

## LM25056A System Power Measurement IC with PMBus

Check for Samples: [LM25056A](#)

### FEATURES

- Input Voltage Range: 3V to 17V
- I<sup>2</sup>C/SMBus Interface with PMBus Compliant Command Structure
- Remote Temperature Sensing with Programmable Warning and Shutdown Thresholds
- Real Time Monitoring of  $V_{IN}$ ,  $I_{IN}$ ,  $P_{IN}$ ,  $V_{AUX}$  with 12-bit Resolution and 1 kHz Sampling Rate
- Current Measurement Error:  $\pm 0.5\%$ : +10°C to +85°C
- Voltage Measurement Error:  $\pm 1.0\%$ : +10°C to +85°C
- Power Measurement Error:  $\pm 1.5\%$ : +10°C to +85°C
- True Input Power Measurement Using Simultaneous Sampling of  $V_{IN}$  and  $I_{IN}$  Accurately Averages Dynamic Power Readings
- Averaging of  $V_{IN}$ ,  $I_{IN}$ ,  $P_{IN}$ , and  $V_{AUX}$  Over Programmable Interval Ranging from 0.001 to 4 Seconds
- User Programmable WARN and FAULT Thresholds with SMBus Notification
- Black Box Capture of Telemetry Measurements and Device Status Triggered by WARN and FAULT Conditions
- Full Featured Application Development Software
- WQFN-24 Package

### APPLICATIONS

- Server Backplane Systems
- Base Station Power Distribution Systems
- Subsystem Power Measurement

### DESCRIPTION

The LM25056A combines high performance analog and digital technology with a PMBus™ compliant SMBus™/I<sup>2</sup>C interface to accurately measure the operating conditions of electrical systems including computing and storage blades connected to a backplane power bus. The LM25056A continuously supplies real-time power, voltage, current, and temperature data to the system management host via the SMBus interface.

The LM25056A monitoring block captures both real-time and average values of subsystem operating parameters ( $V_{IN}$ ,  $I_{IN}$ ,  $P_{IN}$ ,  $V_{AUX}$ ) as well as peak power. Accurate power measurement is accomplished by measuring the product of the input voltage and current through a shunt resistor. LM25056A current measurement has a  $\pm 0.5\%$  accuracy over the temperature range of +10°C to +85°C with operation from -40°C to +125°C. A black box (Telemetry/Fault Snapshot) function captures and stores telemetry data and device status in the event of a warning or a fault.



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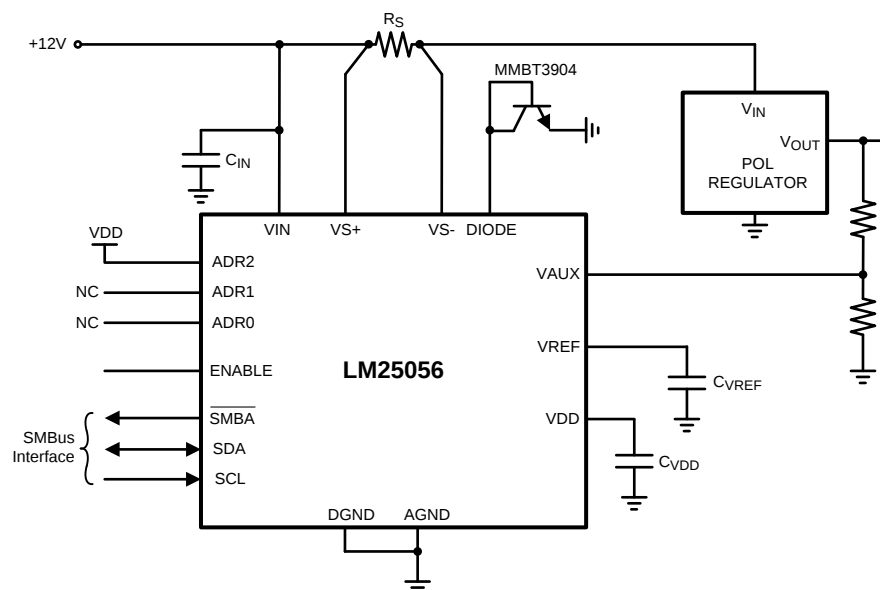
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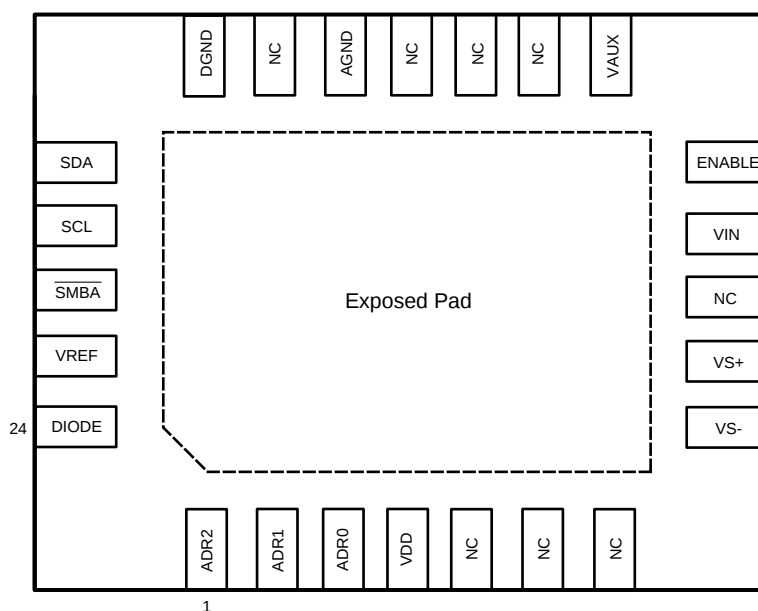
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## Typical Application Schematic



### Connection Diagram



Solder exposed pad to ground.

**Figure 1. Top View  
WQFN-24**

### PIN DESCRIPTIONS

| Pin No. | Name                     | Description                   | Applications Information                                                                                                                                                                  |
|---------|--------------------------|-------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| PAD     | Exposed Pad              | Exposed pad of WQFN package   | No internal electrical connections. Solder to the ground plane to reduce thermal resistance.                                                                                              |
| 1       | ADR2                     | SMBus address line 2          | 3 - state address line. Should be connected to GND, VDD, or left floating.                                                                                                                |
| 2       | ADR1                     | SMBus address line 1          | 3 - state address line. Should be connected to GND, VDD, or left floating.                                                                                                                |
| 3       | ADR0                     | SMBus address line 0          | 3 - state address line. Should be connected to GND, VDD, or left floating.                                                                                                                |
| 4       | VDD                      | Internal sub-regulator output | Internally sub-regulated 3.7V bias supply. Connect a 1 $\mu$ F capacitor on this pin to ground for bypassing. VDD can be driven from an external voltage for low voltage operation.       |
| 5       | NC                       | No Connect                    | Not bonded to die. Can be connected to the ground plane.                                                                                                                                  |
| 6       | NC                       | No Connect                    | Not bonded to die. Can be connected to the ground plane.                                                                                                                                  |
| 7       | NC                       | No Connect                    | Not bonded to die. Can be connected to the ground plane.                                                                                                                                  |
| 8       | VS-                      | Current sense input (-)       | Negative IIN sense amplifier input. The voltage across the current sense resistor ( $R_S$ ) is measured from VS+ to this pin.                                                             |
| 9       | VS+                      | Current sense input (+)       | Positive IIN sense amplifier input. The voltage across the current sense resistor ( $R_S$ ) is measured from this pin to VS-.                                                             |
| 10      | NC                       | No Connect                    | Not bonded to die. Can be connected to the ground plane.                                                                                                                                  |
| 11      | VIN                      | Positive supply input         | A small 0.1 $\mu$ F ceramic bypass capacitor close to this pin is recommended. VIN is measured from this pin.                                                                             |
| 12      | ENABLE                   | Enable                        | Enable pin. This pin has a rising threshold of +1.2V to enable the LM25056A. Lowering this pin below the 75mV hysteresis from the +1.2V threshold will put the part into power down mode. |
| 13      | VAUX                     | Auxiliary voltage input       | Auxiliary pin allows voltage telemetry from an external source. Full scale input of 1.2V                                                                                                  |
| 14      | NC                       | No Connect                    | Not bonded to die. Can be connected to the ground plane.                                                                                                                                  |
| 15      | NC                       | No Connect                    | Not bonded to die. Can be connected to the ground plane.                                                                                                                                  |
| 16      | NC                       | No Connect                    | Not bonded to die. Can be connected to the ground plane.                                                                                                                                  |
| 17      | AGND                     | Analog ground                 | Connect analog ground to digital ground and then to a quiet system ground. Be sure to avoid high current return ground lines.                                                             |
| 18      | NC                       | No Connect                    | Not bonded to die. Can be connected to the ground plane.                                                                                                                                  |
| 19      | DGND                     | Digital ground                | Connect analog ground to digital ground and then to a clean system ground. Be sure to avoid high current return ground lines.                                                             |
| 20      | SDA                      | SMBus data pin                | Data pin for SMBus.                                                                                                                                                                       |
| 21      | SCL                      | SMBus clock                   | Clock pin for SMBus.                                                                                                                                                                      |
| 22      | $\overline{\text{SMBA}}$ | SMBus alert line              | Alert pin for SMBus. Active low.                                                                                                                                                          |
| 23      | VREF                     | Internal reference            | Internally generated precision 2.82V reference used for analog to digital conversion. Connect a 1 $\mu$ F ceramic capacitor on this pin to ground for bypassing.                          |
| 24      | DIODE                    | External diode                | Connect this to a diode-configured MMBT3904 NPN transistor for temperature monitoring.                                                                                                    |



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

### Absolute Maximum Ratings<sup>(1)(2)</sup>

|                                                                                              |                  |                 |
|----------------------------------------------------------------------------------------------|------------------|-----------------|
| VIN, VS-, VS+ to AGND/DGND                                                                   |                  | -0.3V to 24V    |
| SCL, SDA, $\overline{\text{SMBA}}$ , ADR0, ADR1, ADR2, VDD, VAUX, DIODE, ENABLE to AGND/DGND |                  | -0.3V to 6V     |
| VS+ to VS-                                                                                   |                  | -0.3V to +0.3V  |
| ESD Rating <sup>(3)</sup>                                                                    | Human Body Model | 2kV             |
| Storage Temperature                                                                          |                  | -65°C to +150°C |
| Junction Temperature                                                                         |                  | +150°C          |

- (1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional. For specifications and conditions see the Electrical Characteristics.
- (2) If Military/Aerospace specified devices are required, please contact the TI Office/Distributors for availability and specifications.
- (3) The human body model is a 100 pF capacitor discharged through a 1.5 k $\Omega$  resistor into each pin.

## Operating Ratings

|                       |                 |
|-----------------------|-----------------|
| VIN, VS-, VS+ voltage | 3V to 17V       |
| VDD                   | 3V to 5.5V      |
| Junction Temperature  | -40°C to +125°C |

## Electrical Characteristics

Limits in standard type are for  $T_J = +25^\circ\text{C}$  only; limits in boldface type apply over the junction temperature ( $T_J$ ) range of  $-40^\circ\text{C}$  to  $+85^\circ\text{C}$  unless otherwise stated. Minimum and Maximum limits are specified through test, design, or statistical correlation. Typical values represent the most likely parametric norm at  $T_J = +25^\circ\text{C}$ , and are provided for reference purposes only. Unless otherwise stated the following conditions apply:  $V_{IN} = 12\text{V}$ . See <sup>(1)</sup> and <sup>(2)</sup>.

| Symbol                         | Parameter                                                                          | Conditions                                                                                                       | Min.        | Typ.  | Max.        | Units         |
|--------------------------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|-------------|-------|-------------|---------------|
| <b>Input (VIN Pin)</b>         |                                                                                    |                                                                                                                  |             |       |             |               |
| $I_{\text{SUPPLY-EN}}$         | Supply current, enabled                                                            | ENABLE > 1.2V                                                                                                    |             | 1.7   | <b>2.8</b>  | mA            |
| $I_{\text{SUPPLY-DIS}}$        | Supply current, disabled                                                           | ENABLE < 1.2V                                                                                                    |             | 10    | <b>100</b>  | $\mu\text{A}$ |
| <b>VREF Reference</b>          |                                                                                    |                                                                                                                  |             |       |             |               |
| VREF                           | Reference voltage                                                                  |                                                                                                                  |             | 2.82  |             | V             |
| <b>VDD Regulator (VDD pin)</b> |                                                                                    |                                                                                                                  |             |       |             |               |
| VDD                            |                                                                                    |                                                                                                                  | <b>3.1</b>  | 3.7   | <b>4.1</b>  | V             |
| $I_{\text{VDDLIM}}$            | VDD current limit                                                                  | $V_{IN} = 12\text{V}$                                                                                            |             | 50    |             | mA            |
| $\text{POR}_{\text{VDD}}$      | Power on reset threshold at VDD                                                    | VDD increasing                                                                                                   |             | 2.4   | <b>3.0</b>  | V             |
| $\text{POR}_{\text{HYS}}$      | POR hysteresis                                                                     | VDD decreasing                                                                                                   |             | 90    |             | mV            |
| <b>ADC and MUX</b>             |                                                                                    |                                                                                                                  |             |       |             |               |
| Resolution                     |                                                                                    |                                                                                                                  |             | 12    |             | Bits          |
| $t_{\text{RR}}$                | Acquisition round robin time                                                       | Update all telemetry channels                                                                                    |             | 1     |             | ms            |
| <b>Telemetry Accuracy</b>      |                                                                                    |                                                                                                                  |             |       |             |               |
| $I_{\text{INIB}}$              | Current sense input bias current                                                   |                                                                                                                  |             | 20    |             | $\mu\text{A}$ |
| $I_{\text{INFSR}}$             | Current sense full scale range, $V_{\text{SENSE}} = V_{\text{S+}} - V_{\text{S-}}$ | GAIN = 0                                                                                                         |             | 29.68 |             | mV            |
|                                |                                                                                    | GAIN = 1                                                                                                         |             | 60.88 |             | mV            |
| $I_{\text{INLSB}}$             | Current sense input LSB                                                            | GAIN = 0                                                                                                         |             | 7.25  |             | $\mu\text{V}$ |
|                                |                                                                                    | GAIN = 1                                                                                                         |             | 14.87 |             | $\mu\text{V}$ |
| $\text{VAUX}_{\text{FSR}}$     | VAUX input full scale range (ADC native range)                                     |                                                                                                                  |             | 1.199 |             | V             |
| $\text{VAUX}_{\text{LSB}}$     | VAUX input LSB                                                                     |                                                                                                                  |             | 293   |             | $\mu\text{V}$ |
| $\text{VIN}_{\text{FSR}}$      | Supply voltage measurement full scale range                                        | For calculation only, observe maximum voltage ratings.                                                           |             | 25.13 |             | V             |
| $\text{VIN}_{\text{LSB}}$      | Supply voltage measurement LSB                                                     |                                                                                                                  |             | 6.14  |             | mV            |
| $I_{\text{INERR}}$             | Current sense measurement error                                                    | GAIN = 0, $V_{\text{SENSE}} = 25\text{ mV}$ , $+10^\circ\text{C}$ to $+85^\circ\text{C}$                         | <b>-0.5</b> |       | <b>+0.5</b> | %             |
| $I_{\text{INERR}}$             | Current sense measurement error                                                    | GAIN = 0, $V_{\text{SENSE}} = 25\text{ mV}$                                                                      | <b>-1.5</b> |       | <b>+1.5</b> | %             |
| $I_{\text{INERR}}$             | Current sense measurement error                                                    | GAIN = 0, $V_{\text{SENSE}} = 5\text{ mV}$ , $+10^\circ\text{C}$ to $+85^\circ\text{C}$                          | <b>-5</b>   |       | <b>+5</b>   | %             |
| $I_{\text{INERR}}$             | Current sense measurement error                                                    | GAIN = 1, $V_{\text{SENSE}} = 55\text{ mV}$                                                                      |             | 1     |             | %             |
| $P_{\text{ERR}}$               | Input power measurement error                                                      | GAIN = 0, $V_{IN} = 12\text{V}$ , $V_{\text{SENSE}} = 25\text{ mV}$ , $+10^\circ\text{C}$ to $+85^\circ\text{C}$ | <b>-1.5</b> |       | <b>+1.5</b> | %             |
| $P_{\text{ERR}}$               | Input power measurement error                                                      | GAIN = 0, $V_{IN} = 12\text{V}$ , $V_{\text{SENSE}} = 25\text{ mV}$                                              | <b>-3</b>   |       | <b>+3</b>   | %             |
| $P_{\text{ERR}}$               | Input power measurement error                                                      | GAIN = 1, $V_{IN} = 12\text{V}$ , $V_{\text{SENSE}} = 55\text{ mV}$                                              |             | 2     |             | %             |
| $\text{VIN}_{\text{ERR}}$      | Input voltage measurement error                                                    | $V_{IN} = 12\text{V}$ , $+10^\circ\text{C}$ to $+85^\circ\text{C}$                                               | <b>-1.0</b> |       | <b>+1.0</b> | %             |
| $\text{VIN}_{\text{ERR}}$      | Input voltage measurement error                                                    | $V_{IN} = 12\text{V}$                                                                                            | <b>-1.5</b> |       | <b>+1.5</b> | %             |
| $\text{VAUX}_{\text{ERR}}$     | Auxiliary measurement error                                                        | $\text{VAUX} = 1\text{V}$ , $+10^\circ\text{C}$ to $+85^\circ\text{C}$                                           | <b>-1.5</b> |       | <b>+1.5</b> | %             |

(1) Current out of a pin is indicated as a negative value.

(2) All electrical characteristics having room temperature limits are tested during production at  $T_A = +25^\circ\text{C}$ . All bold limits are specified by correlating the electrical characteristics to process and temperature variations and applying statistical process control.

## Electrical Characteristics (continued)

Limits in standard type are for  $T_J = +25^{\circ}\text{C}$  only; limits in boldface type apply over the junction temperature ( $T_J$ ) range of  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  unless otherwise stated. Minimum and Maximum limits are specified through test, design, or statistical correlation. Typical values represent the most likely parametric norm at  $T_J = +25^{\circ}\text{C}$ , and are provided for reference purposes only. Unless otherwise stated the following conditions apply:  $V_{IN} = 12\text{V}$ . See <sup>(1)</sup> and <sup>(2)</sup>.

| Symbol                                       | Parameter                              | Conditions                 | Min.        | Typ. | Max.        | Units              |
|----------------------------------------------|----------------------------------------|----------------------------|-------------|------|-------------|--------------------|
| $VAUX_{ERR}$                                 | Auxiliary measurement error            | $VAUX = 1\text{V}$         | <b>-2.5</b> |      | <b>+2.5</b> | %                  |
| <b>Remote Diode Temperature Sensor</b>       |                                        |                            |             |      |             |                    |
| $T_{ACC}$                                    | Temperature accuracy using local diode |                            |             | 3    |             | $^{\circ}\text{C}$ |
|                                              | Remote diode resolution                |                            |             | 9    |             | bits               |
| $I_{DIODE}$                                  | External diode current source          | High Level                 |             | 240  | <b>325</b>  | $\mu\text{A}$      |
|                                              |                                        | Low Level                  |             | 9.2  |             | $\mu\text{A}$      |
| Diode Current Ratio                          |                                        |                            |             | 26   |             |                    |
| <b>PMBus Pin Thresholds (SMBA, SDA, SCL)</b> |                                        |                            |             |      |             |                    |
| $V_{IL}$                                     | Data, clock input low voltage          |                            |             |      | <b>0.9</b>  | V                  |
| $V_{IH}$                                     | Data, clock input high voltage         |                            | <b>2.1</b>  |      | <b>5.5</b>  | V                  |
| $V_{OL}$                                     | Data output low voltage                | $I_{PULLUP} = 5\text{ mA}$ | <b>0</b>    |      | <b>0.4</b>  | V                  |
| $I_{LEAK}$                                   | Input leakage current                  | SDA, SMBA, SCL = 5.5V      |             |      | <b>1</b>    | $\mu\text{A}$      |
| <b>ENABLE Pin</b>                            |                                        |                            |             |      |             |                    |
| $V_{EN}$                                     | ENABLE threshold voltage               | Rising threshold           | <b>1.4</b>  | 1.2  |             | V                  |
| $V_{EN-HYS}$                                 | ENABLE threshold voltage hysteresis    |                            |             | 75   |             | mV                 |
| $I_{LEAK}$                                   | Input Leakage Current                  | ENABLE = 5V                |             |      | <b>1</b>    | mA                 |
| $I_{PULLUP}$                                 | ENABLE pin pullup current              |                            |             | 2.8  |             | $\mu\text{A}$      |

## Typical Performance Characteristics

Unless otherwise specified the following conditions apply:  $T_J = +25^\circ\text{C}$ ,  $V_{IN} = 12\text{V}$ . All graphs show junction temperature.

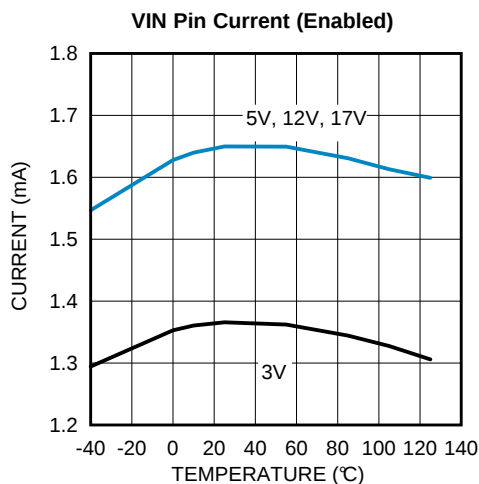


Figure 2.

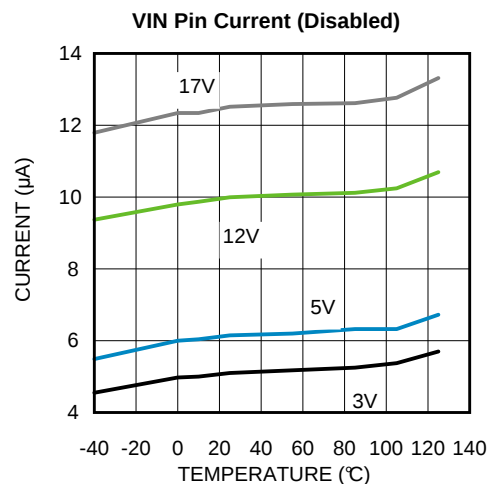


Figure 3.

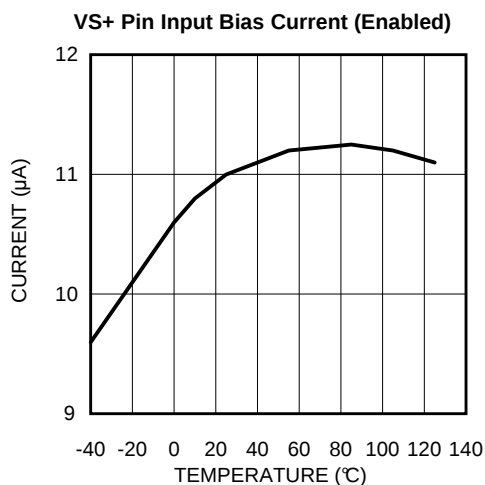


Figure 4.

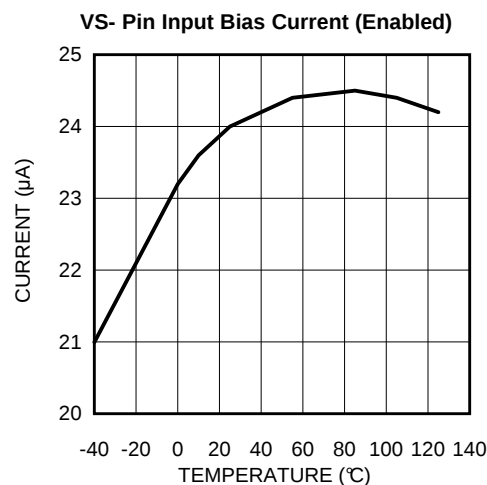


Figure .

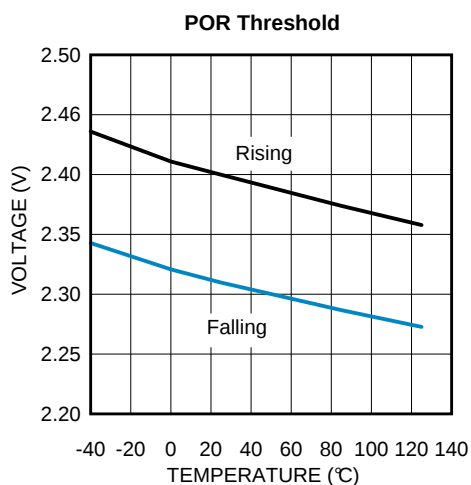


Figure 5.

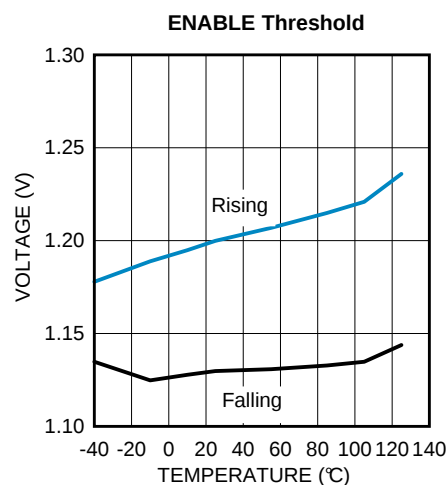


Figure 6.

## Typical Performance Characteristics (continued)

Unless otherwise specified the following conditions apply:  $T_J = +25^\circ\text{C}$ ,  $V_{IN} = 12\text{V}$ . All graphs show junction temperature.

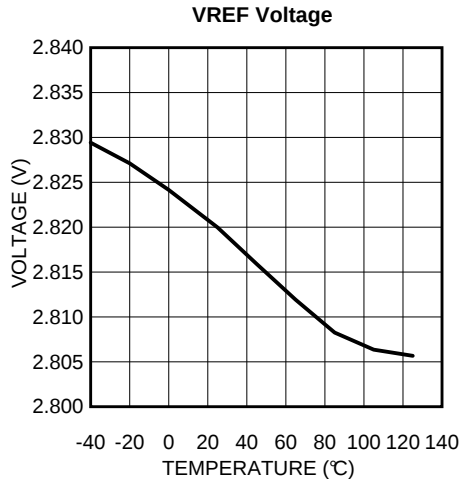


Figure 7.

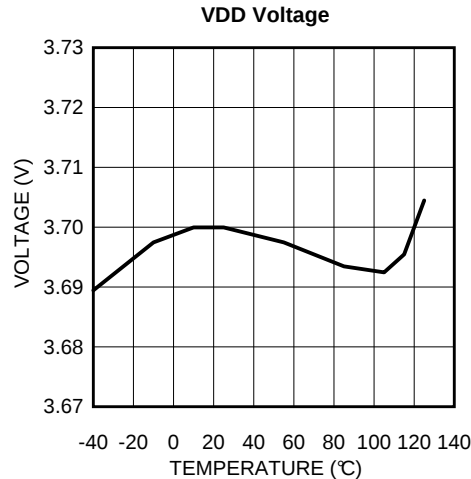


Figure 8.

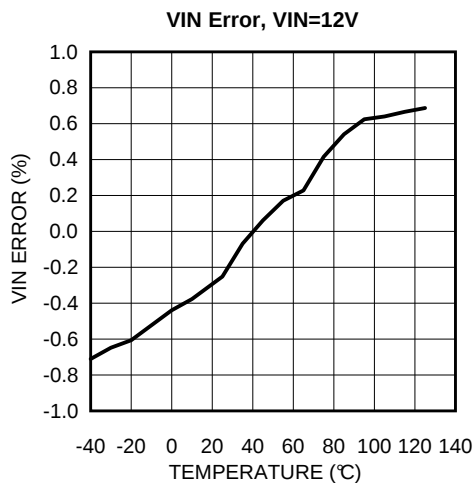


Figure 9.

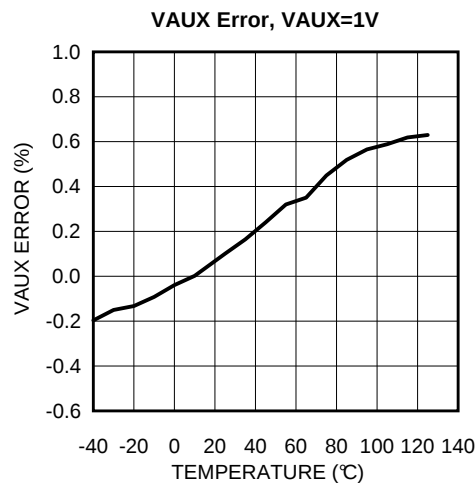


Figure 10.

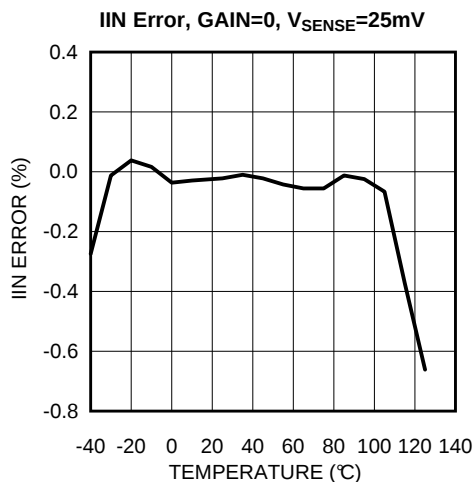


Figure 11.

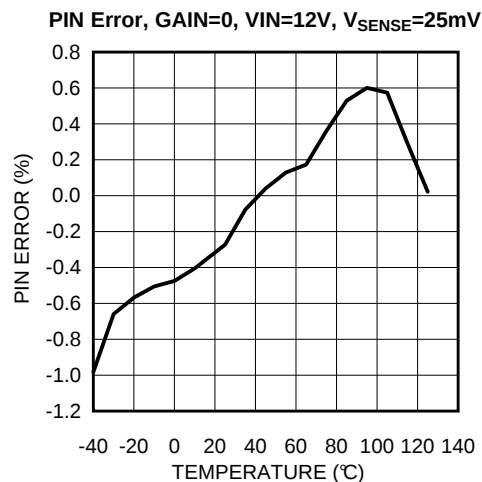


Figure 12.

### Typical Performance Characteristics (continued)

Unless otherwise specified the following conditions apply:  $T_J = +25^\circ\text{C}$ ,  $V_{IN} = 12\text{V}$ . All graphs show junction temperature.

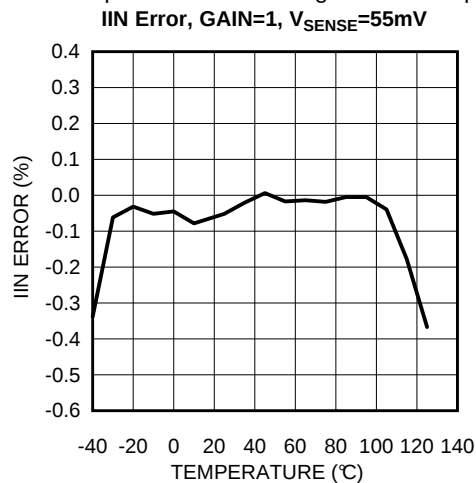


Figure 13.

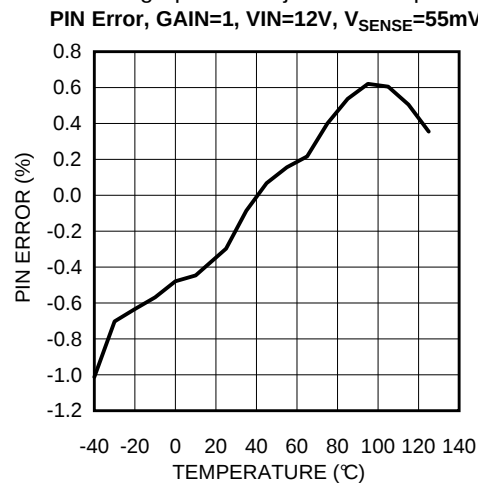
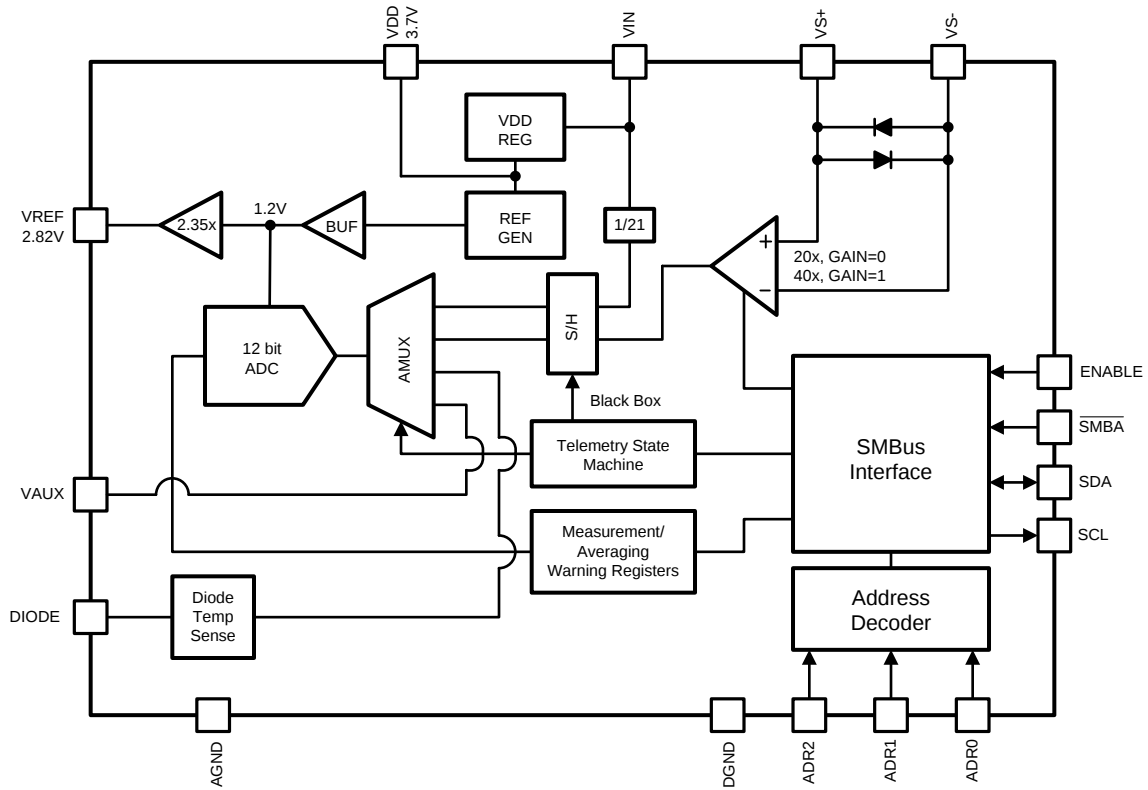


Figure 14.

## Block Diagram



## FUNCTIONAL DESCRIPTION

The LM25056A provides intelligent monitoring of the input voltage, input current, input power, temperature, and an auxiliary input. The LM25056A also provides a peak capture of the input power and programmable hardware averaging of the input voltage, current, power, temperature, and the auxiliary voltage. Warning thresholds which trigger the SMBA pin may be programmed for input and auxiliary voltage, current, power, and temperature via the PMBus interface.

### Enabling/Disabling and Resetting

The LM25056A has an ENABLE pin that can be used to power on and off the device. If desired, the LM25056A can be kept in shutdown until the supply reaches a particular threshold using ENABLE with a resistor divider or with an active control as shown in Figure 15.

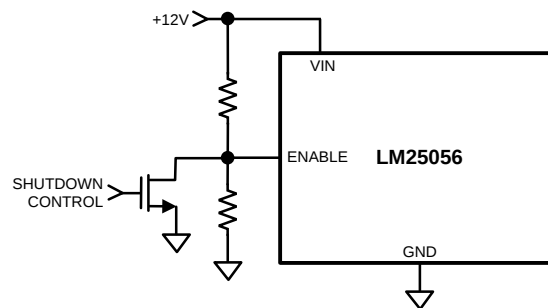


Figure 15. ENABLE Control

When taken low, this logic pin will reduce the quiescent current for the device and will no longer respond to PMBus commands. Also, taking the ENABLE low is a functional reset of the LM25056A. Raising ENABLE sets the part to its default operation. If this functionality is not used, then ENABLE should be left floating (an internal pull-up will maintain its operation) or tied to an external VDD voltage. Do not tie ENABLE to the onboard VDD. The VDD power-up is delayed and when power is first applied, and VDD starts low. This in turn will keep ENABLE low and the LM25056A will not start up.

VDD and VREF also have a power-on-reset (POR) circuit that holds the LM25056A in reset until it reaches the operating state. Note that if either of these output lines are inadvertently pulled low, the device is reset to its initial default state, erasing the volatile memory the same as ENABLE pulled low. Once VDD and VREF have reached the POR threshold of 2.4V, the device comes out of reset.

As an example, the SMBus address of the LM25056A is captured based on the states (GND, NC, VDD) of the ADR0, ADR1, and ADR2 pins during turn on and is latched into a volatile register once the ENABLE pin is determined to be high and the VDD and VREF has exceeded its POR threshold of 2.4V. Reassigning or postponing the address capture can be accomplished by holding the ENABLE pin to AGND. For more information on the operation of these pins, please see the [PMBus Address Lines](#) section of this datasheet.

The logic and volatile memory can also be reset with a PMBus write to the MFR\_DEVICE\_SETUP (D9h) register into the software reset bit. However, this software reset will not trigger a read of the states of the address pins as the ENABLE pin or VDD and VREF POR events will.

### VDD Sub-Regulator

The LM25056A contains an internal linear sub-regulator which steps down the input voltage to generate a 3.7V rail used for powering low voltage and low power circuitry. When the input voltage is below 3.7V, VDD will track VIN. For input voltages 3.3V and below, VDD should be tied directly to VIN to avoid the dropout of the sub-regulator. The VDD sub-regulator should be used as the pull-up supply for the ADR2, ADR1, and ADR0 pins if they are to be tied high. It may also be used as the pull-up supply for SMBus signals (SDA, SCL, SMBA). The VDD sub-regulator is not designed to drive high currents and should not be loaded to drive high current circuits. The VDD pin is current limited to 50 mA in order to protect the LM25056A in the event of a short. The sub-regulator requires a ceramic bypass capacitance of 1  $\mu$ F or greater to be placed as close to VDD as the PCB layout allows.

Additionally, VDD can be driven from an external source to maintain telemetry readings for VIN and temperature if the VIN drops below its operation point. To do this, use an external 5V supply driving the VDD through a Schottky diode. This allows for telemetry readings down to VIN=0. A large capacitor (100uF) can also be placed at on the VDD line to momentarily supply current to the device to similarly maintain telemetry readings that would normally shutdown and reset the device. Note that when using an external VDD drive, ENABLE will not operate independently. To use this functionality, simply connect the external VDD source to ENABLE and lower this source to put the LM25056A into low power mode.

## Remote Temperature Sensing

The LM25056A is designed to measure temperature remotely using an MMBT3904 NPN transistor. The base and collector of the MMBT3904 should be connected to the DIODE pin and the emitter of the MMBT3904 connected to AGND. Place the MMBT3904 near the device whose temperature is to be monitored. In noisy environments with large currents or switching noise, it is especially important to bring this connection back to AGND and not just to the nearest ground plane. If the temperature of a pass MOSFET is to be measured, the MMBT3904 should be placed as close to device as the layout allows. The temperature is measured by means of a change in an external diode voltage in response to a step in current supplied by DIODE. DIODE sources 9.2  $\mu$ A but pulses 240  $\mu$ A once every millisecond in order to measure the diode temperature. Care must be taken in the PCB layout to keep the parasitic resistance between DIODE and the MMBT3904 low so as not to degrade the measurement. Additionally, a small 100 pF bypass capacitor can be placed in parallel with the MMBT3904 to reduce the effects of noise. The temperature can be read using the READ\_TEMPERATURE\_1 PMBus command (8Dh). The default warning limit of the LM25056A will cause SMBA to be pulled low if the measured temperature code exceeds 07D0h. The PMBus will also indicate an over temperature fault if the measured temperature code exceeds 0960h. These thresholds can be reprogrammed via the PMBus interface using the OT\_WARN\_LIMIT (51h) and OT\_FAULT\_LIMIT (4Fh) commands. If the temperature measurement and protection capability of the LM25056A is not used the DIODE pin should be grounded.

## Application Section

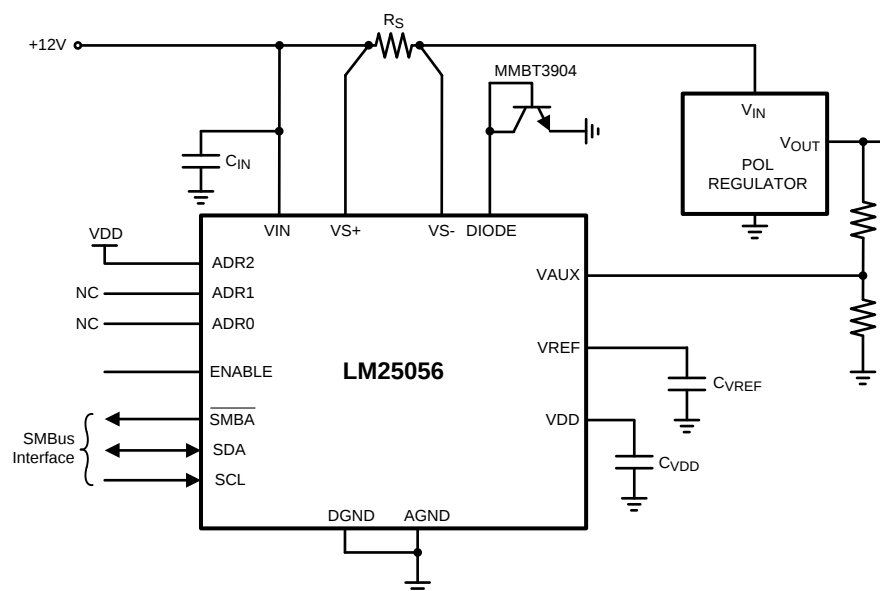


Figure 16. Typical Application Circuit

## DESIGN-IN PROCEDURE

(Refer to Figure 16 for Typical Application Circuit) Shown here is the step-by-step procedure for hardware design of the LM25056A. This procedure refers to section numbers that provide detailed information on the following design steps. The recommended design-in procedure is as follows:

**Current Range,  $R_S$ :** Determine the current range based on the voltage dropped across the sense resistor ( $R_S$ ). Depending on the GAIN setting, the voltage across the sense resistor to get a full scale reading for the current measurement should be 30 mV for GAIN=0 and 60 mV for GAIN=1. Use the [Equation 1](#) to determine the value for  $R_S$ .

**Refer to Programming Guide section:** After all hardware design is complete, refer to the programming guide for a step by step procedure regarding software.

### CURRENT RANGE, ( $R_S$ )

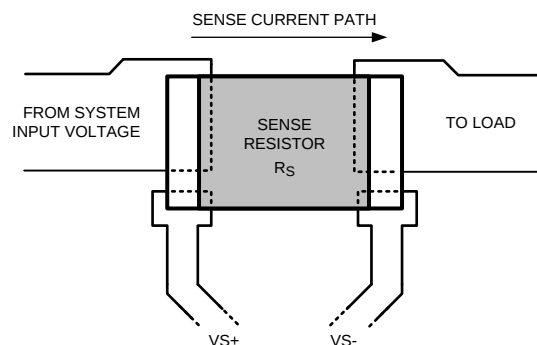
The LM25056A monitors current by measuring the voltage across the sense resistor ( $R_S$ ) connected from  $VS+$  to  $VS-$ . The required resistor value is calculated from:

$$R_S = \frac{V_S}{I_{FS}} \quad (1)$$

where  $I_{FS}$  is the expected full scale current range based on the current sense gain setting (GAIN). If the voltage across  $R_S$  reaches  $V_S$ , the current measurement will reach the full scale measurement. As mentioned before, it is important to limit the current to the full scale reading. While there is internal circuitry intended to maintain the integrity of the other readings in the telemetry, the ADC and MUX are shared and overranging an input may compromise the integrity of the other readings.

$V_S$  can be set to either 30 mV or 60 mV through software commands. This setting defaults to the sense voltage full scale of 30 mV (GAIN = 0), or it can be set to 60 mV (GAIN = 1). The value can be set via the PMBus with the MFR\_DEVICE\_SETUP (D9h) command, which defaults to the 30 mV setting. Once the current measurement full scale is known and the  $V_S$  range is chosen, calculate the shunt based on that input voltage and maximum current range. The maximum load current in normal operation can be used to determine the required power rating for resistor  $R_S$ .

Connections from  $R_S$  to the LM25056A should be made using Kelvin techniques. In the suggested layout of [Figure 17](#), the small pads at the lower corners of the sense resistor connect only to the sense resistor terminals and not to the traces carrying the high current. With this technique, only the voltage across the sense resistor is applied to  $VS+$  and  $VS-$ , eliminating the voltage drop across the high current solder connections.



**Figure 17. Sense Resistor Connections**

### PC BOARD GUIDELINES

The following guidelines should be followed when designing the PC board for the LM25056A:

- Place the LM25056A close to the board's input connector to minimize trace inductance from the connector to following devices.
- Place a small capacitor,  $C_{IN}$ , (0.1μF) directly adjacent to the VIN and AGND and DGND pins of the LM25056A to help minimize transients which may occur on the input supply line. Transients of several volts can easily occur when the load current is shut off.
- Place a 1 μF capacitor as close as possible to VREF pin.
- Place a 1 μF capacitor as close as possible to VDD pin.
- The sense resistor ( $R_S$ ) should be placed close to the LM25056A. In particular, the traces to the  $VS+$ ,  $VS-$ ,

and VIN pins should be made as low resistance as practical to ensure maximum current and power measurement accuracy. Connect  $R_S$  using the Kelvin techniques shown in [Figure 17](#).

- The high current path from the board's input to the load and the return path should be parallel and close to each other to minimize loop inductance.
- The ground connections for the various components around the LM25056A should be connected directly to each other, and to the LM25056A's DGND and AGND pins, and then connected to the system ground at one point. Do not connect the various component grounds to each other through the high current ground line. The ground of the MMBT3904 should also be connected to the AGND pin to prevent corruption of the temperature diode measurement.

## PMBus Command Support

The device features an SMBus interface that allows the use of PMBus commands to set warn levels, error masks, and get telemetry on  $V_{IN}$ ,  $V_{AUX}$ ,  $I_{IN}$ ,  $P_{IN}$ , and temperature. The supported PMBus commands are shown in [Table 1](#).

**Table 1. Supported PMBus Commands**

| Code | Name                             | Function                                                                      | R/W       | Number Of Data Bytes | Default Value                                        |
|------|----------------------------------|-------------------------------------------------------------------------------|-----------|----------------------|------------------------------------------------------|
| 03h  | CLEAR_FAULTS                     | Clears the status registers and re-arms the black box registers for updating. | Send Byte | 0                    |                                                      |
| 19h  | CAPABILITY                       | Retrieves the device capability.                                              | R         | 1                    | B0h                                                  |
| 4Fh  | OT_FAULT_LIMIT                   | Retrieves or stores over temperature fault limit threshold.                   | R/W       | 2                    | 0960h                                                |
| 51h  | OT_WARN_LIMIT                    | Retrieves or stores over temperature warn limit threshold.                    | R/W       | 2                    | 07D0h                                                |
| 57h  | VIN_OV_WARN_LIMIT                | Retrieves or stores input over-voltage warn limit threshold.                  | R/W       | 2                    | 0FFFh                                                |
| 58h  | VIN_UV_WARN_LIMIT                | Retrieves or stores input under-voltage warn limit threshold.                 | R/W       | 2                    | 0000h                                                |
| 78h  | STATUS_BYTE                      | Retrieves information about the parts operating status.                       | R         | 1                    | 01h                                                  |
| 79h  | STATUS_WORD                      | Retrieves information about the parts operating status.                       | R         | 2                    | 1001h                                                |
| 7Ch  | STATUS_INPUT                     | Retrieves information about input status.                                     | R         | 1                    | 00h                                                  |
| 7Dh  | STATUS_TEMPERATURE               | Retrieves information about temperature status.                               | R         | 1                    | 00h                                                  |
| 7Eh  | STATUS_CML                       | Retrieves information about communications status.                            | R         | 1                    | 00h                                                  |
| 80h  | STATUS_MFR_SPECIFIC              | Retrieves information about manufacturer specific device status.              | R         | 1                    | 10h                                                  |
| 88h  | READ_VIN                         | Retrieves input voltage measurement.                                          | R         | 2                    | 0000h                                                |
| 8Dh  | READ_TEMPERATURE_1               | Retrieves temperature measurement.                                            | R         | 2                    | 0000h                                                |
| 99h  | MFR_ID                           | Retrieves manufacturer ID in ASCII characters (NSC).                          | R         | 3                    | 4Eh<br>53h<br>43h                                    |
| 9Ah  | MFR_MODEL                        | Retrieves Part number in ASCII characters. (LM25056A).                        | R         | 8                    | 4Ch<br>4Dh<br>32h<br>35h<br>30h<br>35h<br>36h<br>00h |
| 9Bh  | MFR_REVISION                     | Retrieves part revision letter/number in ASCII (e.g., AA).                    | R         | 2                    | 41h<br>41h                                           |
| D0h  | MFR_SPECIFIC_00<br>MFR_READ_VAUX | Retrieves auxiliary voltage measurement.                                      | R         | 2                    | 0000h                                                |
| D1h  | MFR_SPECIFIC_01<br>MFR_READ_IIN  | Retrieves input current measurement.                                          | R         | 2                    | 0000h                                                |
| D2h  | MFR_SPECIFIC_02<br>MFR_READ_PIN  | Retrieves input power measurement.                                            | R         | 2                    | 0000h                                                |

**Table 1. Supported PMBus Commands (continued)**

| Code | Name                                        | Function                                                                                                                   | R/W       | Number Of Data Bytes | Default Value                                      |
|------|---------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|-----------|----------------------|----------------------------------------------------|
| D3h  | MFR_SPECIFIC_03<br>MFR_IIN_OC_WARN_LIMIT    | Retrieves or stores input current limit warn threshold.                                                                    | R/W       | 2                    | 0FFFh                                              |
| D4h  | MFR_SPECIFIC_04<br>MFR_PIN_OP_WARN_LIMIT    | Retrieves or stores input power limit warn threshold.                                                                      | R/W       | 2                    | 0FFFh                                              |
| D5h  | MFR_SPECIFIC_05<br>MFR_READ_PIN_PEAK        | Retrieves maximum input power measurement.                                                                                 | R         | 2                    | 0000h                                              |
| D6h  | MFR_SPECIFIC_06<br>MFR_CLEAR_PIN_PEAK       | Resets the contents of the peak input power register to zero.                                                              | Send Byte | 0                    |                                                    |
| D8h  | MFR_SPECIFIC_08<br>MFR_ALERT_MASK           | Retrieves or stores user <u>SMBA</u> fault mask.                                                                           | R/W       | 2                    | 0000h                                              |
| D9h  | MFR_SPECIFIC_09<br>MFR_DEVICE_SETUP         | Retrieves or stores information about the LM25056A setup.                                                                  | R/W       | 1                    | 0000h                                              |
| DAh  | MFR_SPECIFIC_10<br>MFR_BLOCK_READ           | Retrieves most recent diagnostic and telemetry information in a single transaction.                                        | R         | 12                   | 0080h<br>0000h<br>0000h<br>0000h<br>0000h<br>0000h |
| DBh  | MFR_SPECIFIC_11<br>MFR_SAMPLES_FOR_AVG      | Exponent value AVGN for number of samples to be averaged, range = 00h to 0Ch .                                             | R/W       | 1                    | 00h                                                |
| DCh  | MFR_SPECIFIC_12<br>MFR_READ_AVG_VIN         | Retrieves averaged input voltage measurement.                                                                              | R         | 2                    | 0000h                                              |
| DDh  | MFR_SPECIFIC_13<br>MFR_READ_AVG_VAUX        | Retrieves averaged auxiliary voltage measurement.                                                                          | R         | 2                    | 0000h                                              |
| DEh  | MFR_SPECIFIC_14<br>MFR_READ_AVG_IIN         | Retrieves averaged input current measurement.                                                                              | R         | 2                    | 0000h                                              |
| DFh  | MFR_SPECIFIC_15<br>MFR_READ_AVG_PIN         | Retrieves averaged input power measurement.                                                                                | R         | 2                    | 0000h                                              |
| E0h  | MFR_SPECIFIC_16<br>MFR_BLACK_BOX_READ       | Captures diagnostic and telemetry information which are latched when an <u>SMBA</u> occurs after faults have been cleared. | R         | 12                   | 0080h<br>0000h<br>0000h<br>0000h<br>0000h<br>0000h |
| E1h  | MFR_SPECIFIC_17<br>MFR_DIAGNOSTIC_WORD_READ | Manufacturer-specific parallel of the STATUS_WORD to convey all FAULT/WARN data in a single transaction.                   | R         | 2                    | 0080h                                              |
| E2h  | MFR_SPECIFIC_18<br>MFR_AVG_BLOCK_READ       | Retrieves most recent average telemetry and diagnostic information in a single transaction.                                | R         | 12                   | 0080h<br>0000h<br>0000h<br>0000h<br>0000h<br>0000h |
| E3h  | MFR_SPECIFIC_19<br>MFR_VAUX_OV_WARN_LIMIT   | Retrieves or stores auxiliary over-voltage warn limit threshold.                                                           | R         | 2                    | 0FFFh                                              |
| E4h  | MFR_SPECIFIC_20<br>MFR_VAUX_UV_WARN_LIMIT   | Retrieves or stores auxiliary under-voltage warn limit threshold.                                                          | R         | 2                    | 0000h                                              |

**STANDARD PMBus Commands****CLEAR\_FAULTS (03h)**

The CLEAR\_FAULTS command is a standard PMBus command that resets all stored warning and fault flags and the SMBA signal. If a fault or warning condition still exists when the CLEAR\_FAULTS command is issued, the SMBA signal may not clear or will re-assert almost immediately. This command uses the PMBus send byte protocol.

**CAPABILITY (19h)**

The CAPABILITY command is a standard PMBus command that returns information about the PMBus functions supported by the LM25056A. This command is read with the PMBus read byte protocol.

**Table 2. CAPABILITY Register**

| Value | Meaning                                                         | Default |
|-------|-----------------------------------------------------------------|---------|
| B0h   | Supports Packet Error Check, 400Kbits/sec, Supports SMBus Alert | B0h     |

#### OT\_FAULT\_LIMIT (4Fh)

The OT\_FAULT\_LIMIT is a standard PMBus command that allows configuring or reading the threshold for the overtemperature fault detection. Reading and writing to this register should use the coefficients shown in the Telemetry and Warning Conversion Coefficients Table. Accesses to this command should use the PMBus read or write word protocol. If the measured temperature exceeds this value, an Overtemperature fault is triggered, OT Fault flags are set and the SMBA signal is asserted.

**Table 3. OT\_FAULT\_LIMIT Register**

| Value      | Meaning                                  | Default |
|------------|------------------------------------------|---------|
| 0h – 0FFEh | Overtemperature Fault Threshold Value    | 0960h   |
| 0FFFh      | Overtemperature Fault detection disabled | n/a     |

#### OT\_WARN\_LIMIT (51h)

The OT\_WARN\_LIMIT is a standard PMBus command that allows configuring or reading the threshold for the overtemperature warning detection. Reading and writing to this register should use the coefficients shown in the Telemetry and Warning Conversion Coefficients Table. Accesses to this command should use the PMBus read or write word protocol. If the measured temperature exceeds this value, an Overtemperature warning is triggered and the OT Warning flags are set and the SMBA signal is asserted.

**Table 4. OT\_WARN\_LIMIT Register**

| Value      | Meaning                                 | Default |
|------------|-----------------------------------------|---------|
| 0h – 0FFEh | Overtemperature Warn Threshold Value    | 07D0h   |
| 0FFFh      | Overtemperature Warn detection disabled | n/a     |

#### VIN\_OV\_WARN\_LIMIT (57h)

The VIN\_OV\_WARN\_LIMIT is a standard PMBus command that allows configuring or reading the threshold for the VIN overvoltage warning detection. Reading and writing to this register should use the coefficients shown in the Telemetry and Warning Conversion Coefficients Table. Accesses to this command should use the PMBus read or write word protocol. If the measured value of VIN rises above the value in this register, VIN OV Warn flags are set and the SMBA signal is asserted.

**Table 5. VIN\_OV\_WARN\_LIMIT Register**

| Value      | Meaning                                     | Default          |
|------------|---------------------------------------------|------------------|
| 0h – 0FFEh | VIN Overvoltage Warning detection threshold | 0FFFh (disabled) |
| 0FFFh      | VIN Overvoltage Warning disabled            | n/a              |

#### VIN\_UV\_WARN\_LIMIT (58h)

The VIN\_UV\_WARN\_LIMIT is a standard PMBus command that allows configuring or reading the threshold for the VIN undervoltage warning detection. Reading and writing to this register should use the coefficients shown in the Telemetry and Warning Conversion Coefficients Table. Accesses to this command should use the PMBus read or write word protocol. If the measured value of VIN falls below the value in this register, VIN UV Warn flags are set and the SMBA signal is asserted.

**Table 6. VIN\_UV\_WARN\_LIMIT Register**

| Value      | Meaning                                      | Default          |
|------------|----------------------------------------------|------------------|
| 1h – 0FFFh | VIN Undervoltage Warning detection threshold | 0000h (disabled) |
| 0000h      | VIN Undervoltage Warning disabled            | n/a              |

**STATUS\_BYTE (78h)**

The STATUS\_BYTE is a standard PMBus command that returns the value of a number of flags indicating the state of the LM25056A. Accesses to this command should use the PMBus read byte protocol. To clear bits in this register, the underlying fault should be cleared and a CLEAR\_FAULTS command issued.

**Table 7. STATUS\_BYTE Definitions**

| Bit | Name              | Meaning                                                  | Default |
|-----|-------------------|----------------------------------------------------------|---------|
| 7   | BUSY              | Not supported                                            | 0       |
| 6   | OFF               | Not supported                                            | 0       |
| 5   | VOUT_OV           | Not supported                                            | 0       |
| 4   | IOUT_OC           | Not supported                                            | 0       |
| 3   | VIN_UV            | An input undervoltage fault has occurred                 | 0       |
| 2   | TEMPERATURE       | A temperature fault or warning has occurred              | 0       |
| 1   | CML               | A Communication Fault has occurred                       | 0       |
| 0   | NONE OF THE ABOVE | A fault or warning not listed in bits [7:1] has occurred | 1       |

**STATUS\_WORD (79h)**

The STATUS\_WORD is a standard PMBus command that returns the value of a number of flags indicating the state of the LM25056A. Accesses to this command should use the PMBus read word protocol. To clear bits in this register, the underlying fault should be cleared and a CLEAR\_FAULTS command issued. The INPUT and VIN UV flags will default to 1 on startup.

**Table 8. STATUS\_WORD Definitions**

| Bit | Name              | Meaning                                                  | Default |
|-----|-------------------|----------------------------------------------------------|---------|
| 15  | VOUT              | Not supported                                            | 0       |
| 14  | IOUT/POUT         | Not supported                                            | 0       |
| 13  | INPUT             | An input voltage or current fault has occurred           | 0       |
| 12  | MFR               | A manufacturer specific fault or warning has occurred    | 1       |
| 11  | POWER_GOOD#       | Not supported                                            | 0       |
| 10  | FANS              | Not supported                                            | 0       |
| 9   | OTHER             | Not supported                                            | 0       |
| 8   | UNKNOWN           | Not supported                                            | 0       |
| 7   | BUSY              | Not supported                                            | 0       |
| 6   | OFF               | Not supported                                            | 0       |
| 5   | VOUT_OV           | Not supported                                            | 0       |
| 4   | IOUT_OC           | Not supported                                            | 0       |
| 3   | VIN_UV            | An input undervoltage fault has occurred                 | 0       |
| 2   | TEMPERATURE       | A temperature fault or warning has occurred              | 0       |
| 1   | CML               | A communication fault has occurred                       | 0       |
| 0   | NONE OF THE ABOVE | A fault or warning not listed in bits [7:1] has occurred | 1       |

## STATUS\_INPUT (7Ch)

The STATUS\_INPUT is a standard PMBus command that returns the value of the of a number of flags related to input voltage, current, and power. Accesses to this command should use the PMBus read byte protocol. To clear bits in this register, the underlying fault should be cleared and a CLEAR\_FAULTS command issued.

**Table 9. STATUS\_INPUT Definitions**

| Bit | Name                 | Meaning                                    | Default |
|-----|----------------------|--------------------------------------------|---------|
| 7   | VIN OV Fault         | Not supported                              | 0       |
| 6   | VIN OV Warn          | An input overvoltage warning has occurred  | 0       |
| 5   | VIN UV Warn          | An input undervoltage warning has occurred | 0       |
| 4   | VIN UV Fault         | Not supported                              | 0       |
| 3   | Insufficient Voltage | Not supported                              | 0       |
| 2   | IIN OC Fault         | Not supported                              | 0       |
| 1   | IIN OC Warn          | An input overcurrent warning has occurred  | 0       |
| 0   | PIN OP Warn          | An input overpower warning has occurred    | 0       |

## STATUS\_TEMPERATURE (7Dh)

The STATUS TEMPERATURE is a standard PMBus command that returns the value of the of a number of flags related to the temperature telemetry value. Accesses to this command should use the PMBus read byte protocol. To clear bits in this register, the underlying fault should be cleared and a CLEAR\_FAULTS command issued.

**Table 10. STATUS\_TEMPERATURE Definitions**

| Bit | Name     | Meaning                                 | Default |
|-----|----------|-----------------------------------------|---------|
| 7   | OT FAULT | An overtemperature fault has occurred   | 0       |
| 6   | OT WARN  | An overtemperature warning has occurred | 0       |
| 5   | UT WARN  | Not supported                           | 0       |
| 4   | UT FAULT | Not supported                           | 0       |
| 3   | reserved | Not supported                           | 0       |
| 2   | reserved | Not supported                           | 0       |
| 1   | reserved | Not supported                           | 0       |
| 0   | reserved | Not supported                           | 0       |

## STATUS\_CML (7Eh)

The STATUS\_CML is a standard PMBus command that returns the value of a number of flags related to communication faults. Accesses to this command should use the PMBus read byte protocol. To clear bits in this register, a CLEAR FAULTS command should be issued.

**Table 11. STATUS\_CML Definitions**

| Bit | Meaning                                         | Default |
|-----|-------------------------------------------------|---------|
| 7   | Invalid or unsupported command received         | 0       |
| 6   | Invalid or unsupported data received            | 0       |
| 5   | Packet Error Check failed                       | 0       |
| 4   | Not supported                                   | 0       |
| 3   | Not supported                                   | 0       |
| 2   | Reserved                                        | 0       |
| 1   | Miscellaneous communications fault has occurred | 0       |
| 0   | Not supported                                   | 0       |

**STATUS\_MFR\_SPECIFIC (80h)**

The STATUS\_MFR\_SPECIFIC command, is a standard PMBus command that contains manufacturer specific status information. Accesses to this command should use the PMBus read byte protocol. To clear bits in this register, the underlying fault should be cleared and a CLEAR\_FAULTS command should be issued.

**Table 12. STATUS\_MFR\_SPECIFIC Definitions**

| Bit | Meaning                                  | Default |
|-----|------------------------------------------|---------|
| 7   | Not supported                            | 0       |
| 6   | Not supported                            | 0       |
| 5   | Not supported                            | 0       |
| 4   | Defaults loaded                          | 1       |
| 3   | Not supported                            | 0       |
| 2   | Not supported                            | 0       |
| 1   | A VAUX Overvoltage Warning has occurred  | 0       |
| 0   | A VAUX Undervoltage Warning has occurred | 0       |

**READ\_VIN (88h)**

The READ\_VIN is a standard PMBus command that returns the 12 bit measured value of the input voltage as read from the VIN pin. Reading this register should use the coefficients shown in the [Telemetry and Warning Conversion Coefficients](#) Table. Accesses to this command should use the PMBus read word protocol. This value is also used internally for the VIN Over and Under Voltage Warning detection.

**Table 13. READ\_VIN Register**

| Value      | Meaning                | Default |
|------------|------------------------|---------|
| 0h – 0FFFh | Measured value for VIN | 0000h   |

**READ\_TEMPERATURE\_1 (8Dh)**

The READ\_TEMPERATURE\_1 is a standard PMBus command that returns the signed value of the temperature measured by the external temperature sense diode. Reading this register should use the coefficients shown in the [Telemetry and Warning Conversion Coefficients](#) Table. Accesses to this command should use the PMBus read word protocol. This value is also used internally for the Over Temperature Fault and Warning detection. This data has a range of -256°C to + 255°C after the coefficients are applied.

**Table 14. READ\_TEMPERATURE\_1 Register**

| Value      | Meaning                        | Default |
|------------|--------------------------------|---------|
| 0h – 0FFFh | Measured value for TEMPERATURE | 0000h   |

**MFR\_ID (99h)**

The MFR\_ID is a standard PMBus command that returns the identification of the manufacturer. To read the manufacturer ID, use the PMBus block read protocol.

**Table 15. MFR\_ID Register**

| Byte | Name            | Value   |
|------|-----------------|---------|
| 0    | Number of bytes | 03h     |
| 1    | MFR ID-1        | 4Eh 'N' |
| 2    | MFR ID-2        | 53h 'S' |
| 3    | MFR ID-3        | 43h 'C' |

**MFR\_MODEL (9Ah)**

The MFR\_MODEL is a standard PMBus command that returns the part number of the chip. To read the manufacturer model, use the PMBus block read protocol.

**Table 16. MFR\_MODEL Register**

| Byte | Name            | Value   |
|------|-----------------|---------|
| 0    | Number of bytes | 08h     |
| 1    | MFR ID-1        | 4Ch 'L' |
| 2    | MFR ID-2        | 4Dh 'M' |
| 3    | MFR ID-3        | 32h '2' |
| 4    | MFR ID-4        | 35h '5' |
| 5    | MFR ID-5        | 30h '0' |
| 6    | MFR ID-6        | 35h '5' |
| 7    | MFR ID-7        | 36h '6' |
| 8    | MFR ID-8        | 00h     |

**MFR\_REVISION (9Bh)**

The MFR\_REVISION is a standard PMBus command that returns the revision level of the part. To read the manufacturer revision, use the PMBus block read protocol.

**Table 17. MFR\_REVISION Register**

| Byte | Name            | Value   |
|------|-----------------|---------|
| 0    | Number of bytes | 02h     |
| 1    | MFR ID-1        | 41h 'A' |
| 2    | MFR ID-2        | 41h 'A' |

**Manufacturer Specific PMBus Commands**
**MFR\_SPECIFIC\_00: MFR\_READ\_VAUX (D0h)**

The MFR\_READ\_VAUX command will report the 12-bit ADC measured auxiliary voltage. Voltages greater than or equal to 1.199V to AGND will be reported at plus full scale (0FFFh). Voltages less than or equal to 0V referenced to AGND will be reported as 0 (0000h). Coefficients for the VAUX value are dependent on the value of the external divider (if used). To read data from the MFR\_READ\_VAUX command, use the PMBus Read Word protocol.

**Table 18. MFR\_READ\_VAUX Register**

| Value      | Meaning                      | Default |
|------------|------------------------------|---------|
| 0h – 0FFFh | Measured value for AUX input | 0000h   |

**MFR\_SPECIFIC\_01: MFR\_READ\_IIN (D1h)**

The MFR\_READ\_IIN command will report the 12-bit ADC measured current sense voltage. To read data from the MFR\_READ\_IIN command, use the PMBus Read Word protocol. Reading this register should use the coefficients shown in the [Telemetry and Warning Conversion Coefficients](#) Table. Please see the section on [coefficient calculations](#) to calculate the values to use.

**Table 19. MFR\_READ\_IIN Register**

| Value      | Meaning                                        | Default |
|------------|------------------------------------------------|---------|
| 0h – 0FFFh | Measured value for input current sense voltage | 0000h   |

**MFR\_SPECIFIC\_02: MFR\_READ\_PIN (D2h)**

The MFR\_READ\_PIN command will report the upper 12-bits of the VIN x IIN product as measured by the 12-bit ADC. To read data from the MFR\_READ\_PIN command, use the PMBus Read Word protocol. Reading this register should use the coefficients shown in the [Telemetry and Warning Conversion Coefficients](#) Table.

**Table 20. MFR\_READ\_PIN Register**

| Value      | Meaning                                 | Default |
|------------|-----------------------------------------|---------|
| 0h – 0FFFh | Value for input current x input voltage | 0000h   |

**MFR\_SPECIFIC\_03: MFR\_IIN\_OC\_WARN\_LIMIT (D3h)**

The MFR\_IIN\_OC\_WARN\_LIMIT PMBus command sets the input overcurrent warning threshold. In the event that the input current rises above the value set in this register, the IIN Overcurrent flags are set in the status registers and the SMBA is asserted. To access the MFR\_IIN\_OC\_WARN\_LIMIT register, use the PMBus Read/Write Word protocol. Reading/writing to this register should use the coefficients shown in the [Telemetry and Warning Conversion Coefficients](#) Table.

**Table 21. MFR\_IIN\_OC\_WARN\_LIMIT Register**

| Value      | Meaning                                 | Default |
|------------|-----------------------------------------|---------|
| 0h – 0FFEh | Value for input over current warn limit | 0FFFh   |
| 0FFFh      | Input over current warning disabled     | n/a     |

**MFR\_SPECIFIC\_04: MFR\_PIN\_OP\_WARN\_LIMIT (D4h)**

The MFR\_PIN\_OP\_WARN\_LIMIT PMBus command sets the input overpower warning threshold. In the event that the input power rises above the value set in this register, the PIN Overpower flags are set in the status registers and the SMBA is asserted. To access the MFR\_PIN\_OP\_WARN\_LIMIT register, use the PMBus Read/Write Word protocol. Reading/writing to this register should use the coefficients shown in the [Telemetry and Warning Conversion Coefficients](#) Table.

**Table 22. MFR\_PIN\_OP\_WARN\_LIMIT Register**

| Value      | Meaning                               | Default |
|------------|---------------------------------------|---------|
| 0h – 0FFEh | Value for input over power warn limit | 0FFFh   |
| 0FFFh      | Input over power warning disabled     | n/a     |

**MFR\_SPECIFIC\_05: MFR\_READ\_PIN\_PEAK (D5h)**

The MFR\_READ\_PIN\_PEAK command will report the maximum input power measured since a Power On reset or the last MFR\_CLEAR\_PIN\_PEAK command. To access the MFR\_READ\_PIN\_PEAK command, use the PMBus Read Word protocol. Use the coefficients shown in the [Telemetry and Warning Conversion Coefficients](#) Table.

**Table 23. MFR\_READ\_PIN\_PEAK Register**

| Value      | Meaning                                                                   | Default |
|------------|---------------------------------------------------------------------------|---------|
| 0h – 0FFEh | Maximum Value for input current x input voltage since reset or last clear | 0000h   |

**MFR\_SPECIFIC\_06: MFR\_CLEAR\_PIN\_PEAK (D6h)**

The MFR\_CLEAR\_PIN\_PEAK command will clear the MFR\_READ\_PIN\_PEAK register. This command uses the PMBus Send Byte protocol.

**MFR\_SPECIFIC\_08: MFR\_ALERT\_MASK (D8h)**

The MFR\_ALERT\_MASK is used to mask the SMBA when a specific fault or warning has occurred. Each bit corresponds to one of the 9 different analog and digital faults or warnings that would normally result in an SMBA being asserted. When the corresponding bit is high, that condition will not cause the SMBA to be asserted. If that condition occurs, the registers where that condition is captured will still be updated (STATUS registers, MFR\_DIAGNOSTIC\_WORD, OT\_FAULT\_LIMIT). This register is accessed with the PMBus Read / Write Word protocol.

**Table 24. MFR\_ALERT\_MASK Definitions**

| BIT | NAME                             | DEFAULT |
|-----|----------------------------------|---------|
| 15  | VAUX UNDERVOLTAGE WARN           | 0       |
| 14  | IIN LIMIT WARN                   | 0       |
| 13  | VIN UNDERVOLTAGE WARN            | 0       |
| 12  | VIN OVERVOLTAGE WARN             | 0       |
| 11  | Reserved, always set to 0        | 0       |
| 10  | OVERTEMPERATURE WARN             | 0       |
| 9   | VAUX OVERVOLTAGE WARN            | 0       |
| 8   | OVERPOWER LIMIT WARN             | 0       |
| 7   | Reserved, always set to 0        | 0       |
| 6   | Reserved, always set to 0        | 0       |
| 5   | Reserved, always set to 0        | 0       |
| 4   | Reserved, always set to 0        | 0       |
| 3   | Reserved, always set to 0        | 0       |
| 2   | OVERTEMPERATURE FAULT            | 0       |
| 1   | CML FAULT (Communications Fault) | 0       |
| 0   | Reserved, always set to 0        | 0       |

**MFR\_SPECIFIC\_09: MFR\_DEVICE\_SETUP (D9h)**

The MFR\_DEVICE\_SETUP command may be used to define operation or reset the LM25056A under host control. This command is accessed with the PMBus read / write byte protocol.

**Table 25. MFR\_DEVICE\_SETUP Byte Format**

| Bit | Name                      | Meaning                       |
|-----|---------------------------|-------------------------------|
| 7   | Reserved, always set to 0 |                               |
| 6   | Reserved, always set to 0 |                               |
| 5   | Reserved, always set to 0 |                               |
| 4   | Current sense gain        | GAIN = 0, Low setting (30mV)  |
|     |                           | GAIN = 1, High setting (60mV) |
| 3   | Reserved, always set to 0 |                               |
| 2   | Reserved, always set to 0 |                               |
| 1   | Reserved, always set to 0 |                               |
| 0   | Software reset            | 0 = Default                   |
|     |                           | 1 = Reset                     |

Within this command byte, the current sense gain bit changes the range and coefficients used for current and power measurements as well as relevant warning registers. The software reset bit is used to reset the LM25056A. Writing a 1 to this bit will reset the device back to its default startup values.

**MFR\_SPECIFIC\_10: MFR\_BLOCK\_READ (DAh)**

The MFR\_BLOCK\_READ command concatenates the MFR\_DIAGNOSTIC\_WORD\_READ with input telemetry information (IIN, VAUX, VIN, PIN) as well as READ\_TEMPERATURE\_1 to capture all of the operating information of the LM25056A in a single SMBus transaction. The block is 12 bytes long with telemetry information being sent out in the same manner as if an individual READ\_XXX command had been issued (shown below). The contents of the block read register are updated every clock cycle (85 ns) as long as the SMBus interface is idle. MFR\_BLOCK\_READ also specifies that the VIN, VAUX, IIN and PIN measurements are all time-aligned whereas there is a chance they may not be if retrieved with individual PMBus commands.

The Block Read command is read via the PMBus block read protocol.

**Table 26. MFR\_BLOCK\_READ Register Format**

|                        |          |
|------------------------|----------|
| Byte Count (always 12) | (1 byte) |
| DIAGNOSTIC WORD        | (1 Word) |
| IIN_BLOCK              | (1 Word) |
| VAUX_BLOCK             | (1 Word) |
| VIN_BLOCK              | (1 Word) |
| PIN_BLOCK              | (1 Word) |
| TEMP_BLOCK             | (1 Word) |

**MFR\_SPECIFIC\_11: MFR\_SAMPLES\_FOR\_AVG (DBh)**

The MFR\_SAMPLES\_FOR\_AVG is a manufacturer specific command for setting the number of samples used in computing the average values for IIN, VIN, VAUX, PIN. The decimal equivalent of the AVGN nibble is the power of 2 samples (e.g. AVGN=12 equates to 4096 samples used in computing the average). The LM25056A supports average numbers of 1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024, 2048, 4096. The MFR\_SAMPLES\_FOR\_AVG number applies to average values of IIN, VIN, VAUX, PIN simultaneously. The LM25056A uses simple averaging. This is accomplished by summing consecutive results up to the number programmed, then dividing by the number of samples. Averaging is calculated according to the following sequence:

$$Y = (X_{(N)} + X_{(N-1)} + \dots + X_{(0)}) / N \quad (2)$$

When the averaging has reached the end of a sequence (for example, 4096 samples are averaged), then a whole new sequence begins that will require the same number of samples (in this example, 4096) to be taken before the new average is ready.

**Table 27. MFR\_SAMPLES\_FOR\_AVERAGE**

| AVGN | N = 2 <sup>AVGN</sup> | Averaging/Register Update Period (ms) |
|------|-----------------------|---------------------------------------|
| 0000 | 1                     | 1                                     |
| 0001 | 2                     | 2                                     |
| 0010 | 4                     | 4                                     |
| 0011 | 8                     | 8                                     |
| 0100 | 16                    | 16                                    |
| 0101 | 32                    | 32                                    |
| 0110 | 64                    | 64                                    |
| 0111 | 128                   | 128                                   |
| 1000 | 256                   | 256                                   |
| 1001 | 512                   | 512                                   |
| 1010 | 1024                  | 1024                                  |
| 1011 | 2048                  | 2048                                  |
| 1100 | 4096                  | 4096                                  |

Note that a change in the MFR\_SAMPLES\_FOR\_AVG register will not be reflected in the average telemetry measurements until the present averaging interval has completed. The default setting for AVGN is 0000 and therefore the average telemetry will mirror the instantaneous telemetry until a value higher than zero is programmed.

The MFR\_SAMPLES\_FOR\_AVG register is accessed via the PMBus read / write byte protocol.

**Table 28. MFR\_SAMPLES\_FOR\_AVG Register**

| Value    | Meaning                                        | Default |
|----------|------------------------------------------------|---------|
| 0h – 0Ch | Exponent for number of samples to average over | 00h     |

**MFR\_SPECIFIC\_12: MFR\_READ\_AVG\_VIN (DCh)**

The MFR\_READ\_AVG\_VIN command will report the 12-bit ADC measured input average voltage. If the data is not ready, the returned value will be the previous averaged data. However, if there is no previously averaged data the default value (0000h) will be returned. This data is read with the PMBus Read Word protocol. This register should use the coefficients shown in the [Telemetry and Warning Conversion Coefficients](#) Table.

**Table 29. MFR\_READ\_AVG\_VIN Register**

| Value      | Meaning                                      | Default |
|------------|----------------------------------------------|---------|
| 0h – 0FFFh | Average of measured values for input voltage | 0000h   |

**MFR\_SPECIFIC\_13: MFR\_READ\_AVG\_VAUX (DDh)**

The MFR\_READ\_AVG\_AUX command will report the 12-bit ADC measured auxiliary average voltage. If the data is not ready, the returned value will be the previous averaged data. However, if there is no previously averaged data the default value (0000h) will be returned. This data is read with the PMBus Read Word protocol. This register should use the coefficients shown in the [Telemetry and Warning Conversion Coefficients](#) Table.

**Table 30. MFR\_READ\_AVG\_VAUX Register**

| Value      | Meaning                                          | Default |
|------------|--------------------------------------------------|---------|
| 0h – 0FFFh | Average of measured values for auxiliary voltage | 0000h   |

**MFR\_SPECIFIC\_14: MFR\_READ\_AVG\_IIN (DEh)**

The MFR\_READ\_AVG\_IIN command will report the 12-bit ADC measured current sense average voltage. If the data is not ready, the returned value will be the previous averaged data. However, if there is no previously averaged data the default value (0000h) will be returned. This data is read with the PMBus Read Word protocol. This register should use the coefficients shown in the [Telemetry and Warning Conversion Coefficients](#) Table.

**Table 31. MFR\_READ\_AVG\_IIN Register**

| Value      | Meaning                                              | Default |
|------------|------------------------------------------------------|---------|
| 0h – 0FFFh | Average of measured values for current sense voltage | 0000h   |

**MFR\_SPECIFIC\_15: MFR\_READ\_AVG\_PIN (DFh)**

The MFR\_READ\_AVG\_PIN command will report the upper 12-bits of the average VIN x IIN product as measured by the 12-bit ADC. If the data is not ready, the returned value will be the previous averaged data. However, if there is no previously averaged data the default value (0000h) will be returned. This data is read with the PMBus Read Word protocol. This register should use the coefficients shown in the [Telemetry and Warning Conversion Coefficients](#) Table.

**Table 32. MFR\_READ\_AVG\_PIN Register**

| Value      | Meaning                                                                   | Default |
|------------|---------------------------------------------------------------------------|---------|
| 0h – 0FFFh | Average of measured value for input voltage x input current sense voltage | 0000h   |

**MFR\_SPECIFIC\_16: MFR\_BLACK\_BOX\_READ (E0h)**

The MFR\_BLACK\_BOX\_READ command retrieves the MFR\_BLOCK\_READ data which was latched in at the first assertion of SMBA. It is re-armed with the CLEAR\_FAULTS command. It is the same format as the MFR\_BLOCK\_READ registers, the only difference being that its contents are updated with the SMBA edge rather than the internal clock edge. This command is read with the PMBus Block Read protocol.

**MFR\_SPECIFIC\_17: MFR\_DIAGNOSTIC\_WORD\_READ (E1h)**

The MFR\_DIAGNOSTIC\_WORD\_READ PMBus command will report all of the LM25056A faults and warnings in a single read operation. The standard response to the assertion of the SMBA signal of issuing multiple read requests to various status registers can be replaced by a single word read to the MFR\_DIAGNOSTIC\_WORD\_READ register. The MFR\_DIAGNOSTIC\_WORD\_READ command should be read with the PMBus Read Word protocol. The MFR\_DIAGNOSTIC\_WORD\_READ register is also returned in the MFR\_BLOCK\_READ, MFR\_BLACK\_BOX\_READ, and MFR\_AVG\_BLOCK\_READ operations.

**Table 33. MFR\_DIAGNOSTIC\_WORD\_READ Format**

| Bit | Name                               | Meaning                                | Default |
|-----|------------------------------------|----------------------------------------|---------|
| 15  | Reserved                           |                                        | 0       |
| 14  | MFR_IIN_OC_WARN or MFR_PIN_OP_WARN | Input Overcurrent or Overpower Warning | 0       |
| 13  | VIN_UV_WARN                        | Input Undervoltage Warning             | 0       |
| 12  | VIN_OV_WARN                        | Input Overvoltage Warning              | 0       |
| 11  | Reserved                           |                                        | 0       |
| 10  | OT_WARN                            | Overtemperature Warning                | 0       |
| 9   | MFR_VAUX_UNDERVOLTAGE_WARN         | VAUX Undervoltage Warning              | 0       |
| 8   | MFR_VAUX_OVERVOLTAGE_WARN          | VAUX Overvoltage Warning               | 0       |
| 7   | CONFIG_PRESET                      |                                        | 1       |
| 6   | Reserved                           |                                        | 0       |
| 5   | Reserved                           |                                        | 0       |
| 4   | Reserved                           |                                        | 0       |
| 3   | Reserved                           |                                        | 0       |
| 2   | OT_FAULT                           | Over Temperature Fault                 | 0       |
| 1   | CML_FAULT                          | Communications Fault                   | 0       |
| 0   | Reserved                           |                                        | 0       |

**MFR\_SPECIFIC\_18: MFR\_AVG\_BLOCK\_READ (E2h)**

The MFR\_AVG\_BLOCK\_READ command concatenates the DIAGNOSTIC\_WORD with input average telemetry information (IIN, VAUX, VIN, PIN) as well as TEMPERATURE to capture all of the operating information of the part in a single PMBus transaction. The block is 12 bytes long with telemetry information being sent out in the same manner as if an individual READ\_AVG\_XXX command had been issued (shown below). AVG\_BLOCK\_READ also specifies that the VIN, VAUX, IIN, and PIN measurements are all time-aligned whereas there is a chance they may not be if read with individual PMBus commands. To read data from the AVG\_BLOCK\_READ command, use the SMBus Block Read protocol.

**Table 34. MFR\_AVG\_BLOCK\_READ Register Format**

|                        |          |
|------------------------|----------|
| Byte Count (always 12) | (1 byte) |
| DIAGNOSTIC WORD        | (1 word) |
| AVG_IIN                | (1 word) |
| AVG_VAUX               | (1 word) |
| AVG_VIN                | (1 word) |
| AVG_PIN                | (1 word) |
| TEMPERATURE            | (1 word) |

**MFR\_SPECIFIC\_19: VAUX\_OV\_WARN\_LIMIT (E3h)**

The VAUX\_OV\_WARN\_LIMIT command allows configuring or reading the threshold for the VAUX overvoltage warning detection. Reading and writing to this register should use the coefficients shown in the [Telemetry and Warning Conversion Coefficients](#) Table. Accesses to this command should use the PMBus read or write word protocol. If the measured value of VAUX rises above the value in this register, VAUX OV Warn flags are set and the SMBA signal is asserted.

**Table 35. VAUX\_OV\_WARN\_LIMIT Register**

| Value     | Meaning                                      | Default         |
|-----------|----------------------------------------------|-----------------|
| 0h – 0FFh | VAUX Overvoltage Warning detection threshold | 0FFh (disabled) |
| 0FFh      | VAUX Overvoltage Warning disabled            | n/a             |

## MFR\_SPECIFIC\_20: VAUX\_UV\_WARN\_LIMIT (E4h)

The VAUX\_UV\_WARN\_LIMIT command allows configuring or reading the threshold for the VAUX undervoltage warning detection. Reading and writing to this register should use the coefficients shown in the [Telemetry and Warning Conversion Coefficients](#) Table. Accesses to this command should use the PMBus read or write word protocol. If the measured value of VAUX falls below the value in this register, VAUX UV Warn flags are set and the SMBA signal is asserted.

Table 36. VAUX\_UV\_WARN\_LIMIT Register

| Value      | Meaning                                       | Default          |
|------------|-----------------------------------------------|------------------|
| 1h – 0FFFh | VAUX Undervoltage Warning detection threshold | 0000h (disabled) |
| 0000h      | VAUX Undervoltage Warning disabled            | n/a              |

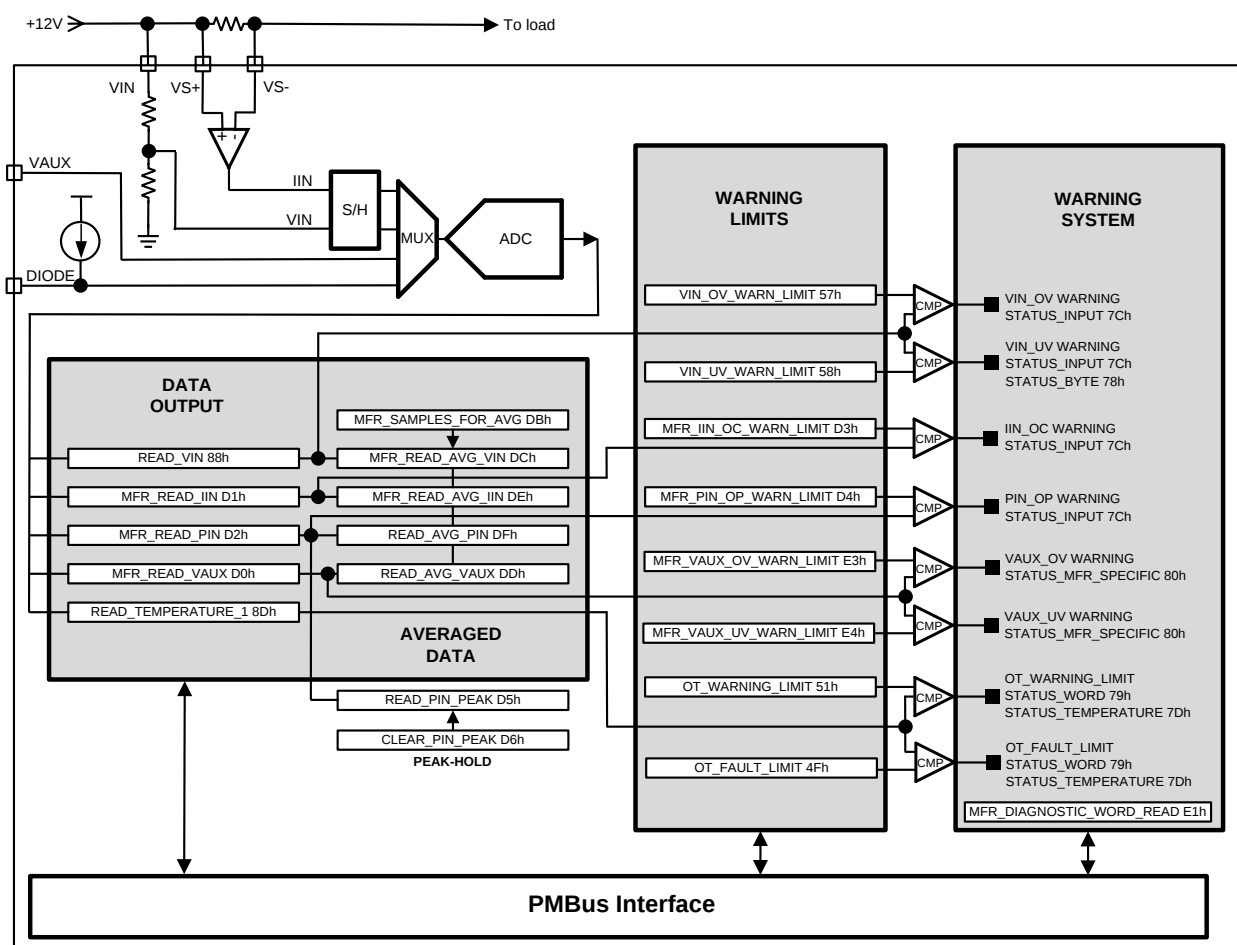


Figure 18. Command/Register and Alert Flow Diagram

## Reading and Writing Telemetry Data and Warning Thresholds

All measured telemetry data and user programmed warning thresholds are communicated in 12 bit two's complement binary numbers read/written in 2 byte increments conforming to the Direct format as described in section 8.3.3 of the PMBus Power System Management Protocol Specification 1.1 (Part II). The organization of the bits in the telemetry or warning word is shown in [Table 37](#), where Bit\_11 is the most significant bit (MSB) and Bit\_0 is the least significant bit (LSB). The decimal equivalent of all warning and telemetry words are constrained to be within the range of 0 to 4095, with the exception of temperature. The decimal equivalent value of the temperature word ranges from 0 to 65535.

**Table 37. Telemetry and Warning Word Format**

| Byte | B7    | B6    | B5    | B4    | B3     | B2     | B1    | B0    |
|------|-------|-------|-------|-------|--------|--------|-------|-------|
| 1    | Bit_7 | Bit_6 | Bit_5 | Bit_4 | Bit_3  | Bit_2  | Bit_1 | Bit_0 |
| 2    | 0     | 0     | 0     | 0     | Bit_11 | Bit_10 | Bit_9 | Bit_8 |

Conversion from direct format to real world dimensions of current, voltage, power, and temperature is accomplished by determining appropriate coefficients as described in section 7.2.1 of the PMBus Power System Management Protocol Specification 1.1 (Part II). According to this specification, the host system converts the values received into a reading of volts, amperes, watts, or other units using the following relationship:

$$X = \frac{1}{m}(Y \times 10^{-R-b})$$

Where:

- **X**: the calculated "real world" value (volts, amps, watt, etc.)
- **m**: the slope coefficient
- **Y**: a two byte two's complement integer received from device
- **b**: the offset, a two byte, two's complement integer
- **R**: the exponent, a one byte two's complement integer

R is only necessary in systems where m is required to be an integer (for example, where m may be stored in a register in an integrated circuit). In those cases, R only needs to be large enough to yield the desired accuracy. (3)

**Table 38. Telemetry and Warning Conversion Coefficients**

| Commands                                                                                         | Condition | Format | Number of Data Bytes | m     | b     | R  | Units |
|--------------------------------------------------------------------------------------------------|-----------|--------|----------------------|-------|-------|----|-------|
| READ_VIN, MFR_READ_AVG_VIN,<br>VIN_OV_WARN_LIMIT<br>VIN_UV_WARN_LIMIT                            |           | DIRECT | 2                    | 16296 | 1343  | -2 | V     |
| MFR_READ_VAUX, MFR_READ_AVG_VAUX,<br>MFR_VAUX_OV_WARN_LIMIT<br>MFR_VAUX_UV_WARN_LIMIT            |           | DIRECT | 2                    | 3416  | -4    | 0  | V     |
| <sup>(1)</sup> MFR_READ_IIN,<br>MFR_IIN_OC_WARN_LIMIT,<br>MFR_READ_AVG_IIN ,                     | GAIN = 0  | DIRECT | 2                    | 13797 | -1833 | -2 | A     |
| <sup>(1)</sup> MFR_READ_IIN,<br>MFR_IIN_OC_WARN_LIMIT,<br>MFR_READ_AVG_IIN ,                     | GAIN = 1  | DIRECT | 2                    | 6726  | -537  | -2 | A     |
| <sup>(1)</sup> MFR_READ_PIN,<br>MFR_PIN_OP_WARN_LIMIT,<br>MFR_READ_PIN_PEAK,<br>MFR_READ_AVG_PIN | GAIN = 0  | DIRECT | 2                    | 5501  | -2908 | -3 | W     |
| <sup>(1)</sup> MFR_READ_PIN,<br>MFR_PIN_OP_WARN_LIMIT,<br>MFR_READ_PIN_PEAK,<br>MFR_READ_AVG_PIN | GAIN = 1  | DIRECT | 2                    | 26882 | -5646 | -4 | W     |

(1) \* The coefficients relating to current/power measurements and warning thresholds shown in [Table 38](#) are normalized to a sense resistor (R<sub>S</sub>) value of 1mΩ. In general, the current/power coefficients can be calculated using the relationships shown in [Table 39](#).

**Table 38. Telemetry and Warning Conversion Coefficients (continued)**

| Commands                                             | Condition | Format | Number of Data Bytes | m    | b      | R  | Units |
|------------------------------------------------------|-----------|--------|----------------------|------|--------|----|-------|
| READ_TEMPERATURE_1,<br>OT_FAULT_LIMIT, OT_WARN_LIMIT |           | DIRECT | 2                    | 1580 | -14500 | -2 | °C    |

**Table 39. Current and Power Telemetry and Warning Conversion Coefficients (R<sub>S</sub> in mΩ)**

| Commands                                                                           | Condition | Format | Number of Data Bytes | m                      | b     | R  | Units |
|------------------------------------------------------------------------------------|-----------|--------|----------------------|------------------------|-------|----|-------|
| *MFR_READ_IIN,<br>MFR_IIN_OC_WARN_LIMIT,<br>MFR_READ_AVG_IIN ,                     | GAIN = 0  | DIRECT | 2                    | 13797 x R <sub>S</sub> | -1833 | -2 | A     |
| *MFR_READ_IIN,<br>MFR_IIN_OC_WARN_LIMIT,<br>MFR_READ_AVG_IIN ,                     | GAIN = 1  | DIRECT | 2                    | 6726 x R <sub>S</sub>  | -537  | -2 | A     |
| *MFR_READ_PIN,<br>MFR_PIN_OP_WARN_LIMIT,<br>MFR_READ_PIN_PEAK,<br>MFR_READ_AVG_PIN | GAIN = 0  | DIRECT | 2                    | 5501 x R <sub>S</sub>  | -2908 | -3 | W     |
| *MFR_READ_PIN,<br>MFR_PIN_OP_WARN_LIMIT,<br>MFR_READ_PIN_PEAK,<br>MFR_READ_AVG_PIN | GAIN = 1  | DIRECT | 2                    | 26882 x R <sub>S</sub> | -5646 | -4 | W     |

Care must be taken to adjust the exponent coefficient, R, such that the values of m and b remain within the range of -32768 to +32767. For example, if a 5 mΩ sense resistor is used, the correct coefficients for the MFR\_READ\_IIN command with GAIN = 0 would be m = 3363, b = -537, R = -1.

#### A Note on the "b" Coefficient

Since b coefficients represent offset, for simplification b is set to zero in the following discussions.

#### Reading Current

The current register actually displays a value equivalent to a voltage across the user specified sense resistor, R<sub>S</sub>. The coefficients enable the data output to be converted to amps. The values shown in the example are based on having the device programmed for a 30 mV current sense range (GAIN = 0). In the 30 mV range, the LSB value is 7.25 μV and the full scale range is 29.68 mV. In the 60 mV current sense range (GAIN = 1), the LSB value is 14.87 μV and the full scale range is 60.88 mV.

| Step                                                                                                                                                                                                                                         | Example                                                                                                                                |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|
| 1. Determine full scale current and shunt value based on 29.68 mV across shunt at full scale. Use either:<br><br>$I_{IN\_MAX} = \frac{29.68 \text{ mV}}{R_S} \quad (4)$ or:<br>2. Determine m':<br>$m' = \frac{4095}{I_{IN\_MAX}} \quad (6)$ | Example: Application with 250 μΩ shunt.<br><br>$I_{IN\_MAX} = \frac{29.68 \text{ mV}}{0.25 \text{ m}\Omega} = 118.7\text{A} \quad (5)$ |
| 3. Determine exponent R necessary to set m' to integer value m:<br><br>$10^R = \frac{m'}{m} \quad (8)$                                                                                                                                       | Select R to provide integer value of m:<br><br>$R = \log_{10} \left( \frac{34.50}{3450} \right) \quad (9)$ R = -2                      |
| 4. Final values                                                                                                                                                                                                                              | m = 3450<br>R = -2<br>b = 0                                                                                                            |

## Reading Input Voltage

Coefficients for VIN are consistent between read telemetry measurements (e.g., READ\_VIN, READ\_AVG\_VIN) and warning thresholds (e.g., VIN\_OV\_WARN\_LIMIT, VIN\_UV\_WARN\_LIMIT). Input voltage values are read/written in Direct format with 12-bit resolution and a 6.14 mV LSB. An example of calculating the PMBus coefficients for input voltage is shown below. Reading the auxiliary voltage (e.g. MFR\_READ\_VAUX, MFR\_READ\_AVG\_VAUX) and setting the warning threshold (e.g. MFR\_VAUX\_UV\_WARN\_LIMIT) is done in similar manner with different coefficients provided in [Table 38](#).

| Step                                                                                                                                               | Example                                                                                                                                                                                          |
|----------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. Determine m' based on full scale analog input and full scale digital range:<br>$m' = \frac{4095}{V_{IN\_MAX}} = \frac{4095}{25.13V} \quad (10)$ | $m' = \frac{4095}{25.13V} = 162.95 \quad (11)$                                                                                                                                                   |
| 2. Determine exponent R necessary to set m' to integer value m with desired accuracy:<br>$10^R = \frac{m'}{m} \quad (12)$                          | Select R to provide 5 digit accuracy for the integer value of m (which would be 16295 in this example):<br>$R = \log_{10} \left( \frac{162.95}{16295} \right) \quad (13)$<br>R = -2<br>m = 16295 |
| 3. Final values                                                                                                                                    | R = -2<br>b = 0                                                                                                                                                                                  |

## Reading Power

The power calculation of the LM25056A is a relative power calculation meaning that full scale of the power register corresponds to simultaneous full scale values in the current register and voltage register such that the power register has the following relationship based on decimal equivalents of the register contents:

$$PIN = \frac{IIN \times VIN}{4095} \quad (14)$$

For this reason power coefficients will also vary depending on the shunt value and must be calculated for each application. The power LSB will vary depending on shunt value according to 374 mW/R<sub>S</sub> for the GAIN=1 range or 182 mW/R<sub>S</sub> for the GAIN=0 range.

| Step                                                                                                                                                | Example                                                                                                                                                                           |
|-----------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. Determine full scale power from known full scale of input current and input voltage<br>$P_{IN\_MAX} = V_{IN\_MAX} \times I_{IN\_MAX} \quad (15)$ | Example: Application with 250 μΩ shunt.<br>$P_{IN\_MAX} = (25.13V) \times (118.7A) = 2983W \quad (16)$                                                                            |
| 2. Determine m':<br>$m' = \frac{4095}{P_{IN\_MAX}} \quad (17)$                                                                                      | $m' = \frac{4095}{2983W} = 1.3728 \quad (18)$                                                                                                                                     |
| 3. Optional: Determine exponent R necessary to set m' to integer value m with desired accuracy:<br>$10^R = \frac{m'}{m} \quad (19)$                 | Select R (in this case selected to provide 4 digit accuracy for the integer value of m):<br>$R = \log_{10} \left( \frac{1.3728}{13728} \right) \quad (20)$<br>R = -4<br>m = 13728 |
| 4. Final values                                                                                                                                     | R = -4<br>b = 0                                                                                                                                                                   |

## Determining Telemetry Coefficients Empirically with Linear Fit

The coefficients for telemetry measurements and warning thresholds presented in [Table 38](#) are adequate for the majority of applications. Current and power coefficients must be calculated per application as they are dependent on the value of the sense resistor,  $R_S$ , used. [Table 39](#) provides the equations necessary for calculating the current and power coefficients for the general case. The small signal nature of the current measurement make it and the power measurement more susceptible to PCB parasitics than other telemetry channels. This may cause slight variations in the optimum coefficients ( $m$ ,  $b$ ,  $R$ ) for converting from Direct format digital values to real-world values (e.g., amps and watts). The optimum coefficients can be determined empirically for a specific application and PCB layout using two or more measurements of the telemetry channel of interest. The current coefficients can be determined using the following method:

1. While the LM25056A is in normal operation measure the voltage across the sense resistor using kelvined test points and a high accuracy DVM while controlling the load current. Record the integer value returned by the MFR\_READ\_AVG\_IIN command (with the MFR\_SAMPLES\_FOR\_AVG set to a value greater than 0) for two or more voltages across the sense resistor. For best results, the individual MFR\_READ\_AVG\_IIN measurements should span nearly the full scale range of the current (For example, voltage across  $R_S$  of 5mV and 20mV).
2. Convert the measured voltages to currents by dividing them by the value of  $R_S$ . For best accuracy the value of  $R_S$  should be measured. [Table 40](#) assumes a sense resistor value of 5 m $\Omega$ .

**Table 40. Measurements for linear fit determination of current coefficients:**

| Measured voltage across $R_S$ (V) | Measured Current (A) | READ_AVG_IIN (integer value) |
|-----------------------------------|----------------------|------------------------------|
| 0.005                             | 1                    | 672                          |
| 0.01                              | 2                    | 1362                         |
| 0.02                              | 4                    | 2743                         |

3. Using the spreadsheet or math program of your choice determine the slope and the y-intercept of the returned by the MFR\_READ\_AVG\_IIN command values versus the measured current. For the data shown in [Table 39](#):
  - (a) MFR\_READ\_AVG\_IN value = slope x (Measured Current) + (y-intercept)
  - (b) slope = 690.4
  - (c) y-intercept = -18.5
4. To determine the ' $m$ ' coefficient, simply shift the decimal point of the calculated slope to arrive at an integer with a suitable number of significant digits for accuracy (typically 4) while staying with the range of -32768 to +32767. This shift in the decimal point equates to the ' $R$ ' coefficient. For the slope value shown above, the decimal point would be shifted to the right once hence  $R = -1$ .
5. Once the ' $R$ ' coefficient has been determined, the ' $b$ ' coefficient is found by multiplying the y-intercept by  $10^R$ . In this case the value of  $b = -185$ .
  - (a) Calculated Current Coefficients:
  - (b)  $m = 6904$
  - (c)  $b = -185$
  - (d)  $R = -1$

$$X = \frac{1}{m}(Y \times 10^{-R} - b)$$

Where:

- **X**: the calculated "real world" value (volts, amps, watts, temperature)
- **m**: the slope coefficient, is the two byte, two's complement integer
- **Y**: a two byte two's complement integer received from device
- **b**: the offset, a two byte, two's complement integer
- **R**: the exponent, a one byte two's complement integer (21)

Step 5 can be repeated to determine the coefficients of any telemetry channel simply by substituting measured current for some other parameter (e.g., power, voltage, etc.).

## Writing Telemetry Data

There are several locations that will require writing data if their optional usage is desired. Use the same coefficients previously calculated for your application, and apply them using this method as prescribed by the PMBus™ revision section 7.2.2 "Sending a Value"

$$Y = (mX + b) \times 10^R$$

where

- **X**: the calculated "real world" value (volts, amps, watts, temperature)
- **m**: the slope coefficient, is the two byte, two's complement integer
- **Y**: a two byte two's complement integer to send to the device
- **b**: the offset, a two byte, two's complement integer
- **R**: the exponent, a one byte two's complement integer

(22)

## PMBus Address Lines (ADR0, ADR1, ADR2)

The three address lines are to be set high (connect to VDD), low (connect to GND), or open to select one of 27 addresses for communicating with the LM25056A. These lines are read after the ENABLE pin is returned high, and the VDD and VREF are out of a POR condition. Table 41 depicts 7-bit addresses (eighth bit is read/write bit):

**Table 41. Device Addressing**

| ADR2 | ADR1 | ADR0 | Decoded Address |
|------|------|------|-----------------|
| Z    | Z    | Z    | 40h             |
| Z    | Z    | 0    | 41h             |
| Z    | Z    | 1    | 42h             |
| Z    | 0    | Z    | 43h             |
| Z    | 0    | 0    | 44h             |
| Z    | 0    | 1    | 45h             |
| Z    | 1    | Z    | 46h             |
| Z    | 1    | 0    | 47h             |
| Z    | 1    | 1    | 10h             |
| 0    | Z    | Z    | 11h             |
| 0    | Z    | 0    | 12h             |
| 0    | Z    | 1    | 13h             |
| 0    | 0    | Z    | 14h             |
| 0    | 0    | 0    | 15h             |
| 0    | 0    | 1    | 16h             |
| 0    | 1    | Z    | 17h             |
| 0    | 1    | 0    | 50h             |
| 0    | 1    | 1    | 51h             |
| 1    | Z    | Z    | 52h             |
| 1    | Z    | 0    | 53h             |
| 1    | Z    | 1    | 54h             |
| 1    | 0    | Z    | 55h             |
| 1    | 0    | 0    | 56h             |
| 1    | 0    | 1    | 57h             |
| 1    | 1    | Z    | 58h             |
| 1    | 1    | 0    | 59h             |
| 1    | 1    | 1    | 5Ah             |

## SMBus Communications Timing Requirements

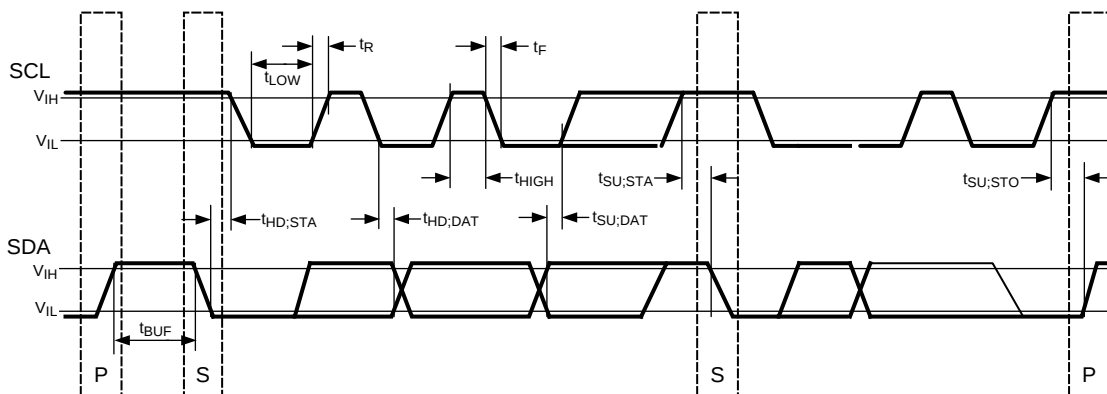


Figure 19. SMBus Timing Diagram

Table 42. SMBus Timing Definition

| Symbol         | Parameter                                                                                    | Limits |     | Units   | Comments              |
|----------------|----------------------------------------------------------------------------------------------|--------|-----|---------|-----------------------|
|                |                                                                                              | Min    | Max |         |                       |
| $f_{SMB}$      | SMBus Operating Frequency                                                                    | 10     | 400 | kHz     |                       |
| $t_{BUF}$      | Bus free time between Stop and Start Condition                                               | 1.3    |     | $\mu s$ |                       |
| $t_{HD,STA}$   | Hold time after (Repeated) Start Condition. After this period, the first clock is generated. | 0.6    |     | $\mu s$ |                       |
| $t_{SU,STA}$   | Repeated Start Condition setup time                                                          | 0.6    |     | $\mu s$ |                       |
| $t_{SU,STO}$   | Stop Condition setup time                                                                    | 0.6    |     | $\mu s$ |                       |
| $t_{HD,DAT}$   | Data hold time                                                                               | 300    |     | ns      |                       |
| $t_{SU,DAT}$   | Data setup time                                                                              | 100    |     | ns      |                       |
| $t_{TIMEOUT}$  | Clock low time-out                                                                           | 25     | 35  | ms      | See <sup>(1)</sup>    |
| $t_{LOW}$      | Clock low period                                                                             | 1.5    |     | $\mu s$ |                       |
| $t_{HIGH}$     | Clock high period                                                                            | 0.6    |     | $\mu s$ | See <sup>(2)</sup>    |
| $t_{LOW,SEXT}$ | Cumulative clock low extend time (slave device)                                              |        | 25  | ms      | See <sup>(3)</sup>    |
| $t_{LOW,MEXT}$ | Cumulative low extend time (master device)                                                   |        | 10  | ms      | See <sup>(4)</sup>    |
| $t_F$          | Clock or Data Fall Time                                                                      | 20     | 300 | ns      | See <sup>(4)(5)</sup> |
| $t_R$          | Clock or Data Rise Time                                                                      | 20     | 300 | ns      | See <sup>(6)(5)</sup> |

- (1) Devices participating in a transfer will timeout when any clock low exceeds the value of  $t_{TIMEOUT,MIN}$  of 25 ms. Devices that have detected a timeout condition must reset the communication no later than  $t_{TIMEOUT,MAX}$  of 35 ms. The maximum value must be adhered to by both a master and a slave as it incorporates the cumulative stretch limit for both a master (10ms) and a slave (25ms).
- (2)  $t_{HIGH,MAX}$  provides a simple method for devices to detect bus idle conditions.
- (3)  $t_{LOW,SEXT}$  is the cumulative time a slave device is allowed to extend the clock cycles in one message from the initial start to the stop. If a slave exceeds this time, it is expected to release both its clock and data lines and reset itself.
- (4)  $t_{LOW,MEXT}$  is the cumulative time a master device is allowed to extend its clock cycles within each byte of a message as defined from start-to-ack, ack-to-ack, or ack-to-stop.
- (5) Fall time is defined as:  $t_F = 0.9 V_{DD}$  to  $(V_{ILMAX} - 0.15)$
- (6) Rise time is defined as:  $t_R = (V_{ILMAX} - 0.15)$  to  $(V_{IHMIN} + 0.15)$

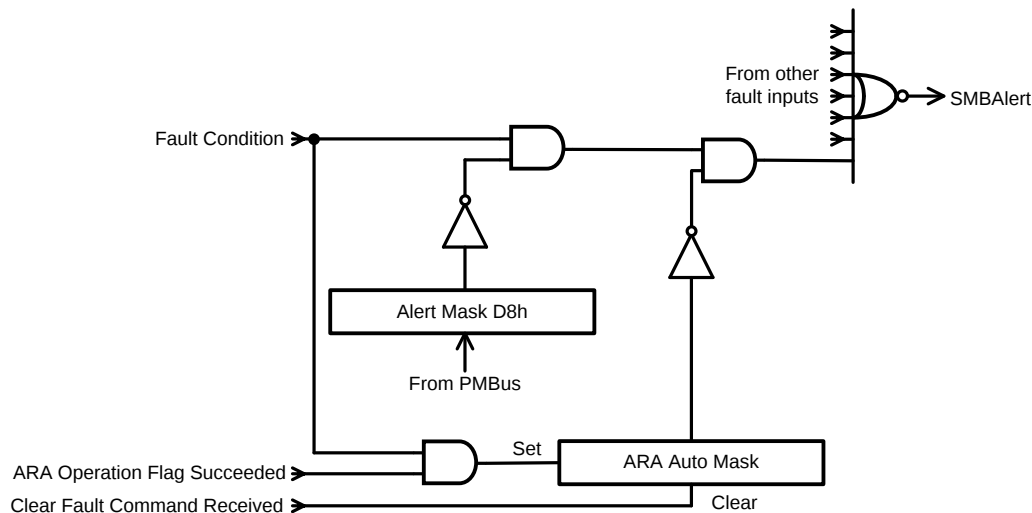
## SMBA Response

The SMBA effectively has two masks:

1. The Alert Mask Register at D8h, and
2. The ARA Automatic Mask.

The ARA Automatic Mask is a mask that is set in response to a successful ARA read. An ARA read operation returns the PMBus™ address of the lowest addressed part on the bus that has its  $\overline{\text{SMBA}}$  asserted. A successful ARA read means that THIS part was the one that returned its address. When a part responds to the ARA read, it releases the  $\overline{\text{SMBA}}$  signal. When the last part on the bus that has an SMBA set has successfully reported its address, the  $\overline{\text{SMBA}}$  signal will de-assert.

The way that the LM25056A releases the  $\overline{\text{SMBA}}$  signal is by setting the ARA Automatic mask bit for all fault conditions present at the time of the ARA read. All status registers will still show the fault condition, but it will not generate and  $\overline{\text{SMBA}}$  on that fault again until the ARA Automatic mask is cleared by the host issuing a Clear Fault command to this part. This should be done as a routine part of servicing an SMBA condition on a part, even if the ARA read is not done. Figure 20 depicts a schematic version of this flow.



**Figure 20. Typical Flow Schematic for  $\overline{\text{SMBA}}$  Fault**

## REVISION HISTORY

| Changes from Original (April 2013) to Revision A           | Page               |
|------------------------------------------------------------|--------------------|
| • Changed layout of National Data Sheet to TI format ..... | <a href="#">32</a> |

## PACKAGING INFORMATION

| Orderable Device  | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2)            | Lead/Ball Finish | MSL Peak Temp<br>(3) | Op Temp (°C) | Top-Side Markings<br>(4) | Samples                 |
|-------------------|---------------|--------------|--------------------|------|----------------|----------------------------|------------------|----------------------|--------------|--------------------------|-------------------------|
| LM25056APSQ/NOPB  | ACTIVE        | WQFN         | NHZ                | 24   | 1000           | Green (RoHS<br>& no Sb/Br) | CU SN            | Level-3-260C-168 HR  |              | L25056A                  | <a href="#">Samples</a> |
| LM25056APSQE/NOPB | ACTIVE        | WQFN         | NHZ                | 24   | 250            | Green (RoHS<br>& no Sb/Br) | CU SN            | Level-3-260C-168 HR  |              | L25056A                  | <a href="#">Samples</a> |
| LM25056APSQX/NOPB | ACTIVE        | WQFN         | NHZ                | 24   | 4500           | Green (RoHS<br>& no Sb/Br) | CU SN            | Level-3-260C-168 HR  |              | L25056A                  | <a href="#">Samples</a> |

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) Multiple Top-Side Markings will be inside parentheses. Only one Top-Side Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Top-Side Marking for that device.

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**TAPE AND REEL INFORMATION**


\*All dimensions are nominal

| Device            | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|-------------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| LM25056APSQ/NOPB  | WQFN         | NHZ             | 24   | 1000 | 178.0              | 12.4               | 4.3     | 5.3     | 1.3     | 8.0     | 12.0   | Q1            |
| LM25056APSQE/NOPB | WQFN         | NHZ             | 24   | 250  | 178.0              | 12.4               | 4.3     | 5.3     | 1.3     | 8.0     | 12.0   | Q1            |
| LM25056APSQX/NOPB | WQFN         | NHZ             | 24   | 4500 | 330.0              | 12.4               | 4.3     | 5.3     | 1.3     | 8.0     | 12.0   | Q1            |

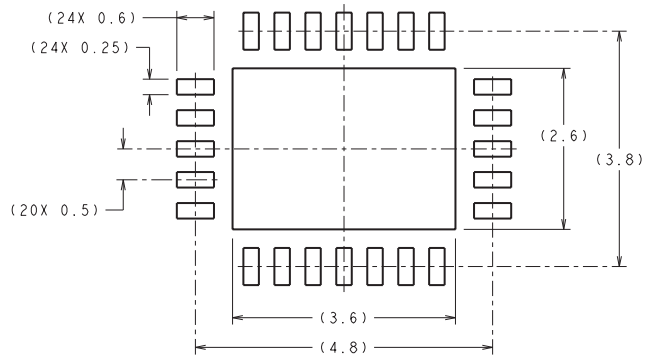
## TAPE AND REEL BOX DIMENSIONS



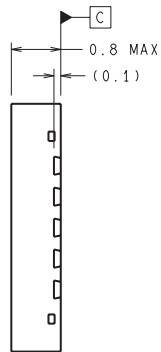
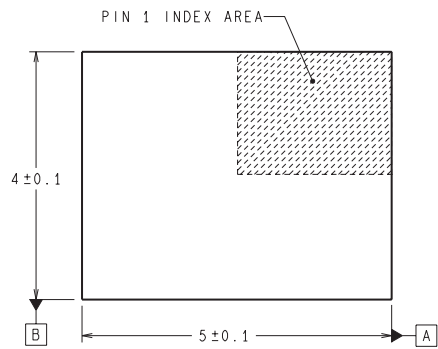
\*All dimensions are nominal

| Device            | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|-------------------|--------------|-----------------|------|------|-------------|------------|-------------|
| LM25056APSQ/NOPB  | WQFN         | NHZ             | 24   | 1000 | 213.0       | 191.0      | 55.0        |
| LM25056APSQE/NOPB | WQFN         | NHZ             | 24   | 250  | 213.0       | 191.0      | 55.0        |
| LM25056APSQX/NOPB | WQFN         | NHZ             | 24   | 4500 | 367.0       | 367.0      | 35.0        |

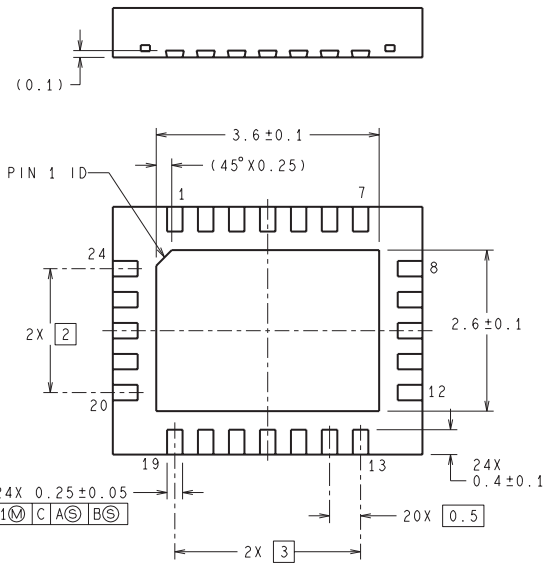
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