



# Linear Output Magnetic Field Sensor

## AD22151

### FEATURES

- Adjustable Offset to Unipolar or Bipolar Operation
- Low Offset Drift Over Temperature Range
- Gain Adjustable Over Wide Range
- Low Gain Drift Over Temperature Range
- Adjustable First Order Temperature Compensation
- Ratiometric to  $V_{CC}$

### APPLICATIONS

#### Automotive

- Throttle Position Sensing
- Pedal Position Sensing
- Suspension Position Sensing
- Valve Position Sensing

#### Industrial

- Absolute Position Sensing
- Proximity Sensing

### GENERAL DESCRIPTION

The AD22151 is a linear magnetic field transducer. The sensor output is a voltage proportional to a magnetic field applied perpendicularly to the package top surface.

The sensor combines integrated bulk Hall cell technology and instrumentation circuitry to minimize temperature related drifts associated with silicon Hall cell characteristics. The architecture maximizes the advantages of a monolithic implementation while allowing sufficient versatility to meet varied application requirements with a minimum number of components.

Principle features include dynamic offset drift cancellation and a built-in temperature sensor. Designed for single +5 volt supply operation, the AD22151 achieves low drift offset and gain operation over  $-40^{\circ}\text{C}$  to  $+150^{\circ}\text{C}$ . Temperature compensation can accommodate a number of magnetic materials commonly utilized in economic position sensor assemblies.

The transducer may be configured for specific signal gains dependent upon application requirements. Output voltage can be adjusted from fully bipolar (reversible) field operation to fully unipolar field sensing.

The voltage output achieves near rail-to-rail dynamic range, capable of supplying 1 mA into large capacitive loads. The signal is ratiometric to the positive supply rail in all configurations.

### FUNCTIONAL BLOCK DIAGRAM

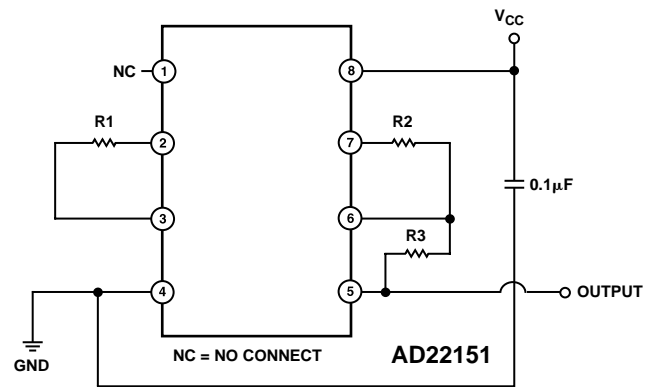
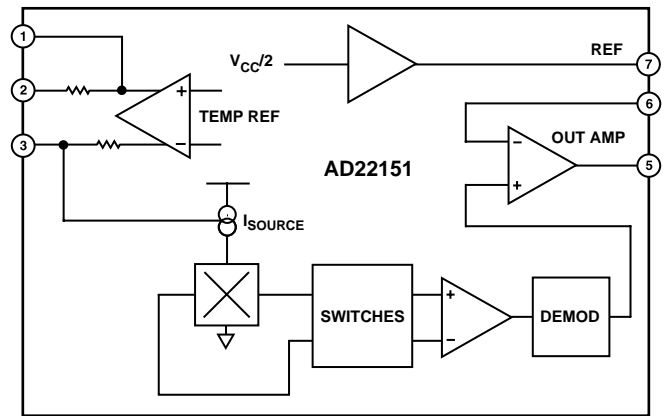


Figure 1. Typical Bipolar Configuration with Low ( $< -500$  ppm) Compensation

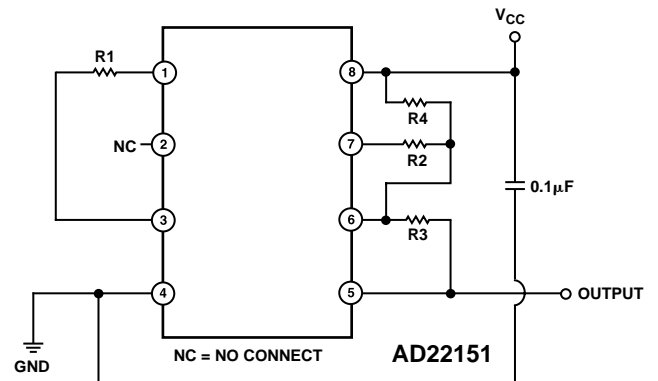


Figure 2. Typical Unipolar Configuration with High ( $\approx -2000$  ppm) Compensation

### REV. 0

Information furnished by Analog Devices is believed to be accurate and reliable. However, no responsibility is assumed by Analog Devices for its use, nor for any infringements of patents or other rights of third parties which may result from its use. No license is granted by implication or otherwise under any patent or patent rights of Analog Devices.

One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.  
 Tel: 781/329-4700 World Wide Web Site: <http://www.analog.com>  
 Fax: 781/326-8703 © Analog Devices, Inc., 1997

# AD22151-SPECIFICATIONS (T<sub>A</sub> = +25°C and V<sub>+</sub> = +5 V unless otherwise noted)

Parameters	Min	Typ	Max	Units
<b>OPERATION</b>				
V <sub>CC</sub> Operating	4.5	5.0	6.0	V
I <sub>CC</sub> Operating		6.0	10	mA
<b>INPUT</b>				
TC3 (Pin 3) Sensitivity/Volt		160		μV/G/V
Input Range <sup>1</sup>		$\frac{V_{CC}}{2} \pm 0.5$		V
<b>OUTPUT<sup>2</sup></b>				
Sensitivity (External Adjustment, Gain = 1)		0.4		mV/G
Linear Output Range	10		90	% of V <sub>CC</sub>
Output Min		5		% of V <sub>CC</sub>
Output Max (Clamp)		93		% of V <sub>CC</sub>
Drive Capability		1.0		mA
Offset @ 0 Gauss		$\frac{V_{CC}}{2}$		V
Offset Adjust Range	5		95	% of V <sub>CC</sub>
Output Short Circuit Current		5.0		mA
<b>ACCURACIES</b>				
Nonlinearity (10% to 90% Range)		0.1		% FS
Gain Error (Over Temperature Range)		±1		%
Offset Error (Over Temperature Range)		±6.0		G
Uncompensated Gain TC (G <sub>TCU</sub> )		950		ppm
<b>RATIOMETRICITY ERROR</b>				
			1	%V/V <sub>CC</sub>
<b>3 dB ROLL-OFF (5 mV/G)</b>				
		5.7		kHz
<b>OUTPUT NOISE FIGURE (6 kHz BW)</b>				
		2.4		mV/rms
<b>PACKAGE</b>				
		8-Lead SOIC		
<b>OPERATING TEMPERATURE RANGE</b>				
	-40		+150	°C

**NOTES**

<sup>1</sup>-40°C to +150°C.

<sup>2</sup>R<sub>L</sub> = 4.7 kΩ.

Specifications subject to change without notice.

**ABSOLUTE MAXIMUM RATING\***

Supply Voltage	12 V
Package Power Dissipation	25 mW
Storage Temperature	-50°C to +160°C
Output Sink Current, I <sub>O</sub>	15 mA
Magnetic Flux Density	Unlimited
Lead Temperature (Soldering 10 sec)	+300°C

\*Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; the functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to the absolute maximum rating conditions for extended periods may affect device reliability.

**ORDERING GUIDE**

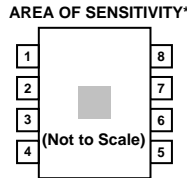
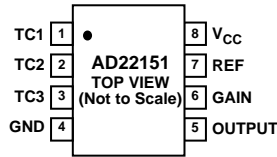
Model	Temperature Range	Package Description	Package Option
AD22151YR	-40°C to +150°C	8-Lead SOIC	SO-8

**CAUTION**

ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although the AD22151 features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.



**PIN CONFIGURATION**



- \* SHADED AREA REPRESENTS MAGNETIC FIELD AREA OF SENSITIVITY (20MILS × 20MILS)
- \* POSITIVE B FIELD INTO TOP OF PACKAGE RESULTS IN A POSITIVE VOLTAGE RESPONSE

**PIN FUNCTION DESCRIPTIONS**

Pin No.	Description	Connection
1	Temperature Compensation 1	Output
2	Temperature Compensation 2	Output
3	Temperature Compensation 3	Input/Output
4	Ground	
5	Output	Output
6	Gain	Input
7	Reference	Output
8	Positive Power Supply	

**CIRCUIT OPERATION**

The AD22151 consists of epi Hall plate structures located at the center of the die. The Hall plates are orthogonally sampled by commutation switches via a differential amplifier. The two amplified Hall signals are synchronously demodulated to provide a resultant offset cancellation (see Figure 3). The demodulated signal passes through a noninverting amplifier to provide final gain and drive capability. The frequency at which the output signal is refreshed is 50 kHz.

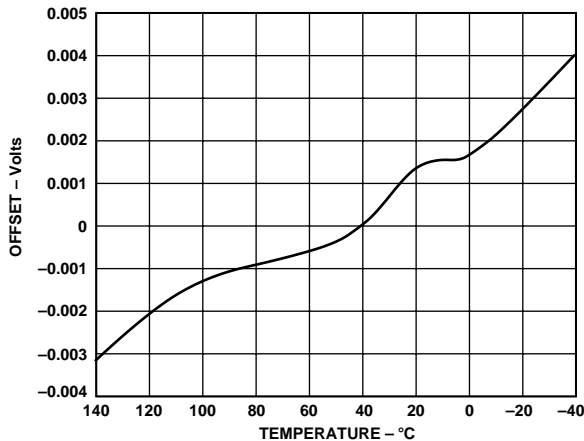


Figure 3. Relative Quiescent Offset vs. Temperature

**TEMPERATURE DEPENDENCIES**

The uncompensated gain temperature coefficient ( $G_{TCU}$ ) of the AD22151 is the result of fundamental physical properties associated with silicon bulk Hall plate structures. Low doped Hall plates operated in current bias mode exhibit a temperature relationship determined by the action of scattering mechanisms and doping concentration.

The relative value of sensitivity to magnetic field can be altered by the application of mechanical force upon silicon. The mechanism is principally the redistribution of electrons throughout the

“valleys” of the silicon crystal. Mechanical force on the sensor is attributable to package-induced stress. The package material acts to distort the encapsulated silicon altering the Hall cell gain by  $\pm 2\%$  and  $G_{TCU}$  by  $\pm 200$  ppm.

Figure 4 shows the typical  $G_{TCU}$  characteristic of the AD22151. This is the observable alteration of gain with respect to temperature with Pin 3 (TC3) held at a constant 2.5 V (uncompensated).

If a permanent magnet source used in conjunction with the sensor also displays an intrinsic TC ( $B_{TC}$ ), it will require factoring into the total temperature compensation of the sensor assembly.

Figures 5 and 6 represent typical overall temperature/gain performance for a sensor and field combination ( $B_{TC} = -200$  ppm). Figure 5 is the total drift in volts over a  $-40^{\circ}\text{C}$  to  $+150^{\circ}\text{C}$  temperature range with respect to applied field. Figure 6 represents typical percentage gain variation from  $+25^{\circ}\text{C}$ . Figures 7 and 8 show similar data for a  $B_{TC} = -2000$  ppm.

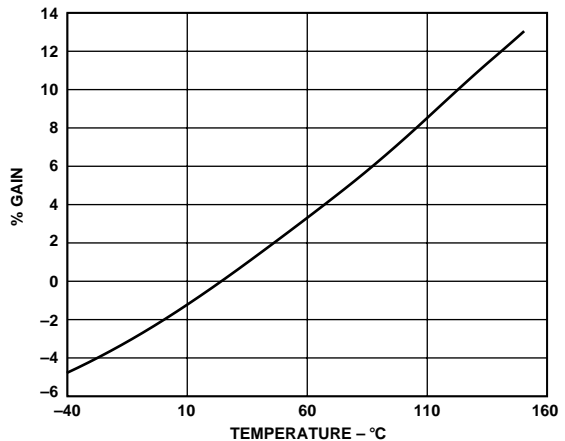


Figure 4. Uncompensated Gain Variation (from  $+25^{\circ}\text{C}$ ) vs. Temperature

# AD22151

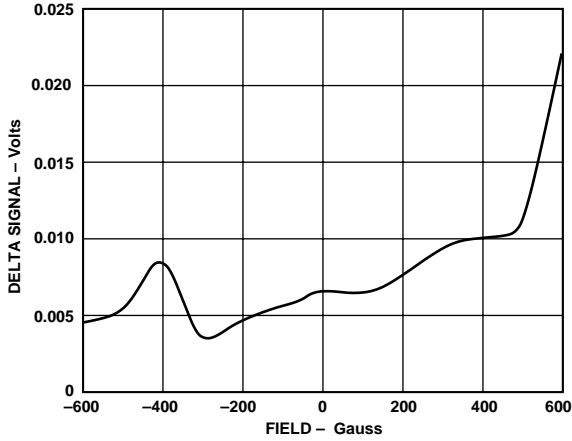


Figure 5. Signal Drift Over Temperature (-40°C to +150°C) vs. Field (-200 ppm); +5 V Supply

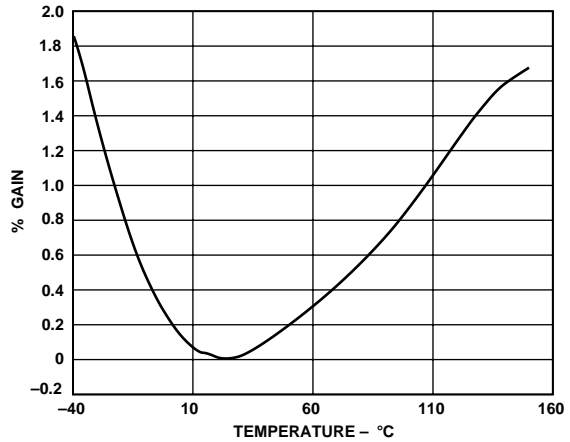


Figure 8. Gain Variation (from +25°C) vs. Temperature (-2000 ppm Field; R1 = 12 kΩ)

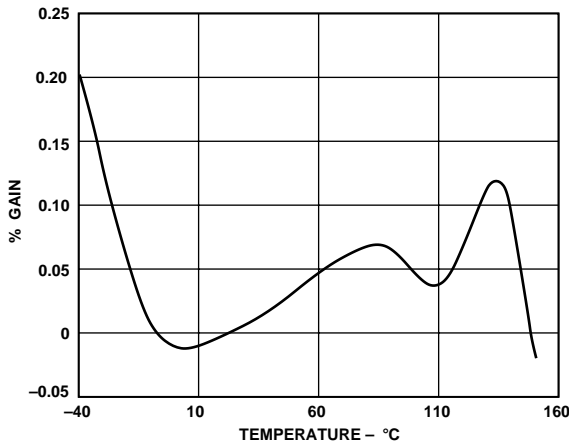


Figure 6. Gain Variation from +25°C vs. Temperature (-200 ppm) Field; R1 -15 kΩ

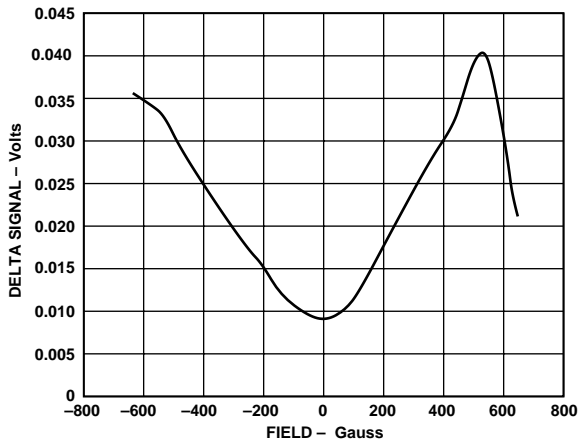


Figure 7. Signal Drift Over Temperature (-40°C to +150°C) vs. Field (-2000 ppm); +5 V Supply

## TEMPERATURE COMPENSATION

The AD22151 incorporates a “thermistor” transducer that detects relative chip temperature within the package. This function provides a compensation mechanism for the various temperature dependencies of the Hall cell and magnet combinations. The temperature information is accessible at Pins 1 and 2 ( $\approx +2900$  ppm/°C) and Pin 3 ( $\approx -2900$  ppm/°C) as represented by Figure 9. The compensation voltages are trimmed to converge at  $V_{CC}/2$  at +25°C. Pin 3 is internally connected to the negative TC voltage via an internal resistor (see Functional Block Diagram). An external resistor connected between Pin 3 and Pins 1 or 2 will produce a potential division of the two complementary TC voltages to provide optimal compensation. The aforementioned Pin 3 internal resistor provides a secondary TC designed to reduce second order Hall cell temperature sensitivity.

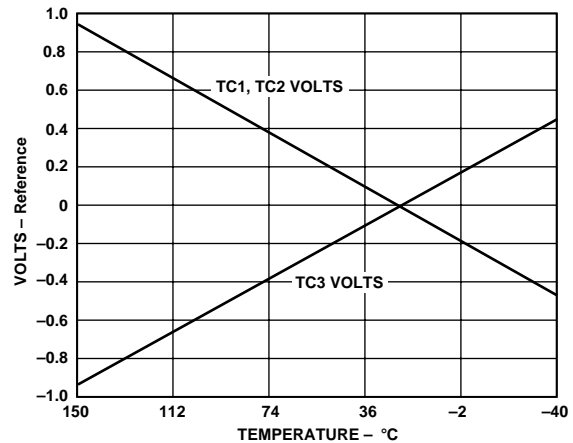


Figure 9. TC1, TC2 and TC3 with Respect to Reference vs. Temperature

The voltages present at Pins 1, 2 and 3 are proportional to the supply voltage. The presence of the Pin 2 internal resistor distinguishes the effective compensation ranges of Pins 1 and 2 (see temperature configuration in Figures 1 and 2, and typical resistor values in Figures 10 and 11).

Variation occurs in the operation of the gain temperature compensation for two reasons. First, the die temperature within

the package is somewhat higher than the ambient temperature due to self-heating as a function of power dissipation. Second, package stress effect alters the specific operating parameters of the gain compensation, particularly the specific cross over temperature of TC1, TC3 ( $\approx \pm 10^\circ\text{C}$ ).

**CONFIGURATION AND COMPONENT SELECTION**

There are three areas of sensor operation that require external component selection. Temperature compensation (R1), signal gain (R2 and R3), and offset (R4).

**Temperature**

If the internal gain compensation is used, an external resistor is required to complete the gain TC circuit at Pin 3. A number of factors contribute to the value of this resistor.

- a. The intrinsic Hall cell sensitivity TC  $\approx 950$  ppm.
- b. Package induced stress variation in a.  $\approx \pm 150$  ppm.
- c. Specific field TC  $\approx -200$  ppm (Alnico),  $-2000$  ppm (Ferrite), 0 ppm (electromagnet) etc.
- d. R1, TC.

The final value of target compensation also dictates the use of either Pin 1 or Pin 2. Pin 1 is provided to allow for large negative field TC such as ferrite magnets, thus R1 would be connected to Pins 1 and 3.

Pin 2 uses an internal resistive TC to optimize smaller field coefficients such as Alnico, down to 0 ppm coefficients when only the sensor gain TC itself is dominant. The TC of R1 itself will also effect the compensation and as such a low TC resistor ( $\pm 50$  ppm) is recommended.

Figures 10 and 11 indicate R1 resistor values and their associated effectiveness for Pins 1 and 2 respectively. Note that the indicated drift response in both cases incorporates the intrinsic Hall sensitivity TC ( $B_{TCU}$ ).

For example, the AD22151 sensor is to be used in conjunction with an Alnico material permanent magnet. The TC of such magnets is  $\approx -200$  ppm (see Figures 5 and 6). Figure 11 indicates that a compensating drift of  $+200$  ppm at Pin 3 requires a nominal value of  $R1 = 18$  k $\Omega$  (assuming negligible drift of R1 itself).

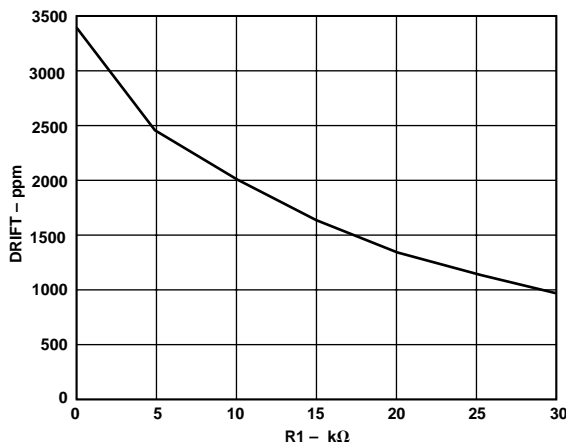


Figure 10. Typical Resistor Value R1 vs. (Pins 1 and 3) Drift Compensation

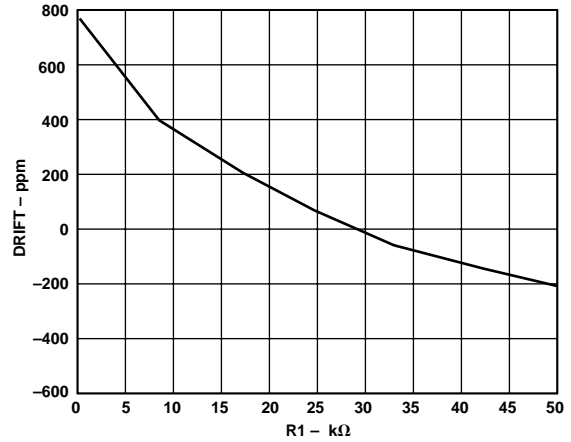


Figure 11. Typical Resistor Value R1 (Pins 2 and 3) vs. Drift Compensation

**GAIN AND OFFSET**

The operation of the AD22151 can be bipolar (i.e., 0 Gauss =  $V_{CC}/2$ ) or a ratiometric offset can be implemented to Position Zero Gauss point at some other potential (i.e., 0.25 V).

The gain of the sensor can be set by the appropriate R2 and R3 resistor values (see Figure 1) such that:

$$Gain = 1 + \frac{R3}{R2} \times 0.4 \text{ mV/G} \tag{1}$$

However, if an offset is required to position the quiescent output at some other voltage then the gain relationship is modified to:

$$Gain = 1 + \frac{R3}{(R2 \parallel R4)} \times 0.4 \text{ mV/G} \tag{2}$$

The offset that R4 introduces is:

$$Offset = \frac{R3}{(R3 + R4)} \times (V_{CC} - V_{OUT}) \tag{3}$$

For example:

At  $V_{CC} = 5$  V at room temperature, the internal gain of the sensor is approximately 0.4 mV/Gauss. If a sensitivity of 6 mV/Gauss is required with a quiescent output voltage of 1 V, the following calculations apply (see Figure 2).

A value for R3 would be selected that complied with the various considerations of current and power dissipation, trim ranges (if applicable), etc. For the purpose of example assume a value of 85 k $\Omega$ .

To achieve a quiescent offset of 1 V requires a value for R4 as:

$$\left(\frac{V_{CC}}{2}\right) - 1 = \frac{R3}{R3 + R4} \times (V_{CC} - 1) \tag{4}$$

Thus:

$$R4 = \left(\frac{85 \text{ k}\Omega}{0.375}\right) - 85 \text{ k}\Omega = 141.666 \text{ k}\Omega \tag{5}$$

The gain required would be  $6/0.4$  (mV/Gauss) = 15

# AD22151

Knowing the values of R3 and R4 from above, and noting Equation 2, the parallel combination of R2 and R4 required is:

$$\frac{85 \text{ k}\Omega}{(15 - 1)} = 6.071 \text{ k}\Omega$$

Thus:

$$R2 = \left( \frac{1}{\left( \frac{1}{6.071 \text{ k}\Omega} \right) - \left( \frac{1}{141.666 \text{ k}\Omega} \right)} \right) = 6.342 \text{ k}\Omega$$

## NOISE

The principle noise component in the sensor is thermal noise from the Hall cell. Clock feedthrough into the output signal is largely suppressed with application of a supply bypass capacitor.

Figure 12 shows the power spectral density (PSD) of the output signal for a gain of 5 mV/Gauss. The effective bandwidth of the sensor is approximately 5.7 kHz. This is shown by Figure 13 small signal bandwidth vs. gain. The PSD indicates an rms noise voltage of 2.8 mV within the 3 dB bandwidth of the sensor. A wideband measurement of 250 MHz indicates 3.2 mV rms (see Figure 14a).

In many position sensing applications bandwidth requirements can be as low as 100 Hz. Passing the output signal through an LP filter, for example 100 Hz, would reduce the rms noise voltage to ≈1 mV. A dominant pole may be introduced into the output amplifier response by connection of a capacitor across feedback resistor R3, as a simple means of reducing noise at the expense of bandwidth. Figure 14b indicates the output signal of a 5 mV/G sensor bandwidth limited to 180 Hz with a 0.01 μF feedback capacitor.

Note: Measurements taken with 0.1 μF decoupling capacitor between V<sub>CC</sub> and GND at +25°C.

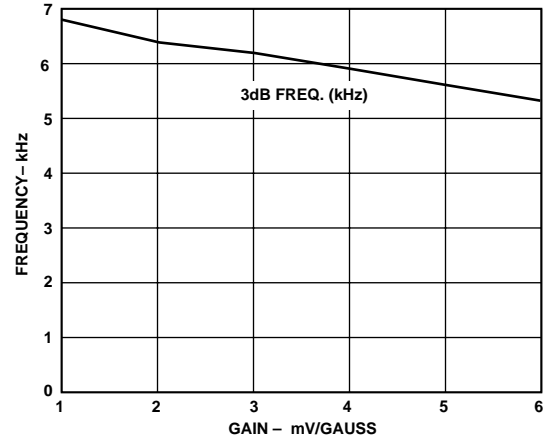


Figure 13. Small-Signal Gain Bandwidth

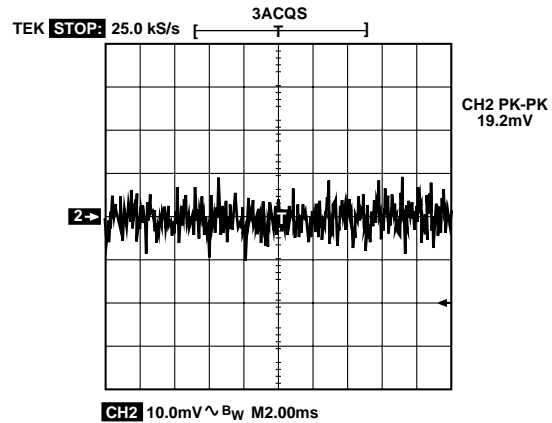


Figure 14a. Peak-to-Peak Full Bandwidth (10 mV/Division)

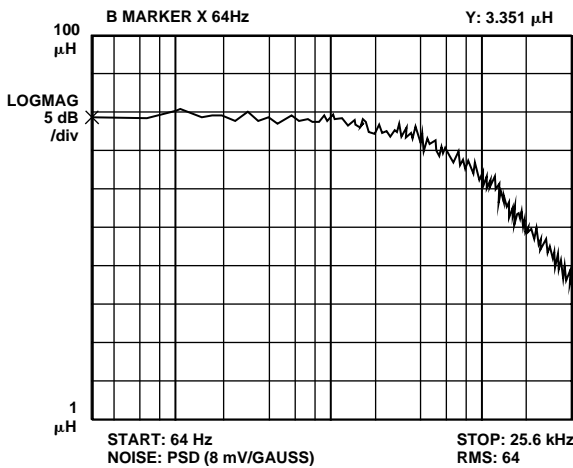


Figure 12. Power Spectral Density (5 mV/G)

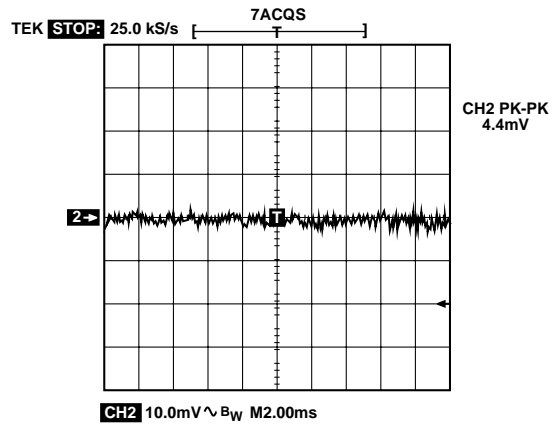


Figure 14b. Peak-to-Peak 180 Hz Bandwidth (10 mV/Division)

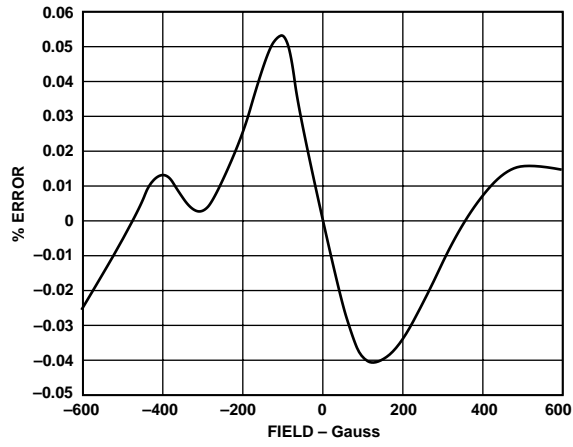


Figure 15. Integral Nonlinearity vs. Field

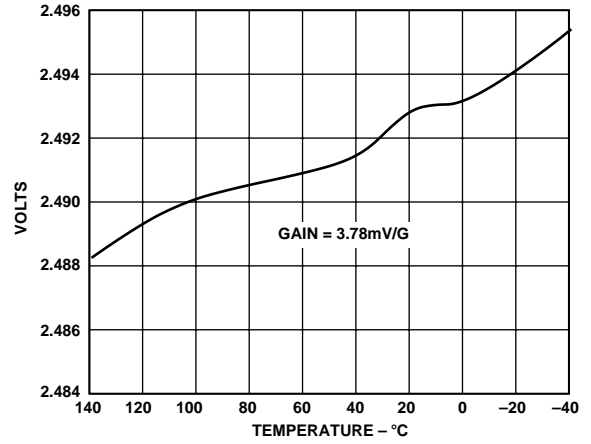


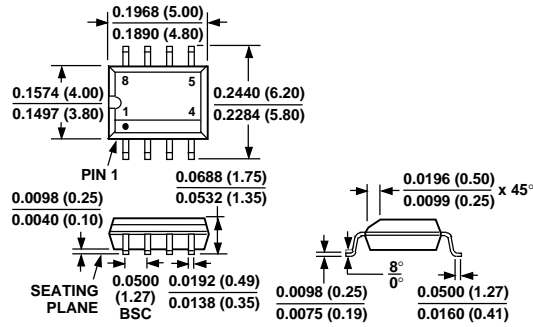
Figure 16. Absolute Offset Volts vs. Temperature

# AD22151

## OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).

### 8-Lead SOIC (SO-8)



C3213-8-10/97

PRINTED IN U.S.A.



SUNSTAR商斯达实业集团是集研发、生产、工程、销售、代理经销、技术咨询、信息服务等为一体的高科技企业，是专业高科技电子产品生产厂家，是具有10多年历史的专业电子元器件供应商，是中国最早和最大的仓储式连锁规模经营大型综合电子零部件代理分销商之一，是一家专业代理和分销世界各大品牌IC芯片和电子元器件的连锁经营综合性国际公司。在香港、北京、深圳、上海、西安、成都等全国主要电子市场设有直属分公司和产品展示展销窗口门市部专卖店及代理分销商，已在全国范围内建成强大统一的供货和代理分销网络。我们专业代理经销、开发生产电子元器件、集成电路、传感器、微波光电元器件、工控机/DOC/DOM电子盘、专用电路、单片机开发、MCU/DSP/ARM/FPGA软件硬件、二极管、三极管、模块等，是您可靠的一站式现货配套供应商、方案提供商、部件功能模块开发配套商。专业以现代信息产业（计算机、通讯及传感器）三大支柱之一的传感器为主营业务，专业经营各类传感器的代理、销售生产、网络信息、科技图书资料及配套产品设计、工程开发。我们的专业网站——中国传感器科技信息网（全球传感器数据库）[www.SENSOR-IC.COM](http://www.SENSOR-IC.COM) 服务于全球高科技生产商及贸易商，为企业科技产品开发提供技术交流平台。欢迎各厂商互通有无、交换信息、交换链接、发布寻求代理信息。欢迎国外高科技传感器、变送器、执行器、自动控制产品厂商介绍产品到中国，共同开拓市场。本网站是关于各种传感器-变送器-仪器仪表及工业自动化大型专业网站，深入到工业控制、系统工程计 测量、自动化、安防报警、消费电子等众多领域，把最新的传感器-变送器-仪器仪表买卖信息，最新技术供求，最新采购商，行业动态，发展方向，最新的技术应用和市场资讯及时的传递给广大科技开发、科学研究、产品设计人员。本网站已成功为石油、化工、电力、医药、生物、航空、航天、国防、能源、冶金、电子、工业、农业、交通、汽车、矿山、煤炭、纺织、信息、通信、IT、安防、环保、印刷、科研、气象、仪器仪表等领域从事科学研究、产品设计、开发、生产制造的科技人员、管理人员、和采购人员提供满意服务。我们公司专业生产、代理、经销、销售各种传感器、变送器、敏感元器件、开关、执行器、仪器仪表、自动化控制系统：专业从事设计、生产、销售各种传感器、变送器、各种测控仪表、热工仪表、现场控制器、计算机控制系统、数据采集系统、各类环境监控系统、专用控制系统应用软件以及嵌入式系统开发及应用等工作。如热敏电阻、压敏电阻、温度传感器、温度变送器、湿度传感器、湿度变送器、气体传感器、气体变送器、压力传感器、压力变送、称重传感器、物（液）位传感器、物（液）位变送器、流量传感器、流量变送器、电流（压）传感器、溶氧传感器、霍尔传感器、图像传感器、超声波传感器、位移传感器、速度传感器、加速度传感器、扭距传感器、红外传感器、紫外传感器、火焰传感器、激光传感器、振动传感器、轴角传感器、光电传感器、接近传感器、干簧管传感器、继电器传感器、微型电泵、磁敏（阻）传感器、压力开关、接近开关、光电开关、色标传感器、光纤传感器、齿轮测速传感器、时间继电器、计数器、计米器、温控仪、固态继电器、调压模块、电磁铁、电压表、电流表等特殊传感器。同时承接传感器应用电路、产品设计和自动化工程项目。

更多产品请看本公司产品专用销售网站：

商斯达中国传感器科技信息网：<http://www.sensor-ic.com/>

商斯达工控安防网：<http://www.pc-ps.net/>

商斯达电子元器件网：<http://www.sunstare.com/>

商斯达微波光电产品网：[HTTP://www.rfoe.net/](http://www.rfoe.net/)

商斯达消费电子产品网：<http://www.icasic.com/>

商斯达军工产品网：<http://www.junpinic.com/>

商斯达实业科技产品网：<http://www.sunstars.cn/>传感器销售热线：

地址：深圳市福田区福华路福庆街鸿图大厦1602室

电话：0755-83607652 83376489 83376549 83370250 83370251 82500323

传真：0755-83376182 (0) 13902971329 MSN: [SUNS888@hotmail.com](mailto:SUNS888@hotmail.com)

邮编：518033 E-mail: [szss20@163.com](mailto:szss20@163.com) QQ: 195847376

深圳赛格展销部：深圳华强北路赛格电子市场2583号 电话：0755-83665529 25059422

技术支持：0755-83394033 13501568376

欢迎索取免费详细资料、设计指南和光盘；产品凡多，未能尽录，欢迎来电查询。

北京分公司：北京海淀区知春路132号中发电子大厦3097号

TEL: 010-81159046 82615020 13501189838 FAX: 010-62543996

上海分公司：上海市北京东路668号上海赛格电子市场D125号

TEL: 021-28311762 56703037 13701955389 FAX: 021-56703037

西安分公司：西安高新开发区20所(中国电子科技集团导航技术研究所)

西安劳动南路88号电子商城二楼D23号

TEL: 029-81022619 13072977981 FAX:029-88789382