Electronic Inductor Standard

1. Scope

This recommended practice pertains to applications, definitions, testing information and performance characteristics such as loss evaluation, inductance characteristics and operation limitations regarding inductors.

The information provided in this document is to be utilized as a guide and is based upon commonly used industry practices.

2. References-TBD

3. Definitions

For the purpose of this standard, the following terms and definitions apply. IEEE Std 100-1996-????, The IEEE Standard Dictionary of Electronics and Electrical Terms , should be referenced for terms not defined in this clause.

3.1. inductor: (general) A device consisting of one or more associated windings, with or without a magnetic core, for introducing inductance into an electric circuit.

3.2. reactor: (general) An electromagnetic device, the primary purpose of which is to introduce inductive reactance into a circuit. This device is more recently referred to as an inductor.

3.3. choke: (coil) An inductor used in a special application to impede the current in a circuit over a specified frequency range while allowing relatively free passage of the current at lower frequencies.

3.4. filter inductor: An inductor used as an element of an electric wave filter.

3.5. DC inductor: An inductor designed to carry a predominately DC component of current.

3.5.1. DC output filter inductor: A differential mode inductor used in the output LC filter of a DC power supply that maintains a specified value of minimum inductance value for the required DC current.

3.5.2. non-linear inductor: (swinging choke) A differential mode inductor which must have specified inductance values at specified values of DC current. The different values of inductance are associated with saturation of some or all portions of the magnetic core.

3.6. line inductor: (line reactor) An inductor used for current limiting and notch filtering applications carrying only AC current.

3.7. common mode inductor: An AC filter inductor with two or more windings phased to reduce the net flux in it's magnetic core.

3.8. load coil: An electric conductor that, when energized with alternating current, is adapted to deliver energy by induction to a charge to be heated. (Used in induction heating.)

3.9. loading coil: An inductor inserted in a circuit to increase it's inductance for the purpose of improving it's transmission characteristics in a given frequency band.

3.10. Saturation: A condition in which any further increase of input no longer results in appreciable change in output.

3.10.1. material: The region of the B-H loop for which the flux density does not increase with increasing mmf.

3.10.2. magnetic component: The point at which the magnetization inductance decreases sharply with increasing current or volt-seconds.

3.11. mag amp: An inductor used to regulate the output voltage of a DC power supply through it's saturation characteristics.

3.12. magnetic amplifier: A device using one or more saturable reactors, either alone or in combinations with other circuit elements to secure power gain. This may include frequency conversion. (This term is commonly used to describe a saturable reactor for voltage regulation.)

3.13. power factor correction inductor: An inductor used to correct a circuit with a leading power factor.

3.14. emi/rfi inductor: An inductor used to suppress unwanted electromagnetic emissions created by transients in electronic devices.

3.15. commutating inductor: (commutating reactor) An inductor having one or more windings that modifies or couples the transient current produced by the commutating voltage between rectifier elements.

3.16. trap inductor: An inductor used in conjunction with a capacitor to form a filter to capture a specific harmonic component of current.

3.17. A_L inductance factor: Under stated conditions the inductance of a coil-core combination adjusted to a single turn. The stated conditions must include specified coil shape, coil dimensions, position of the coil on the core, temperature, frequency and flux density.

$$A_L = \frac{L}{N^2}$$

L = Inductance of the coil on the core (H)
N = Number of turns of the coil

4. Inductor Applications

4.1. Coupled Inductor

These inductors are intended for use in LC filters for switchmode power supplies. They provide differential mode filtering. The filter is generally designed to operate in the continuous buck mode. These inductors are multiple winding versions of DC-DC inductors. In addition to the filter performance, these inductors are used to enhance cross regulation between the multiple outputs of a power supply.

4.1.1. Design considerations

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

4.1.1.1. 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. Typically the DC loss dominates however the AC loss can become significant if the number of layers becomes large, the conductor thickness is much greater than the skin depth and/or the AC component of current is significant relative to the DC component.

4.1.1.2. Core loss

By design each winding will have the same flux density swing. The ac flux densities of each winding are not added to obtain a resultant flux density. Calculation of the ac flux density in any one of the windings is the value used in determination of core loss. If the AC component of flux density is significant for the core material than the thermal characteristics of core loss may need to be considered in temperature rise calculations.

4.1.1.3. 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 in each winding with dc bias. Typically graphs of inductance as a function of dc current at a specified temperature are used as used to characterize these types of inductors. The operating flux density in the magnetic core is related to dc current in each of the windings and the common flux swing shared by all of the windings.

$$B_{PK} = \frac{L_{Sn} ?I_{DC\_Sn} ?100}{N_{Sn} ?A_{MIN}} + \frac{0.5 ?L_{REF} ?\Delta I ?100}{N_{REF} ?A_{MIN}}$$

L_{Sn}: Inductance of winding Sn (μH)
L_{REF}: Inductance of reference winding (μH)
I_{DC_Sn}: DC component of current in winding Sn(A_{DC})
ΔI: Current swing in reference winding (A_{P-P})
N_{Sn}: Turns of winding Sn
N_{REF}: Turns of reference winding
A_{MIN}: Minimum cross-sectional area of core (cm^2)
B_{PK}: Peak flux density in core (Gauss)

1.1.1.4. Inductance value

The value of inductance is typically chosen such that the AC component of current is small compared to the DC component of current.

1.1.1.5. Turns ratio

The turns ratio between the windings of the couples inductor must be matched to the turns ratio of the transformer with which it is used.

1.1.1.6. Typical circuit application

A typical circuit application of this inductor is shown below in figure ? Coupled Inductor.

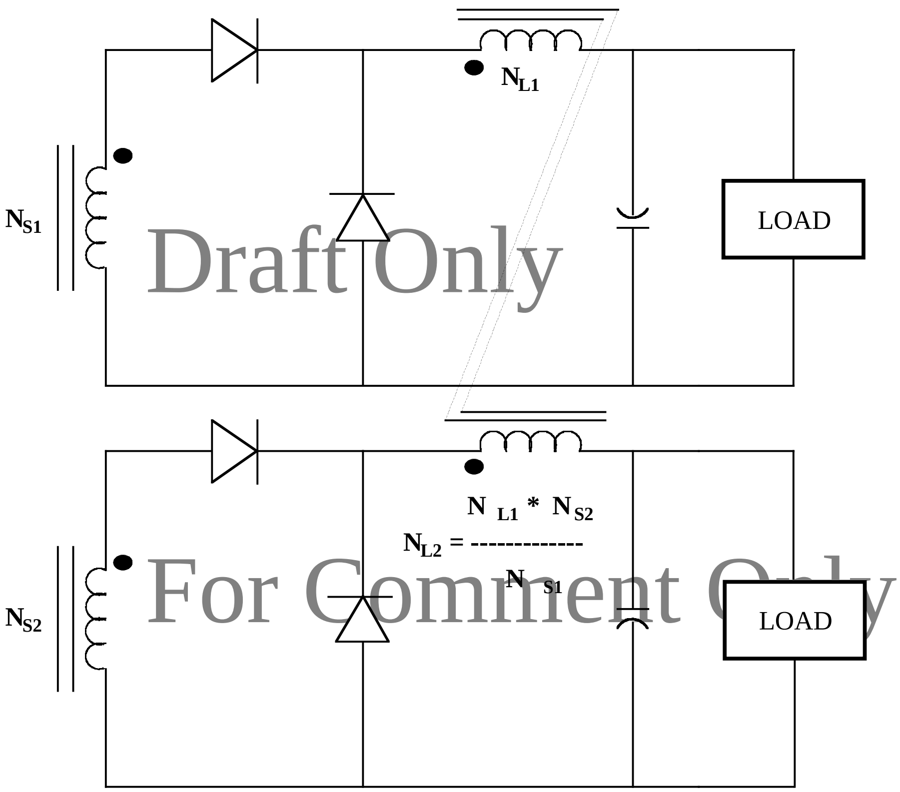


Figure ?: Coupled Inductor

1.2. Mag-Amp

A mag-amp regulates the output of a switchmode power supply 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, in this case, an inductor wound on a magnetic core, typically 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 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. The impedance of the mag-amp inductor limits current flow to the output

filter. In the saturation region, the mag-amp inductor has low impedance relative to the output filter and thus the output filter absorbs the majority of the voltage pulse.
The mag-amp inductor must be reset during each switching cycle. This is typically performed by applying the output voltage to the mag-amp during that portion of the switching cycle that the output inductor supplies current to the load.

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).

1.2.1. Design considerations

Factors to consider during the design of Mag-Amps include but are not limited to the following:

1.2.1.1. Squareness ratio

For mag-amp applications, it may be necessary to define the frequency and maximum excitation force conditions for the measurements of B_R and B_{SAT}. Add equation from IEC390

1.2.1.2. Effects of squareness ratio in the mag-amp performance

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 trivial portion of the required blocking time. A lower squareness ratio attains a lower core loss but may increase the overall circuit losses. Higher losses are attributed to transition currents flowing through switching elements.

1.2.1.3. Saturation flux density of the magnetic material

The larger the saturation flux density value, fewer turns 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. Add formula and revise text to explain formula

1.2.1.4. Temperature sensitivity

Temperature sensitivity of the magnetic material squareness ratio, saturation flux density value and power loss density. Since output regulation is determined by the inductor's 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. This is determined by the selection of the magnetic core material.

1.2.1.5. Power loss density of the magnetic material

The flux density in the magnetic core is generally required to change by a large amount at a very fast rate. This type of excitation (i.e large dB/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 and/or degrade insulation.

1.2.1.6. Typical circuit application

A typical circuit application of this inductor is shown below in figure ? Mag-Amp

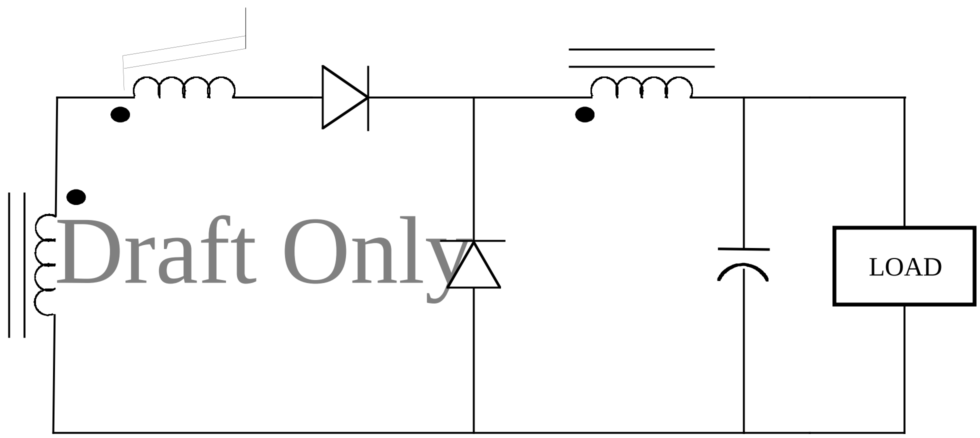


Figure Mag-Amp-add primary winding, expand on circuit to account for reset

Figure ?: Mag-Amp

1.3. EMI/RFI Inductor (Combination Line Filter Inductors)

These inductors are typically composed of two **or more** windings on a single magnetic core. They combine common mode and differential mode filtering into a single component.

There are applications that only require a single winding. For these applications the design considerations are the same except for 4.3.1.3 Leakage inductance between the windings and 4.3.1.4 Susceptibility to ambient magnetic fields.

1.3.1. Design Considerations

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

1.3.1.1. Frequency sensitivity of inductance

Generally high permeability materials are used to obtain high inductance with a given number of turns. High inductance is generally associated with high common mode impedance. However, quite often materials with permeability greater than 10000, only exhibit these values below signal frequencies of 10 kHz. If the effective permeability of the material decreases with increasing frequency, the impedance value of the inductor may not increase. This phenomenon may severely limit the inductor's ability to attenuate common mode signals at the fundamental switching frequency or switching harmonics.

1.3.1.2. 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. At the self-resonance frequency the impedances associated with the winding inductance and with the distributed capacitance are equal. 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.

1.3.1.3. Leakage inductance between two windings.

Ideally all the flux established by current flow in one of the windings is cancelled by current flow in the other winding. 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. The resultant net flux density in the core is governed by the equation:

$$B_{PK} = \frac{L_{DM}\ ?I_{PK}}{N\ ?A_{MIN}}$$

B_{PK} = Peak flux density (T).
L_{DM} = The inductance measured across both windings when the windings are connected in series opposing (H)
N = The total number of turns of the series combination of the windings.
A = The minimum cross sectional area of the magnetic core (m^2).
I_{PK} = The peak current flowing through the windings (A_{PK}).

1.3.1.4. Susceptibility to ambient magnetic fields

The mechanical spacings required to meet regulatory and/or high voltage requirements on toroidal structures will create an antenna capable of radiating or receiving unwanted EMI/RFI.

1.3.1.5. Temperature sensitivity of the magnetic material characteristics such as permeability and saturation flux density

Generally, acceptable performance is obtained using the minimum values of these parameters within the operating temperature range.

1.3.1.6. Quality factor, Q

When designing the EMI/RFI inductors the value of Q will affect the attenuation versus frequency characteristic.

1.3.1.7. Power loss

Typically these inductors have no core loss since the net flux density in the core is negligible. The conductor loss is predominately I^2R where the I is either a dc current or a line frequency (50/60 Hz) current and R is the dc resistance.

1.3.1.8. Typical circuit application

A typical circuit application of this inductor is shown below in figure? EMI/RFI Inductor.

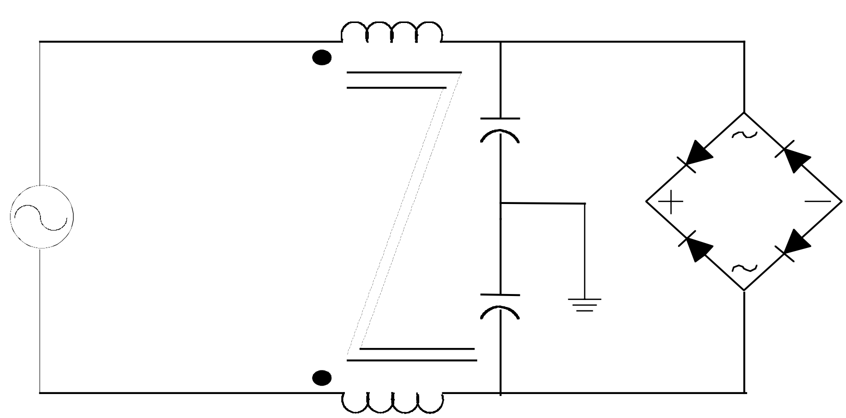


Figure ?: EMI/RFI Inductor

1.4. DC Output Filter Inductor

These inductors are intended for use in LC filters for switchmode power supplies. They provide differential mode filtering. The filter is generally designed to operate in the continuous buck mode, however the design consideration discussed can be applied to other dc-output filter inductor circuit topologies.

1.4.1. Design Considerations

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

1.4.1.1. 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 dc and ac components, and both must be considered independently. DC losses are equal to the dc resistance and the square of the average current. AC resistance and the square of the RMS value of the ripple current govern the AC losses. The dc conductor loss typically dominates, however the ac conductor loss can become significant if the number of conductor layers becomes large or the conductor thickness is much greater than the skin depth and/or the ac component of current is significant relative to the dc component.

1.4.1.2. Core Loss

If the ac component of flux density is significant for the core material then core loss may need to be considered in temperature rise calculations.

TBD Insert Equations-Steinmetz/Philips/EPCOS equation, constants depending on material, temp.

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

$$B_{PK} = \frac{L\left(I_{DC} + 0.5\,?\Delta I\right)}{NA_{MIN}}$$

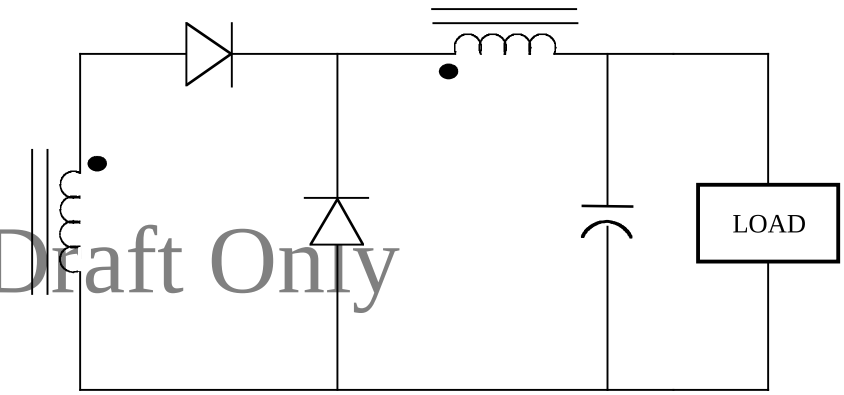
L: Inductance (H)
I_{DC}: DC component of current (A_{DC})
ΔI: Current swing (A_{P-P})
N: Turns of Inductor
A_{MIN}: Minimum cross-sectional area of core (m^2)
B_{PK}: Peak flux density in core (Tesla)

1.1.1.4. Inductance Value

The value of inductance is typically chosen such that the AC component of current is small compared to the DC component of current.

1.1.1.5. Typical circuit application

A typical circuit application of this inductor is shown below in figure ???DC output filter inductor.



Figure??? DC Output Filter Inductor **Add primary winding, and switch on pri side**

1.5. 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 either the continuous or discontinuous boost modes. The inductor used in either mode experiences a switching current that is superimposed on an envelope of the rectified line frequency current.

For boost inductors used in a power factor application, the input voltage to the boost circuit is a function of time since it follows the line frequency. The boost converter itself operates independently at a switching frequency about three orders of magnitude greater than the line frequency. Since the duty cycle of the boost circuit is a function of both the input voltage and the output voltage, the switching current through the inductor varies as a function of input voltage and consequently time. So for each switching interval along the rectified line frequency envelope, the ac signal is different.

Analysis techniques for boost inductors used in PFC applications must take into account the variation of the ac signal along the envelope of the input line current. Taking into account the ac conditions that exist for the switching interval that occurs at the peak rectified line current will allow for worst case design of inductance relative to saturation characteristics but will not account for worst case design due to copper and core loss. Worst case copper and core losses occur during those switching intervals for which the output voltage is twice the input voltage. However the worst-case switching interval can only occur during a limited number of intervals along the rectified line voltage envelope. During all other intervals the ac losses are less than worst case. The worst-case switching interval may never happen if the input voltage is such that its peak voltage is never equal to one half of the output voltage during a rectified line current period.

Since the time variation of the input signal is periodic, average losses can be estimated for the period. Size optimization is more achievable and loss prediction is more accurate with the use of average losses rather than the use of single instantaneous loss occurrences. Successful analysis techniques require the averaging of calculations of ac losses during each switching interval of the rectified line current period.

1.5.1. Design Considerations

Factors to consider during the design of Power Factor Correction inductors include but are not limited to the following:

1.5.1.1. AC loss analysis

The ac signals are greater for inductors used in the discontinuous boost mode than the ac signals experienced in the continuous boost mode. However, the ac flux density and current signals can create substantial losses for both the continuous and discontinuous modes of boost operation. For the discontinuous mode of operation it is always required to use low loss magnetic materials and winding configurations suitable for operation at the switching frequency of the boost converter. For the continuous mode of operation, the magnitude of the switching current can be small in comparison to the rectified line frequency current so that lossy magnetic materials and windings that do not take into account high frequency effects may be suitable.

1.5.1.2. DC loss analysis

The I^2R_{DC} conductor loss associated with the full wave rectified line current typically accounts for all of the dc loss. Since the conductor geometry is configured to accommodate the switching frequency (typically >10 kHz) currents, the use of R_{DC} is sufficient to account for the copper losses at the ripple frequency of the full-wave bridge feeding the boost converter.

1.5.1.3. 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 at a peak value of current. Typically graphs of inductance as a function of dc current at a specified temperature are used to characterize these types of inductors. Since the input voltage and current to the boost converter are a function of time, the switching current and instantaneous line current through the inductor are also a function of time. Since the input voltage varies with time, the volt seconds applied to the inductor vary with time. The instantaneous operating flux density in the magnetic core can be related to the peak current by the following equation:

$$B_{PK} = \frac{L\left(I_{INST} + 0.5\,?\Delta I\right)}{NA_{MIN}}$$

L: Inductance (H)
I_{INST}: Instantaneous value of line current for a particular switching interval (A)
ΔI: Current swing associated with a particular switching interval (A_{P-P})
N: Turns of Inductor
A_{MIN}: Minimum cross-sectional area of core (m^2)
B_{PK}: Peak flux density in core (Tesla)

<u>1.1.1.4.</u> Core Loss

If the AC component of flux density is significant for the core material than the thermal characteristics of core loss may need to be considered in temperature rise calculations.

1.1.1.5. Typical circuit application

A typical circuit application of this inductor is shown in figure ???? PFC inductor.

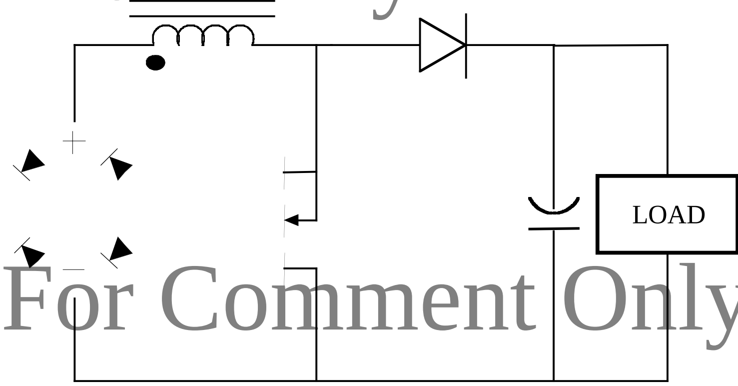


Figure ?????: Power Factor Correction (PFC) Inductor

1.6. DC Inductor

DC inductors are generally used to filter or smooth alternating current in several different types of circuits that contain a dc component. Filter networks often use dc inductors as a part of but not limited to high-pass, low-pass, π, T or notch filters. Several applications also utilize the dc inductor for current limiting during instantaneous peak or high current demand periods such as dc motor loads.

1.1.1. Design Considerations

Factors to consider during the design of DC Inductors include but are not limited to the following:

1.1.1.1. DC flux density, B_{DC}

The flux density to which the magnetic core is driven by the DC ampere-turns. **NEED FORMULA AND/OR FIGURE**

1.1.1.2. AC flux density, B_{AC}

The flux density to which the magnetic core is driven by the ac ripple current in dc circuits. **NEED FORMULA AND/OR FIGURE**

1.1.1.3. Saturation current

Termed as I_{SAT}, this is the current at which $B_{DC} + B_{AC}$ flux levels will cause a decrease in inductance below a specific value.

1.1.1.4. Continuous current rating

The continuous or duty cycled load current rating of the inductor.

1.1.1.5. Peak current rating

The peak current that can affect the saturation point of the inductor. Stated as an instantaneous value.

1.1.1.6. Quality factor (Q) ADD Q FACTOR DEFINITION OR SEPARATE SECTION?

HOW DOES QUALITY FACTOR AFFECT THE DESIGN OF THIS TYPE OF INDUCTOR!

1.1.1.7. Ripple current frequency

Rectification causes ripple currents, which affects the ac flux density. It is important to know the rectification method to determine the ripple current frequency. This frequency largely dictates the core losses of the magnetic components.

1.1.1.8. Discontinuous Current

John DeCramer definition from (George Chryssis)

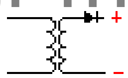
1.1.1.9. Maximum Current Rating

The maximum value of current at which the device meets its specifications. This value is usually determined by temperature rise and/or saturation considerations.

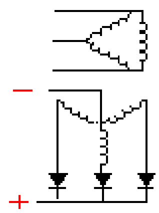
1.1.1.10. Rueben Lee's rectifier diagrams as demonstration of different rectifier topologies.Insert Bill Goethe schematic

RECTIFIER TYPES

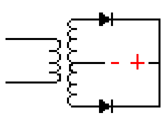
1.1.1.10.1. Single-phase Half Wave



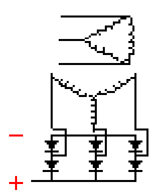
1.1.1.10.2. Three-phase Half Wave



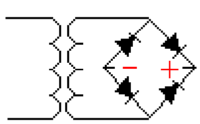
1.1.1.10.3. Single-phase Full Wave



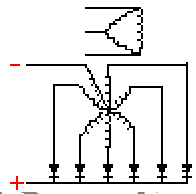
1.1.1.10.4. Three-phase Full Wave



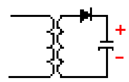
1.1.1.10.5. Single Phase Bridge



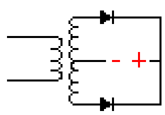
1.1.1.10.6. Three-phase Bridge (Star)



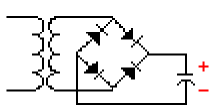
1.1.1.10.7. Half wave capacitive filter



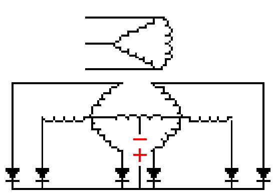
1.1.1.10.8. Full wave capacitive filter



1.1.1.10.9. **Bridge capacitive filter**



1.1.1.10.10. Three-phase Double Wye



1.7. Load Coil

An inductor inserted in a circuit to increase its inductance for the purpose of improving its transmission characteristics in a given frequency band.

Distributed capacitance cancellation

A specified value of impedance to cancel a known value of capacitance.

1.8. Non Linear Filter Inductor (Swinging Choke)

Swinging Inductors are used in applications where a change of Inductance is required over a range of current requirements. The change of inductance is accomplished by utilizing the change in the cores effective permeability as a function of current level. It is important to specify inductance values at specified AC/DC currents. Note that an increase in DC current will decrease inductance. Initially an increase in AC current may increase Inductance values. However, as current continues to increase and change flux density a decrease in Inductance can occur.

1.8.1. Design Considerations

Factors that influence the design of the swinging choke includes but is not limited to the following:

1.8.1.1. Operating Current Spectrum

The range of current that the Swinging Inductor is required to operate.

1.8.1.2. Nominal Inductance Value

The nominal desired value of Inductance at a specified Load current rating.

1.8.1.3. Peak Current Inductance Value

The Inductance that is desired at peak load current periods.

1.8.1.4. Step Gap

The core cross section is divided into at least two separate sections, each with different gap and cross sectional areas.

1.8.1.5. Composite Core

The combination of multiple magnetic materials with different reluctance as a function of current.

1.9. AC Line Reactor:

The AC Line Reactor is a component used in single and three phase circuit applications. Such as, motor drives or straight motor loads. The Line reactor is used as a current filtering device. The Line reactor also acts as a current limiting device. Line reactors can also limit unwanted currents produced by semi-conductor circuitry.

1.9.1. Design Considerations

Factors that influence the design of AC Line Reactors includes but is not limited to the following:

1.9.1.1. Continuous operating current

The nominal full load current AC current required by the load for proper operation. Full load currents can fluctuate and should be identified and addressed as worst case operation values. The thermal rating is based upon continuous operating current.

1.9.1.2. Saturating current

Start up of equipment can cause high inrush currents. It is at this time that the Line Reactors performance is the most critical. The Line Reactor core structure should not saturate at these current levels. If saturation does occur, Inductance values will decline allowing large unwanted peak currents to pass through to the load and potentially damage the load.

1.9.1.3. Gap fringing losses

Gap fringing losses can adversely effect core and coil heating. Gap fringing losses can be reduced by keeping the effective gap distance as small as possible. Large gap areas located in one confined spot greatly increase the possibility of large fringing losses. The fringing losses are created when magnetic flux builds up at core gap spaces and tries to jump the gap spacing. When the flux is crossing this gap boundary it is forced out into the windings and causes eddy current losses in the conductor. At the same time when the flux is re-entering the core material, it is re-entering as perpendicular flow, causing additional core loss.

1.9.1.4. Operating frequency

The operating frequency directly affects the core flux density and core watts loss. Line Reactors can be either installed on the line or load side of the system. The line side of the system will see the nominal system frequencies. Load side applications will be subject to nominal system frequencies and switching frequencies from semi-conductor circuits. Care should be taken in identifying these switching frequencies because they will affect the performance of the core material.

***** Add impedance calculation to calculations page (equation to be based upon system impedance).**

1.10. Commutating Inductor

An Inductor having one or more windings that modifies or couples the transient current produced by the commutating voltage.

1.10.1. Design Considerations

Factors that influence the design of commutating inductors includes but is not limited to the following:

1.10.1.1. Continuous current

1.10.1.2. Peak Current

1.10.1.3. Frequency Considerations

1.10.1.4. Core Loss

1.11. Trap Inductors

Trap Inductors are used in Filter Tank applications. Usually it is the intent to deign the trap Inductor to form a resonant filter with a capacitor to Trap unwanted harmonic switching frequencies. The trap Inductor will absorb the unwanted harmonic currents in its magnetic field thus promoting longer life to the associated filter Capacitor. Sometimes these trap Inductors can be used, as a stand-alone device to smooth and or partially absorb unwanted harmonic currents. In either scenario it is important to recognize the complete harmonic spectrum you are dealing with. These harmonics can cause dramatic differences in core and coil watts loss values. These losses can cause extreme temperature rises and premature component failures.

1.11.1. Design Considerations

Factors that influence the design of the trap Inductor include but is not limited to the following:

1.11.1.1. Harmonic Current Spectrum

The spectrum of harmonic currents that are present in the system application you are addressing. These currents can cause significant changes in core flux density levels. These increased flux levels can cause increased core watts loss. The coils can also be subject to skin effect and elevated eddy currents near core gap location. All of these factors can lead to increased temperature rise conditions.

1.11.1.2. Core Watts Loss

Due to the different harmonic currents that exist in the application. Careful attention should be made to the flux density and watts loss calculations at each individual frequency.

1.11.1.3. Gap losses

Gap fringing losses in these types of Inductors are usually greater than in fixed frequency Inductors. Gap losses will change in regard to the different frequencies that exist in the frequency spectrum of the application. Gap losses should be calculated at each individual frequency of the spectrum. Total gap loss is the summation of these individual gap loss values.

1.11.1.4. Thermal Current

The current that is the vector sum of each harmonic current that is present in the applications current spectrum. This current is normally used to properly size the conductor of the Inductor winding.

1.11.1.5. Saturation Current

The current that will cause a (-10%) change in the nominal value of the Inductance. This value is also associated with the knee in the saturation curve of the core material. This value also is dependent on the flux values calculated based on the current spectrum of the application.

5. Test Methods

Recommended tests and specifications for specific inductor applications are listed in Table ????. Insert Inductor tests.xls

6. Ratings

6.1. Equivalent VA rating based upon energy storage and conduction current.

6.2. Specification Considerations

6.2.1. Electrical Parameters

6.2.1.1. Inductance

6.2.1.2. Conduction currents

6.2.1.3. Working Voltage

6.2.1.4. Saturation Requirements

6.2.1.5. Duty Cycle

6.2.1.6. Frequency Spectrum

6.2.1.6.1. Operating Frequency Range
6.2.1.6.2. Self Resonant Frequency
6.2.1.7. Waveforms
6.2.1.8. Stray Field Emissions
6.2.1.9. Acoustic Noise
6.2.1.10. Power Loss
6.2.1.10.1. Quality Factor
6.2.1.10.2. Efficiency
6.2.1.11. Temperature
6.2.1.11.1. Ambient
6.2.1.11.2. Operating

6.2.2. Physical
6.2.2.1. Footprint
6.2.2.2. Profile
6.2.2.3. Mounting Configurations
6.2.2.3.1. Chassis
6.2.2.3.2. Surface Mount
6.2.2.3.3. Through Hole
6.2.2.4. Termination Types
6.2.2.4.1. Surface Mount
6.2.2.4.1.1. Coplanarity
6.2.2.4.2. Through Hole
6.2.2.4.3. Lug Terminals
6.2.2.4.4. Flying Leads
6.2.2.4.5. Bus Bar
6.2.2.5. Packaging
6.2.2.6. Marking

6.2.3. General Environmental
6.2.3.1. Storage
6.2.3.1.1. Temperature
6.2.3.1.2. Humidity
6.2.3.2. Operating Conditions
6.2.3.2.1. Temperature
6.2.3.2.2. Airflow

6.2.4. End Product Manufacturing Considerations
6.2.4.1. Soldering considerations

6.2.4.1.1. Temperature
6.2.4.1.2. Solvent Resistance
6.2.4.1.3. Solderabilty
6.2.4.2. Encapsulation Considerations

6.2.5. Safety

6.2.5.1. Temperature/Insulation Class
6.2.5.2. Flammability
6.2.5.3. Dielectric Integrity
6.2.5.3.1. Operational

7. Reliability
7.1. Thermal Aging
7.2. High Voltage Considerations

7.3. Shock and Vibration

8. Annex
8.1. Inductance Calculations
8.2. Inductor AC Resistance Calculations
8.3. Bibliography
8.3.1.1. 1. J.E. Elias, “Amorphous Magnetic Materials – Part II: High Frequency Mag-Amp Output Regulator,” Power conversion Intelligent Motion, September 1993