Design Guide: TIDA-050044

Small, Efficient Power Supply Reference Design for M.2 Form Factor SSD

Description

This small and efficient power supply reference design demonstrates a power solution for M.2 form factor client Solid State Drives. This solution uses 3 DC/DC converters and a 1 Linear Regulator. Furthermore, one of the outputs offers the flexibility to change the output voltage through I^2C communication.

Resources

TIDA-050044	Design Folder
TPS62864	Product Folder
TPS62088	Product Folder
TLV733P	Product Folder

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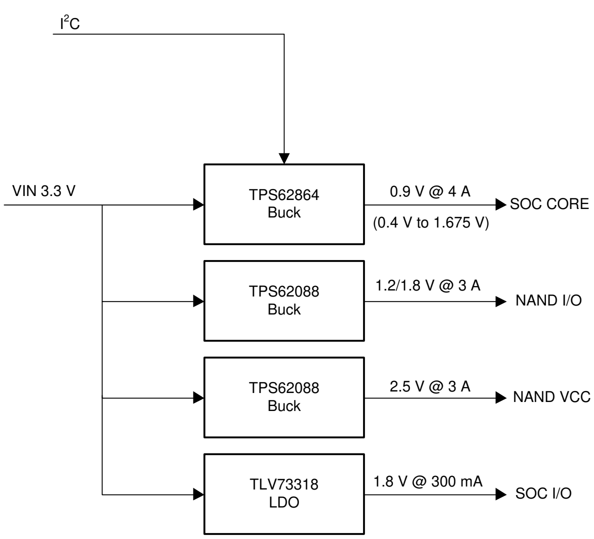
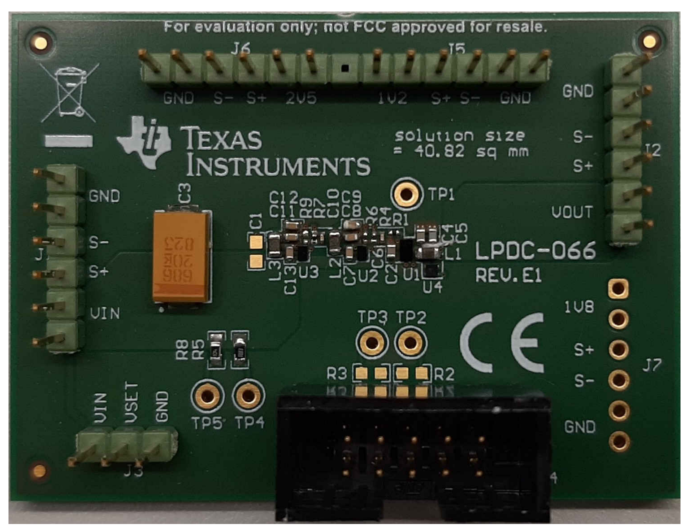
Features

- 3.3-V input voltage
- 40.8 mm² space area
- High efficiency
- Automatic power save mode for light load efficiency
- Adjustable output voltage using I^2C

Applications

- Solid State Drive (SSD)





1 System Description

The TIDA-050044 optimizes the TPS62864 DC/DC converter, the TPS62088 DC/DC converter and the TLV73318 LDO to produce a small, efficient power solution for M.2 form factor. This power solution supply 2.5-V, 1.8-V, 1.2-V and 0.9-V rails from a 3.3 V rail. The DC/DC converters can operate in power save mode for maximum efficiency at light loads.

Both the TPS62864 and TPS62088 come in ultra-small wafer-chip-scale packages (WCSP) for smallest solution size, and switch at high frequencies, 2.4 MHz and 4MHz respectively, which decreases the size of output filter. External components have been optimized also optimized to produce a small solution size. The TLV73318 capacitor-free LDO comes in a 1 sq mm package and does not require external component to operate.

1.1 Key System Specifications

Table 1-1. Key System Specifications

<table>
<tr><th colspan="2">PARAMETERS</th><th>CONDITIONS</th><th>MIN</th><th>TYP</th><th>MAX</th><th>UNIT</th></tr>
<tr><td colspan="2">Input voltage range</td><td></td><td>2.7</td><td>3.3</td><td>5.5</td><td>V</td></tr>
<tr><td colspan="2">OUTPUTS PROVIDED</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">TPS62864 0V9 SOC_CORE</td><td>Output voltage</td><td rowspan="2">VIN = 3.3 V</td><td>0.4</td><td>0.9</td><td>1.675</td><td>V</td></tr>
<tr><td>Output current</td><td></td><td></td><td>4</td><td>A</td></tr>
<tr><td rowspan="2">TP62088 1V2 NAND_IO</td><td>Output voltage</td><td rowspan="2">VIN = 3.3 V</td><td>0.6</td><td>1.2</td><td>3.1</td><td>V</td></tr>
<tr><td>Output current</td><td></td><td></td><td>3</td><td>A</td></tr>
<tr><td rowspan="2">TPS62088 2V5 NAND_VCC</td><td>Output voltage</td><td rowspan="2">VIN = 3.3 V</td><td>0.6</td><td>2.5</td><td>3.1</td><td>V</td></tr>
<tr><td>Output current</td><td></td><td></td><td>3</td><td>A</td></tr>
<tr><td rowspan="2">TLV73318 1V8 SOC_IO</td><td>Output voltage</td><td rowspan="2">VIN = 3.3 V</td><td></td><td>1.8</td><td></td><td>A</td></tr>
<tr><td>Output current</td><td></td><td></td><td>300</td><td>mA</td></tr>
</table>

2 System Overview

2.1 Block Diagram

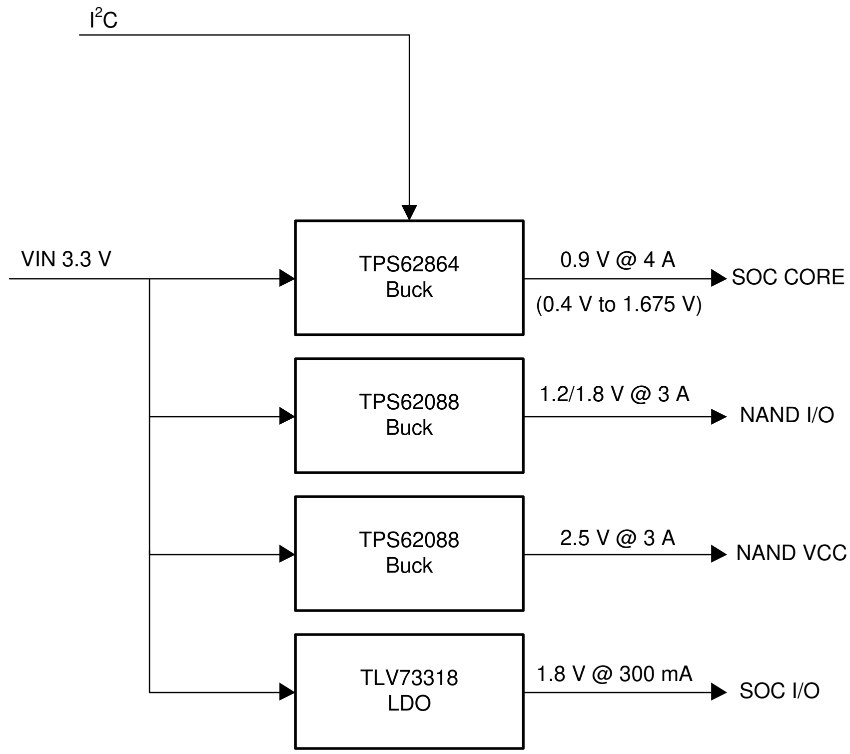


Figure 2-1. TIDA-050044 Block Diagram

2.2 Design Considerations

The design uses the adjustable output voltage version of TPS62088 which sets the output voltage of U2 and U3 depending of the value of the resistors R4, R6 and R7, R9 respectively.

The supply of the NAND IO is usually 1.2 V or 1.8 V. By default, U2 is set to output 1.2 V. However, it is also possible to use the IC fixed versions TPS6208812 or TPS6208818 to obtain 1.2 V or 1.8 V respectively. In that case, R4, R6 and C6 should be removed and the FB pin should be connected to the output. The difference in the design is shown in Figure 2-2 and Figure 2-3.

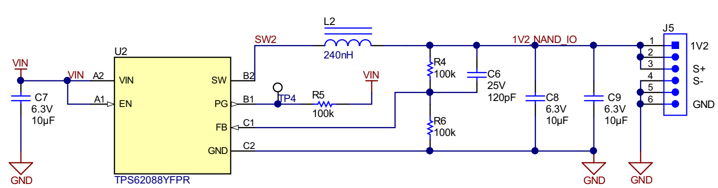


Figure 2-2. Typical Reference Design of Adjustable Output

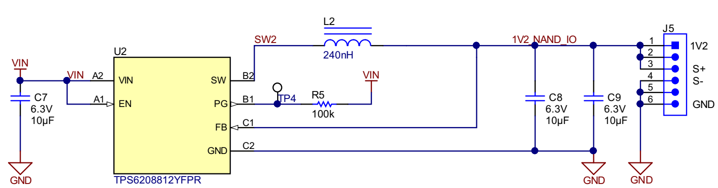


Figure 2-3. Typical Reference Design of Fixed Output

2.3 Highlighted Products

2.3.1 TPS62864

The TPS62864 device is a high-frequency synchronous step-down converter with I^2C interface which provide a high power density solution. At medium to heavy loads, the converter operates in PWM mode and automatically enters Power Save Mode operation at light load to maintain high efficiency over the entire load current range. The device can also be forced in PWM mode operation for small output voltage ripples. Together with its DCS-control architecture, excellent load transient performance and tight output voltage accuracy are achieved. The devices are available in a 15-pin WCSP package.

2.3.2 TPS62088

The TPS62088 device is a high-frequency synchronous step-down converter optimized for small solution size and high efficiency. At medium to heavy loads, the converter operates in PWM mode and automatically enters Power Save Mode operation at light load to maintain high efficiency over the entire load current range. The 4-MHz switching frequency allows TPS62088 to use small external components. Together with its DCS-control architecture, excellent load transient performance and output voltage regulation accuracy are achieved. Other features like over current protection, thermal shutdown protection, active output discharge and power good are built-in. The device is available in a 6-pin WCSP package.

This device offers three variations that have fixed output voltage as shown in Table 2-1. In this reference design, the adjustable version is used but it can be scaled to use a fixed voltage version.

Table 2-1. Device Comparison Table

PART NUMBER	OUTPUT VOLTAGE
TPS62088YFP	Adjustable
TPS6208812YFP	1.2 V
TPS6208818YFP	1.8 V
TPS6208833YFP	3.3 V

2.3.3 TLV73318

The TLV733P family of low dropout (LDO) linear regulators are ultra-small, low quiescent current LDOs that can source 300 mA with good line and load transient performance. These devices provide a typical accuracy of 1%.

The TLV733P family is designed with a modern capacitor-free architecture to ensure stability without an input or output capacitor. The removal of the output capacitor allows for a very small solution size, and can eliminate inrush current at startup.

In addition, the TLV733P family is also stable with ceramic output capacitors if an output capacitor is necessary. The TLV733P family also provides foldback current control during device power-up and enabling if an output capacitor is used. This functionality is especially important in battery operated devices.

The TLV733P family provides an active pulldown circuit to quickly discharge output loads when disabled.

In this reference design, the TLV73318 uses the 4-pin DQN (X2SON) package and the 1.8 V voltage output version.

2.4 System Design Theory

2.4.1 Designing Buck Converter Circuit TPS62864

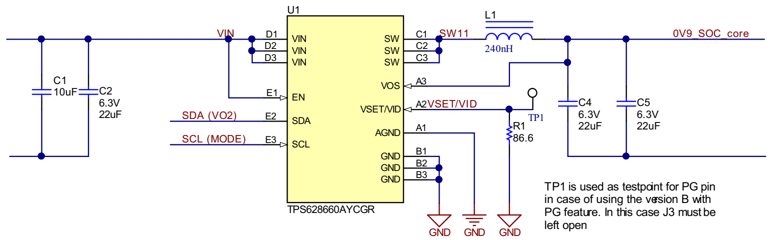


Figure 2-4. Designing Buck Converter Circuit TPS62864

To support a simple evaluation, a tantalum input capacitor C3 is used to ensure a steady, low-impedance supply voltage for the ICs.

Also, to achieve a smaller package size, the GRM155R60J226ME11 22uF 0402 capacitors were used in C2, C4, and C5. The recommended minimum input capacitance for this device is 8uF. According to the characteristics of this capacitor, this would mean that the maximum input voltage should be 3.3 V to ensure that C2 effective capacitance is 8uF. Similar considerations were applied for the TPS62088 designs.

2.4.2 Designing Buck Converter Circuit TPS62088

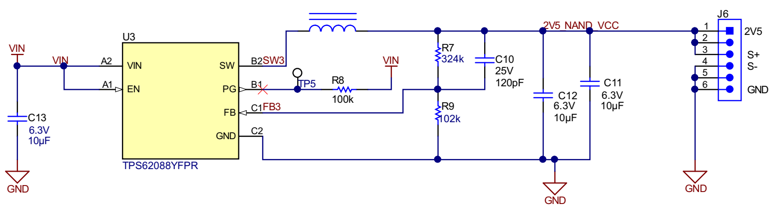


Figure 2-5. Designing Buck Converter Circuit TPS62088 - 2.5 V Voltage Rail

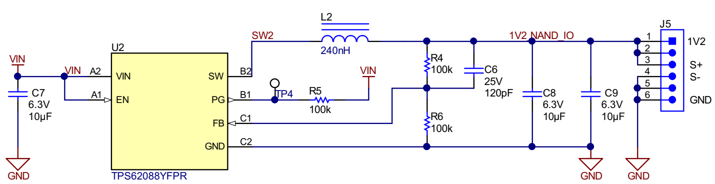


Figure 2-6. Designing Buck Converter Circuit TPS62088 - 1.2V Voltage Rail

2.4.3 Designing Buck Converter Circuit TLV73318

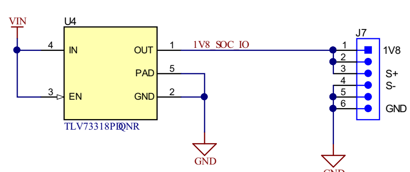


Figure 2-7. Designing Buck Converter Circuit TLV73318

3 Hardware, Software, Testing Requirements, and Test Results

3.1 Testing and Results

3.1.1 Test Setup

Load Transient measurements were performed in the four DC/DC converters using typical values for an SSD application. Every module was measured while the other modules had a constant load with the following operating values:

- SoC 0.9 V – 2.0 A
- NAND I/O 1.2 V – 1.3 A
- NAND VCC 2.5 V – 1.7 A
- SOC I/O 1.8 V – 10mA

3.1.2 Test Results

3.1.2.1 Startup with no load

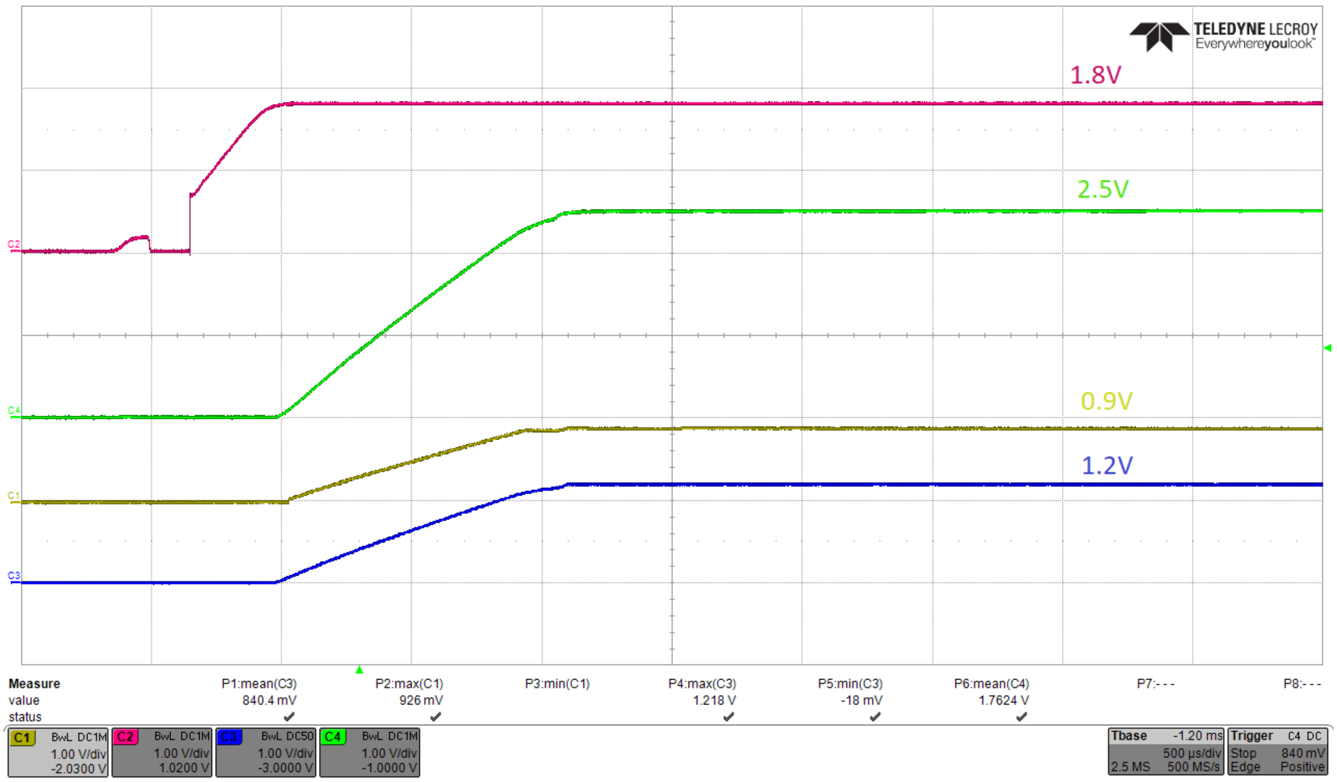


Figure 3-1. Startup with no Load

3.1.2.2 Load Transient Rail SoC 0.9V

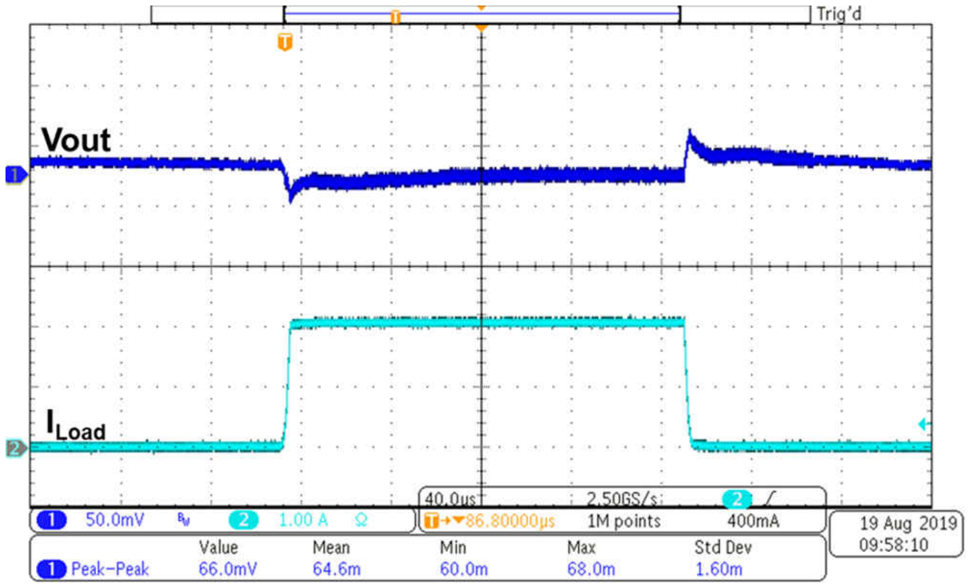


Figure 3-2. Vin = 3.3 V, Vout = 0.9 V, ILoad 5mA to 2A and Vpp ~ ±35mV

3.1.2.3 Load Transient Rail NAND I/O 1.2 V

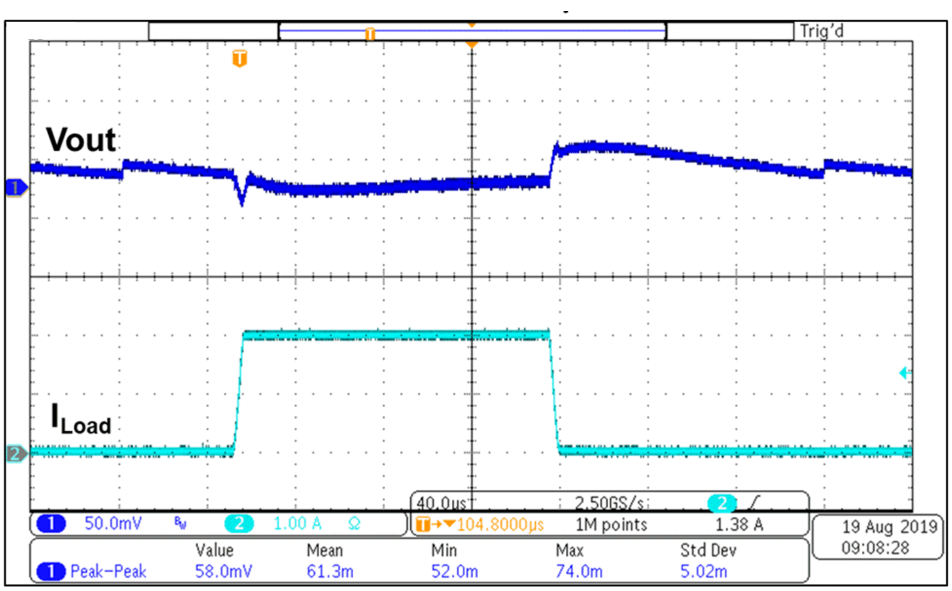


Figure 3-3. Vin = 3.3V, Vout = 1.2 V, ILoad 10mA to 2A and Vpp ~ ±37mV

3.1.2.4 Load Transient Rail NAND VCC 2.5 V

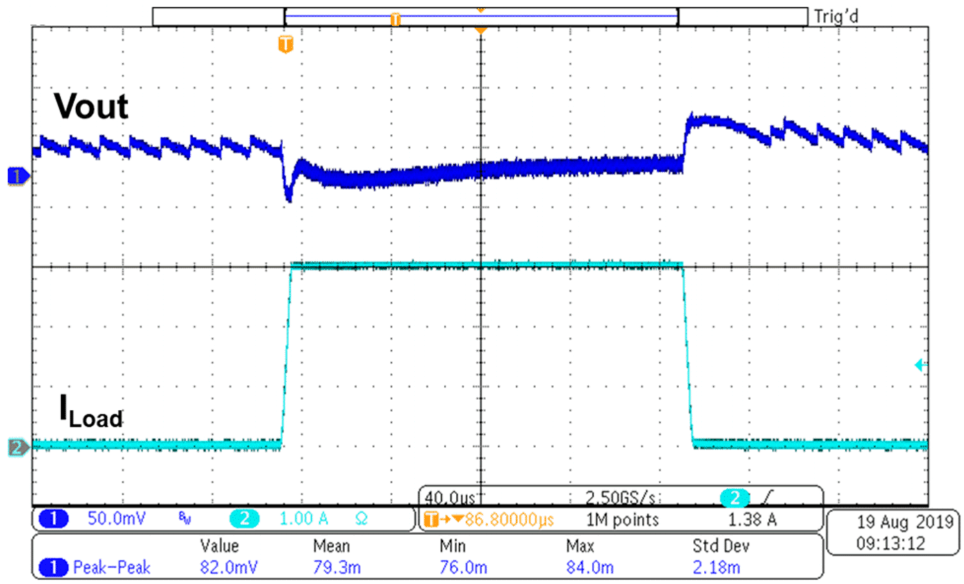


Figure 3-4. Vin = 3.3V, Vout = 2.5 V, ILoad 10mA to 3A and Vpp ~ ±42mV

3.1.2.5 Output Ripple Rail SoC 0.9 V

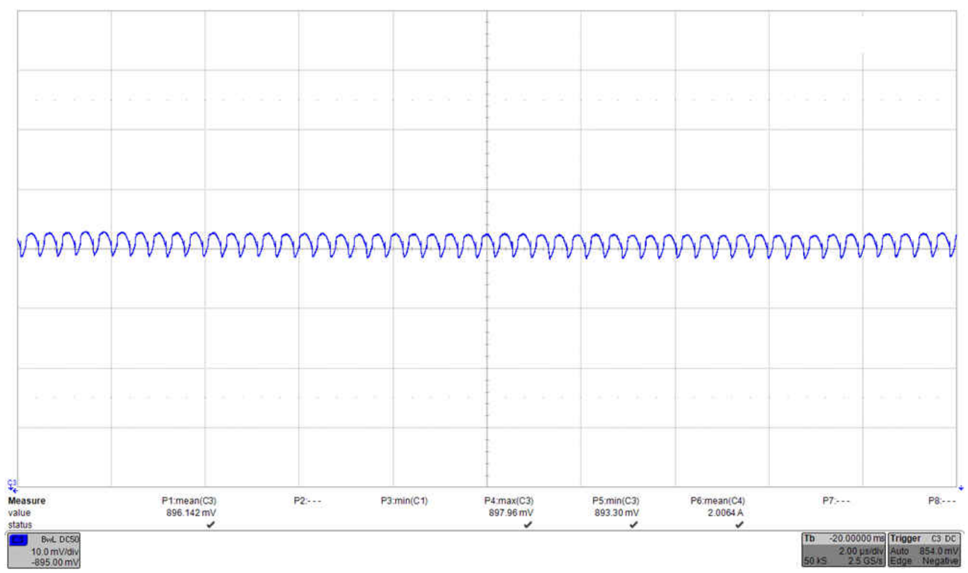


Figure 3-5. Vin = 3.3 V, Vout = 0.9V, ILoad = 2.0A and Vpp ~ 5mV

3.1.2.6 Output Ripple Rail NAND I/O 1.2 V

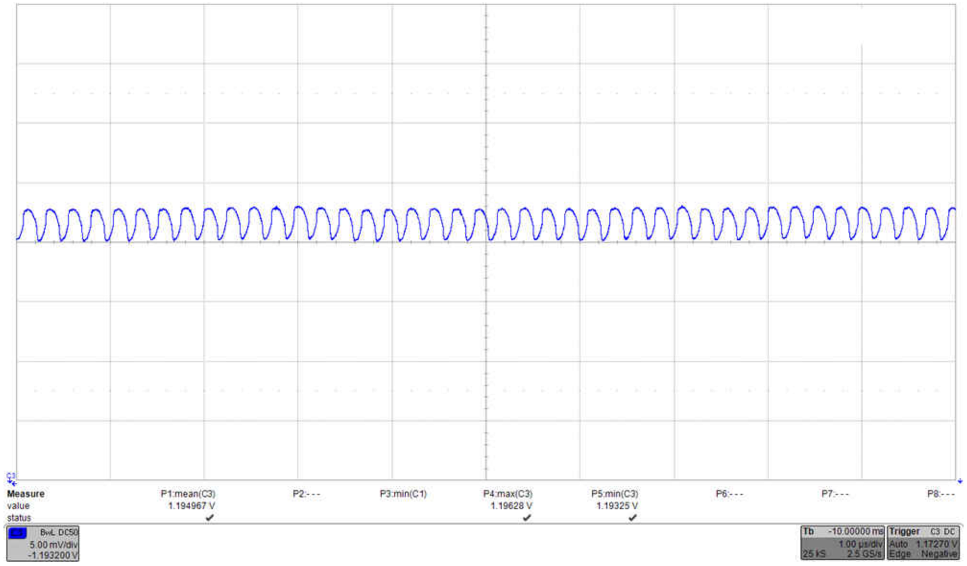


Figure 3-6. Vin = 3.3 V, Vout = 1.2 V, ILoad = 1.2A and Vpp ~ 3mV

3.1.2.7 Output Ripple Rail NAND VCC 2.5 V

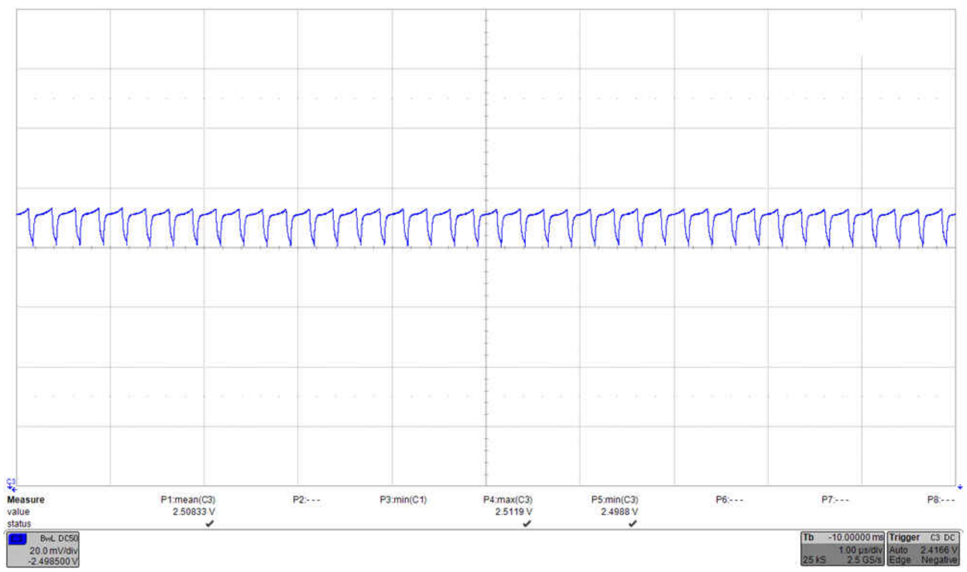


Figure 3-7. Vin = 3.3 V, Vout = 2.5 V, ILoad = 1.7A and Vpp ~13.0mV

3.1.2.8 Output Ripple Rail SOC I/O 1.8 V

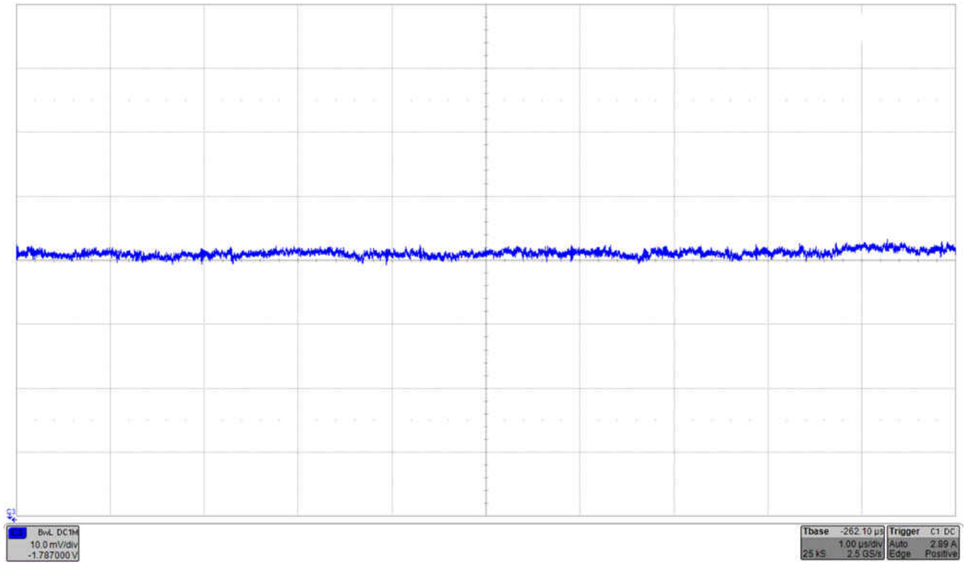


Figure 3-8. 3.3 V, Vout = 1.8 V, ILoad = 0.15A

3.1.2.9 Efficiency

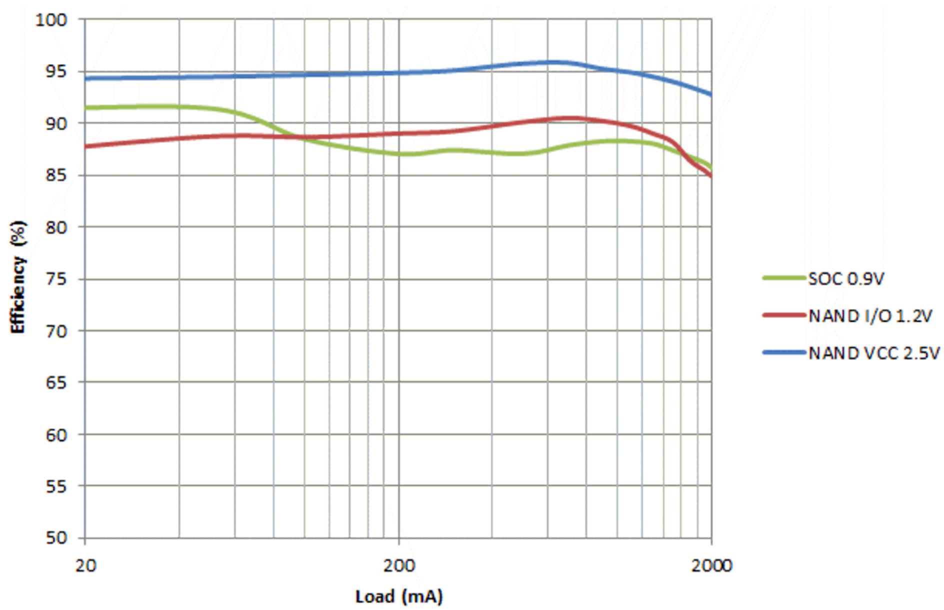


Figure 3-9. Efficiency

The thermal measurements were done with the following parameters:

- SoC 0.9 V – 2.0 A
- NAND I/O 1.2 V – 1.3 A
- NAND VCC 2.5 V – 1.7 A
- SOC I/O 1.8 V – 10mA

The measurements were taken after the device has been working with this load for an hour.

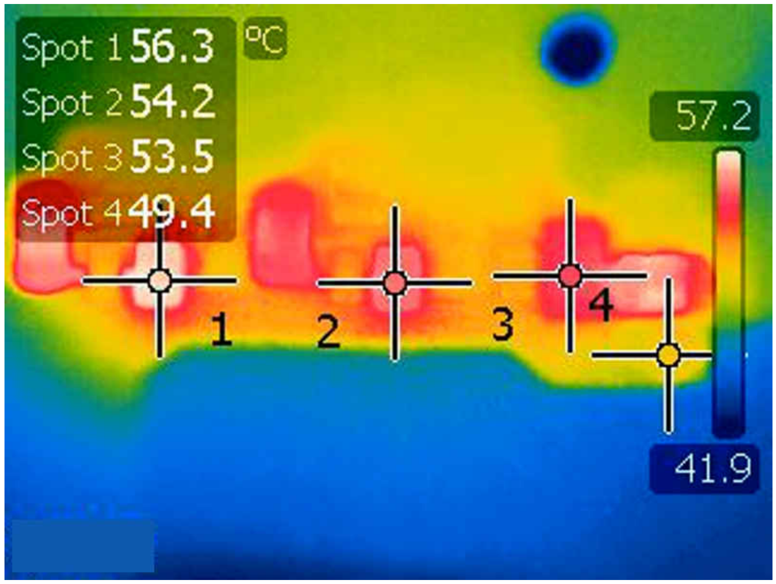


Figure 3-10. Vin = 3.3 V, Iin = 2.452 A

4 Design Files

4.1 Schematics

To download the schematics, see the design files at TIDA-050044.

4.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDA-050044.

4.3 PCB Layout Recommendations

4.3.1 Layout Prints

To download the layer plots, see the design files at TIDA-050044.

4.4 Altium Project

To download the Altium Designer® project files, see the design files at TIDA-050044.

4.5 Gerber Files

To download the Gerber files, see the design files at TIDA-050044.

4.6 Assembly Drawings

To download the assembly drawings, see the design files at TIDA-050044.

5 Software Files

To download the software files, see the design files at TIDA-050044.

6 Related Documentation

1. Texas Instruments, *TPS62864/6 2.4-V to 5.5-V Input, 4-A and 6-A Synchronous Step-Down Converter with I^2C Interface in WCSP and QFN Package data sheet*
2. Texas Instruments, *TPS62088, 2.4-V to 5.5-V Input, Tiny 6-pin 3-A Step-Down Converter in 1.2-mm x 0.8-mm Wafer Chip Scale Package and Suitable for Embedding data sheet*
3. Texas Instruments, *TLV733P Capacitor-Free, 300-mA, Low-Dropout Regulator in 1-mm × 1-mm X2SON Package data sheet*

6.1 Trademarks

6.2 Third-Party Products Disclaimer