

LM25056 Evaluation Board

Texas Instruments
Application Note 2144
Joseph Wu
January 16, 2012



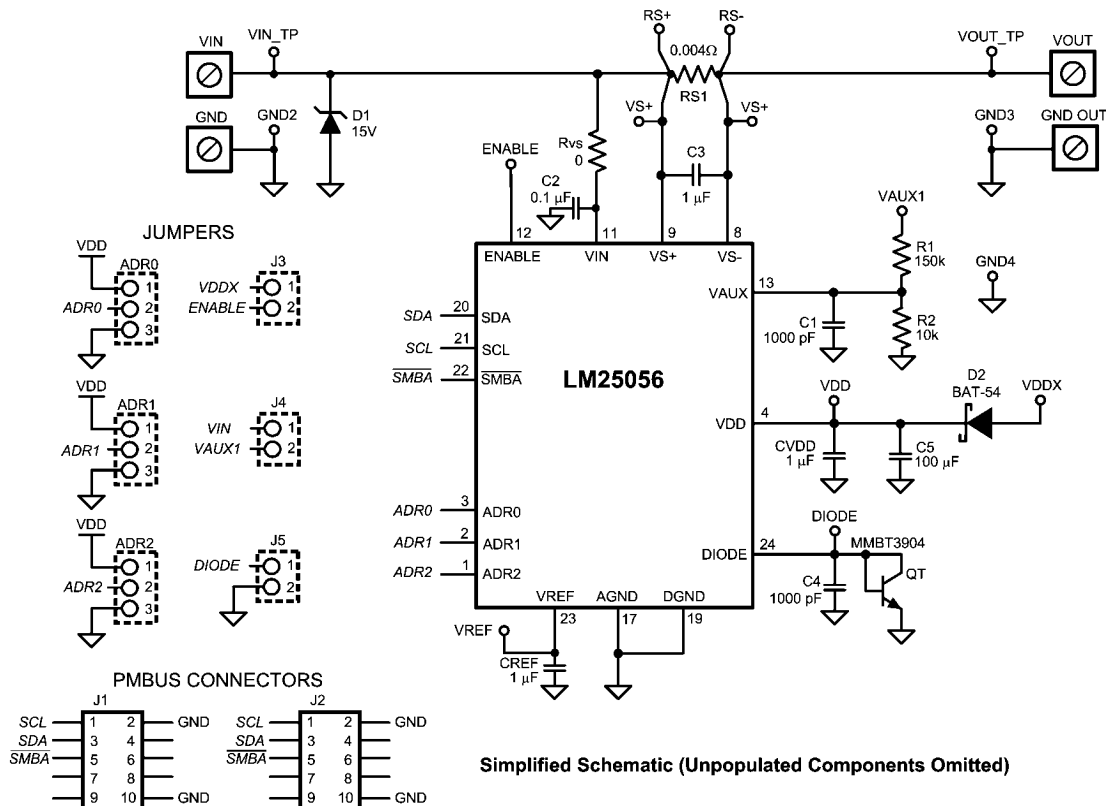
Introduction

The LM25056EVK evaluation kit provides the design engineer with a telemetry measurement IC board with a PMBus™ compliant SMBus™/I2C interface. This application note describes the various functions of the board, how to test and evaluate it, and how to use the companion graphical user interface (GUI). The GUI is used to collect telemetry, configure warning and fault thresholds, and assist the designer with selection of external components for a specific application. Use of the advanced telemetry and monitoring capabilities of this device requires the installation of the Intelligent Power Manager graphical user interface. Please check the LM25056 webpage for the latest software and datasheet information.

PCB Features

- Input voltage range: 3V to 15V (limited by input clamp D1)
- Programmable Current Measurement Range: 7.5 Amps or 15 Amps
- Computer connection to communications dongle, through USB cable
- PCB Size: 3.5" x 3.5"
- Solution Size: 0.75" x 0.75"

Simplified Schematic



30160361

FIGURE 1. Simplified Evaluation Board Schematic

The simplified schematic for the LM25056 evaluation board is shown in Figure 1. Connections to the PMBus interface are provided by J1. Panduit® terminal lugs bolt down to the PCB to provide input and output connections. Jumpers ADR0, ADR1, and ADR2 set the PMBus address of the device to one of 27 unique addresses. Jumpers also exist to connect ENABLE to an external VDD supply, VIN to a voltage divider to

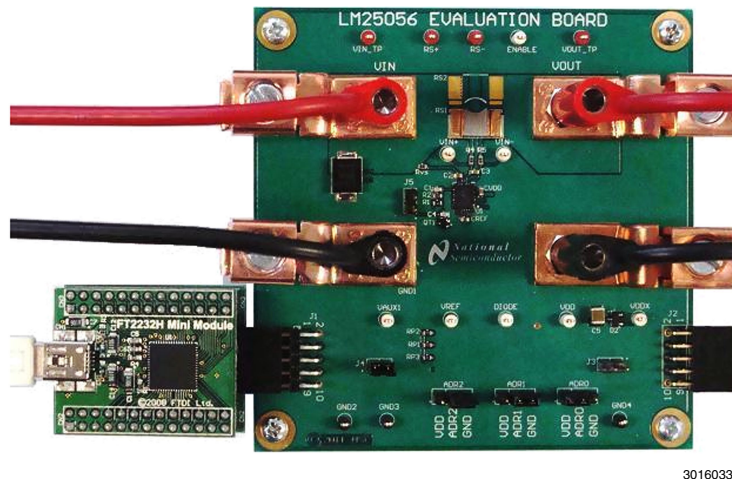
be measured with VAUX, and a DIODE bypass to disable the temperature measurement. Test points are provided to measure the input voltage, output voltage, VDD, VREF, the sense resistor voltage (through RS+ and RS-), and the temperature DIODE. Other test points can be used to apply voltage to ENABLE and VDDX pins.

Getting Started

The LM25056 evaluation kit hardware is shown in [Figure 2](#). The board offers two connections for the system input voltage and load. In the board's current form, the system voltage and load can be plugged directly into the female banana receptacles. To measure higher currents, the sense resistors can be paralleled or replaced to maintain the full-scale measurement voltage of the sense resistor. A footprint for RS2 is not popu-

lated and is provided to accommodate evaluation of designs for measuring currents greater than 15A. For currents higher than 15A, it is recommended to use the copper Panduit® lugs with low gauge wire to minimize the cable power dissipation and voltage drops.

The LM25056EVB is supplied with the PMBus address set to 16h as dictated by the jumper configuration of the ADR0, ADR1, and ADR2 jumper connections.



30160333

FIGURE 2. Connection Illustration

The first step to evaluate the telemetry features of LM25056 demonstration is to install the GUI software. The software 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. This file should be executed on a PC running Windows XP or later to install the software. Once the GUI software is installed the hardware should be configured as shown in [Figure 2](#)

Hardware Setup Steps

1. Connect the input supply to the VIN and GND banana plugs.
2. Connect the load to the VOUT and GND banana plugs.
3. Connect the FTDI Dongle to the 10 pin connector on the left side of the board.
4. Connect the supplied mini USB cable from the FTDI dongle to an USB port on a PC.

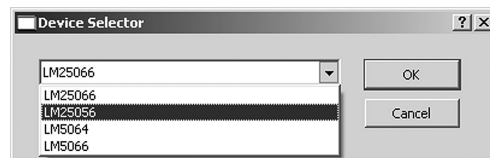
When the FTDI dongle is connected for the first time the user will be prompted to install the device drivers. For the most current driver installation procedure refer to the README.TXT file in the installation directory.

For testing the board functionality, 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. If not careful, wiring inductance in the supply lines will generate a voltage transient at shutoff

which can exceed the absolute maximum rating of the LM25056, resulting in its destruction. To protect against such voltage transients, a transient voltage suppression (TVS) diode D1 is provided to clamp the voltage at the input to within safe operating limits.

Device Evaluation

After configuring the hardware connections, apply an input voltage of 12V to the device. The current hardware configuration allows the LM25056 device to work with 3V to 15V system rails; however, this getting started guide will assume an input voltage of 12V. Launch the GUI by going to the Windows Start menu -> All Programs -> PMBManager-x.xxxxx -> PMBManager. A pulldown menu should come up with a list of possible devices that the PMBManager can run. Select the "LM25056" option as shown in [Figure 3](#).

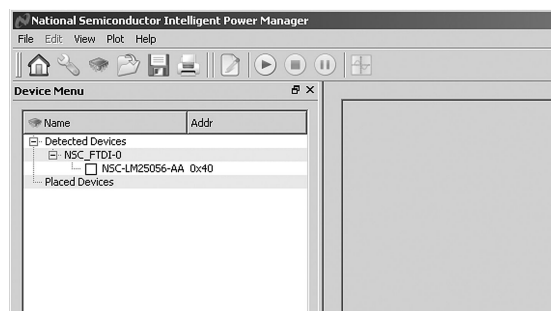


30160301

FIGURE 3. Device Selector

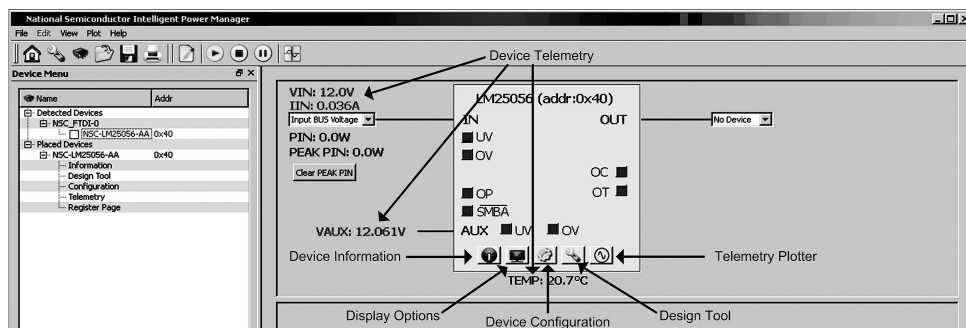
The device should be detected on the PMBus and the initial load screen should appear as shown in [Figure 4](#).

If a device 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 PCB, FTDI connection to the evaluation module, and verify that the power is present on the evaluation PCB by measuring the voltage between the GND and VIN testpoints. Ignoring the detection message allows use of the integrated design tool without the hardware connected.



30160331

FIGURE 4. Initial GUI Screen



30160303

FIGURE 5. LM25056 Block Level Representation

Click on the detected device ID (NSC-LM25056-AA) to display a block level representation of the device as shown in [Figure 5](#). The block level view of the device provides a display of all the telemetry data as well as the faults and warnings supported by the device. The faults and warnings supported are generally associated with an invalid input or output condition.

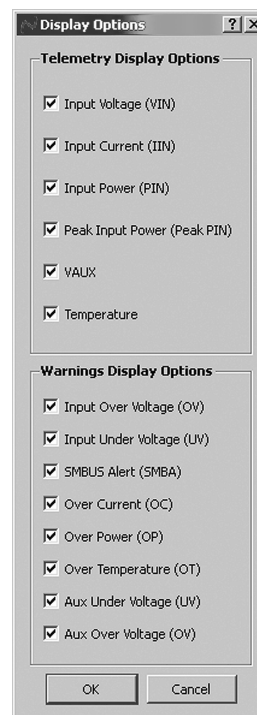
The warnings shown on the left side of the block representation are generally associated with the input. These include input under voltage (UV), input over voltage (OV), and input over power (OP). The SMBus alert status (SMBA) is also shown on the left side and will turn red during any warning or fault event. To facilitate the evaluation of the device, SMBus alerts are automatically cleared by the GUI.

The warnings or faults shown on the right side of the block representation include input over current (OC), and over temperature (OT).

The warnings shown at the bottom of the block representation are associated with the VAUX measurement. The VAUX undervoltage (UV) and the VAUX overvoltage (OV) indicators are shown next to the auxiliary measurement.

To show a repetitive update of the device telemetry and status click on the play icon at the top of the screen. The play button starts an active telemetry log of the gathered data. Clicking the stop icon stops the telemetry collection and allows for the log file to be viewed and saved. The pause button pauses both the displaying and logging of telemetry information.

To disable displaying undesired telemetry click the display icon on the block representation. This will open the window shown in [Figure 6](#) that will allow the user to disable the undesired telemetry, fault, and warning information from appearing on the block level device representation.



30160338

FIGURE 6. LM25056 Telemetry Display Options

Note that turning off the various warning options does not mask the faults from issuing an SMBus alert - it just does not display them if they occur. The device is capable of masking various faults and this functionality can be setup in the device configuration panel.

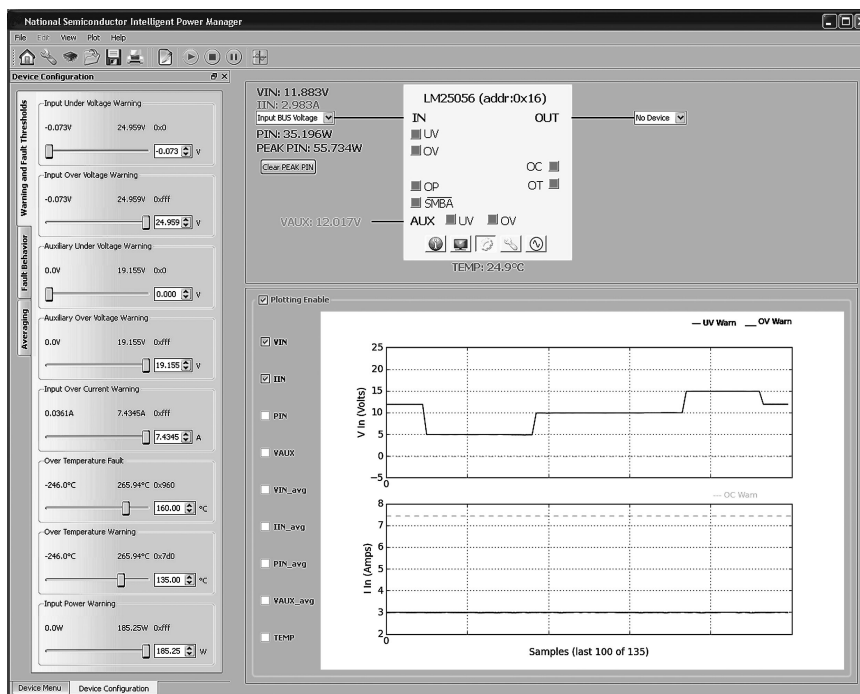
GUI Event Log

A GUI event log is provided to keep track of GUI configuration changes and device fault events. To display the event log select View from the main menu bar and then View Event Log. The event log will appear in the bottom right of the main GUI window. The event log can be detached and expanded if de-

sired by left clicking on the event log window and dragging window with the mouse to the desired location.

Plotting Telemetry

To enable telemetry data plots click on the sine wave icon located on the LM25056 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 2 different parameters may be plotted at the same time as shown in [Figure 7](#).



30160335

FIGURE 7. LM25056 GUI with Telemetry Plotting Tool Enabled

Device telemetry data is plotted as a black line that continually updates as the device is queried. In addition to the device data the relevant warning and fault thresholds are also plotted. Warning thresholds are shown as orange lines while fault thresholds are shown in red.

By going to the plot menu option the user can disable the plotting grid as well as the warning and fault lines.

Configuring the LM25056

Warning thresholds, temperature fault threshold, protection ranges, fault masking, and averaging can be configured in the Device Configuration panel. The first tab of this panel, shown in [Figure 8](#), is enabled by clicking the gear icon shown on the LM25056 block representation.

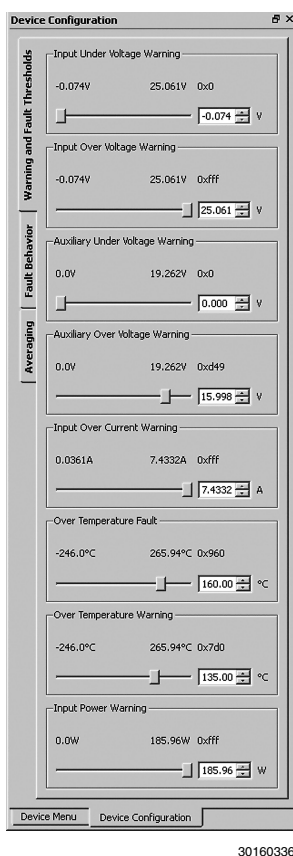


FIGURE 8. Device Configuration Panel - Warning and Fault Thresholds Tab

The Warning and Fault Threshold 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. Fault threshold for the current limit and power limit are set by the hardware design based on the sense resistor. 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; which can be useful when developing software for this device.

The Fault Behavior tab shown in [Figure 9](#) allows the user to set the device fault and warning configuration and masking. By selecting Fault Masking, it allows individual faults and warnings to be masked and not be shown as an SMBus alert. Faults and warnings that only issue a SMBus alert allow masking of the alert.

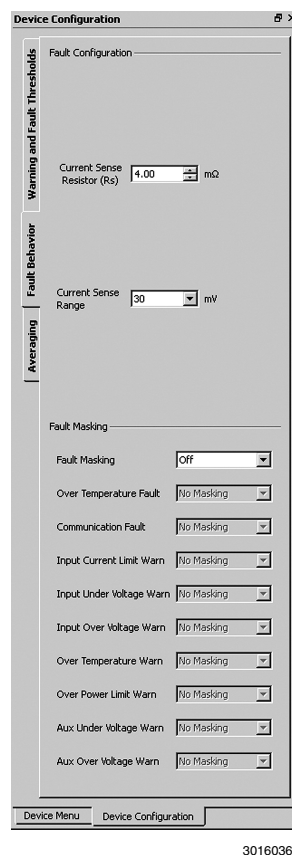


FIGURE 9. Device Configuration Window - Fault Behavior Tab

The Averaging tab allows the user to set the value of the MFR_SAMPLES_FOR_AVG register of the LM25056 and sets the number of samples averaged for telemetry of VIN, IIN, PIN and VAUX. This is selectable from 1 to 4096 in powers of 2. Detail of the Averaging tab is shown below in [Figure 10](#).

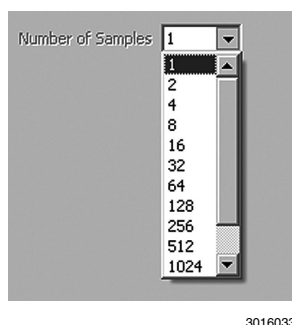


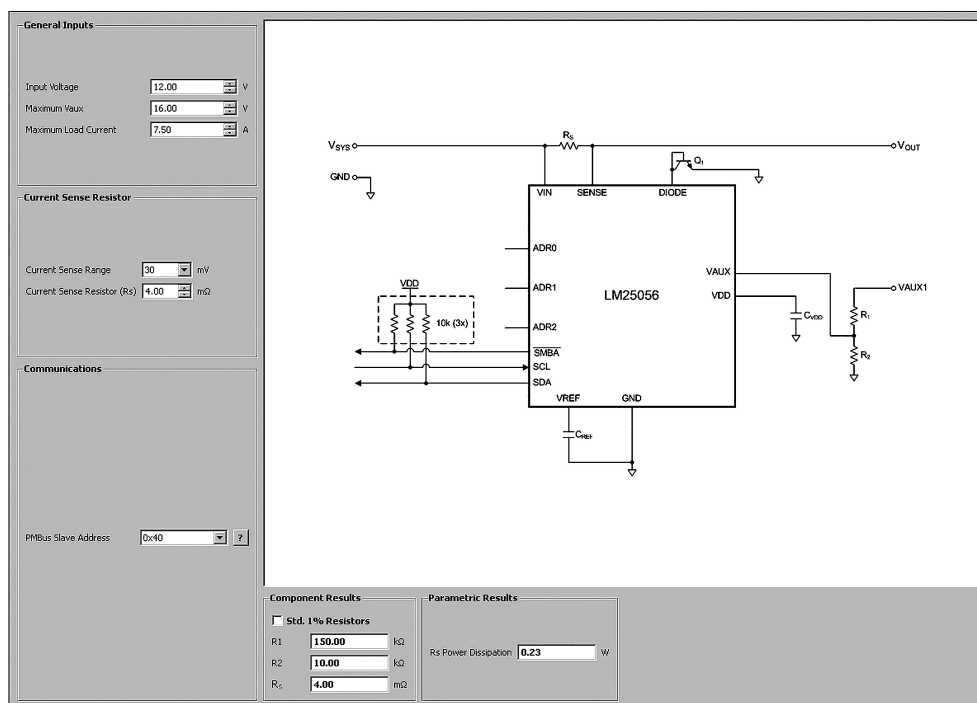
FIGURE 10. Device Configuration Window - Averaging Tab

For convenience, the Device Configuration Panel can be undocked by holding down the left mouse button while the cursor is at the top of the panel and dragging it to where you would like it to be placed.

GUI Design Page

The GUI assumes the hardware configuration is set to default evaluation board configuration. If any of the components are

changed, the device hardware configuration needs to be updated in the design tool section. To open the design tool click the wrench icon located on the LM25056 block representation which will open the window displayed in [Figure 11](#).



30160337

FIGURE 11. LM25056 GUI Design Tool

Activating the design page pulls several adjustable inputs a typical applications schematic. Design inputs are keyed in on the left side of the window.

The input voltage for the LM25056 runs from 3 to 17V. In this tool, it only shows the range for informational purposes and is not used for calculation in the remainder of the window.

The Maximum VAUX1 window is used to calculate the resistor divider for R_1 and R_2 . The calculator assumes that the maximum measured value of the VAUX pin is 1.0V. In operation, the maximum measured value is near 1.2V and the difference allows for a buffer to the full scale. The tool also assumes that R_2 is 10.0 kΩ and calculates the required R_1 value. Once the Maximum VAUX1 value is entered, Values for R_1 and R_2 appear in the Component Results section. The Std. 1% Resistors checkbox will enter in the closest standard 1% values that are available to the resistors.

The Maximum Load Current window is used to determine the size of the sense resistor needed based on the current sense range. The LM25056 has two current sense ranges. The GAIN=0 has an approximate current sense range of 30mV across the sense resistor and is the default state. The GAIN=1 sets the current sense range to approximately 60mV. The current sense range is set with the pull down window on the left side of the design tool.

Once the Maximum Load Current and the Current Sense Range windows are set, the current sense resistor is set in the Current Sense Resistor and Component Results sections. As a default, a setting of 7.5A as the maximum load current at the current sense range of 30mV will set the current sense resistor R_S to 4 mΩ. Entering these values will also show the

power dissipation of R_S in the Parametric Results section at the bottom of the design tool.

The PMBus Slave Address pulldown window shows the possible PMBus addresses that the LM25056 can be set to respond to. By selecting the one of the 27 possible addresses, the necessary connection to the ADR0, ADR1, and ADR2 pins is shown on the circuit diagram. As an example, if 0x17 is selected, the ADR0 would be floating, ADR1 would be connected to VDD, and ADR2 would be grounded. This set of connections would be shown on the circuit diagram, and can be tested on the demo board.

Once a design is 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 device 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 icon 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 correct coefficients to scale the raw telemetry data. 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.

However, note the design tool calculates parameters factoring in worst case tolerances, while the equations in the datasheet based on typical thresholds.

tionality of the LM25056. These features include the ability to read telemetry, device identification and status registers, as well monitoring the SMBus Alert interrupt.

GUI Register Page

The GUI Register Page, as shown in [Figure 12](#), provides the user with several features to help better understand the func-

The screenshot displays the LM25056 GUI Register Page, organized into several sections:

- Telemetry:**
 - Averaged (IO Mode: AVG_BLOCK_READ -- time aligned):** Includes checkboxes for IIN (A), VAUX (V), VIN (V), and PIN (W), along with a SAMPLES_FOR_AVERAGE dropdown set to 1. Values are 0.000, 0.000, 0.000, 0.000, and 1. Buttons: Update Telemetry, CLEAR_PIN_PEAK.
 - Immediate (IO Mode: BLOCK_READ -- time aligned):** Includes checkboxes for IIN (A), VAUX (V), VIN (V), PIN (W), and TEMP_1 (°C). Values are 0.000, 0.000, 0.000, 0.000, and 0.0. Buttons: Update Telemetry, CLEAR_PIN_PEAK.
 - Immediate (IO Mode: discrete):** Includes a checkbox for PEAK PIN (W) with a value of 0.000.
 - Identification Information (IO Mode: discrete):** Includes checkboxes for Capability, Manufacturer ID, Manufacturer Model, and Manufacturer Revision. Buttons: Update ID Information.
- Status:**
 - Immediate (IO Mode: BLACK_BOX_READ -- time aligned):** Values for IIN (A), VAUX (V), VIN (V), PIN (W), and TEMP_1 (°C) are 0.036, 0.000, -0.074, 0.000, and 35.0.
 - Interrupts (IO Mode: real-time):** Shows /SMB and PGOOD status.
 - Register Operation Control:** Buttons for Update Status and CLEAR_FAULTS.
- STATUS_WORD (IO Mode: discrete):**
 - MSB (msb - lsb):** VOUT, IOUT/POUT, INPUT, MFR, POWER GOOD #, FANS, OTHER, UNKNOWN. All values are 0.
 - LSB (msb - lsb):** BUSY, DEVICE OFF, VOUT OV FAULT, IOUT OC FAULT, VIN UV FAULT, TEMP WARN/FAULT, CML FAULT, NONE OF ABOVE. All values are 0.
- Second Tier (IO Mode: discrete):**
 - STATUS_INPUT (msb - lsb):** VIN OV FAULT, VIN OV WARN, VIN UV WARN, VIN UV FAULT, NOT USED, IIN OC FAULT, IIN OC WARN, PIN OP WARN. All values are 0.
 - STATUS_CML (msb - lsb):** INV CMD, INV DATA, PEC FAILED, MEM FAULT, PROC FAULT, RSRVD, MISC FAULT, OTHER. All values are 0.
- DIAGNOSTIC_WORD (IO Mode: discrete):**
 - MSB (msb - lsb):** RSRVD, IIN OC/OP WARN, VIN UV WARN, VIN OV WARN, RSRVD, OVER TEMP WARN, VAUX UV WARN, VAUX OV WARN. All values are 0.
 - LSB (msb - lsb):** CFG PRESET, RSRVD, RSRVD, RSRVD, RSRVD, OVER TEMP FAULT, CML FAULT, RSRVD. All values are 0.
- DIAGNOSTIC_WORD (IO Mode: BLACK_BOX_READ -- time aligned):**
 - MSB (msb - lsb):** RSRVD, IIN OC/OP WARN, VIN UV WARN, VIN OV WARN, RSRVD, OVER TEMP WARN, VAUX UV WARN, VAUX OV WARN. All values are 0.
 - LSB (msb - lsb):** CFG PRESET, RSRVD, RSRVD, RSRVD, RSRVD, OVER TEMP FAULT, CML FAULT, RSRVD. All values are 0.

30160362

FIGURE 12. LM25056 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 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. PEAK PIN is 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 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 SMBA interrupt will indicate if a warning or fault has occurred and if the output voltage is within specifications. It is always active and there is no need to click an Update button to change their state. The LM25056 does not have a PGOOD indicator and is not used in this device. Clicking the Update Status button under the Register Operation Control heading will update the bits in all of the registers under the Status section as well as the telemetry in the BLACK_BOX_READ. 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 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 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 SMBA assertion following the CLEAR_FAULTS. This allows the user to determine device conditions at the first occurrence of the SMBA assertion.

Shutdown

With the circuit in normal operation, the LM25056 can be shutdown by grounding the ENABLE pin.

External VDD

The LM25056 VDD can be powered from an external source to maintain some telemetry readings if the VIN fails. On the evaluation board, a connection of VDDX to 5V can be used to power the VDD line and maintain telemetry readings for VIN and temperature. The VDDX supplies power through a Schottky diode and a large capacitor.

Note that with an external VDD connected to the VDDX line, the LM25056 cannot be put into a low power mode with the ENABLE pin. In this case, simply connect the ENABLE to VDDX and lower this line down to disable the part.

Board Layout and Probing Cautions

Refer to the product datasheet for detailed layout guidelines. For most applications the layout of this evaluation module as detailed in the PC Board Layout section of this document 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 larger load current (>15A), the wire size and length used to connect the power source and the load may 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 LM25056 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 LM25056 and is connected to the PCB power ground planes at a single point.

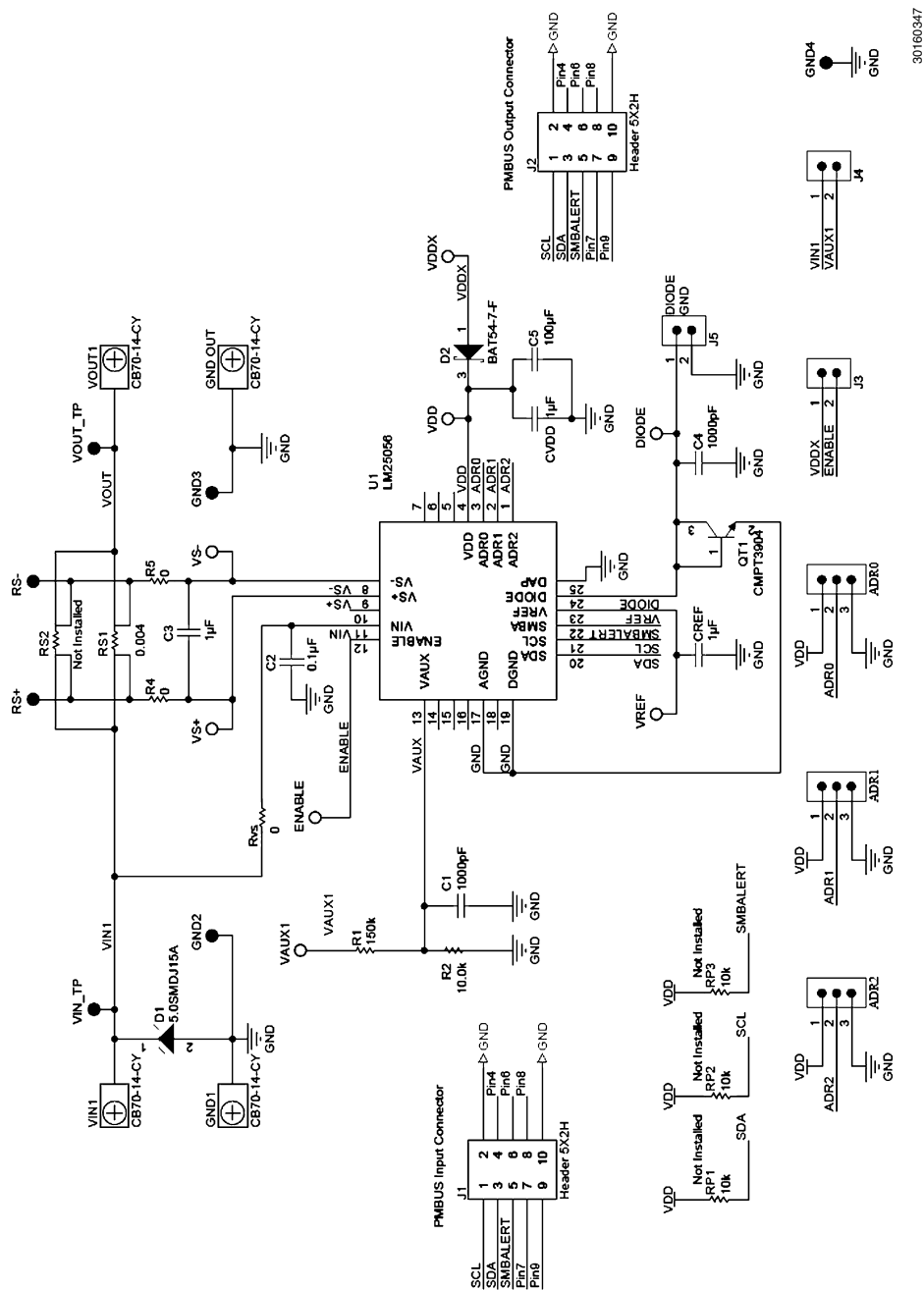
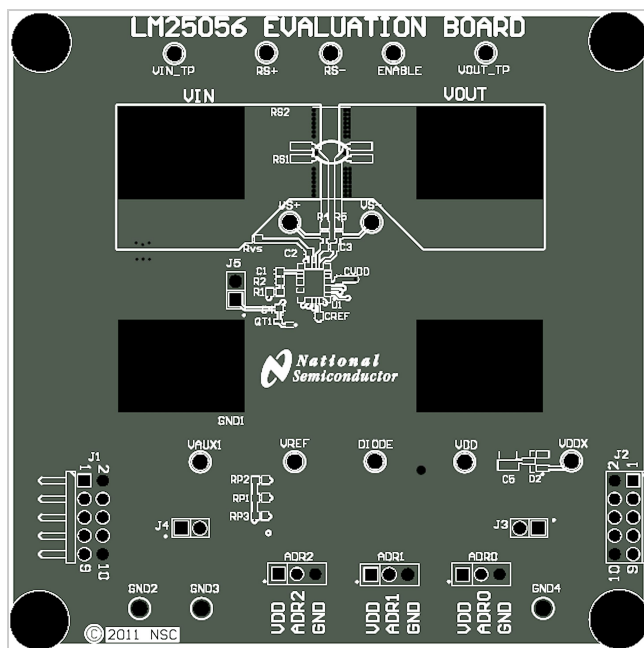


FIGURE 13. Evaluation Board Schematic

Bill of Materials

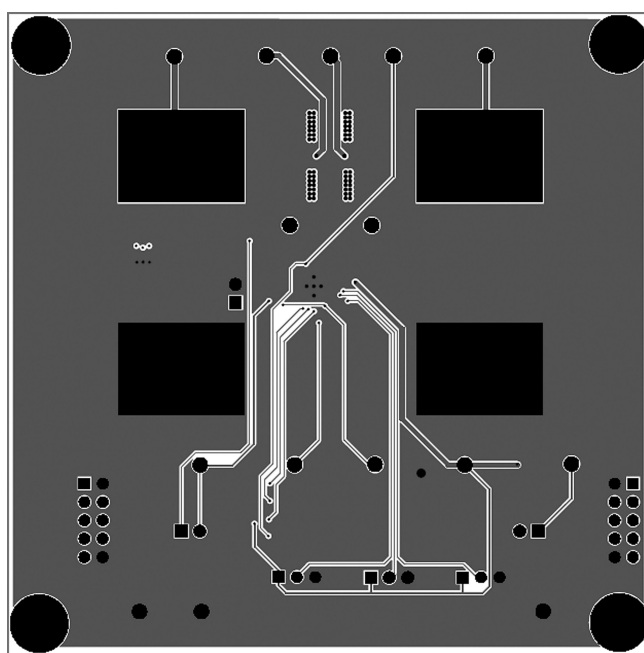
Designator	Value	Description	Manufacturer	Part Number	Qty.
ADR0, ADR1, ADR2	1x3	Header, TH, 100mil, 1x3, Gold plated, 230 mil above insulator	Samtec Inc.	TSW-103-07-G-S	3
C1, C4	1000pF	Ceramic, NPO, 50V, 10%, 0603	AVX	06035A102KAT2A	2
C2	0.1uF	Ceramic, X7R, 25V, 10%, 0603	AVX	06033C104KAT2A	1
C3, CREF, CVDD	1uF	Ceramic, X7R, 16V, 10%, 0603	Murata	GRM188R71C105KA12D	3
C5	100uF	Ceramic, X5R, 6.3V, 20%, 1210	Kemet	C1210C107M9PACTU	1
D1	15V	Diode TVS 15V 5kW SMC	Littlefuse Inc.	5.0SMDJ15A	1
D2	30V, 0.2A	Diode, Schottky, SOT-23	Diodes Inc.	BAT54-7-F	1
GND2, GND3, GND4		Test Point, TH, Miniature, Black	Keystone Electronics	5001	3
DIODE, ENABLE, VAUX1, VDD, VDDX, VS+, VS-, VREF		Test Point, TH, Miniature, White	Keystone Electronics	5002	8
VIN1, VOUT1, GND OUT, GND1		Terminal 90A Lug	Panduit	CB70-14-CY	4
H1, H2, H5, H6		Screw Machine, PHIL 4-40x1/4 SS	B&F Fastener Supply	NY PMS 440 0025 PH	4
H3, H4, H7, H8		Standoff, Hex, 4-40THR ALUM 1"L	Keystone	2205	4
J1		Male Header, 5-Pin, Dual row, Right Angle	Samtec, Inc.	TSW-105-08-L-D-RA	1
J2		Female Header, 5-Pin, Dual row, Right Angle	Sullins Connector Solutions	PPPC052LJBN-RC	1
J3, J4, J5		Header, TH, 100mil, 1x2, Gold plated, 230 mil above insulator	Samtec, Inc.	TSW-102-07-G-S	3
QT1	40V, 0.2A	NPN, SOT-323	Central Semiconductor	CMPT3904	1
R1	150k	RES, 150k ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW0603150KFKEA	1
R2	10.0k	RES, 10.0k ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW060310K0FKEA	1
R4, R5, Rvs	0	RES, 0 ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW06030000Z0EA	3
RS+, RS-, VIN_TP, VOUT_TP		Test Point, TH, Miniature, Red	Keystone Electronics	5000	4
RS1	0.004 Ohm	RES, 0.004 ohm, 1%, 3W, 3921	Vishay-Dale	WSL39214L000FEA	1
Shunt		Shunt LP w/ Handle 2 Pos 30AU, Black	TE Connectivity	881545-2	4
Banana Jack		HDWR Banana Jack Uninsulated	Pomona Electronics	3267	4
U1	LLP-24	System Power Managment IC	Vishay-Dale	LM25056APSQ	1

PC Board Layout



Board Top Layer

30160342



Board Mid Layer 1

30160343

Notes

Notes

IMPORTANT NOTICE

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

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

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

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

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

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

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

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

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

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

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

Products

Audio	www.ti.com/audio
Amplifiers	amplifier.ti.com
Data Converters	dataconverter.ti.com
DLP® Products	www.dlp.com
DSP	dsp.ti.com
Clocks and Timers	www.ti.com/clocks
Interface	interface.ti.com
Logic	logic.ti.com
Power Mgmt	power.ti.com
Microcontrollers	microcontroller.ti.com
RFID	www.ti-rfid.com
OMAP Applications Processors	www.ti.com/omap
Wireless Connectivity	www.ti.com/wirelessconnectivity

Applications

Automotive and Transportation	www.ti.com/automotive
Communications and Telecom	www.ti.com/communications
Computers and Peripherals	www.ti.com/computers
Consumer Electronics	www.ti.com/consumer-apps
Energy and Lighting	www.ti.com/energy
Industrial	www.ti.com/industrial
Medical	www.ti.com/medical
Security	www.ti.com/security
Space, Avionics and Defense	www.ti.com/space-avionics-defense
Video and Imaging	www.ti.com/video

TI E2E Community

e2e.ti.com