IMPROVISATION OF LABORATORY POWER SUPPLY FOR POWERING LABORATORY ELECTRONIC INSTRUMENTS

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Abstract

The implementation and progress of science and technology education in Nigeria is faced with multidimensional problems especially from the power sector. Power outage, low voltage and over voltage supplies are common phenomena, and many have resulted to using batteries, power inverters and/or generators to generate needed electrical energy in laboratories. Most of these sources and electronic devises are not equipped with over voltage and current limiting protection circuits which are relevant to the security of the devices and their users. Power supply constructed with 14-pin 723-voltage regulator IC gives output voltage range of 0.5 to 24.0V and is capable of maintaining a constant voltage irrespective of changes in the load current and unregulated input voltage.

Key words: electronic laboratory instruments, current limiting protection circuit, over voltage protection circuit.

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INTRODUCTION

Power sector reforms in Nigeria started in 2000 with the aim of utilizing the financial, human and other resources of the country for the development of the electricity industry effectively and to spread the electricity supply across the country. The supply of electricity is not adequate in Nigeria and power outage, dropout, brownout (power reduction), and low voltage and over voltage supplies are very common. Citizens and institutions are already using other means such as generators and power inverters to meet their energy needs. Laboratories in higher institutions of learning are adversely affected because most equipments require steady flow of electrical energy for their normal operation and consequently the problem affects research, teaching and learning. Power supply provides stable d.c. and/or a. c. output suitable for operating electronic instruments and systems [1].

The power supply converts the a.c mains into a stable d. c. voltage suitable for the internal circuitry of the system. The d. c. output has to remain substantially constant against changes in load current, main input voltage and temperature. The power supply must also effectively isolate the internal circuit from the raw mains and provide automatic overload and over voltage protection. The simple transformer-bridge-capacitor unregulated power supply cannot provide these functions. The unregulated output must be fed into a form of voltage regulator chip, inside which the voltage output is compared with a stable reference voltage and any difference or error between the output and the reference is amplified and fed into the base of the series control element [2]. This study is aim at improvising a laboratory power supply for laboratory equipments. This study shall be guided by the following research questions:

1. Do fluctuations in input voltage alter the load current and d. c. output voltage?
2. Does increase in the temperature of equipment being powered alter the load current and d. c. output voltage?
3. At what value of current does the limiter begin to function?

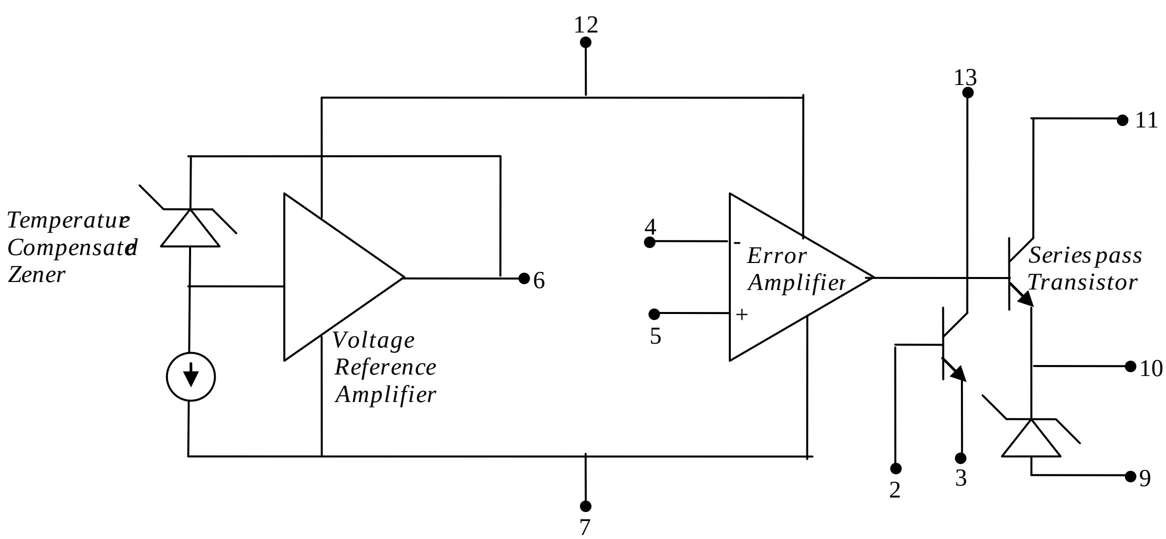
VOLTAGE REGULATOR IC's

The simplest units are the three terminal voltage regulators; fixed voltage regulator and adjustable voltage regulator. All that is needed to set it up is to connect the input and the common (or adjust as the case may be) to the unregulated supply and the regulated voltage is taken from the output. The LM7915 and LM7815 are some fixed-voltage regulator while LM337, LM117, LM217 and LM317 produce ranges of variable voltage based on the value of the voltage divider connected across the output terminal and the adjust [3, 1]. Any of these simpler units can be connected to give either positive or negative voltage.

The $\mu A723A$ monolithic regulator is older and its circuit shows many of the elements standard to any regulator and reveals what goes on in many other regulators [4, 5]. It's usually presented in a dual-in-line (DIL) 14-pin moulded package and in a 10-pin metal can package. There is virtually no difference between their equivalent circuits except in the pin numbering, however three pins of the DIL are not connected internally.

THE μA723 MONOLITHIC REGULATOR

This is available in a 14-pin DIL ($\mu A723A$) encapsulation or as a metal can version ($\mu A723L$) with ten leads [2, 6]. The $\mu A723A$ was used in this study because it dissipates less power internally at ambient temperature of 25˚C. According to [4], the internal circuitry contains a temperature compensated voltage reference, error amplifier, series pass transistor and a current-limiting protection circuit as shown in Figure 1. The current limiting resistor R_{sc} ensures that maximum current output is not beyond a safe limit. A variety of extra components are required to make the regulator performs its functions of either providing output more and/or less than the voltage reference. It can also be made to provide a range of output voltage around the voltage reference. The compensation capacitor C_s reduces high-frequency gain in error amplifier for the purpose of avoiding high-frequency instability. The stable, temperature compensated voltage reference gives a voltage whose value is between 6.8 to 7.5 volts at pin 6 but the particular IC used for this study gives 7.15 volts.



1, 8, 14 = *No Connection*, 5 = *Non − inverting*, 10 = V_{out}
2 = *Current Limit*, 6 = *Voltage refernce*, 11 = V_C
3 = *Current Sence*, 7 = $V-$, 12 = $V+$
4 = *Inverting Input*, 9 = V_Z, 13 = *frquency compesation*

*Fig.*1 *Internal Circuit of* $\mu A723$ *IC Regulator*

CIRCIUT DESCRIPTION

For regulator providing output voltage more than the voltage reference, a voltage divider is connected between current sense and ground to compare a fraction of the output with the voltage reference [4, 2].

The voltage divider may be replaced with potentiometer so that the output can be set precisely. For output voltage less than the voltage reference, the voltage divider is connected between the voltage reference and ground, so that the output voltage is compared with a fraction of the reference [5, 4, 2]. A potentiometer can also replace the voltage divider with the variable arm connected to pin 5 to give a voltage range between 0 and 7.15V.

The third method is a combination of the first two methods above. A divided fraction of the output is compared with a fraction of the voltage reference [4]. This method was used in this study and the actual circuit is presented in Figure 2. The mains voltage is stepped down to 20 volts a.c. The bridge rectifier comprises of four IN4002 diodes and C_1 is the reservoir capacitor for producing smoothing effect. R_L is a preload resistor and LED is a light emitting diode which turns on when mains is on.

Potentiometer R_4 in Figure 2 sets the output voltage to the desired value by adjusting the reference input voltage. It is connected between pin 6 and the ground. The centre arm of R_4 is connected to pin 5 to selects any value between 0 and 7.15V. Resistors R_5 and R_6 are connected in series across the supply output. The junction of these two resistors is connected to the inverting input of the error amplifier to establish an input voltage reference. This voltage reference is compared to the selected voltage at the non-inverting input of the error amplifier to set the level of the output voltage.

The maximum current that can be taken via the series pass transistor is 150 mA but the safe maximum current in any particular application depends on the value of the unregulated input voltage V_u. Therefore the safe current limit I_{limit} when the output is short circuited is given by [2]

$$I_{limit} = \frac{P_{max}}{V_u} \qquad (1)$$

The safe current limit can be preset by appropriately choosing the value of the current limiting resistor R_{sc} such that

$$I_{\lim it} = \frac{V_{sence}}{R_{sc}} \qquad (2)$$

where V_{sence} is 0.65V. Using an external power transistor T_R mounted on a heat sink increases the output current. The T_R is a PNP suitable for forming Darlington connection with the internal transistor. The heat sink keeps the transistor junction below some maximum specified operating temperature to prolong the life of the device. According to [4], the temperature of the transistor junction is given by

$$T_j = T_A + (\theta_{jc} + \theta_{cs} + \theta_{sa})P \qquad (3)$$

where T_A is the operating temperature of the IC

θ_{jc} is the thermal resistance from junction to case

θ_{cs} is the thermal resistance from case to heat sink

θ_{sa} is the thermal resistance from heat sink to ambient and

P is the power being dissipated

The external transistor should be connected to form a Darlington pair with the internal transistor [4]. The R_3 discharges the carriers in the base emitter junction of the external transistor T_R when the drive is reduced. The value of R_3 can be determined by [7].

$$R_3 = \frac{voltage\, of\, T_R\, at\, po\text{int}\, of\, conduction}{Leakage\, current\, of\, T_R\, and\, \mu A723} \qquad (4)$$

The voltage at which T_R conducts is typically 0.4V [4].

A low value capacitor needs to be connected from the frequency compensation to the inverting input to ensure the circuit does not oscillate at high frequencies [2]. Another must be connected across the output terminals to improve the overall output ripple voltage. The only disadvantage of this IC is lack of over voltage protection.

The current output from the regulator (150mA) is boasted by the power transistor T_R, which is a series pass transistor mounted on Wakefield model 421 heat sink. The manufacturer specifications for 2N3055 are maximum T_j =200°C, θ_{jc} =1.5°C/W, θ_{cs} =0.3°C/W, Power dissipation P at 25°C ambient =115W. The calculated T_j is 381.5°C against 200°C specified by the manufacturer. The heat sink was therefore mounted on the casing externally to increase the rate of cooling. The Wakefield model 421 with θ_{sa} =1.3°C/W was selected to ensure that the transistor junction temperature is kept below the maximum because it has the minimum θ_{sa} among available heat sinks whose parameters are known. R_3 was deduced using (4) as

$$R_3 = \frac{0.4V}{0.0002A} = 2000\Omega$$

where the leakage current (collector-base) of T_R plus the collector-emitter leakage of IC output transistor is 0.0002A (worst case). The input voltage of μA723 was ensured to be at least 3V greater than the output voltage because the internal series pass transistor dissipates some power as heat thereby reducing the available output. Using (1) the total power dissipation is the sum of the power dissipated by the transistor (115W) and that of the IC (0.6W).

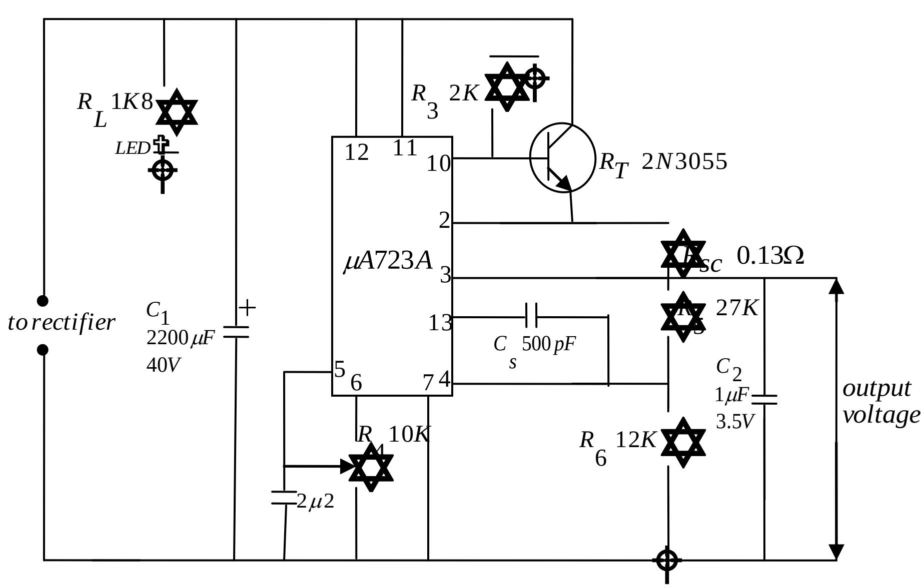


Fig.2 Power Supply Circuit

The safe current limit is 6.084A if V_u =19V at pin 12. The calculated value of R_{sc} is 0.1068 Ω but because the targeted value of output current is 500mA, therefore 0.13Ω was used. A low value capacitor 500pF is connected between pins 13 and 4 to guide against oscillation of the circuit at high frequencies and another 1μF across the output terminals to improve the overall output ripple voltage.

MEASUREMENT, RESULT AND DISCUSSION

Without load, the output current at pin 10 is 150mA and 500mA at the output terminals. The output voltage ranges from 0.5 to 24.0V. Table 1 shows the value of currents and their corresponding voltages at a fixed output voltage when the output terminals are connected to a load. A typical load regulation line is obtained as shown on the graph that the voltage starts dropping after a current of 0.4A, which is the maximum load current for the load applied. This means that the current limiting circuit starts to function at this point and finally short down at 0.42V. The output impedance is about 0.2502 Ω.

A power supply is considered to have good stability if the output voltage remains constant with line when the unit is in thermal equilibrium and that the load current and the ambient temperature are all held constant. The unit was monitor for about 70 minutes and it was found that the load current and the output voltage were substantially constant irrespective of changes in the main voltage and temperature. Therefore, the power supply is considered to be of good stability.

Table 1: Measured load voltage and current

$V_L(V)$	15.0	15.0	14.9	14.8	14.6	14.4
$I_L(A)$	0.08	0.38	0.40	0.41	0.42	0.43

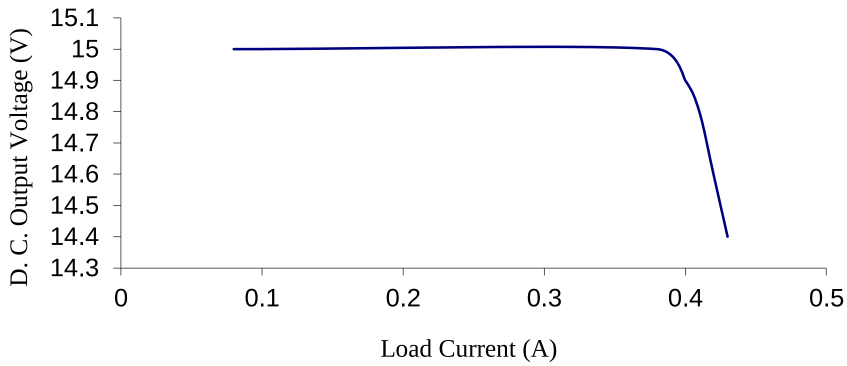


Fig. 3 Load Regulation Curve

SUMMARY AND CONCLUSION

The $\mu A723A$ monolithic regulator is a device suitable for the protection of laboratory instruments against excess current and voltage. The power supply unit has excellent stability. Fluctuations in the input voltage and increase in the temperature of the equipment being powered have no effect on the load current and the d.c. output voltage. The current limit function switch on at about 0.4A for a steady d. c. output voltage of 15V. The power supply protects laboratory equipments and the lives of researchers, thereby, fostering research for technological and economical advancements while the government battling with the power menace. The power supply constructed in this study gives output voltage range of 0.5 to 24.0V and is capable of maintaining a constant voltage irrespective of changes in the load current and unregulated input voltage. However, electrical equipments that require higher value of voltages exist in some laboratories. Therefore, it is recommended that the study be extended to a power supply capable of 1 to 50V d. c. output range.

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