

Using the TPSM831D31 Power Module Evaluation Module

This user's guide contains information for the TPSM831D31EVM evaluation module (BSR048). This guide provides information regarding the proper setup and use of the board to permit an in-depth evaluation of the performance and characteristics of the power module.

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1 Description

The TPSM831D31 is a PMBus-controlled, dual output 4-phase power module that combines a high-performance DCAP+ controller with four high-efficiency smart power stages and low-loss inductors, into a rugged, thermally enhanced surface-mount package. The first output is configured as a 3-phase power stage that can deliver up to 120 A of continuous output current. The second output is a single phase power stage that can deliver up to 40 A of output current. The input voltage range is 8 V to 14 V. The output voltage range is 0.25 V to 1.52 V.

The PMBus interface provides for configuration of each VOUT, UVLO, soft start, overcurrent, and thermal shutdown parameters. The interface provides support for telemetry that can report the actual input voltage, output voltage, output current, and device temperature. The computed input and input power can also be reported. Standard PMBus “warning” and “fault” functions are also supported. The device supports PMBus communication speeds up to 1 MHz, with 1.8-V or 3.3-V logic levels, as detailed in Section 4.3 of SMBus Specification V3.0. The module supports a subset of the commands in the PMBus 1.3 specification.

This evaluation board is designed to demonstrate the functionality and performance of the TPSM831D31 power module. Monitoring test points are provided to allow measurement of efficiency, power dissipation, input ripple, output ripple, line and load regulation. A special high-speed transient load generator is also included on the board that can produce load transients up to 60A at slew rates in excess of 100 A/ μ s.

2 Getting Started

[Figure 1](#) highlights the user interface items associated with the EVM. The polarized input power terminal block (J10) is used for connection to the host input supply. Note that under full load conditions, the input current can approach 20 A. Terminal blocks J1, J2, and J3 provide connections for VOUT_A. Each terminal block has a receptacle for VOUT_A and GND for connection to the load. These terminal blocks are rated for 60 A of current and can accept up to 6 AWG wire. Terminal block J4 provides the connections for the VOUT_B output. This terminal block is rated for 60 A of current and can accept up to 6 AWG wire.

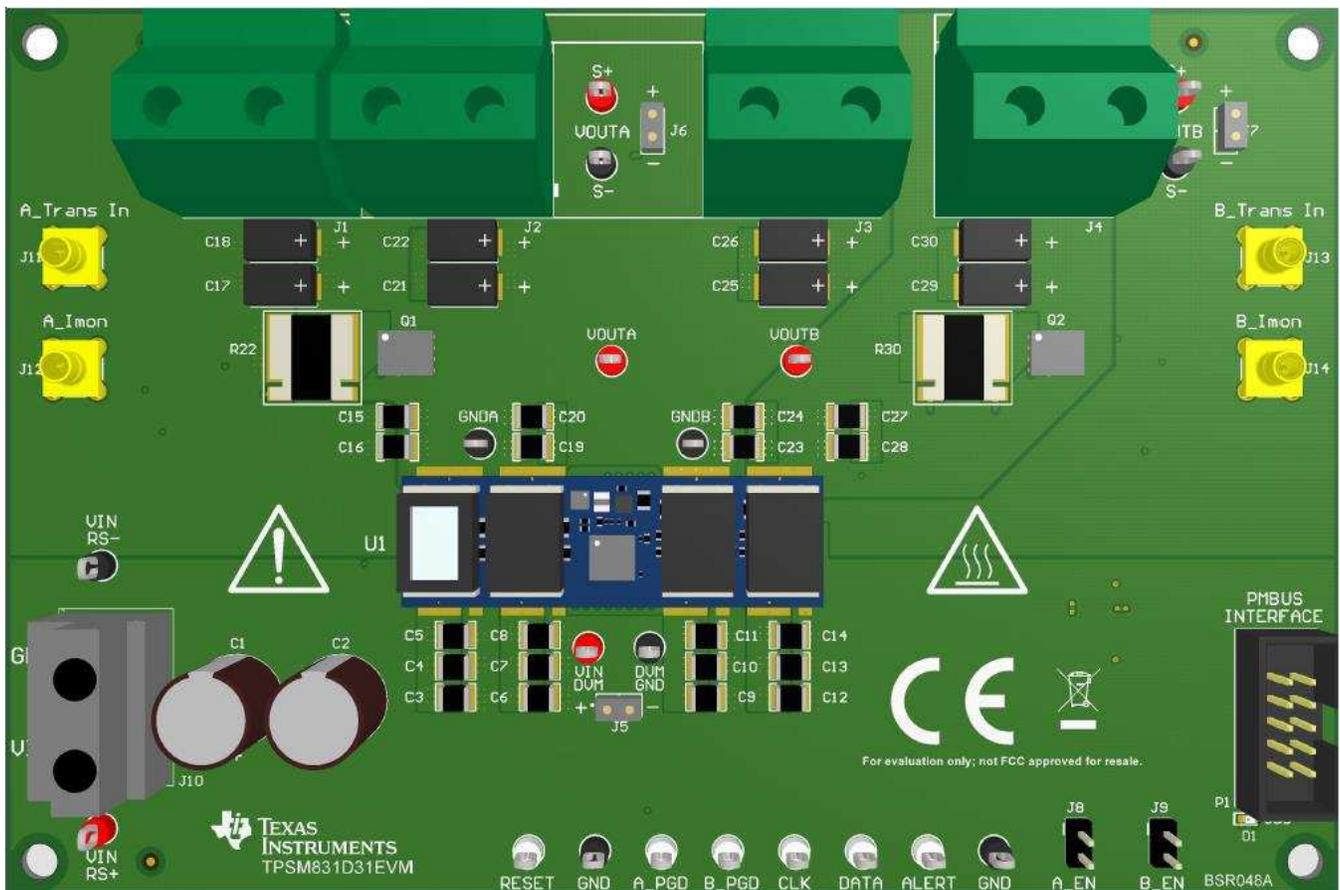


Figure 1. EVM User Interface

The VIN RS+ and VIN RS- test points provide convenient connection points for the remote sense leads of the host input supply. These test points monitor the input voltage at the input pins of the module. **Do not use these monitoring test points as the input supply connection points. The PCB traces connected to these test points are not designed to support high currents.**

The VIN DVM and DVM GND test points allow easy connection of a DVM to monitor the input voltage at the input pins of the module. This monitoring point should be used as the VIN reading for efficiency measurements. Header J5 provides a test point for monitoring the VIN waveform with an oscilloscope using an un-hooded scope probe outfitted with a low-inductance ground lead (ground spring) mounted to the scope probe GND barrel. The scope tip should be inserted in the + side of J5. The ground lead should be inserted in the – side of J5. It is strongly suggested that these connections be made with the host power turned off.

The VOUTA and GND A test points provide connection points for a DVM that monitors the output voltage of VOUT_A at the module pins. This monitoring point should be used as the VOUT_A reading for efficiency measurements. The VOUTB and GND B test points provide connection points for a DVM that monitors the VOUT_B voltage at the module pins. This monitoring point should be used as the VOUT_B reading for efficiency measurements. **Do not use these monitoring test points as the output load connection points. The PCB traces connected to these test points are not designed to support high currents.**

The VOUTA S+ and S- test points are wired to the points where the remote sense connections are made for the VOUT_A output. Connect a DVM to these points to evaluate the load regulation of VOUT_A. **Do not pull load current from these test points.** Header J6 is provided as an oscilloscope monitoring test point for VOUT_A for a probe equipped with a low inductance ground lead. Use this test point to evaluate ripple and transient response of the VOUT_A rail. It is strongly suggested that the scope connections be made with VOUT_A turned off.

The VOUTB S+ and S- test points are wired to the points where the remote sense connections are made for the VOUT_B output. Connect a DVM to these points to evaluate the load regulation of VOUT_B. **Do not pull load current from these test points.** Header J7 is provided as an oscilloscope monitoring test point for VOUT_B for a probe equipped with a low inductance ground lead. Use this test point to evaluate ripple and transient response of the VOUT_B rail. It is strongly suggested that the scope connections be made with VOUT_B turned off.

The test points along the bottom edge of the EVM provide access to the Power Good, PMBus, and Enable signals. Pullup resistors to 3.3 V have been provided on the board for these open-drain signals.

The PMBus Interface connector (P1) is provided to connect the USB to GPIO interface pod to the EVM. (The pod can be ordered from TI at <http://www.ti.com/tool/usb-to-gpio>.) The USB to GPIO interface pod connects the EVM to a computer USB port which allows the TI “Fusion” Graphical User Interface (GUI) to communicate and control the EVM. To download the latest software visit, http://www.ti.com/tool/fusion_digital_power_designer. Make certain to obtain version V7.0.25 or later to insure proper operation of the EVM. When the USB to GPIO pod is properly connected to a USB port, diode D1 (USB) will glow green. The LED will light even if no input power is applied to the EVM.

The PMBus address is set by resistor R10. The PMBus address of the EVM is set to 105 (decimal), 69 (hex).

3 Test Point Descriptions

Wire-loop test points and scope probe test points are provide as convenient connection points for digital voltmeters (DVM) or oscilloscope probes to aid in the evaluation of the module. A description of each test point follows.

Table 1. Test Points

VIN RS+, VIN RS-	Remote sense connection points for host input supply. Use these to maintain the desired input voltage at the input to the module.
VIN DVM, DVM GND	Input voltage monitor. Connect a DVM across these points to measure efficiency.
VIN MON (J5)	Input voltage scope monitor. Connect an oscilloscope to this set of points to measure input ripple.
VOUTA, GNDA	VOUT_A output voltage monitor. Connect a DVM across these points to measure efficiency.
VOUTB, GNDB	VOUT_B output voltage monitor. Connect a DVM across these points to measure efficiency.
VOUTA S+, S-	VOUT_A remote sense points. Connect a DVM across these points to measure load and line regulation.
VOUT_A MON (J6)	VOUT_A output voltage scope monitor. Connect an oscilloscope to this set of points to measure output ripple and transient response.
VOUTB S+, S-	VOUT_B remote sense points. Connect a DVM across these points to measure load and line regulation.
VOUT_B MON (J7)	VOUT_B output voltage scope monitor. Connect an oscilloscope to this set of points to measure output ripple and transient response.
RESET	Module reset pin. Normally high. Pull low to reset module to default VOUT values.
A_PG D	VOUT_A Power Good. Open drain signal pulled up via a 10k to 3.3V. When high, VOUT_A is converting power with no faults detected.
B_PG D	VOUT_B Power Good. Open drain signal pulled up via a 10k to 3.3V. When high, VOUT_B is converting power with no faults detected.
CLK	PMBus CLK line. Used to monitor the CLK signal.
DATA	PMBus DATA line. Used to monitor the DATA signal.
ALERT	PMBus ALERT line. Used to monitor the ALERT signal.
A_EN (J8)	VOUT_A enable pin. Open drain signal pulled up via a 10k to 3.3V. When jumper is removed, VOUT_A is allowed to convert power. Place a jumper across both pins to stop power conversion. Note that the USB to GPIO pod can also control this pin.
B_EN (J9)	VOUT_B enable pin. Open drain signal pulled up via a 10k to 3.3V. When jumper is removed, VOUT_B is allowed to convert power. Place a jumper across both pins to stop power conversion. Note that the USB to GPIO pod can also control this pin.
GND	Convenience GND connection for DVMs or scope probes.
5V, 3V3	Monitor points for on-board 5V and 3.3V bias rails generated by the EVM. These voltages are used for pull-up resistors and the fast transient generation circuitry. These do not monitor the bias rails on the TPSM831D31 module.
A_Trans In (J11)	SMB jack input from external function generator to drive the VOUT_A fast transient generator.
A_Imon (J12)	SMB jack for current monitor output of VOUT_A transient generator. 3mV/A, 50Ω output impedance.
B_Trans In (J13)	SMB jack input from external function generator to drive the VOUT_B fast transient generator.
B_Imon (J14)	SMB jack for current monitor output of VOUT_B transient generator. 3mV/A, 50Ω output impedance.

4 Connecting the EVM

When connecting the EVM for evaluation at high currents, care must be taken to use heavy gauge wire that can safely conduct the currents as high as 120 A on VOUT_A and 40 A on VOUT_B. The length of the output connections must be kept as short as possible to minimize the voltage drop in the wiring. Many electronic loads cannot produce the desired load current if the voltage at their input terminals falls below ~700mV. The use of multiple loads connected in parallel, operated in constant current mode permits the load current to be shared over multiple paths. This reduces the overall voltage drop and enables operation to high currents and lower voltages before the loads reach their saturation point. [Figure 2](#) shows a test configuration that allows testing to 120 A on VOUT_A and 40 A on VOUT_B. A total of four 60 A-rated electronic load modules are used in this setup. The input voltage wiring should be rated to handle at least 20 A of current. If the host input supply supports remote sensing, its use is recommended.

As an added precaution, the user of the EVM is strongly encouraged set the maximum current of their host input power supply to no higher than 25A.

The TPMS831D31 module requires communication over the PMBus to allow for configuration, control, and transmission of telemetry data. Connect the 10-pin ribbon cable from the USB Interface Adapter pod to the PMBus Interface header (P1). Connect a USB cable from the pod to a USB port of a computer that has the Fusion Digital Power Designer application loaded. If the pod is properly recognized by the computer, LED D1 should light on the EVM.

Before launching the fusion digital power GUI software, apply input power to the EVM. Set the input voltage in the range from 8 V to 14 V. Set any electronic loads to no-load. After power has been applied, launch the GUI software using the Fusion Designer Online shortcut icon, if present. As the software loads, it should detect the presence of the USB to GPIO pod and begin scanning for devices on the PMBus. It should detect the EVM at address 105 (decimal), 69 (hex) on the bus. The EVM must be powered-up for this device scan to be successful. The GUI may identify the device as a TPS53681. This is normal. That is the device used as the controller in the module.

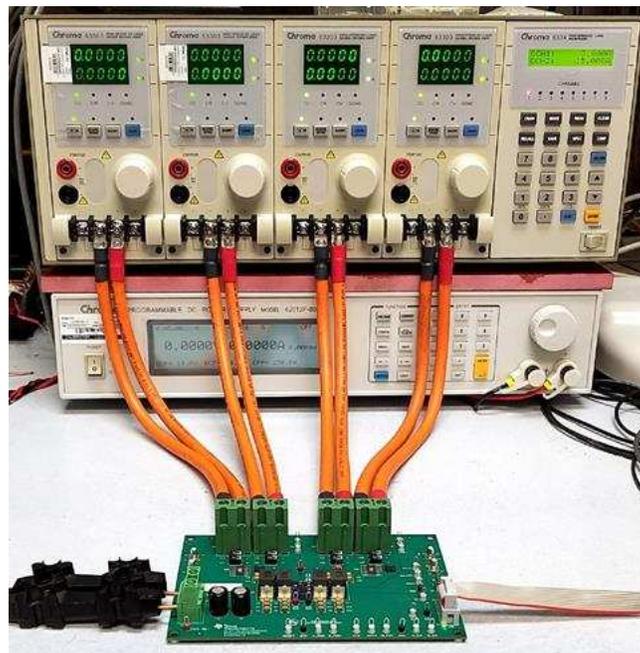


Figure 2. Example Test Setup

5 Using the Fusion Digital Power Designer GUI

When the GUI correctly detects the presence of the EVM, the System View screen will be presented as shown in [Figure 3](#). It shows two output rails have been detected. Rail #1 is the three-phase 120 A-rated rail. Rail #2 is the single phase 40 A-rated rail. Click on the “Click to configure device” link to activate the Configuration window.

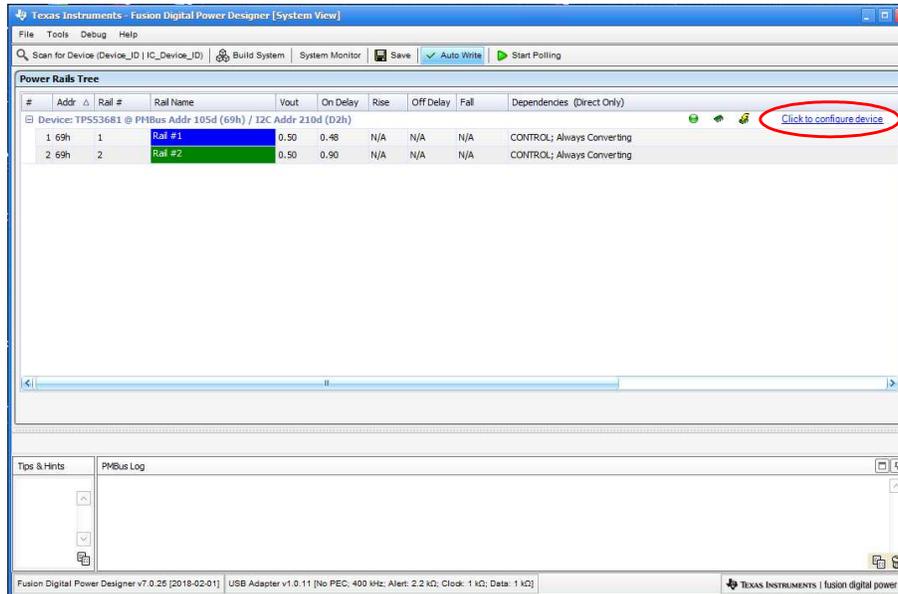


Figure 3. System View Window

[Figure 4](#) shows the General tab of the Configuration window. The drop-down box in the top right corner selects the rail that is currently being configured. The various tabs across the top select different groups of parameters that can be displayed and modified. The buttons along the lower left side select different display modes. In the General tab settings, the switching frequency, Fsw, can be selected from the drop-down box. When values are changed, they are not transmitted to the module until the Write To Hardware button is clicked. When it is clicked, the new values are written to RAM in the controller. (This button will be greyed-out until a parameter is changed.) The new values are not permanently stored in the device Non-Volatile Memory (NVM). If power is removed from the module, the new values are lost. If you want to retain the new configuration values, then the Store Config to NVM button must be clicked. Keep in mind that a Store Config to NVM command stores any and all new settings to NVM. The original factory settings cannot be restored if they are altered.

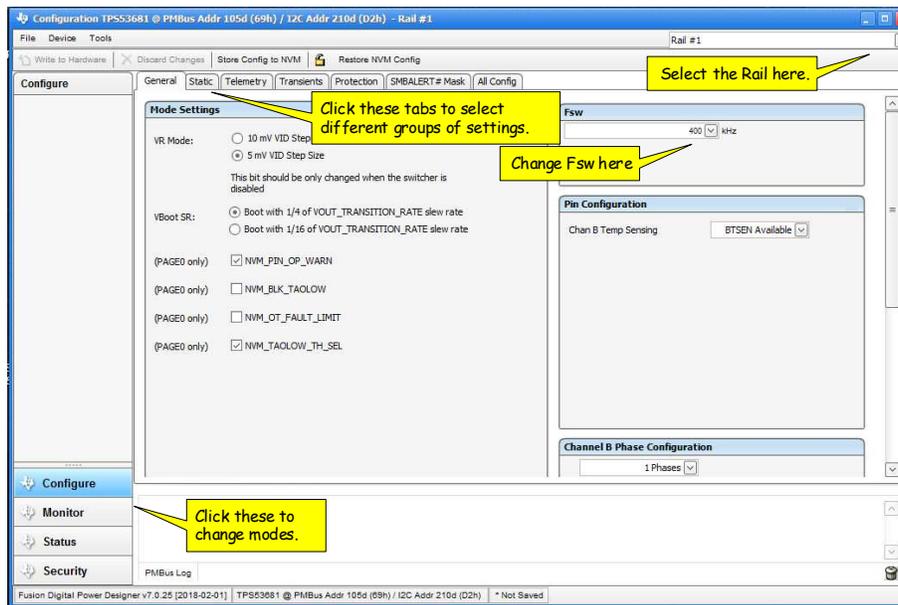


Figure 4. Configuration Window: General Tab

The Static tab of the Configuration page is shown in Figure 5. This is where the output voltage parameters are displayed and altered. The default power-up/restart voltage is set by the VBOOT (MFR_11) value. The present output voltage can be altered by changing the value of the Vout Command setting. Changes do not take effect until the Write to Hardware button is clicked. Each rail has its own settings. Use the Rail drop-down box to switch and display the other rail's settings.

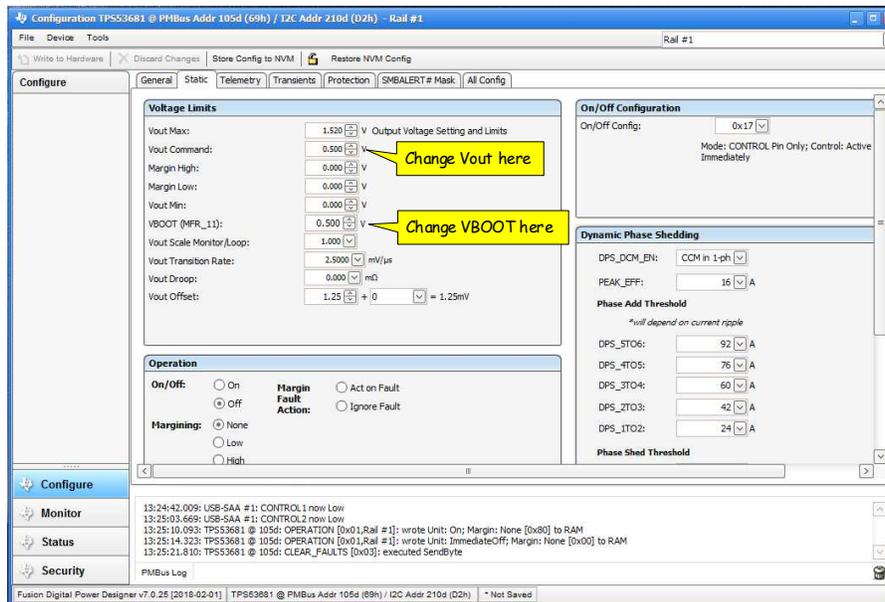


Figure 5. Configuration Window: Static Tab

Once configuration is complete, the performance of the module can be displayed by clicking the Monitor button. This brings up the telemetry page. A typical display is shown in Figure 6. You can select which parameters to plot using the check-boxes on the upper left side. The selected parameters will be plotted as a collection of strip-charts in their separate windows. Axis limits can be set within each plot. Start/Stop Polling button starts or stops the collection of data over the PMBus.

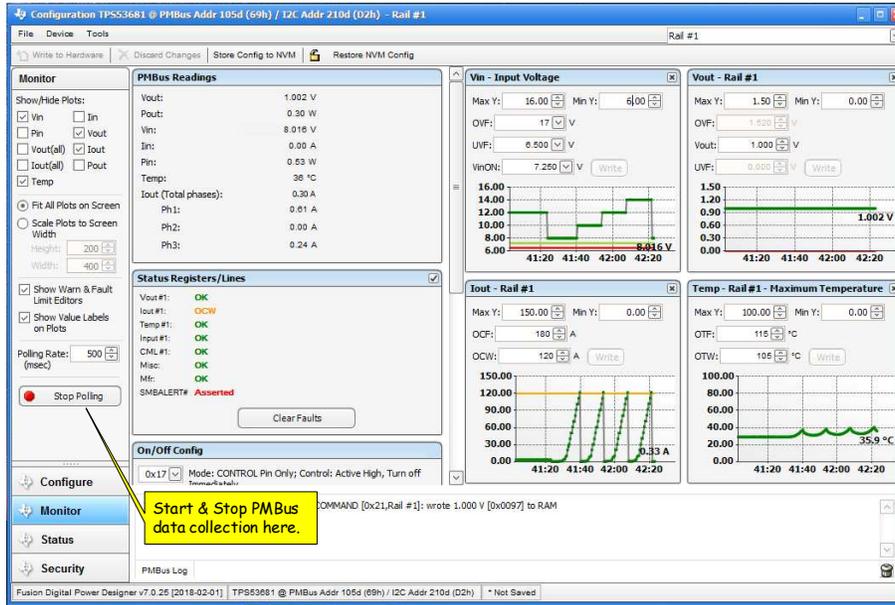


Figure 6. Monitor Window: Parametric Data Plots

For power conversion to start, the EN line for the rail must be high. The EN lines are driven by the USB to GPIO pod. Control Line #1 drives the A_EN pin. Control Line #2 drives the B_EN pin. To gain access to the Control Lines, go back to the System View window (Figure 3) and click on the System Monitor button on the top row. This will open the System Monitor window as shown in Figure 7. The state of the Control Lines is selected by the buttons in the box at the top of the window. Clicking on a control line button will immediately change the state of the line. This window offers another way to select and display the telemetry data. You can customize the display to your liking.

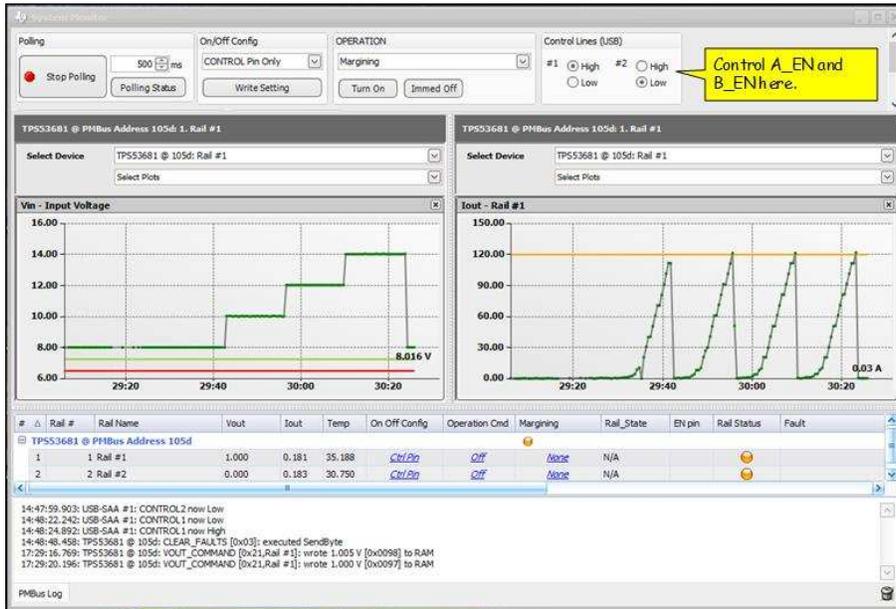


Figure 7. System Monitor Window: Control Lines

For optimum performance of the GUI, the PMBus Bus Speed should be set to 400kHz. This parameter is set in the USB to GPIO pod. To see the current pod settings, go to the System View window (Figure 3) and click on the “Tools” option in the very top menu bar. Select “USB Adapter Settings” from the drop-down menu that appears. This will display the current settings of the pod. Set the pod to match the settings shown in Figure 8. The GUI works best when the USB to GPIO pod is connected to a USB port that is directly connected to the host computer. Performance may be degraded if the USB connection is thru multiple hubs.

Note that when using the Monitor Mode window (Figure 6), some parameters are displayed in the plot windows. These can be changed as desired. The Vout plot also displays the present Vout setting and allows it to be changed on-the-fly. When a parameter is changed, click the “Write” button in the plot window to transfer the new value to the module RAM. If a Fault or Warning threshold is changed to a new value and the module is presently exceeding that new value, a Fault or Warning condition will be asserted as soon as the new value is stored to RAM.

When exploring the GUI, there are many settings displayed that can be altered. Great care should be exercised before altering any setting whose function is not obvious to the user. Altering certain settings could allow the module to operate outside of its design limits and potentially cause damage to the device. Remember that the “Store Config to NVM” button permanently stores any changes made to settings that have NVM backup. The factory settings cannot be recalled once they are overwritten.

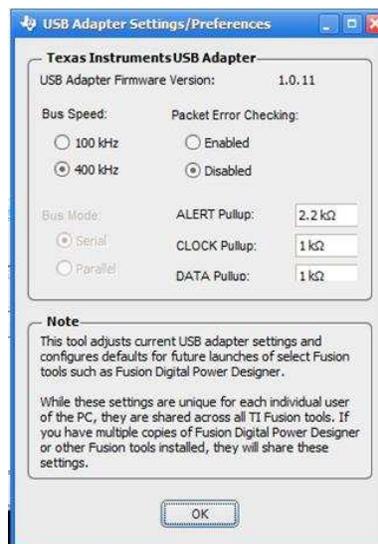


Figure 8. USB Adapter Settings

6 Using the On-board Fast Transient Load Generator

The TPSM831D31 is equipped with two high speed transient load circuits, one for each output rail. The transient load circuits are capable of producing load transients up to 60 A at slew rates in excess of 100 A/ μ s. The load circuits are designed for brief transient pulses only. Steady state load currents should be drawn by external electronic loads. The load is designed to be controlled by an external function generator that can generate low duty cycle, short duration (< 500 μ s) pulses, with adjustable amplitude, and variable rising and falling edge slew rates. The Tektronix AFG3102 Function Generator family is an example of a suitable instrument.

The high speed transient load circuit uses a high-speed closed-loop circuit to operate a power FET in its linear region to produce a current pulse that follows the amplitude and shape of an externally supplied voltage pulse. During the time that the FET is operating in its linear region, it is dissipating a large amount of power. To prevent damage and overheating, it is important to limit the amplitude, duration and repetition rate of the current pulses. The following operational guidelines should be observed:

- Transient amplitudes should not exceed 60 A.
- Transient duration should be limited to 500 μ s maximum.
- The repetition rate should be such that the effective duty cycle of the circuit is 1% or less. This keeps the average power dissipation in the FET to safe levels. Example: For a 500 μ s pulse, limit the repetition rate to 20 Hz or less.
- Make certain the function generator parameters are set correctly before applying the drive signal to the EVM connectors.
- The “gain” of the Trans_In input is nominally 10 A per volt. A 5-V amplitude pulse will produce a 50-A load current. It exhibits 50 Ω input impedance.
- The Imon current monitoring output signal produces 3 mV per Ampere of current. It exhibits 50- Ω output impedance.

6.1 Setting the Function Generator Parameters

To obtain the desired transient current pulse characteristics, it is critical to set the function generator drive parameters properly. Observe the following check list:

- Verify that the Load Impedance setting of the generator is set to 50 Ω . This insures that the displayed voltage level for the pulse amplitude will match what is actually delivered to the EVM.
- Set the output voltage High Limit to at least 6.5 V. Some generators have a default drive limit of 5 V.
- Set the function generator to continuous pulse mode with the following settings:
 - Set Frequency to 20 Hz.
 - Set the High level to the desired current value using the 10 A/V rule. (6.000 V = 60 A)
 - Set the Low level to 10mV. Do not set to zero or a negative value. This small offset is required to keep the pulse generating circuit within its linear operating range. A small continuous load current (~100 mA) will be produced.
 - Set the Width to the desired current pulse duration. Do not exceed 500 μ s.
 - Set the Rise and Fall times to achieve the desired current slew rate. The current slew rate is the (High level \times 10)/rise time (in μ s). The result is A/ μ s. Example: For 6V High amplitude and a 600-ns rise and fall time, the current slew rate is (6 * 10)/0.6 μ s = 100 A/ μ s.

When complete, the settings should be similar to what is displayed in [Figure 9](#).



Figure 9. Function Generator Settings

6.2 Measuring the Transient Response

The transient response of the module can be displayed by connecting the function generator and an oscilloscope as shown in Figure 10. This shows the connections required for measuring the VOUT_A rail. The VOUT_B connections are similar.

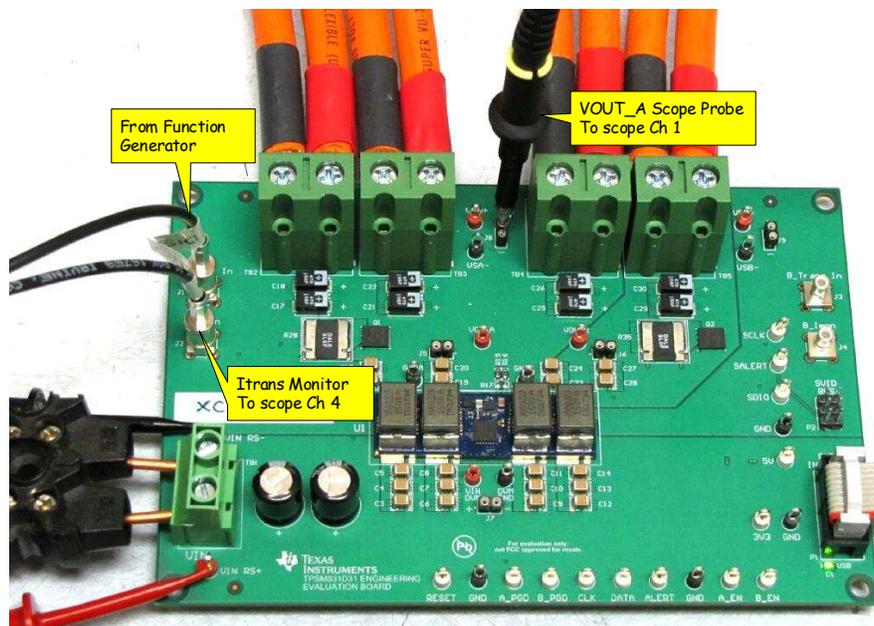


Figure 10. Transient Measurement Connections

- Connect the output of the Function Generator to the A_Trans_In SMB jack (J11).
- Connect the A_Imon output to an oscilloscope input using SMB jack (J12). Do NOT set the scope input to 50-Ω input impedance. Set the scope to 100 mV/div, dc coupled. Set the scope to trigger on the rising edge of this signal. (Some oscilloscopes allow the user to set the channel to display current per division. The EVM Imon signal is equivalent to 333 A/V.)

- Monitor the VOUT_A output voltage with a scope probe connected at header J6. Use a low inductance ground spring as shown. Set the scope to 20mV/div, ac coupled, 20-MHz bandwidth.
- Power up the EVM and set the desired output voltage. A static pedestal current, if desired, can be supplied by external electronic loads. Make certain the combined transient current and static current does not exceed the rated output current of the rail being tested. If it does, an overcurrent fault may be triggered.
- Turn the output of the function generator on. The transient response of the module to the load pulse should be present. The results should be similar to that shown [Figure 11](#).

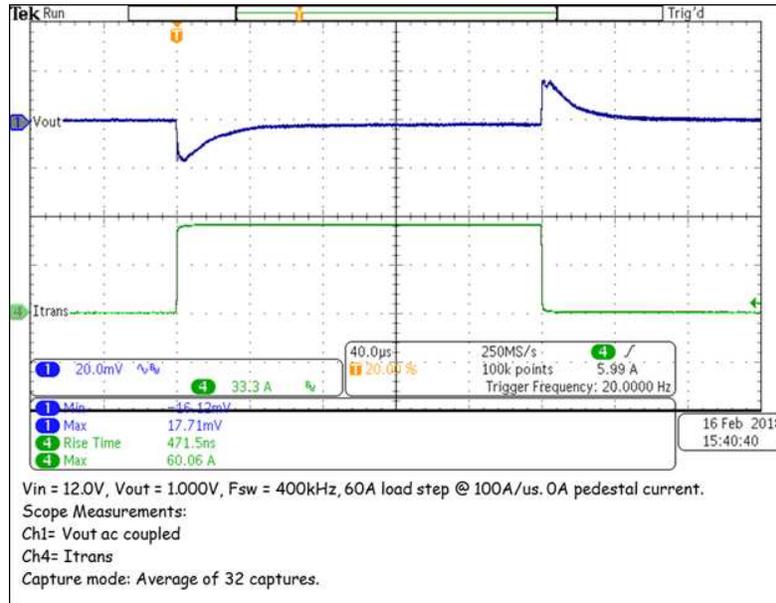


Figure 11. Response to 60 A, 100 A/µs Load Transient

7 Evaluation Board Schematic

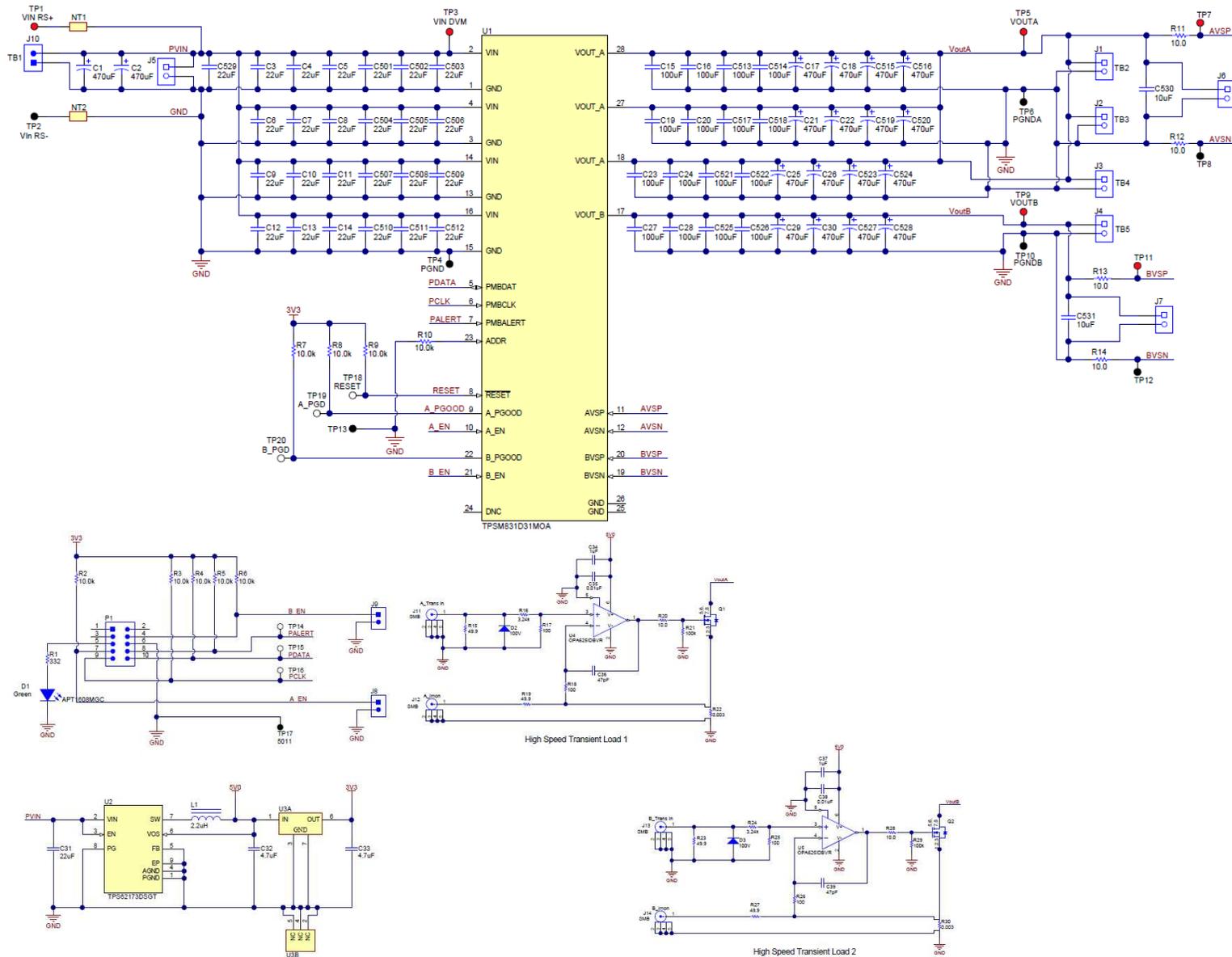


Figure 12. EVM Schematic

8 Bill of Materials (BOM)

Table 2. TPSM831D31EVM BOM

Designator	Qty	Value	Description	Part Number	Manufacturer
C1, C2	2	470µF	CAP, AL, 470 uF, 25 V, +/- 20%, TH	EKZE250ELL471MJ16S	Chemi-Con
C3, C4, C5, C6, C7, C8, C9, C10, C11, C12, C13, C14, C31, C501, C502, C503, C504, C505, C506, C507, C508, C509, C510, C511, C512, C529	26	22µF	CAP, CERM, 22 uF, 25 V, +/- 10%, X5R, 1210	GRM32ER61E226KE15L	MuRata
C15, C16, C19, C20, C23, C24, C27, C28, C513, C514, C517, C518, C521, C522, C525, C526	16	100µF	CAP, CERM, 100 uF, 6.3 V, +/- 20%, X5R, 1210	GRM32ER60J107ME20L	MuRata
C17, C18, C21, C22, C25, C26, C29, C30, C515, C516, C519, C520, C523, C524, C527, C528	16	470µF	CAP, Tantalum Polymer, 470 uF, 6.3 V, +/- 20%, 0.01 ohm, 7343-40 SMD	6TPF470MAH	Panasonic
C32, C33	2	4.7µF	CAP, CERM, 4.7 uF, 50 V, +/- 10%, X7S, 0805	GRM21BC71H475KE11K	MuRata
C34, C37	2	1µF	CAP, CERM, 1 uF, 25 V, +/- 10%, X7R, 0603	C0603C105K3RACTU	Kemet
C35, C38	2	0.01µF	CAP, CERM, 0.01 uF, 100 V, +/- 20%, X7R, 0603	06031C103MAT2A	AVX
C36, C39	2	47pF	CAP, CERM, 47 pF, 50 V, +/- 1%, COG/NP0, 0603	GRM1885C1H470FA01J	MuRata
C530, C531	2	10µF	CAP, CERM, 10 uF, 25 V, +/- 10%, X7R, 1210	C1210C106K3RACTU	Kemet
D1	1	Green	LED, Green, SMD	APT1608MGC	Kingbright
D2, D3	2	100V	Diode, P-N, 100 V, 0.2 A, SOT-23	MMBD914	Fairchild Semiconductor
J1, J2, J3, J4	4		Terminal Block, 10.16mm, 2x1, Tin, R/A, TH	EM292902-UL	Eaton
J5, J6, J7	3		Socket Strip, 2x1, 100mil, Black, Tin, TH	310-43-102-41-001000	Mill-Max
J8, J9	2		Header, 100mil, 2x1, Tin, TH	PEC02SAAN	Sullins Connector Solutions
J10	1		Terminal Block, 30A, 9.52mm (.375) Pitch, 2-Pos, TH	OSTT7022150	On-Shore Technology
J11, J12, J13, J14	4		JACK, SMB 50 Ohm, TH	903-499J-51P2	Amphenol RF
L1	1	2.2µH	Inductor, Shielded, Metal Composite, 2.2 uH, 1.5 A, 0.12 ohm, SMD	DFE201612P-2R2M=P2	MuRata Toko
P1	1		Header, 2.54mm, 5x2, Gold, Black, TH	302-S101	On-Shore Technology
Q1, Q2	2	30V	MOSFET, N-CH, 30 V, 34 A, DNK0008A (VSON-CLIP-8)	CSD17556Q5B	Texas Instruments
R1	1	332	RES, 332, 1%, 0.1 W, 0603	RC0603FR-07332RL	Yageo
R2, R3, R4, R5, R6, R7, R8, R9, R10	9	10.0k	RES, 10.0 k, 1%, 0.1 W, 0603	RC0603FR-0710KL	Yageo
R11, R12, R13, R14, R20, R28	6	10.0	RES, 10.0, 1%, 0.1 W, 0603	CRCW060310R0FKEA	Vishay-Dale
R15, R23	2	49.9	RES, 49.9, 1%, 0.25 W, 1206	CRCW120649R9FKEA	Vishay-Dale
R16, R24	2	3.24k	RES, 3.24 k, 1%, 0.1 W, 0603	CRCW06033K24FKEA	Vishay-Dale

Table 2. TPSM831D31EVM BOM (continued)

Designator	Qty	Value	Description	Part Number	Manufacturer
R17, R18, R25, R26	4	100	RES, 100, 1%, 0.1 W, 0603	CRCW0603100RFKEA	Vishay-Dale
R19, R27	2	49.9	RES, 49.9, 1%, 0.1 W, 0603	CRCW060349R9FKEA	Vishay-Dale
R21, R29	2	100k	RES, 100 k, 1%, 0.1 W, 0603	CRCW0603100KFKEA	Vishay-Dale
R22, R30	2	0.003	RES, 0.003, 1%, 3 W, AEC-Q200 Grade 0, 9.14x9.4mm	WSL36373L000FEA	Vishay-Dale
TP1, TP3, TP5, TP7, TP9, TP11	6		Test Point, Multipurpose, Red, TH	5010	Keystone
TP2, TP4, TP6, TP8, TP10, TP12, TP13, TP17	8		Test Point, Multipurpose, Black, TH	5011	Keystone
TP14, TP15, TP16, TP18, TP19, TP20	6		Test Point, Multipurpose, White, TH	5012	Keystone
U1	1		8V to 14V Input, 0.25V to 1.5V Dual Output, 120A + 40A, PMBus(TM) Power Module, MOA0028A (QFM-28)	TPSM831D31MOA	Texas Instruments
U2	1		Buck Step Down Regulator with 3 to 17 V Input and 5 V Output, -40 to 85 degC, 8-Pin WSON (DSG), Green (RoHS & no Sb/Br)	TPS62173DSGT	Texas Instruments
U3	1		Single Output LDO, 80 mA, Fixed 3.3 V Output, 2.5 to 24 V Input, with Low IQ, 6-pin SON (DRV), -40 to 85 degC, Green (RoHS & no Sb/Br)	TPS715A33DRV1T	Texas Instruments
U4, U5	2		High Bandwidth, High Precision, Low Noise & Distortion Amplifier SAR ADC Driver with Power Scaling, DBV0006A (SOT-23-6)	OPA625IDBVR	Texas Instruments

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 - 2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, 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:*

FCC NOTICE: 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 or RSS-247

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. 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/lstds/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/lstds/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 to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

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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3.4 *European Union*

3.4.1 *For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive):*

This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

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.

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