

# TECHNICAL GUIDE

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## Electrical specifications Terminology - Definitions and Explanations -

### Output mode

This refers to the type of signal output from switching part. There are two types of signals as indicated below.

- (1) Normally open NO
- (2) Normally close NC

### How to select

#### Characteristics of normally open (NO) type

- All types have pretravel (the distance it needs to be pressed to output the signals), and in the case of dry contact types, there is no occurrence of chattering since the switching part is normally open.
- NPN open collector output types can be easily connected to programmable controllers (PLC), sequencers and CNC.

#### Characteristics of normally close (NC) type

- Types with and without pretravel are available. In case of dry contact types, since the switching part is normally closed, chattering may occur due to vibrations (mainly in cases of low contact force).
- Normally close circuits are failsafe (any input errors are notified immediately). The use of this interlock system makes it possible to diagnose malfunctions such as cable disconnections and signal transmission problems.

### Inversion (Level Conversion) method: NO→NC, NC→NO

#### Electrical:

- By connecting an I/F unit to either the NO type or NC type, the output of the I/F unit can be inverted (NO→NC, NC→NO).
- NC types converted from an NO type by an I/F unit are no longer failsafe.

#### Mechanical:

Inversion is possible depending on the installation method.

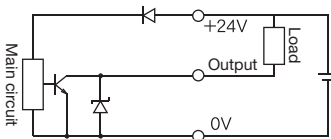
- By initially pushing in the free position.
- Inverted by means of a lever.

### Open collector

The output terminal of this transistor circuit is the collector of the transistor (see diagram below).

#### NPN transistor output (Open collector)

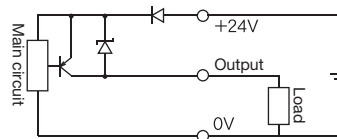
Since circuits using an NPN transistor absorb the load current (in the manner of a sink), the load is connected between a power supply having a potential higher than ground and the collector.



- NPN transistors are commonly used transistor. Connections can be directly made to a programmable controller or counter.
- These are popular in Japan and the US in the form that absorbs current (sink type).

#### PNP transistor output (Open collector)

Since circuits using a PNP transistor discharge the load current (in the manner of a source), the load is connected between the circuit ground and the collector.



- These are incorporated primarily in devices exported to overseas destinations such as Europe.
- These are in the form that discharges current (source type).

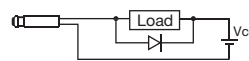
### Types of loads

#### Resistance loads (Expressed in the output rating)

- These mainly refer to loads in the form of resistors.
- These loads make it difficult for large current to flow when the circuit is switched on and off, and the current that flows to the circuit can essentially be calculated using the following equation:  
Current value = voltage value ÷ resistance value

#### Inductive loads

- These primarily refer to relay coils, motors and solenoids.
- Load can be used only when the driving current of these loads is within the switch contact rating. When the switch is turned off, counter electromotive force is generated and will require a diode or surge absorbing element to be connected in parallel to absorb this.

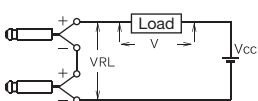


e.g.) Relay driven (Use a relay of which driving coil current 15mA or less)

## Switch series and parallel connection methods

### Direct current 2-line type

#### Series connection (AND)

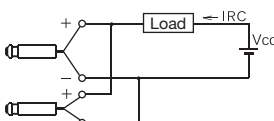


#### Wiring precautions:

When the connected switch is on, the load voltage VRL is defined as  $VRL = V_{cc} - n \times 3$  (V), caution is required with respect to defective load operation.

Vcc: Power supply voltage 24V (max)  
n: No. of switches  
3(V): Switch drive voltage  
V: Vcc-VRL

#### Parallel connection (OR)

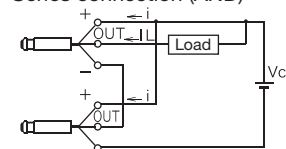


When the connected switch is off, the leakage current IRC flowing to the load is defined as  $IRC = n \times 0.8$  (mA), caution is required with respect to defective load return.

There is no limit in the number that can be connected in the case of contact switch (no LED or built-in interface unit)

### Direct current 3-line type

#### Series connection (AND)

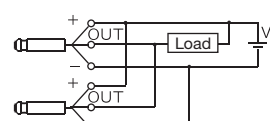


#### Wiring precautions:

The number of connected switches must be within the range that satisfies the following relationship:

$IL + (n-1) X_i \leq$  Upper limit of switch control output\*  
10mA (max) in case of non-contact switches.

#### Parallel connection (OR)



In case of using an AND/OR connection, since there may be cases in which this type of connection cannot be used due to erroneous signals or leakage current, please confirm the absence of such problems before using.

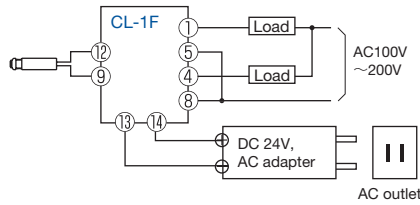
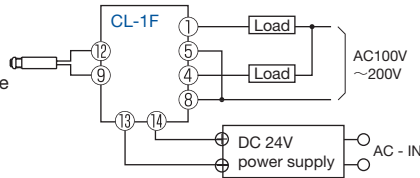
## Conditions of use

Please use dry contact types at a voltage and current within the contact rating.

### Use with AC 100V-200V

- These switches cannot be directly controlled with AC 100-200V.
- Please refer the diagrams below in the case of desiring to operate a solenoid valve or AC 100V relay with the switch signal in the absence of a DC power supply within the device.

A DC power supply (DC 24V, approx. 0.2 A) is provided and the switch and interface unit (CL-1F) are used to operate the valve and relay.



Interface unit (Refer to P2-2)

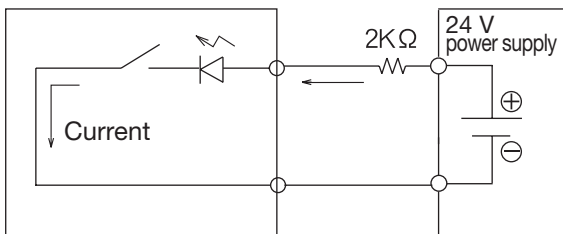
### Use with micro load

Use the switch within the range of DC 24 V, 0.2 mA to 10 mA (max.)

## Confirmation of switch operation

### Dry contact type

- Connect the switch in the manner shown in the diagram below.
- Limit the LED forward current to about 10mA by inserting a resistor.
- Resistance value = (power supply voltage - LED forward voltage) ÷ current = (24-2) ÷ 0.01 = 2KΩ The LED forward voltage is about 2V.
- The resistor may be installed on the DC 24V or 0V side.
- The LED glows when the circuit is closed. Switch operation is normal.
- In case of using a sequencer, a resistor is not required if the outflow current of the sequencer is about 7mA.
- Operation might not be properly confirmed using a digital test (multi-meter)



### Confirming operation by using resistance

- Set the tester to a resistance range of x 10, and connect the minus lead of the tester to the switch output (brown), and connect the plus lead of the tester to the switch 0V (blue).
- The deflection of the tester needle indicates around 0Ω when the switch plunger is pushed in and roughly infinity (∞) when switch tip is returned.
- For switches with LED, note that the tester may not swing.

### Effect on accuracy due to electrical delay

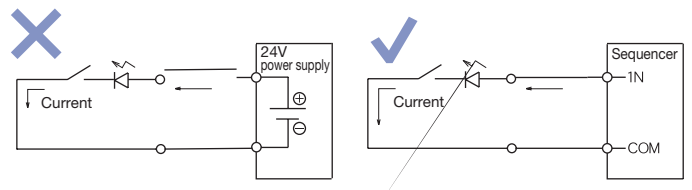
- If there is a difference in the sampling times of the switch signal and positioning data, large variations occur in repetitive accuracy when the measuring speed is increased.

### Connecting to a load

- Do not attempt to drive an inductive load directly with these switches. Direct driving can damage the switching parts and semiconductors of the internal circuitry.
- In case of driving an inductive load, connect a surge absorber in parallel with the load, and connect an external load such as a relay or transistor allowing an adequate flow of current for load driving.

### In case of using a switch with LED

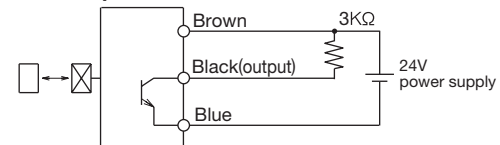
- The LED can be damaged if the switch is connected directly to the power supply (DC 24V). In case of using a sequencer, a resistor is not required if the outflow current of the sequencer is about 7mA.



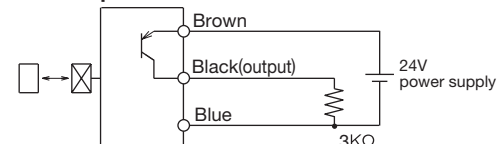
### Non-contact type

- Connect the switch in the manner shown in the diagram below.
- Please note that output circuit will be damaged by over current, when switch output under NPN output form is directly connected to +24V or when switch output under PNP output form is directly connected to 0V.
- Please insert resistor with resistance around 3kΩ so that a current of about 10mA will flow
  - (1) between +24V and output in case of NPN output type,
  - (2) between 0V and output in case of PNP output type, in the output circuit.
- In case of using a sequencer, a resistor is not required when the outflow current of the sequencer is about 7mA.

#### NPN Output



#### PNP Output



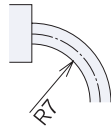
### Confirming operation by using voltage

- Set the tester to a voltage range of 50V and measure the voltage between the switch output (black) and 0V (blue).
- For NPN output type, when the tip of the switch is pressed, the indicator of the tester changes from 24V down close to 0V.
- For PNP output type, when the tip of the switch is pressed, the indicator of the tester changes from 0V up close to 24V.

## Wiring precautions

### Cables

- Do not subject cabtyre cables or core wire cables to excessive pulling or twisting of 30N or more. The bending radius should be at least R7. (Except for heat resistance cable)
- In case of attaching an extension to cables of these switches, since there is greater susceptibility to increased residual voltage, waveform distortion and induction due to the effects of wire resistance and inter-wire capacitance, try to use the shortest length possible. Furthermore, please use a cabtyre cable having a cross-sectional area of 0.3mm<sup>2</sup> or more.



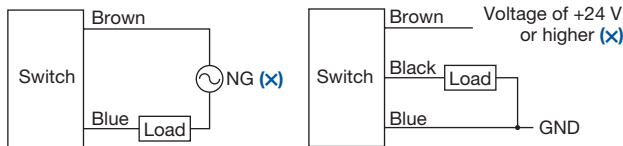
- Since operating errors may occur due to induction when high-voltage lines or power lines are wired within the same conduit or duct as switch wires, wire them in separate ducts.
- Cabtyre cables are used as robot cables without any safety compromise since the working voltage and current are low, though cabtyre cables are not applicable to UL, CSA, En or other safety standards.
- Use a molding when waterproofing is required so that there are no exposed portions of the terminals.
- Please use a wire braid or protective tube in harsh environments where cuttings may be generated.

## Precautions for switch connection

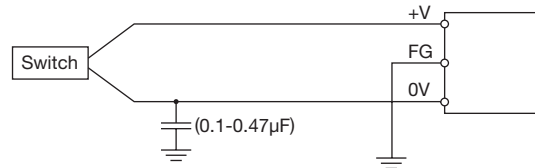
Always make sure to turn off the power before installing or removing switches.

This is to prevent damage to the device caused by improper wiring or short-circuits of output lines.

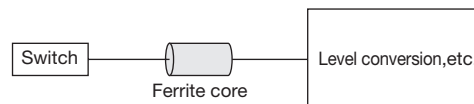
Application of an excessive voltage or application of an alternating current power supply (AC 24 V or higher) to sensors using a direct current power supply has the risk of damaging the switch.



Either ground the switch with a switching power supply in close proximity to the switch or ground through a capacitor (approx. 0.1-0.47  $\mu$ F) for the purpose of lowering the impedance of the frame in order to increase the resistance to entrance of induction noise by servo drivers or similar devices.



Alternatively, attach a ferrite core to the switch cable.



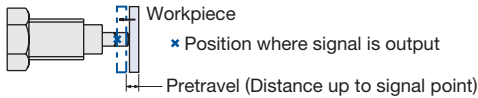
Lined area for notes with horizontal dashed lines.

## Mechanical specification Terminology - Definitions and Explanations -

### Signal point (Operating point)

#### Position Where a Signal is generated

- Although this is normally indicated with pretravel, it may also be expressed as the distance from the stopper surface in case of stopper bolt switches.
- Since it is easier to make a judgment on the signal point based on the contacting part position and this does not vary according to the conditions of use or type of contact used, position and accuracy can be clearly indicated.



### Pretravel PT (Distance up to signal point)

#### Amount of plunger movement from free position to signal point

- In the following explanation, amount refers to a distance or angle (units, mm or degrees).
- There is always pretravel in case of normally open (NO) switches.
- Pretravel is nearly 0 in case of normally closed (NC) switches.
- In addition, there is pretravel even in normally closed (NC) switches in case of having an intermediate shaft. Pretravel is normally about 0.2 to 0.4mm.

### Overtravel OT (Movement after signal point)

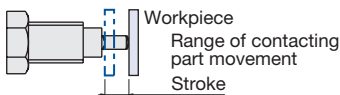
#### Amount of movement from signal point to operating limit position

- The greater the amount of overtravel, the less chance of colliding and causing a malfunction. This can be made large for all contact type switches.
- When using the switch the plunger is normally pressed and released in operation, OT becomes PT and normally open output mode is converted to normally close.

### Stroke TT (Overall movement : Total travel)

#### Amount of movement by the contacting part from free position to operating limit position

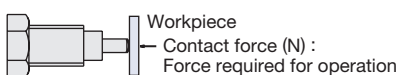
- This is the sum of pretravel and overtravel



### Contact force

#### Amount of force required for the contacting part to move from free position to signal point (Units : N)

- In case of contact switches with dry contact for switching part, the contact force is the sum of the spring force required to make the moving parts to reliably return and the spring force required for the dry contacts to make a stable connection. The contact force is normally about 1N.
- Furthermore, contact force may be indicated in terms of return force. This is for prevention of defective return of the plunger. And the frictional force of the shaft is subtracted from the spring force.
- In case of non-contact types, since the switching parts do not require contact force to operate, it can be reduced to about 0.1N.
- In lever types, the contact force is reduced due to the lever ratio.
- Since contact force may vary depending on the orientation at the time of use in cases in which the moving parts are heavy, check the return contact force under the conditions of use (particularly in case replaceable contacting parts have been fabricated by the user).
- In addition, pay attention to bracket rigidity in case of types having a large contact force.



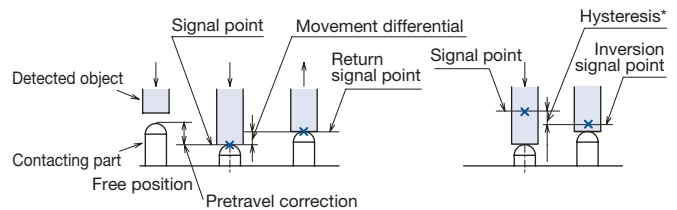
### Movement differential MD

#### Amount of movement until signal is inverted after returning from signal point

This region is an undetected area. METROL contact switches with dry contact for switching part don't have movement differential.

Movement differential occurs for any types of electrical switches, including limit switches, micro switches, proximity sensors and optical sensors.

- Since the signal is not inverted unless the contacting surface returns by greater than the amount of the movement differential in case of using in such a manner that the contacting surface returns immediately after operating, thickness less than the movement differential as shown in the diagram cannot be discriminated.
- Therefore pretravel greater than or equal to the movement differential is required in case of non-contact devices.



#### Note : Hysteresis (Return Difference)

This refers to a difference in the operating point when the contacting part has returned after being pushed beyond the operating position.

In addition to the switch itself, the amount of deflection of a retaining portion (support column) may be added due to the contact force.

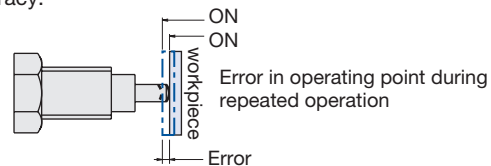
Hysteresis does not result in error if signals operating from the same direction at all times are obtained.

Please pay attention that it is different from hysteresis.

### Repetitive accuracy

The detected object is pressed from the vertical direction towards the contacting part of the switch. The difference between the maximum value and minimum value obtained from the variation in the signal point (dimensions) when pushed in 20 times or more is represented with the range (R) (defined by METROL).

- The limit of reliability is  $\pm R$
- In case of automatic measurement, judgments are typically made on the basis of a single measurement.
- However, values cannot be clearly indicated with average values and standard deviation alone (the  $\sigma$  value is displayed lower than the actual value). The use of **R** is the strictest means of representing accuracy.



### Temperature drift (Temperature characteristics)

This indicates the amount of fluctuation in the operating position caused by fluctuations in parameters of an electronic component corresponding to a change in the working temperature.

- It represents the maximum fluctuation in the operating distance over a temperature range of 10 to 40°C.
- Temperature drift occurs due to fluctuations in the switching part of electronic components caused by changes in temperature, and occurs in non-contact switches.
- Furthermore, it is necessary to additionally take physical thermal expansion of the attachment into consideration.

### Contacting part

This refers to the portion of the switch that contacts a detected object.

- Contacting part is also referred to as a probe.

## Protective structure

### IP Code

Protective structure refers to the level of dust resistance and moisture resistance.

All products in this catalog are indicated with characteristic numbers in the form of an IP code based on IEC 529:1989 (Degrees of Protection Provided by Enclosures).

**IP 6 7**

( International Protection )

First characteristic number (0-6) : Penetration of extraneous solid objects.

Second characteristic number (0-8) : Penetration of moisture accompanying detrimental effects.

Number	Intrusion of Extraneous Solid Objects	Intrusion of Moisture Accompanying Detrimental Effects
0	Unprotected	Unprotected
1	Protected against extraneous solid objects 50mm or more in diameter	Protected against vertically dripping water
2	Protected against extraneous solid objects 12.5mm or more in diameter	Protected against dripping water at an angle of within 15 degrees of vertical
3	Protected against extraneous solid objects 2.5mm or more in diameter	Protected against spraying water
4	Protected against extraneous solid objects 1.0mm or more in diameter	Protected against splashing water
5	Dustproof: No intrusion of an amount of dust that impairs enclosure operation	Protected against pressurized water from any direction
6	Dust-resistant: No intrusion of dust	Protected against jetted pressurized water from any direction (high pressure)
7		No intrusion of water in an amount that causes detrimental effects even with respect to temporary penetration
8		No intrusion of water in an amount that causes detrimental effects when continuously immersed in water under strict conditions determined by relevant authorities

### Waterproofing (Coolant)

The water-resistant performance of this standard refers to water. However, the following measures are adopted since coolant and cutting oil are commonly used for machine tools.

- Rubber materials used in some products (boots, O-rings) provide protection against water-soluble coolants and alkaline liquids.
- When covering of cables are broken, liquids penetrates into the cable due to the capillarity action, causing short circuits and contact failure. Attach protective blades for cables when cables might be damaged due to chips. (Refer to P.2-10.)
- Install rubber boot and O-rings after disassembly so that sealing can be kept. Whenever they are damaged, replace them by a new one. Apply seal locking agent to the screw threads.
- When there is a risk of damage to the cable by cuttings and so on, please attach a protective braid to the cable. (Refer to P.2-6)
- Please make sure that the sealing properties of rubber boots and O-rings are maintained when assembling disassembled rubber boots and O-rings. Replace any boots or O-rings if they have been damaged. Apply a sealing thread-lock to all threads.
- When making a connection to extend the cable, use a molding so that there are no exposed portions when the end of the cable is connected to a terminal.
- Please note that adhesive and sealants may be eroded by coolant.

### Dustproofing

Air blowing is effective for removing dust, cuttings or coolant adhered to the contacting surface depending on the type of adhered debris. However, the following measures are required for highly viscous substances that can not be removed by blowing with air.

- Provide boot protectors (option) if the rubber boot might be damaged due to chips
- Provide automatic opening and closing covers (especially when operating without operators).
- If a protective cover is still insufficient, provide a separate protector against chips.
- Provide a separate cover if high pressure coolants or water stream hit the contact or boot protector.

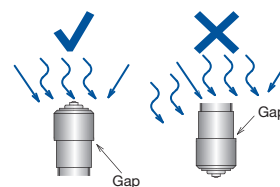
### Protective cover

Protective cover are for preventing damage to rubber boots and impairment of water-resistance or dustproofing caused by metal fragments and other cutting.

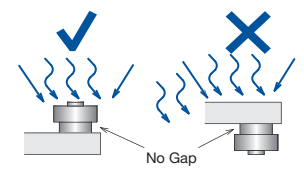
Please select the shape of the rubber boot protective covering while considering the factors indicated below.

- Choose the shape of protective covers (U type, U2 type, and D type) in consideration of mounting direction, the direction of coolant or air blower, and the gap.
- When there is no risk of damage to the rubber boots as in the case of plastic or wood cutting of grindings, it may be better to rinse off such debris with coolant or blow it off with blowing air, without attaching a protective cover.
- An extra cover is recommended to avoid direct hit by high-pressure coolant or heavy cuttings.

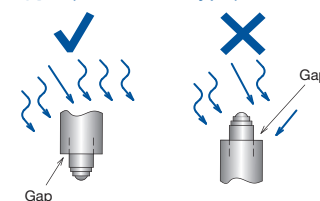
#### U type (Upward type)



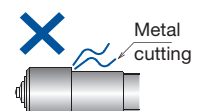
#### U2 type (Upward type)



#### D type (Downward type)



- In the case of using a boot protective cover when installed horizontally (see diagram at right), provide a cover and so on so that cuttings to not accumulate in the switch body.



## Switch installation and signal setting methods

The methods used to install switches and set the signal operating points vary depending on the purpose in which the switch is to be used.

### 1. Classification according to purpose

#### 1) Setting the signal point as the origin or reference point.

There is no particular need to set an operating point if the signal output at the position where the contact switch is to be installed, is the origin or reference point.

- The following points are selecting factors of the contact switches.
- High repetitive accuracy
  - No influence by external environment (e.g. Drifts caused by power supply voltage, temperature, intensity of light, magnetic field, etc.)
  - Small movement differential and hysteresis
  - No restriction on the materials and shapes of detected objects.

As the switches with an amplifier magnify not only the accuracy but also the fluctuation and drifts, there are the cases where these switches are not suitable for use in such a harsh environment.

#### 2) Applications involving making a judgment of pass or failure using a defined position or dimension as a limiting criterion.

These applications require heightened setting accuracy of signal points. Generally, the following 2 types of setting errors are known.

- **Type 1 Errors**  
misjudging good products as defective ones.
- **Type 2 Errors**  
misjudging defective products as good ones.

Trying not to commit the type 2 errors is important since the setting errors of the signal point, to some extent, are unavoidable. When the application only needs existence detection and doesn't require high position accuracy, there still is the same idea applying to the settings of pass/ fail border.

### 2. Important factors regarding installation methods and signal setting methods when accuracy is required

#### 1) Ease of making fine adjustments

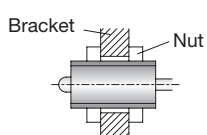
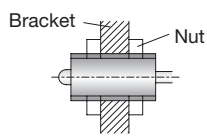
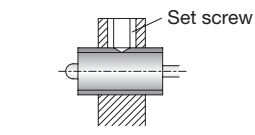
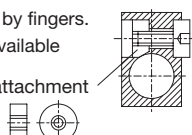

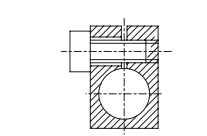
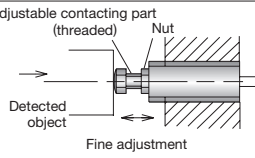
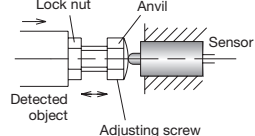
- The direction of adjustment of the switch body should be coaxial.
- In case of split clamping, there should be no engagement or screw rattle in the semi-clamped state, and movement should be smooth.

#### 2) No occurrence of position shifting when locked

- The locking position should be near the core.
- There should be no application of thrust in the axial direction during locking.

#### 3) Adopting preliminary installation and off-line settings (Refer to P7-9)

### 3. Installation using a switch bracket and adjusting signal operating point

Installation and setting using a switch bracket	Signal setting methods and characteristics	Switch fixing methods
<b>A</b> Switch outline: <b>Threaded</b> Bracket: <b>Large clearance (straight hole)</b>	 <ul style="list-style-type: none"> <li>· Alternatively tighten the 2 nuts and set and fix the switch</li> <li>· Not suitable for accurate positioning.</li> <li>· Suitable for existence detection</li> </ul>	The switch is locked in. Position shifting occurs during setting. Note that the rigidity of commercially produced brackets.
<b>B</b> Switch outline: <b>Threaded</b> Bracket: <b>Tapped</b>	 <ul style="list-style-type: none"> <li>· Screw in and out the switch for position setting.</li> <li>· Accurate position setting is available (Fine thread is recommended)</li> <li>· Do not twist the cables</li> </ul>	The switch is locked in position with 1 or 2 nuts. Position shifting may occur during setting.
<b>C</b> Switch outline: <b>Non-threaded (h7)</b> Bracket: <b>Small clearance (H7)</b>	 <ul style="list-style-type: none"> <li>· Set the position of the switch by fingers.</li> <li>· Accurate position setting is available</li> </ul> <p>Fixing attachment </p>	There is limitation for tightening strength. Malfunction may occur due to excessive force applied to the fastening part. When using a frame, there is less possibility of deformation. 
<b>D</b> Switch outline: <b>Non-threaded (h7)</b> Bracket: <b>Small clearance (H7)</b> Split clamping	 <ul style="list-style-type: none"> <li>· Setting the position in the semi-clamped state.</li> <li>· <b>Most accurate setting is available.</b></li> </ul>	No occurrence of position shifting when fastening the switch.
<b>E</b> Setting by the <b>adjustable contacting part</b> (Refer to P2-7)	 <ul style="list-style-type: none"> <li>· No need for position setting. Suitable to inline adjustment.</li> <li>· Combinations with A-F are available.</li> </ul> <ol style="list-style-type: none"> <li>1) Turn the threaded contacting part or anvil up to the signal point.</li> <li>2) Make a half-turn backward and fix it by the nut.</li> <li>3) Next, slightly loosen the nut and then fasten in the signal output position by turning the anvil when there is no play in the screw. Lock in position by tightening the nut.</li> </ol>	The switch is locked in the position with the nut.
<b>F</b> Setting by the anvil of detected objects such as moving tables. (Not available when the detected object is workpiece.)		



## Benefit of preliminary installation and offline settings

1. Accuracy improvement of signal point (signal setting by using dial gauges or micrometers).
2. Save a great deal of time for setups and changeover of machines. (Improvement in availability ratio of the machine and cut-down of maintenance time.)
3. Reduction of on-line setups, adjustment, and assembly.
4. Cut down the Mean Time To Failure. (MTTF)
5. As the repair work is simplified, skilled technician is not required. (No visit to customers, Cut down on maintenance cost)

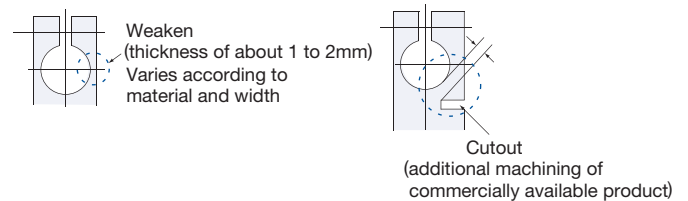
## Preliminary installation and offline settings

### 1. Preliminary installation and setting for 1-signal type switches

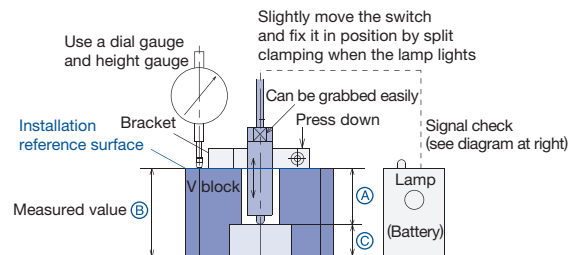
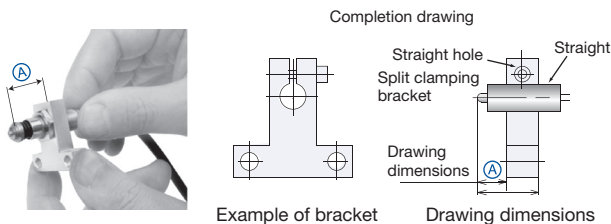
- Preliminary adjustment of the signal point refers to installing the flange, bracket and other parts on the switch outside the machine and setting to the predetermined dimensions so as to eliminate or minimize adjustments within the machine.
- In case of contact switches, the signal is output at a fixed position from the switch body. Thus, if the installation reference surface is set in advance for the switch outside the machine, and the distance from the operating point is set to the predetermined dimensions indicated in the design, position adjustment is not required to be performed inside the machine.
- Unlike non-contact switches, contact switches are not affected by the surrounding environment, such as the material, shape or brightness of the detecting body or magnetic fields. (Refer to P7-8 for signal setting method)

#### Installation reference surface

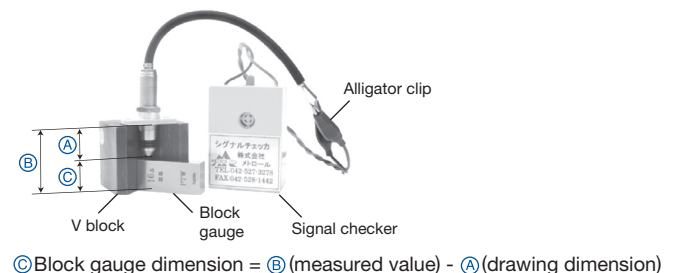
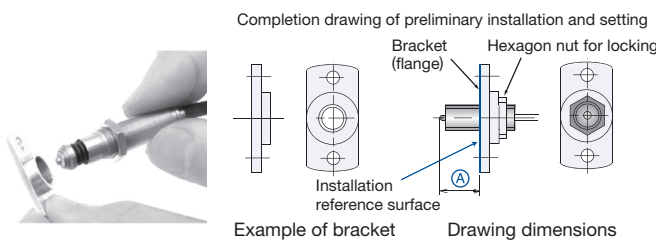
Slit types of commercially available split clamping brackets are frequently produced for the purpose of powerfully tightening balls and so on, and caution is required since there are many that are not suitable for switch inching and adjustment. Additional machining is required in such cases.



#### In case of using the switch with a non-threaded switch case.



#### In case of using the switch with a threaded switch case.



### 2. Preliminary installation and setting for multi-signal type switches

#### Compatible products

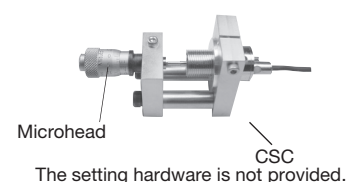
#### CS-Touch Switch CSC (Refer to P4-21)

- This is effective in cases of a switch unit containing two or more internal switches.
- In such cases, The following two tasks are always required:
  - (i) Setting the interval (tolerance) between points
  - (ii) Adjusting the signal points within the machine with a master.
- Although a small signal setting screw is provided for setting the signal points, there are cases in which this work may not be easy in machines having limited space.

First, preliminarily set the interval between signal points. Next, install the bracket on the switch unit according to the design dimensions. As a result, since these preparations eliminate all adjustment performed within the machine, corrections can also be made simply by inching the switch head for either one of signal points.

#### Preliminary installation and offline setting hardware

This hardware using a microhead was made available for this preliminary installation and offline setting. The signal interval can be set in cases when not using a bracket.



**Please consult us if you like us to send you drawings for production.**

## Basics of measurement

Generally speaking, dimensional measuring instruments, having a built-in scale, not only convert values of displacement to electrical quantity or light intensity, but also amplify, calculate, and record the value. These instruments output signals as threshold values. The price for the instruments is relatively high because an amplifier is required.

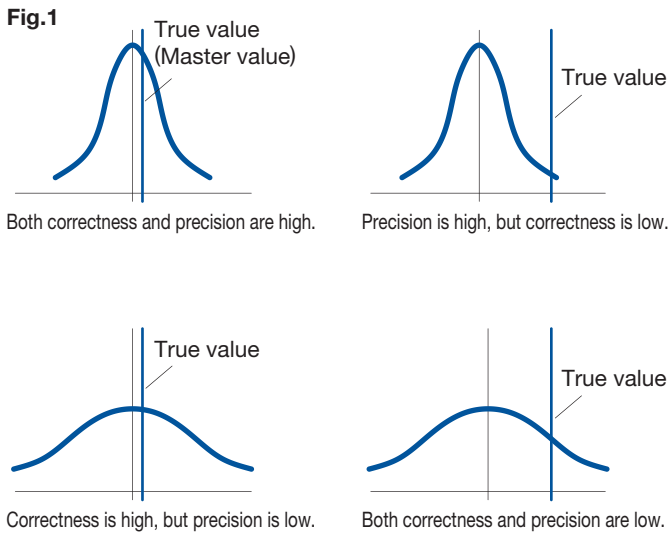
On the other hand, METROL contact switches don't require the built-in scale, and output accurate signals as limit values from a built-in switching part.

Except off-line use, there are the cases, mostly in machines, where general instruments are only required to output signals as limit values. In that case, METROL contact switches can show a great cost-effectiveness replacing those expensive instruments. Since the basic knowledge of measurement is required to make full use of METROL contact switches, refer to the following for your information.

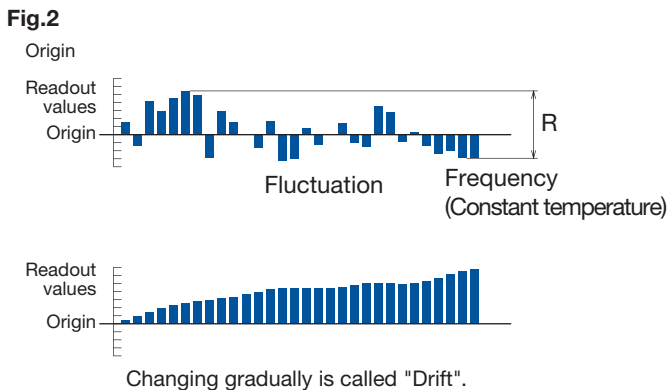
### 1. Accuracy

Accuracy consists of "Precision" and "Correctness".

The fluctuation range of numerical values obtained from multiple measurements is called "**Precision**", and the difference between the obtained values and true values is called "**Correctness**".



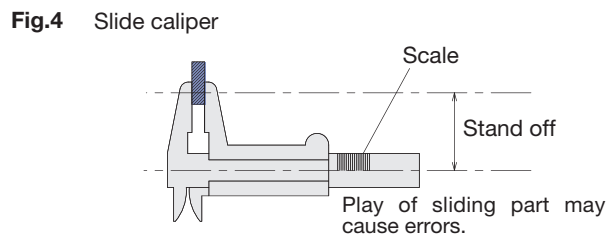
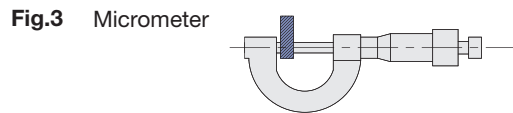
There is the practice of indicating "**Precision**" as "Average value", "Deviation value" or "Range" by taking operating point signals output from the measuring instruments such as digital micrometers or NC scales, etc. measuring displacement of detected objects



### 2. Abbe theory

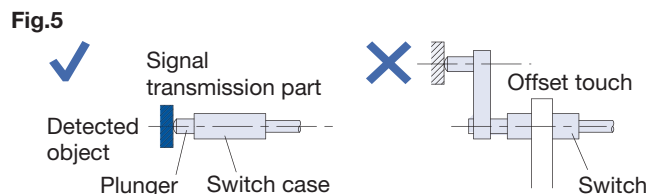
**A detected object and a standard scale need to be arranged on the same axis to heighten measurement accuracy.**

That is known as Abbe theory. Close to our hand for example, this theory applies to micrometers but doesn't apply to slide calipers.

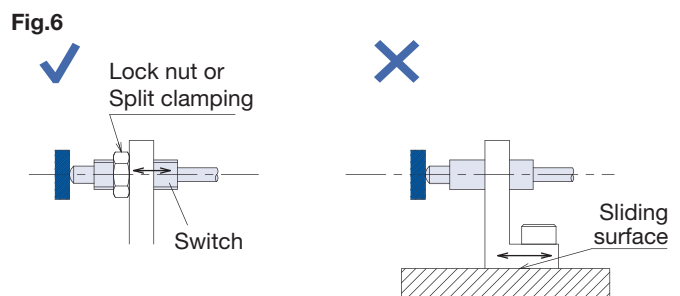


When using a switch, offset touch, as shown below, is not recommended. This can also apply to fine position setting methods. Offset touch is subjected to rattle of sliding part, loss of perpendicularity, and deflection of the holder.

Consequently, the way in which the highest accuracy can be obtained by using cylindrical type switch is to locate the plunger of the switch on the same axis as the measuring direction and slide the switch on the same axis for precise position setting.



In addition, accidentally applying sideways tightening force to the plunger may cause errors. (e.g. Split clamping, Set screws)



## 3. Temperature

Instruments and workpiece are subjected to expansion and contraction according to temperature change.

20°C is standard in industrial standard. The expansion and contraction cannot be clearly calculated under the condition of different materials and thermal capacities as well as changes over time.

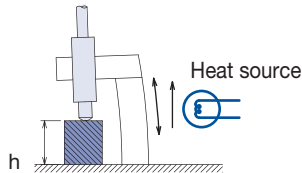
Consequently, the following points are important to minimize the risk of expansion and contraction of instruments or workpiece.

- 1) Keep the temperature constant.
- 2) Set the origin by using masterwork whenever a great temperature change occurs.
- 3) Select a switch that is least subject to temperature changes.

These attempts results in only minimum compensation required for use (for example, expansion of high-speed machining spindle).

In that case, a METROL tool setter for machining centers can compensate thermal expansion of high-speed spindle. Since there are cases where dimensions realistically affected by flexure (bimetal) greater than expansion and contraction, it may be more effective to bring countermeasure for the flexure.

Fig. 7



Keep it in mind that simple expansion and contraction of iron is 1 μm by 10°C (Brass is 1.9 μm, Aluminum is 2.8 μm).

There are measures as heat sources such as external temperature, motor, shock absorber, cylinder, high-speed spindle, coolant, weld, cutting, and body heat, and their conduction and radiation are also taken into account.

In addition, as constant numbers for elements of electrical parts vary by temperature change, contact-less type switches with an electrical circuit in term of amplifier inevitably has temperature drift. Refer to section 6, Fig. 8

## 4. Shape of contacting part and contact force

These two measures are closely related to each other. And changing the two measures results in instrument errors. The following points are to be noticed.

- When contacting detected surface, point contact is the best way to obtain the highest accuracy. But the smaller the dimension of contacting point becomes, the larger the contact force can be. That may cause deformation of either contacting part or detected surface. (This can be calculated by Hertz equation. But it doesn't make a big difference in reality).
- Point contact is subjected to plane roughness and friction.
- Large contacting surface may cause errors by deflection due to geometric deformation.
- Since excessive contact force may cause errors by flexure of switch holder, commercially produced less-rigid brackets can be used only for low contact force type switches.
- Flexure (Range of elastic deformation) can be a main factor of hysteresis and may generate drift.
- Deformation of switch holders can be caused not only due to excessive contact force but also by excessive force applied while fixing.
- The contacting force is defined mainly by spring force. But the frictional force of the plunger should be subtracted from the spring force. Absence of this idea may cause return errors.
- Since non-contact switches (Proximity switches and photoelectric switches) detect objects with the detecting surface and output average values calculated from dimension of the surface, the values are different from actual measurement values and actual dimensions. Installing contact type actuators marks up the total cost and causes loss of accuracy.

## 5. Timing of measurement

Measurement before processing is called **Pre-Process Measurement**.

(e.g. Measurement of unprocessed workpiece and parts dimension before assembly. Detecting process errors from previous operation. Upside-down detection of workpiece.)

Measurement during process is called **In-Process Measurement**.

(e.g. During grinding process, measure the work piece dimension and stop the process when the dimension comes in the allowance. Checking bending radius when the object bent.)

On-line measurement after process is called **Post-Process Measurement**.

(e.g. Eliminate defectives after process while giving feedback to previous process.)

## 6. Contacting point

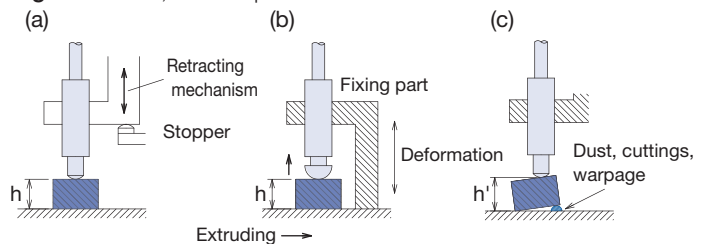
In case of contact measurement, accuracy varies according to how to make the detecting part contact with objects.

### 1-point measurement method (Thickness measurement)

In Fig. 8 (a)(b), deformation and thermal displacement of the fixing part, retracting part cause errors.

In Fig. 8 (c), warpage of workpiece, dust and cuttings are error factors.

Fig. 8 Deflection, thermal displacement



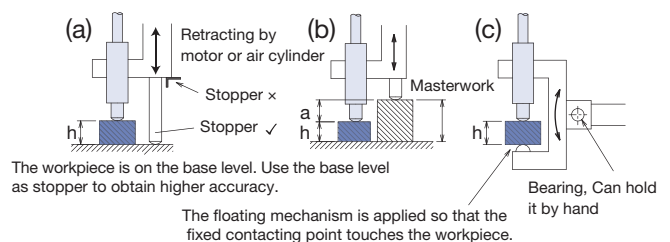
### 2-point measurement method

In Fig. 9 (a), making the stopper prop with base level prevent errors shown in (a)(b) in Fig. 8.

In Fig. 9 (b), errors can be prevented by comparative tolerance between the masterwork and the detected workpiece. Equivalent to step measurement.

In Fig. 9 (c), errors caused by dust or warpage can be prevented by holding the workpiece between 2 points. Plate spring hinge or bearing is used for the floating mechanism.

Fig. 9 (Errors may occur due to repeatability of the movement or temperature change.)



### 3-point measurement method

In Fig. 10 (a)(b)(c), though large diameter or sphere workpiece are measured as center-less, magnification ratio drops according to opening angle. This results in loss of accuracy.

Fig. 10

