Relays
Technical Information

Glossary

Contacts

Contact Form

The contact mechanism of the Relay.

Number of Contact Poles

The number of contact circuits.

Rated Load

The rated load of the contact of the Relay, which determines the characteristic performance of the contact of the Relay, is expressed by the switching voltage and switching current.

Maximum Switching Voltage

The switching voltage of the Relay determines the characteristic performance of the contact of the Relay. Do not apply voltage that exceeds the maximum switching voltage of the Relay.

Carry Current

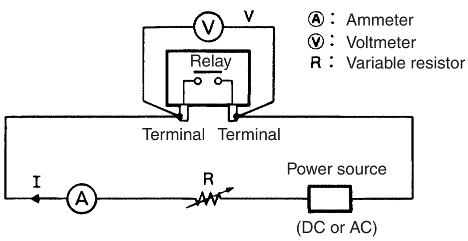
The value of the current which can be continuously applied to the Relay contacts without opening or closing them, which also allows the Relay to stay within the permissible temperature rise limit.

Maximum Switching (Contact) Current

A current which serves as a reference in determining the performance of the Relay contacts. This value will never exceed the carry current. When using a Relay, plan not to exceed this value.

Contact Resistance

The total resistance of the conductor, which includes specific resistivities, such as of the armature and terminal, and the resistance of the contacts. This value is determined by measuring the voltage drop across the contacts by the allowed test current shown in the table below.

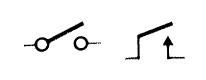
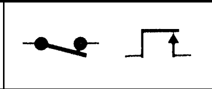
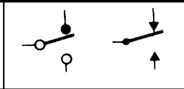
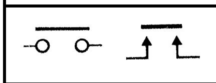
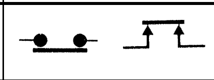
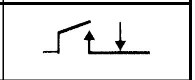
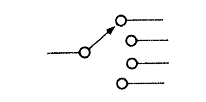
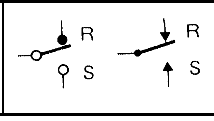
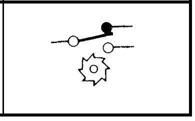


Test Current

Rated current or switched current (A)	Test current (mA)
0.01 or higher but less than 0.1	10
0.1 or higher but less than 1	100
1 or higher	1,000

To measure the contact resistance, a milliohmmeter can be also used, though the accuracy drops slightly.

Contact Symbol

NO contact	NC contact	SPDT contact
		
Double-break NO contact	**Double-break NO contact**	**Make-before-break contact**
		
Wiper contact	**Latching Relay contact**	**Ratchet Relay contact**
		

Make-before-break Contact

A contact arrangement in which part of the switching section is shared between both an NO and an NC contact. When the Relay operates or releases, the contact that closes the circuit operates before the contact that opens the circuit releases. Thus both the contacts are closed momentarily at the same time.

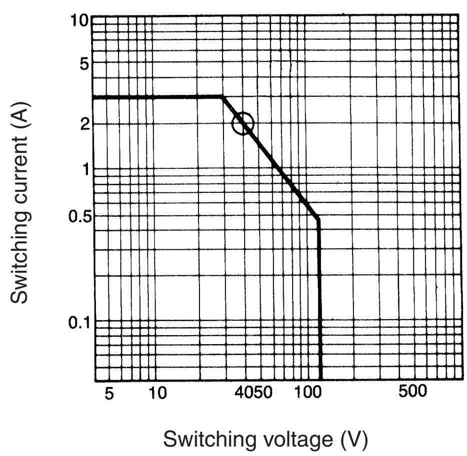
Maximum Switching Power

The maximum capacity value of the load which can be switched without causing problems of material break-down and/or electrical overload. When using a Relay, be careful not to exceed this value. For example, when switching voltage V_1 is known, max. switching current I_1 can be obtained at the point of intersection on the characteristic curve "Maximum switching power" below. Conversely, max. switching voltage V_1 can be operated if I_1 is known.

Max. switching current (I_1) =

$$\frac{\text{Maximum switching power [W(VA)]}}{\text{Switching voltage } (V_1)}$$

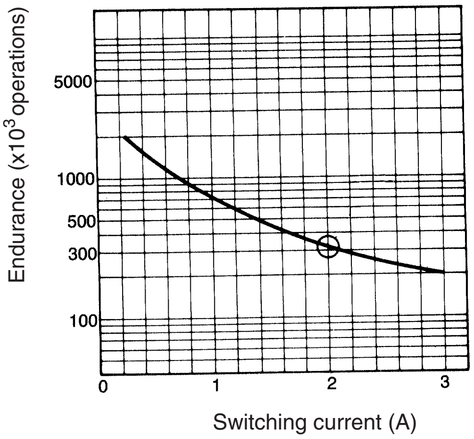
For instance, if the switching voltage = 40 V, the max. switching current = 2 A (see circled point on graph).



Electrical Endurance

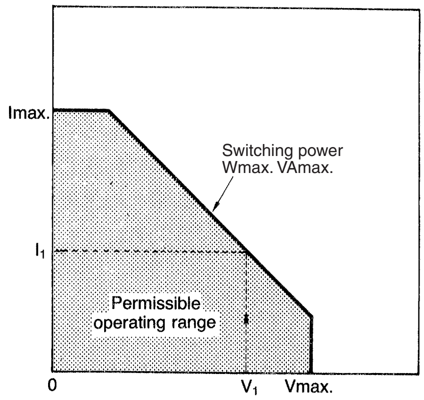
The electrical endurance of the Relay can be determined from the "Electrical life" curve shown below, based on the rated switching current (I_1) obtained above.

For instance, the electrical endurance for the max. switching current of 2 A is slightly over 300,000 operations (see circled point on graph below).



However, with a DC load, it may become difficult to break a circuit of 48 V or more, due to arcing. Determine suitability of the Relay in actual usage testing. Correlation between the contact ratings is as shown below.

Maximum Switching Power



Failure Rate

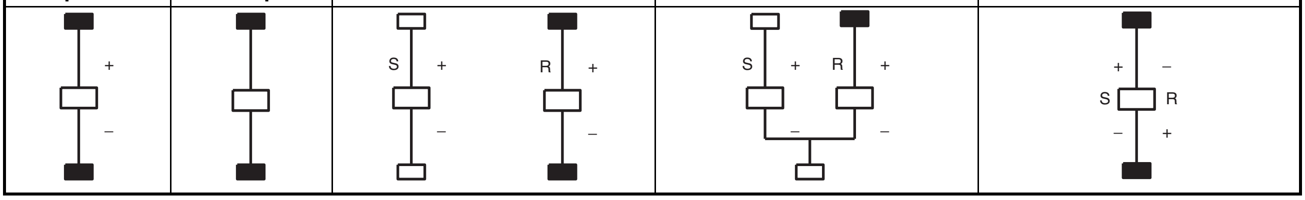
The failure rate indicates the lower limit of the switching power of a Relay. Such minute load levels are found in microelectronic circuits. This value may vary, depending on operating frequency, operating conditions, expected reliability level of the Relay, etc. It is always recommended to double-check Relay suitability under actual load conditions.

In this catalog, the failure rate of each Relay is indicated as a reference value. It indicates error level at a reliability level of 60% (γ_{60}).

$\gamma_{60} = 0.1 \times 10^{-6}$/operation means that one error is presumed to occur per 10,000,000 operations at the reliability level of 60%.

Coil

Single-stable		Double-winding		Single-winding latching
With pole	Without pole	4 terminals	3 terminals	



Coil Current (Applicable to AC-switching Type Only)

A current which flows through the coil when the rated voltage is applied to the coil at a temperature of 23°C. The tolerance is +15%, -20% unless otherwise specified.

Coil Voltage

A reference voltage applied to the coil when the Relay is used under the normal operation conditions. The following table lists the 100/110 VAC voltages.

Applicable power source	Inscription on Relay	Denomination in catalog
100 V 50 Hz	100 VAC 60 Hz	100 VAC 60 Hz
100 VAC 50 Hz 100 VAC 60 Hz	100 VAC	100 VAC
100 VAC 50 Hz 100 VAC 60 Hz 110 VAC 60 Hz	100/110 VAC 60 Hz 100 VAC 50 Hz	100/(110) VAC
100 VAC 50 Hz 100 VAC 60 Hz 110 VAC 50 Hz 110 VAC 60 Hz	100/110 VAC	100/110 VAC

Power Consumption

The power (=rated voltage x rated current) consumed by the coil when the rated voltage is applied to it. A frequency of 60 Hz is assumed if the Relay is intended for AC operation.
The current flows through the coil when the rated voltage is applied to the coil at a temperature of 23°C and with a tolerance of +15% and -20% unless otherwise specified.

Coil Resistance (Applicable to DC-switching Type Only)

The resistance of the coil measured at a temperature of 23°C with a tolerance of ±10% unless otherwise specified. (The coil resistance of an AC-switching Relay may be given for reference when the coil inductance is specified.)

Must-release (Must-reset) Voltage

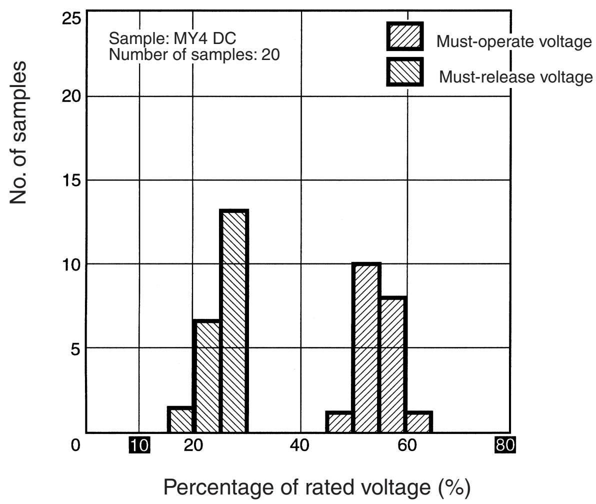
The threshold value of a voltage at which a Relay releases when the rated input voltage applied to the Relay coil in the operating state is decreased gradually.

Must-operate (Must-set) Voltage

The threshold value of a voltage at which a Relay operates when the input voltage applied to the Relay coil in the reset state is increased gradually.

Example: MY4 DC Models

The distributions of the must-operate voltage and the must-release voltage are shown in the following graph.
As shown in the graph, the Relay operates at voltages less than 80% of the rated voltage and releases at voltages greater than 10% of the rated voltage. Therefore, in this catalog, the must-operate and must-release voltages are taken to be 80% max. and 10% min. respectively of the rated voltage.



Hot Start

The ratings set forth in the catalog or data sheet are measured at a coil temperature of 23°C unless otherwise specified. However, some catalogs have the description “Hot start 85% (at Ta = 40°C)”. This means that the must-operate voltage when the Relay is operated after the rated current is consecutively applied to the coil at an ambient temperature of 40°C satisfies a maximum of 85% of the rated must-operate voltage.

Maximum Switching Voltage

The maximum value (or peak value, not continuous value) of permissible voltage fluctuations in the operating power supply of the Relay coil.

Minimum Pulse Width

The minimum width of the pulsating voltage required to set and reset a Latching Relay at a temperature of 23°C.

Coil Inductance

With DC Relays, the coil inductance is obtained by adding the square waveform to a time constant. With AC Relays, it is the value at the rated frequency. In both cases, the values will be different depending on whether the Relay is in the set or the reset condition.

Electrical Characteristics

Mechanical Endurance

The life of a Relay when it is switched at the rated operating frequency, but without the rated load.

Electrical Endurance

The life of a Relay when it is switched at the rated operating frequency, with the rated load applied to its constants.

Bounce

Bouncing is the intermittent opening and closing between contacts caused by vibration or shock resulting from collision between the Relay’s moving parts (poles and terminals) and the iron core and backstop, and collision between contacts.

Operate Bounce Time

The bounce time of the normally open (NO) contact of a Relay when the rated coil voltage is applied to the Relay coil, at an ambient temperature of 23°C.

Operate Time

The time that elapses after power is applied to a Relay coil until the NO contacts have closed, at an ambient temperature of 23°C. Bounce time is not included. For the Relays having an operate time of less than 10 ms, the mean (reference) value of its operate time is specified as follows:

Operate time	5 ms max. (mean value: approx. 2.3 ms)

Release Bounce Time

The bounce time of the normally closed (NC) contact of a Relay when the coil is deenergized at an ambient temperature of 23°C.

Release Time

The time that elapses between the moment a Relay coil is deenergized until the NC contacts have closed, at an ambient temperature of 23°C. (With a Relay having SPST-NO or DPST-NO contacts, this is the time that elapses until the NO contacts have operated under the same condition.) Bounce time is not included. For Relays having a release time of less than 10 ms, the mean (reference) value of its release time is specified as follows:

Release time	5 ms max. (mean value: approx. 2.3 ms)

Reset Time (Applicable to Latching Relays Only)

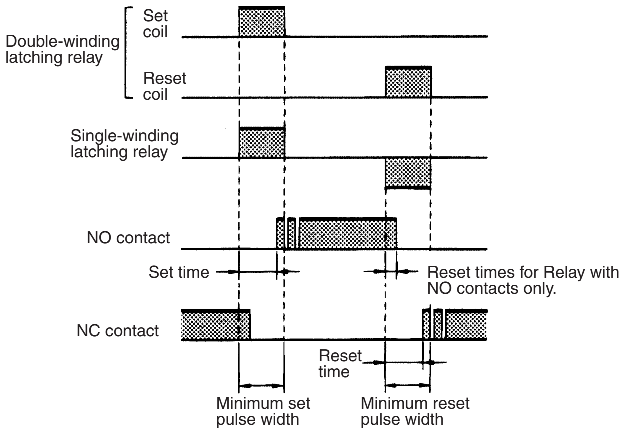
The time that elapses from the moment a Relay coil is deenergized until the NC contacts have closed, at an ambient temperature of 23°C. (With a Relay having SPST-NO or DPST-NO contacts, this is the time that elapses until the NO contacts have operated under the same condition.) Bounce time is not included. For Relays having an operate time of less than 10 ms, the mean (reference) value of its operate time is specified as follows:

Reset time	5 ms max. (mean value: approx. 2.3 ms)

Set Time (Applicable to Latching Relays Only)

The time that elapses after power is applied to a Relay coil until the NO contacts have closed, at an ambient temperature or 23°C. Bounce time is not included. For the Relays having an operate time of less than 10 ms, the mean (reference) value of its operate time is specified as follows:

Set time	5 ms max. (mean value: approx. 2.3 ms)



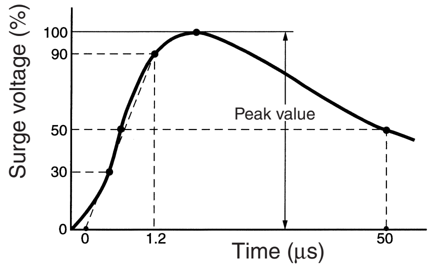
Dielectric Strength

The critical value which a dielectric can withstand without rupturing, when a high-tension voltage is applied for 1 minute between the following points:
Between coil and contact
Between contacts of different polarity
Between contacts of same polarity
Between set coil and reset coil
Between current-carrying metal parts and ground terminal

Note that normally a leakage current of 3 mA is detected; however, a leakage current of 1 mA or 10 mA may be detected on occasion.

Impulse Withstand Voltage

The critical value which the Relay can withstand when the voltage surges momentarily due to lightning, switching an inductive load, etc. The surge waveform which has a pulse width of +1.2 x 50 µs is shown below:



Insulation Resistance

The resistance between an electric circuit (such as the contacts and coil), and grounded, non-conductive metal parts (such as the core), or the resistance between the contacts. The measured values are as follows:

Rated insulation voltage	Measured value
60 V max.	250 V
61 V min.	500 V

Switching Frequency

The frequency or intervals at which the Relay continuously operates and releases, satisfying the rated mechanical and electrical service lives.

Shock Resistance

The shock resistance of a Relay is divided into two categories: Destruction, which quantifies the characteristic change of, or damage to, the Relay due to considerably large shocks which may develop during the transportation or mounting of the Relay, and malfunction durability, which quantifies the malfunction of the Relay while it is in operation.

Stray Capacitance

The capacitance measured between terminals at an ambient temperature of 23°C and a frequency of 1 kHz.

Vibration Resistance

The vibration resistance of a Relay is divided into two categories: Destruction, which quantifies the characteristic changes of, or damage to, the Relay due to considerably large vibrations which may develop during the transportation or mounting of the Relay, and Malfunction durability, which quantifies the malfunction of the Relay due to vibrations while it is in operation.

$\alpha = 0.002f^2A$

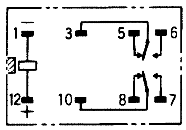
α: Acceleration of vibration
f: Frequency
A: Double amplitude

Operating

Single Stable Relays (Standard Type)

These are Relays in which the contacts switch in response to the energization and deenergization of the coil and do not have any special functions.

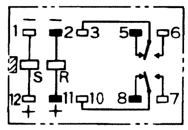
Terminal Arrangement/Internal Connections (Bottom view)



Double-winding Latching Relays

These are Relays that have a set coil and a reset coil, and have a latching mechanism enabling the set or reset condition to be locked.

Terminal Arrangement/Internal Connections (Bottom view)

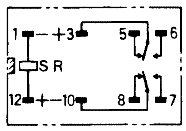


S: set coil
R: reset coil

Single-winding Latching Relays

These are Relays that have one coil, and switch between the set and reset condition according to the polarity of the applied voltage, and have a latching mechanism enabling this status to be locked.

Terminal Arrangement/Internal Connections (Bottom view)



S: set coil
R: reset coil

Stepping Relays

These are Relays in which the contacts shift ON or OFF sequentially with each coil input pulse.

Ratchet Relays

These are Relays in which the contacts alternately turn ON and OFF, or sequentially operate, when a pulse signal is input.

Precautions

General handling

- To maintain initial performance, be careful not to drop the Relay or subject it to shock.
- The case is so constructed that it will not come off with normal handling. To maintain initial performance, do not allow the case to come off.
- Use the Relay in a dry atmosphere containing little dust, SO_2, H_2S, and organic gases.
- Ensure that the voltage applied to the coil is not applied continuously in excess of the maximum permissible voltage.
- With DC-operated Relays that have a built-in diode or a built-in operation indication lamp, do not reverse the polarity connections when the polarity of the coil is specified.
- Do not use the Relay at a voltage or current greater than the specified values.
- Ensure that the ambient operating temperature does not exceed the specified value.
- With General-purpose Relays, leaving or using the Relay for a long time in an atmosphere of hydrogen sulfide gas or high temperature and high humidity will lead to the formation of a sulfide film or an oxidation film on the surface of the contact. In Miniature Relays, the contact force is weak and so the film cannot be destroyed mechanically. Also, with the very small loads, destruction of the film is not possible by arcing and so there will be contact instability and the occurrence of problems in performance and function. For these reasons, Fully Sealed Relays or Hermetically Sealed Relays should be used in atmospheres of harmful gases (such as H_2S, SO_2, NH_3, and Cl_2), humidity, and dust.
- The contact ratings of Relays approved by standards and the general ratings of the Relays could be different.
  When combining Relays with various types of Sockets, check the contact ratings of the Relays before use.

Operating Coils
AC-operated Relays

The power supply used to operate AC-operated Relays is almost always at the commercial frequency (50 or 60 Hz). Standard voltages are 6, 12, 24, 48, 100, and 200 VAC. Because of this, when the voltage is other than a standard voltage, the Relay will be a special-order item and so inconvenience may arise with respect to price, delivery period, and stability of performance. Consequently, a Standard-voltage Relay should be selected if at all possible.
In AC-operated Relays, there is a resistance loss of the shading coil, an overcurrent loss of the magnetic circuit, a hysteresis loss, as well as other losses. The coil input also increases and so in general it is normal for the temperature rise to be higher than in a DC-operated Relay. Also, at voltages less than the must-operate voltage (i.e., the minimum operation voltage), a vibration is produced which necessitates that attention be paid to the fluctuation of the power supply voltage.
For example, when the power supply voltage drops at the time of motor stating, the Relay will be reset while vibrating and the contacts will burn, fuse, or the self holding will go out of place. In AC-operated Relays, there is an inrush current. (When the armature is in a separated condition, the impedance is low and a current flows that is larger than the rated current; when the armature is in the closed condition, the impedance increases and a current flows which is of the rated value.) When a large number of Relays are used connected in series, this factor must be taken into account together with the power consumption.

DC-operated Relays

The power supply used to operate DC-operated Relays may have voltage as a standard or it may have current as a standard. When voltage is the standard, the rated coil voltages include 5, 6, 12, 24, 48, and 100 VDC. When current is the standard, the rated current in mA is listed in the catalog.
In DC-operated Relays, when the Relay is used in an application where it is operated at some limit value, either voltage or current, the current applied to the coil will gradually increase or decrease. It is important to note that this may delay the movement of the contacts resulting in failure to meet the specified control capacity. The coil resistance value of a DC-operated Relay may change by approximately 0.4% per °C due to changes in the ambient temperature and the heat radiated by the Relay itself. Therefore, it is important to note that increases in temperature will be accompanied by higher must-operate and must-release voltages.

Power Supply Capacity

The fluctuation of the power supply voltage over a long period will of course affect Relay operation, but momentary fluctuations will also be the cause of incorrect Relay operation.
For example, when a large solenoid, Relay, motor, heater, or other device is operated from the same power supply as the one that operates the Relay, or when a large number of Relays are used, if the power supply does not have sufficient capacity when these devices are operated simultaneously, the voltage drop may prevent the Relay from operating. On the other hand, when the voltage drop is estimated and the voltage increased accordingly, if the voltage is applied to the Relay when there is no voltage drop, this will cause heating of the coil.
Provide leeway in the capacity of the power supply and keep the voltage within the switching voltage range of the Relay.

Lower Limit Value of the Must-operate Voltage

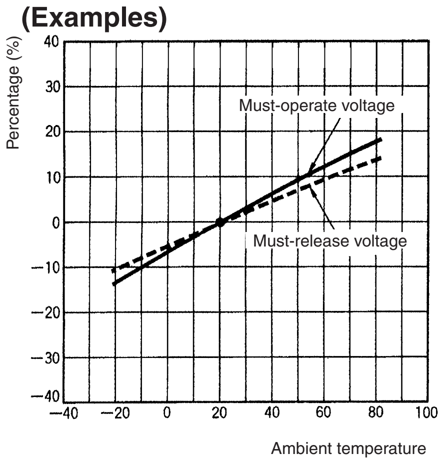
Use of Relays at high temperatures or rise of coil temperature due to a continuous flow of current through the coil will result in an increase in coil resistance which means the must-operate voltage will also increase. This matter requires attention be paid to determining a lower limit value of the operation power supply voltage. The following example and explanation should be referred to when designing the power supply.

Note: Even though the rating is a voltage rating (as is the rating for all Standard Relays), the Relay should be thought of as being current operated.

Catalog values for model MY
Rated voltage: 24 VDC, coil resistance: 650 Ω, must-operate voltage: 80% or less of rated voltage, at a coil temperature of 23°C.

A rated current of 36.9 mA (24 VDC/650 Ω = 36.9 mA) flows through this Relay, which operates at 80% or less of this value i.e., at 29.5 mA or less (36.9 mA x 0.8 = 29.5 mA). When the present coil temperature rises by 10°C, the coil resistance will be 676 Ω (650 Ω x 1.04 = 676 Ω). To have the must-operate current of 29.5 mA flow in this condition, it will be necessary to apply a voltage of 19.94 V (29.5 mA x 676 Ω =19.94 v). This voltage (which is the must-operate voltage when the coil temperature is 33°C (23°C +10°C), is 83.1% (19.94/24 = 83.1%) of the rated voltage which represents an increase compared to when the coil temperature was 23°C.

• **Coil Temperature vs. Mustoperate/release Voltage**



[Determining lower-limit value of must-operate voltage]

ET > E x (Epv + 5*)/100 x {(T – Ta)/(234.5 + Ta) + 1}
where,
E: Rated coil voltage [V]
Epv: Must-operate voltage [%]
Ta: Coil temperature determining Epv. Unless otherwise specified, 23°C
T: Operating ambient temperature [°C]
ET: Lower-limit value of must-operate voltage [V]

Note: In the above expression, it is assumed that the coil temperature is the same as the ambient temperature, and that T is the value to which the coil temperature has risen as a result of energizing the coil. *5 denotes the safety margin of 5 %.

Continuous Energization for Extended Periods (Months or Years)

In a circuit where the Relay does not release for months or even years with the power supplied, such as an emergency lamp, alarm facility, and error detector circuit in which the Relay releases only in case of an abnormality to issue an alarm signal through its NC contacts, it is recommended that the circuit be designed so that the Relay coil is not excited. This is because, as the coil temperature rises, the Relay is heated and, as a result, the contacts are increasingly corroded. In such applications, therefore, use of Latching Relays and stepping relays is recommended. If the use of the Single Stable Relay is essential, use a fully sealed model which has excellent environmental durability. It is also recommended that the fully sealed model of the Latching Relay be used.

Permissible Voltage for Continuous Use of Coil

The value of the permissible voltage for the continuous use of the coil is generally +10% to 15% of the rated voltage in the case of the AC-operated model and +15% to 20% of the rated voltage in the case of the DC-operated model. The temperature rise at this time is usually 30° to 65°C. This voltage of the DC-operated model may sometimes be expressed in terms of wattage [W], which is obtained by multiplying the coil current squared by the coil resistance (coil current^2 x coil resistance), so that the coil current is limited. The permissible voltage for the continuous use of the coil specified in the Data Sheet of the Relay in question is very important because, unless it is correctly observed, the insulation of the Relay may be thermally degraded, deformed, the other devices connected to the Relay, or even human beings using the Relay may be damaged. Therefore, be sure to observe the permissible voltage. Although Relays employing new wire materials for their coils to improve their characteristics are increasingly available in recent years, it is appropriate to assume that the insulation for these Relays is actually of type E and that the upper-limit value of the temperature rise is 80°C at an ambient temperature of 40°C.

Operate Time

The operate time of the AC-operated Relay considerably varies because of the phase when the switch for energizing the coil is turned ON, and, though it is expressed within a certain range, is about half a cycle (about 10 ms) in the case of a small Relay. However, if the Relay is large in size, the bounce increases, and the operate time is 7 to 10 ms and the release time is 9 to 18 ms. In the case of the DC-operated model, the greater the coil input, the shorter the operate time. However, if the operate time is too short, the bounce time of the NC contact may be prolonged.

Maximum Voltage

Do not use a Relay in such a manner that the maximum voltage specified in the Datasheet of the Relay is exceeded. The maximum voltage of a Relay is determined by various factors, such as coil temperature rise, durability of coil insulation materials, electrical and mechanical life expectancies, and general characteristics. If the maximum voltage is exceeded, the insulation materials may be degraded and the coil may be damaged by burning. In actual applications, however, Relays are often used with their maximum voltage exceeded in order to cope with the fluctuations in the supply voltage. In this case, observe the following points:

(1) Do not allow the coil temperature to exceed the value up to which the spool, the coil insulation materials, and winding wire can withstand.
The temperature up to which the frequently used wiring materials can endure is as shown in the table below (the values in this table are measured by the resistance method).

Wiring materials	Upper-limit value of coil temperature
Polyurethane	120°C
Polyester	130°C

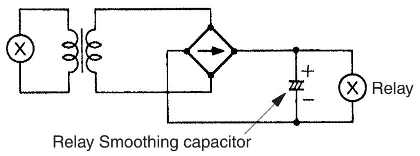
[Measuring coil temperature by resistance method]

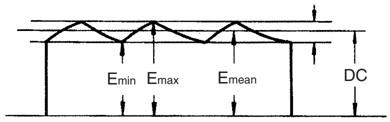
t = (R_2 – R_1)/R1 x (234.5 + T_1) + T_1 [°C]
where,
R1: coil resistance before energization [Ω]
R2: coil resistance after energization [Ω]
T1: coil temperature before energization (ambient temperature): T1 [°C]
t: coil temperature after energization [°C]

(2) Confirm that there is not problem when the Relay is used in the actual application system.

Input Power Source

• The power source for DC-operated Relays is in principle either a battery or a DC power supply with a maximum ripple percentage of 5%. If the power is supplied to the Relay via a rectifier, the must-operate and must-release voltages vary with the ripple percentage. Therefore, check the voltages before actually using the Relay. If the ripple component is extremely large, vibration may occur. If this happens, it is recommended that a smoothing capacitor be inserted as shown below.





Ripple ratio (%) = $(E_{max} - E_{mm})/E_{mean}$ x 100%

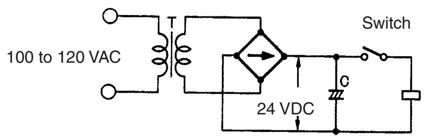
DC component Ripple percentage where, Emax: maximum value of ripple component;
Emin: minimum value of ripple component;
Emean: mean value of DC component

- If a circuit where the voltage applied to the DC-operated coil increases or decreases extremely slowly, each contact of a Multi-pole Contact Relay may not operate at the same time as the other contacts, or the must-operate voltage may vary each time the Relay operates. As a consequence, the sequence of the circuit will not be correctly established. Therefore, the use of a Schmitt circuit is recommended in an important circuit to shape desirable waveforms.
- In a circuit where the Relay coil is applied voltage for a long time, use of a DC-operated Relay is recommended. If an AC-operated model is used, the coil temperature rises to a great value because of the interaction of the copper loss and iron loss (hysteresis of magnetic materials). From the viewpoints of reducing the temperature within the control panel and eliminating the vibration, therefore, the use of the DC model is more advantageous.

Voltage Applied to AC-operated Model

In principle, apply a voltage within +10% to –20% of the rated voltage to an AC-operated Relay to ensure the stable operation of the Relay. Note, however, that the voltage applied to the coil must be a sine wave. If the voltage is applied from a commercial power source, there is no problem. However, when using a AC voltage regulator, beat or abnormal heating may occur depending on the distortion of the waveform of the equipment. Although an AC-operated Relay is of construction that beat is eliminated by a standing coil, the distorted waveform may prevent the standing coil from operating correctly.
When motors, solenoids, or transformers are connected to the same power lines as those of the power supply of the control circuit of a Relay, the supply voltage to the Relay may drop when these devices operate, causing the Relay to vibrate and the contacts to be damaged by burning. This symptom is conspicuous especially when a small-capacity transformer is connected to the Relay, when the wiring length is too long, or when household or commercial cables small in diameter are used. If a trouble of this kind has occurred, examine how the voltage changes by using an oscilloscope or other instruments and take appropriate countermeasures such as employing Special Relays having operation characteristics suitable to the environments of your application and changing the Relay circuit into a DC circuit like the one shown below to absorb the fluctuations in the voltage by a capacitor.

- **Voltage Fluctuation Absorber Circuit with Capacitor 100-VAC Switch**



■ Coil

The most fundamental point to be observed is to apply the rated voltage to a Relay to make sure that the Relay accurately operates. Therefore, when using a Relay, this point must be abided by under any circumstances. Applying the rated voltage to the coil of a Relay is also important for the reason that the coil resistance changes depending on the type of the coil, voltage fluctuation, and temperature rise. On the other hand, however, the voltage applied to the coil must not exceed the maximum voltage specified in the Datasheet of the Relay; otherwise, the coil may be short-circuited and damaged by burning.

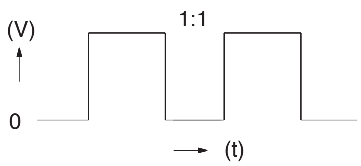
Coil Temperature Rise

When a current flows through the coil of a Relay, heat is generated because of the joule heat (copper loss) of the coil or, on alternate current, of the iron loss of the magnetic materials such as iron core. Consequently, the coil temperature rises. In addition, when a current flows through the contacts, heat is also generated from the contacts, which help the coil temperature rise further.

Temperature Rise Due to Pulse Voltage

When a Relay is applied a pulse voltage whose ON time is 2 minutes or less, the rise in the coil temperature is independent of the ON time, but is influenced by the ratio of the ON time to the OFF time. This temperature rise is much smaller than that when the Relay is used with continuously supplied power, and almost the same for any models of Relays.

Energization time	Temperature rise:
Continuous energization	100%
ON:OFF = 3:1	Approx. 80%
ON:OFF = 1:1	Approx. 50%
ON:OFF = 1:3	Approx. 35%



Changes in Must-operate Voltage Due to Coil Temperature Rise (Hot Start)

When the coil of a DC-operated Relay has been continuously energized, and when the power to the Relay has been once turned OFF and then immediately back ON again, the coil resistance increases because of the coil temperature rises. As a result, the must-operate voltage slightly increases. If the Relay is used in an atmosphere where the ambient temperature is high, the operate voltage also increases. The resistance thermal coefficient of a copper wire is about 0.4% per 1°C, and the coil resistance increases at this ratio. Therefore, to operate a Relay, a current higher than the operate current is necessary, and the current value increases with the coil resistance.

Surge Protection when Coil is OFF

The reverse voltage that is generated by the coil when it is OFF may cause the semiconductor to be damaged and equipment to malfunction. As a countermeasure, either attach a surge suppressor to both ends of the coil or select a model with a built-in surge suppressor (e.g., MY, LY). If a surge suppressor is attached, the release time for the Relay will be longer. Confirm operation with the circuit that will actually be used.

■ Contacts

The contacts are the most important constituents of a Relay. Their operations and characteristics are influenced by various factors such as contact materials, applied voltage and current (especially, voltage and current waveforms on turning ON/OFF power), load type, switching frequency, ambient temperature, contact construction, and the presence or absence of the switching speed bounce phenomena. When the contacts have been adversely influenced by any of or combination of these factors, phenomena such as contact transfer, metal deposition, abnormal wear, and increase in contact resistance occur. To extend the endurance of the contacts and to make sure that they always operate correctly, pay attention to the following points.

Voltage and Current of Contact Circuit

If a contact circuit contains induction, a considerably high counter electromotive force (emf) is generated. The higher the voltage applied to the contacts, the greater the energy of the counter emf, wearing the contacts. Therefore, the value of the current up to which the Relay makes or breaks must be appropriately controlled. If a DC voltage is applied to the contacts, the control capacity of the Relay significantly drops. This is because, on DC voltage, there is no zero point (current zero cross point) unlike on AC voltage, and therefore, if the Relay has generated arc once, the arc is difficult to disappear, resulting in a long arc time. In addition, because the current flows in only one direction, contact transfer, a phenomenon described shortly, occurs, wearing the contacts. The control capacity of a Relay is generally set forth on the Data Sheet of the Relay. However, observing this control capacity is not sufficient. Especially, in a special contact load circuit, the control capacity of the Relay must be confirmed by conducting a test with the actual load.

Current

When the contacts are closed or opened, the current has a significant influence on the contacts. For example, if the load is a motor or lamp, the higher the inrush current when the contacts are closed, the more the contacts are worn and the quantity of contact transfer increases. Consequently, the contacts will fuse and cannot be separated.

Contact Materials

It is important to select appropriate contact materials depending on the load current the contacts are to break or make. The following table lists the contact materials widely used and their features.

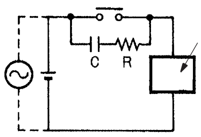
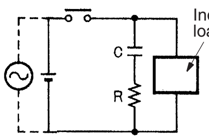
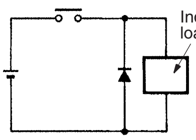
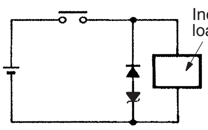
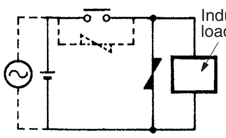
Contact Materials and Their Features

Low load current ◄					► High load current
P.G.S alloy (platinum, gold, silver)	**AgPd (silver palladium)**	**Ag (silver)**	**AgNi (silver nickle)**	**AgSnIn (silver, tin, indium)**	**AgW (silver tungsten)**
High resistance to corrosion. Mainly used in minute current circuit (Au:Ag:Pt = 69:25:6)	High resistance to corrosion and sulfur. In dry circuit, likely to absorb organic gas and generate polymer, and thus gold-clad.	Highest conductance and thermal conductance of all metals. Low contact resistance, but easy to create sulfide film in sulfide gas. May cause faulty contact at low voltage and current.	Rivals with Ag in terms of conductance. Excellent resistance to arc.	Excellent resistance to metal deposition and wear.	High hardness and melting point. Excellent resistance to arc, metal deposition, and transfer, but high contact resistance and poor environmental durability.

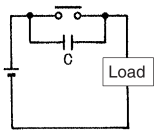
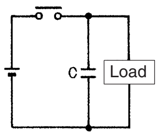
Contact Protection Circuit

It is recommended to employ a contact protection circuit to increase the service life of the Relay, to suppress noise, and to prevent generation of carbide and nitric acid which otherwise will be generated at the contacts when the Relay is opened. Unless used correctly, however, the protection circuit may produce adverse effects. Anyway, the release time of the Relay may be somewhat prolonged. The following table lists examples of contact protection circuits. Note that even Fully Sealed Relays, when used to break a load that may generate arc (for example, an inductive load such as a Relay coil) in highly humid environments, may generate nitric acid due to the NOx generated by the arc and water content, which may corrode the metallic parts of the Relay, causing the Relay to malfunction. Use a surge suppressor as the one shown in the table on the next page when the Relay is used in highly humid environments to break an arc-generating circuit frequently.

Examples of Surge Suppressors

Circuit example		Applicability		Features and remarks	Element selection
		AC	DC		
CR type		* (OK)	OK	*Load impedance must be much smaller than the RC circuit when the Relay operates on an AC voltage.	Optimum C and R values are: C: 1 to 0.5 uF for 1 A switching current R: 0.5 to 1 ohm for 1 V switching voltage However, these values do not always agree with the optimum values due to the nature of the load and the dispersion in the Relay characteristics. Confirm the optimum values through experiment. Capacitor C suppresses the discharge when the contacts are opened, while resistor R limits the current applied when the contacts are closed the next time. Generally, employ C whose dielectric strength is 200 to 300 V. If the circuit is used with AC power source, employ an AC capacitor (without polarity).
		OK	OK	The release time of the contacts will be delayed when a Relay or solenoid is used as the load. This circuit is effective if connected across the load when the supply voltage is 24 to 48 V. When the supply voltage is 100 to 240 V, connect the circuit across the contacts.	
Diode type		NG	OK	The energy stored in a coil (inductive load) is flowed to the coil as current by the diode connected in parallel with the coil, and is dissipated as Joule heat by the resistance of the inductive load. This type of circuit delays the release time more than the RC type.	Employ a diode having a reverse breakdown voltage of more than 10 times the circuit voltage, and a forward current rating greater than the load current. A diode having a reverse breakdown voltage two or three times that of the supply voltage can be used in an electronic circuit where the circuit voltage is not particularly high.
Diode + Zener diode type		NG	OK	This circuit is effective in an application where the diode type protection circuit alone is not sufficient because the release time is delayed too much.	The breakdown voltage to the Zener diode should be about the same as the supply voltage.
Varistor type		OK	OK	This circuit prevents a high voltage from being applied across the contacts by using the constant-voltage characteristic of a varistor. This circuit also somewhat delays the release time. This circuit is effective if connected across the load when the supply voltage is 24 to 48 V. If the supply voltage is 100 to 240 V, connect the circuit across the contacts.	The cutoff voltage Vc must satisfy the following conditions (on AC, it should be multiplied by 2) Contact dielectric strength > Vc > Supply voltage

Avoid use of a surge suppressor in the manners shown below.

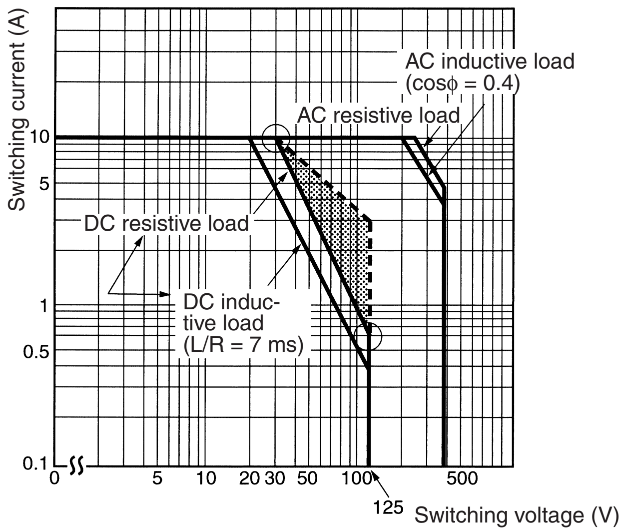
 This circuit arrangement is very effective for diminishing sparking (arcing) at the contacts when breaking the circuit. However, since electrical energy is stored in C (capacitor) when the contacts are open, short-circuit current of C flows into the contacts when they are closed. Therefore, metal deposition is likely to occur between mating contacts.	 This circuit arrangement is very useful for diminishing sparking (arcing) at the contacts when breaking the circuit. However, since the charging current to C flows into the contacts when they are closed, metal deposition is likely to occur between the mating contacts.

Note: Although it is considered that switching a DC inductive load is more difficult than a resistive load, an appropriate contact protection circuit can achieve almost the same characteristics.

Load Switching

When the Relay is actually used, the switching power, switching lifetime, and switching conditions will vary greatly with the type of load, the ambient conditions, and the applied load. Confirm operation under the actual conditions in which the Relay will be used. The maximum switching powers for the Relays are shown in the following graph.

Maximum Switching Powers



Contacts

Load	Resistive load	Inductive load (cosϕ = 0.4, L/R = 7 ms)
Rated load	AC: 250 V, 10 A DC: 30 V, 10 V	AC: 250 V, 7.5 A DC: 30 V, 5 V
Rated carry current	10 A	
Max. switching voltage	380 VAC, 125 VDC	
Max. switching current	10 A	

1. Resistive Loads and Inductive Loads

The switching power for an inductive load will be lower than the switching power for a resistive load due to the influence of the electromagnetic energy stored in the inductive load.

2. Switching voltage

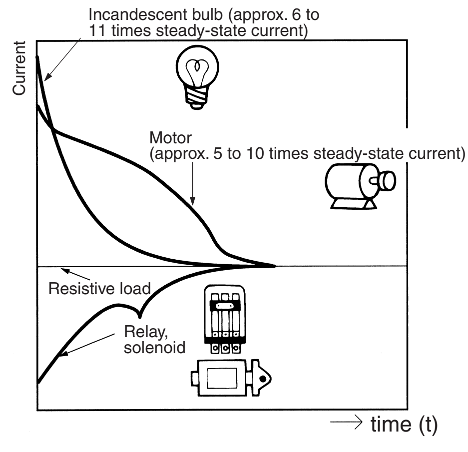
The switching power will be lower with DC loads than it will with AC loads. With DC loads, the switching power will be smaller for higher voltages. Using the values given in the graph *Maximum Values for Switching Power*, the switching power for DC loads at the minimum voltage is $W_{max.}$ = 300 W and at the maximum voltage it is lower, i.e., $W_{max.}$ = 75 W. This difference is the amount that the switching power drops because of the high switching voltage. Applying voltage or current between the contacts exceeding the maximum values will result in the following:

1. The carbon generated by load switching will accumulate around the contacts and cause deterioration of insulation.
2. Contact deposits and locking will cause contacts to malfunction.

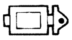
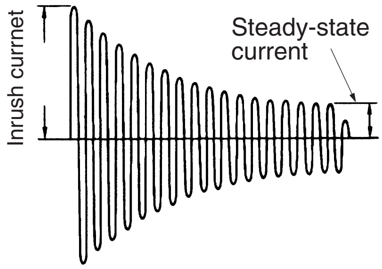
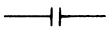
3. Switching current

Current applied to contacts when they are open or closed will have a large effect on the contacts. For example, when the load is a motor or a lamp, the larger the inrush current, the greater the amount of contact exhaustion and contact transfer will be, leading to deposits, locking, and other factors causing the contacts to malfunction. (Typical examples illustrating the relationship between load and inrush current are given below.) If a current greater than the rated current is applied and the load is from a DC power supply, the connection and shorting of arcing contacts will result in the loss of switching capability.

DC Loads and Inrush Current



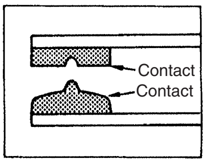
AC Loads and Inrush Current

Type of load		Ratio of inrush current to steady-state current	Waveform
Solenoid		Approx. 10	
Incandescent bulb		Approx. 10 to 15	
Motor		Approx. 5 to 10	
Relay		Approx. 2 to 3	
Capacitor		Approx. 20 to 50	
Resistive load		1	

DC Load Switching

To switch a DC load, the arching can be diminished more accurately by connecting contacts in series because this is equivalent to expanding the contact gap.

In switching a DC load, contact transfer may occur and the contacts may be prevented from releasing by the projection and recess created on the contact surface as shown below.

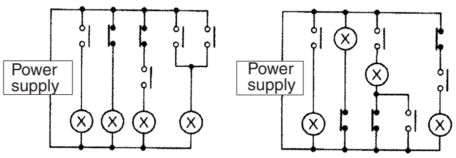


The projection is created because the surface of the contact is virtually spot-welded by the heat generated on the contact surface, and the recess is caused by vaporization and chemical actions. This may happen even when the Relay is used at a load current below the rated current of the Relay. It is therefore important to conduct an experiment to examine if this phenomenon occurs by mounting the Relay in the actual application system.

When the Relay is used to break a DC load, sometimes bluish green substances may be generated in the Relay case. These substances are nitric acid (HNO3) solidified by nitrogen contained in air combining with water content due to the arc discharge that is generated when the contacts are closed and opened. Models MMX and G7X are housed in cases with hole through which the gas is let out to prevent this solidification of nitric acid.

Potential Difference Circuit

In a circuit where the gap between adjacent contacts is small, the power source will be short-circuited if the potential difference exists between the adjacent contacts and the contacts are short-circuited. To prevent the power source from being short-circuited when using, for example, a Multi-pole Contact Relay, perform load connection as in the following figure:

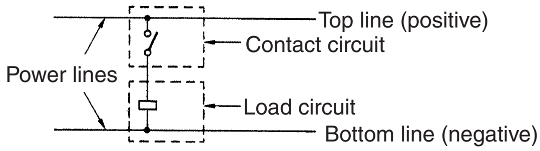


a. Desirable connection   b. Undesirable connection

If the voltage of the load circuit is 20 V or less, or if no arc is generated by the switching of the Relay, use of load connection b is possible. Study your intended application carefully to determine whether load connection b can be used.

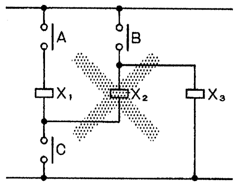
Sneak Circuit

When configuring a sequence circuit, care must be exercised that the circuit does not malfunction due to sneak current. When writing a sequence circuit diagram, it is important that, of the two power lines, the top be considered to be positive and the bottom, to be negative (this does not only apply to a DC circuit but also to an AC circuit), and that contact circuits (such as Relay contacts, timer contacts, and limit switch contacts) be connected to the positive line, while the load circuit (Relay coil, timer coil, magnet coil, solenoid coil, motor, and lamp) be connected to the negative line.



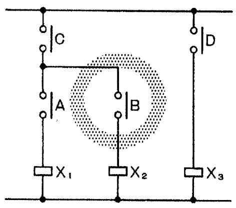
An example of a sneak circuit is shown below. After contacts A, B, and C have been closed, and thus Relays X1, X2, and X3 have operated, when contacts B and C are opened, a series circuit consisting of A, X1, X2, and X3 are formed, causing the Relay to generate beat or not to release.

Incorrect:



An example of a correct circuit is shown below. In a DC circuit, the sneak current can be effectively prevented by using diodes.

correct:



■ Notes on Environment

Contact Degradation Due to Environment

Even if the Relay is not used and just stored, the degradation of the contacts may progress, if the storage environment is not appropriate, due to the influences of the sulfur and chlorine contained in atmosphere. If the Relay is to be stored for such a long period as years, it is recommended to perform a conductivity test when the Relay is actually used, or to use Relays with gold-plated or gold-clad contacts.

Area	Detected elements	Result of observation of contact surface (Ag contact. Left for 12 months)
Chemical plant	Ag, S	Almost uniform and dense corrosive substances were observed on the entire surface of the contacts. As a result of analysis, Ag_2S was detected.
Steal mill	Ag, S	Irregular projections and recesses were observed and pillars of crystal were dispersed. As a result of analysis, Ag_2S was detected.
Highway	Ag, S, Cl	Circular crystal was sporadically observed. Ag_2S was extremely thin at the white portions.

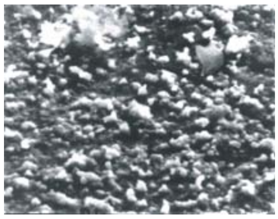
Chemical factory

x 5,000

Steel mill

x 5,000

Highway



x 5,000

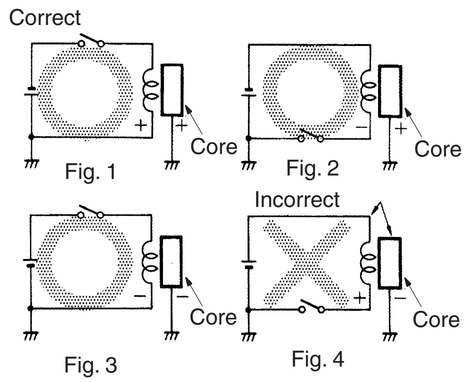
Electrolytic Corrosion

To prevent electrolytic corrosion, it is better not to ground the ground terminal or mounting stud of Relay. If it must be grounded and used in a high-temperature and high-humidity environment, electrolytic corrosion may occur if the grounding is improper, causing the coil wire to sever. In such a case, perform the grounding as follows:

(1) Ground the positive side of the power supply (see Figs. 1 and 2).

(2) In case the positive side cannot be grounded and therefore, the negative side of the power supply has to be grounded, connect a switch to the positive side so that the coil is connected to the negative side (see Fig. 3).

(3) Grounding the negative side of the power supply and connecting a switch to that side may cause electrolytic corrosion (see Fig. 4). Therefore, avoid such a practice.



Influences of External Magnetic Field

If devices having strong magnetic field, such as transformers and loudspeakers, are placed near these Relays, the characteristics of the Relays may be changed or the Relays may malfunction, though the extent of the characteristic change and malfunction varies depending on the intensity of the external magnetic field.