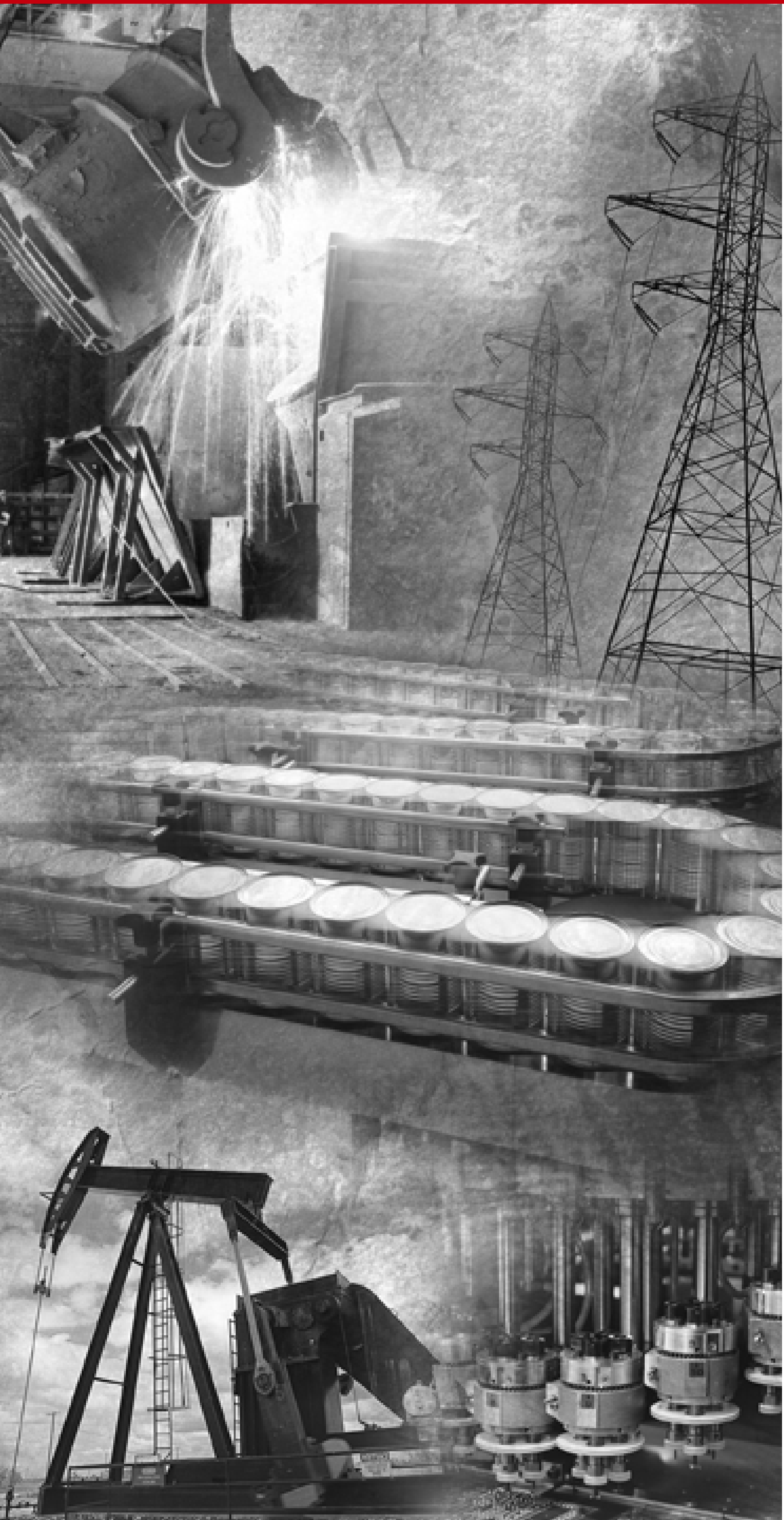


Allen-Bradley

Solid-State Relays

700-SA -SC, -SE, -SF, -SH, -SK

Application Guide

Rockwell Automation

Important User Information

Because of the variety of uses for the products described in this publication, those responsible for the application and use of this control equipment must satisfy themselves that all necessary steps have been taken to assure that each application and use meets all performance and safety requirements, including any applicable laws, regulations, codes and standards.

The illustrations, charts, sample programs and layout examples shown in this guide are intended solely for purposes of example. Since there are many variables and requirements associated with any particular installation, Allen-Bradley does not assume responsibility or liability (to include intellectual property liability) for actual use based upon the examples shown in this publication.

Allen-Bradley publication SGI-1.1, *Safety Guidelines for the Application, Installation and Maintenance of Solid-State Control* (available from your local Allen-Bradley office), describes some important differences between solid-state equipment and electromechanical devices that should be taken into consideration when applying products such as those described in this publication.

Throughout this manual we use notes to make you aware of safety considerations:

ATTENTION	Identifies information about practices or circumstances that can lead to personal injury or death, property damage or economic loss

Attention statements help you to:

- identify a hazard
- avoid a hazard
- recognize the consequences

IMPORTANT	Identifies information that is critical for successful application and understanding of the product.

European Communities (EC) Directive Compliance

If this product has the CE mark it is approved for installation within the European Union and EEA regions. It has been designed and tested to meet the following directives.

EMC Directive

This product is tested to meet the Council Directive 89/336/EC Electromagnetic Compatibility (EMC) by applying the following standards, in whole or in part, documented in a technical construction file:

- EN 61000-6-2 EMC — Generic Standards — Immunity for Industrial Environments

This product is intended for use in an industrial environment.

Low Voltage Directive

This product is tested to meet Council Directive 73/23 EEC as ammended by 93/68 EEC Low Voltage, by applying the safety requirements of EN 60950 and safety requirements for “Safety of Information Technology Equipment — General Requirements.”

This equipment is classified as open equipment and must be mounted as instructed in an enclosure during operation to provide safety protection.

Preface

Chapter 1 — Basic Concepts of SSRs

Chapter 2 — Considerations When Designing SSR Control Systems

Chapter 3 — Mounting and Installation

Chapter 4 — Q and A

Appendix

Preface

Manual Objectives

The purpose of this manual is to provide you with the additional information necessary to apply Bulletin 700-S Solid-state Relays . Described in this manual are methods for applying and troubleshooting this product.

Who Should Use This Manual

This manual is intended for qualified personnel responsible for setting up and servicing these devices. You must have previous experience with and a basic understanding of wiring diagrams, configuration procedures, related equipment, and safety precautions.

Manual Explanation

"SSR" stands for solid-state relay. First marketed in the 1970's, SSRs have become very popular for the following reasons:

• They provide a means of creating no-contact relays in output power sections enabling conversion of control circuits to ICs.

• They provide a means of increasing the service life of the application and reducing maintenance time and costs.

• They provide a means of preventing operating errors caused through noise by isolating signal circuits and outputs.

• They provide a means of eliminating the clicking sounds produced when mechanical relay load currents turn ON.

In these and other ways, SSRs have proven to provide many special characteristics to meet market needs.

This manual has been produced in response to demand from customers to provide the product and technical information required to select the best SSRs according to purpose and application.

For Further Information

Relays and Timers Selection Guide

- Publication 700-SG003B-EN-P

Basic Concepts of SSRs

Overview

What are SSRs?

Difference between SSRs and Mechanical Relays

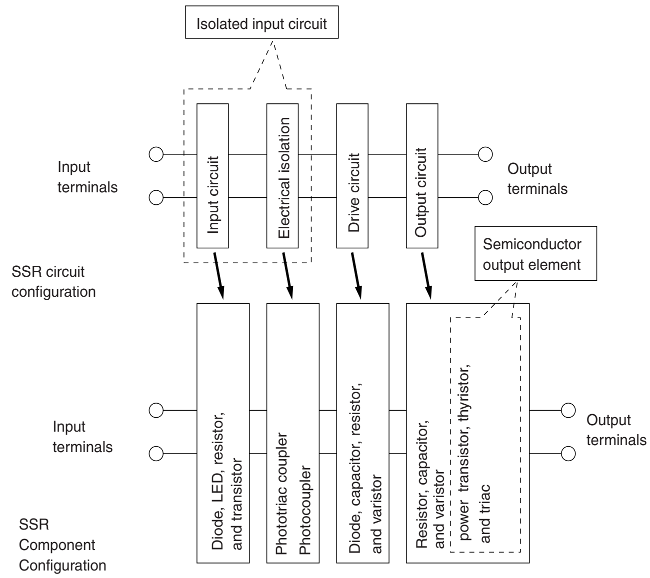
SSRs (solid-state relays) have no movable contacts. SSRs are not very different in general operation from mechanical relays that have movable contacts. SSRs, however, employ semiconductor switching elements, such as thyristors, triacs, diodes, and transistors. Furthermore, SSRs employ optical semiconductors called photocouplers to isolate input (control) and output (load) signals. Photocouplers change electric signals into optical signals and transmit the signals through space, thus fully isolating the input and output sections while transferring 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:

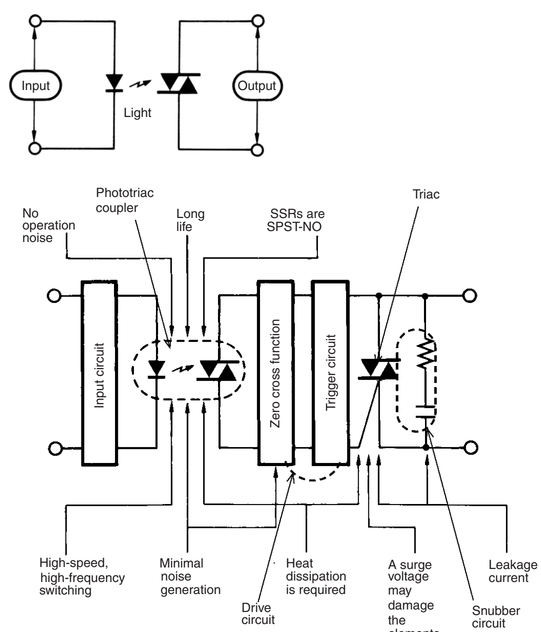
- They provide high-speed, high-frequency ON/OFF switching operations.
- They have no contact failures.
- They generate little noise.
- They have no arc noise.

Configuration of SSRs



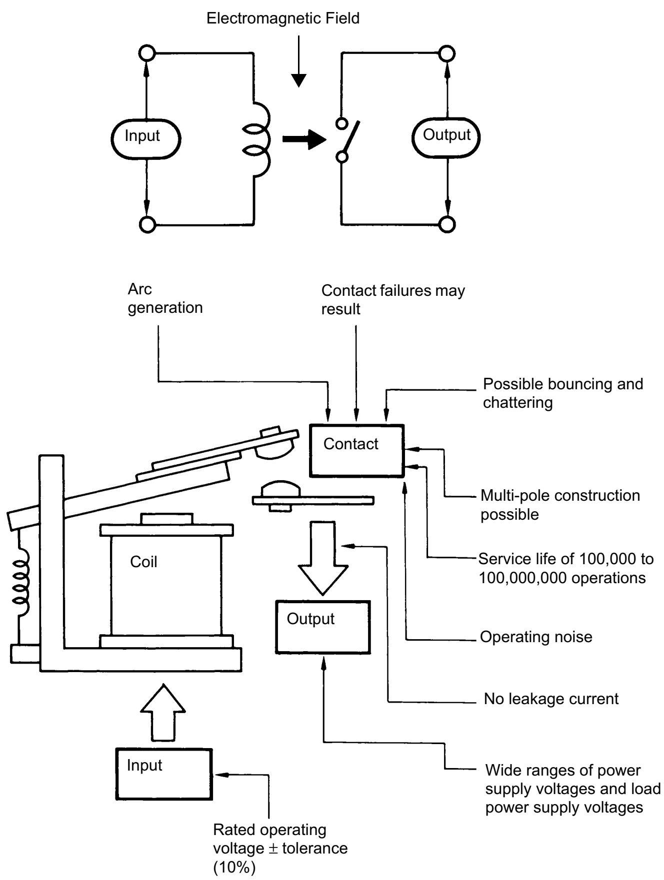
Power transistor (for DC loads)
Thyristor (for AC loads)
Triac (for AC loads)

Representative Example of Switching AC Loads



Electromagnetic Relay (EMR)

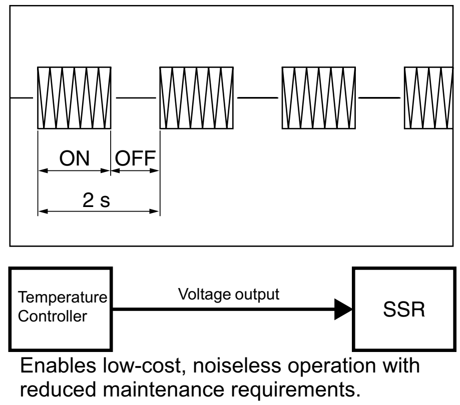
An EMR generates electromagnetic force when input voltage is applied to the coil. The electromagnetic force moves the armature that switches the contacts in synchronization. EMRs are used for a wide range of applications. The principle of the operation of EMRs is simple and it is possible to manufacture EMRs at low costs.



Control of SSRs (ON/OFF Control)

ON/OFF control is a form of control where a device such as a heater is turned ON or OFF by turning a 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 the heater is turned ON and OFF at intervals of a few seconds (high-frequency switching) over a period of several years, then an SSR must be used.

ON/OFF Control

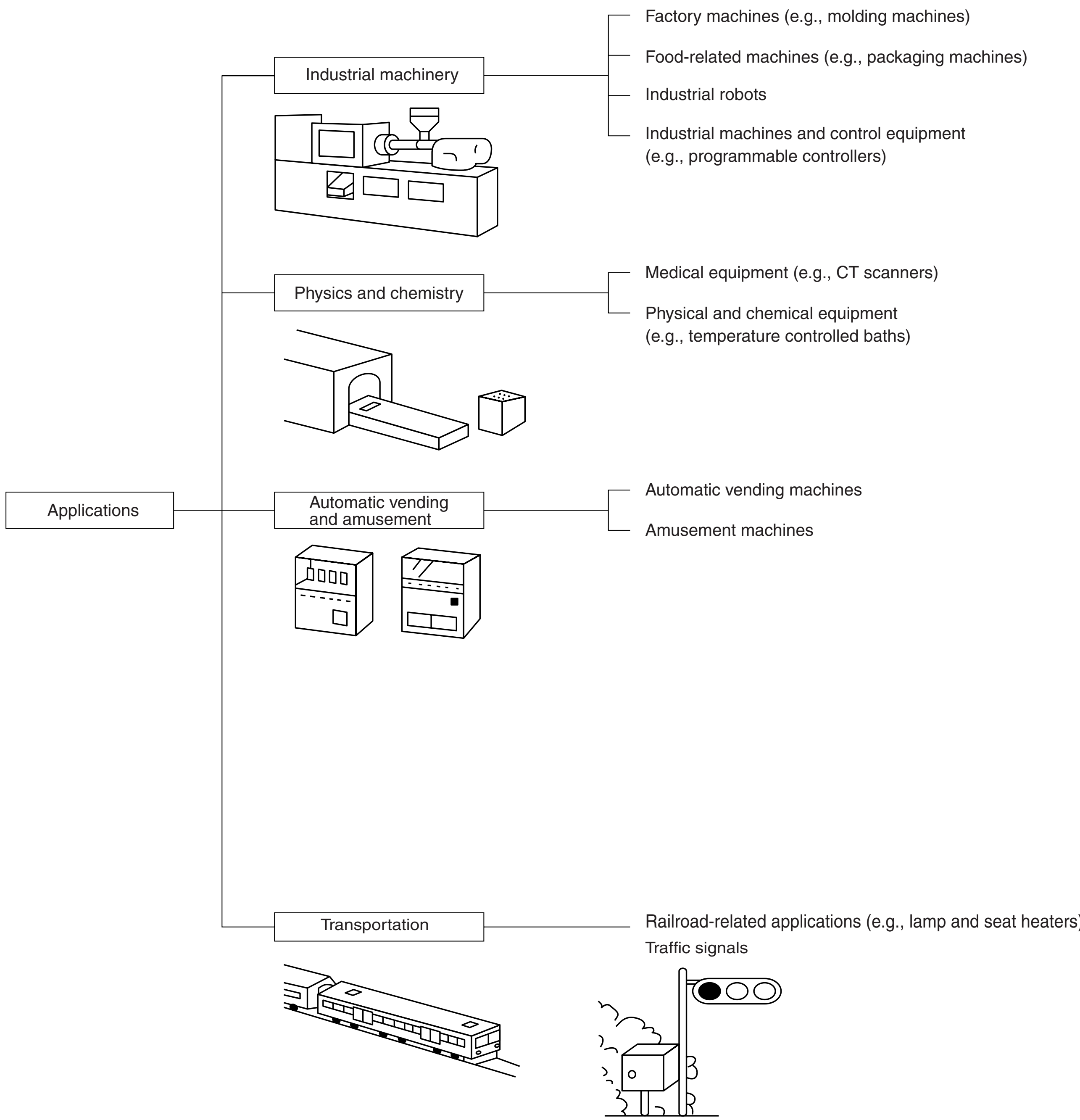


SSR Application Examples

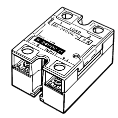
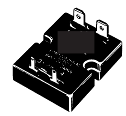
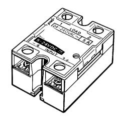
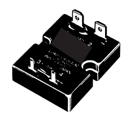
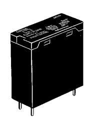
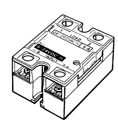
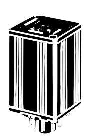
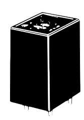
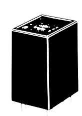
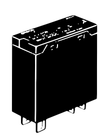
SSRs are used for a variety of electric machines and devices

SSR Classifications

SSRs can be classified by appearance, such as panel-mounting models, socket models, or by applications, as shown below. The optimum SSR can be selected depending on the purpose.


Applications
Industrial machinery
Factory machines (e.g., molding machines)
Food-related machines (e.g., packaging machines)
Industrial robots
Industrial machines and control equipment (e.g., programmable controllers)
Physics and chemistry
Medical equipment (e.g., CT scanners)
Physical and chemical equipment (e.g., temperature controlled baths)
Automatic vending and amusement
Automatic vending machines
Amusement machines
Transportation
Railroad-related applications (e.g., lamp and seat heaters)
Traffic signals

Classification by Application

Application	Recommended SSRs
Heater Control 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. They meet the high-capacity, high ON/OFF frequency requirements of heater control.	  700-SH 700-SE
Motor Control 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.	  700-SH 700-SE
I/O These SSRs meet the requirements for isolated transmission of control output from PCs and Position Controllers to an actuator.	 700-SK
Amusement Machines These SSRs have high ON/OFF frequency, noiseless operation, and when compared to mechanical relays, have greater resistance to vibration, shock, dust and dirt, and gas, making them ideal for situations where these factors are important.	 700-SH
Panel-mounted Interfaces 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.	    700-SA 700-SC 700-SF 700-SK

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.

Terms		**Meaning**
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 (continuous)	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).
	Output 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 (load switching device)	This is a generic name for semiconductors such as the thyristor, triac, and power transistor. 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 is used in a SSR for AC loads.
	Collector-emitter voltage (VCEO)	This is a rating for an output semiconductor that is used in an SSR for DC loads.
Characteristics	Operating time (pick-up 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 (drop-out 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.

Terms		**Meaning**
Others	Inrush current	A current which can be applied for short periods of time to the electrical element.
	Counter-electro motive 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.)

Considerations When Designing SSR Control Systems

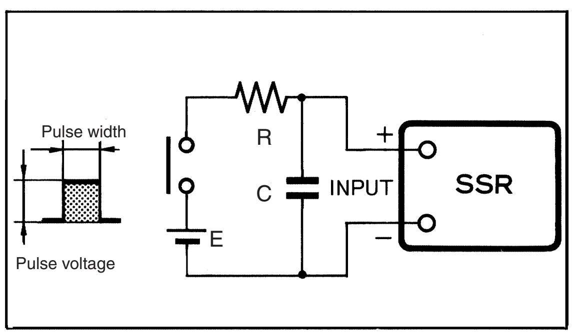
Input Circuit

Input Noise

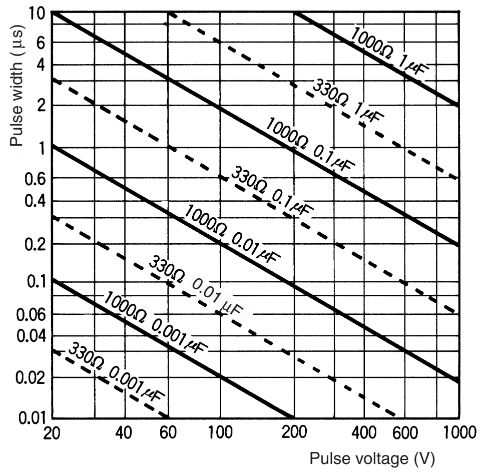
SSRs need only a small amount of input/control power to operate. This is why the input terminals must shut out electrical noise as much as possible. Noise applied to the input terminals may result in malfunction. The following describe measures to be taken against electrical pulse noise and inductive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

1. Pulse Noise

A combination of capacitor and resistor on the input/control circuit 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 SSR's required input must operate (ON) voltage value. The larger the value of C, 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.

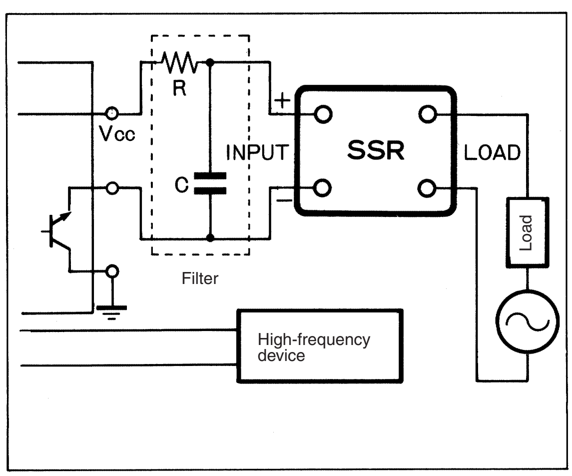
2. Inductive Noise

Do not wire high voltage power lines alongside the low voltage SSR input/control lines. Inductive noise may cause the SSR to malfunction, turn off unexpectedly, or both. If inductive noise is imposed on the input terminals of the SSR, use the following cables according to the type of inductive noise, to help 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.

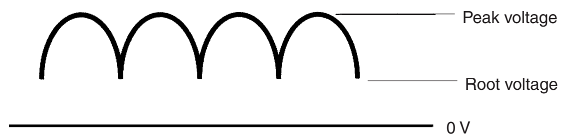


Note: R: 20…100 Ω
C: 0.01… 1 µF

Input Conditions

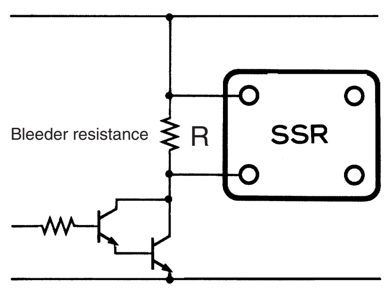
1. Input Voltage Ripples

When there is a ripple in the input control voltage, ensure that the peak voltage of the ripple is lower than the maximum operating SSR voltage and the root voltage is above the SSR minimum operating voltage.



2. Countermeasures for Leakage Current

When the SSR input circuit is powered by a transistor output, the SSR reset voltage may be insufficient due to leakage current of the transistor during power OFF. To counteract this, connect a 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.

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

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

I_L: 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:

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

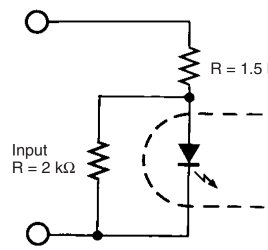
For SSRs with constant-current input circuits (e.g., 700-SH) calculation is performed at 0.1 mA.

3. ON/OFF Frequency

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

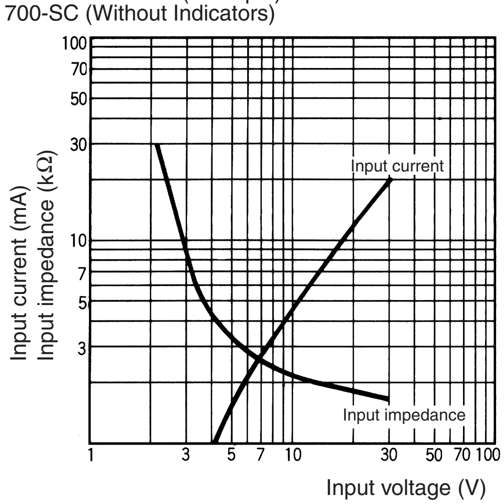
4. Input Impedance

In SSRs that have a wide input voltage range (such as 700-SC and 700-SF), 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.

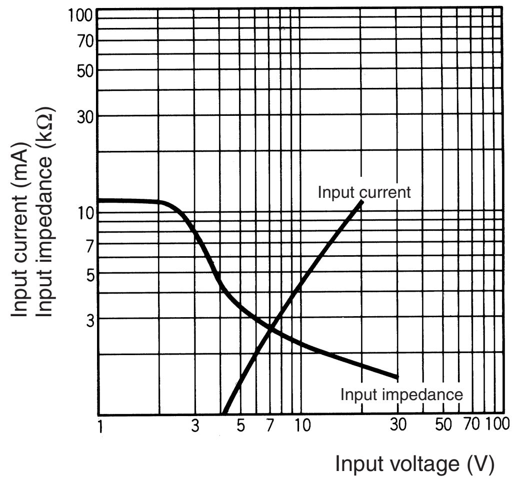


For semiconductor-driven SSRs, changes in voltage can cause malfunction of the semiconductor, so be sure to check the actual device before usage. See the following examples. Refer to the SSR's datasheet for the impedance of individual SSR models.

Applicable Input Impedance for a Photocoupler-type SSR without Indicators (Example)
700-SC (Without Indicators)



Applicable Input Impedance for a Photocoupler-type SSR with Indicators (Example)
700-SA, -SC, -SF (With Indicators)



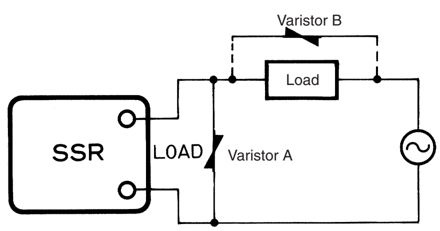
Output Circuit

AC ON/OFF SSR Output Noise Surges

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

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

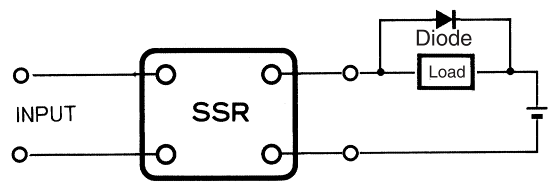


Select an element which meets the conditions in the table below as the surge absorbing element.

Line Voltage	Varistor (MOV) voltage	Surge resistance
100…120V AC	240…270 V	1,000 A min.
200…240V AC	440…470 V	
380…480V AC	820…1000 V	

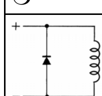
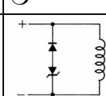
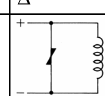
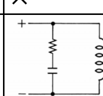
DC ON/OFF Output Noise Surges

When an inductive load, such as a solenoid or electromagnetic valve is the SSR load, connect a diode that prevents counter-electromotive force. If the counter-electromotive force exceeds the withstand voltage (V_{DRM}) 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 with a diode. 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.

DC Absorption Element Example

Absorption element				
	Diode	Diode + Zener diode	Varistor	RC
Effectiveness	❍	❍	Δ	✕
				
❍ **= most** Δ = **marginal** ✕ **= not**				

Reference

1. Selecting a Diode
   Withstand voltage = $V_{DRM} \geq$ Power supply voltage ✕ 2
   Forward current = $I_F \geq$ load current

2. Selecting a Zener Diode
Zener voltage = Vz < SSR's connector-emitter voltage - (Power supply voltage + 2 V)
Zener surge reverse 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.

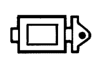
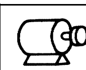
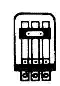
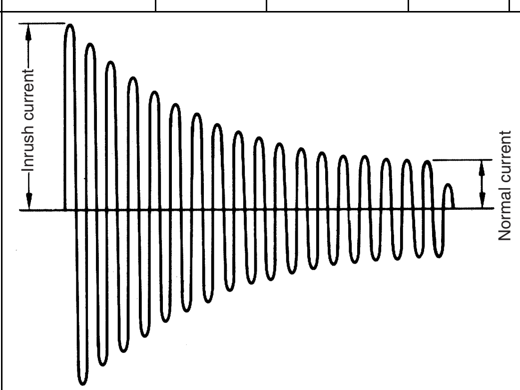
Self-Holding (Latching) Circuits

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

Selecting a SSR For Different Loads

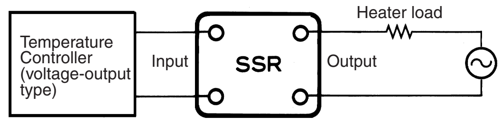
The following provides examples of the inrush currents for different loads:

AC Loads and Inrush Current

Load	 Solenoid	 Incan descent lamp	 Motor	 Relay	Capacitor	Resis- tance /Heater
Inrush cur- rent/Nor- mal 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						

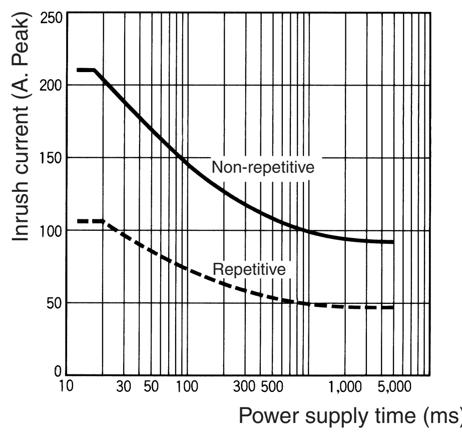
1. Heater Load (Resistive Load)

A resistive load is essentially a load without an inrush current. The SSR is generally used together with a voltage-output temperature controller for heater ON/OFF switching. When used with an SSR with a zero cross function, it suppresses most noise generated by the load. 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 constant-current type SSR.



2. Lamp Load

Large inrush current flows through incandescent lamps, halogen lamps, and so on (approx. 10…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 Section.)



If a 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…10 times the motor’s rated current flows and the inrush current flows for a period approximately 50% longer than a lampload 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 a 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.

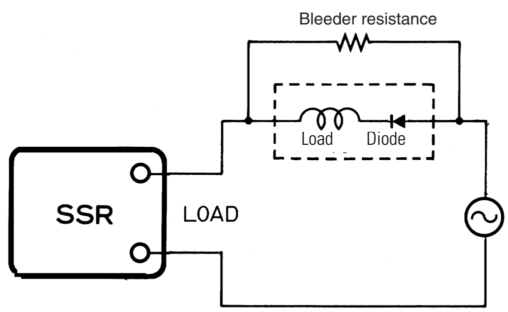
4. Transformer Load

When the SSR is switched ON, an energizing current of 10…20 times the rated current flows through the SSR for 10…500 milliseconds. If there is no load in the secondary circuit of the transformer, 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 2-7).

5. Half-wave Rectified Circuit

Some 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.

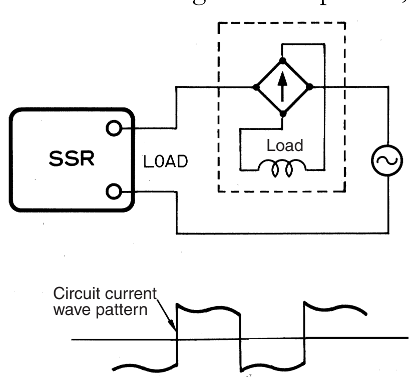
(a) Connect a bleeder resistance with approximately 20% of the SSR load current.



(b) Use SSRs without the zero cross function.

6. Full-wave Rectified Loads

Some 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.



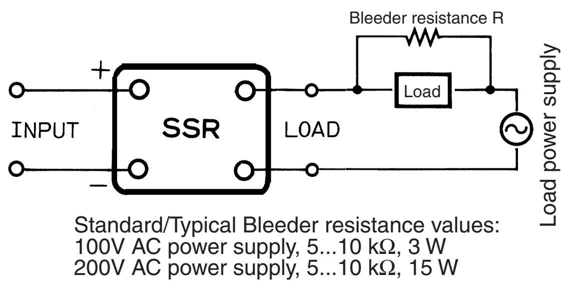
Accordingly, AC SSRs use a triac (which turns OFF the element only when the circuit current is 0 A) in the output element. If the load current waveform is rectangular, it will result in a SSR reset error. Therefore, do not use with SSRs with full-wave rectified loads. When switching ON and OFF a load whose waves are all rectified, use a 700-SF and 700-SCT without zero cross function.

7. Small-capacity Loads

Even when there is no "ON" control 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 load may fail to reset (turn off).

To increase the SSR switching current, connect a bleeder resistance R in parallel to the load.

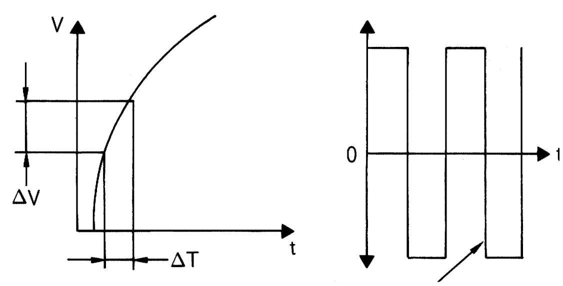
$R < \frac{E}{I_L - I}$ E: Load (relays etc.) reset voltage
I: Load (relays etc.) reset current



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.



ΔV/ΔT = dV/dt: voltage increase ratio

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

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.

Inrush Currents From 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.

$I\ peak = V\ peak/R = (\sqrt{2} \times V)/R$

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.

$I\ peak = (1.414 \times 220)/3 = 103.7\ A$

The inrush current resistance of Bulletin 700-S_ SSRs is specified on condition that the the SSR is 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 (Ipeak).

In the case above, use a 700-S_ SSR 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.

$R = V\ peak/I\ peak = (\sqrt{2} \times V)/I\ peak$

For applicable SSRs based on the DC resistance, refer to the tables on page 2-12.

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

SSR Rated Current

The rated current of Bulletin 700-S_ Relays is indicated in the Relays and Timers Selection Guide, pub. 700-SG003B-EN-P.

Load Power Supply Voltage: 100…120 V

Load power supply voltage			Inrush current (A)	SSR inrush current resistance (A)	Applicable SSR	
100V AC	110V AC	120V AC				
Transformer DC resistance (Ω)					Cat. No.	Cat. No.
4.8 min.	5.2 min.	5.7 min.	30	60	700-SH05G_	700-SE05G_
1.9 … 4.7	2.1 … 5.1	2.3 … 5.6	75	150	700-SH010G_	700-SE010G_
1.3 … 1.8	1.5 … 2.0	1.6 … 2.2	110	220	700-SH025G_	700-SE020G_
0.65 … 1.2	0.71 … 1.4	0.78 … 1.5	220	440	700-SH040G_	—

Load Power Supply Voltage: 200…240 V

Load power supply voltage			Inrush current (A)	SSR inrush current resistance (A)	Applicable SSR	
200V AC	220V AC	240V AC				
Transformer DC resistance (Ω)					Cat. No.	Cat. No.
9.5 min.	10.4 min.	11.4 min.	30	60	700-SH05G_	700-SE05G_
3.8 … 9.4	4.2 … 10.3	4.6 … 11.3	75	150	700-SH010G_	700-SE010G_
2.6 … 3.7	2.9 … 4.1	3.1 … 4.5	110	220	700-SH025G_	700-SE020G_
1.3 … 2.5	1.5 … 2.8	1.6 … 3.0	220	440	700-SH040G_	—

Load Power Supply Voltage: 400 V

Transformer DC resistance (Ω)	Inrush current (A)	SSR inrush current resistance (A)	Applicable SSR
			Cat. No.
7.6 min.	75	150	700-SH10H_
5.2 … 7.5	110	220	700-SH40H_
2.6 … 5.1	220	440	700-SH40H_

Load Power Supply Voltage: 440 V

Transformer DC resistance (Ω)	Inrush current (A)	SSR inrush current resistance (A)	Applicable SSR
			Cat. No.
8.3 min.	75	150	700-SH10H_
5.7 … 8.2	110	220	700-SH40H_
2.9 … 5.6	220	440	700-SH40H_

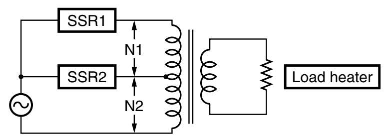
Load Power Supply Voltage: 480 V

Transformer DC resistance (Ω)	Inrush current (A)	SSR inrush current resistance (A)	Applicable SSR
			Cat. No.
9.4 min.	75	150	700-SH10H_
6.2…9.0	110	220	700-SH40H_
3.1…6.1	220	440	700-SH40H_

Transformer Tap Selection

SSRs can be used to switch between transformer taps. In this case, however, be aware of voltage induced in the OFF-side SSR. The induced voltage increases in proportion to the number of turns of the winding that is almost equivalent to the tap voltage.

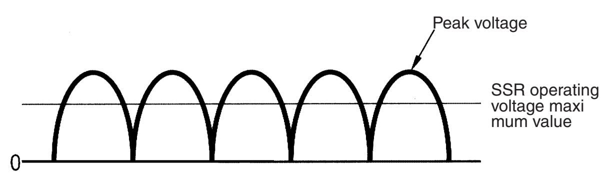
See the following example. The power supply voltage is at 200 V, N1 is 100, N2 is 100, and SSR2 is ON. Then the difference in voltage between output terminals of SSR1 is at 400 V (i.e., twice as high as the power supply voltage).



Load Power Supply

Rectified Supplies

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



Operating Frequency for AC Load Power Supply

The SSR operating frequency range for AC load power supply is 47…63 Hz. This is due to the response speed of the internal triac or thyristor elements of the SSR. Although the SSR operates at less than 47 or 63…100 Hz, the performance of the SSR cannot be guaranteed in these ranges. If the frequency exceeds 100 Hz, the SSR cannot switch the load.

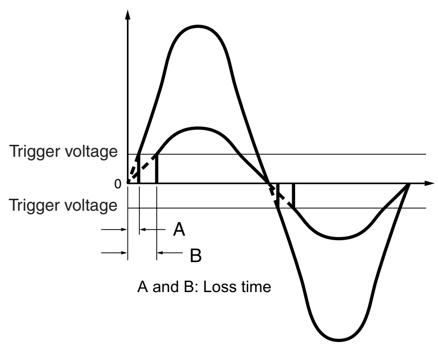
If a AC load SSR with a triac or thyristor output element operates at a frequency of 0 Hz (i.e., like a DC load), reset failure (can't turn off) occurs. This kind of SSR cannot be used for this operation.

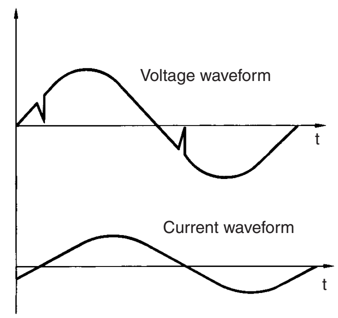
Low AC Voltage Loads

If the load power supply is used 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 no lower than the minimum for the SSR (e.g. 75V AC minimum for the 700-SH_ SSR).





An inductive (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.

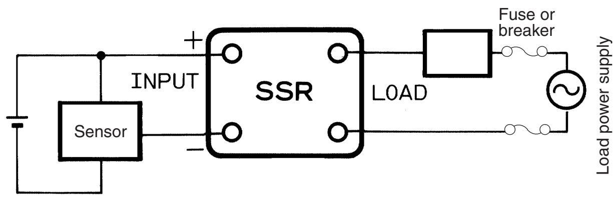
Phase-controlled AC Power Supplies

Do not use a phase-controlled power supply for SSRs that have triac or thyristor output.

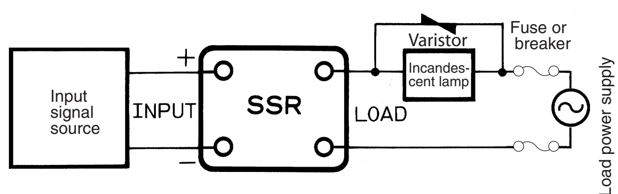
Application Circuit Examples

Connection to a Sensor

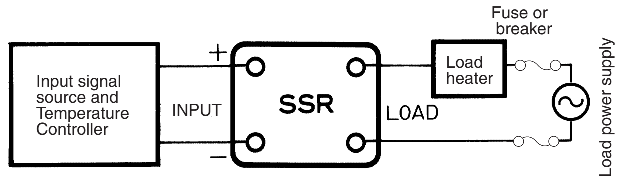
The SSR connects directly to the Proximity Sensor and Photoelectric sensor



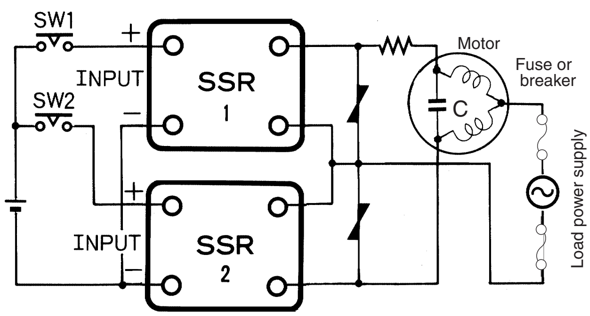
Switching Control of an Incandescent Lamp



Temperature Control of an Electric Furnace



Forward and Reverse Operation of a Single-phase Motor



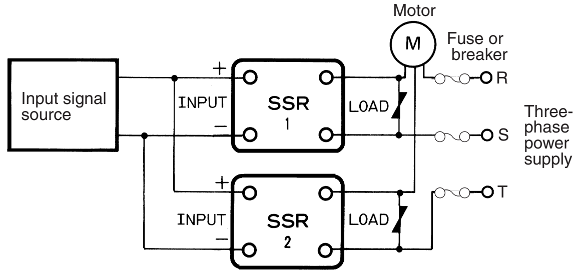
Note: The voltage between the load terminals of either SSR 1 or SSR 2 turned OFF is approximately twice as high as the supply voltage due to LC coupling. Be sure to apply an SSR model with a rated output voltage of at least twice the supply voltage.

1 For example, if the motor operates at a supply voltage of 100 V AC, the SSR must have an output voltage of 200 V AC or higher.

2 Make sure that there is a time lag of 30 milliseconds or more to switch over SW1 and SW2.

ON/OFF Control of a Three-phase Inductive Motor

Single SSRs in Combination



Forward and Reverse Operation of a Three-phase Motor

Single SSRs in Combination

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 milliseconds 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.

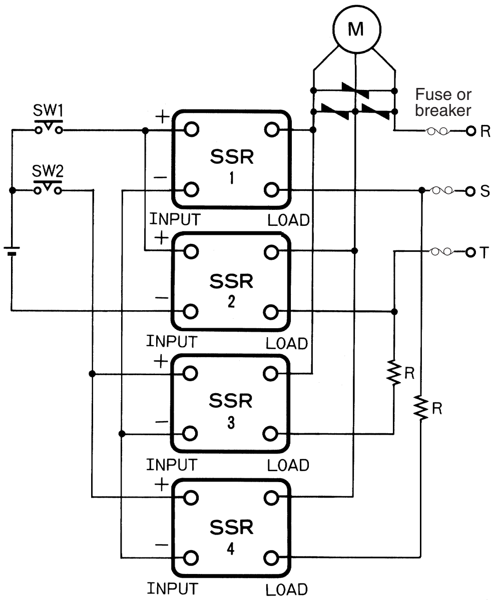
The value of the protective resistance R must be determined according to the withstanding inrush current of the SSR. For example, the 700-SH25G_ withstands an inrush current of 220 A. The value of the protective resistance R is obtained from the following.

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

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)



Fail-safe Concept

Error Mode

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

Therefore, to provide a fail-safe feature for a load using an SSR, a control circuit should be designed 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 as the control element. 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.

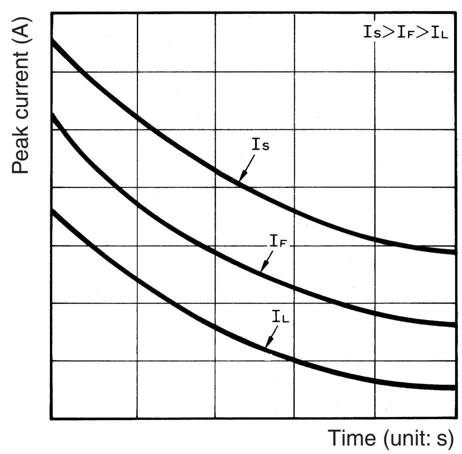
SSR Failures

Location	Cause	Effect to SSR
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	

Short-circuit Protection (Fuse Selection) and Overcurrent Protection

A short-circuit current or an overcurrent flowing through the load side of the SSR will damage the output switching element of the SSR. Connect a quick-break fuse in series with the load as an overcurrent protection measure.

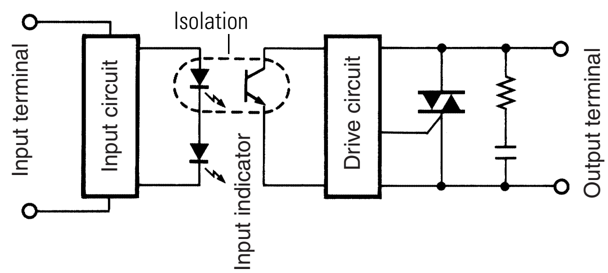
Design a circuit so that the protection coordination conditions for the quick-break fuse satisfy the relationship between the SSR surge resistance (I_S), quick-break fuse current-limiting feature (I_F), and the load inrush current (I_L), shown in the following chart.



Provide an appropriate circuit breaker for each machine to provide overcurrent protection of the machine. Refer to page 4-5, "What is the Meaning of I^2t" for more details.

SSR Operation Indicator (LED)

The operation indicator turns ON when current flows through the SSR's input/control circuit. The LED on the SSR does not indicate that the output element/device is ON.



Heat Radiation Design Basics

SSR Heat Radiation

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

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

For example, if a load current of 8 A flows through Bulletin 700-SH, the following heating value will be obtained:

$P = 1.6\ V \times 8\ A = 12.8\ W$

The SSR in typical normal operation switches a current of approximately 5 A with no heat sink required. 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 likely exceed a single mechanical relay. This is a disadvantage of SSRs for control panel downsizing purposes.

Heat Sink Selection

High current capable SSR models with no heat sinks incorporated into their construction such as Bulletin 700-SH_ and Bulletin 700-SE_ need external heat sinks when load current exceeds 3…6 A. When using either of these SSRs, select an ideal combination of the SSR and heat sink according to the load current.

The following combinations of SSR and heat sinks are ideal:

SSR Cat. No.	Heat Sink Cat. No.
700-SH40_	700-S30
700-SE10_	700-S10

A standard, non-Allen-Bradley heat sink can be used, on condition that the thermal resistance of the heat sink is lower than that of Allen-Bradley's heat sink.

For example, cat. no. 700-S20 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 Bulletin 700-SH_.

Thermal resistance indicates a temperature rise per unit (W). Heat radiation efficency increases with a decrease in thermal resistance.

Calculating Heat Sink Area

An SSR that uses 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 equal or greater to 10 A, because the heat conductivity of steel is less than that of aluminum. Heat conductivity (in units of W • m • °C) varies with the material as described below.

- Steel: 20…50
- Aluminum: 150…220

The use of an aluminum-made heat sink is recommended if the SSR is directly mounted to control panels. Refer to the installation guide of the SSR for the required heat sink area.

Apply heat-radiation silicon❶ or non-silicon❷ grease between the SSR and heat sink. There will be a small 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.

❶ Toshiba type YG6240 or equivalent silicon
❷ AOS company type 53300 or equivalent non-silicon recommended for automotive plant applications

Designing for Control Panel Heat Radiation

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.

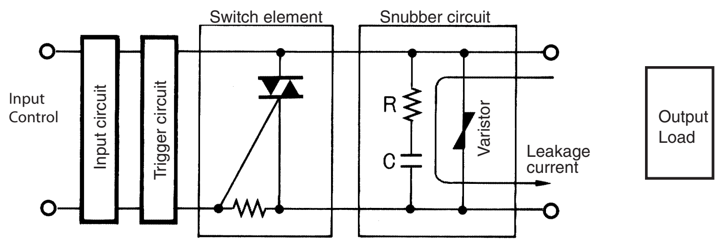
Therefore, it is absolutely necessary to suppress the interior temperature rise of the control panel in order to ensure the long, reliable operation of the control equipment. In this respect the installation of a cooling fan is an advantage and should be considered.

SSR Mounting and Installation

Operation

Leakage Current

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



Screw Tightening Torque

Tighten the SSR terminal screws properly. If the screws are not tight, the SSR may be damaged by heat generated when the power is ON. Perform wiring checks using the tightening torque shown in the following table.

SSR Terminal Screw Tightening Torque

Screw size	Recommended tightening torque
M3.5	0.78 …1.18 N • m
M4	0.98 …1.37 N • m
M5	1.57… 2.35 N • m
M6	3.92 … 4.9 N • m
M8	8.82 … 9.8 N • m

SSR Panel Mounting Quality

If Bulletin 700-SH or Bulletin 700-SE SSRs are to be mounted directly on the control panel, without the use of a heat sink, be sure to use a panel material with low thermal resistance such as aluminum or steel (refer to page 2-20). 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, potentially 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.

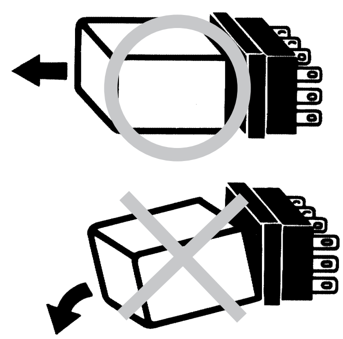
Panel/Surface-mounting Socket

1. Make sure that the surface-mounting socket screws are tightened securely when panel mounted. If the Unit is subjected to shock or vibration and the socket mounting screws are loose, the Socket and the SSR, or the lead wires may detach. The surface-mounting Sockets can be snapped on to the 35-mm DIN Track (Cat. No. 199-DR1).
2. Use a retainer clip such as cat. no. 700-HN102 to help ensure a secure connection between the SSR and Socket. Otherwise the SSR may detach from the socket if an excessive vibration or shock is applied.

SSR Insertion and Removal Direction

Insert and remove the SSR from the Socket perpendicular to the Socket surface. If it is inserted and removed with an inclination from the diagonal line, terminals of the SSR may bend and the SSR may not be properly inserted in the socket.

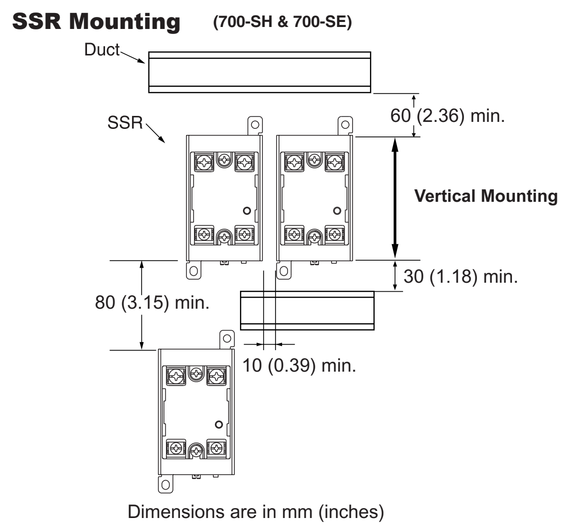
Socket-Mounted SSR



Panel Mounting

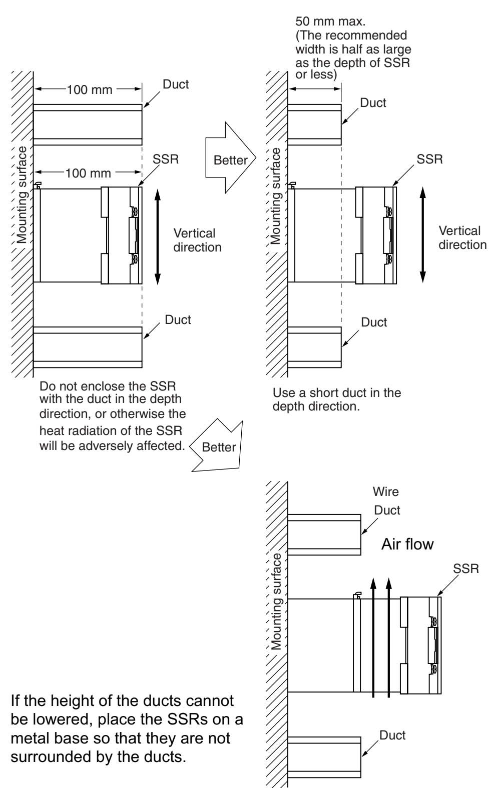
When SSRs are mounted inside an enclosed panel, the radiated heat of the SSR will stay inside, thus not only dropping the carry-current capacity of the SSRs but also adversely affecting other electronic device mounted inside when possible. Open some ventilation holes on the upper and lower sides of the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

The following illustrations provide a recommended mounting example for SSR units. They provide only a rough guide, so be sure to confirm operating conditions using the procedure detailed on page 3-4.



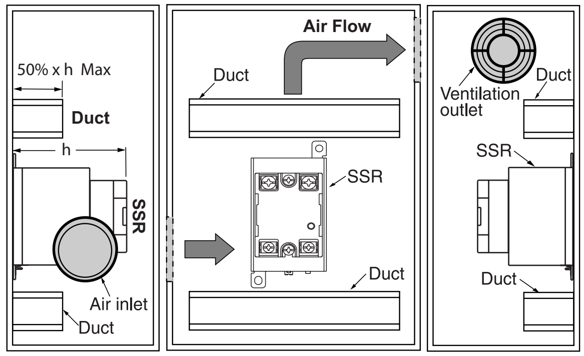
Relationship Between SSRs and Wire Ducts

Duct Depth Example



Ventilation

Ventilation / Wire Duct Height



Clean air inlet filter regularly, if one is used.

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, otherwise the objects may obstruct the proper ventilation of the control panel.

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

Confirmation after Installation

The above conditions are typical examples. Your specific application environment may affect conditions and ultimately the ambient temperature must be measured under power application to confirm that the load current-ambient temperature ratings are satisfied for your system.

Ambient Temperature Measurement Conditions

a. Measure the ambient temperature under the power application conditions that will produce the highest temperature in the control panel and after the ambient temperature has stabalized.

b. Refer to *Figure 1* for the measurement position. If there is a duct or other equipment within the measurement distance of 100 mm, refer to *Figure 2*. If the side temperature cannot be measured, refer to *Figure 3*.

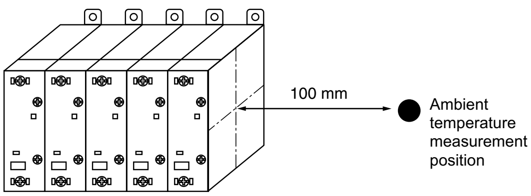


Figure 1: Basic Measurement Position for Ambient Temperature

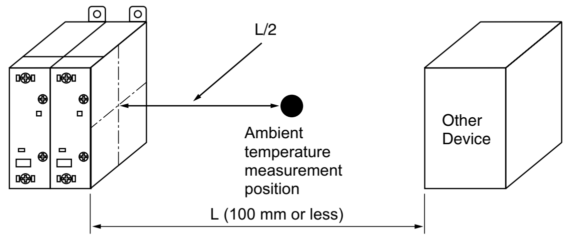


Figure 2: Measurement Position when a Duct or Other Device is Present

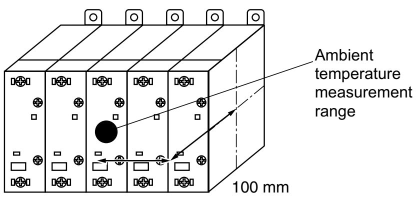


Figure 3: Measurement Position when Side Temperature Cannot be Measured

c. If more than one row of SSRs are mounted in the control panel, measure the ambient temperature of each row and use the position with the highest temperature.

Operation and Storage Environment Precautions

Ambient Temperature (Operating)

The rated operating ambient temperature of an SSR is determined with proper ventilation conditions. 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 may fail prematurely.

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).

Operation and Storage Locations

Do not operate or store the SSR in the following locations. Doing so may result in malfunction or deterioration of performance specifications.

- Locations subject to direct sunlight.
- Locations subject to corrosive or flammable gases.
- Locations subject to dust (especially iron dust) or salts.
- Locations subject to shock or vibration.
- Locations subject to exposure to water, oil, or chemicals.

Vibration and Shock

Do not subject the SSR to excessive vibration or shock. Refer to the SSRs shock and vibration specifications pages in pub. no. 700-SG003B-EN-P , otherwise the SSR will malfunction and may cause damage to the internal components. To prevent the SSR from abnormal vibration, do not install the Unit in locations or by means that will subject it to the severe vibrations from other devices, such as motors.

Solvents

Do not allow the SSR to come in contact with solvents such as thinners or gasoline. Doing so will dissolve the markings on the SSR.

Oil

Do not allow the SSR terminal cover to come in contact with oil. Doing so will cause the cover to crack and become cloudy.

Handling the SSR

Do Not Drop

The SSR is a high-precision component. Do not drop the SSR or subject it to excessive vibration or shock regardless of whether the SSR is mounted or not.

The maximum vibration and shock that an SSR can withstand varies with the model. Refer to pub. 700-SG003B-EN-P.

The SSR cannot maintain its full performance capability if it is dropped or subjected to excessive vibration or shock resulting in possible damage to its internal components.

The impact of shock given to the SSR that is dropped varies upon the case, and depends on the floor material, the angle of collision with the floor, and the dropping height. For example, if a single SSR is dropped on a plastic tile from a height of 10 cm, the SSR may receive a shock of 1,000 m/s^2 (100 Gs) or more.

Q & A

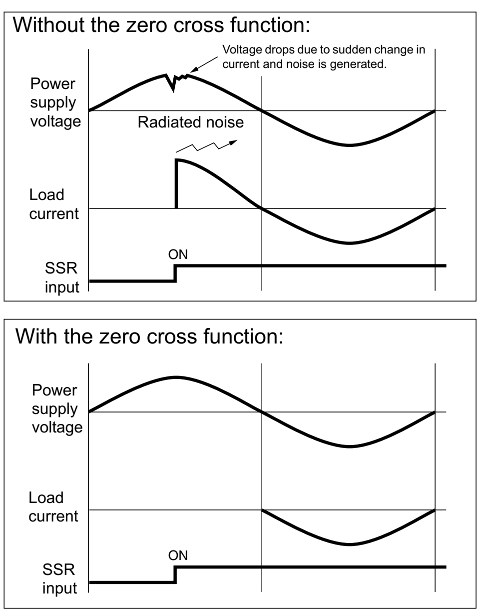
What Is The Zero Cross Function?

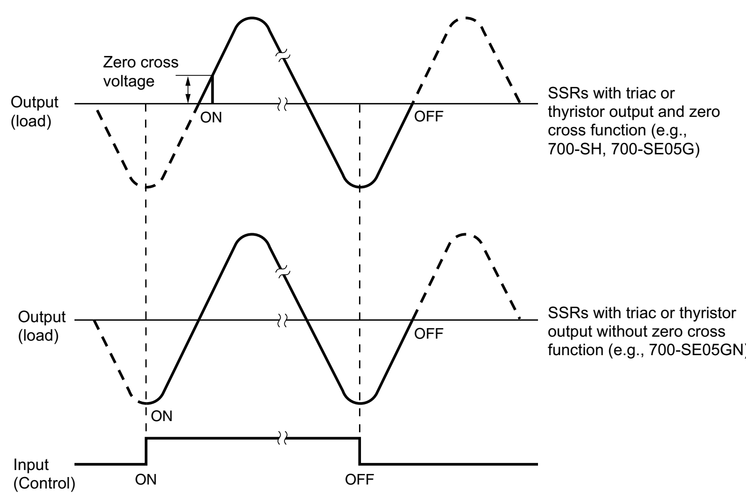
The zero cross function turns ON the SSR when the AC load voltage is close to 0 V, thus suppressing the noise generation of the load when the load current rises quickly.

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

A high inrush current will flow when the load is turned ON. When the zero cross function is used, the load current always starts from a point close to 0 V. This will reduce/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 ± 20 V. The difference in voltage between this point and the 0 V point is called zero cross voltage.



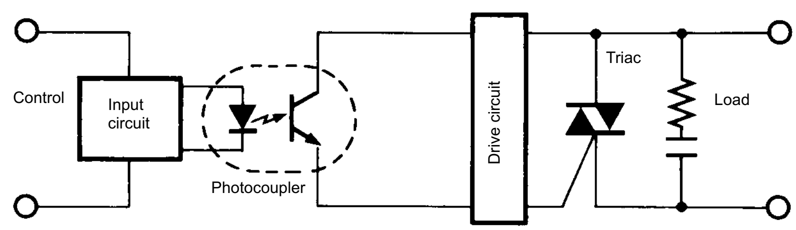


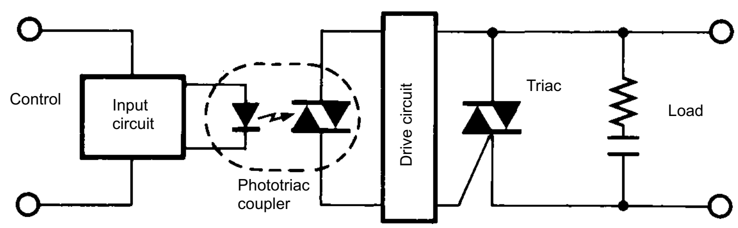
Why Does the Input Current Vary With the SSR?

Due to design characteristics, a SSR with photocoupler isolation has different input current requirements from an SSR with phototriac isolation.

An SSR with photocoupler isolation does not require as high an input current as a phototriac ensures efficient signal transmission. The SSR, however, requires a drive circuit of complicated construction therefore both versions are offered.

Photocoupler input current < Phototriac input current

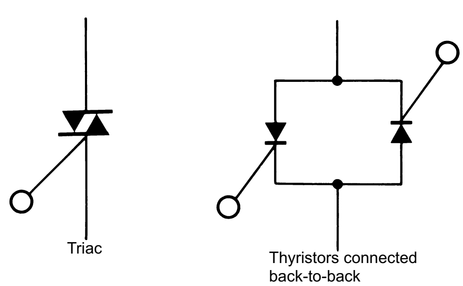




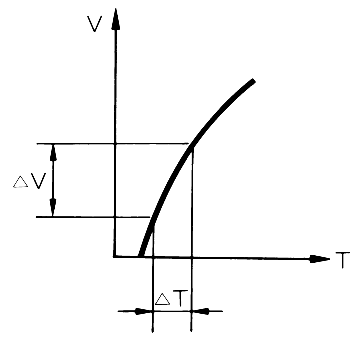
What Is The Difference in Switching with a Thyristor and a Triac?

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/ms) (Refer to “What is a Snubber Circuit” on page 4-3). This value (rate of change) 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.



ΔV/∇T = dv/dt: Voltage rise rate

	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

What Are the Characteristics of Thyristors and Triacs?

Both triacs and thyristors turn ON and OFF to provide or stop current flow to loads to be controlled. SSRs for AC switching employ either triacs or thyristors.

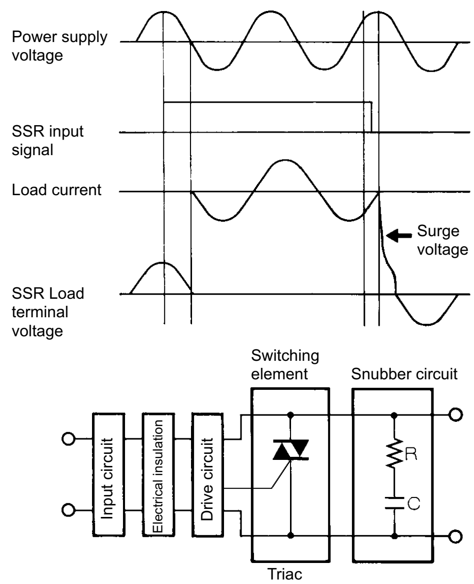
Unlike power transistors, triacs, and thyristors are semiconductor elements with no self-arc suppression. This means a current flows into triacs or thyristors that are turned ON with a gate signal. However, the current cannot be, turned OFF when the gate signal turns OFF. The triacs and thyristors are kept ON until the *output* current is turned OFF (at zero cross point). These semiconductor elements are easy to break when they are short-circuited. Be aware of these characteristics from a viewpoint of safety when designing equipment or systems that employ SSRs.

What Is a Snubber Circuit?

When SSRs with triac or thyristor outputs are used to switch AC inductive loads, excessive voltage changes (surge) 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 for excessive voltage changes of triacs or thyristors 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, the SSR will need a surge suppressing measure (snubber circuit) installed by you.



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.

Are There Any SSRs With Normally Closed Contacts?

An SSR with a triac or thyristor output cannot have normally closed contacts unless a drive power supply is employed. To use normally closed contacts, the output semiconductors need to be normally closed. Therefore, depression-type transistors must be used for the semiconductor element. Allen-Bradley currently does not offer a SSR with this type of design.

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.

A 20 to 30% 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. Refer to Appendix A, page 6-1 .

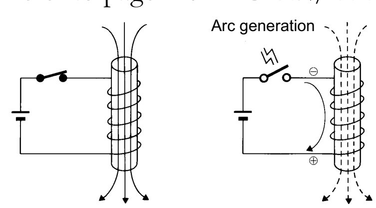
What Is Counter-electromotive Force?

Counter-electromotive force is generated from a DC inductive load when the load coil is turned OFF.

As shown below, magnetic flux is generated when voltage is applied to a coil.

When the switch is turned OFF, the magnetic flux will disappear. Due to the self-induction of the coil, counter-electromotive force voltage will be generated in the direction required to maintain the magnetic flux even though the switch is already closed. Therefore, the counter-electromotive force has no way to escape, and a very high voltage is generated.

The counter-electromotive force may cause contact friction damage and fatal element damage. Pay utmost attention when using DC inductive loads. As shown below, the power supply voltage and counter-electromotive force will be imposed on the closed switch. Refer to page 2-6 "DC ON/OFF Noise Surges."



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 examples of permissible I^2t values for the respective SSRs. When using a high-speed breaking fuse for an SSR, check in pub. 700-SG003B-EN-P that the I^2t is the same as or less than the specified value.

I^2t Values

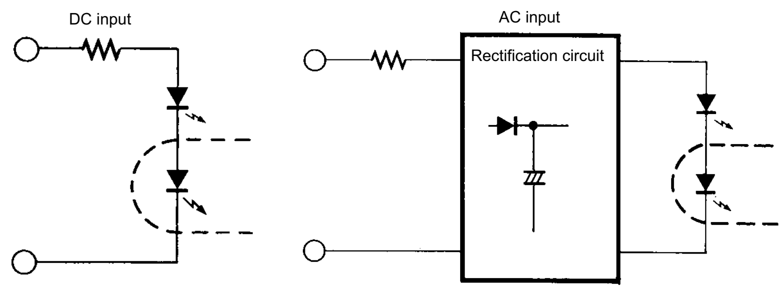
Cat. No.	Value
700-SH10_	112.5 A^2s

700-SH40_	1260 A^2s

Note: Refer to pub. 700-SG003B-EN-P for a complete list of values.

Why Does the Operating Time Vary Between AC Inputs and DC Inputs?

An SSR with an AC input has a rectification circuit. A capacitor is included in the rectification circuit. The operating time of the SSR will be slower than an SSR with a DC input due to the charge time of the capacitor.



What Is the Relationship Between the Leakage Current and Load Voltage?

The leakage current of a SSR increases in proportion to the load voltage.

Is It Possible to Connect SSRs In a Series?

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

However, a high operating voltage 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.

Is It Possible to Connect Two 200V AC SSRs in Series to a 400V AC Load?

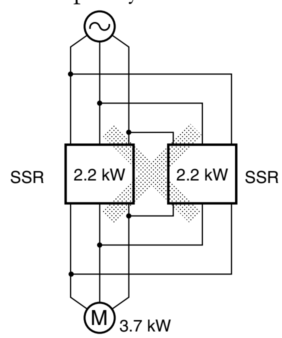
No, it is not. The two SSRs are slightly different to each other in operating time. Therefore, 400V AC will be imposed on the SSR with a longer operating time.

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.

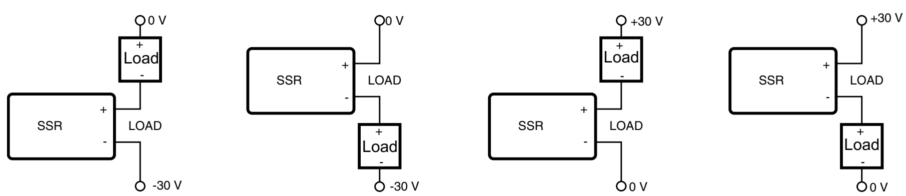
Do not connect two or more SSRs in parallel to drive a load exceeding the capacity of each SSR; the SSR may fail to operate.



Note: SSR capacity too small for the load.

Is It Possible to Connect a DC Output Load to a Negative Electrode? Can Either a Positive or Negative Load Be Connected?❶

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.



❶ Make sure you follow national and local codes when wiring electrical equipment.

What Portion of the Power Factor of the Load Is Practically Applicable?

A power factor range between COSϕ 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 “What is a Snubber Circuit” on page 4-3).

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.

Why Can Most SSRs Not Switch Micro-loads?

SSRs with AC Outputs

Presently, the minimum load current of most SSRs is limited to 100 mA (0.1 A). At an ambient temperature of 25°C or higher, this value will be a maximum of 50 mA. There are two reasons for this. One is for the prevention of load reset failures that may be caused by current leakage. The other is for the holding current required by each SSR in operation.

A smaller micro-load can be connected to the SSR with a bleeder resistor connected in parallel with the load.

Bleeder Resistor Values

100V AC	5…10 kΩ	3 W
200V AC	5…10 kΩ	15 W

SSRs with DC Outputs

The leakage current of an SSR may cause load reset failures.

If the maximum leakage current of the SSR is 0.1 mA, the SSR can switch most micro-loads. Refer to the following table for bleeder resistor values.

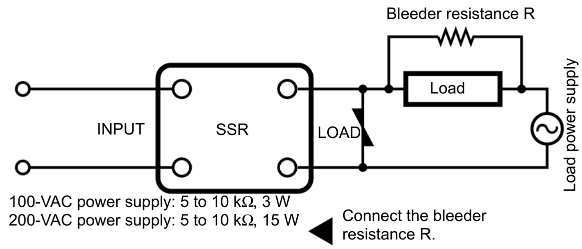
Bleeder Resistor Values

5V DC	1.6 kΩ	1/4 W
12V DC	620 Ω	1 W
24V DC	330 Ω	5 W

Why Does a Relay Sometimes Make A Buzzing Noise When Switched With a SSR?

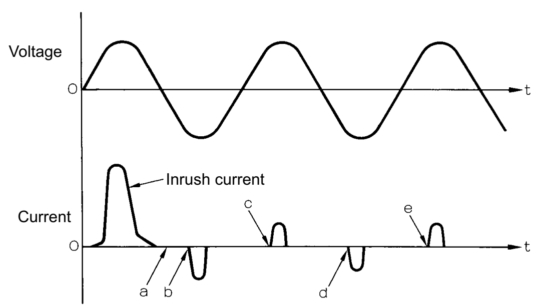
A SSR has a leakage current whether or not the input of the SSR is ON or OFF. If a small relay is driven by the SSR, the relay coil will be slightly energized. As a result, the relay will make noise.

This problem can be solved by connecting a bleeder resistor in parallel to the relay coil. If two or more relay coils are connected in parallel or the relay coil is connected to another load in parallel, an effect similar to the bleeder resistor can be produced.



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” (refer to above graph), 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

100V AC	5…10 kΩ	3 W
200V AC	5…10 kΩ	15 W

How Much Thermal Resistance Is Required in the Heat Sink? What Is the Thermal Resistance of the SSR?

Thermal Resistance of Heat Sinks

Cat. No.	Thermal Resistance
700-S10	2.8° C/W
700-S20	1.63° C/W
700-S30	1.38° C/W

Note: Values indicate the degree of resistance to heat. The smaller the value is, the better the heat conductivity will be. It is normally expressed using °C/W units, i.e. the temperature rise per watt.

Thermal Resistance (Rth) of SSRs (with Junctions ❶ On the Back)

Cat. No.	Thermal Resistance
700-SH05G_	3.22° C/W
700-SH10G_	2.62° C/W
700-SH25G_	1.99° C/W
700-SH25H	1.90° C/W
700-SH40G_	0.45° C/W
700-SE05_	2.72° C/W
700-SE10_	2.12° C/W
700-SE20_	2.22° C/W

❶ "Junction" refers to the PN junction of the semiconductor element and is used as a representative point on the element to express temperature. Refer to pub. 700-SG003B-EN-P for further details.

Can A Panel Frame Be Used in Place of Heat Sink?

Yes, but steel plates used for standard panels have lower heat conductivity than aluminum plates and thus is not suitable for high-current applications. If the steel plate is used in place of a heat sink, check that the continuous current flow is a maximum of 10 A. (For details, refer to pub. 700-SG003B-EN-P.)

See the following table for heat radiation for aluminum plates.

Cat. No.	Carry current	Required aluminum plate size (mm)
700-SE05	5 A	Not required
700-SH05	5 A	75 × 75 × 13.2
700-SE10	10 A	100 × 100 × 12
700-SH10	10 A	150 × 150 × 13.2
700-SE20	20 A	300 × 300 × 13
700-SE25	20 A	200 × 200 × 13.2
700-SH40	40 A	300 × 300 × 13.2

Approximate values of heat conductivity (at room temperature) of different metals :

Metal type	Heat conductivity W/m°C
Iron-based	20…50
Aluminum-based	150…220
Pure copper	330
Plastics	0.1…1

Copper plates have a higher heat conductivity than aluminum plates, making them an excellent material. They easily corrode, however, and must be protected from corrosion by nickel plating or other method to ensure long-term application. Plastics have poor heat conductivity, making them unsuitable for heat sinks.

Why Is It Necessary to Apply Grease to the SSR/Heat Sink?

Special silicon and non-silicon grease is used to aid heat dissipation. The heat conduction of this special compound is five to ten times higher than standard silicon grease.

This special grease is used to fill the space between a heat-radiating part, such as an SSR, and the heat sink to improve the heat conduction of the SSR.

Unless special grease is applied, the generated heat of the SSR will not be radiated properly. As a result, the SSR may fail prematurely or deteriorate due to overheating.

Available Silicon Grease Products for Heat Dissipation

Toshiba Silicone: YG6240
AOS Company: Non-silicon type 53300 (for use in automotive plant applications)

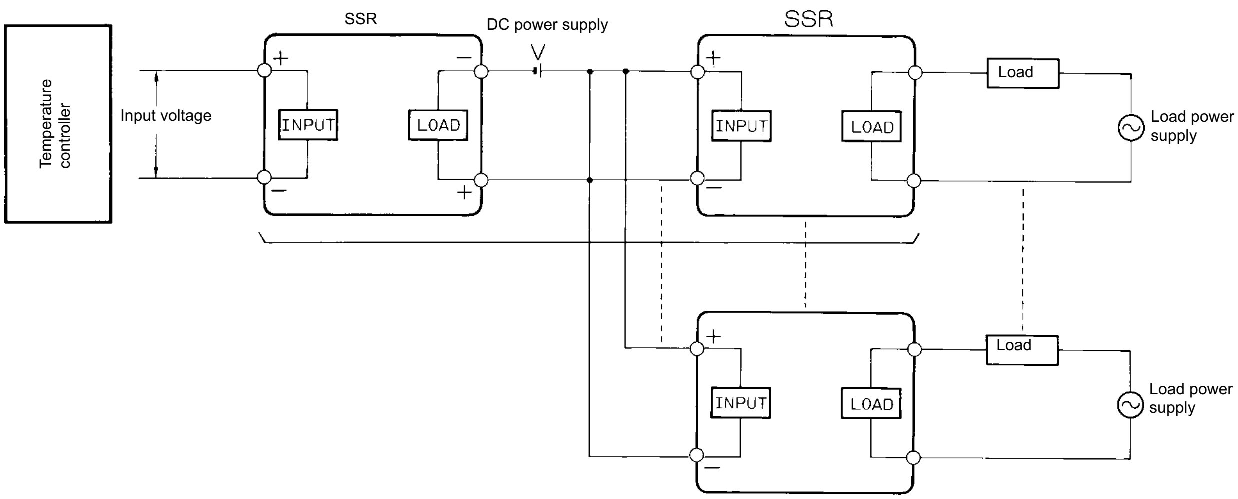
What Output Configuration Is Suitable When the SSR Is Used in Combination With a Temperature Controller?

Use a SSR in combination with a temperature controller with a voltage output.

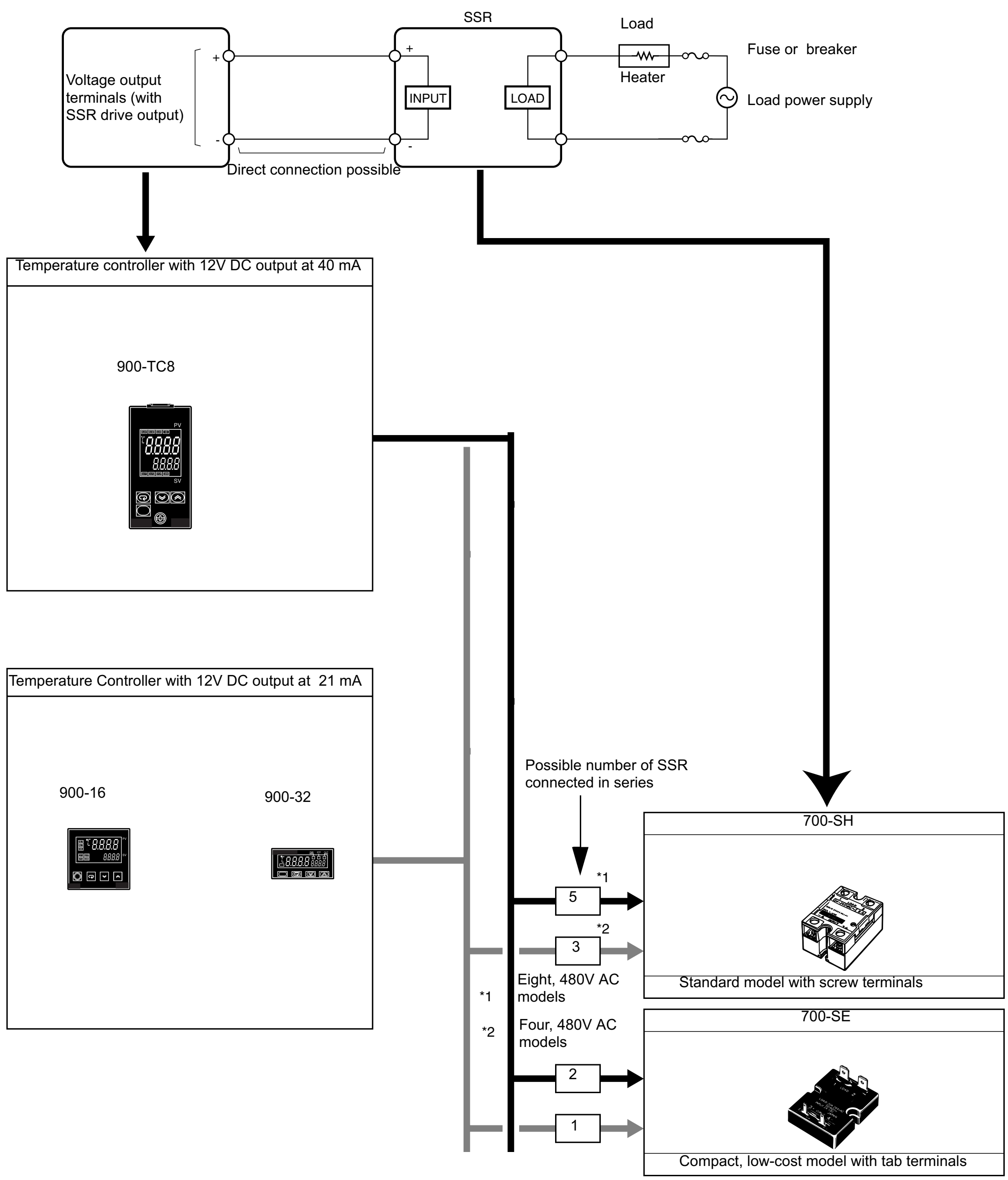
What Precautions Are Necessary When Driving a Number of SSRs With a Temperature Controller Output?

Refer to the diagrams below for the number of SSRs that can be connected to an Allen-Bradley temperature controller.

Interface SSRs will be required to drive more SSRs. With SSRs, leakage currents can cause reset failures.



Examples of Connections Between Temperature Controllers and SSRs



Equation to determine Possible Number of SSRs Connected in Series:
A: Max. load current of the SSR-driving voltage output of each temperature controller
B: Input current of SSRs.
A/B = Possible Number of SSRs

What Precautions Are Necessary For Forward/Reverse Operation of a Single-phase Motor?

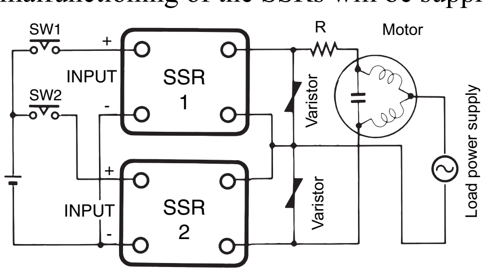
Refer the following table for the protection of capacitor motors driven by SSRs:

Single-phase 100 V	Load current of recommended SSR	Protection of motor in forward/reverse operation	
		R	L
25 W	AC 2 …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	

Precautions for Forward/Reverse Operation

1. In the following circuit, if SSR1 and SSR2 are turned ON simultaneously, the discharge current, I, of the capacitor may damage the SSRs. Therefore, a minimum 30 milliseconds time lag is required to switch between SSR1 and SSR2. If the malfunction of the SSRs is possible due to external noise or the counter-electromotive force of the motor, connect an inductor (L) or resistor (R) in series with either SSR1 or SSR2 whichever is less frequently used. A RC absorber (consisting of 0.1-µF capacitor withstanding 630V and 22-Ω resistor withstanding 2 W) can be connected in parallel to each SSR so that the malfunctioning of the SSRs will be suppressed.



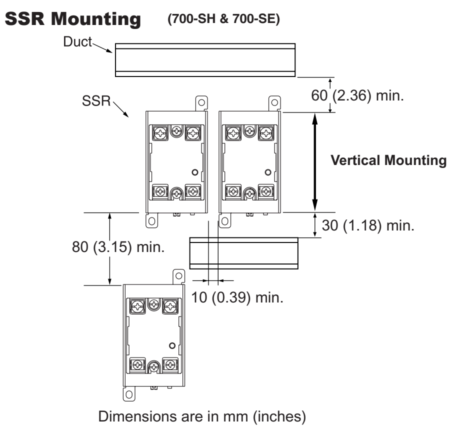
2. When the motor is in forward/reverse operation, a voltage that is twice as high as the power supply voltage may be imposed on an SSR that is OFF due to the LC resonance of the motor. Ensure the SSR can handle this 2x line voltage rating before starting the forward/reverse operation of the motor line voltage. Measure the voltage that is imposed on the SSR turned OFF and make sure that the SSRs are capable to withstand this value.

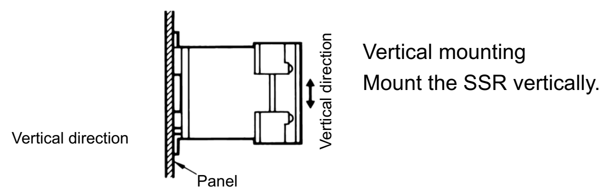
Does an SSR Have a Mounting Direction?

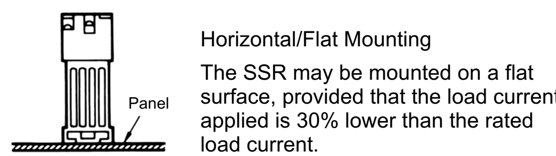
An SSR consists of semiconductor elements. Therefore, unlike mechanical relays that incorporate movable parts, gravity changes have no influence on the characteristics of the SSR.

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.







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 Publication 700-SG003B-EN-P. If there are no data, check that the load current applied is 70% of the rated load current.

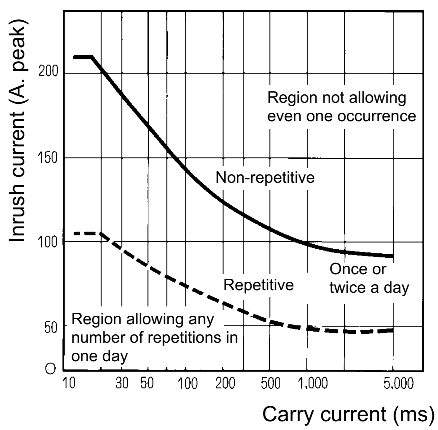
If the SSRs are mounted in two or more rows, it is necessary to confirm the temperature rise of the SSR separately.

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 Publication 700-SG003B-EN-P for details.

What Is the Non-Repetitive Inrush Current?

Publication 700-SG003B-EN-P gives the non-repetitive inrush current values for 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).



What Kind of Failure Do SSRs Have Most Frequently?

Data indicates that most failures are caused by overvoltage or overcurrent resulting in a short-circuited SSR. 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.

What Will Happen if the Load Voltage Eceeeds the Upper Limit?

Bulletins 700-SH__G and 700-SE family of SSRs have a built-in varistor and a maximum rated load voltage of 264V AC. These SSRs withstand a maximum of 264V AC. The built-in varistor operates when the load voltage exceeds about 400V AC and the varistor will be destroyed.

The 700-SCZY, -SCTY, -SCTN, and SCZN SSR does not incorporate a varistor. These SSRs with 200V AC output withstand a maximum of 264V AC. The output triac of the SSR in actual operation will be destroyed due to an overvoltage of approximately 600V AC, 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 264V AC.

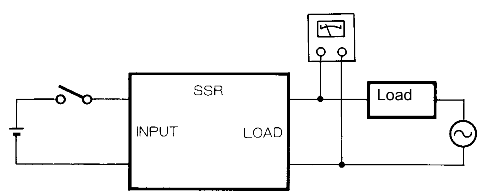
Is It Possible to Replace a Defective Part in a SSR?

No parts of any SSR are replaceable because the SSR is sealed with plastic resin.

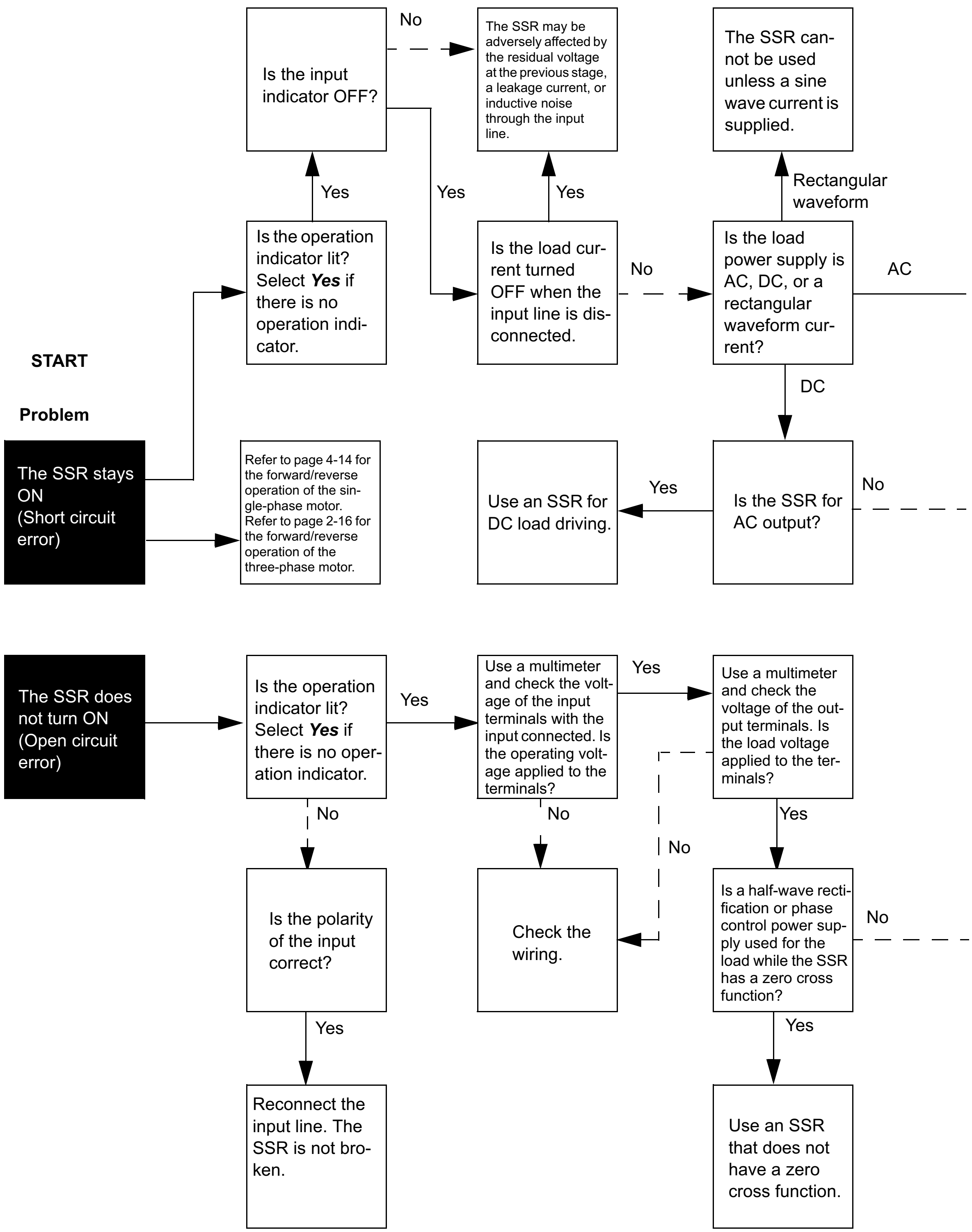
How Can We Use a Multimeter to Check If the SSR is ON or OFF?

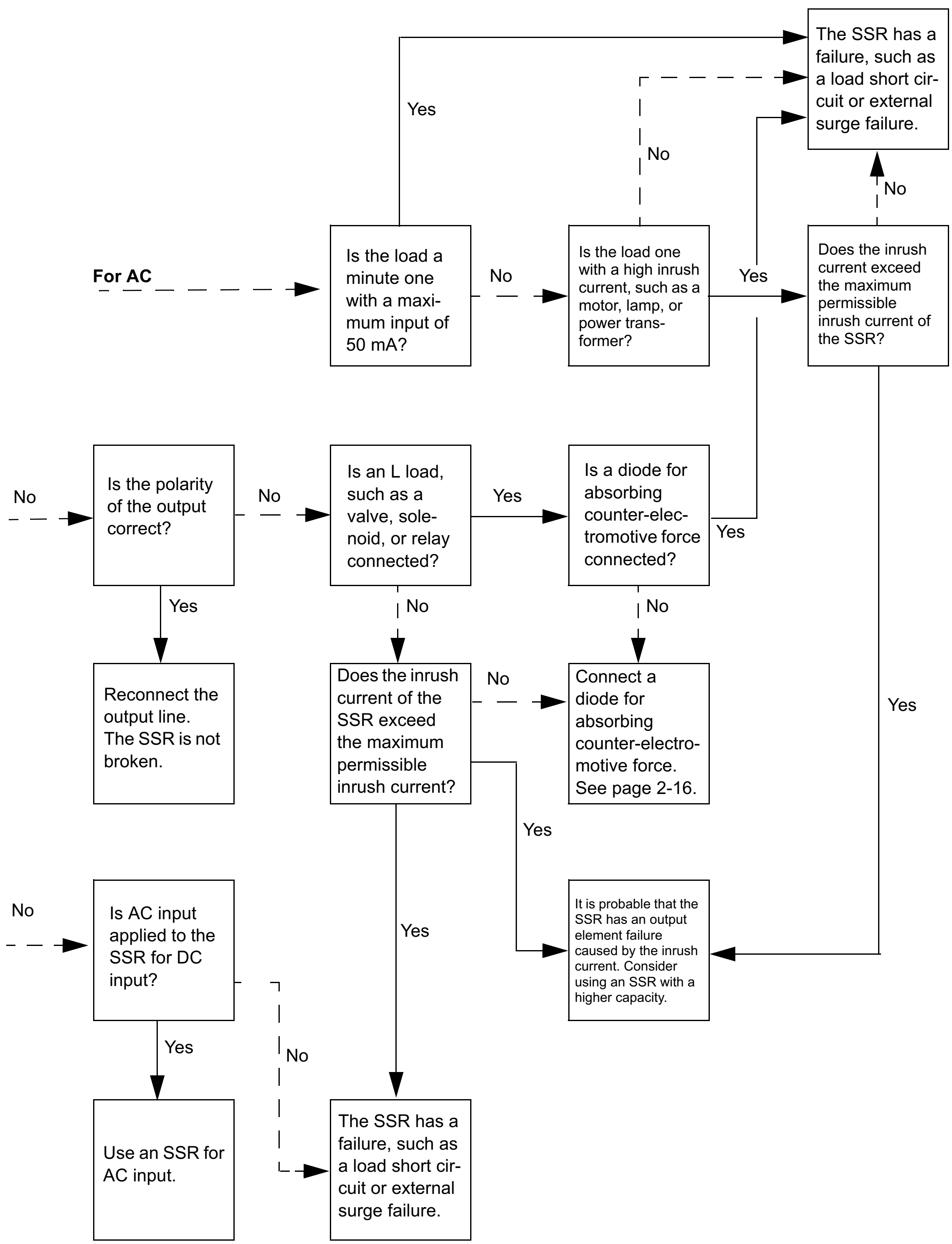
The resistance of the load terminals of the SSR does not make clear changes when the input turns ON and OFF.

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.



SSR Troubleshooting Flowcharts




The SSR has a failure, such as a load short circuit or external surge failure.
Yes
No
No
For AC
Is the load a minute one with a maximum input of 50 mA?
No
Is the load one with a high inrush current, such as a motor, lamp, or power transformer?
Yes
Does the inrush current exceed the maximum permissible inrush current of the SSR?
No
Is the polarity of the output correct?
No
Is an L load, such as a valve, solenoid, or relay connected?
Yes
Is a diode for absorbing counter-electromotive force connected?
Yes
Yes
No
No
Reconnect the output line. The SSR is not broken.
Does the inrush current of the SSR exceed the maximum permissible inrush current?
No
Connect a diode for absorbing counter-electromotive force. See page 2-16.
Yes
Yes
No
Is AC input applied to the SSR for DC input?
Yes
It is probable that the SSR has an output element failure caused by the inrush current. Consider using an SSR with a higher capacity.
Yes
No
Use an SSR for AC input.
The SSR has a failure, such as a load short circuit or external surge failure.

Technical Information

List of Recommended Loads

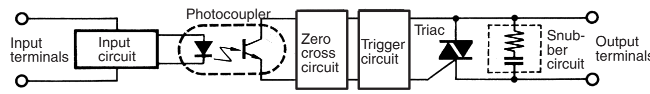
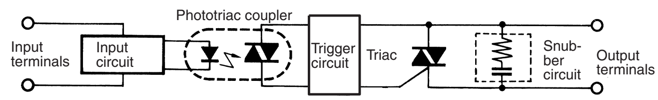
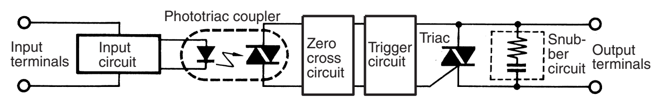
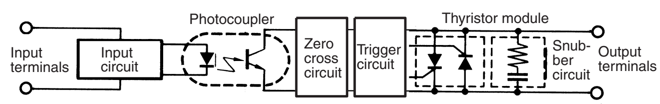
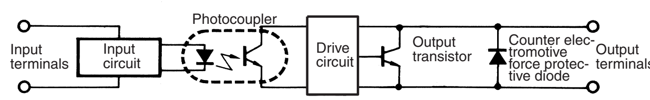
Use the following table for reference when selecting the load of your SSR. The data in this table are all measured at an SSR ambient temperature of 25°C or 40°C. Load current applied to SSR should be considered at ambient temperature. Engineering data of load current vs. ambient temperature for each SSR model shows the curve in order to derate the carry current (for details, refer to pub. 700-SG003B-EN-P). The peak value in the list applies when the SSR inrush current is within the permissible range.

Load Voltage	Cat. No.	Max. Load Current	Type					
			Heater	Single-Phase Motor	Three-Phase Motor	Lamp Load	Valve	Transformer
110V AC	700-SCZY, 700-SCTY, 700-SCZN, 700-SCTN, 700-SFT, 700-SFZ	3 A	2.4 A	35 W	—	1.5 A	1.5 A	150 W
	700-SE05, 700-SH05, 700-SAZY	5 A	4 A	65 W	—	2.5 A	2.5 A	250 W
	700-SE10	10 A	8 A	100 W	—	5 A	5 A	500 W
	700-SE20	20 A	16 A	300 W	—	10 A	10 A	1 kW
220V AC	700-SFTY, 700-SFZY, 700-SCTN, 700-SCZY, 700-SCTY, 700-SCZN	3 A	2.4 A	65 W	200 W	1.5 A	1.5 A	300 W
	700-SEO5, 700-SAZY5, 700-SHO5	5 A	4 A	100 W	400 W	2.5 A	2.5 A	500 W
	700-SE10, 700-SH10G	10 A	8 A	250 W	750 W	5 A	5 A	1 kW
	700-SE20	20 A	16 A	750 W	1.5 kW	10 A	10 A	2 kW
	700-SH25G	25 A	25 A	750 W	1.5 kW	12.5 A	12.5 A	2 kW
	700-SH40G	40 A	32 A	1.5 kW	2.2 kW	20 A	20 A	4 kW
440V AC	700-SH10H	10 A	8 A	—	2.2 kW	5 A	—	—
	700-SH25H	25 A	20 A	—	—	12.5 A	—	—
48V DC	700-SFNY3, 700-SCNY3, 700-SCNN3	3 A	2.4 A	—	—	1.5 A	1.5 A	—
100V DC	700-SCNN	2 A	1.6 A	—	—	1 A	1 A	—
	700-SANY	3 A	2.4 A	—	—	1.5 A	1.5 A	—

If a transformer load is connected to an SSR, limit the inrush current to 1/2 of the maximum rated value to be applied to the SSR.

The maximum SSR load current was determined assuming that a single resistance load is installed. It is expected, however, that the SSR will be exposed to harsher conditions in actual operation than in the trial testing because of power voltage fluctuations and control panel space limitations. To allow for a sufficient safety margin, the recommended values are 20…30% lower than the rated values. The safety margins for inductive loads such as transformers and motors should be higher because these loads generate an inrush current.

Circuit Configuration

Load Specifications	Zero Cross Function	Insulation	Circuit Configuration	Cat. No.
AC load	Yes	Photocoupler		700-SH_ _GA 700-SCZY 700-SCZN 700-SFZ 700-SAZ
	No	Phototriac		700-SKON 700-SE_ _ _N 700-SCTN 700-SCTY 700-SFT
	Yes	Phototriac		700-SH_ _GZ 700-SE_ _ _Z 700-SKOZ
AC load	Yes	Photocoupler		700-SH_ _NZ
DC load	—	Photocoupler		700-SCNN 700-SFN 700-SCNY 700-SKOC 700-SAN