

## Flyback Transformer Calculations

### *Electrical Parameters*

$V_{acmin} := 88$	VrmsMinimum AC Input Voltage
$V_{acmax} := 264$	Vrms Maximum AC Input Voltage
$F_{acMainsMin} := 47Hz$	Minimum AC Mains Frequency
$i := V_{acmin} .. V_{acmax}$	Forward voltage drop of the diode in the input bridge rectifier
$V_{brfd} := 1.2V$	ACInput Voltage Range
$V_{pkmin} := V_{ac} V_{acmin} \cdot \sqrt{2} - 2 \cdot V_{brfd}$	Peak Rectified voltage at the Vac min point
$V_{pkmin} = 122.051 V$	
$V_{pkmax} := V_{ac} V_{acmax} \cdot \sqrt{2} - 2 \cdot V_{brfd}$	Peak Rectified voltage at the Vac max point
$V_{pkmax} = 370.952 V$	
$V_{o1} := 32V$	Output Voltage
$I_{o1} := 2.656A$	Output Current
$V_{fd1} := 0.9V$	Forward Voltage drop of the output rectifier
$V_{o2} := 13V$	Output Voltage
$I_{o2} := 0.04A$	Output Current
$V_{fd2} := 1.2V$	Forward Voltage drop of the output rectifier
$C_{bulk} := 150\mu F$	Nominal input bulk capacitance
$TolC_{bulk} := 20\%$	
$thold := 4ms$	Minimum Holdup requirements
$\tan\delta := 0.24$	Tan Delta of the Bulk Capacitor
$V_{brownout} := 80V$	Bulk Cap DC Voltage the brownout protection circuit trips in
$\eta := 88\%$	Expected PSU efficiency

$$PF := 0.55$$

**Expected Power Factor**

$$Vacnom := 115V$$

**Nominal AC Line voltage to consider the holdup time with**

$$DutyCycle := 56\%$$

**Max Primary side duty cycle at peak power**

$$Fsw := 80KHz$$

**Switching Frequency**

$$Leakage\% := 1\%$$

**Target ratio of Leakage Inductance to Primary Inductance**

$$Kcoupling := \sqrt{1 - Leakage\%}$$

**Transformer Coupling Factor**

$$Kcoupling = 0.995$$

$$Po := Vo1 \cdot Io1 + Vo2 \cdot Io2$$

**Output Power**

$$Po = 85.512 \text{ W}$$

$$Pin := \frac{Po}{\eta}$$

**Estimated Input Power**

$$Pin = 97.173 \text{ W}$$

### **Core Parameters**

$$Ac := 0.773 \text{ cm}^2$$

**Core cross sectional winding area**

$$MPL := 5.8 \text{ cm}$$

**Magnetic Path Length from core data sheet**

$$MLT := 4.9 \text{ cm}$$

**Mean Length per Turn from bobbin data sheet**

$$Volfe := 5.5 \text{ cm}^3$$

**Core Fe Volume**

$$CoreWid := 2.125 \text{ cm}$$

**Core Width**

$$CoreLen := 3.95 \text{ cm}$$

**Core Length**

$$CoreHt := 1.075 \text{ cm}$$

**Core Height**

$$WindowWidth := 3.17 \text{ cm}$$

**Winding Window Width**

$$WindowHt := 0.32 \text{ cm}$$

**Window Winding Height (B-φC)/2**

$$\mu := 2300$$

**Core Permeability**

$$Wa := WindowWidth \cdot WindowHt$$

**Window Area**

$$Wa = 1.014 \cdot \text{cm}^2$$

$$\text{BobbinWidth} := \text{WindowWidth} - 8.2\text{mm}$$

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

$$\text{BobbinWidth} = 2.35 \cdot \text{cm}$$

$$A_p := W_a \cdot A_c$$

$$A_p = 0.784 \cdot \text{cm}^4$$

Power Handling ability of the core

$$A_t := 2 \cdot \text{CoreLen} \cdot \text{CoreWid} + 2 \cdot \text{CoreLen} \cdot \text{CoreHt} + 2 \cdot \text{CoreWid} \cdot \text{CoreHt}$$

$$A_t = 29.849 \cdot \text{cm}^2$$

Surface Area for heat dissipation

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

### **Constants**

$$K_i := 0.0388$$

Gap Loss Coefficient

$$K_u := 0.32$$

Window utilization factor use 40% for most cases

$$K_f := 4$$

Waveform coefficient use 4 for a square wave or 4.4 for a sinewave

$$\text{offset} := 0.72\text{V}$$

Used on the bulk cap below

$$\text{offset115} := \text{offset} \cdot \frac{\text{Vacnom}}{\text{Vacmin} \cdot 1\text{V}}$$

New Offset for operation at 115V

## ***Bulk Capacitor Calculations***

$$C_{esr} := \frac{\tan \delta}{2 \cdot \pi \cdot 2 \cdot F_{acMainsMin} \cdot C_{bulk} \cdot (1 - TolC_{bulk})}$$

$$C_{esr} = 3.386 \, \Omega$$

This section is an approximation courtesy of Dr. Aaron Jungreis. These seem to be good for  $\Delta V$  less than about 50V

$$V_{BulkMin} := V_{pkmin} - \left[ \left( \frac{C_{esr}}{25\Omega} \right)^2 \cdot 1V + offset \right] \cdot \frac{P_{in}}{1W} \cdot \left[ \frac{100\mu F}{C_{bulk} \cdot (1 - TolC_{bulk})} \right]$$

$$V_{BulkMin} = 62.261 \, V \quad \text{Minimum Bulk Cap Voltage at Min Line and Frequency}$$

$$V_{acNomPk} := V_{acnom} \cdot \sqrt{2} - 2 \cdot V_{brfd}$$

$$V_{NomBulk} := V_{acNomPk} - \left[ \left( \frac{C_{esr}}{25\Omega} \right)^2 \cdot 1V + offset115 \right] \cdot \frac{P_{in}}{1W} \cdot \left( \frac{100\mu F}{C_{bulk}} \right)$$

$$V_{NomBulk} = 98.092 \, V$$

## ***Transformer Calculations***

$$I_{dc} := \frac{P_{in}}{V_{BulkMin} \cdot DutyCycle} \quad \text{Primary Side Square wave current}$$

$$I_{dc} = 2.787 \, A$$

$$\Delta \beta_m := 0.36967T \quad \text{Peak Operating Flux Density for the transformer Tesla}$$

$$\Delta I\% := 45.7\% \quad \text{Primary Side \% of IDC for Lp slope}$$

$$\Delta I := \Delta I\% \cdot I_{dc} \quad \Delta I = 1.274 \, A \quad \text{Slope defined by the primary inductance 200% is TM/DC}$$

$$I_{pk} := I_{dc} + \frac{\Delta I}{2} \quad \text{Peak Current through the primary side transformer}$$

$$I_{pk} = 3.424 \, A$$

$$T_{sw} := \frac{1}{F_{sw}} \quad \text{Switching Period}$$

$$T_{on} := T_{sw} \cdot DutyCycle \quad \text{On Time for the converter}$$

$$T_{on} = 7 \cdot \mu s$$

$$T_{off} := T_{sw} - T_{on}$$

$$L_p := \frac{V_{BulkMin} \cdot T_{on}}{\Delta I}$$

Required Primary Inductance

$$L_p = 342.188 \cdot \mu H$$

Primary Side Inductance

$$L_k := L_p \cdot \text{Leakage\%}$$

Leakage Inductance

$$L_k = 3.422 \cdot \mu H$$

Set to 342uH

$$L_m := L_p - L_k$$

Magnetizing Inductance

$$L_m = 338.766 \cdot \mu H$$

$$N_p := \frac{I_{pk} \cdot L_p}{\Delta \beta_m \cdot A_c}$$

Adjust  $\Delta I$  and  $\Delta \beta_m$  above to get a whole number

$$N_p = 41$$

$$l_g := .605 \text{ mm}$$

**Adjust  $l_g$  (Core Gap) until  $L_{gapped} = L_p$**

$$FFlux := 1 + \frac{l_g}{\sqrt{A_c}} \cdot \ln \left( \frac{2 \cdot \text{WindowWidth}}{l_g} \right)$$

Fringing Flux Caused by gapping the core

$$FFlux = 1.32$$

$$L_{gapped} := \frac{\left( 0.4 \frac{H}{m} \cdot \pi \cdot 10^{-6} \right) \cdot N_p^2 \cdot FFlux \cdot A_c}{l_g + \frac{MPL}{\mu}}$$

$$L_{gapped} = 3.42 \times 10^{-4} \text{ H}$$

**This needs to equal  $L_p$**

$$B_{max} := \frac{0.4 \frac{H}{m} \cdot \pi \cdot N_p \cdot FFlux \cdot (I_{pk}) \cdot 10^{-6}}{l_g + \frac{MPL}{\mu}}$$

Double Check this against your input requirement

$$B_{max} = 0.37 \text{ T}$$

$$\beta_{ac} := \frac{0.4 \frac{H}{m} \cdot \pi \cdot N_p \cdot FFlux \cdot \left( \frac{\Delta I}{2} \right) \cdot 10^{-6}}{l_g + \frac{MPL}{\mu}}$$

$$\beta_{ac} = 0.069 \text{ T}$$

AC Component

$$\beta_{dc} := B_{max} - \beta_{ac}$$

DC component

$$\beta_{dc} = 0.301 \cdot T$$

$$\text{Energy} := \frac{L_p \cdot I_{pk}^2}{2}$$

Energy in W-S

$$\text{Energy} = 2.006 \times 10^{-3} \text{ J}$$

Available energy storage in the gap

$$\text{Energy} \cdot F_{sw} = 160.453 \text{ W}$$

Max Power available at that frequency and inductance

$$A_{Le} := \frac{L_p}{N_p^2 \cdot 10^{-3}}$$

Effective  $A_{Le}$  gapped uH/1000 turns

$$A_{Le} = 203.563 \cdot \mu\text{H}$$

$$\underline{H} := \frac{0.4 \cdot \pi \cdot N_p \cdot I_{pk}}{MPL}$$

Oersteds

$$H = 30.414 \cdot \frac{\text{A}}{\text{cm}}$$

Check this against data sheet curves

$$P_g := K_i \cdot \frac{10^4 \text{ W}}{(\text{m}^2 \text{ T}^2)_{\text{Hz}}} \cdot \text{WindowWidth} \cdot l_g \cdot F_{sw} \cdot \beta_{ac}^2$$

McLyman - Transformer and Inductor design Handbook

$$P_g = 2.812 \text{ W}$$