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Kit Corner: The DSE Radio Direction Finder

Excerpted with permission from the February, 1986, issue of Electronics Australia.

Most readers will be broadly familiar with the concept of a radio direction finder (RDF). A basic RDF consists of a receiver and an antenna which can be rotated on its own axis. The direction of the transmitter is found by rotating the antenna for a signal peak or null.

You can easily demonstrate the effect for yourself using a portable transistor radio fitted with a ferrite rod antenna. By tuning the radio to a station and rotating the radio about its vertical axis, a null will be found in the signal strength. The ferrite rod antenna will then point in the direction of the station.

Of course, this method requires that "fixes" be taken at two or more widely spaced locations in order to find the true location of the transmitter. The exact location of the transmitter is determined by simple triangulation.

The classic application of this radio direction finding technique was in World War II. Many war movies showed how it was possible to track down enemy transmitters using special vans fitted with RDF equipment. Typically, these vans were fitted with a large external loop antenna which could be manually rotated. An operator inside the van listened in on headphones for peaks and dips in the signal strength. Provided the transmitter remained in the one location for long enough, its location could eventually be pinpointed.

The Dick Smith Radio Direction Finder is just the ticket for tracking down illegal transmitters and antisocial radio operators. Depending on the antenna system, it can operate on any band from 50 to 500 MHz and will work with FM receivers ranging from pocket scanners to amateur radio and CB transceivers.

Physically, the radio direction finder consists of two separate units. One contains the control and display electronics, and the other is a special antenna-switching unit (ASU) which is connected to the control unit via a 4-conductor cable.

An electronic "compass" display consisting of 32 LEDs indicates the transmitter bearing. When a signal is received, its relative bearing to the antenna system is indicated by whichever of the 32 LEDs illuminates.

In fixed installations, this allows the compass bearing of the signal to be directly indicated to within ± 5.6 degrees. When an RDF unit is installed in a car, successive readings allow you to pinpoint the exact location of the transmitter.

How It Works

The theory of operation is reasonably simple. Radio signals received on a rapidly moving antenna undergo a frequency shift due to the Doppler effect, an effect well known to anyone who has observed a moving car with its horn blowing.

Consider a single antenna mounted on the edge of a rapidly spinning disc (Fig. 1). As the antenna moves towards the source of the rf carrier, the apparent frequency will increase due to the Doppler effect (Fig. 2). Conversely, as the antenna moves away, the frequency will decrease.

Thus, the rotating antenna causes frequency modulation of the received carrier. When this type of antenna is connected to an FM receiver, a tone is heard. By analyzing the phase of this tone, the direction of the transmitter can be determined.

To avoid the obvious drawback of a mechanically rotated system, the Dick Smith RDF simulates a rotating antenna electronically. Four vertical whip antennas are arranged around a circle with a diameter of 0.07–0.4 wavelengths. The antennas are electronically switched clockwise in sequence such that all four antennas are scanned once every 1/1250th of a second.

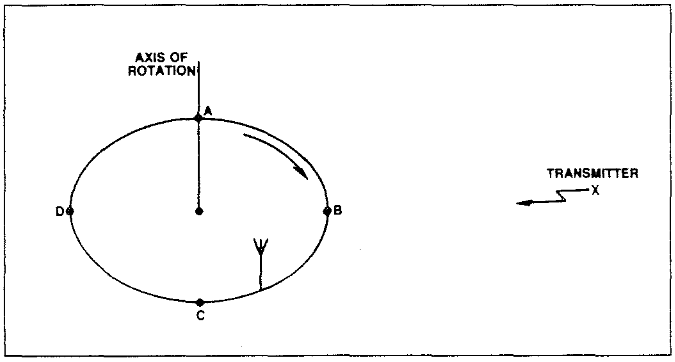


Fig. 1. Signals received by an antenna mounted on the edge of a rotating disc are frequency modulated due to the Doppler effect.

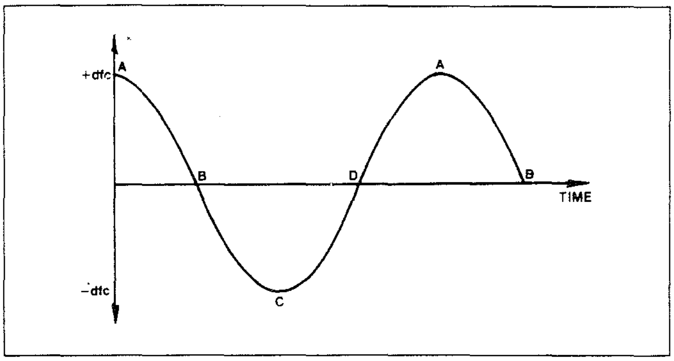


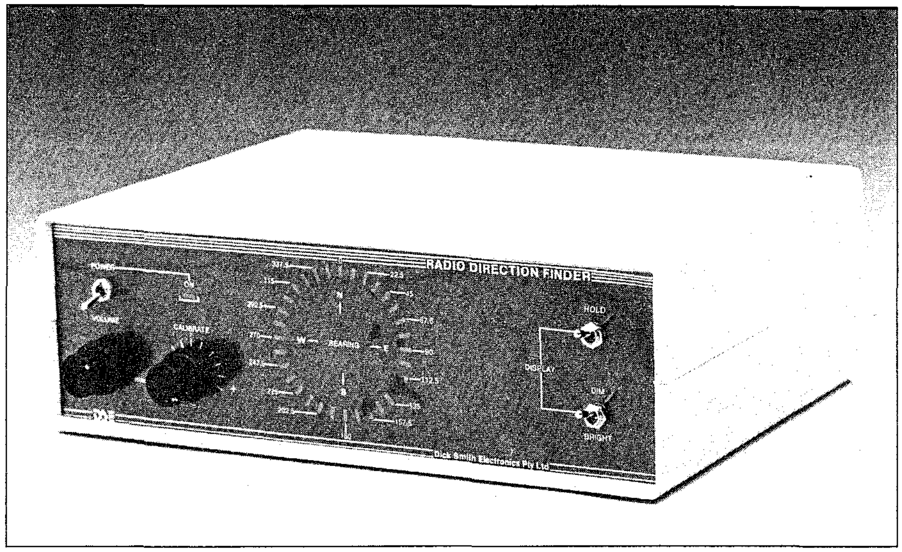
Fig. 2. This graph illustrates the frequency shift as the antenna moves towards and away from the transmitter.

This situation is equivalent to one vertical antenna mounted on the perimeter of a disc spinning at 1250 revolutions per second. A diameter of, say, 800 mm (for the 2-meter band) results in a tangential velocity of 3140 meters per second.

If the carrier frequency is 144 MHz, the carrier will deviate 1.5 kHz at a rate of 1250 Hz. For lower carrier frequencies, the deviation will be proportionally lower. Note, however, that the 1250-Hz modulating tone remains constant, as it is a function of the antenna switching rate only.

The output from the FM receiver is applied to the signal input of the RDF adapter and compared with an internal reference phase. The resultant phase angle appears as a 5-bit binary code which is decoded to a one-of-32 output to drive the appropriate LED indicator.

In addition, the detected audio tone can be monitored on an internal loudspeaker. This provides an audible indication that the receiver is correctly tuned to the transmitter frequency.



The Dick Smith Electronics Radio Direction Finder.

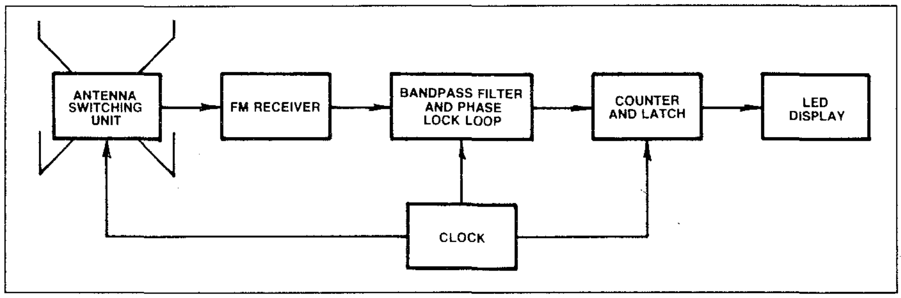


Fig. 3. Block diagram of the Radio Direction Finder. Signals from the antenna-switching unit are fed to an FM receiver and the output is compared to a reference phase.

The Circuit

Antenna switching is accomplished by first deriving a 2-bit binary code from a 1-MHz master oscillator. Here's how it's done:

Inverter stages IC2a, b, and c (4069) form the 1-MHz oscillator, with buffering provided by IC2d. This clocks decade counters IC4 and IC7, both of which divide by five to produce a 40-kHz signal on pin 1 (CK) of IC10.

IC10 is a 4024 7-stage binary counter. Its Q1–Q5 outputs directly drive the D1–D5 inputs of IC12, a 40174 hex latch, while Q4 and Q5 also drive IC9, which is a 4555 one-of-four decoder.

What happens is that IC9 accepts a 2-bit binary code from IC10 and provides the quadrature antenna-switching signals. These signals are interfaced by a 1488 line driver (IC6). The outputs of IC6 swing positive and negative in sequence to provide bias for the matrix diodes (D201–D208) in the antenna-switching unit (ASU).

The diode matrix is arranged so that, at any given instant, three of the antennas are effectively shorted and only one is coupled to the receiver. For example, when pin 11 of IC6 is low (−9 V), D205–D207 are forward-biased and short out antennas 2 to 4. At the same time, D201 will also be forward-biased while D202–D204 are turned off. Antenna 1 will thus be connected to the receiver.

The detected audio tone from the FM receiver is applied to the input of the RDF adapter, limited by D1 and D2, and filtered by a single-pole active low-pass filter stage (IC5). This chip is described by National Semiconductor as an MF5 Universal Monolithic Switched Capacitor Filter. Basically, it is a general-purpose active-filter building block.

The rest of IC5 is configured as a second-order bandpass filter to remove unwanted audio modulation from the 1250-Hz tone. The center frequency of the filter is set to 1250 Hz by the clock signal applied to pin 8. This clock signal is derived via IC3, which divides the 1-MHz master oscillator signal by eight.

Note that the clock for the bandpass filter is derived from the same source as that used to switch the antennas. This means that the filter is automatically centered on the scanning tone, even when there is some frequency drift.

The output of IC5 (pin 1) is a sine wave with a nominal frequency of 1250 Hz. This signal is applied to op amp IC11a, which functions as a phase shifter. Adjustment of the phase shifter is by means of VR1.

The job of the phase shifter is to allow calibration of the circuit and to compensate for any audio phase shifts in the receiver.

From there, the signal is further processed by a 4046 phase-locked loop (PLL). The function of this stage is to average out any modulation present in the passband of IC5 and to produce a 1250-Hz square wave which is essentially free of noise and jitter.

It is this signal that is used to latch IC12. The output of the PLL (pins 3 and 4) is first inverted by IC2f and applied to D-type flip-flop IC13a. Subsequently, when the flip-flop's D input goes high, IC13a latches IC12 on the first positive-going clock pulse from pin 10 of IC4.

The result of all this is that IC12 is latched with a 5-bit code that is directly related to the transmitter direction. A phase-comparator function is thus performed.

Note that IC13a is necessary to prevent the latching signal from coinciding with a change of data on IC12's inputs.

A pair of 74LS154 one-of-16 decoders (IC101 and IC102) on the display board converts the 5-bit code to a one-of-32 output. These decoders directly drive the 32 display LEDs to indicate that transmitter position.

Switch SW102 allows the display to be held or "frozen" by resetting IC13a. SW101 serves as a power on/off switch, while SW103 allows the display to be dimmed by switching a 330-Ohm resistor into the common anode circuit of the LED display.

To make the unit as easy as possible to use, the audio output from the FM receiver is also fed to an internal loudspeaker. The volume is adjusted by means of potentiometer VR102, which is mounted on the front panel.

Power Supply

Power for the RDF unit is derived from an external 12-V source which connects to a 2-conductor socket on the rear panel. This supplies +12 V direct to several ICs and to the input of 3-terminal regulator IC1. IC1, in turn, supplies a regulated +5-V rail to the remaining ICs.

Op amp IC11b provides a buffered +6-V rail to IC5 and also to the phase-calibration control (VR101).

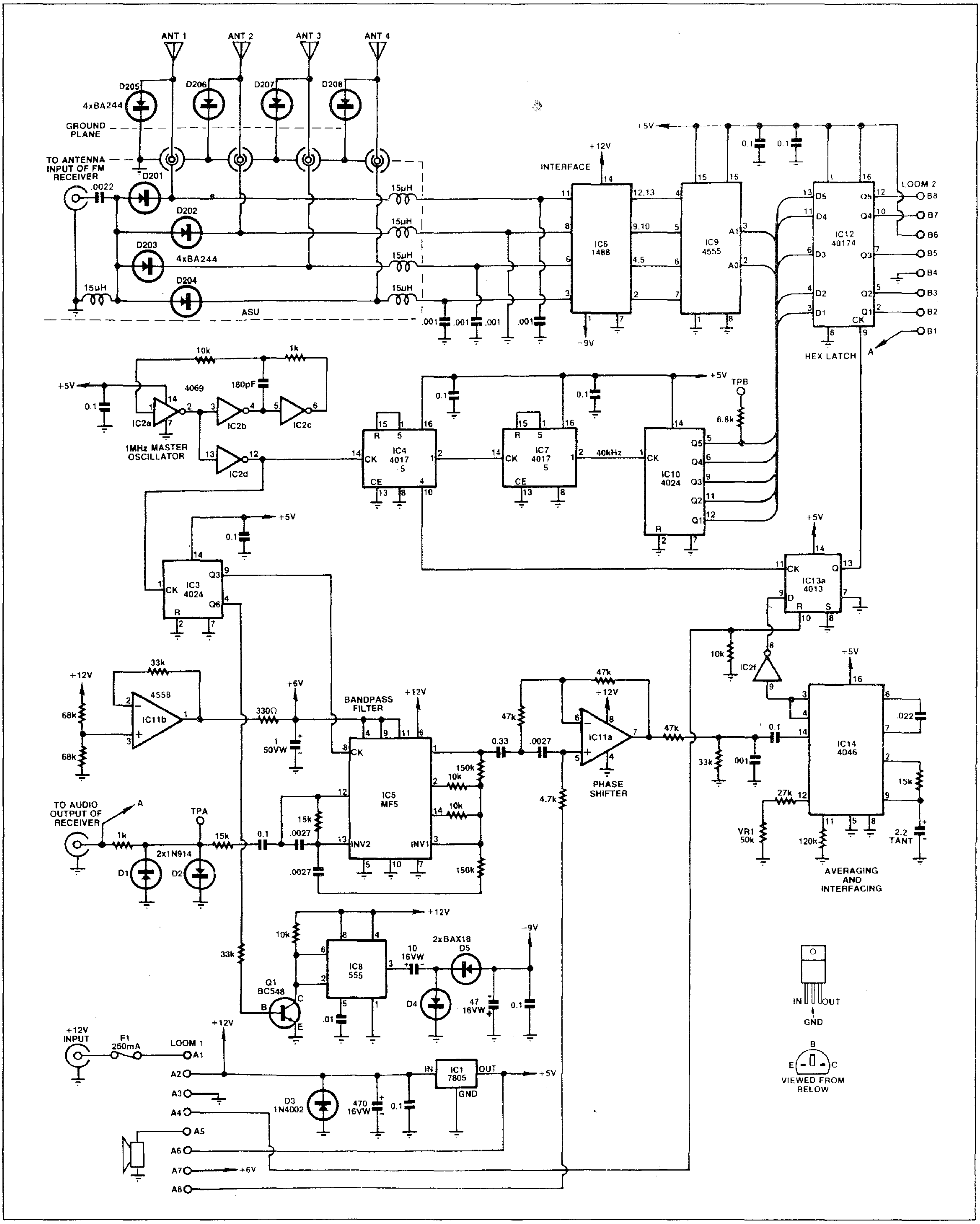


Fig. 4. The control and antenna-switching circuitry.

Finally, a −9-V supply rail is required for the 1488 line-driver IC. This is generated by a dc-to-dc converter circuit based on 555 timer IC8. It buffers a 16-kHz square wave derived from IC3 and drives a diode charge pump based on D4 and D5 to produce the required −9-V rail.

Transistor Q1 simply functions as a switch. Its job is to interface the +5-V CMOS circuit to the +12-V timer circuit.

Construction

Construction is straightforward, with most of the parts mounted on three PC boards, two in the main unit and one in the ASU.

A plastic instrument case fitted with a per-

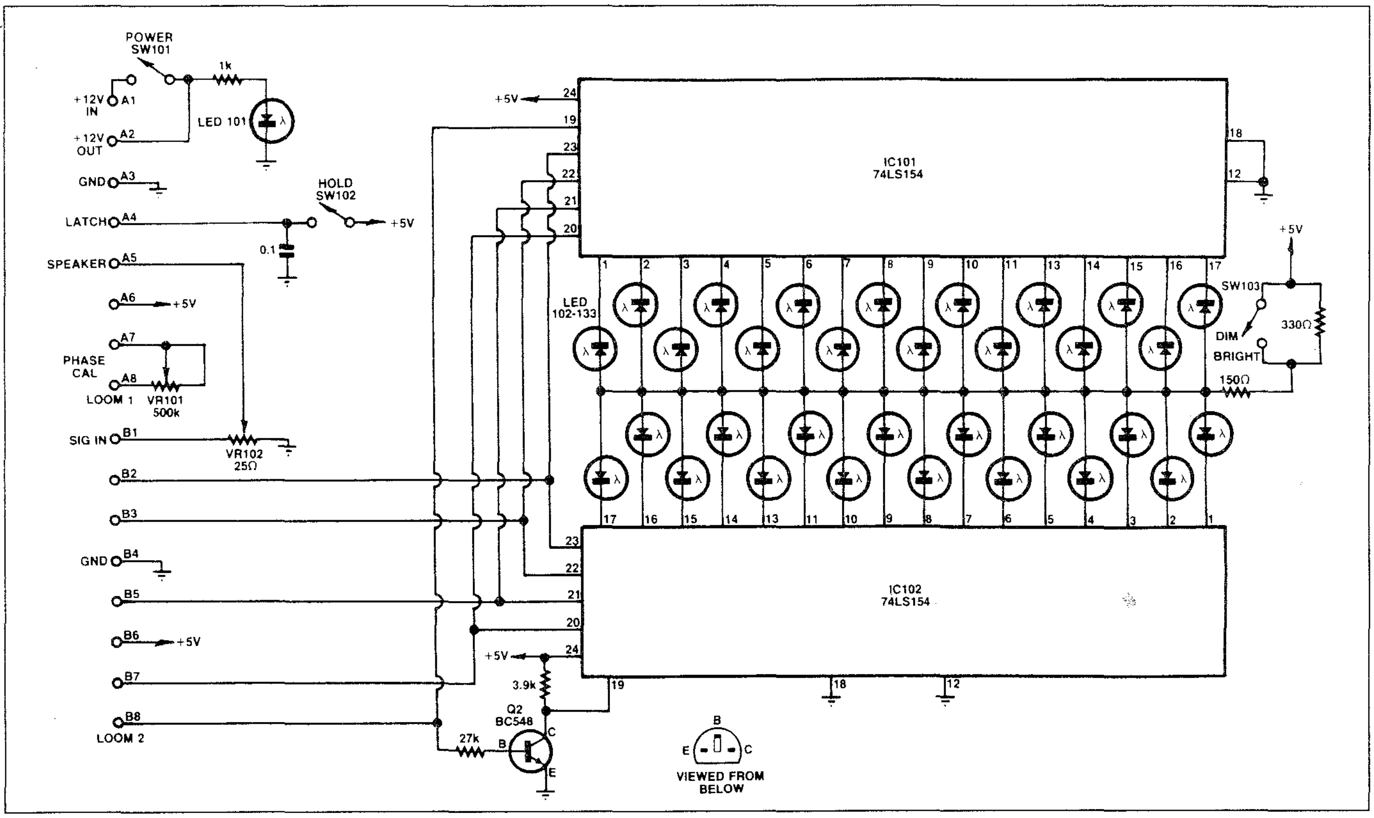


Fig. 5. The display circuit.

spex front panel houses the control electronics, while the ASU board is housed in a plastic project box.

Connections between the ASU and the control unit should be run using 4-conductor cable, while the connection to the FM receiver should be run using coaxial cable. All you have to do is trim the cables to the desired lengths and terminate them with the appropriate plugs.

Note that the wiring connections to the plugs at both ends of the control cable must be made on a one-to-one basis, otherwise the antennas will not rotate in the correct sequence.

Setting Up

An alligator clip lead and a small screwdriver are all that is necessary to adjust the unit.

Connect up a 12-V supply (be careful of polarity!) and switch on with the hold off and the ASU disconnected. All the LEDs in the display should rapidly flicker on and off as the display is scanned.

Assuming all is well, connect the two test points (TPA and TPB) together using the clip lead and adjust VR1 until a single LED is latched. Confirm this adjustment by unhooking and reconnecting the clip lead.

If the display does not latch when the test lead is reconnected, repeat the above procedure. This adjustment brings the vco to within the capture range of the PLL.

Note that, with the calibration control at mid-position, the latched LED should be the one at the top of the circle.

ANTENNAS AND OPERATION

For mobile operation, four 1/4-wave vertical whip antennas attached to a roof-rack assembly would be the best approach. The ASU could then be conveniently located between the antennas. It should be weather-proofed using a silicone sealant.

In most cases, a separate ground plane will have to be provided adjacent to the antenna bases. A suggested method is to secure a sheet of aluminum to the roof-rack. Make sure that the assembly cannot come loose!

A hand-held transceiver can be used to aid the initial setting-up procedure. Depending on the setup, it may be necessary to rotate the antenna array until the compass rose reads true relative to the direction of the vehicle.

The calibration control can be used to make the final adjustment. A walk around the antenna array with the hand-held transceiver will then reveal if the installation is functioning correctly. This should take place in an open area to avoid strong signal reflections.

In the case of a fixed installation, four ground-plane antennas should be mounted symmetrically on a vertical mast, together with the ASU. The array can then be adjusted so that the compass rose displays the true bearing with the calibration control set to mid-position.

Note that, in either case, the distance between opposing antennas should be between 0.07 and 0.4 wavelengths.

If a dual-trace oscilloscope is available, VR1 can be adjusted for a 90° phase angle between the signal input (pin 14, IC14) and the PLL comparator input (pin 3, IC14).

Finally, the control unit can be checked out by connecting outputs 1, 2, 3, and 4 (to the ASU) in sequence to test point TPA. First, connect output 1 to TPA and adjust the calibration control so that the latched LED is at 0°. The 90° LED should now light when output 2 is shorted, the 180° LED when output 3 is shorted, and the 270° LED when output 4 is shorted.

That completes the construction. Your Radio Direction Finder is now ready for use.

Where To Buy The Kit

The Radio Direction Finder described here was developed by the Research and Development Department at Dick Smith Electronics Pty Ltd. It is available as a complete kit of parts by mail order or from your nearest Dick Smith Electronics store.

The kit comes complete and includes a perspex front panel, screenprinted fiberglass PC boards, antenna bases, plugs and sockets, and a detailed construction manual. The cost is $99 plus postage and packing charges where applicable.

Mail orders should be sent to: Dick Smith Electronics, PO Box 8021, Redwood City CA 94063; (800)-332-5373. ■