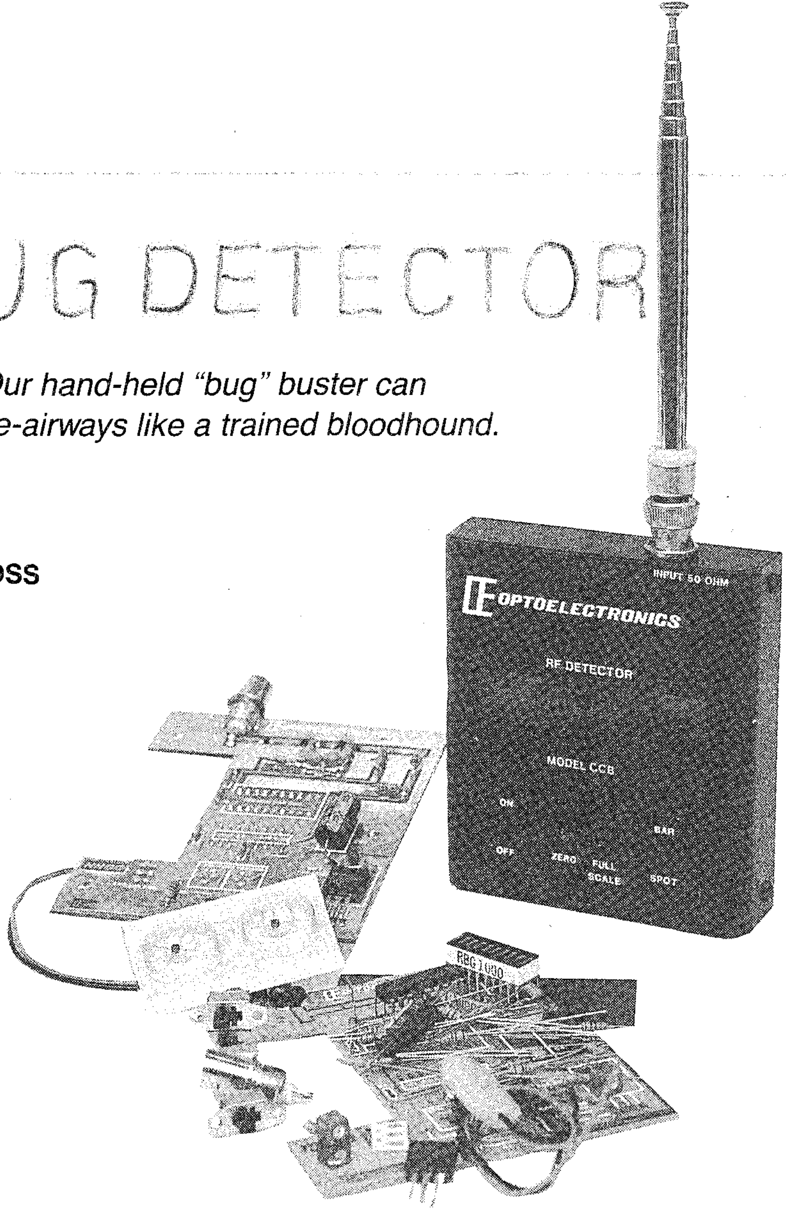
BUG DETECTOR

Our hand-held "bug" buster can sniff-the-airways like a trained bloodhound.

L. K. ROSS



IF YOU'VE EVER HAD THE FEELING THAT someone was illegally bugging your conversations, you were probably at a loss at how to find out for sure. Signal-detection equipment is expensive, and paying a professional to sniff out bugs is even more so. Here we show you how to build an RF detector that can locate low-power transmitters (bugs) that are hidden from sight. It can sense the presence of a 1-mW transmitter at 20 feet, which is sensitive enough to detect the tiniest bug.

As you bring the RF detector closer to the bug, more and more segments of its LED bargraph display light, which aids in direction finding. Furthermore, our bug buster costs less than $60 to construct, and is more effective than most high-priced gadgets to be found in flashy mail-order catalogs.

Little-known ability

Enter the cloak and dagger world of counter-surveillance electronics. Frequency counters have been used for years by the federal government, and police agencies for security work. You see, counters have the little-known ability to pick up and display the frequency of a hidden transmitter.

Our bug buster was developed to solve a problem that law-enforcement personnel were having when using frequency counters to locate bugs. A sensitive frequency-counter with an antenna input will continuously display random numbers caused by the counter's own oscillating circuitry. Nontechnical users tend to stare into the meaningless display, attempting to interpret the constantly changing numbers. Of course, the counter locks in solid when a real signal is present.

The bug buster is a frequency counter that doesn't self-oscillate, and is useful when knowing the bug's transmitter frequency is unimportant. As a field-strength meter, it will respond as the distance to the RF transmitter changes, allowing any bug to be precisely located.

Circuit theory

As shown in Fig. 1, the front end has a two-stage wideband RF amplifier, and a forward-biased hot-carrier diode for a detector. After detection, the signal is filtered and fed to IC1, a LM3915N bar-graph driver having a logarithmic (log) output; that means each successive LED segment represents a 3-dB step, which helps display the wide dynamic-range signals that the bug buster will encounter.

The front-end RF amplifiers are wideband *M*onolithic *M*icrowave *I*ntegrated *C*ircuit (MMIC) devices from Mini-Circuits, PO Box 350166, Brooklyn, NY 11235-0003: (718) 934-4500. They have 50-ohm input and output impedances from DC to 2000 MHz. The gain is 20 dB through 500 MHz, dropping to 11 dB at 2000 MHz. The amplifiers are surface mounted on a .1" wide microstrip lead. Surrounding the amplifiers are surface-mounted coupling capacitors, standard (current limiting) resistors, decoupling capacitors, and chokes. Chip components were selected based on information supplied in the Mini-Circuits Publication entitled, *A handy "how-to-use" guide for MAR monolithic drop-in amplifiers*. The amplifiers perform exactly as described by the manufacturer; the agreement with specifications is really quite good.

The input-sensitivity plot is shown in Fig. 2. Up to five amplifiers were connected in series in an attempt to increase the front-end sensitivity down to the level of a few microvolts. Although using more amplifiers does, in fact, increase apparent sensitivity when tested by a signal generator, the effective transmitter detection range does not increase. That's because the amplifiers are wideband, and have no tuning; therefore, increased amplification is applied across the entire RF spectrum. The signal being measured in the real world must appear larger than the RF noise background in order to be detected. In conclusion, a gain of about 40 dB was found to work best for detecting hidden transmitters.

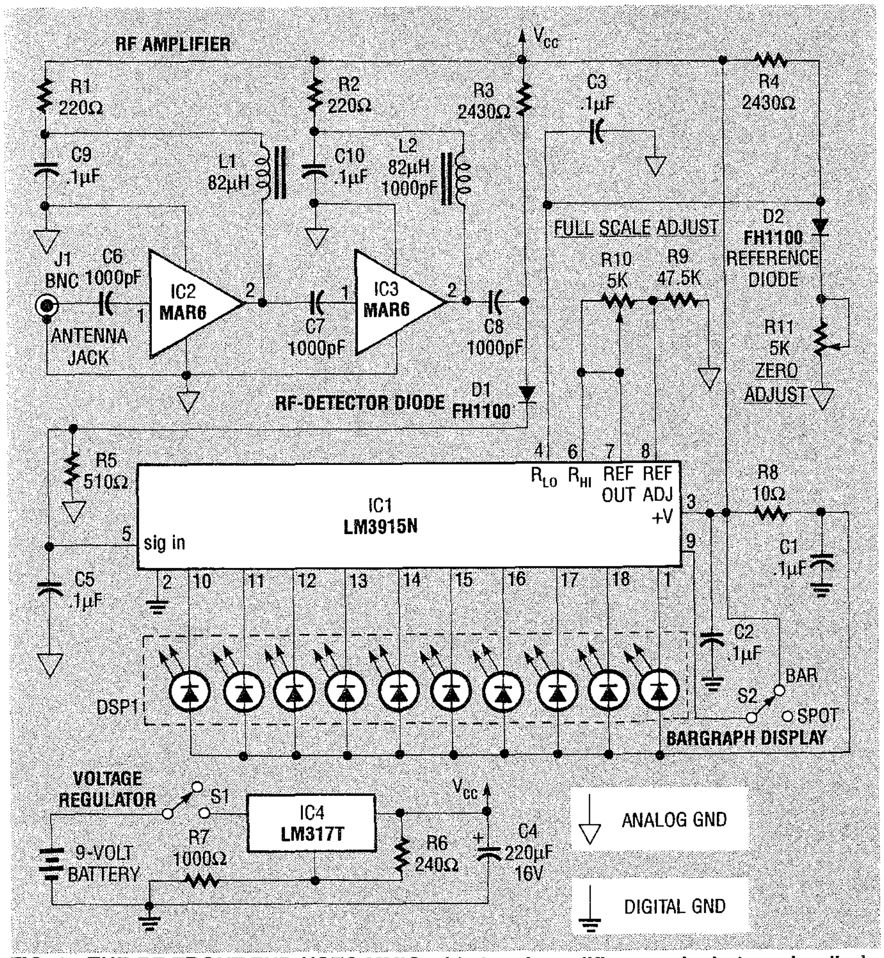


FIG. 1—THE RF FRONT-END USES MMIC wide-band amplifiers, and a hot-carrier diode detector.

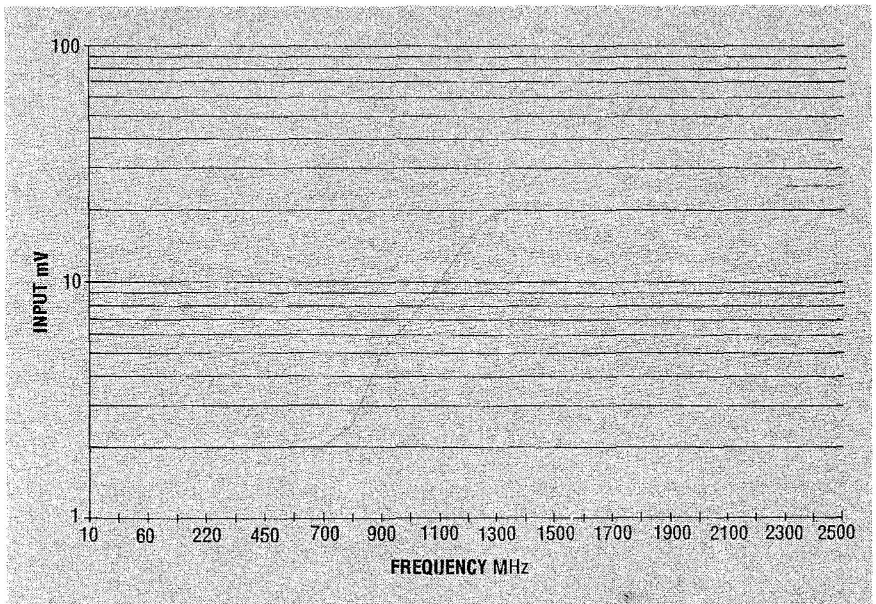


FIG. 2—THE INPUT RF-SENSITIVITY is greatest between 10 and 700 MHz. It then rolls off between 700 MHz and 1300 MHz, and remains almost constant out to 2500 MHz.

To ensure stable operation without having to constantly re-adjust the full-scale or zero-adjust potentiometers, voltage regulator IC4, an LM317T, is programmed for approximately 6 volts by R6 and R7. A 9-volt alkaline battery supplies the regulator.

Figure 3 shows the block diagram of the LM3915, consisting of a resistor-divider network and a chain of op-amp comparators. The output of each comparator is open (no current in or out) when the noninverting input is higher than the inverting input; the output goes low (sinking current) when the inverting input is higher. Each comparator controls a single LED segment, which lights when the comparator's output is low.

The noninverting inputs can be considered as reference inputs. The resistor string has log-weighted values, so that the current flowing from pin 6 to pin 4 generates the appropriate reference voltages at each of the ten comparator inputs. Those ten voltages always maintain the same relative relationship even when the reference voltage changes. The signal input is buffered (amplified with a voltage gain of 1) to prevent loading the source. As the signal input increases between the reference low and reference high voltages, each comparator will change state as its noninverting voltage is exceeded.

The LM3915 has an internal 1.25-volt reference source. Trimmer R10 will adjust the reference voltage according to this formula:

$$V_{REF\ HI} = 1.25\ (1 + {}^{R9}/_{R10}) + R2\ I_{ADJ}$$

The I_{ADJ} current is internally set to be less than 120 µA, while the LED brightness is controlled by the reference current out of pin 7. The current through each LED segment is equal to ten times the current through R9 and R10; therefore, changing R9 and or R10 will change the LED brightness.

Switch S2 programs the LM3915 for either a bar or a spot display. The spot display conserves battery life because only one segment is on at any given time; however, the bar display is more pleasing visually.

The SIG IN voltage is the sum of the bias voltage on detector diode D1, plus any rectified and filtered RF from the input amplifiers IC2 and IC3. To offset the bias voltage, a low-voltage reference is generated by R4, D2, and R11; it should track the bias voltage

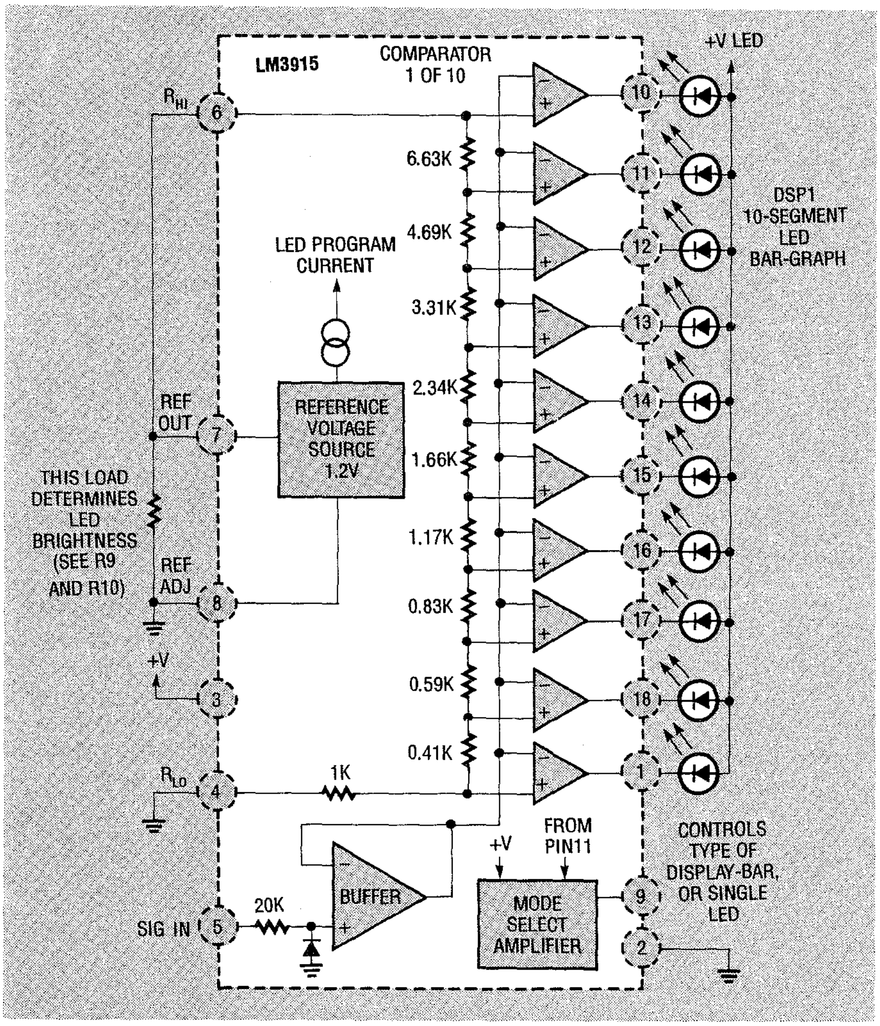


FIG. 3—INSIDE THE BARGRAPH DRIVER is a series of op-amp comparators driving a LED bargraph.

despite temperature changes, while capacitor C3 bypasses any RF to ground.

Construction

Figure 4 shows the parts placement for the bug buster's double-sided PC board. A plated-through silk-screened G10 glass-epoxy board is available from the source listed in the parts list, or you can etch your own using the artwork provided in "PC Service."

In Fig. 5, the MMIC surface-mounted amplifiers and chip capacitors require a little extra care during installation. They can be hand-soldered with a small-tipped iron, but must not be overheated—and watch out for solder bridges. The LM3915 bargraph-driver IC (IC1), the two trimmer potentiometers (R10, R11), and the two slide switches (S1, S2), all install on the solder side (also referred to as the far side) of the PC board. All remaining components install on the silk-screen printed side of the PC board. Holes are not provided in the microstrip for component leads; just solder the leads directly on top. Be sure to check polarity on the electrolytic capacitor, and the two diodes.

The LM317T bolts to the PC board without any insulator. Solder the battery leads to the appropriate locations labeled red and black. The BNC connector was modified with a 0.06″ grove to fit in the PC-board cut out. Solder the BNC connector to both sides of the PC board as well as soldering the BNC center-pin to the foil trace. Snap on a 9-volt battery and you're ready.

Calibration

The BNC-mounted telescoping-antenna is convenient and works well in the 100-MHz to 470-MHz range where the majority of all bugs operate. To increase sensitivity to other frequencies, you have to use an antenna specifically for that service.

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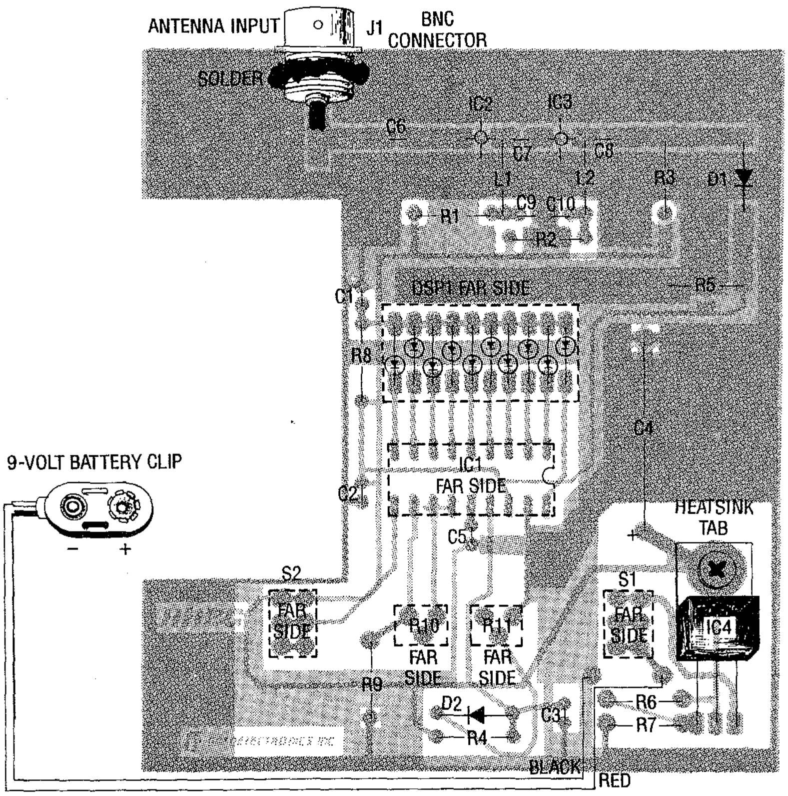
FIG. 4—THIS IS THE PARTS-PLACEMENT DIAGRAM. Opposite the side that's silk screened is the solder side—called the far side. Install the components on the correct side, with the polarity in the right direction.



video gain, and bandwidth, R37 provides feedback around the modulator; however, R33 sets the exact Q-point (voltage seen at point A, Q12's emitter), under zero-drive conditions at about 5- to 6-volts DC, to Q6 and Q7. R33 is adjusted for maximum undistorted symmetrical video at point A, while R32 controls video drive to Q11. Supply bypassing must be effective at Q12's collector due to the high current and fast waveforms handled. The main supply bypass, C44, a 10-µF, 15-volt, tantalum chip was used because standard electrolytics are somewhat less effective.

Power feed

DC power is fed to the transmitter at J4. Diode D4, a 1N4007, is provided to serve as reverse-polarity protection. It's cheap insurance against inadvertent damage to Q6, Q7, Q10, Q11, and Q12, should the negative and positive leads of the power supply be reversed by accident. Diode D1 is connected directly across J4. The 12-volt supply (11–14 V is OK) may come from Nickel-Cadmium batteries, an auto's electrical system, or any kind of AC-operated power supply.

Audio feed

Audio is fed to gain control R22 from jack J3. Input level should be between 10 mV and 1 volt at high impedance, allowing direct interfacing with most microphones, or other audio sources. From R22 the audio is coupled through C35 to Q8, which is biased from R23, R24, and R25. Bypass C36 will prevent audio degenerative feedback, and loss of gain. Collector-load R26 supplies DC to Q8, while C37 blocks DC and couples audio through R27 to the frequency modulator.

Note that no pre-emphasis (high-frequency boost) has been used. If you want to use it, for better high-frequency audio response, change C37 to 0.001 µF, and set the gain-control R22 up higher to compensate for loss. The author found that pre-emphasis was unnecessary for most applications.

Audio is coupled to the varactor-diode D2, an MV2112, where R29 biases D2 at 9 V. The varactor diode varies its capacitance at an audio rate from 56 pF at 4 V, to about 33 pF at 9 V. The capacitance of D2 appears across 4.5-MHz oscillator coil L14. Then, Q9, an MPF102 FET, together with C41, C42, C40, and L14 form a Colpitts RF oscillator operating at 4.5 MHz. Trimmer C40 is used to set the frequency to exactly 4.5 MHz, while toroidal coil L14 is used to minimize stray magnetic field generation.

The audio voltage on the DC bias causes D2 to change capacitance, which shifts the oscillator frequency causing frequency modulation (FM) of the 4.5-MHz generated in Q9, the Colpitts oscillator. Bias for Q9 is provided by R30, while R31 couples the audio subcarrier (4.5-MHz FM) into the video amplifier, which modulates it and the video onto the RF.

Zener-diode D1, R28, and C38 and C39 (which provide bypass) supply a regulated 9-V DC voltage to Q9, and varactor D2. The regulation prevents oscillator drift if the supply voltage were to vary. A frequency counter can be connected to point A to set C40 to exactly the value needed for 4.5-MHz audio subcarrier.

Looks like we've run out of space. Next month we'll focus on construction techniques, like how to wind coils, how to solder tantalum-chip capacitors, and circuit modifications. **R-E**

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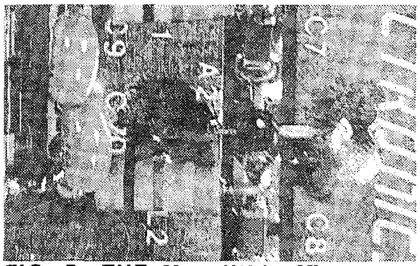

FIG. 5—THE *M*onolithic *M*icrowave *I*ntegrated *C*ircuit (MMIC) looks like a tiny dot with microstrip leads.

Put the PC board into its cabinet, and install the antenna before making any adjustments. Start with the zero-adjust set counter-clockwise, and the full-scale adjust set clockwise.

To properly calibrate our bug buster, a low-power transmitter is needed. A cordless-telephone handset is ideal. (Cordless phones are in the 40-MHz to 60-MHz region, and radiate less than most bugs!) Set the zero adjust until the left-most segment is about to come on. Set the full-scale adjust until all segments are lit when placed next to the cordless phone.

PARTS LIST

All resistors are ¼-watt, 5%, unless otherwise noted
R1, R2—220 ohms, ⅛-watt
R3, R4—2430 ohms, 1%
R5—510 ohms
R6—240 ohms
R7—1000 ohms
R8—10 ohms
R9—47,500 ohms, 1%
R10, R11—5000-ohm trimmer potentiometer

Capacitors
C1–C3, C5, C9, C10—0.1 µF, 50 volt, monolithic ceramic
C6–C8—1000 pF, ceramic chip
C4—220 µF, 16 volt, electrolytic

Semiconductors
IC1—LM3915N, log-bargraph display driver
IC2, IC3—Mini-Circuits, Inc., MAR6, MMIC
IC4—LM317T, voltage regulator
D1, D2—FH1100, hot-carrier diode

Inductors
L1, L2—82 µH RF choke

Other components
DSP1—RGB 1000, 10-segment bargraph display
J1—CP1094 modified, BNC connector

Miscellaneous
Cabiner assembly, cable, and battery clip.

Notes: A complete set of all parts except cabinet for $59.95; cabinet is $20; telescoping BNC antenna $12; lined zipper carrying-case $10; PC board only $25; all IC's and bargraph $30. Order from Optoelectronics, Inc. 5821 N.W. 14th Avenue, Fort Lauderdale, FL 33334; phone (800) 327-5912, in FL (305) 771-2050. Add $3.50 for shipping; FL address include 6% state sales tax. Master card and Visa orders must be over $20.

Some hints

You are now ready to put your bug buster to work. To effectively sweep a room, you need to get familiar with your bug buster's operating characteristics in as many situations as possible. Be sure to leave the power switch off when not in use. **R-E**