SWITCHES, FUSES, AND CIRCUIT BREAKERS

OBJECTIVES
On completion of this lesson, the student will have learned to:

1. Explain the purpose of a switch.

2. Identify the different types of switches and their schematic symbols.

3. Describe how the different types of switches are used in electronic and electrical circuits.

4. Identify a fuse and its schematic symbol and explain the purpose of fuses.

5. Identify a circuit breaker and its schematic symbol and explain the purpose of circuit breakers.

OVERVIEW
This lesson introduces students to switches, fuses, and circuit breakers.

Students first learn what switches are. They then learn why and how we use switches in electronic and electrical circuits.

The discussion next describes the different types of switches available. The lesson also explains the advantages and disadvantages of the different types of switches.

Students then learn the schematic symbols that represent the different switches.

Next, the lesson describes the construction of switches and explains how switches are rated both electrically and mechanically.

After explaining what electronic protective devices are, the lesson describes and discusses fuses and circuit breakers.

Students learn to identify these electronic protection devices and the schematic symbols that represent them.

PREREQUISITES
None

EQUIPMENT REQUIRED (OPTIONAL)
Nida Model 130E Test Console
Nida Series 130 Experiment Card
PC130-4A
INTRODUCTION

Did you ever see a radio, television, computer, or home appliance that didn’t have an ON/OFF switch? How about the lights in your house? What would you do if you couldn’t turn them on when you need them and turn them off when you don’t? Imagine the problems you’d have if your car had no switch to apply power to the starter when you wanted to go somewhere.

An essential requirement for any electrical or electronic circuit or system is having some way to turn it ON or OFF with the flick of the finger. Every piece of electronic equipment has a power ON/OFF switch, including the Nida Model 130E Test Console.

Understanding switches and their construction, functions, and operation is just as essential to an electronics technician as understanding all about resistors.

Have you ever read or heard about a house fire that started in the electrical wiring because someone slipped a penny behind a blown fuse in the fuse box instead of replacing the fuse? Or what about the fire that started when someone bypassed a circuit breaker because he was tired of its tripping all the time due to an overloaded circuit?

Another essential requirement for any electrical or electronic circuit or system is having some way to protect that system. Almost all electronic equipment has some kind of built-in protection device. The Nida Model 130E Test Console certainly does.

Understanding fuses and circuit breakers and their construction, electrical ratings, functions, and operation is just as essential to an electronics technician as understanding all about switches and resistors.

What are we waiting for? Let’s get started.

SWITCH

When you think of a switch, what picture comes to mind? Most of us picture some sort of mechanical device like a light switch or a push button. When we flip the switch or push the push button, something moves that turns the electricity on or off. We are visualizing a mechanical device, not an electronic device.

In reality, both mechanical and electronic switches are available today, and these switches come in a wide variety of types, shapes, and sizes. This lesson covers only the mechanical switches. You will learn about electronic switches later on in your training.

What is a switch? We can define a switch as a device that is used to open or close electrical current paths, thereby either stopping the current flow or allowing the current to flow in an electrical circuit or through an electrical component.

That’s a very long definition to remember, even though it is accurate. Here’s a shorter one.
**DEFINITION**

**SWITCH:** A mechanical or electrical device which makes or breaks an electrical circuit path.

The function a switch serves in an electrical circuit is very important. An ideal switch offers an open circuit when the switch is open and a short circuit when the switch is closed. What do we mean by open circuit and short circuit?

Let’s say we have an electrical circuit where the voltage source (Ea) is connected through a switch (S) to a load (L). This is basically the circuit you have in a simple flashlight.

Look at the schematic diagram of this circuit in Figure 1. The schematic diagram shows the switch in the open position.

You can see that with the switch open, Ea cannot deliver its electrical power to the load. If this circuit represents your flashlight, your flashlight would not light up because the switch is OFF.

With the switch OFF, switch (S) in the circuit is open, which breaks the conductive path. Thus electrical current (I) cannot flow from your battery (Ea) through the light bulb (L) to produce light from your flashlight. If you turn your flashlight switch ON, you close the switch in the circuit.

Look at the schematic diagram of the same circuit in Figure 2. Now the switch is in the closed position.

With the switch ON, switch (S) in the circuit is closed, which connects the conductive path. The electrical current (I) can now flow from the battery (Ea) through the light bulb (L) and you have light from your flashlight.

In the closed position, the switch is like a short circuit—a piece of conducting material. In the open position, the switch is like a broken conductor or a cut wire.

**SWITCH RATINGS**

When an engineer selects a switch for a particular use, he must consider the mechanical configuration and actions of the switch. He also must consider what electrical effects the switch produces during the switching action.
Electrically, the engineer is concerned about several things.

- How much current will flow through the circuit containing the switch?
- How high will the voltages be in the circuit containing the switch?
- Can the switch’s contact handle the in-rush of current during the switching action that opens and closes the circuit?

Because of problems such as these, we have several switch ratings to consider when selecting a switch. These switch ratings are:

1. **Current Rating**: The current rating is the most important one of the ratings. It is identified as a current level at a particular voltage, such as 6 amperes (A) at 125 volts (V) alternating current (AC), or 3 A at 250 VAC, or 6 A at 28 VAC.

   This specification indicates that the contact of the switch can carry the current specified at no greater voltage than specified. If the stated specifications are exceeded, the switch contacts could be damaged.

   Damage to the contacts could be such things as the contacts being permanently welded closed or the contact resistance increasing to an unacceptable value.

2. **Initial Contact Resistance**: This rating is the value of resistance across the closed contacts of the switch. Ideally, the value should be zero ohms. Some small resistance, however, can be expected.

   The rating might specify 10 milliohms maximum at 3 VDC, 100 mA. This means a resistance of 0.01 ohms maximum can be expected across the switch contacts while 0.1 amperes of current flow through the closed contacts.

3. **Insulation Resistance**: This resistance is what the switch looks like in terms of resistance when the switch is in the open position. A typical resistance is 10,000 megohms. This value is very high and for all practical purposes is considered as an open circuit.

4. **Dielectric Strength**: This rating, stated in volts, is a measure of how much potential difference (voltage) can be applied across the open contacts of the switch without a voltage breakdown. A voltage breakdown is when voltage jumps across the open switch contacts.

5. **Life Under Load**: This rating, the life expectancy rating of the switch, specifies how many times the switch can be activated (turned on and off) without failure. It might read 150,000 activations, which means you could turn the switch on and off 150,000 times without failure.

Electronics technicians, in most cases, do not have to worry about these ratings unless asked to replace a damaged switch with one of the different types. In that case, the ratings would have to be checked to be certain that the new switch has ratings equal to or higher than the old switch.

Mechanically, only one rating is of interest. This rating is the life under load or life expectancy rating (see 5 above).
COMMON SWITCH CIRCUITS

The wide variety of switches available differs mechanically, electrically, and in the arrangement of the switch contacts. Let’s look at the circuits of some of the more common switches.

Figure 3 is the schematic representation of Form A, the simplest, most common arrangement of switch contacts.

Figure 3. Form A: SPST-NO

What does all that mean? A single-pole switch is a single-circuit switch--it closes or opens only one circuit or current path. Notice that the single-pole switch in Figure 3 has only one moving arm and one stationary contact. These are characteristics that identify it as a single-throw switch. By saying the single-pole, single-throw switch in Figure 3 is a normally open switch, we mean that the normal position for the switch is in the open position.

The arm in the switch can be moved mechanically from the open position to the closed position. If the normal position for the switch contacts is in the closed position, the switch is a normally closed (NC) switch.

When we close the switch, we have the schematic representation shown in Figure 4.

Figure 4. Form B: SPST-NC

This switch is Form B, a single-pole, single-throw, normally closed switch--a SPST-NC switch.

Most switches, however, come with a three-terminal or contact arrangement. Look at the schematic representation in Figure 5.

Figure 5. Form C: SPDT

Here we see two stationary contacts and an arm which swings from one contact to the other.

This switch is the Form C arrangement, which is a single-pole, double-throw switch--a SPDT switch.

What’s a double-throw switch? It’s one in which the mechanical activator can throw the arm from one contact to another. As the switch is activated, the arm breaks contact with one terminal in order to make contact with the other terminal.

Even though the switch is a double-throw switch, it is still a single-pole switch. That’s because it still has only one arm and, therefore, can break or make only one current path at a time.
Exercise 1: SPST-NO, SPST-NC, and SPDT Switches.

Answer the following questions in reference to the schematic diagram in Figure 6. As you can see, we have a circuit with Ea (a battery) connected through switches S1, S2, and S3 to three lamps, L1, L2, and L3. S1 is a SPST-NO switch, S2 is a SPST-NC switch, and S3 is SPDT switch.

L1: YES            NO
L2: YES            NO
L3: YES            NO

2. Which lamps are lit if you activate switch S1?
   L1: YES            NO
   L2: YES            NO
   L3: YES            NO

3. Which lamps are lit if you activate switches S1 and S2?
   L1: YES            NO
   L2: YES            NO
   L3: YES            NO

4. Which lamps are lit if you activate switches S1, S2, and S3?
   L1: YES            NO
   L2: YES            NO
   L3: YES            NO
Look at the schematic representation in Figure 7. This is another very popular switch, the double-pole, double-throw switch--the DPDT switch.

![Diagram of DPDT switch]

This switch has two sets of SPDT contacts. The two SPDT contacts are ganged together so that one activator moves both arms simultaneously.

Notice the dotted line joining the two arms. This dotted line indicates that the two arms activate simultaneously and are part of one switch assembly.

This is a multipole (more than one pole) switch. Multipole switches can have two, three, four, or any number of poles.

Look at the schematic representation in Figure 8. This drawing shows an assembly of three sets of SPDT contacts ganged together--a 3PDT switch. Remember, the dotted line shows that the arms are mechanically connected together so that one activator moves all three arms simultaneously.

Specific multipole switches are named by the number of poles they have.

- Three-pole, double-throw: 3PDT
- Four-pole, double-throw: 4PDT

Single-throw switches can also be double-pole switches. These, too, are named by the number of poles they have.

- Double-pole, single throw: DPST
- Three-pole, single throw: 3PST

As stated above, multipole switches can have two, three, four, or any number of poles. Their names would follow the pattern shown above.

The switch contact arrangements just discussed (Form A, Form B, and Form C) are the ones most often used. Other arrangements, however, are available. Don’t be surprised if you see an arrangement you’ve never seen before. If you use common sense, you should have no trouble reasoning out how it works.

**TYPES OF SWITCHES**

You're probably familiar with a lot of the types of switches available today, such as toggle switches, push button switches, rotary switches, and slide switches. Each type of switch has been designed for a specific application. Each type of switch comes in hundreds of shapes and sizes; miniature, microminiature, and ultraminiature are not uncommon. Each type of switch has advantages and disadvantages. Here are some of the most popular types.
TOGGLE SWITCHES

The toggle switch is probably the most familiar switch. The activator of a toggle switch, the toggle, looks like a little bat. Most of the wall switches for the lights in our homes are toggle switches.

Even though you know that the voltmeter switch is a toggle switch, you can’t really tell what kind of toggle switch it is just from looking at it on the outside of the test console. If you were to look inside the test console, however, you would see that it is a DPDT switch.

If the test console is available, try activating the toggle switch to see how it feels. Notice that toggle switches have only two positions.

Some toggle switches are slightly different in their toggle action. They are three-position DPDT switches—ON/OFF/ON switches. Look at the schematic representation of a toggle switch in Figure 10.

Toggle switches usually come in the following arrangements.

- Single-pole, double-throw: SPDT
- Double-pole, double-throw: DPDT
- Four-pole, double-throw: 4PDT
Toggle switches are usually very reliable. They also are usually very small. Depending upon their size, they have the capability of switching circuits carrying current up to 25 A.

We use toggle switches for power ON/OFF applications where we need to make or break one or two separate circuits. You will notice that many times SPDT switches are used even though a simple SPST action is required. When this is the case, the switch wiring can be like any one of the three shown in Figure 11.

![Figure 11A. Switch Wiring of SPDT Switches Used as SPST Switches](image)

Notice that the unneeded terminal is left without being connected in the circuit, as shown in Figure 11A. Another way is to show the circuit with the arm contact shorted out, as shown in Figure 11B.

Figure 11C shows the switch as it would normally appear on a schematic diagram: as a SPST switch. That’s because, schematically, you do not have to physically show what contacts the switch has or how they are wired. All you need to show is the function the switch performs. As Figure 11C shows, the switch functions as a single-pole, single-throw switch.

**ROTARY SWITCHES**

A rotary switch is used primarily as a selector switch. Rotary switches are also very popular, and you’ve undoubtedly used them many times, even though perhaps you didn’t know they were rotary switches. Older television sets, for instance, were provided with rotary channel selector switches.

Rotary switches serve a very important function in electronics. That’s because they can be designed in many different ways, which lets the design engineer choose from many options for performing a switching operation. Rotary switches can have as many poles as you want; ten or twelve poles are not at all uncommon. They can have as many positions as is mechanically feasible, too. Twenty-four positions are not uncommon.

Look at the selection of rotary switches in Figure 12. The switches are usually made up of sections—wafers or decks, stacked like a sandwich.
Each section is mounted on a metallic shaft which, when turned, moves a wiper or arm on that section. As the shaft turns, the wipers break and make contacts in a circuit.

Figure 13 shows two typical contact arrangements for a two-pole, six-position rotary switch. Figure 13A shows a switch with nonshorting contacts, or make-and-break contacts. When you activate this switch, the arm breaks contact with the terminal it is shorted to before making contact with the next switch terminal. In other words, it breaks before it makes the contact.

Figure 13B shows a switch with shorting contacts, or make-before-break contacts. As you can see, the drawing shows the shape of the wiper arm. This indicates whether the switch contacts are shorting or nonshorting. When you activate or rotate this switch, the arm first makes contact with the next switch terminal before it breaks contact with the one it was shorted to before being activated. In other words, it makes before it breaks the contact.

Look at the drawing of a two-position switch in Figure 14. This drawing shows how the make-and-break contacts work.

In Figure 14A, you see the switch before rotation starts. In Figure 14B, you see rotation taking place. Contact 1 shorts (makes) to contact 2. In Figure 14C, you see the final position when rotation is finished. Contacts 1 and 2 no longer connect—they break.
PUSH BUTTON SWITCHES

Push Button switches also are available in a wide variety. These switches come in various combinations of contacts, in many sizes and shapes, and often in ganged configurations. A selection of push button switches is shown in Figure 15.

The test console has many kinds of push button switches.

Some push button switches are alternate action with an indicator, push-ON/push-OFF switches. This type of switch is usually a DPDT switch where one set of contacts makes and breaks the incoming power line, while a second set of contacts applies the internal power to the lamp that illuminates the switch.

Some push button switches are momentary, that is, the switch is spring-activated, and its contacts open or close only during the time that the button is depressed. As soon as the force on the button is removed, the switch returns to its original position.

As you can see, Figure 16 is a schematic representation of a momentary push button switch, both normally open and normally closed.

Push Button switches are used primarily for control applications on the front panels of instruments or other electronic equipment.
SLIDE SWITCHES

The slide switch is also a very popular mechanical device. Normally, slide switches are used on instruments directly mounted on printed circuit boards where material costs must be kept low.

Most slide switches are of very simple construction, being mass produced from plastic parts. Figure 17 shows the contact arrangements for three different slide switches. Notice that Figures 17A and 17B show the arm or common terminal in the middle. The common terminal in Figure 17C is not as apparent.

Figure 17. Slide Switch Contact Arrangements

Take a look at experiment card PC130-4A, if it is available. This card has a slide switch mounted on it. The contact arrangement of this switch is the same as that shown in Figure 17B. Examples of slide switches are found on many of the Nida experiment cards.

Exercise 2: Slide Switches.

You need a single-pole, three position switch. You have the switch pictured in Figure 17C. How would you wire this switch to get the circuit of the switch shown in Figure 18A? Draw the connections on the switch in Figure 18B.

ROCKER SWITCHES

The activator for a rocker switch, as you might well image, is a rocker. To activate rocker switches, you push down on one side of the rocker. As that side goes down, the other side pops up. A selection of rocker switches is pictured in Figure 19.
Many appliances use rocker switches. Often, the switches are illuminated. These switches, however, are not very popular in the electronics industry.

You will sometimes find the rocker portion of a rocker switch mounted on a slide switch. The mechanical design is such that the low-cost slide switch is converted to a rocker switch. This design gives you the convenience of a push button switch at low cost.

**LEVER SWITCHES**

A lever switch mounted on the front panel of an instrument looks just like a toggle switch. That’s because a lever looks like a toggle.

Some lever switches are spring activated, allowing for one of the positions to be momentary. You depress the lever to make contact, but as soon as you release the lever, it springs back to its original position.

Lever switches were popular during the days of manually operated telephone exchanges. These switches are seldom found in modern electronic equipment.

**SNAP-ACTION SWITCHES**

Snap-action switches are quite different in their application from the ones we have discussed so far. A snap-action switch is not activated by a person physically touching it. Instead, these switches are activated by some part of a machine or mechanical arm or gear.

Snap-action switches are sometimes called limit switches. A selection of these switches is shown in Figure 20.

Snap-action switches are often mounted inside equipment as safety switches. For instance, the switch could be mounted so that it removes power from a unit if someone opens the back panel, exposing dangerous voltages.

Sometimes a snap-action switch is mounted on a machine where movement of certain parts must be detected. They are also mounted in such a way that when the mechanical activator of the switch is touched, the switch turns on a lamp or an event counter. This gives the user an indication of the part making contact with the switch.
OTHER SWITCHES

This discussion has not covered all the types of switches available today. The electronics industry uses many other kinds of switches, such as DIP switches, key lock switches, and knife switches.

As you progress through your training, you will see switches that are unfamiliar to you. Reasonable explanations of the switches will be given to acquaint you at that time. For now, however, you already have a good idea of what switches can do for you and how best to use these switches.

CIRCUIT PROTECTIVE DEVICES

Circuit protective devices protect both you and your equipment from electrical damage. What are protective devices? How do they protect you?

Imagine you are working on electrical equipment which contains dangerous high voltages. The design of the equipment is such that it is possible for you to accidentally touch some of the dangerous parts. The design of the equipment, therefore, should also include circuit protective devices.

While working on this electrical equipment, you accidentally touch a part of an electrical circuit which causes a current to flow through your body. The protective device built into the circuit quickly senses the increase in current drain in the system. It immediately shuts down the circuit. The fast shutdown limits the time you are exposed to the electrical shock. Because of this, you avoid injury or the possibility of death.

Protective devices also protect the electrical equipment from damage. For instance, while you are working on electrical equipment which contains dangerous high voltages, a component in the system unexpectedly fails. The failed component causes an electrical short. Perhaps instead of component failure, you drop or spill something across active circuit components. This also might cause an electrical short.

A shorted circuit in an electrical system can cause excessive current to flow through some of the components in the system. These components heat up and eventually burn up, perhaps destroying the whole electrical system. You're fortunate, though, for an inexpensive built-in protective device quickly senses the short-circuit condition. The device immediately shuts down the entire system before any components burn up. Your equipment has not been damaged.

We use two types of protective devices in the electronics industry: fuses and circuit breakers. These two types of devices are different, but the principle of their operation is the same, and they produce the same results. They protect you and/or your equipment.

FUSES

A fuse is the simplest and least expensive circuit protective device available. A fuse is a metallic component which is placed within an electrical circuit to monitor the electrical current that passes through it. The schematic representation of a fuse is shown in Figure 21.
If the level of current in a protected circuit becomes excessive, the metal part of the fuse heats up and melts, opening the electrical circuit the fuse is protecting. We say that the fuse opens, blows, or pops. No matter how you say it, the blown fuse opens the circuit which, of course, immediately stops the flow of current.

Look at the drawing of the fuses in Figure 22. These fuses are typical of those which are used in electronic instruments and equipment.

You’ve undoubtedly seen similar fuses in the electrical circuits of your car.

Perhaps you’ve even had one of your fuses unexpectedly go bad. As a result, you suddenly found yourself with no headlights, brake lights, or windshield wipers, for example.

Fuses are usually housed in fuse holders. Three types of holders are shown in Figure 23. The Nida Model 130E Test Console has one fuse in a fuse holder on its rear panel.

Look at your test console and find the fuse.

To remove the fuse, push in on the fuse holder cap and then turn it counterclockwise. Do not force it.

If you have trouble removing the fuse holder, call your instructor.

You’ve just learned that switches have what we call ratings. Fuses also have ratings. The most important one is the current rating, which is stated in amperes. The amperage value is marked on every fuse. This amperage value is the maximum current level that the fuse can carry.

If you use a fuse with too high a rating for the circuit it is protecting, the fuse cannot protect the circuit. In this case, a short would damage the circuit before blowing the fuse. If you use a fuse with too low a rating for the circuit, the fuse will blow even under normal operating conditions.

In addition to ratings, we have two categories of fuses: fast-acting fuses and slow-blow fuses. A fast-acting fuse blows within about one second after it senses an overload condition. A slow-blow fuse blows between one and thirty seconds after it senses an overload condition, depending on the amount of the overload.
If you have a very delicate circuit with a steady current flowing through it, a fast-acting fuse is the correct fuse to use. If you have a circuit with excessive inrush current or other momentary normal rushes of current, then a slow-blow fuse is the correct fuse to use. That’s because the slow-blow fuse would not blow prematurely when power is applied to the circuit or during some normal transient peak current condition.

When a fuse blows, it is destroyed. It cannot be reused; it must be replaced. Fortunately, the cost of fuses is relatively low.

If you replace a slow-blow fuse with a fast-acting fuse in a circuit that calls for a slow-blow fuse, the fuse probably will keep blowing. In this case, replacing fuses can be very costly and irritating.

Any time you have a fuse that repeatedly blows, you should check the type of fuse and its rating. Perhaps the rating or type of fuse should be changed or the circuit and its use should be analyzed to be sure that circuit design and operation are correct. A better solution might even be to replace the fuse with a circuit breaker.

**CIRCUIT BREAKERS**

A circuit breaker is really two things in one: a switch and an indestructible fuse. The function of a circuit breaker is the same as that of a fuse.

![Circuit Breakers](image)

With a push button-type circuit breaker, the button pops out when the circuit breaker is tripped, which opens the circuit. To reset the circuit breaker, you push the button back in.

With a toggle-type circuit breaker, the toggle of the circuit breaker automatically drops to the OFF position, indicating that the breaker has tripped and the circuit is open. After the circuit problem has been rectified, you reset the circuit breaker by flipping the toggle back to its ON position.

Each of the two types of circuit breakers can be either magnetic or thermal. The drawing in Figure 25 is the schematic representation of a magnetic circuit breaker, which works on the principle of magnetism.
The current flowing through the circuit passes through a coil in the circuit breaker housing. As the current flows, it develops a magnetic field.

The strength of the magnetic field depends on the amount of current that flows through the circuit and the coil. If the current exceeds the rating of the breaker, the magnetic field becomes strong enough to produce a force to trip the breaker action. This separates the switch contacts, thus opening the circuit.

Magnetic circuit breakers are very common in the electrical field, especially in house wiring circuits. You probably have them in your home.

Thermal circuit breakers operate on the principle of temperature rise in the activator’s sensing element. This sensor is usually a bimetallic element which heats up when the current flows through the element. The size, physical shape, and electrical resistivity of the thermal element are what determines the current capacity of the circuit breaker.

Thermal circuit breakers are not as convenient to use as magnetic circuit breakers are. A thermal circuit breaker must cool off before you can reset it. In addition, ambient temperatures affect the trip point. Thus a thermal circuit breaker will require more current and take a longer time to trip in a very cold environment than it will in a hot environment.

Circuit breakers are many times more expensive than fuses. Circuit breakers, however, are more convenient, in that you can see at a quick glance if it is tripped and if it is, reset it with the push of a button or the flick of a finger. This convenience is what makes circuit breakers more popular than fuses.

SUMMARY

You have learned a lot of things about switches, fuses, and circuit breakers in this lesson. Here’s a summary of the important points you should remember about them.

- A switch is a mechanical device used to open or close electrical current paths.

- The ideal switch offers an open circuit when it is in the open position and a short circuit when it is in the closed position.

- The current rating, indicating how much current the switch can make or break without damage, is the most important electrical rating of a switch.

- The life expectancy rating, indicating how many times a switch can be activated without failure, is the most important mechanical rating of a switch.

- A single-pole switch is a single circuit switch which can open or close only one circuit or current path.
- Toggle switches, which are the most popular switches, come in SPDT, DPDT, and 4PDT contact arrangements.

- Rotary switches, used primarily as selector switches, can have up to 24 positions and as many poles as required.

- Illuminated alternate action push button switches are very popular as power application switches.

- Slide switches are generally low-cost devices very seldom used on front panels.

- Snap-action switches, primarily used in industrial applications, are activated by mechanical devices instead of by human touch.

- Fuses are low-cost metallic protective devices which heat up, melt, and are destroyed when subjected to overload conditions.

- Fast-acting fuses blow within one second of an overload condition.

- Slow-blow fuses blow within one to thirty seconds of an overload condition, depending on the amount of the overload.

- Circuit breakers are indestructible fuses which open or trip a circuit when they sense an overload condition.

- Thermal circuit breakers react to an increase in temperature resulting from an overload condition.

- Magnetic circuit breakers are activated by a magnetic force developed by the load current flowing through the circuit breaker coil.