Application Note

Current Limiting

Introduction

The purpose of current limiting is to prevent any transient current spikes or fault conditions from damaging the relay and any circuit components "downstream" from the relay. Current limiting technology has been designed into a variety of Solid State Optronics (SSO) relay products. This application note is designed to provide insight into the technology of current limiting and how it can be utilized for certain applications.

Description

Current Limiting Technology

A MOSFET with a driver component and current limiting circuitry is shown below in Figure 01. The figure does not represent the actual design, but is rather intended to reveal the technology incorporated into a modified driver component.

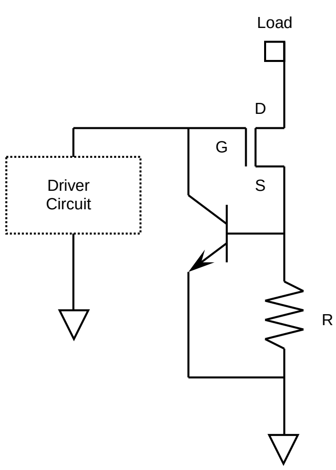

Figure 01: *Current Limiting Diagram*

The two devices which comprise the current limiting circuitry are a resistor and a bipolar transistor. These two devices work together to limit the current and set the value at which the current will be limited.

While the relay is in the "on" state, current is flowing through the MOSFET as well as the resistor (R). As current flows through the resistor, there is a corresponding forward voltage drop (V_{BE}) across the transistor. When the voltage drop across the bipolar transistor reaches a typical value of 0.6 volts, it begins to turn on. When the npn conducts, V_{CE} = 0.1-0.2V and VGS ≈ -0.4V causing the MOSFET to turn off. As the MOSFET shuts off, the load current flowing though it decreases. A push and pull effect then begins whereby the decreased load current through the resistor causes V_{BE} to drop below the transistor's forward voltage value, shutting the transistor off and allowing the MOSFET to turn back on. This push and pull effect creates a limiting effect on the load current, not allowing it to rise above a specified value.

The load value at which current limiting begins is determined by the resistor value and the forward voltage of the transistor. For example, let us say that normal currents for a typical application are between 100mA and 150mA, and we would like the current limiting feature to allow a maximum current of 250mA. The resistor value can be found by using Ohm's Law, setting V_{BE} = 0.6V:

$$V = I * R$$
$$R = (0.6V) / (0.250A)$$
$$R = 2.4\Omega$$

Thus, a 2.4Ω resistor will cause the transistor to turn on when a load of 250mA is reached, and current limiting will begin.

There are other parameters which affect the level of current limiting. These include variations in the resistor value, variations in the transistor forward voltage, and changes in temperature. For instance, if we assume that the resistor has a tolerance of 10% and the transistor's forward voltage is between 0.55-0.65 volts, then the actual load level at which current limiting begins may fluctuate by 20-30mA. Changes in ambient temperature conditions may magnify these fluctuations as well. So, in the previous example where 250mA was the specified value for current limiting action, load levels of 230mA to 270mA could actually initiate the limiting action. The design engineer must take these fluctuations into account.

Operation

During normal operation, there is a typical voltage drop across the output of 3 volts. During a fault condition this voltage drop begins to rise. When the current limiting feature is triggered, the resistance value across the output drastically increases causing an immediate rise in the corresponding voltage drop, in some cases driving the value up to several hundred volts. Figure 02 on the following page shows acceptable voltage drop values across the output during the On State before power dissipation becomes too high.

The bipolar transistor used in the current limiting circuitry has an inherent negative temperature coefficient for V_{BE} of approximately –2.2mV/°C. Thus, V_{BE} for the transistor can drop from 0.6 volts to almost 0.35 volts at junction temperatures of close to 100°C. As temperature is increasing, the bipolar transistor helps limit current through the package to lower and lower values, thereby offsetting the increasing voltage and maintaining a constant power dissipation level.

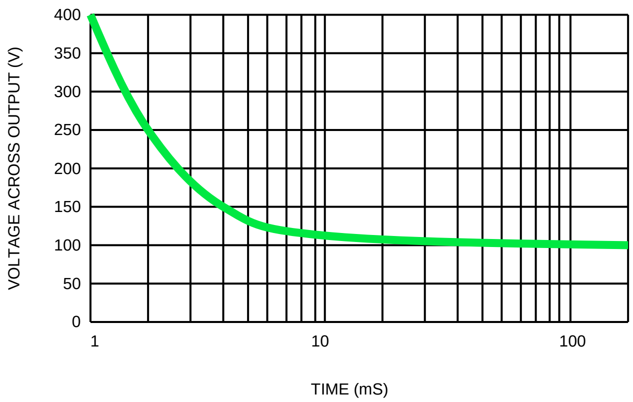

Figure 02: *On State Voltage Drop*

Extended current limiting operation basically translates into a reliability experiment for the relay. While in current limiting mode, the package is exceeding its maximum continuous power dissipation and die temperature is increasing quite dramatically (~100°C/W). For short bursts of high current or extended lengths of minimal current increase, the limiting features will protect downstream circuitry without damaging the relay, so reliability is not a huge concern. When only a small percentage of the relay population undergoes lengthy fault conditions, statistical reliability does not present an issue. SSO relays have demonstrated excellent reliability during testing where devices are repetitively pushed into current limiting.

Application

The FCC requires that devices connecting with the phone lines must meet certain Off-Hook (or "On State") voltage transient spikes. While in the Off-Hook state, a typical phone line access system has an equivalent line impedance of approximately 100Ω. The voltage transient can be up to 1000 volts which creates possible load currents of up to 10 Amps!! Although the duration of the pulse is quite short (~10µS), the fault could quite possibly damage any inadequately protected equipment.

With a current limiting relay from SSO serving as the hook switch mechanism, damage to the access system can be prevented during the transient. To further increase functionality, a voltage-limiting protection device can be placed across the SSR's output as shown in Figure 03:

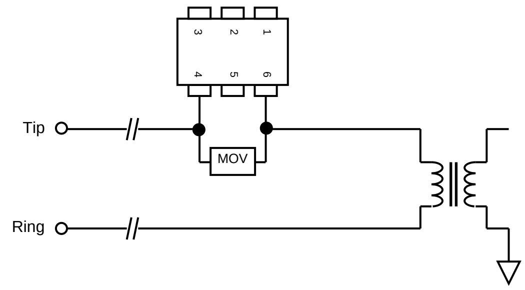

Figure 03: *Voltage Protection Circuit*

In this case, a MOV (Metal Oxide Varistor) is shown. By placing a voltage suppressing device across the output, a second source for power dissipation is established. During a transient, the current through the relay drastically increases. The current limiting action pulls the gate towards ground, immediately raising the resistance and voltage across the output. The MOV will trigger when the voltage reaches a certain value, and help dissipate the heat that would normally affect the relay.

Conclusion

SSO devices with current limiting can help protect not only the relay itself in surge / spike conditions; they can also help protect downstream components.

Visit www.ssousa.com or contact your local sales agent to learn more.