

ISTANBUL TECHNICAL UNIVERSITY
DEPARTMENT OF ELECTRICAL
ENGINEERING



POWER ELECTRONIC CIRCUITS FALL 2008, CRN: 11473

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PROJECT REPORT

MINIPROJECT I	
15V, 500mA AC/DC Standard Household Adapter (Rectifier)	
GROUP MEMBERS	
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SUBMISSION DATE: OCTOBER 23, 2008

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.

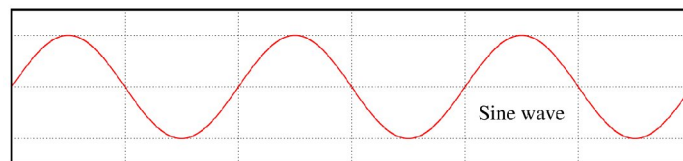


Figure 1.1 - Sinusoidal wave

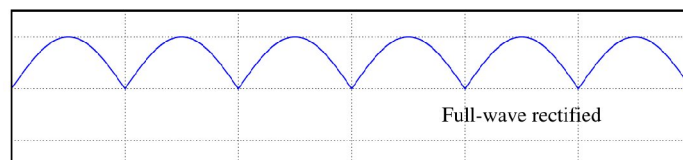


Figure 1.2 - Fully rectified sinusoidal wave

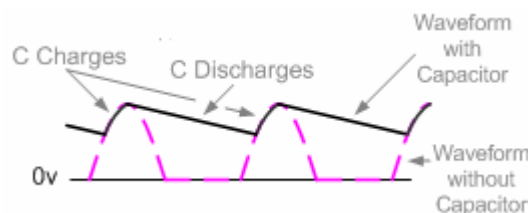


Figure 1.3 - Filtered wave

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.

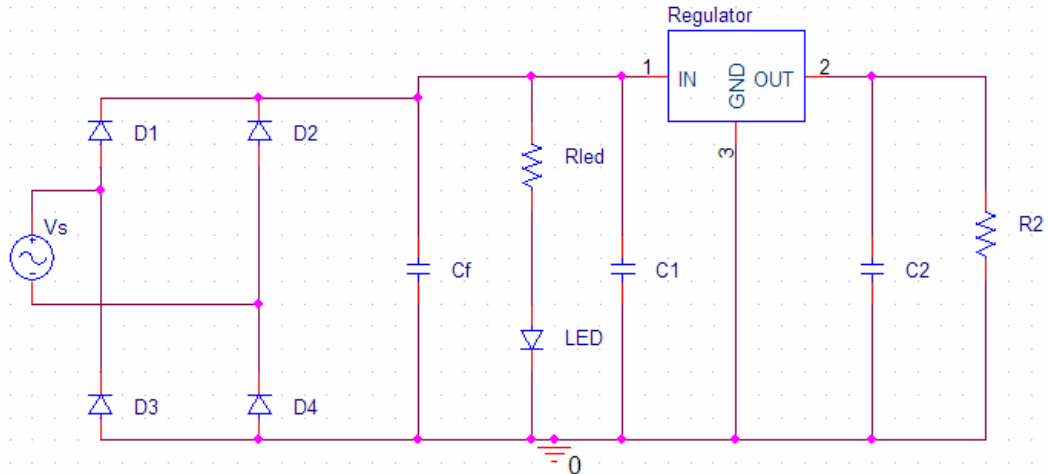


Figure 2.1 - Typical Circuit Diagram of an AC/DC Adapter

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.

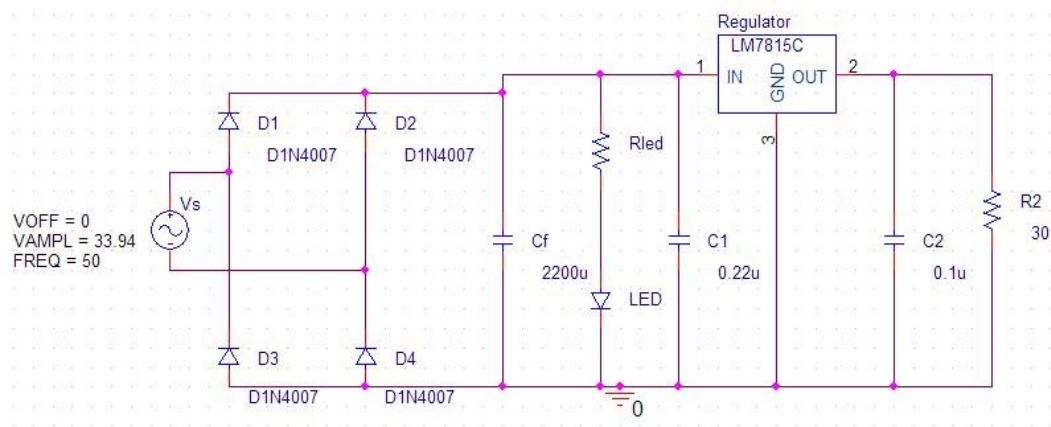


Figure 3.1 – Simulated circuit diagram

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

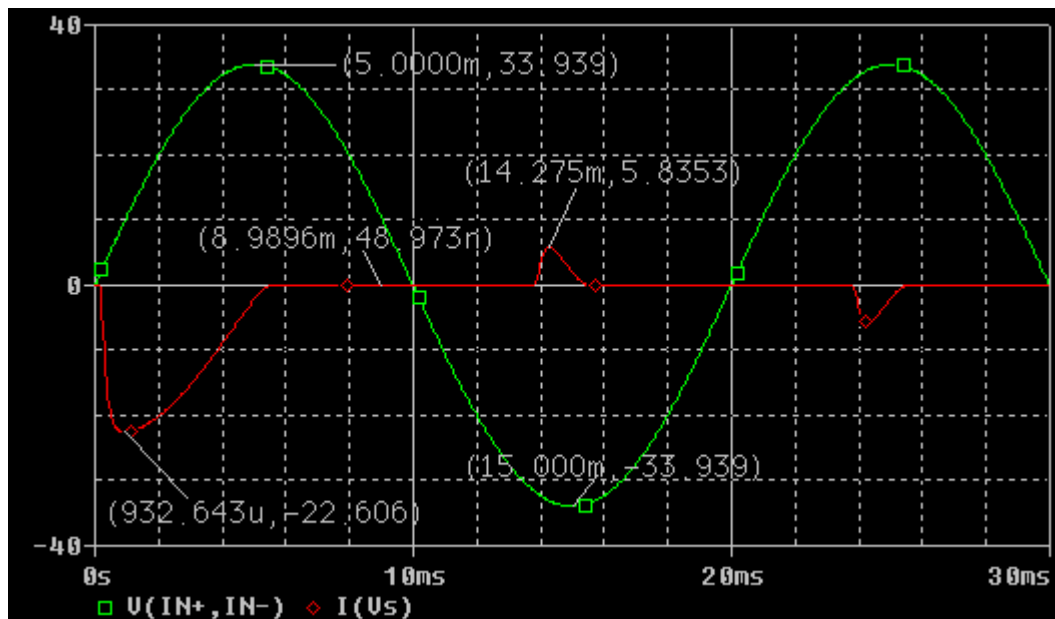


Figure 3.2 – Waveforms of AC input voltage and current values with load

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.

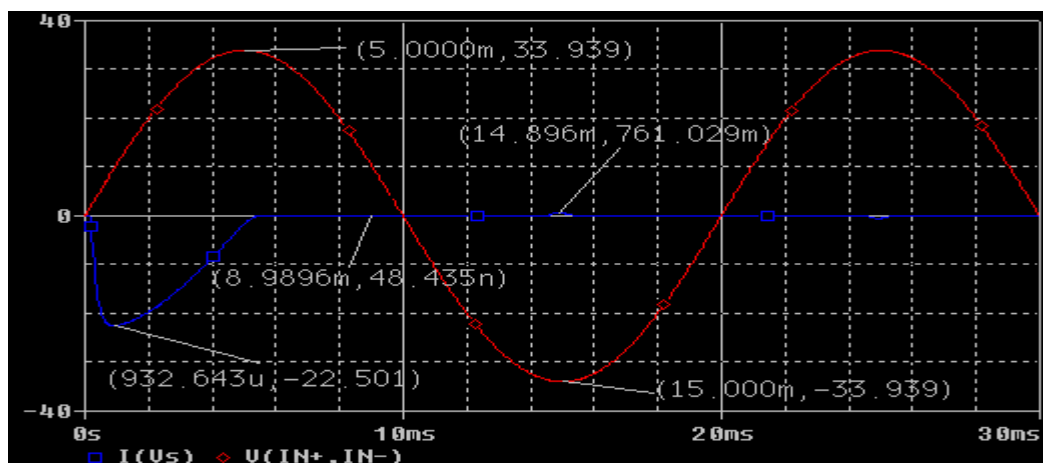


Figure 3.3 – Waveforms of AC input voltage and current values without load

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.

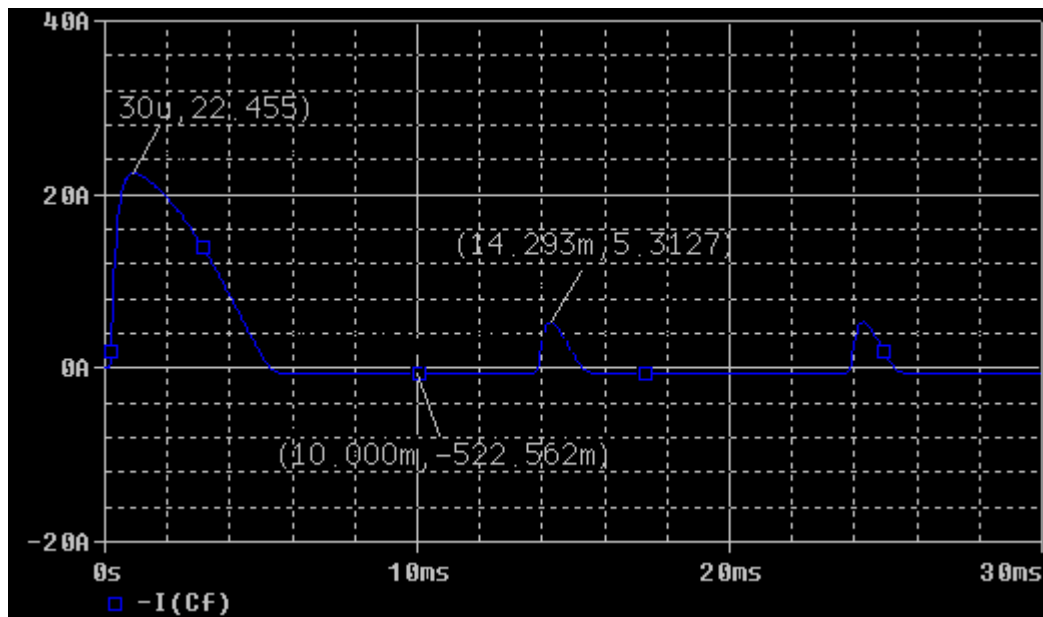


Figure 3.4 – Current value flowing through the C_f capacitor (with load)

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.

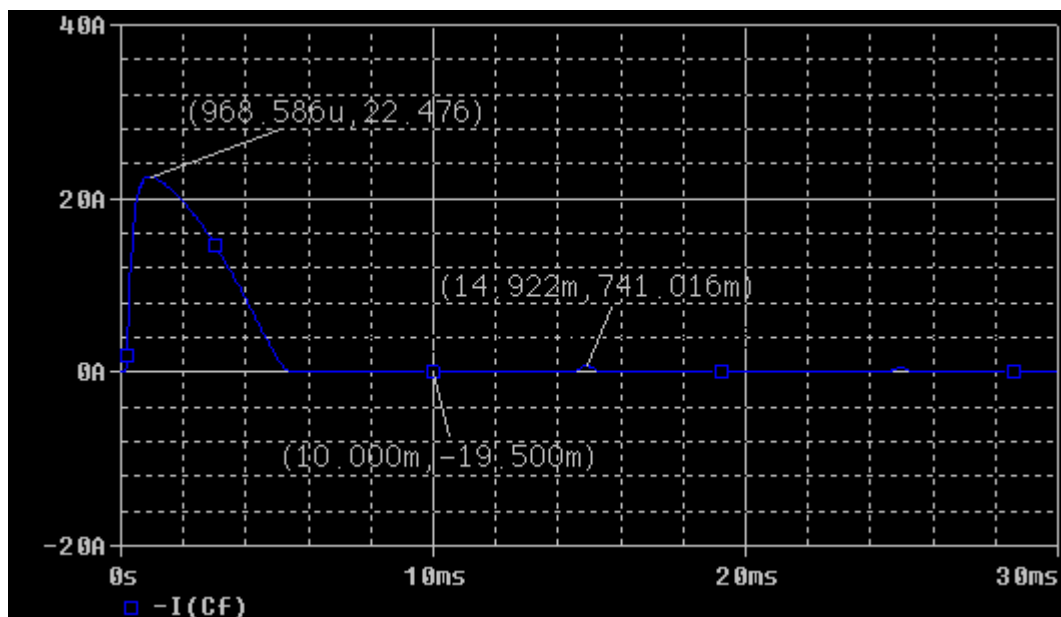


Figure 3.5 - Current value flowing through the C_f capacitor (without load)

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

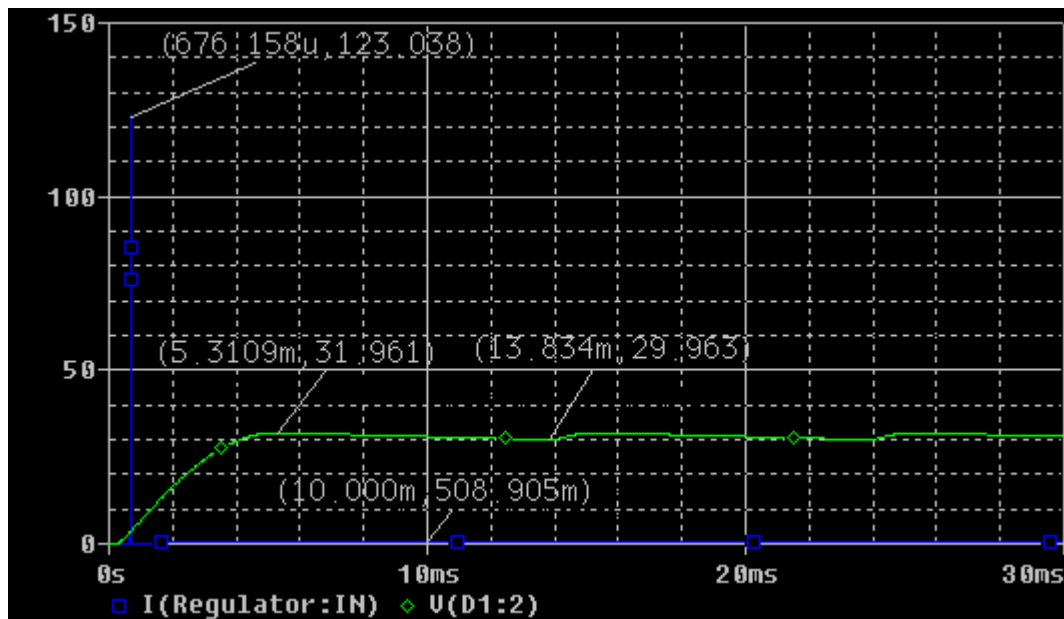


Figure 3.6 – Current and voltage waveforms at regulator's input (with load)

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.

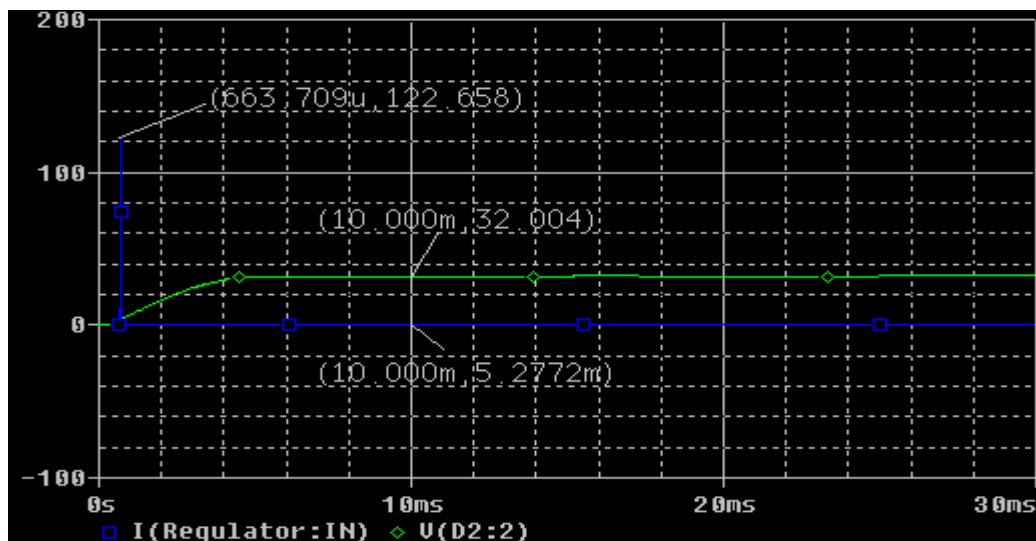


Figure 3.7 – Current and voltage waveforms at regulator's input (without load)

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

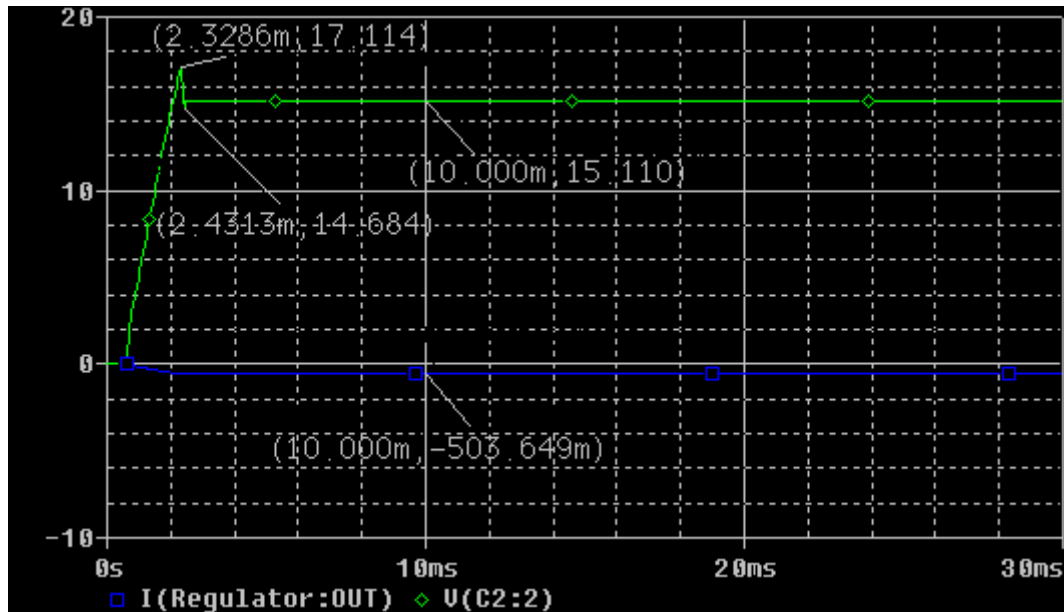


Figure 3.8 - Current and voltage waveforms at regulator's output (with load)

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.

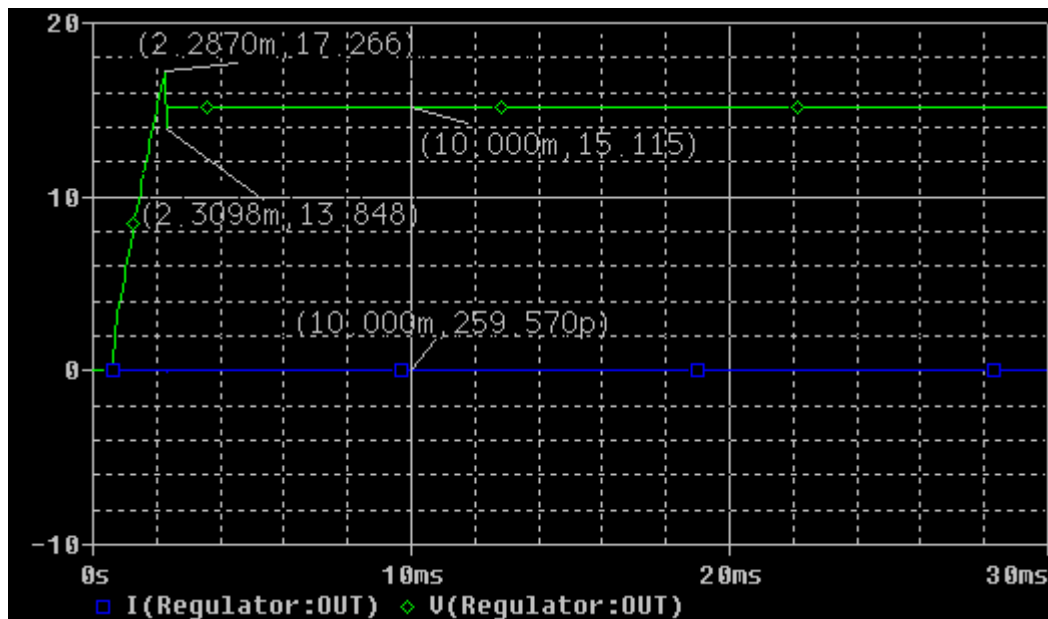


Figure 3.8 - Current and voltage waveforms at regulator's output (without load)

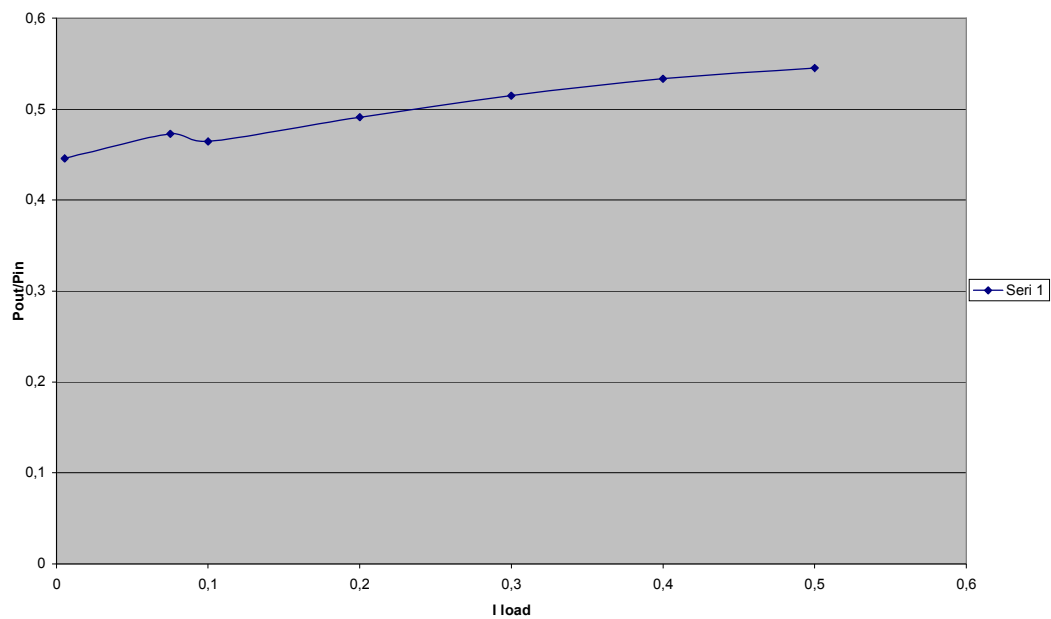
When there is a 30 ohm resistance as a load, the output current is about 500mA as it is shown in figure 3.7. If we remove the load then there is a current flow slightly through output of the regulator.

4. Testing

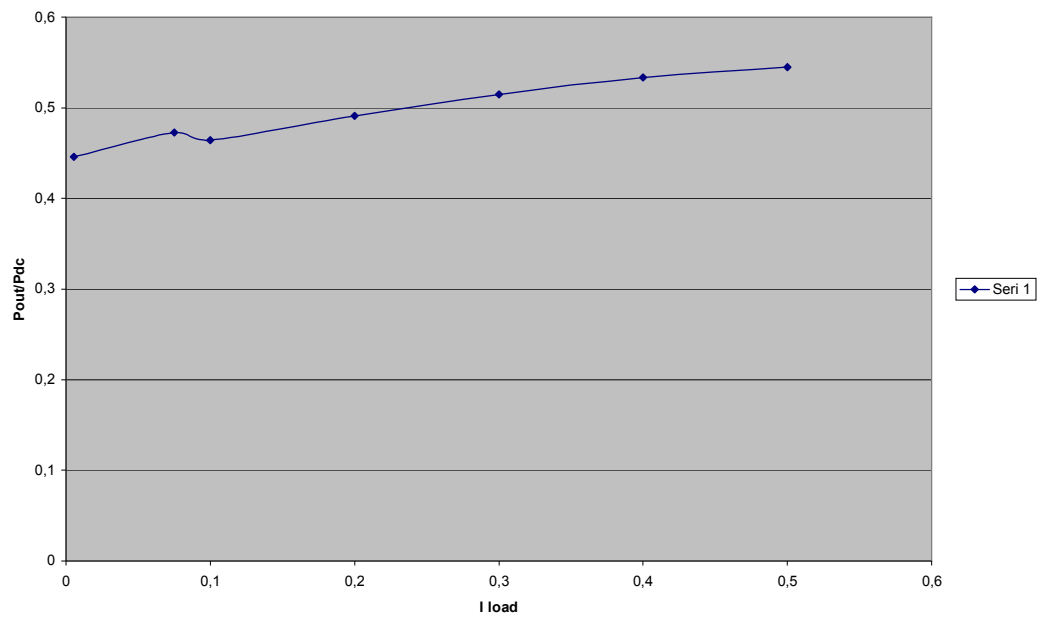
Table-1 shows the results of the circuits when it is tested.

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}

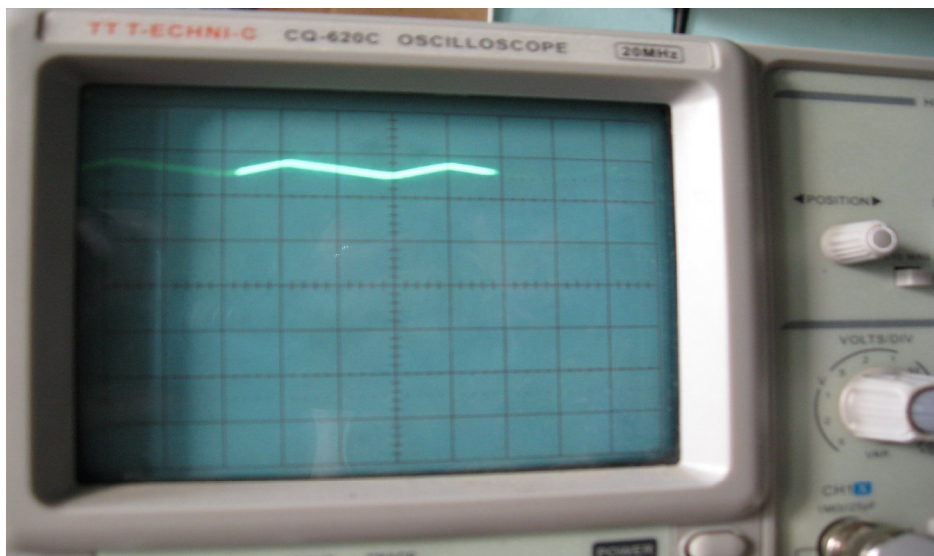


Figure 4.1 – The voltage ripple at capacitor input

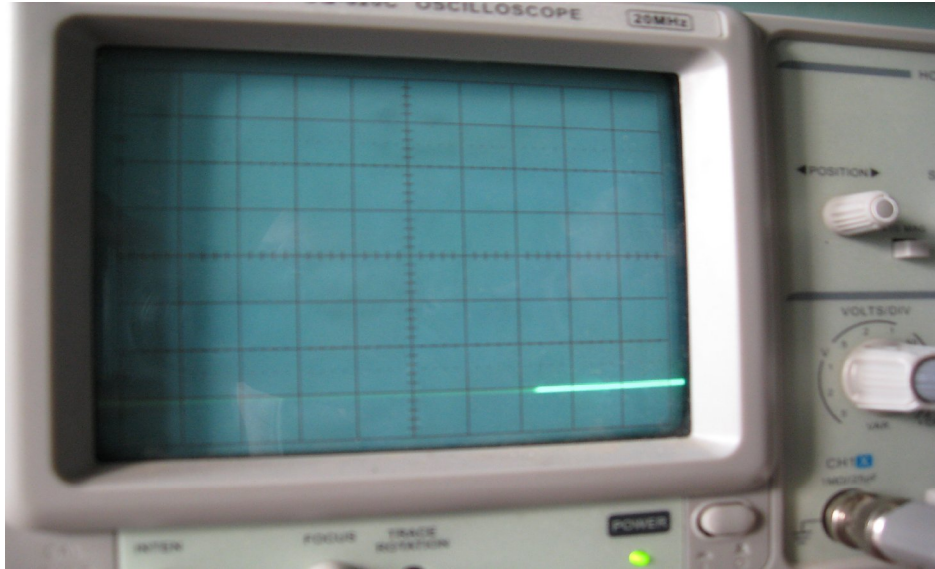


Figure 4.2 – The ground of Osilloscope

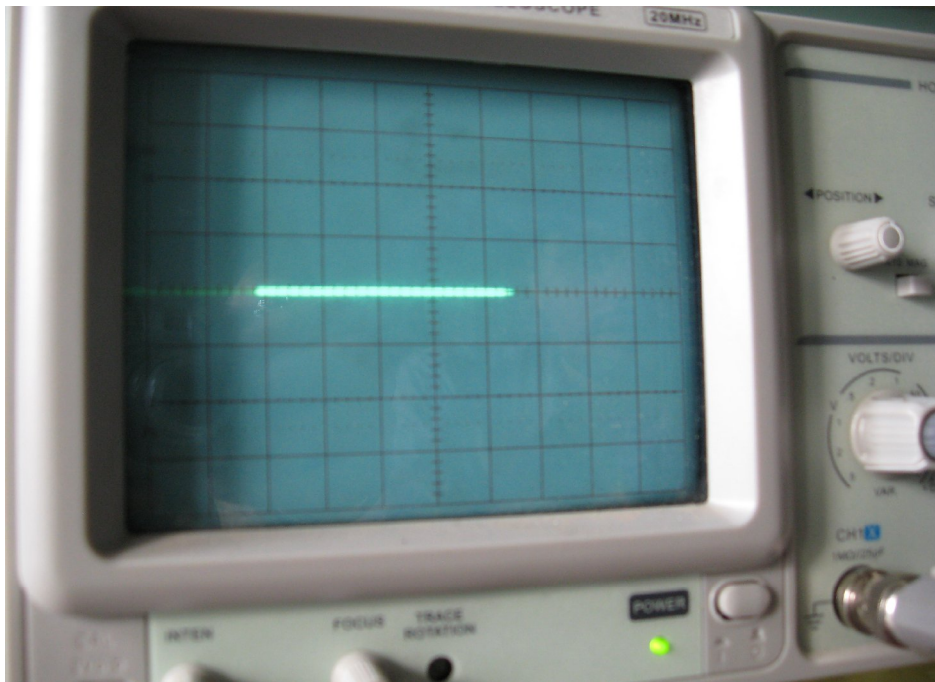


Figure 4.3 – The output voltage of regulator

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

LM78XX

Series Voltage Regulators

General Description

The LM78XX series of three terminal regulators is available with several fixed output voltages making them useful in a wide range of applications. One of these is local on card regulation, eliminating the distribution problems associated with single point regulation. The voltages available allow these regulators to be used in logic systems, instrumentation, HiFi, and other solid state electronic equipment. Although designed primarily as fixed voltage regulators these devices can be used with external components to obtain adjustable voltages and currents.

The LM78XX series is available in an aluminum TO-3 package which will allow over 1.0A load current if adequate heat sinking is provided. Current limiting is included to limit the peak output current to a safe value. Safe area protection for the output transistor is provided to limit internal power dissipation. If internal power dissipation becomes too high for the heat sinking provided, the thermal shutdown circuit takes over preventing the IC from overheating.

Considerable effort was expended to make the LM78XX series of regulators easy to use and minimize the number of external components. It is not necessary to bypass the out-

put, although this does improve transient response. Input bypassing is needed only if the regulator is located far from the filter capacitor of the power supply.

For output voltage other than 5V, 12V and 15V the LM117 series provides an output voltage range from 1.2V to 57V.

Features

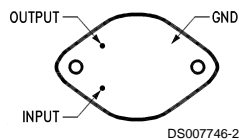
- Output current in excess of 1A
- Internal thermal overload protection
- No external components required
- Output transistor safe area protection
- Internal short circuit current limit
- Available in the aluminum TO-3 package

Voltage Range

LM7805C	5V
LM7812C	12V
LM7815C	15V

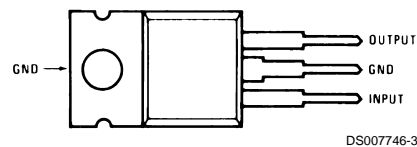
Connection Diagrams

**Metal Can Package
TO-3 (K)
Aluminum**



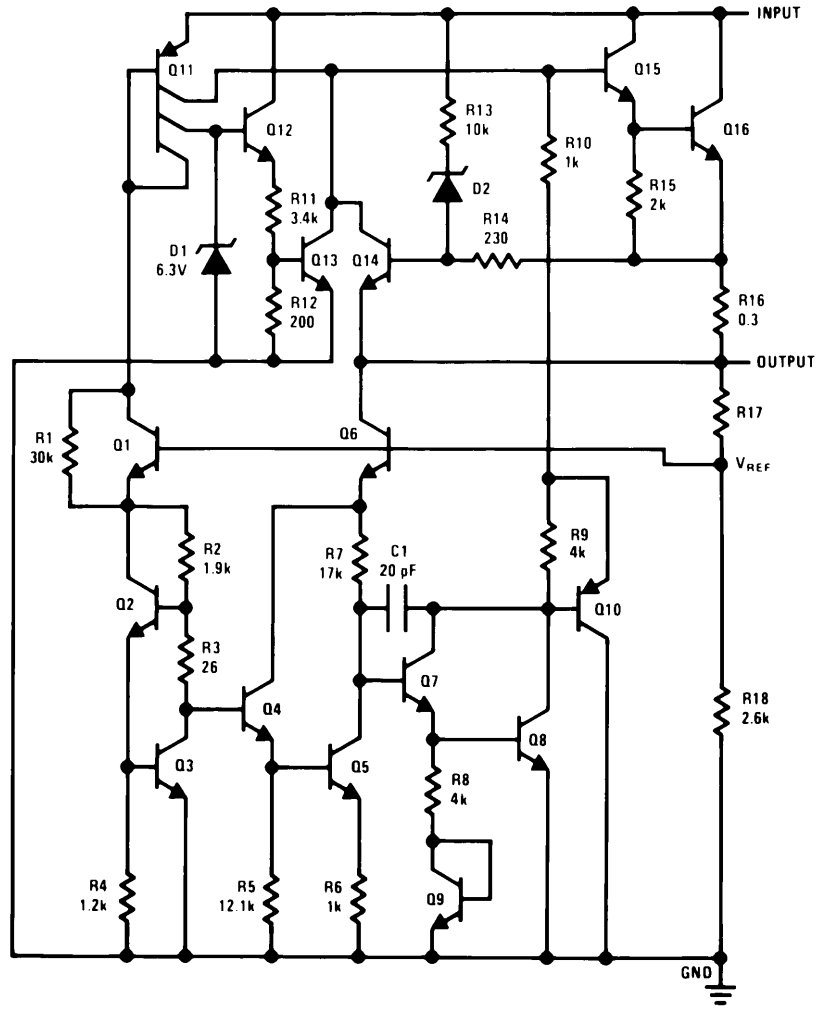
Bottom View
Order Number LM7805CK,
LM7812CK or LM7815CK
See NS Package Number KC02A

**Plastic Package
TO-220 (T)**



Top View
Order Number LM7805CT,
LM7812CT or LM7815CT
See NS Package Number T03B

Schematic



DS007746-1

Absolute Maximum Ratings (Note 3)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Input Voltage

 $(V_O = 5V, 12V \text{ and } 15V)$

35V

Internal Power Dissipation (Note 1)

Internally Limited

Operating Temperature Range (T_A)

0°C to +70°C

Maximum Junction Temperature

(K Package)

150°C

(T Package)

150°C

Storage Temperature Range

-65°C to +150°C

Lead Temperature (Soldering, 10 sec.)

TO-3 Package K

300°C

TO-220 Package T

230°C

Electrical Characteristics LM78XXC (Note 2)0°C ≤ T_J ≤ 125°C unless otherwise noted.

Output Voltage			5V			12V			15V			Units	
Input Voltage (unless otherwise noted)			10V			19V			23V				
Symbol	Parameter	Conditions	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max		
V_O	Output Voltage	$T_J = 25^\circ\text{C}$, $5 \text{ mA} \leq I_O \leq 1 \text{ A}$	4.8	5	5.2	11.5	12	12.5	14.4	15	15.6	V	
		$P_D \leq 15\text{W}$, $5 \text{ mA} \leq I_O \leq 1 \text{ A}$	4.75		5.25	11.4		12.6	14.25		15.75	V	
		$V_{\text{MIN}} \leq V_{\text{IN}} \leq V_{\text{MAX}}$	(7.5 ≤ V_{IN} ≤ 20)			(14.5 ≤ V_{IN} ≤ 27)			(17.5 ≤ V_{IN} ≤ 30)			V	
ΔV_O	Line Regulation	$I_O = 500 \text{ mA}$	$T_J = 25^\circ\text{C}$	3 50		4 120		4 150		mV			
			ΔV_{IN}	(7 ≤ V_{IN} ≤ 25)		14.5 ≤ V_{IN} ≤ 30)		(17.5 ≤ V_{IN} ≤ 30)		V			
		0°C ≤ T_J ≤ +125°C	ΔV_{IN}		50		120		150		mV		
			(8 ≤ V_{IN} ≤ 20)		(15 ≤ V_{IN} ≤ 27)		(18.5 ≤ V_{IN} ≤ 30)		V				
		$I_O \leq 1 \text{ A}$	$T_J = 25^\circ\text{C}$	ΔV_{IN}		50		120		150		mV	
			(7.5 ≤ V_{IN} ≤ 20)		(14.6 ≤ V_{IN} ≤ 27)		(17.7 ≤ V_{IN} ≤ 30)		V				
0°C ≤ T_J ≤ +125°C	ΔV_{IN}		25		60		75		mV				
	(8 ≤ V_{IN} ≤ 12)		(16 ≤ V_{IN} ≤ 22)		(20 ≤ V_{IN} ≤ 26)		V						
ΔV_O	Load Regulation	$T_J = 25^\circ\text{C}$	$5 \text{ mA} \leq I_O \leq 1.5 \text{ A}$	10 50		12 120		12 150		mV			
			$250 \text{ mA} \leq I_O \leq 750 \text{ mA}$	25		60		75		mV			
		$5 \text{ mA} \leq I_O \leq 1 \text{ A}$, 0°C ≤ T_J ≤ +125°C	50		120		150		mV				
I_Q	Quiescent Current	$I_O \leq 1 \text{ A}$	$T_J = 25^\circ\text{C}$	8		8		8		mA			
			0°C ≤ T_J ≤ +125°C	8.5		8.5		8.5		mA			
ΔI_Q	Quiescent Current Change	$5 \text{ mA} \leq I_O \leq 1 \text{ A}$		0.5		0.5		0.5		mA			
		$T_J = 25^\circ\text{C}$, $I_O \leq 1 \text{ A}$	$V_{\text{MIN}} \leq V_{\text{IN}} \leq V_{\text{MAX}}$		1.0		1.0		1.0		mA		
			(7.5 ≤ V_{IN} ≤ 20)		(14.8 ≤ V_{IN} ≤ 27)		(17.9 ≤ V_{IN} ≤ 30)		V				
0°C ≤ T_J ≤ +125°C	$V_{\text{MIN}} \leq V_{\text{IN}} \leq V_{\text{MAX}}$		1.0		1.0		1.0		mA				
	(7 ≤ V_{IN} ≤ 25)		(14.5 ≤ V_{IN} ≤ 30)		(17.5 ≤ V_{IN} ≤ 30)		V						
V_N	Output Noise Voltage	$T_A = 25^\circ\text{C}$, 10 Hz ≤ f ≤ 100 kHz		40		75		90		μV			
$\frac{\Delta V_{\text{IN}}}{\Delta V_{\text{OUT}}}$	Ripple Rejection	$f = 120 \text{ Hz}$	$I_O \leq 1 \text{ A}$, $T_J = 25^\circ\text{C}$ or $I_O \leq 500 \text{ mA}$	62 80		55 72		54 70		dB			
			0°C ≤ T_J ≤ +125°C	62		55		54		dB			
		$V_{\text{MIN}} \leq V_{\text{IN}} \leq V_{\text{MAX}}$		(8 ≤ V_{IN} ≤ 18)		(15 ≤ V_{IN} ≤ 25)		(18.5 ≤ V_{IN} ≤ 28.5)		V			
R_O	Dropout Voltage	$T_J = 25^\circ\text{C}$, $I_{\text{OUT}} = 1 \text{ A}$		2.0		2.0		2.0		V			
	Output Resistance	$f = 1 \text{ kHz}$		8		18		19		mΩ			

Electrical Characteristics LM78XXC (Note 2) (Continued)

$0^{\circ}\text{C} \leq T_J \leq 125^{\circ}\text{C}$ unless otherwise noted.

Output Voltage			5V			12V			15V			Units
Input Voltage (unless otherwise noted)			10V			19V			23V			
Symbol	Parameter	Conditions	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
	Short-Circuit Current	$T_J = 25^{\circ}\text{C}$	2.1			1.5			1.2			A
	Peak Output Current	$T_J = 25^{\circ}\text{C}$	2.4			2.4			2.4			A
	Average TC of V_{OUT}	$0^{\circ}\text{C} \leq T_J \leq +125^{\circ}\text{C}$, $I_O = 5\text{ mA}$	0.6			1.5			1.8			mV/ $^{\circ}\text{C}$
V_{IN}	Input Voltage Required to Maintain Line Regulation	$T_J = 25^{\circ}\text{C}$, $I_O \leq 1\text{A}$	7.5			14.6			17.7			V

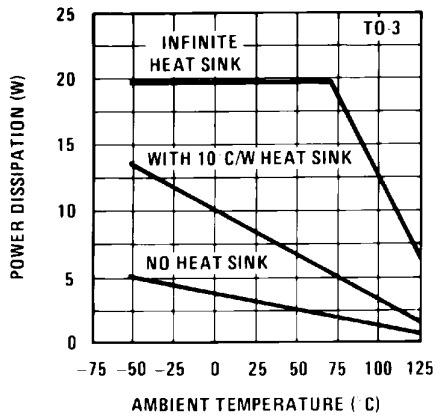
Note 1: Thermal resistance of the TO-3 package (K, KC) is typically $4^{\circ}\text{C}/\text{W}$ junction to case and $35^{\circ}\text{C}/\text{W}$ case to ambient. Thermal resistance of the TO-220 package (T) is typically $4^{\circ}\text{C}/\text{W}$ junction to case and $50^{\circ}\text{C}/\text{W}$ case to ambient.

Note 2: All characteristics are measured with capacitor across the input of $0.22\ \mu\text{F}$, and a capacitor across the output of $0.1\ \mu\text{F}$. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ($t_w \leq 10\text{ ms}$, duty cycle $\leq 5\%$). Output voltage changes due to changes in internal temperature must be taken into account separately.

Note 3: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. For guaranteed specifications and the test conditions, see Electrical Characteristics.

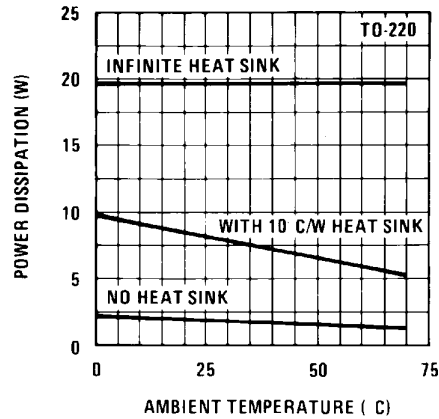
Typical Performance Characteristics

Maximum Average Power Dissipation



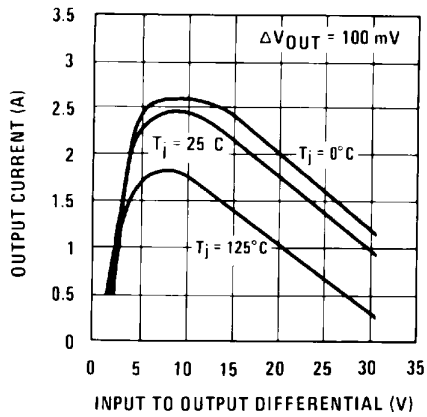
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Maximum Average Power Dissipation



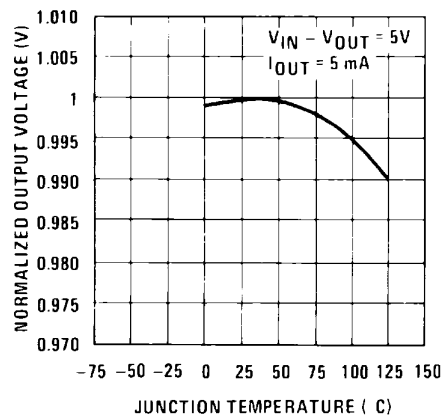
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Peak Output Current



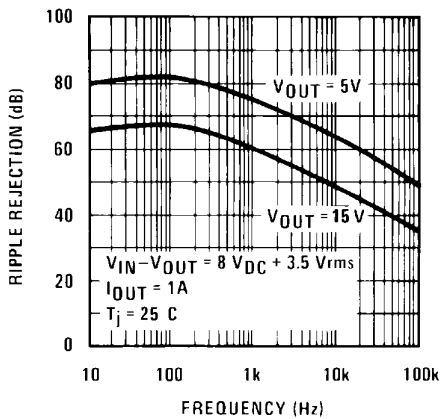
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Output Voltage (Normalized to 1V at Tj = 25°C)



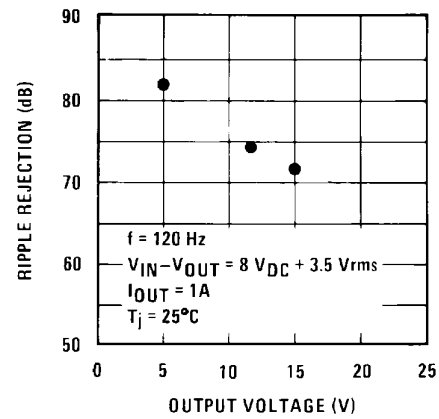
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Ripple Rejection



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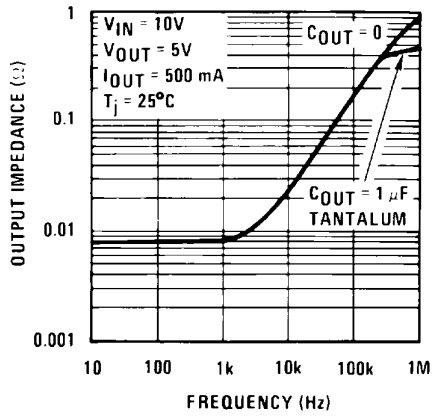
Ripple Rejection



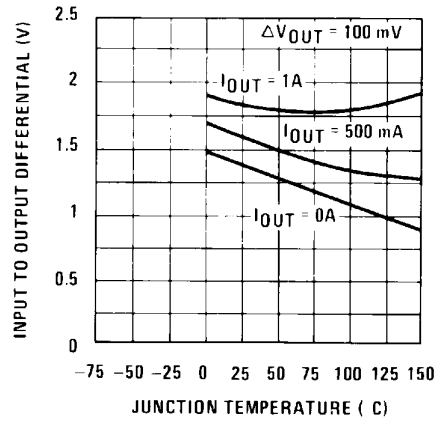
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Typical Performance Characteristics (Continued)

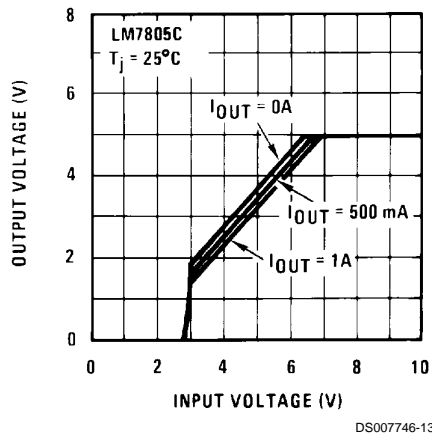
Output Impedance



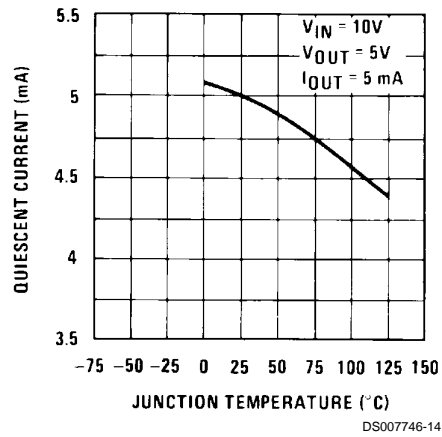
Dropout Voltage



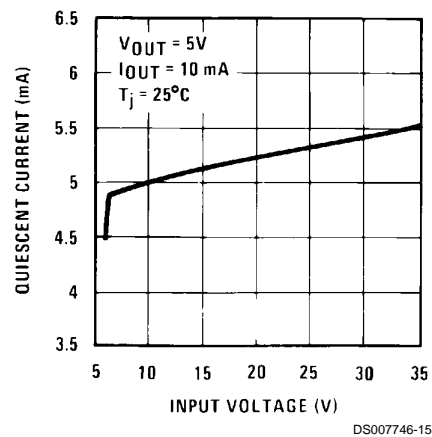
Dropout Characteristics



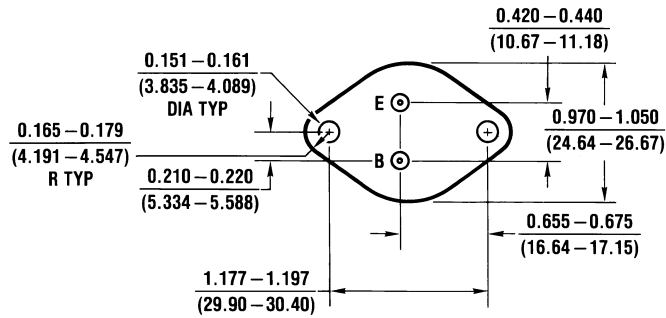
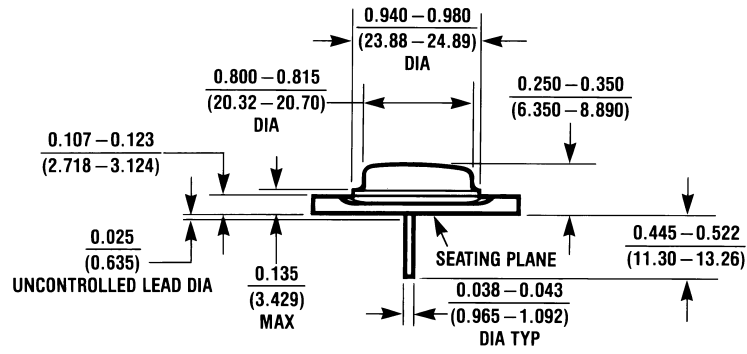
Quiescent Current



Quiescent Current



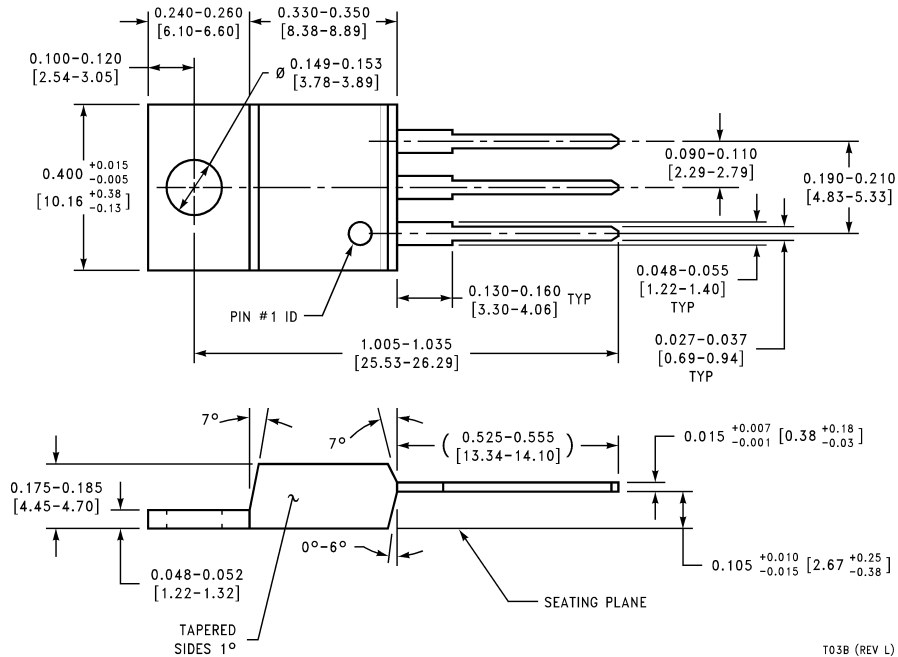
Physical Dimensions inches (millimeters) unless otherwise noted



KC02A (REV C)

Aluminum Metal Can Package (KC)
 Order Number LM7805CK, LM7812CK or LM7815CK
 NS Package Number KC02A

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



TO-220 Package (T)
Order Number LM7805CT, LM7812CT or LM7815CT
NS Package Number T03B

LIFE SUPPORT POLICY

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2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.



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