

Automotive Wide- V_{IN} to Point-of-Load Power Supply With Front-End Circuit Protection Reference Design

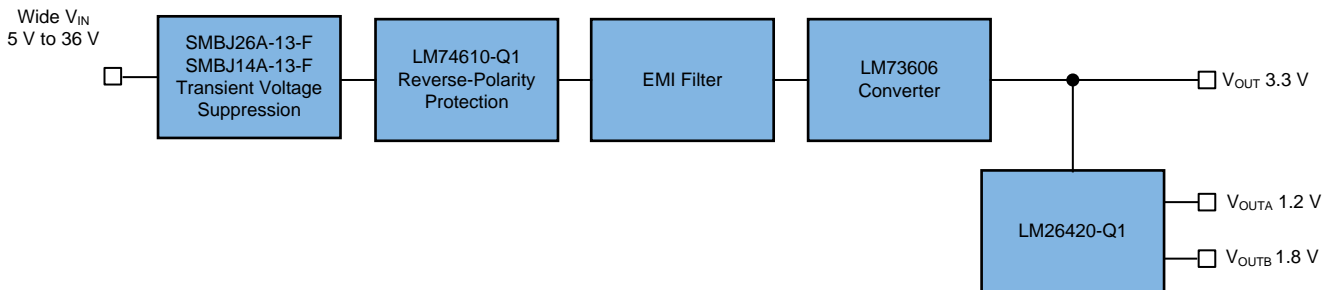


Description

This automotive point-of-load power supply reference design features complete front-end protection in a small overall solution size. The system can clamp fast, high-voltage, electrical transients and maintain operation through these events. The system can also properly respond to a reverse battery polarity event and shut down appropriately. This three-output design employs sequencing of two buck regulators to ensure proper power-on and power-down timing, and features an input pi filter to reduce conducted EMI. The design accepts an input voltage of 5 V to 36 V and provides outputs of 3.3 V, 1.2 V, and 1.8 V. This supply is capable of supplying 2 A on the 1.8-V and 1.2-V outputs, while the 3.3-V output simultaneously supplies 3.55 A.

Features:

- Complete wide- V_{IN} front-end automotive power supply
- Off-battery operation with reverse battery protection
- Positive and negative transient voltage protection
- Auto-sequencing of all three power rails
- Reduced EMI with included pi filter



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Figure 1. Functional Block Diagram

This design was built on a 4-layer board (2 oz. copper on top and bottom layers and 1 oz. copper on two inner layers), see [Figure 2](#) and [Figure 3](#).

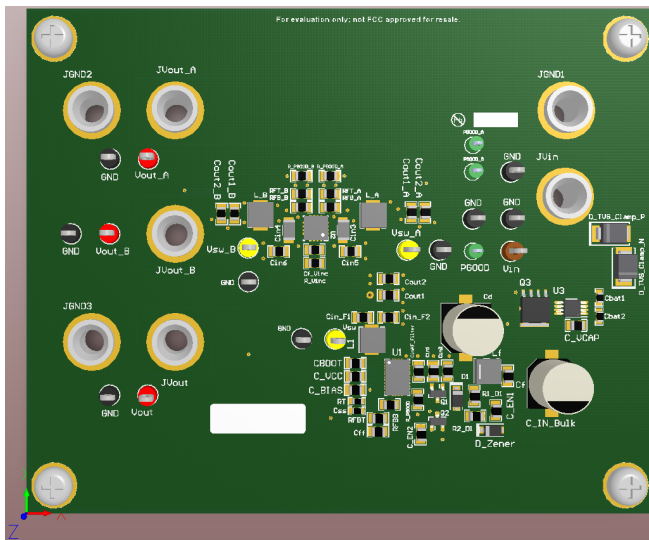


Figure 2. PCB 3D Render: Top View

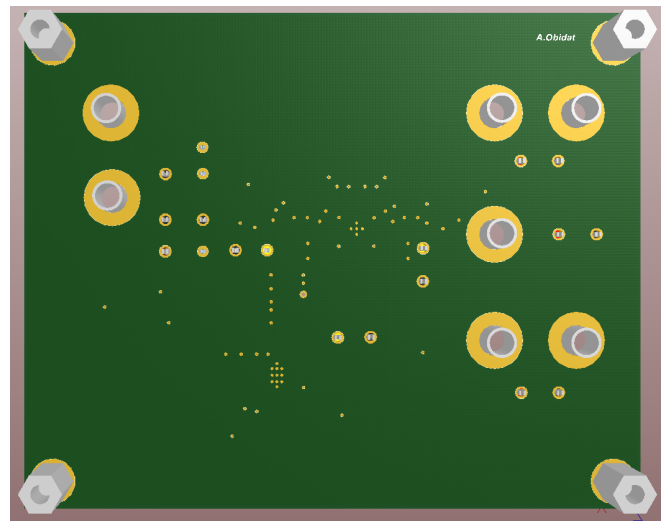


Figure 3. PCB 3D Render: Bottom View



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1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1. Voltage and Current Requirements

PARAMETER	SPECIFICATION
Minimum V_{IN}	5 VDC
Maximum V_{IN}	36 VDC
V_{OUT}	3.3 VDC
V_{OUT_A}	1.2 VDC
V_{OUT_B}	1.8 VDC
Switching frequency	2200 kHz

For this design, two buck converters were placed in series to generate three independent output voltage rails. The relation between the input and output voltage is as follows in [Equation 1](#):

$$V_{OUT} = D \times V_{IN} \quad (1)$$

The LM73606 is a synchronous buck converter IC and it generates the first output voltage rail. The maximum output current of the LM73606 is 6 A, which is less than the input current required for the secondary buck converter. The secondary buck, LM26420-Q1, is an automotive grade synchronous buck converter that provides dual, regulated output voltages, each capable of sourcing a maximum output current of 2 A. The LM73606 output is capable of supplying a maximum of 3.55 A when all three outputs are supplying their maximum load currents.

The voltage loop regulation of each output is achieved using a resistive divider between V_{OUT} , the feedback node, and GND. A constant reference voltage is maintained on the feedback node, such that the output voltage can be set by selecting the appropriate values of the resistors on the divider.

1.2 Circuit Description

The PMP15023 is a wide V_{IN} to point-of-load solution that demonstrates the proper precautions that are taken to protect point-of-load regulators from the typical fault conditions that occur in an automotive application. The design features three output voltages using two sequenced buck converters placed in series. The circuit also includes transient voltage suppression using the SMBJ26A-13-F and SMBJ14A-13-F components and it provides reverse-polarity protection by means of a smart diode circuit.

The smart diode circuit controller, LM74610-Q1, and accompanying FET ensure that the impedance remains high when the polarity is reversed, such that, effectively no current flows from the output to the input of the circuit.

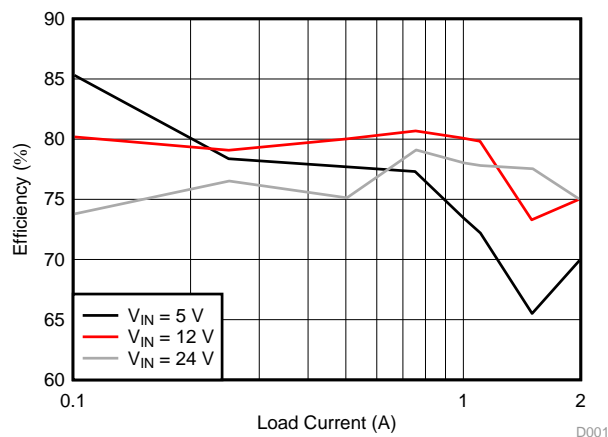
The buck converters are both sequenced by a subcircuit that uses two transistors, a bypass diode and a pair of capacitors, and series resistors. The circuit ensures that the primary regulator powers up before the secondary regulator, and that the secondary regulator powers down before the primary regulator.

The design accepts an input voltage of 5 V to 36 V, and provides outputs of 3.3 V, 1.2 V, and 1.8 V, capable of supplying 2 A of load on the 1.8 V and 1.2-V outputs, while the 3.3-V output simultaneously supplies 3.55 A.

2 Testing and Results

2.1 Efficiency Graphs

Figure 4 shows the efficiency versus load current graph.



- (1) The load current for each output was set to the same value for each data point shown.

Figure 4. Efficiency Versus Load Current

2.2 Load Regulation

Figure 5, Figure 6, and Figure 7 show load regulation.

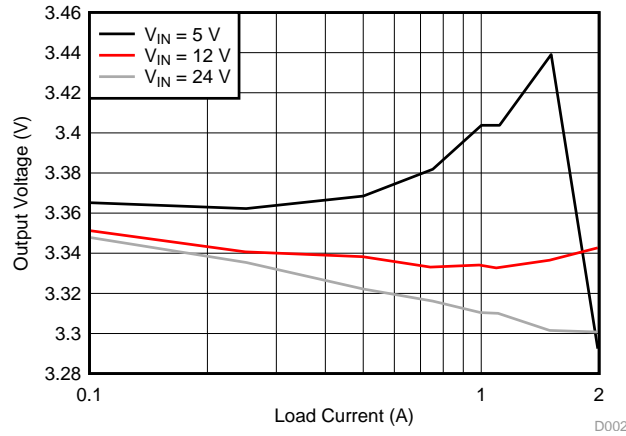


Figure 5. Load Regulation – LM73606 Output

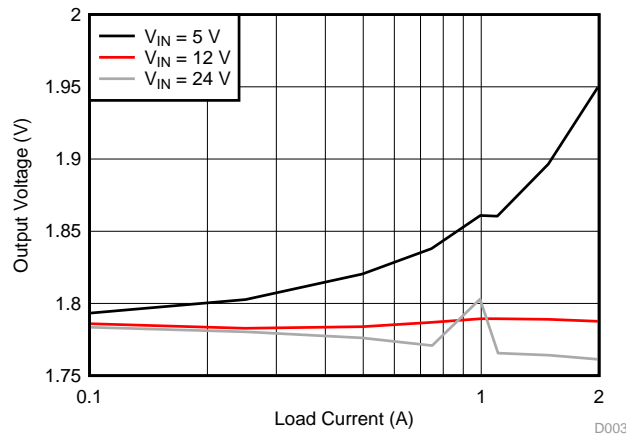


Figure 6. Load Regulation – LM26420-Q1 Output A

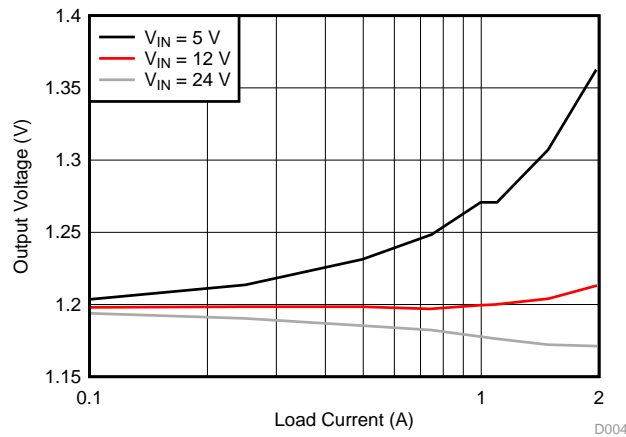


Figure 7. Load Regulation – LM26420-Q1 Output B

2.3 Load Cross-Regulation

Figure 8, Figure 9, and Figure 10 show load cross regulation.

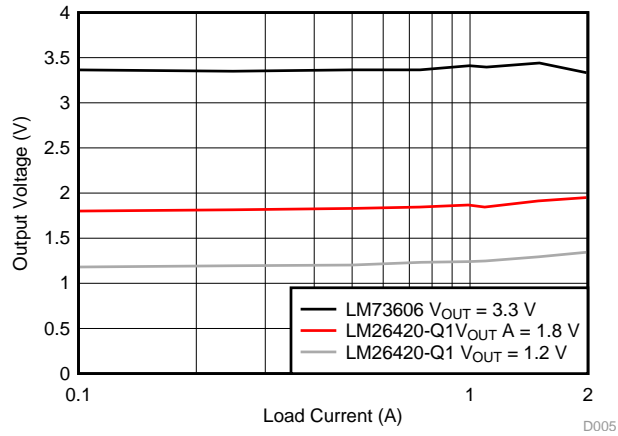


Figure 8. Load Cross-Regulation ($V_{IN} = 5$ V)

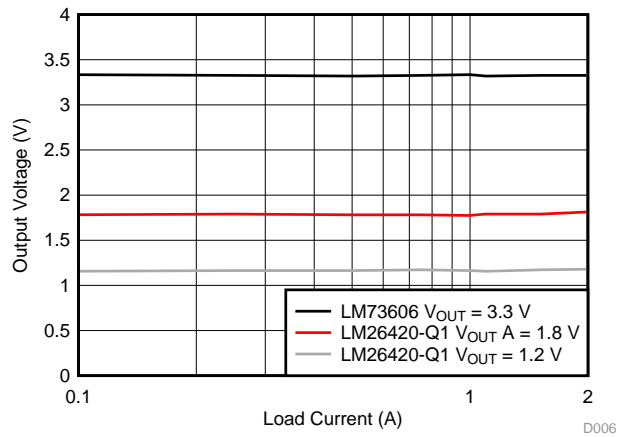


Figure 9. Load Cross-Regulation ($V_{IN} = 12$ V)

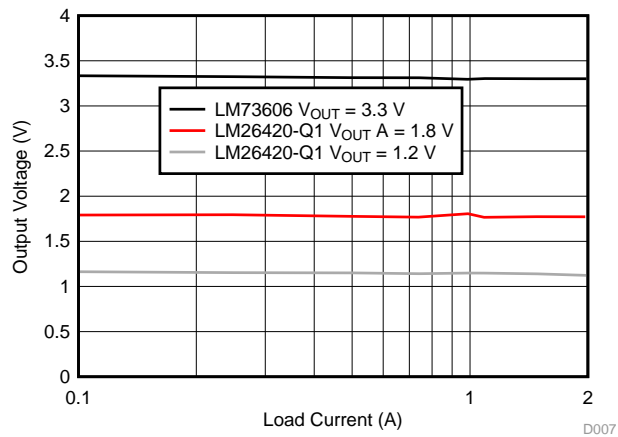


Figure 10. Load Cross-Regulation ($V_{IN} = 24$ V)

2.4 Thermal Images

Figure 11 and Figure 12 show thermal images.

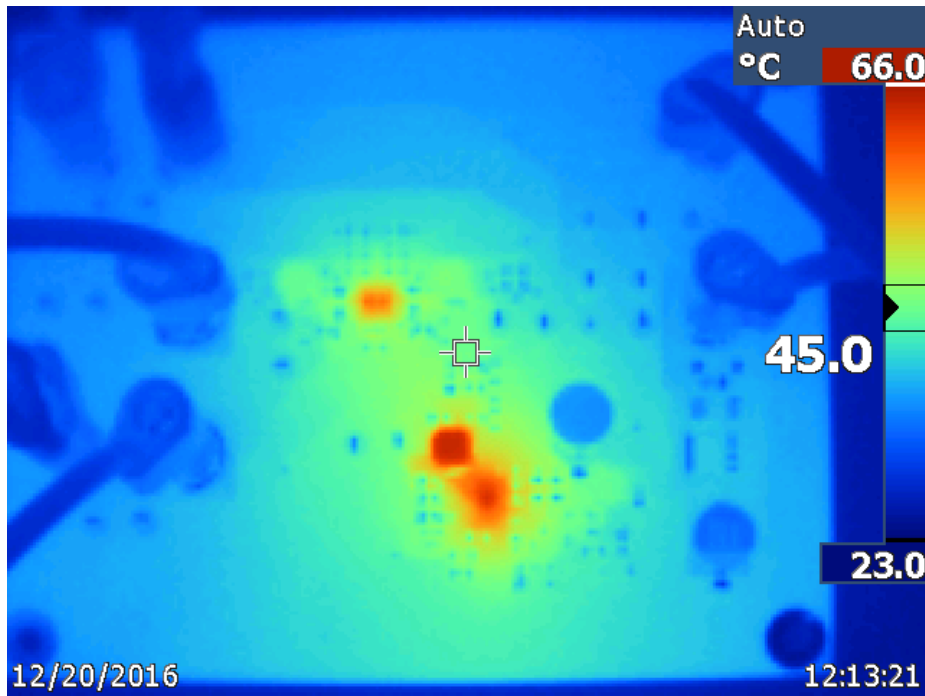


Figure 11. IR Thermal Image at Steady State With 12 V_{IN}, All Outputs at 2-A Load (No Airflow)

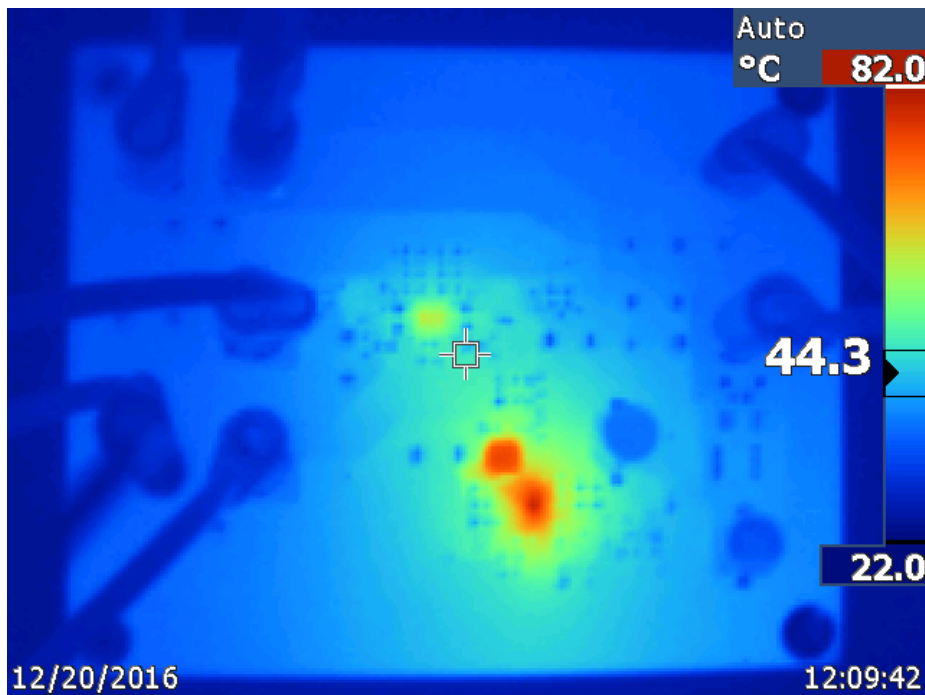


Figure 12. IR Thermal Image at Steady State With 24 V_{IN}, All Outputs at 2-A Load (No Airflow)

2.5 Schematic

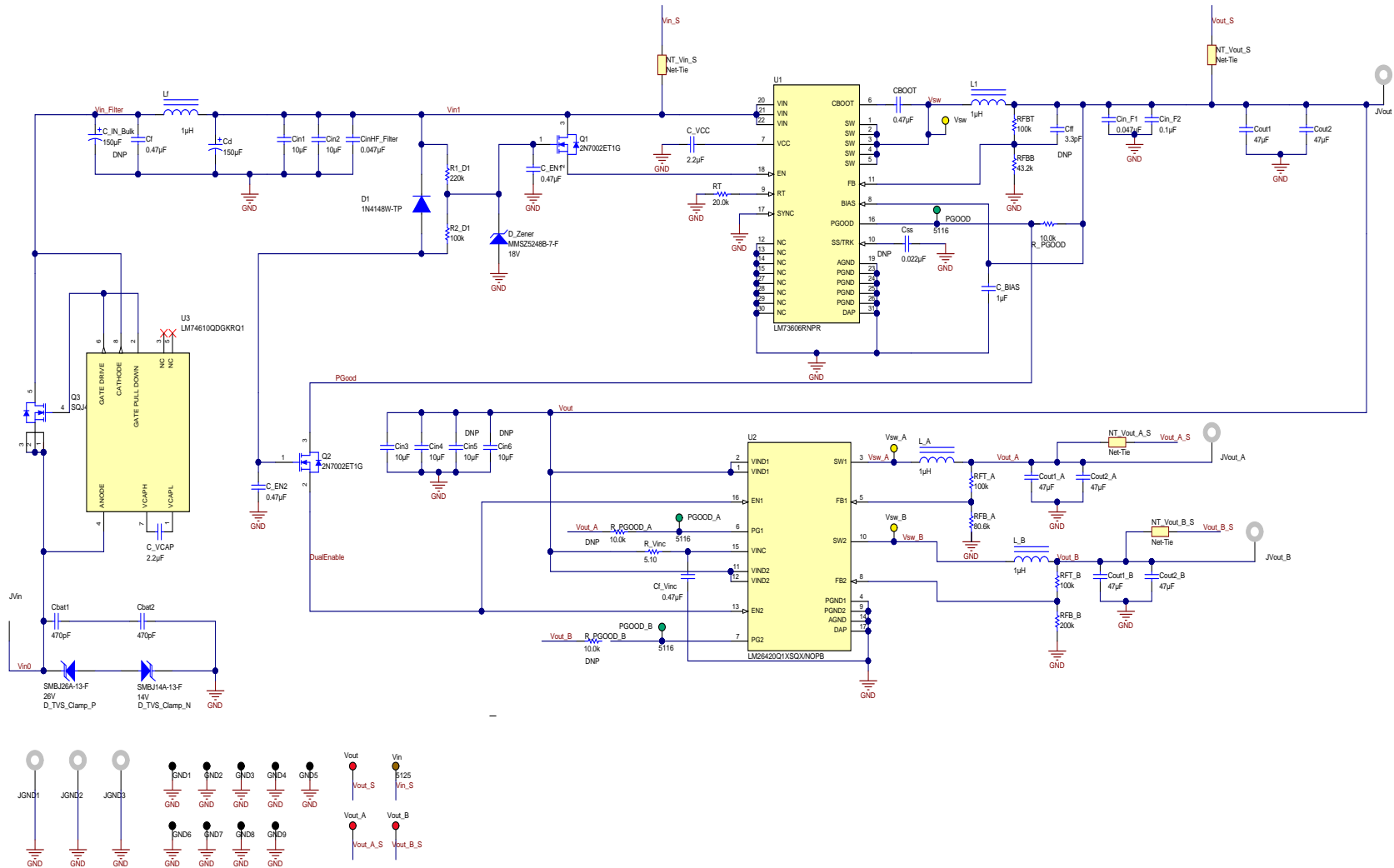


Figure 13. PMP15023 Schematic

3 Waveforms

3.1 Startup from V_{IN}

Figure 14 through Figure 19 show the startup from V_{IN} .

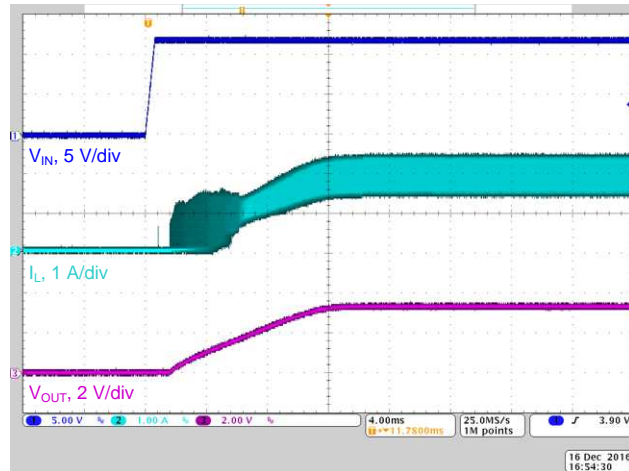


Figure 14. LM73606 – Startup Into 2-A Load, V_{IN} at 12 V

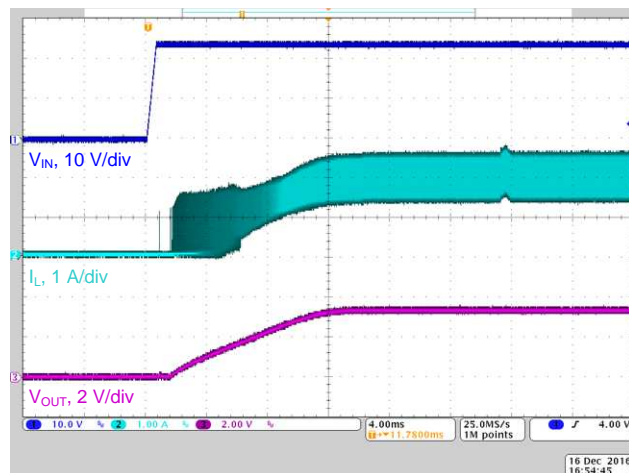


Figure 15. LM73606 – Startup Into 2-A Load, V_{IN} at 24 V

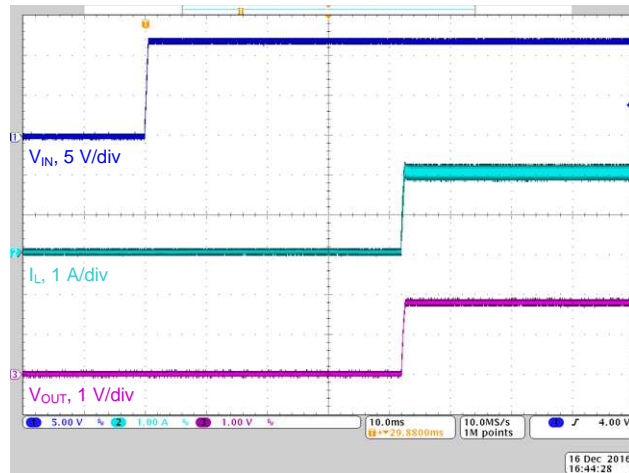


Figure 16. LM26420-Q1 (A) - Startup Into 2-A Load, V_{IN} at 12 V

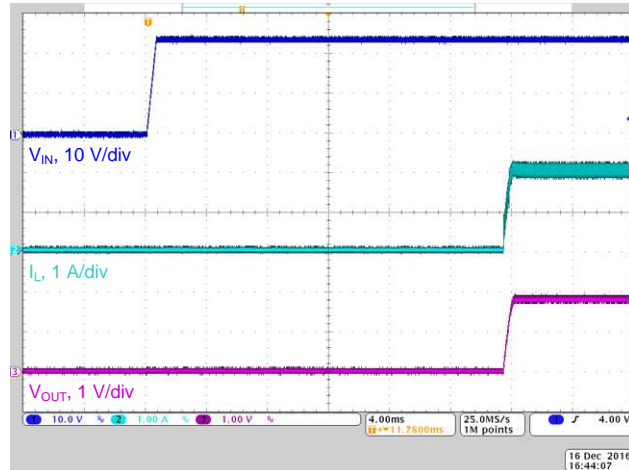


Figure 17. LM26420-Q1 (A) - Startup Into 2-A Load and V_{IN} at 24 V

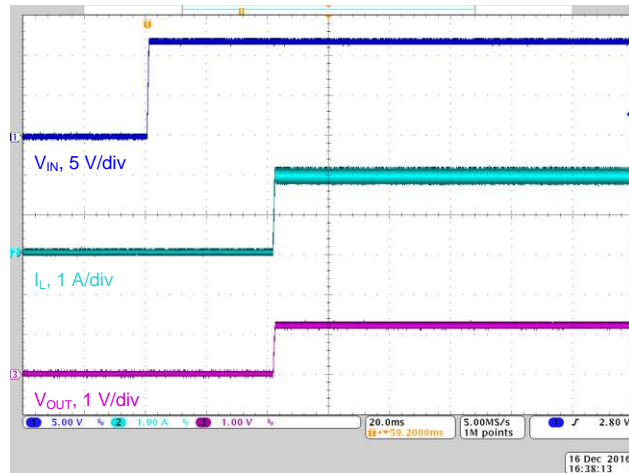


Figure 18. LM26420-Q1 (B) - Startup Into 2-A Load, V_{IN} at 12 V



Figure 19. LM26420-Q1 (B) - Startup Into 2-A Load, V_{IN} at 24 V

3.2 Steady State

Figure 20 through Figure 25 show steady state graphs.

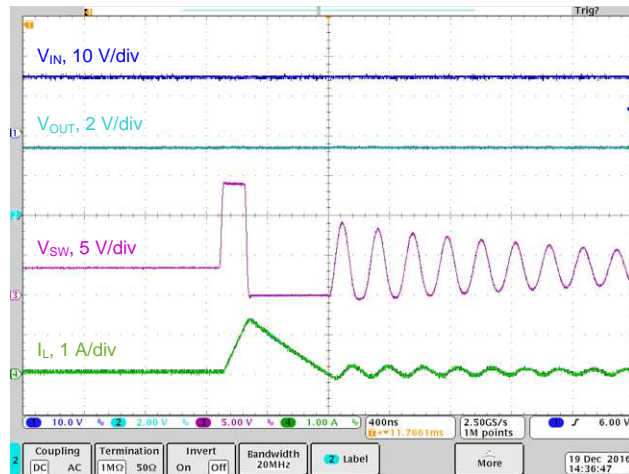


Figure 20. Switch Node Voltage, Inductor Current, and LM73606 Output Voltage at 12 V_{IN} , No Load

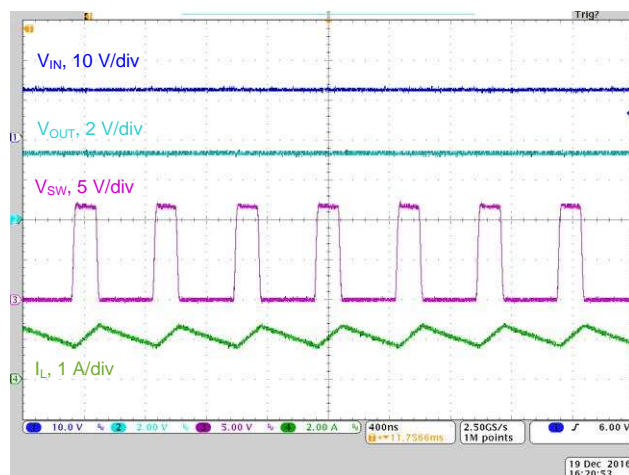


Figure 21. Switch Node Voltage, Inductor Current, and LM73606 Output Voltage at 12 V_{IN} , 2-A Load

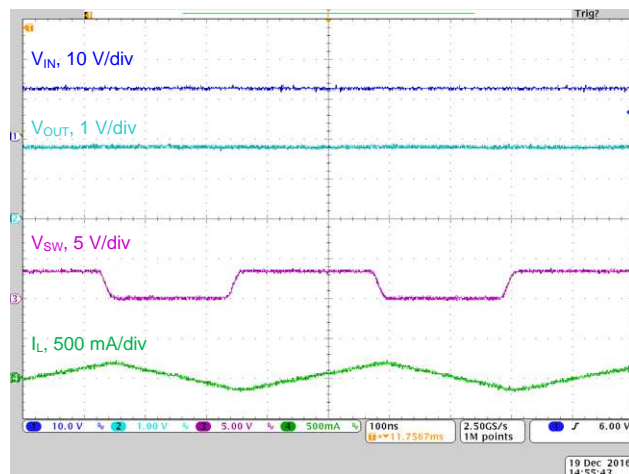


Figure 22. Switch Node Voltage, Inductor Current, and LM26420-Q1 Output Voltage (A) at 12 V_{IN} , No Load

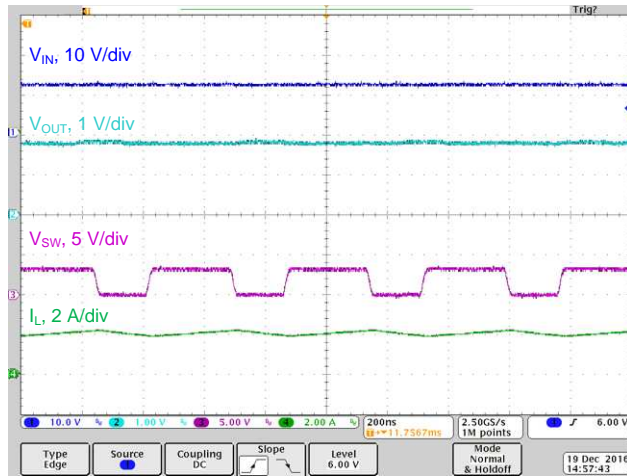


Figure 23. Switch Node Voltage, Inductor Current, and LM26420-Q1 Output Voltage (A) at 12 V_{IN}, 2-A Load

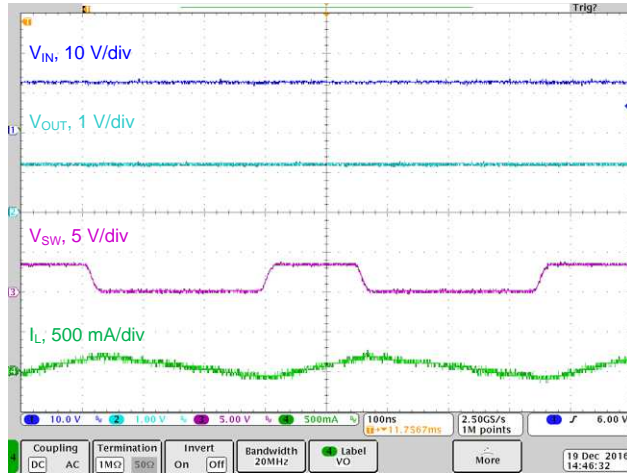


Figure 24. Switch Node Voltage, Inductor Current, and LM26420-Q1 Output Voltage (B) at 12 V_{IN}, No Load

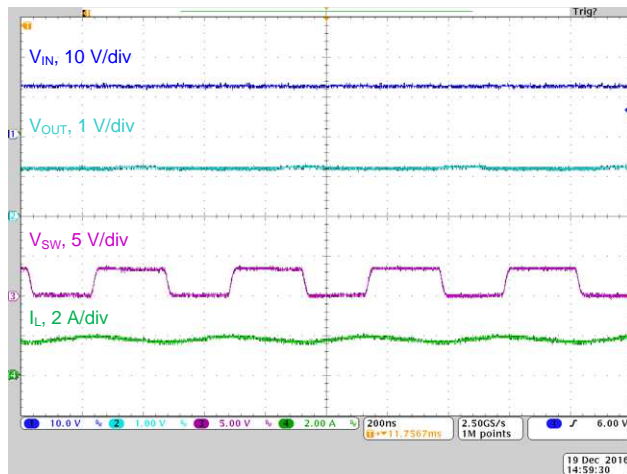


Figure 25. Switch Node Voltage, Inductor Current, and LM26420-Q1 Output Voltage (B) at 12 V_{IN}, 2 A Load

3.3 Short Circuit Application and Recovery

Figure 26 through Figure 29 show the hiccup behavior graphs.

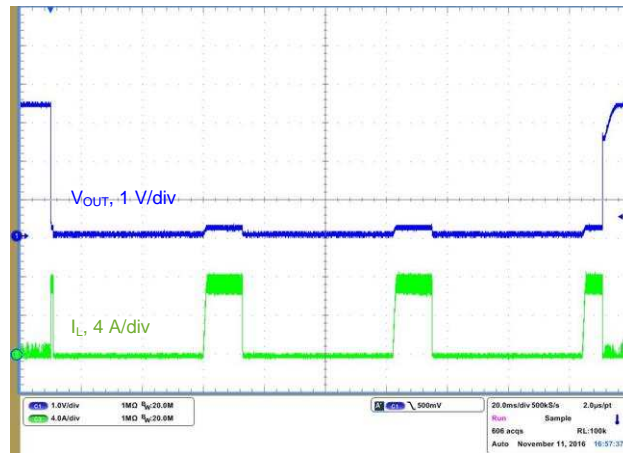


Figure 26. LM73606: Hiccup Mode Behavior (No Load) at 12 V_{IN}

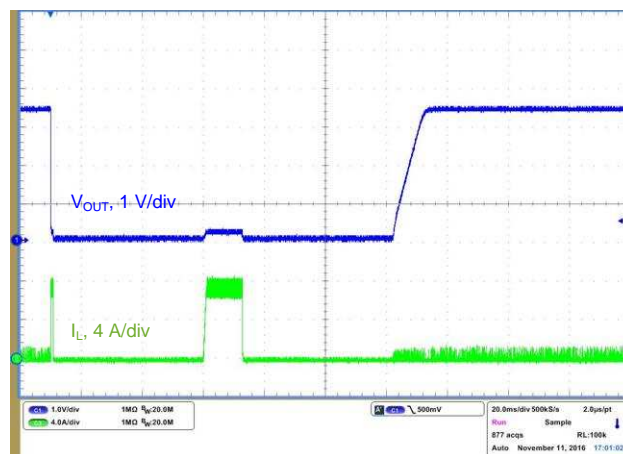


Figure 27. LM73606: Hiccup Mode Behavior With Recovery (No Load) at 12 V_{IN}

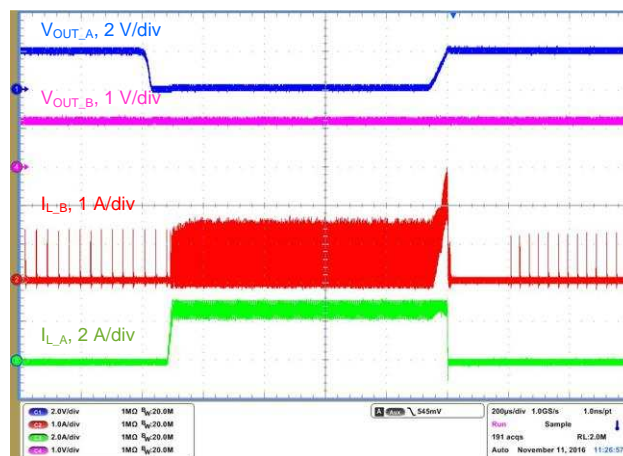


Figure 28. Short-Circuit Behavior for LM26420-Q1 (A) With Recovery (No Load) at 12 V_{IN}

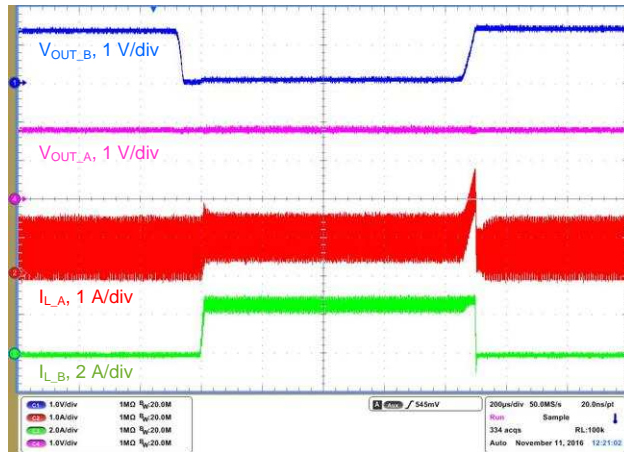


Figure 29. Short-Circuit Behavior for LM26420-Q1 (B) With Recovery (No Load) at 12 V_{IN}

3.4 Load Transient Response

Figure 30 through Figure 35 show the load transient response.

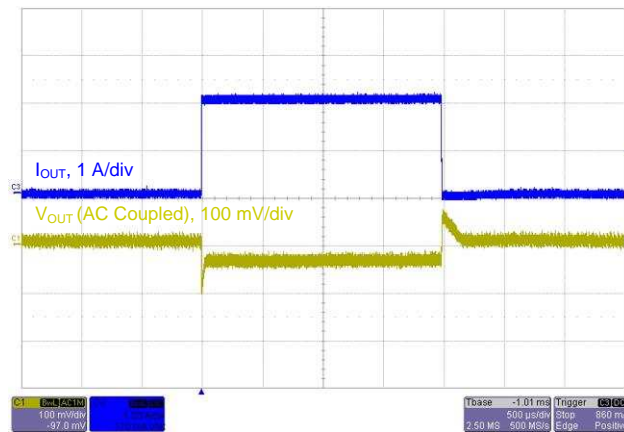


Figure 30. LM73606 – Load Transient Response at 12 V_{IN}, 0- to 2-A Load Step

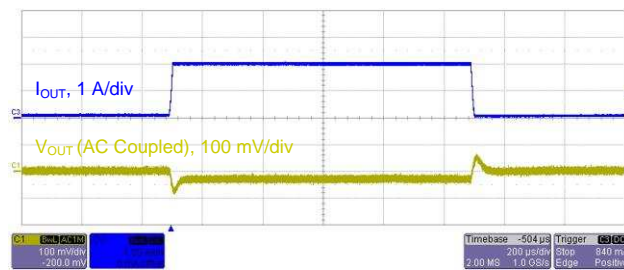


Figure 31. LM73606 –Load Transient Response at 12 V_{IN}, 0.1- to 2-A Load Step

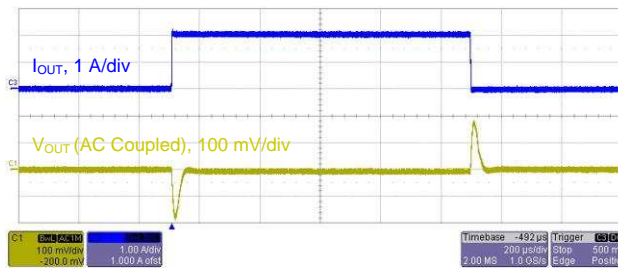


Figure 32. LM26420-Q1 (A) - Load Transient Response at 12 V_{IN}, 0- to 2-A Load Step

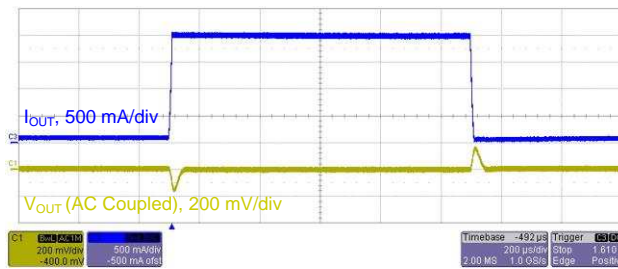


Figure 33. LM26420-Q1 (A) - Load Transient Response at 12 V_{IN}, 0.1- to 2-A Load Step

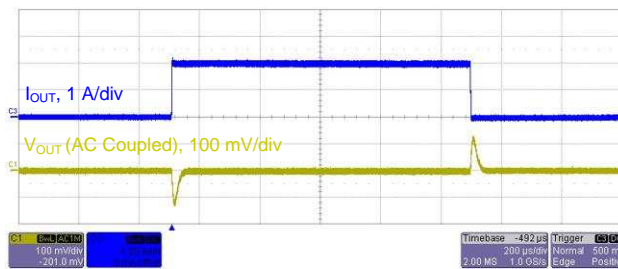


Figure 34. LM26420-Q1 (B) - Load Transient Response at 12 V_{IN}, 0- to 2-A Load Step

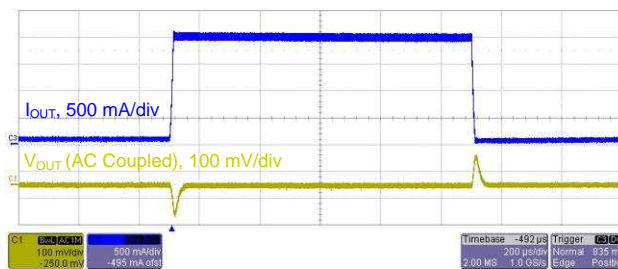


Figure 35. LM26420-Q1 (B) - Load Transient Response at 12 V_{IN}, 0.1- to 2-A Load Step

3.5 Line Transient Response

Figure 36 through Figure 41 show the line transient response.

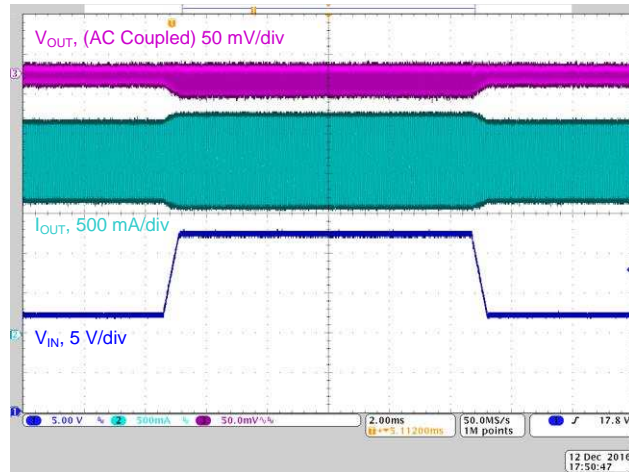


Figure 36. LM73606 – Line Transient Response at 2-A Load, 12-V to 24-V Line Step

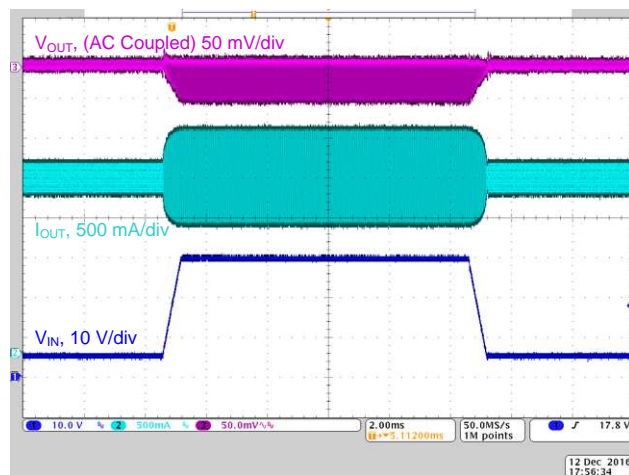


Figure 37. LM73606 –Line Transient Response at 2-A Load, 5-V to 30-V Line Step

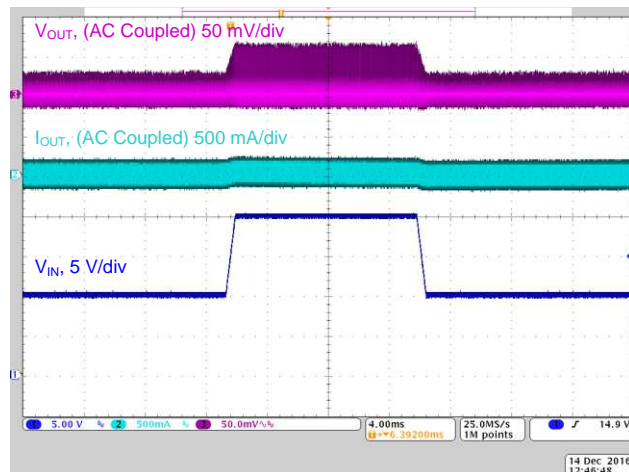


Figure 38. LM26420-Q1 (A) – Line Transient Response at 2-A Load, 10-V to 20-V Line Step

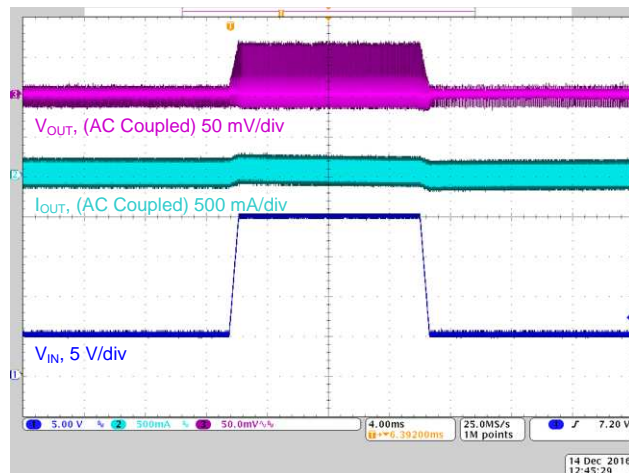


Figure 39. LM26420-Q1 (A) – Line Transient Response at 2-A Load, 5-V to 20-V Line Step

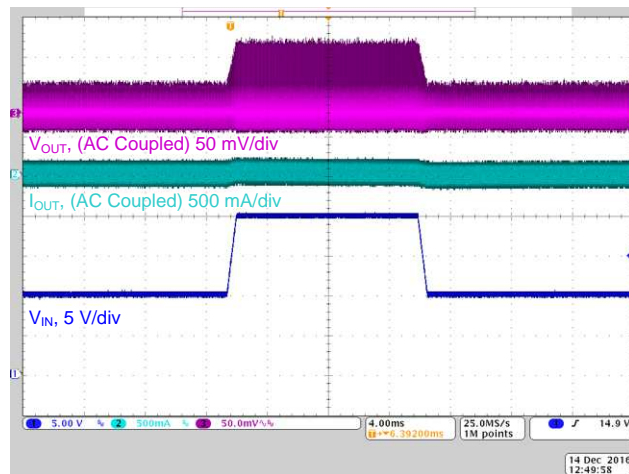


Figure 40. LM26420-Q1 (B) – Line Transient Response at 2-A Load, 10-V to 20-V Line Step

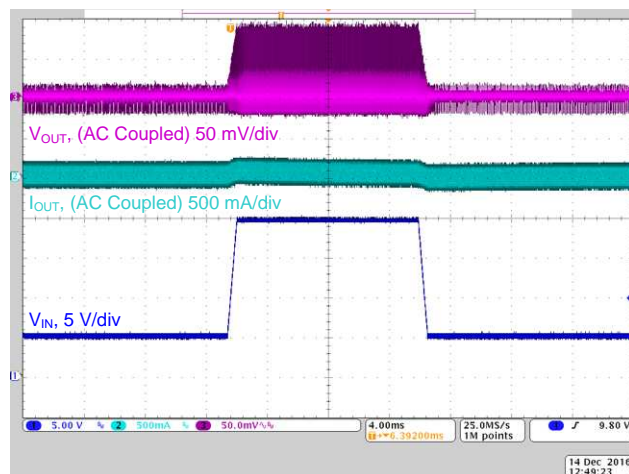


Figure 41. LM26420-Q1 (B) – Line Transient Response at 2-A Load, 5-V to 20-V Line Step

4 About the Author

ABDALLAH OBIDAT is an Applications Engineer at Texas Instruments. He supports power controllers, converters and other power electronics products. Abdallah earned his bachelor of science in electrical engineering (BSEE) from the Georgia Institute of Technology.

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