Siemens STEP 2000 Course

Basics of Sensors

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Introduction

Welcome to another course in the STEP 2000 series, **S**iemens **T**echnical **E**ducation **P**rogram, designed to prepare our distributors to sell Siemens Energy & Automation products more effectively. This course covers **Sensors** and related products.

Upon completion of **Sensors** you should be able to:

- Describe advantages, disadvantages, and applications of limit switches, photoelectric sensors, inductive sensors, capacitive sensors, and ultrasonic sensors
- Describe design and operating principles of mechanical limit switches
- Identify components of International and North American mechanical limit switches
- Describe design and operating principles of inductive, capacitive, ultrasonic, and photoelectric sensors and describe differences and similarities
- Apply correction factors where appropriate to proximity sensors
- Identify the various scan techniques of photoelectric sensors
- Identify ten categories of inductive sensors and sensors in each category
- Describe the effects of dielectric constant on capacitive proximity sensors
- Identify environmental influences on ultrasonic sensors
- Identify types of ultrasonic sensors that require manual adjustment, can be used with SONPROG, and require the use of a signal evaluator

- Describe the difference between light operate and dark operate modes of a photoelectric sensor

- Describe the use of fiber optics and laser technology used in Siemens photoelectric sensors

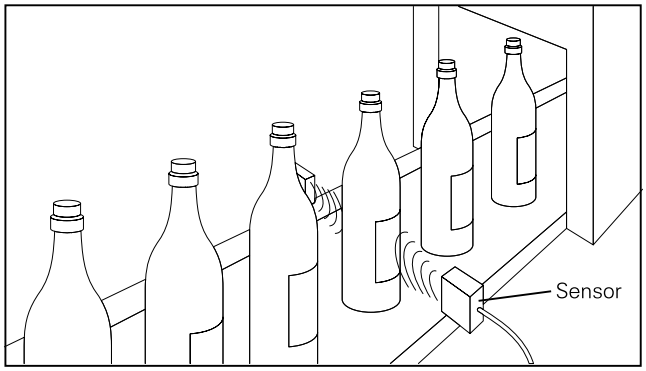
- Select the type of sensor best suited for a particular application based on material, sensing distance, and sensor load requirements

This knowledge will help you better understand customer applications. In addition, you will be better able to describe products to customers and determine important differences between products. You should complete **Basics of Electricity** and **Basics of Control Components** before attempting **Sensors**. An understanding of many of the concepts covered in **Basics of Electricity** and **Basics of Control Components** is required for **Sensors**.

If you are an employee of a Siemens Energy & Automation authorized distributor, fill out the final exam tear-out card and mail in the card. We will mail you a certificate of completion if you score a passing grade. Good luck with your efforts.

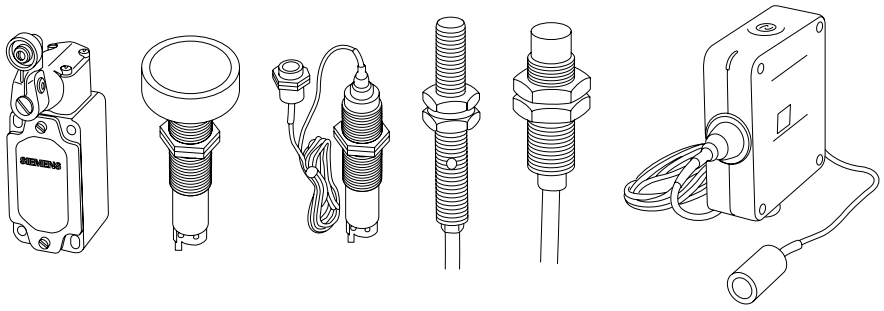
Sensors

One type of feedback frequently needed by industrial-control systems is the position of one or more components of the operation being controlled. Sensors are devices used to provide information on the presence or absence of an object.



Siemens Sensors

Siemens sensors include limit switches, photoelectric , inductive, capacitive, and ultrasonic sensors. These products are packaged in various configurations to meet virtually any requirement found in commercial and industrial applications. Each type of sensor will be discussed in detail. At the end of the course an application guide is provided to help determine the right sensor for a given application.



Technologies

Limit switches use a mechanical actuator input, requiring the sensor to change its output when an object is physically touching the switch. Sensors, such as photoelectric, inductive, capacitive, and ultrasonic, change their output when an object is present, but not touching the sensor.

In addition to the advantages and disadvantages of each of these sensor types, different sensor technologies are better suited for certain applications. The following table lists the sensor technologies that will be discussed in this course.

Sensor	Advantages	Disadvantages	Applications
Limit Switch	•High Current Capability •Low Cost •Familiar "Low-Tech" Sensing	•Requires Physical Contact with Target •Very Slow Response •Contact Bounce	•Interlocking •Basic End-of-Travel Sensing
Photoelectric	•Senses all Kinds of Materials •Long Life •Longest Sensing Range •Very Fast Response Time	•Lens Subject to Contamination •Sensing Range Affected by Color and Reflectivity of Target	•Packaging •Material Handling •Parts Detection
Inductive	•Resistant to Harsh Environments •Very Predictable •Long Life •Easy to Install	•Distance Limitations	•Industrial and Machines •Machine Tool •Senses Metal-Only Targets
Capacitive	•Detects Through Some Containers •Can Detect Non-Metallic Targets	•Very Sensitive to Extreme Environmental Changes	•Level Sensing
Ultrasonic	•Senses all Materials	•Resolution •Repeatability •Sensitive to Temperature Changes	•Anti-Collision •Doors •Web Brake •Level Control

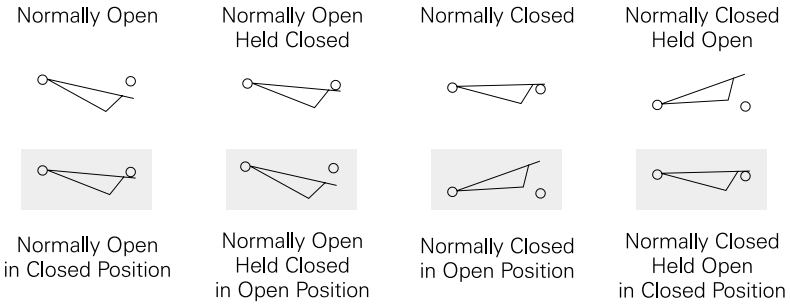
Contact Arrangement

Contacts are available in several configurations. They may be normally open (NO), normally closed (NC), or a combination of normally open and normally closed contacts.

Circuit symbols are used to indicate an open or closed path of current flow. Contacts are shown as normally open (NO) or normally closed (NC). The standard method of showing a contact is by indicating the circuit condition it produces when the contact actuating device is in the deenergized or nonoperated state. For the purpose of explanation in this text a contact or device shown in a state opposite of its normal state will be highlighted. Highlighted symbols used to indicate the opposite state of a contact or device are not legitimate symbols. They are used here for illustrative purposes only.

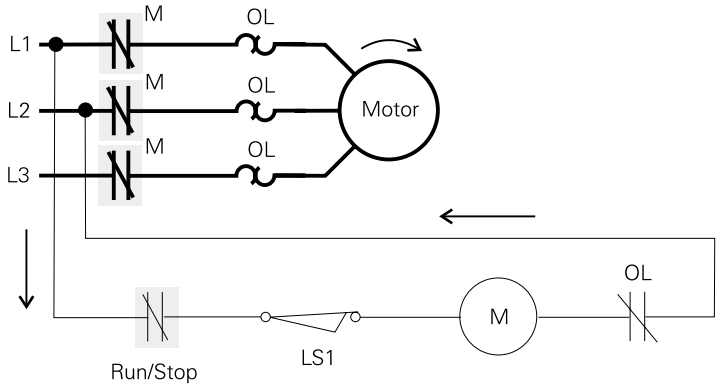
Normally Open Deenergized State | Normally Open Energized State | Normally Closed Deenergized State | Normally Closed Energized State

Mechanical limit switches, which will be covered in the next section, use a different set of symbols. Highlighted symbols are used for illustrative purposes only.

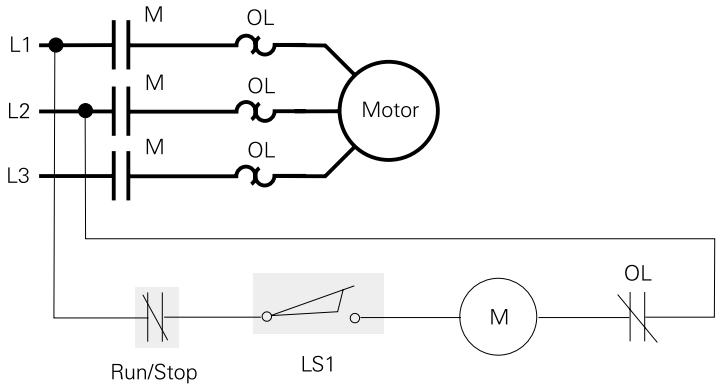


Circuit Example

In the following diagram a mechanical limit switch (LS1) has been placed in series with a Run/Stop contact and the "M" contactor coil. The Run/Stop contact is in the Run condition and the motor is running a process. This could be a conveyor or some other device. Note that the "M" contacts and the "Run/Stop" are shown highlighted, indicating they are normally open contacts in the closed position. LS1 is a normally closed contact of the mechanical limit switch.



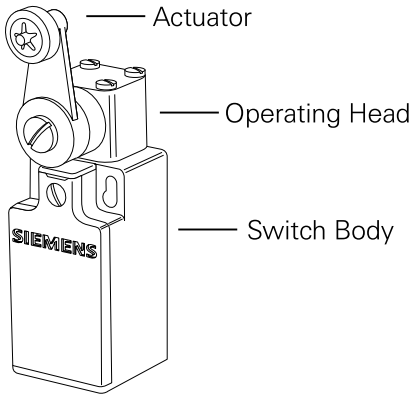
When an object makes contact with the mechanical limit switch the LS1 contacts will change state. In this example the normally closed contacts of LS1 open. The mechanical limit switch symbol is highlighted. The "M" contactor coil is deenergized, returning the normally open contacts of the "M" contactor to their normal position, stopping the motor and the process.

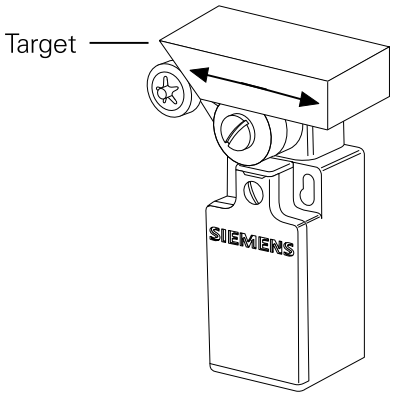


Limit Switches

A typical limit switch consists of a switch body and an operating head. The switch body includes electrical contacts to energize and deenergize a circuit. The operating head incorporates some type of lever arm or plunger, referred to as an actuator.

The standard limit switch is a mechanical device that uses physical contact to detect the presence of an object (target). When the target comes in contact with the actuator, the actuator is rotated from its normal position to the operating position. This mechanical operation activates contacts within the switch body.





Principle of Operation

A number of terms must be understood to understand how a mechanical limit switch operates.

The free position is the position of the actuator when no external force is applied.

Pretravel is the distance or angle traveled in moving the actuator from the free position to the operating position.

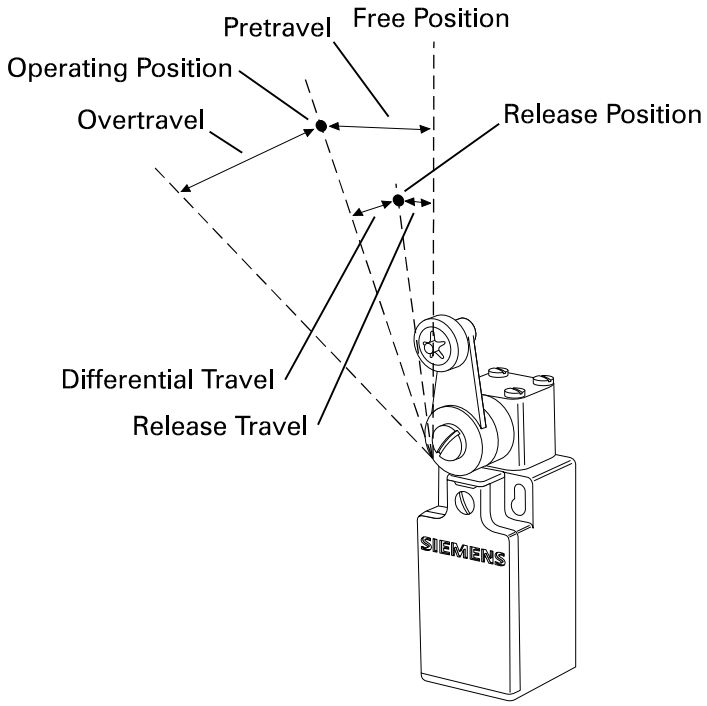
The operating position is where contacts in the limit switch change from their normal state (NO or NC) to their operated state.

Overtravel is the distance the actuator can travel safely beyond the operating point.

Differential travel is the distance traveled between the operating position and the release position.

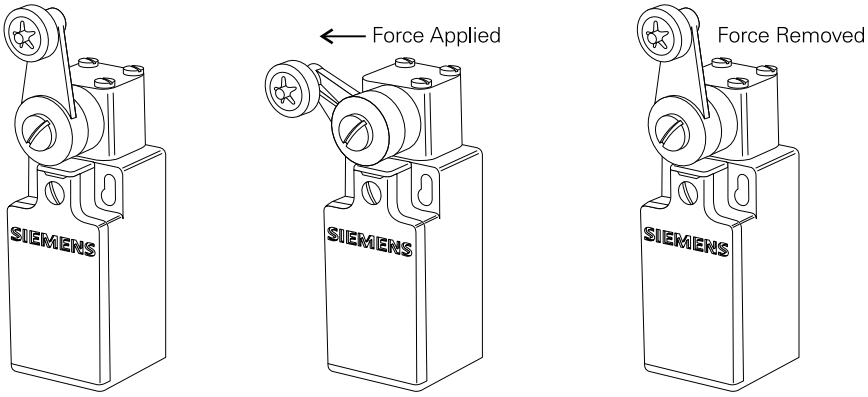
The release position is where the contacts change from their operated state to their normal state.

Release travel is the distance traveled from the release position to the free position.



Momentary Operation

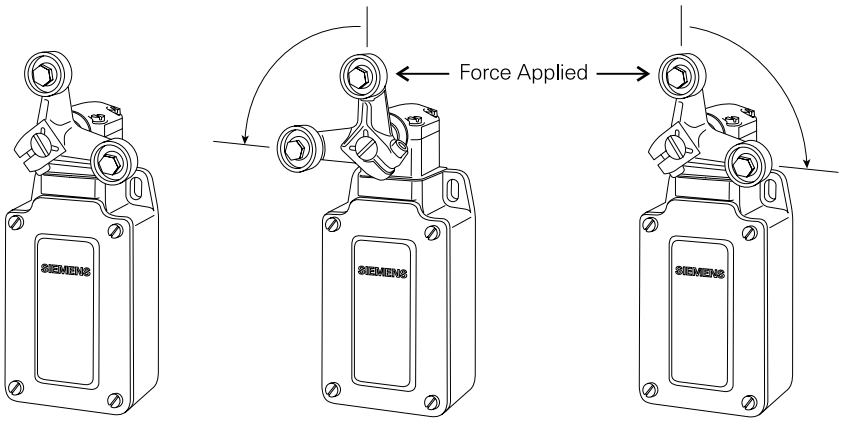
One type of actuator operation is momentary. When the target comes in contact with the actuator, it rotates the actuator from the free position, through the pretravel area, to the operating position. At this point the electrical contacts in the switch body change state. A spring returns the actuator lever and electrical contacts to their free position when the actuator is no longer in contact with the target.



Free Position | Operating Position | Free Position

Maintained Operation

In many applications it is desirable to have the actuator lever and electrical contacts remain in their operated state after the actuator is no longer in contact with the target. This is referred to as maintained operation. With maintained operation the actuator lever and contacts return to their free position when a force is applied to the actuator in the opposite direction. A fork-style actuator is typically used for this application.



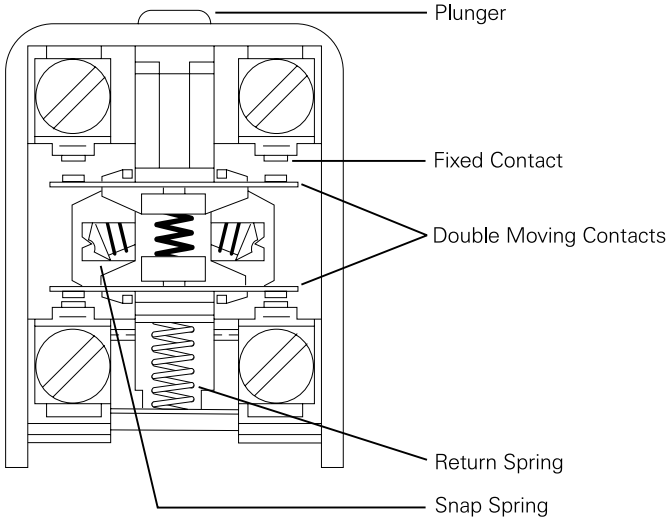
Free Position | Operated Position | Free Position

Snap-Action Contacts

There are two types of contacts, snap-action and slow-break. Snap-action contacts open or close by a snap action regardless of the actuator speed. When force is applied to the actuator in the direction of travel, pressure builds up in the snap spring. When the actuator reaches the operating position of travel, a set of moveable contacts accelerates from its normal position towards a set of fixed contacts.

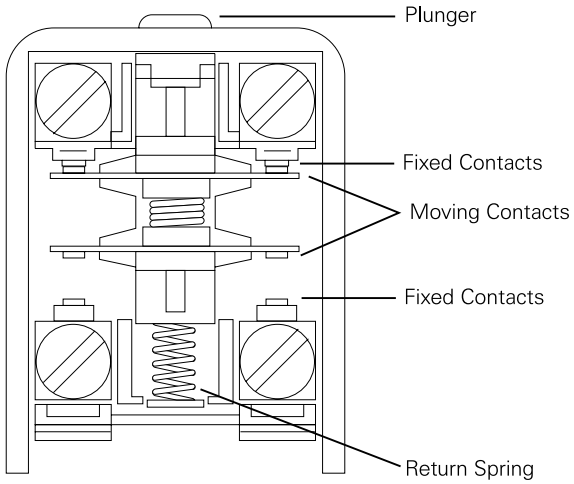
As force is removed from the actuator it returns to its free position. When the actuator reaches the release position the spring mechanism accelerates the moveable contact back to its original state.

Since the opening or closing of the contacts is not dependent on the speed of the actuator, snap-action contacts are particularly suited for low actuator speed applications. Snap-action contacts are the most commonly used type of contact.



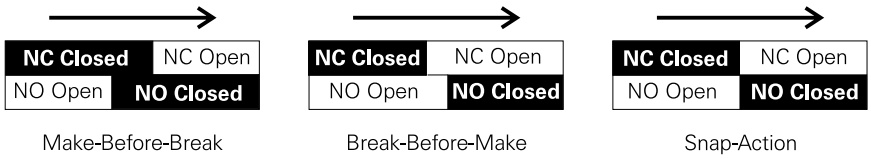
Slow-Break Contacts

Switches with slow-break contacts have moveable contacts that are located in a slide and move directly with the actuator. This ensures the moveable contacts are forced directly by the actuator. Slow-break contacts can either be break-before-make or make-before-break.



In slow-break switches with break-before-make contacts, the normally closed contact opens before the normally open contact closes. This allows the interruption of one function before continuation of another function in a control sequence.

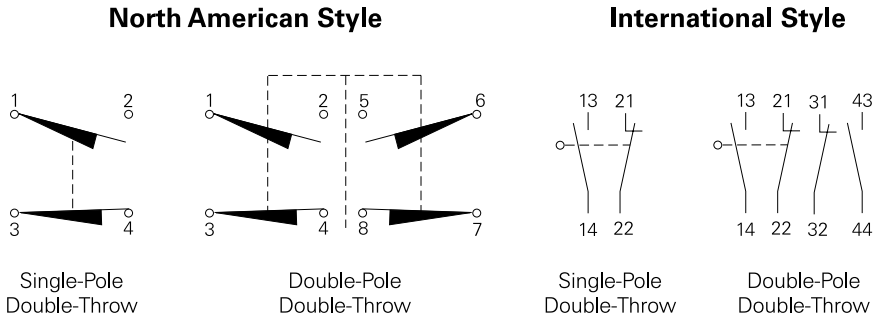
In slow-break switches with make-before-break contacts, the normally open contact closes before the normally closed contact opens. This allows the initiation of one function before the interruption of another function.



Contact State	Break-Before-Make		Make-Before-Break	
	NO	**NC**	**NO**	**NC**
Free Position	Open	Closed	Open	Closed
Transition	Open	Open	Closed	Closed
Operated State	Closed	Open	Closed	Open

Contact Arrangements

There are two basic contact configurations used in limit switches: single-pole, double-throw (SPDT) and double-pole, double-throw (DPDT). This terminology may be confusing if compared to similar terminology for other switch or relay contacts, so it is best just to remember the following points. The single-pole, double-throw contact arrangement consists of one normally open (NO) and one normally closed (NC) contact. The double-pole, double-throw (DPDT) contact arrangement consists of two normally open (NO) and two normally closed (NC) contacts. There are some differences in the symbology used in the North American and International style limit switches. These are illustrated below.



Electrical Ratings

Contacts are rated according to voltage and current. Ratings are generally described as inductive ratings. A typical inductive load is a relay or contactor coil. There are three components to inductive ratings:

Make The load a switch can handle when the mechanical contacts close. This is associated with inrush currents. This is typically two cycles or less.

Break The load a switch can handle when the mechanical contacts are opened. This is the maximum continuous switch current.

Continuous The load that a switch can handle without making or breaking a load.

The following ratings are typical of Siemens International and North American style limit switches.

Inductive AC Contact Ratings

AC Volts	International and North American Style			
	Make		Break	
	Amp	VA	Amp	VA
120	60	7200	6	720
240	30	7200	3	720

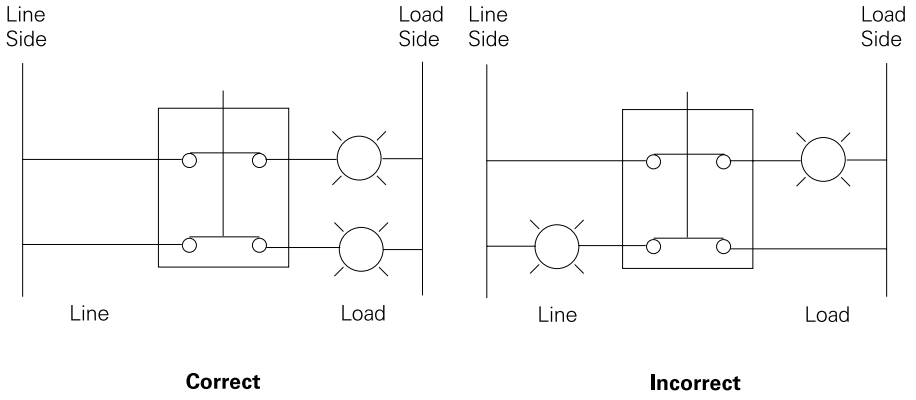
Inductive DC Contact Ratings

DC Volts	International Style			
	Make		Break	
	Amp	VA	Amp	VA
120	0.55	69	0.55	69
240	0.27	69	0.55	69

DC Volts	North American Style			
	Make		Break	
	Amp	VA	Amp	VA
120	0.22	-	0.22	-
240	0.11	-	0.11	-

Load Connection

Care must be made to ensure that multiple loads on one switch are properly connected. The correct way to wire a switch is so that the loads are connected to the load side of the switch. Loads should never be connected to the line side of the switch.

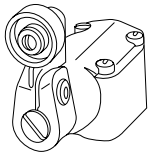


Actuators

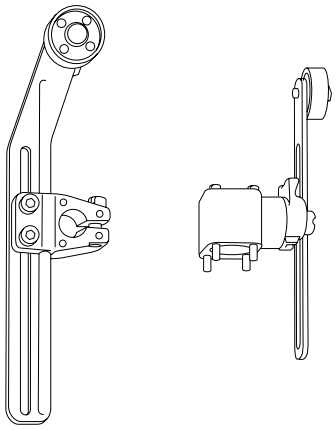
Several types of actuators are available for limit switches, some of which are shown below. There are also variations of actuator types. Actuators shown here are to provide you with a basic knowledge of various types available. The type of actuator selected depends on the application.

Roller Lever

The standard roller is used for most rotary lever applications. It is available in various lengths. When the length of the roller lever is unknown, adjustable length levers are available.



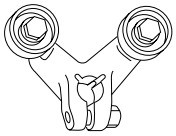
Standard Roller Lever



Adjustable Length Roller Crank Levers

Fork

The fork style actuator must be physically reset after each operation and is ideally suited for transverse movement control.



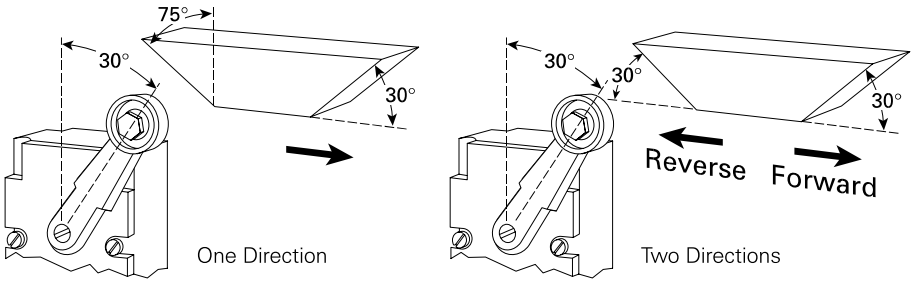
Mounting Considerations

Limit switches should be mounted in locations which will prevent false operations by normal movements of machine components and machine operators. An important aspect of limit switch mounting is cam design. Improper cam design can lead to premature switch failure.

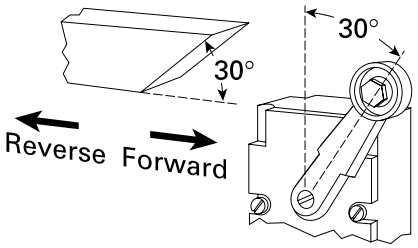
For lever arm actuators it is always desirable to have the cam force perpendicular to the lever arm. For applications in which the cam is traveling at speeds less than 100 feet per minute a cam lever angle of 30 degrees is recommended.

Overriding and Non-Overriding Cams

In overriding cam applications it is necessary to angle the trailing edge of the cam in order to prevent the lever arm from snapping back. Snapping back of the lever arm can cause shock loads on the switch which will reduce the life of the switch.

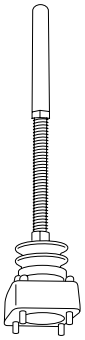


Non-Overriding cams are cams which will not overtravel the actuating mechanism.

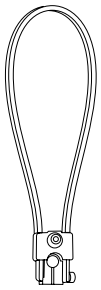


Flexible Loop and Spring Rod

Flexible loop and spring rod actuators can be actuated from all directions, making them suitable for applications in which the direction of approach is constantly changing.



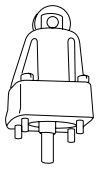
Spring Rod



Flexible Loop

Plungers

Plunger type actuators are a good choice where short, controlled machine movements are present or where space or mounting does not permit a lever type actuator. The plunger can be activated in the direction of plunger stroke, or at a right angle to its axis.

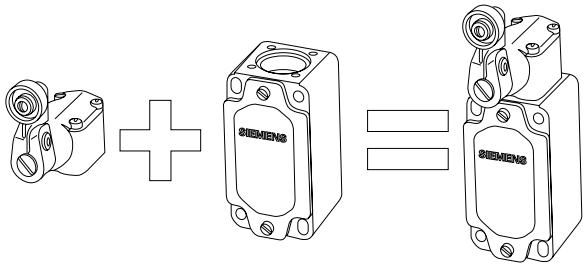


Mounting Considerations

When using plain and side plunger actuators the cam should be operated in line with the push rod axis. Consideration should be given so as not to exceed the overtravel specifications. In addition, the limit switch should not be used as a mechanical stop for the cam. When using roller top plunger the same considerations should be given as with lever arm actuators.

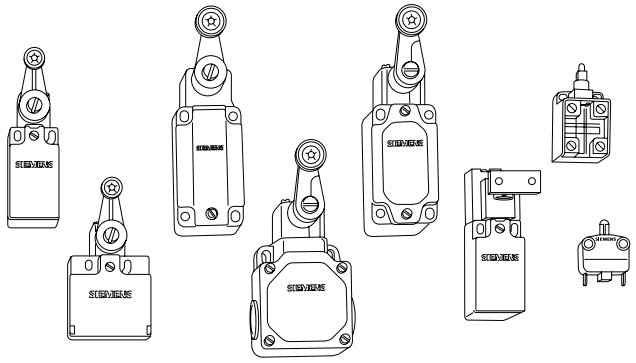
International Limit Switches

International mechanical limit switches are widely used in many countries, including North America. The International Electrotechnical Commission (IEC) and the National Electrical Manufacturers Association (NEMA) develop standards for electrical equipment. Siemens international mechanical switches are built to IEC and NEMA standards. In addition, they are UL listed and CSA certified. International style switches consist of two major components, the operating head and switch body.



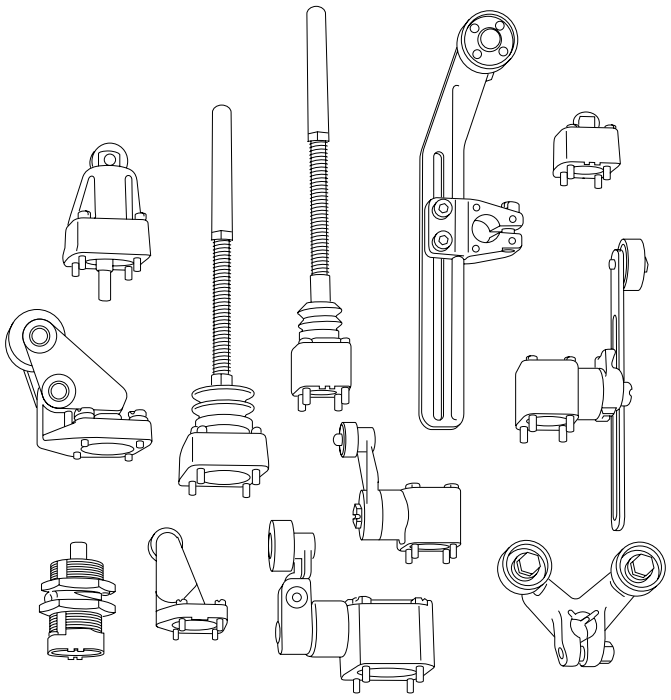
International Limit Switch Family

A large family of mechanical limit switches is available in the international style to meet virtually any mechanical limit switch application.

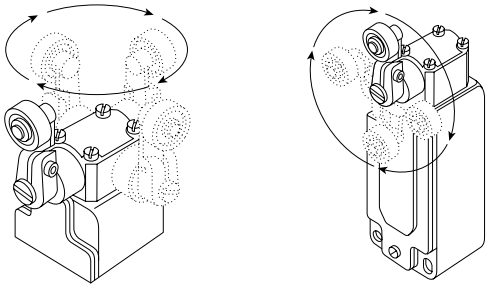


Operating Heads

Depending on the switch, Siemens international style limit switches can be fitted with any of several interchangeable operating heads and actuators. Overtravel plunger, roller plunger, roller or angular roller lever, plain or adjustable length roller lever, plain or spring rod, fork lever, or coded sensing heads are available.

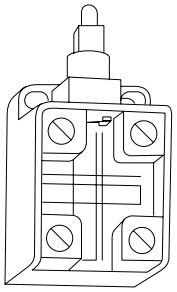


The actuator head can be rotated so that the switching direction of limit switches with roller crank, adjustable-length roller crank or rod actuators can operate from any side of the switch body. In addition, roller cranks can be repositioned to the left or right around the operating shaft.

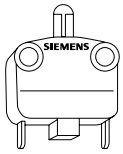


Open-Type Limit Switches

Open-type limit switches are intended for use as auxiliary switches in cabinets, large enclosures, or locations where they are not exposed to dust and moisture. A miniature version is available for limited space applications such as automatic door interlocking. Open-type switches use a plunger actuator.



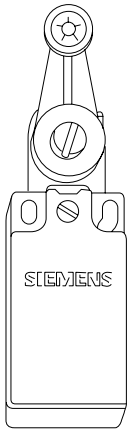
Open Type



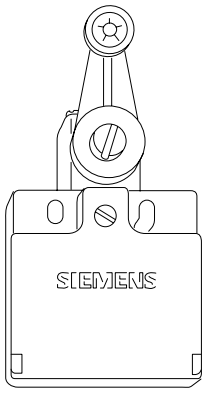
Miniature Open Type

Miniature Formed Housing Limit Switches

Miniature formed housing limit switches are used in applications where space is restricted. The glass-reinforced fiber, flame-retardant molded plastic enclosure resists most shocks, impacts, cutting oils, and penetration from dust and water.



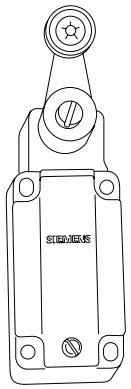
Miniature Formed Housing



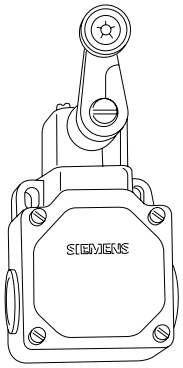
Wide Miniature Formed Housing

Replaceable Contact Block Limit Switches

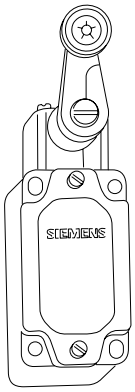
Siemens has developed two limit switch models with replaceable contact blocks, one with a formed plastic enclosure and one with a metal enclosure. The formed plastic version is in an enclosure similar to the miniature limit switches discussed previously. The metal version is enclosed in die-cast aluminum. It is impervious to most mechanical shocks.



Formed Housing
Replaceable
Contact Block



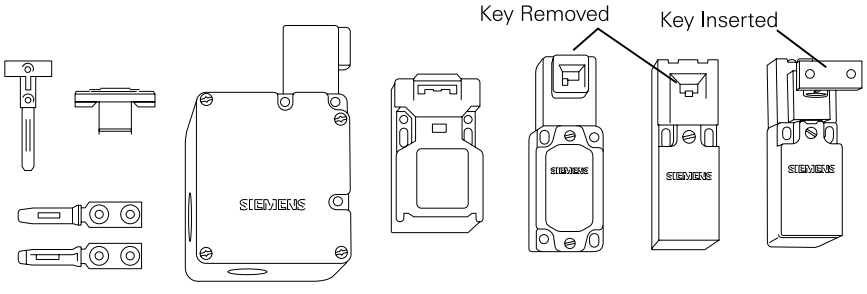
Wide Metal Housing
Replaceable
Contact Block



Metal Housing
Replaceable
Contact Block

SIGUARD Mechanical Interlock Switches

Sensitivity to safety is an increasing priority for the workplace. Most sensors cannot be used in safety circuits, including proximity sensors and photoelectric sensors which will be covered in later sections. Sensors used in safety circuits must meet stricter design and test standards specified by DIN and IEC. The SIGUARD line of International style switches is designed for safety circuits. SIGUARD mechanical interlock switches have triple coded actuators that act as a key. These devices can be used to control the position of doors, machine guards, gates, and enclosure covers. They can also be used to interrupt operation for user safety. They are available in miniature formed housing and metal housing models.

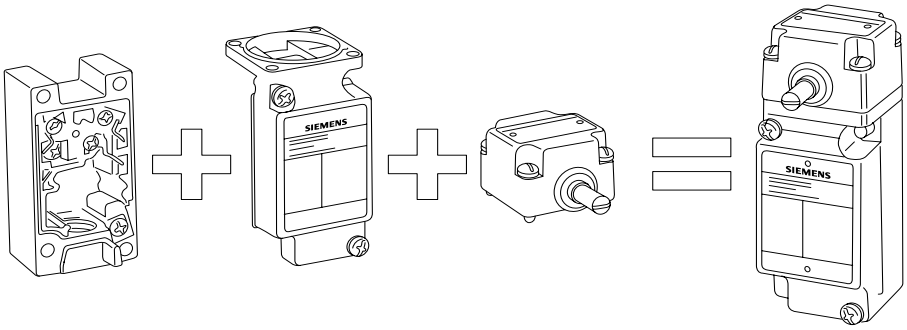


Interlock Keys

Interlock Switches

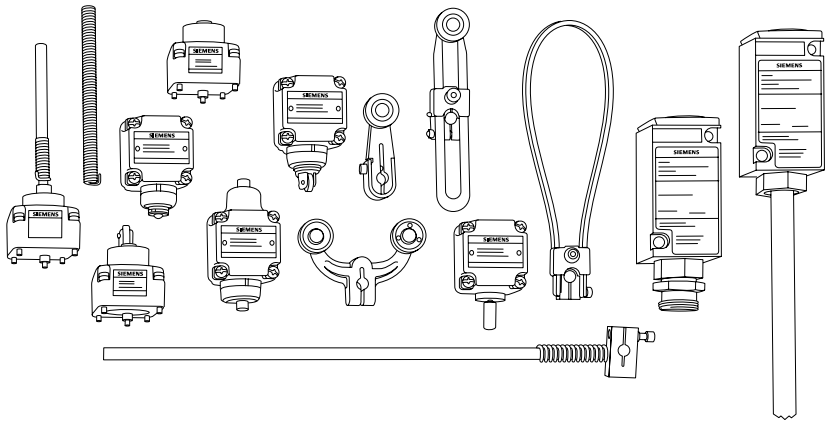
North American Limit Switches

North American mechanical limit switches are specifically designed to meet unique requirements of the North American market. These switches are comprised of three interchangeable components; contact block, switch body, and sensing head. North American limit switches meet UL (Underwriters Laboratory) and CSA (Canadian Standards Association).



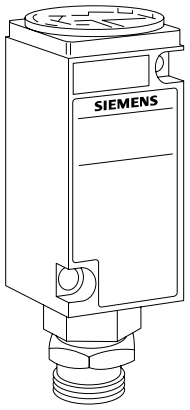
Actuators

Like the International limit switches, Siemens North American limit switches also accept a variety of operating heads and actuators.



NEMA Type 6P Submersible

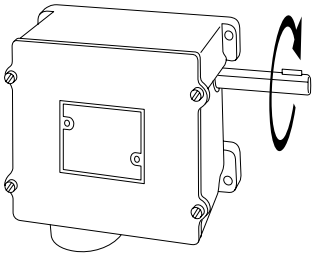
The housing for North American NEMA Type 6P submersible limit switch is die-cast metal with an epoxy finish for harsh industrial environments. In addition, the Siemens 6P submersible switch can be used for watertight applications.



NEMA Type 6P Submersible
Without Acuator Head

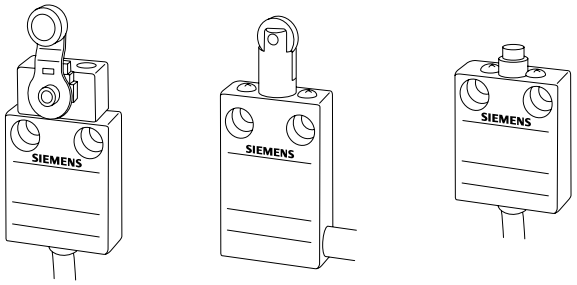
Class 54, Rotating Type

Class 54 rotating limit switches are used to limit the travel of electrically operated doors, conveyors, hoists, and similar applications. The contacts are operated when the external shaft is rotated sufficiently. Siemens rotating switches employ a simple reduction worm and gear(s) to provide shaft-to-cam ratios of 18 to 1, 36 to 1, 72 to 1, or 108 to 1. In addition, long dwell cams are available which keeps contacts closed for longer periods of time. This may be necessary in hoist or similar applications. A fine adjustment cam is also available to increase the accuracy of the number of shaft turns required to cause the contacts to operate.



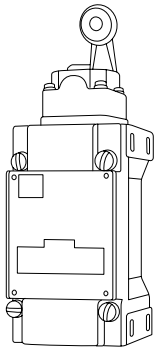
Miniature, Prewired, Sealed Switches

Miniature, prewired, sealed switches allow for miniaturization of the electrical connection. The switch is prewired and the terminals and connection are encapsulated in epoxy. The switch uses a single-pole, double-throw contact. The contact can be wired either normally open (NO) or normally closed (NC). Depending on the load voltage, the contact can make up to 7.5 amps and break up to 5 amps.



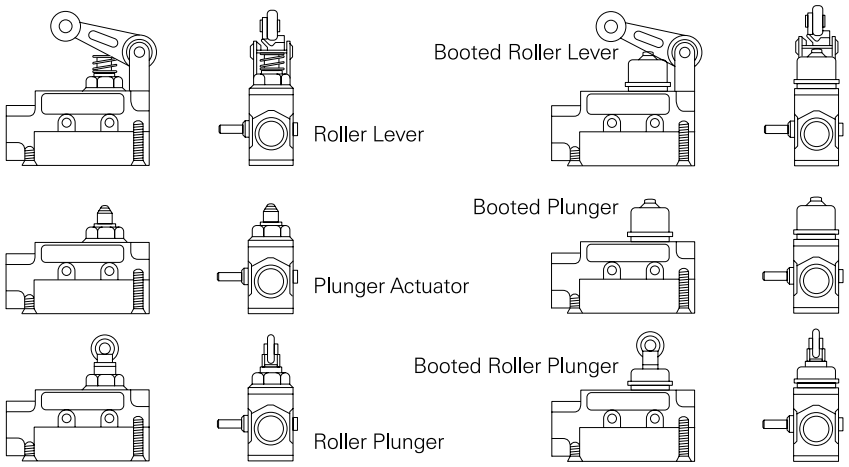
3SE03 Hazardous Locations, Type EX

Type EX limit switches are designed for extreme environmental service in locations where there exists a danger of an internal or external explosion of flammable gasses, vapors, metal alloy, or grain dust. EX switches are designated by the catalog number 3SE03-EX.



Enclosed Basic Switches

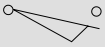
North American limit switches are also available in an enclosed basic version. These switches are designated by the catalog number 3SE03-EB. Enclosed basic switches are preconfigured with a plunger actuator, booted plunger, roller lever, booted roller lever, roller plunger, or a booted roller plunger.



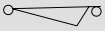
Review 1

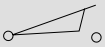
1) A _____ _____ is a type of sensor that requires physical contact with the target.

2) Which of the following symbols identifies a Normally Closed, Held Open limit switch?

a. 

b. 

c. 

d. 

3. _____ is the distance or angle traveled in moving the actuator from the free position to the operating position.

4. The _____ _____ is where contacts in the limit switch change from their normal state to their operated state.

5. In slow-break switches with _____ - _____ - _____ contacts, the normally closed contact opens before the normally open contact closes.

6. _____ defines the load a switch can handle when the mechanical contacts are opened. This is the maximum continuous switch current.

7. For applications in which the cam is travelling at speeds less than 100 feet per minute a cam lever angle of _____ degrees is recommended.

8. An International switch consists of an _____ _____ and switch body.

9. _____ is the trade name for a type of International switch suitable for safety circuits.

10. The Siemens _____ submersible switch can be used for watertight applications.