Design Considerations on Solid-State Relays in DC Configuration

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INTRODUCTION

A solid-state relay (SSR) is an electronic switching device in semiconductor technology. An SSR has a high efficient GaAlAs infrared emitter on the input which is optically coupled to the high performance MOSFETs at the output.

An SSR is capable of switching AC loads where both output MOSFETs are required as well as DC loads where one MOSFET, or two in parallel, can be used.

AC/DC AND DC-ONLY CONFIGURATION

In AC/DC configuration as shown in Fig. 1 a load is connected across pins 4 and 6. This configuration makes both AC and DC switching possible.

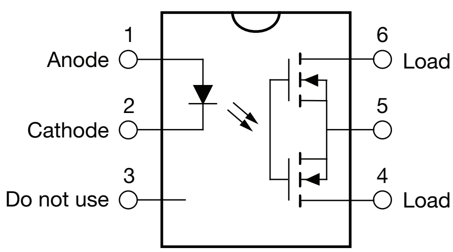

Fig. 1 - AC/DC Configuration

In the DC only configuration MOSFETs can be arranged back to back to lower the on-resistance (R_{ON}) and increase the current handling capabilities. However, in this configuration the switch will operate only in one direction. For switching different loads, like ohmic, capacitive or inductive loads some design considerations should be done.

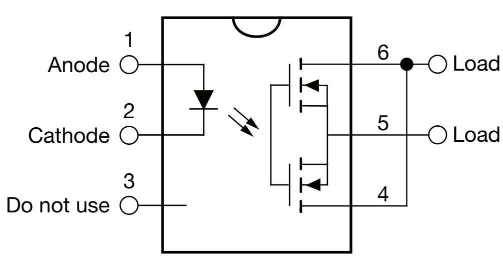

Fig. 2 - DC Only Configuration

In the DC only configuration MOSFETs can be arranged back-to-back to lower the on-resistance (R_{ON}) and increase the current handling capabilities. However, in this configuration the SSR will operate only in one direction. For switching different loads, like resistive, capacitive, or inductive loads, there are some design considerations.

RESISTIVE LOADS

When a resistive load (heating application) is switched with an SSR, there is only a load current on the output. This is defined by the supply voltage (V_{CC}), the minimum load resistor ($R_{Lmin.}$) and minimum on-resistance ($R_{ONmin.}$). The maximum load current (I_L) of the SSR is specified in the datasheet and should be not exceeded. The minimum load resistance value can be calculated with equation 1 below.

$$R_{Lmin.} = \left(\frac{V_{CC}}{I_L}\right) - R_{ONmin.} \qquad (1)$$

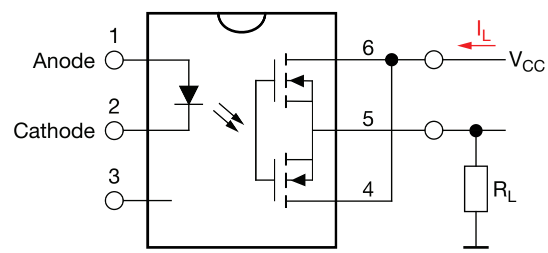

Fig. 3 - SSR With a Resistive Load

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CAPACITIVE LOADS

When a capacitive load is switched with an SSR, the high inrush current starts to flow through the SSR during the charging phase. This current may be higher than the maximum allowed load current and may exceed the current level that could trigger the internal current limitation circuit.

To limit the high inrush current an additional resistor (R_{LIMIT}) should be added in series to the SSR and the capacitive load.

The resistance value can be calculated with the maximum allowed load current (I_L), equivalent series resistance of the capacitor (ESR_{DC}), minimum on-resistance ($R_{ONmin.}$), which is specified in the datasheet and the connected supply voltage (V_{CC}) to the load or SSR with the equation 2 below.

$$R_{LIMIT} = \left(\frac{V_{CC}}{I_L}\right) - R_{ONmin.} - ESR_{DC} \qquad (2)$$

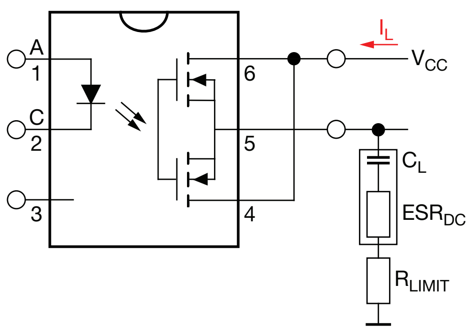
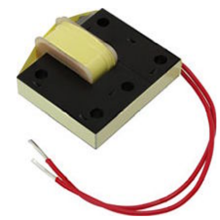


Fig. 4 - SSR With a Capacitive Load

INDUCTIVE LOADS



When an inductive load is switched with an SSR, the current starts to flow through the inductive load during the charging phase, until it reaches the maximum value. The maximum value is dependent on the DC resistance (DCR) of the load and the connected supply voltage (V_{CC}) to the load or SSR. In case of very low DC resistance and the possibility to exceed the maximum load current (I_L), an additional resistor (R_{LIMIT}) should be added in series to the SSR and the inductive load. The value of R_{LIMIT} can be calculated with the following equation 3.

$$R_{LIMIT} = \left(\frac{V_{CC}}{I_L}\right) - R_{ONmin.} - DCR \qquad (3)$$

A freewheel diode (D_1) should be placed parallel do the inductive load to protect the SSR against the induced voltage during the switching off phase.

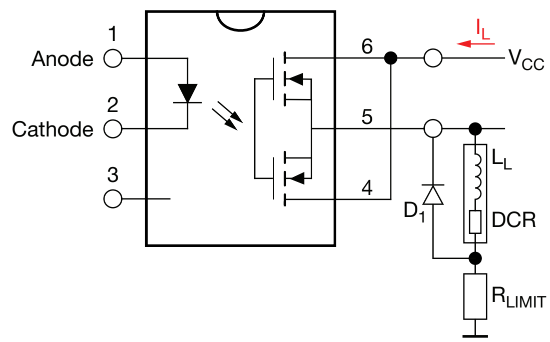


Fig. 5 - SSR With an Inductive Load