Experimenting With Hall-Effect Devices

By Forrest M. Mims III

Hall-effect devices are the principal solid-state sensors of magnetic fields. Last month, I discussed magnetic fields, the compass and the Hall effect in some detail. This month, I will present several experimental and practical applications for Hall-effect devices.

Basic Magnetic Field Indicator

It is sometimes necessary to know when a tool or other piece of hardware possesses a magnetic field. For example, magnetized tools and hardware should ordinarily not be used near mechanical clocks and watches, instruments that have steel gears and both magnetic disk and tape drives.

The presence of a magnetic field is obvious if small ferrous objects adhere to the implement in question. A small compass can also be used as a sensitive indicator of a magnetic field.

A digital Hall-effect sensor can also be used to detect magnetized tools and implements. Figure 1 shows a simple circuit that turns on an LED when a magnetized object is placed near a Hall-effect sensor. This circuit can be assembled in a small plastic box and placed near a computer disk drive. Objects that might be magnetized can then be checked before being placed near floppy disks.

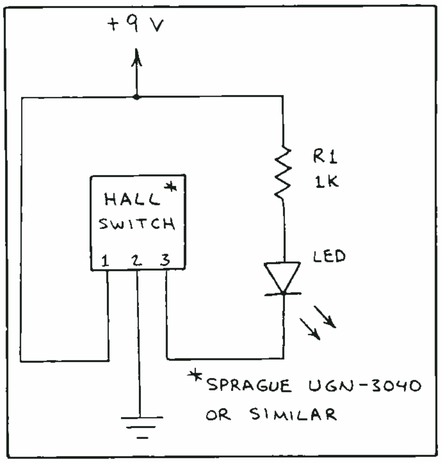

Fig. 1. Simple magnetic field indicator.

Using a Calibrated Hall Sensor

Several makers of Hall-effect sensors sell specially calibrated devices designed to measure magnetic flux densities. These devices can be used to make calibrated gaussmeters. One such device is the calibrated version of Sprague's 3503U.

The 3503U is a linear-output Hall-effect sensor that includes a built-in amplifier. Figure 2 shows how the 3503U is connected to an external power supply and a voltmeter. A calibrated 3503U is supplied with a calibration curve, such as that shown in Fig. 2 for a typical 3503U. Calibration is performed in both a north and south 500-gauss magnetic field. According to Sprague, calibration can be reliably extrapolated to 1,000 G. Therefore, the flux density given in Fig. 2 extends from +1,000 G to −1,000 G. Beyond 1,000 G, however, extrapolation may not be valid due to inherent nonlinearities.

A carefully regulated power supply is required for utmost accuracy when making magnetic flux density measurements with a calibrated 3503U. Sprague recommends a 5-volt supply regulated to a tolerance of ±10 millivolts. Since Hall-effect devices are temperature-sensitive, Sprague recommends that the ambient temperature be maintained within the range of 21 to 25 degrees Celsius.

Before using the 3503U to make a flux measurement, the circuit should be powered up and allowed to stabilize for at least a minute. The sensor can then be placed in the field to be measured. The output voltage can then be compared with the sensor's calibration curve to determine the flux density.

Alternatively, the device's sensitivity coefficient (sens), which is printed on the calibration chart, can be used to deter-

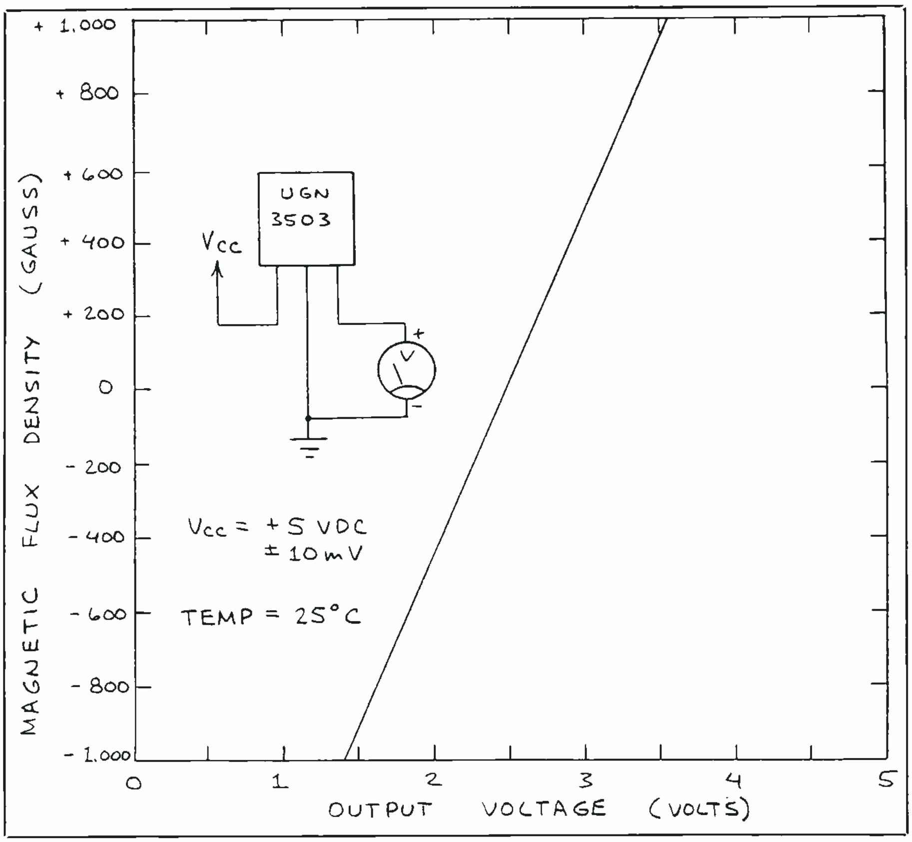

Fig. 2. Typical calibration curve for Sprague 3503U Hall sensor.

mine flux density. First, the output voltage when no magnetic field is present, the null voltage (V_{00}), is measured. The sensor is then placed in the magnetic field being measured and the resultant output voltage (V_{oB}) is measured. Flux density in gauss (B) can be calculated according to:

$$B = [(V_{oB} - V_{o0}) \times 1{,}000]/sens$$

The sensitivity coefficient for the device whose calibration is plotted in Fig. 2 is 1.087 mV/G. Its null voltage is 2.485 volts. Therefore, an output of 2.83 volts indicates a magnetic flux density of 317.39 gauss.

Detecting the Earth's Magnetic Field

The use of flux concentrators to increase the sensitivity of Hall-effect devices was discussed last month. A suitable flux concentrator will enable a Hall device to detect the Earth's magnetic field. The F.W. Bell Co. makes a high-sensitivity Hall device (Model BH-850) suitable for this purpose. The sensor is installed at the center of a 9-inch-long flux concentrator.

Figure 3 is the schematic of a simple circuit that uses a linear-output Hall sensor to detect the Earth's magnetic field. A 2.5-inch-long steel nail or lag screw can provide sufficient flux concentration to cause the LED to switch off and on when the plastic breadboard on which the circuit is installed is rotated. This high degree of sensitivity, however, is possible only with a very careful adjustment of the reference voltage via *R1*.

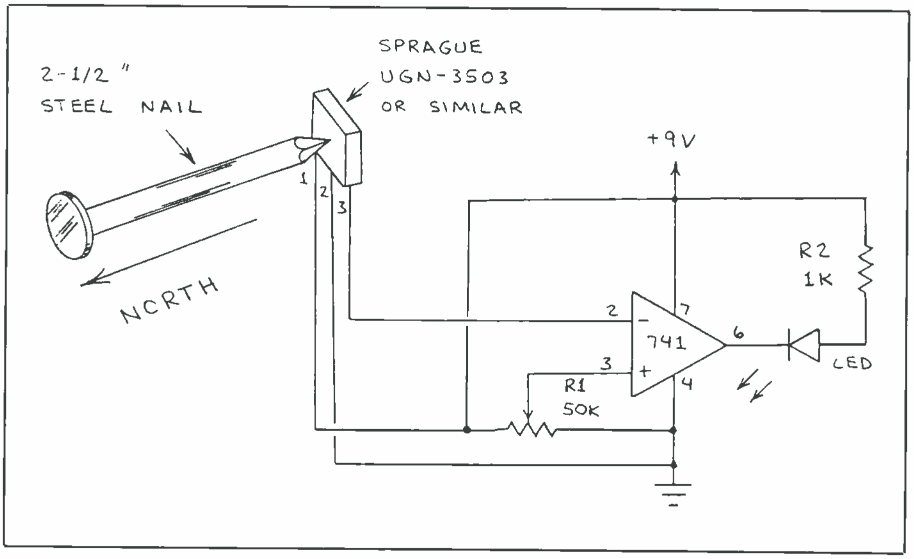

Fig. 3. Earth's magnetic field sensor.

After the circuit is assembled, apply power and adjust trimmer *R1* until the LED just switches off. Now the LED should switch on when the south pole of the magnet is placed within an inch or two of the front surface of the Hall-effect device.

When the circuit is operating, move the magnet and all other ferrous materials a foot or more away. Then place the circuit on a piece of cardboard that can be rotated on your workbench. The circuit should be rotated until the front face of the Hall sensor faces north. Now *carefully* readjust *R1* until the LED just switches off. When the pointed end of the steel nail is touched to the center of the front surface of the Hall device, the LED should switch on when the head of the nail points anywhere within a few tens of degrees of north (see Fig. 4).

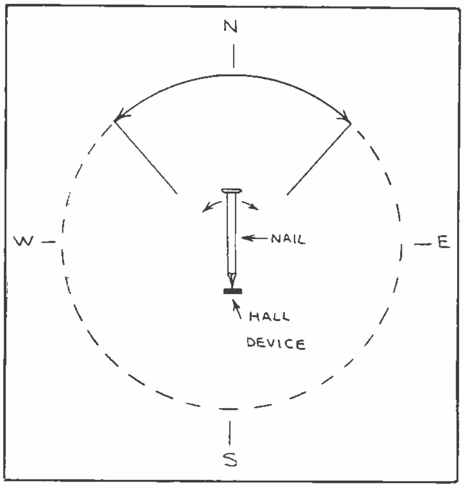

Fig. 4. Detecting the Earth's magnetic field.

If the LED fails to glow, try readjusting *R1*. If the circuit still fails to respond, use a larger nail or try a steel lag screw with a pointed tip. A 5.5-inch-long steel lag screw having a pointed end should provide so much flux concentration that the LED will glow when the screw and Hall sensor are rotated as much as 60 degrees from due north.

A pair of Hall devices equipped with optimized flux concentrators can be used to make a solid-state compass. The hall devices should be arranged at right angles to each other and their signals fed into a phase-detector circuit. In the late 1960s, Airborne Navigation Corp. manufactured an early version of such a compass that was used in an aircraft inertial navigation system or autopilot. The flux concentrators for this system were made of ferrite.

Keep in mind that the basic circuit in Fig. 3 can be used for applications other than sensing the Earth's magnetic field. For instance, it can detect a magnet at a much greater range than can a Hall sensor alone.

Nail Finder

The simplest way to locate studs in a wall is to locate the nails that anchor the wallboard (or plaster lath) to the studs. The traditional method of finding these nails is a gadget called a stud finder. This simple device consists of a small magnet mounted on a swivel or axle. As the stud finder is moved across a wall, the magnet will swing toward any nearby steel nails.

Figure 5 shows how a Hall sensor can

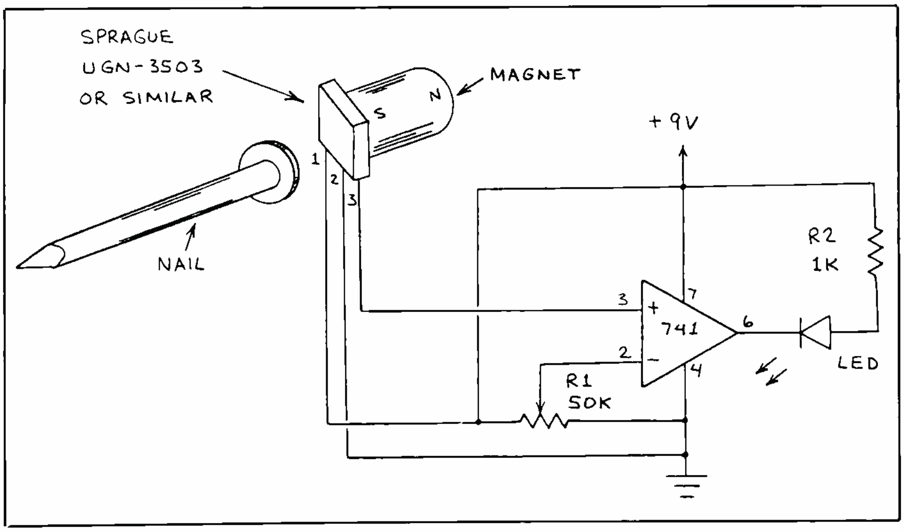

Fig. 5. Hall-effect stud finder circuit.

be used as a sensitive solid-state stud finder. Of course, the circuit can also be used in many other applications where it is necessary to detect either magnets or ferrous materials.

Referring to Fig. 5, a 741 operational amplifier is configured as a noninverting voltage comparator. Trimmer R1 is connected as a voltage divider that supplies an adjustable reference voltage to the inverting (–) input of the comparator. The output from a linear Hall-effect sensor is connected to the comparator's noninverting (+) input. Normally, the reference voltage is set just below the voltage from the Hall sensor. Therefore, the output of the comparator is high, and the LED is not forward biased. When the voltage from the Hall device falls below the reference voltage, the output of the comparator switches from high to low, thereby causing the LED to turn on.

Note that this circuit requires that the south pole of a small bias magnet be placed behind the Hall sensor. Even a piece of inexpensive flexible magnet material will permit the circuit to detect a steel nail a centimeter away.

Operation of this circuit can be reversed by reversing the input connections to the comparator. The LED will then glow until the Hall sensor is placed near a nail. The advantage of this operating mode is that the LED doubles as an on/off indicator. A disadvantage is that the LED is continuously on, constantly drawing current from the battery.

Another way to reverse the circuit's operating mode is to place the south pole of the bias magnet adjacent to the *front* of the Hall sensor, rather than its back surface. The back of the sensor will then sense the presence of a nearby nail.

Hall-Effect Pushbutton Switch

Some computer keyboards use Hall-effect devices at each keyswitch location. A small magnet inside each key actuates the Hall device when the key is pressed. An important advantage of this kind of switch is the total absence of the electrical bounce inherently produced by mechanical switches.

Figure 6 shows how a simple bounceless pushbutton switch can be assembled from a Hall-effect sensor and readily available materials. The plunger and barrel can be machined from plastic tubing and rod stock available from a hobby shop. Alternatively, the plunger can be cut from a length of solid rod and the barrel from a length of tubing. The protruding collars on the plunger and barrel can be formed from rings cut from plastic tubing and cemented in place.

A small magnet should be cemented in a receptacle bored in the end of the plunger. A short section of inexpensive flexible magnet material should work fine, but be sure to test the magnet you select before completing assembly of the switch. The switch's return spring can be a disk of foam plastic or an actual spring slipped inside the barrel.

Ideally, the lower end of the barrel should be threaded to accept a threaded retainer. If this is not practical, the retainer can be a disk cut from a solid rod that has the same diameter as the barrel. The disk should be cemented to the end of the barrel.

Output Interfacing for Hall Sensors

Each of the preceding circuits uses an LED to indicate the output status of a Hall-effect device. Often, it is necessary to interface Hall-effect sensors, especially the digital-output kind, to other types of devices.

The output of digital Hall-effect devices is often the collector of an npn transistor. This type of output is very easy to interface. In the case of the output LEDs

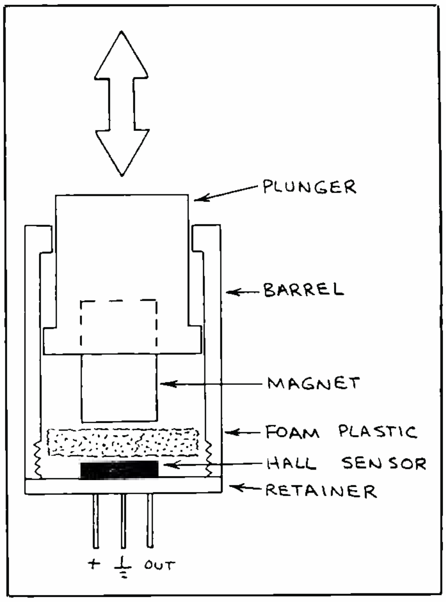

Fig. 6. Details of simple do-it-yourself Hall-sensor switch.

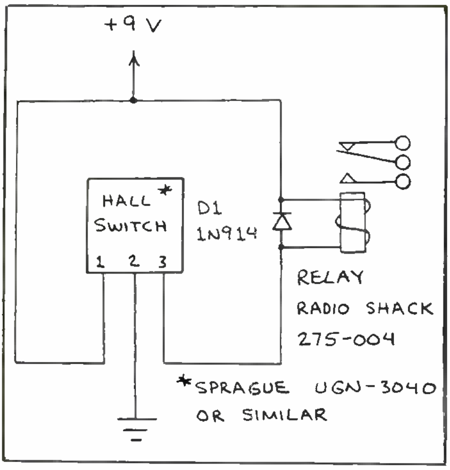

Fig. 7. Adding a relay to a magnetic field detector.

used in the circuits discussed above, the open collector is connected to V_{cc} through a current-reducing series resistor and an LED. The output transistor then acts as a switch that either applies or interrupts the current through the LED.

Figure 7 shows how a Hall-effect sensor with an open-collector output can directly drive a small relay. This permits the Hall sensor to switch both dc and ac loads at much higher currents and potentials than can be safely handled by the output transistor alone. Diode *D1* protects the sensor from the voltage spike spontaneously generated in the relay's coil when the output transistor is switched off.

Figure 8 shows how to interface a Hall-effect sensor with an open-collector output to both CMOS and TTL logic elements. In both cases, all that is necessary is a pull-up resistor of appropriate value. The values given in Fig. 8 for pull-up resistors are those recommended in *Hall Effect IC Applications* (Sprague Electric Co., 1986).

Going Further

Last month's installment of this column discussed the operating principles of Hall-effect devices. Sprague's *Hall Effect IC Applications* is an excellent introduction to Hall-effect devices. A more detailed reference is *Hall Effect Transducers*, a 280-page book published in 1982 by Micro Switch. **ME**

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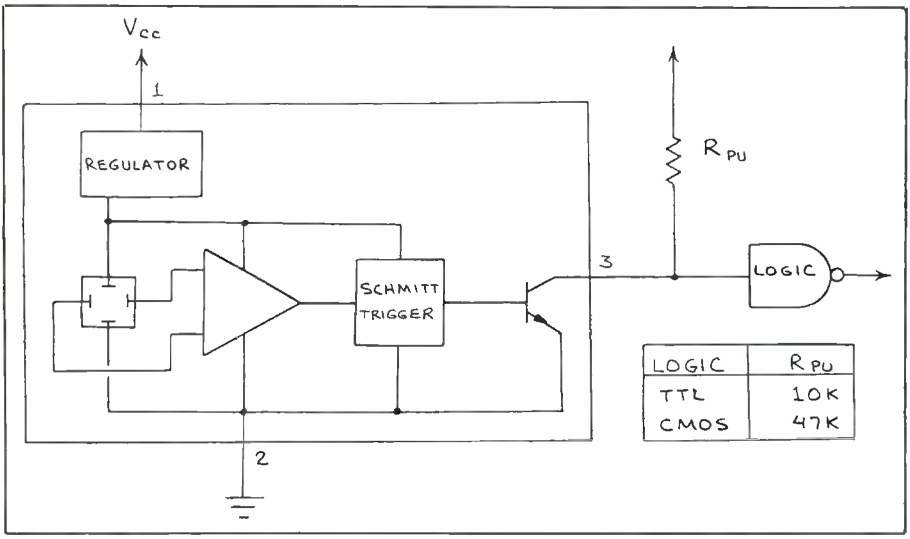

LOGIC	R PU
TTL	10K
CMOS	47K

Fig. 8. Digital logic interfacing for a digital Hall-effect sensor.