

OMRON



SWITCH

Fundamentals of SWITCHES

A switch responds to an external force to mechanically change an electric signal.

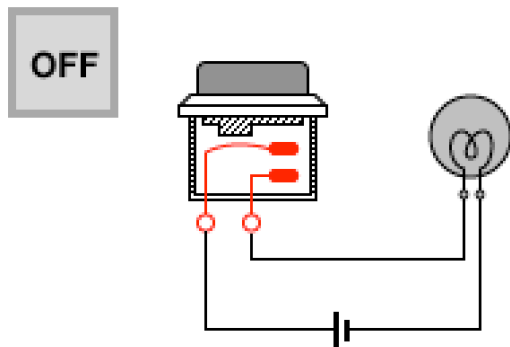
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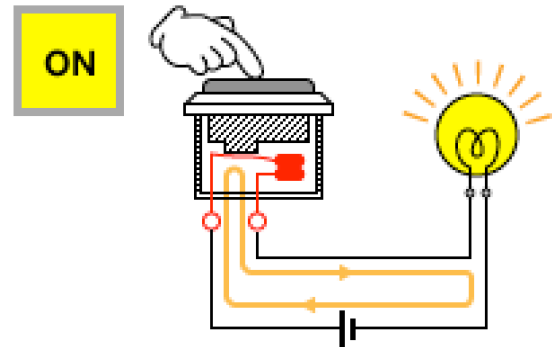
Switch Definition

A switch responds to an external force to mechanically change an electric signal. Switches are used to turn electric circuits ON and OFF and to switch electric circuits.

1. Circuit ON/OFF Operation

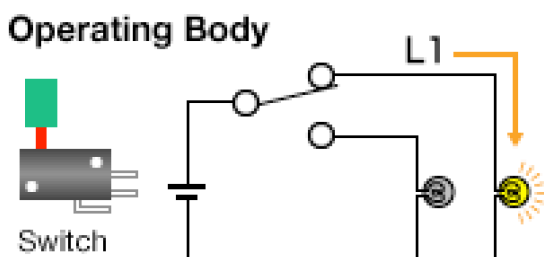


The contacts are separated while the switch is not pressed, so the circuit is not connected and the lamp is not lit.

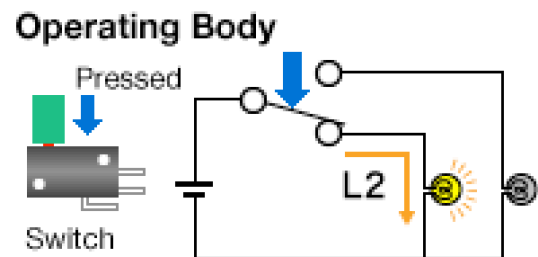


When the switch is pressed, the contacts come into contact, closing the circuit and lighting the lamp.

2. Circuit Switching Operation



While the switch is not operated, the lamp on circuit L1 is lit.

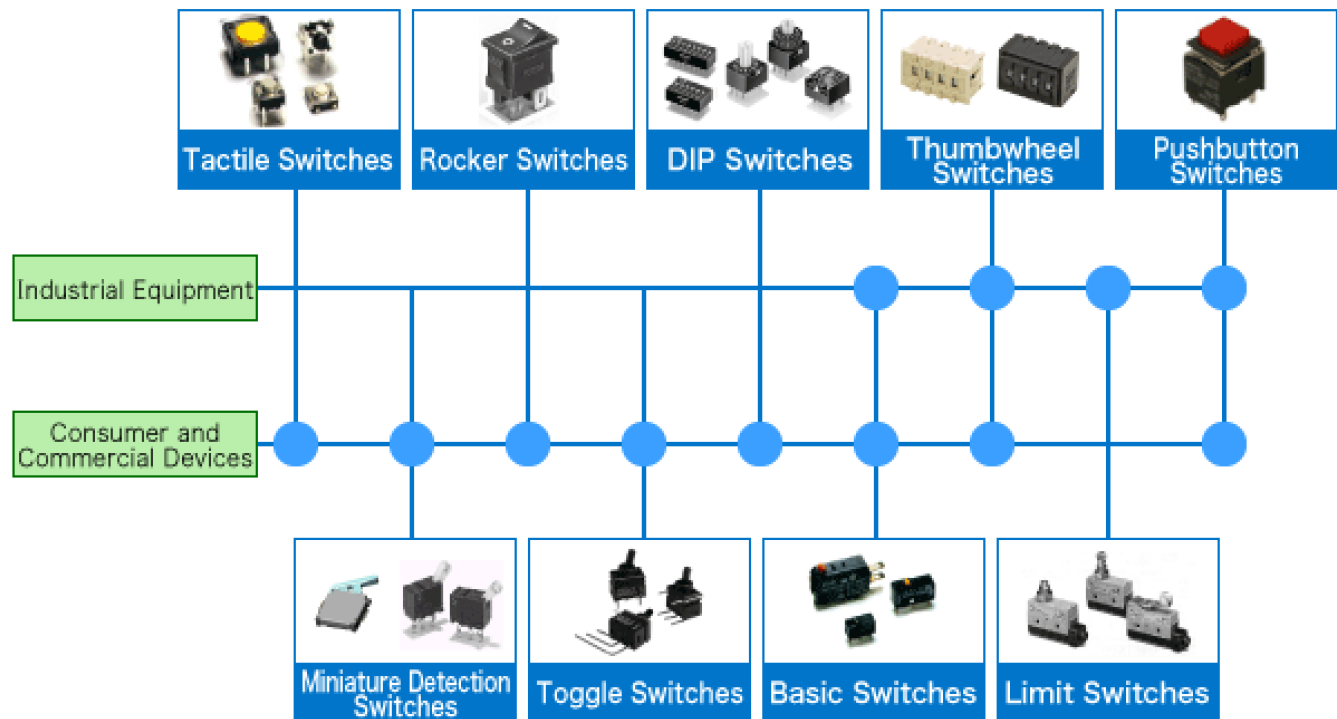


When the switch is pressed, the circuit is switched so that the lamp on circuit L2 is lit.

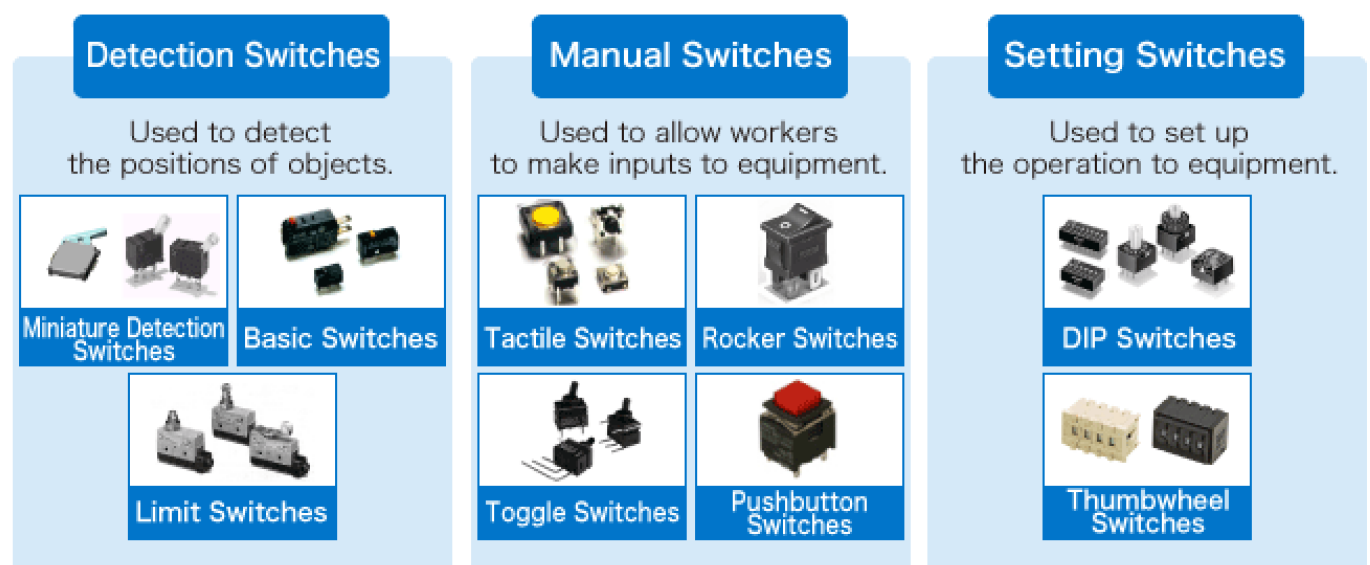
Switch Types & Classifications

1. Types of Switches

There are many different types of switches. Based on their size, robustness, environmental resistance and other characteristics, they are divided into switches for industrial equipment and switches for consumer and commercial devices.



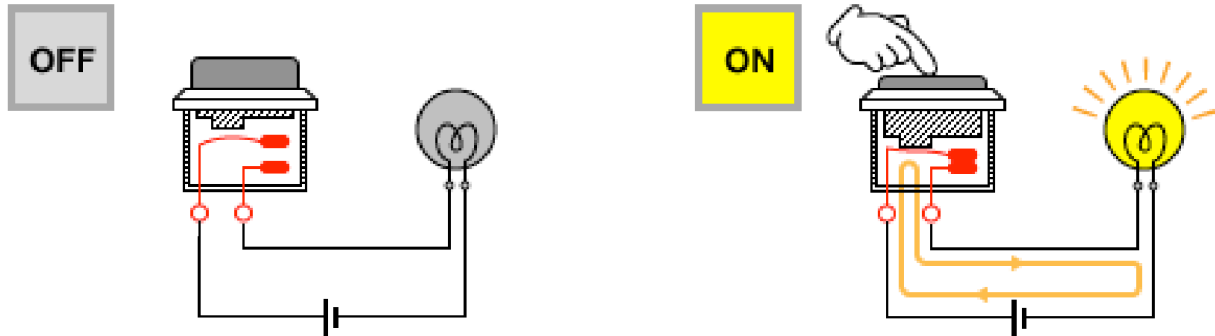
2. Switch Classifications



Contact Form

1. SPST-NO (Single Pole Single Throw Normally Open)

The contacts close when the switch is operated. They are normally open.



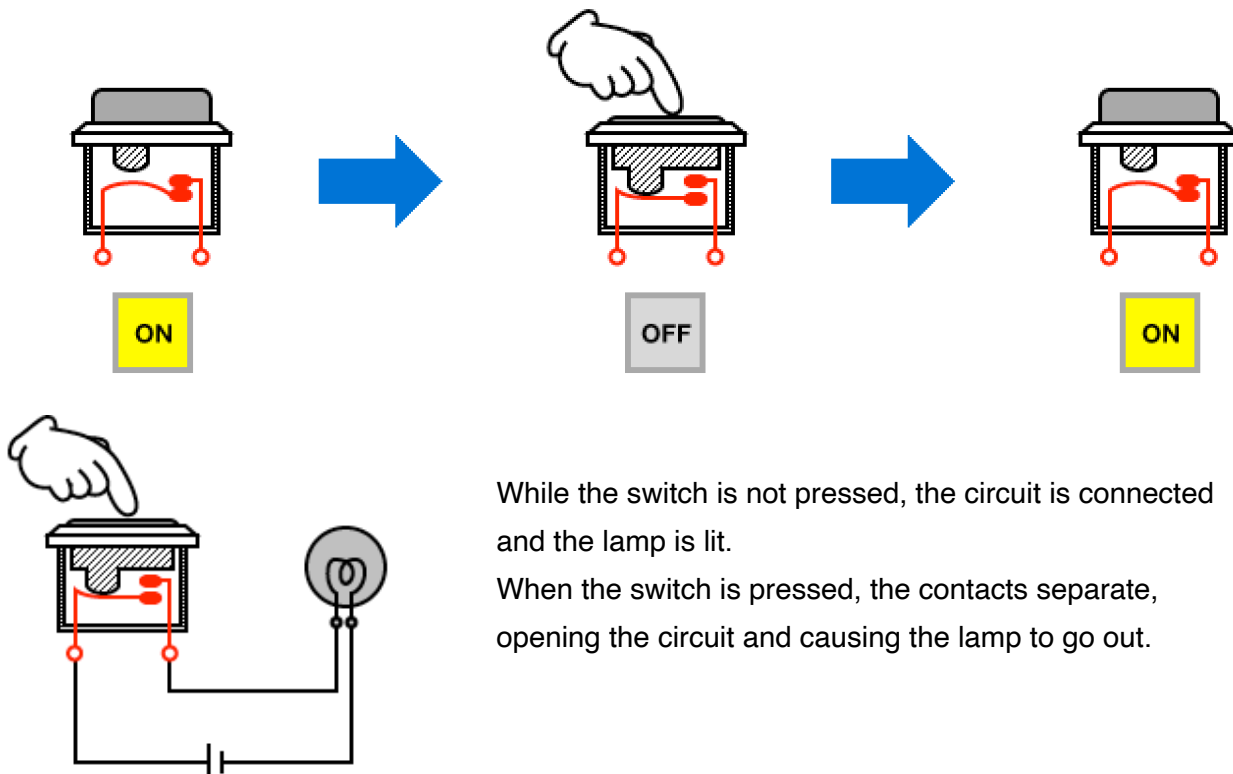
The contacts are separated while the switch is not pressed, so the circuit is not connected and the lamp is not lit.

When the switch is pressed, the contacts come into contact, closing the circuit and lighting the lamp.

Use NO contacts when you want the load to operate when the switch is operated.

2. SPST-NC (Single Pole Single Throw Normally Closed)

The contacts open when the switch is operated. They are normally closed.



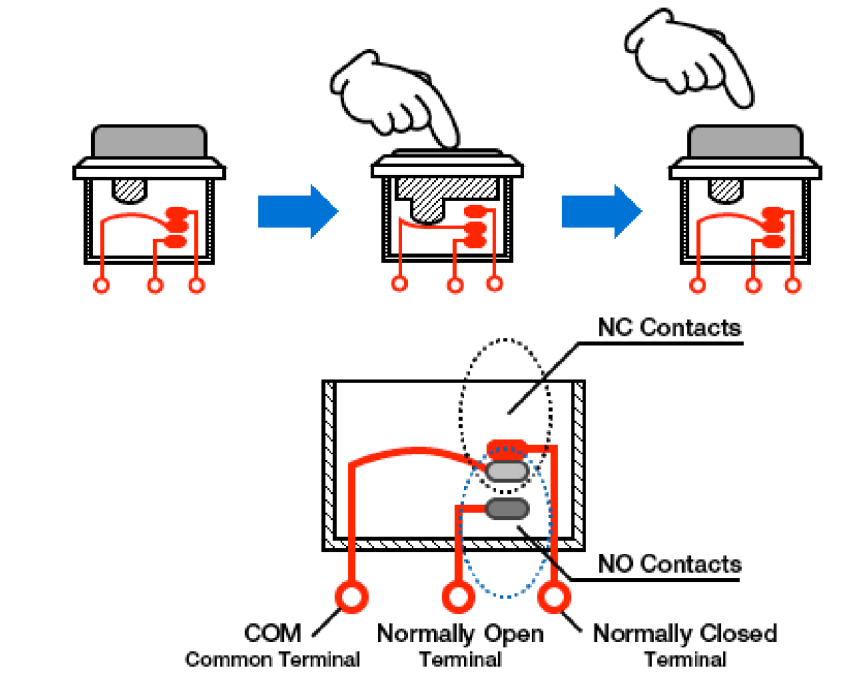
While the switch is not pressed, the circuit is connected and the lamp is lit.

When the switch is pressed, the contacts separate, opening the circuit and causing the lamp to go out.

Use NC contacts when you want the load to stop operating when the switch is operated.

3. SPDT (Single Pole Double Throw)

Changeover contacts have the functions of the both NO and NC contacts.

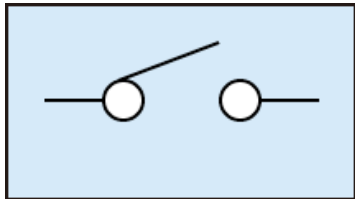
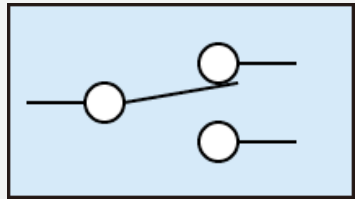
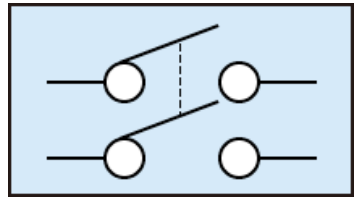
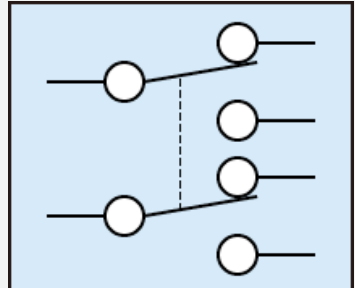


Use changeover contacts when you want to switch two circuits when the switch is operated.

Switches in Electrical Circuits: Pole & Throw

“Pole” indicates the number of circuits that one switch can control for one operation of the switch. “Throw” indicates the number of contact points. [NO and NC contacts](#) are single throw. Changeover contacts are double throw.

If one switch can control one circuit for one operation, it is a single-pole switch. If it can control two or three circuits for one operation, it is a double-pole or a triple-pole switch.

Single-pole, Single-throw	The switch contains one circuit with NO or NC contacts .	
Single-pole, Double-throw	The switch contains one circuit with changeover contacts.	
Double-pole, Single-throw	The switch contains two circuits with NO or NC contacts .	
Double-pole, Double-throw	The switch contains two circuits with changeover contacts.	

Use a multipole switch when you want to control more than one circuit at the same time.

Manual Switch Operation

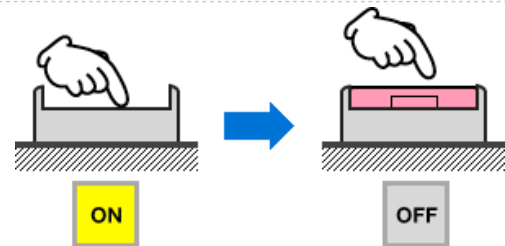
There are two operation patterns for Manual Switches: Momentary Operation and Alternate Operation

For a momentary operation, the switch stays ON only while it is being pressed.

For alternate operation, the ON state is held after the switch is released. The switch turns OFF when the switch is pressed again.

1. Momentary Operation

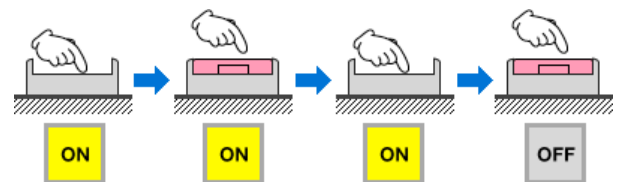
The switch is ON only while it is pressed. The switch turns OFF when it is released. For example, in crane games, the crane moves only while the switch is being pressed.



2. Alternate Operation

After you press the switch, the ON state is held even when the switch is released. To turn OFF the switch, you must press it again.

For example, the power switch on a TV uses alternate operation.



Alternate switches are used to maintain the ON state for a long period of time, such as for main power switches.

Switch Loads

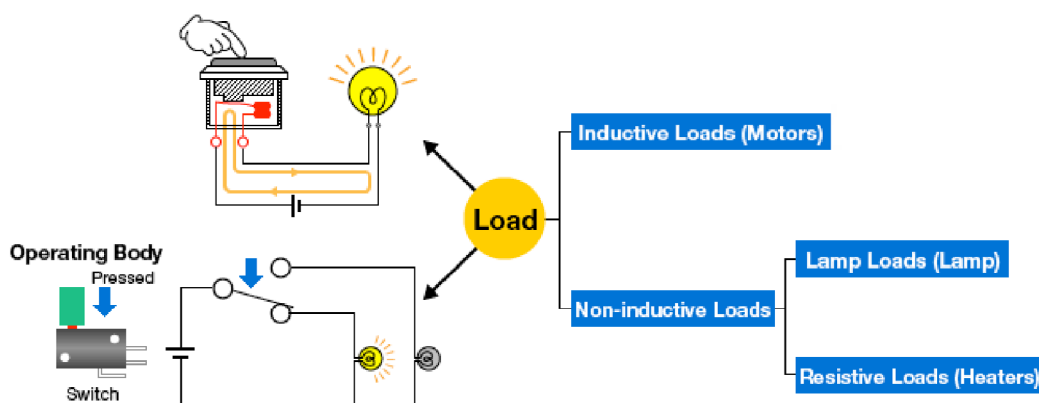
The load is the device that the switch turns ON and OFF.

The load is connected to an electric circuit and it consumes electric energy.

Loads are divided into inductive loads and non-inductive loads.

An inductive load contains a coil, such as a motor.

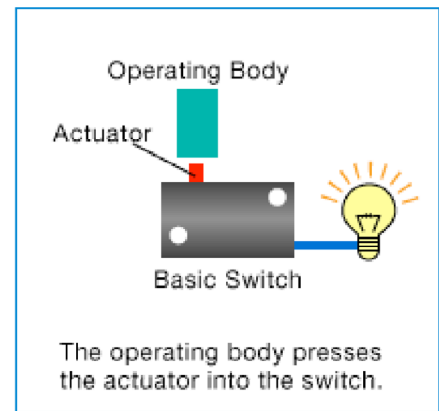
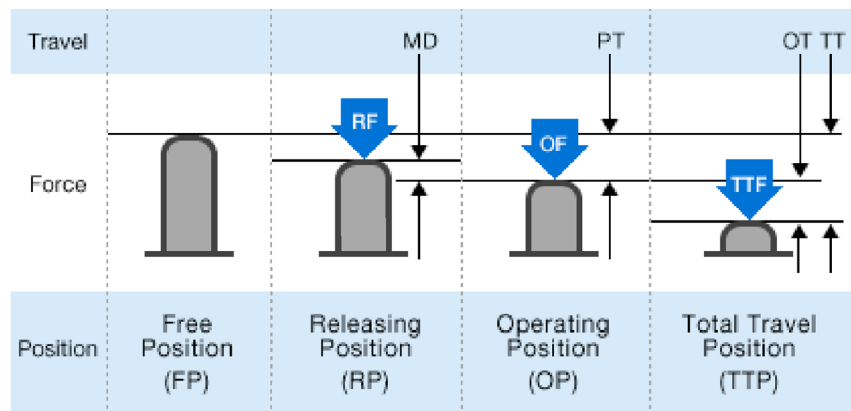
Non-inductive loads are divided into lamp loads and resistive loads.



You must select a suitable switch for the load that will be used.

Actuator Operation & Positions

1. Operation and Positions

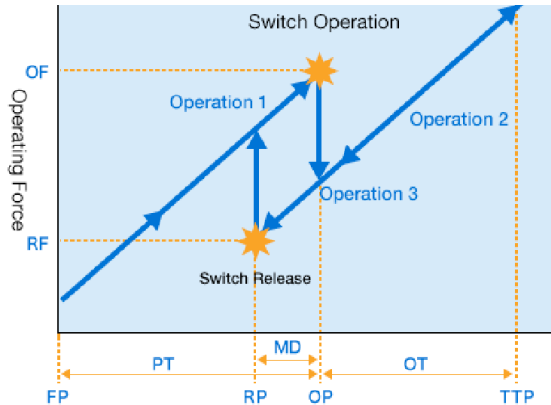


2. Terminology

Classification	Term	Abbreviation	Definition
Force	Operating Force	OF	The force required to press the actuator from the free position to the operating position.
	Releasing Force	RF	The force required to move the actuator from the total travel position to the releasing position.
	Total Travel Force	TTF	The force required to move the actuator from the operating position to the total travel position.
Travel	Pre Travel	PT	The travel distance of the actuator from the free position to the operating position.
	Over Travel	OT	The travel distance of the actuator from the operating position to the total travel position.
	Total Travel	TT	The travel distance of the actuator from the free position to the total travel position.
	Movement Differential	MD	The travel distance of the actuator from the operating position to the releasing position.
Position	Free Position	FP	The position of the actuator when not subjected to an external force.
	Operating Position	OP	The position of the actuator at which the moving contact reverses from the free position when external force is applied.
	Releasing Position	RP	The position of the actuator where the movable contact reverses from the operating position to the free position when the external force on the actuator is reduced.
	Total Travel Position	TTP	The position of the actuator when it reaches the stopper.

Operating Characteristics

1. Force-Stroke Characteristics



Operation 1: FP to OP

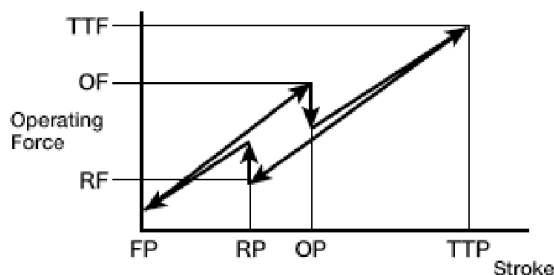
The actuator is pressed and the switch operates (turns ON) at the operating force (OF).

Operation 2: OP to TTP

The actuator is pressed farther and the switch maintains an ON state.

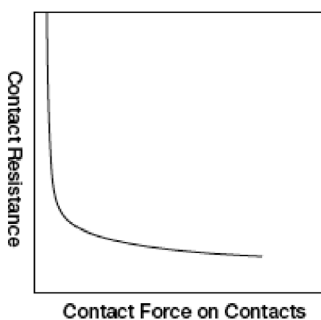
Operation 3: TTP to RP

The actuator is no longer pressed and when the operating force drops to the release force, the switch releases (turns OFF).



As the operating force (OF) increases, the contact force between the contacts increases and the contact resistance decreases.

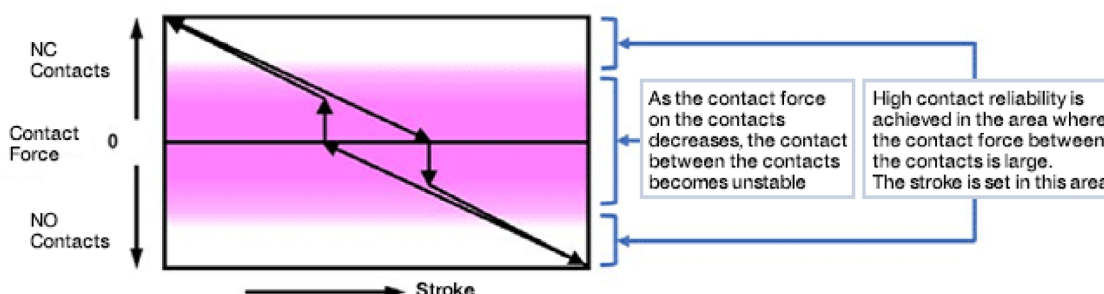
2. Contact Resistance - Contact Force Characteristics



The contact resistance varies with the contact force on the contacts.

As the contact force increases, the contact resistance decreases, creating stability between the contacts.

3. Contact Force-Stroke Characteristics



Mechanical Characteristics

The mechanical characteristics are the characteristics when there is no current flowing through the contacts.

Item		
Operating speed		0.1mm to 1m/s (for pin plunger)
Operating frequency	Mechanical	300 operations/min
	Electrical	60 operations/min
Insulation resistance		100MΩ min. (at 500 VDC with insulation resistance meter)
Contact resistance (initial value)		30 mΩ max.
Dielectric strength	Between contacts of same polarity	1,000 VAC, 50/60 Hz for min
	Between current-carrying metal parts and ground	1,500 VAC, 50/60 Hz for min
	Between each terminal and current-carrying metal parts	1,500 VAC, 50/60 Hz for min
Vibration resistance	Malfunction	10 to 55 Hz, 1.5-mm double amplitude
Shock resistance	Destruction	1,000 m/s ² max.
	Malfunction	300 m/s ² max.
Durability	Mechanical	5,000,000 operations min. (60 operations/min)
	Electrical	200,000 operations min. (30 operations/min at 3 A 125 VAC)
Degree of protection		IEC IP67
Electric shock protection class		Class 1
Proof tracking index (PTI)		175
Ambient operating temperature		-40 to 85°C (with no icing or condensation)
Ambient operating humidity		95% max. (at 5 to 35°C)

These are the ranges of operating conditions that will not cause malfunction, failure, or damage.

The vibration resistance characteristic is the range in which the contacts will not open for 1 ms or longer when the closed contacts are subject to vibration.

The durability characteristic is the number of operations that can be performed without power supplied to the contacts at the specified operating frequency and stroke.

The shock resistance characteristic is the range for which correct operation is possible even if the switch is subjected to shock during transportation or installation.

The shock resistance characteristic is the range in which the contacts will not open for 1 ms or longer when the closed contacts are subject to vibration.

The degree of protection is the level of protection from solid foreign objects or water entering the switch from the exterior.

Electrical Characteristics

The electrical characteristics are the characteristics when there is current flowing through the contacts.

Item		
Operating speed		0.1mm to 1m/s (for pin plunger)
Operating frequency	Mechanical	300 operations/min
	Electrical	60 operations/min
Insulation resistance		100MΩ min. (at 500 VDC with insulation resistance meter)
Contact resistance (initial value)		30 mΩ max.
Dielectric strength	Between contacts of same polarity	1,000 VAC, 50/60 Hz for min
	Between current-carrying metal parts and ground	1,500 VAC, 50/60 Hz for min
	Between each terminal and current-carrying metal parts	1,500 VAC, 50/60 Hz for min
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	Malfunction	300 m/s ² max.
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The operating frequency characteristic is the range of operating speeds under which the contacts can keep up with switching and operate correctly.

The dielectric strength characteristic is the limit value of a high AC voltage applied to specified locations that will not cause insulation breakdown.

The durability characteristic is the number of operations that can be performed at the specified operating frequency and stroke with the contacts connected to the rated load.

The insulation resistance is the resistance between discontinuous terminals, between terminals and non-charged metal parts, and between terminals and ground.

The contact resistance characteristic is the electric resistance between the contacts, including the conductor resistance of the spring and terminal section.

The electric shock protection class tells the protection against electric shock. (EN 61058-1)

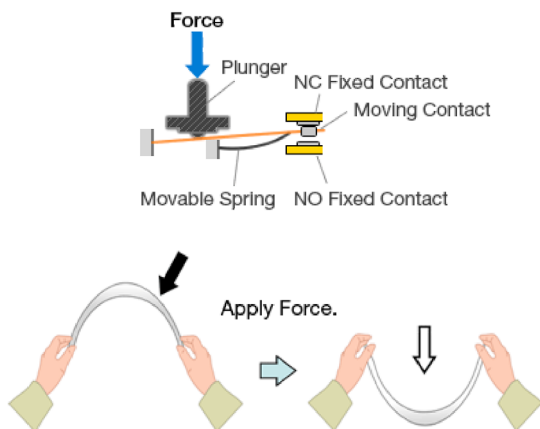
The proof tracking index is the maximum voltage that will not cause loss of insulation when a carbonized conductive path forms on the surface of an insulation between electric poles with a difference in electric potential. (EN 61058-1)

Snap-Action Mechanism in Electrical Switches

With a snap-action mechanism, the contacts will instantaneously switch at a specific stroke position without relation to the switch operating speed or operating force.

As opposed to a snap-action mechanism, with a slow-action mechanism, the operating speed of the switch is always the travel speed of the contacts.

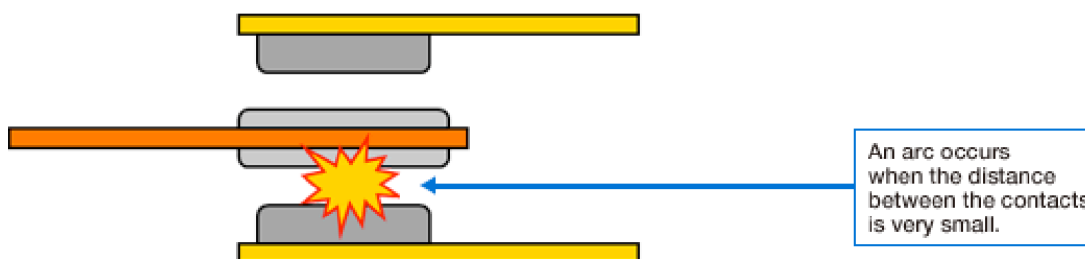
1. Principles of snap-action mechanisms in electrical switches



If you press down on the top of a sheet of plastic that is bent into an arc, the sheet will suddenly reverse to a U shape at a certain point. This is like a snap-action mechanism.

2. Features of snap-action mechanisms in electrical switches

- Because the contacts switch at high speed, any arc between the contacts will not continue for a long period of time. This reduces contact wear and maintains contact reliability.
- Even miniature switches can make and break large currents.
- With AC, the current flow alternates, so arcs are cut off more easily at the same voltage and current in comparison with DC. Therefore, contact damage is less with AC.

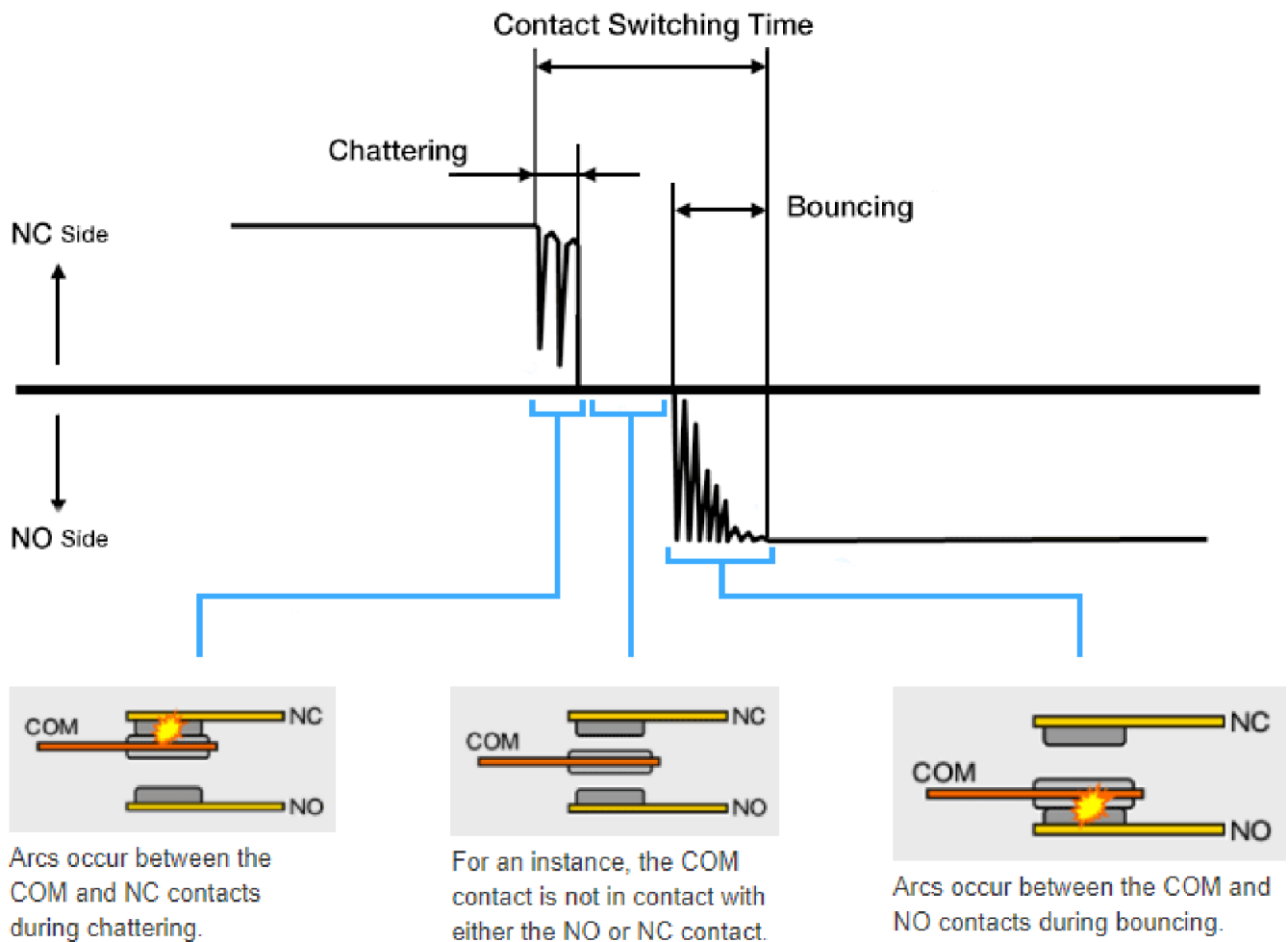


An arc occurs when the distance between the contacts is very small.

When pressure is applied to the pushbutton of a switch, the force of the movable spring causes the moving contact to quickly switch from the NC fixed contact to the NO fixed contact.

When pressure is released from the pushbutton of a switch, the force of the movable spring causes the moving contact to quickly switch from the NO fixed contact to the NC fixed contact.

Contact Switching Time



If the operating speed is too high, bouncing time increases. This causes repeated switching with minute contact gaps, which in turn increases contact wear due to arcing.

Resin Materials

Resin materials that provide insulation and mechanical strength are used for the cases and covers that protect the internal mechanisms of switches.

Material name	Material symbol	Characteristics
Phenol Resin	PF	A thermosetting resin. It provides superior resistance to combustion and tracking.
Polybutyrene terephthalate Resin	PBT	A thermoplastic resin. A type of this resin that is reinforced with fiberglass is used for basic switches.
Polyamide (nylon) Resin	PA	A thermoplastic resin. This type of resin has high heat resistance. It slides well and absorbs water well.
Polyphenylene sulfide Resin	PPS	A thermoplastic resin. It provides better resistance to heat than PA. It is used when heat resistance is required, e.g., for soldering.

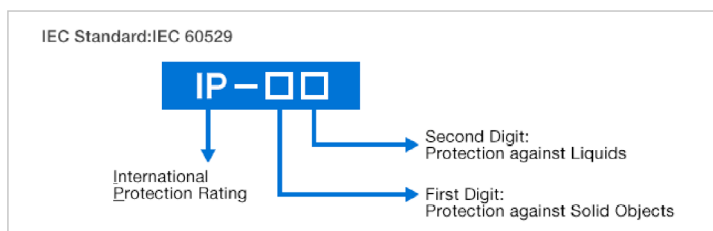
Materials are divided into two types: **Thermosetting resin** and **thermoplastic resin**.

- **Thermosetting resin:** These resins harden when heat is applied to them. They cannot be reused.
- **Thermoplastic resin:** These resins melt when heat is applied to them. They can be reformed to recycle the materials.

Cases and covers are mainly made from PBT and other thermoplastic resins so that the materials can be recycled.

Ingress Protection

Ingress protection tells how much the structure of the Switch provides protection against solid objects and water.



1. First Digit: Protection against Solid Objects

Code	Level of protection	
0		No protection against entry of dust or dirt.
1		Round test object with 50-mm diameter will only partially enter the interior.
2		Round test object with 12.5-mm diameter will only partially enter the interior.
3		Round test object with 2.5-mm diameter will not enter the interior.
4		Test object with 1.0-mm diameter will not enter the interior.
5		No dust or dirt that would affect the correct operation of the device or safety will enter the interior.
6		Dust and dirt will not enter the interior.

2. Second Digit: Protection against Liquids

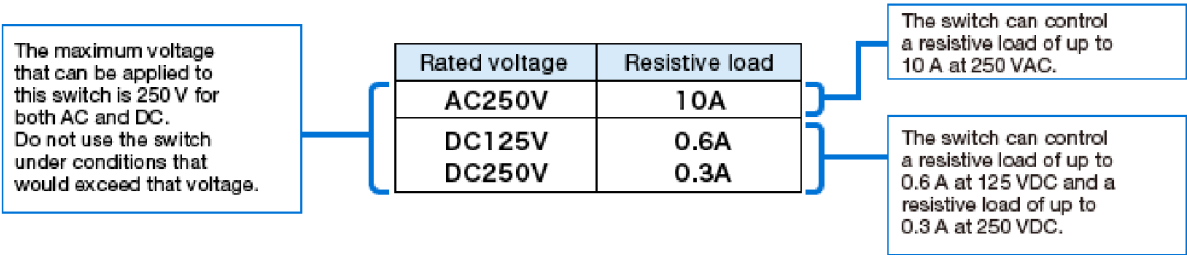
Code	Level of protection		Test method outline (test performed using pure water)	
0	No protection	No protection against entry of water	No test	
1	Protection against water drops		No harmful effects from vertical water drips	By using water drip tool vertically and dropping water for 10 min
2	Protection against water drops		No harmful effects of water drips from vertical direction when the enclosure is tilted at 15° from its normal position	By using water drip tool, moving it at an angle of 15°, and dripping water for 10 min (2.5 min per direction)
3	Protection against water spray		No harmful effects of water spray at any angle up to 60° from the vertical direction	By using the tool shown on the right, and spraying water vertically at angles up to 60° for 10 min
4	Protection against water splash		No harmful effects of water splash from all directions	By using the tool shown at the right, and splashing water from all directions for 10 min
5	Protection against water jets		No harmful effects of water jets from all directions	By using the tool shown on the right, and jetting the water from all directions to the object surfaces for 1 m ² /min, for at least 3 min total.
6	Protection from strong water jet		No harmful effects of strong water jets from all directions	By using the tool shown on the right, and jetting the water from all directions to the object surfaces for 1 m ² /min, for at least 3 min total.
7	Protection against submersion in water		No harmful effects from submersion in water to a certain level of pressure and length of time	Submerge to 1 m depth in water (when device height is 850 mm or less) for 30 min

This does not imply that the device can be operated under water.

Standard switches are often IP40. Sealed switches are often IP67.

Ratings

The ratings are the values that warranty standards for the characteristics and performance of a switch. This generally indicates the maximum current that can flow through the contacts. The value of the current depends on the size of the voltage and the type of load. The maximum current that can flow through the switch contacts for each applied voltage and load is specified. Generally, a large current can flow if the voltage is low.



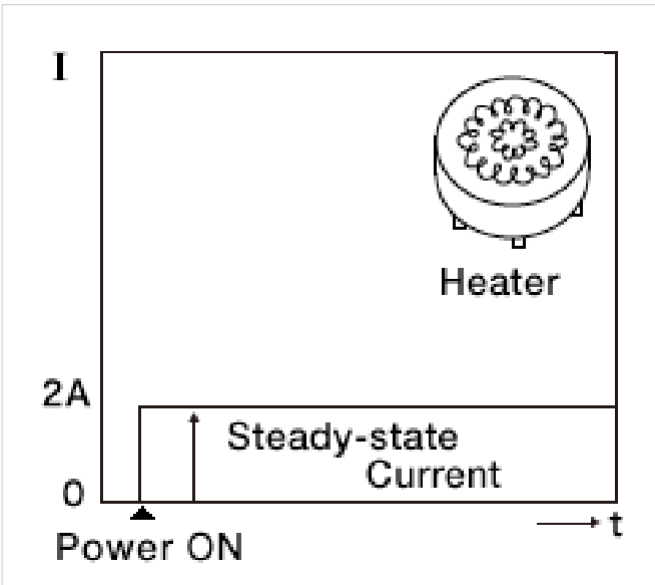
Select switches that are suitable for the applied load and conditions (current and voltage).

Load Types & Ratings

Inrush current is a current that is much larger than the steady-state current and that flows as soon as power is input to the electric circuits that operate the load. Inrush current occurs for loads such as motors and incandescent lamps.

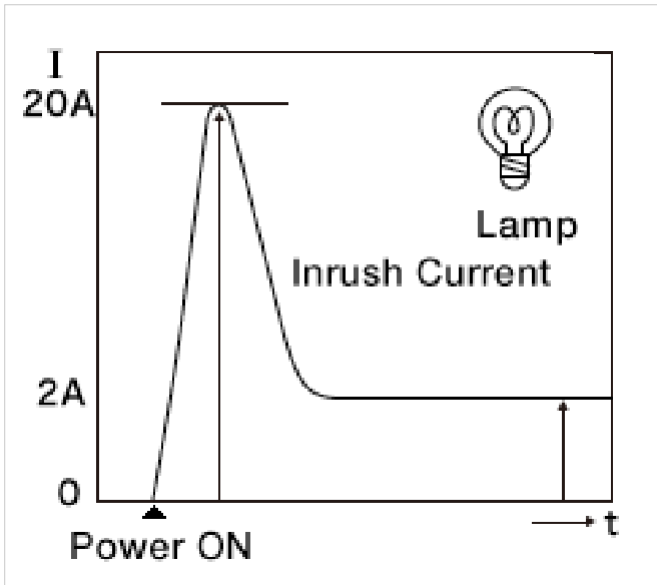
1. Inrush Current

Resistive Loads



The current is constant from the time that power is turned ON.

Lamp Loads



Inrush current of approximately 10 times the steady-state current flows as soon as power is turned ON and then the current becomes constant.

2. Inrush Current and Rating

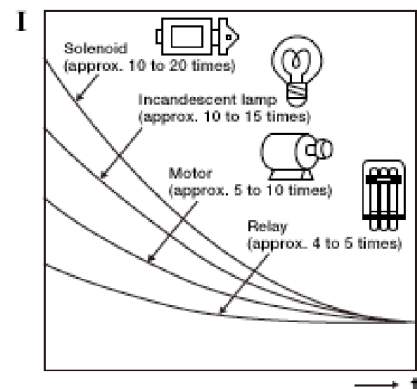
If ratings are given for both motor loads and lamp loads, switch applicability is determined with the relevant value.

If the rating is given only for a resistive load, the inrush current for the actual load is calculated to determine if the rating would be exceeded.

Examples:

Heater	→	A resistive load.	The steady-state current must be less than the resistive load rating.
Incandescent lamp	→	A lamp load.	Ten times the steady-state current must be less than the resistive load rating.
Motor	→	A motor load.	Six times the steady-state current must be less than the resistive load rating.

Load Types and Inrush Current

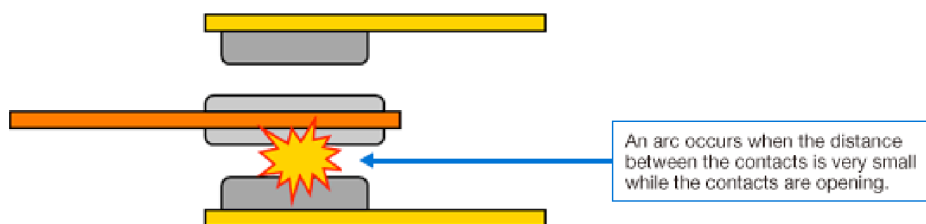


Include the inrush current when you consider ratings.

Switching DC Circuits

An arc is a spark that occurs between the contacts when the switch turns OFF an electric circuit.

Arcing is more common at higher currents and lasts longer with slower contact switching speeds. If arcing lasts too long, contacts will wear drastically.



Switching DC Circuits

In AC circuits, where the direction of current flow changes, arcing is extinguished every time the voltage goes to 0 V.

With DC circuits, the current always flows in the same direction, which increases arcing time, causes contact wear, and reduces durability.

Contact transfer can also occur, causing rough contact surfaces which can catch and cause failure-to-open malfunctions.

For a DC circuit, always use a switch with a DC rating.

Rated voltage	Resistive load
AC250V	10A
DC125V	0.6A
DC250V	0.3A

Reducing the current flow is necessary to suppress arcing. Therefore, switches with DC ratings have low carry current ratings.

In DC circuits, always use switches with DC ratings and use the switches so that the ratings are not exceeded.

There is also the X Series of Basic Switches for DC currents that provides a magnetic blowout mechanism.

Operating Speeds

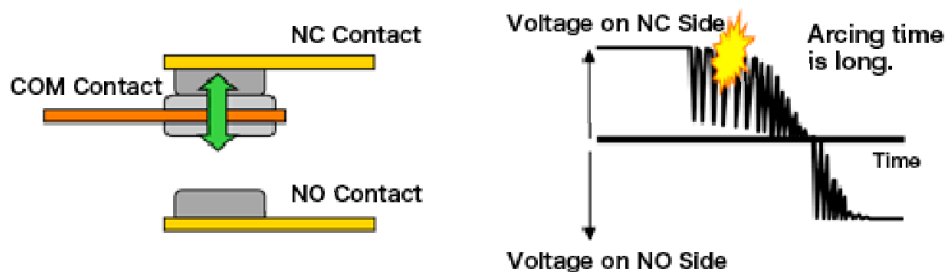
Chattering is when the switch repeatedly turns ON and OFF while it is in an ON state because external vibration or other force causes the contacts to open momentarily.

Bouncing is when the switch repeatedly turns ON and OFF because the COM contact bounces due to the shock from switching immediately after the switch operates.

1. Extremely Slow Operating Speeds

The contact between the contacts becomes unstable and chattering occurs.

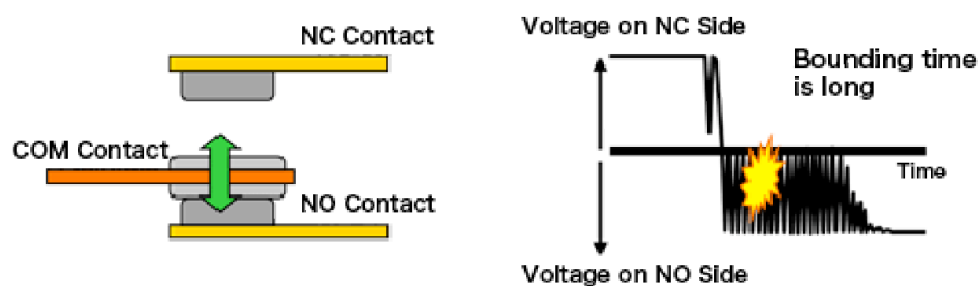
Incorrect signals are output and arcing causes contact deterioration.



2. Extremely Fast Operating Speeds

The COM contact bounces due to vibration and shock.

Incorrect signals are output and mechanical stress causes damage.



Set the operating speed so that it is within the specified values.

Microloads

A microload is a load that is switched with a circuit current of a few milliamperes.

Microloads are used for signal pulses to input to electronic devices such as those used in microcomputers.

1. Switches for Microloads

For a microload, there is not sufficient energy to destroy the film on the contact surfaces that results from oxidation and sulfurization. This makes contact failure a problem.

We recommend the use of switches for microloads that use contact materials that resist the influence of films (e.g., gold) or that use crossbar contacts, which also resist the influence of films.

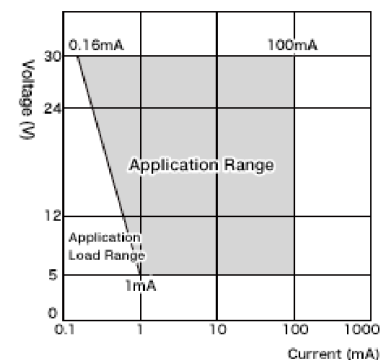
They are included in the main models of basic switches.

2. Microload Application

To prevent contact failure, confirm the current-voltage application range that is specified for the switch.

For example,

a switch rated for 0.1 A for 30 VDC with a minimum applicable load of 1 mA at 5 VDC would be used within the trapezoidal area.



The minimum applicable load is the N-level reference value (JIS C5003). This level indicates only one random failure caused by unstable contact resistance for every two million operations.

When you use a switch for a microload, confirm that the application conditions are within the application range.

Install CR circuits or other absorption circuits to prevent noise and incorrect pulses due to bouncing and chattering.

For loads that cause inrush current during switching, insert contact protection circuits because the durability of the switch will be reduced.

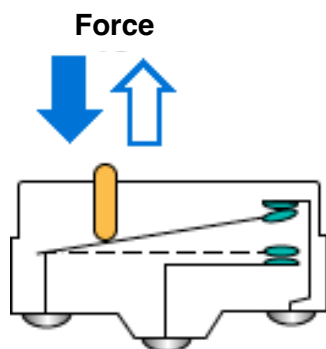
Switch Durability

The durability (life) of a switch is the number of switching operations that can be performed by the switch before the specified operating characteristics and performance can no longer be achieved.

There are two types of durability (life): mechanical durability and electrical durability.

1. Mechanical Switch Durability (Life)

This is the durability for operation at the specified frequency and stroke test conditions without supplying power to the switch.

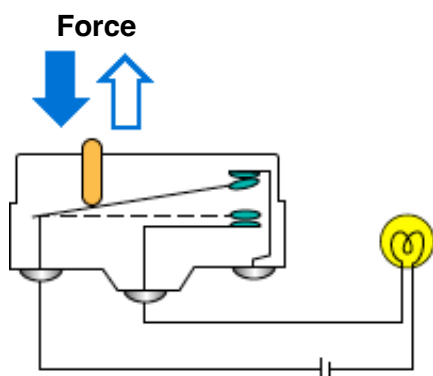


When the contacts are switched, Contact Wear occurs. *1

*1 Contact Wear:
Wear that occurs in contacts.

2. Electrical Switch Durability (Life)

This is the durability for operation at the specified frequency and stroke test conditions with a load connected and the rated current and voltage applied.



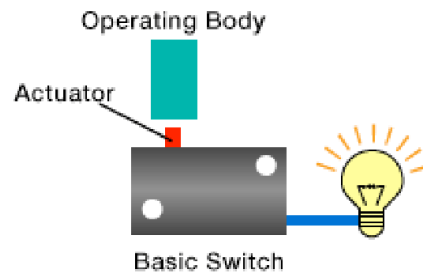
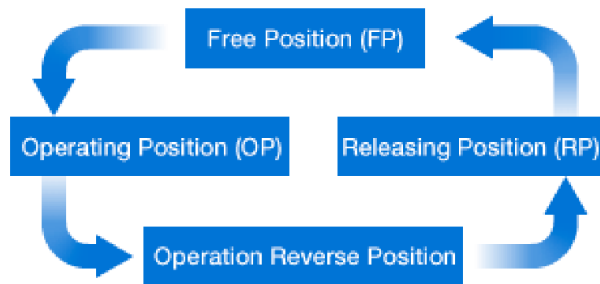
When the contacts are switched, Contact Erosion occurs. *2

*2 Contact Erosion:
The fusing and spattering of contact material caused by arcing and other factors.

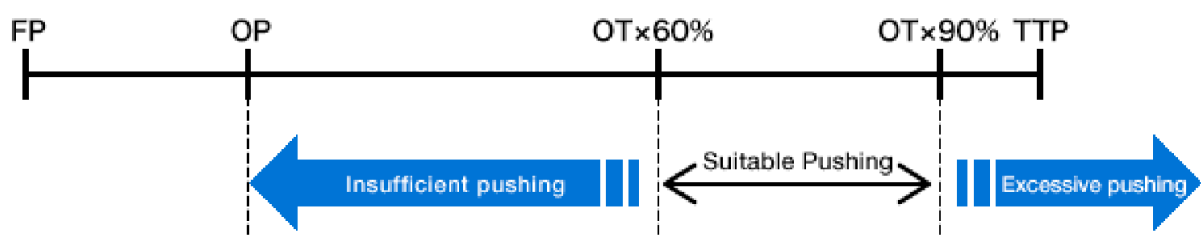
The life of a switch is affected by the load conditions, operating conditions and application environment. Evaluate switch performance under the actual application conditions.

Operating Stroke

The operating stroke is the movement of the actuator caused by the operating body that is required for the switch to operate correctly.



1. The actuator must normally be in the free position(FP).(The operating body is separated from the actuator.)
2. The motion of the operating body must not stop at the operating position (OP) and the reversing position(RP).
3. When the operation reverse position(suitable pushing of the actuator) is set, the motion of the operating body must be adjustable based on the specified operating travel(OT) value.
4. When the switch is placed in a device, the suitable pushing point of the operating body has to be 60% to 90% in the operating position(OP) to the total travel position (TTP).



Set the switch pushing distance from 60% to 90% of the specified OT value.

Failure

Causes and Countermeasures for Main Switch Failure

Failure		Assumed cause	Countermeasure
Failure in electrical characteristics	Contact failure	Foreign matter is attached to the contacts.	Use sealed switches to prevent the entry of foreign matter.
		Films forming on contact surfaces	Use switches with gold contacts, which have wiping effects.
		Insufficient contact force between the contacts caused by an incorrect stroke.	Set a suitable stroke.
	Malfunction	Contact chattering caused by vibration or shock.	Use switches with large contact forces between the contacts (i.e., with a high operating force (OF)).
	Welding	The switching capacity of the contacts was exceeded.	Use a high-capacity switch. Insert a contact protection circuit.
	Insulation deterioration	The contacts are spattering due to arcing.	Use a high-capacity switch.
Failure in mechanical characteristics	Failure to operate	The mechanism is damaged due to an incorrect stroke, overload, or shock.	Set a suitable stroke and operate the switch at a suitable operating speed and with a suitable load.
		Foreign matter has entered the switch and is caught in the mechanism or contacts.	Use sealed switches to prevent the entry of foreign matter.
	External damage	An overload was placed on the actuator because of the dog or cam shape or because an unsuitable operating method was used.	Change the design of the dog or cam and use suitable operating methods.

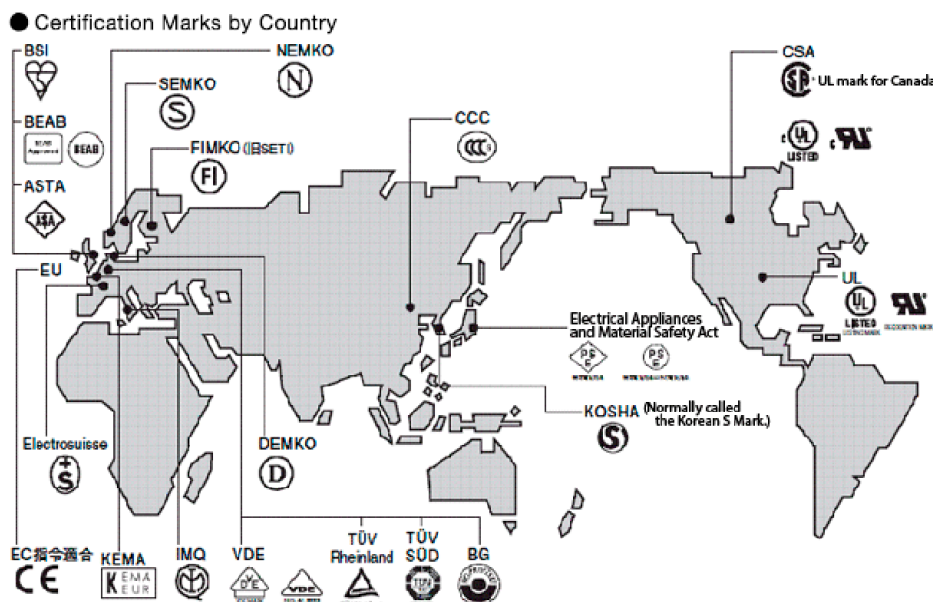
Safety Standards

Safety standards represent the minimum standards that are required from devices and components to prevent accidents and protect consumers who use electric devices from the hazards presented by electric shock and fire.

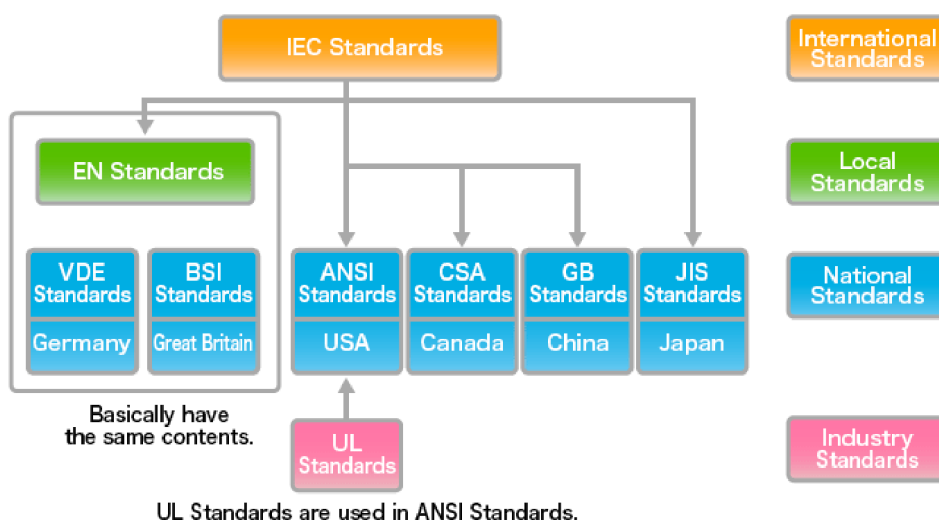
Each country has different voltage conditions, weather conditions and safety concepts, and they all set safety standards.

If the switches are certified for the safety standards, the switches are exempt from testing when applying standard certification to devices that use those switches.

Safety Standards and Certification Bodies by Country



Safety Standards by Country



Basic Safety Standards Requirements by Region

North America:

The combustibility and ignitability of the insulation materials used in devices and components and temperature increases are regulated to emphasize the prevention of fires caused by electric devices. The main standards are UL in the USA and CSA in Canada.

Europe:

The Insulation distances and proof tracking of devices and components are regulated to emphasize the prevention of electric shock accidents caused by electric devices. The main standards are VDE (Germany).

*Proof Tracking

The proof tracking index is degree of loss of insulation when a carbonized conductive path forms on the surface of an insulation between electric poles with a difference in electric potential.

Area	Voltage	Accidents	Most Important Requirement
North America	120 / 240 Vac	Fire	Combustibility
Europe	230 / 400 Vac	Electric Shock	Insulation Distance

Main Safety Standards

Name	National Standards	Country	Description	Certification Body	Certification Mark
IEC	-	International	Technical electric standards based on the most recent scientific technology. Forms the basis for standards in other countries.	-	-
UL	ANSI Standards	United States	To prevent fires, standards are enforced for the sale of electric products in the USA by state and city. Components must also be certified.	UL	 
CSA	CSA Standards	Canada	North American safety standards are applied and operated to prevent fire accidents, in the same way as in the USA.	CSA	
EU	EN Standards	Europe	Standards are designed to prevent electric shock and fires, but are not legally enforced. Enforcement is achieved through strict penalties.	VDE, TÜV-Rh	 
CCC	Chinese National Standards: GB Standards	China	Items for which certification is enforced are specified, and the import and sale of uncertified items in China is prohibited.	CCC	 

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