PRODUCT DESCRIPTION

Technical Paper
STP 00-1

Technical Advances in Hall-Effect Sensing

by Joe Gilbert

Introduction

For more than two decades Hall-effect technology has provided solutions for reliable solid-state magnetic switching and linear magnetic sensing. Evolutionary improvements have increased operational temperatures, tightened magnetic switch points, and improved sensitivity and stability. Until recently, improvements and new product introductions were not outpacing requirements. Today, product developments and introductions are occurring at a very rapid rate with new silicon processing techniques and design tools allowing the introduction of vastly improved sensor capabilities and intriguing new sensor functions. Technical advances, often driven by automotive requirements, are resulting in vast improvements to standard Hall-effect switches, latches, linear and specialty sensors available for consumer, medical, and industrial needs.

This paper will discuss several new designs recently introduced, including programmable switches and proximity sensors as well as a unique micro-power Hall-effect switch.

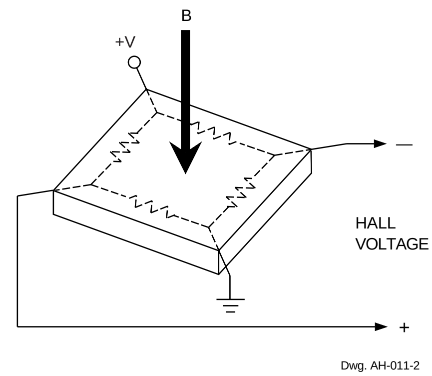

Figure 1a — Single Hall-plate

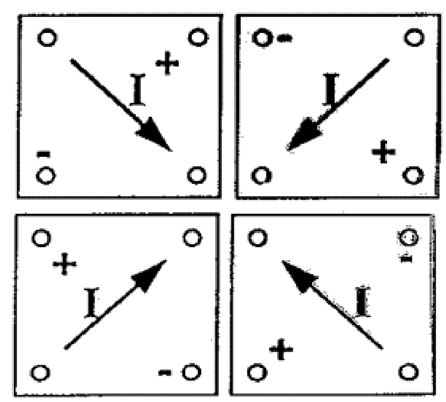

Figure 1b — Quadratic Hall-plate

Past and present Hall-effect sensors

Early Hall-effect sensor designs utilized a single Hall element (figure 1a), while many designs originated within the last ten years utilized a four-plate Hall-element array (figure 1b), which can be considered a resistor array similar to a Wheatstone bridge. The quadratic array placed four Hall-plates in parallel providing a “mechanically averaged” Hall voltage. Offset errors and mechanical stresses tended to cancel out; nearly a 10x improvement in stability and stress immunity can be realized using this scheme (figure 2).

Present and future Hall-effect sensors

Most Hall-effect sensors are now designed using a chopped Hall-plate (figures 3a and 3b). Terms such as “chopper stabilized” or “dynamic offset cancellation” are used to describe this function. This newest technique again utilizes a single Hall-plate. The four-terminal element is chopped (electrically rotated) at a high frequency (typically 100 kHz to 500 kHz, depending upon the sensor function and the manufacturer.

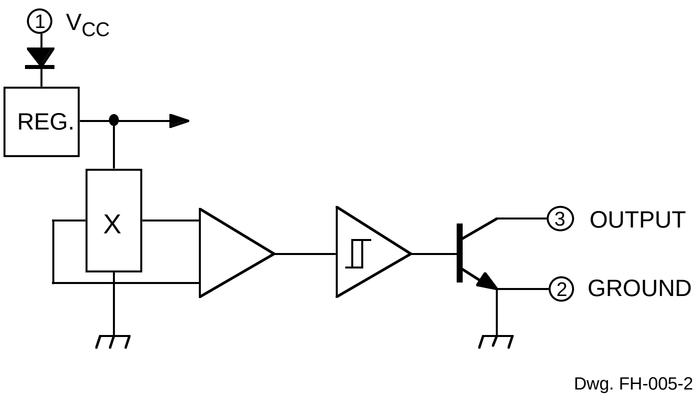

Figure 2 — Second generation digital sensor

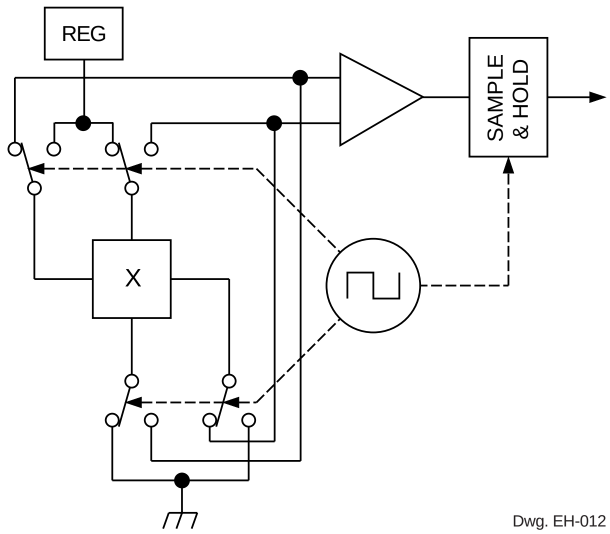

Figure 3a — "Chopped" Hall element

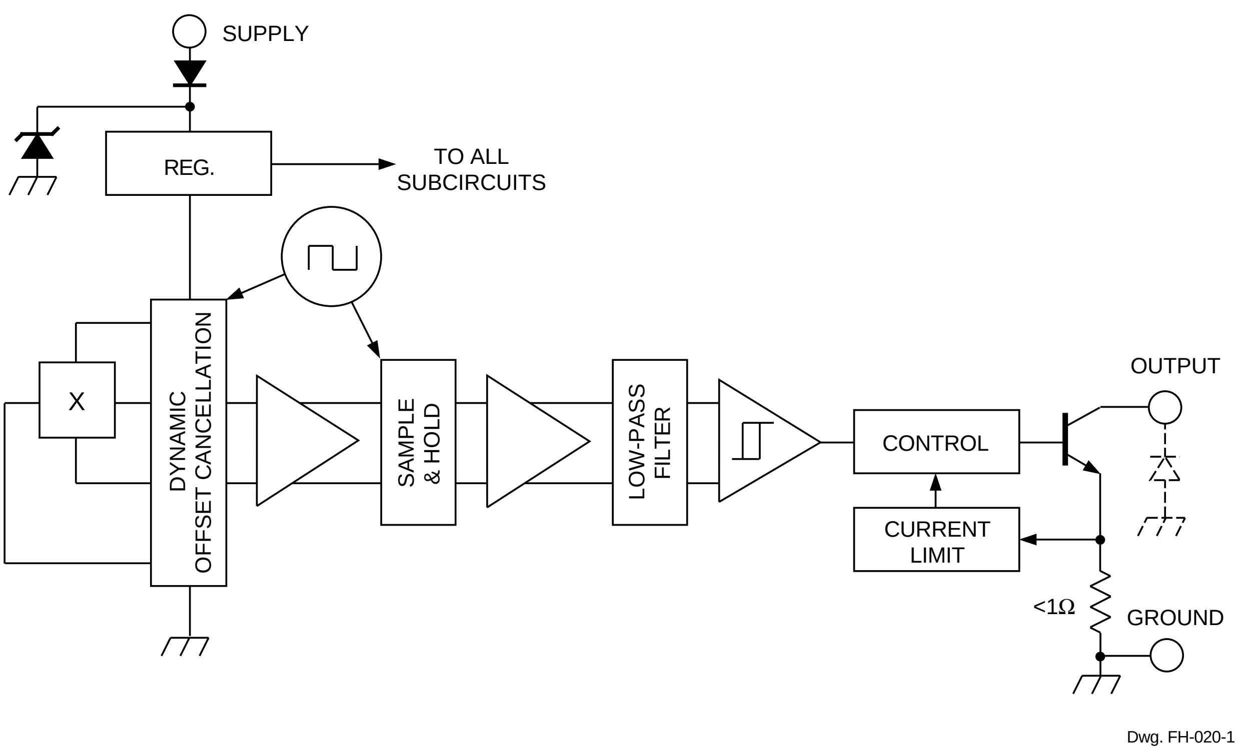

Figure 3b — Third generation chopper-stabilized digital switch

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Low-voltage, micro-power, magnetic pole-independent switch

In answer to requests for a solid-state replacement for fragile reed switches a low-voltage, low-power consumption, Hall-effect switch was introduced. Initial targets were for 3 V operation and a very low current draw. Because of the physics of practical silicon Hall-plate technology, the normal minimum 4 mA Hall-current necessary for satisfactory performance was not avoidable. To reduce current draw to a level suitable for battery operation, this sensor operates at 1/1000 duty cycle, sampling the magnetic environment every 60 ms (figure 4). The average current drain is then the product of duty cycle and Hall-element current. The A3210 sensor (figure 5) is designed for operation between 2.5 V and 3.5 V with a specified maximum voltage of 5.0 V (12 V BiCMOS process).

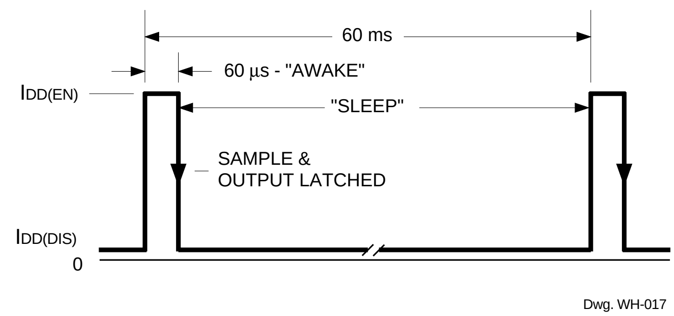

Figure 4 — Low duty cycle operation

In search of low power consumption

A BiCMOS silicon process was selected for wafer fabrication with a feature size of about 1.2 microns. To reduce current draw the normal voltage regulator was not included on the single silicon IC necessitating the use of a regulated supply voltage. To further reduce current draw, an NMOS open-drain output replaces the traditional npn output transistor. As a compromise, the duty cycle was set at 0.10% with on-chip capabilities to set this to 12.5% for possible future applications (the A3209).

Mission accomplished. *Average* current draw has been reduced from between 4 mA and 5 mA to about 9 µA with a supply voltage of 3 V.

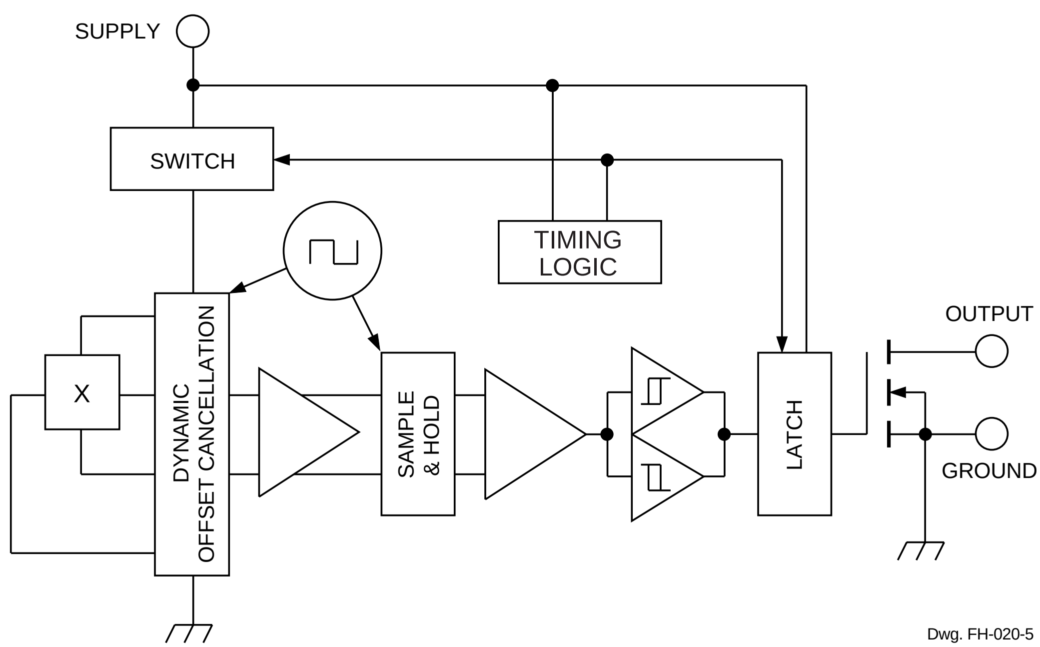

Figure 5 — Micro-power Hall switch

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Pole independence

Because reed switches do not normally require magnetic orientation, dual comparators were incorporated into the IC allowing the sensor to switch with either magnetic polarity; when the magnetic flux density is greater than B_{OPS} (a south pole) or less than (algebraic convention) B_{OPN} (a north pole).

Latched output

The sensor output is set and/or held in the correct state at each sample. The output state will change only with a change in magnetic field during the sample period, as long as power is applied.

Sensitivity and stability

To achieve high sensitivity, stability, and immunity to stress, a chopper-stabilized single Hall-element is utilized with the necessary timing and sample-and-hold circuitry included.

Applications

The A3210 sensor is being used in many cellular flip-phone designs for the flip-cover position sensor. This sensor is also suitable for many other applications requiring low power consumption, including battery-operated pagers, palmtop, and laptop computers and is a good choice for applications using strings of sensors for position or liquid-level sensing.

Applications not suitable for the A3210 would be those that involve moving magnets or magnetic fields, which could be missed by time periods greater than the 60 ms sampling rate allows. The newer A3209 features a shorter sampling period at the expense of increased average power drain.

Programmable digital Hall-effect switch

The A3250 and the A3251 are chopper-stabilized, programmable, unipolar digital switches.

The A3250 output turns on (switches low) in the presence of a positive magnetic field; the A3251 turns off (switches high) in the presence of a positive magnetic field.

Features

- Chopper stabilized
- Reverse-battery protection
- Supply transient protection
- Output short-circuit protection
- Standard 3-lead SIP package
- Programmable switch points
- 1.2 micron BiCMOS process

Switch point programming

Programming is performed over the sensors supply pin and can be factory programmed or programmed after assembly (preferred).

The operate point (B_{OP}) can be set between 50 G and 500 G. Once set, hysteresis will typically be 20 G. That is to say that if B_{OP} is programmed to be 50 G, the release point (B_{RP}) will typically be 30 G; or if B_{OP} is set to 500 G B_{RP} will typically be 480 G.

Programming protocol

There are basically three programming steps: (1) program enable; (2) set operate point; and (3) set lock-bit.

Program enable

A sequence of pulses on the sensor supply pin will place the sensor into the programming mode (see figure 6a).

Set Ooerate point

The magnetic operate point may be set to any of 64 address codes (with resolution being typically 11 gauss/step) starting with a non-programmed switch point that is

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typically 20 gauss (see figure 6b). The programmer can be set to program all devices to a specified code. However, best total system performance will be achieved if each device is programmed in the actual assembly or application. This way variations in flux density, due to magnet and air gap variation and other stacked up assembly tolerances, are minimized.

Set lock-bit

After the desired codes are set a lock bit is set (figure 6c). This prevents accidental re-programming.

Applications

Any application requiring accurate, specific, or uniform switch points with low hysteresis will benefit from this technology.

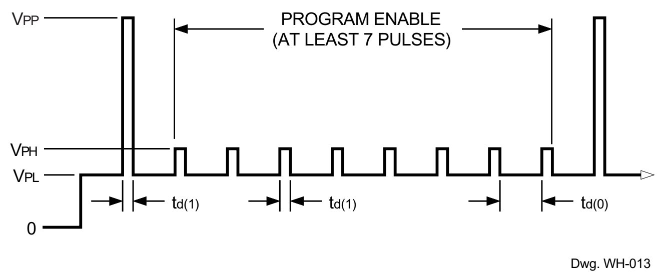

Figure 6a — Program enable

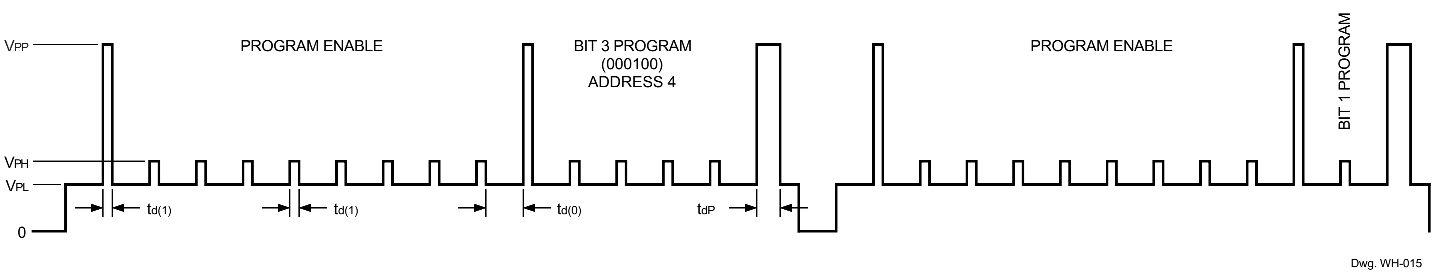

Figure 6b — Set operate point

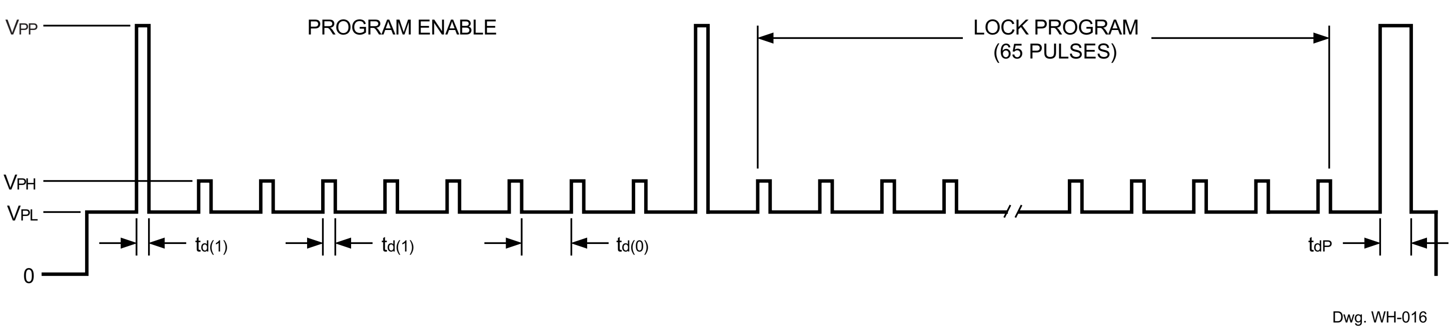

Figure 6c — Set lock bit

Programmable proximity switch

The ATS535 incorporates the programmable A3250 into an assembly with a biasing magnet. Such a subassembly (figure 7) is well suited for switching in proximity to a ferrous target, cam, or gear.

Features

- Chopper stabilized
- Reverse-battery protection
- Supply transient protection
- Output short-circuit protection
- 4-pin nylon subassembly
- Programmable switch point
- True power-on sensor
- True zero-speed sensing
- 1.2 micron BiCMOS process

Programming

Switch-point programming is identical to that previously discussed for the A3250. The basic difference is mind-set and the use of a ferrous target instead of a separate magnet.

Mind-set enters the equation as we are now programming in terms of proximity or distance to the target (airgap), not in terms of flux density. Air gaps of 0.5 mm to 3 mm are achievable with most small or fine-pitched targets. Air gaps out to 5 mm are achievable with larger targets.

The sensor is programmed by positioning the target at the desired switch point and incrementing the address code until the switch point is detected. Or, in the case of a cam or gear type target, the target can be rotated in front of the sensor at the intended air gap and the switch point set.

Applications

Applications are diverse for this device. Simple head-on sensing where the target moves directly towards the sensor is a primary use. This sensor is also ideal for zero-speed gear-tooth sensing, providing accurate edge detection and a true power-on position signal (low in the presence of a target, high with absence of target).

One successful application accurately senses the head of a machine screw 5 mm in diameter at a 3 mm air gap.

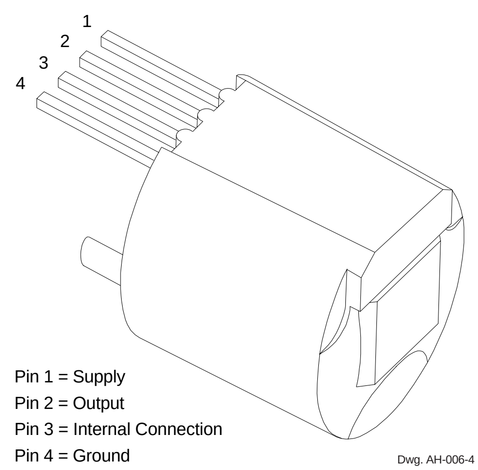

Figure 7 — Proximity sensor subassembly (with SmCo magnet)

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