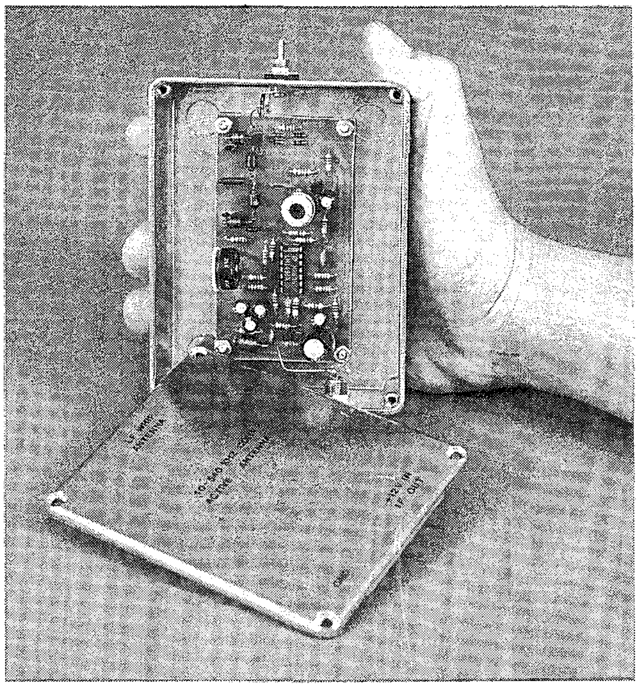

LOW FREQUENCY CONVERTER

Find out what's happening below the AM-broadcast band with our low-frequency converter.

WILLIAM SHEETS AND RUDOLF F. GRAF

THE FREQUENCY RANGE JUST BELOW THE AM-BROADCAST band (from 10 kHz to 550 kHz) has been clearly omitted from most communication receivers. How come? It appears that the extra coil sets, increased assembly costs, and additional RF circuitry has not justified the inclusion of the low-frequency band. But that doesn't have to stop you from sneaking a peek at the band "down-under." Among the signals you'll find below 550 kHz are maritime mobile, distress, radio beacons, aircraft weather, European longwave-AM broadcast, and point-to-point communications. A brief summary of those signals is found in Table 1.

Up convert

Low frequencies make conventional shortwave radio design impractical. In the usual four-band general-coverage receiver, four coil sets are used to cover the frequencies from 550 kHz to 25 MHz, and sometimes up to 30 MHz, the upper limits of shortwave reception. To adequately cover the low-frequency (LF) spectrum an additional three, and more likely four coil sets are needed; moreover, with the usual 400-pF variable capacitors used in medium-frequency (MF) tank circuits, inductances of around 600 mH are needed to reach the 100-kHz low-frequency limit used for radio communications.

Many radios produced for the European markets cover the 150-kHz to 400-kHz range; however, they're usually designed solely for AM reception where a high-sensitivity figure is not required. That's because European longwave stations generally run 50–100 kW (or possibly more) to their antennas.

Here in America, it's more practical to up-convert the low-frequency range to a medium-frequency range. Our converter does just that. It converts the 10-kHz to 550-kHz LF range to a 1.01-MHz to 1.55-MHz MF range, by simply adding 1 MHz to all received signals. Connect our converter to any communications receiver, or AM-broadcast radio for that matter, and bingo—you have a longwave receiver. Radio calibration is unnecessary because signals are received at the AM-radio's dial setting, plus 1 MHz. A 100-kHz signal is received at 1100 kHz, a 335-kHz signal at 1335 kHz, etc., just drop the first digit to read the longwave frequency.

One problem at low frequencies is man-made noise; many of our everyday devices and appliances are notorious in that regard. Motors, fluorescent lighting, light dimmers, computes, TV-receiver sweep radiation, and many small household digital devices generate "hash" in the spectrum below 550 kHz. Fortunately, most noise is carried chiefly on power lines, and doesn't radiate very far.

One misconception is that tremendous antennas are needed for longwave reception. It's easy to understand why someone might think that way. At *shortwave* frequencies (3–30 MHz), it's common to errect a halfwave dipole at the operating frequency; the resulting antenna length is usually quite reasonable for anyones backyard. Try to do the same for *longwave* (10–550 kHz), and you'd end up with a dipole 1-mile long. The remedy is to use an active antenna, where excellent longwave reception can be had with a simple vertical only a few-meters long. In fact, our converter (using an active antenna) even picks up quite a few signals with a clip lead only 30-centimeters long.

Circuit description

According to Fig. 1-*a*, low-frequency signals that are picked up by an 8-inch whip antenna (a standard CB/ham 10-meter whip) are fed to the Q1's gate, a source follower. FET-transistor Q1 matches the whip's high-impedance (which looks like a small 20–30-pF capacitor) to the low-pass filter formed by C1 through C3, and L1 through L4. That filter rejects signals above 500 kHz, preventing break-through and cross modulation from strong broadcast and shortwave signals. Coupling capacitor C4 is selected to attenuates frequencies below 10 kHz.

Resistor R1 provides a DC ground for Q1's gate. Resistor R2 is needed for a return path for Q1's drain current because capacitor C1 blocks the DC-path to ground. Diodes D1–D4 bleed-off any static charge on the antenna that

TABLE 1—LONGWAVE SIGNALS BELOW 550 kHz

Frequency Range	Signals Found	Remarks
510–535 kHz	Misc. Radio Beacons	
500 kHz	Distress (CW)	Ship to Shore
415–490 kHz	Maritime Mobile (CW)	
285–400 kHz	Radio Beacons, Weather: Aeronautical and Marine	Weather info, AM, voice and Carrier Current (Power Line) Transmissions
190–285 kHz	Radio Beacons, Weather: European Longwave Broadcast	
160–190 kHz	Fixed Public, License-Free Experimental, European Long Wave Broadcast, Fixed	Some experimenters run 1-watt transmitters in this band, no license needed
110–160 kHz	Maritime Mobile, Lowest Freq. Long-Wave Broadcast, Fixed (point to point)	Tends to be noisy, also some RTTY transmissions
90–110 kHz	Loran Navigation	
30–90 kHz	Fixed, Mobile, Standard Freq. and Time Signals	RTTY transmissions, some CW, noisy
14–30 kHz	Submarine Communications, VLF Worldwide High-Power, Military and Commercial	RTTY transmissions, some CW heard at times, noisy
10–14 kHz	Omega Signals, Freq. Standards, Atmospheric Phenomena, Whistlers	Lowest part of radio spectrum, frequently used
Below 10 kHz	Atmospheric Noise, Whistlers, Experimental Transmissions, Military	Experimental

might have accumulated, while having no effect on RF signals that are less than about 1 volt on the antenna.

The low-frequency signals are fed to IC1, a doubly-balanced mixer, that's easy to use and quite reliable. It has balanced (dual polarity) inputs and outputs but, as used here, single-ended (unbalanced) inputs and outputs may be accommodated by using only one of the balanced lines (either will do). Resistors R3–R7 provide an adjustable bias network for the input pins 1 and 4. Resistors R8–R10 and R14 provide the correct DC operating voltages and bias levels. Capacitors C5–C7 are supply-bypass capacitors. Resistor R11 sets the mixer's gain (at about ×3). Resistors R12 and R13 feed bias to the local-oscillator inputs 8 and 10.

Transistor Q2 and associated circuitry form a Hartley 1.000-MHz local-oscillator, which is coupled from Q2's drain, through C8, to IC1 pin 8. Signals in the 10–550 kHz range are converted to 1010–1550 kHz. A 450–990-kHz output is also produced, but it's ignored because direct readout of those frequencies isn't possible with most AM radios, which only cover down to 530 kHz, or thereabouts. (Actually, if you're so inclined, other local-oscillator frequencies may be used. For example, to receive the 80-meter ham band use a 3.500-MHz crystal-controlled oscillator.) Components R15 and C9 are supply decoupling components. Resistor R16 provides bias to Q2. Tank circuit L5-C11 is slug-tuned to resonant at 1 MHz. Capacitor C10 couples Q2's source to the top of the tank. The local-oscillator signal via R17 is set to the correct level at pin 8 of IC1.

The mixer heterodynes the incoming low-frequency signal and local-oscillator signal. The output frequencies then appears at both pins 6 and 12 of IC1: Pin 12 is used arbitrarily for easier PC-board layout. Small-value resistor R21 is used as a PC board jumper, so its value is not critical. Resistors R18 and R20 provide bias to the output stages of IC1, while R19 and C12 decouple the DC power supply. Transistor Q3 reduces IC1's high-output impedance to about 100 ohms to match most receiver inputs. Capac-

PARTS LIST

All resistors are ¼-watt, 5%.
R1—2.2 megohms
R2, R12, R13, R15, R16—2200 ohms
R3, R4—100,000 ohms
R5, R6—22,000 ohms
R7—25,000-ohm trimmer potentiometer
R8—680 ohms
R9—470 ohms
R10, R19, R23—220 ohms
R11—1000 ohms
R14—1500 ohms
R17—15,000 ohms
R18, R20, R22—3300 ohms
R21—10 ohms

Capacitors
C1, C3—82 pF, ±5%, NPO, ceramic disc
C2—270 pf, ±5%, NPO, silver mica
C4—0.001 µF, 50 volt, mylar
C5, C6, C7, C9, C12—47 µF, 16 volt, electrolytic
C8, C10, C13, C15, C16, C18—0.01 µF, 50 volt, ceramic disc
C11—180 pF, ±5%, NPO, ceramic disc
C14—470 µF, 16 volt, electrolytic
C17—22,000 µF, 16 volt, electrolytic

Inductors
L1, L4—680 µH, ±5%
L2, L3—1000 µH, ±5%
L5—100–160 µH, tapped
L6—4.7 µH, RF choke

Semiconductors
D1–D5—1N914B diode
Q1, Q2—MPF102 transistor
Q3—2N3563 transistor
IC1—MC1496L

Other components
J1, J2, J5, J6—suitable connector of your choice
J3, J4—F-type chassis connector

Miscellaneous: Weatherproof box for the main converter, small metal box for the RCVR/DC adaptor, CB-whip antenna and mounting hardware, PC board, wire, cable, solder, hardware, etc.

Note: A kit containing the PC board and all parts that mount on the board is available from North Country Radio, P.O. Box 53, Wykagyl Station, New Rochelle, NY 10804. Price is $33.75 plus $2.50 postage and handling.

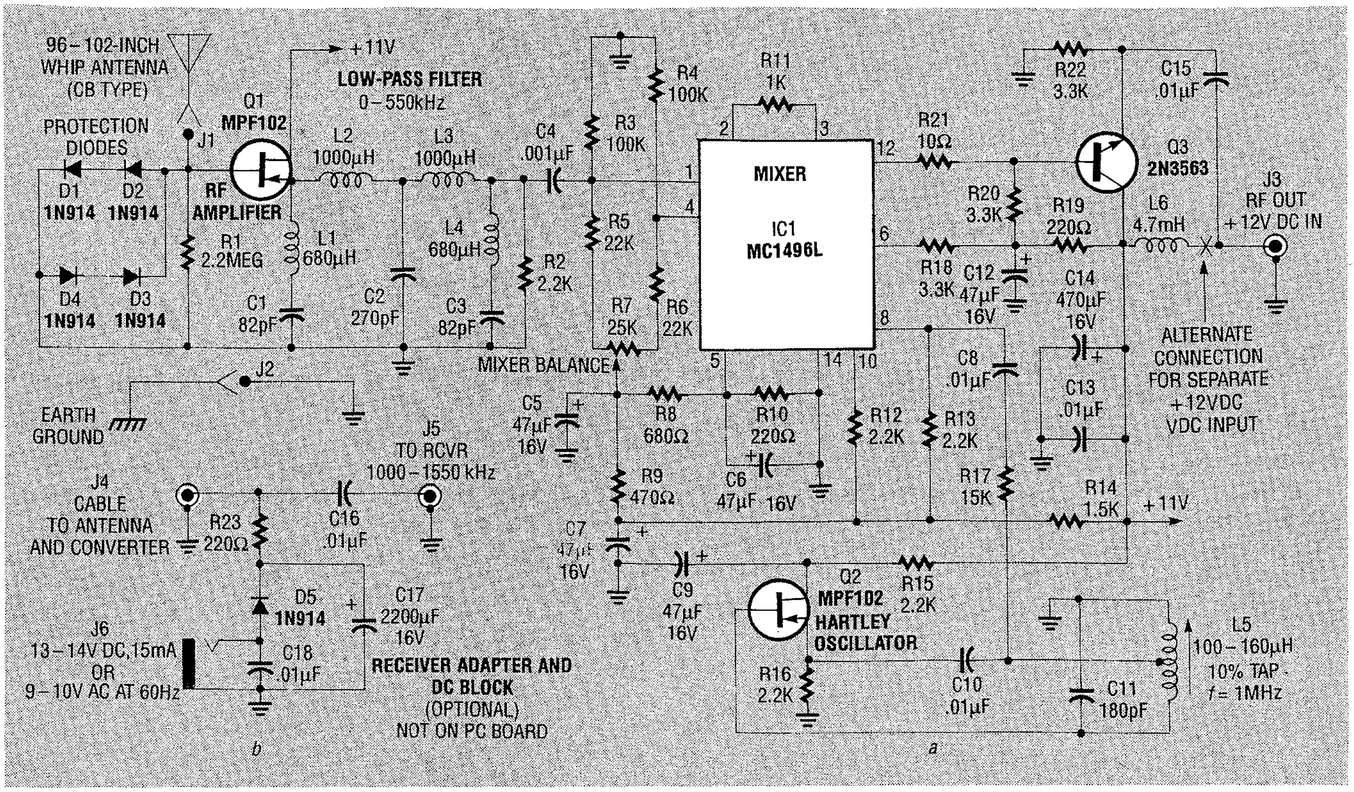

FIG. 1—THIS LOW-FREQUENCY CONVERTER *(a)* USES A FET-transistor front end, an IC mixer, and Hartley oscillator. Up-converted signals can be heard on any standard AM radio. The receiver/DC adaptor *(b)* doesn't need a PC board, and can be hard wired in its own metal box.

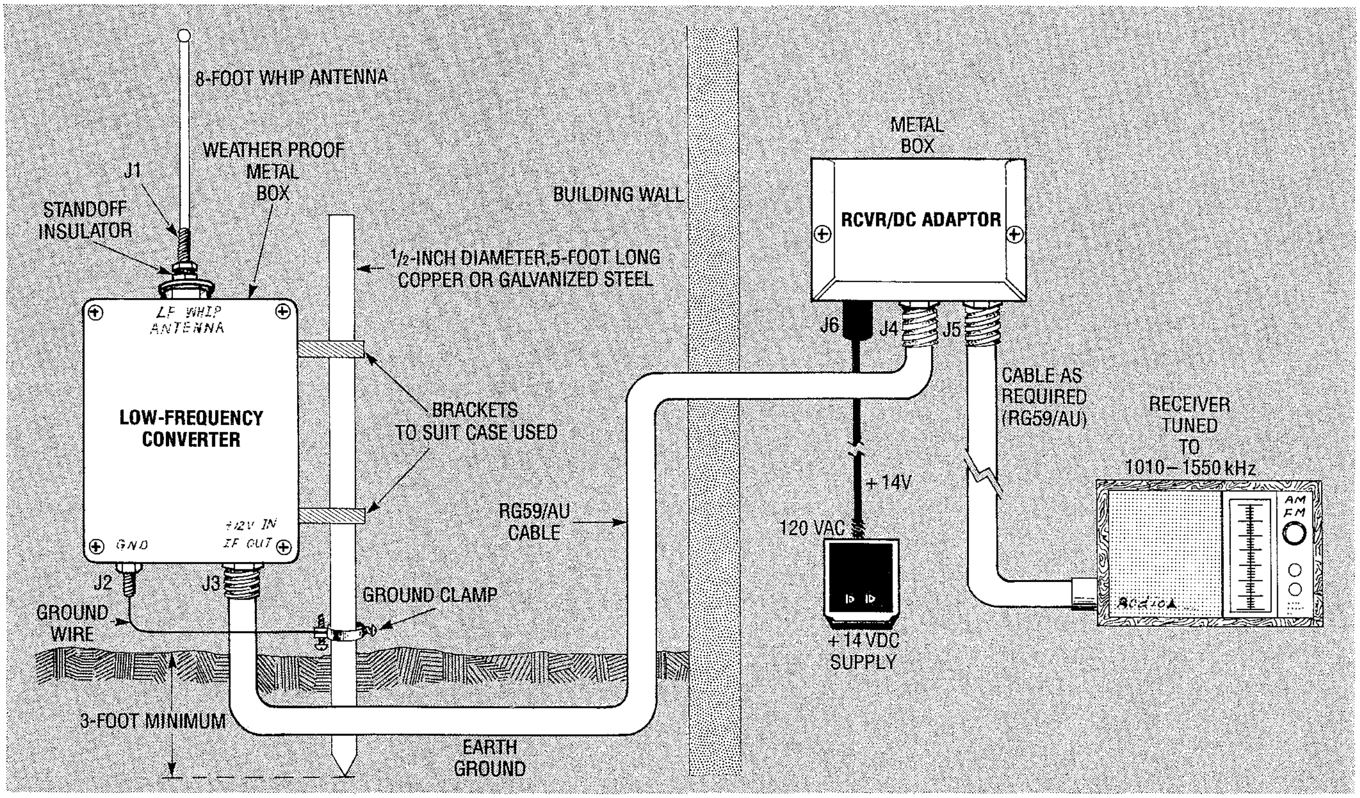

FIG. 2—YOU CAN REDUCE RECEIVED NOISE (HASH) by *not* mounting the LF converter within 50 feet of AC high-tension lines (power poles), near any AC outlet, or near any telephone-service entrance cables.

itor C15 couples the 1010–1550 kHz frequencies from Q3's emitter to output-jack J3, while blocking any DC bias. Resistor R22 is a DC return and bias resistor for Q3.

Inductor L6 couples the DC voltage that's carried in the RF-signal cable from the RCVR/DC adaptor. The DC voltage and RF signals don't interfere with one another at all; that saves running a separate power-supply wire, which simplifies installation at a remote location. Capacitors C14 and C13 provide DC supply filtering.

Figure 1-*b* shows that the RCVR/DC adaptor is small enough to fit in a small shielded box containing J4, J5, DC-blocking (RF coupling) component C16, and DC filter capacitors C17 and C18. DC is fed in via J6, which should be well filtered (less than 1% ripple).

Installation

The converter with its antenna works best, and has the least noise and interference, when remotely mounted as far away from any AC wiring and other interfering devices as possible. If you live in a quiet country location or are willing to tolerate some line noise, the converter can be mounted near the receiver. The location is entirely up to you.

Figure 2 shows one possible remote installation. The coaxial cable from J3 carries both RF signals and DC power; that cable is run from the remote converter to a RCVR/DC adaptor located in your radio shack. The RCVR/DC adaptor helps out in two ways. It pumps DC power down the cable to the converter, and routes RF from the converter into the receiver. An extra volt or two of output DC is recommended to make up for losses in L6 and L7 that have about 60-ohms DC resistance each, and cable losses as well.

For local installation (non-remote), inductor L6 may be disconnected from jack J3. The +12-volts DC is then fed directly from any convenient supply, about 11–15 milliamps is all that's required.

Construction

You can etch your own PC board using the artwork in PC service, or order the kit of parts that includes an etched and drilled PC board from the source in the Parts List. Figure 3 should help you stuff the PC board correctly. As you might expect, first mount the resistors and capacitors, then mount D1 through D4, Q1, Q2, Q3, and last install L1 through L6, and IC1. A socket for IC1 is desirable but unnecessary. If you are using a remote installation, then assemble the RCVR/DC adaptor; its parts layout isn't critical, but be sure to completely shielded the adaptor in its own metal box to avoid picking up strong AM stations in the 1010–1550-kHz range.

Tuneup

Tuneup is simple. First check all your wiring and components to make sure they're all properly seated and polarities are correct. If everything checks out, connect +12 volts to the adaptor-box jack J6. Now check for +12 volts at J3, or L6 if you are not using a remote setup. Next verify that +11 volts or so is across capacitor C14. Measure the current drain from your +12-volt DC supply, and if you measure more than 15 mA, that may indicate problems.

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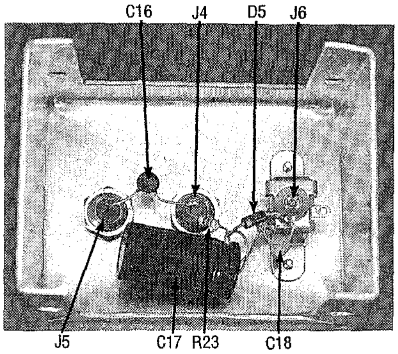

FIG. 5—RECEIVER/DC ADAPTOR allows the converter to be powered through its RF output in remote installations. That way you don't have to run an extra power-supply line all the way out to the converter.

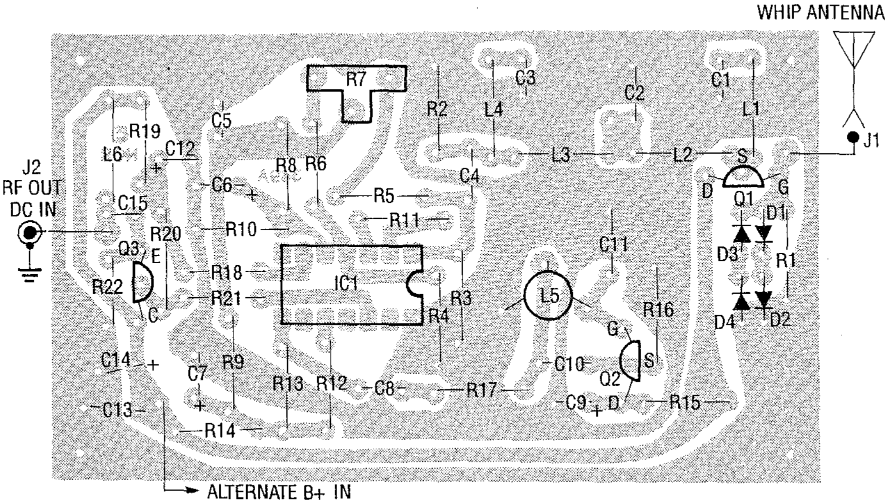

FIG. 3—STUFFING THIS PC BOARD should be easy, even for the inexperienced.

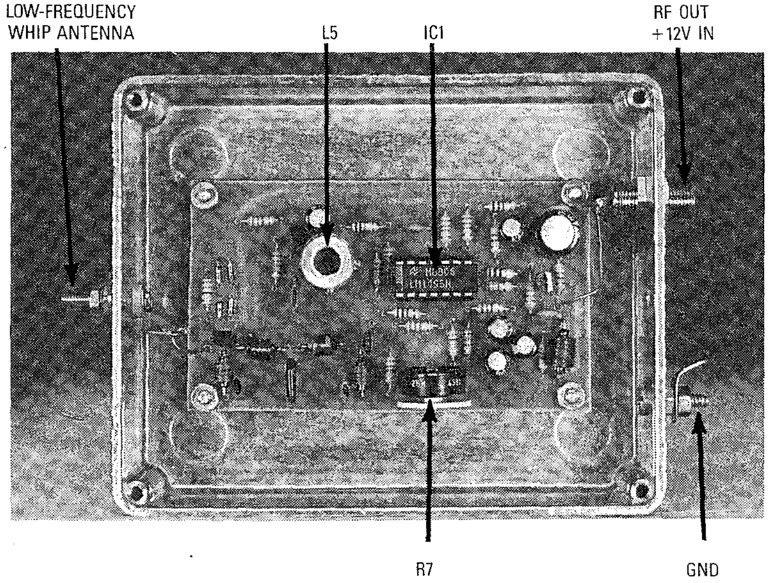

FIG. 4—THE PC BOARD IS MOUNTED IN A METAL BOX FOR RF SHIELDING. Make sure you use small standoffs under the PC board to prevent the copper traces from shorting against the metal box. The author shimmed up the PC-board 1/8 inch by screwing an extra *nut* under the board at all four corners.

earization and absolute-to-relative humidity conversions for you.

Since absolute humidity is being measured, your operation should be equally good for low, medium, or high relative-humidity.

The same company offers thermistors for temperature measurement and for air-flow measurement using *hot wire anemometer techniques*. Lots of free data sheets, price lists, and ap-notes are available on request.

One handy source of ready-to-use industrial-grade humidity sensors is *General Eastern. Weather-Tronics* is a second.

A final company that has a very wide line of humidity sensors is *Omega Engineering.* Their stuff is usually very expensive, but be sure to pick up their free catalogs.

Two good sources for humidity sensing info are *Measurements and Control* and *Pollution Equipment News*.

For our third contest this month, just tell me how or why you would like to measure either the relative or absolute humidity.

A low-end digital compass

We have looked at some solid-state digital fluxgate compasses in previous columns. They are probably the best way to electronically measure a magnetic heading. Important uses of fluxgate sensors are for cave mapping, navigation, for car compasses, and for satellite-dish pointing.

I've recently found a cheaper and simpler method for electronic sensing of a magnetic heading. It is also considerably less accurate than a fluxgate and, being a moving mechanical device, has all of your typical compass damping and hunting problems.

This is the *Dinsmore digital compass sensor*. It is available for $10 in hacker quantities, and much less in production quantities. The sensor consists of four hall-effect transistors facing each other and a moving central magnet on a carefully damped pivot. The maximum theoretical resolution is plus or minus 22.5 degrees. The intended market is for low-end auto and bike compasses, but there should be plenty of other low-end robotic and toy uses.

A simple four-LED display is shown in Fig. 5. A liquid-crystal display showing N, NE, E, SE, S, SW, W, and NW is also available. It uses the same sensor in a slightly more complex circuit.

For our fourth contest, just show me some new or unusual use for a low-accuracy but very cheap digital compass.

New tech literature

New data books this month include the "must have" *TTL Logic Data Book* from *Texas Instruments*, that *LSI Products Data Book* from *TRW*, a *Specialty Memory Products Data Book* from *Advanced Micro Devices*, and a major upgrade of the *Smart Analog Data Book* from *Crystal Semiconductor.* That last jewel has some outstanding digital-audio integrated circuits in it.

A $15 kit full of unusual tilt and impulse switches is now available from *Fifth Dimension*, while a free new *PLC-V8 Design Kit* is available from *Signetics*, that involves their new *erasable* logic arrays. Free electroluminescent lamp samples are available from *Nordic Lite*, while free force-sensing resistor cards are provided by *Interlink Electronics*.

Turning to mechanical samples, free baggies of vinyl-dipped products are gotten through *PMP*. One great place to pick up free samples of any mechanical goodie is through *New Equipment Digest*.

The new trade journals this week include *Surface Mount Technology* and *Electronic Manufacturing*. As usual, you can qualify with your own laser-printed business letterhead.

For those of you that want or need more info on all my book-on-demand publishing, there's my *Ask the Guru* reprints, volumes I and II, and the *Hardware Hacker* reprints for this column series. We also stock lots of PostScript books, software, and even videos. The *Hardware Hacker* help line may also be used for PostScript, book-on-demand and laser printing help, or networking.

Note that there are two *Names and Numbers* sidebars this month, one for the humidity stuff and one for just about everything else. Let's hear from you, and get to work on those contests. **R-E**

VLF CONVERTER

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If all is OK so far, check these measurements:

1. +0.5–+2 volts at junction of L1 and L2.
2. +2–+4 volts at Q2 source.
3. +8–+10 volts across R22.
4. +5–+7 volts, IC1 pins 8, 10.
5. +3.5–+5 volts across C5.
6. +0.8–+1.5 volts, IC1 pin 5.
7. +8–+10 volts, IC1 pins 6, 12.

So far so good. Now connect any radio that covers the AM-broadcast band to J3, and tune to 1.000 MHz on the AM dial (you're actually tuning to 000 kHz). Adjust L5 for the strongest signal. Adjust R7 to minimize that signal. Resistor R7 should cause a definite null around the middle of its range; if not, check IC1, R7, and R3 to R6. Tune the radio dial between 1010 kHz and 1550 kHz, where you should hear signals in the 10-kHz to 550-kHz longwave range. At 1100 kHz on the AM dial (you're actually tuning to 100 kHz), a loud rattling noise will be heard in most areas of the US and Canada; that's the LORAN navigational signals.

Obviously, you shouldn't hear any AM-broadcast stations; if you do, check your cables and grounding because something's wrong. Make sure the shielding is adequate, especially the box used for the DC block. As a last resort, check L1 through L4, C1, C2, C3, and R7's setting. The circuit should work when it's fired up.

An extremely strong AM-broadcast signal may occasionally cause "crud" to seep through that rides on all the longwave signals. That may occur when you live within a few miles of a high-powered broadcast station. If so, try installing a 47-pF capacitor across R1. If that helps, then try smaller values (or larger) until the smallest value is found that reduces the interference to a satisfactory level. You might also try using a smaller whip antenna, or try removing D1 through D4, although the protection they afford Q1 will be lost.

With the LF converter assembled and operating properly, you can now put it to use. Try listening to the wide variety of unusual broadcasts that you'll receive in the low-frequency band, such as maritime, distress, military, and amateur. **R-E**