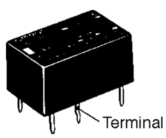
General Information

Options

Straight PCB terminal
PCB terminals are normally straight.

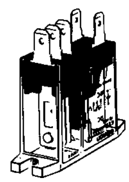
Curved-tail (S-shaped) PCB terminal
Some relays have terminals that are bent into an “S” shape. This secures the PCB relay to the PCB prior to soldering, helping the terminals stay in their holes, keeping the relay level.



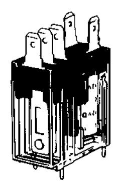
Built-in diode
A diode is built into some relays, wired in parallel with the coil to absorb the counterelectromotive force (counter emf) generated by the coil.

Operation indicator
Some relays are provided with a light-emitting diode (LED), wired in parallel with the coil. This permits a fast-check of the relay’s operating status.

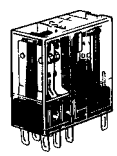
Quick-connect terminal



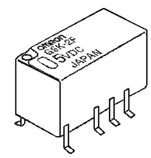
Quick-connect/PCB terminal



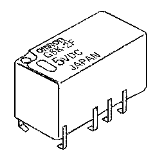
Plug-in terminal



Gull-wing SMT terminal

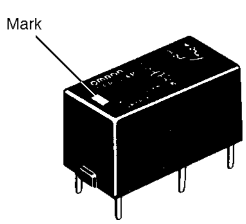


“Inside L” SMT terminal

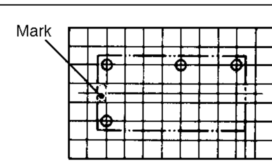
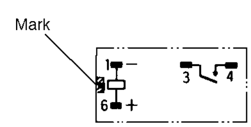


Dimensions

Mounting orientation mark
On top of all OMRON relays is a mark indicating where the relay coil is located. Knowing the coil location aids in designing PC boards when spacing components. Also, pin orientation is easy to discern when automatic or hand-mounting relays.

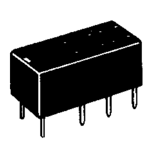


On dimensional drawings in all OMRON literature this mark is left-oriented. Mounting holes, terminal arrangements, and internal connections follow this alignment. The following two symbols are used to represent the orientation mark:

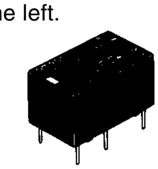
Drawing View	Bottom	Top
Detail	Mounting holes	Terminal arrangement/Internal connection
Symbol		
Example	 (bottom view)	 (bottom view)

Terminal arrangement/Internal connections
Top view
If the terminal arrangement of a relay can be seen from above the PCB, the top view of the relay is provided in the “Dimensions” section of the catalog or data sheet. This example shows DIP-style relay terminals, which are visible even when the relay is mounted.

Bottom view
However, if the relay terminal cannot be seen from above the PC board, as in this example, a bottom view will be shown.



Rotation direction to bottom view
The bottom view shown in the catalog or data sheet is rotated in the direction indicated by the arrow, with the coil always on the left.



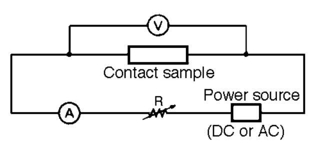
Contact Information

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

Contact form
The arrangement of contacts on a relay.
Form A: SPST-NO
Form B: SPST-NC
Form C: SPDT - B -M

Contact resistance
The total resistance of the conductor, as well as 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 allowing test current as shown in the table):

Rated current (A)	Test current (mA)
Under 0.01	1
0.01 to 0.1	10
0.1 to 1	100
Over 1	1000



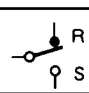
A: Ammeter V: Voltmeter R: Variable resistor

For most applications, use at least 1 A, 5 VDC for contact resistance measurements.

Contact symbols

NO	NC	DT
		

Double-break	NC
	

Make-before-break	Latching relays
	

Make-before-break
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 contacts are closed momentarily at the same time.

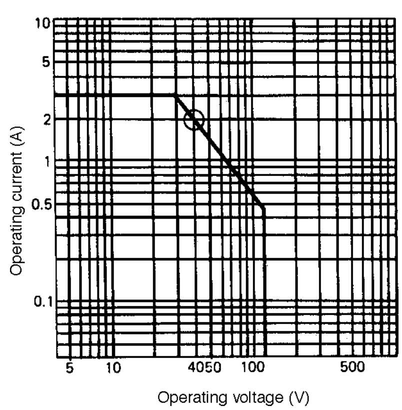
Maximum switching capacity
The maximum value of the load capacity which can be switched without a problem. When using a relay, be careful not to exceed this value.

For example, when switched voltage V_1 is known, maximum switched current I_1 can be obtained at the point of intersection on the characteristic curve "Maximum switching capacity" shown below. Conversely, maximum switched voltage V_1 can be obtained if I_1 is known.

$$\text{Maximum operating current } (I_1) = \frac{\text{Maximum switching capacity [W(VA)]}}{\text{Operating voltage } (V_1)}$$

$$\text{Maximum operating current } (V_1) = \frac{\text{Maximum switching capacity [W(VA)]}}{\text{Operating current } (I_1)}$$

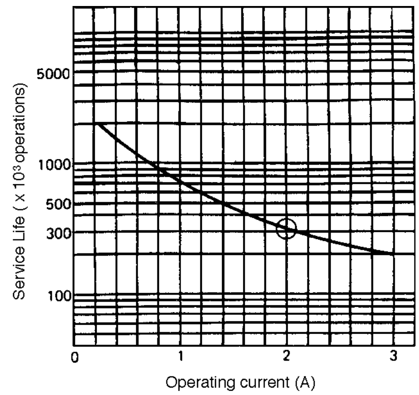
For instance, if operating voltage = 40 V, maximum operating current = 2 A (see circled point on graph)



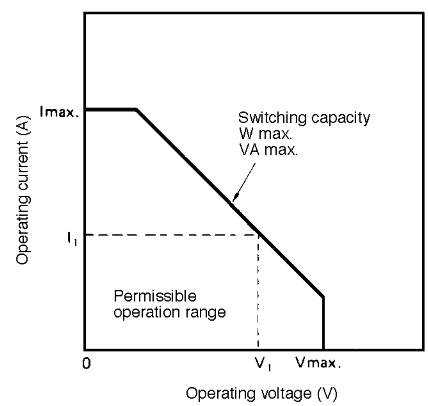
The life expectancy of the relay can be determined from the "Electrical service life" curve, based on the rated operating current (I_1) obtained above.

For instance, the electrical service life at the obtained maximum operating current of 2 A is slightly over 300,000 operations (see circled point on following graph).

Electrical service life



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



Minimum permissible load
The minimum permissible load indicates the lower limit of the switching capability of the relay. Such minute load levels can be found in microelectronic circuits. This value may vary, depending on operating frequency, operating conditions, expected reliability level of the relay, etc. It is recommended to double-check relay suitability under actual load conditions. In this catalog, the minimum permissible load of each relay is indicated as a reference value. It indicates failure level at a reliability level of 60% ($\lambda_6 0$).
$\lambda_6 0 = 0.1 \times 10^{-6}$/operation means that one failure is presumed to occur per 10,000,000 (ten million) operations at the reliability level of 60%.

Number of poles
The number of individual contact circuits.

Contact Information

Contacts

The contacts are the most important constituent of a relay. Their characteristics are significantly affected by factors such as the material of the contacts, voltage and current values applied to them (especially, the voltage and current waveforms when energizing and de-energizing the contacts), the type of load, operating frequency, atmosphere, contact arrangements, and bounce. If any of these factors fail to satisfy a predetermined value, problems such as metal degradation between contacts, contact welding, wear, or a rapid increase in the contact resistance may occur.

Contact Voltage and Current

Voltage (AC, DC)

When a relay breaks an inductive load, a fairly high counterelectromotive force (counter emf) is generated in the relay's contact circuit. The higher the counter emf, the greater the damage to the contacts. This may result in a significant decrease in the switching capacity of the DC-switching relay. This is because, unlike the AC-switching relay, the DC-switching does not have a zero-cross point. Once arc has been generated, it does not easily diminish, prolonging the arc time. Moreover, the unidirectional flow of the current in a DC circuit may cause metal degradation to occur between contacts and the contacts to wear rapidly (this is discussed later).

If the voltage applied to the DC-operated coil increases or decreases slowly, each contact of a multi-pole contact relay may not operate at the same time. It is also possible for this situation to result in the pickup voltage varying each time the relay operates. Either way, circuit sequencing will not be correct. In critical applications, the use of a Schmitt circuit is recommended, used to reshape the DC waveform to trigger all contacts of the relay at the same time.

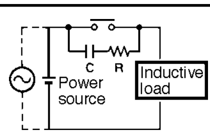
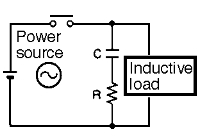
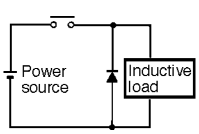
Despite the information a catalog or data sheet sets forth as the approximate switched power of the relay, always confirm the actual switched power by performing a test with actual load.

Current

The quality of electrical current which flows through the contacts directly influences the contacts' characteristics. For example, when the relay is used to control an inductive load such as a motor or tungsten load such as a lamp, the contacts will wear faster, and metal decomposition between the mating contacts will occur more often as the inrush current to the contacts increases. Consequently, at some point the contacts may weld.

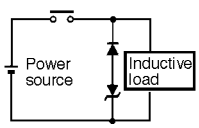
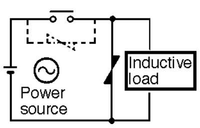
Contact Protection Circuit

A contact protection circuit, designed to prolong the life expectancy of the relay is recommended. This protection will have the additional advantage of suppressing noise, as well as preventing the generation of carbon at the contact surface when the relay contact is opened. However, unless designed correctly, the protection circuit may produce adverse effects, such as prolonging the release time of the relay. The following table lists examples of contact protection circuits:

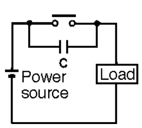
	Circuit example	Applicability AC	Applicability DC	Features and remarks	Element selection
RC		Fair*	Good	* Load impedance must be much smaller than the RC circuit when the relay operates on an AC voltage.	Optimum C and R values are: C: 1 to 0.5 μF for 1 A contact current R: 0.5 to 1 Ω for 1 V contact voltage 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 optimum values experimentally. Capacitor C suppresses discharge when the contacts are opened, while resistor R limits the current applied when the contacts are closed the next time. Generally, employ a capacitor C whose dielectric strength is 200 to 300 V or more than double the switching voltage. If the circuit is powered by an AC power source, employ an AC capacitor (non-polarized).
		Good	Good	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		NA	Good	The diode protects the coil from any inductive kickback. Relays with a diode connected in parallel with the relay coil tend to experience increased release times.	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 to three times that of the supply voltage can be used in an electronic circuit where the circuit voltage is not particularly high.

Contact Information

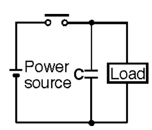
Contact Protection Circuit

Circuit example		Applicability AC	DC	Features and remarks	Element selection
Diode + Zener diode		NA	Good	This circuit effectively shortens release time in applications where the release time of a diode protection circuit proves to be too slow.	The Zener diode breakdown voltage should be about the same as the supply voltage.
Varistor		Good	Good	By utilizing the constant-voltage characteristic of a varistor, this circuit prevents high voltages from being applied across the contacts. This circuit also delays somewhat the release time. This circuit, if connected across the load, is effective when the supply voltage is 24 to 48 V. If the supply voltage is 100 to 240 V, connect the circuit across the contacts.	—

Avoid use of a surge suppressor in the manner 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, the current from C flows additionally into the contacts when they close. Therefore, metal degradation is likely to occur between mating contacts.

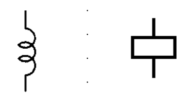


This circuit arrangement is very useful for diminishing sparking (arcing) at the contacts when breaking the circuit. However, since the charging current to C flows into the contacts when they are closed, metal degradation is likely to occur between the mating contacts.

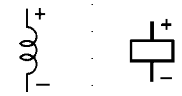
Although it is thought that switching a DC inductive load is more difficult than a resistive load, an appropriate contact protection circuit can achieve almost the same characteristics.

Coil Information

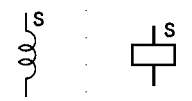
Coil Symbols



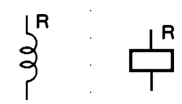
Coils with polarity designations



Set coil



Reset coil



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

Cold start
The ratings set forth in the catalog or data sheet are measured at a coil temperature of 23°C unless otherwise specified.

Maximum voltage
The maximum value of permissible over voltage in the operating power supply to the relay coil.

Minimum pulse width
The minimum width of the pulse voltage required to set and reset a latching relay at a temperature of 23°C

Pickup (set pickup) 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.

Must dropout (reset pickup) 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.

Rated coil voltage
A reference voltage applied to the coil when the relay is used under normal operating conditions. The following table lists the AC rated voltages:

Rating	Applicable power source	Inscription on relay	Description in catalog
Rating 1	100 V 60 Hz	100 VAC 60 Hz	100 VAC 60 Hz
Rating 2	100 VAC 50 Hz 100 VAC 60 Hz	100 VAC	100 VAC
Rating 3	100 VAC 50 Hz 100 VAC 60 Hz 110 VAC 60 Hz	100/110 VAC 60 Hz 100 VAC 50 Hz	100/110 VAC
Rating 4	100 VAC 50 Hz 100 VAC 60 Hz 110 VAC 50 Hz 110 VAC 60 Hz	100/110 VAC	100/110 VAC

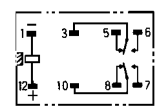
Power consumption
The power consumed by the coil (= rated voltage x rated current) when the rated voltage is applied to it. A frequency of 60 Hz is assumed if the relay is intended for AC operation.

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.

Single-side stable type (standard)
The contacts of this simple type of relay momentarily turn ON and OFF, depending on the energized state of the coil.

Terminal arrangement/Internal connections
(Bottom view)

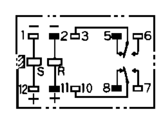
Mounting orientation mark



Dual-winding, latching type
This latching relay has two coils: set and reset. It can retain the ON or OFF states even when a pulsating voltage is supplied, or when the voltage is removed.

Terminal arrangement/Internal connections
(Bottom view)

Mounting orientation mark

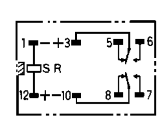


S: set coil
R: reset coil

Single-winding, latching type
Unlike the dual-winding latching relay, the single-winding latching relay has only one coil. This coil serves as both the set and reset coils, depending on the polarity (direction) of current flow. When current flows through the coil in the forward direction, the coil serves as a set coil; when the current flows in the reverse direction, it functions as a reset coil.

Terminal arrangement/Internal connections
(Bottom view)

Mounting orientation mark



S: set coil
R: reset coil

Coil Information

Notes on Coil Input

To guarantee accurate and stable relay operation, the first and foremost condition to be satisfied is the application of the rated voltage to the relay. Additionally, details concerning the type of power source, voltage fluctuation, changes in coil resistance due to temperature rise and the rated voltage must also be considered. If a voltage higher than the rated maximum voltage is applied to the coil for a long time, layer short-circuiting and damage to the coil by burning may take place.

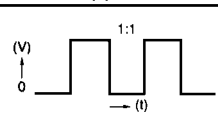
Coil Temperature Rise

When a current flows through the coil, the coil's temperature rises to a measurable level, because of copper loss. If an alternating current flows, the temperature rises even more, due not only to the copper loss, but to the iron loss of the magnetic materials, such as the core. Moreover, when a current is applied to the contacts, heat is generated on the contacts, raising the coil temperature even higher (however, with relays whose contact current is rated at 2 A or lower, this rise is insignificant).

Temperature Rise by Pulsating Voltage

When a pulsating voltage having an ON time of less than 2 minutes is applied to the relay, the coil temperature rise varies, and is independent of the duration of the ON time, depending only on the ratio of the ON time to the OFF time. The coil temperature in this case does not rise as high as when a voltage is continuously applied to the relay.

Energizing time	Relative temperature rise (%)
Continuously energized	100
ON: OFF = 3:1 Approx.	80
ON: OFF = 1:1 Approx.	50
ON: OFF = 1:3 Approx.	35



Changes in Pickup Voltage by Coil Temperature Rise (Hot start)

The coil resistance of a DC-switching relay increases (as the coil temperature rises) when the coil has been continuously energized, de-energized once, and then immediately energized again. This increase in the coil resistance raises the voltage value at which the relay operates. Additionally, the coil resistance rises when the relay is used at a high ambient temperature.

Upper-Limit Pickup Voltage

The maximum voltage applicable to a relay is determined in accordance with the coil temperature rise and the coil insulation materials' heat resistivity, electrical as well as mechanical service life, general characteristics, and other factors.

If a voltage exceeding the maximum voltage is applied to the relay, it may cause the insulation materials to degrade, the coil to be burnt, and the relay to malfunction at normal levels.

- The coil temperature must not exceed the temperature that the coil can withstand.

How to calculate coil temperature

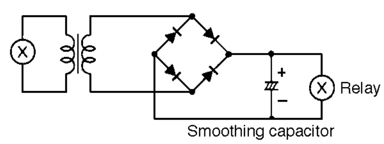
t = R2 - R1/R1 (234.5 = T1) + T1 (°C)

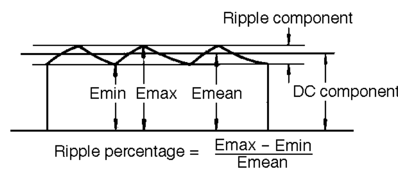
where,
R1 (Ω): coil resistance before energizing
R2 (Ω): coil resistance after energizing
T1 (°C): coil temperature (ambient) before energizing
t (°C): coil temperature after energizing

- Before using the relay, confirm that no problem occurs.

DC Input Power Source

Pay attention to the coil polarity of the DC-switching relay. Power sources for DC-operated relays are usually a battery or a DC power supply, either with a maximum ripple of 5%. If power is supplied to the relay via a rectifier, the pickup and dropout voltages vary with the ripple percentage. Therefore, check the voltages before actually using the relay. If the ripple component is extremely large, chatter may occur. If this happens, it is recommended that a smoothing capacitor be inserted as shown below. The use of a regulated, filtered power supply is preferred for DC coils.





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

Electrical Characteristic Terms

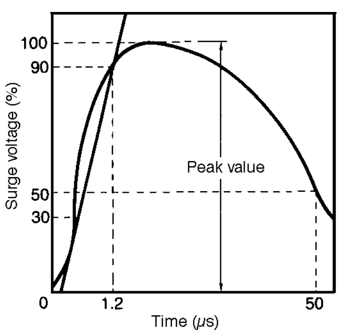
Dielectric strength
The critical value which a dielectric can withstand without rupturing when a high-tension voltage is applied for 1 minute between the following points:

Between coil and contact
Between contacts of different poles
Between contacts of same poles
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.

Electrical service life
The life of a relay when it is switched at the rated operating frequency with the rated load applied to its contacts.

Surge suppression 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

Maximum operating frequency
The frequency or intervals at which the relay continuously picks up and drops out, satisfying the rated mechanical and electrical service life.

Mechanical service life
The life of a relay when it is switched at the rated operating frequency without the rated load.

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 first NO contacts have closed, at an ambient temperature of 23°C. Bounce time is not included. For the relays having a pickup time of less than 10 ms, the mean (reference) value of its pickup time is specified as follows:

Pickup 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 de-energized at an ambient temperature of 23°C.

Dropout time
The time that elapses between the moment a relay coil is de-energized 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 the relays having a dropout time of less than 10 ms, the mean (reference) value of its dropout time is specified as follows:

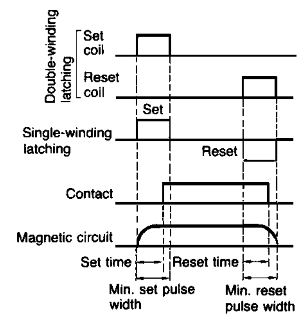
Dropout time	5 ms max. (mean value: approx. 2.3 ms)

Reset pickup time (applicable to latching relays only)
The time that elapses from the moment a relay coil is de-energized 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 the relays having a pickup time of less than 10 ms, the mean (reference) value of pickup time is specified as follows:

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

Set pickup 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 a pickup time of less than 10 ms, the mean (reference) value of the pickup time is specified as follows:

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



Shock
The shock resistance of a relay is divided into two categories: "Mechanical durability" that 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" that 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.

VSWR (applicable to high-frequency relays only)
Stands for voltage standing-wave ratio. The degree of reflected wave that is generated in the transmission line.

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

$\propto = 0.002f^2A$
where,
$\propto$: G-force equivalence
f: Frequency (Hz)
A: Double amplitude (in.)

Notes on Correct Use

Before actually committing any component to a mass-production situation, Omron strongly recommends situational testing, in as close to actual production situations as possible. One reason is to confirm that the product will still perform as expected after surviving the many handling and mounting processes involved in mass production. Although Omron relays are individually tested a number of times and each meets strict requirements, a certain testing tolerance is permissible. When a high-precision product uses many components, each depends upon the rated performance thresholds of the other components. Thus, the overall performance tolerance may accumulate to undesirable levels. To avoid problems, always conduct tests under the actual application conditions.

General

To maintain the initial characteristics of a relay, exercise care that it is not dropped or mishandled. For the same reason, do not remove the case of the relay; otherwise, the characteristics may degrade. Avoid using the relay in an atmosphere containing chemicals such as sulfuric acid (SO_2), hydrogen sulfide (H_2S), or other corrosive gases.

Do not continuously apply a voltage higher than the rated maximum voltage to the relay. Never try to operate the relay on a voltage and a current other than those rated.

If the relay is intended for DC operation, the coil has a polarity. Pay particular attention to this polarity. Connect the power source to the coil in the correct direction.

Do not use the relay at a temperature higher than that specified in the catalog or data sheet.

Coil

AC-switching relays

Generally, the coil temperature of the AC-switching relay rises higher than that of the DC-switching version. This is because of resistance losses in the shaded coil, eddy-current losses in the magnetic circuit, and hysteresis losses. Moreover, a phenomenon known as "chatter" may take place when the AC-switching relay operates on a voltage lower than that rated. For example, chatter may occur if the relay's supply voltage drops. This often happens when a motor (which is to be controlled by the relay) is activated. This results in damage to the relay contacts by burning, contact weld, or disconnection of the self-holding circuit. Therefore, countermeasures must be taken to prevent fluctuation in the supply voltage.

One other point that requires attention is the "inrush current." When the relay operates, and the armature of the relay is released from the magnet, the impedance drops. As a result, a current much higher than that rated flows through the coil. This current is known as the inrush current. (When the armature is attracted to the magnet, however, the impedance rises, decreasing the inrush current to the rated level.) Adequate consideration must be given to the inrush current, along with the power consumption, especially when connecting several relays in parallel.

DC-switching relays

This type of relay is often used as a so-called "marginal" relay that turns ON or OFF when the voltage or current reaches a critical value, as a substitute for a meter. However, if the relay is used in this way, its control output may fail to satisfy the ratings because the current applied to the coil gradually increases or decreases, slowing down the speed at which the contacts move.

The coil resistance of the DC-switching relay changes by about 0.4% per degree C change in the ambient temperature. It also changes when the relay generates heat. This means that the pickup and dropout voltages may increase as the temperature rises.

Coil Operating Voltage Source

If the supply voltage fluctuates, this relay will malfunction regardless of whether the fluctuation lasts for a long time or only for a moment. For example, assume that a large-capacity solenoid, relay, motor, or heater is connected to the same power source as the relay, or that many relays are used at the same time. If the capacity of the power source is insufficient to operate these devices at the same time, the relay may not operate, because the supply voltage has dropped. Conversely, if a high voltage is applied to the relay (even after taking voltage drop into account), chances are that the full voltage will be applied to the relay. As a consequence, the relay coil will generate heat. Therefore, be sure 1) to use a power source with sufficient capacity and 2) that the supply voltage to the relay is within the rated pickup voltage range of the relay.

Lower Limit Pickup Voltage

When a relay is used at high temperatures, or when the relay coil is continuously energized, the coil temperature rises and coil resistance increases. Consequently, the pickup voltage increases. This increase in the pickup voltage requires attention when determining the lower-limit pickup value of the pickup voltage. An example and outline for determining this lower-limit pickup voltage is given below for reference when designing a power source appropriate for the relay.

Assuming a coil temperature rise of 10°C, the coil resistance will increase about 4%. The pickup voltage increases as follows:

Rated values of Model G5LE are taken from catalog or data sheet.
Rated voltage: 12 VDC
Coil resistance: 360 Ω
Pickup voltage: 75% max. of rated voltage at 23°C coil temperature

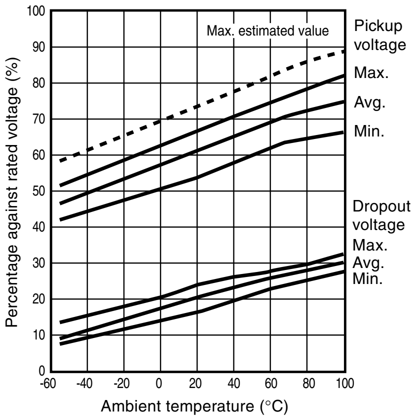
The rated current that flows through this relay can be obtained by dividing the rated voltage by the coil resistance. Hence,

12 VDC ÷ 360 Ω = 33.3 mA

However, the relay operates at 75% maximum of this rated current, i.e., 25 mA (= 33 mA x .75). Assuming that the coil temperature rises by 10°C, the coil resistance increases 4% to 374 Ω (= 360 Ω x 1.04). The voltage that must be applied to the relay to flow an operating current of 25 mA through the relay under this condition is 25 mA x 374 Ω = 9.35 V.

Notes on Correct Use

Ambient Temperature vs. Pickup/ Dropout Voltage (Model G6S)



As can be seen in the above chart, pickup and dropout voltage are affected by changes in ambient temperature. These changes should be taken into account if the relay will operate outside of a controlled environment.

Classification by Degree of Protection

Relays are divided by classification of the degree of protection.

Construction

Unsealed

This type of relay cannot be immersion-cleaned.

Semi-sealed type

Special design construction prevents flux from penetrating into the relay base housing, for example, due to capillary action up the terminals when the relay is soldered onto a PCB. This type of relay cannot be immersion-cleaned.

Fully sealed type

These relays are sealed in a thermoplastic case or cover as protection against an atmosphere containing corrosive gases.

The plastic sealed relay is of simple construction in which the relay is placed in a plastic case. The gaps of the joints between the case and relay terminals, and between terminals and terminal block (base) are sealed with epoxy resin.

Fully sealed relays are protected from flux and any cleaning solvent from penetrating into the relay housing. This type of relay can be immersion-cleaned. Relays are tested in flourinert at 90°C for 1 minute before being shipped.

Due to its simple construction, the plastic sealed relay is not suitable for applications in an environment or installation location that requires a particularly high level of sealing. For applications in an atmosphere containing flammable or explosive gases, use an hermetically sealed relay.

The following points require your particular attention to effectively prevent noxious gases or liquids from penetrating inside the relay.

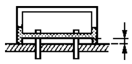
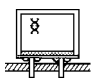
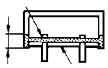
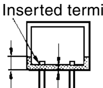
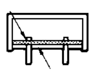
1. There is no problem as long as the relay is used on a flat surface. However, as much as possible, use it in an atmosphere pressure of 1,013 mb ±20%.
2. Do not use clean flux or water wash.

Operating atmosphere

Use of the plastic sealed or hermetically sealed relay is recommended under the following conditions:

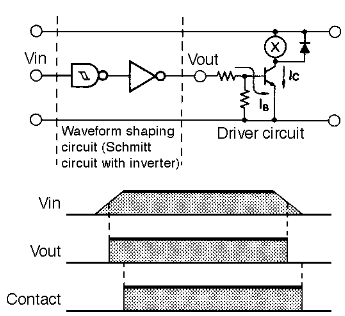
- When the relay is soldered on a PC board to be immersion-cleaned.
- In an atmosphere containing organic gases such as ammonia or hydrogen sulfide, SO_2 and chloride gas.
- On the control panel for machine tools that produce dust and oil.
- In terminal equipment installed at a location where people move about to create a dusty atmosphere.
- In automatic vending machines and showcases installed outdoors.

Notes on Correct Use

Classification	Construction	Features	Automatic flux application	Automatic soldering	Automatic cleaning	Manual soldering	Protection from dust	Protection from corrosive gas
Unsealed type	 Terminals separated from PCB	Terminals are separated from PCB surface when relay is mounted.	Poor	Poor	Poor	Good	Fair	Poor
	Contacts located at upper part of relay case 	Contacts are positioned away from base.	Poor	Poor	Poor	Good		
Semi-sealed type	Press-fit terminals  Terminals separated from PCB; Resin seal	Terminals are pressed into base.	Good	Good	Poor	Good	Fair	Poor
	Inserted terminals  Terminals separated from PCB; 0.3 mm min. base thickness	Terminals are inserted into base 0.3 mm or more thick.	Good	Good	Poor	Good		
Fully-sealed type	Press-fit terminals  Resin seal	Terminals, base, and case are sealed.	Good	Good	Good	Good	Good	Fair

Relay Driving Signal Waveform

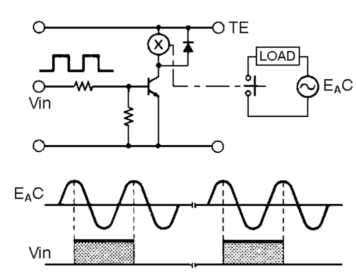
A long rise time and/or fall time of the signal driving the relay may prolong the pickup time and/or dropout time of the relay. This situation may shorten the life expectancy of the contacts. If this situation cannot be avoided, providing a Schmitt trigger circuit at the circuit stage preceding the relay circuit will shape a waveform with sharp transitions, as shown:



NOTE: If the Schmitt trigger circuit is configured of transistors, a residual voltage may exist in the output of the circuit. Therefore, confirm that the rated voltage is present across the relay coil, or that the residual voltage drops to zero when the relay releases.

Cyclic Switching of AC Load

If the relay operates in synchronization with the supply voltage, the life of the relay may be shortened. When designing the control system in which the relay is used, estimate the life expectancy of the relay and thus the reliability of the overall system under the actual operating condition. Moreover, make an arrangement so that the relay operates in a random phase or in the vicinity of the zero point.



Notes on Correct Use

PC Board Design

Temperature and humidity

PCBs expand or contract with changes in temperature. Should expansion occur with a relay mounted on the PCB, the internal components of the relay may be shifted out of operational tolerance. As a result, the relay may not be able to operate with its normal characteristics.

PCB materials have “directionality”, which means that a PCB generally has expansion and contraction coefficients 1/10 to 1/2 higher in the vertical direction than in the horizontal direction. Conversely, then, it follows that its warp in the vertical direction is 1/10 to 1/2 less than in the horizontal direction. Therefore, take the adequate countermeasures against humidity by coating the PCB.

Should heat or humidity be too high, the relay’s physical characteristics will be affected. For example, as the heat rises the PCB’s insulation resistance degrades. Mechanically, PCB parts will continue to expand as heat is applied, eventually passing the elastic limit, which will permanently warp components. If the relay is used in a humid environment, silver migration may take place.

Gas

Exposure to gases containing substances such as sulfuric acid, nitric acid, or ammonia can cause malfunctions such as faulty contacting in unsealed relays. They can also cause the copper film of a PCB to corrode, or prevent positive contacts between the PCB’s connectors. Of the gases mentioned, gas containing nitric acid is particularly damaging as it tends to accelerate the silver migration. As a countermeasure against gas exposure damage, the following processes on the relay and PCB have proved useful:

Item	Process
Outer casing, housing	Sealed construction by using packing, etc.
Relay	Use of simplified hermetically sealed type relay, DIP relay.
PCB, copper film	Coating
Connector	Gold-plating, rhodium-plating process

Vibration and shock

Although the PCB itself is not usually a source of vibration or shock, it may simplify or prolong the vibration by sympathetically vibrating with external vibrations or shocks. Securely fix the PCB, paying attention to the following points:

Mounting method	Remarks
Rack mounting	No gap between rack’s guide and PCB
Screw mounting	▪ Securely tighten screw. Place heavy components such as relays on part of PCB near screws. ▪ Attach rubber washers to screws when mounting components that are affected by shock noise (such as audio devices).

Mounting Relay on PC Board

Mounting direction

To allow a relay to operate to its full capability, adequate consideration must be given to the mounting direction of the relay. Relay characteristics that are considerably influenced by mounting direction are shock resistivity, life expectancy, and contract reliability.

Shock resistivity

Ideally, the relay must be mounted so that any shock or vibration is applied to the relay at right angles to the operating direction of the armature of the relay. Especially when a relay’s coil is not energized, the shock resistivity and noise immunity are significantly affected by the mounting direction of the relay.

Life expectancy

When switching a heavy load that generates arc (generally, a load having a greater impedance than that of the relay coil), substances spattered from the contact may accumulate in the vicinity, resulting in degradation of the insulation resistance of the circuit. Mounting the relay in the correct direction is also important in preventing this kind of degradation of the insulation resistance.

Contact reliability

Switching both a heavy and a minute load with a single relay contact is not recommended. The reason for this is that the substances scattered from the contact when the heavy load is switched degrade the contact when switching the minute load. For example, when using a multi-pole contact relay, avoid the mounting direction or terminal connections in which the minute load switching contact is located below the heavy load switching contact.

Mounting interval

When mounting multiple relays side by side on a PCB, pay attention to the following points:

- When multiple relays are mounted side by side, they may generate abnormally high heat due to the thermal interference between the relays. Provide an adequate distance between the relays to dissipate the heat. When using a relay, be sure to check the minimum mounting interval of the relay.
- If the multiple PCBs are mounted to a rack, the temperature may rise. In this case, preventive measures must be taken so that the ambient temperature falls within the rated value.

Notes on Correct Use

Conformal coating

Coating the PCB is recommended to prevent the circuitry from being degraded by harmful gases. When coating the PCB, care should be taken to avoid relay contamination. Otherwise, faulty contact of the relay may occur due to sticking or coating. Some coating agents may degrade or adversely affect the relay. Select the coating agent carefully.

Type of coating

	Applicability to PCB with relay mounted	Feature
Epoxy	Good	Good insulation. Applying this coating is a little difficult, but has no effect on relay contact.
Urethane	Good	Good insulation and easy to coat. Be careful not to allow the coating on the relay itself, as thinner-based solvents are often used with this coating.
Silicon	Poor*	Good insulation and easy to coat. However, silicon gas may cause contact contamination and mis-operation.

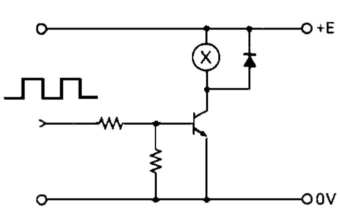
* Satisfactory for sealed, but totally unsatisfactory for unsealed relays.

Driving by Transistor

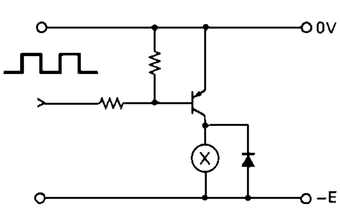
When a transistor is used to drive the relay, be sure to ground the emitter of the transistor.

When the transistor is used in emitter-follower configuration (i.e., the collector is grounded), give adequate consideration to the voltage across the collector and emitter. The required voltage must be applied to the relay.

NPN transistor

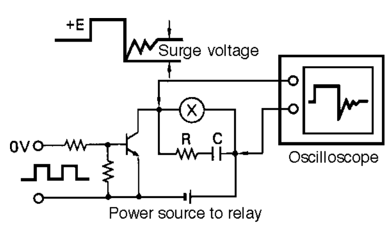


PNP transistor



Advice on selecting a transistor for driving the relay

1. From the relay catalog or data sheet, ascertain the following coil characteristics:
   Rated voltage ________ VDC
   Rated current ________ mA
   Coil resistance _______ Ω
2. Determine the lower- and upper-limit values of the pickup voltage from the rated voltage.
   Lower-limit pickup voltage _____V
   Upper-limit pickup voltage _____V
   (If surge is contained in the rated voltage, obtain the maximum value including the surge.)
3. By determining the component for suppressing surge, obtain the dielectric strength of the transistor for driving the relay.
   <In the case of diode>
   (Upper-limit of pickup voltage + 0.6) x 2* $\cong V_{CEO} \cong V_{CBO}$ = ___V
   <In the case of diode and zener diode>
   (Upper-limit of pickup voltage + 0.6 + breakdown voltage**) x 2* $\cong V_{CEO} \cong V_{CBO}$ = ___V
   <In the case of varistor>
   (Upper-limit pickup voltage + varistor voltage***) x 2* $\cong V_{CEO} \cong V_{CBO}$ = ___V
   <In the case of RC>
   (Upper-limit pickup voltage + surge voltage****) x 2* $\cong V_{CEO} \cong V_{CBO}$ = ___V



where,
R ≅ Coil resistance of relay (measured changing the value of C)
C = 0.01 to 0.2μF

4. Determine collector current Ic.
   Ic = Upper-limit pickup voltage/Coil resistance x 2*
5. Select the transistor that satisfies the conditions determined in steps 3 and 4.
6. After selecting the transistor, observe the I_C vs. V_{CE} characteristics of the transistor indicated in its ratings.

   The characteristic curve illustrates the relation between collector current I_C and collector-emitter voltage V_{CE} at base current I_B. From this graph, obtain collector-emitter voltage V_{CE} where,

   I_C = Maximum value of must operate voltage/Coil resistance

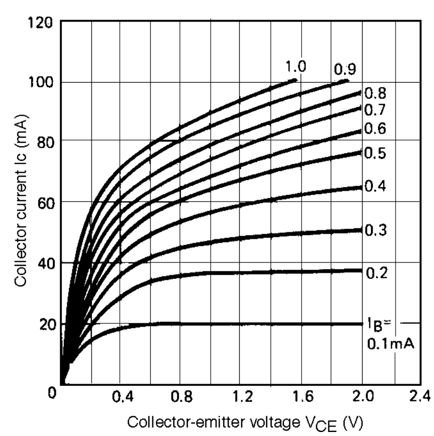
   I_B = Base current of the switching transistor which is determined by the driver stage.

   Thus, Collector-emitter voltage V_{CE} = V

   Use the transistor in its switching (saturation) area. An adequate base current is required.

* This safety factor must be determined by the user.
** The breakdown voltage differs depending on the component. If multiple zener diodes are to be used, use their maximum breakdown voltage.
*** The varistor voltage differs depending on the component. In addition, the varistor voltage of a single varistor may vary depending on the current. Consult the manufacturer of the varistor to be used to determine the varistor voltage.
**** The surge voltage differs depending on the type and rating of the relay, and tde`constants of C and R of the circuit in which the relay is used. Positively determine the surge voltage by experiment.

I_C vs. V_{CE} characteristics



Notes on Correct Use

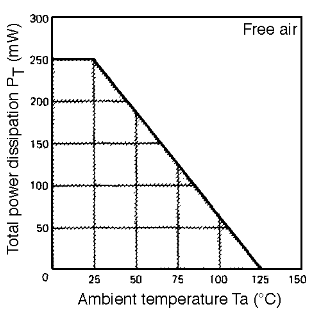
7. Using the following formula, calculate the power dissipated by the transistor to confirm that it is within the range of permissible power dissipation of the transistor.

   Total power dissipation P_T = Collector dissipation P_C + Base dissipation P_B where,

   P_C= Maximum value of pickup voltage/ Coil resistance x V_{CE}
   (V_{CE} is determined in step 6.)
   $P_B = I_B$ x 0.6 to 1
   (For details on I_B, refer to step 6.)

   Confirm that P_T obtained by the above formula is within the curve representing the total power dissipation vs. ambient temperature characteristics.

Total power dissipation vs. ambient temperature



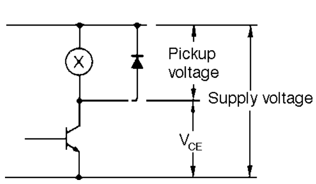
In case the total dissipation exceeds the permissible power dissipation, either attach a radiator plate to the transistor, or replace the transistor.

8. Determine the supply voltage to the relay.

   The maximum and minimum values of the supply voltage to the relay are determined by the following expressions using the upper- and lower-limit values of he pickup voltage V_{CE} obtained in step 6.

   Maximum supply voltage = Upper-limit pickup voltage + V_{CE}

   Minimum supply voltage = Lower-limit pickup voltage + V_{CE}



9. Verify that the following conditions are satisfied.

   V_{CEO} > (Maximum supply voltage + surge voltage) x safety factor*

   V_{CBO} > (Maximum supply voltage + surge voltage) x safety factor*

   * Determine the safety factor giving consideration to external surge (such as lightning and surge from other devices).

10. Check the following items during actual use of the relay.

    - Is the upper-limit value of the pickup voltage equal to or less than the rated value when the maximum supply voltage is applied?
    - Is the lower-limit value of the pickup voltage equal to or more than the rated value when the minimum supply voltage is applied?
    - Are the above conditions satisfied within the operating temperature range?
    - Is there any abnormality found in a test run?

    In addition to checking the above items, take into consideration the items listed in this table.

Rated voltage of relay	Low	High
Coil current*	High	Low
I_C of switching transistor	High	Low
V_{ECO}, V_{CEO} of switching transitistor**	Low	High
Driving current of transistor	High	Low
Voltage drop V_{CE} in transistor	High	Low
Total power dissipation P_T of transistor	High	Low

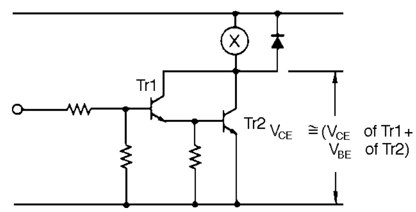
* Inversely proportional to voltage
** Often used V_{CEO}: 35 to 60 V

From the above discussion, the best relay coil should be rated at 12 VDC or 24 VDC when the relay is driven by a transistor.

Driving by Darlington-Connected Transistors

To reduce the current of the transistor to drive the relay (i.e., base current of the transistor), two transistors may be used, via Darlington connection. Darlington-connected transistors are available enclosed in a single package.

NPN-NPN Darlington Connection

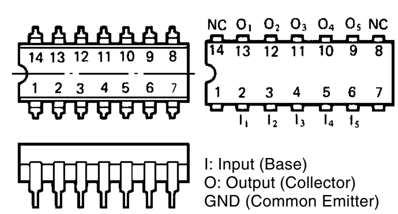


When the Darlington-connected transistors are used, the required value of V_{CE} is higher than when using a single transistor. For this reason, consideration must be given to designing the total power dissipation and supply voltage for the second transistor, Tr2.

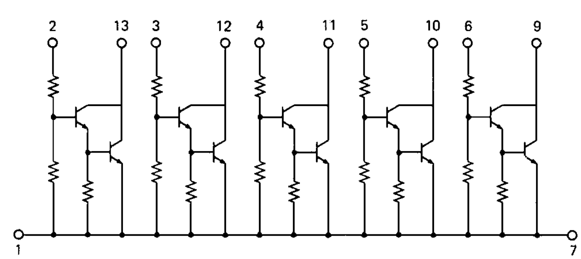
Driving by IC

Recently, an IC on which multiple driving transistors are integrated has become available. The designing of the circuit or PCB to drive multiple relays, a small-size solenoid, or a small-size lamp can be simplified by using this IC. Consult the manufacturer of the IC for details. For V_{CE}, refer to the description of the related voltage and surge suppressor.

Dimensions Connection (Top view)



Equivalent circuit



Notes on Correct Use

Driving by TTL

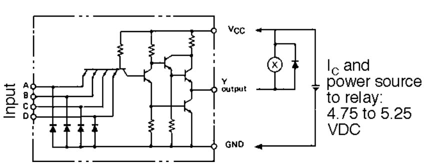
TTLs can be divided into two types by classification of the output: totem-pole and open-collector outputs. Connection of each type of TTL is described below.

Use a diode as surge suppressor.

In the specifications of some ICs, such a phrase as “fan-out 10” may be used in place of the legend I_{OL}. This denotes that 10 standard TTLs can be connected in parallel. In terms of current, fan-out 1 equals 1.6 mA. Hence,
Fan-out n = 1.6 x n (mA)

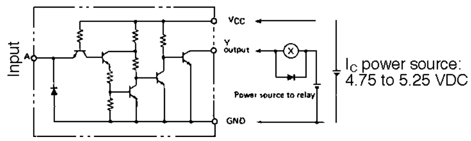
1. To drive a relay by the totem-pole output of a TTL, these conditions must be satisfied:
   - I_{OL} (low-level output current) > Maximum supply voltage/Coil resistance.
   - I_{OH} (high-level output current) < Rated current x pickup voltage (%)/Coil resistance
   - Minimum supply voltage (4.75 V) - Maximum V_{OL} (low-level output voltage) > Lower-limit value of pickup voltage (Refer to Driving by Transistor)

Totem-pole output



2. To drive a relay with open-collector output type TTL, a degree of freedom is allowed in the ratings of the relay coil. However, these, conditions must be satisfied:
   - I_{OL} > Maximum supply voltage to the relay coil/Coil resistance
   - I_{OH} < Rated current x pickup voltage (%)/200
   - V_O = Dielectric strength of the output transistor (Refer to Driving by Transistor.)
   - V_{OL} = Collector emitter voltage V_{CE} of the output transistor (Refer to Driving by Transistor.)

Open-collector output

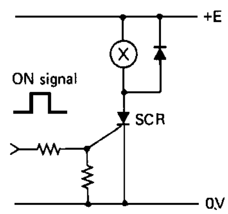


The above description of the standard TTL is applicable when using S, H, and LS type TTLs.

Driving by Other Switching Devices

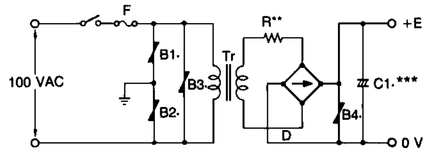
Consult the manufacturer of the switching device. The upper- and lower-limit values of the pickup voltage can be determined in the same manner as described in Upper-limit Pickup Voltage and Lower-limit Pickup Voltage.

Example of Driving by SCR



Designing Power Circuit

Since many documents and reference books on the power circuit are available, a detailed description is omitted here.

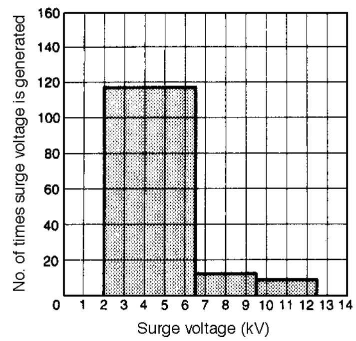


* In the circuit above, varistors B_1 and B_2 are used to protect the power circuit elements, as well as elements related to the power circuit, in case the voltage on the power line experiences surges (due to lightning or the surge voltage generated in other devices connected to the power circuit). Connect an appropriate surge suppressor across the output terminals of the power circuit to prevent a surge voltage from being generated. The surge suppressor must keep the surge voltage, if generated, from exceeding the breakdown voltage of each element in the power circuit.

** Resistor R protects diode bridge D from the inrush current that flows through the power circuit upon power application. Although the resistance of R is determined according to the resistance of the load coil and the ratings of the diodes, the use of a resistor having a resistance of 0.1 to 100 Ω is recommended.

*** C_1 is a smoothing capacitor. Its capacitance must be as large as possible to reduce the surge percentage.

Connection of Surge Suppressor



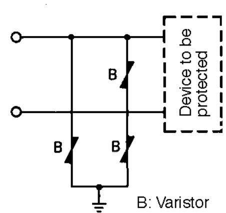
NOTE:
This graph is plotted by measuring the surge voltage in the line of low-tension overhead wiring (cable length: 200 to 500 m).

When connecting a surge suppressor, pay attention to the following points:

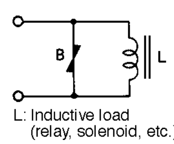
1. Place the surge suppressor near the device to be protected. For example, to protect a device from external surge, set the surge suppressor at the inlet of the device’s power cable.

   To suppress an internal surge, the suppressor must be placed near the surge generating source.

External surge



Internal surge

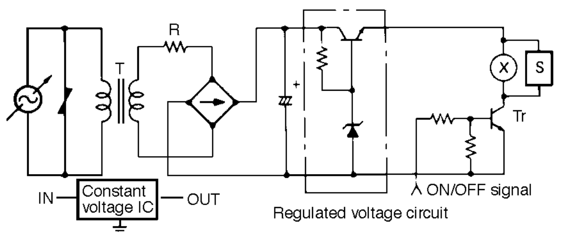


2. The cable for connecting the surge suppressor must be as short as possible in length, and thick enough in diameter so that it can sufficiently withstand the surge current. The short length and thick diameter are important to reduce the inductance and generated voltage, and to protect the device from heat damage.

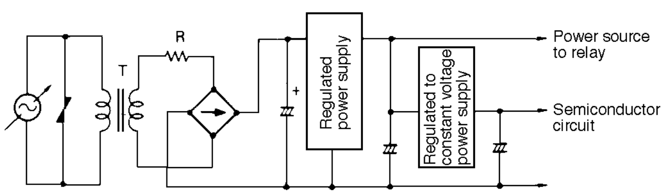
3. When using a surge suppressor between cable and ground, the lower the ground resistance of the surge suppressor, the better the protective effect of the surge suppressor. Perform grounding at a ground resistance of 10 Ω or less.

Countermeasures Against Supply Voltage Fluctuation

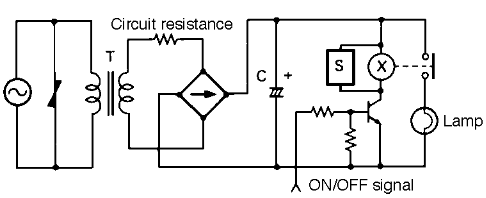
In case the supply voltage fluctuates heavily, insert a regulated voltage circuit or constant-voltage circuit in the application circuit as shown below.



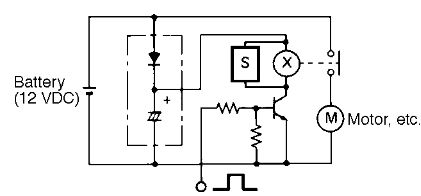
Relays consume more power than semiconductor elements. The following circuit configuration is recommended to improve the characteristics.



Countermeasures Against Inrush Current

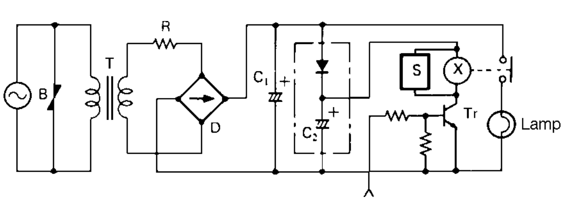


The same circuit also applies when the relay is driven by a battery.



If a load such as a capacitor or lamp through which an inrush current flows is connected to the power source and contact of the relay, the supply voltage may drop when the contact is closed, causing the relay to abnormally release.

Increasing the capacity of the transformer or providing an additional control circuit can be used to prevent this drop in the supply voltage. On some occasions, use of the following circuit may prevent voltage drop.

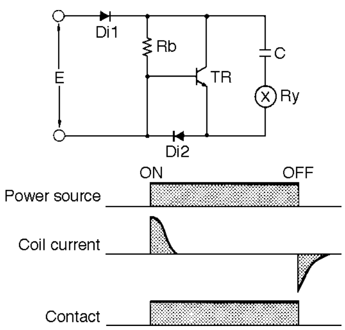


Notes on Correct Use

Designing Power-Conserving Driver Circuit with Single-Winding Latching Relay (Pat. 1239293)

This section introduces a patented drive circuit for the single-winding latching relay that can be driven on several milliwatts. This drive circuit not only allows the relay to be used in the same manner as semiconductor devices but also offers a wide range of applications.

Operating principle



Set

When a specified voltage is applied across E, the current flows through the circuit in the sequence of diode Di1, capacitor C, relay Ry, and diode Di2. C is then charged, setting the relay.

Energization

When C has been fully charged, the relay is biased by the current flowing from Di1 to Rb. C does not discharge. The power consumption at this time is very small, several milliwatts at best, and its value can be calculated as follows:

$P = (E–VF)^2/Rb$

where,
P: power consumption
VF: voltage drop across diode Di1

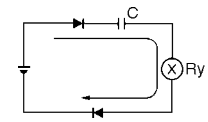
The current that is to flow through Rb at this time is dependent on the transfer ratio hfe of transistor TR which is required for TR to turn ON.

Reset

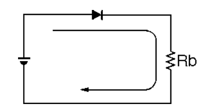
When the voltage placed across E is removed, the electricity charged in C is discharged, causing the current to flow through the circuit in the sequence of Rb, the base, and the emitter of TR. In this way, the relay is reset by the current flowing in the direction opposite to when the relay is set.

The following equivalent circuits respectively illustrate the current flows when the relay is set, energized, and reset.

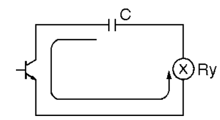
Set



Energization



Reset

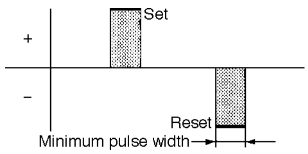


Notes on Correct Use

Circuit design

Fundamental

Generally, the latching relay is set and reset when a pulse having a square waveform is applied to it for a short time. The minimum pulse width required to set and reset the relay is predetermined.

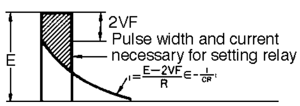


The charging current shown in the above equivalent circuit diagrams, has a sawtooth waveform that can be expressed by the following formula, because it is the primary circuit of C and R.

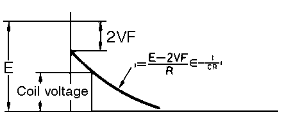
$i = E-2VF/R \in - 1/CRt$

(2 Forward voltage diode drops)

If applied voltage E and the rated coil voltage of the relay are the same, the current to the relay falls short by the quantity indicated by the shaded portion in the following figure.

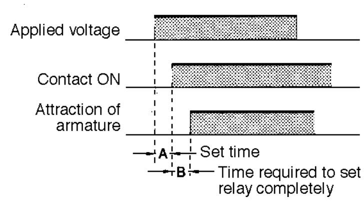


Therefore, the current must be applied to the relay as follows when designing this driver circuit.



Time constant

When the rated voltage is applied to the relay, time A in the timing chart below is required to turn ON the contacts. After this time has elapsed, time B is required until the armature attraction to the magnet is complete.

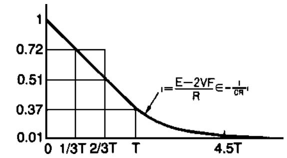


Therefore, it is apparent that time constant T obtained as the product of C and R must be equal to or longer than the sum of A and B. Actually, however, T should not be equal to the sum of A and B but must be longer than that to ensure the stable operation of the circuit. Thus,

$T = A + B + X$

where X is the time margin.

The set time A of OMRON's moving-loop relays (with a pickup power of 200 mW) is rated at about 3 milliseconds. Time constant T for them should be about three times that of A. The following graph illustrates this. This graph indicates that, if C is completely charged (I_{PEAK}), it takes 4.6T to discharge I to 1%. Note that time constant T is broken down into three segments. The first 1/3T equals A, the second 1/3T, B. The remaining 1/3T is the time margin expressed as X in the above equation. T is three times A.



Voltage drop E1 across the total resistance of the capacitance C's resistance and relay coil's internal resistance is the difference between the supply voltage E and voltage drops across two diodes:
Di1 and Di2. Hence,

$E1 = E – 2VF$

Assuming the supply voltage to be 5 V and VF to be 0.6 V,

$E1 = 5 – 2 \times 0.6 = 3.8$ V

From E1 and the above graph, the required coil voltage of a relay can be obtained. Again assuming the E, i.e., the supply voltage of a single-winding latching relay is 5 V, the coil voltage is:

$3.8 \times 0.72 = 2.7$ V

At this time, the capacitance of C is 246.9 µF, according to the equation shown in the above graph.

Notes on Correct Use

Coil ratings and capacitance of C

In the example, the coil voltage obtained by calculation is 2.7 V, which is 0.3 V less than the value at which the coil voltage of commercially available standard latching relay is rated. The standard coil voltages of relays at a supply voltage of 6, 9, 12, and 24 V can be respectively calculated in the same way. Table 1 compares the results of the calculation and the coil voltages of standard relays.

The calculated coil voltages significantly deviates from the standard values. It is therefore necessary to determine the time constant of the relay by adjusting the capacitance of C when the relay coil is to operate on the standard voltage.

As an example, calculate the capacitance of C and time constant T of a relay with a rated supply voltage of 5 V. The coil voltage E_1 has been calculated above (3.8 V). To determine how much current I flows through the coil at 3.8 V, from Table 1, note that the coil resistance is 45 Ω. So,

I = 3.8/45 = 84.4 mA

Therefore, the peak current of capacitor C to be used must be 84.4 mA.

Remember, that time A of an OMRON relay is 3 ms. Capacitance C must be a value that allows 66.6 mA to flow through 3 ms after 5 V is applied to the relay. Thus,

$66.6 = 84.4 \in {}^{1}/_{cx45}{}^{3x10-3}$

From this,

C = 280 µF

At this time, time constant T is:

$280 \times 10^{-6} \times 45 = 12.6$ ms

By calculating the C of each of the relays listed in Table 1, the values in Table 2 are obtained.

Again, these calculated capacitances deviate from the commercially available standard capacitors. There is no problem in using standard capacitors but, if the cost and circuit space permit, it is recommended to use two or more capacitors so that a capacitance as close to the calculated value as possible is obtained. At this time, pay attention to the following points:

Table 1

Supply voltage	Coil voltage (calculated)	Standard voltage	Coil resistance
5 V	2.7 V	3 V	45 Ω
6 V	3.5 V	3 V	45 Ω
9 V	5.6 V	5 V	125 Ω
12 V	7.8 V	6 V	405 Ω
24 V	16.4 V	12 V	720 Ω

Table 2

Supply voltage	Coil voltage (calculated)	Coil resistance	Capacitance of C
5 V	2.7 V	45 Ω	280 µF
6 V	3.5 V	45 Ω	142 µF
9 V	5.6 V	125 Ω	54 µF
12 V	7.8 V	405 Ω	40 µF
24 V	16.4 V	720 Ω	6.5 µF

- Confirm that the relay operates normally even when the supply voltage is brought to 80%-120% of the rated value.
- Even if a voltage of two or three times the rated voltage is applied to this driver circuit, the coil wire will not sever. That is why, for example, when the driver circuit is mounted in an automobile where a supply voltage of 12 VDC is available from the battery, it is recommended to use a relay whose coil voltage is rated at 6 VDC, taking a voltage fluctuation of 8 to 16 VDC into consideration.

Determining Rb

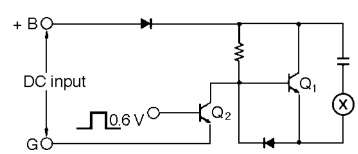
The current flows into Rb should be enough to turn ON TR when the relay is reset. When determining value of Rb, the following points must be noted:

- TR must be sufficiently turned ON even when T equals the time constant.
- Give adequate consideration to changes in hfe due to changes in ambient temperature.

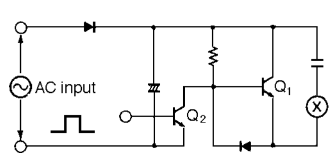
Simple as it is, the driver circuit introduced here can efficiently control the relay, consuming a tiny amount of power.

An experiment reveals that the relay sufficiently operates with a capacitance of 100 µF + 47 µF where the relay is rated at a supply voltage of 5 VDC and a coil voltage of 3 VDC. It can therefore be said that the capacitance can be lower than the calculated value. This is because the time constant is determined with a relatively wide margin. So it is recommended to perform experiments to determine the time constant.

Application circuit example



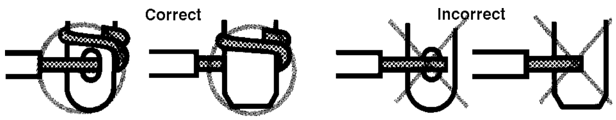
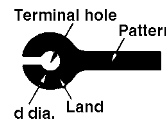
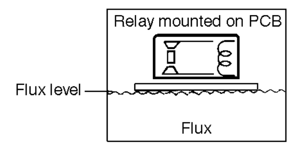
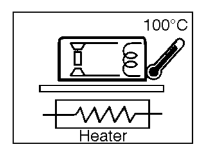
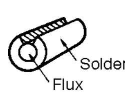
The TTL output of a solid-state switch can be used as Q_2.



Half-wave rectified AC power is applied to the circuit. Q_1 is the output of a TTL, and drives the relay.

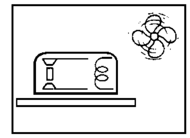
Mounting Relay on PCB

Manual soldering is the best way to mount the relay onto a PCB. However, depending on the construction of the relay, dip or automatic soldering can be performed. The following tables list the processes required for mounting the relay onto a PCB and the points to be noted in each process.

	Manual soldering	Automatic soldering
1. Connection and mounting	To connect a lead wire to the terminal or to mount the relay on a PC board, securely wind the lead wire around the terminal as shown.  	Process the land part of the printed circuit board as illustrated on the right to prevent the terminal hole of the relay from being filled with solder, and to improve the reliability of the solder connection. 
2. Flux application	Use an anticorrosive rosin-type flux or water washable organic fluxes with consideration given to the applicability of the flux to the relay's components. For flux solvent, use alcohol type, which is less chemically reactive. Apply flux sparingly and evenly to prevent penetration of solder flux into the relay. When dipping the relay terminals into solder flux, be sure to adjust the position of the flux level, so that the upper surface of the PC board is not flooded with flux.	
3. Preheating	—	Preheat the PC board to dry the applied flux at a temperature of 100°C max. 
4. Soldering	Complete soldering quickly and firmly with a soldering iron while smoothing the applied solder with the tip of the soldering iron. ■ Soldering iron: rated at 30 to 60 W ■ Tip temperature: 280 to 300°C ■ Soldering time: 3 sec. max. ■ The following is an example of the solders recommended for use in hand soldering.  The solder shown above is provided with a cut section to prevent flux from being scattered.	■ Flow soldering is recommended to assure uniform quality of soldering. ■ Solder temperature and soldering time: 260°C… 3 sec. max. ■ Adjust the position of the solder level so that the PC board is not flooded with solder.

Type	Sparkle solder V
Applicable solder diameter	0.03 to 0.06 in.
Sn	58.8%
Flux content	1.67%
Impurities	JIS Z 3282 Class A
Spread rate	90%
Storage	3 months max.

Mounting Relay on PCB

	Manual soldering	Automatic soldering
5. Cooling		Upon completion of the automatic soldering, forcibly cool the PC board with a fan, etc., so that the relay and other components on the PC board will not deteriorate from the inertial heat of soldering. 

6. General cleaning procedures

Avoid cleaning the solder terminals whenever possible. If cleaning cannot be avoided, exercise care in selecting an appropriate cleaning solvent. Some types of relays employ molding materials resistant to chemicals, and can be cleaned with chlorine or fluorine-based solvents. Direct solvent to only the soldered areas, in order to prevent the possibility of flux-contaminated solvent entering the relay.

Recommended cleaning solvents: Alcohol-based solvents.

List of cleaning methods

	Solvent	Unsealed	Semi-sealed	Fully-sealed
Chloride-based	■ Perochlene ■ Trichloroethane ■ Trichloroethylene	No	●	Yes
Water-based	■ Indusco ■ Holys	No	No	Yes
Alcohol-based	■ IPA ■ Ethanol	No	●	Yes
Cleaning method		Cleaning is not recommended	Automatic cleaning	Automatic cleaning

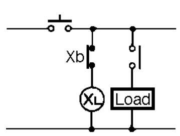
NOTE: 1. Contact Omron representative for recommended cleaning procedures of specific relays.
2. ● Consult Factory.

Latching Relays

Notes on Drive Circuit

Double-winding type (MY, MK)

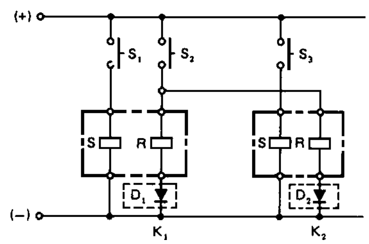
- When a DC-switching latching relay is used in one of the circuits shown at the right, the relay contacts may be released from the locked state unless a diode (enclosed in the dotted box in the circuit diagram) is connected to the circuit.
- When connecting a diode to the relay circuit, be sure to use a diode with a repetitive peak-inverse voltage, and a DC reverse voltage sufficient to withstand external noise or surge. Determine also that the diode has an average rectified current greater than the coil current.
- If the contact of the relay is used to de-energize the relay, the relay may not operate normally. Avoid using the relay in a circuit as shown:



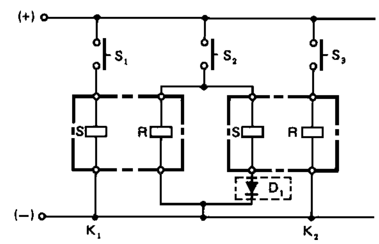
X_L: Latching relay
Xb: NC contact of relay

Notes on Circuit

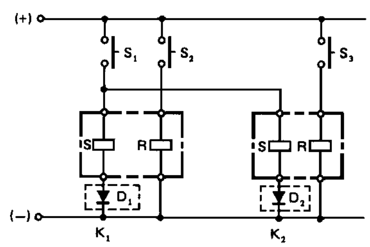
Circuit connecting two reset coils in parallel



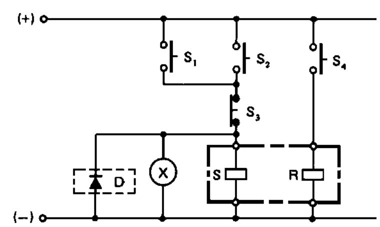
Circuit connecting set coil to reset coil



Circuit connecting two set coils in parallel



Circuit connecting set coil of latching relay in parallel with another relay coil



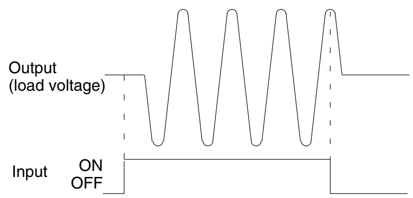
Hints on Correct Use

- Avoid use in locations subject to excessive magnetic particles or dust.
- Avoid use in a magnetic field (over 8,000 A/m)
- Give thought to preventing problems caused by vibration or shock. Consider that these problems may originate from other relay(s) operating or releasing on the same panel.
- Avoid simultaneous energization of the set and reset coils, even though both coils can be continuously energized.
- Avoid use under conditions where excessive surge-generating sources exist in the coil power source.
- When planning to mount multiple relays side-by-side, observe the minimum mounting interval of each type of the relay.

Solid State Relays — Precautions and Notes on Correct Use

Zero Cross Function

An SSR with a zero cross function operates when the AC load voltage approaches the zero point or its vicinity and releases when the current reaches the zero point. An SSR with a zero cross function reduces clicking noises that may be generated when the load is turned ON.



Life Expectancy (MTTF)

The mean time to failure (MTTF) of SSRs is 100,000 hours, which varies with the operating conditions. To ensure long life and stable operation, take proper countermeasures against extremely high or low operating temperature, heavy fluctuations of ambient temperature, and/or long continuous energization.

> ⚠ **WARNING**
>
> Do not touch the SSR terminal section (charged section) when the power supply is ON. For SSRs with terminal covers, be sure to attach the cover before use. Touching the charged section may cause electric shock.
>
> Do not touch the SSR or the heat sink either while the power supply is ON, or immediately after the power is turned OFF. The SSR/heat sink will be hot and will cause burns.
>
> Do not touch the SSR LOAD terminal immediately after the power is turned OFF. The internal snubber circuit is charged and may cause electric shock.

- Do not apply excessive voltage or current to the SSR input or output circuits, or SSR malfunction or fire damage may result.
- Do not operate if the screws on the output terminal are loose, or heat generated by a terminal error may result in fire damage.
- Do not obstruct the air flow to the SSR or heat sink, or heat generated from an SSR error may cause the output element to short, or cause fire damage.
- Be sure to conduct wiring with the power supply turned OFF, or electric shock may result.
- Follow the *Correct Use* section when conducting wiring and soldering. If the product is used before wiring or soldering are complete, heat generated from a power supply error may cause fire damage.
- When installing the SSR directly into a control panel so that the panel can be used as a heat sink, use a panel material with low thermal resistance such as aluminum or steel. If a material with high thermal resistance such as wood is used, heat generated by the SSR may cause fire or burning.

Before Using the SSR

1. Unexpected events may occur before the SSR is used. For this reason it is important to test the SSR in all possible environments. For example, the features of the SSR will vary according to the product being used.
2. All rated performance values listed in this catalog, unless otherwise stated, are all under the JIS C5442 standard test environment (15° to 30°C, 25% to 85% relative humidity, and 86 to 106 kPa atmosphere). When checking these values on the actual devices, it is important to ensure that not only the load conditions, but also the operating environmental conditions are adhered to.

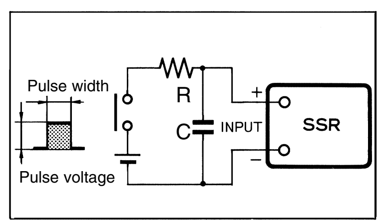
Input Circuit

Input noise

SSRs need only a small amount of power to operate. This is why the input terminals must shut out electrical noise as much as possible. Noise applied to the input terminals may result in malfunction. The following describe measures to be taken against pulse noise and inductive noise.

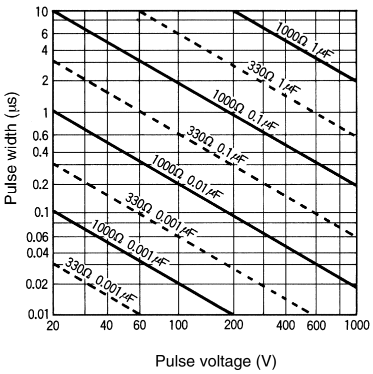
1. Pulse Noise

A combination of capacitor and resistor can absorb pulse noise effectively. The following is an example of a noise absorption circuit with capacitor C and resistor R connected to an SSR incorporating a photocoupler.



The value of R and C must be decided carefully. The value of R must not be too large, or the supply voltage (E) will not be able to satisfy the required input voltage value.

The larger the value of C is, the longer the release time will be, due to the time required for C to discharge electricity.



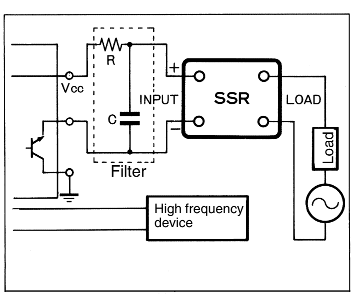
Note: For low-voltage models, sufficient voltage may not be applied to the SSR because of the relationship between C, R, and the internal impedance. When deciding on a value for R, check the input impedance for the SSR.

2. Inductive Noise

Do not wire power lines alongside the input lines. Inductive noise may cause the SSR to malfunction. If inductive noise is imposed on the input terminals of the SSR, use the following cables according to the type of inductive noise, and reduce the noise level to less than the reset voltage of the SSR.

Twisted-pair wire: For electromagnetic noise
Shielded cable: For static noise

A filter consisting of a combination of capacitor and resistor will effectively reduce noise generated from high-frequency equipment.

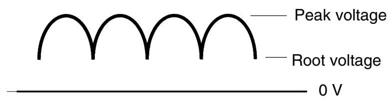


Note: R: 20 to 100 Ω
C: 0.01 to 1 μF

Input conditions

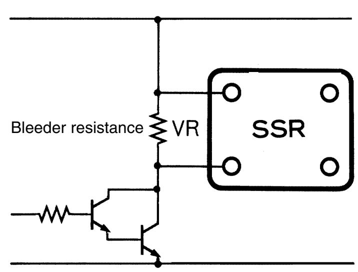
1. Input Voltage Ripples

When there is a ripple in the input voltage, set so that the peak voltage is lower than the maximum operating voltage and the root voltage is above the minimum operating voltage.



2. Countermeasures for Leakage Current

When the SSR is powered by transistor output, the reset voltage may be insufficient due to leakage current during power OFF. To counteract this, connect bleeder resistance (as shown in the diagram below) and set the bleeder resistance so that VR is 0.5 V or less.



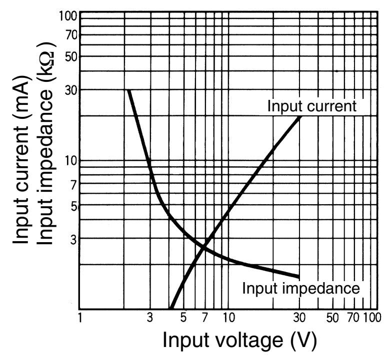
3. ON/OFF Frequency

The ON/OFF frequency should be set to 10 Hz maximum for AC load ON/OFF and 100 Hz maximum for DC load ON/OFF. If ON/OFF occurs at frequencies exceeding these values, SSR output will not be able to follow-up.

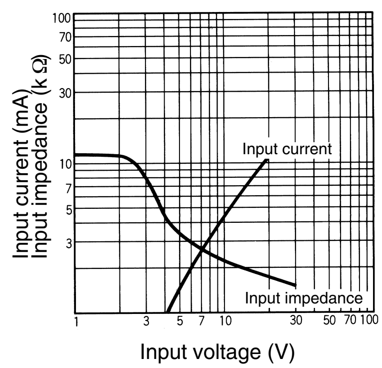
4. Input Impedance

In SSRs which have wide input voltages (such as G3F and G3H), the input impedance varies according to the input voltage and changes in the input current. For semiconductor-driven SSRs, changes in voltage can cause malfunction of the semiconductor, so be sure to check the actual device before usage. See the following examples.

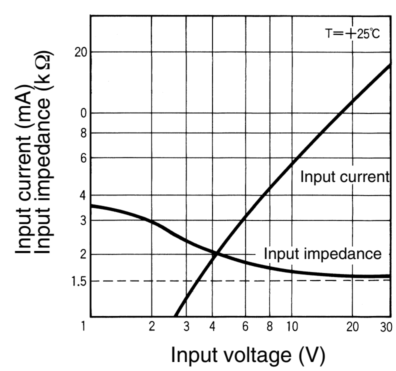
Applicable Input Impedance for a Photocoupler-type SSR without Indicators (Example)
G3F, G3H (Without Indicators)



Applicable Input Impedance for a Photocoupler-type SSR with Indicators (Example)
G3B, G3F, G3H (With Indicators)



Applicable Input Impedance (Example)
G3CN



Solid State Relays — Precautions and Notes on Correct Use

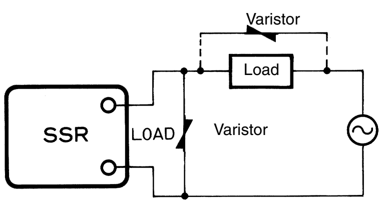
Output Circuit

AC ON/OFF SSR output noise surges

If there is a large voltage surge in the AC current being used by the SSR, the C/R snubber circuit built into the SSR between the SSR load terminals will not be sufficient to suppress the surge, and the SSR transient peak element voltage will be exceeded, causing overvoltage damage to the SSR.

Only the following models don't have a built-in surge absorbing varistor: G3NA, G3S, G3PA, G3NE, G3JC, G3NH, G9H, G3DZ (in part), G3RZ, and G3FM. When switching the inductive load ON and OFF, be sure to take countermeasures against surge, such as adding a surge absorbing element.

In the following example, a surge voltage absorbing element is added.

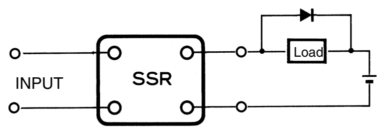


Select an element which meets the conditions in the table below as the surge absorbing element.

Voltage	Varistor voltage	Surge resistance
10 to 120 VAC	240 to 270 V	1,000 A min.
200 to 240 VAC	440 to 470 V	
380 to 480 VAC	820 to 1,000 VAC	

DC ON/OFF SSR output noise surges

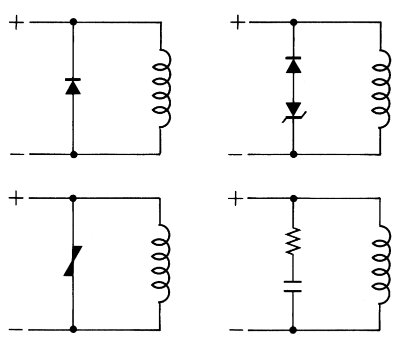
When an L load, such as a solenoid or electromagnetic valve is connected, connect a diode that prevents counter-electromotive force. If the counter-electromotive force exceeds the withstand voltage of the SSR output element, it could result in damage to the SSR output element. To prevent this, insert the element parallel to the load, as shown in the following diagram and table.



As an absorption element, the diode is the most effective at suppressing the counter-electromotive force. The release time for the solenoid or electromagnetic valve will, however, increase. Be sure to check the circuit before use. To shorten the time, connect a Zener diode and a regular diode in series. The release time will be shortened at the same rate that the Zener voltage (Vz) of the Zener diode is increased.

- Absorption Element example

Absorption element	Diode	Diode + Zener diode	Varistor	CR
Effectiveness	○	○	△	×



(Reference)

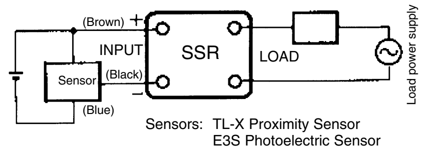
1. Selecting a Diode
   Withstand voltage = $V_{RM} \geq$ Power supply voltage × 2
   Forward current = $I_F \geq$ load current
2. Selecting a Zener Diode
   Zener voltage = Vz < SSR withstand voltage – (Power supply voltage + 2 V)
   Zener surge power = P_{RSM} > Vz × Load current × Safety factor (2 to 3)

Note: When the Zener voltage is increased (Vz), the Zener diode capacity (P_{RSM}) is also increased.

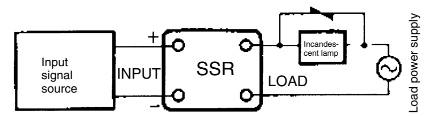
Application Circuit Examples

Connection to sensor

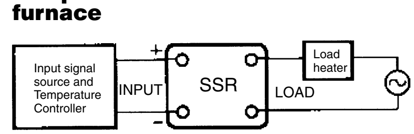
The SSR connects directly to the Proximity Sensor and Photoelectric Sensor.



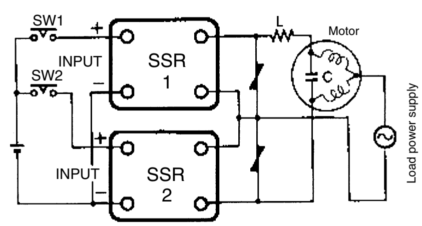
Switching control of incandescent lamp



Temperature control of electric furnace

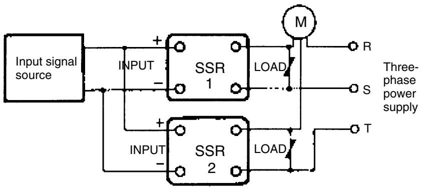


Forward and reverse operation of single-phase inductive motor



Note: 1. The voltage between the load terminals of either SSR 1 or SSR 2 turned OFF is approximately twice as high as the supply voltage due to LC coupling. Be sure to apply an SSR model with a rated output voltage of at least twice the supply voltage.
For example, if the motor operates at a supply voltage of 100 VAC, the SSR must have an output voltage of 200 VAC or higher.
2. Make sure that there is a time lag of 30 ms or more to switch over SW1 and SW2.

ON/OFF control of three-phase inductive motor



Forward and reverse operation of three-phase inductive motor

Make sure that signals input into the SSR Units are proper if the SSR Units are applied to the forward and reverse operation of a three-phase motor. If SW1 and SW2 as shown in the following circuit diagram are switched over simultaneously, a phase short-circuit will result on the load side, which may damage the output elements of the SSR Units. This is because the SSR has a triac as an output element that is turned ON until the load current becomes zero regardless of the absence of input signals into the SSR.

Therefore, make sure that there is a time lag of 30 ms or more to switch over SW1 and SW2.

The SSR may be damaged due to phase short-circuiting if the SSR malfunctions with noise in the input circuit of the SSR. To protect the SSR from phase short-circuiting damage, the protective resistance R may be inserted into the circuit.

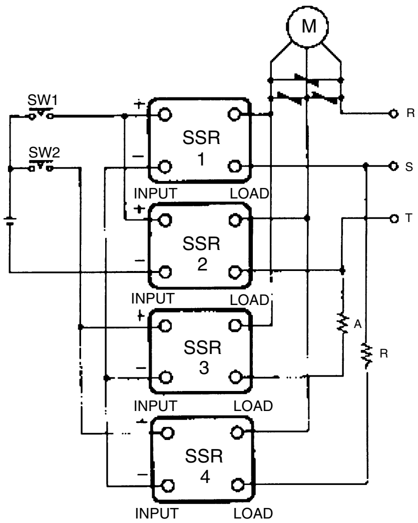
The value of the protective resistance R must be determined according to the withstanding inrush current of the SSR. For example, the G3NA-220B withstands an inrush current of 220 A. The value of the protective resistance R is obtained from the following.

$R > 220V \times \sqrt{2} / 200A = 1.4\ \Omega$

Considering the circuit current and weld time, insert the protective resistance into the side that reduces the current consumption.

Obtain the consumption power of the resistance from the following.

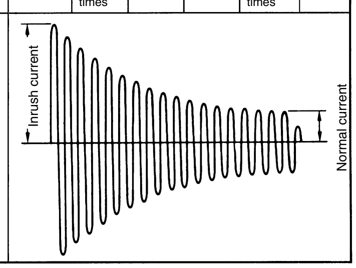
$P = I^2R \times$ Safety factor
(I = Load current, R = Protective resistance, Safety factor = 3 to 5)



Selecting an SSR with differing loads

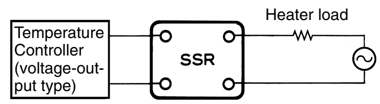
The following provides examples of the inrush currents for different loads.

• AC Load and Inrush Current

Load	Solenoid	Incandescent lamp	Motor	Relay	Capacitor	Resistance load
Inrush current/ Normal current	Approx. 10 times	Approx. 10 to 15 times	Approx. 5 to 10 times	Approx. 2 to 3 times	Approx. 20 to 50 times	1
Waveform						

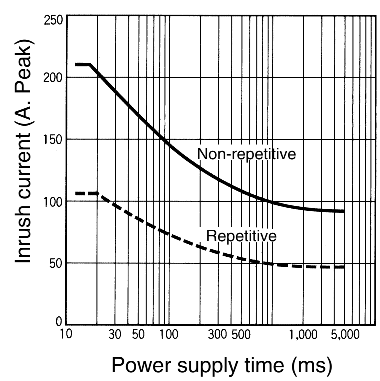
1. Heater Load (Resistance Load)

Load without an inrush current. Generally used together with a voltage-output temperature controller for heater ON/OFF switching. When used with an SSR with zero cross function, suppresses most noise generated. This type of load does not, however, include all-metal and ceramic heaters. Since the resistance values at normal temperatures of all-metal and ceramic heaters are low, an overcurrent will occur in the SSR, causing damage. For switching of all-metal and ceramic heaters, select a Power Controller (G3PX) with a long soft-start time, or a constant current type switch.



2. Lamp Load

Large inrush current flows through incandescent lamps, halogen lamps, and so on (approx. 10 to 15 times higher than the rated current value). Select an SSR so that the peak value of inrush current does not exceed half the inrush current resistance of the SSR. Refer to "Repetitive" (indicated by dashed lines) shown in the following figure. When a repetitive inrush current of greater than half the inrush current resistance is applied, the output element of the SSR may be damaged.



3. Motor Load

When a motor is started, an inrush current of 5 to 10 times the rated current flows and the inrush current flows for a longer time. In addition to measuring the startup time of the motor or the inrush current during use, ensure that the peak value of the inrush current is less than half the inrush current resistance when selecting an SSR. The SSR may be damaged by counter-electromotive force from the motor. So when the SSR is turned OFF, be sure to install overcurrent protection.

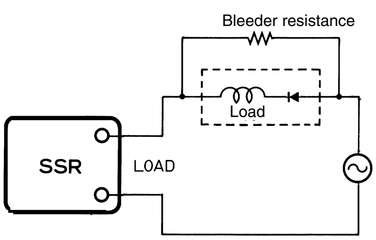
4. Transistor Load

When the SSR is switched ON, an energizing current of 10 to 20 times the rated current flows through the SSR for 10 to 500 ms. If there is no load in the secondary circuit, the energizing current will reach the maximum value. Select an SSR so that the energizing current does not exceed half the inrush current resistance of the SSR.

5. Half-wave Rectifying Circuit

AC electromagnetic counters and solenoids have built-in diodes, which act as half-wave rectifiers. For these types of loads, a half-wave AC voltage does not reach the SSR output. For SSRs with the zero cross function, this can cause them not to turn ON. Two methods for counteracting this problem are described below.

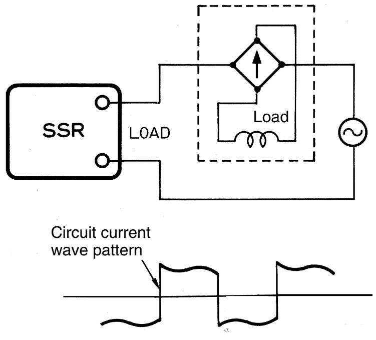
(a) Connect a bleeder resistance with approximately 20% of the SSR load current.



(b) Use SSRs without the zero cross function.

6. Full-wave Rectified Loads

AC electromagnetic counters and solenoids have built-in diodes which act as full-wave rectifiers. The load current for these types of loads has a rectangular wave pattern, as shown in the diagram which follows.



Accordingly, AC SSRs use a triac (which turns OFF the element only when the circuit current is 0 A) in the output element. If the load current waveform is rectangular, it will result in a SSR reset error. When switching ON and OFF a load whose waves are all rectified, use a -V model or Power MOS FET Relay.

-V model SSRs:	G3F-203SL-V G3H-203SL-V
Power MOS FET Relay:	G3DZ, G3RZ G3FM

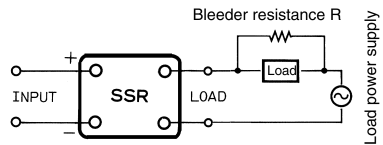
7. Small-capacity Loads

Even when there is no input signal to the SSR there is a small leakage current (I_L) from the SSR output (LOAD). If this leakage current is larger than the load release current the SSR may fail to reset.

Connect the bleeder resistance R in parallel to increase the SSR switching current.

Load (relays etc.) release voltage
Load (relays etc.) release current

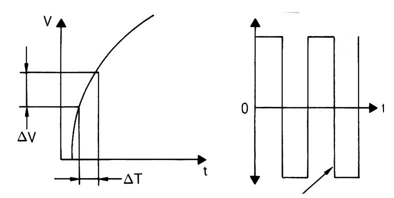
$R < \frac{E}{I_L - I}$ E: Load (relays etc.) reset voltage
I: Load (relays etc.) reset current



Bleeder resistance standards:
100-VAC power supply, 5 to 10 kΩ, 3 W
200-VAC power supply, 5 to 10 kΩ, 15 W

8. Inverter Load

Do not use an inverter-controlled power supply as the load power supply for the SSR. Inverter-controlled waveforms become rectangular, so the dV/dt ratio is extremely large and the SSR may fail to reset. An inverter-controlled power supply may be used on the input side provided the effective voltage is within the normal operating voltage range of the SSR.



Voltage increase ratio

The dV/dt ratio tends to infinity, so the SSR will not turn OFF.

$\Delta V/\Delta T = dV/dt$: voltage increase ratio

9. Capacitive Load

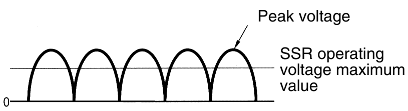
The supply voltage plus the charge voltage of the capacitor is applied to both ends of the SSR when it is OFF. Therefore, use an SSR model with an input voltage rating twice the size of the supply voltage.

Limit the charge current of the capacitor to less than half the peak inrush current value allowed for the SSR.

Load Power Supply

Rectified currents

If a DC load power supply is used for full-wave or half-wave rectified AC currents, be sure that the peak load current does not exceed the maximum usage load power supply of the SSR. Otherwise, overvoltage will cause damage to the output element of the SSR.



Operating frequency for AC load power supply

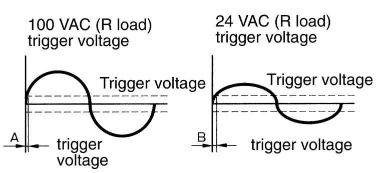
The operating frequency range for AC load power supply is 47 to 63 Hz.

Low AC voltage loads

If the load power supply is used under voltage below the minimum operating load voltage of the SSR, the loss time of the voltage applied to the load will become longer than that of SSR operating voltage range. See the following load example. (The loss time is A < B.)

Make sure that this loss time will not cause problems, before operating the SSR.

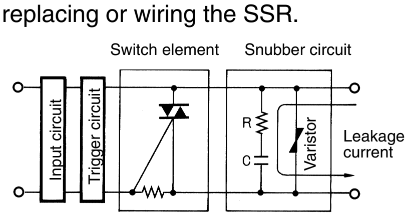
If the load voltage falls below the trigger voltage the SSR will not turn ON, so be sure to set the load voltage to 24 VAC minimum. (Except for G3PA-VD and G3NA-2□□B.)



Operation

Leakage current

A leakage current flows through a snubber circuit in the SSR even when there is no power input. Therefore, always turn OFF the power to the input or load and check that it is safe before replacing or wiring the SSR.



Fail-safe Concept

Error mode

The SSR is an optimum relay for high-frequency switching and high-speed switching, but misuse or mishandling of the SSR may damage the elements and cause other problems. The SSR consists of semiconductor elements, and will break down if these elements are damaged by surge voltage or overcurrent. Most faults associated with the elements Xare short-circuit malfunctions, whereby the load cannot be turned OFF.

Therefore, to provide a fail-safe feature for a control circuit using an SSR, design a circuit in which a contactor or circuit breaker on the load power supply side will turn OFF the load when the SSR causes an error. Do not design a circuit that only turns OFF the load power supply with the SSR. For example, if the SSR causes a half-wave error in a circuit in which an AC motor is connected as a load, DC energizing may cause overcurrent to flow through the motor, thus burning the motor. To prevent this from occurring, design a circuit in which a circuit breaker stops overcurrent to the motor.

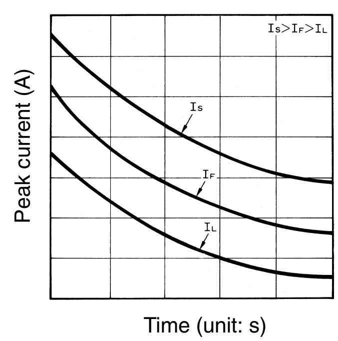
Location	Cause	Result
Input area	Overvoltage	Input element damage
Output area	Overvoltage	Output element damage
	Overcurrent	
Whole Unit	Ambient temperature exceeding maximum	Output element damage
	Poor heat radiation	

SSR mounting panel quality

If G3NA or G3NE SSRs are to be mounted directly onto the control panel, without the use of a radiator, be sure to use a panel material with low thermal resistance such as aluminum or steel. Do not mount the SSR on a panel with high thermal resistance such as a panel coated with paint. Doing so will decrease the radiation efficiency of the SSR, causing heat damage to the SSR output element. Do not mount the SSR on a panel made of wood or any other flammable material. Otherwise the heat generated by the SSR will cause the wood to carbonize, and may cause a fire.

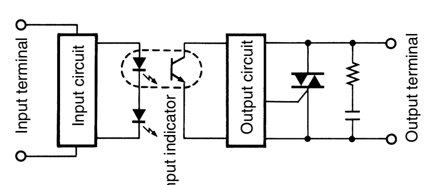
Overcurrent protection

A short-circuit current or an overcurrent flowing through the load of the SSR will damage the output element of the SSR. Connect a quick-break fuse in series with the load as an overcurrent protection measure. Design a circuit so that the protection coordination conditions for the quick-break fuse satisfy the relationship between the SSR surge resistance (I_S), quick-break fuse current-limiting feature (I_F), and the load inrush current (I_L), shown in the following chart.



Operation indicator

The operation indicator turns ON when current flows through the input circuit. It does not indicate that the output element is ON.



SSR life expectancy

The SSR is not subject to mechanical wear. Therefore, the life expectancy of the SSR depends on the rate of internal component malfunction. For example, the rate for the G3M-202P is 321 Fit (1 Fit = 10^{-9} = λ (malfunctions/time)). The MTTF calculated from this value is as follows:

MTTF = 321 /λ_{60} = 3.12 x 10^{6} (time)

The effects of heat on the solder also need to be considered in estimating the total life expectancy of the SSR. The solder deteriorates due to heat-stress from a number of causes. OMRON estimates that the SSR begins to malfunction due to solder deterioration approximately 10 years after it is first installed.

Terms and Conditions of Sale

1. Offer; Acceptance. These terms and conditions (these "Terms") are deemed part of all quotations, acknowledgments, invoices, purchase orders and other documents, whether electronic or in writing, relating to the sale of products or services (collectively, the "Products") by Omron Electronic Components LLC ("Seller"). Seller hereby objects to any terms or conditions proposed in Buyer's purchase order or other documents which are inconsistent with, or in addition to, these Terms.
2. Prices; Payment. All prices stated are current, subject to change without notice by Seller. Buyer agrees to pay the price in effect at time of shipment. Payments for Products received are due net 30 days unless otherwise stated in the invoice.
3. Discounts. Cash discounts, if any, will apply only on the net amount of invoices sent to Buyer after deducting transportation charges, taxes and duties, and will be allowed only if (i) the invoice is paid according to Seller's payment terms and (ii) Buyer has no past due amounts owing to Seller.
4. Currencies. If the prices quoted herein are in a currency other than U.S. dollars, Buyer shall make remittance to Seller at the then current exchange rate most favorable to Seller and which is available on the due date; provided that if remittance is not made when due, Buyer will convert the amount to U.S. dollars at the then current exchange rate most favorable to Seller available during the period between the due date and the date remittance is actually made.
5. Governmental Approvals. Buyer shall be responsible for, and shall bear all costs involved in, obtaining any government approvals required for the importation or sale of the Products.
6. Taxes. All taxes, duties and other governmental charges (other than general real property and income taxes), including any interest or penalties thereon, imposed directly or indirectly on Seller or required to be collected directly or indirectly by Seller for the manufacture, production, sale, delivery, importation, consumption or use of the Products sold hereunder (including customs duties and sales, excise, use, turnover and license taxes) shall be charged to and remitted by Buyer to Seller.
7. Financial. If the financial position of Buyer at any time becomes unsatisfactory to Seller, Seller reserves the right to stop shipments or require satisfactory security or payment in advance. If Buyer fails to make payment or otherwise comply with these Terms or any related agreement, Seller may (without liability and in addition to other remedies) cancel any unshipped portion of Products sold hereunder and stop any Products in transit until Buyer pays all amounts, including amounts payable hereunder, whether or not then due, which are owing to it by Buyer. Buyer shall in any event remain liable for all unpaid accounts.
8. Cancellation; Etc. Orders are not subject to rescheduling or cancellation unless Buyer indemnifies Seller fully against all costs or expenses arising in connection therewith.
9. Force Majeure. Seller shall not be liable for any delay or failure in delivery resulting from causes beyond its control, including earthquakes, fires, floods, strikes or other labor disputes, shortage of labor or materials, accidents to machinery, acts of sabotage, riots, delay in or lack of transportation or the requirements of any government authority.
10. Shipping; Delivery. Unless otherwise expressly agreed in writing by Seller:
    1. Shipments shall be by a carrier selected by Seller;
    2. Such carrier shall act as the agent of Buyer and delivery to such carrier shall constitute delivery to Buyer;
    3. All sales and shipments of Products shall be FOB shipping point (unless otherwise stated in writing by Seller), at which point title to and all risk of loss of the Products shall pass from Seller to Buyer, provided that Seller shall retain a security interest in the Products until the full purchase price is paid by Buyer;
    4. Delivery and shipping dates are estimates only.
    5. Seller will package Products as it deems proper for protection against normal handling and extra charges apply to special conditions.
11. Claims. Any claim by Buyer against Seller for shortage or damage to the Products occurring before delivery to the carrier must be presented in writing to Seller within 30 days of receipt of shipment and include the original transportation bill signed by the carrier noting that the carrier received the Products from Seller in the condition claimed.
12. Warranties. (a) Exclusive Warranty. Seller's exclusive warranty is that the Products will be free from defects in materials and workmanship for a period of twelve months from the date of sale by Seller (or such other period expressed in writing by Seller). Seller disclaims all other warranties, express or implied. (b) Limitations. SELLER MAKES NO WARRANTY OR REPRESENTATION, EXPRESS OR IMPLIED, ABOUT NON-INFRINGEMENT, MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OF THE PRODUCTS. BUYER ACKNOWLEDGES THAT IT ALONE HAS DETERMINED THAT THE PRODUCTS WILL SUITABLY MEET THE REQUIREMENTS OF THEIR INTENDED USE. Seller further disclaims all warranties and responsibility of any type for claims or expenses based on infringement by the Products or otherwise of any intellectual property right. (c) Buyer Remedy. Seller's sole obligation hereunder shall be to replace (in the form originally shipped with Buyer responsible for labor charges for removal or replacement thereof) the non-complying Product or, at Seller's election, to repay or credit Buyer an amount equal to the purchase price of the Product; provided that in no event shall Seller be responsible for warranty, repair, indemnity or any other claims or expenses regarding the Products unless Seller's analysis confirms that the Products were properly handled, stored, installed and maintained and not subject to contamination, abuse, misuse or inappropriate modification. Return of any Products by Buyer must be approved in writing by Seller before shipment. Seller shall not be liable for the suitability or unsuitability or the results from the use of Products in combination with any electrical or electronic components, circuits, system assemblies, or any other materials or substances or environments. Any advice, recommendations or information given orally or in writing are not to be construed as an amendment or addition to the above warranty.
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Certain Precautions on Specifications and Use

1. Suitability for Use. Seller shall not be responsible for conformity with any standards, codes or regulations which apply to the combination of the Product in Buyer's application or use of the Product. At Buyer's request, Seller will provide applicable third party certification documents identifying ratings and limitations of use which apply to the Product. This information by itself is not sufficient for a complete determination of the suitability of the Product in combination with the end product, machine, system, or other application or use. Buyer shall be solely responsible for determining appropriateness of the particular Product with respect to Buyer's application, product or system. Buyer shall take application responsibility in all cases but the following is a non-exhaustive list of applications for which particular attention must be given:
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   (ii) Energy control systems, combustion systems, railroad systems, aviation systems, medical equipment, amusement machines, vehicles, safety equipment, and installations subject to separate industry or government regulations.
   (iii) Use in consumer products or any use in significant quantities.
   (iv) Systems, machines and equipment that could present a risk to life or property. Please know and observe all prohibitions of use applicable to this product.
   NEVER USE THE PRODUCT FOR AN APPLICATION INVOLVING SERIOUS RISK TO LIFE OR PROPERTY WITHOUT ENSURING THAT THE SYSTEM AS A WHOLE HAS BEEN DESIGNED TO ADDRESS THE RISKS, AND THAT THE OMRON PRODUCT IS PROPERLY RATED AND INSTALLED FOR THE INTENDED USE WITHIN THE OVERALL EQUIPMENT OR SYSTEM.
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