TI Designs: TIDA-01491

Automotive Camera PMIC Power Supply Reference Design With Power Over Coax Filter

Description

This reference design incorporates a power over coax (POC) filter network, mid-V_{IN} synchronous step-down DC/DC converter, and low-V_{IN} power management IC (PMIC) to demonstrate a typical automotive camera power solution within an 18-mm×18-mm footprint. The solution accepts both data and power from a coaxial cable using a FAKRA connector, isolates data from the loads using a low-pass filter network, and supplies sequenced output voltages that can be adjusted with external feedback resistors. Four output terminals for data, analog power, digital power, and IO power are extended from the solution space to evaluate with external loads.

Resources

TIDA-01491	Design Folder
TPS62160-Q1	Product Folder
TPS65000-Q1	Product Folder

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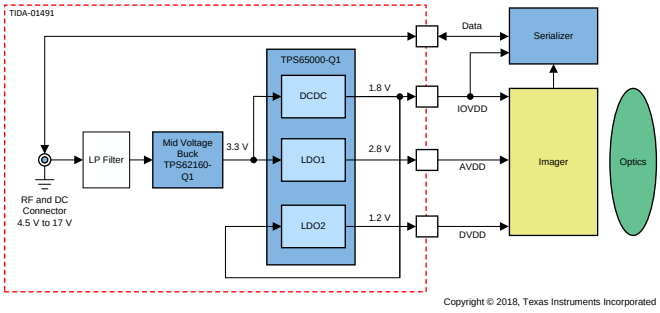
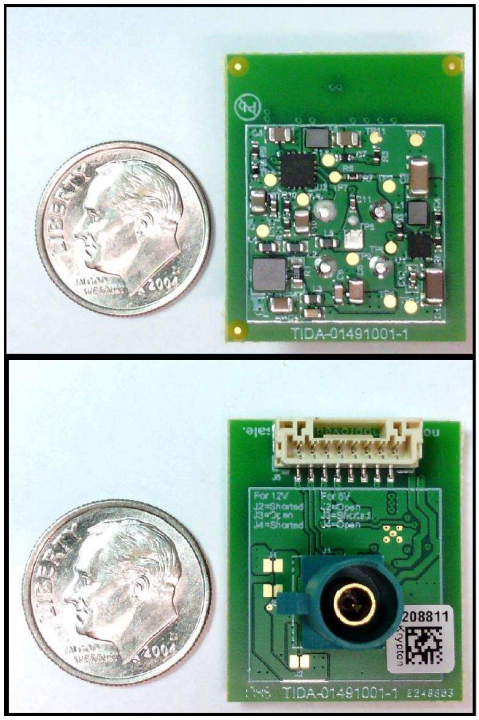


Features

- Supports 4.5-V to 17-V Input
- User Configurable Voltages
- Single-Sided, Space-Optimized Design Within 18-mm×18-mm
- TPS62160-Q1 Pre-Regulator, Mid-V_{IN} Buck
- TPS65000-Q1 PMIC for Camera Sensor Rails
- POC Filter Network

Applications

- Front Camera
- Rear Camera
- Surround View
- Machine Vision



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1 System Description

This reference design demonstrates a versatile 18-mm×18-mm solution capable of isolating data from analog (AVDD), digital (DVDD), and IO (IOVDD) power domains typically used in a power-over-coax (POC) camera application. The design uses only automotive qualified capacitors, inductors, and semiconductors and includes useful test points, external feedback resistors, and configuration jumpers for versatility and experimentation. The system uses a FAKRA coaxial connector, a high-frequency filter network, a mid-V_{IN} buck pre-regulator, and a low-V_{IN} camera power management IC (PMIC) to efficiently supply voltages typically used for imagers and their accompanying serializers. This module is made flexible enough to support various low-power digital and analog applications that could benefit from POC installations.

1.1 Key System Specifications

Table 1. Key System Specifications

PARAMETER	SPECIFICATIONS	DETAILS
Input voltage range	4.5 V to 17 V	Section 2.2.1
Input connector type	FAKRA Coaxial HF (DIN 72594-1)	Section 4.2
Pre-regulator output voltage	3.3 V	Section 2.4.2
PMIC buck input voltage range	2.5 V to 5.5 V	Section 2.4.3
PMIC buck output voltage	1.8 V	Section 2.4.3
PMIC buck output current	600 mA	Section 2.2.2
PMIC LDO1 output voltage	2.8 V	Section 2.4.3
PMIC LDO1 output current	300 mA	Section 2.2.2
PMIC LDO2 output voltage	1.2 V	Section 2.4.3
PMIC LDO2 output current	300 mA	Section 2.2.2
Regulator power sequence	Pre-regulator (3.3 V) → PMIC LDO1 (2.8 V), PMIC Buck (1.8 V) → PMIC LDO2 (1.2 V)	Section 2.4.3
Form factor	18 mm × 18 mm	Section 4.3.1

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2 System Overview

POC allows a single cable to transmit both data and power to remote communication modules, providing installation benefits for applications such as camera imagers. Imagers are often installed in remote locations and require separate power rails for analog, digital, and IO domains and typically bidirectional communication. Camera imagers only consume moderate amounts of power while operating. This reference design demonstrates a two-chip solution capable of supporting various camera imagers as well as accompanying serializers or other sensor modules that can benefit from robust remote installations.

To increase the versatility of this platform, a small footprint is targeted for space constrained installations. A pre-regulator allows DC cable voltages up to 17 V, capable of supporting typical 12-V or 9-V systems. For 5-V systems, the pre-regulator can be bypassed to demonstrate a single-chip power solution. All output voltages are adjustable for versatility using external feedback resistors, and both regulators offer fixed voltage alternatives for further component reduction.

2.1 Block Diagram

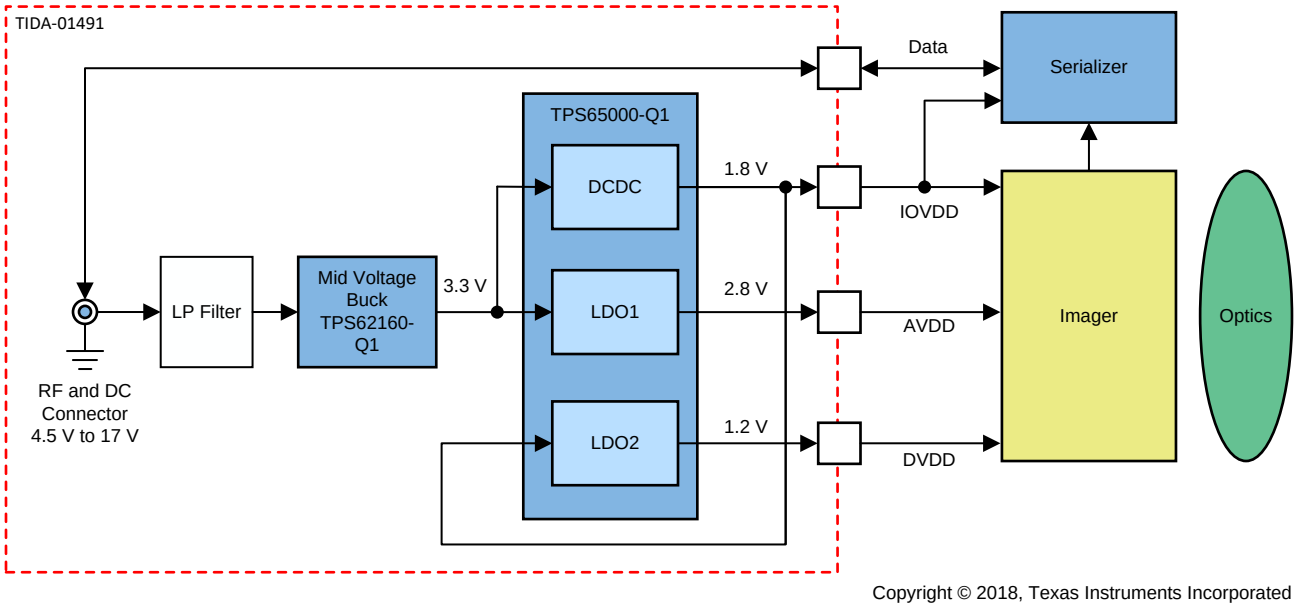

Figure 1. TIDA-01491 Block Diagram

This reference design incorporates an automotive grade coaxial connector, low-pass filter, mid-V_{IN} step-down converter, and low-V_{IN} PMIC for distributing power and data to the imager and serializer of a camera.

2.2 Highlighted Products

This reference design uses the following TI products:

- TPS62160-Q1: Automotive Qualified Wide-V_{IN} Synchronous Step-Down Converter
- TPS65000-Q1: Automotive Qualified PMIC

For more information on each of these devices, see their respective product folders at TI.com.

2.2.1 TPS62160-Q1

The TPS62160-Q1 is a Texas Instruments automotive-qualified, step-down DC/DC converter with a wide operating input voltage range of 3 V to 17 V. The converter supports up to 1 A of continuous output current. The device has a high switching frequency of typically 2.25 MHz that uses a DCS-Control™ topology for high output voltage accuracy. The device is offered in small 8-pin, WSON, 2×2-mm package (DSG).

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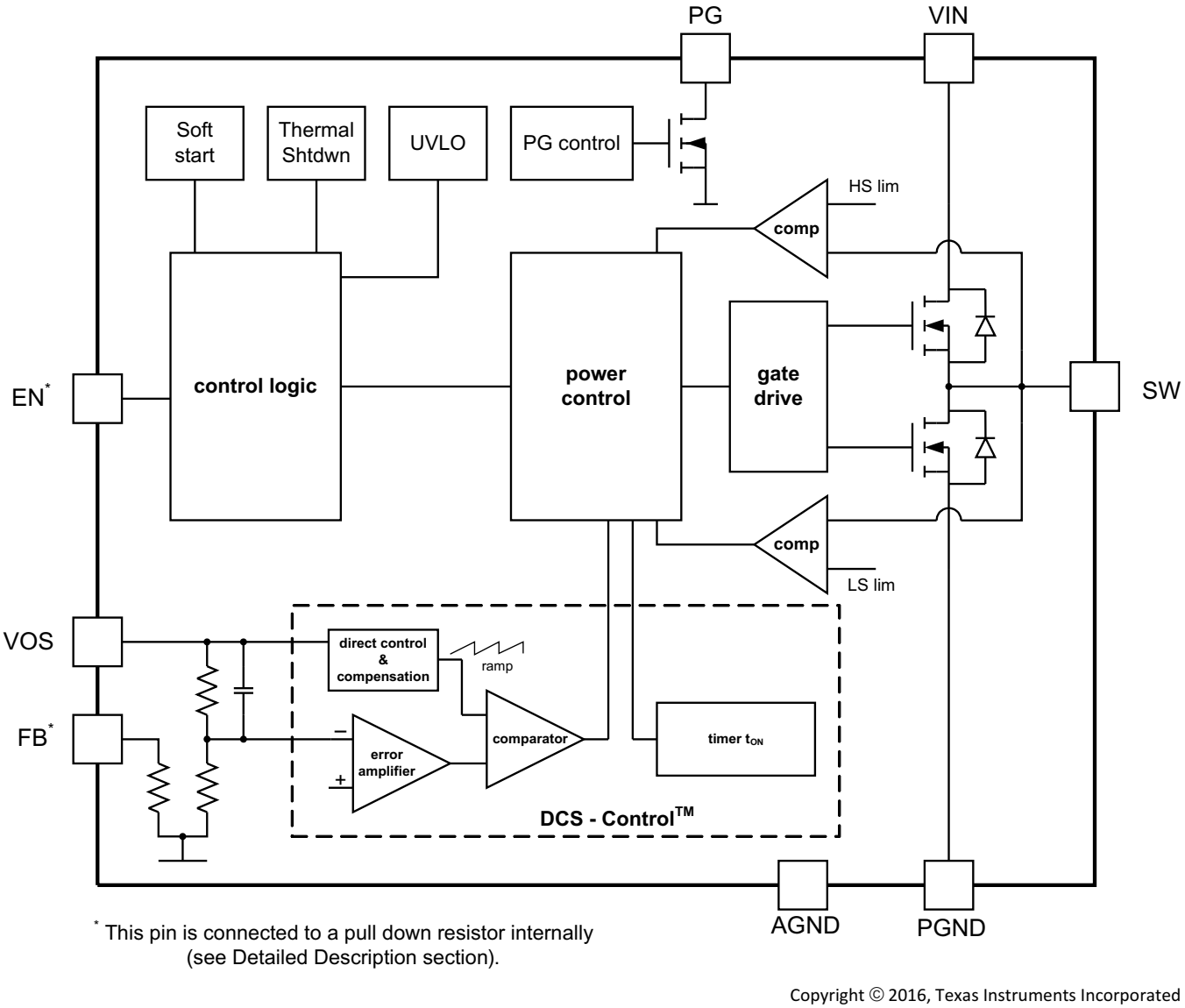

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Figure 2. TPS62160-Q1 Functional Block Diagram

Key features of this device include:

- Switching frequency: 2.25 MHz
- Wide V_{IN}: 3 V to 17 V
- Adjustable output voltage range: 0.9 V to 6 V
- 1-A continuous output current
- Power sequencing, enable, and open-drain Power Good pins
- Short circuit protection
- Undervoltage lockout (UVLO)
- Overtemperature Protection
- WSON package, 2×2-mm (DSG)

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2.2.2 TPS65000-Q1

The TPS65000-Q1 is a Texas Instruments automotive qualified PMIC. The device combines a single step-down converter and two low-dropout regulators. This PMIC has a maximum input voltage of 6 V for all regulators, a minimum input of 2.3 V for the DC/DC, and a minimum input of 1.6 V for the LDOs. The TPS65000-Q1 supports either a 2.25-MHz forced PWM operation with spread-spectrum or an automatic transition to PFM mode for maximum light load efficiency. The device is available in a small 16-pin, leadless, 3×3-mm QFN package.

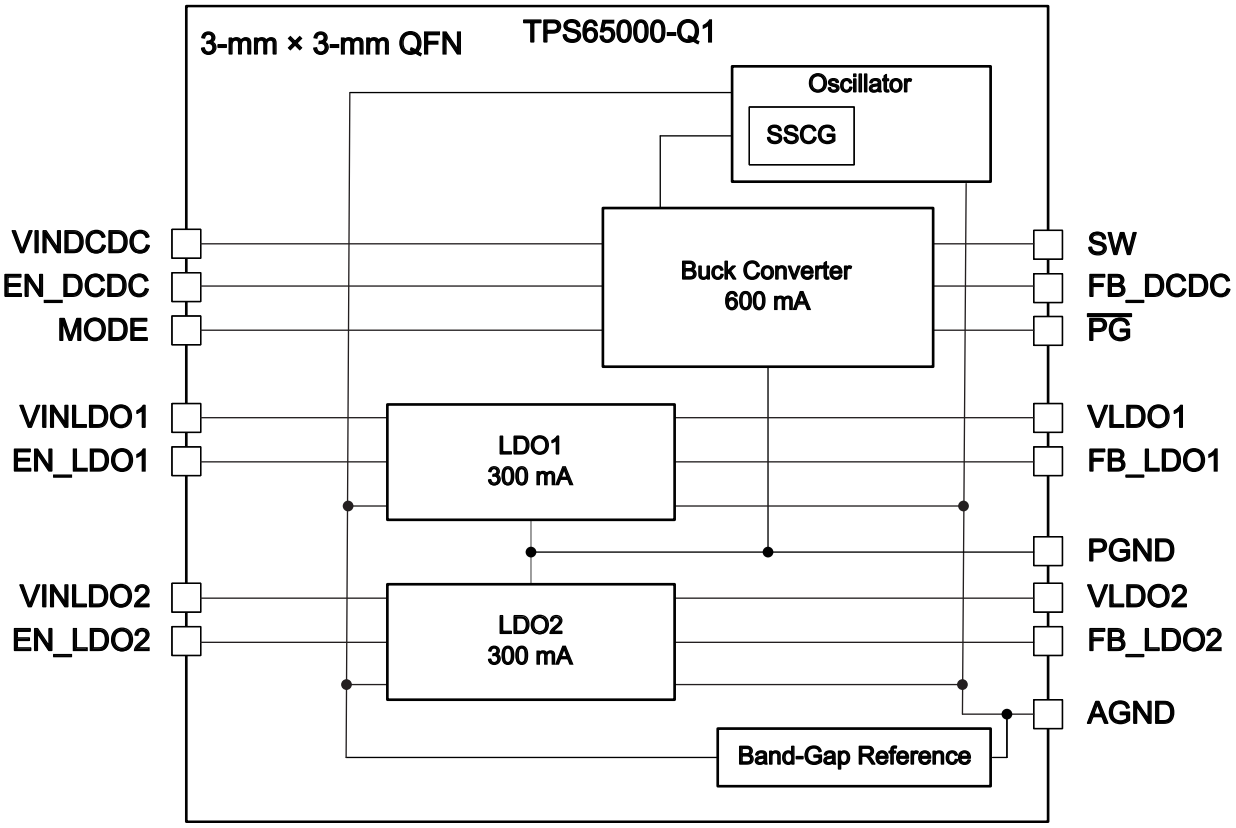

Figure 3. TPS65000-Q1 Functional Block Diagram

Key features of this device include:

- V_{IN} = 2.3 V to 6 V
- Spread-spectrum clock (SSC) generation for reduced EMI
- 2.25-MHz fixed-frequency operation
- Step-down converter: V_{IN} = 2.3 V to 6 V, 600-mA output current
- LDOs: V_{IN} = 1.6 V to 6 V, 300-mA output current
- Separate power inputs and enables
- Power Good
- 3-mm×3-mm, 16-pin QFN
- Step-down converter and LDOs: Adjustable output voltage

2.3 Design Considerations

This reference design implements automotive qualified components in a flexible platform for experimenting with various loads and conditions. For configurability, all output voltages are adjustable through the use of external feedback resistors at the expense of overall component count and solution size. Both regulator devices are capable of fixed voltage variants, and the total solution size can further be reduced through the use of non-automotive qualified passives, which are often available in smaller package footprints.

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2.4 System Design Theory

This reference design targets a solution size less than 20 mm × 20 mm, capable of delivering power from a POC transmission line to a generic remote camera application. Typical cameras sensors operate with separate analog and digital domains, which can require sequencing for reliable behavior, and often have strict input requirements for analog domains to reduce imaging noise. For this reason, many cameras implement LDOs to separate supply rails for simplicity and reduce the power supply ripple at the expense of system efficiency. The power lost in an LDO is dependent on the current through the device multiplied by the difference between input and output voltage; therefore, larger differences decrease efficiency and increase heat generated in the regulator.

In contrast, POC installations benefit from larger bus voltages because less current is required to deliver equivalent power to the loads, reducing DC voltage drop across the intrinsic resistance of the transmission line.

A solution for remote camera power must therefore efficiently distribute a moderately large input voltage into separate and sequenced low voltage domains while maintaining the integrity of the transmitted data. For this purpose, a wide-band filter is leveraged from the TIDA-01130 reference design, a mid-V_{IN} buck generates an intermediate rail, and a flexible PMIC regulates the individual power domains for a typical imaging application.

2.4.1 POC Filter

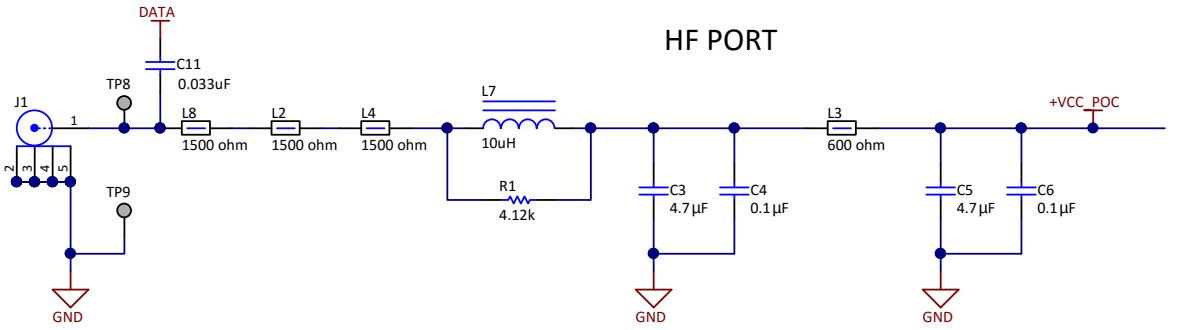

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Figure 4. Schematic of Power-Over-Coax (POC) Filter

The input filter leverages the TIDA-01130 reference design, which mostly relies on series inductive elements to isolate frequencies above 10 MHz from the low-frequency DC current. For more details on input filter designs, see *Automotive 2-MP Camera Module Reference Design With MIPI CSI-2 Video Interface, FPD-Link III and POC* and *Sending Power Over Coax in DS90UB913A Designs*.

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2.4.2 Pre-Regulator

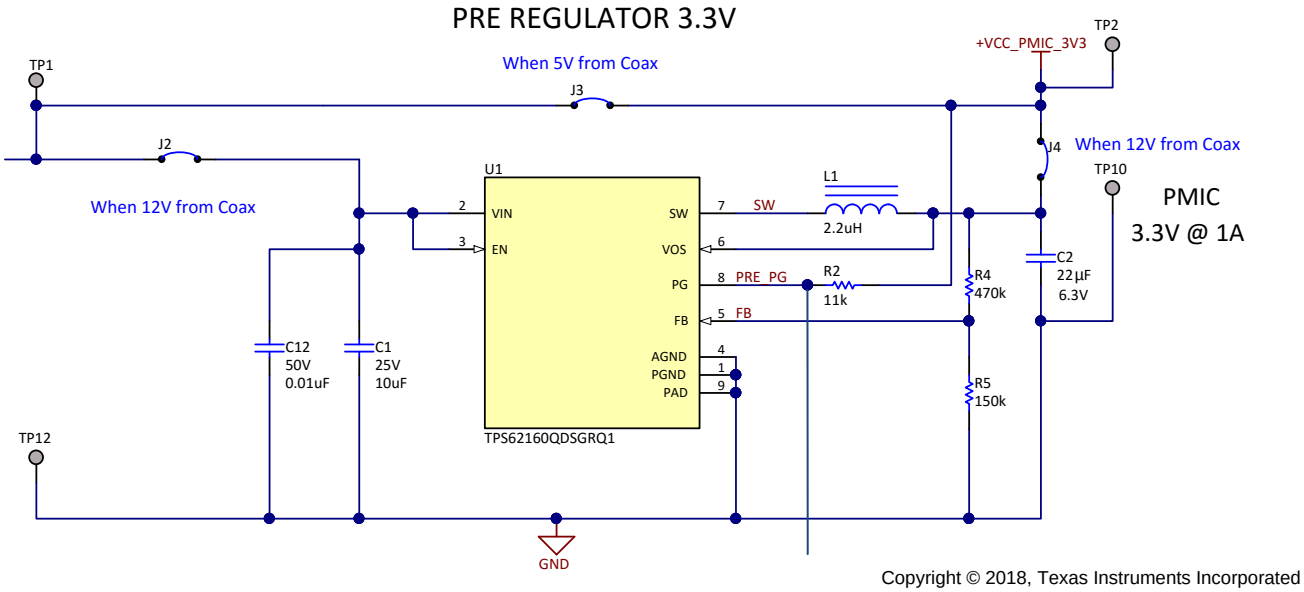

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Figure 5. Schematic of Pre-Regulator

The TPS62160 regulates a target voltage of 3.3 V through the use of an external resistor divider using Equation 1.

$$R1 = R2 \quad (VOUT VREF - 1) \tag{1}$$

For this device, V_{REF} is defined as 800 mV and R_2 designates the resistor connecting feedback to ground. This output voltage is a common configuration for the TPS62160, where a 2.2-µH inductor and 22-µF output filter capacitor are typically recommended. The total load of the PMIC is not expected to exceed 1.5 W, resulting in a maximum load current of 450 mA. Using the following equations from the TPS62160 data sheet, the maximum expected inductor current must be less than 730 mA; however, a larger inductor has been selected allowing additional loads up to 500 mA on the 3.3-V rail.

$$IL(max) = IOUT(max) + \Delta IL(max) 2 \Delta IL(max) = VOUT \times 1 - VOUT VIN(max) L(min) \times fsw \tag{2}$$

- $I_{L(max)}$ is the maximum inductor current
- ΔI_L is the peak-to-peak inductor ripple current
- $L_{(min)}$ is the minimum effective inductor value, and
- f_{sw} is the actual PWM switching frequency

A 25-V, 10-µF input capacitor adequately supplements transient currents without excessive derating, and a 10-nF capacitor is included to reduce potential high-frequency noise. Once the regulator is within 95% of the targeted output voltage, the active high power-good signal asserts the subsequent supplies in the PMIC. For flexibility, a jumper network allows bypassing the pre-regulator for testing 5-V POC systems directly into the PMIC.

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2.4.3 PMIC

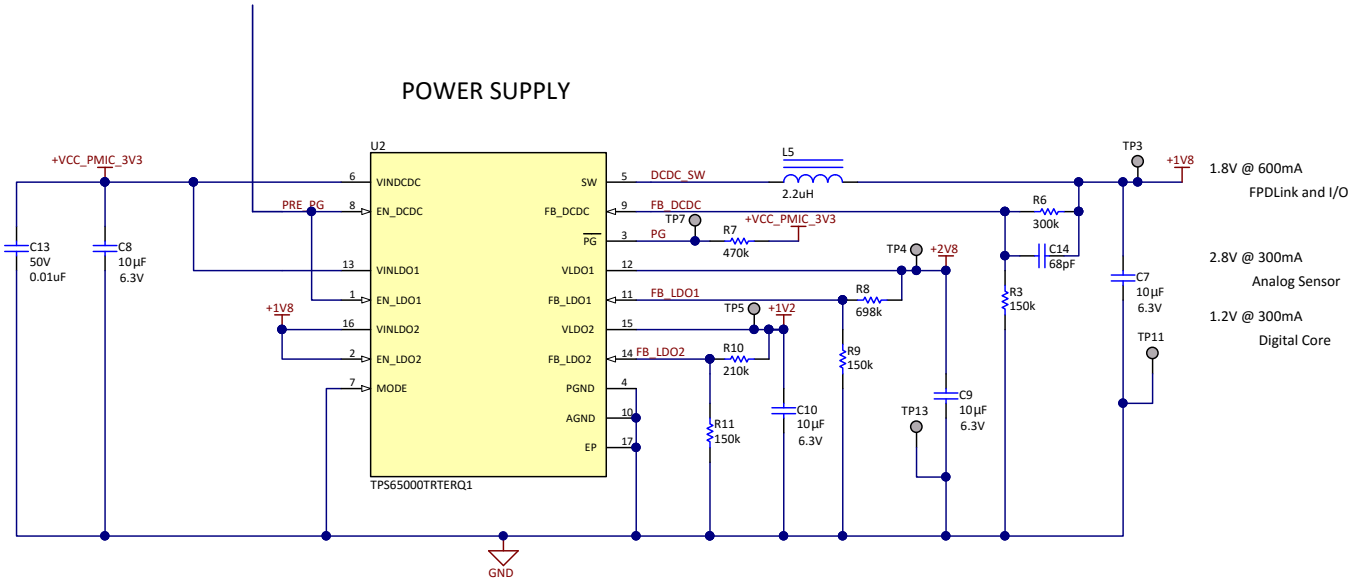

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Figure 6. Schematic of Power Management IC (PMIC)

The PMIC accepts 3.3 V from the pre-regulator or 5 V directly from the POC filter network to supply the 2.8-V LDO and the 1.8-V DC/DC. The 1.8-V IO domain can then supply the input voltage to the 1.2-V LDO, assuming that both domains do not require more than 300 mA concurrently.

The resistor divider equation used for the TPS62160 also applies to the regulators within the TPS65000, where both LDOs have a reference voltage of 500 mV, while the DC/DC has a reference voltage of 600 mV. The DC/DC also recommends a feedforward capacitor in the feedback loop for optimum load transient response, recommending a 22-pF to 33-pF capacitor when the parallel equivalent of the feedback resistors approximates to 300 kΩ. In this reference design, the parallel equivalent resistance of R_1 and R_2 approximates to 100 kΩ, resulting in a feedforward capacitor of 68 pF to maintain a similar RC constant.

Each LDO requires a 10-µF output capacitor for stability, and dedicated input capacitors are omitted due to the close proximity of the supplying regulator output capacitors. The DC/DC uses the typically recommended 10-µF input capacitor, 2.2-µH inductor, and 10-µF output capacitor.

The 2.8-V analog domain and the 1.8-V IO domain are gated by either the power-good signal from the pre-regulator or directly by the 5-V POC bus. The PMIC features soft-start and an enable delay for the DC/DC, allowing the analog rail to regulate first with the same enable source. The DC/DC subsequently enables the 1.2-V LDO, allowing the analog rail to regulate first in the sequence, followed by the IO domain, which is then followed by the 1.2-V digital core.

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3 Hardware, Testing Requirements, and Test Results

3.1 Required Hardware

This reference design accepts 12 V or 5 V into an onboard FAKRA connector. For the purposes of this design guide, a modified TIDA-01005 camera hub board supplied with a 12-V and 5-V bench supply is connected to the reference design by using a 6-meter 50-Ω coaxial cable to evaluate performance.

3.2 Testing and Results

The following test results demonstrate the start-up behavior, DC/DC voltage ripple, load transient response, typical current consumption, thermal performance, and shutdown behavior of the camera supply reference design. For the purposes of these tests, the analog rail is supplying 70 mA, the IO rail is supplying 225 mA, and the digital rail is supplying 150 mA to dedicated load resistors. Start-up and shutdown events are initiated through enabling or disabling of the camera hub bench supply.

3.2.1 Start-up Behavior

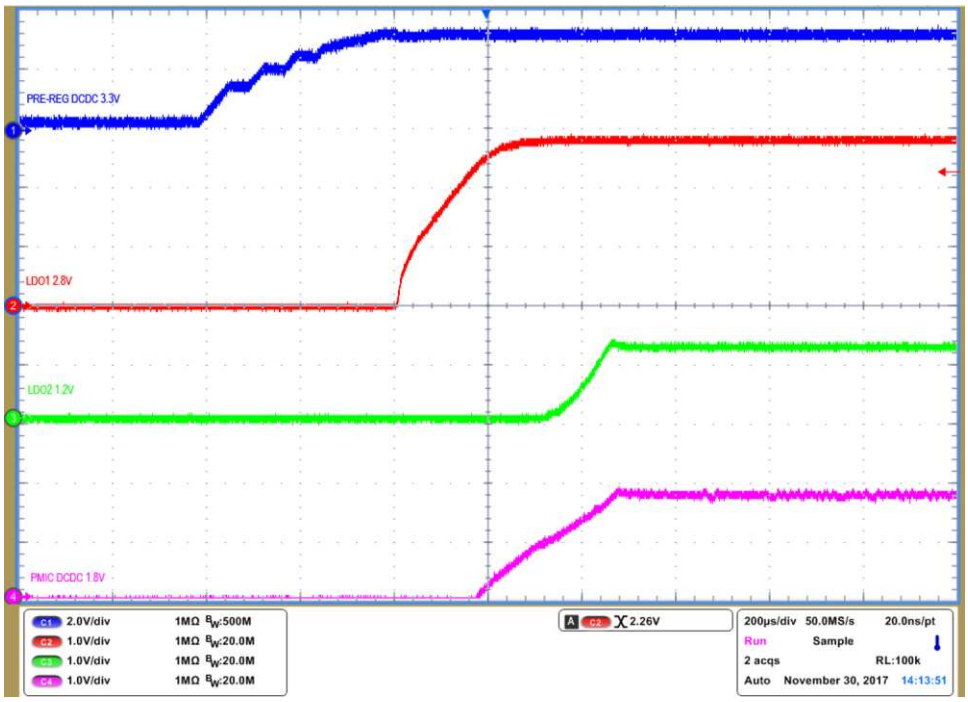

Figure 7. Power-Up Sequence With Pre-Regulator

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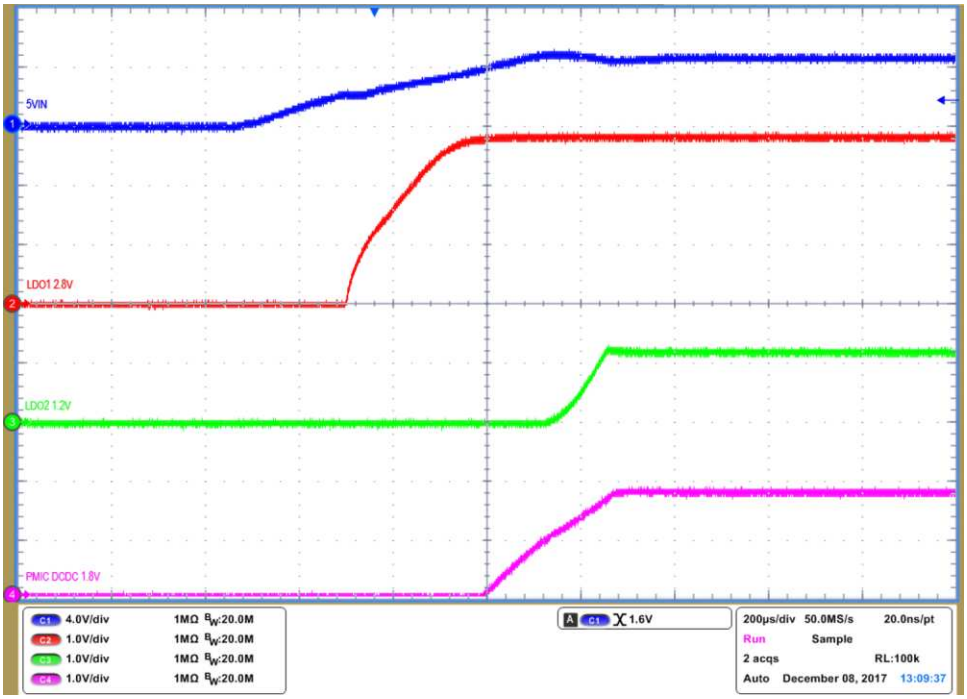

Figure 8. Power-Up Sequence Without Pre-Regulator

3.2.2 DC/DC Voltage Ripple

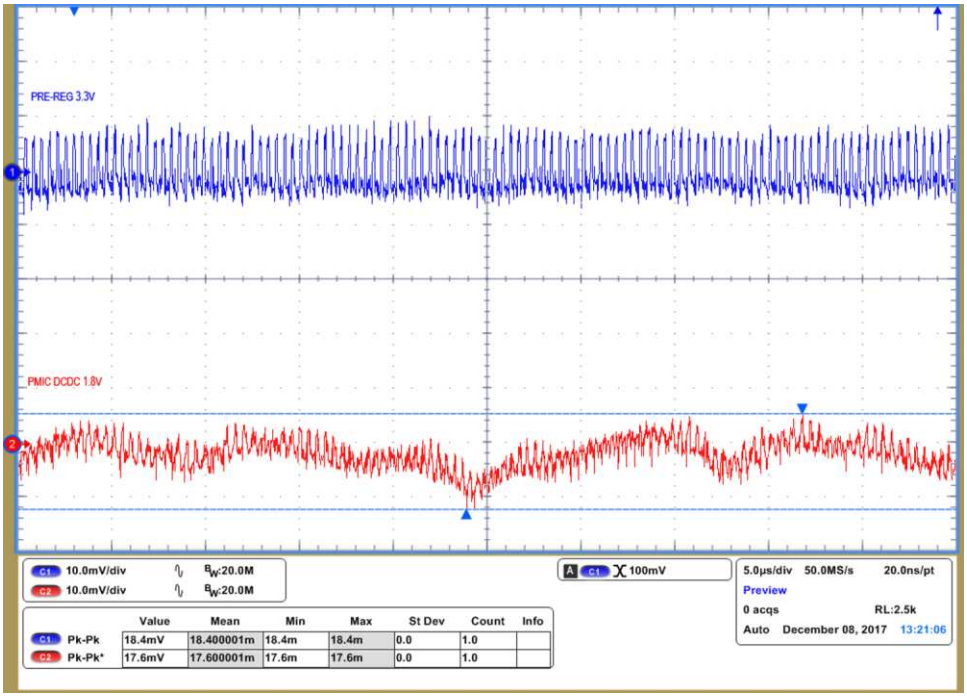

Figure 9. Pre-Regulator and PMIC DC/DC Voltage Ripple

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3.2.3 Transient Stability

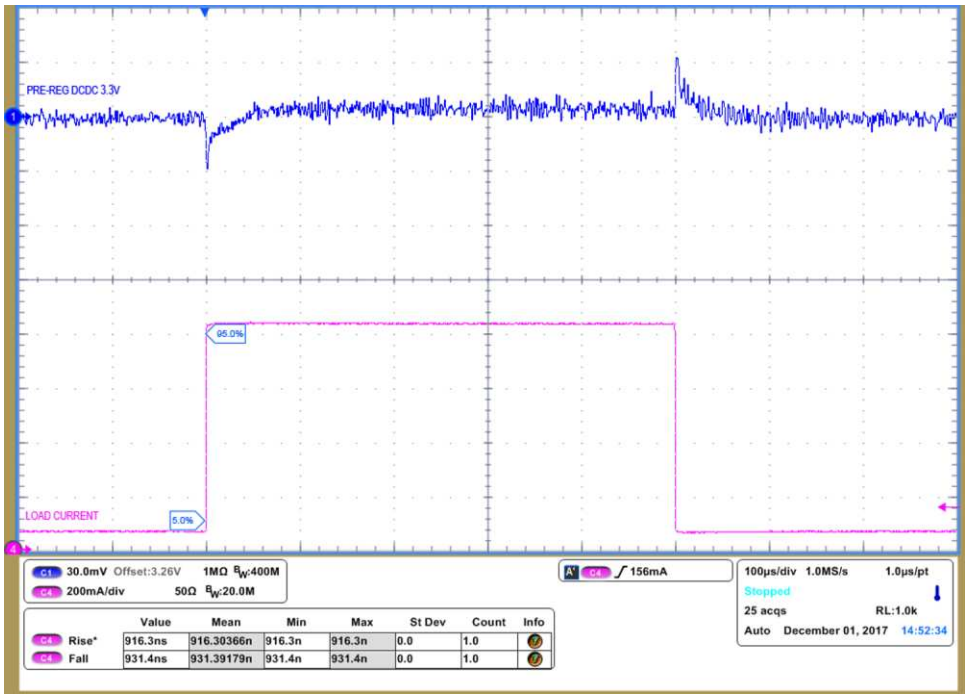

Figure 10. Pre-Regulator 3.3-V Load Transient

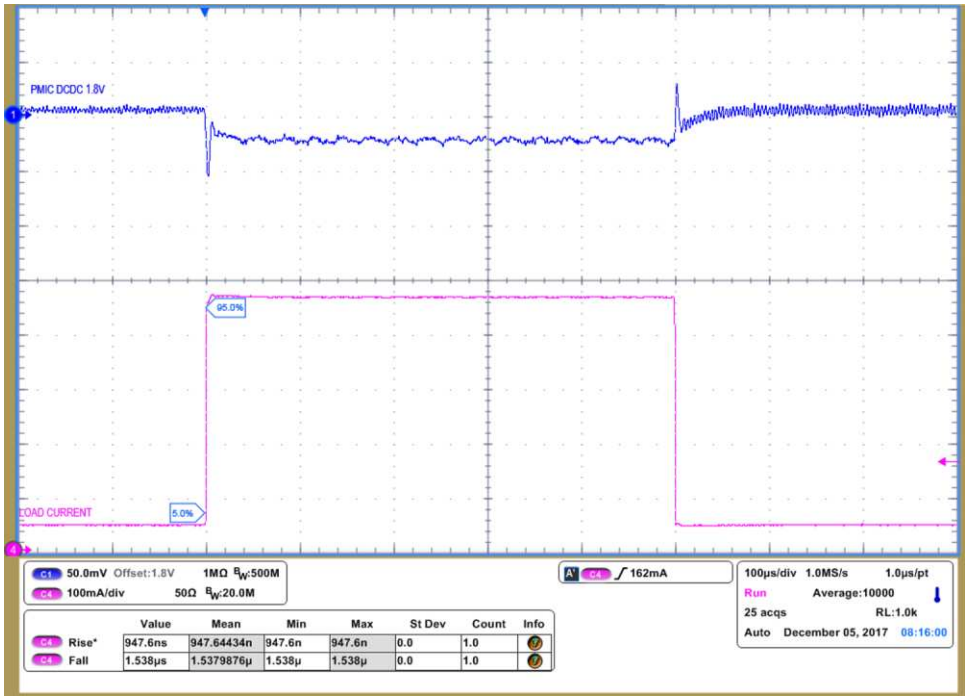

Figure 11. PMIC DC/DC 1.8-V Load Transient

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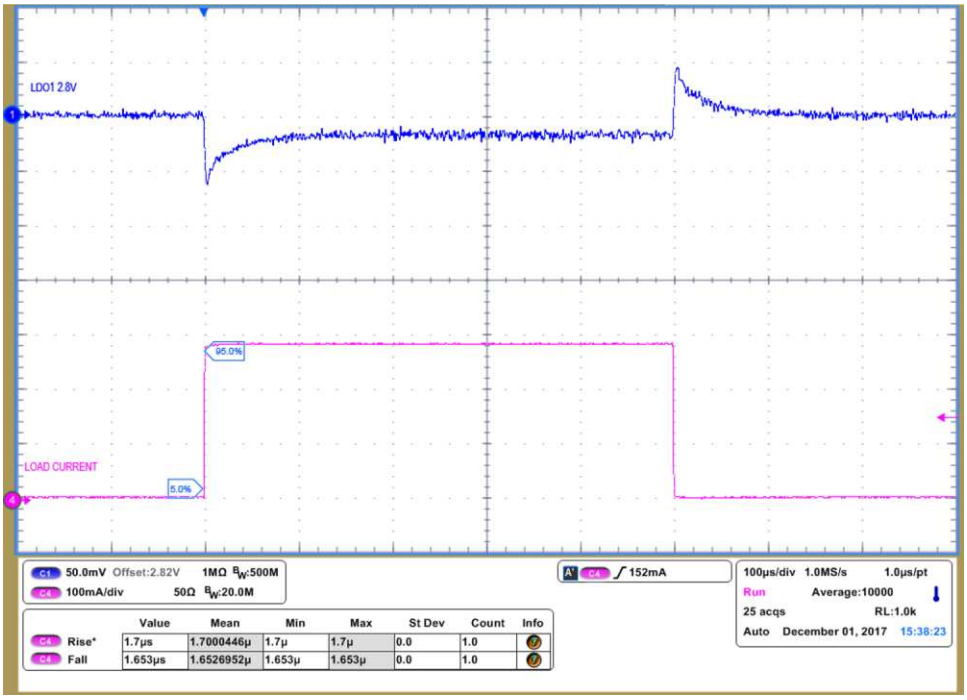

Figure 12. LDO1 2.8-V Load Transient

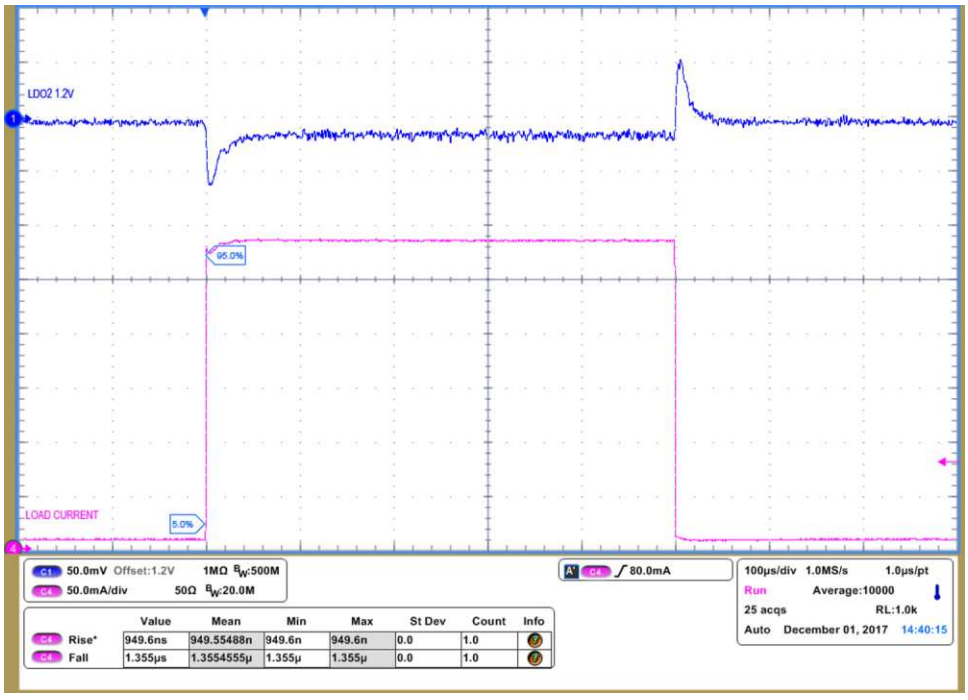

Figure 13. LDO2 1.2-V Load Transient

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3.2.4 Typical Current Consumption

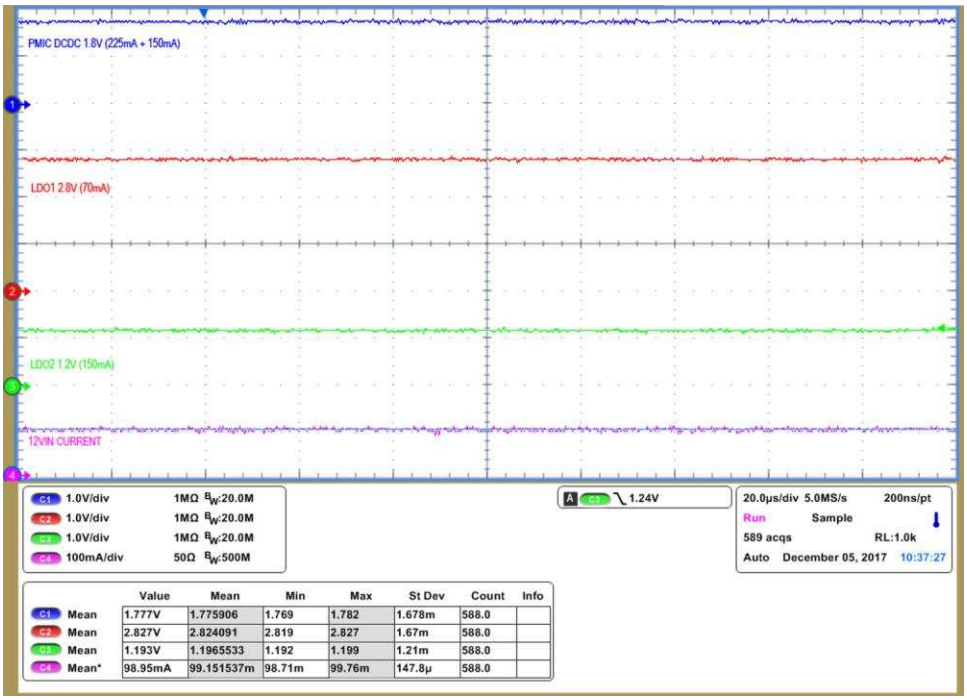

Figure 14. Typical Current Consumption With Pre-Regulator (12 V)

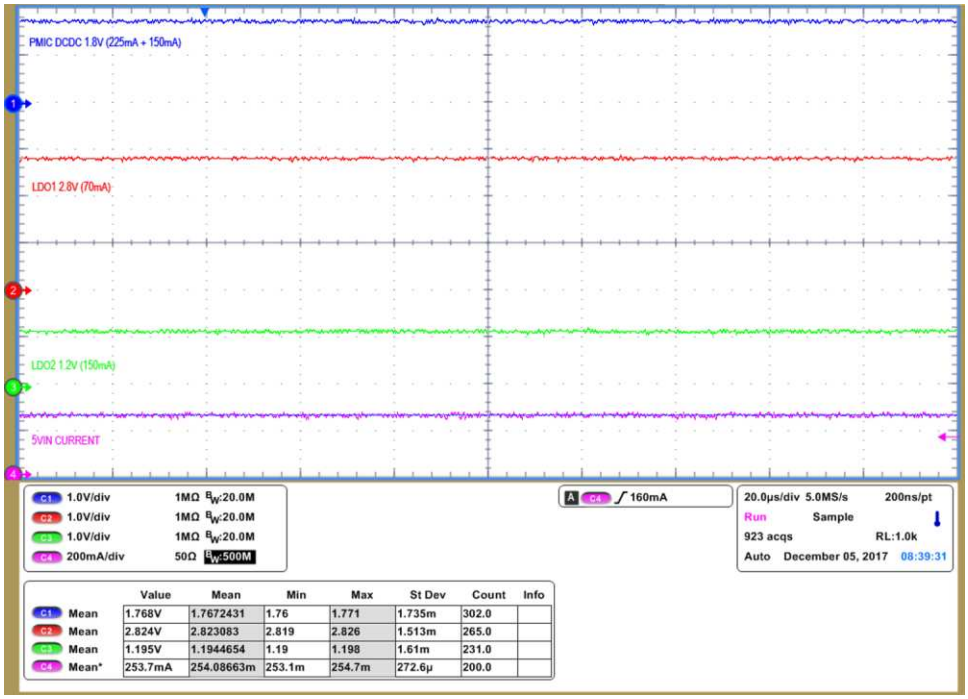

Figure 15. Typical Current Consumption Without Pre-Regulator (5 V)

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3.2.5 Thermal Performance

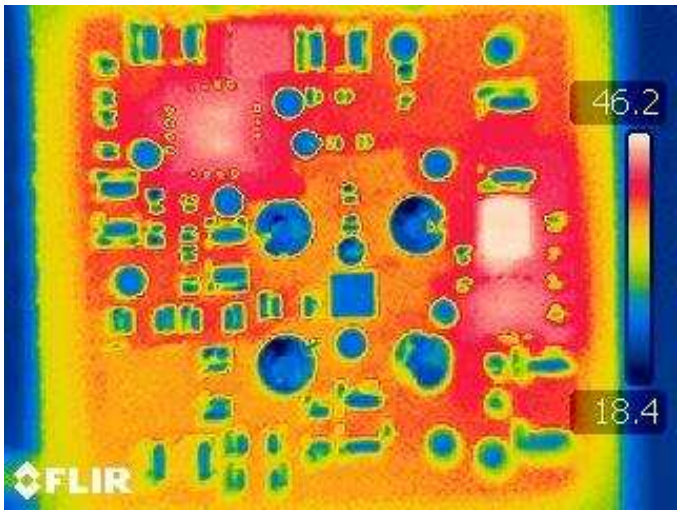

Figure 16. Thermal Capture With Pre-Regulator (12 V)

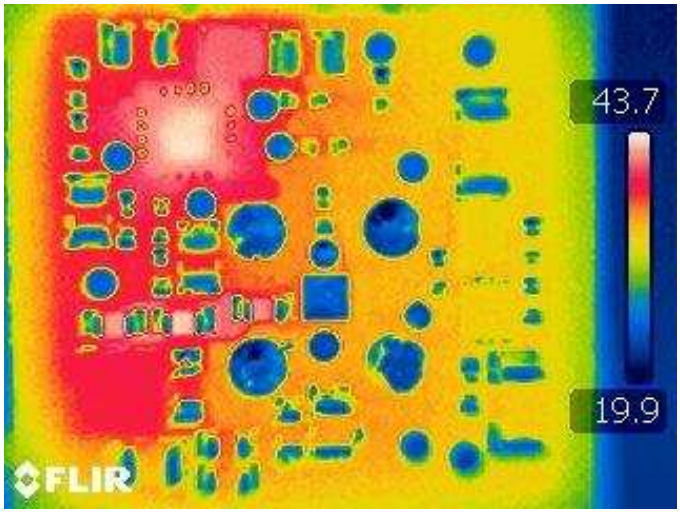

Figure 17. Thermal Capture Without Pre-Regulator (5 V)

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3.2.6 Shutdown Behavior

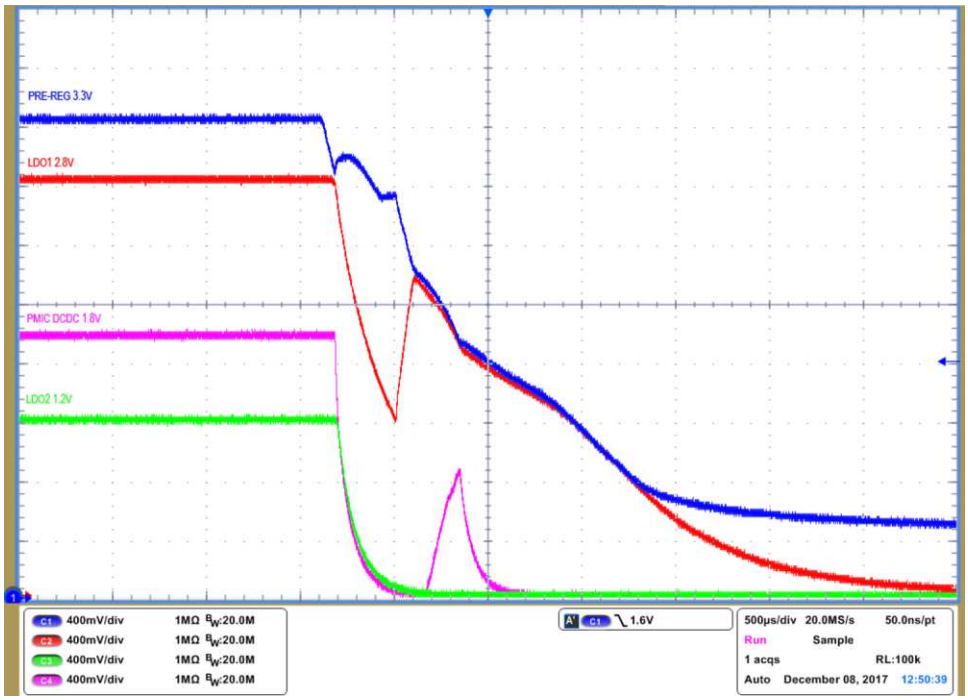

Figure 18. Shutdown With Pre-Regulator (12 V)

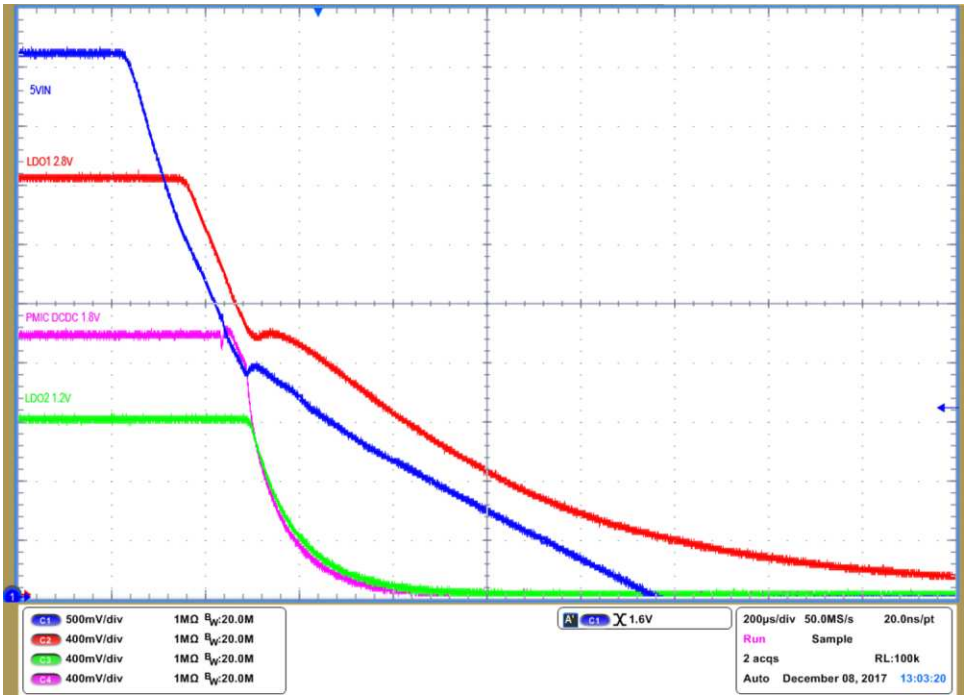

Figure 19. Shutdown Without Pre-Regulator (5 V)

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4 Design Files

4.1 Schematics

To download the schematics, see the design files at TIDA-01491.

4.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDA-01491.

4.3 PCB Layout Recommendations

Place input capacitors as close as possible to the device. Minimize the area of the switching currents by reducing all trace lengths, and minimizing distance from ground pins of output filter capacitors to the ground pads of their associated input capacitors. Use star connections to bridge ground domains to a common ground plane, and connect thermal pads to this ground plane with multiple vias.

4.3.1 Layout Prints

To download the layer plots, see the design files at TIDA-01491.

4.4 Altium Project

To download the Altium project files, see the design files at TIDA-01491.

4.5 Gerber Files

To download the Gerber files, see the design files at TIDA-01491.

4.6 Assembly Drawings

To download the assembly drawings, see the design files at TIDA-01491.

5 Related Documentation

1. Texas Instruments, *TPS6216x-Q1 3-V to 17-V 1-A Step-Down Converter with DCS-Control™ Data Sheet*
2. Texas Instruments, *TPS65000-Q1 2.25-MHz Step-Down Converter With Dual LDOs Data Sheet*
3. Texas Instruments, *TIDA-01130 Automotive 2-MP Camera Module Reference Design With MIPI CSI-2 Video Interface, FPD-Link III and POC*
4. Texas Instruments, *Sending Power Over Coax in DS90UB913A Designs Application Report*

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