



# Solid State Relays Overvoltage Protection

## INTRODUCTION

Since their inception, solid state relays (SSRs) have relied on overvoltage suppression devices such as metal oxide varistors (MOVs) to protect their outputs from voltage extremes such as overvoltage transients. Any voltage that exceeds the SSR's DC or peak AC load voltage, as specified in the absolute maximum ratings of the data sheet, could potentially damage the SSR. If overvoltage conditions are likely to occur (e.g., lightning or power-cross inductions from telephone lines, voltage spikes from turning off inductive loads like motors and transformers, or even surges from raw utility power), the outputs of the SSRs require an overvoltage suppression device. This application note explores the various types of protection devices and provides suggested recommendations on their selection and use with Vishay SSRs. Table 1 lists some suppression devices that are suitable for protecting Vishay SSRs.

## SUPPRESSION DEVICES

There are many types of overvoltage suppressors. Most of these suppressors can be categorized into one of the following four groups.

**Zener Diodes:** These devices clamp voltages at their reverse avalanche breakdown value. They can be used back-to-back for bidirectional clamping.

**Metal Oxide Varistors (MOVs):** The MOV is a voltage-dependent variable resistor. Its structure consists of metal oxide grains with boundaries between the grains acting as PN junctions. The MOVs behave in a similar manner to the back-to-back zener diodes.

**Gas Discharge Tubes:** The miniature microgap gas tube clips the voltage and then crowbars energy after its spark-over threshold is exceeded.

**Semiconductor Suppressors:** These devices are monolithic transient suppressors integrating SCR type thyristor and zener functions. These solid state suppressors clip voltage and then crowbar energy after their zener threshold voltage is achieved.

When choosing a suppression device, trade-offs between voltage overshoot, current handling capability, capacitance, leakage current, physical size, surface-mount capability, failure mode, and price need to be considered.

## ATTRIBUTES OF COMMON SUPPRESSION DEVICES

**Zener Diodes:** Low-voltage overshoot, small size, surface-mount versions available, short-circuit failure mode.

**MOVs:** Capable of handling large surge currents, surface-mount versions available, short-circuit failure mode, inexpensive.

**Gas Discharge Tubes:** Capable of handling large surge currents, low capacitance, low leakage current.

**Semiconductor Suppressors:** Low-voltage overshoot, capable of handling large surge currents, low capacitance, low leakage current, short-circuit failure mode.

## SUPPRESSION TECHNIQUES

There are various techniques available to protect an SSR and load from an overvoltage condition. Figure 1A shows an SSR wired in its DC configuration controlling an inductive load. To protect the relay from inductive fly back energy, a diode is placed across the load. When the relay turns the load off, fly back energy is shunted across the coil by the diode, thus eliminating extreme voltage potentials. However, this diode will not protect the relay from transients generated from other sources.

To fully protect the SSR, a zener diode placed across the contacts of the SSR is highly recommended. The zener diode will protect the SSR from any positive voltage transients when the SSR is off, while diodes, intrinsic to the MOSFET switch, will protect the SSR from any negative voltage transients. These transients should not exceed the SSR's peak load current value (approximately 400 mA per MOSFET). If larger currents are anticipated, use a discrete suppressor to provide an external shunt path. Figure 1B shows a similar application using an AC source with an SSR wired in its AC/DC configuration. Here MOVs are utilized for bidirectional protection. A third MOV (not shown) could be added, shunting both the load and the SSR.

This MOV would keep excessive AC source surge currents away from the load and SSR. This technique is commonly used in industrial and telecom applications. A variety of other techniques can be used where lightning surges are prevalent.

Figure 2 shows a basic data access arrangement (DAA) consisting of a telephone loop terminated into a transformer

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primary wet circuit, an SSR for on/off-hook control, and transient voltage suppression (TVS). Placing suppression devices across the SSR and the load is the safest approach to circuit protection. In this configuration, both suppressors need to be sized accordingly to handle surge currents.

An improvement of the circuit in figure 2 is shown in figure 3. Here the suppression device across the load is relocated and placed across both the load and the SSR. This suppressor will take the brunt of the surge current. The suppression device across the SSR has now reduced its role to solely protecting the SSR against inductive kicks from the load. Therefore, a suppression device with lower current handling capability can now be used. If the load is not inductive, the circuit can be further simplified by eliminating the protector across the relay as shown in figure 4.

Another protection scenario is portrayed in figure 5. If the load is capable of handling surge currents, then a suppression device placed directly across the SSR is adequate.

The most common protection technique is depicted in figure 6. A TVS placed directly across the telephone loop bounds the transient voltage to a value lower than the SSR's load voltage value. A second suppressor device, usually a zener diode residing in the DC termination loop holding circuit, free wheels on inductive fly back from this dry transformer DAA circuit.

### SUPPRESSION DEVICE SELECTION

The first selection criteria is whether to use a suppression device that clamps (zeners) an overvoltage or one that clips the overvoltage and then crowbars the energy.

A crowbar device is necessary when the desired operating voltage approaches the SSR's maximum load voltage rating. At threshold voltage, crowbar protectors pull the transient voltage low keeping the voltage overshoot to a minimum. In contrast, the voltage across an MOV will rise as the current flowing through it increases.

Another important difference between a clamp and a crowbar suppressor when placed directly across an SSR is impressed voltage.

**APPLICATION NOTE** A crowbar protector minimizes power dissipated in the SSR when a fault occurs by virtue of its a low impedance. If a crowbar protector is placed directly across the SSR's outputs, only a few volts will be across the SSR, thus keeping current flow through the SSR to a minimum. A clamp suppressor, on the other hand, allows its full clamp voltage across the SSR output. This could potentially damage an SSR if precautions are not taken. Vishay SSRs with current limiting minimize current flow through the SSR when they are exposed to a high clamp voltage. These SSRs allow the designer to use an inexpensive MOV clamp suppressor without concern of damaging the SSR.

The main electrical parameters to consider when selecting a suppression device are clamping voltage and current capacity. The clamping voltage or break overvoltage should never exceed the SSR breakdown voltage. To prevent this from happening, determine the worst-case clamping voltage at peak pulsed current. MOVs have the highest voltage clamping ratio. For these devices, a large differential exists between voltages experienced under normal circuit operation and peak transient voltage. Whatever suppressor is used, size the device appropriately to absorb the worst-case fault current.

Other electrical considerations include suppressor capacitance, leakage, effects on circuit performance, and, if using a semiconductor suppressor, holding current. A semiconductor suppressor is a gated SCR-thyristor structure. Turn-on current is supplied to the gate of the SCR by a zener diode structure. The zener diode sets the threshold voltage of the suppressor. Once triggered, the SCR conducts current until the source current drops below a certain value. This value is referred to as holding current. It is important to select a suppressor that exhibits a holding current value higher than the circuit's highest operating current. In selecting a holding current value, note that the holding current will decrease with increased temperature and load impedance. Proper holding current selection will prevent the suppressor from remaining on after the overvoltage condition has passed.

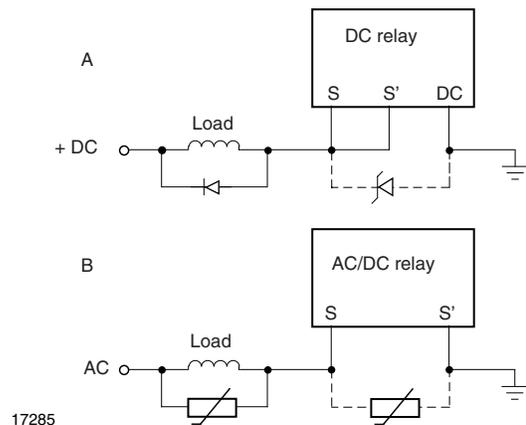


Fig. 1 - SSR Overtoltage Protection

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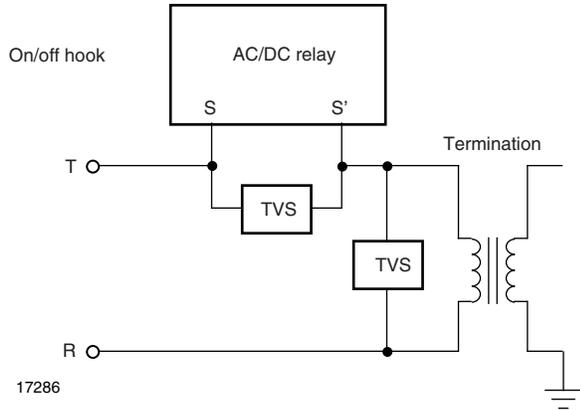


Fig. 2 - Basic DAA Protection

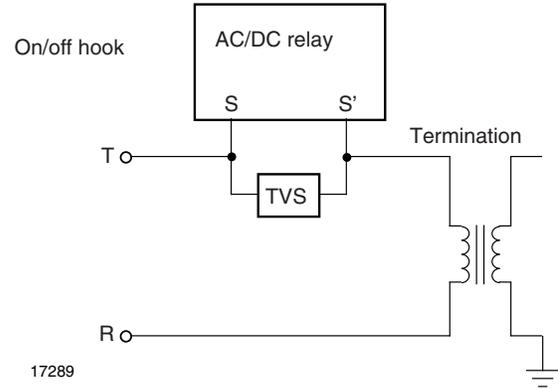


Fig. 5 - Basic DAA with Load Current Capable of Handling Surge Current

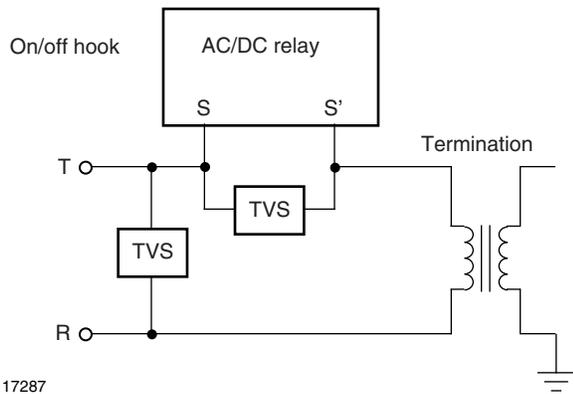


Fig. 3 - Basic DAA with Lower-Current TVS Across the SSR

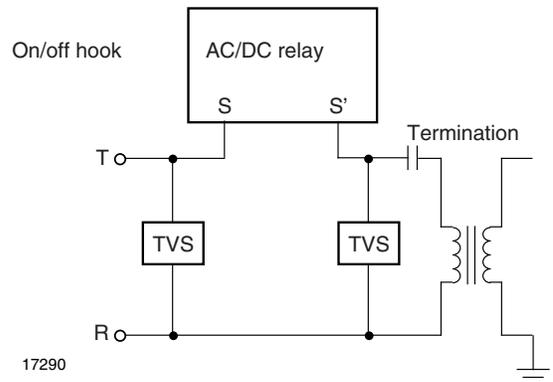


Fig. 6 - Typical DAA Protection

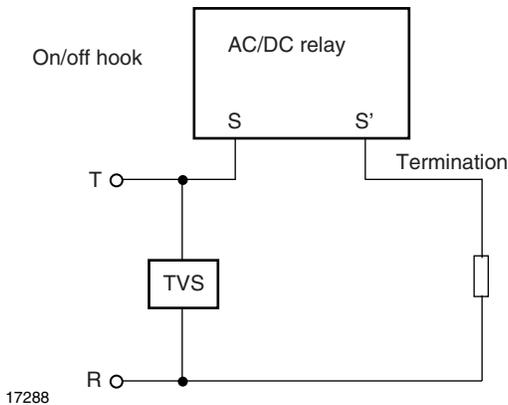


Fig. 4 - Basic DAA with Resistor Termination



## Solid State Relays Overtoltage Protection

OVERVOLTAGE PROTECTION DEVICE SELECTION GUIDE												
DEVICE TYPE	MANUFACTURER	SUPPRESSION METHOD	PACKAGE TYPE	CURRENT CAPABILITY	PART #	VISHAY SSR LOAD VOLTAGE (V)						
						150	200	250	280	350	400	440
MOV	EPCOS	Clamp	Disc Radial	2 J to 90 J, 2 ms	DC Op V	SxxK50 65	SxxK75 100	SxxK95 125	S14K115 150	SxxK130 170	SxxK150 200	SxxK175 225
			Surface Mount	4 J to 11 J, 2 ms		CU4032K50G 65	CU4032K75G 100	CU4032K95G 125	CU4032K95G 125	CU4032K130G 170	CU4032K150G 200	CU4032K150G 200
MOV	Harris	Clamp	Disc Radial	6 J to 80 J, 10 x 1000 s	DC Op V	V82ZA12 66	V120ZA1 102	V150ZA1 127	V150ZA1 127	V130LAXX 175	V150LAXX 200	V175LA10A 225
Trisil	SGS-Thompson	Crowbar	Axial	30 A, 20 ms	DC Op V	TPA100A 100	TPA150A 150	TPA200B 200	TPA220B 200	TPA270A 240	TPA270A 270	TPA270A 270
				50 A, 20 ms		TPB100A 100	TPB150A 150	TPB200B 200	TPB220B 220	TPB270A 270	TPB270A 270	
Gas Discharge	Mitsubishi	Crowbar	Radial	-	DC Op V	-	-	-	-	-	-	DSS-301L 250
Sidactor	TECCOR	Crowbar	TO-92/ TO-220	50 A, 10 x 1000 s	DC Op V	P1300EA70 120	P1500EA70 135	P2400AA61 220	P2500AA61 240	P3000AA61/ P3100EA70	P3300AA61 300	P3300AA61 300
Surgecitor	G.E.	Crowbar	TO-220	100 A, 10 x 1000 s	DC Op V	-	-	SGT23B13 230	SGT27B13 270	SGT27B13 270	SGT27B13 270	SGT27B13 270

Note: All suppressors are bidirectional