

Appendix C

Glossary of Common Terms

Active Area – The surface of a Hall-effect sensor or transducer that is sensitive to magnetic field. For many integrated Hall ICs, the active area is beneath the package surface by a short distance (~0.020" or 0.5 mm), and may only be a few thousandths of an inch square (~0.1 mm × 0.1 mm).

Air Gap – The distance from the face of a magnet to the face of a sensor housing.

Alnico – A permanent magnet material made primarily from aluminum, nickel, and cobalt. Alnico magnets have relatively low energy products, but offer high stability, especially over temperature.

Ampere – MKS unit of electrical current. Equivalent to the passage of $\approx 6 \times 10^{18}$ electrons (or other unit charge carriers) per second.

Ampere-turn – One ampere passing through one turn of wire, typically used to refer to the effective current in a winding in a magnetic circuit such as a toroid.

Ampere-turns/meter – See Amperes/meter.

Amperes/meter (A/m) – MKS unit of magnetic field intensity. If you construct a very long conductive cylinder (ideally infinitely long), and set up a circumferential current flowing around it of one ampere for every meter of cylinder length, you will develop a magnetic field intensity of one ampere/meter inside. Equivalent to about 0.0126 oersteds.

Anisotropic (Oriented) – An anisotropic magnet has a preferred axis of magnetization, and can be magnetized to a much higher degree along this axis than any other. Compare Isotropic.

Auto-Nulling – A group of techniques in which a system's configuration is briefly and periodically changed to measure and eliminate offset errors. After performing an error measurement, the system is then returned to the “operating” configuration and the measured error is subtracted from the signal of interest.

Auto-Zeroing – See Auto-nulling.

Bandwidth – The frequency range over which a device or channel can pass signals. Higher bandwidth is often associated with higher speed.

B-H curve – A curve relating the magnetic flux density (B) in a material to the applied magnetic field intensity (H). Because of magnetization effects, B-H curves often take the form of a hysteresis loop.

B_H – See Hysteresis, Magnetic.

Bipolar – Having two polarities. A signal that can attain either positive or negative values (e.g., ranging from -10 to +10 volts) is said to be bipolar. Contrast Unipolar.

Bipolar Switch – A digital-output Hall-effect sensor whose magnetic switch-points (B_{OP}, B_{RP}) are not necessarily of the same sign. A bipolar switch can therefore be either a normally ON switch, a normally OFF switch, or a latch, depending on manufacturing variations.

Bipolar Transistor – A transistor consisting of a three-layer semiconductor sandwich. Comes in either NPN or PNP versions. Terminals are emitter, base, and collector.

Capacitor – A circuit component consisting of two conductive plates separated by an insulator. Stores energy in the form of an electric field between the conductive plates. Capacitance is measured in farads.

CGS – The metric system of units based on centimeters, grams, and seconds. Gauss and oersted are CGS-derived units. Compare MKS.

Charge Carrier – Something that carries a unit electrical charge. In metals the charge carriers are negatively charged electrons. In semiconductors, positive “holes” can also be charge carriers.

Chopper-Stabilized – See Auto-nulling

Closed-Loop – A description of a system employing negative feedback. In a closed-loop system, the actual output state is monitored and compared to a desired output state. The difference is then fed back to an earlier stage of the system to correct the output towards the desired state. Compare open-loop.

CMOS – Complementary metal-oxide silicon – A technology for building logic circuits that employs both N and P-channel MOS transistors. Allows one to make ICs with lots of transistors that consume small amounts of power.

Coercive Force (H_c) – For a saturated material, the amount of magnetic field intensity (H) required to drive the residual induction (B_r) to zero.

Coercivity – A material's degree of resistance to demagnetization. See Coercive Force.

Comparator – An electronic circuit that compares two voltages, and provides either a HIGH output condition if one is greater than the other, and a LOW output condition otherwise.

Concentrator – See Flux Concentrator.

Corner Frequency – The frequency at which the response or gain of a circuit, especially a filter, drops to 0.707 of its nominal value. Also called *-3dB frequency*.

Cunife – A permanent magnet material containing copper, nickel, and iron (Cu-Ni-Fe). One of the few permanent magnet materials that is mechanically ductile.

Curie Temperature (T_c) – The temperature above which a given magnetic material loses its magnetic properties. Not to be confused with the maximum service temperature of a magnet, which is usually considerably lower.

Demagnetization – The process of removing some or all of a magnet's residual induction. Demagnetization can be caused in a number of ways. A magnet conditioner can be used to selectively and deliberately demagnetize a magnet. Heating a magnet beyond its Curie temperature will also cause demagnetization. Finally, the inclusion of an airgap in the path through which a magnet's flux must flow will also demagnetize it (self-demagnetization).

Demagnetization Curve – Quadrant II (upper left quadrant) of a material's B-H curve.

Differential – A difference between two separate measurements. See also Gradient.

Differential Geartooth Sensor – A geartooth sensor that operates based on measuring a gradient in a local magnet field caused by passing gear teeth or other similar ferrous targets.

Digital Hall-Effect Sensor – A Hall-effect sensor that incorporates threshold-sensing circuitry to provide a digital (ON/OFF) output. Common digital Hall-effect sensors include switches, latches, and bipolar switches.

Duty-Cycle – The ratio of ON time to total time. A device operating at a 10% duty cycle is ON 10% of the time, and OFF the remaining 90%. When applied to signals, duty cycle refers to the ratio of time the signal is in a HIGH state compared to total time.

Encoder – A rotation-sensing device using two sensors, providing output signals 90° out of phase. An encoder can be used to determine direction of rotation, as well as speed, and consequently can be used to monitor position.

Ferrite – A family of ceramic compounds that exhibit magnetic properties. Soft ferrites have low coercivity and are used in applications such as current-sensor toroids. Hard ferrites have higher coercivities, making them suitable for use as permanent magnets. Both soft and hard ferrites are mechanically hard and brittle.

Ferrous – Containing iron.

Filter – An electronic circuit designed to pass or attenuate signals of certain specified frequencies. A low-pass filter attenuates signals greater than a particular corner frequency, a high-pass filter attenuates signals below its corner frequency (including DC), while a band-pass filter attenuates signals that fall outside a specified range of frequencies.

Flux – See Magnetic Flux.

Flux Concentrator – A device made from a high-permeability material used to direct magnetic flux in a magnetic circuit.

Flux Density – See Magnetic Flux Density.

Flux Map – A one or two (or maybe even three!) dimensional plot representing magnetic flux density as a function of spatial position. Flux maps of magnetic systems are extremely useful in understanding how to design a compatible sensor.

Fluxmeter – A device that measures changes in magnetic flux, by integrating the voltage induced in a search coil. Useful for characterizing magnets.

Gain – The incremental ratio of an output signal to an input signal. Expressed either in units of output to input (e.g., millivolts/gauss) or as a unitless quantity if the input and output are in the same units (volts/volt). Gain can be used to describe amplifiers, transducers, and many other elements of a system.

Gauss (G) – CGS unit of magnetic flux density. The earth's magnetic field is about 0.5 gauss. 10,000 gauss is equal to one tesla.

Gaussmeter – An instrument for measuring magnetic flux density, typically using a calibrated Hall-effect transducer as the measuring device.

Geartooth Sensor – A sensor used to sense the passage of gear teeth or other similarly shaped features on a ferrous target. A geartooth sensor typically outputs a single pulse as each target feature passes by.

Gradient – A change in a variable vs. a change in position. A magnetic field that varies uniformly by 100 gauss over a distance of 1 cm has a gradient of 100 G/cm.

Head-On – A proximity-sensing mode in which a pole face of a magnet approaches the sensor in a direction normal to the sensor's face.

Helmholtz Coil – An arrangement consisting of two coils of wire of radius R spaced apart coaxially by a distance of R . Helmholtz coils produce a very uniform magnetic field in the region between the coils.

Hysteresis – For an electronic threshold detector, the difference between the input signal levels at which it turns on and at which it turns off.

Hysteresis Loop – The nonoverlapping shape of the B-H curve of a magnetic material. The width of the loop is related to the coercivity of the material, with wider loops indicating higher coercivity.

Hysteresis, Magnetic (B_H) – For a digital Hall-effect sensor, the difference in flux density between the turn-on point (B_{OP}) and the turn-off point (B_{RP}). $B_H = B_{OP} - B_{RP}$

Impedance – Electrical resistance. Impedance is also used to describe the complex “resistance” of circuits containing inductors and capacitors at non-DC frequencies.

Inductor – A circuit component consisting of one or more windings of wire, sometimes with a ferromagnetic core. Used to store energy in the form of magnetic field. Inductance is measured in henries.

Instrumentation Amplifier (IA, InAmp) – An amplifier having differential inputs and well-controlled gain. Used for precisely amplifying signals from transducers.

Intrinsic Coercive Force (H_{ci}) – A property of a material indicating its resistance to demagnetization. Intrinsic coercive force is the coercive force required to reduce residual induction (B_r) to zero after the material has been magnetized to saturation. On a B-H curve, H_{ci} is the value of H for which $B=0$ in Quadrant II.

Intrinsic Induction (B_i) – In a magnetic material, the difference between the magnetic induction and a magnetizing force, whether applied externally or developed by the material itself.

Irreversible Losses – Reductions in magnetization in a permanent magnet that can be recovered from by remagnetization. Irreversible losses are often caused by exposure to large magnetic fields, or by heating the magnet.

Isotropic (Unoriented) – An isotropic magnet has no preferred axis of magnetization, and can be magnetized to an equal degree in any direction. Compare Anisotropic.

Keeper – A piece of steel used to form a closed magnetic path around a magnet for shipping and storage. Keepers are used both because they protect a magnet from demagnetization and, in the case of very strong magnets, can make them safer to handle.

Latch – A digital Hall-effect sensor that has B_{OP} and B_{RP} switch points with opposite polarities. Requires a field of one polarity to turn ON, and a field of the opposite polarity to turn OFF.

Leakage Flux – Magnetic flux that escapes from a magnetic circuit.

Linear Hall-Effect Sensor – A Hall-effect sensor that provides an output proportional to sensed magnetic field.

Magnet Conditioner – An instrument for the controlled demagnetization of magnets.

Magnetic Field Intensity (H) – The quantity that defines the ability of an electric current or a magnet to induce a magnetic field (B). Measured in oersteds. In empty space, a magnetic field intensity of 1 oersted will induce a magnetic field (B) of 1 gauss. Also known as Magnetizing Force.

Magnetic Field Strength (H) – See Magnetic Field Intensity

Magnetic Flux (Φ) – The integral of flux density over area. CGS unit is maxwell, MKS unit is weber. For a uniform normal field over a uniform surface, can be approximated as area times flux density.

Magnetic Flux Density (B) – This is what is commonly called a “magnetic field,” and is what you measure when you use a gaussmeter. Analogous to current in an electrical circuit. CGS unit is gauss, MKS unit is tesla.

Magnetic Induction (B) – See Magnetic Flux Density.

Magnetizer – An instrument that can produce intense magnetic fields, used to permanently magnetize or “charge” magnets from their initial unmagnetized state.

Magnetizing Force – See Magnetic Field Intensity.

Maximum Energy Product (BH_{max}) – The point on a material’s demagnetization curve where the product of B and H assumes a maximum value. BH_{max} is useful as a measure of how much mechanical potential energy can be “stored” per unit volume of magnet for a given magnet material.

Maximum Service Temperature – The maximum temperature at which a magnet can be exposed without experiencing long-term degradation or structural changes. This temperature is normally lower than, and should not be confused with, the Curie temperature (T_c) for a magnetic material.

Maxwell – CGS unit of magnetic flux. One maxwell is equivalent to a uniform field of 1 gauss normal to an area of 1 cm².

MKS – The metric system of units based on meters, kilograms, and seconds. Amperes/meter and tesla are MKS-derived units. Compare CGS.

MOS Transistor – Metal-oxide-semiconductor transistor. A type of transistor commonly used to make digital logic.

Mu-Metal – A high-permeability magnetic alloy consisting primarily of nickel and iron.

Multipole – Having more than one pole. Since all magnets must have at least two poles, when this term is applied to magnets it usually refers to those having more than two poles.

Neodymium-Iron-Boron (NdFeB) – A family of rare-earth compounds used to make very powerful magnets.

Noise – Any signal you aren't interested in. Noise can come from sources internal to a system or from outside sources (interference).

Oersted (Oe) – A CGS unit of magnetic field intensity. One oersted is equivalent to approximately 79.58 ampere/meters.

Offset Error – A type of measurement error in the form of an error signal added or subtracted from the true signal.

Ohm's Law – Voltage V equals resistance R times the current I flowing through it, or $V = IR$. Terms can be rearranged in various ways, solving for current ($I = V/R$) or resistance ($R = V/I$).

Operational Amplifier – An amplifier with very high gain, intended for use in circuits using feedback.

Open-Loop – A description of a system in which the actual condition or state of the output is not monitored and used to adjust or compensate the input to achieve a desired output value. Contrast Closed-Loop.

Operate Point, Magnetic (B_{OP}) – The value of magnetic flux density required to make a digital Hall-effect sensor turn ON.

Operating Point – For a magnetic circuit, the point along the B-H curve that describes the state of the magnetic materials in terms of B and H.

Oriented – See Anisotropic.

Permalloy – A high-permeability ($\mu_r > 10,000$) magnetic alloy made from nickel and iron.

Permeability (μ_r) – Also called *relative* permeability. Permeability expresses the relationship between magnetic flux density (B) and magnetic field intensity (H) in a material. For an "ideal" soft magnetic material, $B = \mu_r H$. Not to be confused with the permeability constant (μ_0), which is a fundamental physical constant.

Power-On Recognition – The ability of a geartooth sensor to detect if a target is present or absent immediately upon being powered-up.

Proximity Sensor – A device that reports the presence or absence of a nearby target.

Quadrature – The condition where two signals are 90° out of phase. Quadrature signals from a pair of sensors are useful for determining rotational direction.

Quiescent Output Voltage (Q_{vo}) – The voltage output by a linear magnetic sensor when no magnetic field is sensed.

Rare-Earth Magnet – A magnet made with a material incorporating a rare-earth element such as neodymium or samarium. “Rare-earth” is a bit of a misnomer, as many rare-earth elements are not all that rare, just difficult to refine into pure form.

Reference Magnet – A magnet that has been calibrated or adjusted so that it produces a known field. Reference magnets are often used as transfer standards for calibration purposes.

Release Point, Magnetic (B_{RP}) – The value of magnetic flux density at which a digital Hall-effect sensor turns OFF.

Remanent Induction (B_d) – The induction (B) that remains in a magnetic material after it has been saturated, and the saturating field removed.

Resistor – A circuit component consisting of two electrodes separated by a poorly conducting material. Resistors are used to limit the amount of current that can flow for a given applied voltage. Resistance is measured in ohms.

Ring Magnet – Magnet formed in the shape of a ring. Often magnetized so that it has a large number of alternating poles along its circumference.

Samarium-Cobalt – A rare-earth compound used to make very strong magnets.

Saturation – For an electronic circuit, saturation is the point at which increasing the input signal does not cause a corresponding increase in output signal. For a magnetic material, saturation is the region on the B-H curve when most of the magnetic domains are aligned, and further increases in magnetic field intensity (H) do not provide corresponding increases in magnetic flux density (B).

Search Coil – A coil of wire used as a transducer element in a fluxmeter. Changes in flux passing through the search coil are transformed into an output voltage.

Self-Demagnetization – The effect that occurs in a permanent magnet when the flux-path is interrupted. Self-demagnetization reduces the flux density in the magnetic circuit.

Semiconductor – A material like silicon or gallium-arsenide that conducts electricity, but not as well as a metal does. Semiconductors are used to make transistors, integrated circuits, and Hall-effect transducers.

Sensitivity – The degree of response of an output parameter to an input parameter. Used to characterize linear Hall sensors (e.g., sensitivity of 2.4 mV/G). See also Gain.

Sensor – A device that measures the state of some environmental parameter. In this book, the term sensor is used to refer to the combination of a transducer with support electronics, as opposed to a simple transducer.

SI – The International System of units. Fundamental units are: meter, kilogram, second, ampere, Kelvin degree (thermodynamic temperature), and candela (luminous intensity).

Slide-By – A proximity-sensing mode in which a pole face of a magnet passes the sensor in a direction parallel to the sensor's face. Compare Head-on.

SOIC – Small Outline IC. A family of surface-mounted IC packages that are very small.

Speed Sensor – A sensor that detects target speed. In the context of Hall-effect sensors, this usually refers to a geartooth sensor or ring-magnet sensor that provides an output pulse for each target feature passing by. Also implies that the edges of the output pulse may or may not accurately track the physical edge of the target; i.e., a particular speed sensor may not be useful as a timing sensor.

Surface-Mount Device (SMD) – An electronic component designed to be soldered to the surface of a printed-circuit board, without requiring holes for leads.

Switch – A digital-output Hall-effect sensor that is normally OFF in the absence of a magnetic field, and only turns on when a minimum flux density is exceeded.

Tempco – See Temperature Coefficient.

Temperature Coefficient – The fraction or percentage by which a property or quantity varies per unit change in temperature. Often expressed in %/° or in ppm/° (parts-per-million/°).

Tesla – An MKS unit of magnetic flux density: 1 tesla = 10,000 gauss.

Thermal Demagnetization – Demagnetization resulting from excessive heating.

Toroid – A donut-shaped flux concentrator often used to make current sensors.

Total Effective Air Gap (TEAG) – The spacing measured from the surface of a magnet to the actual Hall-effect transducer inside any packaging.

Transducer – A device that converts one physical effect into another physical effect. A Hall-effect transducer converts a magnetic field input into a proportional voltage output. A motor is a transducer that converts electricity to mechanical rotation.

TTL – Transistor-Transistor Logic. A popular family of integrated logic circuits, now largely obsolete and superceded by CMOS logic.

Two-Wire Interface – An electrical interface that uses only two wires. Often this means that data is communicated through changes in current, as opposed to changes in voltage.

Unipolar – Having one polarity. A signal that ranges between 0 to +5V is a unipolar signal. Contrast Bipolar.

Unipolar Switch – A switched-output Hall-effect sensor in which both B_{OP} and B_{RP} are of the same polarity. A unipolar switch is ON in the presence of a magnet, and OFF in its absence. Most commercial Hall-effect sensors turn ON when a south pole of a magnet is brought up to their front surface.

Unoriented – See Isotropic.

Vane – A steel flag-shaped target used to interrupt magnetic field between a magnet and a sensor.

Zero-Flux Output Voltage – The voltage output by a linear sensor when no magnetic field is sensed. Also called Quiescent Output Voltage (Q_{vo}).