## SSRs Technical Information

### SSR Description and Circuit Configurations

#### Phototriac coupler

<table>
<thead>
<tr>
<th>Load</th>
<th>Isolation type</th>
<th>Zero-crossing function</th>
<th>Model</th>
<th>Circuit configuration</th>
<th>I/O wave form (for resistive load)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC</td>
<td>Yes</td>
<td>Phototriac</td>
<td>APT</td>
<td><img src="https://example.com/circuit_diagram.png" alt="Circuit Diagram" /></td>
<td>Load voltage, Input signal, Load current</td>
</tr>
<tr>
<td>AC</td>
<td>No</td>
<td>Phototriac</td>
<td>APT</td>
<td><img src="https://example.com/circuit_diagram.png" alt="Circuit Diagram" /></td>
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</tr>
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#### SSR

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<tr>
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<th>Model</th>
<th>Circuit configuration</th>
<th>I/O wave form (for resistive load)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC</td>
<td>Yes</td>
<td>Phototransistor</td>
<td>AQ1 (2A)</td>
<td><img src="https://example.com/circuit_diagram.png" alt="Circuit Diagram" /></td>
<td>Load voltage, Input signal, Load current</td>
</tr>
<tr>
<td>AC</td>
<td>Yes</td>
<td>AQ-G, AQ1 (3A, 10A)</td>
<td><img src="https://example.com/circuit_diagram.png" alt="Circuit Diagram" /></td>
<td>Load voltage, Input signal, Load current</td>
<td></td>
</tr>
<tr>
<td>AC</td>
<td>Yes</td>
<td>AQ-J, AQ-A</td>
<td><img src="https://example.com/circuit_diagram.png" alt="Circuit Diagram" /></td>
<td>Load voltage, Input signal, Load current</td>
<td></td>
</tr>
<tr>
<td>AC</td>
<td>No</td>
<td>AQ-H</td>
<td><img src="https://example.com/circuit_diagram.png" alt="Circuit Diagram" /></td>
<td>Load voltage, Input signal, Load current</td>
<td></td>
</tr>
<tr>
<td>AC</td>
<td>No</td>
<td>AQ-G (AQ1)<em>, AQ-J (AQ-J)</em>, AQ-A</td>
<td><img src="https://example.com/circuit_diagram.png" alt="Circuit Diagram" /></td>
<td>Load voltage, Input signal, Load current</td>
<td></td>
</tr>
</tbody>
</table>

* AQ1, AQ-J and AQ-A random types are available by special order.
### SSR (continued)

<table>
<thead>
<tr>
<th>Load</th>
<th>Isolation type</th>
<th>Zero-crossing function</th>
<th>Model</th>
<th>Circuit configuration</th>
<th>I/O wave form (for resistive load)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC</td>
<td>Phototransistor</td>
<td>—</td>
<td>AQ1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DC logic output</td>
<td>Phototransistor</td>
<td>—</td>
<td>—</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Load Isolation type**
- Zero-crossing function
- Model
- Circuit configuration
- I/O wave form (for resistive load)

---

**Diagram**: Shows the circuit configuration and I/O wave form for resistive load.
Principle of Operation
SSR Switching Characteristics

1. SSR for AC Loads
   (1) Zero-crossing SSR
   The zero-crossing SSR uses a
   phototransistor or phototriac coupler to
   isolate the input from the output (see the
   circuit configuration on the previous
   page). When the input signal is activated,
   the internal zero-crossing detector circuit
   triggers the triac to turn on as the AC load
   voltage crosses zero.
   The load current is maintained by the
   triac’s latching effect after the input signal
   is deactivated, until the triac is turned off
   when the load voltage crosses zero. The
   following describes voltage and current
   wave forms for different types of loads:
   • Resistive loads
     Since resistive loads cause no phase
     shift between the voltage and current, the
     triac turns on when the AC load voltage
     crosses zero after the input signal is
     activated. The SSR turns off when the
     AC load voltage crosses zero and the
     load current is turned off after the input
     signal is subsequently deactivated.
   • Inductive loads
     The SSR turns on when the load voltage
     crosses zero after the input signal is
     activated. It turns off when the load
     current subsequently crosses zero after
     the input signal is deactivated. A phase
     difference between the voltage and
     current may supply a transient spike to
     the SSR when it is turned off. While the
     snubber circuit absorbs this spike, an
     excessively large spike may result in a
     dv/dt error in the SSR’s internal triac.
   (2) Random type SSR
   Random type SSR uses a phototriac
   coupler to isolate the input from the
   output. When the input signal is
   activated, the output immediately turns
   on, since there is no zero-crossing
   detector circuit. The load current is
   maintained by the triac’s latching effect
   after the input signal is deactivated, until
   the AC load voltage crosses zero.

2. SSR for DC Loads
   The SSR for DC loads uses a
   phototransistor coupler to isolate the
   input from the output. The output
   immediately responds to the input, since
   the phototransistor coupler directly turns
   the output transistor ON or OFF.

Load voltage
Input voltage
SSR output voltage
Load current

AC load voltage
Input voltage
SSR output voltage
Load current

Resistive loads
Inductive loads
Random type SSR

## Terminology of Phototriac Coupler/AQ-H

<table>
<thead>
<tr>
<th>Term</th>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input side</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LED forward current</td>
<td>$I_{F}$</td>
<td>Current that flows between the input terminals when the input diode is forward biased.</td>
</tr>
<tr>
<td>LED reverse voltage</td>
<td>$V_{R}$</td>
<td>Reverse breakdown voltage between the input terminals.</td>
</tr>
<tr>
<td>Peak forward current</td>
<td>$I_{FP}$</td>
<td>Maximum instantaneous value of the forward current.</td>
</tr>
<tr>
<td>LED dropout voltage</td>
<td>$V_{F}$</td>
<td>Dropout voltage between the input terminals due to forward current.</td>
</tr>
<tr>
<td><strong>Output side</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repetitive peak OFF-state voltage</td>
<td>$V_{DRM}$</td>
<td>Maximum voltage with repeatability that can be applied continuously between the output terminals.</td>
</tr>
<tr>
<td>ON-state RMS current</td>
<td>$I_{TRMS}$</td>
<td>Effective current value, based on designated conditions, that can flow continuously between output terminals.</td>
</tr>
<tr>
<td>Non-repetitive surge current</td>
<td>$I_{TSM}$</td>
<td>Maximum current, without repeatability, that is based on designated conditions. Normally this is expressed as the wave height value of one power frequency current sinusoidal cycle.</td>
</tr>
<tr>
<td>Peak ON-state voltage</td>
<td>$V_{TM}$</td>
<td>Effective value of the voltage drop when a regulated load current flows between the output terminals when device is on.</td>
</tr>
<tr>
<td>Peak OFF-state current</td>
<td>$I_{DRM}$</td>
<td>Current that flows to output when a regulated load voltage is applied between the output terminals when device is off.</td>
</tr>
<tr>
<td><strong>Electrical Characteristics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trigger LED current</td>
<td>$I_{FT}$</td>
<td>Current flow when LED current is augmented and output is on, when regulated power supply voltage and load has been connected between the output terminals.</td>
</tr>
<tr>
<td>Holding current</td>
<td>$I_{H}$</td>
<td>Load current to maintain on state after output terminals have been turned on based on designated conditions.</td>
</tr>
<tr>
<td>Critical rate of rise of OFF-state voltage</td>
<td>$dV/dt$</td>
<td>Output terminals do not go to the on state from the off state based on designated conditions.</td>
</tr>
<tr>
<td>Zero-cross voltage</td>
<td>$V_{ZC}$</td>
<td>In the zero-cross method, when input is turned on, the maximum voltage value when the output terminals turn on.</td>
</tr>
<tr>
<td>Turn on time</td>
<td>$T_{on}$</td>
<td>Delay time until the output switches on after a designated LED current is made to flow through the input terminals.</td>
</tr>
<tr>
<td>I/O capacitance</td>
<td>$C_{iso}$</td>
<td>Capacitance between the input and output terminals.</td>
</tr>
<tr>
<td>I/O isolation resistance</td>
<td>$R_{iso}$</td>
<td>Resistance between terminals (input and output) when a specified voltage is applied between the input and output terminals.</td>
</tr>
</tbody>
</table>
### Terminology of SSR

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input side</strong></td>
<td></td>
</tr>
<tr>
<td>Control voltage</td>
<td>Input voltage necessary for normal SSR operation under the specified temperature conditions.</td>
</tr>
<tr>
<td>Activation voltage</td>
<td>Threshold at which the output turns on as the control voltage is gradually increased with the specified voltage applied to the loaded output.</td>
</tr>
<tr>
<td>Recovery voltage</td>
<td>Threshold at which the output turns off as the control voltage is gradually decreased with the specified voltage applied to the loaded output.</td>
</tr>
<tr>
<td>Input impedance</td>
<td>Resistance of the current limiting resistor used in the SSR input side.</td>
</tr>
<tr>
<td>Input line voltage</td>
<td>Input voltage at which an input module SSR operates normally.</td>
</tr>
<tr>
<td>Input current</td>
<td>Input current at which an input module SSR operates normally.</td>
</tr>
<tr>
<td><strong>Load side</strong></td>
<td></td>
</tr>
<tr>
<td>Max. load current</td>
<td>Maximum continuous current allowable across the SSR output terminals under the specified heat dissipation and ambient temperature conditions.</td>
</tr>
<tr>
<td>Load voltage</td>
<td>Output supply voltage range in which the SSR operates normally. AC voltage is specified in RMS units.</td>
</tr>
<tr>
<td>Logic supply voltage/current</td>
<td>Supply voltage/current range in which an input module SSR operates normally.</td>
</tr>
<tr>
<td>Non-repetitive surge current</td>
<td>Maximum non-repetitive load current allowable under the specified heat dissipation and ambient temperature conditions. In general, it is given by the peak value of a single cycle of sinusoidal commercial AC current.</td>
</tr>
<tr>
<td>“OFF-state” leakage current</td>
<td>Current that flows in the SSR output circuit when the specified supply voltage is applied to the output with no control voltage applied to the input.</td>
</tr>
<tr>
<td>“ON-state” voltage drop</td>
<td>Output voltage drop caused by a specified load current supplied to the SSR output which is turned on by a specified input control voltage. AC voltage is specified in RMS units.</td>
</tr>
<tr>
<td>Min. load current</td>
<td>Minimum load current at and above which the SSR operates normally under the specified temperature conditions. AC load current is specified in RMS units.</td>
</tr>
<tr>
<td>Output stage breakdown voltage</td>
<td>Maximum voltage that can be applied across the output and ground of an input module SSR.</td>
</tr>
<tr>
<td>Max. load current</td>
<td>Maximum current allowable for the output circuit of an input module SSR.</td>
</tr>
<tr>
<td>Repetitive peak voltage, max.</td>
<td>Maximum repetitive voltage which can be continuously applied across the SSR output terminals. In general, a voltage of more than 400 V AC is used for 100 V AC applications, and more than 600 V AC for 200-250 V AC applications, to absorb supply voltage variations or on/off surges.</td>
</tr>
<tr>
<td>Critical turn-off voltage rise ratio</td>
<td>SSRs may turn on if a turn-off voltage with a steep rising edge is applied. This phenomenon is called “dv/dt turn on.” Critical turn-off voltage rise ratio refers to the maximum turn-off voltage rise ratio at and below which the SSR remains turned off.</td>
</tr>
<tr>
<td><strong>Electrical Characteristics</strong></td>
<td></td>
</tr>
<tr>
<td>Operate time, max.</td>
<td>Time until the SSR output turns on after the specified control voltage is applied to the input.</td>
</tr>
<tr>
<td>Release time, max.</td>
<td>Time until the SSR output turns off after the specified control voltage is removed from the input.</td>
</tr>
<tr>
<td>Insulation resistance</td>
<td>Resistance measured with a specified voltage applied across the input and output, or across the input or output and frame ground.</td>
</tr>
<tr>
<td>Breakdown voltage</td>
<td>Maximum voltage below which no dielectric breakdown occurs when applied for 1 minute across the same test points as those used for insulation resistance testing.</td>
</tr>
<tr>
<td>Vibration resistance</td>
<td>Functional: The device sustains no damage and meets the specifications if it is exposed to vibration with its magnitude not exceeding this threshold during transit or installation. Destructive: Closed contacts of a relay remain closed for the specified time period if it is exposed to vibration with its magnitude not exceeding this threshold during operation.</td>
</tr>
<tr>
<td>Shock resistance</td>
<td>Functional: The device sustains no damage and meets the specifications if it is exposed to physical impact with its magnitude not exceeding this threshold during transit or installation. Destructive: Closed contacts of a relay remain closed for the specified time period if it is exposed to physical impact with its magnitude not exceeding this threshold during operation.</td>
</tr>
<tr>
<td>Ambient temperature</td>
<td>Ambient temperature range over which the SSR operates normally under the specified heat dissipation and load current conditions.</td>
</tr>
<tr>
<td>Storage temperature</td>
<td>Ambient temperature range over which an SSR can be safely stored for extended periods without sustaining damage or performance degradation.</td>
</tr>
</tbody>
</table>
Cautions for Use of Phototriac Coupler/AQ-H

SAFETY WARNINGS
• Do not use the product under conditions that exceed the range of its specifications. It may cause overheating, smoke, or fire.
• Do not touch the recharging unit while the power is on. There is a danger of electrical shock. Be sure to turn off the power when performing mounting, maintenance, or repair operations on the relay (including connecting parts such as the terminal board and socket).
• Check the connection diagrams in the catalog and be sure to connect the terminals correctly. Erroneous connections could lead to unexpected operating errors, overheating, or fire.

Cautions for Use
1. Applying stress that exceeds the absolute maximum rating
   If the voltage and current value for any of the terminals exceeds the absolute maximum rating, internal elements will deteriorate because of the excessive voltage and current. In extreme cases, wiring may melt, or silicon P/N junctions may be destroyed.
   As a result, the design should ensure that the absolute maximum ratings will never be exceeded, even momentarily.

2. Derating
   Derating is absolutely imperative for reliable design and is an essential factor in determining product life. Therefore, be sure to amply derate the maximum rated values when designing a system. Since it is important to derate in accordance with the type of relay, conditions for use, and environment, please be sure to conduct tests using actual equipment. Also, if there is a possibility that, due to a quality problem, this product might have a great effect on human life or property, do take product liability into consideration by being sure to take even extra leeway against the maximum rated value and implement safety measures such as the construction of redundant circuits.

3. The phototriac coupler is designed solely to drive a triac. As a condition, the triac must be powered beforehand.

4. The internal IC could be damaged if a short forms between the I/O terminals while the phototriac coupler and AQ-H SSR are powered.

5. Output spike voltages
   1) The figure below shows an ordinary triac drive circuit. Please add a snubber circuit or varistor, as noise/surge on the load side could damage the unit or cause malfunctions.

   <Phototriac coupler SOP4, DIP4>  

   <Phototriac coupler DIP6>

6. Recommended input current value
   \[ i_r = 20 \text{ mA} \]

7. Important Notes for Mounting
   1) Temperature rise in the lead portion is highly dependent on package size. If multiple different packages are mounted on the same board, please check your board beforehand in an actual product, ensuring that the temperature conditions of the phototriac coupler fall within the parameters listed.
   2) If the mounting conditions exceed the conditions recommended above, strength of the resin used will decrease and inconsistencies of the thermal expansion coefficients in the component materials will increase greatly. This can cause package cracking and breakage of the bonding wires. Please contact us for consultation.

8. Cleaning
   The phototriac coupler and AQ-H SSR are formed as an optical path by coupling a light-emitting diode (LED) and photodiode via transparent silicon resin. For this reason, unlike other directory element molded resin products (e.g., MOS transistors and bipolar transistors), avoid ultrasonic cleaning if at all possible. We recommend cleaning with an organic solvent. If you cannot avoid using ultrasonic cleaning, please ensure that the following conditions are met, and check beforehand for defects.
   • Frequency: 27 to 29 kHz
   • Ultrasonic output: No greater than 0.25 W/cm²
   • Cleaning time: No longer than 30 s
   • Cleaner used: Asahiklin AK-225
   • Other: Submerge in solvent in order to prevent the PCB and elements from being contacted directly by the ultrasonic vibrations.
   Note: Applies to unit area ultrasonic output for ultrasonic baths.

9. Transportation and storage
   1) Extreme vibration during transport will warp the lead or damage the relay. Handle the outer and inner boxes with care.
   2) Storage under extreme conditions will cause soldering degradation, external appearance defects, and deterioration of the performance. The following storage conditions are recommended:
      • Temperature: 0 to 45°C 32 to 113°F
      • Humidity: Less than 70% R.H.
      • Atmosphere: No harmful gases such as sulfurous acid gas, minimal dust.
   3) Storage of SOP type
      Phototriac couplers implemented in SO packages (SOP 4-pin type) are sensitive to moisture and come in sealed moisture-proof packages. Observe the following cautions on storage.
      • After the moisture-proof package is unsealed, use the devices as soon as possible (use within 1 month ≤ 45°C 113°F/70% R.H.). If the devices are to be left in storage after the moisture-proof package has been unsealed, keep them in another moisture-proof bag containing silica gel and use within 3 months.
10. Soldering

1) When soldering PC board terminals, keep soldering time to within 10 s at 260°C (500°F).
2) When soldering surface-mount terminals or SO package, the following conditions are recommended.
   (1) IR (Infrared reflow) soldering method

   ![Soldering temperature profile]

   \[ T_1 = 150 \text{ to } 180°C \quad T_2 = 320°C \quad T_3 = 350°C \text{ or less} \]
   \[ t_1 = 60 \text{ to } 120 \text{ s or less} \quad t_2 = 30 \text{ s or less} \]
   \[ T_1 = 150 \text{ to } 180°F \quad T_2 = 520°F \quad T_3 = 500°F \text{ or less} \]
   \[ t_1 = 60 \text{ to } 120 \text{ s or less} \quad t_2 = 30 \text{ s or less} \]

   *Tip temperature: 350 to 400°C 662 to 752°F

   *Wattage: 30 to 60 W

   *Soldering time: within 3 s

2) Soldering iron method

   *Tip temperature: 350 to 400°C

   *Composition of Sn3.0Ag0.5Cu

   *Recommend one with an alloy composition of Sn3.0Ag0.5Cu.

   *When using lead-free solder we recommend one with an alloy composition of Sn3.0Ag0.5Cu.

   *Check mounting conditions before using other soldering methods (DWS, VPS, hot-air, hot plate, laser, pulse heater, etc.)

   *The temperature profile indicates the temperature of the soldered terminal on the surface of the PC board. The ambient temperature may increase excessively.

   *Check the temperature under mounting conditions.

   *When using lead-free solder we recommend one with an alloy composition of Sn3.0Ag0.5Cu.

3) Others

   *Check mounting conditions before using other soldering methods (DWS, VPS, hot-air, hot plate, laser, pulse heater, etc.)

   *The temperature profile indicates the temperature of the soldered terminal on the surface of the PC board. The ambient temperature may increase excessively.

   *Check the temperature under mounting conditions.

   *When using lead-free solder we recommend one with an alloy composition of Sn3.0Ag0.5Cu.

11. The following shows the packaging format

1) Tape and reel (Phototriac coupler)

<table>
<thead>
<tr>
<th>Type</th>
<th>Tape dimensions</th>
<th>Dimensions of paper tape reel</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO package</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4-pin type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DIP 4-pin type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DIP 6-pin type</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) When picked from 1/2-pin side: Part No. APT-3333SX (Shown above)
(2) When picked from 3/4-pin side: Part No. APT-3333SZ

(1) When picked from 1/2-pin side: Part No. APT-3333AX
(2) When picked from 3/4-pin side: Part No. APT-3333AZ

(1) When picked from 1/2/3-pin side: Part No. APT-3333AX
(2) When picked from 4/5/6-pin side: Part No. APT-3333AZ
### Tape and Reel (AQ-H)

#### Type
- **DIP 4-pin wide terminal type**
- **DIP 6-pin wide terminal type**
- **8-pin SMD type**

#### Tape Dimensions

<table>
<thead>
<tr>
<th>Type</th>
<th>Tape dimensions</th>
<th>Dimensions of paper tape reel</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DIP 4-pin wide terminal type</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DIP 6-pin wide terminal type</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>8-pin SMD type</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3) Tube
(1) Devices are packaged in a tube as pin No. 1 is on the stopper B side. Observe correct orientation when mounting them on PC boards.
(SOP type)

(DIP type)

13. Applying stress that exceeds the absolute maximum rating
If the voltage and current value for any of the terminals exceeds the absolute maximum rating, internal elements will deteriorate because of the excessive voltage and current. In extreme cases, wiring may melt, or silicon P/N junctions may be destroyed.
As a result, the design should ensure that the absolute maximum ratings will never be exceeded, even momentarily.
Cautions for Use of SSR

SAFETY WARNINGS

• Do not use the product under conditions that exceed the range of its specifications. It may cause overheating, smoke, or fire.
• Do not touch the recharging unit while the power is on. There is a danger of electrical shock. Be sure to turn off the power when performing mounting, maintenance, or repair operations on the relay (including connecting parts such as the terminal board and socket).
• Check the connection diagrams in the catalog and be sure to connect the terminals correctly. Erroneous connections could lead to unexpected operating errors, overheating, or fire.

Cautions for Use

1. Regarding output noise surge protection
   (1) AC Output Type
   A high noise surge voltage applied to the SSR load circuit can cause malfunction or permanent damage to the device. If such a high surge is anticipated, use a varistor across the SSR output.
   ![Varistor Across SSR Output](image)

   Note: AQ-F solid-state relay output terminals are numbered (8) and (12).

   (2) DC Output Type
   When the SSR is loaded with an inductive load, such as a solenoid contactor, motor, or solenoid valve, use a counter-EMF suppression diode across the load.
   ![Diode Across SSR Output](image)

2. When used for the load less than rated
   An SSR may malfunction if it is used below the specified load. In such an event, use a dummy resistor in parallel with the load.
   ![Dummy Resistor](image)

3. Noise and surge protection at the input side
   A high noise surge voltage applied to the SSR input circuit can cause malfunction or permanent damage to the device. If such a high surge is anticipated, use C or R noise absorber in the input circuit.
   ![Noise Absorber](image)

4. When the input terminals are connected with reverse polarity
   Type | If the polarity of the input control voltage is reversed
   --- | ---
   AQ1, AQ-J, AQ-A, AQ-J | Reversing the polarity will not cause damage to the device, due to the presence of a protection diode, but the device will not operate.
   AQ-H, AQ-G | Reversing the polarity may cause permanent damage to the device. Take special care to avoid polarity reversal or use a protection diode in the input circuit.

5. In the case of operating voltage containing ripple
   If the SSR control voltage contains ripple, the peak of the ripple should not exceed the maximum rated control voltage, and the bottom of the ripple should exceed the minimum rated control voltage.
   ![Ripple Voltage](image)

6. Cleaning solvents compatibility
   Dip cleaning with an organic solvent is recommended for removal of solder flux, dust, etc. If ultrasonic cleaning must be used, the severity of factors such as frequency, output power and cleaning solvent selected may cause loose wires and other troubles. Please make sure these conditions before use.

7. Transportation and storage
   1) Extreme vibration during transport will warp the lead or damage the relay. Handle the outer and inner boxes with care.
   2) Storage under extreme conditions will cause soldering degradation, external appearance defects, and deterioration of the characteristics. The following storage conditions are recommended:
      - Temperature: 0 to 45°C (32 to 113°F)
      - Humidity: Less than 70% R.H.
      - Atmosphere: No harmful gasses such as sulfurous acid gas, minimal dust.

8. Others
   (1) If an SSR is used in close proximity to another SSR or heat-generating device, its ambient temperature may exceed the allowable level. Carefully plan SSR layout and ventilation.
   (2) Soldering to SSR terminals should be completed within 5 seconds at 260°C.
   (3) Terminal connections should be made by referring to the associated wiring diagram.
   (4) For higher reliability, check device quality under actual operating conditions.

Load Specifications

<table>
<thead>
<tr>
<th>Type</th>
<th>Load current</th>
</tr>
</thead>
<tbody>
<tr>
<td>AQ-G</td>
<td>20 mA</td>
</tr>
<tr>
<td>AQ-1</td>
<td>50 mA</td>
</tr>
<tr>
<td>AQ-J</td>
<td>50 mA</td>
</tr>
<tr>
<td>AQ-A</td>
<td>100 mA</td>
</tr>
</tbody>
</table>
Cautions for Use of SSR

1. Reduce dv/dt
An SSR used with an inductive load can accidentally fire due to a high load voltage rise rate (dv/dt), even though the load voltage is below the allowable level (inductive load firing).

Our SSRs contain a snubber circuit designed to reduce dv/dt (except AQ-H).

2) R selection

If there is no resistance R (the resistance R controls the discharge current from condenser C), at turn-on of the SSR, there will be a sharp rise in dv/dt and the high peak value discharge current will begin to flow. This may cause damage to the internal elements of the SSR.

Therefore, it is always necessary to insert a resistance R. In normal applications, for the 100 V line, have R = 10 to 100 Ω and for the 200 V line, have R = 20 to 100 Ω. (The allowable discharge current at turn-on will differ depending on the internal elements of the SSR.) The power loss from R, written as P, caused by the discharge current and charging current from C, is shown in formula (3) below. For the 100 V line, use a power of 1/2 W, and for the 200 V line, use a power above 2 W.

\[
P = \frac{C \times V_i \times f}{2}
\]

f = Power supply frequency

(3) Use a surge absorption circuit

By setting C = 0.1 to 0.2 μF, dv/dt can be controlled to be between nV/μs and n+V/μs or lower. For the condenser, use either an MP condenser metallized polyester film. For the 100 V line, use a voltage between 400 and 600 V, and for the 200 V line, use a voltage between 400 and 600 V.

Thermal Design

SSRs used in high-reliability equipment require careful thermal design. In particular, junction temperature control has a significant effect on device function and life time. The rated load current for board-mounting SSRs is defined as the maximum current allowable at an ambient temperature of 40°C (30°C) and under natural cooling. If the ambient temperature exceeds the SSRs derating temperature point (20°C to 40°C, depending on SSR), the load current derating in accordance with the load current vs temperature diagram becomes necessary. If adjacent devices act as heat sources, the SSR should be located more than 10 mm away from those devices. SSRs with a 5 A rating or more must be used with the dedicated heat sinks listed in Table 1 or equivalents. To ensure adequate thermal conduction, apply thermal conductive compound (Toshiba silicone YG6111, TSK5303 or alternate) to the SSR’s mounting surface. For information on external heat sinks for our SSRs and their mounting method, refer to “Data and Cautions for Use for respective relay”.

Table 1. Dedicated on-board heat sinks

<table>
<thead>
<tr>
<th>Load current Type Heat sink</th>
<th>Heat sink</th>
</tr>
</thead>
<tbody>
<tr>
<td>to 10 A</td>
<td>AQ-J (10A)</td>
</tr>
<tr>
<td>10 A AQ-J (10A)</td>
<td>AQP-HS-J10A</td>
</tr>
<tr>
<td></td>
<td>AQP-HS-J10A (for AQ-J)</td>
</tr>
<tr>
<td></td>
<td>AQP-HS-SJ10A*</td>
</tr>
<tr>
<td></td>
<td>AQP-HS-SJ20A*</td>
</tr>
<tr>
<td>15 A AQ-J (15A), AQ-J (15A)</td>
<td>AQP-HS-J10A</td>
</tr>
<tr>
<td></td>
<td>AQP-HS-J10A (for AQ-J)</td>
</tr>
<tr>
<td></td>
<td>AQP-HS-SJ10A (for AQ-J)</td>
</tr>
<tr>
<td></td>
<td>AQP-HS-SJ20A*</td>
</tr>
<tr>
<td>20 A AQ-J (25A)</td>
<td>AQP-HS-J10A</td>
</tr>
<tr>
<td></td>
<td>AQP-HS-J10A (for AQ-J)</td>
</tr>
<tr>
<td></td>
<td>AQP-HS-SJ20A*</td>
</tr>
<tr>
<td>25 to 40 A AQ-A (25A)</td>
<td>AQP-HS-30/40A</td>
</tr>
<tr>
<td>25 A AQ-J (25A)</td>
<td>AQP-HS-J25A</td>
</tr>
<tr>
<td>40 A AQ-A (40A)</td>
<td>AQP-HS-J25A</td>
</tr>
</tbody>
</table>

*It is possible to mounting on the DIN rail.

Protection Circuit

High-reliability SSR circuits require an adequate protection circuit, as well as careful study of the characteristics and maximum ratings of the device.

1. Over-Voltage Protection
The SSR load power supply requires adequate protection against over-voltage errors from various causes. The methods of over-voltage protection include the following:

(1) Use devices with a guaranteed reverse surge withstand voltage (controlled avalanche devices, etc.)

(2) Suppress transient spikes
Use a switching device in the secondary circuit of a transformer or use a switch with a slow opening speed.

(3) Use a surge absorption circuit
Use a CR surge absorber or varistor across the load power supply or SSR. Special care must be taken so power on/off surges or external surges do not exceed the device’s rated load voltage. If a surge voltage exceeding the device’s rated voltage is anticipated, use a surge absorption device and circuit (e.g. a ZNR from Panasonic Electronic Devices Co., Ltd.).
Cautions for Use of SSR

Choosing the Rated Voltage of the ZNR
(1) Peak supply voltage
(2) Supply voltage variation
(3) Degradation of ZNR characteristic
(1 mA ±10%)
(4) Tolerance of rated voltage (10%)

For application to 100 V AC lines, choose a ZNR with the following rated voltage:

\[(1) \times (2) \times (3) \times (4) = (100 \times 2) \times 1.1 \times 1.1 \times 1.1 = 188 \, \text{V}\]

Example of ZNR (Panasonic Electronic Components)

<table>
<thead>
<tr>
<th>Types</th>
<th>Varistor voltage</th>
<th>Max. allowable circuit voltage</th>
<th>Max. control voltage</th>
<th>Max. average pulse electric power ((10/1000\mu s))</th>
<th>Withstanding energy ((2\text{ms}))</th>
<th>Withstanding surge current ((8/20\mu s))</th>
<th>Electrostatic capacitance (Reference)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERZV14D0201</td>
<td>200 (185 to 225)</td>
<td>130</td>
<td>170</td>
<td>340</td>
<td>0.6</td>
<td>70</td>
<td>50</td>
</tr>
<tr>
<td>ERZV14D0221</td>
<td>220 (198 to 242)</td>
<td>140</td>
<td>180</td>
<td>360</td>
<td>0.6</td>
<td>78</td>
<td>55</td>
</tr>
<tr>
<td>ERZV14D0241</td>
<td>240 (216 to 284)</td>
<td>150</td>
<td>200</td>
<td>395</td>
<td>0.6</td>
<td>84</td>
<td>60</td>
</tr>
<tr>
<td>ERZV14D0271</td>
<td>270 (247 to 303)</td>
<td>175</td>
<td>225</td>
<td>455</td>
<td>0.6</td>
<td>99</td>
<td>70</td>
</tr>
<tr>
<td>ERZV14D0361</td>
<td>360 (324 to 396)</td>
<td>230</td>
<td>300</td>
<td>595</td>
<td>0.6</td>
<td>130</td>
<td>90</td>
</tr>
<tr>
<td>ERZV14D0391</td>
<td>390 (351 to 429)</td>
<td>250</td>
<td>320</td>
<td>650</td>
<td>0.6</td>
<td>140</td>
<td>100</td>
</tr>
<tr>
<td>ERZV14D0431</td>
<td>430 (387 to 473)</td>
<td>275</td>
<td>350</td>
<td>710</td>
<td>0.6</td>
<td>155</td>
<td>110</td>
</tr>
<tr>
<td>ERZV14D0471</td>
<td>470 (423 to 517)</td>
<td>300</td>
<td>385</td>
<td>775</td>
<td>0.6</td>
<td>175</td>
<td>125</td>
</tr>
<tr>
<td>ERZV14D0621</td>
<td>620 (558 to 682)</td>
<td>385</td>
<td>505</td>
<td>1,025</td>
<td>0.6</td>
<td>190</td>
<td>136</td>
</tr>
<tr>
<td>ERZV14D081</td>
<td>680 (612 to 748)</td>
<td>420</td>
<td>560</td>
<td>1,120</td>
<td>0.6</td>
<td>190</td>
<td>136</td>
</tr>
</tbody>
</table>

2. Over-Current Protection

An SSR circuit operated without over-current protection may result in damage to the device. Design the circuit so the device’s rated junction temperature is not exceeded for a continuous overload current. (e.g. Surge current into a motor or light bulb)

The surge-on current rating applies to over-current errors which occur less than several tens of times during the service life of a semiconductor device. A protection coordination device is required for this rating.

Methods of over-current protection include the following:

(1) Suppressing over-currents
Use a current limiting reactor in series with the load power supply.

(2) Use a current shut-off device
Use a current limiting fuse or circuit breaker with the load power supply.

Example of executing fuse selection of over-current protection cooperation

1. Heaters (Resistive Load)
The SSR is best suited to resistive loads. Noise levels can be drastically lowered with zero-crossing switching.

2. Lamps
Tungsten or halogen lamps draw a high inrush current when turned on (approximately 7 to 8 times the steady-state current for zero-crossing SSRs; approximately 9 to 12 times, in the worst case, for random type SSRs). Choose an SSR so the peak of the inrush current does not exceed 50% of the SSR surge-on current.

3. Solenoids
AC-driven solenoid contactors or solenoid valves also draw inrush current when they are activated. Choose an SSR such that the peak of the inrush current does not exceed 50% of the SSR surge-on current. For small solenoid valves and AC relays in particular, a leakage current may cause the load to malfunction after the SSR turns off. In such an event, use a dummy resistor in parallel with the load.

* Using an SSR below the Specified Load
4. Motors
When starting, an electric motor draws a symmetrical AC starting current some 5 to 10 times the steady-state load current, superimposed on a DC current. The starting time during which this high starting current is sustained depends on the capacities of the load and load power supply. Measure the starting current and time under the motor’s actual operating conditions and choose an SSR so the peak of the starting current does not exceed 50% of the SSR surge-on current. When the motor load is deactivated, a voltage exceeding the load supply voltage is applied to the SSR due to counter-EMF. This voltage is approximately 1.3 times the load supply voltage for induction motors, and approximately 1.3 times the load supply voltage in synchronous motors.

• Reversible Motor Control
When the direction of motor rotation is reversed, the transient current and time required for the reversal far exceed those required for simple starting. The reversing current and time should also be measured under actual operating conditions.

For a capacitor-starting, single-phase induction motor, a capacitive discharge current appears during the reversal process. Be sure to use a current limiting resistor or reactor in series with the SSR. Also, the SSR should have a high marginal voltage rating, since a voltage twice as high as the load supply voltage develops across the SSR in the reversal process. (For reversible control on a 100 V AC line, use SSRs with a 200 V rating; for use on a 200 V AC line, contact your nearest representative for further information.)

For reversible motor control, carefully design the driver circuit so the forward and reverse SSRs do not turn on at the same time. Transistor-driven reversible motor control circuit

5. Capacitive Load
A capacitive load (switching regulator, etc.) draws an inrush current to charge the load capacitor when the SSR turns on. Choose an SSR so the peak of the inrush current does not exceed 50% of the SSR surge-on current. A timing error of up to one cycle can occur when a switch used in series with the SSR is opened or closed. If this is a problem, use an inductor (200 to 500 µH) in series to the SSR to suppress dv/dt error.

6. Other Electronic Equipment
In general, electronic equipment uses line filters in the primary supply circuit. The capacitors used in the line filters may cause the SSR to malfunction due to dv/dt turn on when the equipment is turned on or off. In such an event, use an inductor (200 to 500 µH) in series to the SSR to suppress dv/dt turn on.

Load Inrush Current Wave and Time

<table>
<thead>
<tr>
<th>(1) Incandescent Lamp Load</th>
<th>(2) Mercury Lamp Load</th>
<th>(3) Fluorescent Lamp Load</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Incandescent Lamp Load" /></td>
<td><img src="image" alt="Mercury Lamp Load" /></td>
<td><img src="image" alt="Fluorescent Lamp Load" /></td>
</tr>
<tr>
<td><img src="image" alt="Incandescent lamp" /></td>
<td><img src="image" alt="The discharge tube, transformer, choke coil, capacitor, etc., are combined in common discharge lamp circuits. Note that the inrush current may be 20 to 40 times, especially if the power supply impedance is low in the high power factor type." /></td>
<td><img src="image" alt="Contacts" /></td>
</tr>
<tr>
<td><img src="image" alt="Approx. 1/3 second Inrush current/rated current: 1/10 to 15 times" /></td>
<td><img src="image" alt="3 to 5 minutes" /></td>
<td><img src="image" alt="10 seconds or less" /></td>
</tr>
<tr>
<td><img src="image" alt="0.2 to 0.5 second" /></td>
<td><img src="image" alt="1/2 to 2 cycles (1/120 to 1/30 seconds)" /></td>
<td><img src="image" alt="1/2 to 2 cycles (1/120 to 1/30 seconds)" /></td>
</tr>
</tbody>
</table>

For (1) to (7) loads power supply is drawn as follows:

- Motor Load: Inrush current/rated current: 10 to 20 times
- Incandescent Lamp Load: Inrush current/rated current: 10 to 15 times
- Mercury Lamp Load: Inrush current/rated current: 3 to 10 times
- Fluorescent Lamp Load: Inrush current/rated current: 10 to 20 times
- Capacitive Load: Inrush current/rated current: 20 to 40 times
- Electromagnetic Contact Load: Inrush current/rated current: 3 to 10 times
- Solenoid Load: Inrush current/rated current: 3 times
- Electromagnetic Contact Load: Inrush current/rated current: 20 to 40 times

Note that since inductance is great, the arc lasts longer when power is cut. The contact may become easily worn.

Cautions for Use of SSR

- The capacitors used in the line filters may cause the SSR to malfunction due to dv/dt turn on when the equipment is turned on or off. In such an event, use an inductor (200 to 500 µH) in series to the SSR to suppress dv/dt turn on.
- Be sure to use a current limiting resistor or reactor in series with the SSR. Also, the SSR should have a high marginal voltage rating, since a voltage twice as high as the load supply voltage develops across the SSR in the reversal process.
- For reversible control on a 100 V AC line, use SSRs with a 200 V rating; for use on a 200 V AC line, contact your nearest representative for further information.
- Transistor-driven reversible motor control circuit
- Load power supply
- C
- SSR
- TR
- R1
- R2
- R3
- C1
- ZNR
- L
- C
- R4
- TR
- R1
- R2
- R3
- C1
- ZNR
- L
- C

- For (1) to (7) loads power supply is drawn as follows:
- Motor Load: Inrush current/rated current: 10 to 20 times
- Incandescent Lamp Load: Inrush current/rated current: 10 to 15 times
- Mercury Lamp Load: Inrush current/rated current: 3 to 10 times
- Fluorescent Lamp Load: Inrush current/rated current: 10 to 20 times
- Capacitive Load: Inrush current/rated current: 20 to 40 times
- Electromagnetic Contact Load: Inrush current/rated current: 3 to 10 times
- Solenoid Load: Inrush current/rated current: 3 times
- Electromagnetic Contact Load: Inrush current/rated current: 20 to 40 times

Note that since inductance is great, the arc lasts longer when power is cut. The contact may become easily worn.

Photo of motor and brake circuit

-条件变得更为恶劣，如果插拔或缓慢运行，则会更加严重。
- 当接触器用于控制直流电动机和刹车时，机械寿命可能会受到刹车电流的影响。
- 检验证实实际负载的电流。
- 当使用继电器控制直流电机刹车时，刹车电流的加载或卸载时间可能会因使用情况的不同而有所差异。
- 特别注意，开机时间、刹车电流和稳定电流的总和取决于是否是自由状态。

电枢反应快速抑制器
- 当开关在给定的电源电压下工作时，使用一个200 V的电压抑制器；对于200 V的电源电压，接触器的最高电压是200 V。
- 通过抑制dv/dt误差来抑制电压抑制器的导通。
- 用于抑制 switching regulator 等电子设备的 dv/dt。
- 一般，电子设备使用线滤波器来抑制 dv/dt。
- 请参考我们的代表处获取进一步的信息。

电容调速器
- 电容起动一相电能机、电容起动型。
- 电容起动型单相电能机、电容起动型。
Cautions for Use of SSR

SSR Driving Circuits

1. Relay Driver

2. NPN Transistor Driver

3. PNP Transistor Driver

4. TTL/DTL/IC Driver

5. C-MOS/IC Driver

(1) SSR fires when IC output is HIGH:

(2) SSR fires when IC output is LOW:

6. Self Sustaining Circuit Using SSR

7. Driving with a Shared Supply

8. SSRs Used in Series

Phototriac Coupler, AQ-H Solid State Relay Driving Circuits

1. NPN Transistor Driver

1) Phototriac Coupler

2) AQ-H Solid State Relay

* Phototriac coupler and AQ-H is current driving type.
Phototriac Coupler/AQ-H Application Examples

Typical Applications
1. Temperature control for heater control

![Temperature control circuit diagram]

2. Airflow control for fan motors

![Airflow control circuit diagram]
SSR Application Examples

Typical Applications

1. Light Bulb

![Light Bulb Diagram]

2. Electric Furnace Temperature Control

![Electric Furnace Temperature Control Diagram]

3. Single-Phase Induction Motor Control

![Single-Phase Induction Motor Control Diagram]

4. Reversible Control for a Single-Phase Induction Motor

![Reversible Control for Single-Phase Induction Motor Diagram]

5. Three-Phase Induction Motor Control

![Three-Phase Induction Motor Control Diagram]

6. Reversible Control for a 3-Phase Induction Motor

![Reversible Control for 3-Phase Induction Motor Diagram]

Note: Take special care in the design to ensure that both the forward and reverse SSRs do not turn on at the same time.

Recommended Temperature Controllers

<KT4H Temperature Controller>
Our temperature controller is recommended for use with our Solid State Relays.

Features
- Data can be collected using the RS485 communications interface via a PLC.
- Improved visibility using a negative type LCD and backlight.
- Depth-wise length (chassis dimension) is 56 mm 2.205 inch.

Substitute part numbers

<table>
<thead>
<tr>
<th>Power supply</th>
<th>Control output</th>
<th>Part No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 to 240 V AC</td>
<td>Relay contact</td>
<td>AKT4H112100</td>
</tr>
</tbody>
</table>

*For detailed product information about temperature controllers, please refer to our website: http://industrial.panasonic.com/ac/e/
Please use this chart when selecting the SSR load. The values presented are for ambient temperatures of 40°C (104°F) and lower. When selected, please measure the load current waveform and use within the range of each surge current characteristic.

### SSR Load Recommendation Chart

<table>
<thead>
<tr>
<th>Load voltage</th>
<th>Voltage Type</th>
<th><strong>Type of load</strong></th>
<th><strong>Max. load current</strong></th>
<th><strong>Remarks</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>110 V AC</strong></td>
<td><strong>110 V AC</strong></td>
<td><strong>Heater</strong></td>
<td><strong>Solenoid bulb</strong></td>
<td><strong>Single-phase motor</strong></td>
</tr>
<tr>
<td>AQG (1A type)</td>
<td>1A</td>
<td>0.8A</td>
<td>0.5A</td>
<td>7W</td>
</tr>
<tr>
<td>AQG (2A type)</td>
<td>2A</td>
<td>1.6A</td>
<td>1A</td>
<td>15W</td>
</tr>
<tr>
<td>AQ (3A type)</td>
<td>3A</td>
<td>2.4A</td>
<td>1.5A</td>
<td>60W</td>
</tr>
<tr>
<td>AQ1 (10A type)</td>
<td>10A</td>
<td>8A</td>
<td>5A</td>
<td>200W</td>
</tr>
<tr>
<td>AQ1 (15A type)</td>
<td>15A</td>
<td>12A</td>
<td>7.5A</td>
<td>300W</td>
</tr>
<tr>
<td>AQ1 (25A type)</td>
<td>25A</td>
<td>20A</td>
<td>12.5A</td>
<td>500W</td>
</tr>
<tr>
<td>AQ1 (40A type)</td>
<td>40A</td>
<td>32A</td>
<td>20A</td>
<td>750W</td>
</tr>
<tr>
<td><strong>220 V AC</strong></td>
<td><strong>220 V AC</strong></td>
<td><strong>Heater</strong></td>
<td><strong>Solenoid bulb</strong></td>
<td><strong>Single-phase motor</strong></td>
</tr>
<tr>
<td>AQG (1A type)</td>
<td>1A</td>
<td>0.8A</td>
<td>0.5A</td>
<td>15W</td>
</tr>
<tr>
<td>AQG (2A type)</td>
<td>2A</td>
<td>1.6A</td>
<td>1A</td>
<td>35W</td>
</tr>
<tr>
<td>AQ (3A type)</td>
<td>3A</td>
<td>2.4A</td>
<td>1.5A</td>
<td>100W</td>
</tr>
<tr>
<td>AQ1 (10A type)</td>
<td>10A</td>
<td>8A</td>
<td>5A</td>
<td>400W</td>
</tr>
<tr>
<td>AQ1 (15A type)</td>
<td>15A</td>
<td>12A</td>
<td>7.5A</td>
<td>600W</td>
</tr>
<tr>
<td>AQ1 (25A type)</td>
<td>25A</td>
<td>20A</td>
<td>12.5A</td>
<td>1kW</td>
</tr>
<tr>
<td>AQ1 (40A type)</td>
<td>40A</td>
<td>32A</td>
<td>20A</td>
<td>1.5kW</td>
</tr>
<tr>
<td><strong>48 V DC</strong></td>
<td><strong>48 V DC</strong></td>
<td><strong>Heater</strong></td>
<td><strong>Solenoid bulb</strong></td>
<td><strong>Single-phase motor</strong></td>
</tr>
<tr>
<td>AQ (2A type)</td>
<td>2A</td>
<td>1.6A</td>
<td>1.0A</td>
<td>—</td>
</tr>
<tr>
<td><strong>100 V DC</strong></td>
<td><strong>100 V DC</strong></td>
<td><strong>Heater</strong></td>
<td><strong>Solenoid bulb</strong></td>
<td><strong>Transformer</strong></td>
</tr>
<tr>
<td>AQ (1A type)</td>
<td>1A</td>
<td>0.8A</td>
<td>0.5A</td>
<td>—</td>
</tr>
</tbody>
</table>