Skin Depth and Wire Selection

$\rho := 1.7241 \cdot 10^{-6} \Omega \cdot cm$ — Nema M1000 pdf

$\alpha := 0.0039$ — Temperature Compensation for Cu

$TempW := 100$ — Degree C Operating Wire temperature

$Tambient := 20$ — Ambient Wire Temperature the Cu constant was derived from

$\rho e := \rho \cdot [1 + \alpha \cdot (TempW - Tambient)]$

$\rho e = 2.262 \times 10^{-6} \cdot \Omega \cdot cm$ — Adjusted electrical Resistivity

$$Kcu := \sqrt{\frac{\rho e}{\rho}}$$

$$\delta := \frac{6.62}{\sqrt{Fsw}} \cdot Kcu \cdot \sqrt{Hz} \cdot cm$$

$\delta = 0.027 \cdot cm$ — Skin Depth in cm

$MaxWireDia := 2 \cdot \delta$

$MaxWireDia = 0.536 \cdot mm$ — Maximum wire Diameter that uses 100% of the Cu area at the fundamental switching frequency

Primary Side Wire Selection

$$IpRMS := \sqrt{\frac{DutyCycle \cdot \left[(Ipk - \Delta I)^2 + (Ipk - \Delta I) \cdot Ipk + Ipk^2\right]}{3}} = 2.104\ A$$ Primary Current

$WireDiaPri := 0.5mm$ — **Bare Cu wire Diameter for the Primary Winding**

$WireODPri := 0.566mm$ — **Uses 2UEW (JIS Grade 2) See wire table**

Expand Table Below for wire gauges

$$\frac{BobbinWidth}{Np} = 0.573 \cdot mm$$ Max wire dia for Np turns

$MaxTurnsPri := floor\left(\frac{BobbinWidth}{WireODPri}\right)$

$MaxTurnsPri = 41$

This is the Maximum Number of turns for single layer construction. Check this value against Np

$Idensity := 800 \frac{A}{cm^2}$

Suggested Wire current density. 300 is very conservative, 500 is normal (often used for continuous power), 800 is high but is often used as the peak power number

$$SuggestedNumbStrands := \frac{IpRMS}{\left(\frac{WireDiaPri}{2}\right)^2 \cdot \pi \cdot Idensity}$$

$SuggestedNumbStrands = 1.339$

$NumPriStrands := 1$

Number of parallel strands of wire to use in the primary winding

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

Cross Sectional area of the stranded wire

$AwbPri = 1.963 \times 10^{-3} \cdot cm^2$

$RcuPri := \frac{\rho e}{AwbPri} \cdot MLT \cdot Np$

DCR Of the Primary Winding

$RcuPri = 0.231 \cdot \Omega$

$PcuPri := IpRMS^2 \cdot RcuPri$

Power Dissipation of the primary winding

$PcuPri = 1.024\,W$

$Ns1 := \frac{(Vo1 + Vfd1) \cdot (1 - DutyCycle) \cdot Np}{DutyCycle \cdot VBulkMin \cdot Kcoupling}$

Need a schottky diode here. Kcoupling compensation for Coupling losses.

$Ns1 = 17.108$

Number of turns on the secondary side

$Ns1 := 17$

$$IdcS1 := \frac{Io1 \cdot \left(1 + \frac{Vfd1}{Vo1}\right)}{(1 - DutyCycle)}$$

Allows for the output power and power dissipation of the output rectifier

$IdcS1 = 6.206\,A$

$\Delta IS1 := \Delta I\% \cdot IdcS1$

$\Delta IS1 = 2.836\,A$

$IpkS1 := IdcS1 + \frac{\Delta IS1}{2}$

$IpkS1 = 7.624\ A$

$Is1RMS := \sqrt{\frac{(1 - DutyCycle)\cdot\left[(IpkS1 - \Delta IS1)^2 + (IpkS1 - \Delta IS1)\cdot IpkS1 + IpkS1^2\right]}{3}}$

$Is1RMS = 4.152\ A$

$NumS1Strands := 2$ **Number of parallel strans on one layer**

$NumS1Layers := 1$ **Number of layers of parallel windings**

$WireDiaS1 := 0.5mm$ **Bare Cu wire Diameter for the Primary Winding**

$WireODS1 := 0.536mm$ **Uses 0.55mm Wire**

$MaxTurnsS1 := floor\left(\frac{BobbinWidth}{WireODS1\cdot NumS1Strands}\right)$

$MaxTurnsS1 = 21$ This is the Maximum Number of turns for single layer construction. Check this value against NS1

$Awbs1 := \pi\cdot\left(\frac{WireDiaS1}{2}\right)^2\cdot NumS1Strands\cdot NumS1Layers$

$Awbs1 = 3.927 \times 10^{-3}\cdot cm^2$

$Rcus1 := \frac{\rho e}{Awbs1}$ Wire resistence ohms/cm

$Rcus1 = 5.76 \times 10^{-4}\cdot\frac{\Omega}{cm}$

$Rs1 := Rcus1\cdot MPL\cdot Ns1$ S1 Wire Resistence

$Rs1 = 0.057\ \Omega$

$Pcus1 := Is1RMS^2\cdot Rs1$ Power Loss to the Cu in the S1 winding

$Pcus1 = 0.979\ W$

$Ns2 := \frac{(Vo2 + Vfd2)\cdot(1 - DutyCycle)\cdot Np}{DutyCycle\cdot VBulkMin\cdot Kcoupling}$ Need a schottky diode here. Kcoupling compensation for Coupling losses.

$Ns1 = 17$ Number of turns on the secondary side

$Ns1 := 17$

$IdcS2 := \frac{Io2\cdot\left(1 + \frac{Vfd2}{Vo2}\right)}{(1 - DutyCycle)}$ Allows for the output power and power dissipation of the output rectifier

$IdcS2 = 0.099\,A$

$\Delta IS2 := \Delta I\%\cdot IdcS2$

$\Delta IS2 = 0.045\,A$

$IpkS2 := IdcS2 + \frac{\Delta IS2}{2}$

$IpkS2 = 0.122\,A$

$Is2RMS := \sqrt{\frac{(1 - DutyCycle)\cdot\left[(IpkS2 - \Delta IS2)^2 + (IpkS2 - \Delta IS2)\cdot IpkS2 + IpkS2^2\right]}{3}}$

$Is2RMS = 0.066\,A$

$NumS2Strands := 1$ **Number of parallel strans on one layer**

$NumS2Layers := 1$ **Number of layers of parallel windings**

$WireDiaS2 := 0.21mm$ **Bare Cu wire Diameter for the Primary Winding**

$WireODS2 := 0.241mm$ **Uses 0.21mm 2UEW Wire**

$MaxTurnsS2 := floor\left(\frac{BobbinWidth}{WireODS2\cdot NumS2Strands}\right)$

$MaxTurnsS2 = 97$ This is the Maximum Number of turns for single layer construction. Check this value against NS1

$Awbs2 := \pi\cdot\left(\frac{WireDiaS2}{2}\right)^2\cdot NumS1Strands\cdot NumS1Layers$

$Awbs2 = 6.927\times 10^{-4}\cdot cm^2$

$Rcus2 := \frac{\rho e}{Awbs2}$ Wire resistence ohms/cm

$Rcus2 = 3.265 \times 10^{-3} \cdot \frac{\Omega}{cm}$

$Rs2 := Rcus2 \cdot MPL \cdot Ns2$ S1 Wire Resistence

$Rs2 = 0.14\,\Omega$

$Pcus2 := Is2RMS^{2} \cdot Rs2$ Power Loss to the Cu in the S1 winding

$Pcus2 = 6.173 \times 10^{-4}\,W$

$PxfmrLoss := Pg + PcuPri + Pcus1 + Pcus2$

$PxfmrLoss = 4.816\,W$

$$\Delta T := \left[\frac{\frac{PxfmrLoss}{W} \cdot 10^{3}}{\left(\frac{At}{cm^{2}}\right)} \right]^{.833} \; °C$$

Estimated Temperature
Rise over Ambient

$\Delta T = 69.035 \cdot °C$