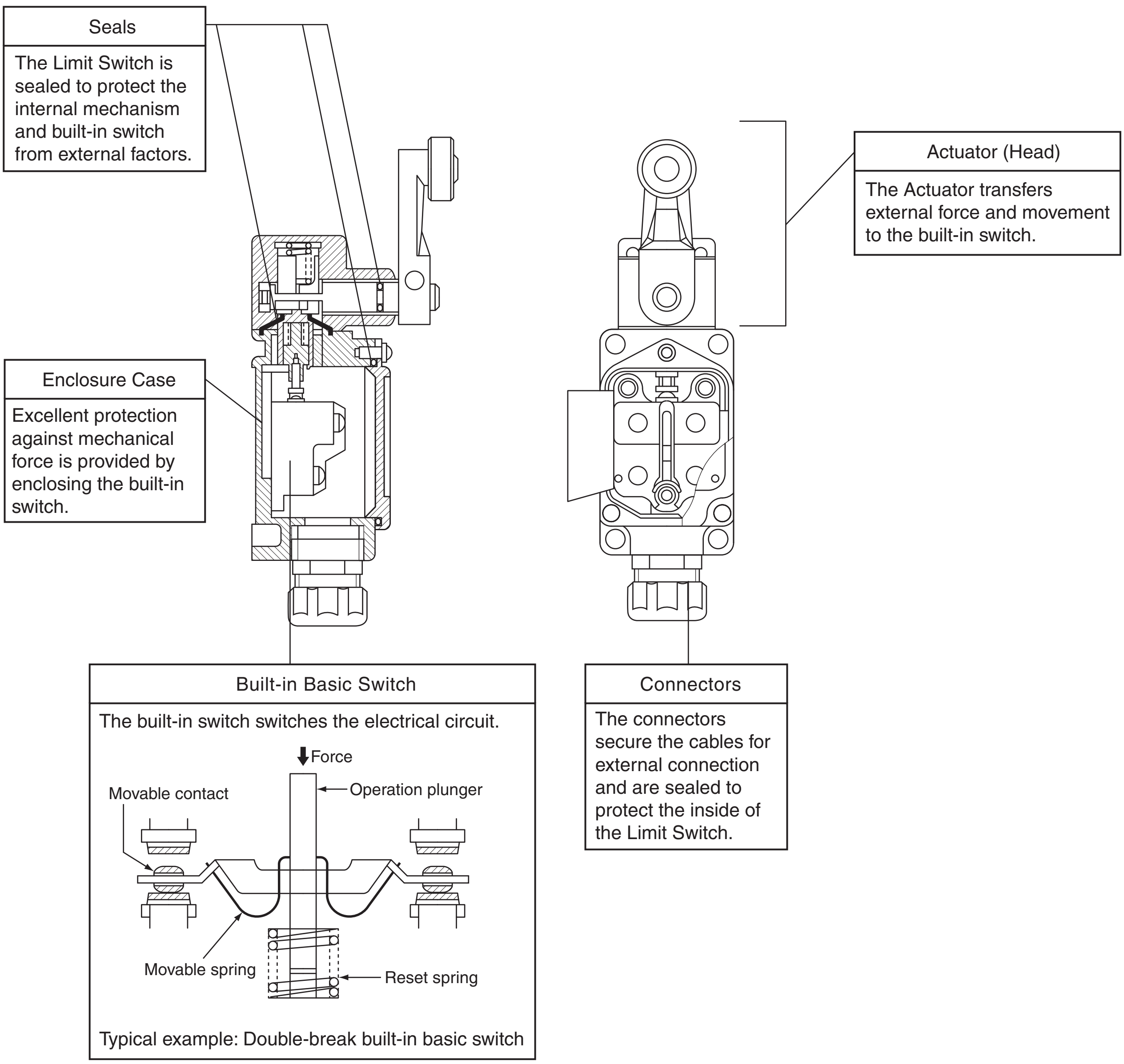
Technical Explanation for Limit Switches

Introduction

What Is a Limit Switch?

A Limit Switch is enclosed in a case to protect a built-in basic switch from external force, water, oil, gas, and dust. Limit Switches are made to be particularly suited for applications that require mechanical strength or environmental resistance.
The shapes of Limit Switches are broadly classified into Horizontal, Vertical, and Multiple Limit Switches. The structure of a typical vertical Limit Switch is shown in the following figure as an example. Limit Switches are generally composed of five components.



Structural Diagram of Typical Vertical Limit Switch

Structures and Principles

Drive Mechanism of Limit Switch

The drive mechanism of the Limit switch is an important part of the Limit Switch and is directly linked to seal performance and operating characteristics. Drive mechanisms are classified into three types, as shown in the following figure.

(1) Plunger

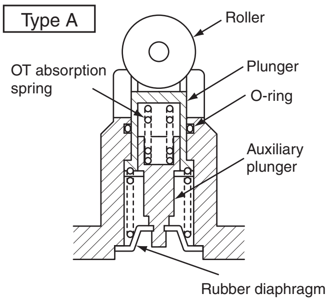
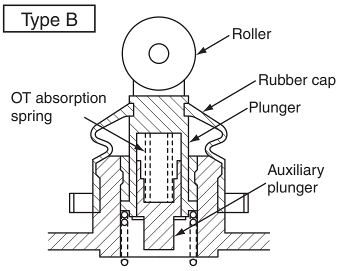
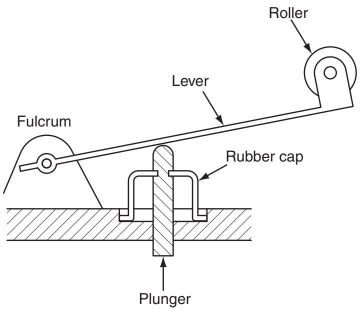
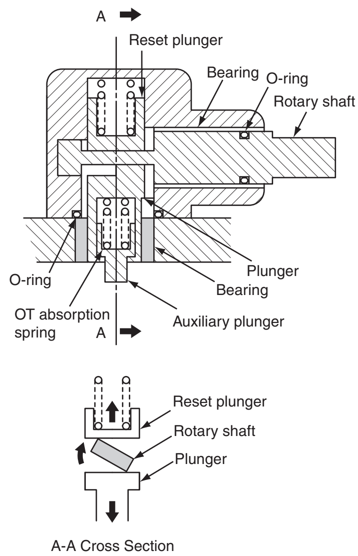
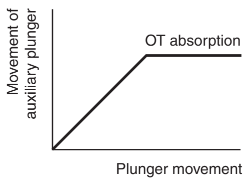
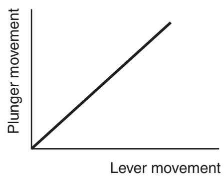
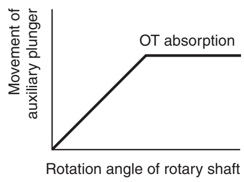
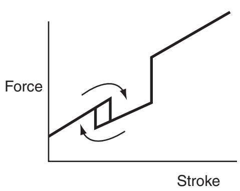
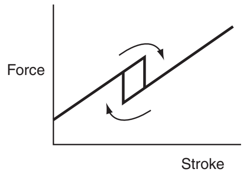
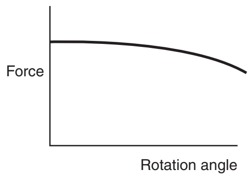
There are two types of plunger (types A and B in the figure) depending on the sealing method. With type A, an O-ring or a rubber diaphragm is used for sealing. The rubber seal is not externally exposed, and so resistance is provided against cutting debris from machine tools, but sand and fine shavings may become stuck on the sliding surface of the plunger. With type B, sand and fine shavings will not become stuck, and the sealing performance is superior to type A, but hot cutting debris striking the Switch may damage the rubber cap.
Whether type A or type B is required depends on the location in which the Switch is to be used.
With the plunger drive, the movement of the plunger piston enables air to be compressed and taken in.
Therefore, if the plunger is left pushed in for a long time, the air in the Limit Switch will escape and the internal pressure will become equivalent to atmospheric pressure. This will cause the plunger to tend to reset slowly even if an attempt is made to quickly reset it. To prevent this problem from occurring, design the system to limit the amount of air compressed by pushing in the plunger to 20% or less of the total air pressure in the Limit Switch. To extend the service life of the Limit switch, the plunger drive includes an OT absorption mechanism that absorbs the remaining plunger movement using an OT absorption spring and stops the movement of an auxiliary plunger that pushes the Built-in switch according to the movement of the plunger.

(2) Hinge Lever

The amount of plunger movement is increased at the end of the lever (i.e., roller) by the lever ratio, and so an absorption mechanism is generally not used.

(3) Roller Lever

The structure of the WL is shown as a typical example. Other drives include those in which the plunger performs the function of the reset plunger and those in which a coil spring is used for the reset force and a cam is used to move the auxiliary plunger.

	(1) Plunger	(2) Hinge Lever	(3) Roller Lever
Drive mechanism of limit switch	 		
Movement of auxiliary plunger			
Force vs. stroke characteristic			
Precision	High	Normal	Low to normal

Sensors
Switches
Safety Components
Relays
Control Components
Automation Systems
Motion / Drives
Energy Conservation Support / Environment Measure Equipment
Power Supplies / In Addition
Others
Common

Switch Component Materials

The main parts of the Switch are formed from the following materials.

Part	Material	Symbol	Characteristics
Contacts	Gold	Au	Gold is extremely resistant to corrosion and is used for microloads. It is soft (Vickers strength: HV25 to HV65), which easily results in adhesion (e.g., contacts sticking together) and the contacts are easily dented if the contact force is large.
	Gold-silver alloy	AuAg	This alloy of 90% Au and 10% Ag is extremely resistant to corrosion, and its hardness (HV30 to HV90) is higher than that of gold, and so it is often used in switches for microloads.
	Platinum-gold-silver alloy	PGS	This alloy of 69% Au, 25% Ag, and 6% Pt is extremely resistant to corrosion, its hardness (HV60) is similar to AuAg, and it is often used in switches for microloads.
	Silver-palladium alloy	AgPd	This alloy has good resistance against corrosion but it easily generates polymers if it adsorbs organic gases. With 50% Ag and 50% Pd, it has a hardness of HV100 to HV200.
	Silver	Ag	Silver has the highest rate of electrical conductivity and heat transfer among metals. It exhibits low contact resistance, but has the disadvantage of easily generating a sulfide film in environments with sulfide gas, and so contact faults easily occur in microload ranges. The hardness is HV25 to HV45. Silver is used in almost all switches for standard loads.
	Silver-nickel alloy	AgNi	With 90% Ag and 10% Ni, this alloy has electrical conductivity about equal to Ag, and it has excellent resistance to arcing and welding. The hardness is HV65 to HV115.
	Silver-indium-tin alloy	AgInSn	This alloy is very hard, has a high melting point, and exhibits excellent resistance to arcing, welding, and contact transfer.
Movable springs and armatures	Phosphor bronze for springs	C5210	Phosphor bronze is very ductile and has resistance against fatigue and corrosion. It is annealed at low temperatures. The spring limit (Kb0.075) is somewhat low at 390 N/mm^2 minimum for C5210-H and 460 N/mm^2 minimum for C5210-EH, but it is often used for armatures of miniature basic switches.
	Age-hardened copper beryllium for springs	C1700 C1720	Copper beryllium is pressed and then age-hardened. It has a high rate of electrical conductivity, and the spring limit (Kb0.075) after age hardening is extremely high at 885 N/mm^2 minimum. for C1700-H and 930 N/mm^2 minimum for C1720-H. It is used for basic switches that require a high spring limit.
	Mill-hardened copper beryllium for springs	C1700-□M C1720-□M	This copper beryllium is age hardened by the materials manufacturer before shipment (i.e., mill hardened). Pressing after age hardening is not required. At 635 N/mm^2 minimum (reference value) for C1700-HM and 635 N/mm^2 for C1720-HM, the spring limit (Kb0.075) is higher than with bronze phosphor for springs. Mill-hardened copper beryllium is often used for the movable springs in basic switches.
	Stainless steel for springs (austenite)	SUS301-CSP SUS304-CSP	Austenite stainless steel has excellent resistance against corrosion. The spring limit (Kb0.075) is 490 N/mm^2 minimum for SUS301-CSP-H and 390 N/mm^2 for SUS304-CSP-H.
Cases and covers	Phenol resin	PF	Phenol resin is heat hardened. It is often used as the material for the casings of basic switches. Phenol resin has a UL heat index of 150°C, a UL fire-retardant grade of at least 94V-1, and a water absorption coefficient of 0.1% to 0.3%. Material without ammonia is used for basic switches.
	Polybutylene terephthalate resin	PBTP	This resin is thermoplastic. A glass-reinforced epoxy type of this resin is often used as the material for the casings of basic switches. The resin has a UL heat index of 130°C, a UL fire-retardant grade of at least 94V-1, and a water absorption coefficient of 0.07 to 0.1.
	Polyethylene terephthalate resin	PETP	This resin is thermoplastic. A glass-reinforced epoxy type of this resin is used as the material for the casings of basic switches. The resin has a UL heat index of 130°C, a UL fire-retardant grade of at least 94V-1, and a water absorption coefficient of 0.07 to 0.1.
	Polyamide (nylon) resin	PA	This resin is thermoplastic. A glass-reinforced epoxy type of this resin has heat resistance that is superior to PBT and PET. The absorption coefficient is large. Select a grade for use with a the lowest possible absorption rate. The resin has a UL heat index of 180°C, a UL fire-retardant grade of at least 94V-1, and a water absorption coefficient of 0.2 to 1.2.
	Polyphenylene sulfide	PPS	This resin is thermoplastic. It has heat resistance that is superior even to PA. The resin has a UL heat index of 200°C, a UL fire-retardant grade of at least 94V-1, and a water absorption coefficient of 0.1.
Switch boxes	Aluminum (die-cast)	ADC	Aluminum is often used as the material for the switch box (case) of Limit Switches. Standards are specified in JIS H5302.
	Zinc (die-cast)	ZDC	Die-cast zinc is more suitable than ADC for thin-walled objects, and its resistance to corrosion is also superior to ADC. Standards are specified in JIS H5301.
Rubber seals	Nitrile-butadiene rubber	NBR	This rubber has excellent resistance to oil, and it is often used for Limit Switches. It is classified into five nitrile levels according to the amount of combined nitrile: Very high (43% or higher), high (36% to 42%), mid-high (31% to 35%), medium (25% to 30%), and low (24% or lower). Resistance to oil, heat, and cold somewhat vary with each level. The ambient operating temperature ranges from –40 to 130°C.
	Silicon rubber	SIR	Silicon rubber has excellent resistance to heat and cold, and the ambient operating temperature ranges from –70 to 280°C. Its resistance to oil, however, is inferior.
	Fluorine rubber	FRM	Fluorine rubber has resistance to heat, cold, and oil that is superior even to NBR and SIR. Depending on the constituents of the oil, however, the oil resistance may be inferior to NBR.
	Chloroprene rubber	CR	Chloroprene rubber has good resistance against ozone and climatic conditions. It is often used as the material for basic switches that require resistance against climatic conditions.

Explanation of Terms

General Terms

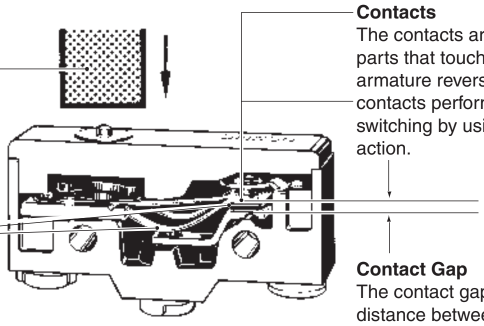
Limit Switch
A Built-in switch enclosed in a metal or resin case to protect it from external forces, water, oil, dust, dirt, etc. Also abbreviated to merely “Switch”.

Ratings
Generally, the ratings of the Switch refer to values that ensures the characteristics and performance of the Switch, such as rated current and rated voltage under specific conditions.

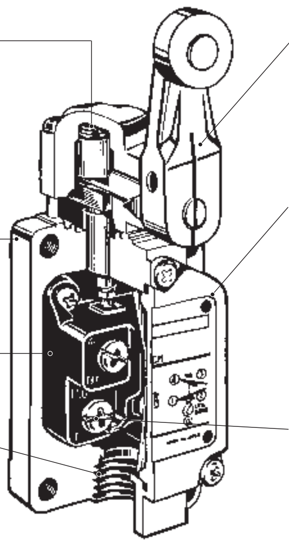
Contacts
Contacts are mechanically opened and closed for current switching.

Contact Configuration
The electrical input/output circuit configuration of contacts which depends on the application.

Resin Molding (Molded Terminals)
Terminals that are hardened by applying resin after lead wires have been connected in order to eliminate any exposed current-carrying parts and to improve sealing performance.



Terms Related to Configuration and Structure



Terms Related to Switch Durability

Mechanical Durability
The mechanical durability refers to the number of available switching operations on condition that the Switch is actuated to the OT position per operation.

Electrical Durability
The electrical durability is the switching durability at the rated load (i.e., a resistive load) with overtravel set as the reference value.

Terms Related to Characteristics

FP (Free Position)
The initial position of the actuator when no external force is applied.

OP (Operating Position)
The position where the movable contact reverses from the free position when an external force is applied to the actuator.

TTP (Total Travel Position)
The position of the actuator when it reaches the stopper.

RP (Releasing Position)
The actuator position where the movable contacts reverse from the operating position to the free position when the external force on the actuator is reduced.

OF (Operating Force)
The force applied to the actuator required to operate the switch contacts.

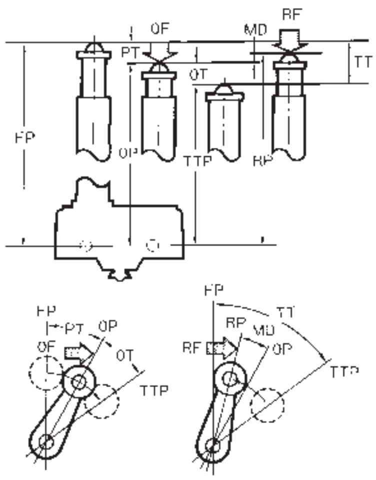
RF (Releasing Force)
The value to which the force on the actuator must be reduced to allow the contacts to return to the normal position.

PT (Pretravel)
The distance or angle through which the actuator moves from the free position to the operating position.

OT (Overtravel)
The distance or angle through which the actuator moves from the operating position to the total travel position.

MD (Movement Differential)
The distance or angle from the operating position to the releasing position.

TT (Total Travel)
The distance or angle through which the actuator moves from the free position to the total travel position.



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Terms Used in EN 60947-5-1 Standards

The following provides information on the following terms used in this catalog.

EN 60947-5-1

EN standards applicable to electronic machine control circuitry, the contents of which are the same as those of IEC 60947-5-1.

Application Category

Switch application categories. Refer to the following examples.

Type of current	Category	Typical application
AC	AC-15	Control of electromagnetic loads exceeding 72 VA
	AC-14	Control of electromagnetic loads not exceeding 72 VA
DC	DC-12	Control of resistive loads and semiconductor loads

Rated Operating Current (Ie)

Rated current for the Switch to operate.

Rated Operating Voltage (Ue)

The rated switch operating voltage, which must not exceed the rated insulation voltage (Ui).

Rated Insulation Voltage (Ui)

The maximum rated voltage at which the insulation voltage of the Switch is maintained. This value is used as the parameter of the dielectric strength and creepage distance of the Switch.

Conventional Enclosed Thermal Current (I the)

The normal carry current that does not increase the permissible upper-limit temperature of the Switch if it is a model with its charged part sealed. The rated permissible upper-limit temperature is 65°C if the terminals are made of brass.

Rated Impulse Dielectric Strength (Uimp)

The peak impulse voltage that the Switch can withstand with no insulation breakage.

Conditional Short-circuit Current

The current that the Switch can withstand until the circuit breaker operates.

Short-circuit Protective Device (SCPD)

The device, such as a breaker or fuse, which breaks the current to protect the Switch from short-circuiting.

Pollution Degree

The environment in which the Switch is used.
The pollution degree is divided into four levels as shown below. The Switch falls under pollution degree 3.

Level	Description
Pollution degree 1	No pollution or only dry, non-conductive pollutants exist.
Pollution degree 2	Normally only non-conductive pollutants exist, which are expected to be temporarily conductive due to condensation.
Pollution degree 3	Conductive pollutants exist or existing nonconductive pollutants will be temporarily conductive due to expected condensation.
Pollution degree 4	There are pollutants that are continuously conductive due to rain, snow, or conductive dust.

Protection Against Electric Shock

This is the electric shock prevention level. There are the following four levels.

Level	Description
Class 0	Electric shocks are prevented by basic insulation only.
Class I	Electric shocks are prevented by basic insulation and grounding.
Class II	Electric shocks are prevented by double insulation or reinforced insulation with no grounding required.
Class III	No countermeasures against electric shocks are required because the electric circuits in use operate in a low-enough voltage range.

Closed-circuit Counter Electromotive Voltage

Instantaneous overvoltage generated from the closed circuit, which must not exceed the Uimp value.

Space Distance

The minimum space distance between two charged parts.

Creepage Distance

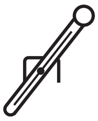
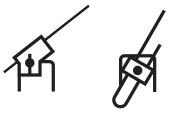
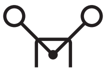
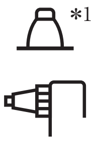
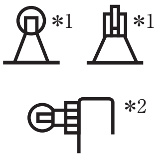
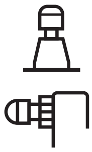
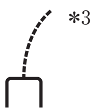
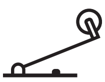
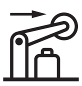
The minimum distance on the surface of the insulator between two charged parts.

Distance through Insulation

The minimum direct distance between the charged part and the nonmetal switch housing through air or any other insulator.

Further Information

Limit Switch Actuator Type and Selection Methods

Appearance	Type	Pretravel (PT)	Overtravel (OT)	Operating force (OF)	Repeat accuracy	Shock and vibration resistance	Description
	Roller lever	Small to large	Large	Medium	★★★/★★	★★★	The stroke in the operating direction is as large as 45° to 90°, the actual angle of which varies with the model. The lever can be set in any angle. Highly sensitive models with small PT values and wide angle models with large OT values are available. These models are applied to a wide range of applications including object positioning and detection.
	Adjustable roller lever	Small to large	Large	Medium	★★★/★★	★★	Dogs are detected roughly by making use of the characteristics of the roller lever. The length of the lever is adjustable. (Countermeasures against lever shaking*4 may be required.)
	Adjustable rod lever	Large	Large	Medium	★★	★★	This lever is convenient when the dogs are wide or not uniform in size. The OF required by this lever is smaller than that of any other rotating actuator used for Limit Switches. The length of the rod is adjustable and the rod itself can be bent easily. (Countermeasures against lever shaking*4 may be required.)
	Fork lever lock	Large	Medium	Medium	★★	★★★	The lever turns by itself when it is operated to an angle of 55° and the lever keeps its position at an angle of 90°. A single dog in reciprocating operation can actuate the Limit Switch. Two dogs can be used to actuate two Limit Switches positioned slightly different from each other.
 *1	Plunger	Small	Medium	Large	★★★	★★★	The plunger operated by hydraulic pressure or air cylinder power detects positions highly accurately. The plunger must be installed according to the movement of the dog so that an incorrect load will not be imposed on the plunger.
 *1 *1 *2	Roller plunger	Small	Medium	Large	★★★	★★★	The roller plunger can be operated in a wide range by employing a cam, dog, cylinder, or auxiliary actuator. Position detection accuracy is high.
	Ball plunger	Small	Medium	Large	★★	★★★	The tip of the plunger is made of a steel ball, which can be operated in any direction with no limitations. The ball plunger is convenient when the mounting side is not aligned with the movement direction of the dog or the Limit Switch is actuated by two dogs in X and Y directions.
	Bevel plunger	Small	Medium	Large	★★★	★★★	Unlike roller plungers, the bevel plunger protects the actuator from abrasion. The bevel plunger is a hardened plunger with an edge angle of 120° that ensures high accuracy and a long life. The bevel plunger is mainly applied to multiple Limit Switches for multi-level control of machining equipment.
 *3	Coil spring	Medium	Large	Small	★	★	The coil spring can be operated in any direction except the axis direction. The OF required by the coil spring is smaller than any other actuator used for Limit Switches. The use of the coil spring is ideal for the detection of dogs that are not uniform in size or direction. The OT is absorbed by the actuator, thus permitting variations in the dog position.
	Hinge lever	Large	Medium	Small	★	★	The hinge lever is used with low-speed, low-torque cams. The lever can be varied in a variety of shapes according to the dog.
	Hinge roller lever	Large	Medium	Small	★	★	This lever consists of a hinge lever with a roller and suitable for a high-speed cam. (The operating speed must be within the permissible rate.)
	Roller arm lever	Medium	Medium	Medium	★	★	The roller position can be changed.

Note: Indications for repeat accuracy and shock and vibration resistance are as follows: ★: OK, ★★: Good, ★★★: Excellent, ★★★★: Superior

***1.** Panel-mounting models are available (D4E-□N, SHL, ZC-□55, and D4MC).
***2.** Horizontal roller models are available (D4A-□N).
***3.** Steel wire modes are available (WL). Plastic rod or wire rod models are available (D4C, D4CC, HL-5000, and D4A-□N).
***4.** Lever shaking may cause the actuator to bounce after being actuated and to move to the operating position on the opposite side. This may result in a failure of the Limit Switch.

Troubleshooting

Problem		Probable cause	Remedy
Mechanical failure	1) The actuator does not operate. 2) The actuator does not return. 3) The actuator has been deformed. 4) The actuator is worn. 5) The actuator has been damaged.	The shape of the dog or cam is incorrect.	• Change the design of the dog or cam and smooth the contacting surface of the cam. • Scrutinize the suitability of the actuator. Make sure that the actuator does not bounce.
		The contacting surface of the dog or cam is rough.	
		The actuator in use is not suitable.	
		The operating direction of the actuator is not correct.	
		The operation speed is excessively high.	• Attach a decelerating device or change the mounting position of the Switch.
		Excessive stroke.	• Change the stroke.
		The rubber or grease hardened due to low temperature.	• Use a cold-resistive switch.
		The accumulation of sludge, dust, or cuttings.	• Change to a drip-proof switch or one that provides a high degree of protection. • Use a protection cover and change the solvent and materials.
		Dissolution, expansion, or swelling damage to the rubber parts of the driving mechanism.	
	There is a large deviation in operating position (with malfunctioning involved).	Damage to and wear and tear of the internal movable spring.	• Regularly inspect the Switch. • Use a better quality switch. • Tighten the mounting screws securely. Use a mounting board.
		Wear and tear of the internal mechanism.	
		The loosening of the mounting screws causing the position to be unstable.	
	The terminal part wobbles. (The mold part has been deformed.)	Overheating due to a long soldering time.	• Solder the Switch quickly. • Change the lead wire according to the carry current and ratings.
		The Switch has been connected to and pulled by thick lead wires with excessive force.	
		High temperature or thermal shock resulted.	• Use a temperature-resistive switch or change mounting positions.
Failures related to chemical or physical characteristics	Contact chattering	Vibration or shock is beyond the rated value.	• Attach an anti-vibration mechanism. • Attach a rubber circuit to the solenoid. • Increase the operating speed (with an accelerating mechanism).
		Shock has been generated from a device other than the Switch.	
		Too-slow operating speed.	
	Oil or water penetration	The sealing part has not been tightened sufficiently.	• Use a drip-proof or waterproof switch. • Use the correct connector and cable. (Use a sealed connector for sealed switches.)
		The wrong connector has been selected and does not conform to the cable.	
		The wrong switch has been selected.	
		The terminal part is not molded.	
		The Switch has been burnt or carbonated due to the penetration of dust or oil.	
	Deterioration of the rubber part	The expansion and dissolution of the rubber caused by solvent or lubricating oil.	• Use an oil-resistant rubber or fluororesin bellows. • Use a weather-resistant rubber or protective cover. • Use a switch with a metal bellows protective cover.
		Cracks due to direct sunlight or ozone.	
		Damage to the rubber caused by scattered or heated cuttings.	
	Corrosion (rusting or cracks)	The oxidation of metal parts resulted due to corrosive solvent or lubricating oil.	• Change the cutting oil or mounting position. • Use a crack-resistant material.
		The Switch has been operated in a corrosive environment, near the sea, or on board a ship.	
		The electrical deterioration of metal parts of the Switch resulted due to the ionization of cooling water or lubricating oil.	
		The cracking of alloyed copper due to rapid changes in temperature.	
Failures related to electric characteristics	No actuation. No current breakage. Contact welding	Inductive interference in the DC circuit.	• Add an erasing circuit.
		Brown powder generated due to switching operations	• Use a switch with a special alloy contact or use a sealed switch.
		A short-circuit or contact weld due to contact migration.	• Reduce the switching frequency or use a switch with a large switching capacity.
		Contact weld due to an incorrectly connected power source.	• Change the circuit design.
		Foreign materials or oil penetrated into the contact area.	• Use a protective box.