Is Now Part of

To learn more about ON Semiconductor, please visit our website at
www.onsemi.com

AN-9091

Boost PFC Inductor Design Guide for PFC SPM® Series

System Configurations

The block diagram in Figure 1 shows PFC SPM® 3 series ver.2, FPAB20BH60B, used in a boost Power Factor Correction (PFC) topology. The inductor (L) is located between pin 24 and pin 25 of the FPAB20BH60B on the boost PFC SPM evaluation board.

Inductor design is crucial to achieving the objective of power factor correction. It should be designed optimally to pass the harmonic guideline without increasing the system cost. Table 1 shows typical operating conditions of the FPAB20BH60B evaluation board under test.

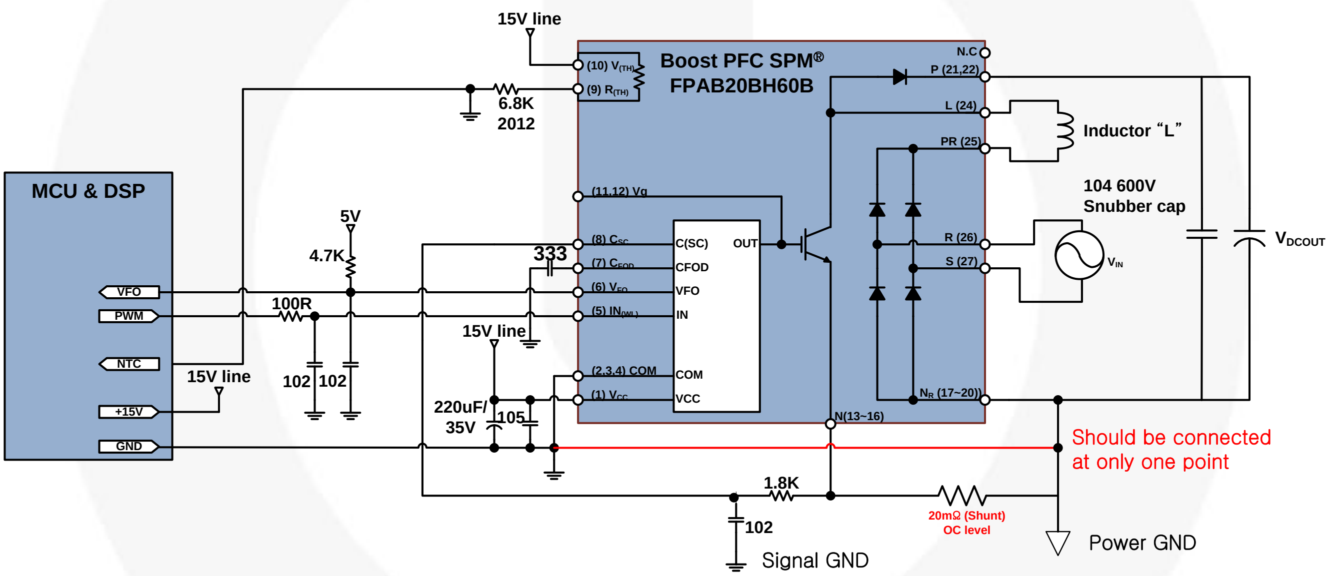


Figure 1. Block Diagram of Boost PFM SPM Evaluation Board

Table 1. Typical Operating Conditions

No.	Item	Symbol	Value	Unit
1	Switching Frequency	f	22	kHz
2	Normal Input Voltage	V_{IN}	220	V_{RMS}
3	Output Maximum Power	P_O	2200	W
4	Nominal Output Voltage	V_{DCOUT}	390	V_{DC}

Calculation of Inductance L

The following equation is used to calculate the inductance value (L) of the inductor. It is obtained from ripple current by the inductor located between the AC input and the DC link voltage. Please refer to AN-42047.

$$\Delta I_{LP\_P} = \frac{V_{IN}(V_{OUTDC}-V_{IN})}{fLV_{OUTDC}}, < \frac{V_{OUTDC}}{V_{IN}} = \frac{1}{1-D}, \quad \Delta I_{LP\_P} = \frac{V_{IN}*D*T}{L} \qquad (1)$$

where:

$\Delta I_{LP\text{-}P}$: Peak to peak current of PFC inductor;

V_{IN}: Input AC voltage (V_{RMS});

V_{OUTDC}: DC link Voltage (V);

f: Switching frequency (Hz); and

L: Inductance of PFC inductor (H).

$$\Delta I_{LP\_P} = \frac{V_{IN}(V_{OUTDC}-V_{IN})}{fLV_{OUTDC}}, \quad \therefore (\Delta I_{LP\_P})_{MAX} = \frac{V_{OUTDC}}{4fL}, \therefore V_{IN} = \frac{1}{2}V_{OUTDC} \qquad (2)$$

Assuming that f=22 kHz, V_{OUTDC}=390 V_{DC}, ΔI_{LP_P}=4.0 A, it's possible to calculate inductance L as follows:

$$L = V_{OUTDC}/(4 \times f \times \Delta I_{LP\_P}) = 390V_{DC}/(4 \times 22kHz \times 4.0A) = 1.108mH \qquad (3)$$

Selection of Wire Diameter

In the operating conditions of Table 1, the rated output power is 2.4 kW and rated voltage of AC input is 220 V_{AC}. Obtain the maximum input current as:

$$I_{AC\_MAX} = 2.2kW/220V_{AC} = 10.0Arms \qquad (4)$$

Assuming that the rms current per square mm of copper wire is 5 [Arms/ mm^2], the area and diameter of wire are calculated as follows:

$$Aw = I_{AC\_MAX}/(5[A/mm^2] = 10.0Arms(5[A/mm\text{^}2]) = 2.0mm^2] \qquad (5)$$

$$\text{Radius of wire} = SQRT(Aw/3.14) = SQRT(2.0/3.14) = 0.80[mm] \qquad (6)$$

From this, 2.0 mm-diameter copper wire with was chosen.

Core Selection

There are many things to consider when choosing a core: core material, core permeability, effective cross-section area (cm^2), magnetic path length (cm), and nominal inductance (nH/N^2). For performance, a Mega Flux® core was selected.

$$\text{Core}: CK740060C \qquad (7)$$

$$\text{Magnetic Path Length } l = 18.38cm = 183.8mm \qquad (8)$$

$$\text{Cross Section Area A} = 5.04cm^2 = 183.8mm \qquad (9)$$

$$\text{Initial permeability u} = 60 \times 4 \times 3.14 \times 1e-10(H/mm) \text{ at } 25kHz \qquad (10)$$

Material Properties

- Chemical composition: Fe – Si alloy
- Saturation flux density: 16.000 Gauss
- Curie temperature: 550°C
- Initial permeability: 60 µ ±12%, Measured at 25 kHz, 1 V, and 0 A_{DC}

Dimensions

Magnetic Dimensions

- Magnetic Path Length: 18.38 cm
- Cross Section Area: 5.04 cm^2

Physical Dimensions (Case)

- OD: 79.50 sm (Maximum)
- ID: 41.14 cm (Minimum)
- HT: 55.0 cm (Maximum)

Case

- Composition: PBT (POLY BUTHYLENE TERPHTALATE)
- Maker: KOLON
- UL FLAME CLASS & FILE NO: UL 94-VO, E88499

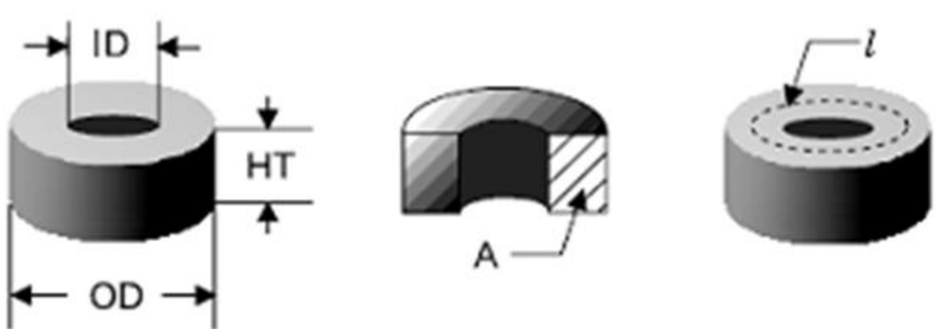


Figure 2. Specification of the Selected Toroidal Core: CK740060C

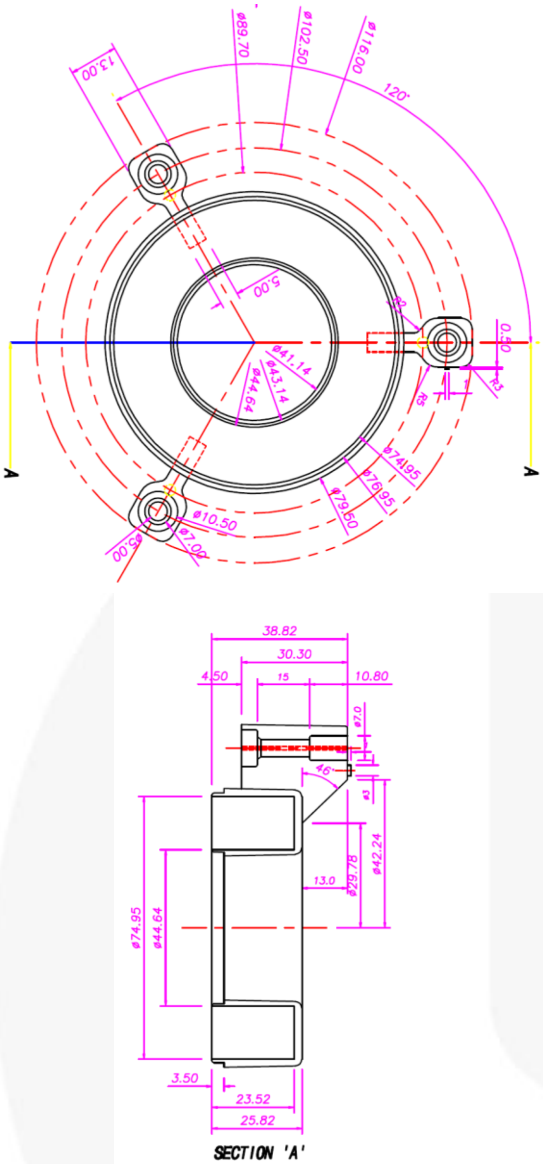


Figure 3. Core Case Sizes

Calculation of Wire Turn Number

A boost PFC inductor with a toroidal core and its wiring is shown in Figure 4.

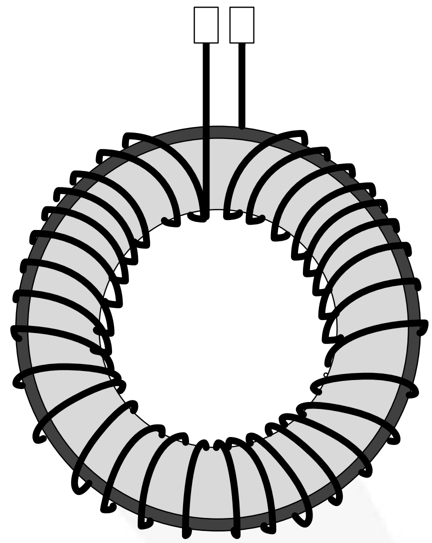


Figure 4. Wiring of Boost PFC SPM Inductor with Toroidal Core

In case of inductor, calculate the turn number (N) of each wire using the following equation and referring to website: http://www.changsung.com:

$$L = \frac{0.4\pi\mu N^2 A * 10^{-2}}{1} \tag{11}$$

From the core parameters in Equations (8) - (10), and (11), N is calculated as follows:

$$N = SQRT(1.108mH \times 183.9 / (60 \times 4 \times 3.14 \times 1e-10 / H \times 504) = 74turn \tag{12}$$

From this, choose a turn number above the obtained 74 turns. 74 turns of wire was selected as the final turn number of the boost PFC SPM® inductor.

Implementation of PFC Inductor

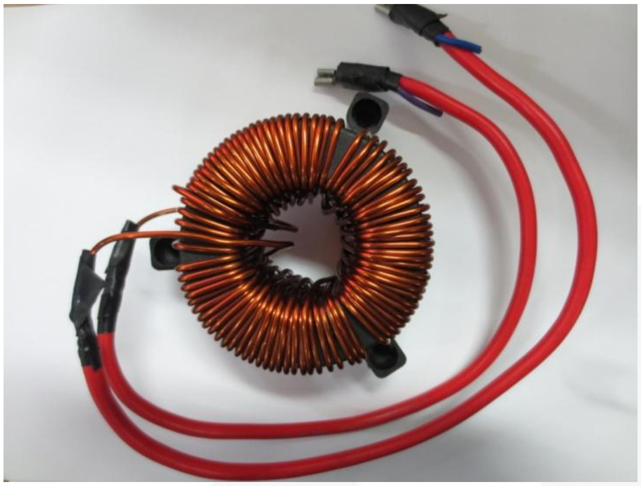


Figure 5. Top View of Inductor

Figure 6. Copper Wire Width (2.01 mm)

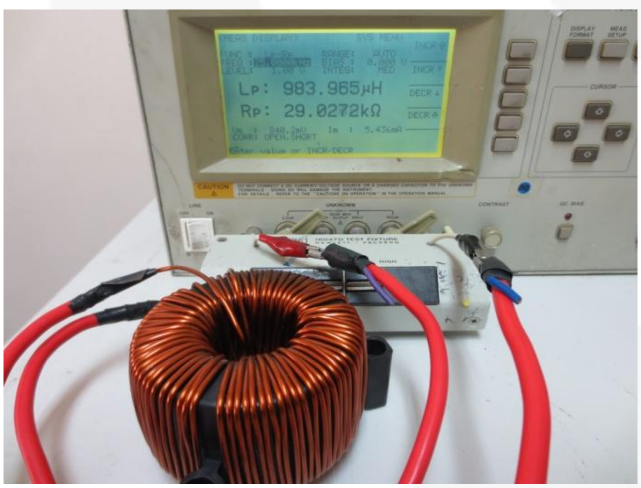
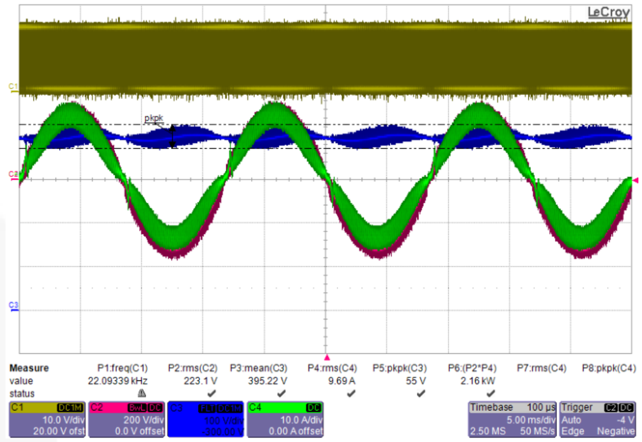


Figure 7. Inductance of Inductor (0.98 mH)

According to calculation, the selected copper wire is 2.0 mm and inductance is 1.1 mH. Actual values were copper wire 2.01 mm and inductance 0.98 mH.

Design Verification through Test



CH1: PWM Signal [10 V/div], CH2: V_{AC_INPUT} [200 V/div], CH3: V_{DC} Voltage [100 V/div], CH4: Inductor Current [10 A/div]

Figure 8. Full Load Test Results (at 9.69 Arms)

It was verified that the maximum ripple current of inductor current is about 4 A_{PK_PK}, which is similar to the assumption of ΔI_{LP_P} in Equation (3).

References

AN-42047 — Power Factor Correction (PFC) Basics

AN-6982 — Power Factor Correction Converter Design with FAN6982

Magnetic Powder Cores: http://www.changsung.com/

PUBLICATION ORDERING INFORMATION

LITERATURE FULFILLMENT:
Literature Distribution Center for ON Semiconductor
19521 E. 32nd Pkwy, Aurora, Colorado 80011 USA
Phone: 303−675−2175 or 800−344−3860 Toll Free USA/Canada
Fax: 303−675−2176 or 800−344−3867 Toll Free USA/Canada
Email: orderlit@onsemi.com

N. American Technical Support: 800−282−9855 Toll Free USA/Canada
Europe, Middle East and Africa Technical Support:
Phone: 421 33 790 2910
Japan Customer Focus Center
Phone: 81−3−5817−1050

ON Semiconductor Website: **www.onsemi.com**

Order Literature: http://www.onsemi.com/orderlit

For additional information, please contact your local Sales Representative