Glossary of Common Magnetic Terms

Air Core

A term used when no ferromagnetic core is used to obtain the required magnetic characteristics of a given coil.

(see Core)

Ampere – Turns

The number of turns multiplied by the instantaneous value in amperes of current flowing in a winding coil. (See magnetizing force and magnetomotive force (mmf))

Bifilar winding

Two strands of wire wound on a core or bobbin to produce two equal and parallel windings.

Bobbin

A winding form usually consisting of a winding surface and end flanges for winding support. Multiple flanges may be used to segregate windings for isolation and dielectric purposes.

Burden Resistor

A load resistor or shunt (R) used to change the output of a current transformer with a turns ratio of 1:N and a primary current (I) into a measurable voltage (E). $E = (I \times R)/N$

Circular mils (CM)

Cross-sectional area of round wire. 1 circular mil is equal to a wire with a diameter of 1 mil or 0.001 inch.

Choke

An inductor used to pass steady current and block or reduce AC signals.

Clearance Distance

The shortest distance between two conductive parts or from one conductive part to ground measured through the air.

Coil

Turns of a single conductor for the purpose of concentrating the magnetic field

Concentric Winding

Winding two or more coils one on top of the other separated by insulating materials

Core

The ferromagnetic material placed in the magnetic path to increase the magnetic field intensity and concentrate the flux

Area (or Effective core area)

Cross-sectional area of a core through which all of the induced magnetic flux will pass, i.e. the center leg of an "E" core, ½ of the flux will pass through each side leg, but all of the flux must pass through the center leg.

Core air Gap

The gap in a core can be used to control the inductance of a coil on that core. It also "tilts" the Hysteresis loop making it possible to drive the core to a higher level.

Core Materials

Laminations - thin sheets of silicone steel alloys annealed and stamped

Ferrite – ceramic materials whose electrical, magnetic and mechanical properties are known and controllable

Powdered Iron – iron powder alloys with a distributed air gap throughout the core

(There are many variations of materials for each general category listed above.)

Corona

Effect of ionization of air around a point at a high voltage potential

Creepage distance

The shortest distance between two conductive parts or from one conductive part to ground measured along the surface of the insulating material

Curie temperature

The temperature at which the atoms in a material can no longer form domains. This changes its ferromagnetic properties and causes it to become paramagnetic

Current density

The amount of current in amperes passing through a cross-section area of a conductor generally expressed in circular mills per amp. (cm/A)

Dielectric

Insulating material which cannot conduct current but can store a charge.

Dielectric Constant

An indicator of an insulator to concentrate electric flux. Its numeric value is specified as the ratio of flux in the insulator compared with the flux in air or vacuum.

Dielectric Strength

> The ability of a dielectric to withstand a potential difference without arcing across the insulator. Note that the dielectric strength of a material does not add linearly as you increase the number of layers. For example, 1 layer of 3M #56 tape has a dielectric breakdown of 5,000 volts, two layers is 7,071 volts, three layers is 8,660 volts, etc. See the manufactures data for more details.

Dielectric withstand voltage (High-pot)

The application of a voltage higher than the rated voltage for a specific time between mutually insulated portions of a component part or between insulated portions and ground.

Disaccommodation

A phenomenon in ferrite cores that causes a reduction of permeability with time after a core is demagnetized.

Duty cycle

The ratio of an electronic component on time (t_{on}) to the total time of one complete cycle (T). Duty cycle = t_{on}/T

Eddy Current

Circulating current induced in the core of a transformer or inductor by the alternating current passing through the coil

Electromagnet

A magnet whose magnetic field is generated by a current in a coil

Encapsulating

Completely enclosing a component in a dielectric compound such as silicone or epoxy resin.

Equivalent circuit

The simplest form of a circuit that retains all of the electrical characteristics of the original (and more complex) circuit.

Exciting Current

The current required in the primary coil to overcome the magnetization, hysteresis and eddy current losses in the core.

Faraday Shield

A conductive material placed around the outside of a device used to control stray electronic fields.

Ferromagnetic material

Material which become strongly magnetized in the same direction as the magnetizing field induced in them with a high permeability of 50 or more.

Field Intensity (H)

The ratio of the ampere-turns and the length of the magnetic path.

H = NI (ampere-turns)/ l meters

Flux Density (B)

The number of magnetic field lines per unit area of a section perpendicular to the direction of flux.

Gauss (10^-4 Tesla)

In the CGS system, this is one line of magnetic flux per square centimeter, or $1Mx/cm^2$

Hall Effect

The production of a voltage difference (the Hall voltage) across an electrical conductor, transverse to an electrical current in the conductor and a magnetic field perpendicular to the current. Edwin Hall discovered this effect in 1879.

Hall Effect Sensor

> A transducer that varies its output voltage in response to changes in a magnetic field. Hall sensors are used for proximity switching, positioning, speed detection, and current sensing applications. They are able to sense both AC magnetic fields as well as DC fields.

Hysteresis

Means “lagging behind”; Magnetic flux in an iron core lags the increase or decrease in magnetizing force.

Hysteresis Loop

Defines the flux density of the material, coercive force, the amount of drive level required to saturate the core and the permeability of the material.

Impregnating (with Varnish)

When an assembly is impregnated, it is soaked or placed under a vacuum in a varnishing material for environmental protection, isolation improvements and/or noise reduction.

Inductance (L)

The ability to produce induced voltage when cut by magnetic flux. Or, the ratio of the electromotive force (in volts) induced across a coil to the change of current (in amperes/sec.) producing it.

Inductance Index (A_L)

Inductance index is given in millihenrys (mH) per 1000 turns for a given core geometry, material and air gap length. Inductance $L = N^2 (A_L/10^6)$ mH

Inductor

A single coil device with the ability to resist changes in current.

Intra-winding Capacitance

The capacitance that develops from turn to turn within the same winding of a coil.

Inter-winding Capacitance

The capacitance that develops between the primary winding and the secondary winding of a transformer.

Leakage Current

The amount of current that flows between mutually insulated portions of a component part or between insulated portions and ground when a specified voltage potential is applied.

Leakage Inductance

The property of a transformer that causes a winding to appear to have some inductance in series with the mutually-coupled transformer windings. This is due to imperfect coupling of the windings and creation of leakage flux which does not link with all of the turns of the winding.

Lenz' Law

The direction of an induced current must be such that its own magnetic field will oppose the action that produced the induced current.

Litz wire

The term is derived from the German word **litzendraht** meaning woven wire. Generally defined, it is a conductor made of individual film insulated wires bunched or braided together in a uniform pattern of twists and length of lay. The multi-strand configuration minimizes the power losses due to the "skin effect."

Load

Anything that draws current from a voltage source. For a transformer, this is anything connected across the secondary winding that draws current.

Loaded Voltage

The output voltage of each secondary winding of a transformer with the primary at full rated input power and all secondary windings loaded to the rated output current.

Losses

Wasted or lost power that produces heat in the core and coils of a transformer or inductor caused by hysteresis losses and eddy currents in the core as well as voltage drops across the windings due to winding resistance.

Magnetic path

The path that the magnetic flux follows. Usually controlled by a ferromagnetic material in the form of a core.

Magnetizing force

The number of turns multiplied by the instantaneous value in amperes of current flowing in a winding coil. (See Ampere-turns and magnetomotive force (mmf))

Magnetomotive Force

The number of turns multiplied by the instantaneous value in amperes of current flowing in a winding coil. (See ampere-turns and magnetizing force)

Magnetostriction

When magnetic materials are magnetized a small change in the dimensions occur. The relative change is in the order of several parts per million. This is used in ultrasonic equipment, but is not a desirable result in most applications and can result in an audible hum.

Maxwell (Mx)

One Maxwell is equal to one line of magnetic flux.

Mummy wrap

When insulating material such as tape is wrapped completely around the winding so there are no exposed conductors

Mutual Inductance (L_M)

When an induced current in one coil produces voltage in another coil through the linked magnetic fields, they have mutual inductance. Two coils have a mutual inductance of 1 henry when a current change of one ampere per second in one coil induces one volt in the other coil.

Open Circuit Voltage

The voltage potential across the secondary of a transformer with no loads on the secondary and the primary at full input voltage.

Paramagnetic

> Material which becomes weakly magnetized in the same direction as the magnetizing field induced in them with a permeability slightly above 1.

Permeability

The ability of a material to concentrate magnetic flux.

$U = B/H$

Phase of a Winding

The winding phase is a comparison to a specific end point (start or finish) of a primary winding to a specific end point of any other winding of a transformer. It is important to note that the phase point of a winding IS NOT necessarily the start of the winding, and may not be the same end point on each winding. Some core and/or winding configuration cause a reversal of the phase of a given winding.

Phase Shift

The difference in degrees from the point in time that the source voltage or current wave form crosses zero and the point in time that the output voltage or current wave form crosses zero. If this difference nears 180 degrees, the windings are considered out of phase.

Potting

Refers to the process of encapsulating a component in silicone or epoxy resin

Regulation

Refers to the difference between the open circuit voltage output to the loaded voltage output of a transformer. Regulation = (V open – V loaded)/V open

Remanence flux

The remaining magnetic flux or induction in a magnetic circuit when the magnetizing force is reduced to zero.

Relative Permeability

Numeric values of permeability for materials compared with air or a vacuum

Saturation Flux Density

The maximum intrinsic induction possible in a given core material

Shield

A foil conductor usually copper placed between, but isolated from, the primary(s) and secondary(s) of a transformer. With a connection to ground, the purpose is to divert any potential arcing between the two.

Shroud

A cover that fits around a winding into groves of the bobbin flange and isolates the winding from surrounding materials.

Skin Effect

A concentration of current near the surface of a conductor at high frequencies. The depth of the skin effect is expressed by:

Depth (cm) = $(6.61/f^{1/2})K$, K is a constant, for copper K = 1

Staking Factor

Represents inefficiencies in the magnetic path due to air gaps in the mating points of the core stack.

Systems of Units

The CGS system is an abbreviation of its basic units of centimeters, grams and seconds. The MKS system is an abbreviation of meters, kilograms and seconds. The SI system is based on and very similar to the MKS system.

Tesla (10^4 Gauss)

In the SI, this is one weber of magnetic flux per square meter, or 1 Wb/m^2

Thermal Runaway

When current passes through a resistive component it heats the component causing the resistance to increase. If the resistance increases, so does the heat. If the component cannot dissipate the heat fast enough this cycle continues until the circuit opens.

Thermal fuse

A fuse placed in series with the protected circuit that opens if a set temperature is reached. It may be a one-time fuse or resettable.

Transformer

Usually consists of two or more windings in the same magnetic field. Induced voltage is produced when the current changes in any one winding. The voltage produced can be increased or decreased depending on the turns ration between the two windings.

Transformer Types:

Audio: Wide frequency range transformer usually operating from 20 to 20,000 Hertz.

Auto: A one winding transformer that uses taps in place of individual windings to step the voltage up or down.

Current: A transformer designed to measure the current through a primary conductor.

Ferroresonant: A constant output transformer using a large capacitor and a segregated core to control saturation levels and the peak output.

Flyback: A gapped core transformer that stores energy from the primary and releases in through the secondary in a discontinuous mode.

Isolation: A transformer placed at a point in a circuit for the express purpose of isolating the circuit on secondary side form the primary side, coupling them with the magnetic field only.

Planar: Consisting of winding(s) as traces on a printed circuit board and a low profile core assembled around the PCB.

Power: A transformer designed for the purpose of transforming the input power (voltage and current) and delivering a specific rated output power to a load or loads on the secondary side.

Output power = Input power + Losses

Potential: A transformer that provides a very specific output voltage with little or no output current, at a rated input voltage for the purpose of monitoring the input voltage.

Pulse: Usually a unipolar transformer that operates on a volt-second basis rather then a given frequency.

Switching: A high frequency transformer used in switching power supplies that switch the polarity of a DC input signal instead of using an AC sinusoidal signal.

Turns

A conductor passing one time through a core is considered 1 turn. Depending on the core geometry, the conductor may pass through the centre of the core, or must pass through both sides to be considered a complete turn.

VA

The power rating of a transformer is given in VA as opposed to watts because the inductive effects cause the voltage and current to be out of phase with each other and therefore may not be occurring in the transformer at the same time.

Weber

One weber is equal to 1×10^8 lines of magnetic flux.

Windings

One or more turns of a coil passing through a magnetic field

“**Rules of Thumb” used in designing a transformer or inductor:**

1. Generally use a fully shrouded bobbin if possible for regulatory agency approvals such as UL and VDE.

2. A thermal fuse on the primary also aids in regulatory agency approvals.

3. Vacuum impregnating ferrite core should be avoided. The varnish can migrate into the core material and change the core characteristics.

4. Surface bonding ferrites can cause manufacturability issues. A bond on the outer surface or a clamp is a much better solution.

5. Use the design, fixture and/or tooling so that the finished product can only be built 1 way. Don’t leave anything up to the manufacturer.