Internship Report – Hong Kong

Design and Realization of Flyback DC/DC Converter

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Introduction

I was accepted on internship in Hong Kong at The Hong Kong Polytechnic University as part of the IAESTE International Exchange Program. It started on 6. 7. 2016 and ended on 27. 8. 2016. I was assigned a supervisor Dr. Kevin K. W. Chan and after discussion with him and with my project leader Dr. Nelson Chan, we agreed on my assignment. The topic was flyback DC/ DC converter. I was supposed to study the working principle at first. Then design my own flyback DC/ DC converter of 100 W output power with output voltage around 25 V and at the end I was supposed to create a prototype from the design and test it.

Design

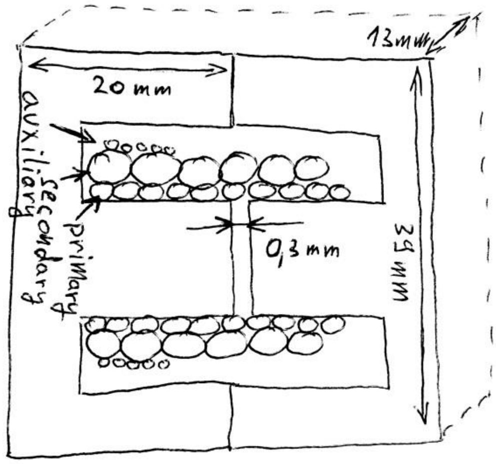
The design of whole device consisted of several partial tasks. They were the input rectifier, transformer, MOSFET, output rectifier, output filter and load.

Input rectifier and input filter

As input rectifier the four-diode bridge with capacitor of 100 µF capacity was chosen. The maximal input voltage for rectifier is expected to be from AC line up to 265 V AC and the minimum value to be 195 V.

Transformer

Transformer is used in the flyback topology for decreasing the voltage level to required value and to separate the electrical grounds. For decreasing the dimension of the transformer the high working frequencies are usually utilized. So for this high frequency transformer the ETD core with dimension 39/ 20/ 13 mm was selected. The necessary air gap was calculated to 0.3 mm. The number of primary turns was calculated to be 39 turns and because of the size of the transformer it needed to be laid in two layers. The necessary transformer ratio is 6.5:1 so the number of secondary turns was 6. Working frequency of the primary side of the transformer was determined to be 100 kHz and therefore according to that the maximum allowed width of the wire was AWG 26. The number of wires in parallel was determined according to the transferred current. On the primary winding, the RMS value of current was almost then 1 A so three wires in parallel were needed. On the secondary winding the RMS value of current was expected to be 7.5 A so there needed to be 22 wires in parallel. The designed transformer is shown in the picture below.



Power MOSFET

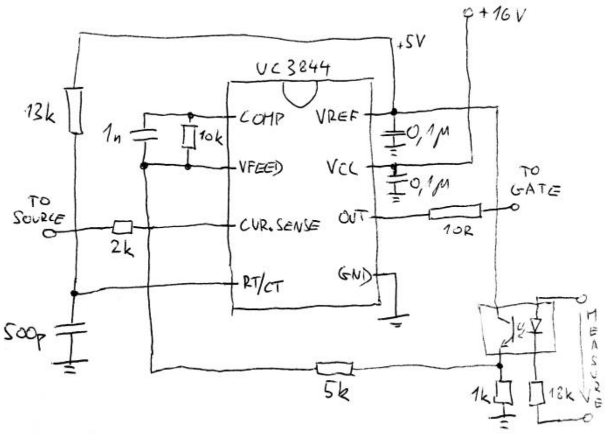
Power MOSFET is necessary to chop the rectified DC input into high frequency for the transformer. The most important parameter is the current switching ability. The transformer is connected to primary side of the transformer with current RMS value of 1 A but the transistor needed to be designed for current peaks which can go up to 2 A. Also the transistor’s switching and conduction losses had to be calculated. According to these parameter the right MOSFET was chosen.

Output rectifier and filter

The secondary side of the transformer needed to be rectified. Fast diodes are required because of the high working frequency. The UFR diode was chosen over Schottky diode thanks to its capability of higher current transmission. Output filter consisted of capacitors with high ripple current ability and low ESR. Because of the high current ripples five capacitors in parallel were necessary. LC filter at the output is then used to maintain constant voltage with load changes.

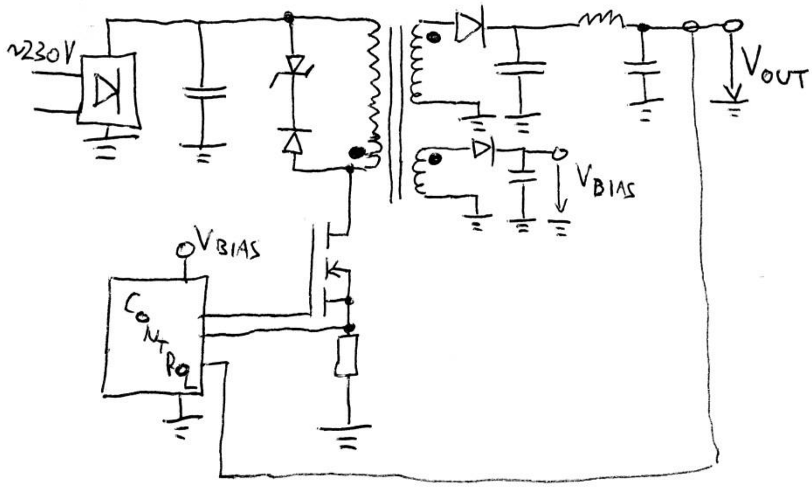
Control mechanism

This circuit creates PWM signal according to measured values. The MOSFET is then directly controlled by output of this circuit. For the control mechanism the UC3844 chip was chosen. The maximum duty cycle of the chip is 50%. The circuit for oscillator was designed for 200 kHz frequency in order to achieve 100 kHz output frequency of the PWM. The over-current measuring resistor was calculated to be 0.25 Ω so the circuit should turn off the MOSFET when the current exceeds 4 A. Also the circuit for optocoupler to separate power and control part with voltage divider for voltage feedback was calculated. The control circuit is shown in the picture below.



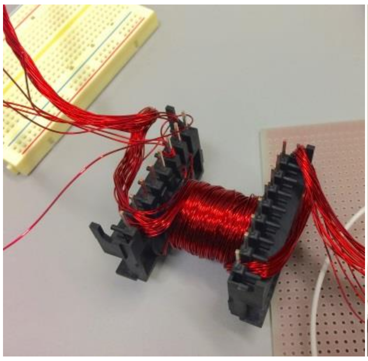
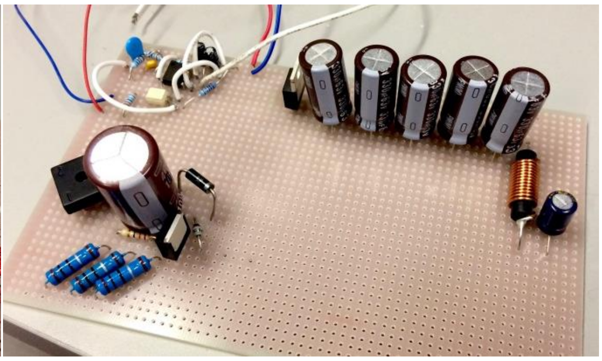
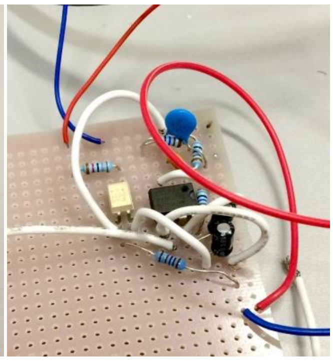
Load

The load was expected to be purely ohmic and fixed. The output power was according to the assignment 100 W and the voltage level was designed to be 25 V. It means the current is 4 A which makes the resistance around 6 Ω. The scheme of the whole design is shown in the picture below.

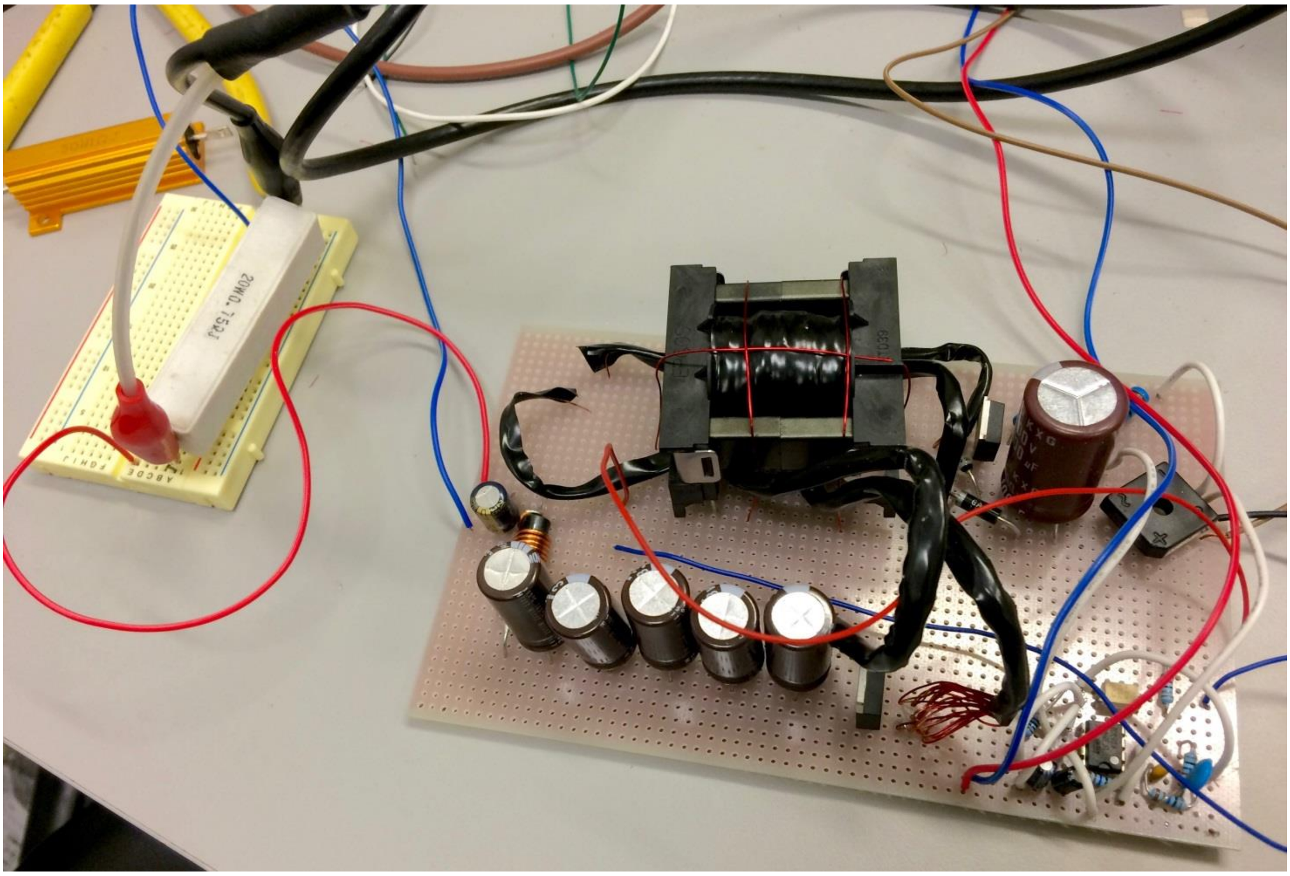


Prototype

Due to time limitation I was working on prototyping board. In general, it is not suitable for high frequency but there was not enough time to design and create PCB. At first, I created the transformer, control circuit and power part separately and then connected them together. The individual parts are shown on the pictures below.

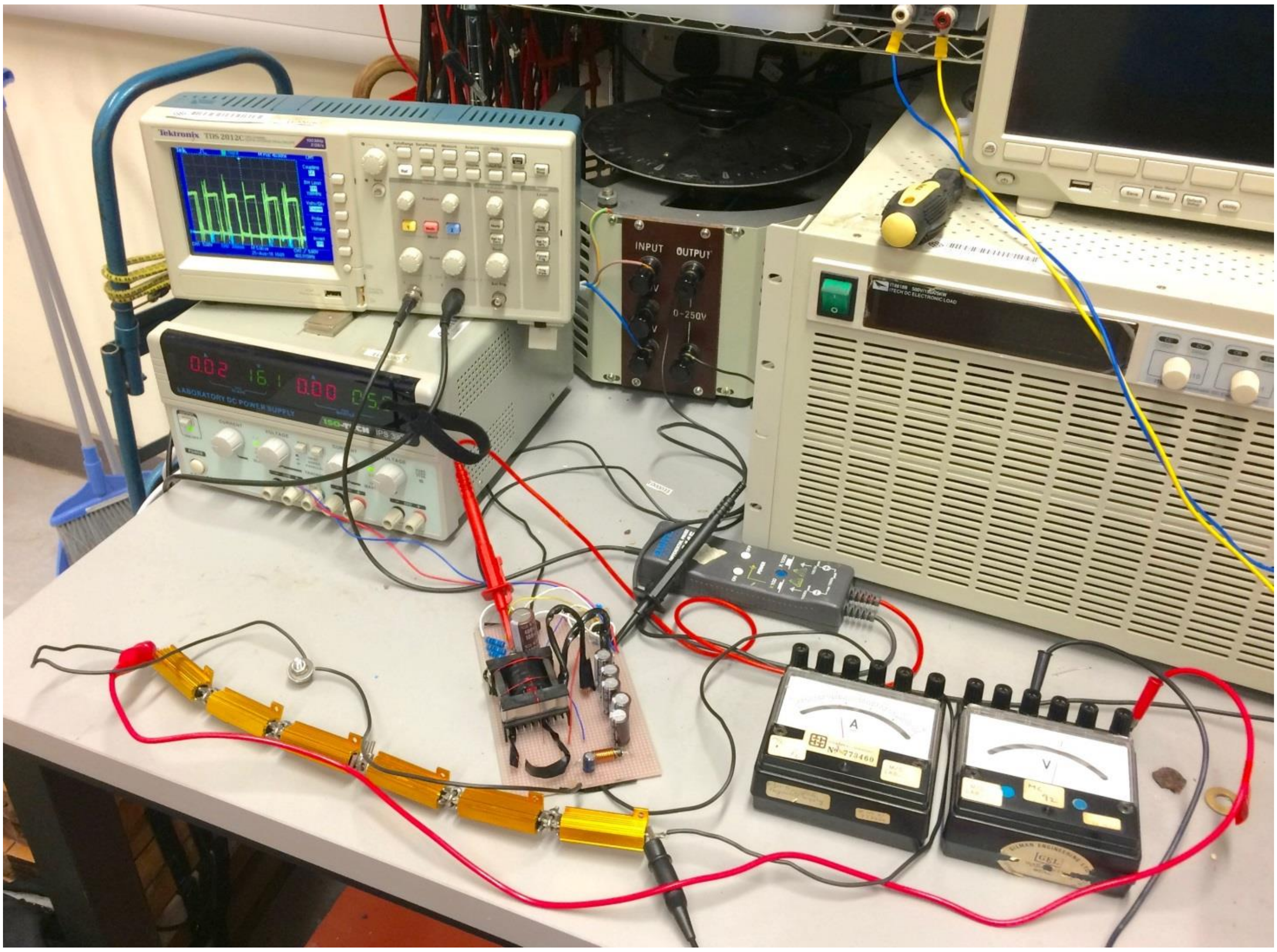
The only part that is missing is power supply for control circuit. Everything is prepared for this function but it was not connected and tested yet. For now it requires independent voltage source. The final prototype is in the picture below.



Testing

As power source for the power part the autotransformer was chosen and for the control circuit the laboratory DC source was chosen. During the tests a fixed load was used and the supply voltage on autotransformer was changing up to 230 V AC. Then the load was changed and the tests were repeated with voltage increasing. This was tested up to output power 70 W. The voltage level at the output was maintained at the value 25 V until 25 W load. During measurements behind this value the voltage started to sink slowly to 20 V. And finally at 70 W output power the voltage dropped suddenly from

20 V to 0 V. This drop was caused by the high current in the primary winding which triggered the over-current protection of the control circuit which shut down the device. As the device should handle the current at 70 W, the over-current protection was removed from the circuit in order to continue testing. During this test the current in primary winding of the transformer destroyed MOSFET and as a result from following short-circuit the control circuit got damaged as well. This happened even though the MOSFET was designed for higher current. The most probable cause of this is the fact that power transistor was used without cooling radiator, which reduced its current switching capabilities much more than it had been expected in the design. Because of the lack of time the repair was not possible, so the testing was ended at this point. The photo from measurement is shown below.



Result

To summarize what I have accomplished from the assignment. I designed the transformer for the 100 W output power with output voltage level 25 V. And I created the prototype. The device worked for 25 W well. With bigger power the device was working, but was unable to maintain the voltage level exactly on the desired value. The device was not able to work with load 70 W.