed.

Note: The following items are available from North Country Radio, P.O. Box 53, Wykagyl Station, New Rochelle, NY 10804: PC board and all components that mount on it including all resistors, capacitors, semiconductors, L1–L3, cores and wire for L4 and L5 (LED and 1K resistor, power-supply components, cabinet, on/off switch, and phono jacks NOT included) $57.50 + $2.50 S/H. PC board only $14.00 + $2.50 S/H. NY residents must include sales tax.

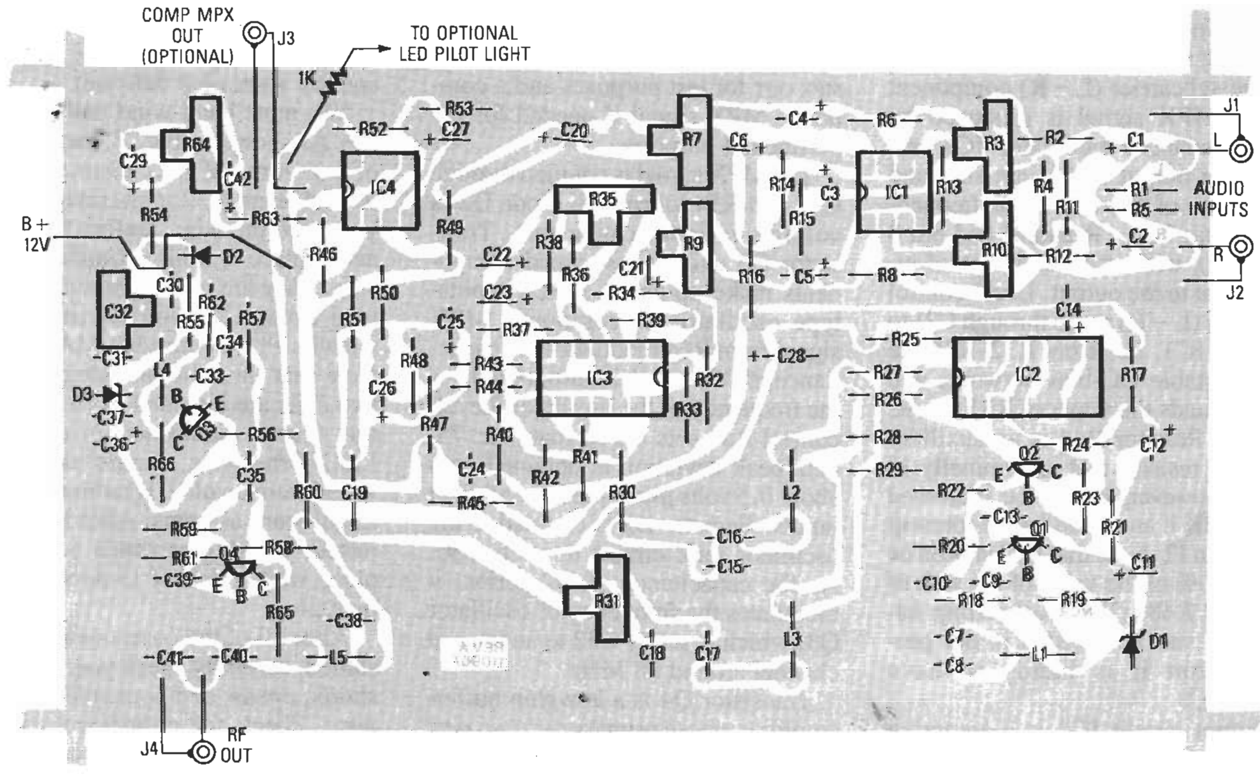


FIG. 6—FOLLOW THIS PARTS-PLACEMENT diagram when you are constructing the MPX transmitter.

ing input (pin 3), would be 2 if R11 is equal to R8 and R10 is at midpoint, R12 and R13 divide the input signal by 2. Resistor R10 is set so that when the left and right inputs are exactly equal (shorted together with a clip lead), the output from IC1-b (measured across R9) is exactly zero. That fulfills the necessary condition that the L − R signal be equal to 0 when both inputs are identical.

As we discussed earlier, the transmitter must generate a pilot signal at 19 kHz and a 38-kHz subcarrier signal. Oscillator Q1's output is 76 kHz. The frequency-determining network is formed by capacitors C7–C10, and inductor L1, which is adjustable and used to set the oscillator frequency to exactly 76 kHz. The oscillator signal is coupled by C13 to buffer-amplifier Q2. Resistors R22–R24 bias Q2, while C12 and R17 provide filtering to remove 76-kHz components from the B+ line. The collector of Q2 provides a negative going pulse train to IC2, a dual JK flip-flop. That flip-flop divides the 76-kHz signal by 2 to get 38 kHz, and again by 2 to get 19 kHz. The 38-kHz and 19-kHz signals are square waves. Since we need sine waves, two filters (L2, C15, C16) and (L3, C17, C18) provide harmonic filtering to pass only the fundamental frequencies. Resistor R30 couples the 38-kHz sine wave (about 1 volt p-p) to modulator IC3. The pilot-level control, potentiometer R31, couples a variable-level 19-kHz signal via capacitor C19 to the output-summing circuit. Phase adjustment of the subcarrier and the pilot is achieved by adjusting L2 and L3, respectively.

The subcarrier (L − R) component of the MPX signal is produced by IC3, a balanced modulator. IC3 produces an output that is the sum and difference of the two input frequencies at pin 1 (L − R audio) and pin 8 (38 kHz), without feedthrough of either input to the output. Level-control R9 feeds (L − R) audio through C21 to pin 1 of IC3. Resistors R32–R36 are an adjustable DC-bias network, and C22 grounds the wiper of R35 for AC signals. Resistor R44 is an auxiliary level-set resistor that is nominally 10 ohms, however, it may be increased up to 2.2K if an excess level is present at IC3 pin 12. Note that R43 should be within 10% of the value of the sum of R44 and R48. (The level-setting adjustment was not needed in our prototype but it is handy to have available.)

Output circuit IC4 is a summing amplifier having a gain of 2. Components R52, C27, and R53 bias the op-amp at half the supply voltage. The L + R audio from the wiper of level-control R7 is coupled via C20 to R49. The L − R subcarrier is coupled via C26 to R50. The 19-kHz pilot signal

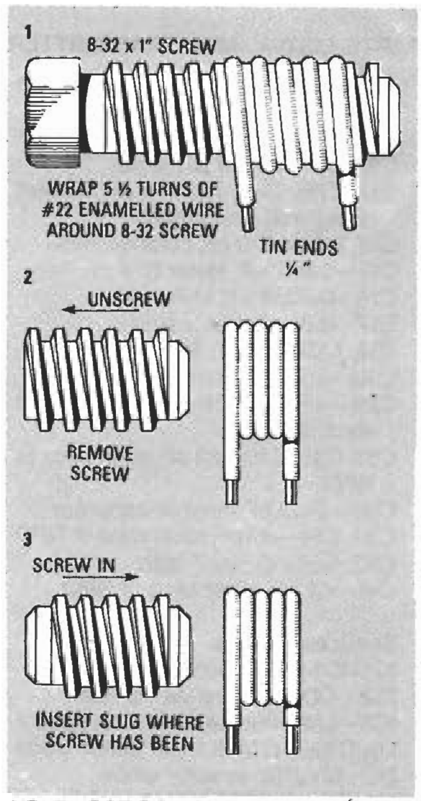


FIG. 7—COILS L4 AND L5 must be hand wound on an 8-32 screw.

from R31 is coupled to R51. Those three signals are summed and amplified, and appear at IC4-a pin 1. Voltage-follower IC4-b provides an AUX MPX OUT for test purposes and a composite MPX signal if needed for experimental purposes.

The MPX signal is coupled through C29 and R54 to varactor diode D2 (a voltage-variable capacitor). Transistor Q3 and its associated components make up an 88-MHz Colpitts-type oscillator. A composite MPX signal from R64 modulates the capacitance of D2, which in turn modulates the frequency of the oscillator. Level-control R64 sets D2 so that a ± 75-kHz peak deviation is obtained with about 0.5 volts p-p at the left and right inputs. Varactor D2 is coupled to the oscillator tank circuit through C30. As the capacitance of D2 varies, it modulates the frequency of oscillator Q3, which is set by C32 to an unused channel around 88 MHz.

Transistor Q4 is a low-gain buffer-amplifier whose primary purpose is to isolate the oscillator (Q3) from the effects of variable loading caused by the antenna. Resistor R65 suppresses a tendency toward unwanted UHF oscillation. A matching circuit for a 50-ohm output load or antenna is made up of L5, C40, and C41. The output level of that matching circuit is 100–120 millivolts rms into 50 ohms, or about ¼ milliwatt.

We did not need any audio pre-emphasis, because the received signal sounded good without it. For those who require pre-emphasis, the optional circuits in Fig. 4 can be added to the audio inputs.

About 50 milliamperes at 12 volts is required to power the transmitter. A schematic for a suitable power supply is shown in Fig. 5. It can be assembled using point-to-point wiring on a terminal strip, or by any other appropriate method. Otherwise, 8 AA penlight cells can be used as the power source.

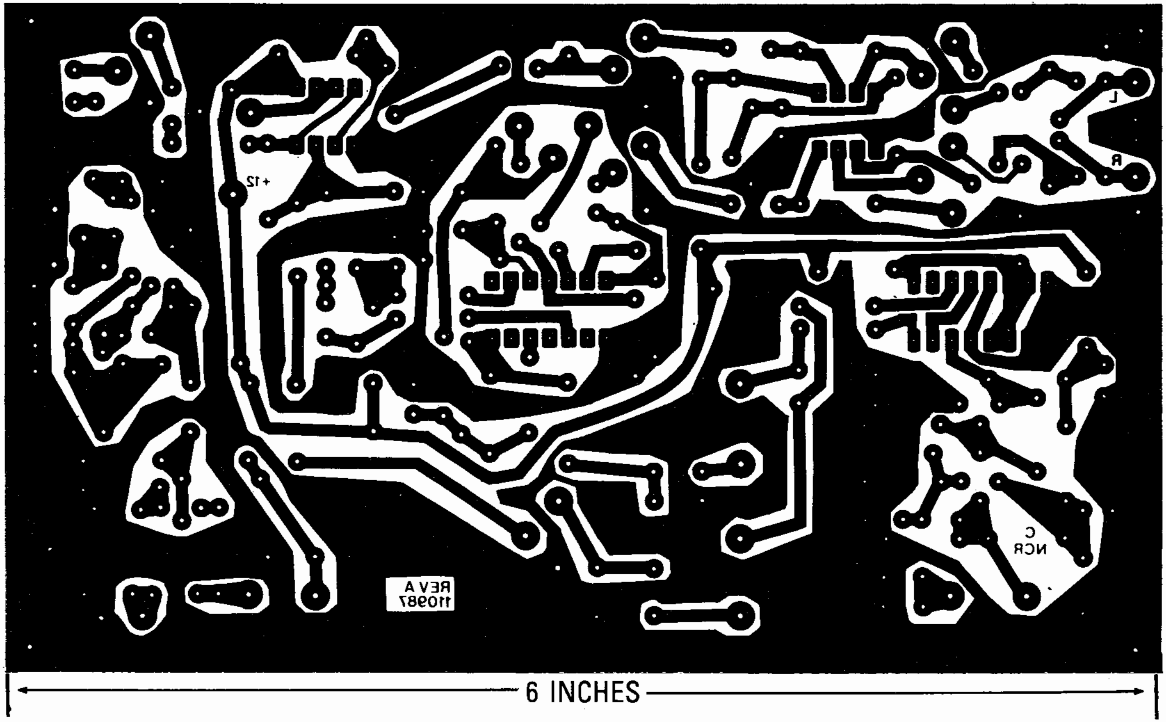
Construction

A PC layout is provided in PC Service. A drilled and plated PC board is available from the source listed in the Parts List, and construction should begin with the mounting of all fixed resistors and diodes. See Fig. 6 for the component placement. Next, install all of the capacitors, being sure to observe the polarity of the electrolytics. Then install the potentiometers, transistors, and IC's. Finally, install coils L1, L2, and L3 (and be careful when handling the coils because they are wound with fine wire and are somewhat delicate).

You must hand-wind coils L4 and L5. As shown in Fig. 7, they consist of 5-½ turns of #22 enameled wire wound on an 8-32 screw thread. After you wind the wire, remove the screw and replace it with a Cambion *blue* slug. They are manufactured by Midland Ross, Cambion Division (One Alewife Pl., Cambridge MA 02140). Note that the wire and slugs for the two coils are included in the kit from the source mentioned in the Parts List. Otherwise, ferrite slugs salvaged from an old CB radio or TV set might work as cores. After being adjusted, the slug can then be held in place with a dab of Q-dope or hot-melt glue.

After all of the components are installed, carefully check your work for shorts, opens, and poor solder joints. Also, check for correct component orientations, since incorrect orientation may cause irreversible damage to the IC's and other circuitry.

That's all we have room for in this installment. Next time we will show you how to check out and align your wireless transmitter. **R-E**



BUILD THE FM WIRELESS LINK using this PC board.