This state-of-the art VHF/UHF direction finder is easy to build, and it uses only three ICs!

The NØGSG Portable Radio Direction Finder

BY TOM WHEELER,* NØGSG

Foxhunting is the art of locating hidden transmitters. Many clubs have organized foxhunts several times a year. Besides being fun, foxhunting is great practice for preparing participants for situations in which real skills are needed, such as locating lost hikers, downed aircraft, and interfering carriers on repeater input frequencies.

The frequency, terrain, and size of the area to be searched all influence the choice of direction-finding technology. Many times several direction-finding methods must be used to find an RF source. Large areas (more than one square mile) are best searched from a moving vehicle using dedicated equipment mounted on the vehicle.

The general area of a transmitter often can quickly be located while driving, but many times the actual transmitter will not be visible from the vehicle. However, the search area has at least been reduced to a walkable size. A portable direction finder then will point the way.

For VHF and UHF hunting, direction-finding based on Doppler frequency shift can be very effective in locating transmitters, especially in close quarters. Using directional antennas poses a problem when approaching a transmitter; when signal strength is high, the receiver may pick up signals leaking through its cabinet and connecting cables, which makes it difficult to get an accurate bearing. Using the Doppler frequency shift eliminates the dependency on signal strength, which effectively will allow the hunter to walk right to the source!

The NØGSG portable RDF (photo A) uses two antennas that are switched alternately at a frequency of 1 kHz. This produces the effect of a rotating antenna. When both antennas are equidistant from the RF source, there is no phase difference between the signal from the antennas, and the receiver produces no audible tone; a null is produced, and the hunter is either walking directly toward or away from the RF source. When either antenna is closer to the source, it produces a signal that is slightly ahead or "leading" in phase compared to the other antenna. This results in a 1 kHz phase-modulated tone being placed onto the incoming carrier (remember, the antennas are being switched alternately at a 1 kHz frequency). An attached FM receiver will demodulate this as a 1 kHz audio tone. The phase of the audio tone will be either 0 or 180 degrees, indicating which antenna is closer to the RF source (and also indicating which way the hunter should walk).

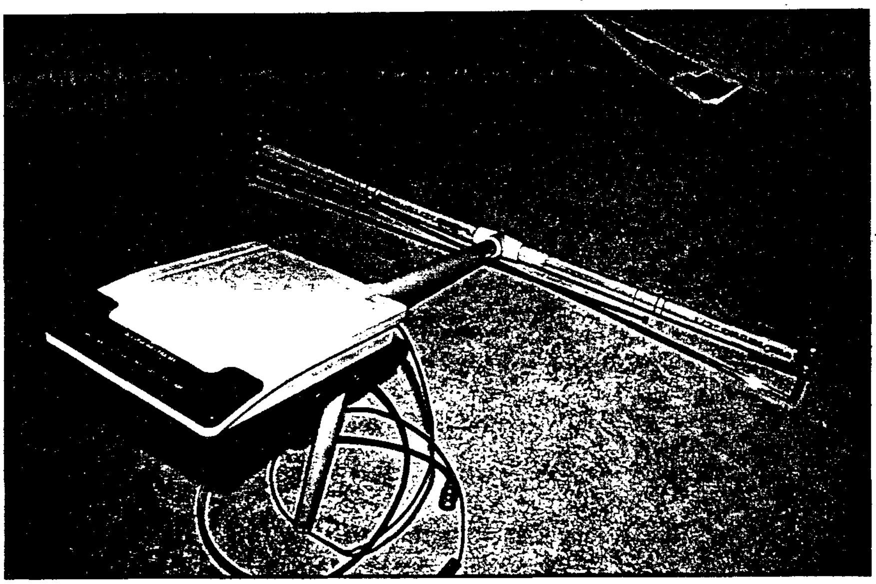

Photo A– The NØGSG portable RDF unit.

Two microprocessors direct all the activity within the direction finder. One generates the antenna and filter timing signals, and the other analyzes the phase of the incoming audio signal from the receiver. There is only one calibration adjustment (a switch), and the circuit is insensitive to the volume level from the receiver. The unit will operate for more than 10 hours from a 9V transistor-radio battery.

Circuit Description

Fig. 1 is the schematic diagram of the unit. There isn't much there! U2, an Atmel AT90S1200A, generates three timing signals: *ANT1*, *ANT2*, and *100 KHZ CLK*. The *ANT1* and *ANT2* signals alternately go high to switch the antennas at a 1 kHz rate as shown in fig. 2. The *ANT1* and *ANT2* signals are shaped by R19, C16, R20, C17 before driving PIN switching diodes D2 and D5. D2 and D5 are wired differentially: When D2 is forward biased (through R6 and R7), D5 is reverse biased through R9 and R11. This is important because the PIN diodes must be reverse biased

*10724 Horton, Overland Park, KS 66211
e-mail: <n0gsg@arrl.net>

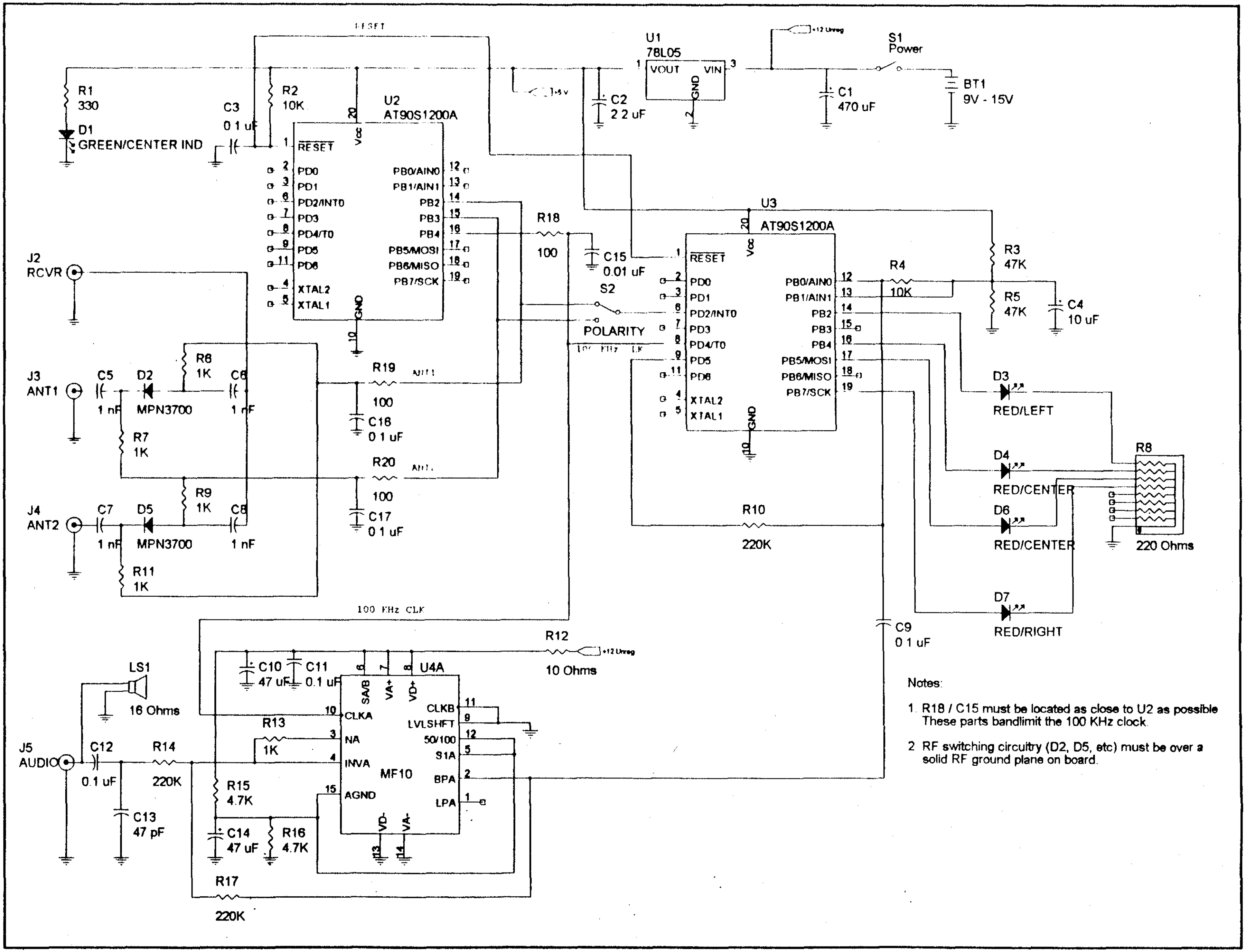

Fig. 1– Portable Doppler direction-finder schematic diagram.

to assure good isolation when they are in the "off" state, especially in the presence of a strong RF signal. Capacitors C5 and C7 couple the RF signals from the antennas, while C6 and C8 couple the switched RF to the receiver.

The receiver audio input (containing the 1 kHz audio tone) is coupled into a loudspeaker and the audio filter IC (U4) through C12. U4 is a monolithic switched-capacitor filter configured as a band-pass with a center frequency of 1 kHz. The center frequency of the filter is controlled by the 100 kHz clock fed to it from U2, so the filter's center frequency *exactly* tracks the switching frequency of the antennas. The filter has a very narrow bandwidth (about 5 Hz), so only the 1 kHz audio tone passes out on U4 pin 2.

The recovered 1 kHz audio tone from U4 is passed to U3, a second AT90S1200A microcontroller, through DC blocking capacitor C9. The signal is applied to the analog comparator input of U3 (pin 12), which is biased to Vcc/2 by R3 and R5. Hysteresis for the comparator is provided in software through port pin PD5 (pin 9) and resistor R10. The software contained in U3 analyzes the phase of the incoming audio signal, comparing it to the signal from either *ANT1* or *ANT2*, depending on the position of the POLARITY switch (which allows different receivers to be used). U3 displays the result on LEDs D3, D4, D6, and D7.

Constructing the Unit

Construction of the main unit is non-critical. The prototype unit is constructed using experimenter's perforated board with point-to-point wiring. Use good grounding practice; use only *one* heavy ground bus on the circuit board. All ICs should be in sockets; do not insert the ICs into their sockets until all soldering is completed. Make sure that R18 and C15 are located close to U2. These components soften the 100 kHz clock waveform to reduce RF interference.

D2 and D5 are Motorola type MPN3700 PIN switching diodes. Common 1N914/1N4148 diodes may be substituted at the cost of reduced receiver sensitivity. Do not use rectifier diodes (such as 1N400x types) for D2 and D5!

Shielded cable must be used for all RF connections. RG174 or similar "mini" 50 ohm cable is quite suitable. The antenna cables can be wired directly to the circuit board, eliminating J3 and J4 (This method is used in the prototype.). For best results, both cables should be equal in length and no longer than necessary. The top half of each dipole should be "hot," and the bottom of each dipole should be "shield."

U2 and U3 are the same microprocessor (Atmel type AT90S1200A) but have different programming. They can *not* be interchanged!

Photo B shows the interior of the prototype, which has been constructed within an old Hayes modem enclosure (the small board on the right contains the indicator LEDs). Note that the RF switching circuitry (upper left) is isolated from the rest of the circuitry on a small piece of copper-clad PC board. This allows the BNC connector for the receiver RF output to be mounted directly to the ground plane for good RF performance.

The antennas are standard FM receiver broadcast units mounted onto a small piece of scrap PC board, which is in turn mounted into the slotted end of a PVC pipe. The shield ground of each coaxial cable should contact the *bottom*, or *downward*, facing antenna. Photo C shows the detail of each antenna's mounting method; fig. 3 shows the overall antenna construction information.

On-Bench Checkout of the Unit

Static Checkout. Remove all ICs from their sockets and apply power (9V–12V). Using a voltmeter, verify proper power supply (5V ±0.1V) to U2 pin 20 and U3 pin 20. Verify power supply at U4 pins 6,7,8 (9V–12V unregulated). Verify bias at U104 pin 15 (4.5V–6V, half of the unregulated 9V–12V power supply). If all checks well, remove power and install the ICs.

Running Checkout. Install all ICs and apply power. Do not connect the audio input to the receiver. At this point, both the *CENTER LEDs* (D4 and D6) should be flashing about three times per second. If you do get this, congratulations. Both microprocessors are running and healthy!

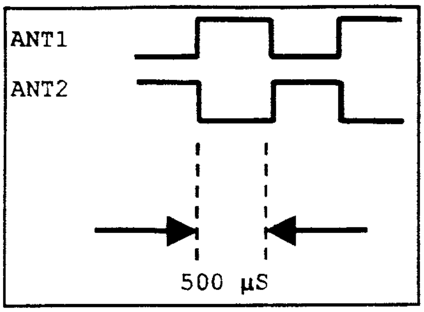

Fig. 2– Antenna-switching timing diagram.

Using the Portable Doppler Direction Finder

Turn on the receiver and tune it to the fox's frequency. Adjust the volume at least halfway up. Turn on the direction finder. Adjust the receiver squelch as desired. Extend the antennas on the direction finder.

Special Parts, Main Unit

U2, U3 – Atmel AT90S1200A microcontroller, Digikey P/N AT90S1200-4PC-ND

U1 – LM78L05 low-power regulator, Digikey P/N LM78L05ACZ-ND

U4 – National MF-10 switched capacitor filter, Digikey P/N MF10CCN-ND

D2, D5 – Motorola MPN3700 PIN diode, Allied Electronics P/N MPN3700

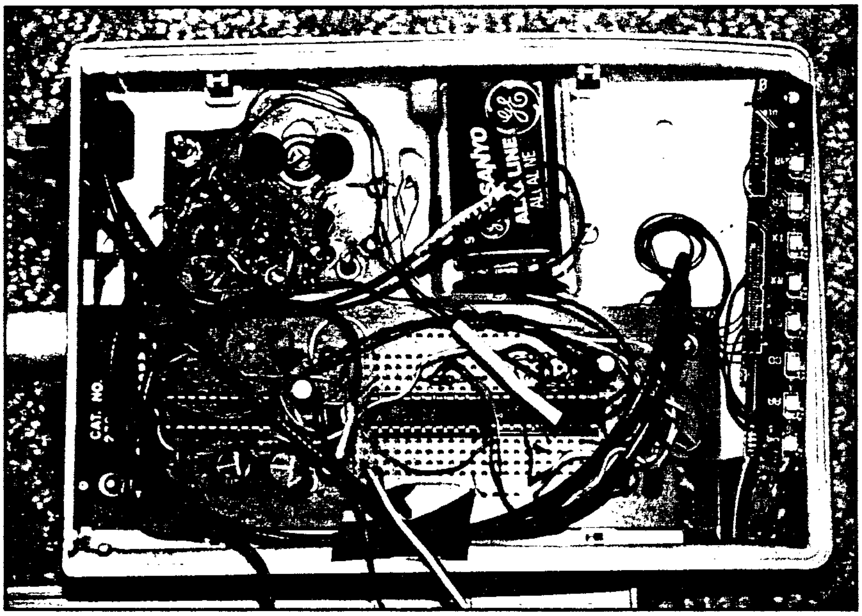

Photo B– Inside view of prototype main unit.

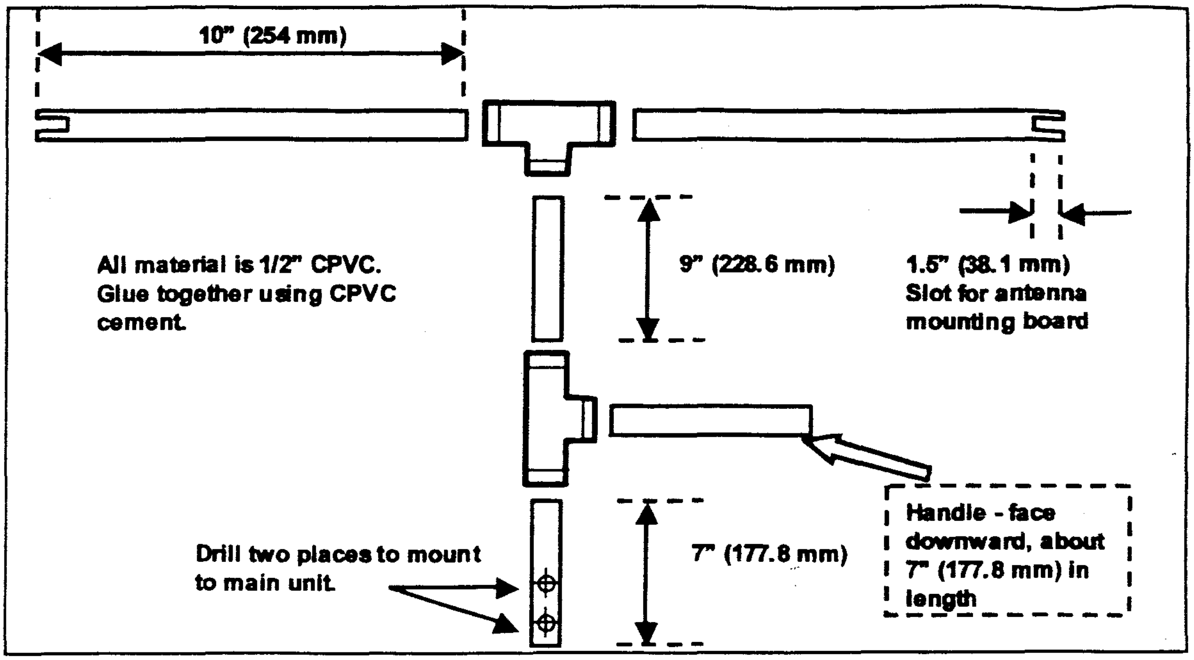

Fig. 3– Antenna construction.

The first time you use the direction finder with a particular receiver, check the setting of the POLARITY switch. Point the direction finder toward a known RF source. If you turn *right* of the bearing to the source, the *left* LED indicator should light. If you turn *left* of the bearing, the *right* LED indicator should light. If this relationship is wrong, move the POLARITY switch to the opposite position to correct the problem.

Listen to the 800 Hz tone and watch the indicator LEDs. The *RIGHT* and *LEFT* LEDs light to indicate the correct direction for walking. The *CENTER* LEDs flash when your bearing to the transmitter is true (or if there is no signal). You will also notice that the 800 Hz tone nulls when you're either facing directly toward or directly away from the fox.

You can determine if you're going the wrong way when

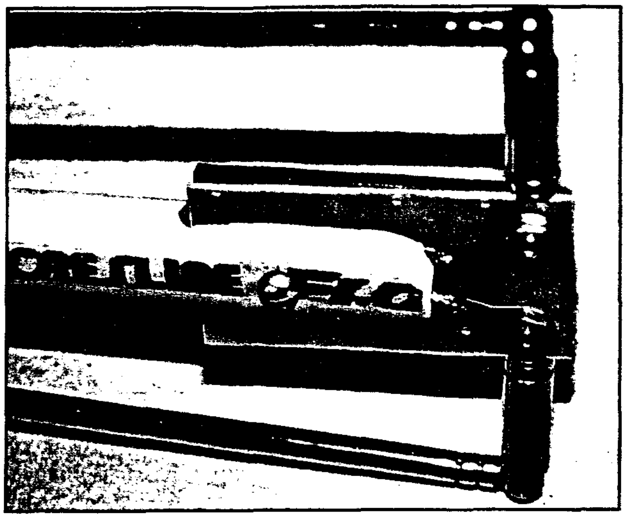

Photo C– Antenna-mounting detail.

hunting. If you turn left of null and the RDF unit tells you to turn left *more*, do what the unit says and you'll find yourself walking in the correct direction to the RF source. You also can use your receiver's signal-strength indicator as a rough indication of distance to the source.

If *both* the LEFT and RIGHT direction LEDs light at the same time, the battery is weak and should be replaced. (The direction finder needs at least 8V DC to work properly.)

Foxhunting Hints

One of the first things new hunters learn is that the world of RF is a very dirty place. RF signals rarely travel in a straight line between transmitters and receivers; radio waves reflect off anything and everything along the way! When walking with a portable direction finder, you will notice that the bearing to the source almost constantly seems to vary as you move. This is completely normal and can be very frustrating if you don't know how to deal with it.

The best bearing information is obtained when the hunter is in a clear location at a high elevation. If you are not getting a clear bearing to the RF source, try moving to a clearing (preferably on a hill). Even if the fox is hiding deep in the woods, you will get a good bearing this way.

Listen carefully to the quality of the signal coming from the speaker. When the tone is clean and pure, the RF signal being captured by the receiver is most likely to be coming to you by line-of-sight, indicating a true bearing to the fox. Multipath signals sound raspy and distorted, and these bearings should be treated with suspicion. Sometimes you will not be able to get a clean signal at all. In this case, move to a different (preferably higher) location and try again.

Don't forget that you can still use signal strength as a general indicator. If the fox signal keeps getting stronger, that's a good indication that you are on the right track!

Summary

The portable direction finder can easily be built in a few evenings. You'll find it to be a valuable part of your direction-finding arsenal. With a little practice, you'll be hunting like a pro!

Notes

1. Preprogrammed ICs for U101 and U103 are available. Send $20.00 (check or money order) to Tom Wheeler, 11224 Holmes Road Room 208, Kansas City, MO 64131. ■