

AN-2293 LM25066I/A Node Manager Compliant Evaluation Board

1 Introduction

The LM25066I/A EVK evaluation kit provides the design engineer with a fully functional, intelligent monitoring and hot-swap protection board designed for positive voltage systems. This user's guide describes the various functions of the evaluation board, how to test and evaluate it, and how to use the companion GUI. The GUI is used to collect telemetry, configure warning and fault thresholds, and assist the designer with selection of the external components for a specific application. Use of the advanced telemetry and monitoring capabilities of the LM25066I/A requires external control via the PMBus™ interface. However, the LM25066I/A is capable of acting as a hot-swap and protection circuit without any PMBus intervention. For the latest software and datasheet information, see *Intel Node Manager Compliant System Power Management and Protection IC with PMBus* ([SNVS824](#)) and *LM25066, LM5066, LM5064, LM25056 PMBus Manager GUI Software*.

2 PCB Features

- Input voltage range: 2.9V to 16V (limited by input clamp D1)
- Programmable current limit: set to 50A (±8%)
- Q1 power limit: 80W (typical)
- UVLO thresholds: 2.9V and 3.1V
- PGD thresholds: 10.8V and 10.25V
- Insertion delay: 147 ms (typical)
- Fault time-out period: 8.9 ms
- Restart time: 1.1 seconds
- PCB size: 3.5" x 4.2"
- Solution size: 0.7" x 0.7"

3 Simplified Schematic

The simplified schematic for the LM25066I/A evaluation board is shown in [Figure 1](#). Connections to the PMBus interface are provided by connector J1. Terminal lugs bolt down to the PCB to provide input and output connections. Jumpers ADR0, ADR1, and ADR2 set the PMBus slave address of the LM25066I/A to one of 27 unique addresses. Jumpers also exist to set the retry, circuit breaker, and current limit behavior. Test points are provided for VIN, VOUT, GATE, UVLO, VAUX, PGD, VREF, TIMER, and GND.

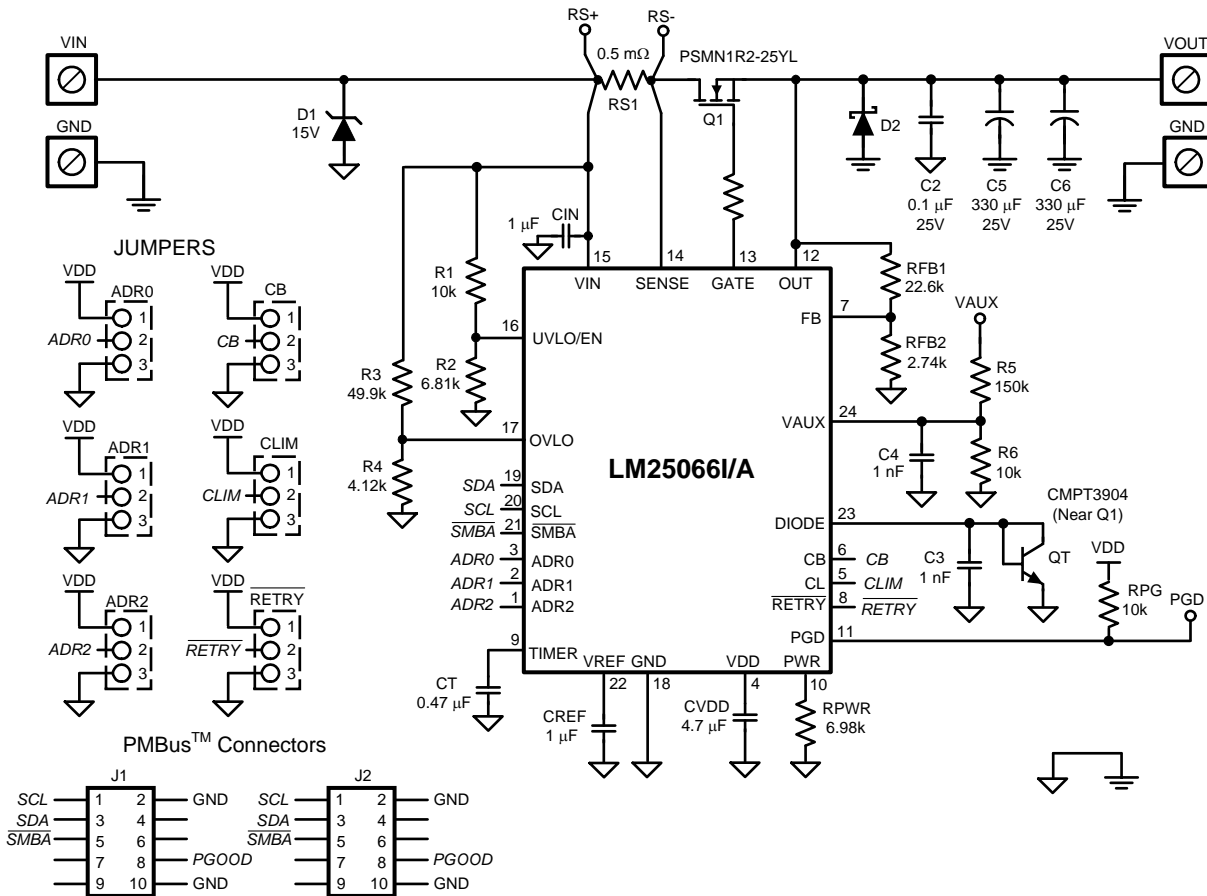


Figure 1. Simplified Evaluation Board Schematic

4 Getting Started

The LM25066I/A evaluation kit hardware is shown in [Figure 2](#). The board offers two connection methods for the system input voltage and load. For evaluation at currents below 15A, the system voltage and load can be plugged directly into the female banana receptacles. For higher currents, it is recommended to use the copper Panduit lugs with low gauge wire to minimize the cable power dissipation and voltage drop. Capacitors C5 and C6 represent capacitance which is typically present at the input of the load circuit and are present on this evaluation board so that the turn-on characteristics of the LM25066I/A may be tested starting into a capacitive load. Footprints for components RS2 and Q2 are not populated and are provided to accommodate evaluation of hot-swap designs with current levels greater than 50A.

The LM25066I/A I/AEVK is supplied with the PMBus slave address set to 0x16 as dictated by the configuration of the ADR0, ADR1, and ADR2 jumper connections.

The first step to evaluate the telemetry features of the LM25066I/A is to install the GUI application. The application distribution is included on a CD in the evaluation kit and is titled PMBManager-x.x.x-xxxxxxx.exe, where the x characters indicate the software version and build date. To install the application, this file should be executed on a PC running Windows XP or later. Once the application is installed, the hardware should be connected as shown in [Figure 2](#).

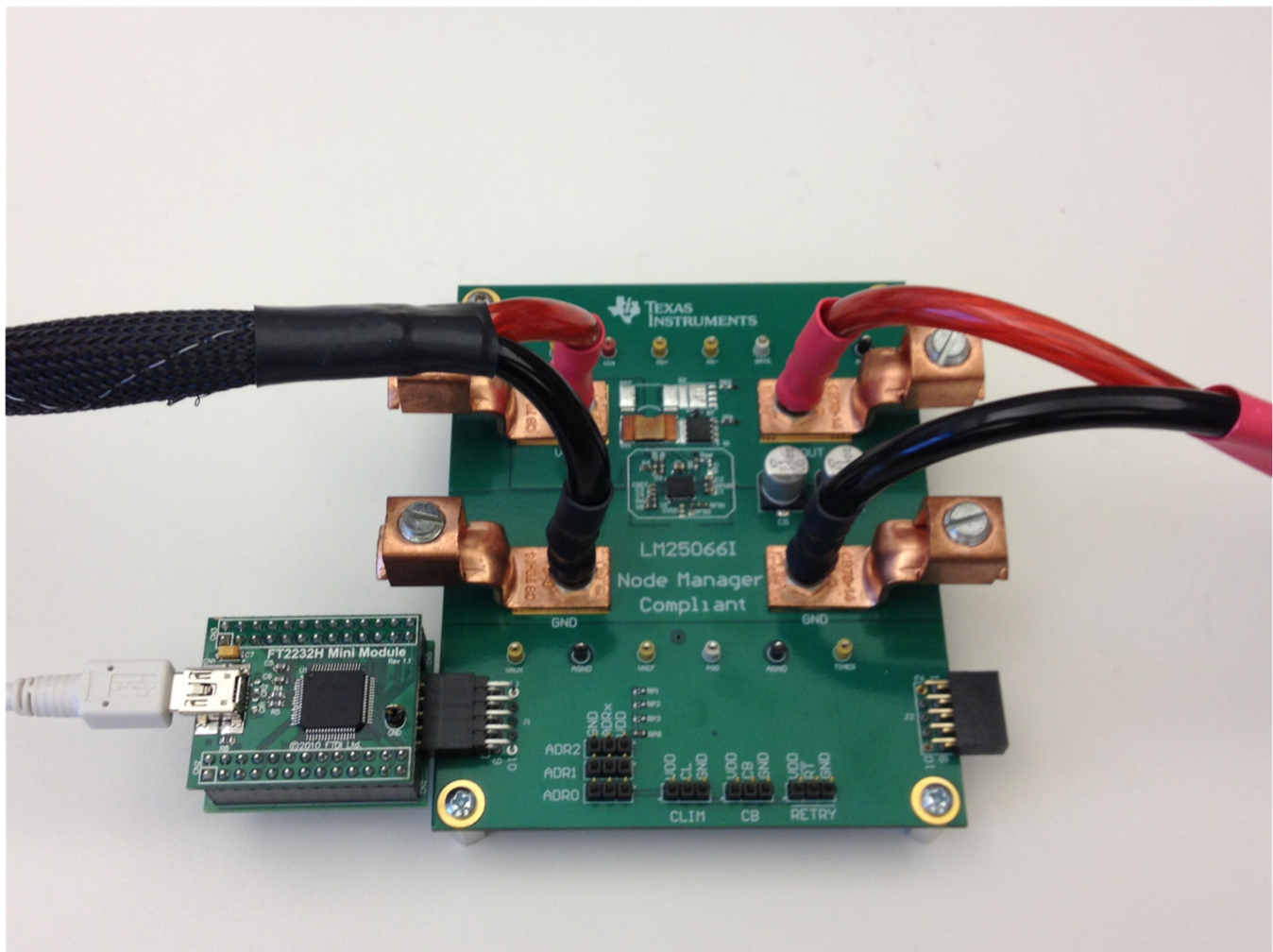


Figure 2. Connection Illustration

5 Hardware Setup Steps

Step 1: Connect the input supply to either the VIN and GND banana plugs (IOUT < 15A) or to the input terminal lugs (IOUT > 15A).

Step 2: Connect the load to either the VOUT and GND banana plugs (IOUT < 15A) or to the output terminal lugs (IOUT > 15A).

Step 3: Connect the FTDI Dongle to the 10-pin connector on the left side of the board.

Step 4: Connect the supplied mini USB cable from the FTDI dongle to a USB port on a PC.

When the FTDI dongle is connected for the first time, the user will be prompted to install the device drivers. For the most recent driver installation procedure, please refer to the README.TXT file in the installation directory.

For a hot-swap circuit to function reliably, a low inductance connection to the input supply is recommended. Its purpose is to minimize voltage transients which occur when the load current changes or is shut off. High parasitic inductance in the supply lines coupled with the rapid change of current when the FET turns off will induce a voltage spike. This spike can exceed the absolute maximum voltage rating of the LM25066I/A I/A, resulting in its destruction. To protect against such voltage spikes, TVS diode D1 is provided to clamp the input voltage to within safe operating limits. Likewise, Schottky diode D2 is provided at the output to clamp the output voltage from going too negative during short circuit events.

6 GUI Evaluation

After the hardware connections have been made, apply an input voltage of 12V. The current hardware configuration allows the LM25066I/A to work with 3.3V, 5.0V, and 12V system rails. However, this Quick Start guide will assume an input voltage of 12V. From the Windows Start menu, launch the GUI application. The LM25066I/A should be detected on the PMBus and an initial screen should appear as shown in [Figure 3](#).

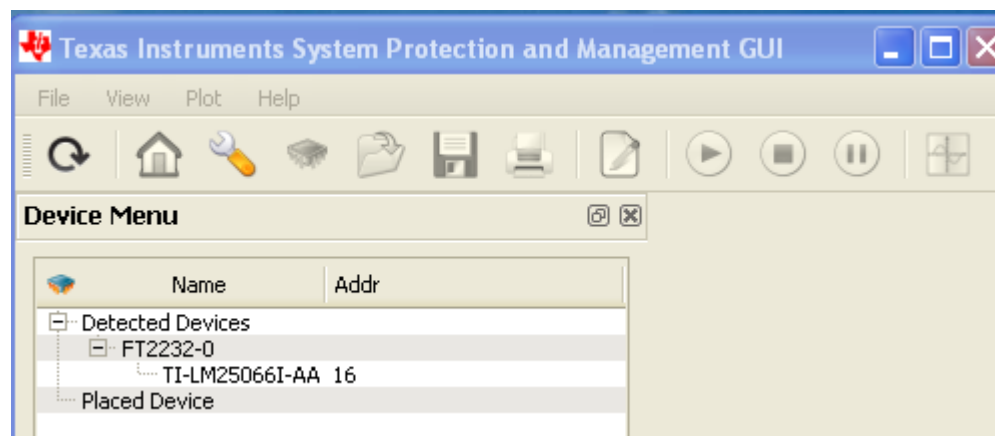


Figure 3. Initial GUI Screen

If the LM25066I/A is not detected, an option is provided to rescan, ignore, or exit the GUI. If the hardware is intended to be connected, check the USB connection to the PC, the FTDI connection to the evaluation board, and verify that the power is present on the evaluation board by measuring the voltage between the VIN and GND test points. Choosing the Ignore option causes the application to bypass additional attempts to detect the LM25066I/A on the PMBus and facilitates access to the GUI integrated design tool.

Single-click on the detected device ID, NSC-LM25066I/A I/A-AA, to display a block level representation as shown in [Figure 4](#). The block level view of the device provides a display of all the telemetry as well as most of the faults and warnings supported by the LM25066I/A I/A. The faults and warnings supported are generally associated with an invalid input or output condition.

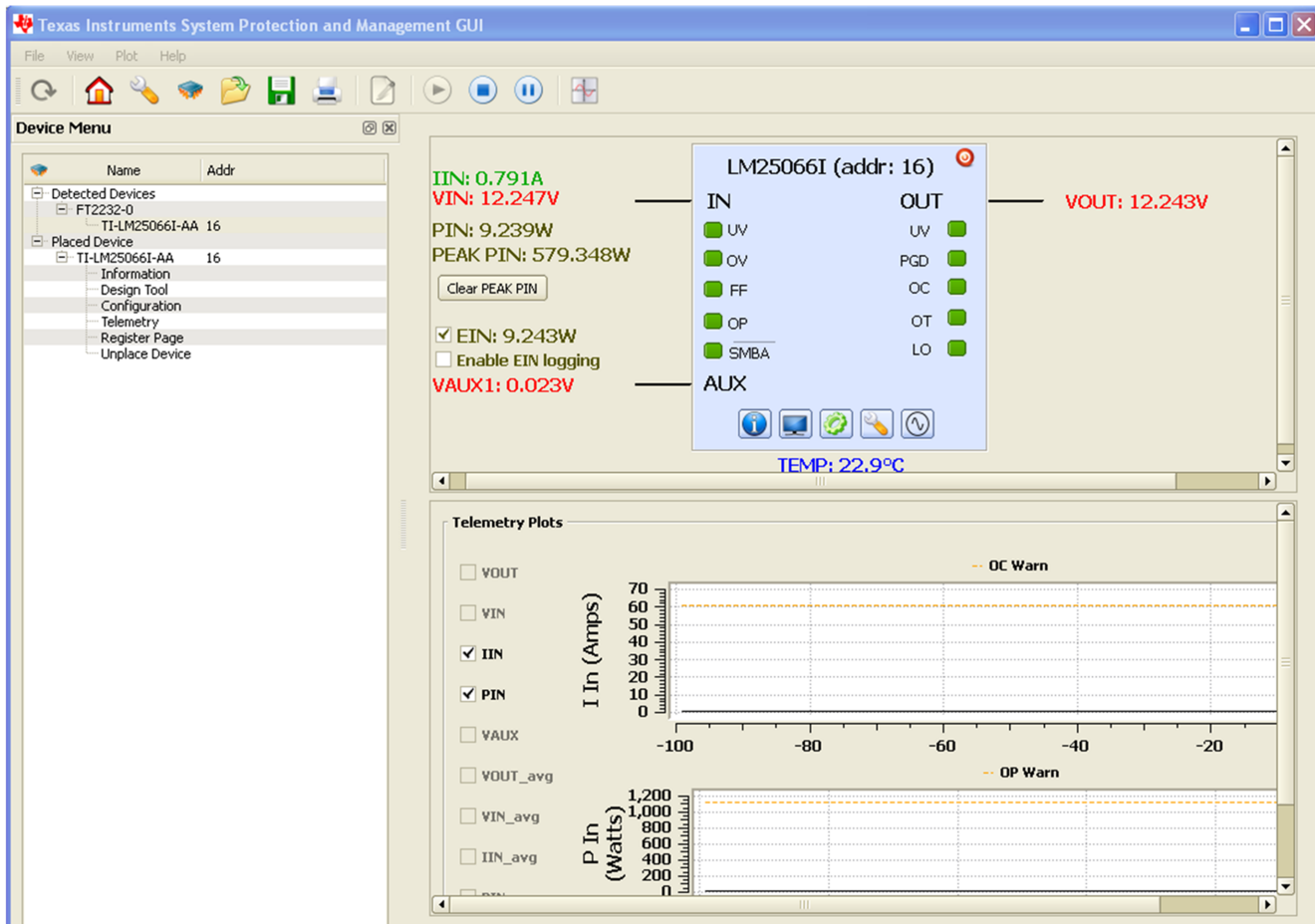


Figure 4. LM25066I/A Block Level Representation

The faults shown on the left side of the block representation are generally associated with the input. The faults include input under-voltage (UV), input over-voltage (OV), FET Fail (FF), and input over-power (OP). The SMBus alert status, $\overline{\text{SMBA}}$, is also shown on the left side and will turn red during any warning or fault event. To facilitate evaluation of the LM25066I/A I/A, SMBus alerts are automatically cleared by the GUI while telemetry is monitored.

The faults shown on the right side of the block representation are associated with the output. These include output under-voltage (UV), power good status (PGD), output over-current (OC), and over-temperature (OT). There is also an indicator if the output is in the latched-off state (LO). The LM25066I/A will latch the output off after the number of programmed retries is exceeded. To clear the latched-off condition, the output can be toggled off and then on by the red Power button located at the top right of the LM25066I/A block representation.

To show a continuous update of the LM25066I/A telemetry and status, click on the Play button at the top of the screen. The Play button starts an active telemetry log of the gathered data. Clicking the Stop button stops the telemetry collection and allows the log file to be viewed and saved. The Pause button pauses both the displaying and logging of telemetry information, but does not clear the log.

To enable/disable display of specific telemetry, click the Display Options button on the block representation and choose the desired telemetry to display (see Figure 5).

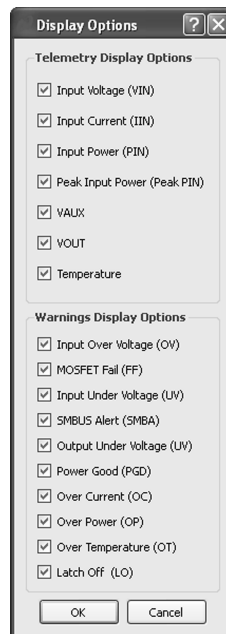


Figure 5. LM25066I/A Telemetry Display Options

Note that enabling/disabling the various warning and fault options has no affect on the Fault mask.

7 GUI Event Log

A GUI Event Log is provided to keep track of GUI configuration changes and LM25066I/A fault events. To display the Event Log, select View from the main menu bar and then View Event Log. The dockable window housing the Event Log can be detached (or docked to a different region of the GUI) by dragging its title bar to the desired location.

8 Plotting Telemetry

To enable telemetry data plots, click on the Device Telemetry (sinewave) button located in the LM25066I/A block representation. After enabling the telemetry, a prompt will appear requesting entry of the GUI sample rate, plot rate, and plot depth. For most cases, the default rates and depths will be acceptable. The plotting tool allows the user to select the desired data to be plotted. Up to two different parameters may be plotted simultaneously, as shown in Figure 6.

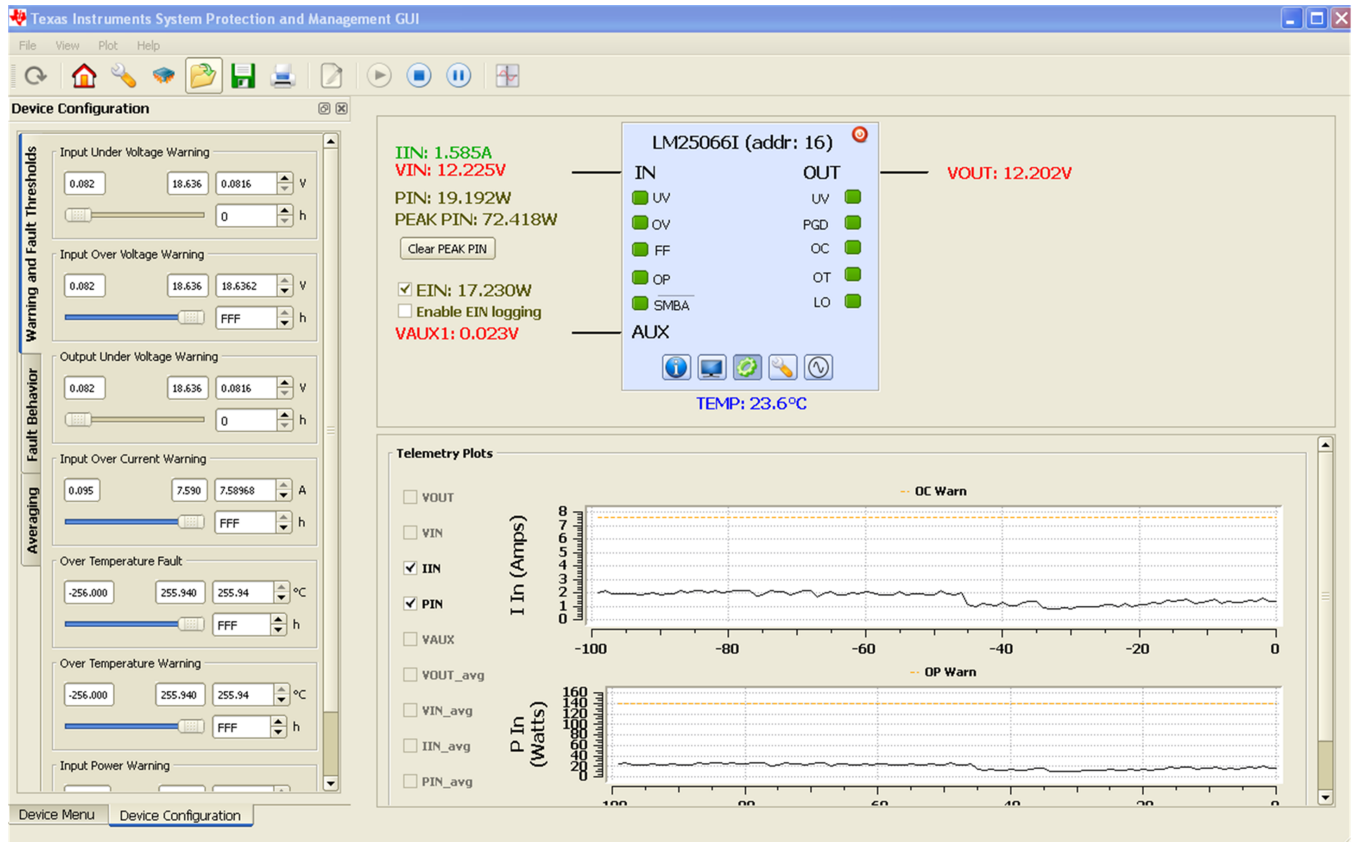


Figure 6. LM25066I/A GUI with Telemetry Plotting Tool Enabled

Telemetry is plotted as a black line that continually updates as the LM25066I/A is queried. In addition to the telemetry, the relevant warning and fault thresholds are also plotted. Warning thresholds are shown as orange lines while fault thresholds are shown in red and blue.

From the Plot menu option in the main menu bar, the user can disable the plotting grid as well as the warning and fault lines.

9 Configuring the LM25066I/A I/A

Warning Thresholds, Temperature Fault Threshold, Protection Ranges, Fault Masking, and Averaging can be configured in the Device Configuration panel. This panel, shown in [Figure 7](#), is enabled by clicking the Gear button shown in the LM25066I/A block representation.

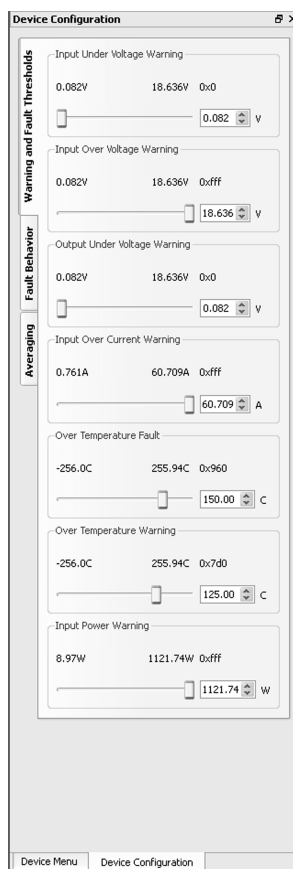


Figure 7. Device Configuration Panel - Warning and Fault Thresholds Tab

The Warning and Fault Thresholds tab allows configuration of the input under-voltage, input over-voltage, output under-voltage, input over-current, input power, and over-temperature warnings. This tab also allows adjustment of the over-temperature fault threshold. Adjustments can be made by moving the slider button with the mouse, by clicking on the slider line, or by clicking on the up/down arrows in the number box. Fault thresholds for the input under- and over-voltage, current limit, power limit, and power good are set by external configuration components. Decimal values for the thresholds are shown in the text box located to the right of the slider bar. Above the decimal values setting is the value of the setting in hexadecimal; this can be useful when developing software/firmware to control and configure the LM25066I/A I/A.

The Fault Behavior tab, shown in [Figure 8](#), allows the user to set the LM25066I/A fault configuration and fault masking. The fault configuration section allows the user to set the number of retries, as well as the circuit breaker and current limit thresholds. The number of retries is set by the `RETRY` pin at power-on-reset (POR) to be infinite or latched-off. Subsequently, the number of retries can be set via the `PMBus™` interface to 0 (latch-off), 1, 2, 4, 8, 16 or infinite. The software settings are independent of the hardware settings. However, if the power is cycled, the LM25066I/A will default to the setting based on the `RETRY` pin. Current limit and circuit breaker power-up settings are set by the `CL` and `CB` pins, respectively. The current limit threshold can be set to either 25 mV (`CL = GND`) or 46 mV (`CL = VDD`). The circuit breaker threshold can also be set to either 1.8 times (`CB = GND`) or 3.6 times (`CB = VDD`) the current limit threshold. Fault masking is possible for many of the LM25066I/A fault conditions. Fault conditions allow

masking of both the MOSFET response and the SMBus alert signal. Note that if a fault persists while the MOSFET gate masking is enabled, damage to the MOSFET may occur. This option is allowed primarily for debug purposes. Faults that issue only a SMBus alert (for example, FET Fail, Communications Fault) allow masking of the alert. Note that the power-up default setting for the Power Good signal is to mask the SMBus alert.

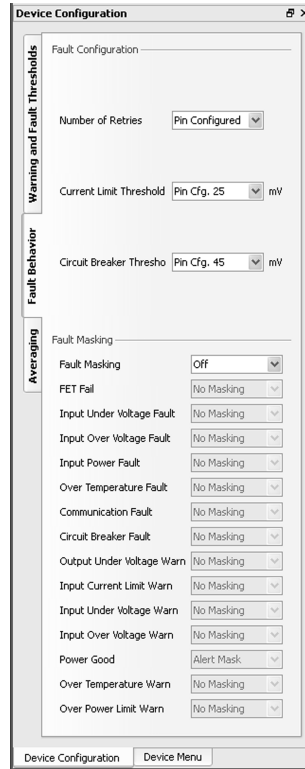


Figure 8. Device Configuration Panel - Fault Behavior Tab

For convenience, the dockable window containing the Device Configuration tabs can be detached (or docked to a different region of the GUI) by dragging its title bar to the desired location.

10 GUI Design Page

The GUI assumes the hardware configuration is set to the default LM25066I/A evaluation board configuration. If any of the components are changed, the LM25066I/A hardware configuration needs to be updated in the Design Tool section. To open the design tool, click the Wrench button located in the LM25066I/A block representation which will display the window as shown in Figure 9.

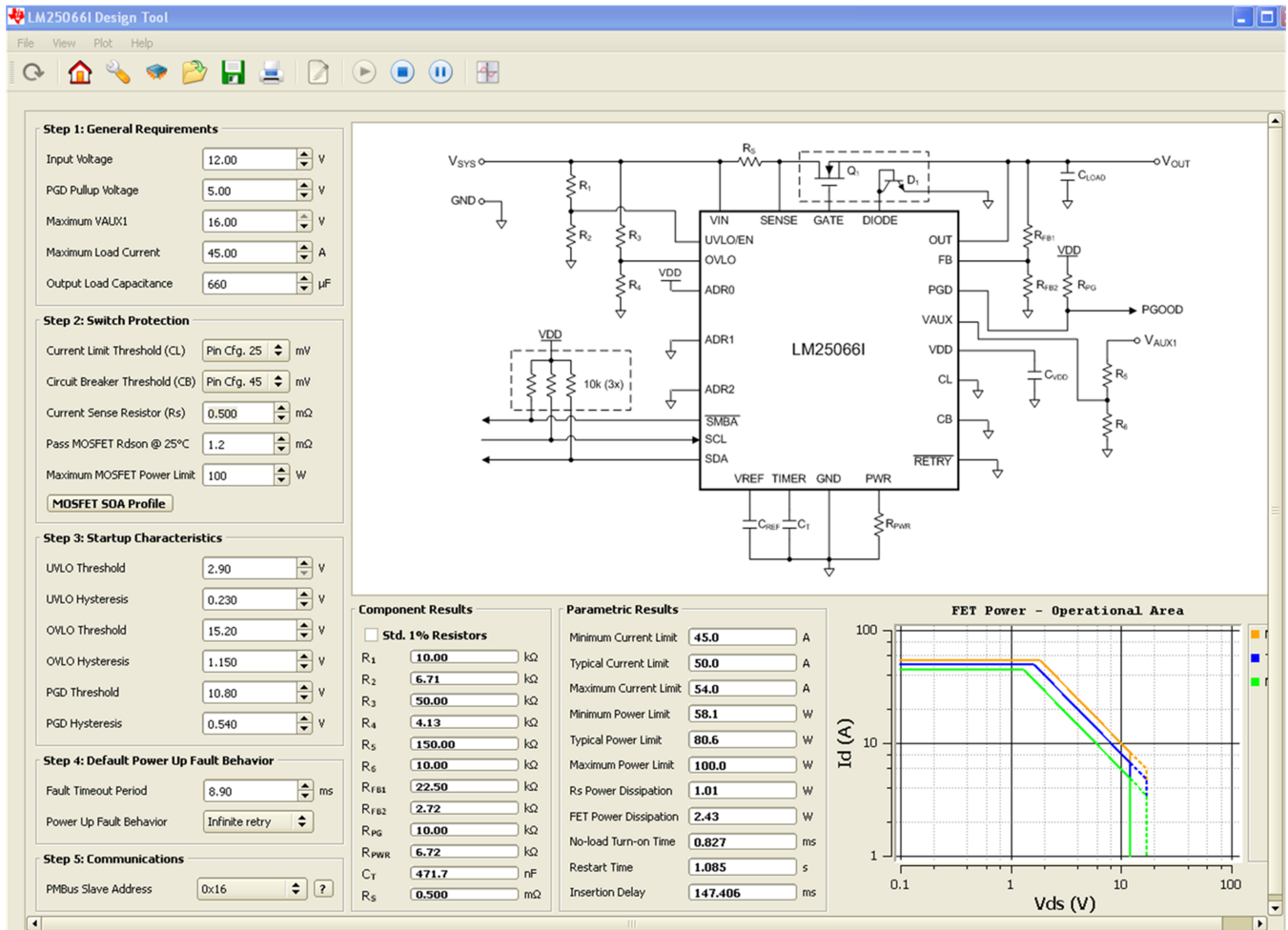


Figure 9. LM25066I/A Design Tool

Design inputs are keyed in on the left side following steps 1 through 5. General operating conditions should be entered in step 1 of the design tool. These inputs help set bounds on the startup time and application voltage and current ranges.

Step 2 allows the user to tailor the MOSFET protection features specific to the target application. Both pin and software configurable ranges are available for the circuit breaker and current limit circuits. If a pin configuration is selected, please make sure the CB and CL jumpers are set to match the GUI selection. Note that the state of all jumpers is sampled only at startup (POR). Thus, if any changes are made to the jumpers, be sure to cycle power. By clicking on the MOSFET SOA Profile button, the user can select SOA data from several popular MOSFETs or enter the SOA data for the desired MOSFET.

Step 3 allows the user to select the under- and over-voltage lockout (UVLO/OVLO) levels, and power good (PGD) thresholds. Note that with the correct values for R1 - R4, and RFB1 and RFB2 installed, the LM25066I/A will indicate a fault condition when the input and/or output voltages are outside of their respective ranges.

Step 4 allows the user to set the fault timeout period and the fault response. The fault timeout should be set to be below the MOSFET SOA data for a given time. For example, if a design is to adhere to the 10 ms pulsed MOSFET SOA data, the desired fault timeout must be less than 10 ms. The fault timeout time entered will set the value for CT. It also sets the insertion delay and fault retry delay. The initial power up retry behavior is also selected in this design step. Make sure to change the `RETRY` jumper to match the design tool schematic when changing the default retry setting.

In Step 5, the user enters the desired PMBus™ slave address. Note that changing the PMBus™ slave address in this step does not change the physical address, but shows how the address pins of the LM25066I/A need to be configured to achieve a desired address. Once the ADR pin jumpers are configured for a particular address, power to the LM25066I/A needs to be cycled and the GUI restarted in order for the new address to take effect.

When invalid or incorrect inputs are given to the design tool, text associated with the faulty input will turn red. Positioning the mouse cursor over the red text will give additional information about any design conflict.

Component and parametric results are shown to the right as well as the LM25066I/A operational area chart. The operational area chart shows the minimum, typical, and maximum SOA protection areas for a given design. For a robust design, the SOA of the MOSFET used should be above the MAX protection SOA line for all operating areas. To help make this determination, step 2 allows the user to select the SOA curves for several popular MOSFETs or to input the SOA data for the desired MOSFET.

Once complete, the design should be saved by selecting the File menu, and then Save. Once the hardware is modified to match the design, the GUI should be restarted and the hardware configuration file loaded right after the LM25066I/A is detected and placed. If the values in the design tool are different than the values on the board, erroneous telemetry and fault data will be reported by the GUI. To return to the block view of the device, press the Home button located at the far left in the menu bar.

The design tool is also useful to calculate the PMBus™ coefficients. With the correct value for current sense resistor (RS1), the tool will calculate the coefficients to scale the raw telemetry. The coefficients can be viewed by selecting View from the main menu bar, and then selecting the PMBus™ Coefficient Editor. When the PMBus™ Coefficient Editor is opened, press the Get All button to show the currently used coefficients.

If desired, the equations used in the design tool can be calculated by hand using the equations provided in the datasheet ([SNVS824](#)). However, note that the design tool calculates parameters factoring in worst case tolerances, while the equations in the datasheet are based on typical thresholds.

11 GUI Register Page

The GUI Register Page, as shown in [Figure 10](#), provides the user with several features to help better understand the functionality of the LM25066I/A I/A. These features include the ability to read telemetry, device identification and status registers, as well as being able to monitor the SMBus Alert and PGOOD interrupts, and to turn the output on and off with the OPERATION button.

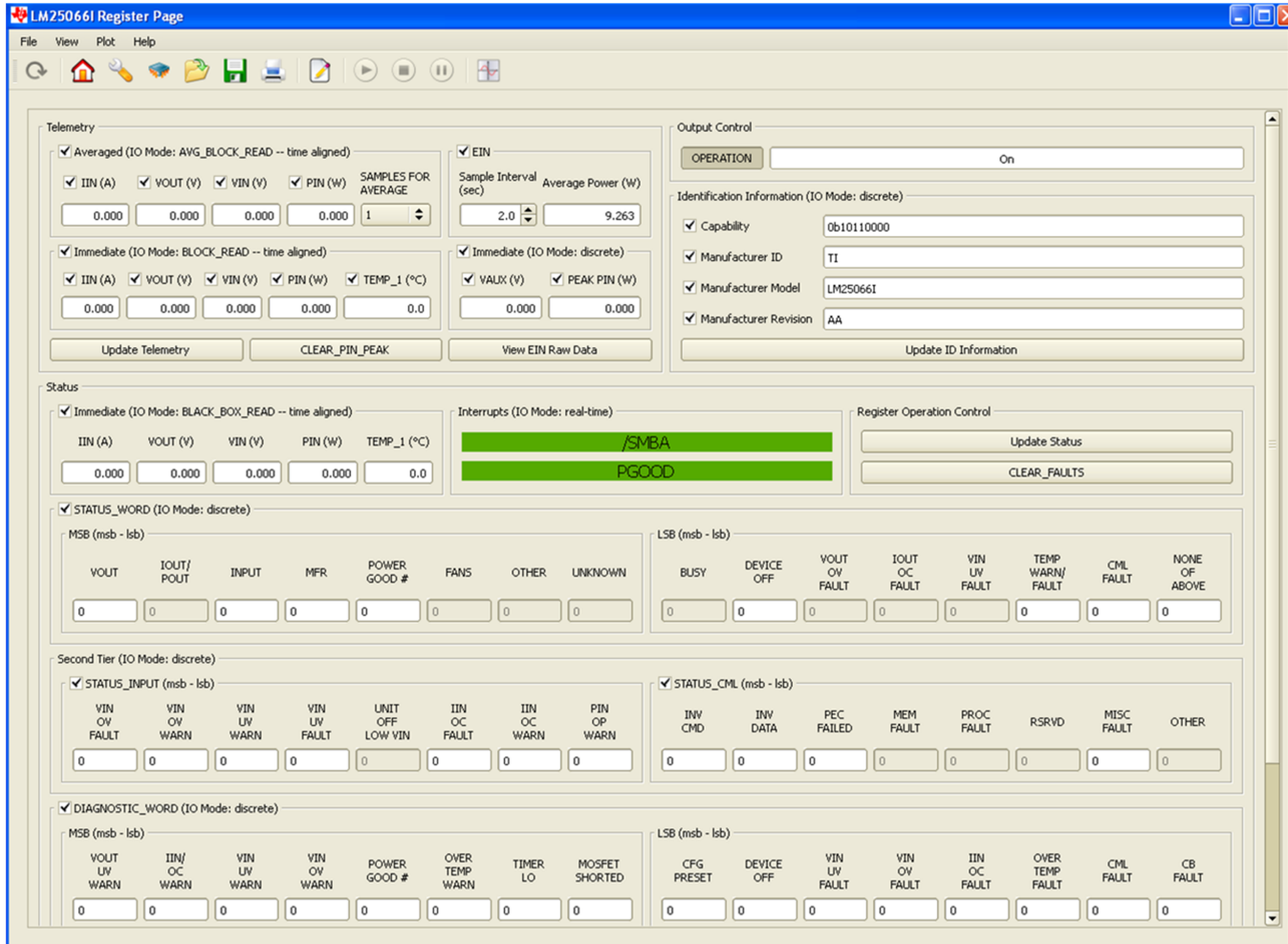


Figure 10. LM25066I/A GUI Register Page

Telemetry is updated by clicking the Update Telemetry button. This action will update the fields under the Averaged heading and under the Immediate heading along with VAUX and PEAK PIN. Select which parameters to update by clicking in the box next to each parameter. If all parameter boxes under a given heading are checked, the Update will use the block read PMBus commands (AVG_BLOCK_READ and BLOCK_READ) to update the fields, ensuring that the readings are time aligned. If one or more of the boxes under the headings is not checked, the Update will use the respective individual read PMBus commands to make the telemetry readings and the measurements will not be time aligned. VAUX and PEAK PIN are always read with discrete PMBus commands and, therefore, are never time aligned. The CLEAR_PIN_PEAK button is provided to clear the PEAK PIN reading which is often much higher than one would expect under steady state conditions. This is related to the large inrush current during power-on that gets sampled by the internal power measurement circuitry and used to calculate PEAK PIN.

The output can be turned off and on using the OPERATION button, and the Identification Information can be obtained by clicking the Update ID Information button.

The rest of this page is used to monitor and diagnose warning and fault conditions. The $\overline{\text{SMBA}}$ and PGOOD interrupts will indicate if a warning or fault has occurred and if the output voltage is within specifications. They are always active and there is no need to click an Update button to change their state. Clicking the Update Status button under the Register Operation Control heading will update the bits in all of the registers, as well as the telemetry, under the Status section. Clicking the CLEAR_FAULTS will reset all warning and fault bits and issue an Update Status. If the warning and/or fault condition has been remedied, the bits will reset. If the warning and/or fault condition still exists, the registers will be updated within a millisecond and thus will appear to never have been cleared. The STATUS_WORD, STATUS_INPUT, STATUS_CML and DIAGNOSTIC_WORD registers operate in a cumulative way. That is, these registers display any and all warnings and errors that have occurred since the last CLEAR_FAULTS command was issued.

The telemetry and DIAGNOSTIC_WORD that are part of the BLACK_BOX_READ are also updated by clicking the Update Status button. These telemetry parameters and bits are latched at the moment the $\overline{\text{SMBA}}$ signal was asserted. They are not reset or cleared by the CLEAR_FAULTS command but rather, they are re-armed, or readied, to be over-written with new values at the onset of the next $\overline{\text{SMBA}}$ signal assertion. Note that these telemetry fields and this register are not cumulative. That is, they can only be updated once after the CLEAR_FAULTS command is issued, and it will be at the first occurrence of the $\overline{\text{SMBA}}$ assertion following the CLEAR_FAULTS. This allows the user to determine device conditions at the first occurrence of the $\overline{\text{SMBA}}$ assertion.

12 Theory of Operation

The LM25066I/A provides intelligent control of the power supply connections of a load which is to be connected to a live power source. The three primary functions of the LM25066I/A are to limit inrush current during turn-on, respond to warnings and faults, and to provide system telemetry for the following parameters: Input Voltage (VIN), Input Current (IIN), Input Power (PIN), Output Voltage (VOUT), Auxilliary Voltage (VAUX), and Temperature. Additional functions include under- and over-voltage lockouts (UVLO/OVLO) to ensure voltage is supplied to the load only when the system input voltage is within a specified range, power limiting of the series pass MOSFET (Q1) during turn-on, and a Power Good logic output (PGD) to indicate the output voltage status.

Upon applying the input voltage to the LM25066I/A I/A, Q1 is initially held off for the insertion delay (≈ 147 ms) to allow ringing and transients on the input to subside. At the end of the insertion delay, if the input voltage and temperature are within acceptable limits, Q1 is turned on in a controlled manner to limit the inrush current. If the inrush current were not limited during turn-on, the current would be high as the load capacitors (C5 and C6) charge up, limited only by the surge current capability of the voltage source, the capacitor characteristics, and the wiring resistance (a few milliohms). That very high current could damage the edge connector, PC board traces, and possibly the load capacitors receiving the high current. Additionally, the dV/dt at the load's input is controlled to reduce possible EMI problems.

The LM25066I/A limits inrush current to a safe level using a two step process. In the first portion of the turn-on cycle, when the voltage differential across Q1 is highest, Q1's power dissipation is limited to a peak value (80W typically, set by RPWR) by monitoring its drain current (the voltage across shunt RS1) and its drain-to-source voltage. Their product is maintained constant by controlling the drain current as the drain-to-source voltage decreases (corresponding to an increasing output voltage). This is shown in the constant power portion of [Figure 11](#) where the drain current is increasing to I_{LIM} . When the drain current reaches the current limit threshold (50A), it is then maintained constant as the output voltage continues to increase. When the output voltage reaches the input voltage level (V_{DS} decreases to near zero), the drain current then reduces to a value determined by the load. Q1's gate-to-source voltage then increases to its final value. The circuit is now in normal operation mode.

Monitoring of the load current for faults during normal operation is accomplished using the current limit circuit described above. If the load current increases to 50A (25 mV across RS1), Q1's gate is controlled to prevent the current from increasing further. When current limiting takes effect, the fault timer limits the duration of the fault. At the end of the fault time-out period, Q1 is shut off, denying current to the load. The LM25066I/A then initiates a restart every 1.1 seconds. The restart consists of turning on Q1 and monitoring the load current to determine if the fault is still present. After the fault is removed, the circuit powers up to normal operation at the next restart.

In a sudden overload condition (for example, when the output is shorted to ground), it is possible that the current could increase faster than the response time of the current limit circuit. In this case, the circuit breaker feature shuts off Q1's gate rapidly when the voltage across RS1 reaches 45 mV. When the current reduces to the current limit threshold, the current limit circuitry then takes over.

The PGD logic level output is low during turn-on and switches high when the output voltage at VOUT is above 10.8V. PGD switches low when the voltage at VOUT is below 10.25V. The high level voltage at PGD can be any appropriate voltage up to 17V and can be higher or lower than the voltages at VIN and OUT.

The UVLO thresholds are set by resistors R1 and R2, the OVLO thresholds are set by R3 and R4, and the PGD thresholds are set by resistors RFB1 and RFB2. Internal current sources at the UVLO, OVLO, and FB pins provide hysteresis for these thresholds.

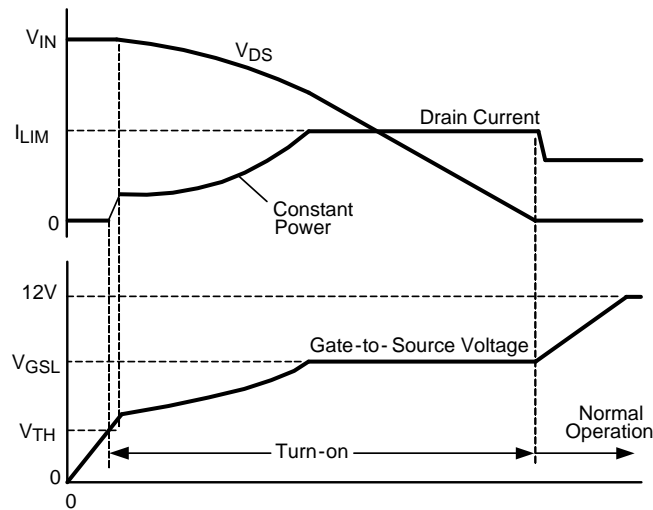


Figure 11. Power Up Using Power Limit and Current Limit

13 Fault Detection and Restart

If the load current increases to the fault level (the current limit threshold of 50A), an internal current source charges the timing capacitor at the TIMER pin. When the voltage at the TIMER pin reaches 1.7V, the fault time-out period is complete and the LM25066I/A shuts off Q1. The restart sequence then begins, consisting of seven cycles at the TIMER pin between 1.7V and 1V, as shown in Figure 12. When the voltage at the TIMER pin reaches 0.3V during the eighth high-to-low ramp, Q1 is turned on. If the fault is still present, the fault time-out period and the restart sequence repeat.

The waveform at the TIMER pin can be monitored at the TIMER test point. On this evaluation board, the initial fault time-out period is 8.9 ms and the restart time is 1.1 seconds. See Figure 20.

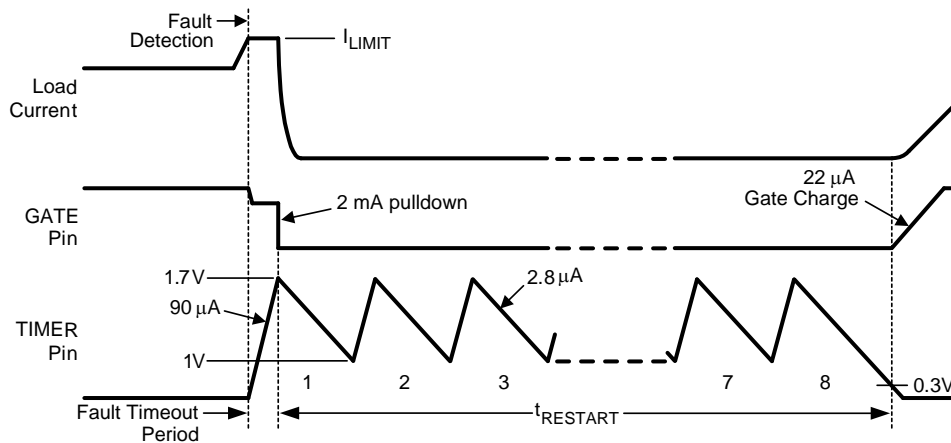


Figure 12. Fault Time-Out and Restart Sequence

14 UVLO and OVLO Input Voltage Threshold

Programming the UVLO thresholds sets the minimum system voltage to enable the series pass MOSFET (Q1). If VIN is below the UVLO thresholds, Q1 is switched off, denying power to the load. Programmable hysteresis is adjustable by changing the value of R1.

The UVLO thresholds are set with two resistors (R1, R2) as shown in Figure 13.

The OVLO threshold sets the maximum voltage that can be present on the input before the LM25066I/A turns off the series pass MOSFET. The OVLO threshold is set with the two resistors (R3, R4). The hysteresis voltage is set by the internal 23 µA current source and the value of R3.

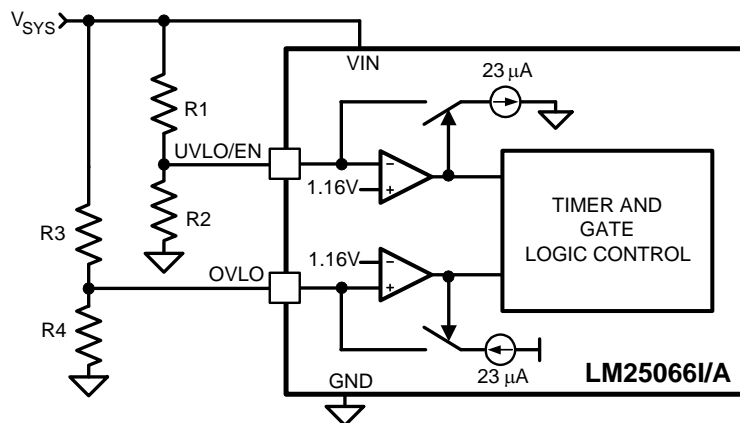


Figure 13. Programming the UVLO Threshold

15 Power Good and FB Pins

During turn-on, the Power Good pin (PGD) will not be able to pull low until the voltage at VIN increases above $\approx 1.6\text{V}$. Using VDD as the pull-up voltage source will keep the PGD pin low during this region because VDD does not turn on until VIN increases above $\approx 2.5\text{V}$. When the voltage at the board's output pin increases above 10.8V (typ), PGD switches high. PGD switches low when the output voltage decreases below 10.25V (typ). Additionally, PGD switches low if the UVLO/EN pin is taken below its threshold regardless of the output voltage.

The output voltage threshold for the PGD pin is set with two resistors (RFB1, RFB2) at the FB pin.

A pull-up voltage and pull-up resistor are required at PGD as shown in [Figure 14](#). As mentioned previously, the pull-up voltage can be as high as 17V with transient capability to 20V and can be higher or lower than the voltages at VIN and OUT.

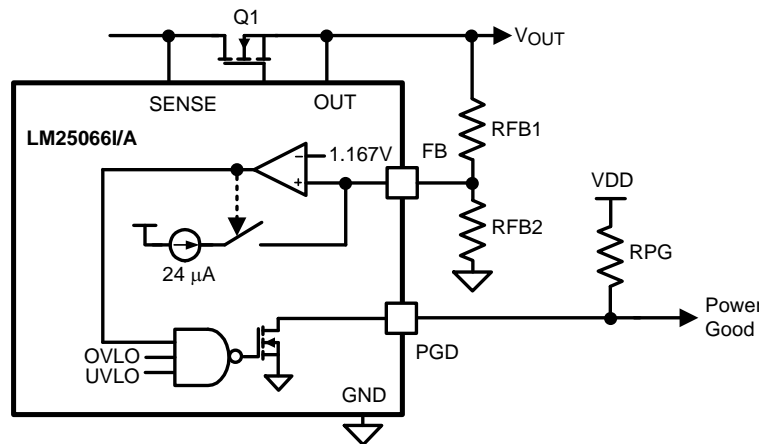


Figure 14. Programming the PGD Threshold

16 Shutdown

With the circuit in normal operation, the LM25066I/A can be shutdown by grounding the UVLO/EN pin or by clicking the Power button on the LM25066I/A block representation in the GUI.

17 Board Layout and Probing Cautions

Refer to the datasheet ([SNVS824](#)) for detailed layout guidelines. For most applications, the layout of this evaluation module as detailed in [Section 20](#) should be sufficient to provide a working solution with accurate telemetry. The following should be kept in mind when the board is powered:

1. Use CAUTION when probing the circuit to prevent injury as well as possible damage to the circuit.
2. At maximum load current (50A), the wire size and length used to connect the power source and the load become very important. The wires connecting this evaluation board to the power source SHOULD BE TWISTED TOGETHER to minimize inductance in those leads. The same applies for the wires connecting this board to the load. This recommendation is made in order to minimize high voltage transients from occurring when the load current is shut off.
3. A 15V TVS diode located as close as possible to the LM25066I/A VIN and GND pins provides the critical function of clamping inevitable input voltage overshoots when the pass MOSFET turns off.
4. An analog signal ground plane is used local to the LM25066I/A and is connected to the PCB power ground planes at a single point.
5. Input capacitor, C1, local to the LM25066I/A provides a decoupling function. During hot-plug events, the input current spike to charge this capacitor may be deemed unacceptable. Note that it has been verified, assuming correct TVS placement, that operation of the LM25066I/A without C1 is feasible.

18 Performance Characteristics

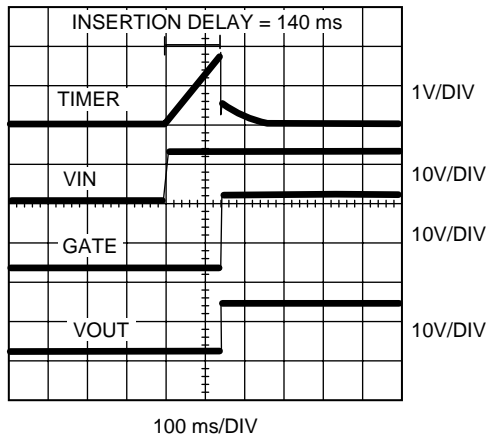


Figure 15. Insertion Time Delay

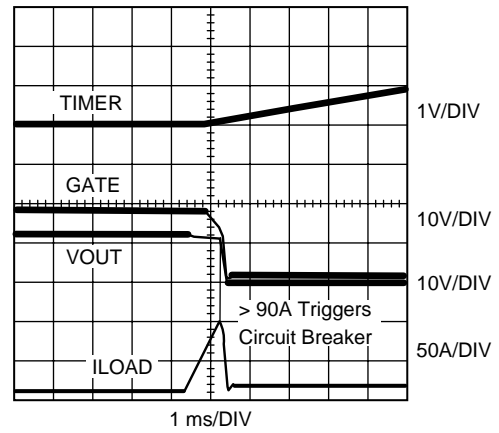


Figure 16. Circuit Breaker Response

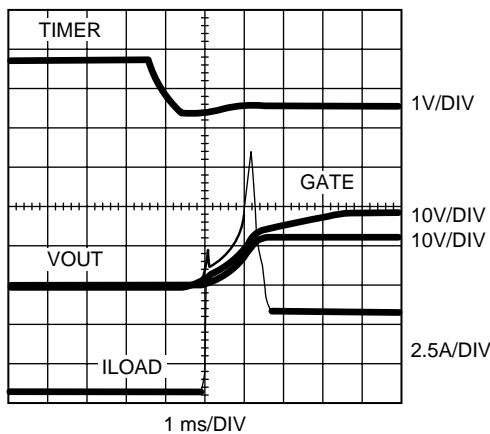


Figure 17. Turn-On Sequence into a 4Ω Load

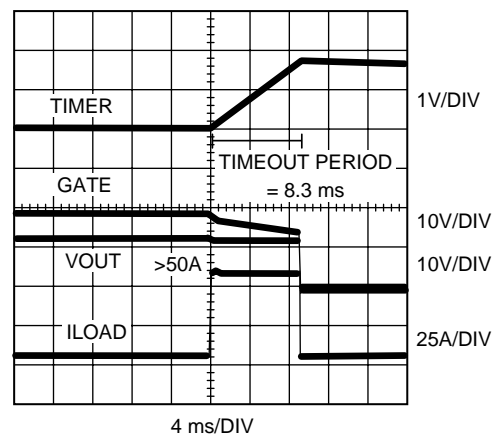


Figure 18. Initial Fault Timeout

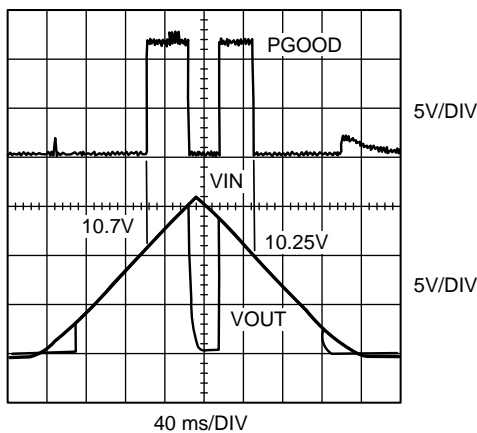


Figure 19. PGD Power up/Power down behavior

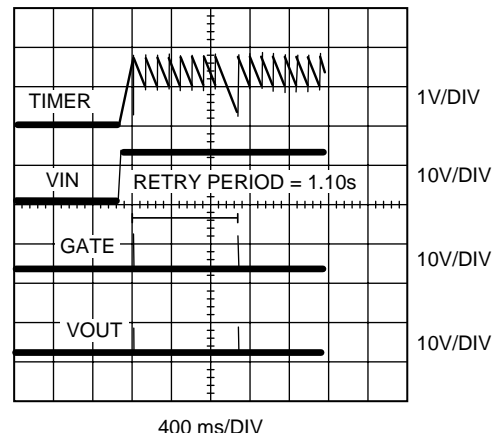


Figure 20. Restart Timing

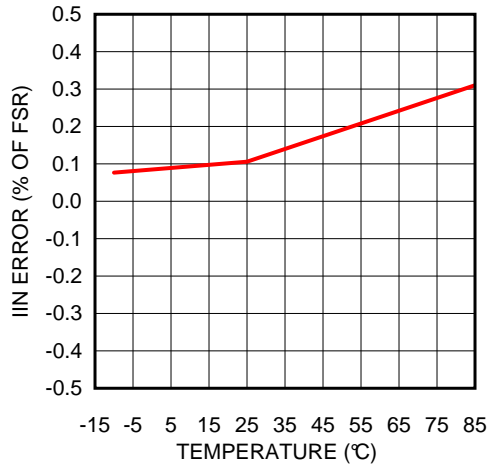


Figure 21. IIN Error vs Temperature

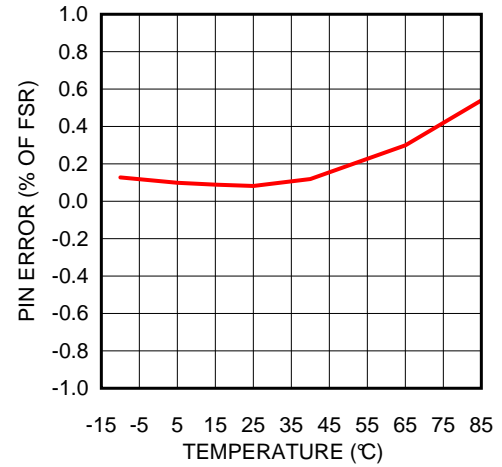
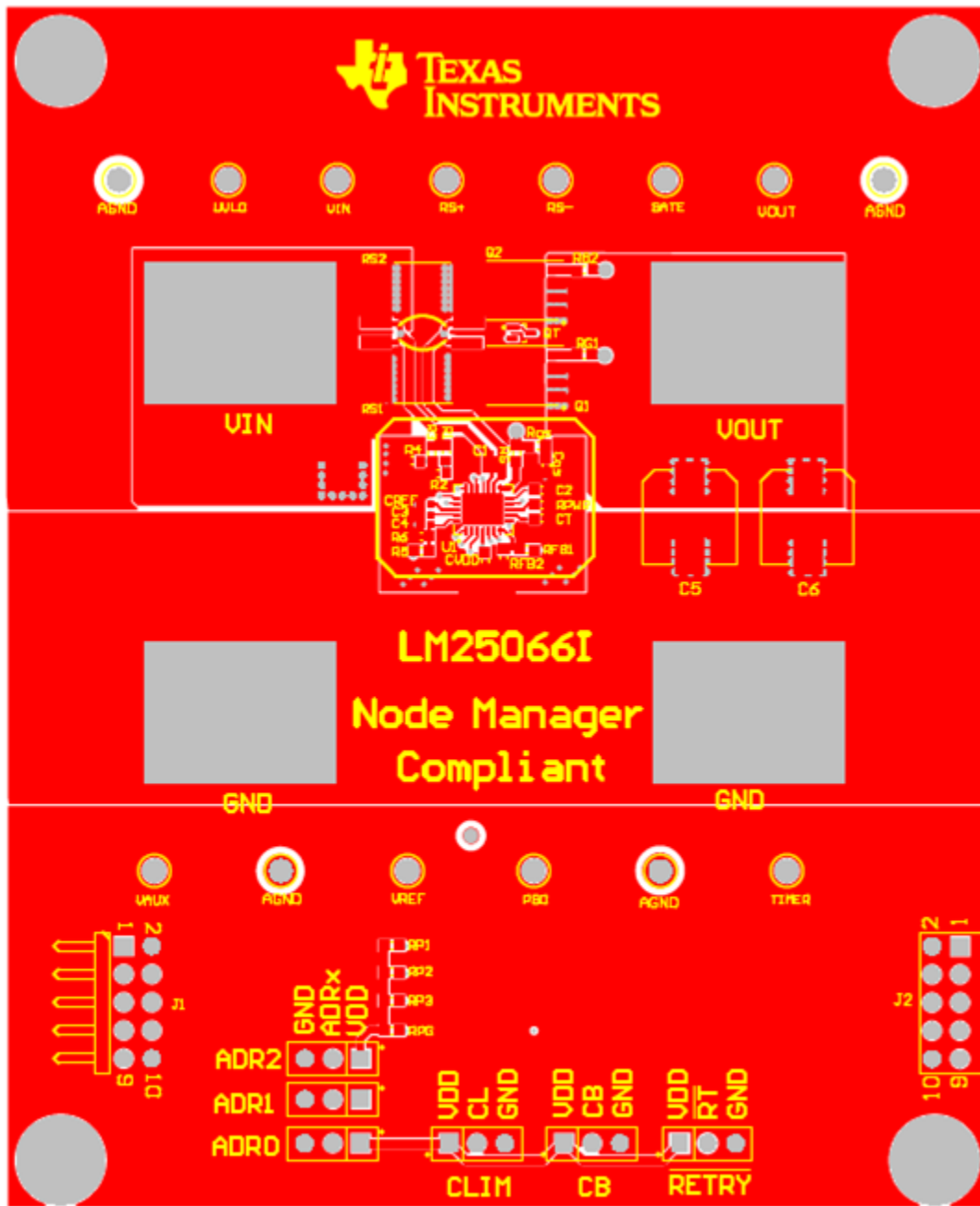


Figure 22. PIN Error vs Temperature

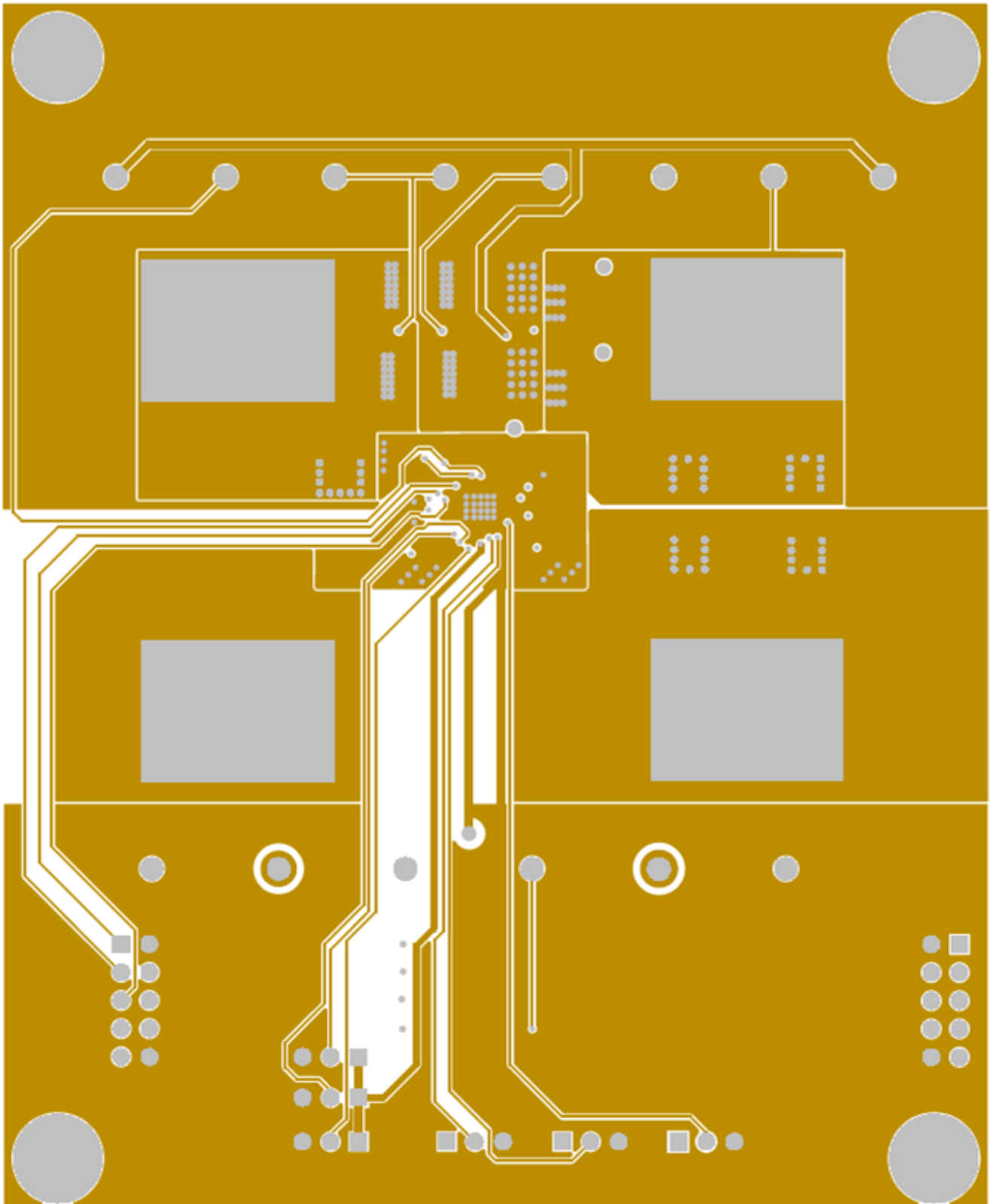
19 Bill of Materials

Designator	Value	Description	Manufacturer	Part Number	Qty
RETRY, ADR0, ADR1, ADR2, CB, CLIM	1x3	Header, TH, 100mil, 1x3, Gold plated, 230 mil above insulator	Samtec Inc.	TSW-103-07-G-S	6
C1	1 μ F	Ceramic, X7R, 50V, 10%, 0805	MuRata	GRM21BR71H105KA12L	3
C2	0.1 μ F	Ceramic, X7R, 50V, 10%, 0603	AVX	06033C104KAT2A	1
C3, C4	1000 pF	Ceramic, X7R, 25V, 10%, 0402	TDK	C1005X7R1H102K	2
CVdd	4.7 μ F	Ceramic, X5R, 10V, 20%, 0603	Taiyo Yuden	EMK107ABJ475KA-T	1
CREF	1 μ F	Ceramic, X5R, 10V, 20%, 0402	MuRata	GRM155R61A105KE15D	1
C5, C6	330 μ F	AL, 25V, 20%, 0.17 Ohm ESR	Nichicon	UUD1E331MNL1GS	2
CT	0.47 μ F	Ceramic, 0.47 μ F, 16V, 10%, X7R, 0603	MuRata	GRM188R71C474KA88D	1
D1	15V	Diode TVS 15V 5kW SMC	Littlefuse	5.0SMDJ15A	1
D2	30V 15A	Diode Schottky 30V 15A SMC	Micro	SK153-TP	1
GNDin, GNDout, VIN, VOUT		Terminal 90A Lug	Panduit	CB70-14-CY	4
GND1, GND2, GND3		Test Point, TH, Miniature, Black	Keystone Electronics	5001	3
H1, H2, H3, H4		Screw Machine, PHIL 4-40x1/4 SS	B&F Fastener Supply	NY PMS 440 0025 PH	4
H5, H6, H7, H8		Standoff, Hex, 4-40THR ALUM 1"L	Keystone	2205	4
J1		Header, 5-pin, dual row, right angle	Samtec	TSW-105-08-L-D-RA	1
J2		CONN, Female 10 POSDL 0.1"RA	Sullins Connector Solutions	PPPC052LJBN-RC	1
PGD, GATE		Test Point, TH, Miniature, White	Keystone Electronics	5002	1
Q1		MOSFET, N-CH, 25V, 100A	NXP	PSMN1R2-25YL	1
QT		NPN, 0.2A, 40V	Central Semiconductor	CMPT3904	1
R1, R6, RPG	10.0k	RES, 10.0k ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW060310K0FKEA	3
R2	6.34k	RES, 6.34k ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW06036K34FKEA	1
R3	49.9k	RES, 49.9k ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW060349K9FKEA	1
R4	4.12k	RES, 4.12k ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW06034K12FKEA	1
R5	150k	RES, 150k ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW0603150KFKEA	1
RFB1	22.6k	RES, 22.6k ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW060322K6FKEA	1
RFB2	2.74k	RES, 2.74k ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW06032K74FKEA	1
RG	10	RES, 10 ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW060310R0FKEA	1
RG1	0	RES, 0 ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW06030000Z0EA	1
RPWR	6.98k	RES, 6.98k ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW06036K98FKEA	1
RS+, RS-, TIMER, VAUX, VREF		Test Point, TH, Miniature, Yellow	Keystone Electronics	5004	5
RS1	0.5 m Ω	RES, 0.0005 ohm, 1%, 3W, 3921	Vishay-Dale	WSL3921L5000FEA	1
U1	WQFN-24	System Power Management and Protection IC	Texas Instruments	LM25066I/A	1
VIN_TP, VOUT_TP		Test Point, TH, Miniature, Red	Keystone Electronics	5000	2

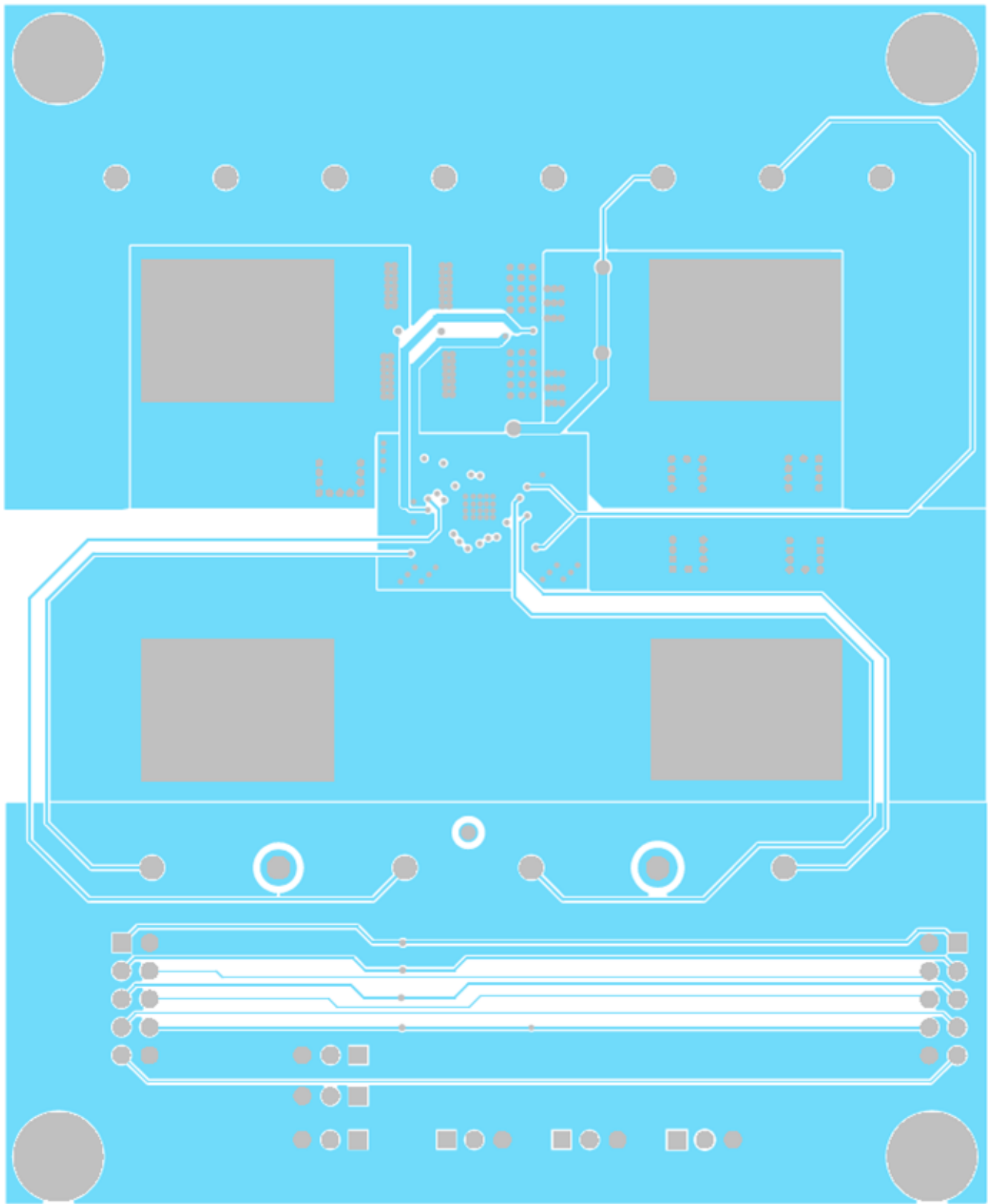
20 PC Board Layout



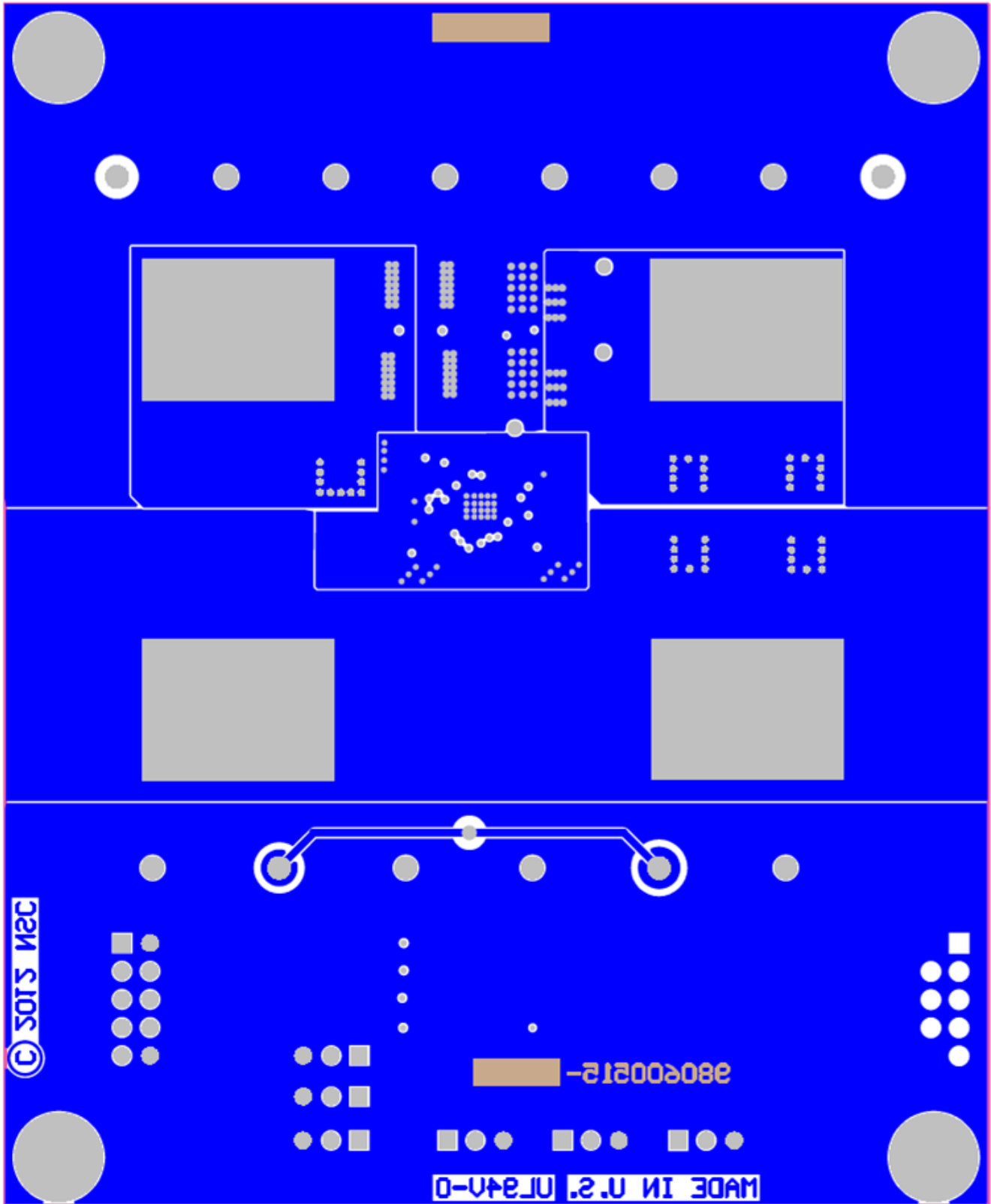
Top Layer



Mid Layer 1



Mid Layer 2



Bottom Layer

21 Schematic

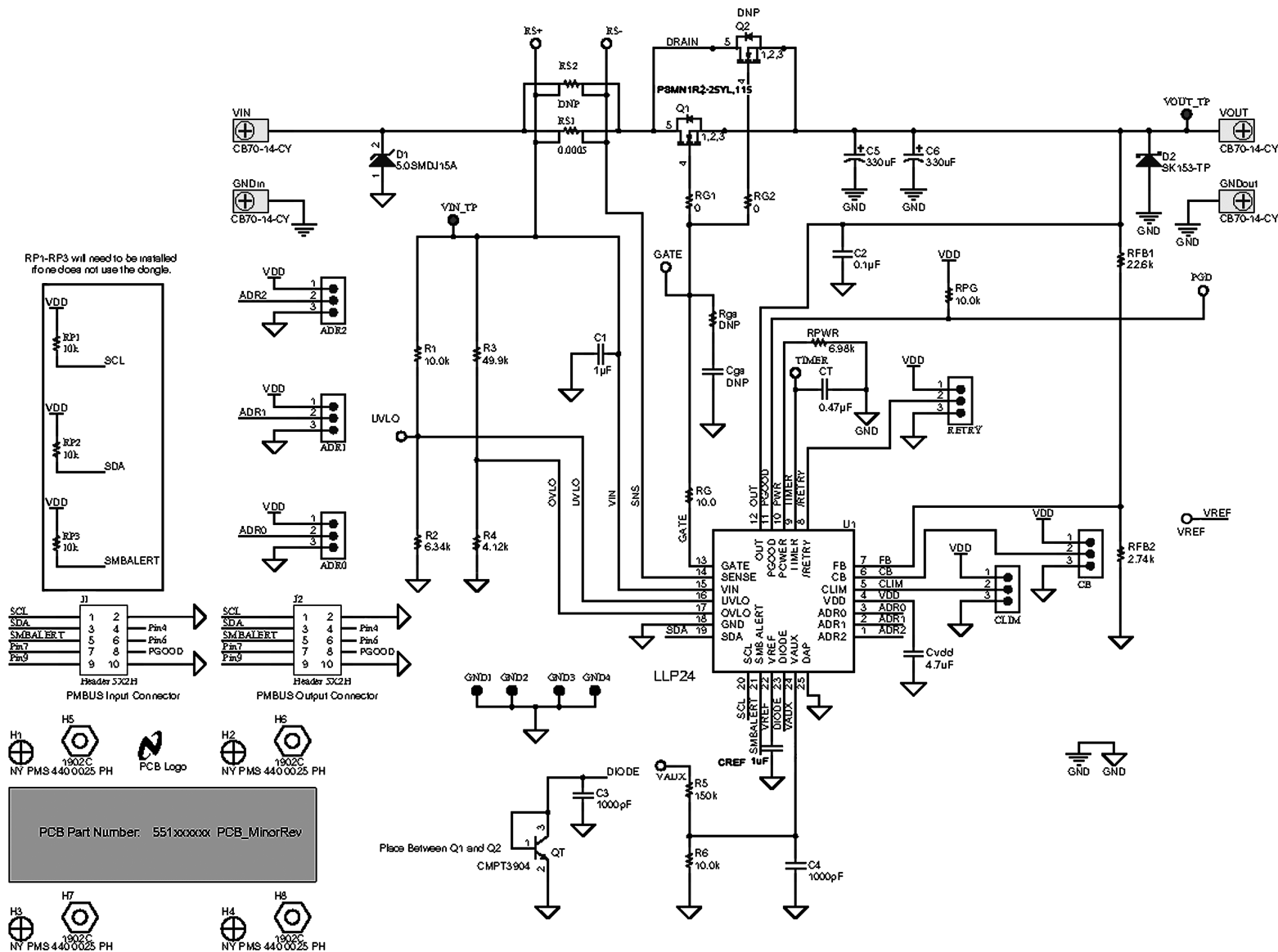


Figure 23. LM25066/A Evaluation Board Schematic

STANDARD TERMS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, and/or documentation which may be provided together or separately (collectively, an "EVM" or "EVMs") to the User ("User") in accordance with the terms set forth herein. User's acceptance of the EVM is expressly subject to the following terms.
 - 1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM ("Software") shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms that accompany such Software
 - 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 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 a nonconforming EVM if (a) the nonconformity was 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, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.
 - 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.

WARNING

Evaluation Kits 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 shall operate the Evaluation Kit within TI's recommended guidelines and any applicable legal or environmental requirements as well as reasonable and customary safeguards. Failure to set up and/or operate the Evaluation Kit within TI's recommended guidelines may result in personal injury or death or property damage. Proper set up entails following TI's instructions for electrical ratings of interface circuits such as input, output and electrical loads.

NOTE:

EXPOSURE TO ELECTROSTATIC DISCHARGE (ESD) MAY CAUSE DEGRADATION OR FAILURE OF THE EVALUATION KIT; TI RECOMMENDS STORAGE OF THE EVALUATION KIT IN A PROTECTIVE ESD BAG.

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。

<https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-delivered-in-japan.html>

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.

【無線電波を送信する製品の開発キットをお使いになる際の注意事項】 開発キットの中には技術基準適合証明を受けていないものがあります。技術適合証明を受けていないものご使用に際しては、電波法遵守のため、以下のいずれかの措置を取っていただく必要がありますのでご注意ください。

1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。
2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。

上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。日本テキサス・イ

ンスツルメンツ株式会社

東京都新宿区西新宿 6 丁目 2 4 番 1 号

西新宿三井ビル

3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lstds/ti_ja/general/eStore/notice_02.page

電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。 <https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-for-power-line-communication.html>

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.
 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:*
 - 6.1 EXCEPT AS SET FORTH ABOVE, EVMS AND ANY MATERIALS PROVIDED WITH THE EVM (INCLUDING, BUT NOT LIMITED TO, REFERENCE DESIGNS AND THE DESIGN OF THE EVM ITSELF) ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." TI DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING SUCH ITEMS, INCLUDING BUT NOT LIMITED TO ANY EPIDEMIC FAILURE WARRANTY OR IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADE SECRETS OR OTHER INTELLECTUAL PROPERTY RIGHTS.
 - 6.2 EXCEPT FOR THE LIMITED RIGHT TO USE THE EVM SET FORTH HEREIN, NOTHING IN THESE TERMS SHALL BE CONSTRUED AS GRANTING OR CONFERRING ANY RIGHTS BY LICENSE, PATENT, OR ANY OTHER INDUSTRIAL OR INTELLECTUAL PROPERTY RIGHT OF TI, ITS SUPPLIERS/LICENSORS OR ANY OTHER THIRD PARTY, TO USE THE EVM IN ANY FINISHED END-USER OR READY-TO-USE FINAL PRODUCT, OR FOR ANY INVENTION, DISCOVERY OR IMPROVEMENT, REGARDLESS OF WHEN MADE, CONCEIVED OR ACQUIRED.
 7. *USER'S INDEMNITY OBLIGATIONS AND REPRESENTATIONS.* USER WILL DEFEND, INDEMNIFY AND HOLD TI, ITS LICENSORS AND THEIR REPRESENTATIVES HARMLESS FROM AND AGAINST ANY AND ALL CLAIMS, DAMAGES, LOSSES, EXPENSES, COSTS AND LIABILITIES (COLLECTIVELY, "CLAIMS") ARISING OUT OF OR IN CONNECTION WITH ANY HANDLING OR USE OF THE EVM THAT IS NOT IN ACCORDANCE WITH THESE TERMS. THIS OBLIGATION SHALL APPLY WHETHER CLAIMS ARISE UNDER STATUTE, REGULATION, OR THE LAW OF TORT, CONTRACT OR ANY OTHER LEGAL THEORY, AND EVEN IF THE EVM FAILS TO PERFORM AS DESCRIBED OR EXPECTED.
-

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 OR THE USE OF THE EVMS , 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 TWELVE (12) MONTHS AFTER THE EVENT THAT GAVE RISE TO THE CAUSE OF ACTION HAS OCCURRED.

8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY USE OF AN EVM PROVIDED HEREUNDER, INCLUDING FROM ANY WARRANTY, INDEMNITY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS, , EXCEED THE TOTAL AMOUNT PAID TO TI BY USER FOR THE PARTICULAR EVM(S) AT ISSUE DURING THE PRIOR TWELVE (12) MONTHS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM 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
Copyright © 2023, Texas Instruments Incorporated

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you fully indemnify TI and its representatives against any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#), [TI's General Quality Guidelines](#), or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products. Unless TI explicitly designates a product as custom or customer-specified, TI products are standard, catalog, general purpose devices.

TI objects to and rejects any additional or different terms you may propose.

Copyright © 2026, Texas Instruments Incorporated

Last updated 10/2025