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A practical design of a low voltage electronic power supply in its primitive form and its efficiency analysis at a few representative values of loads

Saiful Islam
Department of Physics, Darrang College, Tezpur - 784001, Assam, India

ABSTRACT

A primitive low voltage electronic power supply has been designed and its efficiency, corresponding to different classes commonly used of diodes, at a few reasonable load values are calculated. Measurements are done by using Digital Oscilloscope – 'Aplab D36100C' and a sophisticated Source Meter – 'Keithley 2401' with high accuracy in our laboratory. Capacitor has no rule in μF efficiency calculations apparently and hence only one capacitor of 16 volt and 330 capacitance is used throughout these measurements. The measured values of the efficiencies of the rectifier are in accordance with the theoretical predictions hence well acceptable.

Key words : Electronic power supply, Load.

INTRODUCTION

A power supply unit (PSU) or commonly known as power supply (PS) is an electric or electronic device that empowers the electrical loads or electronic devices (Kelley, A. W. and Yadusky, W. F., 1992.).

The power supply that has been designed in the our laboratory is a very primitive full-wave centre-tap type power supply which consists of a step down centre-tap transformer and only a few components such as two diodes for rectification and a capacitor for filtration of voltage fluctuations

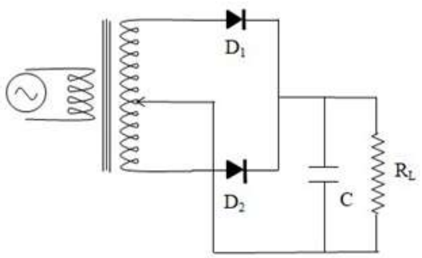

Figure 1. Centre tap full-wave rectifier.

THEORY

The A.C. voltage is applied to the primary of the centre tap transformer. The reduced a.c. voltage appeared across the secondary of the transformer is feed to the two diodes D_1 and D_2.

The rectified output, i.e., d.c. voltage is extracted from the capacitor terminals (http://www.circuitstoday.com and http://visionics.a.se/html) for practical uses – mainly to recharge rechargeable batteries as the output from such power supplies produces moderately fluctuating d.c. because of its poor filtration quality with less number of filtering components which in our design, is only a single capacitor (https://www.popsci.com).

The efficiency of a full-wave rectifier (Sze, S. M. and Lee, M. K., 2010) is given by,

**Corresponding author's Email: s.phys.res@gmail.com*

$$\eta_f = \frac{P_{dc}}{P_{ac}} = \frac{I_{dc}^2 R_L}{I_{rms}^2 (r_f + R_L)}$$

where, r_f and R_L are the diode forward resistance and load resistance.

No diode, in practice, is an ideal diode. That is, a diode neither acts as a perfect conductor (when forward biased) nor it acts as an insulator (when it is reverse biased). A practical diode possesses a some resistance under forward biased condition. Such resistance of a diode is known as forward resistance.

In a full-wave rectifier , the output average current (which is also called d.c. current) is given by (Rashid, M. H., 2001),

$$I_{av} = I_{dc} = \frac{1}{T}\int_0^T I\,dt$$

where I is input a.c. current.

Taking the input a.c. current be $I = I_0 \sin \omega t$,

$$I_{av} = I_{dc} = \frac{1}{T}\int_0^T I_0 \sin \omega t dt$$

Simplifying,

$$I_{av} = I_{dc} = \frac{2I_0}{\pi}$$

In a full-wave rectifier, the input r.m.s. current is given by,

$$I_{rms} = \sqrt{\frac{1}{T}\int_0^T I^2 dt}$$

$$= \sqrt{\frac{1}{T}\int_0^T (I_0 \sin \omega t)^2 dt}$$

Simplifying, $I_{rms} = \frac{I_0}{\sqrt{2}}$

Thus the efficiency of a full-wave rectifier becomes,

$$\eta_f = \frac{\left(2I_0/\pi\right)^2 R_L}{\left(I_0/\sqrt{2}\right)^2 (r_f + R_L)}$$

$$= \frac{0.812}{\left(1 + r_f/R_L\right)}$$

The efficiency will be maximum if r_f is negligible as compared to R_L.

The efficiency of a full-wave rectifier is double that of a half-wave rectifier. That is, a full-wave rectifier is twice as effective as half-wave rectifier.

MATERIALS AND METHODS

The designed power supply has been tested with four different popular types of diodes, viz., 1N4007, 1N5401, 6A4 and 10A6 with different forward resistances and current capacities (https://www.alldatasheet.com).

Also three representational load values, viz., 10 Ω , 50 Ω and 100 Ω of moderate importance are used with each type of such diodes.

Resistances are measured using Digital Oscilloscope – 'Aplab D36100C' and a sophisticated Source Meter – 'Keithley 2401' with high accuracy in our laboratory.

Capacitor has no rule in efficiency calculations apparently and hence only one capacitor of 16 volt and 330 μF capacitance is used throughout these measurements.

RESULTS AND DISCUSSION

Experimentally measured efficiencies at a few representative load resistances 10Ω, 50Ω and 100Ω and their comparison with theoretical values are enlisted in table 1. The measured values of the efficiencies of the rectifier increases with decrease in forward resistances of the different types of diodes. The efficiencies also increases with increase in loads. These are in accordance with the theoretical predictions and hence well acceptable within the regime of this primitive design of the rectifier.

These measurements also reveal that diode class IN5401 is slightly better performer in terms of their rectification efficiencies. Similarly, it may be noted that the diode class IN4001 is a bit less efficient

Table 1. Experimentally measured efficiencies and their comparison with theoretical values

Diode (from a family of diodes)	Forward Current I_f (in Amp)	Forward Voltage V_f (in Volt)	Forward Diode Resistance r_f in Ω		Repre-sentativ e Loads	Efficiency η_f in %		Error %
			$r_{f(th)} = \frac{V_f}{I_f}$	$r_{f(ex)}$	R_L in Ω	$\eta_{f(th)}$	$\eta_{f(ex)}$	
1N4007	1	1.1	1.10	1.62	10	73.09	69.88	4.39
					50	79.45	78.68	0.97
					100	80.32	79.91	0.51
1N5401	3	1	0.33	0.38	10	78.61	78.23	0.48
					50	80.67	80.59	0.09
					100	80.93	80.89	0.04
6A4	6	0.9	0.15	0.21	10	80.00	79.53	0.59
					50	80.96	80.86	0.12
					100	81.08	81.03	0.06
10A6	10	1.1	0.11	0.20	10	80.32	79.61	0.88
					50	81.02	80.67	0.43
					100	81.11	81.04	0.08

CONCLUSION

Though not good or recommended for modern complex and costly electronic devices, such moderately fluctuating d.c. voltage is little more suitable for charging rechargeable batteries and can also safely be used to light up LED bulbs, small motors, devices run by small motors, etc. Lastly, the simple structure and low cost production is an added feature to be considered in such circuits.

The fluctuations in the output voltage can be minimized by inserting more filter sections such as L- and Pi-section filters across the output voltage of the power supply. These filters smoothes out the output voltage of the power supply making it more suitable for modern complex and costly electronic devices. Such studies have also been performed and the results may be published in future communications.

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