Voltage Regulators with Working Principle

In the power supply, voltage regulators play a key role. So before going to discuss a voltage regulator, we have to know that what is the role of a power supply while designing a system?. For instance, in any working system like a smartphone, wristwatch, computer, or laptop, the power supply is an essential part to work the owl system, because it provides consistent, reliable, and continuous supply to the inside components of the system. In electronic devices, the power supply provides a stable as well as regulated power to work the circuits properly. The sources of power supply are two types like the AC power supply that gets from the mains outlets and the DC power supply that gets from the batteries. So, this article discusses an overview of different types of voltage regulators and their working.

Voltage Regulator

A voltage regulator is used to regulate voltage levels. When a steady, reliable voltage is needed, then the voltage regulator is the preferred device shown in figure 5.2.1. It generates a fixed output voltage that remains constant for any changes in an input voltage or load conditions. It acts as a buffer for protecting components from damages. A voltage regulator is a device with a simple feed-forward design and it uses negative feedback control loops.

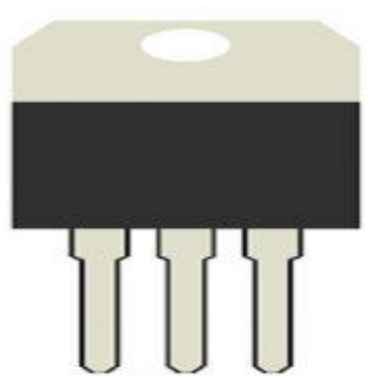

Figure 5.2.1 Voltage Regulator

Diagram Source elprocus.com

There are mainly two types of voltage regulators: Linear voltage regulators and switching voltage regulators; these are used in wider applications. The linear voltage regulator is the easiest type of voltage regulator. It is available in two types, which are compact and used in low power, low voltage systems. Let us discuss different types of voltage regulators.

The **main components used in the voltage regulator** are

- Feedback Circuit
- Stable Reference Voltage
- Pass Element Control Circuit

The voltage regulation process is very easy by using the above three components. The first component of the voltage regulator like a feedback circuit is used to detect the changes within the DC voltage output. Based on the reference voltage as well as feedback, a control signal can be generated and drives the Pass Element to pay off the changes.

Here, pass element is one kind of solid-state semiconductor device similar to a BJT transistor, PN-Junction Diode otherwise a MOSFET. Now, the DC output voltage can be maintained approximately stable.

Working of Voltage Regulator

A voltage regulator circuit is used to make as well as maintain a permanent output voltage even when the input voltage otherwise load conditions are changed. The voltage regulator gets the voltage from a power supply and it can be maintained in a range that is well-suited with the remaining electrical components. Most commonly these regulators are used for converting DC/DC power, AC/AC otherwise AC/DC.

Types of Voltage Regulators and Their Working

These regulators can be implemented through integrated circuits or discrete component circuits. Voltage regulators are classified into two type's namely linear voltage regulator & switching voltage regulator. These regulators are mainly used to regulate the voltage of a system, however, linear regulators work with low efficiency as well as switching regulators which work through high efficiency. In switching regulators with high-efficiency, most of the i/p power can be transmitted to the o/p without dissipation shown in figure 5.2.2.

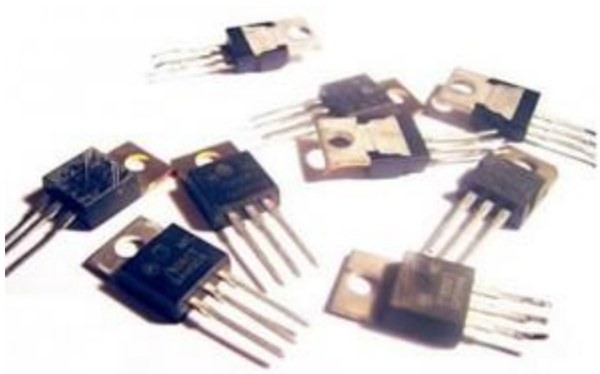

Figure 5.2.2 Types of Voltage Regulator

Diagram Source elprocus.com

Basically, there are two types of Voltage regulators: Linear voltage regulator and Switching voltage regulator.

- There are two types of Linear voltage regulators: Series and Shunt.
- There are three types of Switching voltage regulators: Step up, Step down, and Inverter voltage regulators.

Linear Voltage Regulators

The Linear regulator acts as a voltage divider. In the Ohmic region, it uses FET. The resistance of the voltage regulator varies with load resulting in constant output voltage. Linear voltage regulators are the original type of regulators use to regulate the power supplies. In this kind of regulator, the variable conductivity of the active pass element like a MOSFET or a BJT is accountable to change the output voltage.

Once a load is allied, the changes in any input otherwise load will consequence in a difference in current throughout the transistor to maintain the output is constant. To change the current of the transistor, it should be worked in an active otherwise Ohmic region.

Throughout this procedure, this kind of regulator dissipates a lot of power because the net voltage is dropped within the transistor to dissipate like heat. Generally, these regulators are categorized into different categories.

- Positive Adjustable
- Negative Adjustable
- Fixed Output
- Tracking
- Floating

Advantages

The **advantages of a linear voltage regulator** include the following.

- Gives a low output ripple voltage
- Fast response time to load or line changes
- Low electromagnetic interference and less noise

Disadvantages

The **disadvantages of a linear voltage regulator** include the following.

- Efficiency is very low
- Requires large space – heatsink is needed
- Voltage above the input cannot be increased

Series Voltage Regulators

A series voltage regulator uses a variable element placed in series with the load. By changing the resistance of that series element, the voltage dropped across it can be changed. And, the voltage across the load remains constant.

The amount of current drawn is effectively used by the load; this is the main advantage of the series voltage regulator. Even when the load does not require any current, the series regulator does not draw full current. Therefore, a series regulator is considerably more efficient than a shunt voltage regulator.

Shunt Voltage Regulators

A shunt voltage regulator works by providing a path from the supply voltage to the ground through a variable resistance. The current through the shunt regulator has diverted away from the load and flows uselessly to the ground, making this form usually less efficient than the series regulator. It is, however, simpler, sometimes consisting of just a voltage-reference diode, and is used in very low-powered circuits wherein the wasted current is too small to be of concern. This form is very common for voltage reference circuits. A shunt regulator can usually only sink (absorb) current.

Applications of Shunt Regulators

Shunt regulators are used in:

Low Output Voltage Switching Power Supplies

Current Source and Sink Circuits

Error Amplifiers

Adjustable Voltage or Current Linear and Switching Power Supplies

Voltage Monitoring

Analog and Digital Circuits that require precision references

Precision current limiters

Switching Voltage Regulators

A switching regulator rapidly switches a series device on and off. The switch's duty cycle sets the amount of charge transferred to the load. This is controlled by a feedback mechanism similar to that of a linear regulator. Switching regulators are efficient because the series element is either fully conducting or switched off because it dissipates almost no power. Switching regulators are able to generate output voltages that are higher than the input voltage or of opposite polarity, unlike linear regulators.

The switching voltage regulator switches on and off rapidly to alter the output. It requires a control oscillator and also charges storage components.

In a switching regulator with Pulse Rate Modulation varying frequency, constant duty cycle and noise spectrum imposed by PRM vary; it is more difficult to filter out that noise. A switching regulator with Pulse Width Modulation, constant frequency, varying duty cycle, is efficient and easy to filter out noise.

In a switching regulator, continuous mode current through an inductor never drops to zero. It allows the highest output power. It gives better performance. In a switching regulator, discontinuous mode current through the inductor drops to zero. It gives better performance when the output current is low.

Switching Topologies

It has two types of topologies: Dielectric isolation and Non- isolation.

Isolated

It is based on radiation and intense environments. Again, isolated converters are classified into two types which include the following.

Flyback Converters

Forward Converters

Non –Isolation

It is based on small changes in Vout/ Vin. Examples are Step Up voltage regulator (Boost) – Raises input voltage; Step Down (Buck) – lowers input voltage; Step up/ Step Down (boost/ buck) Voltage regulator – Lowers or raises or inverts the input voltage depending on the controller; Charge pump – It provides multiples of input without using an inductor.

Again, non-isolated converters are classified into different types however the significant ones are

Buck Converter or Step-down Voltage Regulator

Boost Converter or Step-up Voltage Regulator

Buck or Boost Converter

Advantages of Switching Topologies

The main advantages of a switching power supply are efficiency, size, and weight. It is also a more complex design, which is capable of handling higher power efficiency. A switching voltage regulator can provide output, which is greater than or less than or that inverts the input voltage.

Disadvantages of Switching Topologies

Higher output ripple voltage

Slower transient recovery time

EMI produces very noisy output

Very expensive

Step-up switching converters also called boost switching regulators, provide a higher voltage output by raising the input voltage shown in figure 5.2.3. The output voltage is regulated, as long as the power is drawn is within the output power specification of the circuit. For driving strings of LEDs, Step up Switching voltage regulator is used.

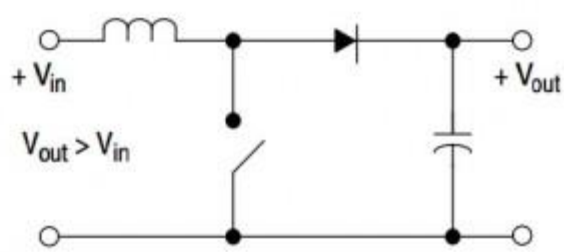

Figure 5.2.3 Step up Switching voltage regulator

Diagram Source elprocus.com

Step Up Voltage Regulators

Assume Lossless circuit Pin= Pout (input and output powers are same)

Then V_{in} I_{in} = V_{out} I_{out} ,

I_{out} / I_{in} = (1-D)

From this, it is inferred that in this circuit

Powers remain the same

Voltage increases

Current decreases

Equivalent to DC transformer

Step Down (Buck) Voltage Regulator

It lowers the input voltage. Figure shows Step Down Voltage Regulators.

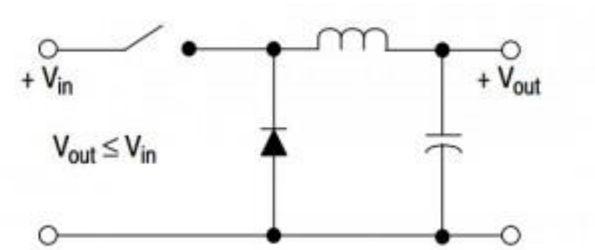

Figure 5.2.4 Step Down Voltage Regulators

Diagram Source elprocus.com

Step Down Voltage Regulators

If input power is equal to output power, then

P_{in} = P_{out}; V_{in} I_{in} = V_{out} I_{out},

I_{out} / I_{in} = V_{in} /V_{out} = 1/D

Step down converter is equivalent to DC transformer wherein the turns ratio is in the range of 0-1.

Step Up/Step Down (Boost/Buck)

It is also called a Voltage inverter. By using this configuration, it is possible to raise, lower or invert the voltage as per the requirement was shown in figure 5.2.4

- The output voltage is of the opposite polarity of the input sh.
- This is achieved by VL forward- biasing reverse-biased diode during the off times, producing current and charging the capacitor for voltage production during the off times By using this type of switching regulator, 90% efficiency can be achieved.
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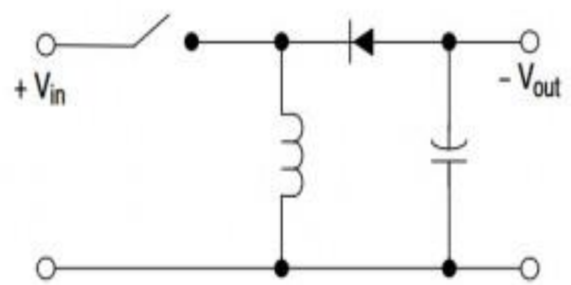

Figure 5.2.4 Step Down / Step Up Voltage Regulators

Diagram Source elprocus.com

Step Up/Step Down Voltage Regulators

Alternator Voltage Regulators

Alternators produce the current that is required to meet a vehicle's electrical demands when the engine runs. It also replenishes the energy which is used to start the vehicle. An alternator has the ability to produce more current at lower speeds than the DC generators that were once used by most of the vehicles. The alternator has two parts shown in figure 5.2.5.

Figure 5.2.5 Alternator Voltage Regulator

Diagram Source elprocus.com

Alternator Voltage Regulator

Stator – This is a stationary component, which does not move. It contains a set of electrical conductors wound in coils over an iron core.

Rotor / Armature – This is the moving component that produces a rotating magnetic field by anyone of the following three ways: (i) induction (ii) permanent magnets (iii) using an exciter.

Electronic Voltage Regulator

A simple voltage regulator can be made from a resistor in series with a diode (or series of diodes). Due to the logarithmic shape of diode V-I curves, the voltage across the diode changes only slightly due to changes in current drawn or changes in the input. When precise voltage control and efficiency are not important, this design may work fine shown in figure 5.2.6.

Figure 5.2.6 Electronic Voltage Regulator

Diagram Source elprocus.com

Transistor Voltage Regulator

Electronic voltage regulators have an astable voltage reference source that is provided by the Zener diode, which is also known as reverse breakdown voltage operating diode. It maintains a constant DC output voltage. The AC ripple voltage is blocked, but the filter cannot be blocked. The voltage regulator also has an extra circuit for short circuit protection, and current limiting circuit, over-voltage protection, and thermal shutdown.

Basic Parameters of Voltage Regulators

The basic parameters that need to consider while operating a voltage regulator mainly include the i/p voltage, o/p voltage as well as o/p current. Generally, all these parameters are mainly used for determining the VR type topology is well-matched or not with the IC of a user. Other parameters of this regulator are switching frequency, quiescent current; feedback voltage thermal resistance may be applicable based on the requirement.Quiescent current is significant once efficiency throughout standby modes or light-load is the main concern.

Once switching frequency is considered as a parameter, exploiting the switching frequency can lead to the solutions of a small system. Also, the thermal resistance can be dangerous to get rid of heat from the device as well as dissolve the heat from the system.If the controller has a MOSFET, afterward all the conductive as well as dynamic losses will be dissipated within the package & must be considered once measuring the utmost temperature of the regulator.The most important parameter is feedback voltage as it decides the less o/p voltage that the IC can hold. The key parameters play a key role while selecting the voltage regulator by the designer like Vin, Vout, Iout, system priorities, etc. Some extra key features like enable control or power good indication, When the designer has described these necessities, then employ a parametric search table to discover the best apparatus to meet up the preferred necessities. For designers, this table is very valuable because it provides several features as well as packages obtainable to meet up the necessary parameters for the requirement of a designer. The devices of MPS are available with their datasheets which describe in detail of required external parts, how to measure their values to get a stable, efficient design with high performance. This datasheet mainly helps in measuring the values of components like capacitance of output, feedback resistance, o/p inductance, etc.

Limitations/Drawbacks

The limitations of voltage regulators include the following.

- One of the main limitations of the voltage regulator is they are inefficient due to the dissipation of huge current in some applications
- The voltage drop of this IC is similar to a resistor voltage drop. For example, when the input of the voltage regulator is 5V & generates output like 3V then the voltage drop among the two terminals is 2V.
- The efficiency of the regulator can be restricted to 3V or 5V, which means these regulators are applicable with fewer Vin/ Vout differentials.

- In any application, it is very significant to consider the expected power dissipation for a regulator, because when the input voltages are high then power dissipation will be high so that can damage different components because of overheat.
- Another limitation is that they are simply capable of buck conversion as compared with switching types because these regulators will provide buck and conversion.
- The regulators like switching type are efficient highly however they have some drawbacks like cost-effectiveness as compared with linear type regulators, more complex, large size & can generate more noise if their exterior components are not chosen cautiously.