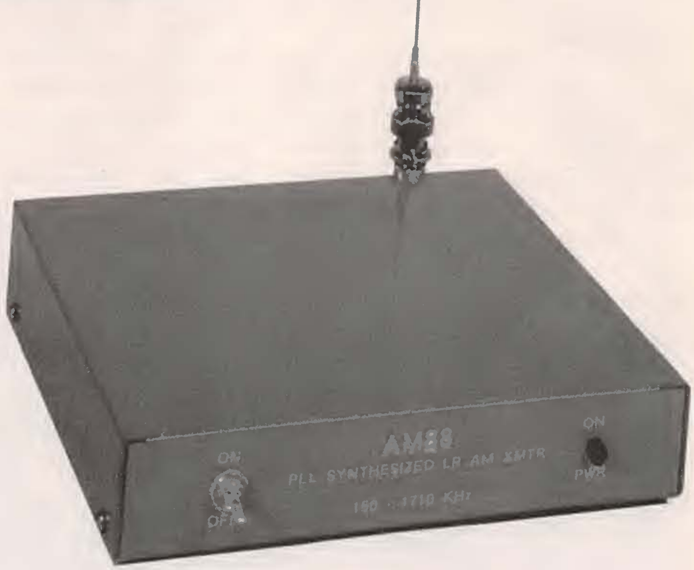
BUILD A LOW-POWER AM TRANSMITTER

What once was old is new again with this AM transmitter project!



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Back in the 1950s, one type of popular construction project was the "phono oscillator" that was able to transmit music from the record player (a device that played music from large plastic discs in the days before the CD) to a nearby radio in another room. Transmitting was done on the AM band—FM was still in its infancy and stereo transmission was yet to be developed. Those transmitters were also used for hobby AM broadcasting and general experimentation with low-power transmitters that were (and still are) legal to use under Part 15 of the FCC regulations for unlicensed transmissions. Although those devices worked well, they were really toys that were used mainly as wireless microphones.

While these days the FM band is much more popular for such applications and offers the additional advantage of supporting stereo audio, for some applications the AM band might be better. The higher field strengths allowed can increase the usable distance between the transmitter and the receiver. Signal bandwidths are narrower, and AM signals are easier to pick up under weak-signal conditions than FM. There are generally more usable frequencies on the AM band than the FM band, especially during daylight hours. Construction is less critical as frequencies are low, and only simple test equipment is needed to set up an AM transmitter. There are also many areas in parts of the world where FM reception is poor or limited because of a lack of "line-of-sight" between the transmitter and the receiver.

One of the more unusual examples of an application where AM works better is the "talking house" used by real-estate agents. In that instance, real-estate brokers use a small transmitter planted in a house so that the prospective buyers can hear the sales pitch on their car radio as they drive by. That arrangement works well since almost every car has an AM radio, but they might not have FM. Also, a simple AM transmitter is an excellent learning tool for beginners, who might find the very high frequencies and the added complexities of FM stereo a bit daunting as a first-time learning experience.

The low-power AM transmitter described here has features that would have been science fiction in 1950. For example, it has a crystal-controlled phase-locked loop (PLL) for frequency stability. Carrier frequencies can be selected in 1-kilohertz steps between 100 kHz and 2000 kHz. That range includes the standard AM broadcast band (from 530 kHz to 1710 kHz) and the long-wave AM broadcast band (from 150 kHz to 285 kHz) used in Europe and Asia. Both 9- and 10-kHz channel spacing is supported, meaning the unit could be used almost anywhere in the world.

While the transmitter is AM, carrier-wave (CW) under Part 15 experimental license-free operation between 160 kHz and 190 kHz is also possible. For that application, the transmitter's normal 100-milliwatt output can be increased up to 1 watt.

Circuit Description. The Low-Power AM Transmitter uses four ICs and nine transistors to create a complete PLL-synthesized AM transmitter. The design of the transmitter is simplified if it is divided into several sections. Those sections are the audio amplifier, the AM modulator, the phase-locked-loop frequency synthesizer, and the RF-output amplifier and filters. The schematic diagram in Fig. 1 should be followed as we describe each of the following sections.

Audio Amplifier. Incoming audio is input at J1 and then fed to gain control R1 and diode-controlled attenuator D1, D2, and R1. The diodes act as a variable resistance to small signals below 50 mV. That gives the audio section a form of automatic gain control.

The signal is passed to IC3-a through C31 and C1. The frequency response of the amplifier is limited to 10 kHz by C2. The need for a negative voltage source is eliminated by R5, R6, and C3. The audio gain of that stage is about 20X (26 dB) as long as D1 and D2 are not conducting.

The audio is coupled to R7, C5, S2-a, and S2-b. The switches route the audio signal to the AM modulator either for normal AM operation or to the PLL circuit for FM. It might seem odd to use frequency modulation at such low frequencies, but a use for that technique will be discussed later.

AM Modulator. The AM modulator is built around Q6 and Q7. The circuit is set up as a shunt-feedback pair with the bias point set by R14–R16. The audio signal with a DC offset appears at the emitter of Q7. It is used as a source of modulated DC for the RF-output stage. The voltage at the emitter of Q7 normally sits at around 5-volts DC. With audio from S2-b, the voltage swings from below 1 volt to within 1 volt of the supply voltage. Base-drive resistors R12 and R13 form a split resistance so that the modulated audio can be coupled to the junction of those resistors. Since the voltage across a capacitor does not change instantaneously, a large capacitor can also act like a battery. The effect is a constant voltage across R13, and therefore a constant drive current. That lets the base of Q6 swing above the supply voltage by about 0.7 volt, making sure that the emitter of Q7 can reach almost to the full supply voltage. That technique, widely used in audio power amplifiers, is called *bootstrapping*. Since the RF output of the RF stage is proportional to the supply voltage, full AM modulation of the RF output voltage is achieved. The bias point is set for symmetrical modulation with R16.

If the peak voltage of the audio signal were not limited, severe distortion would result from the clipping of the RF output peaks and cutoff of the RF output on the negative peaks. That type of distortion is called *overmodulation*. To prevent overmodulation, a sample of the modulator's output is taken through R17–R19. The sampled voltage is compared with IC3-a's bias voltage in IC3-b. If the sampled voltage exceeds the bias voltage, the output of IC3-b goes positive. That voltage is then applied to R8 and R9, forward biasing D3 and charging C4. Capacitor C4 is an audio-bypass capacitor that prevents audio signals from feeding back through the automatic gain-control (AGC) network, in addition to setting the time constant for the AGC network. The DC bias that is developed across C4 forward biases D1

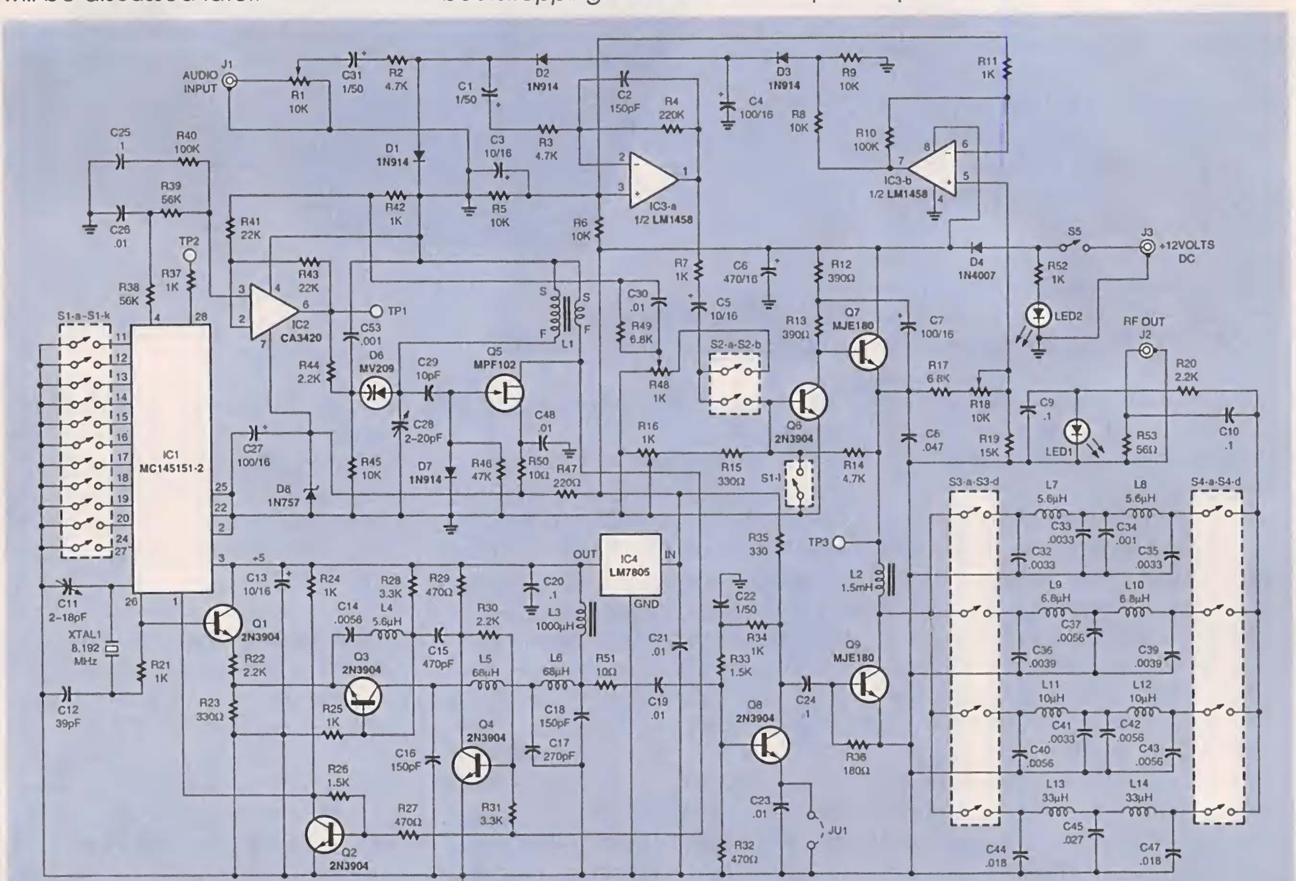


Fig. 1. The AM transmitter is built around a phase-locked loop synthesizer for frequency control of the carrier wave.

and D2 if it is more than about 1.2 volts. That causes the dynamic impedance of the diodes to drop from nearly infinite down to under 100 ohms. When that happens, the audio input present at the junction of R2, C1, D1, and D2 is attenuated, reducing the modulation level. In practice, R18 is adjusted so that attenuation will occur at a modulation level of 85–90%. While that method does not prevent any negative clipping or deliberate overmodulation, it works well for normal speech or music.

PARTS LIST FOR THE LOW-POWER AM TRANSMITTER

SEMICONDUCTORS

IC1—MC145151-2 Phase-locked loop synthesizer, integrated circuit
IC2—CA3420 op-amp, integrated circuit
IC3—LM1458P dual op-amp, integrated circuit
IC4—LM7805 5-volt regulator, integrated circuit
Q1–Q4, Q6, Q8—2N3904 transistor, NPN
Q5—MPF102 field-effect transistor
Q7, Q9—MJE180 transistor, NPN
D1–D3, D7—1N914 or 1N4148 silicon diode
D4—1N4007 silicon diode
D5—Not used
D6—MV209 varactor diode
D8—1N757A, Zener diode
LED1, LED2—Light-emitting diode, red

RESISTORS

(All resistors are ¼-watt, 5% units unless otherwise noted.)
R1, R18—10,000-ohm potentiometer
R2, R3, R14—4700-ohm
R4—220,000-ohm
R5, R6, R8, R9, R45—10,000-ohm
R7, R11, R21, R24, R25, R34, R37, R42, R52—1000-ohm
R10, R40—100,000-ohm
R12, R13—390-ohm
R15, R23, R35—330-ohm
R16, R48—1000-ohm potentiometer
R17, R49—6800-ohm
R19—15,000-ohm
R20, R22, R30, R44—2200-ohm
R26, R33—1500-ohm
R27, R29, R32—470-ohm
R28, R31—3300-ohm
R36—180-ohm
R38, R39—56,000-ohm
R41, R43—22,000-ohm
R46—47,000-ohm
R47—220-ohm
R50, R51—10-ohm
R53—56-ohm

CAPACITORS

C1, C22, C31—1-µF, 50-WVDC, electrolytic
C2, C16, C18—150-pF, ceramic-disc
C3, C5, C13—10-µF, 16-WVDC, electrolytic
C4, C7, C27—100-µF, 16-WVDC, electrolytic
C6—470-µF, 16-WVDC, electrolyt
C8—0.047-µF, Mylar
C9, C10, C20, C24, C25—0.1-µF, Mylar
C11—2–20-pF trimmer
C12—39-pF, ceramic-disc
C14, C37, C40, C42, C43—0.0056-µF, Mylar
C15—470-pF, ceramic-disc
C17—270-pF, ceramic-disc
C19, C21, C23, C48—0.01-µF, ceramic-disc
C26, C30—0.01-µF, Mylar
C28—2–20-pF trimmer
C29—10-pF, ceramic-disc
C32, C33, C35, C41—0.0033-µF, Mylar
C34, C53—0.001-µF, Mylar
C36, C39—0.0039-µF, Mylar
C38, C46—Not used
C44, C47—0.018-µF, Mylar
C45—0.027-µF, Mylar

ADDITIONAL PARTS AND MATERIALS

J1—RCA connector, panel-mount
J2—BNC or UHF connector, panel-mount
J3—Co-axial power jack
JU1—jumper wire
L1—Toroid core, 0.375-inch outside diameter (see text)
L2—1.5-mH, 240-mA choke
L3—1000-µH choke
L4, L7, L8—5.6-µH coil
L5, L6—68-µH coil
L9, L10—6.8-µH coil
L11, L12—10-µH coil
L13, L14—33-µH coil
S1—SPST switch, 12-position, dual-inline
S2—SPST switch, 2-position, dual-inline
S3, S4—SPST switch, 4 position, dual-inline
S5—Single-pole, single-throw switch, panel-mount
XTAL1—8192-kHz crystal
24-gauge enameled wire for L1, case, wire, hardware, etc.

Note: The following items are available from: North Country Radio, PO Box 53, Wykagyl Station, New Rochelle, NY 10804-0053; E-mail: NCRadio200@aol.com; Web: http://www.northcountryradio.com: A complete kit of parts including drilled and etched PC board and all parts that mount on it, $78.50 plus $4.50 postage/handling ($10.00 postage/handling outside the US); Package of suitable hardware, including connectors, wires etc., $10.50 plus $1.00 postage/handling; undrilled metal case, $21.50 plus $1.00 postage/handling. NY residents must add appropriate sales tax.

Phase-Locked Loop. The PLL-synthesizer section is built around IC1, a complete phase-locked loop circuit. That chip has a reference oscillator, a reference divider, a charge-pump phase detector, and a variable divider that can be set for division ratios from 3 to 16383.

The AM-broadcast band between 530 kHz and 1710 kHz has channels that are spaced 10 kHz apart in the US and Canada, including the newly-expanded 1600-kHz–1710-kHz section in the US. In other parts of the world, channels with 9-kHz spacing are used. Additionally, in Europe and parts of Asia, the longwave band is used with frequencies between 150 kHz and 285 kHz and with 9-kHz channel spacing. The synthesizer will cover all of those frequencies, but in the interest of ideal synthesizer performance, cost limitations, and circuit simplicity, the tuning range has been restricted to a 2-MHz spread. The synthesizer supports all of the channels between 150 kHz and 1710 kHz in 1 kHz increments. Frequencies from as low as 50 kHz to as high as 2047 kHz can be generated, but the values chosen for the various circuit components, mainly in the filters and RF chokes, will prevent the transmitter from working at peak performance at those extreme frequencies. In order to cover those frequencies, some changes in values of those components will be necessary. That type of modification is beyond the scope of this article.

While direct generation of a frequency between 150 kHz and 1710 kHz can be done with a single-loop synthesizer, it would be difficult to control a voltage-controlled oscillator with an 11:1 frequency ratio and still get reasonable performance over such a wide range. However, there is an easier way. Synthesizer

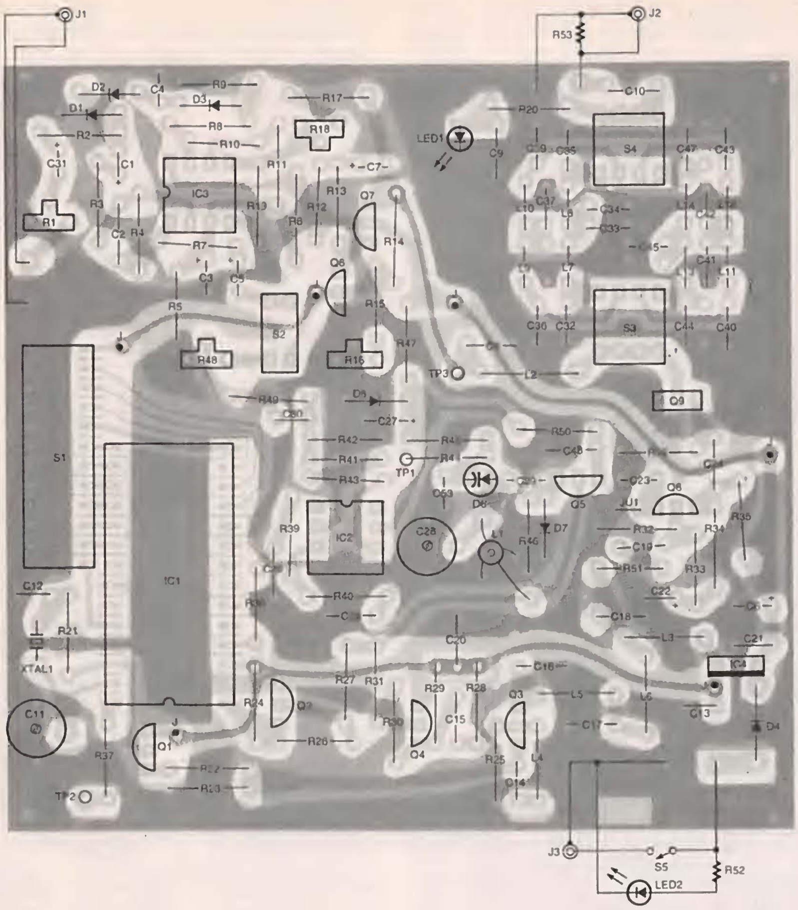


Fig. 2. Use this parts-placement diagram when building the AM transmitter. Don't forget to solder the connections on both sides of the board.

chip IC1, a Motorola MC145151-2, has a programmable-reference divider. The reference divider is set with digital inputs that select various fixed ratios that are mostly powers of two. For the AM Transmitter, it is set up to divide by 8192 so that a standard 8.192-MHz crystal will result in a reference frequency of 1 kHz. That reference frequency sets the resolution of the synthesizer.

Since the chip can be programmed to divide by up to 16383, the variable divider section of the chip can be set up to divide by 8192 by permanently tying its most significant digit high and grounding the next two significant bits low. By setting the remaining 11 bits with S1, a dipswitch with 12 switches, the divider can be set to divide by ratios from 8192 to 10239. That will let the synthesizer generate a frequency range between 8.192 MHz and 10.239 MHz—well within the chip's maximum rating of 12 MHz. If we take that frequency range and mix it with the 8192-kHz reference-oscillator signal using a mixer circuit and a low-pass filter on its output, we will end up with an output frequency that is (in theory) between 0 Hz (DC) and 2047 kHz. That means that S1 only has to produce a binary code that is the binary equivalent of the output frequency. That method is simple, cheap, and lets a synthesizer loop be designed with a 1.25 to 1 range—a task that is easy to do. The chip can directly handle those frequencies with no additional circuitry needed. Of course, a mixer and filter is needed, but that is simple, straightforward, and does not require any loop-design compromises. However, we are only concerned with the 150 kHz to 1710 kHz frequencies due to the need for larger coupling capacitors and RF chokes in the transmitter for lower frequencies.

In most populated areas, there are relatively few clear channels—especially at night when distant stations can be heard. Once a clear channel is found, the transmitter will normally be set and left alone. By using S1, an electrically-noisy microprocessor and complex display is eliminated from the design.

The heart of the PLL's voltage-controlled oscillator is Q5. The frequency at which the VCO oscillates is set to the 8.2-MHz-to-10.2-MHz range by L1 and the combined capacitance of D6, C28, and the input capacitance of Q5. The oscillator is DC biased by R46. A variable DC control voltage is fed to the anode of D6 by R44 and R45. Any stray RF on D6 is shunted to ground by C53. The voltage on D6 changes its capacitance, and therefore the frequency of the oscillator. The oscillator signal on the source of Q5 is passed to Q2 and Q4. A signal large enough to drive the input of the variable-divider section of IC1 (pin 11) appears at the collector of Q2. The output of the variable divider is sent to IC1's phase detector, which compares that signal with a 1-kHz reference signal. That reference signal comes from IC1's internal reference oscillator/divider, which is set by external components R21, C12, XTAL1, and C11. The output frequency accuracy depends on having an exact 1-kHz reference frequency, which in turn needs an exact 8192-kHz crystal oscillator frequency.

The phase detector generates a voltage that depends on the relative phase difference between the reference waveform and the variable divider waveform. If the divider output starts to lag the reference, the VCO frequency is too low, and the phase detector produces positive-going pulses. Those pulses go to a sample-and-hold network (R38–R40, C25, and C26). The accumulated charge on C25 is buffered by IC2 and is fed back to D6 through R44 and R45, causing the VCO frequency to increase. The opposite happens if the VCO frequency is too high, causing the divider output to lead the reference. The result is that the VCO frequency is locked to the reference frequency and will not drift. It will be exactly equal, in kilohertz, to the programmed divide ratio plus 8192.

The final output frequency is obtained by mixing the PLL output frequency with the 8192-kHz reference oscillator in a mixer circuit. The 8192-kHz frequency comes from Q1 and divider R22 and R23, while the VCO frequency is buffered by Q4. The signals are mixed together by Q3, and the signal at that transistor's collector terminal contains the sum frequency and the difference frequency. A low-pass filter consisting of C16, L56, C17, L6, and C18 passes only the difference frequency.

RF Output. Amplifying the output of the mixer's low-pass filter produces the RF-output signal that will be modulated with an audio signal. The amplification and mixing is done by Q8, Q9, and the associated circuitry. The emitter of Q8 is connected to ground with a jumper. If that jumper is removed and replaced with a transmitter key and capacitor, Morse-code carrier-wave (CW) transmission can be done. For low-power transmitters being used under the Part 15 regulations, the frequencies should be between 160 kHz and 190 kHz (also known as the 1750-meter band).

The final signal is then fed to a set of 5-element low-pass harmonic filters built around L7–L14 and C32–C47. Those filters attenuate the second harmonic of the signal by 20–30 dB or more. Since a filter is useful only to about 65–90 percent of its cutoff frequency, four filters are used in order to cover the AM-broadcast band and the 150- to 280-kHz range. Only one filter is used at a time; S3 and S4 select which circuit is active.

A light-emitting diode is used as an output indicator. It is also used as a crude form of VU meter—it will flicker slightly when a signal is being transmitted. Furthermore, it will not light at all if S3 and S4 are not selecting the same filter circuit.

Obviously, any transmitter needs some form of antenna. For many applications, a 56-ohm resistor shunted with a simple whip antenna will do. The whip antenna should be only as long as needed; under no circumstances should it be longer than 10 feet (3 meters). Longer lengths will violate the Part 15 regulations that limit the radiated power from the transmitter.

Construction. Since the AM Transmitter deals with radio frequencies, printed-circuit construction is the only recommended method of building the circuit. The circuit will fit nicely onto a double-sided layout; foil patterns are included if you want to etch your own board. A kit that contains a pre-etched PC board is available from the source given in the Parts List.

If you use the foil patterns or purchase the kit, the parts-placement diagram in Fig. 2 should be followed. Before building the board, some important points should be noted. First, the grounded leads on all of the resistors are to be soldered on both sides of board. That is essential for good grounding. Second, all of the parts are to be mounted as close to the board as possible, with the exception of the chokes. That is very important in order to reduce any audio noise pickup and for proper operation of the synthesizer and RF circuits. It also gives a professional appearance to the finished board.

Begin construction by inserting all of the resistors into the PC board.

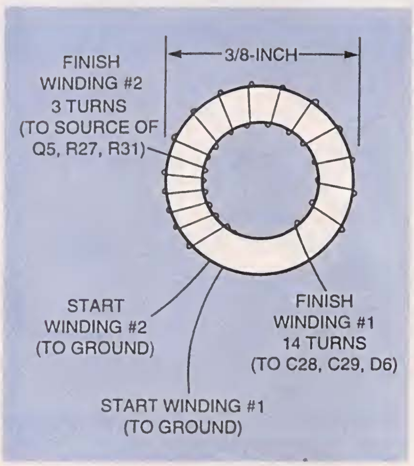


Fig. 3. Wind L1 on a toroidal (doughnut-shaped) coil form. Use 24-gauge enameled wire.

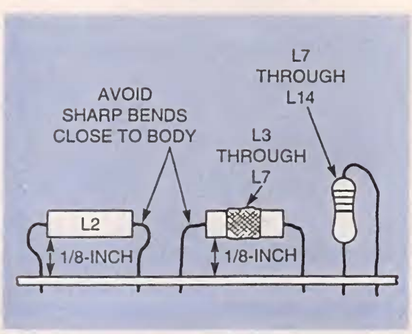


Fig. 4. Some of the coils and chokes should be mounted off of the board. Others will need to be mounted vertically.

Don't forget to also solder all of the ground connections on the top of the board. Install all of the diodes next, carefully observing their polarity. The capacitors are then installed. Again, make sure to observe the polarity of all of the electrolytic capacitors.

When installing the transistors, double-check the device pinouts—especially Q7 and Q9. Continue installing the remainder of the components. If you want, you can use low-profile sockets for the ICs. As always, carefully check your work as you go. Any mistakes corrected now will make testing the completed transmitter that much easier when the time comes.

Carefully fabricate coil L1 according to the illustration in Fig. 3. The doughnut-shaped core is wound with 24-gauge enameled wire. Make sure to connect the leads as shown or the VCO will not work. Leave an extra 1–2 inches of lead length on the lead of the 14 turn winding connected to C28, C29, and D6. That extra turn will be used to adjust the inductance of L1 during testing and setup.

Install L2 as shown in Fig. 4, being careful not to bend the leads sharply too close to the choke body as that might damage the choke. Install L3–L6 in the same way. The remaining inductors are mounted vertically. Again, carefully inspect all of your work as you go. Look for solder shorts, poor joints, missing parts, incorrect parts placement, etc. Once the board is completed, mount it in a suitable case and wire it as shown in Fig. 5.

One final item that will be needed for use is an antenna. The size of the antenna will depend on the frequency being used, but for general AM broadcasting the design shown in Fig. 6 will do the job.

With everything finished, the unit is ready for testing.

Testing the Transmitter. Before applying power to the transmitter, all of the controls and switches need to be preset. On S1–S4, set all of the switch positions to off, then turn on S2-a, S3-a, and S4-a. Potentiometers R1 and R16 should be set to ¼ full turn clockwise; R18 and R49 are set to ¾ full turn. Likewise, C11 should be

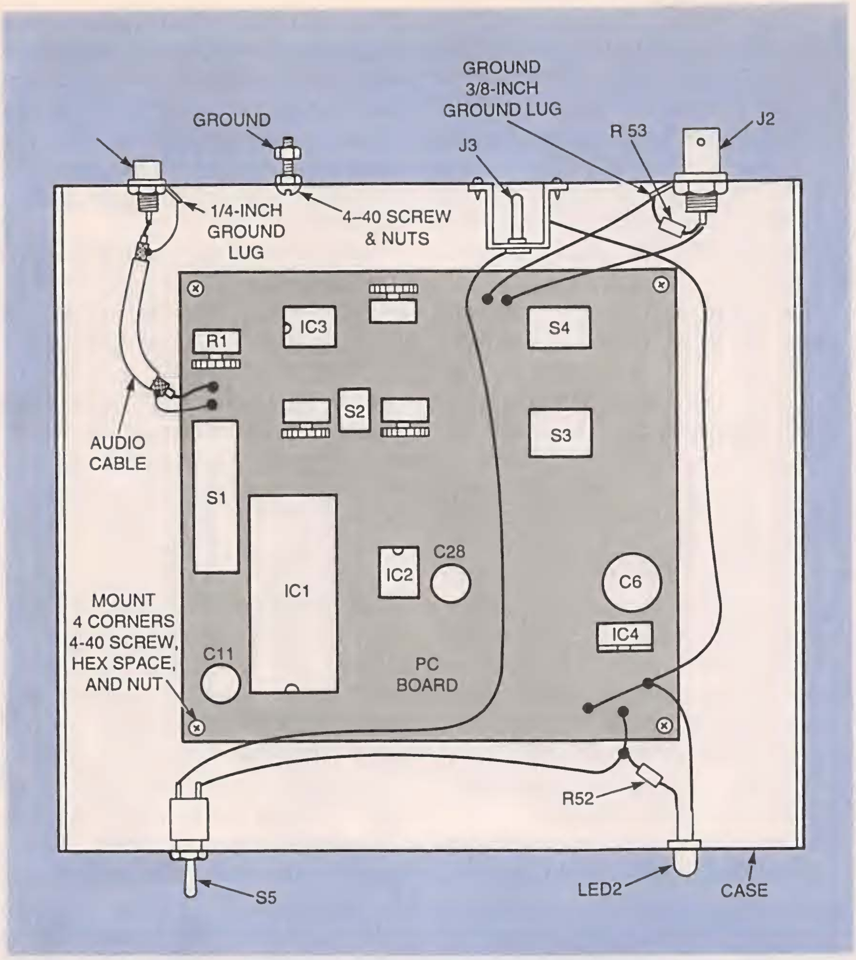


Fig. 5. The completed board fits neatly into a project case.

set so that its plates are 50% meshed; C28 should have its plates completely meshed.

With a 56-ohm resistor connected between the RF output and ground, connect a 12-volt power supply to the unit. The transmitter should draw between 50 and 200 mA. None of the components should get hot, although Q7 will normally run a bit warm after a few minutes of operation. A hot component or excessive current draw will indicate that something is wrong. If, on the other hand, the current draw is way too low, the unit will not be damaged—the cause of the problem should be found during testing.

With a voltmeter, the following voltages should be verified:

D4 cathode—11.4 volts
C6 positive lead—11.4 volts
IC4, pin 1—11.4 volts
IC1, pin 3—5 volts
IC2, pin 7—9 volts +/-0.6 volts
TP3—5 volts (varies when R16 rotated)
Q9 collector—5 volts (varies when R16 rotated)
Q3 collector—4-5 volts
Q4 collector—0.5-1 volt
Q5 drain—8.8 volts +/-0.6 volts
IC3, pins 1, 2, 3, 6—5.8 volts +/-0.8 volts
IC1, pin 7—2.5-7.5 volts (varies when R16 rotated)
D3 anode—1-1.5 volts (varies when R18 rotated)

A variation of 10 percent is normal. Remember to allow for meter accuracy and component and supply-voltage variations. If any major variations are noted, stop and look for the source of the trouble. Once the cause of the problem has been found and corrected, reset any potentiometers that were moved during testing back to their original preset positions, with the exception of R16; set that device so that a reading of 4.5-5 volts is observed at TP3.

Set S1 for a frequency of 1700 kHz, or within 20 kHz if 1700 kHz is being used in your area. See Table 1 for the switch settings. Remember to only set the first 11 switches; the twelfth switch is left off. Tune a nearby AM receiver to 1700 kHz, or the frequency that you set the transmitter to. A voltmeter connected to TP1 should read about 9 volts. If the reading is less than 9 volts but more than 2 volts, note the voltage. While listening to the AM receiver, rotate C28 so that its plates start to separate. At some point, the voltage at TP1 should drop. If it does not, try removing a turn from the end of the 13-turn winding on L1 that is connected to C28.

If you initially saw less than 9 volts at TP1, it should drop immediately when C28 is rotated. If the voltage is "stuck" low or will not reach as high as 7.5 volts (but will change with C28), you should add a turn to L1. Set C28 for a reading of 7.5 volts at TP1. At that point, the plates of C28 should be between 10% and 60% engaged. If C28 has to be set to more than 75%, add a turn to L1.

You should hear a dead carrier (a signal without audio) on the AM receiver. As a further test, disconnect or shut off the transmitter. The carrier should disappear. It should reappear when power is restored. If all checks out, the PLL synthesizer and mixer sections are OK.

Turn the transmitter off and set the frequency to 128 kHz with S1. Close S3-d and S4-d, opening the other switches in those banks. Turn the unit back on and measure the voltage at TP1—it should be between 2 and 4 volts. Rotating C28, the voltage at TP1 should change. Reset C28 so that the voltage on TP1 is the same as it was when the transmitter was turned on. That test verifies the synthesizer range. If the voltage at TP1 is too low and C28 has no effect, add a turn to L1, and repeat the test where the transmitter was set to 1700 kHz.

If the transmitter passes all of the tests so far, remove the extra lead length from L1 and re-solder it to the PC board. It is a good idea to coat L1 and fasten it to the PC board with clear lacquer-base cement such as Duco cement, Q dope, or

TABLE 1—SWITCH SETTINGS FOR VARIOUS FREQUENCIES

Frequency (kHz)	S1-a	S1-b	S1-c	S1-d	S1-e	S1-f	S1-g	S1-h	S1-i	S1-j	S1-k	Notes
128	0	0	0	1	0	0	0	0	0	0	0	Test frequency
140	0	0	0	1	0	0	0	1	1	0	0	
150	0	0	0	1	0	0	1	0	1	1	0	Lowest long- wave AM frequency
160	0	0	0	1	0	1	0	0	0	0	0	
188	0	0	0	1	0	1	1	1	1	0	0	
189	0	0	0	1	0	1	1	1	1	0	1	
190	0	0	0	1	0	1	1	1	1	1	0	
230	0	0	0	1	1	1	0	0	1	1	0	
256	0	0	1	0	0	0	0	0	0	0	0	
280	0	0	1	0	0	0	1	1	0	0	0	
285	0	0	1	0	0	0	1	1	1	0	1	Highest long-wave AM frequency
455	0	0	1	1	1	0	0	0	1	1	1	Common AM IF frequency
512	0	1	0	0	0	0	0	0	0	0	0	
530	0	1	0	0	0	0	1	0	0	1	0	Common TIS frequency
570	0	1	0	0	0	1	1	1	0	1	0	Low end AM broadcast band
600	0	1	0	0	1	0	1	1	0	0	0	
650	0	1	0	1	0	0	0	1	0	1	0	
700	0	1	0	1	0	1	1	1	1	0	0	
750	0	1	0	1	1	1	0	1	1	1	0	
800	0	1	1	0	0	1	0	0	0	0	0	
850	0	1	1	0	1	0	1	0	0	1	0	
900	0	1	1	1	0	0	0	0	1	0	0	
950	0	1	1	1	0	1	1	0	1	1	0	Middle of AM band
1000	0	1	1	1	1	1	0	1	0	0	0	
1024	1	0	0	0	0	0	0	0	0	0	0	
1053	1	0	0	0	0	0	1	1	1	0	1	
1089	1	0	0	0	1	0	0	0	0	0	1	
1100	1	0	0	0	1	0	0	1	1	0	0	
1200	1	0	0	1	0	1	1	0	0	0	0	
1250	1	0	0	1	1	1	0	0	0	1	0	
1300	1	0	1	0	0	0	1	0	1	0	0	
1350	1	0	1	0	1	0	0	0	1	1	0	
1400	1	0	1	0	1	1	1	1	0	0	0	
1440	1	0	1	1	0	1	0	0	0	0	0	
1500	1	0	1	1	1	0	1	1	1	0	0	
1550	1	1	0	0	0	0	0	1	1	1	0	
1575	1	1	0	0	0	1	0	0	1	1	1	
1585	1	1	0	0	0	1	1	0	0	0	1	
1595	1	1	0	0	0	1	1	1	0	1	1	
1600	1	1	0	0	1	0	0	0	0	0	0	
1610	1	1	0	0	1	0	0	1	0	1	0	Common TIS frequency
1620	1	1	0	0	1	0	1	0	1	0	0	
1630	1	1	0	0	1	0	1	1	1	1	0	
1640	1	1	0	0	1	1	0	1	0	0	0	
1650	1	1	0	0	1	1	1	0	1	0	0	
1660	1	1	0	0	1	1	1	1	1	0	0	
1670	1	1	0	1	0	0	0	0	1	1	0	
1680	1	1	0	1	0	0	1	0	0	0	0	
1690	1	1	0	1	0	0	1	1	0	1	0	Used for setup
1700	1	1	0	1	0	1	0	0	1	0	0	Used for setup
1710	1	1	0	1	0	1	0	1	1	1	0	Used for setup. Top of AM band

A zero (0) means that a switch is ON; a one (1) signifies a switch section is OFF.

TIS—Travel Information Service. Used for motorist information

clear fingernail polish. Hot-melt glue can also be used. Do not use anything with a pigment in it as it might damage the coil. After the coating hardens, recheck the voltage at TP1. If necessary, reset C28 so that TP1 has a voltage of 7.5 volts when the transmitter is set to 1700 kHz.

Connect an audio source to the transmitter's audio input and adjust R1 for the loudest signal in the receiver before any distortion can be heard. Adjust R16 so that TP3 is between 4.5 volts and 5 volts. Increase R1 until distortion is evident. Adjust R18 so that the distortion is just eliminated. It should be possible now to increase the setting of R1 a little without experiencing much of a change in the audio level at the receiver, although some compression might be noticed. At this point, the audio-limiter circuit is tested and adjusted. If an oscilloscope is available, R16 and R18 can be adjusted for the best modulation pattern by observing the modulated carrier across a 56-ohm resistor connected across the RF output terminals.

If a scope or RF voltmeter is available, check the voltage across the 56-ohm resistor that is connected across the RF output terminals to verify that the transmitter is producing RF output. About 2 volts rms across 56 ohms or 5.64 volts peak-to-peak will be present. The modulated RF signal is best seen with an oscilloscope, but a detector probe on a DVM will do as a relative indicator. If you do not have the equipment to do that final test, don't worry; just make sure that LED1 lights.

With the AM transmitter tested and calibrated, set the final transmission frequency, select the appropriate RF filter, and close up the case. The transmitter is now ready for use.

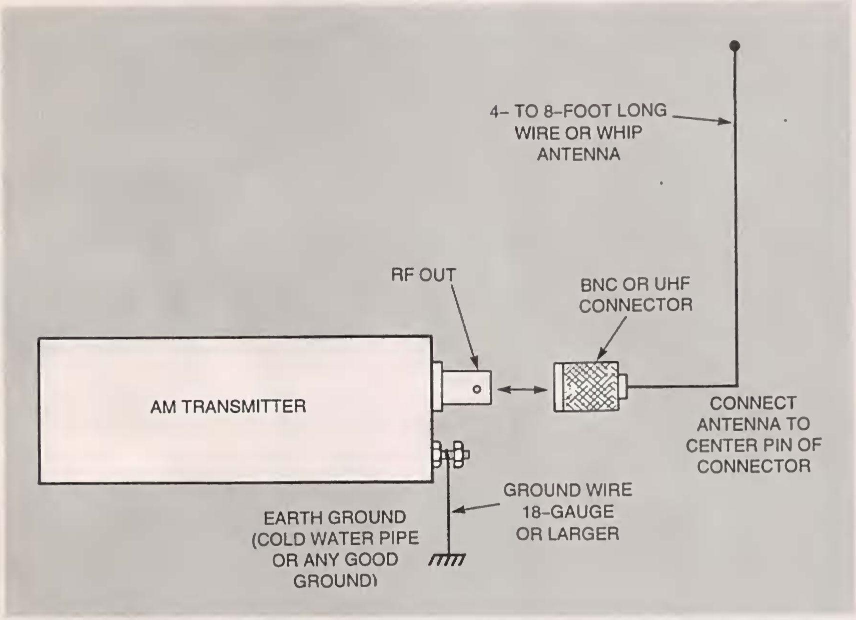
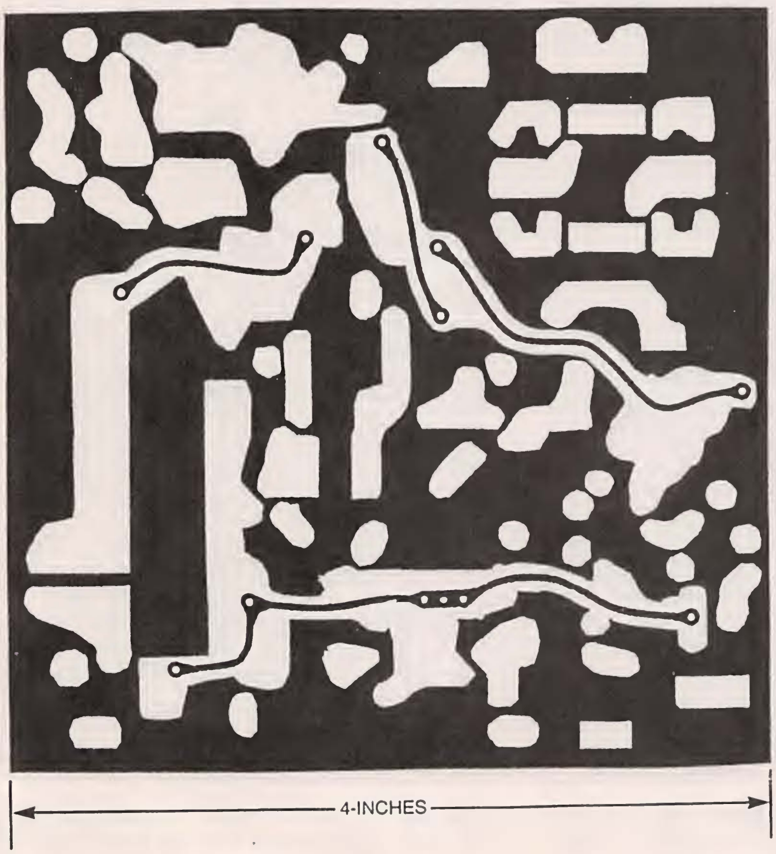


Fig. 6. An unmatched antenna can be made from a length of wire connected to the AM transmitter.

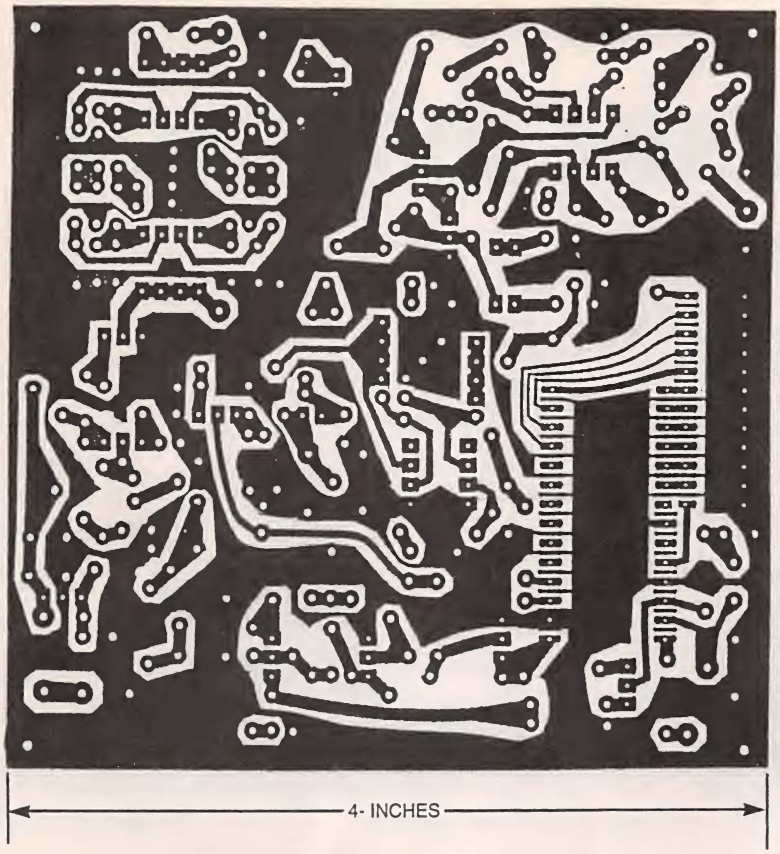


Here is the foil pattern for the component side of the AM transmitter board.

Using the Transmitter. The power supply for the transmitter should be 12 volts DC. The actual voltage can vary from 12 volts to 13.2 volts, but going outside those limits can cause problems. Voltages above 16 volts might damage some of the components, while dropping below 10 volts will produce poor results. Excessive noise on the supply line might be heard on the transmitted signal as interference and hum. Remember that it is normal for Q7 to get warm in operation. If you prefer, although it is not necessary, a small clip-on heat sink can be placed on Q7 to cool it.

Each time the frequency or transmitting mode is to be changed, the unit must be opened up and the dipswitches reset. Although that might seem inconvenient, in practice there are often only a few available clear channels in the AM broadcast band. Once set, the frequency will probably not be changed often. The mode settings will probably be rarely changed unless you are doing a lot of experimental work. There are over 2000 frequencies that can be programmed.

At the time that this article was written, the new AM band between 1600 kHz and 1710 kHz is lightly occupied and has generally less power-line noise than the lower frequencies. As new stations move into the expanded band, that is



Here is the foil pattern for the solder side of the AM transmitter board.

sure to change.

For routine Part 15 operation, try to use as high of a frequency as possible. It is a good idea to confine the signal to only the area in which it is needed. A 4-foot whip antenna will cover an average house and is easy to build from scratch or to salvage from a junked TV set. The antenna should be wired in parallel with a 56-ohm resistor connected to the RF output.

According to Part 15, the formula for the maximum field strength allowed between 510 kHz and 1600 kHz is $24000/f_{kHz}$ microvolts per meter at 30 meters. That works out to 15 microvolts per meter at 1600 kHz at a distance of 100 feet from the transmitter. Below 490 kHz, a field strength of $2400/f_{kHz}$ at 300 meters is allowed. That works out to about 12 microvolts per meter at 1000 feet.

Those levels represent a weak AM-broadcast-band station. Alternatively, 100 mW of RF into a 10-foot antenna is allowed in the AM-broadcast band, and 1-watt of RF is allowed into a 50-foot antenna between 160 kHz and 190 kHz. Those figures actually assume a power-amplifier efficiency of 100% with the power being defined as the amount of input into the final RF-amplifier stage. That method of measurement is from the vacuum-tube days when RF power was not easily measured with simple equipment. However, solid-state RF amplifiers are specified in terms of RF output. An efficiency of 60–80% is typical of transistor-based power amplifiers, although 90% or more can be reached in some instances. Therefore, in order to comply with the Part 15 rules, either make sure that the RF output is kept at 1.6 to 2 volts rms or below when connected to a 50-ohm load or use an unmatched 4-foot whip antenna. Do not use a 10-foot antenna unless you can measure and verify the RF-output power. Although you can operate anywhere in the AM band, the high end (1600 kHz) is better because of antenna efficiency.

There you have it—an AM transmitter that updates old technology with the newest circuits and designs. Ω

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