Solid-State Relays

INTRODUCTION

Vishay offers a full line of miniature MOSFET solid-state relays (SSRs) for use in telecommunication, industrial control, security, and instrumentation applications.

MOSFET SSRs feature an optocoupler construction, but have a pair of MOSFETs on the output instead of a phototransistor. A pair of source-coupled MOSFETs emulate an electromechanical relay by providing bidirectional switch capability and a linear contact. No output power supply is required.

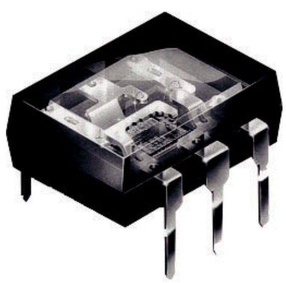

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Fig. 1 - SSR Internal View

The advantages of the MOSFET contacts are solid-state reliability and long life as well as very low thermal switch offset, extremely high off-resistance, and lack of contact bounce. Thermal switch offset is actually a misnomer for SSRs. Any contact offset voltage is photo induced. This photo-induced voltage is extremely low and typically runs about 0.1 µV. These attributes make SSRs a significant contender in applications historically served by reed relays.

In some designs, however, the user must consider the contact on-resistance and capacitance. Because MOSFET on-resistance is dominated by the bulk resistivity in the n-drift region and there is no bipolar junction, no diode offset exists in the MOSFET SSR I-V characteristics and the on-resistance is extremely linear. The contact capacitance of a MOSFET SSR is higher than an open contact of an electromechanical relay.

The majority of Vishay SSRs have LED inputs and monolithic switch outputs (figure 1). The switch is built using BiCMOS technology. Individual components are fabricated in dielectrically isolated tubs. A fully integrated die has many advantages. Higher reliability is achieved due to a reduction in the number of wire bonds. Finer control over circuit operating parameters is realized for higher-performance circuits like current limiting.

These miniature SSRs are offered in 6 pin packages, DIP or surface mount, with single pole, normally open (1 form A) or normally closed (1 form B) contacts. They also come in 8 pin DIP or surface-mount packages with two normally open (dual or 2 form A) or normally closed (dual form B) contacts. Some SSRs are also available in a low-profile, small-outline package (SOP).

FUNCTIONAL DESCRIPTION

The infrared light emitted by a gallium-aluminum-arsenide (GaAIAs) LED within the relay, controls the switch output. The LED is placed over the output-control switch, directing light downward onto a stack of photodiodes.

Both input and output silicon are fully encapsulated in a translucent inner-mold compound that passes light while providing a reliable, sustaining dielectric barrier in the thousands of volts. A dark outer mold compound, with a matched thermal expansion coefficient to the inner-mold compound, is then called an over under double molded design.

In a basic schematic for an optically coupled MOSFET SSR, the photodiode array acts as a floating power source for the MOSFET switches (figure 2). Each diode is fabricated in its own dielectrically isolated tub. Current-transfer ratios are small, and dielectric isolation provides optimum light reception with no leakage to the substrate. Each diode acts as a 0.6 V battery when illuminated by the LED. With 20 to 30 diodes, ample voltage is generated to turn on the MOSFET pair, even at high operating temperatures where LED and photodiode output drop.

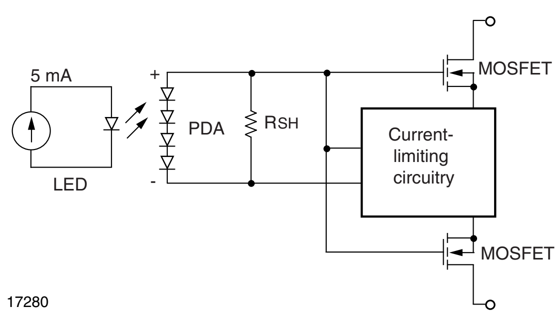

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Fig. 2 - SSR Functional Diagram

To turn-on the relay, current is applied to the LED. The LED emits light, illuminating the inner mold and the photodiode array. The amount of light emitted is dependent upon the

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amount of forward current applied. For high-temperature or high load current operation, more LED current is required. The photodiode voltage biases the normally open, enhancement-mode MOSFET gates positive with respect to their sources. For a normally closed depletion-mode MOSFET, the photodiode array would be wired to bias the gates negative with respect to their sources.

Figure 2 portrays a current-limiting circuit. This circuit is a unique feature on many of Vishay form A SSRs. When current through the MOSFETs becomes greater than the SSRs‘ rated value, the integrated current-limit circuit is activated. This circuit increases the impedance of the MOSFET switches thereby regulating the amount of current flowing through the SSR. When LED current is removed, the gate-to-source shunt resistance (R_{SH}) turns the MOSFET switches off by providing a discharge path for the gate charge. Vishay SSRs use either a JFET or MOS circuit for the gate-to-source shunt resistance in order to achieve fast turn-off. This control circuitry ensures a smooth “click free” turn-on and a slower turn-on than turn-off. This feature can sometimes be used to achieve break-before-make operation when using multiple relays.

OUTPUT OPERATION

Figure 3 shows the bidirectional or AC/DC I-V characteristics of a current-limited SSR. Figure 4 shows the bidirectional I-V characteristics of an SSR without current limiting. In operation, the SSR is exceptionally linear up to the knee current (I_K). This linearity provides a distortion-free contact, making it ideal for small-signal applications such as V.34 modems. Beyond I_K, the incremental resistance decreases, by approximately 35 %, thereby minimizing internal power dissipation.

For SSRs with current limiting, overload currents are clamped at I_{LMT} by internal circuitry. The current-limiting circuitry exhibits a negative temperature coefficient, thereby reducing the current-limit value when relay temperature is increased. An extended clamp condition, which increases relay temperature, decreases the current-limit value, resulting in a current-fold back characteristic. When the overload current is removed, the relay immediately resumes its normal I-V characteristics.

Most 6 pin SSRs can be used in a unidirectional or DC mode. In this mode, on-resistance is reduced by 75 % and load currents are doubled. For unidirectional applications, pins 4 and 6 become the positive output of the relay and pin 5 becomes the negative output of the relay. Only the LH1510 provides current limiting in this configuration.

Figure 5 shows the unidirectional I-V characteristics of the LH1510 SSR. Figure 6 shows the unidirectional characteristics of the SSRs without DC current limiting. Here the SSRs are exceptionally linear up to and beyond their rated load current.

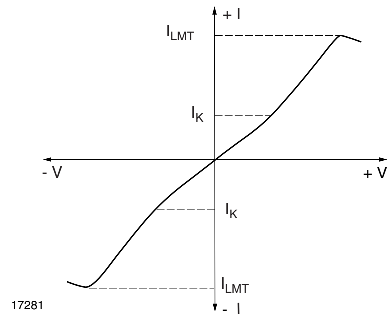

Fig. 3 - Typical AC/DC On-Characteristics of a Current Limited SSR-LH1540

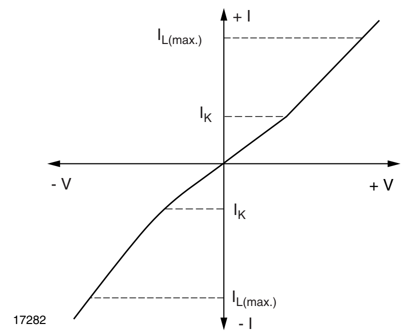

Fig. 4 - Typical AC/DC On-Characteristics of a SSR without Current Limiting

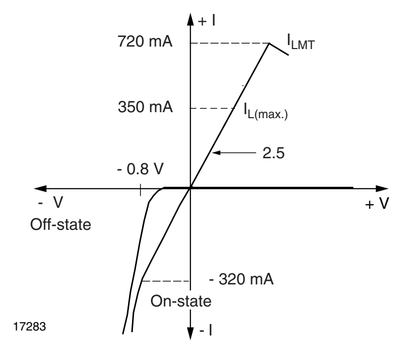

Fig. 5 - Typical DC Characteristics of the LH1510, Pins 4 and 6 Shorted

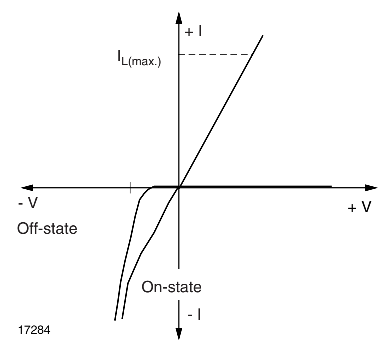

Fig. 6 - Typical DC Characteristics of an SSR without DC Current Limiting, Pins 4 and 6 Shorted-LH1540