Designing with Hall-Effect Switches & Latches

TI Precision Labs – Magnetic Position Sensing

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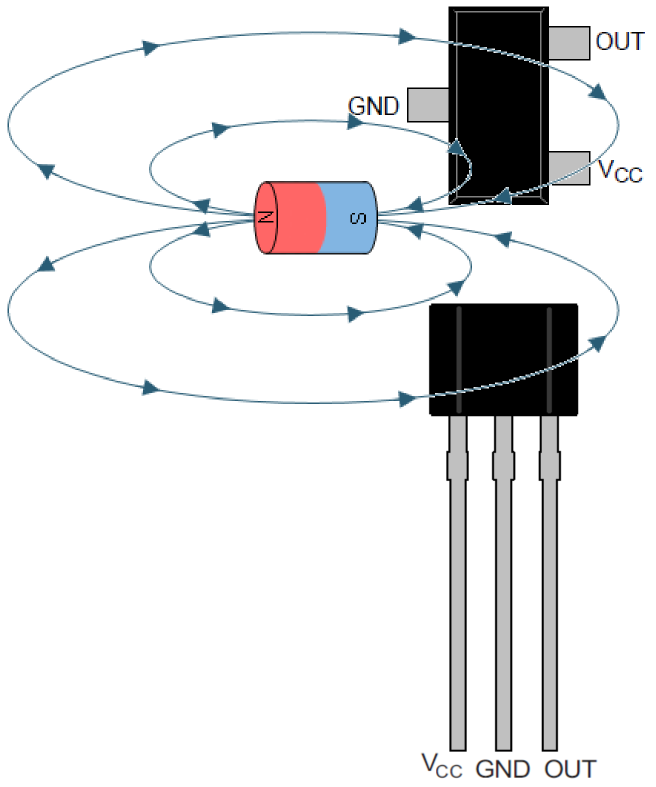
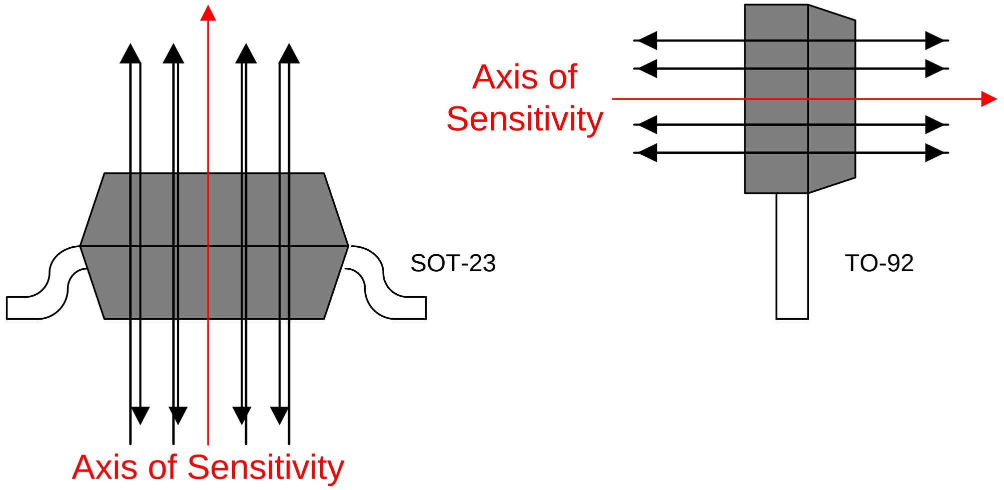
What are Hall-Effect Switches and Latches?

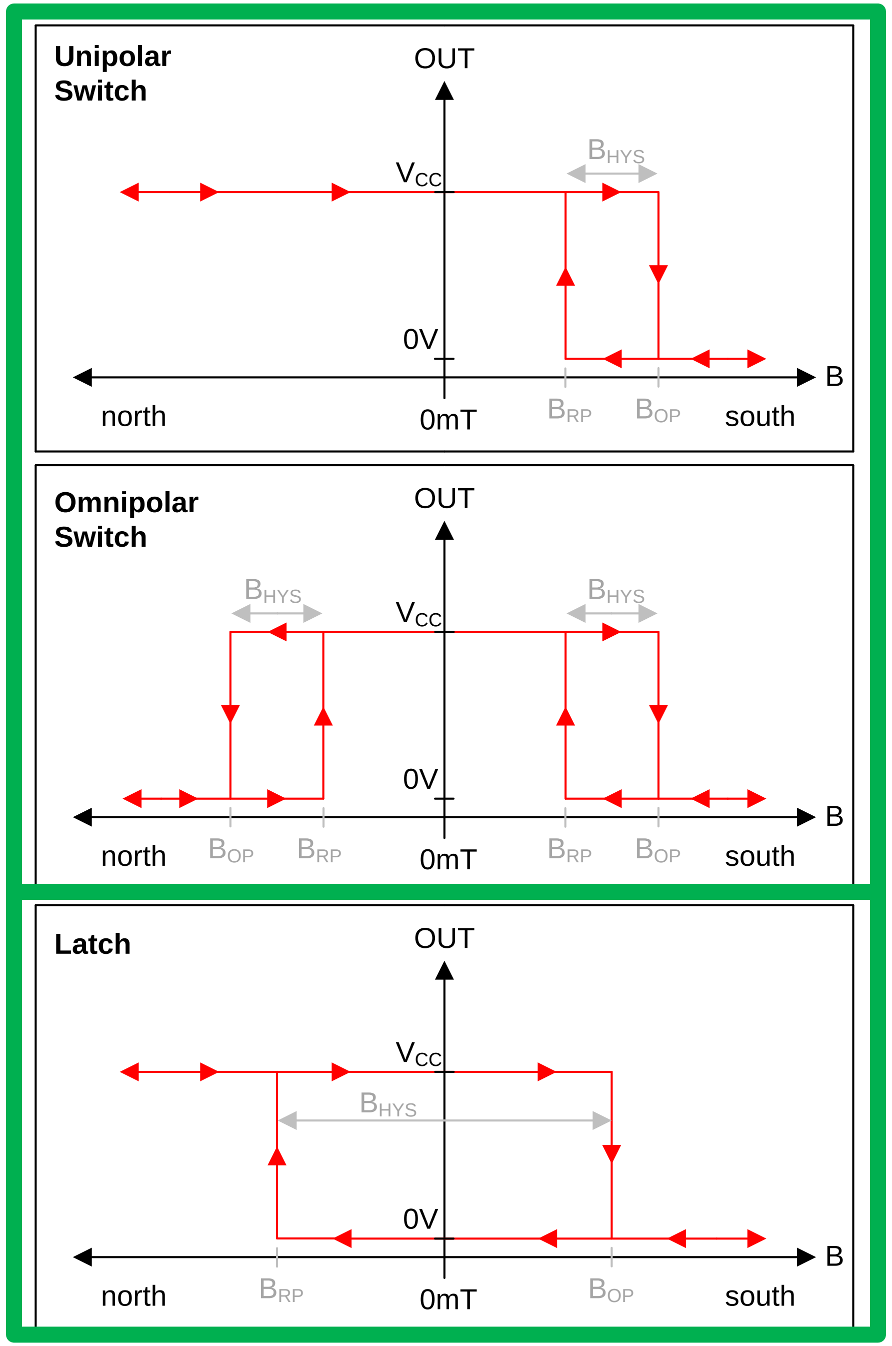
- Magnetic flux density (B) to binary output
  - Typically used with moving permanent magnets for contactless motion sensing
  - Applications: hinges, buttons, levers, knobs, valves, relays, fans, etc.
- Directional
  - Most sense B in 1-D
  - Up to 3 axes of sensitivity possible
- Sense B amplitude and polarity
  - Switches detect changes in B amplitude
  - Latches detect changes in B polarity



B ≭ 0



Implemented as Hysteresis Comparators



Upper magnetic threshold, B_{OP}: “Operate Point”
Lower magnetic threshold, B_{RP}: “Release Point”
Amount of hysteresis, $B_{HYS} = |B_{OP} - B_{RP}|$

Switches and latches have similar responses

$|B| > |B_{OP}|$ ➔ V_{OUT} LOW
$|B| < |B_{RP}|$ ➔ V_{OUT} HIGH

Behaviors differ due to polarities of B_{OP} and B_{RP}

Switches ➔ B_{OP} and B_{RP} have same polarity

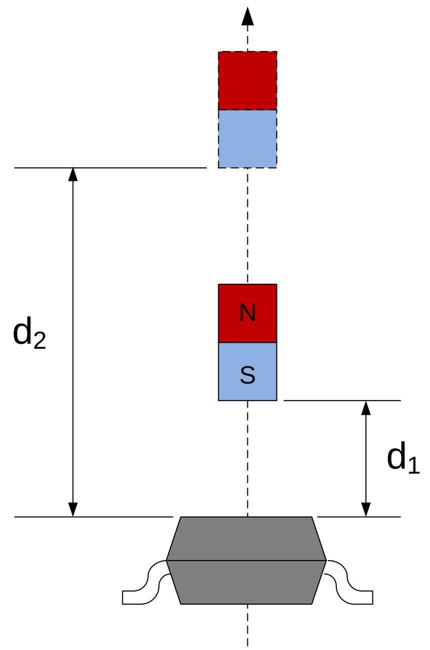
Latches ➔ B_{OP} and B_{RP} have opposite polarity

Typical Switch Application: Proximity Sensing

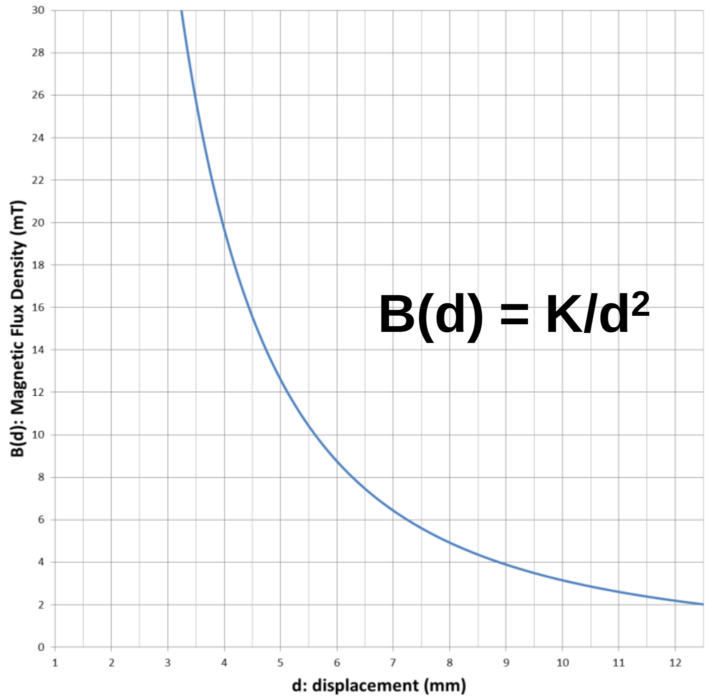
- Magnet moves towards or away from switch along axis
  - Need V_{OUT} HIGH when d > d_2 and LOW when d < d_1
  - Pick suitable sensor and magnet

- First-order algebraic analysis for sensor selection
  - Need $B(d_1) > B_{OP,MAX}$ and $B(d_2) < B_{RP,MIN}$ ➔ need $\frac{B(d_1)}{B(d_2)} > \frac{B_{OP,MAX}}{B_{RP,MIN}}$ (1)
  - NOTE: **B(d) α 1/d²** (approximately) for common magnet shapes

$$\left.\begin{array}{l} B(d_1) = \dfrac{K}{{d_1}^2} \\ \\ B(d_2) = \dfrac{K}{{d_2}^2} \end{array}\right\} \quad \frac{B(d_1)}{B(d_2)} = \frac{{d_2}^2}{{d_1}^2} > \frac{B_{OP,MAX}}{B_{RP,MIN}} \quad ➡ \quad \boxed{\frac{B_{OP,MAX}}{B_{RP,MIN}} < \left(\frac{d_2}{d_1}\right)^2 \qquad (2)}$$



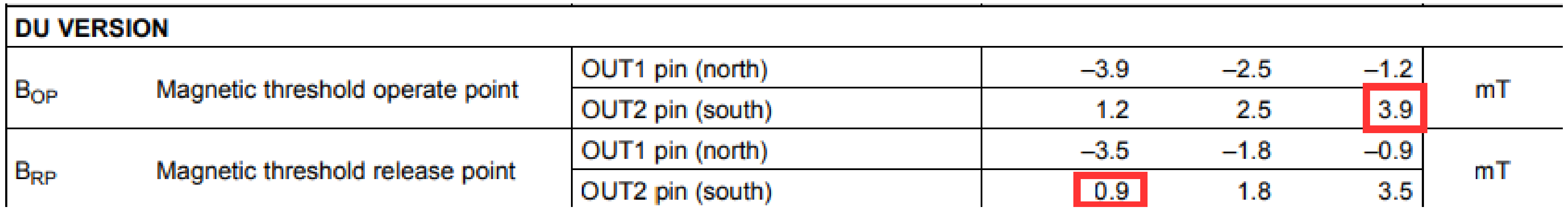
Axis of sensitivity



Switch Design Example: Sensor Selection

- If d_1 = 2mm and d_2 = 6mm, need: $$\frac{B_{OP,MAX}}{B_{RP,MIN}} < \left(\frac{6mm}{2mm}\right)^2 = 9$$

- Compute $B_{OP,MAX}/B_{RP,MIN}$ for devices of interest
  - If DRV5032 is considered, DU, AJ and ZE will likely work:

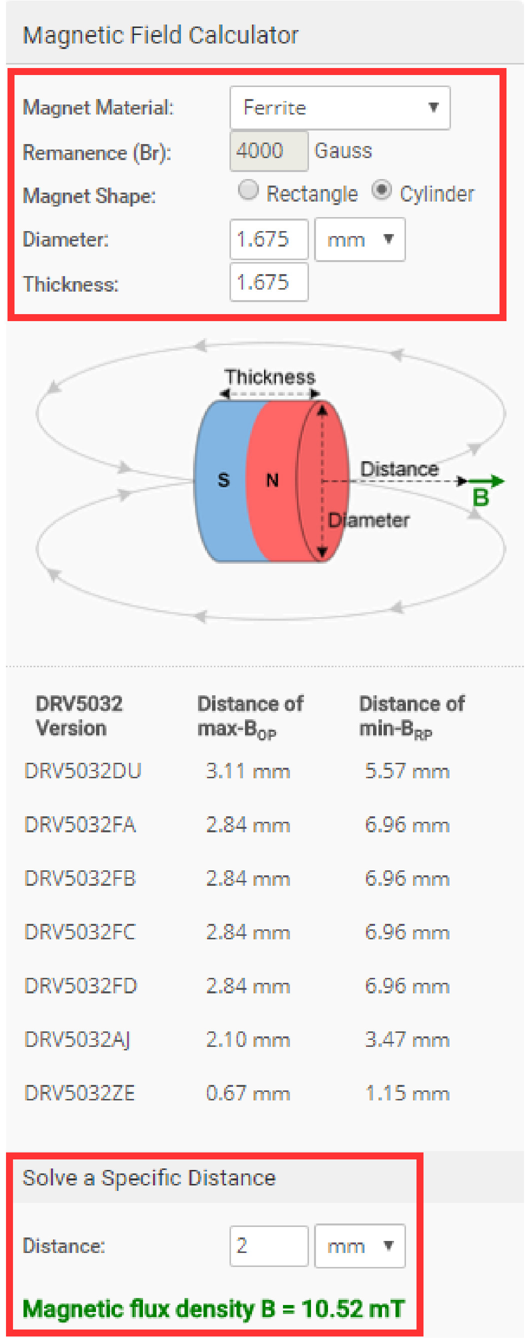


DU VERSION						
B_{OP}	Magnetic threshold operate point	OUT1 pin (north)	–3.9	–2.5	–1.2	mT
		OUT2 pin (south)	1.2	2.5	3.9	
B_{RP}	Magnetic threshold release point	OUT1 pin (north)	–3.5	–1.8	–0.9	mT
		OUT2 pin (south)	0.9	1.8	3.5	

DRV5032 variant	$B_{OP,MAX}$	$B_{RP,MIN}$	$B_{OP,MAX}/B_{RP,MIN}$
DU	3.9	0.9	4.33
FA, FB, FC, FD	4.8	0.5	9.6
AJ	9.5	3	3.17
ZE	63	30	2.1

Switch Design Example: Magnet Selection

- Use online tool available on product page
- Adjust magnet properties until B(2mm) > $B_{OP,MAX}$ and B(6mm) < $B_{RP,MIN}$
- For example, magnet selected works for both DRV5032DU and AJ
- Similarly a 6mm x 4mm cylindrical ferrite magnet would work for the DRV5032ZE



Magnetic Field Calculator

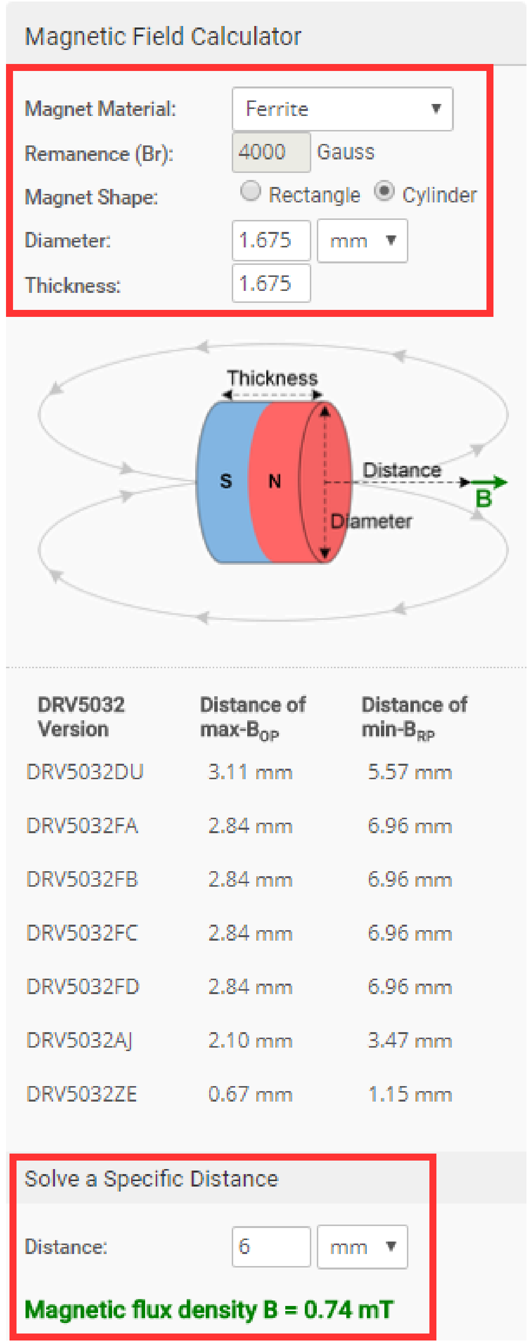
Magnet Material: Ferrite ▾
Remanence (Br): 4000 Gauss
Magnet Shape: ○ Rectangle ● Cylinder
Diameter: 1.675 mm ▾
Thickness: 1.675

DRV5032 Version	Distance of max-B_{OP}	Distance of min-B_{RP}
DRV5032DU	3.11 mm	5.57 mm
DRV5032FA	2.84 mm	6.96 mm
DRV5032FB	2.84 mm	6.96 mm
DRV5032FC	2.84 mm	6.96 mm
DRV5032FD	2.84 mm	6.96 mm
DRV5032AJ	2.10 mm	3.47 mm
DRV5032ZE	0.67 mm	1.15 mm

Solve a Specific Distance

Distance: 2 mm ▾

Magnetic flux density B = 10.52 mT



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Solve a Specific Distance

Distance: 6 mm ▾

Magnetic flux density B = 0.74 mT

Typical Latch Application: Incremental Rotary Encoding

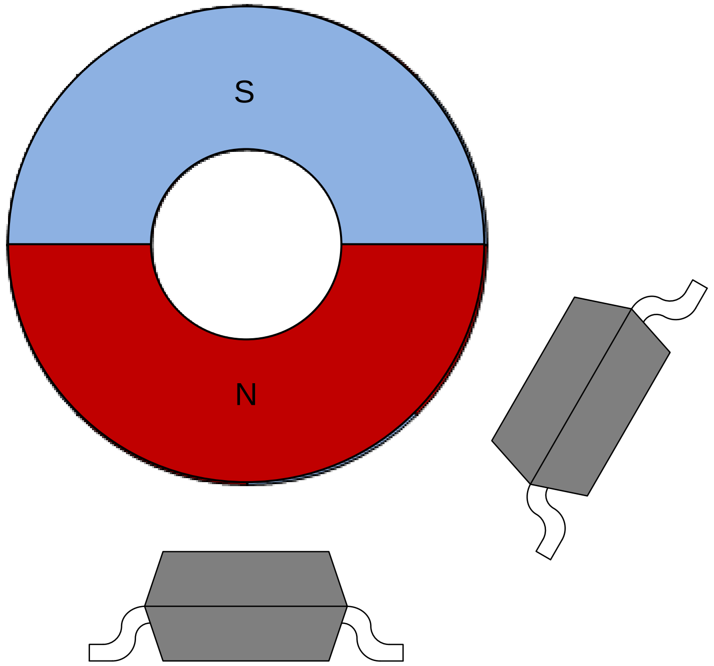
- N-pole magnet on rotary shaft, with M latch sensors
  - Target angle resolution specified ➔ **select N, M**

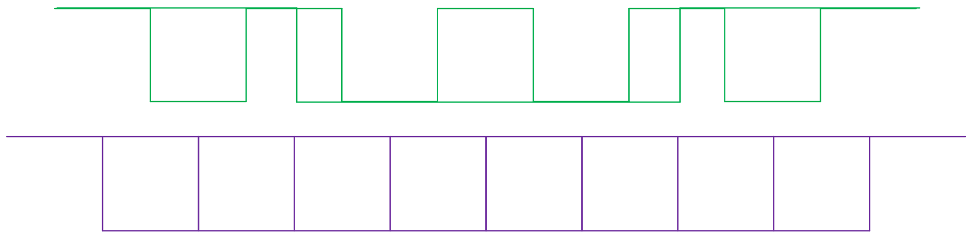
$$\# \, transitions = M \times N \geq \frac{360°}{Resolution} \qquad (3a)$$

  - Need M ≥ 2 out-of-phase sensors to resolve spin direction
  - Need N even ➔

$$N \geq 2 \times CEIL\left(\frac{180°}{Resolution \times M}\right) \qquad (3b)$$

  - Magnet can be placed arbitrarily close to sensor(s)





- Other sensor selection criteria
  - Sufficient sampling rate to support angular speed (RPM)

$$f_{SAMPLE}[Hz] > \frac{RPM}{60} \times N \times 2 \qquad (4)$$

Latch Design Example

- Target angle resolution = 5°, RPM ≤ 10000

$$\#transitions = M \times N \geq \frac{360°}{Resolution} = 72$$

$$Use\ M = 2\ for\ sensing\ spin\ direction$$

$$\therefore N \geq 2 \times CEIL\left(\frac{180°}{Resolution \times M}\right) = \mathbf{36\ (18\ pairs)}$$

- If only 20-pole magnet available

$$M \geq \frac{72}{N} = 3.6 \Longrightarrow Use\ \boldsymbol{M} = \mathbf{4\ sensors}$$

$$Resolution = \frac{360°}{M \times N} = 4.5°$$

- Sensor sampling rate (for N = 36)

$$f_{SAMPLE}[Hz] > \frac{RPM}{60} \times N \times 2 = \mathbf{12kHz}$$

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