

# High Power Density 12-Vin, 3.3-Vout, 1-A Buck Converter Reference Design



## Description

TIDA-050056 is a 5-V to 17-V input voltage buck converter reference design which is intended for applications that have a very limited design space. Featuring the TPS629210-Q1 buck converter, the reference design steps down the input voltage to 3.3-Vout and is capable of delivering up to 1-A of load with high efficiency and low quiescent current. The inductor used in this design is a 1.5- $\mu$ H inductor with about 138-m $\Omega$  DCR. The total solution size including all external components is 20-mm<sup>2</sup>. This design delivers highly efficient DC/DC conversion and small solution size with the lowest operating quiescent current ( $I_Q$ ) in the industry. The same design is applicable to the TPS629210 device which is pin to pin compatible with TPS629210-Q1.

## Resources

[TIDA-050056](#)

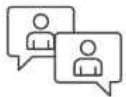
Design Folder

[TPS629210-Q1](#)

Product Folder

[TPS629210](#)

Product Folder



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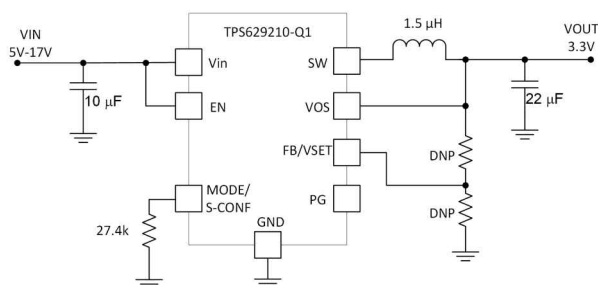
## Features

- Small total solution size of 20-mm<sup>2</sup>
- 50-mA/mm<sup>2</sup> power density
- 5-V to 17-V input voltage
- Up to 1-A continue output current
- Low  $I_Q$ : 4- $\mu$ A typical
- Total system voltage accuracy of -1.5% and +1.1% across temperature range (-40°C to 150°C)
- Operating junction temperature: -40°C to 150°C
- DCS-Control™ topology with 100% duty-cycle mode

## Applications

- [ADAS and Infotainment](#)
- [Telecom and Wireless infrastructure](#)
- [Factory Automation and Control](#)
- [Engineering Smarter Appliances](#)
- [Building Automation](#)
- [Grid Infrastructure](#)
- [Retail Automation and Payment](#)
- [Wireless infrastructure](#)

## Design Images



## 1 System Description

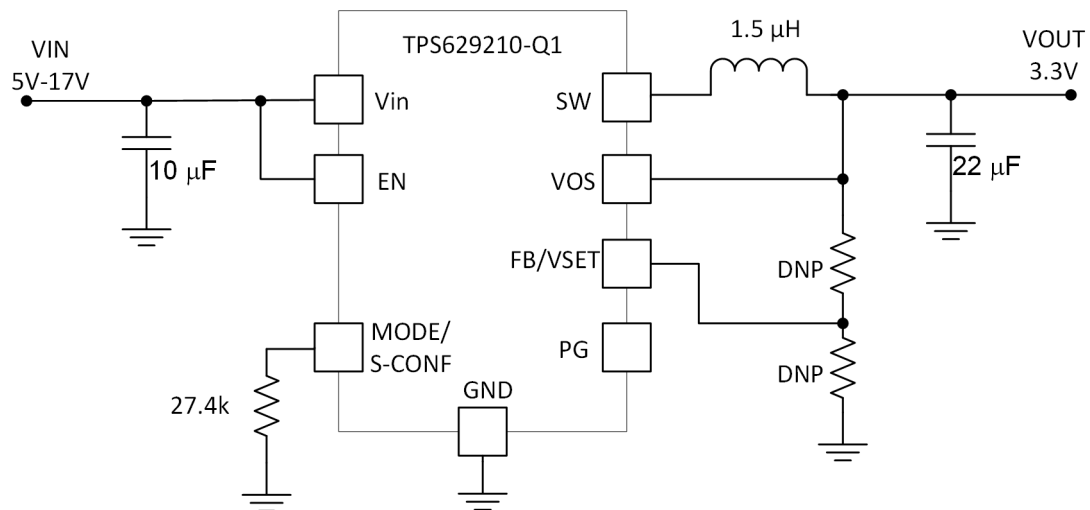
The TIDA-050056 is designed by using the TPS629210-Q1 high efficiency and low  $I_Q$  DC/DC Buck converter. The design is optimized for small total solution size, low BOM count, high efficiency, best thermal performance and lowest quiescent current possible. TPS629210-Q1 allows high switching frequency that enables small component selection without compromising on efficiency. The internal feedback (VSET) feature eliminates need of external feedback resistors. Small size and less pin count reduces external component counts. This design is ideal for applications where is limited space such as smart lock, wearable devices and so on. The efficiency and low  $I_Q$  are ideal for battery operating systems. The design allows to efficiently use the battery power and extend its life time.

**Table 1-1. Key System Specifications**

Parameter	Min	Typ	Max	Unit
Input Voltage	5	12	17	V
Output Voltage	3.267	3.3	3.333	V
Output Current	0		1	A
Switching Frequency		2.5		MHz
Operating Quiescent Current		4		$\mu$ A
Junction Temperature	-40		150	$^{\circ}$ C
Output Discharge		Enabled		

## 2 System Overview

### 2.1 Block Diagram



**Figure 2-1. TIDA-050056 Block Diagram**

## 2.2 Design Considerations

By connecting 27.4-k $\Omega$  resistor on MODE/S-CONF pin, the device is configured to:

- **VSET operation:** VOUT is sensed only through the VOS pin by an internal resistor divider. The target output voltage is programmed by an external resistor connected between the FB/VSET pin and GND. In this design, FB/VSET pin is floating and thus the VOUT is programmed to 3.3-V
- **2.5-MHz Switching Frequency with AEE (Automatic Efficiency Enhancement):** The MODE/S-CONF pin is configured to AEE mode which provides efficiency enhancement over the entire input voltage and output voltage range by automatically adjusting the switching frequency of the converter. The efficiency decreases if VOUT decreases, VIN increases, or both. To keep the efficiency high over the entire duty cycle range (VOUT/VIN ratio), the switching frequency is adjusted while maintaining the ripple current. The AEE feature provides an efficiency enhancement for various duty cycle, especially for lower VOUT values where fixed frequency converters suffer from a significant efficiency drop. Furthermore, this feature compensates for the very small duty cycle of high VIN to low VOUT conversion, which limits the control range in other topology.
- **Power Save Mode Operation(Auto PFM/PWM):** The MODE/S-CONF pin is configured for power save mode(Auto PFM/PWM). The device operates in PWM mode as long as the output current is higher than half of the ripple current of the inductor. To maintain high efficiency at light loads, the device enters power save mode at the boundary to discontinuous conduction mode (DCM). This happens if the output current becomes smaller than half of the ripple current of the inductor. The power save mode is entered seamlessly when the load current decreases. This ensures a high efficiency in light load operation. The device remains in power save mode as long as the inductor current is discontinuous. In power save mode, the switching frequency decreases linearly with the load current maintaining high efficiency. The transition in and out of power save mode is seamless in both directions.
- **Output Discharge Function Enabled:** The output discharge function is enabled to ensure a defined down-ramp of the output voltage when the device is being disabled but also to keep the output voltage close to 0-V when the device is off. The output discharge feature is only active once TPS629210-Q1 have been enabled at least once since the supply voltage is applied.

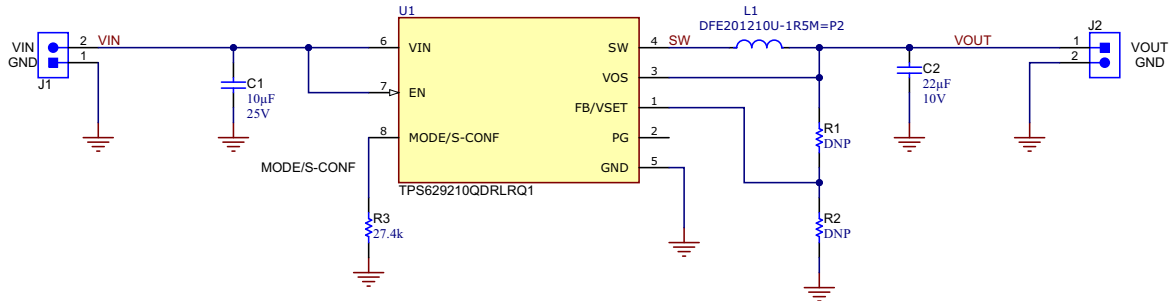
## 2.3 Highlighted Features

The TPS629210-Q1 is a high efficiency, small and flexible synchronous step-down DC/DC converter that is easy to use. A selectable switching frequency of 2.5-MHz or 1.0-MHz allows the use of small inductors and provides fast transient response. The device supports high output voltage accuracy of -1.5% and +1.1% across temperature range (-40°C to 150°C) using VSET feature. The wide input voltage of 3-V to 17-V supports a variety of nominal inputs, like 12-V supply rails, single-cell or multi-cell Li-Ion, and 5-V or 3.3-V rails.

The TPS629210-Q1 provides a MODE/S-CONF input to set the internal/external feedback, switching frequency, output voltage discharge and auto PFM/PWM or forced PWM operation. To maintain high efficiency at light load, auto PFM/PWM should be selected. Additionally, to provide high efficiency at very small load, the device has a low typical quiescent current of 4- $\mu$ A. If enabled AEE mode, the device provides automatic efficiency enhancement across VIN, VOUT and load current. The device is available in small 8-pin SOT583 package.

## 2.4 System Design Theory

The TPS629210-Q1 is optimized to work within a range of external components. The LC output filters inductance and capacitance have to be considered together, creating a double pole, responsible for the corner frequency of the converter. See the [TPS629210-Q1](#) data sheet for more details.



**Figure 2-2. Buck Converter Circuit Design Using TPS629210-Q1**

The TIDA-050056 is designed with a nominal 1.5- $\mu\text{H}$  inductor to support 3.3-V output voltage. A shielded wire-wound inductor from Murata (DFE201210U-1R5M=P2) is used in this design. It has 2.5-A saturation current and 138-m $\Omega$  maximum DCR. 1.5- $\mu\text{H}$  inductance is ideal for size and ripple given the VOUT of this 3.3-V design. The larger values can be used to achieve a lower inductor ripple current but they can have a negative impact on efficiency and transient response. Small values that 1.5- $\mu\text{H}$  will cause a larger inductor ripple current which causes a larger negative inductor current in forced PWM mode at low or no output current.

A small low equivalent series resistance (ESR) multilayer ceramic capacitor (MLCC) is recommended to obtain the best filtering. For this design, a 10- $\mu\text{F}$  /25-V multilayer ceramic chip capacitor from Murata (GRM188R61E106MA73L) is used as an input capacitor. It is designed to withstand up to 25-V which is enough for input voltage range that we want to cover in this design.

For the output capacitor, the voltage rating is much smaller than the input, only 6-V to 10-V capacitor rating is needed. A 22- $\mu\text{F}$ /10-V multilayer ceramic chip capacitor from Murata (GRM188R61A226ME15D) is chosen.

The MODE/S-CONF requires an E96 resistor series, 1% accuracy, temperature coefficient better or equal than  $\pm 200$ -ppm/ $^{\circ}\text{C}$ . A small size 0402 package (CRCW040227K4FKED) from Vishay is used in this design.

### 3 Hardware Requirements, Test Setup, 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 1-A of current and up to 20-V.
- Current and voltage multimeters to measure the currents and voltages during the related tests.
- The TIDA-050056 board is a printed circuit board(PCB) with all the components in this design.
- Resistive load and electronic load that are capable at least 1-A.
- Thermal camera used to measure the thermal rise of the board during operation.
- Oscilloscope to capture voltage and current waveforms.

#### 3.2 Test Setup

Figure 3-1 shows test setup for TIDA-050056.

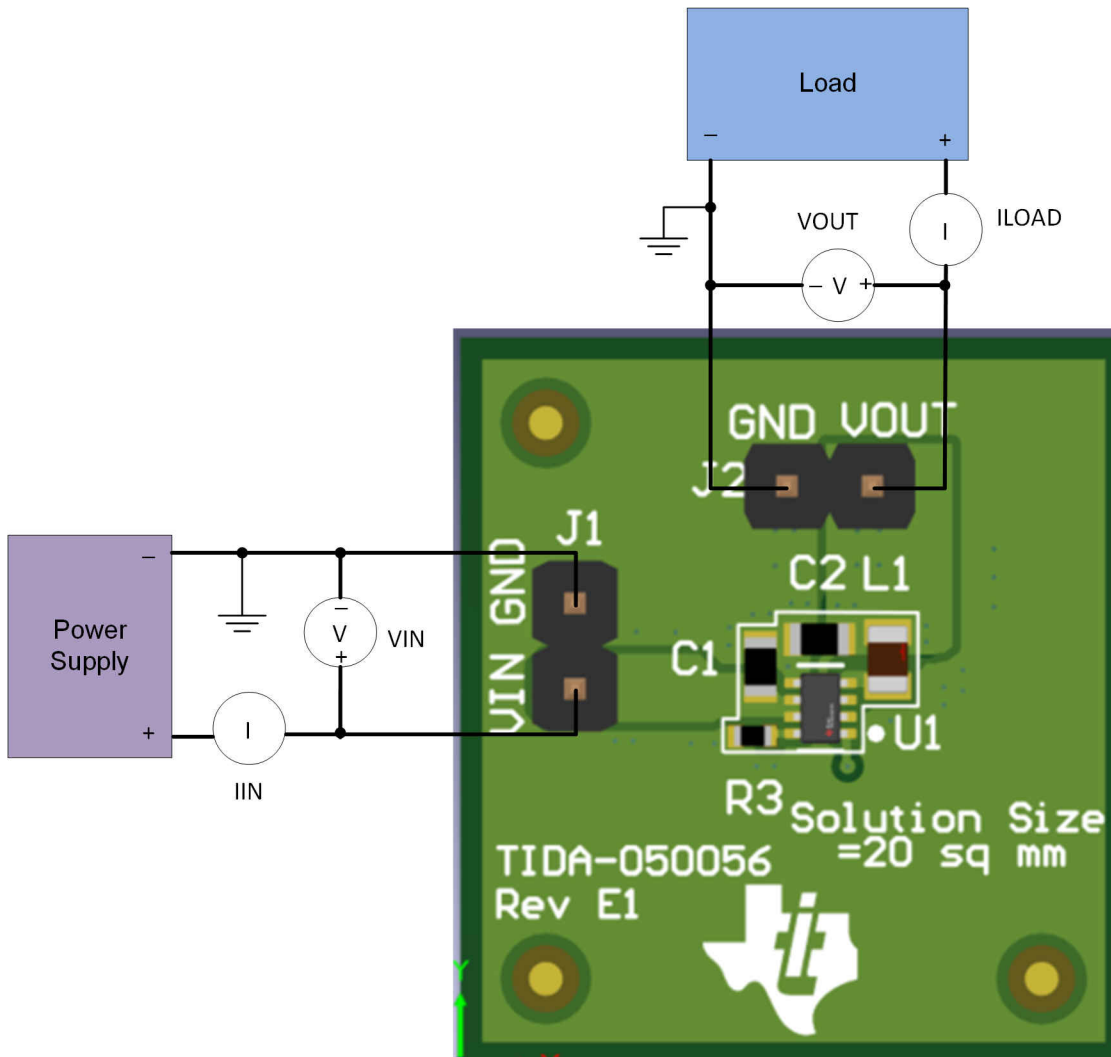


Figure 3-1. Test Setup

### 3.3 Test Results

This section provides the test results of TIDA-050056.

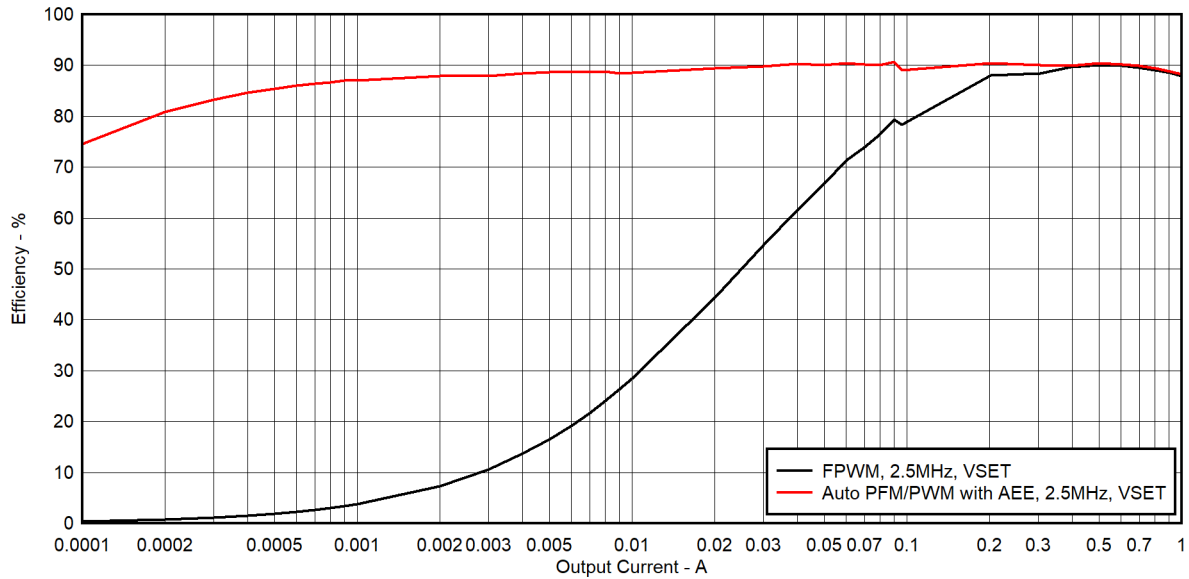


Figure 3-2. Efficiency  $V_{IN}=12\text{-V}$ ,  $V_{OUT}=3.3\text{-V}$ ,  $F_{SW}=2.5\text{-MHz}$ , VSET

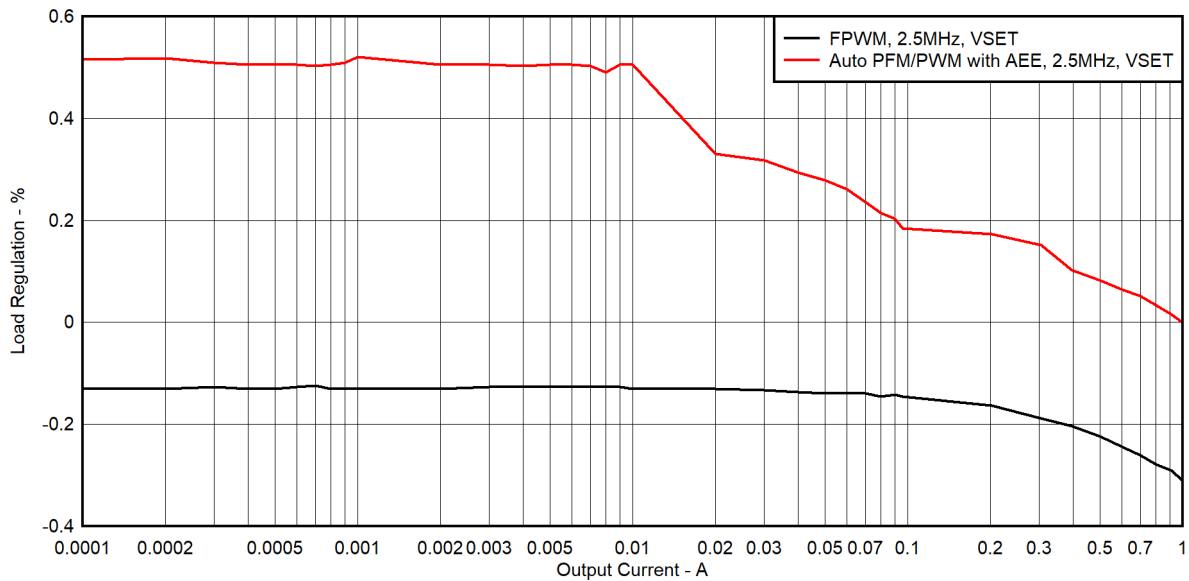
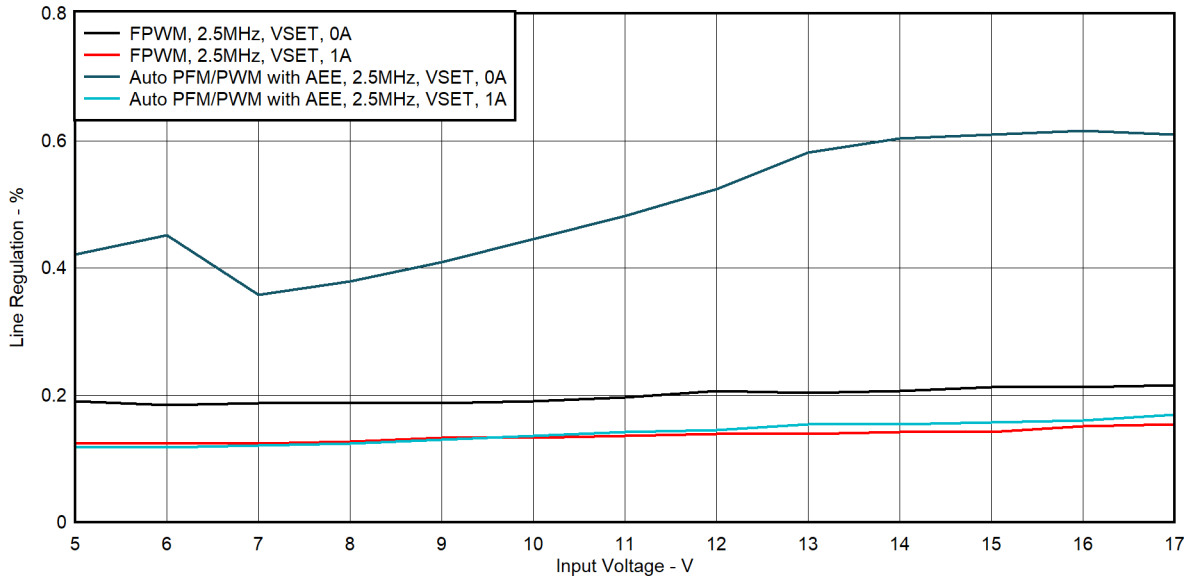
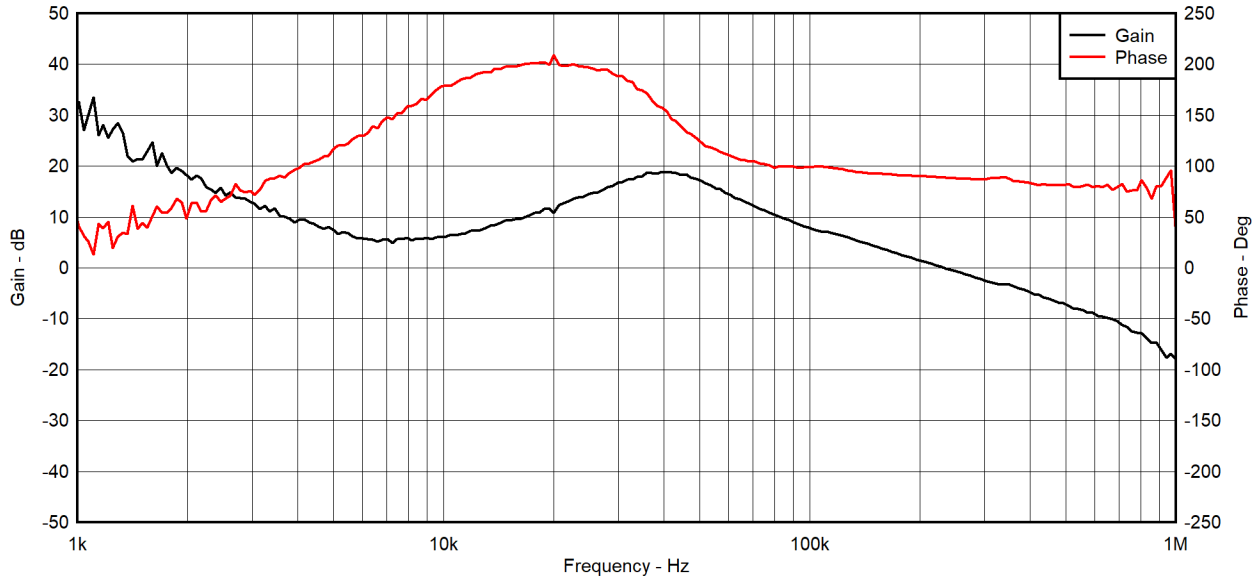


Figure 3-3. Load Regulation  $V_{IN}=12\text{-V}$ ,  $V_{OUT}=3.3\text{-V}$ ,  $F_{SW}=2.5\text{-MHz}$ , VSET



**Figure 3-4. Line Regulation  $V_{IN}=5\text{-V}$  to  $17\text{-V}$ ,  $I_{OUT}=0\text{-A}$  and  $1\text{-A}$ ,  $F_{SW}=2.5\text{-MHz}$ , VSET**



**Figure 3-5. Loop Response Auto PFM/PWM with AEE, VSET,  $V_{IN}=12\text{-V}$ ,  $V_{OUT}=3.3\text{-V}$ ,  $I_{OUT}=1\text{-A}$**

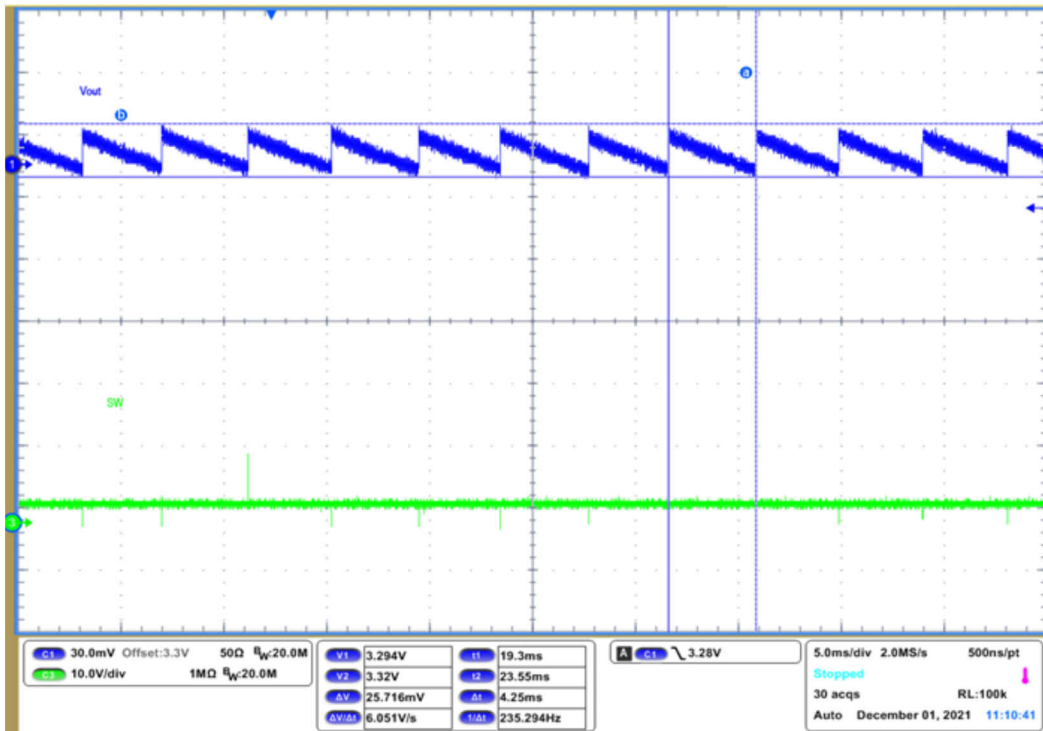


Figure 3-6. Output Voltage Ripple Auto PFM/PWM,  $V_{IN}=12\text{-V}$ ,  $V_{OUT}=3.3\text{-V}$ ,  $I_{OUT}=0\text{-A}$

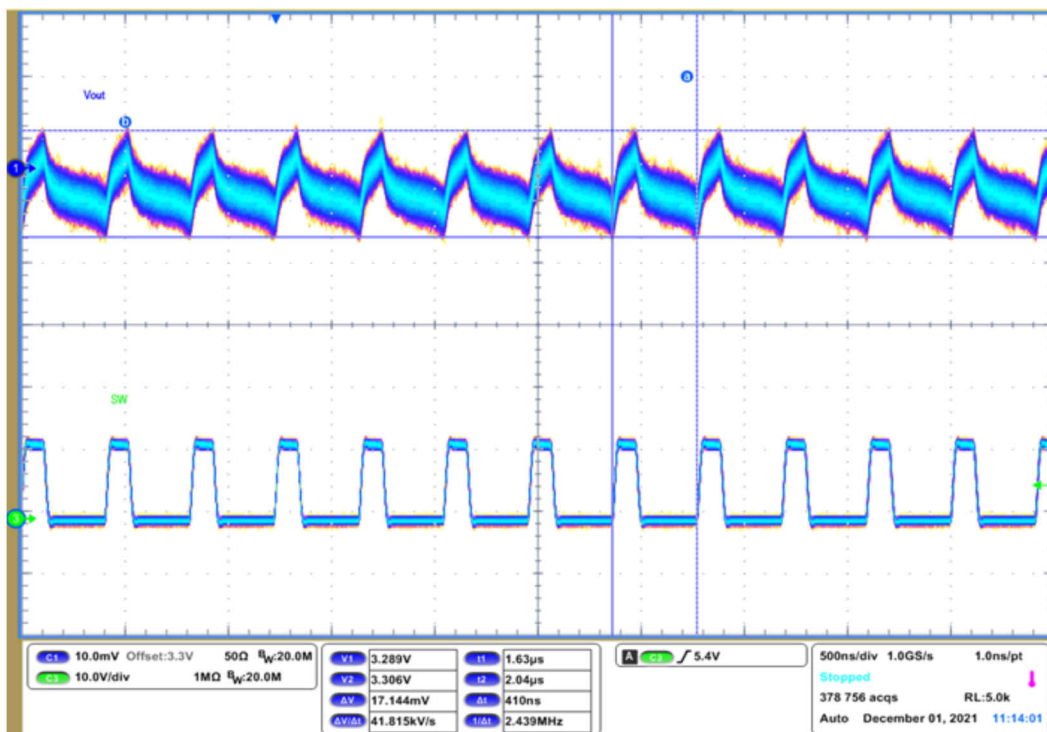


Figure 3-7. Output Voltage Ripple Auto PFM/PWM,  $V_{IN}=12\text{-V}$ ,  $V_{OUT}=3.3\text{-V}$ ,  $I_{OUT}=1\text{-A}$



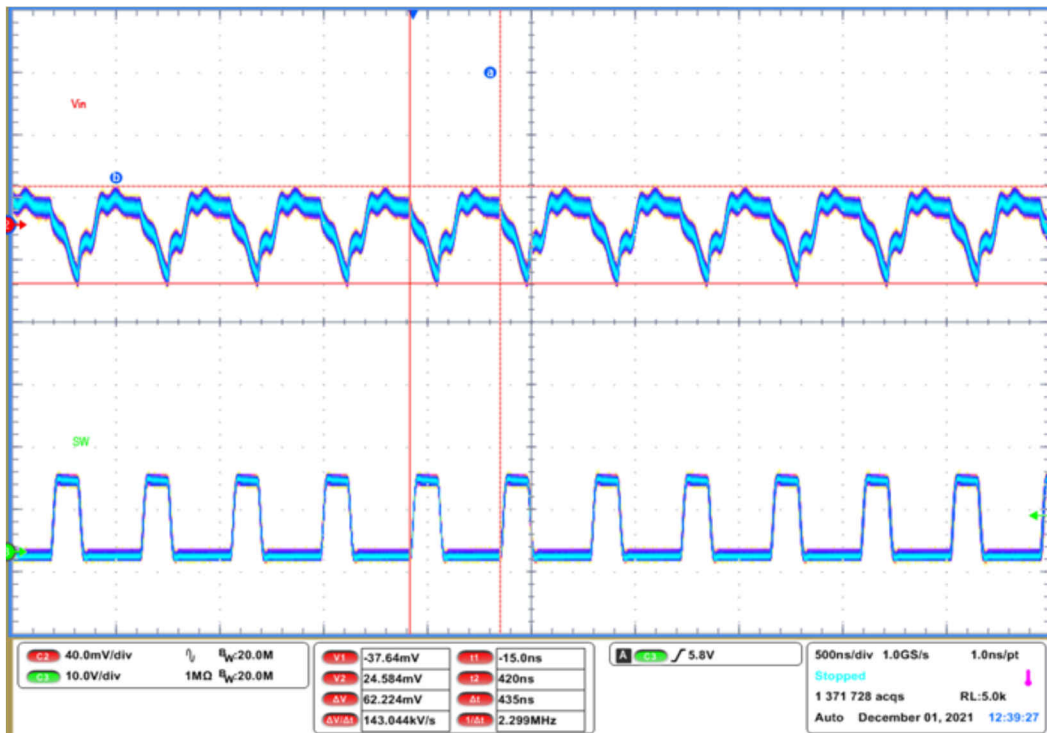


Figure 3-8. Input Voltage Ripple Auto PFM/PWM,  $V_{IN}=12\text{-V}$ ,  $V_{OUT}=3.3\text{-V}$ ,  $I_{OUT}=1\text{-A}$

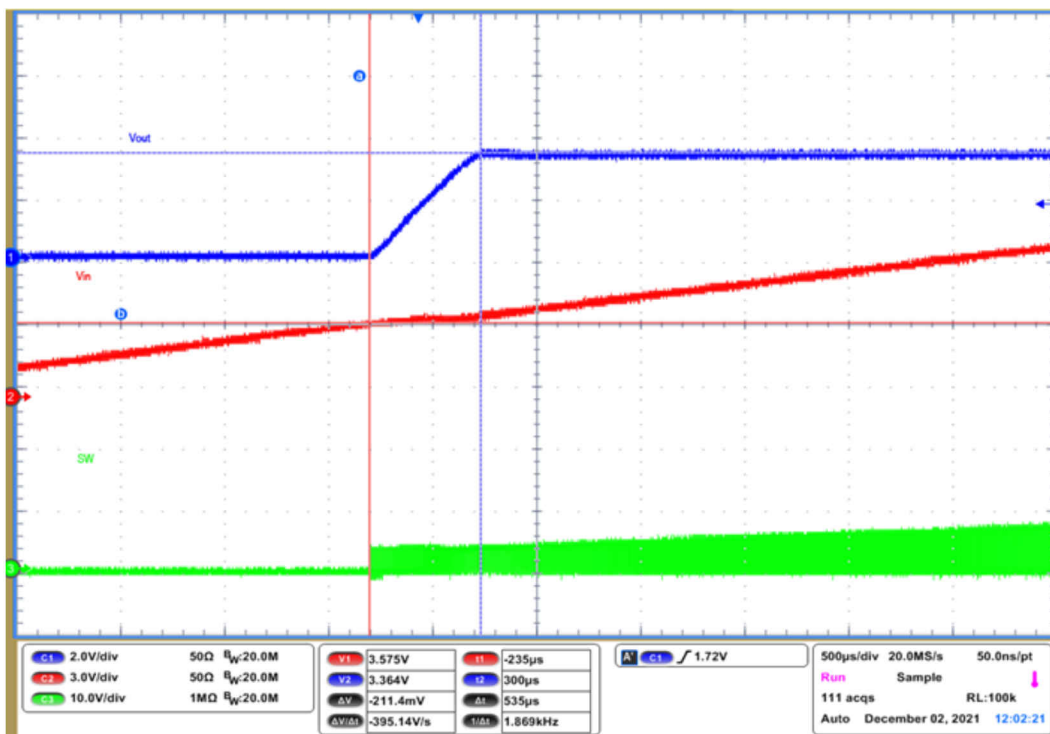


Figure 3-9. Start up Auto PFM/PWM with AEE,  $V_{IN}=12\text{-V}$ ,  $V_{OUT}=3.3\text{-V}$ ,  $I_{OUT}=1\text{-A}$

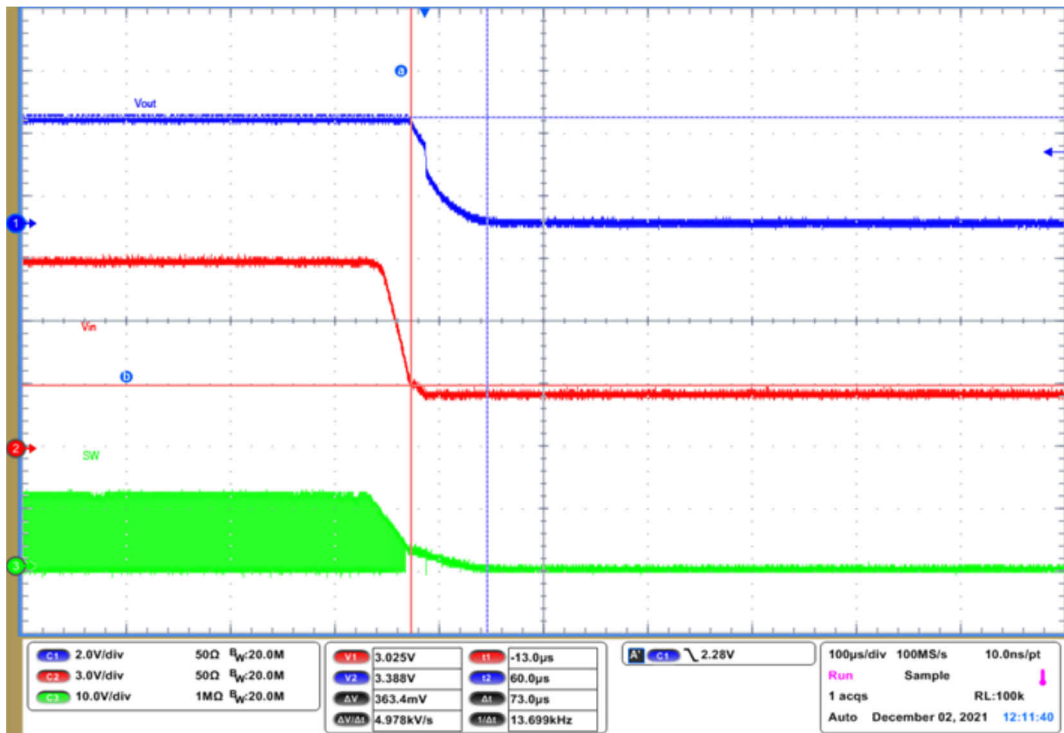


Figure 3-10. Shut down Auto PFM/PWM with AEE,  $V_{IN}=12\text{-V}$ ,  $V_{OUT}=3.3\text{-V}$ ,  $I_{OUT}=1\text{-A}$

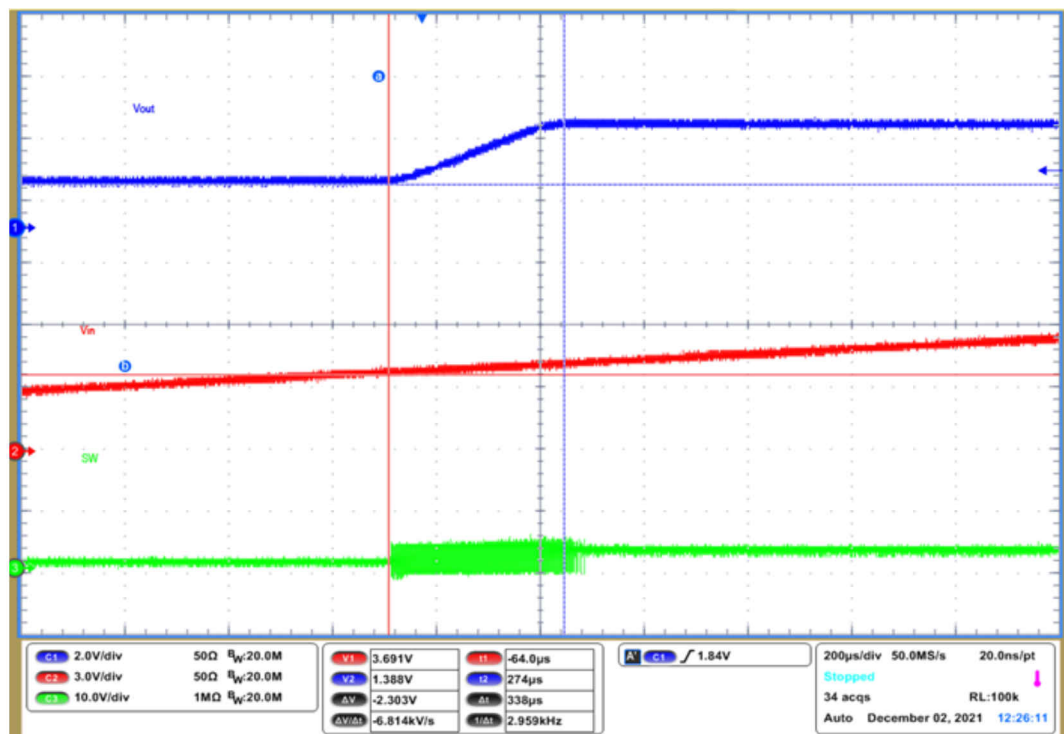


Figure 3-11. Pre-bias start up Auto PFM/PWM,  $V_{IN}=12\text{-V}$ ,  $V_{OUT}=3.3\text{-V}$ ,  $I_{OUT}=0\text{-A}$

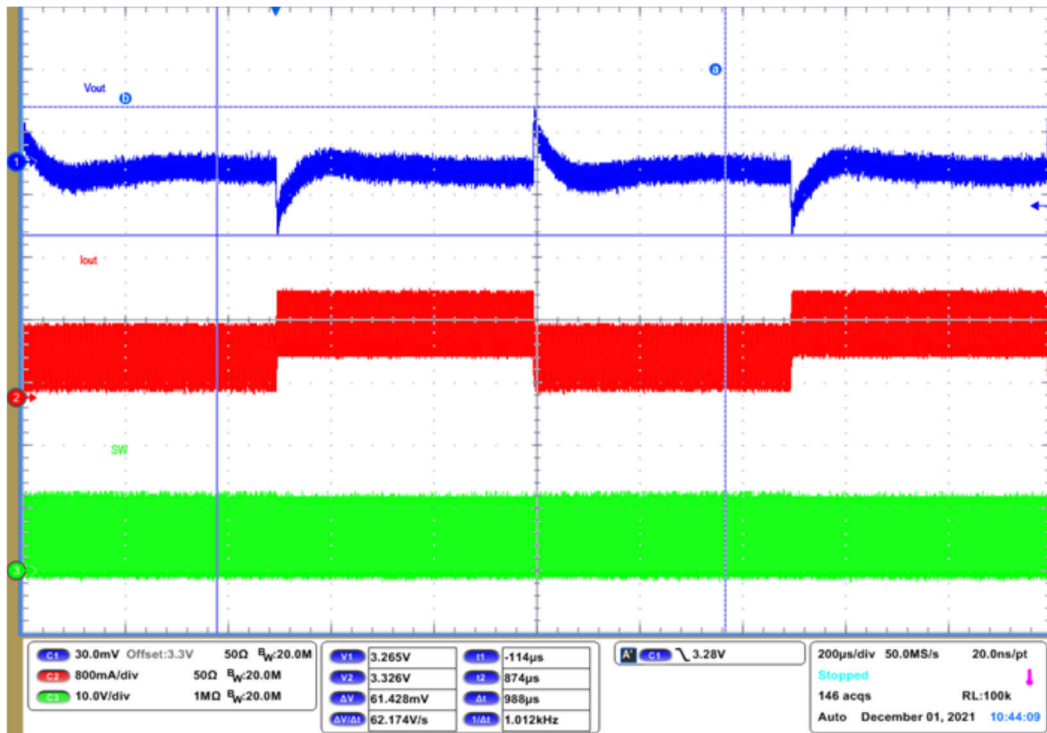


Figure 3-12. Load Transient Auto PFM/PWM,  $V_{IN}$ =12-V,  $V_{OUT}$ =3.3-V,  $I_{OUT}$ =0.5-A to 1-A, Slew rate= 1-A/μs

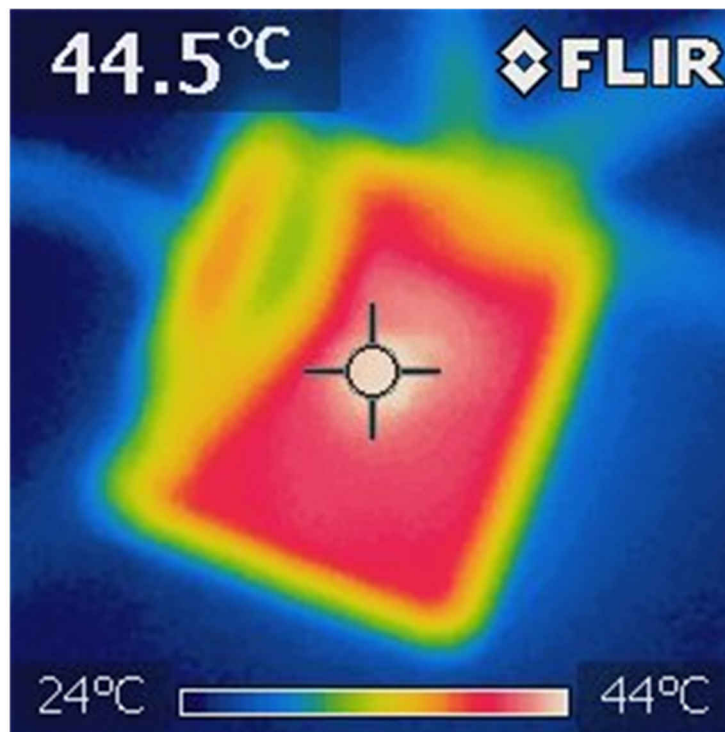


Figure 3-13. Thermal Image Auto PFM/PWM,  $V_{IN}$ =12-V,  $V_{OUT}$ =3.3-V,  $I_{OUT}$ =1-A

## 4 Design and Documentation Support

### 4.1 Design Files

#### 4.1.1 Schematics

To download the schematics, see the design files at [TIDA-050056](#).

#### 4.1.2 BOM

To download the bill of materials (BOM), see the design files at [TIDA-050056](#).

#### 4.1.3 PCB Layout Recommendations

##### 4.1.3.1 Layout Prints

To download the layer plots, see the design files at [TIDA-050056](#).

#### 4.1.4 Altium Projects

To download the Altium Designer project files, see the design files at [TIDA-050056](#).

#### 4.1.5 Gerber Files

To download the Gerber files, see the design files at [TIDA-50056](#).

#### 4.1.6 Assembly Drawings

To download the assembly drawings, see the design files at [TIDA-050056](#).

### 4.2 Documentation Support

1. Texas Instruments, [TPS629210-Q1 3-V to 17-V, 1-A Low I<sub>Q</sub> Converter in a SOT583 Package](#) data sheet.
2. Texas Instruments, [TPS629210 3-V to 17-V1-A, Low I<sub>Q</sub> Buck Converter in SOT583 Package](#) 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 Author

**Matthew Murdock** is System Engineer at Texas Instruments for over a decade responsible for defining new products and technology platforms based on our marketing strategy and business opportunities.

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**Matthew Murdock and Nancy Zhang** also provides application support and system design for customers to understand their overall product ecosystem and how best to use mid-voltage buck converters.

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