TMR SENSORS AND THEIR APPLICATIONS

XtremeSense TMR Technology

April 2024

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TMR technology provides the highest accuracy, highest speed Magnetic Sensor ICs available in the market today

Hall Effect and TMR bring value to market

Hall Effect Sensor

- Leading sensing technology with majority of market through 2030
- Most proven reliability over wide temperature ranges

Tunneling Magneto-Resistive (TMR) Sensor

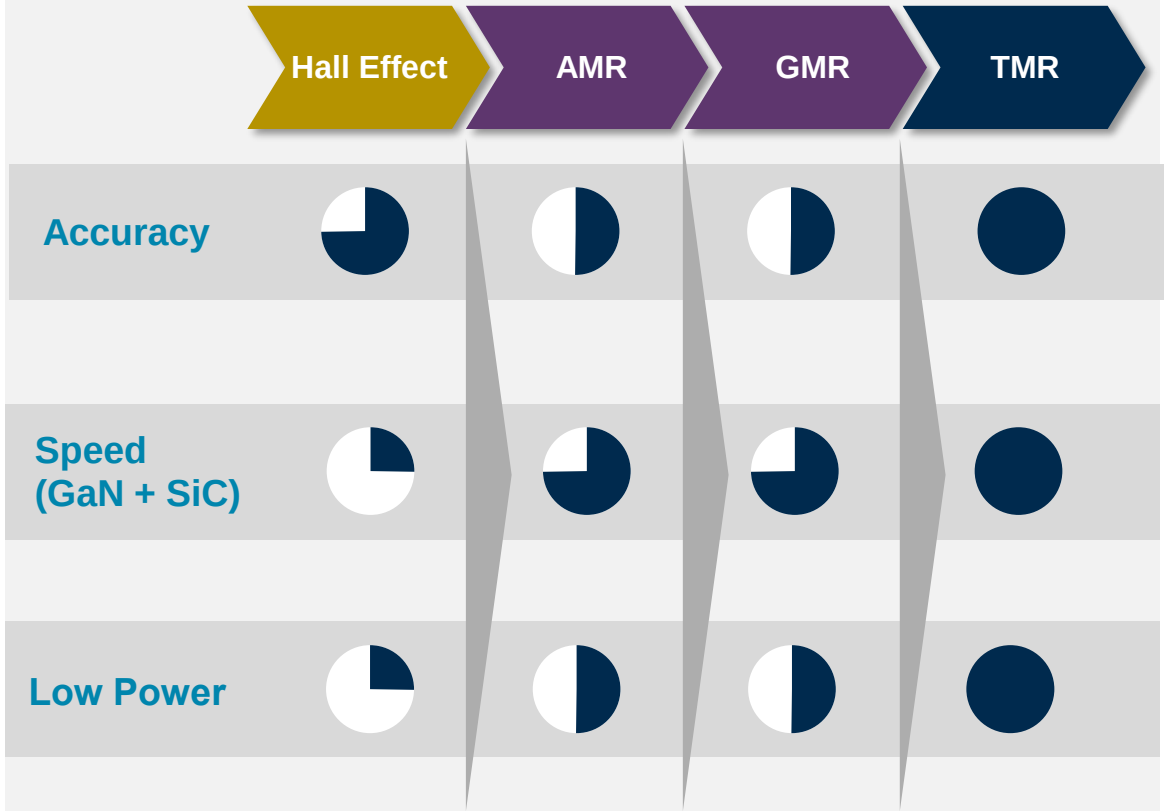
- TMR technology adoption significantly accelerating over 10-year horizon
- TMR technology results in 100 to 1000x larger signal than Hall, delivering greater accuracy and speed with lower power consumption

20x Higher Resolution at 5 MHz: TMR Current Sensors facilitate the GaN/SiC transition and make xEV/EVCI power electronics more efficient, with increased reliability

8x Higher Resolution at 40K RPM: TMR Angle Sensors provide extreme precision and heterogeneous redundancy in a small form factor for safety critical motor control systems (ADAS)

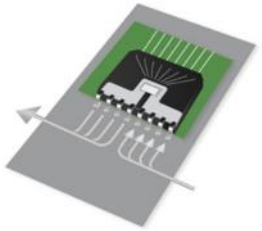
<1 uW power consumption: TMR Sensors enable ultra-low power for battery powered applications

TMR technology to lead the high-performance Magnetic Sensing market of the future

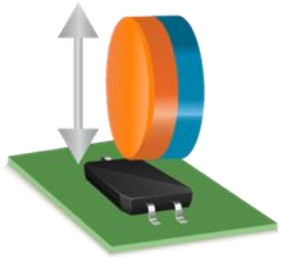


The Future of Sensing: XtremeSense TMR Technology

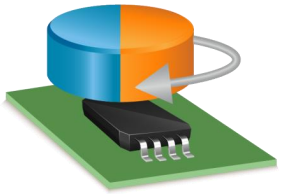
XtremeSense TMR technology delivers unprecedented performance breakthroughs in magnetic sensing



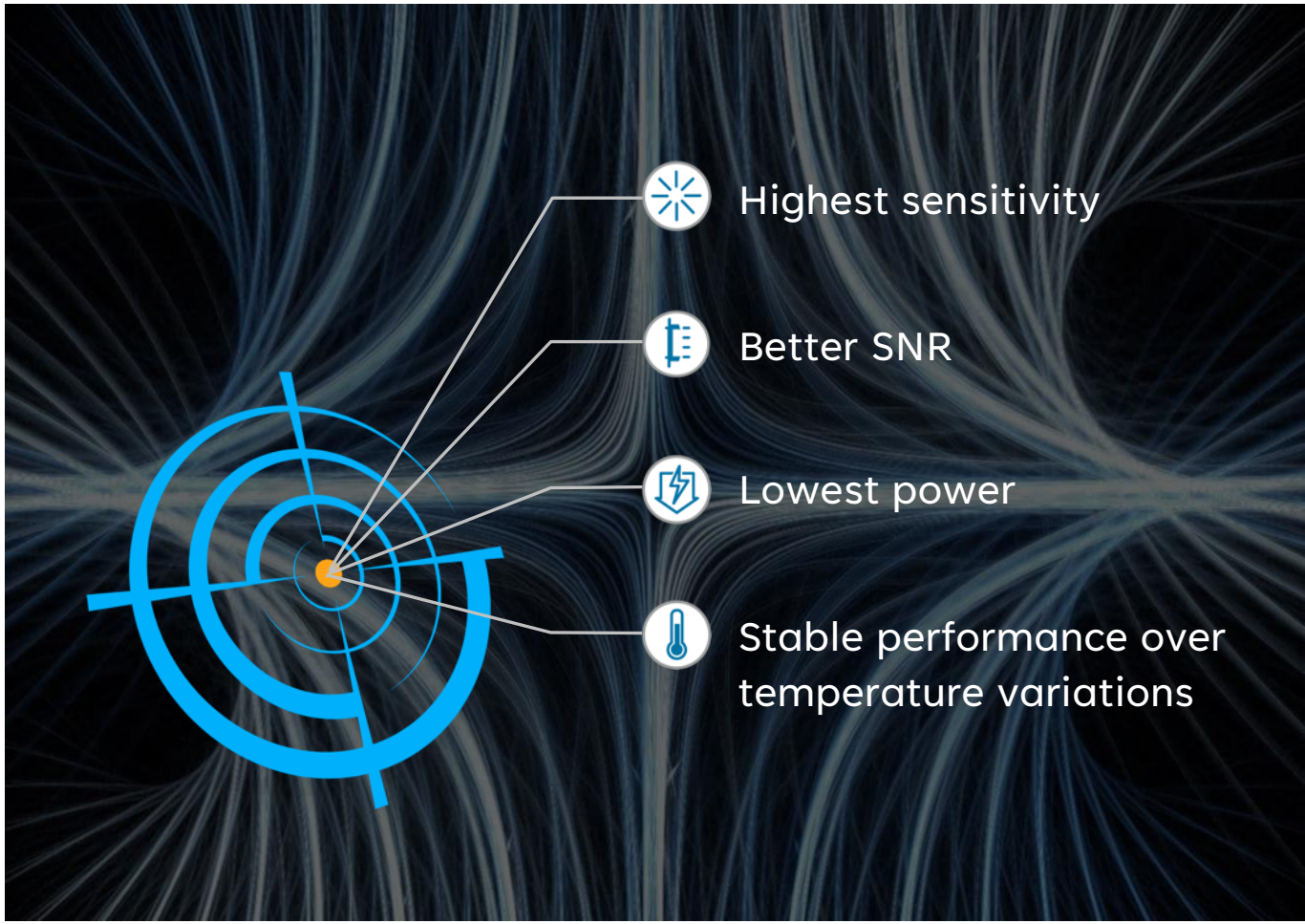
XtremeSense
Current Sensor



XtremeSense
Switches/Latches



XtremeSense
Angle Sensors



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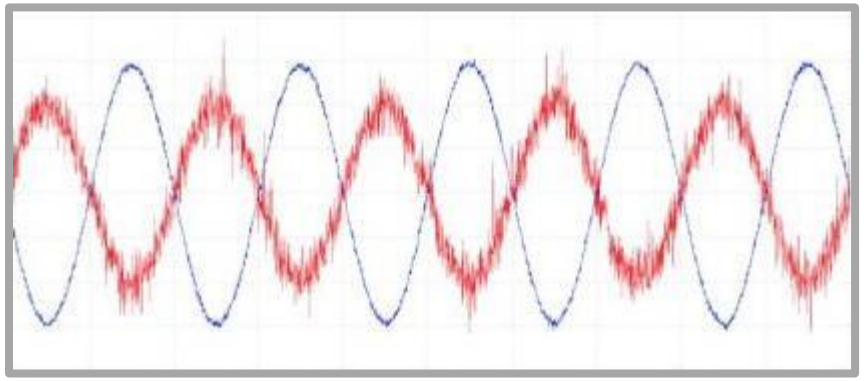
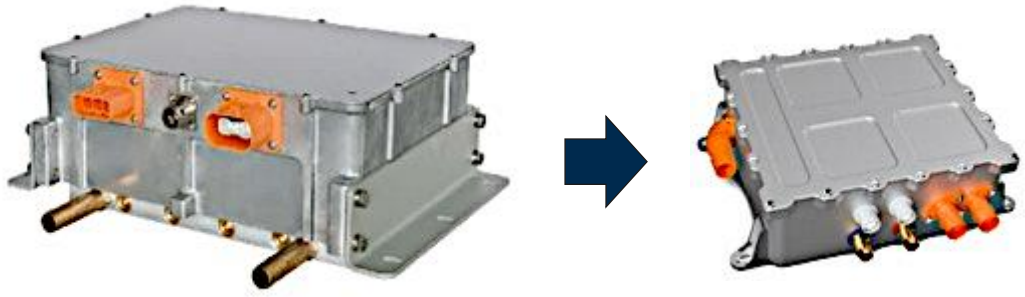
TMR preferred for Current Sensing in GaN and SiC Power Systems

Emerging preference for TMR Sensors in Coreless inverter applications as well

- **Better (20x) signal to noise ratio at high speed (5 MHz) vs. Hall → more precise and efficient power control**
- **High speed Sensor ICs facilitate fast switching for protection of GaN and SiC → enhanced efficiency and reliability**
- **Results in smaller, lighter and higher efficiency power electronics systems**



TMR Current Sensor **Hall Current Sensor**



TMR ICs facilitate higher efficiency and smaller automotive on-board chargers and clean energy power systems

Waveform from https://www.embedded.com/tiny-sensors-benefit-current-sensing-applications/

TMR Angle Sensors preferred for BLDC motor position control

Better (8x) signal to noise ratio at high rotational speed (40K rpm) vs. Hall → more accurate and more efficient motor control

TMR technology adds value across Industrial (Automation) motor applications

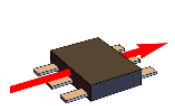
- Lower torque ripple / vibration, reduced audible noise, higher efficiency

TMR Switches ideal for very low power applications

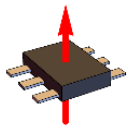
Ultra low active power consumption for switches and latches (< 1 uW) ideal for battery operated applications

Unique Z-axis TMR as “drop-in replacement” across legacy hall sensor applications requiring very low active power

Axis of magnetic sensitivity



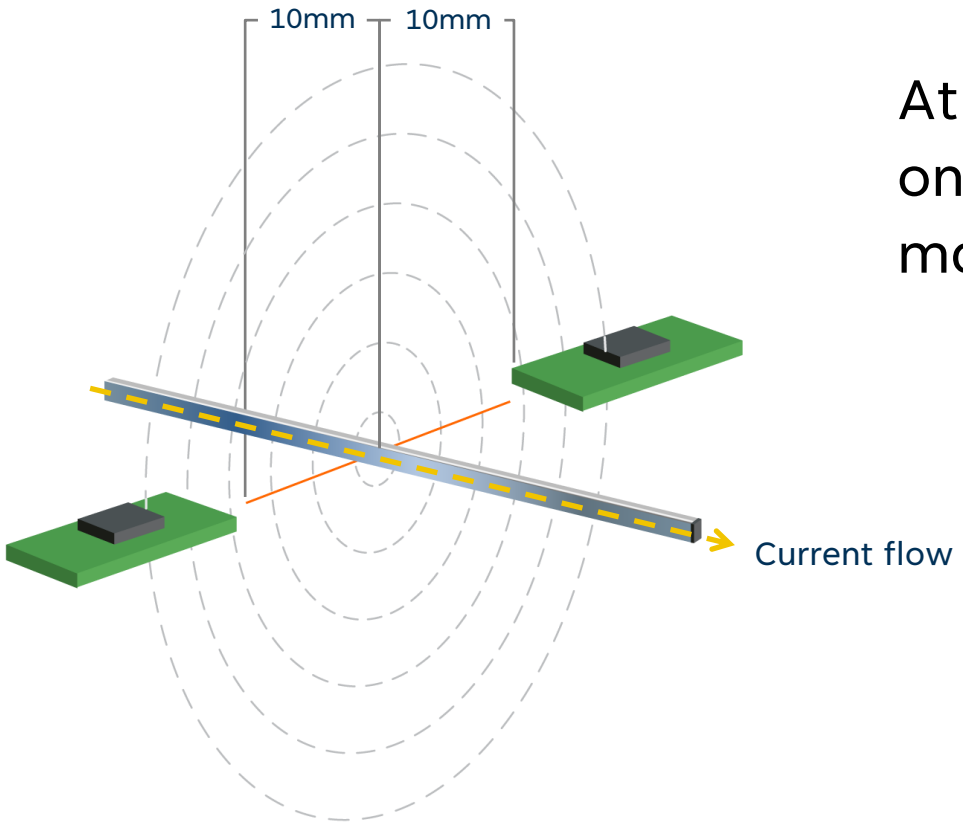
Typical TMR



Traditional Hall and Z-Axis TMR

XtremeSense TMR is Less Sensitive to Stray Magnetic Fields

Robust Stray Field Immunity due to its axis of sensitivity.



At 10mm, **XtremeSense TMR** is only impacted by 2% of stray magnetic fields

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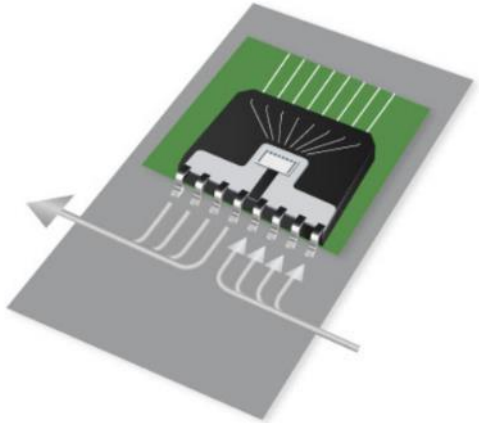
TMR Current Sensors

XtremeSense Current Sensors

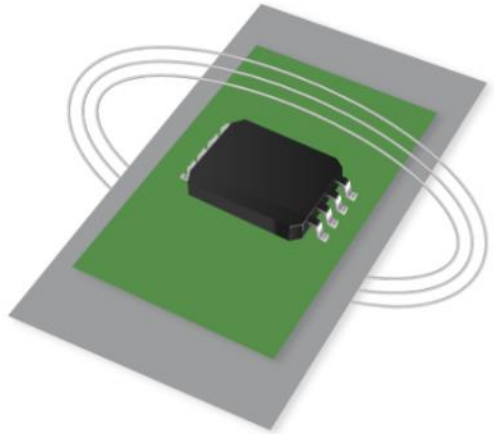
Integrated Conductor (Contact)

- CT110
- CT41x
- CT42x
- CT43x



Field Sensors (Contactless)

- CT100
- CT220
- CT45x



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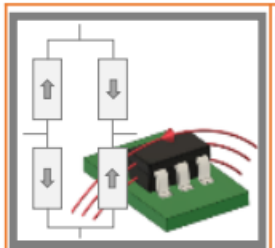
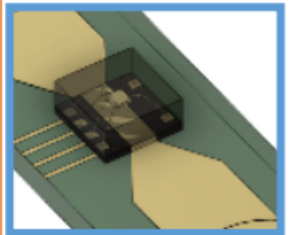
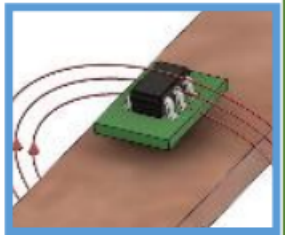
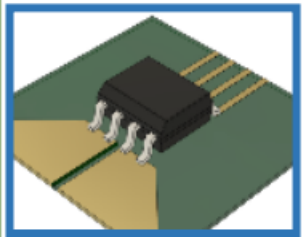
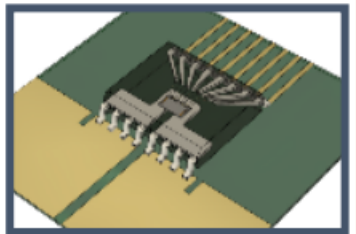
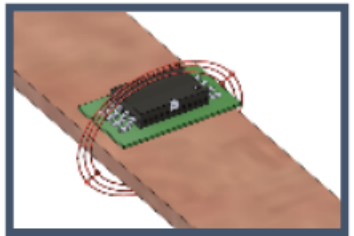
TMR Current Sensor Product Selection

Parameter	 CT100	 CT110	 CT220	 CT41x/42x	 CT430/431	 CT45x
Type	Contactless	Integrated	Contactless	Integrated	Integrated	Contactless
Current Range	±20 mT	±5 A, ±10 A, ±15 A	±1.5 mT, ±5 mT, ±10 mT, ±15 mT	±20 A, ±30 A, ±50 A, ±65 A	±20 A, ±30 A, ±50 A, ±65 A	Programmable, ±6 mT, ±24 mT
Bandwidth	1 MHz	30 kHz	30 kHz	1 MHz	1 MHz	1 MHz
Total Error over Temp	E_{TOT} < 3% FS	E_{TOT_3V} < 3% FS E_{TOT_5V} < 5% FS	E_{TOT_3V} < 3% FS E_{TOT_5V} < 5% FS	E_{TOT} < 1% FS	E_{TOT} < 0.7% FS	E_{TOT} < 0.5% FS
Common Mode Rejection				✓	✓	✓
Design Complexity	High	Low	Medium	Low	Low	Medium
Package	SOT23-6, DFN-6	DFN-6	SOT23-5	SOIC-8	SOICW-16	SOIC-8/TSSOP-16

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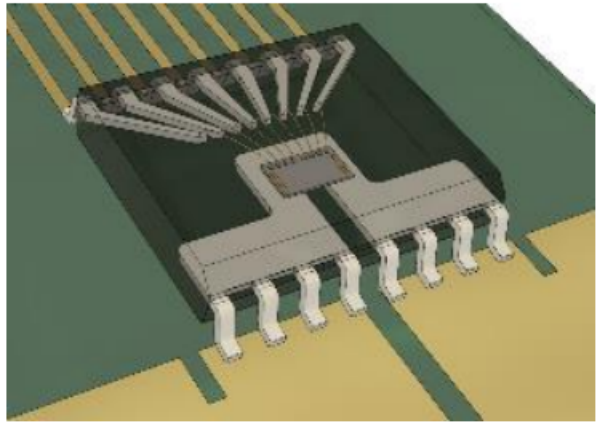
TMR Current Sensors – CT430 has super-hero performance

Description

Ultra-Low Noise
Galvanic Isolation
<1% Total Error
1MHz Bandwidth



Package: SOICW-16

Features

- Supports AC & DC Current
- Current range ±20A to ±65.0 A
- Resolution (SNR): <10 mA_{RMS}
- Immunity to common mode fields
- 1 MHz Bandwidth
- Total Error: ±0.7%
- 5kV Isolation
- Over-Current Detection (OCD™)
- Supply Voltage:
  - CT430 = 4.75 V to 5.50 V
  - CT431 = 3.00 V to 3.60 V
- Operating Temperature:
  - -40°C to +125°C

Advantages

- Immunity to external interreference
- <1% Total error over temperature
- 8mm creepage
- AEC-Q100

Applications

- Solar/Power Inverters
- Motor Drives
- HVAC, UPS, BMS
- Appliances

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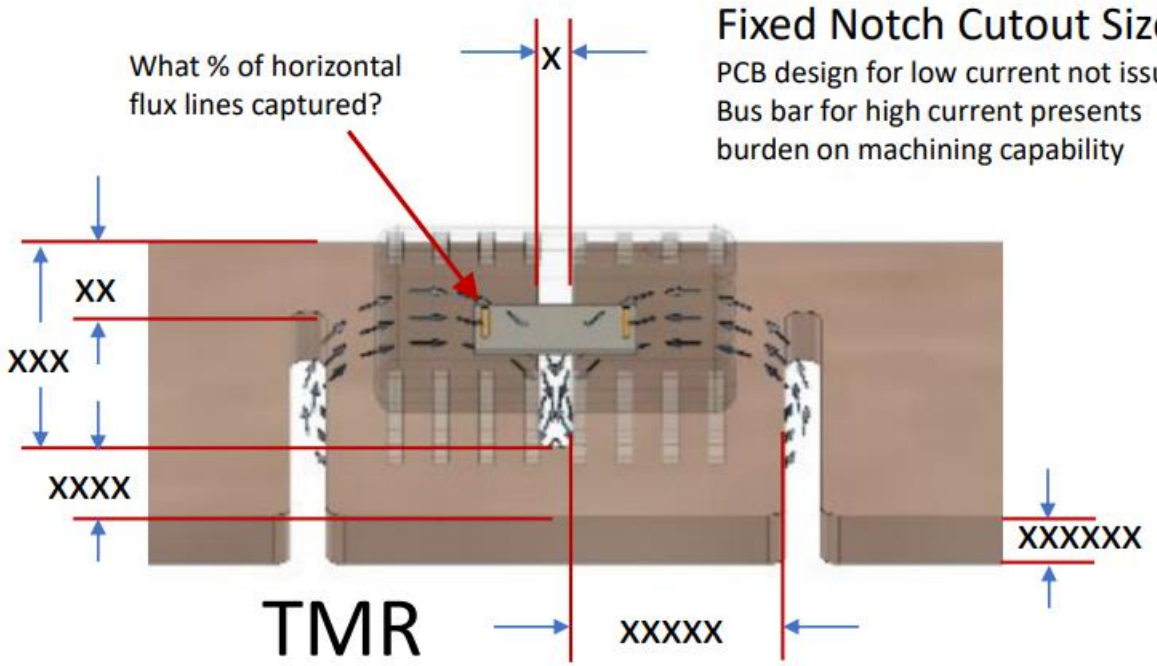
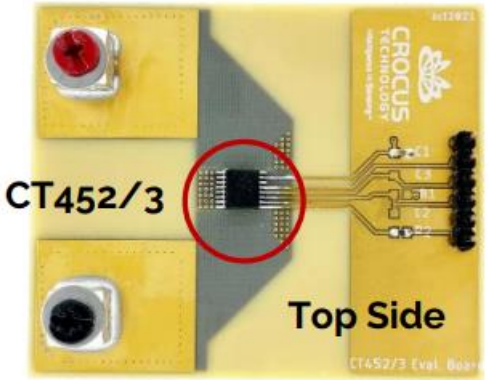
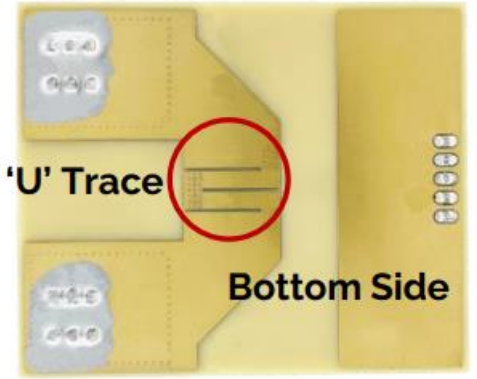
TMR Contactless Current Sensors – CT45x
Differential Common Mode Field Rejection

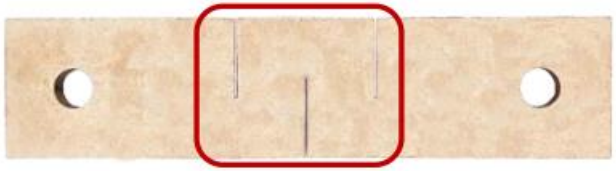


Fixed Notch Cutout Size

PCB design for low current not issue
Bus bar for high current presents burden on machining capability







Bus Bar With 'U' Cutout

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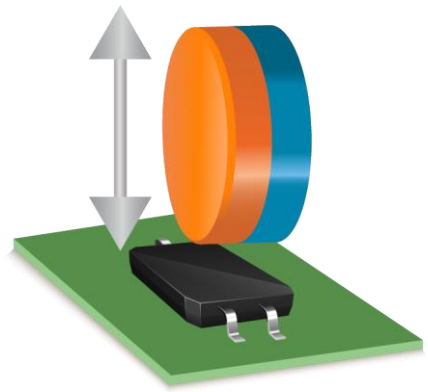
TMR Position Sensors

TMR Switches

Switch



Features

- ✓ Low Power consumption 100nA
- ✓ High Sensitivity and resolution
- ✓ Small LGA package 1.5mm²

Product Selection Guide

Product Name	Polarity	Sensitivity Axis	Output Type
CT811x	Unipolar	X-axis	Push-pull & Open-drain
CT812x	Bipolar	X-axis	
CT813x	Omnipolar	X-axis	

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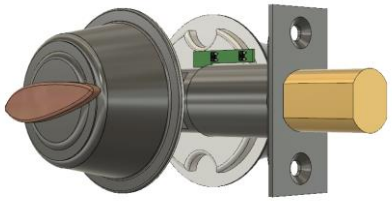
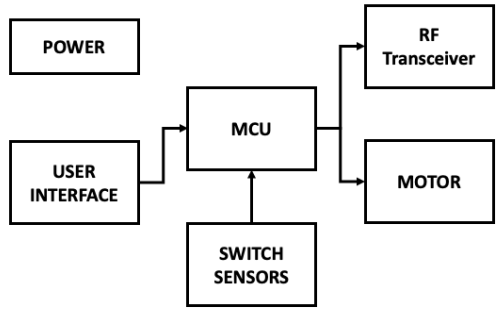
TMR SWITCH SENSORS

Smart Door Lock

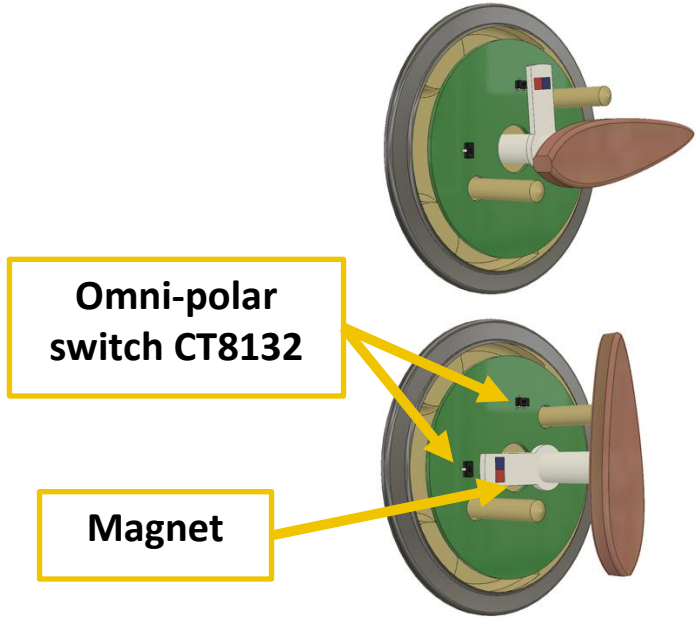




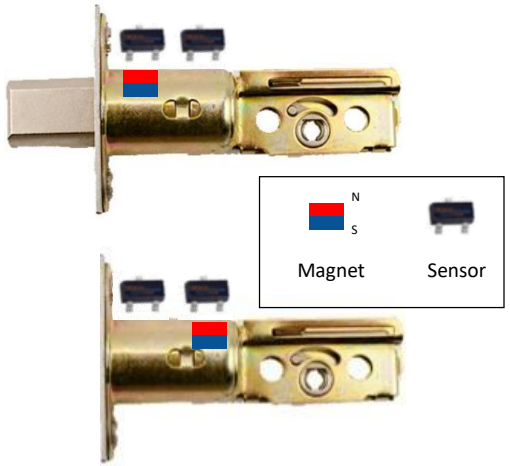
Benefits of Allegro XtremeSense TMR:

- High Sensitivity for accurate dead bolt position detection
- Long battery life with < 110 nA active current consumption
- Digital output for easy interface

Cylinder knob implementation



Dead bolt implementation



CONFIDENTIAL INFORMATION

Medical Devices

Benefits of Allegro XtremeSense TMR:

- Small package size (LGA) for integration in disposables
- Long battery life with < 110 nA active current consumption
- TMR sensor can be used as wake-up device for other electronics (low active current)
- Very high sensitivity allows for lower cost smaller magnets

CONFIDENTIAL INFORMATION

Wireless Ear buds

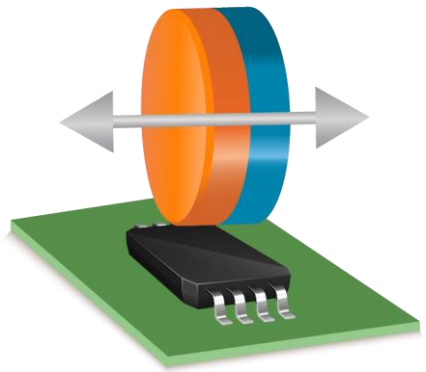
Benefits of Allegro XtremeSense TMR:

- Small package size (LGA) for integration in small personal electronics
- Long battery life with < 110 nA active current consumption
- TMR sensor used as open/close detect for charging
- Very high sensitivity allows for lower cost smaller magnets

CONFIDENTIAL INFORMATION

TMR Linear Sensors

Linear



Features

- ✓ Low Power consumption < 1µA
- ✓ High Sensitivity and resolution
- ✓ Both planar and out-of-plane sensitivity axis

Product Selection Guide

Product Name	Sensitivity @ 3.3V	Sensitivity Axis	Output Type
CT100	12mV/mT	X-axis	Differential
CT130	2.5mV/mT	Z-axis	Differential
CT815x	154mV/mT	X-axis	Single-ended
CT220	990mV/mT	X-axis	Single-ended

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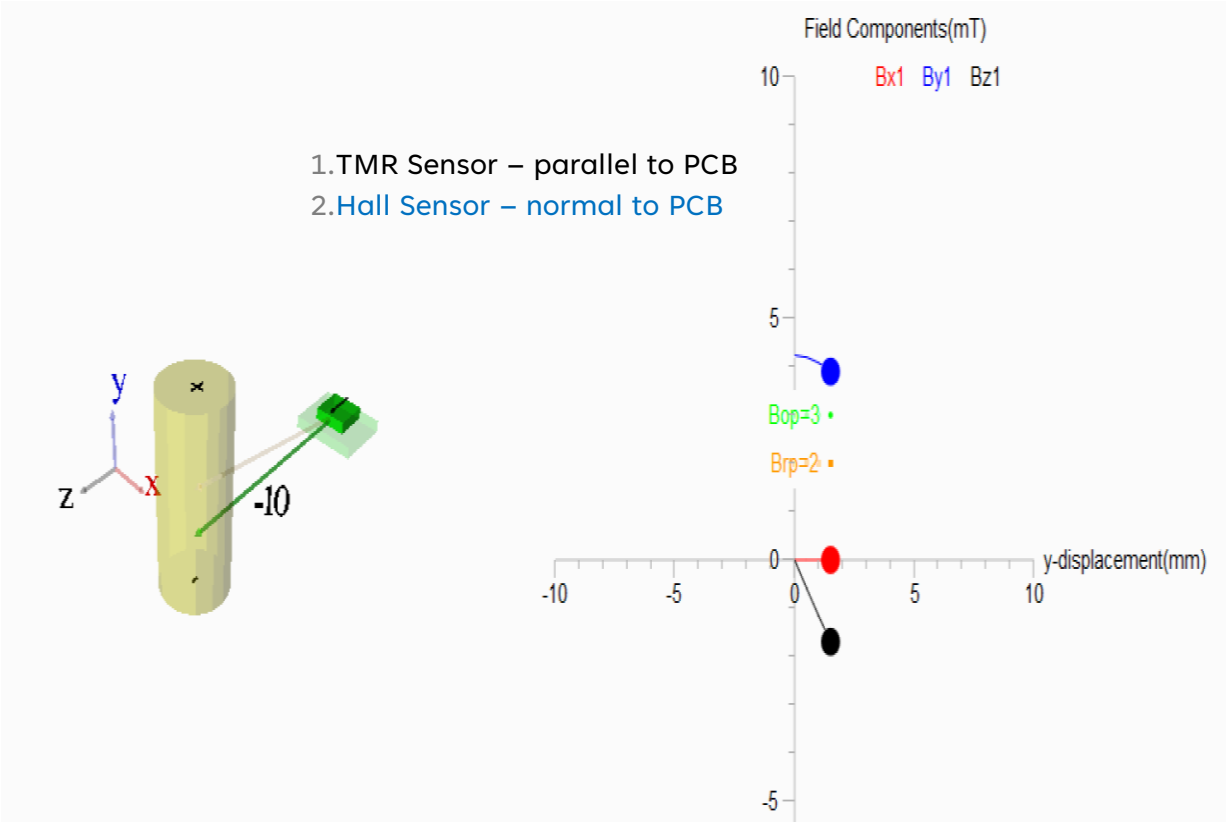
Linear Applications – Axis of sensitivity

Human Interface

- **Game controller**, triggers, sliders , joysticks
- **Power Tools** , triggers, dials, throttle
- **Medical**, pipettes, syringe, surgical instruments, catheters
- **Audio**, analog vibration sensing
- **Video and Camera**, image stabilization
- **Wearables**, shoe compression, gesture ID

Machine Interface

- **Magnetic Ruler**, absolute position encoder
- **DC motor**, 3-phase position feedback
- **Dynamic motion analysis**, shock absorbers, table balance



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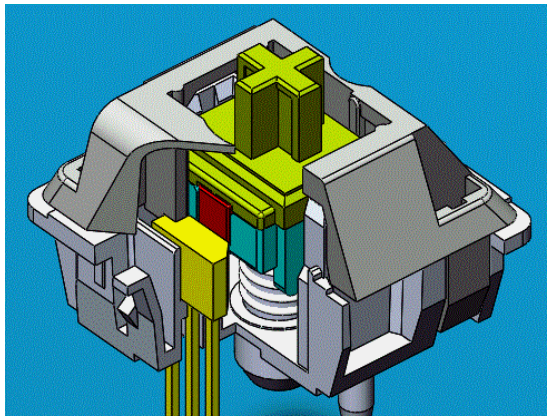
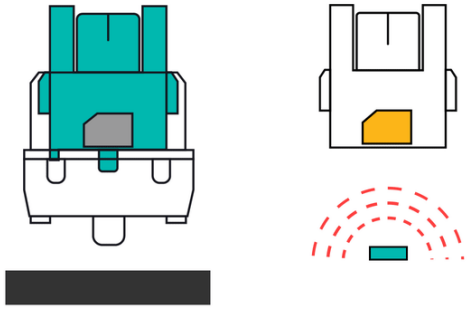
TMR LINEAR SENSORS

Magnetic Keyboard

Benefits of Allegro XtremeSense TMR:

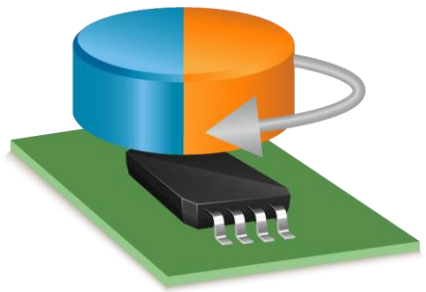
- Faster Actuation
- Adjustable Actuation point
- linear output
- Faster Response time
- More durability over mechanical or optical
- Lower Power consumption compared to Capacitive or Hall Effect





TMR Angle Sensors

Angle



Features

- ✓ Absolute Angular Error < 0.25°
- ✓ Insensitive to airgap variation
- ✓ Differential Analog outputs

Product Selection Guide

Product Name	Operating Range	Angular Error	Output Type
CT310	25mT – 90mT	0.25°	Differential SIN and COS

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TMR ANGLE SENSORS

Industrial Motors

Benefits of Allegro XtremeSense TMR:

- Angular error < 0.25 is ideal for precision motor position
- Incremental plus absolute position
- Insensitive to airgap variations
- Differential Analog outputs

CONFIDENTIAL INFORMATION

Additional Information

XtremeSense TMR: Product List

Product Portfolio	Allegro Product	Key Differentiator
Current Sensors (0 - 50A)	CT110	High Linearity/High Resolution Contact Current Sensor
	CT415	TMR Current Sensor with Ultra-Low Noise and <1% Total Error
	CT416	
	CT417	
	CT418	
	CT425	TMR Current Sensor with Ultra-Low Noise and <0.7% Total Error
	CT426	
	CT427	
	CT428	
	CT430	TMR Current Sensor with Ultra-Low Noise, <0.7% Total Error and Common-Mode Field Rejection in SOICW-16 Package
	CT431	
	CT432	
	CT433	
Current Sensors (0 - 1000A)	CT220	High Linearity, High-Resolution TMR Contactless Current Sensor in Miniature Form Factor
	CT450	TMR Contactless Current Sensor with 1 MHz Bandwidth and Programmable Gain
	CT452	TMR Coreless, Differential and Contactless Current Sensor with Programmable Gain
	CT453	
	CT455	1 MHz Bandwidth Contactless Current Sensor
	CT456	

Product Portfolio	Allegro Product	Key Differentiator
Switches and Latches	CT8111	Integrated Unipolar TMR Switch/Latch
	CT8112	
	CT8122	Integrated Bipolar TMR Switch/Latch
	CT8131	Integrated Omnipolar TMR Switch/Latch
	CT8132	
Position Sensor	CT8150	Ominpolar TMR Analog Sensor with Dual Analog and Digital Output Operation Capability
	CT8152	
	CT100	1D TMR Linear Sensor with Analog Differential Outputs
	CT310	2D TMR Angle Sensor with Sine/Cosine Outputs

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XtremeSense® TMR Sensors: Automotive Grade-1 Qualified

Integrated Current Sensor			
PN	**CT41x**	**CT42x**	**CT43x**
AEC-Q100 Grade 1	✓	✓	✓

Angle Sensor	
PN	**CT310**
AEC-Q100 Grade 1	✓

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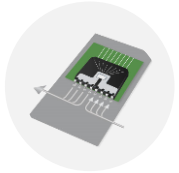
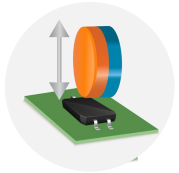
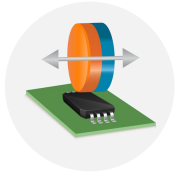
XtemeSense TMR Sensors and Target Applications



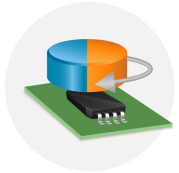
Current Sensors



Switch Latch



Linear Sensors



Angle Sensors

	SENSOR		
	Current	Position	Application/Use case
xEV Powertrain	◉	◉	Current for OBC, DC-DC, Inverter, & PDU power conversion and SiC/GaN protection Position for motor position and battery disconnect unit
ADAS	◉	◉	Current for in-phase current sensing in EPS and EMB motors Position sensor for motor position, pedal and low power system wake up
Body Electronics		◉	Position for in-cabin motors, user interface, infotainment and HVAC systems
Clean Energy	◉	◉	Current for power conversion in solar, EV charging, and Energy Storage Position for EV plug and solar tracker
Data Centers	◉		Current for power conversion and protection in power supply units and server motherboards
Industrial	◉	◉	Current for in-phase current sensing in VFDs, Servo Drives, and E-Bikes Position sensors for motor commutation and motor position sensing
Consumer	◉	◉	Current sensor for fault monitoring and protection Very low power position sensor for battery operated personal, medical, gaming etc.

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Thank You

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