Using Hall Effect Sensors for Rotary Encoding Applications

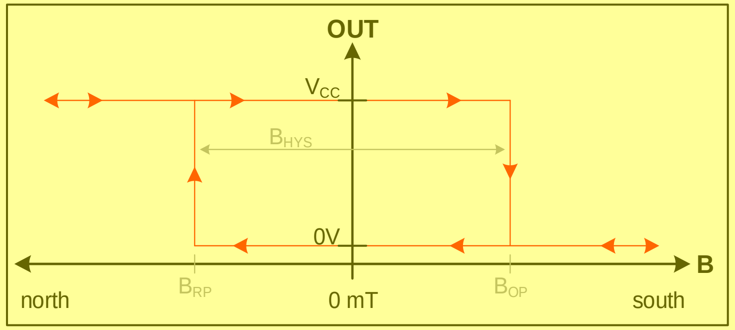
TI Precision Labs – Magnetic Position Sensing

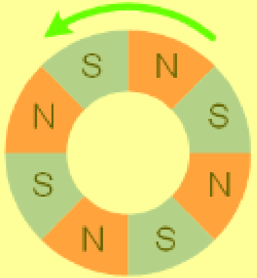
Presented and prepared by Dan Harmon

Hall effect sensors

Hall effect latch

Indicates the most recently measured magnetic flux density. These are used in rotary applications such as BLDC motor sensors and incremental encoding.

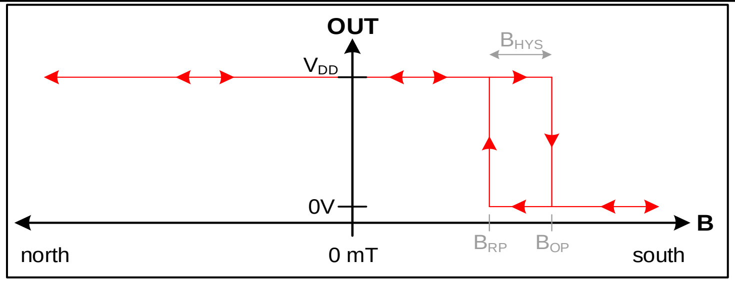




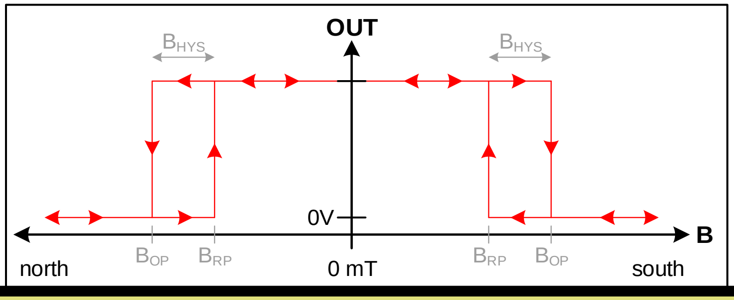
Hall effect switch

Indicates the presence or absence of magnetic flux density compared to a defined threshold.

- Unipolar switch – Responds only to south magnetic poles
- Omnipolar switch – Responds to both south and north magnetic poles



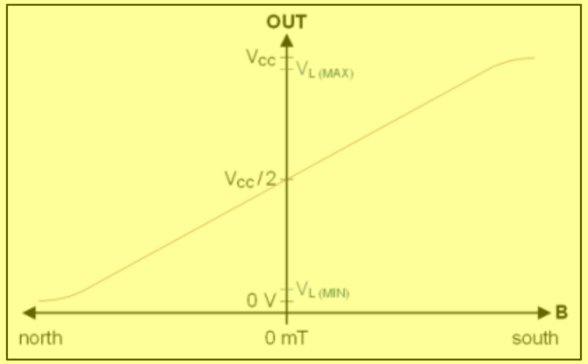
Unipolar

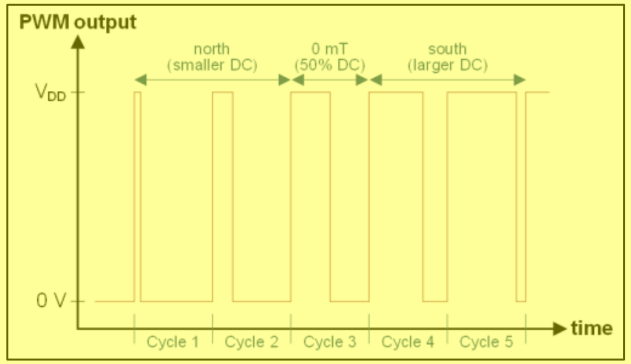


Omnipolar

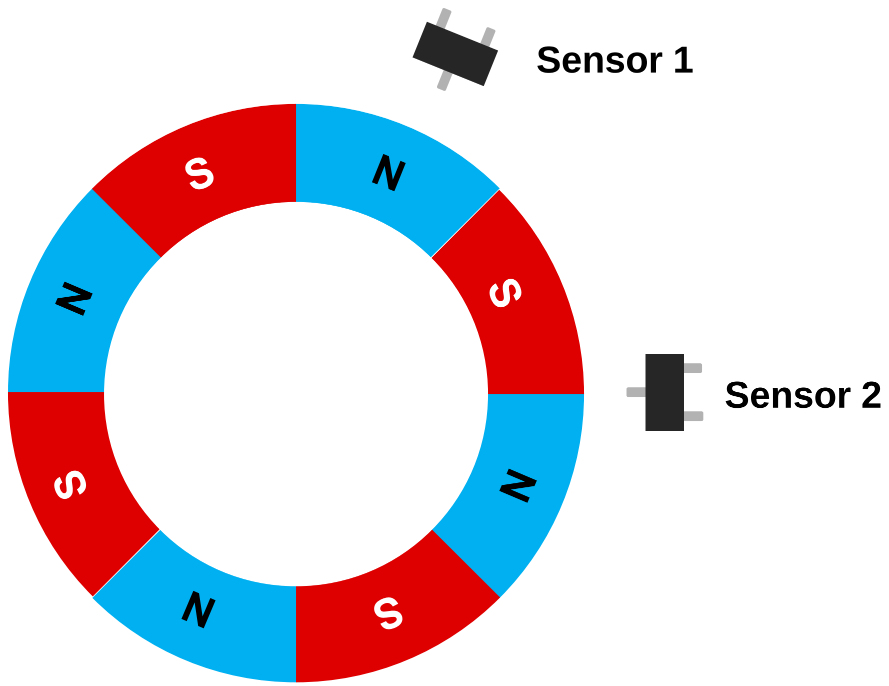
Linear Hall effect sensors

Outputs a signal that is proportional to magnetic flux density in order to measure precise movement.



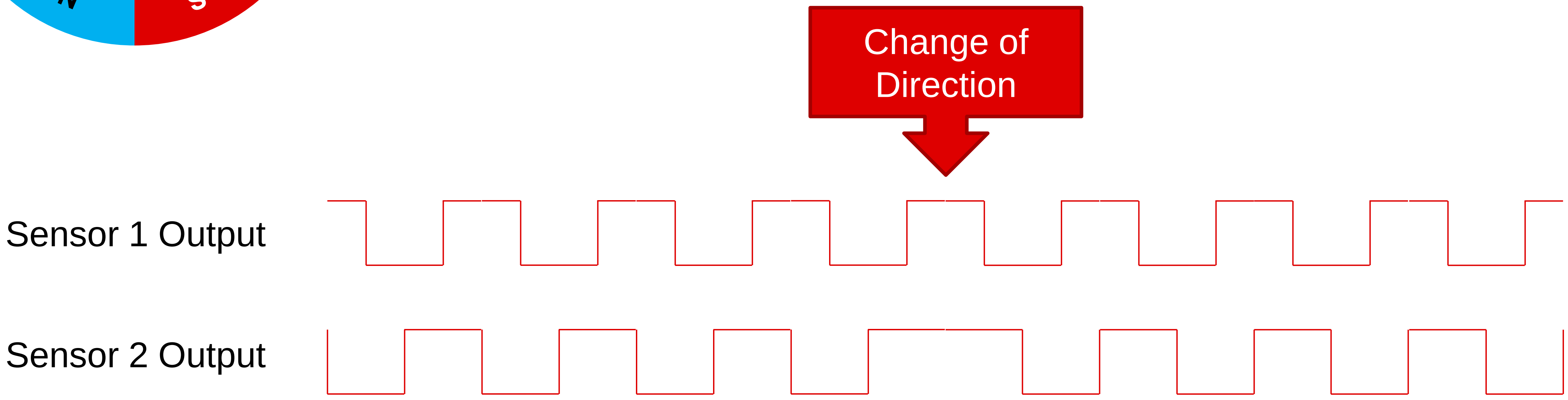


Rotary encoding using a Hall effect latch

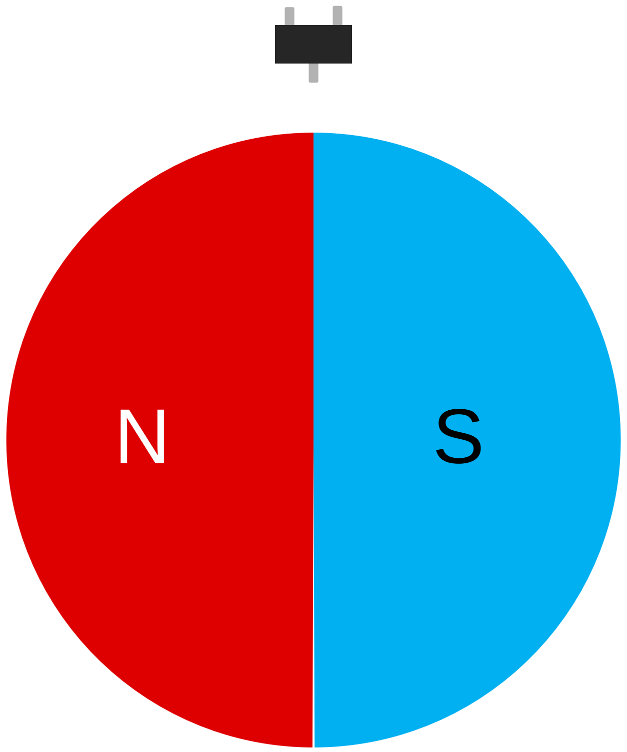


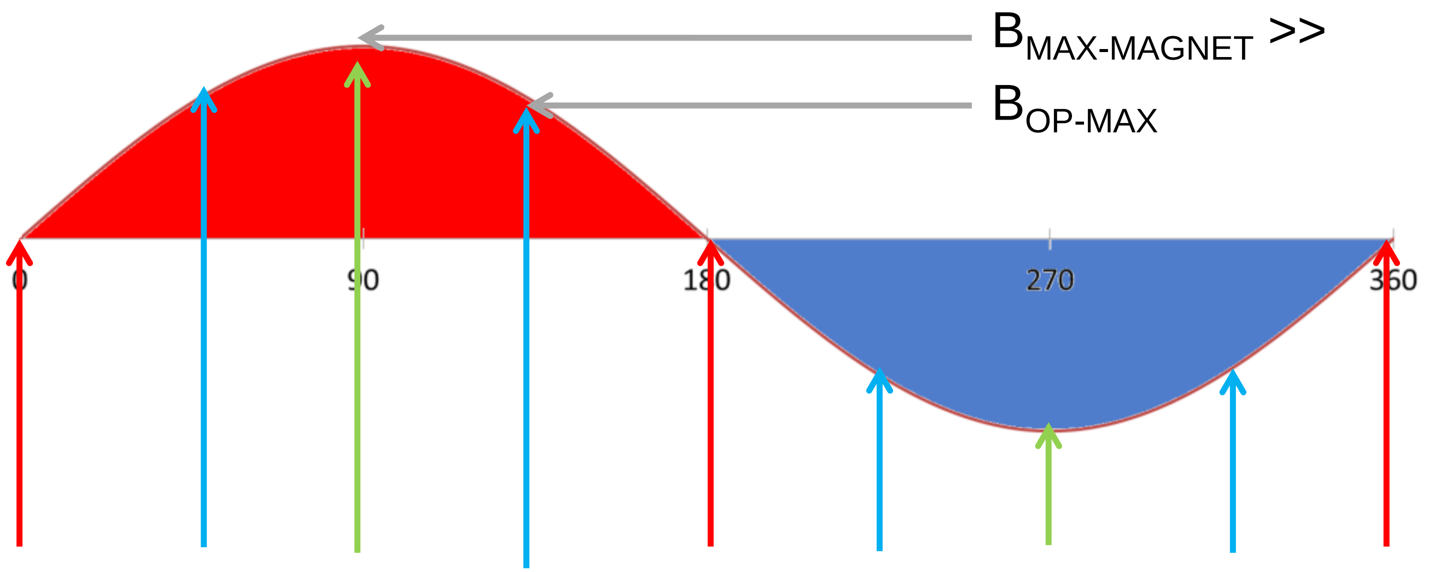
Latch Spacing = ½ Pole + Integer # of Poles

Output transitions = 360° / # poles / # sensors



Sampling frequency vs. RPM





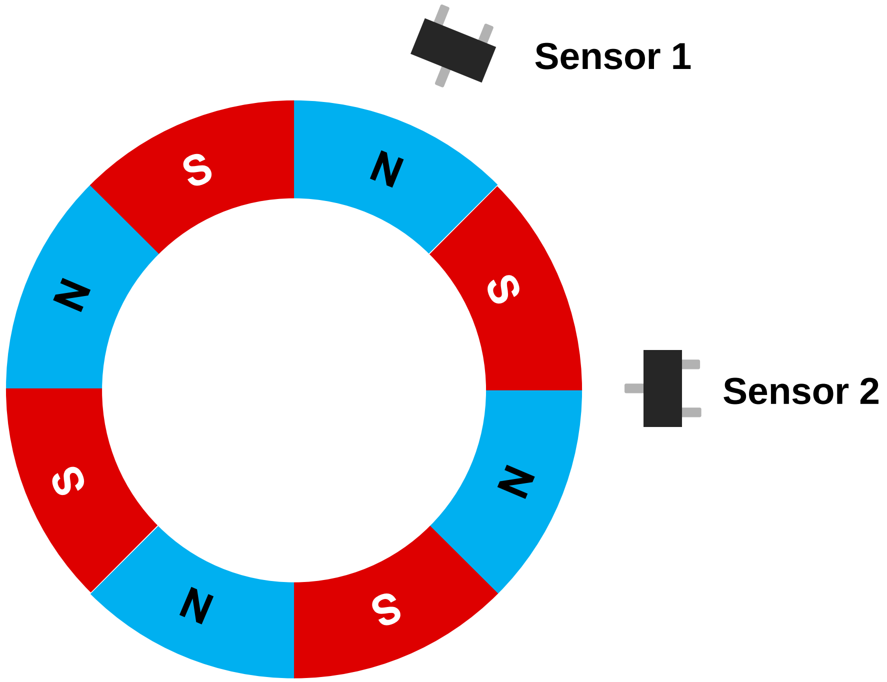
Sampling Times to be avoided

Ideal Sampling Times

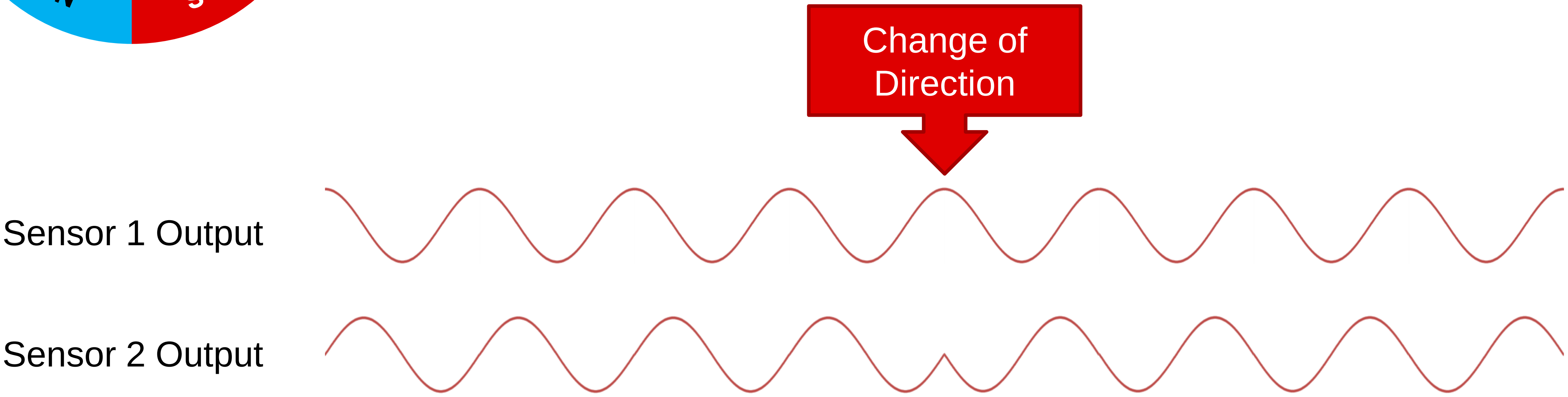
Sampling at twice the pole frequency insures at least one non-zero reading

Rotational speed: 60,000 RPM → 1000 revs/sec → 2000 poles/sec → Sample frequency ≥ 4000Hz

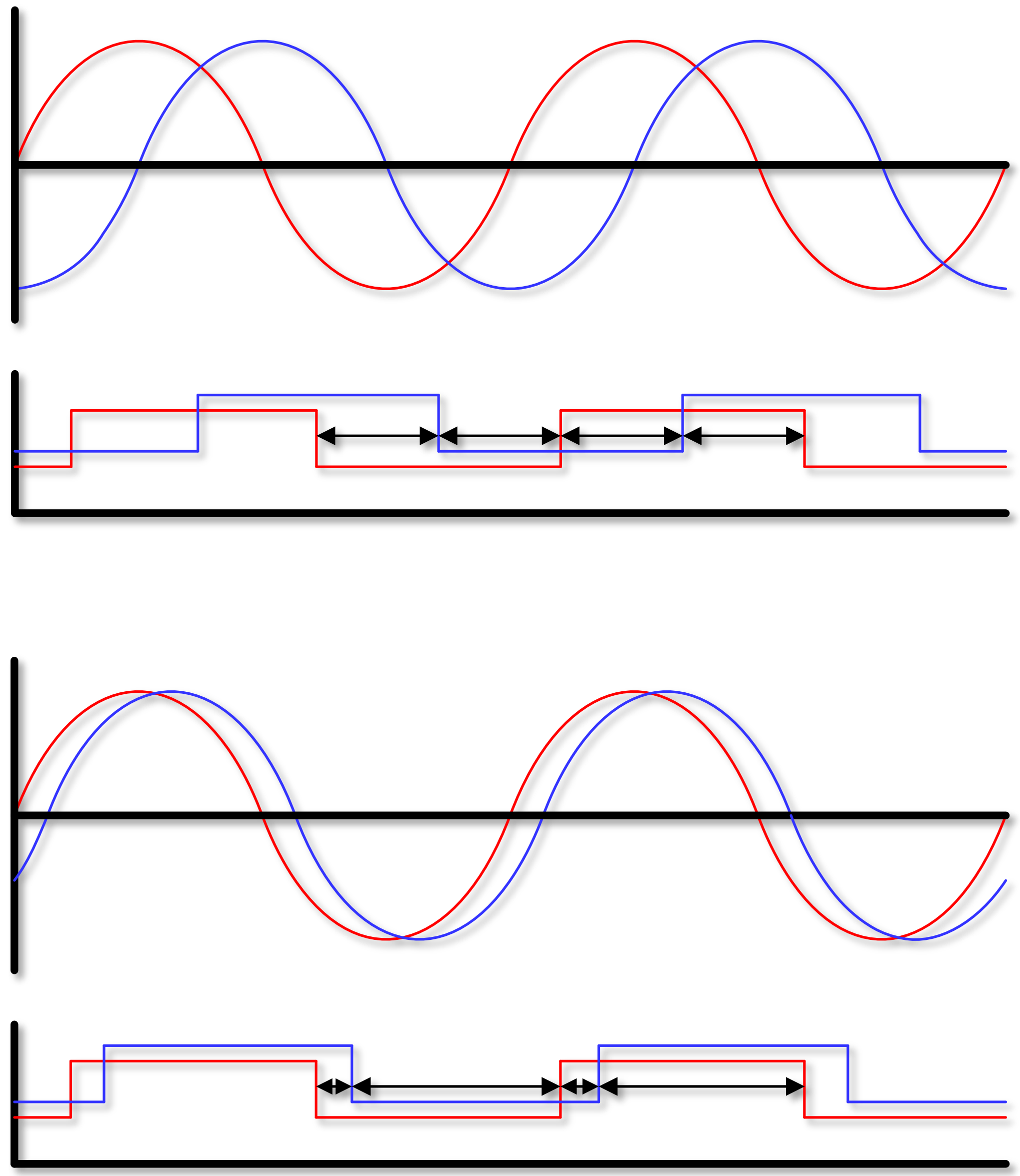
Rotary encoding using a linear Hall effect devices



Sensor Spacing = ½ Pole + Integer # of Poles



Magnet Pole-Pitch Challenges

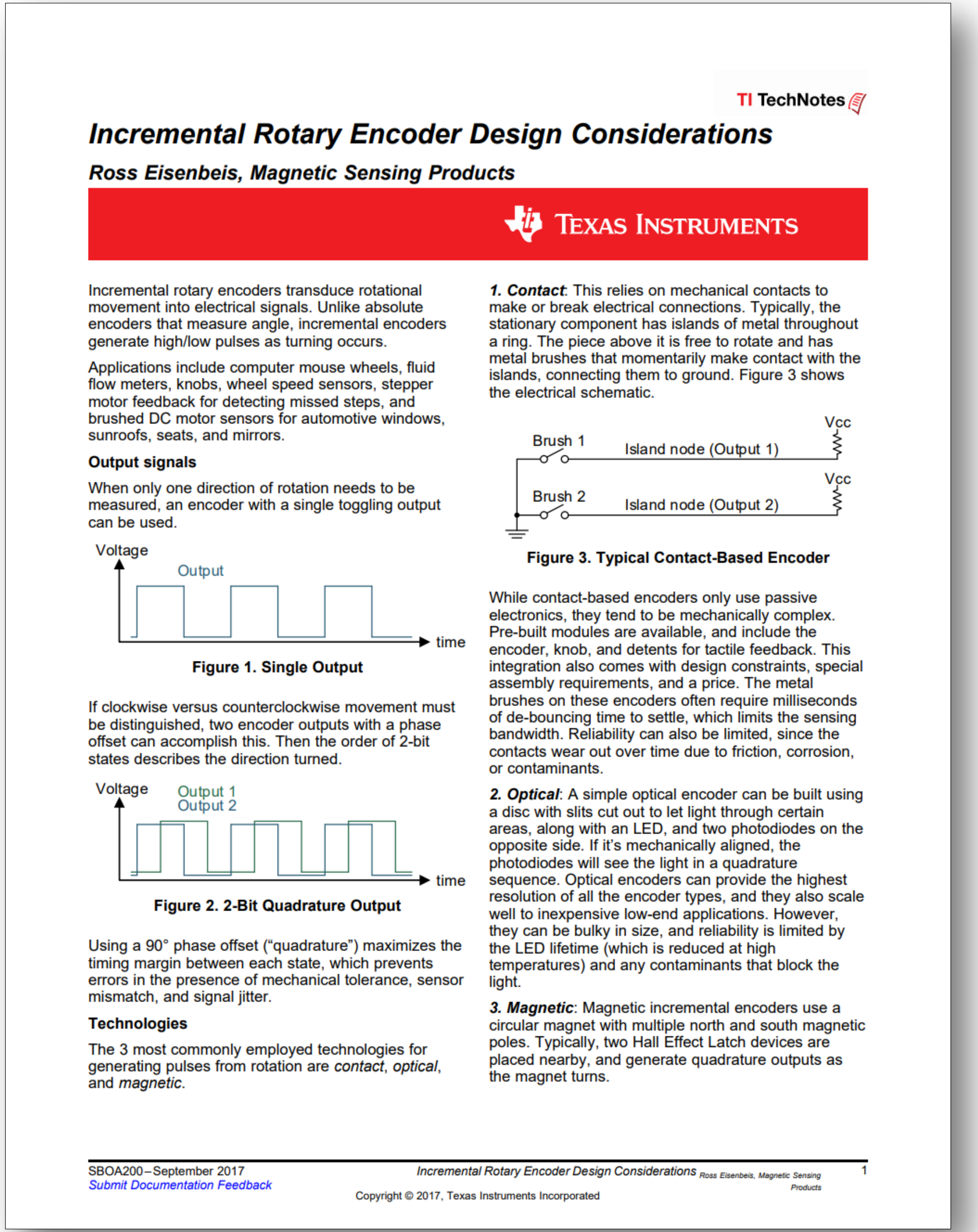


- Direction determination requires definitive quadrature
- Magnet pole placement & strength variation
  - Pole “size” variation up to ±3%
  - Pole field strength variation up to ±25%
- Precise design of pole pitch to optimize switching point needed

Support collateral

TIDesigns

TIDA-00480: Hall Sensor Rotary Encoder



TI TechNotes

Incremental Rotary Encoder Design Considerations

Ross Eisenbeis, Magnetic Sensing Products

TEXAS INSTRUMENTS

Incremental rotary encoders transduce rotational movement into electrical signals. Unlike absolute encoders that measure angle, incremental encoders generate high/low pulses as turning occurs.

Applications include computer mouse wheels, fluid flow meters, knobs, wheel speed sensors, stepper motor feedback for detecting missed steps, and brushed DC motor sensors for automotive windows, sunroofs, seats, and mirrors.

Output signals

When only one direction of rotation needs to be measured, an encoder with a single toggling output can be used.

Figure 1. Single Output

If clockwise versus counterclockwise movement must be distinguished, two encoder outputs with a phase offset can accomplish this. Then the order of 2-bit states describes the direction turned.

Figure 2. 2-Bit Quadrature Output

Using a 90° phase offset ("quadrature") maximizes the timing margin between each state, which prevents errors in the presence of mechanical tolerance, sensor mismatch, and signal jitter.

Technologies

The 3 most commonly employed technologies for generating pulses from rotation are *contact*, *optical*, and *magnetic*.

1. Contact: This relies on mechanical contacts to make or break electrical connections. Typically, the stationary component has islands of metal throughout a ring. The piece above it is free to rotate and has metal brushes that momentarily make contact with the islands, connecting them to ground. Figure 3 shows the electrical schematic.

Figure 3. Typical Contact-Based Encoder

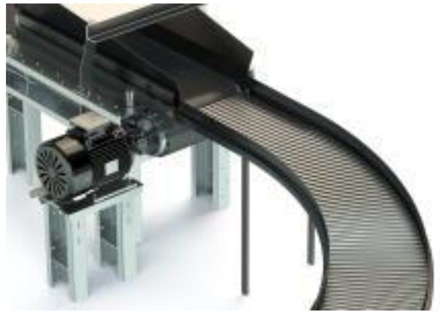
While contact-based encoders only use passive electronics, they tend to be mechanically complex. Pre-built modules are available, and include the encoder, knob, and detents for tactile feedback. This integration also comes with design constraints, special assembly requirements, and a price. The metal brushes on these encoders often require milliseconds of de-bouncing time to settle, which limits the sensing bandwidth. Reliability can also be limited, since the contacts wear out over time due to friction, corrosion, or contaminants.

2. Optical: A simple optical encoder can be built using a disc with slits cut out to let light through certain areas, along with an LED, and two photodiodes on the opposite side. If it's mechanically aligned, the photodiodes will see the light in a quadrature sequence. Optical encoders can provide the highest resolution of all the encoder types, and they also scale well to inexpensive low-end applications. However, they can be bulky in size, and reliability is limited by the LED lifetime (which is reduced at high temperatures) and any contaminants that block the light.

3. Magnetic: Magnetic incremental encoders use a circular magnet with multiple north and south magnetic poles. Typically, two Hall Effect Latch devices are placed nearby, and generate quadrature outputs as the magnet turns.

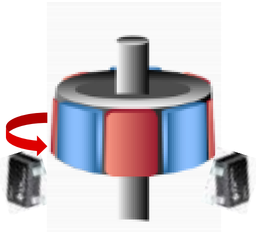
Common rotary encoding applications

Linear measurement systems



Conveyor belts

Rotary encoders



Servo motors

Printers

Human interface knobs

To find more magnetic position sensing technical resources and search products, visit ti.com/halleffect