

## Steel 50-60Hz Transformer Design

$$V_{ACinmin} := 80$$

$$V_{ACinmax} := 136$$

$$V_{ACnom} := 115$$

$$i := V_{ACinmin} .. V_{ACinmax}$$

$$V_{ac_i} := i \cdot \sqrt{2} \cdot V$$

$$P_o := 25W$$

$$\eta := 0.95$$

$$\Delta\beta_m := 1.3T$$

$$F_{mains} := 50Hz$$

$$V_o := 32V$$

$$V_{fd} := 1.2V$$

$$A_c := 4.0827cm^2$$

Assumes laminated EI112-0.5 FeSi core EI core

$$MLT := 13.7cm$$

Mean Length per Turn

$$K_u := 4.44$$

Use 4 for a square wave or 4.44 for a sin

$$\rho_{cu} := 8.96 \cdot 10^{-3} \frac{kg}{cm^3}$$

Assumes pure copper

$$T_w := 100$$

Wire Temperature

$$I_o := \frac{P_o}{V_o}$$

$$n := \frac{V_{ac} V_{ACnom}}{V_o + 2V_{fd}}$$

$$n = 4.728$$

$$V_{omax} := \frac{V_{ac} V_{ACinmax}}{n}$$

Max loaded Rectified output at no load

$$V_{omax} = 40.682 \text{ V}$$

$$V_{omin} := \frac{V_{ac} V_{ACinmin}}{n}$$

Min loaded Rectified output at no load

$$V_{omin} = 23.93 \text{ V}$$

$$V_{opkmax} := V_{omax} \cdot \sqrt{2}$$

Unloaded Peak voltage

$$V_{opkmax} = 57.533 \text{ V}$$

$$V_{opkmin} := V_{omin} \cdot \sqrt{2}$$

Unloaded peak voltage

$$V_{opkmin} = 33.843 \text{ V}$$

Min Max swing with line and load is 29.61V to 55.8V

$$N_p := \frac{V_{ac} V_{ACnom} \cdot \frac{1}{V} \cdot 10^4}{4.44 \cdot \frac{\Delta \beta_m}{T} \cdot \frac{F_{mains}}{\text{Hz}} \cdot \frac{A_c}{\text{cm}^2}}$$

$$N_p = 1.38 \times 10^3$$

$$N_s := \frac{N_p}{n}$$

$$N_s = 291.954$$

$$J := 400 \frac{\text{A}}{\text{cm}^2}$$

Current density design

$$I_{prms} := \frac{P_o}{\eta \cdot V_{ACinmin} \cdot V}$$

$$I_{prms} = 0.329 \text{ A}$$

$$I_{diode} := \frac{P_o}{V_o}$$

$$A_w := \frac{I_{prms}}{J}$$

$$A_w = 8.224 \times 10^{-8} \text{ m}^2$$

$$DiaPri := 2 \sqrt{\frac{A_w}{\pi}}$$

$$DiaPri = 3.236 \times 10^{-4} \text{ m}$$

$$WireDiaPri := 0.32 \text{ mm}$$

$$P_{diodeloss} := 2 V_{fd} \cdot I_{diode} \quad \text{Power Loss in the Bridge Rectifier}$$

$$P_{diodeloss} = 1.875 \text{ W}$$

$$WireDiaSec := 0.5 \text{ mm}$$

$$A_{wp} := \pi \cdot \left( \frac{WireDiaPri}{2} \right)^2$$

$$A_{ws} := \pi \cdot \left( \frac{WireDiaSec}{2} \right)^2$$

$$CuWtPri := N_p \cdot MLT \cdot A_{wp} \cdot \rho_{cu}$$

$$CuWtPri = 0.136 \text{ kg}$$

$$CuWtSec := N_s \cdot MLT \cdot A_{ws} \cdot \rho_{cu}$$

$$CuWtSec = 0.07 \text{ kg}$$

$$CuWt := CuWtPri + CuWtSec$$

$$CuWt = 0.207 \text{ kg} \quad \text{Copper Weight}$$

$$CuWirePricePerLb := 3.3412 \frac{1}{lb} \quad \text{Spot pricing as of 1/14/08}$$

$$CuCost := CuWt \cdot CuWirePricePerLb$$

$$CuCost = 1.522 \quad \text{Cu cost by weight in \$US}$$

$$\rho := 1.68 \cdot 10^{-6} \quad \text{Electrical Resistivity } \Omega\text{cm}$$

$$\alpha := 0.0039 \quad \text{Temperature coefficient for Cu}$$

$$\rho_e := \rho \cdot [1 + \alpha \cdot (T_w - 20)] \quad \text{Temperature compensation}$$

$$\rho_e = 2.204 \times 10^{-6} \quad \text{New resistivity in } \Omega\text{cm}$$

$$R_{CuPri} := \frac{\rho_e}{A_{wp} \cdot \frac{1}{\text{cm}^2}}$$

$$R_{CuPri} = 2.741 \times 10^{-3}$$

$$P_{CuPri} := \left( \frac{I_{prms}}{A} \right)^2 \cdot R_{CuPri} \cdot \frac{MLT}{\text{cm}} \cdot N_p$$

$$P_{CuPri} = 5.608 \quad \text{Cu Loss}$$

$$R_{CuSec} := \frac{\rho_e}{A_{ws} \cdot \frac{1}{\text{cm}^2}}$$

$$R_{CuSec} = 1.123 \times 10^{-3}$$

$$P_{CuSec} := \left( \frac{I_o}{A} \right)^2 \cdot R_{CuSec} \cdot \frac{MLT}{\text{cm}} \cdot N_s$$

$$P_{CuSec} = 2.74$$

$$\eta_{calc} := \frac{P_o}{P_o + [(P_{CuPri} + P_{CuSec})W + P_{diodeloss}]}$$

$$\eta_{calc} = 0.71 \quad 82.7 \text{ for } 10W$$