TPS549D22EVM-784, 40-A Single Synchronous Step-Down Converter With Full Differential Sense and PMBus™

This user's guide describes the characteristics, operation, and use of the TPS549D22 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, TPS549D22EVM, and the term evaluation module are synonymous with the TPS549D22EVM-784, unless otherwise noted.

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1 Introduction

The PWR784EVM evaluation module uses the TPS549D22 device. The TPS549D22 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 TPS549D22 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
- PMBus™ connector for easy connection with the TI USB adapter

3 EVM Electrical Performance Specifications

Table 1. PWR-784EVM Electrical Performance Specifications

Parameter		Test Conditions	Min	Typ	Max	Units
Input Characteristics						
	Voltage range	V_{IN} tied to VDD	5	12	16	V
	Maximum input current	V_{IN} = 12 V, I_O = 40 A			12	A
	No load input current	V_{IN} = 12 V, I_O = 0 A		60		mA
Output Characteristics						
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 V, I_{OUT} = 40 A		10		mV_{PP}
V_{OUT}	Output overcurrent			46		A
Systems Characteristics						
	Switching frequency	F_{SW}		650		kHz
V_{OUT}	Peak efficiency	V_{IN} = 12 V, I_O = 18 A, F_{SW} = 650 kHz		89%		
	Operating temperature	T_{oper}	0		105	ºC

4 Schematic

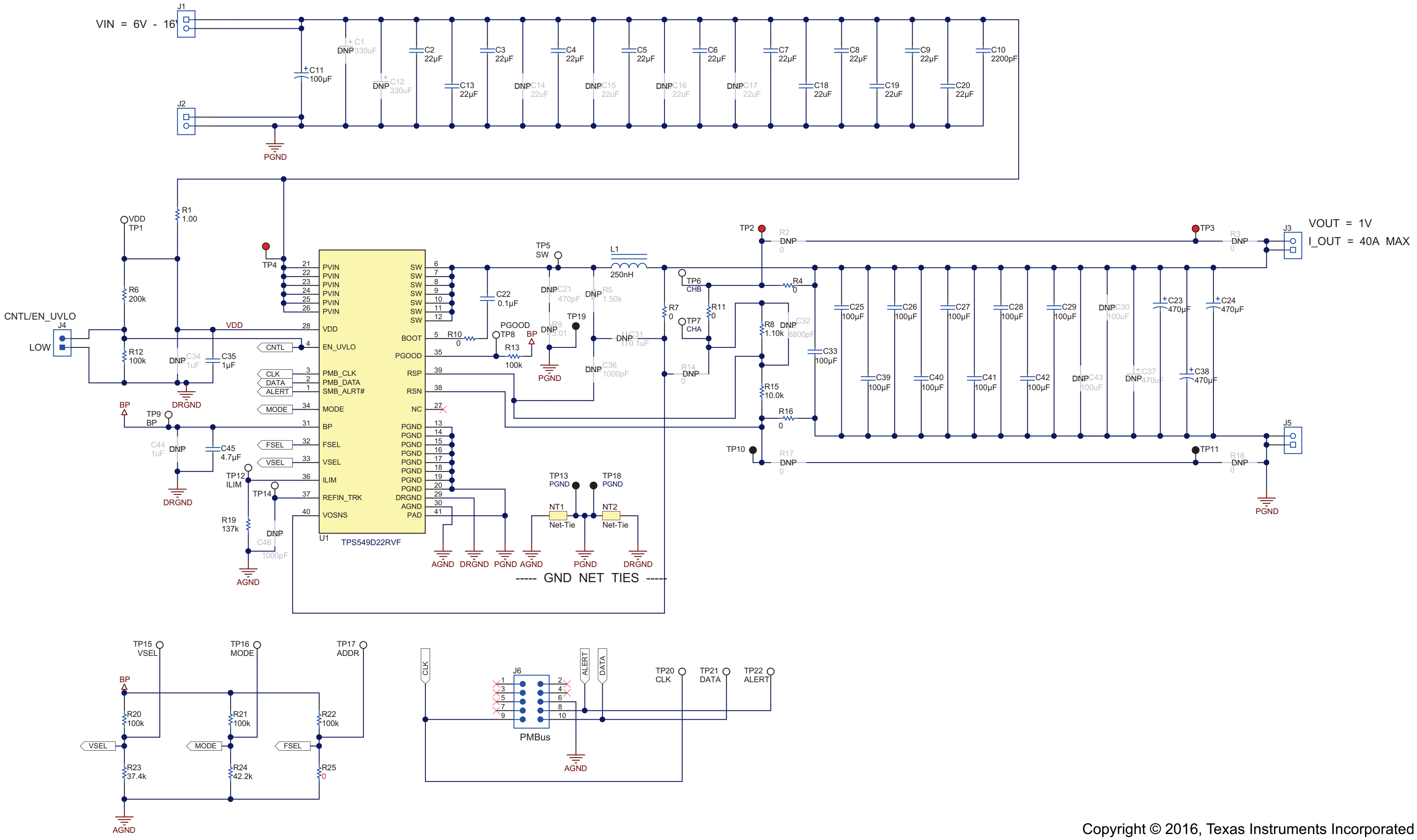

Figure 1. PWR-784EVM Schematic

5 Test Setup

5.1 Test and Configuration Software

To change any of the default configuration parameters on the EVM, it is necessary to obtain the TI Fusion Digital Power Designer software. This can be downloaded from the TI website.

5.1.1 Description

The Fusion Digital Power Designer is the graphical user interface (GUI) used to configure and monitor the Texas Instruments TPS549D22 power converter installed on this evaluation module. The application uses the PMBus protocol to communicate with the controller over serial bus by way of a TI USB adapter. This adapter can be purchased at http://www.ti.com/tool/usb-to-gpio.

NOTE: The TI USB adapter must be purchased separately. It is not included with this EVM kit.

5.1.2 Features

Some of the tasks performed with the GUI include:

- Turn on or off the power supply output, either through the hardware control line or the PMBus operation command.
- Monitor status registers. Items such as input voltage, output voltage, output current, temperature, and warnings and faults are continuously monitored and displayed by the GUI.
- Configure common operating characteristics such as VOUT, UVLO, soft-start time, warning and fault thresholds, fault response, and ON/OFF.

This software is available for download at http://www.ti.com/tool/fusion_digital_power_designer.

6 Test Equipment

Voltage Source: The input voltage source VIN must be a 0-V to 18-V variable DC source capable of supplying at least 12 A_{DC}.

Multimeters: It is recommended to use two separate multimeters Figure 2. 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 2. 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 3.The scope must be adjusted to 20-MHz bandwidth, AC coupling at 50 mV/division, and must be set to 1-µs/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.

USB-to-GPIO Interface Adapter: A communications adapter is required between the EVM and the host computer. This EVM was designed to use TI's USB-to-GPIO adapter. Purchase this adapter at http://www.ti.com/tool/usb-to-gpio.

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 VOUT positive and 2 wires parallel for the VOUT 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.

7 PWR-784EVM

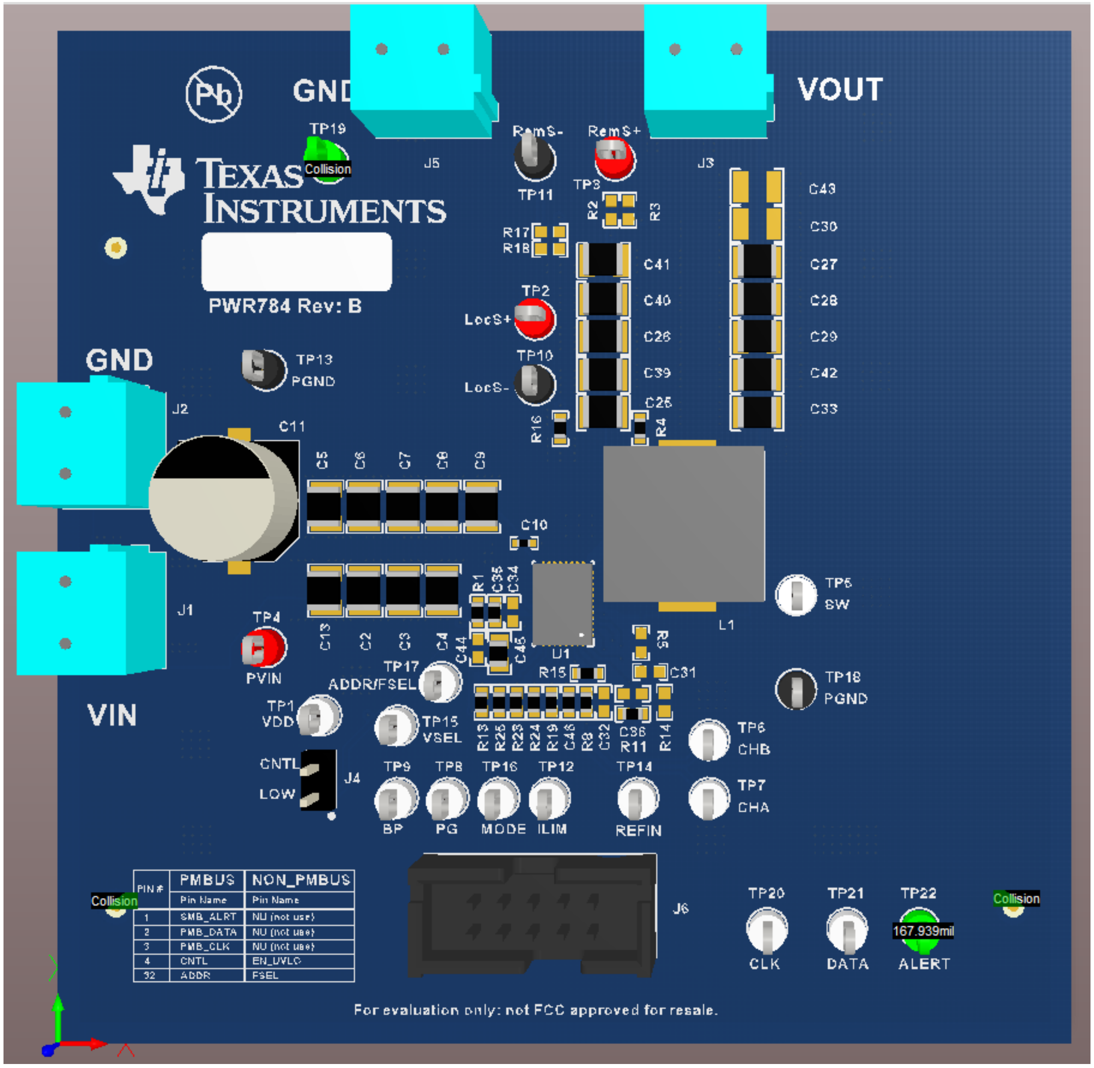

Figure 2. PWR-784EVM Overview

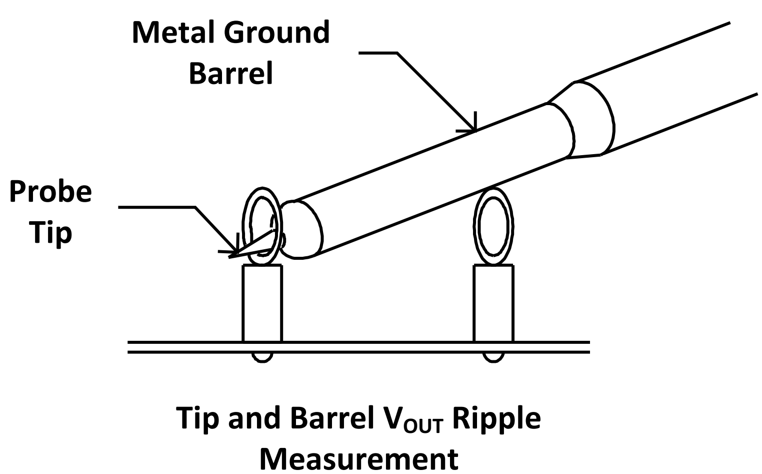

Figure 3. Tip and Barrel Measurement

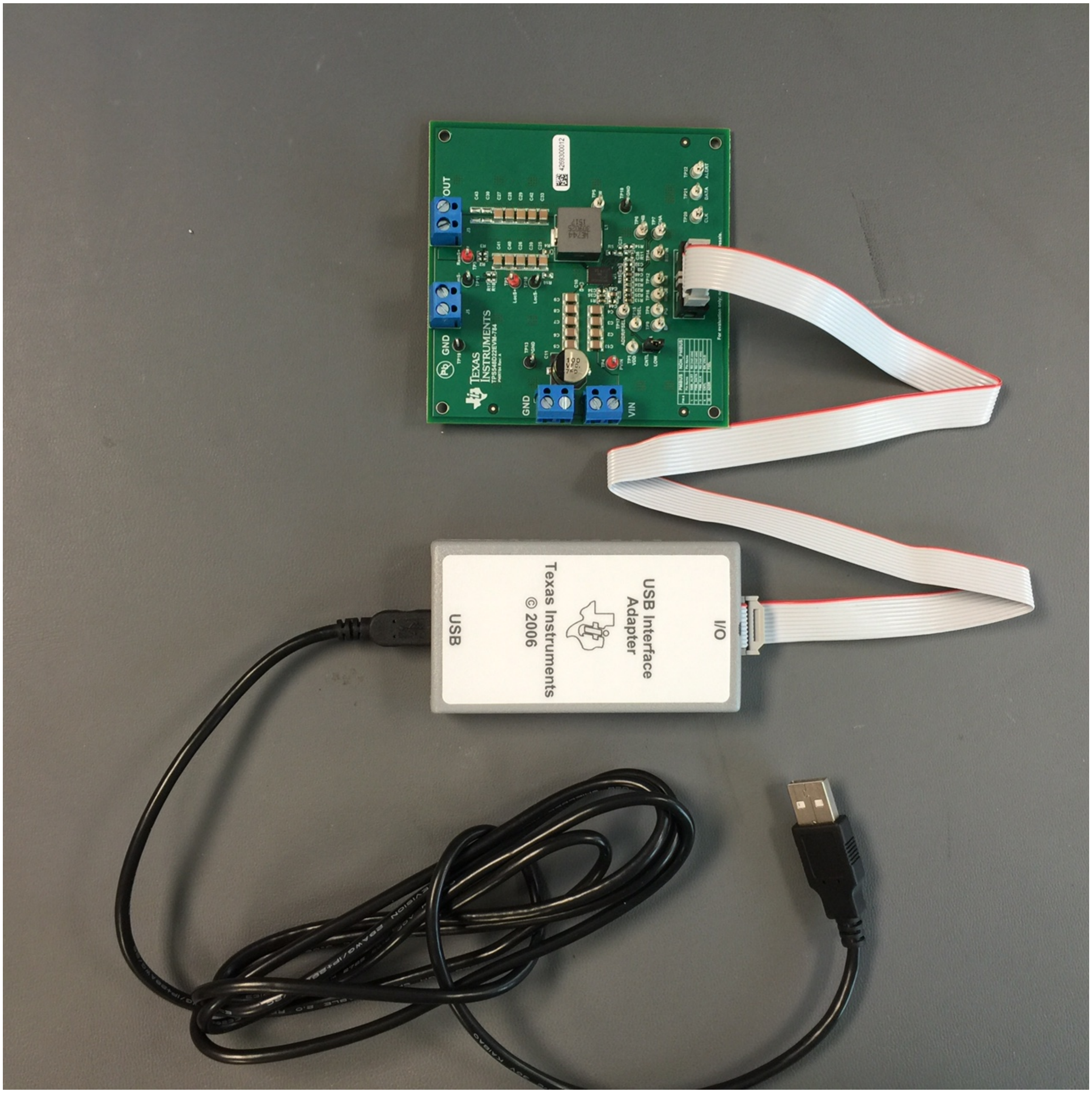

Figure 4. EVM and USB Interface Adapter

8 List of Test Points, Jumpers, and Switch

Table 2 lists the test points and their descriptions.

Table 2. 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	RESV_TRK	Do not connect.
TP19	T-H loop	PGND	Common GND
TP18	T-H loop	PGND	Common GND
TP20	T-H loop	PMB_CLK	Clock input for the PMBus interface.
TP21	T-H loop	PMB_DATA	Data I/O for the PMBus interface.
TP22	T-H loop	SMB_ALRT#	$\overline{\text{Alert}}$ output for the PMBus interface.
JP4	2-pin jumper	CNTL	Shunts control pin to GND

9 EVM Configuration Using the Fusion GUI

The TPS549D22 installed on this EVM leave the factory pre-configured. See Table 3 for a short list of key factory configuration parameters as obtained from the configuration file.

Table 3. Key Factory Configuration Parameters

Cmd ID With Phase	Cmd Code Hex	Encoded Hex [HiByte|LoByte]	Comments
CAPABILITY	0x19	0xD0	Max Bus: 1000 khz; PEC: Yes; SMBALERT#: Yes
MFR_00	0xD0	0x00	0
MFR_01 (PGOOD_DLY)	0xD1	0x12	PGD:1024?s [010b], POD:1024?s [010b]
MFR_02	0xD2	0x13	CM: True, HICLOFF: True, SST: 0x00, FORCESKIPSS: True, SEQ: False, TRK: False
MFR_03	0xD3	0x93	FS:625kHz [011b], RCSP:R ? 1 [01b], DCAP3:True
MFR_04	0xD4	0x80	DCAP3_Offset:0mV [00b], DCAP3_Offset_Sel:True
MFR_06	0xD6	0x05	VDDUVLO:4.25V [101b]
MFR_07	0xD7	0x8F	VTRKIN:1.25V [1111b], TRKOPTION:False, SPARE:False, VPBAD:True
MFR_33	0xF1	0x00	0
MFR_42	0xFA	0x00	0
MFR_44	0xFC	0x0201	ID: 0x020 (TPS549C20), Revision: 0x1
ON_OFF_CONFIG	0x02	0x17	Mode: CONTROL Pin Only; Control: Active High, Turn off Immediately
OPERATION	0x01	0x00	Operation is not used to enable regulatio; Unit: ImmediateOff; Margin: None
STATUS_BYTE	0x78	0x00	Status: Output Off, Vout OV Fault, IOUT OC Fault, Vin UV Fault, Temperature, CML
STATUS_CML	0x7E	0x00	Status: Invalid Command, Invalid Data, PEC Fault, Other Comms Fault
STATUS_IOUT	0x7B	0x00	Status: Iout OC Fault, Iout OC Fault with LV Shutdown, Iout UC Fault
STATUS_VOUT	0x7A	0x00	Status: Vout OV Fault, OV Warning, UV Fault, UV Warning
VOUT_COMMAND	0x21	0x01CD	VOUT_COMMAND=0.900 V
VOUT_MARGIN_HIGH	0x25	0x0266	VOUT_MARGIN_HIGH=1.199 V
VOUT_MARGIN_LOW	0x26	0x0266	VOUT_MARGIN_LOW=1.199 V
WRITE_PROTECT	0x10	0x00	Enable Writes To All Commands

If it is desired to configure the EVM to settings other than the factory settings shown in Table 3, the TI Fusion Digital Power Designer software can be used for reconfiguration. It is necessary to have input voltage applied to the EVM prior to launching the software so that the TPS549D22 installed is active and able to respond to the GUI and the GUI can recognize the device.

10 Test Procedure

10.1 *Line and Load Regulation Measurement Procedure*

Use the following procedures for line and load regulation measurement.

1. Connect VOUT to J3 and VOUT_GND to J5 Figure 2.
2. Ensure that the electronic load is set to draw 0 A_{DC}.
3. Connect VIN to J1 and VIN_GND to J2 Figure 2.
4. Connect the USB interface adapter as shown in Figure 4.
5. Increase V_{IN} from 0 V to 12 V using the digital multimeter to measure input voltage.
6. Launch the Fusion GUI software. See the screen shots in Section 12 for more information.
7. Configure the EVM operating parameters as desired.
8. Use the other digital multimeter or the oscilloscope to measure output voltage V_{OUT} at TP2 and TP10 as you vary the external voltage source.

Table 4. 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

9. Vary the load from 0 A_{DC} to maximum rated output 40 A_{DC}. V_{OUT} must remain in regulation as defined in Table 1.
10. Vary V_{IN} from 5 V to 16 V. V_{OUT} must remain in regulation as defined in Table 1.
11. Decrease the load to 0 A.
12. Decrease V_{IN} to 0 V or turn off the supply.

10.2 *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 5. 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.

10.3 *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.

11 Performance Data and Typical Characteristic Curves

Figure 5 through Figure 19 present typical performance curves for the PWR-784EVM.

11.1 Efficiency

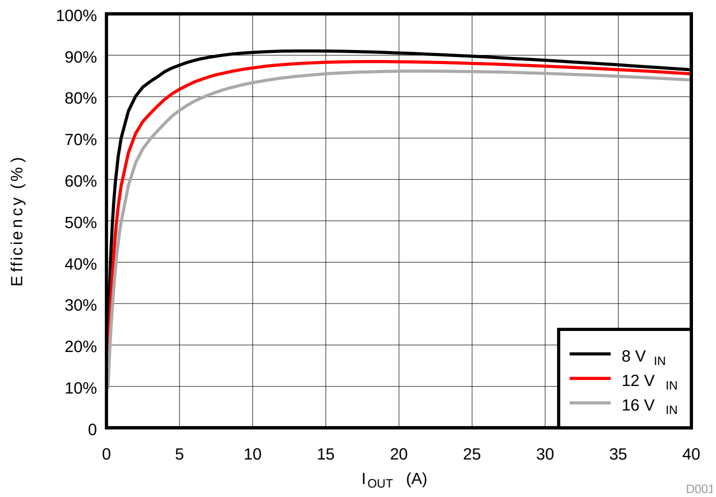

Figure 5. Efficiency of 1-V Output vs Load

11.2 Load Regulation

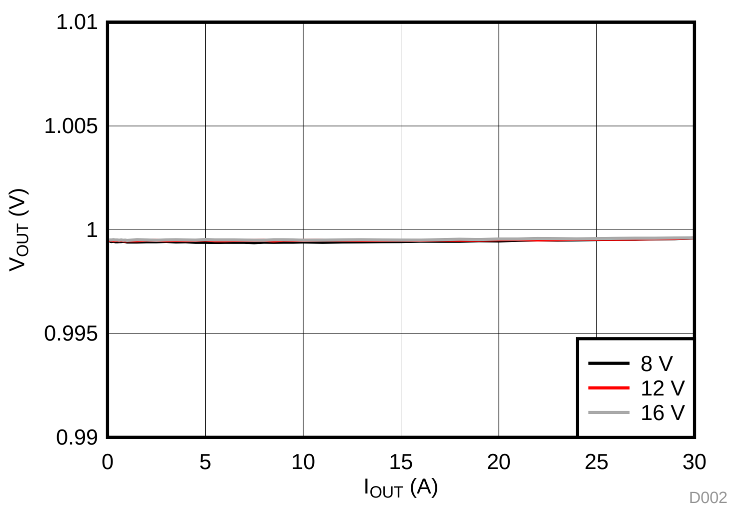

Figure 6. Load Regulation of 1-V Output

11.3 Line Regulation

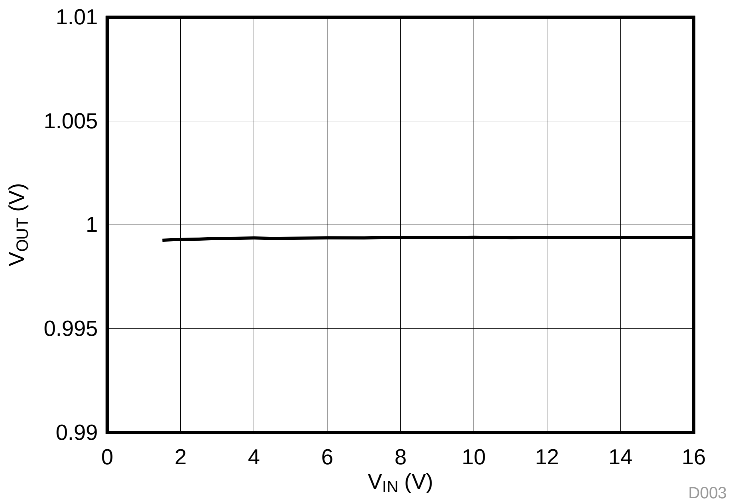

Figure 7. Line Regulation of 1-V Output

Figure 8. PMBus V_{OUT} Step-Up = 0.6 V to 1.2 V at 0 A

Figure 9. PMBus V_{OUT} Step-Down = 1.2 V to 0.6 V at 0 A

Figure 10. PMBus V_{OUT} Step-Up = 0.6 V to 1.2 V at 40 A

Figure 11. PMBus V_{OUT} Step-Down = 1.2 V to 0.6 V at 40 A

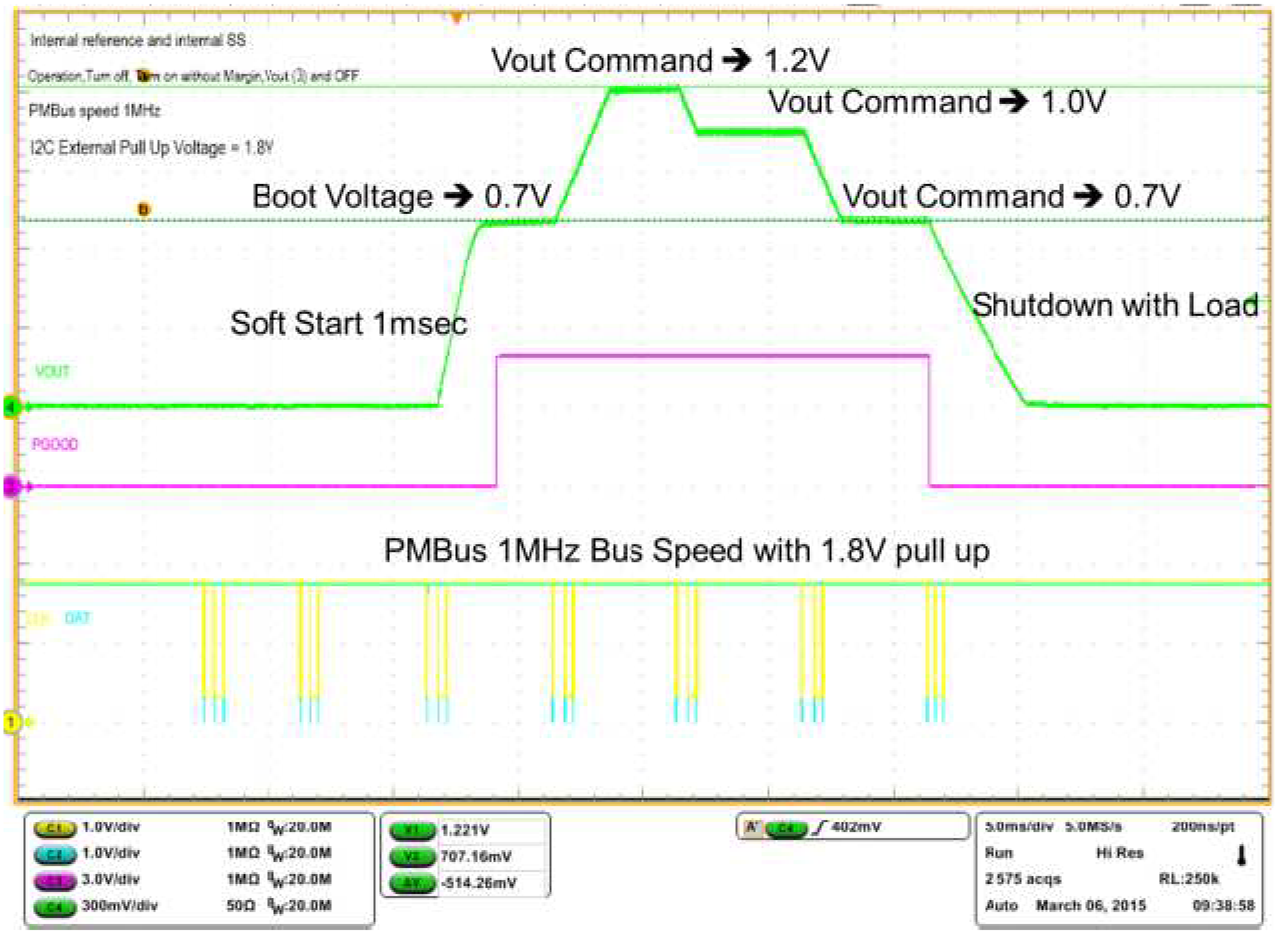

Figure 12. PMBUS Multiple Commands

11.4 Transient Response

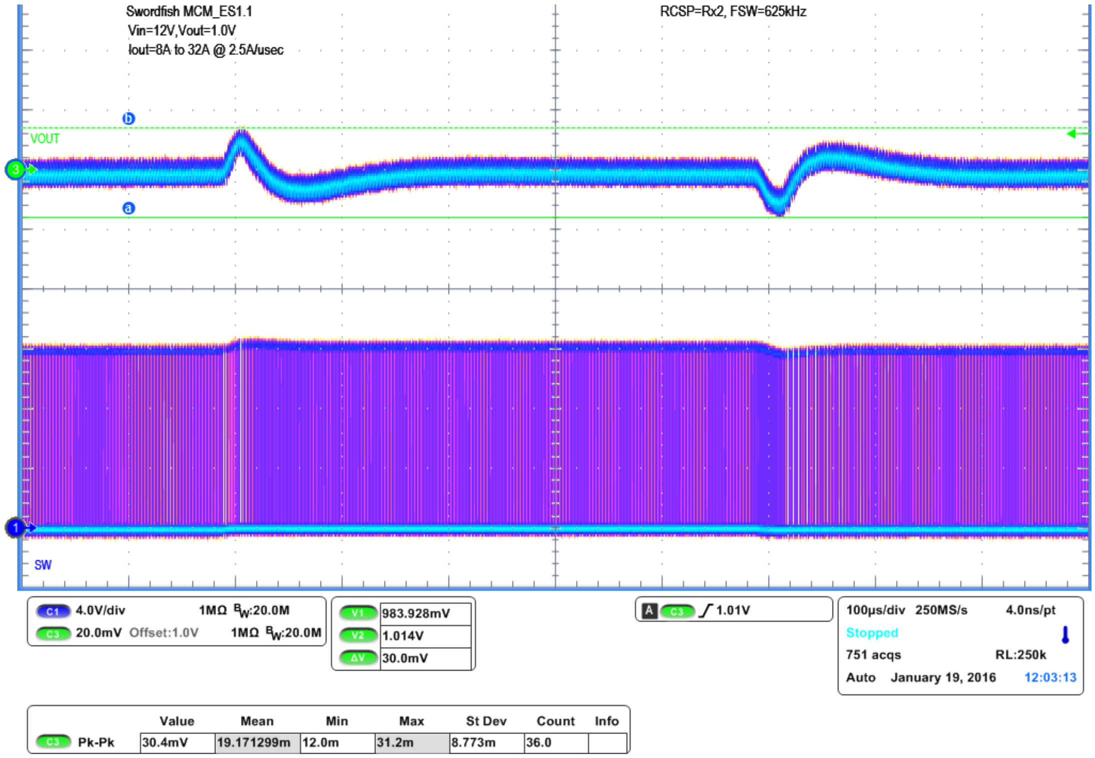

Figure 13. Transient Response of 1-V Output at 12 V_{IN}, Transient is 8 A to 32 A, 2.5 A/µs

11.5 Output Ripple

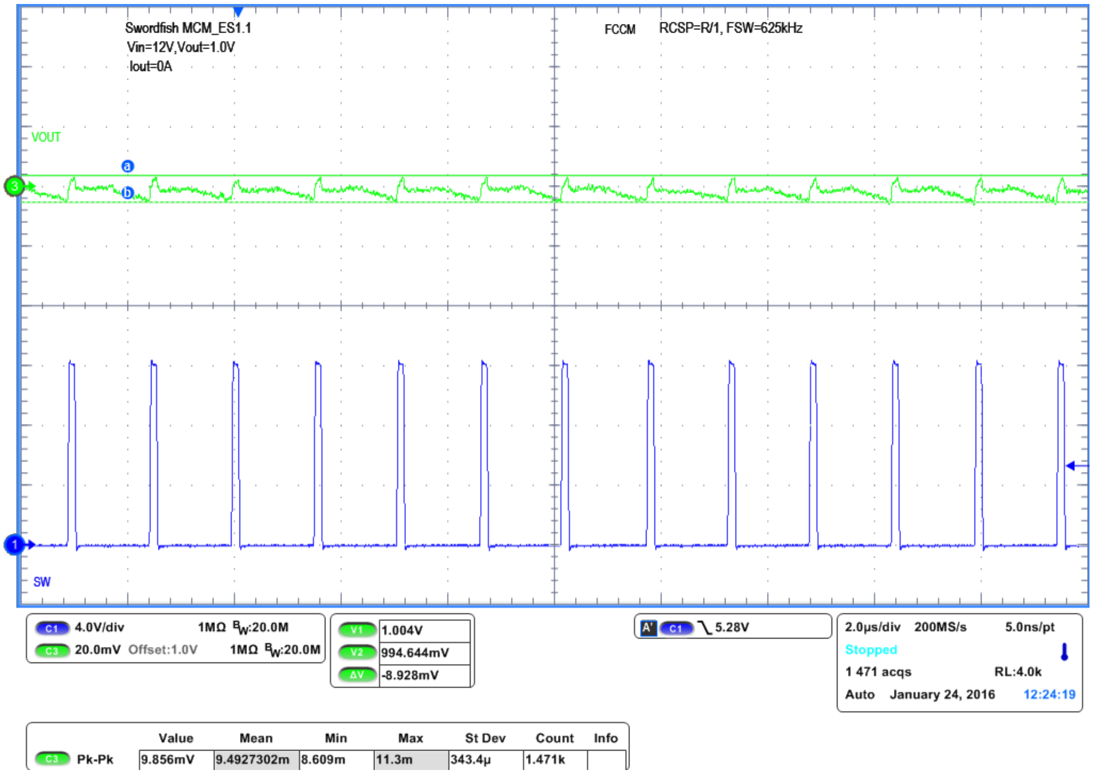

Figure 14. Output Ripple and SW Node of 1-V Output at 12 V_{IN}, 0-A Output

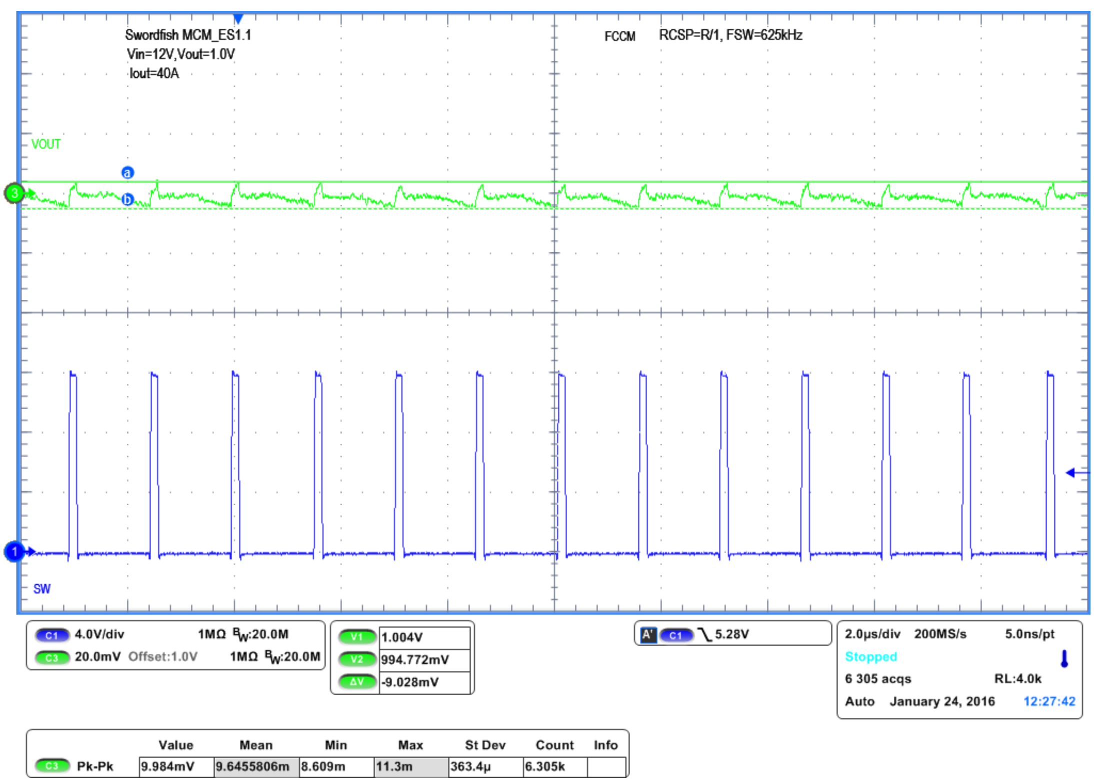

Figure 15. Output Ripple and SW Node of 1-V Output at 12 V_{IN}, 40-A Output

11.6 Control On

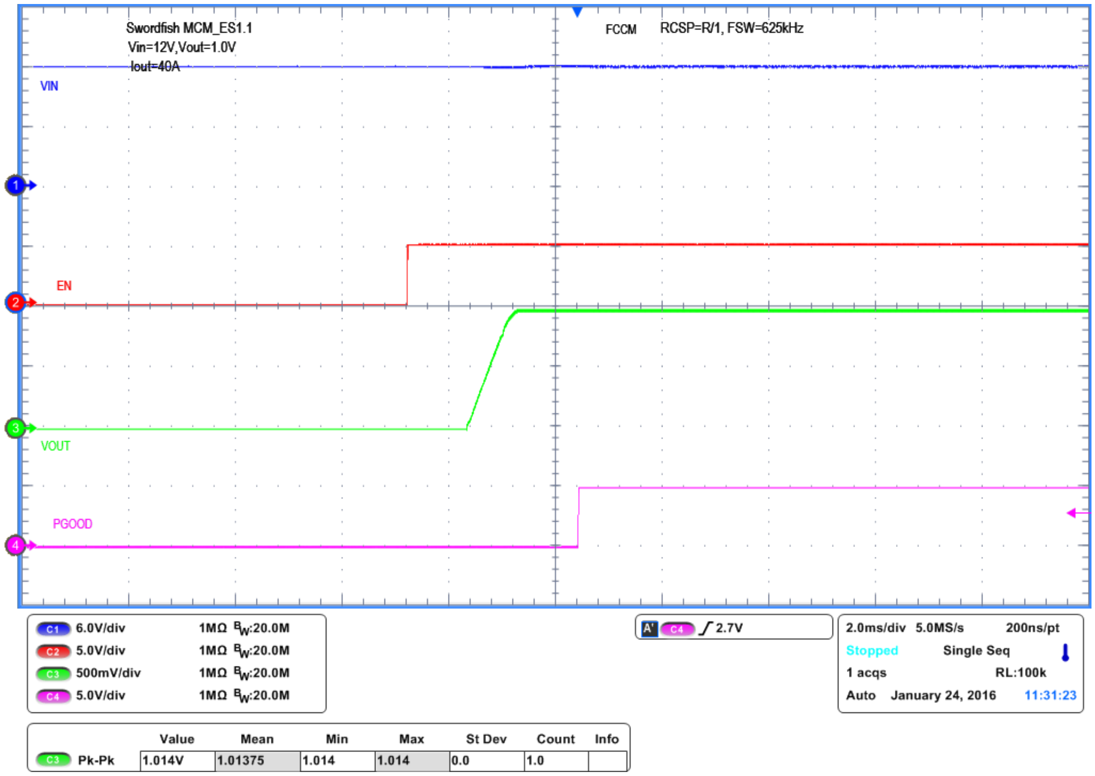

Figure 16. Start up from Control, 1-V Output at 12 V_{IN}, 40-A Output

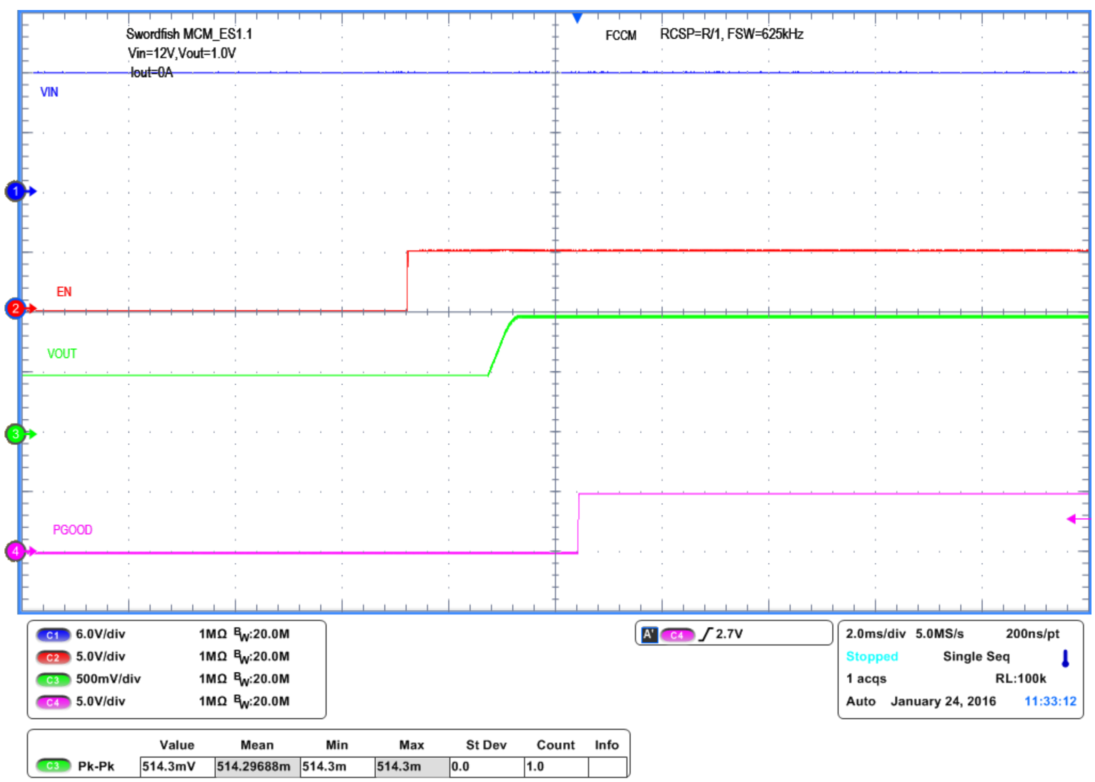

Figure 17. 0.5-V Pre-bias start up from Control, 1-V Output at 12 V_{IN}, 40-A Output

11.7 Control Off

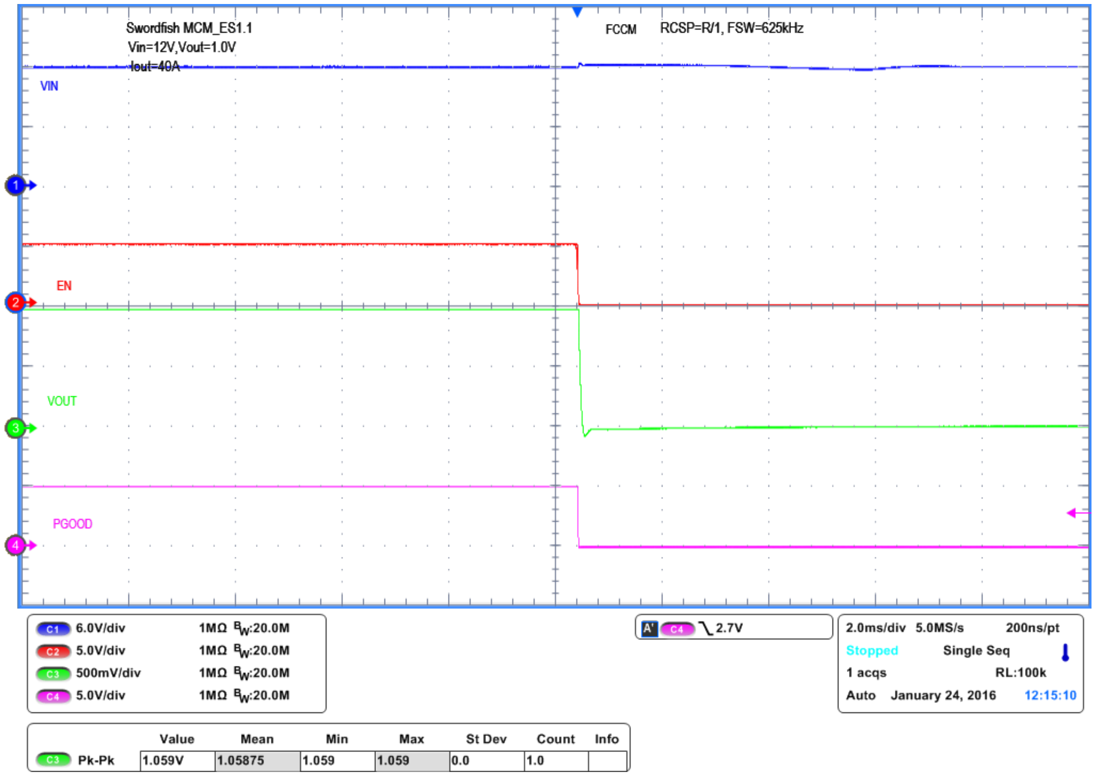

Figure 18. Soft Stop from Control, 1-V Output at 12 V_{IN}, 40-A Output

11.8 Thermal Image

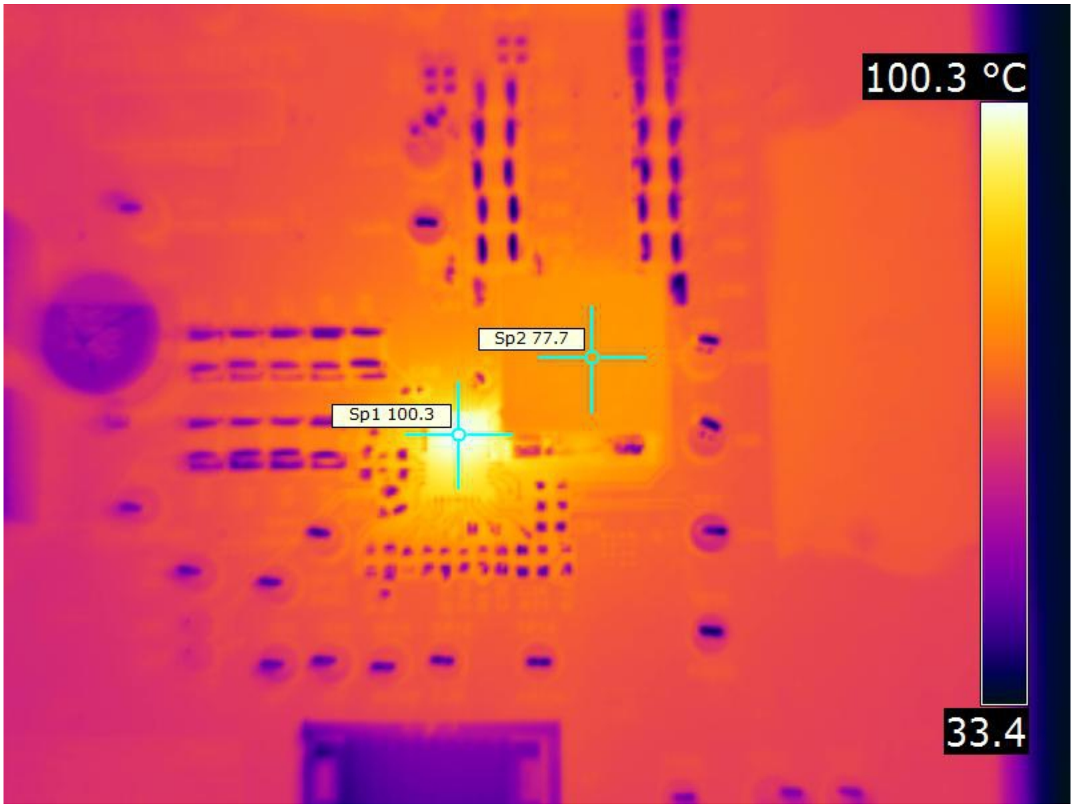

Figure 19. Thermal Image at 1-V Output at 12 V_{IN}, 40-A Output

12 Fusion GUI

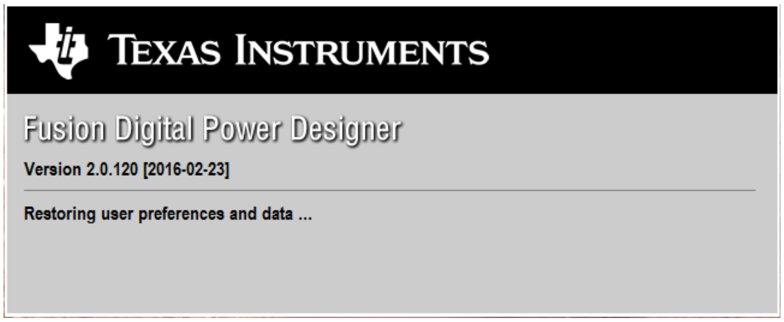

Figure 20. First Window at Fusion Launch

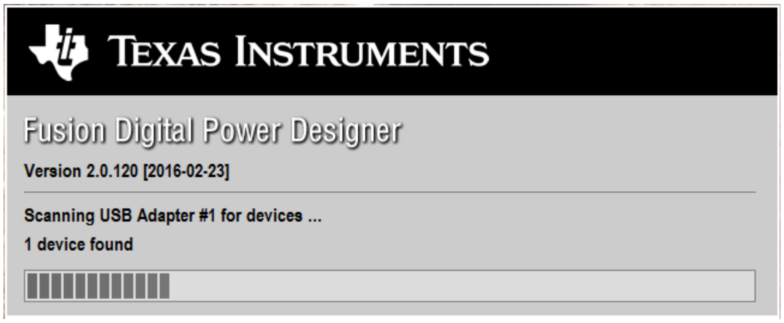

Figure 21. Scan Finds Device Successfully

Figure 22. Software Launch Continued

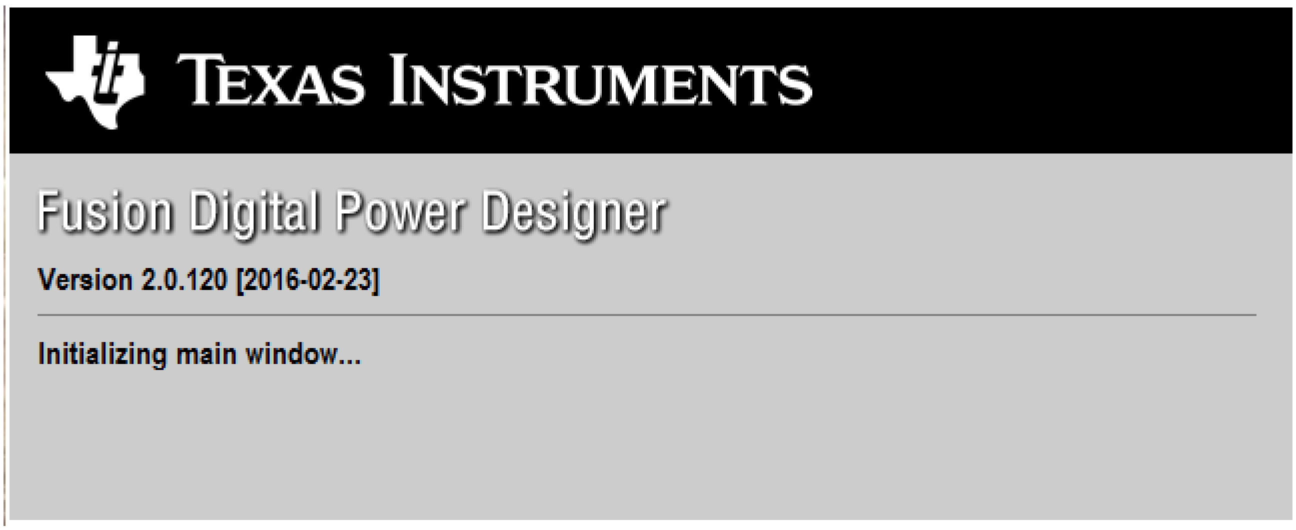

Figure 23. Software Launch Continued

Use the *All Config* tab to configure all of the configurable parameters (Figure 24). The screen also shows other details like hexadecimal (hex) encoding. Use this screen to configure:

- Power Good Delay
- Power On Delay
- Mode Settings
- Frequency, RAMP, DCAP3
- VDD UVLO
- On/Off Configuration
- Track and Sequencing
- Write Protect
- VOUT Command Voltage
- VOUT Margin
- Operation

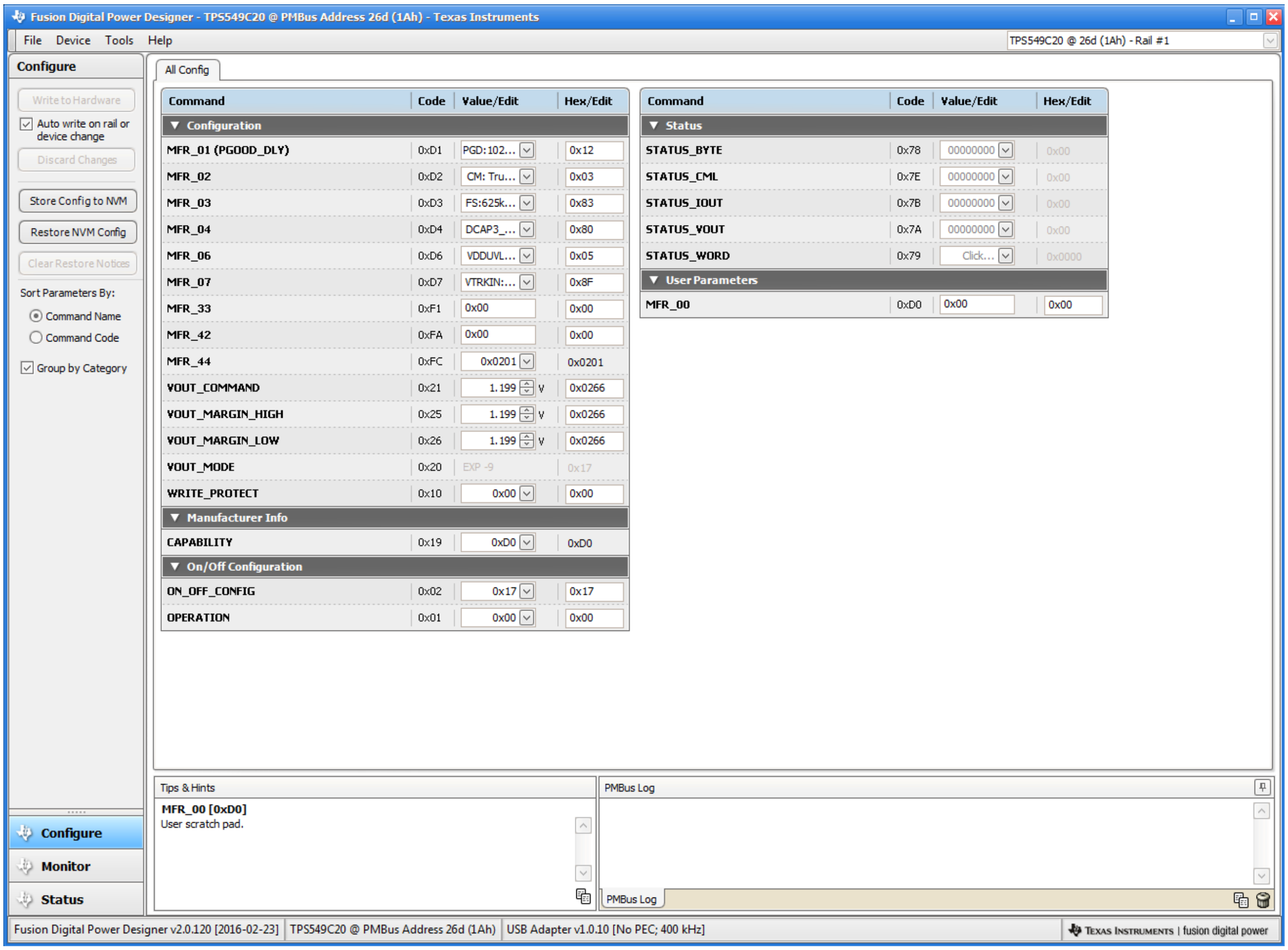

Figure 24. First Screen After Successful Launch Configure: Limits and On/Off

Changing the frequency prompts a pop-up window with details of the options Figure 25).

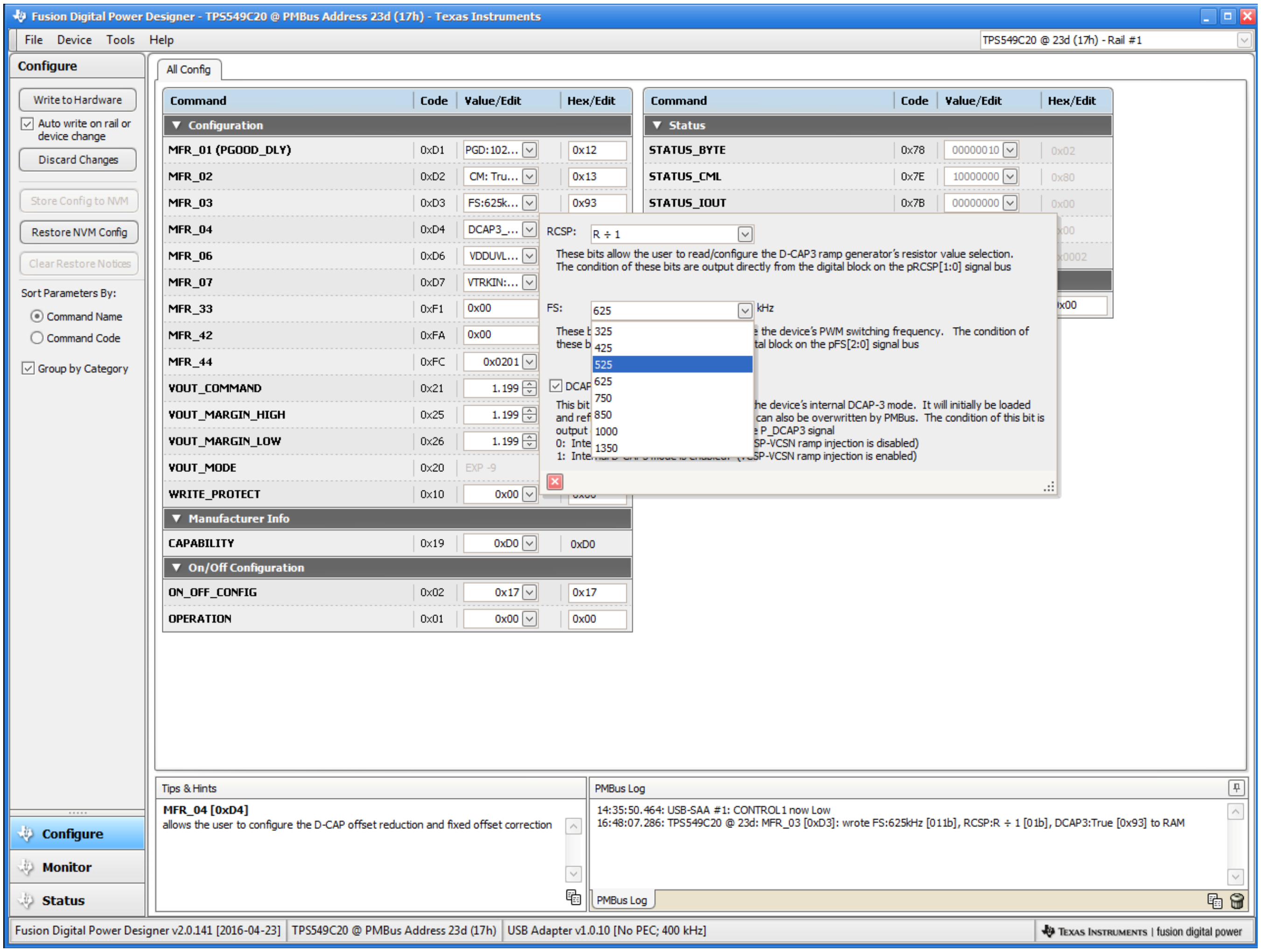

Figure 25. Configure: Frequency- FS Configuration Pop-up

After a change is selected, orange **U** icon is displayed to offer *Undo Change* option. Change is not retained until either *Write to Hardware* or *Store Config to NVM* is selected. When *Write to Hardware* is selected, change is committed to volatile memory and defaults back to previous setting on input power cycle. When *Store Config to NVM* is selected, change is committed to nonvolatile memory and becomes the new default (Figure 26).

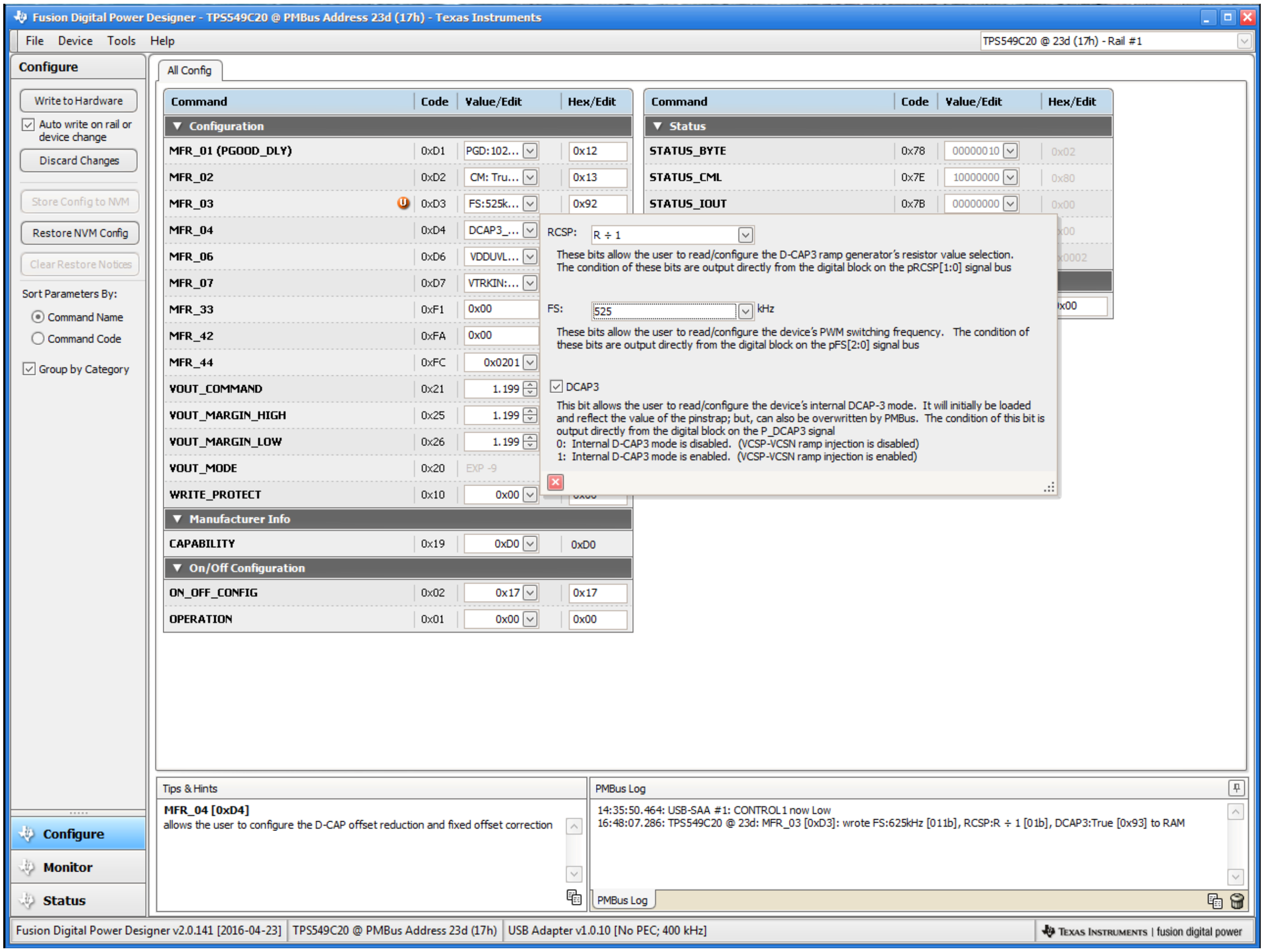

Figure 26. Configure: Frequency- FS Config Pop-Up with Change

After making changes to one or more configurable parameters, the changes can be committed to nonvolatile memory by selecting *Store Config to NVM*. This action prompts a *confirm selection* pop-up, and if confirmed, the changes are committed to nonvolatile memory (Figure 27).

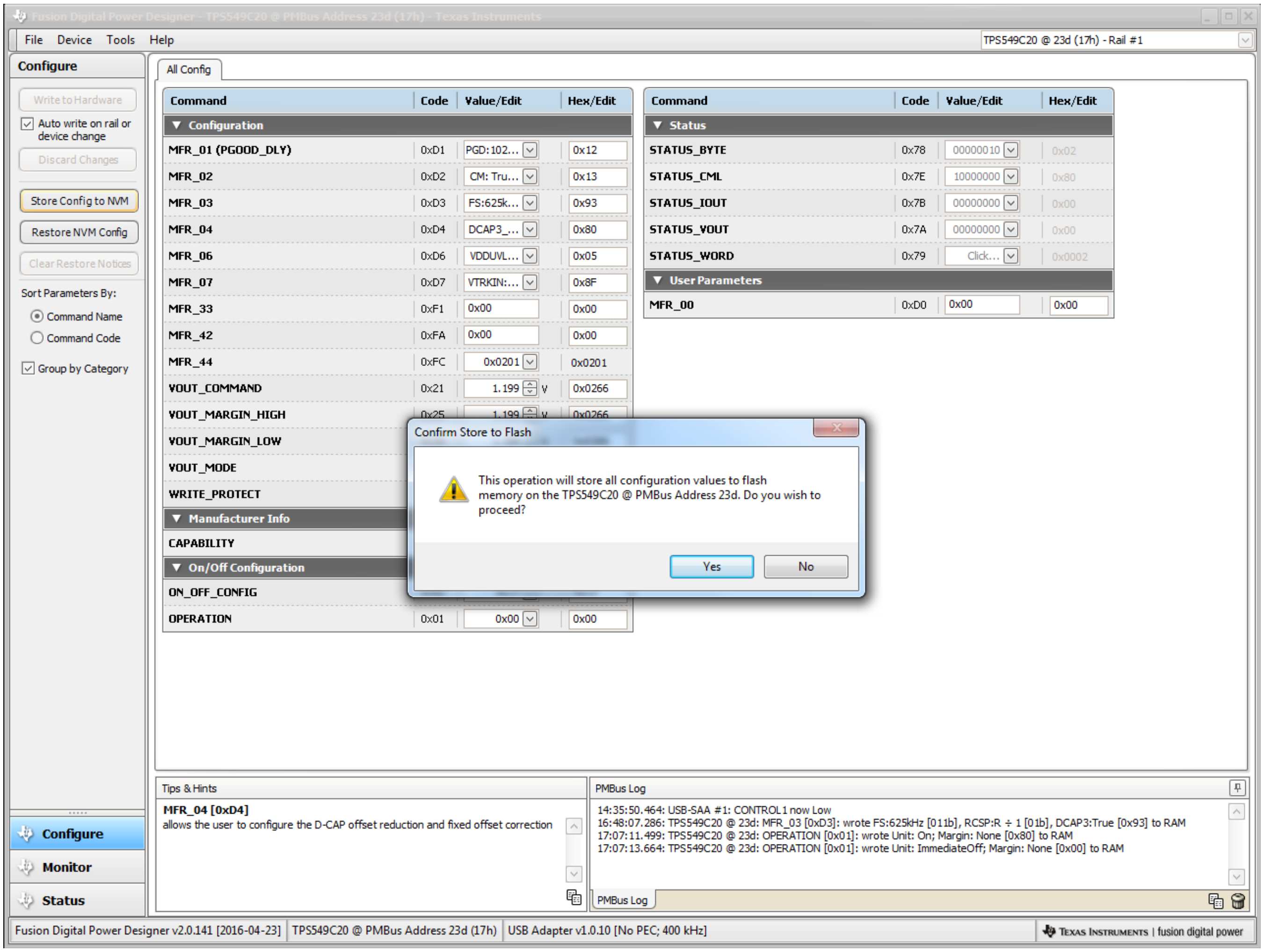

Figure 27. Configure: *Store Config to NVM*

In the lower left corner, the different view screens can be changed. The view screens can be changed between *Configure*, *Monitor* and *Status* as needed (Figure 28).

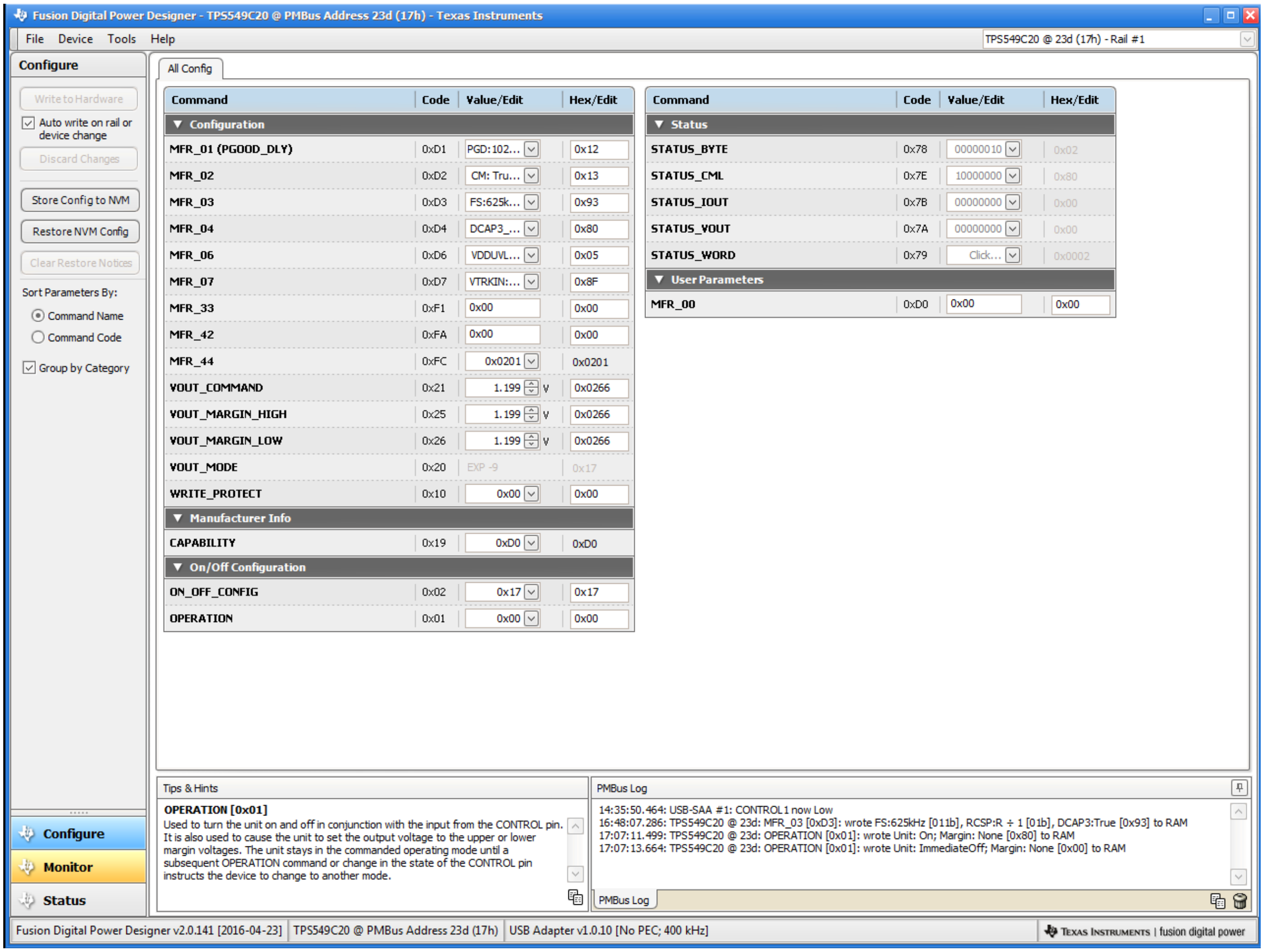

Figure 28. Change View Screen to Monitor Screen

Selecting *System Dashboard* from mid-left screen adds a new window which displays system-level information (Figure 29).

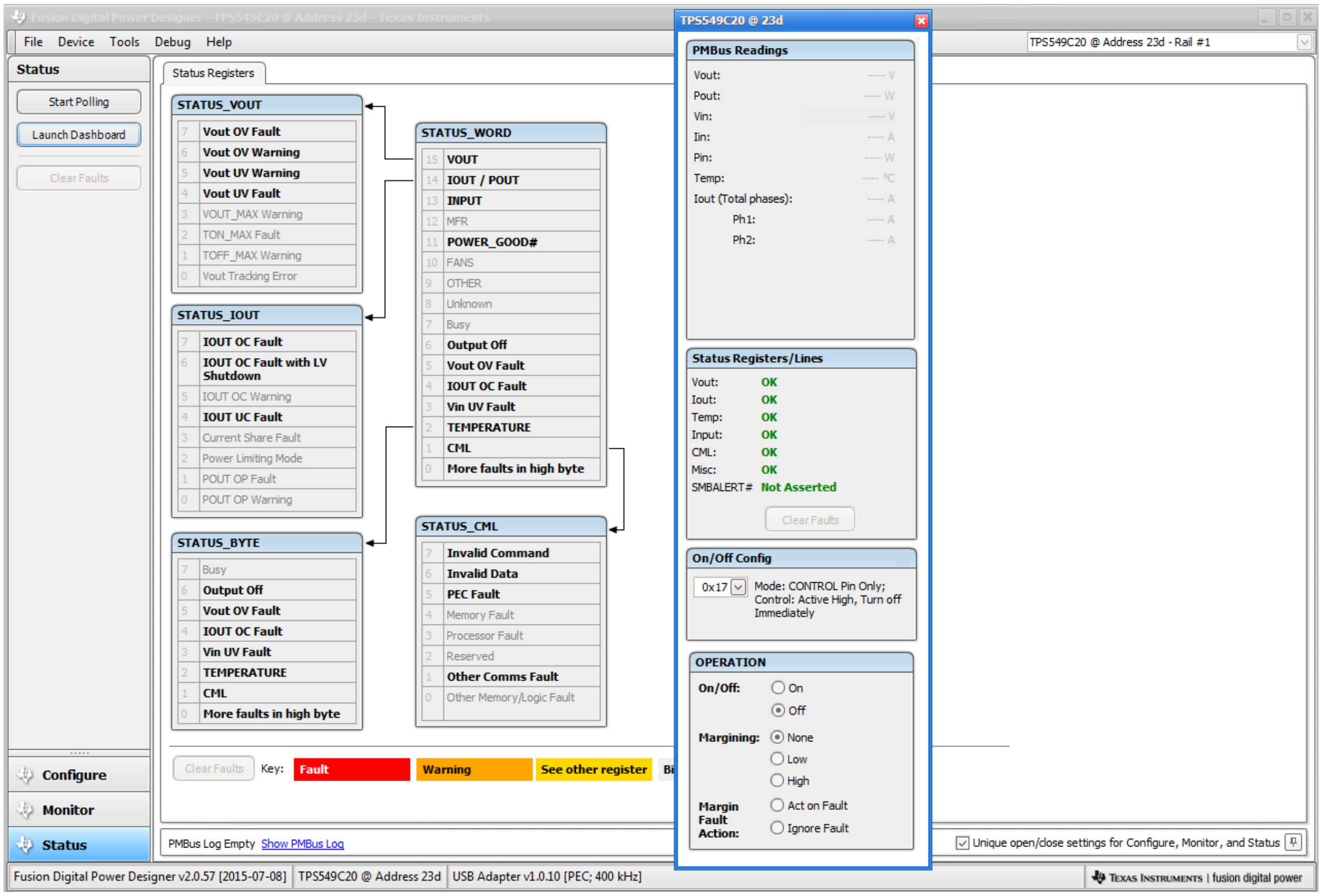

Figure 29. System Dashboard

Selecting *Status* from lower left corner shows the status of the controller (Figure 30).

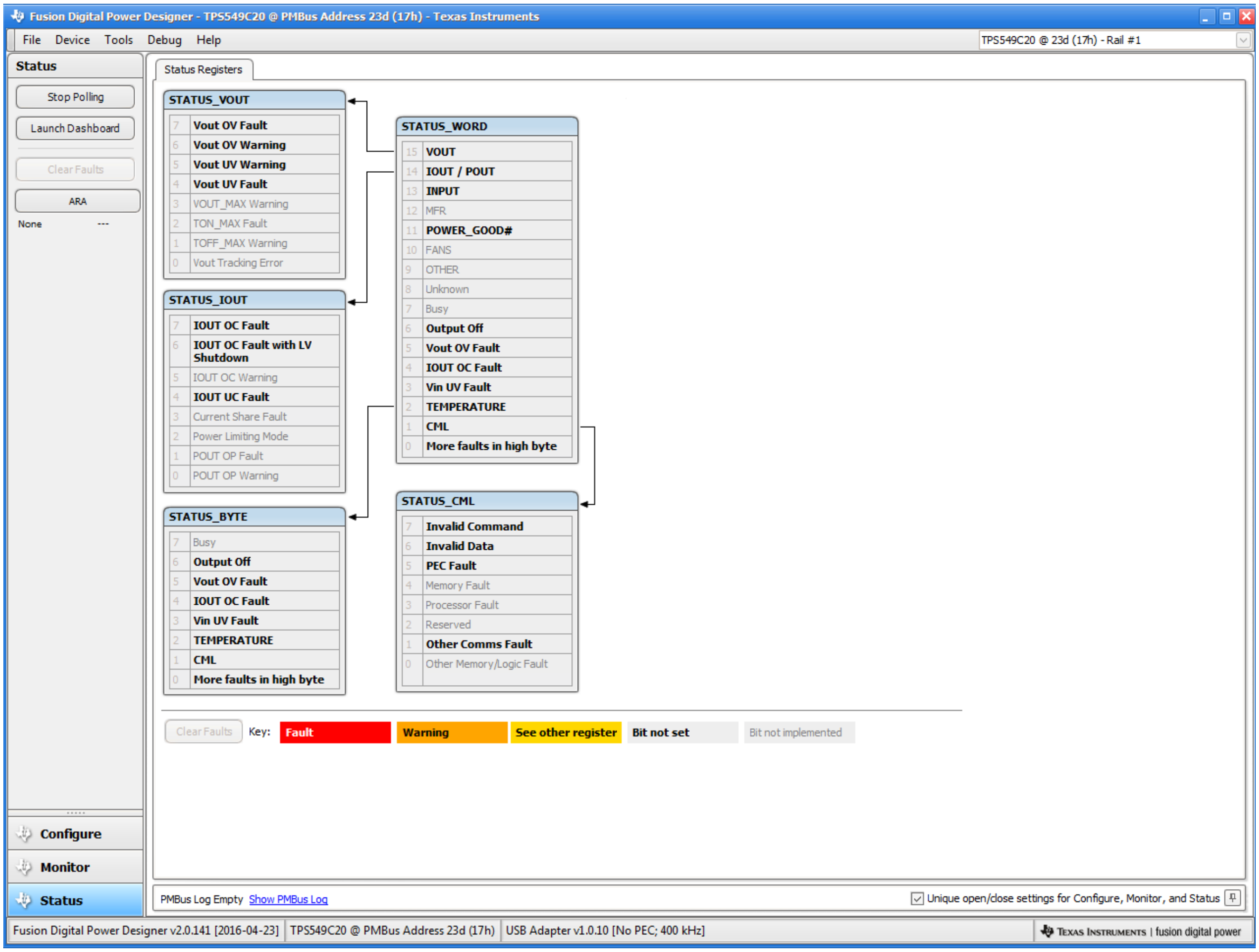

Figure 30. Status Screen

Selecting *Store User Configuration to Flash Memory* from the device pull-down menu has the same functionality as the *Store Config to NVM* button from the configure screen. It results in committing the current configuration to nonvolatile memory (Figure 31).

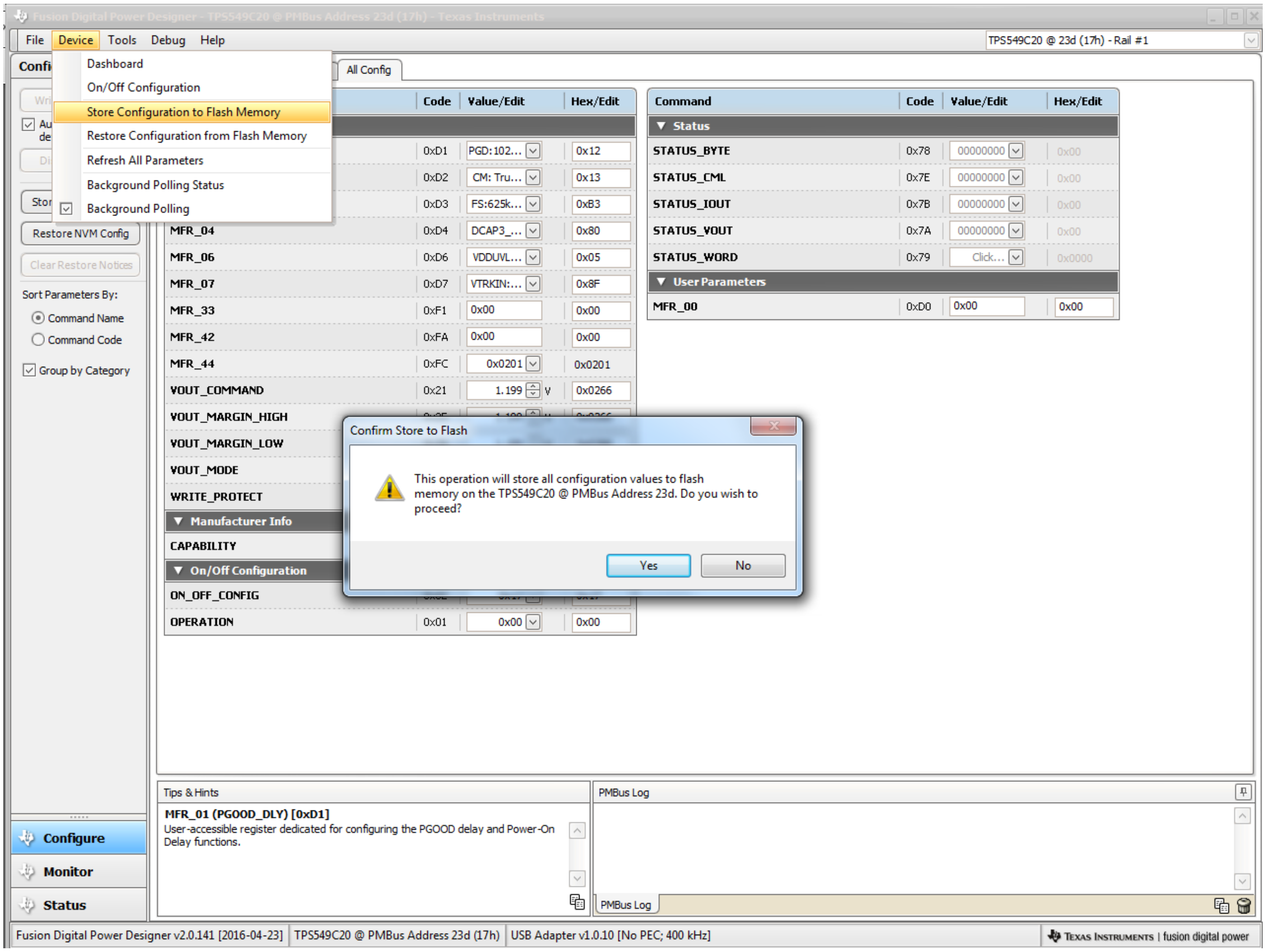

Figure 31. Store Configuration To Memory

Selecting *PMBus Logging* (Figure 32) from the Tools drop-down menu enables the logging of all PMBus activity. This includes communications traffic for each polling loop between the GUI and the device. The user is prompted to select a location for the file to be stored. See next screen (Figure 33).

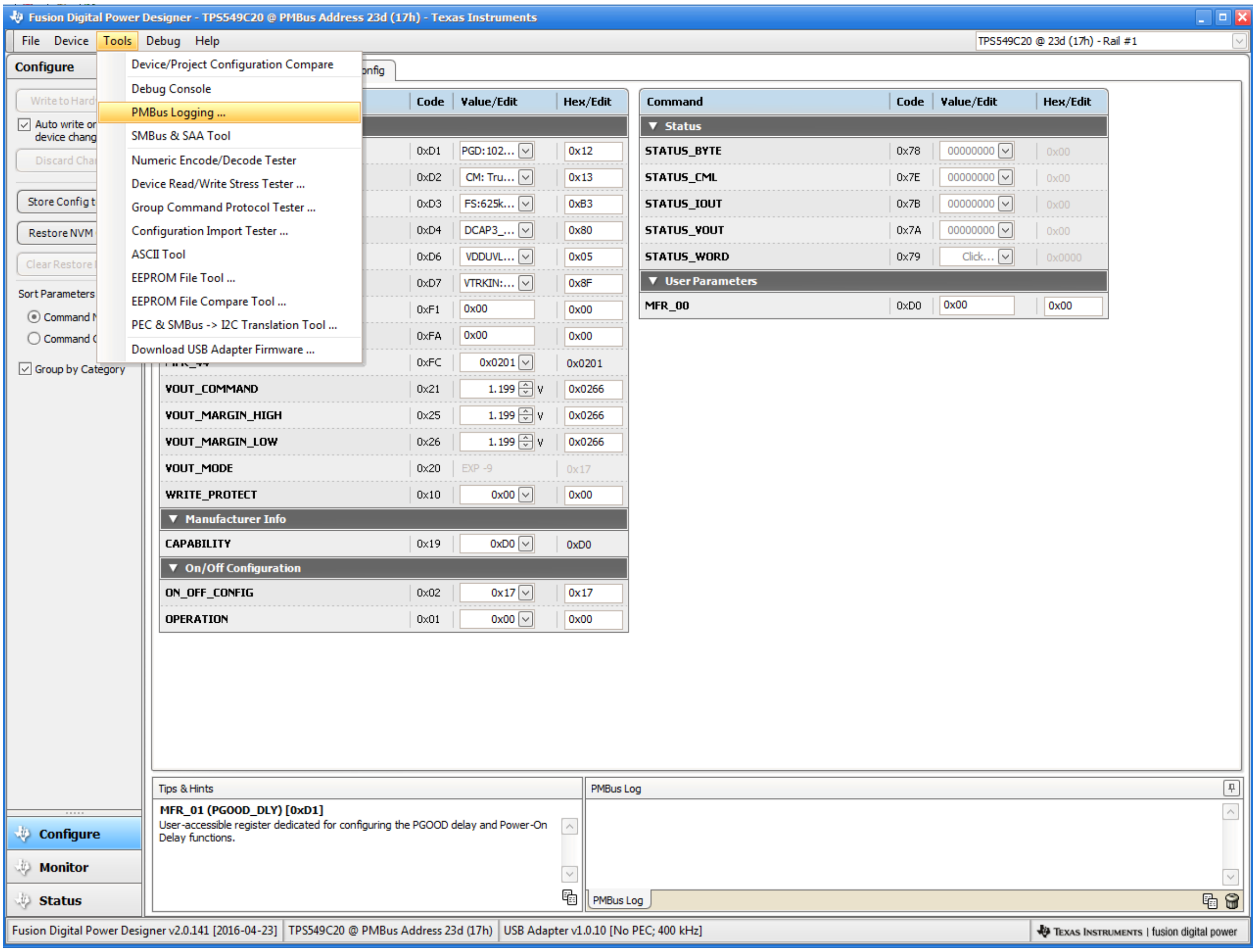

Figure 32. PMBus Logging

Select the storage location for the file and the type of file. As shown (Figure 33), the file is a CSV file to be stored in the directory path shown. Logging begins when the *Start Logging* button is selected, and stops when it is reselected (as *Stop Logging*). This file can rapidly grow in size, so caution is advised when using this function.

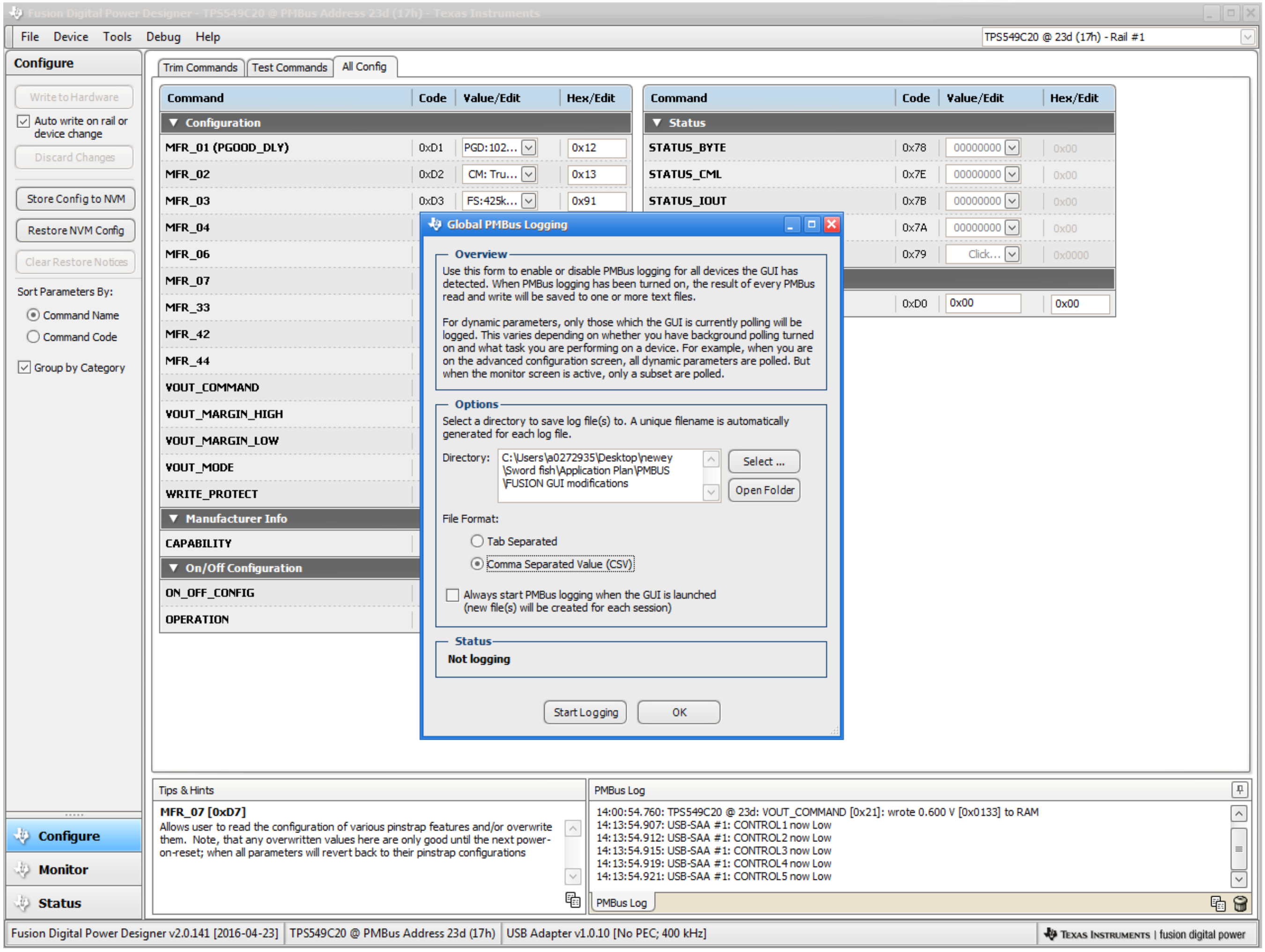

Figure 33. PMBus Log Details

13 EVM Assembly Drawing and PCB Layout

Figure 34 through Figure 41 show the design of the PWR-784EVM printed-circuit board (PCB). The PWR-784EVM has a 2-oz. copper finish for all layers.

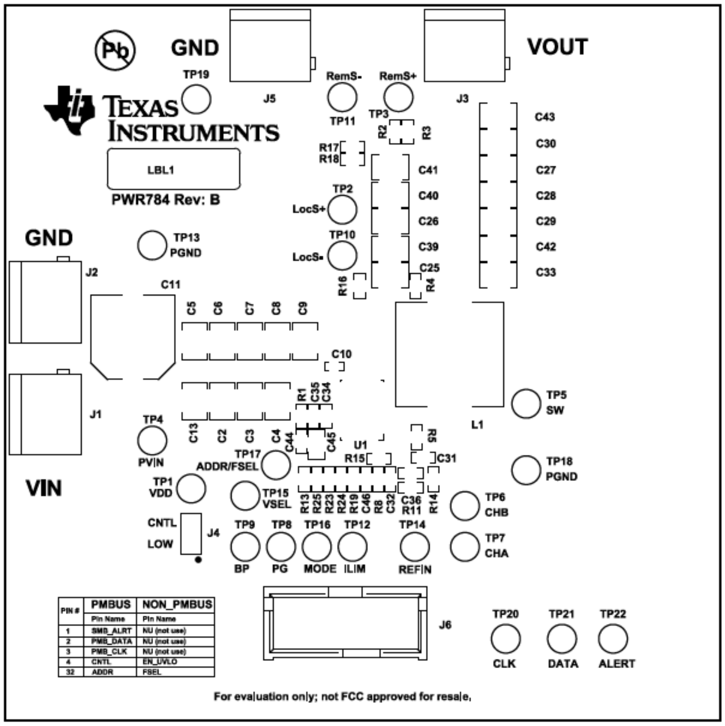

Figure 34. PWR-784EVM Top Layer Assembly Drawing (Top View)

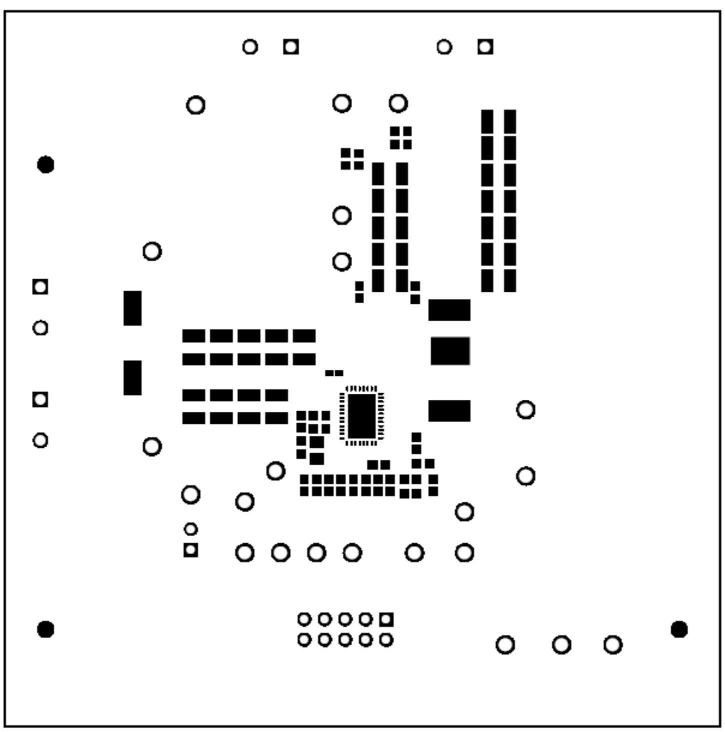

Figure 35. PWR-784EVM Top Solder Mask (Top View)

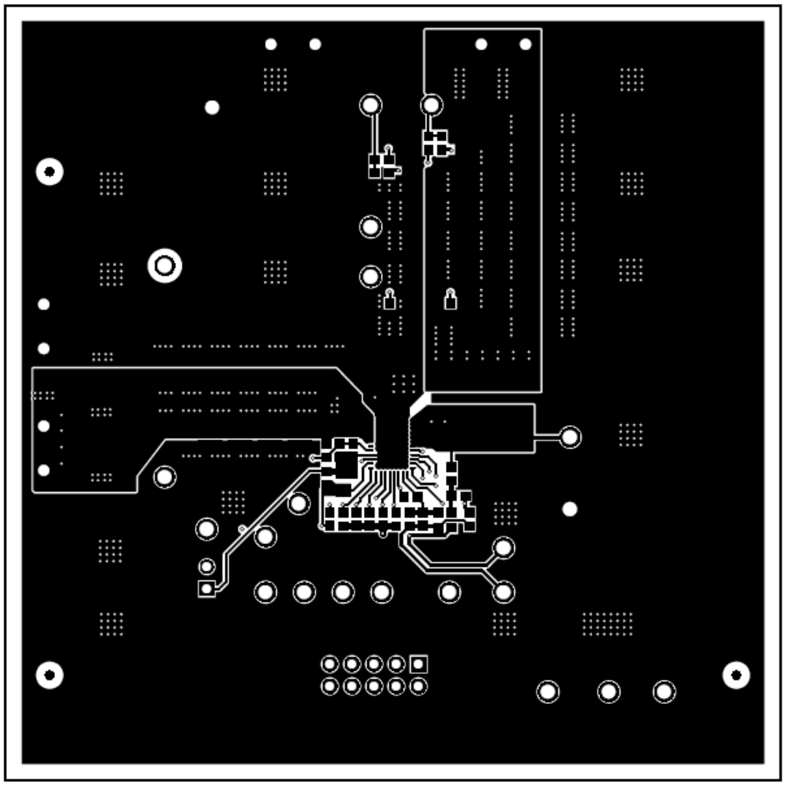

Figure 36. PWR-784EVM Top Layer (Top View)

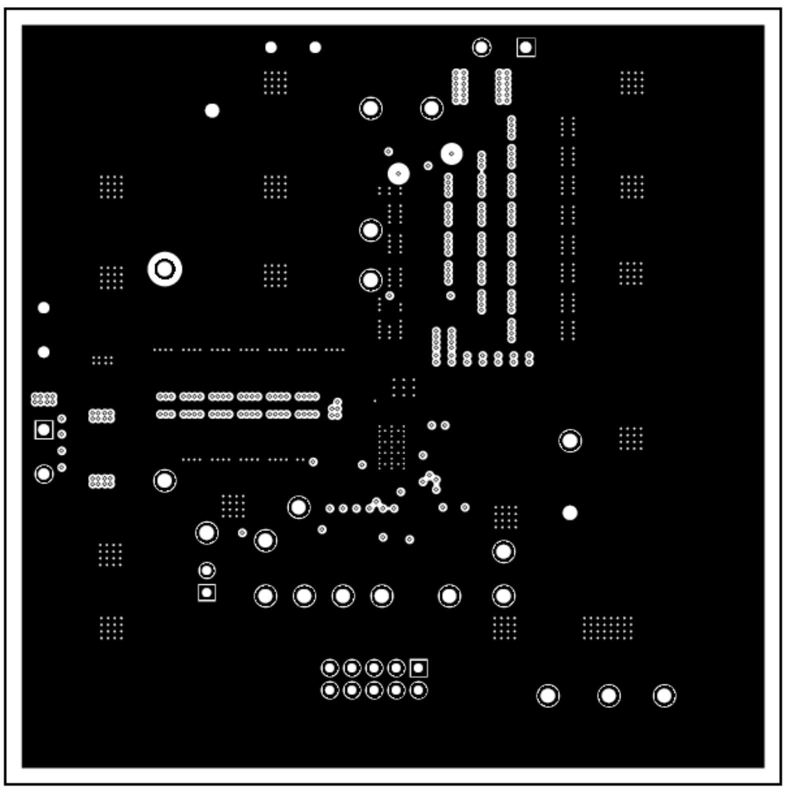

Figure 37. PWR-784EVM Inner Layer 1 (Top View)

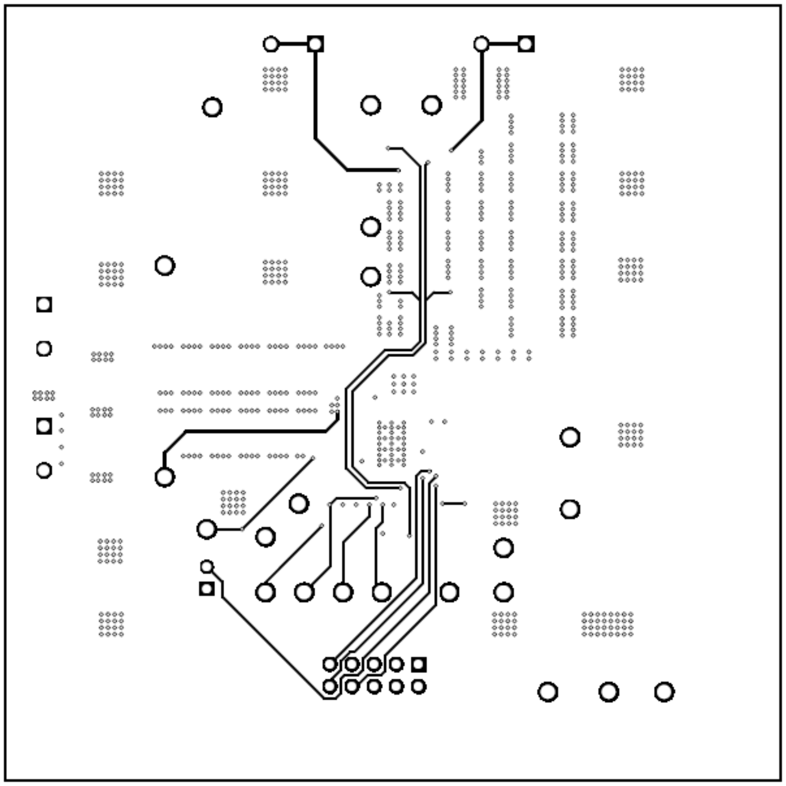

Figure 38. PWR-784EVM Inner Layer 2 (Top View)

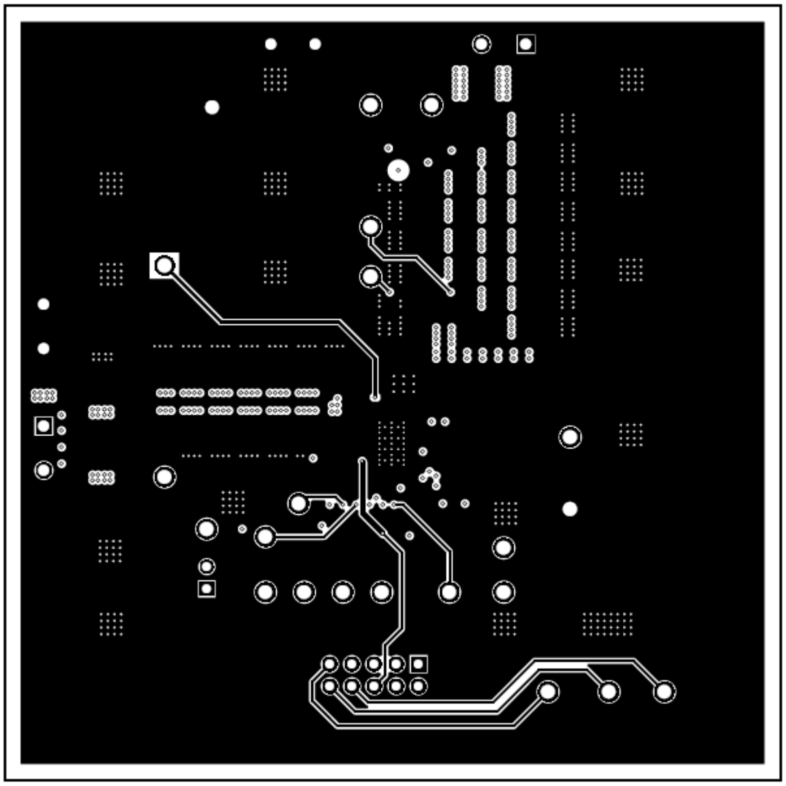

Figure 39. PWR-784EVM Inner Layer 3 (Top View)

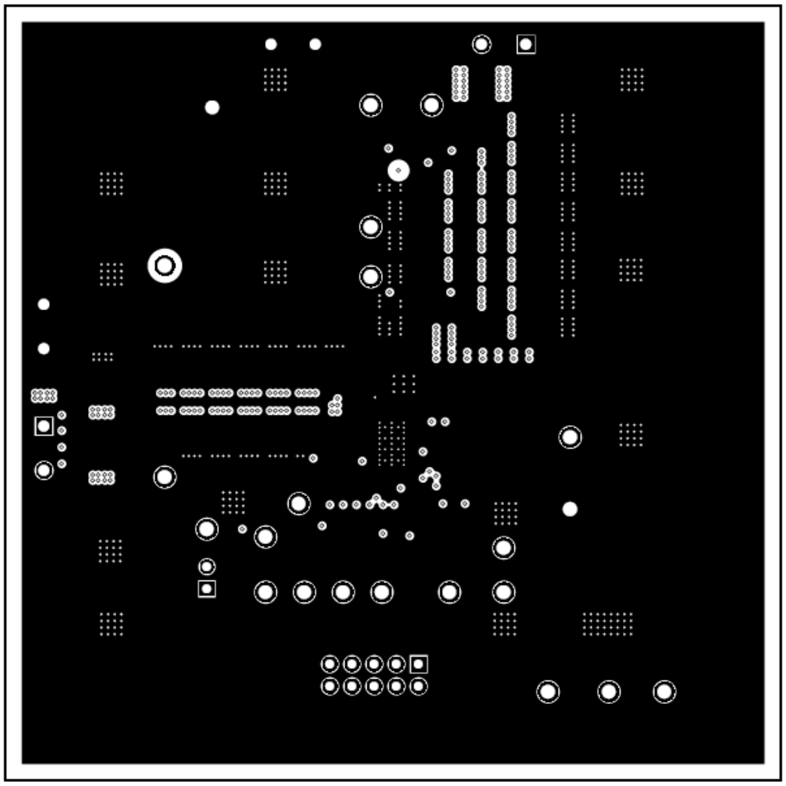

Figure 40. PWR-784EVM Inner Layer 4 (Top View)

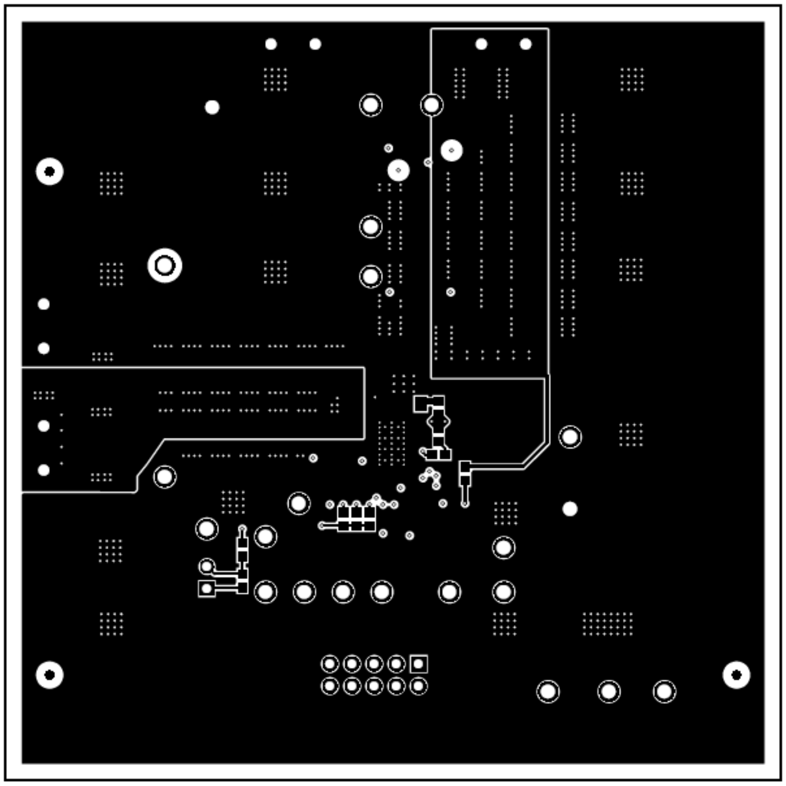

Figure 41. PWR-784EVM Bottom Layer (Top View)

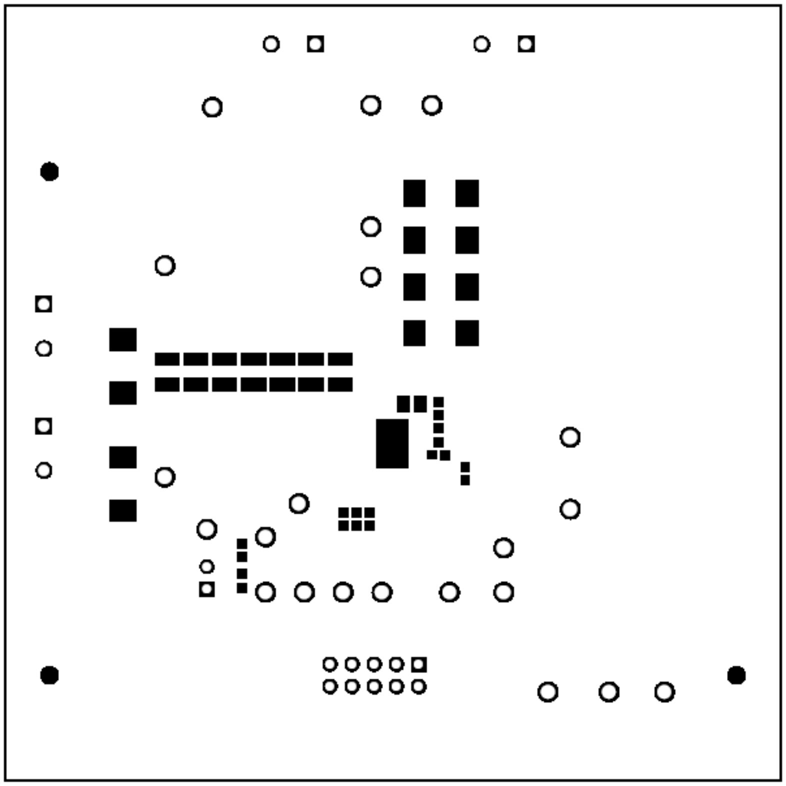

Figure 42. PWR-784EVM Bottom Solder Mask (Top View)

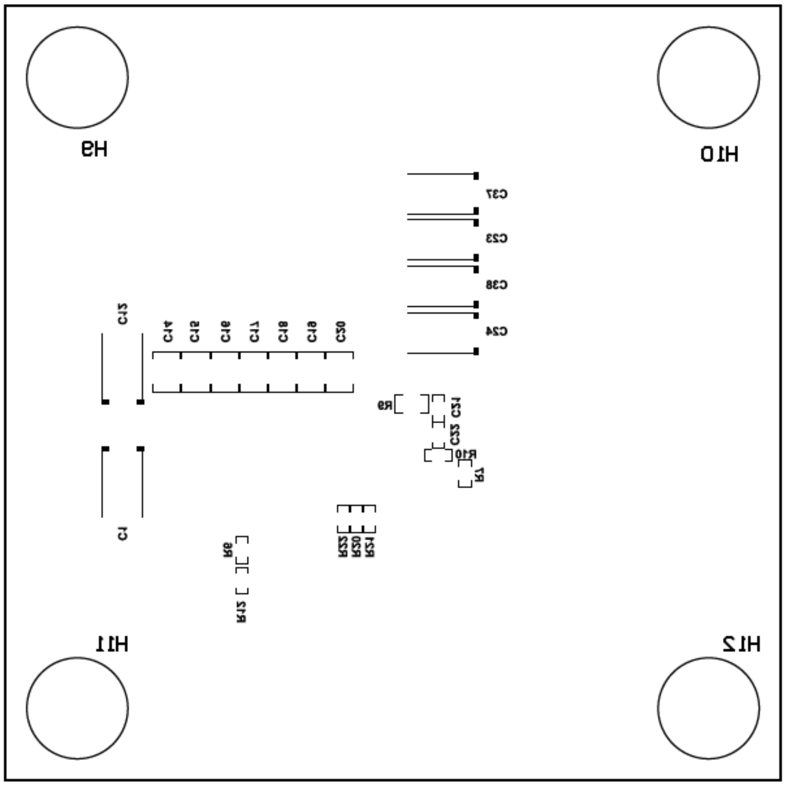

Figure 43. PWR-784EVM Bottom Overlay Layer (Top View)

14 List of Materials

The EVM components list, according to the schematic, is shown in Table 6.

Table 6. 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
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
J6	1		Header (shrouded), 100mil, 5x2, Gold, TH	5x2 Shrouded header	5103308-1	TE Connectivity
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, R25	6	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	CRCW06031K10FKEA	Vishay-Dale
R12, R13, R20, R21, R22	5	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
R24	1	42.2k	RES, 42.2 k, 1%, 0.1 W, 0603	0603	CRCW060342K2FKEA	Vishay-Dale
TP1, TP5, TP6, TP7, TP8, TP9, TP12, TP14, TP15, TP16, TP17, TP20, TP21, TP22	14	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

Table 6. PWR784 List of Materials (continued)

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer
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 PMBus, RVF0040A	RVF0040A	TPS549D22RVF	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
C30, C43	0	100uF	CAP, CERM, 100 µF, 6.3 V, +/- 20%, X5R, 1210	1210	GRM32ER60J107ME20L	Murata
C31	0	0.1uF	CAP, CERM, 0.1 µF, 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 µF, 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 µF, 2.5 V, +/- 20%, 0.006 ohm, 7.3x2.8x4.3mm SMD	7.3x2.8x4.3mm	2R5TPF470M6L	Panasonic
C46	0	1000pF	CAP, CERM, 1000 pF, 50 V, +/- 5%, C0G/NP0, 0603	0603	C0603C102J5GACTU	Kemet
FID1, FID2, FID3, FID4, FID5, FID6	0		Fiducial mark. There is nothing to buy or mount.	Fiducial	N/A	N/A
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

STANDARD TERMS AND CONDITIONS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, or documentation (collectively, an "EVM" or "EVMs") to the User ("User") in accordance with the terms and conditions set forth herein. Acceptance of the EVM is expressly subject to the following terms and conditions.

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   1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

2 *Limited Warranty and Related Remedies/Disclaimers*:

   2.1 These terms and conditions do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.

   2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for any defects that are caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI. Moreover, TI shall not be liable for any defects that result from User's design, specifications or instructions for such EVMs. Testing and other quality control techniques are used to the extent TI deems necessary or as mandated by government requirements. TI does not test all parameters of each EVM.

   2.3 If any EVM fails to conform to the warranty set forth above, TI's sole liability shall be at its option to repair or replace such EVM, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

3 *Regulatory Notices:*

   3.1 *United States*

   3.1.1 *Notice applicable to EVMs not FCC-Approved:*

   This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

   3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

   CAUTION

   This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

   Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

   FCC Interference Statement for Class A EVM devices

   NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。
http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required by Radio Law of Japan to follow the instructions below with respect to EVMs:

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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4 *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user 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, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

6. *Disclaimers:*

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8. *Limitations on Damages and Liability:*

   8.1 *General Limitations*. IN NO EVENT SHALL TI BE LIABLE FOR ANY SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL, OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THESE TERMS ANDCONDITIONS OR THE USE OF THE EVMS PROVIDED HEREUNDER, REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. EXCLUDED DAMAGES INCLUDE, BUT ARE NOT LIMITED TO, COST OF REMOVAL OR REINSTALLATION, ANCILLARY COSTS TO THE PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES, RETESTING, OUTSIDE COMPUTER TIME, LABOR COSTS, LOSS OF GOODWILL, LOSS OF PROFITS, LOSS OF SAVINGS, LOSS OF USE, LOSS OF DATA, OR BUSINESS INTERRUPTION. NO CLAIM, SUIT OR ACTION SHALL BE BROUGHT AGAINST TI MORE THAN ONE YEAR AFTER THE RELATED CAUSE OF ACTION HAS OCCURRED.

   8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY WARRANTY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS AND CONDITIONS, OR ANY USE OF ANY TI EVM PROVIDED HEREUNDER, EXCEED THE TOTAL AMOUNT PAID TO TI FOR THE PARTICULAR UNITS SOLD UNDER THESE TERMS AND CONDITIONS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM AGAINST THE PARTICULAR UNITS SOLD TO USER UNDER THESE TERMS AND CONDITIONS SHALL NOT ENLARGE OR EXTEND THIS LIMIT.

9. *Return Policy.* Except as otherwise provided, TI does not offer any refunds, returns, or exchanges. Furthermore, no return of EVM(s) will be accepted if the package has been opened and no return of the EVM(s) will be accepted if they are damaged or otherwise not in a resalable condition. If User feels it has been incorrectly charged for the EVM(s) it ordered or that delivery violates the applicable order, User should contact TI. All refunds will be made in full within thirty (30) working days from the return of the components(s), excluding any postage or packaging costs.

10. *Governing Law:* These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and TI may seek injunctive relief in any United States or foreign court.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265