SWITCH TRAINING MANUAL

Commercial Controls Division

EATON

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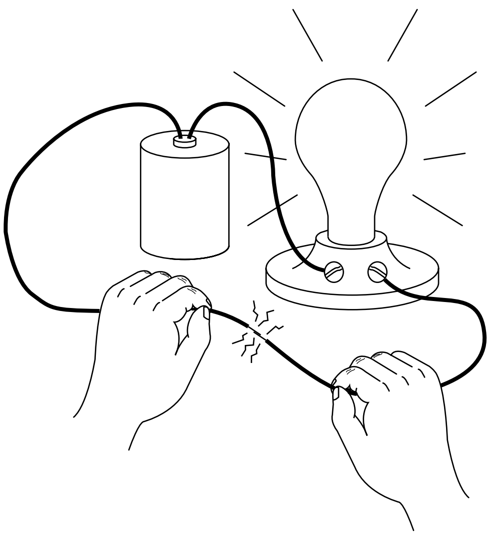
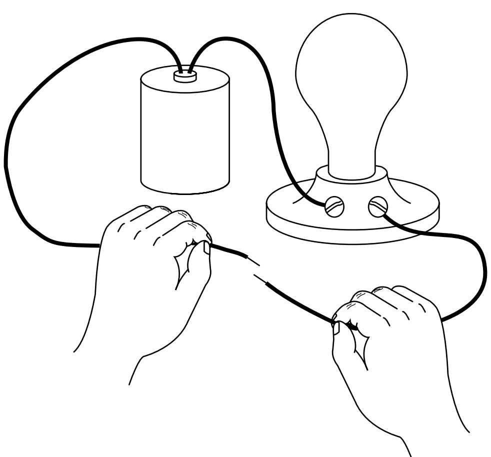
SWITCH FUNDAMENTALS

INTRODUCTION

An electrical switch is a device for making or breaking an electrical circuit. The definition suggests the ultimate in simplicity — that a switch need be no more than the bare ends of two wires that can be touched to make circuit or separated to break circuit. (See figures below.)



ON (Make)



OFF (Break)

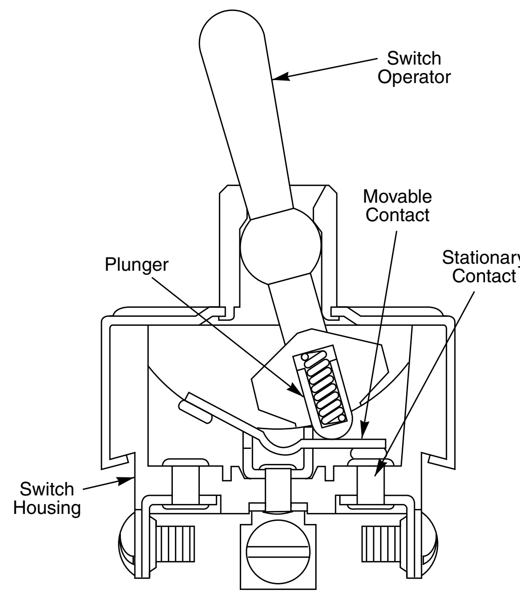
The fact that a switch is nothing more than a device for making or breaking a circuit might suggest that the technology is equally simple. Far from it! The design of modern switches calls upon advanced knowledge in such areas as vibration analysis, metallurgy and polymer chemistry. However, this manual is not concerned with the technical complexities that face the designer.

It is concerned with providing the basics of switches, the fundamental facts that will provide a good working knowledge of switches.

ANATOMY OF A SWITCH

Although there are relatively few switch mechanisms, the number of switch varieties extends into the thousands. The reason: Each switch mechanism heads up its own family of switches. As a result, Eaton Commercial Controls Division manufactures some 25,000 different basic switches, which results in over a million specific combinations.

Despite the great number of switches, these devices have a common denominator in basic components, i.e., the operator which initiates switch operation; the contacts, low-resistance metal, that make or break the electrical circuit; and the switch mechanism which is linked to the operator and opens and closes the contacts.

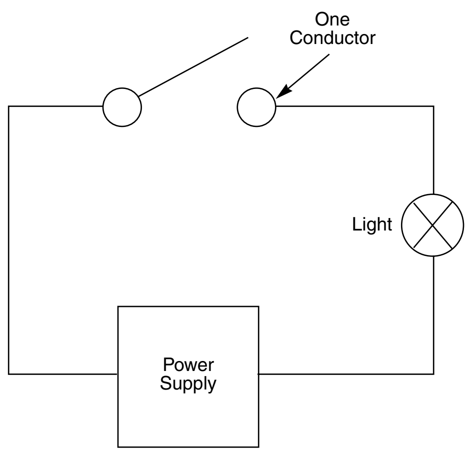


AC Toggle Switch

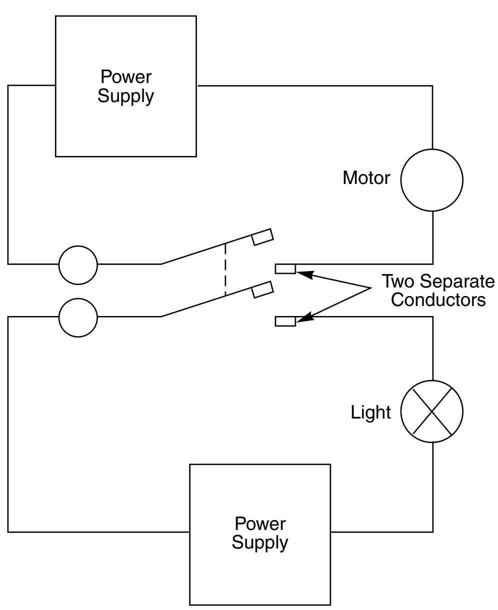
Functional Design

Three major terms designate a switch's function — POLE, THROW, and BREAK.

The term POLE refers to the number of circuits that can be controlled by the switch. In the example below, the single-pole switch is capable of interrupting the current in a single circuit. A double-pole switch, on the other hand, is capable of simultaneously interrupting the current in two separate circuits.

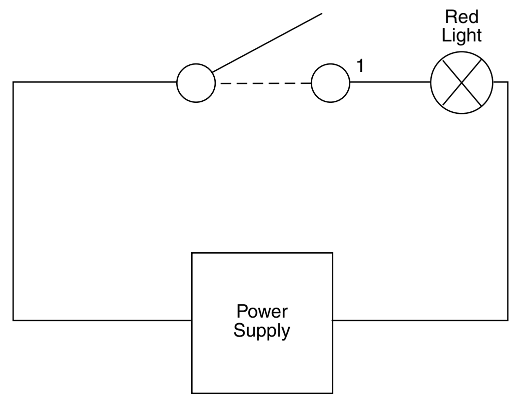


Single-Pole Switch Interrupts One Conductor

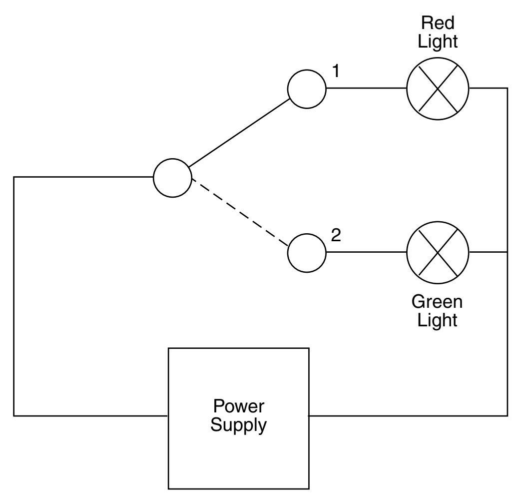


Double-Pole Switch Simultaneously Interrupts Two Conductors in Separate Circuits

The term THROW indicates the number of conductors or paths the switch can control. In the example below, the movable contact member of the single-throw switch completes a circuit to only one conductor. However, a circuit to a double-throw switch permits its movable contact element to alternately complete two different paths.



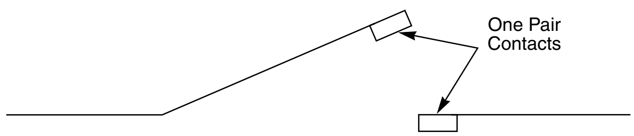
Single-Throw Switch



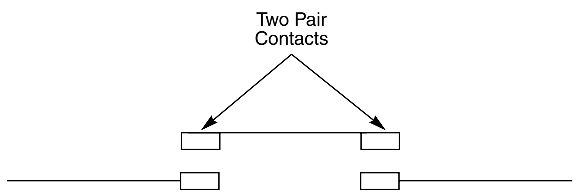
Double-Throw Switch Has Two Positions to Control Either the Red or Green Light

The term POSITION refers to the number of stops the switch actuator will make when moved from one extreme position to the opposite position. For example, an ON-NONE-OFF is a two POSITION switch and an ON-OFF-ON is a three POSITION switch.

The term BREAK is self-explanatory. It refers to the breaking or opening of a circuit. For example, single-break means that the contacts are separated at only one place. A double-break switch has two pairs of contacts that open the circuit at two places.



Single-Break



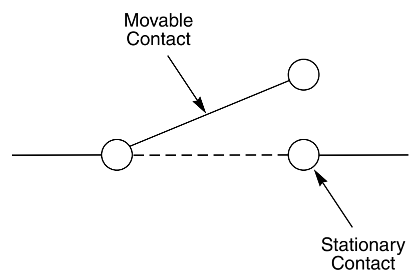
Double-Break

What might be the reason for having a double-break switch? A double-break switch provides greater volume of contact material, permitting greater heat dissipation and thereby longer switch life. The double-break switch also has twice the voltage breaking capacity, a desirable feature for DC circuit applications.

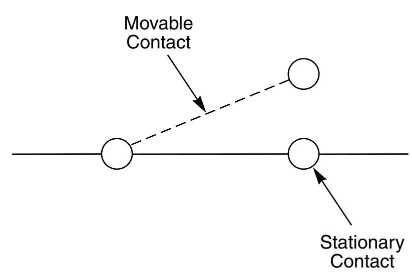
Normally Open or Normally Closed

The terms NORMALLY OPEN and NORMALLY CLOSED refer to the physical position of the contacts in reference to each other. In a normally open switch, the contacts are separated or open; thus the circuit is open and no current can flow through the switch. Typical is a pushbutton switch where depressing the pushbutton causes the contact element to move to the other of its extreme positions and close the circuit.

In a normally closed switch, the contacts are closed, thereby making electrical contact and electrical circuit. Operation of the switch causes the contact element to move and open the circuit.



**Normally Open (NO) Switch
(Off Circuit)**

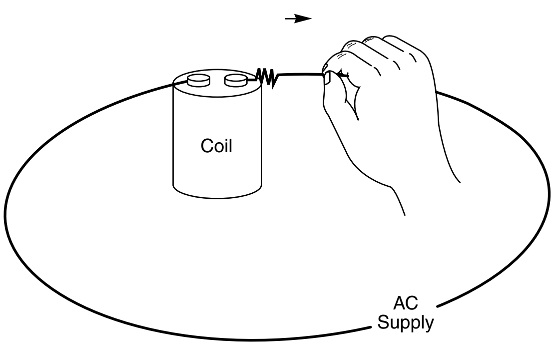


**Normally Closed (NC) Switch
(On Circuit)**

Slow or Quick-Break?

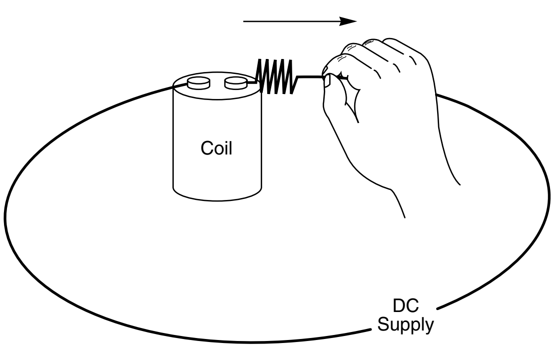
Should switch contacts be broken slowly or quickly? It all depends on whether the electricity is AC or DC. This may appear odd since electricity is electricity. One electron is no different from another. True. But because AC varies in magnitude and direction while DC maintains a steady unidirectional flow, an interesting phenomenon exhibits itself when AC and DC circuits are broken.

Consider an AC and a DC circuit, each carrying the same amperage. When we slowly break the AC circuit, the spark is extinguished quickly — a desirable condition. But when we slowly break the DC circuit, the spark can be drawn much longer before it is extinguished — an undesirable condition.



AC = Small, Weak Spark

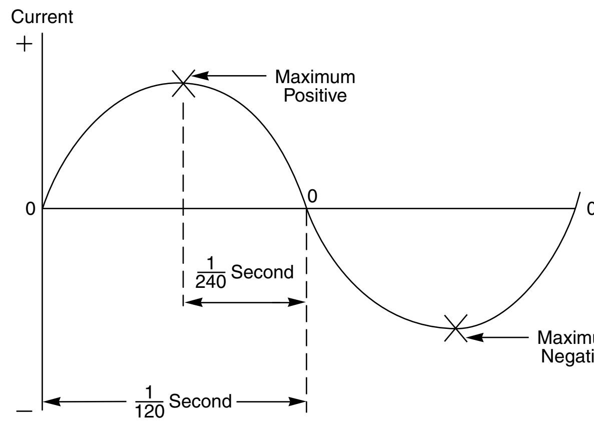
Example: Household current or power supply



DC = Longer, Stronger Spark

Example: Battery operated

The reason for the smaller spark in the AC circuit is found by studying the AC sine wave. It will be noted that no matter where the AC is broken — even at maximum current — it takes only a fraction of a second for the AC to go through zero. So why be in a hurry? Why not break the circuit slowly and give the AC time to go through zero and extinguish the arc. That's what switch engineers do — purposely design AC switches with slow-make, slow-break mechanisms.



60 Hz Sine Wave
Current takes only a fraction of a second to go through zero, even when switched off at maximum (X) points on wave

BASIC SWITCH MECHANISMS

The two basic switch mechanisms are the slow-make, slow-break (AC base) and the quick-make, quick-break (AC/DC base) devices. The other mechanisms are simply variations of these two fundamental devices. Let's first consider the slow-make, slow-break mechanism.

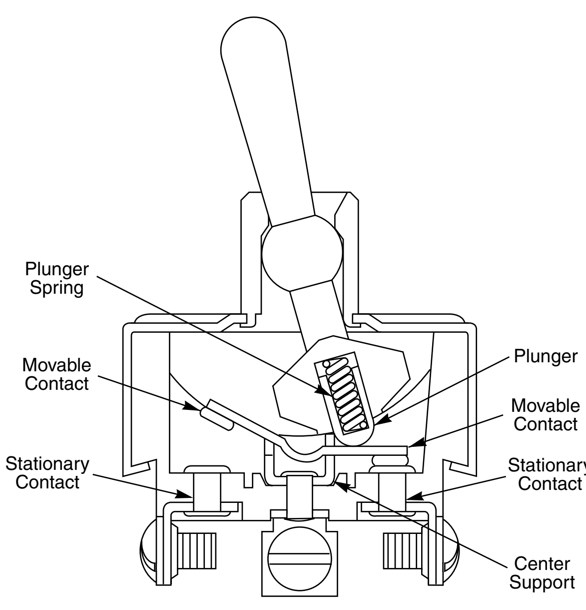
This type of mechanism is usually associated with AC applications for the reason stated earlier, i.e., its slowness of operation provides the slight delay in time to permit the AC wave to go through its zero energy level.

The mechanism can be operated by toggle, slide button, rocker button, or pushbutton, to name a few.

Slow-Make, Slow-Break (AC Base)

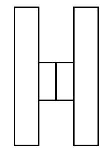
An analogy of the slow-make, slow-break mechanism is a teeter-totter or seesaw. Looking at the figure below, you will note a center support member, a stationary contact on one end and a stationary contact on the opposite end. A movable contactor pivots on the center support. Manipulating the toggle lever in either extreme position will either make or break the circuit. Since the mechanism is spring loaded, a very positive force is necessary to close the contacts. But despite this force, the contacts can still be teased.

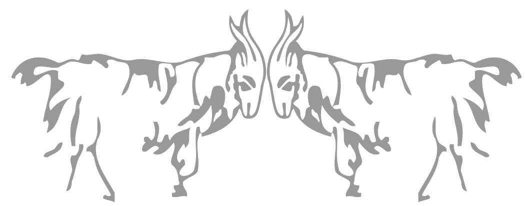
The very slow manipulation of the teeter-totter mechanism is called teasing. A characteristic of the teeter-totter mechanism is that it can be operated as slowly or as quickly as the user chooses.



Slow-Make, Slow-Break "Teeter-Totter" Mechanism

Butt Contacts — The movable contacts in the switch shown below are positioned to meet face-to-face with the stationary contacts — a construction that suggested the name butt contacts.





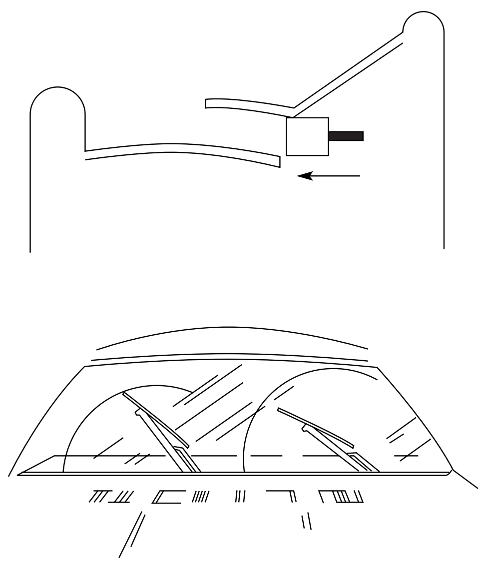
Butt Contacts Meet Face-to-Face

Butt contacts are employed in slow-make, slow-break AC applications and perform well under normal applications. But what if the contacts are subject to oxidation or atmospheric contaminants? The resulting film on the contacts, being nonconductive, could seriously affect electrical continuity. While high energy circuits would probably not be affected because of their breakthrough ability, low energy circuits could be affected. In such cases we must look to self-wiping contacts associated with the quick-make, quick-break mechanism.

Some typical applications for slow-make, slow-break switches include refrigerator door control lights, commercial vacuum cleaners, portable hair dryers, electric dryers and washers, bench saws and sanders.

Quick-Make, Quick-Break (AC/DC Base)

The quick-make, quick-break mechanism differs dramatically from the slow-make, slow-break mechanism. Here the independent snap-acting mechanism virtually eliminates possible teasing. Another difference is found in the self-wiping contacts which by their cleansing action provide reliability of circuit closure.

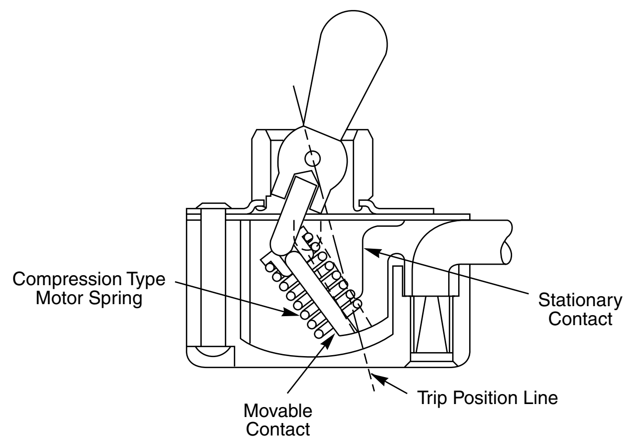


Wiping Contacts Cleanse as They Move

The operator on a quick-make, quick-break mechanism can be likened to a trigger on a gun. When the trigger is pulled to its trip position, the gun fires an irreversible action. Likewise when the operator of a quick-make, quick-break mechanism is moved to its trip position, the switch "fires." It should be noted that the switch contacts snap to the ON or OFF position with absolutely no vacillation.

The "snap-acting" fast speed of the mechanism lends itself to DC applications where, you will recall, the quicker the contacts are separated the sooner the arc is extinguished.

Non-Teasing Contacts — The quick-make, quick-break mechanism employs a compression type motor spring which provides the power to produce the snap action. This spring can have one of two positions in its free state. Movement of the switch operator compresses the motor spring, causing it to move from its end position to the trip position. It is here where the switch operator, like the trigger on a gun, causes the contactor mechanism to snap irrevocably from one position to the next position. During this change of position, the movable contact physically wipes across the stationary contact. The resultant abrasive action cleans the contact surface, thereby minimizing contact resistance.



Quick-Make, Quick-Break "Snap-Action" Mechanism

In addition to the snap-action and self-cleaning contacts, the quick-make, quick-break mechanism differs from the slow-make, slow-break mechanism in size. The quick-make, quick-break mechanism is typically more compact and smaller in size. Unfortunately, the design of the quick-make, quick-break mechanism also makes it more costly than the slow-make, slow-break mechanism.

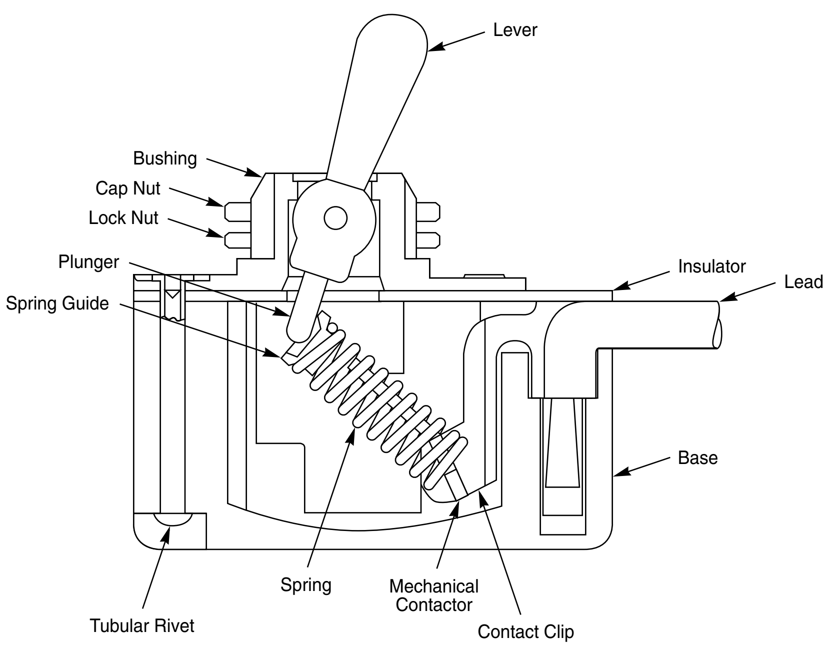
AC/DC CAPABILITY

Almost all DC switch mechanisms have dual capability, i.e., they can be used on DC and AC loads. Such dual use involves a compromise, since the switch is not always capable of the same level AC value that is associated with its DC value. Despite the compromise in rating, which acknowledges that the switch will do better in one or the other power supply, the switch will perform well for both AC and DC at the published rating marked on the unit.

The reliability of circuit (there's never any "in-between") identified with the snap-action DC switch can be used to an advantage in certain AC applications where vibration is a problem. Many domestic and industrial-rated AC products utilize the DC switch because of the positive feel of its snap-action mechanism. Quality is enhanced in such switches offering an additional sales advantage.

DC CAPABILITY OF AC SWITCHES

It is important to also note that many AC rated switches can be used in applications where less than 30V DC is required, provided current does not exceed the full current 125V AC rating of the switch. In general, the 125V AC rating would be equivalent to the 28V DC rating.

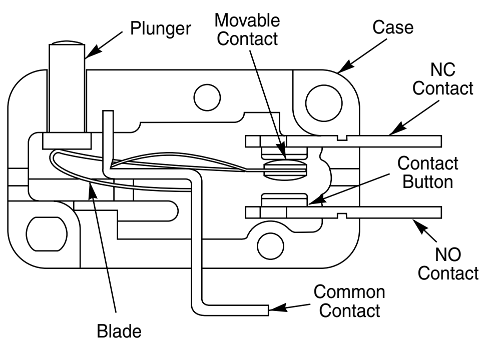


DC Toggle Switch
(Circuit Shown Is ON-OFF)

PRECISION SNAP SWITCH MECHANISM

The precision snap switch, also called the sensitive or micro switch in the industry, has a snap-action mechanism. Its precision characteristics, however, distinguish it from the switches we have just discussed. Critically designed and balanced, the switch requires only a few thousandths of an inch for operation. This is considerably less than the 1/32nd, 1/8th or 1/4th inch required for conventional snap-action switches.

The sensitive snap-action switch is commonly found in vending machines where the small amount of travel and sensitivity of the operator are necessary requirements.

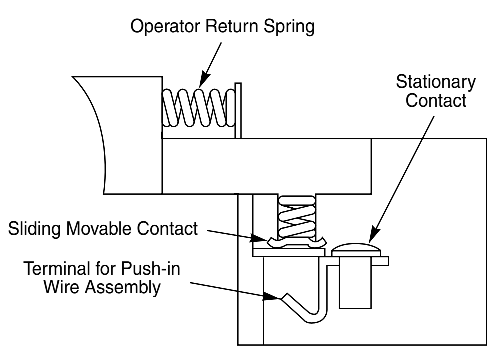


Snap Switch

IN-LINE SWITCH (SLIDE SWITCH) MECHANISM

The in-line switch normally utilizes a slow-make, slow-break switch mechanism. A few are of snap-action design and have application in DC power supplies. A member of the tool handle switch family, the in-line switch gets its name from its line of motion which is at right angles to the conventional pushbutton switch.

The in-line switch was created for specific market areas — electric drills, edgers, sanders, soldering guns and hair dryers, to name a few.

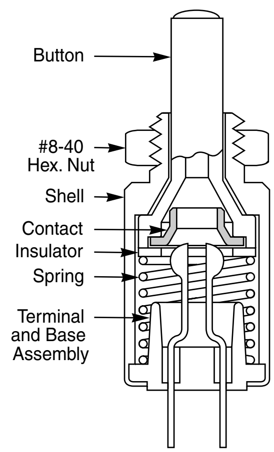


Slow-Make, Slow-Break In-Line Mechanism

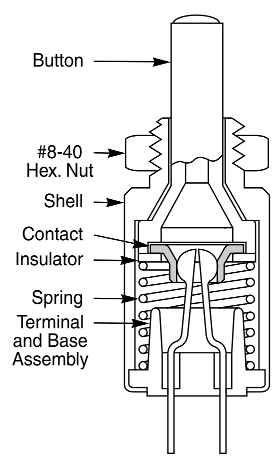
NON-ILLUMINATED PUSHBUTTON MECHANISM

Generally, the only different feature in the construction of the pushbutton switch is the pushbutton operator. The push-button drives the movable contact directly, making or breaking the circuit with a wiping action. The pushbutton operators can be used on slow-make, slow-break; quick-make, quick-break; or on intermediate types of mechanism construction.

The majority of pushbutton switches are slow-make, slow-break because manufacturing costs on pushbutton operators for snap-action or quick-make, quick-break are very expensive.



Circuit Shown Is Normally Open



Circuit Shown Is Normally Closed

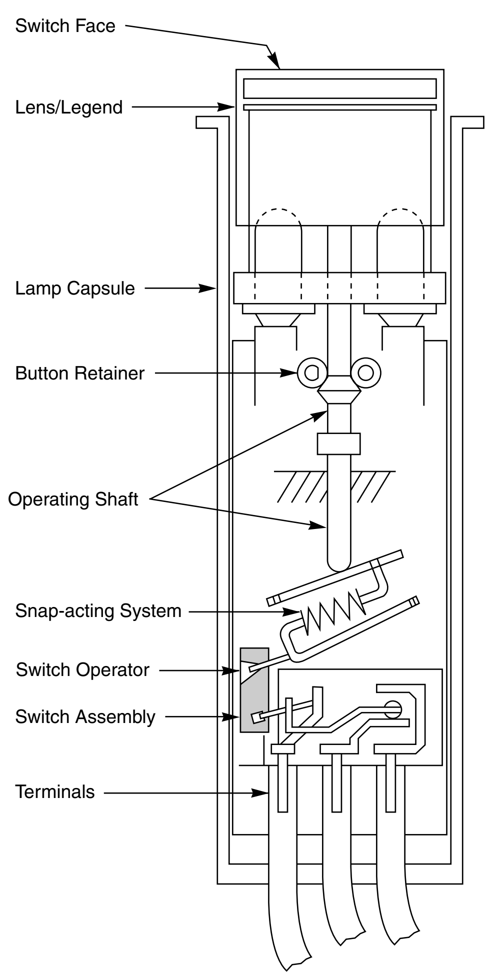
Slow-Make, Slow-Break Pushbutton Mechanism

ILLUMINATED PUSHBUTTON MECHANISM

The lighted momentary pushbutton switch is similar in operation to the unlighted pushbutton switch. Depressing the switch face transfers this motion through the stationary lamp holder module to the switch mechanism to effect the switching action. When the mechanism is released, the switch returns to its normal state. This mechanism can be a teeter-totter (AC) or a snap-action (AC/DC).

Alternate-action switches are similarly designed except that a latch or other holding mechanism is included to hold the external switch face down until a second actuation returns the pushbutton mechanism to its original position. The term alternate-action describes a button that is latched **down** every other actuation (has two normal button positions).

The lighted pushbutton switch includes a lamp capsule that holds the lamps in place as well as the lens and legend assembly. The lamps are typically independent of the switch mechanism in pushbutton applications.

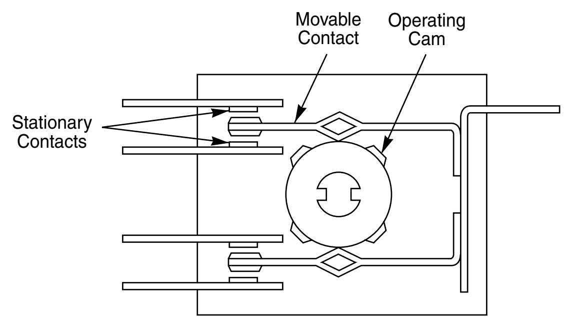


Illuminated Pushbutton Mechanism

ROTARY MECHANISM

The flexibility of the rotary switch is an outstanding advantage. By rotating a shaft any one of a number of circuits can be selected. They can be used in AC or DC applications utilizing slow-make, slow-break or quick-make, quick-break mechanisms.

Typical applications are for multi-position selections such as ranges and instruments.

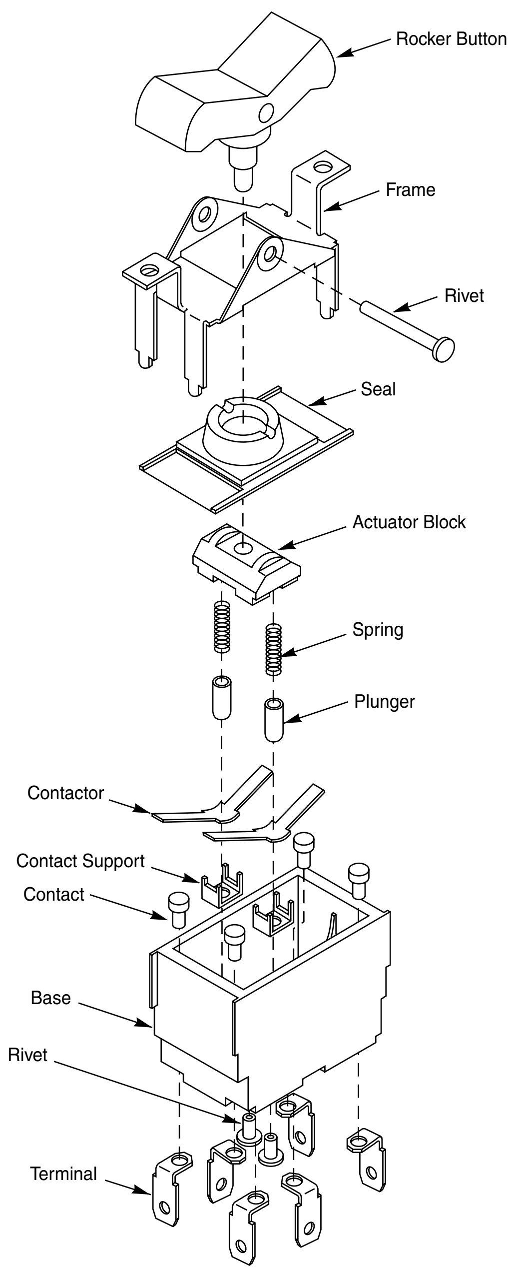


Slow-Make, Slow-Break Rotary Mechanism

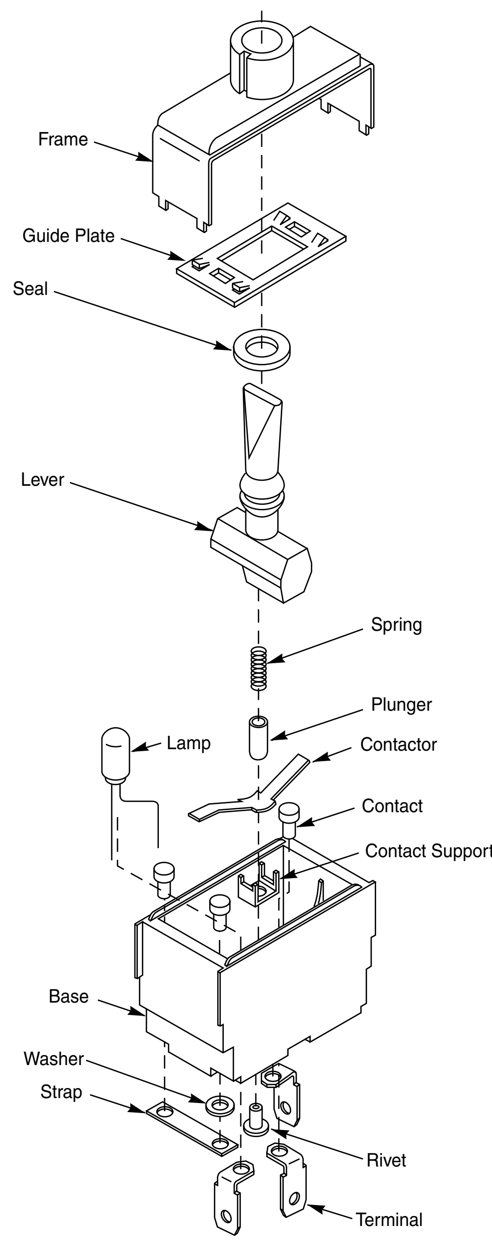
ROCKER AND TOGGLE MECHANISM

The rocker and toggle switch designs share the qualities of versatility and adaptability. Both can be made available as slow-make, slow-break or quick-make, quick-break. Some styles use the same contact construction while varying the superstructure (actuator and bezel). Both can be illuminated.

The use of legends and colors serve to make the devices user friendly and aesthetically practical. The current carrying capacity and number of poles available is limited only by what is currently tooled. The contact construction of the teeter-totter mechanism is the most versatile in that it can be modified to create a variety of special circuits. Some of these special circuits are described later in this manual.



Rocker Switch AC Base
(Circuit Shown Is Double Pole, Double Throw)



Illuminated Toggle Switch AC Base
(Circuit Shown Is Single Pole, Single Throw)

RATINGS AND LOADS

The rating is an indication of the maximum electrical load that the switch is capable of handling. A switch may be rated in either current (amps) or in horsepower. Often both ratings are provided, along with operating voltages.

According to Underwriters Laboratories (UL), switches with a current rating only will have an overload test capability of 150% rated current if the switch rating is 10A (amps) or less, and a capability of 125% rated current if the switch rating is greater than 10A.

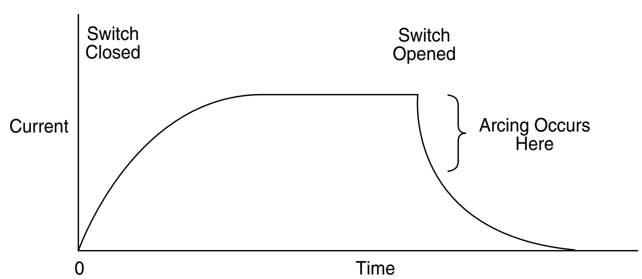
To be meaningful, the rating must be associated with the type of load. These loads consist of:

- Inductive load
- Resistive load
- Motor load
- Lamp load

INDUCTIVE LOAD

Inductive loads have inductance, a circuit property that significantly affects current whenever it changes, whether it be AC or DC. Eaton, in its commercial switches, does not distinguish between the current ratings for resistive and inductive loads. Eaton switches are inductive rated only.

Inductive circuits are more severe on switch contacts than resistive circuits. This is because of the property of inductance which opposes a change in the current. Referring to the DC inductive load graph, we note that upon closing the switch, the current rises slowly to steady or continuous state. A voltage of opposite polarity is induced that opposes the rise of voltage and consequently current. This explains why the spark is minimal upon switch closure.



DC Inductive Load

Reason for Break Spark

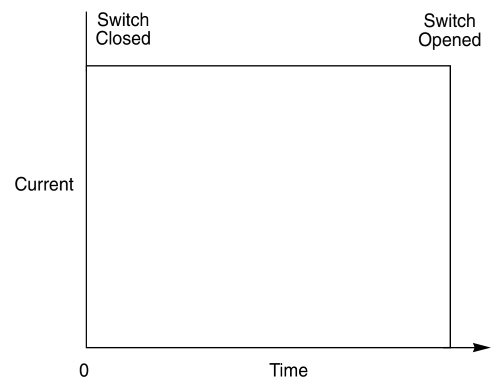
Everyone who has had occasion to operate switches has observed that the spark on break is much greater than on make. Why? Again, it is the property of inductance. Referring again to the curve, note that the current does not fall instantly to zero. Now the rapidly collapsing magnetic field is in such direction that it induces a voltage that causes a current that tends to maintain the dying current, thereby prolonging the spark.

More Theory

The self-induced voltage that is set up by a rapidly collapsing magnetic field can be much higher than the normal supply voltage. This is because the rate of change of the decreasing current on break is very high. And since the induced voltage is proportional to the rate of current change, this voltage (inductive kick) can be great — accounting for the arcing upon opening of switch contacts.

RESISTIVE LOAD

Resistive loads are ohmic or almost pure resistance. The implication here is that the circuit contains little or no inductance. It should be noted that when resistance only is present, AC loads are also called resistive. Examples of resistive loads are electric heaters, ranges, toasters and irons. This is the easiest load to switch.



DC Resistive Load

Two conditions should be noted in the DC resistive load graph:

1. The steady-state or continuous current is instant on close or make.
2. The current drops almost instantly to zero on open or break.

Power Factor Criterion

In agreement with Underwriters Laboratories, our AC switch ratings are based on an inductive power factor of 75 to 80%. As already stated, resistive loads are less severe on switch contacts. Therefore, we would expect greater electrical life for a given switch in resistive load applications.

MOTOR LOAD

The inductive load is normally associated with the series or universal motor, since it is here where the bulk of the commercial switches are employed. This AC/DC motor is widely used to power portable drills, typewriters and such household appliances as sewing machines, vacuum cleaners, dishwashers and food mixers.

Although an inductive load could apply to any circuit containing coiled conductors, such as electromagnets, solenoids and motors, we shall concern ourselves with motors only.

The series motor is quite efficient. Its power factor is generally greater than 75%, therefore it is less severe on switch contacts. However, its inrush current can be six or more times the steady-state or continuous current. Peak inrush is equal to the locked motor current.

The reason for the high inrush can be attributed to the low armature resistance (usually less than one ohm) and the initial absence of counter electromotive force.

Horsepower Rating

Why is it necessary to rate a switch for motor application in horsepower rather than in current? The current rating alone is inadequate, i.e., it does not take in consideration the high inrush current. In other words, the current rating does not signify the capability of a switch to make or break levels that are higher than its current rating.

On the other hand, a switch that is horsepower rated signifies make and break capability for a minimum of fifty operations as required by UL that is six times its current rating in the case of AC motors, and ten times its current rating in the case of DC motors.

An example of a typical switch will serve to illustrate horse-power verses current rating. Consider a switch that has a current rating of 16A at 125V AC, and is also rated one horsepower. The one horsepower rating signifies a make or break capability of 6 x 16A or 96A.

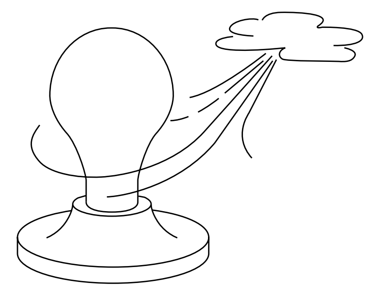
But the 16A, 125V AC rating, standing by itself, tells us that for a UL listed product, this switch has a make and break capability of no more than 20A.

Where did the 20A come from? From Underwriters Labora-tories. According to UL, switches with an ampere rating only will have an overload test capability of 150% rated current if the switch rating is 10A or less. And if the switch rating is greater than 10A, the switch will have a capability of 125% of rated current. Using the 125% figure for our 16A switch, we multiply 1.25 by 16A and get 20A . . . a far cry from the 96A make and break capability indicative of the horsepower rating.

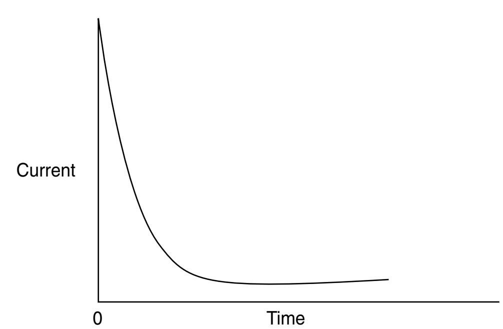
LAMP LOAD

Lamp loads are similar to motor loads in that they too have heavy inrush currents. An inrush of ten times the steady-state current is typical. The reason for the high inrush current is found in the tungsten filament which has a very low cold resistance. But once the filament becomes hot, the resistance increases appreciably.

Lamps are rated in watts. Typical lamp loads are: 500, 750, and 1000W.



“I’m cold! Rush in the heat.”



Lamp Load

The 10:1 inrush ratio is not representative of the bulk of lamps manufactured today. Because of advancements in design and manufacture, it is not uncommon to have ratios of 12, 14, or 16:1. Some quartz lamps, for example, have an inrush ratio of 14:1.

Where do we obtain information on inrush values? The customer can provide us with cold and hot filament values for a switch application.

Here's a situation that can occur on occasion. We have a load application for a switch, but we may not have a lamp load rating. But if we have a horsepower rating on this switch, we can get ourselves out of a bind by recalling that the switch has a make and break capability of six or ten times its current rating.

Typical Examples

For example, a switch with a 1 hp rating signifies a capability of making and breaking at 96A at 120V. Therefore, we can expect this switch to handle successfully a cold filament inrush value of up to 96A.

Let's look at another example — a specific switch with the rating of 16A at 120V AC and 1 hp at 120V AC, and a lamp load of 1000W. The hot filament rating in this case equals 8.3A, obtained from the formula:

$$I = \frac{W}{V} = \frac{1000}{120} = 8.3$$

The cold filament rating, using the 10:1 inrush ratio, equals 83A. Therefore, in the case of lamp loads, we see the similarity of switch capabilities where both current and horsepower ratings are provided.

CONTACT MATERIAL VARIATION

Switches that have a current rating only can employ either silver or non-ferrous contacts with satisfactory results. With the addition of a horsepower rating, the contact material will probably consist of silver alloys. This alloy material provides the non-weld characteristics necessary for the much higher current levels that the switch will control.

A low energy, or dry circuit, typically requires gold contacts for reliable operation. A dry circuit is typically characterized by 0.4 VA maximum at 28V AC/DC maximum.

The type of rating desired demands coordination of contact material and switch mechanism. Obviously, non-weld contacts are required for a switch that includes current, horsepower and lamp load ratings, as opposed to a switch having a current rating only.

Similarly, a different type of contact material or mechanism is required for applications requiring a million cycles of operation in contrast to a switch requiring only 1000 life cycles.

Many elements must be considered in the construction of a switch for an individual application. They are:

1. Type of mechanism
2. Type of contact mechanism and material
3. Relative proportion, i.e., the size of contacts and mechanism verses switch rating
4. Heat rise

ENVIRONMENTAL CONSIDERATIONS

"Not snow, nor rain, nor gloom of night stays these couriers from the swift completion of their appointed rounds."

The above eulogy that honors our letter carriers could apply to many switches that must operate in hostile environments. And hostile they are: from the dry, cold air of the Arctic to the hot, humid air of the Tropics.

Let's consider what happens to a switch in a very cold environment. If the lubricant is not suitable for low temperatures it can become sticky and impair operation. For example, commercial vaseline can be used as a lubricant for commercial switches. It will provide good operation from 32°F to 140°F. But if the switch must endure an environment of -32°F, then the lubricant becomes very solid with resultant sluggish mechanical action. For military applications, special lubricants are employed that permit efficient switch operation in temperatures ranging from -55°F to 175°F.

The switch in an outdoor fire alarm box is an excellent example of an application that is not unlike the rigors the letter carrier must face! Not only is the switch subjected to extremes of temperature, it also doesn't get much exercise. The fire alarm box may be only used once or twice a year when tested.

Add to this the low current and low voltage levels associated with this type of application, and you can see that the climate is right for a malfunction. That is, the lubricants dry out and will prevent electrical contact.

In the case we have just discussed, we probably would not want to use lubricants. Nor would we want to use lubricants in switches used in business machines. Here the unavoidable paper dust could be a real menace, i.e., the lubricants would tend to absorb the paper dust. So in these cases, to insure circuit performance, we would want to eliminate lubricants and use wiping contacts and teflon plungers.

HUMIDITY AND TEMPERATURE

How about humidity? We do quite well here. Our switches operate efficiently in up to 95% humidity without deterioration of the materials in switch construction.

We discussed the effects of cold temperature. What about hot temperatures? Here care must be taken not to use materials that soften at high temperatures. A case in point is nylon which should not be used in applications where temperatures exceed 150°F. What happens at 170°F, for example, is that a nylon rocker button, under a certain amount of pressure, may distort and change its design configuration and possibly become nonfunctional.

Phenolics fare better under high temperatures, suffering no adverse effects even at 200°F.

HARSH ENVIRONMENTS

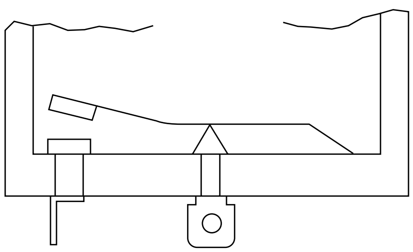
Sealing should be considered when the switch is used in an environment where concentrations of sand, dust, metal particles and/or moisture could penetrate the switch housing and make the switch ineffective.

TYPICAL SWITCH CIRCUITS

Versatility is the name for switch circuits. The possibilities are practically endless. That's why we have illustrated only a few. Many new applications call for special circuitry. The "working out" of details for such a circuit is an exciting challenge to those in both sales and engineering. In fact, we know of no more stimulating mental exercise!

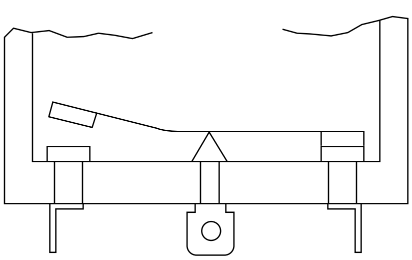
SINGLE-THROW (TWO POSITION)

This is the simplest and most basic circuit. The ON-OFF electrical circuit function is called single-throw in circuit terminology.



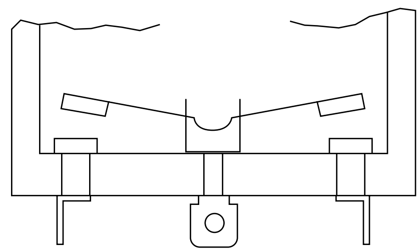
DOUBLE-THROW WITHOUT CENTER OFF (TWO POSITION)

Without the center OFF position, this double-throw circuit is seen electrically as ON-ON. The switch has two manual positions and reflects two independent electrically ON positions. Examples of applications include a selector function, such as 6- or 12V on a battery charger or HI-LOW on an automobile headlight switch. It is also apparent that when this switch is used in a selector function, it can be used in conjunction with another ON-OFF control switch.



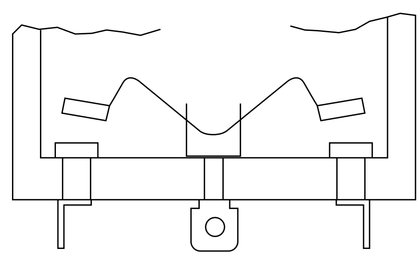
DOUBLE-THROW WITH CENTER OFF (THREE POSITION)

This circuit is very similar to the DOUBLE-THROW WITHOUT CENTER OFF except that mechanically it has a third switch position that is electrically OFF. In addition to the two independent ON positions, this circuit has the capacity to be the electrical ON-OFF control. A typical example is the HI-OFF-LO circuit for the exhaust fan in a kitchen range hood.



DOUBLE-THROW MOMENTARY ACTION WITH CENTER OFF (THREE POSITION)

Until now we have discussed only switch circuits with maintained positions. However, momentary or non-maintained positions are also used. A momentary position, which can be electrically ON or OFF, generally employs spring loading. Thus, the position is maintained only for as long as pressure is applied to the actuator. In the momentary switch circuit illustrated, the inclined slope of the movable contactor helps return the actuator to center position when pressure is released in a slow-make, slow-break mechanism.



Generally, most momentary action switch mechanisms are not as positive and effective as a maintained make and break mechanism. Because they are operator dependent, derating may be necessary (i.e., the switch may not be able to handle full rating load.)

The double-throw momentary action circuits are common in two-pole devices where they are used for reversing motor applications. Examples are: UP-DOWN for projector screens, station wagon tailgate windows, and FORWARD-REVERSE for such devices as electric drills and screwdrivers. Incidentally, a single-throw momentary circuit is commonly employed in electric drills, hedge trimmers, electric sensors and soldering guns.

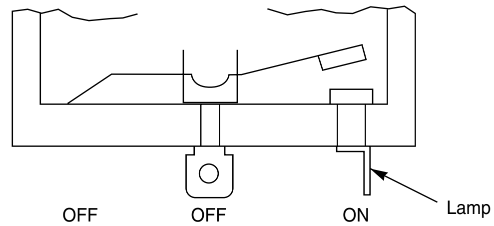
DOUBLE-POLE SPECIAL CIRCUIT

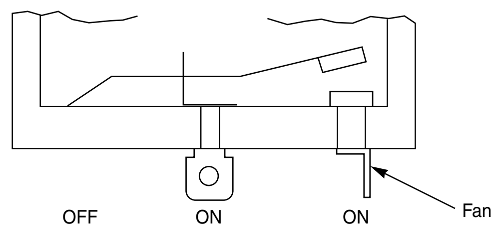
Commonly called a projector circuit because of its use in motion picture and slide film projectors, this circuit provides three switching functions:

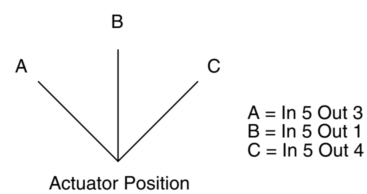
1. OFF
2. Fan only
3. Fan and lamp

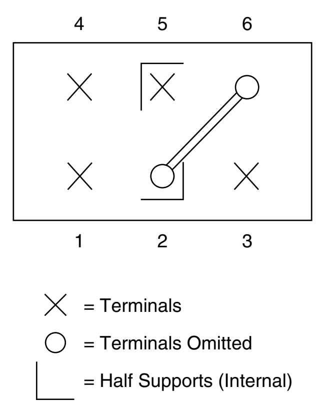
It is sometimes referred to as an OFF - ONE ON - TWO ON circuit in which the two ON circuits represent two independent electrical functions.

Referring to the circuit on the right, you will note that two individual electrical poles are used. Also, that the center support terminals have been jumpered with a metal bus or connector to provide a single line connection for these two poles. Since the two poles are now electrically coupled, they function as a single switch control.

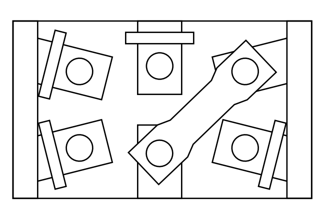








OFF - One ON - Two ON
Internal Construction



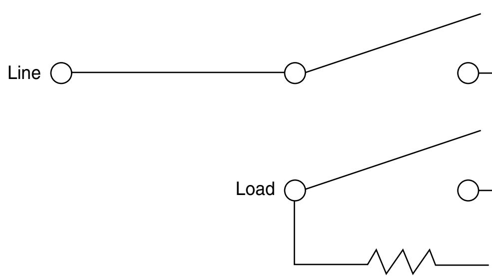
OFF - One ON - Two ON
Bottom View

JUMPER OR CONNECTOR CONSTRUCTION

The projector circuit is an example of how jumpers provide flexibility to the switch. These jumpers or connectors, which are factory assembled, serve many purposes. For example, we can change a two-pole switch into either a single-pole series switch or a single-pole parallel contact switch (see figures below).

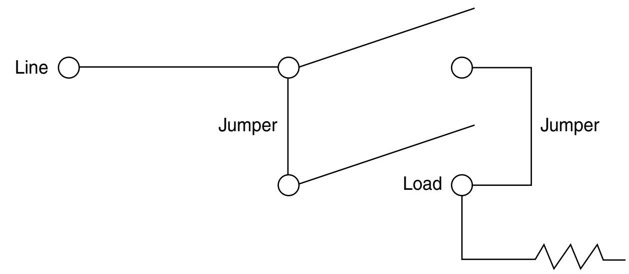
The primary purpose in creating the series switch is to obtain double-break characteristics. We recall from earlier discussions that the double-break provides greater volume of contact material, permitting greater heat or energy dissipation. This feature is also advantageous for DC circuits.

Want a switch to last longer? Use parallel contact construction which has the advantage of contact mass. In effect, this construction features redundancy in its double contact and double contact mass. The double contact provides increased switch life in that if one contact pair were to fail to make or break circuit for any reason including wear-out of contact material, the other contact pair will continue to make and break circuit with actuator operation.



Single-Pole Series Switch

It should be noted that unlike the series switch, the parallel contact construction does not have the double-break characteristic. Only one of the contact pairs will make or break electrical circuit.

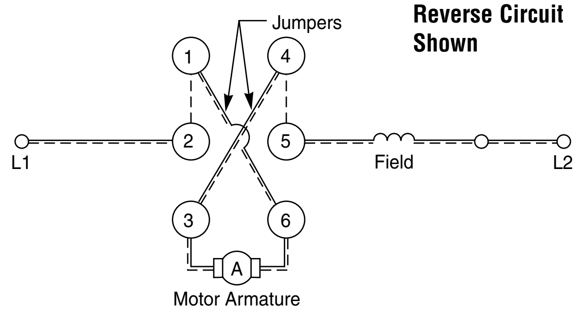


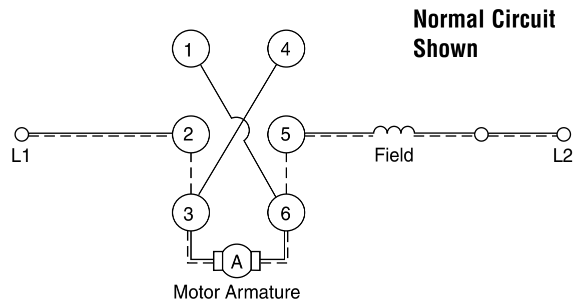
Single-Pole Parallel Contact Switch

REVERSING CIRCUIT

The reversing circuit is a very popular combination of a two-pole switch and jumpers. Recall that many of our commercial switch applications are for series or universal motor control. In this type of motor, it is only necessary to reverse the direction of current in either the field windings or the armature to reverse the mechanical output direction of a motor shaft. Referring to the sketch, we can see how the reversing effect is provided by the diagonal jumpers.

Trace the circuit and see for yourself how the switch performs its reversing function. Let's assume that the switch is making contact at 2 – 3 and 5 – 6. Here the circuit traces simply without the need of jumpers. Current direction is from left to right or counter-clockwise through the armature. But now we wish to reverse motor direction. We simply transfer circuit so that L1 and L2 are connected to 1 – 2 and 5 – 4 respectively. Tracing the circuit with the aid of dotted lines, we see how the jumpers serve to reverse the current. Just a few applications include the rewind on movie projectors, forward and reverse on electric drills and screwdrivers, UP-DOWN on car windows and movie screens, and UP-DOWN on dump trucks.



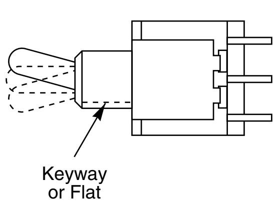


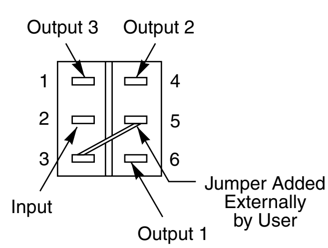
Internal Circuit Flow
(Back of Switch Showing Cross Jumpers)

ON-ON-ON CIRCUIT

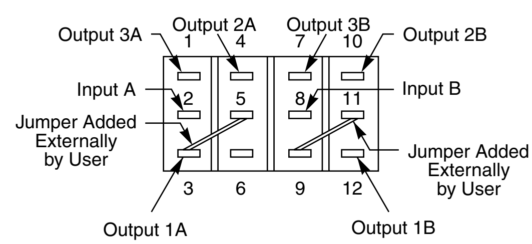
The three on circuit is a popular modification of a two-pole base. This will change a two-pole, three position base to a single-pole three output switch (ON-ON-ON).

This is done by the addition of opposing half support center contacts to the switch base. This allows only a single contact movement for each actuator position. This type of actuation can be maintained in three positions or it can have one or two of the actuator positions momentary.





Single-Pole Using Double-Pole Switch



Double-Pole Using 4-Pole Switch

TOGGLE UP	Output 1	Output 1A, 1B
TOGGLE CENTER	Output 2	Output 2A, 2B
TOGGLE DOWN (Keyway or Flat)	Output 3	Output 3A, 3B

Three On (ON-ON-ON) Conversion Wiring

LIGHTING OPTIONS — INCANDESCENT, LED AND NEON

INCANDESCENT

Incandescent bulbs are composed of a thin resistive metal filament suspended between two electrodes and encased in a glass envelope. This filament is literally burned away as energy passes through it to generate light. Most of the energy, however, dissipates as heat which is why incandescent lamps are so energy inefficient. Because they generate large amounts of heat, incandescent bulbs have limited life and are generally restricted to circuits less than 30V. They are also not suitable for high vibration applications.

Incandescent bulbs are commonly used in low voltage AC and DC applications because they are less expensive than other lighting options and small in size.

LED

By contrast, LEDs are solid state devices consisting of a semiconductor mounted on a conducting lead with a bond wire connecting the top of the semiconductor to the other conducting lead. This assembly is then encapsulated in epoxy that provides optics and protection from shock and vibration.

LED indicators are used when the heat generated by incandescent bulbs is not acceptable for the application. In addition, LED operating life is much longer than that of incandescent lamps. LEDs never burn out if not mistreated, they merely grow dimmer. The disadvantage, however, is that LED light output radiates almost entirely straight ahead, whereas incandescent output spreads out uniformly. As a result, the LED brightness is less intense than an incandescent bulb and functions more as an indicator than an illuminator. Also, it is important that the filter matches the light source because LEDs are color limited and do not emit the full spectrum.

LED indicators generally require a resistor in series to limit current. When operating from AC sources, LEDs sometimes also require an additional diode in series with the resistor to limit reverse breakdown voltage. LED breakdown voltage is generally limited to about 3 to 6V.

NEON

Neon lamps are recommended for high voltage AC applications, such as 120V AC and 240V AC. Neon lamps have two electrodes sealed inside a glass envelope filled with neon gas. When a starting voltage is applied, current flows through the gas, ionizing it and causing it to glow near the negative electrode.

Neon lamps are very rugged and not affected by vibration, mechanical shock or frequent ON/OFF operation. Their cool operation allows the neon lamp to be located near heat-sensitive components. Neon lamps may be operated at higher temperatures (up to 150°C) and are not damaged by voltage transients.

Standard brightness neon lamps gradually decline in light output as electrodes evaporate and condense on the inside of the glass envelope. Neon lamps are typically the most expensive of the lighting alternatives.

The table below gives a quick comparison of key features of these three lighting options:

Features	Incandescent	LED	Neon
Life	5,000 to 10,000 hours	>100,000 hours on most types	30,000 to 50,000 hours
Shock & Vibration	Fair (-)	Excellent	Good (+)
Heat Generation	High	Low	Low
Input Volts	5 to 28V	3 to 6V — other voltages available with use of a resistor	120V and 240V resistor required
Brightness	(+)	(-)	(+)
Color Variation	white — requires color filters	red, green, yellow, blue — with custom coloring, intensity and frequency available	orange, green, blue — requires color filter for other variations

LEGENDING METHODS

Four of the most common and flexible ways of decorating plastic parts with graphics or text are done as secondary operations (as opposed to being molded into a part). These processes are Laser Etching, Pad Printing, Hot Stamping and Engraving. There are advantages and disadvantages to each and limitations stemming from the basic design requirements of the part being decorated.

LASER ETCHING

Laser etching is the most reliable and permanent marking technique on the market. It is uniquely suited to today's demanding, fast paced manufacturing environment. The process is material dependent, however, and not available on all molded parts.

The technology is based on a simple principle. A quick burst of intense light, lasting only a millionth of a second, passes through a mask and burns an .0002 to .001" image into the surface layer of the product. The marking process occurs so rapidly as the object passes before the laser, the flow of the manufacturing line is uninterrupted. Product can be marked accurately and without physical contact regardless of line speed. Marking placement is exact. The beam can mark flat as well as hidden, curved or irregular surfaces. The image becomes an indelible part of the product.

By incorporating colored product and paints, then removing the surface material with laser etching, switches can be back-lit achieving an aesthetically pleasing lighted device.

PAD PRINTING

Pad printing involves transferring ink from an engraved template (pad plate or cliché) to the part through the use of a soft rubber pad. The ink is either heat cured or allowed to dry naturally. Various inks are available to meet stringent requirements so durability is quite good. The most forgiving of the decorating techniques, pad printing is ideal for putting complex graphics and text on almost any kind of surface because the ink is deposited in all the cracks and crevices of the surface. It is overall the most economical process.

HOT STAMPING

Hot stamping is a method by which ink, in tape form, is transferred to the part through the use of heat, time and pressure. The tape is pressed into the part, about .002" deep, using a heated steel stamp, engraved with the desired graphic, at a little less than the melt temperature of the plastic. The ink is activated by the heat and pressure from the hot stamp machine and deposited onto the part. The pressure is removed from the heated stamp and the plastic and ink are allowed to cool and cure. Less durable than engraving, the print quality is somewhat more difficult to maintain because part variations dramatically affect the process. Hot stamping works best on smooth surfaces and is restricted to high volume applications.

ENGRAVING

The engraving process involves machining the required graphics into the part, usually about .010" deep, using an engraving machine with templates that can be traced to duplicate the desired decoration on the part. The machined area is filled using a contrasting lacquer stick, with the excess lacquer being hand wiped off with solvent. While this technique is durable, it is considerably more expensive than the other methods of marking. It is difficult to use on matte surfaces and marking placement can be a challenge. On the other hand, it is the most versatile technique for smaller runs.

	Laser Etching	Pad Printing	Hot Stamping	Engraving
Typical Volume	Medium to High (350 piece min.)	Low to Medium (temporary cliché) Medium to High (permanent cliché) (100 piece min.)	High (500 piece min.)	Low (5 piece min.)
Relative Cost	Low to Medium	Low to Medium	Medium	High

SWITCH INFORMATION GUIDE

The following topics are commonly referenced terms used by switch customers. Additional information on these topics can be found in the switch training manual, catalog, or by calling the Eaton service center.

SWITCH BASICS

What Is a Switch?

A switch is a device that will either open or close a circuit.
- Single-Throw

A switch will establish a connection between two or more circuits.
- Double-Throw
- Three Position
- Multi-Position

Switch Terminology

Poles
- Number of circuits a switch controls

Throws
- Number of conductors to which a switch can complete a circuit

Positions
- Number of stops the switch actuator makes

Break
- Single
- Double

Normally Open (NO)
- Contacts are separated (open) when nothing is touching the switch

Normally Closed (NC)
- Contacts are made (closed) when nothing is touching the switch

Anatomy of a Switch

Actuator
- Toggle
- Pushbutton
- Rocker
- Bellows
- Lever

Mounting Style
- Bushing
- Bezel
- Screw
  - OBM (Outlet Box Mounting)
  - OHM (One Hole Mounting)
  - Flush Frame
  - Through Holes
- Nest

Mechanisms
- Slow-Make, Slow-Break
  - AC Applications
  - Teeter-Totter
  - Butt Contacts
- Quick-Make, Quick-Break
  - DC Applications
  - Snap-Acting
  - Over Center
  - Wiping Contacts
- Positive Action
- Slide
- Rotary

Contacts
- Copper
- Silver
- Silver CAD Oxide
- Gold

Terminal Types
- Screw — Standard and Clamp
- Solder
- Spade (Quick Connect)
  - 0.110
  - 0.187
  - 0.250
- Wire Leads
- Plug In
- PC (Printed Circuit Mount)
  - Through Hole or Surface Mount
- Wire Wrap

SWITCH RATINGS

The switch rating is the maximum electrical load the switch is capable of handling.

- Voltage
  - AC
  - DC
- Current
  - Amps
  - Horsepower

Voltage

AC (Minimum UL Requirements)
- Resistive or Inductive
  - 6000 operations at rated load
  - 50 operations at 150% of load (<10A)
  - 50 operations at 125% of load (>10A)
- Horsepower
  - 6000 operations at rated load
  - 50 operations at 6 times rating

DC (Minimum UL Requirements)
- Resistive or Inductive
  - 6000 operations at rated load
  - 50 operations at 150% of load (<10A)
  - 50 operations at 125% of load (>10A)
- Horsepower
  - 6000 operations at rated load
  - 50 operations at 10 times rating

Lamp Load

AC or DC
- Inrush 10 times rated load
- Similar to horsepower rating
- UL “L” rating for AC
- UL “T” rating for DC

Dry Circuit

Minimum Rating
- Load is so small that contact resistance does not change when the load is applied to switch.

Typical Load = 0.4 VA max. @ 20V DC

Requires gold contacts

Life

Electrical Life
- At Rated Load
- At Reduced Load

Mechanical Life
- Environment

Approvals

UL

CSA

VDE

CE

Others

ENVIRONMENTAL CONSIDERATIONS

Shock and Vibration

Violent Blow
Rapid Continuous
Altitude

Contaminants

Sand
Dust
Water
Flux

Temperature

Cold
Heat
Thermal Shock

Corrosion

Salt Spray
Corrosive Atmosphere
Dissimilar Materials

Seals

Actuator
- “O” Ring
- Washer
- Barrel
- Bonded
- Gasket

Panel
Base
Terminal
Ratings
- IP
- MIL
- NEMA

GLOSSARY

AC	Alternating Current; electric current that continually reverses direction at a fixed frequency.
Actuation Force (Operating Force)	The force required to change the actuator of a switch from one position to the other.
Actuator	A movable part of a switch which causes a change in the electrical configuration of the switch. Examples: Toggle, Rocker, Slider, Trigger, Plunger, Paddle, Shaft, Button
Alternate Action	Commonly describing pushbutton switches; remaining in a given circuit condition after removal of actuating force; when actuating force is applied a second time, the opposite circuit is engaged; also known as push-push switching action; may or may not be latchdown.
Arcing	A visible electric discharge between separated contacts.
Bifurcated Contact	A two-pronged, wiping movable contact.
Bounce	The repeated rebounding of the movable contact during the transfer from one throw to the next; measured in milliseconds.
Break Before Make	Interrupting one circuit of a pole before completing another of the same pole (non-shorting contact).
Butt Contact	A contact mechanism in which the movable contact makes contact with the fixed (stationary) contact without wiping motion between the surfaces.
Capacitive Load	A load in which the initial current on make is higher than steady state.
Contact Gap	The distance between a stationary contact and a moveable contact in the open position.
Contact Resistance	The resistance across a pair of closed contacts which is in series with the load; this resistance increases with the age of the switch at a rate varied by environment, frequency of use, voltage, and load conditions; measured in milliohms.
Current Rating	The maximum electrical load the switch is designed to handle at a given voltage.
Cycles	The number of times a switch can be actuated from one extreme position to the opposite extreme position and back to the original position.
DC	Direct Current; electric current that flows only in one direction.
Dielectric Strength	The ability of an insulating material to withstand high voltage without electric degradation.
Double-Break	Having two pairs of contacts that open the circuit at two places. Having this added contact material improves heat dissipation and increases life; desirable in DC circuit applications.
Dry Circuit	A low energy circuit condition where no arcing, melting or softening of the contacts occurs during contact switching. Typically requires gold contacts for reliable operation. For example, 0.4 VA maximum @ 28V AC/DC maximum.
DT	Double-Throw; see throw.
Electrical Life	The number of operations at a given electrical load that does not result in a degradation of any electrical or mechanical parameter beyond the standard set by the applicable end-of-life criteria.
Environmental Seal	A seal that totally encapsulates the switch or relay providing a specified level of protection against intrusion of solids, liquids or gases into the body of the device.

Fixed Contact (Stationary Contact)	The non-moving contact. Typically integral to the end of the terminal inside the switch body.
Flash Plating	A very thin or "instant plating" of usually less than 10 millionths in thickness, i.e., gold flash.
Gold Flash	A plating of gold typically less than 10 millionths thick. Used only as a barrier to oxidation or corrosion of terminals to maintain solderability.
Heat Rise	An indirect measurement of contact resistance used by rating agencies. The temperature rise over ambient of a contact set carrying a prescribed current is measured to determine whether it falls within safe limits.
Inductive Load	A load in which the initial current on make is lower than steady state and upon break is greater than steady state. The long arcing time, due to stored energy in the inductor at the time of breaking, is severe on the switch contacts. Motors are the most common.
Inrush	The initial, transitory high-level of current through contacts upon making (closing); can cause severe degradation of contacts; applicable to resistive and capacitive loads.
Insulation Resistance	The electrical resistance between two normally insulated parts; measured at a specific high potential; usually greater than 1 megohm.
IP	Part of the IEC 529 standard recommending the degree of protection of enclosures for low-voltage switch gear; specifically concerned with protection of persons against contact with live or moving parts and the prevention of ingress of solid foreign bodies and liquid; an industrial specification used internationally and similar to NEMA.
Lamp Load	Most notably characterized by the high inrush current at make (approximately 10 to 16 times the steady state).
Load	The amount of current being carried in a given circuit.
Logic Level	An application in which power levels do not cause arcing, melting, or softening of contacts; also referred to as dry circuit or low energy; specified 0.4 VA max. @ 28V AC/DC max.; typically requiring gold contacts for reliability.
Maintained Action	Remaining in a given circuit condition until actuated to the opposite circuit condition where it is again maintained; opposite momentary action.
Make Before Break	Completing one circuit of a pole before interrupting another of the same pole (shorting contact).
Momentary Action	Mechanically returning from a temporary circuit condition to the normal circuit condition as soon as the actuating force is removed.
NC	Normally Closed contacts; circuit is closed when actuator is in relaxed or normal position.
NO	Normally Open contacts; circuit is open when actuator is in relaxed or normal position; applies to momentary or alternate action switches.
Non-shorting Contacts	Contacts which break before make; usually much higher than the switching rating.
Operating Temperature	The range of temperature within which the device may be used.
Overtravel	The distance an actuator moves beyond the point at which electrical contacts transfer.

Panel Seal	Liquid is prevented from reaching the switch contacts from the front of the panel if the panel is subjected to spills or splashing.
Pole	A completely independent circuit within a switch, i.e., a single pole controls one circuit, a double pole controls two circuits, etc.
Position	The mechanical detents or stops of a switch actuator.
Power Factor	A measure of the inductive or capacitive character of an electrical load.
Push-Push	Also known as alternate action; is not latchdown.
Quick-Connect Terminals	Flat tab or blade style terminals designed to accept push-on female wire connectors (instead of soldering). The most popular sizes are: 0.250", 0.187", 0.110" wide.
Resistive Load	The easiest load to switch because current and voltage are in a steady state on make and drop instantly to zero on break; produces minimal arcing which maximizes contact life.
Single-Break Contacts	A contact mechanism using one set of contacts to make or break a given circuit. Typical of electronic or low power switches.
Shorting Contacts	Contacts which make before break.
Snap-Action	The abrupt transfer of contacts from one position to another; this action is relatively independent of the speed of actuator travel.
SPST	Single-Pole Single-Throw; see pole, also throw.
Surface Mount	Component terminals are soldered to pads on the surface of the PC boards as opposed to using holes for mounting; terminal shapes vary: gull wing, J-bend, and others.
Terminal	The metal portion of the switch, exterior to the body, that is used to connect the switch to an electrical circuit. Examples: PC, Wire Lug, Turret, Quick-Connect, Wire-Wrap, etc.
Thermal Shock	An excessive temperature change, particularly in reference to movement from one process to another in soldering and cleaning.
Throw	The number of electrical circuits (outputs) within a pole.
Translucent	Transmitting and diffusing light so that objects beyond cannot be seen clearly.
Transparent	Transmitting light without appreciably scattering so that objects lying beyond are entirely visible.
Travel	The total distance the actuator moves to change electrical position.
Voltage Breakdown	A build-up of electrical potential across the movable and stationary contacts causing an arc at the air gap that shorts the circuit.
Washable	Capable of being subjected to automated washing procedures after wave soldering without diminishing electrical or mechanical life specifications; other terms such as process compatible, totally sealed, and immersible are sometimes used to describe washability.
Wave Soldering	A method of soldering in which a wave of molten solder contacts surfaces as the PC board with components is conveyed through the process; wave width, travel speed, dwell time, etc. are varied to achieve desired results.

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