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Electronic Fundamentals

Student Guide

Caterpillar Service Technician Module
APLTCL002
Electronic Fundamentals

Published by Asia Pacific Learning
1 Caterpillar Drive
Tullamarine Victoria Australia 3043

Version 3.2, 2003

Acknowledgements

A special thanks to the Caterpillar Family for their contribution in reviewing the curricula for this program, in particular:

- Caterpillar engineers and instructors
- Dealer engineers and instructors
- Caterpillar Institutes.

MODULE INTRODUCTION

Module Title

Electronic Fundamentals.

Module Description

This module covers the knowledge and skills of Electronic Fundamentals. Upon satisfactory completion of this module students will hte underpinning knowledge of Electronic Fundamentals.

Pre-Requisites

The following must be completed prior to delivery of this module:

- Occupational Health & Safety
- Electrical Fundamentals.

Learning & Development

Delivery of this facilitated module requires access to the Electronic Fundamentals Activity Workbook.

Source References

- Caterpillar material.

Assessment Methods

Classroom and Workshop

To demonstrate satisfactory completion of this module, students must show that they are competent in all learning outcomes. Consequently, activities and assessments will measure all the necessary module requirements.

For this module, students are required to participate in classroom and practical workshop activities and satifactorily complete the following:

- Activity Workbook
- Knowledge Assessments
- Practical Activity.

KNOWLEDGE AND SKILLS ASSESSMENT

Learning Outcome 1: Demonstrate knowledge of semi-conductors used in heavy vehicle applications.

Assessment Criteria

1.1 Introduction to electronics
- 1.1.1 What is electronics
- 1.1.2 Applications.

1.2 Identify semi-conductor materials and their characteristics
- 1.2.1 Semi-conductor characteristics
- 1.2.2 PN junction
  - 1.2.2.1 Characteristics
  - 1.2.2.2 Current flow through semi-conductors
    - – Positive and negative charged electronic transfer
- 1.2.3 Depletion region
- 1.2.4 Barrier voltage
- 1.2.5 Photonic semi-conductors
- 1.2.6 Testing semi-conductors.

Learning Outcome 2: Demonstrate knowledge of diodes used in heavy vehicle applications.

Assessment Criteria

2.1 Introduction to diodes
- 2.1.1 What is a diode
- 2.1.2 Applications.

2.2 Identify semi-conductor materials and their characteristics
- 2.2.1 Diode characteristics
  - 2.2.1.1 Anode
  - 2.2.1.2 Cathode
  - 2.2.1.3 Diode bias
    - – Forward bias
    - – Reverse bias
    - – Threshold voltage
- 2.2.2 Diode leakage current
- 2.2.3 Zener point.

2.3 Explain diode operation
  - 2.3.1 Zener diodes and voltage regulation
  - 2.3.2 Light emitting diodes (LEDs) and illumination
    - 2.3.2.1 LED versus incandescent lamps
  - 2.3.3 Diodes as rectifiers
  - 2.3.4 Rectifier/Generator
  - 2.3.5 Power diodes
  - 2.3.6 Heat sink
  - 2.3.7 Diodes in circuit protection
  - 2.3.8 Photo diode.

2.4 Identify diode ratings
  - 2.4.1 Wattage
  - 2.4.2 Forward and reverse voltage
  - 2.4.3 Current
  - 2.4.4 Testing diodes
  - 2.4.5 Replacing diodes.

2.5 Describe the application of diodes in heavy vehicles
  - 2.5.1 Rectifier in alternator
  - 2.5.2 Blocking and control of current flow direction
  - 2.5.3 Spike voltage protection of relays
  - 2.5.4 Zener diode as an over voltage protection
  - 2.5.5 Zener diode as a voltage stabiliser
  - 2.5.6 Photo diode as a switching device.

Learning Outcome 3:

Demonstrate knowledge of transistors used in heavy vehicle applications.

Assessment Criteria

3.1 Introduction to transistors
  - 3.1.1 What is a transistor
  - 3.1.2 Applications.

3.2 Identify transistor types, construction, function and operation
  - 3.2.1 Types
    - 3.2.1.1 Bipolar
    - 3.2.1.2 Unipolar
  - 3.2.2 Construction
    - 3.2.2.1 Emitter
    - 3.2.2.2 Base
    - 3.2.2.3 Collector
  - 3.2.3 Basic function
    - 3.2.3.1 Base path
    - 3.2.3.2 PNP or NPN transistors
  - 3.2.4 Operation
  - 3.2.5 Solid state relays

3.2.6 Thyrister

3.2.7 Darlington pair

3.2.8 Resistors in transistor circuits

3.2.9 Transistor terminology

3.2.10 Other applications

3.2.11 Testing transistors.

Learning Outcome 4: Demonstrate knowledge of electronic systems used in heavy vehicle applications.

Assessment Criteria

4.1 Identify a basic electronic system in block diagram

4.1.1 Basic electronic system block diagram.

4.2 Explain the use of electronic signals

4.2.1 Circuits used

4.2.2 Frequency

4.2.3 Duty cycles

4.2.4 Pulse width modulation

4.2.4.1 Square wave low frequency

4.2.4.2 Square wave high frequency

4.2.4.3 Sine wave low frequency

4.2.4.4 Sine wave high frequency

4.2.5 Sensors

4.2.6 Signal processor

4.2.7 Displays

4.2.8 Actuators

4.2.9 Microprocessors

4.2.10 Data input

4.2.10.1 Thermistors

4.2.10.2 Variable capacitance sensor

4.2.10.3 Potentiometers

4.2.10.4 Piezo-resistive pressure sensor

4.2.10.5 Hall effects sensors

4.2.10.6 Induction pulse generator

4.2.10.7 Switches

4.2.10.8 Data processing

– Control process unit (CPU)

4.2.11 Outputs

4.2.11.1 Multiplexing.

4.3 Describe data retention in vehicle Electronic Control Modules

4.3.1 Random access memory (RAM)

4.3.2 Read-only memory (ROM)

4.3.3 Programmable ROM (PROM)

4.3.4 Electronically Erasable PROM (EEPROM)

4.3.5 Integrated circuits.

Learning Outcome 5:

Conduct tests on basic electronic components.

Assessment Criteria

5.1 State and follow the safety precautions that must be observed to prevent personal injury or damage to equipment.

5.2 Tasks:

- 5.2.1 Inspection of components for serviceability
- 5.2.2 Reading of component value
- 5.2.3 Measurement of wire resistance.

5.3 Tasks also include individual testing for serviceability of a:

- 5.3.1 Diode
- 5.3.2 Transistor.

5.4 Tasks are completed:

- 5.4.1 Without causing damage to components or equipment
- 5.4.2 Using appropriate tooling, techniques and materials
- 5.4.3 According to industry/enterprise guidelines, procedures and policies
- 5.4.4 Using and interpreting correct information from the manufacturer's specifications.

TABLE OF CONTENTS

TOPIC 1

Semiconductors

INTRODUCTION

This module introduces electronic fundamentals and solid state components.

Electronics is that aspect of electrics that deals with the behaviour of electrons. However, with use of semiconductor materials in so-called 'solid-state devices', such as diodes and transistors, the term electronics has been applied generally to units and system that use these components.

Electronic components are used in radios, television sets, computers, industrial control systems and automotive systems, to name just a few common examples. There are a number of earthmoving applications, such as:

- Electronic engine control
- Electronic fuel injection
- Electronic instruments
- Electronic monitoring
- Electronic transmission control
- Electronic hydraulic control
- Electronic retarding systems
- Traction control.

The expansion of electronics in so many fields has only been possible because of the development of semiconductor materials and the manufacture of the silicon chip, which is the basis of most electronic components.

Some elements, such as copper, are good conductors, while other elements are poor conductors, but good insulators. There are still other elements, however, which are neither good conductors nor good insulators. If an element falls into this group, but can be changed into a useful conductor, it is called a semiconductor. Silicon and germanium are the most commonly used elements for semiconductors.

Examples of semiconductors include diodes, transistors, and integrated circuits (ICs). Semiconductors are used throughout most vehicles, often to replace mechanical switches. We'll look at diodes, transistors and IC's in this module.

All semiconductors are solid state devices. A solid state device is one that can control current without moving parts, heated filaments or vacuum bulbs. There are other solid state devices that are not semiconductors, such as transformers.

How Semiconductors Work

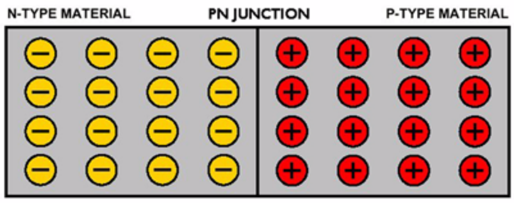

Figure 1 - The PN junction of a diode

Pure semiconductors have tight electron bonding and consequently there's no place for electrons to move. In this natural state, these elements are not useful for conducting electricity.

However, semiconductors can be made into good conductors through "doping". "Doping" is the addition of impurities that effect how many free electrons the semiconductor has. Depending on which impurity is added, the resulting material will have either an excess of free electrons or a shortage of free electrons.

If the added material creates an excess of free electrons, the semiconductor is negative or "N" type. If it creates a shortage of free electrons, the semiconductor is positive or "P" type.

Semiconductors are made from a sandwich of at least one slice of "N" type material and at least one slice of "P" type material. These slices are mounted inside a plastic or metal housing. The area where the "N" type material and "P" type material meet is called the "PN" junction (Figure 1).

Current Flow Through Semiconductors

The flow of electricity through a semiconductor is referred to a little differently to other electrical devices. Usually, the movement of electricity is defined as the movement of free electrons bumping each other from the positive terminal of the voltage source through the conductor and towards the negative terminal.

When discussing semiconductors, not only the flow of electrons is described, but also the flow of "holes", that is, spaces in an electron shell to which an electron will be attracted.

The flow of electrons is relatively easy to visualise. For instance, think of a flow of marbles through a channel. The flow of holes is slightly harder to visualise.

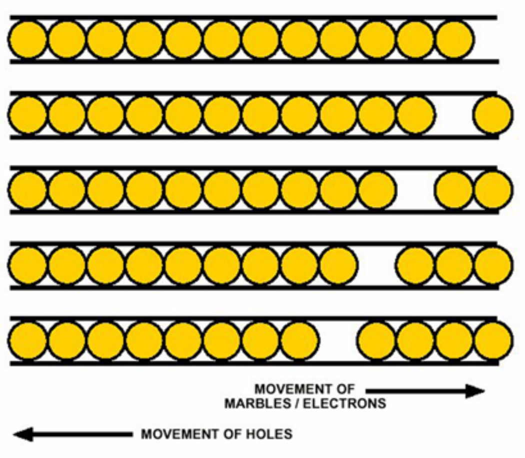

Figure 2 - Movement of holes

The same channel, filled with marbles, is shown in Figure 2. One marble moves ahead, leaving a hole in its place. The next marble moves into the position vacated by the first marble; at the same time, the hole can be said to be moving from the position that the first marble had held to the position that the second marble had held. As marbles move in one direction in the channel, holes can be said to be moving in the opposite direction.

With no voltage applied to a semiconductor, the free electrons at the “PN” junction are attracted to the holes in the “P” type material. Some electrons drift across the junction to combine with holes.

Similarly, holes from the “P” type material can be said to be “attracted” to the free electrons in the “N” type material. Holes, although they are not particles themselves, can be visualised as crossing the “PN” junction to combine with electrons.

Depletion Region

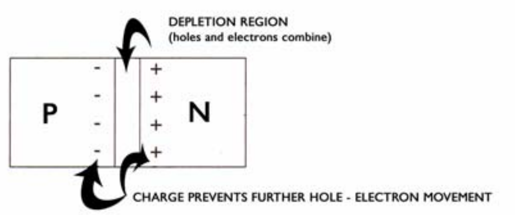

Figure 3 - Formation of depletion region

As long as no external voltage is applied to the semiconductors, there is a limit to how many electrons and holes will cross the “PN” junction. Each electron that crosses the junction leaves behind an atom that is missing a negative charge. Such an atom is called a positive ion. In the same way, each hole that crosses the junction leaves behind a negative ion.

As positive ions accumulate in the “N” type material, they exert a force (a potential) that prevents any more electrons from leaving. As negative ions accumulate in the “P” type material, they exert a potential that keeps any more holes from leaving. Eventually, this results in a stable condition that leaves a deficiency of both holes and electrons at the “PN” junction. This zone is called the Depletion Region.

Barrier Voltage

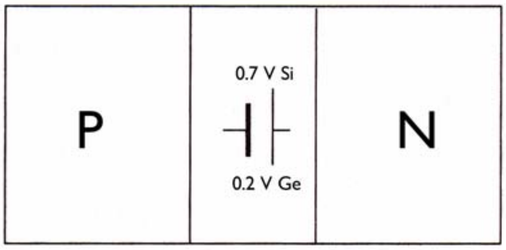

Figure 4

When voltage is applied to a "PN" semiconductor and assuming that the semiconductor is configured in the circuit to allow electricity to flow; electrons flow from the "N" side, across the junction, and through the "P" side. Holes flow in the opposite direction. The effect of the "PN" junction on current flow in a circuit depends on where it is placed and on the order of the "P" and "N" type materials.

The voltage potential across the "PN" junction is called the barrier voltage. Doped germanium has a barrier voltage of approximately 0.2 Volts. Doped silicon has a barrier voltage of approximately 0.7 Volts.

Photonic Semiconductors

Photonic semiconductors emit and detect light or *photons*. A photon is a unit of light energy. Photons are produced electrically when certain electrons excited to a higher than normal energy level return to a more normal view. Photons behave like waves. The distance between the wave nodes and anit-nodes (wave crests and valleys) is known as *wavelength*. Electrons excited to higher energy levels emit photons with shorter wavelengths than electrons excited to lower levels. Photons are not necessarily visible and it is perhaps important to note that they may truly be described as *light* only when they are visible.

All visible light is classified as electromagnetic radiation. The specific wavelength of light rays will define its characteristics. Light wavelengths are specified in nanometers; that is, billionths of a metre.

The Optical Light Spectrum

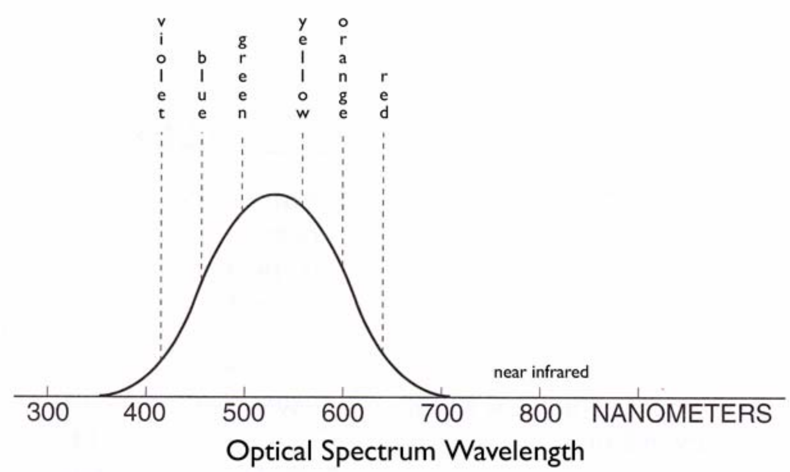

Figure 5

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The optical light spectrum includes ultraviolet, visible and infrared radiation. Figure 5 shows a graphic representation of the optical light spectrum. Photonic semiconductors either emit or can detect near-infrared radiation frequencies. Near-infrared means that the frequency is slightly greater than the visible red end of the visible light spectrum and is therefore usually referred to as light.

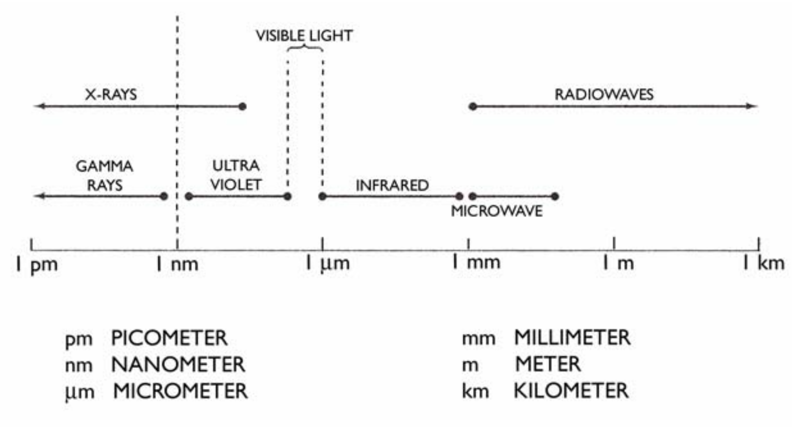

Figure 6

Figure 6 shows the full optical light, or electromagnetic, spectrum. Note the portion of the spectrum that is classified as visible light.

Devices

There are a number of devices that change resistance when light falls on them.

Some detect only ultra violet light or infra red light; others detect broad spectrum or white light.

The list includes photo resistors (light dependent resistors-LDR's) photo diodes; Light Activated Silicon Controlled Rectifiers (LASCR's), infra red receiving diodes, photo transistors, photo darlington transistors and others.

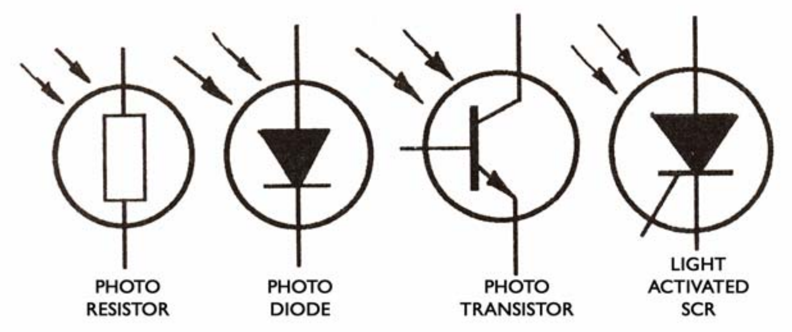

Figure 7

When they are put into a circuit, they all operate in a similar manner. When no light is present, they have a high resistance. When light falls on their active surface, their resistance decreases.

But the amount of change varies for each device and to determine which is most suitable for a particular application there is a need to place each into a circuit and supply it with a varying intensity light to see how it reacts.

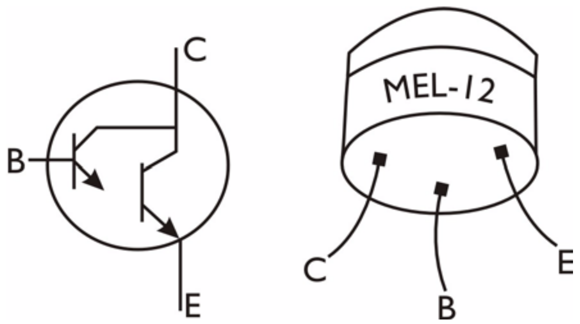

Figure 8

Possibly the most sensitive device on the list is the photo darlington transistor as it is really a photo transistor with an amplifying transistor to increase the sensitivity about 50 - 100 times.

LIGHT DEPENDENT RESISTOR

Figure 9

The least sensitive device is the photo resistor as it does not have any amplifying properties at all.

Each device has its own application and the right one will depend on cost, sensitivity, availability and capability to withstand the applied voltage. Some photo resistors can withstand 50 - 250 Volts whereas the photo darlington transistor can only withstand 25V max.

TOPIC 2

Diodes

INTRODUCTION

The simplest kind of semiconductor is a diode. It is made of one layer of “P” type material and one of “N” type material. Diodes allow current flow in only one direction. On a schematic, the triangle in the diode symbol points in the direction current is permitted to flow using conventional current flow theory. Diodes are used for many purposes in electrical circuits, including illumination, rectification and voltage spike protection.

Anode/Cathode

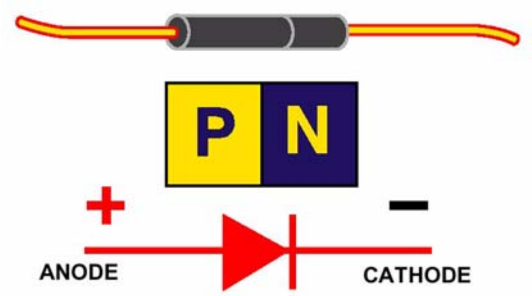

Figure 10 - Diode Diagram and Schematic Symbol

Current flows from left to right in Figure 10. This is indicated by a positive (plus) sign to the left and a negative (minus) sign to the right of the diode. The positive side of the diode is the anode and the negative side is the cathode.

There’s an easy way to remember the names “anode” and “cathode”. Associate “anode” with A+ (it’s the positive side) and “cathode” with C- (the negative side). The cathode is the end with the stripe. Current flows through a diode when the anode terminal is more positive than the cathode terminal.

Diode Bias

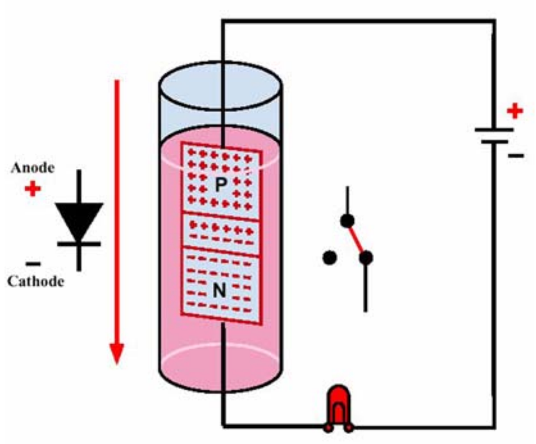

Figure 11 - Forward Biased Diode

The term “bias” is used to refer to a diode’s ability to allow or prevent the flow of current in a circuit.

A forward biased diode (see Figure 11) is connected to a circuit in such a way as to allow the flow of electricity. This is done by connecting the N side of the diode (the cathode) to the negative voltage, and the P side (the anode) to the positive voltage. When the diode is connected in this way, both electrons and holes are being forced into the depletion zone, connecting the circuit. Current flows in the direction of the arrowhead indicating that the diode is forward biased.

When a forward biased diode is connected to a voltage source in this way, it acts as a switch closing a circuit. Voltage is forcing both electrons and holes into the depletion region, which allows current to flow.

A diode will not conduct (current flowing) until the forward voltage (bias) reaches a certain threshold. The type of material used to construct the diode determines the threshold voltage. A germanium diode usually starts conducting when the forward voltage reaches approximately 300 milli-volts while a silicon diode requires approximately 600 milli volts.

A diode is limited to how much current can flow through the junction. The internal resistance of the diode will produce heat when current is flowing. Too much current produces too much heat, which can destroy the diode.

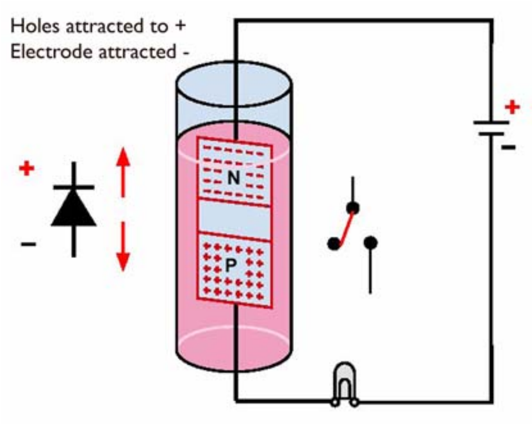

Figure 12 - Reverse Biased Diode

A diode that is connected to voltage so that current cannot flow is reverse biased (Figure 12). This means that the negative terminal is connected to the P side of the diode, and the positive terminal is connected to the N side. The positive potential is on the cathode terminal and, as such, current is being blocked (against the arrowhead).

When voltage is applied to this circuit, the electrons from the negative voltage terminal combine with the electron holes in the “P” type material. The electrons in the “N” type material are attracted towards the positive voltage terminal. This enlarges the depletion area. Since the holes and electrons in the depletion area don’t combine, current can’t flow.

When a diode is reverse-biased, the depletion region acts like an open switch, blocking current. With the negative terminal connected to the P material, holes are attracted away from the depletion region. With the positive terminal connected to the N material, electrons are likewise attracted away from the depletion region. The result is an enlarged zone, that contains neither holes nor electrons that cannot support current flow.

Diode Leakage Current

In reality, a very, very small amount of current can flow through a reverse biased diode. If the supply voltage becomes high enough, the atomic structure inside the diode will break down, and the amount of current that flows through it will rise sharply. If the reverse current is large enough and lasts long enough, the heat will damage the diode.

In summary, if a diode is forward biased, it acts like a small resistance, or a short circuit. If the diode is reverse biased, it acts like a very large resistance or open circuit.

Zener Point

The applied voltage at which the diode fails is called the maximum reverse voltage or Zener Point. Diodes are rated according to this voltage. Circuits are designed to include diodes with a rating high enough to protect the diode and the circuit during normal operation.

Uses

Common uses for diodes in electrical circuits include:

- Voltage regulation (using Zener diodes)
- Indicators (using LEDs)
- Rectification (changing AC current to DC current)
- Clamping to control voltage spikes and surges that could damage solid state circuits (acting as a circuit protector).

Zener Diodes and Voltage Regulation

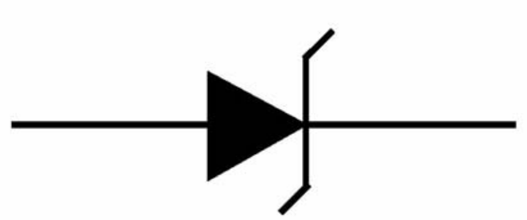

Figure 13 - Zener Diode and Voltage Regulation

A Zener diode (Figure 13) is a special kind of diode that's heavily doped during manufacture, resulting in a high number of free electrons and electron holes. These additional current carriers permit reverse current flow when a certain reverse bias voltage is reached (avalanche point or Zener point).

In forward bias, the Zener diode acts like a regular diode. A common Zener diode won't conduct current in the reverse direction if the reverse bias voltage is below the rate voltage. It will conduct reverse current if the reverse bias voltage reaches or exceeds the rated voltage. This Zener diode is often used in voltage control circuits.

An example of Zener diodes is inside the alternator in a charging system. These diodes act as a safety mechanism to limit the output. The Zener diodes in 24 V alternators are rated to turn on at approximately 28 Volts.

Zener diode applications

In a 24 volt system

A Zener diode can be used as a voltage-dependent switch. This has an application in transistorised voltage regulators, which are fitted to alternators, the Zener diode being used as a limiting device to prevent excess alternator output.

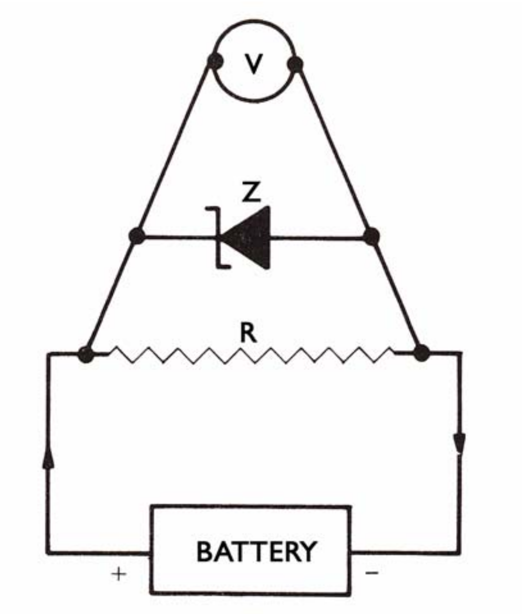

Figure 14 - Zener diode in parallel with a voltmeter is used as a protective device

A Zener diode can be used as a protection for an electrical instrument. It is wired in parallel with the instrument (Figure 14) and arranged to break down at the maximum safe voltage that the instrument can stand.

When breakdown voltage is reached, the Zener diode acts as a shunt and carried current away from the instrument. This decreases the current that flows through the instrument and, in the event of an overload, protects it from damage. Should the voltage drop, the Zener diode will again become non-conducting, and the meter will register correctly.

Light Emitting Diodes (LEDs) & Illumination

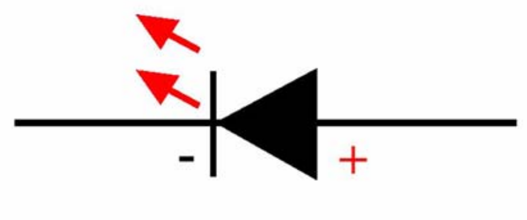

Figure 15 - Schematic Symbol for LED

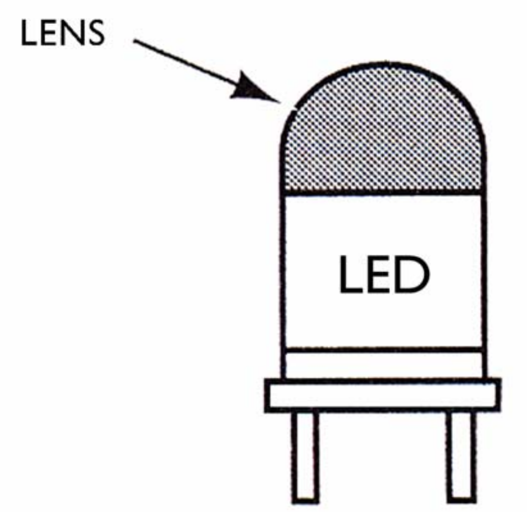

Figure 16 - Light-emitting diode (LED)

Another type of diode commonly used is a Light Emitting Diode (LED) (Figure 15) which is used for indicator lamps. Like all diodes, LEDs allow current flow in only one direction. The difference is that when forward voltage is applied to an LED, the LED radiates light. Many LEDs connected in series can be arranged to light as numbers or letters in a display.

While most silicon diodes need about 0.5 or 0.7 Volts to be turned on, LEDs need approximately 1.5 to 2.2 Volts. This voltage results in currents high enough to damage an LED. Most LEDs can handle only about 20 to 30 mA of current. To prevent damage to an LED, a current-limiting resistor is placed in series with the LED.

LEDs versus Incandescent Lamps

In complex electrical circuits, LEDs are an excellent alternative to incandescent lamps. They produce much less heat and need less current to operate. They also turn on and off more quickly.

Diodes as Rectifiers

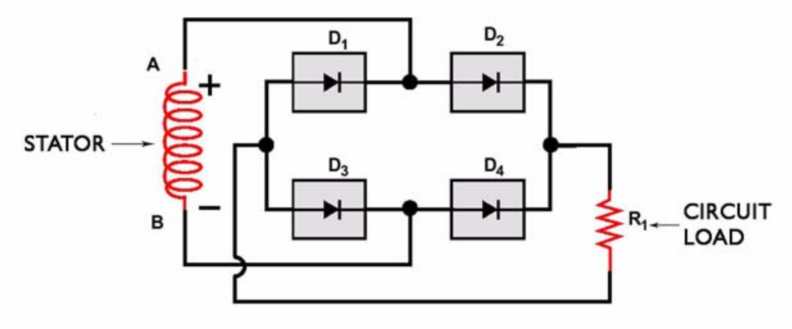

Figure 17 - Simple Diode Rectifier Bridge

Rectifiers change alternating current (AC) to direct current (DC). Several diodes can be combined to build a diode rectifier, which is also called a rectifier bridge (Figure 17).

Alternator Rectifier

The most common use of a rectifier in electrical systems is in the alternator. The alternator produces alternating current (AC). Because electrical systems use direct current (DC), the alternator must somehow convert the AC to DC. The DC is then provided at the alternator's output terminal.

Alternators use a Diode Rectifier Bridge to change AC current to DC current. The use of diodes in an alternator will be covered in more detail in the next level unit.

Study Figure 17 in terms of conventional theory. The stator voltage is alternating. That means the voltage at A alternates between positive and negative. When the voltage at A is positive, current flows from A to the junction between diodes D1 and D2. Notice the direction of the arrows on each diode. Current can't flow through D1, but it can flow through D2. The current reaches another junction, between D2 and D4, but again the current cannot flow through D4, nor can it return through D2. The current must pass through the circuit load because it can't flow through D4 or D2.

NOTE:
The circuit load in this simplified example is a resistor; in a real charging system, the load would be the battery, plus any electrical systems in use, such as ignition system and lights.

The current continues along the circuit until it reaches the junction of D1 and D3.

Even though the voltage applied to D1 is forward biased, current can't flow through it because there's positive voltage on the other side of the diode; in other words, there is no voltage potential. Current flows through D3, and from there to ground at B.

When the stator voltage reverses so that point B is positive, current flows along the mirror-opposite path. Whether the stator voltage at point A is positive or negative, current always flows from top to bottom through the load (R1). This means the current is DC.

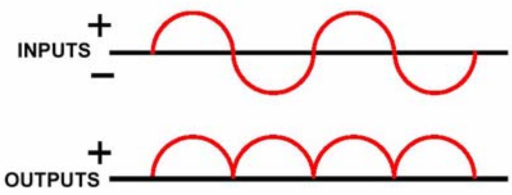

Figure 18 - AC Input to Full-wave Pulsating DC Output

The rectifiers in generators are designed to have an output (positive) and an input (negative) diode for each alternation of current. This type of rectifier is called a full wave rectifier. In this type of rectifier, there is one pulse of DC for each pulse of AC. The DC that's generated is called full-wave pulsating DC as shown in Figure 18.

Power Diodes

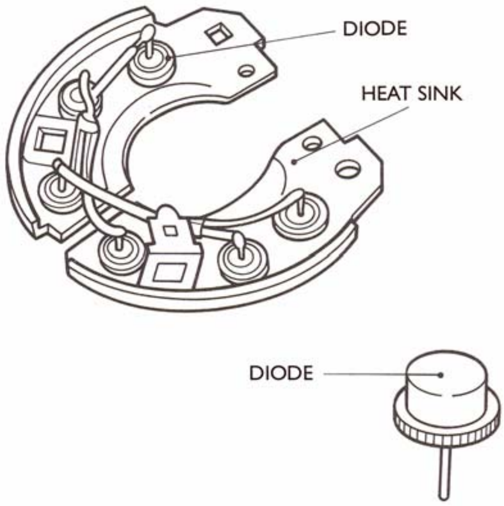

Figure 19

Diodes which carry relatively large currents are referred to as power diodes. The currents carried by these diodes generate heat, which is detrimental to the diode.

To prevent damage from overheating, power diodes (such as those in an alternator) are enclosed in a metal case and the diodes are then fitted into a heat sink. The heat sink is an aluminium moulding or extrusion which is large enough to absorb and dissipate heat from the diode and so prevent it from reaching too high a temperature.

Diodes in Circuit Protection

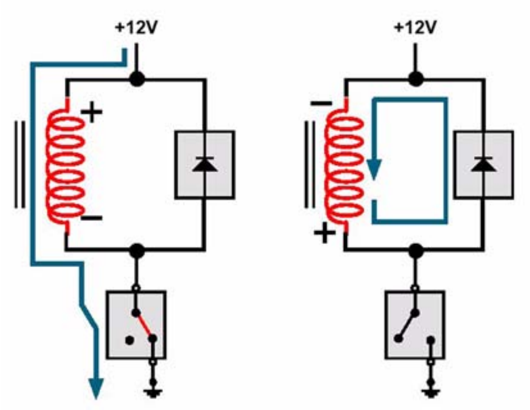

Figure 20 - Voltage spike generated in coil as field collapses

Electromagnetic devices like solenoids and relays have a unique characteristic that can cause voltage spikes if not controlled. The coil in such a device sets up a magnetic field as current flows through it. When the circuit is abruptly opened and the supply voltage is removed, the collapsing magnetic field actually generates its own voltage potential. The voltage potential may be high enough to damage some circuit components, especially sensitive solid state controllers.

To protect against sparks or surges, Clamping Diodes are added in parallel with the coil (Figure 20). While voltage is applied to the circuit, the diode is reverse-biased and doesn't conduct electricity.

When voltage is removed and the induced current is flowing, the diode is forward biased and does conduct. The current flows in a circular path through the diode and coil until it dissipates. Induced current can cause problems other than sparks. The computers in today's earthmoving machines make decisions based on circuit voltages. The computers make the wrong decisions if electromagnetic devices cause abnormal voltages.

Photo Diodes

All diodes produce some electrical response when subjected to light. A photo diode is designed to detect light and therefore has a clear window through which light can enter. Silicon is the usual semiconductor crystal medium used in photo diodes.

Photo diodes are used as switches eg. night lights.

Diode Rating

Diodes will fail if excess heat or voltage is applied.

Excess voltage comes in the form of reverse voltage (called peak inverse voltage or PIV). A diode can withstand a PIV voltage of 120% of the forward voltage.

Above this, the voltage will spike or puncture the junction and failure will occur.

Excess current will also destroy a diode. This is due to the heat generated when a current flows.

The heat generated is Watts (volts x amps) and can be determined by measuring the two values for a range of current flow.

As the current increases the voltage across a diode also increases and will vary from one diode to another. The product (multiplication) of the two creates Watts (or heat) and this will damage the junction by overheating it.

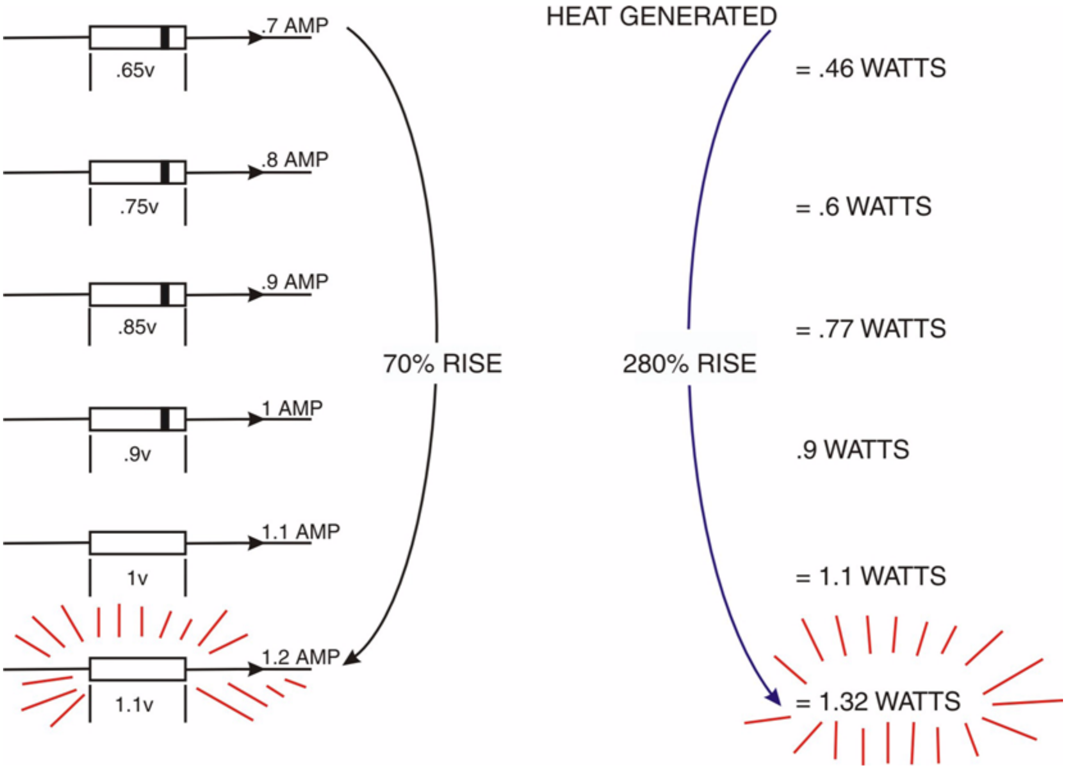

Figure 21

It can be seen in Figure 21 that the wattage, which must be dissipated by the diode, rises faster than the current. This heat is generated in the junction and can even melt the silicon material or cause an explosion to physically blow the diode apart.

The Zener

The current flow through a Zener must be kept within a maximum and minimum value for it to operate.

For instance, if the current falls below 5mA, for a 400mW Zener, it may drop put of regulation.

If the flow is greater than the dissipation of the Zener, it may be damaged through overheating.

Here are some specific examples:

Small glass Zener diodes are rated at 400mW (.4 Watt). This means the maximum current flow will vary according to the voltage rating. This is because the product of Volts x Amps must equal .4 Watts.

Testing Diodes

When a diode is functioning properly in a circuit, it acts as a large voltage drop in one direction, and as a very small voltage drop in the other. Unfortunately, testing diodes is not always this simple.

1. Take the diode out of the circuit (sometimes this is not possible), or isolate it from the circuit.

2. Testing with an analog ohmmeter.

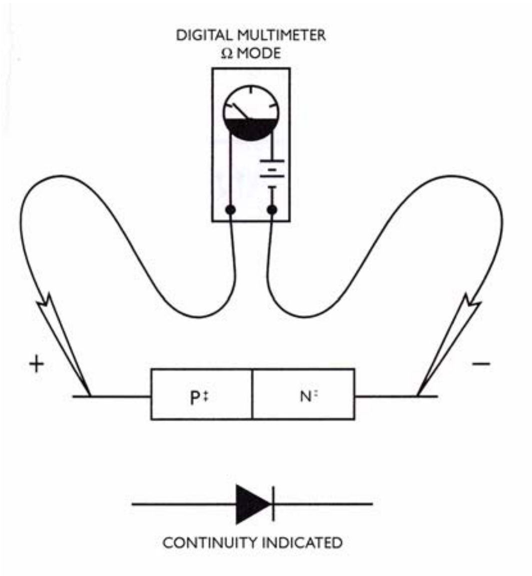

Figure 22 - Testing a diode in forward bias

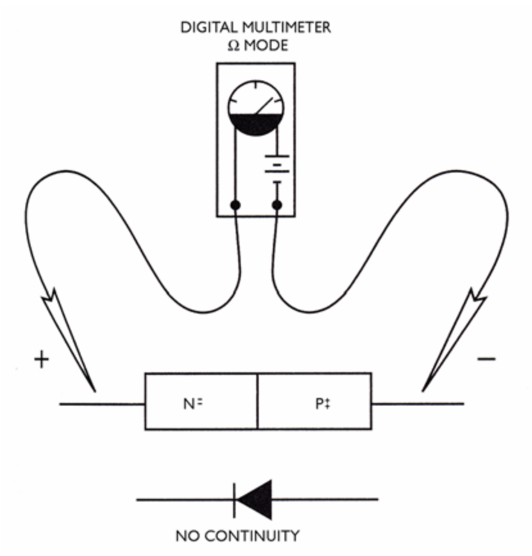

Figure 23 - Testing a diode in reverse bias

a. Diode should have a low resistance in one direction and a high resistance in the other.

b. Check the low resistance on the lowest ohmmeter scale and the high resistance on the high ohmmeter scale.

c. The high resistance should be at least 100 times the low resistance.

d. Steps b and c also apply to Zener diodes and full-wave rectifiers.

3. Testing with digital multimeter.
   a. Some meters have a special diode testing function and may have an audible or visible continuity alarm for quick diagnosis
   b. Always follow the actual meter's instructions, as for example, forward and reverse readings are voltage drop readings, not resistance with some meters.
   c. A typical diode will have approximately 0.6 to 0.9 Volts voltage drop in the forward direction and should read "OL" (overload) in the reverse direction.

Replacing a Diode

Diodes, like any other electronic component, should be replaced with a diode having the same part number to the original. This way the characteristics will be the same and the diode's operation will be compatible with circuit operation.

Diode characteristics vary tremendously from one type to another. For example, the maximum continuous forward current that a 1N4001 diode can handle is 1 ampere, while the BYV22 can handle 60 amperes continuously. Other diodes may take up to 400 amperes, but they are rarely used in the type of electronic circuits that we are interested in here.

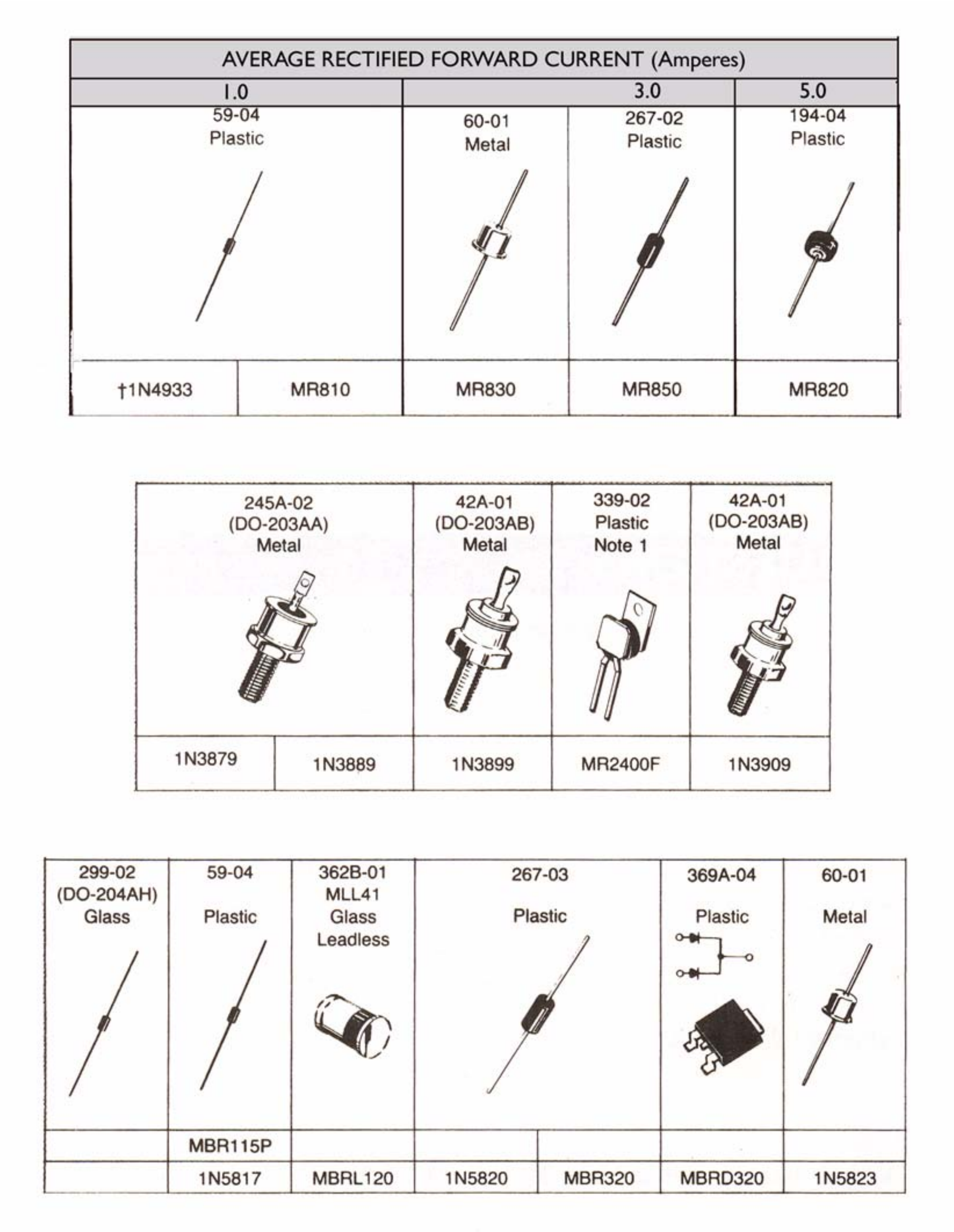

Figure 24 - Sample diodes

Figure 24 shows some of the most common packaging styles used in electronics. The band on the end of the small, cylindrical diodes indicates the cathode. The cathode of the larger devices is usually the end with the screw thread, but not always. If unsure, check the manufacturer’s data sheets for the diode being used.

TOPIC 3

Transistors

INTRODUCTION

A diode is only one type of semiconductor. By combining several kinds of semiconductor material, transistors are created. Like diodes, transistors control current flow.

Transistors can perform practically all the functions which were once performed by vacuum tubes (used to amplify radio signals), but in much less space and without creating as much heat. Transistors are used in many applications, including radios, electronic control modules and other solid-state switches.

TRANSISTOR TYPES

There are many kinds of transistors. They can be divided into two major groups:

- bipolar
- unipolar (also called Field Effect Transistors or FETs).

While there are several differences between the two types, the most important difference for our purposes is this:

- Bipolar transistors vary current in order to control voltage
- FET transistors vary voltage in order to control current.

Bipolar transistors are more common in Caterpillar electrical circuits, so we'll concentrate on them.

TRANSISTOR CONSTRUCTION

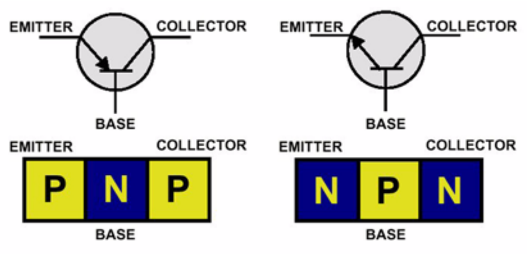

Figure 25 - Bipolar Transistor

Like diodes, transistors contain a combination of "N" type and "P" type material. However, transistors contain three materials instead of two. The three materials are arranged so that "N" type and "P" type materials alternate (either as a NPN or a PNP group). In practical terms, this means that diodes have two leads while transistors have three. Figure 25 above is a symbolic representation of transistor construction.

Emitter, Base and Collector

In Figure 25, the material on the left is called the emitter. The material sandwiched in the middle is the base. The material on the right is the collector.

The symbols are the schematic symbols for a transistor. The arrow indicates current flow direction (using conventional theory), and is always on the emitter. The arrow points in a different direction depending on whether the transistor is PNP or NPN.

FETs also have three sections; they are referred to as the gate (which approximates the function of the base), the source (similar to the emitter), and the drain (similar to the collector).

BASIC FUNCTION

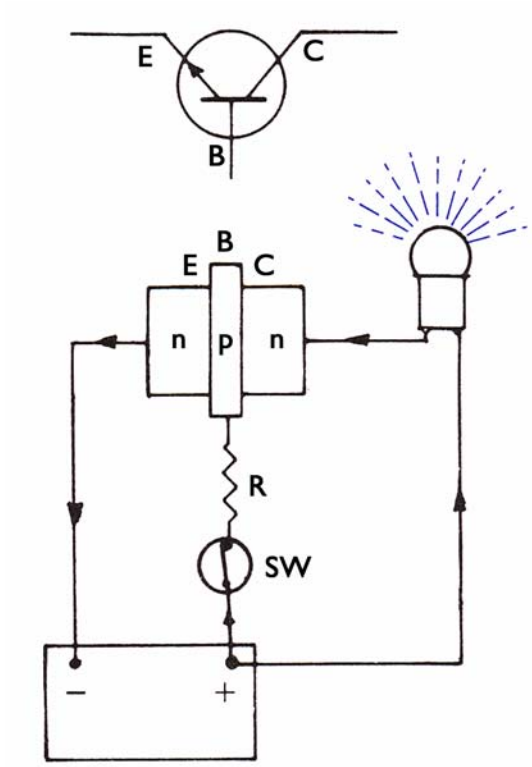

Figure 26 - Action of an n-p-n transistor; the transistor symbol is shown at the top of the diagram

A transistor works by using the base to control the current flow between the emitter and the collector. When the transistor is turned on current can flow in the direction of the arrow only. When the transistor is off current can't flow in either direction.

Base Paths

It's important to realise that the base leg of a bipolar transistor controls the flow of current. Although it accounts for only a small amount of the total current flow (typically around 2% of the total), it is current flow through the base that allows current to flow from emitter to collector.

PNP or NPN Transistors?

There is an easy way to identify the kind of transistor without thinking about the movement of electrons or electron holes. Just remember that the arrow always points towards the N material and away from the P material. So, for a PNP transistor, the arrow points inward towards the base. For a NPN transistor, the arrow points away from the base. In Caterpillar designed electrical circuits, NPN transistors are much more common than PNP.

TRANSISTOR OPERATION

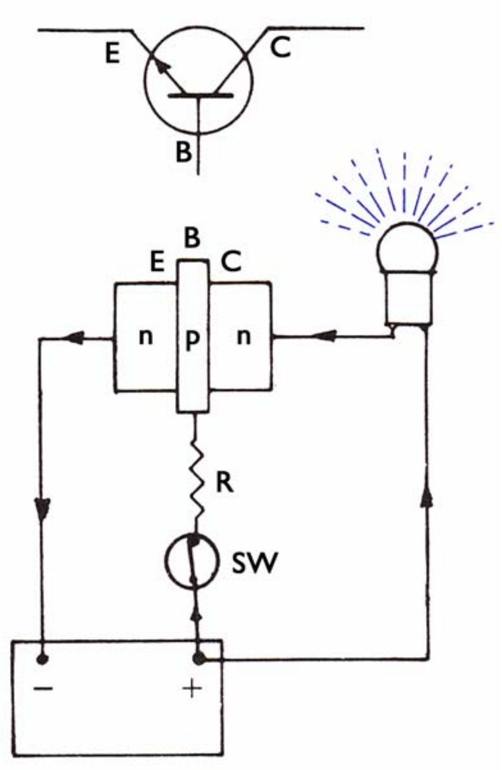

Figure 27 - Action of an n-p-n transistor;
the transistor symbol is shown at the top of the diagram

When trying to understand how a transistor functions in a specific circuit, there are two facts that must be remembered. First, a NPN transistor is turned on by applying voltage to the base leg, and turned off by removing voltage from the base leg. This is very similar to the operation of a relay, which is turned on and off by applying and removing voltage to the coil.

Second, the current through the base circuit is always much smaller than the current across the collector circuit. Changing the base current a little results in a big change in the collector current. The current through the emitter circuit is always the largest of all. In fact, the emitter current must be equal to the base current added to the collector current. Put another way, the current in the emitter circuit is split between the base circuit and the collector circuit.

