Design Guide: TIDA-050015

Automotive ADAS Camera Power Supply Reference Design Optimized for Solution Size and Low Noise

Description

This wide-input power-supply reference design is specifically designed for space-constrained automotive ADAS camera applications. This size-optimized design uses front-end protection paired with a wide input voltage DC/DC converter to enable off-battery operation. The front-end filter and component selection are optimized to comply with stringent CISPR 25 Class 5 conducted electromagnetic interference (EMI) standards. This reference design has already been tested to CISPR 25 Class 5 standards, which accelerates the customer design time. This power system offers four regulated power rails for system components, including an imager, image processor, and data and video interfaces.

Resources

TIDA-050015	Design Folder
LMR33630-Q1	Product Folder
LMR34215-Q1	Product Folder
TPS62420-Q1	Product Folder
LM2775-Q1	Product Folder
LP5907-Q1	Product Folder
LMR36015-Q1	Product Folder

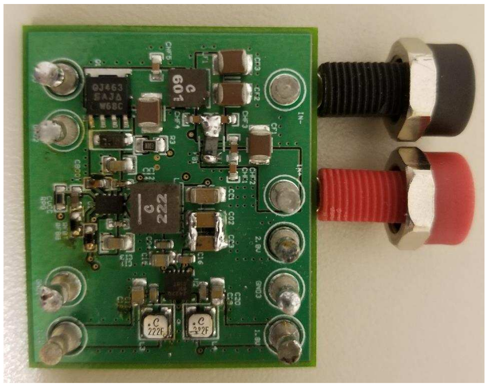
TI E2E™ Community — ASK Our E2E™ Experts

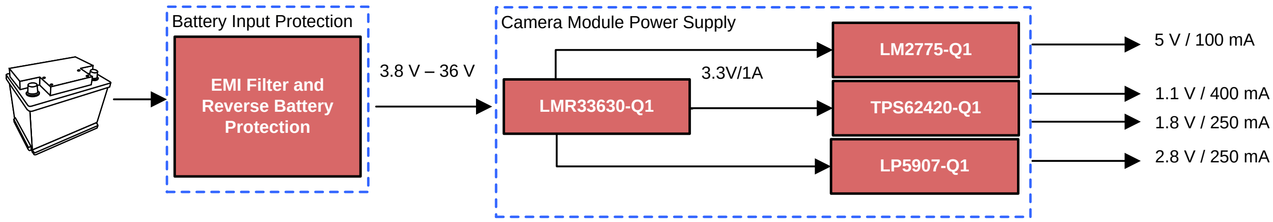
Features

- No additional components required for direct connection to battery
- Overall solution size of 1272 mm^2 for ADAS camera modules
- Wide 4 V to 36 V input range supports start-stop and load dump operation
- Designed to protect against reverse battery condition
- Tested against CISPR 25 Class 5 conducted EMI standards
- Provides four regulated power rails: 5 V (100 mA maximum), 2.8 V (200 mA maximum), 1.8 V (250 mA maximum), 1.1 V (400 mA maximum)
- All devices are qualified according to AEC-Q100

Applications

- Rear camera
- Camera module without processing
- Automotive thermal camera

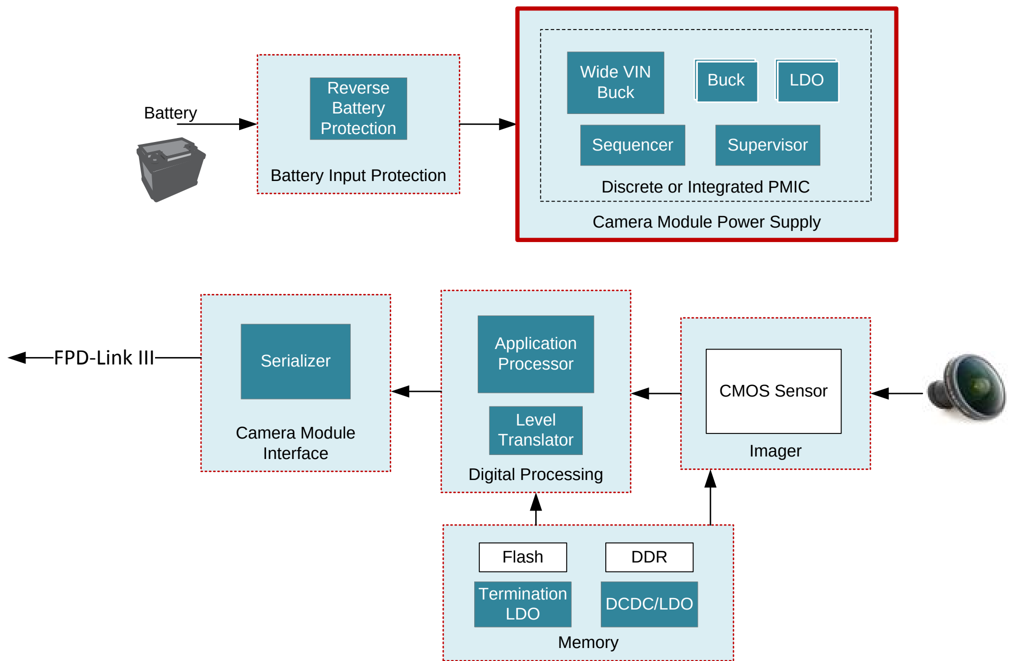




1 System Description

The TIDA-050015 power-supply design is optimized for size-sensitive automotive applications, specifically rear camera modules. The block diagram for a rear camera module is shown in Figure 1, and the TIDA-050015 reference design highlights the camera module power supply highlighted below in red. This design has complete front-end protection and correspondingly accepts a wide input range from 3.8 V to 36 V. This design includes an electromagnetic interference (EMI) filter and is tested to CISPR 25 Class 5 conducted EMI standards without the use of additional shielding.

Figure 1. ADAS Rear Camera Module Block Diagram



The design is divided into four major blocks:

1. Front-end protection: Front-end protection has been implemented against positive and negative pulses (ISO7630 Pulse 1, 2a, 3a/b) through transient voltage suppression (TVS). A PMOSFET is responsible for implementing reverse battery protection.
2. EMI filter: The design uses a differential EMI filter for conducted EMI suppression. The design is tested to CISPR25 Class 5 conducted EMI standards without using any shielding or common-mode filters.
3. Low EMI front-end DC/DC converter: The design uses the LMR33630-Q1 as the front-end DC/DC converter, which is an automotive-qualified, low EMI, 2.1-MHz switching frequency, 3-A synchronous buck regulator. The device comes in an automotive-qualified HotRod™ QFN package with wettable flanks, which reduces parasitic inductance and resistance while increasing efficiency, minimizing switch node ringing, and dramatically lowering EMI. For lower power applications, the LMR34215-Q1 (1.5A) and LMR34206-Q1 (0.6A) offers a pin-to-pin capability that features fixed output voltages, spread spectrum, and forced PWM.
4. Point-of-load converters: The design uses LM2775-Q1, TPS62420-Q1, and LP5907-Q1 to provide regulated voltage for system components like the CMOS imager, CAN, high-speed serial interface, micro controllers or image signal processors. All three components enable a size-optimized, low-noise solution, which is designed to pass CISPR 25 class 5 limits.

1.1 Key System Specifications

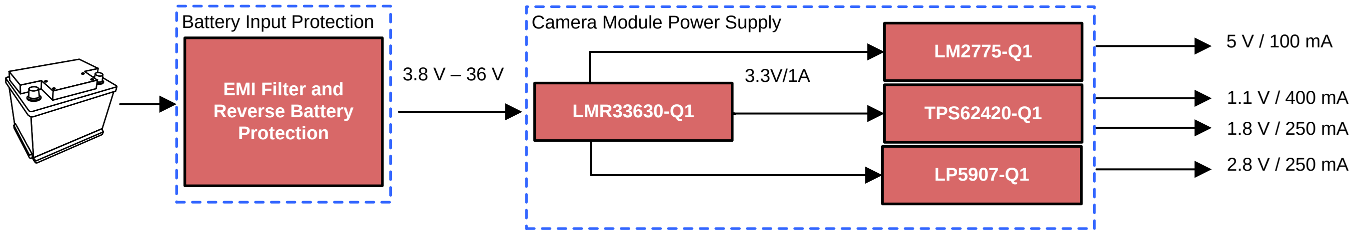
Table 1. Key System Specifications

PARAMETER	SPECIFICATIONS
V_{IN} minimum	3.8 V
V_{IN} maximum	36 V
V_{OUT1}	3.3 V
I_{OUT1}	1 A
V_{OUT2}	5 V
I_{OUT2}	100 mA
V_{OUT3}	1.1 V
I_{OUT3}	400 mA
V_{OUT4}	1.8 V
I_{OUT4}	250 mA
V_{OUT5}	2.8 V
I_{OUT5}	250 mA
f_{SW}	2.1 MHz
ISO pulse test	TVS diode used for protection
EMI	Passes CISPR 25 Class 5 limits

2 System Overview

2.1 Block Diagram

Figure 2. TIDA-050015 Block Diagram



2.2 Design Considerations

The TIDA-050015 reference design is the power management subsystem designed specifically for ADAS camera module applications. This reference design uses a wide V_{IN} converter (LMR33630-Q1) and three point-of-load converters (LM2775-Q1, TPS62420-Q1, LP5907-Q1) with optimized switching frequencies, thermal performance, and form factor.

This camera module power supply has multiple protections at the front-end of the design.

- The TVS functions to clamp both positive and negative transient voltage pulses. These pulses included clamped load dump (up to 38 V) and other transients outlined in ISO 7637-2:2004.
- The PFET is used in the front end so that the system properly responds to a reverse battery polarity event and shuts down appropriately.

A front-end EMI filter enables compliance with the CISPR 25 class 5 automotive EMI standards, with respect to conducted emissions.

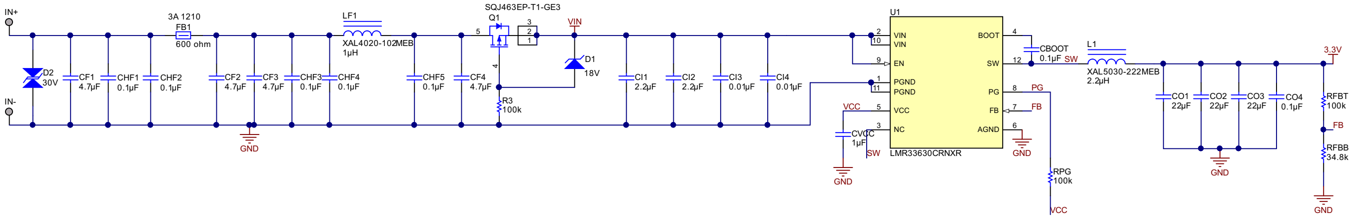
The LMR33630-Q1 synchronous buck converter is a wide-input-voltage, low-quiescent-current, high-performance regulator with internal compensation. The LMR33630-Q1 was chosen as the front-end, wide VIN converter for the TIDA-050015 because of small package size (3 mm × 2 mm), the switching frequency, the 3-A current capability, and the input voltage range of the regulator. The operating frequency for the LMR33630-Q1 regulator is 2.1 MHz, and the device implements a precise current limit. Consequently, the output filter size and component values are minimized. The device is designed with a flip-chip or HotRod technology, which greatly reduces the parasitic inductance of the pins. In addition, the layout of the device can help reduce the radiated noise generated by switching action through the partial cancellation of the current-generated magnetic field.

The 3.3-V output option for the LMR33630-Q1 was chosen to support cold crank conditions. When the engine cranks at low ambient temperature, a car battery voltage can drop to 4 V. This behavior is referred to as cold crank. With a 3.3-V output, the power supply must output a constant voltage rail as the battery voltage drops and ramps to a nominal voltage of 12 V to 13.5 V.

The LMR336xx family of devices offer flexibility to use this size-optimized layout for various power demands of additional automotive applications. For TIDA-050015, the LMR33630-Q1 output voltage is set to 3.3 V with a resistor divider from FB to V_{OUT}. Depending on the power requirement of the downstream components, the output voltage can be adjusted. In addition, the output current can be scaled down to 2 A with the use of the LMR33620-Q1. The LMR33620-Q1 uses a lower current limit and consequently enables the capability to shrink the inductor size.

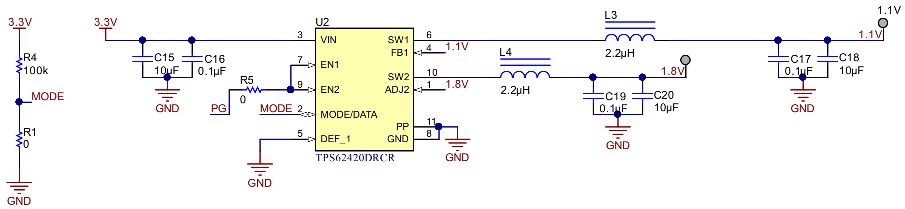
For lower current applications, the output current can be scaled down to 1.5 A or 600mA with the use of pin compatible devices, LMR34215-Q1 (42 V, 1.5 A) and LMR34206-Q1 (42 V, 600 mA). The LMR342xx-Q1 device family offers key features such as fixed output voltages, spread spectrum, and forced PWM. Fixed output voltages removes the need for external resistor devices that can cause inaccuracies. Spread spectrum eliminates peak emissions by spreading the emissions across a wider range of frequencies which will help pass stringent automotive EMI standards. For higher voltage variants, the LMR36006-Q1 (60 V, 600 mA) and LMR36015-Q1 (60 V, 1.5 A) are pin compatible devices with the same features .

Figure 3. Schematic of LMR33630-Q1



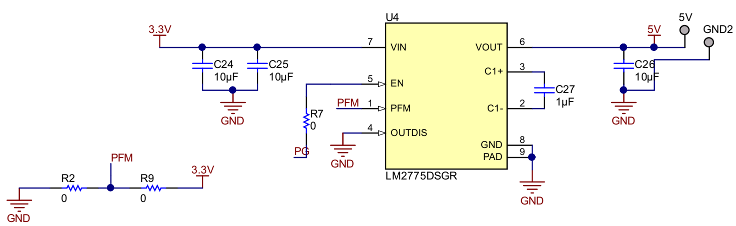
The TPS62420-Q1 is a dual-channel, step-down converter that can operate from a standard 3.3-V input rail and regulate dual output rails at 1.8-V and 1.1-V. The 1.8-V output rail powers both the FPD-Link III serializer and the imager IO rails while the 1.1-V rail powers the imager core voltage rail. The TPS62420-Q1 was chosen as one point-of-load converter for the TIDA-050015 because of the small package (3 mm × 3 mm), the switching frequency, the 600-mA current capability, and the input voltage range of the regulator. The operating frequency of the TPS6240-Q1 is a fixed 2.25-MHz switching frequency. At low output currents, the TPS62420-Q1 reduces its quiescent current by operating in pulse frequency modulation (PFM).

Figure 4. Schematic of TPS62520-Q1



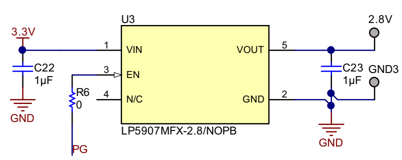
The LM2775-Q1 is a 5-V boost converter capable of powering the CAN communication. The LM2775-Q1 is a switch-capacitor boost converter that enables a small and cost optimized solution by eliminating the need for an inductor. In addition the LM2775-Q1 is selected as one of the point-of-load converters for the TIDA-050015 because of its switch-capacitor topology small package (2 mm × 2 mm), the switching frequency, and the 200-mA current capability. The operating frequency of the LM2775-Q1 is 2-MHz switching frequency. At low output currents, the LM2775-Q1 reduces its quiescent current by operating in PFM.

Figure 5. Schematic of LM2775-Q1



The LP5907-Q1 is a ultra-low-noise, low-$I_Q$device that powers the analog rail or pixel rail of the imager. The LP5907-Q1 is selected as one of the point-of-load converters for the TIDA-050015 because of the small package (0.675 mm × 0.675 mm) and low component count solution, which requires two external components. Ultimately, the LP5907-Q1 enables an ultra-small solution with good noise performance.

Figure 6. Schematic of LP5907-Q1



For design calculations and layout examples, see the data sheets for the relevant devices:

- LMR33630-Q1: *LMR33630-Q1 3.8-V to 36-V, 3-A Synchronous Step-Down Voltage Converter*

- TPS62420-Q1: *2.25-MHz 600-mA/1000-mA Dual Step-Down Converter*
- LM2775-Q1:*LM2775-Q1 Switched Capacitor 5-V Boost Converter*
- LP5907-Q1:*LP5907-Q1 Automotive 250-mA, Ultra-Low-Noise, Low-I_Q LDO*

2.3 Highlighted Products

2.3.1 LMR33630-Q1

Features:

- Synchronous buck converter
- Wide operation input voltage: 3.8 V to 36 V (with transient protection up to 38 V)
- 2.1-MHz switching frequency
- Low quiescent current: 25 µA
- Maximum load current: 2 A for LMR33620-Q1 and 3 A for LMR33630-Q1
- QFN package: 3 mm × 2 mm
- Pin-to-pin capability with LMR34215-Q1 (42 V, 1.5 A) and LMR34206-Q1 (42 V, 600 mA)

2.3.2 LM2775-Q1

Features:

- Synchronous boost converter
- Fixed 5-V output
- Inductorless solution: Only requires 3 small ceramic capacitors
- 2.7-V to 5.5-V input range
- 2-MHz switching frequency
- Maximum load current: 200 mA
- QFN package: 2 mm × 2 mm

2.3.3 TPS62420-Q1

Features:

- Synchronous buck converter
- Adjustable output voltage from 0.6 V to V_{IN}
- 2.5-V to 6-V input range
- 2.25-MHz switching frequency
- Maximum load current: 1000 mA
- QFN package: 3 mm × 3 mm

2.3.4 LP5907-Q1

Features:

- Solution requires 1-µF ceramic input and output capacitors
- Adjustable output voltage from 1.2 V to 4.5 V
- 2.2-V to 5.5-V input range
- Low quiescent current: 12 µA
- QFN package: 2.96 mm × 1.60 mm

3 Hardware, Software, Testing Requirements, and Test Results

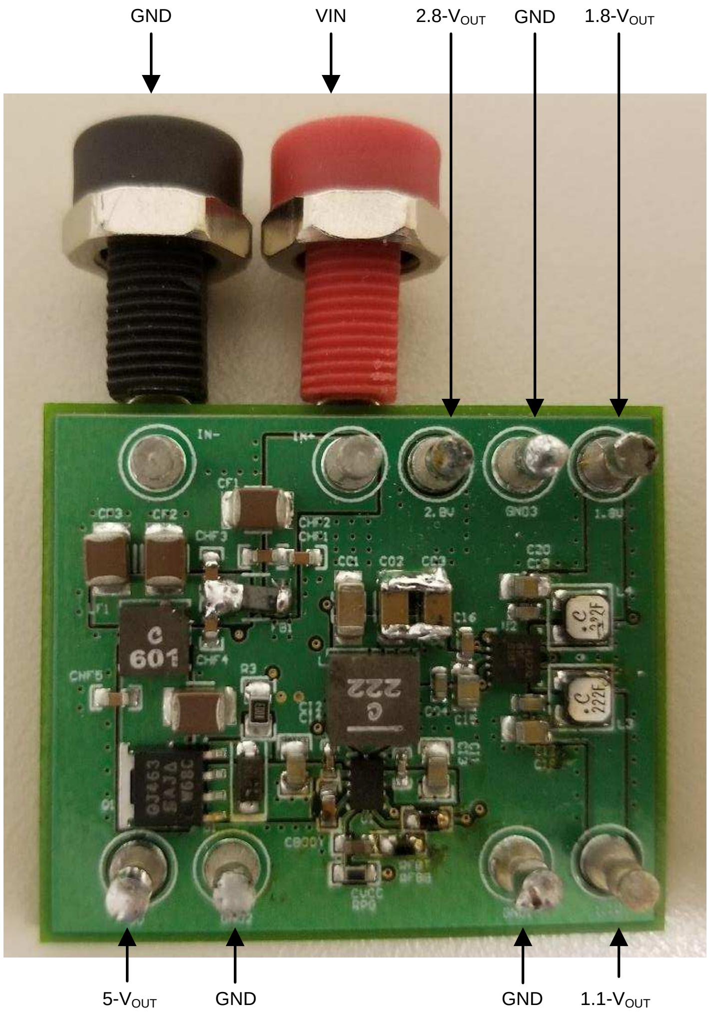
3.1 Required Hardware

3.1.1 Hardware

The following steps outline the hardware setup.

1. Connect a DC power supply to VIN and GND, as labeled in Figure 7.
2. Connect electronic or resistive load to the four output posts (2.8-V_{OUT}, 1.8-V_{OUT}, 5-V_{OUT}, 1.1-V_{OUT}), as labeled in Figure 7.

Figure 7. Hardware Setup



3.2 Testing and Results

3.2.1 Test Set Up

For the following test results the TIDA-050015 was set up as detailed in Section 3.1.1.

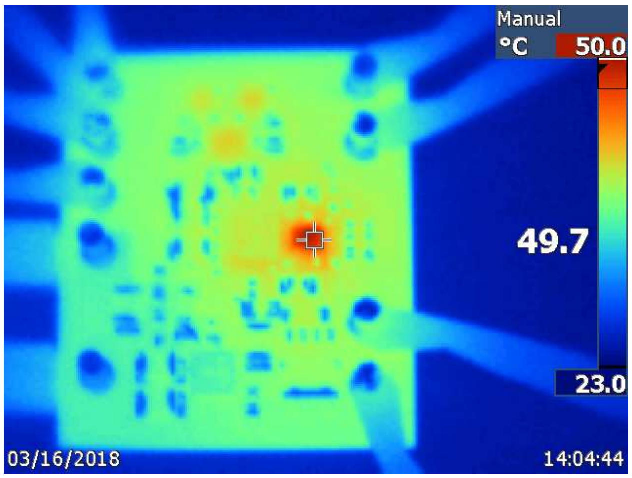
3.2.2 Test Results

The following diagrams show the design performance.

3.2.2.1 Thermal Data

The infrared (IR) thermal image in Figure 8 was taken at steady-state with V_{IN} = 12V and the TPS62821 output at a full load (no airflow). The ambient temperature is approximately 22°C. The maximum IC temperature is 47°C.

Figure 8. TIDA-050015 Thermal Image: V_{IN} = 12 V, I_{OUT1} = 1 A, V_{OUT1} = 3.3 V, V_{OUT2} = 5 V, I_{OUT2} = 100 mA, V_{OUT3} = 1.1 V, I_{OUT3} = 400 mA, V_{OUT4} = 1.8 V, I_{OUT4} = 250 mA, V_{OUT5} = 2.8 V, I_{OUT5} = 250 mA



3.2.2.2 Efficiency Data

Figure 9 shows the efficiency of the LMR33630-Q1 device versus the load current. Figure 10 shows the total system efficiency versus the input voltage at full load.

Figure 9. LMR33630-Q1 Efficiency Versus Load Current: I_{OUT1} = 0 A to 3 A (Includes Front End Protection and EMI Filter)

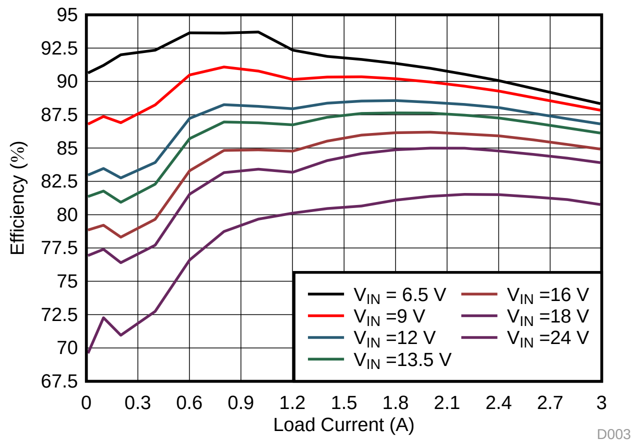
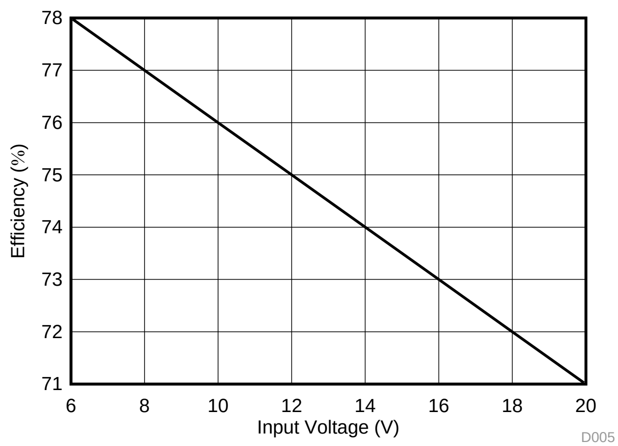


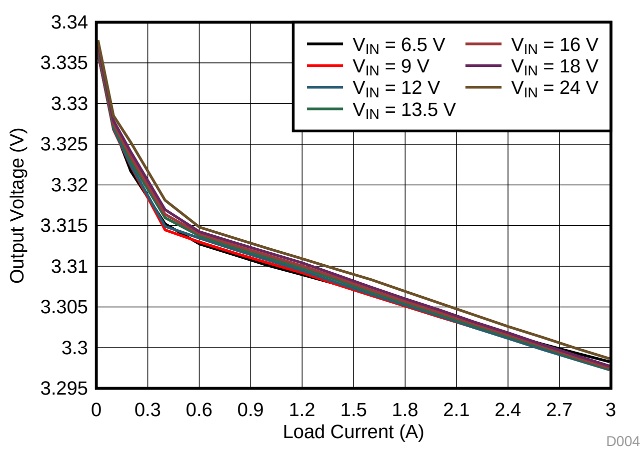
Figure 10. System Efficiency vs Input Voltage: I_{OUT1} = 1 A, I_{OUT2} = 100 mA, I_{OUT3} = 400 mA, I_{OUT4} = 250 mA, I_{OUT2} = 250 mA



3.2.2.3 Output Load Regulation

Figure 11 shows the output load regulation of the wide input converter (LMR33630-Q1).

Figure 11. LMR33630-Q1 Load Regulation: V_{OUT1} vs I_{OUT1}



3.2.2.4 Reverse Battery Protection

This design has implemented protection against a reverse battery connection. Figure 12 and Figure 13 show this performance.

Figure 12. Continuous Reverse Voltage at Input - C1: V_{IN} (Input for DC/DC Converter), C3: Input (Input Terminal for Battery)

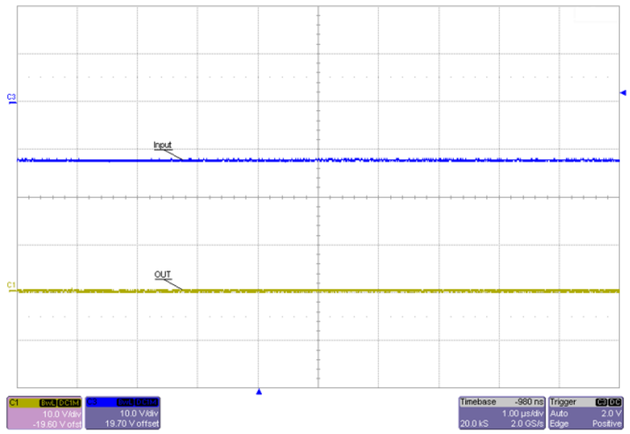
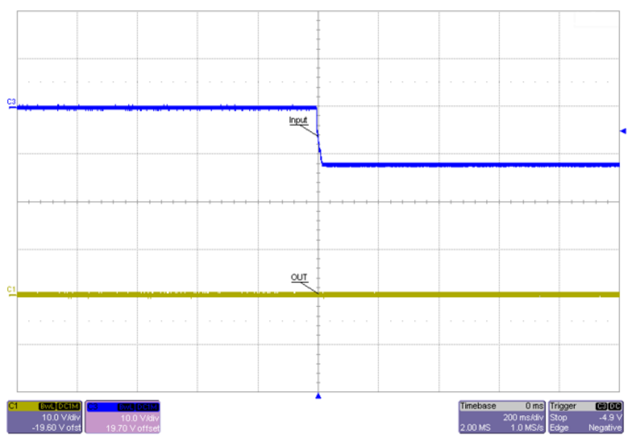


Figure 13. Transition to Reverse Voltage at Input - C1: V_{IN} (Input for DC/DC Converter), C3: Input (Input Terminal for Battery)



3.2.2.5 Switch Node and Output Voltage Ripple

Figure 14 shows the steady-state performance of LMR33630-Q1 for the switch-node and output voltage ripple at 12 V_{IN} and full load. Figure 15 shows the steady-state performance of TPS62420-Q1 for the switch-node and output voltage ripple at 12 V_{IN}, 1.8 V_{OUT}, and full load. Figure 16 shows the steady-state performance of TPS62420-Q1 for the switch-node and output voltage ripple at 12 V_{IN}, 1.1 V_{OUT}, and full load.

Figure 14. LMR33630-Q1 Steady-State Waveform at 12 V_{IN} and Full Load - C1: 3.3-V_{OUT} (AC Coupled), Ch3: Switch Node

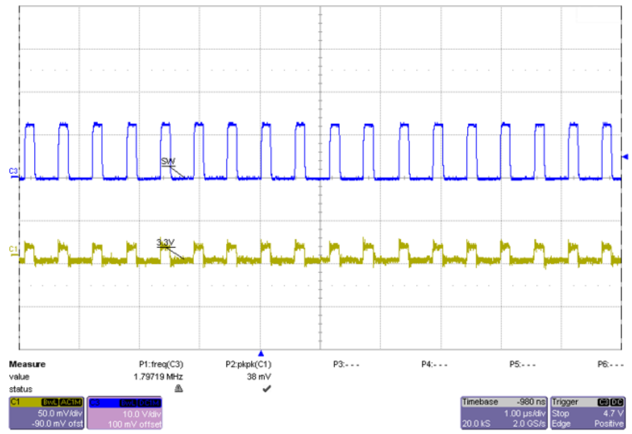


Figure 15. TPS62420-Q1 Steady-State Waveform at 12 V_{IN} and Full Load - C1: 1.8 V_{OUT} (AC Coupled), Ch3: Switch Node

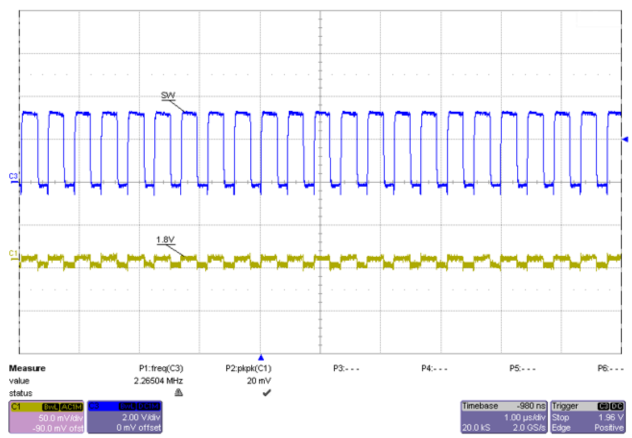
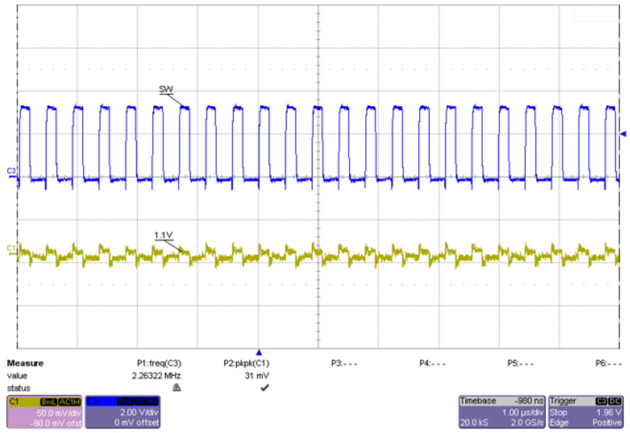


Figure 16. TPS62420-Q1 Steady-State Waveform at 12 V_{IN} and Full Load - C1: 1.1 V_{OUT} (AC Coupled), Ch3: Switch Node



3.2.2.6 Load Transient

The load transient waveform monitor the output voltage and the load current. Channel 1 (yellow) represents the output current of the LMR33630-Q1 or TPS62420-Q1. Channel 3 (blue) represents the output current. Figure 17 to Figure 20 show the load transient results.

Figure 17. LMR33630-Q1 Load Transient: 12 V_{IN}, I_{OUT1} = 0.4 A to 3 A, t_r = t_f = 5 µs - C1: 3.3 V_{OUT} (AC Coupled), Ch3: I_{OUT1}

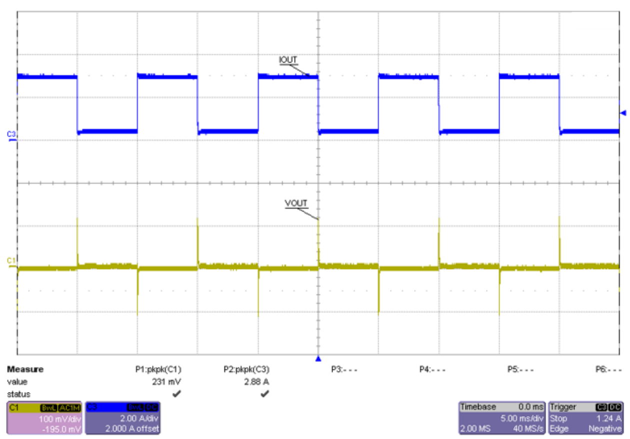


Figure 18. PS62420-Q1 Load Transient: 12 V_{IN}, I_{OUT2} = 0.1 A to 0.4 A, t_r = t_f = 3 µs - C1: 1.8 V_{OUT} (AC Coupled), Ch3: I_{OUT2}

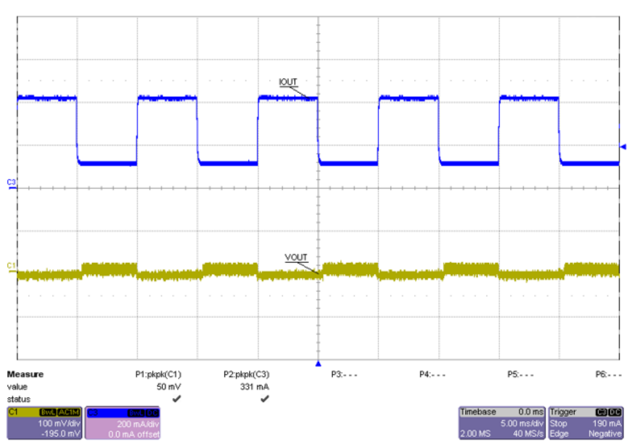


Figure 19. TPS62420-Q1 Load Transient: 12 V_{IN}, I_{OUT3} = 0.2 A to 0.8 A, t_r = t_f = 6 µs - C1: 1.1 V_{OUT} (AC Coupled), Ch3: I_{OUT3}

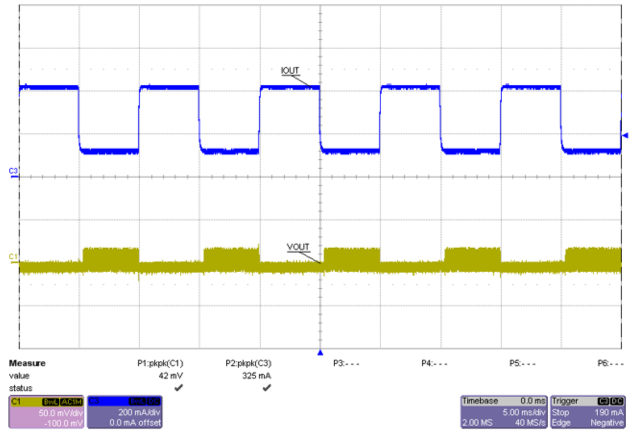
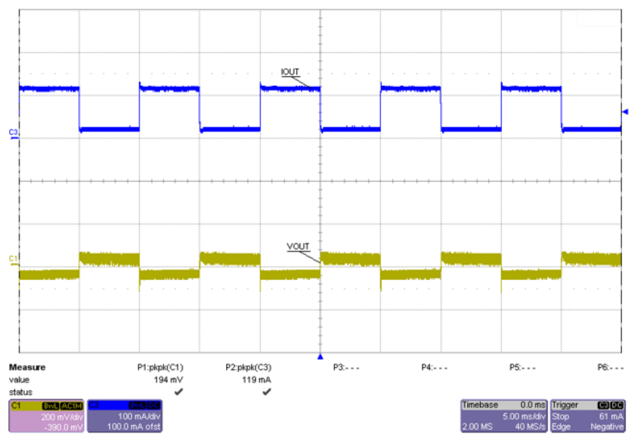


Figure 20. LM2775-Q1 Load Transient:12 V_{IN}, I_{OUT4} = 0.01 A to 0.1 A, t_r = t_f = 1 µs - C1: 5 V_{OUT} (AC Coupled), Ch3: I_{OUT2}



3.2.2.7 Conducted Emissions

Figure 21 and Figure 22 show the conducted emissions plots based on the CISPR 25 class 5 standards. The input voltage is 12 V, and all outputs are at full load.

Figure 21. EMI Performance From 150 kHz to 30 MHz: V_{IN} = 12 V (Yellow: Peak Detection Result; Blue: Average Detection Result; Red: CISPR 25 Class 5 Limits)

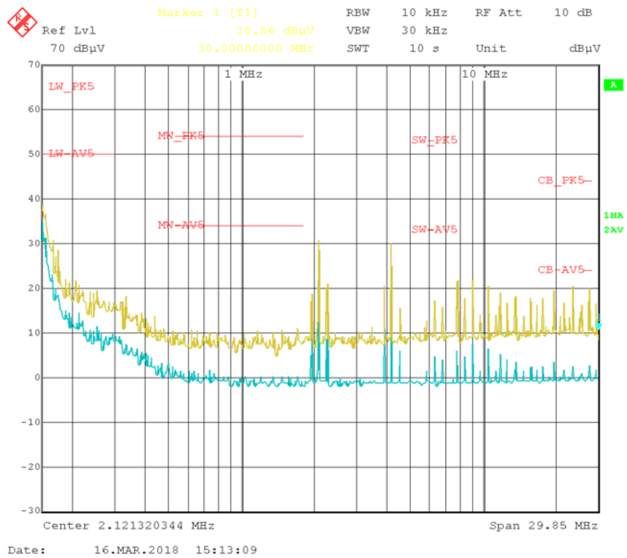
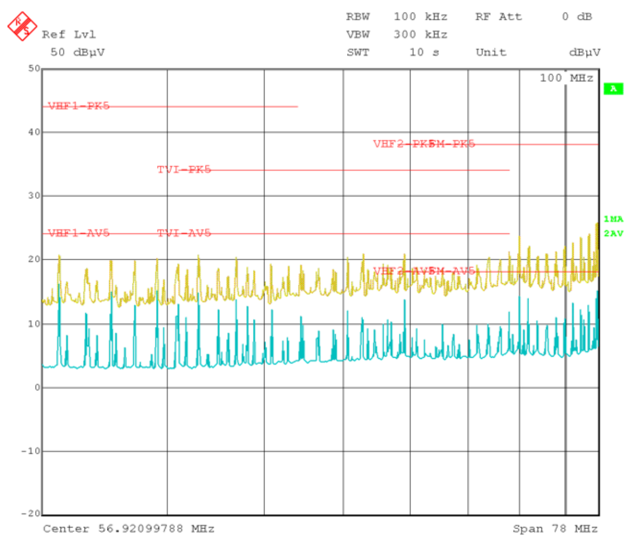


Figure 22. EMI Performance From 30 MHz to 108 MHz: V_{IN} = 12 V (Yellow: Peak Detection Result; Blue: Average Detection Result; Red: CISPR 25 Class 5 Limits)



4 Design Files

4.1 Schematics

To download the schematics, see the design files at TIDA-050015.

4.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDA-050015.

4.3 PCB Layout Recommendations

4.3.1 Layout Prints

To download the layer plots, see the design files at TIDA-050015.

4.4 Altium Project

To download the Altium Designer® project files, see the design files at TIDA-050015.

4.5 Gerber Files

To download the Gerber files, see the design files at TIDA-050015.

4.6 Assembly Drawings

To download the assembly drawings, see the design files at TIDA-050015.

5 Software Files

To download the software files, see the design files at TIDA-050015.

5.1 Trademarks

E2E, HotRod are trademarks of Texas Instruments.
Altium Designer is a registered trademark of Altium LLC or its affiliated companies.
All other trademarks are the property of their respective owners.

6 Related Documentation

1. Texas Instruments, *LMR33630-Q1 3.8-V to 36-V, 3-A Synchronous step-down voltage converter*
2. Texas Instruments: *2.25-MHz 600-mA/1000-mA Dual step-down converter* (TPS62420-Q1)
3. Texas Instruments, *LM2775-Q1 Switched capacitor 5-V boost converter*
4. Texas Instruments,*LP5907-Q1 Automotive 250-mA, ultra-low-noise, low-I_Q LDO*

6.1 Trademarks

E2E, HotRod are trademarks of Texas Instruments.
Altium Designer is a registered trademark of Altium LLC or its affiliated companies.
All other trademarks are the property of their respective owners.

6.2 Third-Party Products Disclaimer

TI'S PUBLICATION OF INFORMATION REGARDING THIRD-PARTY PRODUCTS OR SERVICES DOES NOT CONSTITUTE AN ENDORSEMENT REGARDING THE SUITABILITY OF SUCH PRODUCTS OR SERVICES OR A WARRANTY, REPRESENTATION OR ENDORSEMENT OF SUCH PRODUCTS OR SERVICES, EITHER ALONE OR IN COMBINATION WITH ANY TI PRODUCT OR SERVICE.

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Original (February 2019) to A Revision **Page**

- Added LMR34215-Q1 product folder 1
- Added "For lower power applications, the LMR34215-Q1 (1.5A) and LMR34206-Q1 (0.6A) offers a pin-to-pin capability that features fixed output voltages, spread spectrum, and forced PWM." 2
- Added "For lower current applications, the output current can be scaled down to 1.5 A or 600mA with the use of pin compatible devices, LMR34215-Q1 (42 V, 1.5 A) and LMR34206-Q1 (42 V, 600 mA). The LMR342xx-Q1 device family offers key features such as fixed output voltages, spread spectrum, and forced PWM. Fixed output voltages removes the need for external resistor devices that can cause inaccuracies. Spread spectrum eliminates peak emissions by spreading the emissions across a wider range of frequencies which will help pass stringent automotive EMI standards. For higher voltage variants, the LMR36006-Q1 (60 V, 600 mA) and LMR36015-Q1 (60 V, 1.5 A) are pin compatible devices with the same features ." 4
- Added "Pin-to-pin capability with LMR34215-Q1 (42 V, 1.5 A) and LMR34206-Q1 (42 V, 600 mA)" 6

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