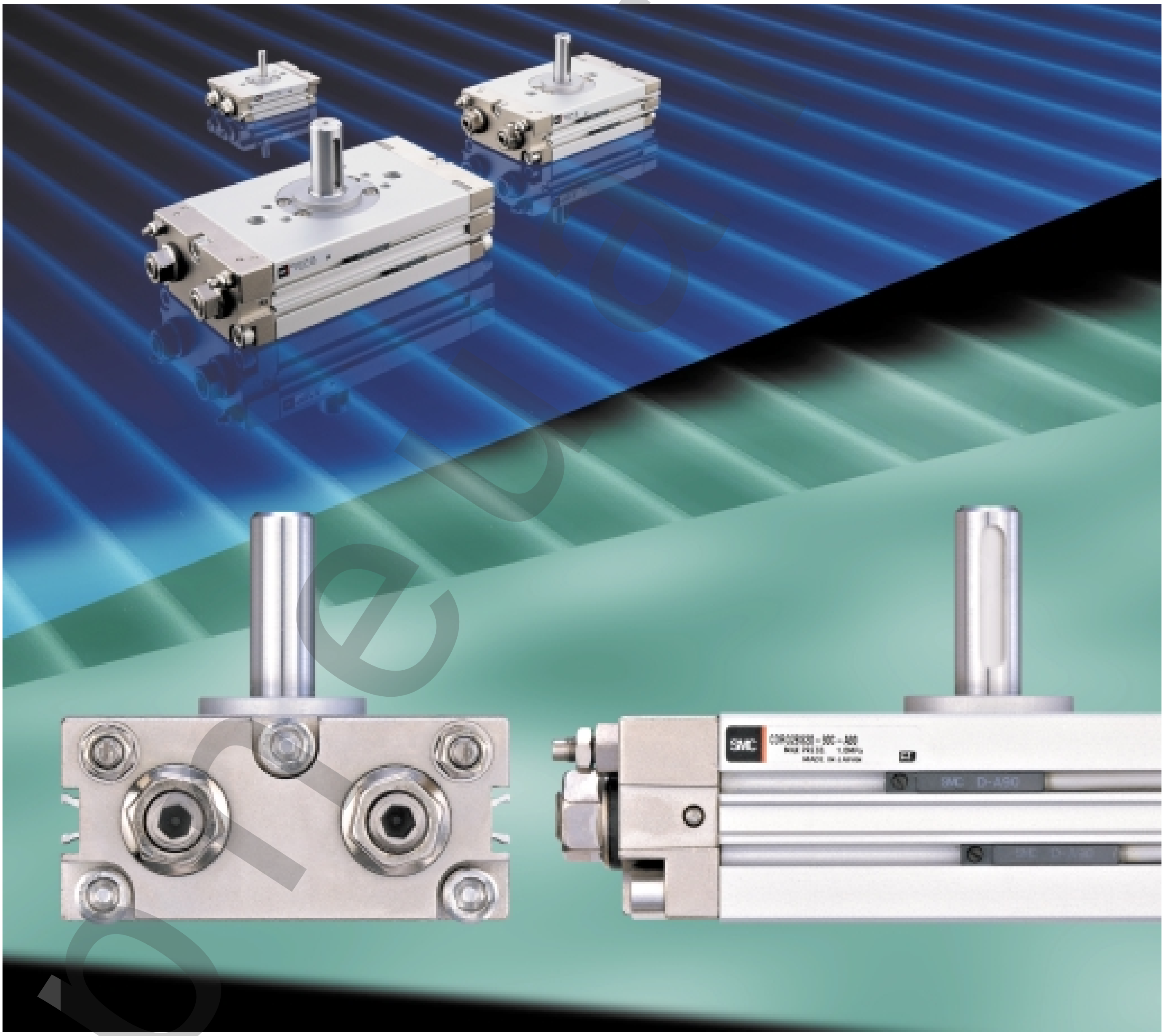
# Compact Rotary Actuator
## Rack-and-Pinion Type/Sizes: 10, 15, 20, 30, 40

# *Series CRQ2*



# Compact Rotary Actuator
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# Series CRQ2

## Piping can be installed from one end

## Body can be used as a flange

## Uses internal cushioning

10, 15 : Rubber bumper
20, 30, 40: Air cushion

## Compact design saves mounting space

10: 17mm
15: 20mm
20: 29mm
30: 33mm
40: 37mm

## 2 auto switches can be mounted on same side (both sides)

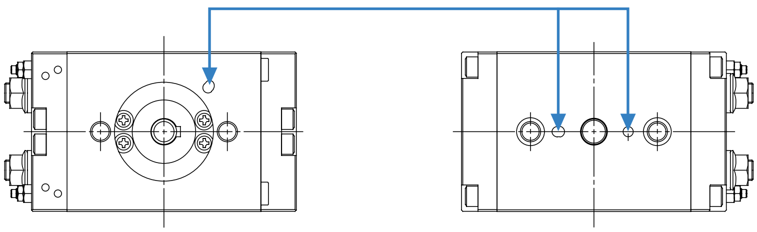
Miniature auto switches do not protrude from the body when installed and require no extra space.

## Angle adjustment bolts are standard

## Use of double piston eliminates backlash

## Easy alignment when mounting body

**Body positioning pin holes**



## Single and double shaft types available in all sizes

## Variations

| | 10 | 15 | 20 | 30 | 40 |
|---|---|---|---|---|---|
| Rotation (80° to 100°, 170° to 190°) | ● | ● | ● | ● | ● |
| Auto switches | ● | ● | ● | ● | ● |
| Air cushion | | | ● | ● | ● |
| Rubber bumper | ● | ● | | | |
| Single shaft type (S) | ● | ● | ● | ● | ● |
| Double shaft type (W) | ● | ● | ● | ● | ● |

# Compact Rotary Actuator Rack-and-Pinion Type

# *Series* CRQ2

## How to Order

### Standard type

**CRQ2B S 20 – 90 [ ]**

**Shaft type**

| | |
|---|---|
| **Single shaft** | S |
| **Double shaft** | W |

**Size**

| |
|---|
| **10** |
| **15** |
| **20** |
| **30** |
| **40** |

**Rotation**

| | |
|---|---|
| **90** | 80° to 100° |
| **180** | 170° to 190° |

**Air cushion**

| **Sizes** | Air cushion | |
|---|---|---|
| **10, 15** | Without | Nil |
| **20, 30, 40** | Without | Nil |
| | With | C |

### With auto switch

**CDRQ2B S 20 – 90 [ ] – A90 S**

**Built-in magnet**

**Shaft type**

| | |
|---|---|
| **Single shaft** | S |
| **Double shaft** | W |

**Size**

| |
|---|
| **10** |
| **15** |
| **20** |
| **30** |
| **40** |

**Rotation**

| | |
|---|---|
| **90** | 80° to 100° |
| **180** | 170° to 190° |

**Air cushion**

| **Sizes** | Air cushion | |
|---|---|---|
| **10, 15** | Without | Nil |
| **20, 30, 40** | Without | Nil |
| | With | C |

**Auto switch model**

| | |
|---|---|
| **Nil** | Without auto switch (built-in magnet) |

∗ Select applicable auto switch models from the table below.

**Number of auto switches**

| | |
|---|---|
| **Nil** | 2 pcs. |
| **S** | 1 pc. |

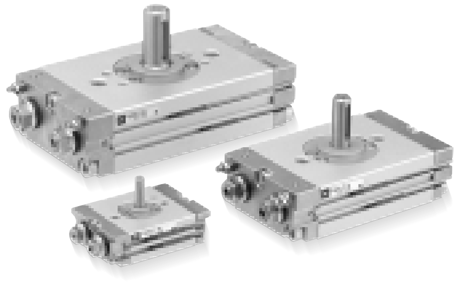
### Applicable auto switches

| Type | Special function | Electrical entry | Indicator light | Wiring (output) | Load voltage | | | Auto switch part no. | | Lead wire length (m)∗ | | | Applicable loads | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | DC | | AC | Electrical entry direction: Perpendicular | In-line | 0.5 (Nil) | 3 (L) | 5 (Z) | | |
| Reed switch | — | Grommet | Yes | 3 wire (NPN equiv.) | — | 5V | — | **A96V** | **A96** | ● | — | — | IC circuit | — |
| | | | | | | | | **A96VL** | **A96L** | — | ● | — | | |
| | | | | 2 wire | 24V | — | 100V | **A93V** | **A93** | ● | — | — | — | Relay, PLC |
| | | | | | | | | **A93VL** | **A93L** | — | ● | — | | |
| | | | No | | | 5V, 12V | 100V or less | **A90V** | **A90** | ● | — | — | IC circuit | |
| | | | | | | | | **A90VL** | **A90L** | — | ● | — | | |
| Solid state switch | — | Grommet | Yes | 3 wire (NPN) | 24V | 5V, 12V | — | **F9NV** | **F9N** | ● | — | — | — | Relay, PLC |
| | | | | | | | | **F9NVL** | **F9NL** | — | ● | — | | |
| | | | | | | | | **F9NVZ** | **F9NZ** | — | — | ○ | | |
| | | | | 3 wire (PNP) | — | — | | **F9PV** | **F9P** | ● | ● | — | | |
| | | | | | | | | **F9PVL** | **F9PL** | — | ● | — | | |
| | | | | | | | | **F9PVZ** | **F9PZ** | — | — | ○ | | |
| | | | | 2 wire | 24V | 12V | | **F9BV** | **F9B** | ● | — | — | | |
| | | | | | | | | **F9BVL** | **F9BL** | — | ● | — | | |
| | | | | | | | | **F9BVZ** | **F9BZ** | — | — | ○ | | |
| | Diagnostic indication (2 color indicator) | | | 3 wire (NPN) | | 5V, 12V | | **F9NWV** | **F9NW** | ● | — | — | | |
| | | | | | | | | **F9NWVL** | **F9NWL** | — | ● | — | | |
| | | | | | | | | **F9NWVZ** | **F9NWZ** | — | — | ○ | | |
| | | | | 3 wire (PNP) | — | — | | **F9PWV** | **F9PW** | ● | — | — | | |
| | | | | | | | | **F9PWVL** | **F9PWL** | — | ● | — | | |
| | | | | | | | | **F9PWVZ** | **F9PWZ** | — | — | ○ | | |
| | | | | 2 wire | 24V | 12V | | **F9BWV** | **F9BW** | ● | — | — | | |
| | | | | | | | | **F9BWVL** | **F9BWL** | — | ● | — | | |
| | | | | | | | | **F9BWVZ** | **F9BWZ** | — | — | ○ | | |

∗Lead wire length symbols 0.5m … Nil (Example) F9B
3m ........ L (Example) F9BL
5m ........ Z (Example) F9BZ

∗ Solid state auto switches marked with a ○ are produced upon receipt of order.

# Series CRQ2

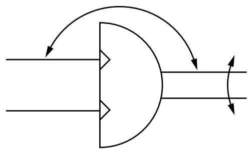


## Specifications

| Size | 10 | 15 | 20 | 30 | 40 |
|---|---|---|---|---|---|
| Fluid | Air (unlubricated) | | | | |
| Maximum operating pressure | 0.7MPa | | 1MPa | | |
| Minimum operating pressure | 0.15MPa | | 0.1MPa | | |
| Ambient and fluid temperature | 0 to 60°C (with no freezing) | | | | |
| Cushion | Rubber bumper | | None, Air cushion | | |
| Angle adjustment | ± 5° | | | | |
| Rotation | 80° to 100°, 170° to 190° | | | | |
| Port size | M5 x 0.8 | | Rc1/8 | | |
| Mounting brackets | Basic type | | | | |
| Output Nm* | 0.3 | 0.75 | 1.8 | 3.1 | 5.3 |

*) Indicates output with operating pressure at 0.5MPa. Refer to Page 14 for details.

JIS symbol



## Allowable Kinetic Energy and Rotation Time Adjustment Range

| Size | Allowable kinetic energy | | | | Stable operational rotation time adjustment range |
|---|---|---|---|---|---|
| | Allowable kinetic energy (J) | | | Cushion angle | |
| | Without cushion | Rubber bumper | With air cushion * | | Rotation time (s/90°) |
| **10** | — | $0.25 \times 10^{-3}$ | — | — | 0.2 to 0.7 |
| **15** | — | $0.39 \times 10^{-3}$ | — | — | 0.2 to 0.7 |
| **20** | 0.025 | — | 0.12 | 40° | 0.2 to 1 |
| **30** | 0.048 | — | 0.25 | 40° | 0.2 to 1 |
| **40** | 0.081 | — | 0.40 | 40° | 0.2 to 1 |

*) Allowable kinetic energy with cushion
Maximum energy absorption with optimal adjustment of cushion needle

## Weight Table

(g)

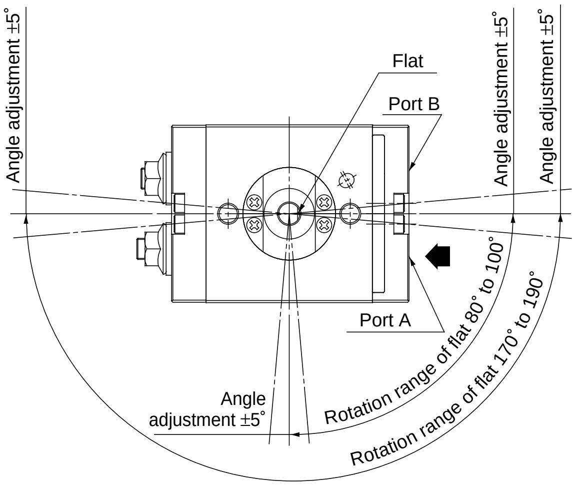
| Size | Standard weight* | |
|---|---|---|
| | 90° | 180° |
| **10** | 120 | 150 |
| **15** | 220 | 270 |
| **20** | 600 | 700 |
| **30** | 900 | 1100 |
| **40** | 1400 | 1600 |

*) Value excluding the weight of auto switches.

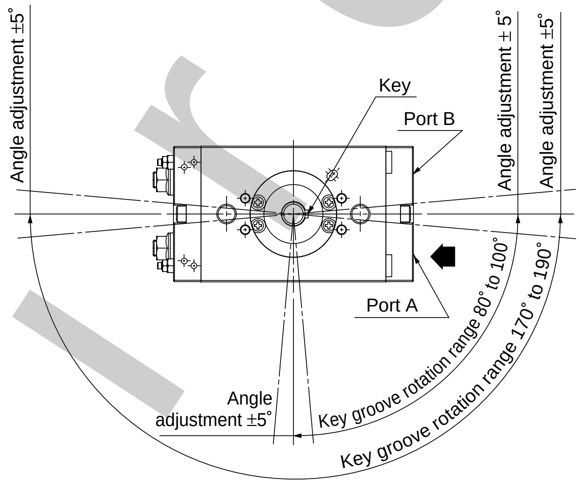
## Rotation Range

When pressure is applied to the port on the side with the arrow, the shaft rotates clockwise.

### Sizes 10, 15

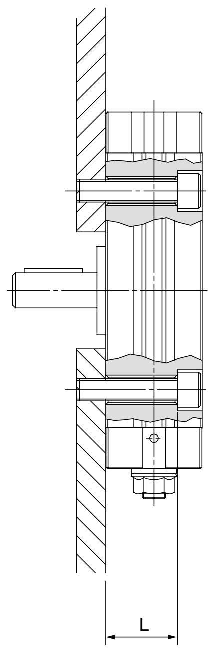



### Sizes 20, 30, 40




## Using the Body as a Flange

The body's L dimensions are shown in the drawing on the right.
When JIS standard hexagon socket head cap screws are used, the actuator grooves should be used to contain the heads of the screws.

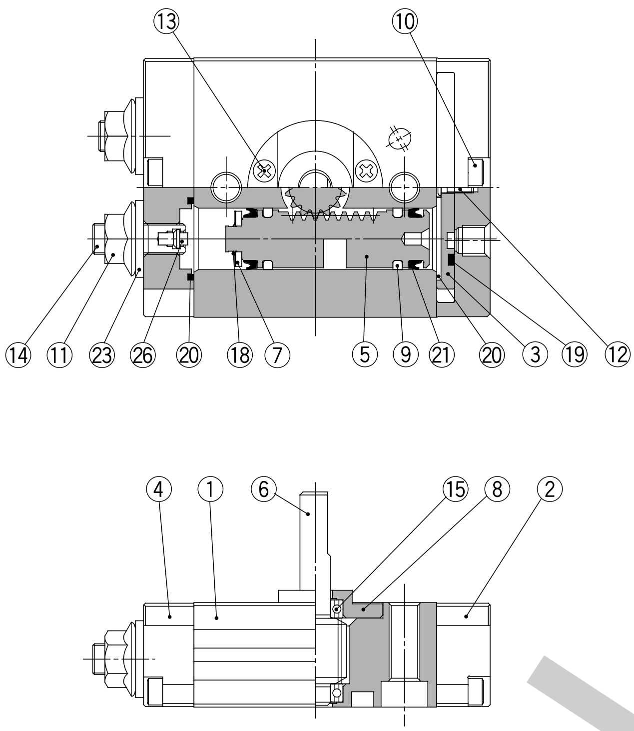



| Size | L | Screw |
|---|---|---|
| **10** | 13 | M4 |
| **15** | 16 | M4 |
| **20** | 22.5 | M6 |
| **30** | 24.5 | M8 |
| **40** | 28.5 | M8 |

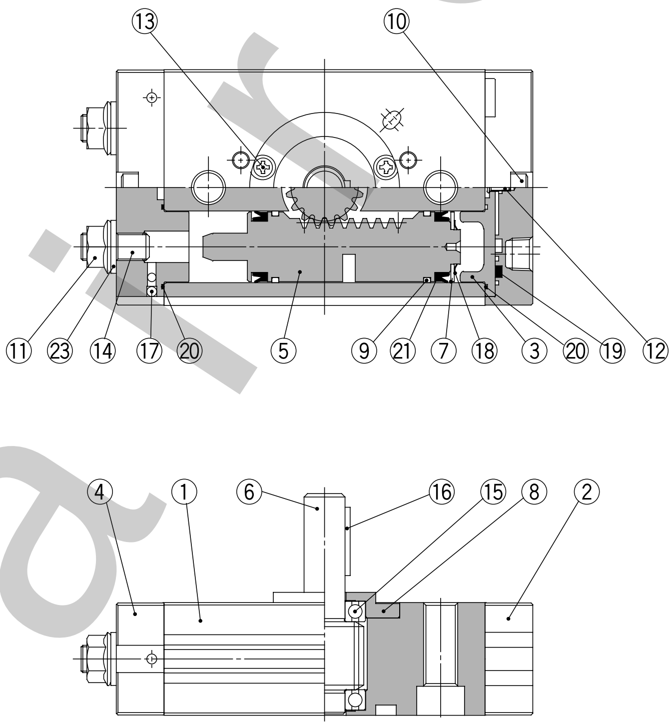
# Series CRQ2

## Construction

**Standard type**
**Sizes 10, 15**




**Standard type**
**Sizes 20, 30, 40**




**Parts list**

| No. | Description | Material | Note |
|---|---|---|---|
| 1 | **Body** | Aluminum alloy | Clear hard anodized |
| 2 | **Cover** | Aluminum alloy | Electroless nickel plated |
| 3 | **Plate** | Aluminum alloy | |
| 4 | **End cover** | Aluminum alloy | Electroless nickel plated |
| 5 | **Piston** | Stainless steel | |
| 6 | **Shaft** | Stainless steel | Sizes: 10, 15 |
| | | Chromium molybdenum steel | Sizes: 20, 30, 40 |
| 7 | **Seal retainer** | Aluminum alloy | Chromated |
| 8 | **Bearing retainer** | Aluminum alloy | Clear hard anodized |
| 9 | **Wear ring** | Resin | |
| 10 | **Hexagon socket head cap screw** | Stainless steel | |
| 11 | **Hexagon nut with flange** | Steel wire | Electroless nickel plated |
| 12 | **Round head No. 0 Phillips screw** | Steel wire | Zinc chromated |
| 13 | **Round head No. 0 Phillips screw** | Steel wire | 10, 15 nickel plated |
| | **Round head Phillips screw** | | 20, 30, 40 nickel plated |

**Parts list**

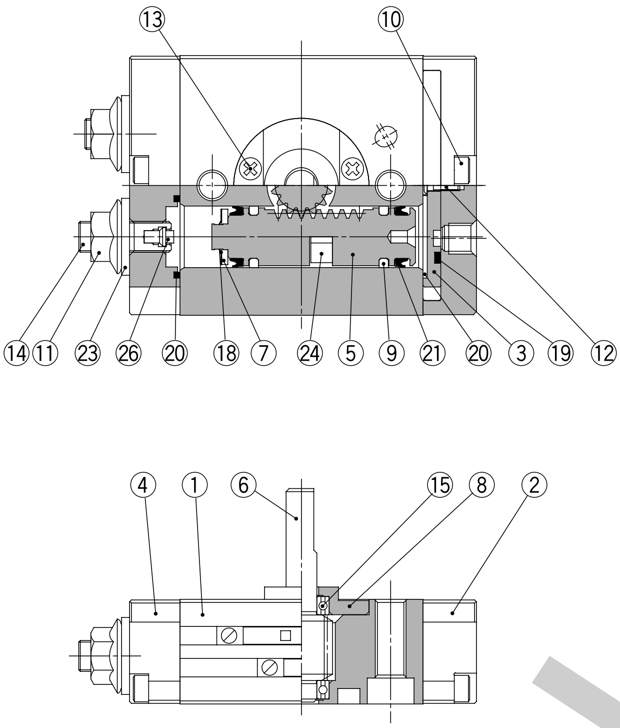
| No. | Description | Material | Note |
|---|---|---|---|
| 14 | **Hexagon socket head set screw** | Chromium molybdenum steel | Electroless nickel plated |
| 15 | **Bearing** | Bearing steel | |
| 16 | **Parallel key** | Carbon steel | 20, 30, 40 |
| 17 | **Steel balls** | Stainless steel | 20, 30, 40 |
| 18 | **C S type snap ring** | Stainless steel | |
| 19 | **Seal** | NBR | |
| 20 | **Gasket** | | |
| 21 | **Piston seal** | | |
| 22 | **Cushion seal** | | 20, 30, 40 with cushion |
| 23 | **Seal washer** | | |
| 24 | **Magnet** | Magnetic material | With auto switch |
| 25 | **Cushion valve assembly** | | 20, 30, 40 with cushion |
| 26 | **Cushion pad** | Elastic material | 10, 15 |

**Replacement parts**

| Description | Kit number | | | | | Contents |
|---|---|---|---|---|---|---|
| | 10 | 15 | 20 | 30 | 40 | |
| **Seal kit** | P473010-1 | P473020-1 | P473030-1 | P473040-1 | P473050-1 | 19, 20, 21, 23 |

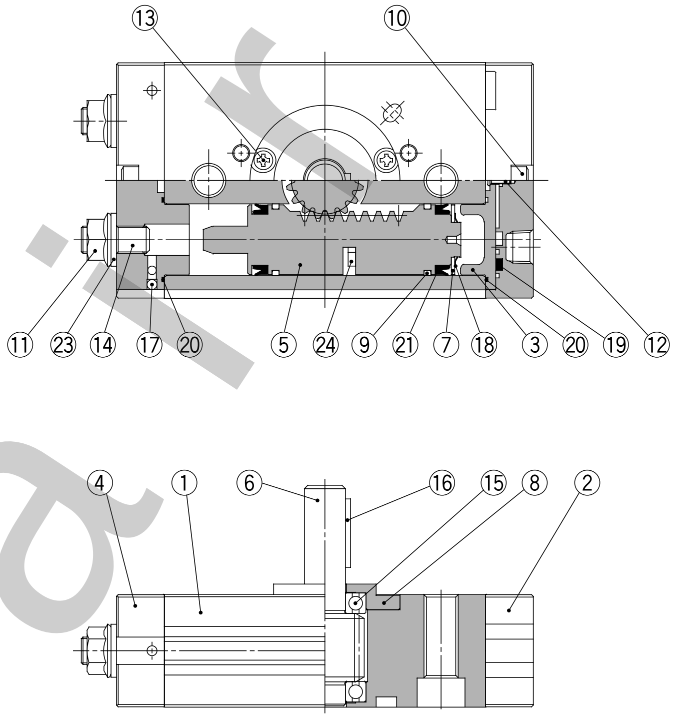
**With auto switch**

## Sizes 10, 15



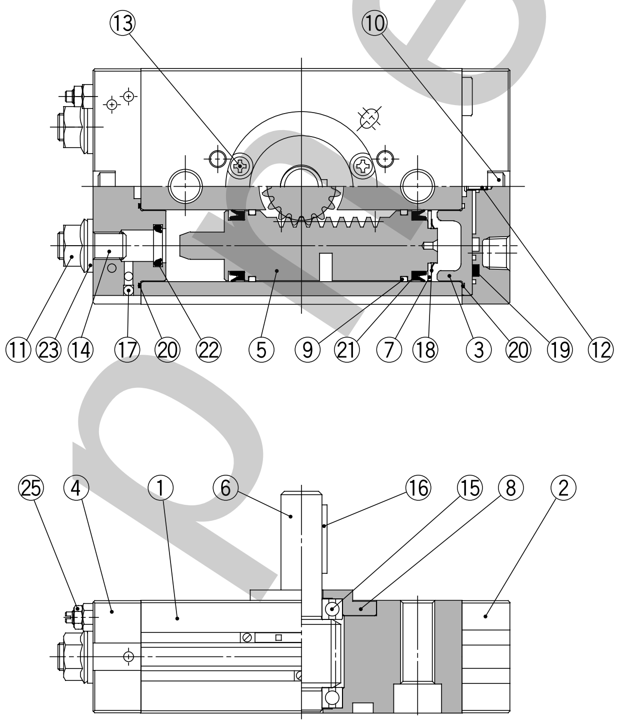

**With auto switch**

## Sizes 20, 30, 40



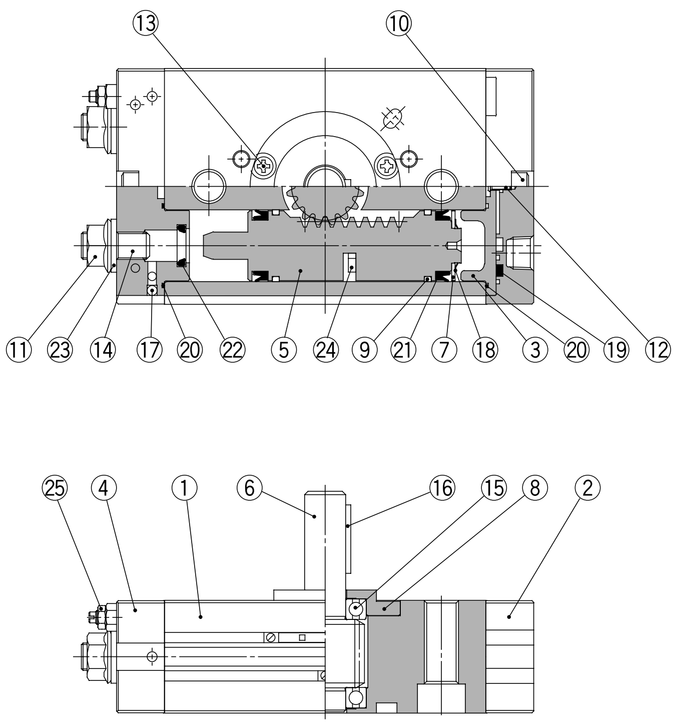

**With cushion**

## Sizes 20, 30, 40




**With auto switch and cushion**

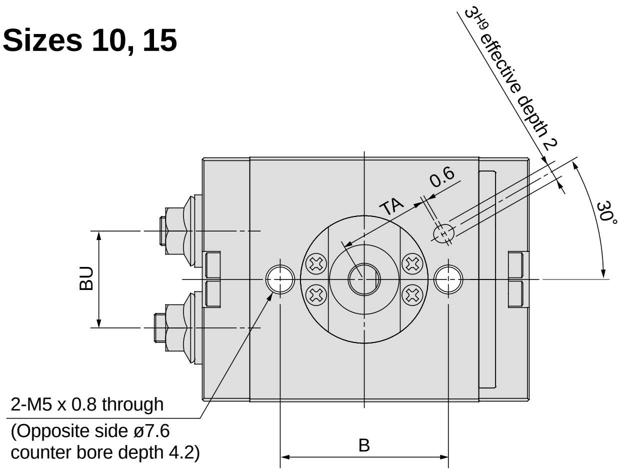
## Sizes 20, 30, 40



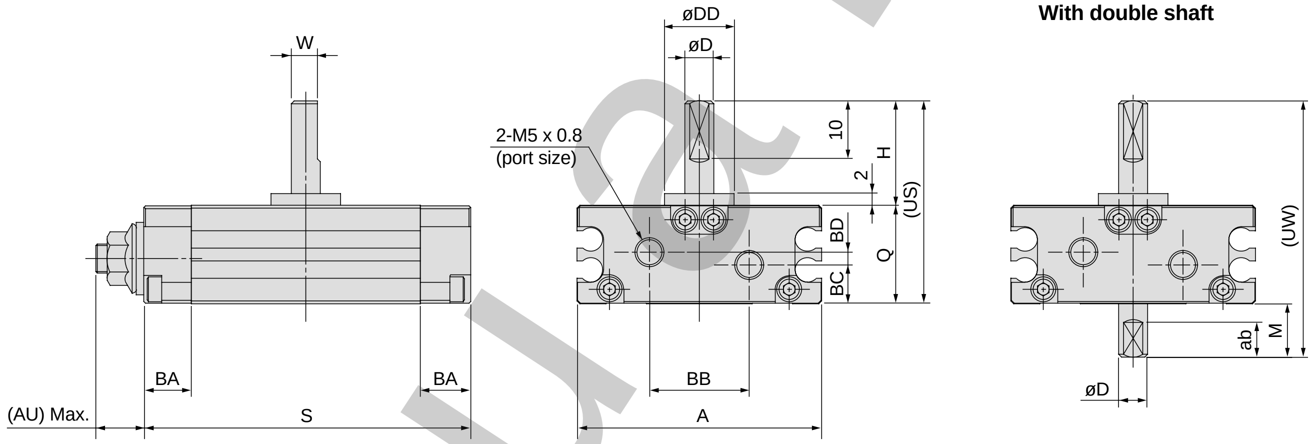
# Series CRQ2

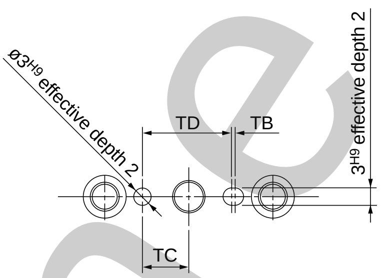
## Dimensions

### Sizes 10, 15




**With double shaft**



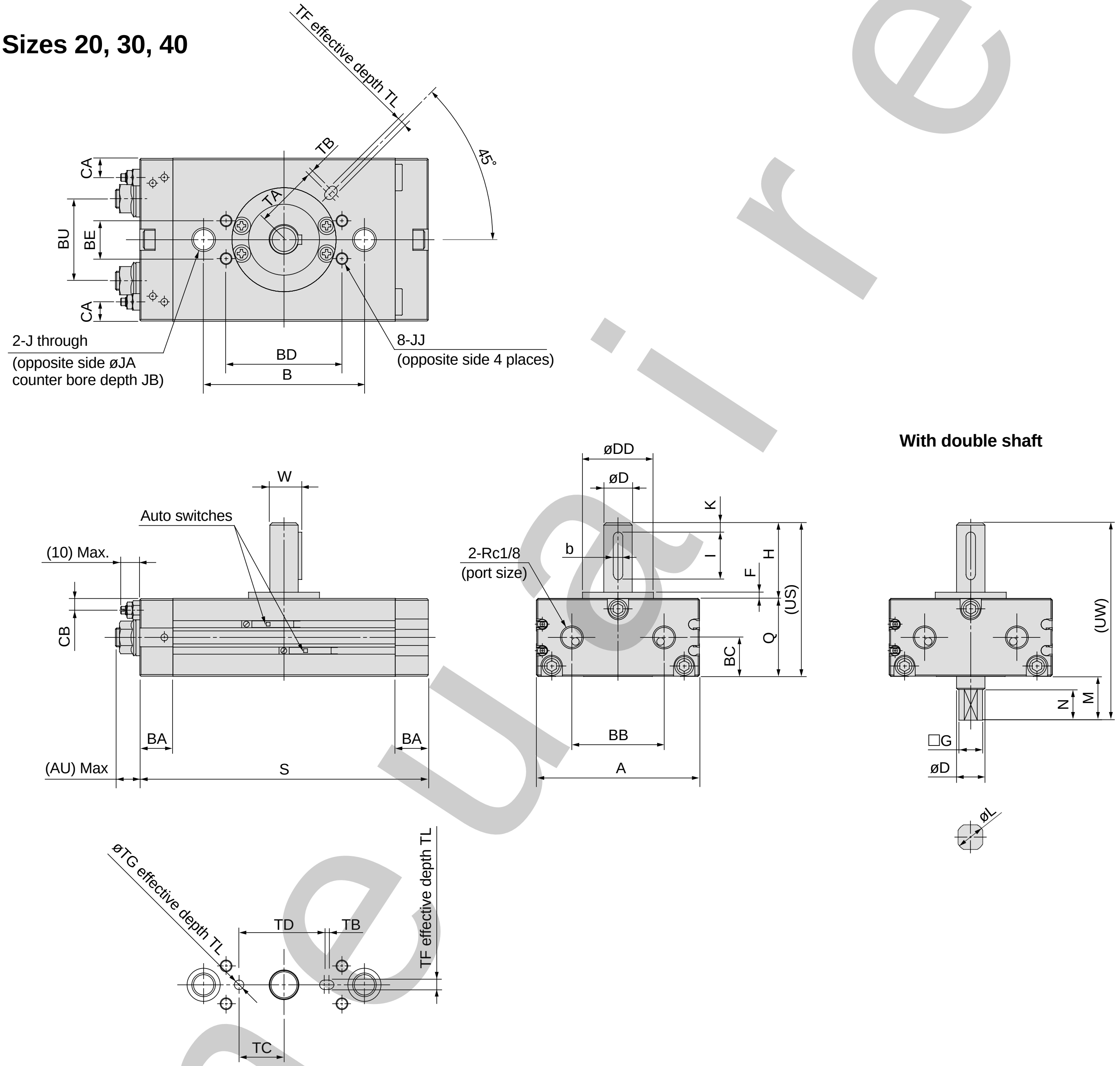




| Size | Rotation | A | AU* | B | BA | BB | BC | BD | BU | D (g6) | DD (h9) | H |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **10** | **90°, 180°** | 42 | (8.5) | 29 | 8.5 | 17 | 6.7 | 2.2 | 16.7 | 5 | 12 | 18 |
| **15** | **90°, 180°** | 53 | (9.5) | 31 | 9 | 26.4 | 10.6 | – | 23.1 | 6 | 14 | 20 |

| Size | Rotation | W | Q | S | US | UW | ab | M | TA | TC | TD |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **10** | **90°** | 4.5 | 17 | 56 | 35 | 44 | 6 | 9 | 15.5 | 8 | 15.4 |
| | **180°** | | | 69 | | | | | | | |
| **15** | **90°** | 5.5 | 20 | 65 | 40 | 50 | 7 | 10 | 16 | 9 | 17.6 |
| | **180°** | | | 82 | | | | | | | |

* Dimension AU does not indicate the dimension when shipped because of the adjustment section. S: Upper space 90°, Lower space 180°

## Sizes 20, 30, 40




| Size | Rotation | A | AU* | B | BA | BB | BC | BD | BE | BU | CA | CB | D (g6) | DD (h9) | F | H | J | JA | JB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **20** | **90°, 180°** | 63 | (11) | 50 | 14 | 34 | 14.5 | – | – | 30.4 | 7 | 4.7 | 10 | 25 | 2.5 | 30 | M8 x 1.25 | 11 | 6.5 |
| **30** | **90°, 180°** | 69 | (11) | 68 | 14 | 39 | 16.5 | 49 | 16 | 34.7 | 8.1 | 4.9 | 12 | 30 | 3 | 32 | M10 x 1.5 | 14 | 8.5 |
| **40** | **90°, 180°** | 78 | (13) | 76 | 16 | 47 | 18.5 | 55 | 16 | 40.4 | 8.3 | 5.2 | 15 | 32 | 3 | 36 | M10 x 1.5 | 14 | 8.6 |

| Size | Rotation | JJ | K | Q | S | W | Key dimensions | | US | TA | TB | TC | TD | TF (H9) | TG (H9) | TL | UW | G | M | N | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | b | l | | | | | | | | | | | | | |
| **20** | **90°** | – | 3 | 29 | 104 | 11.5 | $4^{0}_{-0.03}$ | 20 | 59 | 24.5 | 1 | 13.5 | 27 | 4 | 4 | 2.5 | 74 | 8 | 15 | 11 | 9.6 |
| | **180°** | | | | 130 | | | | | | | | | | | | | | | | |
| **30** | **90°** | M5 x 0.8 depth 6 | 4 | 33 | 122 | 13.5 | $4^{0}_{-0.03}$ | 20 | 65 | 27 | 2 | 19 | 36 | 4 | 4 | 2.5 | 83 | 10 | 18 | 13 | 11.4 |
| | **180°** | | | | 153 | | | | | | | | | | | | | | | | |
| **40** | **90°** | M6 x 1 depth 7 | 5 | 37 | 139 | 17 | $5^{0}_{-0.03}$ | 25 | 73 | 32.5 | 2 | 20 | 39.5 | 5 | 5 | 3.5 | 93 | 11 | 20 | 15 | 14 |
| | **180°** | | | | 177 | | | | | | | | | | | | | | | | |

∗ Dimension AU does not indicate the dimension when shipped because of the adjustment section.

S: Upper space 90°, Lower space 180°

*Series CRQ2*

# Auto Switch Specifications

## Reed Switches

| Auto switch part no. | Load voltage | Maximum load current or load current range | Internal voltage drop | Indicator light (lights when ON) | Applications |
|---|---|---|---|---|---|
| **D-A90**<br>**D-A90V** | AC/DC 24V or less | 50mA | 0 | None | Relay, PLC, IC circuit |
| | AC/DC 48V or less | 40mA | | | |
| | AC/DC 100V or less | 20mA | | | |
| **D-A93**<br>**D-A93V** | 24VDC | 5 to 40mA | 2.6V or less | ● | Relay, PLC |
| | 100VAC | 5 to 20mA | | | |
| **D-A96**<br>**D-A96V** | 4 to 8VDC | 20mA | 0.8V or less | ● | IC circuit |

- Lead wires —— D-A90□, A93□ : Oil resistant heavy duty vinyl cord ø2.7
  0.18mm² x 2 wire (Brown, Blue [Red, Black]) 0.5m
  D-A96□: Oil resistant heavy duty vinyl cord ø2.7
  0.15mm² x 3 wire (Brown, Black, Blue [Red, White, Black]) 0.5m
- Insulation resistance —— 50MΩ or more at 500VDC (between lead wire and case)
- Withstand voltage —— 1000VAC for 1 min. (between lead wire and case) • Operation time ——1.2ms
- Ambient temperature —— 10 to 60°C • Impact resistance —— 300m/s² {30.6G} • Leakage current —— 0
- Enclosure —— IEC529 standard IP67 (JIS0920) watertight
- For a lead wire length of 3m, "L" is added to the end of the part number. Example) D-A90L

## Solid State Switches

| Auto switch part no. | Output type | Power supply voltage | Current consumption | Load voltage | Max. load current or load current range | Internal voltage drop | Leakage current | Indicator light | Applications |
|---|---|---|---|---|---|---|---|---|---|
| **D-F9N**<br>**D-F9NV** | NPN type | 24VDC (10 to 28VDC) | 8mA or less | 28VDC or less | 50mA or less | 0.4V or less | 10μA or less at 24VDC | Lights when ON | Relay, PLC |
| **D-F9NW**<br>**D-F9NWV** | | | 12mA or less | | | | | 2 color indicator | |
| **D-F9P**<br>**D-F9PV** | PNP type | | 10mA or less | — | | 1.5V or less | | Lights when ON | |
| **D-F9PW**<br>**D-F9PWV** | | | | | | | | 2 color indicator | |
| **D-F9B**<br>**D-F9BV** | — | — | — | 24VDC (10 to 28VDC) | 5 to 30mA | 4.5V or less | 1mA or less at 24VDC | Lights when ON | 24VDC Relay, PLC |
| **D-F9BW**<br>**D-F9BWV** | | | | | | 5V or less | | 2 color indicator | |

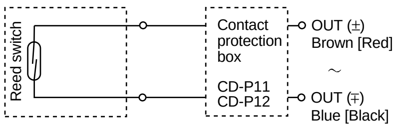
- Lead wires —— Oil resistant heavy duty vinyl cord ø2.7, 0.15mm² x 3 wire (Brown, Black, Blue [Red, White, Black) 0.5m,
  0.18mm² x 2wire (Brown, Blue [Red, Black]) 0.5m
- Insulation resistance —— 50MΩ or more at 500VDC (between lead wire and case)
- Withstand voltage —— 1000VAC for 1 min. (between lead wire and case)
- Ambient temperature —— 10 to 60°C • Operation time —— 1ms or less
- Impact resistance —— 1000m/s² {102G}
- Enclosure —— IEC529 standard IP65 (JIS0920) splash proof
- For a lead wire length of 3m, "L" is added to the end of the part number. Example) D-F90NL

## Auto Switch Internal Circuits

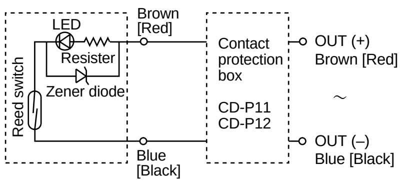
Lead wire colors inside [ ] are those prior to conformity with IEC standards.

### Reed switches

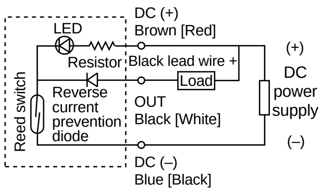
#### D-A90 (V)




#### D-A93 (V)

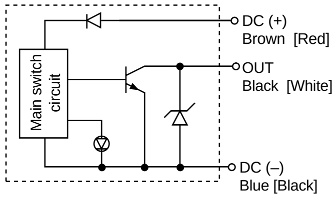



#### D-A96 (V)

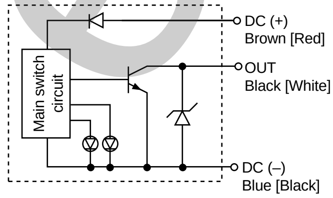



### Solid state switches

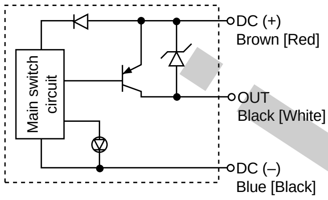
#### D-F9N (V)



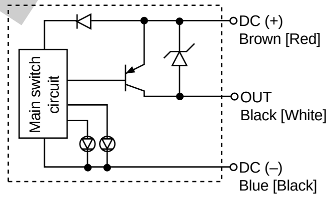

#### D-F9NW (V)



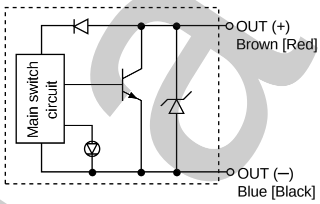

#### D-F9P (V)



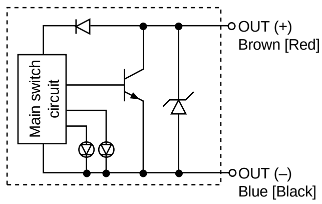

#### D-F9PW (V)



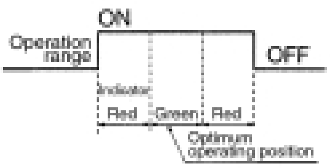

#### D-F9B (V)



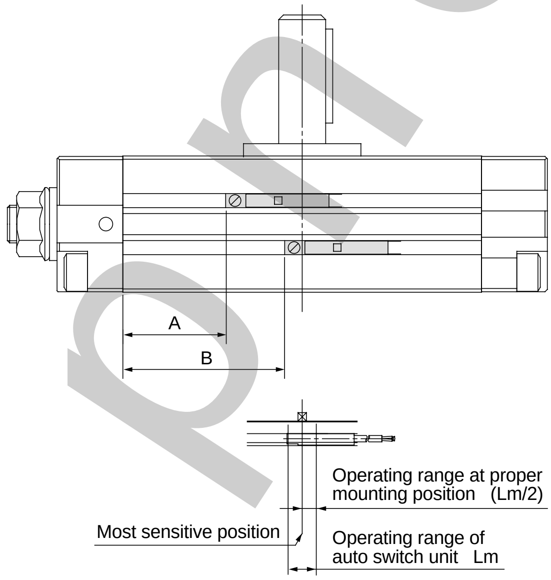

#### D-F9BW (V)




### Indicator light/Display method




## Proper Auto Switch Mounting Positions




| Size | Rotation angle | Reed switches | | | | Solid state switches | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | A | B | Operation range θm | Switch actuation range | A | B | Operation range θm | Switch actuation range |
| 10 | 90° | 6.5 | 13 | 63° | 12° | 10.5 | 17 | 75° | 3° |
| | 180° | 9.5 | 22.5 | | | 13.5 | 26.5 | | |
| 15 | 90° | 9.5 | 18 | 52° | 9° | 13.5 | 22 | 69° | 3° |
| | 180° | 13.5 | 30.5 | | | 17.5 | 34.5 | | |
| 20 | 90° | 22 | 34.5 | 41° | 9° | 26 | 38.5 | 56° | 4° |
| | 180° | 28 | 53.5 | | | 32 | 57.5 | | |
| 30 | 90° | 29 | 45 | 32° | 7° | 33 | 49 | 43° | 3° |
| | 180° | 37 | 68 | | | 41 | 72 | | |
| 40 | 90° | 34 | 53 | 24° | 5° | 38 | 57 | 36° | 4° |
| | 180° | 43.5 | 81.5 | | | 47.5 | 85.5 | | |

Operation range θm: The value of the auto switch operating range Lm converted to the shaft rotation angle

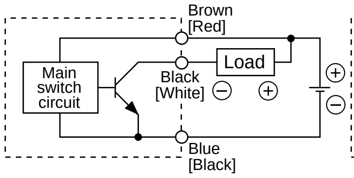
Switch actuation range: The value of the auto switch hysteresis converted to an angle

# Series CRQ2
# Auto Switch Connections and Examples

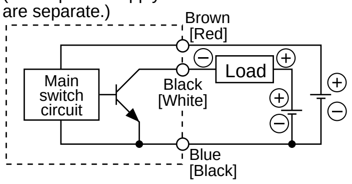


## Basic Wiring

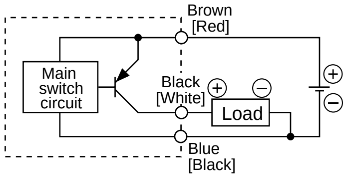
### Solid state 3 wire, NPN



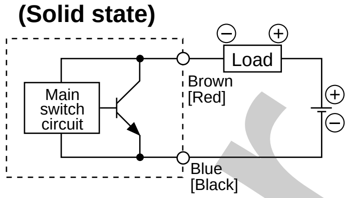

(When power supply for switch and load are separate.)

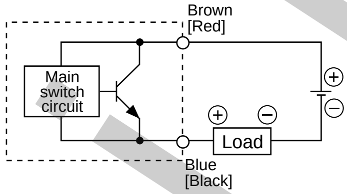



### Solid state 3 wire, PNP

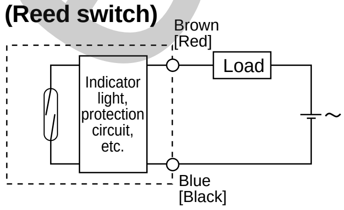


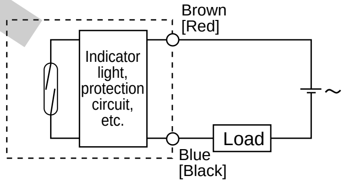

### 2 wire (Solid state)




### 2 wire (Reed switch)

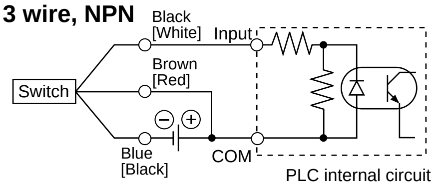


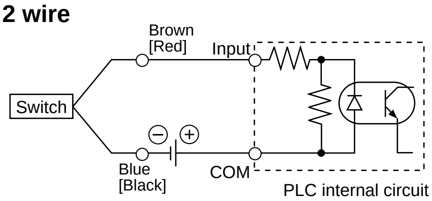

## Examples of Connection to PLC

### Sink input specifications

**3 wire, NPN**

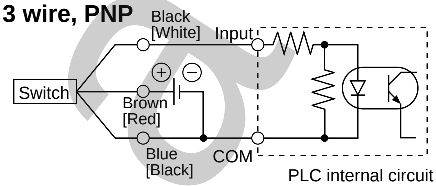



**2 wire**

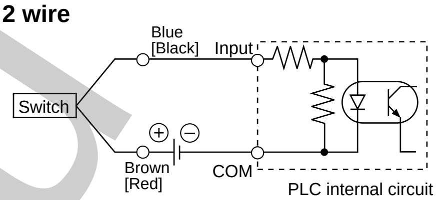



### Source input specifications

**3 wire, PNP**




**2 wire**

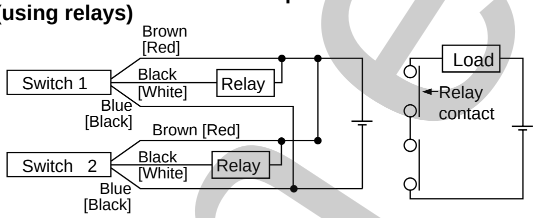



Connect according to the applicable PLC input specifications, as the connection method will vary depending on the PLC input specifications.

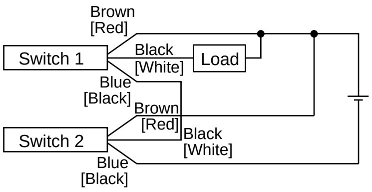
## Connection Examples for AND (Series) and OR (Parallel)

### 3 wire

**AND connection for NPN output (using relays)**

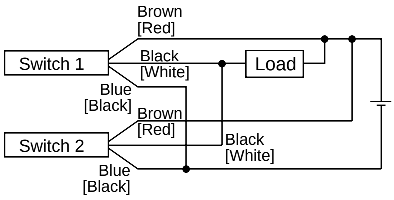



**AND connection for NPN output (performed with switches only)**

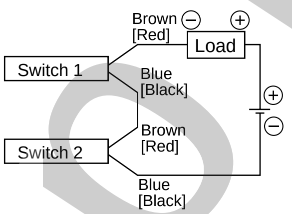



The indicator lights will light up when both switches are turned ON.

**OR connection for NPN output**




### 2 wire with 2 switch AND connection

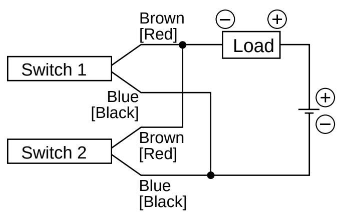



When two switches are connected in series, a load may malfunction because the load voltage will decline when in the ON state.
The indicator lights will light up if both of the switches are in the ON state.

Load voltage at ON = Power supply voltage – Residual voltage x 2 pcs.
= 24V – 4V x 2 pcs.
= 16V

Example: Power supply is 24VDC
Voltage decline in switch is 4V

### 2 wire with 2 switch OR connection




(Solid state)
When two switches are connected in parallel, malfunction may occur because the load voltage will increase when in the OFF state.

(Reed switch)
Because there is no current leakage, the load voltage will not increase when turned OFF. However, depending on the number of switches in the ON state, the indicator lights may sometimes get dark or not light up, because of dispersion and reduction of the current flowing to the switches.

Load voltage at OFF = Leakage current x 2 pcs. x Load impedance
= 1mA x 2 pcs. x 3kΩ
= 6V

Example: Load impedance is 3kΩ
Leakage current from switch is 1mA

# *Series CRQ2*
# Model Selection

## Series CRQ2 Technical Information

Refer to pages 14 through 18 for detailed technical information other than series CRQ2 model selection procedures.
[Data 1] Effective torque  [Data 2] Moment of Inertia  [Data 3] Air consumption

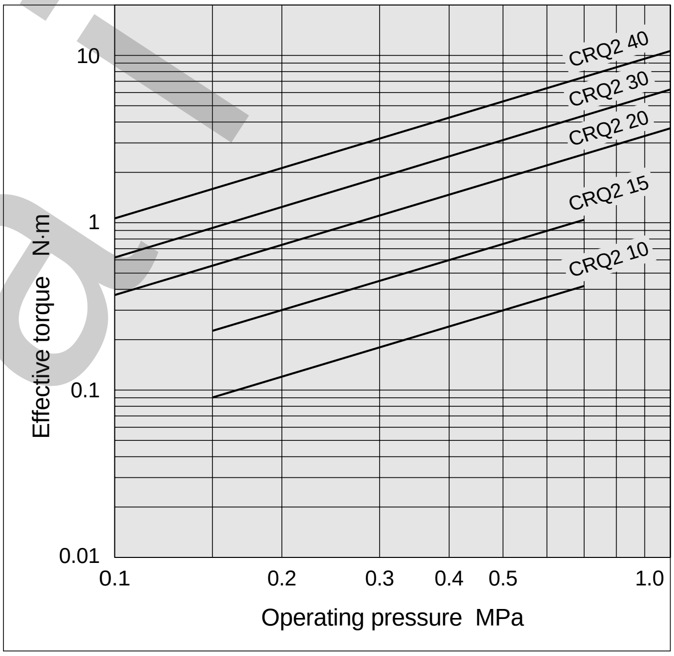
Step
## 1 Select the actuator torque.

1. Find the required turning torque for the intended objective.

| Work objective | Type of load | Required torque formula N·m*3 |
|---|---|---|
| Static operation | Static load | Ts |
| Dynamic*1 operation | Resistance load | (3 to 5 ) · Tf |
| | Inertial load*2 | S · Ta or more |

*1. In the case of dynamic operation, there may be a combination of resistance and inertial loads.
*2. Since it is also necessary to examine inertial load in selection step [2] in calculating the kinetic energy of the work piece, make the selections together.
*3. Refer to load types below for details regarding the terms Ts, Tf, S and Ta in the table.

2. Determine the operating pressure
3. Determine the proper size from the effective torque table.



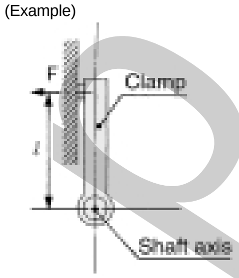

## Load Types

### ● Static load: Ts

The load represented by the clamp which requires pressing force only

(During the course of examination, if it is decided to consider the mass of the clamp itself in the drawing below, it should be regarded as an inertial load.)

(Example)

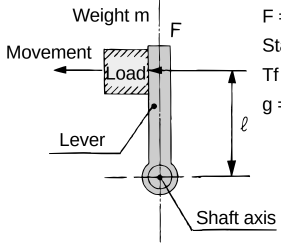



F: Pressing force (N)
Static torque calculation
Ts = F x *l* (N·m)

### ● Resistance load: Tf

The load that is affected by external forces such as friction or gravity
Since the object is to move the load, and speed adjustment is necessary, allow an extra margin of 3 to 5 times in the effective torque.
* Actuator effective torque ≥ (3 to 5) Tf
(During the course of examination, if it is decided to consider the mass of the lever itself in the drawing below, it should be regarded as an inertial load.)

(Example)

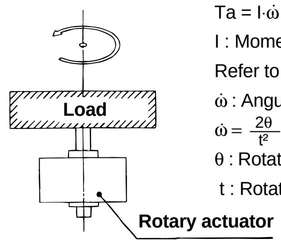



Friction coefficient μ
F = μmg
Static torque calculation
Tf = F x *l* (N·m)
g = 9.8m/s²

### ●Inertial load: Ta

The load which must be rotated by the actuator
Since the object is to rotate the load, and speed adjustment is necessary, allow an extra margin of 10 times or more in the effective torque.
*Actuator effective torque ≤ S·Ta
(S is 10 times or more)

**Accelerating torque calculation**



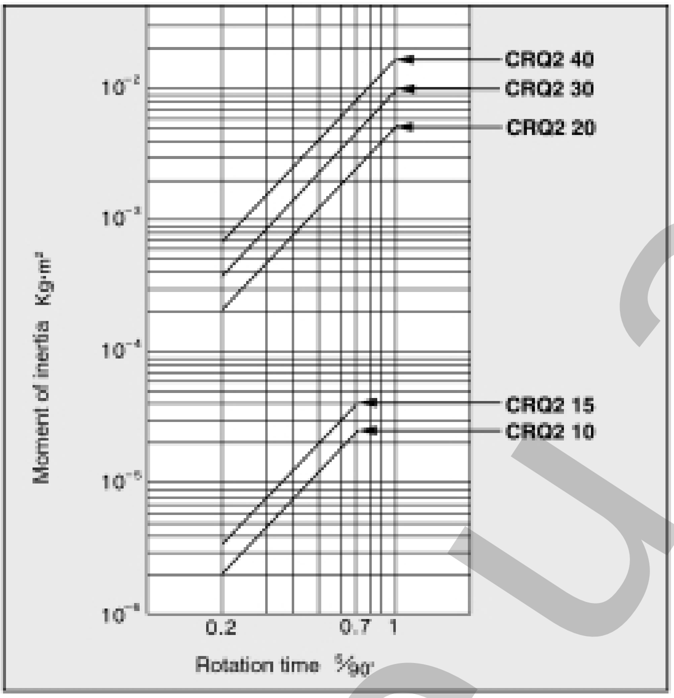

$Ta = I \cdot \dot{\omega}$ (N·m)
I : Moment of inertia
Refer to page 11.
$\dot{\omega}$ : Angular acceleration
$\dot{\omega} = \frac{2\theta}{t^2}$ (rad/s²)
θ : Rotation angle (rad)
t : Rotation time (S)

Step
## 2 Consider the impact at the end of the rotation.

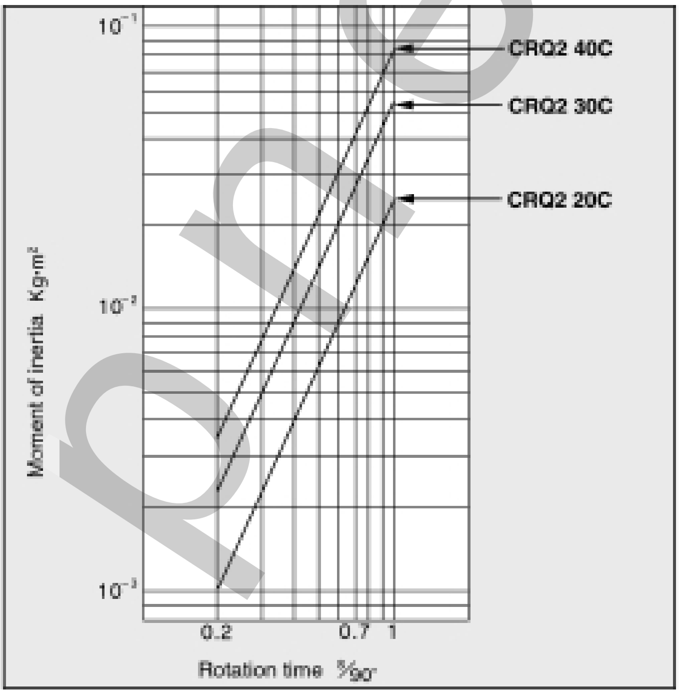
1. When an external stopper (shock absorber) is provided to absorb the impact, be sure to use one which has sufficient absorption capacity.
2. When relying on the actuator's internal cushion without using a stopper, the model selection graphs consider the absorption capacity of the actuator's internal cushion, making it possible to select a model from the rotation time within the speed adjustment range and the moment of inertia of the work piece.

1) Rubber bumper ... Kinetic energy is absorbed by placing an elastic body (rubber) at the end of the rotation.
2) Air cushion ............ The exhaust air is compressed shortly before the end of the rotation, and the load's kinetic energy is absorbed by its repulsive force.

**Without cushion**

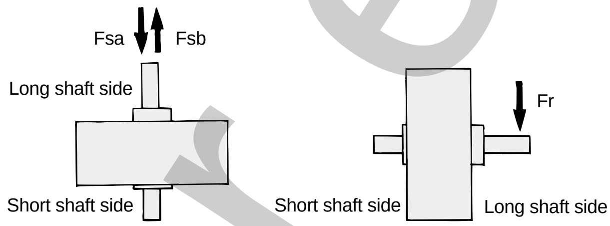



**With cushion**




Step
## 3 Consider the allowable shaft load.

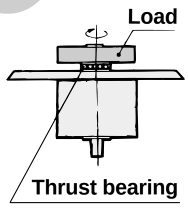
A load can be applied in the axial direction up to the values shown in the table below provided that a dynamic load is not generated. However, applications which apply a load directly to the shaft should be avoided whenever possible.

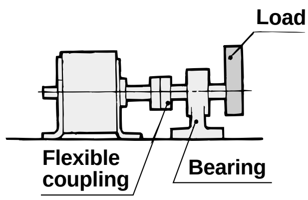



**Rack-and-pinion type (double rack)** Unit: N

| Size | Load direction | | |
|---|---|---|---|
| | Fsa | Fsb | Fr |
| **10** | 15.7 | 7.8 | 14.7 |
| **15** | 19.6 | 9.8 | 19.6 |
| **20** | 49 | 29.4 | 49 |
| **30** | 98 | 49 | 78 |
| **40** | 108 | 59 | 98 |

A load up to the allowable radial/thrust load can be applied provided that a dynamic load is not generated. However, applications which apply a load directly to the shaft should be avoided whenever possible. In order to further improve the operating conditions, a method such as that shown in the drawing below is recommended so that a direct load is not applied to the shaft.




Step
## 4 Find the air consumption of the actuator.

Find the air consumption necessary to calculate the running cost of the air supply. Refer to air consumption on page 18.

# Rotary Actuator Technical Data 1 and 2
# Effective Torque/Moment of Inertia

## Effective Torque

**Effective torque values are typical values and are not guaranteed.**
**Use them as guide values in actual applications.**

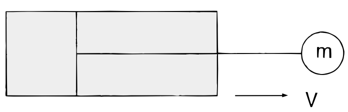
Unit: N·m

| Size | Operating pressure (MPa) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.10 | 0.15 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 | 0.80 | 0.90 | 1.00 |
| **10** | — | 0.09 | 0.12 | 0.18 | 0.24 | 0.30 | 0.36 | 0.42 | — | — | — |
| **15** | — | 0.22 | 0.30 | 0.45 | 0.60 | 0.75 | 0.90 | 1.04 | — | — | — |
| **20** | 0.37 | 0.55 | 0.73 | 1.10 | 1.47 | 1.84 | 2.20 | 2.57 | 2.93 | 3.29 | 3.66 |
| **30** | 0.62 | 0.94 | 1.25 | 1.87 | 2.49 | 3.11 | 3.74 | 4.37 | 4.99 | 5.60 | 6.24 |
| **40** | 1.06 | 1.59 | 2.11 | 3.18 | 4.24 | 5.30 | 6.36 | 7.43 | 8.48 | 9.54 | 10.6 |

## Moment of Inertia

When an object (load) is moved by the actuator, inertial force (kinetic energy) is created in the object. Conversely, in order to stop the moving object, it is necessary to absorb the object's kinetic energy with a stopper or shock absorber, etc. When the load moves in a straight line (air cylinder) or turns (rotary actuator), the kinetic energies can be calculated with the formulas shown in Figures 1 and 2 respectively.

**Air cylinder**

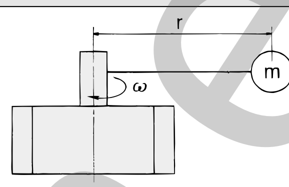



$$E = \frac{1}{2} \cdot m \cdot V^2 \quad \text{............ Formula (1)}$$

E : Kinetic energy
m : Load mass
V : Speed

**Figure 1. Linear motion**

**Rotary actuator**




$$E = \frac{1}{2} \cdot I \cdot \omega^2 = \frac{1}{2} \cdot m \cdot r^2 \cdot \omega^2 \quad \text{... Formula (2)}$$

E : Kinetic Energy
I : Moment of Inertia (=m·r²)
ω : Speed

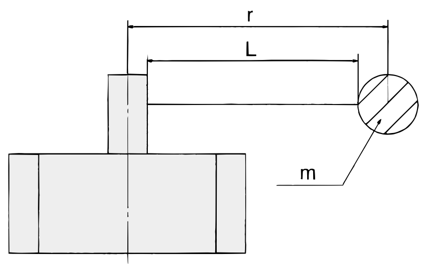
**Figure 2. Turning motion**

In the case of linear motion, if the speed "V" from Formula (1) is constant, the kinetic energy "E" is readily determined by the mass "m". However, in the case of turning motion it is clear from Formula (2) that the kinetic energy "E" varies in proportion to the square of the turning radius "r", even if the angular speed "ω" and mass "m" are constant. Thus, even if the mass is small, when "r" is large the resulting moment of inertia ($I = m \cdot r^2$) is large, and since the kinetic energy "E" also becomes large, this may lead to damage of the shaft, etc. When a load is moved in this way by a rotary actuator, it is particularly necessary to exercise caution regarding the moment of inertia ($= m \cdot r^2$) of the load.

### A Moment of Inertia

The moment of inertia indicates the difficulty of turning an object, or conversely, the difficulty of stopping an object which is turning. Since there is a limit to the kinetic energy allowed in a rotary actuator, the limit value of the rotation time can be found by finding the moment of inertia. How to find the moment of inertia is explained below.

**The basic formula for moment of inertia is shown below.**




$$I = m \cdot r^2 \qquad m : \text{Mass (kg)}$$

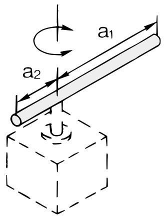
(However, the weight of the L section is ignored)

This indicates the moment of inertia with respect to the rotation axis of a mass "m" which is a distance "r" from the rotational axis. The formula for finding the moment of inertia differs depending on the shape of the object. A reference table of formulas for calculating the moment of inertia is shown on page 15.
Concrete examples of how to calculate the moment of inertia are shown on the following pages.

## B Moment of Inertia Formula Table (Calculation of Moment of Inertia) I: Moment of Inertia kg m$^2$ m: Load mass kg

### 1. Thin shaft

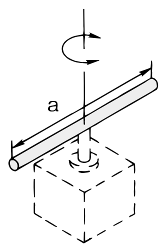
Position of rotational axis: Perpendicular to the shaft through one end




$$I = m_1 \cdot \frac{a_1^2}{3} + m_2 \cdot \frac{a_2^2}{3}$$

### 2. Thin shaft

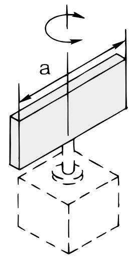
Position of rotational axis: Through the shaft's center of gravity




$$I = m \cdot \frac{a^2}{12}$$

### 3. Thin rectangular plate (rectangular parallelopiped)

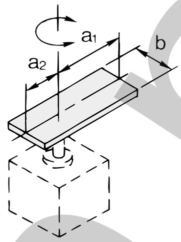
Position of rotational axis: Through the plate's center of gravity




$$I = m \cdot \frac{a^2}{12}$$

### 4. Thin rectangular plate (rectangular parallelopiped)

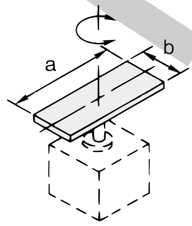
Position of rotational axis: Perpendicular to the shaft through one end (also the same in case of a thicker plate)




$$I = m_1 \cdot \frac{4a_1^2 + b^2}{12} + m_2 \cdot \frac{4a_2^2 + b^2}{12}$$

### 5. Thin rectangular plate (rectangular parallelopiped)

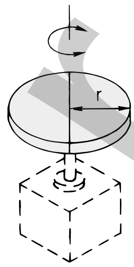
Position of rotational axis: Through the center of gravity and perpendicular to the plate (also the same in case of a thicker plate)




$$I = m \cdot \frac{a^2 + b^2}{12}$$

### 6. Column (including thin round plate)

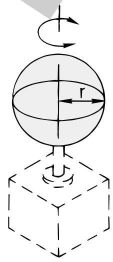
Position of rotational axis: Central axis




$$I = m \cdot \frac{r^2}{2}$$

### 7. Solid sphere

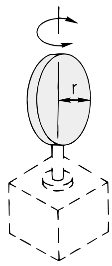
Position of rotational axis: Diameter




$$I = m \cdot \frac{2r^2}{5}$$

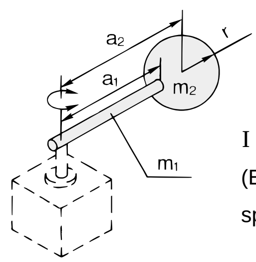
### 8. Thin round plate

Position of rotational axis: Diameter




$$I = m \cdot \frac{r^2}{4}$$

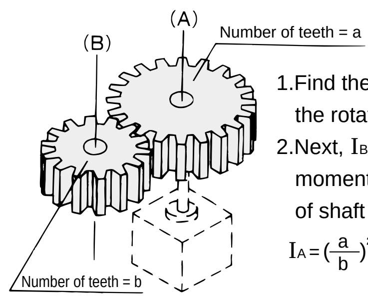
### 9. Load at end of lever




$$I = m_1 \cdot \frac{a_1^2}{3} + m_2 \cdot a_2^2 + K$$

(Example) When shape of $m_2$ is a sphere refer to 7 and $K = m_2 \cdot \frac{2r^2}{5}$

### 10. Gear transmission

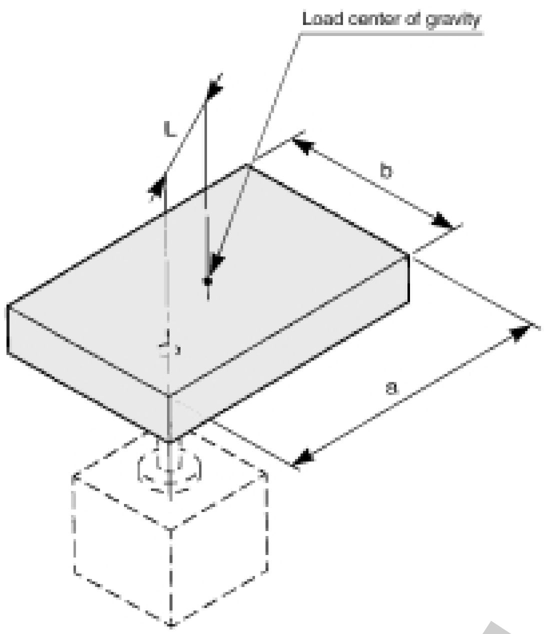



1. Find the moment of inertia $I_B$ for the rotation of shaft (B).
2. Next, $I_B$ is entered to find $I_A$ the moment of inertia for the rotation of shaft (A) as

$$I_A = \left(\frac{a}{b}\right)^2 \cdot I_B$$

## C Moment of Inertia Calculation Examples

### 1 Rotational Axis at Random Point in Load




Example) When load is a rectangular shape as in technical data 5
Find $I_1$ with the load center of gravity at the tentative rotational axis.

$$I_1 = m \cdot \frac{a^2 + b^2}{12} \qquad kg \cdot m^2$$

Find the moment of inertia $I_2$ for rotation around the actual rotational axis with the mass of the load concentrated at the load's center of gravity.

$$I_2 = m \cdot L^2 \qquad kg \cdot m^2$$

Find the actual moment of inertia I.

$$I \quad I_1 + I_2 \qquad kg \cdot m^2$$

(m: Load mass kg
L: Distance from the rotational axis to the load center of gravity m)

Calculation example

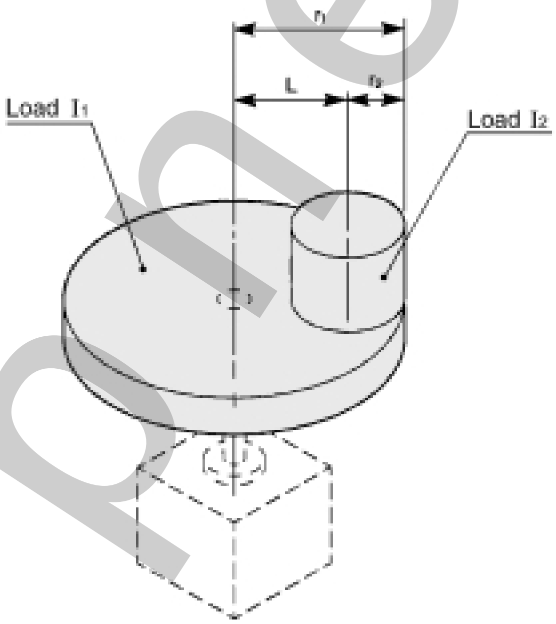
When a = 0.2m, b = 0.1m, L = 0.05m, m = 1.5kg

$I_1 = 1.5 \times \frac{0.2^2 + 0.1^2}{12} = 6.25 \times 10^{-3}$ kg·m²

$I_2 = 1.5 \times 0.05^2 = 3.75 \times 10^{-3}$ kg·m²

$I = (6.25 + 3.75) \times 10^{-3} = 0.01$ kg·m²

### 2 Load Divided into Multiple Parts




Example) When load is divided into two columns such as shown in technical data 6
{The center of gravity of load $I_1$ coincides with the rotational axis
The center of gravity of load $I_2$ is different than the rotational axis}
Find the inertial moment of load $I_1$

$$I_1 = m_1 \cdot \frac{r_1^2}{2} \qquad kg \cdot m^2$$

Find the moment of inertia of load $I_2$.

$$I_2 = m_2 \cdot \frac{r_1^2}{2} + m_2 \cdot L^2 \qquad kg \cdot m^2$$

Find the actual moment of inertia I.

$$I = I_1 + I_2 \qquad kg \cdot m^2$$

($m_1$, $m_2$: Mass of loads $I_1$ and $I_2$ kg
$r_1$, $r_2$: Diameters of loads $I_1$ and $I_2$ m
L: Distance from the rotational axis to load $I_2$ center of gravity m)

Calculation example

When $m_1$ 2.5kg, $m_2$ = 0.5kg, $r_1$ = 0.1m, $r_2$ = 0.02m, L = 0.08m

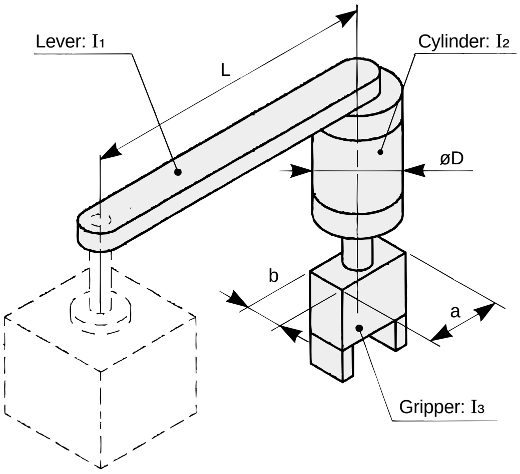
$I_1 = 2.5 \times \frac{0.1^2}{2} = 1.25 \times 10^{-2}$ kg·m²

$I_2 = 0.5 \times \frac{0.02^2}{2} + 0.5 \times 0.08^2 = 0.33 \times 10^{-2}$ kg·m²

$I = (1.25 + 0.33) \times 10^{-2} = 1.58 \times 10^{-2}$ kg·m²

## Specific Application Example

### 3 Lever attached to shaft with cylinder and gripper mounted at end of lever




Example) Find the lever's moment of inertia.

$I_1 \; m1 \cdot \frac{L_2}{3}$ kg·m²

Find the cylinder's moment of inertia.

$I_2 \; m_2 \cdot \frac{D^2}{8} + m_2 \cdot L^2$ kg·m²

Find the gripper's moment of inertia.

$I_3 = m_3 \cdot \frac{a^2+b^2}{12} + m_3 \cdot L^2$ kg·m²

Find the actual moment of inertia.

$I = I_1 + I_2 + I_3$ kg·m²

($m_1$: Lever mass kg
$m_2$: Cylinder mass kg
$m_2$: Gripper mass kg)

Calculation example

When L = 0.2m, øD = 0.06m, a = 0.06m, b = 0.03m, $m_1$ = 0.5kg, $m_2$ = 0.4kg, $m_3$ = 0.2kg

$I_1 = 0.5 \times \frac{0.2^2}{3} = 0.67 \times 10^{-2}$ kg·m²

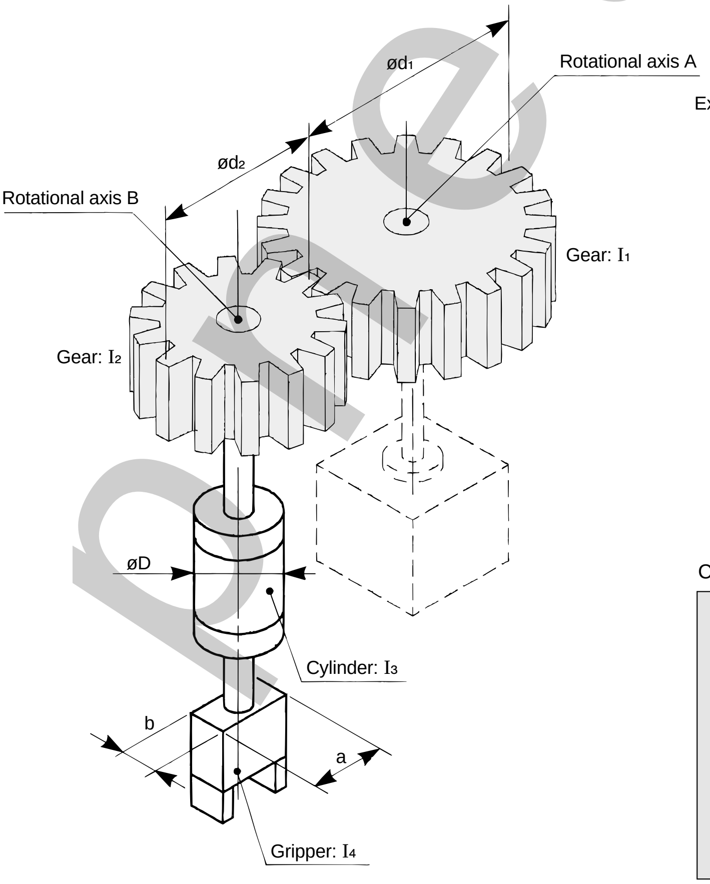
$I_2 = 0.4 \times \frac{0.06^2}{8} + 0.4 \times 0.2^2 = 1.62 \times 10^{-2}$ kg·m²

$I_3 = 0.2 \times \frac{0.06^2 + 0.03^2}{12} + 0.2 \times 0.2^{-2} = 0.81 \times 10^{-2}$ kg·m²

$I = (0.67 + 1.62 + 0.81) \times 10^{-2} = 3.1 \times 10^{-2}$ kg·m²

## Specific Application Example

### 4 Load is rotated via gears




Example) Find the moment of inertial $I_1$ for rotation around shaft A.

$I_1 \; m_1 \cdot \frac{d_1^2}{8}$ kg·m²

Find the moments of inertial $I_2$, $I_3$, $I_4$ for rotation around shaft B.

$I_2 \; m_2 \cdot \frac{d_2^2}{8}$ kg·m² $\quad I_3 = m_3 \cdot \frac{D^2}{8}$ kg·m²

$I_4 = m_4 \cdot \frac{a^2 + b^2}{12}$ kg·m² $\quad I_B = I_2 + I_3 + I_4$ kg·m²

Substitute the moment of inertia $I_B$ for rotation around shaft B with the moment of inertia $I_A$ for rotation around shaft A.

$I_A = (A/B)^2 \cdot I_B$ [A/B: Gear tooth ratio]

Find the actual moment of inertia.

$I = I_1 + I_A$ kg·m²

($m_1$ to $m_4$ : Mass of $I_1$ to $I_4$ kg)

Calculation example

When d1 = 0.1m, $d_2$ = 0.05m, D = 0.04m, a = 0.04m, b = 0.02m
$m_1$ = 1kg, $m_2$ = 0.4kg, $m_3$ = 0.5kg, $m_4$ = 0.2kg, Gear tooth ratio = 2

$I_1 = 1 \times \frac{0.1^2}{8} = 1.25 \times 10^{-3}$ kg·m²

$I_2 = 0.4 \times \frac{0.05^2}{8} = 0.13 \times 10^{-3}$ kg·m²

$I_3 = 0.5 \times \frac{0.04^2}{8} = 0.1 \times 10^{-3}$ kg·m²

$I_4 = 0.2 \times \frac{0.04^2+0.02^2}{12} = 0.03 \times 10^{-3}$ kg·m²

$I_B = (0.13 + 0.1 + 0.03) \times 10^{-3} = 0.26 \times 10^{-3}$ kg·m²

$I_A = 2^2 \times 0.26 \times 10^{-3} = 1.04 \times 10^{-3}$ kg·m²

$I = (1.04 + 1.25) \times 10^{-3} = 2.29 \times 10^{-3}$ kg·m²

# Rotary Actuator Technical Data 3
# Air Consumption

Air consumption is the volume of air which is expended by the rotary actuator's reciprocal operation inside the actuator and in the piping between the actuator and the switching valve, etc. This is necessary for selection of a compressor and for calculation of its running cost.

∗ The air consumption ($Q_{CR}$) required for one reciprocation of the rotary actuator alone is shown in the table below, and can be used to simplify the calculation.

Formulas

$Q_{CR}$: Since the internal volume is different when the A/B ports are pressurized in vane type sizes 10, 15, 20 and 30, use formula (1). Use formula (2) for vane type sizes 50, 80, 100 and the rack-and-pinion type.

$$Q_{CR} = V \times \left(\frac{P + 0.1013}{0.1013}\right) \times 10^{-3} \quad \text{.......... Formula (1)}$$

$$Q_{CR} = 2V \times \left(\frac{P + 0.1013}{0.1013}\right) \times 10^{-3} \quad \text{.......... Formula (2)}$$

$$Q_{CP} = 2 \times a \times l \times \frac{P}{0.1013} \times 10^{-6} \quad \text{.......... (3)}$$

$$Q_C = Q_{CR} + Q_{CP} \quad \text{.......... (4)}$$

| | | |
|---|---|---|
| $Q_{CR}$ | = Air consumption of rotary actuator | [$l$ (ANR)] |
| $Q_{CP}$ | = Air consumption of tubing or piping | [$l$ (ANR)] |
| V | = Internal volume of rotary actuator | [cm³] |
| P | = Operating pressure | [MPa] |
| $l$ | = Length of piping | [mm] |
| a | = Internal cross section of piping | [mm²] |
| $Q_C$ | = Air consumption required for one reciprocation of rotary actuator | [$l$ (ANR)] |

When selecting a compressor, it is necessary to choose one which has sufficient reserve for the total air consumption of pneumatic actuators downstream. This is affected by factors such as leakage in piping, consumption by drain valves and pilot valves, etc., and reduction of air volume due to drops in temperature.

Formula

$$Q_{C2} = Q_C \times n \times \text{Number of actuators} \times \text{Reserve factor}$$

$Q_{C2}$ = Compressor discharge flow rate

n = Actuator reciprocations per minute

### Internal cross section of tubing and steel piping

| Nominal size | O.D. (mm) | I.D. (mm) | Internal cross section a (mm²) |
|---|---|---|---|
| **T□ 0425** | 4 | 2.5 | 4.9 |
| **T□ 0604** | 6 | 4 | 12.6 |
| **TU 0805** | 8 | 5 | 19.6 |
| **T□ 0806** | 8 | 6 | 28.3 |
| **1/8B** | — | 6.5 | 33.2 |
| **T□ 1075** | 10 | 7.5 | 44.2 |
| **TU 1208** | 12 | 8 | 50.3 |
| **T□ 1209** | 12 | 9 | 63.6 |
| **1/4B** | — | 9.2 | 66.5 |
| **TS 1612** | 16 | 12 | 113 |
| **3/8B** | — | 12.7 | 127 |
| **T□ 1613** | 16 | 13 | 133 |
| **1/2B** | — | 16.1 | 204 |
| **3/4B** | — | 21.6 | 366 |
| **1B** | — | 27.6 | 598 |

### Rack-and-pinion type: Series CRQ2

Air consumption of rotary actuator: $Q_{CR}$ $l$ (ANR)

| Size | Rotation angle (°) | Internal volume V (cm³) | Operating pressure (MPa) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0.1 | 0.15 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
| **10** | 90 | 1.2 | — | 0.0060 | 0.0071 | 0.0095 | 0.0119 | 0.0142 | 0.0166 | 0.0190 | — | — | — |
| | 180 | 2.2 | — | 0.0109 | 0.0131 | 0.0174 | 0.0218 | 0.0261 | 0.0305 | 0.0348 | — | — | — |
| **15** | 90 | 2.9 | — | 0.0144 | 0.0173 | 0.0230 | 0.0287 | 0.0344 | 0.0402 | 0.0459 | — | — | — |
| | 180 | 5.5 | — | 0.0273 | 0.0327 | 0.0436 | 0.0544 | 0.0653 | 0.0762 | 0.0870 | — | — | — |
| **20** | 90 | 7.8 | 0.0310 | 0.0387 | 0.0464 | 0.0618 | 0.0772 | 0.0926 | 0.108 | 0.123 | 0.139 | 0.154 | 0.170 |
| | 180 | 13.4 | 0.0533 | 0.0665 | 0.0797 | 0.106 | 0.133 | 0.159 | 0.186 | 0.212 | 0.233 | 0.265 | 0.291 |
| **30** | 90 | 11.8 | 0.0469 | 0.0585 | 0.0702 | 0.0935 | 0.117 | 0.140 | 0.163 | 0.187 | 0.210 | 0.233 | 0.257 |
| | 180 | 22.7 | 0.0902 | 0.113 | 0.135 | 0.180 | 0.225 | 0.269 | 0.314 | 0.359 | 0.404 | 0.449 | 0.494 |
| **40** | 90 | 20 | 0.0795 | 0.099 | 0.119 | 0.158 | 0.198 | 0.237 | 0.277 | 0.316 | 0.356 | 0.395 | 0.435 |
| | 180 | 38.5 | 0.153 | 0.191 | 0.229 | 0.305 | 0.381 | 0.457 | 0.533 | 0.609 | 0.685 | 0.761 | 0.837 |