Latte Phase Control Inductor Design

$f := 60$ Line frequency

$Acmin := 74$

$Acmax := 137$

$i := Acmin .. Acmax$

$Vac_i := i$ AC Input Voltage Range

$Po := 600$ RMS Power Delivered to load

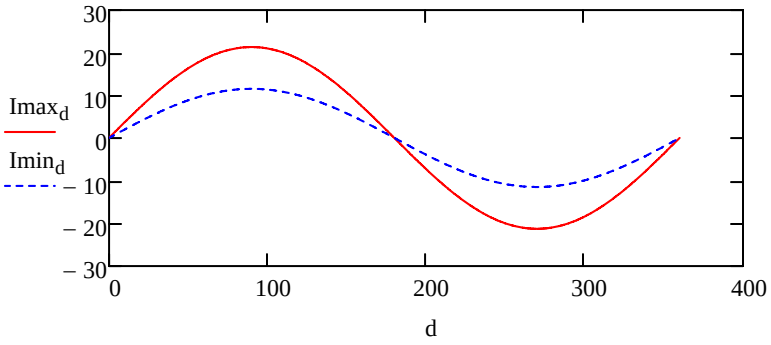
$Rl := 9.1$ Load resistor

$d := 0 .. 360$

$\theta_d := \frac{2 \cdot \pi \cdot d}{360}$

$Imin_d := \frac{Vac_{Acmin} \cdot \sin(\theta_d) \cdot \sqrt{2}}{Rl}$ $Imin_{90} = 11.5$ Peak Current Low Line

$Imax_d := \frac{Vac_{Acmax} \cdot \sin(\theta_d) \cdot \sqrt{2}}{Rl}$ $Imax_{90} = 21.291$ Peak Current High Line



Maximum Current if no Phase Control

$Irmsmin := \frac{Imin_{90}}{\sqrt{2}}$ $Irmsmin = 8.132$

$Irmsmax := \frac{Imax_{90}}{\sqrt{2}}$ $Irmsmax = 15.055$

$Pmax := Vac_{Acmax} \cdot Irmsmax$ $Pmax = 2.063 \times 10^3$ Max RMS Power

$Pmin := Vac_{Acmin}\ Irmsmin$ $Pmin = 601.758$

$Phasemax := \frac{Po}{Pmin} \cdot 180$ $Phasemax = 179.474$

$Phasemin := \frac{Po}{Pmax} \cdot 180$ $Phasemin = 52.363$

$P90 := 2 \cdot Po$ Power at 105Vac $P90 = 1.2 \times 10^3$

$I90 := \sqrt{\frac{P90}{Rl}} \cdot \sqrt{2}$ Peak Current for a Phase angle of 90 and a power of Po

$I90 = 16.24$ $I90rms := \frac{I90}{\sqrt{2}}$

$Vac90 := \frac{P90 \cdot \sqrt{2}}{I90}$

$Vac90 = 104.499$ Maximum Inductor current is at 104.5Vac

$Ipk := \frac{Vac90}{Rl} \cdot \sqrt{2}$

$Ipk = 16.24$ maximum current for 90 degree phase anble

$L := 400 \cdot 10^{-6}$ Target Loaded Inductance

$Energy := \frac{L \cdot Ipk^2}{2}$

$Energy = 0.053$ Joules Of Energy Storage

$I90rms = 11.483$

Micrometals T157-70 Core Data

$OD := 3.99$ Outside Dia

$ID := 2.41$ Inside Dia

$HT := 1.45$ Height

$WOD := 4.503$ Wound OD

$WHT := 2.655$ Wound Height

$MPL := 10.1$ Magnetic Path Length

$MLT := 5.5$ Mean Length per turn

$Vol := 10.706$ Core Volume

$\rho := 7.4$ Core Density

$Wtfe := \rho \cdot Vol$ Core weight

$Wtfe = 79.224$

$Wtcu := 89.4$ Copper weight of fully wound core

$Ac := 5.5$

$Wa := 4.559$

$Ap := 4.833$

$Kg := 0.371763$

$At := 85.3$

$\mu := 100$ Initial Permeability

$AL := 130$ nH/N^2

Core Turns Calculations

$a := 10120$ $b := 8.81 \cdot 10^{-4}$ $c := 11.4$ $d := 8.82 \cdot 10^{-9}$ $e := -8.29 \cdot 10^{-4}$

Iterate until Bmax and N below until you hit your target

$Bmax := 9100$ Set Bmax to 1 tesla

$$\%\mu := \sqrt{\frac{a + c \cdot Bmax + e \cdot Bmax^2}{1 + b \cdot Bmax + d \cdot Bmax^2}}$$

$\%\mu = 68.104$

$$ALe := AL \cdot \frac{\%\mu}{100}$$

$ALe = 88.535$

$N := 1000 \cdot \sqrt{\frac{L \cdot 1000}{ALe}}$

$N = 67.216$

$N := 67$

$\left(\frac{N}{1000}\right)^2 \cdot \frac{ALe}{1000} = 3.974 \times 10^{-4}$ Loaded Inductance

$\left(\frac{N}{1000}\right)^2 \cdot \frac{AL}{1000} = 5.836 \times 10^{-4}$ Unloaded Inductance

$J := 600$

$Awb := \frac{Po}{J \cdot Vac90}$

$Awb = 9.569 \times 10^{-3}$ Minimum Bare Cu wire cross sectional area requirement.

$Irms := \frac{Po}{Vac90}$ Rms curent through the wire under phase control

Choose a 18AWG (1mm)

$Awb := 8.228 \cdot 10^{-3}$

$Rw := 209.5 \cdot 10^{-6}$ ohms / cm

$Pcu := Irms^2 \cdot MLT \cdot Rw \cdot N$ I90rms = 11.483

$Pcu = 2.545$

Core Loss Calculation

$a := 1 \cdot 10^{10}$ $b := 1.3 \cdot 10^{9}$ $c := 7.9 \cdot 10^{6}$ $d := 4.2 \cdot 10^{-14}$

$$Pfe := \left(\frac{f}{\frac{a}{Bmax^3} + \frac{b}{Bmax^{2.3}} + \frac{c}{Bmax^{1.65}}} + d \cdot f^2 \cdot Bmax^2 \right) \cdot \frac{Vol}{1000}$$

$Pfe = 0.192$

$PL := Pcu + Pfe$ Power Loss

$\Delta T := \left(\frac{PL \cdot 10^3}{At} \right)^{0.833}$ General equation for predicting Temperature rise from Pd and Surface are

$\Delta T = 17.979$ Expected Temperature Rise

:a