Application Report
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Understanding & Applying Hall Effect Sensor Datasheets

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ABSTRACT

Hall effect sensors measure magnetic fields, and their datasheet parameters can initially be difficult to understand and apply toward system design. This article provides a baseline of information.

Units

A magnet produces a magnetic field that travels from the North pole to the South pole. The total amount of field through a 2-dimensional slice is the "flux", in units of weber. Webers per square meter describes flux density, in units of tesla (T). The unit of gauss (G) also describes flux density, where 1 T = 10000 G. In millitesla, 1 mT = 10 G. Tesla is the official SI unit, and it's used by TI datasheets, but many other sources use gauss.

Practical Concepts

- The closer you are to a magnet, the higher the flux density.
- The flux density at the surface of the magnet depends on its material and the magnetization amount. Typical magnets have surface fields between 40 to 600 mT.
- At a given distance, physically large magnets project a larger flux density.

Polarity

The symbol "B" is used for flux density. TI Hall sensors use the convention that magnetic fields traveling from the bottom of the device through the top are "positive B", and fields traveling from the top to the bottom of the device are "negative B". Only the perpendicular vector component of the magnetic field is sensed by the internal element.

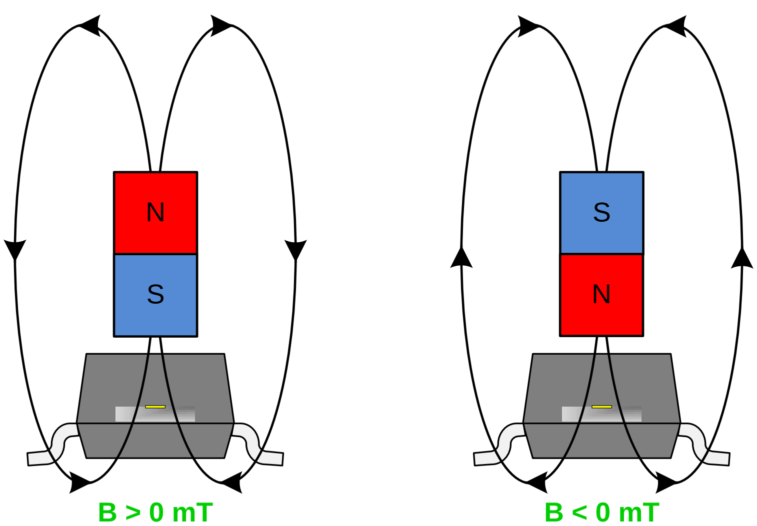

Figure 1. Polarity of field directions

Digital Hall Sensor Functionality

Digital Hall sensors have an open-drain output that pulls Low if B exceeds the threshold B_{OP} (the Operate Point). The output then stays Low until B decreases below the threshold B_{RP} (the Release Point), and then the output becomes High-Impedance. An external pull-up resistor is normally used. B_{OP} and B_{RP} are always separated with hysteresis (B_{hys}), which prevents noise-induced toggling at a threshold.

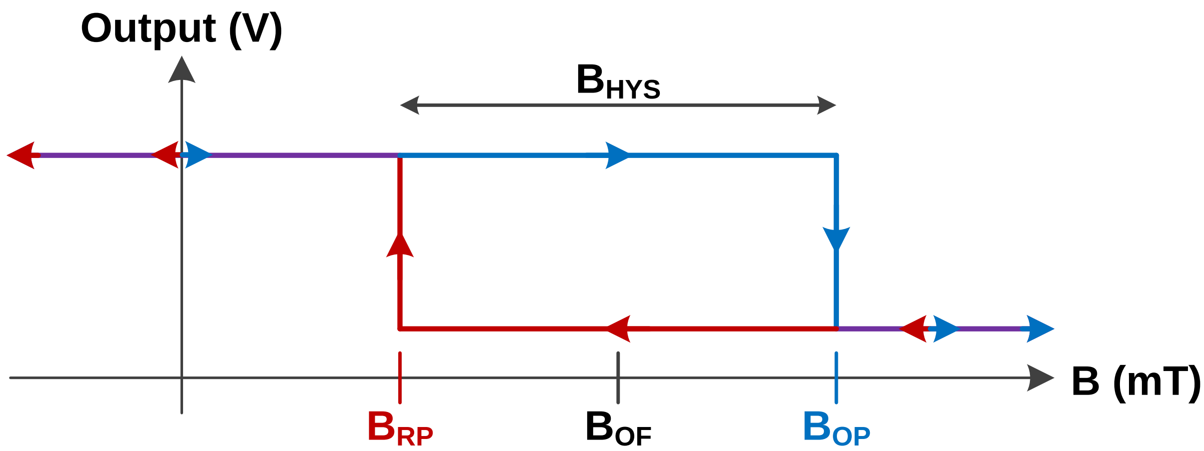

Figure 2. B-field response of the DRV5023

Like all datasheet parameters, the actual B thresholds vary due to semiconductor process variation, operating voltage, and temperature.

PARAMETER		MIN	TYP	MAX	UNIT
B_{OP}	Operate point	3	6.9	12	mT
B_{RP}	Release point	1	2.3	4	
B_{hys}	Hysteresis; $B_{hys} = (B_{OP} – B_{RP})$	3	4.6	7	
B_O	Magnetic offset; $B_O = (B_{OP} + B_{RP}) / 2$	3.1	4.6	6.1	

A magnet and Hall sensor should be selected so that the field at the sensor exceeds the specified max-B_{OP}, in order to guarantee that the magnetic threshold is crossed.

Design Example with Digital Hall Sensors

Consider the switches used to control power windows in a vehicle.

Each rocker switch could contain two small magnets for the forward and backward directions, along with a digital Hall sensor mounted below each one. The goal here is to ensure that when the button is not pushed, the B-field at the sensor is *below the min-*B_{RP}, and pushing the button brings the B-field at the sensor *above the max-*B_{OP}. This involves a combination of magnet and sensor selection, considering the distance of separation.

When selecting a DRV5023 switch, there are two different versions:

	PARAMETER	MIN	TYP	MAX	UNIT
DRV5023AJ	B_{OP}	3	6.9	12	mT
	B_{RP}	1	2.3	4	
DRV5023BI	B_{OP}	6	13.8	24	
	B_{RP}	2	4.6	8	

When choosing a magnet, the designer must select the material and size. Available materials include ceramics and different ferromagnetic metal alloys, and there are tradeoffs in flux density, temperature performance, mechanical characteristics, and cost. The physical size must be chosen to produce the appropriate B-fields at the sensor. There are also flux concentrators available that redirect and amplify the B-field of a magnet.

So how does one determine the B-field a magnet produces? The best way is to measure it using a gaussmeter (or teslameter). While there are many online calculators, and some magnet suppliers specify limited B-field characteristics, the field in a particular system will vary somewhat based on the materials being permeated and potential interactions from nearby components.

Analog Hall Sensor Functionality

TI's analog Hall sensors, such as the DRV5053, have an analog voltage output that changes proportionally with the magnetic field.

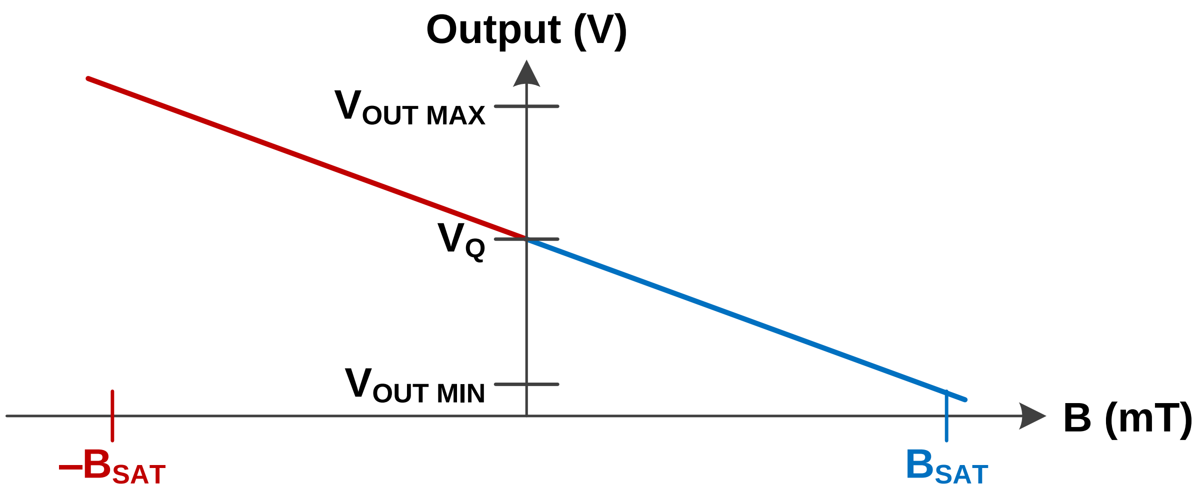

Figure 3. B-field response of the DRV5053

When no magnet is present (B = 0), the output voltage is V_Q (typically 1V). The presence of a magnetic field scales the output toward 2V or 0V.

PARAMETER		MIN	TYP	MAX	UNIT
V_Q	Quiescent output	0.9	1	1.1	V
$V_{OUT\ MIN}$	Output saturation voltage (min)			0.2	
$V_{OUT\ MAX}$	Output saturation voltage (max)	1.8			

The usable range is between 0.2V and 1.8V, since the B-response becomes nonlinear close to the rails.

The slope of the response is called "Sensitivity", in units of "mV/mT". Using the DRV5053OA as an example, typical Sensitivity is -10mV/mT, and so a B-field of 15mT will typically shift the output by -150mV from V_Q, bringing the output to 850mV. A B-field >80mT saturates the DRV5053OA, since the output drops below 0.2V.

	PARAMETER		MIN	TYP	MAX	UNIT
DRV5053OA	S	Sensitivity	-5	-10	-17.5	mV/mT
	B_{SAT}	Input saturation field		80		mT
DRV5053PA	S	Sensitivity	-10	-20	-35	mV/mT
	B_{SAT}	Input saturation field		40		mT
DRV5053RA	S	Sensitivity	-20	-45	-70	mV/mT
	B_{SAT}	Input saturation field		18		mT
DRV5053VA	S	Sensitivity	-35	-80	-140	mV/mT
	B_{SAT}	Input saturation field		10		mT
DRV5053CA	S	Sensitivity	10	20	35	mV/mT
	B_{SAT}	Input saturation field		40		mT
DRV5053EA	S	Sensitivity	20	45	70	mV/mT
	B_{SAT}	Input saturation field		18		mT

Linearity

The Linearity parameter defines how much Sensitivity can change across the B-range, with a fixed operating voltage and temperature. Although Sensitivity varies greatly device-to-device, Linearity constrains the variation for one device.

PARAMETER		MIN	TYP	MAX	UNIT
L_E	Linearity		1		%

Noise

The output-referred noise (V_N) parameter simply describes the voltage noise always present on the device output. It equals the input-referred noise times Sensitivity. V_N can be settled with an external RC low-pass filter.

PARAMETER		MIN	TYP	MAX	UNIT
V_N	Output-referred noise		6		mV_{pp}
B_N	Input-referred noise	0.40	0.57	0.79	mT_{pp}

DRV5053 Calculator

This calculator is an Excel file that solves the possible output voltages for any B-field, for each DRV5053 version. Download it here: http://www.ti.com/lit/zip/slic020

Design Example with Analog Hall Sensors

Consider a directional control valve, which has 3 different mechanical positions to allow fluid to flow in different paths.

The DRV5053 can determine which of the 3 positions the valve is in. The valve cylinder moves in 1 dimension (forward and back). By mounting the sensor in the center of the cylinder, and placing a magnet on each end of the moving piece, the sensor can detect “Strong North”, “No field”, or “Strong South”. The corresponding output voltages will be roughly 2V, 1V, or 0V, and a microcontroller ADC can use this to understand the valve position.

If, for example, the ADC has a voltage accuracy of ±100mV (based on its resolution and system noise), then there would need to be >200mV of separation between each magnetic state. Using the DRV5053 Calculator, it becomes evident that fields of -12mT, 0mT, and 12mT provide at least 220mV of separation between each state, with the DRV5053VA. Stronger fields on each end provide additional margin.

For More Information

To get your questions answered, post to the DRV5000 Engineer to Engineer (E2E) forum at: http://e2e.ti.com/support/applications/motor_drivers/f/966.aspx