MM9105-DC Rev. E

DC: 60V, 10A, SPST Power Relay Prototype

POWERED BY ideal switch®

Product Overview

Description

The Menlo Microsystems MM9105-DC (Rev E) SPST, normally open Power Relay utilizes Menlo's Ideal Switch™ devices to enable hot switching of DC loads of up to 60 VDC @ 10A. The MM9105-DC allows customers to evaluate Menlo's Ideal Switch technology for power electronics applications. It is intended for evaluation and prototyping purposes and is not qualified for high volume production.

The MM9105-DC utilizes a MOSFET device in parallel with a Menlo Ideal Switch to ensure zero-volt conditions across the Ideal Switch during switch transitions (opening or closing). The parallel MOSFET conducts only during switch transitions so that applications benefit from the exceptionally low on resistance, off-state capacitance and leakage, and the high reliability of Ideal Switch technology. Galvanic isolation is assured by isolation transformers for both the control and the power supply sections.

Features

- Built-in programmable overcurrent protection
- Contact Rating - 60 VDC @ 10 Amp
- Very low Ron 10 mΩ
- High Reliability > $1.0\text{x}10^9$ Cycles
- Compact 88 mm X 60 mm X 21.4 mm
- 1 KV control-to-line side isolation

Applications

- Automotive Control
- DC Motor Control
- Fuel Cell Systems
- Smart Electric Meters
- PV Inverter – Solar
- Factory Automation
- EV Chargers

Description

The block diagram of the MM9105-DC power relay is depicted in Figure 1. The MM9105-DC is a 5-terminal relay with 3 terminals (5 V, Ground and Switch Control) on the control side, and 2 terminals on the line side (J1+ Positive — Line Side Load/Power, and J1- Negative — Line Side Ground).

The relay consists of a Menlo Ideal Switch in parallel with a MOSFET based voltage limiting circuits that prevent hot-switching damage to the Ideal Switch during on/off transitions. The MOSFET is on very briefly during switch transitions to achieve near-zero voltage switching of the Ideal Switch.

Transformer based isolation circuitry provides isolation of power and switch-state control from the line side.

Internal control of the MOSFET is achieved with a micro controller that monitors the Ideal Switch carry current (monitors not shown in diagrams) and protects it from excessive current conditions.

A Snubber circuit prevents voltage spikes when switching inductive loads.

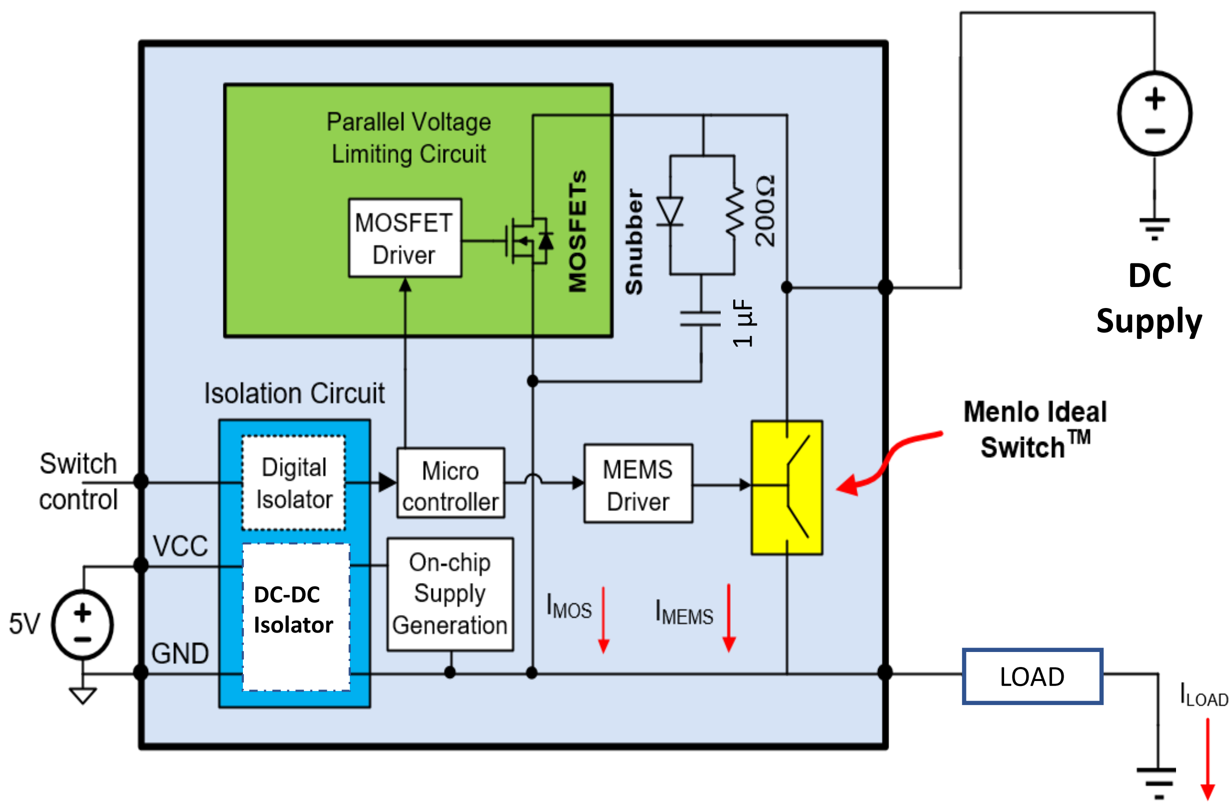

Figure 1. Block Diagram of DC Relay, MM9105-DC

Operating Characteristics

Absolute Maximum Ratings

Exceeding the maximum ratings as listed in Table 1 may reduce the reliability of the device or cause permanent damage. Operation of the MM9105-DC should be restricted to the limits indicated in the recommended operating conditions listed in Table 2.

Electrostatic Discharge (ESD) Safeguards

The MM9105-DC is a Class 0 ESD device. The Ideal Switch load terminals are connected directly to the screw terminals of the relay and are thus subject to ESD-related damage. ESD mitigation procedures must be used when handling and setting up the Power Relay.

Table 1. Absolute Maximum Ratings[1]

Parameter	Minimum	Maximum	Unit
Open State Voltage[2]		60	V
Transient Voltage		300	V
DC Current Rating (RMS, @25 ºC)		10	A
Operating Temperature Range	-40	+85	ºC
Storage Temperature Range	-65	+150	ºC

Notes:

1. All parameters must be within recommended operating conditions.
2. This also applies to ESD events. This is a Class 0 device.

Table 2. Recommended Operating Conditions

Parameter	Minimum	Typical	Maximum	Unit
Operating Temperature Range	-40		85	˚C
VCC Power Supply	4.5	5	6	V
Full Cycle Frequency			50	Hz

Table 3. Line-Side Operating Specifications

Line-Side Specifications	Minimum	Typical	Maximum	Unit
Contact Ratings (R load)			10/60	A/V DC
On-board Snubber Capacitance		2		uF
Snubber Resistance		200		Ω
Overcurrent Protection (default setting)		12		A
On-State Resistance (R_{ON})		10		mΩ
Off-State Leakage Current		75		uA
On/Off Switching Time				
Instantaneous mode **On Time**		1.50		msec
Instantaneous mode **Off Time**		1.02		msec
Control to Line Side Isolation (1 minute)		1000		V
MM9105-DC Endurance[1]				
No load		1B		Cycles
10 Amps – Instantaneous switching		> 1M[2]		Cycles

Notes:
1. Endurance testing in process. Initial results provided here.
2. No noticeable degradation in operating characteristics (Based on 50Hz, 50% Output Duty Cycle).

Table 4. Control-Side Operating Specifications

Parameter	Minimum	Typical	Maximum	Unit
Control Input Thresholds				
V_{IH}	0.7 x V_{cc}			V
V_{IL}			0.3 x V_{cc}	V
Control Input Current (0 V ≤ V_{IN} ≤ V_{CC})	0		2	mA
V_{CC} Supply Current				
Switch Off		150		mA
Switch On		160		mA

Operation

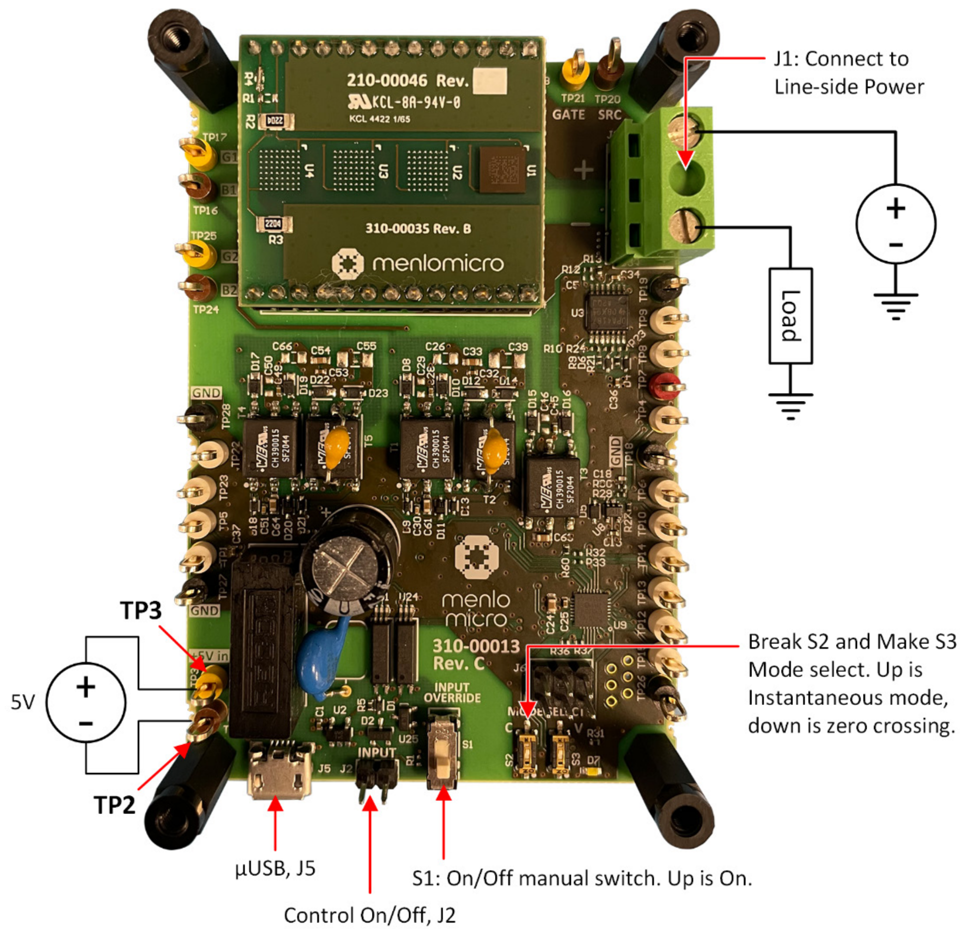

Figure 2. Photo of Relay Board (Top Side) with Typical Use Schematic

Operational Notes

The following operational notes refer to the relay board photo shown in Figure 2 above.

Relay State Control

Manual mode: Use slider switch S1 with up position for relay Closed (On), and down position for relay Open (Off). **When using Manual mode to control the relay state, do not apply a control signal to J2 pin 1.**

Electrical mode: Apply a 0V signal to J2 pin 1 for relay Closed (On) and a 5V signal for relay Open (Off). **When using Electrical mode to control the relay state, S1 must be in the up position.**

Power Supply

Relay control circuitry is powered with a 5 V power supply connected to TP3. Alternatively, the relay may be powered with a standard micro USB connector at J5. Use either TP3 to apply +5V power or power from USB, do not connect both at the same time.

Make Mode

When S3 is switched Off (up), instantaneous voltage Make mode is selected. For MM9105-DC boards, the selection must be instantaneous mode for normal operation, see Table 5.

Break Mode

When S2 is switched Off (up), instantaneous current Break mode is selected. Break mode is selected. For MM9105-DC boards, the selection must be instantaneous mode for normal operation (see Table 5). Switch positions are described with the relay board oriented as shown in Figure 2 on page 5.

Table 5. MM9105-DC Switch Descriptions

Switch	Control	Position	Action
S1	Relay state	Up	Relay Closed
		Down	Relay Open
S3	Relay **Make** Mode	Up	Instantaneous Make
		Down	**Do not use in MM9105-DC**
S2	Relay **Break** Mode	Up	Instantaneous Break
		Down	**Do not use in MM9105-DC**

Overcurrent Protection

The microcontroller is programmed to protect the Ideal Switch devices and has an overcurrent protection mode that performs a controlled shutdown of the device at 120% of rated current. This value and the overcurrent protection sequence are programmable and can be changed by reprogramming the microcontroller.

Operating the Unit

1. Before connecting and applying power to the control or line side of the relay, make sure:
   a. Switch S1 is in the down position so that the relay will be open when the control-side power is applied.
   b. The relay is configured for the desired mode of operation as described in step 2.
2. When using the DC relay **MM9105-DC**, make sure that microswitches S2 and S3 are positioned up, selecting instantaneous mode as shown in Table 5 on page 6.
3. Before applying power to either the control side or the line side of the relay, make sure all control and line-side connections have been made.
4. Connect the ground terminal of a DC power supply capable of at least 200 mA to TP2. Connect pin 1 the positive terminal of the power supply to TP3.

   Alternatively, the control side of the relay may be powered through the micro USB connector at J5 shown near the bottom left corner of Figure 2 on page 5. **Do not apply both sources of power simultaneously, use one or the other exclusively.**
5. Connect the J1 + terminal to the line-side power as shown in Figure 2.
6. Connect the J1 - terminal to the load as shown in Figure 2.
7. Turn on the control side DC +5V power supply. The LED should turn on and the current from the supply should read about 150 mA.

Note: A lab bench supply with 200 mA current limit may trip falsely due to initial inrush current; therefore, it may be necessary to increase the current limit somewhat higher to avoid false trip.

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8. Turn on the line-side supply.
9. The relay is ready for operation and will be in the open state (provided S1 is in the down Off position). The state of the relay may be controlled manually with switch S1 or electrically with a 5 V signal on J2 as described in Table 5.
   a. Manual: Switch S1 controls relay state with relay open when in down position and relay closed when in up position (board oriented as in Figure 2. **Do not connect control signal to J2 when controlling the relay manually.**
   b. Electrical: Apply a 5 V control signal to J2 pin 1 with pin 2 ground. When controlling the switch state electrically, switch S1 must be in the up position.

Turn-off Procedures

1. Open the relay:
   a. If operating the relay state manually, slide switch S1 to the down position (board oriented as in Figure 2).
   b. If operating the relay state electrically, drive signal on connector J2-1 high (5 V).
2. Turn the line-side power supply off.
3. Turn the control-side power supply off.

LED Behavior

Table 6. LED Behavior

LED Status	Description
LED Flashing at 1Hz	Relay is Open with or without Line Power.
LED ON	Relay is Closed with or without Line Power.
LED Flashing at 4Hz	Over-Current Protection is invoked.
LED OFF	Unit is not operational.

Test Points and Measurements

The PCB includes numerous test points with silk screen designations TP #. The more commonly used test points include additional naming such as GND or GATE. Refer to the electrical schematic to identify the test point and its corresponding net.

Note: Exercise care when performing measurements on test points using lab equipment because the electrical design consists of multiple levels of isolation which must not be electrically shorted.

Referring to the schematic, INP_GND (associated with the 5V control side) is isolated from GND (associated with the relay control circuits and load-side J1 – terminal). In addition, the MOSFET GATE/SRC and both Ideal Switch banks G1/B1 and G2/B2 are isolated from each other and GND. Single-ended measurements performed using a multi-channel oscilloscope risk electrical shorts from the shared channel ground.

When connecting to GND for reference, single ended measurements should normally be made only to test points referenced to the GND domain. Differential probes are required to observe isolated nets including MOSFET SRC/GATE and Ideal Switch G1/B1 and G2/B2.

When performing lab measurements on the DC board, the load-side DC supply must be isolated from the power grid to avoid risk of electrical shock and damage to lab equipment.

Table 7 lists commonly used test points.

Table 7. Commonly Used Test Points

TP	Name	Type or Ref	Description
21,20[1]	GATE/SRC	Differential	MOSFET gate to source voltage
17,16[1]	G1/B1	Differential	Ideal Switch bank 1 Gate to Body
25,24[1]	G2/B2	Differential	Ideal Switch bank 2 Gate to Body
1	ON/OFF INPUT	GND	Manual control (S1): relay ON (high) or OFF (low) Electrical control (J2): relay ON (low) or OFF (high)
none	J1 + Terminal	GND	Voltage across relay, noting that GND is J1 – terminal
4	OCP	GND	Analog overcurrent protection signal
5	5V PWR GOOD	GND	Control-side 5V input OK active low

Notes:

1. Refrain from connecting probes to these test points when subjecting the device under cycling conditions.

MM9105-DC Test Results

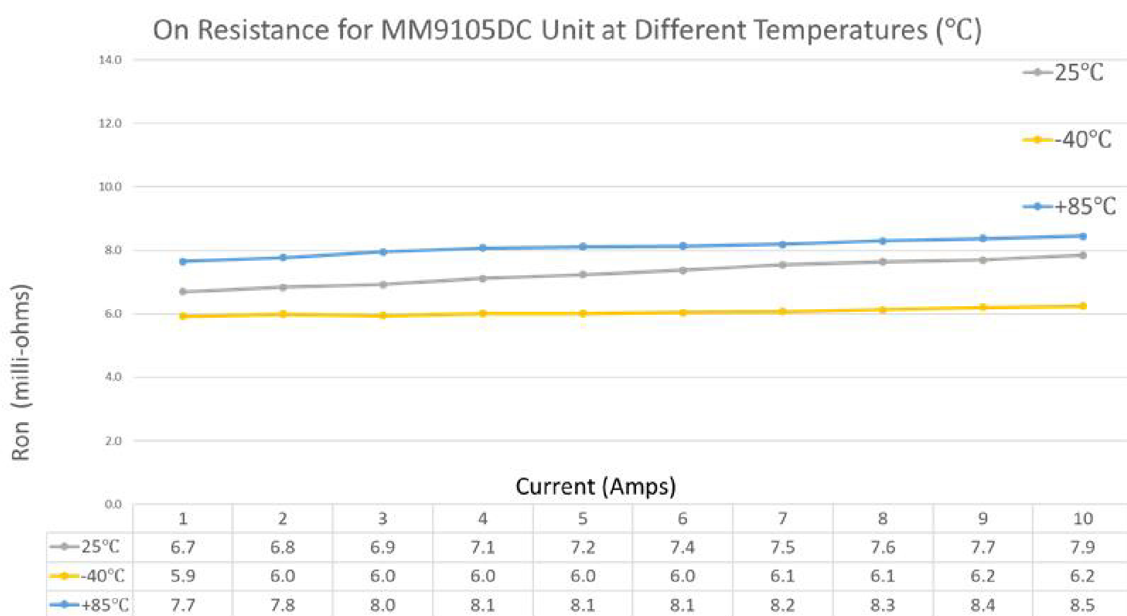
Test results were performed on the 9105-DC under two conditions:

- Steady state operation
- Make and Break operation captured by an oscilloscope for both instantaneous and zero-cross switching

Steady State Measurements of On Resistance and Thermal Characteristics

Steps 1 through 9 stated in Operating the Unit on page 7 were followed using low-value, high-power load resistors with an adjustable, line-side DC power supply capable of putting out more than 10 Amps. The following measurements were made as the line-side supply was increased incrementally to achieve 1-to-10 Amps of load current:

- Load testing and Ron measurement across daughter card terminals J1 and J2
- Load current vs. case temperature
- FLIR camera thermal imaging of a relay at each load current value



	1	2	3	4	5	6	7	8	9	10
25°C	6.7	6.8	6.9	7.1	7.2	7.4	7.5	7.6	7.7	7.9
-40°C	5.9	6.0	6.0	6.0	6.0	6.0	6.1	6.1	6.2	6.2
+85°C	7.7	7.8	8.0	8.1	8.1	8.1	8.2	8.3	8.4	8.5

Figure 3. MM9105-DC On-resistance vs Current

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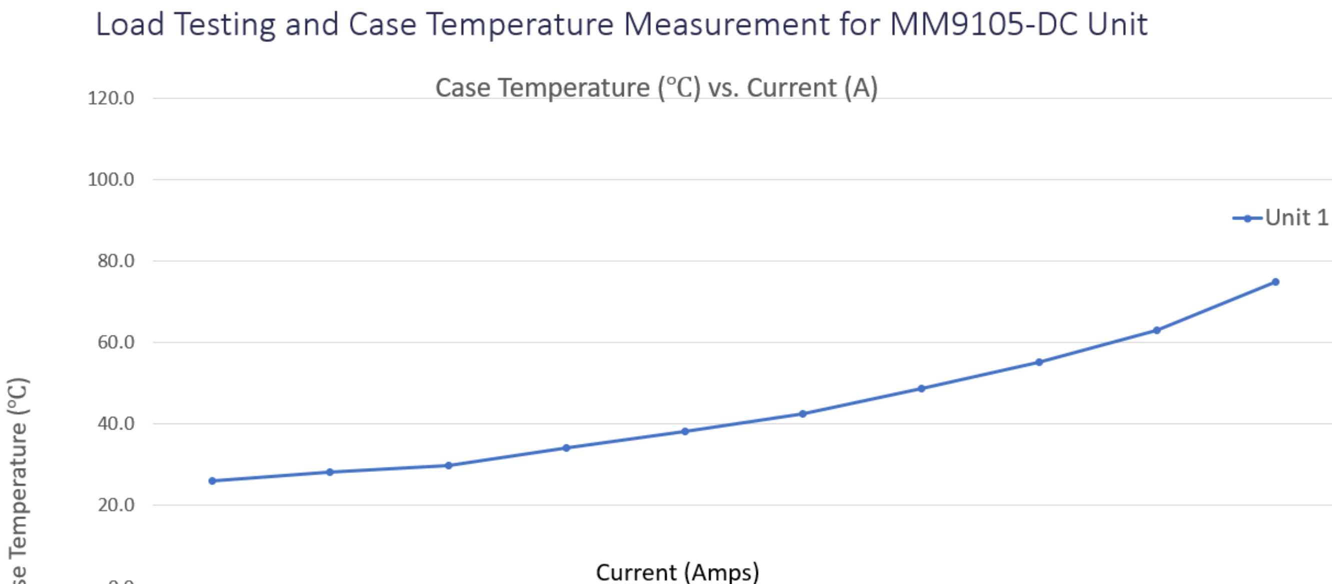


	1	2	3	4	5	6	7	8	9	10
Unit 1	26.0	28.3	29.7	34.2	38.2	42.6	48.6	55.1	63.1	74.8

Figure 4. MM9105-DC Case Temperature vs Current

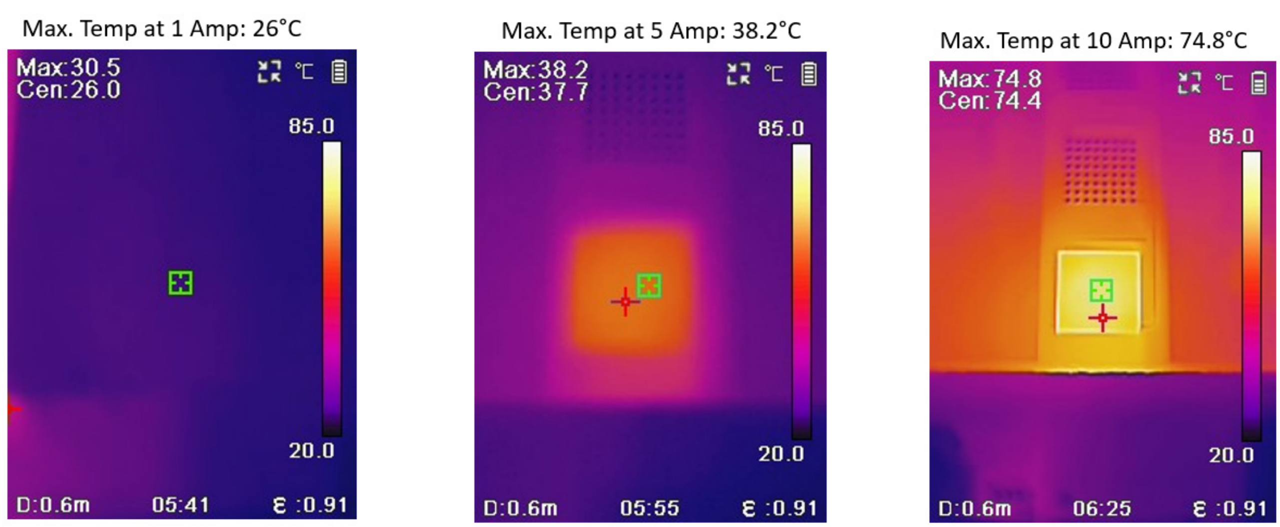
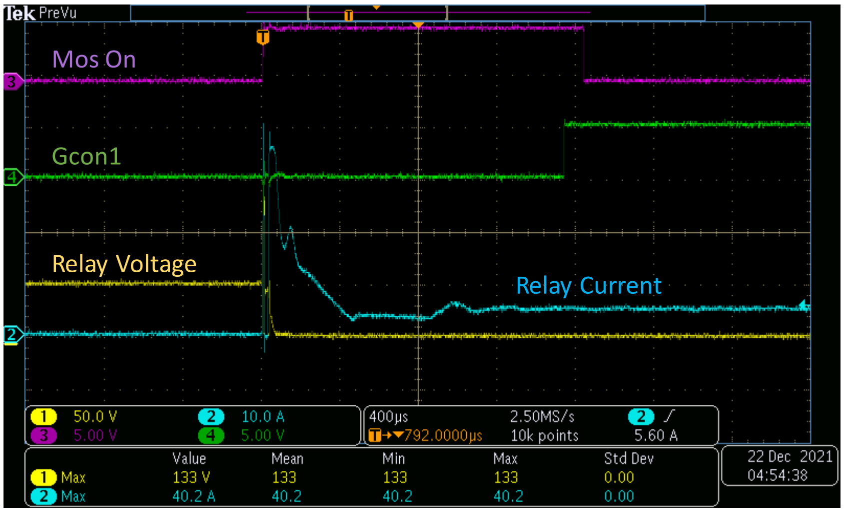


Figure 5. FLIR Camera Thermal Images of MM9105-DC Relay at Varying Currents

DC In-Rush Current Test Results

DC Relay Inrush Current Test with 5A Continuous Current Operation



Load defined as: 10 Ohm resistive Load with 60 µF Capacitor

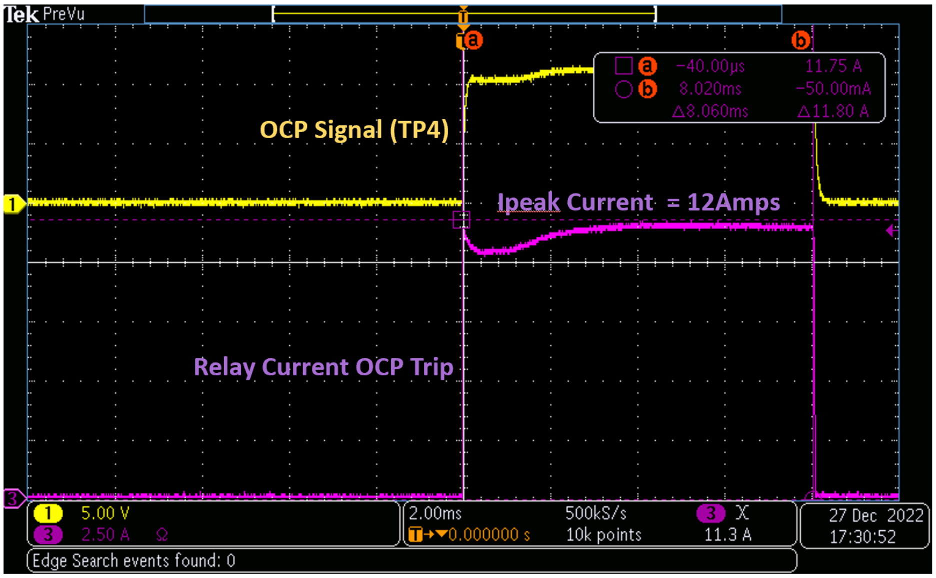
With 40 Amp Peak Inrush Current

Mos On – MOSFET Gate Drive Signal
Gcon1 – Ideal Switch Gate Drive signal

Figure 6. In-Rush Current Test of an MM9105-DC Relay– 10Ω/60uF Resistive/Capacitive Load

DC Overcurrent Protection (OCP) Test Results

MM9105-DC Relay: Over Current Protection



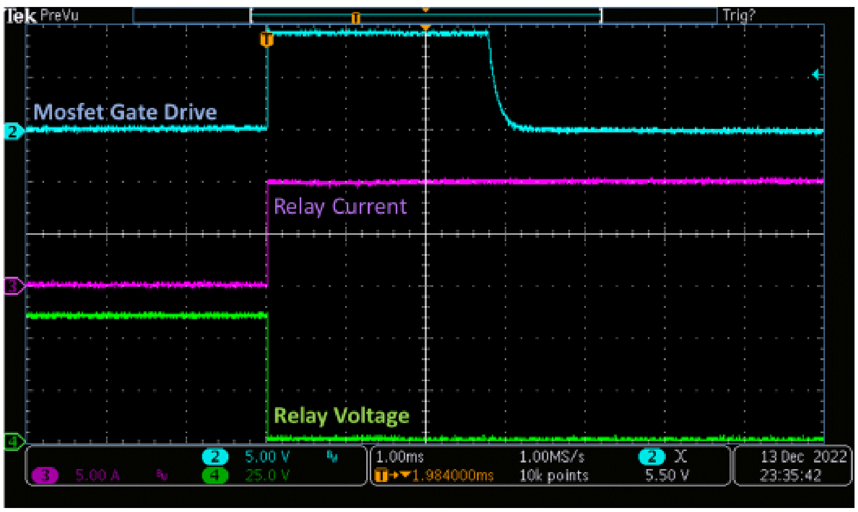
- DC Power Relay has been set for an OCP of 12A.

Figure 7. MM9105-DC OCP Test Results

Operation of MM9105-DC

Using a 6 Ω load resistor and a DC power supply set to 60 V, an oscilloscope was used to capture operation of an MM9105-DC relay switching 10 A. Figure 8 and Figure 9 show the voltage and current during relay make and break transitions respectively. The signal on the hot-switch protection MOSFET Gate is also shown in each figure.

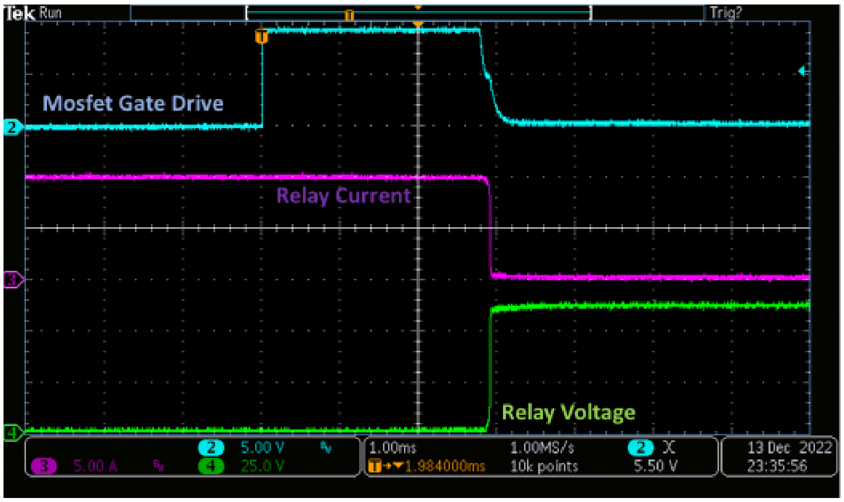
Turn On Time for MM9105-DC, Make Operation (Instantaneous Mode)



- Load set @: 60V, 10A Continuous

Figure 8. MM9105-DC Ideal Switch Relay Make Transition with 60 V and 10 A

Turn Off Time for MM9105-DC, Break Operation (Instantaneous Mode)



- Load set @: 60V, 10A Continuous

Figure 9. MM9105-DC Ideal Switch Relay Break Transition with 60 V and 10 A

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