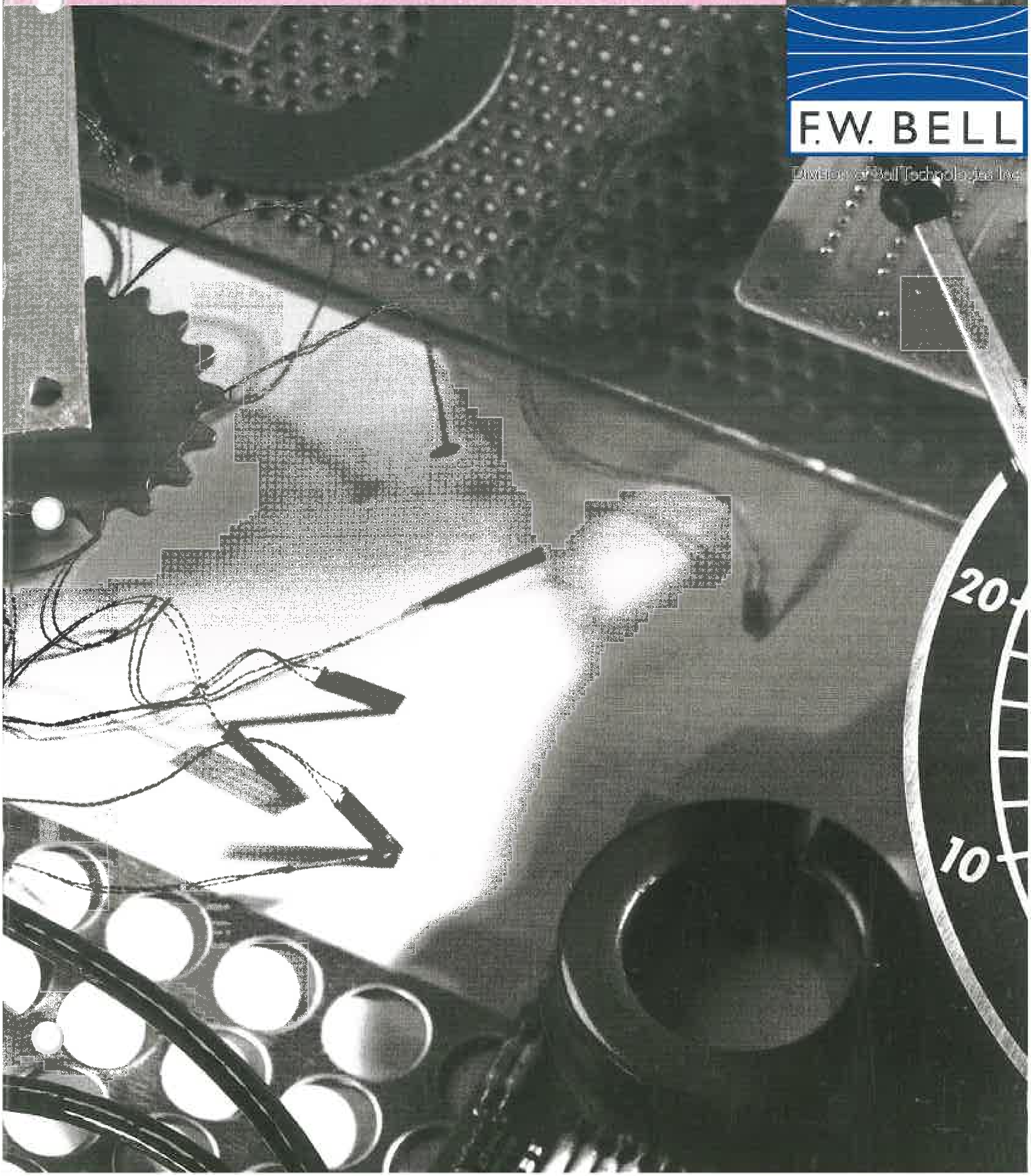
HALL GENERATORS

F.W. BELL

Division of Bell Technologies Inc.



AN INTRODUCTION TO THE HALL EFFECT

Early Magnetics

Far back in the recesses of time man discovered the loadstone (Lodestone) in Magnesia in the district of Thessaly, Greece (hence the word "magnet"). They soon learned about its tendency to orient itself with the pole star, and used it as a guide to and from far away lands.

The first manufactured permanent magnets were needles that had been rubbed on the loadstone. The first electro-magnet was constructed in 1825, and the first scientific treatise in the nature of magnets was published 20 years later.

By the time that first electromagnet was built, permanent magnets had been in use for a variety of experimental and practical uses. Their strength was classified by the ratio of their weight to their lifting strength.

Photograph of Dr. Edwin Herbert Hall, 1887, courtesy of the Harvard University Archives

The 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 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, $F=Q(\bar{V}x\bar{B})$. 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,

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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 uneven 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 $\bar{E}$ 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:

$V_H = \gamma IB$

V_H = Hall voltage

γ = a constant product sensitivity

I = Hall current

B = magnetic field perpindicular to Hall plate surface

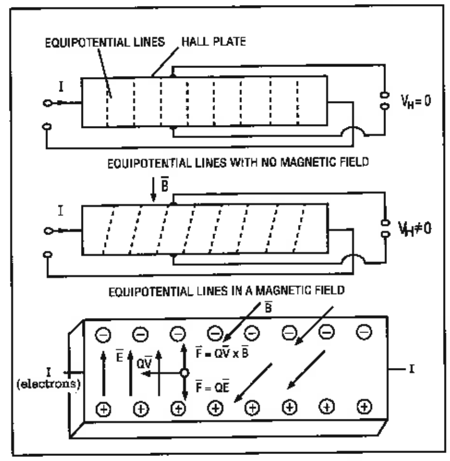


Figure 1
Explanation of the Hall effect.

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

Note: All $\bar{B}$ fields in the article refer to the component of the external $\bar{B}$ field that is normal to the surface of the Hall plate. A more general equation for Hall voltage is $V_H = \gamma IB \cos\theta$, where θ is the angle between B and the normal to the Hall plate surface.

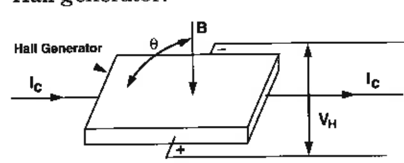
THE HALL GENERATOR

From Theory To Practice

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 generator.

What Is A Hall Generator

A Hall generator 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 between B and the plane of the Hall generator.



$V_H = K_{HOC}\, I_C\, B \sin\theta$ or if $\sin\theta = 1$ (i.e., $\theta = 90°$)
$V_H = K_{HOC}\, I_C\, B$ or $V_H = \gamma_B\, B$

where: V_H = Hall output 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)

Figure 2

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

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.

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

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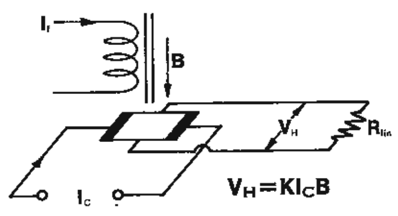

This schematic representation illustrates both the measuring and multiplying capabilities of a Hall generator. By holding I_C constant, V_H becomes a direct function of B, the magnetic flux density. If both I_C and B are variable, V_H is proportional to the product of the two functions. Holding B and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

The devices listed on the following pages are standard and available from stock.

Special units are available to fit your application.

Figure 3

the polarity the same. By holding the control current constant, the Hall voltage may be used to measure magnetic flux density. Multiplication may be accomplished by varying both the control current and the magnetic field.

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, reproducibility and reliability when compared to other semiconductor 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 generators 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 material for many Hall effect applications.

InAs Hall generators 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 lower cost. For those applications where excellent linearity and stability are required, bulk-material Hall generators are recommended.

Typical Applications Of Hall Generators

The following are just some of the many applications where Hall generators 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

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- Nondestructive Memory Readouts
- Linear/Angular Transducers
- Magnetic Tape Heads
- Guidance Systems
- Ignition Systems

Typical Shapes and Sizes

Hall generators are available in a wide variety of shapes and sizes for adaptability to many different applications. The two basic types are transverse and axial, as illustrated in Figure 4.

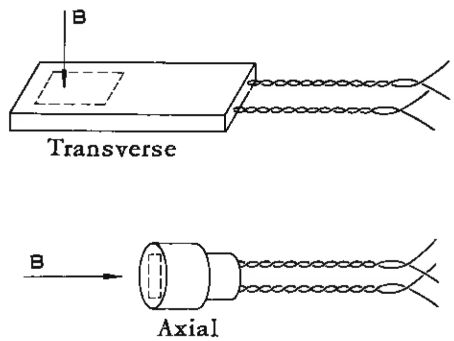

Figure 4
The two basic types of Hall generators are transverse and axial.

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 generator 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. Units with somewhat larger Hall plates are usually less expensive because they are easier to make, and since they can generally handle larger currents they can produce more output voltage and dissipate more power.

4. Epstein, M., et al, "Principles 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 to February 28, 1959, pp. 12-17.

USING A F.W. BELL HALL GENERATOR

CAUTION!

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

Connecting The Hall Generator

The following schematic diagram illustrates the proper connections for the Hall generator:

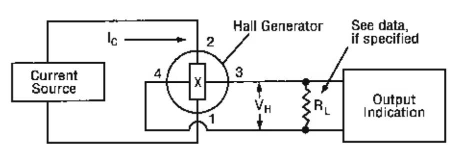

Figure 5
Hall generator Circuit Configuration.

Lead 1 and 2 are control current (I_C) leads
3 and 4 are Hall voltage (V_H) leads

Color Code: AWG 34 red ($+I_C$), black ($-I_C$)
blue ($+V_H$), yellow ($-V_H$)
AWG 36 neutral ($+I_C$), green
($-I_C$) red ($+V_H$), neutral ($-V_H$)

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Refer to the Hall generator specification for the AWG size of the leads. If a loading resistor, R_L, is specified, then it 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 applications requiring fixed control current. This eliminates effects of input resistance changes resulting from temperature or field variations (magnetoresistance effect). A "brute-force" 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 generator. The control current may be either ac or dc. This is determined by the nature of the field and the type 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.

CAUTION! ISOLATION REQUIRED!

Since the four Hall generator 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 and the output indicator cannot 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 generator, 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.

Affects of Residual Magnetism

Care should be taken to ensure that what appears to be an offset voltage of the Hall generator is not really the result of a residual magnetic field. Any magnetic material with a residual field in close proximity to the Hall generator could effect a slight Hall output voltage, V_H Items such as fixtures, 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.

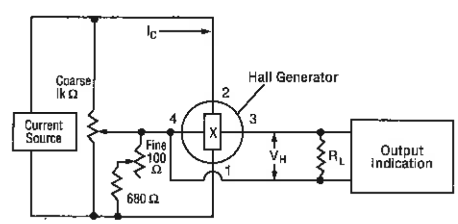

Figure 6

Null Voltage Compensation

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HALL GENERATOR MOUNTING

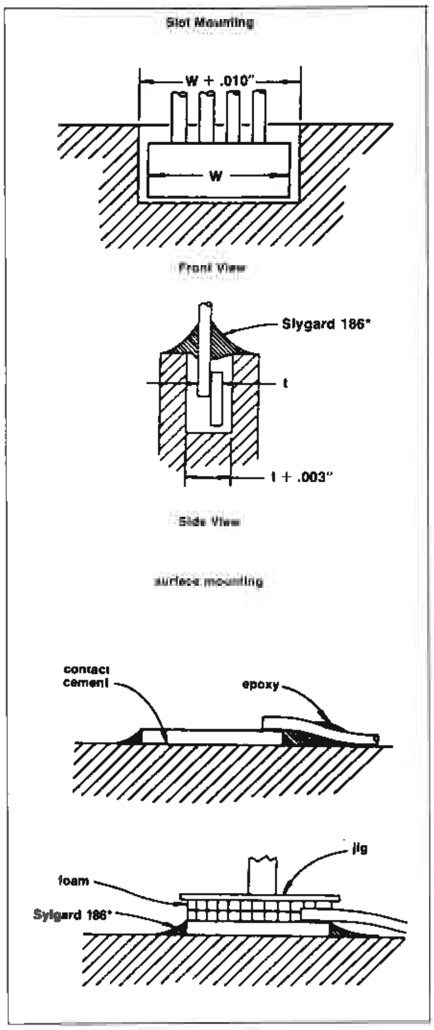

Figure 7:
Mounting Configurations

*Product of Dow Corning Corporation

Handling

The Hall generator 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 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 at least 1/8" away from the substrate connection.

Slot Mounting

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

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 $\cong 7\times10^{-6}\frac{IN}{°C}$

For a 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.

For a 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 generator has been mounted, check the misalignment voltage per the proper specification. A large misalignment voltage shift (100 µV or more) is a sign of Hall generator physical damage.

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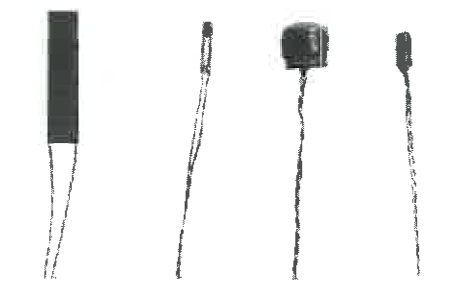
BH-200 SERIES

INSTRUMENTATION QUALITY



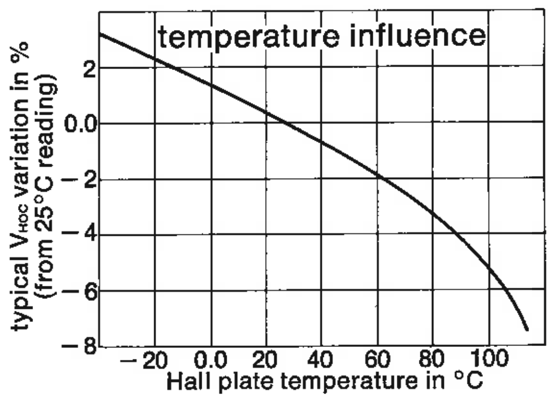
(Above is only a portion of models available)

General Description

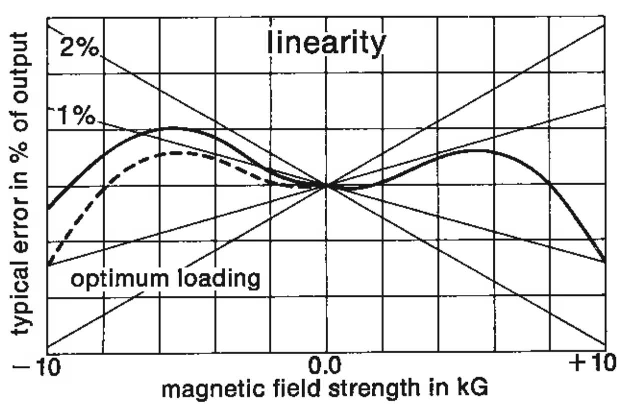
The BH-200 series of Hall effect magnetic field sensors consists of ten models designed to meet the requirements of most magnetic field measurement applications.

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 60 mV/kG with input and output resistance of several ohms.

Models:	Features:
BH-200	General Purpose Transverse
BH-201	Ultra-thin, Transverse
BH-202	Small Axial
BH-203	General Purpose, Axial
BH-204	Mini Axial
BH-205	Mini Transverse
BH-206	High Sensitivity, Low-cost Transverse
BH-207	High Resolution, Tangential
BH-208	Ultra-mini, Axial
BH-209	Ultra-mini, Transverse



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



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

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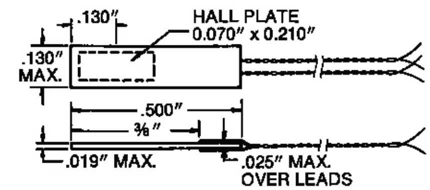
BH-200 SERIES

INSTRUMENTATION QUALITY

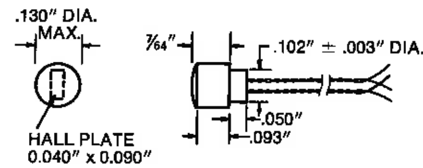
MECHANICAL SPECIFICATIONS

MODEL BH-200: GENERAL-PURPOSE TRANSVERSE



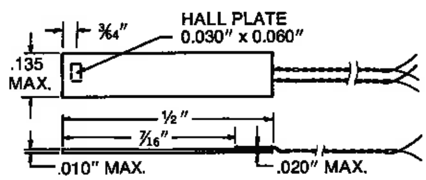
LEADS: AWG 34, 10″ long

MODEL BH-202 SMALL AXIAL



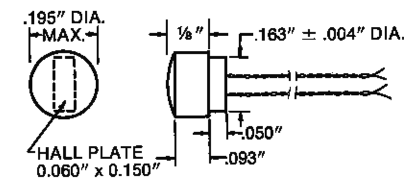
LEADS: AWG 36, 10″ long

MODEL BH-201 ULTRA-THIN TRANSVERSE



LEADS: AWG 36, 10″ long

MODEL BH-203 GENERAL-PURPOSE AXIAL



LEADS: AWG 34, 10″ long

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.

LEADS

MATERIAL: AWG34 or AWG36 copper with heavy polyurethane insulation.
COLOR CODE: Control Current (I_c): AWG34-red ($+I_c$), black ($-I_c$), AWG36-neutral ($+I_c$), green ($-I_c$)
HALL VOLTAGE: (V_H): AWG34-blue ($+V_H$), yellow ($-V_H$), AWG36-red ($+V_H$), neutral ($-V_H$)

ELECTRICAL SPECIFICATIONS

MODELS	BH-200	BH-201	BH-202
Rated control current, I_{cn}	150mA	100mA	100mA
Maximum continuous control current, I_{cmos} (in 25°C static air)	250mA	150mA	150mA
Open circuit magnetic sensitivity, γ_B (at rated I_{cn}, B=1.0 kG)	15mV/kG ±25%	12mV/kG ±25%	10mV/kG ±25%
Misalignment voltage, V_M (B = 0, I_c = 100 mA)	100µV max	250µV max	100µV max
Inductive null constant, A (see note)	.003 cm²*	.01 cm²*	.002 cm²*
Hall output load resistance, R_{lin} (for optimum linearity 0 to 10 kG)	15Ω*	15Ω*	15Ω*
Linearity error with R_{lin} termination (0 to 10 kG)	1% max	1.5% max	1% max
Product sensitivity, γ_B (B = 10 kG)	0.10V/A•kG ±25%	0.12V/A•kG ±25%	0.10V/A•kG ±25%
Input resistance, R_{in} (including leads)	2.0Ω*	2.3Ω*	2.6Ω*
Output resistance, R_{out} (including leads)	1.7Ω*	1.8Ω*	1.8Ω*
Mean temperature coefficient of V_{HOC}** (-10°C to +80°C)	-0.08%/°C*	-0.08%/°C*	-0.08%/°C*
Mean temperature coefficient of resistance (-10°C to +80°C)	0.15%/°C*	0.15%/°C*	0.15%/°C*
Reversibility error of V_{HOC} (0 to 10 kG)	1% max	3% max	1% max
Mean temperature coeeficient of misalignment voltage, (IC = 100 mA), D_T	1µV/°C max	1µV/°C max	1µV/°C max
Storage temperature range	-40° C to +105°C	0.0 to +50°C	-40°C to +105°C
Operating temperature range (at rated I_c)	-40°C to +100°C	0.0 to +50°C	-40°C to +100°C

*Approximate
**Constant I_c

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 $I_c = 0$) = $A \frac{dB}{dt} \times 10^{-8}$

V_{ind} = volts, A = cm², B = gauss, t = sec.

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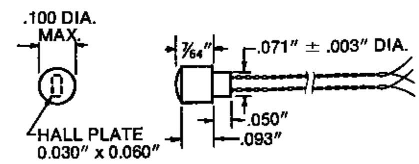
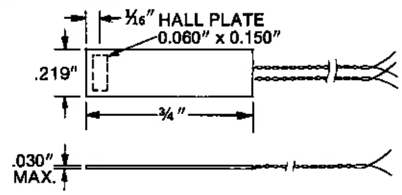
MODEL BH-204 MIDGET AXIAL



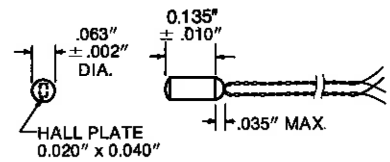
LEADS: AWG 36, 10″ long

MODEL BH-206 HIGH SENSITIVITY LOW COST TRANSVERSE



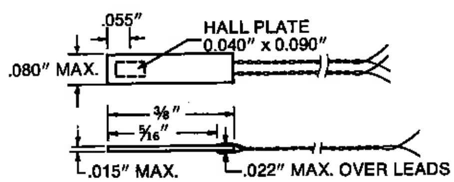
LEADS: AWG 34, 10″ long

MODEL BH-208 ULTRA-MIDGET AXIAL



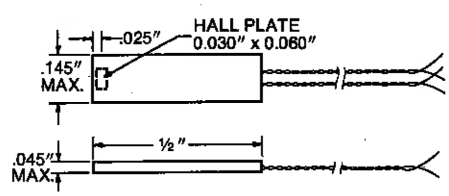
LEADS: AWG 36, 10″ long

MODEL BH-205 MIDGET TRANSVERSE



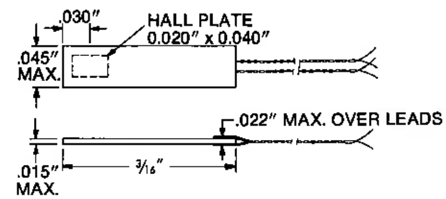
LEADS: AWG 36, 10″ long

MODEL BH-207 HIGH RESOLUTION TANGENTIAL



LEADS: AWG 36, 10″ long

MODEL BH-209 ULTRA-MIDGET TRANSVERSE



LEADS: AWG 36, 10″ long

	BH-203	BH-204	BH-205	BH-206	BH-207	BH-208	BH-209
	100mA	100mA	125mA	200mA	150mA	100mA	75mA
	250mA	150mA	200mA	250mA	250mA	150mA	150mA
	10mV/kG ±25%	11mV/kG ±25%	12.5mV/kG ±25%	55mV/kG ±25%	16mV/kG ±25%	10mV/kG ±25%	6.75mV/kG ±25%
	100µV max	200µV max	100µV max	500µV max	200µV max	250µV max	100µV max
	.003 cm²*	.002 cm²*	.002 cm²*	.006 cm²*	.002 cm²*	.02 cm²*	.003 cm²*
	15Ω*	15Ω*	15Ω*	25Ω*	15Ω*	15Ω*	15Ω*
	1% max	1.5% max	1% max	2%*	1.5% max	1.5% max	1.5% max
	0.10V/A•kG ±25%	0.11V/A·kG ±25%	0.10V/A·kG ±25%	.30V/A·kG ±25%	0.11V/A·kG ±25%	0.10V/A·kg ±25%	0.10V/A·kG ±25%
	1.9Ω*	2.7Ω*	2.1Ω*	5Ω*	2Ω*	3.0Ω*	2.5Ω*
	1.3Ω*	1.9Ω*	2.0Ω *	3.5Ω*	1.5Ω*	3.0Ω*	2.0Ω*
	-0.08%/°C*	-0.08%/0°C*	-0.08%/°C*	-0.2%/°C*	-0.08%/°C *	-0.08%/°C*	-0.05%/°C*
	0.15%/°C*	0.15%/°C*	0.15%/°C*	0.2%/°C*	0.15%/°C *	0.15%/°C*	0.15%/°C*
	1% max	1% max	1% max	1.5% max	1% max	1.5% max	1% max
	1µV/°C max	1µV/°Cmax	1µV/°C max	6µV/°C max	1µV/°C max	1µV/°C max	0.5µV/°C max
	-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 +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

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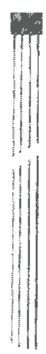
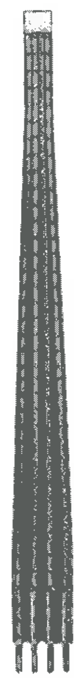
FH-301/FH-500 SERIES

InAs THIN FILM, GENERAL PURPOSE, TRANSVERSE



Model FH-301



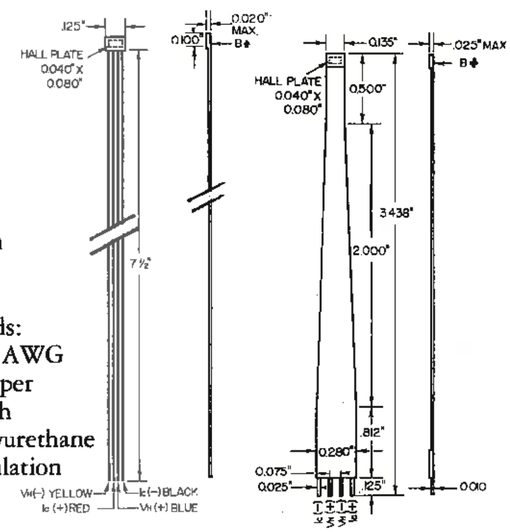
Model FH-500 Series with Flexstrip™ lead

General Desription:

FH-301 & FH-500 Series Hall generators are miniature solid-state Hall effect magnetic field sensing devices. The FH-500 series uses a lead strip which is composed of printed curcuit leads encased in DuPont's Kapton and terminating in contacts on .075" centers. This flexible and tough lead strip provides for exceptionally easy handling. The lead strip can be made in a variety of configurations. The model FH-301 has conventional wire leads. The Models FH-301 and FH-500 are available in two different sensitivity ranges: 10.0 mV/kG and 12.0 mV/kG.

Models:	Features:
FH-301-020	• Low Current
FH-301-040	• Leaded
FH-520	• Lowest Cost
FH-540	• Low Current
	• On-Lead Strip

MECHANICAL SPECIFICATIONS



MODEL FH-301 SERIES MODEL FH-500 SERIES

NOTE: All tolerances unless specified are ± 0.010"

ELECTRICAL SPECIFICATIONS

MODELS	FH-301-020/FH-520	FH-301-040/FH-540
Input Resistance, R_{in}	20-40Ω	40-80Ω
Output Resistance, R_{out}	2.2 R_{in} approx.	2.2 R_{in} approx.
Magnetic Sensitivity γ_B, min. @ I_{cn}	10.0 mV/kG	12.0 mV/kG
Product Sensitivity, γ_{IB}, min.	0.4 V/A•kG	0.8 V/A•kG
Resistive Residual Voltage, V_M@ I_{cn}, B=0	5 mV max.	6 mV max.
Nominal Control Current, I_{cn}	25 mA	15 mA
Maximum Continuous Control Current, I_{cmos}	50 mA	30 mA
Mean Temperature Coefficient of V_H (-20°C to +80°C),β_T	-0.1%/°C max.	-0.1%/°C max.
Mean Temperature Coefficient of Resistance (-20C to +80°C), α_T	0.1%/°C max.	0.1%/°C max.
Temperature Dependence of Resistive Residual Voltage, @ I_{cn} (-20°C to +80°C), D_T	10μV/°C max.	10μV/°C max.
Thermal Resistance, Hall Plate to Ambient $R\theta_{P-A}$	0.8°C/mW	0.8°C/mW
Thermal Resistance, Hall plate to Encapsulation, $R\theta_{P-E}$	0.04°C/mW	0.04°C/mW
Operating Temperature Range	-55°C to +100°C	-55°C to +100°C
Storage Temperature Range	-55°C to +120°C	-55°C to +120°C

Specifications may change without notice

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.
NOTE: Unless otherwise specified, all specifications apply at nominal control current with T 25°C. Heat sinking can enhance performance in several respects. For information concerning operating on a heat sink, such as the pole face of a magnet, contact F.W.Bell, Inc.

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F.W. BELL

Model GH-601

Description:

The Model GH-601 Hall effect generator is a solid-state device that produces an output voltage, V_H, proportional to the product of the input current, I_C, and the magnetic flux density, B. A specially designed lead strip allows operation up to 50 kHz.

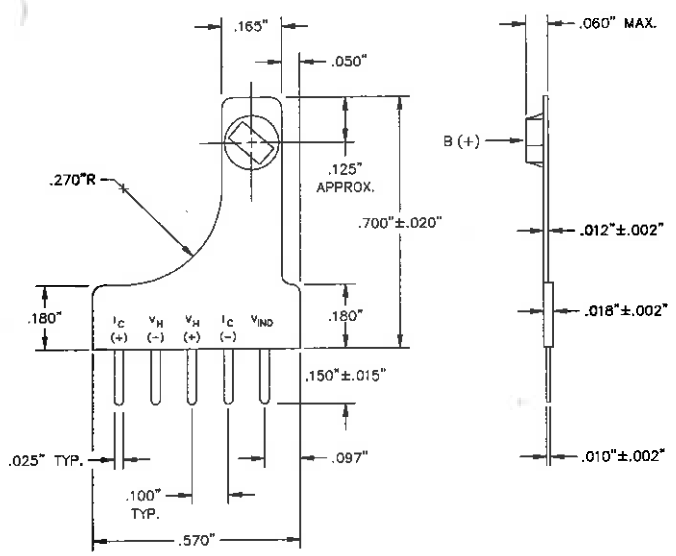
Features:

- Low Cost
- Gallium Arsenide
- Extended Frequency Range
- High Sensitivity
- Low Current Requirement
- Flexible Lead Strip

GH-601

MECHANICAL DIMENSIONS

ALL DIMENSIONS ARE IN INCHES



Specifications	Units	GH-601
Input resistance, R_{in}	ohms	450 to 900
Output resistance, R_{out}	ohms	580 to 1700
Magnetic sensitivity, V_H (1)	mV/kG	50 to 140
Max. resistive residual voltage, V_M @ B = 0 (1)	±mV	16
Maximum control current @ 25 °C, static air	mA	10
Nominal control current, I_{cn}	mA	5
Max. linearity error (-10 kG to +10 kG)	±% of RDG	2
Mean temperature coefficient of V_H (-10 °C to +80 °C) (1)	%/°C	-0.07
Mean temperature coefficient of resistance (-10 °C to +80 °C) (1)	%/°C	0.15 Typical
Temperature dependence of resistive residual voltage (-10 °C to +80 °C) (2)	±µV/°C	1 Typical
Operating temperature range	°C	-55 °C to +125 °C
Storage temperature range	°C	-55 °C to +150 °C

Notes:

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

As a result of continuos process improvement, specifications subject to change without notice

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F.W. BELL

Models GH-600/GH-700/GH-800

Description:

The GH Series Hall effect generators 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 generator uses a lead strip which is composed of DuPont's Kapton. The lead strip is terminated with tin plated copper alloy contacts spaced 0.100 " (2.54 mm) on center. 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.

Features:

- Low Cost
- Gallium Arsenide
- Extended Temperature Range
- High Sensitivity
- Low Current Requirement
- Choice of Mounting Configurations

Specifications	Units	GH-600	GH-700	GH-800
Input resistance, R_{in}	ohms	450 to 900	450 to 900	600 to 1200
Output resistance, R_{out}	ohms	580 to 1700	580 to 1700	600 to 1200
Magnetic sensitivity, V_H (1)	mV/kG	50 to 140	50 to 140	95 to 130
Max. resistive residual voltage, V_M @ B = 0 (1)	±mV	16	16	20
Maximum control current @ 25 °C, static air	mA	10	10	7
Nominal control current, I_{cn}	mA		5	
Max. linearity error (-10 kG to +10 kG)	±% of RDG	2	2	0.7 (4)
Mean temperature coefficient of V_H (-10 °C to +80 °C) (1)	%/°C		0.07	
Mean temperature coefficient of resistance (-10 °C to +80 °C) (1)	%/°C	0.15 Typical	0.15 Typical	0.18 Max.
Temperature dependence of resistive residual voltage (-10 °C to +80 °C)	±μV/°C	1 Typical (2)	1 Typical (2)	40 Max. (1,3)
Operating temperature range	°C	-55 to +125	-55 to +125	-40 to +175
Storage temperature range	°C	-55 to +150	-55 to +150	-50 to +180

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 to + 5 kG

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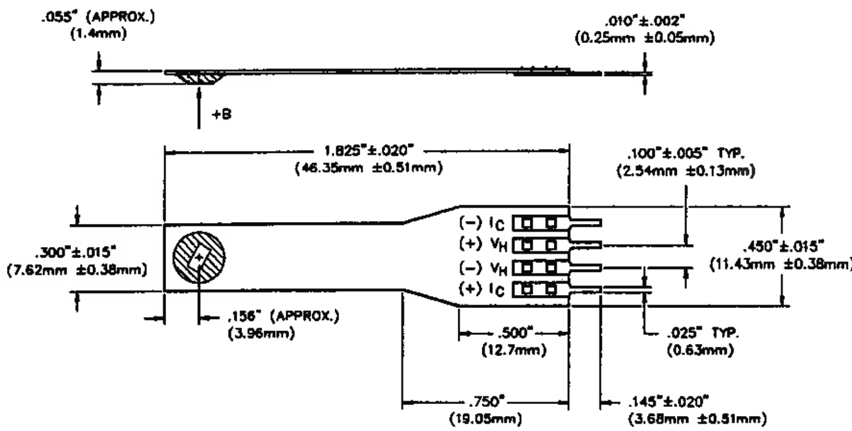
Models GH-600/GH-700/GH-800

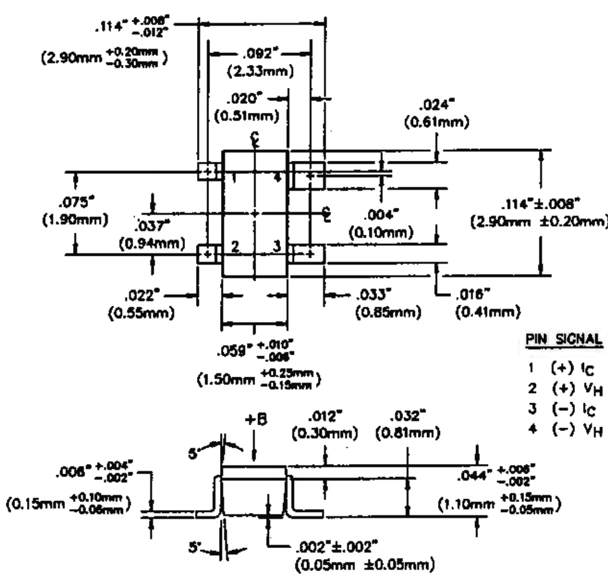
MECHANICAL DIMENSIONS

ALL DIMENSIONS ARE IN INCHES (MILLIMETERS)

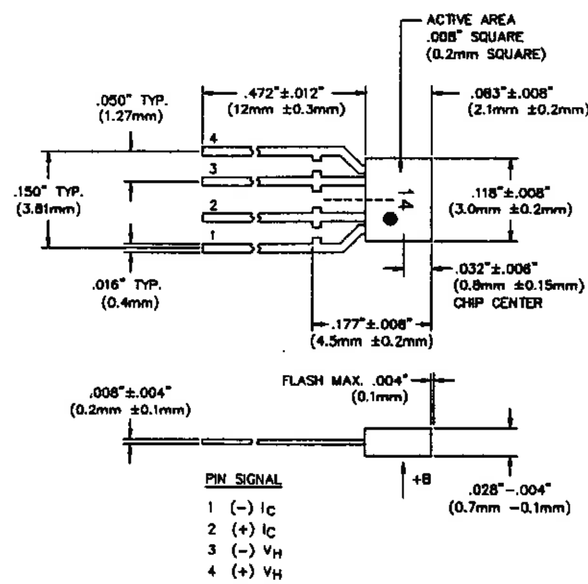


UNLESS OTHERWISE NOTED, ALL TOLERANCES ARE ±0.010" (±0.25mm)

MODEL GH-600



MODEL GH-700



MODEL GH-800

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Models GH-810/GH-820/GH-830

Description:

The GH Series Hall effect generators 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-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 Temperature Range
- High Sensitivity
- Low Current Requirement
- Choice of Mounting Configurations

Specifications	Units	GH-810	GH-820	GH-830
Input resistance, R_{in}	ohms	400 to 700	450 to 900	450 to 900
Output resistance, R_{out}	ohms	aprox. 2,000	3,200 max.	aprox. 3,000
Magnetic sensitivity, V_H (1)	mV/kG	22 to 31	80 to 190	65 to 170
Max. resistive residual voltage, V_M @ B = 0 (1)	±mV	5	20	25
Maximum control current @ 25 °C, static air	mA	15	10	10
Nominal control current, I_{cn}	mA		5	
Max. linearity error (-10 kG to +10 kG)	±% of RDG		2	
Mean temperature coefficient of V_H (-10 °C to +80 °C) (1)	%/°C	-0.05	-0.06	-0.05
Mean temperature coefficient of resistance (-10 °C to +80 °C) (1)	%/°C	0.5 Max. (2)	0.15 Typical	0.3 Max.
Temperature dependence of resistive residual voltage (-10 °C to +80 °C)	±μV/°C	1 Typical (2)	1 Typical (2)	5 Typical (2)
Operating temperature range	°C		-55 to +125	
Storage temperature range	°C		-55 to +150	

Notes:

(1) Nominal Control Current, I_{CN} (5 mA)
(2) Control current = 1 mA

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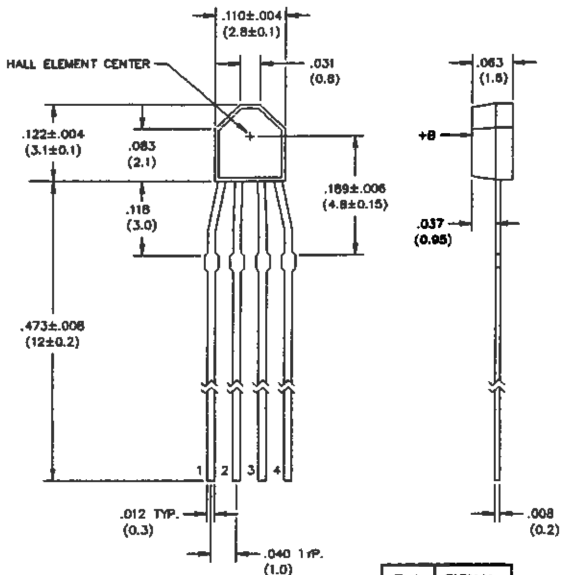
Models GH-810/GH-820/GH-830

MECHANICAL DIMENSIONS

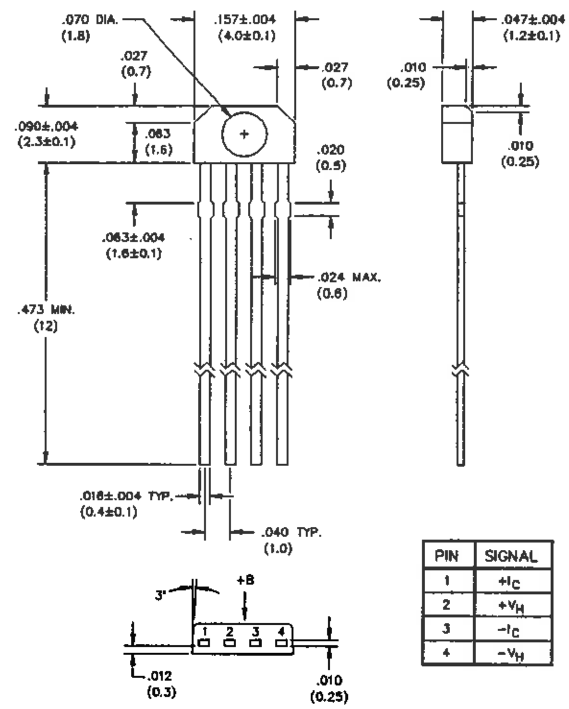
ALL DIMENSIONS ARE IN INCHES (MILLIMETERS)

GH - 810



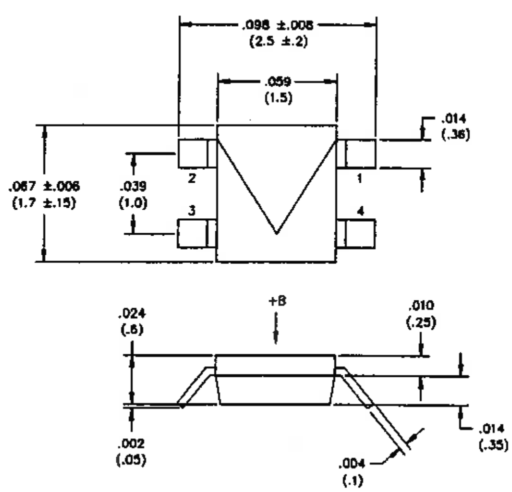
PIN	SIGNAL
1	$+I_C$
2	$+V_H$
3	$-I_C$
4	$-V_H$

GH - 820



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

GH - 830



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

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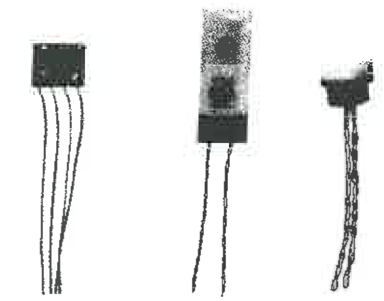
BH-700 SERIES

SINGLE AXIS



BH-700 BH-701 BH-704

Above is only a portion of the models available

General Description:

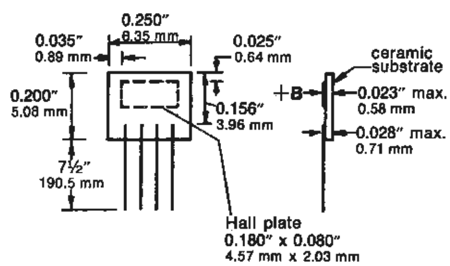
Designed to meet the requirements of a wide range of magnetic field measurement applications, the BH-700 Series are small, solid-state devices that provide an output voltage proportional to the product of control current and ambient flux density.

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.

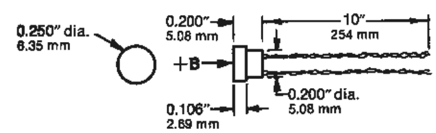
Models	Features
BH-700	Low Cost, Transverse, General Purpose
BH-701	Rugged, High-Linearity, Transverse, Instrumentation Quality
BH-702	Low Field (ferrite-embedded), Transverse
BH-704	Rugged, High Linearity, Axial, Instrumentation Quality
BH-705	General Purpose, Transverse

MECHANICAL SPECIFICATIONS

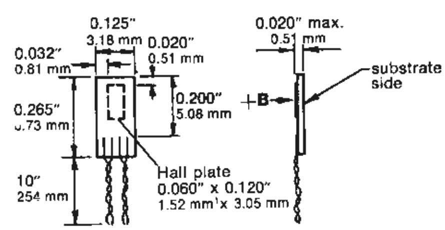
Model BH-700 Low cost transverse



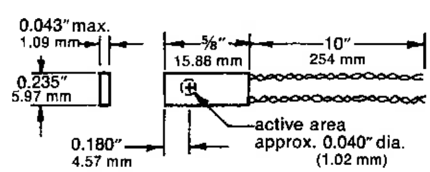
Model BH-704 high linearity axial



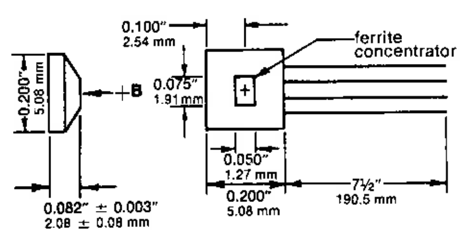
Model BH-705 General purpose transverse



Model BH-701 High linearity transverse



Model BH-702 ferrite imbedded transverse



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

COLOR CODE:

Control Current (I_C): Red ($+I_C$)
Black ($-I_C$)
Hall Voltage (V_H): Blue ($+V_H$)
Yellow ($-V_H$)

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.

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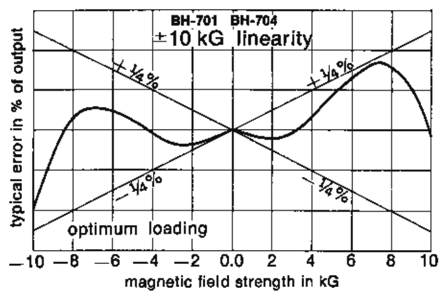
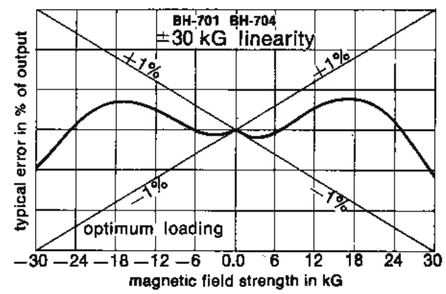
BH-700 SERIES

SINGLE AXIS

ELECTRICAL SPECIFICATIONS



NOTE: Optimum loading range for ±10kG operation is 20-50Ω.



NOTE: Optimum loading range for ±30kG operation is 90-200Ω.

***BH-702**

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

Sensitivity: With the unit suspended in a free field of 100 oersteds and 200 mA control current, the open circuit Hall voltage is 9.0 mV minimum. In a closed magnetic circuit driven with 2.5 ampere-turns, V_H is at least 8 mV with 200 mA control current.

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**

Linearity: (See below)

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.

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.

JA0701

MODELS	BH-700	BH-701	BH-702	BH-704	BH-705
Rated control Current, I_{cn}	200 mA	100 MA	200 mA	100 mA	100 mA
Maximum continuous control current I_{cmos} (B≤3kG)	250 mA	300 MA	300 mA	300 mA	250 mA
Product sensitivity	0.25 V/A•k min.	0.075 V/A•kG ±20%	–	0.075V/A•kG ±20%	0.1 V/A•kG ±25%
Open circuit magnetic senitivity, γ_B	50 mV/kG min.	7.5 mV/kG±20% $I_c=I_{cn}$ 22 mV/kG±20% $I_c=I_{cmos}$	***	7.5 mV/kG±20% $I_c=I_{cn}$ 22 mV/kG±20% $I_c=I_{cmos}$	10 mV/kG ±25%
Misalignment voltage, $V_M(B=0)$	1.5 mV max.	75 μV max.	250 μV max.	75μV max.	300 μV max.
Linearity error with R_{in} termination (% of reading)	3.0% 0 to 10 kG	**	–	**	1% 0 to 10 kG
Input resistance, R_{in}	5.5 Ω max.	2Ω max.	3.5Ω max.	2.5Ω max.	2.2Ω max.
Output resistance, R_{out}	5.5 Ω max.	2 Ω max.	3.5Ω max.	2.5Ω max.	2Ω max.
Mean temperature coefficient of V_{HOC}, β_T	-0.2%/°C* (-10°C to + 80°C)	-0.04%/°C* (-10°C to +80°C)	-0.07%/°C* (-10°C to +60°C)	-0.04%/°C* (-10°C to +80°C)	-0.08%/°C max. (-10°C to + 80°C)
Mean temperature coefficient of resistance	+0.20%/°C* (-10°C to +80°C)	+0.18%/°C* (-10°C to +80°C)	+0.18%/°C* (-10°C to 60°C)	+0.18%/°C* (-10°C to +80°C)	+0.2%/°C* (-10°C to +80°C)
Mean temperature coefficient of misalignment voltage	6μV/°C typ	0.3 μV/°C typ	2.5μV/°C typ	0.5μV/°C max.	1μV/°C max.
Storage temperature range	-40°C to +105°C	-40°C to +105°C	-40°C to +105°C	-40°C to +105°C	-65°C to +105°C
Operating temperature range	-40°C to +100°C	-40°C to +100°C	-40°C to +75°C	-40°C to +100°C	-65°C to +100°C
Zero field thermal voltage	–	5μV max.	–	5μV max.	5μV max.
Thermal resistance, plate to ambient	–	0.1°C/mW*	–	–	0.5 C/mW*
Thermal resistance, plate to substrate	–	0.01°C/C/mW*	–	–	0.025°C/mW*

*Approximate Specifications may change without notice. Unless otherwise noted: B=1 kG, $I_c=I_{cn}$, T=25C, Static air.

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F.W. BELL

BH-703

THREE AXIS

General Description:

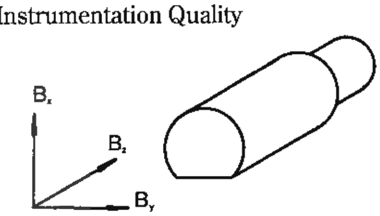
The BH-703 multi-axis Hall generator consists of three individual Hall elements oriented in mutually perpindicular planes and encapsulated in a small epoxy package. This enables the BH-703 to produce voltages proportional to the three orthogonal components (B_X, B_Y, B_Z) of a magnetic flux in any direction. 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: $B=\sqrt{B_x^2+B_y^2+B_z^2}$

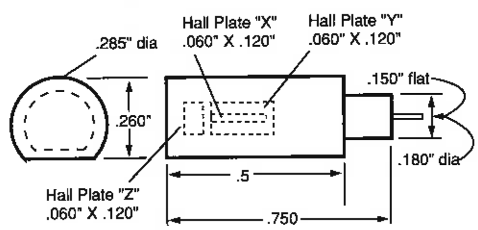
The flux direction may be found using the following relations:
$\alpha = \cos^{-1} B_x/B$, $\beta = \cos^{-1} B_y/B$, $\delta = \cos^{-1} B_z/B$ where α, β, δ are the angles between B and B_x, B_y, B_z respectively.

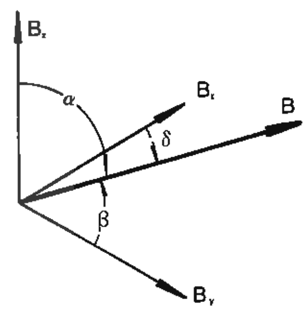
Model Features

- Three Axis, simultaneous measurement
- Instrumentation Quality



MECHANICAL SPECIFICATIONS





Multi-Axis Linearity
The linearity is within ±1.0% of reading from -10 kG to +10kG with resistive null voltage compensated to zero and with R_{lin} termination.

NOTE: All tolerances unless specified are ±0.010".

NOTE: Unless otherwise noted: B=1kG, $I_c=I_{cn}$, T=25°C, Static air.
Leads: #34 AWG copper with polyurethane insulation, approximately 20" long. The BH-703 has 12 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.

ELECTRICAL SPECIFICATIONS

MODELS	BH-703
Zero field residual voltage V_{MT} (B=0), Ic=100 mA	100 µV maximum
Angularity	Hall plates, perpindicular within ±2°
Control current (a) nominal (b) max continuous	 100 mA 300 mA
Input and output resistance, B=0	3Ω maximum
Magnetic sensitivity (when terminated into optimum load, R_{lin})	7.5 mV/kG ± 20%
Sensitivity matching	within ±1%
Temperature dependance (a) of Hall voltage (b) of resistance (c) zero field residual voltage	 -0.04%/°C max. +0.15%/°C approx. 0.5 µV/°c max.
Operating temperature range	-40°C to +100°C

Specifications may change without notice.

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BH-706

TWO AXIS

General Description:

A single Hall element produces a voltage proportional to the magnetic flux density normal to its surface. The BH-706 multi-axis Hall generator consists of two Hall elements mounted in mutually perpindicular planes and encapsulated in a small epoxy package. This enables the BH-706 to produce voltages proportional to two perpindicular 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.

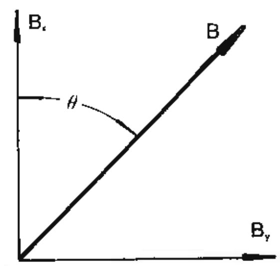
The magnitude of the flux vector, B, within the X,Y plane can be found using the following equation.

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

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

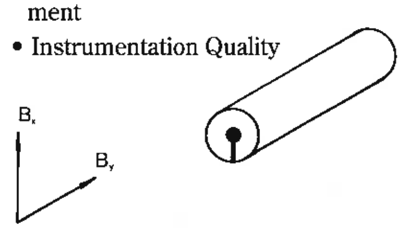
$$\theta=\tan^{-1} B_y/B_x$$

where θ is the angle between B and B_x.

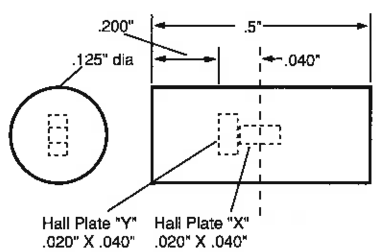


Model Features:

- 2 Axis, simultaneous measurement
- Instrumentation Quality



MECHANICAL SPECIFICATIONS



Multi-Axis Linearity
The linearity is within ±1.0% of reading from -10 kG to +10kG with resistive null voltage compensated to zero and with R_{lin} termination.

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 Ic enters the red leads, the positive Hall voltage appears at the blue leads.

NOTE: All tolerances unless specified are ±0.010".

ELECTRICAL SPECIFICATIONS

Unless otherwise noted: B=1 kG, $I_c=I_{cn}$, T=25 C, Static air.

MODELS	BH-706
Zero field residual voltage V_{MT} (B=0), I_c=100 mA	200 μV maximum
Angularity	Hall plates, perpindicular within ±2°
Control current (a) nominal (b) max continuous	100 mA 300 mA
Input and output resistance, B=0	3Ω maximum
Magnetic sensitivity (when terminated into optimum load, R_{lin})	7.5 mV/kG ± 20%
Sensitivity matching	within ±1%
Temperature dependance (a) of Hall voltage (b) of resistance (c) zero field residual voltage	-0.04%/°C max. +0.15%/°C approx. 0.5 μV/°c max.
Operating temperature range	-40°C to +100°C

Specifications may change without notice.

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BH-850

ULTRA LOW FIELD

LEADS:
Material: AWG 34 Stranded (7x42) Silver Plated Copper, Thin Wall Teflon Insulation.

COLOR CODE:
Control Current (I_C): Red ($+I_C$)
Black ($-I_C$)
Hall Voltage (V_H): Blue ($+V_H$)
Yellow ($-V_H$)

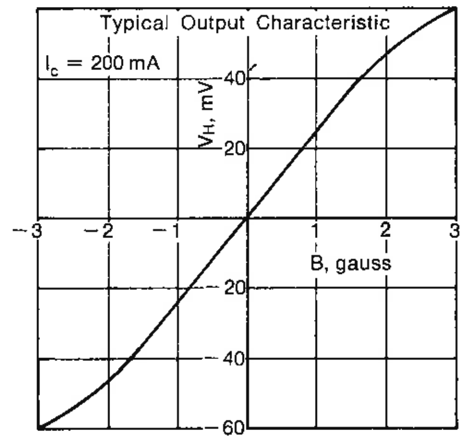
Polarity:
With field direction as shown I_C entering the red lead, the positive Hall output voltage will appear at the blue lead.

General Description

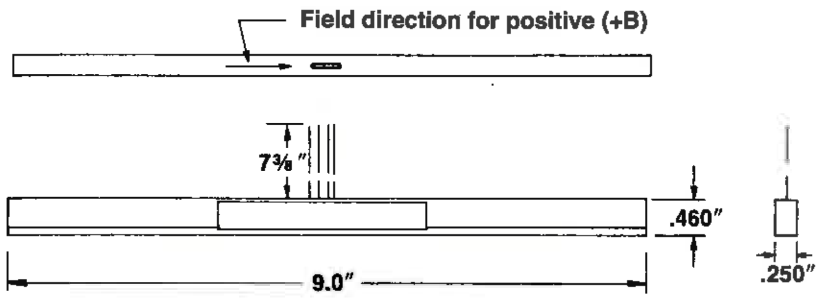
Ideal for applications such as the construction of solid state compasses, the BH-850 offers high sensitivity for very low magnetic fields at a relatively low cost.

Model Features

- High Sensitivity
- Rugged construction



MECHANICAL SPECIFICATIONS



ELECTRICAL SPECIFICATIONS

MODEL	BH-850
Nominal control current, I_{cn}	200 mA
Maximum continuous control current, I_{cmos} (in static air with T=25°C)	300 mA
Input resistance, R_{in}	3.5Ω max.
Output resistance, R_{out}	3.5Ω max.
Sensitivity, B (I_C=200 mA, open circuit)	18 mV/g. min.
Misalignment voltage, V_M (β=0, I_C=200mA, T=25°C)	±200µV/°C max.
Temperature dependence of misalignment voltage	±2.5 µV/°C max.
Temperature coefficient of open circuit hall voltage, V_{HOC}, from -55° C to +85°C	-0.18%/°C max.
Operating temperature range	-55°C to +85°C
Storage temperature range	-55°C to +85°C

Specifications may change wothout notice

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BH-900 SERIES

HIGH LINEARITY

LEADS:
Material: AWG 34 Copper with Teflon Insulation (Model 921) or Polyurethane Insulation (Models 900 & 910).

COLOR CODE: Control Current I_C
Control Current (I_C) Red ($+I_C$)
Black ($-I_C$)
Hall Voltage (V_H) Blue ($+V_H$)
Yellow ($-V_H$)

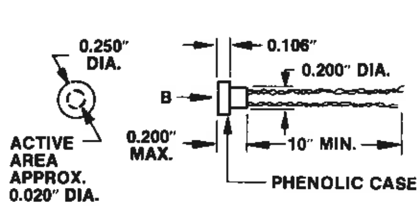
POLARITY
With the magnetic field vector (+B) entering the top of the Hall plate and I_C entering the red lead, the positive Hall voltage will appear at the blue lead.

General Description:

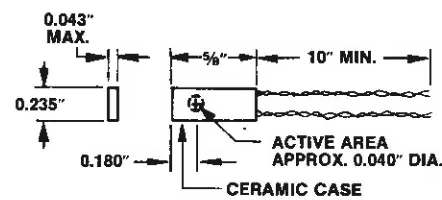
F.W.Bell 900 Series Hall Generators are high-performance units providing high linearity and broad field and temperature ranges for a wide variety of magnetic field measurements. All units in the series are encapsulated in rugged, epoxy-sealed cases. A room temperature linearity error curve from -30 to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

Models	Features:
BH-910	High Linearity
BH-921	Cryogenic Operation (1.5 to 350° k)
BH 921 & 900	Wide Dynamic Range

MECHANICAL SPECIFICATIONS



Axial Hall Generators BHA-900, 910 & 921



Transverse Hall Generators BHT-900, 910 & 921

NOTE: Cross indicates tail of magnetic field vector.

ELECTRICAL SPECIFICATIONS

Note: Unless otherwise stated, all specifications apply at nominal control current with T=25°C.

MODELS	BHT-900	BHT-910	BHT-921	BHA-900	BHA-910	BHA-921
Nominal control current, I_{cn}	100mA	100mA	100mA	100mA	100mA	100mA
Maximum continuous control current, I_{cmos} (in 25°C static air)	300mA	300mA	300mA	300mA	300mA	300mA
Magnetic sensitivity, γB, I_c = 100 mA	0.8mV/kG ±30%	0.8mV/kG ±30%	0.8mV/kG ±30%	0.8mV/kG ±30%	0.8mV/kG ±30%	0.8mV/kG ±30%
Typical load required for proper linearity	500Ω	50 to 500Ω	500Ω	500Ω	50 to 500Ω	500Ω
Linearity error (I_c=100mA) -30 to +30kG	±1.0% (max.)	±0.1% (max.)	±1.0% (max.)	±1.0% (max.)	±0.25% (max.)	±1.0% (max.)
Linearity error (I_c=100 mA) -150 to +150kG	±1.5% (max.)	–	±2.0% (max.)	±1.5% (max.)	–	±2.0% (max.)
Operating temperature range	-40 to +100°C	-40 to 100°C	-269 to +100°C	-40 to +100°C	-40 to +100°C	-269 to +100°C
Mean temperature coefficient of Hall voltage, β_T	±50 ppm/°C*	±50 ppm/°C*	±100 ppm/°C*	±50 ppm/°C*	±50 ppm/°C*	±100 ppm/°C*
Mean temperature coeffient of resistive residual voltage, D_T	±0.4 µV/°C	±0.4µV/°C*	±0.4µV/°C*	±0.4µV/°C*	±0.4µV/°C*	±0.4µV/°C*
Mean temperature coefficient of resistance α_T	±0.15%/°C*	±0.15%/°C*	±0.6%/°C*	±0.15%/°C*	±0.15%/°C*	±0.6%/°C*
Resistive residual voltage, Vm, (I_c=100mA)	50µV (max.)	50µV (max.)	200µV (max.)	50µV (max.)	50µV (max.)	200µV (max.)
Input resistance in zero field, R_{in} (including leads)	1.0Ω*	1.0Ω*	1.0Ω*	1.0Ω*	1.0Ω*	1.0Ω*
Output resistance in zero field, R_{out} (including leads)	1.0Ω*	1.0Ω*	1.0Ω*	1.0Ω*	1.0Ω*	1.0Ω*

*Approximate value. Specifications may change without notice.

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General Purpose Amplifier & Current Supply Circuit

Below is a schematic for a modest, linear, fixed-gain amplifier and simple current excitation scheme. This would be considered a moderate performance circuit. This circuit can be used with F.W.Bell Hall Generators. Refer to Table 1 for specific models.

$^{**}R_1$ & R_2: R is adjusted to calibrate sensor to a fixed output sensitivity

R_4 & R_f : Feedback resistors selected for desired gain

R_4 & R_5: Input resistors should be 10kΩ (min.) to avoid loading the output

R_4 & R_f : For proper common mode rejection (CMR)

Amplifier Requency Response: dc to 10 kHz

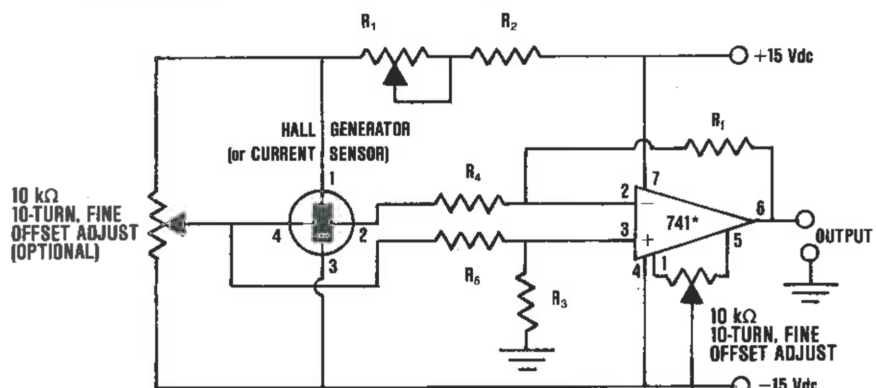

FIGURE 1

Note: Adjust offset pots, only when the Hall generator is in a zero gauss field

**The 741 operational amplifier is merely for the purpose of illustration, any other appropriate operational amplifier can be used.*

***For a true constant source that affords improved line regulation & temperature compensation, refer to "Constant Current Supply" below.*

TABLE 1 HALL GENERATOR CONNECTIONS

PIN OUT PER FIG. 1	1	2	3	4
BH-200, FH-300, BH-700, BH-900 SERIES	Red	Yellow	Black	Blue
FH-500 & GH-600 SERIES	$+I_C$	$-V_H$	$-I_C$	$+V_H$

Constant current supply

On the following page is a typical schematic for a simple, low cost, constant current source that can be used to supply the excitation current needed to drive most thin film Hall generators. As shown, it has a variable current range of about 15 to 40mA dc. This variable supply can be adjusted to fix the output sensitivity at a given current. This circuit has two inherent advantages:
1) It reduces the effects of sensitivity changes due to changes in ambient temperature to ≤0.05%/°C (-40°C to +80°C) maximum and 2) 1% variations of the input voltage (at +15V dc) will affect the accuracy by only 0.1%.

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APPLICATION AIDS

Constant Current Supply (continued)

For variations to this circuit to accomodate other Hall generators (for example: different input voltages, different current swings, different regulator voltages, etc.), consult the data books and application notes furnished by the manufacturer of the voltage regulator.

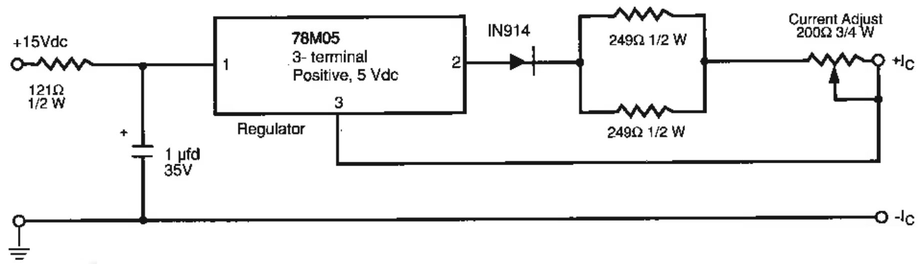


Figure 2

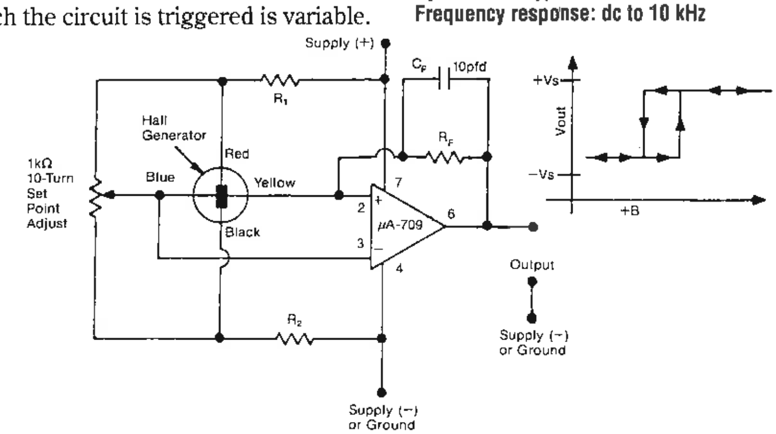
Hall generator switching circuit

Below is a schematic for an easy to build switching circuit for use with an F.W.Bell, Inc. Hall generator. The circuit is triggered by the output voltage of the Hall generator, and the point at which the circuit is triggered is variable.

The amplitude of the circuit's output voltage is approximately:

$V_{OUT} = 2\,V_S \;\; -2(V).$

R_1 = R_2: Selected for desired Hall generator control current
R_F: Feedback resistor selected for the required hysteresis. Typical value is 100Ω
Frequency response: dc to 10 kHz



* *The 709 operational amplifier is merely for the purpose of illustration. Any other appropriate operational amplifier can be used.*

Figure 3

***Values for testing BH-Series Hall generators**
****Values for testing FH-Series Hall generators**
*****Values for testing GH-Series Hall generators**

Testing F.W. Bell Hall generators

1. Test Current Calibration
   (Refer to Fig. 4)

With switch S-1 in the "CAL" position, adjust the constant current supply output until the dc voltmeter reads 100 mV* (or 10mV** or 1 mV***). The test current is now calibrated at 100 mA* (or 10 mA** or 1 mA***).

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Testing F.W.Bell Hall generators (continued)

2. Input Resistance Measurement

Place the test Hall generator leads in the proper Kelvin Klips. Move switch S-1 to the "R_{in}" position. The reading on the voltmeter in millivolts, divided by 100* (or 10** or 1***), is the value of the input resistance.

3. Output Resistance Measurement

Same procedure as input resistance except readings taken with S-1 in position 3.

4. Zero Field Residual Voltage

With the hall generator still in the Kelvin Klips, move the selector switch to the "V_H" position. Place the Hall generator active area into F.W.Bell Model YA-111 zero gauss chamber. The zero field residual voltage at a control current of 100 mA* (or 10 mA** or 1 mA***) is read on the dc voltmeter.

The value at higher control current can be calculated from the fact that the zero field residual voltage is directly proportional to the control current. If desired, the control current may be re-calibrated, as in Step 1, to the desired value prior to reading zero field residual voltage.

5. Magnetic Sensitivity Measurement

Remember or record the polarity and value of the zero field residual voltage.

Place the Hall generator in a known magnetic field (1 kilogauss is convenient) with the red surface toward the north pole of the magnet. Subtract algebraically the zero field residual voltage from the field-generated reading. This gives the output voltage swing. Dividing the voltage swing by the field value gives the magnetic sensitivity of the Hall generator at the calibrated test current.

When tests are complete move S-1 to the "CAL" position, **then** remove the Hall generator.

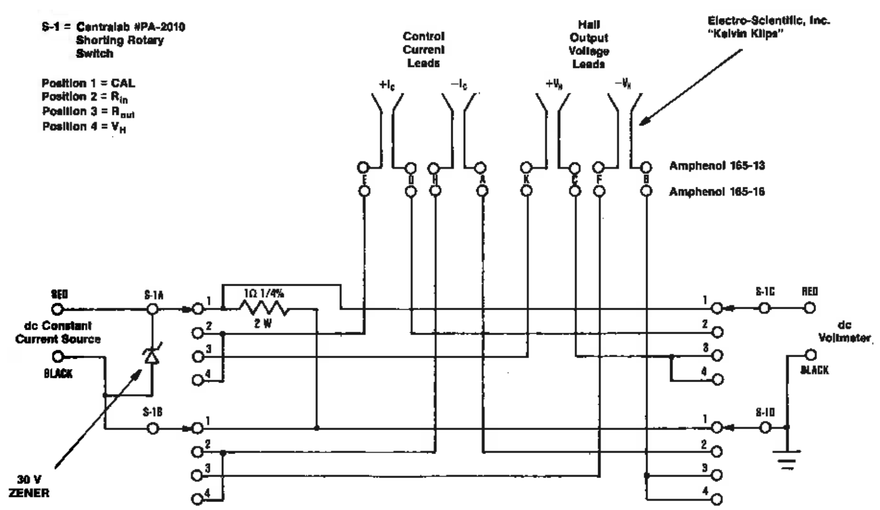

Figure 4

*Values for testing BH-Series Hall generators
**Values for testing FH-Series Hall generators
***Values for testing GH-Series Hall generators

The circuits described herein are intended only to illustrate typical applications. This information is believed reliable, however, no reponsibility is assumed for inaccuracies.

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Techniques for temperature compensating Hall generators

Temperature effects can rarely be ignored in the application of a Hall generator. Selecting a generator with a low-temperature coefficient of sensitivity may suffice, but compensation is occasionaly required. If the designer understands the parameters involved, their effects on the Hall device output, and knows the ambient operating conditions, applying the compensating networks is simple. Due to the wide range of parameter variations among Hall generators of the same type, however, it is difficult to have one compensation network work for all generators that are used.

The compensation circuits offered below represent the basics; the total possibilities are limited only by the user's imagination. Only N-type indium arsenide Hall generators will be considered. Conduction is by majority carriers, no semiconductor junctions exist, and all contacts to the semiconductor material are ohmic.

An indium arsenide Hall generator usually exhibits a positive temperature coefficient of resistance (α_T) over its normal operating range. If a constant voltage supply provides the generator control current, this current decreases as the Hall plate temperature increases. The result is an output sensitivity inversely related to temperature. A constant current supply eliminates the effects of Hall generator input resistance changes. This condition can also be approximated by a voltage supply with high output impedance. If conditions require a low-impedance voltage supply, the designer who wants to compensate for α_T must be aware of a sign reversal on it, as shown in Figure 5.

For most hall generators with product sensitivities below 0.2 volts per ampere kilogauss, the sign change on α_T takes place at temperatures above the normal operating range. In this case, the compensating networks discussed in the following sections may be used. Higher sensitivity devices exhibit the sign reversal within their operation range, however (see Figure 5). This behavior can make compensation very difficult, and the designer may have to accept the input resistance temperature effect or change to a higher source impedance.

Sensitivity Variation

The relation of electron mobility to temperature causes Hall generator sensitivity to decrease as temperature increases. This phenomenon is independent of the temperature coefficient of resistance effect. Normally, Hall generators with higher sensitivities exhibit higher temperature coefficients of sensitivity (β_T) at constant current. The output variation is approximately linear from -60° to 60°C. Above 60°C, the rate of change increases rapidly (see Figure 6).

Several methods exist for compensating for temperature variation of the parameters discussed above. Since all the suggested procedures require trial-and-error calculations and testing, only the overall configuration is described.

A positive temperature coefficient (PTC) resistor can be used as a compen-

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sating element. (Figure 7). Nickel or copper wire resistance are possibilities, or PTC silicon resistors may be considered. Nickel exhibits a positive temperature coefficient of about 0.5%/°C; copper, 0.4%/°C; and silicon resistors, about 0.7%/°C.

Negative temperature coefficient (NTC) thermistors are the most widely used devices for compensating Hall generator temperature drift (Fig. 9). This configuration with a voltage supply causes the control current I_C to increase as the temperature rises.

Another compensation method, using an NTC thermistor, is shown in Figure 10. In implementing this concept, the designer must make sure that two conditions exist. Ample output must be maintained across resistor R_1, and the total load, R_L, presented to the Hall generator must adversely affect output linearity. (Consult the Hall generator manufacturer if linearity is a critical parameter.) If amplication is required, an alternative to the circuit in Figure 10 would be to place a thermistor circuit in the feedback network of the amplifier.

Single thermistor or PTC resistor circuits usually exhibit good high-temperature correction. Improved compensation over a wider temperature range may be achieved through use of two temperature sensor networks. The two may be a combination of those mentioned above.

The following example (Figure 11) illustrates the results of negative temperature coefficient thermistor compensation in the Hall generator input circuit. The Hall generator has the characteristics listed below:

Input Resistance (R_{in}), 4Ω
Magnetic Sensitivity (γ_B), 30 mV/kG
(At I_C= 100 mA and T = 25°C)
Temperature Coefficient of Input Resistance (α_T), +0.2%/°C
Temperature Coefficient of Magnetic Sensitivity (β_T), -0.22%/°C

Improved Hall generator temperature drift is desired between 25° and 60°C. Uncompensated, the generator sensitivity at 60°C would decrease approximately 8% from its value at 25°C. A first attempt to improve this temperature drift might be the circuit shown in Figure 11. The real problem is to select proper values for R_1 and R_T.

Increasing the Hall generator control

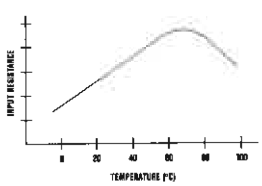

Figure 5. "Worst case" temperature characteristics of input resistance.

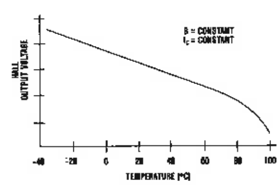

Figure 6. The sensitivity of a Hall generator decreases with the temperature

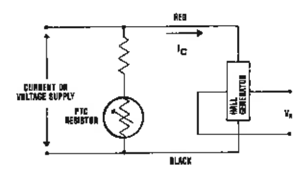

Figure 7. A positive temperature coefficient thermistor can be used in temperature compensation of Hall generators

Test results on sensitivity with compensated and uncompensated circuits.

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current by about 8% at 60° C will eliminate the drop in sensitivity due to β_T. The next step is to calculate a thermistor-resistor parallel resistance, R_{TOT} which will supply 108 mA control current at 60° C. (Changes in resistor R_1 and in the Hall generator input resistance are small and will be ignored throughout this example).

$$R_{TOT} = (V_S/I) - R_{IN}$$
$$= 5/(0.108) - 4 \cong 42.3\Omega$$

Since thermistor resistance will be selected at 60° C, R_T will generally be high in value at 25° C. Assuming that R_1 will be moderately high, let R_1 be 47Ω. If our assumptions are correct, the Hall genrator control current will be near 100 mA at 25° C. Next, the thermistor resistance at 60° C must be calculated;

$$R_T = \frac{R_1 (R_{TOT})}{R_1 - R_{TOT}}$$

The table gives a comparison of sensitivity change for both the uncompensated and compensated circuits (a thermistor temperature coefficient of -3.9%/° C was used). A higher R_1 might be selected for better low-temperature response.

T (°C)	γ (mV/kG)	R_T (Ω)	R_{TOT} (Ω)	I (mA)	γ_B (comp.) (mV/kG)
-10	32.3	6447	46.66	98.7	31.88
+10	31.0	2636	46.18	99.6	30.88
+25	30.0	1440	45.51	101.0	30.30
+40	29.0	827	44.47	103.2	29.93
+60	27.7	423	42.30	108.0	29.92

Figure 8

Zero Field Residual Voltage

In most cases, the zero field residual voltage (V_{MT}) temperature drift is separate, but not distinguishable, from sensitivity drift. When magnetic flux densities are low, the effect of (V_{MT}) temperature drift of the residual voltage may be equal to or larger than the sensitivity change. The inability to consistently and accurately predict the rate and direction of drift in this offset voltage is the most difficult part of compensation.

Since the major portion of the V_{MT} is caused by unbalanced output contact positioning (misalignment voltage), the characteristics of the temperature drift may be predicted with fair accuracy. For devices with a room temperature V_{MT} greater than 500 µV, the magnitude of the zero field residual voltage increases at a rate approximately equal to the temperature coefficient of resistance, α_T. Units with V_{MT} between 100 and 500 µV normally exhibit an increase in residual voltage magnitude, but at rates varying within ±100% of the resistive coefficient. Below 100 µV, the task of predicting the offset drift becomes difficult because the

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APPLICATION AIDS

direction and rate are random. A circuit that can be used to compensate for the zero field residual voltage temperature drift is shown in Figure 12.

The thermistor shown compensates for a positive-going temperature drift (with respect to the output terminals). If zero field residual voltage varies negatively with increasing temperature, the thermistor network and R_1 must be interchanged.

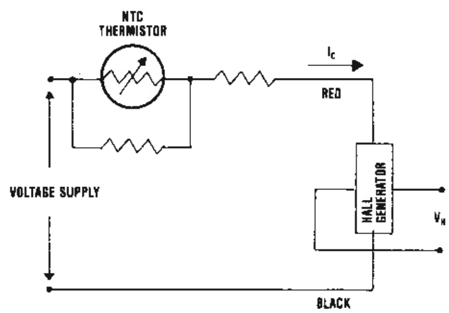

Figure 9

Hall generator can be compensated at its input by a negative temperature coefficient thermistor.

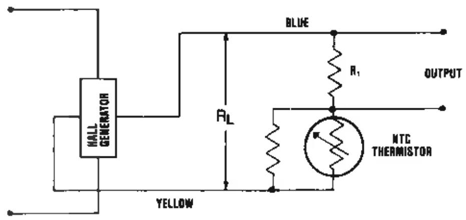

Figure 10

Temperature compensation of a Hall generator using a negative temperature coefficient thermistor.

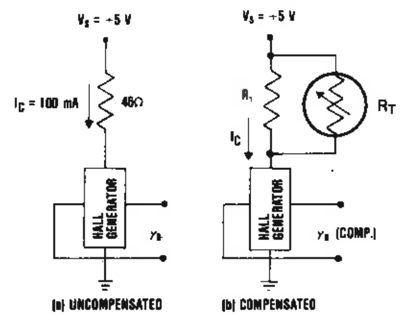

Figure 11

The use of a negative temperature coefficient thermistor as a compensator in the Hall generator input.

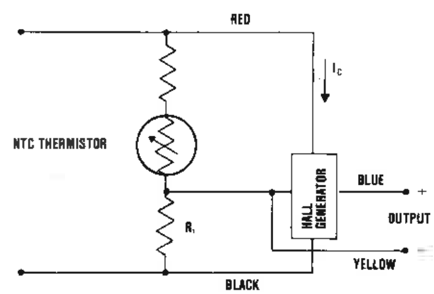

Figure 12

Compensation of zero field voltage temperature drift of Hall generators.

H.Weiss. Structure and Application of Galvanomagnetic Devices, Pergamon Press

H.H.Weider. Hall Generators and Magneto-resistors, Pion Limited

MIL-STD-793-1 (WP), "Definitions Letter Symbols", Color Code and Circuit Code and Circuit Symbol for Devices Hall Effect

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