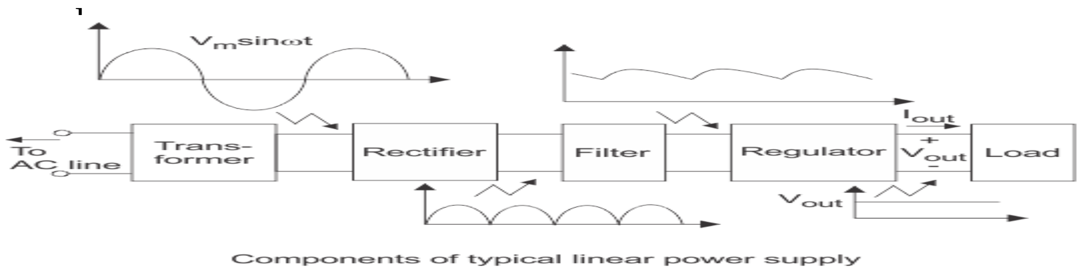
Linear mode power supply

A **regulated power supply** converts unregulated AC (Alternating Current) to a constant DC (Direct Current). A regulated power supply is used to ensure that the output remains constant even if the input changes.

A regulated DC power supply is also known as a linear power supply, it is an embedded circuit and consists of various blocks.



The regulated power supply will accept an AC input and give a constant DC output. The figure 5.1.1 below shows the block diagram of a typical regulated DC power

Figure 5.1.1 A Linear mode power Supply Components

Diagram Source Electrical4u

The basic building blocks of a regulated DC power supply are as follows:

1. A step-down transformer
2. A rectifier
3. A DC filter

4. A regulator

Operation of Regulated Power Supply

Step Down Transformer

A step down transformer will step down the voltage from the ac mains to the required voltage level. The turn's ratio of the transformer is so adjusted such as to obtain the required voltage value. The output of the transformer is given as an input to the rectifier circuit.

Rectification

Rectifier is an electronic circuit consisting of diodes which carries out the rectification process. Rectification is the process of converting an alternating voltage or current into corresponding direct (DC) quantity. The input to a rectifier is AC whereas its output is unidirectional pulsating DC.

Although a half wave rectifier could technically be used, its power losses are significant compared to a full wave rectifier. As such, a full wave rectifier or a bridge rectifier is used to rectify both the half cycles of the ac supply (full wave rectification). The figure below shows a full wave bridge rectifier.

Figure 5.1.2 A Full Wave Rectifier Power Supply

Diagram Source Electrical4u

A bridge rectifier consists of four p-n junction diodes connected in the manner shown above figure 5.1.2. In the positive half cycle of the supply, the voltage induced across the secondary of the electrical transformer i.e. VMN is positive. Therefore point E is positive with respect to F. Hence, diodes D_3 and D_2 are reversed biased and diodes D_1 and D_4 are forward biased. The diode D_3 and D_2 will act as open switches (practically there is some voltage drop) and diodes D_1 andD_4 will act as closed switches and will start conducting. Hence a rectified waveform appears at the output of the rectifier as shown in the first figure. When voltage induced in secondary i.e. VMN is negative than D_3 and D_2 are forward biased with the other two reversed biased and a positive voltage appears at the input of the filter.

DC Filtration

The rectified voltage from the rectifier is a pulsating DC voltage having very high ripple content. But this is not we want, we want a pure ripple free DC waveform. Hence a filter is used. Different types of filters are used such as capacitor filter, LC filter, Choke input filter, π type filter. The figure below shows a capacitor filter connected along the output of the rectifier and the resultant output waveform in figure 5.1.3. As the instantaneous voltage starts increasing the capacitor charges, it charges until the waveform reaches its peak value. When the instantaneous value starts reducing the capacitor starts discharging exponentially and slowly through the load (input of the regulator in this case). Hence, an almost constant DC value having very less ripple content is obtained.

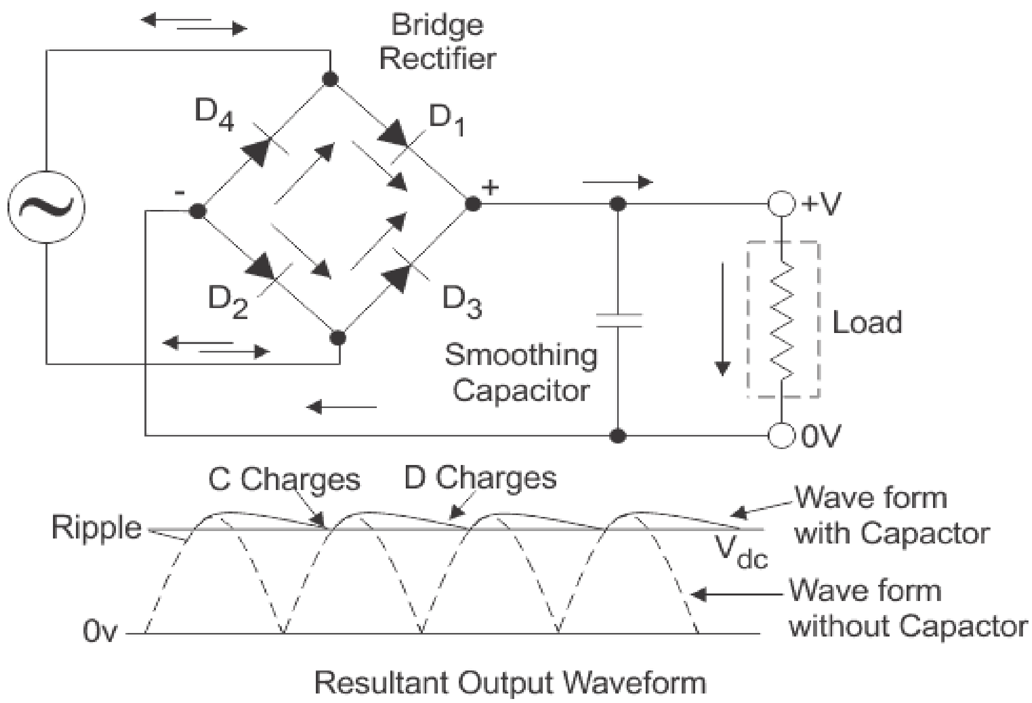


Figure 5.1.3 A Bridge Rectifier Power Supply and its resultant Waveform

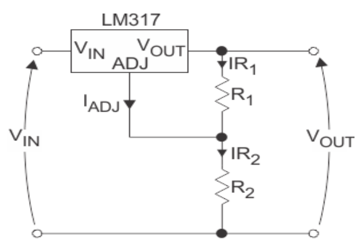
Diagram Source Electrical4u

Regulation

This is the last block in a regulated DC power supply. The output voltage or current will change or fluctuate when there is a change in the input from ac mains or due to change in load current at the output of the regulated power supply or due to other factors like temperature changes. This problem can be eliminated by using a regulator. A regulator will maintain the output constant even when changes at the input or any other changes occur. Transistor series regulator, Fixed and variable IC regulators or a zener diode operated in the zener region can be used depending on their applications. IC's like 78XX and 79XX (such as the IC 7805) are used to obtained fixed values of voltages at the output.

With IC's like LM 317 and 723, we can adjust the output voltage to a required constant value. The figure below shows the LM317 voltage regulator. The output voltage can be adjusted by adjusting the values of resistances R_1 and R_2. Usually, coupling capacitors of values about 0.01μF to 10μF need to be connected at the output and input to address input noise and output transients. Ideally, the output voltage is given by

$$V_{OUT} = V_{REF}\left(1 + \frac{R_2}{R_1}\right)$$



The figure above shows the complete circuit of a regulated +5V DC power supply.

Over-voltage protection basics

There are many ways in which a power supply can fail. However to understand a little more at over-voltage protection and the circuit issues it is easy to take a simple example of a linear voltage regulator using a very simple Zener diode and a series pass transistor in figure 5.3.1.

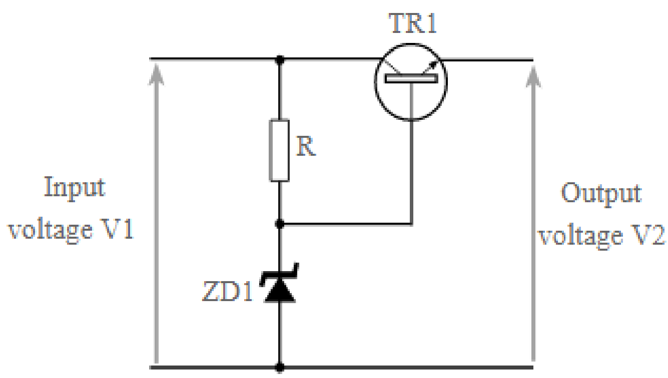


Figure 5.3.1 Basic series regulator using a zener diode and emitter follower

Diagram Source electronics-notes.com

Although more complicated supplies give better performance, they also rely on a series transistor to pass the output current. The main difference is the way in which the regulator voltage is applied to the base of the transistor. Typically the input voltage is such that several volts are dropped across the series voltage regulator element. This enables the series pass transistor to regulate the output voltage adequately. Often the voltage dropped across the series pass transistor is relatively high - for a 12 volts supply, the input may be 18 volts of even more to give the required regulation and ripple rejection, etc.

This means that there can be a significant level of heat dissipated in the voltage regulator element and combined with any transient spikes that could appear at the input, this means there is always a possibility of failure.The transistor series pass device would more usually fail in an open circuit condition, but under some circumstances, the transistor may develop a short circuit between the collector and emitter. If this occurs, then the full unregulated input voltage would appear in the output of the voltage regulator. If the full voltage appeared on the output, then it could damage many of the ICs that are in the circuit being supplied. In this case the circuit could well be beyond economic repair.

The way in which switching regulators operate is very different, but there are circumstances in which the full output could appear on the output of the power supply. For both linear regulated power supplies and switch mode power supplies, some form of over-voltage protection is always advisable.

Types of over-voltage protection

Many electronic techniques there are several ways of implementing a particular capability. This is true for over-voltage protection. There are several different techniques that can be used, each with its own characteristics. Performance, cost, complexity and mode of operation all need to be weighed up when determining which method to use during the electronic circuit design stage.

SCR Crowbar

As the name implies the crowbar circuit places a short circuit across the output of the power supply in figure 5.3.2 if an over-voltage condition is experienced. Typically thyristors, i.e. SCRs are used for this as they can switch large currents and remain on until any charge has dispersed. The thyristor can be linked back to a fuse which blows and isolates the regulator from having any further voltage placed upon it. In this circuit, the Zener diode is chosen so that its voltage is above the normal operating voltage of the output, but below the voltage where damage would occur. In this conduction, no current flows through the Zener diode because its breakdown voltage has not been reached and no current flows into the gate of the thyristor and it remains off. The power supply will operate normally.

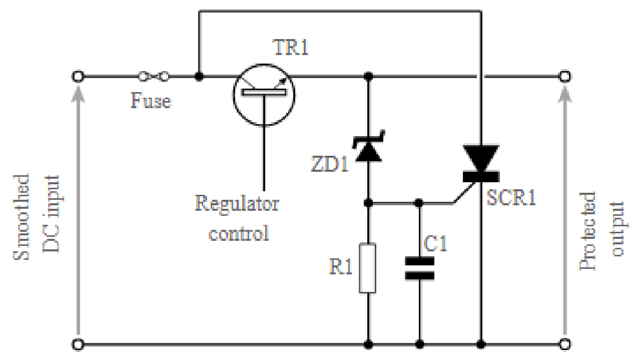


Figure 5.3.2 Thyristor crowbar overvoltage protection circuit

Diagram Source electronics-notes.com

If the series pass transistor in the power supply fails, the voltage will start to rise the decoupling in the unit will ensure it does not rise instantly. As it rises, it will rise above the point where the Zener diode starts to conduct and current will flow into the gate of the thyristor causing it to trigger. When the thyristor triggers, it will short the output of the power supply to ground, preventing damage to the circuitry it powers. This short circuit can also be used to blow a fuse or other element, taking the power off the voltage regulator and isolating the unit from further damage. Often some decoupling in the form of a small capacitor is placed from the gate of the thyristor to ground to prevent sharp transients or RF from the unit being power from getting on to the gate connection and causing a spurious trigger. However this should not be made too large as it may slow the circuit firing in a real case of failure and the protection may be in place too slowly.

The Thyristor or SCR, Silicon Controlled Rectifier can be used to provide overvoltage protection in a power supply circuit. By detecting the high voltage, the circuit can fire the thyristor to place a short circuit or crowbar across the voltage rail to ensure it does not rise to high in voltage.

Voltage clamping

Another very simple form of over-voltage protection uses an approach called voltage clamping. In its simplest form it can be provided by using a Zener diode placed across the output of the regulated power supply. With the Zener diode voltage chosen to be slightly above the maximum rail voltage, under normal conditions it will not conduct. If the voltage rises too high, then it will start to conduct, clamping the voltage at a value slightly above the rail voltage.

If a higher current capability is needed for the regulated power supply then a Zener diode with a transistor buffer can be used shown in **figure 5.3.3(a) & (b)**. This will increase the current capability over the simple Zener diode circuit, by a factor equal to the current gain of the transistor. As a power transistor is required for this circuit, the likely current gain levels will be low - possibly 20 - 50.

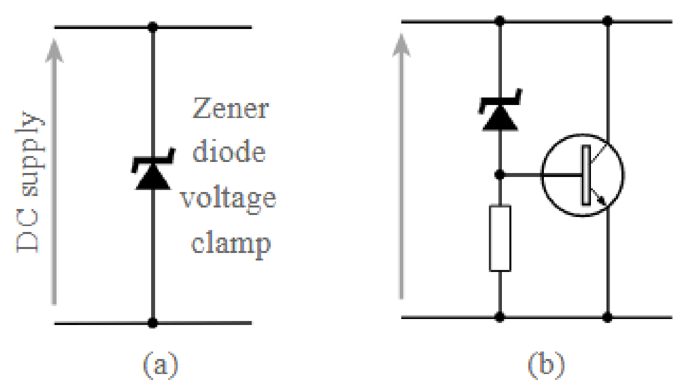


Figure 5.3.3(a) , Zener diode over-voltage clamp simple Zener diode, (b) higher current with transistor buffer

Diagram Source electronics-notes.com

Voltage limiting

When over-voltage protection is required for switch mode power supplies, SMPS the clamp and crowbar techniques are less widely used because of the power dissipation requirements and the possible size and cost of the components.

Fortunately most switch mode regulators fail in a low voltage condition. However it is often prudent to put in place voltage limiting capabilities in case of over-voltage conditions. Often this can be achieved by sensing the over-voltage condition and shutting down the converter. This is particularly applicable in the case of DC-DC converters. When implementing this, it is necessary to incorporate a sense loop that is outside the main IC regulator - many switch mode regulators and DC-DC converters use a chip to achieve the majority of the circuit. It is very important to use an external sense loop because if the switch mode regulator chip is damaged causing the over-voltage condition, the sense mechanism may also be damaged.

Obviously this form of over-voltage protection requires circuits that are specific to the particular circuit and switch mode power supply chips used.

All three techniques are used and can provide effective power supply over-voltage protection. Each has its own advantages and disadvantages and the choice of technique needs to be made dependent upon the given situation.

Power Supply Performance and Testing - Troubleshooting and Fault Analysis

Performance and Testing

A faulty power supply can lead to improper sensor operation. Issues with a power supply will manifest throughout the entire circuit. Conduct power supply testing early in the troubleshooting process

Required Equipment for Power Supply Testing

- Properly calibrated voltmeters and current meters (resolution should be 10 times the parameter being measured)
- Oscilloscope with bandwidth up to 20MHz
- Sufficient input power source
- Programmable adjustable load

Issues with a power supply can limit the performance of your equipment, and it even has the potential to damage your fine electronics. Proper and regular power supply testing can help minimize this risk.

Input Power

The power provided by your power supply is the key factor, but the first parameter to test is the voltage and current on the input side of your power supply. Verify the input power supply falls in the operating range for your power supply as listed in the specification or datasheet. Just like our sensors, an improper input voltage to a power supply hinders proper operation whether you are using an AC/DC or a DC/DC power supply.

Output Voltage Accuracy

The LED display (when applicable) on your power supply may read 5.00VDC, but this may not always be accurate. Checking the accuracy of the output voltage with a properly calibrated voltmeter is a great way to verify this output voltage. Strictly speaking, you only need to verify that the output voltage is stable and within the operating range of your device. However, you may wish to continue to calculate the output voltage accuracy in figure 5.5.1.

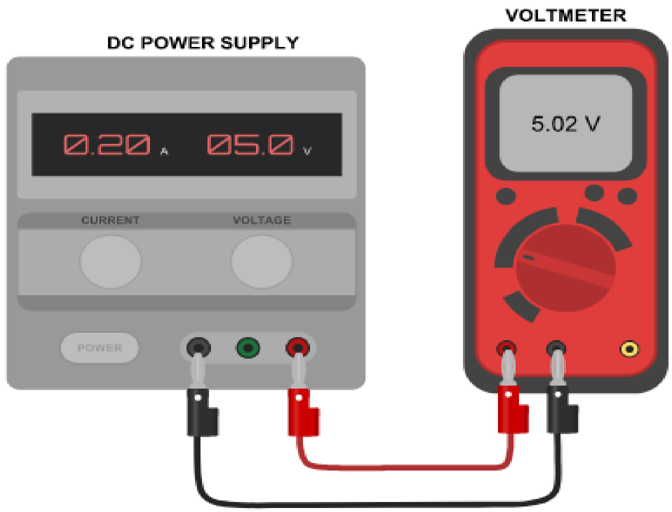


Figure 5.5.1 Power Supply general setup for measuring output voltage accuracy

Diagram Source maxbotix.com

Test Procedure

1. Set the input voltage to the nominal requirement for your power supply.
2. Set the output voltage load to its maximum rated value.
3. Measure the output voltage (**V_{OUT}**) with the calibrated voltmeter.
4. The output voltage accuracy can be calculated using the following formula

$$OutputVoltageAccuracy(\%) = \frac{V_{OUT} - V_{NOM}}{V_{NOM}} * 100$$

The DC/DC power supplies typically have a set output voltage where AC/DC have a variable output voltage. This displayed or set output voltage is (**V_{NOM}**).

Noise & Output Ripple

Sensors operate at peak performance when they receive smooth and clean voltage with minimum noise and output ripple. Output ripple and noise are also known as Periodic And Random Deviation (**PARD**). When there is noise on the voltage entering the part, it gets added to the amount of noise the part sees.

Specifically, output ripple and noise can be split into separate factors. Noise is a set of random high or low-frequency spikes to the power supply. Noise is best mitigated by shielding the wires and operating as far from electrical noise sources as possible. Output ripple is periodic where noise is random. Output ripple is a periodic shift visible in the output voltage. This ripple is often generated by the periodic nature of AC power.

Viewing the power supply with an oscilloscope is required to view both output ripple and noise. Excess ripple or noise outside of a window that you would typically see in a controlled environment will degrade sensor performance. When testing the noise and output ripple the bandwidth should be sufficient to capture the full cycle of any output ripple.

Additional noise can be picked up on the oscilloscope probe itself. Using the shortest probe to ground length possible minimizes the amount of noise the probe receives. Take care to minimize any error and noise that you may add to the system.

Line Regulation

When there is a ripple or instability to the input voltage, it affects the output voltage. Line regulation specification indicates how much a change in output voltage you can expect due to a change in input voltage. The specification is typically presented as the change from the minimum to the maximum operating input voltage. Testing the line regulation in figure 5.5.2 may not be feasible if you are using an AC/DC power supply.

Test Setup

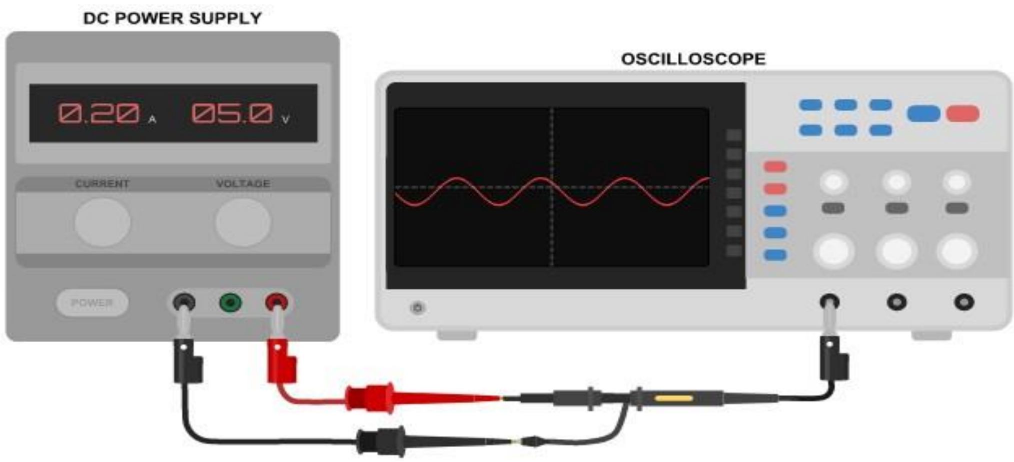


Figure 5.5.2 Power Supply general setup for testing Line Regulation

Diagram Source maxbotix.com

Test Procedure

1. Set the input voltage to the nominal requirement for your power supply
2. Measure the output voltage (**V_{OUTNUM}**)using the calibrated voltmeter
3. Set the input voltage to the maximum operating voltage of the power supply
4. Measure the output voltage (**V_{OUTMIN}**)using the calibrated voltmeter
5. Set the input voltage to the minimum operating voltage of the power supply
6. Measure the output voltage (**V_{OUTMAX}**)using the calibrated voltmeter
7. Find (**V_{DEV}**), the maximum deviation from (**V_{OUTNUM}**)

   (**V_{DEV}**) is the maximum of $|V_{OUTNUM} - V_{OUTMIN}|$ or $|V_{OUTNUM} - V_{OUTMAX}|$
8. Line regulation can be calculated using the following formula

$$LineRegulation(\%) = \frac{V_{OUTNOM} - V_{DEV}}{V_{OUTNOM}} * 100$$

Load Regulation

The system being powered by the sensor will draw current from the power supply. The voltage will be affected by the total current drawn. On the DC output, we can review Ohm's Law to see that V=IR. If we instantly increase the resistance of the circuit, the voltage will shift. Load regulation works to minimize any shifts due to a change in the loading of the circuit shown in figure 5.5.3.

An output load change, a change in the resistance of the circuit, in terms of percentage of the max load should also be mentioned. The load regulation should be tested to these values.

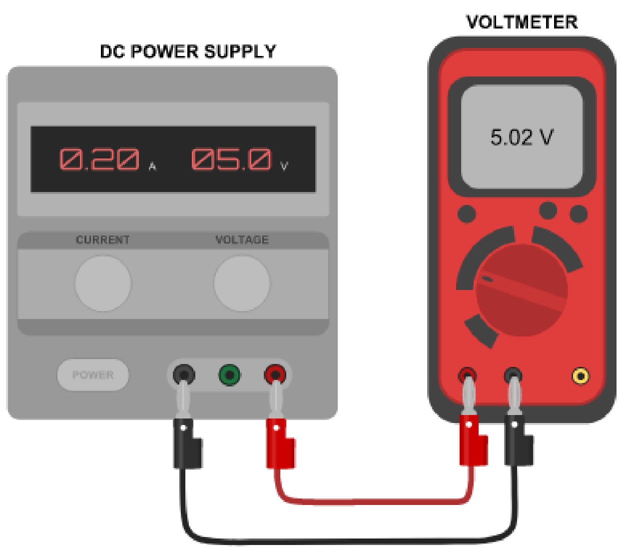


Figure 5.5.3 Power Supply general setup for testing Load Regulation

Diagram Source maxbotix.com

Test Setup

Test Procedure

1. Set the input voltage to the nominal requirement for your power supply
2. Apply the maximum rated load, resistance, to the power supply
3. Measure the output voltage at max load (**V_{OUTML}**)using the calibrated voltmeter
4. Set the load to the specified level for load regulation
5. Measure the output voltage at the new load (**V_{OUTNL}**)using the calibrated voltmeter
6. Load regulation can be calculated using the following formula

$$LoadRegulation(\%) = \frac{V_{OUTML} - V_{OUTNL}}{V_{OUTML}} * 100$$

Transient Recovery Time

Load regulation allows a power supply to adjust itself to continue providing the proper voltage after a change in load, but this adjustment doesn't happen instantaneously. The amount of time required for the voltage to return to the proper level (within an error band) is the transient recovery time.

The transient recovery time will be rated between two levels of the rated load.

Please check your power supply datasheet to find the rated levels. As an additional note, the transient recovery time is measured from the moment that the load is changed until the voltage returns within the error band.

Test Setup

Test Procedure

1. Set the input voltage to the nominal requirement for your power supply
2. Locate the step load change specified for the power supply
3. Program your adjustable load stepper according to the previous step

4. Externally trigger your oscilloscope and switch the load over the specified range
5. Measure the transient recovery time on your oscilloscope

Efficiency

Efficiency is a ratio that relates the total output power to the input power. While efficiency will exist for both AC/DC and DC/DC power supplies, it may not be feasible for all users to measure the efficiency of an AC/DC power supply.

Test Procedure

1. Set the input voltage to the nominal requirement for your power supply
2. Apply the maximum rated load to the power supply
3. Measure the current (**I_{IN}**) and voltage (**V_{IN}**) to the power supply as well as the current (**I_{OUT}**) and the voltage (**V_{OUT}**) of the power supply
4. Calculate the efficiency with the following equation

$$Efficiency(\%) = \frac{I_{OUT} * V_{OUT}}{I_{IN} * V_{IN}} * 100$$

Switched Mode Power Supply SMPS

The disadvantages of LPS such as lower efficiency, the need for large value of capacitors to reduce ripples and heavy and costly transformers etc. are overcome by the implementation of Switched Mode Power Supplies. The working of SMPS is simply understood by knowing that the transistor used in LPS is used to control the voltage drop while the transistor in SMPS is used as a controlled switch.

Linear Power Supply

The Linear Power Supply LPS is the regulated power supply which dissipates much heat in the series resistor to regulate the output voltage which has low ripple and low noise. This LPS has many applications.

A linear power supply requires larger semiconductor devices to regulate the output voltage and generates more heat resulting in lower energy efficiency. Linear power supplies have transient response times up to 100 times faster than the others, which is very important in certain specialized areas.

Advantages of LPS

The power supply is continuous. The circuitry is simple. These are reliable systems. This system dynamically responds to load changes. The circuit resistances are changed to regulate the output voltage. As the components operate in linear region, the noise is low.The ripple is very low in the output voltage.

Disadvantages of LPS

The transformers used are heavier and large. The heat dissipation is more. The efficiency of linear power supply is 40 to 50%Power is wasted in the form of heat in LPS circuits. Single output voltage is obtained. The block diagram of a Linear Power Supply is as shown in the following figure 5.4.1. In spite of the above disadvantages, Linear Power Supplies are widely used in low-noise amplifiers, test equipment, control circuits. In addition, they are also used in data acquisition and signal processing.

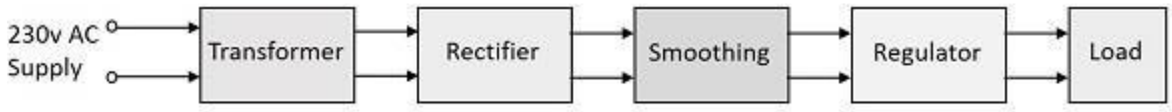


Figure 5.4.1 A Linear mode power Supply Components

Diagram Source Electrical4u

All the power supply systems that needs simple regulation and where efficiency is not a concern, the LPS circuits are used. As the electrical noise is lower, the LPS is used in powering sensitive analog circuitry. But to overcome the disadvantages of Linear Power Supply system, the Switched Mode Power Supply SMPS is used.

Working The working of SMPS

Working The working of SMPS can be understood by the following figure 5.4.2.

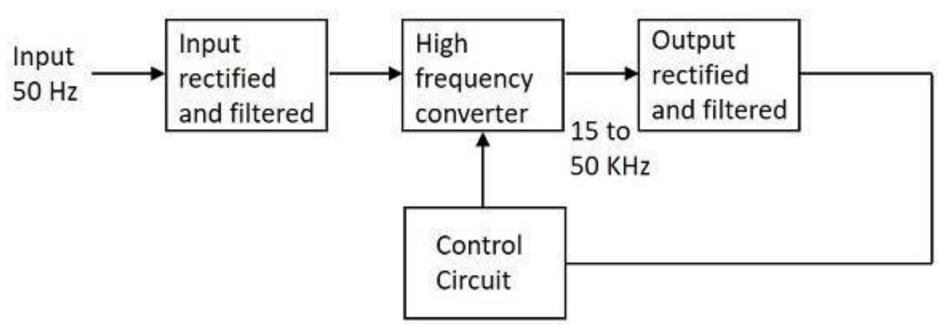


Figure 5.4.2 Working of SMPS functional diagram

Input Stage

Diagram Source Electrical4u

The AC input supply signal 50 Hz is given directly to the rectifier and filter circuit combination without using any transformer. This output will have many variations and the capacitance value of the capacitor should be higher to handle the input fluctuations. This unregulated dc is given to the central switching section of SMPS.

Switching Section

A fast switching device such as a Power transistor or a MOSFET is employed in this section, which switches ON and OFF according to the variations and this output is given to the primary of the transformer present in this section. The transformer used here are much smaller and lighter ones unlike the ones used for 60 Hz supply. These are much efficient and hence the power conversion ratio is higher.

Output Stage

The output signal from the switching section is again rectified and filtered, to get the required DC voltage. This is a regulated output voltage which is then given to the control circuit, which is a feedback circuit. The final output is obtained after considering the feedback signal.

Control Unit

This unit is the feedback circuit which has many sections. Let us have a clear understanding about this from The following figure 5.4.3.

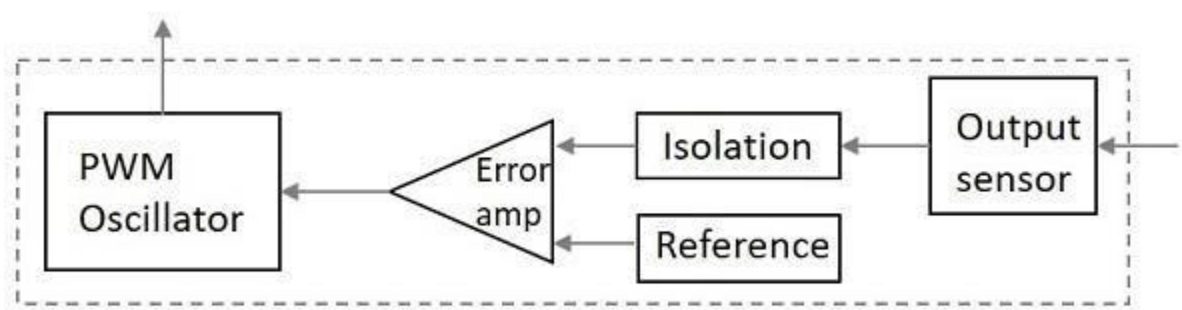


Figure 5.4.3 Inner parts of a control unit.

Diagram Source Electrical4u

The above figure explains the inner parts of a control unit. The output sensor senses the signal and joins it to the control unit. The signal is isolated from the other section so that any sudden spikes should not affect the circuitry. A reference voltage is given as one input along with the signal to the error amplifier which is a comparator that compares the signal with the required signal level.

By controlling the chopping frequency the final voltage level is maintained. This is controlled by comparing the inputs given to the error amplifier, whose output helps to decide whether to increase or decrease the chopping frequency. The PWM oscillator produces a standard PWM wave fixed frequency.

We can get a better idea on the complete functioning of SMPS by having a look at the following figure 5.4.4.

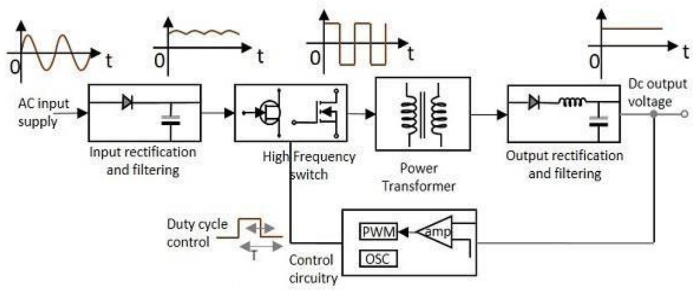


Figure 5.4.4 SMPS The functional Block Diagram

Diagram Source Electrical4u

The SMPS is mostly used where switching of voltages is not at all a problem and where efficiency of the system really matters. There are few points which are to be noted regarding SMPS. They are SMPS circuit is operated by switching and hence the voltages vary continuously. The switching device is operated in saturation or cut off mode. The output voltage is controlled by the switching time of the feedback.Switching time is adjusted by adjusting the duty cycle. The efficiency of SMPS is high because, instead of dissipating excess power as heat, it continuously switches its input to control the output.

Types of SMPS

SMPS is the Switched Mode Power Supply circuit which is designed for obtaining the regulated DC output voltage from an unregulated DC or AC voltage. There are four main types of SMPS such as

- DC to DC Converter
- AC to DC Converter
- Fly back Converter
- Forward Converter

The AC to DC conversion part in the input section makes the difference between AC to DC converter and DC to DC converter. The Fly back converter is used for Low power applications. Also there are Buck Converter and Boost converter in the SMPS types which decrease or increase the output voltage depending upon the requirements. The other type of SMPS include Self-oscillating fly-back converter, Buck-boost converter, Cuk, Sepic, etc.

Disadvantages

There are few disadvantages in SMPS, such as The noise is present due to high frequency switching.The circuit is complex. It produces electromagnetic interference.

Advantages

The advantages of SMPS include, The efficiency is as high as 80 to 90% ,Less heat generation; less power wastage. Reduced harmonic feedback into the supply mains. The device is compact and small in size. The manufacturing cost is reduced.Provision for providing the required number of voltages.

Applications

There are many applications of SMPS. They are used in the motherboard of computers, mobile phone chargers, HVDC measurements, battery chargers, central power distribution, motor vehicles, consumer electronics, laptops, security systems, space stations, etc.

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.

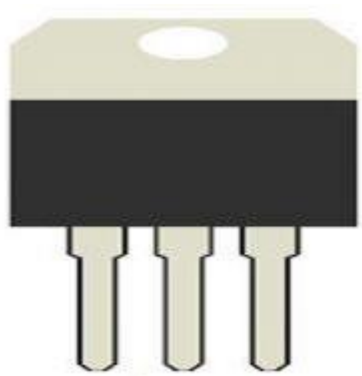


Figure 5.2.1 Voltage Regulator

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.

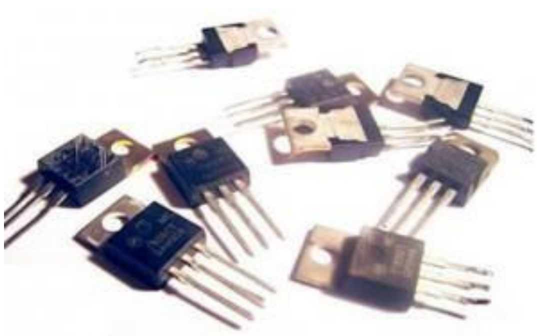


Figure 5.2.2 Types of Voltage Regulator

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.

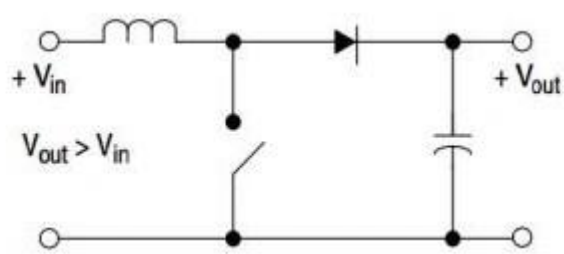


Figure 5.2.3 Step up Switching voltage regulator

Diagram Source elprocus.com

Step Up Voltage Regulators

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

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

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

From this, it is inferred that in this circuit

Powers remain the same

Voltage increases

Current decreases

Equivalent to DC transformer

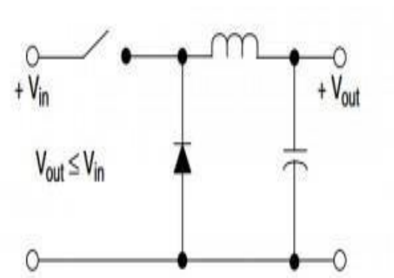
Step Down (Buck) Voltage Regulator

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.
-

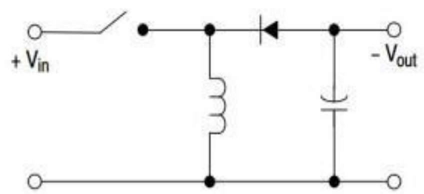


Figure 5.2.4 Step Down / Step Up Voltage Regulators

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.