EEE 208 (Software) Project

Adjustable Ripple-Regulated DC Voltage Power Supply using OP AMP 741

EEE | L-2, T-2 | Lab Group: B2 | Group No: 03

Submitted By:

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Introduction

Unregulated voltage source is a voltage source that does not have a constant value for output. Now for any power supply, the two important parameters are the line regulation and the load regulation. and these two parameters defines how well the supply can provide the constant output voltage even if there is a change in the line voltage or the load. So, the line regulation defines if there is any change in the line voltage then how it will affect the output voltage. So, this line regulation is defined as the change in the output voltage divided by the change in the input voltage. So, for the ideal power supply this line regulation should be equal to zero. that means even if there is any change in the line voltage then it should not affect the output voltage.

$$\%\ \boldsymbol{Line\ Regulation} = \frac{\boldsymbol{Change\ in\ the\ output\ voltage}}{\boldsymbol{Change\ in\ the\ input\ voltage}} \times \mathbf{100}$$

But the output voltage does change with the variation in the line voltage. So, for good power supply this line regulation should be as minimum as possible.

Similarly, the second parameter is the load regulation which defines if there is any change in the load then how it will affect the output voltage. and it is defined as the no load voltage minus full load voltage divided by full load voltage. So, here this no-load voltage is the voltage of the power supply where there is a no load connected or we can say that whenever the load current IL is equal to 0. the full load voltage is the voltage of the power supply with the load when the load current IL is maximum. So, for the ideal power supply this load regulation should be zero that means even if there is any change in the load then it should not affect the output voltage.

$$\%\ \boldsymbol{Load\ Regulation} = \frac{\boldsymbol{Vnl - Vfl}}{\boldsymbol{Vfl}} \times \mathbf{100}$$

Vnl = Voltage at no load (When Il =0)

Vfl = Voltage at full load (When Il = Il max)

but if there is any change in the load that it will affect the output voltage. So, for the good power supply this load regulation should be as minimal as possible.

So, if the power supply is unregulated or for the power supply without any regulator the line and the load regulations are very poor. So to improve the line and the load regulation and to get this table output voltage this voltage regulator is necessary.

Construction of a voltage regulator

This voltage regulator consists of the following components and based on the arrangement of this components, this voltage regulator can be defined in two categories: the series voltage regulator and the shunt voltage regulator.

In case of the series voltage regulator the controlling element is in series with the load, while in case of shunt voltage regulator it is in parallel with the load. if we talk about the series voltage regulator then the output voltage is sampled using this sampling circuit and it is compared with the reference voltage and based on the error voltage the control circuit takes the corrective action. if the output voltage increases or decreases and the control circuit tries to maintain the output voltage to the previous voltage.

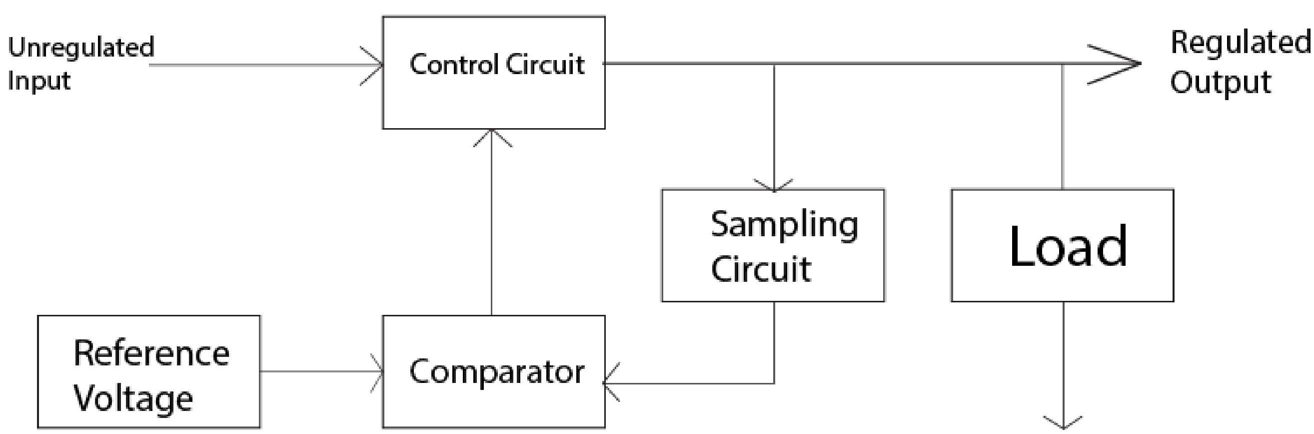


Figure 2: Flow chart of series voltage regulator.

Sample schematic diagram:

Series voltage regulator:

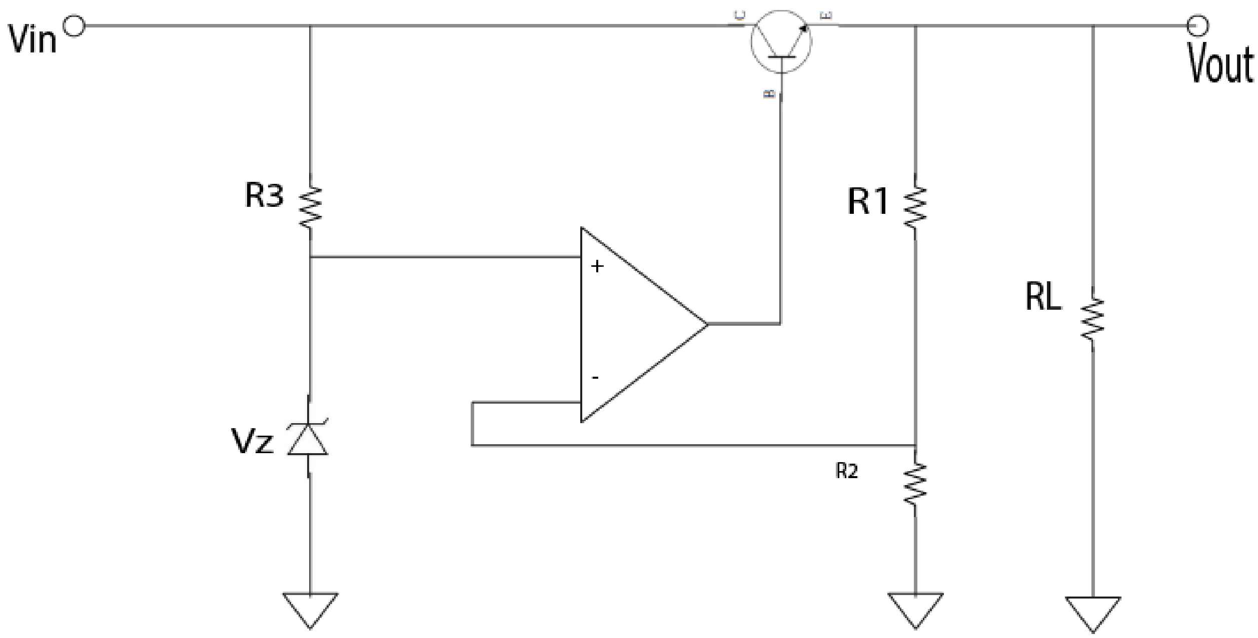
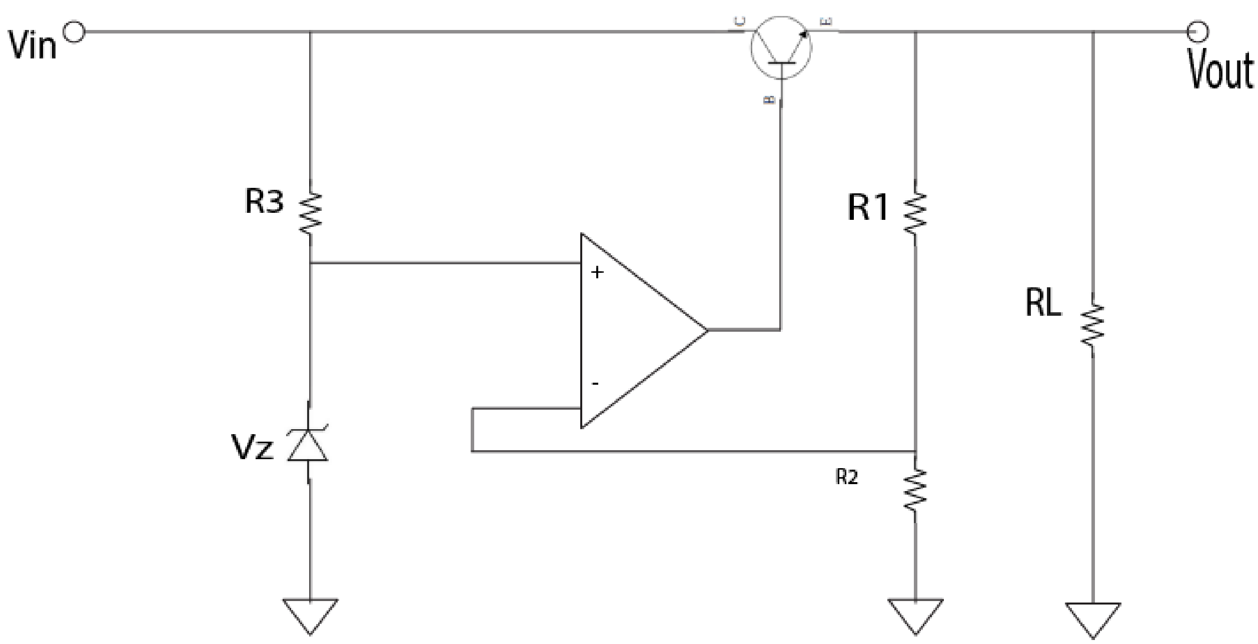


Figure 3: Simple schematic diagram of series voltage regulator.

Here the control circuit comprises of the OP AMP and the transistor and the output voltage is sampled using this voltage divider circuit, so this sample voltage is applied at the inverting terminal and through this Zener diode reference voltage is applied at the non-inverting terminal

Sample calculation:



Let's say the voltage at the non-inverting terminal is equal to V+ and the voltage at the inverting terminal is equal to V-. so here if the output voltage tries to increase then the feedback voltage V- will also increase. But if you notice over here the Op Amp is operating in the closed loop configuration and in fact, this is operating in the negative feedback and when V- will increase the voltage difference between 2 and 3 will decrease and so is the V'o. So, if the load voltage tries to increase then the output of the Op Amp will reduce. On the other hand, if the Vload decreases then the opposite thing happens, and Vo restores to its previous higher value. Here,

$$V_o = V'_o - V_{be}$$

where Vbe is the voltage drop across the base emitter junction of the transistor.

Due to this closed loop configuration the voltage at the inverting and non-inverting terminals are equal. We can say that this voltage V+ is equal to V- and as you can see we're here the voltage V+ is equal to Vz and at the same time if you notice over here this voltage V- can also be represented as:

$$V_- = V_+ = V_z = \frac{R_2}{R_1 + R_2} \times V_o$$

$$V_o = V_z \times (1 + \frac{R_1}{R_2})$$

by selecting the value of Vz, R1 and R2 we can decide the regulated output voltage.

Simulation Diagram:

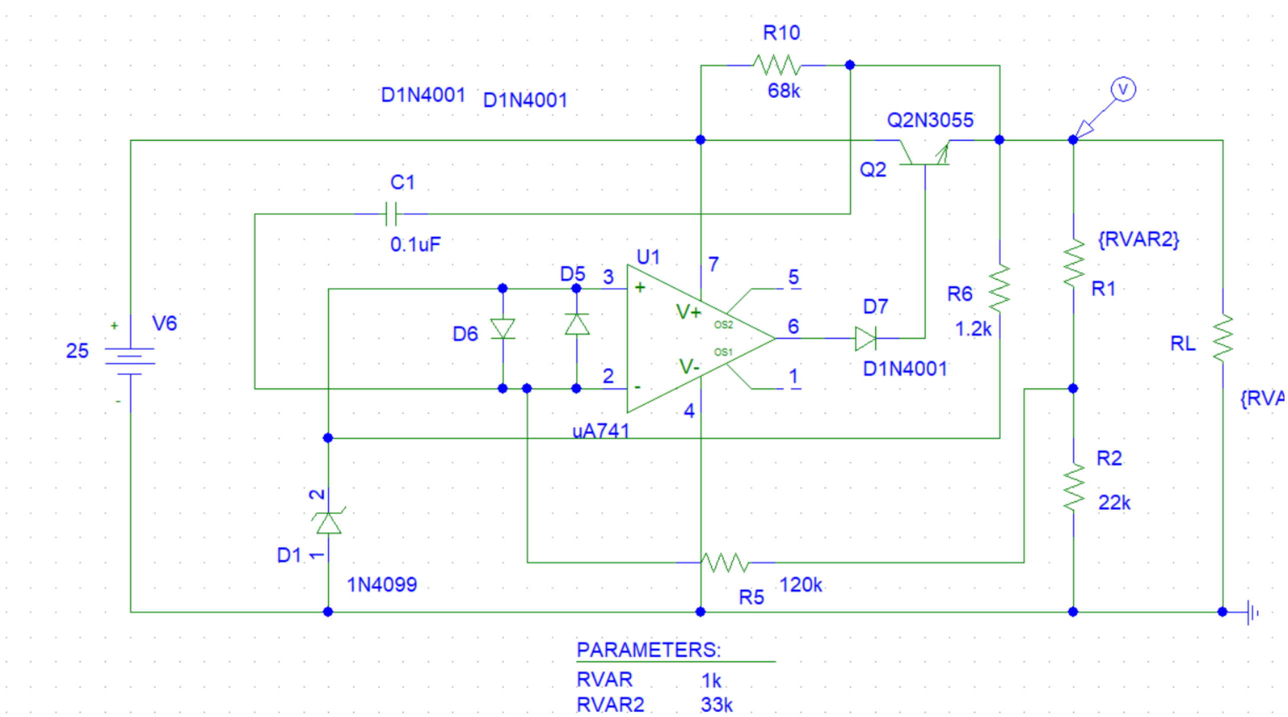
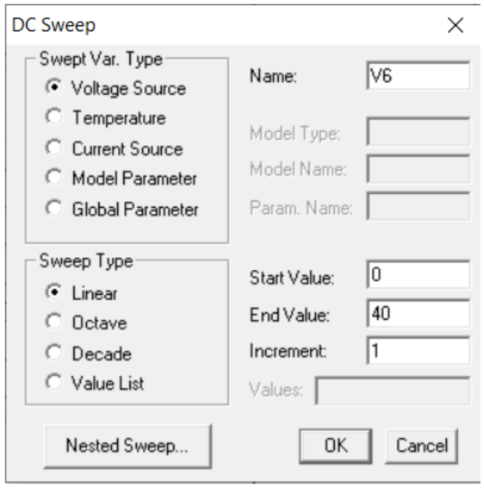


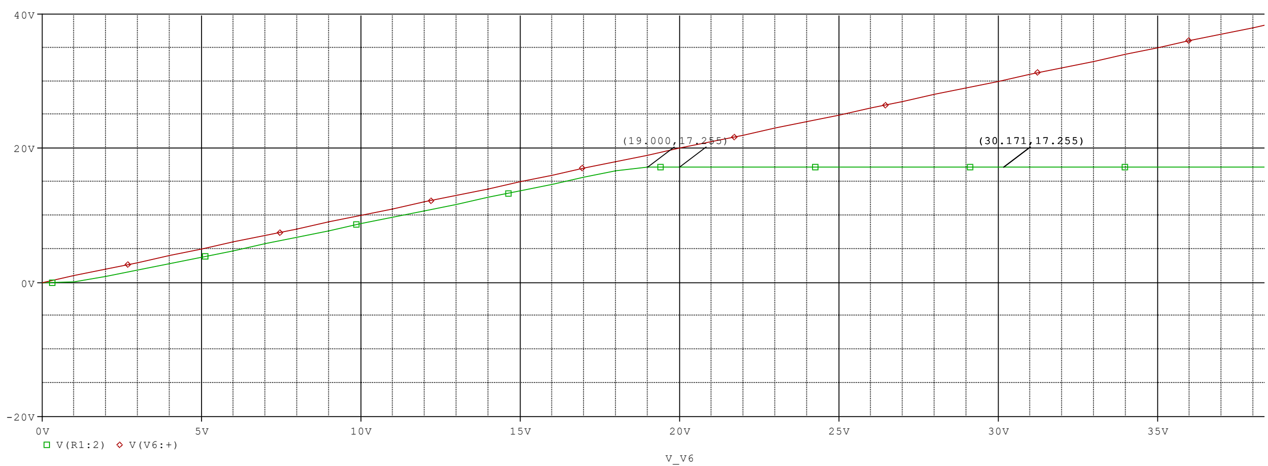
Figure: Simulation diagram for voltage regulator.

Observations:

1. Changing the input voltage keeping the load resistance fixed:

If we change the input voltage and keep the load resistance fixed, then the output parameter looks like this:





Output has been fixed to 17.255V after some increment. Here the Zener diode voltage is 6.889 V. So, the corresponding calculation for the output voltage is:

$$V_o = V_z \times (1 + \frac{R_1}{R_2})$$

$$V_o = 6.889 \times \left(1 + \frac{33k}{22k}\right) = 17.255V$$

In the same way if we change the value of voltage dividing resistor (RVAR), the output voltage also changes.

Here,

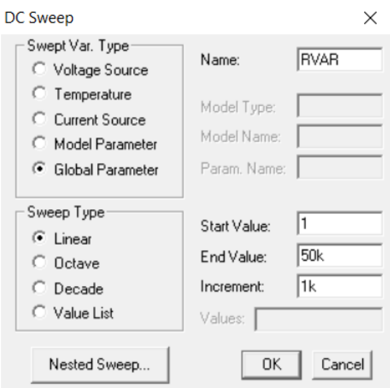
$$\%\, \boldsymbol{Line\ Regulation} = \frac{\boldsymbol{Change\ in\ the\ output\ voltage}}{\boldsymbol{Change\ in\ the\ input\ voltage}} \times \mathbf{100}$$

$$= \frac{\mathbf{17.255 - 17.255}}{\mathbf{30.00 - 19.00}} \times \mathbf{100}$$

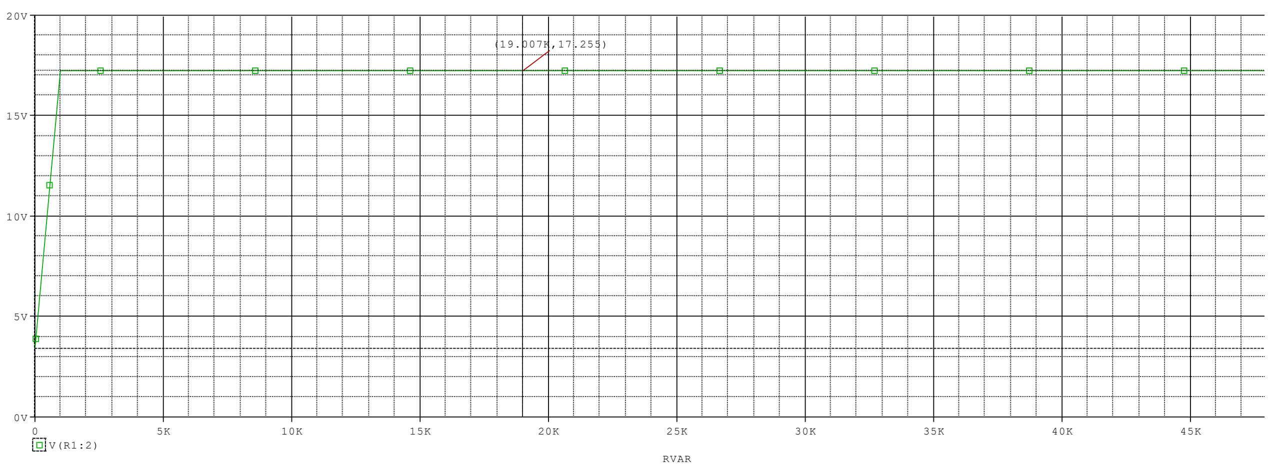
$$= 0\%$$

2. Changing the load resistance keeping the input voltage fixed:

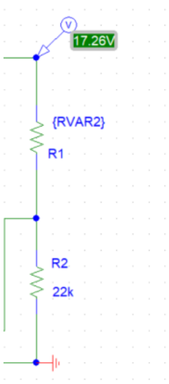
Now, if we change the load resistance keeping the input voltage fixed,



The output of this simulation looks like this:



Output voltage if we disconnect the load resistance: 17.255V



We know from the theory,

$$\% \, \boldsymbol{Load\ Regulation} = \frac{\boldsymbol{Vnl - Vfl}}{\boldsymbol{Vfl}} \times \mathbf{100}$$

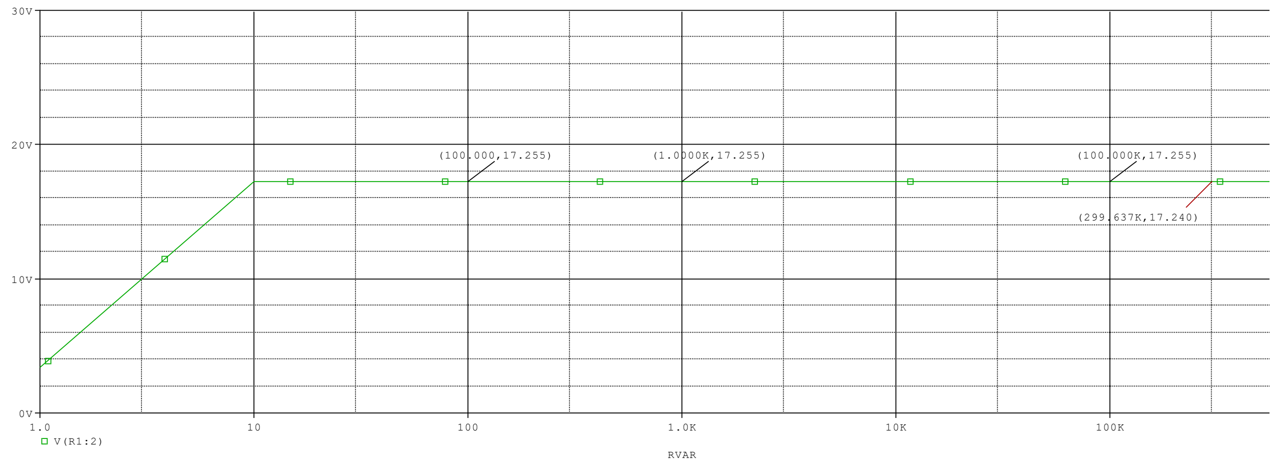
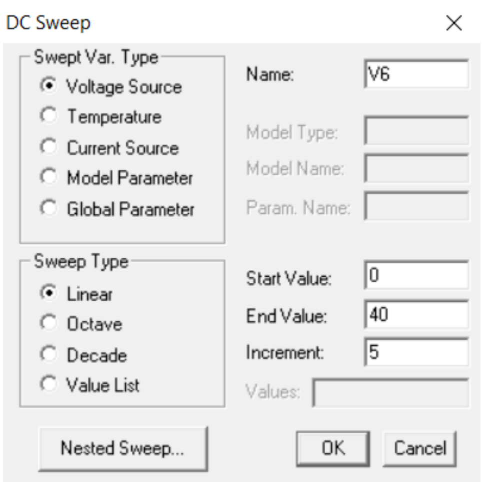


Table for calculating the load regulation:

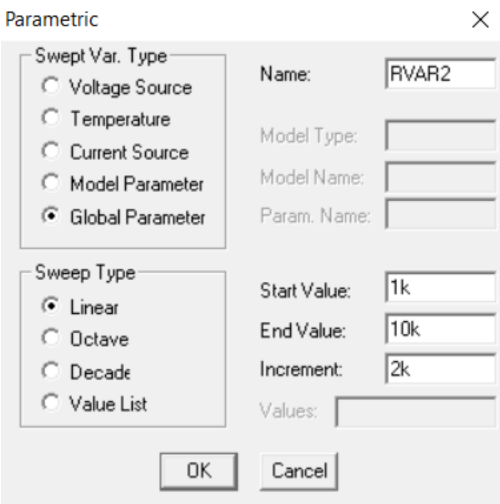
Load Resistance (ohm)	No load voltage (V)	Full load voltage	Load regulation
100	17.255	17.255	0%
1k		17.255	0%
100k		17.255	0%
300k		17.240	0.087%

3. Changing the input voltage and RVAR simultaneously to observe the effect of feedback system:

If we change the voltage divider circuit, then our overall output voltage will considerably change. We can regulate the output voltage using a variable resistance or a potentiometer. The nested sweep parameters for these phenomena are given below:

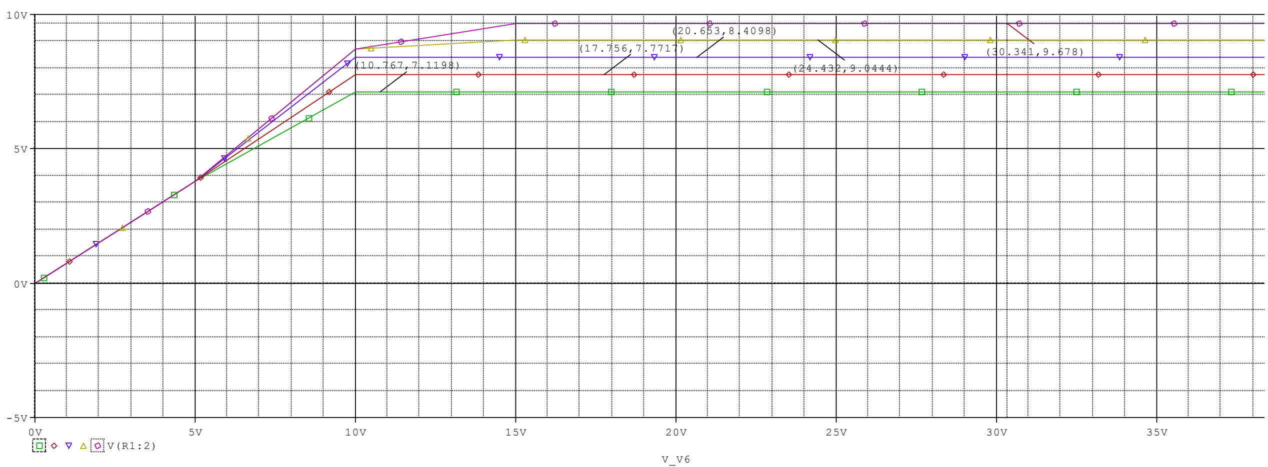


First, we sweep the voltage source from 0 to 40 V with 1V increment.



And the variable resistance from 1k to 10k with 2k ohm increment.

Then we observe the output of the circuit due to the change in the potentiometer modeled as RVAR in this circuit:

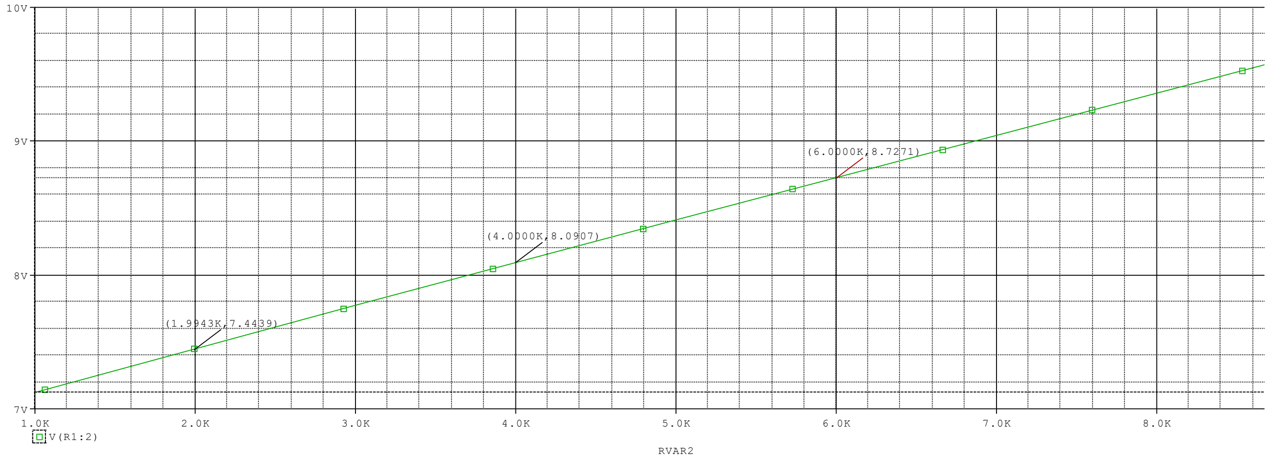


RVAR	Output regulated voltage
1kΩ	7.12V
3kΩ	7.77V
5kΩ	8.41V
7kΩ	9.04V
9 kΩ	9.68

Here, we can conclude that the output regulated voltage changes as we change the variable resistance using potentiometer.

4. Changing RVAR to observe the effect of feedback:

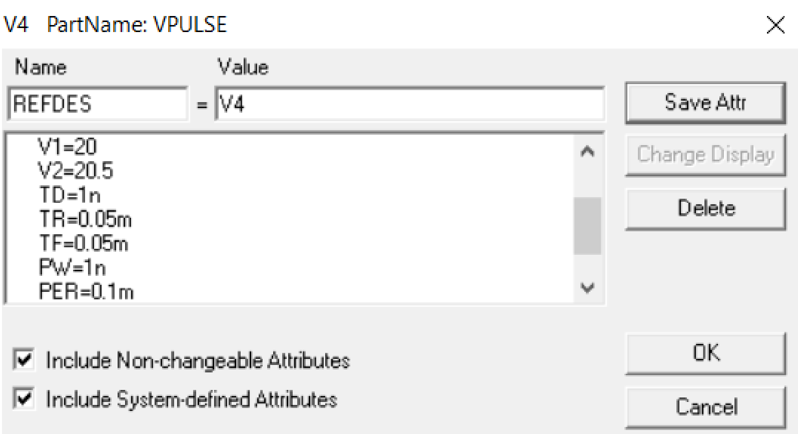
If we keep the input voltage fixed at a value, we can change RVAR to get any output voltage wanted in the output terminal using a potentiometer. This is effectively used in a DC voltage adapter which can supply a variable voltage output.

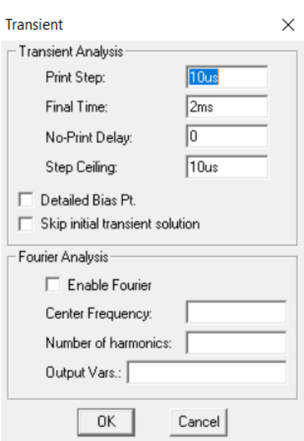


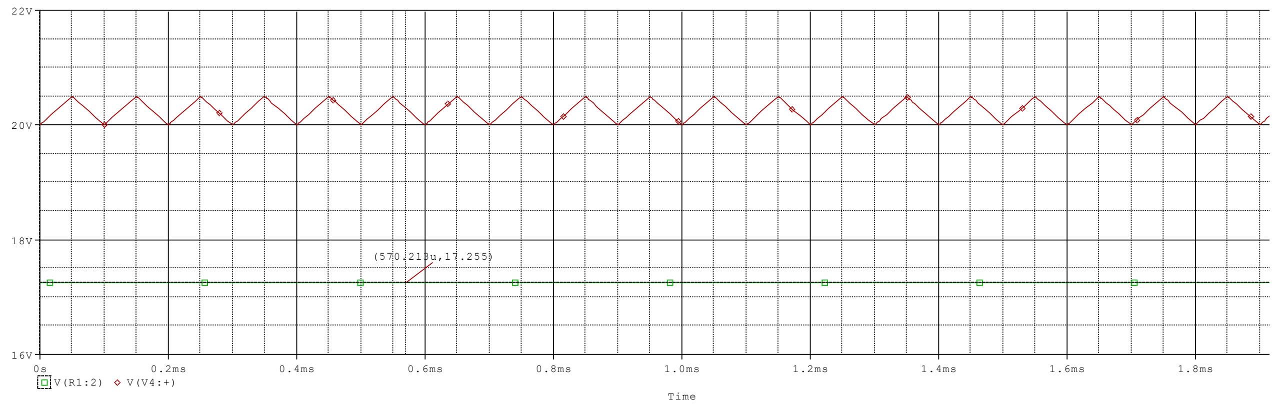
So, we can regulate the output voltage at any desired output using this voltage regulator circuit.

5. Checking Output with Ripple:

To check the ripple regulation of our circuit, we adjusted a Vpulse to create a 0.5V pulse within 20V and 20.5V and observed the output.

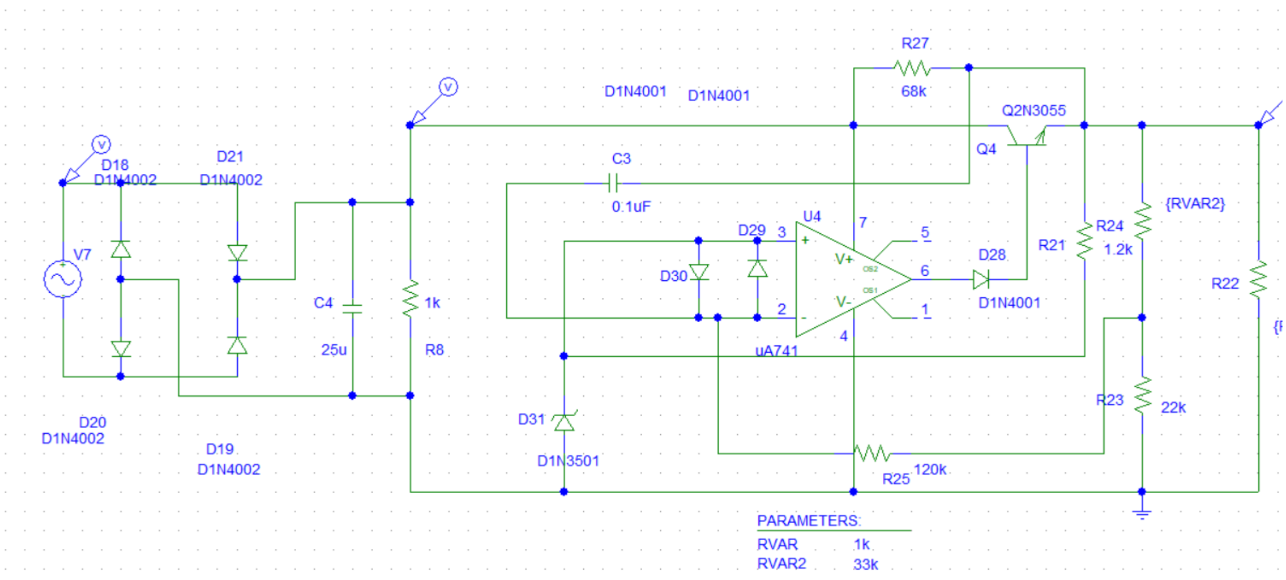






As can be seen, the circuit regulates the ripple and sticks to our desired output while we can adjust it with potentiometer knob.

Discussion



We tried to show the ripple regulated circuit in this way but could not because of the convergence error of pspice.

In various applications where the ripple is not desired, the circuit adjustable ripple-regulated power supply using 741 for adjustable ripple regulated power supply works quite satisfactorily. Here the advantage of op-amps' enormous gain is utilized along with op-amps' property of keeping the inverting and non-inverting terminals at the same potential by the feedback loop comprising series-pass transistor Q2, R1, R6, and R5 op-amp 741 and diode D7. A minor difference in the two potentials at the input of the op-amp is highly amplified due to the IC's enormous gain quality, which guides the series-pass transistor to bring the two input terminals of the op-amp to equal potentials at a very fast feedback repetition.

Resistors R10 and R1 have been used in the circuit to provide the starting current to the circuit and to sample the positive ripple of the input at the inverting input of the op-amp, thereby generating a negative ripple at the output. Once the circuit starts working, it is further stabilized due to constant current, resulting in a highly regulated power supply.

Here a 6.889V zener diode is used because this particular Zener provides the lowest temperature coefficient, i.e., it does not give any change in its voltage due to temperature change. Diode D5 and D6 have been incorporated into the circuit to protect the input of op-amp by latching both at the difference of 0.6V.

Since Vz, R2, R10, R6, and R5 are fixed, the output voltage is fully controlled by resistance R1, which is higher than R2 . A sample of any change at the output due to load or input variation is reflected at the inverting input of the op-amp. This change is amplified by op-amp in the opposite phase and delivered to transistor Q2 to compensate for the same.

Diode D_3 opposes the flow of any reverse leakage current by transistor into the op-amp and thereby protects it. Ripple compensation is achieved as a portion of unregulated positive ripple is fed into the op-amp's inverting input terminal which generates an amplified negative ripple at the output. Capacitor C_1 is used to filter out DC voltage associated with the positive ripple done by varying RL. This negative ripple gets added to the positive ripple already in the output, ultimately nullifying it.

Conclusion

From our observation, we can regulate ripples using this circuit. So, our circuit can now be attached with rectifier circuits to generate a fixed DC voltage. A small ripple made by the Vpulse is enough to prove the functionality of our circuit. We also succeeded at adjusting the output using potentiometer.

Reference: bestengineeringprojects.com/adjustable-ripple-regulated-power-supply-using-741

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