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**EE464 STATIC POWER CONVERSION II**

**Simulation and Magnetic Design Report**

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## Introduction

This report is a combination of both “HW2” and “Simulation and Magnetic Design Report”. The contents include the topology selection, magnetizing inductor calculations, core selection steps, the simulation results and loss analysis. The aim of the report is to prepare a template for the hardware project circuit and face the design problems before implementation.

## Topology Selection

The topology selection is done via comparing the topology types that we learnt during the lectures. The selected topologies to compare are as follows:

* Flyback
* Forward
* Push-pull
* Full Bridge
* Half Bridge

Table 1: A basic comparison between several isolated DC-DC converters

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Topology Name | Optimal Power Demand | Efficiency | Number of Components | Voltage Stress | Cost |
| Flyback | Low (<500W) | High | 4 | High | Low |
| Half Bridge | Low (<500W) | High | 7 | High | Medium |
| Full Bridge | High (>1kW) | Medium | 9 | Medium | High |
| Push Pull | High (>1kW) | Medium | 8 | High | High |
| Forward | Low (<500W) | High | 7 | Medium | Low |

Table 2: A more detailed analysis between the topologies

|  |  |  |
| --- | --- | --- |
| Topology Type | Advantages | Disadvantages |
| Flyback | Simplest and most commonly used isolated DC-DC converter | Additional snubber circuit for the leakage inductance di/dt |
| Does not require a separate storage inductor | Relatively lower efficiency |
| Half Bridge | Higher power levels | Need to be careful with the switches not to short the input (leave dead time) |
| The switching stresses are equal to the input voltage | Less suitable for high output currents |
| Full Bridge | Even higher power levels | Need to be careful with the switches not to short the input (leave dead time) |
| Allows the power flow in both directions | Switching losses increase |
| Push Pull | Utilizes the core more efficiently, reaching high power levels | Switching control is a bit difficult |
| Output current is regulated with the output inductor | Switching stresses are high |
| Forward | Can supply high output currents with less di/dt | Extra inductor at the output |
| Gain equation is linear with the duty cycle | Not suitable for high output voltage |

Considering the positives and the negatives, our final topology choice is the flyback converter. The most critical factor is the component number and the cost for us. The control method is also relatively easier. The flyback converter also makes same as the highest efficiency is not required and the project is a low-power project. As a disadvantage, a snubber design is required.

## Flyback Converter Design

Specifications of the project are listed as follows:

* **Minimum Input Voltage**: 12 V
* **Maximum Input Voltage**: 18 V
* **Output Voltage**: 48 V
* **Output Power**: 48 W
* **Output Voltage Peak-to-Peak Ripple**: 3%
* **Line Regulation**(Deviation of percent output voltage when input voltage is changed from its minimum to maximum or vice versa): 3%
* **Load Regulation**(Deviation of percent output voltage when load current is changed from 10% to 100% or vice versa): 3%

Let’s choose duty cycle range as

for safe operation After that, boundaries of turns ratio becomes,

Let’s select turns ratio = N1/N2 = 1/3. After that,

Then,

when N2/N1 = 3.

In order to design convenient transformer, the magnetizing inductance should be decided. Maximum, average and RMS value magnetizing current should be calculated. When the switch is on, input current is equal to magnetizing current. However, input current is equal to 0 when the switch is off.

When the input voltage is equal to 12 V, duty cycle is equal to 0.58. Then,

When the input voltage is equal to 18 V, duty cycle is equal to 0.47. After that,

The ripple current formula is given below as;

We assume that fs = 50 kHz because a lot of controllers work at that frequency. Moreover, we should consider the case of input voltage = 18 V and D = 0.47 because ripple current is larger for larger Vin\*D values for same inductance value. In this case, the maximum ripple current would be equal to 5.67\*2 = 11.34 A to stay at continous conduction mode. Hence,

For the case of input voltage = 12 V, D = 0.58 and ripple current = 6.9\*2 = 13.8 A;

This result also verifies that Lm should be greater than 14.92 uH.

To decide the Lm current ripple we consider the 25% load case. For Vin = 18V, the minimum inductor current should not be dropping to zero. Then;

= 2.835 A

Imax = 6.9 + 2.835/2 = 8.318 A

Iavg\_max = 6.9 A

Then,

For the core selection, we consider magnetic flux, cross sectional area of the core and copper properties. First, we searched the ferrite cores, however, they are not suitable for flyback converter design if we do not use air gap. The reason is that they have large permeability so that they are not convenient for storing energy. Then, we look at Kool Mu cores from Magnetics from the excel table. We prepared Matlab Script that we also added it to the Github repository. We compared different cores from the Excel table that are already in the lab and will come in the May. Moreover, we have benefitted from the Magnetics Powder Core Catalog. We have specifications of;

* Minimum inductance = 59.68 uH
* The maximum current = 8.318 A (without losses)

After that, from the formula of

we moved on the core selector charts. Then, the core 00K4022E090 satisfied the requirements of our project. Moreover, it is also available in the lab.

The inductance factor of the core is AL = 281 nH/T^2. However, it can be as ±8%. Therefore, the minimum inductance factor is calculated as 258.52 nH/T^2.

We have calculated to primary number of turns as;

However, the number of turns should be integer number. Therefore, we have taken as

This number of turns is calculated assuming there are no change in AL. However, since AL changes with MMF, we have calculated MMF when I=.

According to the Typical DC Bias Performance from the datasheet, and assuming it is decreasing linearly from 0 to 420 A-t,

Since it can be as ±8%, AL = 274.19\*0.92=252.26. When we recalculate the turn number with new AL value

Hence the .

Now, we have to calculate the copper losses and core losses.

Approximate length of cable for 1 turn is equal to 2\*(F+C+2\*M)=100.9 mm. Additionally since we are working with 50kHz we choose AWG-23 cable which has and Hence,

Where : number of parallel cables at primary side

: number of parallel cables at secondary side

For core losses B=µ\*H.

Since both equation is related to when , we made iterative solution using MATLAB:

## A

## A

## Component Selection

Mosfet:

The maximum mosfet voltage is

On the other hand, the maximum switch current is

We have chosen IRF 540 N Mosfet because it has a current rating of 28 A and voltage rating of 100 V. This values guarantees proper operation. Moreover, it has a drain to source resistance of 44 mohm which is quite low.

Diode:

The maximum reverse voltage of the diode is equal to output voltage when the switch is on case and it is 48 V. Moreover, maximum current on the diode is

For the diode selection, we have chosen MBR10100G diode which has a current rating of 10A and voltage rating of 100V. Moreover, it has a forward voltage drop 0.8 V

1. **Figures with white background, axes names with good font.**
2. **Grammarly.**

## Conclusions

NOT SUMMARY

## References

[Switch Mode Power Supply Topologies: A Comparison (we-online.com)](https://www.we-online.com/en/news-center/blog?d=switch-mode-power-supply#:~:text=The%20difference%20between%20flyback%20vs,additional%20storage%20choke%20is%20needed.)

[The comparisons of DC DC converters | Download Table (researchgate.net)](https://www.researchgate.net/figure/The-comparisons-of-DC-DC-converters_tbl2_327422059)