Solid State Relay Transient Immunity

White Paper

Introduction

The Solid State Relay (SSR) is a solid-state replacement of the electro-mechanical relay, and is commonly used for general purpose switching of signals and low power AC/DC loads. It consists of a light-emitting diode (LED), a photo-sensitive FET driver, and high-voltage MOSFETs. The relay turns on (contact closes) when the LED is on, and turns off (contact opens) when the LED is off. The SSR provides both switching and galvanic isolation functions.

The SSR is usually used in applications where there is a need to separate high voltage circuits from low voltage, or low power, circuits. By using an SSR, circuits can exchange signals, and, at the same time, are galvanically isolated. The SSR allows for a safe interface between the high voltage and low voltage circuits. It breaks the ground loop to eliminate cross talk and interference between the high voltage and low voltage circuits.

The SSR has been extensively used in telephone sets, modems, fax machines, PBX systems, or central office equipment. In telephone applications, it is always necessary to isolate the telephone equipment from the incoming telephone lines. It is also important to protect the electronic equipment from harmful voltages or current caused by lightning. The SSR with high input-output transient rejection specifications can provide good isolation and surge protection. This paper introduces two common phenomena of the transient voltage effect on the SSR, as well as the various methods of transient rejection measurements. In addition, an over-voltage protection device is recommended to further shield the SSR from hazardous surge voltage.

Common Mode Transient Effect

When a transient voltage with a high dv/dt exists across the input and output sides of the SSR as shown in Figure 1a, the SSR may turn-on or turn-off because the voltage couples into the LED, the drive circuit, or the gates of MOSFET. When the LED is on, the voltage across the output pins of the SSR is negligible as the voltage source is applied to the load. When a voltage transient exists across the ground between the input and the output sides of the SSR, an instantaneous voltage drop occurs in the load voltage as shown in Figure 1b. When the LED is off, the voltage across the load is negligible. Under the influence of the voltage transient across the SSR, an instantaneous voltage peak occurs in the load voltage as shown in Figure 1c. The isolation between the input side and output side of the SSR is defined by the input-output transient rejection specification, and is also commonly known as the Common Mode Rejection (CMR) specification.

a) Transient Voltage across the ground between the input side and the output side

b) The voltage across the load when the LED is on

c) The voltage across the load when the LED is off

Figure 1a, b, c. Common Mode Transient across the SSR and the Voltage Transient at the Load

Input-Output Transient Rejection Measurements

Figure 2 shows the input-output transient rejection test circuit performed on Avago Technologies' ASSR-322R. The test parameters are: V_{I-O}=1000V, I_O=200mA, T_A=25°C. The common mode transient pulse, V_{I-O}=1000V, is generated by a pulse generator, and is applied between the input and output grounds of the SSR. A 5V supply is applied to the output through a load. The test is performed with the anode of the input LED switching between position 'A' and 'B', and the cathode of the LED connected to the pulse generator. At position 'A', the anode and cathode of the LED are shorted to the pulse generator, and the SSR is turned off. If the perturbation voltage at the output, $V_{O(OFF)}$, is less than 4V due to the common mode transients, the device fails the transient rejection test. At position 'B', an input current, I_F=5mA, is applied to the anode of the LED, and turns on the SSR. If the perturbation voltage, $V_{O(ON)}$, supposedly at zero voltage, is greater than 0.8V due to the common mode transients, the device fails the test. The typical input-output transient rejection, dV_{I-O}/dt, of ASSR-322R is ≥ 10kV/µs.

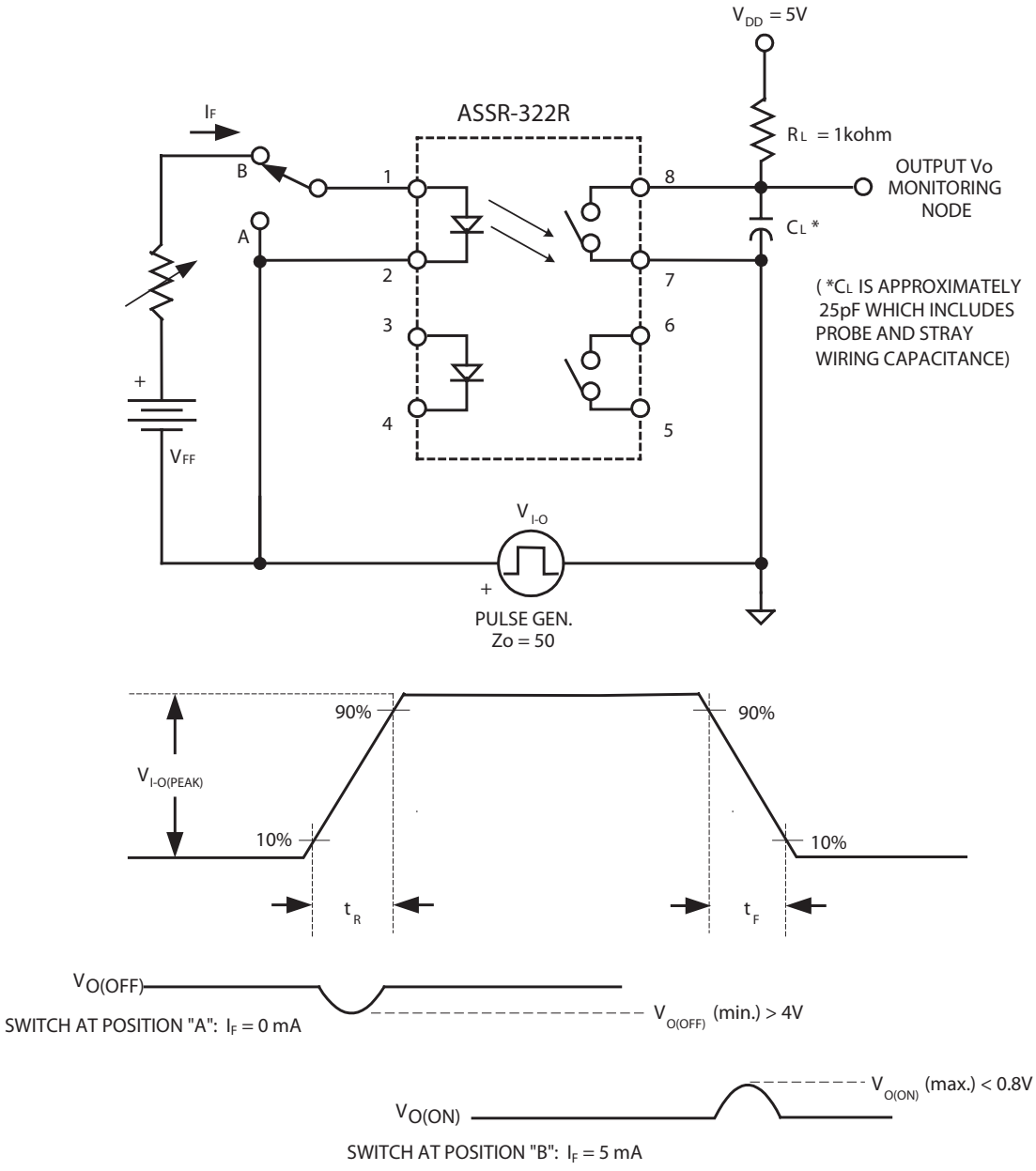

Figure 2. Input-Output Transient Rejection Test Circuit

dv/dt Turn-On Effect

The isolation between the two output pins of an SSR is specified by measuring the output transient rejection. High transient voltage in a power line or telephone network can exist, mainly due to lightning, causing an inductive load or disturbances in the power line system. The rapid rising or falling time of the load voltages can couple to the gates of the MOSFET through the parasitic capacitance, which causes the MOSFET to turn on even though the LED is off. This dv/dt turn-on effect often occurs with a highly inductive load even when the circuits attempt to turn it off.

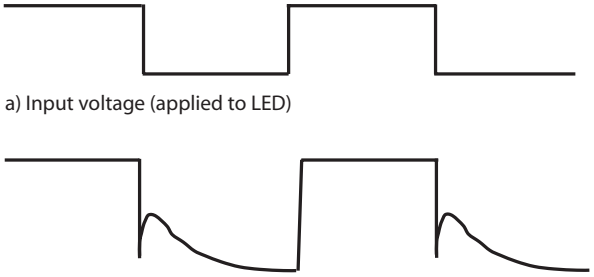

Figure 3. Turn On Effect in an SSR when it should be in the Off State

Figure 3 shows the turn-on effect in an SSR where a DC voltage is applied to the output side of the SSR, while control pulses are applied to the input side. After the LED turns off, the MOSFET does turn off, but turns on again. This effect is called the dv/dt turn-on effect. An SSR device with a high output transient immunity specification can withstand high dv/dt. In order to improve the output transient immunity, the voltage coupling can be reduced through the parasitic capacitors or an increase in the switching time of the SSR, which excludes the propagation delay.

Output Transient Rejection Measurement

The output transient rejection measurement schematics are shown in Figure 4. When the LED is off, a high voltage pulse generated by a pulse generator is applied to the output side of the SSR. A capacitor with a high withstand voltage is connected in parallel, and its voltage is monitored by an oscilloscope. For example, the output transient rejection of ASSR-322R, with $C_{(OFF)}$ capacitance of about 45pf, is tested under the following conditions: V_O = 250V, T_A = 25°C, C_M = 1000pf, R_M > 1MΩ. If the voltage level, V_M, across the capacitor, measured at the

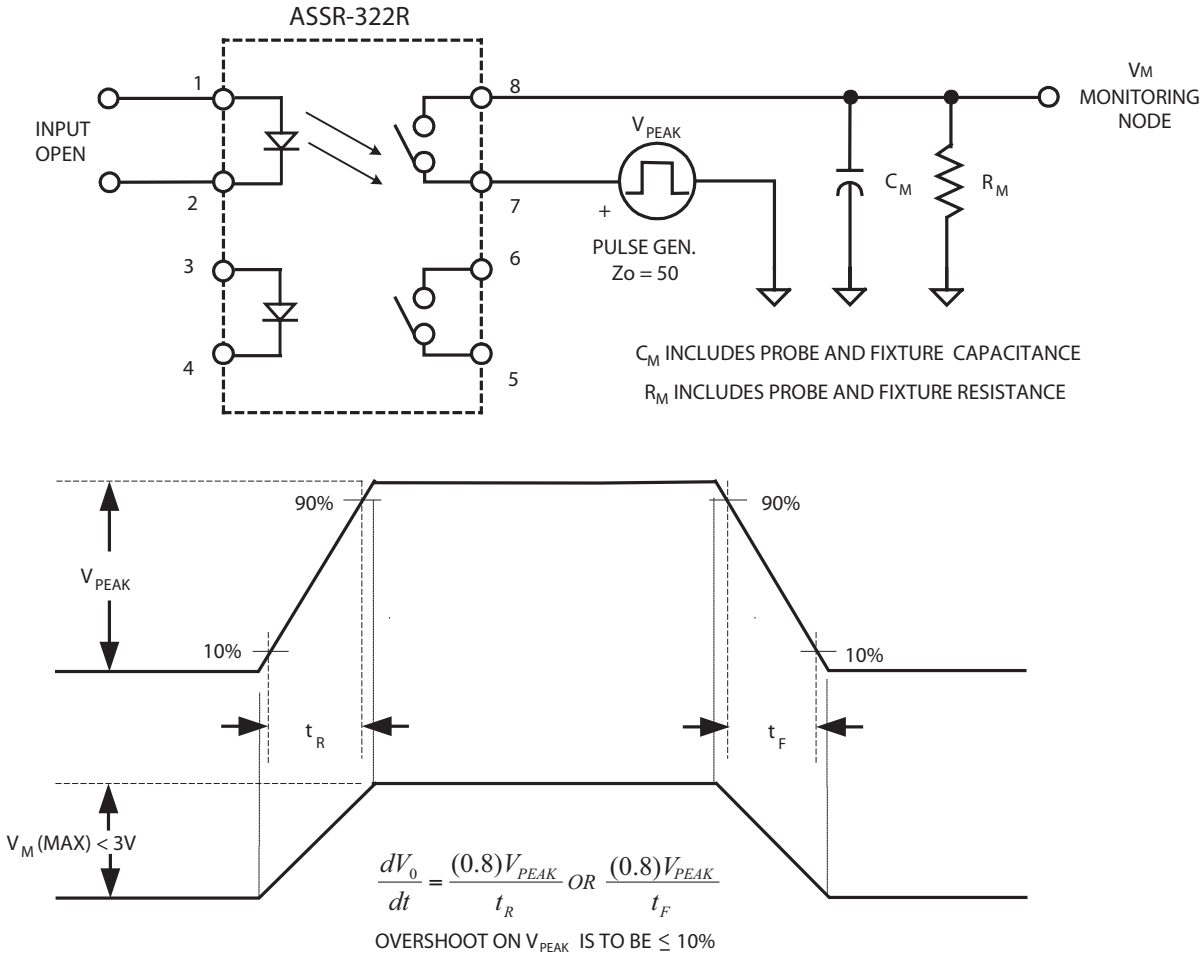

Figure 4. Output Transient Rejection Test Circuit

center of the pulse, is greater than 3V, the device being tested fails the output transient test. It indicates that the MOSFETs of the SSR have turned on and the C_M has been charged. An SSR must have a high output transient immunity to keep the SSR operating properly. The output transient rejection specification, dV_O/dt, of the ASSR-322R is typically 7kV/µs. It is sufficiently high for an SSR with an output withstand voltage of 250V.

To reject the output transient effectively, Avago Technologies' ASSR products are designed with a high-speed photo-sensitive driver and output transient protection circuitry.

Over Voltage Protection

When the SSR drives inductive loads, very high peak voltages can occur across the output side when it is turned off. Lightning can also cause a very high voltage surge in the telephone network. Over-voltage protection is always recommended whenever such a hazardous event is possible. External components such as the metal oxide varistor (MOV) or TransZorbs® can be used for the overvoltage protection of the output contacts of the SSRs. These protection devices break down and conduct heavily when the voltage across them rises above a specific level. These devices fail short so protection is always in place. Figure 5 shows how the protection device is connected externally to the output contacts of the SSR. A properly selected protection device ensures that the transient voltage across the SSR is never higher than the SSR output withstand voltage rating, and the protection device is in a fully conductive state when the SSR is operating within the output voltage rating.

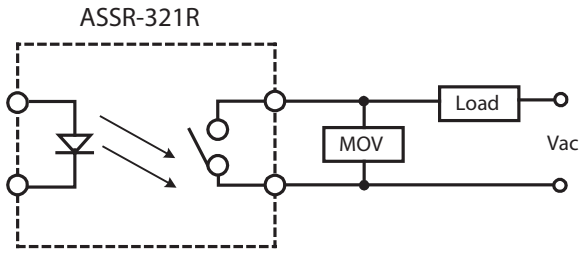

Figure 5. Connection of the Overvoltage Protection Device to the SSR

When the load is capacitive, current surge may occur. To avoid the damage caused by the current surge, the resistance of the load should be larger than V_{RMS}/I_{MAX}, where the V_{RMS} is the RMS voltage on the load and the I_{MAX} is the allowable maximum output current.

Conclusion

The output transient rejection, dV_O/dt, and input-output transient rejection, dV_{I-O}/dt, are critical specifications to be considered in the selection of an SSR. High transient rejection ensures minimal perturbation of the output signal and the safe operation of the SSR. Unlike many other SSR manufacturers, Avago Technologies' has attained competitively high transient rejection with the ASSR Series without compromising speed performance.

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AV02-2390EN - March 20, 2010