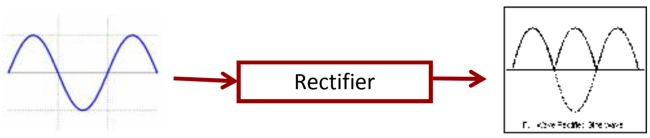
MEE210 Electrical Machines

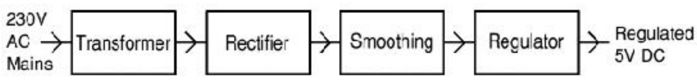
Diodes and Rectifiers

Rectification

Rectification

Electricity is transferred from power plants to houses or business as alternate current because of decreasing losses during transfer.
On the other hand, semi conductors use direct current. Thus, it is needed to be transformed into the direct current.
A rectifier is a circuit which converts the Alternating Current (AC) input power into a Direct Current (DC) output power.



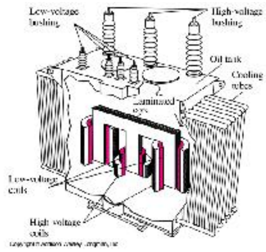


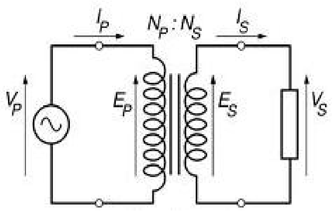
Block Diagram of a Regulated Power Supply System

Rectification

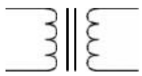
Transformers

Transformers convert AC electricity from one voltage to another with little loss of power.
The input coil is called the **primary** and the output coil is called the **secondary**.
There is no electrical connection between the two coils, instead they are linked by an alternating magnetic field created in the soft-iron core of the transformer
The ratio of the number of turns on each coil, called the **turns ratio**, determines the ratio of the voltages





$$K_{trafo} = \frac{N_S}{N_P} = \frac{V_S}{V_P} = \frac{I_P}{I_S}$$



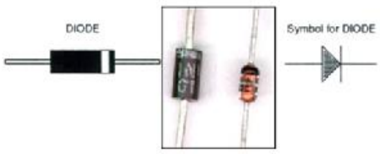
Rectification

Diodes

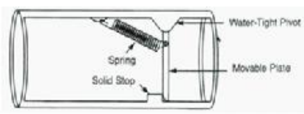
Diodes are basic unidirectional semiconductor devices that will only allow current to flow through them in one direction only, acting more like a one way electrical valve.

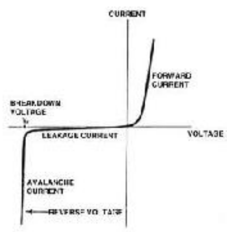
Unlike a resistor, a diode does not behave linearly with respect to the applied voltage as it has an exponential I-V relationship and therefore can not be described simply by using Ohm's law

Diodes are made from a single piece of **Semiconductor** material which has a positive "P-region" at one end and a negative "N-region" at the other, and which has a resistivity value somewhere between that of a conductor and an insulator



A diode is an semiconductor component that, in general, will pass current in only one direction





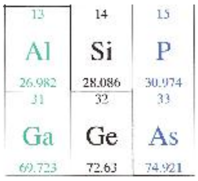
Diodes

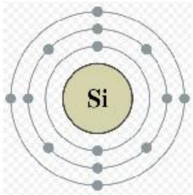
Semiconductors

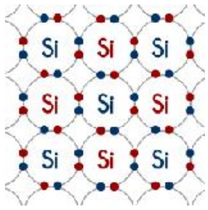
Semiconductors materials such as silicon (Si), germanium (Ge) and gallium arsenide (GaAs), have electrical properties somewhere in the middle, between those of a "conductor" and an "insulator".

They are not good conductors nor good insulators (hence their name is "semi"-conductors).

They have very few "free electrons" because their atoms are *closely grouped*. That is due to the strength of the molecular bounds However, their ability to conduct electricity can be greatly improved by adding certain "impurities" to this crystalline structure thereby, producing more free electrons than holes







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Semiconductors

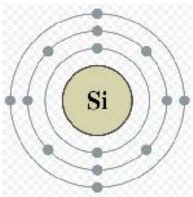
Silicon

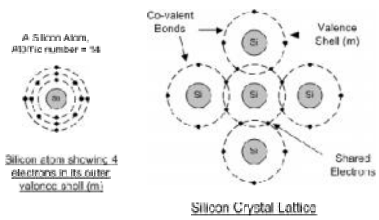
The most commonly used semiconductor basics material by far is silicon. Its atomic number is 14

Silicon has four valence electrons in its outermost shell

The structure of the bond between the two silicon atoms is such that each atom shares one electron with its neighbour

This bound is very stable and called as co valent bound crystals of pure silicon (or germanium) are therefore good insulators.





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Semiconductors

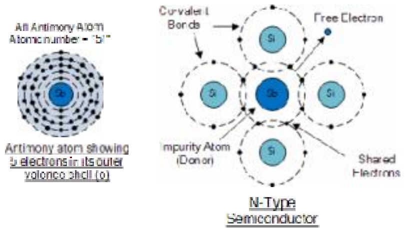
N-type

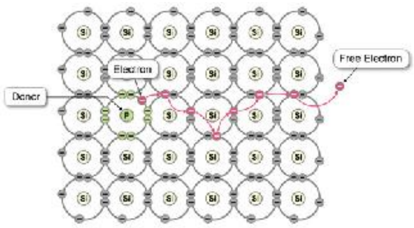
In order for our silicon crystal to conduct electricity, we need to introduce an impurity atom such as Arsenic, Antimony or Phosphorus

These atoms have five outer electrons in their outermost orbital to share with neighbouring atoms.

This allows four out of the five orbital electrons to bond with its neighbouring silicon atoms leaving one "free electron" to become mobile when an electrical voltage is applied.

The resulting semiconductor material has extra electrons, each with a negative charge, and is therefore referred to as an "N-type" material





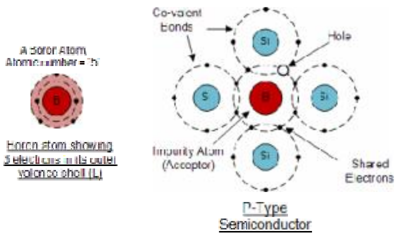
Semiconductors

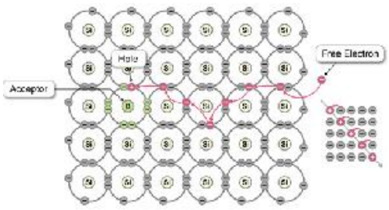
P-type

Another way to make silicon crystal conduct electricity is to add impurity atoms such as Aluminium, Boron or Indium, which have only three valence electrons.

Therefore, a complete connection is not possible, giving the semiconductor material an abundance of positively charged carriers known as "holes" in the structure of the crystal where electrons are effectively missing

The doping of such atoms causes conduction to consist mainly of positive charge carriers resulting in a "P-type" material with the positive holes



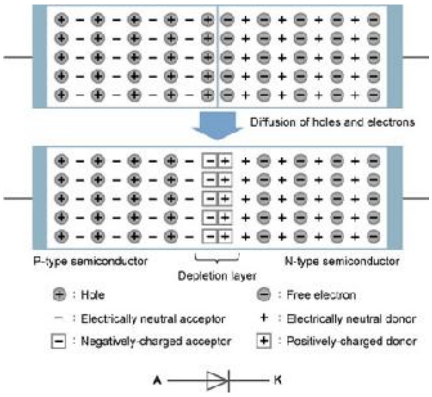


Diodes

Semiconductors– PN Junction

These semiconductor N and P-type materials do very little on their own as they are electrically neutral.
But when we join (or fuse) them together these two materials behave in a very different way producing what is generally known as a PN Junction.

When the N and P-type semiconductor materials are first joined together a diffusion phenomena occurs.
The free electrons from the N-type impurity atoms begin to migrate across this newly formed junction to fill up the holes in the P-type material.



Eventually a state of equilibrium (electrically neutral situation) will occur producing a **"potential barrier"** zone around the area of the junction This area around the junction is now called the **Depletion Layer**.(gerilim seti

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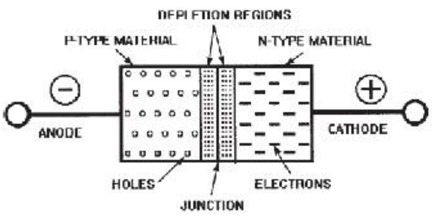
Diodes

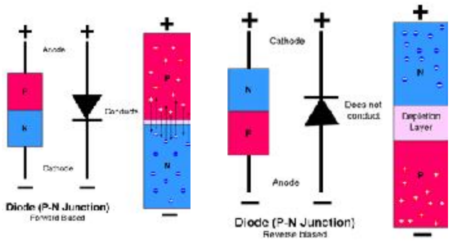
PN Junction Diode

However, if we were to make electrical connections at the ends of both the N-type and the P-type materials and then connect them to a battery source.

This additional energy source overcomes the barrier resulting in free charges being able to cross the depletion region from one side to the other.

The behaviour of the PN junction with regards to the potential barrier width produces an asymmetrical conducting two terminal device, better known as the Junction Diode





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Diodes

PN Junction Diode Operation

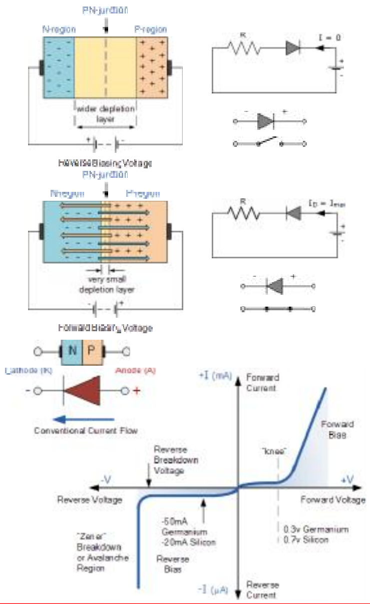
Reverse biased

When a diode is connected in a Reverse Bias condition, a positive voltage is applied to the N-type material and a negative voltage is applied to the P-type material.

Forward biased

When a diode is connected in a Forward Bias condition, a negative voltage is applied to the N-type material and a positive voltage is applied to the P-type material.

However, unlike a resistor, a diode does not behave linearly with respect to the applied voltage as the diode has an **exponential I-V relationship**



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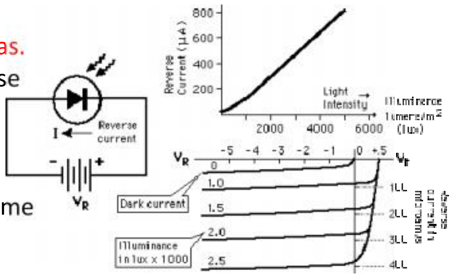
Diodes

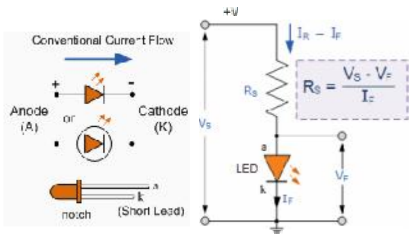
Types of Diodes

A photodiode consists of an active p-n junction which is operated in reverse bias. When light falls on the junction, a reverse current flows which is proportional to the illuminance.

The linear response to light makes it an element in useful photodetectors for some applications. It is also used as the active element in light-activated switches.



When the applied forward voltage on the diode of the Light Emitting Diode (LED) drives the electrons and holes into the active region between the n-type and p-type material, the energy can be converted into infrared or visible photons. This implies that the electron-hole pair drops into a more stable bound state, releasing energy on the order of electron volts by emission of a photon.



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Diodes

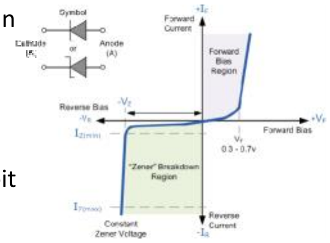
Types of Diodes

Rectifier diodes are used in power supplies to convert alternating current (AC) to direct current (DC), a process called rectification.

Diode	Maximum Current	Maximum Reverse Voltage
1N4001	1A	50V
1N4002	1A	100V
1N4007	1A	1000V
1N5401	3A	100V
1N5408	3A	1000V

They are also used elsewhere in circuits where a large current must pass through the diode. All rectifier diodes are made from silicon and therefore have a forward voltage drop of 0.7V.

A Zener diode is a diode which allows current to flow in the forward direction in the same manner as an ideal diode, but will also permit it to flow in the reverse direction when the voltage is above a certain value known as the breakdown voltage or zener voltage. the diode is *reverse-biased*, and intentionally to exploit this diode's reverse breakdown properties

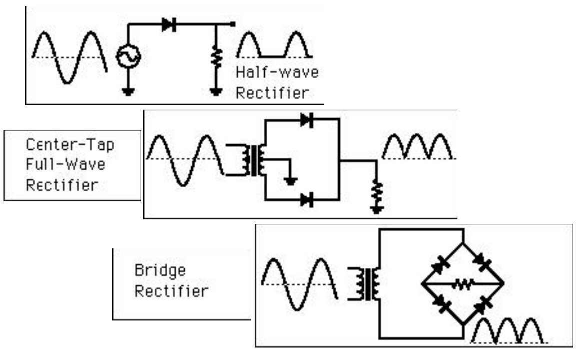


Rectification

Rectifiers

A rectifier is a circuit which converts the Alternating Current (AC) input power into a Direct Current (DC) output power.

Power (rectifiers) diodes can be used individually as above or connected together to produce a variety of rectifier circuits such as "Half-Wave", "Full-Wave" or as "Bridge Rectifiers".



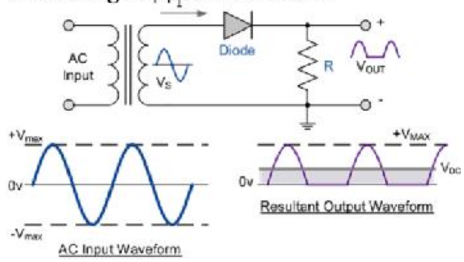
Rectification

Half Wave Rectifier

During each "positive" half cycle of the AC sine wave, the diode is *forward biased* as the anode is positive with respect to the cathode resulting in current flowing through the diode. Since the DC load is resistive, voltage across the load resistor will therefore be the same as the supply voltage.

During each "negative" half cycle of the AC sine wave, the diode is *reverse biased* as the anode is negative with respect to the cathode therefore, No current flows through the diode or circuit and no voltage appears across it.

$$V_{out} = 0.318V_{max} = 0.45V_{rms}$$



This type of circuit is called a "half-wave" rectifier because it passes only half of the incoming AC power supply

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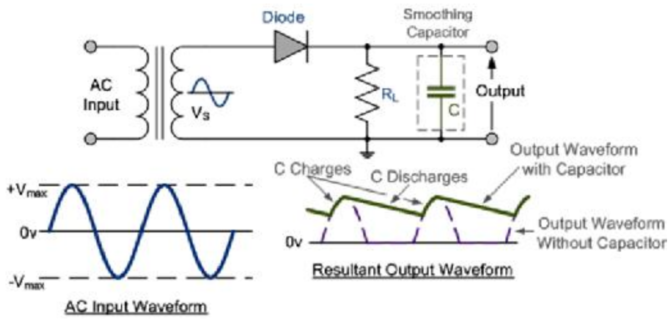
Rectification

Half Wave Rectifier

When rectification is used to provide a direct voltage power supply from an alternating source, the amount of ripple can be further reduced by using larger value capacitors. This process is called as smoothing.

The capacitor charges with ascending part of the positive half wave and it starts to discharge until the next positive half wave.

Size of the capacitor changes the deviation. Due to longer or shorter time constant.



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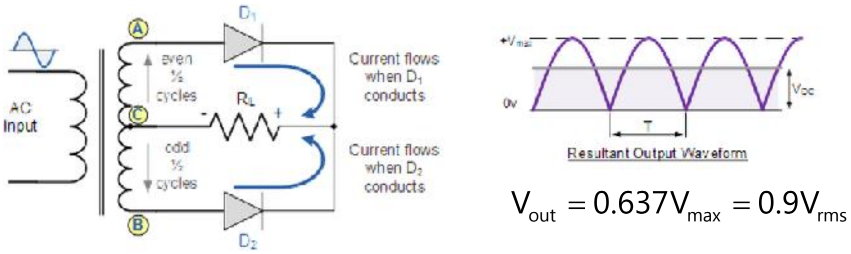
Rectification

Full Wave Rectifier

In a Full Wave Rectifier circuit, two diodes are used, one for each half of the cycle. A transformer is used whose secondary winding is split equally into two halves with a common centre tapped connection, (C).

This configuration results in each diode conducting in turn when its anode terminal is positive with respect to the transformer centre point C producing an output during both half-cycles, twice that for the half wave rectifier.

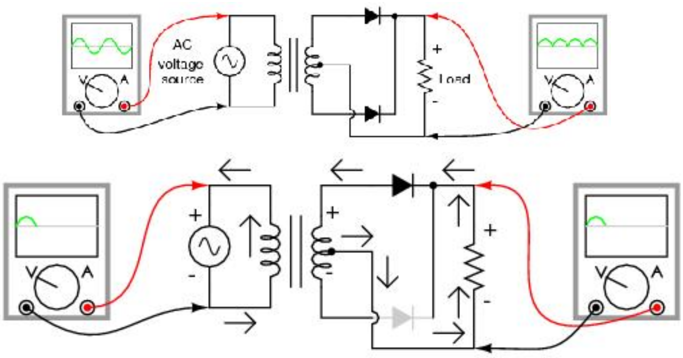


$$V_{out} = 0.637V_{max} = 0.9V_{rms}$$

Rectification

Full Wave Rectifier

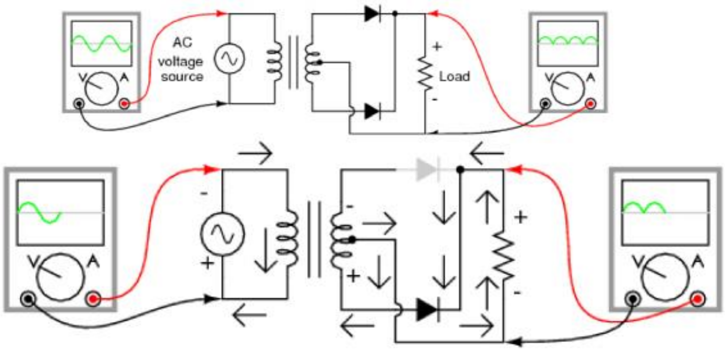
Consider the first half-cycle, when the source voltage polarity is positive (+) on top and negative (-) on bottom.
At this time, only the top diode is conducting; the bottom diode is blocking current, and the load "sees" the first half of the sine wave, positive on top and negative on bottom.
Only the top half of the transformer's secondary winding carries current during this half-cycle



Rectification

Full Wave Rectifier

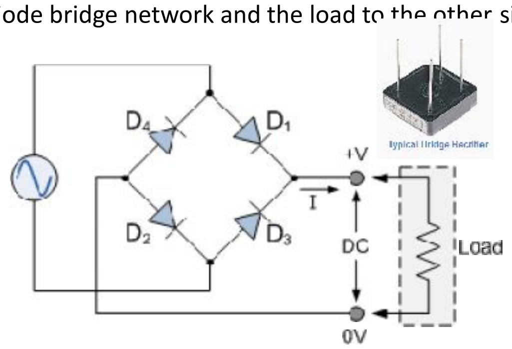
During the next half-cycle, the AC polarity reverses.
Now, the other diode and the other half of the transformer's secondary winding carry current while the portions of the circuit formerly carrying current during the last half-cycle sit idle.
The load still "sees" half of a sine wave, of the same polarity as before
One disadvantage of this full-wave rectifier design is the necessity of a transformer with a center-tapped secondary winding.

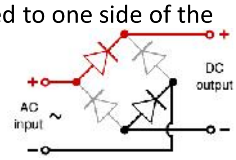


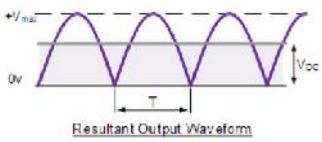
Rectification

Bridge Rectifier

Another type of circuit that produces the same output waveform as the full wave rectifier circuit is that of the Full Wave Bridge Rectifier. This type of single phase rectifier uses four individual rectifying diodes connected in a closed loop "bridge" configuration to produce the desired output.
The main advantage of this bridge circuit is that it does not require a special centre tapped transformer. The single secondary winding is connected to one side of the diode bridge network and the load to the other side







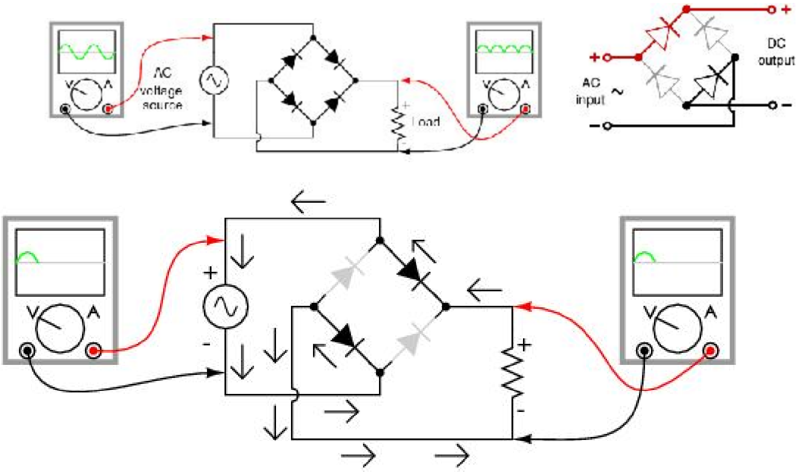
$$V_{out} = 0.637V_{max} = 0.9V_{rms}$$

However in reality, during each half cycle the current flows through two diodes instead of just one so the amplitude of the output voltage is two voltage drops (2 x 0.7 = 1.4V) less than the input V_{MAX} amplitude

Rectification

Bridge Rectifier

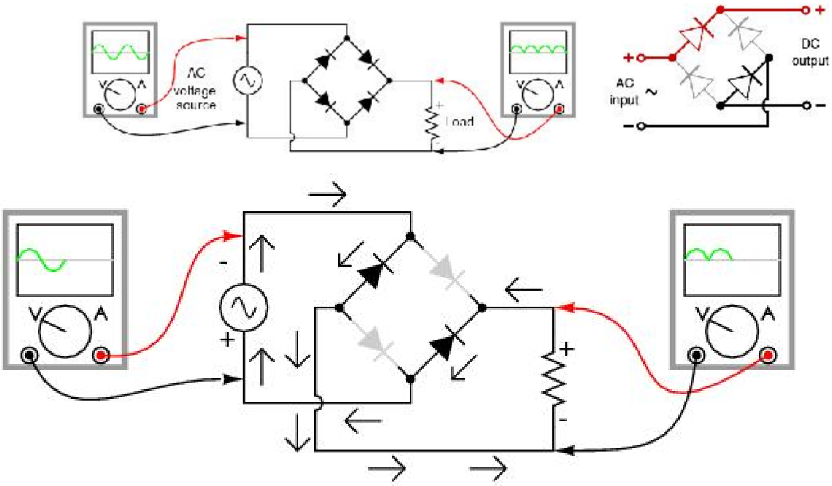
During the positive half cycle of the supply, diodes D1 and D2 conduct in series while diodes D3 and D4 are reverse biased and the current flows through the load as shown below.



Rectification

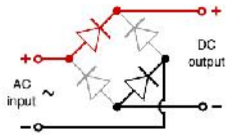
Bridge Rectifier

During the negative half cycle of the supply, diodes D_3 and D_4 conduct in series, but diodes D_1 and D_2 switch "OFF" as they are now reverse biased. The current flowing through the load is the same direction as before.

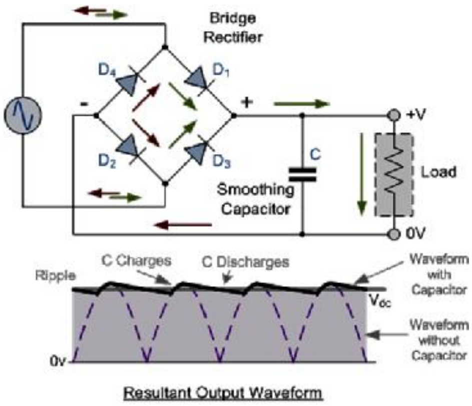


Rectification
Bridge Rectifier

during each half cycle the current flows through two diodes instead of just one so the amplitude of the output voltage is two voltage drops (2 x 0.7 = 1.4V) less than the input V_{MAX} amplitude

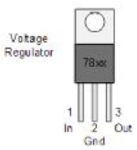


The smoothing capacitor converts the full-wave rippled output of the rectifier into a smooth DC output voltage.
Generally for DC power supply circuits the smoothing capacitor is an Aluminium Electrolytic type that has a capacitance value of 100uF or more with repeated DC voltage pulses from the rectifier charging up the capacitor to peak voltage.

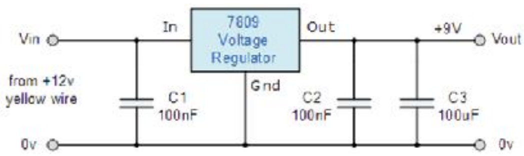


Rectification
Voltage Regulators

Voltage regulators dimnishes the oscilations in rectifier circuits. In fact they are more generally used for to obtain stable voltage in wide variety of electronic circuits.



Type	Min Input Voltage	Output Voltage
7805	7V	+5V
7806	8V	+6V
7808	10V	+8V
7809	11V	+9V
7812	15V	+12V
7815	18V	+15V
7818	22V	+18V
7824	30V	+24V



Negative voltage regulators are available, mainly for use in dual supplies