Application Brief

Designing With Hall-Effect Sensors for Rotary Flow Meter Applications

Jacob Nogaj

Current and Position Sensing

Introduction

Rotary flow meters utilize flow of fluid to rotate a mechanical assembly proportional in speed to flow rate. Implementation with Hall-effect sensors enables smaller form-factor design, longer device lifetime, and reduction in assembly error when compared to flow meters using reed switches.

A robust contactless method for measuring fluid flow rate can be implemented via a magnetic impeller, and a Hall-effect sensor as shown in Figure 1. In this approach, magnets are placed on the impeller such that the Hall sensor can detect the changing magnetic field as the impeller rotates. This changing magnetic field causes the Hall device to change output states upon crossing the magnetic thresholds. Thus, the Hall sensor output frequency can be used to measure the flow rate of fluid through the meter.

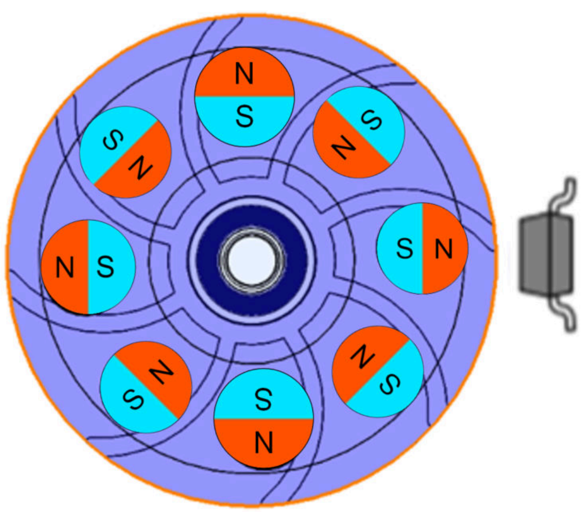

Figure 1. Flow Meter Operational Diagram

When designing a mechanical based flow meter, it is necessary to evaluate fundamental requirements for system implementation. Characteristics such as minimum and maximum flow rate dictate mechanical factors such as impeller size. Magnet selection influences the type of Hall-effect sensor best suited to the application. System accuracy requirements will consequently influence the total number of magnetic poles or Hall sensors required to realize measurements.

Device Sensitivity

Select a Hall-effect sensor to have adequate sensitivity for the magnet used in the flow meter. The positioning and size of the magnet can have significant influence on magnetic flux density sensed by the Hall-effect sensor. Hall-effect devices are often avaliable with multiple sensitivity options to suit the specific sensitivity requirements for the application. It is neccesary to select a Hall-effect sensor with enough magnetic headroom to reliably trigger on changes in magnetic field.

Unipolar Switch

Unipolar switches are the most simple Hall-effect device available, with sensing capability in one direction, either the North or South pole of a magnet, for B_{OP} and B_{RP}. When using sensors that have a unidirectional sensing direction, proper magnet orientation is required for B-field sensing. Common magnet implementations for Hall-effect switches include alternating North or South orientation magnets, or single orientation magnets spaced far enough apart to allow the B-field to fall below the B_{RP} threshold between magnets. In digital Hall-effect devices, B_{OP} and B_{RP} dictate the switching thresholds for the device. For a Hall-effect switch, this characteristic makes the output duty cycle dependent on the magnetic threshold levels and magnet movement. Generally, more care must be taken to implement Hall-effect switches into a flow meter design compared to latches. Switches; however, can be used with various magnet implementations, further adding to flexibility in terms of flow meter mechanical design. Figure 2 displays the unipolar switch operation.

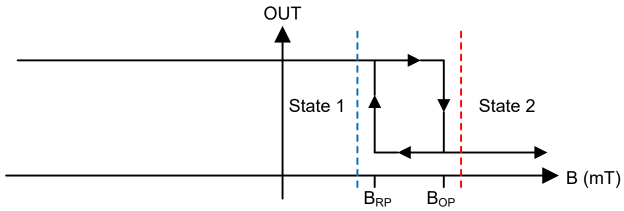

Figure 2. Unipolar Switch Operation

Omnipolar Switch

Omnipolar switches act as two opposite polarity unipolar switches connected together. Therefore, the switch still operates using B_{OP} and B_{RP}, however the polarity of the B-field no longer influences the output of the sensor. This implementation requires the magnets be positioned far enough apart to allow the B-field to fall below the B_{RP} threshold between magnets. Use of the omnipolar switch enables the magnets to be positioned in any orientation (North facing or South facing) with no polarity influence to the sensor operation. Magnets can be positioned in either orientation, simplifying overall mechanical assembly of the flow meter. Omnipolar switch operation is displayed in Figure 3.

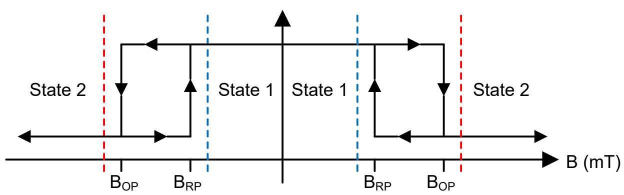

Figure 3. Omnipolar Switch Operation

1D Latch

One-dimensional (1D) Hall-effect latches share similar operational characteristics as switches, but uniquely retain the previous output state until a magnetic pole of the opposite polarity is detected. Therefore, it is necessary that the sensor detect changing magnetic polarities to create corresponding changes on the output. Assuming equal spacing of magnets, the output waveform of a latch is approximately 50% duty cycle regardless of sensing frequency. Figure 4 demonstrates the operational characteristics of a Hall-effect latch.

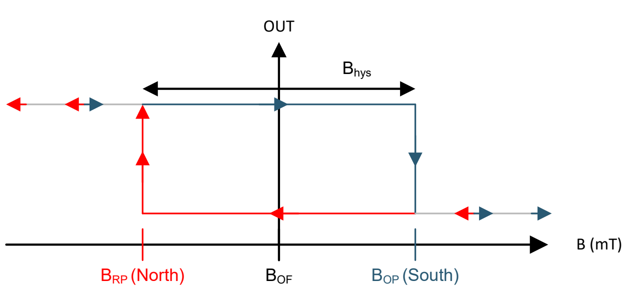

Figure 4. Latch Operation

2D Integrated Latch

Two-dimendional (2D) latches operate in a similar fashion to their 1D counterparts, but possess multiple sensing elements integrated in a package. In the case of the TMAG5111 device, this feature allows for rotation sensing as well as direction sensing. With multiple sensing elements, 2D latches can increase the resolution of the sensing system without requiring additional magnetic poles. Furthermore, the inherent quadrature nature of the 2D Hall-effect latch replaces the requirement to alternatively position two 1D Hall-effect latches precisely 90° apart from one another. The quadrature output results in more accurate frequency measurement, and backwards flow detection capability in mechanical flow meters.

Bandwidth

Hall-effect sensor bandwidth is specified as a digital characteristic, differing from analog bandwidth in devices like operational amplifiers. Bandwidth determines the maximum frequency capable of being sensed by a Hall-effect sensor. It is necessary to consider the total number of magnetic poles present in the flow meter to verify if the maximum rotational speed of the impeller is less than the bandwidth of the device. For example, a flow meter using a high bandwidth DRV5013 Hall-effect latch (30 kHz) and ring magnet with 32 poles (16 North oriented, 16 South oriented) has a maximum typical theoretical sensing speed of 1875 rotations per second. Use the calcuated maximum rotational sensing speed to verify the maximum flow rate will not cause the mechanical assembly to exceed the sensing capability for the Hall-effect device.

Operating Voltage Range

Different systems have different available supply voltages. If the available supply voltages of a system are all outside of the operating voltage range of the Hall sensor, an additional voltage regulator device is needed to generate a voltage rail for powering the Hall sensor. Devices such as the DRV5013 have a wide supply voltage range (2.5 V–38 V), making the Hall-effect sensor suitable in various high- or low-voltage applications.

Package

Package selection can influence the mechanical design of the flow meter, as size of the package and plane of sensitivity dictates Hall-effect sensor location. This is most realized in comparing surface mount packages to a leaded TO-92 package. Figure 5 displays the difference in sensing direction of traditional and in-plane Hall-effects sensors in SOT-23 and TO-92 packages. Alternatively, if mechanical constraints limit Hall-sensor mounting options, in-plane sensors can be used to sense magnetic fields lateral to the package (Figure 5).

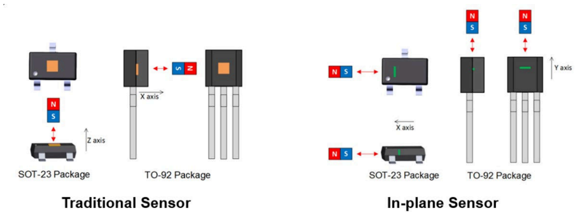

Figure 5. Package Sensitivity

Power Consumption

Low-power Hall-effect devices enable longer operating life in battery-reliant systems through reduction of active current consumption. For example, the DRV5032 low power Hall-effect switch has a 5-Hz sample rate device which consumes a typical current of just 0.54 µA at 1.8-V supply. Current consumption generally has an inverse correlation with device bandwidth, so it is necessary to balance the two characteristics for the intended flow monitoring application. If high bandwidth and low power are required, it may be necessary to lower the average current consumption by externally duty-cycling a sleep or enable pin (if the device has one), or by duty-cycling the V_{CC} pin of the device.

See Table 1 for a comparative summary on Hall-effect sensor functionality.

Table 1. Hall-Effect Sensor Summary

	Unipolar Switch	Omnipolar Switch	1D Latch	2D Latch
Magnet Implementation	Alternating poles, Spaced single orientation magnet	Spaced magnets (North or South facing)	Alternating poles	Alternating poles
Cost	Average	Average	Less expensive	More expensive
Direction Sensing Capability	Requires multiple sensors	Not possible	Requires multiple sensors	Integrated
Package Options	X2SON, TO-92, SOT-23	X2SON, TO-92, SOT-23	X2SON, TO-92, SOT-23, DSBGA	SOT-23
Output Stage	Push pull, Open drain, Current	Push pull, Open drain	Push pull, Open drain	Open drain

For more details and guides related to using Hall-effect sensors in flow meter applications, see Table 2 and Table 3.

Table 2. Alternative Device Recommendation

Device	Characteristics	Design Considerations
TMAG5231	Low-power, low-voltage (1.65 V to 5.5 V) omnipolar Hall-effect switch. Available in SOT-23 package	Minimum supply voltage of 1.65 V. 20-Hz bandwidth, low-power omnipolar switch designed to optimize the total system cost for compact, battery-operated consumer and industrial applications. Push-pull output stage does not require external pullup resistor.
TMAG5123	High-voltage (up to 38 V), in-plane, high-precision switch. Available in SOT-23 package	Wide supply voltage range (2.5 V – 38 V). High bandwidth unipolar switch (40 kHz). In-plane switch enables lateral sensing of magnetic fields, which can provide flexibility in sensor and magnet in space-constrained systems.
DRV5011	Low-voltage Hall-effect latch. Available in DSBGA, SOT-23, TO-92, and X2SON packages	Minimum supply voltage of 2.5 V. High bandwidth 1D latch (30 kHz). Various package options enable use in small form-factor flow meter designs. Push-pull output stage does not require external pullup resistor.
TMAG5110	High-sensitivity 2D Hall-effect latch. Available in SOT-23 package	Wide supply voltage range (2.5 V – 38 V). High bandwidth 2D latch (40 kHz). 2D integrated latch enables additional sensitivity compared to 1D latch. Implementation enables bidirectional sensing for reverse flow detection.

Table 3. Related Technical Resources

Name	Description
TI Precision Labs - Magnetic Sensors	A helpful video series describing the Hall-effect and how it is used in various applications
Magnetic Sensing Proximity Tool	A tool that can be used to help determine a possible magnet sensor design
Hall-Effect Sensors in Low-Power Applications	An application report on designing Hall-effect sensors in low-power applications
What is a Hall-effect sensor?	A discussion about the Hall-effect and how it is used to create magnetic sensors
Transition Detection Using Hall-Effect Sensors	An application report on a similar Hall-effect switch application
Hall Adapter EVM	Provides a fast, easy, and inexpensive way to interface with Hall-effect ICs