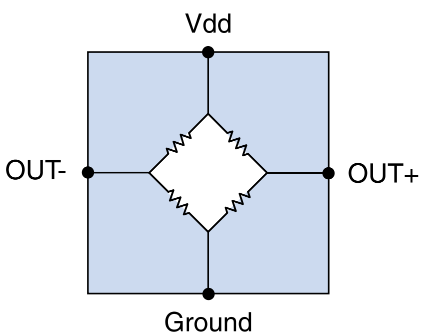
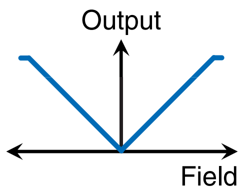
AKT001 High-Field TMR Magnetic Sensor

Schematic Diagram



Magnetic Response



Features

- Tunneling Magnetoresistance (TMR) technology
- 0.05 to 0.8 tesla linear range
- 1.5 tesla saturation
- High resistance for battery powered applications
- Output does not depend on field direction or polarity
- Ratiometric Wheatstone bridge outputs
- Wide supply voltage range (<1 V to 5.5 V)
- Ultraminiature 1.1 x 1.1 mm package

Applications

- MRI magnetic fields
- Battery powered applications
- Noncontact high-current measurement
- Linear position sensing
- Harsh industrial applications

Description

The AKT001-14E is a high-field TMR magnetometer that provides low-power sensing of magnetic fields up to 1.5 T (15 kOe) in any direction. TMR technology generates very large signals, typically 25 mV/V at 0.5 T, for high signal-to-noise ratio measurements and high-reliability applications.

AKT001 sensors are not adversely affected by magnetic fields larger than the saturation field.

The sensor is configured as a Wheatstone bridge. The differential output is ratiometric with supply voltage and is temperature compensated.

The sensor response is both omnipolar and omnidirectional. The sensor output is unchanged by the field polarity or direction. Only the magnetic field magnitude increases the sensor output.

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Absolute Maximum Ratings

Parameter	Min.	Max.	Units
Supply voltage		7	Volts
Inverse supply voltage		–12	Volts
Storage temperature	–65	170	°C
Junction temperature	–65	170	°C
ESD[1]		2000	Volts
Applied magnetic field		Unlimited	

Operating Specifications

Specifications valid overall operating voltage and temperature ranges unless otherwise noted.						
Parameter	**Symbol**	**Min.**	**Typ.**	**Max.**	**Units**	**Test Conditions**
Supply voltage	V_{DD}	<1		5.5	Volts	
Operating temperature	T_{MIN}; T_{MAX}	–40		125	°C	
Minimum detectable field[2]	H_{MIN}		0.02		T	
Saturation field[2]	H_{SAT}	1.5			T	
Linear range[2]	H_{LIN}	0.05		0.8	T	
Non-Linearity	Lin			25	%	Unipolar
Sensitivity[2]	$\Delta V_{OUT}/\Delta H$		25		mV/V/T	
Device resistance	R_{DEVICE}	0.9	1	1.2	MΩ	$T_A = 25°C$
Electrical offset	V_O	–10		10	mV/V	
Maximum output	$V_{OUT-MAX}$	35	50		mV/V	$T_A = 25°C$
Operating frequency	f_{MIN}; f_{MAX}	DC		50	kHz	
Hysteresis	H_c			4	%	
Device resistance vs. temperature	TC_R		–0.08		%/°C	Constant applied field
Output vs. temperature	TC_V[4]		–0.21		%/°C	Constant-voltage supply
Saturation field temperature coefficient	TC_{HSAT}[6]		–0.09		%/°C	Constant-voltage supply

1. Human Body Model (HBM) per JESD22-A114
2. 1 tesla (T) = 10000 Gauss (G) = 10 kOe in air

Thermal Characteristics

Parameter	Symbol	Min.	Typ.	Max.	Units	Test Conditions
Junction–Ambient Thermal Resistance	θ_{JA}		500		°C/W	Soldered to double-sided board
Power Dissipation	P_D			100	mW	

Operation

Omnidirectional and Omnipolar Sensitivity

The AKT001 output is proportional to the magnitude of the magnetic field in any direction. The output is “omnipolar” for fields along a single axis. This means that the output is equally sensitive to either magnetic field polarity and the differential output voltage is always positive:

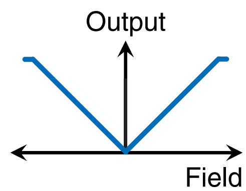


Figure 1. Omni-polar magnetic sensitivity.

The output is also “omnidirectional.” The AKT001 sensor is sensitive to magnetic fields in any direction, so multiple sensors are not needed for orthogonal or unknown directions of applied fields, unlike single-axis sensors like Hall effect or other sensors. The diagrams in Figure 2 below show three permanent magnet orientations that will activate the sensor:

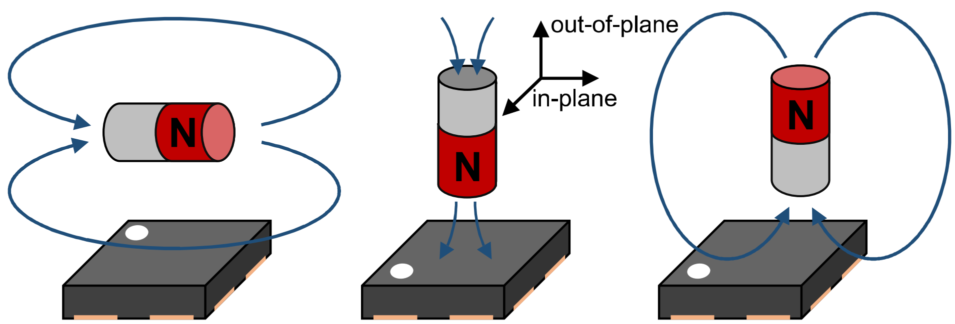


Figure 2. Planar magnetic sensitivity.

The sensitivity of the AKT001 is virtually unaffected by the angle of magnetic fields in the plane of the sensor, and increases proportional to the cosine of the angle between the applied field and the plane of the sensor package for out-of-plane magnetic fields.

Ultra Wide Linear Range

The AKT001 is sensitive over an incredibly wide range of magnetic fields. The minimum detectable field is 0.01 T, and the saturation field is 1.5 T for a dynamic range of 44 dB.

Typical Operation

Figure 3 shows an AKT001 sensor mounted to an available evaluation board:

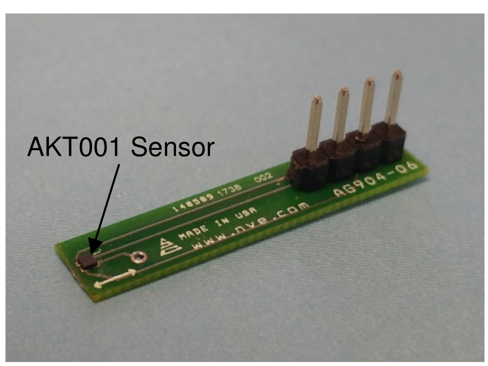


Figure 3. AKT001-14E on an evaluation board.

Typical Performance Graphs

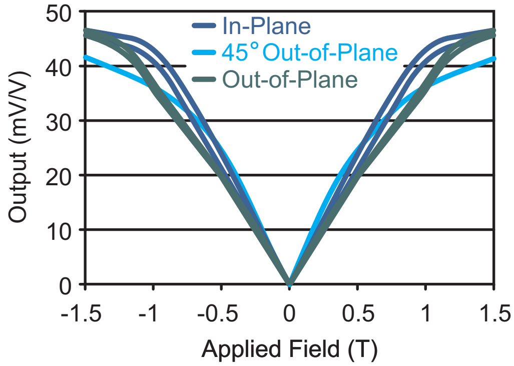


Figure 4. Typical output, -1.5 to +1.5 T.

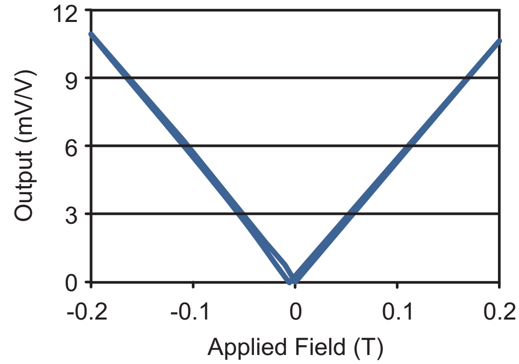


Figure 5. Typical output, -0.2 to +0.2 T (in-plane).

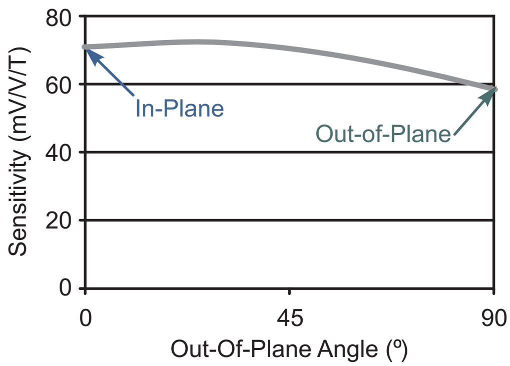


Figure 6. Sensitivity versus out-of-plane angle (0.3 T).

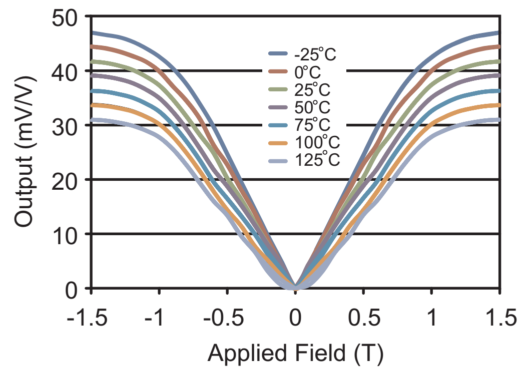


Figure 7. Typical output at various temperatures (in-plane).

Typical Applications

Traditional Differential Amplifier

Traditional differential amplifiers use low-cost op-amps to provide a single-ended analog output. The circuit below has a gain of 10, which provides a full-scale output at slightly less than the sensor's saturation. A low-cost, low bias-current op amp allows large resistors to avoid loading the sensor bridge.

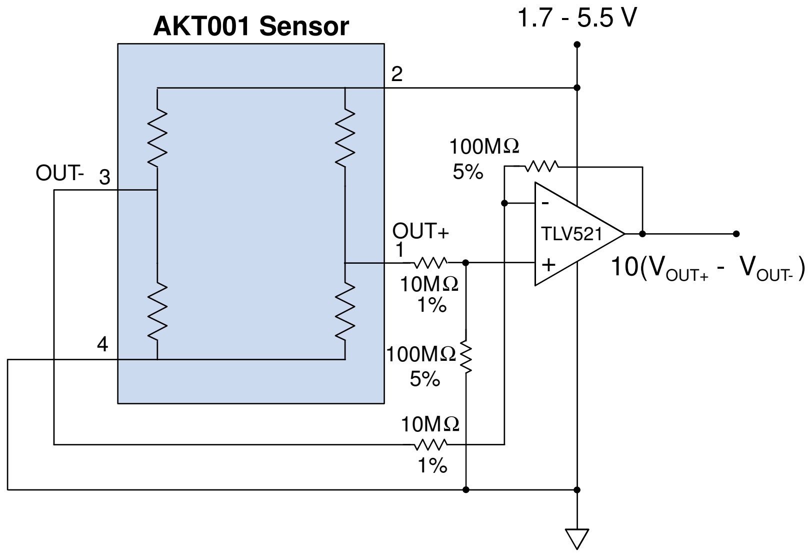


Figure 8. Traditional op-amp differential amplifier. A nanopower op-amp keep total power consumption low. The 10 MΩ input resistors are more than 10 times the typical sensor output impedance to minimize loading. The 100 MΩ resistors are inexpensive with a 5% tolerance. 1% resistors are relatively expensive in that resistance range, but maximize the amplifier's common mode rejection ratio.

Sensor Instrumentation Amplifier

Instrumentation amplifiers such as the INA826 are popular bridge sensor preamplifiers because they have a low component count, high input impedance, and high common-mode rejection ratios without needing to match resistors. These amplifiers can run on single or dual supplies.

The circuit below provides a single-ended, amplified output with offset correction:

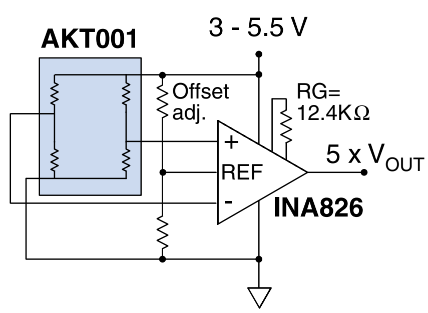


Figure 9. Single-ended analog sensor instrumentation amplifier.

The circuit has a gain of five, which will provide full-scale output of half the power supply with the typical maximum sensor output of 50 mV/V. The general equation for the output voltage is:

$$V_{OUT} = (1 + 49.4K / R_G)V_{IN} + V_{REF}\,;\;\; V_{IN} = V_{OUT+} - V_{OUT-}$$

Variable Threshold Magnetic Switch

AKT001 sensors can be used as high-field magnetic switches with thresholds as high as 1.5 T and variable hysteresis, using a circuit such as this:

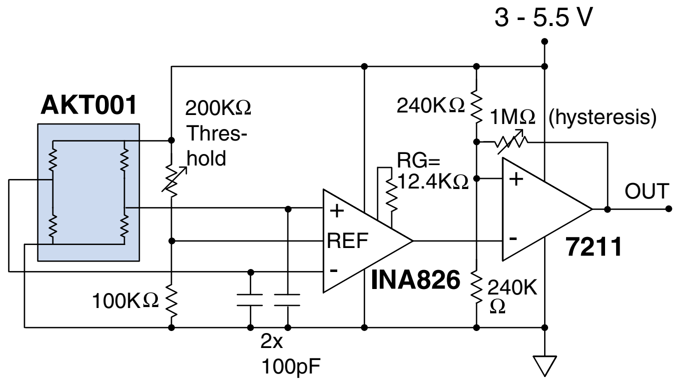


Figure 10. Variable threshold magnetic switch.

LED Field-Strength Indicator

The op-amp circuit in Figure 8 can be used to indicate magnetic field strength with the brightness of an LED:

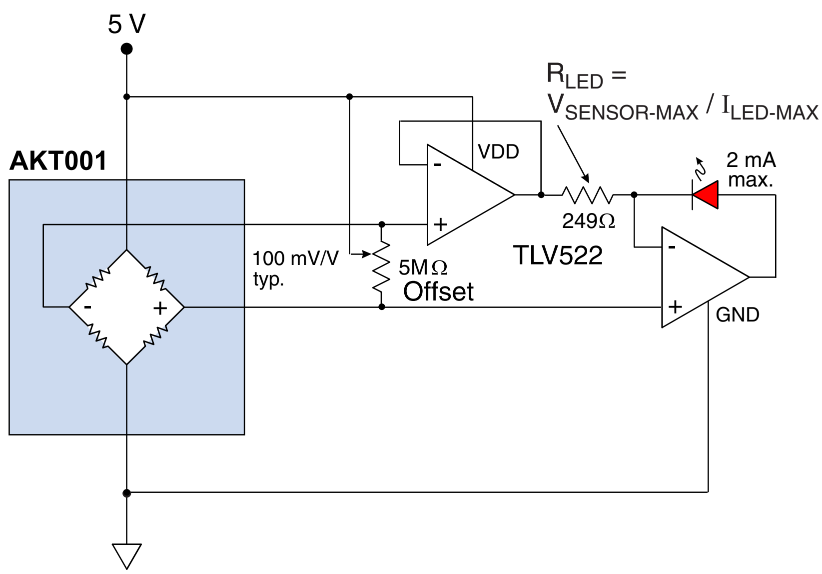


Figure 11. LED brightness changes with magnetic field.

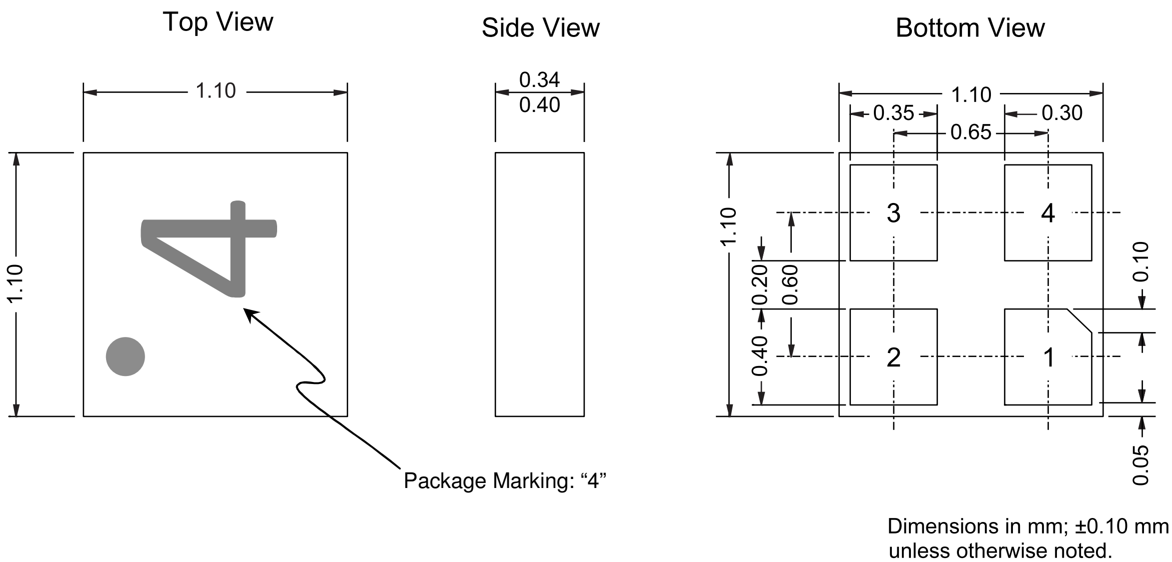
The LED current is proportional to the sensor output:

$$I_{LED} = (V_{OUT+} - V_{OUT-}) / R_{LED}$$

The maximum LED current is set to approximately 2 mA for a high-efficiency LED.

The 5 MΩ potentiometer can be used to correct for sensor offset or to set the minimum field to turn on the LED.

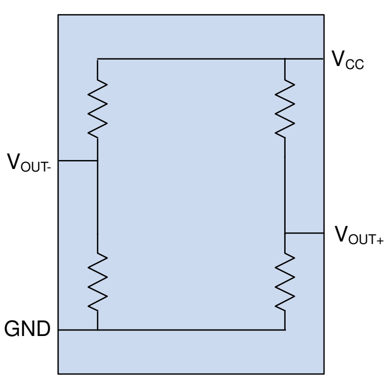
1.1 x 1.1 x 0.37 mm DFN4 (ULLGA) Package (-14E suffix)



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

RoHS COMPLIANT

AKT001-14E Pinout and Functional Diagram:



Pin	Function	Description
1	Out+	Positive bridge output (increases with field).
2	V_{cc}	Positive bridge supply.
3	Out−	Negative bridge output (decreases with field).
4	Ground	Negative bridge supply or ground.

This product has been tested for electrostatic sensitivity to the limits stated in the specifications. However, NVE recommends that all integrated circuits be handled with appropriate care to avoid damage. Damage caused by inappropriate handling or storage could range from performance degradation to complete failure.

Part Numbering

AKT001-14E

Base Part
AKT = High-Field TMR Sensors

Sensitivity Code
001 = 1.5 T Saturation

Package Type
14 = DFN4 (ULLGA)
E = RoHS

Part Marking

Available Part	Marking
AKT001-14E	4

Bare Circuit Board

NVE offers a bare circuit board for easy connections to 1.1 mm DFN4 sensors. These very small sensors generally require reflow or hot-air soldering techniques:

(actual size)

AG904-06: DFN4 PCB
1.2 x 0.25 inch (30 x 6 mm) PCB for demonstrating 1.1 x 1.1 mm DFN4 (ULLGA) sensors (sensors with a -14E suffix).

Revision History

SB-00-107 – Rev. B
June 2020

Change
- Dropped references to constant-current drive since there's no advantage.

SB-00-107 – Rev. A
June 2020

Changes
- Lowered minimum linear field and TCOV for improved linearity and sensitivity over temperature.

- Initial release

SB-00-107 - Prelim
August 2019

Change
- Preliminary Release

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