Using the TPS51513EVM-549 A Single-Phase, D-CAP+™ Synchronous Buck Controller With Integrated Drivers for General IC V_{CORE} Applications

User's Guide



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1 **Description** 6
1.1 Typical Application 6
1.2 Features 6
2 **Electrical Performance Specifications** 7
3 **Schematic** 8
4 **Test Setup** 10
4.1 Test Equipment 10
4.2 Recommended Test Setup 11
5 **Configuration** 11
5.1 Current Limit Trip Selection (J8: Trip Select) 12
5.2 Frequency Selection (J7: TON Select) 12
5.3 Overshoot Reduction Selection (J9: OSRTM Select) 12
5.4 VID Bits Selection(S1) 12
5.5 Sleep Mode Selection (SLP) 13
5.6 1.2-V Output Voltage Option (J10: Vout selection) 13
6 **Test Procedure** 13
6.1 Line/Load Regulation and Efficiency Measurement Procedure 13
6.2 List of Test Points 13
6.3 Equipment Shutdown 14
7 **Performance Data and Typical Characteristic Curves** 14
7.1 Efficiency 14
7.2 Load Regulation 15
7.3 Line Regulation 15
7.4 Current Monitor Voltage 16
7.5 Output Ripple 16
7.6 Switching Node 17
7.7 Output Transient 17
7.8 Turn On Waveform 18
7.9 Turn Off Waveform 18
7.10 Bode Plot 19
8 **EVM Assembly Drawing and PCB Layout** 19
9 **Bill of Materials** 24

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List of Figures

1 TPS51513EVM-549 Schematic, Sheet 1 of 2 8
2 TPS51513EVM-549 Schematic, Sheet 2 of 2 9
3 Tip and Barrel Measurement for Vout Ripple 10
4 TPS51513EVM-549 Recommended Test Set Up 11
5 TPS51513EVM-549 Efficiency 14
6 TPS51513EVM-549 Load Regulation 15
7 TPS51513EVM-549 Line Regulation 15
8 TPS51513EVM-549 IMON Voltage 16
9 TPS51513EVM-549 Output Ripple (12 Vin, 1.05 V/20 A) 16
10 TPS51513EVM-549 Switching Node (12 Vin, 1.05 V/20 A) 17
11 TPS51513EVM-549 Output Transient (12 Vin, 1.05 V/10 A-20 A) 17
12 TPS51513EVM-549 Enable Turnon Waveform (12 Vin, 1.05 V/20 A) 18
13 TPS51513EVM-549 Enable Turnoff Waveform (12 Vin, 1.05 V/10 A) 18
14 TPS51513EVM-549 Bode Plot (12 Vin, 1.05 V/17 A) 19
15 TPS51513EVM-549 Top Layer Assembly Drawing (Top view) 20
16 TPS51513EVM-549 Bottom Assembly Drawing (Bottom view) 20
17 TPS51513EVM-549 Top Copper (Top View) 21
18 TPS51513EVM-549 Internal Layer 2 (Top View) 21
19 TPS51513EVM-549 Internal Layer 3 (Top View) 22
20 TPS51513EVM-549 Internal Layer 4 (Top View) 22
21 TPS51513EVM-549 Internal Layer 5 (Top View) 23
22 TPS51513EVM-549 Bottom Copper (Top View) 23

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List of Tables

1 TPS51513EVM-549 Electrical Performance Specifications 7
2 Current Limit Trip Selection 12
3 Frequency Selection 12
4 Overshoot Reduction Selection 12
5 VID Bits Selection 12
6 SLP Mode Selection 13
7 1.2-V Output Option Selection 13
8 Functions of Each Test Points 13
9 The EVM Components List According to the Schematic Shown in and 24

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Using the TPS51513EVM-549 A Single-Phase, D-CAP+™ Synchronous Buck Controller With Integrated Drivers for General IC V_{CORE} Applications

The TPS51513EVM-549 evaluation module (EVM) is a single-phase, D-CAP+™ synchronous buck converter providing 3-bit VID with 0.70-V to 1.05-V output range at up to 20 A from a 12-V input bus. The EVM uses the TPS51513 synchronous buck controller with selectable 250/300/350/500-kHz switching frequency.

1 Description

The TPS51513EVM-549 is designed to use a regulated 12-V (8-V to 14-V) bus to produce a high-current, regulated variable output at up to 20 A of the load current. The output voltage varies from 0.70 V to 1.05 V via a 3-bit VID digital-to-analog converter (DAC). The TPS51513EVM-549 is designed to demonstrate the TPS51513 in a typical low-voltage application while providing a number of test points to evaluate the performance of the TPS51513.

1.1 Typical Application

- General integrated circuit (IC) V_{CORE} application

1.2 Features

The TPS51513EVM-549 features:

- Output voltage variable from 0.70 V to 1.05 V via a 3-bit VID DAC or fixed 1.2-V option
- 20-Adc steady-state current
- Selectable 250/300/350/500-kHz switching frequency
- Selectable current limit
- Selectable output overshoot reduction (OSR™)
- J6 for enable function
- Convenient test points for probing critical waveforms
- Six-layer PCB with 2-oz copper on the outside layer

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2 Electrical Performance Specifications

Table 1. TPS51513EVM-549 Electrical Performance Specifications[(1)]

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Input Characteristics					
Voltage range	VIN	8	12	14	V
Maximum input current	VIN = 8 V,1.05 V/20 A at 300 kHz			3.0	A
No load input current	Vin = 14 V, Io = 0 A			10	mA
Output Characteristics					
Output voltage VOUT	VID0 = VID1 = VID2 = 0		1.05		V
Output voltage regulation	Line regulation		0.1%		
	Load regulation (Nondroop)		1.0%		
Output voltage ripple	Vin = 12 V, Io = 20 A at 300 kHz			30	mVpp
Output load current		0		20	A
Output over current			30		A
Systems Characteristics					
Switching frequency	Selectable	250	300	500	kHz
Peak efficiency	Vin = 12 V, 1.05 V/10 A at 300 kHz		90.9 %		
Full load efficiency	Vin = 12 V, 1.05 V/20 A at 300 kHz		89.2 %		
Operating temperature			25		°C

(1) Jumpers set to default locations; see Section 6 of this user's guide.

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3 Schematic

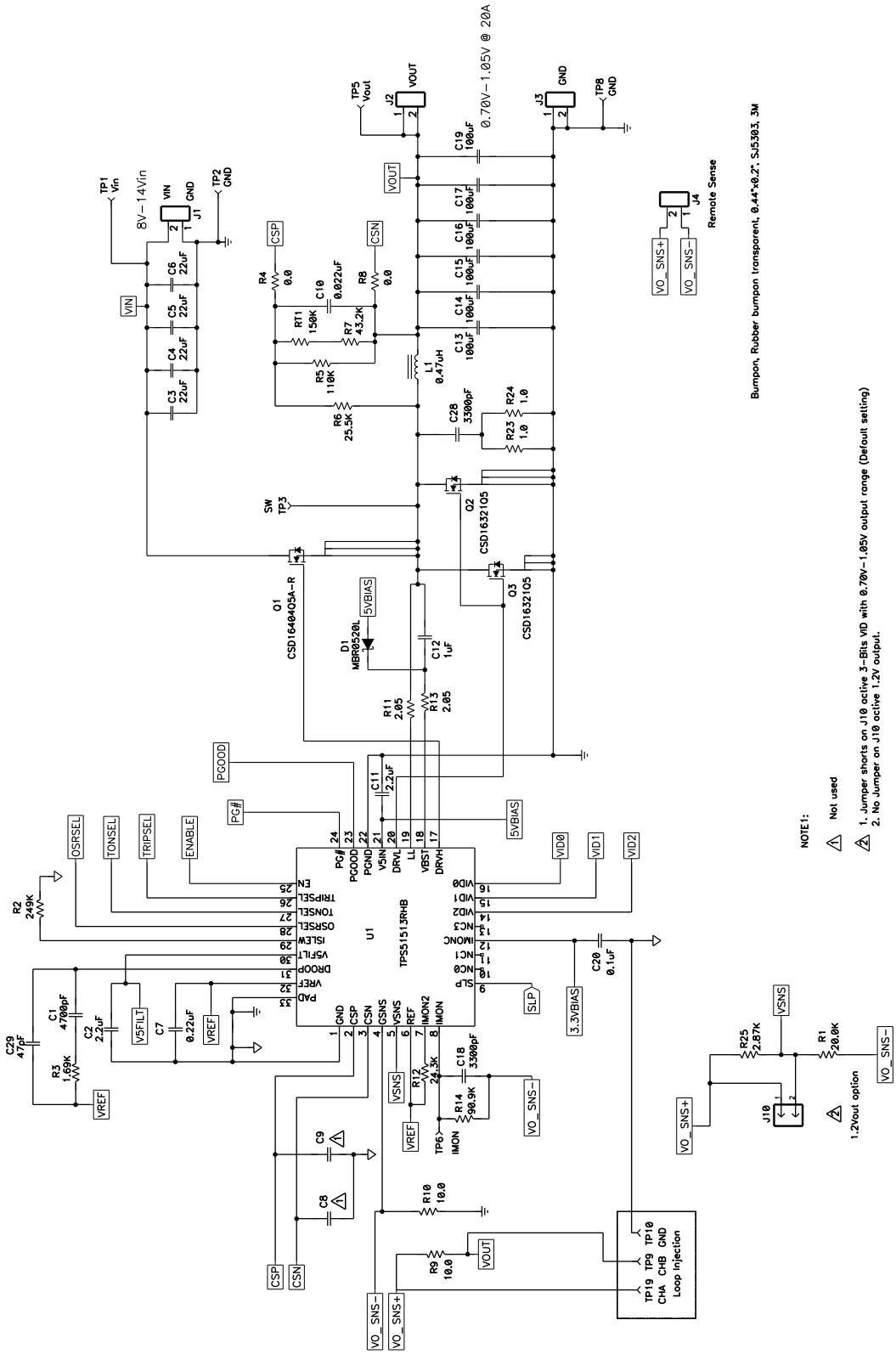


Figure 1. TPS51513EVM-549 Schematic, Sheet 1 of 2

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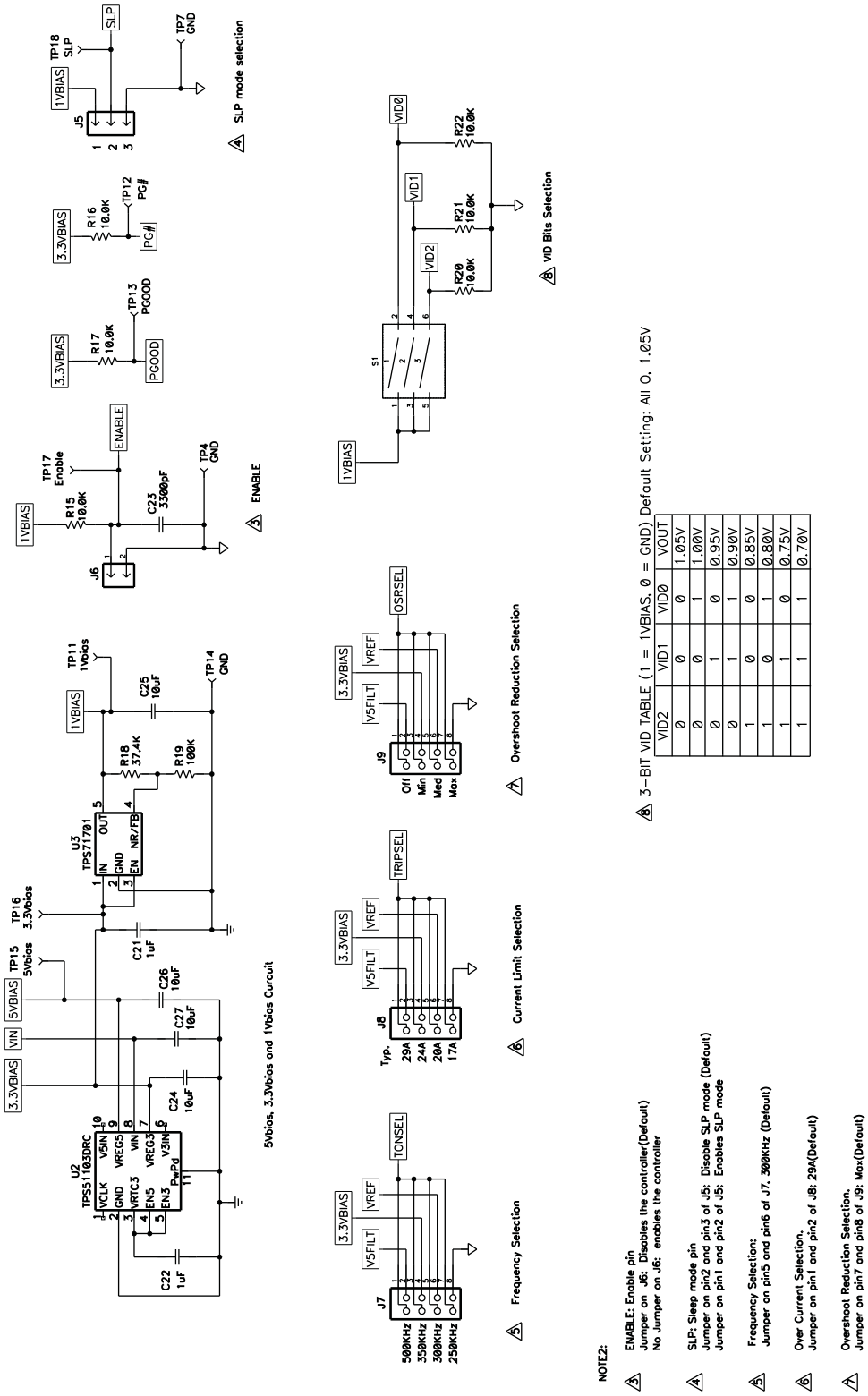


Figure 2. TPS51513EVM-549 Schematic, Sheet 2 of 2

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4 Test Setup

4.1 Test Equipment

Voltage Source: The input voltage source Vin must be a 0-V to 14-V variable dc source capable of supplying 10 Adc. Connect Vin to J1 as shown in Figure 4.

Multimeters: A 0-V to 14-V voltmeter (V1) must be used to measure Vin at TP1 (Vin) and TP2 (GND). A 0-V to 5-V voltmeter (V2) is necessary for Vout measurement at TP5(Vout) and TP8(GND). A 0-A to 10-A current meter (A1) as shown in Figure 4 is used for input current measurements.

Output Load: The output load must be an electronic constant resistance mode load capable of 0 Adc to 30-Adc at 1.05 V.

Oscilloscope: A digital or analog oscilloscope can be used to measure the output ripple. The oscilloscope must be set for 1-MΩ impedance, 20-MHz bandwidth, ac coupling, 2-µs/division horizontal resolution, 20-mV/division vertical resolution. Test points TP5 and TP8 can be used to measure the output ripple voltage by placing the oscilloscope probe tip through TP5 and holding the ground barrel TP8 as shown in Figure 3. Do not use a leaded ground connection as this may induce additional noise due to the large ground loop.

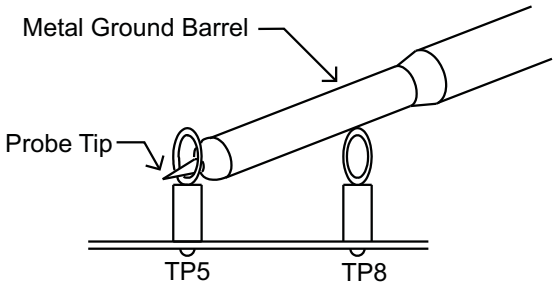


Figure 3. Tip and Barrel Measurement for Vout Ripple

Fan: Some of the components in this EVM may get hot and approach temperatures of 60°C during operation. A small fan capable of 200–400 LFM is recommended to reduce component temperatures while the EVM is operating. The EVM must not be probed if the fan is not running.

Recommended Wire Gauge: For VIN to J1 (12-V input) the recommended wire size is AWG 14 per input connection, with the total length of wire less than 4 feet (2-foot input, 2-foot return). For J2, J3 to LOAD, the minimum recommended wire size is 2x AWG 14, with the total length of wire less than 4 feet (2-foot output, 2-foot return)

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4.2 Recommended Test Setup

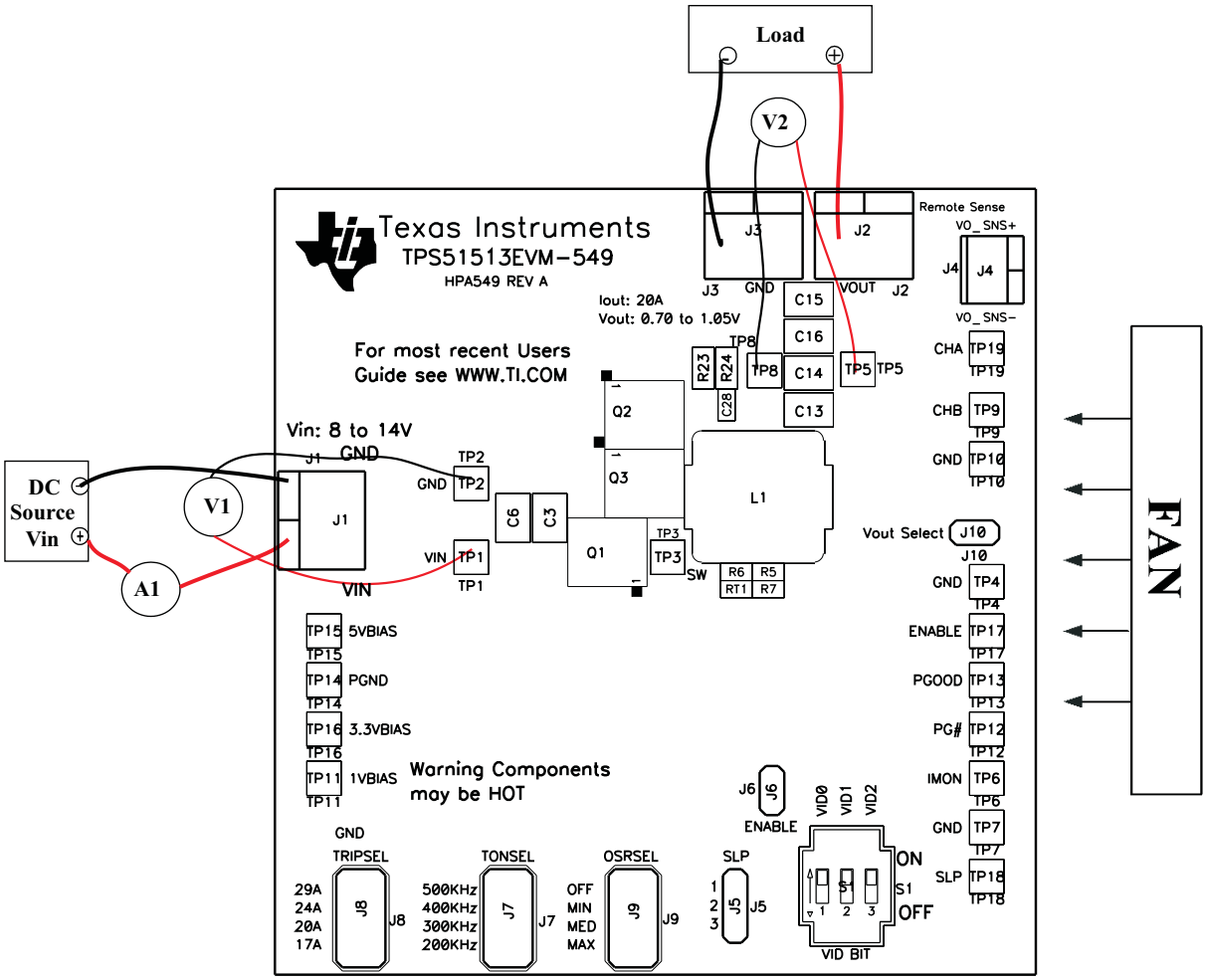


Figure 4. TPS51513EVM-549 Recommended Test Set Up

Figure 4 is the recommended test set up to evaluate the TPS51513EVM-549. Working at an ESD workstation, ensure that any wrist straps, bootstraps, or mats are connected, referencing the user to earth ground before handling the EVM.

Input Connections:

1. Prior to connecting the dc input source Vin, it is advisable to limit the source current from Vin to 10 A maximum. Ensure that Vin is initially set to 0 V as shown in Figure 4.
2. Connect a voltmeter V1 at TP1 (Vin) and TP2 (GND) to measure the input voltage.
3. Connect a current meter A1 between Vin dc source and J1.

Output Connections

1. Connect Load to J2, J3, and set Load to constant resistance mode to sink 0 Adc before Vin is applied.
2. Connect a voltmeter V2 at TP5(Vout), and TP8 (GND) to measure the output voltage.

Other Connections:

Place a fan as shown in Figure 4, and turn it on, ensuring that air is flowing across the EVM.

5 Configuration

All jumper selections must be made prior to applying power to the EVM. Users can configure this EVM with the following configurations.

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5.1 Current Limit Trip Selection (J8: Trip Select)

The overcurrent protection (OCP) can be set by J8 Trip Select (TRIPSEL).

Default setting is 29A.

Table 2. Current Limit Trip Selection

Jumper Set to	TRIPSEL	OCP Limit per Phase(Typ.)
Top (1-2 pin shorted)	**5VFILT**	**29A**
Second (3-4 pin shorted)	3.3VBIAS	24A
Third (5-6 pin shorted)	VREF	20A
Bottom(7-8 pin shorted)	GND	17A

5.2 Frequency Selection (J7: TON Select)

The operating frequency can be set by J7 TON Select (TONSEL).

Default setting is 300 kHz.

Table 3. Frequency Selection

Jumper Set to	TONSEL	Frequency (kHz)
Top (1-2 pin shorted)	5VFILT	500
Second (3-4 pin shorted)	3.3VBIAS	350
Third (5-6 pin shorted)	**VREF**	**300**
Bottom(7-8 pin shorted)	GND	250

5.3 Overshoot Reduction Selection (J9: OSRTM Select)

The overshoot reduction can be set by J9 OSRTM Select (OSRSEL).

Default setting is Maximum.

Table 4. Overshoot Reduction Selection

Jumper set to	OSR	Overshoot Voltage Reduction
Top (1-2 pin shorted)	5VFILT	OFF
Second (3-4 pin shorted)	3.3VBIAS	Minimum
Third (5-6 pin shorted)	VREF	Medium
Bottom (7-8 pin shorted)	**GND**	**Maximum**

5.4 VID Bits Selection(S1)

The output voltage can be set by Switch S1 (VID Bits).

Default setting is 000.

Table 5. VID Bits Selection

3-Bit VID Table (1 = 1VBIAS, 0 = GND)			
VID2	**VID1**	**VID0**	**Vout (V)**
0	**0**	**0**	**1.05**
0	0	1	1.00
0	1	0	0.95
0	1	1	0.90
1	0	0	0.85
1	0	1	0.80
1	1	0	0.75

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Table 5. VID Bits Selection (continued)

3-Bit VID Table (1 = 1VBIAS, 0 = GND)			
VID2	**VID1**	**VID0**	**Vout (V)**
1	1	1	0.70

5.5 Sleep Mode Selection (SLP)

The SLP can be set by J5 (SLP).

Default setting Jumper on pin2 and pin3 of J5 to disable the SLP mode.

Table 6. SLP Mode Selection

Jumper set to	SLP mode selection
2-3 pin shorted	**Disable SLP mode**
1-2 pin shorted	Enable SLP mode

5.6 1.2-V Output Voltage Option (J10: Vout selection)

The 1.2-V output can be set by J10 (Vout Select).

Default setting : Jumper shorts on J10 to set 0.7 V to 1.05-V output.

Table 7. 1.2-V Output Option Selection

Jumper Set to	Output Range
No Jumper	1.2-V Output
Jumper shorted	**0.70 V to 1.05 V controlled by 3-bit VID**

6 Test Procedure

6.1 Line/Load Regulation and Efficiency Measurement Procedure

1. Ensure that Load is set to constant resistance mode and to sink 0 Adc.
2. Ensure that the jumper provided with the EVM on J6 is present before Vin is applied.
3. Increase Vin from 0 V to 12 V. Using V1 to measure input voltage.
4. Remove the jumper on J6 to enable the controller.
5. Vary Load from 0 Adc to 20 Adc, Vout must remain in load regulation.
6. Vary Vin from 8 V to 14 V; Vout must remain in line regulation.
7. Put the jumper on J6 to disable the controller.
8. Decrease Load to 0 A
9. Decrease Vin to 0 V.

6.2 List of Test Points

Table 8. Functions of Each Test Points

Test Points	Name	Description
TP1	Vin	12 Vin
TP2	GND	12 Vin Ground
TP3	SW	Switching Node
TP4	GND	Ground
TP5	Vout	Vout
TP6	IMON	Current Monitor Output, Refer to section 8.4
TP7	GND	Ground

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Table 8. Functions of Each Test Points (continued)

Test Points	Name	Description
TP8	GND	Vout Ground
TP9	CHB	Input B for loop injection
TP10	GND	Ground
TP11	1Vbias	1-V bias
TP12	PG#	Negative Power Good, Active low
TP13	PGOOD	Power Good, Active high
TP14	GND	Ground
TP15	5Vbias	5-V bias
TP16	3.3Vbias	3.3-V bias
TP17	Enable	Enable, Active high
TP18	SLP	Sleep mode
TP19	CHA	Input A for loop injection

6.3 Equipment Shutdown

1. Shut down Load.
2. Shut down Vin.
3. Shut down FAN.

7 Performance Data and Typical Characteristic Curves

Figure 5 through Figure 14 present typical performance curves for TPS51513EVM-549. Jumpers are set to default locations; see Section 6 of this user's guide.

7.1 Efficiency

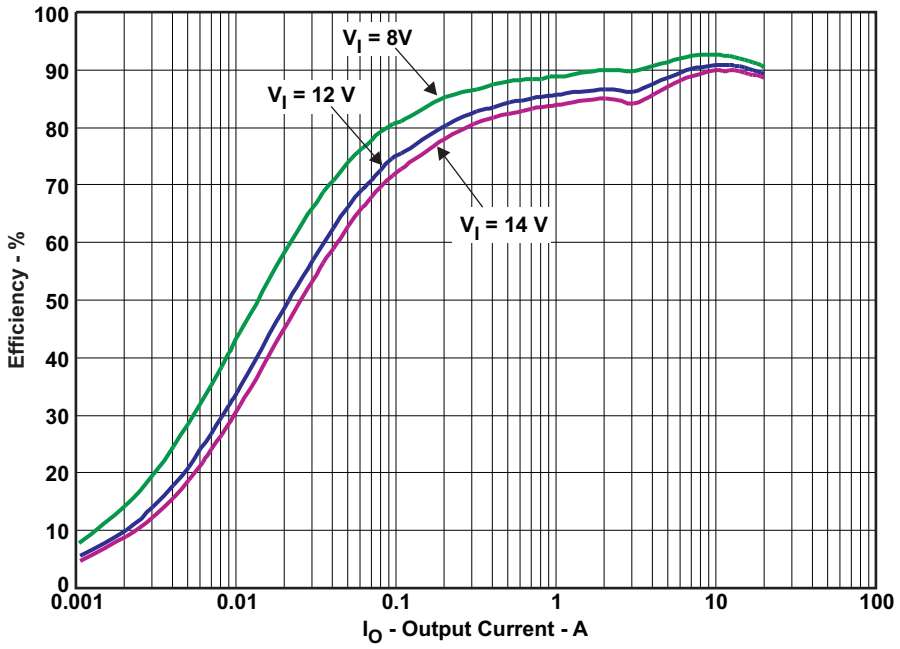


Figure 5. TPS51513EVM-549 Efficiency

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7.2 Load Regulation

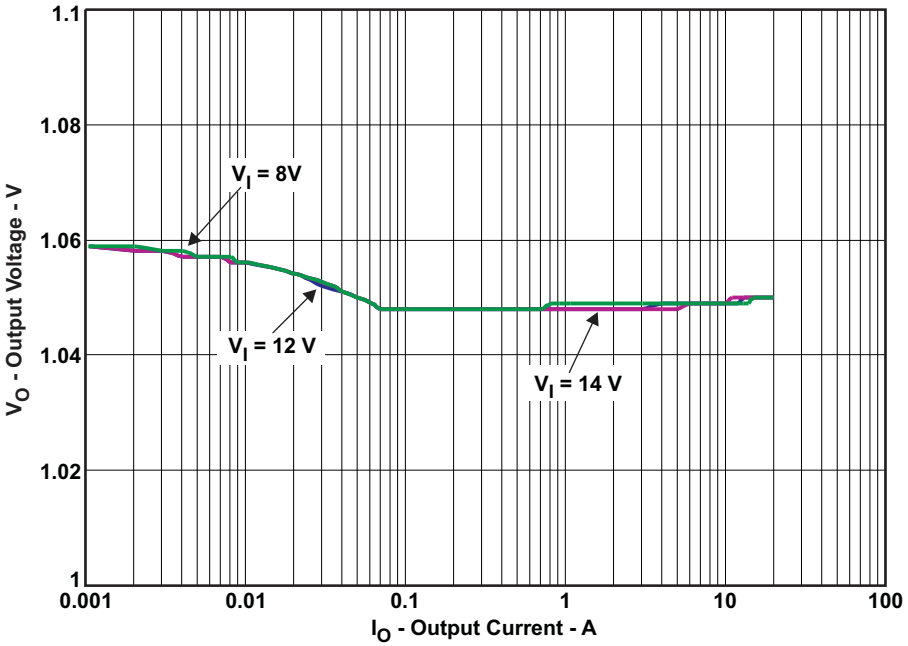


Figure 6. TPS51513EVM-549 Load Regulation

7.3 Line Regulation

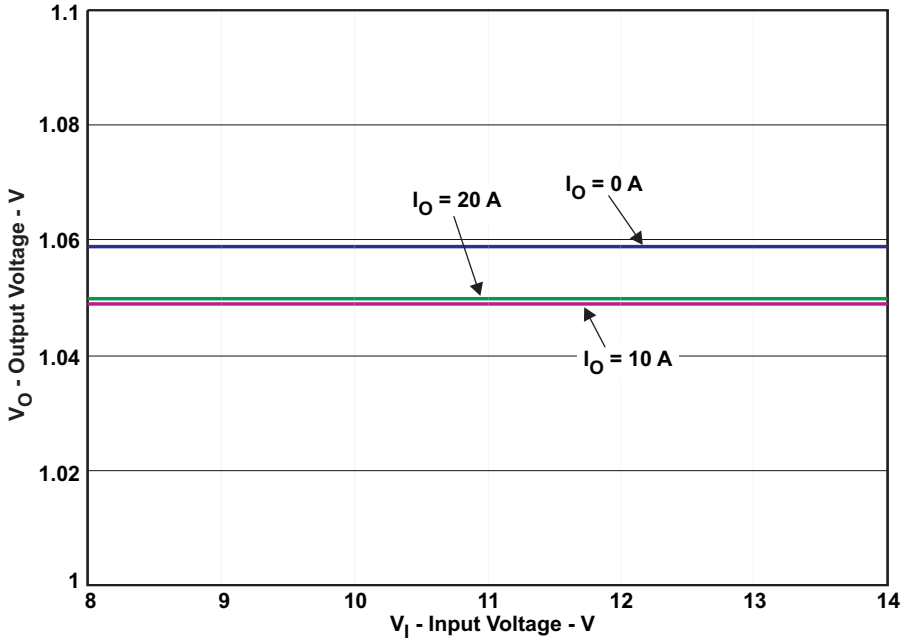


Figure 7. TPS51513EVM-549 Line Regulation

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7.4 Current Monitor Voltage

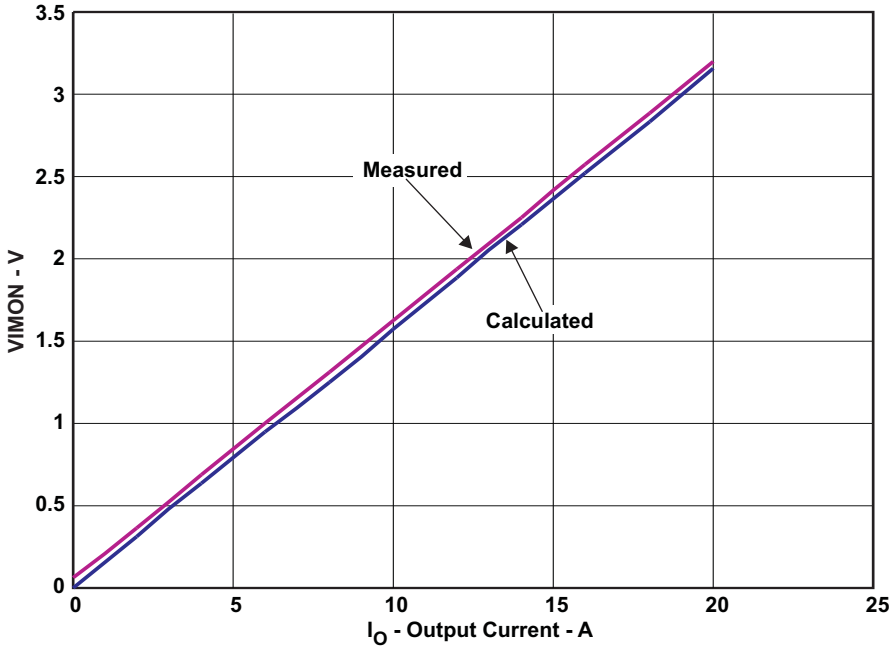


Figure 8. TPS51513EVM-549 IMON Voltage

7.5 Output Ripple

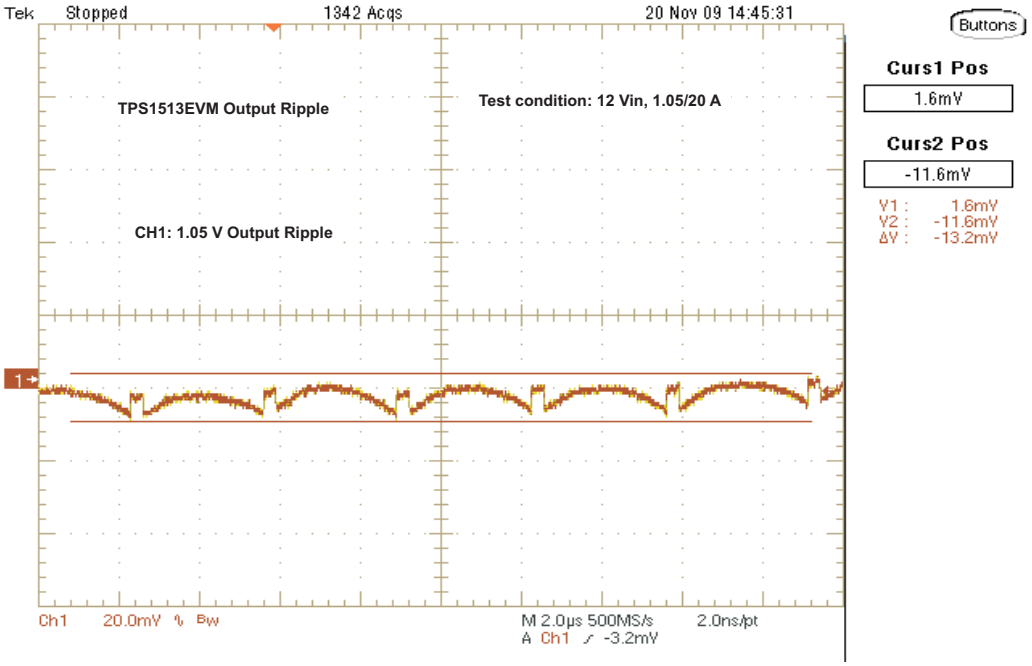


Figure 9. TPS51513EVM-549 Output Ripple (12 Vin, 1.05 V/20 A)

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7.6 Switching Node

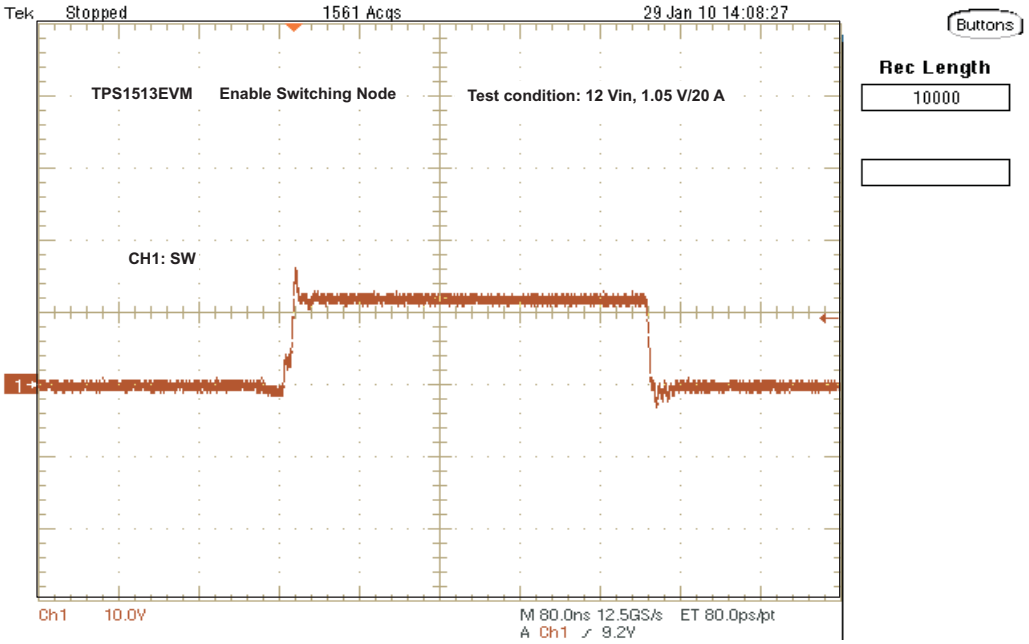


Figure 10. TPS51513EVM-549 Switching Node (12 Vin, 1.05 V/20 A)

7.7 Output Transient

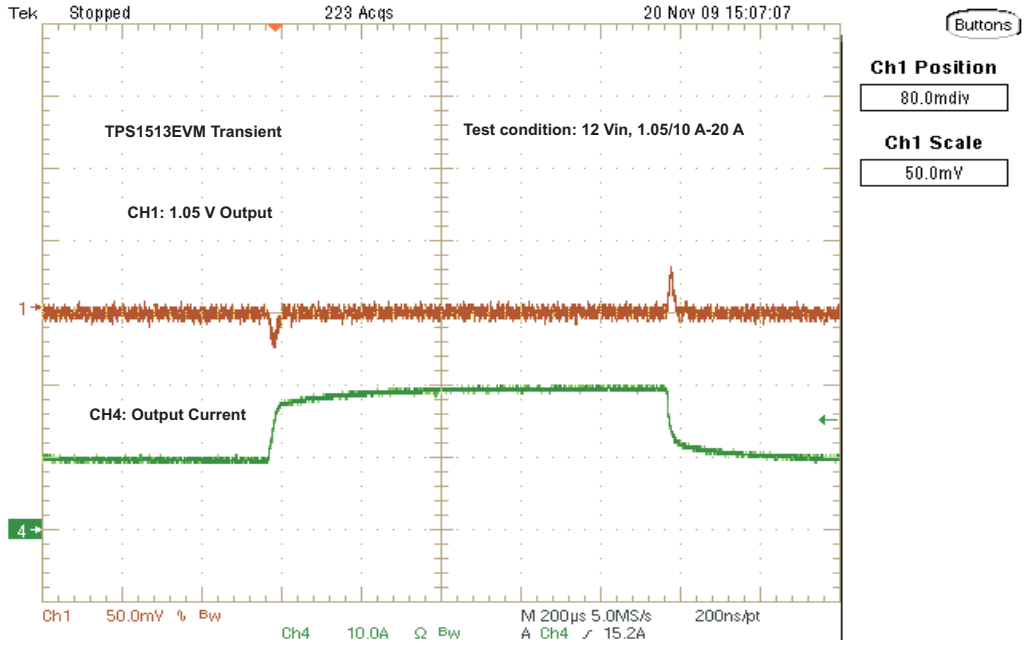


Figure 11. TPS51513EVM-549 Output Transient (12 Vin, 1.05 V/10 A-20 A)

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7.8 Turn On Waveform

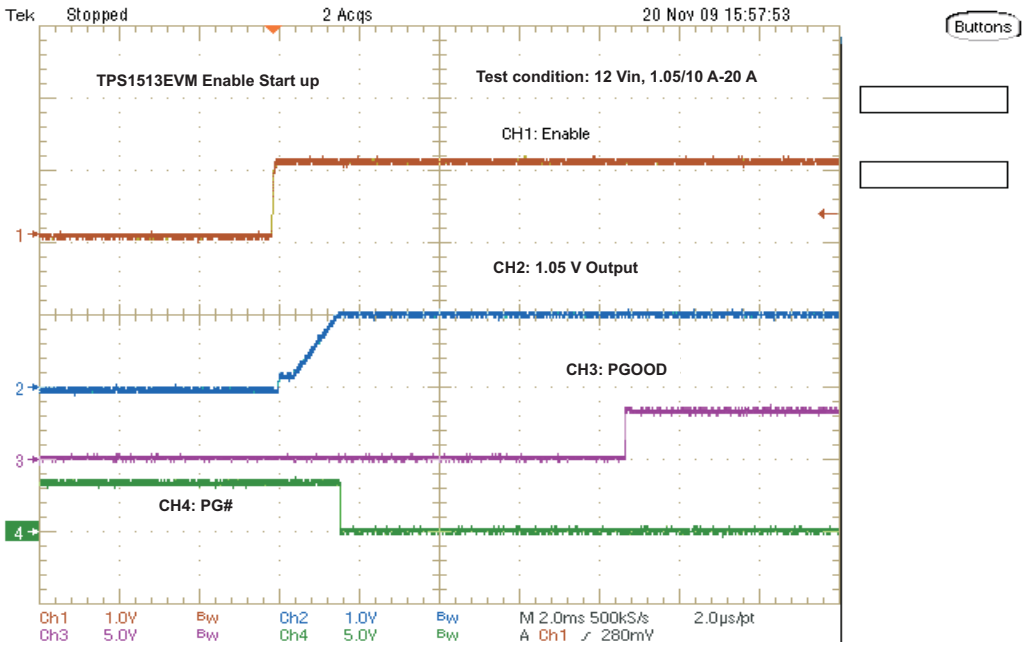


Figure 12. TPS51513EVM-549 Enable Turnon Waveform (12 Vin, 1.05 V/20 A)

7.9 Turn Off Waveform

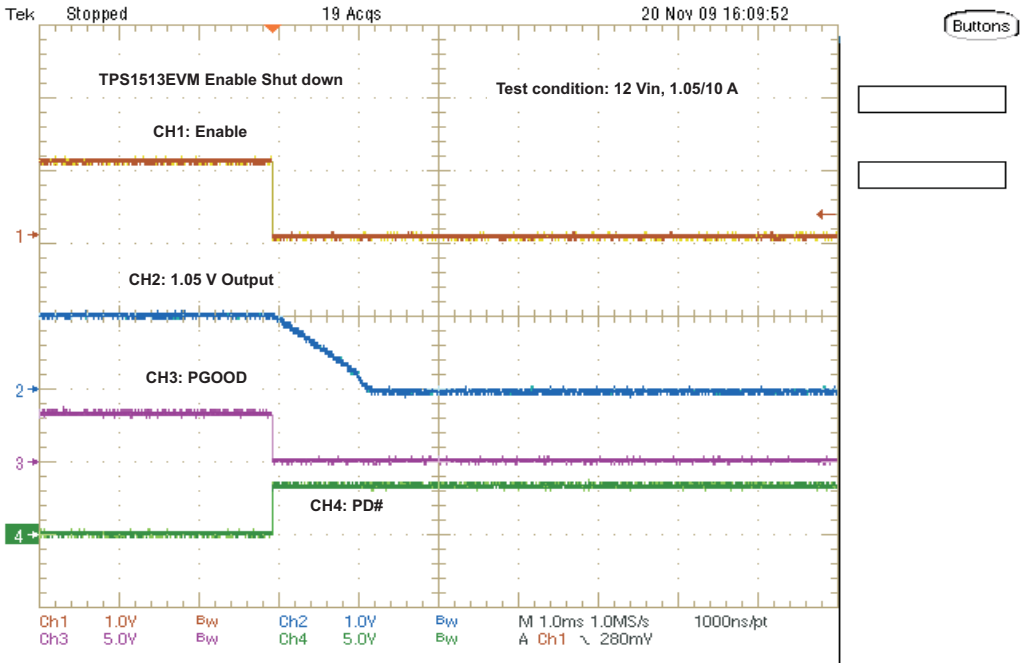


Figure 13. TPS51513EVM-549 Enable Turnoff Waveform (12 Vin, 1.05 V/10 A)

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7.10 Bode Plot

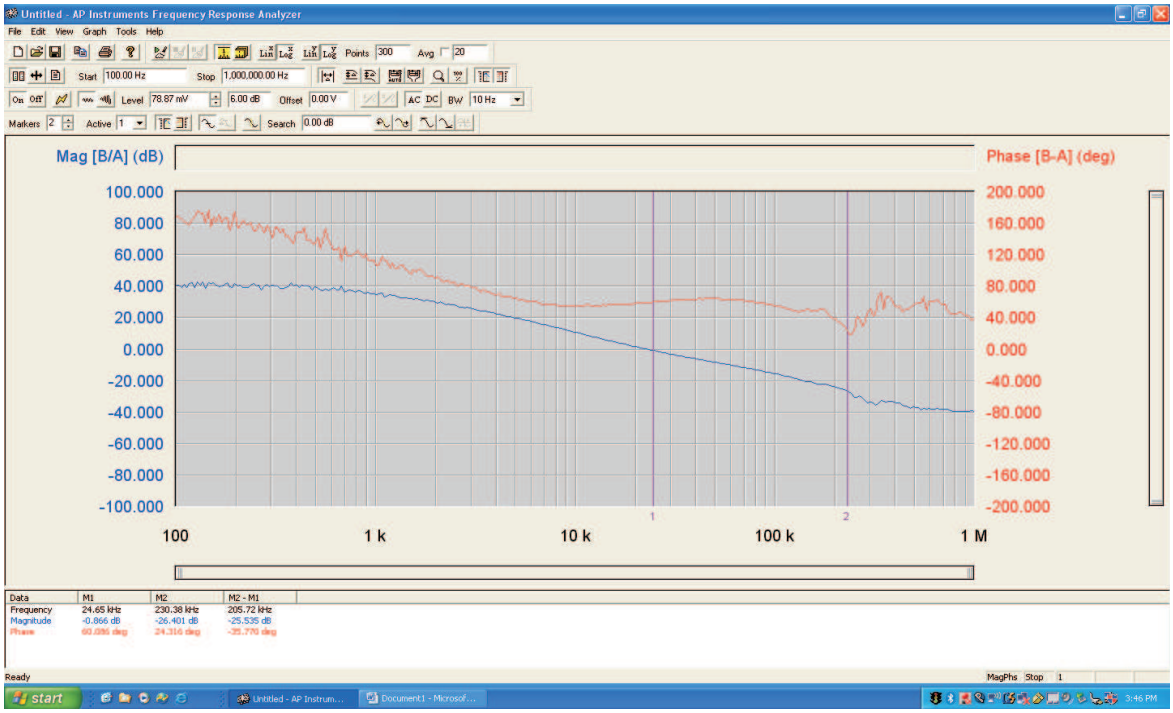


Figure 14. TPS51513EVM-549 Bode Plot (12 Vin, 1.05 V/17 A)

8 EVM Assembly Drawing and PCB Layout

The following figures (Figure 15 through Figure 22) show the design of the TPS51513EVM-549 printed-circuit board. The EVM has been designed using a six-layer circuit board with 2-oz copper on outside layers.

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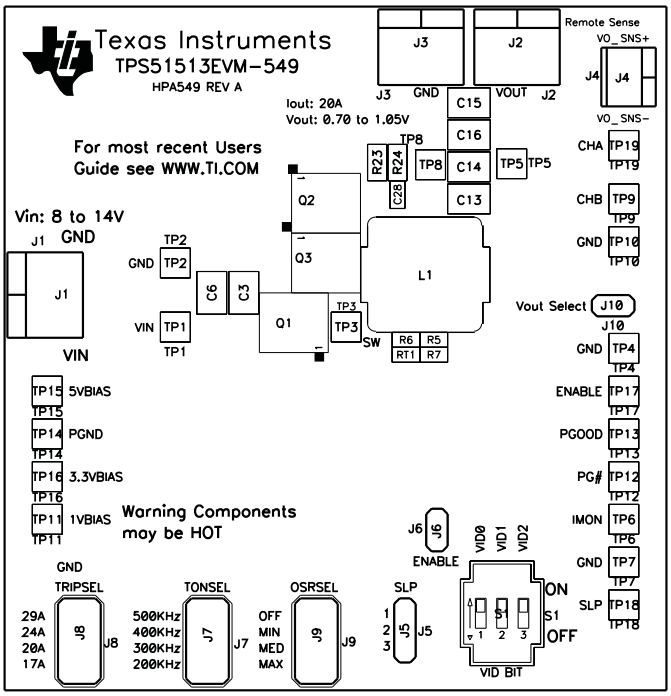


Figure 15. TPS51513EVM-549 Top Layer Assembly Drawing (Top view)

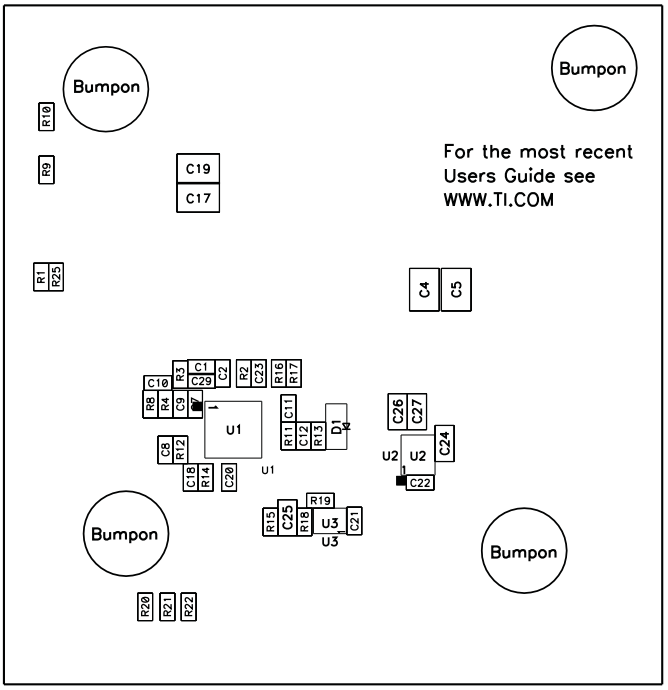


Figure 16. TPS51513EVM-549 Bottom Assembly Drawing (Bottom view)

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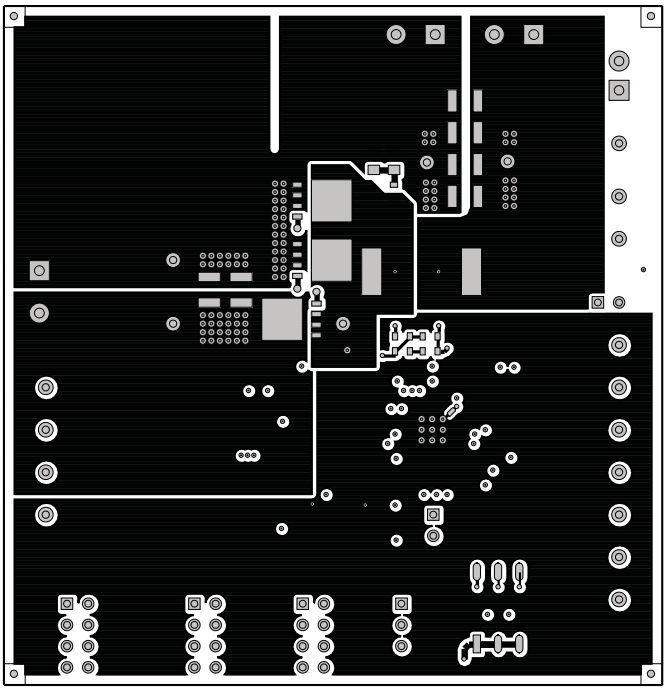


Figure 17. TPS51513EVM-549 Top Copper (Top View)

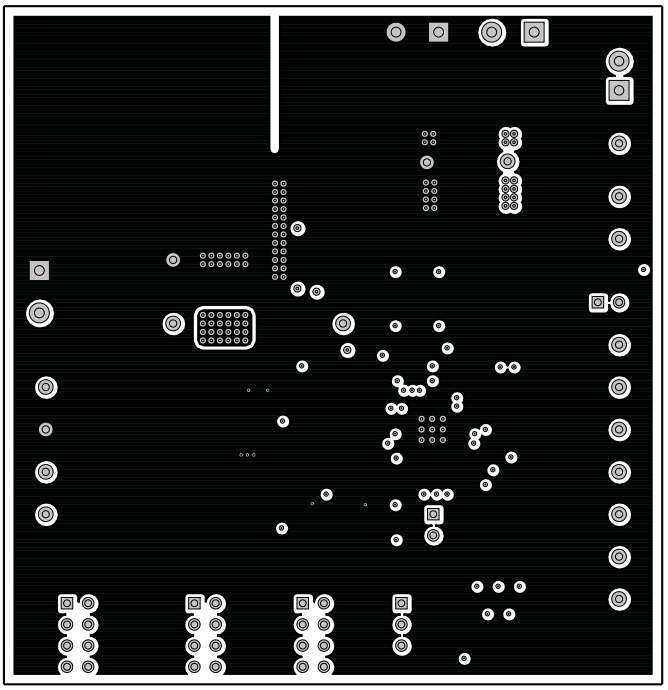


Figure 18. TPS51513EVM-549 Internal Layer 2 (Top View)

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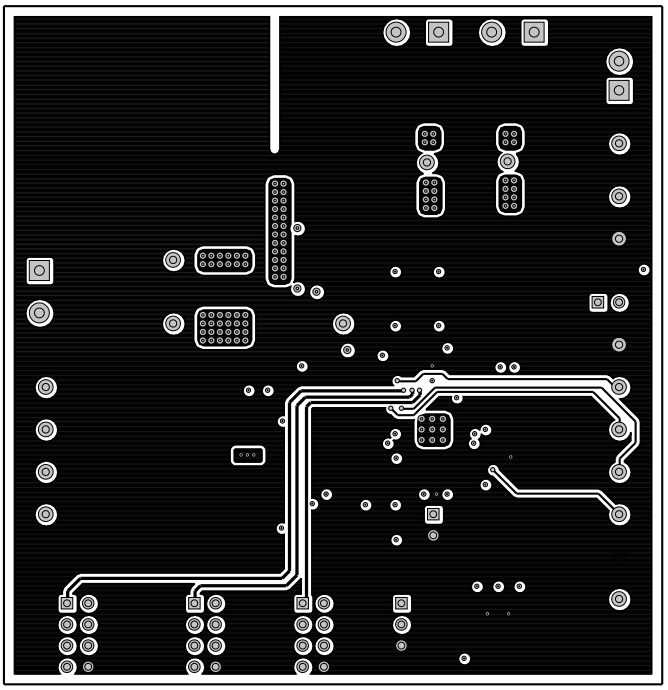


Figure 19. TPS51513EVM-549 Internal Layer 3 (Top View)

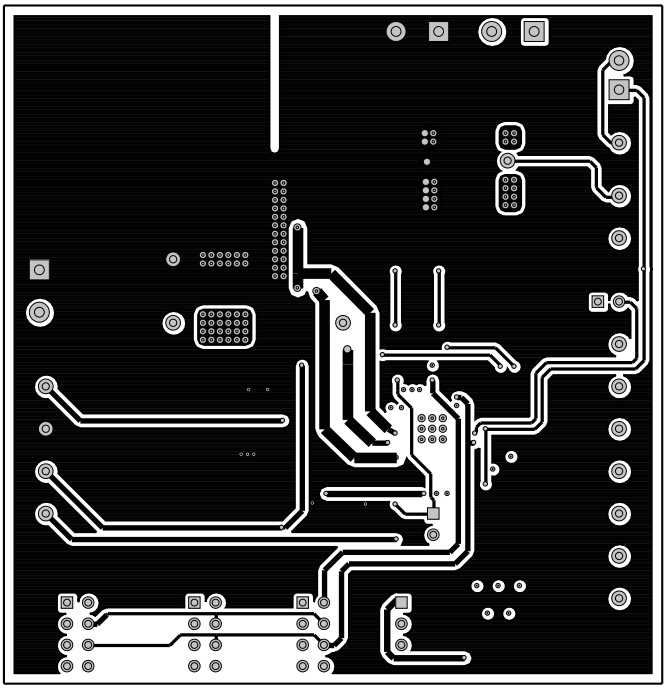


Figure 20. TPS51513EVM-549 Internal Layer 4 (Top View)

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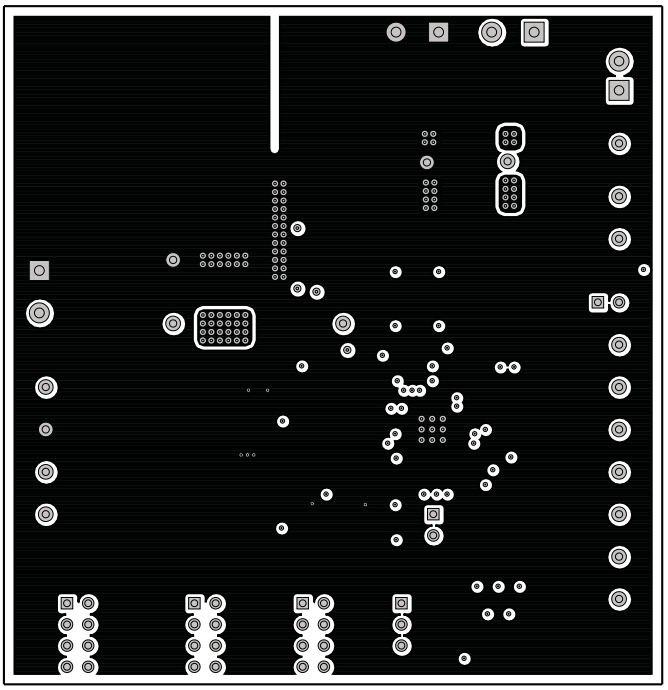


Figure 21. TPS51513EVM-549 Internal Layer 5 (Top View)

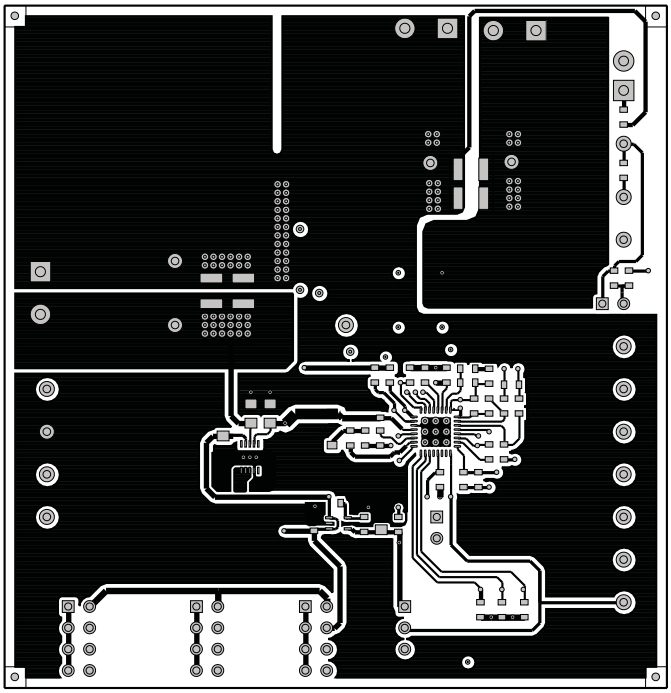


Figure 22. TPS51513EVM-549 Bottom Copper (Top View)

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9 Bill of Materials

Table 9. The EVM Components List According to the Schematic Shown in Figure 1 and Figure 2

QTY	RefDes	Description	MFR	Part Number
1	C1	Capacitor, Ceramic, 4700pF, 25V, X7R, 10%, 0603	STD	STD
1	C10	Capacitor, Ceramic, 0.022µF, 25V, X7R, 10%, 0603	STD	STD
1	C12	Capacitor, Ceramic, 1µF, 50V, X5R, 10%, 0603	STD	STD
6	C13, C14, C15, C16, C17, C19	Capacitor, Ceramic, 100µF, 6.3V, X5R, 20%, 1210	Murata	GRM32ER60J107ME20L
2	C18, C23	Capacitor, Ceramic, 3300pF, 10V, X7R, 10%, 0603	STD	STD
1	C29	Capacitor, Ceramic, 47pF, 25V, C0G&NPO, 10%, 0603	STD	STD
2	C2, C11	Capacitor, Ceramic, 2.2µF, 10V, X5R, 10%, 0603	STD	STD
1	C20	Capacitor, Ceramic, 0.1µF, 16V, X7R, 10%, 0603	STD	STD
2	C21, C22	Capacitor, Ceramic, 1µF, 10V, X7R, 10%, 0603	STD	STD
1	C28	Capacitor, Ceramic, 3300pF, 50V, X7R, 10%, 0603	STD	STD
4	C24, C25, C26, C27	Capacitor, Ceramic, 10µF, 16V, X5R, 10%, 0805	STD	STD
4	C3, C4, C5, C6	Capacitor, Ceramic, 22µF, 16V, X5R, 10%, 1210	Murata	GRM32ER61C226KE20L
1	C7	Capacitor, Ceramic, 0.22µF, 6.3V, X7R, 10%, 0603	STD	STD
1	D1	Diode, Schottky, 0.5A, 30V, SOD-123	On Semi	MBR0520L
1	L1	Inductor, SMT, 0.47µH, 41A, 0.001ohms, 20%	Vishay	IHLP5050FDERR47M01
2	R11, R13	Resistor, Chip, 2.05, 1/16W, 1%, 0603	STD	STD
1	R12	Resistor, Chip, 24.3K, 1/16W, 1%, 0603	STD	STD
1	R14	Resistor, Chip, 90.9K, 1/16W, 1%, 0603	STD	STD
6	R15, R16, R17, R20, R21, R22	Resistor, Chip, 10K, 1/16W, 1%, 0603	STD	STD
1	R18	Resistor, Chip, 37.4K, 1/16W, 1%, 0603	STD	STD
1	R19	Resistor, Chip, 100K, 1/16W, 1%, 0603	STD	STD
1	R2	Resistor, Chip, 249K, 1/16W, 1%, 0603	STD	STD
2	R23, R24	Resistor, Chip, 1.0, 1/10W, 5%, 0805	STD	STD
2	R4, R8	Resistor, Chip, 0, 1/16W, 1%, 0603	STD	STD
1	R3	Resistor, Chip, 1.69K, 1/16W, 1%, 0603	STD	STD
1	R25	Resistor, Chip, 2.87K, 1/16W, 1%, 0603	STD	STD
1	R1	Resistor, Chip, 20.0K, 1/16W, 1%, 0603	STD	STD
1	R5	Resistor, Chip, 110K, 1/16W, 1%, 0603	STD	STD
1	R6	Resistor, Chip, 25.5K, 1/16W, 1%, 0603	STD	STD
1	R7	Resistor, Chip, 43.2K, 1/16W, 1%, 0603	STD	STD
1	RT1	NTC, Chip, Thermistor, 150K, 5%, 0603	Panasonic-ECG	ERT-J1VV154J
2	R9, R10	Resistor, Chip, 10, 1/16W, 1%, 0603	STD	STD
1	Q1	MOSFET, Nch, 25V, 21A, 5.7mΩ, QFN5X6mm	TI(Ciclon)	CSD16404Q5A
2	Q2, Q3	MOSFET, Nch, 25V, 31A, 2.1mΩ, QFN5X6mm	TI(Ciclon)	CSD16321Q5
1	U1	IC, Single-phase, D-CAP+, Synchronous Buck Controller, QFN-32	TI	TPS51513RHB
1	U2	IC, Integrated LDO with switch-over circuit, DGS10	TI	TPS51103DRC
1	U3	IC, 150mA, LDO Linear Regulator, SC70	TI	TPS71701DCK

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EVM Warnings and Restrictions

It is important to operate this EVM within the input voltage range of 3 V to 28 V and the output voltage range of 0 V to 1.2 V .

Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the EVM. If there are questions concerning the input range, please contact a TI field representative prior to connecting the input power.

Applying loads outside of the specified output range may result in unintended operation and/or possible permanent damage to the EVM. Please consult the EVM User's Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative.

During normal operation, some circuit components may have case temperatures greater than <60° C. The EVM is designed to operate properly with certain components above <60° C as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.

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