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The Study, Design and Construction of Laboratory Power Supply with Adjustable 723 Regulator Chip

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Abstract: The necessary d. c. supply for electronics instrument may be drawn from batteries. However, the e.m.f. of batteries is not usually constant throughout life and also there is the danger of leakage which may endanger both the electronic circuit and the users. Power supply is a constant d.c voltage source suitable for operating electronic instruments without the danger associated with batteries. The 14-pin DIL (μA723A) version of voltage regulator IC was incorporated to continuously monitors the d.c voltage output and automatically holds it constant irrespective of changes in the load current and unregulated input voltage. A divided fraction of the output voltage is compared with a fraction of the stable voltage reference to give a current of 150mA, which is boasted to 500 mA by an external transistor. The unit has excellent stability.

Key words: Voltage divider, μA723A regulator, current-limiting protective circuit

INTRODUCTION

A power supply is an assembly of components designed to drive from the mains input, output suitable for operating electronic instruments and systems. The power to drive a system or instrument may of course, be obtained from batteries, but more often, it is derived from the single-phase a. c. mains (Wobschall, 1987). 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 and temperature. The power supply must also effectively isolate the internal circuit from the raw mains and provide automatic overload and overvoltage 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 (Loveday, 1995). There are many regulator IC's but the μA723A monolithic regulator is chosen for this study, even though it is an old regulator but its circuit shows many of the elements standard to any regulator and reveals what goes on in many other regulators (Horowitz and Winfield, 1995; Hayes and Horowitz, 1989).

VOLTAGE REGULATOR IC's

The simplest units are the three terminal voltage regulator; fixed voltage regulator and adjustable voltage regulator. All that needed to set it up is to connect the input and the common (or the adjust as the case may be) to the unregulated supply and the regulated voltage is taken from the output. The LM7915and 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 (On Semiconductor, 2006; Wobschall, 1987). Any of these simpler units can be connected to give either positive or negative voltage.

An older, more complex but versatile regulator is the 723 chip, which are usually presented in a dual-in-line 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 μA723A MONOLITHIC REGULATOR

This is available in a 14-pin DIL (μA723A) encapsulation or as a metal can version (μA723A) with ten leads (RS Data, 1983; Loveday, 1995; National Semiconductor, 1999). The μA723A was used in this study because it dissipates less power internally at ambient temperature of 25°C. According to Horowitz and

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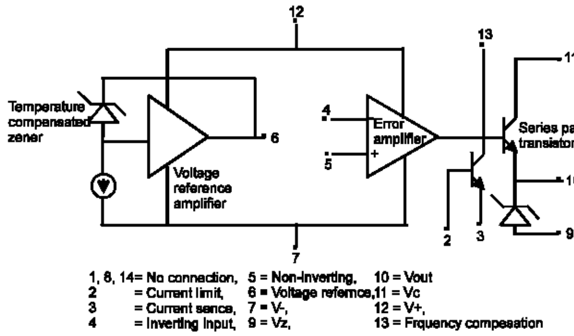

Fig. 1: Internal circuit of μA723IC regulator

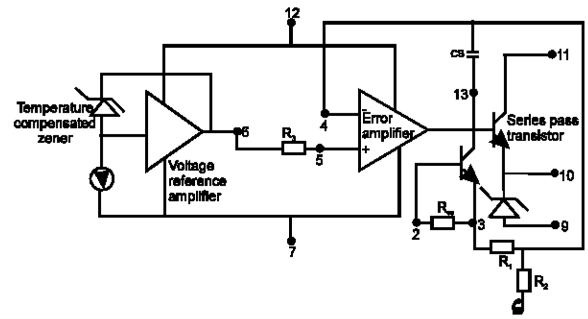

Fig. 2: Output voltage above reference voltage

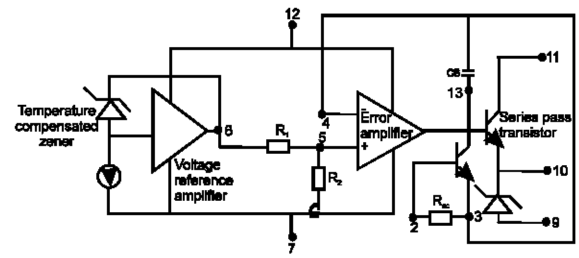

Fig. 3: Output below reference voltage

Winfield (1995) the internal circuitry contains a temperature compensated voltage reference, error amplifier, series pass transistor and a current-limiting protection circuit as show in Fig. 1. 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. A third variation of this circuit is necessary if the regulator is to provide a range of output voltage around the voltage reference. One of the extra components is the current limiting resistor R_{SC}, which ensures that maximum current output is not beyond a safe limit. Another one is the compensation capacitor C_c, this 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.

CIRCIUT DESCRIPTION

Figure 2 shows the circuitry of the regulator providing output voltage more than the voltage reference. The voltage divider formed by R_1 R_2 is connected between current sense and ground to compare a fraction of the output with the voltage reference (RS Data, 1983; Horowitz and Winfield, 1995; Loveday, 1995).
R_3 should be chosen so that

$$R_3 = \frac{R_1 R_2}{R_1 + R_2} \quad (1)$$

The voltage divider may be replaced with potentiometer so that the output can be set precisely. The regulated output above the voltage reference is given by

$$V_a = V_{ref} \frac{R_1 + R_2}{R_2} \quad (2)$$

For output voltage less than the voltage reference, the voltage divider is connected between the voltage reference and ground as show in Fig. 3, so that the output voltage is compared with a fraction of the reference (Hayes and Horowitz, 1989; Horowitz and Winfield, 1995; Loveday, 1995). A potentiometer can replace the voltage divider with the variable arm connected to pin 5 to give a voltage range between 0 and 7.15V. The regulated output voltage is given by

$$V_b = V_{ref} \frac{R_1}{R_1 + R_2} \quad (3)$$

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 (Horowitz and Winfield, 1995). This method was used in this study.

THE ACTUAL CIRCUIT

This actual circuit is presented in Fig. 4. The mains voltage is stepped down to 20 volts a.c. The bridge rectifier comprises of four IN4002 diodes. C_1 is the reservoir capacitor for producing smoothing effect. R_1 is a preload resistor and LED is a light emitting diode which turns on when mains is on.

Potentiometer R_4 sets the output voltage to the desired value by adjusting the reference input voltage. It

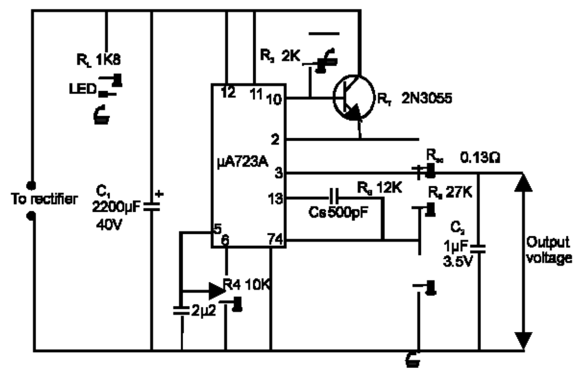

Fig. 4: Power supply circuit

is connected between pin 6 and ground. The centre arm of R_4 is connected to pin 5 selects any point 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 establishes 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 regulation.

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_μ. Therefore, the safe current limit I_{limit} when the output is short circuited is given by (Loveday, 1995):

$$I_{limit} = \frac{P_{max}}{V_u} \tag{4}$$

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

$$I_{limit} = \frac{V_{sence}}{R_{sc}} \tag{5}$$

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 Horowitz and Winfield (1995) the temperature of the transistor junction is given by:

$$T_j = T_A + (\theta_{jc} + \theta_{cs} + \theta_{sa})P \tag{6}$$

Where:

TA : Is the operating temperature of the IC.
θjc : Is the thermal resistance from junction to case.
θcs : Is the thermal resistance from case to heat sink.
θsa : Is the thermal resistance from heat sink to ambient.
P : Is the power being dissipated.

The external transistor should be connected to form a Darlington pair with the internal transistor (Horowitz and Winfield, 1995). 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:

$$R_3 = \frac{\text{voltage of } T_R \text{ at point of conduction}}{\text{Leakage current of } T_R \text{ and } \mu A723} \tag{7}$$

The voltage at which T_R conducts is typically 0.4V (Horowitz and Winfield, 1995).

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 (Loveday, 1995). 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 (150 mA) 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 (7) 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 ìA723 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 (4) the total power dissipation is the sum of the power dissipated by the transistor i.e. 115W and the IC. The safe current limit is 6.087A if V_u = 19V at pin 12. the calculated value of R_{SC} is 0.11V 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 1iF across the output terminals to improve the overall output ripple voltage.

RESULTS AND DISCUSSION

Without load, the output current at pin 10 is 150 and 500 mA ta the output terminals. The output voltage ranges from 0.5 to 23.2V. 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 from the graph (Fig. 5) that the voltage starts dropping after 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.

Table 1: Value of current and their corresponding voltafe

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

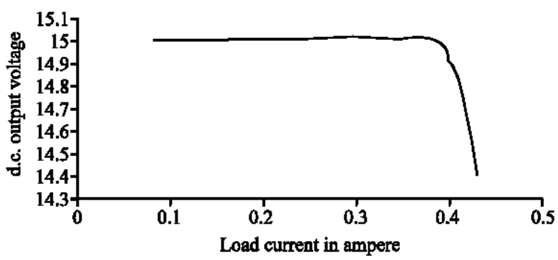

Fig. 5: Load regulation curve

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

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