

## DC INDUCTOR DESIGN USING AMORPHOUS CORE

### DESIGN OF OUTPUT INDUCTOR FOR THE PHASE SHIFTED FULL BRIDGE.

The purpose of the output inductor is to store energy for the load during the time each switching cycle when the power switches (BJTs, MOSFETs or IGBTs) are turned off. The electrical function of the output inductor is to integrate the rectangular switching pulses (pulse width modulated signals with varying duty cycle) into DC.

To keep the RMS current in the output capacitance to a minimum,  $L_{out}$  will be designed for specified inductor ripple.

#### SPECIFICATION

$$V_{in} := 700 \text{ V}$$

$$P_{out} := 10 \text{ kW}$$

$$f_{sw} := 50 \text{ kHz}$$

In this particular design  $V_{out}$ :

$$V_{out} := 650 \text{ V}$$

Turns ratio  $a1 = N_p/N_s$ :

$$D_{max} := 0.7$$

$$a1 := 1$$

$$V_{rdson} := 0.3 \text{ V}$$

$$I_{rms} := 20 \text{ A}$$

$$L := 360 \text{ } \mu\text{H}$$

$$dI_{max} := 0.6 \text{ A}$$

$$I_{rms} := 20 \text{ A}$$

$$B_{max} := 0.8 \text{ T}$$

$$dT_{max} := 40 \text{ } ^\circ\text{C}$$

$$I_{short} := 25 \text{ A}$$

#### SELECT CORE MATERIAL

Amorphous:

- Extremely Low Core Loss
- High Permeability
- High Efficiency
- Smaller Size and Weight

SELECT CORE SIZE USING AREA PRODUCT FORMULA, SEE TI SLUP132

$$K := 0.03$$

$$AP := \left( L \cdot I_{short} \cdot \frac{I_{rms}}{B_{max} \cdot K} \right)^{\frac{4}{3}} = 14.681 \text{ m}^3 \cdot \text{A}^{\frac{4}{3}}$$

See TI slup132

$$AP := 14.681 \text{ cm}^4$$

Conservatively choose amorphous core AMCC25:

$$a := 13 \text{ mm}$$

$$d := 25 \text{ mm}$$

$$b := 15 \text{ mm}$$

$$c := 41 \text{ mm}$$

$$c := 56 \text{ mm}$$

$$f := 82 \text{ mm}$$

$$Aw := b \cdot c = 8.4 \text{ cm}^2$$

$$lm := 19.6 \text{ cm}$$

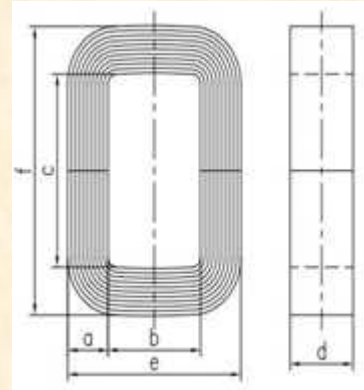
$$Ap := 22.7 \text{ cm}^4$$

$$Mass := 0.38 \text{ kg}$$

$$Ae := 2.7 \text{ cm}^2$$

$$AP := Aw \cdot Ae = 22.68 \text{ cm}^4$$

It is more than min AP value according to calculation above equal to 14.68cm<sup>4</sup>



CALCULATE MAX TURNS

Bobbin C0025I for AMCC25 core

$$ab := 14.5 \text{ mm}$$

$$bb := 26.3 \text{ mm}$$

$$cb := 28.4 \text{ mm}$$

$$db := 44 \text{ mm}$$

$$t := 1 \text{ mm}$$

$$eb := 8.8 \text{ mm}$$

$$fb := 54.4 \text{ mm}$$

$$hb := 52.4 \text{ mm}$$

$$jb := 60.4 \text{ mm}$$

#### AWG HEAVY INSULATION DIAMETER:

according to slup132:

$$J := 420 \frac{A}{cm^2}$$

$$Area := \frac{I_{rms}}{J} = 0.048 \text{ cm}^2$$

Tentatively choose AWG12 double insulation copper wire

$$D12 := 2.16 \text{ mm}$$

$$D12 = 0.085 \text{ in}$$

$$Area := \pi \cdot \left(\frac{D12}{2}\right)^2 = 0.037 \text{ cm}^2$$

Core losses are expected to be low as dB is low.

Wire thicker than AWG12 is difficult to use in production, therefore AWG12 stays.

#### MAX TURNS PER LAYER:

$$N12 := \text{floor}\left(\frac{hb}{D12}\right) = 24$$

Conservatively choose 20 turns per layer.

40 turns total for 2 bobbins

$$N := 40$$

#### MAX FLUX DENSITY SWING AND MIN INDUCTANCE FROM GIVEN DIMAX:

$$dB := L \cdot \frac{dI_{max}}{N \cdot Ae} = 0.02 \text{ T}$$

$$lg = 59.369 \text{ mil}$$

$$L := N \cdot dB \cdot \frac{Ae}{dI_{max}} = 0.36 \text{ mH}$$

Gap in each leg:

$$lg := \mu_0 \cdot N^2 \cdot \frac{Ae}{L} = 1.508 \text{ mm}$$

$$lg_{leg} := \frac{lg}{2} = 30 \text{ mil}$$

$$lg := 60 \text{ mil}$$

#### EFFECTIVE RELATIVE PERMEABILITY

$$\mu_e := lg \cdot \frac{L}{N^2 \cdot Ae \cdot \mu_0} = 1.011$$

## WIRE LENGTH AND DCR

$$\text{turn}_{12} := 2 \cdot (ab + D_{12}) + (2) (bb + D_{12}) = 0.09 \text{ m}$$

$$\text{Length} := N \cdot \text{turn}_{12} = 3.61 \text{ m}$$

$$\text{Length} = 11.843 \text{ ft}$$

$$R_{12ft} := (1.588) 10^{-3} \frac{\Omega}{\text{ft}}$$

$$R_{12} := R_{12ft} \cdot \text{Length} = 0.019 \Omega$$

## POWER LOSS CALCULATION

$$P_{\text{coreWkg}} := 6.5 \cdot \left( \frac{f_{sw}}{1000} \right)^{1.51} \cdot dB^{1.74} = 2.643 \frac{\text{kg}^{\frac{87}{50}}}{\text{s}^{\frac{499}{100}} \cdot \text{A}^{\frac{87}{50}}} \quad \text{See Power Loss curve}$$

$$\text{Mass} = 0.38 \text{ kg}$$

$$P_{\text{core}} := (P_{\text{coreWkg}}) \cdot \text{Mass} = 1.004 \frac{\text{kg}^{\frac{137}{50}}}{\text{s}^{\frac{499}{100}} \cdot \text{A}^{\frac{87}{50}}}$$

$$P_{\text{core}} := 1.004 \text{ W}$$

$$P_{\text{wire}} := I_{\text{rms}}^2 \cdot R_{12} = 7.522 \text{ W}$$

$$P_{\text{loss}} := P_{\text{wire}} + P_{\text{core}} = 8.526 \text{ W}$$

## THERMAL RESISTANCE OF THE CORE APPROXIMATION (TI SLUP 132)

$$T_k := 36 \text{ cm}^2 \cdot \frac{\Delta^\circ\text{C}}{\text{W}}$$

$$R_e := \frac{T_k}{A_w} = 4.286 \frac{\Delta^\circ\text{C}}{\text{W}} \quad \text{Temperature rise}$$

$$T_r := R_e \cdot P_{\text{loss}} = 36.542 \Delta^\circ\text{C}$$

RE-CHECK FLUX DENSITY TOTAL:

$$N = 40$$

$$I_{max} := 20.6 \text{ A}$$

$$l_g = 1.524 \text{ mm}$$

$$N := 40$$

Magnetic Field Strength:

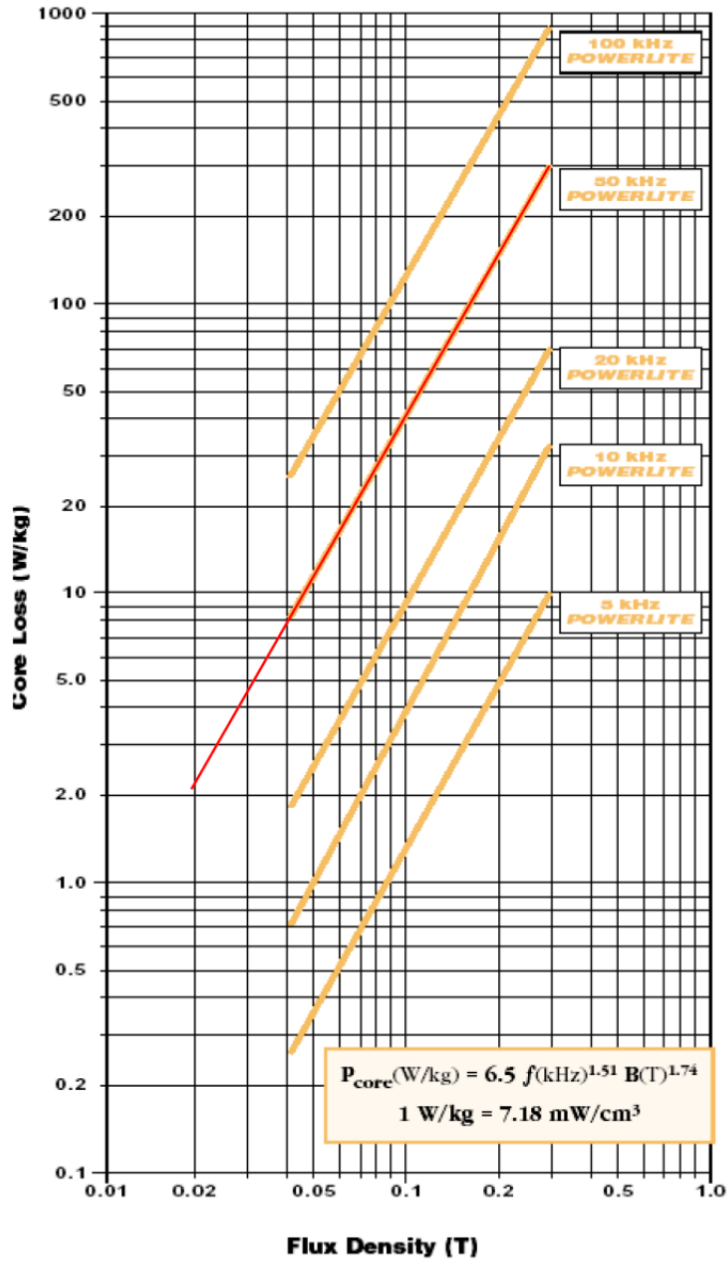
$$H := \frac{0.4 \cdot \pi \cdot N \cdot I_{max}}{l_g} = (8.538 \cdot 10^3) \text{ Oe}$$

$$B := H \cdot \mu_0 = 0.854 \text{ T}$$

$$B_{total} := B + dB = 0.874 \text{ T}$$

Btotal is less than Bmax for amorphous core according to specification/ datasheet

**Core Loss vs. Flux Density† @ 25°C**



† These curves were determined from ac data; use 1/2 the actual B to determine core loss for unidirectional applications.

