Magnetic Field Sensors (Hall Sensors)

Hall sensor theory

A Hall sensor is a solid state sensor which provides an output voltage proportional to magnetic flux density. As implied by its name, this device relies on the Hall effect. The Hall effect is the development of a voltage across a sheet of conductor when current is flowing and the conductor is placed in a magnetic field.

Electrons (the majority carrier most often used in practice) “drift” in the conductor when under the influence of an externally produced electric field. These moving electrons experience a force proportional and perpendicular to the product of their velocity and the magnetic field vector. This force causes the charging of the edges of the conductor, one side positive with respect to the other, resulting in an internally generated transverse electric field which exerts a force on the moving electrons equal and opposite to that caused by the magnetic-field-related Lorentz force. The resultant voltage potential across the width of the conductor is called the Hall voltage and can be measured by attaching two electrical contacts to the sides of the conductor.

The Hall voltage can be given by the expression:

\[ V_H = Y_B B \sin \theta \]

where

- \( V_H \) = Hall voltage (mV)
- \( Y_B \) = Magnetic sensitivity (mV per kG, at a fixed current)
- \( B \) = Magnetic field flux density (kG)
- \( \theta \) = Angle between magnetic flux vector and the plane of Hall sensor

As can be seen from the above formula, the Hall voltage varies with the angle of the sensed magnetic field, reaching a maximum when the field is perpendicular to the plane of the Hall sensor.

Active area

The Hall sensor assembly contains the sheet of semiconductor material to which the four contacts are made. This entity is normally called a “Hall plate.” The Hall plate is, in its simplest form, a rectangular shape of fixed length, width and thickness. Due to the shorting effect of the current supply contacts, most of the sensitivity to magnetic fields is contained in an area approximated by a circle, centered in the Hall plate, whose diameter is equal to the plate width. Thus, when the active area is given, the circle as described above is the common estimation.

Hall sensors come in axial and transverse configurations.

Transverse devices are generally thin and rectangular in shape. They are applied successfully in magnetic circuit gaps, surface measurements, and general open field measurements.

Axial sensors are mostly cylindrical in shape. Their applications include ring magnet center bore measurements, solenoids, surface field detection, and general field sensing. See the individual Hall sensor illustrations for physical dimensions.
Using a Hall sensor

A Hall sensor is a 4-lead device. The control current ($I_c$) leads are normally attached to a current source such as the Lake Shore Model 121. The Model 121 provides several fixed current values compatible with various Hall sensors.

**Caution:** Do not exceed the maximum continuous control current given in the specifications.

The Hall voltage leads may be connected directly to a readout instrument, such as a high impedance voltmeter, or can be attached to electronic circuitry for amplification or conditioning. Device signal levels will be in the range of microvolts to hundreds of millivolts.

The Hall sensor input is not isolated from its output. In fact, impedance levels on the order of the input resistance are all that generally exist between the two ports. To prevent erroneous current paths, which can cause large error voltages, the current supply must be isolated from the output display or the downstream electronics.

### Ordering information

<table>
<thead>
<tr>
<th>Part number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMCBL-6</td>
<td>1.8 m (6 ft) long cable for Model 475 and 455</td>
</tr>
<tr>
<td>HMCBL-20</td>
<td>6.1 m (20 ft) long cable for Model 475 and 455</td>
</tr>
</tbody>
</table>

All specifications are subject to change without notice.

### Attaching discrete Hall sensors to Lake Shore gaussmeters

Lake Shore provides cable assemblies containing the electronic memory (EEPROM) to interface a Hall sensor to a gaussmeter. This allows users to assemble a Hall sensor into a difficult to access area prior to gaussmeter attachment. The figure below shows the general cable configuration. While convenient, this method provides less than optimum performance. Because of the intricacies involved with proper calibration, the user is responsible for the measurement accuracy. A probe fully calibrated by Lake Shore is always suggested. Special probe mechanical configurations are also available.

Certain Hall sensor sensitivity constraints are applicable:

- Sensitivities between 5.5 and 10.5 mV/kG at 100 mA control current.
- Sensitivities between 0.55 and 1.05 mV/kG at 100 mA control current.

**For the Model 475, 455, and 425 gaussmeters**

2 m (6 ft) and 6.1 m (20 ft) cables are available.

The 475, 455, and 425 gaussmeters offer the convenience of front panel programming. No external computer is required. The Hall sensor serial number and single-point sensitivity are directly entered using the keypad.

**For the Model 460, 450, and 421 gaussmeters**

Connection of discrete Hall sensors to these instruments is no longer supported. Contact Service for ongoing support of these instruments.
### Axial Hall sensors

#### Lead colors:
- **Red**: +IC
- **Green**: -IC
- **Blue**: +VH
- **Clear**: -VH

#### HGA-2010
- **Description**: General purpose axial; high sensitivity
- **Active area (approx)**: 0.127 × 0.127 mm (0.005 in × 0.005 in) square
- **Input resistance (approx)**: 450 Ω to 900 Ω
- **Output resistance (approx)**: 550 Ω to 1350 Ω
- **Nominal control current (IC)**: 1 mA
- **Maximum continuous current (non-heat sunked, 25 °C)**: 10 mA
- **Magnetic sensitivity (IC = nominal control current)**: ±1.2 µV/kG (approx)
- **Zero field offset voltage (IC = nominal control current)**: ±2.8 µV (max)
- **Operating temperature range**: -40 °C to +100 °C
- **Temperature coefficient of magnetic sensitivity**: -0.06%/°C (max)
- **Temperature coefficient of offset (IC = nominal control current)**: ±1 µV/°C (approx)
- **Temperature coefficient of resistance**: +0.15%/°C (approx)
- **Leads**: 34 AWG copper with poly-nylon insulation
- **Data**: Single sensitivity value at IC = 1 mA

#### HGA-2303
- **Description**: General purpose axial; 3.30 mm (0.130 in) diameter
- **Active area (approx)**: 0.51 × 0.020 in (0.020 × 0.040 in) rectangle
- **Input resistance (approx)**: 2 Ω
- **Output resistance (approx)**: 2 Ω
- **Nominal control current (IC)**: 1 mA
- **Maximum continuous current (non-heat sunked, 25 °C)**: 150 mA
- **Magnetic sensitivity (IC = nominal control current)**: ±1 (10 kG to +10 kG)
- **Zero field offset voltage (IC = nominal control current)**: ±100 µV (max)
- **Operating temperature range**: -40 °C to +100 °C
- **Temperature coefficient of magnetic sensitivity**: -0.08%/°C (max)
- **Temperature coefficient of offset (IC = nominal control current)**: ±0.4 µV/°C (approx)
- **Temperature coefficient of resistance**: +0.18%/°C (approx)
- **Leads**: 36 AWG copper with poly-nylon insulation
- **Data**: Single sensitivity value at IC = 100 mA

#### HGA-2302
- **Description**: General purpose axial; 3.30 mm (0.130 in) diameter
- **Active area (approx)**: 0.51 × 0.020 in (0.020 × 0.040 in) rectangle
- **Input resistance (approx)**: 2 Ω
- **Output resistance (approx)**: 2 Ω
- **Nominal control current (IC)**: 100 mA
- **Maximum continuous current (non-heat sunked, 25 °C)**: 200 mA
- **Magnetic sensitivity (IC = nominal control current)**: ±1 (10 kG to +10 kG)
- **Zero field offset voltage (IC = nominal control current)**: ±50 µV (max)
- **Operating temperature range**: -40 °C to +100 °C
- **Temperature coefficient of magnetic sensitivity**: -0.04%/°C (max)
- **Temperature coefficient of offset (IC = nominal control current)**: ±0.3 µV/°C (approx)
- **Temperature coefficient of resistance**: +0.18%/°C (approx)
- **Leads**: 34 AWG copper with poly-nylon insulation
- **Data**: Single sensitivity value at IC = 100 mA

#### HGA-3010*, HGA-3030*
- **Description**: Instrumentation quality axial; phenolic package
- **Active area (approx)**: 0.127 × 0.127 mm (0.005 in × 0.005 in) square
- **Input resistance (approx)**: 550 Ω to 1350 Ω
- **Output resistance (approx)**: 550 Ω to 1350 Ω
- **Nominal control current (IC)**: 1 mA
- **Maximum continuous current (non-heat sunked, 25 °C)**: 10 mA
- **Magnetic sensitivity (IC = nominal control current)**: ±1 (10 kG to +10 kG)
- **Zero field offset voltage (IC = nominal control current)**: ±100 µV (max)
- **Operating temperature range**: -40 °C to +100 °C
- **Temperature coefficient of magnetic sensitivity**: -0.06%/°C (max)
- **Temperature coefficient of offset (IC = nominal control current)**: ±1 µV/°C (approx)
- **Temperature coefficient of resistance**: +0.12%/°C (approx)
- **Leads**: 34 AWG copper with poly-nylon insulation
- **Data**: Single sensitivity value at IC = 100 mA

#### Ordering information
- **Part number**: HGA-2010
  - **Description**: General purpose axial Hall sensor; plastic package
- **Part number**: HGA-2302
  - **Description**: General purpose axial Hall sensor; phenolic shoulder
- **Part number**: HGA-2303
  - **Description**: Instrumentation quality axial Hall sensor; phenolic package
- **Part number**: HGA-3010
  - **Description**: Instrumentation quality axial Hall sensor; phenolic package
- **Part number**: HGA-3030
  - **Description**: Instrumentation quality axial Hall sensor; phenolic package

#### Accessories available
- **CAL-1X-DATA**: 1-axis Hall sensor recalibration with certificate and data

*Not compatible with Lake Shore gaussmeters

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All specifications are subject to change without notice
## Transverse Hall sensors

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<thead>
<tr>
<th>Description</th>
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<th>HGT-1020</th>
<th>HGT-1050*</th>
<th>HGT-1070*</th>
<th>HGT-2010*</th>
<th>HGT-2101*</th>
<th>HGT-3010</th>
<th>HGT-3030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active area (approx)</td>
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<tr>
<td>diameter circle</td>
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<tr>
<td>diameter circle</td>
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</tr>
<tr>
<td>No. 1.02 mm (0.040 in)</td>
<td>No. 0.76 mm (0.030 in)</td>
<td>No. 1.52 × 2.03 mm (0.06 × 0.08 in)</td>
<td>No. 0.127 mm (0.005 in) square</td>
<td>No. 0.3 mm (0.012 in) diameter circle</td>
<td>1.02 mm (0.040 in) diameter circle</td>
<td>1.02 mm (0.040 in) diameter circle</td>
<td>1.02 mm (0.040 in) diameter circle</td>
<td>1.02 mm (0.040 in) diameter circle</td>
</tr>
<tr>
<td>Input resistance (approx)</td>
<td>2 Ω</td>
<td>4 Ω (max)</td>
<td>4 Ω (max)</td>
<td>4 Ω (max)</td>
<td>4 Ω (max)</td>
<td>4 Ω (max)</td>
<td>4 Ω (max)</td>
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<tr>
<td>Output resistance (approx)</td>
<td>2 Ω</td>
<td>4 Ω (max)</td>
<td>4 Ω (max)</td>
<td>4 Ω (max)</td>
<td>4 Ω (max)</td>
<td>4 Ω (max)</td>
<td>4 Ω (max)</td>
<td>4 Ω (max)</td>
</tr>
<tr>
<td>Nominal control current (Ic)</td>
<td>100 mA</td>
<td>200 mA</td>
<td>250 mA</td>
<td>300 mA</td>
<td>10 mA</td>
<td>1 mA</td>
<td>10 mA</td>
<td>10 mA</td>
</tr>
<tr>
<td>Maximum continuous current (non-heat sunk, 25 °C)</td>
<td>250 mA</td>
<td>200 mA</td>
<td>250 mA</td>
<td>300 mA</td>
<td>10 mA</td>
<td>10 mA</td>
<td>10 mA</td>
<td>10 mA</td>
</tr>
<tr>
<td>Magnetic sensitivity (Ic = nominal control current)</td>
<td>7.5 mV/kG to 12.5 mV/kG</td>
<td>8 mV at 100 Oe (min)</td>
<td>11 mV/kG to 28 mV/kG</td>
<td>6.0 mV/kG to 10.0 mV/kG</td>
<td>6.0 mV/kG to 10.0 mV/kG</td>
<td>6.0 mV/kG to 10.0 mV/kG</td>
<td>6.0 mV/kG to 10.0 mV/kG</td>
<td>6.0 mV/kG to 10.0 mV/kG</td>
</tr>
<tr>
<td>Maximum linearity error (sensitivity versus field)</td>
<td>±1.0% rdg (-10 to 10 kG)</td>
<td>±1.0% rdg (0 to 10 kG)</td>
<td>±1% rdg (-10 to 10 kG)</td>
<td>±2% rdg (-20 to 20 kG)</td>
<td>±2% rdg (-10 to 10 kG)</td>
<td>±1% rdg (-30 to 30 kG)</td>
<td>±1.5% rdg (-100 to 100 kG)</td>
<td>±1.5% rdg (-30 to 30 kG)</td>
</tr>
<tr>
<td>Zero field offset voltage (Ic = nominal control current)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>150 µV (max)</td>
<td>±2.8 mV (max)</td>
<td>±50 µV (max)</td>
<td>±75 µV (max)</td>
</tr>
<tr>
<td>Operating temperature range</td>
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<tr>
<td>-40 °C to +100 °C</td>
<td>-65 °C to 100 °C</td>
<td>-40 °C to +100 °C</td>
<td>-40 °C to +100 °C</td>
<td>-40 °C to +100 °C</td>
<td>-40 °C to +100 °C</td>
<td>-40 °C to +100 °C</td>
<td>-40 °C to +100 °C</td>
<td>-40 °C to +100 °C</td>
</tr>
<tr>
<td>Temperature coefficient of magnetic sensitivity</td>
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</tr>
<tr>
<td>-0.08%/°C (max)</td>
<td>-0.15%/°C (max)</td>
<td>-0.6%/°C (max)</td>
<td>-0.05%/°C (max)</td>
<td>-0.04%/°C (max)</td>
<td>-0.05%/°C (max)</td>
<td>-0.04%/°C (max)</td>
<td>-0.05%/°C (max)</td>
<td>-0.04%/°C (max)</td>
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<tr>
<td>Temperature coefficient of offset (Ic = nominal control current)</td>
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</tr>
<tr>
<td>±1 µV/°C (approx)</td>
<td>±3 µV/°C (approx)</td>
<td>±1.2 µV/°C (approx)</td>
<td>±6 µV/°C (approx)</td>
<td>±0.4 µV/°C (approx)</td>
<td>±0.3 µV/°C (approx)</td>
<td>±0.4 µV/°C (approx)</td>
<td>±0.3 µV/°C (approx)</td>
<td>±0.4 µV/°C (approx)</td>
</tr>
<tr>
<td>Temperature coefficient of resistance (Ic = nominal control current)</td>
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</tr>
<tr>
<td>+0.18%/°C (approx)</td>
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</tr>
<tr>
<td>Leads</td>
<td>34 AWG copper with poly-nylon insulation</td>
<td>36 AWG copper with poly-nylon insulation</td>
<td>34 AWG copper with Teflon® insulation</td>
<td>34 AWG copper with poly-nylon insulation</td>
<td>34 AWG copper with Teflon® insulation</td>
<td>34 AWG copper with poly-nylon insulation</td>
<td>34 AWG copper with poly-nylon insulation</td>
<td>34 AWG copper with poly-nylon insulation</td>
</tr>
<tr>
<td>Data</td>
<td>Single sensitivity value at Ic = 100 mA</td>
<td>Single sensitivity value at Ic = 100 mA</td>
<td>Single sensitivity value at Ic = 100 mA</td>
<td>Single sensitivity value at Ic = 100 mA</td>
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<td>Single sensitivity value at Ic = 100 mA</td>
</tr>
</tbody>
</table>

*Not compatible with Lake Shore gaussmeters*
Cryogenic Hall sensors

**Lead Colors:**
- Red: $+I_C$
- Black: $-I_C$
- Blue: $+V_H$
- Yellow: $-V_H$

### HGCA-3020
- **Description:** Cryogenic axial; phenolic package
- **Active area (approx):** 0.76 mm (0.030 in) diameter circle
- **Input resistance (approx):** 1 Ω
- **Nominal control current ($I_{CN}$):** 100 mA
- **Maximum continuous current (non-heat sinked, 25 °C):** 300 mA
- **Magnetic sensitivity ($I_C = nominal control current$):** 0.55 mV/kG to 1.05 mV/kG
- **Maximum linearity error (sensitivity vs field):** ±1.0% rdg (-30 kG to +30 kG)
- **Maximum linearity error (sensitivity vs field):** ±2.0% rdg (-150 kG to +150 kG)
- **Zero field offset voltage ($I_C = nominal control current$):** ±200 µV (max)
- **Operating temperature range:** 1.5 K to 375 K
- **Mean temperature coefficient of magnetic sensitivity:** see temperature error table below
- **Mean temperature coefficient of offset ($I_C = nominal control current$):** ±0.4 µV/K (approx)
- **Mean temperature coefficient of resistance:** +0.6%/K (max)
- **Leads:** 34 AWG copper with Teflon® insulation
- **Data:** Room temperature, 50 kG data supplied

### HGCT-3020*
- **Description:** Cryogenic transverse; ceramic package
- **Active area (approx):** 1.02 mm (0.040 in) diameter circle
- **Input resistance (approx):** 1 Ω
- **Nominal control current ($I_{CN}$):** 100 mA
- **Maximum continuous current (non-heat sinked, 25 °C):** 300 mA
- **Magnetic sensitivity ($I_C = nominal control current$):** 0.55 mV/kG to 1.05 mV/kG
- **Maximum linearity error (sensitivity vs field):** ±1.0% rdg (-30 kG to +30 kG)
- **Maximum linearity error (sensitivity vs field):** ±2.0% rdg (-150 kG to +150 kG)
- **Zero field offset voltage ($I_C = nominal control current$):** ±200 µV (max)
- **Operating temperature range:** 1.5 K to 375 K
- **Mean temperature coefficient of magnetic sensitivity:** see temperature error table below
- **Mean temperature coefficient of offset ($I_C = nominal control current$):** ±0.4 µV/K (approx)
- **Mean temperature coefficient of resistance:** +0.6%/K (max)
- **Leads:** 34 AWG copper with Teflon® insulation
- **Data:** Room temperature, 50 kG data supplied

### Temperature error table

<table>
<thead>
<tr>
<th>Temperature (K)</th>
<th>Change in magnetic sensitivity (approximate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 K</td>
<td>+0.05%</td>
</tr>
<tr>
<td>100 K</td>
<td>-0.04%</td>
</tr>
<tr>
<td>80 K</td>
<td>-0.09%</td>
</tr>
<tr>
<td>20 K</td>
<td>-0.4%</td>
</tr>
<tr>
<td>4 K</td>
<td>-0.7%</td>
</tr>
<tr>
<td>1.5 K</td>
<td>-1.05%</td>
</tr>
</tbody>
</table>

*The active area is symmetrical with the center line of the assembly and is located 0.9 mm (0.035 in) ± 0.3 mm (0.012 in) behind the front surface of the assembly.

### Ordering information

**Axial Hall sensors**

<table>
<thead>
<tr>
<th>Part number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HGA-2010</td>
<td>General purpose axial Hall sensor; plastic package</td>
</tr>
<tr>
<td>HGA-2302</td>
<td>General purpose axial Hall sensor; phenolic shoulder</td>
</tr>
<tr>
<td>HGA-2303</td>
<td>General purpose axial Hall sensor; phenolic shoulder</td>
</tr>
<tr>
<td>HGA-3010</td>
<td>Instrumentation quality axial Hall sensor; phenolic package</td>
</tr>
<tr>
<td>HGA-3030</td>
<td>Instrumentation quality axial Hall sensor; phenolic package</td>
</tr>
</tbody>
</table>

**Transverse Hall sensors**

<table>
<thead>
<tr>
<th>Part number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HGT-1010</td>
<td>General purpose transverse Hall sensor</td>
</tr>
<tr>
<td>HGT-1020</td>
<td>General purpose transverse Hall sensor</td>
</tr>
<tr>
<td>HGT-1050</td>
<td>General purpose transverse Hall sensor; flat mount</td>
</tr>
<tr>
<td>HGT-1070</td>
<td>Ferrite embedded transverse Hall sensor</td>
</tr>
<tr>
<td>HGT-2010</td>
<td>General purpose transverse Hall sensor</td>
</tr>
<tr>
<td>HGT-2101</td>
<td>Surface mount transverse Hall sensor</td>
</tr>
<tr>
<td>HGT-3010</td>
<td>Instrumentation quality transverse Hall sensor; ceramic package</td>
</tr>
<tr>
<td>HGT-3030</td>
<td>Instrumentation quality transverse Hall sensor; ceramic package</td>
</tr>
</tbody>
</table>

**Cryogenic Hall sensors**

<table>
<thead>
<tr>
<th>Part number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HGCA-3020</td>
<td>Cryogenic axial Hall sensor; phenolic package</td>
</tr>
<tr>
<td>HGCT-3020</td>
<td>Cryogenic transverse Hall sensor; ceramic package</td>
</tr>
</tbody>
</table>

**Accessories available**

| CAL-1X-DATA | 1-axis Hall sensor recalibration with certificate and data |

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