Electrical Parameters

$\Delta\beta m := 0.32T$ **Peak Operating Flux Density for the transformer Tesla**

$Fsw := 20KHz$ **Switching Frequency**

$IpRMS := 5A$

$Pin := 5W$

Find the size of core Required

$CM := 0.000005067cm^2$

$Idensity := 500\frac{A}{cm^2}$

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

$$Dcma := \frac{m^2}{Idensity \cdot CM}$$

Kt = 100 Push Pull
Kt = 140 Half Bridge
Kt = 140Full Bridge
Kt = 50 Forward Converter
Kt = 33 Flyback (Single Winding)
Kt = 25 Flyback (Multiple Winding)

$Kt := 100$

$$ApRequired := \frac{Pin \cdot Dcma}{Kt \cdot \Delta\beta m \cdot Fsw \cdot 10^7}$$

$ApRequired = 0.031 \cdot cm^4$

Core Parameters EE2005S Cosmo CF139

$Ac := 0.335cm^2$ **Core cross sectional winding area**

$MPL := 4.49cm$ **Magnetic Path Length from core data sheet**

$MLT := 3.64cm$ **Mean Length per Turn from bobbin data sheet**

$Volfe := 0.00cm^3$ **Core Fe Volume**

$CoreWid := 2cm$ **Core Width (C)**

$CoreLen := 0.59cm$ **Core Length (2B)**

$CoreHt := 2.04cm$ **Core Height (A)**

$WindowWidth := 1.4cm$ **Winding Window Width (2F)**

$WindowHt := 0.4cm$ **Window Winding Height (D-E)/2**

$\mu := 2100$ **Core Permeability**

$Wa := WindowWidth \cdot WindowHt$ **Window Area**

$Wa = 0.56 \cdot cm^2$

$UseableWindow := Wa \cdot 0.29 = 0.162 \cdot cm^2$

$BobbinWidth := WindowWidth - 2.2mm$

$BobbinWidth = 1.18 \cdot cm$

Use this equation or enter from bobbin mfg datasheet. Use 2.2mm when using tripple insulated wire and 8.2mm when using margin tape.

$Ap := Wa \cdot Ac$

$Ap = 0.188 \cdot cm^4$ **Power Handling ability of the core**

$At := 2 \cdot CoreLen \cdot CoreWid + 2 \cdot CoreLen \cdot CoreHt + 2 \cdot CoreWid \cdot CoreHt$

$At = 12.927 \cdot cm^2$

Surface Area for heat dissipation
For EE/ER style transformers use the above but
substitute for Core Height the following: CoreHt+2*WindowHt

Constants

$Ki := 0.0388$	**Gap Loss Coefficient**
$Kw := 0.866$	**Winding factor**
$Ku := 0.29$	**Window utilization factor use 40% for most cases**
$Kf := 4$	**Waveform coefficient use 4 for a square wave or 4.4 for a sinewave**

Coil Calculations

$Ipk := 7A$ Peak Current through the Coil

$$Irms := \sqrt{(2 \cdot Ipk)^2} = 14\,A$$

$Lp := 33\mu H$ Primary Side Inductance

$$Np := \frac{Ipk \cdot Lp}{\Delta\beta m \cdot Ac}$$

Adjust ΔI and Δβm above to get a whole number for Np

$Np = 21.549$

$Np := 22$

$lg := 0.94mm$

$$FFlux := 1 + \frac{lg}{\sqrt{Ac}} \cdot \ln\left(\frac{2 \cdot WindowWidth}{lg}\right)$$

$FFlux = 1.551$

$$Lgapped := \frac{\left(0.4 \cdot \frac{H}{m} \cdot \pi \cdot 10^{-6}\right) \cdot Np^2 \cdot FFlux \cdot Ac}{lg + \frac{MPL}{\mu}}$$

$Lgapped = 32.876 \cdot \mu H$ This needs to equal Lp $Lp = 33 \cdot \mu H$

$$Bmax := \frac{0.4\frac{H}{m} \cdot \pi \cdot Np \cdot FFlux \cdot (Ipk) \cdot 10^{-6}}{lg + \frac{MPL}{\mu}}$$

$Bmax = 0.312\ T$ Double Check this against your input requirement

$$\beta ac := \frac{0.4\frac{H}{m} \cdot \pi \cdot Np \cdot FFlux \cdot \left(\frac{Ipk}{1}\right) \cdot 10^{-6}}{lg + \frac{MPL}{\mu}}$$

$\beta ac = 0.312\ T$ AC Component

$\beta dc := Bmax - \beta ac$

$\beta dc = 0\ T$ DC component

$$Energy := \frac{Lp \cdot Ipk^2}{2}$$ Energy in W-S

$Energy = 0.000808\ J$

$Power := Energy \cdot Fsw = 16.17\ W$ Max Power available at that frequency and inductance

$$ALe := \frac{Lp}{Np^2 \cdot 10^{-3}}$$ Effective ALe gapped uH/1000 turns

$ALe = 68 \cdot \mu H$

$$H := \frac{0.4 \cdot \pi \cdot Np \cdot Ipk}{MPL}$$ Oersteds

$H = 43.10069 \cdot \frac{A}{cm}$

Check this against data sheet curves

$Pg := Ki \cdot \frac{10^4 W}{\left(m^2 T^2\right) Hz} \cdot WindowWidth \cdot lg \cdot Fsw \cdot \beta ac^2$

McLyman - Transformer and Inductor design Handbook

$Pg = 9.957\ W$

Skin Depth and Wire Selection

$\rho := 1.7241 \cdot 10^{-6} \Omega \cdot cm$	Nema M1000 pdf
$\alpha := 0.0039$	Temperature Compensation for Cu
$TempW := 90$	Degree C Operating Wire temperature
$Tambient := 20$	Ambient Wire Temperature the Cu constant was derived from

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

$\rho e = 2.195 \times 10^{-6} \cdot \Omega \cdot cm$

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

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

$\delta = 0.053 \cdot cm$ Skin Depth in cm

$MaxWireDia := 2\delta$

$MaxWireDia = 0.106 \cdot cm$ Maximum wire Diameter that uses 100% of the Cu area at the fundamental switching frequency

$MaxWireDia := 0.1cm$

$MaxWireOD := 0.12cm$ Wire Gauge is 18AWG

Primary Side Wire Selection

$WireDia := 1.0mm$

Bare Cu wire Diameter for the Primary Winding

$WireOD := 1.05mm$

Uses 2UEW (JIS Grade 2) See wire table

$$\frac{BobbinWidth \cdot 2}{Np} = 0.107 \cdot cm$$

Max wire dia for Np/2 turns

$$MaxTurn := floor\left(\frac{BobbinWidth}{WireOD}\right)$$

$MaxTurn = 11$

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

$$MaxISWG := Idensity \cdot \left(\frac{MaxWireDia}{2}\right)^2 \cdot \pi$$

$MaxISWG = 3.927\ A$

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

$SuggestedNumbStrands = 3.565$

$NumPriStrands := 4$

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

$WindingAreaPri := Np \cdot WireDia^2 \cdot NumPriStrands \cdot Kw$

$WindingAreaPri = 76.208 \cdot mm^2$

$AwbWinding := \pi \cdot \left(\frac{WireDia}{2}\right)^2 \cdot NumPriStrands$ Cross Sectional area of the stranded wire

$AwbWinding = 3.142 \cdot mm^2$

$RcuWinding := \frac{\rho e}{AwbWinding} \cdot MLT \cdot Np$ DCR Of the Winding

$RcuWinding = 5.595 \times 10^{-3} \Omega$

$PcuWinding := Ipk^2 \cdot RcuWinding$ Power Dissipation of the winding

$PcuWinding = 0.274\,W$

$Coilloss := Pg + PcuWinding$

$Coilloss = 10.231\,W$

$$\Delta T := \left[\frac{\frac{Coilloss}{W} \cdot 10^3}{\left(\frac{At}{cm^2}\right)}\right]^{0.833} {}^{\circ}C$$

Estimated Temperature
Rise over Ambient

$\Delta T = 259.651 \cdot {}^{\circ}C$

$WindingAreaTot := WindingAreaPri$

$WindingAreaTot = 0.762 \cdot cm^2$

$UseableWindow = 0.162 \cdot cm^2$

$PtotLoss := Coilloss$

$PtotLoss = 10.231\,W$