

## Overview

In 1974, Opto 22 introduced the first liquid epoxy-filled line of power solid-state relays (SSR). This innovation in SSR design greatly improved the reliability and reduced the cost of manufacturing. At that time, we also incorporated into our manufacturing process 100% testing under full load conditions of every relay we produced.

By 1978, Opto 22 had gained such a reputation for reliability that we were recognized as the world's leading manufacturer of solid-state relays. Through continuous manufacturing improvements and the same 100% testing policy established 22 years ago, Opto 22 is still recognized today for the very high quality and reliability of its complete line of solid-state relays.

## Description

Opto 22 offers a complete line of solid state relays (SSRs), from the rugged 120/240-volt AC Series to the small footprint MP Series, designed for mounting on printed circuit boards. All Opto 22 relays feature 4,000 volts of optical isolation and are UL and CSA recognized. The innovative use of room temperature liquid epoxy encapsulation, coupled with Opto 22's unique heat-spreader technology, are key to mass-producing the world's most reliable solid state relays.

Every Opto 22 solid state relay is subjected to full load test and six times the rated current surge both before and after encapsulation. This double testing of every part before it leaves the factory means you can rely on Opto 22 solid state relays. All Opto 22 SSRs are guaranteed for life.

## Power Series SSRs



Opto 22 provides a full range of Power Series relays with a wide variety of voltage (110–575 volts) and current options (3–45 amps). All Power Series relays feature 4,000 volts of optical isolation, and have a high PRV rating.

## DC Series

The DC Series delivers isolated DC control to large OEM customers worldwide.

## AC Series

The AC Series offers the ultimate in solid state reliability. All AC Power Series relays feature a built-in snubber and zero voltage turn on. Transient-proof models offer self protection for noisy electrical environments.

## Z Series SSRs



The Z Series employs a unique heat transfer system that makes it possible for Opto 22 to deliver a low-cost, 10-amp, solid state relay in an all-plastic case. The push-on tool-free quick-connect terminals make the Z Series ideal for high-volume OEM applications.

## Printed Circuit Series SSRs



Opto 22's Printed Circuit Series allows OEMs to easily deploy solid state relays on printed circuit boards. Two unique packages are available, both of which will switch loads up to four amps.

## MP Series

The MP Series packaging is designed with a minimum footprint to allow maximum relay density on the printed circuit board.

## P Series

The P Series power relays provide low-profile for 0.5-inch (12.7mm) center mounting on printed circuit boards.

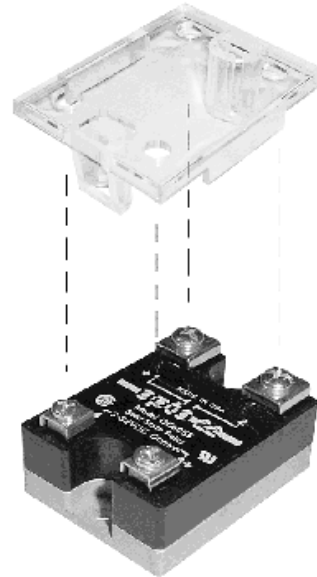
### Specifications (all models)

- 4,000 V optical isolation input to output
- Zero voltage turn-on
- Turn-on time: ½ cycle maximum
- Turn-off time: ½ cycle maximum
- Operating frequency: 25 to 65 Hz  
(operates at 400 Hz with six times off-state leakage)
- Coupling capacitance input to output: 8 pF maximum
- Hermetically sealed
- DV/DT Off-state: 200 volts per microsecond
- DV/DT commutating: snubbed for rated current at 0.5 power factor
- UL recognized
- CSA certified
- CE component

See Opto 22 form #986 for torque specifications.

### Safety Cover for Power Series SSRs

A plastic safety cover (Opto 22 part number SAFETY COVER) is optionally available for Opto 22 Power Series SSRs. The safety cover reduces the chance of accidental contact with relay terminals, while providing access holes for test instrumentation.



Optional plastic safety cover installed on a Power Series SSR

Form 859-050513

### AC Power Series Specifications

#### 120/240 Volt

Opto 22 provides a full range of power series relays with a wide variety of voltage (110–575) and current options (3–45 amps). All Power Series relays feature 4,000 volts of optical isolation and have a high PRV rating.

| Model Number | Nominal AC Line Voltage | Nominal Current Rating (Amps) | 1 cycle Surge (Amps) Peak | Nominal Signal Input Resistance (Ohms) | Signal Pick-up Voltage | Signal Drop-out Voltage | Peak Repetitive Voltage Maximum | Maximum Output Voltage Drop | Off-State Leakage (mA) Maximum** | Operating Voltage Range (Volts AC) | I <sup>2</sup> t Rating t=8.3 (ms) | Isolation Voltage | qjc* (°C/Watt) | Dissipation (Watts/Amp) |
|--------------|-------------------------|-------------------------------|---------------------------|--|------------------------|-------------------------|---------------------------------|-----------------------------|----------------------------------|------------------------------------|------------------------------------|-------------------|----------------|-------------------------|
| 120D3        | 120                     | 3                             | 85                        | 1000                                   | 3VDC (32V allowed)     | 1 VDC                   | 600                             | 1.6 volts                   | 2.5mA                            | 12-140                             | 30                                 | 4,000VRMS         | 11             | 1.7                     |
| 120D10       | 120                     | 10                            | 110                       | 1000                                   | 3VDC (32V allowed)     | 1 VDC                   | 600                             | 1.6 volts                   | 7 mA                             | 12-140                             | 50                                 | 4,000VRMS         | 1.3            | 1.6                     |
| 120D25       | 120                     | 25                            | 250                       | 1000                                   | 3VDC (32V allowed)     | 1 VDC                   | 600                             | 1.6 volts                   | 7 mA                             | 12-140                             | 250                                | 4,000VRMS         | 1.2            | 1.3                     |
| 120D45       | 120                     | 45                            | 650                       | 1000                                   | 3VDC (32V allowed)     | 1 VDC                   | 600                             | 1.6 volts                   | 7 mA                             | 12-140                             | 1750                               | 4,000VRMS         | 0.67           | 0.9                     |
| 240D3        | 240                     | 3                             | 85                        | 1000                                   | 3VDC (32V allowed)     | 1 VDC                   | 600                             | 1.6 volts                   | 5 mA                             | 24-280                             | 30                                 | 4,000VRMS         | 11             | 1.7                     |
| 240D10       | 240                     | 10                            | 110                       | 1000                                   | 3VDC (32V allowed)     | 1 VDC                   | 600                             | 1.6 volts                   | 14 mA                            | 24-280                             | 50                                 | 4,000VRMS         | 1.3            | 1.6                     |
| 240D25       | 240                     | 25                            | 250                       | 1000                                   | 3VDC (32V allowed)     | 1 VDC                   | 600                             | 1.6 volts                   | 14 mA                            | 24-280                             | 250                                | 4,000VRMS         | 1.2            | 1.3                     |
| 240D45       | 240                     | 45                            | 650                       | 1000                                   | 3VDC (32V allowed)     | 1 VDC                   | 600                             | 1.6 volts                   | 14 mA                            | 24-280                             | 1750                               | 4,000VRMS         | 0.67           | 0.9                     |
| 380D25       | 380                     | 25                            | 250                       | 1000                                   | 3VDC (32V allowed)     | 1 VDC                   | 800                             | 1.6 volts                   | 12 mA                            | 24-420                             | 250                                | 4,000VRMS         | 1.2            | 1.3                     |
| 380D45       | 380                     | 45                            | 650                       | 1000                                   | 3VDC (32V allowed)     | 1 VDC                   | 800                             | 1.6 volts                   | 12 mA                            | 24-420                             | 1750                               | 4,000VRMS         | 0.67           | 0.9                     |
| 120A10       | 120                     | 10                            | 110                       | 33K                                    | 85 VAC (280 allowed)   | 10 VAC                  | 600                             | 1.6 volts                   | 7 mA                             | 12-140                             | 50                                 | 4,000VRMS         | 1.3            | 1.6                     |
| 120A25       | 120                     | 25                            | 250                       | 33K                                    | 85 VAC (280 allowed)   | 10 VAC                  | 600                             | 1.6 volts                   | 7 mA                             | 12-140                             | 250                                | 4,000VRMS         | 1.2            | 1.3                     |
| 240A10       | 240                     | 10                            | 110                       | 33K                                    | 85 VAC (280 allowed)   | 10 VAC                  | 600                             | 1.6 volts                   | 14 mA                            | 24-280                             | 50                                 | 4,000VRMS         | 1.3            | 1.6                     |
| 240A25       | 240                     | 25                            | 250                       | 33K                                    | 85 VAC (280 allowed)   | 10 VAC                  | 600                             | 1.6 volts                   | 14 mA                            | 24-280                             | 250                                | 4,000VRMS         | 1.2            | 1.3                     |
| 240A45       | 240                     | 45                            | 650                       | 33K                                    | 85 VAC (280 allowed)   | 10 VAC                  | 600                             | 1.6 volts                   | 14 mA                            | 24-280                             | 1750                               | 4,000VRMS         | 0.67           | 0.9                     |

Notes: qjc\* = Thermal resistance junction to base. Maximum junction temperature is 110°C.

\*\* Operating Frequency: 25 to 65 Hz (operates at 400 Hz with 6 times the offstate leakage)

Form 859-050513

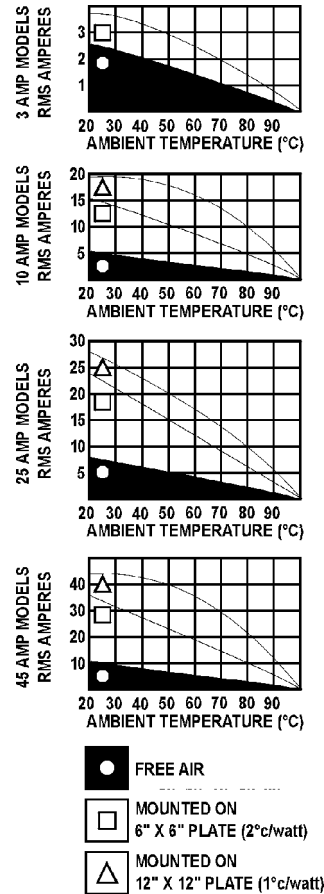
### AC Power Series Specifications 120/240 Volt (cont.)

#### Surge Current Data

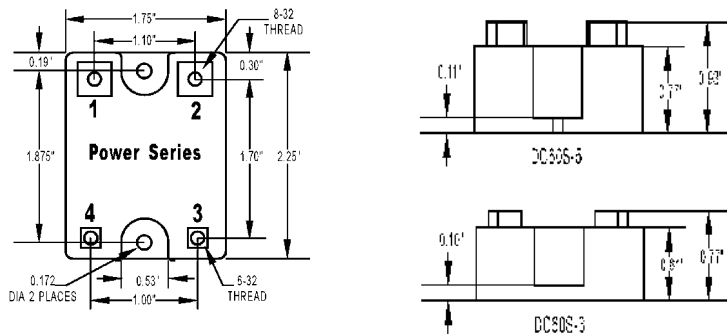
| Time (Seconds) | Time* (Cycles) | 3-Amp Peak Amps | 10-Amp Peak Amps | 25-Amp Peak Amps | 45-Amp Peak Amps |
|----------------|----------------|-----------------|------------------|------------------|------------------|
| 0.017          | 1              | 85              | 110              | 250              | 650              |
| 0.050          | 3              | 66              | 85               | 175              | 420              |
| 0.100          | 6              | 53              | 70               | 140              | 320              |
| 0.200          | 12             | 45              | 60               | 112              | 245              |
| 0.500          | 30             | 37              | 50               | 80               | 175              |
| 1              | 60             | 31              | 40               | 67               | 134              |
| 2              | 120            | 28              | 33               | 53               | 119              |
| 3              | 180            | 27              | 32               | 49               | 98               |
| 4              | 240            | 26              | 31               | 47               | 95               |
| 5              | 300            | 25              | 30               | 45               | 91               |
| 10             | 600            | 24              | 28               | 42               | 84               |

Note: \*60 Hz.

#### Thermal Ratings



#### Dimensional Drawings



Form 859-050513

### AC Power Series Specifications

#### 480/575 Volt

DC SERIES: The DC Series delivers isolated DC control to large OEM customers worldwide.

AC SERIES: The AC Series offers the ultimate in solid-state reliability. All AC power series relays feature a built-in snubber and zero voltage turn-on. Transient proof models offer self-protection for noisy electrical environments.

| Model Number | Nominal AC Line Voltage | Nominal Current Rating (Amps) | 1 cycle Surge (Amps) Peak | Nominal Signal Input Resistance (Ohms) | Signal Pick-up Voltage | Signal Drop-out Voltage | Peak Repetitive Voltage Maximum | Maximum Output Voltage Drop | Off-State Leakage (mA) Maximum ** | Operating Voltage Range (Volts AC) | I <sup>2</sup> t Rating t=8.3 (ms) | Isolation Voltage     | θ <sub>jc</sub> * (°C/Watt) | Dissipation (Watts/Amp) |
|--------------|-------------------------|-------------------------------|---------------------------|--|------------------------|-------------------------|---------------------------------|-----------------------------|-----------------------------------|------------------------------------|------------------------------------|-----------------------|-----------------------------|-------------------------|
| 480D10-12    | 480                     | 10                            | 110                       | 1000                                   | 3VDC (32V Allowed)     | 1 VDC                   | 1200                            | 3.2 volts                   | 11 mA                             | 100-530                            | 50                                 | 4,000V <sub>RMS</sub> | 1.2                         | 2.5                     |
| 480D15-12    | 480                     | 15                            | 150                       | 1000                                   | 3VDC (32V Allowed)     | 1 VDC                   | 1200                            | 3.2 volts                   | 11 mA                             | 100-530                            | 50                                 | 4,000V <sub>RMS</sub> | 1.2                         | 2.5                     |
| 480D25-12    | 480                     | 25                            | 250                       | 1000                                   | 3VDC (32V Allowed)     | 1 VDC                   | 1000                            | 1.6 volts                   | 11 mA                             | 100-530                            | 250                                | 4,000V <sub>RMS</sub> | 1.3                         | 1.3                     |
| 480D45-12    | 480                     | 45                            | 650                       | 1000                                   | 3VDC (32V Allowed)     | 1 VDC                   | 1000                            | 1.6 volts                   | 11 mA                             | 100-530                            | 1750                               | 4,000V <sub>RMS</sub> | 0.67                        | 0.9                     |
| 575D15-12    | 575                     | 15                            | 150                       | 1000                                   | 3VDC (32V Allowed)     | 1 VDC                   | 1200                            | 3.2 volts                   | 15 mA                             | 100-600                            | 90                                 | 4,000V <sub>RMS</sub> | 1.2                         | 2.5                     |
| 575D45-12    | 575                     | 45                            | 650                       | 1000                                   | 3VDC (32V Allowed)     | 1 VDC                   | 1000                            | 1.6 volts                   | 15 mA                             | 100-600                            | 1750                               | 4,000V <sub>RMS</sub> | 0.67                        | 0.9                     |

Note: θ<sub>jc</sub>\* = Thermal resistance junction to base. Maximum junction temperature is 110°C.

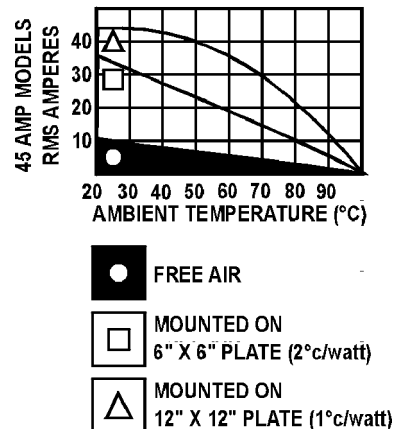
\*\* Operating Frequency: 25 to 65 Hz (operates at 400 Hz with 6 times the offstate leakage)

#### Surge Current Data

| Time Second | Time*** (Cycles) | 10-Amp Peak Amps | 15-Amp Peak Amps | 25-Amp Peak Amps | 45-Amp Peak Amps |
|-------------|------------------|------------------|------------------|------------------|------------------|
| 0.017       | 1                | 110              | 150              | 250              | 650              |
| 0.050       | 3                | 85               | 140              | 175              | 420              |
| 0.100       | 6                | 70               | 110              | 140              | 320              |
| 0.200       | 12               | 60               | 90               | 112              | 245              |
| 0.500       | 30               | 50               | 70               | 80               | 175              |
| 1           | 60               | 40               | 55               | 67               | 134              |
| 2           | 120              | 33               | 49               | 53               | 119              |
| 3           | 180              | 32               | 47               | 49               | 98               |
| 4           | 240              | 31               | 43               | 47               | 95               |
| 5           | 300              | 30               | 40               | 45               | 91               |
| 10          | 600              | 28               | 35               | 42               | 84               |

Note: \*\*\*60 Hz

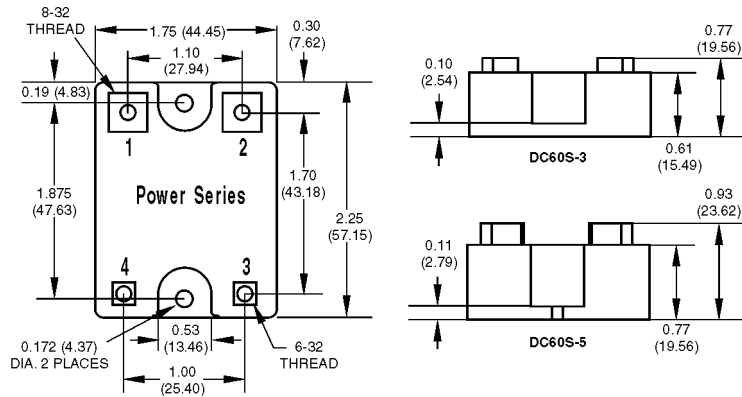
#### Thermal Ratings



### AC Power Series Specifications

480/575 Volt (cont)

#### Dimensional Drawings



### Z Series Specifications

AC Power: 120/240 Volt

The Z Series employs a unique heat transfer system that makes it possible for Opto 22 to deliver a low-cost, 10-amp, solid-state relay in an all-plastic case. The push-on tool-free quick-connect terminals make the Z Series ideal for high-volume OEM applications.

| Model Number | Nominal AC Line Voltage | Nominal Current Rating (Amps) | 1 cycle Surge (Amps) Peak | Nominal Signal Input Resistance (Ohms) | Signal Pick-up Voltage | Signal Drop-out Voltage | Peak Repetitive Voltage Maximum | Maximum Output Voltage Drop | Off-State Leakage (mA) Maximum** | Operating Voltage Range (Volts AC) | I <sub>t</sub> Rating t=8.3 (ms) | Isolation Voltage      | θ <sub>jc</sub> * (°C/Watt) | Dissipation (Watts/Amp) |
|--------------|-------------------------|-------------------------------|---------------------------|--|------------------------|-------------------------|---------------------------------|-----------------------------|----------------------------------|------------------------------------|----------------------------------|------------------------|-----------------------------|-------------------------|
| Z120D10      | 120                     | 10                            | 110                       | 1000                                   | 3VDC (32V allowed)     | 1 VDC                   | 600                             | 1.6 volts                   | 6 mA                             | 12-140                             | 50                               | 4,000 V <sub>RMS</sub> | 4                           | 1                       |
| Z240D10      | 240                     | 10                            | 110                       | 1000                                   | 3VDC (32V allowed)     | 1 VDC                   | 600                             | 1.6 volts                   | 12 mA                            | 24-280                             | 50                               | 4,000 V <sub>RMS</sub> | 4                           | 1                       |

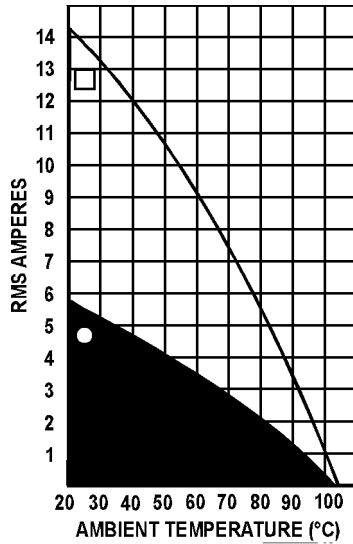
Notes: θ<sub>jc</sub>\* = Thermal resistance junction to base. Maximum junction temperature is 110°C.

\*\* Operating Frequency: 25 to 65 Hz (operates at 400 Hz with 6 times the offstate leakage)

### Z Series Specifications (cont.)

AC Power: 120/240 Volt

#### Current vs. Ambient Ratings

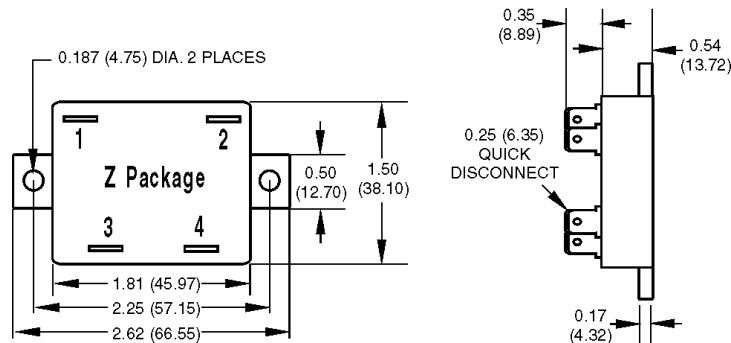


#### Surge Current Data

| Time Second | Time*** (Cycles) | Peak Amps |
|-------------|------------------|-----------|
| 0.017       | 1                | 110       |
| 0.050       | 3                | 85        |
| 0.100       | 6                | 70        |
| 0.200       | 12               | 60        |
| 0.500       | 30               | 50        |
| 1           | 60               | 40        |
| 2           | 120              | 33        |
| 3           | 180              | 32        |
| 4           | 240              | 31        |
| 5           | 300              | 30        |
| 10          | 600              | 28        |

Note: \*\*\*60 Hz

#### Dimensional Drawings



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### Printed Circuit Series Specifications

AC Power: P and MP Series

| Model Number      | Nominal AC Line Voltage | Nominal Current Rating Amps | 1 cycle Surge (Amps) Peak | Nominal Signal Input Resistance (Ohms) | Signal Pick-up Voltage | Signal Drop-out Voltage | Peak Repetitive Voltage Maximum | Maximum Output Voltage Drop | Off-State Leakage mA Maximum** | Operating Voltage Range (Volts AC) | I <sub>t</sub> Rating $\tau=8.3$ (ms) | Isolation Voltage V <sub>RMS</sub> | $\theta_{jc}$ * °C/Watt | Dissipation Watts/Amp |
|-------------------|-------------------------|-----------------------------|---------------------------|--|------------------------|-------------------------|---------------------------------|-----------------------------|--------------------------------|------------------------------------|---------------------------------------|------------------------------------|-------------------------|-----------------------|
| MP120D2 or P120D2 | 120                     | 2                           | 20                        | 1000                                   | 3VDC*** (32V allowed)  | 1 VDC                   | 600                             | 1.6 volts                   | 5 mA                           | 12-140                             | 2                                     | 4,000 V <sub>RMS</sub>             | 20                      | 1.2                   |
| MP120D4 or P120D4 | 120                     | 4                           | 85                        | 1000                                   | 3VDC*** (32V allowed)  | 1 VDC                   | 600                             | 1.6 volts                   | 5 mA                           | 12-140                             | 30                                    | 4,000 V <sub>RMS</sub>             | 6.5                     | 1.2                   |
| MP240D2 or P240D2 | 240                     | 2                           | 20                        | 1000                                   | 3VDC*** (32V allowed)  | 1 VDC                   | 600                             | 1.6 volts                   | 5 mA                           | 24-280                             | 2                                     | 4,000 V <sub>RMS</sub>             | 20                      | 1.2                   |
| MP240D4 or P240D4 | 240                     | 4                           | 85                        | 1000                                   | 3VDC*** (32V allowed)  | 1 VDC                   | 600                             | 1.6 volts                   | 5 mA                           | 24-280                             | 30                                    | 4,000 V <sub>RMS</sub>             | 6.5                     | 1.2                   |
| MP380D4           | 380                     | 4                           | 85                        | 1000                                   | 3VDC*** (32V allowed)  | 1 VDC                   | 800                             | 1.6 volts                   | 5 mA                           | 24-420                             | 30                                    | 4,000 V <sub>RMS</sub>             | 6.5                     | 1.2                   |

Notes:  $\theta_{jc}$ \* = Thermal resistance junction to base. Maximum junction temperature is 110°C.

ency: 25 to 65 Hz (operates at 400 Hz with 6 times the offstate leakage)

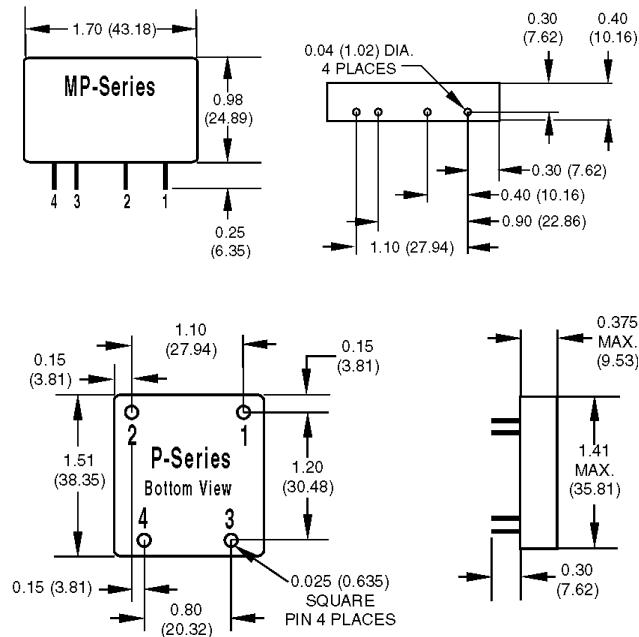
\*\*\* = MP Series 24 volts maximum.

### Surge Current Data

| Time Second | Time* (Cycles) | Peak Amps | Peak Amps |
|-------------|----------------|-----------|-----------|
| 0.017       | 1              | 20        | 85        |
| 0.050       | 3              | 18        | 66        |
| 0.100       | 6              | 15        | 53        |
| 0.200       | 12             | 11        | 45        |
| 0.500       | 30             | 9         | 37        |
| 1           | 60             | 8.5       | 31        |
| 2           | 120            | 8         | 28        |
| 3           | 180            | 7.5       | 27        |
| 4           | 240            | 7         | 26        |
| 5           | 300            | 6.5       | 25        |
| 10          | 600            | 6         | 24        |

Note: \*60 Hz

### Dimensional Drawings



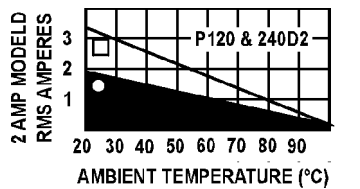
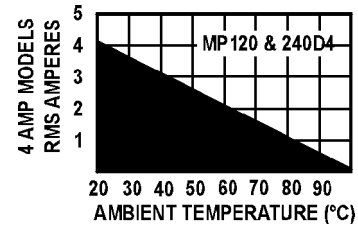
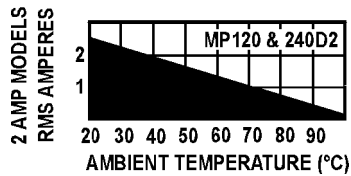


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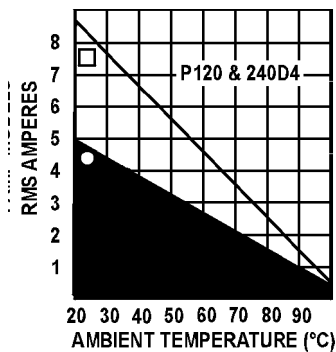
Printed Circuit Series (cont.)

AC Power: P and MP Series (cont.)

### Thermal Ratings



● FREE AIR  
 □ MOUNTED ON 6" X 6" PLATE (2° C/WATT)



● FREE AIR  
 □ MOUNTED ON 6" X 6" PLATE (2° C/WATT)

### Surge Current Data

| Time Second | Time* (Cycles) | Peak Amps | Peak Amps |
|-------------|----------------|-----------|-----------|
| 0.017       | 1              | 20        | 85        |
| 0.050       | 3              | 18        | 66        |
| 0.100       | 6              | 15        | 53        |
| 0.200       | 12             | 11        | 45        |
| 0.500       | 30             | 9         | 37        |
| 1           | 60             | 8.5       | 31        |
| 2           | 120            | 8         | 28        |
| 3           | 180            | 7.5       | 27        |
| 4           | 240            | 7         | 26        |
| 5           | 300            | 6.5       | 25        |
| 10          | 600            | 6         | 24        |

Note: \*60 Hz

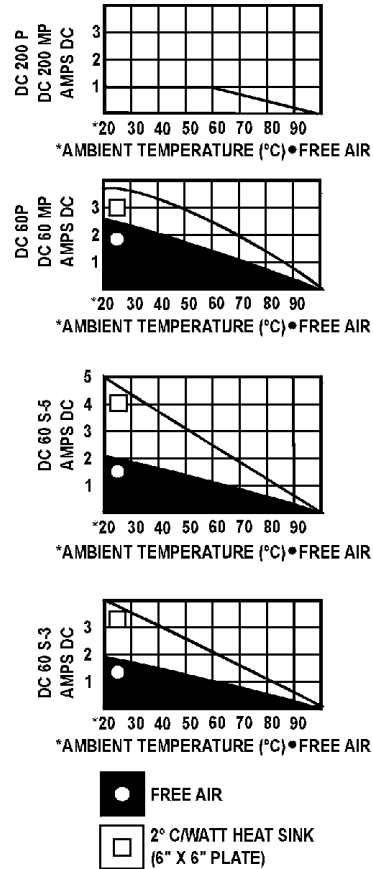
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### DC Switching Series Specifications

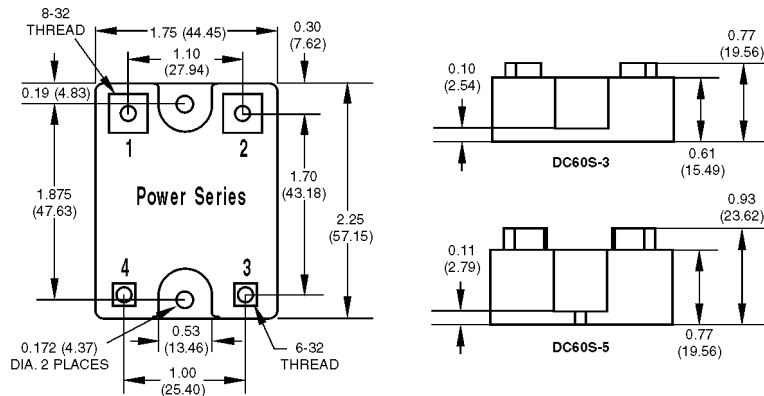
|                         | DC60P or DC60MP        | DC200P or DC200MP             | DC60S-3                      | DC60S-5                      |
|-------------------------|------------------------|-------------------------------|------------------------------|------------------------------|
| Operating Voltage Range | 5-60 VDC               | 5-200 VDC                     | 5-60 VDC                     | 5-60 VDC                     |
| Forward Voltage Drop    | 1.5 volts              | at 1 amp                      | at 3 amps                    | at 5 amps                    |
| Nominal Current Rating  | 3 amps                 | 1 amp                         | 3 amps                       | 5 amps                       |
| Off-State Blocking      | 60 VDC                 | 250 VDC                       | 60 VDC                       | 60 VDC                       |
| Signal Pickup Voltage   | 3 VDC<br>allowed       | 3 VDC<br>32 Volts*<br>allowed | 3 VDC<br>32 Volts<br>allowed | 3 VDC<br>32 Volts<br>allowed |
| Signal Dropout Voltage  | 1 VDC                  | 1 VDC                         | 1 VDC                        | 1 VDC                        |
| Signal Input Impedance  | 1,000 ohms             | 1,000 ohms                    | 1,000 ohms                   | 1,000 ohms                   |
| 1 Second Surge          | 5 amps                 | 2 amps                        | 5 amps                       | 10 amps                      |
| Operating Temp. Range   | -40°C to 100 ° C       | -40°C to 100 ° C              | 100 ° C                      | 100 ° C                      |
| Isolation Voltage       | 4,000 V <sub>RMS</sub> | 4,000 V <sub>RMS</sub>        | 4,000 V <sub>RMS</sub>       | 4,000 V <sub>RMS</sub>       |
| Off-State Leakage       | 1 mA maximum           | 1 mA maximum                  | 1 mA maximum                 | 1 mA maximum                 |
| Package Type            | P/MP series            | P/MP series                   | Power series                 | series                       |
| Turn-on Time            | 100 usec               | 100 usec                      | 100 usec                     | 100 usec                     |
| Turn-off Time           | 750 usec               | 750 usec                      | 750 usec                     | 750 usec                     |

Note: \*MP series maximum allowed control signal at 24 VDC.

### Thermal Ratings

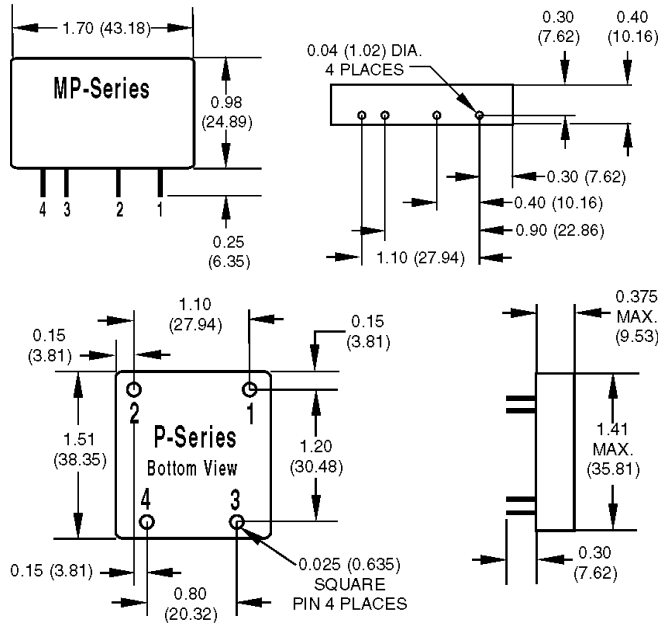


### Dimensional Drawings



Form 859-050513

### Dimensional Drawings (cont.)

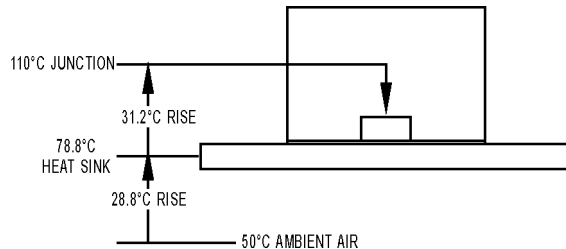


## Applications: Tips

### Heat Sink Calculation

Like all semiconductor devices, SSR current ratings must be based on maximum junction temperature. All Opto 22 SSRs operate conservatively at maximum junction temperatures of 110° C. Determining an adequate heat sink for a given SSR conducting a given current is very simple.

Note: Thermally conductive grease must be used between the relay base and the heat sink.



### Sample Calculation Given

120-Volt, 20-Amp Load; 50° C Ambient Air

Choose Model 120D25 SSR.

Calculate dissipation as: **20 amps x 1.3 Watts per amp = 26 Watts**

Calculate temperature rise junction to SSR base as: **26 Watts x 1.2° C per Watt = 31.2° C**

Calculate allowable temperature of heat sink by subtracting 31.2° C from 110° C allowable junction temperature:

$$110^{\circ}\text{C} - 31.2 = 78.8^{\circ}\text{C}$$

The heat sink is in a 50°C ambient, therefore, allowable temperature rise on heat sink is: **78.8° C - 50° C = 28.8° C**

If heat sink is allowed to rise 28.8° C above ambient, then the thermal resistance of the heat sink is simply the 28.8° C rise divided by the 26 Watt. Any heat sink having a thermal resistance less than 1.1° C per Watt will be adequate.

### Duty Cycle Calculation

When solid-state relays are operated in an on/off mode, it may be advantageous to calculate the RMS value of the current through the SSR for heat sinking or determining the proper current rating of the SSR for the given application.

$I_{\text{RMS}}$  = RMS value of load or SSR

$T_1$  = Time current is on

$T_2$  = Time current is off

$I_{\text{ON}}$  = RMS value of load current during on period

$$I_{\text{RMS}} = \sqrt{\frac{(I_{\text{ON}})^2 \times T_1}{T_1 + T_2}}$$

## Applications: Tips (cont.)

### Transformer Loads

Careful consideration should be given to the selection of the proper SSR for driving a given transformer. Transformers are driven from positive saturation of the iron core to negative saturation of the core each ½ cycle of the alternating voltage. Large inrush currents can occur during the first ½ cycle of line voltage when a zero voltage SSR happens to turn on during the positive ½ cycle of voltage when the core is already in positive saturation. Inrush currents greater than 10 times rated transformer current can easily occur. The following table provides a guide for selecting the proper SSR for a given transformer rating.

| 120-Volt Transformers |               |
|-----------------------|---------------|
| SSR MODEL             | TRANSFORMER   |
| P or MP 120D2         | 100 VA        |
| Z120D10               | 500 VA        |
| 120D3                 | 100 VA        |
| P or MP 120D4         | 250 VA        |
| 120D10 or 120A10      | 500 VA        |
| 120D25 or 120A25      | 1 KVA         |
| 120D45                | 2 KVA         |
| 240-Volt Transformers |               |
| P or MP240D2          | 200 VA        |
| 7240D10               | 1 KVA         |
| 120D3                 | 200 VA        |
| P or MP240D4          | 500 VA        |
| 240D10 or 240A10      | 1 KVA         |
| 240D25 or 240A25      | 2 KVA         |
| 240D45                | 4 KVA         |
| 480-Volt Transformers |               |
| SSR MODEL             | TRANSFORMER   |
| 480D10-12             | 5-Amp Primary |
| 480D15-12             | 5-Amp Primary |

| 120-Volt Coils     |          |             |
|--------------------|----------|-------------|
| SSR CURRENT RATING | SOLENOID | CONTACTOR   |
| 2-Amp              | 1-Amp    | NEMA Size 4 |
| 4-Amp              | 3-Amp    | NEMA Size 7 |
| 240-Volt Coils     |          |             |
| SSR CURRENT RATING | SOLENOID | CONTACTOR   |
| 2-Amp              | 1-Amp    | NEMA Size 7 |
| 4-Amp              | 3-Amp    | NEMA Size 7 |

### Control Current Calculation

All Opto 22 DC controlled SSRs have a control circuit consisting of 1000 ohms in series with an LED. Since 3 volts is required to turn on any SSR, the maximum current required is (3 volt - 1 volt) divided by 1000 ohms which equals 2.0 mA. The 1 volt is subtracted from the 3 volt signal because 1 volt is dropped across the LED. For higher control voltages, an external resistor can be added in series with the control voltage to limit the control current. To limit the control current to 2 mA, calculate the external resistor  $R_c = 500 (E_c - 3)$  where  $E_c$  = the control voltage.

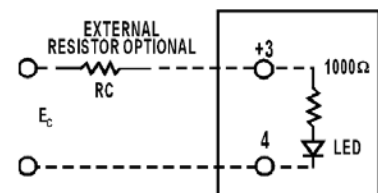
The DC control voltage range is 3–32 VDC. To calculate the control current for any voltage within the 3–32 VDC range, use the formula:

$$I_c = \frac{E_c - 1}{1000}$$

where  $R_c = \text{zero}$ .

With a 5V control signal,

$$I_c = \frac{5 - 1}{1000} = 4 \text{ mA.}$$



### Solenoid Valve and Contactor Loads

All Opto 22 SSRs are designed to drive inductive loads such as solenoid valves and electromechanical contactors. The built-in snubber in each SSR assures proper operation into inductive loads. The following table is a guide in selecting an SSR to drive a solenoid or contactor.

### Applications: Tips (cont.)

Opto 22 SSRs for controlling single-phase motors are shown in the following tables:

| 120-Volt Single-Phase Non-Reversing Motors |              |
|--|--------------|
| SSR Model                                  | MOTOR RATING |
| P or MP120D2                               | 1 Amp        |
| Z120D10                                    | 1/4 HP       |
| 120D3                                      | 1-1/2 Amp    |
| P or MP120D4                               | 1-1/2 Amp    |
| 120D10 or 120A10                           | 1/4 HP       |
| 120D25 or 120A25                           | 1/3 HP       |
| 120D45                                     | 3/4 HP       |

| 240-Volt Single Phase Non-Reversing Motors |              |
|--|--------------|
| SSR Model                                  | MOTOR RATING |
| P or MP240D2                               | 1 Amp        |
| Z240D10                                    | 1/4 HP       |
| 240D3                                      | 1-1/2 Amp    |
| P or MP240D4                               | 1-1/2 Amp    |
| 240D10 or 240A10                           | 1/3 HP       |
| 240D25 or 120A25                           | 1/2 HP       |
| 240D45                                     | 1-1/2 HP     |

| 120-Volt Single-Phase Reversing Motors |              |
|--|--------------|
| SSR Model                              | MOTOR RATING |
| P or MP240D2                           | 1 Amp        |
| Z240D10                                | 1/4 HP       |
| 240D3                                  | 1-1/2 Amp    |
| P or MP240D4                           | 1-1/2 Amp    |
| 240D10 or 240A10                       | 1/4 HP       |
| 240D25 or 120A25                       | 1/3 HP       |
| 240D45                                 | 3/4 HP       |

| 240-Volt Single-Phase Reversing Motors |              |
|--|--------------|
| SSR Model                              | MOTOR RATING |
| 480D10-12                              | 1/4 HP       |
| 480D15-12                              | 1/4 HP       |

### Solid-State Relays In Series

In applications requiring greater current rating at higher voltage, two Opto 22 SSRs may be operated in series for double the voltage rating. The built-in snubber in each SSR assures proper voltage sharing of the two SSRs in series. In the diagram below, two 240-volt, 45-amp SSRs are connected in series for operation on a 480-volt line. The control is shown with a parallel hook-up but it should be noted that a serial connection can also be implemented.

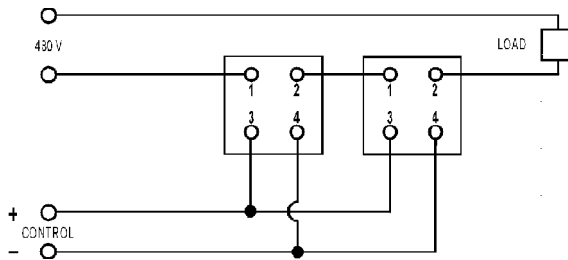
### Lamp Loads

Since all Opto 22 SSRs are zero voltage switching they are ideal for driving incandescent lamps because the initial inrush current into a cold filament is reduced. The life of the lamp is increased when switched by a zero voltage turn on SSR. The following table is a guide to selecting an Opto 22 SSR for switching a given incandescent lamp.

| 120 Volt Lamps     |             |
|--------------------|-------------|
| SSR CURRENT RATING | LAMP RATING |
| 2-Amp              | 100 Watt    |
| 4-Amp              | 400 Watt    |
| 10-Amp             | 1 Kilowatt  |
| 25-Amp             | 2 Kilowatt  |
| 45-Amp             | 3 Kilowatt  |
| 240 Volt Rating    |             |
| SSR CURRENT RATING | LAMP RATING |
| 2-Amp              | 200 Watt    |
| 4-Amp              | 800 Watt    |
| 10-Amp             | 2 Kilowatt  |
| 25-Amp             | 4 Kilowatt  |
| 45-Amp             | 6 Kilowatt  |

### Applications: Tips (cont.)

#### Lamp Loads (cont.)



#### Heater Loads

Care should be taken in selecting a SSR for driving a heater load if the load is cycled on and off in a continuous manner as might occur in a temperature control application. Constant cycling can cause thermal fatigue in the thyristor chip at the point where the chip bonds to the lead frame. Opto 22 employs a thick copper lead frame for mounting the SCR chips in the power series SSRs to eliminate thermal fatigue failures. In addition, Opto 22 recommends operating any SSR at 75% rated current for cycling heater loads to ensure complete reliability.

The following table is a guide to selecting the proper SSR for a given heater load.

| Nominal SSR Current Rating | Maximum Recommended Heater Current |
|----------------------------|------------------------------------|
| 2-Amp                      | 1½-Amp                             |
| 4-Amp                      | 2½-Amp                             |
| 10-Amp                     | 7½-Amp                             |
| 25-Amp                     | 18-Amp                             |
| 45-Amp                     | 35-Amp                             |
| 10 480V                    | 8-Amp                              |
| 10 480V                    | 8-Amp                              |

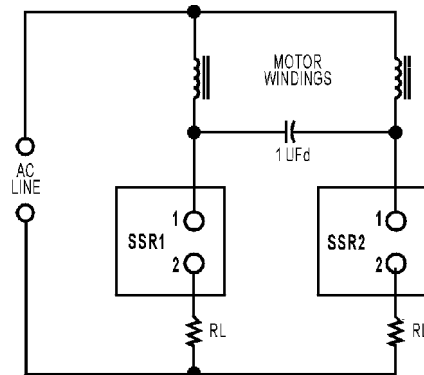
#### Single-Phase Reversing Motor Control

The circuit diagram illustrates a typical 1 Ø motor winding inductance and the phase shift capacitor can cause twice line voltage to appear across the open SSR. A 240-volt SSR should be used for a 120-Volt line. During the transition period when one SSR is turned on and the other SSR is going off, both SSRs may be on. In this case, the capacitor may discharge through the two SSRs, causing large currents to flow, which may destroy the SSRs. The addition of RL as shown will protect the SSRs from the short circuit capacitor discharge current.

$$\text{CALCULATE RL as: } RL = \frac{1.4 \text{ EAC}}{10 \times \text{SSR full load rating}}$$

**EXAMPLE: 10 amp SSR  
120 V AC Line**

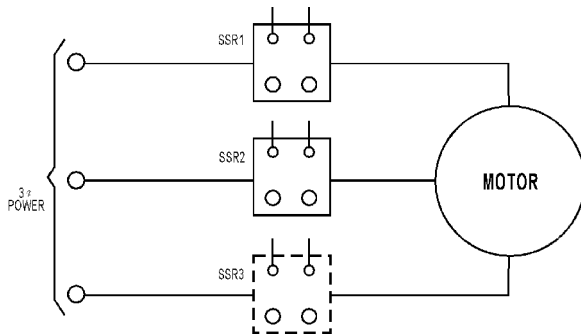
$$RL = \frac{1.4 \times 120}{10 \times 10} = 1.7 \text{ ohm}$$



The resistors are unnecessary if the control circuit is designed to ensure one SSR is off before the other SSR is on.

### Applications: Tips (cont.)

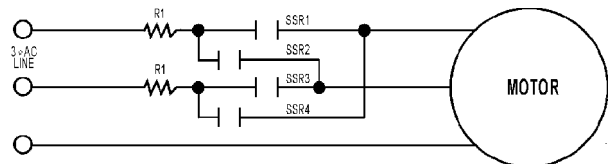
#### Three-Phase Motor Control



Three-phase motors may be controlled by solid-state relays as shown. A third SSR as shown is optional, but not necessary. The control windings may be connected in series or parallel. Care should be taken to ensure that surge current drawn by the motor does not exceed surge current rating of the SSR

| 240-Volt 3φ Motors |        |
|--------------------|--------|
| SSR MODEL          | MOTOR  |
| Z240D25            | 1/3 HP |
| Z240D10            | 3/4 HP |
| 240D10             | 3/4 HP |
| 240A10             | 3/4 HP |
| 240D25             | 2 HP   |
| 240A25             | 2 HP   |
| 240D45             | 3 HP   |
| 480-Volt 3φ Motors |        |
| SSR MODEL          | MOTOR  |
| 480D10-12          | 1-½ HP |
| 480D15-12          | 1-½ HP |

#### Three-Phase Reversing Motor Control



Three-phase reversing motor control can be implemented with four SSRs as shown in the connection diagram. The SSRs work in pairs with SSR1 and SSR3 operated for rotation in one direction and SSR2 and SSR4 operated for rotation in the reverse direction. The resistor R1 as shown in the connection diagram protects against line-to-line shorts if SSR1 and SSR4 or SSR3 and SSR2 are on at the same time during the reversing transition period. Use the following table as a guide to the proper selection of an SSR for this application.

| Opto 22 Relay | Motor Full Load Rating | Resistor for 120V line | Resistor for 240V line |
|---------------|------------------------|------------------------|------------------------|
| 3-Amp         | 1.25-Amp               | 4 ohm 50 W             | 8 ohm 50 W             |
| 10-Amp        | 5-Amp                  | 1 ohm 100 W            | 2 ohm 100 W            |
| 25-Amp        | 8-Amp                  | .5 ohm 100 W           | 1 ohm 100 W            |
| 45-Amp        | 16-Amp                 | 25 ohm 150 W           | .5 ohm 150 W           |
| 15-Amp        | 5-Amp                  | 1 ohm 100 W            | 2 ohm 100 W            |



## FAQ: SSR Applications

### **Q : What is a solid-state relay?**

**A :** A solid-state relay (SSR) is a semiconductor device that can be used in place of a mechanical relay to switch electricity to a load in many applications. Solid-state relays are purely electronic, normally composed of a low current "control" side (equivalent to the coil on an electromechanical relay) and a high-current load side (equivalent to the contact on a conventional relay). SSRs typically also feature electrical isolation to several thousand volts between the control and load sides. Because of this isolation, the load side of the relay is actually powered by the switched line; both line voltage and a load (not to mention a control signal) must be present for the relay to operate.

### **Q : What are the advantages of using an SSR over a mechanical relay?**

**A :** There are many applications that require a moderate amount of power (W to kW) to be switched on and off fairly rapidly. A good example of this would be the operation of a heater element in a controlled-temperature system. Typically, the amount of heat put into the system will be regulated using pulse-width modulation turning a fixed-power heating element on and off for time periods ranging from seconds to minutes. Mechanical relays have a finite cycle life, as their components tend to wear out over thousands to millions of cycles. SSRs do not have this problem; in the proper application, they could be operated almost infinitely.

### **Q : What are the limitations of using an SSR?**

**A :** SSRs have a few limitations when compared to the capabilities of their mechanical counterparts. First, because the relay is semiconductor-based, it will never turn all the way on, nor off. This means that in the "on" state, the relay still has some internal resistance to the flow of electricity, causing it to get hot. When in the "off" state, the relay will exhibit a small amount of leakage current, typically a few mA. This leakage can conspire to keep some loads, especially ones with a high impedance, from turning off! Additionally, SSRs are more sensitive to voltage transients; while Opto 22 relays are very well transient-protected, if a relay gets hit hard enough a sufficient number of times, it will die or degrade. This makes SSRs less ideal for driving highly inductive electromechanical

loads, such as some solenoids or motors. SSRs should also never be used for applications such as safety power disconnects because even in the off state, leakage current is present. Leakage current through an SSR also implies the presence of a potentially high voltage. Even though the relay is not conducting a large amount of current, the switched terminal will still be "hot," and thus dangerous.

### **Q : Do you make multi-pole or multi-throw SSRs?**

**A :** Opto 22 manufactures only single-pole, single-throw SSRs. If multi-phase operation is required, just use a relay on each phase. Because of the limitations on semiconductor devices of the type used in SSRs, it is not practical to build single-device multi-throw SSRs. However, an alternative to multi-throw operation may be accomplished with multiple relays.

### **Q : Can I hook up SSRs in parallel to achieve a higher current rating?**

**A :** No. There is no way to guarantee that two or more relays will turn on simultaneously when operated in parallel. Each relay requires a minimum voltage across the output terminals to function; because of the optical isolation feature, the "contact" part of the SSR is actually powered by the line it switches. One relay turning on before the other will cause the second relay to lose its turn-on voltage, and it won't ever turn on, or at least not until the first relay fails from carrying too much current.

## FAQ: SSR Applications (cont.)

### Q : What does a “zero-crossing” turn-on circuit refer to?

**A :** “Zero-crossing” turn-on and turn-off refer to the point on the AC wave form when the voltage is zero. It is at this point that an AC SSR will turn on or off. All Opto 22 AC relays are designed with a zero-crossing turn-on and turn-off circuit. When the AC circuit voltage is at zero, no current is flowing. This makes it much easier and safer for the semiconductor device in the relay to be turned on or off. It also generates much less electrical EMI/RFI noise.

### Q : Can I use an AC SSR to switch DC?

**A :** No. Because of the zero crossing circuit described above, the relay will most likely never turn on, and even if it is on, it will likely not be able to be turned off, as DC voltage typically never drops to zero.

### Q : Can I use a DC SSR to switch AC?

**A :** No. The semiconductor device used in Opto 22’s DC SSRs is polarized. It may break down and conduct for the portion of the waveform that is reversed in polarity.

### Q : Can a DC SSR be used to switch an analog signal?

**A :** This is not recommended at all, for several reasons. First, the voltage drop across the relay will cause signal loss. Second, the conduction characteristics of the SSR are very non-linear at low operating voltages and currents. Use a mechanical relay; it will work much better.

### Q : What agency approvals do your SSRs carry?

**A :** In general, Opto 22 relays carry UL, CSA, and CE approval. See <http://www.opto22.com/support/agency.aspx>.

Additionally, some SSRs contain VDE-approved optocouplers; contact Opto 22 for more information.

## FAQ: SSR Troubleshooting

### Q : My SSR does not function anymore. What may have happened?

**A :** There is no “normal” mode of failure for SSRs. Most of the time, they just stop working, by refusing to turn on or off. Often, an improper installation is to blame for an SSR failure, as these are very simple, reliable devices. If you have a failed SSR, it is important to look at the normal operating parameters of that relay within the larger system to make sure that the relay being used is appropriate to the application, and that the relay is being properly installed in the system. The three most common causes of SSR failure are as follows:

**1) SSR improperly matched to load.** The relay was destroyed by overheating from carrying too much current too long.

**2) SSR insufficiently protected.** Remember, a semiconductor is less tough than a simple metal contact. Reverse voltages exceeding the PRV rating of the relay will cause damage. Voltage spikes on the switched line, perhaps from inductive kickback, destroyed one or more of the internal switching devices. Remember to use snubbers, transorbs, MOVs, and/or commutating diodes on highly inductive loads.

**3) SSR improperly installed.** The SSR was not mounted to a large enough heat sink, or no thermal compound was used, causing the relay to overheat. Also, insufficient tightening of the load terminals can cause arcing and ohmic heating of the relay. Opto 22 recommends 15 to 16 inch-pounds of torque on the load screw terminals. Similar failures have also been attributed to the use of crimp-on terminal lugs or spades; make sure such terminals are tightly crimped, and even drip some solder into the joint to ensure good electrical contact and protection from corrosion.

**FAQ: SSR Troubleshooting (cont.)****Q : How can I test my SSR?**

**A :** It is not possible to test an SSR by the same methods used to test mechanical relays; a typical SSR will always show an infinite impedance to a resistance meter placed across the output terminals. There are a few reasons for this. First, the SSR requires a small amount of power to operate, derived from whatever voltage source is placed on the load terminals. A typical multimeter will not supply sufficient voltage to cause the relay to change state. Second, AC SSRs contain a zero-crossing circuit, which will not allow them to change state unless zero voltage is applied. Most test equipment will supply a DC voltage to the relay, and the relay will thus never see the zero it requires to change state. To test an SSR, it is best to operate it at the actual line voltage it will be used at, driving a load such as a large light bulb.

**Q : I have an SSR driving a load. The load turns on okay, but never seems to turn off, unless I remove power from the relay entirely. What might be happening?**

**A :** This is normally a problem when using an SSR with a high-impedance load, such as a neon lamp or a small solenoid. Loads like these often have relatively large initial currents, but relatively small "hold in" currents. The result is that the off-state leakage current through the relay (see previous section) is insufficient to cause the load to turn on to start with, but sufficient to keep it on, once started. The solution to this is to place a power resistor, sized for 8–10 times the rated maximum leakage current for the SSR in parallel with the load. Make sure that this resistor has a high enough power rating for the application! For example, for a 5 mA leakage current at 120 VAC, a resistor drawing 50 mA would be desirable. Using Ohm's law, the resistor value becomes 2,400 Ohms. This resistor will dissipate 6 Watts, so a 7.5 or 10-Watt size power resistor should be used.

**Q : I have a new AC SSR driving a solenoid. It turns on okay once, but will not turn on again. What is going on?**

**A :** Some solenoids, some types of halogen lights, and some types of strobe lights incorporate a diode in series with the coil or filament. This causes the light to behave as a half-wave rectifier. Opto 22 SSRs have a built-in R-C snubber circuit in parallel with the output. The capacitor in this circuit charges up, but cannot discharge through the series diode, causing a voltage to appear across the SSR terminals. Because the SSR must see a zero voltage across the terminals to come on, it can't turn on again in this situation. The solution here would be to put a high-value resistor (several tens of Kohms) across the terminals of the relay, to allow the capacitor to drain its charge.

### Products

Opto 22 produces a broad array of reliable, flexible hardware and software products for industrial automation, remote monitoring, enterprise data acquisition, and machine-to-machine (M2M) applications.

### SNAP Ethernet Systems

Based on the Internet Protocol (IP), SNAP Ethernet systems offer flexibility in their network connectivity and in the software applications they work with. The physical network may be a wired Ethernet network, a cellular wireless network, or a modem. A wide variety of software applications can exchange data with SNAP Ethernet systems, including:

- Opto 22's own ioProject™ suite of control and HMI software
- Manufacturing resource planning (MRP), enterprise management, and other enterprise systems
- Human-machine interfaces (HMIs)
- Databases
- Email systems
- OPC client software
- Custom applications
- Modbus/TCP software and hardware.



SNAP Ethernet system hardware consists of controllers and I/O units. Controllers provide central control and data distribution. I/O units provide local connection to sensors and equipment.

### SNAP OEM Systems

Opto 22 SNAP OEM I/O systems are highly configurable, programmable processors intended for OEMs, IT professionals, and others who need to use custom software with Opto 22 SNAP I/O modules.

Linux® applications running on these systems can read and write to analog, simple digital, and serial I/O points on SNAP I/O modules using easily implemented file-based operations. Applications can be developed using several common development tools and environments, including C or C++, Java, and shell scripts.



### M2M Systems

Machine-to-machine (M2M) systems connect your business computer systems to the machines, devices, and environments you want to monitor, control, or collect data from. M2M systems often use wireless cellular communications to link remote facilities to central systems over the Internet, or to provide monitoring and control capability via a cellular phone.

Opto 22's Nvio™ systems include everything you need for M2M—interface and communications hardware, data service plan, and Web portal—in one easy-to-use package. Visit [nvio.opto22.com](http://nvio.opto22.com) for more information.

### Opto 22 Software

Opto 22's ioProject and FactoryFloor® software suites provide full-featured and cost-effective control, HMI, and OPC software to power your Opto 22 hardware. These software applications help you develop control automation solutions, build easy-to-use operator interfaces, and expand your manufacturing systems' connectivity.



### Quality

In delivering hardware and software solutions for worldwide device management and control, Opto 22 retains the highest commitment to quality. We do no statistical testing; each product is made in the U.S.A. and is tested twice before leaving our 160,000 square-foot manufacturing facility in Temecula, California. That's why we can guarantee solid-state relays and optically-isolated I/O modules *for life*.

### Product Support

Opto 22's Product Support Group offers comprehensive technical support for Opto 22 products. The staff of support engineers represents years of training and experience, and can assist with a variety of project implementation questions. Product support is available in English and Spanish from Monday through Friday, 7 a.m. to 5 p.m. PST.

### Opto 22 Web Sites

- [www.opto22.com](http://www.opto22.com)
- [nvio.opto22.com](http://nvio.opto22.com)
- [www.internetio.com](http://www.internetio.com) (live Internet I/O demo)

### Other Resources

- OptoInfo CDs
- Custom integration and development
- Hands-on customer training classes.



### About Opto 22

Opto 22 manufactures and develops hardware and software products for industrial automation, remote monitoring, enterprise data acquisition, and machine-to-machine (M2M) applications. Using standard, commercially available Internet, networking, and computer technologies, Opto 22's input/output and control systems allow customers to monitor, control, and acquire data from all of the mechanical, electrical, and electronic assets that are key to their business operations. Opto 22's products and services support automation end users, OEMs, and information technology and operations personnel.

Founded in 1974 and with over 85 million Opto 22-connected devices deployed worldwide, the company has an established reputation for quality and reliability.