An introduction to the use of Hall Effect devices

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Hall Effect ICs are contactless, magnetically activated switches and sensors with the potential to simplify and improve systems. Modern Hall Effect switches combine Hall voltage generators, signal amplifiers, Schmitt trigger circuits and transistor output circuits on single integrated circuit chips. Output is clean, fast and switched without bounce — an inherent problem with mechanical contact switches. A typical example will give reliable operation at repetition rates up to 100 kHz, yet costs less than many common electromechanical switches.

The Hall Effect sensor is virtually immune to environmental contaminants and is suitable for use under severe service conditions, including dirty or dark locations. A few examples include use in ignition systems, speed control, security systems, alignment controls, micrometers, mechanical limit switches, computers, printers, disk drives, keyboards, machine tools, keyswitches and pushbutton switches. They are also used as tachometer pickups, current limit switches, position detectors, selector switches, current sensors, linear potentiometers and brushless dc motor commutators.

Fig 1 The basic Hall Effect sensor.

The basic Hall sensor is a small sheet of semiconductor material, represented by Figure 1. If a constant voltage is added to this, as shown in Figure 2, it will force a constant bias current to flow in the sensor. The output will take the form of a voltage measured across the width of the sheet, and will have negligible value in the absence of a magnetic field.

Fig 2 Basic Hall Effect sensor with a constant voltage applied across it.

Fig 3 Diagram to demonstrate the Hall Effect.

Two examples of Hall sensors in their simplest form are illustrated in Figure 1. The output voltage of these is quite small, and this can present problems, especially in an electrically noisy environment. But, if a stable high-quality dc amplifier and voltage regulator are added to the circuit (Figures 4 and 5), this will improve the transducer's output and allow it to operate over a wider range of supply voltages. Such a modified device provides an easy-to-use analogue output that is linear and proportional to the applied magnetic flux density.

Fig 4 Stable high-quality DC amplifier added to the Hall device circuit.

Fig 5 The circuit shown in Figure 4, but with the addition of a voltage regulator.

The addition of a Schmitt trigger threshold detector with built-in hysteresis gives a Hall Effect circuit digital output capabilities. When the applied magnetic flux density exceeds a certain limit, the trigger will provide a clean transition from OFF to ON without contact bounce. And the built-in hysteresis eliminates spurious switching of the output by introducing a magnetic dead zone in which switch action is disabled until a threshold value is passed.

Adding an open-collector NPN output transistor will give a Hall Effect circuit digital logic compatibility. The transistor is a saturated switch that shorts the output terminal to ground whenever the applied flux density is higher than the ON threshold of the sensor. Such circuits are compatible with microprocessors and microcontrollers.
current to directly drive many loads – eg. relays, triacs, SCRs, LEDs and lamps.

![Fig 6: Diagram of circuit elements common to all Sprague Hall Effect digital switches.](image)

The circuit elements in Figure 6, fabricated on a monolithic silicon chip and encapsulated in a small epoxy or ceramic package, are common to integrated Hall Effect digital switches. Differences between the device types are generally found in specifications such as magnetic parameters, operating temperature ranges and temperature coefficients.

**Operation of a Hall Effect device**

All Hall Effect devices are activated by a magnetic field, which has two important characteristics – flux density and polarity (or orientation). In the absence of any magnetic field, most Hall Effect digital switches are designed to be OFF (open circuit at output). They will turn ON only if subjected to a magnetic field that has both sufficient density and the correct orientation for the particular device.

Most Hall switches have an active area that is closer to one face of the package. To operate the switch, the magnetic flux lines must be both perpendicular to this face, and have the correct polarity. If a close approach to the appropriate face by the south pole of a small permanent magnet will cause the output transistor to turn ON (Figure 7), a north pole would have no effect.

![Fig 7: To show the switching effect of a magnet on a Hall Effect device.](image)

**Table 1: Characteristics of Sprague Hall Effect switches.**

<table>
<thead>
<tr>
<th>Sprague Type</th>
<th>Package</th>
<th>Description</th>
<th>Operating Temperature Range*</th>
<th>Operate Point</th>
<th>Release Point</th>
<th>Supply Voltage</th>
<th>Supply Current</th>
<th>Type Leakage Current</th>
<th>Typ. Type</th>
<th>Typ. Leakage</th>
<th>Typ. Rise Time</th>
<th>Typ. Fall Time</th>
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<tbody>
<tr>
<td>3913</td>
<td>U</td>
<td>Switch</td>
<td>UGN</td>
<td>Min (G)</td>
<td>Max (G)</td>
<td>Min (V)</td>
<td>Max (mA)</td>
<td>Max (mA)</td>
<td>Max (G)</td>
<td>Max (G)</td>
<td>Min (G)</td>
<td>Max (G)</td>
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<td>Switch</td>
<td>UGN</td>
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<td>125</td>
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<td>24</td>
<td>3.0</td>
<td>3.0</td>
<td>85</td>
<td>0.05</td>
<td>0.05</td>
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<td>L</td>
<td>Switch</td>
<td>UGN</td>
<td>350</td>
<td>50</td>
<td>4.5</td>
<td>24</td>
<td>3.0</td>
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<td>85</td>
<td>0.05</td>
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<td>250</td>
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<td>24</td>
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<td>3.0</td>
<td>85</td>
<td>0.05</td>
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<td>24</td>
<td>3.0</td>
<td>3.0</td>
<td>85</td>
<td>0.05</td>
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<td>24</td>
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<td>UGN</td>
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<td>350 ±50</td>
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<td>24</td>
<td>3.0</td>
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<td>UGN</td>
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<td>350 ±50</td>
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<td>24</td>
<td>3.0</td>
<td>3.0</td>
<td>85</td>
<td>0.2</td>
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<td>3201</td>
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<td>Dual Output Switch</td>
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<td>750</td>
<td>100</td>
<td>5.0</td>
<td>16</td>
<td>20</td>
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<td>300 (Max.)</td>
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<td>—</td>
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<td>16</td>
<td>20</td>
<td>25</td>
<td>300 (Max.)</td>
<td>100</td>
<td>—</td>
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<td>50</td>
<td>4.5</td>
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<td>9.0</td>
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</table>

*UGN = —20°C to +85°C; UGS = —40°C to +125°C.

![Fig 8: A transfer characteristics graph. Output is plotted as a function of magnetic flux density (measured in Gauss) presented to the Hall cell.](image)

In Figure 8, the magnetic flux density is shown on the horizontal axis. The digital output of the Hall switch is shown along the vertical axis.

To acquire data for this graph, a power supply and a pull-up resistor that will limit current through the output transistor was added, and enabled the value of the output voltage of approach zero. In the absence of an applied magnetic field (OG), the switch is OFF, and the output voltage equals the power supply (12 V). A permanent magnet's south pole is then moved perpendicular to the Hall device.
towards the active area of the device. As the magnet’s south pole approaches the branched face of the switch, the Hall cell is exposed to increasing magnetic flux density. At some point (240 G, in this case), the output transistor turns ON and the output voltage goes to zero. That value of flux density is called the operate point. If the field’s strength continues to increase, nothing more happens. The switch turns on and stays on.

To turn the switch OFF, the magnetic flux density must fall to a value far lower than the 240 G operate point because of the built-in hysteresis. For this example, 90 G hysteresis is used, which means the device turns OFF when flux density decreases to 150 G. That value of flux density is called the release point.

The exact magnetic flux density values required to turn Hall switches ON and OFF differ for several reasons, including design criteria and manufacturing tolerances. Extremes in temperature will also somewhat affect the operate and release points.

For each device type, the device manufacturer provides worst-case magnetic characteristics for the operate value, the release value and hysteresis. Maximum and minimum values for the magnetic parameters at the temperature extremes are shown in Table 1.

Typically, Hall Effect switches are guaranteed to turn ON at or below the maximum operate point flux density. When the magnetic field is reduced, all devices will turn OFF before the flux density drops below the minimum release point value. Each device is guaranteed to have at least the minimum amount of hysteresis to ensure clean switching action. This hysteresis ensures that, even if mechanical vibration or electrical noise is present, the switch output is fast, clean and occurs only once per threshold crossing.