11.SERIES VOLTAGE REGULATOR

11.1 OBJECTIVES

Design a voltage regulator using op amp IC741.

11.2 HARDWARE REQUIRED

S.No	Equipment/Component name	Specifications/Value	Quantity
1	IC 741	Refer data sheet in appendix	1
2	Resistors	1 KΩ 24 KΩ 100 Ω 12 KΩ	1 1 1 1
3	Transistor	Q2N2222	1
4	Diode	DIN746	1
5	Dual Regulated power supply	(0 -30V), 1A	1
6	Multimeter		1

11.3 THEORY

A voltage regulator is a voltage stabilizer that is designed to automatically stabilize a constant voltage level. A voltage regulator circuit is also used to change or stabilize the voltage level according to the necessity of the circuit. Thus, a voltage regulator is used for two reasons:

1. To regulate or vary the output voltage of the circuit.
2. To keep the output voltage constant at the desired value in-spite of variations in the supply voltage or in the load current.

All electronic voltage regulators will have a stable voltage reference source which is provided by the reverse breakdown voltage operating diode called zener diode. The main reason to use a voltage regulator is to maintain a constant dc output voltage. It also blocks the ac ripple voltage that cannot be blocked by the filter. A good voltage regulator may also include additional circuits for protection like short circuits, current limiting circuit, thermal shutdown, and over voltage protection. Electronic voltage regulators are designed by any of the three or a combination of any of the three regulators given below.

A zener controlled voltage regulator is used when the efficiency of a regulated power supply becomes very low due to high current. There are two kinds of zener controlled transistor voltage regulators. Zener Controlled Transistor Series Voltage Regulator is a circuit is also named an emitter follower voltage regulator. It is called so because the transistor used is connected in an emitter follower configuration. The circuit consists of an N-P-N transistor and a zener diode. As shown in the figure below, the collector and emitter terminals of the transistor are in series with the load. Thus, this regulator has the name series in. The output of the rectifier that is filtered is then given to the input terminals and regulated output voltage V_{load} is obtained across the load resistor R_{load}. The reference voltage is provided by the zener diode and the transistor acts as a variable resistor, whose resistance varies with the operating conditions of base current, I_{base}. The main principle behind the working of such a regulator is that a large proportion of the change in supply or input voltage appears across the transistor and thus the output voltage tends to remain constant.

The output voltage can thus be written as

$$V_{out} = V_{zener} – V_{be}$$

The transistor base voltage V_{base} and the zener diode voltage V_{zener} are equal and thus the value of V_{base} remains almost constant.

Operation

When the input supply voltage V_{in} increases the output voltage V_{load} also increases. This increase in V_{load} will cause a reduced voltage of the transistor base emitter voltage V_{be} as the zener voltage V_{zener} is constant. This reduction in V_{be} causes a decrease in the level of conduction which will further increase the collector-emitter resistance of the transistor and thus causing an increase in the transistor collector-emitter voltage and all of this causes the output voltage V_{out} to reduce. Thus, the output voltage remains constant. The operation is similar when the input supply voltage decreases. The next condition would be the effect of the output load change in regard to the output voltage.

Let us consider a case where the current is increased by the decrease in load resistance R_{load}. This causes a decrease in the value of output voltage and thus causes the transistor base emitter voltage to increase. This causes the collector emitter resistance value to decrease due to an increase in the conduction level of the transistor. This causes the input current to increase slightly and thus compensates for the decrease in the load resistance R_{load}.

The biggest advantage of this circuit is that the changes in the zener current are reduced by a factor β and thus the zener effect is greatly reduced and a much more stabilized output is obtained. The output voltage of the series regulator is $V_{out} = V_{zener} – V_{be}$. The load current I_{load} of the circuit will be the maximum emitter current that the transistor can pass. For a normal transistor like the 2N3055, the load current can go upto 15A. If the load current is zero or has no value, then the current drawn from the supply can be written as $I_{zener} + I_{c(min)}$. Such an emitter follower voltage regulator is more efficient than a normal zener regulator. A normal zener regulator that has only a resistor and a zener diode has to supply the base current of the transistor.

Limitations

The limitations listed below has proved the use of this series voltage regulator only suitable for low output voltages.

1. With the increase in room temperature, the values of V_{be} and V_{zener} tend to decrease. Thus, the output voltage cannot be maintained a constant. This will further increase the transistor base emitter voltage and thus the load.
2. There is no option to change the output voltage in the circuit.
3. Due to the small amplification process provided by only one transistor, the circuit cannot provide good regulation at high currents.
4. When compared to other regulators, this regulator has poor regulation and ripple suppression with respect to input variations.
5. The power dissipation of a pass transistor is large because it is equal to V_{cc} I_c and almost all variation appears at V_{ce} and the load current is approximately equal to collector current. Thus, for heavy load currents pass transistor has to dissipate a lot of power and, therefore, becoming hot.

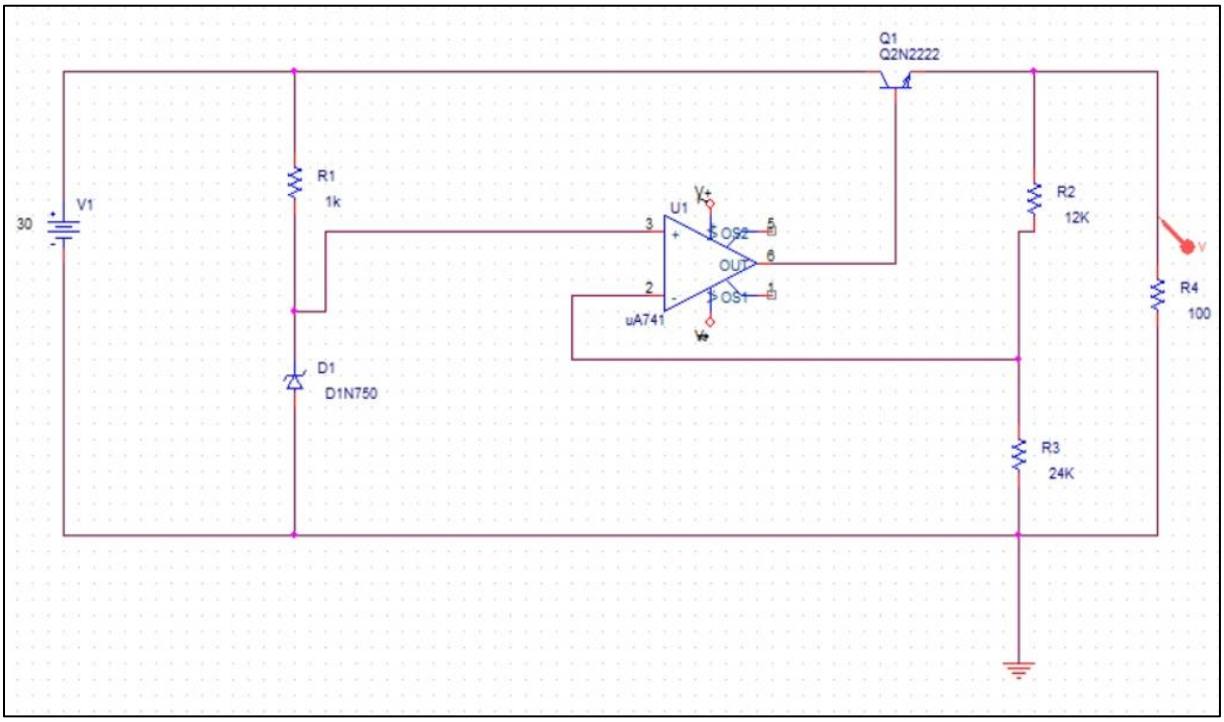

Fig: 1 Voltage regulator

R_1=1kΩ, R_L =R_4=100Ω, R_2=12kΩ, R_3=24kΩ.

11.4 PROCEDURE:

1. Setup the circuit as shown in Figure-1.
2. For Line Regulation, set R_L at 100 **Ω.** Vary the input voltage (V_1) from 5v to 25v. For each setting, find the output enter in the table. Plot the graph of V_o vs V_i.
3. For Load Regulation, set V_1 at 10 V. Vary the load resistance R_L from 100Ω to 1000Ω. For each setting, find the output enter in the table. Plot the graph of V_o vs R_L.

Load Regulation **V_{IN}= 10 V**

S.NO.	**$R_L(\Omega)$**	**V_{OUT}(V)**

Line Regulation **$R_{L=}$**100Ω

S.NO.	**V_{IN} (V)**	**V_{OUT} (V)**

11.5 PRE LAB

1. A voltage regulator with a no-load output dc voltage of 12v is connected to a load with a resistance of 10**Ω**. If the load resistance decreases to 7.5**Ω**, the load voltage will decrease to 10.9v. Calculate load current and the percent load regulation.
2. The ________ regulator is less efficient than the ________ type, but offers inherent short-circuit protection.
3. What is line regulation?

11.6 POST LAB

1. Calculate the voltage regulation of a power supply having V_{NL} = 50 V and V_{FL} = 48 V.
2. What is the purpose of an additional RC filter section in a power supply circuit?
3. Calculate the voltage regulation of a power supply having V_{NL} = 50 V and V_{FL} = 48 V.
4. In a series regulator, what is the purpose of fold-back limiting?

RESULT: