Build A Surface-Mount Shortwave Radio

Build this radio using either surface-mount components, through-hole components, or a mix of the two—the choice is yours.

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Like many other professionals in the electronics field, electronics instructors must keep current with the latest technical changes and products. As technology advances, the skills and knowledge of the technician must advance as well. Therefore, it is often a challenge to develop new classroom projects that demonstrate such advances.

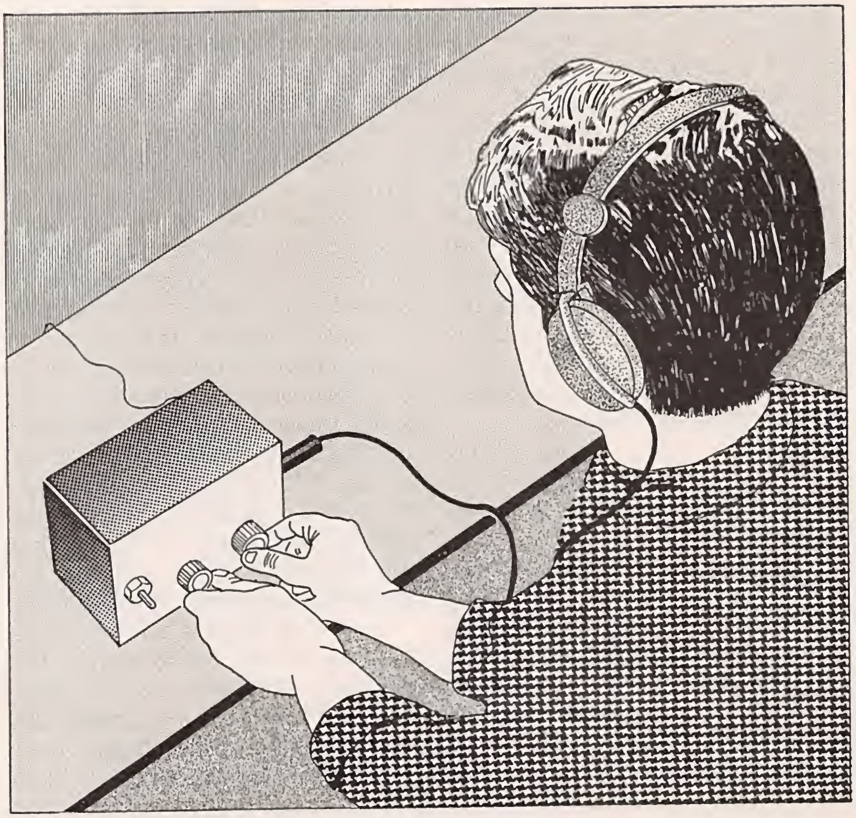
The focus for many new designs is to make the product smaller, lighter, and faster. Because of that, surface-mount devices (SMDs) have rapidly replaced the older traditional through-hole components in many products. Therefore, students (as well as established electronics professionals) should learn about those devices as well. However, demonstration is not enough. To truly educate, the project must be just as interesting as it is educational—nothing is less instructional than a boring project. Fortunately, the Surface-Mount Shortwave Radio presented here combines learning with entertainment by introducing the builder to the fascinating world of shortwave listening.

Although the Surface-Mount Shortwave Radio is a well-designed shortwave receiver, its main purpose is to educate. In many ways, it is a self-contained semiconductor course and lab exercise. During its construction, we will be working with (and learning about) Field-Effect Transistor (FET) circuits, oscillators, operational amplifiers, varactor diodes, L-C circuits, Zener diodes, ceramic filters, bipolar transistors, power amplifiers, specialized IC circuits, and modern surface-mount devices. Yet, what truly makes the Surface-Mount Shortwave Radio project unique is its construction versatility. The board design works with either standard components or their surface-mount equivalents. The builder has the option to use either type or both in any combination on the board. That means that you can practice with SMDs as much—or as little—as you want.

Theory of Operation. The Surface-Mount Shortwave Radio is a superheterodyne receiver with varactor tuning. It operates in the high-frequency (HF) band and is capable of receiving shortwave broadcasts from around the world. On a good night, stations from Africa, Australia, Europe, Asia, and South America can often be heard.

The circuit's block diagram is shown in Fig. 1. It consists of seven main sections: the tuning oscillator, the RF amplifier/mixer, the IF filter, the IF amplifier/detector, the audio preamplifier, the audio power driver, and the voltage regulator. Figure 2 shows the schematic for the circuit. Follow along with those diagrams as we discuss each section in turn.

The Tuning Oscillator. The heart of any good superheterodyne receiver is its tuning oscillator. While that circuit mainly determines the frequency range of operation, it can also affect the sensitivity and clarity



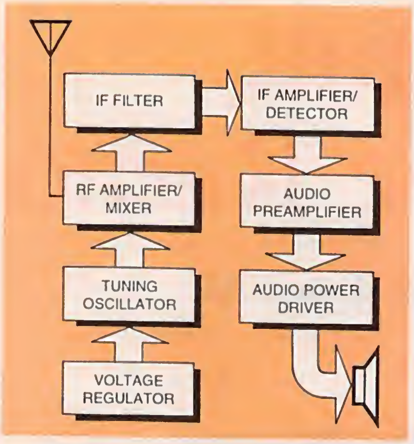


Fig. 1. When reduced to basics, the Surface-Mount Shortwave Radio is simply a superhetrodyne AM receiver that can pick up stations that broadcast on frequencies as high as 17 MHz.

of the station being heard. A properly designed and functioning oscillator is therefore critical for proper operation of the entire receiver. For the Surface-Mount Shortwave Radio, the oscillator section is built around Q1, an MPF102 general-purpose N-channel JFET (Junction Field-Effect Transistor). The tuned part of the circuit is a parallel-resonant LC "tank" circuit, located on the drain lead of Q1. The tank circuit is made up of L1, C8, and D2; those components set the frequency of operation. The part that actually tunes the oscillator is D2, a varactor diode. The term *varactor* is a contraction of the words "variable capacitor."

To understand how it works, remember that a capacitor is made from two conductors that are separated by an insulator. A reverse-biased diode fits that description because it has two conductors (the anode and the cathode) that are separated by an insulator (the reverse-biased junction). That is why a reverse-biased diode acts like a capacitor.

Although every diode or PN junction exhibits that effect, a varactor diode is specifically designed to take advantage of it. In our oscillator, the varactor's cathode is connected to the positive power supply through L1 while its anode is connected to a variable voltage source from R6. As R6 is adjusted, the amount of reverse bias applied to D2 is varied. That, in turn, varies the size of D2's depletion zone and, consequently, its capacitance. In our tank circuit, D2 can be varied from 30 to 90 pF.

The frequency of an LC circuit is determined by the formula:

$$FR=1/(2\sqrt{LC})$$

where FR is the resonant frequency in Hz, L is the inductance value in henries, and C is the capacitance value in farads. In our circuit, the C value is the combination of C8 and D2. However, the capacitance value of C8 is far larger than that of D2 and, because the smaller value rules when capacatances are in series, the total capacitance effectively equals that of the varactor alone. Therefore, we can calculate the operating range of the oscillator by using the upper and lower values of D2's capacitance range (30 to 90 pF) along with the 3.3 microhenry inductor value of L1. Doing the math (which is straightforward and left as an exercise for interested readers) reveals that: FR_{MIN}=9.235 MHz and FR_{MAX}=15.95 MHz.

Theoretically, the oscillator should operate between 9.2 and 16 MHz, but it usually tunes an approximate 5-MHz range somewhere between 7 and 17 MHz. That is caused by component placement and tolerances. Fortunately, that is more than enough range to tune in dozens of stations worldwide.

An analog sinewave oscillator is an amplifier with positive feedback. For the Surface-Mount Shortwave Radio's RF oscillator, feedback is provided by C7, which couples part of the oscillation generated in the tank circuit back to the source lead of Q1. Since output current flows from source to drain in a JFET, they form the same current path. Therefore, the signal is coupled back in phase and oscillation occurs. Source resistor R13 is used to set the proper bias voltage. The actual adjustment of that control will be discussed in detail in the construction section of this article.

Note that there is a Zener diode placed across R6. Because the receiver is battery powered, a problem can occur as the battery discharges and its voltage level declines. Since the oscillator is electrically tuned, any voltage change to D2 will cause a corresponding shift in frequency. The battery voltage for D2 is regulated by D1 to help maintain a steady voltage level in order to minimize that effect.

PARTS LIST FOR THE SURFACE-MOUNT SHORTWAVE RADIO

SEMICONDUCTORS

IC1—NE602A or SA602N RF/IF mixer, integrated circuit, see text
IC2—Not used
IC3—LM741 op-amp, integrated circuit
Q1—MPF102 N-channel field-effect transistor
Q2—2N4401 NPN transistor
Q3—2N3904 NPN transistor
D1—1N4738 8.2-volt Zener diode
D2—MV2209 varactor diode

RESISTORS

(All resistors are ¼-watt, 5% units unless otherwise noted.)
R1—470-ohm
R2—15,000-ohm
R3, R8–R11—1000-ohm
R4—220,000-ohm
R5—10-ohm
R6, R7—50,000-ohm potentiometer
R12—Not used
R13, R14—10,000-ohm potentiometer

CAPACITORS

C1, C4, C5—100-pF, ceramic-disc
C2, C6, C7—47-pF, ceramic-disc
C3, C8—0.001-µF, ceramic-disc
C9—0.01-µF, ceramic-disc
C10—Not used
C11, C12—1-µF, 25-WVDC, electrolytic
C13, C14—10-µF, 25-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS

ANT1—Whip or wire antenna (see text)
B1—9-volt battery
FL1—4.5-MHz ceramic filter
J1—⅛-inch headphone jack
L1—3.3-µH coil
L2—1-mH coil
S1—Single-pole, single-throw switch
9-volt battery clip, case, hardware, etc.

Note: The following items are available from Paul E. Yost, PO Box 32291, Louisville, KY 40232: Complete kit of parts with all the parts listed above including both surface-mount and through-hole components, $24.95 plus $1.25 shipping; Blank PC board, $11.95 plus $1.00 shipping. Kentucky residents must include 6% sales tax. No credit card, C.O.D., or orders outside of the USA or Canada will be accepted.

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The RF Amplifier/Mixer. This section is built around IC1, an NE602 /SA602 chip. Although the NE602 is no longer being manufactured, it is still available from several sources including JDR Microdevices, 1850 South 10th St. San Jose, CA 95112 Tel: 800-538-5000. That chip also comes as part of a kit available from the supplier provided in the Parts List. The SA602, A drop-in replacement, is currently being manufactured.

The NE602 is an IC that has been specifically designed as an RF amplifier and mixer. It first amplifies the weak incoming radio signal on pin 1 and then mixes or "heterodynes" it with the oscillator output coupled to pin 6 through C6. Both signals are sinewaves; whenever two sinewaves mix, four signals result. Besides the two original signals, two new signals are formed at the sum and difference frequencies of the originals. For example, if a 7-MHz signal is mixed with an 11.5-MHz signal, two new sinewaves would occur at 18.5 MHz (the sum) and 4.5 MHz (the difference). As we will see, the difference signal will be used to select the desired station.

The IF Filter. Two important receiver characteristics are *sensitivity* and *selectivity*. Sensitivity is the ability to receive weak or distant stations; selectivity is the ability to receive only the station you want despite the presence of other, possibly stronger, stations. Sensitivity is obtained by proper antenna connection and RF amplification. Selectivity is obtained by the use of FL1, a special filter that is located just after the mixer stage. That filter is known as the IF filter; the letters "IF" stand for *I*ntermediate *F*requency. For most receivers, the IF signal is the difference frequency created by the mixer circuit. It is called the intermediate frequency because it is a middle- or intermediate-frequency signal that is between the higher frequency of the RF input and the lower frequency of the audio output. The Surface-Mount Shortwave Radio uses 4.5 MHz as the IF frequency. It was chosen because 4.5 MHz is a very common and inexpensive filter to obtain. Two other common IF frequencies are 455 kHz and 10.7 MHz—some radio designs use those values instead.

Tuning a radio receiver is quite simple. Although many stations broadcast simultaneously throughout the world, only a station on a frequency that is *exactly* 4.5 MHz away from the oscillator signal will be heard. That occurs because only 4.5 MHz can pass through the IF filter. An example of that effect is the mixing that would occur for the shortwave stations of the *BBC* in England and *Radio Nacional* in Ecuador. Those two stations broadcast at 9.825 MHz and 9.745 MHz respectively. To receive the *BBC*, the oscillator could be tuned to 14.325 MHz. When the two signals mix inside IC1, the resulting difference frequency is 4.5 MHz (14.325 MHz –

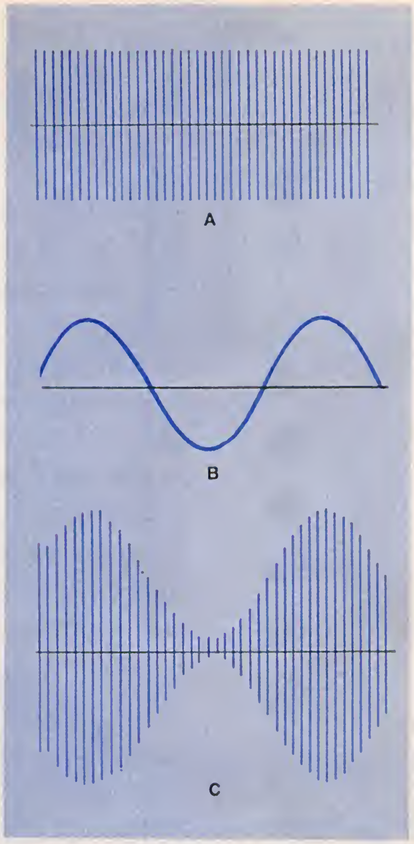


Fig. 3. To create an AM-broadcast signal, you take a carrier at the frequency that you want to broadcast on (A) and modulate it with an audio signal (B). The combined signal is a carrier wave that fluctuates at the rate of the audio signal (C).

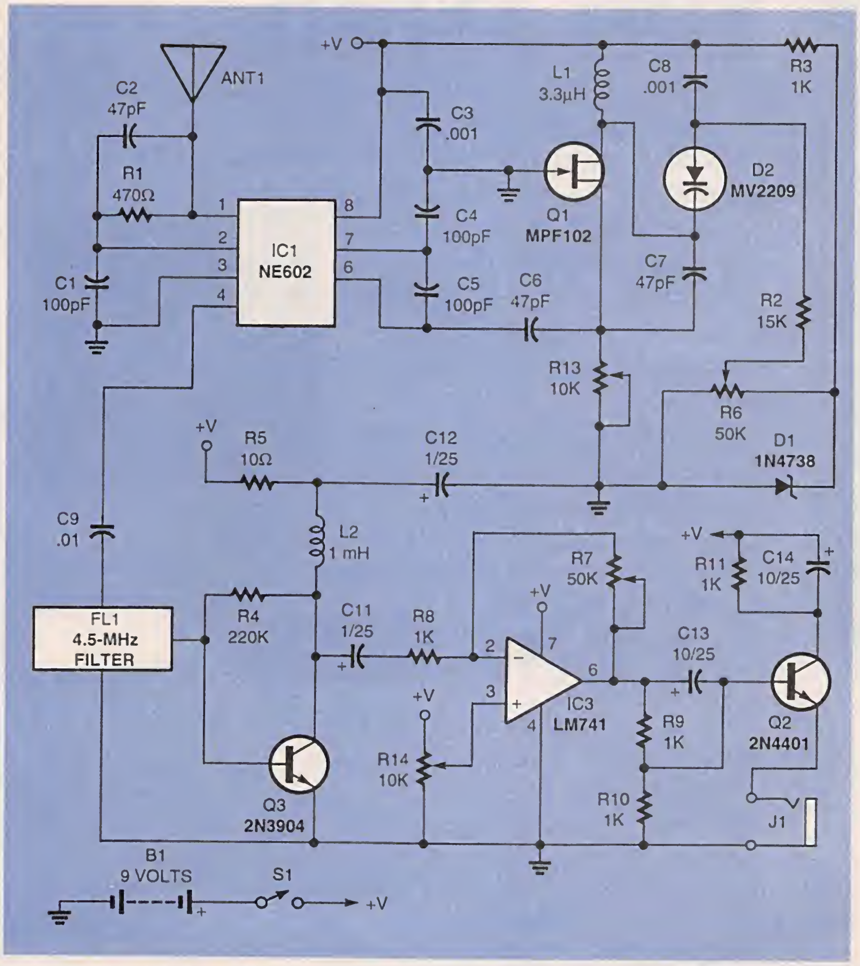


Fig. 2. The Surface-Mount Shortwave Radio is designed for low parts count as well as low cost.

9.825 MHz = 4.5 MHz). That signal would then pass through FL1 for processing by the rest of the receiver; the result is that the *BBC* broadcast would be heard. By contrast, the *Radio Nacional* signal would not be heard because its difference frequency would be 4.58 MHz, which is much too high to pass through the filter.

It should be apparent by now

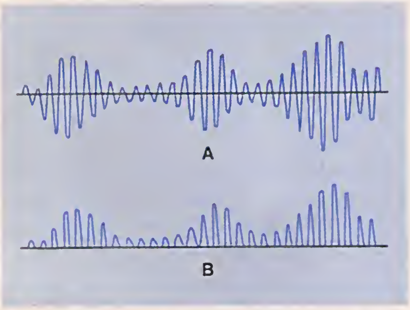


Fig. 4. When an audio signal (A) is half-wave rectified, the resulting signal (B), while odd looking, is nonetheless very usable in recreating the station's audio signal.

that the oscillator/mixer/filter combination of circuits makes selective tuning possible. However, that tuning method does create a potential problem. Occasionally, two separate stations can each be located 4.5 MHz away from the oscillator frequency. For example, while the BBC broadcasts at 9.825 MHz (4.5 MHz *below*), another station could also be transmitting at 18.825 MHz (4.5 MHz *above*)—both of which are exactly 4.5 MHz away from the 14.325 MHz oscillator signal. In that case, the radio would try to receive *both* stations simultaneously. Not surprisingly, that would cause a tremendous interference and neither station would be heard clearly.

That phenomenon is called the

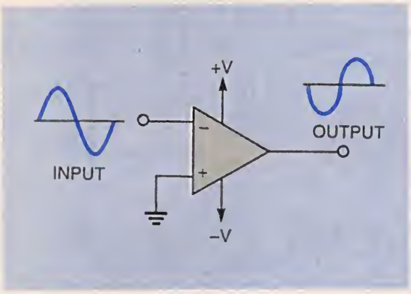


Fig. 5. When a ground-referenced audio signal is applied to the inverting input of an op-amp, the output signal is an exact mirror image of the original signal. Even though the output signal is 180° out of phase with the input signal, our ears can't tell the difference between the two unless we hear them side by side.

image frequency effect. The unwanted station is called the image because it is like an image one would see in a mirror—the exact same distance away from the mirror as the original but on the opposite side. Yet despite that potential problem, the heterodyning or IF system is still an excellent and efficient way to make a good, selective receiver.

The IF Amplifier. Although radio transmitters often use thousands of watts of power to broadcast, the signal is typically just a few microvolts in strength by the time it reaches the receiver. That is due for the most part to the long distance that the signal must travel—sometimes thousands of miles! While the signal level is increased by the RF-amplifier circuit, it is still only a few millivolts in amplitude by the time it exits the IF filter—a level far too weak to properly drive a detector circuit. Additional amplification is required. That amplification is done by Q3, a 2N3904 transistor.

The Detector. Shortwave stations broadcast in the High Frequency or "HF" band and use amplitude modulation (AM). The actual radio signal is called the *carrier* while the music or voice part is called the *intelligence* or *modulating* signal. Some texts also refer to that as the *baseband* signal. For AM systems, the audio actually rides the amplitude of the carrier wave. That is, the audio signal changes or modifies the amplitude of the carrier. The process is shown in Fig. 3. If you looked at a straight RF signal on an oscilloscope, it would look similar to the waveform shown in Fig. 3A. If an audio-frequency signal such as the one shown in Fig. 3B is used to amplitude modulate the RF signal, the result would be the signal shown in Fig. 3C.

Radio theory is a very broad subject area and is beyond the scope of this article. For our purposes, it is only important to know that a signal resembling the waveform in Fig. 3C will be present at the output of FL1 when you receive a station. That signal is amplified by Q3.

The modulated signal has two features that should be noted—it is

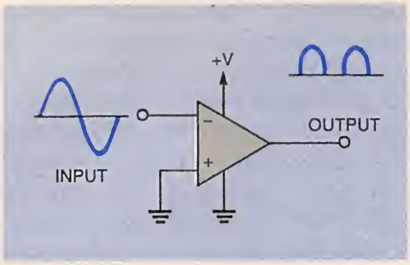


Fig. 6. If we try to feed a ground-referenced audio signal into an op-amp that does not have a negative-voltage source, the result is a half-wave rectified output that will sound terrible. What is needed is to change the reference level of the audio signal so that it is at half of the power-supply voltage.

an AC signal with both a negative- and positive-going peak, and it is symmetrical. With the modulating signal appearing on both halves of the carrier, only one half of the signal is needed to recover the audio signal.

Transistor Q3 also functions as the demodulator stage. Besides providing amplification, Q3 also rectifies the carrier signal of Fig. 4A into the half-wave shape shown in Fig. 4B. The action is similar to the rectifier method used in a power supply. That happens because Q3 uses only a single resistor (R4) to provide the base bias. Because the emitter lead connects straight to ground, the voltage across the emitter-base junction is the standard 0.7-volt drop of a silicon PN junction. That places the transistor right at the point of conduction, making it extremely sensitive to the slightest voltage change on the base.

Having Q3 biased just above ground serves two purposes. First, it creates the maximum gain possible for low-signal conditions. Second, it

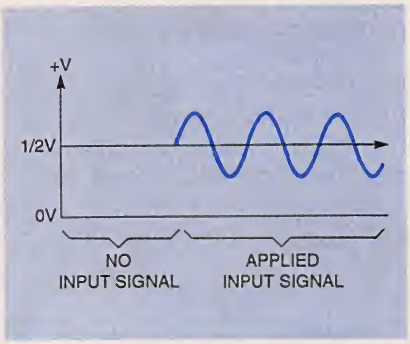


Fig. 7. When an audio signal is referenced at a voltage level above ground, amplifiers that have no negative-voltage source will be able to amplify the signal without clipping the negative-going parts of the waveform. The result is a clean-sounding signal that is not clipped.

rectifies the signal into the half-wave shape discussed earlier. It does that because the base bias is at the exact point of turn on (0.7 volts). When the incoming signal swings positive, it adds to the base voltage, increasing the forward bias. However, when the incoming signal goes negative, it decreases the base bias to a point below the conduction level, turning off Q3. The result is the rectified signal that is needed to complete the demodulation process.

Two signals are present in the resulting waveform—the carrier wave and the modulating wave. The modulation wave, being audio, typically varies between 50 and 5000 Hz, but some stations now broadcast a wider range (up to 15 kHz) to provide a high-fidelity service similar to the American FM broadcast system. The two signals must be separated so that only the audio signal passes through to the output. That is done by the audio preamp circuit, which will be discussed next.

The Audio Preamp. The rectified half-wave audio signal and 4.5-MHz carrier that appear across L2 are passed to IC3 through coupling capacitor C11. Integrated circuit IC3 is a 741-type op-amp. Being an early example of an IC amplifier, IC3 is severely frequency limited. In fact, it is specifically designed to provide no gain for signals above 1 MHz, so it cannot pass the 4.5-MHz carrier signal. However, for lower-frequency signals (like audio), the 741 can provide a gain as high as 100 or more. That is how the audio gets separated from the carrier. The op-amp passes and amplifies the audio signal while blocking the carrier.

For the Surface-Mount Shortwave Radio, IC3 is configured as a basic inverting amplifier. Potentiometer R7 provides a variable negative feedback path in order to control the gain. In an inverting op-amp circuit, gain is set with the formula:

$$Gain = R_F/R_{IN}$$

where R_F is the feedback resistance and R_{IN} is the input resistance.

Let's apply that formula to find the gain of our op-amp circuit. In the circuit, R7, with a variable range

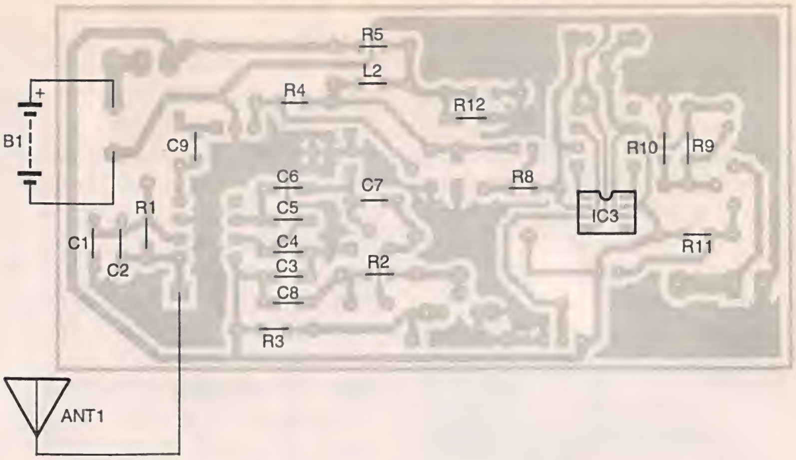


Fig. 8. This parts-placement diagram shows the locations of the surface-mount components for the Surface-Mount Shortwave Radio. Although most (if not all) of the components used in the circuit are available in surface-mount form, some items are too bulky to be used. Other components cannot be used because of constraints in the routing of the PC board's traces.

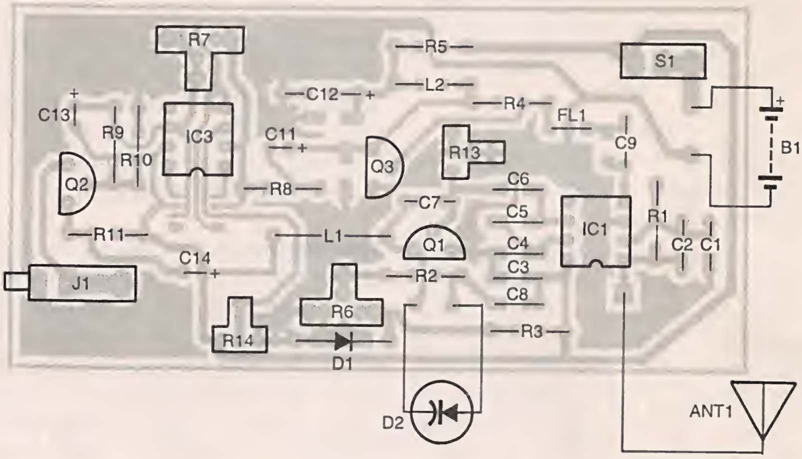
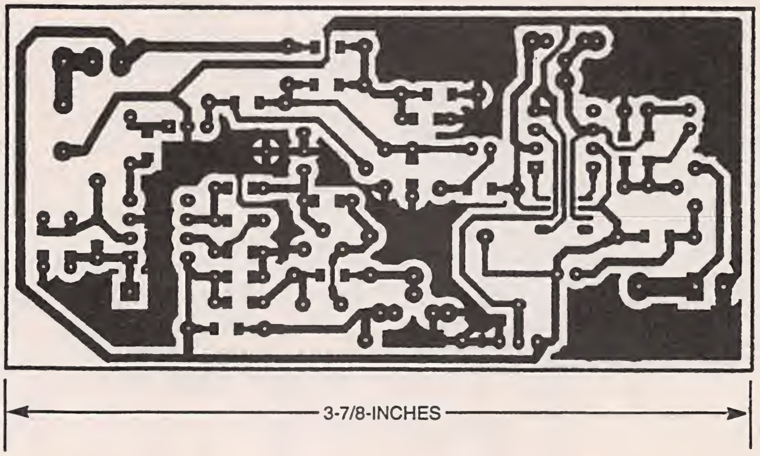


Fig. 9. Follow this parts-placement diagram for locating the through-hole components of the Surface-Mount Shortwave Radio. Remember, if you've used a surface-mount device for a particular component, do not use the through-hole part as well—only one of each type is needed.



Here's the foil pattern for the Surface-Mount Shortwave Radio. Despite using two widely-divergent technologies (surface-mount and through-hole), the entire unit can be built on a single-sided board.

HELPFUL CONSTRUCTION TIPS

Be sure to observe the polarity markings when installing an electrolytic capacitor.

Observe proper IC placement. Pin 1 is marked by either a dot or a notch on the chip.

If you use insertion-mount devices, the disk capacitors, transistors, and the varactor should be mounted above the board with some lead length showing. The other components should be mounted flush to the board with excess lead lengths clipped off.

Refer to the schematic diagram and parts-placement diagrams often in order to make sure that your construction is correct. Since this project is a relatively low-frequency device, actual parts positioning and lead lengths aren't critical but neatness should always be a primary concern.

Use good soldering practices during construction. Before soldering a joint, wipe the soldering iron tip clean on a wet sponge. Melt a small ball of solder on the iron tip. Touch that molten solder to the joint to be soldered first. The liquid solder forms a "heat bridge" that lets the joint area heat up to melting temperature quickly before the heat flows away to the surrounding area. Let the soldering tip heat each component lead and board trace just enough to make the solder flow smoothly. Although most of the parts used in this project are not overly heat sensitive, the copper pads and traces on the PC board can lift up if they are allowed to get too hot.

Mark off each part on the list as you install it. That will help keep track of your work.

of zero to 50,000 ohms, is R_F; and R8, at 1000 ohms, is R_{IN}. Plugging those values into the formula, we see that the maximum gain is 50 (50,000/1000) and that the minimum gain is zero (0/1000). It is easy to see that R7 can be used as the Surface-Mount Shortwave Radio's volume control.

Another feature of the audio preamplifier circuit is that it also provides the bias voltage that drives Q2, the audio output. An op-amp normally requires a dual-polarity power supply to operate. That lets the output signal swing both positive and negative across the ground reference. Unfortunately, dual-polarity supplies are both expensive and inconvenient to use—especially with battery-operated devices. Fortunately, op-amp circuits can be made to operate from a single supply by placing a DC offset voltage on one of its inputs.

An op-amp is a differential amplifier that has two inputs and one output. One of the inputs is "inverting" while the other is "noninverting." A signal applied to the inverting input will be phase shifted 180 degrees (or inverted) at the output. By contrast, a signal applied to the noninverting input will remain unchanged in phase at the output. If two signals are simultaneously applied to both inputs, their difference appears at the output multiplied by the gain of the circuit. Normally, only one of the inputs is used for the signal; the other is referenced to ground. A simplified example of that type of circuit is shown in Fig. 5. Since the unused input is grounded, it effectively stays at zero volts. Therefore, the difference between the two inputs automatically becomes the incoming signal, which is then amplified and passed through to the output. That circuit works fine when both a negative and positive supply are available. What would happen if only a positive supply is available?

In that case, the output signal could only swing positive as shown in Fig. 6. For the op-amp to work from a single supply voltage, the circuit must be able to produce both positive- and negative-going signal swings. The easiest way to do that is to offset the output reference above ground. That is done by referencing the unused input to one-half of the positive supply voltage instead of connecting it to ground as we've done with IC3. The bias voltage is supplied by R14. That will let the output signal swing both positive and negative around the bias level. The resulting waveform on an oscilloscope will look like the waveform shown in Fig. 7.

The output signal has effectively become an AC signal that is riding on top of a DC level. Normally, the DC component is removed before the signal passes on to the next stage (usually by coupling capacitor) but, in this project, we do not remove it. Instead, it is used to bias Q2, the audio power amplifier.

The Audio Power Amplifier. Transistor Q2 is the main component of the audio-output stage. Note that it is wired as a common-collector amplifier. That type of circuit was chosen because its low-impedance output allows a direct connection to a headset. Like all bipolar transistors, Q2 requires a certain amount of DC bias in order to operate. Often, a resistor divider network is used to provide bias; our circuit is no exception. Resistors R9 and R10 form the bias network for Q2. Normally, most amplifiers connect the bias resistors to the power supply. We will not be doing that here because the DC offset from IC3 is providing the bias.

Capacitors C13 and C14 are bypass capacitors that block any DC while passing the AC audio signal. They create a low-impedance audio-signal path around the bias-resistor network, increasing gain. From here, the signal goes on to drive the headset.

Construction. Building the Surface-Mount Shortwave Radio is as simple as mounting the parts to a printed-circuit board; no particular order is required. A foil pattern for a single-sided board has been included here. As an alternative, a pre-etched board is available from the source given in the Parts List. If you purchase a board or make one from the foil pattern, the parts-placement diagrams in Figs. 8 and 9 indicate where the various components should be mounted. Remember that you can use either surface-mount or through-hole components—the option is yours.

If you decide to use surface-mount components, you should place those items on the board first. Figure 8 is specifically for the surface-mount components. For those unfamiliar with the techniques involved, several sidebars on working with SMTs well as information related to them can be found elsewhere in this article. The Glue-Place-Solder method that is demonstrated is probably the best method to use when assembling the Surface-Mount Shortwave Radio. Please keep in mind that this project is "component versatile." If you have trouble in placing an SMD part, you can simply substitute the through-mount device instead; the PC board will accept either type. When deciding whether to use surface-mount or traditional components, remember that you can use as many or as few of the surface-mount components as you want. The receiver works just as well with either type of device installed on the board.

The most important thing to remember when building this project is that either a surface-mount *or* a through-hole component should be used for a particular component. **DO NOT** place both types on the board for the same reference designation.

One last note: While surface-mount components could be used for all parts, in a few instances using standard through-hole components is recommended. Those are C6 (because of a ground trace that the component would have to straddle, increasing the likelihood of a short) and C11–C14 (due to their size).

Figure 9 is the parts-placement diagram for any insertion-mount components you elect to use. None of the parts are particularly sensitive or difficult to mount. Neither S1 nor FL1 are polarity sensitive; you can install them in either direction on the board.

When all of the parts are installed on the board, the basic construction of the unit is complete. Only one more item is necessary for receiver operation—the antenna. The most convenient type to use is a straight piece of wire. The antenna wire should be 18 to 24 gauge with a length between 25 and 50 feet. One end of the wire connects to the PC board at the hole marked "ANT1" on the parts-placement diagrams. The rest of the wire should be stretched out full length away from the radio

The Surface-Mount Shortwave Radio can be mounted in any suitable case. After checking over your work for errors such as bad solder joints, solder bridges or incorrect or backward-mounted components, you can test the unit.

Testing and Adjustment. The Surface-Mount Shortwave Radio is designed to operate from a standard 9-volt battery. Apply power to the radio but **DO NOT** connect a pair of headphones to J1 yet—that will be done later.

The first step is to set the oscillator bias. Set both R6 and R12 to their center range and connect an oscilloscope to Q1's source lead. It is very important to use a 10X probe; any other type of probe will load the circuit and kill the signal. Adjust R12 until you see a sine wave on the oscilloscope that is a good compromise between signal amplitude and symmetrical shape. You need to check the signal across the entire oscillator range, though, so vary R6 (the tuning control) from end to end and readjust R12 as needed to compensate for any distortions that might occur. When the circuit is working properly, the oscillator signal will vary a few megahertz in frequency—somewhere between 7 and 17 MHz.

If the oscillator does not work, check for 9 volts on the drain lead of Q1. If that is missing, check to see if L1 is open, S1 is defective, or for a defective battery clip. If the voltage on the drain is correct, then check the voltage level on the anode of D2. That voltage should vary between zero and 8.2 volts as you turn R6. If you do not obtain those results, then either R2 or R6 might be open or D2 might be installed backwards on the board. If all of the tests check okay but no oscillation occurs, then either Q1 or D2 might be defective.

The audio section is adjusted next. Set R13 for about 4.5 volts on pin 3 of IC3. Plug a pair of headphones into J1. You will probably hear some noise or "hiss" from the

HELPFUL HINTS FOR INSTALLING SMDs

Because of their small size, surface-mount devices (SMDs) are easy to lose. When working with SMDs, you should place and keep all parts on a plain sheet of white paper.

Before you glue or place any parts, you need to clean the PC board. You can do that by using alcohol or some other non-residue cleaning solution specifically made to safely clean electronic equipment. **DO THAT EVEN IF THE BOARD APPEARS TO BE FINE.** If you do not clean the board first, then some of the solder connections that you make during construction might become intermittent and cause improper operation that will be difficult to trace.

Do your best to keep the glue between the trace runs and off the pads.

After you place the part on the board, you should allow the glue to dry first. That will prevent the part from shifting during the soldering process.

For easy soldering, smear some soldering paste (such as RadioShack 64-021) on the pads and terminal ends of the SMD after it has been glued in place. Also, you should use the smallest diameter solder available. For example, RadioShack 64-005 solder is only 0.032 inches in diameter.

None of the SMD resistors or capacitors used in the Surface-Mount Shortwave Radio are polarity sensitive. You may place them either way on the board.

DO NOT use a soldering iron larger than 25 watts and use the finest point possible. You should also have a good set of tweezers, a magnifying glass, and some desoldering wick when working on this project.

headset. The volume should change as you adjust R7. The easiest and best way to adjust the sound is by using an actual shortwave reception. Adjust R6 until you hear a moderately strong station; adjust R13 until the audio sounds most clear to you.

The audio adjustment is quick and easy to make; however, the time of day and location can affect the quality of the Surface-Mount Shortwave Radio's output. The very best time to receive a shortwave signal is at night shortly after sunset. The antenna must also be fully extended and preferably outdoors. If you cannot stretch it outside, then do so inside a non-metallic-frame building. If you attempt to receive shortwave inside a metallic-frame building (like a commercial or industrial building) or during the day, you will hear few or no stations. Like most shortwave receivers, the Surface-Mount Shortwave Radio works best when referenced to an earth ground. The easiest way to do that is to make a strap connection to any cold-water pipe that runs into the ground.

Troubleshooting. Since the oscillator should have already been checked and adjusted, any problems will be located elsewhere. Before you begin the test procedures outlined below, you should first check all of your solder connections. Almost every problem is directly due to either an improper solder connection or an accidental solder bridge across adjacent traces. A lot of aggravation and trouble will be avoided if you thoroughly check the solder work first. If the soldering is okay and the receiver still does not work, then one of the following steps should help to isolate and solve any problems that might occur.

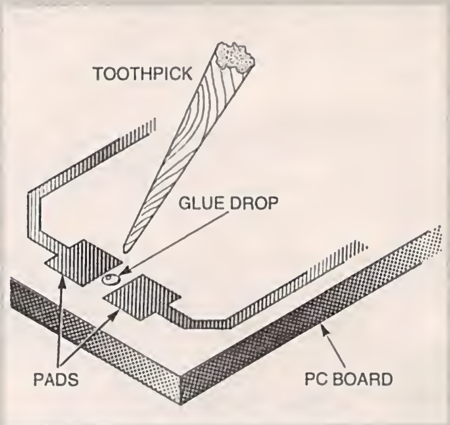
The first step in troubleshooting is to isolate the problem area. For example, is the problem in the RF or the audio portion of the circuit? Fortunately, you can determine that quite easily. Simply remove the antenna wire from its normal connecting point and reconnect it where FL1 meets the base of Q3. You should hear various local AM-broadcast stations through the headset when you do that. If you hear those stations, the receiver is operating properly from Q3 through to the headset; the problem exists between the antenna and the IF filter. Note that for that procedure to work well, you should use the earth grounding method discussed earlier.

If the problem is in the RF section, you should check IC1, FL1, and the oscillator. The oscillator is the easiest to check—simply follow the adjustment procedure used earlier. If the signal still looks good on the oscillo-

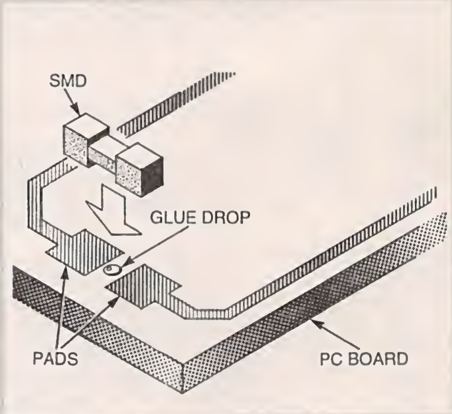
HOW TO INSTALL A SURFACE-MOUNT DEVICE

Working with SMDs is a simple 3-step process when following the G-P-S (Glue-Place-Solder) method:

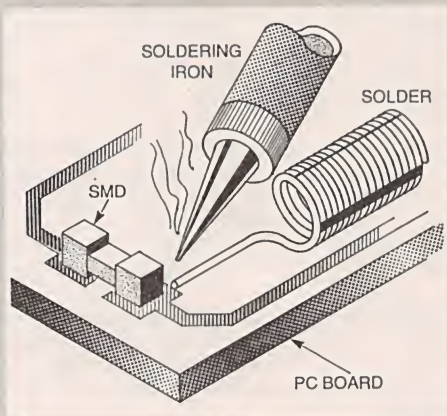
Step 1: Glue
Because glue is used to hold the SMD in place, gluing is the first step in the installation process. The author recommends the plastic glue used to build model cars, but any good plastic glue will work. To perform this step, find the pads on the board and use the tip of a toothpick to lightly smear a drop of glue between them. For best results, you should clean and paste the board first as described in the Helpful Hints sidebar.



Step 2: Place
This is the most critical step in the assembly procedure. After you have placed the glue, you must position the SMD on the board. A good set of tweezers is often the best tool to use. Centering does not have to be perfect but you must make sure that the metallic ends of the component touch the pads to either side.



Step 3: Solder
Lightly touch the tip of the soldering iron to the metal end of the component. At the same time, place the tip of a solder strand against this point as well. Let this heat until the solder flows onto the part and board together making the connection. Remember, neatness is preferred but perfection is not required. Remove any excess solder with the wick.



SMT—ANSWERS TO FREQUENTLY-ASKED QUESTIONS

What is SMT? What is SMD?

The letters "SMT" stand for Surface-Mount Technology. The letters "SMD" stand for Surface-Mount Device. Those terms refer to a style of tiny, leadless electronic components that are made to mount on the PC board's surface as opposed to the larger through-hole style of components that we are more familiar with. Unlike those larger components, SMT devices have no leads. Instead, they use either small metal tabs or metallic terminals to make the electrical connections to the circuit board.

Why is SMT used?

Due to their small size, SMT is often used to construct miniaturized electronic devices such as pocket-sized cellular telephones or keychain-sized car lock controls. Also, SMT devices can be more easily installed in some automated assembly processes due to their lack of leads.

What components are available as SMT devices?

Resistors, capacitors, transistors, diodes, and ICs have been available in SMT style since the 1970s. Today, LEDs, potentiometers, crystals, inductors, fuses, connectors, and certain subassemblies like filters and oscillators are available in large quantities.

What is the size of an SMT device?

Like many electronic components, SMT devices come in various styles and sizes. SMT resistors, for example, commonly come in $^1/_{16}$, $^1/_{10}$-, $^1/_8$-, $^1/_4$-, and 1-watt sizes. The $^1/_{10}$-watt size is 2.00 mm by 1.25 mm by 0.60 mm, while the 1-watt device measures 6.40 mm by 3.20 mm by 1.10 mm. Not suprisingly, the chip-style capacitors and inductors are roughly the same size. The other components, such as transistors and ICs, come in various sizes as well. However, they are usually smaller than their through-hole counterparts.

Other than physical size, what differences are there between SMT and regular components?

Electrically speaking, no difference exists between SMT devices and their counterparts. An SMT resistor of 1000 ohms would act the same as a 1000-ohm leaded resistor. Their differences are purely physical and not electrical.

How can you identify the type and value of an SMT device?

SMT resistors are usually manufactured as small black rectangular chips with metallic-coated ends. Often, the value of the device is printed in a numerical code across its top. The number is similar to the more familiar color-code bands found on leaded resistors. For example, a 390-ohm resistor would have "391" (3, 9, and 1 zero) printed on it while a 3900-ohm unit would be marked "392".

Like resistors, capacitors also resemble a small rectangular chip but they are usually either a yellow or gray in color. Unfortunately, these components don't have a value printed on them. You either have to refer to a manufacturer's reference or physically measure their value.

SMT-style transistors and diodes often look like small black squares but with metal tabs instead of ends. Usually two of the tabs are located on one side of the device while the third tab appears on the opposite side.

SMT ICs look very similar to regular DIPs except that they are generally smaller in size with leads that lay flat to the board.

What tools are needed to work on SMT devices?

Virtually all electronic components are soldered to the board and SMT devices are no exception. Therefore, good soldering equipment is still required. While some shops use specialized (and expensive) equipment to do SMT soldering, a low-wattage standard iron with a fine point tip can still be used for many applications. Other good tools to have on hand are tweezers, a magnifying glass, glue, and soldering paste.

Why should I practice working with SMT devices?

Although most assembly processes are automated, most repairs are not. Employers need people with the knowledge and "hands-on" skill to work with SMT; that need will only grow with time. Practicing with SMT is one good way to prepare for the future.

scope, it is operating properly.

The IF filter is the next component to test. Actually, it's a very easy part to test if you have an RF signal generator. Set the signal generator for an AM modulated output at 4.5 MHz and connect it to the filter input at C9. If the filter is okay, you should hear the signal in the headset.

Check for 9 volts on pin 8 of IC1. If that voltage is present and the receiver still doesn't work, then IC1 might be defective or installed backwards. If it is in backwards, it is almost certain that if it wasn't defective to begin with, it probably is now!

If placing the antenna wire on Q3's base causes no sound to be heard from the headset, the problem is in the audio section and it will involve Q3, IC3, or the audio-output section. The easiest way to troubleshoot those sections is to use the signal injection and tracing method. To do that, simply inject a 10-millivolt peak-to-peak 1000-Hz audio signal into the positive side of C11. If you hear that tone through the headset and it varies in loudness as you turn R7, then IC3 and the output stage are okay; the problem is with the Q3 amplifier/demodulator circuit.

If you do not hear the tone, disconnect the generator. Check the voltage level on the base of Q2. It should read somewhere between 2 and 3 volts DC; the level should vary as you adjust R13. If the proper voltage is on the base, then check the level on the emitter. That voltage should be about 0.7 volts less than the level on the base. Note that the headset must be plugged into J1 for the measurements to be accurate. If that voltage is missing or high, then either Q2, R11, C14, the headset, or J1 might be defective.

Final Notes. Shortwave listening makes for an interesting and worthwhile hobby. Millions of people throughout the world enjoy listening to shortwave and there's quite a variety to hear. There are news broadcasts, religious broadcasts, and even commercial rock-and-roll stations. Many broadcasts occur in English as well as most every spoken language on Earth.

Most important, those broadcasts originate from faraway countries with different ideas, cultures, and perspectives. A very good example of that occurred in 1989 with the fall of the Berlin Wall. Although that was a truly major historical event, most Americans knew about it from only a few short minutes of news broadcast each evening on network television. By contrast, those with shortwave receivers heard first-hand reports continuously throughout the event. Yet we did not hear these broadcasts from American journalists. Instead, we heard from

(Continued on page 50)

SHORTWAVE RADIO

(continued from page 44)

the Germans themselves through such stations as *Radio Deutsche Welle* in Cologne and *Radio Berlin International in Berlin*. In contrast to their American counterparts, the German commentators were far more informed and informative on the subject. To them, it was not just another news story, but a miraculous, healing event for their people and their country. They not only reported the facts of the event but told the stories, the meanings, and the emotions behind it as well. Through the power of shortwave radio, they both clearly and eloquently convyed to the world just what the fall of the Wall meant to Germany and did so in a depth and style that the other journalists could not understand, much less appreciate or convey.

Another fine example of shortwave listening occurred during the Persian Gulf War. When the American public discovered that some of the international stations were continuously broadcasting the war news both day and night, most stores selling shortwave receivers sold out in a few hours time.

Simply put, shortwave listening can be both educational and entertaining in itself. Many of the broadcasts, whether in English or another language, give a glimpse of another place and people. Listen for awhile; you just might enjoy what you hear. Ω