# Ferrite Toroid

## Surface Irregularities

A.) **Chips**:

1. Chip ≤ 25% of Build. with max. dimension ≤ 2.5 mm.
2. Chips must be smooth.
3. Max. # chips per surface ≤ 3. Max. # chips per core ≤ 6.
4. Pullout ≤ 25% of affected surface.

B.) **Cracks**:

1. Radial cracks not permitted.
2. Concentric/Laminated cracks ≤ 25% of circumference.
3. Crazing ≤ 25% of affected surface.

C.) **General**:

1. Edges must be smooth.
2. Any coating must be smooth and free of cracks or chips to the core.
3. All inspections done without magnification.

# SOME INDUCTOR APPLICATION DESCRIPTIONS FOR INCLUSION IN IEEE INDUCTOR STANDARD/RECOMMENDED PRACTICE

Note: There is a definition in the IEEE dictionary for the term magnetic amplifier.
**magnetic amplifier** A device using one or more saturable reactors, either alone or in combination with other circuit elements, to secure power gain. Frequency conversion may or may not be included.
**saturable reactor**
**2 (A) (power and distribution transformer)** A magnetic core reactor whose reactance is controlled by changing the saturation of the core through variation of a super-imposed unidirectional flux. **(B) (power and distribution transformers)** A magnetic core reactor operating in the region of saturation without independent control means. *Note:* Thus a reactor whose impedance varies cyclically with alternating current (or voltage).

## Power Factor Correction (PFC) Inductor

These inductors are intended for use in input filters for switchmode power supplies. The filter is generally designed to operate in the continuous boost mode.

Factors to consider during the design of PFC inductors include but are not limited to the following:

- Power loss density of the magnetic material
- Saturation flux density of the magnetic material.
- Conductor power loss.

## DC-DC Filter Inductor

These inductors are intended for use in output filters for switchmode power supplies. They provide differential mode filtering. The filter is generally designed to operate in the continuous buck mode.

Factors to consider during the design of output filter inductors include but are not limited to the following:

- Conductor Loss. The overall loss and resultant temperature rise of this type of component is typically dominated by conductor loss. The conductor loss is composed of a dc and an ac component. If the number of turns is minimized, the dc component dominates. If there are a significant number of layers of conductors, the ac component can be significant.
- Core Loss. Since the value of inductance for a dc-dc filter application is chosen so that the ac ripple current will be some fractional percentage of the maximum dc current rating, the ac flux density in the magnetic core is typically a small value. If the ac flux density in the core is low and the frequency is low, core loss is in general of no consequence. However, in some instances for which cost is paramount, a high loss material may be used and core loss can be a significant value.
- Saturation flux density of the magnetic material. The usefulness of this type of inductor is determined by its ability to maintain a minimum amount of inductance with dc bias. Typically graphs of inductance as a function of dc current at a specified temperature are used as used to characterize these

**SOME INDUCTOR APPLICATION DESCRIPTIONS FOR INCLUSION IN IEEE INDUCTOR STANDARD/RECOMMENDED PRACTICE**

## Mag-Amp

A mag-amp regulates the output of a switchmode power supply against line against line and load changes by performing as a high gain, fast on/off switch. It controls an output by modifying the width of the voltage pulse that appears between the appropriate secondary of the power transformer and the output filter. It accomplishes this by delaying the leading edge of the pulse, in the same manner as a series switch that would be open during the first portion of the pulse, and then closed for the duration of the pulse. The switching function is performed by a saturable reactor – an inductor wound on a magnetic core with a very square B-H loop. During the leading edge, the magnetic core is operated in the linear region of its B-H loop. In the linear region, the mag-amp inductor has a high impedance relative to the output filter and thus absorbs the majority of the voltage provided by the transformer's secondary winding to the series combination of the mag-amp inductor and the output filter. Current flow to the output filter is limited by the impedance of the mag-amp inductor. In the saturation region, the mag-amp inductor has a low impedance relative to the output filter and thus the majority of the voltage pulse is absorbed by the output filter. Current flow is controlled by the impedance of the output filter.

Factors that influence the design of mag-amp inductors include but are not limited to the following:

- Squareness ratio of the magnetic material's B-H loop. Typically mag-amp inductors are biased such that the transition time from the high impedance linear state to the low impedance saturated state is a non-trivial portion of the required blocking time.
- Saturation flux density of the magnetic material. The larger the saturation flux density value, the fewer turns that are required to absorb the necessary amount of volt seconds of the leading edge of the voltage pulse provided by the secondary of the transformer.
- Temperature sensitivity of the magnetic material squareness ratio, saturation flux density value and power loss density. Since output regulation is determined by the inductor ability to simulate a high gain, fast on/off switch, it is critical that the non ideal switch properties of the inductor remain within reasonable bounds over the entire operating temperature range.
- Power loss density of the magnetic material. The flux density in the magnetic core is generally required to change a large amount at a very high rate. This type of excitation (i.e large $d\phi/dt$) is consistent with high power loss density in most magnetic materials. The resultant core loss can cause the magnetic material to operate at temperatures high enough to change the magnetic material's critical characteristics, thermally age the material or degrade the conductor insulation.

types of inductors. The operating flux density in the magnetic core can be related to the peak current by the following equation:

**EMI/RFI Inductor (Combination Line Filter Inductors)**

These inductors are intended for use in input filters for switchmode power supplies. They combine common mode and differential mode filtering into a single component.

Factors to consider during the design of EMI/RFI inductors include but are not limited to the following:

- Frequency sensitivity of the inductance permeability of the magnetic material. Generally high inductance permeability materials are used to obtain high inductance with the fewest amount of turns. High inductance is generally associated with high common mode impedance. However, quite often materials with inductance permeabilities greater 10000, only exhibit these values below signal frequencies of 10 kHz. If the effective inductance permeability of the material decrease with increasing frequency, the inductance value of the inductor may not increase linearly with increasing frequency. This phenomena may severly limit the inductor's ability to attenuate common mode signals at the fundamental switching frequency or at its harmonics.
- Self-resonant frequency of the inductor due to the parallel combination of winding inductance and capacitance. The common mode impedance increases linearly with increasing frequency as long as the characteristic impedance is inductive. Once the characteristic impedance of the component becomes capacitive, the common mode impedance decreases linearly with increasing frequency. With a capacitive characteristic, the magnitude of the impedance may not be great enough to attenuate common mode signals.
- Leakage inductance between the windings. Ideally all the flux established by current flow in one of the windings is cancelled by current flow in the other winding since the same current flows in both windings but with different polarity. However since there is a measurable leakage inductance between the windings, all the flux created by one winding cannot be cancelled by the other winding, thus creating a net flux in the core. This flux is usually static in nature since the signal frequency of the current is usually dc or line (50/60 Hz). The resultant flux density in the core is governed by the equation:
- Temperature sensitivity of the magnetic material critical characteristics such as inductance permeability and saturation flux density. Generally it is sufficient to design so that acceptable performance is obtained at the minimum values of these parameters within the operating temperature range.

## SOME INDUCTOR APPLICATION DESCRIPTIONS FOR INCLUSION IN IEEE INDUCTOR STANDARD/RECOMMENDED PRACTICE

It is imperative to verify that minimum performance is acceptable as well as typical performance.

- Conductor power loss. Typically these inductors have no core loss since the resultant flux density in the core is static (dc) as opposed to dynamic (ac). Quite often the magnetic materials that are used, have saturation flux density values that are sensitive to temperature. The conductor loss which is predominately $I^2R$ where the I is either a dc current or a line frequency (50/60 Hz) current

### References

1. J.E. Elias, "Amorphous Magnetic Materials – Part II: High Frequency Mag-Amp Output Regulator," Power conversion Intelligent Motion, September 1993