TPS65400 4.5- to 18-V Input Flexible Power Management Unit with PMBus/I^{2}C Interface Evaluation Module

This document presents the information required to operate the TPS65400 PMIC as well as the support documentation including schematic, layout, hardware setup and bill of materials.

Contents

List of Figures

List of Tables

1 Background

The TPS65400 is an integrated power management unit (PMU) optimized for applications that require small form factor and high-power conversion efficiency, enabling small space-constrained equipment with high-ambient operating temperature without cooling. The TPS65400 provides high-power efficiency at a system level by enabling a single-stage conversion from an intermediate distribution bus with an optimized combination of regulators.

The TPS65400 consists of four high-current buck-switching regulators (SW1, SW2, SW3, and SW4) with integrated FETs. The switching power supplies are intended for powering high-current digital circuits such as the processor, FPGA, ASIC, memory, and digital I/Os. SW1 and SW2 support 4 A each, and SW3 and SW4 support 2 A each. Each regulator's switching frequency is independently adjustable up to 2.2 MHz.

Current limit programmability on each switcher enables optimization of inductor ratings for a particular application configuration not requiring the maximum current capability. The TPS65400 can be powered from a single-input voltage rail between 4.5 and 18 V, making it suitable for applications running off a 5- or 12-V intermediate power distribution bus. Sequencing requirements can be met using the individual enable pins or by programming the sequence through the I^2C bus into the onboard EEPROM. Output voltages can be set through external resistor networks and VREF can be programmed from 0.6 to 1.87 V in 10-mV steps. All control and status info can be accessed through a PMBus-compatible I^2C bus.

The TPS65400 provides a high level of flexibility for monitoring and control through the I^2C bus while providing the option of programmability through the use of external components and voltage levels for systems not using I^2C. As there are many possible options to set the converters, Table 1 presents the performance specification summary for the EVM.

The evaluation module is designed to provide access to the features of the TPS65400. Some modifications can be made to this module to test performance at different input and output voltages for bucks. Please contact the TI Field Applications group for advice on these matters.

As there are many possible options to set the converters, Table 1 presents the performance specification summary for the EVM.

Table 1. Summary of Performance

Test Conditions	Performance
VIN = 4.5 to 18 V fsw = 500 kHz (25°C ambient)	Buck1, 1.8 V, up to 4 A
	Buck2, 3.3 V, up to 4 A
	Buck3, 1.2 V, up to 2 A
	Buck4, 2.5 V, up to 2A

2 TPS65400 EVM Schematic

Figure 1 illustrates the TPS65400 EVM schematic.

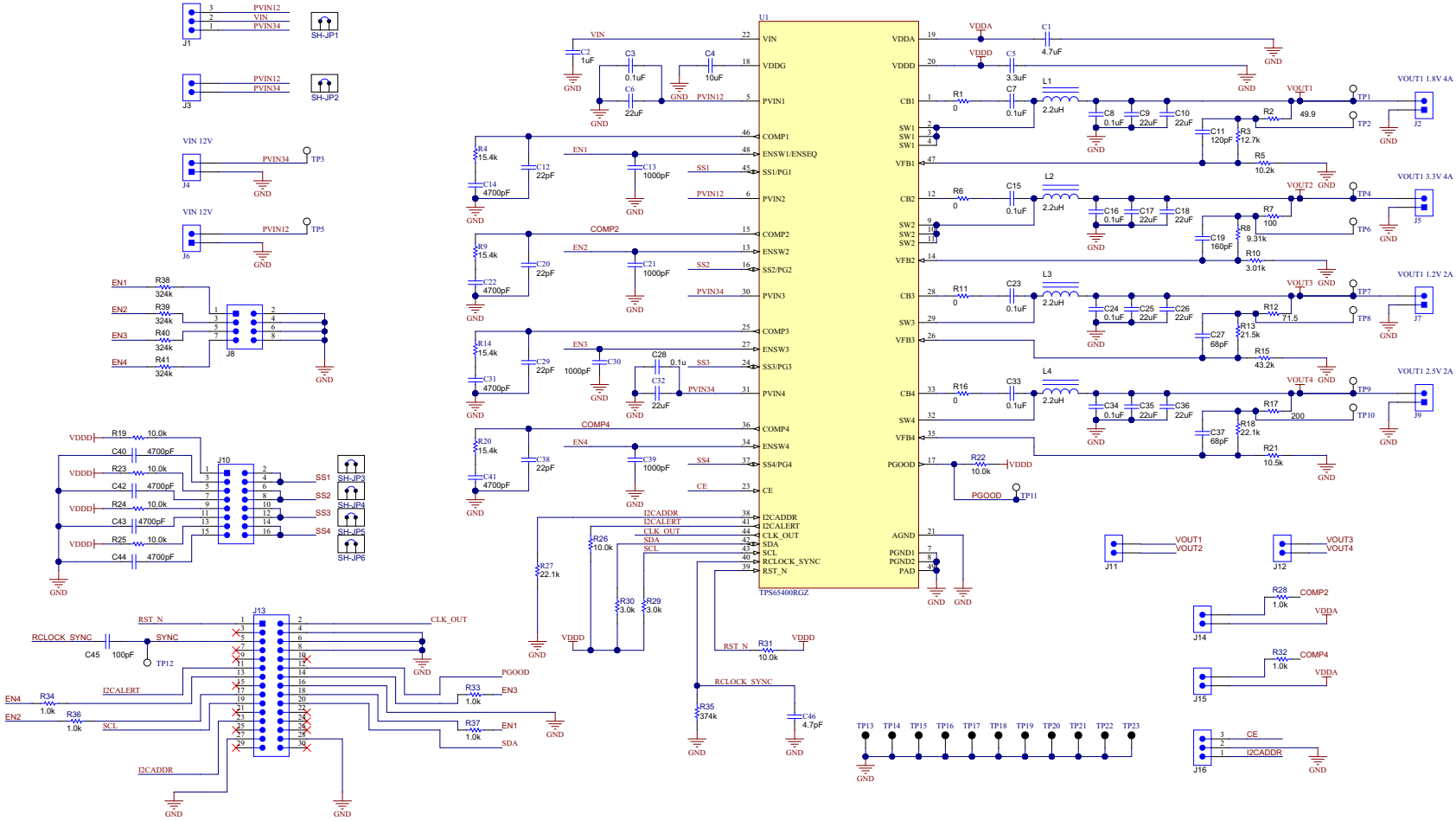

Figure 1. TPS65400 EVM Schematic

3 Board Layout

Figure 2 through Figure 6 illustrate the printed-circuit board (PCB) layouts.

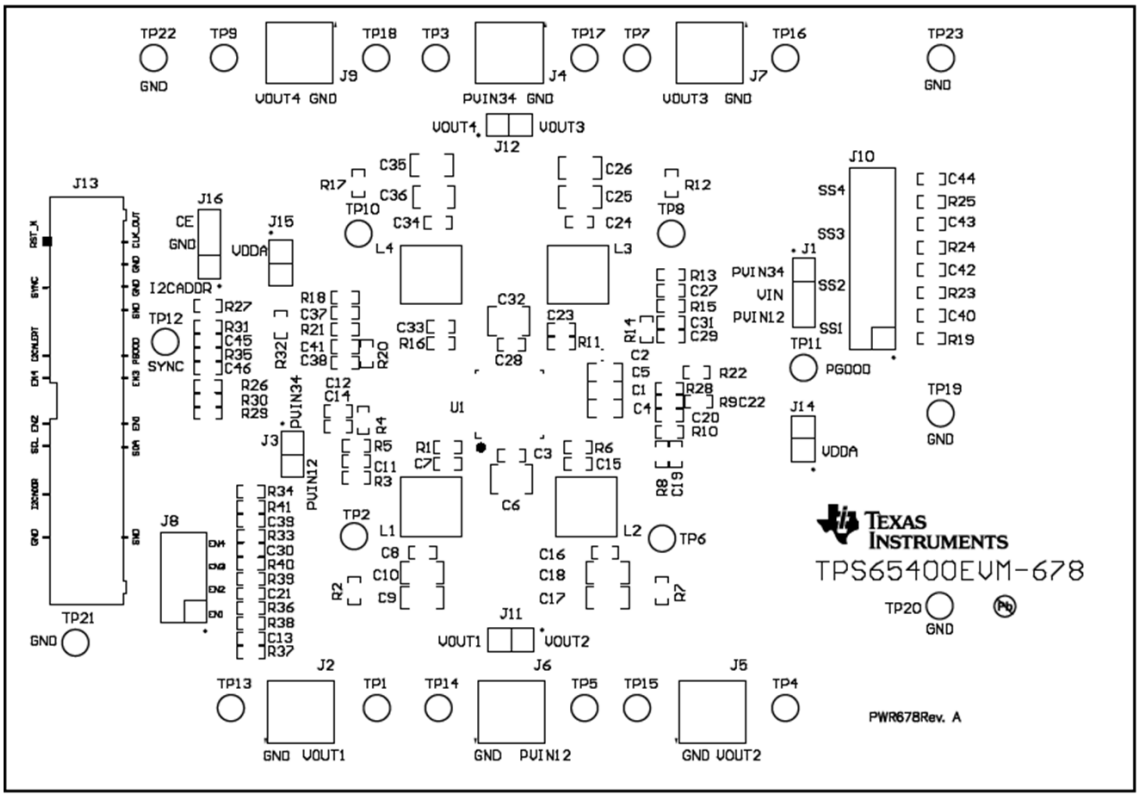

Figure 2. Component Placement (Top Layer)

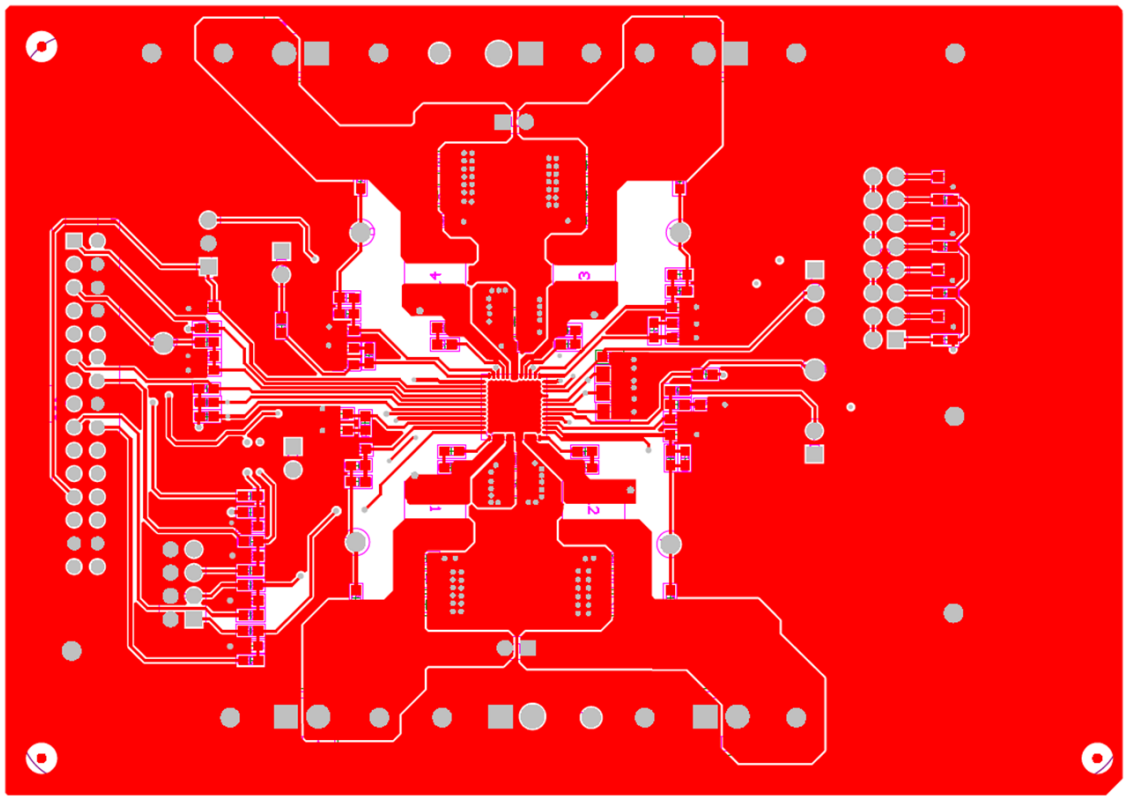

Figure 3. Board Layout (Top Layer)

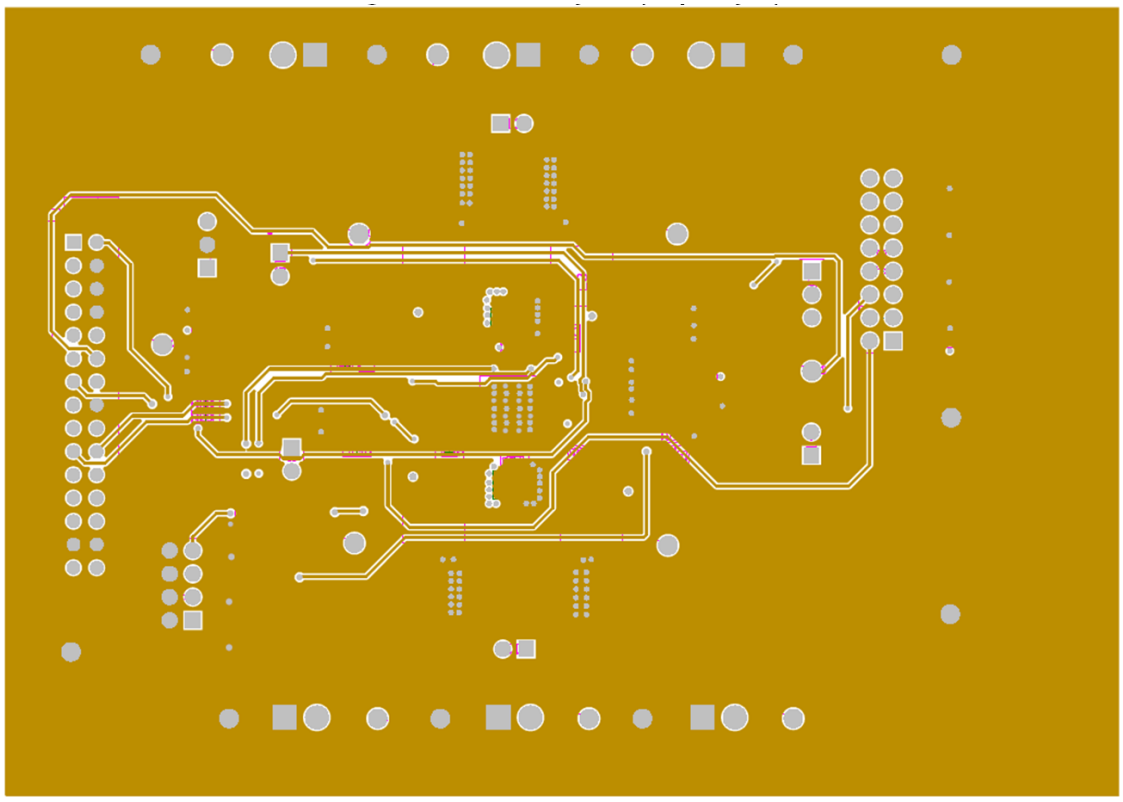

Figure 4. Board Layout (Second Layer)

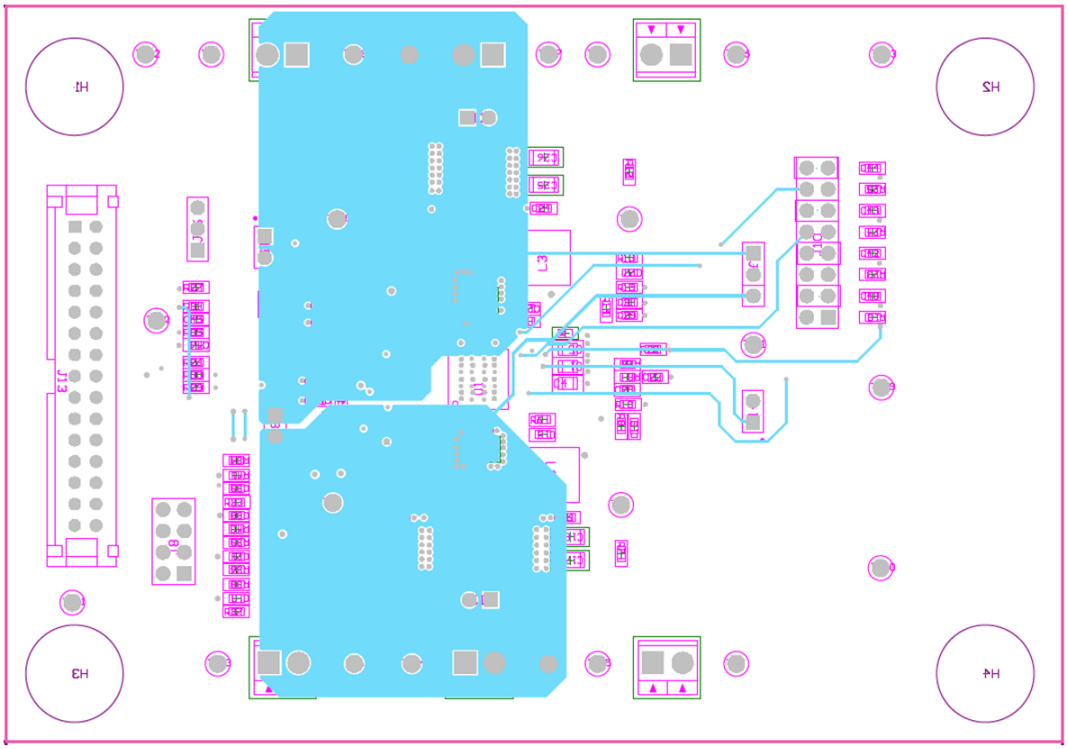

Figure 5. Board Layout (Third Layer)

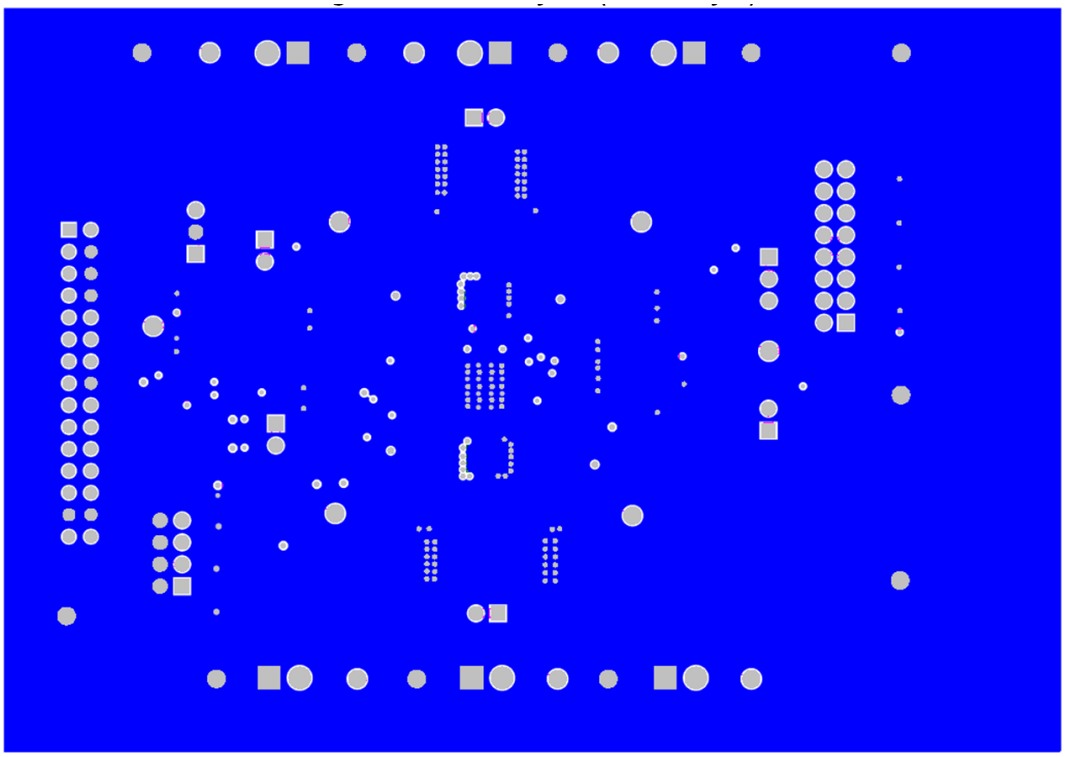

Figure 6. Board Layout (Bottom Layer)

4 Bench Test Setup Conditions

4.1 Headers Description and Jumper Placement

Figure 7 illustrates the header descriptions and jumper placement on the EVM.

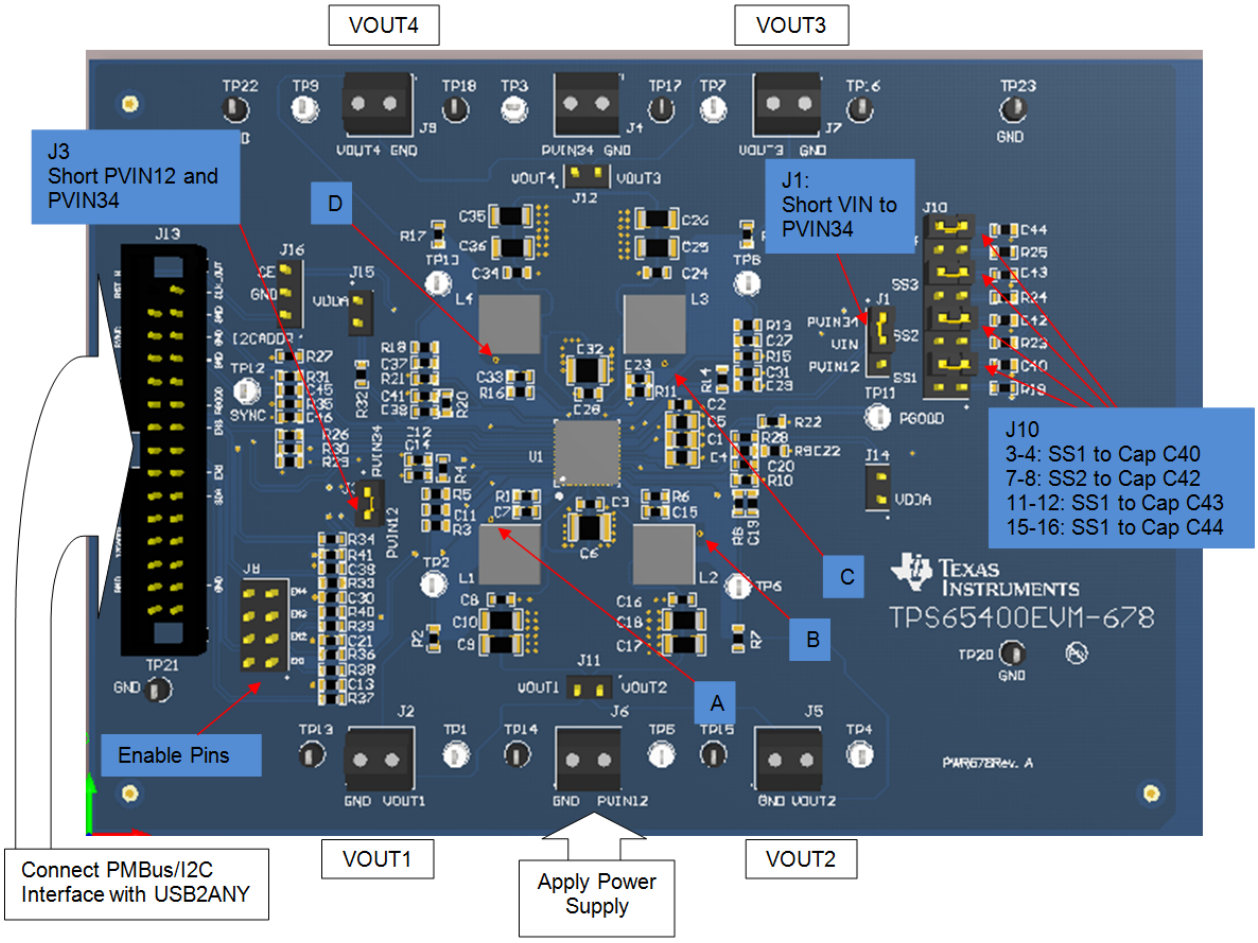

Figure 7. Headers Description and Jumper Placement

Test points:

(A) LX of VOUT1

(B) LX of VOUT2

(C) LX of VOUT3

(D) LX of VOUT4

VOUT1, VOUT2, VOUT3, VOUT4

Table 2. Input/Output Connection

No.	Function	Description
J2	Buck1 Connector	Output of Buck1
J5	Buck2 Connector	Output of Buck2
J7	Buck3 Connector	Output of Buck3
J9	Buck4 Connector	Output of Buck4
J6	Buck1/2/3/4 VIN Connector	Apply power supply to this connector
J13	PMBus/I^{2}C Interface connector	Communication via PMBus/I^{2}C Interface

Table 3. Jumpers

No.	Functions	Description
JP1-PVIN34-Vin-PVIN12	Short VIN to PVIN34	Vin tied to PVIN34
JP3-PVIN12-PVIN34	Short PVIN12 with PVIN34	PVIN34 tied to PVIN12
JP10-3-4	Connect Cap to SS1	tied SS1 to C40
JP10-7-8	Connect Cap to SS2	tied SS2 to C42
JP10-11-12	Connect Cap to SS3	tied SS3 to C43
JP10-15-16	Connect Cap to SS4	tied SS4 to C44

4.2 Hardware Requirement

This EVM requires an external power supply capable of providing 4.5 V to 18 V at 6 A.

The EVM kit includes USB2ANY interface box which, when installed on a PC and connected to the EVM, permits communication with the EVM via a GUI interface. The minimum PC requirements are:

- Microsoft® Windows® 2000, Windows XP, or Windows 7 operating system
- USB port
- Minimum of 30MB of free hard disk space (100MB recommended)
- Minimum of 256MB of RAM

4.3 Hardware Setup

After connecting the power supply to J6 and turning on the power supply, the EVM regulates the output voltages to the value listed in Table 1. Additional input capacitance may be required in order to mitigate the inductive voltage droop that may occur during a load transient event.

In order to change the output voltage by sending the digital control signal via a PC running the TPS65400 controller software and USB2ANY interface box, perform the following steps:

Step 1. Connect the USB port of USB2ANY to the PC using the USB cable and the other end to J13 of the TPS65400 using the supplied 30-pin ribbon cable (Figure 8). The connectors on the ribbon cable are keyed to prevent incorrect installation.

Step 2. Connect the power supply on J6 and turn on the power supply.

Step 3. Run the software as explained in Section 4.4.

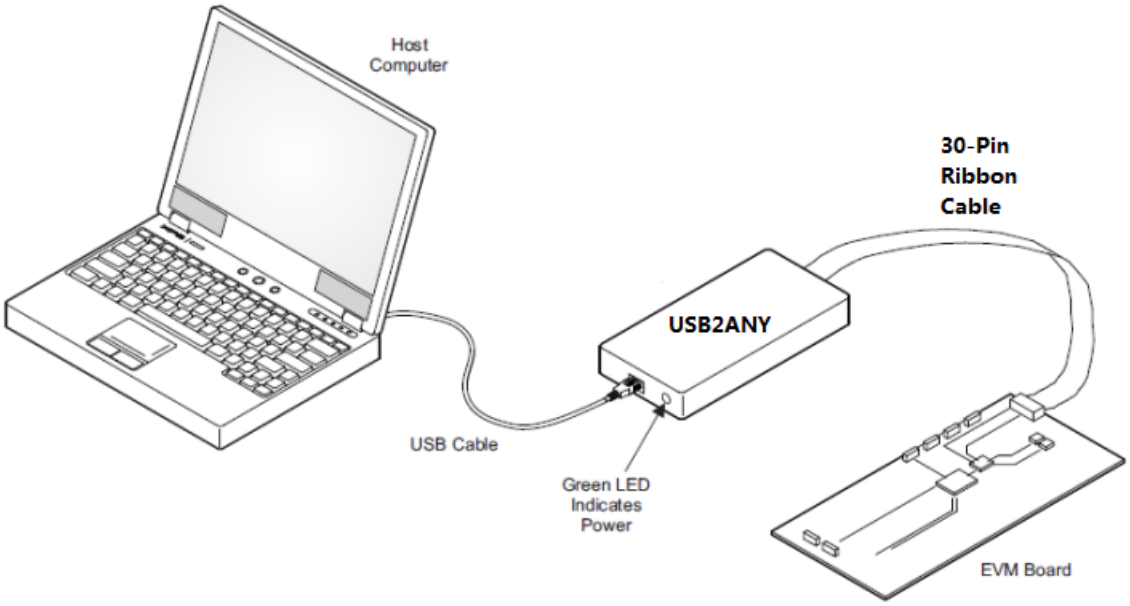

Figure 8. USB Interface Adapter Quick Connection Diagram

4.4 Software Install

If installing from the TI Web site, go to the URL, www.ti.com

NOTE: This installation page is best viewed with the Microsoft® Internet Explorer® browser and may not work correctly with other browsers.

Click on the install button; the PC should give a security warning asking if you want to install this application. Select *Install* to proceed. If a pre-release or Beta version is currently installed on the PC, uninstall this version of the software before installing the final version.

The software attempts to install the Microsoft® .NET Framework 2.0 (if it is not already installed). This framework is required for the software to run.

To run the software after installation, go to
Start → All programs → Texas Instruments → PI-Commander-0.8.4-672M → PI-Commander-PMU.

At start-up, the software first checks the firmware version of the USB2ANY adapter box. If an incorrect firmware version is installed, the software automatically searches on the Internet (if connected) for updates. If a new update is available, the software notifies the user of the update, and downloads and installs the software. Note that after the firmware is updated, the USB cable between the adapter and PC must be disconnected and then reconnected, as instructed during the install process. The host PC software also automatically searches on the Internet (if connected) for updates. If a new update is available, the software notifies the user of the update and downloads and installs it. During future use of the software, it may prompt you to install a new version if one becomes available on the Web.

NOTE: VeriSign® Code Signing is used to prevent any malicious code from changing this application. If at any time in the future the binaries are modified, the code will no longer attempt to run.

4.5 Software Operation

This section provides descriptions of the EVM software.

The supplied software is used to communicate with the TPS65400 EVM. Click on the icon on the host computer to start the software. The software displays the main control panel to connect with the EVM board.

Step 1. Click on *Rescan Slaves*

Step 2. Click on *LM26430-00F1 6a*

Step 3. Click the *No* button on the popup dialog

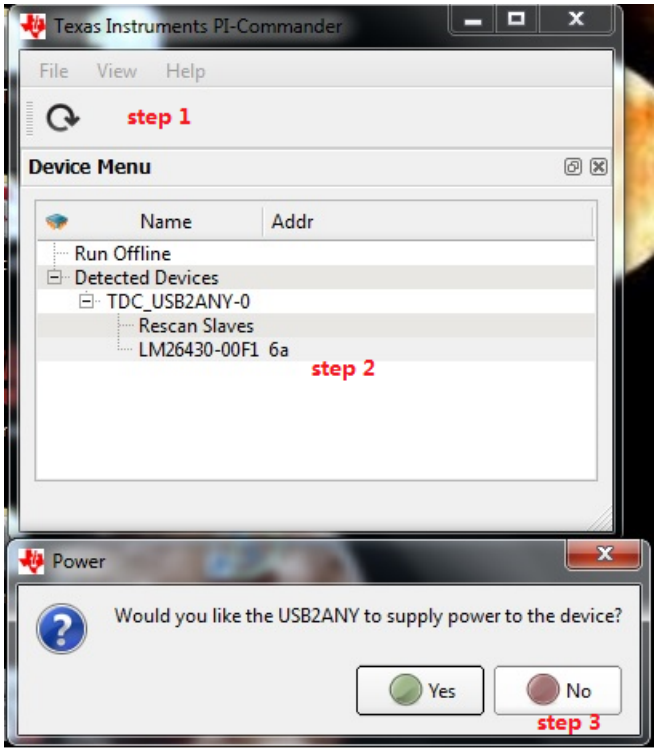

Figure 9. Connect to TPS65400 EVM with EVM GUI

Step 4. Click on *PMBus Register Page*

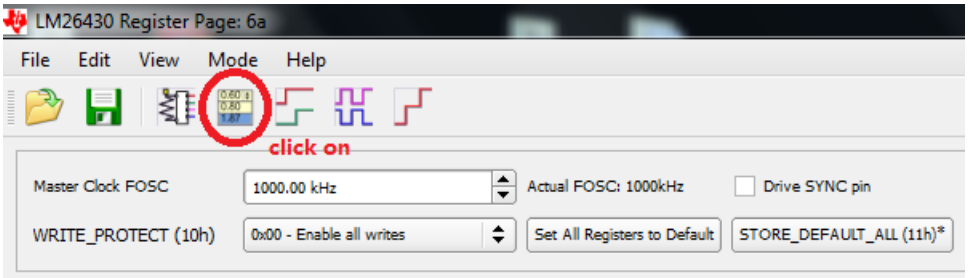

Figure 10. Go to Main Setting Panel

Then, a detail setting panel is presented as shown in Figure 11.

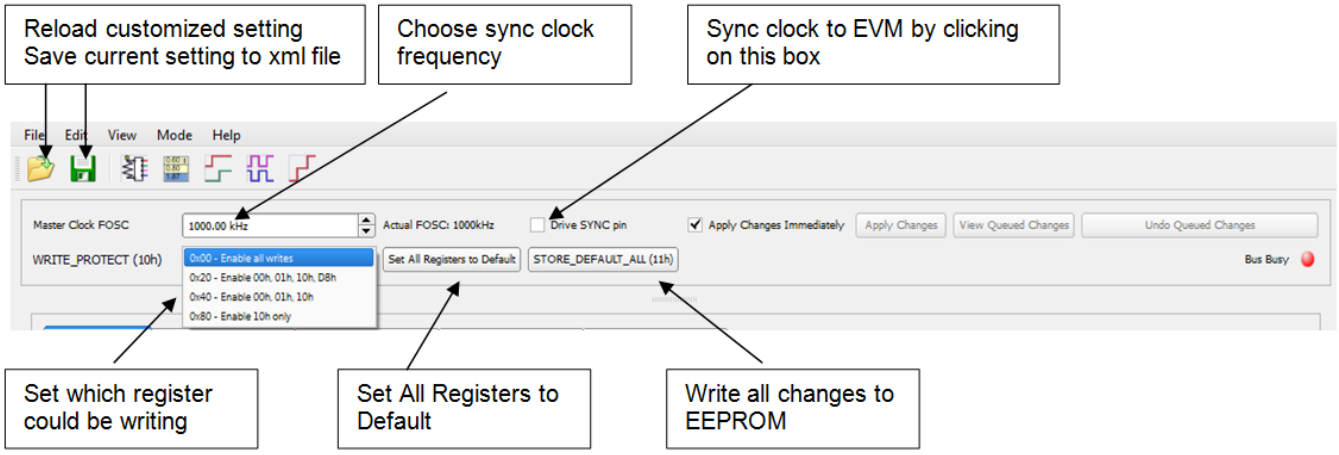

Figure 11. Global Commands

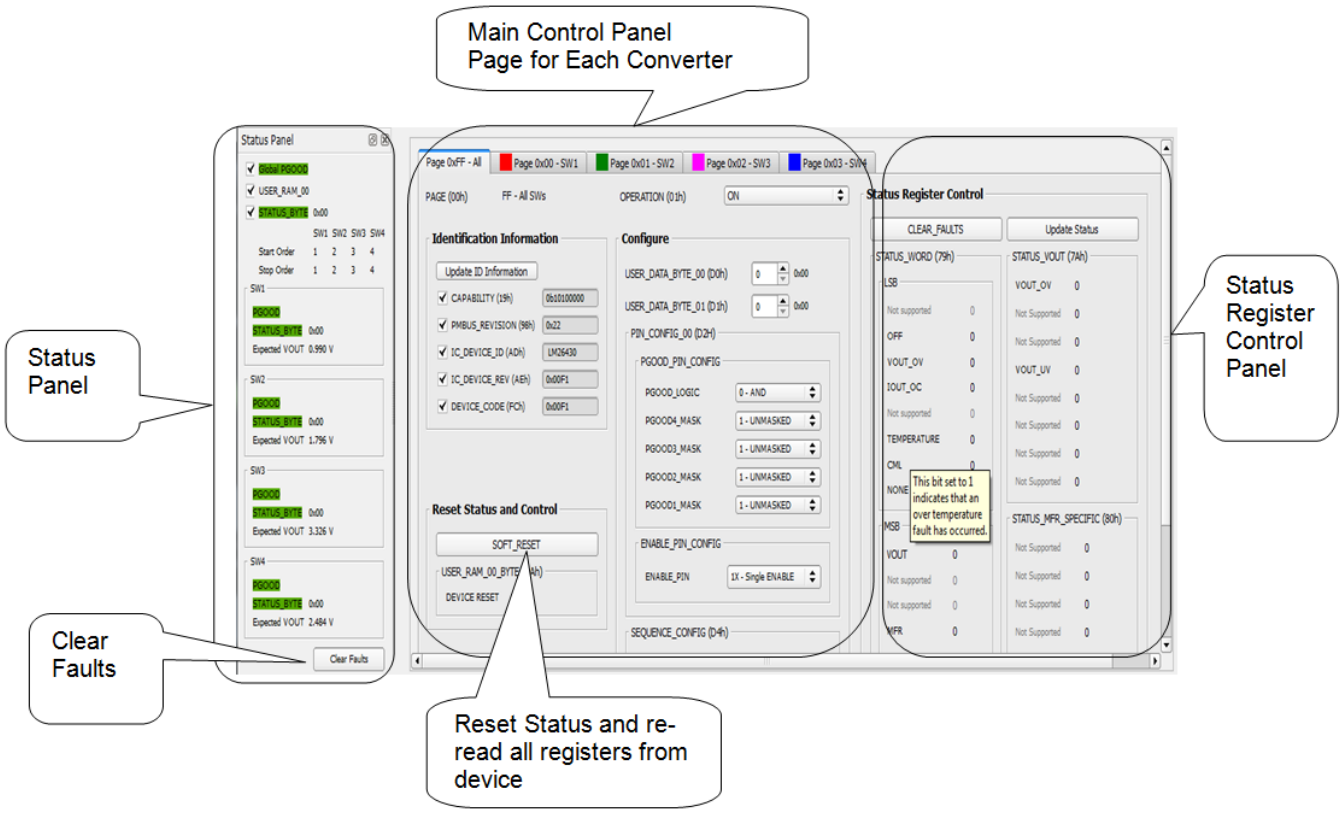

Figure 12. Status and Main Setting Panel

Figure 10 to Figure 15 show the control GUI interface. Vout voltage, phase shift, and power sequence are programmed with this GUI. Detailed information for each option is in the datasheet. Reference the datasheet and select the right option for your application (http://www.ti.com/products/tps65400).

One option is to *Apply Changes Immediately*; if this checkbox is selected, any change is immediately sent to the EVM. *STORE_DEFAULT_ALL* must be clicked to write all settings to EEPROM. EEPROM values can be read back from the EVM by clicking *SOFT_RESET* on *Page 0xFF – ALL*.

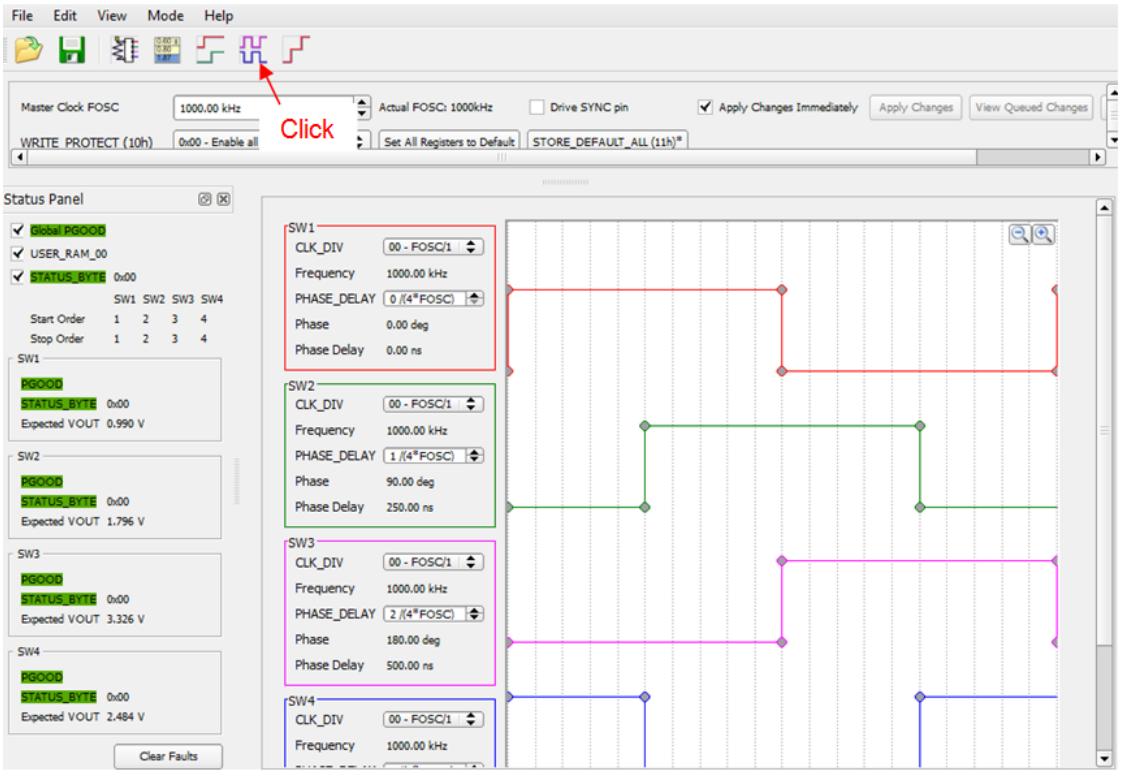

Figure 13. Phase Shift Panel

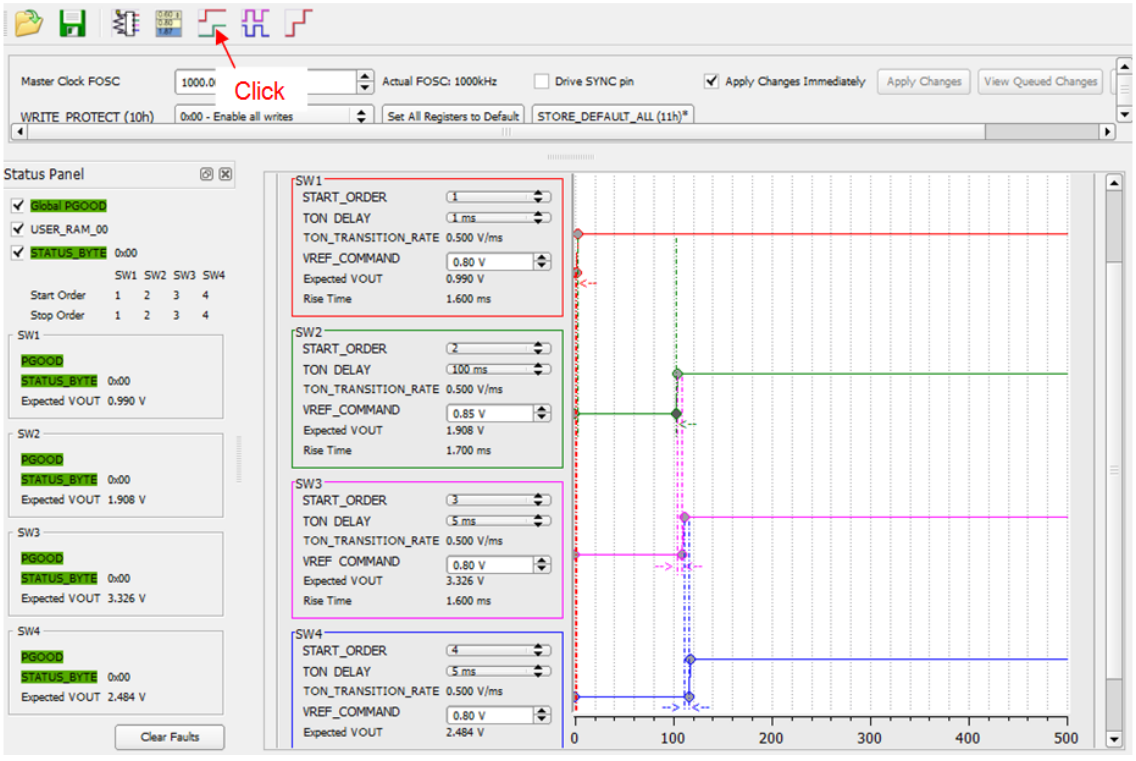

Figure 14. Power Sequence Panel

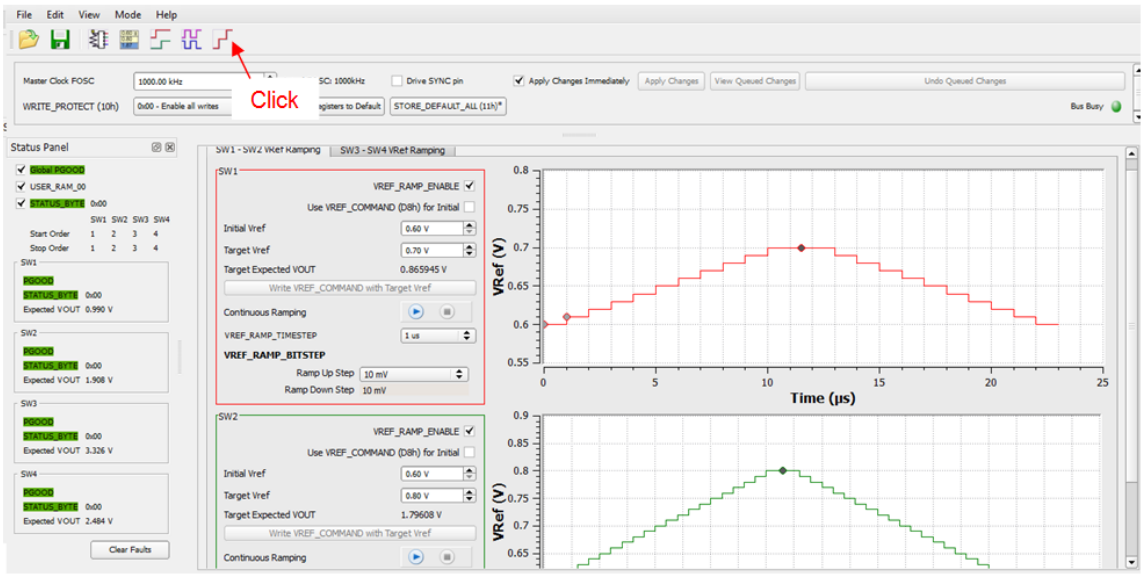

Figure 15. Vref Ramping Up and Down Panel

5 Power-Up Procedure

1. Connect the USB2ANY adaptor to J13 on the EVM board and connect the other port from USB2ANY to the USB port on the host computer
2. Apply 12 V to J6
3. Open the GUI on computer

6 Power-Down Procedure

1. Close the GUI on computer
2. Remove or shutdown 12 V on J6
3. Remove USB2ANY

7 Bill of Materials

Table 4 lists the bill of materials (BOM) for this EVM.

Table 4. Bill of Materials

Designator	Qty.	Value	Description	Package Reference	Part Number	Manufacturer
PCB1	1		Printed Circuit Board		PWR678	Any
C1	1	4.7 µF	CAP, CERM, 4.7 µF, 10 V, ±10%, X7R, 0805	805	LMK212B7475KG-T	Taiyo Yuden
C2	1	1 µF	CAP, CERM, 1 µF, 25 V, ±10%, X7R, 0603_950	0603_950	C0603C105K3RACTU	Kemet
C3	1	0.1 µF	CAP, CERM, 0.1 µF, 25 V, ±10%, X5R, 0603	603	06033D104KAT2A	AVX
C4	1	10 µF	CAP, CERM, 10 µF, 10 V, ±10%, X5R, 0805	805	C0805C106K8PACTU	Kemet
C5	1	3.3 µF	CAP, CERM, 3.3 µF, 10 V, ±10%, X7R, 0805	805	GRM21BR71A335KA99L	Murata
C6, C32	2	22 µF	CAP, CERM, 22 µF, 25 V, ±20%, X5R, 1210	1210	12103D226MAT2A	AVX
C7, C8, C15, C16, C23, C24, C33, C34	8	0.1 µF	CAP, CERM, 0.1µF, 25V, ±10%, X7R, 0603	603	GRM188R71E104KA01D	Murata
C9, C10, C17, C18, C25, C26, C35, C36	8	22 µF	CAP, CERM, 22µF, 10V, ±10%, X7R, 1206	1206	GRM31CR71A226KE15L	Murata
C11	1	120 pF	CAP, CERM, 120 pF, 50 V, ±5%, C0G/NP0, 0603	603	06035A121JAT2A	AVX
C12, C20, C29, C38	4	22 pF	CAP, CERM, 22 pF, 50 V, ±5%, C0G/NP0, 0603	603	06035A220JAT2A	AVX
C13, C21, C30, C39	4	1000 pF	CAP, CERM, 1000 pF, 50 V, ±10%, C0G/NP0, 0603	603	06035A102KAT2A	AVX
C14, C22, C31, C41	4	4700 pF	CAP, CERM, 4700 pF, 50 V, ±10%, X5R, 0603	603	GRM188R61H472KA01D	Murata
C19	1	160 pF	CAP, CERM, 160 pF, 50 V, ±5%, C0G/NP0, 0603	603	GRM1885C1H161JA01D	Murata
C27, C37	2	68 pF	CAP, CERM, 68 pF, 50 V, ±5%, C0G/NP0, 0603	603	06035A680JAT2A	AVX
C28	1	0.1 µF	CAP, CERM, 0.1 µF, 50 V, ±10%, X7R, 0603	603	06035C104KAT2A	AVX
C40, C42, C43, C44	4	4700 pF	CAP, CERM, 4700 pF, 100 V, ±10%, X7R, 0603	603	06031C472KAT2A	AVX
C45	1	100 pF	CAP, CERM, 100 pF, 25 V, ±10%, X7R, 0603	603	06033C101KAT2A	AVX
C46	1	4.7 pF	CAP, CERM, 4.7 pF, 50 V, ±5%, C0G/NP0, 0603	603	06035A4R7CAT2A	AVX
H1, H2, H3, H4	4		Bumpon, Hemisphere, 0.44 X 0.20, Clear	Transparent Bumpon	SJ-5303 (CLEAR)	3M
J1, J16	2		Header, TH, 100mil, 3x1, Gold plated, 230 mil above insulator	TSW-103-07-G-S	TSW-103-07-G-S	Samtec, Inc.
J2, J4, J5, J6, J7, J9	6		Terminal Block, 6A, 3.5mm Pitch, 2-Pos, TH	7.0x8.2x6.5mm	ED555/2DS	On-Shore Technology
J3, J11, J12, J14, J15	5		Header, TH, 100mil, 2x1, Gold plated, 230 mil above insulator	TSW-102-07-G-S	TSW-102-07-G-S	Samtec, Inc.
J8	1		Header, 100mil, 4x2, Gold, TH	4x2 Header	TSW-104-07-G-D	Samtec
J10	1		Header, 100mil, 8x2, Gold, TH	8x2 Header	TSW-108-07-G-D	Samtec
J13	1		Connector, 15x2, 3A 300V STRT DIP, TH	Connector, 15x2, Pitch 2.54mm, TH	XG4C-3031	Omron Electronic Components
L1, L2, L3, L4	4	2.2µH	Inductor, Shielded, Composite, 2.2µH, 12.7A, 0.012 Ω, SMD	IND_6.4x3.1x6.6	XAL6030-222MEB	Coilcraft
R1, R6, R11, R16	4	0	RES, 0, 5%, 0.1 W, 0603	603	CRCW06030000Z0EA	Vishay-Dale
R2	1	49.9	RES, 49.9, 1%, 0.1 W, 0603	603	CRCW060349R9FKEA	Vishay-Dale
R3	1	12.7k	RES, 12.7 k, 1%, 0.1 W, 0603	603	CRCW060312K7FKEA	Vishay-Dale
R4, R9, R14, R20	4	15.4k	RES, 15.4 k, 1%, 0.1 W, 0603	603	CRCW060315K4FKEA	Vishay-Dale
R5	1	10.2k	RES, 10.2 k, 1%, 0.1 W, 0603	603	CRCW060310K2FKEA	Vishay-Dale

Table 4. Bill of Materials (continued)

Designator	Qty.	Value	Description	Package Reference	Part Number	Manufacturer
R7	1	100	RES, 100, 1%, 0.1 W, 0603	603	CRCW0603100RFKEA	Vishay-Dale
R8	1	9.31k	RES, 9.31 k, 1%, 0.1 W, 0603	603	CRCW06039K31FKEA	Vishay-Dale
R10	1	3.01k	RES, 3.01 k, 1%, 0.1 W, 0603	603	CRCW06033K01FKEA	Vishay-Dale
R12	1	71.5	RES, 71.5, 1%, 0.1 W, 0603	603	CRCW060371R5FKEA	Vishay-Dale
R13	1	21.5k	RES, 21.5 k, 1%, 0.1 W, 0603	603	CRCW060321K5FKEA	Vishay-Dale
R15	1	43.2k	RES, 43.2 k, 1%, 0.1 W, 0603	603	CRCW060343K2FKEA	Vishay-Dale
R17	1	200	RES, 200, 1%, 0.1 W, 0603	603	CRCW0603200RFKEA	Vishay-Dale
R18, R27	2	22.1k	RES, 22.1 k, 1%, 0.1 W, 0603	603	CRCW060322K1FKEA	Vishay-Dale
R19, R22, R23, R24, R25, R26, R31	7	10.0k	RES, 10.0 k, 1%, 0.1 W, 0603	603	CRCW060310K0FKEA	Vishay-Dale
R21	1	10.5k	RES, 10.5 k, 1%, 0.1 W, 0603	603	CRCW060310K5FKEA	Vishay-Dale
R28, R32, R33, R34, R36, R37	6	1.0k	RES, 1.0 k, 5%, 0.1 W, 0603	603	CRCW06031K00JNEA	Vishay-Dale
R29, R30	2	3.0k	RES, 3.0 k, 5%, 0.1 W, 0603	603	CRCW06033K00JNEA	Vishay-Dale
R35	1	374k	RES, 374 k, 1%, 0.1 W, 0603	603	CRCW0603374KFKEA	Vishay-Dale
R38, R39, R40, R41	4	324k	RES, 324 k, 1%, 0.1 W, 0603	603	CRCW0603324KFKEA	Vishay-Dale
SH-JP1, SH-JP2, SH-JP3, SH-JP4, SH-JP5, SH-JP6	6	1x2	Shunt, 100mil, Gold plated, Black	Shunt	969102-0000-DA	3M
TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP11, TP12	12	White	Test Point, Miniature, White, TH	White Miniature Testpoint	5002	Keystone
TP13, TP14, TP15, TP16, TP17, TP18, TP19, TP20, TP21, TP22, TP23	11	Black	Test Point, Miniature, Black, TH	Black Miniature Testpoint	5001	Keystone
U1	1		4.5V to 18V Input Flexible Power Management Unit with PMBus/ I2C and Integrated Sequencing, RGZ0048G	RGZ0048G	TPS65400RGZ or LM26430RGZ	Texas Instruments
FID1, FID2, FID3	0		Fiducial mark. There is nothing to buy or mount.	Fiducial	N/A	N/A

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as “components”) are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers’ products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers’ products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have ***not*** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		

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