

# TPS548D21 SWIFT™ Step-Down Converter Evaluation Module User's Guide



## ABSTRACT

This user's guide describes the characteristics, operation, and use of the TPS548D21 Evaluation Module (EVM). The user's guide includes test information, descriptions, and results. A complete schematic diagram, printed-circuit board layouts, and bill of materials are also included in this document. Throughout this user's guide, the abbreviations EVM, TPS548D21EVM, and the term evaluation module are synonymous with the TPS548D21EVM-784, unless otherwise noted.

## Table of Contents

<b>1 Introduction</b> .....	3
<b>2 Description</b> .....	3
2.1 Typical End-User Applications.....	3
2.2 EVM Features.....	3
<b>3 EVM Electrical Performance Specifications</b> .....	4
<b>4 Schematic</b> .....	5
<b>5 Test Equipment</b> .....	6
<b>6 PWR-784EVM</b> .....	7
<b>7 List of Test Points, Jumpers, and Switch</b> .....	8
<b>8 Test Procedure</b> .....	9
8.1 Line and Load Regulation Measurement Procedure.....	9
8.2 Efficiency.....	9
8.3 Equipment Shutdown.....	10
<b>9 Performance Data and Typical Characteristic Curves</b> .....	10
9.1 Efficiency.....	10
9.2 Load Regulation.....	10
9.3 Line Regulation.....	11
9.4 Transient Response.....	13
9.5 Output Ripple.....	13
9.6 Control On.....	14
9.7 Control Off.....	15
9.8 Thermal Image.....	16
<b>10 EVM Assembly Drawing and PCB Layout</b> .....	17
<b>11 List of Materials</b> .....	22
<b>12 Revision History</b> .....	24

## List of Figures

Figure 4-1. PWR-784EVM Schematic.....	5
Figure 6-1. PWR-784EVM Overview.....	7
Figure 6-2. Tip and Barrel Measurement.....	7
Figure 9-1. Efficiency of 1-V Output vs Load.....	10
Figure 9-2. Load Regulation of 1-V Output.....	10
Figure 9-3. Line Regulation of 1-V Output.....	11
Figure 9-4. Real Tracking POD, 256 $\mu$ s PGD 8 ms.....	11
Figure 9-5. Sequencing POD, 256 $\mu$ s PGD 8 ms Ext SS Pulldown PG.....	12
Figure 9-6. Transient Response of 1-V Output at 12 $V_{IN}$ , Transient is 8 A to 32 A, 2.5 A/ $\mu$ s.....	13
Figure 9-7. Output Ripple and SW Node of 1-V Output at 12 $V_{IN}$ , 0-A Output.....	13
Figure 9-8. Output Ripple and SW Node of 1-V Output at 12 $V_{IN}$ , 40-A Output.....	14
Figure 9-9. Start up from Control, 1-V Output at 12 $V_{IN}$ , 40-A Output.....	14

Figure 9-10. 0.5-V Pre-bias start up from Control, 1-V Output at 12 V <sub>IN</sub> , 40-A Output.....	15
Figure 9-11. Soft Stop from Control, 1-V Output at 12 V <sub>IN</sub> , 40-A Output.....	15
Figure 9-12. Thermal Image at 1-V Output at 12 V <sub>IN</sub> , 40-A Output.....	16
Figure 10-1. PWR-784EVM Top Layer Assembly Drawing (Top View).....	17
Figure 10-2. PWR-784EVM Top Solder Mask (Top View).....	17
Figure 10-3. PWR-784EVM Top Layer (Top View).....	18
Figure 10-4. PWR-784EVM Inner Layer 1 (Top View).....	18
Figure 10-5. PWR-784EVM Inner Layer 2 (Top View).....	19
Figure 10-6. PWR-784EVM Inner Layer 3 (Top View).....	19
Figure 10-7. PWR-784EVM Inner Layer 4 (Top View).....	20
Figure 10-8. PWR-784EVM Bottom Layer (Top View).....	20
Figure 10-9. PWR-784EVM Bottom Solder Mask (Top View).....	21
Figure 10-10. PWR-784EVM Bottom Overlay Layer (Top View).....	21

### List of Tables

Table 3-1. PWR-784EVM Electrical Performance Specifications.....	4
Table 7-1. Test Point Functions.....	8
Table 8-1. List of Test Points for Line and Load Measurements.....	9
Table 8-2. List of Test Points for Efficiency Measurements.....	9
Table 11-1. PWR784 List of Materials.....	22

### Trademarks

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## 1 Introduction

The PWR784EVM evaluation module uses the TPS548D21 device. The TPS548D21 is a highly integrated synchronous buck converter that is designed for up to 40-A current output.

## 2 Description

The PWR784EVM is designed as a single output DC-DC converter that demonstrates the TPS548D21 in a typical low-voltage application while providing a number of test points to evaluate the performance. It uses a nominal 12-V input bus to produce a regulated 1-V output at up to 40-A load current.

### 2.1 Typical End-User Applications

- Enterprise storage, SSD, NAS
- Wireless and wired communication infrastructure
- Industrial PCs, automation, ATE, PLC, video surveillance
- Enterprise server, switches, routers
- ASIC, SoC, FPGA, DSP core and I/O rails

### 2.2 EVM Features

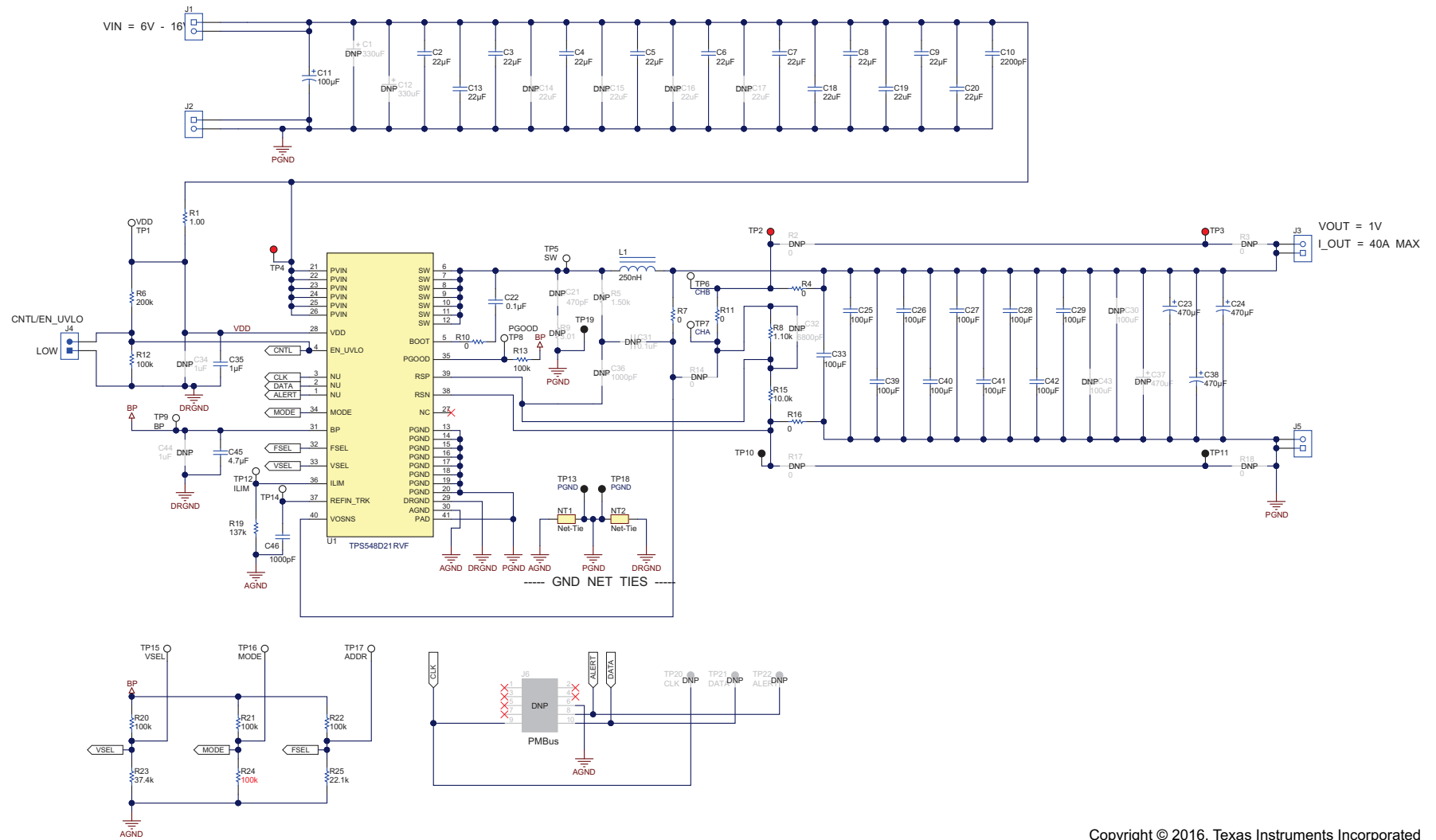
- Regulated 1-V output up to 40-A, steady-state output current
- Convenient test points for probing critical waveforms

### 3 EVM Electrical Performance Specifications

**Table 3-1. PWR-784EVM Electrical Performance Specifications**

Parameter	Test Conditions	Min	Typ	Max	Units
<b>Input Characteristics</b>					
Voltage range	$V_{IN}$ tied to VDD	5	12	16	V
Maximum input current	$V_{IN} = 12\text{ V}$ , $I_O = 40\text{ A}$			12	A
No load input current	$V_{IN} = 12\text{ V}$ , $I_O = 0\text{ A}$		60		mA
<b>Output Characteristics</b>					
$V_{OUT}$ Output voltage	Output current = 10 A		1		V
$I_{OUT}$ Output load current	$I_{OUT(min)}$ to $I_{OUT(max)}$	0		40	A
Output voltage regulation	Line regulation: input voltage = 5 V to 16 V		0.5%		
	Load regulation: output current = 0 A to $I_{OUT(max)}$		0.5%		
$V_{OUT}$ Output voltage ripple	$V_{IN} = 12\text{ V}$ , $I_{OUT} = 40\text{ A}$		10		mV <sub>PP</sub>
$V_{OUT}$ Output overcurrent			46		A
<b>Systems Characteristics</b>					
Switching frequency	$F_{SW}$		650		kHz
$V_{OUT}$ Peak efficiency	$V_{IN} = 12\text{ V}$ , $I_O = 18\text{ A}$ , $F_{SW} = 650\text{ kHz}$		89%		
Operating temperature	$T_{oper}$	0		105	°C

## 4 Schematic



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Figure 4-1. PWR-784EVM Schematic

## 5 Test Equipment

**Voltage Source:** The input voltage source  $V_{IN}$  must be a 0-V to 18-V variable DC source capable of supplying at least 12 A<sub>DC</sub>. The external voltage source on the REFIN\_TRK pin must be between 0.5 V and 1.25 V. Also, the output impedance of the external voltage source must be much less than 100 k $\Omega$ .

**Multimeters:** It is recommended to use two separate multimeters [Figure 6-1](#). One meter is used to measure  $V_{IN}$  and one to measure  $V_{OUT}$ .

**Output Load:** A variable electronic load is recommended for testing [Figure 6-1](#). It must be capable of 40 A at voltages as low as 0.6 V.

**Oscilloscope:** An oscilloscope is recommended for measuring output noise and ripple. Output ripple must be measured using a tip-and-barrel method or better as shown in [Figure 6-2](#). The scope must be adjusted to 20-MHz bandwidth, AC coupling at 50 mV/division, and must be set to 1- $\mu$ s/division.

**Fan:** During prolonged operation at high loads, it may be necessary to provide forced air cooling with a small fan aimed at the EVM. Temperature of the devices on the EVM must be maintained below 105°C.

**Recommended Wire Gauge:** The voltage drop in the load wires must be kept as low as possible in order to keep the working voltage at the load within its operating range. Use the AWG 14 wire (2 wires parallel for V<sub>OUT</sub> positive and 2 wires parallel for the V<sub>OUT</sub> negative) of no more than 1.98 feet between the EVM and the load. This recommended wire gauge and length should achieve a voltage drop of no more than 0.2 V at the maximum 40-A load.

6 PWR-784EVM

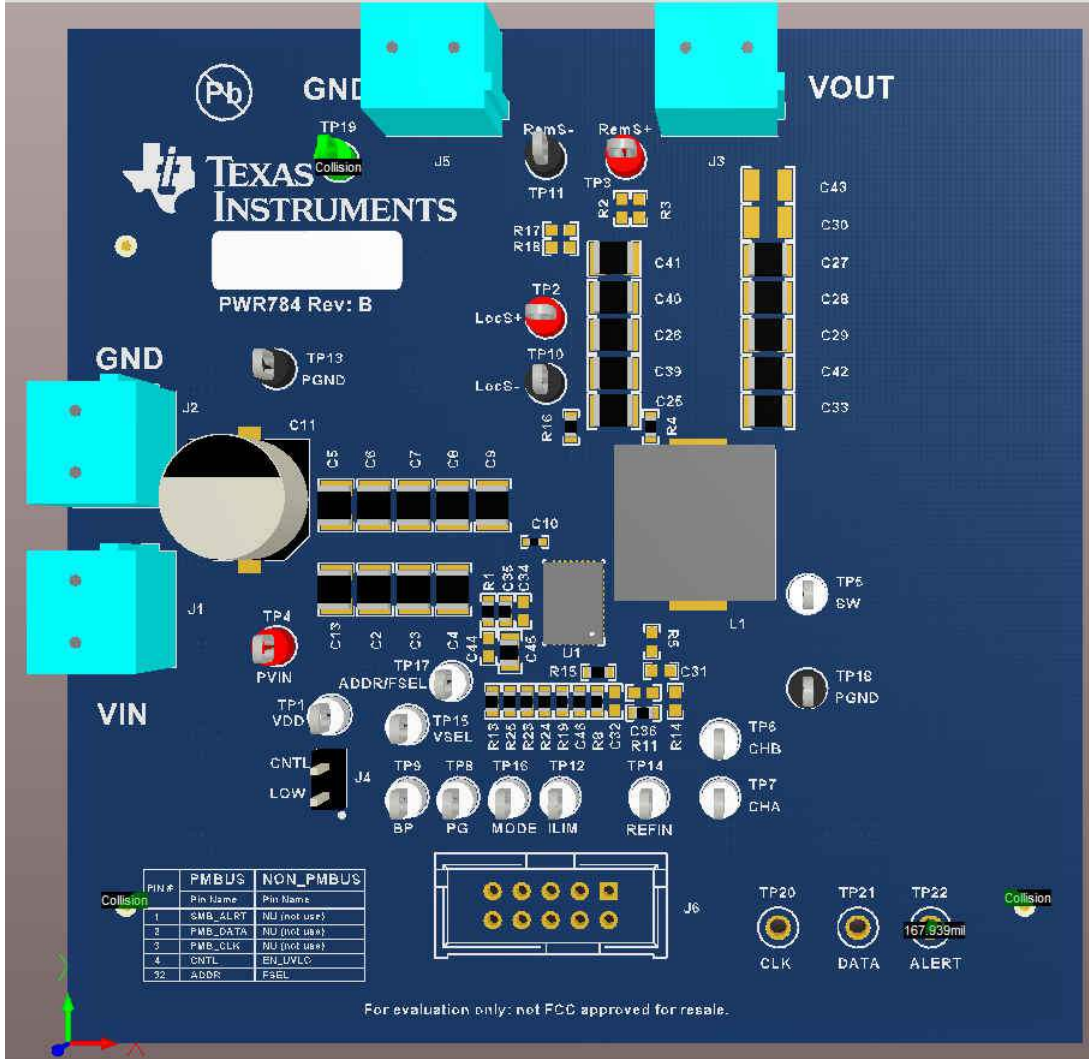


Figure 6-1. PWR-784EVM Overview

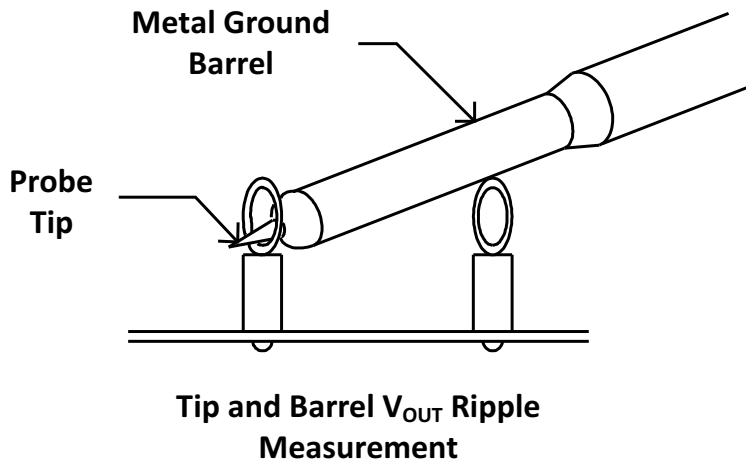


Figure 6-2. Tip and Barrel Measurement

## 7 List of Test Points, Jumpers, and Switch

**Table 7-1. Test Point Functions**

Item	Type	Name	Description
TP5	T-H loop	SW	Power supply Switch node
TP7	T-H loop	CH-A	Measure loop stability
TP6	T-H loop	CH-B	Measure loop stability
TP2	T-H loop	LocS+	Sense VOUT + locally across C5. Use for efficiency and ripple measurements
TP10	T-H loop	LocS-	Sense VOUT- locally across C5. Use for efficiency and ripple measurements
TP3	T-H loop	RemS+	Remote sense +
TP11	T-H loop	RemS-	Remote sense -
TP4	T-H loop	PVIN	Sense VIN + across C10
TP13	T-H loop	PGND	Sense VIN - across C10
TP1	T-H loop	VDD	Supplies the internal circuitry
TP17	T-H loop	FSEL	Monitor the FSEL external resistor divider ratio during initial power up.
TP15	T-H loop	VSEL	Monitor the VSEL external resistor divider ratio during initial power up.
TP9	T-H loop	BP	LDO output
TP8	T-H loop	PG	Power good
TP16	T-H loop	MODE	Monitor the MODE external resistor divider ratio during initial power up.
TP12	T-H loop	ILIM	Program over-current limit.
TP14	T-H loop	REFIN_TRK	System reference voltage that can be overridden by the external voltage source for the tracking and sequencing application.
TP19	T-H loop	PGND	Common GND
TP18	T-H loop	PGND	Common GND
TP20	T-H loop	CLK	Not used
TP21	T-H loop	DATA	Not used
TP22	T-H loop	ALERT	Not used
JP4	2-pin jumper	CNTL	Shunts control pin to GND



## 8 Test Procedure

### 8.1 Line and Load Regulation Measurement Procedure

1. Connect VOUT to J3 and VOUT\_GND to J5 [Figure 6-1](#).
2. Ensure that the electronic load is set to draw 0 A<sub>DC</sub>.
3. Ensure the jumper provided on the EVM shorts on J4 before V<sub>IN</sub> is applied
4. Connect VIN to J1 and VIN\_GND to J2 [Figure 6-1](#).
5. Increase V<sub>IN</sub> from 0 V to 12 V using the digital multimeter to measure input voltage.
6. Connect the external voltage source to TP14. Note: Make sure the external source is noise free.
7. Increase the external voltage source from 0 V to 0.9 V.
8. Remove the jumper on J4 to enable the controller.
9. Use the other digital multimeter or the oscilloscope to measure output voltage V<sub>OUT</sub> at TP2 and TP10.

**Table 8-1. List of Test Points for Line and Load Measurements**

Test Point	Node Name	Description
TP2	LocS+	Sense VOUT + locally across C5. Use for efficiency and ripple measurements
TP10	LocS-	Sense VOUT - locally across C5. Use for efficiency and ripple measurements
TP4	PVIN	Sense VIN + across C10
TP13	PGND	Sense VIN - across C10

10. Vary the load from 0 A<sub>DC</sub> to maximum rated output 40 A<sub>DC</sub>. V<sub>OUT</sub> must remain in regulation as defined in [Table 3-1](#).
11. Vary V<sub>IN</sub> from 5 V to 16 V. V<sub>OUT</sub> must remain in regulation as defined in [Table 3-1](#).
12. Decrease the load to 0 A.
13. Put the jumper back on J4 to disable the converter.
14. Decrease V<sub>IN</sub> to 0 V or turn off the supply.
15. Decrease the external voltage source to 0 V, or turn off the supply.

### 8.2 Efficiency

To measure the efficiency of the power train on the EVM, it is important to measure the voltages at the correct location. This is necessary because otherwise the measurements will include losses in efficiency that are not related to the power train itself. Losses incurred by the voltage drop in the copper traces and in the input and output connectors are not related to the efficiency of the power train, and they must not be included in efficiency measurements.

**Table 8-2. List of Test Points for Efficiency Measurements**

Test Point	Node Name	Description
TP2	LocS+	Sense VOUT + locally across C5. Use for efficiency and ripple measurements
TP10	LocS-	Sense VOUT - locally across C5. Use for efficiency and ripple measurements
TP4	PVIN	Sense VIN + across C10
TP13	PGND	Sense VIN - across C10

Input current can be measured at any point in the input wires, and output current can be measured anywhere in the output wires of the output being measured. Using these measurement points result in efficiency measurements that do not include losses due to the connectors and PCB traces.

### 8.3 Equipment Shutdown

1. Reduce the load current to 0 A.
2. Reduce input voltage to 0 V.
3. Shut down the external fan if in use.
4. Shut down equipment.

## 9 Performance Data and Typical Characteristic Curves

Figure 9-1 through Figure 9-12 present typical performance curves for the PWR-784EVM.

### 9.1 Efficiency

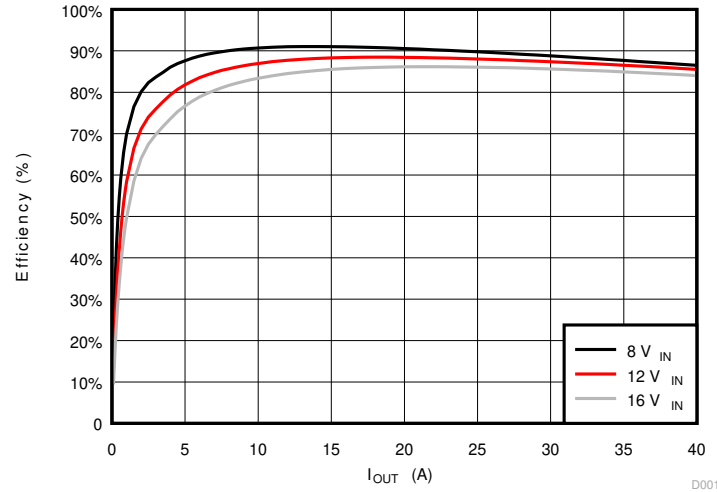


Figure 9-1. Efficiency of 1-V Output vs Load

### 9.2 Load Regulation

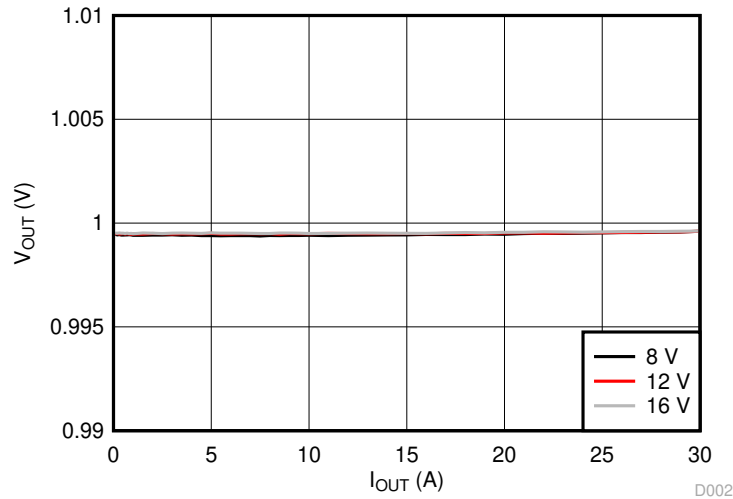


Figure 9-2. Load Regulation of 1-V Output

### 9.3 Line Regulation

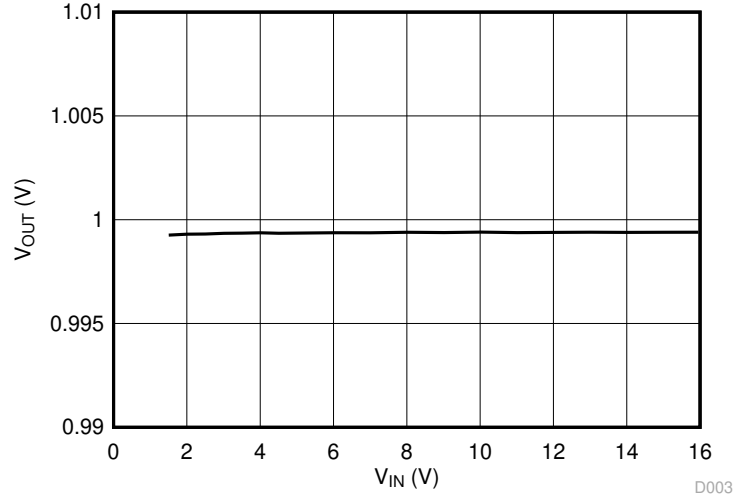


Figure 9-3. Line Regulation of 1-V Output



Figure 9-4. Real Tracking POD, 256  $\mu$ s PGD 8 ms



Figure 9-5. Sequencing POD, 256 μs PGD 8 ms Ext SS Pulldown PG

### 9.4 Transient Response

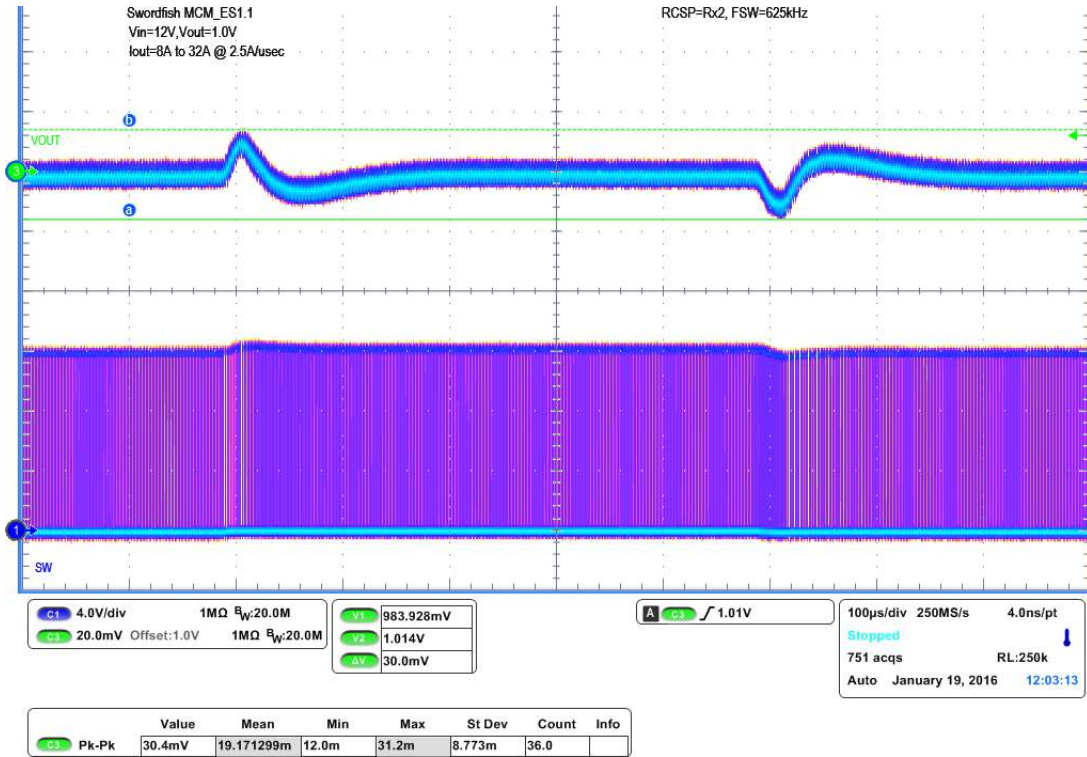


Figure 9-6. Transient Response of 1-V Output at 12 V<sub>IN</sub>, Transient is 8 A to 32 A, 2.5 A/μs

### 9.5 Output Ripple

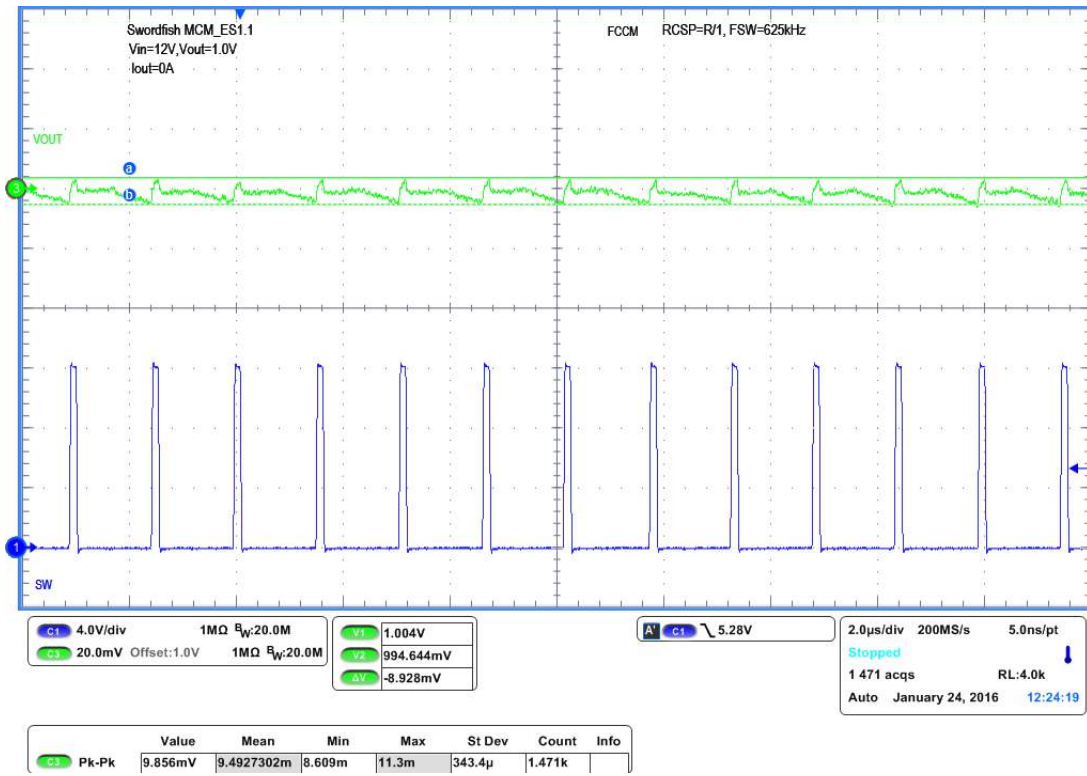


Figure 9-7. Output Ripple and SW Node of 1-V Output at 12 V<sub>IN</sub>, 0-A Output

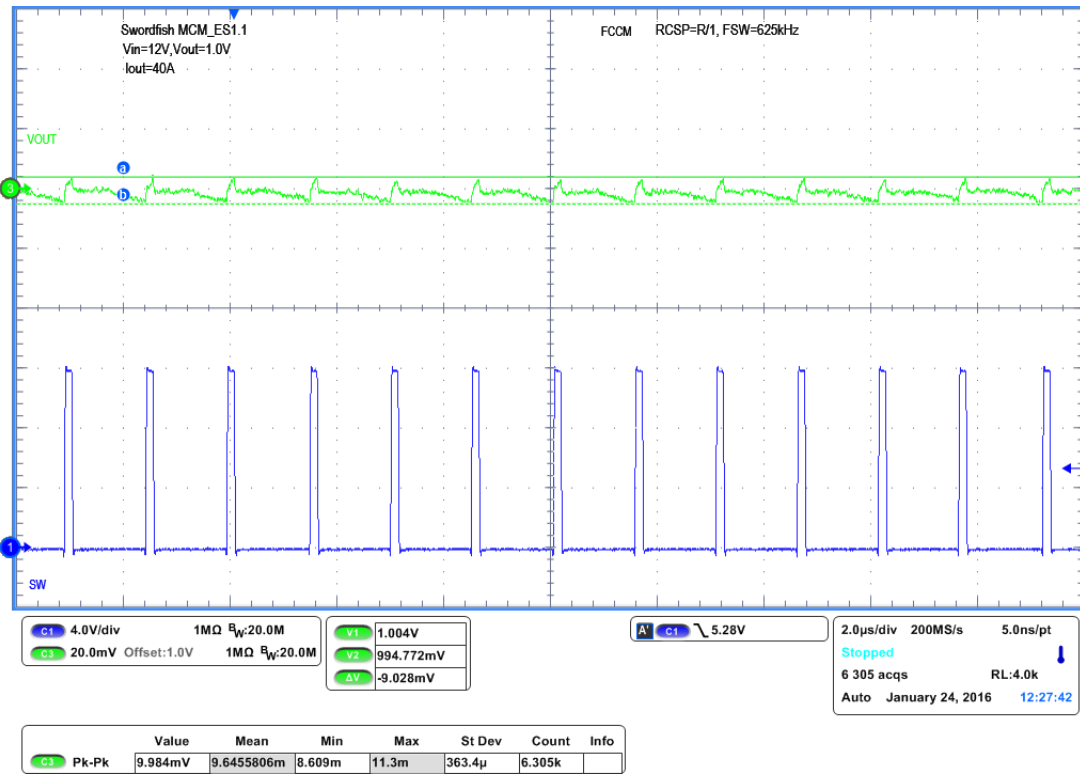


Figure 9-8. Output Ripple and SW Node of 1-V Output at 12 V<sub>IN</sub>, 40-A Output

## 9.6 Control On

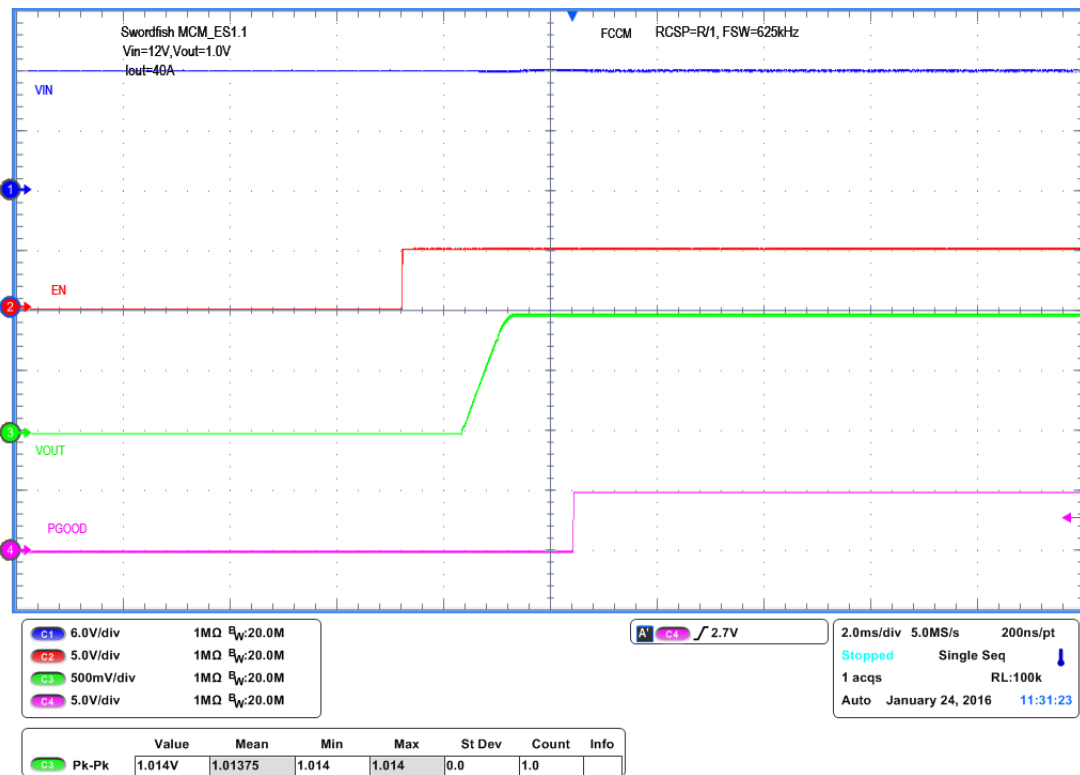


Figure 9-9. Start up from Control, 1-V Output at 12 V<sub>IN</sub>, 40-A Output

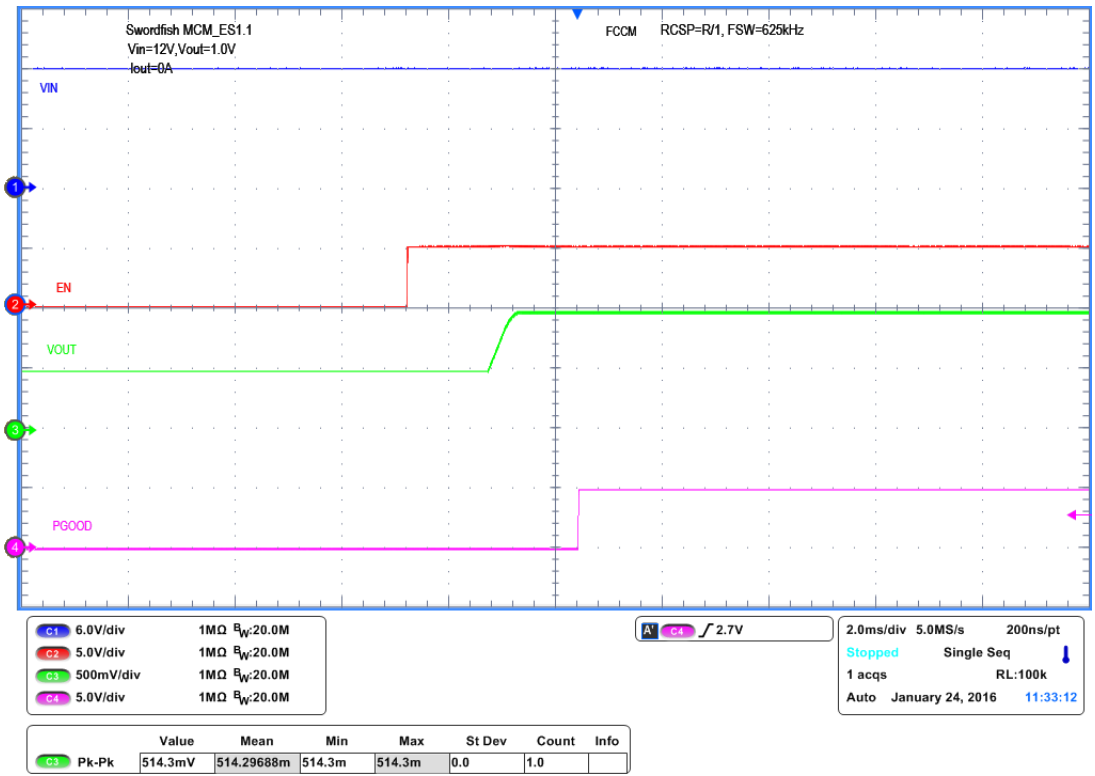


Figure 9-10. 0.5-V Pre-bias start up from Control, 1-V Output at 12 V<sub>IN</sub>, 40-A Output

### 9.7 Control Off

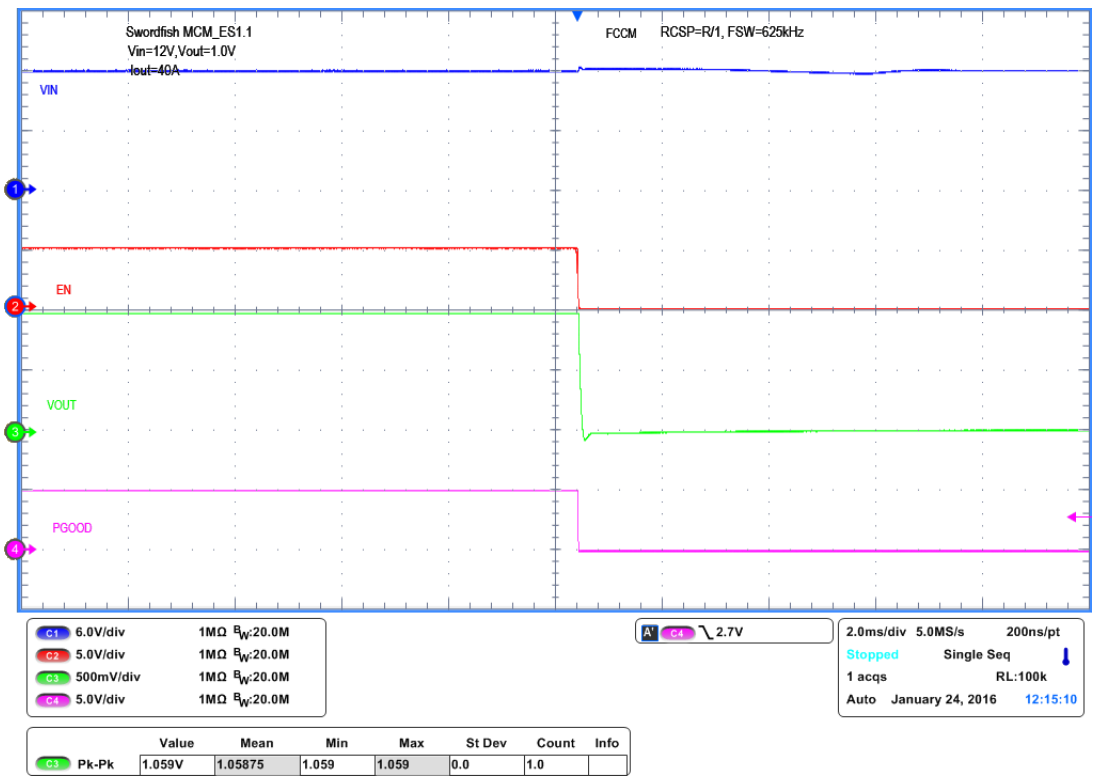


Figure 9-11. Soft Stop from Control, 1-V Output at 12 V<sub>IN</sub>, 40-A Output

## 9.8 Thermal Image

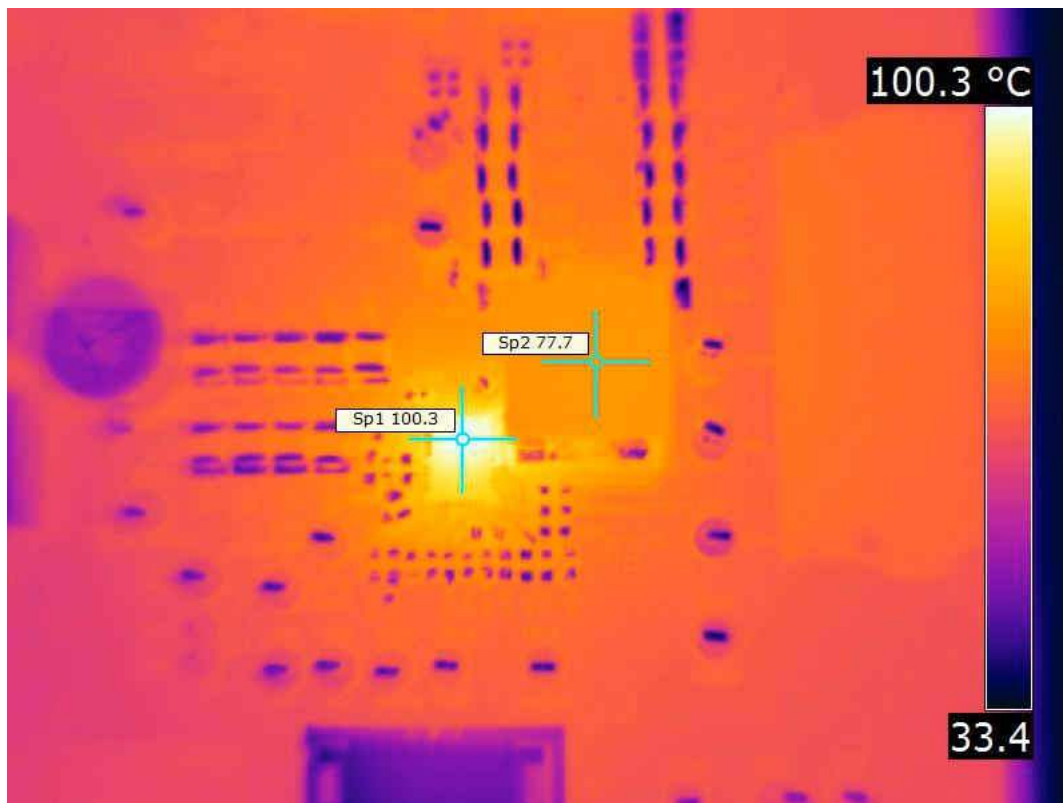


Figure 9-12. Thermal Image at 1-V Output at 12 V<sub>IN</sub>, 40-A Output



## 10 EVM Assembly Drawing and PCB Layout

Figure 10-1 through Figure 10-8 show the design of the PWR-784EVM printed-circuit board (PCB). The PWR-784EVM has a 2-oz. copper finish for all layers.

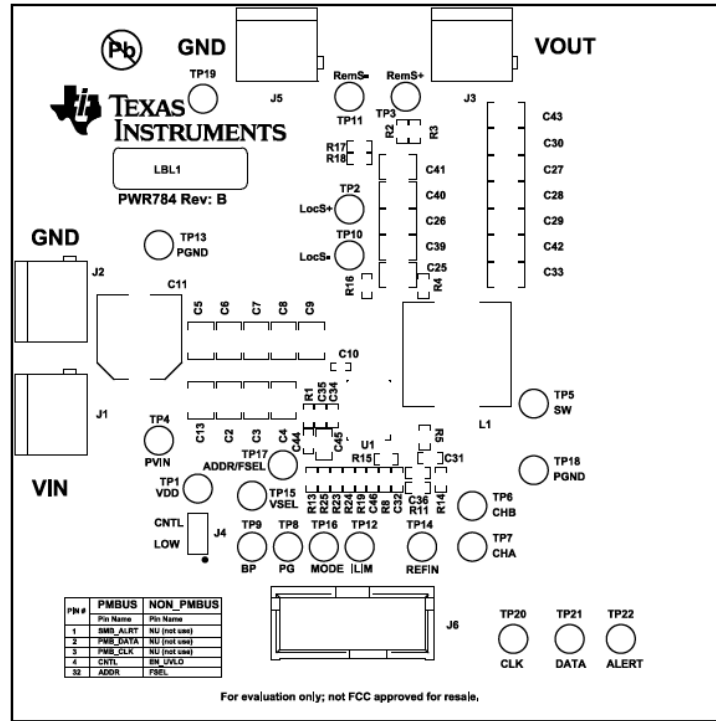


Figure 10-1. PWR-784EVM Top Layer Assembly Drawing (Top View)

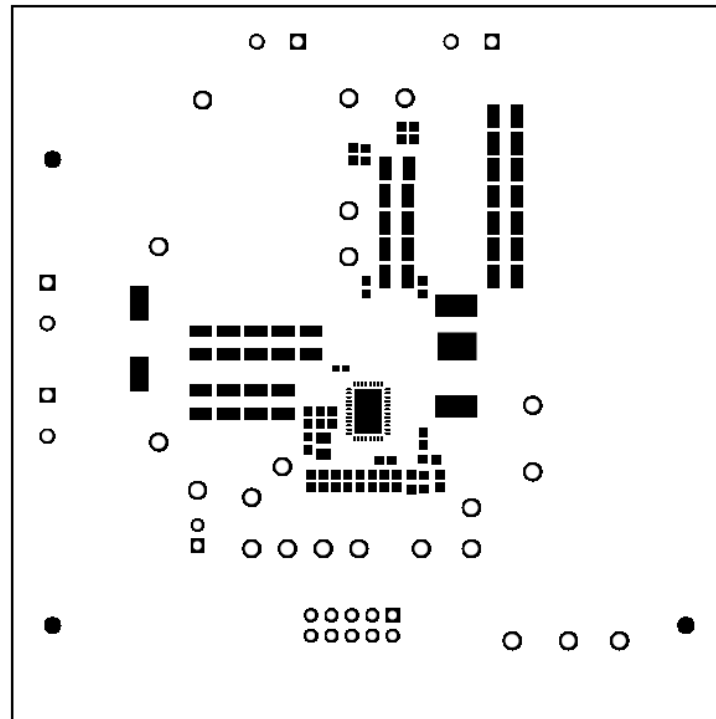
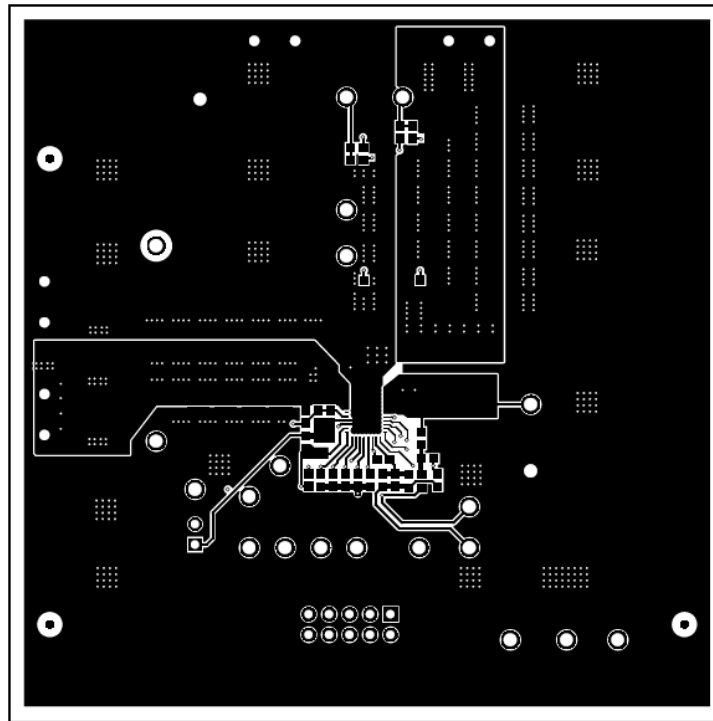
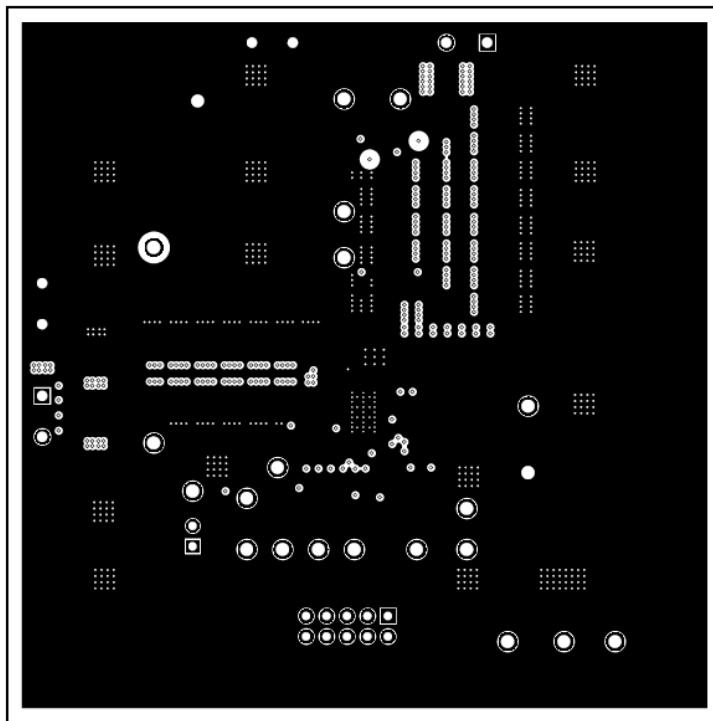


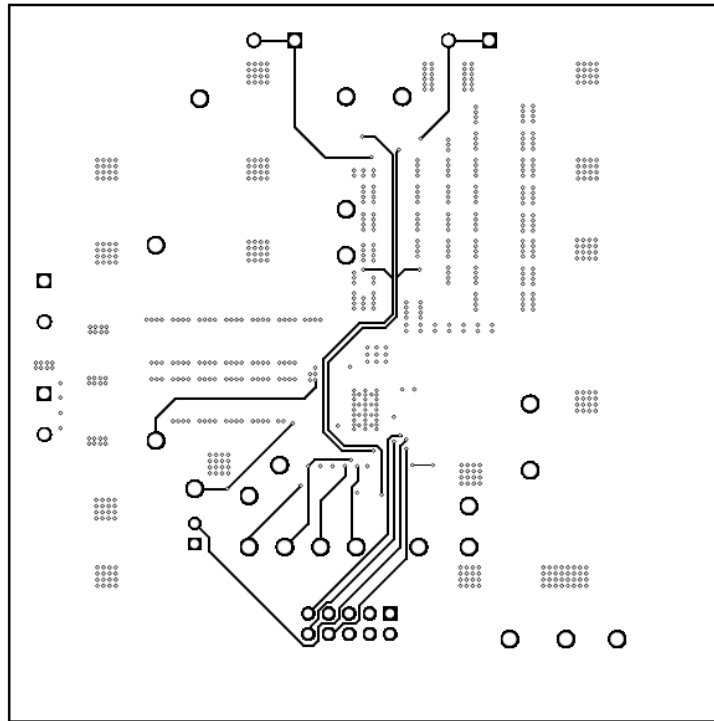
Figure 10-2. PWR-784EVM Top Solder Mask (Top View)



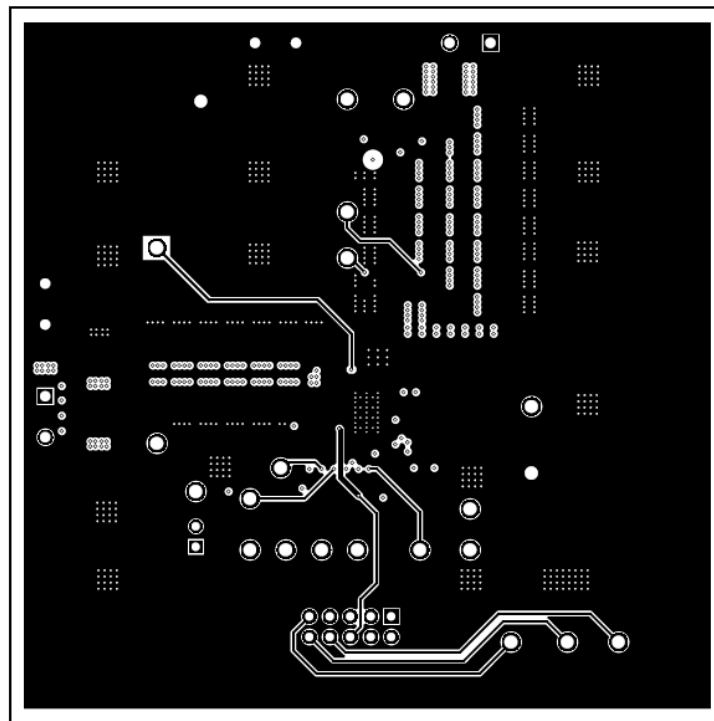
**Figure 10-3. PWR-784EVM Top Layer (Top View)**



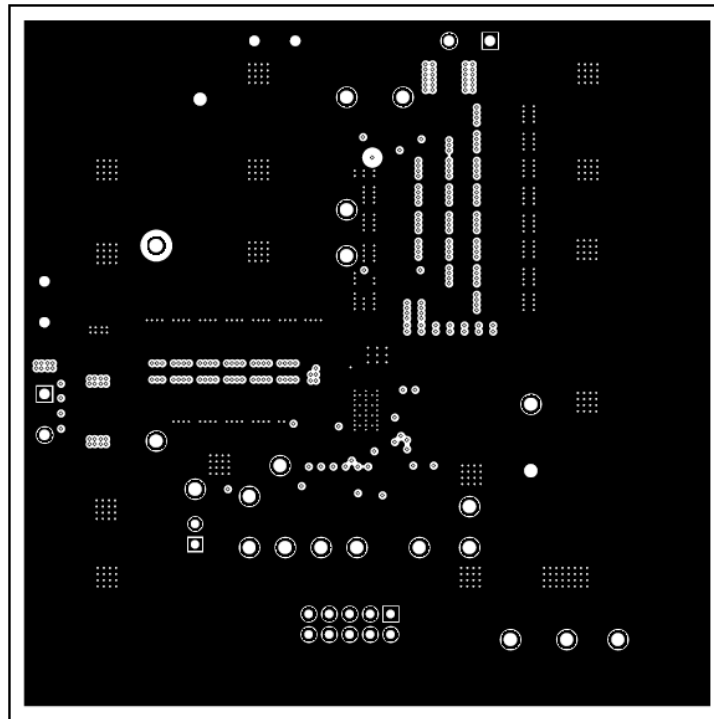
**Figure 10-4. PWR-784EVM Inner Layer 1 (Top View)**



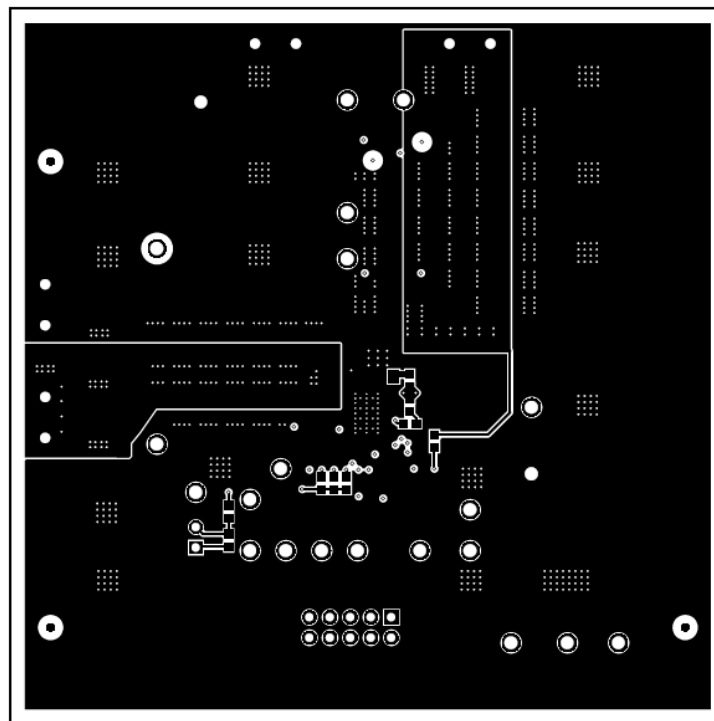
**Figure 10-5. PWR-784EVM Inner Layer 2 (Top View)**



**Figure 10-6. PWR-784EVM Inner Layer 3 (Top View)**



**Figure 10-7. PWR-784EVM Inner Layer 4 (Top View)**



**Figure 10-8. PWR-784EVM Bottom Layer (Top View)**

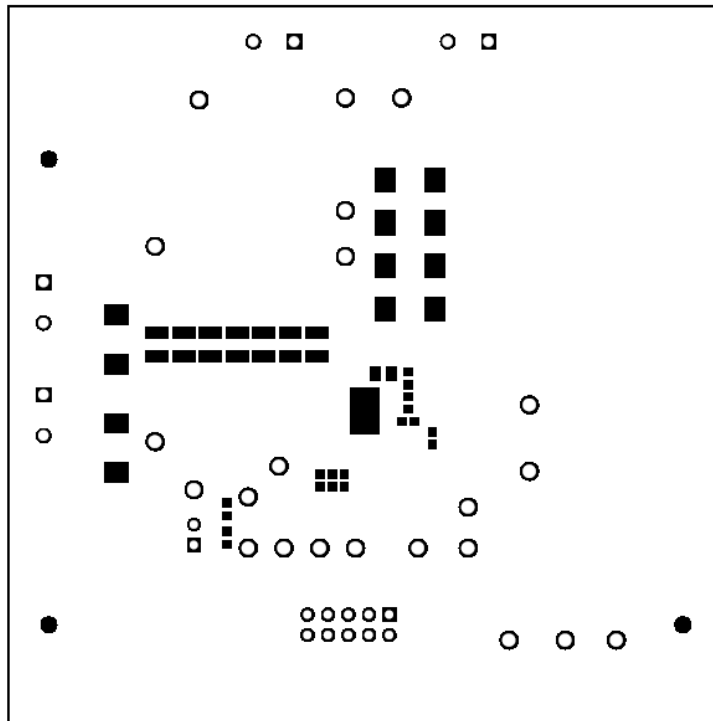


Figure 10-9. PWR-784EVM Bottom Solder Mask (Top View)

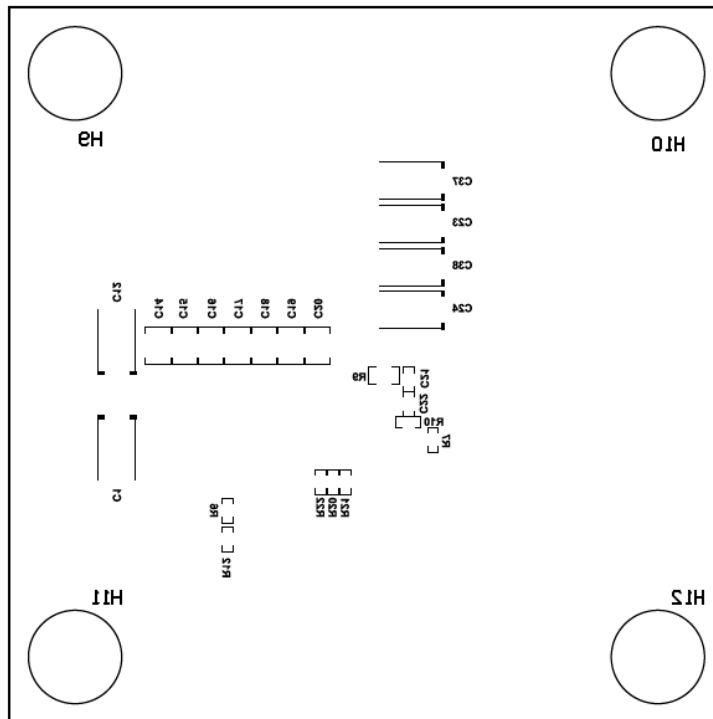


Figure 10-10. PWR-784EVM Bottom Overlay Layer (Top View)

## 11 List of Materials

The EVM components list, according to the schematic, is shown in [Table 11-1](#).

**Table 11-1. PWR784 List of Materials**

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer
!PCB1	1		Printed Circuit Board		PWR784	Any
C2, C3, C4, C5, C6, C7, C8, C9, C13, C18, C19, C20	12	22uF	CAP, CERM, 22 µF, 25 V, +/- 10%, X7R, 1210	1210	GRM32ER71E226KE15L	Murata
C10	1	2200pF	CAP, CERM, 2200 pF, 25 V, +/- 10%, X5R, 0402	0402	GRM155R61E222KA01D	Murata
C11	1	100uF	CAP, AL, 100uF, 35V, +/-20%, 0.15 ohm, SMD	SMT Radial G	EEE-FC1V101P	Panasonic
C22	1	0.1uF	CAP, CERM, 0.1 µF, 50 V, +/- 10%, X7R, 0603	0603	GRM188R71H104KA93D	Murata
C23, C24, C38	3	470uF	CAP, Tantalum Polymer, 470 µF, 2.5 V, +/- 20%, 0.006 ohm, 7.3x2.8x4.3mm SMD	7.3x2.8x4.3mm	2R5TPF470M6L	Panasonic
C25, C26, C27, C28, C29, C33, C39, C40, C41, C42	10	100uF	CAP, CERM, 100 µF, 6.3 V, +/- 20%, X5R, 1210	1210	GRM32ER60J107ME20L	Murata
C35	1	1uF	CAP, CERM, 1 µF, 16 V, +/- 10%, X5R, 0603	0603	C0603C105K4PACTU	Kemet
C45	1	4.7uF	CAP, CERM, 4.7 µF, 16 V, +/- 10%, X7R, 0805	0805	GRM21BR71C475KA73L	Murata
C46	1	1000pF	CAP, CERM, 1000 pF, 50 V, +/- 5%, C0G/NP0, 0603	0603	C0603C102J5GACTU	Kemet
H9, H10, H11, H12	4		Bumpon, Hemisphere, 0.44 X 0.20, Clear	Transparent Bumpon	SJ-5303 (CLEAR)	3M
J1, J2, J3, J5	4		TERMINAL BLOCK 5.08MM VERT 2POS, TH	TERM_BLK, 2pos, 5.08mm	ED120/2DS	On-Shore Technology
J4	1		Header, 100mil, 2x1, Tin, TH	Header, 2 PIN, 100mil, Tin	PEC02SAAN	Sullins Connector Solutions
L1	1	250nH	Inductor, Shielded Drum Core, Ferrite, 250 nH, 50 A, 0.000165 ohm, SMD	12.5x13mm	744309025	Wurth Elektronik
LBL1	1		Thermal Transfer Printable Labels, 0.650" W x 0.200" H - 10,000 per roll	PCB Label 0.650"H x 0.200"W	THT-14-423-10	Brady
R1	1	1.00	RES, 1.00, 1%, 0.1 W, 0603	0603	RC0603FR-071RL	Yageo America
R4, R7, R10, R11, R16	5	0	RES, 0, 5%, 0.1 W, 0603	0603	CRCW06030000Z0EA	Vishay-Dale
R6	1	200k	RES, 200 k, 1%, 0.1 W, 0603	0603	CRCW0603200KFKEA	Vishay-Dale
R8	1	1.10k	RES, 1.10 k, 1%, 0.1 W, 0603	0603	CRCW06031K10KFKEA	Vishay-Dale
R12, R13, R20, R21, R22, R24	6	100k	RES, 100 k, 1%, 0.1 W, 0603	0603	CRCW0603100KFKEA	Vishay-Dale
R15	1	10.0k	RES, 10.0k ohm, 1%, 0.1W, 0603	0603	CRCW060310K0FKEA	Vishay-Dale
R19	1	137k	RES, 137 k, 1%, 0.1 W, 0603	0603	CRCW0603137KFKEA	Vishay-Dale
R23	1	37.4k	RES, 37.4 k, 1%, 0.1 W, 0603	0603	CRCW060337K4FKEA	Vishay-Dale
R25	1	22.1k	RES, 22.1 k, 1%, 0.1 W, 0603	0603	CRCW060322K1FKEA	Vishay-Dale
TP1, TP5, TP6, TP7, TP8, TP9, TP12, TP14, TP15, TP16, TP17	11	White	Test Point, Multipurpose, White, TH	White Multipurpose Testpoint	5012	Keystone
TP2, TP3, TP4	3	Red	Test Point, Multipurpose, Red, TH	Red Multipurpose Testpoint	5010	Keystone
TP10, TP11, TP13, TP18, TP19	5	Black	Test Point, Multipurpose, Black, TH	Black Multipurpose Testpoint	5011	Keystone
U1	1		High Performance, 40-A Single Synchronous Step-Down Converter with Analog REFIN, RVF0040A	RVF0040A	TPS548D21RVF	Texas Instruments
C1, C12	0	330uF	CAP, TA, 330 µF, 6.3 V, +/- 20%, 0.025 ohm, SMD	7.3x2.8x4.3mm	6TPE330ML	Sanyo
C14, C15, C16, C17	0	22uF	CAP, CERM, 22 µF, 25 V, +/- 10%, X7R, 1210	1210	GRM32ER71E226KE15L	Murata
C21	0	470pF	CAP, CERM, 470 pF, 50 V, +/- 10%, X7R, 0603	0603	GRM188R71H471KA01D	Murata

**Table 11-1. PWR784 List of Materials (continued)**

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer
C30, C43	0	100uF	CAP, CERM, 100 $\mu$ F, 6.3 V, +/- 20%, X5R, 1210	1210	GRM32ER60J107ME20L	Murata
C31	0	0.1uF	CAP, CERM, 0.1 $\mu$ F, 50 V, +/- 10%, X7R, 0603	0603	GRM188R71H104KA93D	Murata
C32	0	6800pF	CAP, CERM, 6800 pF, 50 V, +/- 10%, X7R, 0603	0603	GRM188R71H682KA01D	Murata
C34, C44	0	1uF	CAP, CERM, 1 $\mu$ F, 16 V, +/- 10%, X5R, 0603	0603	C0603C105K4PACTU	Kemet
C36	0	1000pF	CAP, CERM, 1000 pF, 25 V, +/- 10%, X7R, 0603	0603	GRM188R71E102KA01D	Murata
C37	0	470uF	CAP, Tantalum Polymer, 470 $\mu$ F, 2.5 V, +/- 20%, 0.006 ohm, 7.3x2.8x4.3mm SMD	7.3x2.8x4.3mm	2R5TPF470M6L	Panasonic
FID1, FID2, FID3, FID4, FID5, FID6	0		Fiducial mark. There is nothing to buy or mount.	Fiducial	N/A	N/A
J6	0		Header (shrouded), 100mil, 5x2, Gold, TH	5x2 Shrouded header	5103308-1	TE Connectivity
R2, R3, R14, R17, R18	0	0	RES, 0, 5%, 0.1 W, 0603	0603	CRCW06030000Z0EA	Vishay-Dale
R5	0	1.50k	RES, 1.50 k, 1%, 0.1 W, 0603	0603	RC0603FR-071K5L	Yageo America
R9	0	3.01	RES, 3.01 ohm, 1%, 0.125W, 0805	0805	CRCW08053R01FKEA	Vishay-Dale
TP20, TP21, TP22	0	White	Test Point, Multipurpose, White, TH	White Multipurpose Testpoint	5012	Keystone

## 12 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

<b>Changes from Revision A (August 2016) to Revision B (August 2021)</b>	<b>Page</b>
• Updated user's guide title.....	<a href="#">3</a>
• Updated the numbering format for tables, figures, and cross-references throughout the document. ....	<a href="#">3</a>
<b>Changes from Revision * (July 2016) to Revision A (August 2016)</b>	<b>Page</b>
• Added and edited steps in the <i>Line and Load Regulation Measurement Procedure</i> section.....	<a href="#">9</a>



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