TIDA-00304- "Last Gasp" Hold Up Energy Storage Solution

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1. System Description:

This solution stores and delivers "last gasp" energy for systems, such as SSDs, that require functionality for a short time after power loss in order to shut down in a controlled fashion. By storing holdup energy at higher than bus voltage the amount of capacitance can be reduced by up to 80%, significantly reducing solution size and cost while improving reliability.

Typically a complex electronics circuit is needed to boost the input voltage, mux it with the buck input during power failure, and bucking it down to 3.3V or 5V for the load.
This design uses TI's TPS25942 on the input side to control inrush, protect against over voltage, under voltage, short circuits, and prevent stored energy from flowing back to a shorted input bus. The boost converter charges the capacitor bank to 12V if input supply is 5V, or 18V if input supply is 12V. When the TPS25942 detects and declares a fault the FLTb signal is used to drive a P-MOSFET that connects the storage capacitors to the buck input.

2. System Operation

Figure 1 shows a very simple and cost effective way to meet the power back up requirements. This concept uses TI's TPS25940 and supplies the power to the output load thru the buck- converter (TPS54495) and to the boost converter (TPS61170), which charges the energy hold-up capacitor bank(1000uF,25V) to voltage configured by the boost converter. The boost converter configured for the 12V (for 5V input supply) and 18V (for 12V input supply). The P-MOSFET is used to discharge the filled capacitor into the load to meet the power back- up requirement.
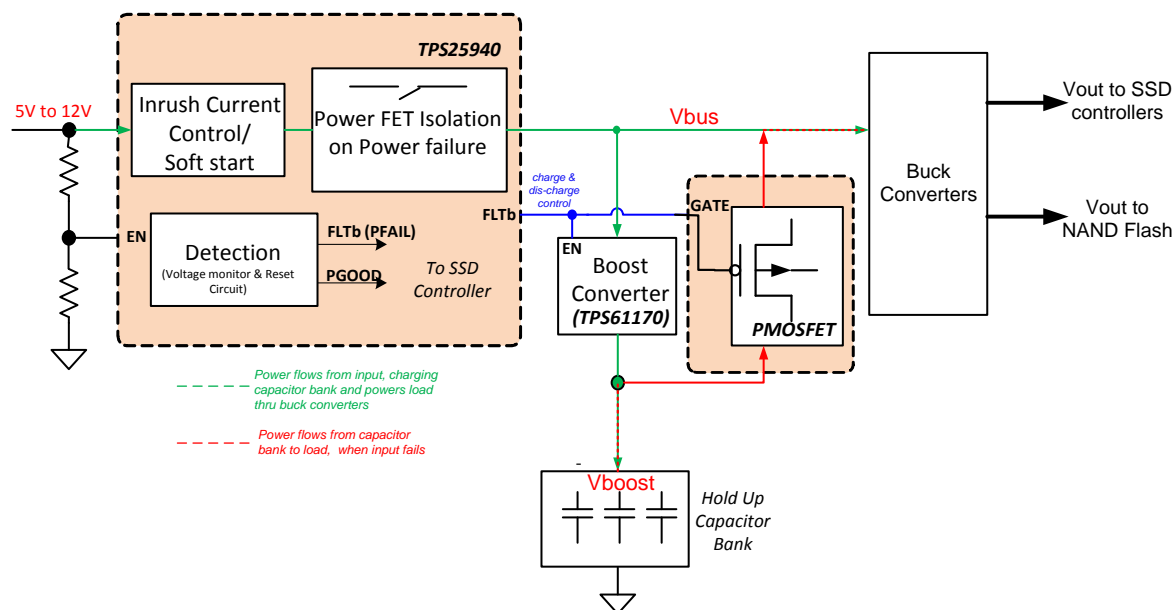

Figure 1: Block Diagram of Hold Up Energy Storage Solution

When the input power is available, TPS25940 enables the boost converter by inserting FLTb high and disable the P-MOSFET. This power path is indicated by green dotted line in Figure 1.

Whenever the input power fails, the FLTb goes low and turns "off" the boost converter and at the same time P-MOSFET is turned "ON" which allows the discharge of the capacitor bank thru buck converter to the load. This power path is indicated by red dotted line in figure1.

The boost converter and buck converter configured depends on the input supply voltage as below.

- ➢ When input supply voltage Vin= 5V
  - ○ Boost converter configured for 12V output and
  - ○ Buck converter is configured for 3.3V output.
- ➢ When input supply voltage, Vin= 12V
  - ○ Boost converter configured for 18V output and
  - ○ Buck converter is configured for 5V output.

The tests conducted on the above described system is provided the power back-up as summarized below.

1. 30W@5V   for 15.8ms (for Vin=12V, Vboost = 18V)
2. 15W@5V   for 31.0ms (for Vin=12V, Vboost = 18V)
3. 16W@3.3V for 8.8ms (for Vin=5V,   Vboost = 12V)
4. 8W@3.3V   for 17.8ms (for Vin=5V,   Vboost = 12V)

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This design uses TI's TPS25942 on the input side to control inrush, protect against over voltage, under voltage, short circuits, and prevent stored energy from flowing back to a shorted input bus. The boost converter charges the capacitor bank to 12V if input supply is 5V, or 18V if input supply is 12V. When the TPS25942 detects and declares a fault the FLTb signal is used to drive a P-MOSFET that connects the storage capacitors to the buck input.
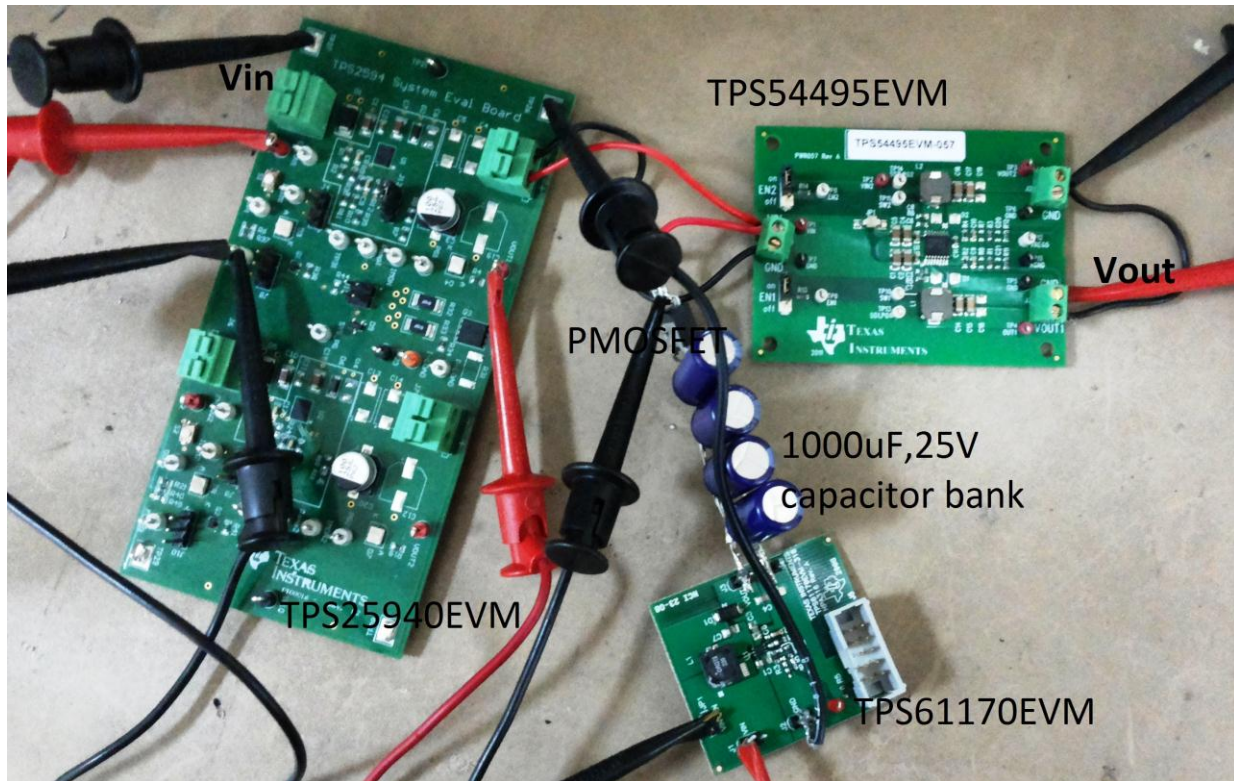
Figure 2 : Test Set-up made by using three EVMs

3. Test Results

Design Configuration for 12V input and 5V buck output
- Vin to TPS25940 12V, UVLO = 10.8V
- Vbus when Vin is present = 12V
- Vboost (output from TPS61170EVM to 1000uF capacitor bank) = 18V
- Buck converter output = 5V
- Pout = 30W @5V, and 15W @5V

Scope label information
- Imon1- Input supply current monitored by TPS25940
- Iboost - Current supplied by the Capacitor bank
- Vout - Buck Converter output (5V)
- Vbus - The output of the TPS25940 and the input of TPS61170 (Boost Converter) and TPS544959 (buck converter)
- VIN - Input supply voltage to the system (5V to 12V)

The next 6 waveforms are with Pout = 30W @5V
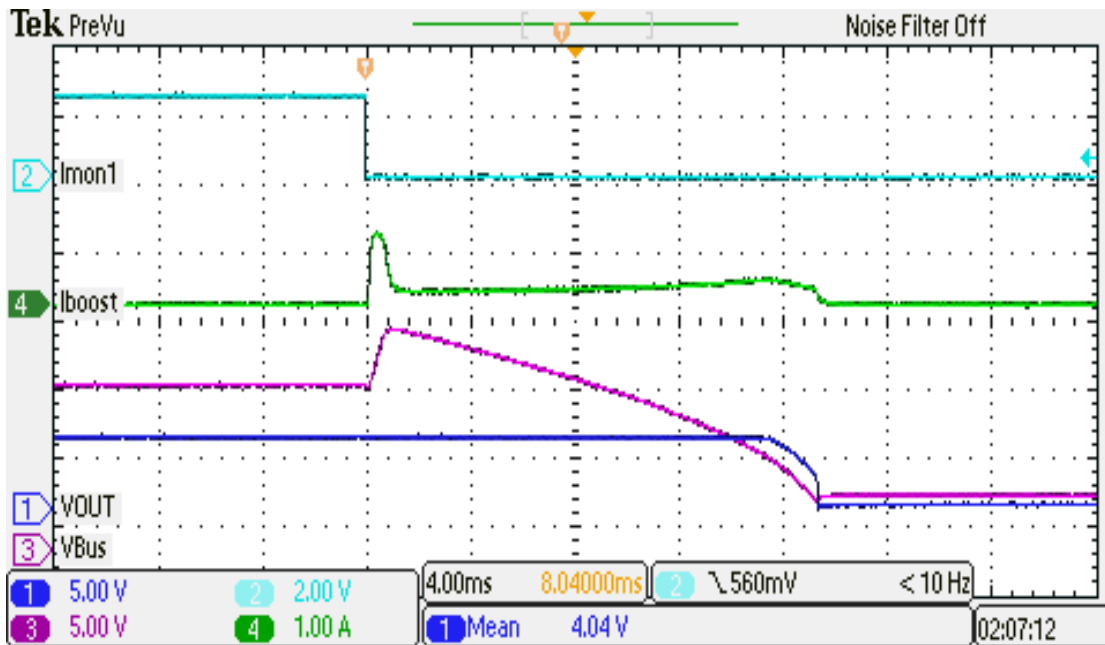
Figure 3: Input current (Imon1), Boost Current (Iboost), Vboost and Vout at 30W power output (when VIN fails)

Figure 3 show the uninterrupted operation of the system when Vin fails (Imon1 goes down), PFET get enabled and Vbus start rising as the capacitor was charged to 18V, and shows that Vout is stable during the backup time.

Figure 4 below shows the backup time (15.8ms) when Vin fails (input current Imon1 drops), Vbus start raising, 1000uF capacitor bank feeds 30W power to the load and finally Vout drops after 15.8ms of back up time.
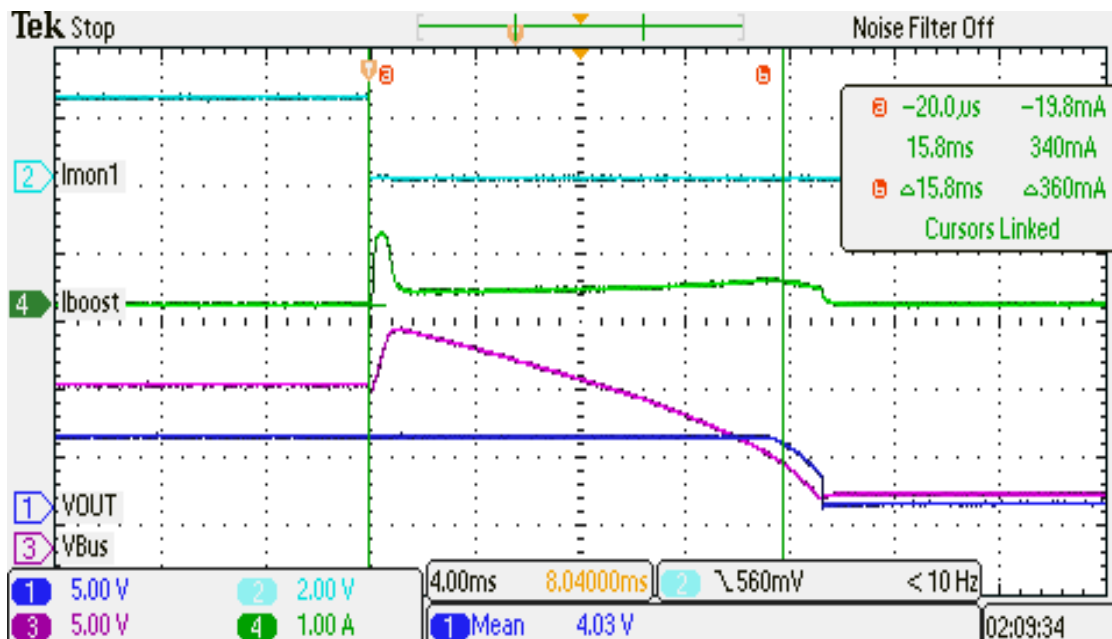
Figure 4: Power back- up time (15.8ms) while delivering 30W

Figure 5 below shows when input power is plugged out and Vin Floats, system shows the smooth and stable changeover from input to capacitor bank while feeding power (30W) to load for 15.8ms back-up time without interruption.
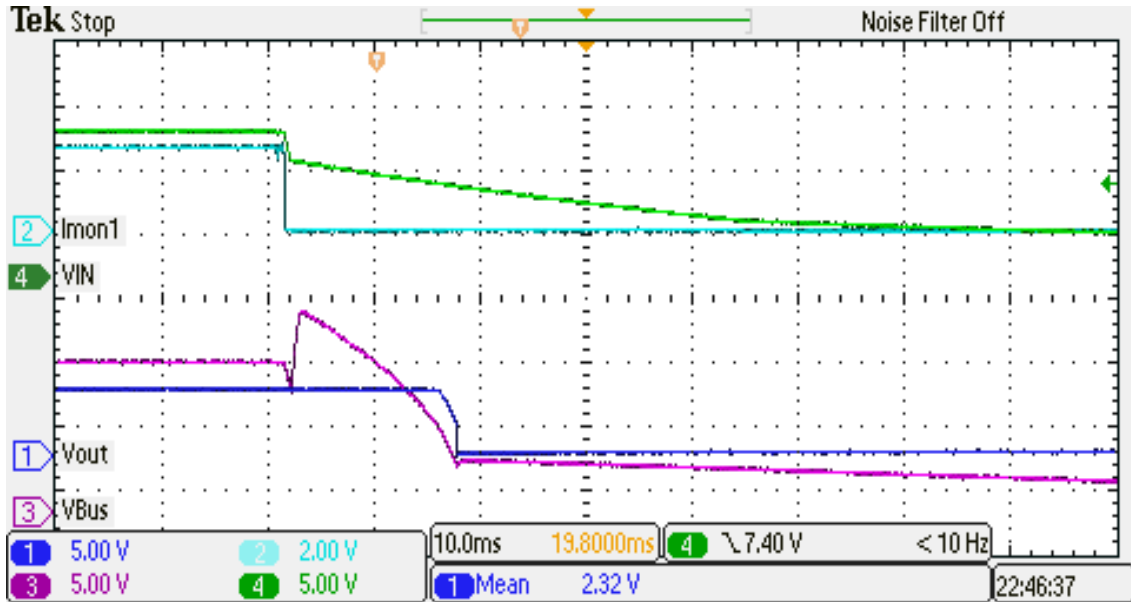

Figure 5: VIN, Input current (Imon1), VBus and Vout at 30W power output with VIN float

Figure 6 below shows the power turn "ON" (Startup) operation of system, Vin , Vboost, Vbus and Vout are up.
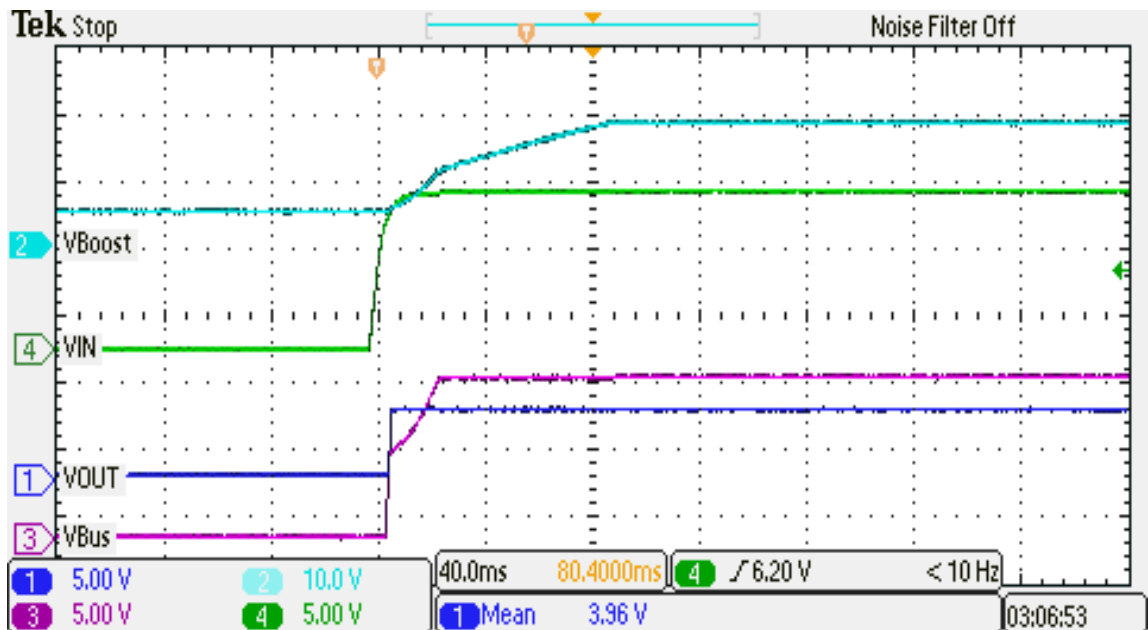

Figure 6: Vin, Vboost, Vbus, Vout at 30W power output with Vin turn "ON"
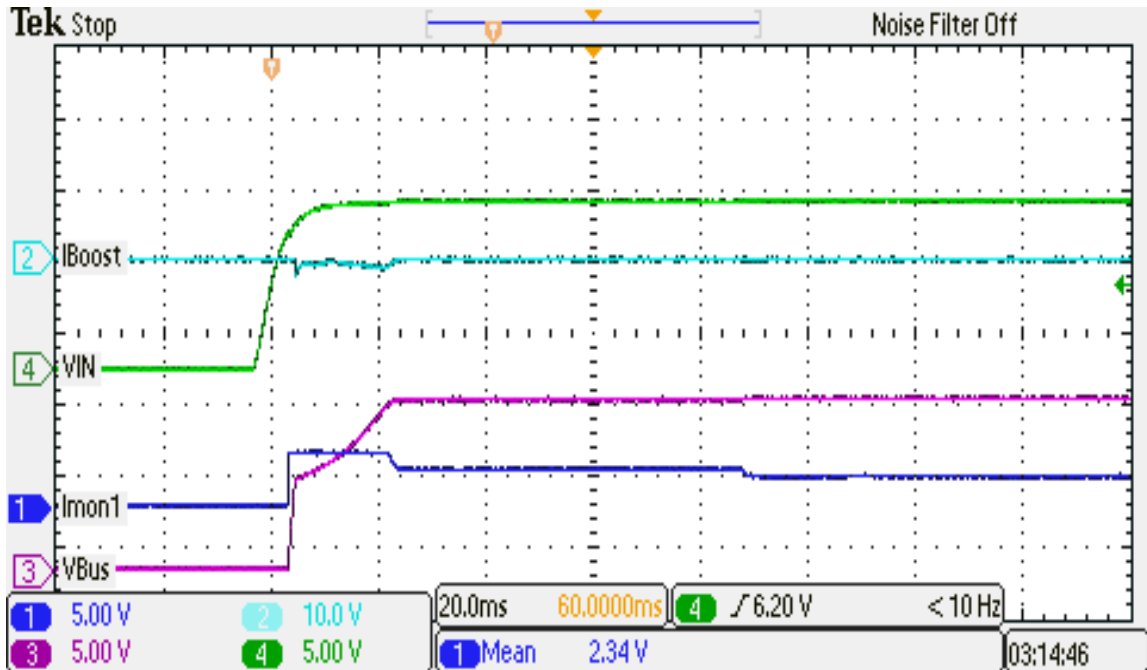
Figure 7: VIN, Vbus, IMON1 and Iboost with VIN turn "ON" with 30W load connected

The current (Iboost) from capacitor bank to load and Vbus operation is shown in figure 8, when, VIN pulled out from the system.
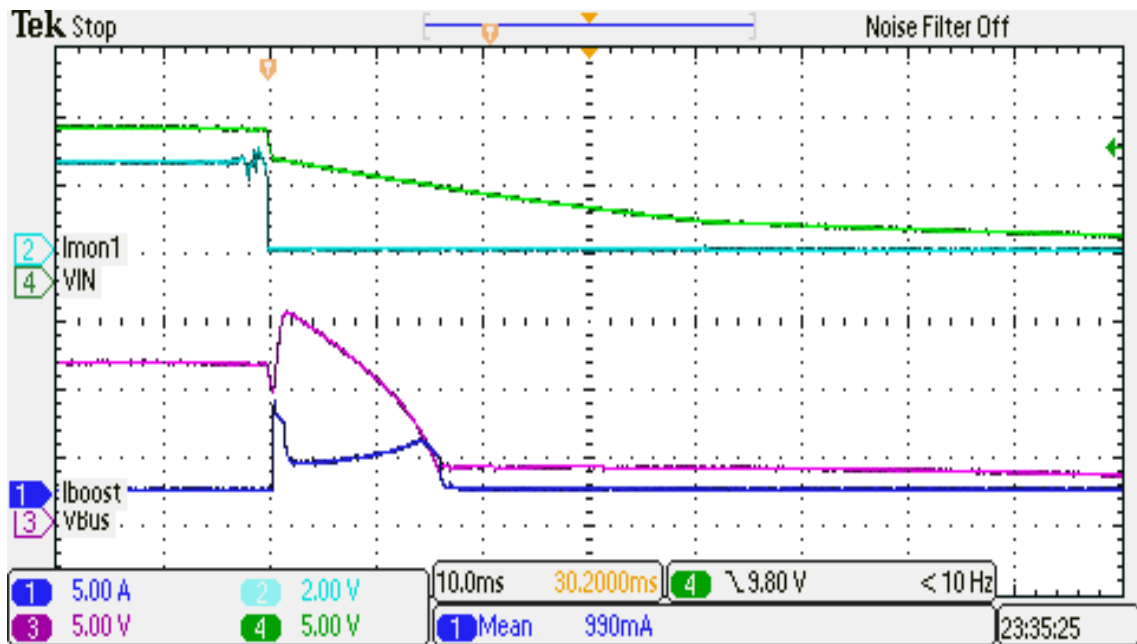

Figure 8: VIN, Vbus, IMON1 and Iboost at 30W power output with Vin pulled out

The next 7 waveforms are with Pout = 15W @5V

The similar system performance (as for 30W) is shown for the 15W@ 5V, with increased back-up time (31ms) in figure 9 thru figure 13 below.   The waveforms are explained under every figure.
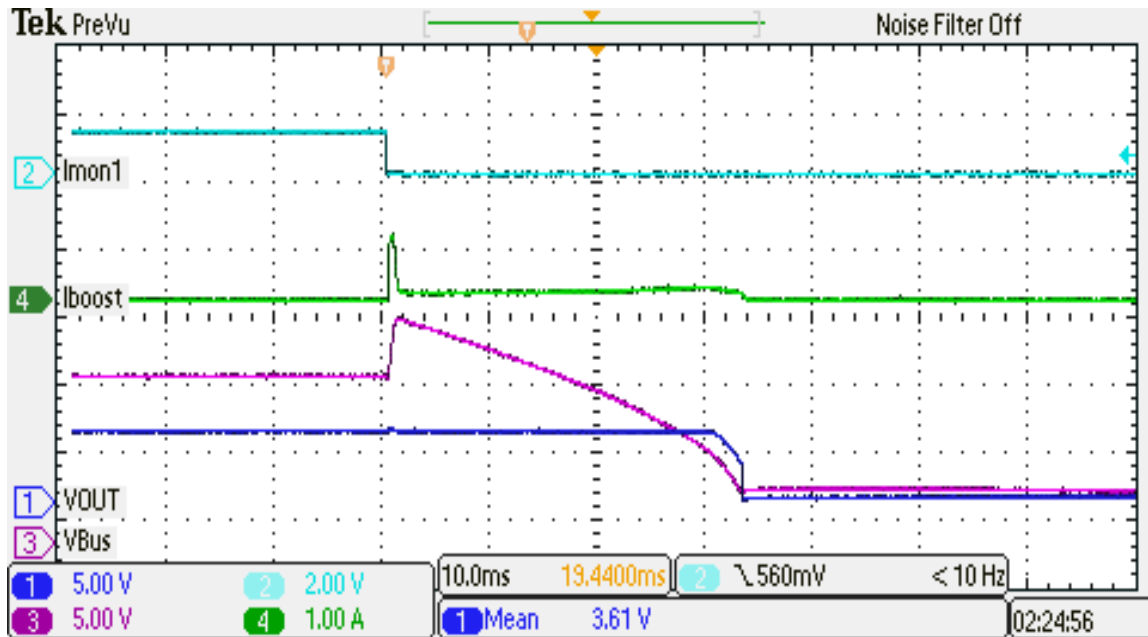

Figure 9: Input current (Imon1), Boost Current (Iboost), Vboost and Vout at 15W power output (when VIN fails)
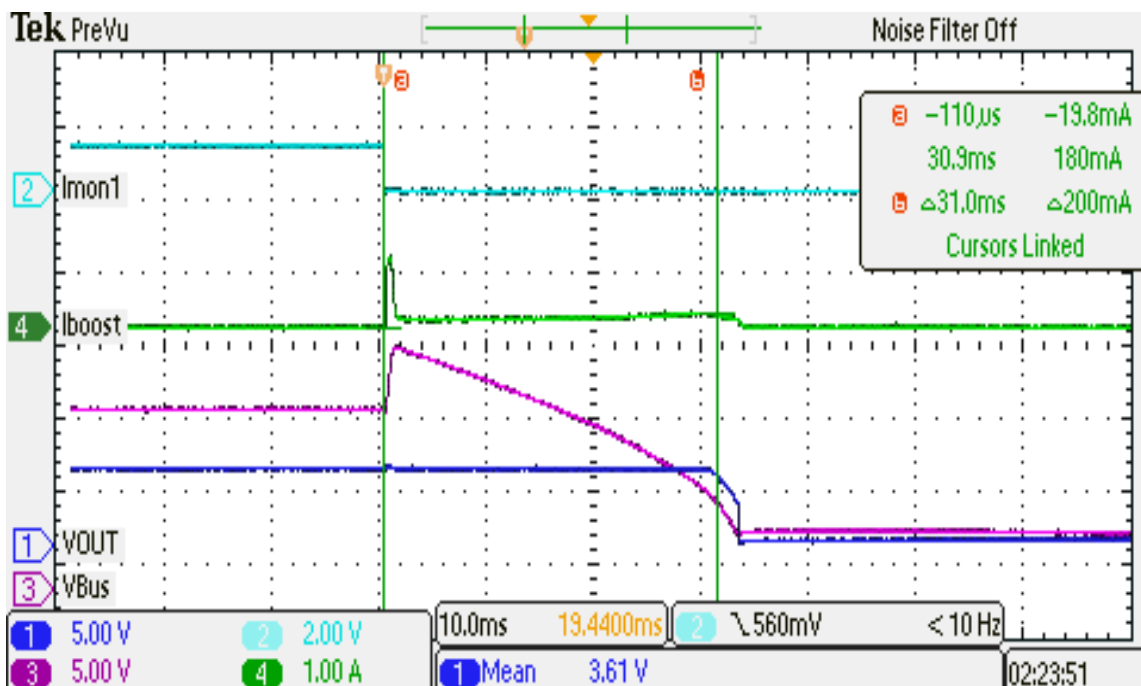

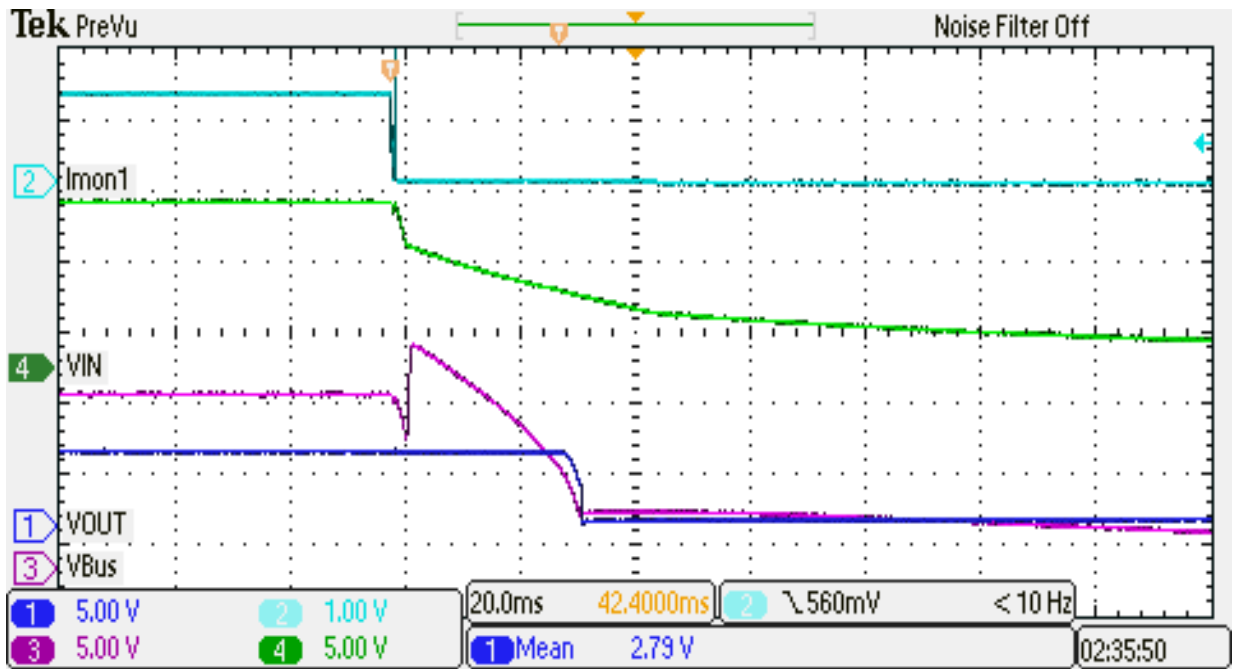**Figure 10: Power back- up time (31.0ms) while delivering 15W**

Figure 11: Vin, Input current (Imon1), Vbus and Vout at 15W power output with Vin float
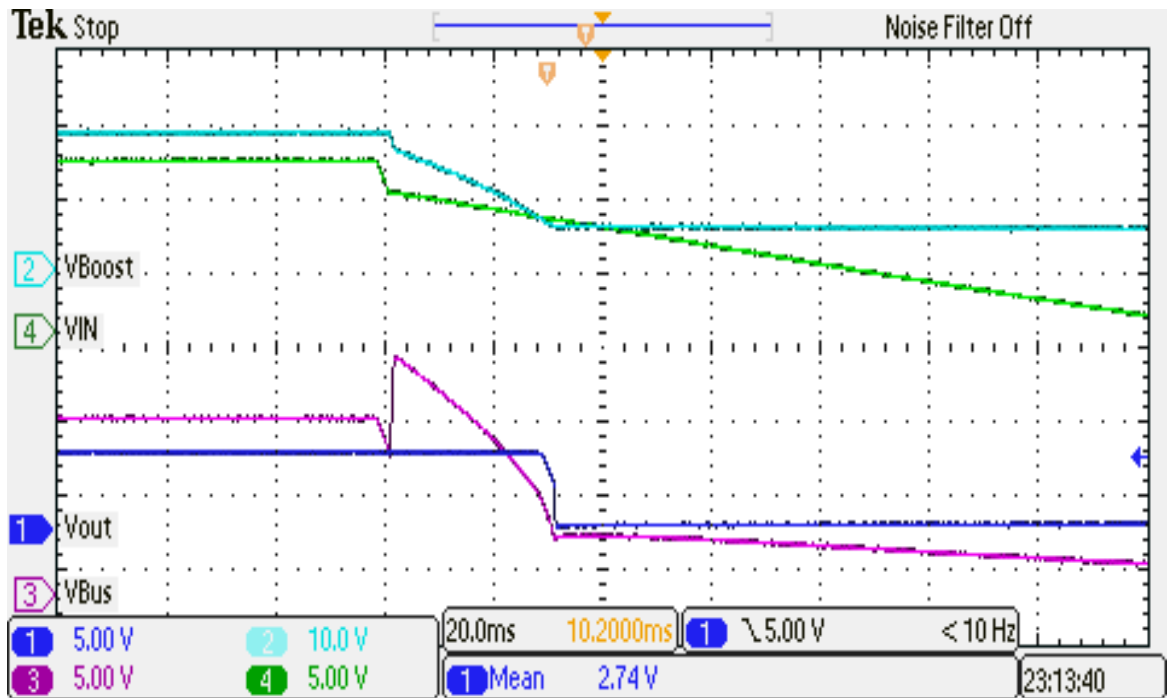
Figure 12: VIN, Vboost, Vbus, and Vout at 15W power output with Vin turn "OFF"
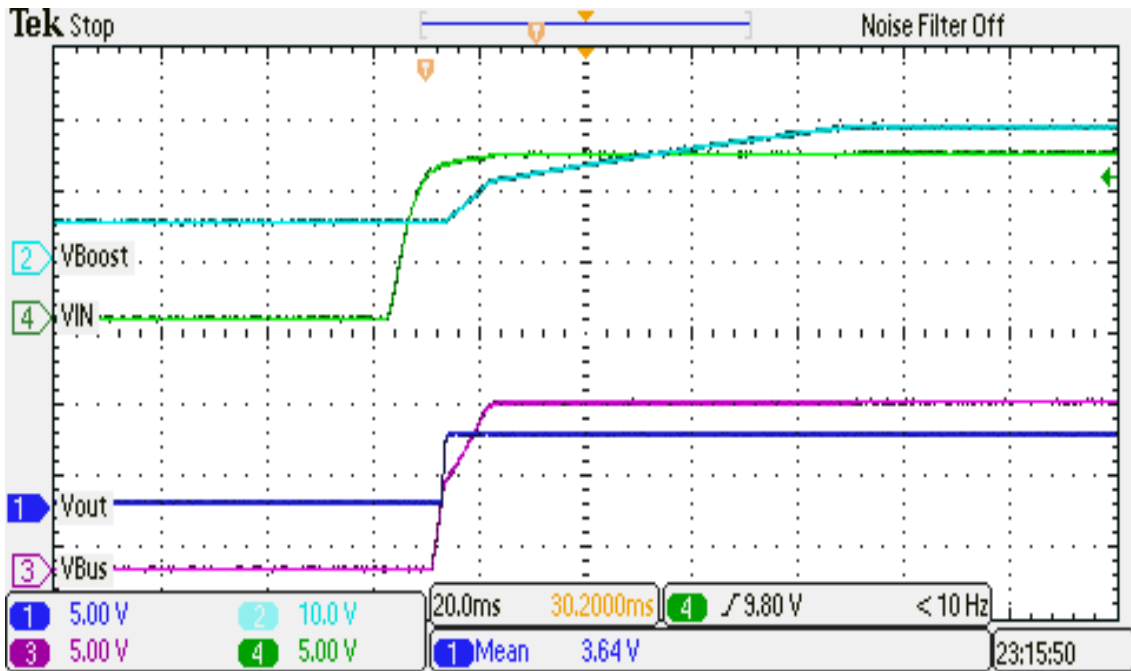
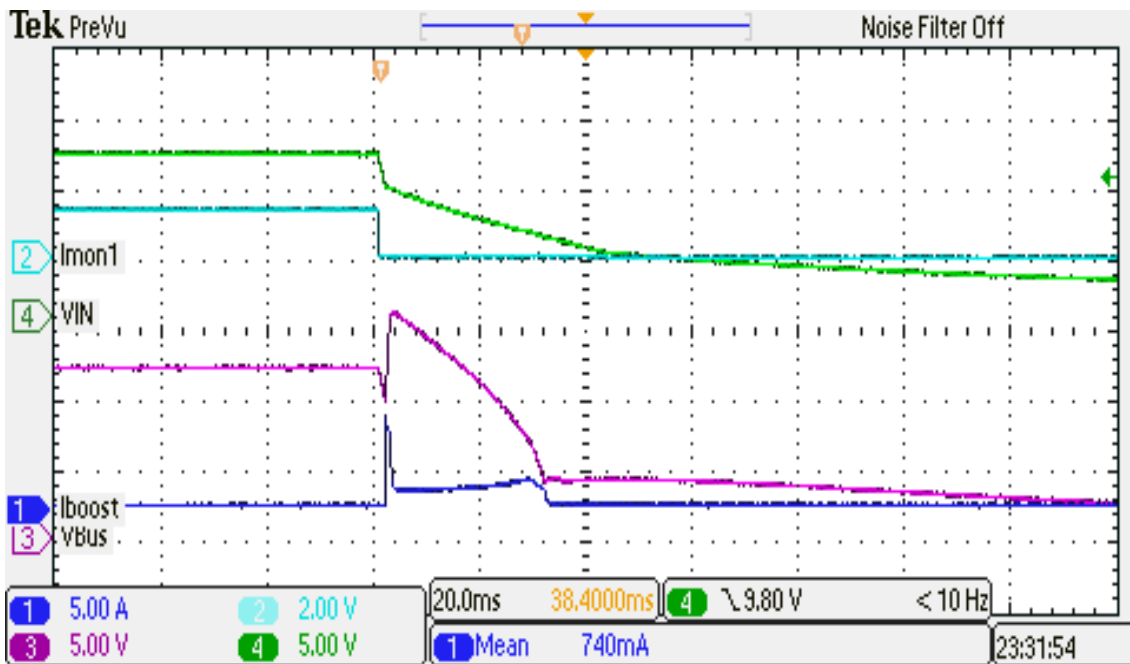**Figure 13: Vin, Vboost, Vbus, Vout at 15W power output with Vin turn "ON"-**

Figure 14: VIN, Vbus, IMON1 and Iboost at 15W power output with VIN pulled out
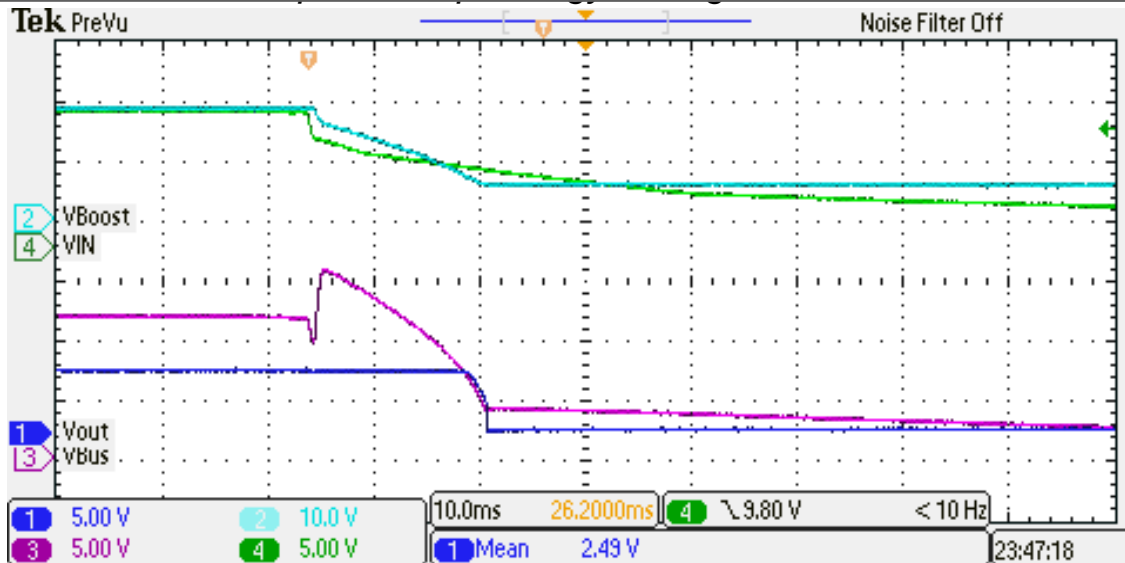
Figure 15: VIN, Vboost, Vbus, Vout at 15W power output when VIN pulled out

Design Configuration for 5V input and 3.3V buck output
- Vin to TPS25940 =5V, UVLO= 4.75V
- Vbus when Vin is present = 5V
- Vboost (output from TPS61170EVM to 1000uF capacitor bank) = 12V
- Buck converter output = 3.3V
- Pout = 16W @3.3V, and 8W @3.3V

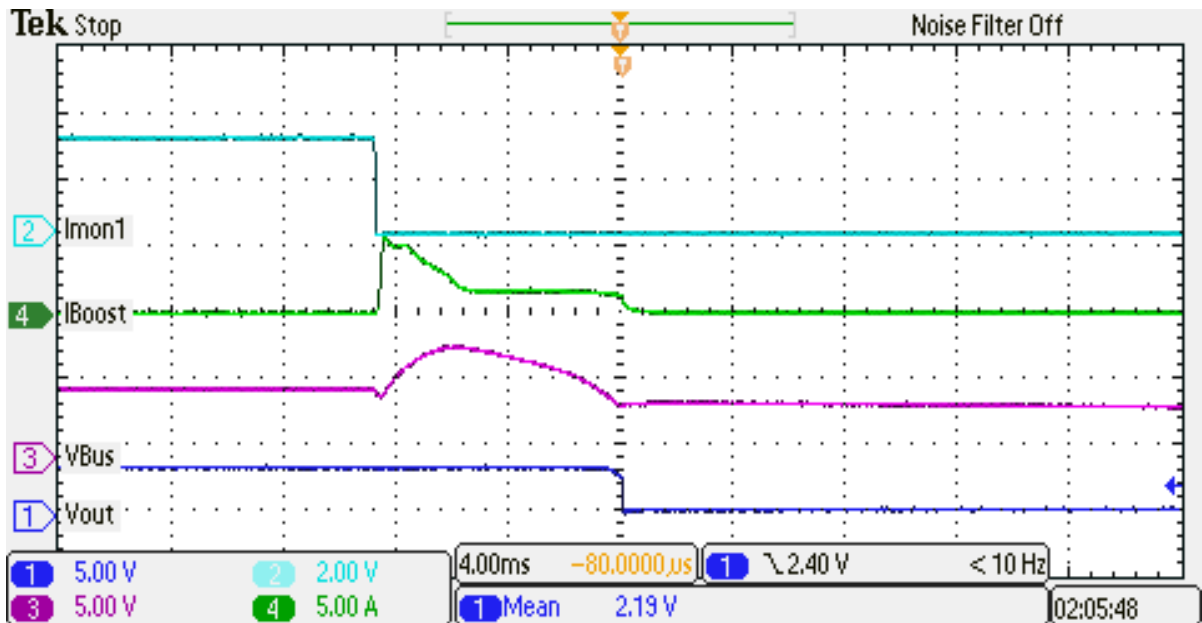**The next 5 waveforms are with Pout = 16W @3.3V**

Figure 16: Input current (Imon1), Iboost, Vbus, Vout at 16W output (when VIN fails)

Figure 16 shows the uninterrupted operation of the system when Vin fails (Imon1 goes down), PFET get enabled and Vbus start rising as the capacitor was charged to 12V, and shows that Vout is stable during the backup time.

Figure 17 below shows the back-up time (8.8ms) when Vin fails (input current, Imon1 drops), and Vbus start raising, 1000uF capacitor bank feeds 16W power to the load and finally Vout drops after 8.8ms back up time.
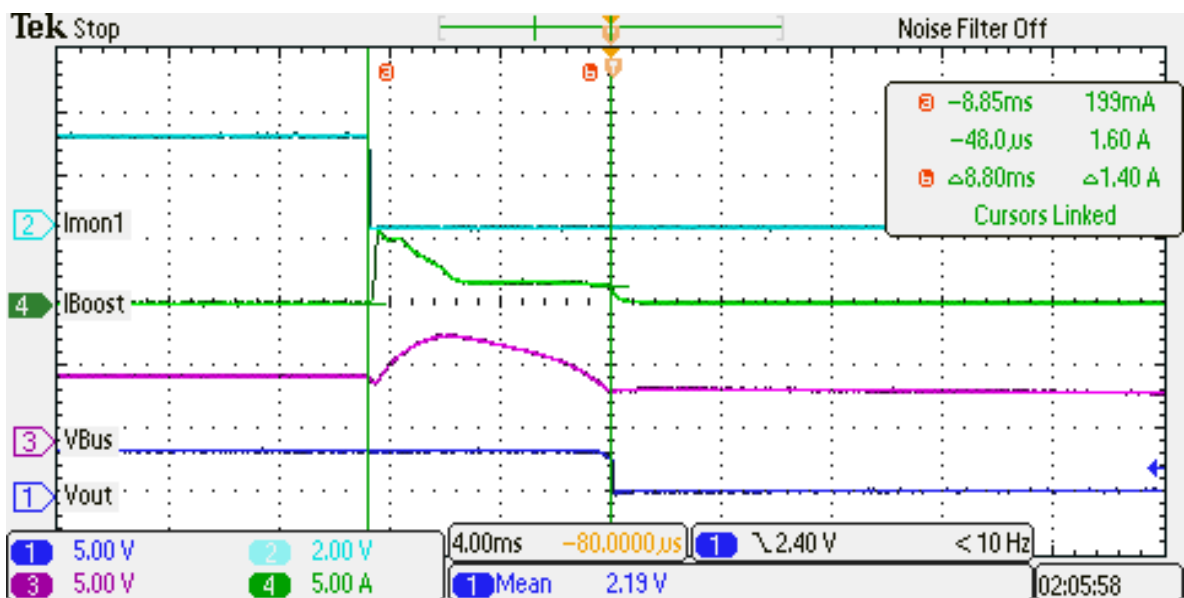

Figure 17: Power back- up time (8.8ms) while delivering 16W

The Figure 18 shows when input power is turned "OFF", system show the stable change over from input to capacitor back, fees power(16W) to load for (8.8ms) back-up time without interruption.
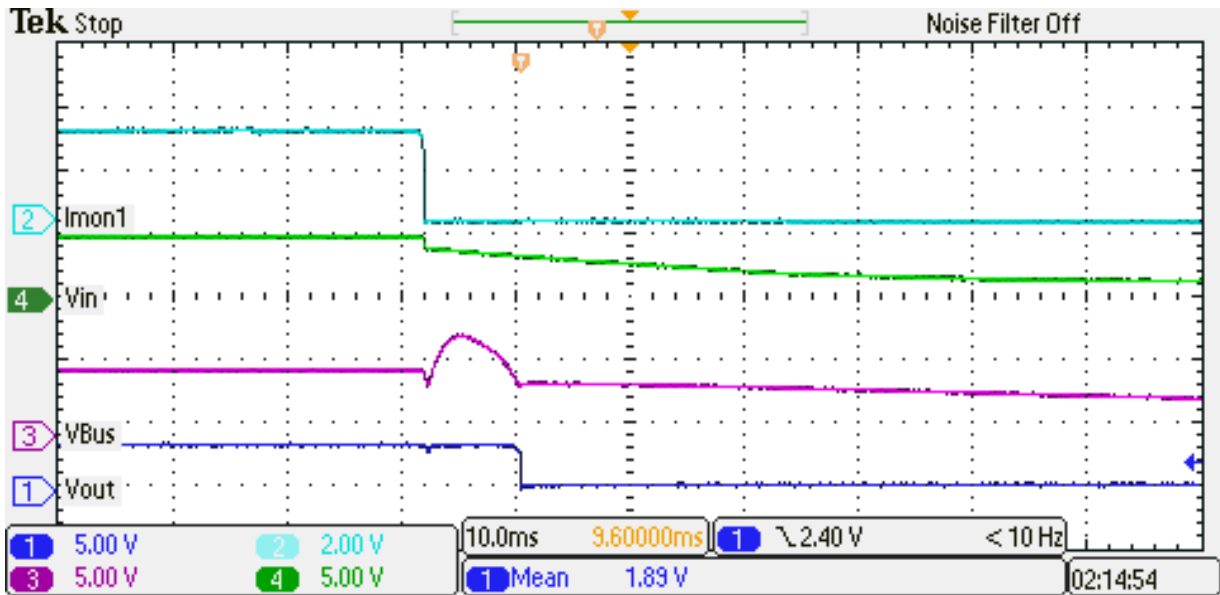

Figure 18: Vin, Input current (Imon1), Vbus and Vout at 16W power output with Vin Turned "OFF"

Figure 19 below shows the Vin, Vboost, Vbus and Vout operations when input power turned "ON" (Startup).

Figure 19:Vin, Vboost, Vbus, Vout at16W power output with Vin turn "ON"
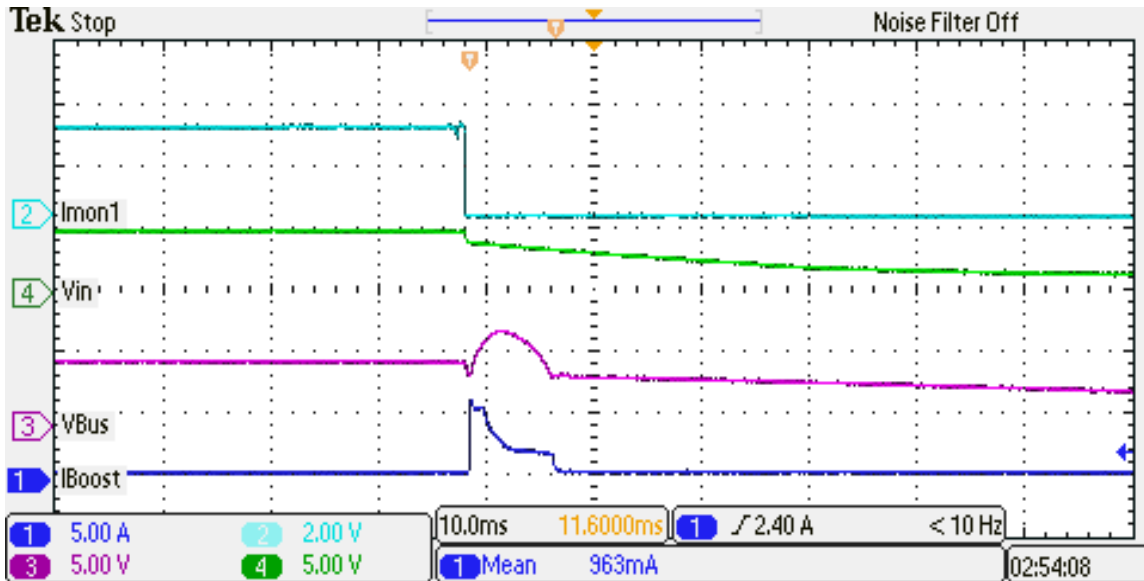
Figure 20: Vin, Vbus, Imon1 and Iboost at 16W power output with Vin pulled out

The current (Iboost) from capacitor bank to load and Vbus operation is shown in figure 20, when Vin is pulled out from the system.

The next 5 waveforms are with Pout = 8W @3.3V

The similar system performance (as for 16W) is shown for the 8W@ 5V, with increased back-up time (17.8ms) in figure 21 thru figure 24. The waveforms explanation is shown under the every figure.
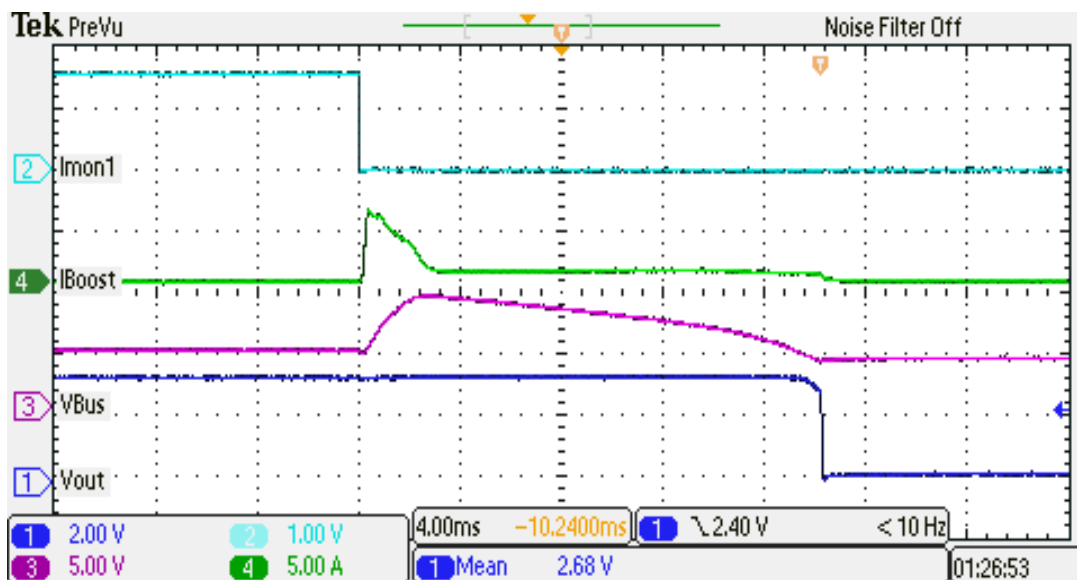
Figure 21: Input current (Imon1), Boost Current (Iboost), Vboost, Vout, delivering 8W Output

Figure 22: Power back- up time (17.8ms) while delivering 8W (with EN Control)

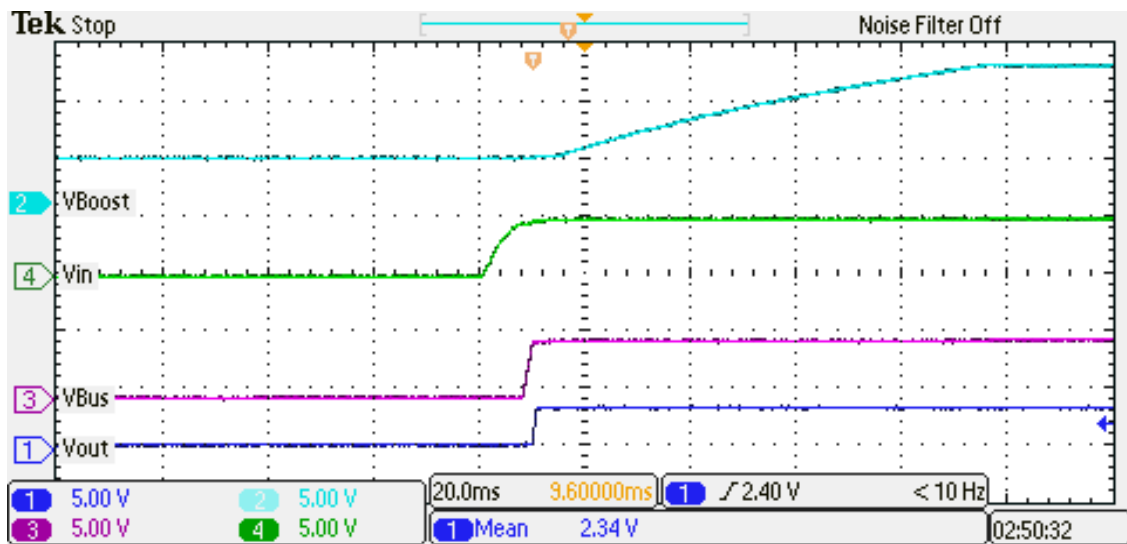**Figure 23: Vin, Vboost, Vbus, Vout at 8W power output with Vin turn "off"**

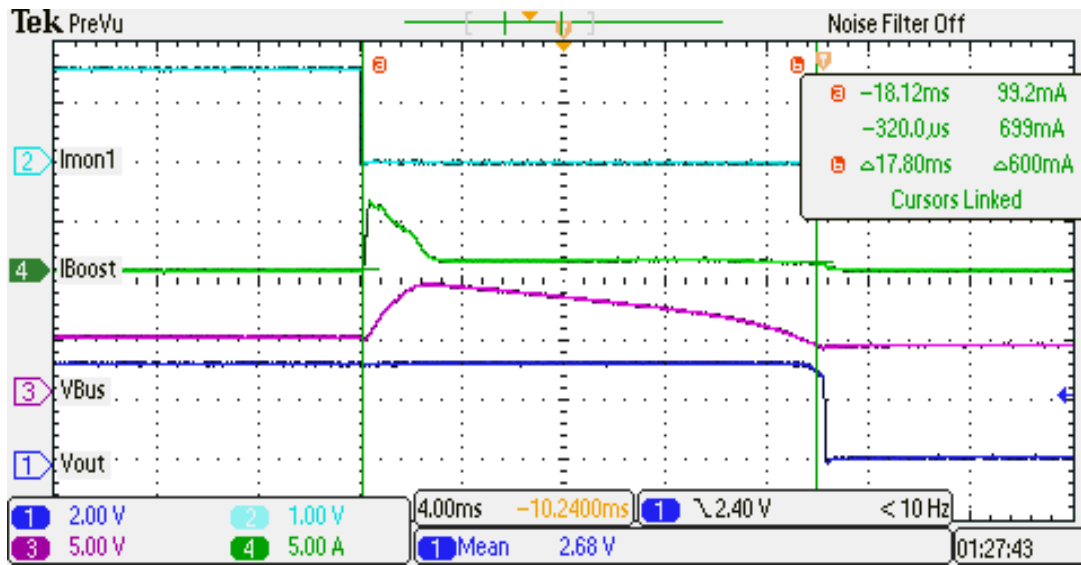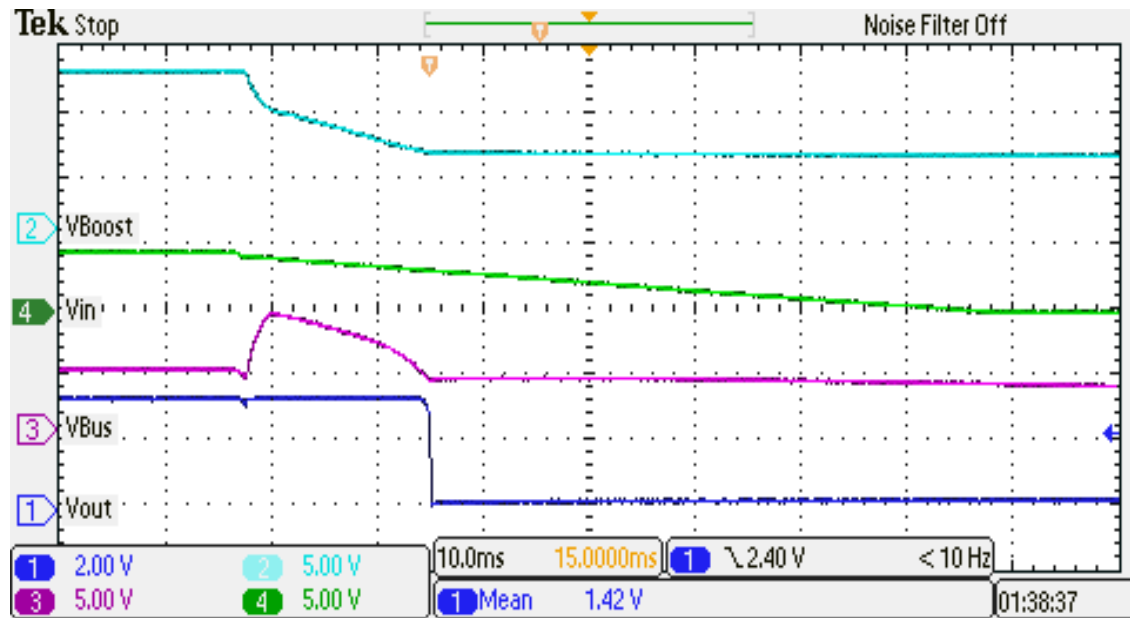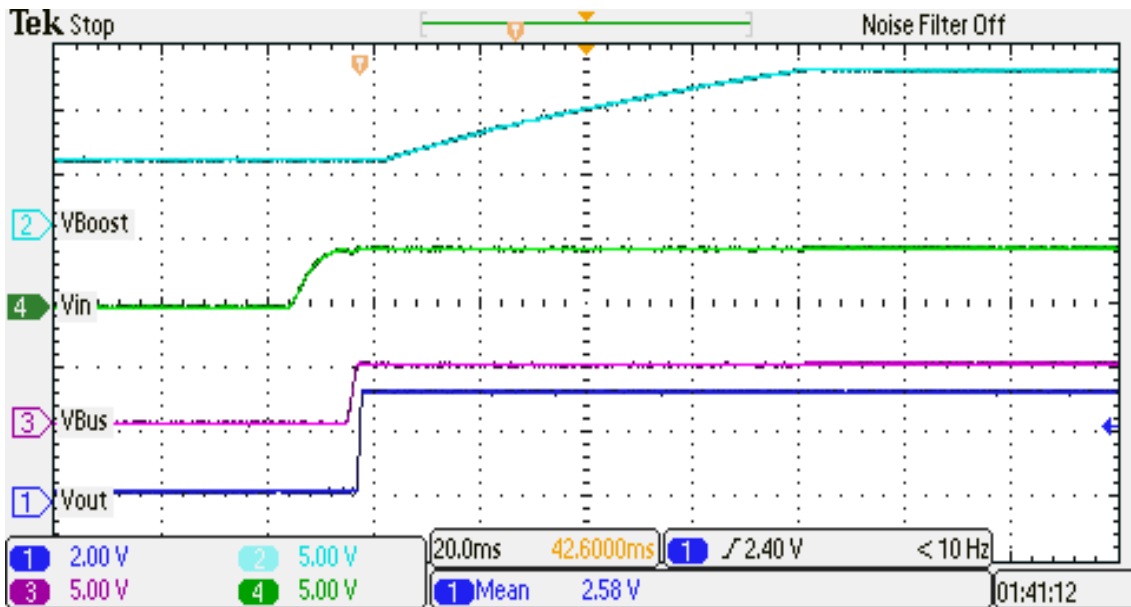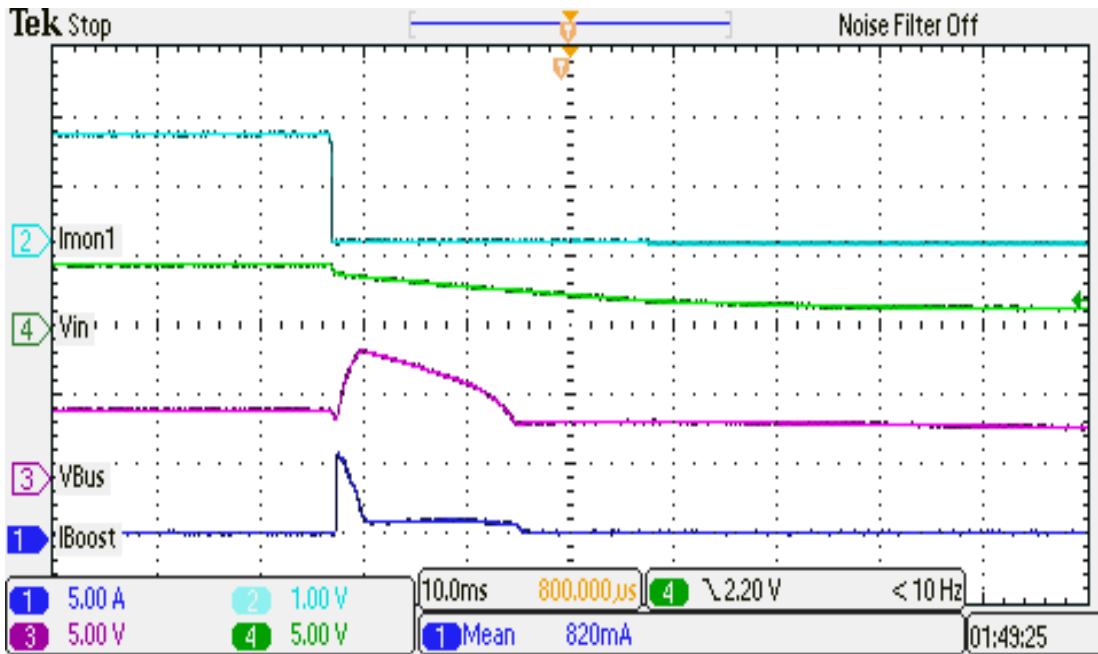**Figure 24: Vin, Vboost, Vbus, and Vout at 8W power output with Vin turn "ON**

Figure 25: Vin, Vbus, IMON1 and Iboost at 8W power output with input supply (Vin) pulled out

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