Design Guide: TIDA-050057

Power Solution for Alder Lake and Raptor Lake VCCIN_AUX Rail in PC Applications Reference Design

Description

This power-supply reference design supports VCCIN_AUX rail in Intel® Alder Lake and Raptor Lake platform. Using TPS51215A controller combined with an operational amplifier could support the control functions including VID control, load line (LL) and current monitor (IMON). The position for test tool interposer is reserved in this reference design to help with evaluation.

Resources

TIDA-050057	Design Folder
TPS51215A	Product Folder
TLV9051	Product Folder
CSD87355Q5D	Product Folder

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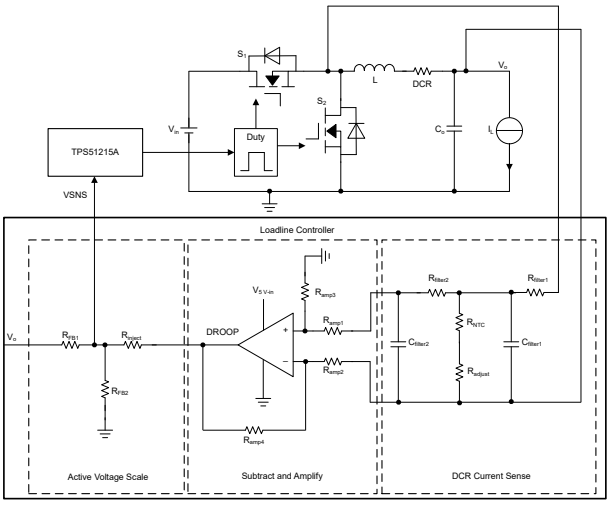
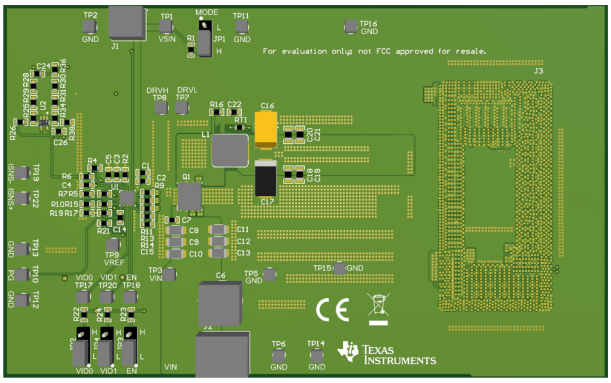
Features

- Differential voltage feedback
- Flexible output voltage from 0.5-V to 2.0-V and 0-V VOUT supported by 2-bit VID
- Programmable soft-start time and output voltage transition time
- Enhanced load transient with 2 mΩ load line (LL)

Applications

- Standard Notebook PC
- Desktop PC Motherboard
- Industrial Factory Automation and Control





1 System Description

The TIDA-050057 provides a power solution design for VCCIN_AUX rail in Intel® Alder Lake and Raptor Lake platform. TPS51215A is a synchronous buck controller with VID control bit. Combined with an operational amplifier, 2 mΩ load line is implemented. The position for test tool interposer is reserved in the reference design to help fast evaluation.

2 System Overview

2.1 Block Diagram

The basic block diagram of TPS51215A power solution with load line and IMON features is shown as Figure 2-1.

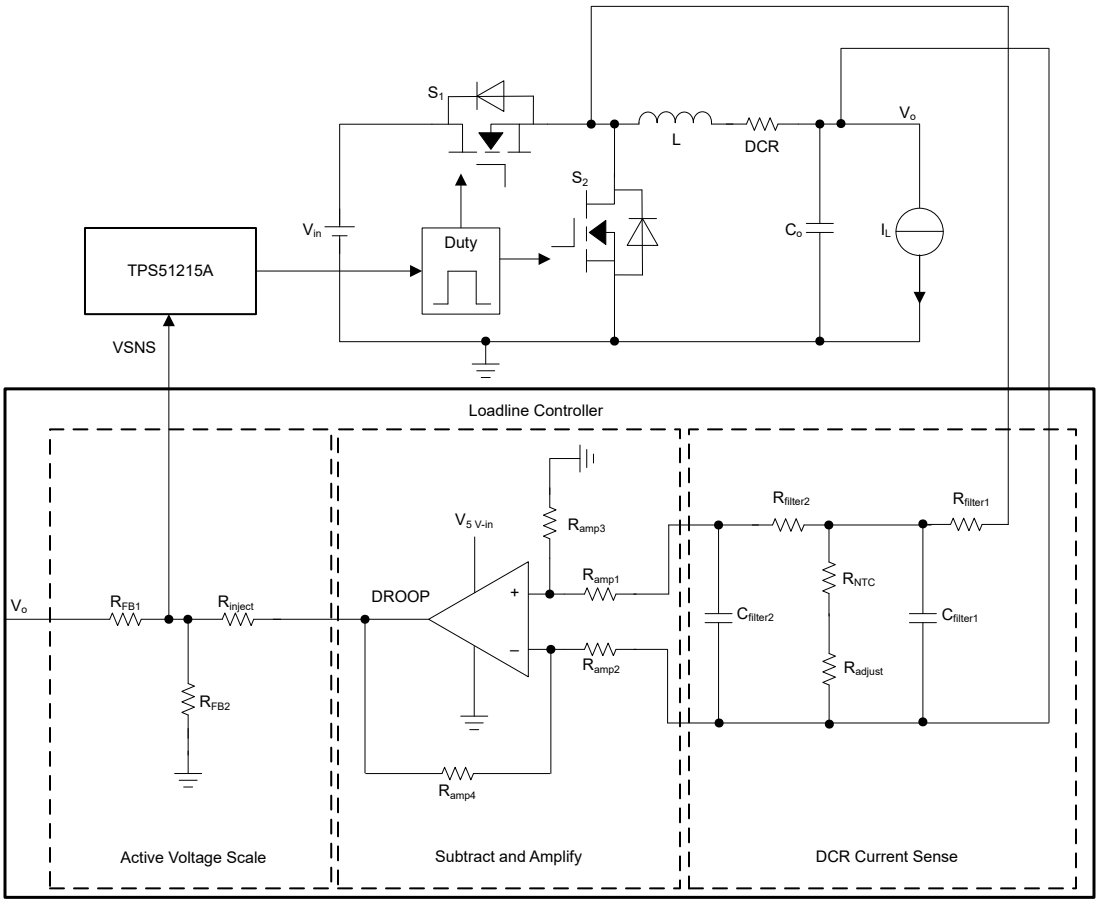


Figure 2-1. TPS51215A Power Solution with Load Line Feature Block Diagram

2.2 Design Considerations

There are three functional blocks for load line controller and IMON implementation:

2.2.1 DCR current sense

Load line control will get the output voltage decreased with the increasing output current linearly, while the IMON feature needs to have a voltage output proportional to output current. The output current needs to be sensed for both of the two features. An inductor DCR current sense is implemented in the proposed method. Compared with current sense with sensing resistor, additional cost can be saved. Two stage RC filter is used to filter the inductor current ripple and get the DC output current information.

2.2.2 Subtract and Amplify

Inductors with small DCR are always used for TPS51215A due to large current rating of VCCIN_AUX rail. So the sensed DCR voltage amplitude is small and the amplification is needed to implement. At the same time, the sensed voltage is a signal referenced to Vout and floating to ground. To get the sensed current signal used

for active voltage scaling, it needs to be converted to a signal referenced to ground. Those two functions are achieved with an operational amplifier.

2.2.3 Active Voltage Scale

Active voltage scaling is used to create the output voltage load line based on sensed current information. By injecting the sensed current signal into voltage sense pin through a resistor network, the output voltage could be regulated.

2.2.4 IMON Output

IMON output is needed by IMVP multiphase VR controller. IMVP controller has related pins for the input and they should be connected with the IMON output from VCCIN_AUX solution.

Currently, there are two major types of IMON output signal, which is determined by the used IMVP VR controller:

- The first type of IMON output is inductor DCR current sensing signal. For this type of IMON, the IMVP VR controller has two pins for differential IMON input. The solution proposed in this reference design is compatible with this type of IMVP VR controller. The differential voltage signals on $C_{filter1}$ in Figure 2-1 are the IMON output and could be directly connected with VR controller.
- The second type of IMON output is a single-ended voltage proportional to inductor average current and referenced to ground. The solution proposed in this reference design is not compatible with this type of IMVP controller.

The schematic design is shown as Figure 2-2.

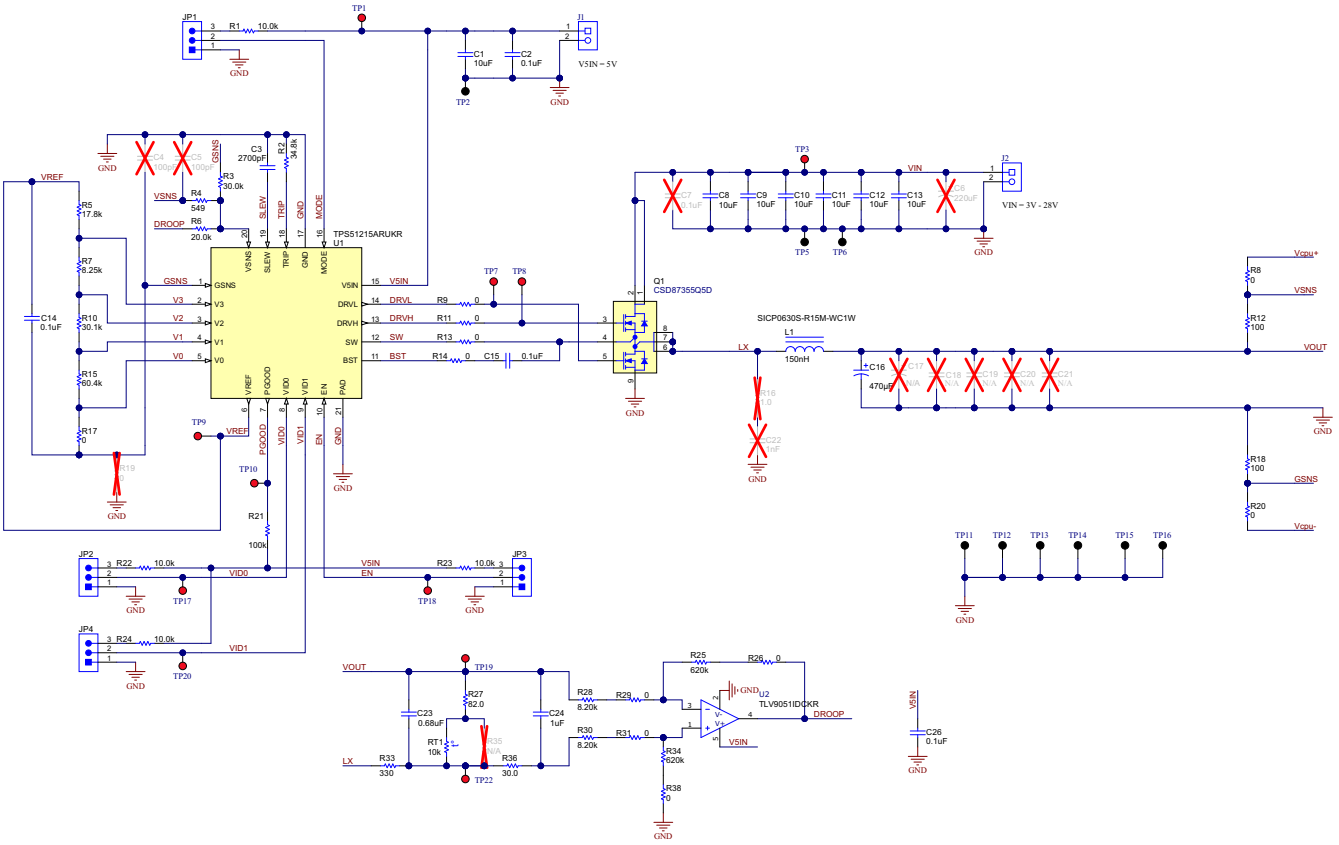


Figure 2-2. TPS51215A Power Solution with Load Line Feature Schematic

Figure 2-2 is the major page of schematic in this reference design, which only includes the circuits around voltage regulator. The symbol for test tool interposer and the output capacitors placed at loading side (interposer side) are not shown here.

The complete schematics of the reference design are at TIDA-050057.

The principle for implementation will be introduced in Section 2.4.

2.3 Highlighted Products

TPS51215A is a single-phase, D-CAP2™ synchronous buck controller with a 2-bit VID input supporting 0 V and three other independent externally programmable output voltage levels, where full external programmability of the voltage level, step setting, and voltage-change slew rate is desired.

The TPS51215A supports all POS/SPCAP and/or all ceramic MLCC output capacitor options in applications where remote sense is a requirement. Tight DC load regulation is achieved through external programmable integrator capacitor. The TPS51215A provides full protection suite, including OVP, OCL, 5-V UVLO, and thermal shutdown. It supports the conversion voltage up to 28 V, and output voltages adjustable from 0.5 V to 2 V.

2.4 System Design Theory

2.4.1 DCR Current Sense

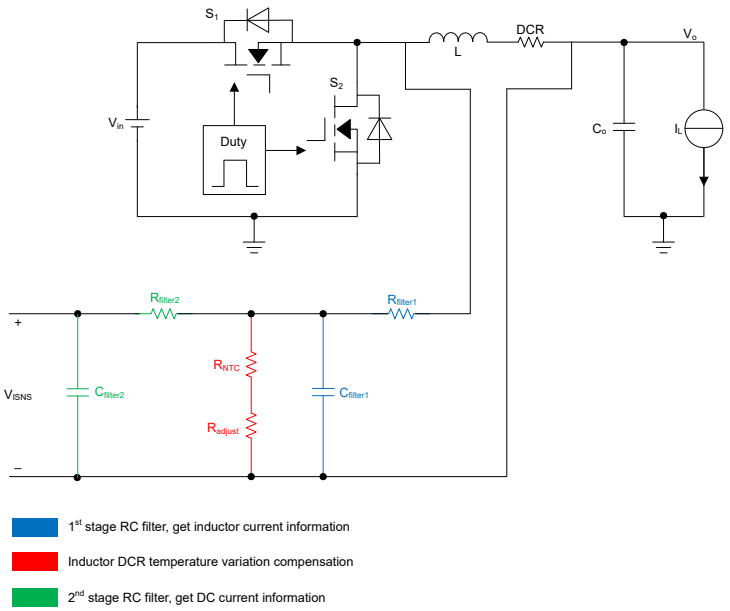


Figure 2-3. DCR Current Sense Block

A voltage proportional to inductor DC current (V_{ISNS}) can be got with DCR current sense block as shown in Figure 2-3. First stage filter with $R_{filter1}$ and $C_{filter1}$ is used to get inductor current information from SW pulse voltage. Second stage filter is used to get DC value from sensed inductor current and filter the ripple. R_{NTC} is a negative thermal coefficient resistor, which is used to compensate the DCR variation with temperature. R_{adjust} is used for matching the thermal coefficient of R_{NTC} and DCR. It's targeted to let the V_{ISNS} not changed with temperature variation.

Why do we need a second stage RC filter to extract DC current information?

- Low frequency and middle frequency inductor current information are needed for feedback to reflect output current DC value and dynamic changing.
- High frequency response needs to be limited, since the inductor current ripple needs to be filtered.
- Two stage filter can bring -40 dB/dec gain slope at high frequency. Figure 2-4 shows how the two stage filter can have lower gain at high frequency while maintaining larger gain in middle frequency range.

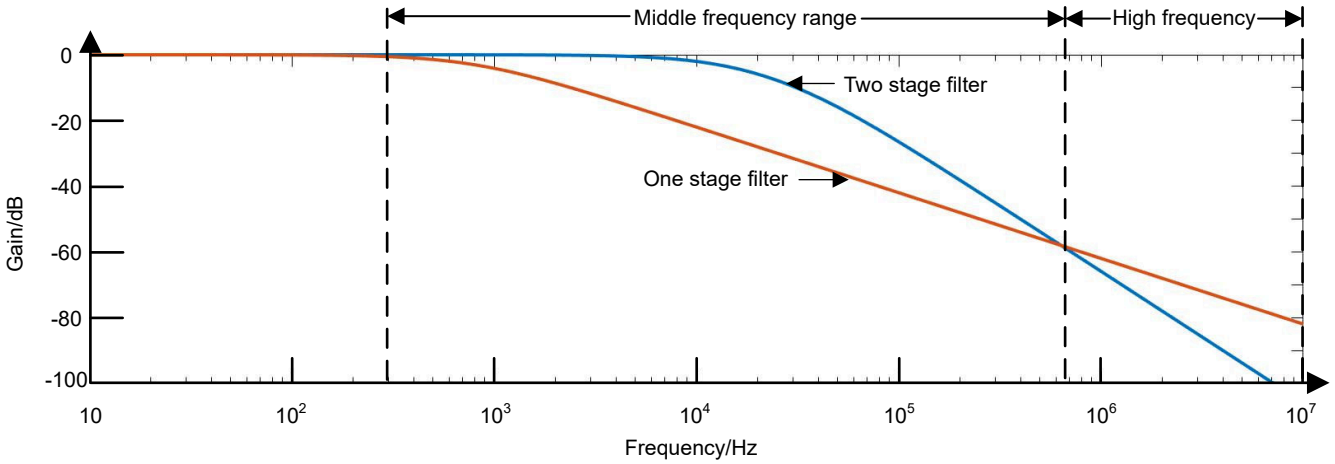


Figure 2-4. Comparison of Frequency Response with One-Stage RC Filter and Two-Stage RC Filter

2.4.2 Subtract and Amplify

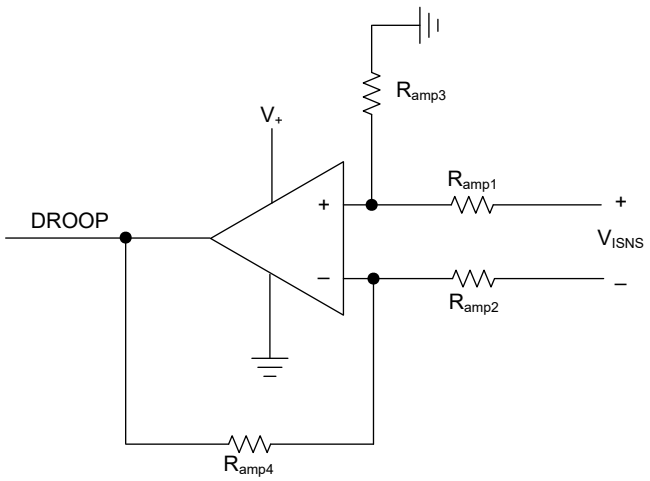


Figure 2-5. Operational Amplifier for Subtraction

Operational amplifier shown in Figure 2-5 is used to convert the differential V_{ISNS} to single-ended DROOP signal. The resistor network is also set to amplify the voltage amplitude.

Normally, we just set R_{amp1}=R_{amp2}, R_{amp3}=R_{amp4}. Amplification ratio is equal to R_{amp3}/R_{amp1}.

2.4.3 Active Voltage Scale

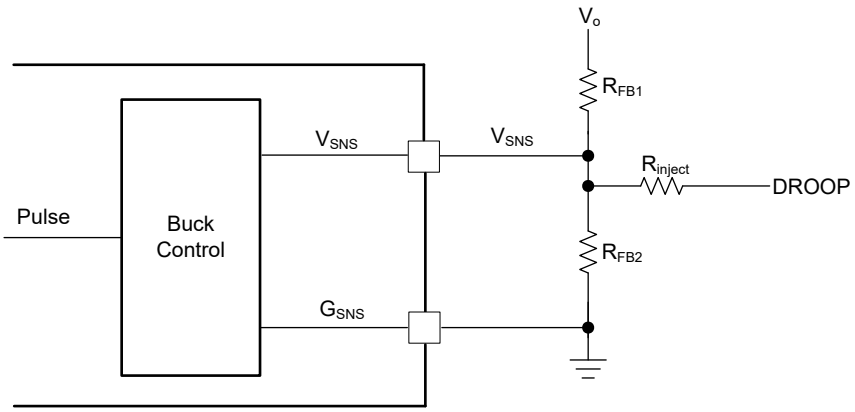


Figure 2-6. Resistor Network for Voltage Scaling

The voltage scaling block to achieve output voltage load line is shown as Figure 2-6.

Based on superposition theorem:

$$V_{SNS}=V_o\times\frac{R_{FB2}||R_{inject}}{R_{FB1}+R_{FB2}||R_{inject}}+DROOP\times\frac{R_{FB1}||R_{FB2}}{R_{inject}+R_{FB1}||R_{FB2}} \quad (1)$$

Since $V_{SNS}=V_{ref}$ and DC value of V_{ref} is fixed in regulation, when load current becomes larger, DROOP will increase and V_O will decrease.

The DROOP is proportional to output current, thus the decrease of V_O is also proportional to output current, which corresponds to the load line needed.

2.4.4 IMON Output

As introduced in Section 2.2.4, IMON output signals with this reference design are inductor DCR current sensing signals. A pair of differential IMON output wires ISNS+ (TP22) and ISNS- (TP19) in schematic Figure 2-2 needs to be connected with the corresponding pins of IMVP multi-phase VR controller.

3 Hardware, Software, Testing Requirements, and Test Results

3.1 Hardware Requirements

For testing purposes, this reference design requires the following equipment:

- A power supply that is capable of supplying at least 7-A of load and up to 24-V.
- A power supply that is capable of supplying 5-V.
- Current and voltage multimeters to measure the currents and voltages during the related tests.
- Oscilloscope to capture voltages and a current.
- The TIDA-050057 board is a printed circuit board (PCB) with all the devices in this design.
- Resistive load or electronic load that is capable at least 32-A.

3.2 Test Setup

Figure 3-1 shows the set up used to test the TIDA-050057. Test tool refers to Intel® VR Test Tool. The following start-up procedure is shown below.

1. Jump the JP2 and JP4 according to required VID output voltage or connect external drive signals to the TP17 and TP20.
2. Apply proper DC voltage to J1 and J2. Apply J2 with external power source first and then apply J1 5 V with another power source.
3. Jump the JP3 to high to enable the device or connect external drive signals to TP18.
4. Check the output.

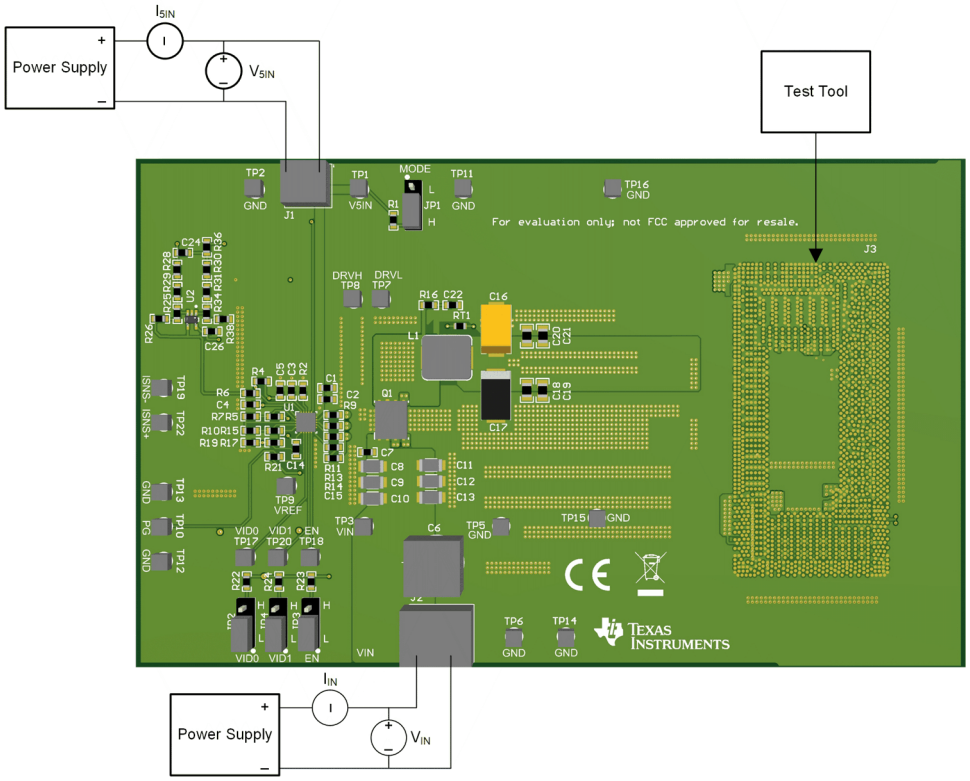


Figure 3-1. Test Setup

3.3 Test Results

3.3.1 Start-up

Figure 3-2 shows the start-up behavior.

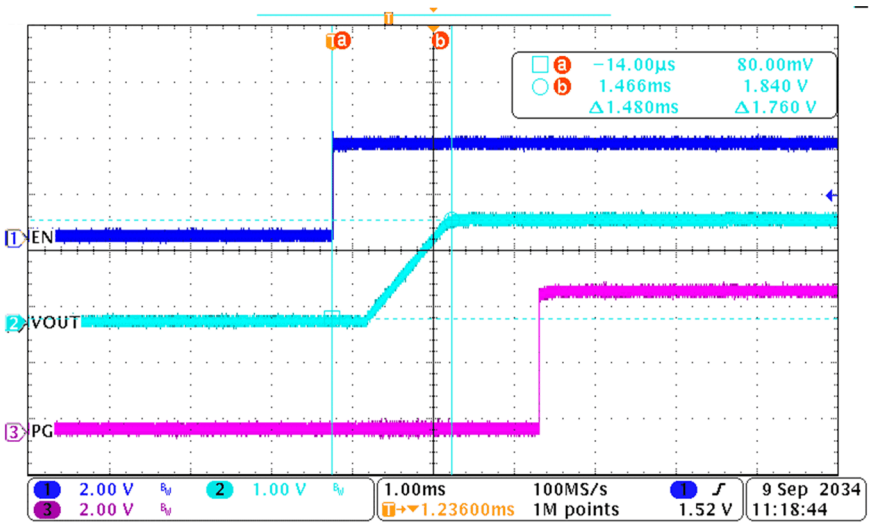


Figure 3-2. Start-up Behavior

3.3.2 VID Change

Figure 3-3 shows the VID change behavior. VID changes from 00 to 11 and Vout changes from 0 V to 1.8 V.

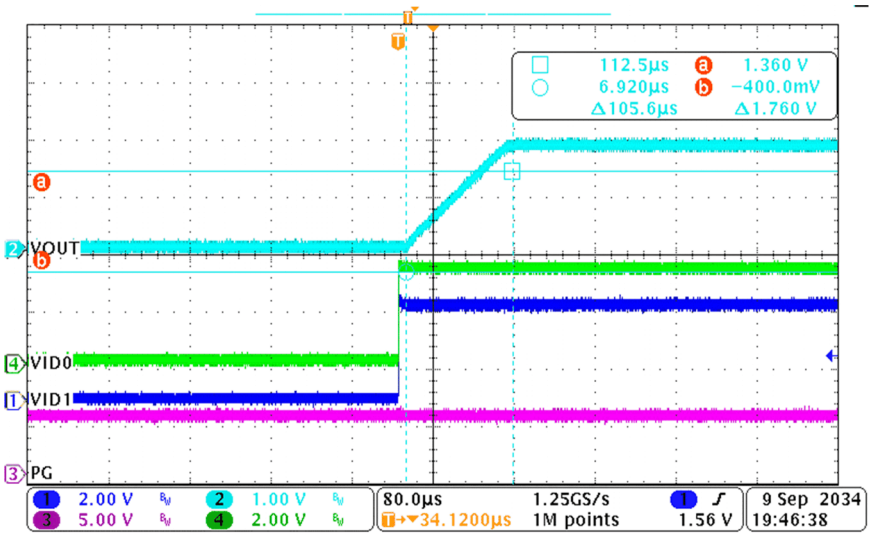


Figure 3-3. VID Change Behavior

3.3.3 Load Transient

Figure 3-4 shows the transient response. Output current varies between 9.6 A-32 A with 250ns rise or fall time. Output voltage varies in the range of 1.69 V-1.85 V.

In the waveform, total output current is the combined measured current of channel 1 and channel 4.

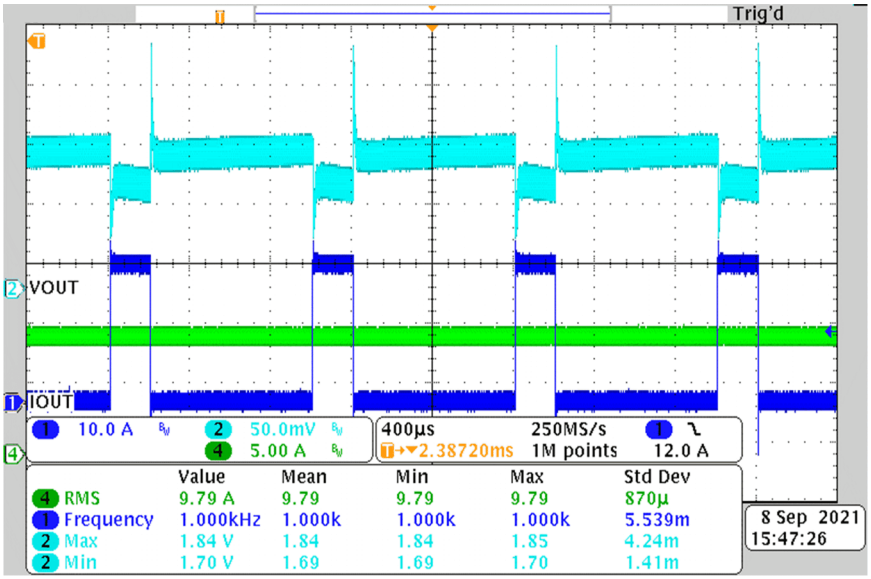


Figure 3-4. Load Transient Behavior

3.3.4 Load-Line Test

Figure 3-5 shows the load line test results.

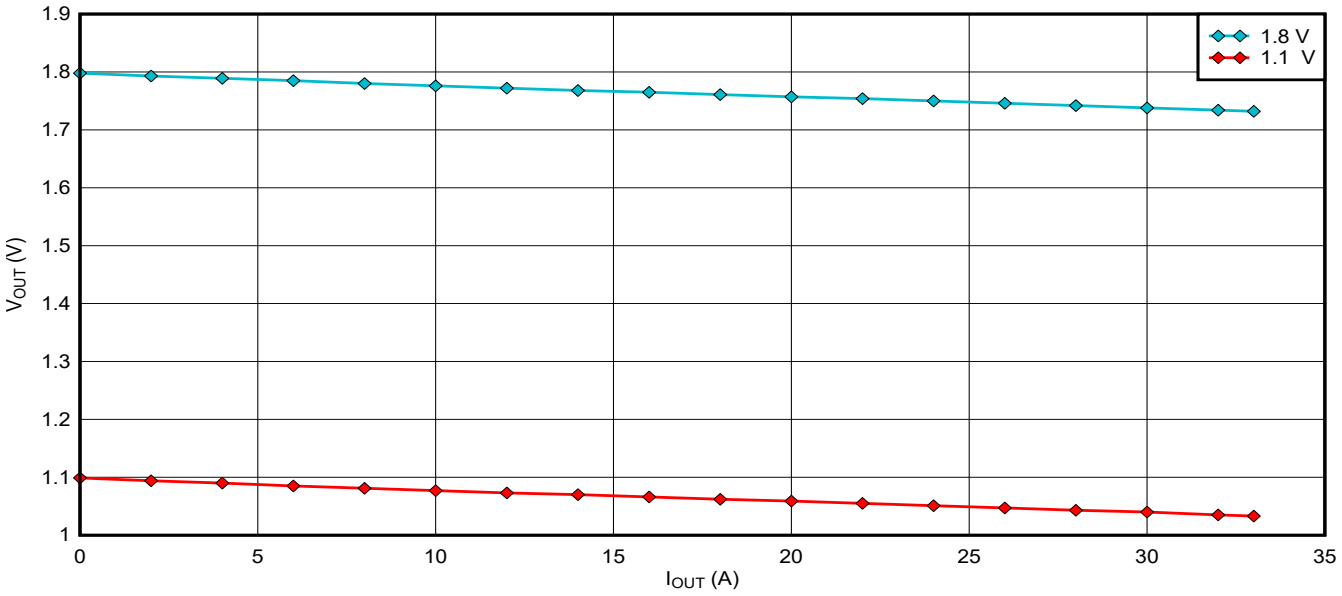


Figure 3-5. Load-Line Test Results

4 Design and Documentation Support

4.1 Design Files

4.1.1 Schematics

To download the schematics, see the design files at TIDA-050057.

4.1.2 BOM

To download the bill of materials (BOM), see the design files at TIDA-050057.

4.1.3 PCB Layout Recommendations

To download the layer plots, see the design files at TIDA-050057.

4.1.4 Altium Project

To download the Altium Designer® project files, see the design files at TIDA-050057.

4.1.5 Gerber Files

To download the Gerber files, see the design files at TIDA-050057.

4.1.6 Assembly Drawings

To download the assembly drawings, see the design files at TIDA-050057.

4.2 Documentation Support

1. Texas Instruments, *TPS51215A Single Phase, D-CAP2TM Controller with 2-Bit VID Control and Low Power Mode* data sheet.
2. Texas Instruments, *TLV9051 / TLV9052 / TLV9054 5-MHz, 15-V/µs High Slew-Rate, RRIO Op Amp* data sheet.
3. Texas Instruments, *CSD87355Q5D Synchronous Buck NexFET™ Power Block* data sheet.

4.3 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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5 About the Authors

Andrew Xiong is a systems and applications engineer at Texas Instruments responsible for defining new products based on business opportunities and providing application support to assist customers with technical challenges.

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