PMP9498 Report
10/01/2015

I. Overview

The PMP9498 Reference Design is a complete automotive input protection solution which features zero-Iq reverse polarity protection, load switch capability, over-voltage protection, and over-current protection. The design utilizes the LM74610 Zero-Iq Smart Diode controller paired with the LM9061 High-Side Protection Controller. Both devices drive external N-channel MOSFETs and are available in automotive grade AEC-Q100 Grade 1.

II. Power Specification

INPUT Voltage: 12 V nominal, 7.7 V – 30 V operating voltage

Maximum DC voltage range: -17 V DC to +40 V DC

Overvoltage Protection (OVP): Activated when INPUT > 30 V, fixed with LM9061

Overcurrent Protection (OCP): Activated when Load > 12 A, adjustable with LM9061 Rthreshold (R1)

III. Simplified Block Diagram

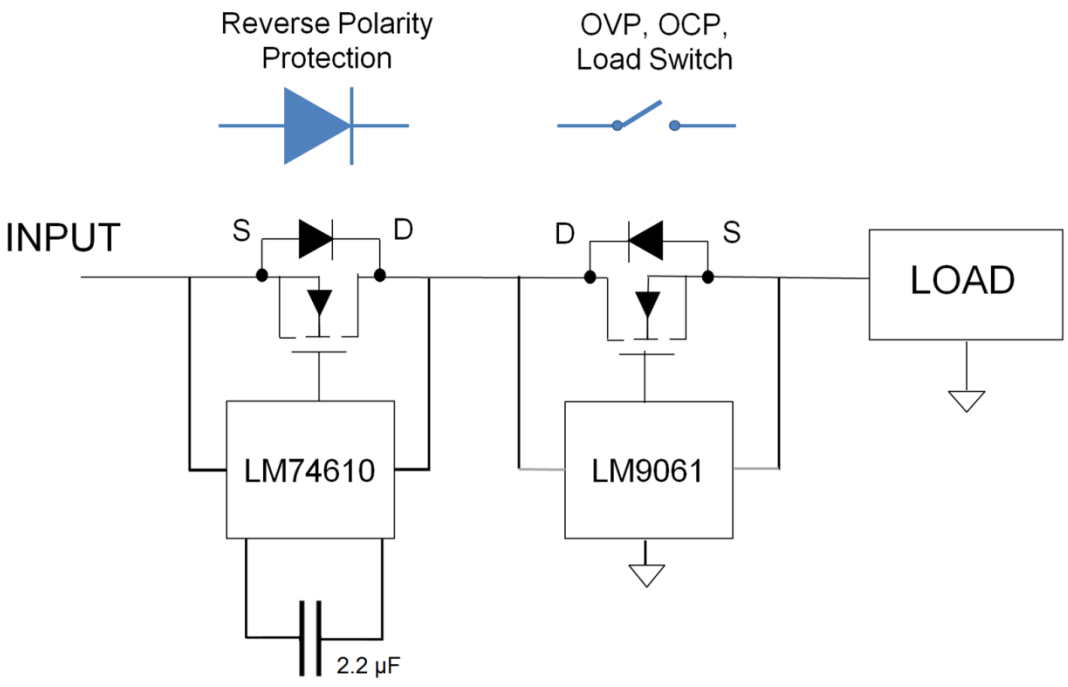

Figure 1 Simplified Block Diagram

IV. Schematic

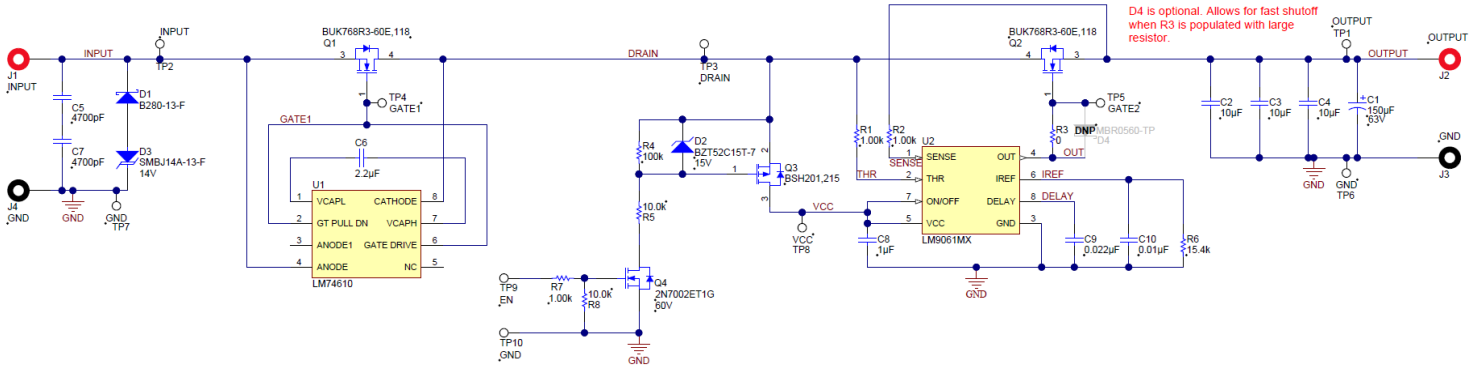

Figure 2 Schematic

V. Reference Board

The board measures 3.29 x 1.95 inch.

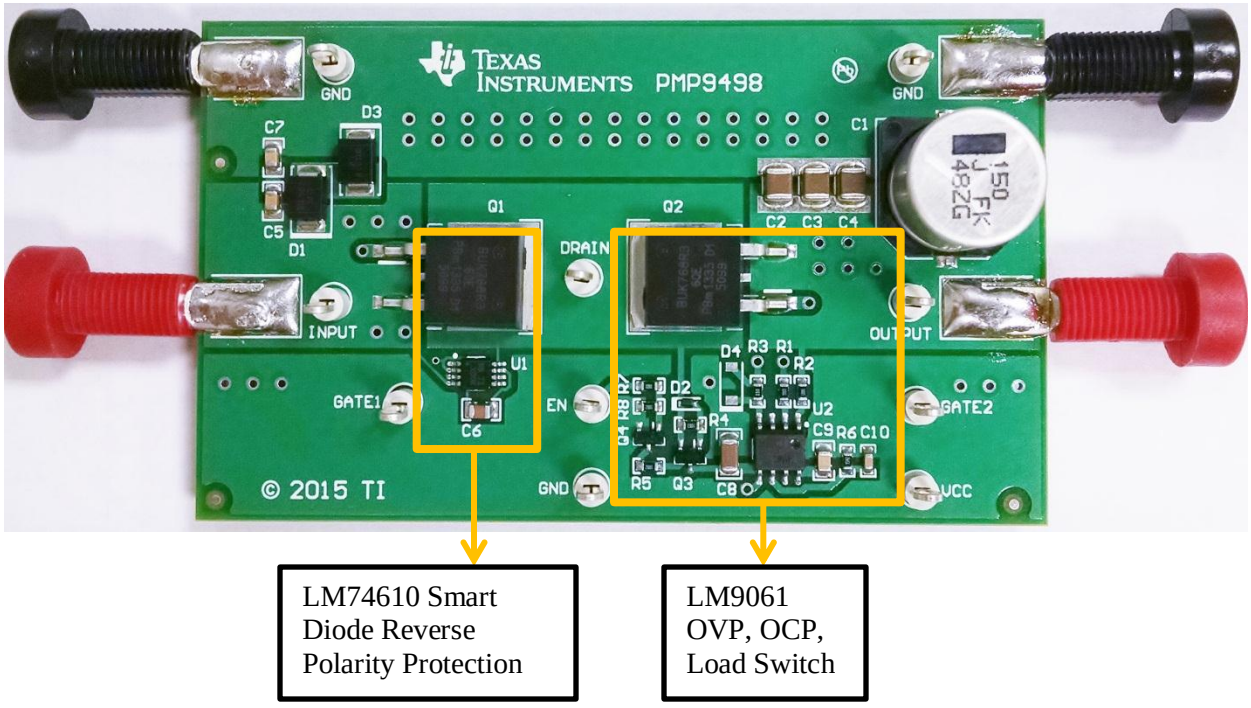

Figure 3 Reference board top view

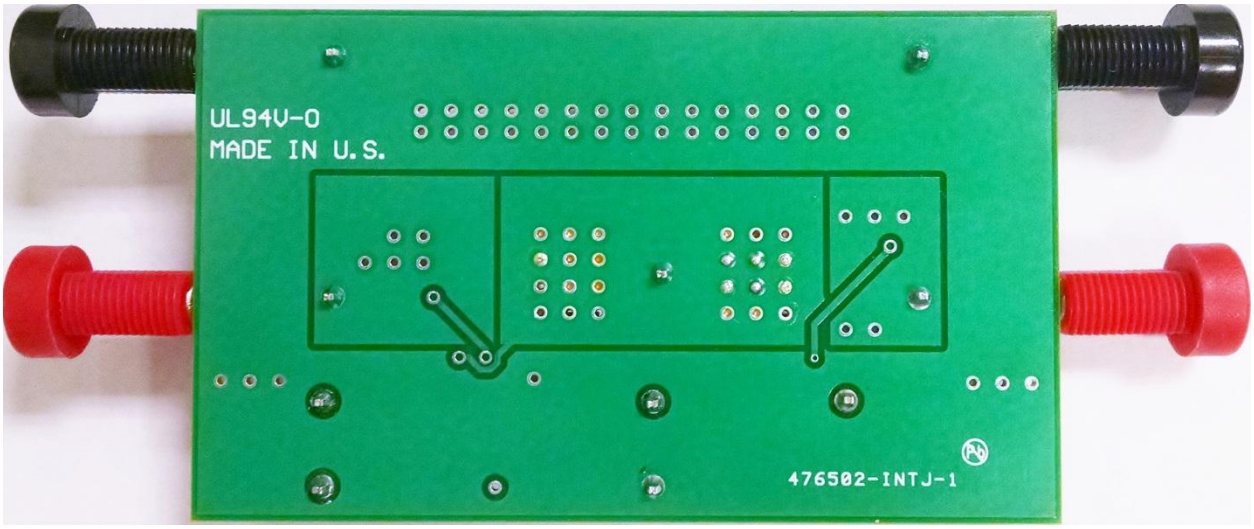

Figure 4 Reference board bottom view

VI. LM74610 Smart Diode Operation

The LM74160 smart diode solution is a floating solution with a charge pump to drive an external N-channel MOSFET. The advantage of this is zero-Iq operation since there is no ground pin. In order to operate and charge the charge pump capacitor (C6), the MOSFET (Q1) must conduct through its body diode at a 1% duty cycle during forward conduction. Then, the MOSFET gate will be driven for 99% duty cycle, during which the current will flow through its $R_{DS(ON)}$. This operation scheme allows for very efficient, diode-like operation, but without the continuous diode voltage drop.

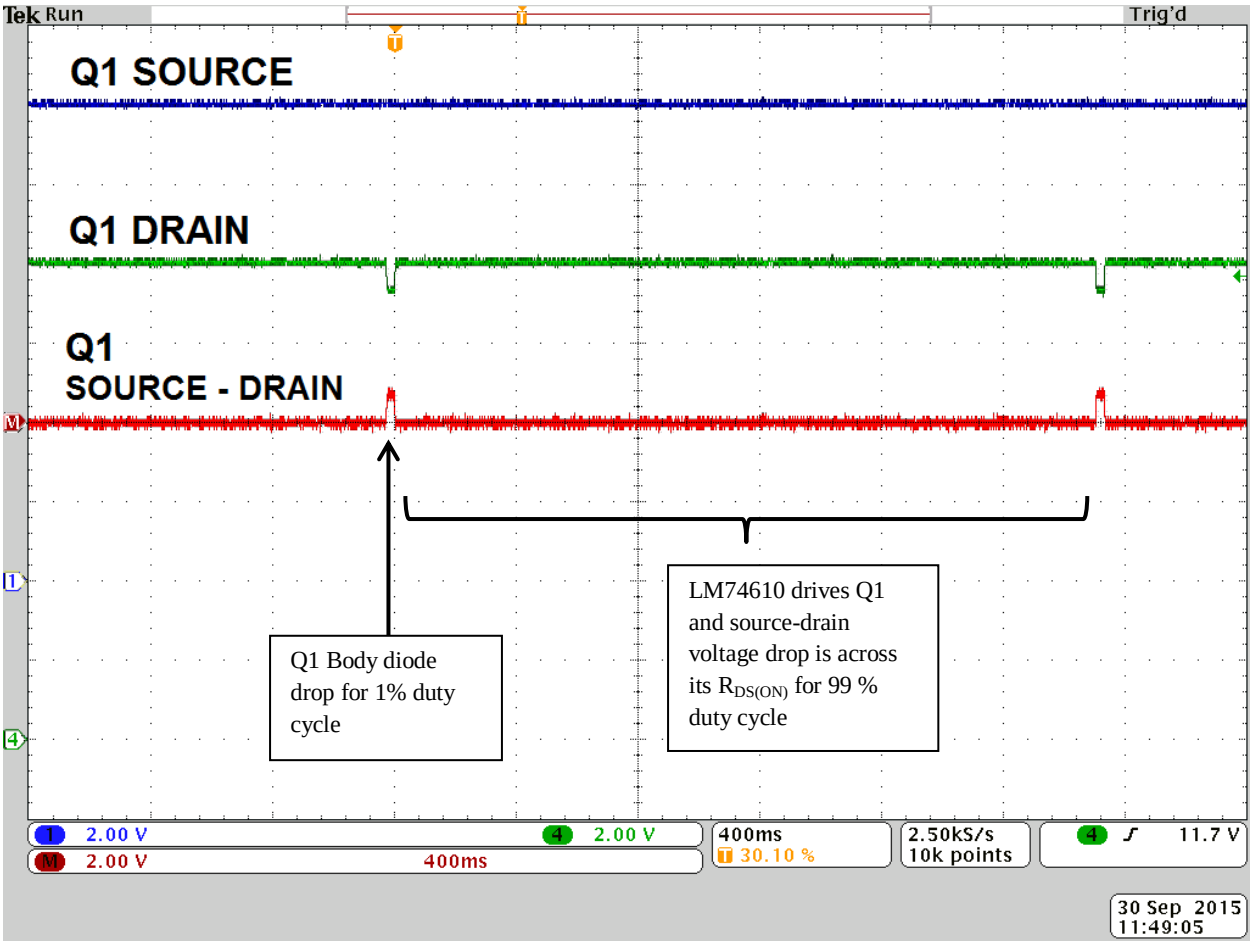

Figure 5 Smart Diode Operation during Forward Conduction

VII. Quiescent Current

The quiescent current into INPUT was measured. The board was operating at INPUT = 12 V, load = 15 Ω at the OUTPUT, and EN (TP9) = 0 V. The measurement was in the order of 90 nA.

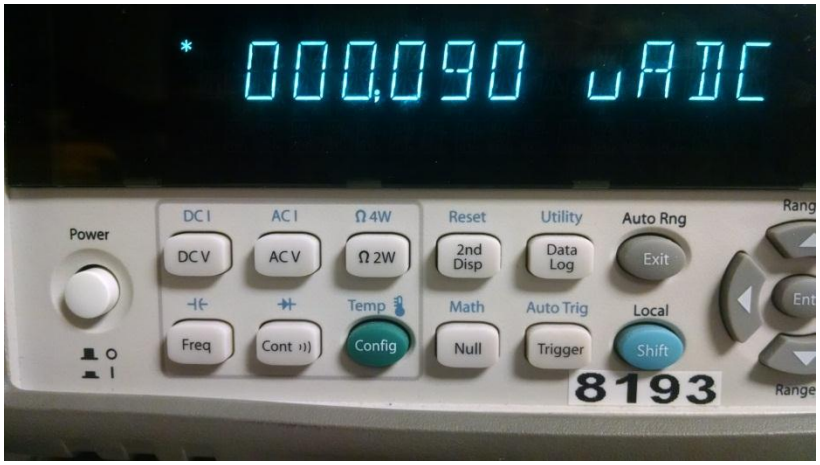

Figure 6 Quiescent Current when Load Switch is Disabled (EN/TP9 = 0V)

VIII. Reverse Polarity Protection (LM74610)

Automotive systems can be subjected to dynamic reverse voltages, even during operation. When using a MOSFET based solution instead of a diode, the MOSFET gate must be discharged very quickly during this time so that the load is protected from negative voltage. The system should also be able to withstand standing negative DC voltages, for example, when the battery is connected in reverse. The reverse polarity protection is performed by the LM74610 circuit of the reference board.

Dynamic Reverse Input Pulse

A dynamic pulse from 12 V to -12 V was applied at the INPUT. Load = 2 Ω at OUTPUT and EN (TP9) = 5 V. The OUTPUT was measured during the INPUT negative pulse and shows that the load is protected and does not see the negative voltage.

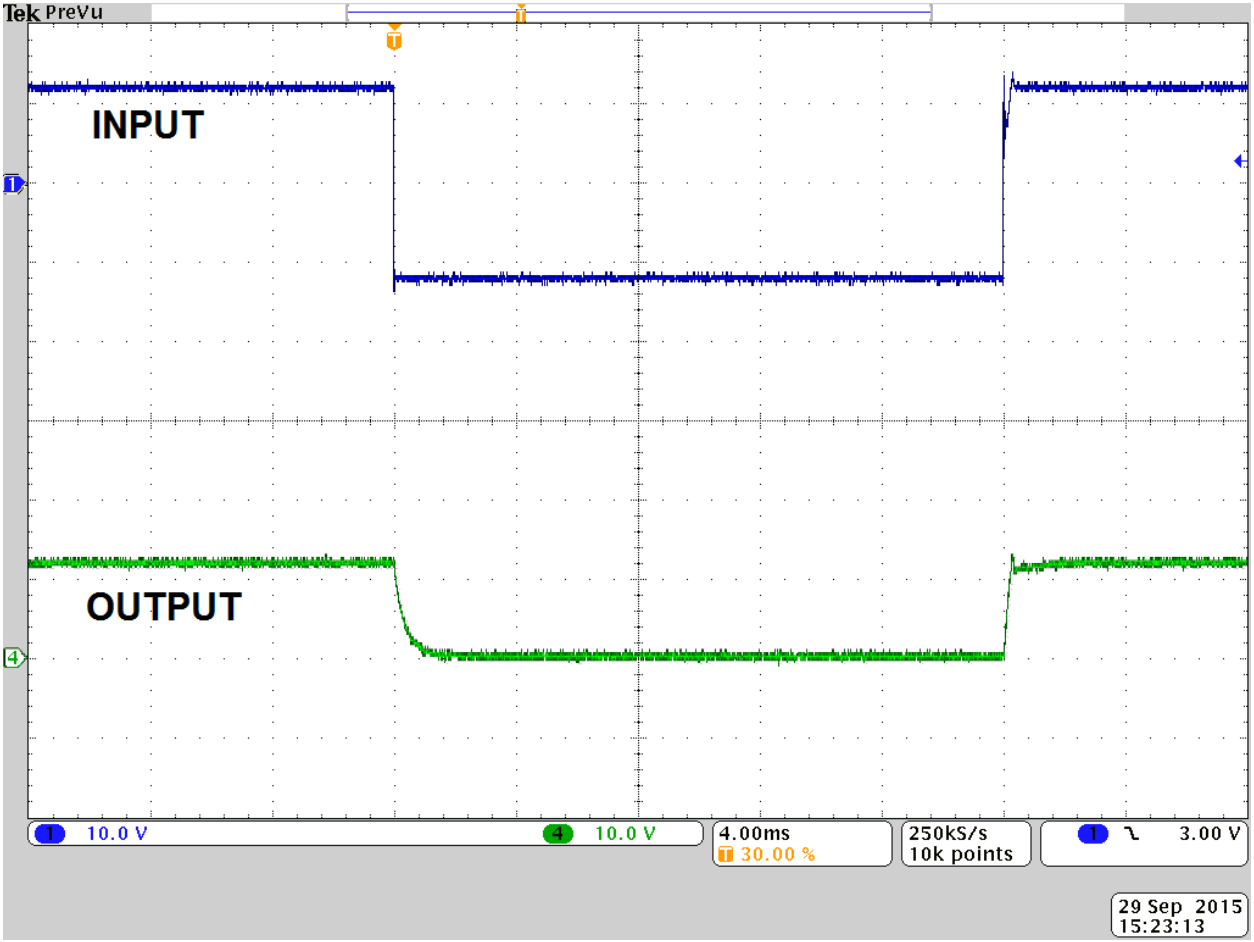

Figure 7 Dynamic Reverse Input Pulse

Standing Reverse DC Voltage

A DC voltage of -17 V was applied at the INPUT. Load = 50 Ω at OUTPUT and EN (TP9) = 0 V. The load was protected from negative voltage and the voltage at OUTPUT was measured at 0 V.

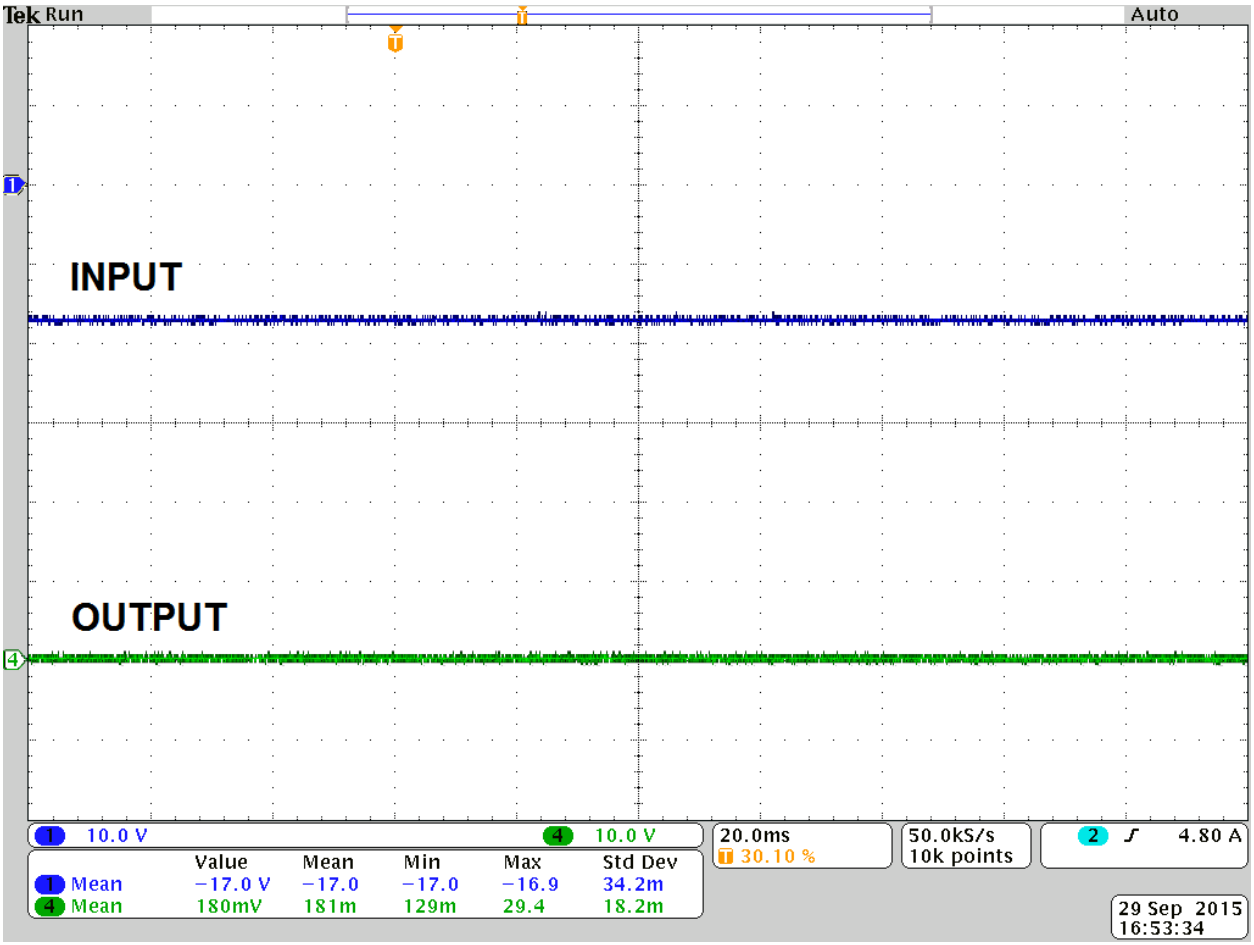

Figure 8 Standing Reverse DC Voltage

IX. Voltage Interruption (LM74610)

During operation, automotive systems may see short interruptions on the input line. During these interruptions, it is sometimes ideal to block reverse current and continue to supply power to the load by capacitors. Reverse current is blocked by the LM74610 circuit of the reference board.

Voltage Interruption

A dynamic pulse from 12 V to 0 V was applied at the INPUT to simulate a short interruption on the input line. Load = 100 Ω at the OUTPUT and EN (TP9) = 5 V. The reverse current is blocked during this time and the output capacitors continue to supply current to the load, keeping the OUTPUT voltage high. This kind of operation is ideal for continuous supply to the load and mimics the behavior of a true diode. By increasing the output capacitors of the reference board, the load voltage can be kept high for a longer period of time.

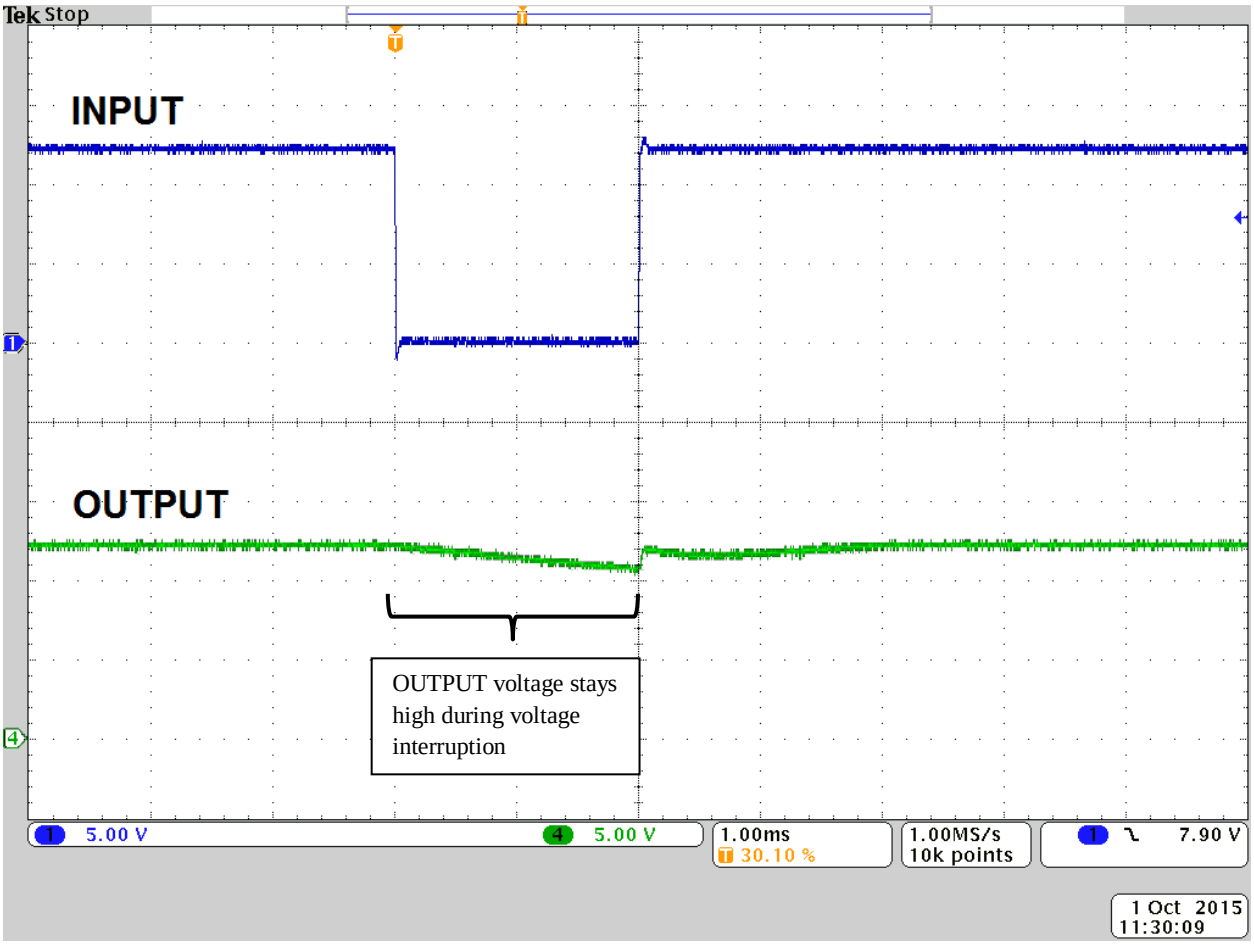

Figure 9 Voltage Interruption

X. Load Switch Operation (LM9061)

The load switch capability is performed by the LM9061 circuit of the reference board and connects or disconnects the load from the INPUT by driving an external N-Channel MOSFET (Q2).

Power Up

The board is tested with INPUT = 12 V, load = 2 Ω at OUTPUT. The EN test point (TP9) was driven with 5 V to enable the load switch and provide power to the load from the INPUT. The MOSFET Q2 VGS (gate-source voltage) reaches its final steady state value in about 120 µs and the OUTPUT voltage reaches 12 V in about 80 µs, both measured from the time EN is pulled high. The OUTPUT voltage rise rate will vary widely with load and output capacitance.

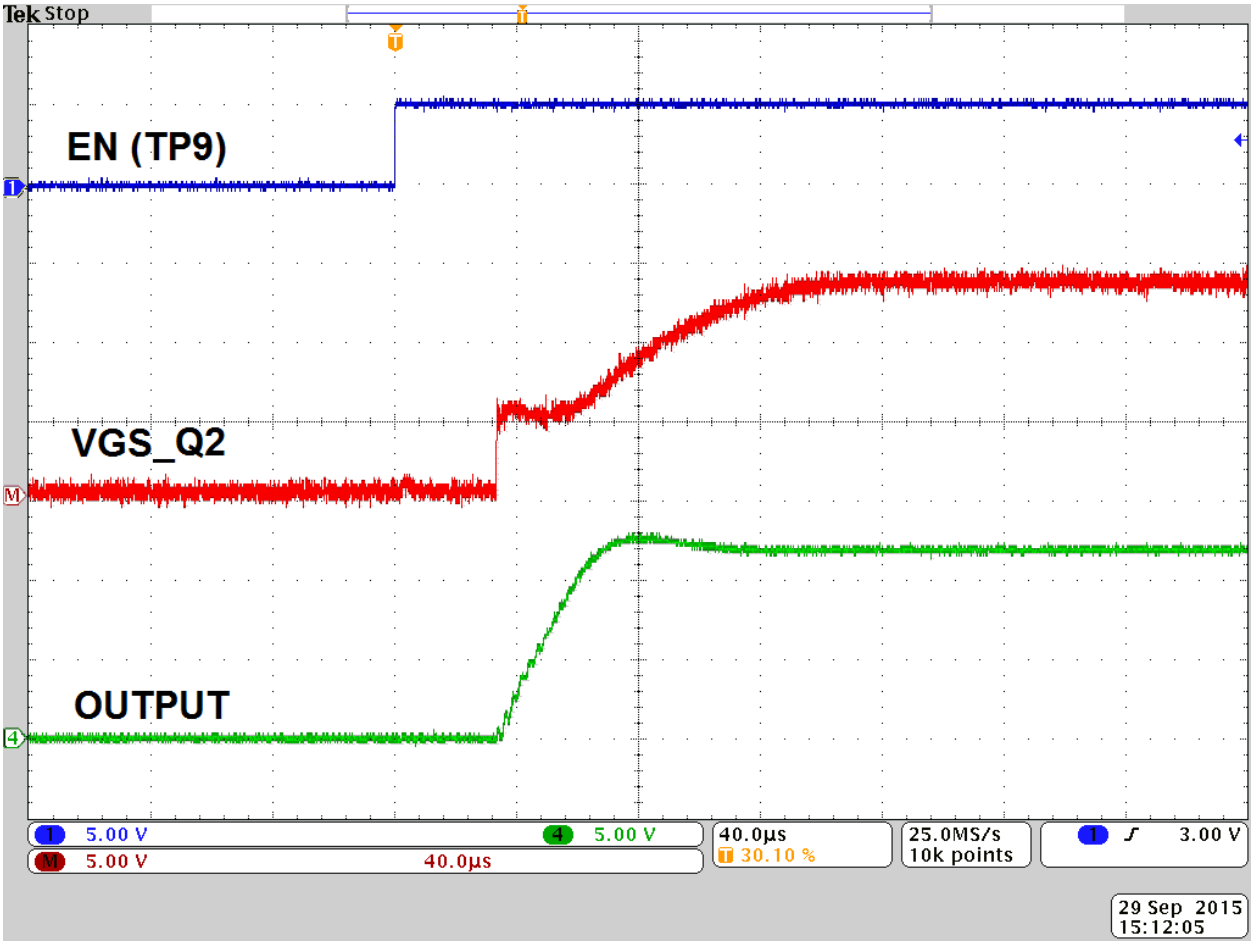

Figure 10 Power up with 12 V Input

Power Down

The board is tested with INPUT = 12 V, load = 2 Ω at OUTPUT. The EN test point (TP9) is initially high at 5 V and power is provided to the load from the INPUT. The EN test point is pulled low to 0 V to open the load switch and disconnect power to the load. The MOSFET Q2 VGS falls to 0 V in about 850 µs and the OUTPUT voltage falls to 0 V in about 2 ms, both measured from the time EN is pulled low. The OUTPUT voltage fall rate will vary widely with load and output capacitance.

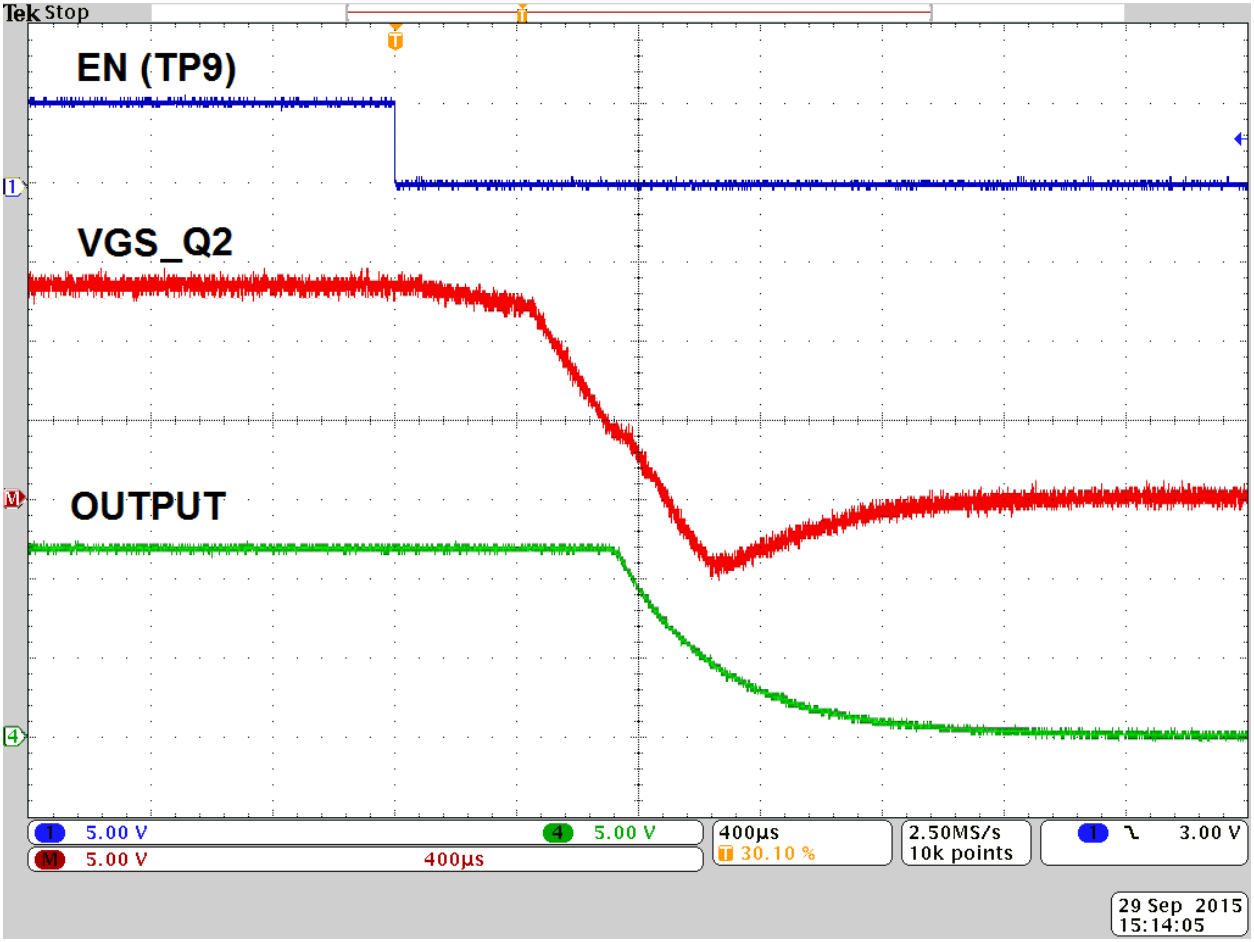

Figure 11 Power down with 12 V input

XI. Over-Voltage and Over-Current Protection (LM9061)

Over-Voltage Protection (OVP)

The LM9061 contains an internal over-voltage shutoff mechanism with a threshold of about 30 V. The INPUT was ramped above 30 V, and the OUTPUT shuts off during this time. This protection feature is not latched, so the OUTPUT will again be driven when the INPUT returns below 30 V.

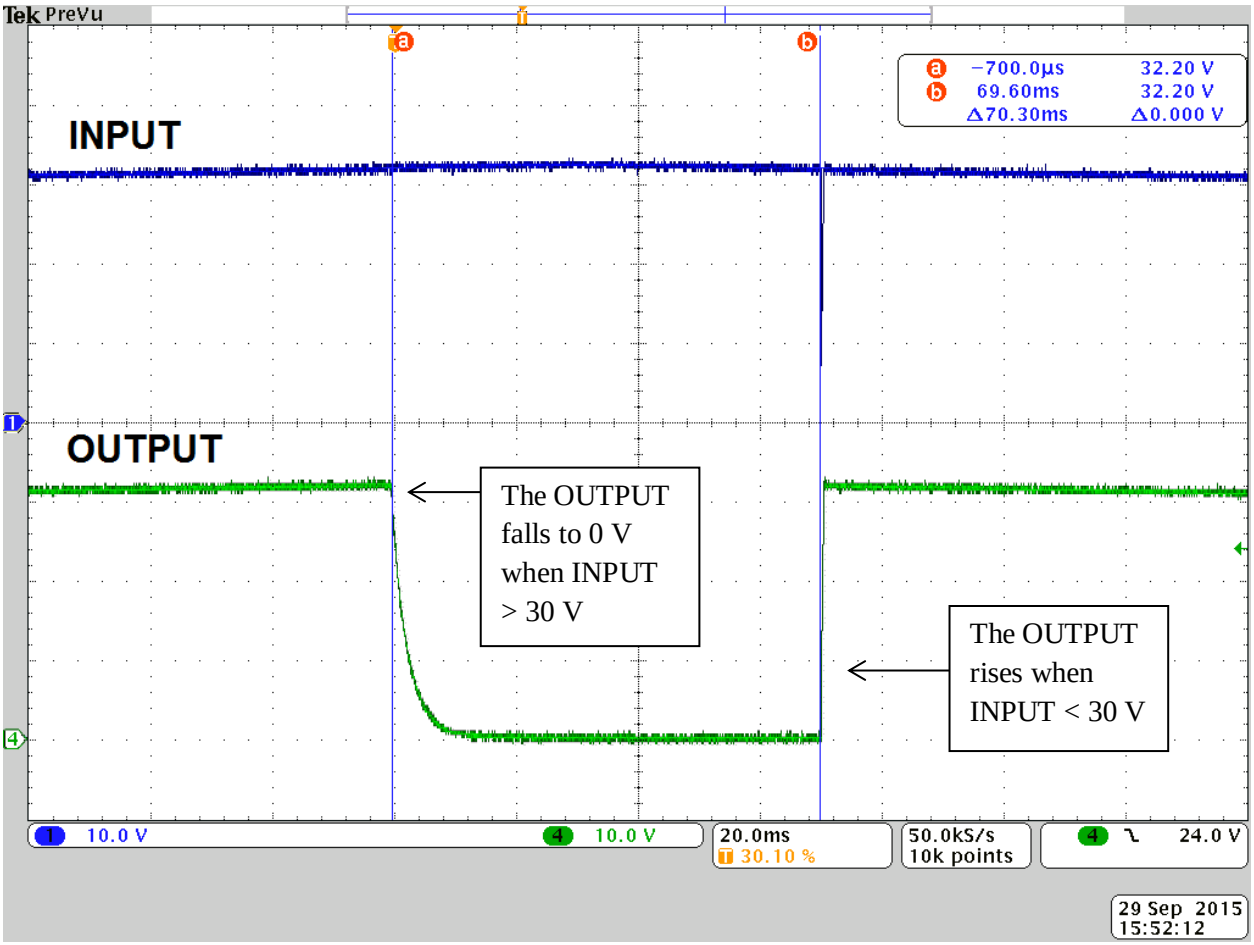

Figure 12 Over-Voltage Protection

Over-Current Protection (OCP)

The current threshold is set by the Rthreshold resistor (R1) and can be adjusted by changing the R1 resistor. When changing the current limit, care should be taken to ensure both MOSFET limits are not exceeded, such as SOA and current capability. The LM9061 will disconnect power to the OUTPUT when there is greater than 12 A of current to the load and is detected by sensing the VDS voltage across Q2 and utilizing its $R_{DS(ON)}$. The actual threshold may vary due to variations in $R_{DS(ON)}$. This protection feature is latched, meaning the EN test point (TP9) must be toggled low, then back high to enable power to the load again. The delay of the OCP is set by Cdelay (C9).

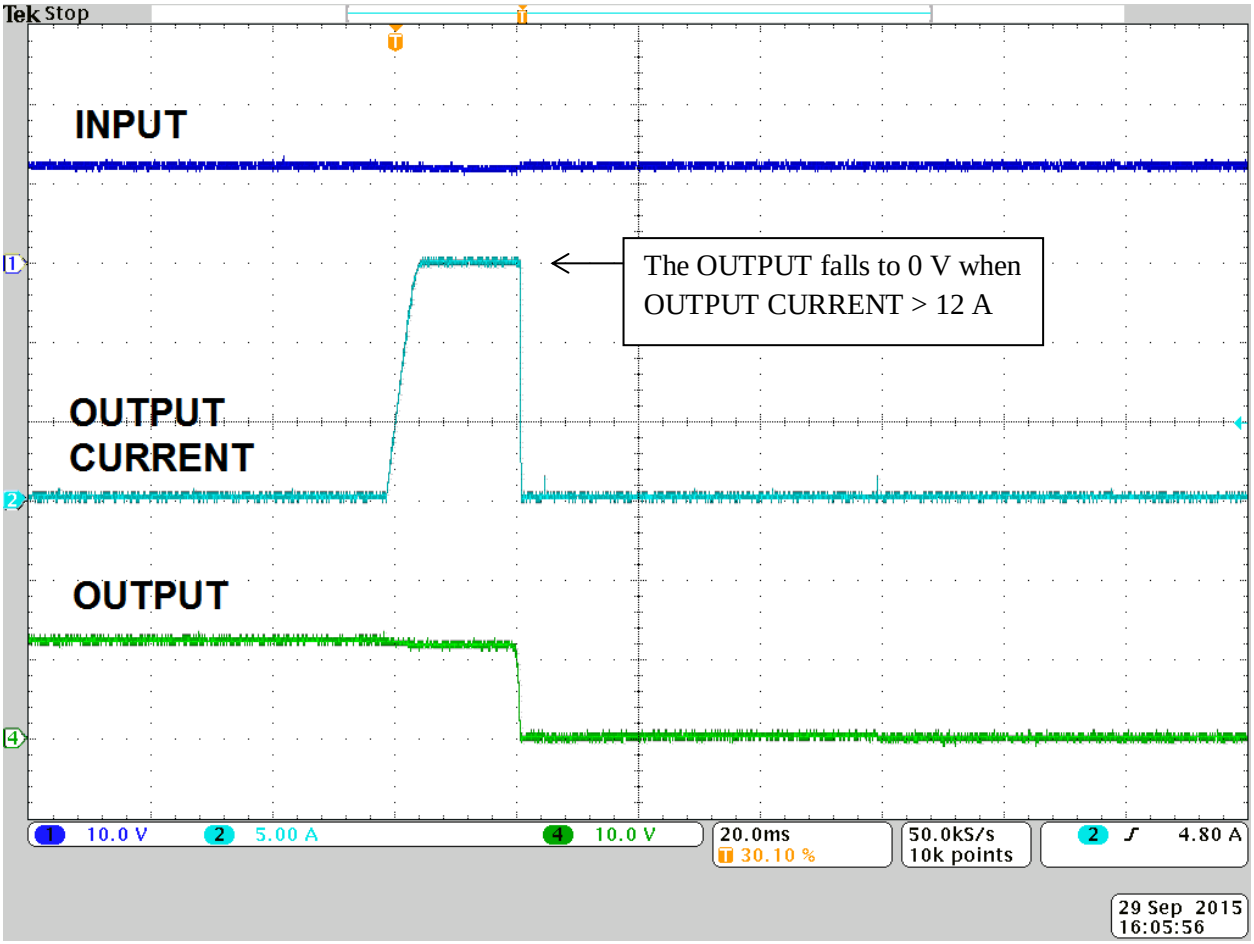

Figure 13 Over-Current Protection

XII. Thermal Image

The thermal image was taken at 25°C room temperature, no air flow. The board was operating at INPUT = 12 V, load = 10 A, for 5 minutes.

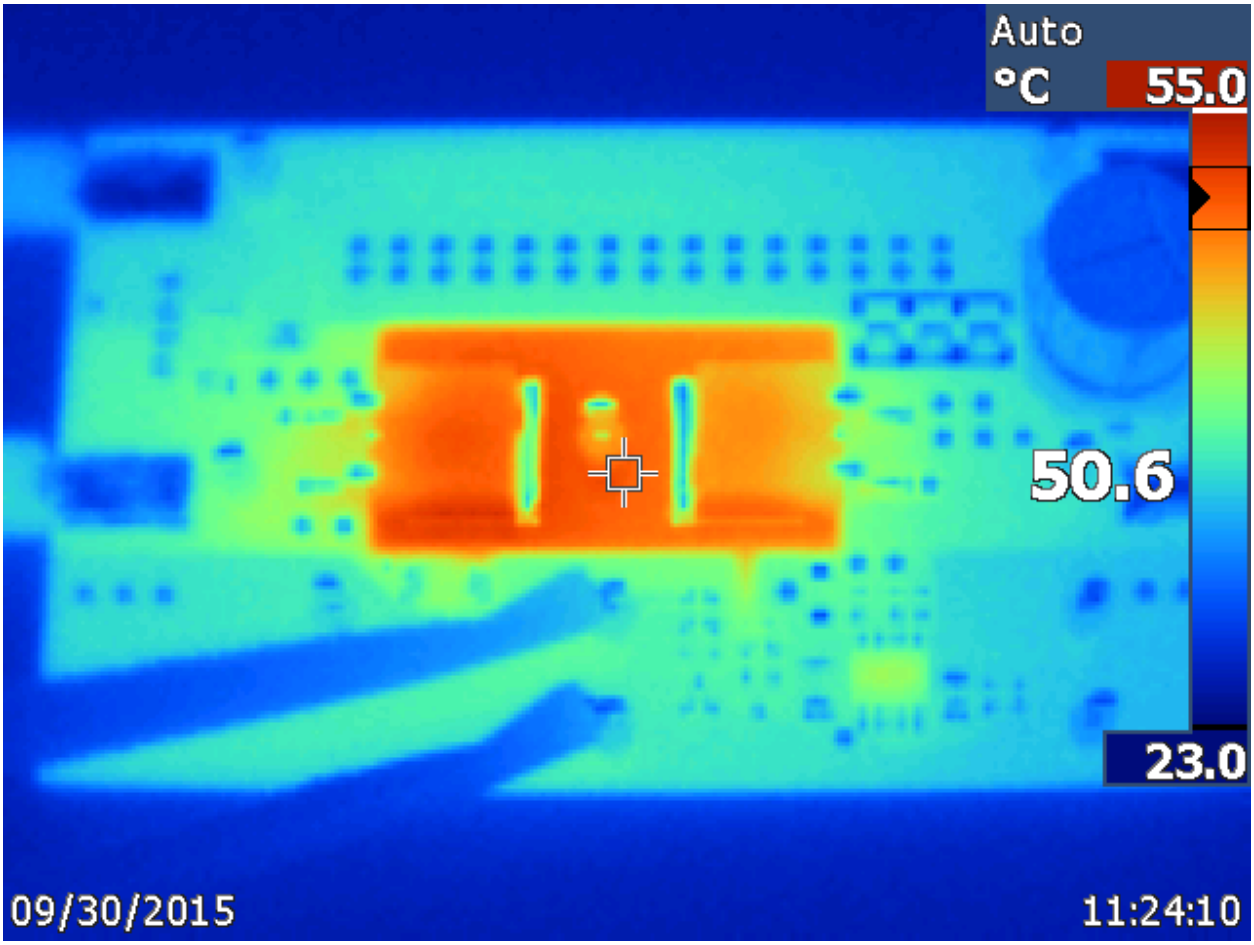

Figure 14 Thermal Image from top view

XIII. Summary

This test report presents a design that meets the low Iq requirements for automotive applications and provides a reliable solution for front-end protection for electronic modules in automotive systems. Various protection features were implemented and tested to provide an all-around front-end protection scheme.

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Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265