

ISTANBUL TECHNICAL UNIVERSITY
DEPARTMENT OF ELECTRICAL
ENGINEERING



POWER ELECTRONIC CIRCUITS FALL 2008, CRN: 11473

ASST. PROF. DENİZ YILDIRIM

PROJECT REPORT

MINIPROJECT I	
15V, 500mA AC/DC Standard Household Adapter (Rectifier)	
GROUP MEMBERS	
040050437 040050442 040060450	BURAK BEŞER ELİF KÖKSAL BİROL ÇAPA

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1. Purpose

The purpose of this project is to design a standard household AC/DC adapter that converts 220 V alternative voltage to 15V direct voltage. It is also desired to have 500 mA at the output.

The main steps of this project are design and testing. In design step, the components of the circuit are chosen according to working principles. The values are calculated properly. After the simulation, the circuit is constructed and tested by some measurement tools.

At the circuit, a transformer is used to drop the voltage to an acceptable value. A full wave rectifier with a capacitor is used to rectify. At last a regulator is integrated to get 15 V DC as desired.

In Figure 1.1, a sinusoidal wave, in figure 1.2 a fully rectified sinusoidal wave and in figure 1.3 a filtered half-wave rectified wave can be seen.

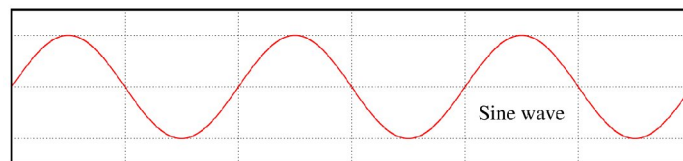


Figure 1.1 - Sinusoidal wave

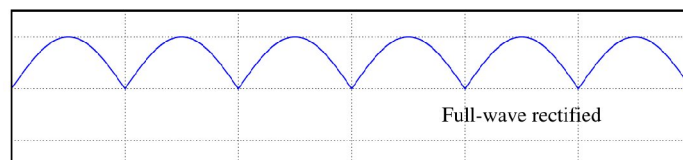


Figure 1.2 - Fully rectified sinusoidal wave

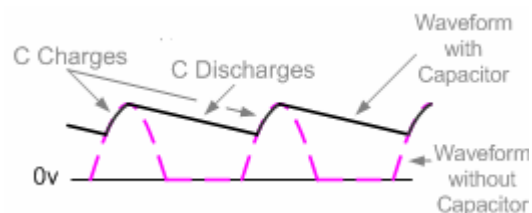


Figure 1.3 - Filtered wave

2. Design

Figure 2.1 is the typical circuit diagram of an AC/DC adapter. PSpice 9.1 Student Version is used to draw and simulate the circuit.

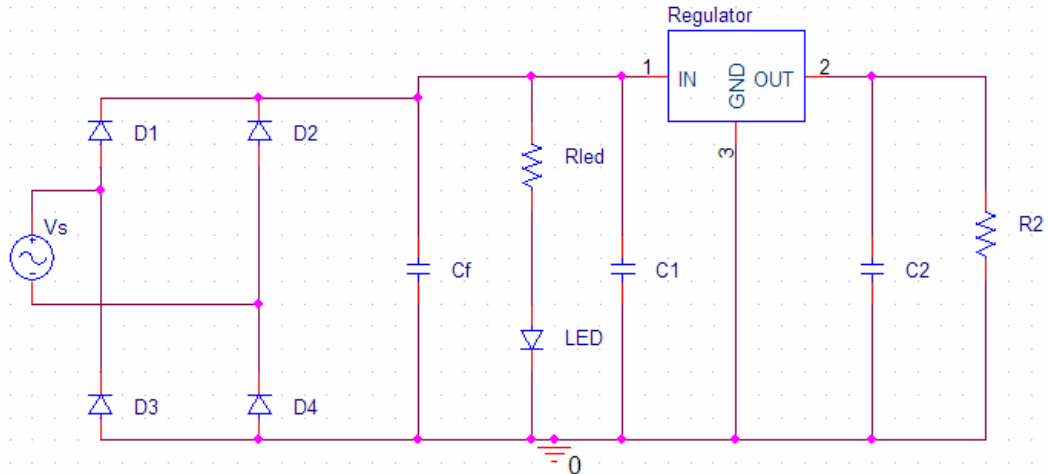


Figure 2.1 - Typical Circuit Diagram of an AC/DC Adapter

The aim of this circuit is to convert 220 V 50 Hz sinusoidal AC voltages to 15V DC at a load current of 500 mA. Moreover, the ripple voltage at the input of the regulator must be less than 10%.

To get 15V DC LM7815C regulator is used. The maximum input voltage of LM7815 is 35V⁽¹⁾ (Appendix 1). The choice of the transformer is based on the input voltage of the regulator and the P_{LOAD} value. The output of the transformer:

$$V_{rms_{trans}} = 24V$$

$$V_{max_{tran}} = 24V * \sqrt{2} \cong 33,9$$

With respect to the “diode-on” mode⁽²⁾ (Appendix 2) the value is calculated as:

$$V_{max_{dcin}} = V_{max_{tran}} - 2 * V_{diode}$$

$$V_{max_{dcin}} = 33,9 - 2 * 1,1$$

$$V_{max_{dcin}} = 31,7V$$

The ripple must be less than 10%, thus the minimum V_{dcin} is:

$$V_{min_{dcin}} = 31,7 * 0,9$$

$$V_{min_{dcin}} = 28,53V$$

From the formula of the ripple voltage⁽³⁾ the capacitor value is calculated:

$$\Delta V_{load} = \frac{I_{DCload}}{2fC} \quad \Delta V_{load} = 31.9 - 28.53 = 3.37V$$

$$3.37 = \frac{500 * 10^{-3}}{2 * 50 * C} \quad C = 1484 \mu F$$

The maximum forward voltage of LED is $4.5V^{(4)}$ (Appendix-3) and the forward current is 20mA. So R_{led} is

$$R_{led} = \frac{V_{maxled}}{I_{led}} = \frac{28.53 - 4.5}{20 * (10^{-3})} = 1201,5 \Omega$$

However, this value of resistor causes to drive led at its maximum voltage. Therefore, the resistor value has to be bigger than 1.2 k Ω . The value of R_{led} is chosen 3.2 k Ω for this project

Load resistor value is calculated as below:

$$V_{out} = 15V$$

$$I_{out} = 500mA$$

$$R_{load} = \frac{V_{out}}{I_{out}} = \frac{15}{0.5} = 30 \Omega$$

After these calculations, the circuit in Figure- 2.2 of the adapter is drawn and simulated.

3. Simulation

Simulations are run at full load and no load. In figure 3.1, source of the circuit is V_s which stands for the transformer's secondary side. As the transformer's ratio is 220:24, the value of V_s is 24V rms.

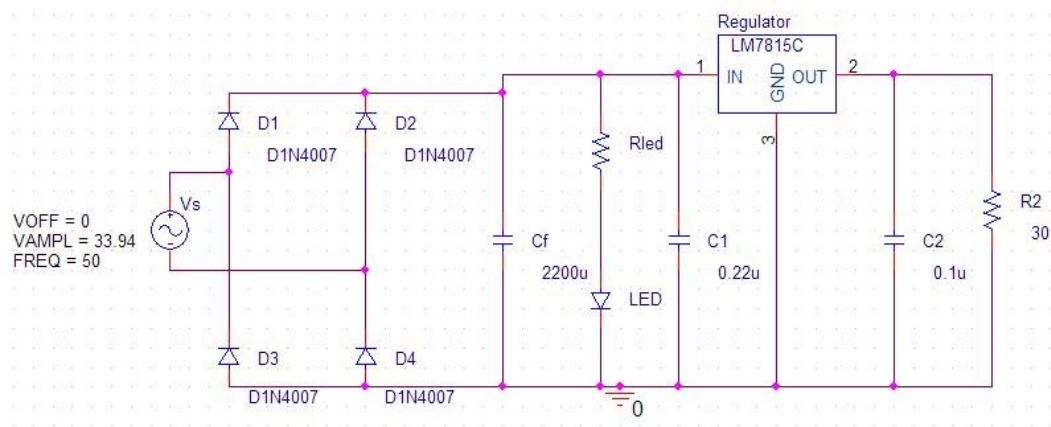


Figure 3.1 – Simulated circuit diagram

In figure 3.2 the waveforms of input AC voltage and input AC current with load are shown.

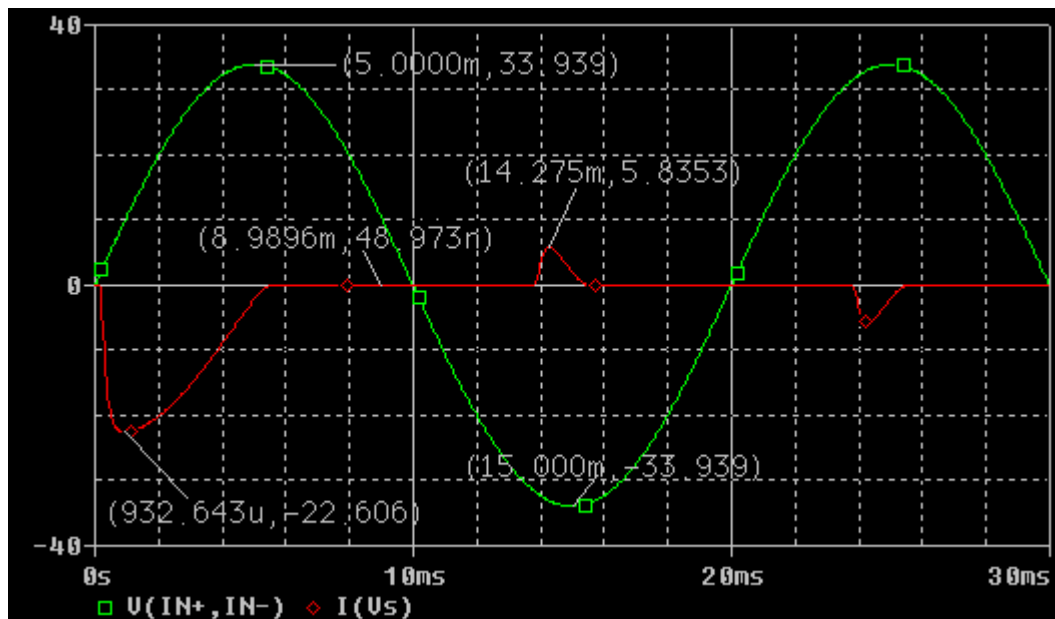


Figure 3.2 – Waveforms of AC input voltage and current values with load

As it is seen, source voltage is a sinusoidal 24V rms wave. Source current has its highest value at 932.643th microsecond and it rises from 0 to 5.8353A periodically. C_f capacitor is charged with these current values.

In figure 3.3 the waveforms of input AC voltage and input AC current without load are shown.

It is clearly seen that the voltage waveform without load is not different from the voltage waveform with load whereas the current is lesser. This means most of the current flows through the load.

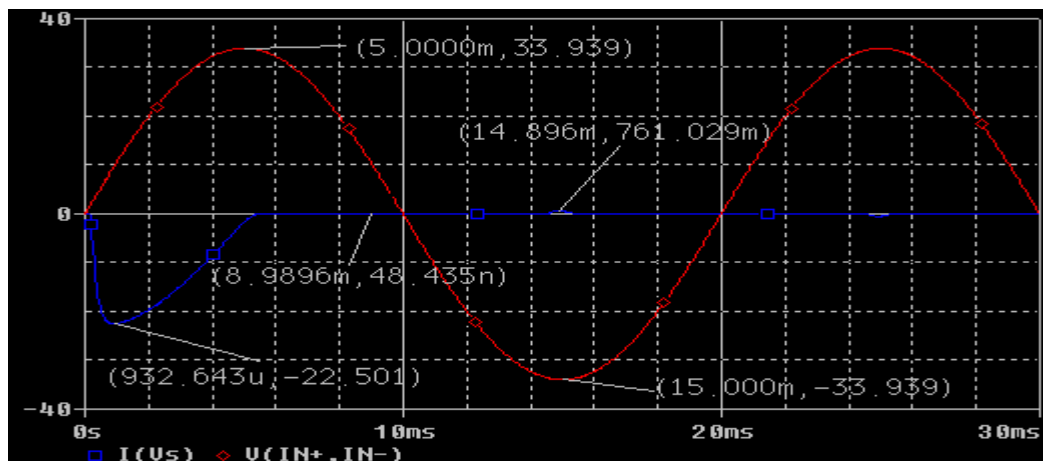


Figure 3.3 – Waveforms of AC input voltage and current values without load

In figure 3.4 the waveform of current that flows through the C_f capacitor is drawn. This waveform belongs to the load attached adapter.

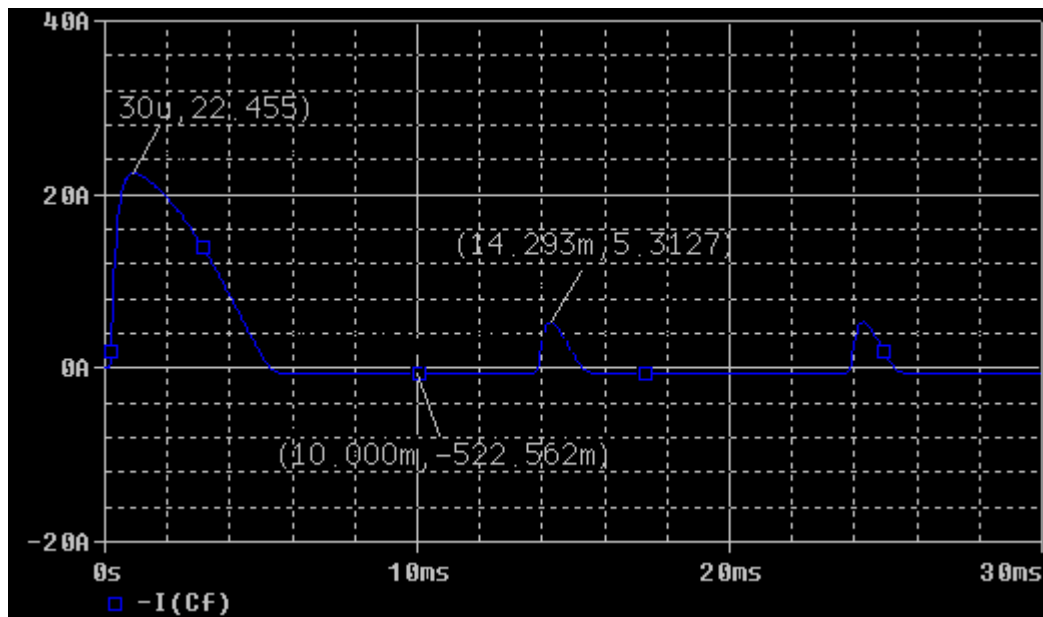


Figure 3.4 – Current value flowing through the C_f capacitor (with load)

Here, the waveform is changing according to the source current waveform. Capacitor's current is dissipated on the load.

When the circuit has no load, the waveform changes as shown in figure 3.5. As there is no load, the current dissipation is at very low levels.

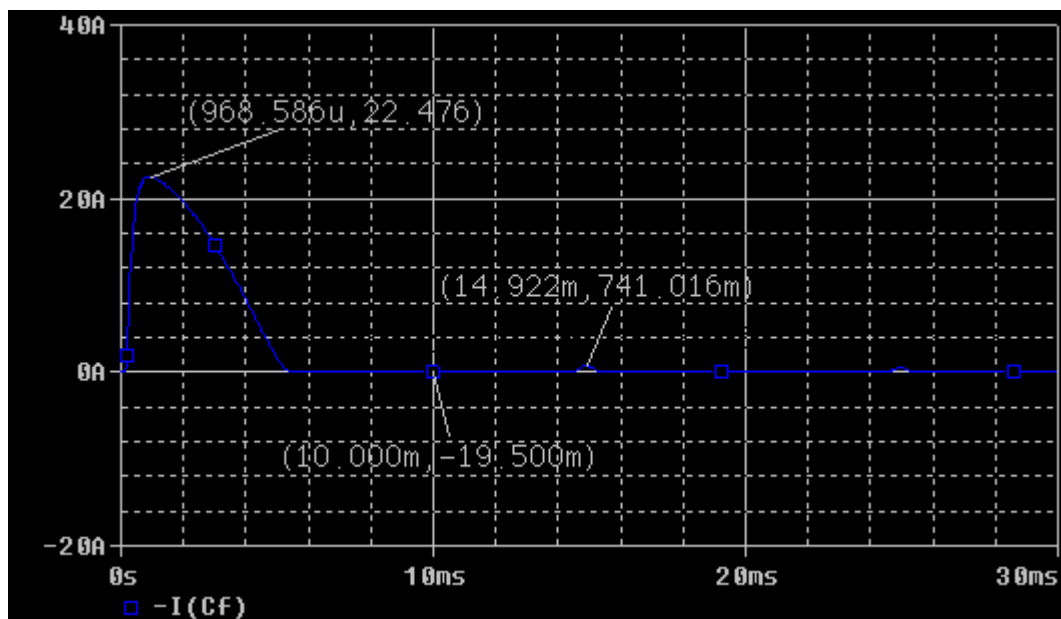


Figure 3.5 - Current value flowing through the C_f capacitor (without load)

In figure 3.6 the voltage and current waveforms at the regulator's input are drawn for adapter with load.

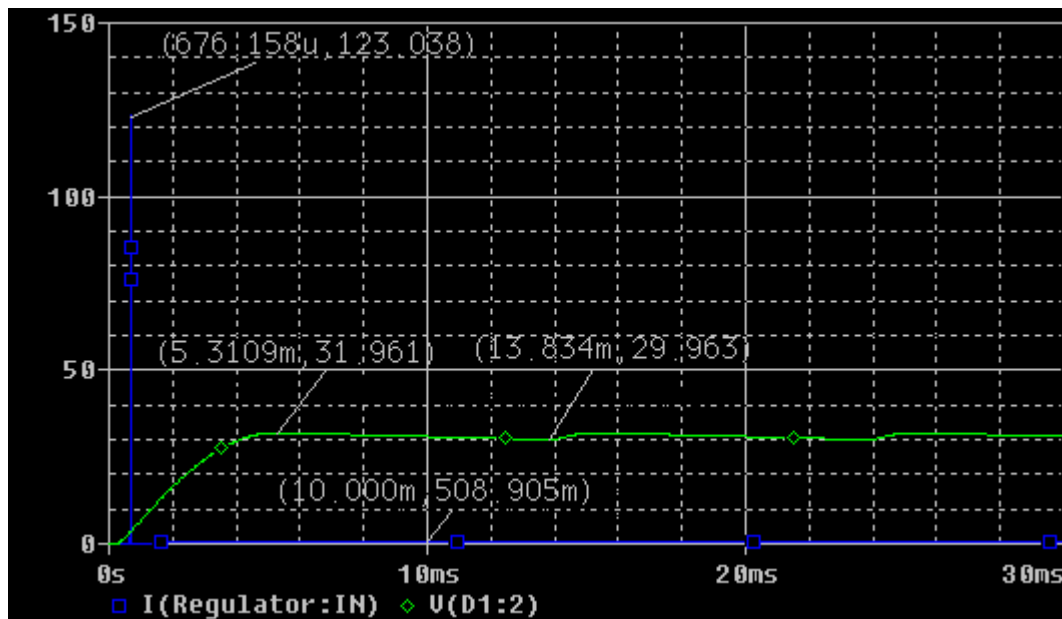


Figure 3.6 – Current and voltage waveforms at regulator's input (with load)

The current has a peak at 123,038A. This peak value depends on the C_f capacitor's value. The peak value gets larger when lower value capacitors are used. The voltage waveform at the regulator's input shows us the ripple voltage. In this case it is about 3,33%.

When there is no load attached to the adapter, current waveform stays approximately the same with loaded one. However, voltage waveform gets almost a straight line where ripple voltage is so low to be mentioned.

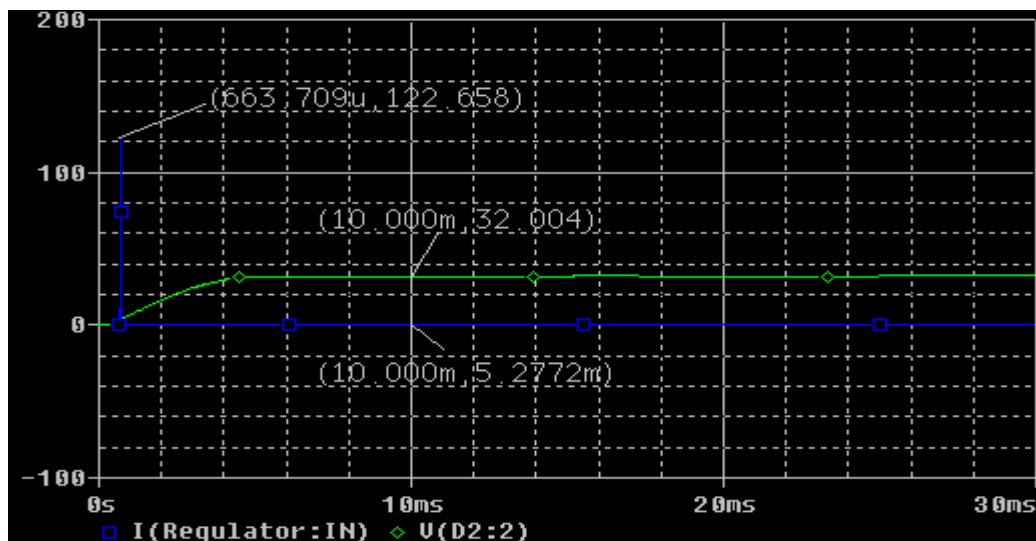


Figure 3.7 – Current and voltage waveforms at regulator's input (without load)

The current and voltage waveforms at the output of the regulator are shown in figure 3.8 for an adapter with load.

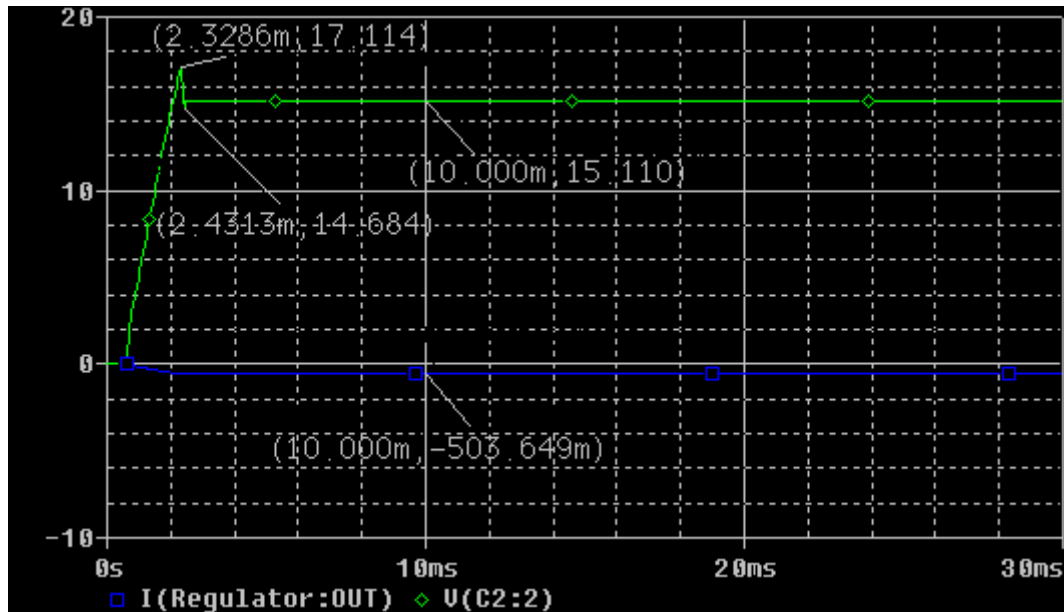


Figure 3.8 - Current and voltage waveforms at regulator's output (with load)

There is a peak value for voltage at 2,3286 milliseconds. This value is regardless of the capacitor and load values. As it can be seen at figure 3.9 removing load does not change peak value. The steady-state value 15V is provided by the regulator LM7815C.

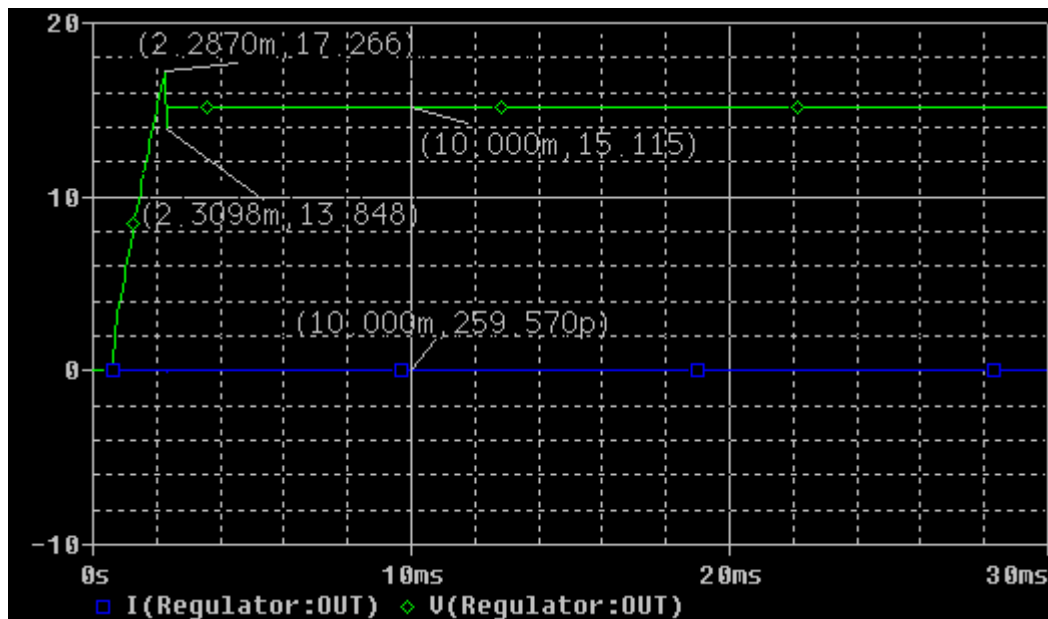


Figure 3.8 - Current and voltage waveforms at regulator's output (without load)

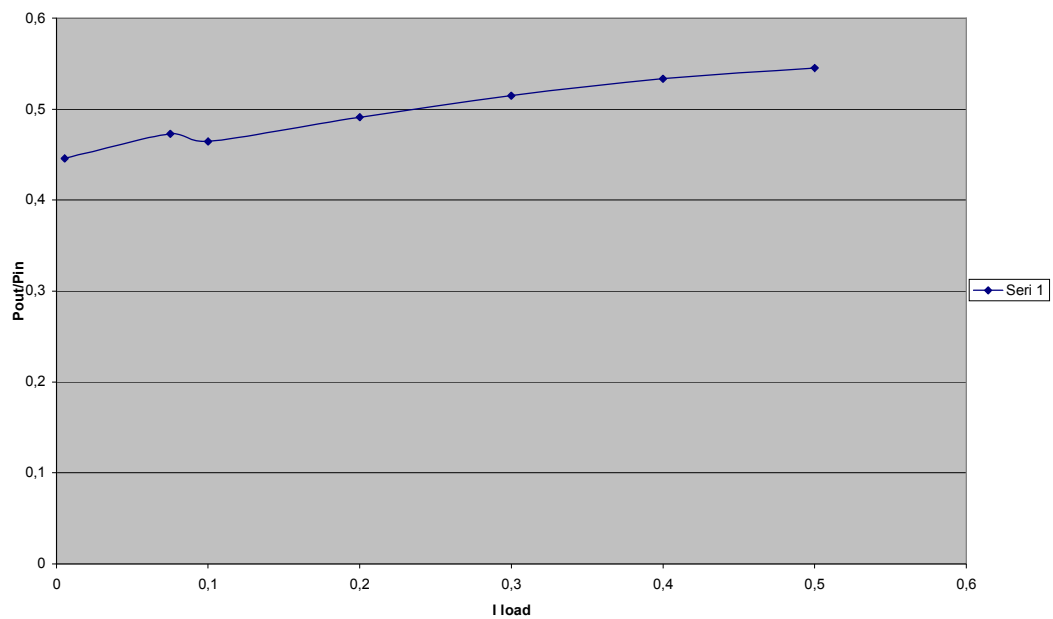
When there is a 30 ohm resistance as a load, the output current is about 500mA as it is shown in figure 3.7. If we remove the load then there is a current flow slightly through output of the regulator.

4. Testing

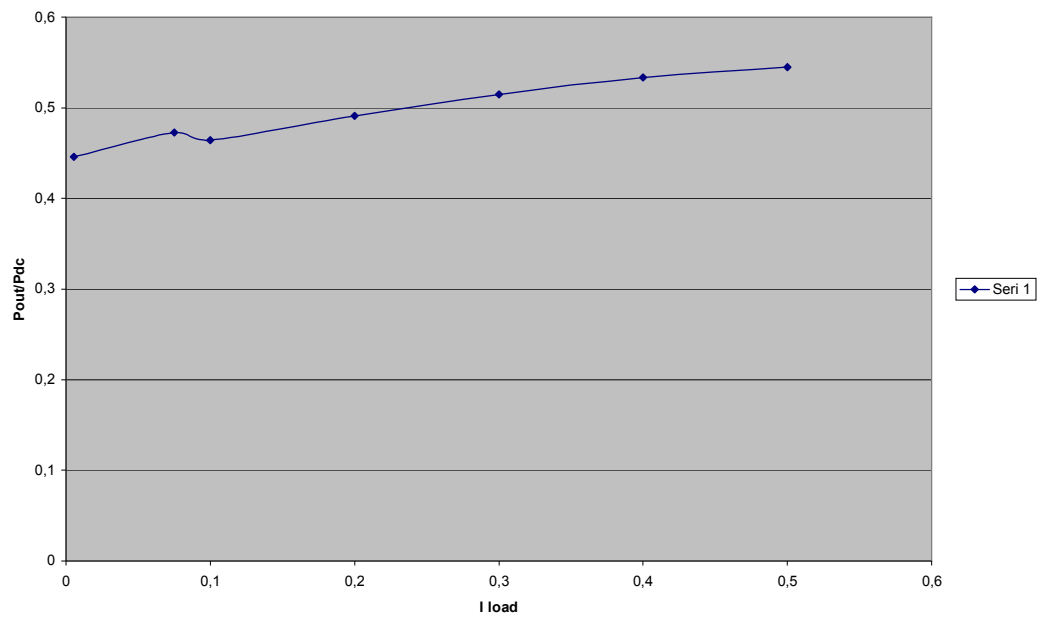
Table-1 shows the results of the circuits when it is tested.

Ripple of Reg.	Ripple Voltage	Vdcin(V)	Load Current(A)	Pin(W)	Pdc(W)	Pout(W)	Rload(Ohm)	Pout/Pdc	Pout/Pin
0,1	3,39	27,25	0,5	18,2	13,76	7,5	30	0,545058	0,412088
0,1	3,385	27,79	0,4	15,4	11,25	6	37,5	0,533333	0,38961
0,102	3,099	28,67	0,3	12	8,74	4,5	50	0,514874	0,375
0,09	2,51	29,82	0,2	11,4	6,11	3	75	0,490998	0,263158
0,088	2,04	30,8	0,1	10,2	3,23	1,5	150	0,464396	0,147059
0,08	1,352	30,94	0,075	9,5	2,38	1,125	200	0,472689	0,118421
0,028	1,124	31,15	0,0054	8	1,83	0,816	280	0,445902	0,102

Table 4.1 – Various results of circuit measurements



Graph 4.1 – Change of P_{out}/P_{in} with I_{load}



Graph 4.2 – Change of P_{out}/P_{dc} with I_{load}

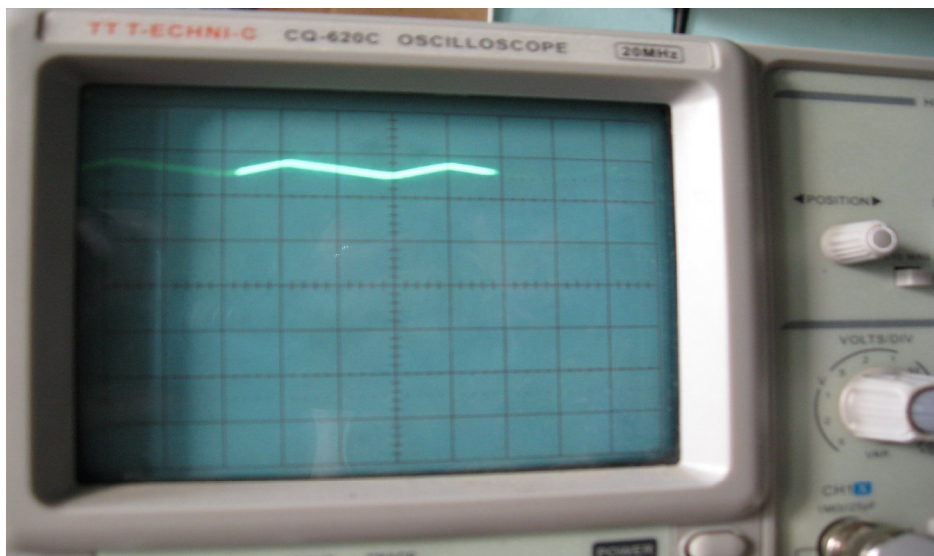


Figure 4.1 – The voltage ripple at capacitor input

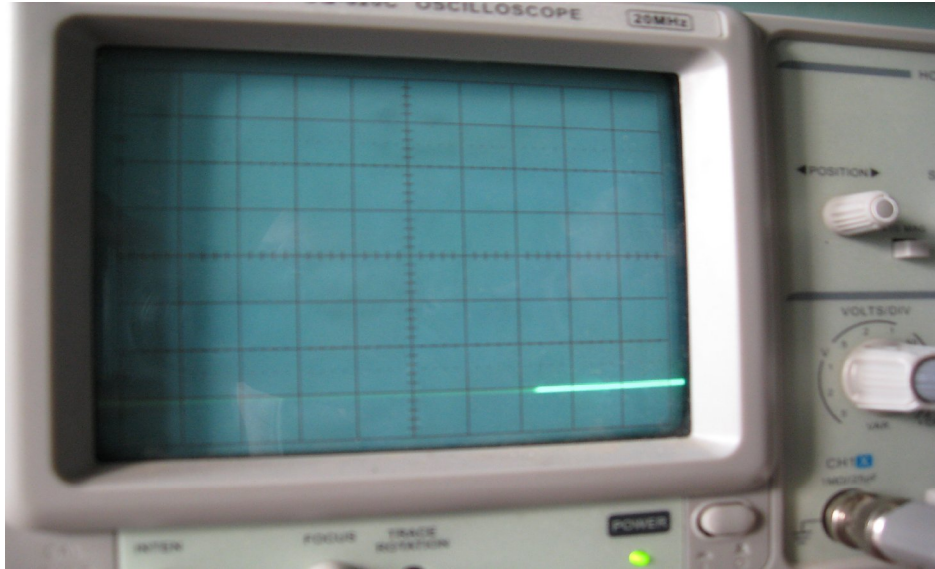


Figure 4.2 – The ground of Osilloscope

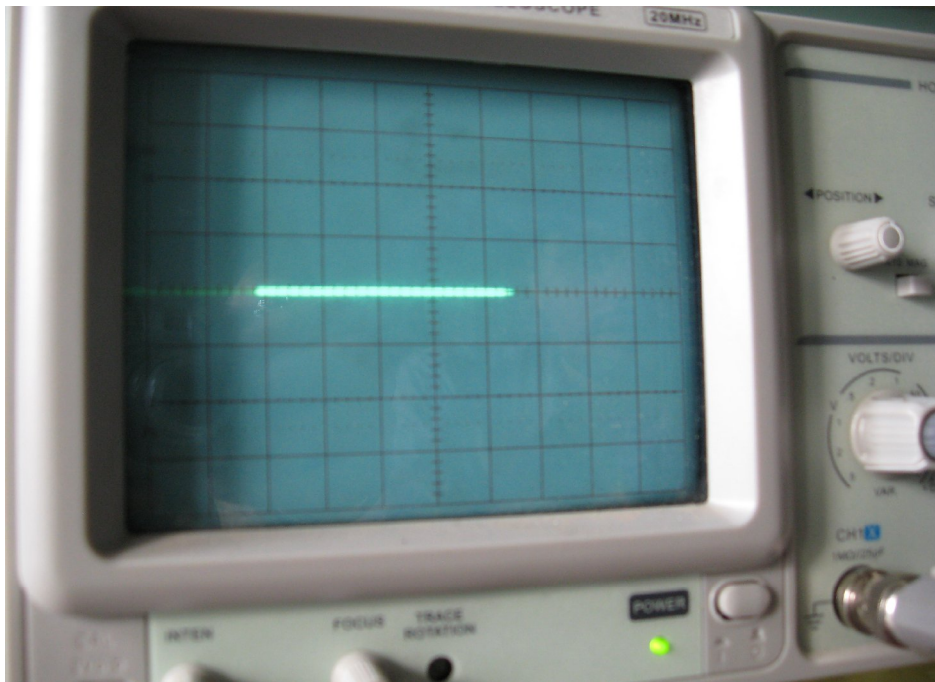


Figure 4.3 – The output voltage of regulator

5. Equipments

- 220:24 transformer
- 3.2 k Ω resistor
- 30 Ω resistor
- 2200 μ F capacity
- 0.22 μ F capacity
- 0.10 μ F capacity

- LM7815C regulator
- 4 x 1N4007 diode
- Blue LED

The equipments are selected according to calculations and simulation results.

6. References

1. National Semiconductor (2000). *LM78XX Series Voltage Regulators*. Retrieved October 13, 2008, from <http://www.datasheetcatalog.com/>
2. Fairchild Semiconductor Corporation (2001). *1N4001 - 1N4007*. Retrieved October 12, 2008, from <http://www.datasheetcatalog.com/>
3. Jacop J.M (2002). *Power Electronics: Principles & Applications*. New York: Delmar, Thomson Learning, Inc.
4. Purdy Electronics Corporation (2007). *GaN High Brightness Blue Light Emission*. Retrieved October 22, 2008 from <http://www.purdyelectronics.com/>

7. Appendix

- Appendix 1 – LM7815C Datasheet
- Appendix 2 – 1N4001 Datasheet
- Appendix 3 – Blue LED Datasheet