ECET 3000

Electrical Principles

Switches, Pushbuttons & Relays

Simple Switch

A simple <u>switch</u> (single pole, single throw) is an electrical device that can either “make” or “break” an electrical circuit.

I.e. – it can either allow current flow from one conductor to another (make a circuit) or stop current flow from one conductor to another (break a circuit).

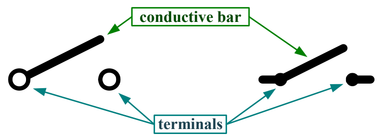
The number of “poles” is the number of electrically separate switches which are controlled by a single physical actuator.

The number of “throws” is the number of separate wiring paths (other than “open”) that the switch can adopt for each pole.

Simple Switch

The following symbols are often used to depict a simple (SPST) switch in an electric circuit:

Note that both switches are shown in their "open" or "off" positions.



Single Pole, Single Throw ≡ SPST

When in the "open" (OFF) position, current cannot flow through the switch due to an air gap between the switch terminals.

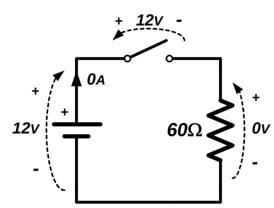
But, in the "closed" (ON) position, a conductive bar connects the terminals, allowing current to flow through the switch.

"open" "closed"

Simple Switch

The following circuit contains a simple (SPST) switch:

By solving a KVL equation, it can be seen that a 12-volt potential will appear across the switch terminals.



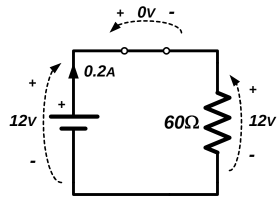
If no current flows through the resistor, then a 0-volt potential will be present across the resistor.

When the switch is in the "open" (OFF) position, it prevents the flow of current from the source to the resistor.

Note that, when in the "open" position, a voltage may appear across the switch terminals. Thus, care must be taken when selecting a switch to be sure that it has a <u>voltage rating</u> that is greater than the maximum voltage that will appear across its terminals when in use.

Simple Switch

The following circuit contains a simple (SPST) switch:



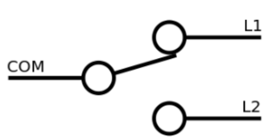
A "closed" switch is equivalent to an idea wire.

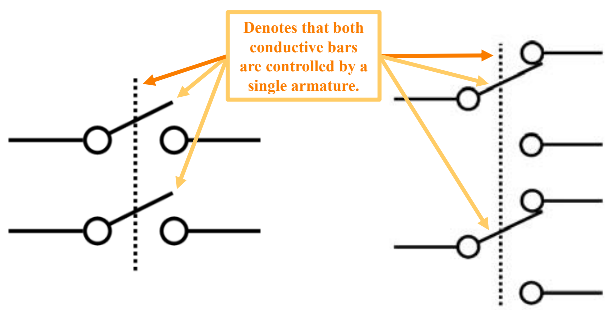
When the switch is in the "closed" (ON) position, current can flow through the switch (provided a closed-loop path exists).

When transitioning from the "closed" to "open", an arc may occur as the switch "breaks" the current. Although switches are designed to mitigate the damaging effects of this arc, care must also be taken when selecting a switch to be sure that it has a current rating that is greater than the maximum current that will flow through the switch when in use.

Other Switches

There are many other switch configurations, including:





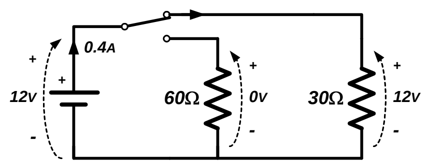
Single Pole, Double Throw SPDT

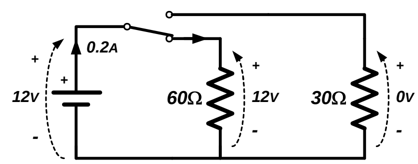
Double Pole, Single Throw DPST

Double Pole, Double Throw DPDT

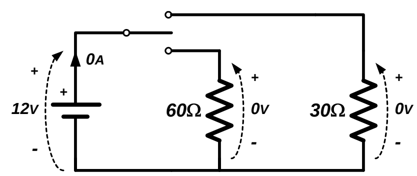
SPDT Switches

The SPDT switch in the following circuit allows the user to select which resistor is supplied by the source:



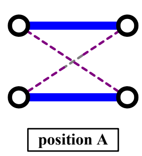


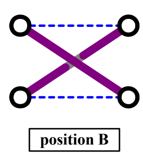
Note that some SPDT switches have a stable "OFF" position in the center in which no current flows through the switch.



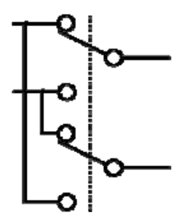
Four-Way Switch

A four-way switch is a two-position switch that allows the polarity of a pair of wires to be reversed:





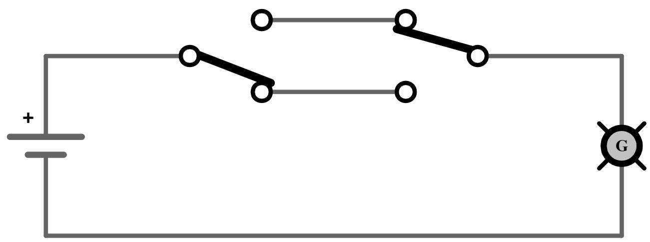
Note that a four-way switch is actually a DPDT switch that is internally wired as shown to the right:



Multiply-Switched Circuits

What if there are two entrances to a room, and you want a switch at both entrances, either of which has the ability to turn-ON or turn-OFF the lights in the room?

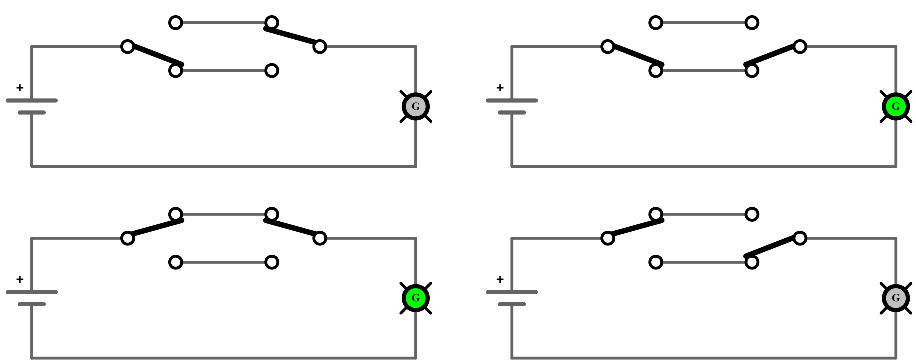
This task can be accomplished by utilizing two SPDT switches:



Multiply-Switched Circuits

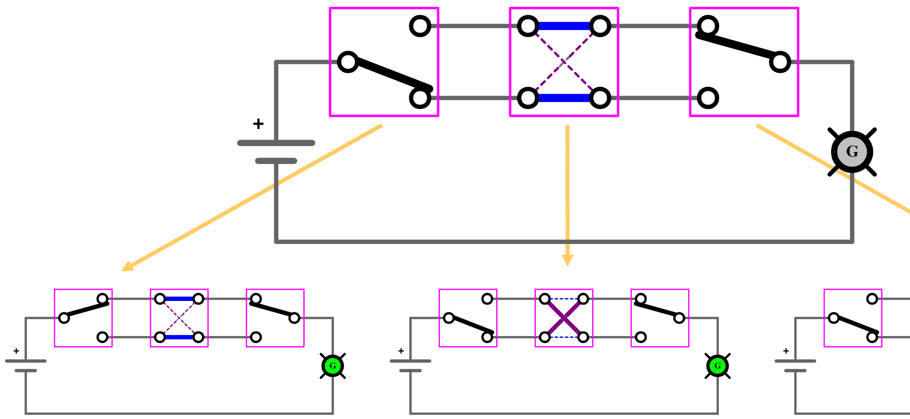
If the light is OFF, flipping either switch will turn the light ON.

If the light is ON, flipping either switch will turn the light OFF.



Multiply-Switched Circuits

If more than two switches are desired, four-way switches can be added between the SPDT switches as follows:



Flipping any switch will turn the light on.

Push-Buttons

A **push-button** is a momentary contact device that contains one or more sets of contacts which actuate when the button is pressed and return back to their “normal” position when the button is released.

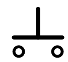
Contacts – Two (or more) pieces of conductive material that are pressed together to complete (close) and pulled apart to break (open) an externally-connected circuit.

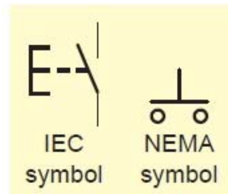
Contacts are said to be “closed” when current can flow from one to the other.

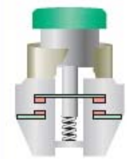
Push-Buttons

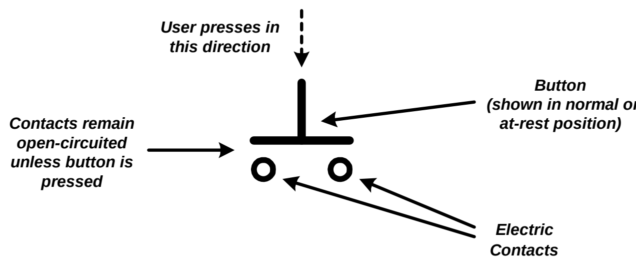
Types of Push-Buttons

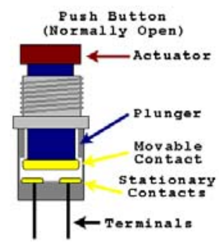
Normally Open (NO)







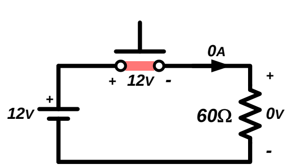




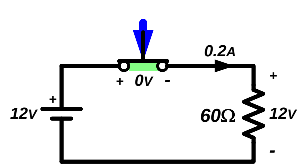
Normally-Open (NO) Push-Buttons

When a normally-open push-button is in its "normal" position, it prevents current from flowing between its terminals.

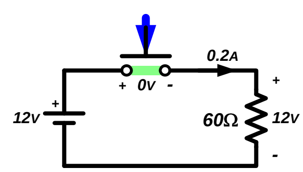
When the NO push-button is "pressed" or "actuated", a conductive bar connects the terminals, allowing current to flow between its terminals.



"open"



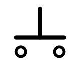
"closed"

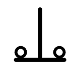


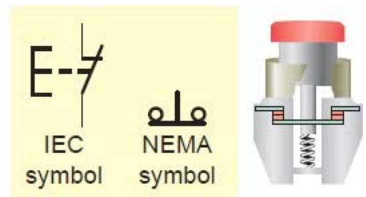
Note that push-buttons are often shown in their "normal" positions whether or not they are being pressed.

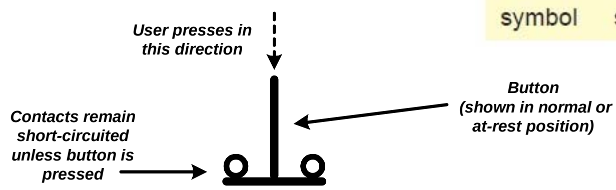
Push-Buttons

<u>Types of Push-Buttons</u>

Normally Open (NO) 

Normally Closed (NC) 

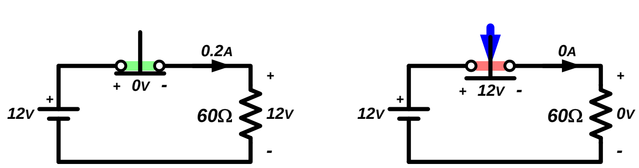




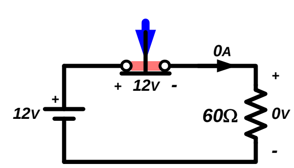
Normally-Closed (NC) Push-Buttons

When a normally-closed push-button is in its "normal" position, it allows current to flow between its terminals.

When the NC push-button is "pressed" or "actuated", a conductive bar is separated from the terminals, preventing current from flowing between its terminals.

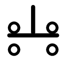


"closed" "open"



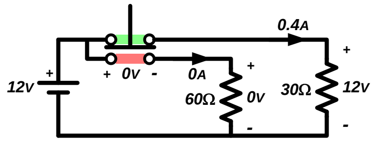
Note that push-buttons are often shown in their "normal" positions whether or not they are being pressed.

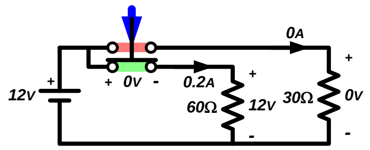
Combination Push-Buttons

Combination push-buttons contain both NO and NC contacts. 

When in its "normal" position, a combination push-button allows current to flow between its NC terminals but prevents current from flowing between its NO terminals.

When the combination push-button is "pressed" or "actuated", the conductive bar changes position, preventing current from flowing between the NC terminals and allowing current to flow between its NO terminals.





Relays

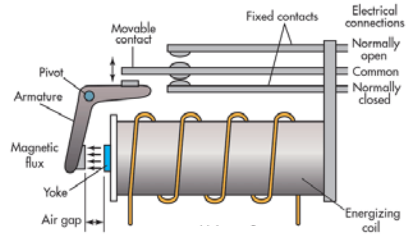
Relay

- A device that contains one or more sets of electrically-controlled contacts (NO and/or NC).
- Often used when circuits need to be switched remotely, when multiple circuits need to be switched simultaneously, or when the switched circuits need to operate at a different voltages.
- May be AC or DC controlled.

Relays

Electro-Mechanical Relays

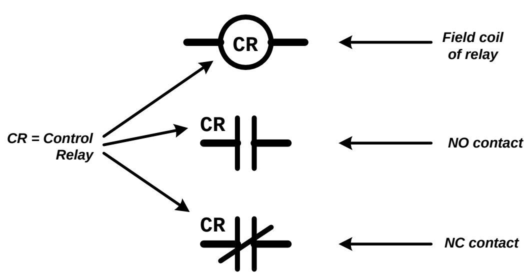
- An electro-magnet, consisting of a field coil wrapped around a ferromagnetic core, is used to actuate the contacts from their normal states.
- When the coil is energized, it creates a magnetic field, attracting a movable armature and actuating the contacts.
- When the field coil is de-energized, the armature is released and the contacts drop out (return to normal).

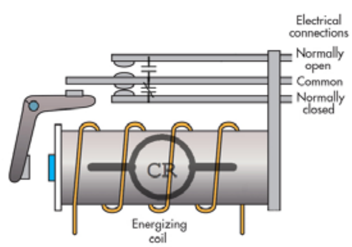


Note that this presentation will not cover solid-state relays.

Relays

The following symbols are used to depict the various components of a relay within an electrical diagram:

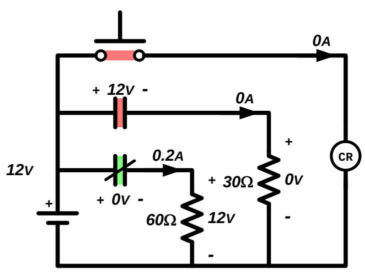


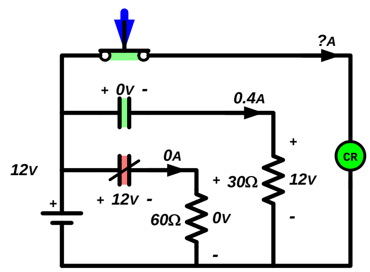


Relay Operation

When the field coil is de-energized, the relay's contacts are in their "normal" positions.

When the field coil is energized, the relay's contacts actuate, similar to a push-button that is being pressed.





The amount of current that will flow into the field coil is based upon the resistance of the field coil.

Fuses

A <u>fuse</u> is a protective device that can be placed in series with a circuit conductor in order to limit the conductor current to a safe level.

A fuse can only interrupt current flow one time, after which the fuse (or the fusible link) must be replaced.

Fuse Operation

A fuse consists of a <u>fusible link</u> (metal strip or wire) that is encapsulated in a non-conductive housing. The link is designed such that it will melt when the current flowing through the fuse exceeds a prescribed value.

During normal operation, the link simply acts as a part of the conductive circuit. But, when an overcurrent occurs, the link melts and open-circuits the conductive path in order to prevent any further damage to the distribution system.

Fuse Ratings

Fuses are characterized by several different criteria, including:

- the <u>current rating</u> of the fuse
- the <u>interrupting rating</u> of the fuse
- the <u>voltage rating</u> of the fuse
- the <u>time-delay</u> or rate at which the fuse operate

The may also be characterized by:

- the circuit/load type for which they are intended (AC, DC, lighting, motor, etc.)
- their performance (current limiting ability, etc.)
- their physical construction

Current Rating of a Fuse

The <u>Current Rating</u> of a fuse provides the maximum current magnitude that may continuously flow through the fuse without the fuse "blowing" (melting).

For example: A 30A fuse will <u>theoretically</u> "blow" if subjected to a current over 30 amps.

Note that the above statement <u>may or may not</u> hold true depending on the specific type of fuse, the actual magnitude of the current (above 30A), and the duration of the current flow exceeding 30A.

Interrupting Rating of a Fuse

A fuse's <u>Interrupting Rating</u> (IR) defines the maximum current magnitude that the fuse can safely interrupt.

Fuses must be chosen such that their IR not less than the available short-circuit current at their location.

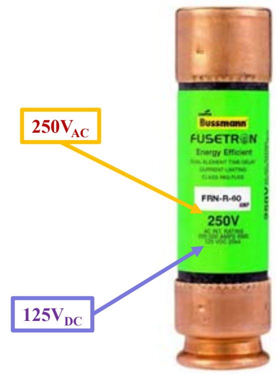
Note that fuses may have different IR values for AC and DC systems.

Voltage Rating of a Fuse

A fuse's <u>Voltage Rating</u> defines the maximum operational voltage of the system in which the fuse can be applied.

For example: A fuse with a 600V_{AC} rating is suitable for use in AC systems having an operational voltage that is less than 600 volts.

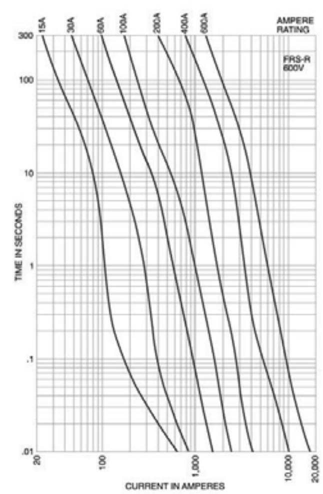
Note that fuses may have different voltage ratings for AC and DC systems.



Fuse Time-Current Curves

A <u>Time-Current Curve</u>, also referred to as an <u>I^2t curve</u>, defines the rate at which a fuse will operate as a function of the current magnitude flowing through the fuse.

The, the speed at which a fuses operates or "blows" depends on both the magnitude of the current and the rating of the fuse.

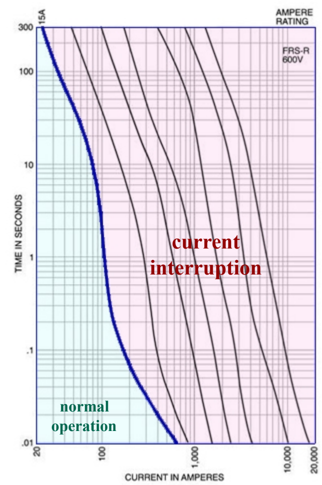


Fuse Time-Current Curves

Operation in the area to the left of any curve defines normal operation (both continuous and transient current flow), while operation in the area to the right of any curve will result in current interruption.

(i.e. – a blown fuse)

Note – the regions for normal operation and for current interruption are highlighted for the 15A fuse.

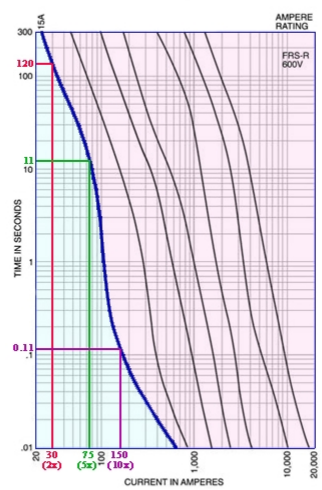


Fuse Time-Current Curves

For example:

The 15A fuse whose time-curve is shown to the right will:

- **blow in 120 seconds for a 30A steady-state circuit current**
- **blow in 11 seconds for a 75A steady-state circuit current**
- **blow in 0.11 seconds for a 150A steady-state circuit current**



Circuit Breakers

A <u>circuit breaker</u> is a switched device that is also provides protection against overcurrents.

When switched on, the occurrence of an overcurrent will cause the circuit-breaker to automatically change to a tripped (off) state.

But, unlike a fuse, the circuit breaker can be reset after operation, allowing it to operate again without replacement.

Circuit Breaker Operation

<u>Magnetic</u> circuit breakers rely on the magnetic pull force created by a solenoid to release a latch, allowing a spring to open a set of electric contacts, thereby interrupting the current flowing in a circuit.

<u>Thermal</u> circuit breakers rely on the heating and bending of a bimetal strip to due to release a latch and allow a spring to open a set of electric contacts.

Note that circuit breakers can be constructed such that they incorporate both techniques; using the magnetic mechanism to provide a quick response to large (short-circuit) currents, and using the thermal mechanism to provide a time-delayed response to lesser currents (overloads).

Circuit Breaker Configuration

Circuit breakers are produced in a variety of different configurations:

- **Single-pole circuit breakers operate based upon the current flowing in a single conductor & protect only that conductor**
- **Multi-pole circuit breakers protect multiple conductors simultaneously; if any one of the protected conductor currents exceed their rated values, the circuit breaker will operation (trip) and disconnect all of the circuit conductors from their source of power**

Circuit Breakers Ratings

Circuit breakers are primarily characterized by:

- **their current rating**
- **their current interrupting ability**
- **their operational system voltage**

Although they also operate based on a time curve, they may also be adjustable, allowing a user to tailor their operation to a specific need.

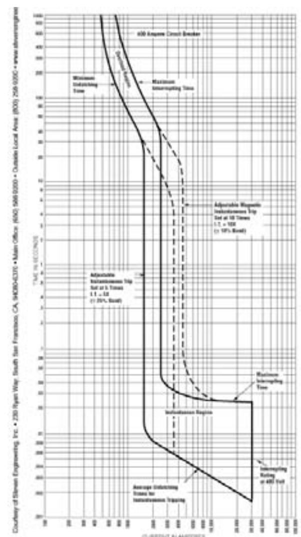


Figure 4. Typical Circuit Breaker Time-Current Characteristic Curve