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Now You Can Enjoy HI-FI Remote Sound

WITHOUT RUNNING WIRES AROUND THE HOUSE

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B·I·C Belt-Drive Record Changer
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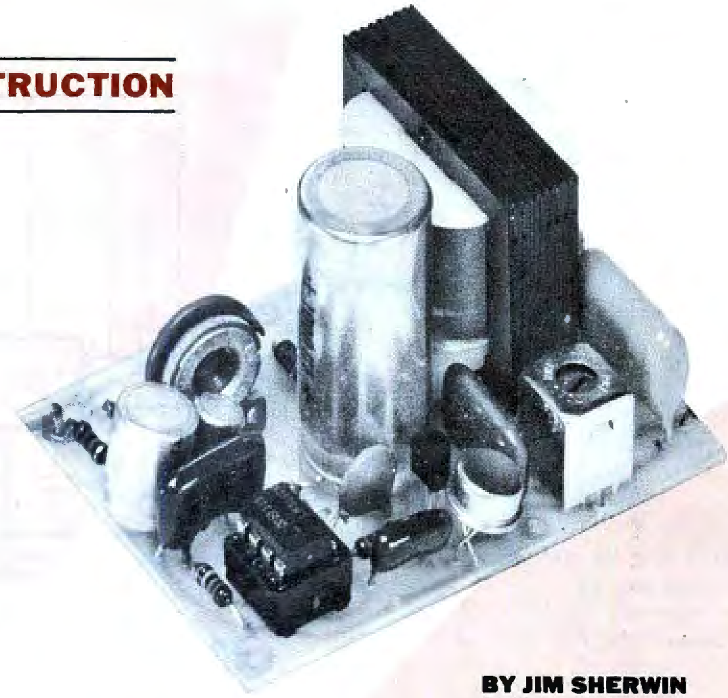
CONSTRUCTION



BY JIM SHERWIN

A Wireless Audio System for Remote Speakers

Now you can enjoy high-quality remote sound without running wires around the house.

CONNECTING extension speakers to one's stereo system or rear speakers for a four-channel setup is a terrifying task for many people. It often means running speaker wires through walls and floors, hiding them under a carpet, or tacking them to baseboards. Presented here is a "wireless" system that eliminates this problem!

The new system uses existing ac power lines, operating in an FM mode. The result is good-quality audio (wide frequency response and low distortion) and a high order of noise immunity.

To overcome the old obstacles of the wireless medium (noise, narrow bandwidth, etc.), as in AM wireless intercoms, the Wireless Hi-Fi System employs an FM carrier, phase-locked-loop (PLL) and voltage-controlled-oscillator (vco) IC's. The result claimed by the author is a 30-to-17,000-Hz ±0.2 dB frequency response, 2% total harmonic distortion (THD), and excellent noise immunity for a fine signal-to-noise (S/N) ratio of −50 dB unweighted, at 2 watts power output into an 8-ohm speaker. (How to achieve higher power output is discussed later in this article.) In addition, putting the signal on the ac line will generally assure good reception at all power outlets in your home—even if the transmitter and receiver are on *opposite* sides of the line.

As structured, the system will accommodate a monophonic signal. To transmit stereo, two systems can be used, each tuned to a different carrier frequency. The drive signals can be taken from the tape monitor and tape output jacks of your amplifier. If your hi-fi system doesn't have these jacks, the signal can be taken from across the speaker terminals, but the advantage of a fixed level will be lost.

About the Circuit. The transmitter, shown schematically in Fig. 1, uses voltage-controlled oscillator *IC1* to drive the *Q1* amplifier. The dc power bus is regulated by *IC2*.

Two inputs are provided so that both left and right channels from a stereo system can be combined for transmission to a remote speaker system. For a monophonic source, resistors *R7* and *R8* can be eliminated and

Fig. 1. Two inputs are provided for the transmitter. For a monophonic source, R7 and R8 can be eliminated.

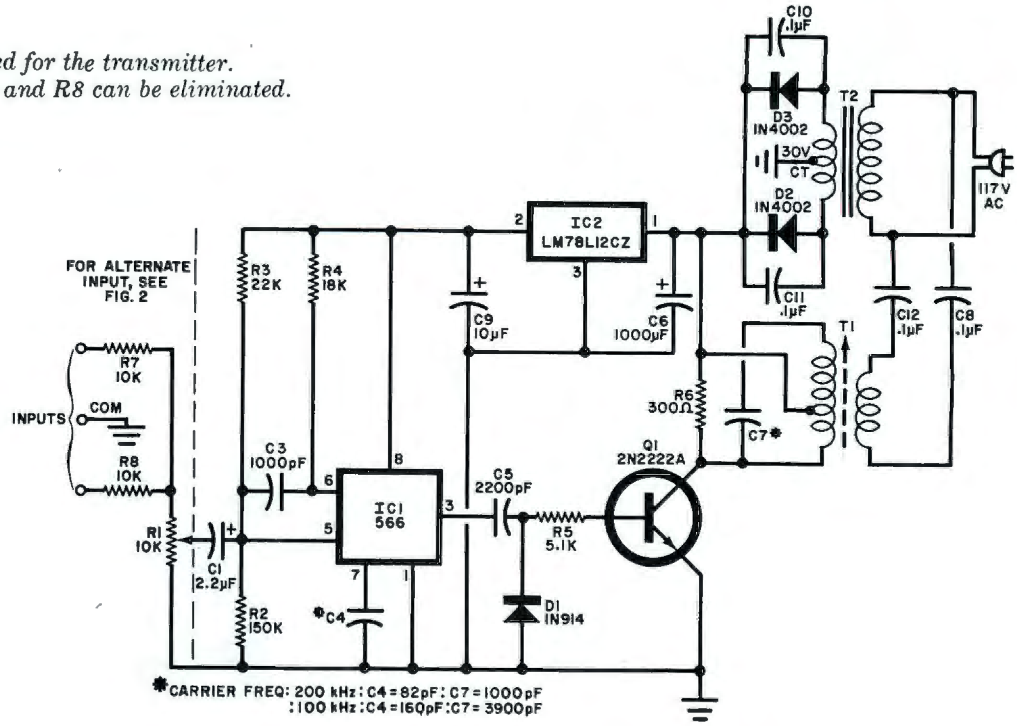
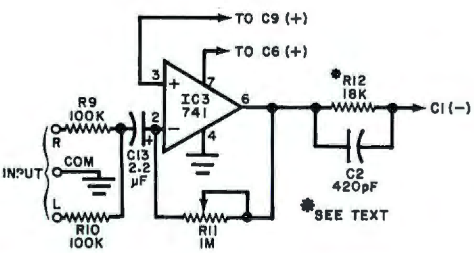


Fig. 2. Use the circuit below to provide pre-emphasis for the transmitter in Fig. 1.



TRANSMITTER PARTS LIST

C1,C13*—2.2-µF, 50-volt electrolytic capacitor
C2*—420-pF mica capacitor
C3—1000-pF disc capacitor
C4—See Fig. 1 for value
C5—2200-pF disc capacitor
C6—1000-µF, 25-volt electrolytic capacitor
C7—See Fig. 1 for value
C8,C10,C11,C12—0.1-µF, 200-volt film capacitor
C9—10-µF, 16-volt electrolytic capacitor
D1—1N914 silicon diode
D2,D3—1N4002 rectifier diode
IC1—566C voltage-controlled oscillator integrated circuit
IC2—78L12CZ—12-volt regulator integrated circuit
IC3*—741C operational amplifier integrated circuit.
Q1—2N2222A transistor
R1—10,000-ohm pc-type potentiometer
R11*—1-megohm pc-type potentiometer
The following resistors are ½ watt:
R2—150,000 ohms, 10%
R3—22,000 ohms, 10%
R4,R12*—18,000 ohms, 5%
R5—5100 ohms, 10%
R6—300 ohms, 5%
R7, R8—10,000 ohms, 10%
R9*, R10*—100,000 ohms, 10%
T1—Line-coupling transformer (see text)
T2—Power transformer with 30-volt center-tapped, 50-mA secondary (Triad No. F133P or similar)
Misc.—Printed circuit board; line cord; machine hardware; hookup wire; solder; etc.
*Optional preemphasis circuit components.
Note—See Fig. 3 Parts List for availability of parts.

POPULAR ELECTRONICS' *performance tests verified that the S/N ratio measured −65 dB, exceeding the author's claimed −50 dB. With "A" weighting it was −93 dB. At 0.9 W, distortion was 0.98%; at 2.5 W, it was 4.9%. Frequency response was 30 to 17,000 Hz ±0.5 dB*—Ed.

the input signal fed directly to the top of potentiometer *R1*. If you want to use the system to feed one channel from a stereo system to the other side of the room, for example, omit *R8* and install a 470-pF capacitor across *R7*. This will improve the frequency response so that it goes out to about 20,000 Hz.

The alternate input circuit shown in Fig. 2 should be used in either of two situations. First, if you are tapping the signal(s) from a high-impedance source, the 10,000-ohm resistor(s) could load down the driving signal in a mono circuit, or introduce unacceptable crosstalk between the two channels of a stereo system (as applied to the main power amplifier). If so, the circuit of Fig. 2 will provide the higher degree of isolation required. The parallel combination *R12-C2* will smooth out the frequency response of the system. To make up for losses in the RC combination, gain is provided (between unity and 10) by op amp *IC1*. Gain is controlled by feedback resistor *R11*.

Because the system's noise immunity is good, no preemphasis/deemphasis is required. However, if you wish to experiment, the alternate input circuit should be used, with a higher RC time constant. For standard 75-µs preemphasis, *R12* should be changed to 180,000 ohms. Then, all program material above 2120 Hz will be emphasized before it enters the transmitter. As above, op amp *IC1* provides gain (set by *R11*) to balance out losses in the preemphasis network. Of course, if preemphasis is introduced in the transmitter, deemphasis must then be incorporated into the receiver.

The free-running frequency, f_c, of voltage-controlled oscillator *IC1* in Fig. 1 is determined by the values of *R4* and *C4*. The sensitivity of the vco with the biasing shown and a V_{cc} of +12 volts is about $\pm 0.66 f_c$/V. For minimum distortion, the deviation should be limited to ±10%, which means that the maximum input signal level at pin 5 of *IC1* should be 0.3 volt peak-to-peak. The output voltage from the tape monitor or tape output jack of an audio system may range from 0.4 to 1.5 volts rms; therefore, *R1* is provided so that an appropriate modulation level can be set.

The frequency-modulated output at

pin 3 of *IC1* is roughly a 6-volt peak-to-peak square wave. This signal is used to modulate the *Q1* r-f oscillator, which uses tuned transformer *T1* as its collector load. Because *T1* is tuned to f_c by adjusting its slug and *C7*, it serves as a high-impedance collector load, which eliminates the need for additional current limiting for *Q1*. Because the collector signal can have as much as a 50-volt peak-to-peak amplitude, *Q1*'s breakdown point must be high. The transistor specified for *Q1* in the Parts List has a 60-volt breakdown to provide a margin of safety. The modulated r-f output from the transmitter is coupled to the power line via *C8* and *C12*.

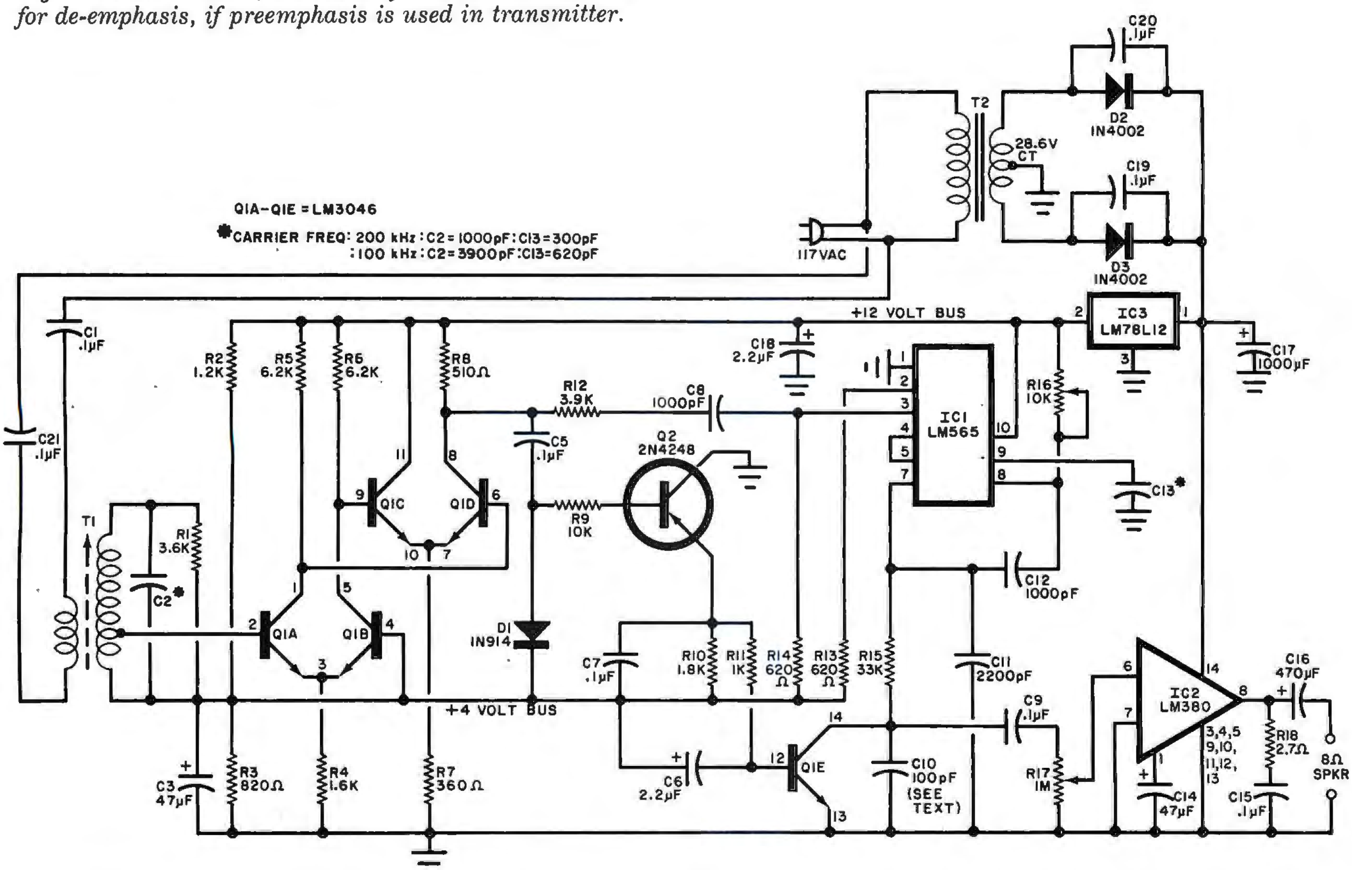
Note that Fig. 1 specifies values for *C4* and *C7* for either 100- or 200-kHz operation. Also note that capacitors *C10* and *C11* are connected across rectifier diodes *D2* and *D3*. These capacitors reduce the small step transient that might be present across the silicon diodes whose upper harmonics fall within the frequency of interest.

The job of the receiver is to amplify, limit, and demodulate the received FM signal riding on the ac power line which can have high-amplitude noise transients. In addition, the receiver must also provide an audio mute in the absence of a carrier.

The circuit shown in Fig. 3 picks up the incoming FM signal and tunes to the carrier frequency via the *T1/C2* circuit. This signal is then applied to a two-stage limiting amplifier (composed of elements inside transistor array *Q1*), phase-locked loop *IC1*, audio amplifier *IC2*, and a mute circuit made up of *Q1E* and discrete transistor *Q2*.

The FM carrier is coupled to the primary of tuned transformer *T1* through *C1* and *C21*. The secondary of

Fig. 3. In the receiver, the value of C10 must be increased for de-emphasis, if preemphasis is used in transmitter.



RECEIVER PARTS LIST

C1,C9,C19,C20,C21—0.1-µF, 200-volt film capacitor
C2—See Fig. 3 for value
C3,C14—47-µF, 16-volt electrolytic capacitor
C4—Not used
C5,C7,C15—0.1-µF, 25-volt disc capacitor
C6,C18—2.2-µF, 25-volt electrolytic capacitor
C8, C12—1000-pF disc capacitor
C10—100-pF disc capacitor (see text)
C11—2200-pF disc capacitor
C13—See Fig. 3 for value
C16—470-µF, 25-volt electrolytic capacitor
C17—1000-µF, 25-volt electrolytic capacitor
D1—1N914 silicon diode
D2,D3—1N4002 rectifier diode
IC1—565C phase-locked loop integrated circuit
IC2—LM380 audio amplifier integrated circuit (National)
IC3—78L12CZ 12-volt regulator integrated circuit
Q1 (A to E)—LM3046 transistor array (National)
Q2—2N4248 transistor.
The following resistors are ½ watt:
R1—3600 ohms, 5%
R2—1200 ohms, 5%
R3—820 ohms, 5%
R4—1600 ohms, 5%
R5,R6—6200 0hms, 5%
R7—360 ohms, 5%
R8—510 ohms, 5%
R9—10,000 ohms, 10%
R10—1800 ohms, 5%
R11—1000 ohms, 5%
R12—3900 ohms, 10%
R13, R14—620 ohms, 5%
R15—33,000 ohms, 10%
R18—2.7 ohms, 10%
R16—10,000-ohm pc-type potentiometer
R17—1-megohm potentiometer
T1—Line-coupling transformer (see text)
T2—Power transformer with 26.8-volt center-tapped, 1-ampere secondary (Triad No. F40X or similar)
Misc.—Printed circuit board; line cord; machine hardware; hookup wire; solder; etc.
Note—The following items are available from American Scientific Corp., 1957 Old Middlefield Rd., Mountain View, CA 94043: etched and drilled transmitter pc board for $3; etched and drilled receiver pc board for $5.50; transmitter IC's and transistors and Toko line-coupling transformer for $6.00; receiver IC's and transistors and Toko transformer for $10.50; complete transmitter kit for $18.95, plus $1.00 shipping; complete electronics receiver kit for $27.95, plus $1.00 shipping. National Semiconductor IC's are available, singly or in quantity from OEMorsco, 2403 Charleston Rd., Mountain View, CA 94043.

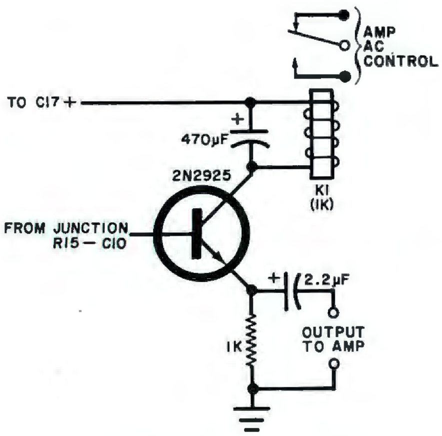


Fig. 4. Use this circuit to change receiver output for more power.

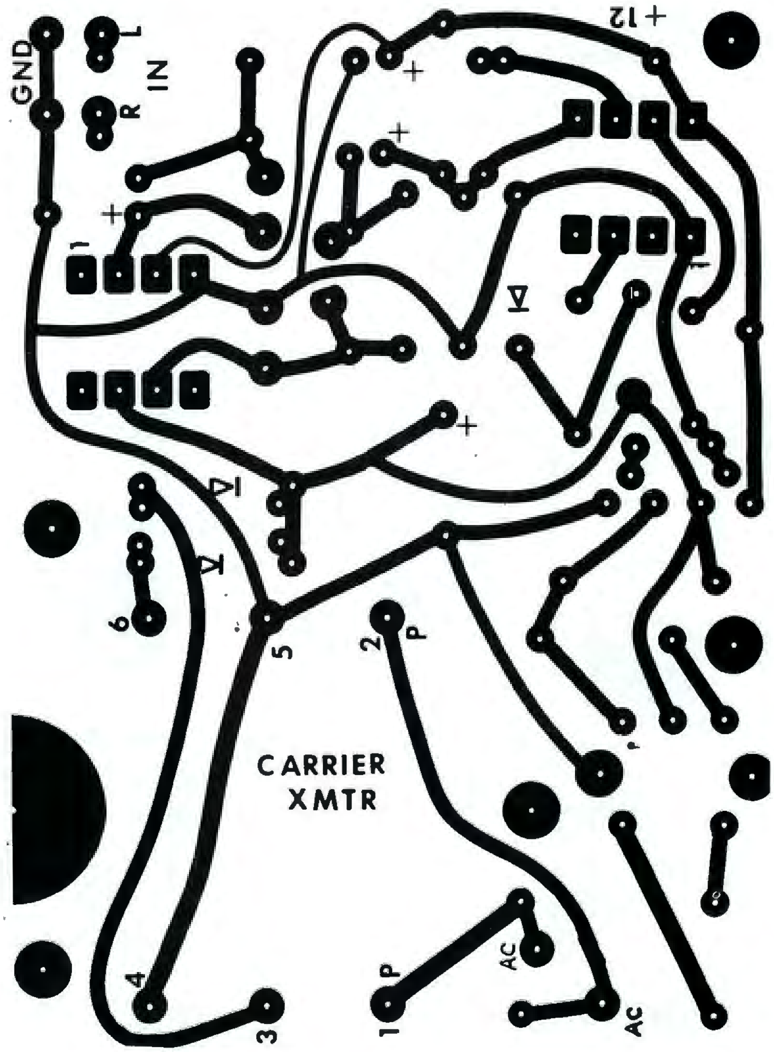
T1 is tuned by *C2*, while *R1* lowers the Q of the circuit to permit it to accept the ±10% modulation and to prevent excessive ringing on noise spikes. Such ringing would cause the mute circuit to deactivate. The secondary of *T1* is tapped to match the input impedance of *Q1A*. The recovered carrier at the secondary of *T1* can have an amplitude of between 0.2 and 45 volts peak-to-peak. The 17:1 turns ratio from the full secondary to the tap reduces the amplitude of the recovered carrier so that the base of *Q1A* "sees" a signal that ranges from 12 mV to 2.6 volts peak-to-peak.

The two-stage limiter amplifier composed of *Q1A* through *Q1D* operates as a fairly fast comparator whose slew rate is about 70 volts/µs and gain is about 3000. The output from this limiter is a roughly 7-volt peak-to-peak square wave that has rise and fall times of 100 ns. (Any fairly fast comparator that delivers more than 5 volts output could be used as the limiting amplifier. However, the transistor array specified is a low-cost item that has the advantage of containing an extra-high beta transistor, *Q1E*, which is used as the mute switch.) The 7-volt peak-to-peak output of the limiting amplifier is applied directly to the mute detector, *Q2*, but is reduced to about 1 volt by the attenuator consisting of *R12* and *R14* before being applied to PLL *IC1*.

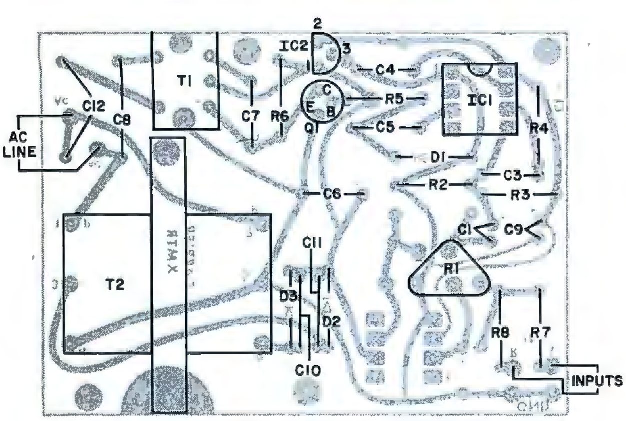
The PLL operates as a narrow-band filter that tracks the incoming FM signal and provides a low-distortion demodulated audio output whose signal-to-noise (S/N) ratio is high. The oscillator inside the PLL is set to free-run at a frequency near that of the carrier by the choice of value for *C13* and setting of *R16*.

If 75-microsecond preemphasis is used, increase the value of *C10* to 2200 pF. Increasing this capacitor's value will reduce the carrier level in the audio line at the expense of high-frequency audio response.

The mute circuit quiets the receiver when no carrier is present. Without this circuit, an excessive noise level would result as the PLL attempts to

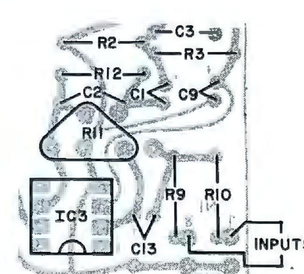


A



B

Fig. 5. Etching and drilling guide for the transmitter are shown above (A). Component placement for standard transmitter is at left (B). If pre-emphasis is used, the component placement at right is necessary (c).



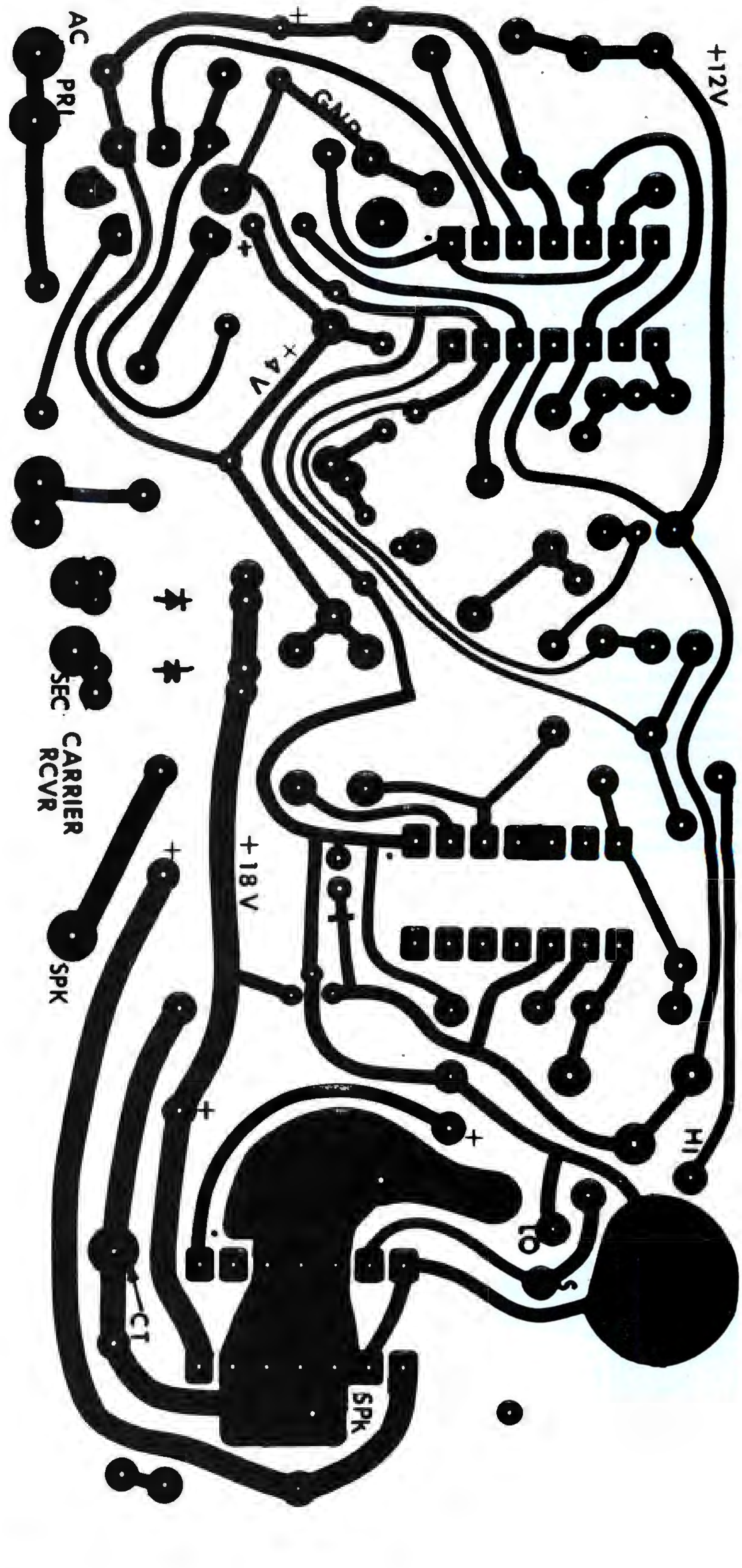
C

lock onto noise spikes when the transmitter is shut off. The mute detector is composed fo *C7*, *D1*, and *Q2*. Note that an emitter-follower transistor stage is used in place of a diode to give the peak detector a high input and a low output impedance. This permits the peak detector to shunt 1 to 2 mA of bias away from *Q1E*, without loading the limiter amplifier.

With no carrier present, the +4-volt line biases *Q1E* into conduction via *R10* and *R11*, shorting the audio signal to ground. When a carrier is present, the 7-volt square wave from the limiter amplifier is peak detected, producing a negative output that is integrated by *R9* and *C7*, averaged by *R10* across *C7*, and further integrated by *C6* and *R11*. The resultant −4-volt output subtracts from the +4-volt bias to deprive *Q1E* of base current. This transistor cuts off and allows the demodulated audio signal to pass to the audio amplifier. Peak detector integration and averaging prevents random noise spikes from deactivating the mute when no carrier is present.

Audio amplifier *IC2* supplies about 2 watts of audio power to an 8-ohm speaker connected across the output of the receiver. Although this amount of power is adequate for casual and background-music listening, if you want to drive relatively inefficient hi-fi speaker systems, you'll have to modify the output of the receiver to drive a hi-fi amplifier. The circuit shown in Fig. 4 does this. To use it, audio power amplifier *IC2* is removed from the receiver circuit and the Fig. 4 circuit goes into the receiver as specified. This switching circuit operates from the mute signal so that when the transmitter is switched on, the relay will energize to apply power to the external power amplifier. In this manner, the power amplifier will automatically switch on when a signal is received. Standby power is less than 1 watt.

Construction. The transmitter is best assembled on a printed circuit board, the etching and drilling guide for which is shown actual size in Fig. 5A. In Fig. 5B is the component placement diagram for the board, while the detail in Fig. 5C shows the additions and changes to be made when preemphasis is used in the transmitter. When comparing B and C, note that *R1* is eliminated from the former and *R11* is installed in the latter, *displaced one pad space to the left* but oriented the same.



A

Fig. 6A. Etching and drilling guide for the receiver is shown above. The component placement diagram (Fig. 6B) is on next page.

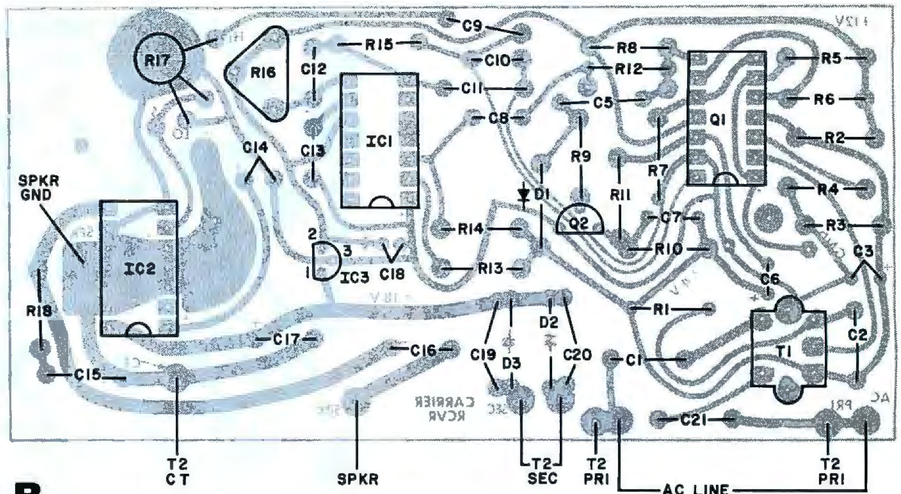


Fig. 6B. Component placement diagram for the receiver is shown above. Foil pattern (Fig. 6A) is on previous page.

Line-coupling transformer *T1* can be made from a 455-kHz AM i-f transformer. In rewinding the turns, the secondary is made up of four turns, while 154 turns are used in the primary, tapped 29 turns from one end of the coil. You can use the wire originally wound on the transformer or 41 AWG enameled wire for the turns.

As with the transmitter, the receiver is best assembled on a printed circuit board. The etching and drilling guide and components placement diagram are shown in Fig. 6A & B.

Line-coupling transformer *T1* is constructed in the same manner as described for *T1* in the transmitter, except that primary is composed of 4 turns the secondary 154 turns, tapped 9 turns from one end.

Adjustments. Make sure that the transmitter and receiver are operating at the same frequency. (See Figs. 1 and 3 for values of frequency-determining components.) Plug the transmitter and receiver into ac outlets and use an oscilloscope or ac voltmeter to check the amplitude of the waveform across the secondary of *T1* in the receiver. There is no need at this time to have the carrier modulated.

Adjust the slugs in the *T1*'s in both the transmitter and the receiver for maximum signal amplitude across the secondary of *T1* in the receiver. If the receiver is to be located some distance from the transmitter or on the opposite side of a 117/220-volt service line, *T1* will have to be readjusted in the receiver to maximize rejection of ac line noise.

The free-running frequency of the PLL in the receiver is trimmed by adjusting *R16*, which should initially be set near the center of its range. Rotate *R16's* wiper slowly in both directions until the PLL loses lock, indicated by a sharp increase in noise and a distorted output from the receiver. Note the two positions where drop-out occurs; center *R16* between these two points. A finer adjustment may be required to obtain minimum noise if an SCR light dimmer is in operation.

The final adjustment is for modulation amplitude in the transmitter. Connect an audio signal source to the input of the transmitter and adjust *R1* for a signal amplitude of about 0.1 volt rms maximum at the input (pin 5) of *IC1*. This can also be accomplished by carefully listening to the receiver while adjusting *R1* in the transmitter until the sound just distorts and then backing off a little.

Because a single transmitter/receiver system will suffice for a monophonic sound system or for one channel of a stereo system, a second receiver and transmitter will be required for stereo sound over the wireless medium. In this case, one transmit/receive system would be tuned to 100 kHz and the other to 200 kHz. You can also use a pair of transmit/receive systems for the rear channels in a 4-channel system to avoid running cables all over your listening room. Again, you would use a different carrier frequency for the different channels.

One final note: Although we have mentioned using carrier frequencies of 100 kHz and 200 kHz for a two transmit/receive system, this spacing needn't be 100 kHz apart. For most purposes, a 40-kHz spacing will do, while still providing maximum frequency response from the system. ◈