Test Report: PMP30963

Backup Battery Reference Design With Preboost, Charger, and 1S Li Fuel Gauge

TEXAS INSTRUMENTS

Description

This design features an automotive backup battery system using a 1S Li battery for emergency operation.

The primary power input is rated for 6- to 18-V nominal (2.7- to 36-V peak) to comply with 12-V automotive requirements. The secondary power input is equipped with a fuel gauge to monitor a single cell Li battery and supports input voltages from 2 V to 4.35 V. The onboard learning load allows the easy implementation of an end-of-life detection for the backup battery.

Both power inputs are connected via ORing MOSFET switches to an 8.5-V boost converter, which can deliver up to 21.5-W continuous output power (30-W peak) with 2.5-V input voltage. At lower output currents, the input voltage of the boost converter can be as low as 2 V.

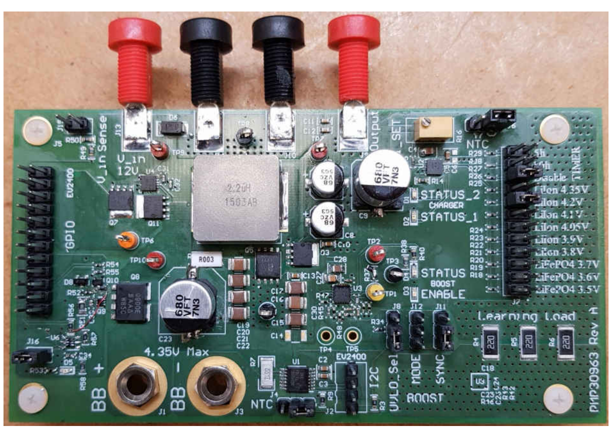
Due to the ORing MOSFET switches, this boost converter covers the emergency operation as well as cold crank situations, where the 12-V rail can drop down to 2.7 V at the primary input.

An ideal diode together with the bypass function of the boost stage minimizes losses during normal operation and allows low cold-crank voltages. Additionally, the ideal diode allows disconnecting the load on demand.

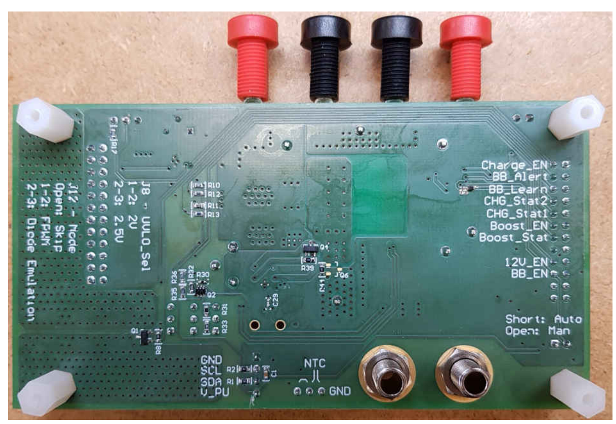
For ease of evaluation, an automated switchover between primary and secondary power input is implemented on this design.

The total power solution is completed by a linear battery charger for the Li battery, which can operate at input voltages as high as 18 V and withstand 40-V spikes during load dumps. The charger supports various cell chemistries.

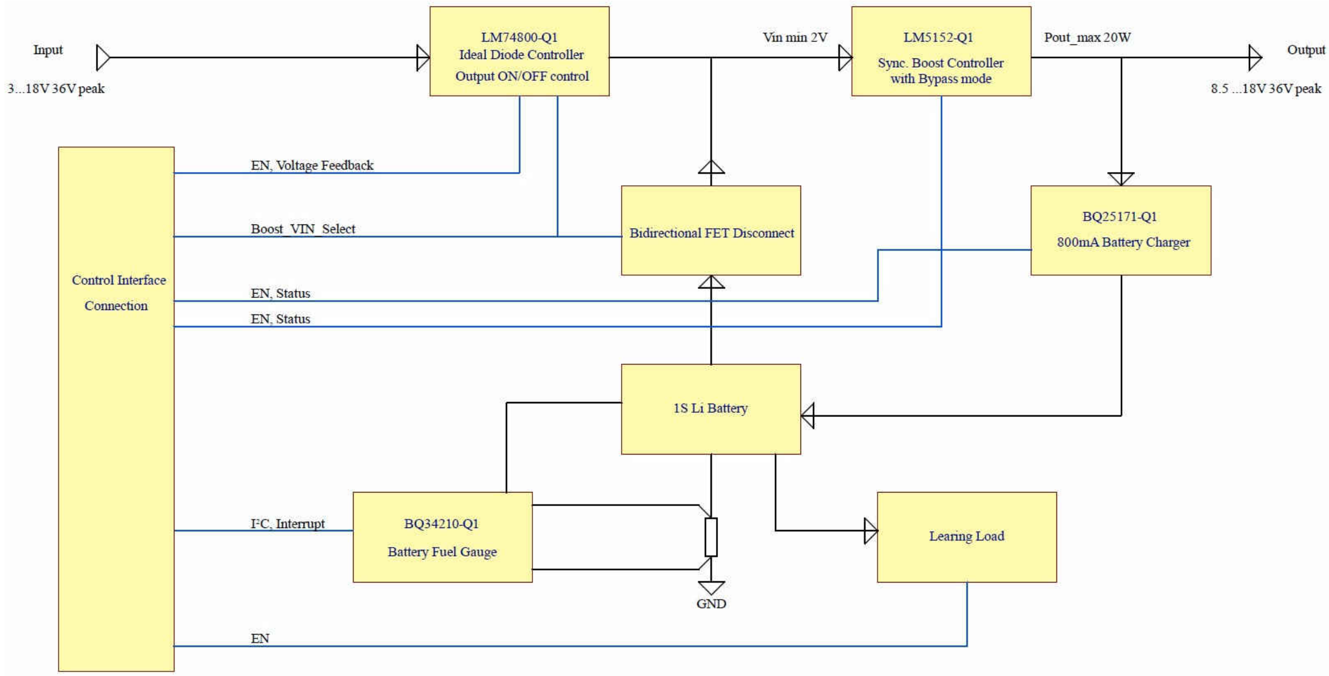
The following images shown the top and bottom photos of the 4-layer PCB, FR4, with 35-µm copper.



Board Top



Board Bottom



Block Diagram

1 Board Connections, Jumpers, and Test Points

Table 1-1 details the board connections, jumpers, and test points.

Table 1-1. Board Connections, Jumpers, and Test Points

Connector	Description
J1	Backup battery, positive terminal
J2	Backup battery, negative terminal
J3	Fuel gauge I²C interface (EV2400 connector)
J4	Fuel gauge NTC connector
J5	IO connector for status and control signals
J6	Battery charger NTC connector
J7	Battery charger voltage and timer selection
J8	Boost converter UVLO selection
J9	Positive output terminal
J10	Negative output terminal
J11	Boost converter SYNC/DITHER configuration
J12	Boost converter MODE selection
J13	Primary power input, positive terminal
J14	Primary power input, negative terminal
J15	Primary power input, voltage sense connector
J16	Automated switchover disconnect jumper
TP1	Frequency response analyzer connection, high impedance side
TP2	Frequency response analyzer connection, low impedance side
TP3	Frequency response analyzer connection, GND
TP4	Boost converter, tracking voltage probe point
TP5	Boost converter, analog GND
TP6	Ideal diode, always on voltage
TP7	Boost converter output voltage
TP8	GND
TP9	Primary power input voltage
TP10	Boost converter input voltage
TP11	GND

2 Pin Functions

Table 2-1 describes the pin functions of the individual connectors.

Table 2-1. Pin Functions

Connector	Pin	Description
J2	1	GND
	2	I²C – SCL
	3	I²C – SDA
	4	Vpu – 3.3-V pullup voltage for open drain IOs and I²C interface
J4	1	10-kΩ resistor – connect to pin 2 if no external NTC is used
	2	BQ25171-Q1 NTC connection
	3	GND
J6	1	10-kΩ resistor – connect to pin 2 if no external NTC is used
	2	BQ25171-Q1 NTC connection
	3	GND
J5	2	BQ25171-Q1 Charge Enable. 10-k pulldown – pull high to disable charger
	4	BQ34210-Q1 Alert output. 10-k pullup to Vpu
	6	Learning load EN. FET input. 10-k pulldown – pullup to enable learning load
	8	BQ25171-Q1 STAT2 output. 22-k pullup to Vpu
	10	BQ25171-Q1 STAT1 output. 22-k pullup to Vpu
	12	LM5152-Q1 enable. Pull high to enable boost converter
	14	LM5152-Q1 status output. 22k pullup to Vpu
	18	LM74800-Q1 enable input. Pull high to connect main power input to boost converter
	20	Backup battery enable. 4.7-k pullup to Vpu. Pull low for normal operation, pull high or leave open with applied pullup voltage for backup battery operation
	All others	No connection
J7	All uneven	GND
	20	Connect to GND to disable charge timer
	22	Connect to GND to set charge timer to 10 h
	24	Connect to GND to set charge timer to 5 h
	2	Connect to GND to set charging voltage to 3.5 V
	4	Connect to GND to set charging voltage to 3.6 V
	6	Connect to GND to set charging voltage to 3.7 V
	8	Connect to GND to set charging voltage to 3.8 V
	10	Connect to GND to set charging voltage to 3.9 V
	12	Connect to GND to set charging voltage to 4.05 V
	14	Connect to GND to set charging voltage to 4.1 V
	16	Connect to GND to set charging voltage to 4.2 V
	18	Connect to GND to set charging voltage to 4.35 V
J12	1	LM5152-Q1 internal VCC. For frequency response analysis, connect 5.5 V to this pin and pin 2 and populate R37 with 49.9 Ω. For normal operation, remove external voltage source and populate R37 with 0 Ω.
	2	LM5152-Q1 MODE pin. Connect to pin 1 for FPWM operation, to pin 3 for Diode Emulation or leave open for skip mode
	3	LM5152-Q1 AGND
J15	1	GND
	2	Voltage sense output of resistive voltage divider. Divider can be disconnected by LM74800-Q1 to avoid leakage current.

3 Quick Start Guide

CAUTION

Manual control of the two power inputs is possible when removing the jumper from J16, but precautions must be taken to *not* switch to the secondary power input while the input capacitor of the boost converter is charged to a voltage above 5 V. This will cause a voltage spike at the battery terminals which can potentially damage the fuel gauge IC.

The switchover also occurs when the ideal diode is disabled by asserting the control input low.

The input voltage of the boost converter can be measured at TP10.

When powering down the board, remove the 12-V input first.

Power up the board:

1. Ensure J16 is shorted.
2. Connect the PMP30963 board to the EV2400 via J2. Ensure 3.3 V are applied to pin 4 of J2.
3. Connect any of the voltage outputs from the EV2400 to J5, pin 6. This pin is used to control the learning load and the EV2400 utilizes the voltage outputs as a control signal.
4. Connect a Li battery to J1/J3. The battery and its connection must be low impedance.
5. Connect a 12-V supply to J10/J14. Ensure that this source is low impedance.
6. Provide the necessary control signals to the following pins of J5: pin 2 (charger enable), pin 12 (booster enable), pin 18 (ideal diode enable).

When all voltages are applied, the ideal diode enable must be pulled high to deliver power to the boost converter.

Now the boost converter and the battery charger can be enabled or disabled using the corresponding control inputs. Switchover between the primary and the secondary power input happens automatically when the voltage at the primary power input drops below approximately 3 V. When the voltage rises above approximately 4.6 V, the boost converter is connected to the primary power input again.

4 Testing and Results

This section includes the thermal image, control loop, and efficiency graphs.

4.1 Thermal Image

The boost converter test results are for 8.5-V output voltage.

The MOSFET switches stay below 70°C at 25°C ambient when constantly loaded with 2.5 A at 2.5-V input voltage.

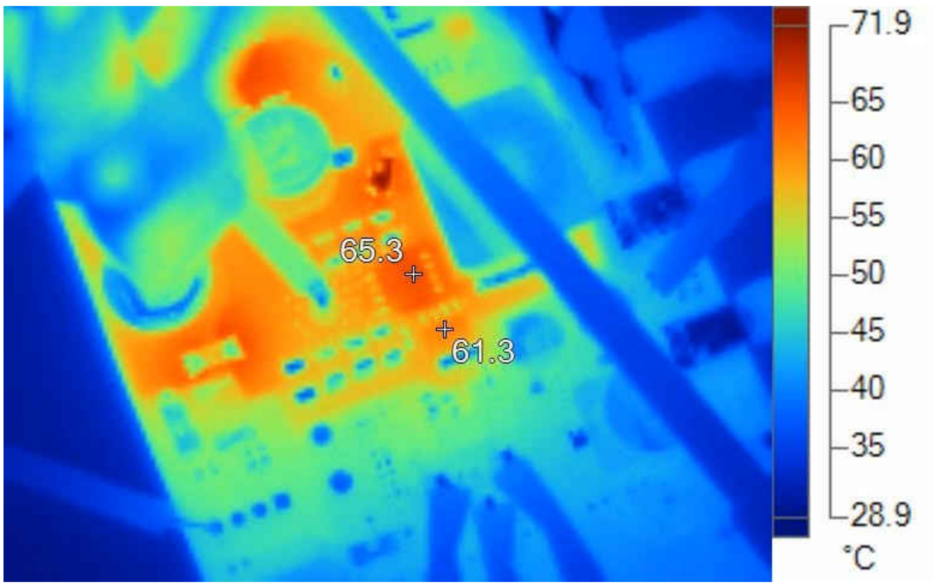


Figure 4-1. Thermal Image

4.2 Control Loop

The control loop is measured at 2.5 V_{IN}, 3-A load current, the temperature was 68.8°C with a phase margin at 322.7 Hz.

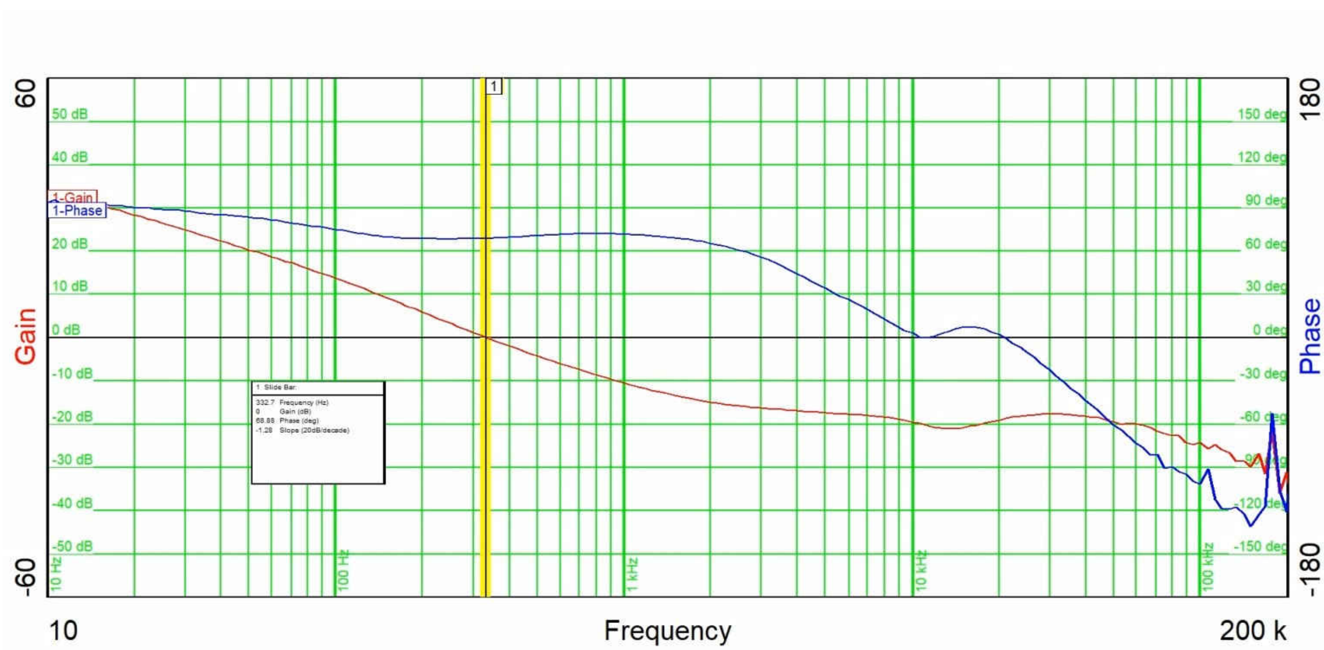


Figure 4-2. Control Loop - Bode Plot

4.3 Efficiency - Output Voltage 8.5 V

The following graphs show the efficiency curves at 3.6-, 3.0-, and 2.5-V_{IN}.

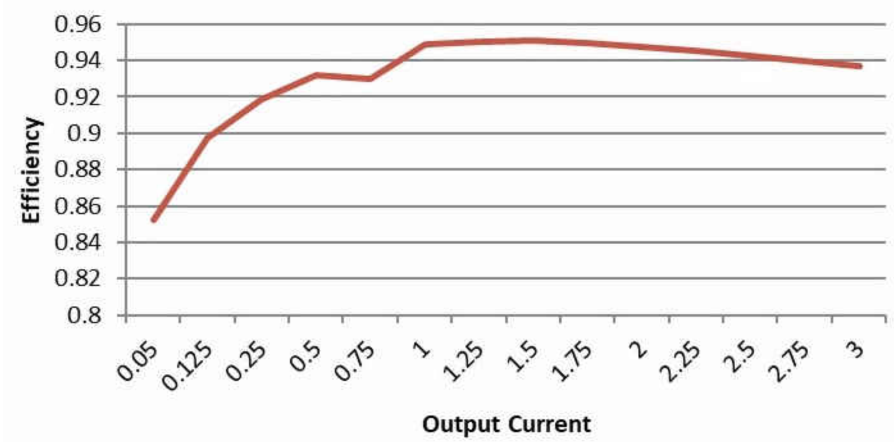


Figure 4-3. Efficiency, 3.6 V_{IN}

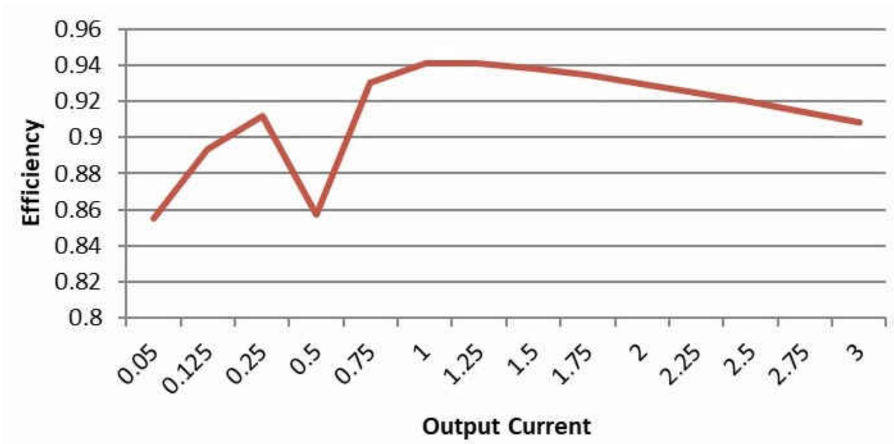


Figure 4-4. Efficiency, 3.0 V_{IN}

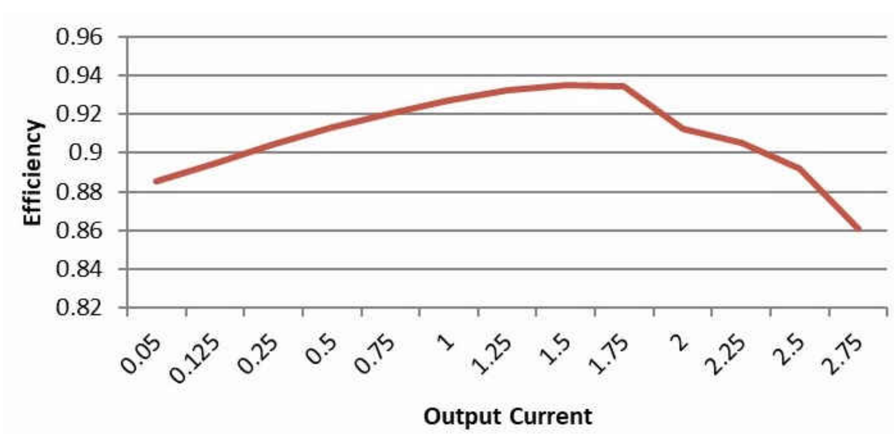
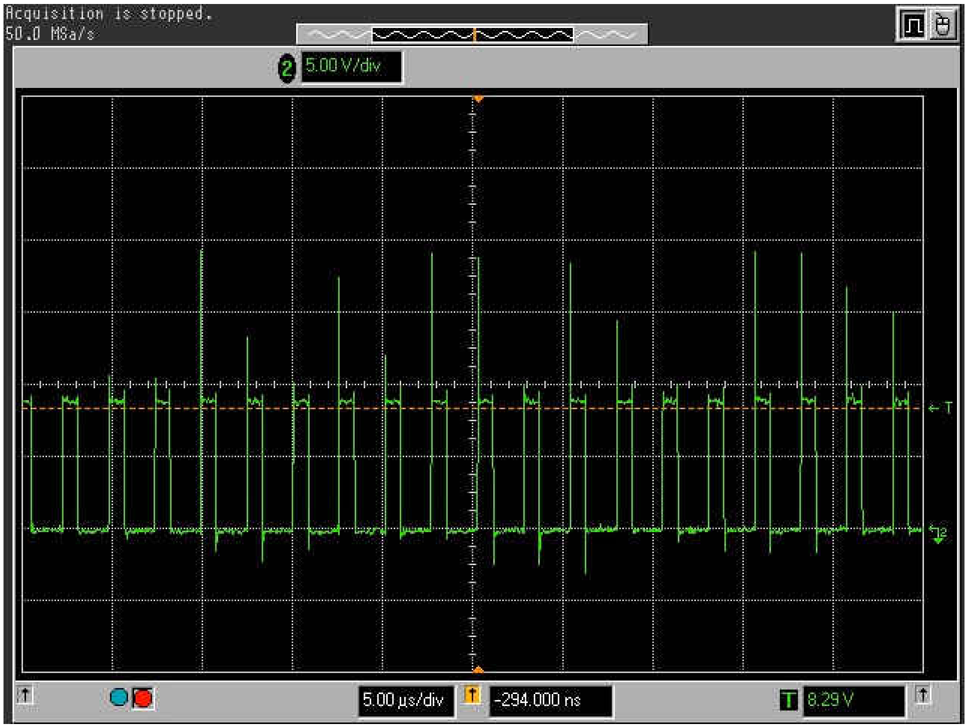


Figure 4-5. Efficiency, 2.5 V_{IN}

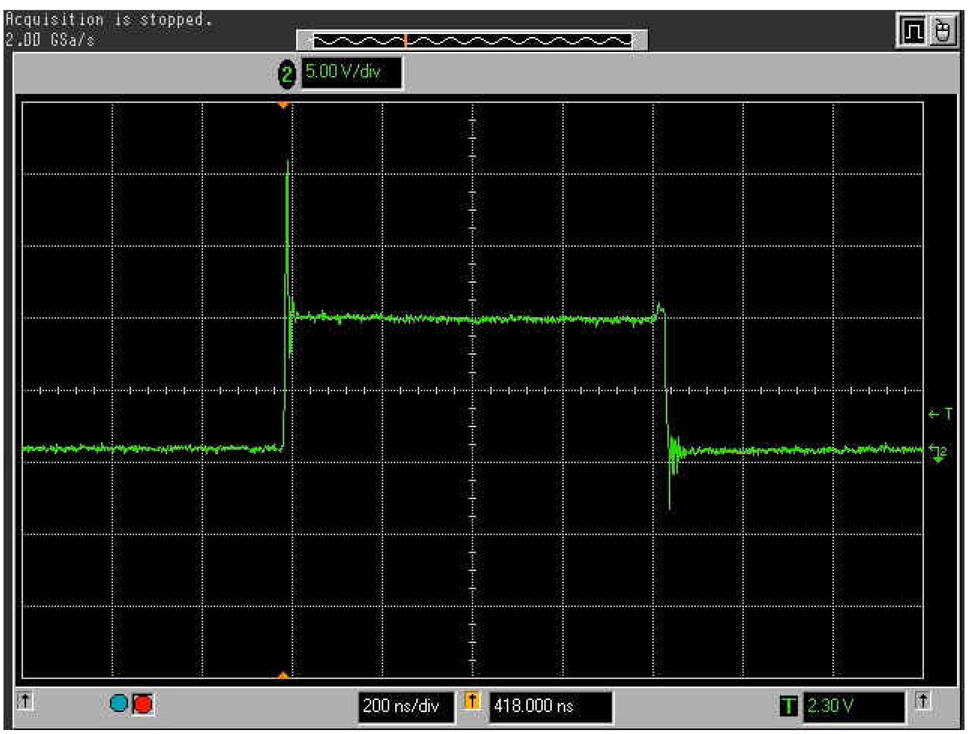
5 Waveforms

In the switch node waveforms in Figure 5-1 and Figure 5-2, no snubber circuit is installed. These are 0-Ω gate resistor at a switching MOSFET.



Channel 2 – 5 V/div

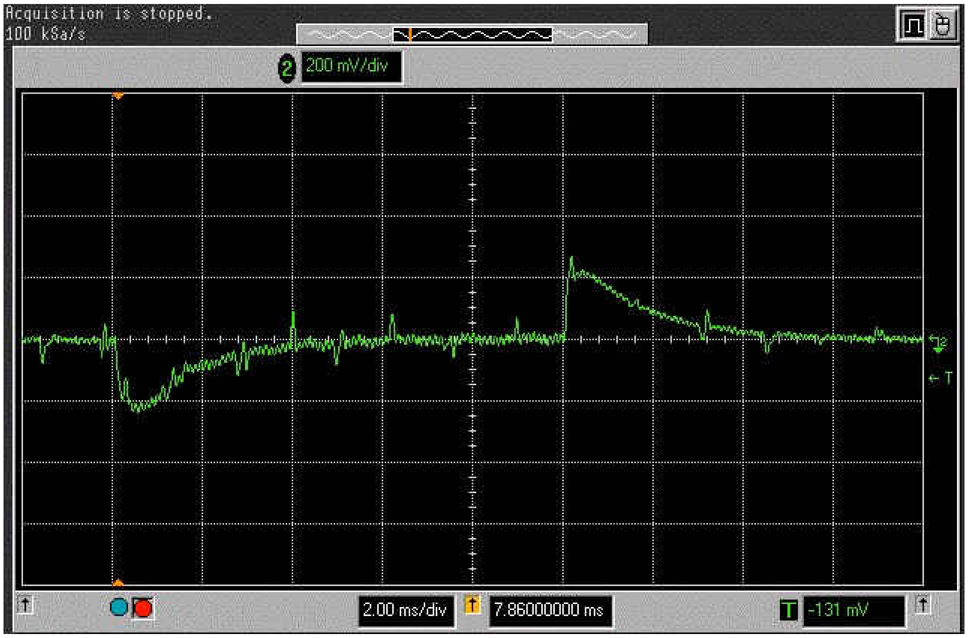
Figure 5-1. Switch Node - 5 µs/div



Channel 2 – 5 V/div

Figure 5-2. Switch Node - 200 ns/div

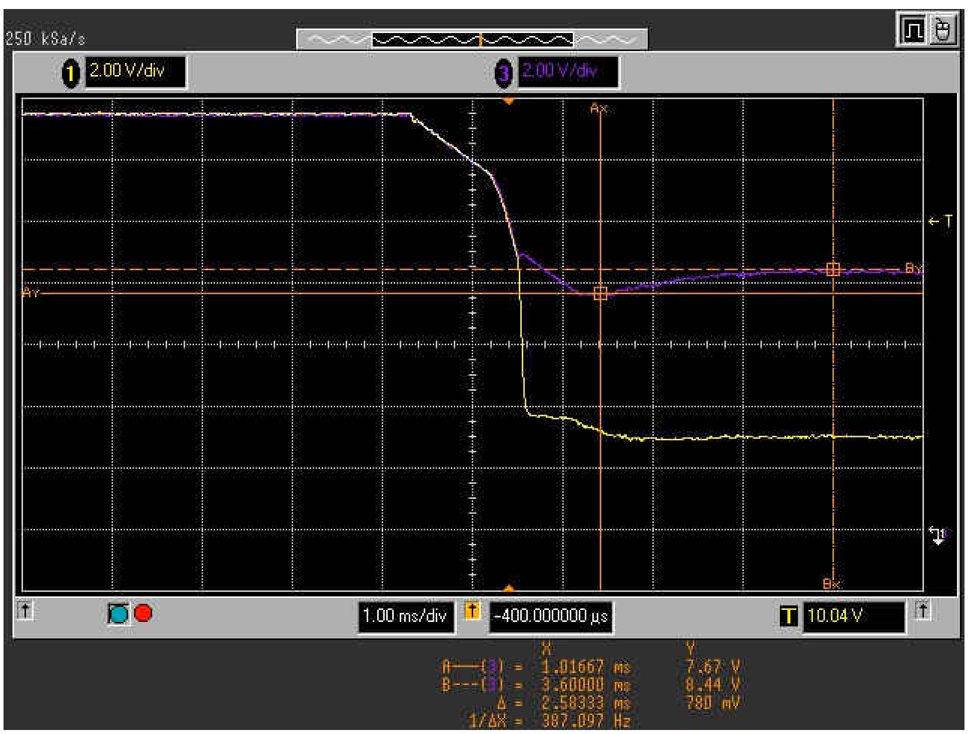
Figure 5-3 shows the load transient waveform.



Channel 2 – output voltage [200 mV/div, 2 ms/div, AC coupled]

Figure 5-3. Load Transient - 1.5 A to 3 A to 1.5 A

Figure 5-4 shows the manual input voltage switchover waveform.



Channel 1 – Boost converter V_{IN} [2 V/div, 1 ms/div, DC coupled]
Channel 3 – Boost converter V_{OUT} [2 V/div, 1 ms/div, DC coupled]

Figure 5-4. Manual Input Voltage Switchover