The Theory of the Hall Effect

The action of the Hall effect in a semiconducting medium is adequately explained by quantum physics. However, in spite of its shortcomings, the classical approach is chosen here for its brevity.

A particle with charge Q, velocity, $\bar{V}$ and moving within a magnetic field, $\bar{B}$, will experience the Lorentz force, $F=Q(\bar{V} \times \bar{B})$. The force direction is mutually perpendicular to the directions of the particle velocity and the magnetic field. If a long, flat current-carrying conductor is placed in a magnetic field, the moving charges will experience a net force mutually perpendicular to the direction of the current flow (longitudinal conductor axis) and the magnetic field. Under the influence of this force, the electrons will "pile up" on one edge of the conductor, and positive charges will gather on the other edge. An un-even lateral charge distribution results and gives rise to an electric field, $\bar{E}$, which exerts a force, $\bar{F} = Q\bar{E}$, opposite in direction to the Lorentz force. At equilibrium, the resultant forces balance (Fig. 2). This field, superimposed on the E in the direction of the current flow, yields the skewed equipotential lines first noted by Hall (Fig. 1). The relation between the voltage, current, and magnetic field can be generalized as follows:

V_H = y IB
V_H = Hall voltage
y = a constant product sensitivity
I = Hall current
B = magnetic field perpindicular to Hall Plate surface

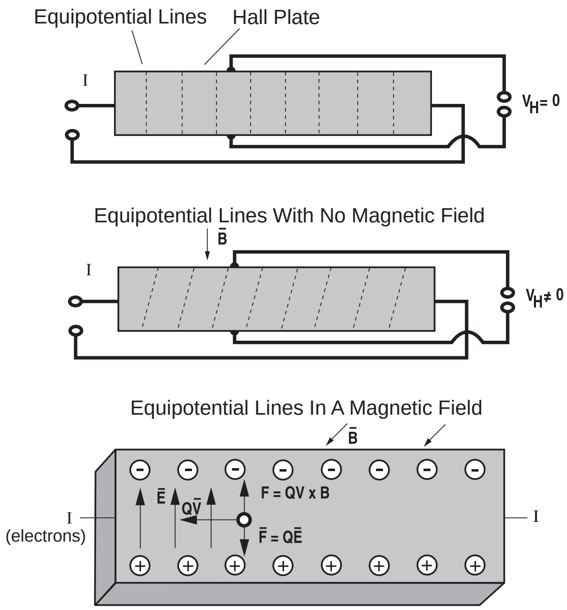


Figure 1
Explanation of the Hall effect

This equation ignores many low level effects but will suffice for the depth of this discussion.

Note:
All B fields in the article refer to the component of the external B field that is normal to the surface of the Hall plate. A more general equation for Hall voltage is V_H = yIB sinØ), where Ø is the angle is between B and the normal to the Hall plate surface.

What Is A Hall Sensor?

A Hall sensor is a four-terminal, solid-state device capable of producing an output voltage V_H, proportional to the product of the input current, I_C,the magnetic flux density, B, and the sine of the angle betweeen B and the plane of the Hall sensor.

A reversal in the direction of either the magnetic field or the control current will result in a polarity change of V_H. A reversal in the direction of both will keep the polarity the same. By holding the control current constant, the Hall voltage may be used to measure magnetic flux density. Multiplication may be accomplish by varying both the control current and the magnetic field..

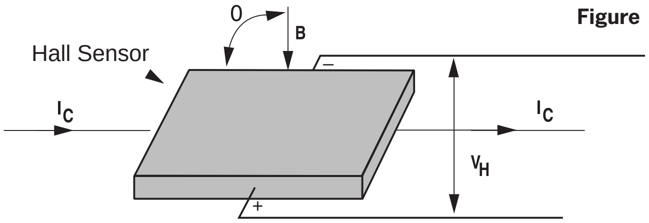


Figure 2

$V_H = K_{HOC}\ I_C\ B \sin - Ø$ or if $\sin - Ø =$ (i.e., $- Ø = 90°$)
$V_H = K_{HOC}\ I_C\ B$ or $V_H = \gamma_B\ B$

where:
V_H = Hall ouput voltage, mV
$K_{HOC} = \gamma_{IB}$ (open circuit product sensitivity constant), mV/mA kG
γ_B =magnetic sensitivity (loaded or unloaded) at a specified control Current, mV/kG
I_C = control current, mA (ac or dc)
B = magnetic flux density, kG (ac or dc)

Discovery of Hall Effect

Edwin Herbert Hall discovered the “Hall effect” in 1879 while working on his doctoral thesis in Physics under the supervision of Professor Henry A. Rollin.[1] Dr. Hall was pursuing the question as to whether the resistance of a coil excited by a current was affected by the presence of a magnet. Through a myriad of experiments and failures, Hall discovered that a magnetic field would skew equipotential lines in a current-carrying conductor. This effect is observed as a voltage (Hall voltage, V_H) perpendicular to the direction of current in the conductor.

Hall conducted an experiment by putting a thin gold leaf on a glass plate and then tapping off the gold leaf at points down its length. He then conducted other experiments using various materials in place of the gold leaf, and various experimental placements of tapping points. In 1880, full details of Hall’s experimentation with this phenomenon formed his doctoral thesis and was published in the *American Journal of Science* and in the *Philosophical Magazine*.[2]

Kelvin, himself a most distinguished scientist, called Hall’s discovery comparable to the greatest ever made by Michael Faraday. The magnitude of this discovery is even more impressive considering how little was known about electricity in Hall’s time. The electron, for instance, was not identified until more than 10 years later.[3]

The “Hall effect” remained a laboratory curiosity until the latter half of this century because materials available prior to recent years only produced low levels of Hall voltage. With the advent of semiconductor technology and the development of various III-V compounds, it became possible to produce Hall voltages many orders of magnitude greater than with earlier materials. Thus, semiconductor technology launched the practical design and production of the Hall sensor.

Typical Shapes and Sizes

Hall sensors are available in a wide variety of shapes and sizes for adaptability of shapes and sizes for adaptability to many different applications. The two basic types are transverse and axial, as illustrated in Figure 4.
The transverse type is useful where the field must be measured in thin gaps and for multiplier applications. The axial type must be used where the field is parallel to the axis of a hole, such as in traveling wave tubes or solenoids. Standard transverse probes as thin as .006" and axial probes as small as .063" in diameter are available. Bulk-material Hall plates may be sandwiched between ferrite pieces to obtain effective air gaps less than .003". This may be useful in applications requiring maximum magnetic efficiency, such as electronic compasses and proximity sensors.

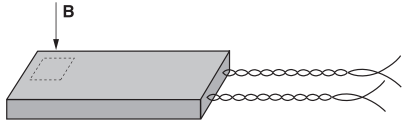
For a Hall sensor to accurately measure flux density, the Hall plate area should be smaller than the cross section of the field to be measured. The output voltage is proportional to flux density, but a Hall plate is not equally sensitive over its entire area. If a high resolution is important, the Hall plate area should be small. Active areas as small 0.010” are available, while even smaller ones have been made.

Typical Applications

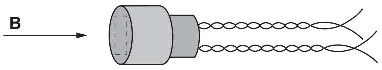
The following are just some of the many applications where Hall Sensors are used:

- Magnetic Card Readers
- Proximity Sensors
- Rotary Speed Sensors
- Watt Measurement
- Multipliers
- Magnet Field Measurements
- Electrical Power Measurements
- Current Sensors
- Brushless dc Motors
- Compasses
- Gaussmeters
- Watt-hour Meters
- Permanent Magnet Measurements
- Air Gap Measurements
- Magnetic Circuit design
- Flux Leakage Measurements
- Nondestructive Memory Readouts
- Linear/Angular Transducers
- Magnetic Tape Heads
- Guidance Systems
- Ignition Systems

Figure 4



Transverse



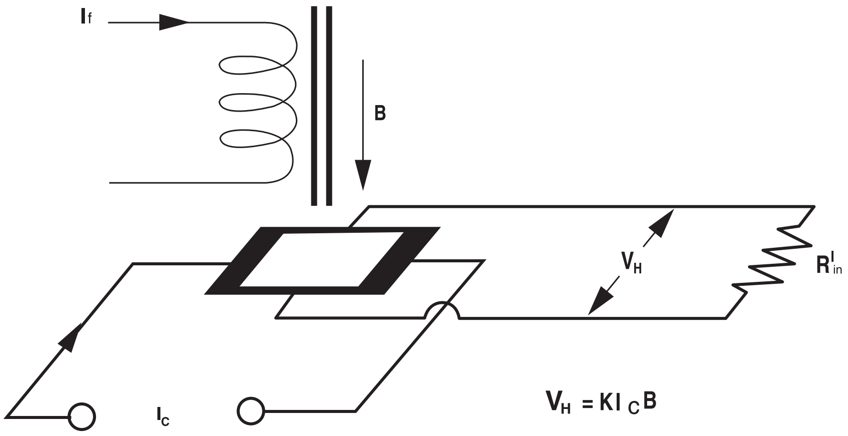
Axial

Materials

The Hall effect is basically a majority carrier mechanism depending on the bulk-material properties of the semiconductor material. Unlike transistors and diodes, it is completely independent of surface effects, juncton leakage currents and junction threshold voltages. These factors account for its high stability, reproductivity and reliability when compared to other semi-conductor devices.

To obtain a high output voltage the active element must have a high Hall coefficient, R_H. Also, since the output is proportional to the current density through the element, its resistance should be as low as practical to prevent excessive heating. Since the noise output is essentially thermal,[4] [5] low resistance is also an important requirement for devices to be used at very low signal levels. Some of the semiconductor materials used for Hall sensors are indium antimonide (InSb), indium arsenide (InAs) and gallium arsenide (GaAs). GaAs generators have high output and very high resistance making them relatively noisy and the temperature coefficient of the output voltage is less than -0.1%/˚C. InSb has high output and low resistance, but the temperature coefficient of the output voltage is about -1%/˚C. InAs has less output than InSb, but its temperature coefficient is less than -0.1%˚C and its resistance is also low. These considerations make InAs the most suitable materials for many Hall effect applications.

Indium Arsenide Hall sensors may also be made of deposited thin films. These units do not exhibit the same low resistance and high mobilities as their bulk-material counterparts, but they do offer advantages which may be realized in many applications. These advantages include lower current requirements for comparable output voltages, and significantly low cost. For those applications where excellent linearity and stability are required, bulk-material Hall sensors are recommended.



This schematic representation illustrates both the measuring and multiplying capabilities of a Hall sensor. By holding I_C constant, V_H becomes a direct function of B, the magnetic flux density. If both Ic and B are variable, V_H is proportional to the product of the two functions. Holding B and I_C constant, V_H becomes a function of the angle between B and the plane of the Hall-sensor active area.

The devices listed on the following pages are standard and available from stock. Special units are available to fit your application.

1. C.L.Chin and C.R.Westgate (Editors), The Hall Effect and Its Applications," Plenum Press, New York, 1979, p.535.

2. Ibid., p. 523.

3. Charles Couleston Gillespie (Editor)), "Dictionary of Scientific Bibliography," Charles Scribner's Sons, New York, 1970, p. 51.

4. Epstein. M., et al, "Principals and Applications of Hall-Effect Devices", Proceedings of the National Electronics Conference, 1959, Vol.15, p.241.

5. Final Engineering Report on Hall Effect Device Investigation", Device Development Corporation, Weston 93, Massachusetts, Contract No. NOBsr-72823, July 1, 1958 toFebruary 28, 1959, pp.12-17

See MIL-STD-793-1 (WP) for definition

Bulk Indium Arsenide BH-200 **Series**

Instrumentation Quality

Description

The BH-200 series of Hall effect magnetic field sensors consists of ten models designed to meet the requirements of most magnetic field measurement applications. Models in the BH-200 Series are built in various configurations to measure axial, transverse, and tangential magnetic field components. Sensitivities range from 6 to 75 mV/kG with input and output resistance of several ohms.

Mechanical Specifications

a. Polarity: With the magnetic field vector (+B) entering the top of the Hall plate and I_C entering the red lead, the positive Hall voltage will appear at the blue lead.

b. Material: AWG 34 or AWG 36 copper with heavy polyurethane insulation.

c. Color Code: Control Current (I_C): AWG 34-red ($+I_C$), black ($-I_C$), AWG 36-neutral ($+I_C$), green ($-I_C$)

d. Hall Voltage: (V_H): AWG 34-blue ($+V_H$), yellow ($-V_H$), AWG 36-red ($+V_H$), neutral ($-V_H$)

Models

1. BH-200 General Purpose Transverse
2. BH-201 Ultra-thin, Transverse
3. BH-202 Small Axial
4. BH-203 General Purpose, Axial
5. BH-204 Mini Axial
6. BH-205 Mini Transverse
7. BH-206 High Sensitivity, Low-cost Transverse
8. BH-207 High Resolution, Tangential
9. BH-208 Ultra-mini, Axial
10. BH-209 Ultra-mini, Transverse

Electrical Specifications

*Approximate

NOTE: In a time varying field the voltage induced into the Hall output leads, V_{ind}, is proportional to the effective area, A, of the Hall output loop and the amplitude and the rate of change of the field, V_{ind} (measured with $I_C=0)=A \frac{dB}{dt} x10^{-8}$

V_{ind}=volts, A=cm^2, B=gauss, t=sec.

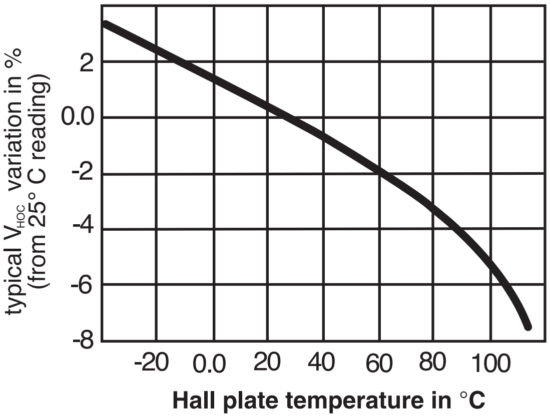
SPECIFICATIONS	UNITS	1. BH-200	2. BH-201	3. BH-202	4. BH-203	5. BH-204	6. BH-205	7. BH-206	8. BH-207	9. BH-208	10. BH-209
Input resistance, R_{in}	ohms	2.5 max.	3 max.	3 max.	3 max.	3 max.	3 max.	7 max.	2.7 max.	3.5 max.	2.5 max.
Output resistance, R_{out}	ohms	2 max.	3 max.	3 max.	3 max.	3 max.	3 max.	5 max.	2.7 max.	3.5 max.	3 max.
Open circuit magnetic sensitivity, V_{HOC} (1)	mV/kG	15±25%	12±25%	10±25%	10±25%	11±25%	12.5±25%	45 to 75	15±25%	10±25%	6.75±25%
Inductive null constant, A	cm^2	.003	.01	.002	.003	.002	.002	.006	.002	.02	.003
Max. resistive residual voltage, V_M @ B=0 (2)	±μV/°C	100 max.	250 max.	100 max.	100 max.	200 max.	100 max.	500 max.	200 max.	250 max.	100 max.
Max. control current @ 25°C, static air	mA	250	150	150	250	150	200	250	25	150	150
Nominal control current, I_{cn}	mA	150	100	100	100	100	125	200	150	100	75
Max. linearity error, (0 to 10 kG) with R_{lin}	±% of RDG	1	1.5	1	1	1.5	1	2	1.5	1.5	1.5
Reversibility error of V_H (0 to 10 kG)	±% of RDG	1	2.5	1	1	1	1	1.5	1	1.5	1
Mean temperature coefficient of V_H (-20°C to +80°C) (2)*	%/°C	-0.08	-0.08	-0.08	-0.08	-0.08	-0.08	-0.25	-0.08	-0.08	-0.08
Mean temperature coefficient of resistance (-20°C to +80°C) (2)*	%/°C	.15	.15	.15	.15	.15	.15	.2	.15	.15	.15
Temperature dependence of resistive residual voltage (-20°C to +80°C) (2)*	±μV/°C	1	1	1	1	1	1	6	1	1	.5
Operating temperature range	°C	-40°C to +100°C	0°C to +100°C	-40°C to +100°C	-40°C to +100°C	-40°C to +100°C	-40°C to +100°C	-40°C to +100°C	-40°C to +100°C	-40°C to +100°C	-40°C to +100°C
Storage temperature range	°C	-40°C to +105°C	0°C to +105°C	-40°C to +105°C	-40°C to +105°C	-40°C to +105°C	-40°C to +105°C	-40°C to +105°C	-40°C to +105°C	-40°C to +105°C	-40°C to +105°C

Notes

(1) Nominal Control Current, I_{cn}

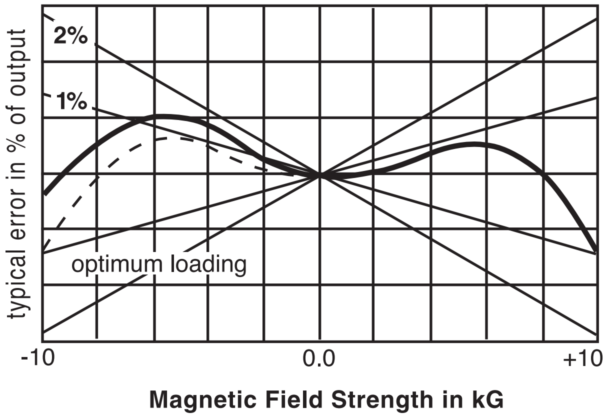
(2) I_C=100 mA

Temperature Influence



NOTE: For an unmounted Hall device supported by its leads, typical Hall plate temperature rise is 20° C for nominal control current.

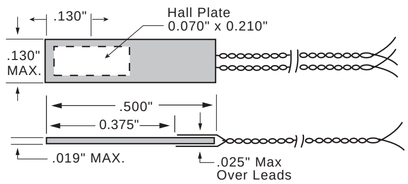
Linearity



NOTE: The dotted line is a mirror image of the curve in the right hand plane and illustrates the reversibility error.

1.

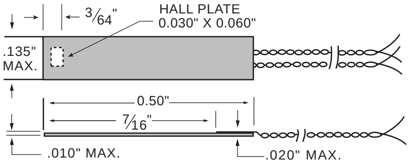
Model BH-200: General-Purpose Transverse



LEADS: AWG 34, 10" long

2.

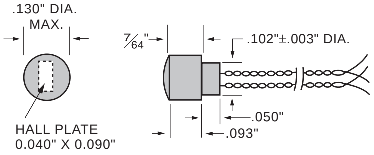
Model BH-201 Ultra-Thin Transverse



LEADS: AWG 36, 10" long

3.

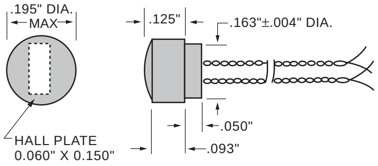
Model BH-202 Small Axial



LEADS: AWG 36, 10" long

4.

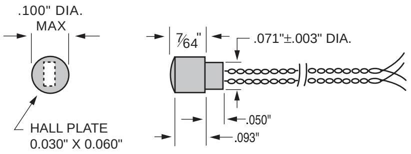
Model BH-203 General-Purpose Axial



LEADS: AWG 34, 10" long

5.

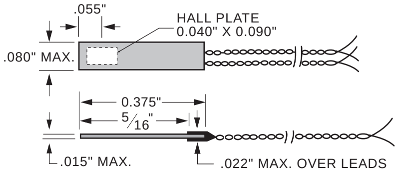
Model BH-204 Midget Axial



LEADS: AWG 36, 10" long

6.

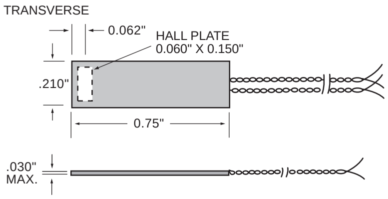
Model BH-205 Midget Transverse



LEADS: AWG 36, 10" long

7.

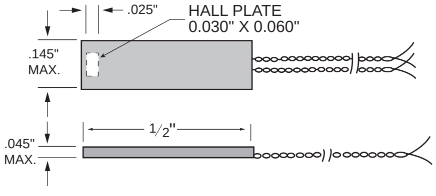
Model BH-206 High Sensitivity Low Cost



LEADS: AWG 34, 10" long

8.

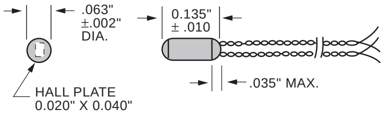
Model BH-207 High Resolution Tangential



LEADS: AWG 36, 10" long

9.

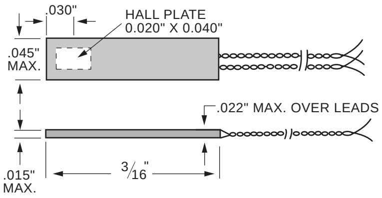
Model BH-208 Ultra-Midget Axial



LEADS: AWG 36, 10" long

10.

Model BH-209 Ultra-Midget Transverse



LEADS: AWG 36, 10" long

F.W. BELL®

Bulk Indium Arsenide BH-700 **Series**

Single Axis

Description

Designed to meet the requirements of a wide range of magnetic field measurement applications, the BH-700 Series are small, solid-state devices that provide an output voltage proportional to the product of control current and ambient flux density. Five single-axis models are available to measure axial and transverse magnetic field components with sensitivities from 7.5 to 50 mV/kG and input and output resistance of several ohms.

Electrical Specifications

BH-702

a. Air gap: between concentrator and substrate, 0.0025" nominal and 0.003" maximum.

b. Sensitivity: Basic sensitivity of Hall element .15 V/A-kG min. With the unit suspended in a free field of 100 oersteds and I_c=200 mA, the open circuit Hall voltage is 8.0 mV min. In a closed magnetic circuit with I_c=200 mA, V_H is 3.mV/Ampere turn min.

c. Polarity: With the magnetic field vector as shown and I_c entering the red lead, the positive Hall voltage will appear at the blue lead.

BH-701
BH-704

a. Linearity:
V_H vs. B, −10 to +10 kG: ±0.25% of reading, max.
V_H vs. B, −30 to +30 kG: ±1.0% of reading, max.
V_H vs. I_c, 0 to 100 mA: ±0.1% of reading, max.
V_H vs. I_c, 0 to 300 mA: ±1.0% of reading, max.

b. Encapsulation: The BH-701 and the BH-704 are encapsulated in a rugged aluminum oxide ceramic and epoxy case for excellent heat transfer and strength.

Mechanical Specifications

a. Color Code:					
	Control Current (I_c):	Red	($+I_c$)	Black	($-I_c$)
	Hall Voltage (V_H):	Blue	($+V_H$)	Yellow	($-V_H$)

b. Polarity: With the magnetic field vector (+B) entering the top of the Hall plate and I_c entering the red lead, the positive Hall voltage will appear at the blue lead.

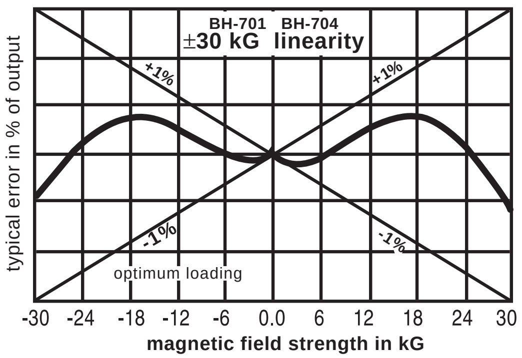
Models

1. BH-700	Low cost, Transverse, General Purpose
2. BH-701	Rugged, High-Linearity, Transverse, Instrumentation Quality
3. BH-702	Low Field (ferrite-embedded), Transverse
4. BH-704	Rugged, High Linearity, Axial, Instrumentation Quality
5. BH-705	General Purpose, Transverse

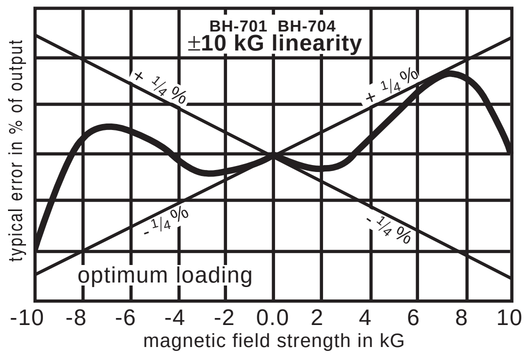
		1.	2.	3.	4.	5.
SPECIFICATIONS	**UNITS**	**BH-700**	**BH-701**	**BH-702**	**BH-704**	**BH-705**
Input resistance, R_{in}	ohms	5.5 max.	2 max.	3.5 max.	2.5 max.	2.2 max.
Output resistance, R_{out}	ohms	5.5 max.	2 max.	3.5 max.	2.5 max.	2 max.
Magnetic sensitivity, V_H (1)	mV/kG	50 min.	7.5±20% (3)	***	7.5±20%	10±25%
Max. resistive residual voltage, V_M @ B=0 (1)	±µV	1500 max.	75 max.	250 max.	75 max.	300 max.
Max. control current @25°C, static air	mA	250	300	300	300	250
Nominal control current	mA	200	100	200	100	100
Max. linearity error, (0 to 10 kG) with R_{lin}	±% of RDG	3	**	–	**	1
Zero field thermal voltage	µV	–	5 max.	–	5 max.	5 max.
Mean temperature coefficient of V_H (-20°C to +80°C) (2)*	%/°C	-0.2	-0.04	-0.07	-0.04	-0.08
Mean temperature coefficient of resistance (-20°C to +80°C) (2)*	%/°C	+0.2	+0.18	+0.18	+0.18	+0.2
Temperature dependence of resistive residual voltage (-20°C to +80°C) (2)*	±µV/°C	6 typical	0.3 typical	2.5 typical	0.5 max.	1 Max
Operating temperature range	°C	-40°C to +100°C	-40°C to +100°C	-55°C to +100°C	-40°C to +100°C	-65°C to +100°C
Storage temperature range	°C	-40°C to +105°C	-40°C to +105°C	-55°C to +105°C	-40°C to +105°C	-65°C to +105°C

Notes

(1) $I_c=I_{cn}$
(2) I_c=100 mA
(3) Loaded Sensitivity



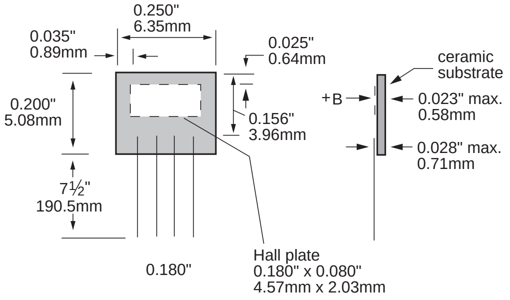
Note: Optimum loading range for ±30kG operation is 90-200ΩΩ



Note: Optimum loading range for ±10kG operation is 20-50ΩΩ

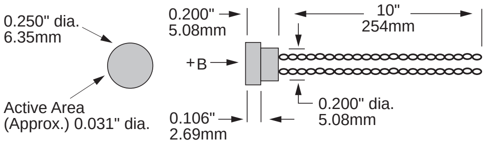
1.

Model BH-700 Low Cost Transverse



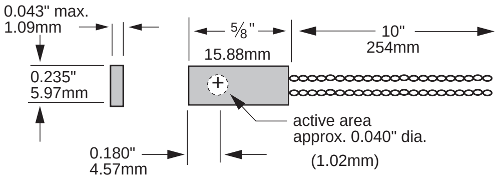
2.

Model BH-704 High Linearity Axial



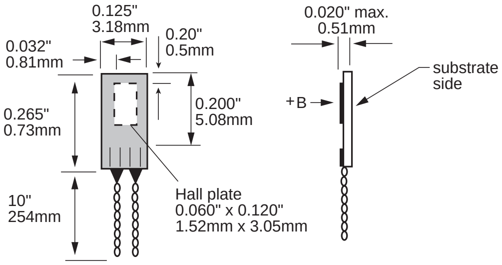
3.

Model BH-701 High Linerarity Transverse



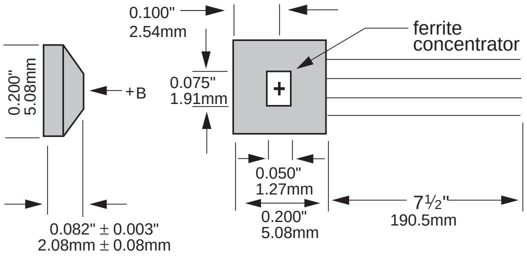
4.

Model BH-705 General Purpose Transverse



5.

Model BH-702 Ferrite Imbedded Transverse

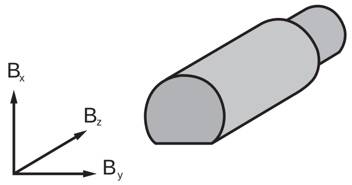


NOTE: All tolerances unless specified are ±0.010"
Specifications may change without notice.

Notes
All tolerances unless specified are .010”

Bulk Indium Arsenide BH-703

Three Axis



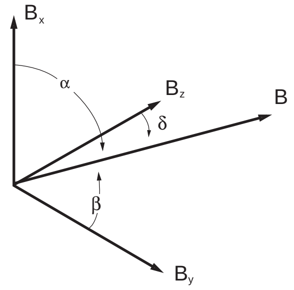
Description

The BH-703 multi-axis Hall sensor consists of three individual Hall elements oriented in mutually perpendicular planes and encapsulated in a small epoxy package. This enables the BH-703 to produce voltages proportional to the three orthogonal components (B_X, B_y, B_Z) of a magnetic flux in any direction. Thus the BH-703 may be permanently mounted or arbitrarily oriented to sense fields in any direction.

The magnitude of the flux vector, B, can be found using the following relation:

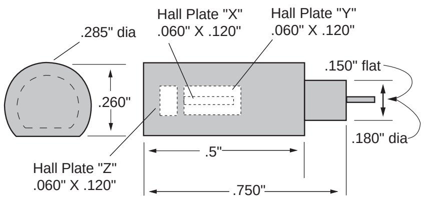
$$B=B_X^2+B_y^2+B_Z^2$$

The flux direction may be found using the following relations:
$\alpha=\cos^{-1}B_X/B$, $\beta=\cos^{-1}B_y/B$, $\delta=\cos^{-1}B_Z/B$ where α, β, δ are the angles between B and B_X, B_y, B_Z respectively.



Features

- Three Axis, simultaneous measurement
- Instrumentation Quality



Mechancal Specifications

a. Notes: All tolerances unless specified are ±0.010".
Unless otherwise noted: B=1kG, $I_C=I_{cn}$, T-25°C, Static air.

b. Leads: #34 AWG copper with polyurethane insulation, approximately 20" long. The BH-703 has 12 leads.

c. Polarity: When the magnetic field vectors are oriented as shown, and I_C enters the read leads, the positive Hall voltage appears at the blue leads.

Electrical Specifications

SPECIFICATIONS	UNITS	BH-703	BH-706
Input resistance, R_{in}	ohms	3.5 max.	3 max.
Output resistance, R_{out}	ohms	3.5 max.	3 max.
Magnetic sensitivity, V_H (loaded)	mV/kG	7 to 10	6 to 9
Max. resistive residual voltage, V_M @ B=0	±µV	100	200
Max. control current @25°C, static air	mA	300	300
Nominal control current	mA	100	100
Angularity	degrees	Hall plates 1 within ±2	Hall plates 1 within ±2
Sensitivity matching	±% of RDG	1	1
Max. linearity error, (-10 kG to +10 kG) with R_{lin}	±% of RDG	1	1
Mean temperature coefficient of V_H (-20°C to +80°C)	%/°C	-0.04 max.	-0.04 max.
Mean temperature coefficient of resistance (-20°C to +80°C)	%/°C	+0.15 max.	+0.15 max.
Temperature dependence of resistive residual voltage (-20°C to +80°C)	µV/°C	0.5 max.	0.5 max.
Operating temperature range	°C	-40 to +100	-40 to +100
Storage temperature range	°C	-40 to 120	-40 to 120

Bulk Indium BH-706

Two Axis

Description

The BH-706 multi-axis Hall sensor consists of two Hall elements mounted in mutually perpendicular planes and encapsulated in a small epoxy package. This enables the BH-706 to produce voltages proportional to two perpendicular components (B_x, B_y) of a magnetic field. Thus the BH-706 may be permanently mounted to sense field components in its X, Y planes.

The magnetic of the flux vector, B within the X, Y plane can be found using the following equation:

$$B = -\sqrt{B_x^2 + B_y^2}$$

The direction of B can be computed using the following equation:

$$0 = \tan^{-1} B_y / B_z$$

where 0 is the angle between B and B_x.

Mechancal Specifications

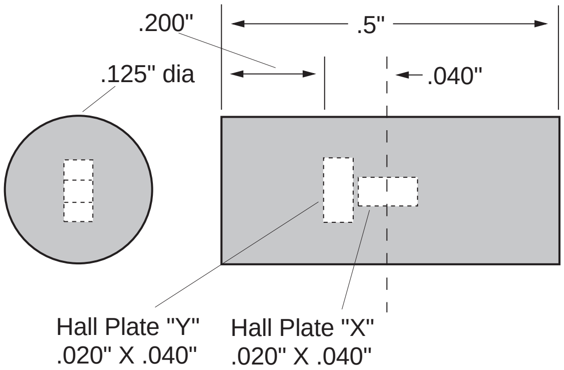
Leads: #34 AWG copper with polyurethane insulation, approximately 20" long. The BH-706 has 8 leads.

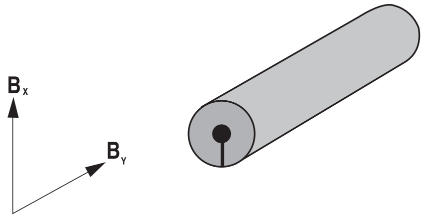
Polarity: When the magnetic field vectors are oriented as shown, and I_c enters the red leads, the positive Hall voltage appears at the blue leads.

Note: All tolerances unless specified are ±0.010".

Features

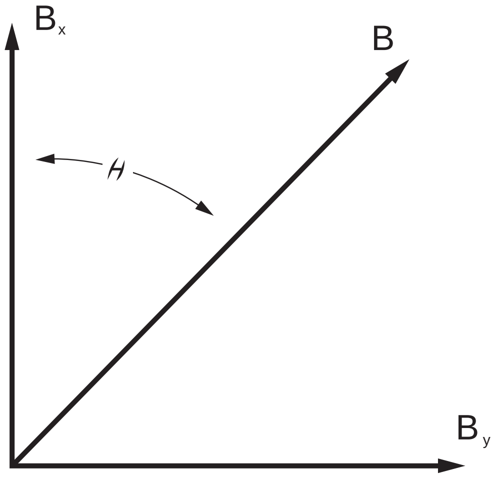
- Two Axis, simultaneous measurement
- Instrumentation Quality





Unless otherwise noted:

B=1 kG, I_c=I_{cn}, T-25 C, Static air.



Bulk Indium BH-850

Ultra Low Field

Description

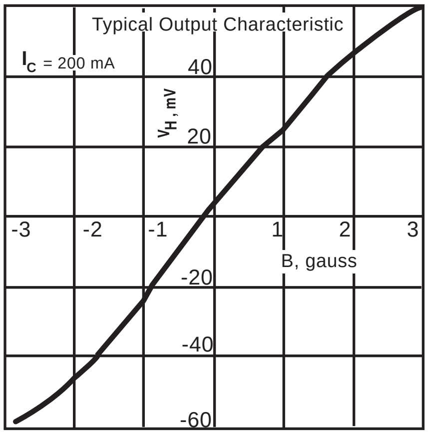
Ideal for applications such as the construction of solid state compasses, the BH-850 offers high sensitivity for very low magnetic fields at a relatively low cost.

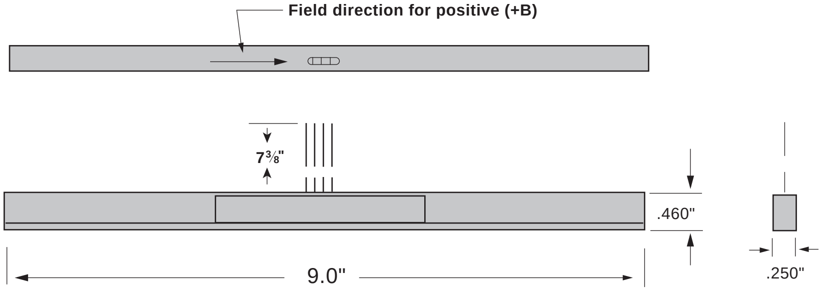
Features

- High Sensitivity
- Rugged construction

Mechanical Specifications

a. Leads
b. Material: AWG 34 Stranded (7x42) Silver Plated Copper, Thin Wall Teflon Insulation.
c. Color Code
d. Control Current (I_C): Red ($+I_C$) Black ($-I_C$)
e. Hall Voltage (V_H): Blue ($+V_H$) Yellow ($-V_H$)
f. Polarity: With field direction as shown I_C entering the red lead, the positive Hall voltage will appear at the blue lead.0





Electrical Specifications

SPECIFICATIONS	UNITS	B-850
Input resistance, R_{in}	ohms	3.5 max.
Output resistance, R_{out}	ohms	3.5 max.
Magnetic sensitivity, V_H	mV/G	18
Max. resistive residual voltage, V_M @ B=0, $I_C = I_{CM}$	µV	±190 max.
Max. control current @ 25°C, static air	mA	300
Nominal control current, I_{cn}	mA	200
Mean temperature coefficient of V_H (-20°C to +80°C)	%/°C	-0.18
Temperature dependence of resistive residual voltage (-20°C to +80°C)	µV/°C	±2.5
Operating temperature range	°C	-55 to +85
Storage temperature range	°C	-55 to +85

Bulk Indium BH-900 **Series**

High Linearity

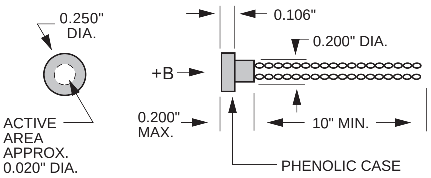
Description

F.W. Bell 900 Series Hall Sensors are high-performance units providing high linearity and broad field and temperatures ranges for a wide variety of magnetic field measurements. All units in the series are encapsulated in rugged, epoxy, sealed cases. A room temperature linearity error curve from -30 to +30 kG is supplied, indicating optimum operating conditions for each device. The models 900 and 921 are not calibrated above 30 kG.

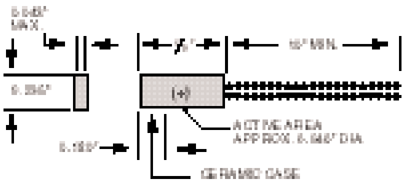
Mechanical Specifications

a. Leads
b. Material: AWG 34 Copper with Teflon Insulation (Model 921) or Polyurethane Insulation (Models 900 & 910).
c. Color Code
d. Control Current (I_C): Red (+I_C) Black (-I_C)
Hall Voltage (V_H): Blue (+V_H) Yellow (-V_H)
e. Polarity: With the magnetic field vector (+B) entering the top of the Hall plate and I_c entering the red lead, the positive Hall voltage will appear at the blue leads.

Axial Hall Sensors BHA-900, 910 & 921



Transverse Hall Sensors BHT-900, 910 & 921



NOTE: Cross indicates tail of magnetic field vector.

Models

a. BH-910 High Linearity
b. BH-921 Cryogenic Operation (1.5 to 350° k)
c. BH 921 & 900 Wide Dynamic Range

SPECIFICATIONS	UNITS	BHT-900	BHT-910	BHT-921	BHA-900	BHA-910	BHA-921
Input resistance, R_{in}	ohms	1.2 max.	1.2 max.	1.2 max.	1.5 max.	1.5 max.	1.5 max.
Output resistance, R_{out}	ohms	1.2 max.	1.2 max.	1.2 max.	1.5 Max	1.5 max.	1.5 max.
Magnetic sensitivity, V_H (1)	mV/kG	.55 to 1.1	.55 to 1.1	.55 to 1.1	.55 to 1.1	.55 to 1.1	.55 to 1.1
Max. resistive residual voltage, V_M @ B=0 (1)	mV	50	50	200	50	50	200
Max. control current @ 25°C, static air	mA	300	300	300	300	300	300
Nominal control current, I_{cn}	mA	100	100	100	100	100	100
Max linearity error (-30 to +30 kG) (1)	±%/to RDG	1	.1 (2)	1	1	.25	1
Max linearity error (-150 to +150 kG) (1)	±%/to RDG	1.5	–	2	1.5	–	2
Typical linearity resistance R_{lin}	ohms	500	50 to 500	500	500	50 to 500	500
Mean temperature coefficient of V_H (-20°C to +80°C) (1)	PPM/°C	-50 max.	-50 max.	+100 max.	-50 max.	-50 max.	+100 max.
Mean temperature coefficient of resistance (-20°C to +80°C) (1)	±%/°C	0.15 max.	0.15 max.	0.6 max.	0.15 max.	0.15 max.	0.6 max.
Temperature dependence of resistive residual voltage (-20°C to +80°C) (1)	µV/°C	0.4 max.	0.4 max.	0.4 max.	0.4 max.	0.4 max.	0.4 max.
Operating temperature range	°C	-40 to +100	-40 to +100	-269 to +100	-40 to +100	-269 to +100	-269 to +100

Notes

(1) $I_C = I_{cn}$
(2) ±.1% linearity error (0-30 kG)
±.3% reversibility error

Thin Film FH-301/FH-500 **Series**

InAs Thin Film, General Purpose, Transverse

Description

FH-301 & FH-500 Series Hall sensors are miniature solid-state Hall effect magnetic field sensing devices. The FH-500 series uses a lead strip which is composed of printed circuit leads encased in DuPont's Kapton and terminating in contacts on .075" centers. This flexible and tough lead strip can be made in a variety of configurations. The model FH-301 has conventional wire leads.

Mechanical Specifications

Leads: #34 AWG copper with polyurethane insulation.

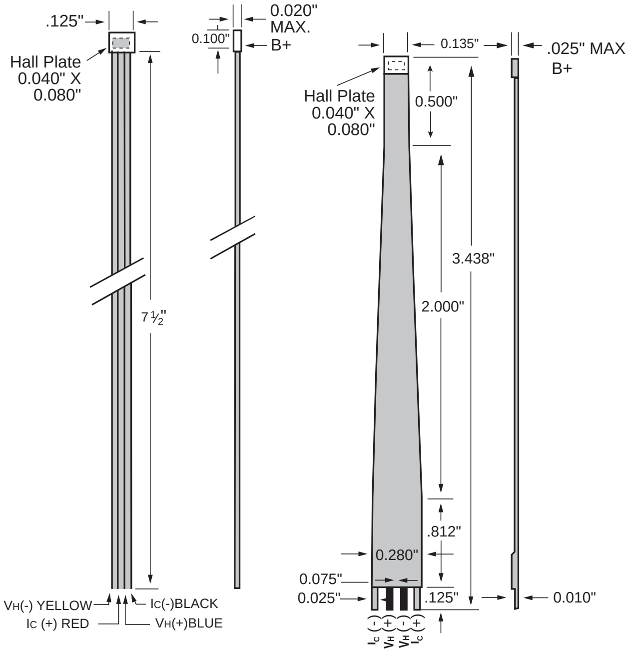
Electrical Specifications

a.Polarity: With field direction (B+) as shown and Ic entering the Ic (+) terminal, the positive Hall voltage will appear at the VH (+) terminal.

b.Note: Unless otherwise specified. all specifications apply at nominal control current with T 25ºC. Heat sinking can enhance performance in several respects.

Models

1. FH-301-020	Low Current
FH-520	Lowest Cost
2. FH-301-040	Leaded
FH-540	Low Current On-Lead Strip
3. FH-301-060	Higher Sensitivity
FH-560	Higher Sensitivity
4. FH-301L	High Linearity
FH-500L	High Linearity



NOTE: All tolerances unless specified are ± 0.010"

Models		1.	2.	3.	4.
SPECIFICATIONS	**UNITS**	**FH-301-020/FH-520**	**FH-301-040/FH-540**	**FH-301-060/FH-560**	**FH-301L/FH-500L**(3)
Input resistance, R_{in}	ohms	20-40	40-80	80-160	20-120
Output resistance, R_{out}	ohms	28-120	56-240	160-480	40-360
Magnetic sensitivity, V_H (1)	mV/kG	10 min.	12 min.	12 min.	6 min.
Max. resistive residual voltage, V_M @ B=0	±mV	2	4	6	4
Max. control current @ 25°C, static air	mA	50	30	25	30
Nominal control current, I_{cn}	mA	25	15	10	10
Mean temperature coefficient of VH (-20°C to +80°C) (2)	%/°C	-0.1 max.	-0.1 max.	-0.1 max.	-0.1 max.
Mean temperature coefficient of resistance (-20 °C to +80 °C) (2)	%/°C	.1 max.	.1 max.	.1 max.	.1 max.
Temperature dependence of resistive residual voltage (-20°C to +80°C) (2)	+μV/°C	10 max.	10 max.	10 max.	7 max.
Operating temperature range	°C	-55 to +100	-55 to +100	-55 to +100	-55 to +100
Storage temperature range	°C	-55 to +120	-55 to +120	-55 to +120	-55 to +120

Notes

(1) $I_c=I_{cn}$
(2) $I_c=10$ mA
(3) mm linearity error (-20 to 20 kg) = ±1% of RDG

Description

The new F.W. Bell HS-100 is the world's thinnest thin film InAs Hall sensor measuring 0.012 inch/0.3 mm thick maximum. Manufactured from Indium Arsenide, the HS-100 offers stable operation over a wide temperature range of -55°C to +185°C. The HS-100, packaged in a unique flip chip configuration, is available in bulk and tape and reel formats. Applications include: use in Brushless DC motors (BLDC), contact-less switches, compasses, magnetizers, and gaussmeters. Sensor applications include current, voltage, power, frequency, position, tilt/level, tachometer, pressure, and thickness sensors.

Mechanical Specifications

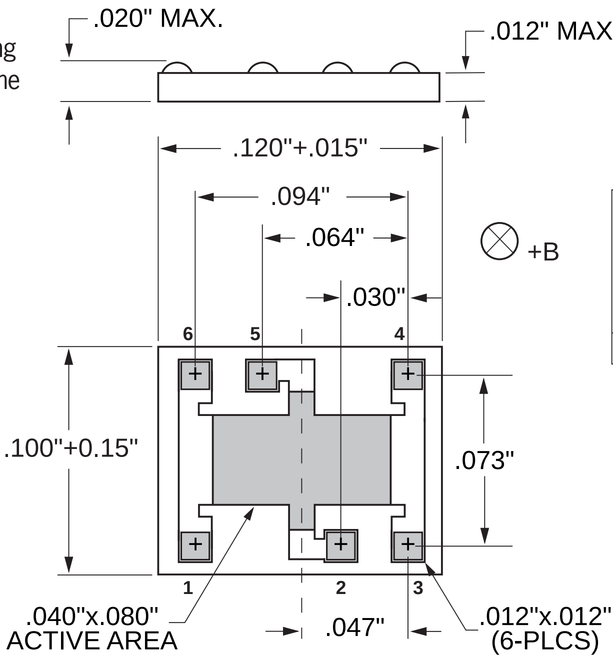
Leads: #34 AWG copper with polyurethane insulation.

Electrical Specifications

a. Polarity: With field direction (B+) as shown and I_C entering the I_C (+) terminal, the positive Hall voltage will appear at the V_H (+) terminal.

b. Note: Unless otherwise specified, all specifications apply at nominal control current and at a temperature of 25°C. Heat sinking can enhance performance in several respects.

Model HS-100



PIN	SIGNAL
1 and 6	$+I_C$
3 and 4	$-I_C$
2	$+V_H$
5	$-V_H$

SPECIFICATIONS	UNITS	HS-100
Input resistance, R_{in}	ohms	30 to 160
Output resistance, R_{out}	ohms	60 to 360
Maximum continuous control current	mA	30
Magnetic sensitivity, V_H @ I_c=10 mA	mV/kG	8 min.
Misalignment voltage, V_M @ I_c=10 mA	mV	6.0 max.
Mean temperature coefficient of magnetic sensitivity (-20°C to +80°C) (I_c=10 mA) (B=5 kG)	%/°C	-0.1 max.
Mean temperature coefficient of input resistance (-20°C to +80°C) (I_c=10 mA)	%/°C	+.1 max.
Temperature dependence of resistive residual voltage (-20°C to +80°C) (I_c=10 mA) (B=0)	µV/°C	10 max.
Operating temperature range	°C	-55 to +185
Storage temperature range	°C	-55 to +190

F.W. BELL®

Gallium Arsenide GH **Series**

Description

The GH Series Hall sensors are four-terminal solid-state devices that produce an output voltage, V_H , proportional to the product of the input current, I_C , and the magnetic flux density, B. The GH-600 Hall sensor uses a lead strip which is composed of DuPon’ts Kapton. The lead strip is terminated with tin plated copper alloy contacts spaced 0.100" (2.54 mm) on center. The Model GH-601 utilizes a specially designed lead strip which allows operation up to 50 kHz. The GH-700 is an ion implanted planar device encased in an epoxy surface-mount package. The GH-800 is a leaded device designed for through hole mounting to a PCB. It features a package 0.28" (0.7 mm) thick for placement in small air gaps. The GH-810 and GH-820 are leaded devices designed for through hole mounting to a PCB. The GH-830 is configured in a low profile package.

Features

- Low Cost
- Gallium Arsenide
- Extended Frequency Range
- High Sensitivity
- Choice of Mounting Configurations
- Flexible Leadstrip
- Extended Temperature Range

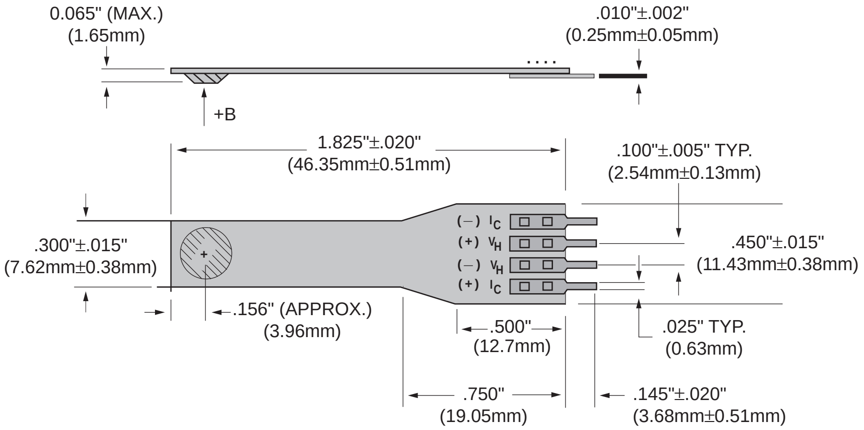
Models

1. GH-600
2. GH-601
3. GH-700
4. GH-800
5. GH-810
6. GH-820
7. GH-830

Mechanical Specifications

Diagrams Below andRight All dimensions are in inches (millimeters).

1. **Model GH-600**



Unless otherwise noted, all tolarences are ±0.010 (±0.25)

		1.	2.	3.	4.	5.	6.	7.
SPECIFICATIONS	**UNITS**	**GH-600**	**GH-601**	**GH-700**	**GH-800**	**GH-810**	**GH-820**	**GH-830**
Input resistance, R_{in}	ohms	450 to 900	450 to 900	450 to 900	600 to 1,200	400 to 700	450 to 900	450 to 900
Output resistance, R_{out}	ohms	580 to 1,700	580 to 1,700	approx. 1,000	600 to 1,200	approx. 2,000	3,200 max.	approx. 3,000
Magnetic sensitivity, V_H (1)	mV/kG	50 to 140	50 to 140	50 to 140	95 to 130	22 to 31	80 to 190	65 to 170
Max. resistive residual voltage, V_M @ B=0 (1)	±mV	14	16	14	20	5	20	25
Max. control current @ 25°C, static air	mA	10	10	10	7	15	10	10
Nominal control current, I_{cn}	mA	5	5	5	5	5	5	5
Max. linearity error, (-10 kG to +10 kG)	±% of RDG	2	2	2	0.7 (4)	2	2	2
Mean temperature coefficient of V_H (-10°C to +80°C)	%/°C	-0.07	-0.07	-0.07	-0.07	-0.05	-0.06	-0.05
Mean temperature coefficient of resistance (-10°C to +80°C)	%/°C	0.15 Typical	0.15 Typical	0.15 Typical	0.18 max.	0.5 max. (2)	0.15 Typical	.3 Max
Temperature dependence of resistive residual voltage (-10°C to +80°C)	±µV/°C	1 Typical (2)	1 Typical (2)	1 Typical (2)	40 max. (1,3)	1 Typical (2)	1 Typical (2)	5 Typical (2)
Operating temperature range	°C	-55 to +125	-55 to +125	-55 to +125	-40 to +175	-55 to +125	-55 to +125	-55 to +125
Storage temperature range	°C	-55 to +150	-55 to +125	-55 to +150	-50 to +180	-55 to +150	-55 to +150	-55 to +150

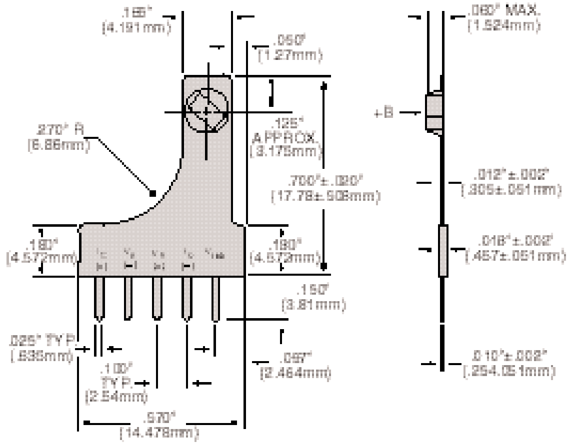
Notes

(1) Nominal Control Current, I_{cn} (5 mA)
(2) Control Current=1 mA
(3) Temperature range +25°C to +75°C
(4) ±0.2% of reading from -5 kG + 5 kG

Gallium Arsenide GH **Series**

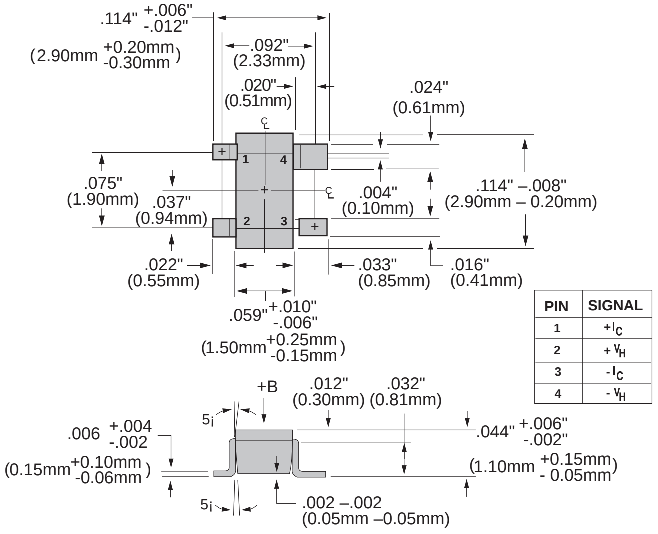
All dimensions are in inches (millimeters).

2. **Model GH-601**



3. **Model GH-700**

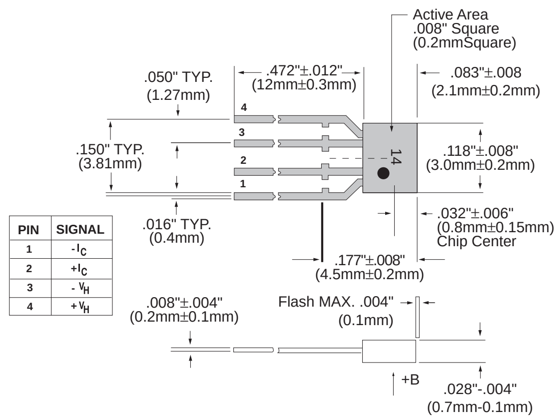
700



PIN	SIGNAL
1	$+I_C$
2	$+V_H$
3	$-I_C$
4	$-V_H$

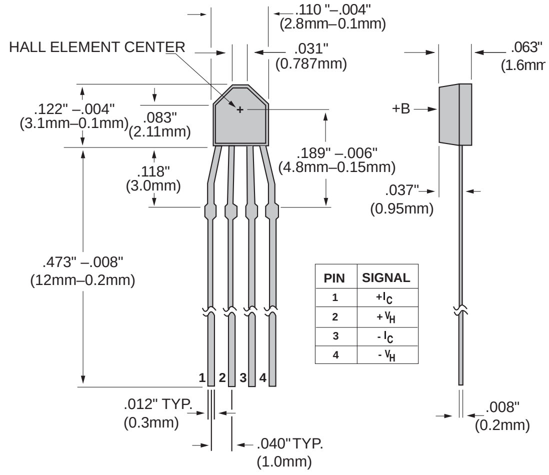
4. **Model GH-800**

Model GH-800



PIN	SIGNAL
1	$-I_C$
2	$+I_C$
3	$-V_H$
4	$+V_H$

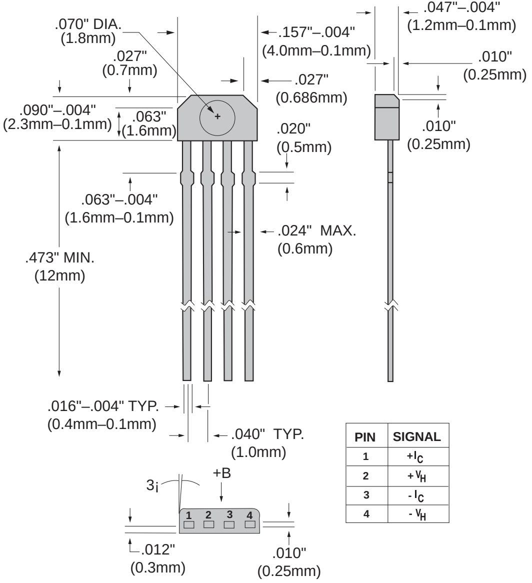
5. **Model GH-810**



PIN	SIGNAL
1	$+I_C$
2	$+V_H$
3	$-I_C$
4	$-V_H$

6. **Model GH-820**

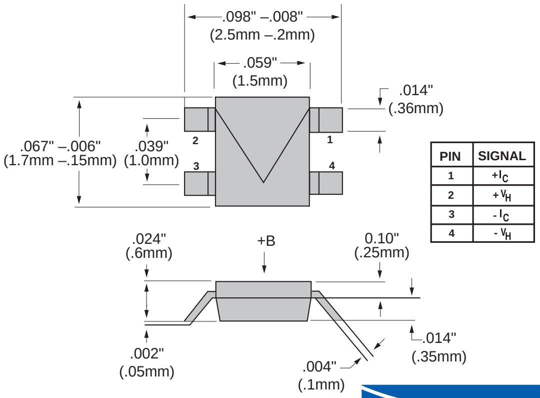
20



PIN	SIGNAL
1	$+I_C$
2	$+V_H$
3	$-I_C$
4	$-V_H$

7. **Model GH-830**

30



PIN	SIGNAL
1	$+I_C$
2	$+V_H$
3	$-I_C$
4	$-V_H$

Indium Antimonide SH **Series**

Description

The SH series Hall effect sensors are four terminal Indium Antimonide devices that are extremely sensitive to low magnetic fields. These devices produce an output voltage, Vh, proportional to the product of the input current, Ic, and the magnetic flux density, B.

Features

- Low Cost
- Indium Antimonide
- Very High Sensitivity
- Low Current Requirement
- Choice of Mounting Configuration

Models

1. SH-400
2. SH-410
3. SH-420
4. SH-430

Models		1.	2.	3.	4.
SPECIFICATIONS	**UNITS**	**SH-400**	**SH-410**	**SH-420**	**SH-430**
Input resistance, R_{in}	ohms	240 to 550	240 to 550	240 to 550	240 to 550
Output resistance, R_{out}	ohms	240 to 550	240 to 550	240 to 550	240 to 550
Magnetic sensitivity, V_H (1)	mV/kG	292 to 1,120	290 to 1,760	100 to 330	290 to 1,760
Max. resistive residual voltage, V_M @ B=0	mV	20	20	16	20
Max. control current @ 25°C, static air	mA	20	20	20	20
Nominal control current, I_{cn}	mA	5	5	5	5
Mean temperature coefficient of V_H (0°C to +40°C) (1)	%/°C	-1.8	-1.8	-1.8	-1.8
Mean temperature coefficient of resistance (0°C to +40°C) (2)	%/°C	-1.8	-1.8	-1.8	-1.8
Operating temperature range	°C	-40 to +110	-40 to +110	-40 to +110	-40 to +110
Storage temperature range	°C	-40 to +125	-40 to +125	-40 to +125	-40 to +125

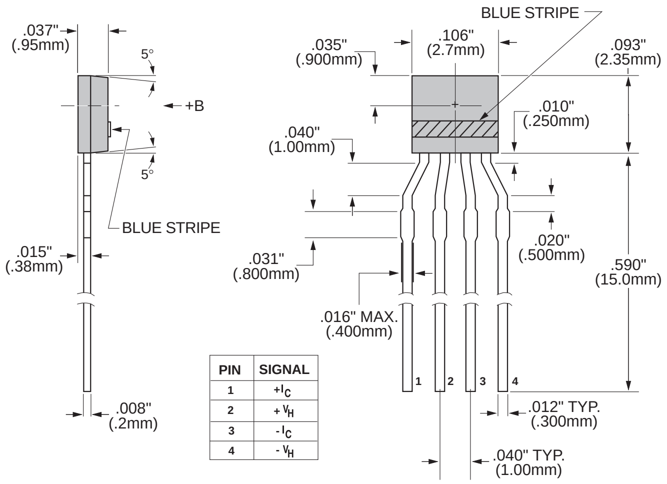
Notes

(1) Nominal Control Current, I_{cn}=5 mA
(2) Control Current=0.1 mA

Mechanical Specifications

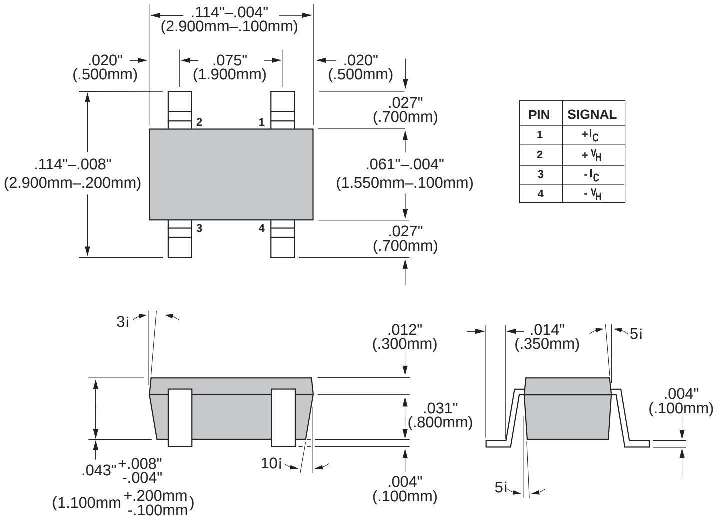
All dimensions are in inches (millimeters).

1. Model SH-400



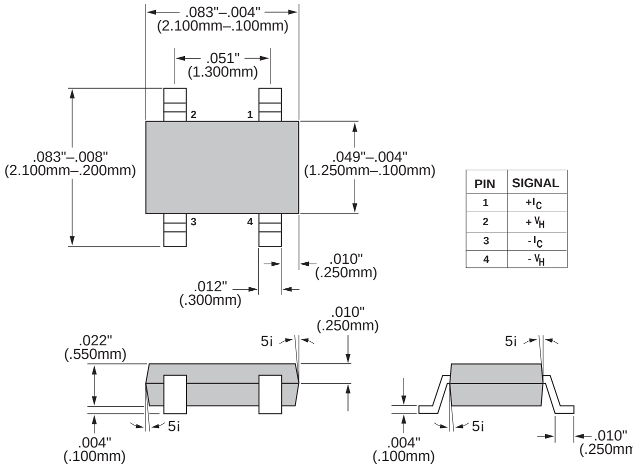
PIN	SIGNAL
1	$+I_C$
2	$+V_H$
3	$-I_C$
4	$-V_H$

2. Model GH-601



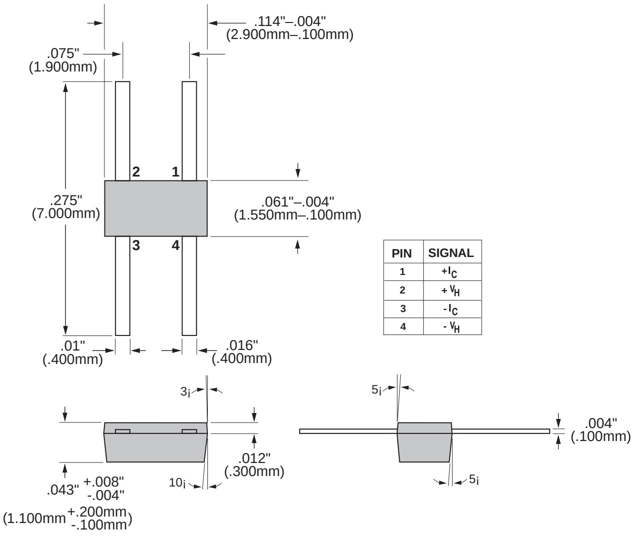
PIN	SIGNAL
1	$+I_C$
2	$+V_H$
3	$-I_C$
4	$-V_H$

3. Model SH-420



PIN	SIGNAL
1	$+I_C$
2	$+V_H$
3	$-I_C$
4	$-V_H$

4. Model SH-430

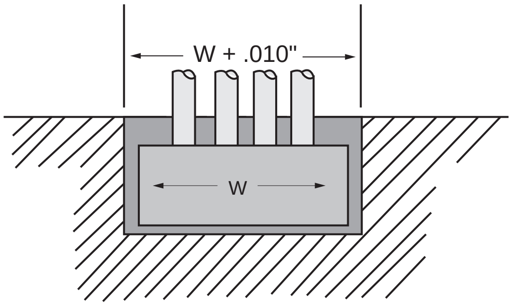


PIN	SIGNAL
1	$+I_C$
2	$+V_H$
3	$-I_C$
4	$-V_H$

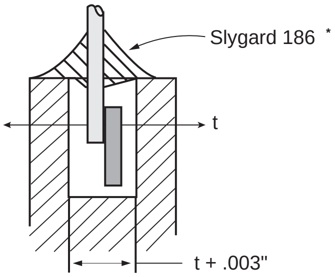
Handling

The Hall sensor is fragile. It cannot be handled the same way most other electronic components are handled. The aluminum oxide substrate is brittle, thin and very sensitive to bending stress. Use the leads to move and locate it. Do not handle the substrate. The lead-to-substrate bond strength bond strength is on the order of an ounce. Avoid tension on the leads and avoid bending them close to the substrate. The leads may be bent at any angle as long as the bend is a least 1/8" away from the substrate connection.

Fig. 1

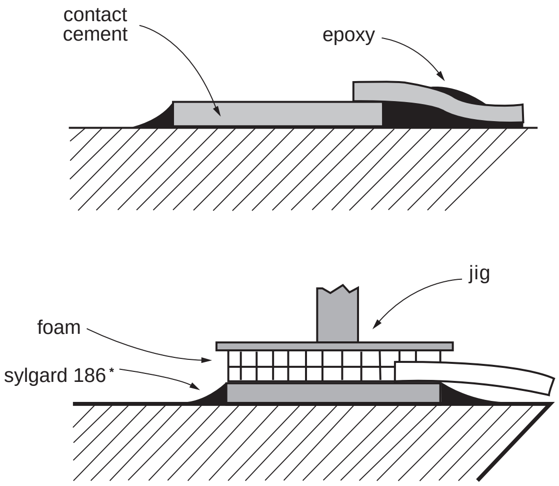


Front View



Side View

Fig. 2



Slot Mounting **Fig. 1**

The preferred mounting procedure is to locate the chip in a slot that is any depth, .003 inch wider and .010 inch longer than the substrate. Tack the leads outside the slot with Sylgard 186* or a similar substance. Don't get Sylgard 186 inside the slot. If an extreme temperature range is expected, check the coefficients of thermal expansion to be certain that the slot will always have clearance for the chip. This procedure is not recommended for installations that will be subject to any acceleration greater than 10 g.

Surface Mounting **Fig. 2**

Surface mounting is acceptable when necessary. The mounting surface may be any non-flexible solid with a flat smooth (±.001") surface at least the size of the substrate. The substrate must not overhang the mounting surface. Steel, ferrite, ceramic, and glass are examples of mounting surfaces. For extended temperature ranges, choose a material with a coefficient of thermal expansion no greater than a factor of three different from that of the aluminum oxide substrate $\cong 7x10^{-6}\,\frac{\text{IN}}{^{\circ}\text{C}}$

Permanent Mount

Sparingly coat the mounting surface with Eastman 910 contact cement or other similar cement. The ceramic side of the substrate is visible as non-red or as opposite the Hall element. Locate the ceramic side on the clean, degreased surface and apply extremely light pressure with a foam pad until the bond is made (see Figure 7). Wipe off the excess contact cement. Use an epoxy such as Bacon Industries FA8 or Emerson and Cuming 2850FT to form a fillet around the plate and to secure the leads. Don't get epoxy on top of the chip. If encapsulation is absolutely necessary, use a light coating of Sylgard 186 or a similar soft material.

Non-Permanent Surface Mount

Secure the substrate against the surface with a foam-padded mounting jig. The jig should apply only light pressure. Temporarily secure the leads with Sylgard 186 or a similar material.

Post-Mounting Test

After the Hall sensor has been mounted, check the misalignment voltage per the proper specification. A large misalignment voltage shift (100 μ V) is a sign of Hall sensor physical damage.

Cautions!

To avoid possible permanent damage to the Hall sensor, please read the following instructions carefully before making connections to a power supply.

The following schematic diagram illustrates the proper connections for the Hall sensor: Refer to the Hall sensor specification for the AWG size of the leads. If a loading resistor, R_L, is specified, then is must be added to the output circuit as shown in Figure 5 to obtain the specified linearity.

Current Source

A constant current supply is recommended for appli-cations requiring fixed control current. This eliminates effects of input resistance changes resulting from temperature or field variations (magnetoresistance effect). A “bruteforce” constant current source may be made by connecting a large resistor (30 times R in or higher) in series with a battery or constant voltage power supply. In any case, the short-circuit current should be within the maximum current rating of the Hall sensor. The control current may be either ac or dc. This is determined by the nature of the field and the bype of output signal desired.

Output Indicator

The Hall output voltage, V_H may be observed on any suitable instrument such as a millivolt meter, oscilloscope, or recorder. The input impedance of the instrument should be greater than approximately 1,000 ohms. Since the four Hall sensor leads connect to four points on a semiconductor plate having different potentials, no two leads can be connected together without upsetting the operation. Therefore, the current source have a common connection, but must be isolated from each other. One or the other, but not both, may be grounded.

Misalignment (Null) Voltage Compensation

In the manufacturing of the Hall sensor, the Hall voltage contacts are placed on the semiconductor plate as accurately as possible so that very little output voltage will exist when there is no magnetic field present. For many applications, this resistive null voltage is low enough to be neglected, but for low field applications, it may be appreciable compared to the Hall output voltage V_H. If this is the case, a null voltage balancing network such as that in Figure 6 will make it possible to reduce the resistive null voltage to zero. The fine control may not be required.

Effects of Residual Magnetism

Care should be taken to ensure that what appears to be an offset voltage of the Hall sensor is not really the result of a residual magnetic field. Any magnetic material with a residual field in close proximity to the Hall sensor could effect a slight Hall output voltage, V_H. Items such as fixures, jigs, probes, metal tables, metal cabinets, etc., are potential sources of residual magnetic fields. Even the Earth’s magnetic field (approximately 1/2 gauss) could cause an undesireable “offset” voltage. The circuit in Figure 6 can also be used to zero out many of these voltages.

Figure 5
Hall Sensor Circuit Configuration

Lead
1 and 2 are control current (I_C) leads 3 and 4 are Hall voltage (V_H) leads
Color Code:
AWG 34red (+I_C), black (-I_C), blue (+V_H), yellow (-V_H)
AWG 36 neutral (+I_C), green (-I_C). red (+V_H), neutral (-V_H)

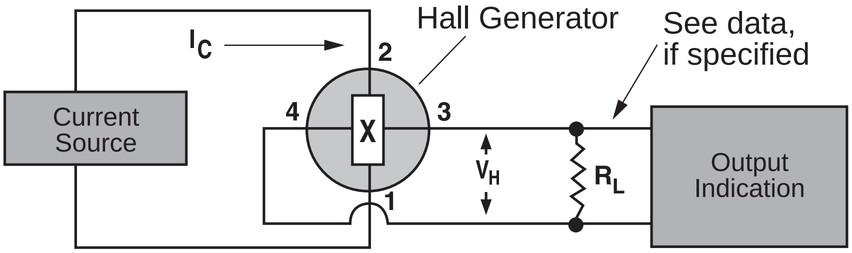


Figure 6 Null Voltage Compensation