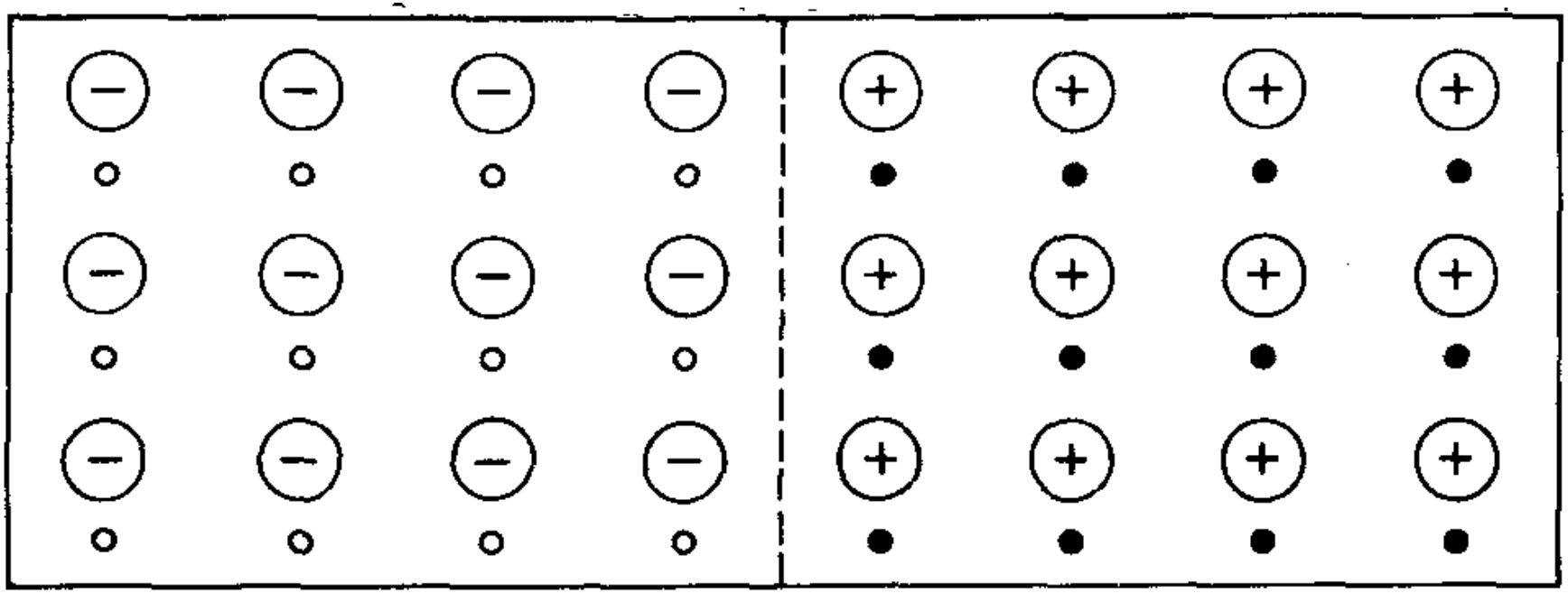
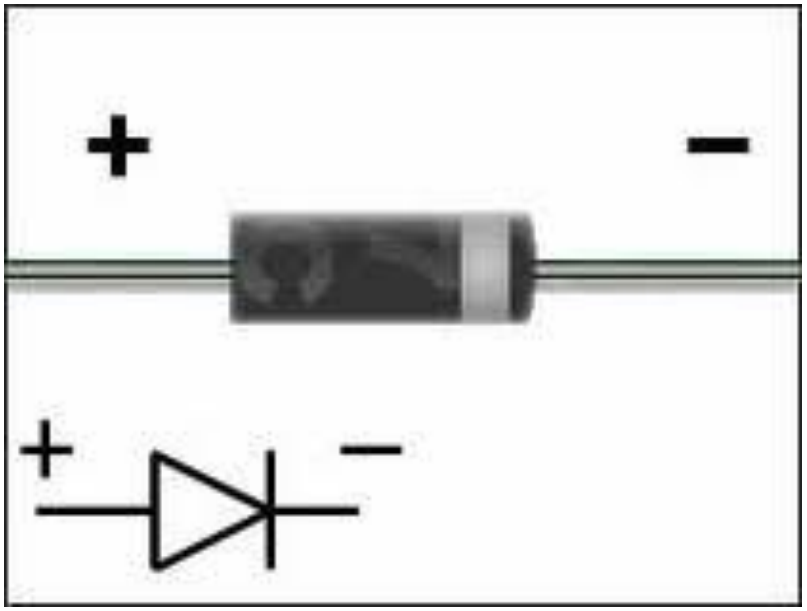
p-n Junctions

- P-n junctions consist of two semiconductor regions of opposite type. Such junctions show a pronounced rectifying behavior. They are also called p-n diodes in analogy with vacuum diodes.
- The p-n junction is a versatile element, which can be used as a rectifier, as an isolation structure and as a voltage-dependent capacitor. In addition, they can be used as solar cells, photodiodes, light emitting diodes and even laser diodes. They are also an essential part of Metal-Oxide-Silicon Field-Effects-Transistors (MOSFETs) and Bipolar Junction Transistors (BJTs).



Diodes allow electricity to flow in only one direction. The arrow of the circuit symbol shows the direction in which the current can flow. Diodes are the electrical version of a valve and early diodes were actually called valves.



Properties of a p–n junction

- The p–n junction possesses some interesting properties that have useful applications in modern electronics. A p-doped semiconductor is relatively conductive. The same is true of an n-doped semiconductor, but the junction
- between them can become depleted of charge carriers, and hence non-conductive, depending on the relative voltages
- of the two semiconductor regions. By manipulating this non-conductive layer, p–n junctions are commonly used as
- diodes: circuit elements that allow a flow of electricity in one direction but not in the other (opposite) direction. This
- property is explained in terms of *forward bias and reverse bias, where the term bias refers to an application of*
- electric voltage to the p–n junction.

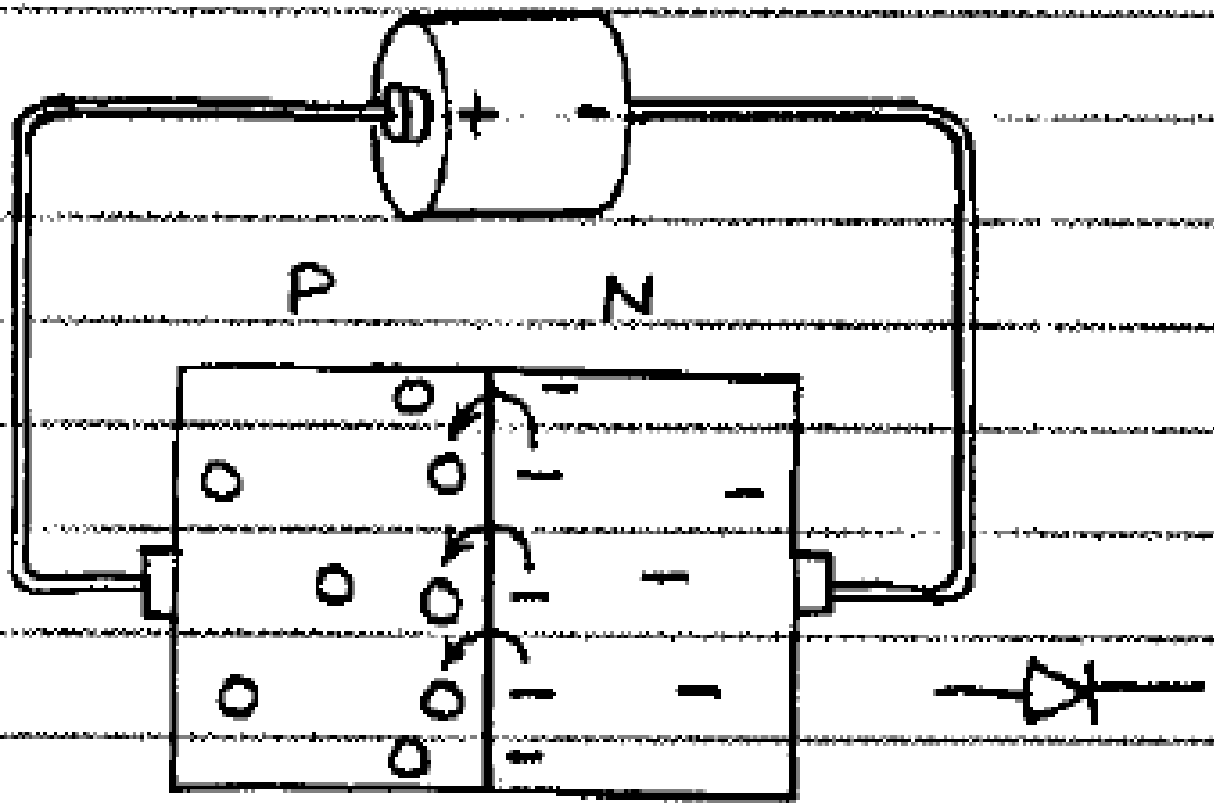
Forward bias

- In forward bias, the p-type is connected with the positive terminal and the n-type is connected with the negative terminal.

Forward bias

- With a battery connected this way, the holes in the P-type region and the electrons in the N-type region are pushed toward the junction. This reduces the width of the depletion zone.
- The positive charge applied to the P-type material repels the holes, while the negative charge applied to the N-type material repels the electrons. As electrons and holes are pushed toward the junction, the distance between them decreases. This lowers the barrier in potential.
- With increasing forward-bias voltage, the depletion zone eventually becomes thin enough that the zone's electric field cannot counteract charge carrier motion across the p–n junction, as a consequence reducing electrical resistance. The electrons that cross the p–n junction into the P-type material (or holes that cross into the N-type material) will diffuse in the near-neutral region. Therefore, the amount of minority diffusion in the near-neutral zones determines the amount of current that may flow through the diode.

FORWARD BIAS

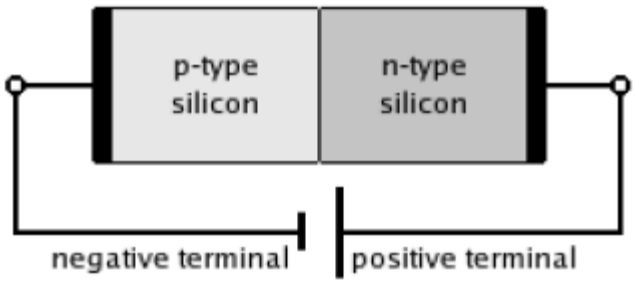


ELECTRON FLOW

HOLE FLOW

Reverse bias

- Reverse-bias usually refers to how a diode is used in a circuit.
- Therefore, no current will flow until the diode breaks down. Connecting the *P-type region to the negative terminal of the battery* and the *N-type region to the positive terminal corresponds to reverse* bias.

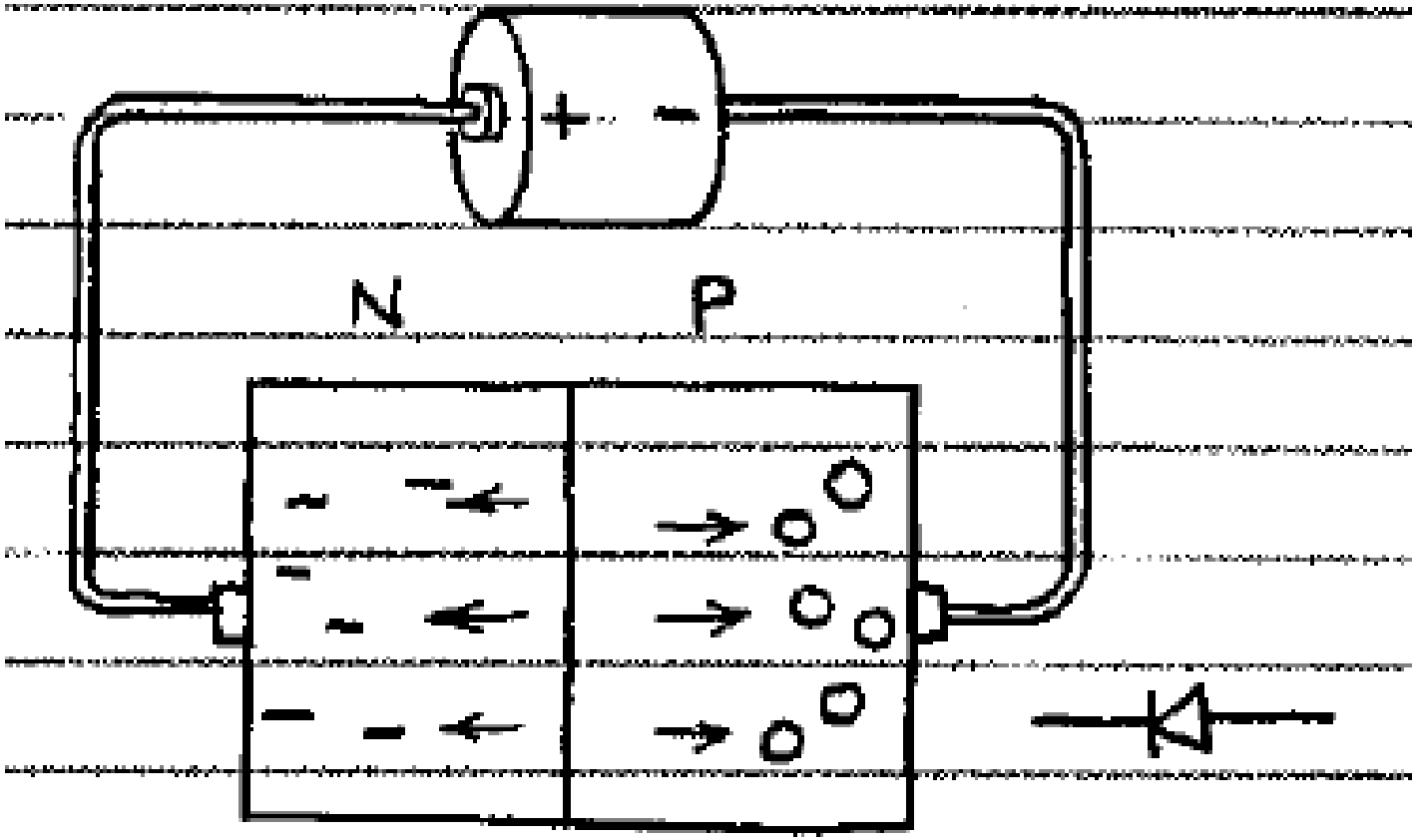


A silicon p–n junction in reverse bias.

Reverse bias

- Because the p-type material is now connected to the negative terminal of the power supply, the 'holes' in the P-type material are pulled away from the junction, causing the width of the depletion zone to increase. Likewise, because the N-type region is connected to the positive terminal, the electrons will also be pulled away from the junction. Therefore, the depletion region widens, and does so increasingly with increasing reverse-bias voltage. This increases the voltage barrier causing a high resistance to the flow of charge carriers, thus allowing minimal electric current to cross the p–n junction. The increase in resistance of the p–n junction results in the junction behaving as an insulator.

REVERSE BIAS



NO

CURRENT FLOW

☐ SUMMING UP DIODE OPERATION—

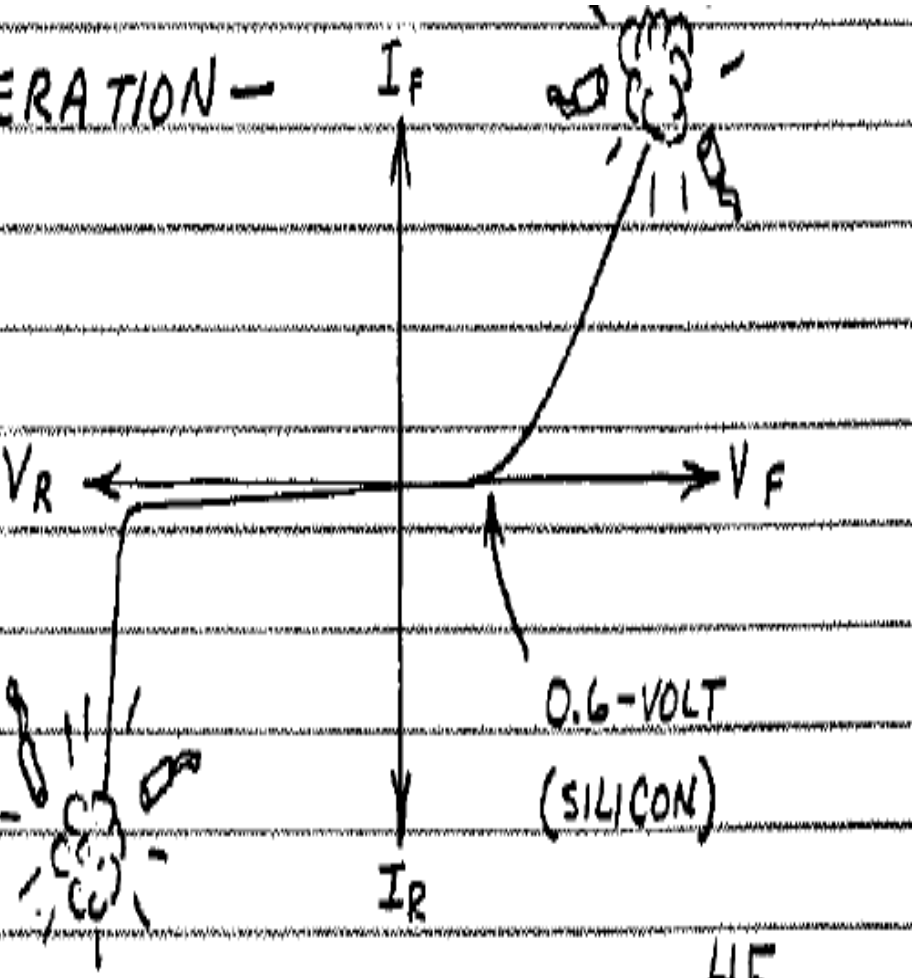
THIS GRAPH SUMS UP DIODE OPERATION. (IT'S APPROXIMATE.)

V_F = FORWARD VOLTAGE

V_R = REVERSE VOLTAGE

I_F = FORWARD CURRENT

I_R = REVERSE CURRENT

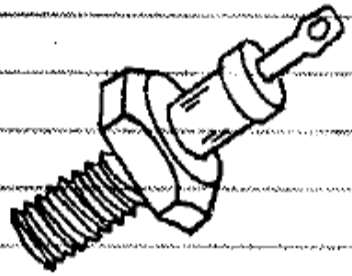


Types Of Diodes

SMALL SIGNAL.

SMALL SIGNAL DIODES ARE USED TO TRANSFORM LOW CURRENT AC TO DC, DETECT (DEMODULATE) RADIO SIGNALS, MULTIPLY VOLTAGE, PERFORM LOGIC, ABSORB VOLTAGE SPIKES, ETC.

POWER RECTIFIER.



FUNCTIONALLY IDENTICAL TO SMALL SIGNAL DIODES, POWER RECTIFIERS CAN HANDLE MUCH MORE CURRENT. THEY ARE INSTALLED IN LARGE METAL PACKAGES THAT SOAK UP EXCESS HEAT AND TRANSFER IT TO A METAL HEAT SINK. USED MAINLY IN POWER SUPPLIES.

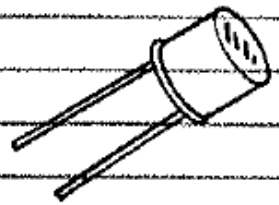
ZENER.

THE ZENER DIODE IS DESIGNED TO HAVE A SPECIFIC REVERSE BREAKDOWN (CONDUCTION) VOLTAGE. THIS MEANS ZENER DIODES CAN FUNCTION LIKE A VOLTAGE SENSITIVE SWITCH. ZENER DIODES HAVING BREAKDOWN VOLTAGES (V_Z) OF FROM ABOUT 2-VOLTS TO 200-VOLTS ARE AVAILABLE.

LIGHT-EMITTING.

ALL DIODES EMIT SOME ELECTROMAGNETIC RADIATION WHEN FORWARD BIASED. DIODES MADE FROM CERTAIN SEMICONDUCTORS (LIKE GALLIUM ARSENIDE PHOSPHIDE) EMIT CONSIDERABLY MORE RADIATION THAN SILICON DIODES. THEY'RE CALLED LIGHT-EMITTING DIODES (LEDs).

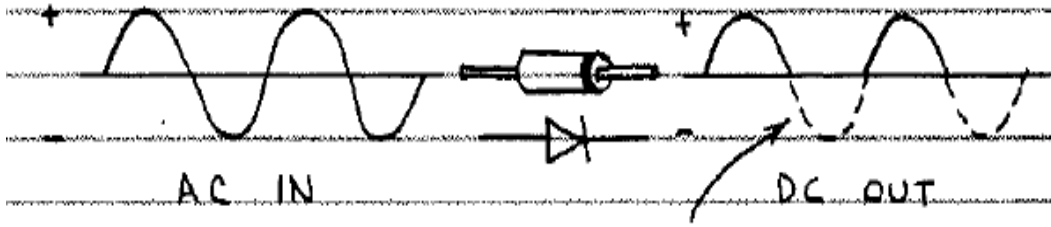
PHOTODIODE.



ALL DIODES RESPOND TO SOME DEGREE WHEN ILLUMINATED BY LIGHT. DIODES DESIGNED SPECIFICALLY TO DETECT LIGHT ARE CALLED PHOTODIODES. THEY INCLUDE A GLASS OR PLASTIC WINDOW THROUGH WHICH THE LIGHT ENTERS. OFTEN THEY HAVE A LARGE, EXPOSED JUNCTION REGION. SILICON MAKES GOOD PHOTODIODES.

How are the Diode Work

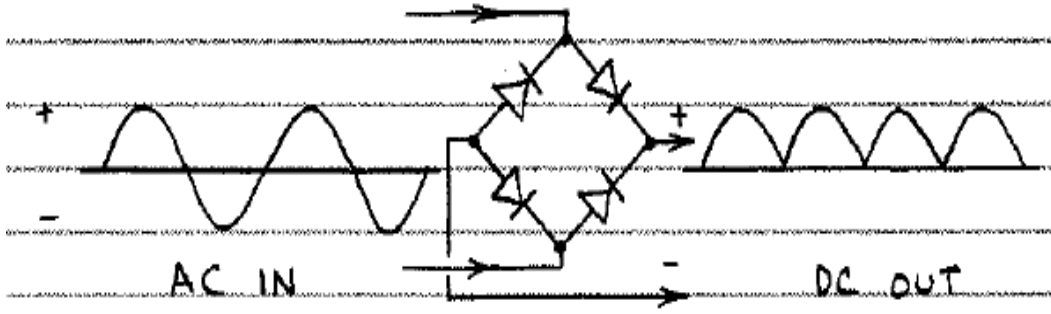
] HALF-WAVE RECTIFIER



AN UNDULATING (AC) SIGNAL (OR VOLTAGE) IS RECTIFIED INTO A SINGLE POLARITY (D.C) SIGNAL (OR VOLTAGE).

] FULL-WAVE RECTIFIER

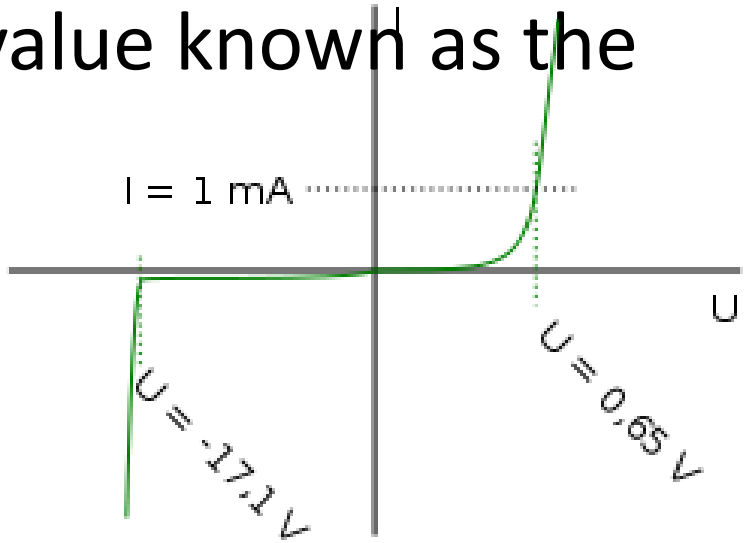
P. 101



THIS 4-DIODE "NETWORK" (OR BRIDGE RECTIFIER) RECTIFIES BOTH HALVES OF AN AC SIGNAL.

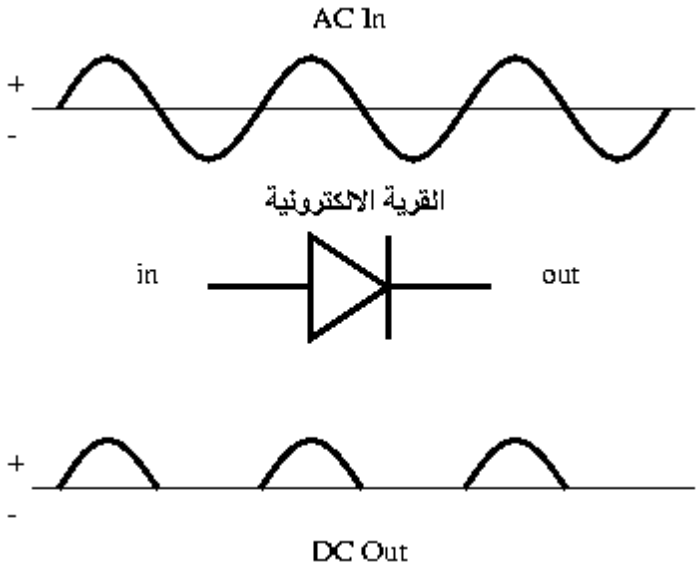
Zener diode

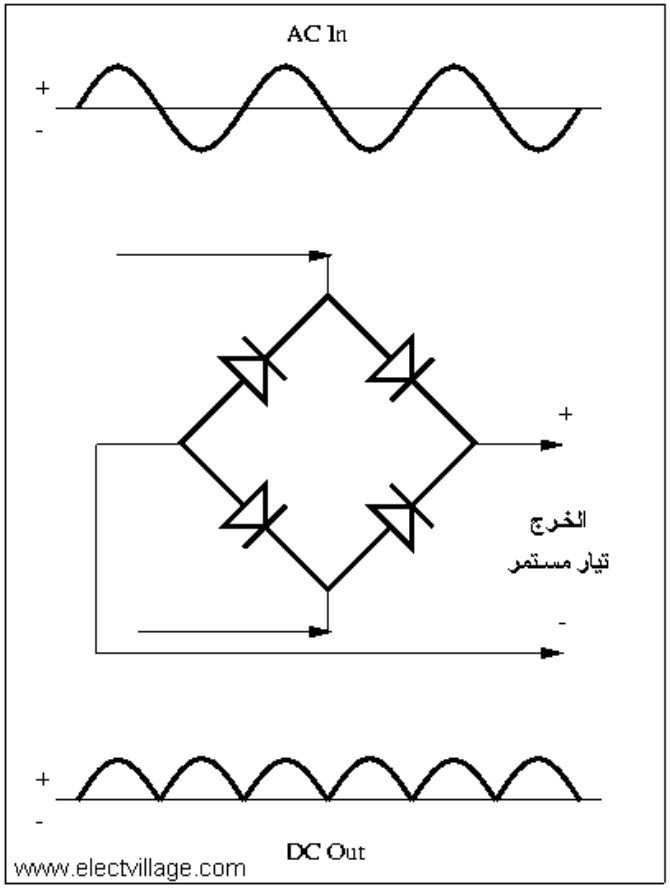
- A **Zener diode** is a diode which allows current to flow in the forward direction in the same manner as an ideal diode, but will also permit it to flow in the reverse direction when the voltage is above a certain value known as the breakdown voltage

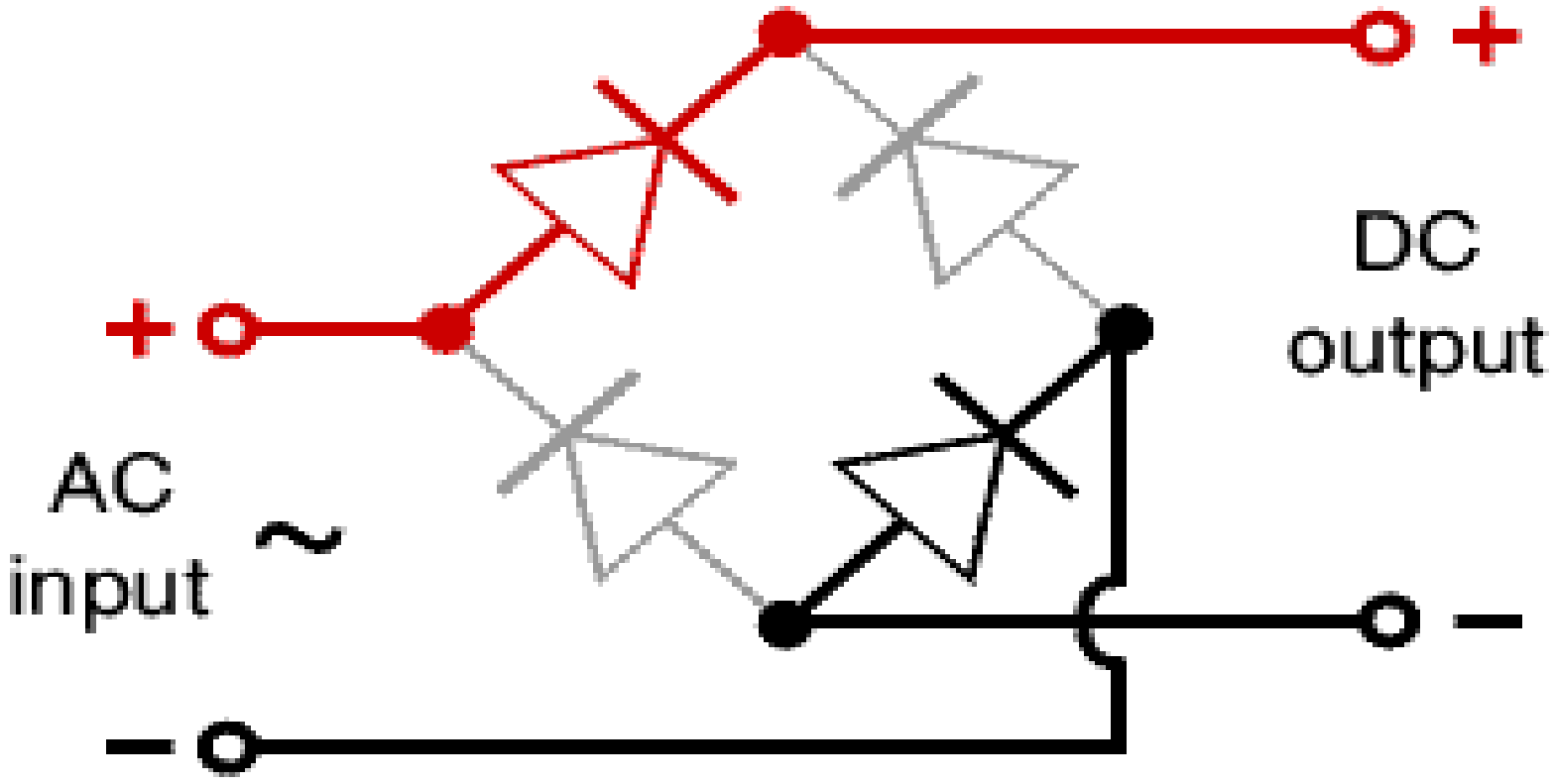


Zener diode

- Zener diode is a special purpose P-N junction diode. It was invented by Clarence Zener. A zener diode works as a normal P-N junction diode in the forward biased condition. The specialty is that, it is designed to operate in the reverse biased condition! The normal diode will not allow current flow in the reverse biased condition, and if the reverse voltage exceeds the breakdown voltage, the diode may get permanently damaged. But the zener diode will not damage, even if the reverse voltage exceeds the breakdown value. The voltage across the zener diode will stay stable, irrespective of the input voltage. So the zener diode is ideal for applications requiring stabilized voltages.


AC In
+
-
القرية الالكترونية
in
out
+
-
DC Out


AC In
+
-
+
الخرج
تيار مستمر
-
+
-
DC Out
www.electvillage.com


+
DC
output
+
AC
input
~
–
–

- http://www.wainet.ne.jp/~yuasa/flash/EngPnJunction.swf
- http://www-g.eng.cam.ac.uk/mmg/teaching/linearcircuits/diode.html

Avalanche Effect (breakdown)

- **Zener diodes are used with reverse bias, making use of the breakdown**
- that occurs across a silicon junction when the reverse voltage causes a large electrostatic field to develop across the junction. This breakdown limit occurs at low voltages (below 6 V) when the silicon is very strongly doped, and such breakdown is termed Zener breakdown, from Clarence Zener who discovered the effect. For such a true Zener diode

Summary

- The forward-bias and the reverse-bias properties of the p–n junction imply that it can be used as a diode. A p–n junction diode allows electric charges to flow in one direction, but not in the opposite direction; negative charges (electrons) can easily flow through the junction from n to p but not from p to n, and the reverse is true for holes.
- When the p–n junction is forward-biased, electric charge flows freely due to reduced resistance of the p–n junction.
- When the p–n junction is reverse-biased, however, the junction barrier (and therefore resistance) becomes greater and charge flow is minimal.

Review Questions

- State the difference between the forward bias and the reverse bias?
- What are the main types of Diodes ? Briefly describe?
- What is meant by :
  - Crystal
  - Recombination
  - Intrinsic Semiconductors
  - Extrinsic semiconductor
  - Avalanche Effect
  - Zener Diode

Review Questions

- What is meant by P-N Junction?
- Explain the difference between the P-type and the N-type?
- What is meant by Hole?
- What is meant by breakdown voltage?
- State the difference between the donor and the accepter Junctions?

Review Questions

- Define the Semiconductors and doped semiconductors?
- Define the depletion layer ?
- State the major usage of semiconductors in industry?
- Illustrate the covalent bond , with figures?