Application Brief

Implementing an Isolated Switch for Relay Weld Detection

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Introduction

Relay welding may occur when a mechanical relay experiences high inrush current and voltage, leading to arcing that can cause the relay contacts to melt and stick to one another. It is crucial to effectively detect relay welding to maintain the safety and reliability of any system. Welding is a common issue in AC and DC applications in many sectors using high voltage, including electric vehicle (EV).

The EV sector implements high voltage contactors to both charge and power the vehicle, so the arcing experienced by the circuits can cause the mechanical relays to weld. Contrary to mechanical relays, a Solid-State Relay's (SSR) lack of moving parts makes it a good option for diagnosing weld detection. This application brief discusses the implementation of SSRs to detect said welding using an EV BMS as an example. Details on weld detection in EV chargers can be found in *L1 and L2 EV Charger Electric Vehicle Service Equipment Design Considerations* .

Weld Detection Schematic

In an EV's architecture, isolated switches can be used along with voltage dividers to detect welded and stuck open relays. Figure 1 shows an MCU level implementation schematic of the TPSI2140-Q1, an automotive isolated switch, that can control high voltage loads via low voltage signals from an MCU whilst providing isolation between the two.

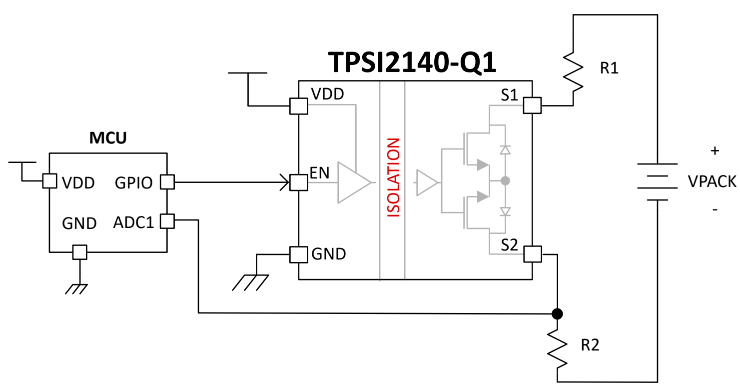

Figure 1. TPSI2140-Q1 Isolation Example

In order to detect welding in general, voltage must be measured after the mechanical relay. This way, the physical integrity of the relay can be determined based on the voltage value being measured. The switches can then be opened or closed in different combinations via the MCU to measure the voltage at the nodes on the ends of the mechanical relays and determine whether or not there is a relay weld or open in the circuit.

Figure 2 shows the implementation of the TPSI2140-Q1 to diagnose weld-shut and stuck-open relays in the main contactors of an EV. After the switches are closed, a voltage difference between HV+ and HV- will be created briefly in order to be able to measure the voltage. These voltages can then be compared to the expected values for when the mechanical relays are functional and faults can be detected. If the measurements taken at the nodes determine that there is welding or an open detected, the MCU may intervene to protect the system.

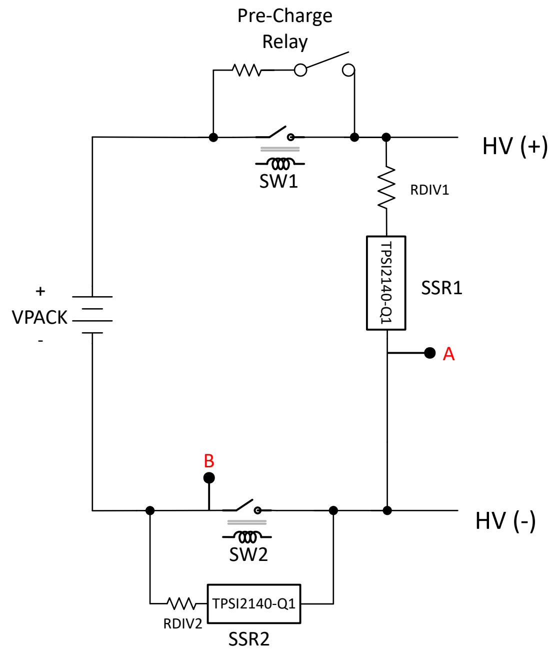

Figure 2. Schematic for Relay Weld Detection

The isolated switches are to be closed in unique combinations in order to create different loops which measure different nodes with node B as reference ground. The truth tables regarding the diagnosis of relay functionality can be seen in Table 1, along with voltage divider formulas for each diagnosis.

Table 1. Diagnosis Table When Relays are Functional

Diagnosis	SW1	SW2	SSR1	SSR2	Expected Voltage Value
SW1 Checking Weld	-	-	Closed	Closed	$V_A = 0V \times \frac{R_{DIV2}}{R_{DIV2} + R_{DIV1}}$
SW1 Checking Open	Closed	-	Closed	Closed	$V_A = V_{PACK} \times \frac{R_{DIV2}}{R_{DIV2} + R_{DIV1}}$
SW2 Checking Weld	Closed	-	Closed	Closed	$V_A = V_{PACK} \times \frac{R_{DIV2}}{R_{DIV2} + R_{DIV1}}$
SW2 Checking Open	Closed	Closed	Closed	Closed	$V_A = 0V \times \frac{R_{DIV2}}{R_{DIV2} + R_{DIV1}}$

Design Notes

1. Select a resistor value for RDIV1 that is significantly larger than RDIV2 so a voltage divider is created where the measured voltage values are easily distinguishable.
2. Select resistor values so the calculated voltage divider values are in the ADC full-scale range.
3. Use node B as the reference ground when measuring voltages because other nodes may be in floating states.

Application Example

1. Select values for RDIV1 and RDIV2. The values can be selected using the Voltage Formulas in the table above, work backwards to calculate desired resistor values.
2. For this application example regarding the main contactors in an EV, it is assumed that an 800V battery and a 3.3V MCU since these values are common practice in industry. The resistor values selected are as follows:
   a. RDIV1 = 1MΩ
   b. RDIV2 = 2kΩ
3. When the physical integrity of a relay is compromised, the voltage values of the nodes will be different than the normal operating conditions. The measurements will be compared to expected values with respect to the scenario we are testing for (weld or open). If there is a weld or open detected, the MCU intervene to protect the system.

Table 2 shows some example outcomes when a relay's physical integrity is compromised, the arrows show how a weld or open effects the state of a mechanical relay:

Table 2. Diagnosis Table when Relay Physical Integrity is Compromised

Diagnosis	SW1	SW2	SSR1	SSR2	Expected Voltage Value	Voltage Value When Physical Integrity Compromised
SW1 Weld Detected	Open ➜ Closed	-	Closed	Closed	$V_A = 0V$	$V_A = 1.6V$
SW1 Open Detected	Closed ➜ Open	-	Closed	Closed	$V_A = 1.6V$	$V_A = 0V$
SW2 Weld Detected	Closed	Open ➜ Closed	Closed	Closed	$V_A = 1.6V$	$V_A = 0V$
SW2 Open Detected	Closed	Closed ➜ Open	Closed	Closed	$V_A = 0V$	$V_A = 1.6V$

Conclusion

As covered in this application brief, the implementation of SSRs to measure and compare voltages is an effective solution to detect welding. Welding is a common issue in both high voltage AC and DC applications and it is crucial to effectively detect relay welding to maintain the safety and reliability of any system. The TPSI2140-Q1 is used in this application brief because our isolated switches have high switching cycles, quick switching speeds, and high reliability. For more information on isolation and SSRs, see the *How to Achieve Higher-reliability isolation and a Smaller Solution Size with Solid-state Relays Technical Article* .

Trademarks

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