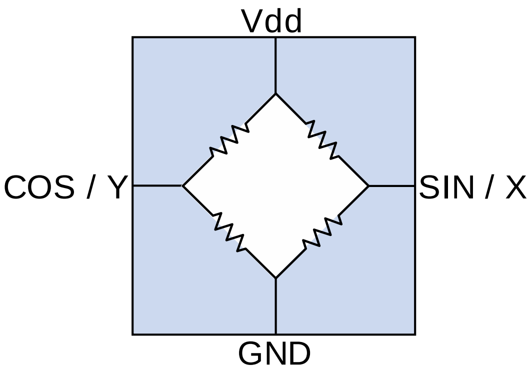
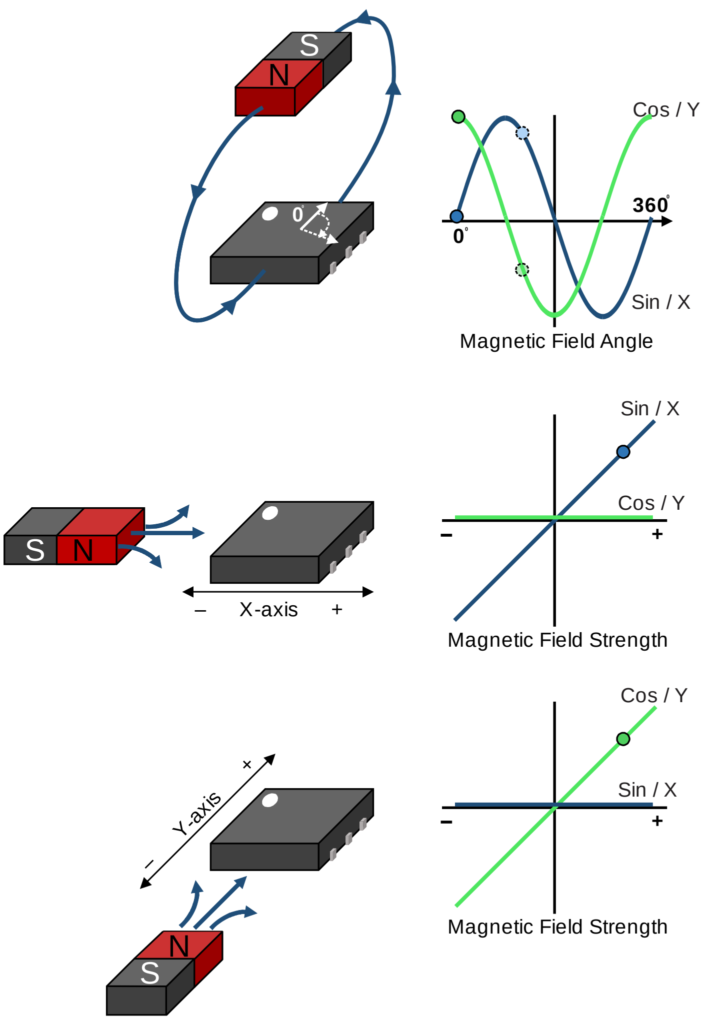
ALT521-10E Ultrasensitive Two-Axis Rotational Sensors

Equivalent Circuit



Transfer Function



Top: angle / rotation detection
Middle: X-axis magnetic field sensing
Bottom: Y-axis magnetic field sensing

Features

- Tunneling Magnetoresistance (TMR) technology
- High sensitivity (up to 170 mV/V/mT)
- Large signals (150 mV/V typ. full scale)
- ±0.5 mT linear range
- Highly linear output (typ. 2% of full scale)
- Low temperature coefficient of output (0.1 %/°C)
- Up to 100 kHz frequency bandwidth
- 2 MΩ typ. device resistance for low power
- Operation to near-zero supply voltage
- Up to 125 °C operating temperature
- 2.5 x 2.5 mm DFN6 package

Applications

- Flowmeter
- Earth magnetic field detection
- Wearable and battery powered devices
- Proximity sensing
- RPM speed measurement
- Ferromagnetic material detection
- Nondestructive testing
- Freepitch Rotary encoder
- Freepitch Linear encoder
- Joystick
- Battery-free servo encoder

Description

ALT521 sensors are Tunneling Magnetoresistance (TMR) Wheatstone bridge sensors with large voltage signal, wide linear range, and ultraminiature package size.

The sensor has two half-bridge outputs for absolute angle detection or both X- and Y-axis magnetic field detection. The outputs are bipolar, meaning they are positive for a positive field and negative for a negative magnetic field polarity.

ALT521 sensors are passive Wheatstone bridges, so the sensors are purely ratiometric with Vdd supply voltage. They can operate at extremely low supply voltages down to 0.1 V, and the output signal is directly proportional to Vdd.

The output is stable over the full operating temperature range of −40 to 125 °C.

Absolute Maximum Ratings

Parameter	Symbol	Min.	Typical	Max.	Units
Operating supply voltage	V_{CC}	0		10	Volts
Supply voltage to diode breakdown	V_{CC}	10		14	Volts
Operating temperature	T_{min}, T_{max}		−40	125	°C
Storage temperature			−65	150	°C
ESD (Human Body Model)[1]				2000	Volts
Applied magnetic field[2]	H			Unlimited	Tesla
Voltage from sensor connections to center pad				63	Volts DC

Rotation Detection Operating Specifications

Parameter	Symbol	Min.	Typical	Max.	Units
Offset voltage	V_{offset}	−10		+10	mV/V
Linear field range	H_{lin}	0		1	mT_{pp}[3]
Saturation field	H_{sat}		3		mT_{pp}
Operating field range	H_{op}	0		200	mT_{pp}
Output sensitivity	V_{amp}	200	280	360	$mV_{pp}/V/mT_{pp}$
Maximum output amplitude	V_{max}		350		mV_{pp}/V
Angular hysteresis (operating field range)	θ_{delta}		5	12	°
Absolute angle accuracy (linear field range)	θ_{error}		10		°
Angle switching points (operating field range)	θ_{op}				°
Quadrant 1		340	0	20	
Quadrant 2		70	90	110	
Quadrant 3		160	180	200	
Quadrant 4		250	270	290	
Device resistance	R	1	2	3	MΩ
Frequency bandwidth[4]	*f*	DC		100	kHz

Dual-Axis Sensor Operating Specifications

Parameter	Symbol	Min.	Typical	Max	Units
Output sensitivity	V_{out}	100	140	180	mV/V/mT
Linear hysteresis	H_{delta}		0.1		mT
Linearity[5,6]	Lin		2		%F.S.
Linear field range	H_{lin}	−0.5		0.5	mT
Saturation field	H_{sat}	−1.5		1.5	mT
Maximum output voltage	V_{max}		175		mV/V
Off-axis characteristic[7]			Cos(θ)		

Thermal Specifications

Parameter	Symbol	Min.	Typical	Max.	Units
Junction–ambient thermal resistance[8]	θja		320		°C/W
Power dissipation	Pd		500		mW
Temperature coefficient of device resistance[9]	TCR		−0.08		%/°C
Temperature coefficient of output voltage[9]	TCO	−0.1	0	0.1	%/°C

Notes to all specifications:

1. Human Body Model (HBM) per JESD22-A114.
2. 1 millitesla (mT) = 10^6 nanotesla (nT) = 10 Gauss (G) = 10 Oersted (Oe) in air.
3. Peak-to-peak amplitude is used for certain specifications. A 0.5 mT amplitude magnetic signal is equal to a 1 mT_{pp} amplitude. Similarly, 350 mV_{pp} = 175 mV magnitude.
4. Specified for amplitude reduction of −3 dB.
5. Full scale is defined as the operating field range.
6. Maximum deviation from best linear fit. Excludes contributions from hysteresis.
7. Theta (θ) is the angle between the positive sensitive direction and the applied field.
8. Measured per JESD51 with ground pad not connected to circuit board.
9. TCR is the device resistance change with temperature in constant applied field. TCO is the output change with temperature using either a constant current or constant voltage source to power the sensor.

Typical Performance Graphs

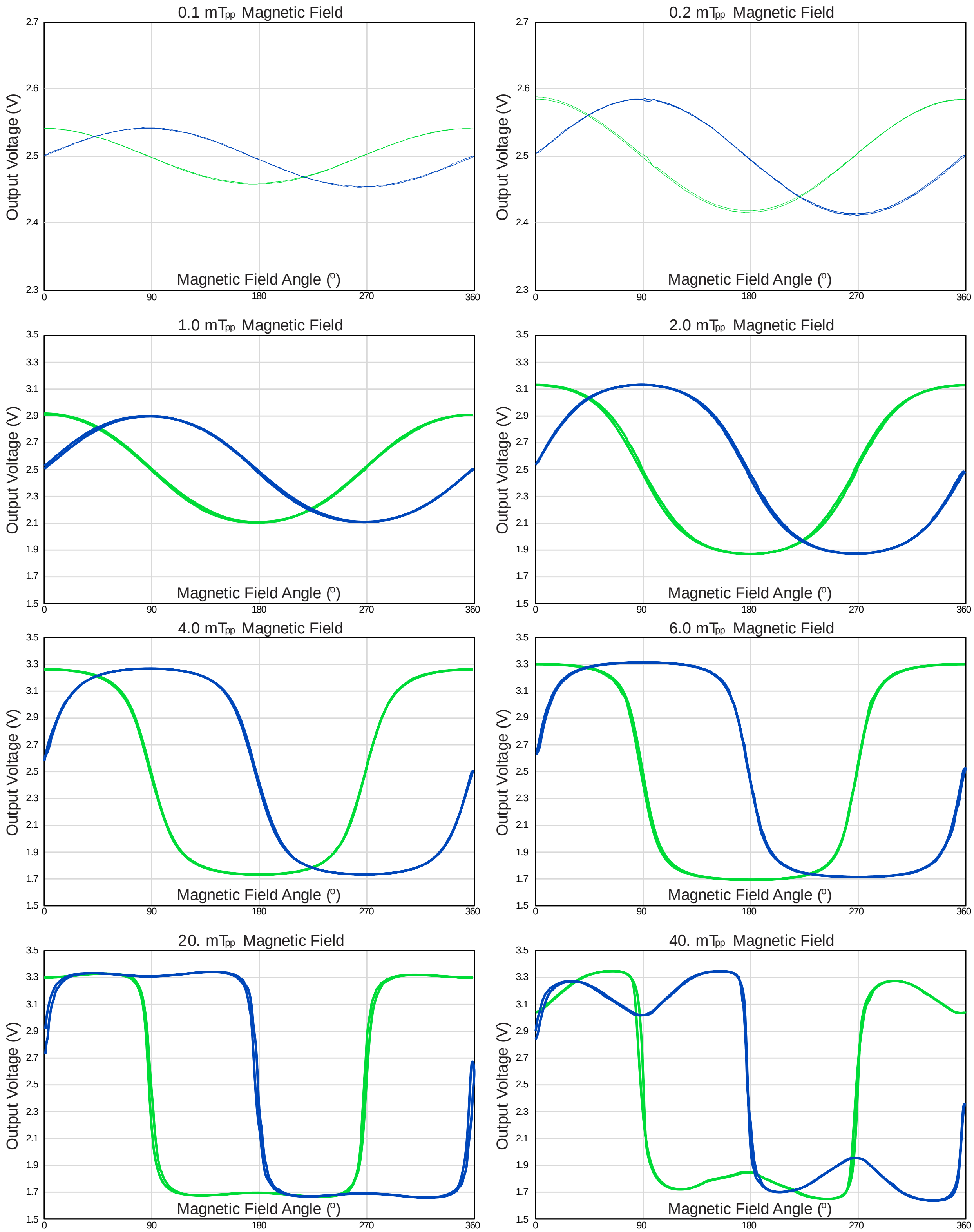


Figure 1. Typical ALT521-10E rotation-mode output at various magnetic field. The supply voltage is 5 V.

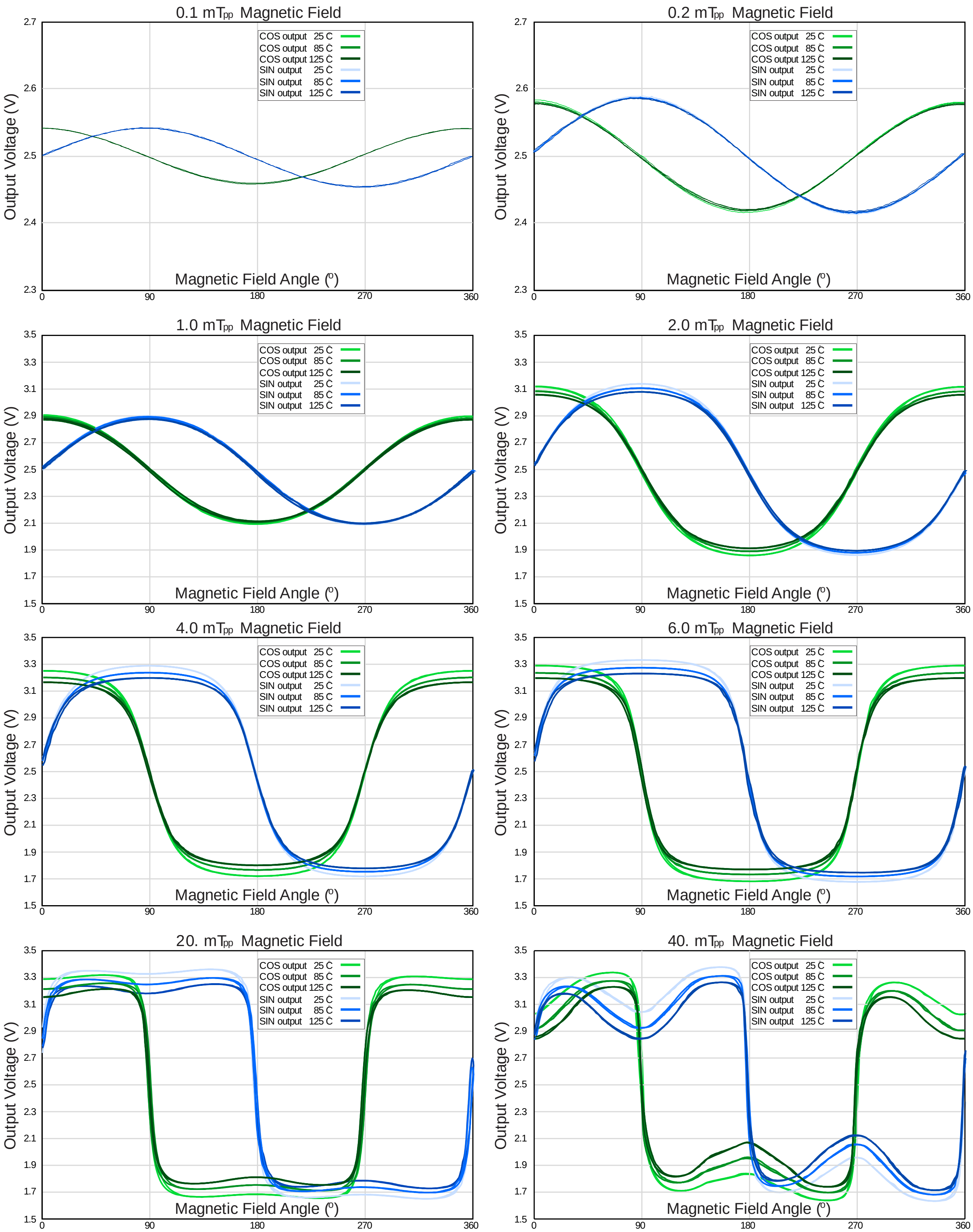
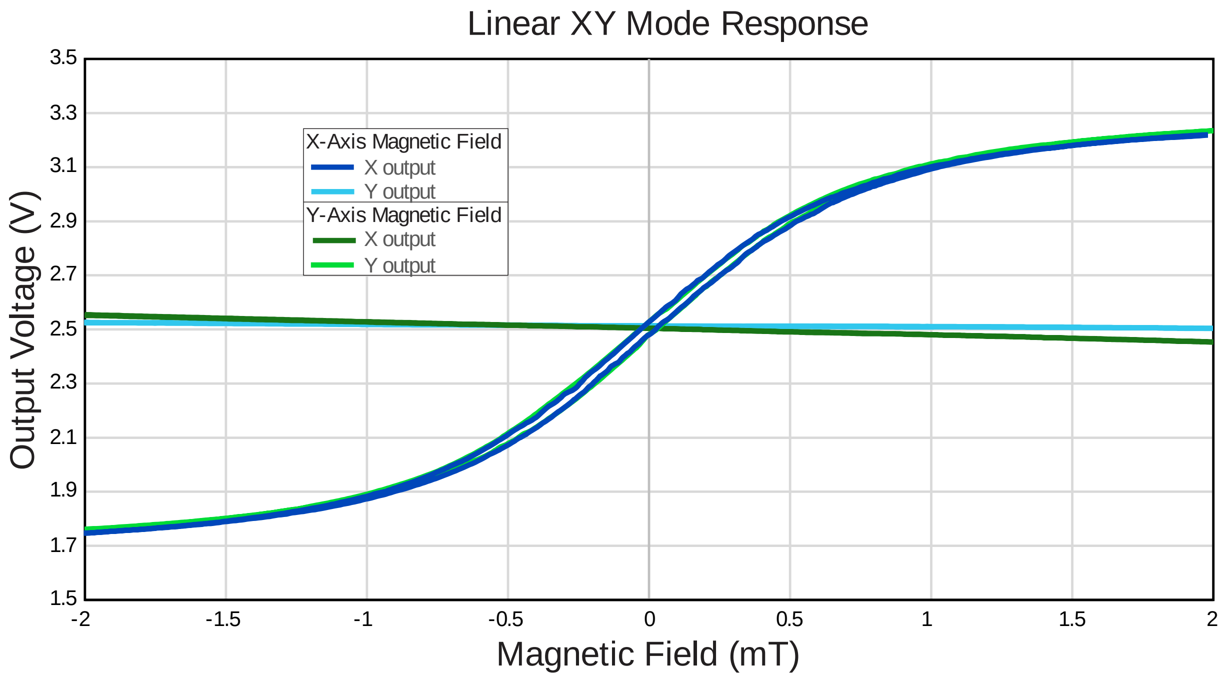


Figure 2. Typical ALT521-10E rotation-mode output at various magnetic field and temperature. The supply voltage is 5 V.



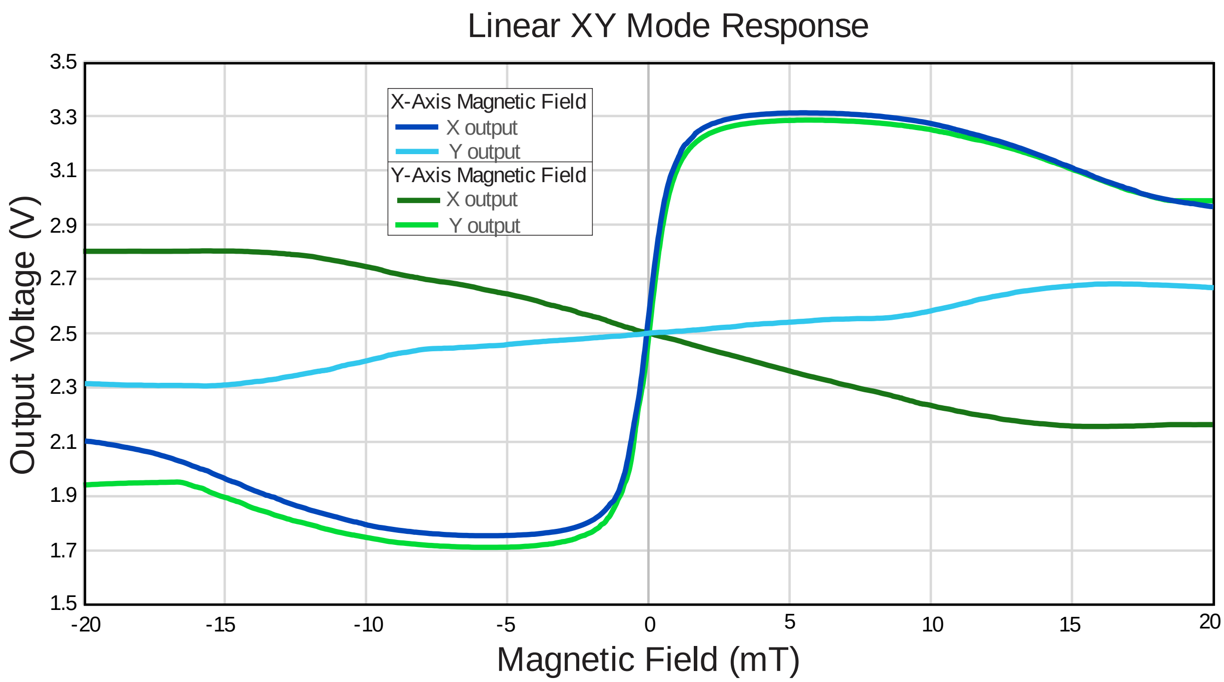


Figure 3. Typical ALT521-10E XY-mode output in linear magnetic fields. The supply voltage is 5 V.

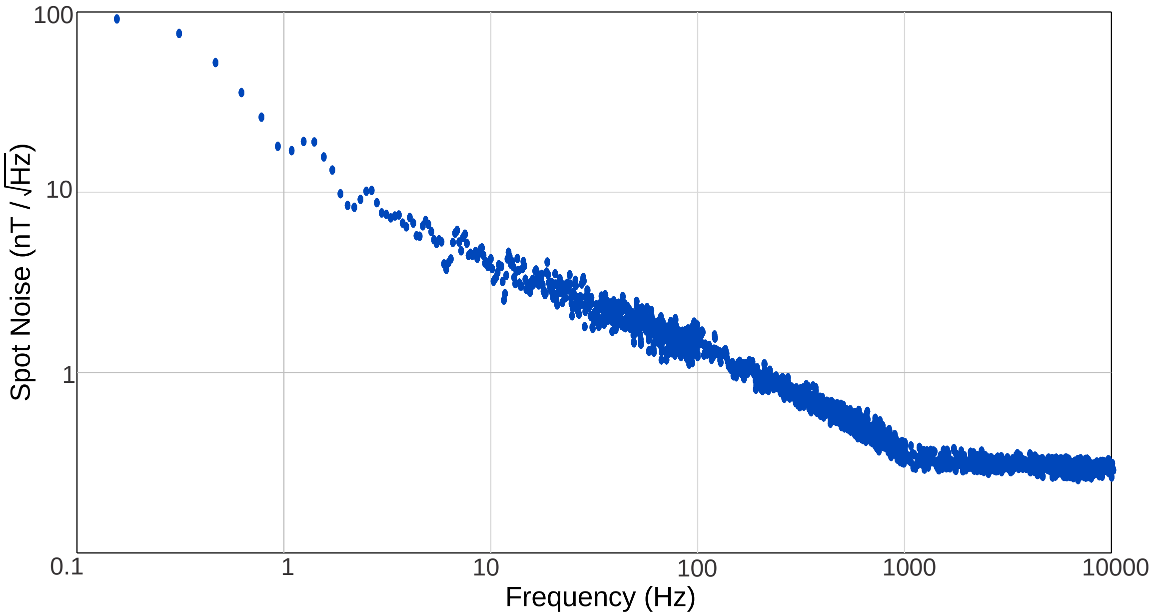


Figure 4. Typical ALT521-10E magnetic noise spectrum at 5 V supply. The magnetic noise is the limit for the smallest detectable field.

Magnetic Field Application

Two-Axis, Bipolar Directional Sensitivity
The ALT521 sensors have two independent sensing elements that can detect both X- and Y-axis magnetic fields. The outputs are bipolar, meaning they detect both positive (north) and negative (south) polarities. Only the vector component of magnetic field along the sensitive axis will generate a voltage output; magnetic fields applied at an angle θ from the sensor's positive sensitive direction will reduce the voltage output by a factor of $Cos\ (\theta)$.

In-Plane Sensitivity
Unlike Hall Effect or other sensors, the ALT521 is sensitive in the plane of the sensor package in both X- and Y-axis directions. The ALT521 does not respond to Z-axis magnetic field perpendicular to the plane of the sensor package. Magnetic fields applied at an angle θ towards the Z-axis will produce a voltage reduced by $Cos\ (\theta)$.

Rotation Counting with Dipole Magnets
The principal application of ALT521-10E is an ultrasensitive rotation counter. The sensor can detect rotating magnetic fields as small as 0.1 µT. The sensor can also be overdriven with large magnetic field up to 100 mT, making it highly robust against misalignment, vibration, and external magnetic field interference. The most common magnet configurations are *two-pole, axial-pole,* and *radial-pole magnets*. ALT521-10E can also be used with *linear magnetic scale*.

Periodicity with Multipole Magnets
ALT521-10E completes one sine and cosine cycle for each pair of north-south magnetic poles. For example:

- A two-pole magnet will produce one cycle per rotation
- A four-pole magnet will produce two cycles per rotation
- An eight-pole magnet will produce four cycles per rotation
- A 12-pole magnet will produce six cycles per rotation

Off-Axis Rotational and Angle Sensing
ALT521-10E are ideal for off-axis angle sensing because of their high-sensitivity and wide dynamic range. They can be used in multipole magnet configurations with minimal zero-field zone (small regions where one of the X or Y field components drops to zero). More traditional end-of-shaft, on-axis rotational and angle sensing is also possible.

Two-Pole Magnet Sensing

With a two-pole magnet (sometimes called "split-pole" or diametrically magnetized), the ALT521-10E will produce one full sine and cosine cycle per rotation. The sensitivity zones are identified in green shaded area. Zero-field zones are marked with "x" and arrows. As you can see, the zero-field zone is very small; this is due to the ALT521-10E's very high sensitivity.

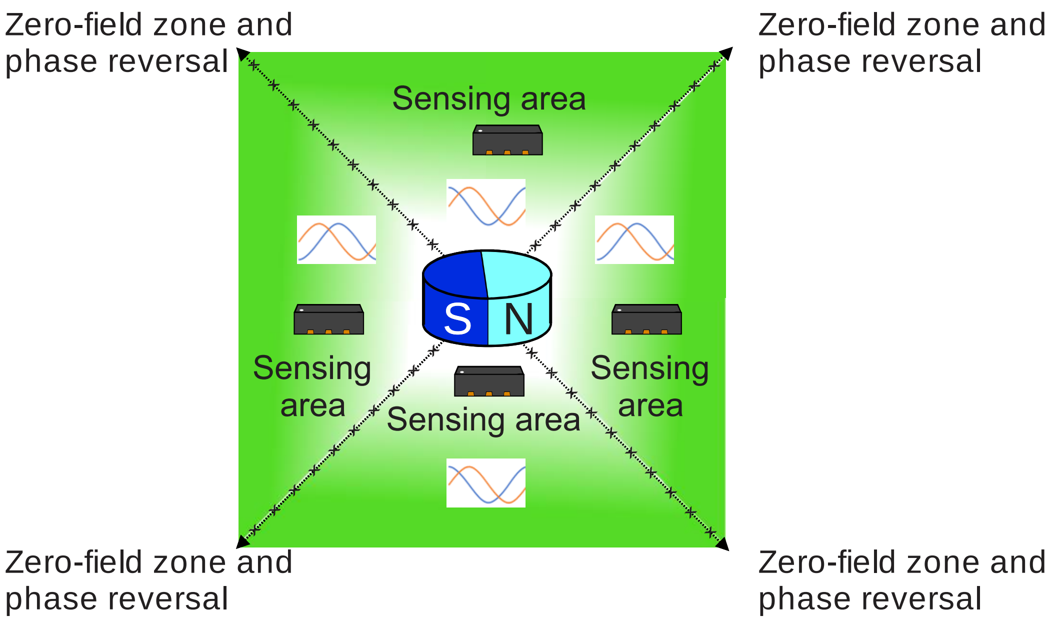


Figure 5. Two-pole magnet detection in the *Parallel Plane* configuration.

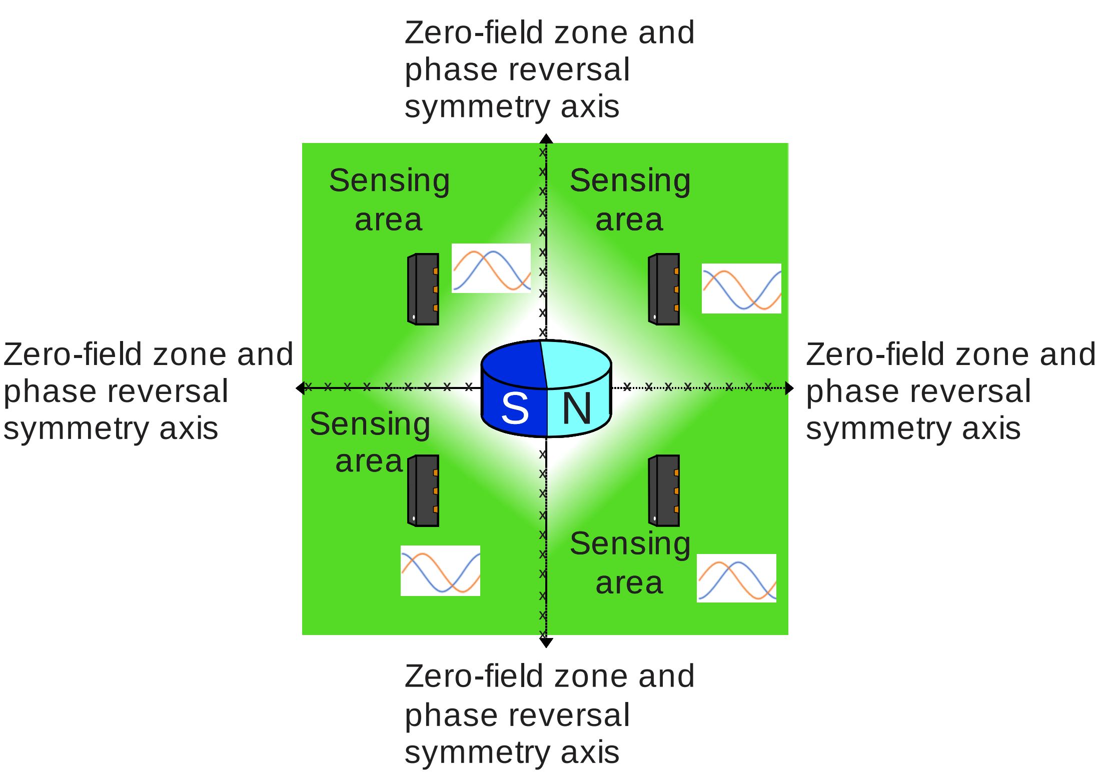


Figure 6. Two-pole magnet detection in the *Perpendicular Plane* configuration.

Axial-Pole Magnet Sensing

A 12-pole magnet is used for illustration. In this case, the ALT521-10E will produce six full sine and cosine cycles per rotation. The sensitivity zones are identified in green shaded area. Zero-field zones are marked with "x" and arrows. As you can see, the zero-field zone is very small; this is due to the ALT521-10E's very high sensitivity.

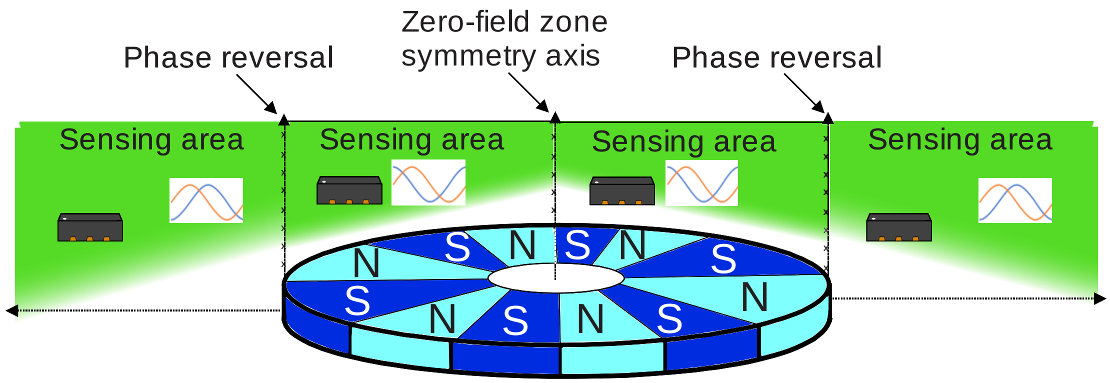


Figure 7. Axial-pole magnet detection in the *Parallel Plane* configuration.

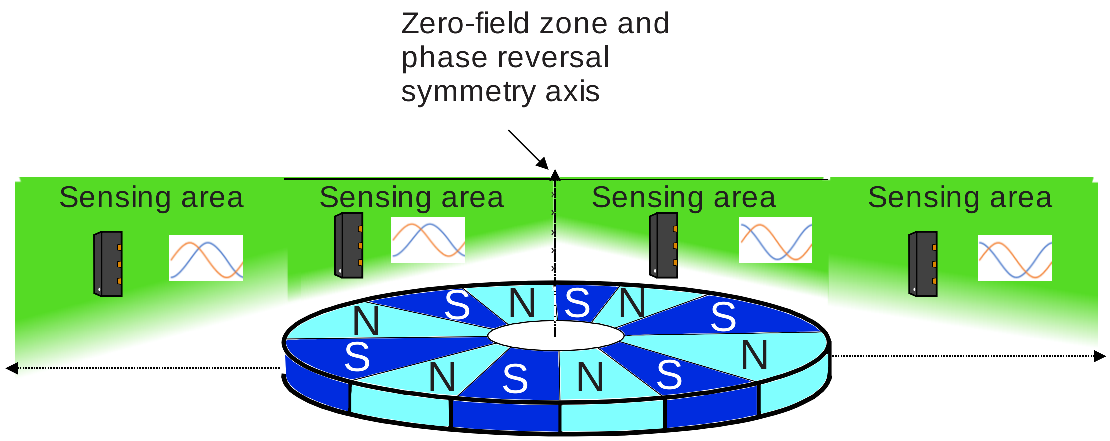


Figure 8. Axial-pole magnet detection in the *Perpendicular Plane* configuration.

Radial-Pole Magnet and Linear Magnetic Scale Sensing

A 12-pole magnet is used for illustration. In this case, the ALT521-10E will produce six full sine and cosine cycles per rotation. The sensitivity zones are identified in green shaded area. Zero-field zones are marked with "x" and arrows. As you can see, the zero-field zone is very small; this is due to the ALT521-10E's very high sensitivity.

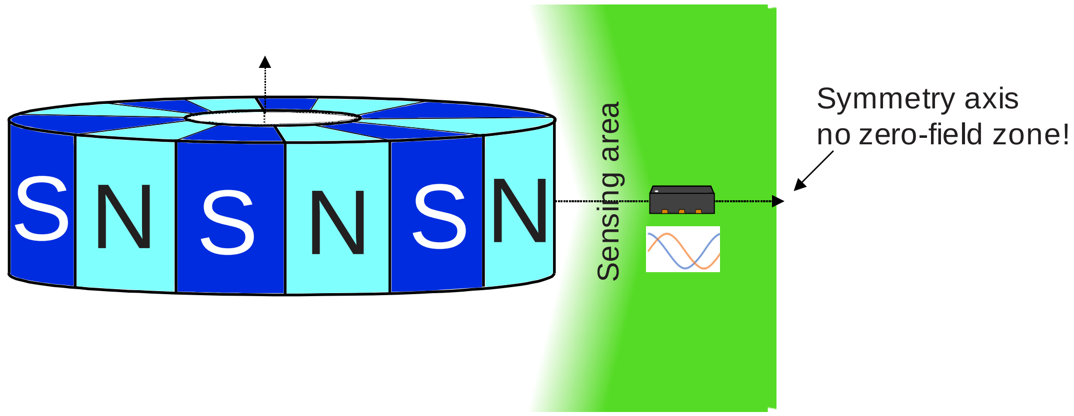


Figure 9. Radial-pole magnet detection in the *Parallel Plane* configuration.

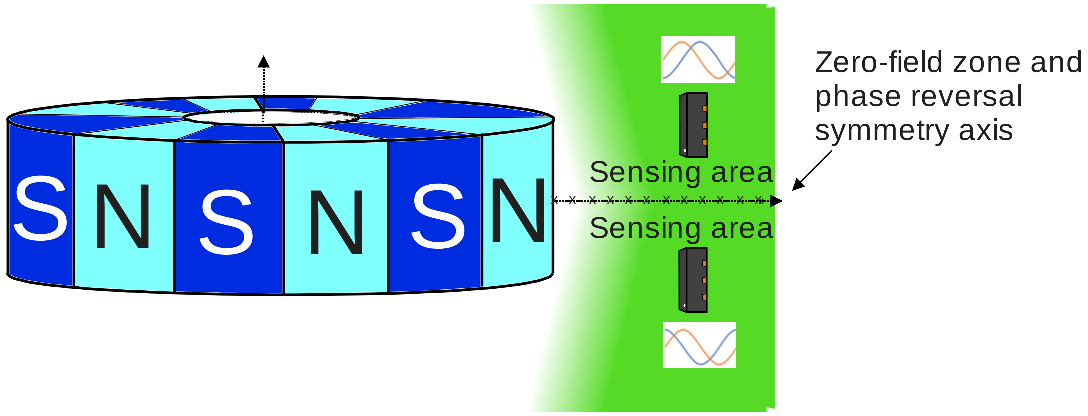


Figure 10. Radial-pole magnet detection in the *Perpendicular Plane* configuration.

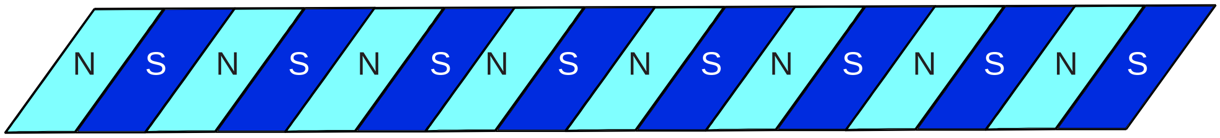


Figure 11. For linear encoders, *linear magnetic scale* can be used in similar configuration to radial-pole magnets.

Example Circuits

Small-Signal Amplifier

A single-supply amplifier can be used to boost small signals, such as the earth magnetic field. The circuit below uses a dual op-amp in a non-inverting configuration for a gain of two. Optional capacitors can be used for low-pass filtering; a value of 100 pF provides a –3dB cutoff frequency around 1600 Hz.

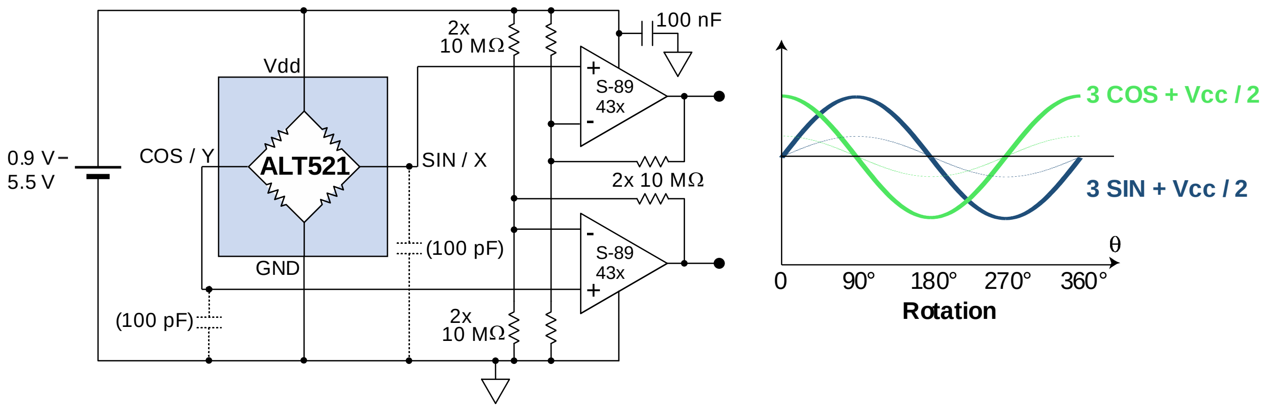


Figure 12. Small-signal amplifier using a low-power, two-element CMOS Op Amp.

A/B Pulses for Rotation Counting

ALT521 can be connected to a low-voltage CMOS comparator to obtain digital outputs.

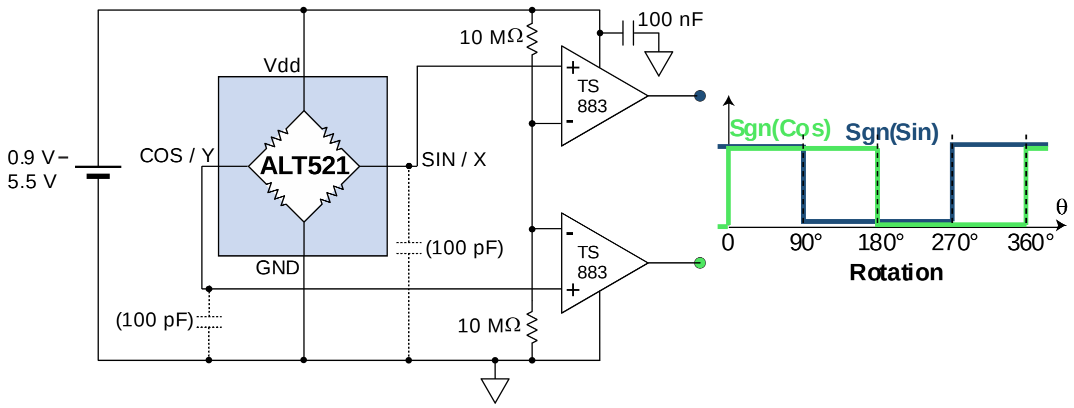


Figure 13. Digital output from a low-power, two-element CMOS comparator.

Ultrasensitive Rotation Sensor

A differential amplifier can be used to focus on small rotation signals. This circuit has a gain of approximately seven, pushing the ALT521-10E sensitivity to 2000 $mV_{pp}/V/mT_{pp}$. Rotations in Earth's 50 µT magnetic field will produce around 330 mV_{pp} when the circuit is powered with a 3.3 V lithium battery. Since the SIN and COS outputs are subtracted, a 45° phase shift is also introduced.

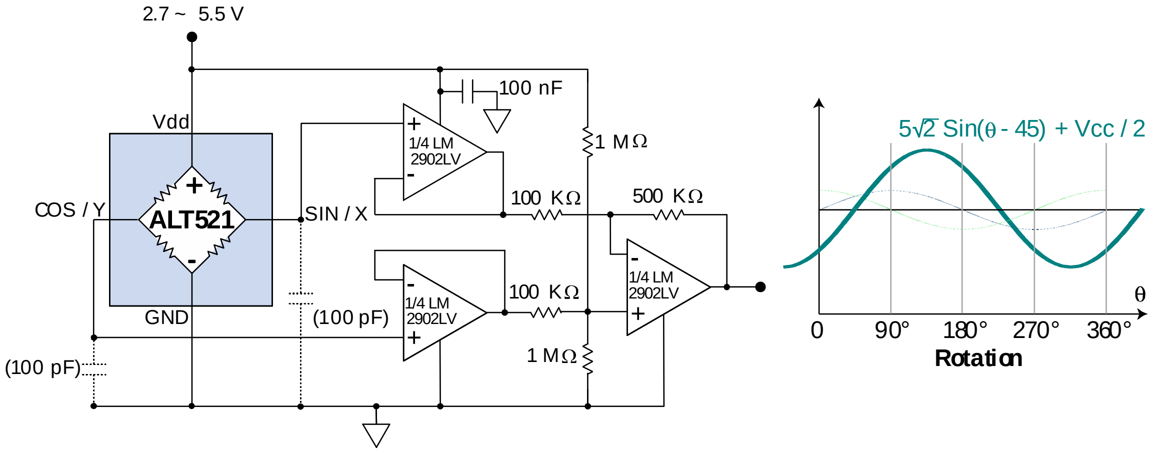


Figure 14. Ultrasensitive rotation counter using a quad Op Amp as a dual-buffered differential amplifer. The gain of the differential amplifer is 5, and subtracting the SIN and COS outputs introduces a 45° phase shift and increases the amplitude by a factor of √2.

Microcontroller Interfaces

ALT521 can connect directly to certain analog peripherals, like an analog comparator for rotation counting and speed measurement.

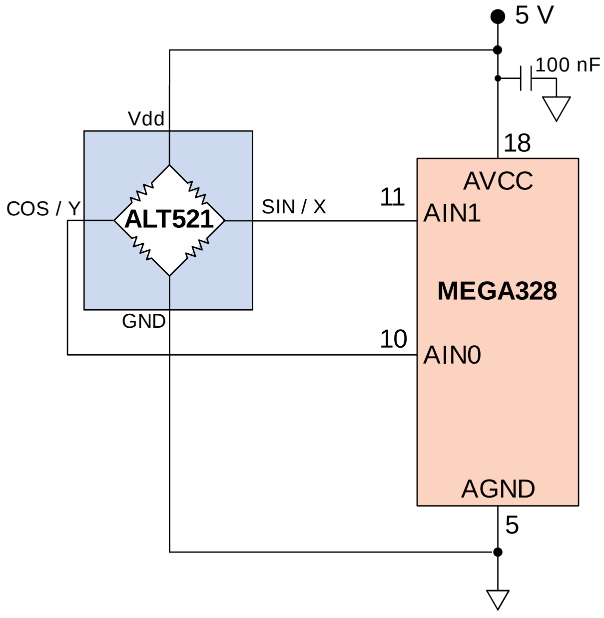


Figure 15. Analog comparator microcontroller interface.

ALT521 can also connect directly to ADC pins, but they should be buffered due to their low-power, high-impedance output.

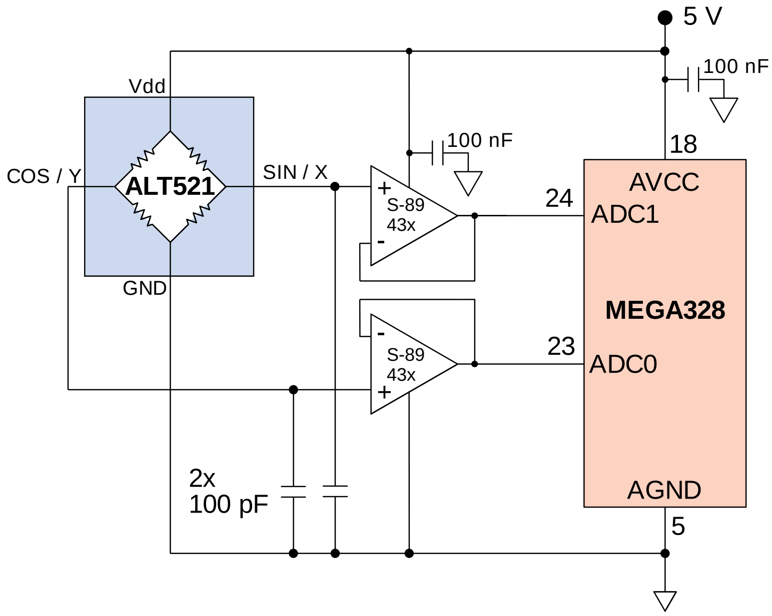
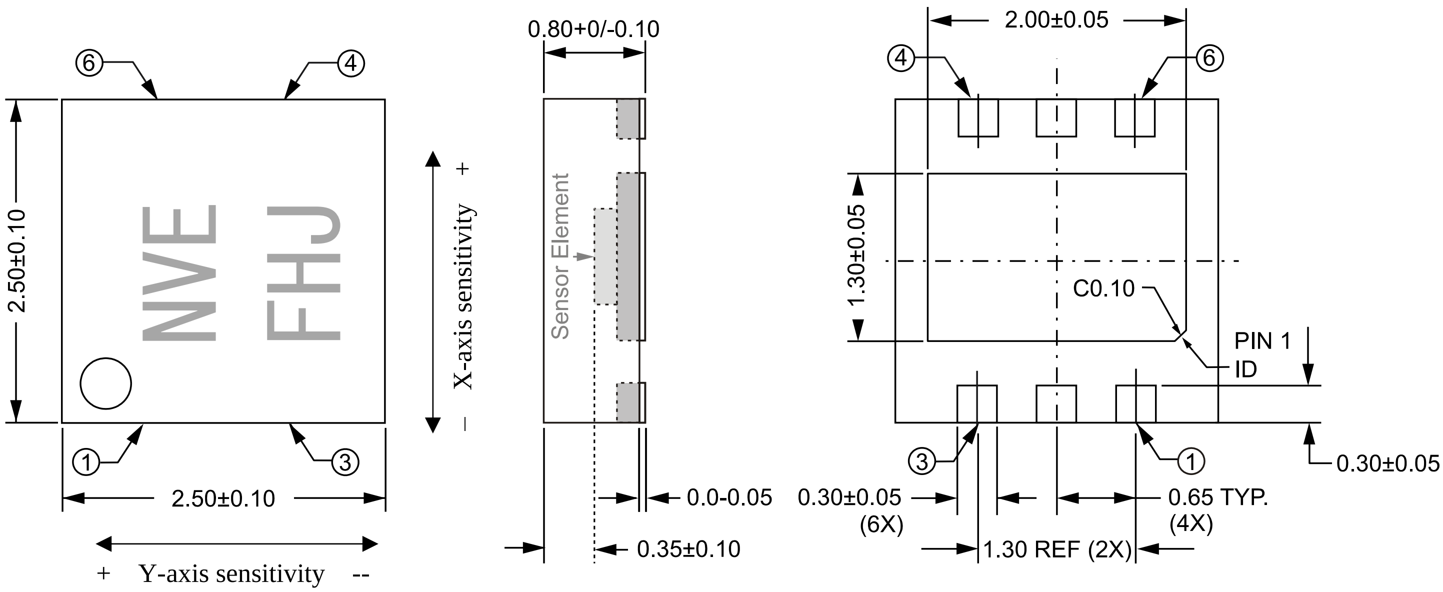


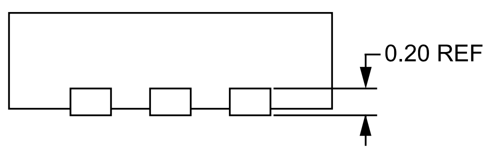
Figure 16. Analog-to-digital converter microcontroller interface.

Here is an illustrative Arduino sketch:

```
/*********************************************************************
Reads an ALT521-10E with an Arduino Uno.
Arduino-Sensor connections: A0 = sensor buffered COS; A1 = SIN; 5V = Vcc
www.nve.com * www.YouTube.com/NveCorporation * sensor-apps@nve.com
*********************************************************************/
#include <math.h>
void setup() {
Serial.begin(57600); //Initialize the serial port
}
void loop() {
//Read, scale, & print sensor output
Serial.print(analogRead(A1)-512);
Serial.println("\t SIN value");
Serial.print(analogRead(A0)-512);
Serial.println("\t COS value");
//Read, scale, & print angle
Serial.print(atan2(analogRead(A1)-512, analogRead(A0)-512)*180/3.14159);
Serial.println("\t Angle value");
delay(100); //10 samples per second
}
```

2.5 mm x 2.5 mm DFN6 Package (-10 suffix)



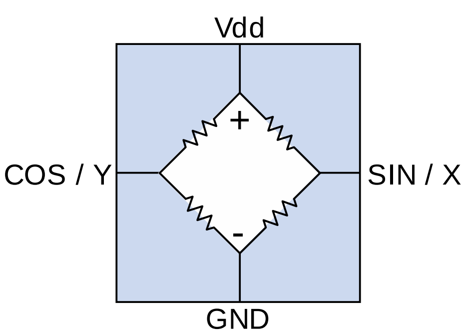


RoHS COMPLIANT

Notes:

- Dimensions in millimeters.
- Soldering profile per JEDEC J-STD-020C, MSL 1.

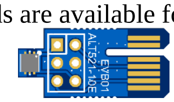
Functional Diagram and Pinout



Symbol	Description	Pads
V_{dd}	Positive bridge supply.	6
GND	Negative bridge supply or ground.	4
SIN / X	Sine output (rotation mode) or X-axis output (dual-axis mode)	5
COS / Y	Cosine output (rotation mode) or Y-axis output (dual-axis mode)	2
NC	No internal connection.	1, 3
---------	Internally connected to leadframe	Center Pad

Breakout Boards

Breakout boards are available for ALT521-10E:



Part number ALT521-10E-EVB01
(0.8" x 0.4" / 21 mm x 10 mm; actual size).

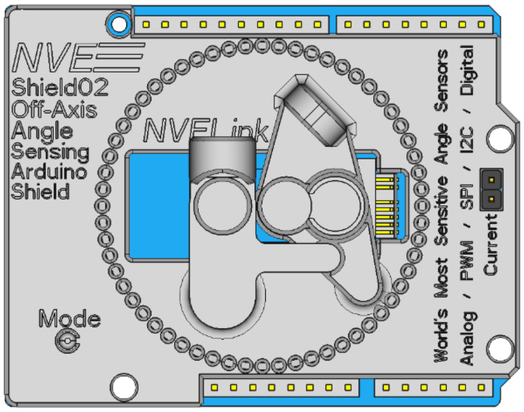
Bare Circuit Boards

NVE offers bare circuit boards for easy connections to DFN6 sensors such as the ALT521-10E:

AG035-06: DFN6 connection board for -10E suffix sensors.
(1.57" x 0.25" /40 mm x 6 mm; actual size).

Off-Axis Rotation Sensor Evaluation Board

This evaluation board allows you to try NVE's unique off-axis angle and rotational sensors.



SHIELD02: Off-Axis Angle Sensor Evaluation Board.
(2.7" x 2.1" / 68.6 mm x 53.3 mm; actual size).

Revision History

SB-00-170 – Rev. A	Change
October 2024	• Initial release.

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