Common Mode Choke Design Calculations

This template contains the following sections:

- Calculation of maximum flux density B_{max} as a function of peak current for a specified core size.
- Plots of B_{max} as a function of leakage inductance
- Plots showing allowable leakage inductance as a function of B_{max}
- Estimate of leakage inductance and corresponding maximum allowable value of peak current.

If you haven't yet built the common mode choke, then use the leakage inductance estimator in the last section to calculate the maximum allowed current. If you have already built the choke, then measure the leakage inductance and use the first three sections to make sure the design does not saturate.

The calculations shown use a Samwa SM100 OR16x8x12 core as an example.

Designers using the template should change items marked with a *.

Revision A1

Maximum Flux Density as a Function of Peak Current

$Al := 4600 \times 10^{-9} H$ * **AL Core value (nH/N^2)**

$AlTol := 30\%$ * **AL Value Tolerance %**

$L := 14.43mH$ * **Common Mode inductance desired**

$Bmax\_allowed := 0.210T$ * **Maximum allowable flux density at maximum expected operating temperature of component.**

$Ipk := 5A$ * **Peak Current through the Core (Measure at AC Plug max Load)**

$Lk := 96\mu H$ * **Measured leakage inductance**

$OD := 1.6cm \quad ID := 1.2cm \quad TH := .8cm$ * **Nominal Core Dimensions**

$ODtol := 0.3mm \quad IDtol := 0.3mm \quad THtol := 0.3mm$ * **Core Tolerances**

$Srf := 350KHz$ * **Measured Self Resonant Frequency**

$$Aemin := \frac{(OD - ODtol) - (ID + IDtol)}{2} \cdot (TH - THtol) \qquad Aemin = 13.1 \times 10^{-6} m^{2.0\times10^{0}}$$

Possible Ae spread

$$Aemax := \frac{(OD + ODtol) - (ID - IDtol)}{2} \cdot (TH + THtol) \qquad Aemax = 19.1 \times 10^{-6} m^{2\times10^{0}}$$

$$Ae := \frac{OD - ID}{2} \cdot TH \qquad Ae = 16.0 \times 10^{-6} m^{2.0\times10^{0}}$$

Nominal Ae (cross sectional core area)

$$N := floor\left(\sqrt{\frac{L}{Al}}\right) \qquad N = 56$$

Number of Turns rounded down to an integer

$$L := N^2 \cdot Al \qquad L = 14.4 \times 10^{-3} H$$

Projected Nominal Inductance

$$Lmin := N^2 \cdot Al \cdot (1 - AlTol) \qquad Lmin = 10.1 \times 10^{-3} H$$

Minimum Inductance

$$Lmax := N^2 \cdot Al \cdot (1 + AlTol) \qquad Lmax = 18.8 \times 10^{-3} H$$

Maximum Inductance

$$Bmax := \frac{Ipk \cdot Lk}{N \cdot Aemin} \qquad Bmax = 0.655 T$$

Peak flux density at worst case core tolerances

$$Bnom := \frac{Ipk \cdot Lk}{N \cdot Ae} \qquad Bnom = 0.536 T$$

Peak flux density at nominal core tolerances

$Bmax\_allowed := 0.210T$

$$Cw := \frac{1}{L (Srf \cdot 2 \cdot \pi)^2} \qquad Cw = 14.33 \times 10^{-12} F$$

Inner Winding capacitance

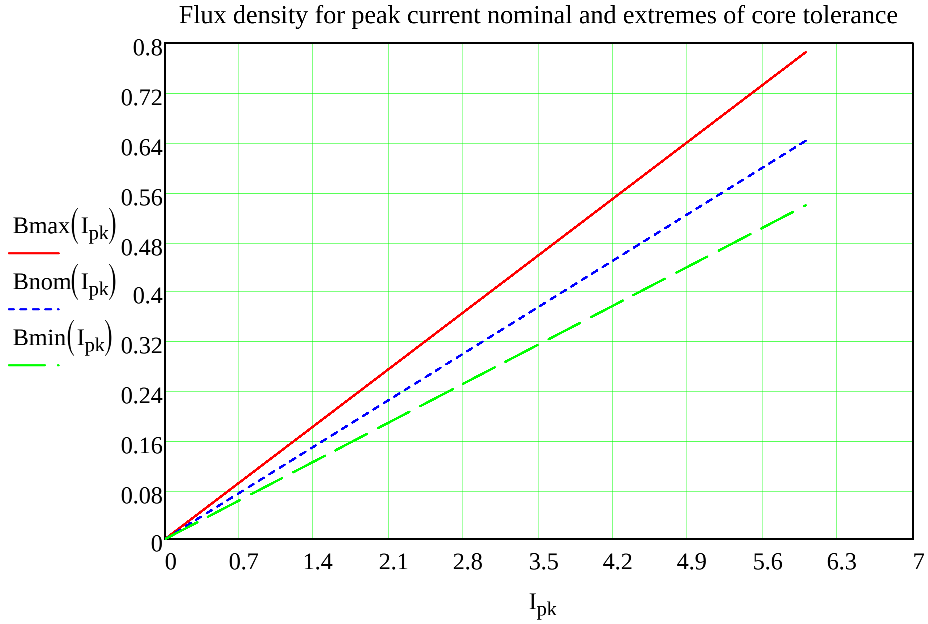
Bmax as a function of Current at Lk

$Imin := 10mA$ * **Min Current to consider**

$Imax := 6000mA$ * **Max Current to consider**

$I_{pk} := Imin, Imin \cdot 1.1 .. Imax$

$Bmax(I_{pk}) := \frac{I_{pk} \cdot Lk}{N \cdot Aemin}$ $Bnom(I_{pk}) := \frac{I_{pk} \cdot Lk}{N \cdot Ae}$ $Bmin(I_{pk}) := \frac{I_{pk} \cdot Lk}{N \cdot Aemax}$



Flux density as a function of peak current. Departure of maximum and minimum values from nominal are a result of core tolerances.

Allowable Leakage Inductance as a Function of Bmax

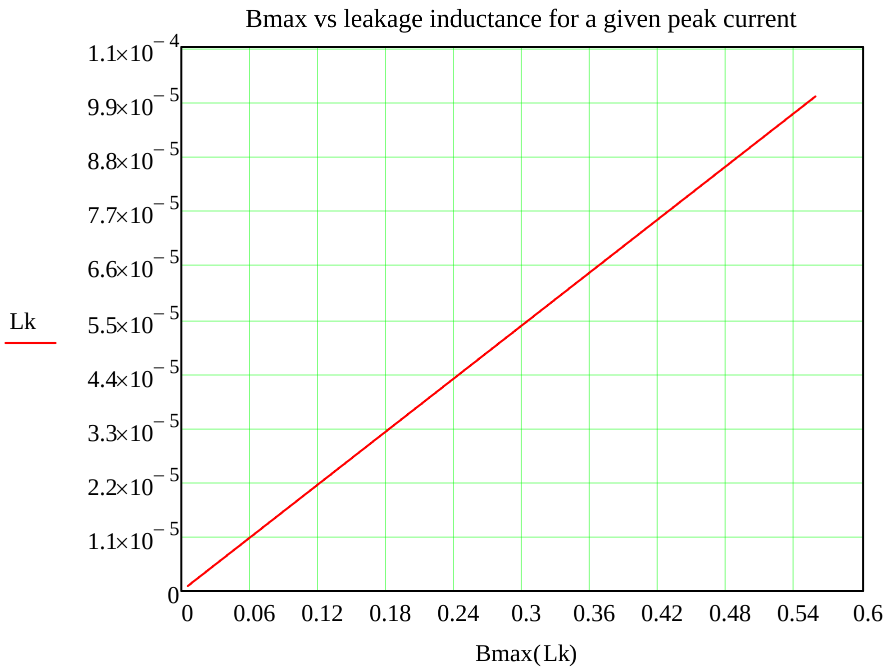
$Lkmin := 1\mu H$ * **Minimum Leakage inductance**

$Lkmax := 100\mu H$ * **Maximum Leakage Inductance**

$Ipk := 5A$ * **Current at which leakage inductance is evaluated**

$Lk := Lkmin, Lkmin \cdot 1.1 .. Lkmax$

$$Bmax(Lk) := \frac{Ipk \cdot Lk}{N \cdot Ae}$$



From this chart you can choose a Bmax appropriate for the operating temperature of your CM Choke and see the maximum leakage your design can have at that value of Bmax

Leakage Inductance Estimation and Corresponding Calculation for Peak Current

$WD := .65mm$ * — **Wire Diameter**

$\delta := 1.15$ — **Multiplier (leave at 1.15 for a single layer winding)**

$$Le := \left(OD - \frac{OD - ID}{2}\right)\cdot\pi \qquad Le = 44 \times 10^{-3}\,m$$

Core Path Length

$$Nf := floor\left[\frac{\pi}{2}\cdot\left(\frac{ID + \frac{WD}{2}}{WD}\right)\cdot\frac{1}{\delta}\right] \qquad Nf = 25$$

Number of Turns on single layer 1/2 toroid

$$\theta := 180\cdot\frac{N}{Nf} \qquad \theta = 403.2$$

Angular Coverage

$$Lssc := \frac{4\cdot\pi\cdot 10^{-7}\cdot\frac{H}{m}\cdot N^2\cdot Ae}{Le + 1cm\sqrt{\frac{\theta}{360} - \frac{\sin\left(\frac{\theta\cdot\frac{\pi}{180}}{2}\right)}{\pi}}} \qquad Lssc = 1.1 \times 10^{-6}\,H$$

H Inductance of the Air

$$\Gamma := \sqrt{\frac{\pi}{Ae}\cdot\frac{Le}{2}} \qquad \Gamma = 9.745$$

[Rod Length / Rod Diameter] Factor

$$\mu dm := 2.5\cdot\Gamma^{1.45} \qquad \mu dm = 67.9$$

Rod Effective Permeability

$$Leakage := \mu dm\cdot Lssc \qquad Leakage = 77.7 \times 10^{-6}\,H$$

Estimated Leakage Inductance.
Experimental results were 96uH but the example choke had 3 layers of fill. Results are most accurate for a single layer.

$B := 0.24T$ * — **Operational Bmax**

$$Ip := \frac{B\cdot N\cdot Ae}{Leakage} \qquad Ip = 2.77\,A$$

Estimated Peak Current capability at B, assuming accuracy of leakage calculation. Use only if leakage has not been measured.