Wireless Camcorder Microphone

Add professional-quality audio to your home videos with our wireless camcorder microphone—for less than $15.00!

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EVERY FEW YEARS, AN ELECTRONIC gadget comes along and changes our lives. Devices such as televisions, cellular phones, VCR's, and personal computers, have had a profound impact on how we live. Today's hot item is the handheld camcorder. Falling prices, smaller sizes, and greater quality have made them quite common.

If you do a lot of camcorder recording, you're sure to notice that it's always harder to record quality audio than it is to record quality video. While the camcorder might be doing a great job recording the picture, the built-in microphone might not be doing as well picking up the sound. That's particularly true for long-distance shots—remember that most lenses can zoom in on a subject, but most microphones can't.

Another difficult situation is shooting a room full of people. If there is a lot of background chatter—and there usually is—that's what the camcorder's internal mike will record. The problem is caused by the automatic audio-level control circuit that most camcorders use—it can't differentiate between the audio you want and the babble you don't want.

The only sure-fire way to get good audio, regardless of the situation, is to use an external microphone, especially if your subject is at a distance. The most convenient mike is a wireless mike, which is the focus of this article. A good wireless mike will guarantee quality audio every time, regardless of the distance to the subject. A wireless mike also eliminates recording those annoying camcorder noises such as the sound of the autofocus mechanism.

While camcorder prices have fallen, microphone prices have not. Unfortunately, a high price does not always guarantee a high-quality wireless mike. The microphone we'll present here can be built from readily available, inexpensive parts. It takes less than 30 minutes to assemble, and requires no complicated setup or adjustment procedures. You don't even need any complicated test equipment. The resulting quality will surprise you.

Operation

The wireless microphone is basically a short-range, low-power FM transmitter. The circuit, as shown in the block diagram of Fig. 1, consists of three main sections: the microphone element, the audio amplifier, and the RF oscillator. Figure 2 shows the schematic.

The heart of the circuit is the oscillator section, which is built around a 2N3904 transistor (Q1). A parallel-resonant LC, or "tank" circuit, consisting of L1, C2, and D2, determines the operating frequency.

Varactor diode D2, a voltage-variable capacitor, tunes the circuit. To understand how the varactor works, recall that a capacitor is basically two conductors separated by an insulator. A reverse-biased diode is similar to a capacitor in that it has two electrodes (the anode and the cathode) separated by an insulator (the reverse-biased junction). Consequently, a reverse-biased diode acts like a capacitor. Although all diodes exhibit that effect, a varactor diode is designed to have as much capacitance as possible.

An oscillator is basically an

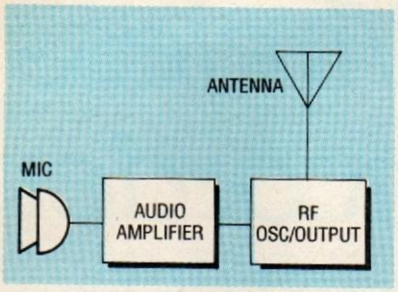


FIG. 1—BLOCK DIAGRAM. The circuit consists of the microphone element, the audio amplifier, and the RF oscillator.

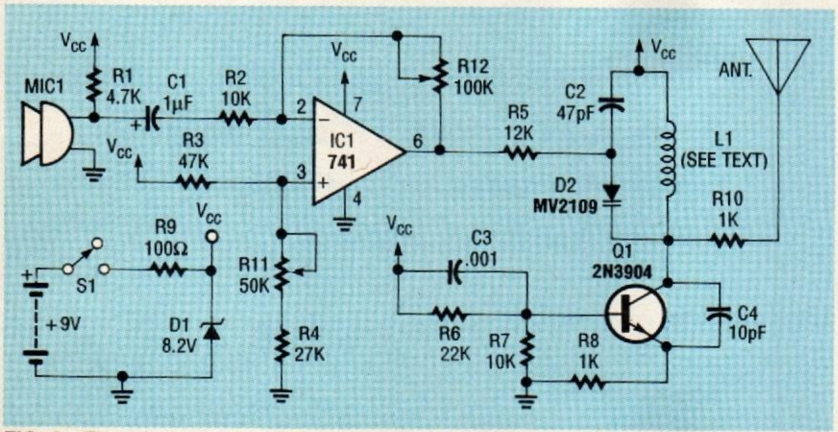


FIG. 2—The wireless microphone is a short-range, low-power FM transmitter.

amplifier with positive feedback. In our circuit, feedback is provided by capacitor C4, so that the part of the oscillation generated in the tank circuit is coupled back from Q1's collector to its emitter. Resistors R6 and R7 bias Q1. Capacitor C3 is the base bypass and R8 is the emitter load. If you want to see the oscillation, you can connect an oscilloscope to the top of R8 with a ×10 probe. The initial oscillation should be somewhere between 60 and 110 MHz, so a high-frequency scope must be used. If an oscilloscope is unavailable, you can use a frequency counter to check the signal.

The audio amplifier is a 741 op-amp chosen because it is one of the most common and versatile op-amps. It is wired as an inverting amplifier with a variable negative feedback gain control. The purpose of the op-amp is to amplify the microphone signal, and to electronically tune the oscillator frequency.

An op-amp normally requires a bipolar power supply. Fortunately, op-amp circuits can be made to operate from a single supply by placing a DC offset voltage on one of the inputs.

An op-amp is basically a differential amplifier with two inputs and one output. One input is inverting while the other is non-inverting. A signal applied to the inverting input will be phase-shifted (or inverted) 180 degrees at the output. A signal applied to the non-inverting input will remain unchanged in phase at the output. If a signal is applied to both inputs simultaneously, their difference appears at the output, multiplied by the gain of the circuit.

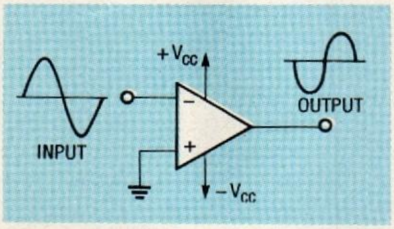


FIG. 3—NORMALLY ONLY ONE OP-AMP INPUT is used for the signal and the other is referenced to ground.

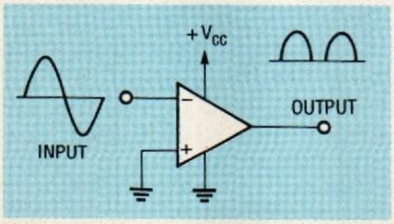


FIG. 4—IF ONLY A POSITIVE SUPPLY IS USED, the output signal can only swing positive.

Normally only one op-amp input is used for the signal and the other is referenced to ground as shown in Fig. 3. Since the unused input is referenced to ground, it effectively stays at a zero-volt potential.

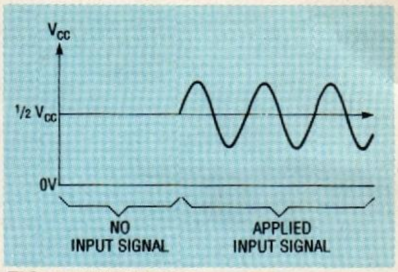


FIG. 5—WITH THE UNUSED INPUT referenced to one-half of V_{CC}, the output signal can swing both positive and negative around the new reference.

Therefore, the difference between the two inputs is the incoming signal, which is amplified and passed through to the output. This circuit works fine when both negative and positive supplies are used. However, if only a positive supply is used, the output signal would only be able to swing positive, as shown in Fig. 4.

For the op-amp to work properly from a single supply voltage, the circuit must be able to produce both positive and negative signal swings. The easiest way to do that is to offset the output reference above ground. That's accomplished by referencing the unused input to one-half of V_{CC}, instead of connecting it to ground. In our circuit, that's done by the voltage-divider network of R3, R4, and R11. The output signal can swing both positive and negative, except that it does so around the new reference as shown in Fig. 5.

Normally, the DC component of the output is removed before the signal is passed on to the next stage, usually by a coupling capacitor. In this project, however, we do not remove the DC offset. Instead, it is used later to tune the oscillator's center frequency.

The cathode of tuning element (varactor D2) is connected to V_{CC} sbC via coil L1, and its anode is connected to the op-amp output via R5. Since the cathode is at V_{CC} and the anode is at approximately one-half V_{CC}, the varactor is reverse-biased, which is its normal operating condition.

One of the primary factors that determines a capacitor's value is the distance between its plates. By controlling the amount of reverse bias applied to the varactor, we can control the thickness of the varactor's barrier region, and consequently the distance between its "plates." When you increase or decrease the reverse bias, the junction barrier increases or decreases. This, in turn, decreases or increases the effective capacitance, and raises or lowers the frequency of oscillation.

As mentioned earlier, the reverse bias is provided by the amplifier's DC offset, created by the voltage divider on pin 3 of IC1. Note that potentiometer R11 is part of that network. When you vary R11, the offset voltage varies as well. That, in turn, changes the bias on the varactor, which results in a frequency shift of oscillation. That's how the tuning is accomplished.

The other potentiometer, R12, is used to set the amplifier's gain. As you increase R12's resistance, you decrease the amount of negative feedback, which then increases the signal gain. The audio output rides on the DC offset, and the offset provides the tuning bias. Therefore, as the signal varies, so, too, does the bias and the oscillator frequency. That's how the frequency modulation (FM) is produced.

In FM, the frequency of the carrier varies with the frequency of the modulating signal; the amount of variation or deviation is determined by the amplitude of the modulating signal. In our case, the modulating signal is the audio picked up by the microphone, so when you adjust R12 you are adjusting the modulating signal's amplitude, which increases its deviation.

A standard FM broadcast signal has a deviation bandwidth (or carrier swing) of plus or minus 75 kHz. That amount of deviation is considered to be 100% modulation. For our transmitter to work properly, we'll need to adjust it to provide approximately the same amount of deviation.

The FM transmitter uses an electret microphone. An electret is a permanently polarized piece of dielectric material, usually a ceramic compound. It is formed by heating the material and then letting it cool in a strong electric field. That realigns the molecular structure of the material so that it retains a mild electric field after cooling. (That's analogous to the way iron can be made into a permanent magnet.) The electret is then used as the diaphragm or moving part of the microphone. The result is a small, though very sensitive, high-fidelity microphone. The microphone also contains an internal FET amplifier that adds to the microphone's fidelity and sensitivity.

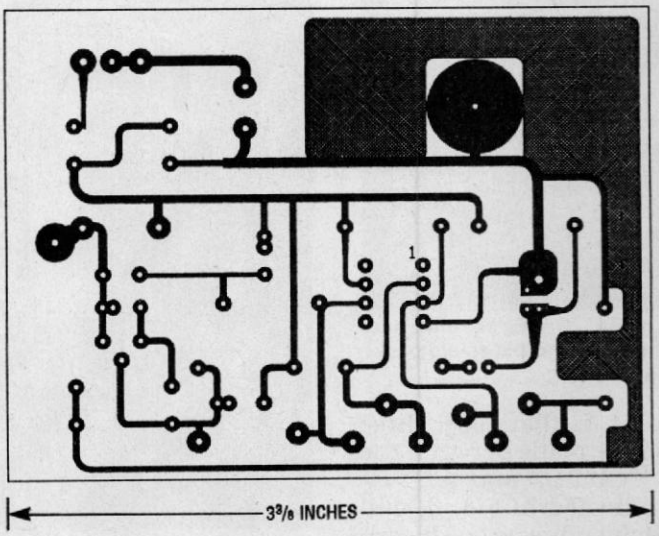
Although the wireless microphone is battery operated, it uses a Zener diode voltage regulator which is absolutely essential for proper operation. A fresh battery may start out at 9 volts but, over time, the voltage slowly drops. Because the oscillator is voltage-tuned, it is voltage-sensitive. Any change in V_{CC} will shift the oscillator frequency. This is so critical that even a 0.1-volt change can shift the oscillator by 100 kHz or more. Obviously, we want the transmitter to stay on frequency so we must make sure that V_{CC} doesn't change; the Zener diode guarantees this.

Construction

Despite the simplicity of the transmitter, you should build it on a PC board. Point-to-point wiring could cause problems at VHF frequencies because of too much interconnection parasitic capacitance. A foil pattern has been provided so you can make your own PC board. You can also purchase a pre-made board from the source mentioned in the Parts List, as well as a kit that includes a PC board.

Install all the parts on the board as shown in parts-placement diagram of Fig. 6. There is room on the board to mount the 9-volt battery holder included in the kit if you intend to install the board in a large enough case. A metal case, like the one used for the author's prototype (see Fig. 7), will provide the best shielding for the circuit. The prototype's case is also available from the source mentioned in the Parts List. If you use the metal case, the PC board must be cut between the two "CUT A" points indicated in Fig. 6. Also, the potentiometers must be mounted on the underside of the board with the battery holder secured to the bottom of the case and the PC board mounted on 7/8-inch spacers (see Fig. 8).

Even though a metal case provides superior shielding, we packaged the board in the pocket-sized plastic case, and the transmitter seems to work just fine. However, to get the



FOIL PATTERN for the wireless microphone PC board.

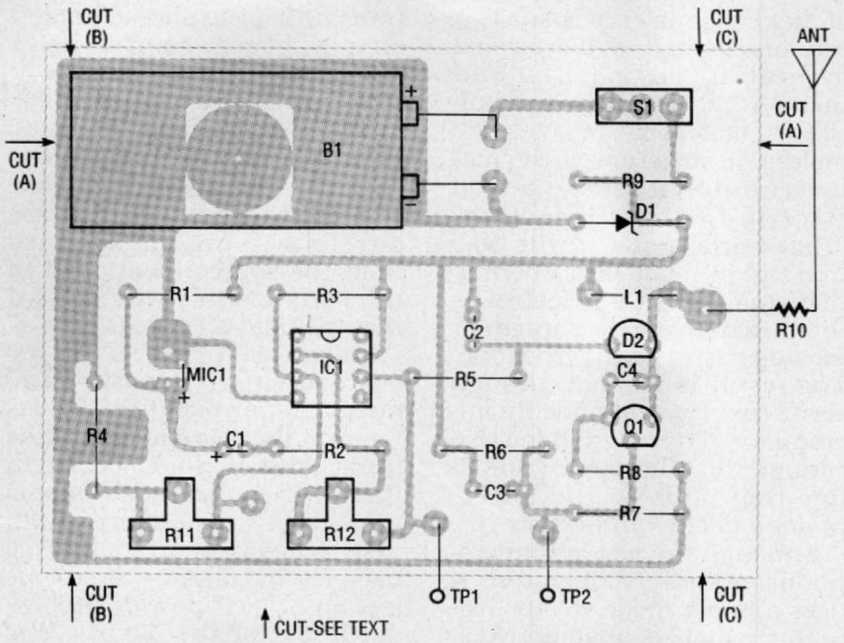


FIG. 6—PARTS-PLACEMENT DIAGRAM. There is room on the board for the 9-volt battery holder if you are installing the board in a large enough case.

FIG. 7—A METAL CASE, like this one, provides the best possible shielding for the circuit.

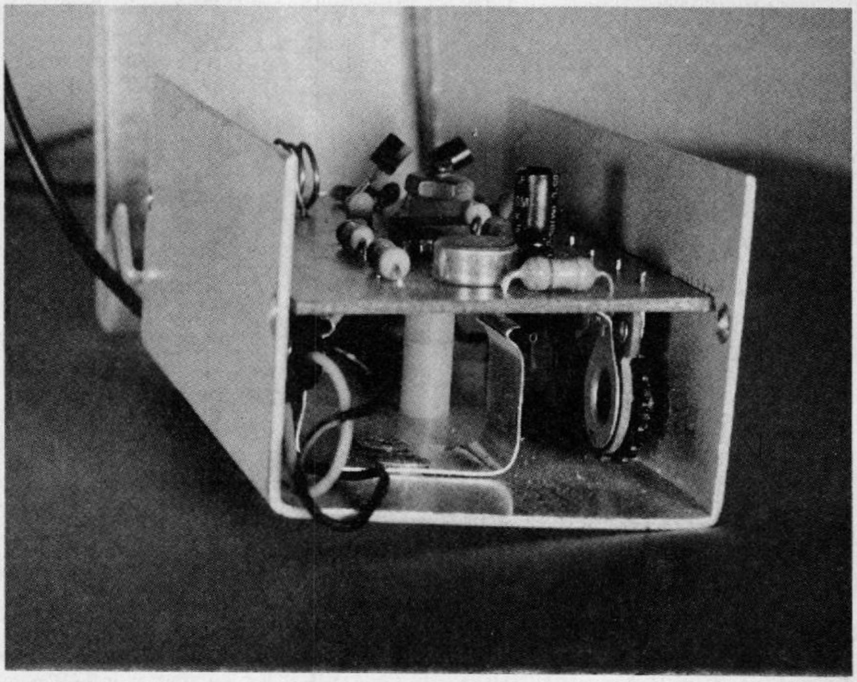


FIG. 8—TO USE THE METAL CASE, the PC board must be cut between the two "CUT A" points indicated in Fig. 6, and the potentiometers must be mounted on the underside of the board.

board to fit in that case, three cuts must be made between the "CUT A," "CUT B," and "CUT C" points indicated in Fig. 6, and R10, which connects to the antenna, must be tack-soldered to the end of L1. Also, the potentiometer leads must be trimmed as shown in Fig. 9 to decrease their overall height so that they fit in the case. The plastic case, made by Pac-Tec, has a built-in compartment for a 9-volt battery. Figure 10 shows how the board fits in the Pac-Tec case.

The final component to connect to the board is the antenna. A 30-inch length of wire is recommended because that's the quarter-wavelength of 98 MHz (the center of the FM band). But you are certainly free to use whatever length antenna works best for your needs, such as the 12-inch telescopic antenna we used for the plastic case.

The antenna connects to the collector of Q1 via a R10, a 1K resistor. The resistor provides isolation for the oscillator, greatly enhancing its stability. Unfortunately the 1K resistor does decrease the unit's range. Without it, the signal will travel about 300 feet. With it, the range is approximately 100 feet, which is comparable to most commercially available products, and adequate for most video production work.

Testing

Unless you have a defective part or have misplaced something on the board, the transmitter should work as soon as power is applied. The easiest way to test it is to tune a standard FM radio to an unused frequency, and adjust R11 until you hear your voice coming from the radio's speaker. It's usually easier to adjust R11 until the microphone can be heard over the radio, and then fine tune the signal by adjusting the receiver.

You will probably have to adjust R12 as well for the proper volume level. Simply listen to the signal on an FM radio; if R12 is set too low, the audio will sound weak. If R12 is set too high, the audio will be too loud

PARTS LIST

All resistors are ¼-watt, 5%.
R1—4700 ohms
R2, R7—10,000 ohms
R3—47,000 ohms
R4—27,000 ohms
R5—12,000 ohms
R6—22,000 ohms
R8, R10—1000 ohms
R9—100 ohms
R11—50,000 ohms, potentiometer
R12—100,000 ohms, potentiometer

Capacitors
C1—1 µF, 25 volts, electrolytic
C2—47 pF, 25 volts, ceramic
C3—0.001 µF, 25 volts, ceramic
C4—10 pF, 25 volts, ceramic

Semiconductors
IC1—741 op-amp
D1—8.2-volt Zener, ½-watt
D2—MV2109 varactor diode
Q1—2N3904 NPN transistor, or equivalent
S1—SPST switch
MIC1—electret microphone

Other components
L1—2.5 turns of #18 wire on a 5/16-inch diameter form.

Miscellaneous: 9-volt battery and connector, battery holder, project case, PC board, 30 inches of antenna wire, solder, etc.

Note: The following items are available from Paul E. Yost, P.O. Box 32291, Louisville, KY 40232:

- **A kit of parts including the PC board (no case)—$14.95 plus $1.50 S&H**
- **PC board only—$6.95 (postpaid USA)**
- **Metal project case (drilled and with rubber grommets)—$6.95 plus $1.75 S&H**

Kentucky residents must please add 6% sales tax.

- **The Pac-Tec HML-9VB plastic case sells for about $5. Call Pac-Tec at (800) 220-9800 for a distributor nearest you.**

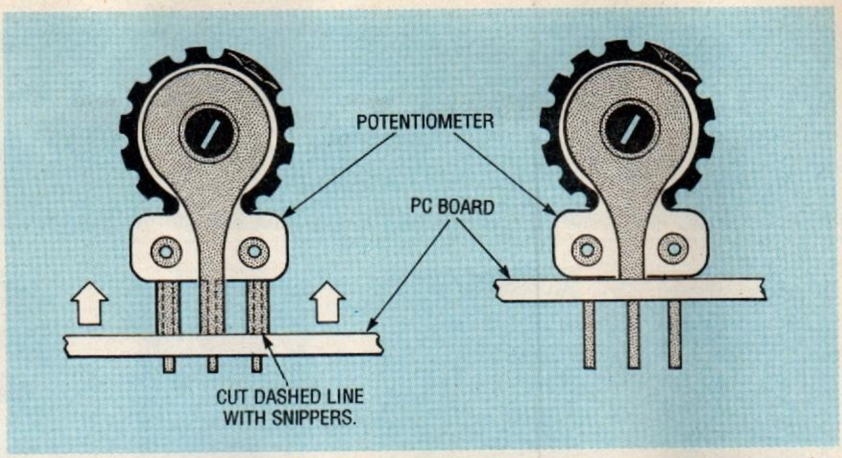


FIG. 9—TO USE THE PLASTIC CASE, the potentiometer leads must be trimmed as indicated by the dashed lines to decrease their overall height so that they have as low a profile as possible.

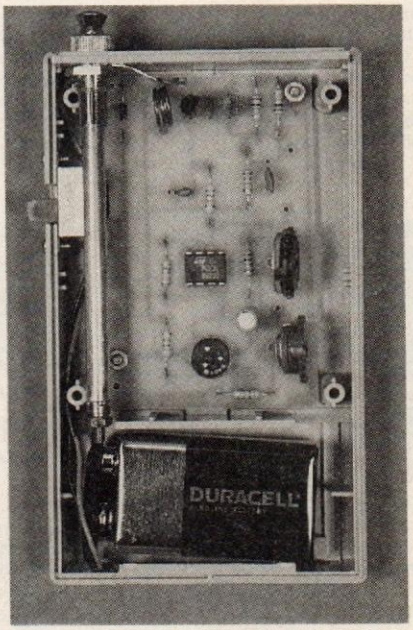


FIG. 10—HERE'S HOW THE BOARD fits in the plastic case. Remember to cut the board between the "CUT A," "CUT B," and "CUT C" points indicated in Fig. 6.

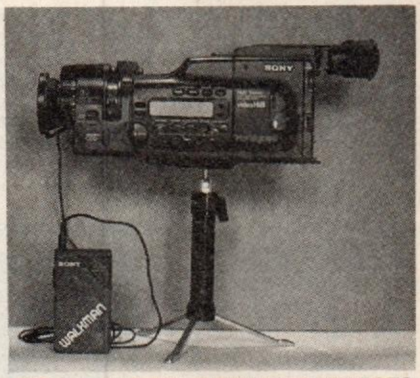


FIG. 11—THE FM RECEIVER CONNECTS to the external microphone input jack on your camcorder.

or distorted.

If you have any trouble, the following steps should help you locate the cause and solve it:

1. Check for 8.2 volts DC at the cathode of D2. If a voltage is missing or low, you either have a bad battery, a defective Zener diode, an open R9, or a short circuit on the board.
2. Check for 8.2 volts DC at the transistor collector, pin 7 of IC1, and the R1-C1 junction.
3. Check for approximately 4-volts DC on pin 3 of IC1. This voltage should be variable by turning R11.
4. Check for approximately 2.4-volts DC on the base of Q1.

If any of the voltages in steps 2, 3, or 4 are missing or the values are wrong, you have an open or short circuit.

5. You can check for an oscillation at the emitter of Q1 by using either a frequency counter or oscilloscope. Make sure that the device you use will work at 100 MHz or more. You must also use a ×10 probe to make this test. Any other probe will load down the circuit and kill the oscillation.

If the oscillation is present, but below the FM frequency range of 88 to 108 MHz, you should be able to increase it by turning R11. If you cannot adjust it high enough, then you can compensate with coil L1, which is simply three turns of wire. Separating the windings slightly will lower its inductance and raise the resonant frequency. Adjust L1 as much as necessary until you are able to correct this situation.

If the oscillator does not work, but all the proper voltages are present, then either Q1 or D2 is probably defective.

6. If the oscillator signal is present, but no audio is present, then use an oscilloscope to check for an audio signal at pin 6 of IC1 as you speak into the microphone. Remember, the signal should be riding a DC

level approximately equal to one-half of V_{CC}.

If no audio appears on pin 6, and R12 has no effect, then check for a signal input on pin 2. If a signal is present there, then IC1 might be defective. If no signal is present, the microphone might be defective.

Using the microphone

The best receiver for the wireless camcorder microphone is a good-quality (sensitive) Walkman-type FM receiver because it is portable and lightweight. The only requirement for the receiver is that it must have a headphone jack.

Tune the receiver to an unused frequency, and adjust the microphone until you hear a sound clearly over the radio's headphones. Now remove the headphones from the receiver and connect an audio cable (see the Parts List) between the headset jack on the radio and the external microphone input jack on your camcorder (see Fig. 11). Experiment to find the maximum volume setting that can be used without distortion.

For best results, the antenna wire should be stretched out full length, such as down the wearer's back or side. Speaking of antennas, many Walkman-type radios use the headset wire as their antennas. Unfortunately, the audio cable used to connect the receiver to the camera is shielded, and does make a good antenna. Thus, the range of that receiver is limited to about 25 feet. If you need greater range, you can either modify the radio to accept an external antenna or use a receiver that already has a built-in external antenna.

There are many applications for this project other than for camcorders. For example, when used in conjunction with a "boom box" receiver, it makes a very effective portable public-address system. It also makes an inexpensive nursery monitor. Another application is for those of you who, like the author, teach electronics: Students always want to do "hands on" work in the lab classes, and this project makes an excellent classroom lab. **R-E**