Design and Construction of a Stabilize Variable Power Supply Unit

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Abstract
The main objective of this work is to design and construct a stabilize variable power supply unit with a voltage range of 0.20v – 15.85v and current range of 0 – 3Amps (45W) with a very low output impedance of 0.008 ohms. We also study the regulation characteristics of a constructed power supply units to a certain load and line regulation so as to determine its stability by comparing it to a standard power supply unit. Test and analysis were carried out using the constructed power supply unit to power loads (Rheostat) of 126ohms 1A and 11ohms 4A. The major components used include transistors, regulator LM317.The output measurements showed that the power supply was functional and the measured values gave minima variation from the nominal designed values. The developed output power supply is much useful in measurements, laboratory works and general applications requiring power supply.
Keywords: variable power supply unit, impedance, line regulation

1.0 INTRODUCTION

With today's technological advancement, new miniaturized electrical and electronic products continue to emerge and these products require either a very low AC source or DC source for their operation[1]. Many of the existing power supply devices with various levels of complexities and sophistication can only give a single DC output which cannot serve the same purpose when a very low AC power output is greatly desired. Hence, the need for designing and developing an output power supply that can serve a dual purpose of providing DC and AC outputs of different values for use in miniaturized electrical and electronic appliances as well as for various domestic and laboratory experimental purposes[1,3,9,6,10,11]. Power supply unit is a fundamental unit in electronics systems, which produces a dc output voltage to the system. The simplest form of power supply is the unregulated power supply which produces a ripple dc output. The use of regulators with the unregulated power supply produces a very smooth dc. These kinds of power supply are termed regulated power supply[5,7,13].

The construction of stabilize variable power supply unit in the department was prompted by unavailability, and deficiency of the available one which is required for experiments most especially physics and electronic experiments. The history of power supply to electronics has caused much attention to scientist and electrical/electronic engineers on the design and construction of regulated power supply.

Power supply has gone through modification over the years until the arrival of a unit to meet consumers' satisfaction. In 1967, the S. G. S Fairchild designs a dual power supply using the zener diode and Darlington transistor as stabilizers[7] [Fair Child Groups; 1967].

In 1973, H. Olsen, design a second generation integrated circuit (IC) voltage regulator that operate between the range of 5volts at 20MA or 7 – 20volts at 100MA [13].

G. L. Tater in 1976[8], design a power supply using the MPC 1000 super regulator for 15v at 10A. He used two Motorola positive voltage regulator each having a separate 18v – 24v secondary winding of the transformer[Tater; 1976]. Capability of the overall packaged optoelectronic system, consisting of the optical fiber, silicon mirror, CMOS photodiode, and the dc/dc converter, is demonstrated by generation of an electrical power of 60 µW [2].

2.0 DESIGN PROCEDURE

The design (Fig.1) of the complete power supply is best understood by analyzing the various stages that constitute the system. The stages involved are the unregulated, the regulated, the gain control, the current amplifier, and the current limiter.

2.1 THE UNREGULATED UNIT

With the use of a 220v-250v transformer, the a.c mains of 220v, 50Hz is step down to a 25Vr.m.s, by the transformer, which is suitable for the system. A bridge rectifier with four power diodes (IN4001) produces a full rectification of a 25Vr.m.s a.c voltage from the transformer to a d.c with an a.c component (ripple).

The rectified ripple voltage is further smoothened with the use of a capacitor (4700µF, 50v), which reduces this ripple. This unregulated voltage is gotten from the circuit (Fig.2) below. The reduce ripple voltage have a mean d.c output given by:

$$^1/_2 \nabla v = v_p - v_{d.c}$$

But $v = {}^1/_2 fc$ for half-wave rectification and $v = {}^1/_4 fc$ for full-wave rectification. Hence, $v_{d.c} = v_p - {}^1/_4 fc$, where $v_p = v_{r.m.s} \times \sqrt{2} = 30 \times 1.4 = 42V$.

$With\ a\ ripple\ of\ 0.05875V$,

$v_{d.c} = 42V - {}^1/_4 \times 50 \times 4700 \times 10^{-6} = 42 - 0.05875 = 41.94$,

2.2 THE REGUALATED UNIT AND GAIN CONTROL UNIT

These units stabilize and control the variation of the output voltage within the specified voltage range as shown in figure below. The IC LM317 stabilizes the output voltage to a very stable one. The LM317 has know ground terminal, it adjust v_{out} to maintain a constant of 1.25v from the output terminal to the adjusted terminal. The regulator puts 1.25v across R_1, so 70mA flows through it. The adjustment terminal draws very little current (50–100A). The output voltage does not depend on the input voltage and it is given by $v_{out=1.25\left(1+\frac{R_{2v}}{R_1}\right)volts}$

Since R_2 and R_v are connected in parallel they act as one resistor with resultant resistance given by $R_T = \frac{R_2 R_V}{R_2+R_V} = \frac{4.2\times10^3\times5\times10^3}{4.2\times10^3+510^3} = \frac{2.1\times10^7}{9.2\times10^3} = 2.82K$

$$V_{OUT} = 1.25\left(1 + {}^{R_{2V}}/_{R_1}\right) = 1.25(1 + {}^{2.82K}/_{220}) = 1.25(1 + 10.4)$$

$$= 1.25 \times 11.4 = 14.25V$$

Since the output terminal produces a voltage of 1.25v, the voltage across the adjustment terminal will produce a voltage given by

$$14.25V - 1.25V = 13V$$

Which is the voltage across R_2 and R_v. Variable resistor 10K pot (R_v) in the gain control varies the output voltage between 0.20v – 15.85v.

The capacitor C_3 improves the ripple (and spike) rejection by about 15dB, thereby increasing the rejection factor of the LM317 from 65Db to 80dB. The diode D_5 acts as safety diode by allowing current not to flow back to the system.

3.0 TEST, ANALYSIS AND OBSERVATION

3.1 TEST AND ANALYSIS

Test and analysis were carried out using the constructed power supply unit to power various loads. The results obtained during the test are tabulated below, where table 1. indicates voltage and current at different conditions. Table 2. explains a load (Rheostat) of 126ohmsand 1A was connected across the power supply , while Table 3 express for load 11 ohms 4A.

$$Load\ regulation = \frac{\Delta v_o}{v} \times 100 \qquad (2)$$

$$Where\ \Delta v_o = I_1 \times Z_o = 3 \times 0.008 = 0.024$$

$$Load\ regulation = \frac{0.024\times100}{15} = 0.016 \times 100 = 0.16\%$$

$$Line\ regulation = \frac{change\ in\ output\times100}{change\ in\ input\ voltage} \qquad (3)$$

$$Line\ regulation = \frac{(15.9-15.5)\times100}{220-180} = \frac{0.4\times100}{40} = 0.1\%$$

3.2 OBSERVATION

It was observed that when the power supply unit (PSU) was used to power a load of 11ohms 4A, the heat of the system increased indicating that load with high current rating would stress the system, while powering 126 Ohms 1A, the heat of the system reduced if using load with low current rating .Figure 4 and 5 shows the characteristic of a stabilized standard power supply voltage. By comparison, the two graphs meet the same standard and their regulation characteristics is the same. Which denote that the constructed stabilize variable power supply met the requirement of a standard power supply unit (SVPSU)

4.0. CONCLUSION

A stabilize variable power supply unit with output voltage ranging from 0.20v – 15.85v , an output current range of 0 – 3A, power of 45W, output impedance of 0.008ohms, line regulation of 0.1%, and load regulation of 0.16% has been designed and successfully constructed. This work has been constructed using materials that are relatively cheap when compared to conventional power supply unit of the same output range in the market. It was tested and it met the requirements for a standard power supply unit for a laboratory.

5.0 RECOMMENDATION/SOLUTIONS

For further improvement on this work, the following recommendation given below will be advantageous: The current range can be increased so that it would be applicable in powering high power devices in the laboratory. A

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voltage protector circuit can be incorporated into the unit to protect the power supply from very low and high mains voltage. A capacitor can be connected in parallel to each of the four power diode, in other to filter out noise.

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TABLE 1: Shows voltage and current at different conditions

FULL VOLTAGE (NO LOAD)	15.85V
LEAST VOLTAGE (NO LOAD)	0.20V
CURRENT FLOW	0A
VOLTAGE (FULL LOAD)	15V
CURRENT FLOW	0.12A

TABLE 2: V/I for 126 ohms 1A

VOLTAGE (V)	CURRENT (I)
15	0.12
15	0.20
15	0.28
15	0.36
14.9	0.44
14.9	0.52
14.9	0.60
14.8	0.68
14.8	0.76
14.8	0.84
10.0	0.92
10.0	1.00
10.0	1.08
5.0	2.5
2.5	2.7
0	3.0

TABLE 3: V/I for 11ohms 4A.

VOLTAGE (V)	CURRENT (A)
15	0.12
15	0.18
15	0.24
15	0.30
15	0.36
14.9	0.42
14.9	0.48
14.9	0.54
14.9	0.60
14.8	0.66
14.8	0.72
14.8	0.78
14.8	0.84
14.7	0.90
14.6	0.96
13.8	1.02
12.4	1.20
10.0	1.50
5.0	2.5
2.5	2.7
0	3.0

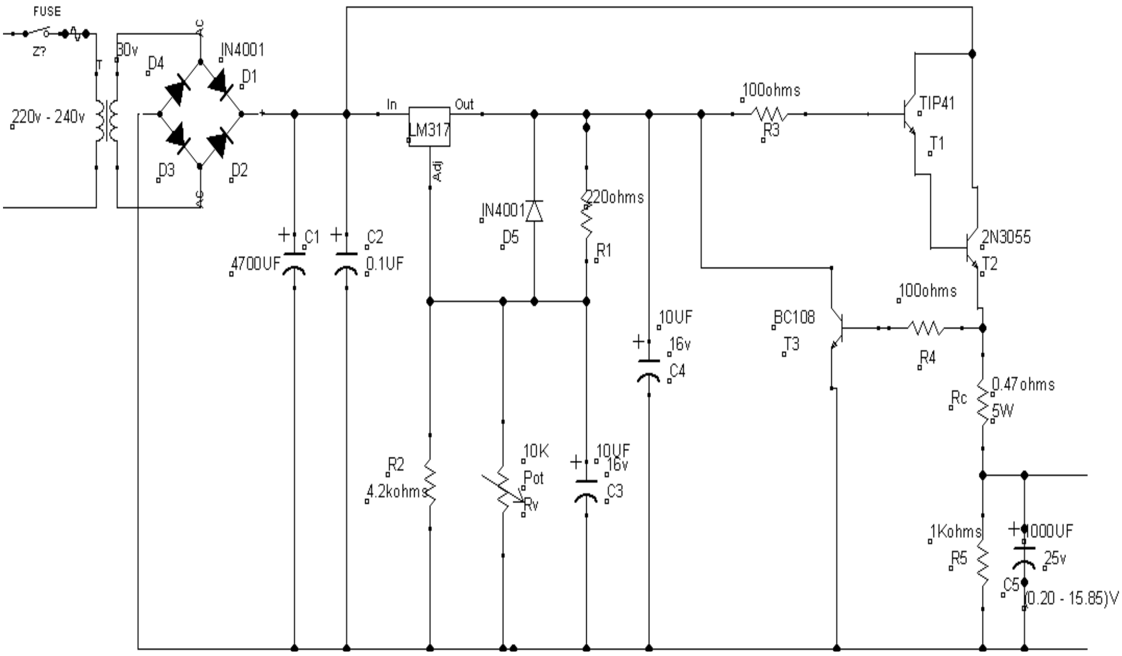

Fig. 1: Circuit diagram of power supply

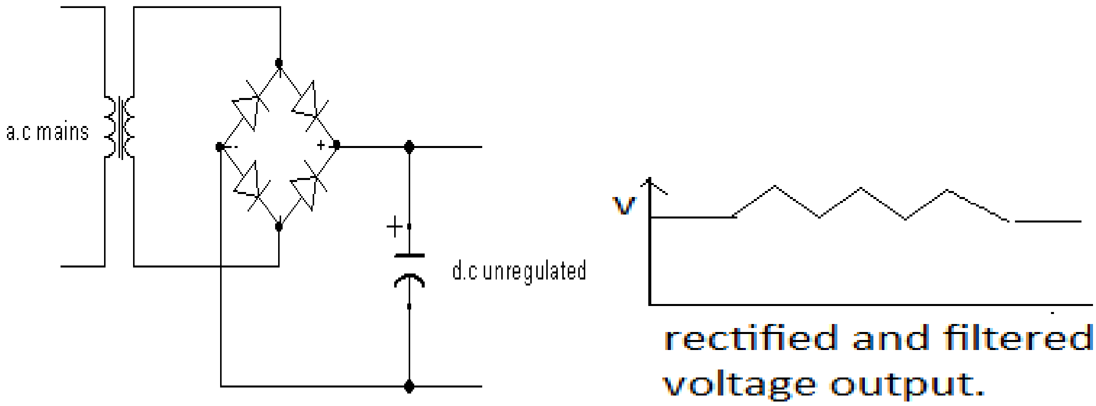

Fig 2: Rectification -Filtration Circuit with its wave form.

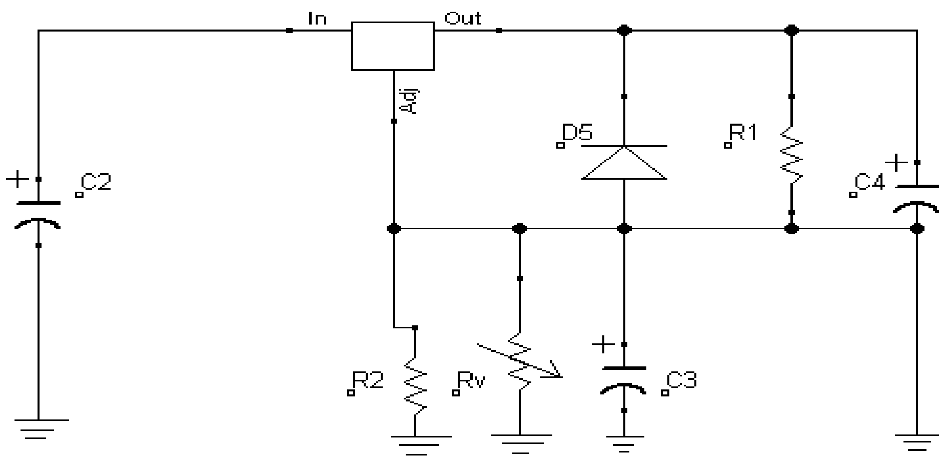

Fig. 3: Regulated unit and Gain Control Unit

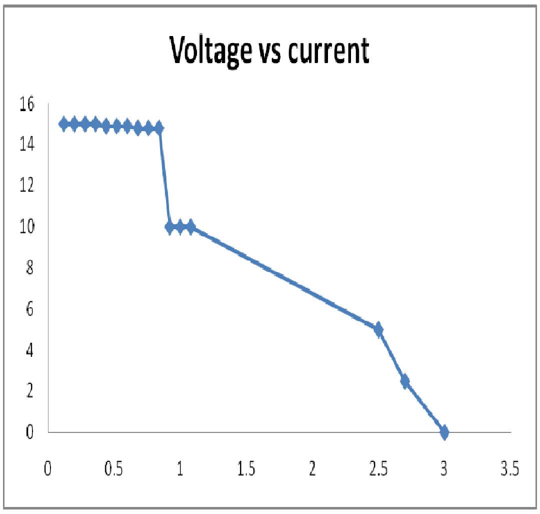

Fig. 4

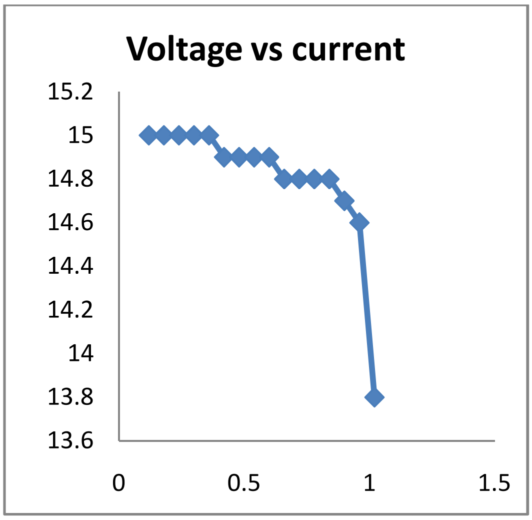

Fig. 5

Regulation Characteristics with load of 126Ω 1A in Figure 4 and load 11Ω 4A in Figure 5 respectively.