Introduction to Solid State Relays

Selecting the Proper SSR

In selecting the SSR for an application, one must consider the input, the output, the load, and the method of installation. The load power will dictate if the SSR is PC board mountable, or if it requires mounting on a heat sink. Load currents greater than 5 to 7 Amps usually require a heat sink despite the current rating of the device. For example, whereas a 10 Amp SSR may have a free air rating of 6 Amps at 40°C, a 40 Amp device in the same package has only an 8 Amp free air rating, thus both would need a heat sink to improve performance.

After selecting an SSR for suitable physical dimensions and terminals, the next parameters of concern are isolation, input drive, output voltage, and output current. Isolation and input considerations are similar to that of Electro–Mechanical relays: output parameters require choosing an SSR with an appropriate nominal voltage rating and current rating in excess of maximum load conditions, and will be sufficient in most cases, but note that the output parameters may differ from those of EMR's.

An important consideration is that of transient voltage spikes. Since transient overvoltage of blocking ratings may vary by as much as 200 Volts, a transient suppressor for protection ***will be*** necessary and the range between the SSR peak operating and blocking voltages must be adequate for the proper function of the suppressor. Even then, an actual test should be performed to determine if the product will "tolerate" over–voltage transients by firing non–destructively for the duration of the half–cycle in which the transient occurred.

If the SSR is optimized for the 120 Volt line, then operation at 24 Volts RMS can be achieved ***if*** two parameters dealing with power loss are considered – on–state voltage drop and peak repetitive turn–on voltage. The former becomes a larger proportion of the applied voltage, subtracting approximately 1.2 Volts RMS from the load. The latter does not change in amplitude, but does change in phase angle – leading to delays before turn–on each half–cycle, with a power loss up to 20% at 24 Volts RMS – suggesting that an SSR optimized for 24 Volts RMS would be a better choice.

The zero voltage point (usually greater than the peak repetitive turn–on voltage) is not a factor in power loss at low voltage, since the SSR is not much of a "zero" switch, with turn–on occuring closer to the peak, not zero, value; but with less than 24 Volts, the peak may actually become lower than the "zero voltage turn–on" and turn–on would occur totally at random.

"Turn–on" voltages of the SSR cannot be measured correctly with an RMS reading meter, because in the AC voltage waveform a discontinuity occurs at the beginning (and sometimes the end) of the half–cycle due to the output thyristor current. With a signal applied, turn–on generally occurs at the earliest possible moment in the next half–cycle, close to the peak repetitive turn–on voltage. The latest point at which an initial signal can achieve turn–on is at the maximum zero voltage turn–on value. Thus the region between these two parameters is designated the permissible switching window.

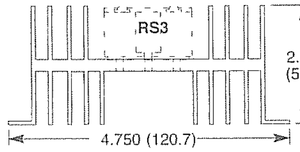
The conduction period, which represents most of the dissipation in the SSR, begins as an on–state DC voltage level followed by a slight sinusoidal AC component and is usually defined to assist in heat sink determination.

Specifications define the minimum and maximum steady–state load current values, and momentary surge current capabilities. Emphasis should be given to thermal and surge conditions in replacement.

Thermal Considerations

A proper heat sink is a most important feature and critical to the life of the SSR. Since "contact" dissipation occurs in excess of 1 Watt per Amp compared to Milliwatts per Amp for a like EMR; lack of attention to this detail can result in improper switching (lock–up) or even destruction of the SSR.

Usually a light duty aluminum extruded heatsink is used for this purpose. The NTE441A heat sink is the ideal choice and comes predrilled for a variety applications including the NTE RS3 series of SSR's. Confirmation of proper heat sink selection can be acheived by actual temperature measurement on the base plate of the SSR. A typical mounting is shown below.



The typical 1.2 Volt on–state drop across the output (at maximum current) is responsible for most of the dissipation in both AC and DC SSR's without regard to operating voltage.

At loads less than 5 Amps, free or forced air flowing around the package can be sufficient, but at higher currents the radiating surface of the SSR needs to be firmly mounted to a good heat–conducting heat sink with thermal bonding enhanced by a conductive compound. In this case the SSR's thermal resistance ($R_{\Theta CS}$) is reduced to a value of 0.1°C/W or less as shown in the data.

Other data supplied defines the internal thermal values such as maximum junction temperature (T_J Max), the thermal resistance junction to case ($R_{\Theta JC}$), the thermal resistance of the SSR case to ambient ($R_{\Theta CA}$) for free–air, and power dissipation versus maximum current.

Protective Measures

Noise Susceptibility

Noise susceptibility depends on circuit design, sensitivity of components, and stabilization techniques.

SSR's do not fail completely due to noise, unless they mistrigger at a point in the cycle where a high surge current might occur, or less remotely, where a repetitive mistriggering of one polarity causes an inductive load to saturate and draw excess currents destructive to both load and relay.

Should they occur, other malfunctions due to noise are usually temporary in nature, and tests should be made to determine levels of susceptibility in these areas – EMI and parasitic noise.

AC SSR's using thyristors in their drive and output circuits, can latch on for a whole half–cycle, if triggered by a brief high–voltage transient; and can also mistrigger if the rate of rise (dv/dt) exceeds certain limits as discussed in the following paragraphs. Transient suppressors and RC snubbers can act as preventive measures.

Rate Effect (dv/dt)

Rate effect is caused capacitive coupling between the anode and gate, which can result in self–induced turn–on when the dv/dt limits are exceeded.

The expression dv/dt, when applied as the "static" or "off–state" dv/dt, can be understood as the maximum allowable rate of rise of voltage across the output terminals that ***will not*** turn on the SSR (a typical value is 200V/µS).

The commutating dv/dt parameter refers to a TRIAC's withstand capability to a rate of rise of reapplied voltage immediately after conduction (typical 5 to 10V/µS). In inductive loads where the current lags voltage, the TRIAC turns off at zero current, but the voltage, advancing to the next half–cycle, instantly appears across the TRIAC. This rise must be limited below the stated value or retriggering occurs, locking on the TRIAC. When the output device is a TRIAC, a snubber is essential for inductive loads; for dual SCR's as the output, the snubber improves static dv/dt.

Snubbers

The internal RC network (snubber) used in AC SSRs is a major factor in transient voltage and dv/dt suppression. For transients, it slows down the rate of rise as seen by the output device and limits the amplitude to which it might rise. The latter's protection is limited however, since a prolonged transient will "staircase" up to the blocking voltage, and a suppressor with a specific clamp voltage is recommended; the snubber then acting to hold down the leading edge of the transient and preventing overshoot.

Snubbers do give rise to a substantial AC component on off–state leakage, proportionately related to frequency – but attempts to use an SSR designed for 60Hz would increase the leakage via:

$$\frac{\text{Frequency (new)} \times \text{Leakage (data)}}{\text{Frequency (old)}} = \text{Leakage (new)}$$

and one should not operate the device beyond the stated limits and expect it to work.

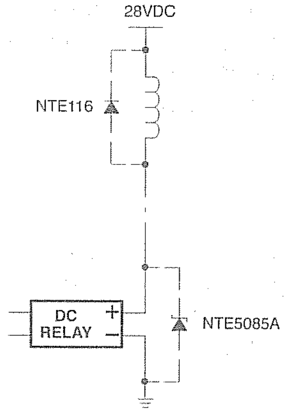
Snubber network capacitors are generally made as large as possible to enhance the dv/dt rating and transient absorption properties, and the resistors are chosen to limit the capacitor discharge current during the turn–on interval.

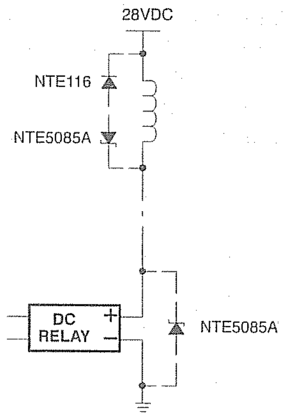
Parameters affecting use due to snubber values are the dv/dt (static) rating (typ 200V/µS) and the power factor rating (typ 0.5V/µS).

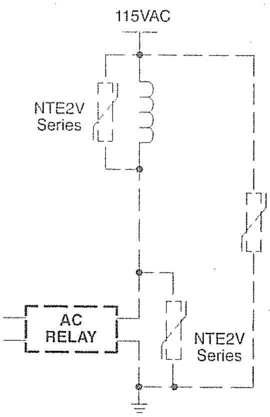
Suppressors

As stated earlier, snubbers are limited in handling overvoltage transients and a clamping device is required. Devices such as spark gaps can be used, although an easy approach is the use of zeners or MOVs.

The following diagrams illustrate typical methods of suppressing transients across the SSR output "contacts", as well as suppression of transients at the source, which can be the load itself for DC inductive type loads.







Suppressors (Cont'd)

For low powered DC SSRs (less than 3 Amps, 60 Volts), a 1 Watt Zener is sometimes built-in to provide protection. An external Zener, whose V_Z is greater than the operating, but less than the breakdown of the SSR, could also be used. For high-powered DC SSRs, Zener dissipation becomes impractical and "arc-suppressor" diodes are used instead.

MOVs *

MOVs (Metal Oxide Varistors) are voltage dependent, non-linear resistors with symmetrical conductive properties. Their response is very similiar to back-to-back zener diodes. Over a wide current range, the voltage remains within a very narrow range for a specific device, and can be referred to as the "varistor voltage" for that device. Their non-linear electrical characteristics makes the device useful in voltage regulation applications, and in particular for limiting surges and transient voltages that may appear on power lines. MOVs can provide protection for SSRs, especially in hostile environments. When used across the incoming line, they suppress external transients attempting to enter the system; across the load, they suppress load generated transients; and across the SSR itself to protect it from all transient sources.

When selecting the proper MOV it is essential to determine the proper voltage rating. First determine the maximum steady-state operating voltage of the circuit where the MOV will be connected. Care must be taken to use the upper tolerance limit of the voltage source. e.g., for a 220VAC line, a 10% high line condition should be assumed, resulting in 242 volts. Once the level is determined, refer to table data titled "Maximum Continuous Voltage" and select a MOV having the nearest greater value to this level. The voltage across a vasistor and the current through it are related by a power law $I=kV^{\propto}$. The exponent $^{\propto}$ will typically have values 25 to 50 or more.

A 30 Joule unit is sufficient for brief spikes across a load impedance in series with the MOV, which also acts as a current limiter. For MOVs directly across a power line, a larger (300 to 600 Joules) device is required to absorb high energy line transients since the current limiting impedance is represented by only the generating source and the wiring.

The MOV can also be used effectively across loads such as transformers and switching power supplies to absorb fast spikes that could be fed back into the primary (SSR load) wiring.

* See NTE1V and 2V series MOV's in our Semiconductor Technical Guide and Cross Reference catalog