香港城市大學
City University
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Department of Electronic Engineering

FINAL YEAR PROJECT REPORT

BEngECE-2007/08-HC-02

Light dimmer for compact fluorescent lamps

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Bachelor of Engineering (Honours) in Electronic and Communication Engineering (Full-time)

Student Final Year Project Declaration

I have read the student handbook and I understand the meaning of academic dishonesty, in particular plagiarism and collusion. I declare that the work submitted for the final year project does not involve academic dishonesty. I give permission for my final year project work to be electronically scanned and if found to involve academic dishonesty, I am aware of the consequences as stated in the Student Handbook.

Project Title : Light dimmer for compact fluorescent lamps

Student Name : Sung Kai Tak

Student ID:

Signature

Date : 22 April 2008

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Acknowledgement

This is a perfect moment to thank my project supervisor Prof Henry Chung. He gave a hand when I can’t solve problems. And I learnt a lot from him, not only about electronic, but also valuable mind sets. Also, I would like to thank my assessor Chair Prof Ron Hui. He showed me fundamental equation which helps to predict circuit waveform precisely. Therefore, the waveform can be identified.

Abstract

In this project, the ac-ac converter, which uses Pulse Width Modulation (PWM) to control the output voltage, was created. This latest technique can be applied to control compact fluorescent lamps or other light devices. In order to improve the voltage and current stress, low loss snubber (approximated to soft switching) means is applied. Therefore, the produce can be compact and reduce the stress.

Chapter 1 Introduction

Nowadays, people in hk are becoming more aware of enviornmental protection and energy saving. Therefore, my project aims to develop a higher efficiency wall dimmer that can control load power of compact fluorescent lamps from 50% to 100%. The topology is using ac-ac converter which is using Pulse Width Modulation (PWM) to change the duty cycle and hence changes the output voltage.

In the control circuit, I had used the 89C2051 to generate the signal waveform. Then, it will pass through the signal to isolation circuit which can separate the power circuit and control circuit. Furthermore, using gate driver drives the MOSFET “ON” or “OFF”.

Specification of ac-ac converter:

Input ac voltage: 100Vac – 240Vac

Switching Frequency: 25 kHz

Switching Topology: Pulse Width Modulation

Power rating: 300W (max: 350W)

Dimming: Compact fluorescent lamps, Fluorescent lamps and lamps

Chapter 2: Comparison with other types dimming method

2.1 Triac

Condition: Output power = 1100W, input voltage = 220V

Advantage:

1) Size is small
2) Simple circuit design
3) Can dim lamps
4) Not expensive

Disadvantage:

1) Switching noise is serious
2) Efficiency is lower
3) Can’t dim compact fluorescent lamps and fluorescent lamps

2.2 ac-dc, dc-ac

Condition: Output power = 1100W, input voltage = 220V

Advantage:

1) Can step up and down the output voltage
2) Can change the output frequency
3) Can dim the compact fluorescent lamps, fluorescent lamps and lamps

Disadvantage:

1) Size is large
2) Complex circuit design
3) Efficiency is not good enough
4) Expensive
5) Higher harmonic noise

2.3 ac-ac converter

Condition: Output power = 1100W, input voltage = 220V

Advantage:

1) Size is medium
2) Efficiency is higher
3) Can dim the compact fluorescent lamps, fluorescent lamps and lamps
4) The load can be mixed with different type, such as inductively + capacitive loading

Disadvantage:

1) Can't step up the output voltage
2) Can't change the output frequency
3) Complex circuit design
4) Higher harmonic noise
5) Expensive

Chapter 3: ac-ac converter

3.1 Function block diagram

Assume the input ac voltage is 220V. The duty cycle changes from 55% to 95% while the output voltage also changes from 121V to 209V.

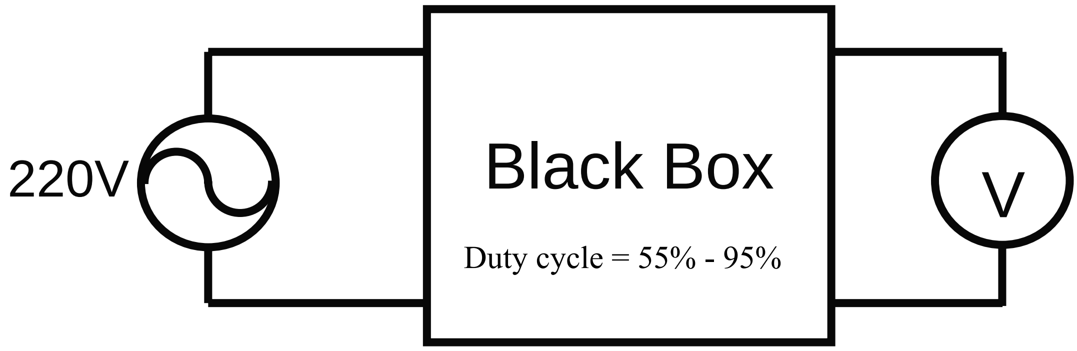


Fig 3.11: Block Diagram of ac-ac Converter

Black Box

Inside the black box, it includes two LC filters and two bi-directional switches.

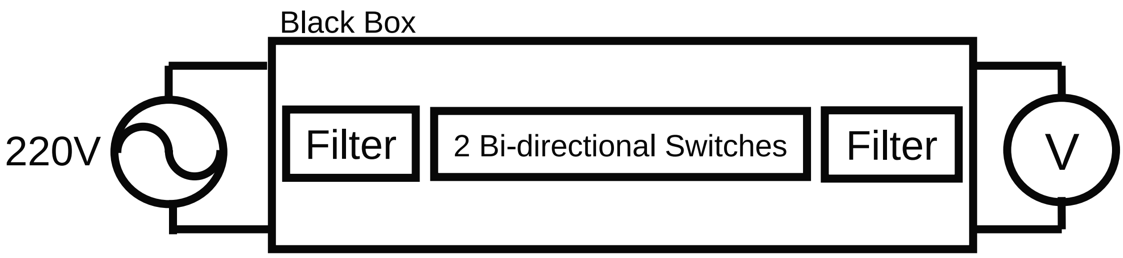


Fig. 3.12 Structure of ac-ac Converter

3.2 ac-ac converter topology

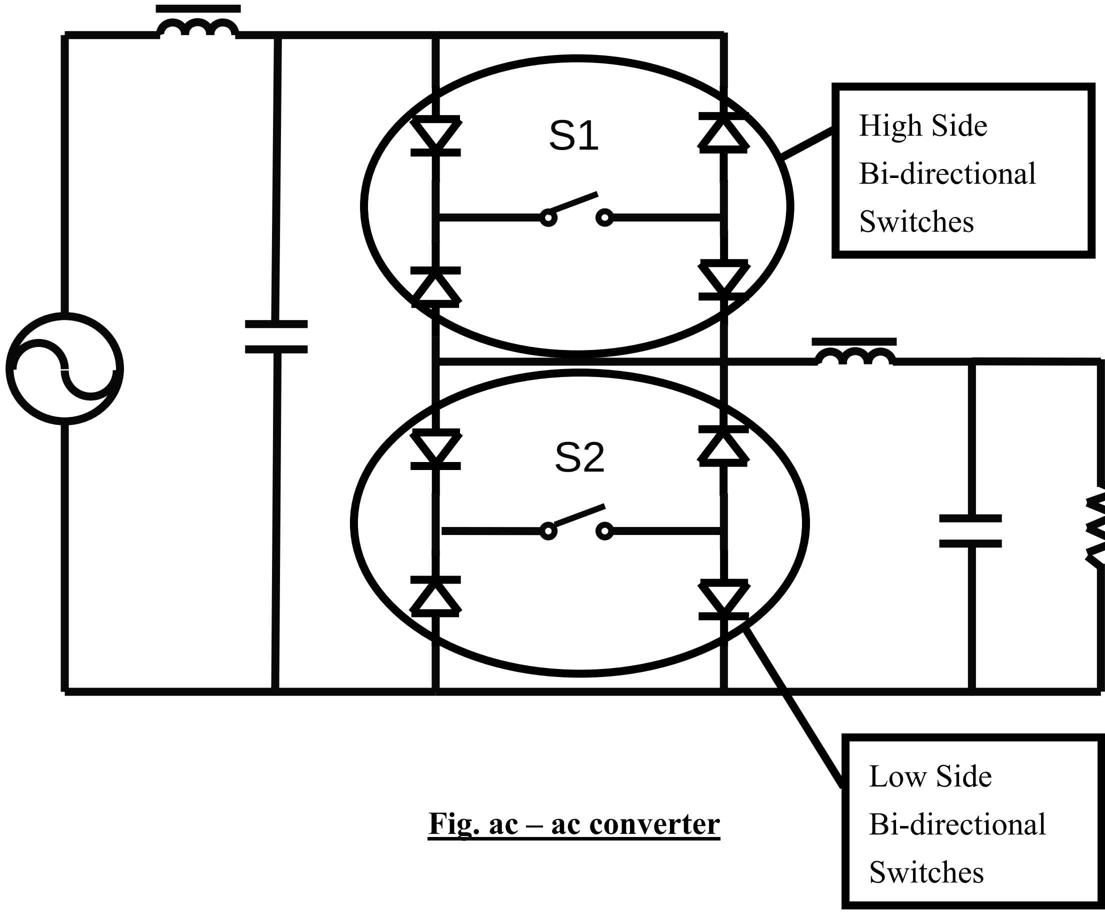


Fig. ac – ac converter

Fig. 3.2: High/ Low side Bi-directional Switches

3.2.1 ac-ac converter operation principle

Assume the ac power line is positive cycle. Then S1 is from “off” to “on” while the S2 is o n the “of f” state. Therefore, the lower side b i-direction s witches can disable.

The power will transfer to the load using the arrow part.

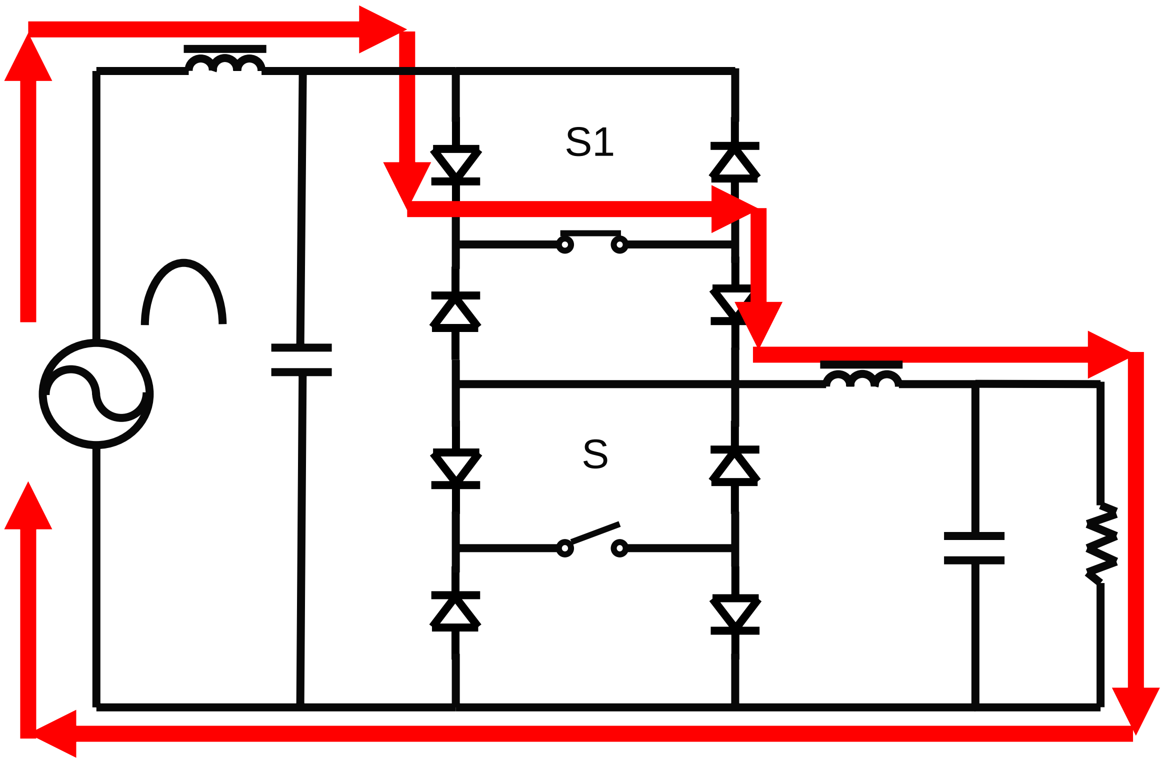


Fig 3.2.11: S1 is “on” and Input voltage is positive cycle.

The S1 is from “on” to “off” while the S2 is from “off” to “on”. The lower side bi-directional switches are for the in ductor current free-wheeling. It is because the inductor current can’t sudden stop.

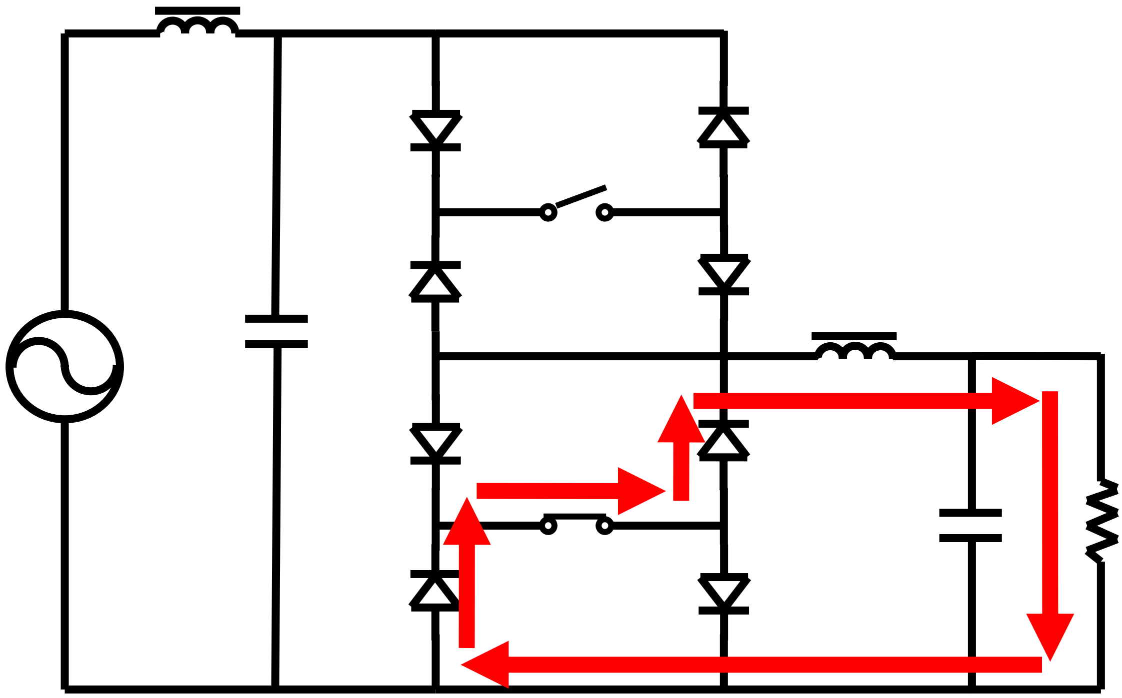


Fig 3.2.12: S1 is “off” and Input voltage is positive cycle.

Assume the ac power line is negative cycle. Then S1 is from “off” to “on” while the S2 is on the “off” state. It is quite similar to the positive cycle operation but the different is the power flow which is the direction reversed .The power will transfer to the load using the arrow part.

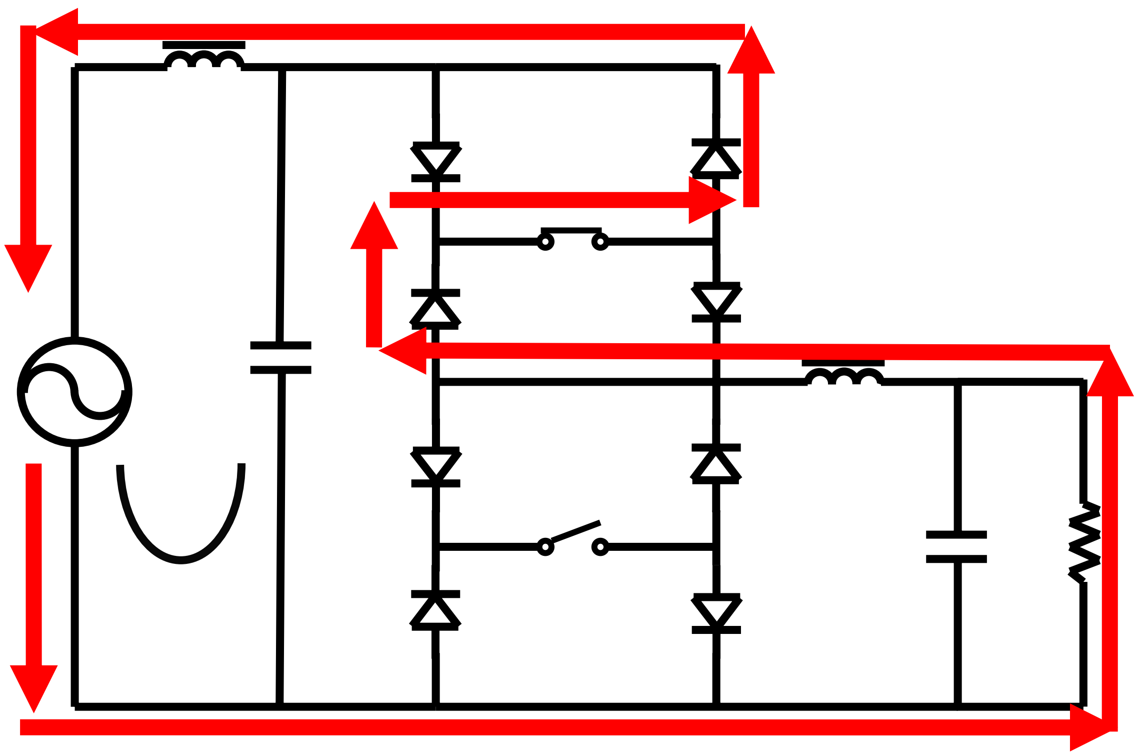


Fig 3.2.13: S1 is “on” and Input voltage is negative cycle.

The S1 is from "on" to "off" while the S2 is from "off" to "on". The lower side bi-directional switches are for the inductor current free-wheeling. It is because the inductor current can't sudden stop.

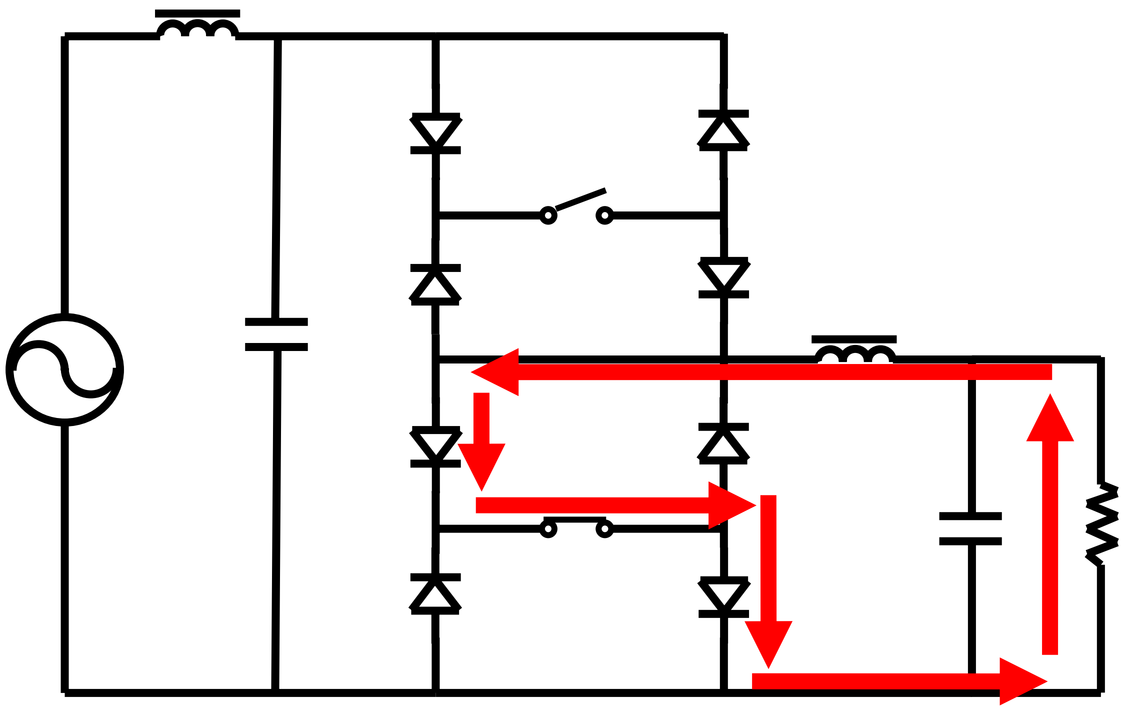


Fig 3.2.14: S1 is "off" and Input voltage is negative cycle.

3.3 Control circuit

The control circuit includes three parts (see Fig 3.3), microprocessor, isolation circuit and gate driver. The block diagram of control circuit is shown in the following:

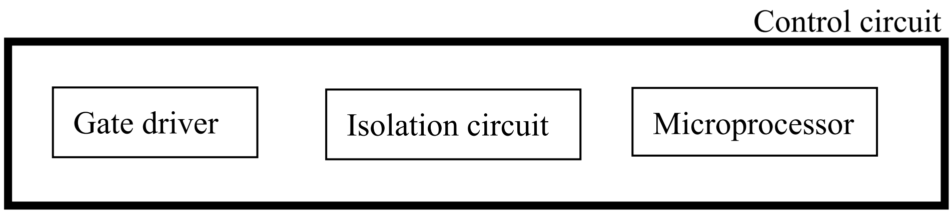


Fig 3.3: Block diagram of control circuit

3.3.1 Microprocessor

The function of microprocessor (MCU) is generated two Pulse Width Modulation (PWM) signal to control two switches (MOSFET) “ON” and “OFF”. The advantage of MCU is easy to control and accuracy. It has 9 steps for step up or down to control the duty cycle from 55% to 95%. Each step is represented 5 %. Therefore, increasing 5% is equal to increase 11V (assume the input ac voltage is 220V) and vice versa.

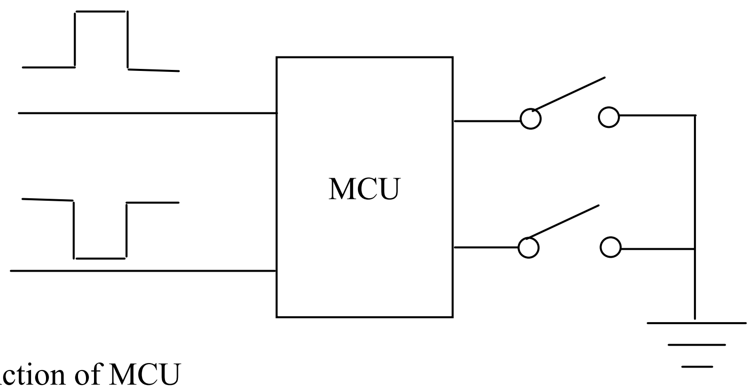


Fig 3.3.1: Function of MCU

3.3.1.1 Dead time

Dead time is one of the most significant parts of control circuit. If the control circuit neglects it, the power circuit must be damaged. Although the "ON" period shortens (see Fig 3.3.11), it will also provide a path to connect L and N directly (see Fig 3.3.12). So the two switches can't "ON" in the both time. It needs give a few hundred nanoseconds for both switches in "OFF" state (see Fig 3.3.13).

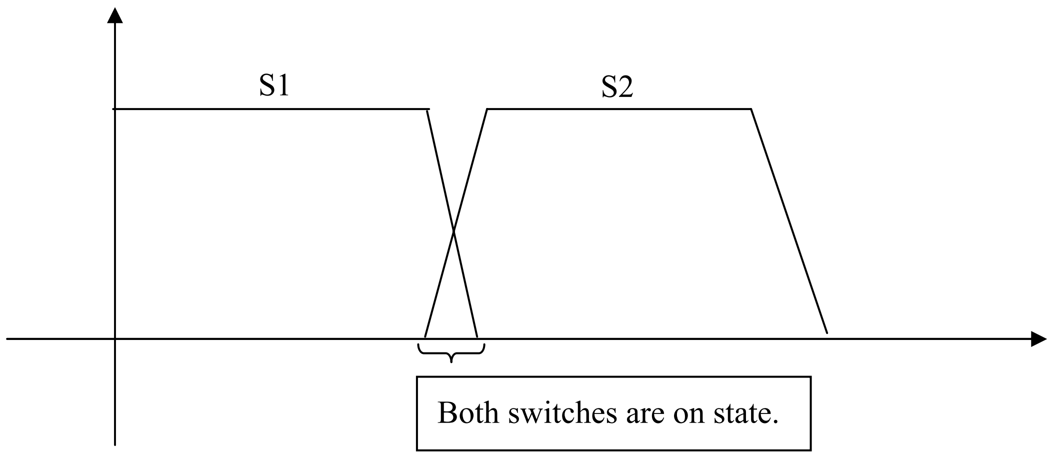


Fig 3.3.11: Both switches are "ON" state

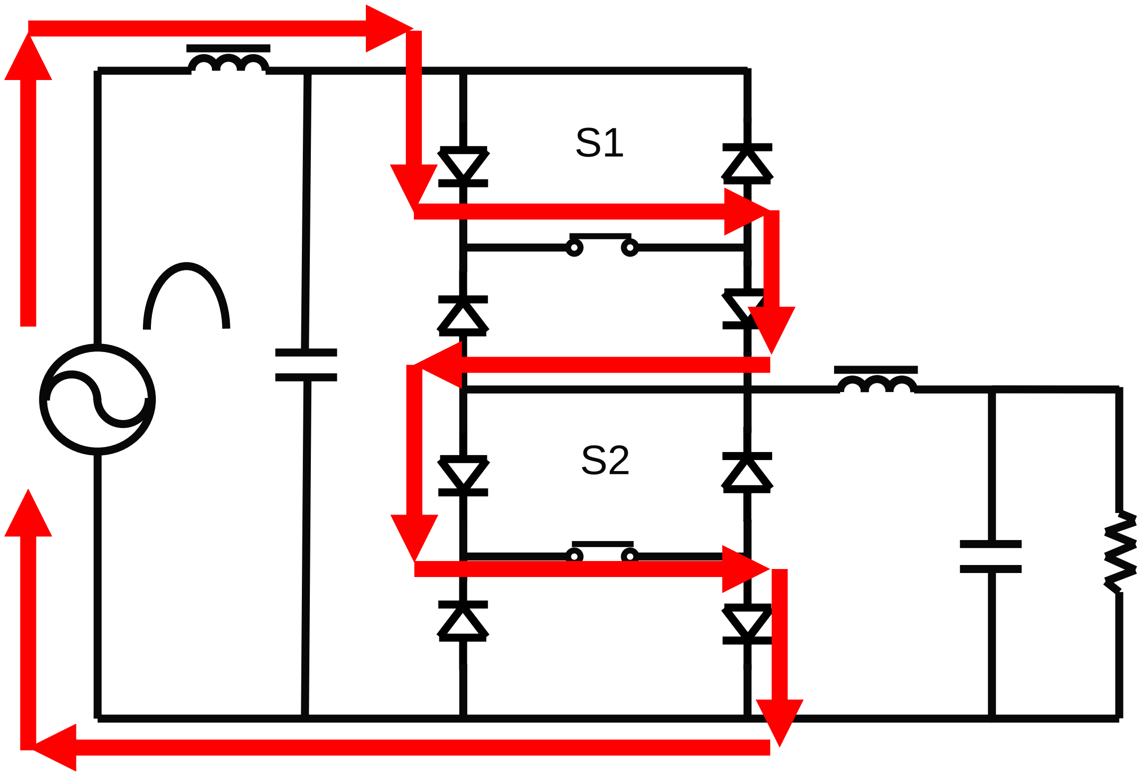


Fig 3.3.12: L and N will connect together

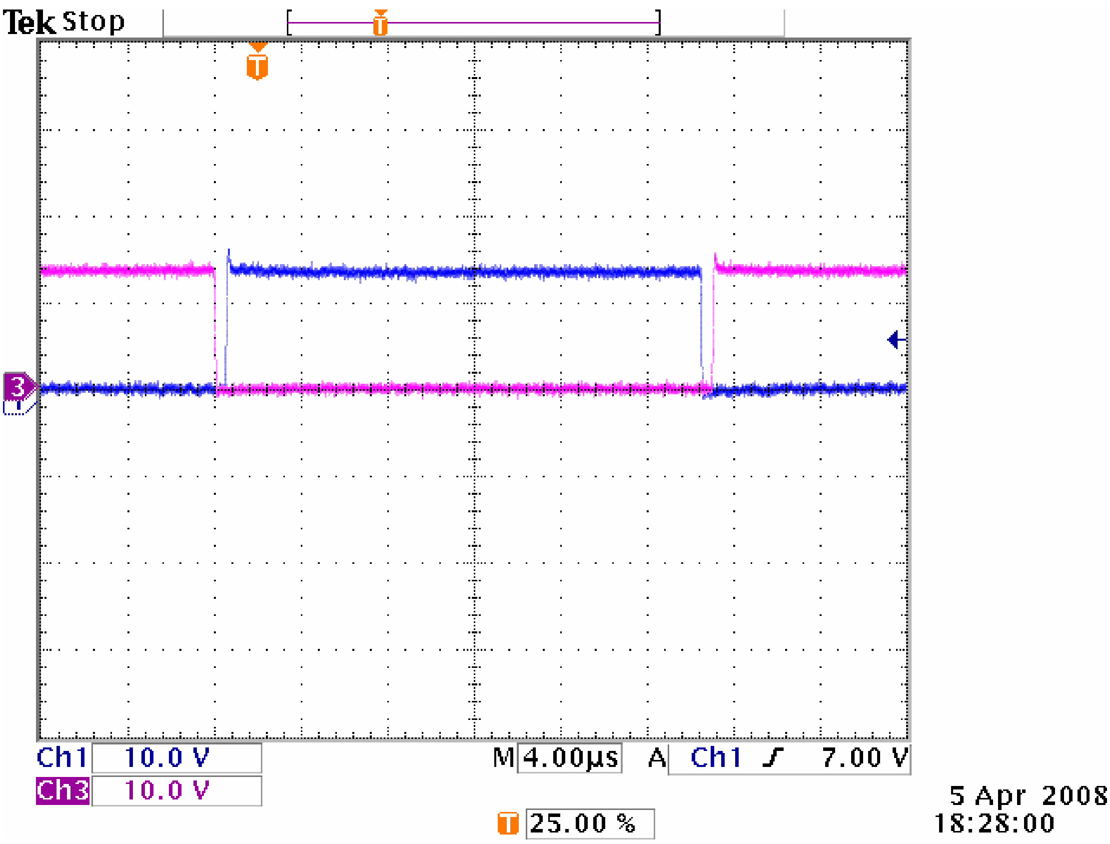


Fig 3.3.13: Dead time of two signals

3.3.2 Isolation circuit

The function of isolation ci rcuit is separated the high power circuit and control circuit. To prevent the h igh power g o into control circuit. T he position of isolation circuit is between MCU and gate driver (see Fig 3.3.2).

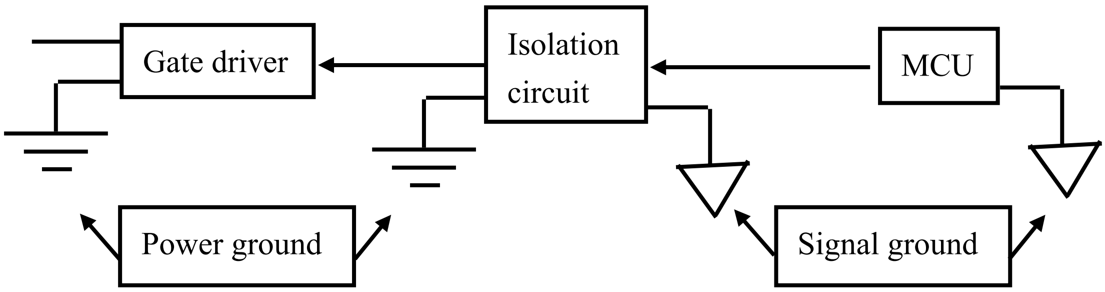


Fig 3.3.2: Position of Isolation circuit

3.3.3 Gate Driver

In power electronics, MOSFET does not use voltage control. It should use current drive for switching "ON". The high output current totem pole of gate driver will have fast switching frequency. Therefore, the function of gate driver is charging up the junction capacitor (See Fig 3.3.3).

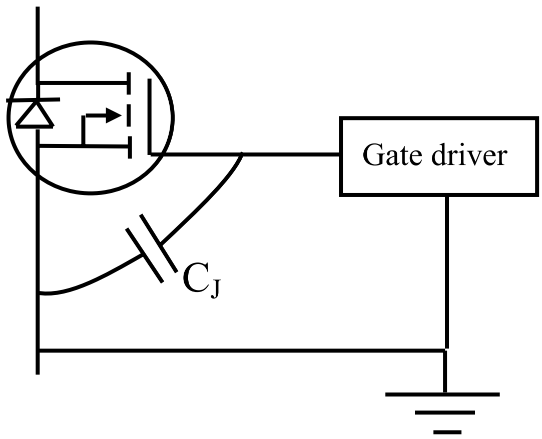


Fig 3.3.3: Gate driver charges pump the junction capacitor

3.4 Low pass filter

The ac-ac converter is using high frequency (25 kHz) to chop the low frequency (50Hz). Therefore, it will generate higher switching harmonic noise in the power circuit. If the noise goes into the ac power line, it will influence other electronic devices. The input and output ac-ac converter (see Fig 3.4), it should add the filter to eliminate the switching harmonic noise.

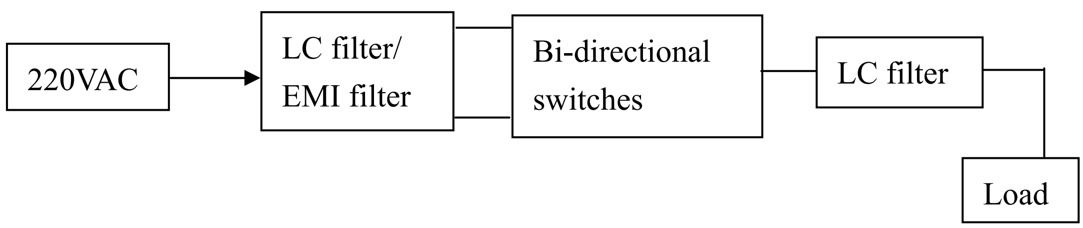


Fig 3.4: Low pass filter

3.4.1 Low pass filter calculus

The cutof f frequency , low pass filter , d epends on th e inductance and capacitance. The following equation is to calculate the cutoff frequency.

$$f_c = \frac{1}{2\pi\sqrt{L \times C}}$$

f_c = cutoff frequency

L = value of inductor

C = value of capacitor

In my circuit, the input a nd output LC filter cu toff frequency is dif ferent. It is because the L and C value are different.

For Input filter,

L = 1mH, C = 4.4uF

$$\therefore \quad f_c = \frac{1}{2\pi\sqrt{1mH \times 4.4uF}}$$

f_c = 2400Hz

For Output filter,

L = 0.6mH, C = 2.2uF

$$\therefore \quad f_c = \frac{1}{2\pi\sqrt{0.6mH \times 2.2uF}}$$

f_c = 4400Hz

Chapter 4 Switching Topology

4.1 Hard switching Topology

The above circuit is using hard switching topology. According to figure 4.1, the power loss area is very large. Therefore, the higher voltage and current stress will come across the switch. The loss will transfer to heat and radiation. These two things are unwanted. In order to reduce the voltage and current stress, the snubber circuit can be applied.

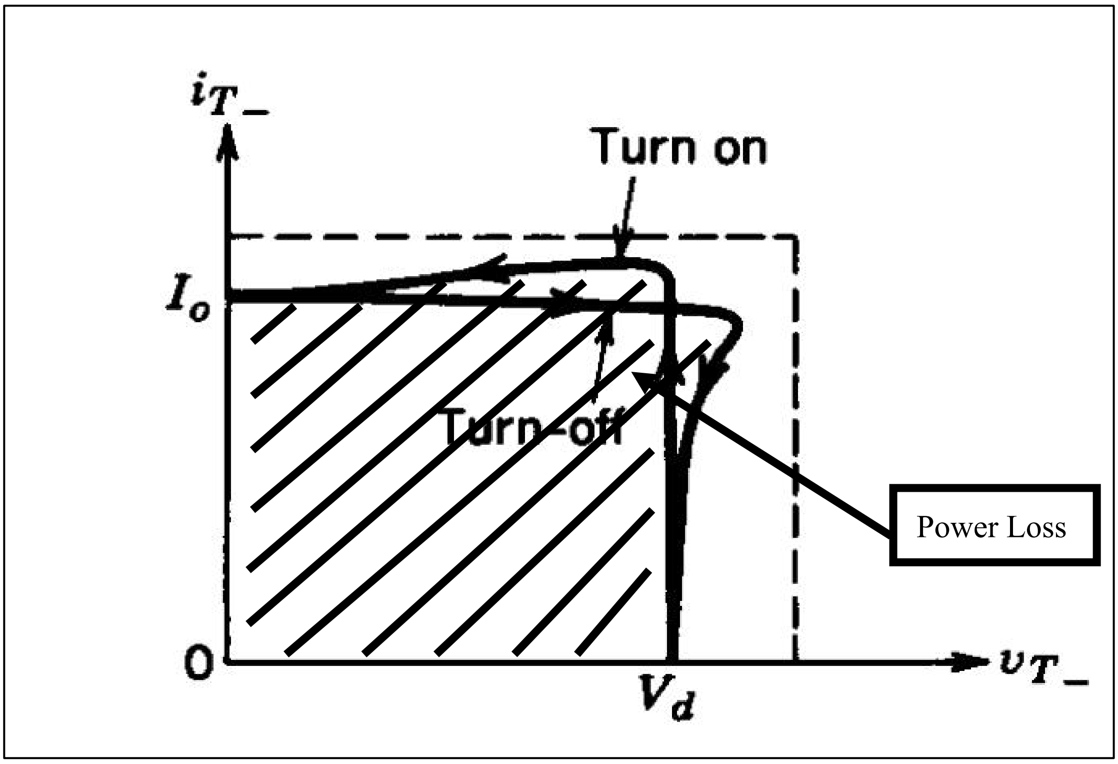
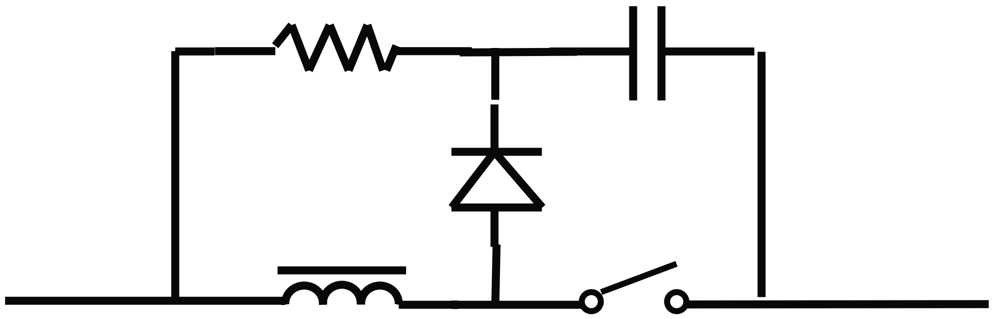


Fig 4.1: Hard switching topology

4.2 Snubber



The function of snubber shif ts the switching power loss from the switch to the snubber circuit and therefore does not prov ide a reduction in the overall switching power loss. It im plies the snubber can' t reduce the power loss. It just only can reduce the voltage and current stress. (see Fig4.2)

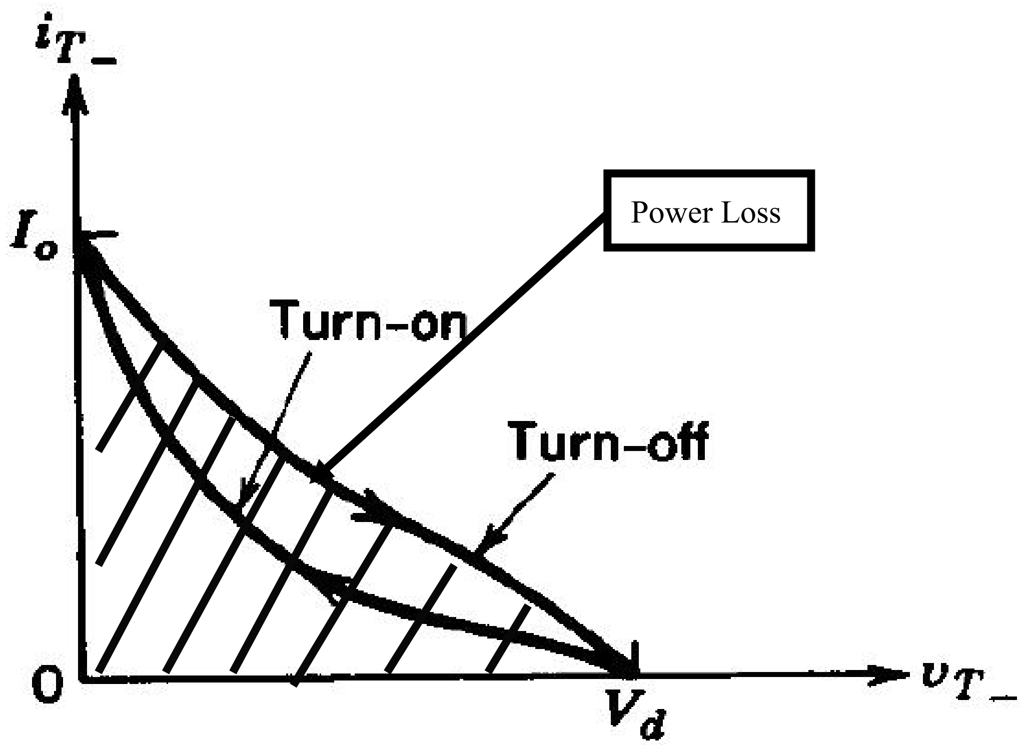


Fig4.2: Switching loci with snubbers

4.2.1 Turn on and turn off snubber operation principle

principle

When the switch is "of f", the curr ent will cha rge up the capacitor (s ee Fig 4.2.11). So, it can reduce the voltage stress (turn of f snubber). W hen the switch is "on", the capacitor across the switch voltage is closed to zero. So, the capacitor will discharge and use the resistor part to release current to the load (see Fig 4.2.12). Also, the function of inducto r is delayed the current ri sing up (turn-on snubber) when the switch is "on". So it can reduce the overlapping area (see Fig 4.2.13).

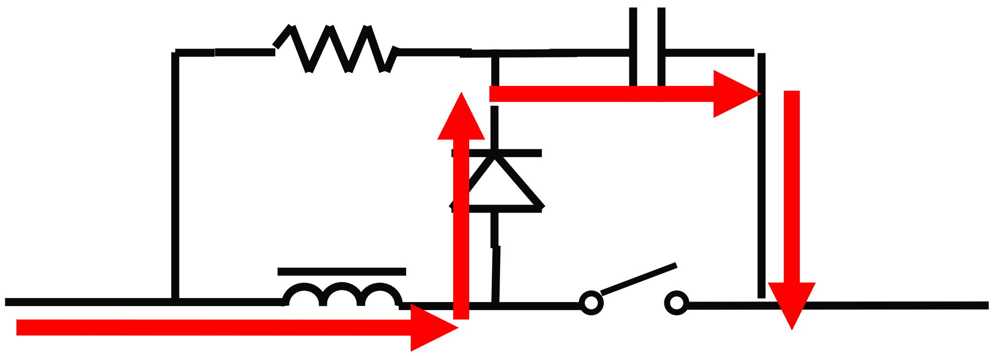


Fig 4.2.11: Turn off snubber current flow
t

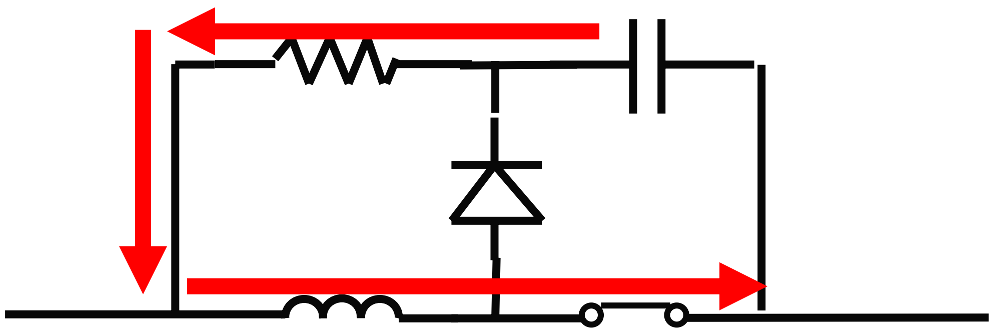


Fig 4.2.12: The capacitor release part

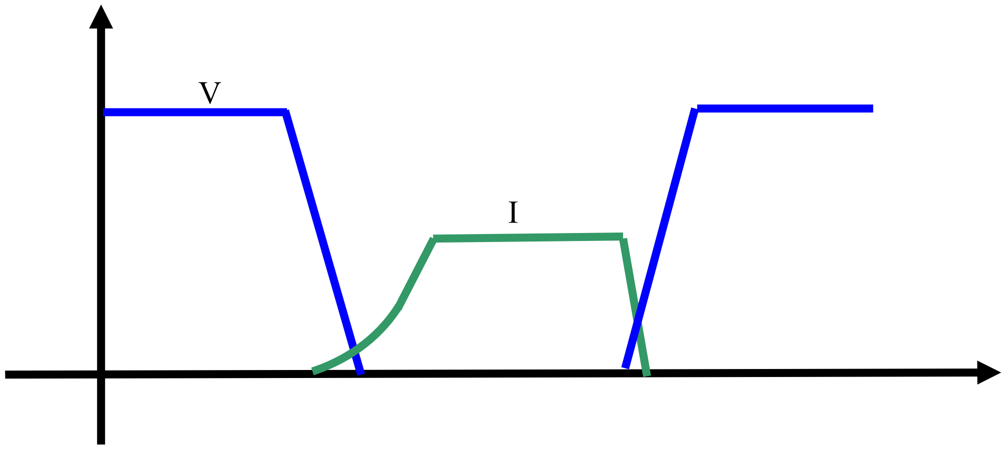


Fig 4.2.13: Overlap area is reduced

4.2.2 Snubber Power loss calculus

Power loss of snubber equation:

$$P = \frac{1}{2} C V^2 f_s \text{ (W)}$$

P = Power

C = Value of Capacitor

V = peak voltage

f_s = Switching frequency

In my circuit, the capacitor value is 2.2nF.

$$P = \frac{1}{2}(2.2n) \times (311)^2 \times (25k)$$

P = 2.66W

4.3 Energy Recovery Snubber

After the measurement, the voltage and current stress are still serious. The maximum voltage across the switch is around 600V (see Fig 4.31) which is double the input voltage level (311V). It is not reasonable so it must apply another method to reduce the voltage and current stress, such as zero voltage/ current switching. But it has a big problem, the loading must be fixed (loading range is narrow). Then, I need to design another snubber to replace the traditional one. The next generation snubber was created. Its name is called "Energy Recovery Snubber" (see Fig 4.32). The benefit of "Energy Recovery Snubber" is no voltage and current stress, wide load range and less switching harmonic noise. It can be said that it is a lossless snubber.

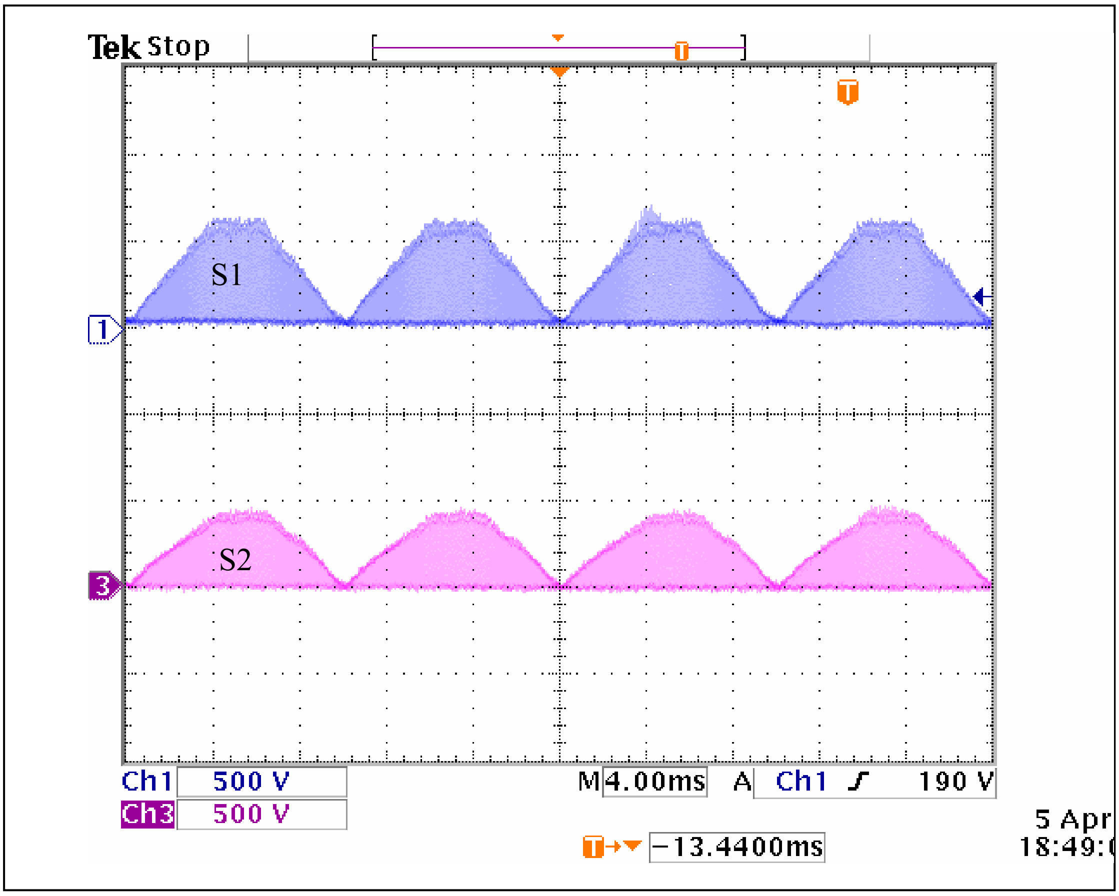


Fig 4.31: Voltage stress of V_{DS}

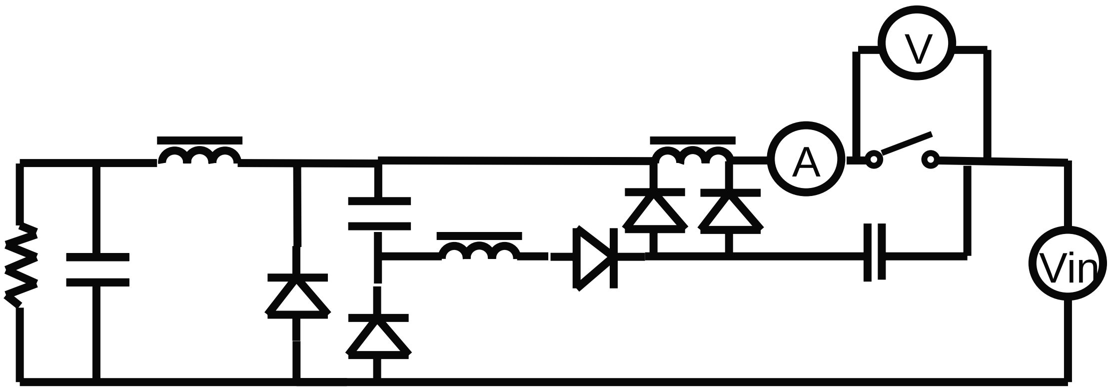


Fig 4.32: Energy Recovery snubber

4.3.1 Energy recovery snubber operation principle

When the sw itch is f rom on to of f, it w ill cha rge up the capacitor C 1. The inductor current can' t sudden stop, so it will use the diode part for free-wheeling. Then it will char ge up capac itor C2 (see Fig 4.3.11). When the sw itch is from off to on, the capacito r w ill dischar ge to the load (see Fig 4..3.12). Theref ore, the ener gy can be reused so that this type snubber calls "Energy recovery snubber".

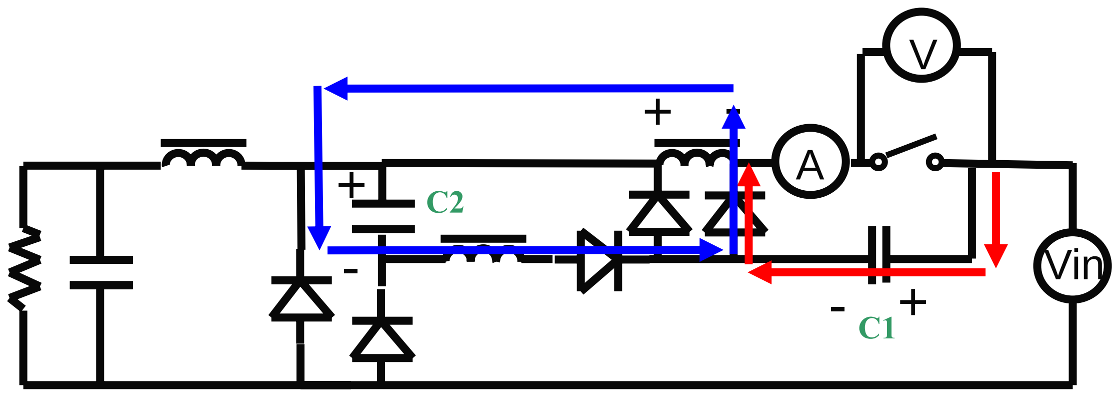


Fig 4.3.11: Turn-off status of "Energy Recovery Snubber"

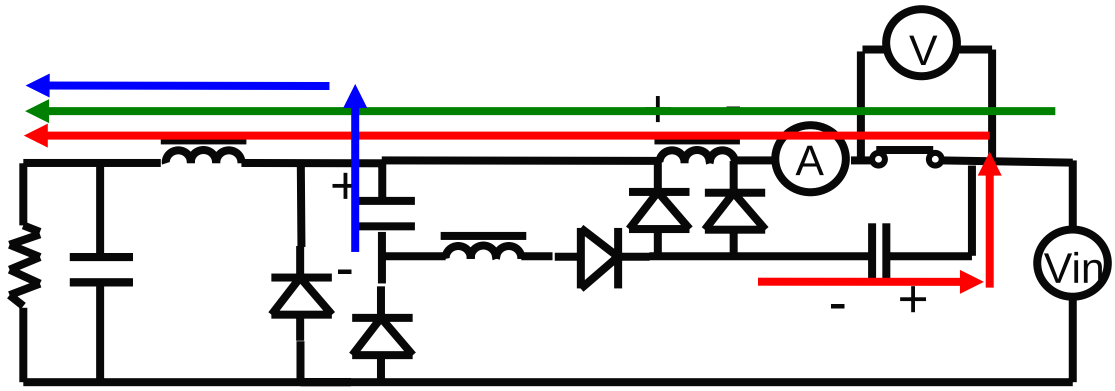


Fig 4..3.12: Turn-on status of "Energy Recovery Snubber"

4.3.2 Energy recovery snubber Waveform

The input dc voltage is 60V . The maximum voltage is 64V (see Fig 4.3.21) so the voltage stress is improved.

Using the Fast Fourier transform (FFT) to measure the switching harmonic noise, the red colour is represent the noise value (see Fig 4.3.22).

In x-y mode, the shape is much closed to ideal soft switching (see Fig.4:3.23). Therefore, the "Energy Recovery Snubber" can solve the high voltage and current stress. Also, the switching harmonic noise is reduced. So the efficiency can be improved.

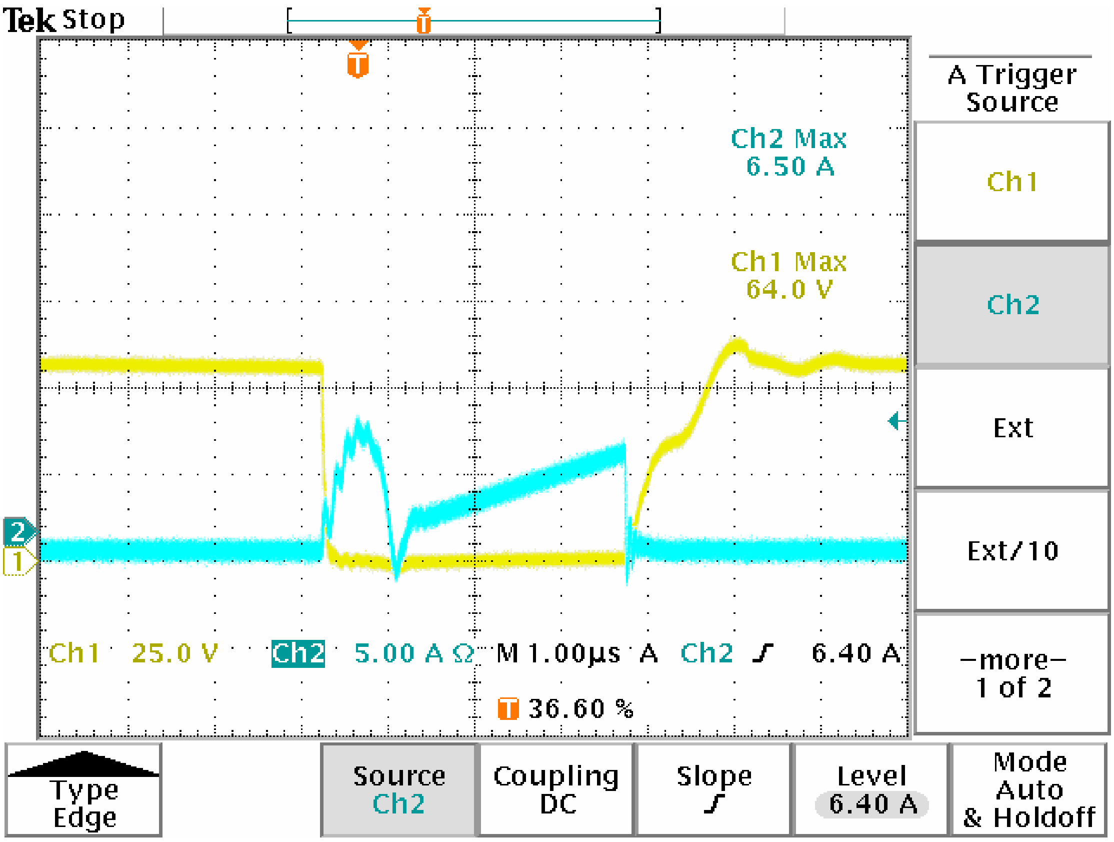


Fig 4.3.21: Voltage VS current

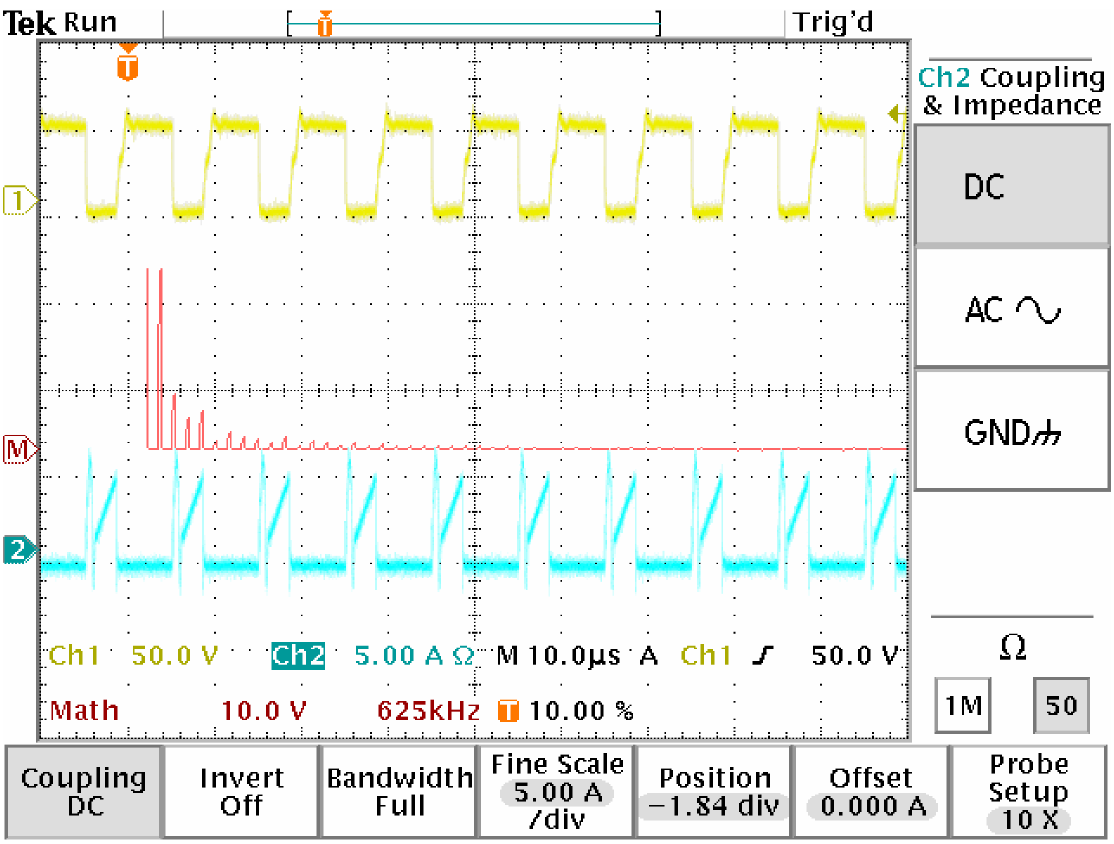


Fig 4.3.22: Fast Fourier Transform

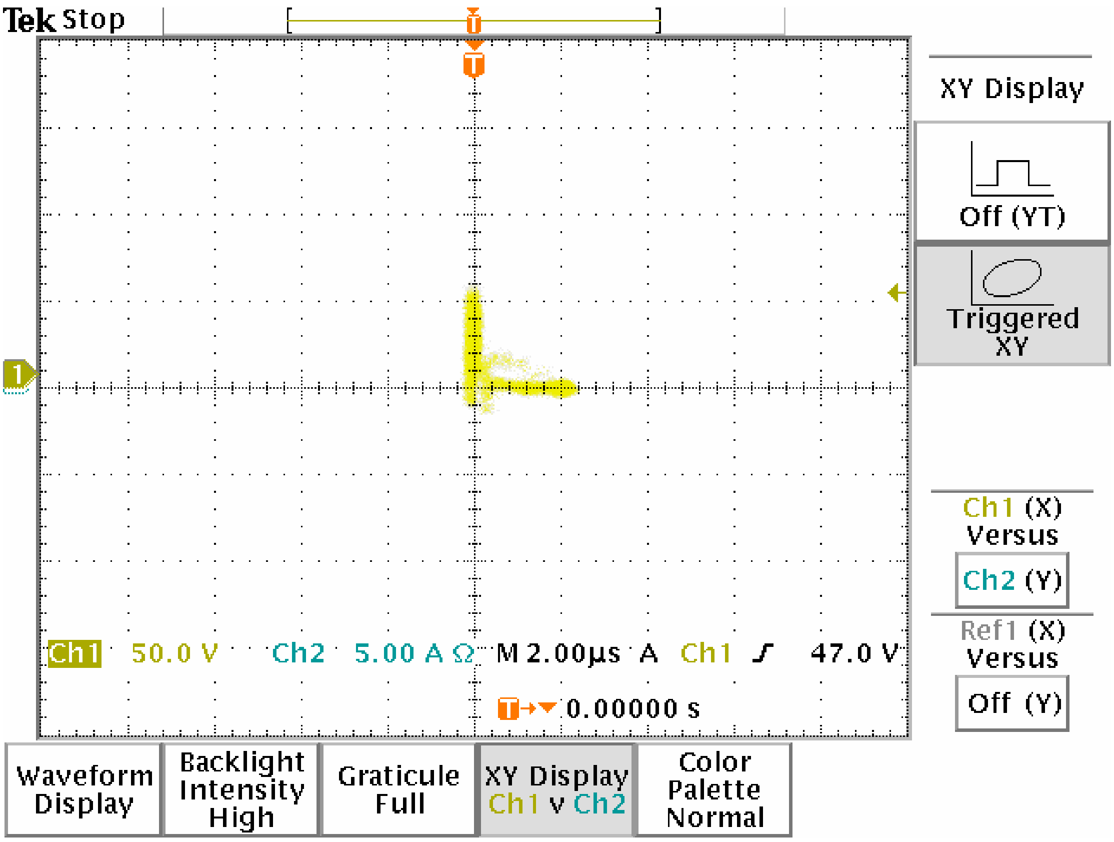


Fig.4:3.23: x-y mode of energy recovery snubber

Chapter 5 Simulation Result

5.1 Schematic of ac-ac converter with snubber circuit

Simulation Software: PSIM

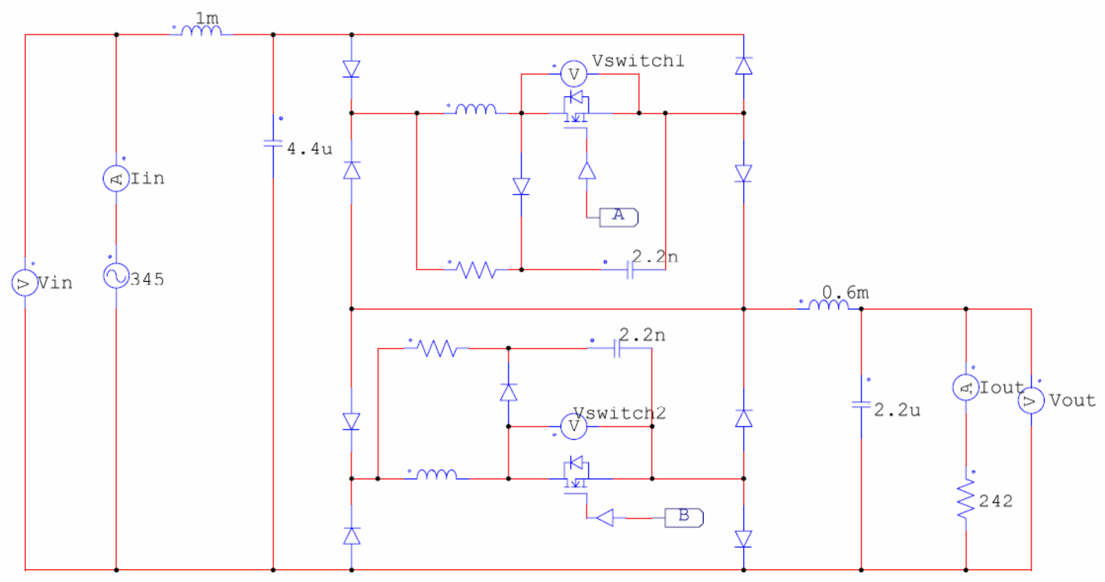


Fig. 5.1.11 Schematic of ac-ac converter with snubber circuit

5.1.1 Simulation of ac-ac converter

Assume the output is 100W, so the R = 484Ω (i.e. = 100W) and D=55%

The output waveform is quite similar to my implementation result but the input current lag the input voltage. It is different with my implementation result.

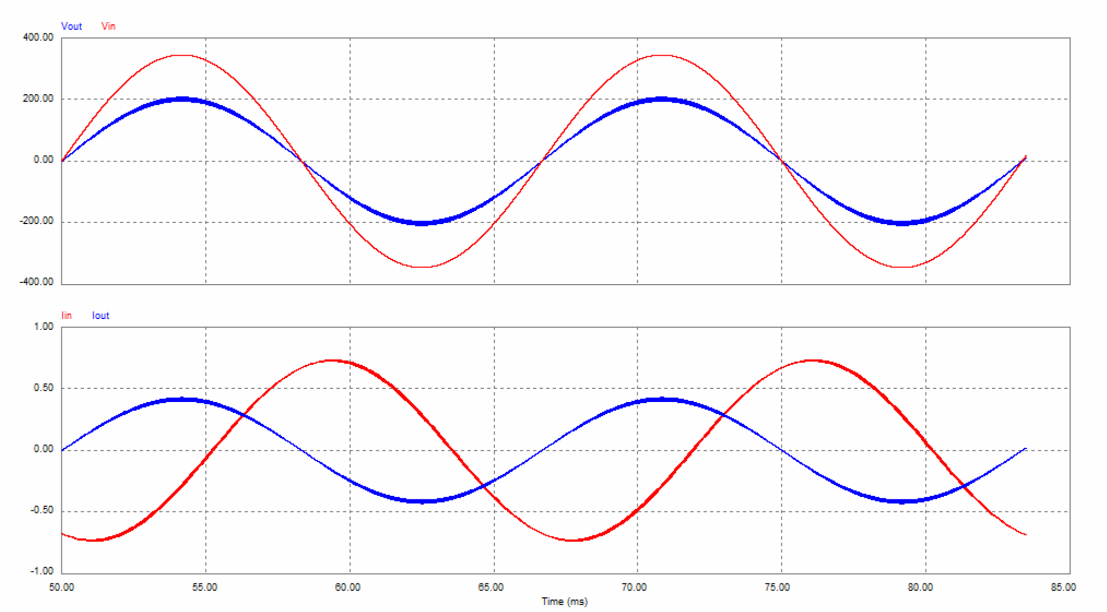


Fig. 5.1.12 Simulation result of 100W

Assume the output is 200W, so the R = 242Ω (i.e. = 200W) and D=55%

The output voltage is fixed but the current is increased. It is much closed to input current. The simulation result is closed to my implementation result.

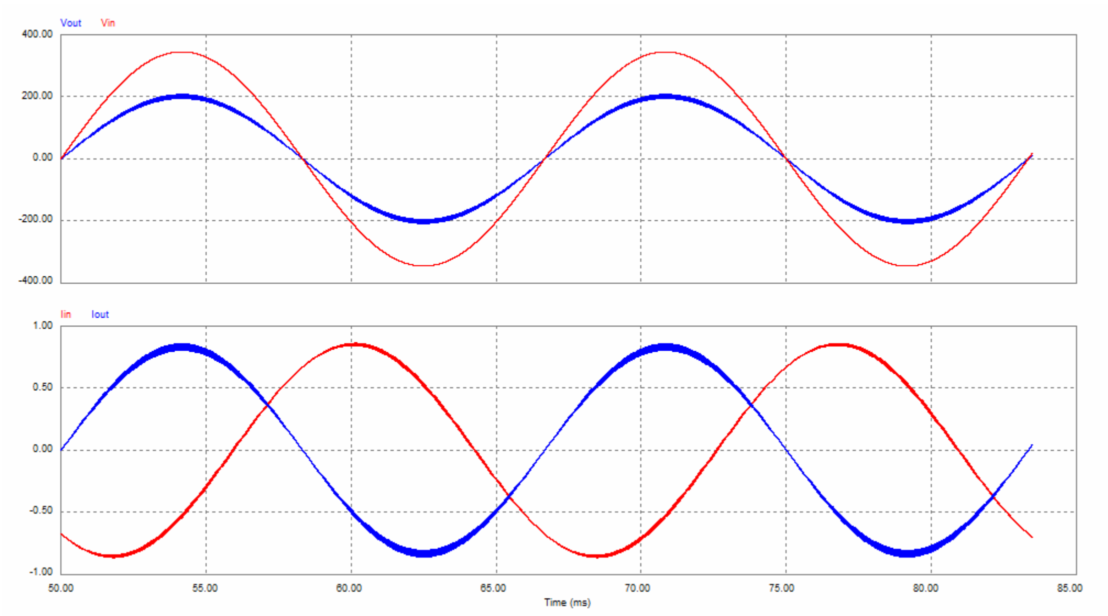


Fig. 5.1.13 Simulation result of 200W

V_{DS} waveform

The shape of V_{DS} waveform is the same of my implementation result

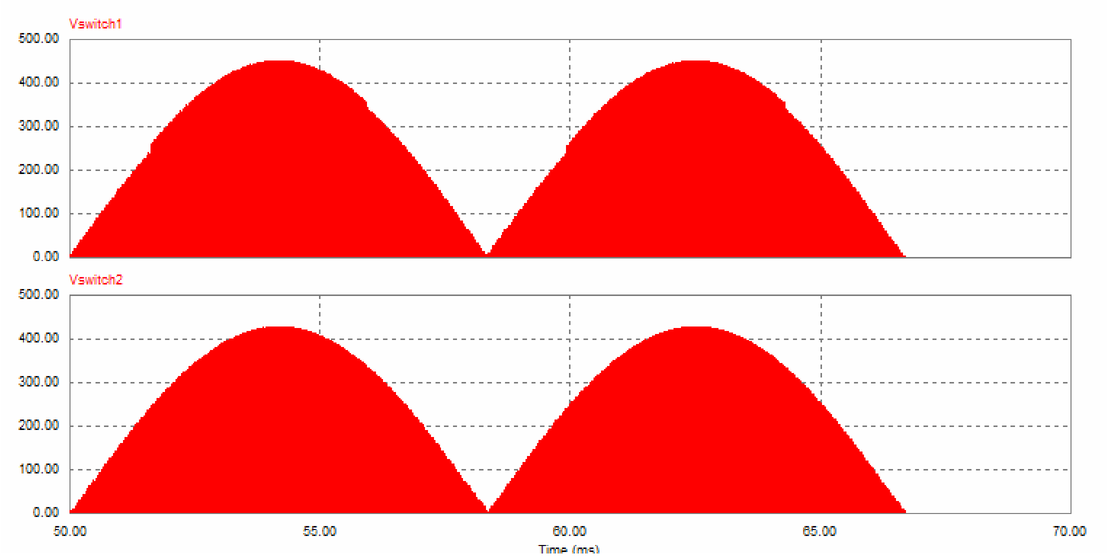


Fig. 5.1.14 Simulation result of V_{DS} waveform

Zoom in to the VDS waveform

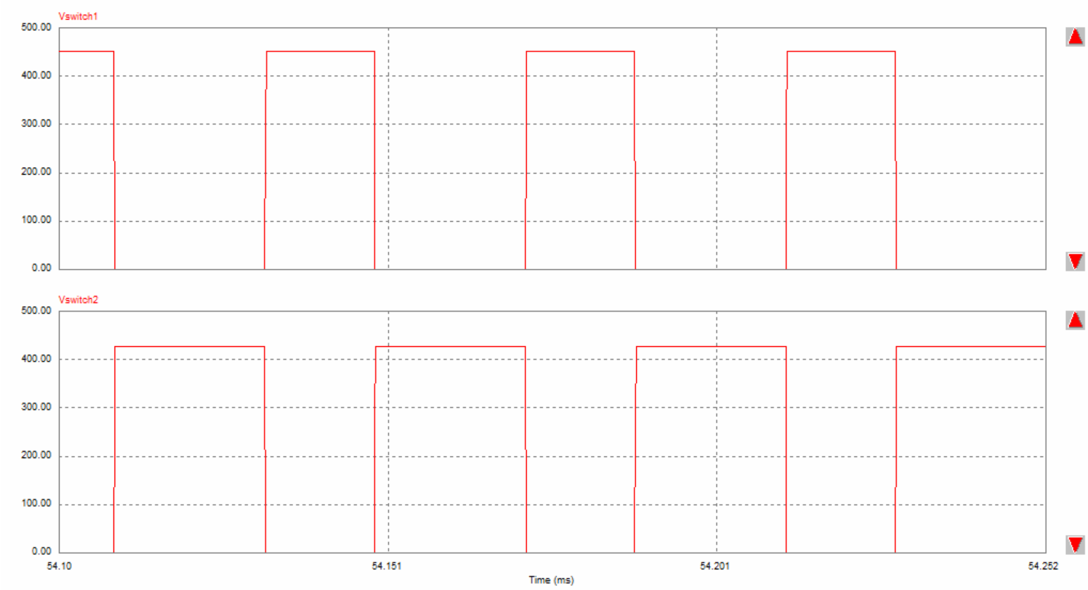


Fig. 5.1.15 Zoom in V_{DS} waveform

5.2 Schematic of energy recovery snubber

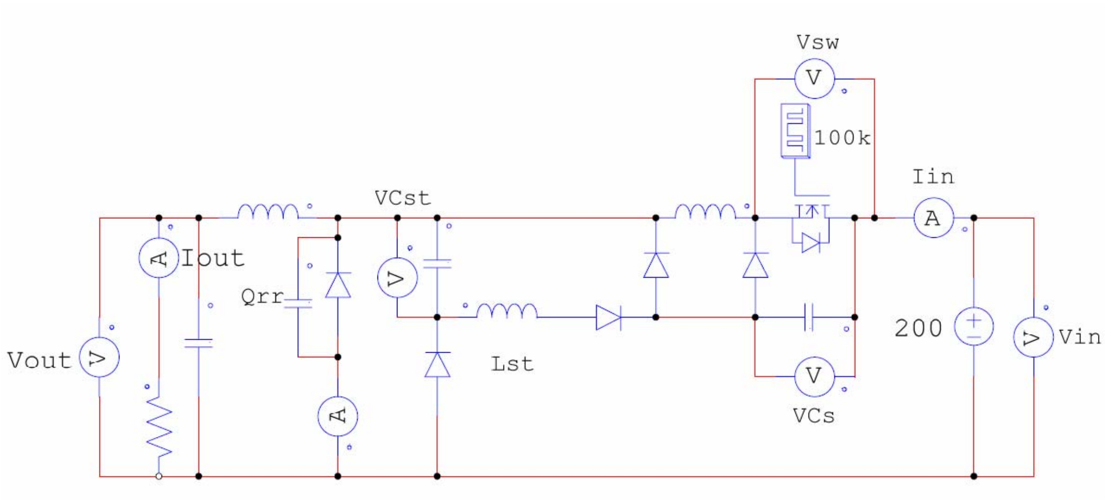


Fig. 5.2 Schematic of ac-ac converter with snubber circuit

5.2.1 Simulation of energy recovery snubber

Vsw VS Isw

The shape of waveform is similar my implementation result.

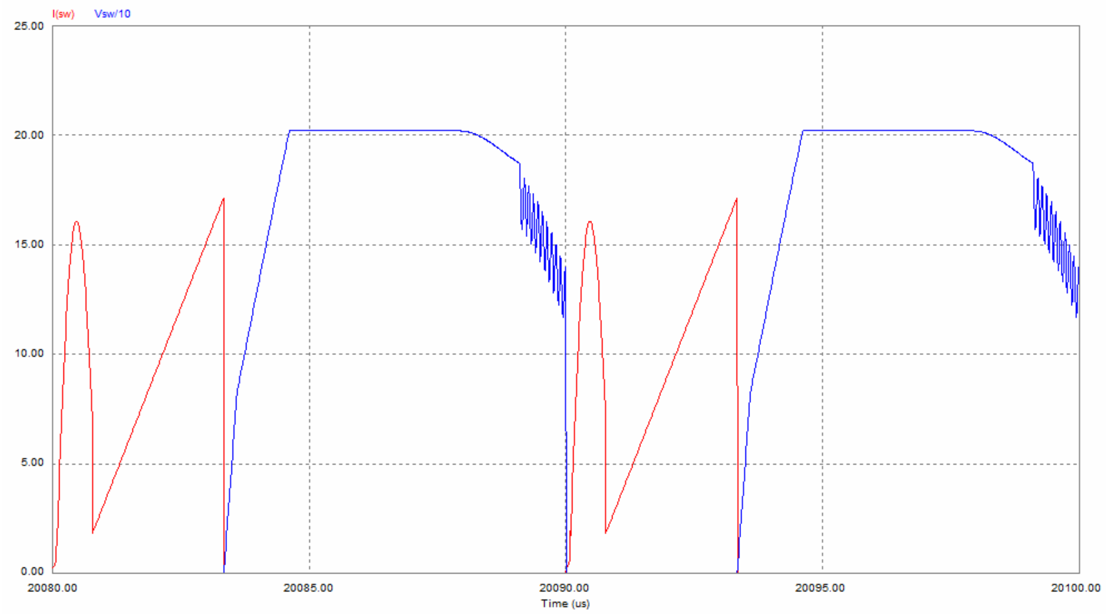


Fig.5.2.11 Vsw/10 VS Isw

Chapter 6 Measurement Result

6.1 Compact Fluorescent lamps

6.1.1 11W Compact Fluoresent lamp implementation result

Condition: Input Voltage = 245V, Duty cycle = 55%

Ch 1 and 2 are output voltage and current.

Ch 3 and 4 are input voltage and current.

The output current wavefor m is dif ferent with the input. It is because the loading is not resistive, inductive and capacit ive. The current waveform, com pact fluorescent lam p, can' t identify what type of lo ad they are but the shap e is lik e a pulsating current.

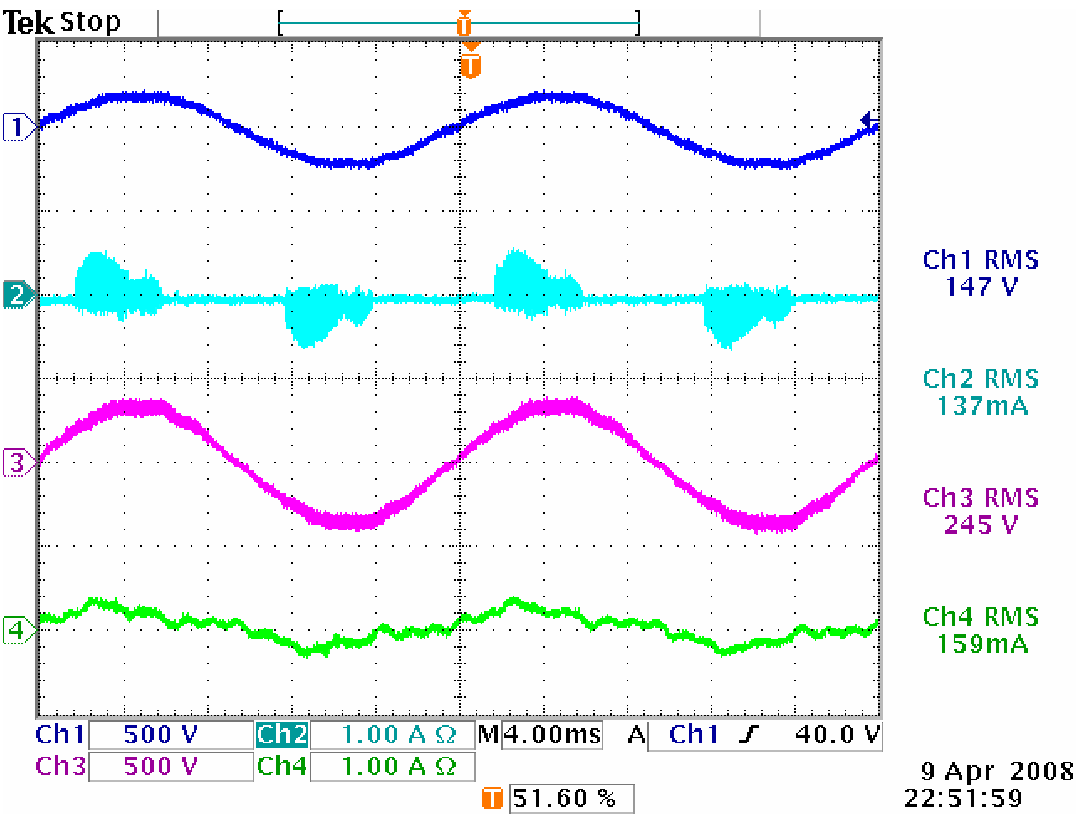


Fig 6.1.11: 11W compact fluorescent lamp (Duty cycle = 55%)

Condition: Input Voltage = 245V, Duty cycle = 95%

Ch 1 and 2 are output voltage and current.

Ch 3 and 4 are input voltage and current.

The duty cycle closes to 95%, the shape is very closed to current pulse.

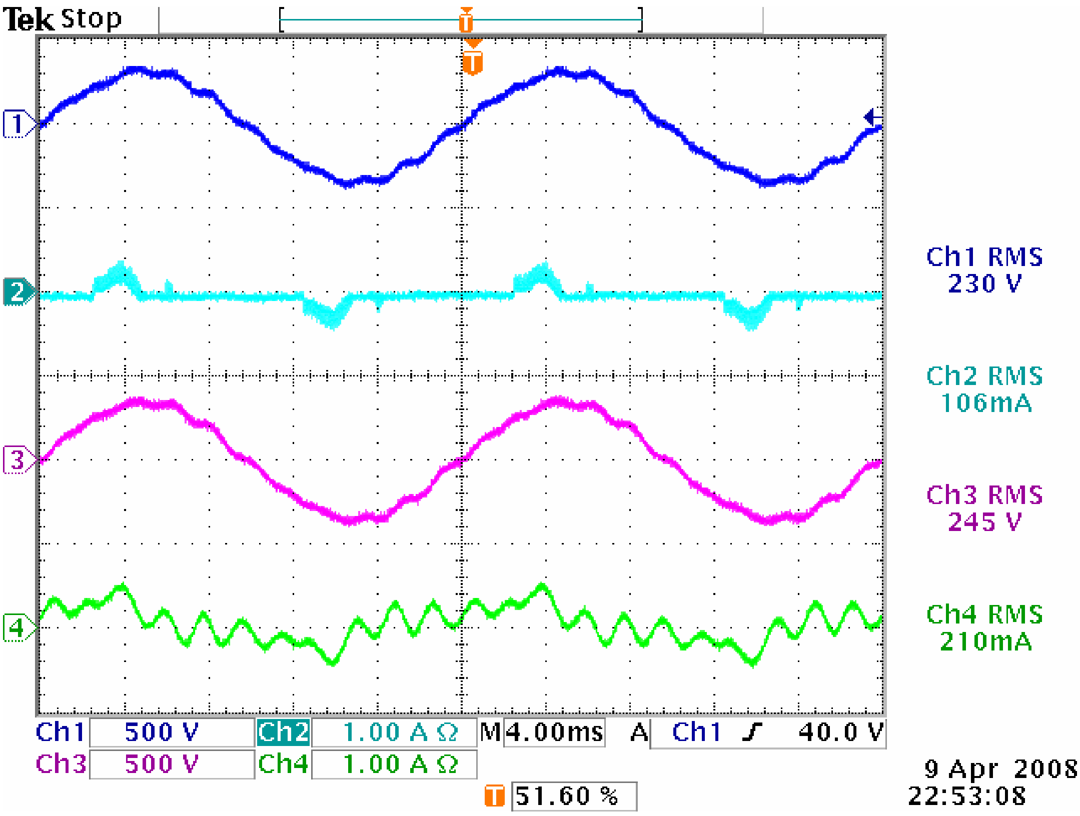


Fig 6.1.12: 11W compact fluorescent lamp (Duty cycle = 95%)

6.1.2 23W Compact Fluoresent lamp implementation result

Condition: Input Voltage = 245Vac, Duty cycle = 55%

Ch 1 and 2 are output voltage and current.

Ch 3 and 4 are input voltage and current.

The situation is similar to the 11W compact fluoresent lamp but the different is the output power.

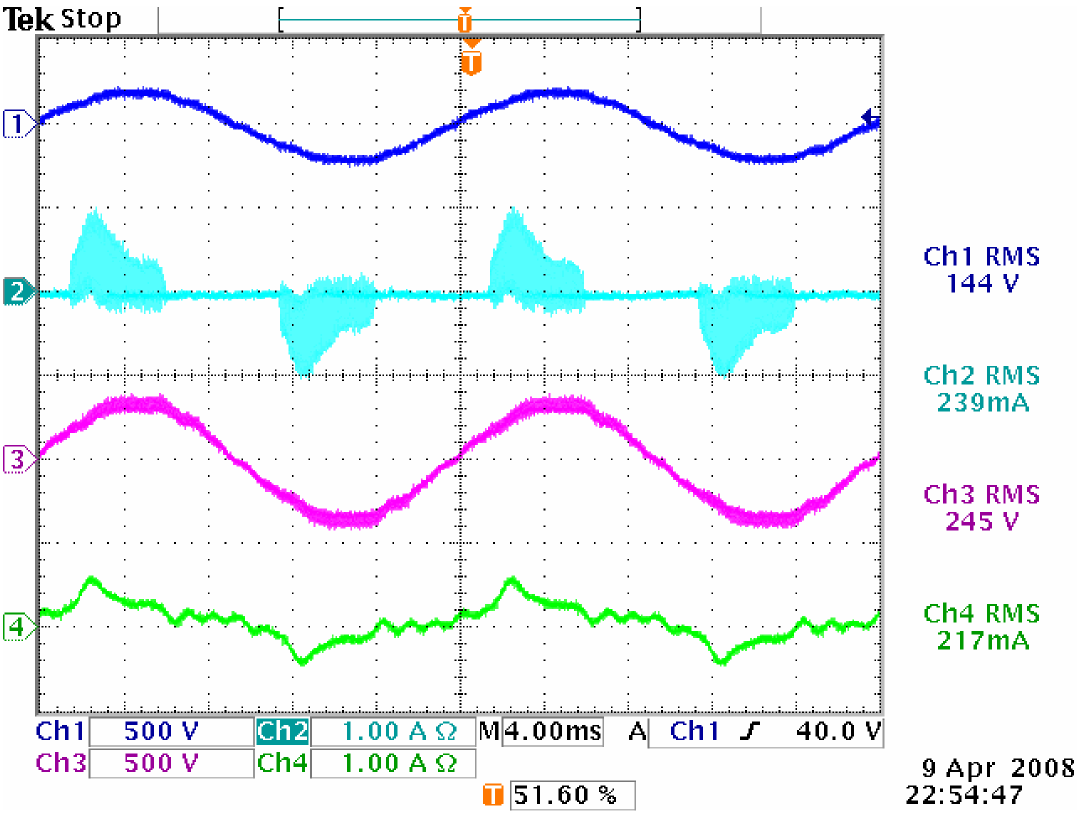


Fig 6.1.13: 23W compact fluorescent lamp (Duty cycle = 55%)

Condition: Input Voltage = 245V, Duty cycle = 95%

Ch 1 and 2 are output voltage and current.

Ch 3 and 4 are input voltage and current.

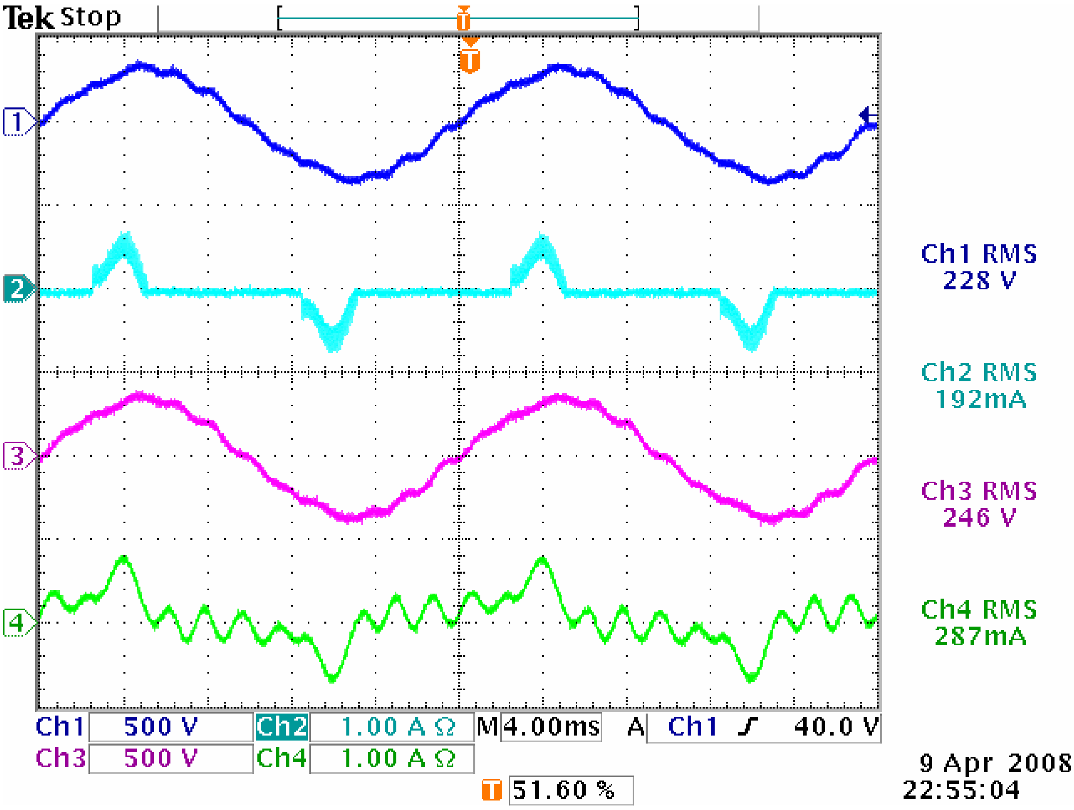


Fig 6.1.14: 23W compact fluorescent lamp (Duty cycle = 95%)

6.1.3 Duty cycle from 55% to 95% implementation result

11W compact fluorescent lamp									
Vin (V)	245								
Duty Cycle (%)	55	60	65	70	75	80	85	90	95
Iin (A)	0.165	0.166	0.167	0.167	0.167	0.173	0.181	0.196	0.213
Vout (V)	145	152	164	174	184	197	207	218	230
Iout (A)	0.139	0.137	0.139	0.139	0.135	0.129	0.119	0.106	0.091
Power mean IN (W)	33.35	33.25	31.55	29.36	27.23	24.63	23.65	23.26	23.9
Power mean OUT (W)	7.72	7.99	8.442	8.87	9.19	9.62	10.07	10.52	11.2
Efficiency (%)	23.15	24	26.76	30.21	33.75	39.06	42.58	45.23	46.86

Table 6.1.31: 11W compact fluorescent lamp

23W compact fluorescent lamp									
Vin (V)	245								
Duty Cycle (%)	55	60	65	70	75	80	85	90	95
Iin (A)	0.199	0.205	0.215	0.218	0.223	0.229	0.241	0.254	0.26
Vout (V)	145	152	162	174	185	194	204	215	226
Iout (A)	0.219	0.229	0.23	0.225	0.218	0.206	0.194	0.18	0.163
Power mean IN (W)	40.75	41.12	40.28	38.82	36.31	34.11	33.41	33.2	33.76
Power mean OUT (W)	14.2	15.31	16.37	17.01	18.03	18.24	19.14	20.16	21.47
Efficiency (%)	34.85	37.23	40.64	43.82	49.66	53.48	57.29	60.72	63. 6

Table 6.1.32: 23W compact fluorescent lamp

6.2 Fluorescent lamps

6.2.1 36W Fluorescent lamps implementation result

Condition: Input Voltage = 243Vac, Duty cycle = 65%

Ch 1 and 2 are output voltage and current.

Ch 3 and 4 are input voltage and current.

The minimum voltage for dimm ing the fl uorescent lamp is 160V. If my ac-ac converter output voltage is lower th an the minimum, the fluorescen t lamp will turn off. It is because the fluorescent lamp is not enough energy to heat up the terminal to emit the ele ctron to the fluorescent pow der. Therefore, th e fluorescen t lam p can't turn on.

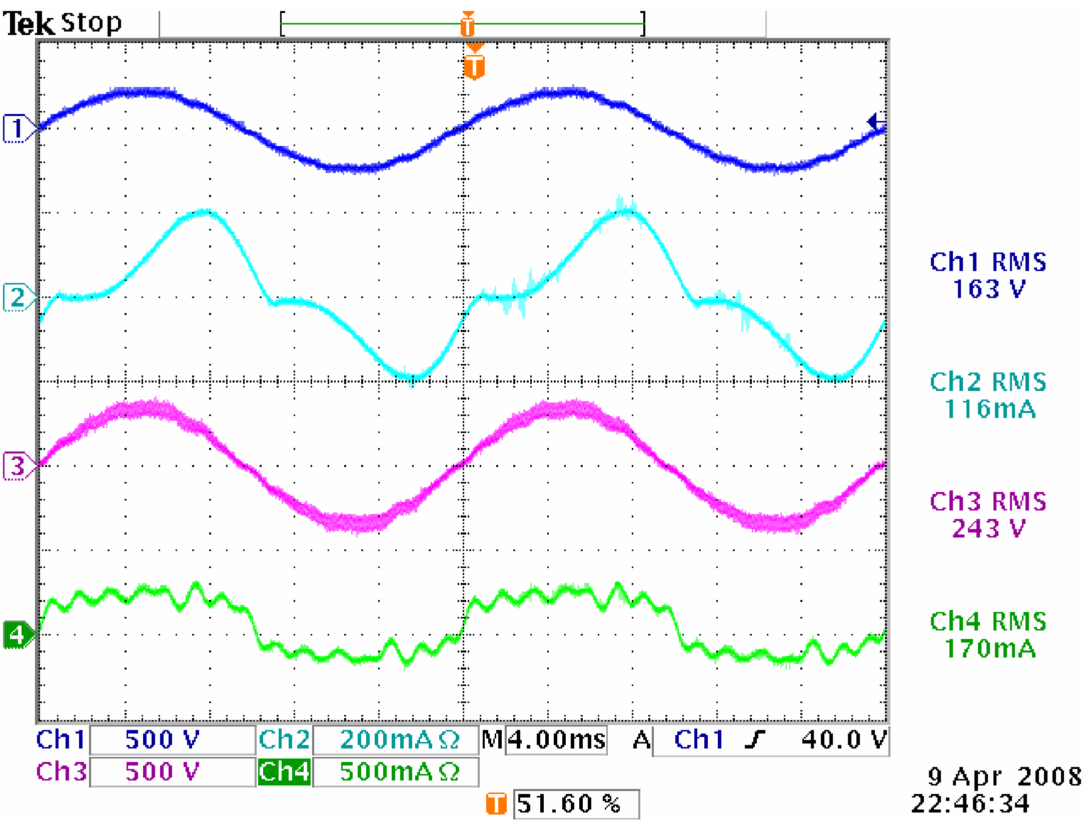


Fig 6.2.11: 36W fluorescent lamp (Duty cycle = 55%)

Condition: Input Voltage = 240Vac, Duty cycle = 95%

Ch 1 and 2 are output voltage and current.

Ch 3 and 4 are input voltage and current.

The traditional fluorescent lamp is connected the large inductor (~1.4H). So the output current lag the output voltage (s ee F ig 6.2.13). Then, I am sure the fluorescent lamp is an inductive load.

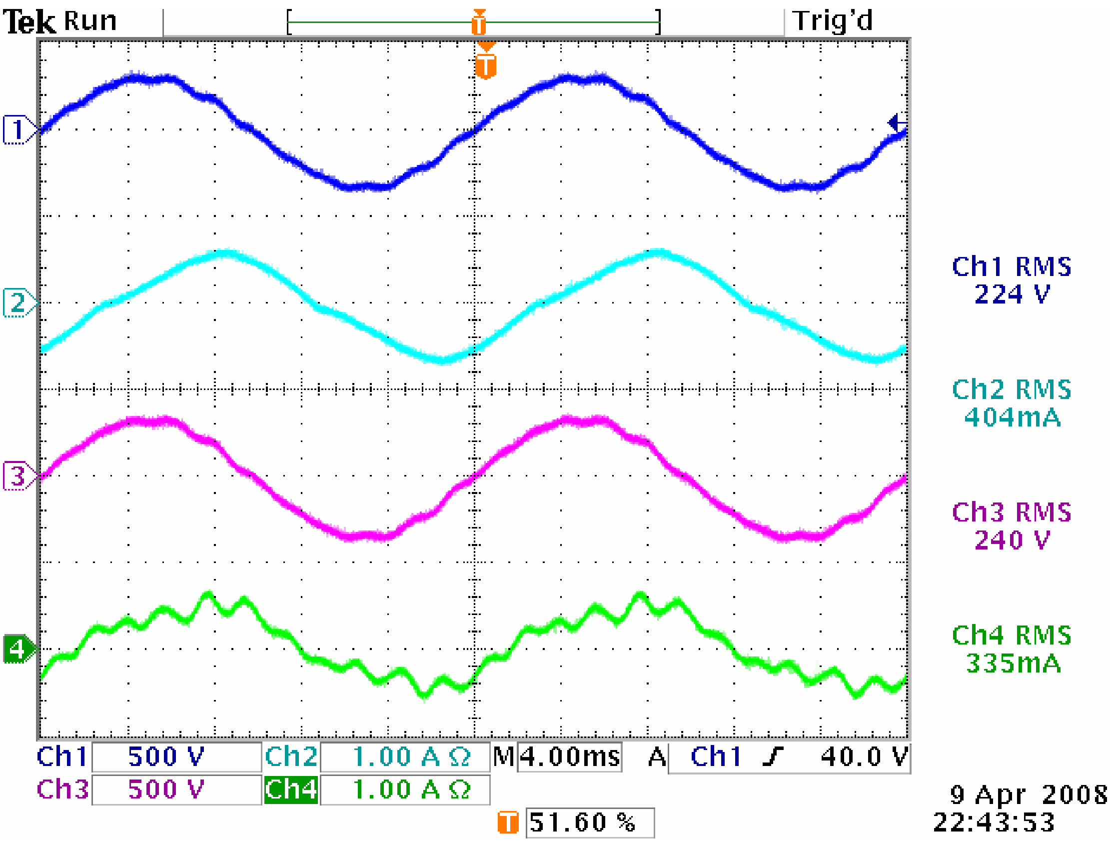


Fig 6.2.12: 36W fluorescent lamp (Duty cycle = 95%)

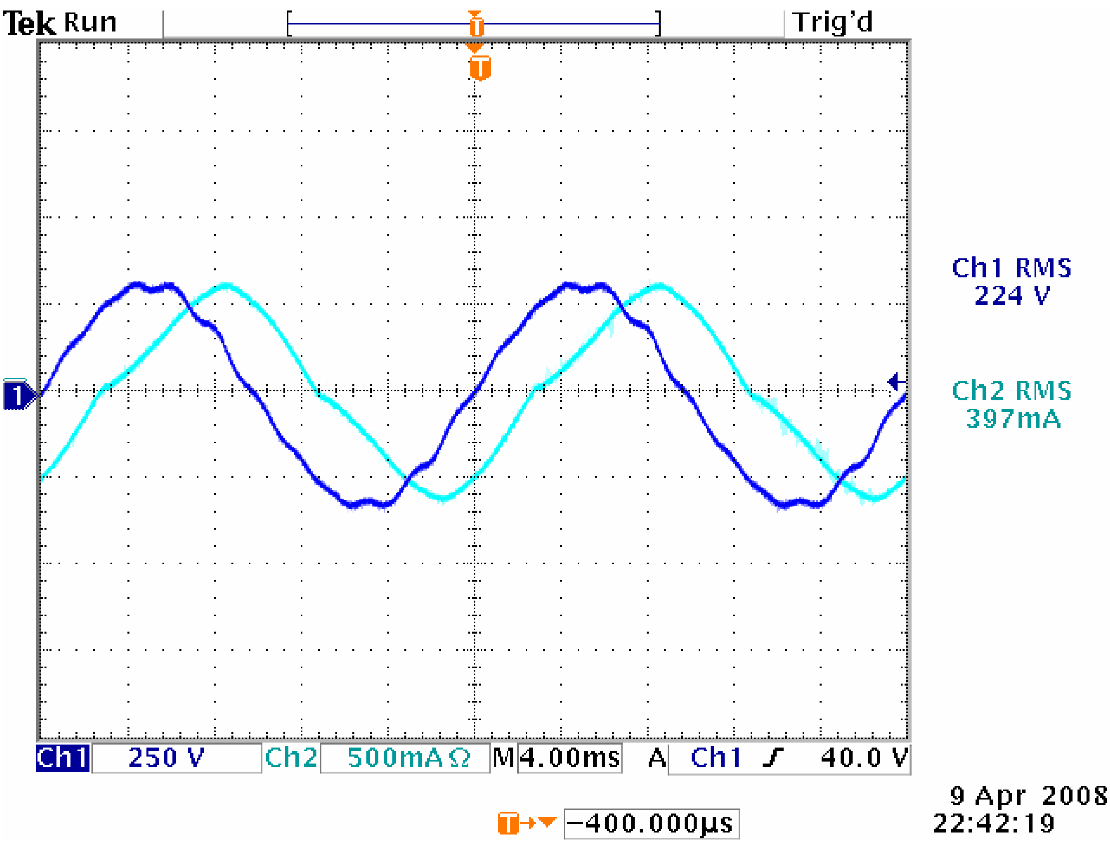


Fig 6.2.13: The current (wathet blue) lag the voltage (blue)

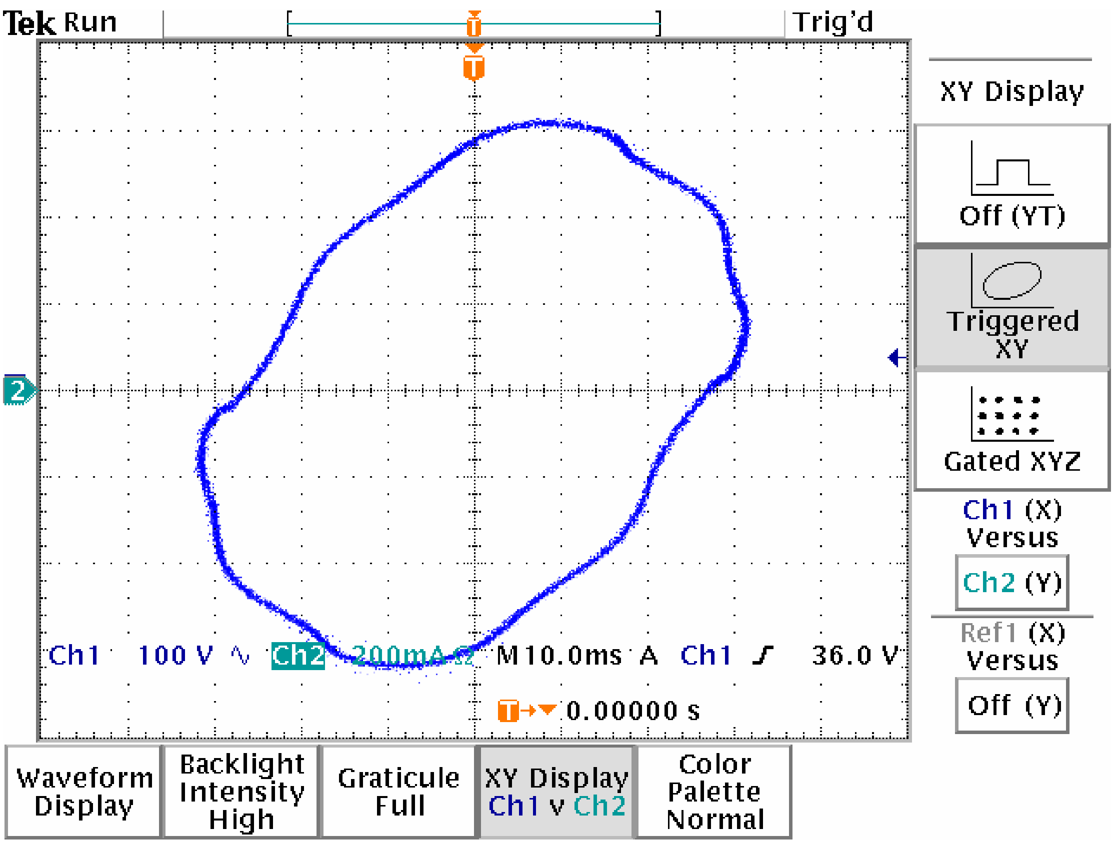


Fig 6.2.14: x-y mode of fluorescent lamp

6.2.2 Duty cycle from 65% to 95% implementation result

36W fluorescent lamp								
Vin (V)	242							
Duty Cycle (%)	55	60	65	70	75	80	85	90	95
Iin (A)			0.166	0.199	0.225	0.248	0.277	0.306	0.333
Vout (V)			160	170	182	192	202	212	220
Iout (A)			0.113	0.189	0.248	0.292	0.331	0.37	0.406
Power mean IN (W)			35.08	41.66	42.97	47.77	50.16	53.3	57.37
Power mean OUT (W)			10.22	17.57	22.3	26.13	28.83	31.9	33.92
Efficiency (%)			29.13	42.17	51.9	54.7	57.48	59.85	59.12

Table 6.2.2: 36W Fluorescent lamp

6.3 Lamp

6.3.1 100W lamp implementation result

Condition: Input Voltage = 244Vac, Duty cycle = 55%

Ch 1 and 2 are output voltage and current.

Ch 3 and 4 are input voltage and current.

The input and output waveform are quite similar because the lamp is resistive load.

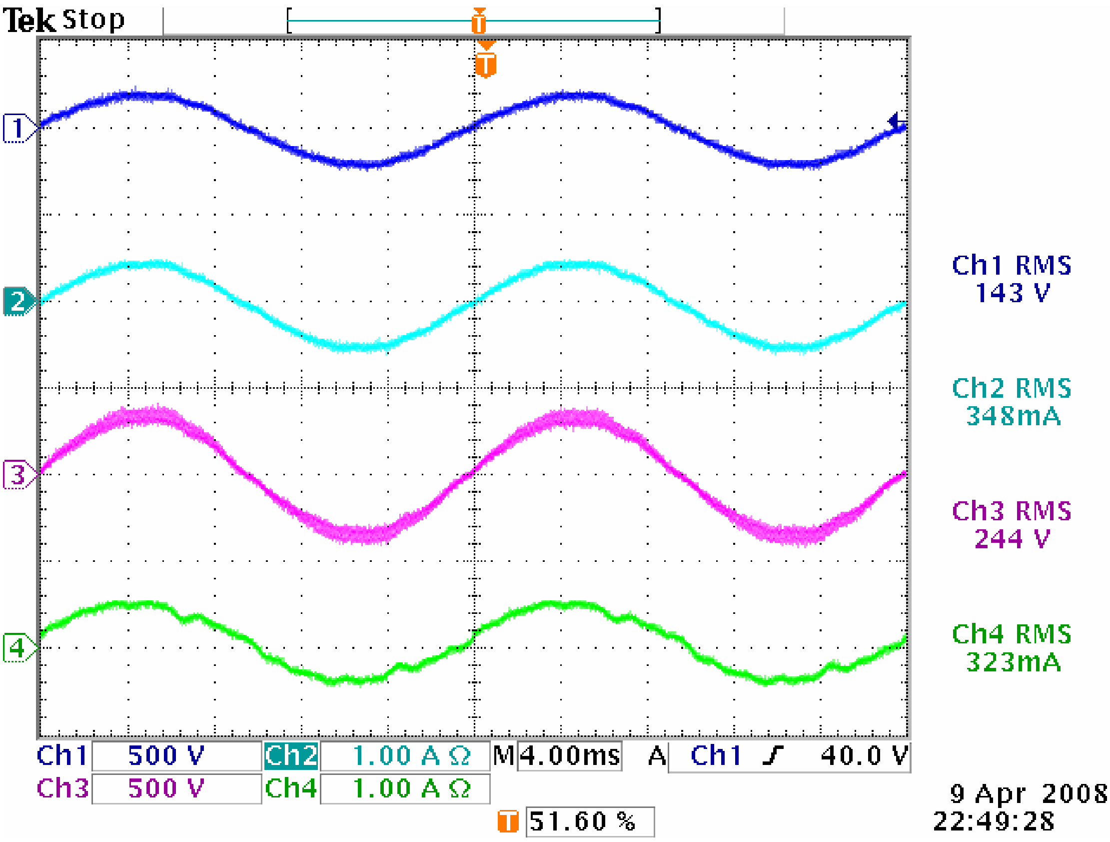


Fig 6.3.11: 100W lamp (Duty cycle = 55%)

Condition: Input Voltage = 244Vac, Duty cycle = 95%

Ch 1 and 2 are output voltage and current.

Ch 3 and 4 are input voltage and current.

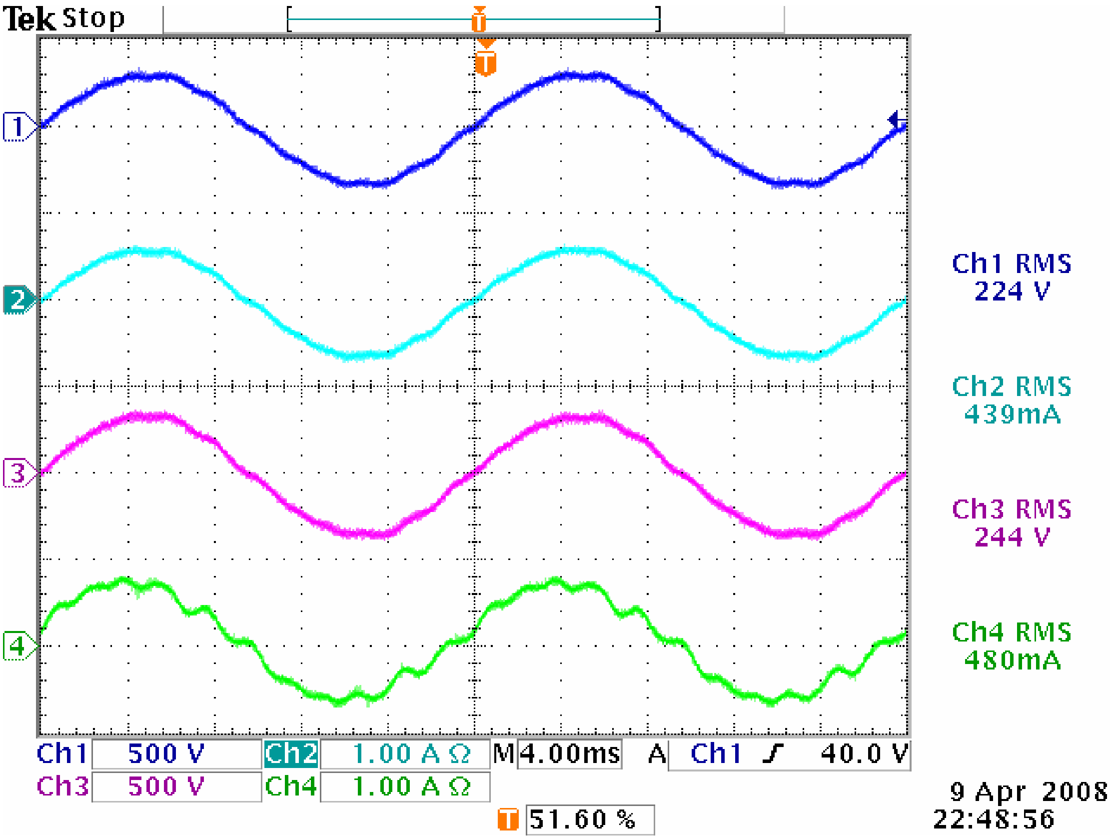


Fig 6.3.12: 100W lamp (Duty cycle = 95%)

6.3.2 200W lamp implementation result

Condition: Input Voltage = 242Vac, Duty cycle = 55%

Ch 1 and 2 are output voltage and current.

Ch 3 and 4 are input voltage and current.

The different is only output power.

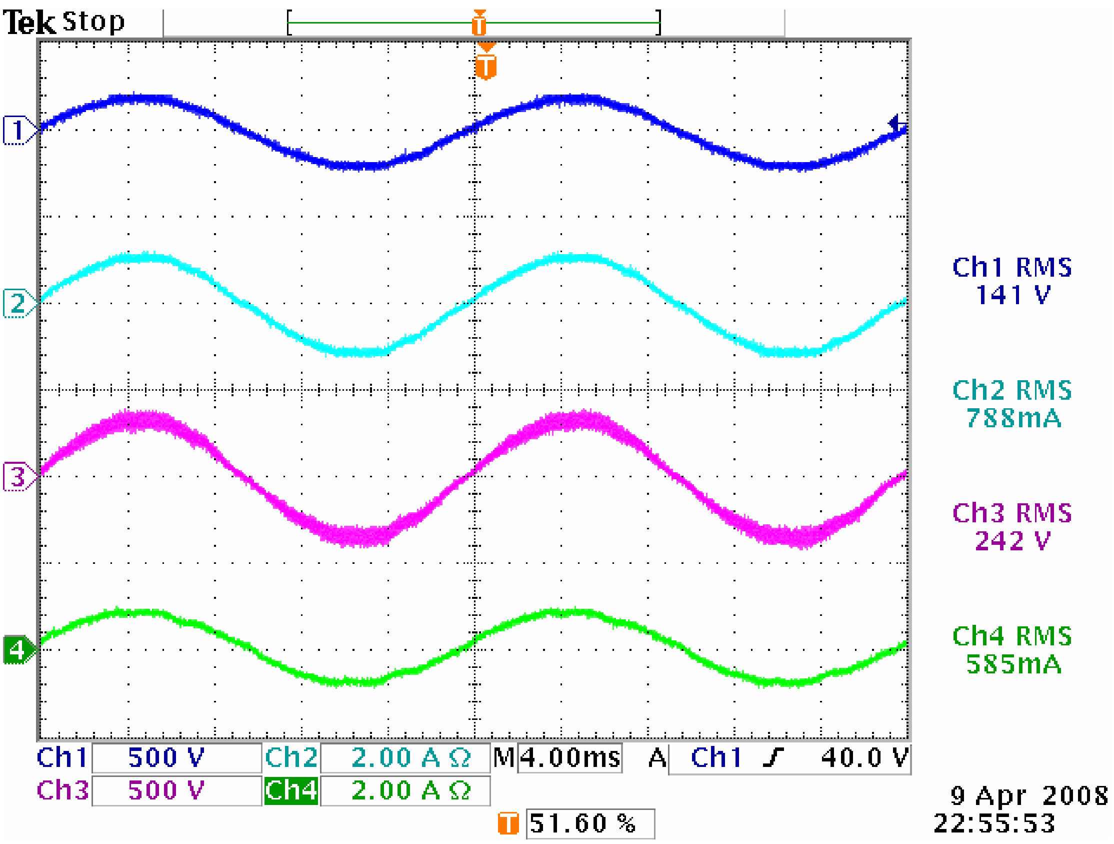


Fig 6.3.21: 200W lamp (Duty cycle = 55%)

Condition: Input Voltage = 238Vac, Duty cycle = 95%

Ch 1 and 2 are output voltage and current.

Ch 3 and 4 are input voltage and current.

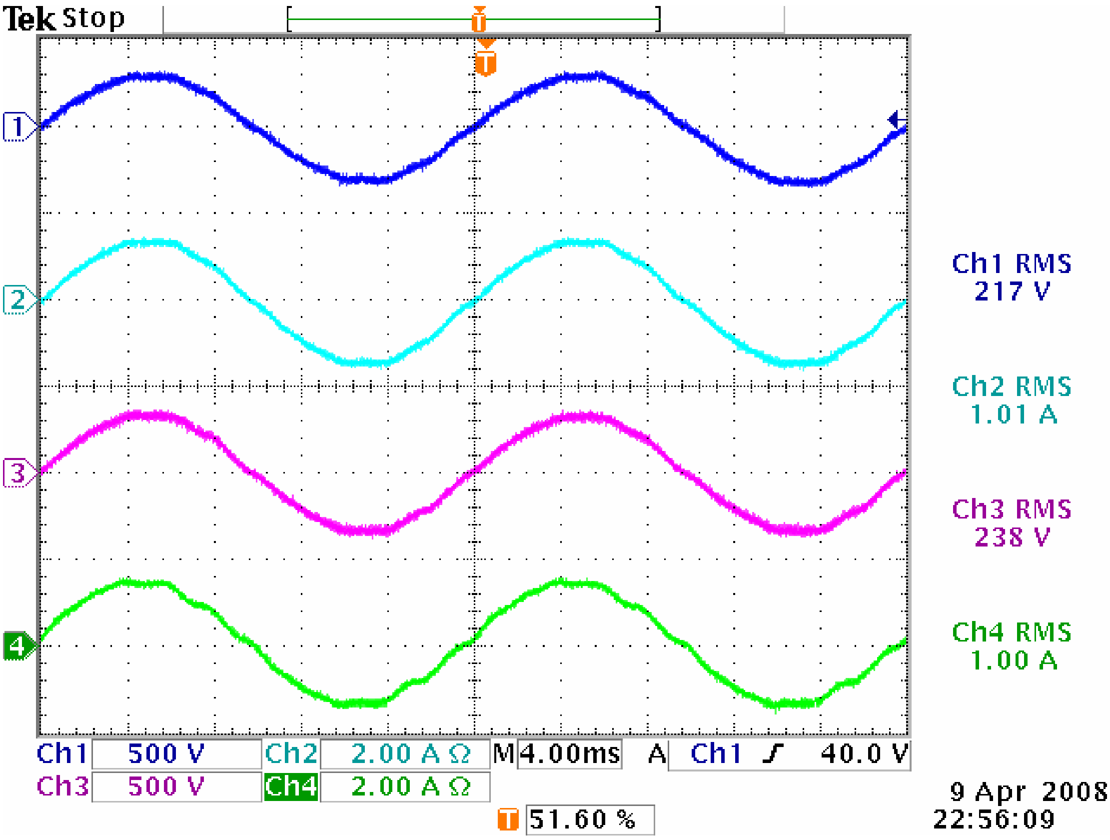


Fig 6.3.22: 200W lamp (Duty cycle = 95%)

6.3.3 Duty cycle from 55% to 95% implementation result

100W lamp									
Vin (V)	245								
Duty Cycle (%)	55	60	65	70	75	80	85	90	95
Iin (A)	0.315	0.327	0.35	0.368	0.386	0.405	0.426	0.45	0.48
Vout (V)	144	150	160	172	182	192	202	212	221
Iout (A)	0.346	0.354	0.374	0.39	0.403	0.418	0.433	0.442	0.45
Power mean IN (W)	75.16	77.72	83.4	87.75	91.33	95.41	100.6	106.1	109.3
Power mean OUT (W)	49.13	52.85	59.62	65.77	72.58	78.25	84.93	90.8	96.64
Efficiency (%)	65.37	68.00	71.49	74.95	79.47	82.01	84.42	85.58	88.42

Table 6.3.31: 100W lamp

200W lamp									
Vin (V)	240								
Duty Cycle (%)	55	60	65	70	75	80	85	90	95
Iin (A)	0.578	0.609	0.662	0.717	0.771	0.823	0.876	0.93	0.994
Vout (V)	139	145	156	167	175	186	196	207	216
Iout (A)	0.784	0.799	0.832	0.865	0.895	0.922	0.947	0.977	1
Power mean IN (W)	135.3	143.1	155.5	169.6	180.7	193.5	205.5	218.4	231.8
Power mean OUT (W)	107.7	115.2	129.6	142.8	157.1	172.7	185.1	201.5	215.9
Efficiency (%)	79.60	80.50	83.34	84. 20	86.94	89.25	90.07	92.26	93.14

Table 6.3.32: 200W lamp

6.4 Duty cycle VS Efficiency

The Duty cycle increase and hence the efficiency increase. Assume the P_{loss} is fixed; the P_{OUT} is proportional to the efficiency. The equation is shown in the following:

$$\eta = \frac{P_{OUT}}{P_{OUT} + P_{loss}} \times 100\%$$

$$\therefore \quad \eta \propto P_{OUT}$$

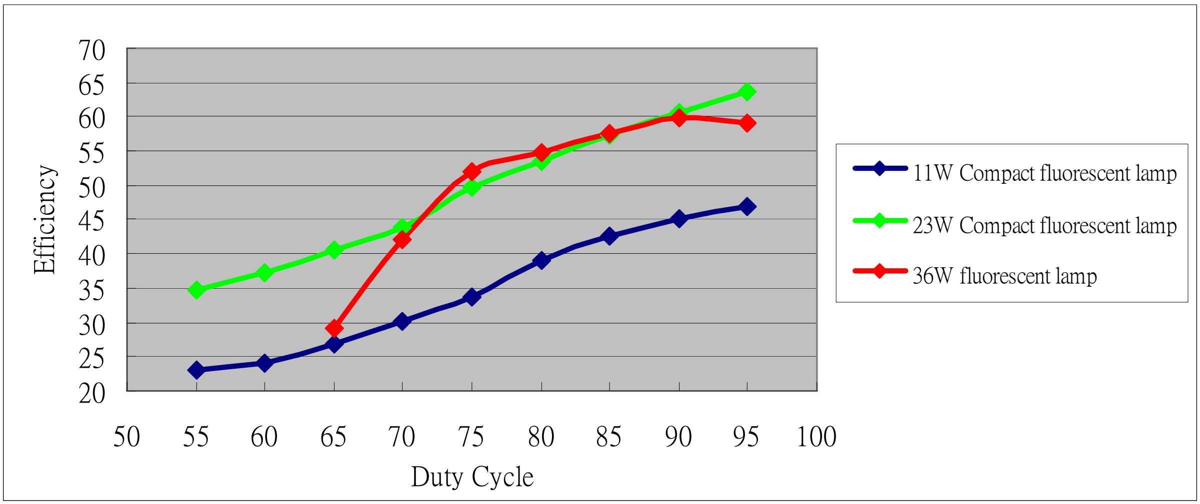


Fig. 6.4.1 Compact fluorescent lamps VS fluorescent lamps

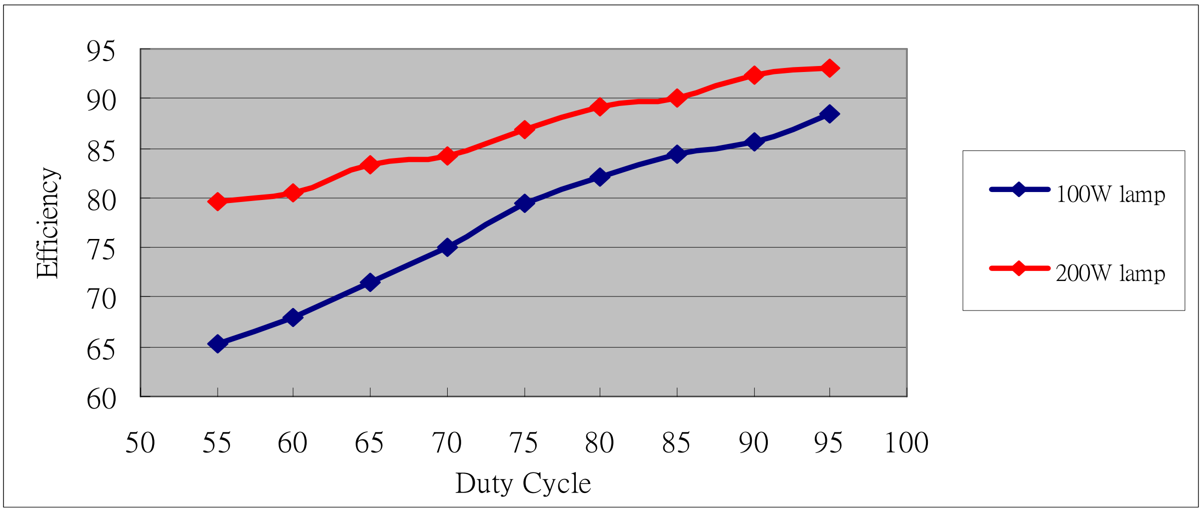


Fig. 6.4.2 Lamps Efficiency VS Duty cycle

6.4.1 Efficiency calculus

$$\eta = \frac{P_{OUT}}{Pin} \times 100\%$$

$P_{OUT} = V_{OUT}$ X I_{OUT}

$P_{IN} = V_{IN}$ X I_{IN}

$$\therefore \eta = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times I_{IN}} \times 100\%$$

e.g. V_{OUT} = 216V; I_{OUT} = 1A

V_{IN} = 240V; I_{IN} = 994mA

So, $\eta = \frac{216 \times 1}{240 \times 0.994} \times 100\%$

$\therefore \eta = 93.14\%$

P_{loss} = Switching loss + Conduction loss (Turn on loss) + Leakage loss (Turn off loss)

+ Gate signal loss (Control loss)

The total P_{loss} is 6.86%.

6.5 Temperature measurement

Condition : Duty cycle = 95%; Room Temperature = 22.8˚C

After 5 mins	11W Compact Fluorescent lamp	23W Compact Fluorescent lamp	100W lamp	200W lamp
Switch 1	26.6℃	35.3˚C 27.2	˚C 29.8	˚C
Snubber Inductor	34.6℃	53.5˚C 32.7	˚C 31.7	˚C

After 15 mins	11W Compact Fluorescent lamp	23W Compact Fluorescent lamp	100W lamp	200W lamp
Switch 1	26.6˚C 36.1	˚C 29.3	˚C 31.1	˚C
Snubber Inductor	38.2˚C 52.8	˚C 37.7	˚C 36.1	˚C

Table 6.5 Temperature Result

Chapter 7 Discussion

The PWM signals are using 89C2051 to generate the control signal. Even though use the 24MHz crystal; it is still not fast enough. The dead time can't shorter than 500ns. Therefore, I have strongly suggested changing the MCU to PIC/AVR/ARM. Then, the dead time can shorten to hundred nanoseconds. The whole circuit performance should be improved.

Also, the control circuit voltage is using LM7815 to provide stable and accurate supply voltage for isolation and gate driver circuit. But the drawback is the efficiency; it should be lower than 45%. Therefore, I would recommend using LM2675 to replace it. It is because LM2675 is a simple step down switching regulator. The efficiency is up to 96%. So the whole circuit efficiency must be improved.

Chapter 8 Conclusion

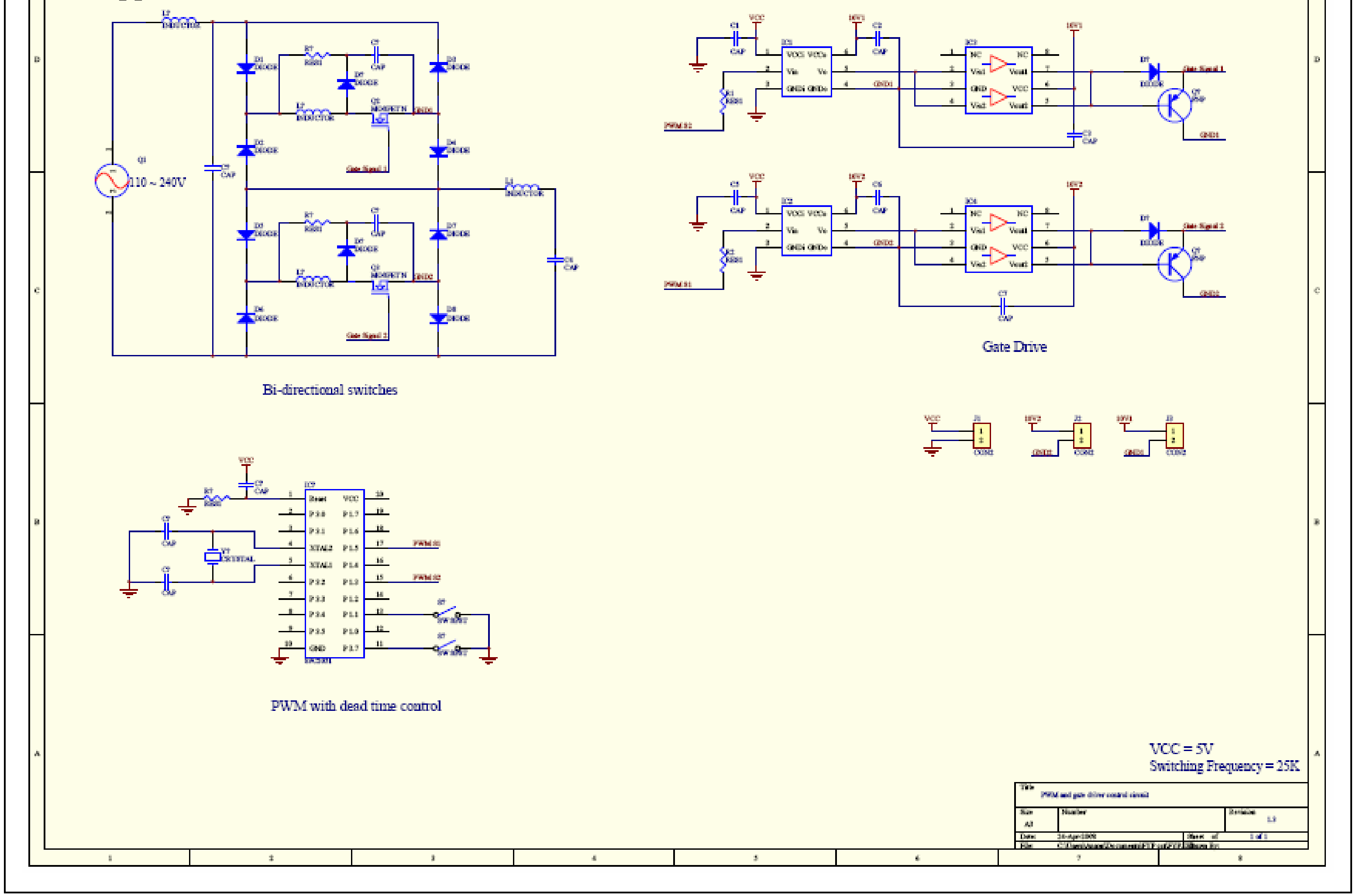
In my project, I have done the ac-ac converter which can dim the compact fluorescent lamps or other light devices. The ac-ac converter is using Pulse Width Modulation (PWM) to change the duty cycle and hence change the output voltage level. The output voltage range is from 121V to 209V (Duty Cycle = 55% to 95%). And the power rating is 300W (max 350W). The efficiency is 93%. After the measurement, I had found that the voltage and current stress are not good enough. Therefore, I need create another circuit to eliminate the voltage and current stress. So the energy recovery snubber was created. Unfortunately, I can't make these two circuits together because the time is limited.

For further improvement, the switching frequency needs to increase from 25 kHz to 100 kHz because the size of inductor and capacitor can be reduced. Therefore, the entire circuit can be compact.

Chapter 9 Reference

1. M H Rashid, "Power Electronic : Circuits, Devices and Applications," Prentice-Hall, 1993.
2. N Mohan, T M Undeland, and W P Robins, "Power Electronics: Converters, Applications, and Design," John Wiley and Sons, 1995.
3. EE4101 Modern Power Electronics, Prof Henry Chung
4. EE6427 Modern Power Electronics, Chair Prof Ron Hui

Appendix I Schematic of ac-ac converter



Appendix II Schematic of Energy Recovery Snubber