TI Designs: TIDA-01412

Power Supply Reference Design for Automotive Microcontroller in Gateway and Body Control Module

TEXAS INSTRUMENTS

Description

This discrete power supply reference design demonstrates a complete power solution for the Freescale™ MPC5748G Microcontroller. This simple solution uses only five DC/DC converters and offers a more flexible, scalable, and cost-effective solution than a power management integrated circuit (PMIC). This design supports numerous automotive applications, such as gateway and central body control modules.

Resources

TIDA-01412	Design Folder
TPS6213013A-Q1	Product Folder
TPS62130A-Q1	Product Folder
TPS62133A-Q1	Product Folder
LM53603-Q1	Product Folder
TPS40210-Q1	Product Folder

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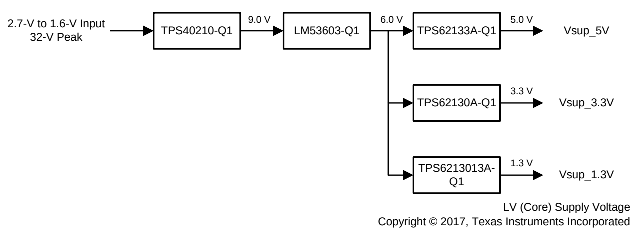
Features

- Supports 2.7-V to 16-V, 32-V Peak Input Voltage
- Flexibility in Terms of Load and Scalability for Future Generations of Microcontrollers
- Less Than 1% Accuracy on LV Core Supply of MCU
- Efficiency Up to 80%
- Requires Only Five DC/DCs for Cost-Effective and Simple Power Solution
- AEC-Q100 Qualified

Applications

- Body Control Module (BCM)
- Automotive Gateway



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1 System Description

The MPC5748G Microcontroller (MCU) is used in a wide variety of automotive applications, such as high-end gateway, combined body controller and gateway, central body, vehicle body controllers, smart junction box, and front module applications. These applications require a small, highly-efficient power supply. Compared to a PMIC solution, this power solution is more flexible in terms of load requirements for different end applications. Additionally, it has the advantage of being easily scalable to future generations of the MCU. The MPC5748G device has multiple supply pins for the core, input and output (I/O), flash, and analog supplies. This reference design provides a power solution to supply all of these components in different power configurations of the MCU. The design has three output rails: 1.3 V ($V_{sup\_1.3V}$), 5 V (V_{sup_5V}), and 3.3 V ($V_{sup\_3.3V}$).

- $V_{sup\_1.3V}$ is used to supply the core logic (V_{DD_LV}).
- V_{sup_5V} can be used to supply the I/O pins ($V_{DD\_HV\_A}$, $V_{DD\_HV\_B}$, and $V_{DD\_HV\_C}$) and analog pins ($V_{DD\_HV\_ADC0}$, $V_{DD\_HV\_ADC1}$, and $V_{DD\_HV\_ADC1\_REF}$), which are also called analog-to-digital converter (ADC) pins depending on the power configuration of the MCU.
- $V_{sup\_3.3V}$ can be used to supply the I/O pins ($V_{DD\_HV\_A}$, $V_{DD\_HV\_B}$, and $V_{DD\_HV\_C}$), the flash ($V_{DD\_HV\_FLA}$), and analog pins ($V_{DD\_HV\_ADC0}$, $V_{DD\_HV\_ADC1}$, $V_{DD\_HV\_ADC1\_REF}$, and $V_{IN1\_CMP\_REF}$), depending on the power configuration of the MCU.

For more details on how to choose the power configuration for each pin, see *MPC5748G Data Sheet* and *MPC5748G Hardware Design Guidelines*.

This reference design provides a tested and documented power solution that is suitable for the MPC5748G MCU. The solution achieves high efficiency by using integrated DC/DC converters and no low dropout (LDO) linear regulators. High efficiency results in a low self-temperature rise and higher reliability.

1.1 Key System Specifications

Table 1. Key System Specifications

PARAMETERS		SPECIFICATIONS	DETAILS
Input voltage range		2.7-V to 16-V, 32-V peak input voltage	—
OUTPUTS PROVIDED			
V_{sup_5V}	Voltage setpoint	5.0 V	Section 4.1
	Ripple	< 25 mV	
	Transient response	< 3%	
	Load regulation	< 1.5%	
$V_{sup\_3.3V}$	Voltage setpoint	3.3 V	Section 4.2
	Ripple	< 25 mV	
	Transient response	< 3%	
	Load regulation	< 1.5%	
$V_{sup\_1.3V}$	Voltage setpoint	1.3 V	Section 4.3
	Ripple	< 20 mV	
	Transient response	< 3%	
	Load regulation	< 1 %	

MPC5748G power requirements:

- $V_{DD\_HV\_ADC0}$: 3.3-V / 5.0-V ADC supply voltage
- $V_{DD\_HV\_ADC1}$: 3.3-V / 5.0-V ADC supply voltage
- $V_{DD\_HV\_ADC1\_REF}$: 3.3-V / 5.0-V ADC1 high reference voltage
- $V_{DD\_HV\_A}$: 3.3-V / 5.0-V input/output supply voltage
- $V_{DD\_HV\_B}$: 3.3-V / 5.0-V input/output supply voltage
- $V_{DD\_HV\_C}$: 3.3-V / 5.0-V input/output supply voltage
- $V_{DD\_HV\_FLA}$: 3.3-V flash supply voltage (generated internally)
- V_{DD_LV}: 1.3-V internal core supply voltage

The I/O and HV ADCx supply voltages can be either in the 5-V range or in the 3.3-V range. When operating in the 3.3-V range, the HV flash supply voltage ($V_{DD\_HV\_FLA}$) must be externally supplied using a 3.3-V source. The 3.3-V flash supply is internally generated when the device operates in the 5-V range. The I/O voltages are all independent supplies that can be set to 3.3 V or 5 V. The core supply voltage (V_{DD_LV}) is set to a fixed voltage of 1.3 V. For more details, see *MPC5748G Data Sheet*.

2 System Overview

2.1 Block Diagram

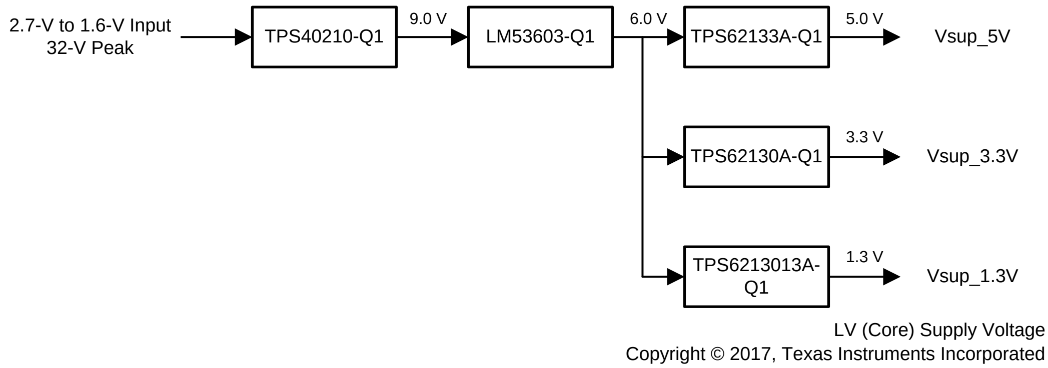

Figure 1. Block Diagram

2.2 Highlighted Products

2.2.1 TPS6213XA-Q1

The TPS6213XA-Q1 devices are easy-to-use, synchronous, step-down DC/DC converters optimized for applications with high power density. A high switching frequency of typically 2.5 MHz allows the use of small inductors and provides fast transient response, as well as high output-voltage accuracy through the use of the DCS-Control™ topology (**D**irect **C**ontrol with **S**eamless Transistion into Power Save Mode). With a wide operating input-voltage range of 3 V to 17 V, the devices are ideally suited for systems that draw power from intermediate bus power rails. The devices support up to a 3-A continuous output current at output voltages between 0.9 V and 6 V (with 100% duty cycle mode). The output-voltage start-up ramp is controlled by the soft-start pin, which allows operation as either a standalone power supply or in tracking configurations. Power sequencing is also possible by configuring the enable and open-drain power-good pins. In power save mode, the devices show quiescent current of approximately 17 µA from V_{IN}. Power save mode, which is entered automatically and seamlessly if the load is small, maintains high efficiency over the entire load range. In shutdown mode, the devices are turned off and shutdown current consumption is less than 2 µA. The devices are packaged in a 16-pin VQFN package measuring 3 mm × 3 mm.

The TPS6213013A-Q1 has a higher precision and provides a precise supply to the core rail of the MCU.

Table 2. Device Comparison Table

PART NUMBER	OUTPUT VOLTAGE	PACKAGE MARKING
TPS62130A-Q1	Adjustable	PA6IQ
TPS62133A-Q1	5 V	PA6JQ
TPS6213013A-Q1	1.3 V	13013Q

2.2.2 TPS40210-Q1

The TPS40210-Q1 is a wide-input voltage (4.5 V to 52 V), nonsynchronous boost controller. This controller is suitable for topologies that require a grounded source N-channel field-effect transistor (FET) including boost, flyback, single-ended primary-inductor converter (SEPIC), and various light-emitting-diode (LED) driver applications. The device features include programmable soft-start, overcurrent protection with automatic retry, and programmable oscillator frequency. Current mode control provides improved transient response and simplified loop compensation.

2.2.3 LM53603-Q1

The LM53603-Q1 buck regulator is specifically designed for automotive applications, providing an output voltage of 5 V or 3.3 V (with ADJ option) at 3 A or 2 A, from an input voltage of up to 36 V. Advanced high-speed circuitry allows the device to regulate from an input of up to 20 V, while providing an output of 5 V at a switching frequency of 2.1 MHz. The innovative architecture allows the device to regulate a 3.3-V output from an input voltage of only 3.5 V. All aspects of this product are optimized for the automotive customer. An input voltage range up to 36 V, with transient tolerance up to 42 V, eases input surge protection design. An open-drain reset output, with filtering and delay, provides an accurate indication of system status. This feature negates the requirement for an additional supervisory component, saving cost and board space. Seamless transition between PWM and PFM modes, along with a no-load operating current of only 24 μA, ensures high efficiency and superior transient response at all loads.

2.3 System Design Theory

The power requirements of the microcontroller are a function of the specific functionality used in a given application. In most cases, the current drawn and the accuracy needed by each rail is not known precisely during the design phase. Only gross estimates are available when the power supply is designed. Therefore the TIDA-01412 reference design uses DC/DC converters to provide flexibility to the designer and scalability for future generations of the microcontroller. Additionally, this design has the advantage of providing high-precision voltage rails compared to the PMIC solution.

This reference design uses five DC/DC converters and provides three output rails to generate appropriate supply voltages for the MCU. Because of the large input range from 2.7 to 16 V, the TPS40210-Q1 was chosen to get a constant voltage of 9 V. The TPS40210-Q1 is capable of a wide input operating voltage range, and is qualified for automotive applications. The voltage is further decreased with a synchronous 2.1-MHz step down converter (LM53603-Q1) to 6 V. The TPS6213x-Q1 step down converters are then used to obtain the suitable I/O and high-voltage (HV) ADC supply voltage of 5 V or 3.3 V and the core supply voltage of 1.3 V. Due to the high switching frequency of the TPS6213x, small inductors can be used and the design can be kept small and efficient. In this design, the TPS6213x-Q1 DC/DC converter provides a precise output regulation; the TPS6213013A-Q1 provides an output load regulation accuracy less than 1% for the low-voltage (LV) core supply.

3 Getting Started Hardware

To test this reference design, apply an input voltage between 2.7 V and 16 V to the J1 input connector. Then, set the enable pins of connector J8 to ON by using a jumper. All DC/DC converters will start working; check the expected output-voltages at the appropriate connectors. J4 should provide a 5-V output, J5 the 3.3-V output, and J6 the 1.3-V output-voltage. To test the design sufficiently, apply certain loads to observe the behavior of the output voltage.

4 Testing and Results

This section includes the relevant test results to power the MPC5748G MCU. Unless otherwise noted, all testing was conducted at room temperature with 14 V for V_{IN} simulating the main supply from the car battery.

Conducted tests:

- Efficiency
- Load regulation
- Load transient
- Output ripple

4.1 V_{sup_5V}

Measurements were performed on the 5-V rail (J4). A load of 300 mA was continuously applied at J6 ($V_{sup\_1.3V}$) to measure a real case behavior of the circuit. Table 3 lists the test conditions.

Table 3. Test Conditions

VOLTAGE RAIL	OUTPUT VOLTAGE	LOAD
V_{sup_5V}	5 V	—
$V_{sup\_3.3V}$	3.3 V	0 mA
$V_{sup\_1.3V}$	1.3 V	300 mA

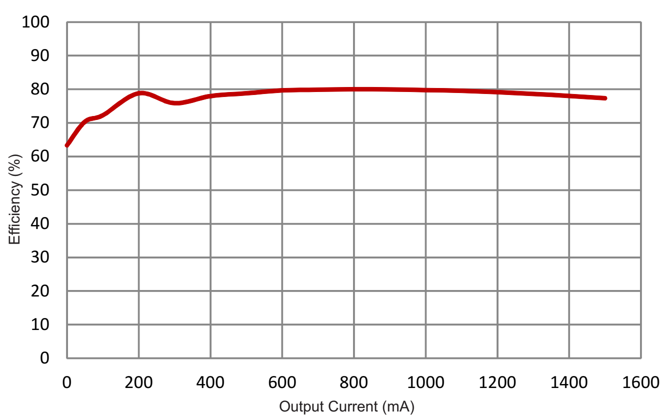

Figure 2. V_{sup_5V} Efficiency (14 V_{IN}, Measured at J4)

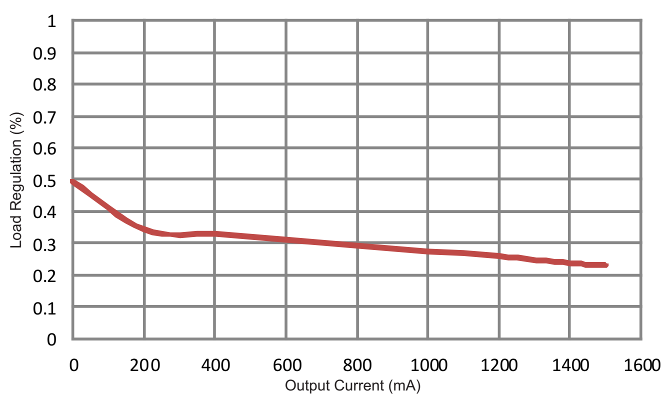

Figure 3. V_{sup_5V} Load Regulation (14 V_{IN}, Measured at J4)

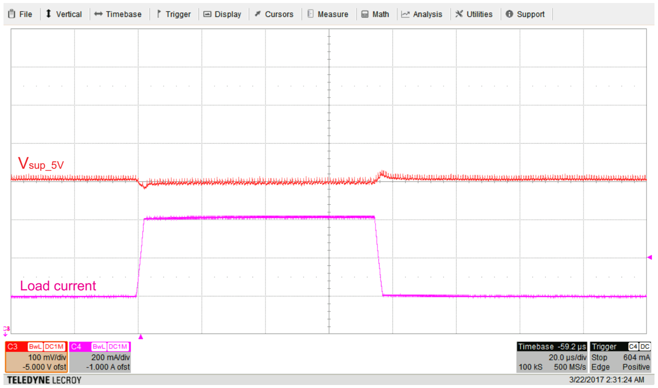

Figure 4. V_{sup_5V} Transient Response (14 V_{IN}, 400-mA to 800-mA Load Step, Measured at J4)

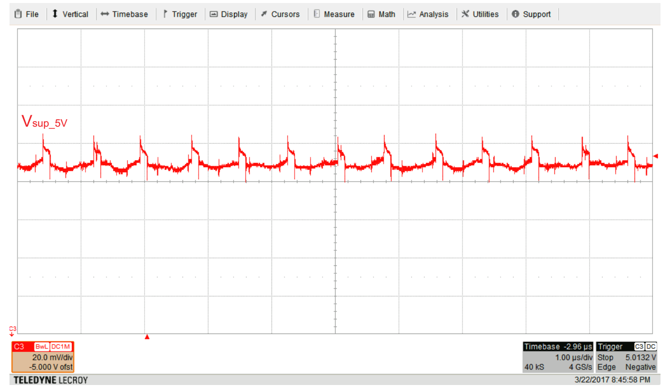

Figure 5. V_{sup_5V} Ripple (14 V_{IN}, 500-mA load at V_{sup_5V}, 300-mA load at $V_{sup\_1.3V}$, Measured at J4)

4.2 $V_{sup\_3.3V}$

The same measurements were performed on the 3.3-V rail (J5). A load of 300 mA was continuously applied at J6 ($V_{sup\_1.3V}$) to measure a real case behavior of the circuit.

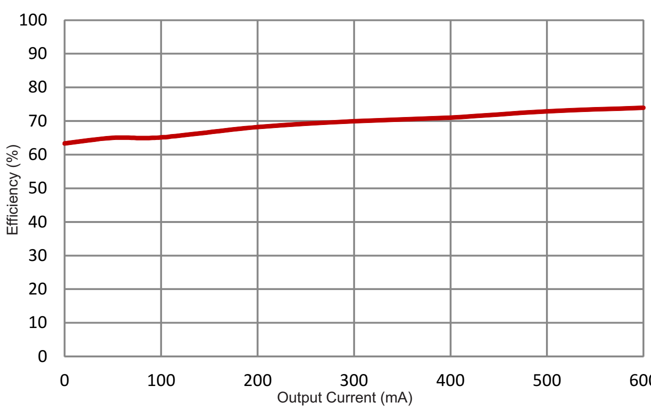

Figure 6. $V_{sup\_3.3V}$ Efficiency (14 V_{IN}, Measured at J5)

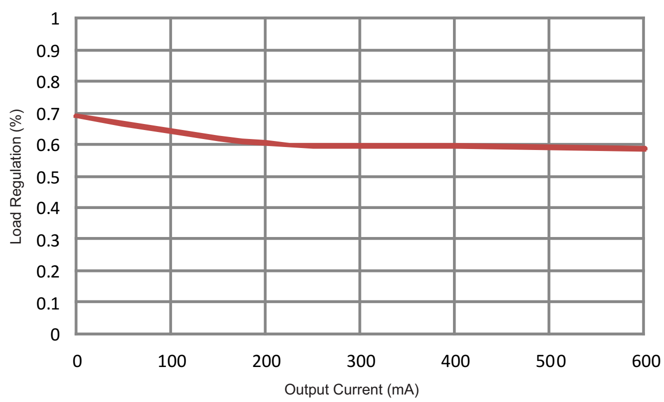

Figure 7. $V_{sup\_3.3V}$ Load Regulation (14 V_{IN} , Measured at J5)

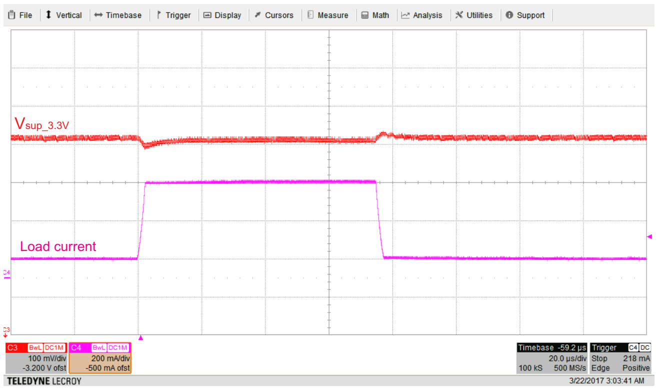

Figure 8. $V_{sup\_3.3V}$ Transient Response (14 V_{IN}, 100-mA to 500-mA Load Step, Measured at J5)

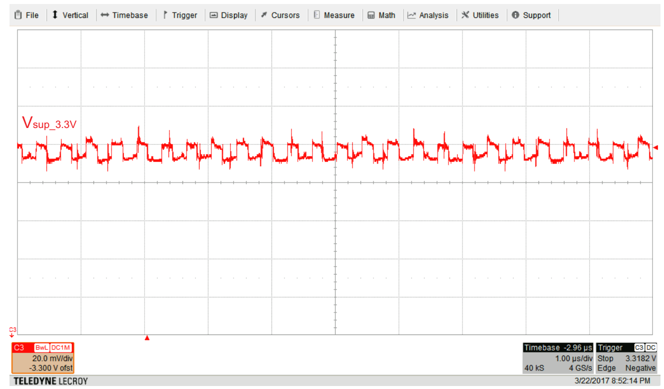

Figure 9. $V_{sup\_3.3V}$ Ripple (14 V_{IN}, 500-mA load on $V_{sup\_3.3V}$, 300-mA load on $V_{sup\_1.3V}$, Measured at J5)

4.3 $V_{sup\_1.3V}$

The same measurements were performed for the 1.3-V rail (J6). A load of 500 mA was continuously applied at J5 ($V_{sup\_3.3V}$) to measure a real case behavior of the circuit.

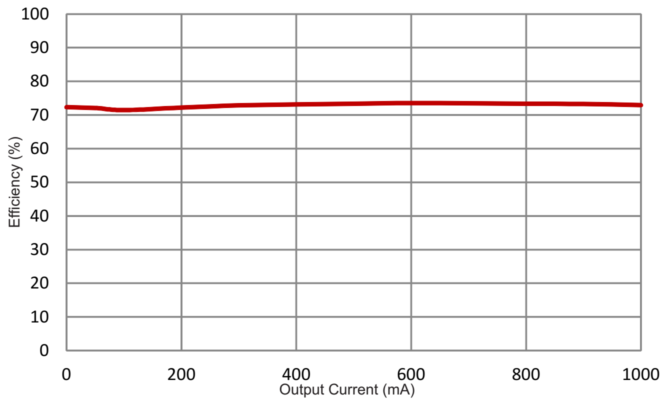

Figure 10. $V_{sup\_1.3V}$ Efficiency (14 V_{IN}, Measured at J6)

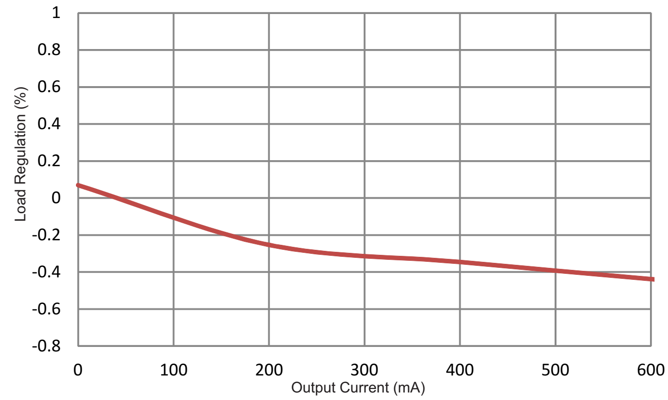

Figure 11. $V_{sup\_1.3V}$ Load Regulation (14 V_{IN}, Measured at J6)

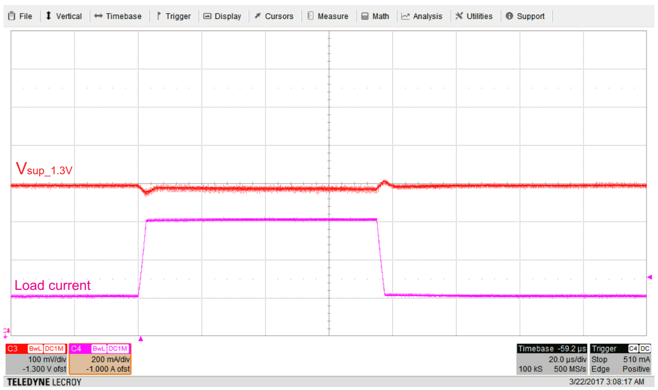

Figure 12. $V_{sup\_1.3V}$ Transient Response (14 V_{IN}, 400- to 800-mA Load Step, Measured at J6)

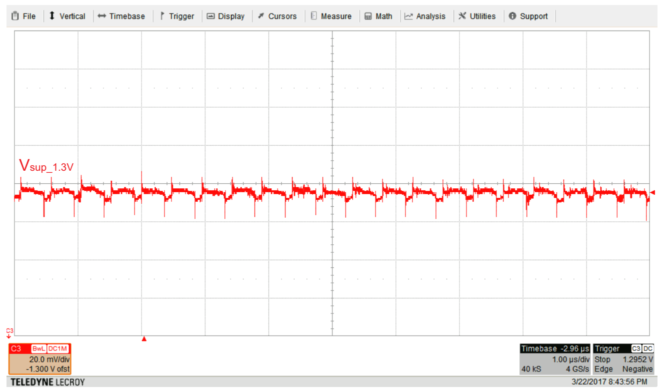

Figure 13. $V_{sup\_1.3V}$ Ripple (14 V_{IN}, 500-mA load on $V_{sup\_1.3V}$, 500-mA load on V_{sup_5V}, Measured at J6)

5 Design Files

5.1 Schematics

To download the schematics, see the design files at TIDA-01412.

5.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDA-01412.

5.3 PCB Layout Recommendations

5.3.1 Layout Prints

To download the layer plots, see the design files at TIDA-01412.

5.4 Gerber Files

To download the Gerber files, see the design files at TIDA-01412.

5.5 Assembly Drawings

To download the assembly drawings, see the design files at TIDA-01412.

6 Related Documentation

1. Texas Instruments, *TPS6213xA-Q1 3-V to 17-V 3-A Step-Down Converter with DCS-Control™*
2. Texas Instruments, *TPS4021x-Q1 4.5-V to 52-V Input, Current-Mode Boost Controllers*
3. Texas Instruments, LM53603-Q1 (3 A), LM53602-Q1 (2 A) 3.5 V to 36 V Wide-V_{IN} Synchronous 2.1 MHz Step- Down Converters for Automotive Applications
4. NXP Semiconductors, MPC5748G One Pager
5. NXP Semiconductors, MPC5748G Data Sheet
6. NXP Semiconductors, MPC5748G Hardware Design Guidelines

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