

## Solid State Relays

# Technical Information

### 1 What are Solid State Relays?

#### (1) Difference between Solid State Relays and Mechanical Relays

Solid State Relays (SSRs) have no movable contacts. Solid State Relays are not very different in operation from mechanical relays that have movable contacts. SSRs, however, employ semiconductor switching elements, such as thyristors, triacs, diodes, and transistors. Furthermore, SSRs employ optical semiconductors called photocouplers to isolate input and output signals. Photocouplers change electric signals into optical signals and relay the signals through space, thus fully isolating the input and output sections while relaying the signals at high speed.

SSRs consist of electronic parts with no mechanical contacts. Therefore, SSRs have a variety of features that mechanical relays do not incorporate. The greatest feature of SSRs is that SSRs do not use switching contacts that will physically wear out.

SSRs are ideal for a wide range of applications due to the following performance characteristics.

- They provide high-speed, high-frequency switching operations.
- They have no contact failures.
- They generate little noise.
- They have no arc noise.

#### (2) Control of SSRs (ON/OFF Control, Cycle Control, Phase Control)

ON/OFF control is a form of control where a heater is turned ON or OFF by turning an SSR ON or OFF in response to voltage output signals from a Temperature Controller. The same kind of control is also possible with an electromagnetic relay but if control where the heater is turned ON and OFF at intervals of a few seconds over a period of several years, then an SSR must be used.

With cycle control (G32A-EA), output voltage is turned ON/OFF at a fixed interval of 0.2 s. Control is performed in response to current output from a Temperature Controller in the range 4 to 20 mA.

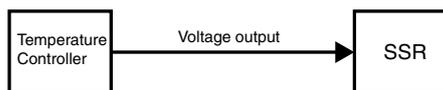
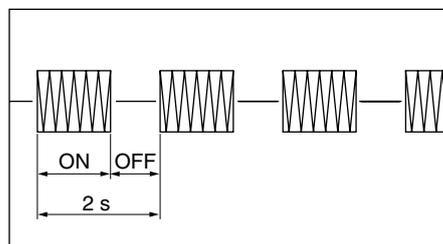
##### Note Precaution for Cycle Control

With cycle control, current flows five times every second (because the control cycle is 0.2 s). With a transformer load, the following problems may occur due to the large input current (approximately 10 times the rated current), and controlling the power at the transformer primary side may not be possible.

1. The SSR may be destroyed if there is not sufficient leeway in the SSR rating.
2. The breaker on the load circuit may be tripped.

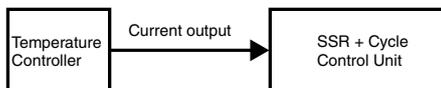
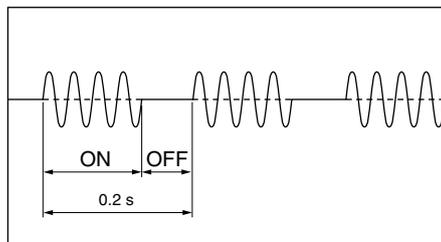
With phase control, output is changed every half-cycle in response to current output signals in the range 4 to 20 mA from a Temperature Controller. Using this form of control, high-precision temperature control is possible, and is used widely with semiconductor equipment.

#### ON/OFF Control



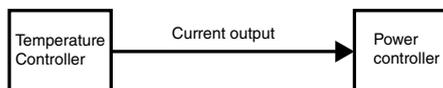
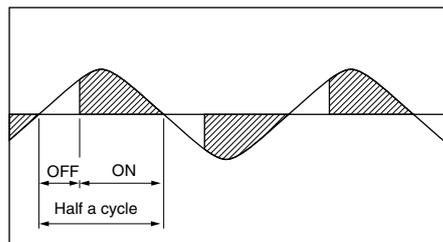
Enables low-cost, noiseless operation without maintenance requirements.

#### Cycle Control



Enables noiseless operation with high-speed response.

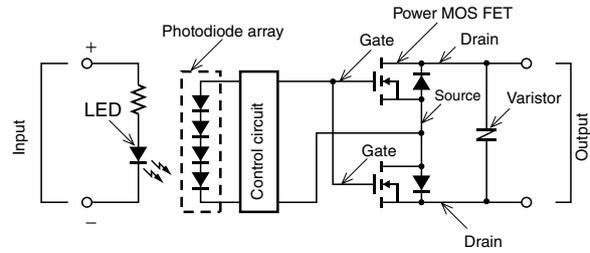
#### Phase Control (Single Phase)



Enables precise temperature control and increases the heater's service life.

**(3) Configuration and Operating Principle of MOS FET Relays**

MOS FET relays are SSRs that use power MOS FETs in output elements. In order to operate the power MOS FETs, photodiode arrays are used as light-receiving elements. When current flows into the input terminal, the LED lights. This light generates a photoelectromotive force in the photodiode array, and this acts as a gate voltage that turns ON the power MOS FET. By connecting 2 power MOS FETs using a source common, control of AC loads is possible. There are models for control of DC loads, which have just one power MOS FET. (Refer to Q43, Q44, and Q45 in Q&A.)



There is no varistor in the G3VM MOS FET relay for signalling.

**(4) SSR Classifications**

SSRs can be classified by appearance, such as panel-mounting models, socket models, or PCB models, or by applications, as shown below. The optimum SSR can be selected depending on the purpose, and this is another important feature of SSRs.

**Classification by Application**

Application	Recommended SSRs
<p><b>Heater Control</b> These SSRs are applicable to machines which require highly sensitive temperature control for turning heaters ON and OFF, such as molding equipment, packaging machines, and solderers. These SSRs feature plug-in models, replaceable power element cartridge models, and built-in heat sink model. They meet the high-capacity, high ON/OFF frequency requirements of heater control.</p>	<p>Single-phase G3PB    Three-phase G3PB    G3PX    G3PA    G3NA    G3NE    G3NH</p>
<p><b>Motor Control</b> These SSRs are applicable to machines which require motor inching operation and reversible operation, such as machine tools, conveyors, and packaging equipment. They have high-speed response time and high ON/OFF frequency, required for inching and reversible operation.</p>	<p>G3J    G3NA    G3NE</p>
<p><b>I/O</b> These SSRs meet the requirements for isolated transmission of control output from PCs and Position Controllers to an actuator. In particular, the G3DZ and G3RZ Relays use MOS FET in the output element to allow shared use of the Relays in both low-leakage-current AC and DC circuits.</p>	<p>G3TB    G3DZ    G3S (D)    G3R (I/O)    G3RZ    G3TA</p>
<p><b>Panel-mounted Interfaces</b> These SSRs are the same shape as general-purpose relays, they have the same sockets and can be mounted according to their respective shapes. They are ideal for interface applications where high-frequency switching is required, and can also be used in a wide variety of general-purpose applications, such as directly switching loads.</p>	<p>G3B    G3F    G3H    G3R</p>

(5) SSR Glossary

Terms		Meaning
Insulation	Basic insulation	Insulation for basic protection from electric shock (IEC950 1.2.9.2)
	Supplemental insulation	Independent insulation provided outside of basic insulation to protect from electric shock when the basic insulation breaks down (IEC950 1.2.9.3)
	Reinforced insulation	A single-layer of insulation (IEC950 1.2.9.5) that provides the same protection from electric shock as double insulation (insulation including both basic and supplemental insulation) according to conditions stipulated in IEC950 standards
Circuit functions	Zero cross circuit	A circuit which starts operation with the AC load voltage at close to zero-phase.
	Trigger circuit	A circuit for controlling the triac or thyristor trigger signal, which turns the load current ON and OFF.
Input	Isolated input circuit	If the external circuit is prone to generating noise, or if wires from external sources are prone to the influence of inductive noise, in order to prevent malfunctions due to noise, it is necessary to electrically isolate internal circuits and external circuits (output circuits). An isolated input circuit is a circuit that isolates inputs and outputs by using components that are not connected electrically but that can transmit signals, such as contact relays or photocouplers.
	Photocoupler	A component that runs the electric signal into a light emitter (e.g., LED), changes it to a light signal, and then returns it to an electric signal using a photoelectric conversion element, such as a photo transistor. The space used for transferring the light signal is isolated thus providing good insulation and a high propagation speed.
	Rated voltage	The voltage that serves as the standard value of an input signal voltage
	Must-operate voltage	Minimum input voltage when the output status changes from OFF to ON.
	Input impedance	The impedance of the input circuit and the resistance of current-limiting resistors used. Impedance varies with the input signal voltage in case of the constant current input method.
	Operating voltage	The permissible voltage range within which the voltage of an input signal voltage may fluctuate.
	Reset voltage	Maximum input voltage when the output status changes from ON to OFF.
	Input current	The current value when the rated voltage is applied.
Output	Load voltage	This is the effective value for the power supply voltage that can be used for load switching or in the continuous-OFF state.
	Maximum load current	The effective value of the maximum current that can continuously flow into the output terminals under specified cooling conditions (i.e., the size, materials, thickness of the heat sink, and an ambient temperature radiating condition).
	Leakage current	The effective value of the current that can flow into the output terminals when a specified load voltage is applied to the SSR with the output turned OFF.
	Output ON voltage drop	The effective value of the AC voltage that appears across the output terminals when the maximum load current flows through the SSR under specified cooling conditions (such as the size, material, and thickness of heat sink, ambient temperature radiation conditions, etc.).
	Minimum load current	The minimum load current at which the SSR can operate normally.
	Snubber circuit	A circuit consisting of a resistor R and capacitor C, which prevents faulty ignition from occurring in the SSR triac by suppressing a sudden rise in the voltage applied to the triac.
	Semiconductor output element (switching element)	This is a generic name for semiconductors such as the thyristor, triac, power transistor, and power MOS FET. In particular, triacs are often used in SSRs because they allow switching to be performed with one element.
	Repetitive peak OFF-state voltage (VDRM)	This is a rating for an output semiconductor that used in an SSR for AC loads.
	Collector-emitter voltage (VCEO)	This is a rating for an output semiconductor that used in an SSR for DC loads.
Characteristics	Operating time	A time lag between the moment a specified signal voltage is imposed to the input terminals and the output is turned ON.
	Release time	A time lag between the moment the imposed signal input is turned OFF and the output is turned OFF.
	Insulation resistance	The resistance between the input and output terminals or I/O terminals and metal housing (heat sink) when DC voltage is imposed.
	Dielectric strength	The effective AC voltage that the SSR can withstand when it is applied between the input terminals and output terminals or I/O terminals and metal housing (heat sink) for more than 1 minute.
	Ambient temperature and humidity (operating)	The ranges of temperature and humidity in which the SSR can operate normally under specified cooling, input/output voltage, and current conditions.
	Storage temperature	The temperature range in which the SSR can be stored without voltage imposition.
Others	Inrush current resistance	A current which can be applied for short periods of time to the electrical element.
	Counter-electromotive force	Extremely steep voltage rise which occurs when the load switched or turned OFF.
	Recommended applicable load	The recommended load capacity which takes into account the safety factors of ambient temperature and inrush current.
	Bleeder resistance	The resistance connected in parallel to the load in order to increase apparently small load currents, so that the ON/OFF of minute currents functions normally. (It is also used to shunt leakage currents.)

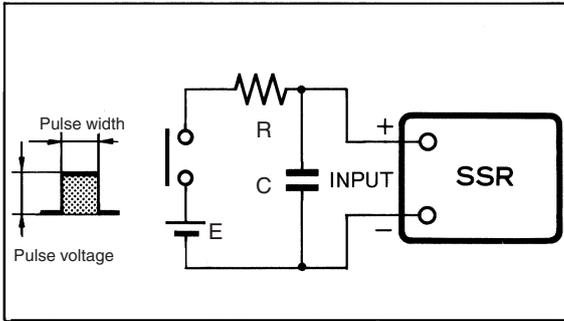
## 2-1 Input Circuit

### (1) Input Noise

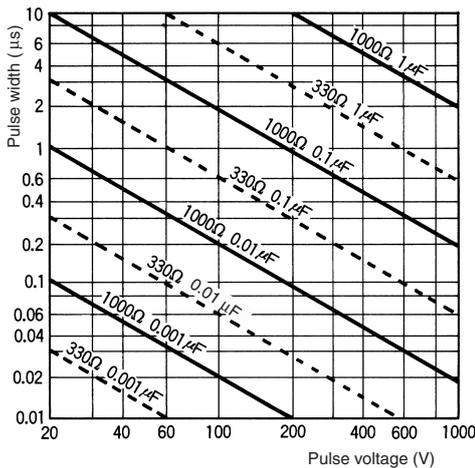
SSRs need only a small amount of power to operate. This is why the input terminals must shut out electrical noise as much as possible. Noise applied to the input terminals may result in malfunction. The following describe measures to be taken against pulse noise and inductive noise.

#### 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.



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.

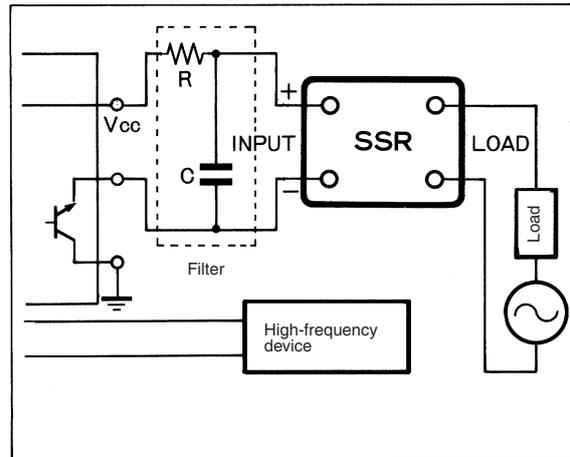
#### 2. Inductive Noise

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 wires: 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.

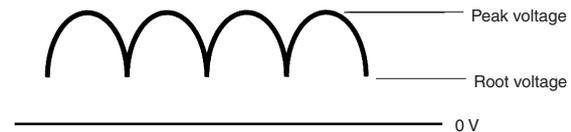


**Note** R: 20 to 100 Ω  
C: 0.01 to 1 μF

### (2) Input Conditions

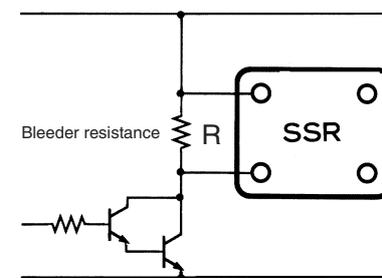
#### 1. Input Voltage Ripples

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 of transistor during power OFF. To counteract this, connect bleeder resistance R as shown in the diagram below and set the resistance so that the voltage applied to both ends of the resistance is less than half of the reset voltage of the SSR.



The bleeder resistance R can be obtained in the way shown below.

$$R \leq \frac{E}{I_L}$$

E: Voltage applied at both ends of the bleeder resistance = half of the reset voltage of the SSR

I<sub>L</sub>: Leakage current of the transistor

I: Reset current of the SSR

The actual value of the reset current is not given in the datasheet and so when calculating the value of the bleeder resistance, use the following formula.

$$\text{Reset current for SSR} = \frac{\text{Minimum value of reset voltage}}{\text{Input impedance}}$$

For SSRs with constant-current input circuits (e.g., G3NA, G3PA, G3PB), calculation is performed at 0.1 mA.

The calculation for the G3M-202P DC24 is shown below as an example.

$$\text{Reset current } I = \frac{1 \text{ V}}{1.6 \text{ k}\Omega} = 0.625 \text{ mA}$$

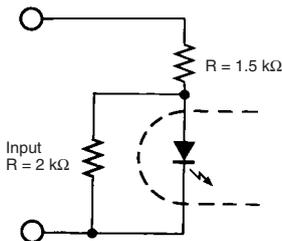
$$\text{Bleeder resistance } R = \frac{1 \text{ V} \times 1/2}{I_L - 0.625 \text{ mA}}$$

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.

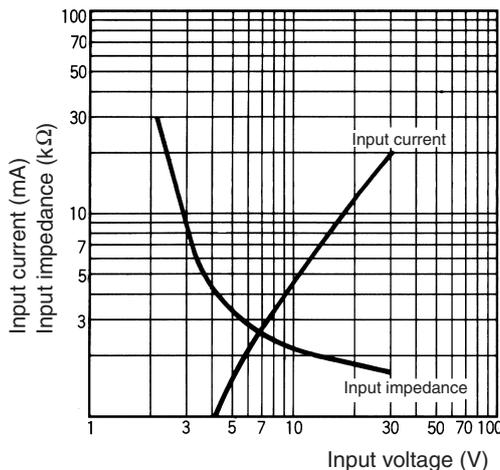
4. Input Impedance

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. If the input voltage is low, the influence of the voltage drop for the input LED is large, and the input impedance will be higher than expected. If the voltage is so high that the LED voltage drop can be ignored, the input impedance will be close to the resistance R.

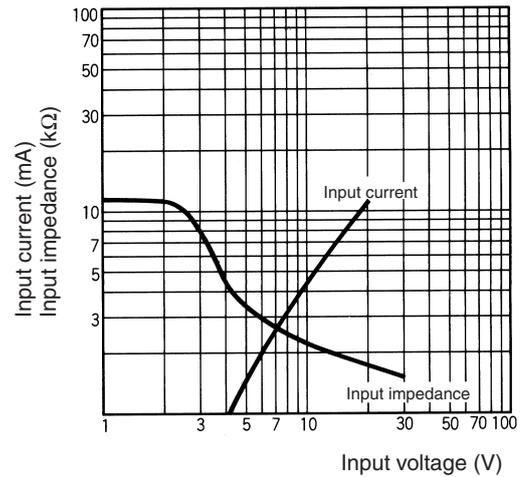


For semiconductor-driven SSRs, changes in voltage can cause malfunction of the semiconductor, so be sure to check the actual device before usage. See the following examples. Refer to the SSR's datasheet for the impedance of individual SSR models.

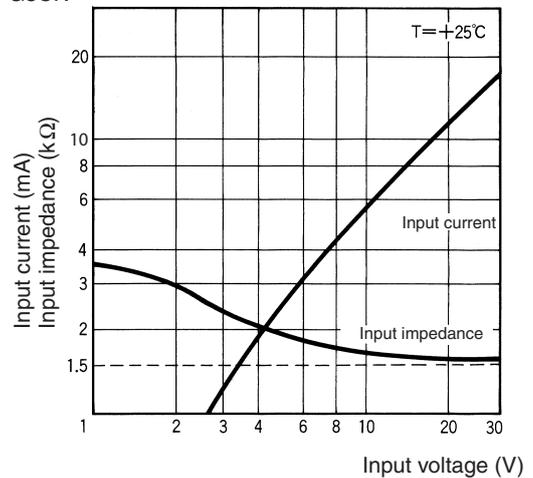
Applicable Input Impedance for a Photocoupler-type SSR without Indicators (Example) G3F, G3H (Without Indicators)



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



Applicable Input Impedance (Example) G3CN



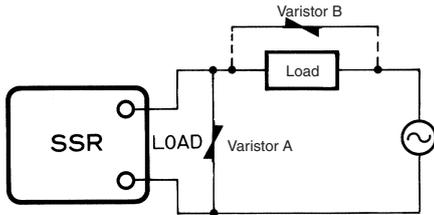
## 2-2 Output Circuit

### (1) 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 over-voltage damage to the SSR.

There are SSR models that do not have a built-in surge absorbing varistor. (Refer to the SSR's datasheet for details.) 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. Basically, if the SSR does not have a built-in varistor, A will be effective, and if the SSR does have a built-in varistor, B will be effective. In practice, it is necessary to confirm correct operation under actual operating conditions.

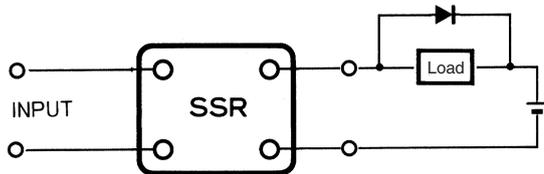


Select an element which meets the conditions in the table below as the surge absorbing element.

Voltage	Varistor voltage	Surge resistance
100 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 V	

### (2) 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 ( $V_z$ ) of the Zener diode is increased.

• Absorption Element Example

Absorption element				
	Diode	Diode + Zener diode	Varistor	CR
Effective-ness	○	○	△	×

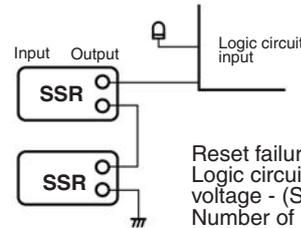
(Reference)

1. Selecting a Diode  
Withstand voltage =  $V_{RM} \geq$  Power supply voltage  $\times$  2  
Forward current =  $I_F \geq$  load current
2. Selecting a Zener Diode  
Zener voltage =  $V_z <$  SSR's connector-emitter voltage - (Power supply voltage + 2 V)  
Zener surge reverse power =  $P_{RSM} > V_z \times$  Load current  $\times$  Safety factor (2 to 3)

**Note** When the Zener voltage is increased ( $V_z$ ), the Zener diode capacity ( $P_{RSM}$ ) is also increased.

### (3) AND Circuits with DC Output SSRs

Use the G3DZ or G3RZ for the following type of circuit. Do not use standard SSRs, or otherwise the circuit may not be reset.



Reset failure will occur in the following case:  
Logic circuit input voltage < Power supply voltage - (SSR's output ON voltage drop  $\times$  Number of SSRs)

### (4) Self-holding Circuits

Self-holding circuits must use mechanical relays. SSRs cannot be used to design self-holding circuits.

### (5) Selecting an SSR with Differing Loads

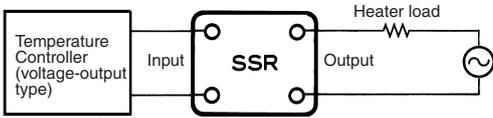
The following provides examples of the inrush currents for different loads.

• AC Load and Inrush Current

Load						
	Solenoid	Incan descent 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
Wave-form						

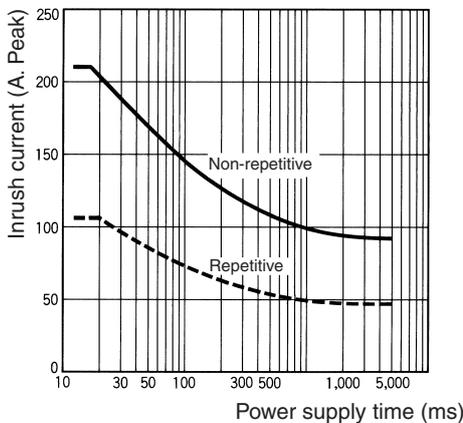
1. Heater Load (Resistive Load)

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 SSR.



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. (Refer to Q37 in Q&A.)



If an SSR is used to switch a fluorescent lamp, the waveform of the power supply voltage will be distorted, and flickering will occur. Fluorescent lamps are discharge tubes, and have transformers for producing high voltages. For this reason, noise and harmonics are generated as a result of distortions in the power supply voltage, small phase gaps, and differences in positive and negative ON-voltages.

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.

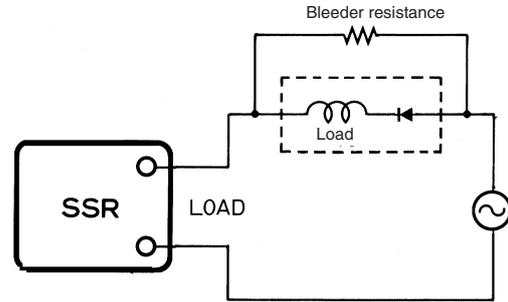
4. Transformer Load

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. (Refer to page 8.)

5. Half-wave Rectified 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.

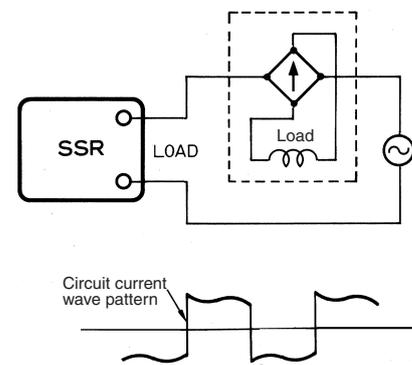
(a) Connect a bleeder resistance with approximately 20% of the SSR load current.



(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 below.



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

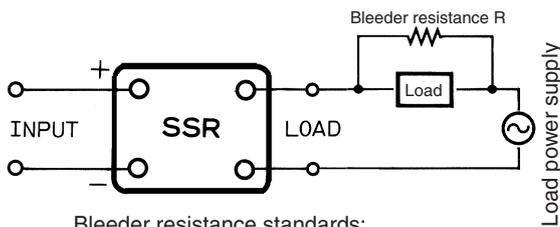
7. Small-capacity Loads

Even when there is no input signal to the SSR there is a small leakage current (I<sub>L</sub>) 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.

$$R < \frac{E}{I_L - I}$$

E: Load (relays etc.) reset voltage  
I: Load (relays etc.) reset current

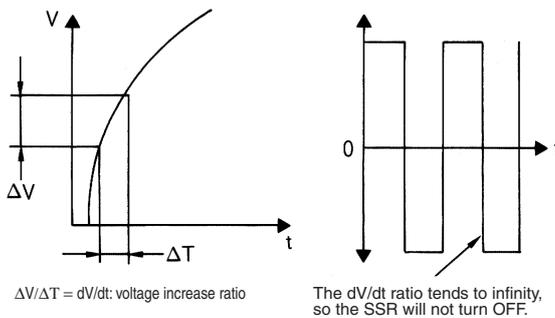


Bleeder resistance standards:  
100-VAC power supply, 5 to 10 kΩ, 3 W  
200-VAC power supply, 5 to 10 kΩ, 15 W

A voltage equal to this SSR's leakage current  $I_L$  (mA) × Impedance of the load is applied to both ends of the resistance. A bleeder resistance is used to make this voltage less than the load's reset voltage.

### 8. Inverter Load

Do not use an inverter-controlled power supply as the load power supply for the SSR. Waveforms for inverter-controlled voltages are rectangular. Semiconductor output elements (triac, thyristor) may not be able to respond to the steep voltage increases ( $dV/dt$  becomes extremely large), and the SSR may fail to reset (also called turn-OFF problem or commutating  $dV/dt$  failure). 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.



### 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.

## (6) Inrush Currents to Transformer Loads

The inrush current from a transformer load will reach its peak when the secondary side of the transformer is open, when no mutual reactance will work. It will take half a cycle of the power supply frequency for the inrush current to reach its peak, the measurement of which without an oscilloscope will be difficult.

The inrush current can be, however, estimated by measuring the DC resistance of the transformer.

Due to the self-reactance of the transformer in actual operation, the actual inrush current will be less than the calculated value.

$$I_{\text{peak}} = V_{\text{peak}}/R = (\sqrt{2} \times V)/R$$

If the transformer has a DC resistance of 3 Ω and the load power supply voltage is 220 V, the following inrush current will flow.

$$I_{\text{peak}} = (1.414 \times 220)/3 = 103.7 \text{ A}$$

The inrush current resistance of OMRON's SSRs is specified on condition that the SSRs are in non-repetitive operation. If your application requires repetitive SSR switching, use an SSR with an inrush current resistance twice as high as the rated value ( $I_{\text{peak}}$ ).

In the case above, use the G3□□-220□ with an inrush current resistance of 207.4 A or more.

The DC resistance of the transformer can be calculated back from the inrush current resistance by using the following formula.

$$R = V_{\text{peak}}/I_{\text{peak}} = (\sqrt{2} \times V)/I_{\text{peak}}$$

For applicable SSRs based on the DC resistance, refer to the tables on page 9.

These tables list SSRs with corresponding inrush current conditions. When using SSRs to actual applications, however, check that the steady-state currents of the transformers satisfy the rated current requirement of each SSR.

### SSR Rated Current

G3□□-240□

The underlined two digits refer to the rated current (i.e., 40 A in the case of the above model).

Three digits may be used for the G3NH only.

G3NH: G3NH-□075B = 75 A  
G3NH-□150B = 150 A

Condition 1: The ambient temperature of the SSR (the temperature inside the panel) is within the rated value specified.

Condition 2: The right heat sink is provided to the SSR.

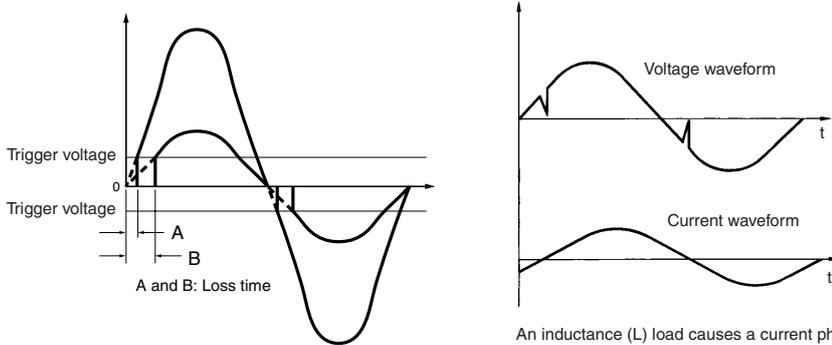
## 2-3 Load Power Supply

### (1) 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 the 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 75 VAC minimum. (24 VAC for G3PA-VD and G3NA-2□□B.)



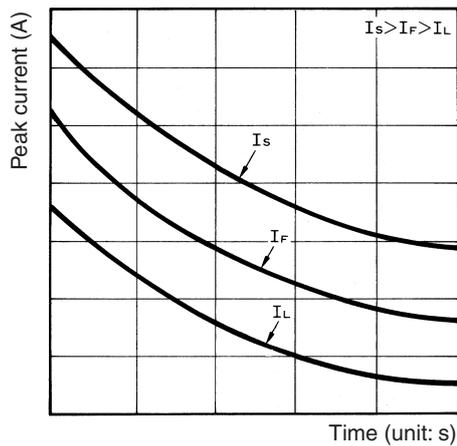
An inductance (L) load causes a current phase delay as shown above. Therefore, the loss is not as great as that caused by a resistive (R) load. This is because a high voltage is already imposed on the SSR when the input current to the SSR drops to zero and the SSR is turned OFF.

## 2-4 Fail-safe Concept

### (1) Short-circuit Protection (Fuse Selection) and 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.



Provide an appropriate non-fuse breaker to each machine for the overcurrent protection of the machine.

## 2-5 Heat Radiation Consideration

### (1) SSR Heat Radiation

Triacs, thyristors, and power transistors are semiconductors that can be used for an SSR output circuit. These semiconductors have a residual voltage internally when the SSR is turned ON. This is called output-ON voltage drop. If the SSR has a load current, the Joule heating of the SSR will result consequently. The heating value P (W) is obtained from the following formula.

Heating value P (W) = Output-ON voltage drop (V) x Carry current (A)

For example, if a load current of 8 A flows from the G3NA-210B, the following heating value will be obtained.

$$P = 1.6 \text{ V} \times 8 \text{ A} = 12.8 \text{ W}$$

If the SSR employs power MOS FET for SSR output, the heating value is calculated from the ON-state resistance of the power MOS FET instead.

In that case, the heating value P (W) will be obtained from the following formula.

$$P \text{ (W)} = \text{Load current}^2 \text{ (A)} \times \text{ON-state resistance } (\Omega)$$

If the G3RZ with a load current of 0.5 A is used, the following heating value will be obtained.

$$P \text{ (W)} = 0.5^2 \text{ A} \times 2.4 \Omega = 0.6 \text{ W}$$

The ON-state resistance of a power MOS FET rises with an increase in the junction temperature of a power MOS FET. Therefore, the ON-state resistance varies while the SSR is in operation. If the load current is 80% of the load current or higher, as a simple method, the ON-state resistance will be multiplied by 1.5.

$$P \text{ (W)} = 1^2 \text{ A} \times 2.4 \Omega \times 1.5 = 3.6 \text{ W}$$

The SSR in usual operation switches a current of approximately 5 A with no heat sink used. If the SSR must switch a higher current, a heat sink will be required. The higher the load current is, the larger the heat sink size will be. If the switching current is 10 A or more, the size of the SSR with a heat sink will exceed a single mechanical relay. This is a disadvantage of SSRs for circuit downsizing purposes.

### (2) Heat Sink Selection

SSR models with no heat sinks incorporated (i.e., the G3NA, G3NE, and three-phase G3PB) need external heat sinks. When using any of these SSRs, select an ideal combination of the SSR and heat sink according to the load current.

The following combinations are ideal, for example.

G3NA-220B: Y92B-N100  
 G3NE-210T(L): Y92B-N50  
 G3PB-235B-3H-VD: Y92B-P200

A standard heat sink equivalent to an OMRON-made one can be used, on condition that the thermal resistance of the heat sink is lower than that of the OMRON-made one.

For example, the Y92B-N100 has a thermal resistance of 1.63°c/w.

If the thermal resistance of the standard heat sink is lower than this value (i.e., 1.5°c/w, for example), the standard heat sink can be used for the G3NA-220B.

Thermal resistance indicates a temperature rise per unit (W). The smaller the value is, the higher the efficiency of heat radiation will be.

### (3) Calculating Heat Sink Area

An SSR with an external heat sink can be directly mounted to control panels under the following conditions.

- If the heat sink is made of steel used for standard panels, do not apply a current as high as or higher than 10 A, because the heat conductivity of steel is less than that of aluminum. Heat conductivity (in units of  $\text{W} \cdot \text{m} \cdot ^\circ\text{C}$ ) varies with the material as described below.  
 Steel: 20 to 50  
 Aluminum: 150 to 220  
 The use of an aluminum-made heat sink is recommended if the SSR is directly mounted to control panels. Refer to the data sheet of the SSR for the required heat sink area.

- Apply heat-radiation silicon grease or a heat conductive sheet between the SSR and heat sink. There will be a space between the SSR and heat sink attached to the SSR. Therefore, the generated heat of the SSR cannot be radiated properly without the grease. As a result, the SSR may be overheated and damaged or deteriorated.

### (4) Control Panel Heat Radiation Designing

Control equipment using semiconductors will generate heat, regardless of whether SSRs are used or not. The failure rate of semiconductors greatly increases when the ambient temperature rises. It is said that the failure rate of semiconductors will be doubled when the temperature rises 10° C.

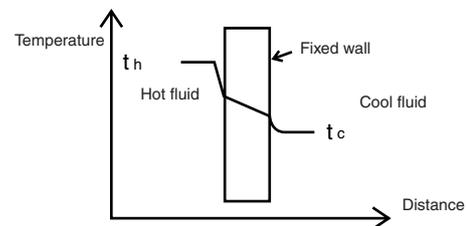
Therefore, it is absolutely necessary to suppress the interior temperature rise of the control panel in order to ensure the long, reliable operation of the control equipment. In this respect, it can be said that the installation of a cooling fan is inevitable.

Heat-radiating devices in a wide variety exists in the control panel. As a matter of course, it is necessary to consider the total temperature rise as well as local temperature rise of the control panel. The following description provides information on the total heat radiation designing of the control panel.

As shown below, the heat conductivity Q will be obtained from the following formula, provided that  $t_h$  and  $t_c$  are the temperature of the hot fluid and that of the cool fluid separated by the fixed wall.

$$Q = k (t_h - t_c) A$$

Where, k is an overall heat transfer coefficient ( $\text{W}/\text{m}^2 \cdot ^\circ\text{C}$ ). This formula is called a formula of overall heat transfer.



When this formula is applicable to the heat conductivity of the control panel under the following conditions, the heat conductivity Q will be obtained as shown below.

Average rate of overall heat transfer of control panel: k ( $\text{W}/\text{m}^2 \cdot ^\circ\text{C}$ )

Internal temperature of control panel:  $T_h$  ( $^\circ\text{C}$ )

Ambient temperature:  $T_c$  ( $^\circ\text{C}$ )

Surface area of control panel: S ( $\text{m}^2$ )

$$Q = k \times (T_h - T_c) \times S$$

The required cooling capacity is obtained from the following formula under the following conditions.

Desired internal temperature of control panel:  $T_h$  ( $^\circ\text{C}$ )

Total internal heat radiation of control panel:  $P_1$  (W)

Required cooling capacity:  $P_2$  (W)

$$P_2 = P_1 - k \times (T_h - T_c) \times S$$

The overall heat transfer coefficient k of a standard fixed wall in a place with natural air ventilation will be 4 to 12 ( $\text{W}/\text{m}^2 \cdot ^\circ\text{C}$ ). In the case of a standard control panel with no cooling fan, it is an empirically known fact that a coefficient of 4 to 6 ( $\text{W}/\text{m}^2 \cdot ^\circ\text{C}$ ) is practically applicable. Based on this, the required cooling capacity of the control panel is obtained as shown below.

Example

- Desired internal temperature of control panel: 40° C
- Ambient temperature: 30° C
- Control panel size 2.5 × 2 × 0.5 m (W × H × D)  
 Self-sustained control panel (with the bottom area excluded from the calculation of the surface area)
- SSR: 20 G3PA-240B Units in continuous operation at 30 A.
- Total heat radiation of all control devices except SSRs: 500 W

$P1 = \text{Output-ON voltage drop } 1.6 \text{ V} \times \text{Load current } 30 \text{ A} \times 20 \text{ SSRs}$   
 $+ \text{Total heat radiation of all control devices except SSRs} = 960 \text{ W} + 500 \text{ W} = 1460 \text{ W}$

Heat radiation Q from control panel: Q

$Q2 = \text{Rate of overall heat transfer } 5 \times (40^\circ \text{C} - 30^\circ \text{C}) \times (2.5 \text{ m} \times 2 \text{ m} \times 2 + 0.5 \text{ m} \times 2 \text{ m} \times 2 + 2.5 \text{ m} \times 0.5 \text{ m}) = 662.5 \text{ W}$

Therefore, the required cooling capacity P2 will be obtained from the following formula.

$P2 = 1,460 - 663 = 797 \text{ W}$

Therefore, heat radiation from the surface of the control panel is insufficient. More than a heat quantity of 797 W needs to be radiated outside the control panel.

Usually, a ventilation fan with a required capacity will be installed. If the fan is not sufficient. An air conditioner for the control panel will be installed. The air conditioner is ideal for the long-time operation of the control panel because it will effectively dehumidify the interior of the control panel and eliminate dust gathering in the control panel.

Axial-flow fan: OMRON's R87B, R87F, and R87T Series

**(5) Types of Cooling Device**

**Axial-flow Fans (for Ventilation)**

These products are used for normal types of cooling and ventilation. OMRON's Axial-flow Fan lineup includes the R87F and R87T Series.



**Note** OMRON does not produce heat exchangers.



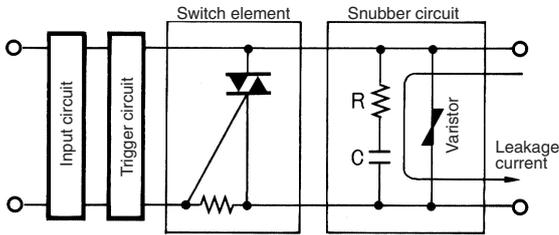
**Note** OMRON does not produce air conditioners for control panels.

### 3 Mounting and Installation

#### 3-1 Operation

##### (1) 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.



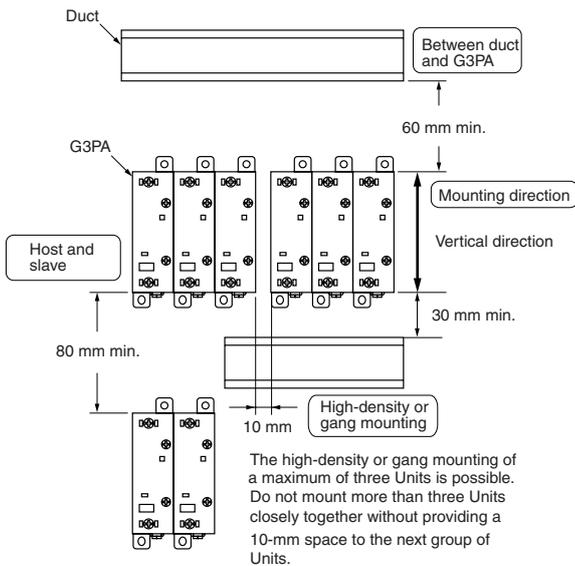
#### 3-2 Panel Mounting

If SSRs are mounted inside an enclosed panel, the radiated heat of the SSR will stay inside, thus not only dropping the carry-current capacity of the SSRs but also adversely affecting other electronic device mounted inside. Open some ventilation holes on the upper and lower sides of the control panel before use.

The following illustrations provide a recommended mounting example of G3PA Units. They provide only a rough guide and so be sure to confirm operating conditions.

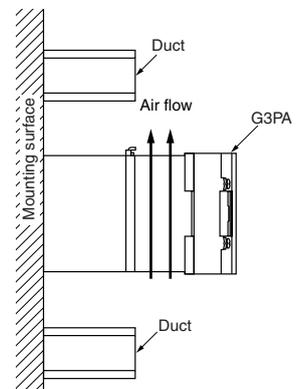
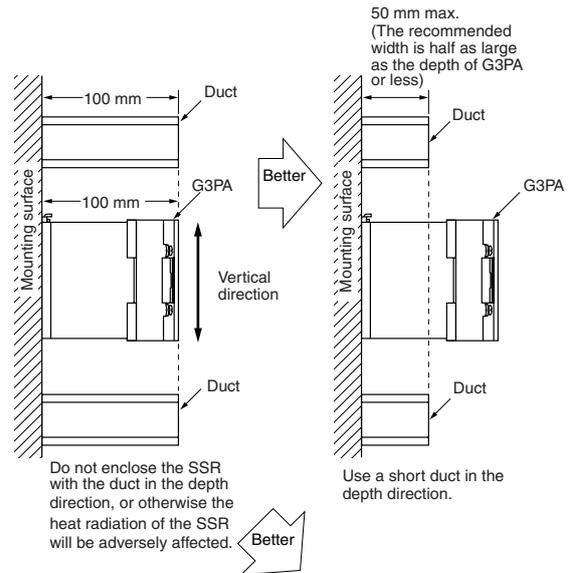
##### (1) SSR Mounting Pitch

###### Panel Mounting

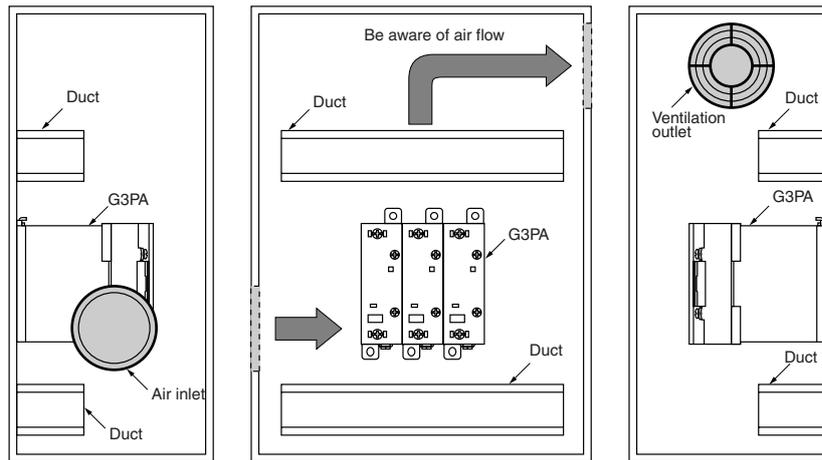


##### (2) Relationship between SSRs and Ducts

###### Duct Depth



(3) Ventilation



If the air inlet or air outlet has a filter, clean the filter regularly to prevent it from clogging and ensure an efficient flow of air.

Do not locate any objects around the air inlet or air outlet, or otherwise the objects may obstruct the proper ventilation of the control panel.

A heat exchanger, if used, should be located in front of the G3PA Units to ensure the efficiency of the heat exchanger.

**3-3 Operation and Storage Environment Precautions**

**(1) Ambient Temperature (Operating)**

The rated operating ambient temperature of an SSR is determined proper ventilation. If the heat radiation conditions of the SSR, such as fresh air supply or ventilation is improper, the operating ambient temperature will exceed the rated value. As a result, the SSR will fail to operate or burn out.

When using SSRs, check that the circuits are designed to satisfy the conditions specified under *Load Currents vs. Ambient Temperatures*.

Be aware that the operating ambient temperature will be excessive, depending on the environmental conditions (e.g., weather and indoor air-conditioning conditions) or operating conditions (e.g., enclosed panel mounting).

## 4 SSR Reliability

### 4-1 Failure Rate and Life Expectancy

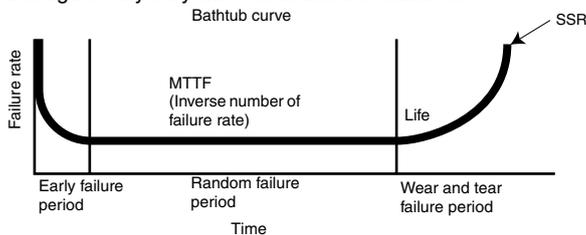
It is said that the failure rate of an electronic component or product can be expressed by a bathtub curve.

- Decreasing failure rate: Early failure period (e.g. design or manufacturing fault)
- Constant failure rate: Random failure period
- Increasing failure rate: Wear and tear failure period

Semiconductors such as triacs or thyristors are used for SSR output and so the SSR is not subject to mechanical wear. Therefore, the life expectancy of the SSR depends on the failure rate of internal components. For example, the rate for the G3M-202P is 321 Fit (1 Fit =  $10^{-9}$  =  $\lambda$  (malfunctions/time)). The MTTF calculated from this value is as follows:

$$\text{MTTF} = 321 / \lambda_{60} = 3.12 \times 10^6 \text{ (time)}$$

With the SSR, however, unlike a single semiconductor, even if it is used correctly, heat-stress resulting from changes in the ambient temperature or heat generated by the SSR itself may have several adverse effects, such as deterioration in the solder in components or a drop in the illumination efficiency of the built-in coupler's LED, and may result in failure. These factors will determine the actual lifetime of the SSR. With OMRON SSRs, we estimate that these failures due to deterioration will start to occur after approximately 10 years, but this figure may vary with the ambient conditions.



5 Q&A

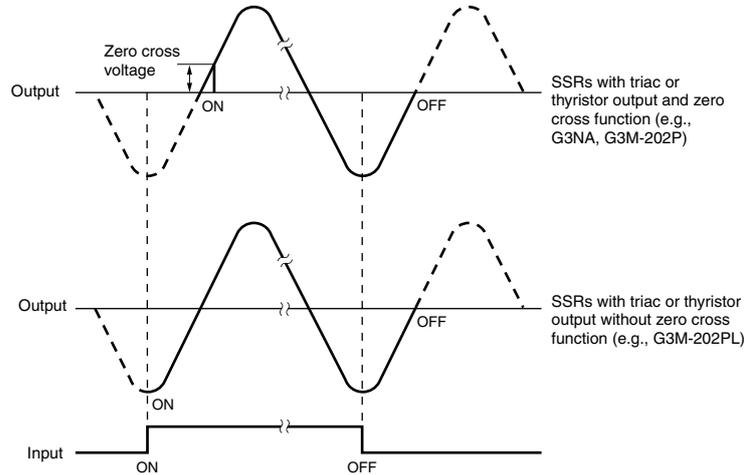
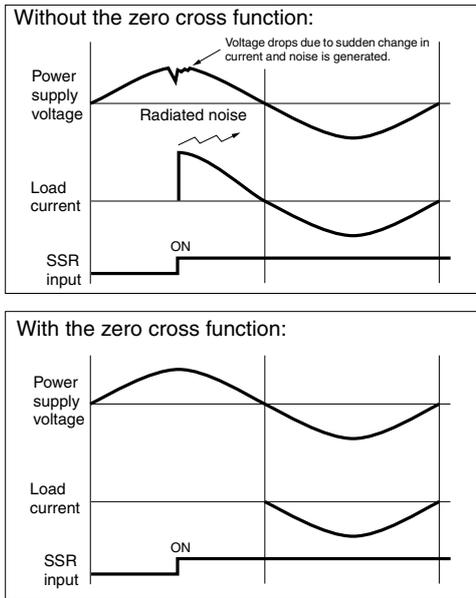
■ Q1. What is the zero cross function?

The zero cross function turns ON the SSR when the AC load voltage is close to 0 V, thus suppressing the noise generation of the load current when the load current rises quickly.

The generated noise will be partly imposed on the power line and the rest will be released in the air. The zero cross function effectively suppresses both noise paths.

A high inrush current will flow when the lamp is turned ON, for example. When the zero cross function is used, the load current always starts from a point close to 0 V. This will suppress the inrush current more than SSRs without the zero cross function.

It is ideal for the load current to start from 0 V when the zero cross function is used. Due to circuit restrictions, however, the load current will start from a point that is  $0 \pm 20$  V. The difference in voltage between this point and the 0 V point is called zero cross voltage.



Zero Cross

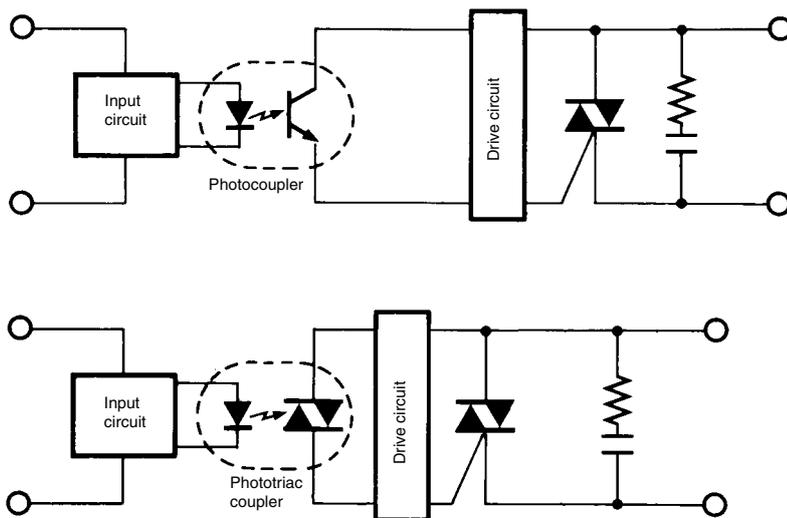
■ Q2. Why does the input current vary with the SSR?

An SSR with photocoupler isolation has a different input current from an SSR with phototriac isolation.

An SSR with a zero cross function with photocoupler isolation does not require a high input current because the photocoupler ensures

efficient signal transmission. The SSR, however, requires a drive circuit of complicated construction.

Photocoupler input current < Phototriac input current



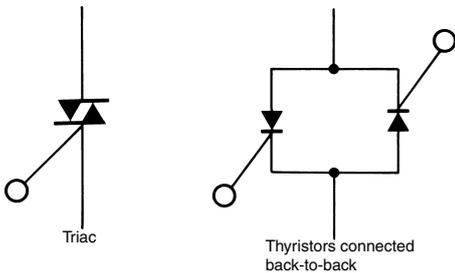
Zero Cross, Photocoupler, and Phototriac

Solid state relays

■ Q3. What is the difference in switching with a thyristor and a triac?

There is no difference between them as long as resistive loads are switched. For inductive loads, however, thyristors are superior to triacs due to the back-to-back connection of the thyristors.

For the switching element, an SSR uses either a triac or a pair of thyristors connected back-to-back.



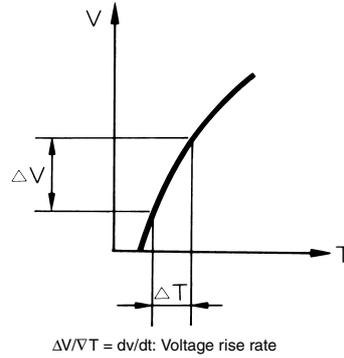
There is a difference between thyristors and triacs in response time to rapid voltage rises or drops. This difference is expressed by  $dv/dt$  ( $V/\mu s$ ) (Refer to Q5 on page 17). This value of thyristors is larger than that of triacs. Triacs can switch inductive motor loads that are as high as 3.7 kW. Furthermore, a single triac can be the functional equivalent of a pair of thyristors connected back-to-back and can thus be used to contribute to downsizing SSRs.

■ Q4. What is a snubber circuit?

When SSRs with triac or thyristor outputs are used to switch inductive loads, excessive voltage changes will occur within a short period when the triacs or thyristors are turned ON and OFF. As a result, the SSRs will malfunction (make mistakes in firing time). A snubber circuit is designed to suppress excessive voltage changes.

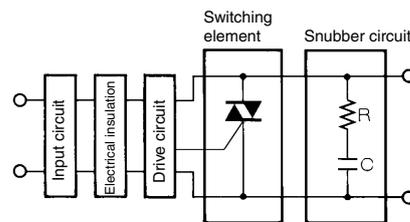
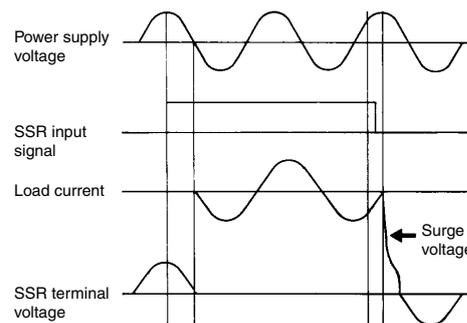
The characteristics of triacs or thyristors for excessive voltages are expressed by  $dv/dt$ . The limit value that turns ON these output semiconductor elements is called the critical rate-of-rise of the OFF-state voltage (or static  $dv/dt$ ). The limit value that cannot turn OFF the output semiconductor elements is called commutation  $dv/dt$ .

A snubber circuit suppresses surge. If the surge voltage is high, however, the output semiconductor elements will be damaged. Therefore, when an SSR with no built-in surge absorbing element (i.e., a varistor) is used for an inductive load, for example, the SSR will need a surge suppressing measure other than the snubber circuit.

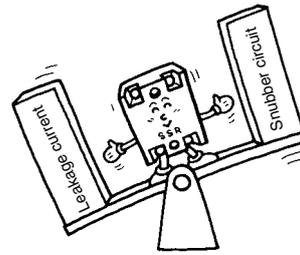


	Resistive load		Inductive load	
	40 A max.	Over 40 A	3.7 kW max.	Over 3.7 kW
Triac	OK	OK	OK	Not as good
Two thyristors	OK	OK	OK	OK

Thyristors, Triacs, and  $dv/dt$



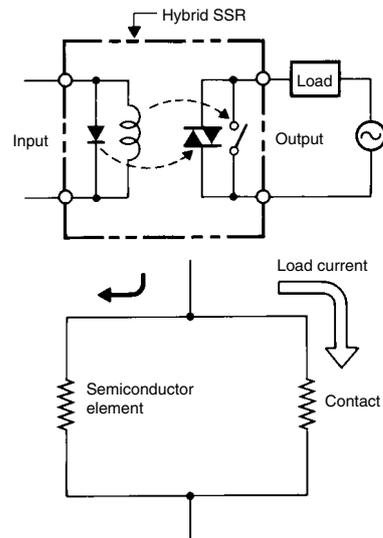
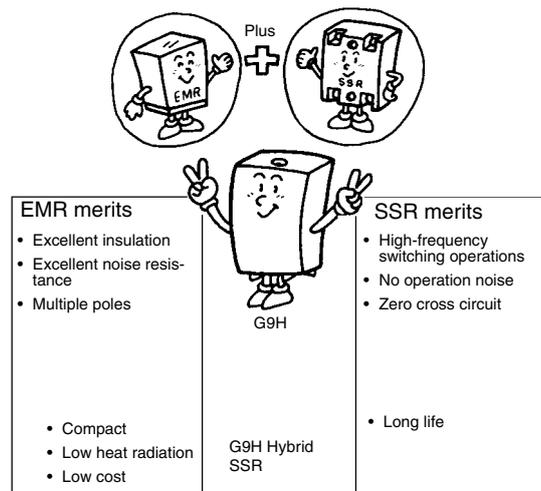
However a snubber circuit is the main cause of current leakage from an SSR. The relationship between the snubber circuit and current leakage is like balancing a seesaw. With the snubber effect increased, the leakage current will increase. With the leakage current suppressed, the SSR will be adversely affected by noise. OMRON selects the best snubber circuit constant for each model according to the rated current of the model.



Static dv/dt, Commutation dv/dt, Snubber Circuits, and Leakage Current

**■ Q5. What is a hybrid SSR?**

A hybrid SSR is a relay that turns the load ON and OFF with a semiconductor element but uses a mechanical relay for normal operation. In other words, a hybrid SSR is a combination of an EMR (electromagnetic relay) and SSR.

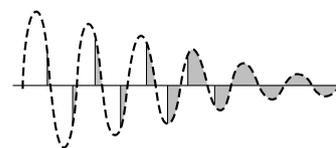


**Principle of Operation**

When the hybrid SSR input is turned ON, the triac turns ON and then the contact turns ON. At that time, the resistance of the contact will be lower than that of the triac, causing most of the load current to flow to the contact. When the SSR input is turned OFF, the contact and triac are turned OFF. The triac is turned OFF after the current to the contact is turned OFF, and therefore, no arc will result. This is the reason a hybrid SSR ensures a long service life.

**■ Q6. What is the soft start function?**

The soft start function increases the AC output of SSRs gradually to 100% using phase control. This suppresses the inrush current of the load power supply that results when the load power supply is turned ON, making it possible to start the load smoothly. This function can be used to effectively control motor and halogen lamp loads. A soft start function is incorporated in the G3PX Power Controller and the G3J-series SSRs for motor control.



Hybrid SSR

Soft Start Function

Solid state relays

## ■ Q7. What do the model numbers mean?

The following model legend applies to OMRON's SSRs.

G3-□□-□□□□□□□□□□-□□  
 12 3 4 5 6 7 8 9

### 1. Product Classification

The prefix G indicates that the product is a relay.

### 2. Basic Model Code

The number 3 indicates that the product is an SSR.

### 3. A specific alphabetic character for the model.

### 4. A specific alphabetic character for the model.

### 5. Load Power Supply Voltage

Used only for series products and not for standard models.

1: Maximum operating voltage is 100 to 200 VAC or DC.

2: Maximum operating voltage is 200 to 300 VAC or DC.

4: Maximum operating voltage is 400 to 500 VAC or DC.

### 6. Load Current

Indicates the maximum load current.

Example: 00075: 75 A

000150: 150 A

00R5: 0.5 A

0010: 10 A

### 7. Terminal Shape

B: Screw terminals

P: PCB terminals

S: Plug-in terminals (for special sockets)

T: Tab terminals

### 8. Zero Cross Function

None: Yes

L: No

### 9. Suffix Code

A code specifying a series product, approved standards, or specific characteristics such as the number of elements.

For the G3NA-220B, for example, the load power supply voltage is 200 V, the load current is 20 A, the zero cross function and screw terminals are provided. For the G3M-102PL, the load power supply voltage is 100 V, the load current is 2 A, the zero cross function is not provided, and PCB terminals are provided.

Model Legend

## ■ Q8. What is the difference between recommended values and rated values?

The maximum load current of an SSR is determined on the assumption that the SSR is used independently connected to a resistive load.

The expected actual operating conditions of the SSR are, however, tougher due to the fluctuation of the power supply voltage or the

panel space. The recommended values of the SSR are provided in consideration of a 20% to 30% safety margin based on the rated values.

A larger safety margin will be required if an inductive load, such as a transformer or motor, is used due to the inrush current that will flow.

Recommended Loads

## ■ Q9. What is the meaning of $I^2t$ for fuse selection?

When a fuse is connected to an SSR, the  $I^2t$  of the SSR is the integral value of an inrush current that flows for a specified time from the fuse into the SSR when the SSR is turned ON.

The following table provides permissible  $I^2t$  values for the respective SSRs. When using a high-speed breaking fuse for an SSR, check that the  $I^2t$  is the same as or less than the specified value.

### $I^2t$ Values

G3NA-210B	121A <sup>2</sup> s
G3NA-220B	260A <sup>2</sup> s
G3NA-240B	2660A <sup>2</sup> s

Fuse and  $I^2t$

## ■ Q10. Is it possible to connect SSRs in series?

Yes, it is. SSRs are connected in series mainly to prevent short circuit failures. Each SSR connected in series shares the burden of the surge voltage. Therefore, the SSRs are protected from overvoltage.

A high operating voltage, however, cannot be applied to the SSRs connected in series. The reason is that the SSRs cannot share the burden of the load voltage due to the difference between the SSRs in operating time and reset time when the load is switched.

Series Connections

**■ Q11. Is it possible to connect two 200-VAC SSRs in series to a 400-VAC load?**

No, it is not. The two SSRs are slightly different to each other in operating time. Therefore, 400 VAC will be imposed on the SSR with a longer operating time.

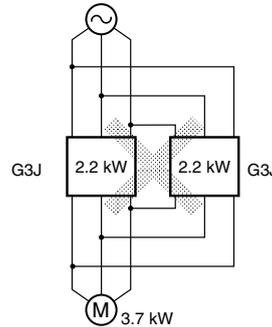
Series Connections

**■ Q12. Is it possible to connect SSRs in parallel?**

Yes, it is. SSRs are connected in parallel mainly to prevent open circuit failures. Usually, only one of the SSR is turned ON due to the difference in output ON voltage drop between the SSRs. Therefore, it is not possible to increase the load current by connecting the SSRs in parallel.

If an ON-state SSR in operation is open, the other SSR will turn ON when the voltage is applied, thus maintaining the switching operation of the load.

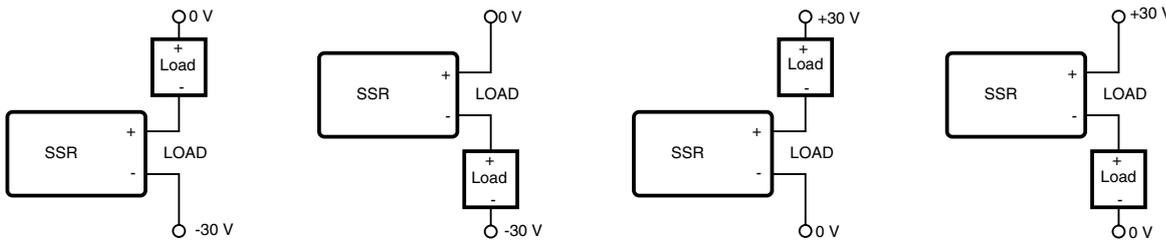
Do not connect two or more SSRs in parallel to drive a load exceeding the capacity each SSRs; the SSRs may fail to operate.



Parallel Connections

**■ Q13. Is it possible to connect a DC output load to a negative electrode? Can either a positive or negative load be connected?**

Any of the following connections will work. If the load has positive and negative polarities, be sure to connect the load with the polarities corresponding in the way shown below.



Negative Power Supply

**■ Q14. What portion of the power factor of the load is practically applicable?**

A power factor range between  $\cos\phi = 1$  and about 0.4 is available. If the power factor is less than 0.4, the phase gap between the current and the voltage will become large, and even if the current becomes 0, an overvoltage state with a changing voltage will occur. In this

state, if  $dv/dt$  exceeds the allowable value for the SSR, the SSR will not be able to turn OFF, and the SSR will malfunction. (Refer to Q5 on page 17.)

Power Factor

**■ Q15. Why is the minimum load current for most SSRs limited to 0.1 A?**

Triac or transistor output elements have a minimum holding current. Considering the ambient operating temperature, the minimum load current based on the minimum holding current is 0.1 A. If the load current is less than 0.1 A, the output element cannot maintain the ON-status of the load. As a result, the output waveform may oscillate or may not turn ON. Usually, an SSR operating at 200 V has a maximum leakage current of 10 mA. To prevent load reset failures caused by the leakage current, the minimum load current is limited to 0.1 A on the assumption that the minimum reset current is 10% of the rated value.

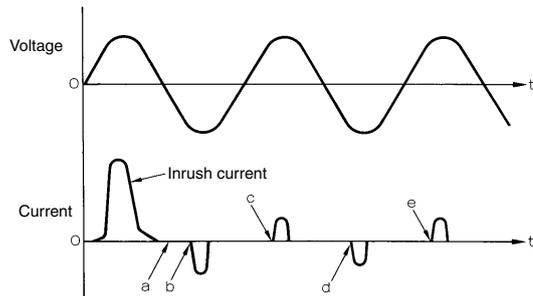
Therefore, for example, if a load with a rated current of 50 mA is used, the leakage current with the SSR turned OFF will be 20% of the rated value. This may cause reset failures, depending on the load. Two characteristics of SSRs with power MOS FET output elements (e.g., G3DZ, G3RZ), are that a holding current is unnecessary, and the leakage current is small. Switching is possible for loads as small as 100  $\mu$ A at 200 VAC.

Minimum Load Current

Solid state relays

**■ Q16. Why is the current not stable when the power supply is switched ON and OFF?**

The power supply for an SSR is a capacitive load due to the built-in smoothing capacitance of the power supply. As clearly shown in the graph below, there are periods where almost no current flows and periods where the capacitance changes quickly.



When the voltage is supplied to the SSR, the SSR will turn ON. Around point a, where there is virtually no current flow, however, the SSR will turn OFF. The moment the charge current starts flowing at point b, the SSR will turn ON. At point c, the SSR will turn ON. If the SSR does not turn ON at point b in time, the capacitance will not be fully charged. Therefore, when the SSR turns ON at point c, a high current will flow into the capacitance to supplement the insufficient charge at point b. The same operation is repeated at point d and point e. As a result, the current flow into the SSR is not stable. To solve this problem, a bleeder resistor can be connected in parallel to the power supply so that a current will always flow into the bleeder resistance, thus keeping the SSR turned ON.

**Bleeder Resistor Values**

100 VAC	5 to 10 kΩ	3 W
200 VAC	5 to 10 kΩ	15 W

Switching Power Supply and Bleeder Resistance

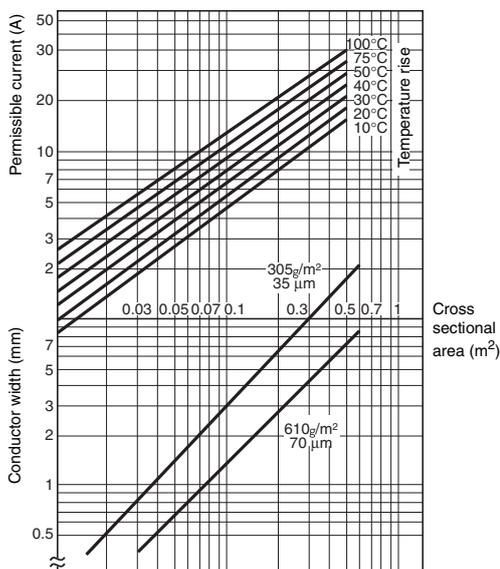
**■ Q17 What are the ideal pattern widths and pitches on a PCB?**

The required pattern widths and pitches vary with the operating conditions, such as the PCB materials and ambient temperature. An example of design standards is provided below.

**Conductor Pattern Width and Thickness**

A standard copper foil is 35 or 70 μm thick. The width of the foil is determined by the carry current and permissible temperature rise. See the following graph for a simple reference.

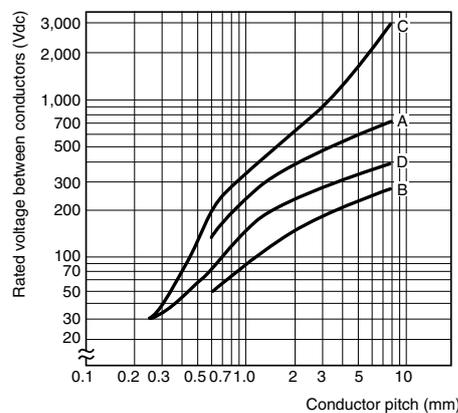
**Conductor Widths vs. Permissible Currents (IEC Publication 326-3)**



**Conductor Pitches**

The conductor pitches on a PCB vary with the insulation characteristics and the degree of environmental stress. See the following graph for a standard reference. If the PCB is manufactured in accordance with the Electrical Appliance and Material Control Law or some international safety standards (e.g., UL, CSA, and VDE), however, the requirements of the standards will take precedence. Wider conductor pitches can be used for multi-layer PCBs.

**Operating Voltages vs. Conductor Pitches (IEC Publication 326-3)**



- A: Up to 3,000 mm in altitude with no coating.
- B: Over 3,000 and less than 15,000 mm in altitude with no coating.
- C: Up to 3,000 mm in altitude with coating.
- D: Over 3,000 mm in altitude with coating.

PCB, Pattern Width, and Pattern Pitch

■ **Q18. Is it possible to protect the motor with an SSR and mechanical thermal?**

Yes, it is.

If the inrush current resistance of the SSR does not match the protective characteristics of the thermal, however, the SSR may be destroyed by overcurrent within a short period. The period is so short that the motor will not burn out.

In this case, a high-speed breaking fuse can be used to protect the SSR.

Recommended thermal relays with harmonized protection are listed for the G3J, which is an SSR for three-phase motors to which a thermal relay can be mounted.

Thermal

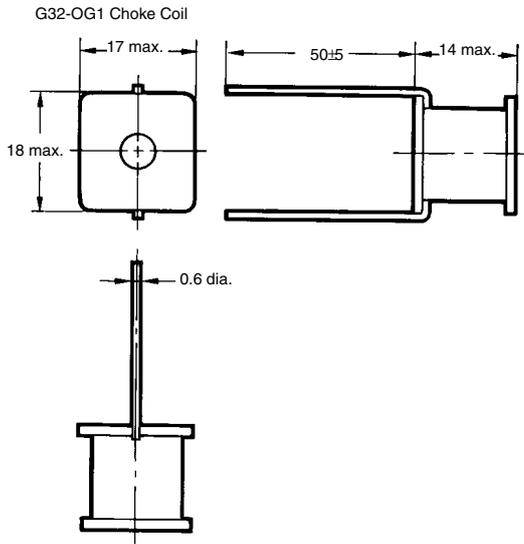
■ **Q19. What precautions are necessary for forward/reverse operation of the single-phase motor?**

Refer the following table for the protection of capacitor motors driven by SSRs.

Single-phase 100 V	Load current of recommended SSR	Protection of motor in forward/reverse operation	
		R	L
25 W	AC 2 to 3 A	R = 6 Ω, 10 W	Choke coil
40 W			
60 W	AC 5 A	R = 4 Ω, 20 W	
90 W		R = 3 Ω, 40 to 50 W	

Single-phase 200 V	Load current of recommended SSR	Protection of motor in forward/reverse operation	
		R	L
25 W	AC 2 to 3 A	R = 12 Ω, 10 W	Choke coil
40 W			
60 W	AC 5 A	R = 12 Ω, 20 W	
90 W		R = 8 Ω, 40 W	

1. When the motor is in forward/reverse operation, a voltage that is twice as high as the power supply voltage may be imposed on an SSR that is OFF due to the LC resonance of the motor. OMRON's PCB SSR product ranges cover a maximum of 200 VAC. Therefore, SSRs cannot be used to control motors in forward/reverse operation at 200 VAC in some cases. Before starting the forward/reverse operation of the motor at 200 VAC, measure the voltage that is imposed on the SSR turned OFF and make sure that the SSRs are operable.



Forward/Reverse Operation

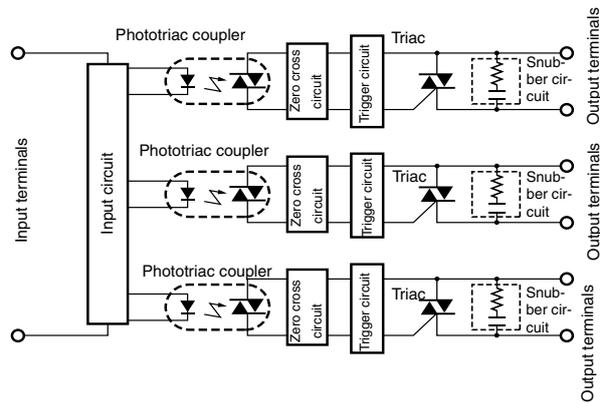
Solid state relays

■ **Q20. Is it possible to use a three-phase SSR to turn three single-phase circuits ON and OFF?**

Three output circuits of the G3J single-function model and those of the G3PB are all separated from each other. Therefore, the output phases can be connected to independent circuits.

Do not use the G3J-S or G3J-T for single-phase circuits, or otherwise the start/stop function will not operate normally.

**Configuration**



Three-phase SSR

■ **Q21. Why is a time lag required between the forward operation and reverse operation of a three-phase motor?**

The forward or reverse operation of a three-phase motor is selected by switching two phases. If the SSR for the forward operation of the motor turns ON simultaneously with that for the reverse operation of the motor, a phase short circuit results through the SSRs, thus destroying the SSRs. The reset time of the SSRs fluctuates within a maximum of a half cycle. Therefore, if the forward operation and

reverse operation of the motor are switched quickly, both SSRs may turn ON at the same time destroying them.

When either one of the SSRs is turned OFF, the motor will generate counter-electromotive force, which easily causes the SSRs to malfunction. To prevent this, a longer time lag (at least 30 ms) will be required to switch between the forward and reverse operation of the motor.

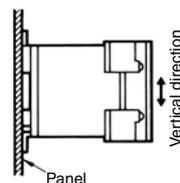
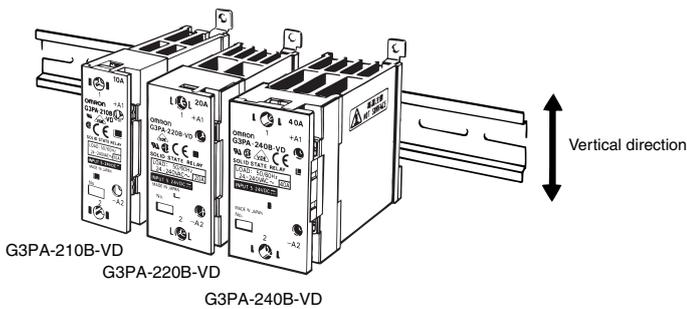
Time Lag and Forward/Reverse Operation

■ **Q22. Does an SSR have a mounting direction?**

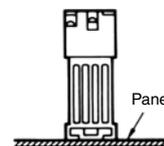
An SSR consists of semiconductor elements. Therefore, unlike mechanical relays that incorporate movable parts, gravity changes have no influence on the characteristics of the SSR.

Changes in the heat radiation of an SSR may, however, limit the carry current of the SSR.

An SSR should be mounted vertically. If the SSR has to be mounted horizontally, check with the SSR's datasheet. If there is no data available for the SSR, use with a load current at least 30% lower than the rated load current.



Vertical mounting  
Mount the SSR vertically.



Flat Mounting  
The SSR may be mounted on a flat surface, provided that the load current applied is 30% lower than the rated load current.

Mounting Direction

**■ Q23. What precautions are required for high-density mounting or gang mounting?**

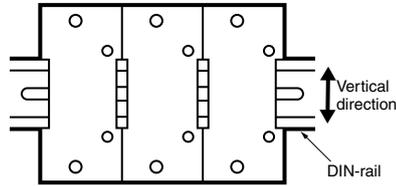
In the case of high-density or gang mounting of SSRs, check the relevant data in the SSR datasheet. If there is no data, check that the load current applied is 70% of the rated load current. A 100% load current can be applied if groups of three SSRs are mounted in a single row with a space as wide as a single SSR between adjacent groups.

If the SSRs are mounted in two or more rows, it is necessary to confirm the temperature rise of the SSR separately.

With side-by-side high-density or gang mounting of SSRs with heat sinks, reduce the load current to 80% of the rated load current.

Refer to the SSR's datasheet for details.

**G3PA**

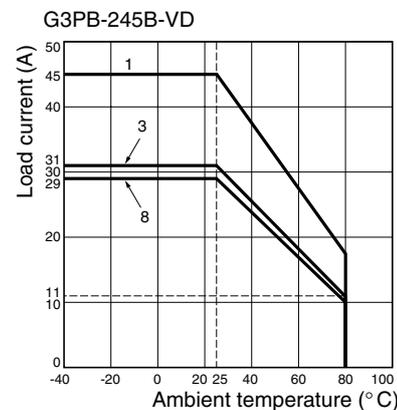
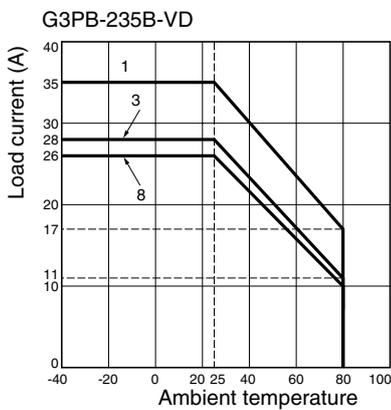
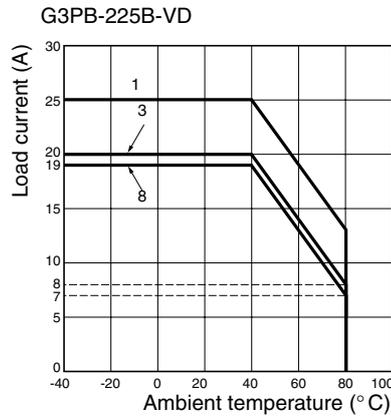
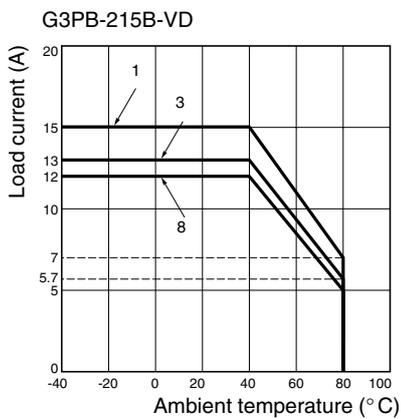


Do not mount more than a group of three Units closely together without providing a 10-mm space to the next group.

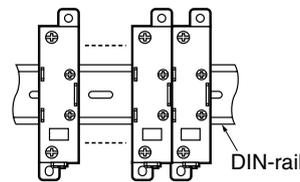
**G3PB**

**Characteristic Data**

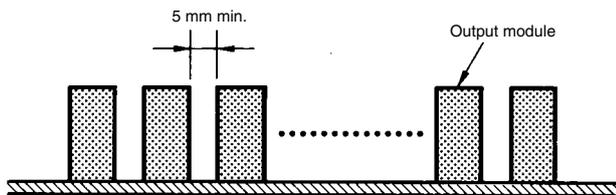
**High-density or Gang Mounting (3 or 8 Units)**



Example of high-density or gang mounting



**G3TB**

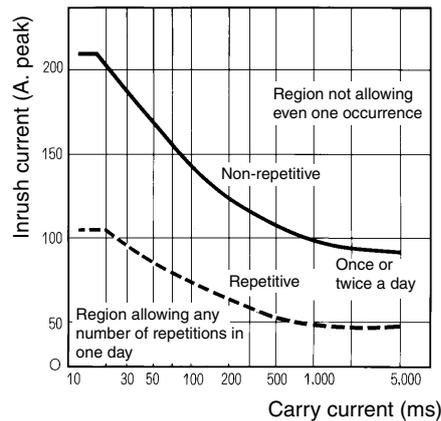


Close-mounting of Output Modules  
Provide a minimum space of 5 mm between adjacent SSRs. A load of 3 A can be switched with a maximum of 16 points.

High-density or Gang Mounting

■ **Q24. What is the non-repetitive inrush current?**

The datasheet of an SSR gives the non-repetitive inrush current of the SSR. The concept of the non-repetitive inrush current of an SSR is the same as an absolute maximum rating of an element. Once the inrush current exceeds the level of the non-repetitive inrush current, the SSR will be destroyed. Therefore, check that the maximum inrush current of the SSR in usual ON/OFF operation is 1/2 of the non-repetitive inrush current. Unlike mechanical relays that may result in contact abrasion, the SSR will provide good performance as long as the actual inrush current is a maximum of 1/2 of the non-repetitive inrush current. If the SSR is in continuous ON/OFF operation and a current exceeding the rated value flows frequently, however, the SSR may overheat and a malfunction may result. Check that the SSR is operated with no overheating. Roughly speaking, inrush currents that are less than the non-repetitive inrush current and greater than the repetitive inrush current can be withstood once or twice a day (e.g., this level of inrush current can be withstood in cases where power is supplied to devices once a day).



Non-repetitive Inrush Current

■ **Q25. What kind of failure do SSRs have most frequently?**

OMRON's data indicates that most failures are caused by overvoltage or overcurrent as a result of the short-circuiting of SSRs. This

data is based on SSR output conditions, which include those resulting from the open or short circuit failures on the input side.

	Failure	Load condition
Input	Short	Does not turn ON.
	Open	Does not turn ON.
Output	Output triac short circuit (80% of failures)	Does not turn OFF.
	Output triac open circuit (20% of failures)	Does not turn ON.

Failure

■ **Q26. What will happen if the load voltage exceeds the upper limit?**

OMRON's G3NA, G3NE, and G3PA SSRs, which have a built-in varistor, have a rated load voltage of 264 VAC. These SSRs withstand a maximum of 264 VAC. The built-in varistor operates when the load voltage in actual operates exceeds around 400 VAC and the varistor will be destroyed.

OMRON's G3M or G3CN or G3F SSR does not incorporate a varistor. These SSRs with 200-VAC output withstand a maximum of 264 VAC. The output triac of the SSR in actual operation will be destroyed due to an overvoltage of approximately 600 VAC, provided that the AC is a sine wave current with no distortion or noise.

For an ordinary power supply, there will be an increase in the failure rate of the SSR if the load voltage exceeds 264 VAC.

Overvoltage

■ **Q27. Is it possible to replace a defective part in an SSR?**

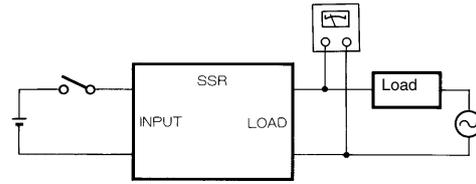
It is possible to replace the power elements of the G3PX, G3PA, and G3NH. No parts of any other OMRON's SSR are replaceable because the SSR is sealed with plastic resin.

Parts Replacement

■ **Q28. How can we use a multimeter to check if the SSR is ON or OFF?**

The resistance of the load terminals of the SSR does not make clear changes when the input turns ON and OFF.

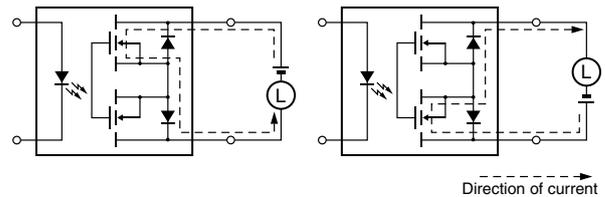
Connect a dummy load to the output terminals and check the voltage of the load terminals with the input ON and OFF. The output voltage will be close to the load power supply voltage with the SSR turned OFF. The voltage will drop to approximately 1 V with the SSR turned ON. This is more clearly checked if the dummy load is a lamp with an output of about 100 W.



Multimeter Check

■ **Q29. Why can MOS FET relays be used for both AC and DC loads?**

With power MOS FET relays, because 2 MOS FET relays are connected in series in the way shown on the right, the load power supply can be connected in either direction. Also, because power MOS FET elements have a high dielectric strength, they can be used for AC loads, where the polarity changes every cycle.

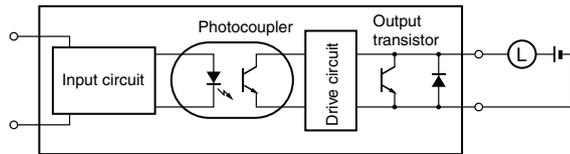


MOS FET Relays

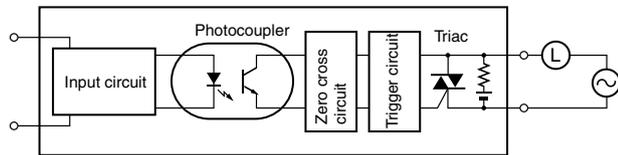
■ **Q30. What are the differences between SSRs and power MOS FET relays?**

**Number 1: There are SSRs for DC loads and SSRs for AC loads.**

SSR for DC Loads (e.g., G3SD)



SSR for AC Loads (e.g., G3H)

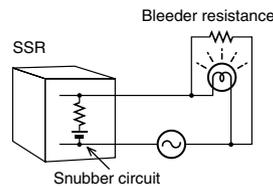


Power MOS FET relays can be used for both DC loads and AC loads.

**Number 2: The leakage current for power MOS FET relays is small compared to that for SSRs.**

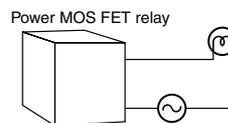
**SSRs**

The lamp (see below) is faintly light by the leakage current. A bleeder resistance is added to prevent this. With SSRs, a snubber circuit is required to protect the output element.



**Power MOS FET Relays**

The leakage current is very small (10 μA max.) and so the lamp does not light. This is because a snubber circuit is not required to protect the MOS FET output element. A varistor is used to protect the MOS FET.



A bleeder resistance is not required and so circuits can be simplified and production costs reduced.

MOS FET Relays

Solid state relays

**■ Q31. What kind of applications can power MOS FET relays be used for?**

1. Applications where it is not known whether the load connected to the relay is AC or DC.

Example: Alarm output of robot controller.

2. Applications with high-frequency switching of loads, such as for solenoid valves, where the relay (e.g., G2R) has to be replaced frequently.

Power MOS FET relays have a longer lifetime than other relays and so the replacement frequency is less.

The terminals of the G3RZ are compatible with those of the G2R-1A-S and so these models can be exchanged.

**Note** Confirm the input voltage, polarity, and output capacity before application.

3. Applications with high-voltage DC loads.

In order to switch a 125-VDC, 1-A load with a relay, an MM2XP or equivalent is required. With the G3RZ power MOS FET relay, however, switching at this size is possible.

4. Applications where SSRs are used with a bleeder resistance.

The leakage current for power MOS FET relays is very small (10  $\mu$ A max.) and so a bleeder resistance is not required.

MOS FET Relays