

Integrated Circuits and Applications
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Voltage Regulators
Lecture – 35
Adjustable Voltage Regulator

In the last lecture, we have discussed about the fixed voltage regulators. So, the drawback of this fixed voltage regulators is the excessive inventory and production cost. To avoid this, we will use adjustable voltage regulators. There are several advantages of this adjustable voltage regulators compared with the fixed voltage regulators. As we have discussed in the last lecture, the fixed voltage regulators can produce the discrete values of the output voltages such as 5V, 6V, 8V, 12V, 15V, 18V, and 24V; if we take 78XX series. So, because of this discrete values of the outputs rather than the continuous fixed output voltages, this fixed voltage regulator is having drawback of excessive inventory and production charges.

Whereas, if I take this adjustable voltage regulator, this will be having less inventory and production cost. This is one advantage of this adjustable voltage regulator. The second advantage is this can have the better load and line regulation. So, the load or line regulation is defined as the amount of the output change due to the load current variation.

Normally, this will be measured in millivolts, and the less value of this output change is desirable. Even if the load current changes output changes by only a few millivolts then the system will be having better load or line regulation. So, in case of adjustable voltage regulator, this can have a load regulation of by factor of 10 or even better. Load regulation is better by a factor of 10 or more. This is the second advantage of the adjustable voltage regulator.

And third one is better overload protection in the sense over a same temperature range. So, this adjustable voltage regulators can provide the larger values of the output current. Adjustable voltage regulators provides greater values of output current. Over a given temperature range. So, this is possible by fixing the current sink in the ICs.

Adjustable voltage regulators

Advantages over fixed voltage regulators

↳ 5V, 6V, 8V, 12V, 15V, 18V and 24V
78XX series

Excessive inventory and production cost

1. Less inventory and production cost
2. Better load and line regulation

↙
The amount of o/p voltage change due to load current variation. (mV)
load regulation is better by a factor of 10 or more

3. Better over-load protection

Adjustable voltage regulator provides greater values of output current over a given temperature range. current-sink

(Refer to the slide at 06:47)

So, most of these voltage regulators will be having current sink. By means of the current sink so, this can give the larger output currents otherwise what happens is the IC becomes heated up. So, to avoid that, normally we will use current sink. And the fourth advantage of adjustable voltage regulators is better thermal breakdown. In the sense, it can operate over the larger temperature ranges.

So, because of this large temperature range, if it provides the more current, then in order to avoid this thermal breakdown, normally these voltage regulators will be fixed with the temperature sensors. So, whenever the current exceeds a limit thereby if it becomes too hot so, if the IC becomes too hot. The IC is switched off by using, IC is switched off till IC cools down to a safer temperature. So, in this way, these variable voltage regulators can have a better thermal breakdown.

So, because of these advantages, nowadays the variable or adjustable voltage regulators are very common in most of the electronic appliances. So, the example

of this adjustable voltage regulator is LM317. This is positive adjustable voltage regulator. This can produce the output voltage in the range of $1.2V$ to up to $57V$.

You can see the large dynamic range of this ICLM317. In case of fixed, we have the 7 discrete output voltages from $5V$ to maximum of $24V$. Whereas, here, we can have a continuous output voltages in the range of $1.2V$ to $57V$. So, if you see the connections of this LM317, this is also 3 terminal device.

One is input terminal, another is output terminal, similar to the fixed voltage regulator. In fixed voltage regulator, the third terminal is ground whereas, here, the third terminal is adjustment terminal. Here the output is connected to the load. See the output voltage V_0 ; here, the input voltage V_{in} is applied, and here we have one variable resistor potentiometer R_2 . Here, we will have one fixed resistor, R_1 .

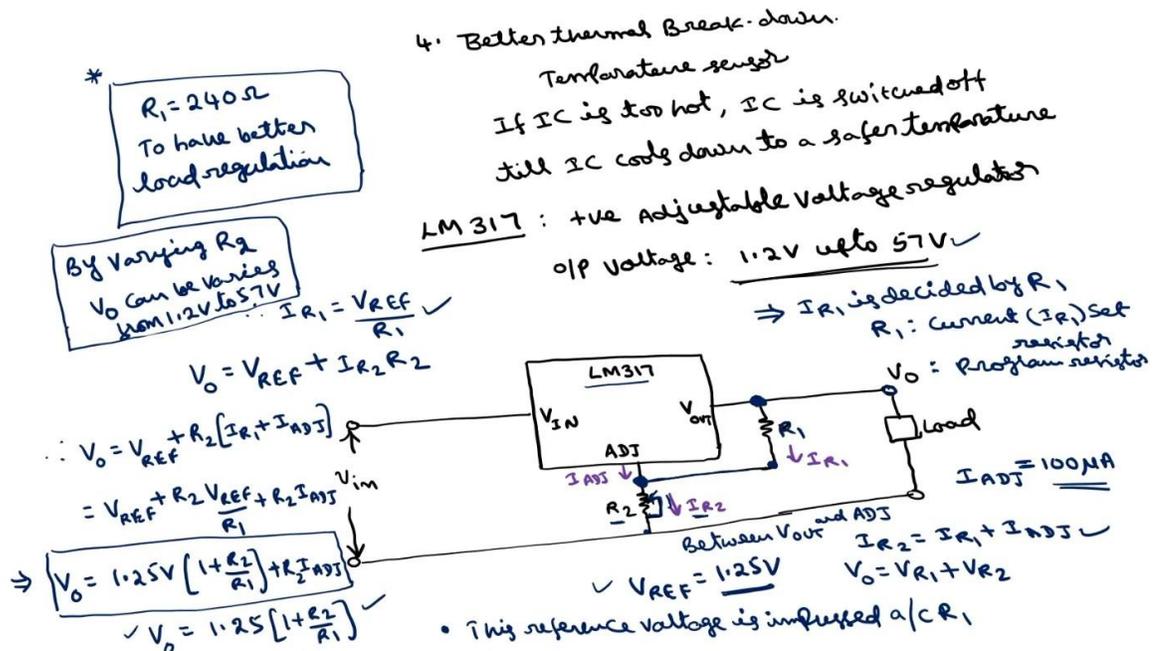
Let this current is I_{R_2} ; this current is I_{ADJ} ; this current is I_{R_1} . Now, here this LM317 is designed to give a reference output voltage of $1.25V$. This $1.25V$ is impressed across this R_1 .

As a result of that what happens is this I_{R_1} is decided by R_1 . And this way, this R_1 is called as current set resistor or also called as program resistor. By varying this R_1 value I_{R_1} current also can be varied. So, this I_{ADJ} is very very, small this is for LM317, this is of the order of $100\mu A$. Now, if you see the analysis of this system.

So, if I apply the KCL at this node I_{ADJ} and I_{R_1} are entering I_{R_2} is leaving. So, $I_{R_2} = I_{R_1} + I_{ADJ}$. And what is V_0 ? V_0 is defined here voltage drop across the R_1 plus voltage drop across R_2 . $V_0 = V_{R_1} + V_{R_2}$, but $V_{R_1} = 1.25V$. This is between V_{out} , and adjustment pin of LM317, that is between these two points between this point and this point is 1.25 . So, what happens to this I_{R_1} ? $\frac{V_{REF}}{R_1}$. So, what is V_0 ? $V_0 = V_{REF} + I_{R_2}R_2$. But what $I_{R_2} = I_{R_1} + I_{ADJ}$. Therefore, $V_0 = V_{REF} + (I_{R_1} + I_{ADJ})R_2$. What is I_{R_1} ? $\frac{V_{REF}}{R_1}$. So, this is equal to $V_{REF} + \frac{V_{REF}}{R_1}R_2 + I_{ADJ}R_2$.

So, implies V_0 is equal to what is V_{REF} is $1.25V$. If I take this $1.25V$ outside this will be $(1 + \frac{R_2}{R_1})R_2$. But this I_{ADJ} is very small value.

So, sometimes this drop is less than this one. So, you can neglect this. If you neglect this second term, this $V_0 = 1.25 \times (1 + \frac{R_2}{R_1})$. Now, we can see that here, normally, this $R_1 = 240\Omega$ to have better load regulation.



(Refer to the slide at 18:45)

Now, by varying this R_2 from here, you can vary the voltage V_0 . So, in the range of this, 1.2V to 57V, that is why here we have a potentiometer. So, by varying R_1 V_0 can be R_2 because R_1 is fixed, R_2 V_0 can be varied from 1.2V to 57V. This is about the variable voltage regulator. This is the normal circuit. So, if this LM317 is placed near the power supply capacitors, then no need of any external capacitors here. In case of fixed voltage regulator, we have some input capacitance and output capacitance. Here also we require the input and output capacitances if you place this LM317 far away from the power supply capacitors.

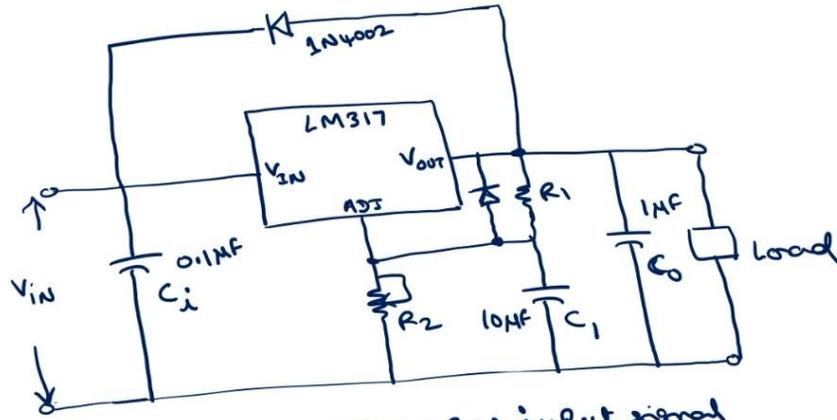
External capacitance are required. So, the resultant circuit by placing the external capacitance is. Here you have to connect input capacitance. Here, you have to connect one capacitor, here another output capacitor which is C_i input capacitance C_o this is another capacitor C_1 . Normally, the order of this one is this is $0.1\mu F$, this is $10\mu F$, and this is $1\mu F$. So, we know that C_i input capacitance is used to bypass input signal, and C_o is used to improve transient response. Here, another C_1 this is used to improve ripple rejection. So, this voltage regulator in addition to providing the constant output voltage it also rejects the ripples. So, we know that if I take this full wave rectifier.

So, this if you apply to the full wave rectifier, we will get waveform like this. This is not pure DC. So, we will pass through the capacitive filter, after that, we will get some ripples. We will not get the perfect DC signal this type of DC signal. So, we will get some ripples because of the charging and discharging of the capacitor.

So, in order to reject that ripples, we will use this C_1 . So, normally, we will be having LM317 is having 80dB ripple rejection. Sometimes there is a chance of discharging the capacitors through the low current paths into the regulator. To avoid this, we will use some protective diodes. Here, one diode is placed, here another diode is placed.

So, these two diodes are easy to avoid this discharging of the capacitor through the low current paths. So, this is possible only if the capacitors values are less than or equal to $25\mu F$ or the output voltage V_0 is greater than 25V. So, in this case, only we require the diodes, otherwise no need of these diodes. So, this will be 1N4002. This is about the complete circuit of adjustable voltage regulator.

• If LM317 is placed far from power supply capacitor, external capacitance are required



• $C \leq 25\mu F$
 $V_0 > 25V$
 Protective diodes are required

C_i : used to by pass input signal
 C_o : " " improve transient response
 C_1 : " " ripple rejection - 80-dB ripple rejection

There is a possibility to discharge capacitors through low current paths into regulator.

(Refer to the slide at 25:12)

Now, we will discuss on problem of designing this adjustable voltage regulator. So, output voltage is between, say, 5V to 12V. Output current, say I_A , use LM317. How to design this adjustable voltage regulator? As you have discussed there are the expression for the output $V_0 = 1.25 \times \left(1 + \frac{R_2}{R_1}\right) + I_{ADJ} R_2$. I_{ADJ} for this LM317 is $10 - 100\mu A$ and normally, we will take this R_1 as 240Ω for the better load regulation. And if I substitute these values, let us first take $V_0 = 5V$. In what will be this expression, $5 = 1.25 \left(1 + \frac{R_2}{240}\right) + 10^{-4} R_2 \Rightarrow R_2 = 0.71k\Omega$. If we solve for this one, we will get R_2 value is approximately equal to $0.71k\Omega$.

Now, if we take the $V_0 = 12V$. So, $12 = 1.25 \left(1 + \frac{R_2}{240}\right) + 10^{-4}R_2 \Rightarrow R_2 = 2.01k\Omega$.
 If we solve for this one, we will get around $R_2 = 2.01k\Omega$.

So, R_2 , by varying from $0.71k\Omega$ to $2.01k\Omega$, we can get the output voltage from $5V$ to $12V$, and this will give the output current of $1A$. So, what is the output current? So, here that you have to use this R_2 0.71 to 2.01 means you have to use $3k\Omega$ potentiometer. And here, we can use the capacitors as we have discussed here; this capacitance, this capacitance, this capacitance, but no need of these diodes.

Ex: Design an adjustable voltage regulator to meet following requirements:

output voltage: $5V$ to $12V$

O/P current: $1A$

use LM317

Sol. :-

$$V_0 = 1.25 \left[1 + \frac{R_2}{R_1}\right] + I_{ADJ} R_2$$

$$I_{ADJ} = 100\mu A = 10^{-4}A$$

$$R_1 = 240\Omega$$

Since $V_0 < 25V$
 and $C < 25\mu F$
 \Rightarrow NO
 protective
 diodes
 are
 required

$$\underline{V_0 = 5V}$$

$$5 = 1.25 \left[1 + \frac{R_2}{240}\right] + 10^{-4}R_2$$

$$\Rightarrow R_2 = 0.71k\Omega$$

$$\underline{V_0 = 12V}$$

$$12 = 1.25 \left[1 + \frac{R_2}{240}\right] + 10^{-4}R_2 \Rightarrow R_2 = 2.01k\Omega$$

(Refer to the slide at 30:02)

The reason for this one is output voltage is less than $25V$, and this is greater than and capacitance are less than 25 . So, no need of protective diodes. This output voltage is less than $25V$ and capacitors are less than $25\mu F$ implies no protective diodes are required. So, this is about the adjustable voltage regulators. So, there is another type of a regulator called as a switching regulators.

As we have discussed in the last lecture, that so, the fixed voltage or adjustable voltage regulators are called as linear regulators because the power transistor operates

in the linear region. Whereas, in case of switched voltage regulators, the power transistor can be used as a on off switch. So, because of that, the switching regulators are non-linear, and there are lot of advantage of the switching regulators. So, we will discuss the switching regulators in the next lecture. Thank you.