Voltage Regulator

Voltage Regulator using Zener Diode

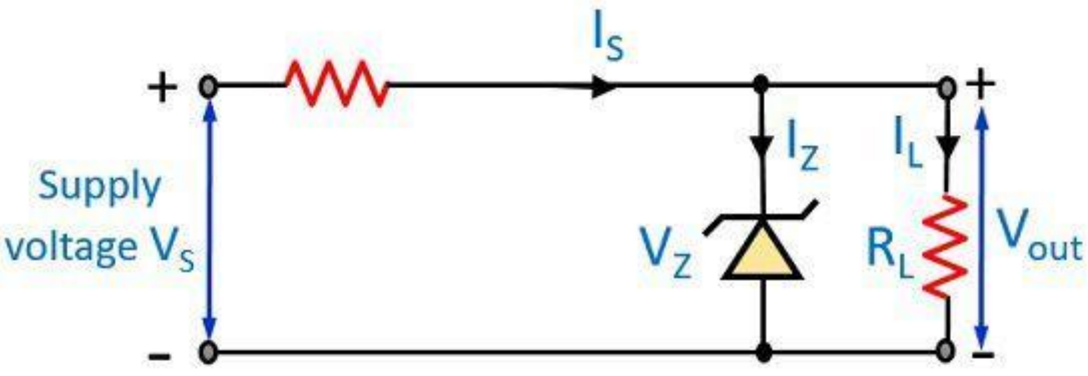
Definition: Voltage regulator is a device that **maintains a constant dc output voltage** irrespective of the changes in input voltage or load conditions. The **ac ripple voltage** that is not removed by the filters is also **rejected by the voltage regulators**.

The combinations of elements present in the design of voltage regulator ensure to have a constant output voltage with a variable input supply.

Whenever there is a need to have a **steady and reliable output voltage** then voltage regulators are the most preferred circuits.

Voltage regulators also **display protective functions** such as overvoltage protection, short circuit protection, thermal shutdown, current limiting etc. It can be a linear regulator or switching regulator, but the easiest and affordable type of voltage regulator is the linear one.

A **Zener diode** is used as a **voltage regulator** that provides a constant voltage from a source whose voltage varies substantially.



Voltage Regulator using Zener Diode

Electronics Coach

As we can see in the figure shown above, a resistor is placed at the beginning of the circuit. In order to limit the reverse current through the diode to a safer value resistor, R_s is employed in the circuit.

The source voltage V_s and resistor R_s are so selected that the diode operates in the breakdown region. The voltage across R_L is known as Zener voltage V_z and diode current is known as I_z.

A steady state voltage is maintained across the load R_L, as the **output voltage fluctuations get absorbed by the resistor R_s**. The input voltage whose changes are to be regulated connects the Zener diode in reverse condition.

The diode does not conduct unless the voltage across R_L is less than Zener diode breakdown voltage V_z, and R_s and R_L constitute a potential divider across V_s.

As the supply voltage V_s is increased, in this case, the voltage drop across R_L will be more as compared to the Zener diode breakdown voltage. Thus, causing Zener diode to conduct in its breakdown region.

The Zener current **I_z is limited** by the series **resistor R_s** from exceeding rated max value **I_{zmax}**.

$$I_S = \frac{V_S - V_Z}{R_S}$$

Current through R_S is given by-Source current gets split into Iz and I_L at the junction-

$$I_S = I_Z + I_L$$

The voltage across Zener diode V_z remains constant until it is operating in breakdown region through the Zener current I_D may vary considerably.

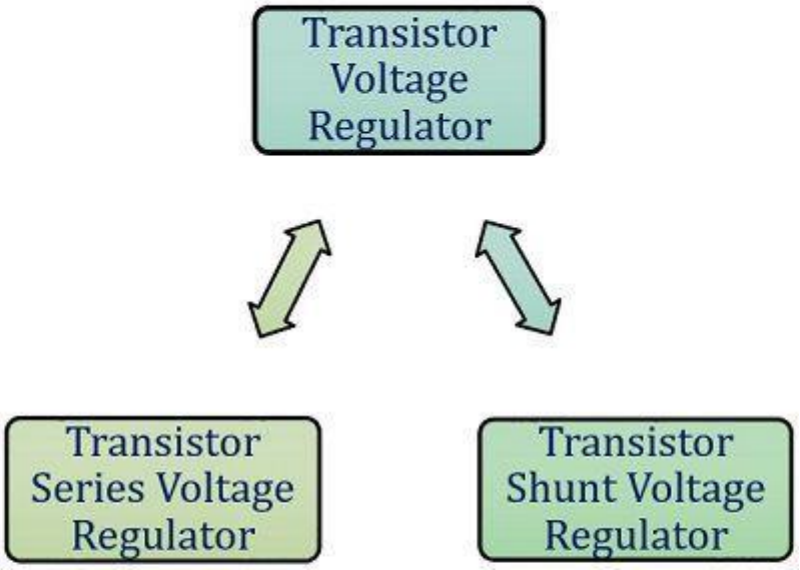
If here, the input voltage is increased further, the current through the diode and load increases. As the resistance across the diode decreases this will cause more current to flow through the diode.

As a result, the voltage drop across R_s will be more thus the voltage at the output will be a value that is close to the input or supply voltage.

Hence we can say, **the Zener diode maintains a uniform voltage** across the load unless the **supply voltage is more than Zener voltage**.

Discrete Transistor Voltage Regulator

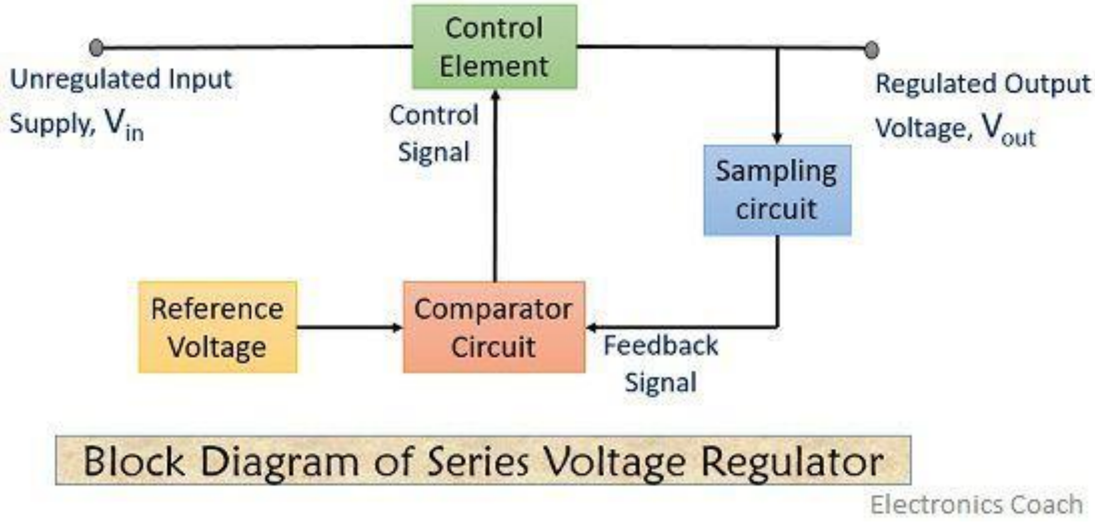
When we talk about transistor voltage regulator it is basically of 2 types –



By the use of any of the above-mentioned types, we can have a constant dc output voltage of a predetermined value. This value is independent of the variation in supply voltage or load at the output.

Series Voltage Regulator

The figure below shows the block diagram of the series voltage regulator-



Block Diagram of Series Voltage Regulator

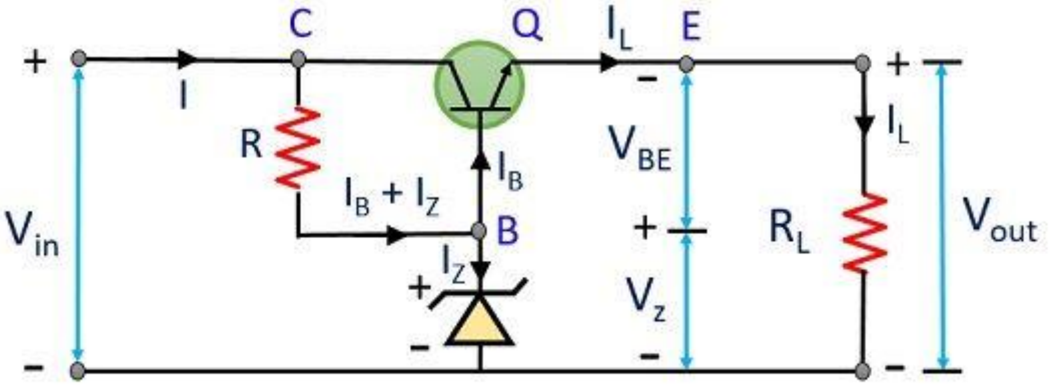
Here, the magnitude of input that gets output voltage is controlled by the series control elements. The circuit that samples output voltage provides feedback that is compared with the reference voltage.

In case if the voltage at the **output increases**, **comparator sends the control signal** to the control element so as **to reduce the magnitude of the**

output. Similarly, if the output voltage decreases, comparator sends control signal so that the magnitude of output can be raised to the desired level.

Working of the transistor series voltage regulator

It is also known as an **emitter follower voltage regulator**. The circuit below shows a simple series voltage regulator that is formed using an NPN transistor and Zener diode.



Circuit Diagram of Transistor Series Voltage Regulator

In the above circuit, the collector and emitter terminals of the transistor are in series with the load that's why it is called series regulator. The transistor Q is known as the **series pass transistor**.

When dc supply is given to the input terminal it causes the regulated output voltage to appear across the load resistor R_L. The transistor employed in the circuit serves as variable resistance and Zener diode supplies the reference voltage.

Its operation is based on the principle that a large variation in input appears across the transistor thus output voltage tends to be constant.

Here, $\mathbf{V_{out} = V_z - V_{BE}}$

The base voltage remains almost constant whose value is somewhat equal to the voltage across the Zener diode V_z.

Moving further and let us consider the case where the output voltage is increased due to increase in the supply voltage. This increase in V_{out} will resultantly decrease V_{BE} as V_z is fixed at a certain level.

This reduction in V_{BE} will automatically reduce the conduction. Due to this, collector-emitter resistance R_{CE} increases, thus causing V_{CE} to increase, ultimately output voltage gets reduced.

Now, what about the effect of the change in load at the output voltage.

Suppose the value of load resistor R_L decreases thus causing the current through it to increase. In such a condition, V_{out} starts decreasing due to which V_{BE} increases. Ultimately, the conduction level of transistor increases that decreases the R_{CE}.

This decrease in the resistance increases the current slightly that compensates for the reduction in R_L.

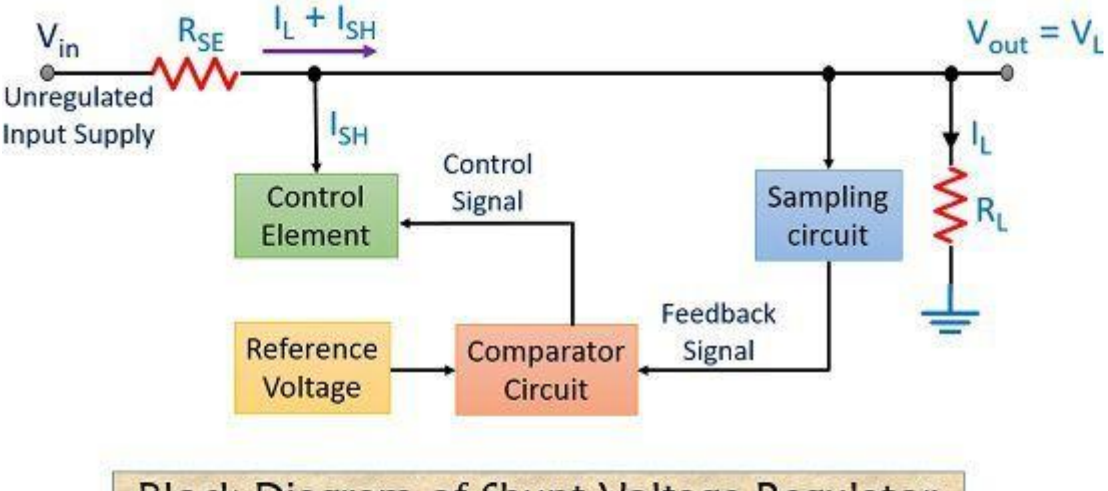
Thus the **output voltage remains constant as it is equal to $I_L R_L$**.

Limitations

1. At room temperature, maintaining an absolutely constant output voltage is difficult because as the room temperature rises up, automatically it will cause reduction in V_{BE} and V_Z.
2. Good regulation is not obtained at high current.

Shunt Voltage Regulator

The block diagram of shunt voltage regulator is shown below-



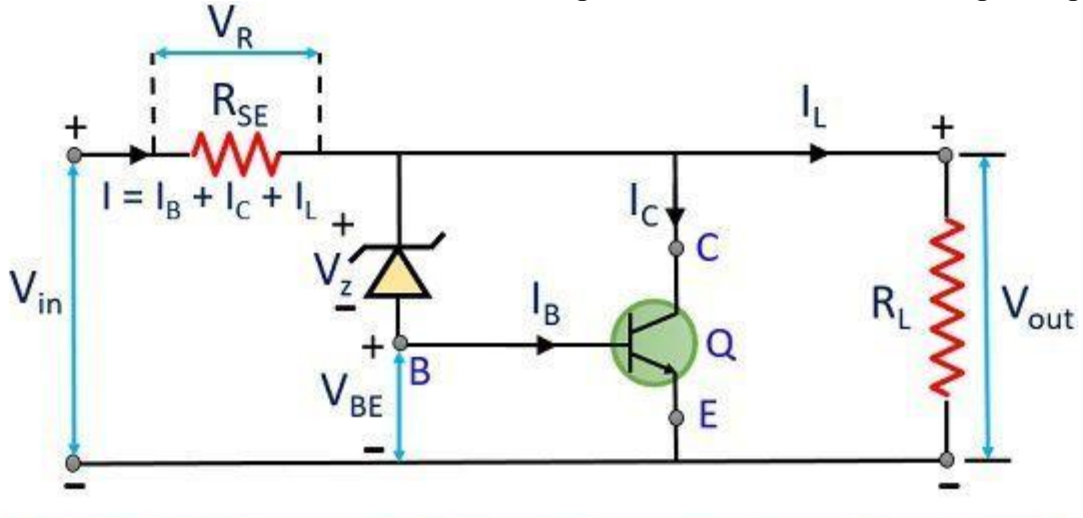
Block Diagram of Shunt Voltage Regulator

In this type of voltage regulator, in order to provide **adequate regulation, the current is shunted away from the load**. To maintain the constant current, by making use of control element some current is shunted away from the load.

Suppose there is a change in load, thus causing the output voltage to change. So, a **feedback signal** is sent to the comparator circuit that provides the **control signal to vary the magnitude** of current shunted away from the load.

Working of transistor shunt voltage regulator

Let's have a look at the circuit diagram of the shunt voltage regulator-



Circuit Diagram of Transistor Shunt Voltage Regulator

Here, R_{SE} is connected in series with supply and the transistor is connected across the output. The supply voltage reduces due to drop across R_{SE}, this reduction in voltage depends on the current supplies to R_L.

$$V_{out} = V_z + V_{BE}$$

$$V_{out} = V_{in} - IR_{SE}$$

Suppose, the input voltage is increased thus causing the rise in V_{out} and V_{BE} resultantly causing the increase in I_B and I_C. So, with this increase in supply voltage, supply current I increase, that creates more voltage drop across R_{SE} thus reducing output voltage. Thus output voltage remains almost constant.

Limitations

1. It causes a large portion of the current to flow through the transistor rather than to load.
2. Overvoltage protection is sometimes a problem in these type of circuits.

Applications

These are used in **computer power supplies** where they regulate dc voltage. In **power distribution system**, voltage regulators are used along distribution lines so as to provide the constant voltage to the consumers.