CIRCUIT CIRCUS

By Charles D. Rakes

An Introduction to Hall-Effect Switches

During this month's visit, we're going to introduce you to a device that's based on a century old discovery—made in 1879 by E.H. Hall—which with today's modern integrated-circuit technology has been transformed into a rather versatile semiconductor. E.H. Hall's findings indicated that a small voltage was developed across a current carrying conductor when placed in a strong magnetic field. The current resulted from negative charges within the conductor being deflected by the magnetic field, thereby producing a small potential difference across the conductor. That phenomena came to be known as the Hall voltage.

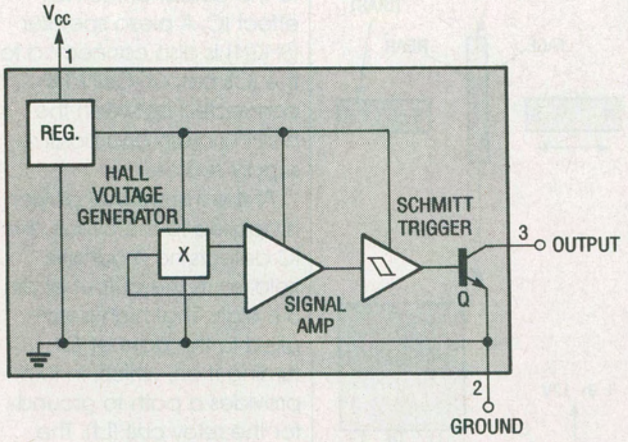

Fig. 1. The UGN-3113U is a magnetically operated, solid-state Hall-effect switch comprised of a Hall-voltage generator, a signal amplifier, a Schmitt trigger, and a transistor-output circuit, as shown by this block pinout diagram.

Sprague Electric produces a line of Hall-effect switches that are user friendly, low cost, and can be an ideal replacement for the "stuttering" mechanical reed relay. The Sprague Hall-effect switches—which are available from D.C. Electronics (P.O. 3203, Scottsdale, AZ 85271-3203; Tel. 800-467-7736 or 800-423-007) for $.98.—are comprised of a Hall-voltage generator, a signal amplifier, a Schmitt trigger, and a transistor-output circuit all contained within a three-terminal, integrated-circuit chip.

Figure 1 is a block pinout diagram of Sprague Electric's UGN-3113U Hall-effect switch, which is used in all of the circuits presented this month. The UGN-3113U is a magnetically operated, solid-state Hall-effect switch whose output transistor is normally off until a magnetic field exceeds the device's specified operating point. Once that point is reached, the output transistor—which will sink 15 mA of current—switches on. The output transistor remains on until the activating field drops below the specified release point, which is lower than the operating point.

Figure 2 illustrates the Hall-effect switch's sensitive area (on the face side), which is activated by bringing the south pole of a permanent magnet within a specified distance of the device.

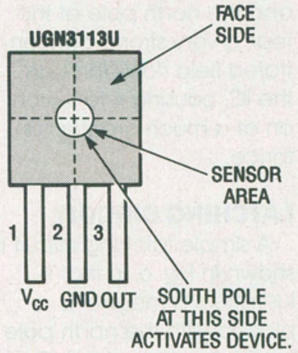

Fig. 2. In operation, the UGN-3113U Hall-effect switch is activated by bringing the south pole of a permanent magnet within a specified distance of the device's sensitive area (located on the face side).

A SIMPLE SWITCH

When connected, as shown in Fig. 3, with no magnetic field present, the output transistor is off (open circuited), so no ground path through the output transistor is provided, thus, LED1 remains dark. If, however, the south pole of a permanent magnet is brought in proximity to the sensor area (within about 0.18 inches of its face), as shown Fig. 4, the Hall-effect IC's output transistor turns on, completing the ground path for LED1, causing it to light.

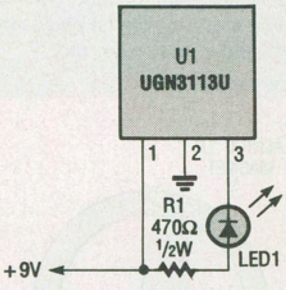

Fig. 3. When U1 is connected as shown and no magnetic field present, the output transistor is off (open circuited), so no ground path through the output transistor is provided, thus, LED1 remains dark.

The IC's built-in hysteresis causes the output transistor to remain on until the magnet is moved about 0.25 inches away before turning off. That feature keeps the IC from being triggered by magnetic fields from other electrical devices. But any magnetic field strong enough and in close-enough proximity to the IC

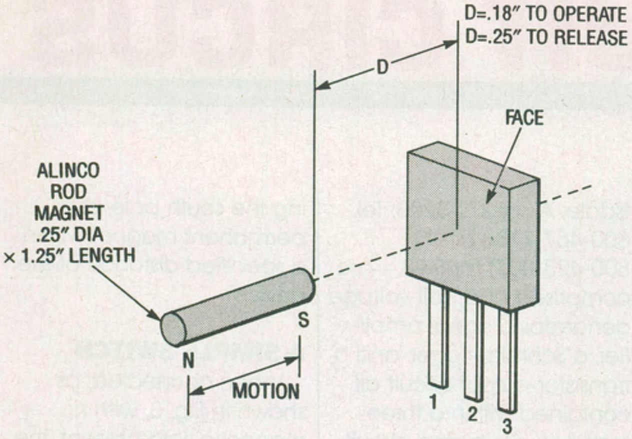

Fig. 4. If the south pole of a permanent magnet is brought in proximity to the sensor area (within about .18 inches of its face), as shown here, the Hall-effect switch's output transistor turns on, completing the ground path for LED1, causing it to light.

PARTS LIST FOR THE SIMPLE SWITCH

U1—UGN3113U Hall-effect digital switch, integrated circuit
LED1—Light-emitting diode (any color)
R1—470-ohm ½-watt, 5% resistor
Perfboard materials, enclosure, 9–12-volt power source, wire, solder, hardware, etc.

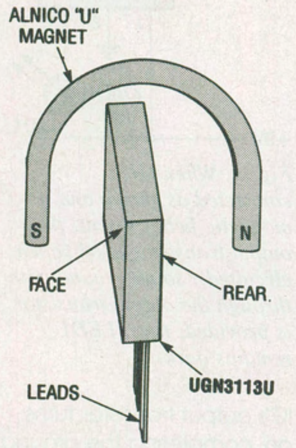

Fig. 5. By placing a strong horseshoe magnet over the IC, with the south pole at the face and the north pole at the rear, a very strong concentrated field flows through the IC, causing it to switch on at a much greater distance.

will cause it to activate. The actual flux density needed to operate the IC at a distance of about 0.18 inches is about 450 to 500 gauss. Stronger magnetic fields will activate the switch at greater distances and, of course, less powerful magnetic fields will lessen the trigger distance.

By placing a strong horseshoe magnet over the IC, as shown in Fig. 5, with the south pole at the face and the north pole at the rear, a very strong concentrated field flows through the IC, causing it to switch on at a much greater distance.

LATCHING CIRCUIT

A simple latching circuit is shown in Fig. 6. In that illustration, a magnet is placed with the north pole facing the rear of the IC in a fixed position just far enough from the IC so as not to activate it, but close enough to hold it on when activated from the face side. When the south pole of another magnet is moved toward the face of the IC, the output transistor switches on and remains on even after the second (movable) magnet is moved out of position. The circuit may be reset by operating S1 or by reversing the pole of the movable magnet.

The Hall-effect IC is primarily designed to operate as a bounce-less, magnetic on/off switch. That circuit feature overcomes the chatter problems that often occur when using a magnetically operated reed switch. Applications for the Hall-effect switch include its use in a timing sensor for a gas-engine ignition system; as a mechanical-motion or position-limit switch; as a keyboard switch, current sensor; as a position sensor; in security systems, etc.

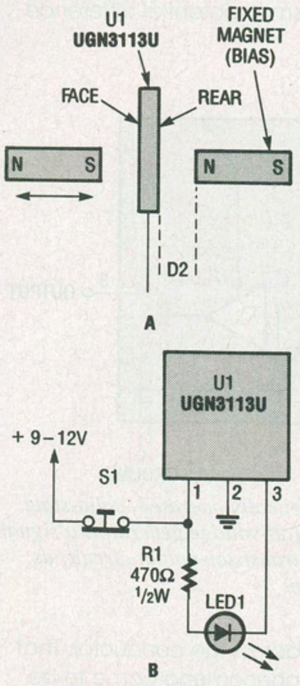

Fig. 6. In this simple latching circuit, a magnet is placed in a fixed position with the north pole facing the rear of the IC. When another magnet (with the south pole face the front of the IC) is moved toward IC, the output transistor switches on and remains on even after the second magnet is moved out of position.

HALL-EFFECT OSCILLATOR

The circuit in Fig. 7 places the Hall-effect IC in an application far from its intended use. Normally for the IC to detect a magnetic field, the spacing between the magnet and the IC must be close. The same magnet when used with our magnetic-regeneration circuit can be detected up to 1 foot away—an increase in distance of over 100 times—and the magnet's pole position will be indicated.

In the circuit of Fig. 7A, a 20- to 30-ohm relay coil (L1) is placed with one end (pole) flush against the rear of the IC (as illustrated in Fig. 7B). The gate of Q1 (an IRF511 hexFET) is connected to the output of the Hall-effect IC. A piezo speaker (SPKR1) is also connected to the IC's output. Coil L1 is connected between the hexFET's drain and positive-supply source.

At the instant that power is applied to the circuit, the IC detects no magnetic field, so its the output at pin 3 is high. That high is applied to the gate of Q1, turning it on, which, in turn, provides a path to ground for the relay coil (L1). The current through L1 produces a strong magnetic (north-pole) field at the rear of U1, turning it on, which pulls U1's output to ground. That removes the high input signal from the gate of Q1, causing it to turn off, which prevents current flow through L1.

With no current flow through L1, the magnetic field associated with L1 collapses. That, in turn, causes U1's output at pin 3 to go high, and the cycle starts over again, producing an oscillating effect. The piezo

PARTS LIST FOR THE LATCHING CIRCUIT

U1—UGN3113U Hall-effect digital switch, integrated circuit
LED1—Light-emitting diode (any color)
R1—470-ohm ½-watt, 5% resistor
S1—Normally closed pushbutton switch
Perfboard materials, enclosure, 9–12-volt power source, wire, solder, hardware, etc.

PARTS LIST FOR THE HALL-EFFECT OSCILLATOR

SEMICONDUCTORS
U1—UGN3113U Hall-effect digital switch, integrated circuit
Q1—IRF511 hexFET
D1—1N4002 1-amp, 100-PIV, rectifier diode

ADDITIONAL PARTS AND MATERIALS
R1—2200-ohm, ¼-watt, 5% resistor
L1—20-to-30-ohm relay coil (see text)
SPKR1—Piezo speaker, (Radio Shack #40-1383)
Perfboard materials, enclosure, 9–12-volt power source, wire, solder, hardware, etc.

PARTS LIST FOR THE RC OSCILLATOR

SEMICONDUCTORS
U1—UGN3113U Hall-effect digital switch, integrated circuit
Q1—IRF511 hexFET
D1—1N4002 1-amp, 100-PIV rectifier diode

ADDITIONAL PARTS AND MATERIALS
R1—220,000-ohm, ½-watt, 5% resistor
C1—0.1–4.7-µF, 35-WVDC, ceramic-disc or electrolytic capacitor (see text)
L1—20-to-30-ohm relay coil (see text)
Perfboard materials, 9–12-volt power source, wire, solder, hardware, etc.

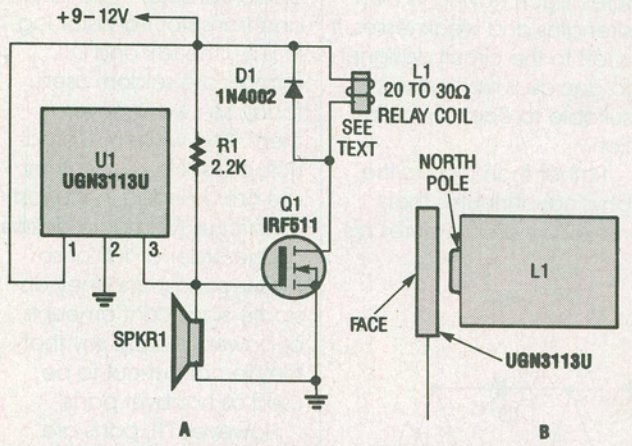

Fig. 7. While not intended for this application, Hall-effect switch can be used a the basis for a rather unusual oscillator, as shown here.

speaker, SPKR1, clicks for each cycle of oscillation. If no oscillation occurs, reverse the leads going to L1. Backing L1 away from the IC should cause the clicks coming from the piezo speaker to be heard less frequently; back L1 off until the clicks occur at a rate of about 1 per second (1 Hz). Then move the magnet toward the face of the IC and note the change in the oscillator's frequency. A magnet with its south pole facing the front of the IC will increase the output frequency as it approaches the IC; the north pole facing the front should decrease the frequency.

The circuit's actual operating voltage depends on the magnetic field generated by L1. A low resistance coil should produce a sufficient field with a lower voltage, power supply, while a higher resistance coil will need a higher supply voltage to trigger the circuit. The Hall-effect switch can be powered from a supply ranging from 4.5 to 24 volts.

RC OSCILLATOR

Another version of the regeneration (oscillator) circuit is shown in Fig. 8. Everything in that circuit remains pretty much the same as in the previous circuit except that the IC's pull-up resistor (R1) has been increased from 2.2k to 220k and a timing capacitor (C1) has replaced the speaker.

When power is first applied to the circuit, U1 detects no magnetic field, thus its output transistor remains at cut-off, and the full voltage of the power source appears at pin 3 (the output) of U1. Because, upon application of power, C1 initially acts as a short, Q1's gate is initially grounded through C1, so it remains at cutoff. The RC time constant of R1 and C1 (which can range between 0.1 and 4.7 µF) will determine the time it takes the voltage across C1 to rise to a level that will turn on Q1. The current drain during the charging time is very low, making the circuit suitable for battery operation. The oscillator's output is sawtooth that varies from near 0 to about 5 volts. Adjust L1's position as in the previous circuit to vary the operating frequency of the oscillator.

That's all for now; see you here next time. ■

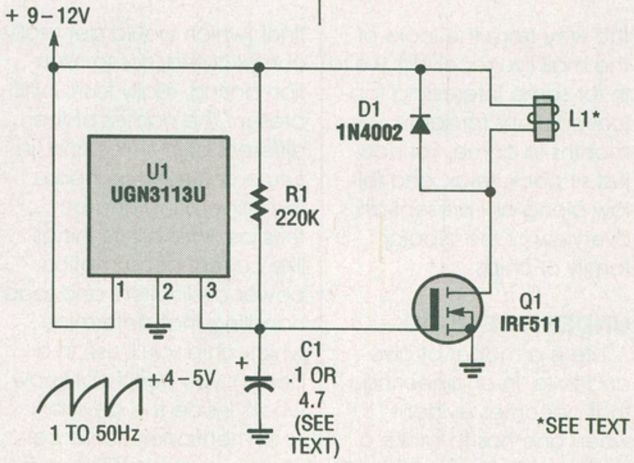

Fig. 8. The oscillator of the previous circuit can be reconfigured, as shown here, so as to allow the circuit's oscillating frequency to be controlled via an RC network, comprised of R1 and C1.