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Tel: +86-755-8981 8866 Fax: +86-755-8427 6832
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EVALUATION KIT AVAILABLE

MAX34460

PMBus 12-Channel Voltage Monitor and Sequencer

General Description

The MAX34460 is a system monitor that is capable of managing up to 12 power supplies. The power-supply manager monitors the power-supply output voltages and constantly checks for user-programmable overvoltage and undervoltage thresholds. If a fault is detected, the device automatically shuts down the system in an orderly fashion. The device can sequence the supplies in any order at both power-up and power-down. With the addition of external current DACs, the device has the ability to close-loop margin the power-supply output voltages up or down to a user-programmable level. The device contains an internal temperature sensor and can support up to four external remote temperature sensors. Once configured, the device can operate autonomously without any host intervention.

Applications

Network Switches/Routers

Base Stations

Servers

Smart Grid Network Systems

Ordering Information and Typical Operating Circuit appear at end of data sheet.

Features

- **12 Channels of Power-Supply Management**
- **Power-Supply Voltage Measurement and Monitoring**
- **Fast Minimum/Maximum Threshold Excursion Detection**
- **Remote Ground Sensing Improves Measurement Accuracy**
- **Automatic Closed-Loop Margining**
- **Programmable Up and Down Time-Based or Event-Based Sequencing**
- **Supports Dual-Sequencing Groups**
- **Supports Up to Five Temperature Sensors (One Internal/Four Remote)**
- **Fault Detection on All Temperature Sensors**
- **Programmable Alarm Outputs**
- **Reports Peak and Average Levels for a Number of Parameters**
- **Watchdog Timer Function**
- **PMBus™-Compliant Command Interface**
- **I²C/SMBus-Compatible Serial Bus with Bus Timeout Function**
- **On-Board Nonvolatile Black Box Fault Logging and Default Configuration Setting**
- **Expandable Channel Operation with Parallel Devices**
- **Up to 20 GPOs**
- **No External Clocking Required**
- **3.0V to 3.6V Supply Voltage**

For related parts and recommended products to use with this part, refer to: www.maximintegrated.com/MAX34460.related

For pricing, delivery, and ordering information, please contact Maxim Direct at 1-888-629-4642, or visit Maxim's website at www.maximintegrated.com.

19-6486; Rev 1; 11/13

PMBus 12-Channel Voltage Monitor and Sequencer

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ABSOLUTE MAXIMUM RATINGS

V_{DD} and V_{DDA} to V_{SS} ..... -0.3V to +4.0V
SDA, SCL, MSDA, and MSCL to V_{SS} ..... -0.3V to +4.0V
RSG0 and RSG1 to V_{SS} ..... -0.3V to +0.3V
RSn to V_{SS} ..... -0.3V to (V_{DD} + 0.3V)*
RSn to V_{SS} with 100Ω of series resistance ..... -0.3V to +2.0V
All Other Pins Relative to V_{SS} ..... -0.3V to (V_{DD} + 0.3V)*
All Other Pins Relative to V_{SS}
with greater than 100Ω of series resistance ..... -0.3V to +4.0V
REG18 to V_{SS} ..... -0.3V to +2.0V
Continuous Power Dissipation (T_A = +70°C)
TQFN (derate 26.3mW/°C above +70°C) 2105.3mW
Operating Temperature Range ..... -40°C to +85°C
Storage Temperature Range ..... -55°C to +125°C
Lead Temperature (soldering, 10s) ..... +260°C
Soldering Temperature (reflow) ..... +260°C

**Not to exceed +4.0V.*

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

RECOMMENDED OPERATING CONDITIONS

(T_A = -40°C to +85°C, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
V_{DD} Operating Voltage Range	V_{DD}	(Note 1)	3.0		3.6	V
Input Logic 1 (Except I²C Pins)	V_{IH1}		0.7 x V_{DD}		V_{DD} + 0.3	V
Input Logic 0 (Except I²C Pins)	V_{IL1}		-0.3		+0.3 x V_{DD}	V
Input Logic 1: SCL, SDA, MSCL, MSDA	V_{IH2}		2.1		V_{DD} + 0.3	V
Input Logic 0: SCL, SDA, MSCL, MSDA	V_{IL2}		-0.3		+0.8	V
Source Impedance to RS		ADC_TIME[1:0] = 00			1	kΩ
		ADC_TIME[1:0] = 01			5	
		ADC_TIME[1:0] = 10			10	
		ADC_TIME[1:0] = 11			20	
V_{DD} Rise Time		From 0V to 3.0V			4	ms
V_{DD} Trace Impedance					10	Ω

ELECTRICAL CHARACTERISTICS

(V_{DD} and V_{DDA} = 3.0V to 3.6V, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at V_{DD}/V_{DDA} = 3.3V, T_A = +25°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
GENERAL						
Supply Current	I_{CPU}	(Note 2)		12		mA
	$I_{PROGRAM}$			18		
System Clock Error	$f_{ERR:MOSC}$	+25°C < T_A < +85°C	-3		+3	%
		-40°C < T_A < +25°C	-4		+4	
Output Logic-Low (Except I²C Pins)	V_{OL1}	I_{OL} = 4mA (Note 1)			0.4	V
Output Logic-High (Except I²C Pins)	V_{OH1}	I_{OH} = -2mA (Note 1)	V_{DD} - 0.5			V

ELECTRICAL CHARACTERISTICS (continued)

(V_{DD} and V_{DDA} = 3.0V to 3.6V, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at V_{DD}/V_{DDA} = 3.3V, T_A = +25°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Output Logic-Low SCL, SDA, MSCL, MSDA	V_{OL2}	I_{OL} = 4mA (Note 1)			0.4	V
SCL, SDA, MSCL, MSDA Leakage	IL_{I2C}	V_{DD} = 0V or unconnected			±5	µA
CONTROL Threshold				2.048		V
CONTROL Hysteresis				50		mV
ADC						
ADC Bit Resolution				12		Bits
ADC Conversion Time		ADC_TIME[1:0] = 00		1000		ns
ADC Full Scale	V_{FS}	T_A = 0°C to +85°C	2.032	2.048	2.064	V
ADC Measurement Resolution	V_{LSB}			500		µV
RS Input Capacitance	C_{RS}			15		pF
RS Input Leakage	IL_{RS}			±0.25		µA
ADC Integral Nonlinearity	INL			±1		LSB
ADC Differential Nonlinearity	DNL			±1		LSB
TEMPERATURE SENSOR						
Internal Temperature-Measurement Error		T_A = -40°C to +85°C		±2		°C
FLASH						
Flash Endurance	N_{FLASH}		20,000			Write Cycles
Data Retention		T_A = +50°C	100			Years
STORE_DEFAULT_ALL Write Time				70		ms
MFR_STORE_SINGLE Write Time				310		µs
RESTORE_DEFAULT_All Time				70		ms
MFR_NV_FAULT_LOG Write Time		Writing 1 fault log		11		ms
MFR_NV_FAULT_LOG Delete Time		Deleting all fault logs		200		ms
MFR_NV_FAULT_LOG Overwrite Time				40		ms
TIMING OPERATING CHARACTERISTICS						
Voltage Sample Rate		Threshold excursion (Note 3)		48		µs
		Data collection		5		ms
Temperature Sample Rate				1000		ms
Device Startup Time				135		ms

I²C/SMBus INTERFACE ELECTRICAL SPECIFICATIONS

(V_{DD} and V_{DDA} = 3.0V to 3.6V, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at V_{DD}/V_{DDA} = 3.3V, T_A = +25°C.)

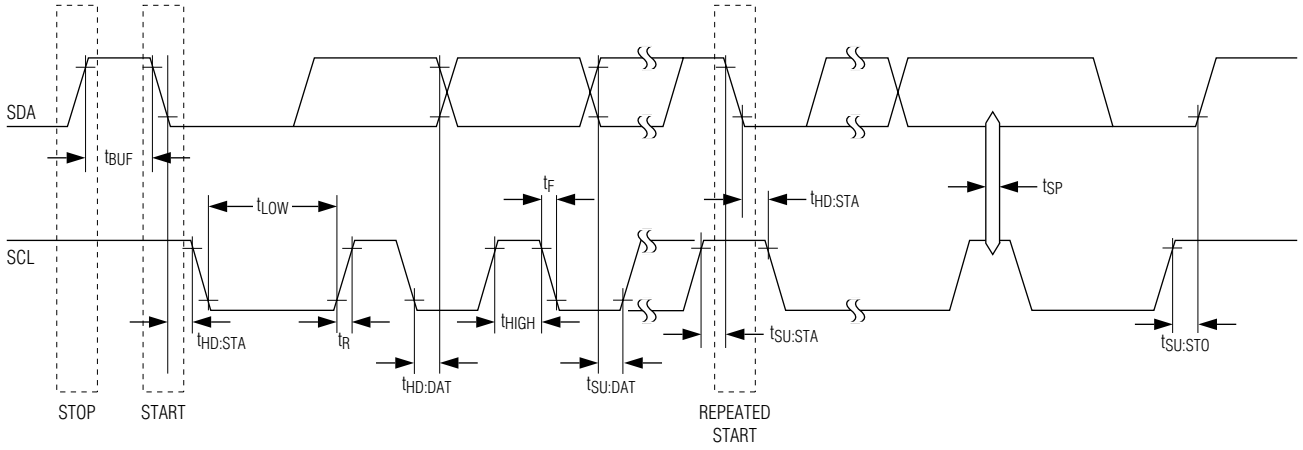
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
SCL Clock Frequency	f_{SCL}		10		400	kHz
MSCL Clock Frequency	f_{MSCL}			100		kHz
Bus Free Time Between STOP and START Conditions	t_{BUF}		1.3			µs
Hold Time (Repeated) START Condition	$t_{HD:STA}$		0.6			µs
Low Period of SCL	t_{LOW}		1.3			µs
High Period of SCL	t_{HIGH}		0.6			µs
Data Hold Time	$t_{HD:DAT}$	Receive	0			ns
		Transmit	300			ns
Data Setup Time	$t_{SU:DAT}$		100			ns
Start Setup Time	$t_{SU:STA}$		0.6			µs
SDA and SCL Rise Time	t_R				300	ns
SDA and SCL Fall Time	t_F				300	ns
Stop Setup Time	$t_{SU:STO}$		0.6			µs
Clock Low Time Out	t_{TO}		25	27	35	ms

Note 1: All voltages are referenced to ground. Current entering the device are specified as positive and currents exiting the device are negative.

Note 2: This does not include pin input/output currents.

Note 3: The round-robin threshold excursion rate can be changed with the ADC_AVERAGE and ADC_TIME bits in MFR_MODE from 12µs (no averaging and 1µs conversion) to 768µs (8x averaging and 8µs conversion).

I²C/SMBus Timing

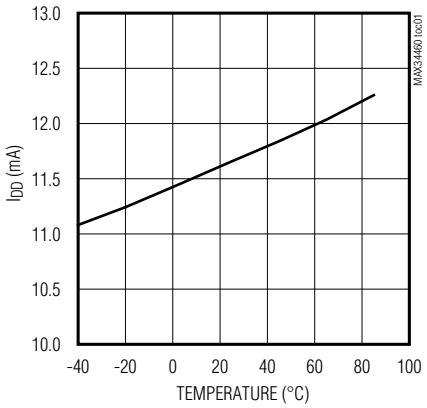


NOTE: TIMING IS REFERENCED TO $V_{IL(MAX)}$ AND $V_{IH(MIN)}$.

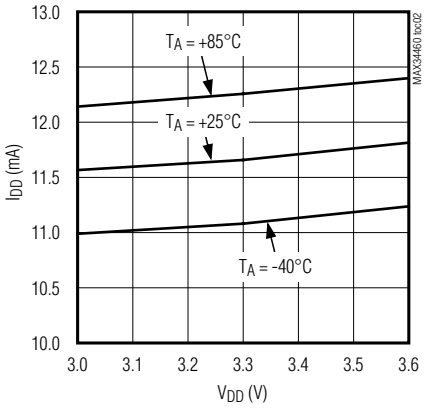
Typical Operating Characteristics

(V_{DD} = 3.3V and T_A = +25°C, unless otherwise noted.)

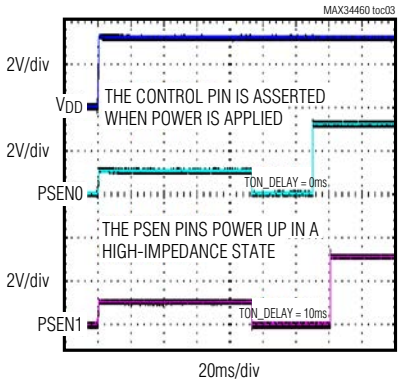
SUPPLY CURRENT vs. TEMPERATURE



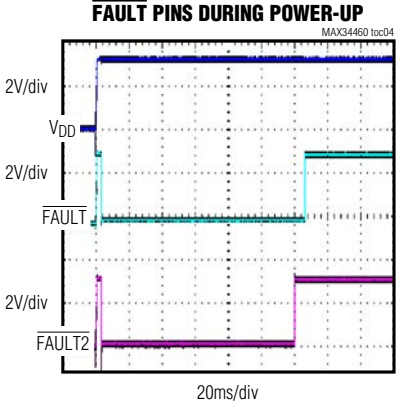
SUPPLY CURRENT vs. SUPPLY VOLTAGE



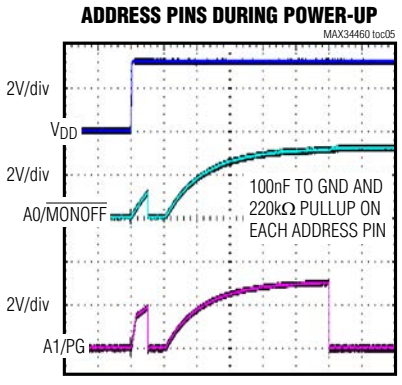
PSEN OUTPUTS DURING POWER-UP



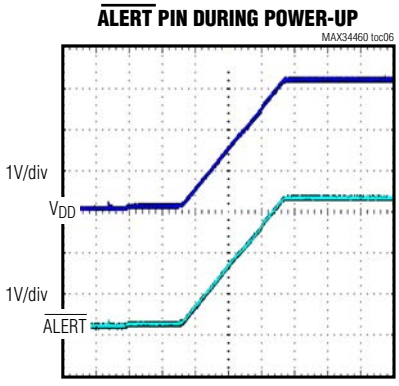
$\overline{\text{FAULT}}$ PINS DURING POWER-UP



ADDRESS PINS DURING POWER-UP



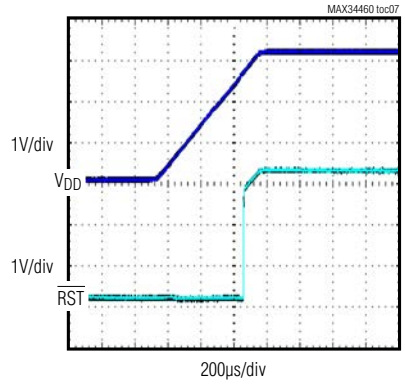
$\overline{\text{ALERT}}$ PIN DURING POWER-UP



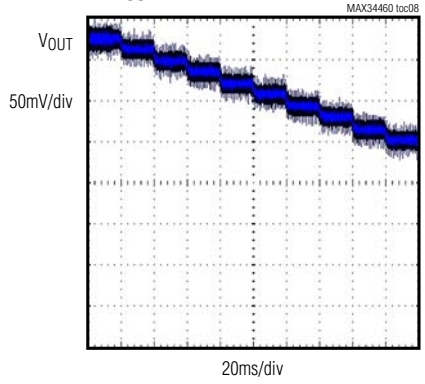
Typical Operating Characteristics (continued)

(V_{DD} = 3.3V and T_A = +25°C, unless otherwise noted.)

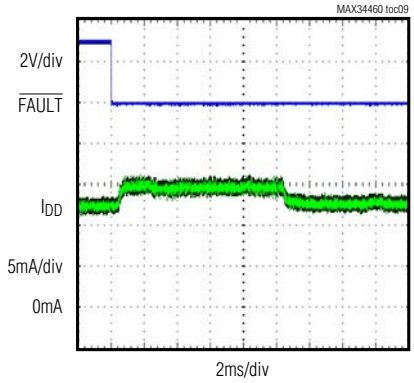
$\overline{RST}$ PIN DURING POWER-UP



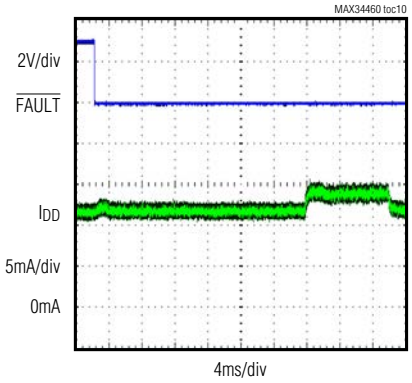
V_{OUT} STEPS DURING MARGINING



I_{DD} vs. TIME DURING A NONVOLATILE LOG WRITE

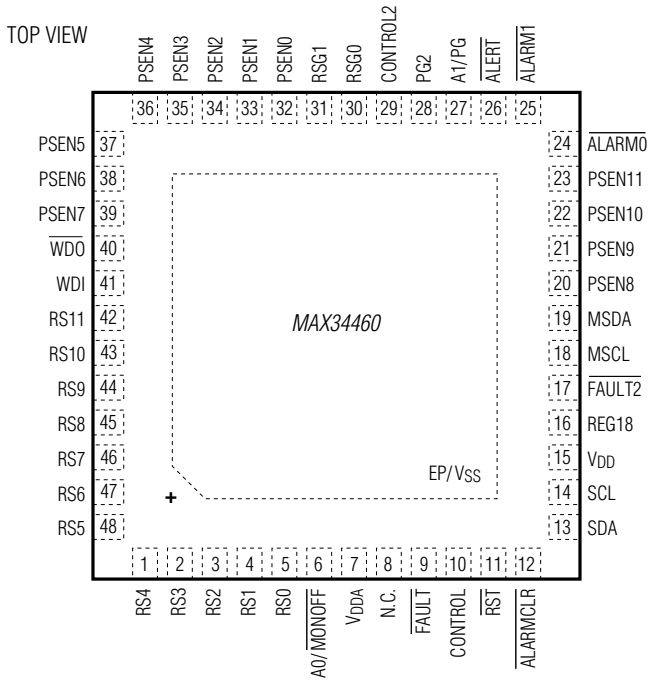


I_{DD} vs. TIME DURING A NONVOLATILE LOG WRITE WITH OVERWRITE ENABLED



PMBus 12-Channel Voltage Monitor and Sequencer

Pin Configuration



TQFN

Pin Description

PIN*	NAME	TYPE**	FUNCTION
1	RS4	AI	ADC Voltage-Sense Input 4. Connect to V_{SS} if unused.
2	RS3	AI	ADC Voltage-Sense Input 3. Connect to V_{SS} if unused.
3	RS2	AI	ADC Voltage-Sense Input 2. Connect to V_{SS} if unused.
4	RS1	AI	ADC Voltage-Sense Input 1. Connect to V_{SS} if unused.
5	RS0	AI	ADC Voltage-Sense Input 0. Connect to V_{SS} if unused.
6	A0/$\overline{MONOFF}$	DI	SMBus Address 0 Input/Active-Low Monitoring Off Input. This dual-function pin is sampled on device power-up to determine the SMBus address. After device power-up, this pin becomes an input, with an internal pullup, that when pulled low defeats the overvoltage and undervoltage monitoring to allow an external device to margin the power supplies.
7	V_{DDA}	Power	Analog Supply Voltage. Bypass V_{DDA} to V_{SS} with 0.1µF. Connect to V_{DD}.
8	N.C.	—	No Connection. Do not connect any signal to this pin.
9	$\overline{FAULT}$	DIO	Active-Low Fault Input/Output for the Primary Sequence. See the *Expanded Pin Description* section for more details.

Pin Description (continued)

PIN*	NAME	TYPE**	FUNCTION
10	CONTROL	AI	Power-Supply Master On/Off Control for the Primary Sequence. Active low or active high based on the ON_OFF_CONFIG command.
11	$\overline{RST}$	DIO	Active-Low Reset Input/Output. Contains an internal pullup.
12	$\overline{ALARMCLR}$	DI	Active-Low Alarm Clear Input with a Weak Pullup. Toggle low to clear the $\overline{ALARM0}$/$\overline{ALARM1}$ outputs. Leave open circuit or connect high if not used.
13	SDA	DIO	I²C/SMBus-Compatible Input/Open-Drain Output
14	SCL	DIO	I²C/SMBus-Compatible Clock Input/Open-Drain Output
15	V_{DD}	Power	Digital Supply Voltage. Bypass V_{DD} to V_{SS} with 0.1µF. Connect to V_{DDA}.
16	REG18	Power	Regulator for Digital Circuitry. Bypass to V_{SS} with 1µF and 10nF (500mΩ maximum ESR). Do not connect other circuitry to this pin.
17	$\overline{FAULT2}$	DIO	Active-Low Fault Input/Output for the Secondary Sequence. See the *Expanded Pin Description* section for more details.
18	MSCL	DIO	Master I²C Clock Input/Open-Drain Output
19	MSDA	DIO	Master I²C Data Input/Open-Drain Output
20	PSEN8	DO	Power-Supply Enable Output 8. See the *Expanded Pin Description* section for more details.
21	PSEN9	DO	Power-Supply Enable Output 9. See the *Expanded Pin Description* section for more details.
22	PSEN10	DO	Power-Supply Enable Output 10. See the *Expanded Pin Description* section for more details.
23	PSEN11	DO	Power-Supply Enable Output 11. See the *Expanded Pin Description* section for more details.
24	$\overline{ALARM0}$	DO	Active-Low Alarm Output 0. See the *Expanded Pin Description* section for more details.
25	$\overline{ALARM1}$	DO	Active-Low Alarm Output 1. See the *Expanded Pin Description* section for more details.
26	$\overline{ALERT}$	DO	Active-Low, Open-Drain Alert Output
27	A1/PG	DIO	SMBus Address 1 Input/Power-Good Output for the Primary Sequence. This dual-function pin is sampled on device power-up to determine the SMBus address. After device power-up, this pin becomes an output that transitions high when all the enabled power supplies are above their associated POWER_GOOD_ON thresholds. This pin is forced low immediately when the CONTROL pin goes inactive or the OPERATION off command is received. This pin contains a weak pullup during device reset.
28	PG2	DO	Power Good for the Secondary Sequence
29	CONTROL2	DI	Power-Supply Master On/Off Control for the Secondary Sequence. Active low or active high based on the ON_OFF_CONFIG command.
30	RSG0	AI	Remote-Sense Ground for RS0–RS3.
31	RSG1	AI	Remote-Sense Ground for RS4–RS11.
32	PSEN0	DO	Power-Supply Enable Output 0. See the *Expanded Pin Description* section for more details.
33	PSEN1	DO	Power-Supply Enable Output 1. See the *Expanded Pin Description* section for more details.
34	PSEN2	DO	Power-Supply Enable Output 2. See the *Expanded Pin Description* section for more details.
35	PSEN3	DO	Power-Supply Enable Output 3. See the *Expanded Pin Description* section for more details.
36	PSEN4	DO	Power-Supply Enable Output 4. See the *Expanded Pin Description* section for more details.
37	PSEN5	DO	Power-Supply Enable Output 5. See the *Expanded Pin Description* section for more details.

Pin Description (continued)

PIN*	NAME	TYPE**	FUNCTION
38	PSEN6	DO	Power-Supply Enable Output 6. See the *Expanded Pin Description* section for more details.
39	PSEN7	DO	Power-Supply Enable Output 7. See the *Expanded Pin Description* section for more details.
40	$\overline{WDO}$	DIO	Open-Drain, Active-Low Watchdog Input/Output. Can be configured with MFR_WATCHDOG_CONFIG as a manual reset input.
41	WDI	DI	Watchdog Input. Rising edge triggered.
42	RS11	AI	ADC Voltage-Sense Input 11. Connect to V_{SS} if unused.
43	RS10	AI	ADC Voltage-Sense Input 10. Connect to V_{SS} if unused.
44	RS9	AI	ADC Voltage-Sense Input 9. Connect to V_{SS} if unused.
45	RS8	AI	ADC Voltage-Sense Input 8. Connect to V_{SS} if unused.
46	RS7	AI	ADC Voltage-Sense Input 7. Connect to V_{SS} if unused.
47	RS6	AI	ADC Voltage-Sense Input 6. Connect to V_{SS} if unused.
48	RS5	AI	ADC Voltage-Sense Input 5. Connect to V_{SS} if unused.
—	EP/V_{SS}	Power	Exposed Pad (Bottom Side of Package). Must be connected to local ground. The exposed pad is the ground reference (V_{SS}) for the entire device.

**All pins except V_{DD}, EP/V_{SS}, $\overline{ALERT}$, A1/PG, and REG18 are high impedance during device power-up and reset.*

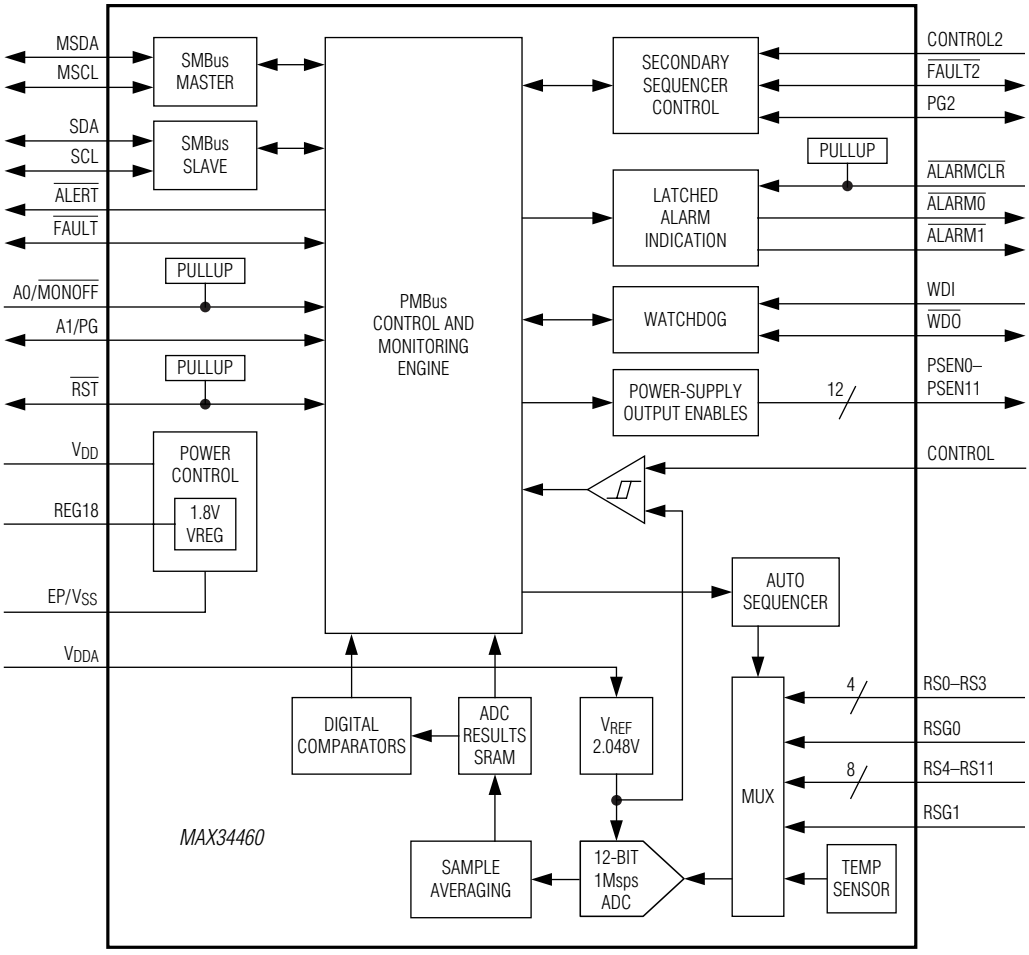
***AI = Analog input, AO = Analog output; DI = Digital input; DIO = Digital input/output; DO = Digital output*

Expanded Pin Description

NAME	FUNCTION
PSEN0–PSEN11	The PSEN0–PSEN11 outputs are programmable with the MFR_PSEN_CONFIG command for either active-high or active-low operation and can be either open-drain or push-pull. If not used for power-supply enables, these outputs can be repurposed as general-purpose outputs using the MFR_PSEN_CONFIG command. If these pins are used to enable power supplies, it is **highly recommended** that these pins have external pullups or pulldowns to force the supplies into an off state when the device is not active.
$\overline{FAULT}$	Open-Drain, Active-Low Fault Input/Output. This pin is asserted when one or more of the power supplies in a global group are being shut down due to a fault condition. Also, this pin is monitored and when it is asserted, all power supplies in a global group are shut down. This pin is used to provide hardware control for power supplies in a global group across multiple devices. This output is unconditionally deasserted when $\overline{RST}$ is asserted or the device is power cycled. Upon reset, this output is pulled low until monitoring starts.
$\overline{ALARM}$	Open-Drain, Active-Low Alarm Output. The outputs can be configured with the MFR_FAULT_RESPONSE command to go active in any combination of channels for undervoltage or overvoltage, or sequencing faults or warnings. These outputs are latched until cleared with the $\overline{ALARMCLR}$ pin or the ALARM_CLR bit in MFR_MODE.

PMBus 12-Channel Voltage Monitor and Sequencer

Block Diagram



Detailed Description

The MAX34460 is a highly integrated system monitor with functionality to monitor up to 12 power supplies. The device provides power-supply voltage monitoring and sequencing. It can also provide closed-loop margining control and local/remote thermal-sensing facilities.

The power-supply manager monitors the power-supply output voltage and constantly checks for user programmable overvoltage and undervoltage thresholds. It also has the ability to margin the power-supply output voltage up or down by a user-programmable level. The margining is performed in a closed-loop arrangement, whereby the device automatically adjusts an external-current DAC

output and then measures the resultant output voltage. The power-supply manager can also sequence the supplies in any order at both power-up and power-down.

Thermal monitoring can be accomplished using up to five temperature sensors including an on-chip temperature sensor and up to four external remote DS75LV digital temperature sensors. Communications with the DS75LV temperature sensors is conducted through a dedicated I2C/SMBus interface.

The device provides $\overline{\text{ALERT}}$ and $\overline{\text{FAULT}}$ output signals. Host communications are conducted through a PMBus-compatible communications port.

Table 1. PMBus Command Codes

CODE	COMMAND NAME	TYPE	PAGE 0–11	PAGE 13–17	PAGE 255	NO. OF BYTES	FLASH STORED/ LOCKED (NOTE 2)	DEFAULT VALUE (NOTE 2)
			(NOTE 1)					
00h	PAGE	R/W byte	R/W	R/W	R/W	1	N/N	00h
01h	OPERATION	R/W byte	R/W		W	1	N/N	00h
02h	ON_OFF_CONFIG	R/W byte	R/W	R/W	R/W	1	Y/Y	1Ah
03h	CLEAR_FAULTS	Send byte	W	W	W	0	N/N	—
10h	WRITE_PROTECT	R/W byte	R/W	R/W	R/W	1	N/Y	00h
11h	STORE_DEFAULT_ALL	Send byte	W	W	W	0	N/Y	—
12h	RESTORE_DEFAULT_ALL	Send byte	W	W	W	0	N/Y	—
19h	CAPABILITY	Read byte	R	R	R	1	N/N	20h/30h
20h	VOUT_MODE	Read byte	R	R	R	1	FIXED/N	40h
25h	VOUT_MARGIN_HIGH	R/W word	R/W	—	—	2	Y/Y	0000h
26h	VOUT_MARGIN_LOW	R/W word	R/W	—	—	2	Y/Y	0000h
2Ah	VOUT_SCALE_MONITOR	R/W word	R/W	—	—	2	Y/Y	7FFFh
40h	VOUT_OV_FAULT_LIMIT	R/W word	R/W	—	—	2	Y/Y	7FFFh
42h	VOUT_OV_WARN_LIMIT	R/W word	R/W	—	—	2	Y/Y	7FFFh
43h	VOUT_UV_WARN_LIMIT	R/W word	R/W	—	—	2	Y/Y	0000h
44h	VOUT_UV_FAULT_LIMIT	R/W word	R/W	—	—	2	Y/Y	0000h
4Fh	OT_FAULT_LIMIT	R/W word	—	R/W	—	2	Y/Y	7FFFh
51h	OT_WARN_LIMIT	R/W word	—	R/W	—	2	Y/Y	7FFFh
5Eh	POWER_GOOD_ON	R/W word	R/W	—	—	2	Y/Y	0000h
5Fh	POWER_GOOD_OFF	R/W word	R/W	—	—	2	Y/Y	0000h
60h	TON_DELAY	R/W word	R/W	—	—	2	Y/Y	0000h
62h	TON_MAX_FAULT_LIMIT	R/W word	R/W	—	—	2	Y/Y	FFFFh
64h	TOFF_DELAY	R/W word	R/W	—	—	2	Y/Y	0000h
79h	STATUS_WORD	Read word	R	R	R	2	N/N	0000h
7Ah	STATUS_VOUT	Read byte	R	—	—	1	N/N	00h
7Dh	STATUS_TEMPERATURE	Read byte	—	R	—	1	N/N	00h
7Eh	STATUS_CML	Read byte	R	R	R	1	N/N	00h
80h	STATUS_MFR_SPECIFIC	Read byte	R	—	R	1	N/N	00h
8Bh	READ_VOUT	Read word	R	—	—	2	N/N	0000h
8Dh	READ_TEMPERATURE_1	Read word	—	R	—	2	N/N	0000h
98h	PMBUS_REVISION	Read byte	R	R	R	1	FIXED/N	11h

Table 1. PMBus Command Codes (continued)

CODE	COMMAND NAME	TYPE	PAGE 0–11	PAGE 13–17	PAGE 255	NO. OF BYTES	FLASH STORED/ LOCKED (NOTE 2)	DEFAULT VALUE (NOTE 2)
			(NOTE 1)					
99h	MFR_ID	Read byte	R	R	R	1	FIXED/N	4Dh
9Ah	MFR_MODEL	Read byte	R	R	R	1	FIXED/N	57h
9Bh	MFR_REVISION	Read word	R	R	R	2	FIXED/N	(Note 3)
9Ch	MFR_LOCATION	Block R/W	R/W	R/W	R/W	8	Y/Y	(Note 4)
9Dh	MFR_DATE	Block R/W	R/W	R/W	R/W	8	Y/Y	(Note 4)
9Eh	MFR_SERIAL	Block R/W	R/W	R/W	R/W	8	Y/Y	(Note 4)
D1h	MFR_MODE	R/W word	R/W	R/W	R/W	2	Y/Y	0008h
D2h	MFR_PSEN_CONFIG	R/W byte	R/W	—	—	1	Y/Y	00h
D3h	MFR_SEQ_TIMESLOT	R/W byte	R/W	—	—	1	Y/Y	00h
D4h	MFR_VOUT_PEAK	R/W word	R/W	—	—	2	N/Y	0000h
D6h	MFR_TEMPERATURE_PEAK	R/W word	—	R/W	—	2	N/Y	8000h
D7h	MFR_VOUT_MIN	R/W word	R/W	—	—	2	N/Y	7FFFh
D8h	MFR_NV_LOG_CONFIG	R/W word	R/W	R/W	R/W	2	Y/Y	0000h
D9h	MFR_FAULT_RESPONSE	R/W word	R/W	—	—	2	Y/Y	0000h
DAh	MFR_FAULT_RETRY	R/W word	R/W	R/W	R/W	2	Y/Y	0000h
DBh	MFR_PG_DELAY	R/W word	R/W	R/W	R/W	2	Y/Y	0000h
DCh	MFR_NV_FAULT_LOG	Block read	R	R	R	255	Y/Y	(Note 5)
DDh	MFR_TIME_COUNT	Block read	R/W	R/W	R/W	4	N/Y	(Note 6)
DFh	MFR_MARGIN_CONFIG	R/W word	R/W	—	—	2	Y/Y	0000h
E3h	MFR_TEMPERATURE_AVG	R/W word	—	R/W	—	2	N/Y	0000h
F0h	MFR_TEMP_SENSOR_CONFIG	R/W word	—	R/W	—	2	Y/Y	0000h
FBh	MFR_GPO_CONFIG	R/W word	R/W	R/W	R/W	2	Y/Y	0000h
FCh	MFR_STORE_SINGLE	R/W word	R/W	R/W	R/W	2	N/Y	0000h
FDh	MFR_WATCHDOG_CONFIG	R/W word	R/W	R/W	R/W	2	Y/Y	0000h

Note 1: Common commands are shaded. Access through any page results in the same device response.

Note 2: In the **Flash Stored/Locked** column, the “N” on the left indicates that this parameter is not stored in flash memory when the STORE_DEFAULT_ALL command is executed; the value shown in the **Default Value** column is automatically loaded upon power-on reset or when the $\overline{RST}$ pin is asserted. In the **Flash Stored/Locked** column, the “Y” on the left side indicates that the currently loaded value in this parameter is stored in flash memory when the STORE_DEFAULT_ALL command is executed and is automatically loaded upon power-on reset, or when the $\overline{RST}$ pin is asserted and the value shown in the **Default Value** column is the value when shipped from the factory. “FIXED” in the **Flash Stored/Locked** column means that the value is fixed at the factory and cannot be changed. The value shown in the **Default Value** column is automatically loaded upon power-on reset, or when the $\overline{RST}$ pin is asserted. The right-side Y/N indicates that when the device is locked, only the commands listed with “N” can be accessed. All other commands are ignored if written and return FFh if read. Only the PAGE, CLEAR_FAULTS, OPERATION, and MFR_SERIAL commands can be written to. The device unlocks if the upper 4 bytes of MFR_SERIAL match the data written to the device.

Note 3: The factory-set value is dependent on the device hardware and firmware revision.

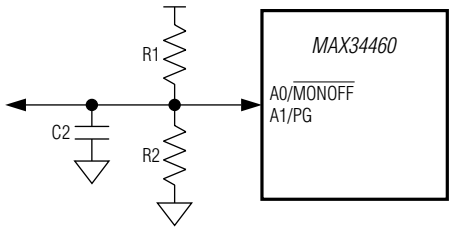
Note 4: The factory-set default value for this 8-byte block is 3130313031303130h.

Note 5: The factory-set default value for the complete block of the MFR_NV_FAULT_LOG is FFh.

Note 6: The factory-set default value for this 4-byte block is 00000000h.

Address Select

On device power-up, the device samples the A0 and A1 pins to determine the PMBus/SMBus serial-port address. The combination of the components shown below determines the serial-port address (see also Table 2).



SMBus/PMBus Operation

The device implements the PMBus command structure using the SMBus format. The structure of the data flow between the host and the slave is shown below for several different types of transactions. All transactions begin with a host sending a command code that is immediately preceded with a 7-bit slave address (R/$\overline{W}$ = 0). Data is sent MSB first.

Table 2. PMBus/SMBus Serial-Port Address

A1			A0			7-BIT SLAVE ADDRESS
R1	R2	C2	R1	R2	C2	
	220kΩ			220kΩ		1110 100 (E8h)
	220kΩ		220kΩ			1110 101 (EAh)
	220kΩ		220kΩ		100nF	0010 010 (24h)
	220kΩ		22kΩ		100nF	0010 011 (26h)
220kΩ				220kΩ		1110 110 (ECh)
220kΩ			220kΩ			1110 111 (EEh)
220kΩ			220kΩ		100nF	0001 100 (28h)
220kΩ			22kΩ		100nF	0001 101 (2Ah)
220kΩ		100nF		220kΩ		1001 100 (98h)
220kΩ		100nF	220kΩ			1001 101 (9Ah)
220kΩ		100nF	220kΩ		100nF	1011 000 (B0h)
220kΩ		100nF	22kΩ		100nF	1011 001 (B2h)
22kΩ		100nF		220kΩ		1001 110 (9Ch)
22kΩ		100nF	220kΩ			1001 111 (9Eh)
22kΩ		100nF	220kΩ		100nF	1011 110 (BCh)
22kΩ		100nF	22kΩ		100nF	1011 111 (BEh)

Note: *The device also responds to a slave address of 34h (this is the factory programming address) and the device should not share the same I²C bus with other devices that use this slave address.*

SMBus/PMBus Communication Examples

READ WORD FORMAT

1	7	1	1	8	1	1	7	1	1	8	1	8	1	1
S	SLAVE ADDRESS	W	A	COMMAND CODE	A	Sr	SLAVE ADDRESS	R	A	DATA BYTE LOW	A	DATA BYTE HIGH	NA	P

READ BYTE FORMAT

1	7	1	1	8	1	1	7	1	1	8	1	1
S	SLAVE ADDRESS	W	A	COMMAND CODE	A	Sr	SLAVE ADDRESS	R	A	DATA BYTE	NA	P

WRITE WORD FORMAT

1	7	1	1	8	1	8	1	8	1	1
S	SLAVE ADDRESS	W	A	COMMAND CODE	A	DATA BYTE LOW	A	DATA BYTE HIGH	A	P

WRITE BYTE FORMAT

1	7	1	1	8	1	8	1	1
S	SLAVE ADDRESS	W	A	COMMAND CODE	A	DATA BYTE	A	P

SEND BYTE FORMAT

1	7	1	1	8	1	1
S	SLAVE ADDRESS	W	A	COMMAND CODE	A	P

KEY:

S = START
Sr = REPEATED START
P = STOP
W = WRITE BIT (0)
R = READ BIT (1)
A = ACKNOWLEDGE (0)
NA = NOT ACKNOWLEDGE (1)
SHADED BLOCK = SLAVE TRANSACTION

Group Command

The device supports the group command. With the group command, a host can write different data to multiple devices on the same serial bus with one long continuous data stream. All the devices addressed during this transaction wait for the host to issue a STOP before beginning to respond to the command.

Group Command Write Format

SLAVE ADDRESS, COMMAND BYTE, AND DATA WORD FOR DEVICE 1

1	7	1	1	8	1	8	1	8	1	
S	SLAVE ADDRESS	W	A	COMMAND CODE	A	DATA BYTE LOW	A	DATA BYTE HIGH	A	• • •

SLAVE ADDRESS, COMMAND BYTE, AND DATA BYTE FOR DEVICE 2

1	7	1	1	8	1	8	1	
Sr	SLAVE ADDRESS	W	A	COMMAND CODE	A	DATA BYTE	A	• • •

SLAVE ADDRESS AND SEND BYTE FOR DEVICE 3

1	7	1	1	8	1	
Sr	SLAVE ADDRESS	W	A	COMMAND CODE	A	• • •

• • •

SLAVE ADDRESS, COMMAND BYTE, AND DATA WORD FOR DEVICE N

1	7	1	1	8	1	8	1	8	1	1
Sr	SLAVE ADDRESS	W	A	COMMAND CODE	A	DATA BYTE LOW	A	DATA BYTE HIGH	A	P

KEY:

S = START

Sr = REPEATED START

P = STOP

W = WRITE BIT (0)

A = ACKNOWLEDGE (0)

SHADED BLOCK = SLAVE TRANSACTION

Addressing

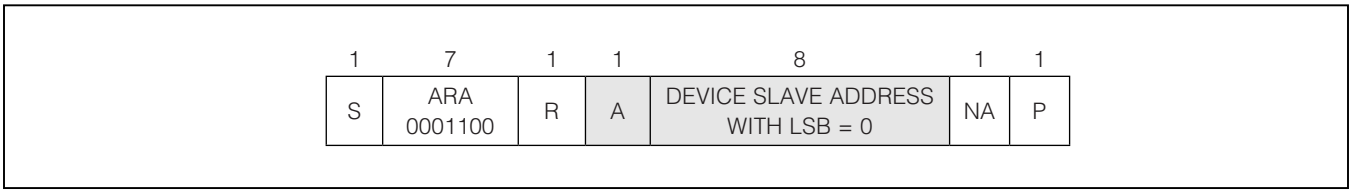
The device responds to receiving its fixed slave address by asserting an acknowledge (ACK) on the bus. The device does not respond to a general call address; it only responds when it receives its fixed slave address or the alert response address (ARA). See the *ALERT and Alert Response Address (ARA)* section for more details.

ALERT and Alert Response Address (ARA)

If the $\overline{\text{ALERT}}$ output is enabled (ALERT bit = 1 in MFR_MODE), when a fault occurs the device asserts the $\overline{\text{ALERT}}$ signal and then waits for the host to send an ARA, as shown in the *Alert Response Address (ARA) Byte Format* section.

When the ARA is received and the device is asserting $\overline{\text{ALERT}}$, the device ACKs it and then attempts to place its fixed slave address on the bus by arbitrating the bus, since another device could also try to respond to the ARA. The rules of arbitration state that the lowest address device wins. If the device wins the arbitration, it deasserts $\overline{\text{ALERT}}$. If the device loses arbitration, it keeps $\overline{\text{ALERT}}$ asserted and waits for the host to once again send the ARA.

Alert Response Address (ARA) Byte Format



Host Sends or Reads Too Few Bits

If, for any reason, the host does not complete writing a full byte or reading a full byte from the device before a START or STOP is received, the device does the following:

1) Ignores the command.
2) Sets the CML bit in STATUS_WORD.
3) Sets the DATA_FAULT bit in STATUS_CML.
4) Notifies the host through $\overline{\text{ALERT}}$ assertion (if enabled).

Host Sends or Reads Too Few Bytes

For each supported command, the device expects a fixed number of bytes to be written or read from the device. If, for any reason, less than the expected number of bytes is written to or read from the device, the device completely ignores the command and takes no action.

Host Sends Too Many Bytes or Bits

For each supported command, the device expects a fixed number of bytes to be written to the device. If, for any reason, more than the expected number of bytes or bits are written to the device, the device does the following:

1) Ignores the command.
2) Sets the CML bit in STATUS_WORD.
3) Sets the DATA_FAULT bit in STATUS_CML.
4) Notifies the host through $\overline{\text{ALERT}}$ assertion (if enabled).

Host Reads Too Many Bytes or Bits

For each supported command, the device expects a fixed number of bytes to be read from the device. If, for any reason, more than the expected number of bytes or bits are read from the device, the device does the following:

1) Sends all ones (FFh) as long as the host keeps acknowledging.
2) Sets the CML bit in STATUS_WORD.
3) Sets the DATA_FAULT bit in STATUS_CML.
4) Notifies the host through $\overline{\text{ALERT}}$ assertion (if enabled).

Host Sends Improperly Set Read Bit in the Slave Address Byte

If the device receives the R/$\overline{\text{W}}$ bit in the slave address set to a one immediately preceding the command code, the device does the following (this does not apply to the ARA):

1) ACKs the address byte.
2) Sends all ones (FFh) as long as the host keeps acknowledging.
3) Sets the CML bit in STATUS_WORD.
4) Sets the DATA_FAULT bit in STATUS_CML.
5) Notifies the host through $\overline{\text{ALERT}}$ assertion (if enabled).

Unsupported Command Code Received/ Host Writes to a Read-Only Command

If the host sends the device a command code that it does not support, or if the host sends a command code that is not supported by the current PAGE setting, the device does the following:

1) Ignores the command.
2) Sets the CML bit in STATUS_WORD.
3) Sets the COMM_FAULT bit in STATUS_CML.
4) Notifies the host through $\overline{\text{ALERT}}$ assertion (if enabled).

Invalid Data Received

The device checks the PAGE, OPERATION, and WRITE_ PROTECT command codes for valid data. If the host writes a data value that is invalid, the device does the following:

1) Ignores the command.
2) Sets the CML bit in STATUS_WORD.
3) Sets the DATA_FAULT bit in STATUS_CML.
4) Notifies the host through $\overline{\text{ALERT}}$ assertion (if enabled).

Host Reads from a Write-Only Command

When a read request is issued to a write-only command (CLEAR_FAULTS, STORE_DEFAULT_ALL, RESTORE_DEFAULT_ALL, OPERATION with PAGE = 255), the device does the following:

1) ACKs the address byte.
2) Ignores the command.
3) Sends all ones (FFh), as long as the host keeps acknowledging.
4) Sets the CML bit in STATUS_WORD.
5) Sets the DATA_FAULT bit in STATUS_CML.
6) Notifies the host through $\overline{\text{ALERT}}$ assertion (if enabled).

Host Writes to a Read-Only Command

When a write request is issued to a read-only command, the device does the following:

1) Ignores the command.
2) Sets the CML bit in STATUS_WORD.
3) Sets the COMM_FAULT bit in STATUS_SML.
4) Notifies the host through $\overline{\text{ALERT}}$ assertion (if enabled).

SMBus Timeout

If during an active SMBus communication sequence the SCL signal is held low for greater than the timeout duration (nominally 27ms), the device terminates the sequence and resets the serial bus. It takes no other action. No status bits are set.

PMBus Operation

From a software perspective, the device appears as a PMBus device capable of executing a subset of PMBus commands. A PMBus 1.1-compliant device uses the SMBus version 1.1 for transport protocol and responds to the SMBus slave address. In this data sheet, the term SMBus is used to refer to the electrical characteristics of the PMBus communication using the SMBus physical layer. The term PMBus is used to refer to the PMBus command protocol. The device employs a number of standard SMBus protocols (e.g., Write Word, Read Word, Write Byte, Read Byte, Send Byte, etc.) to program output voltage and warning/fault thresholds, read monitored data, and provide access to all manufacturer-specific commands.

The device supports the group command. The group command is used to send commands to more than one PMBus device. It is not required that all the devices receive the same command. However, no more than one command can be sent to any one device in one group command packet. The group command must not be used with commands that require receiving devices to respond with data, such as the STATUS_WORD command. When the device receives a command through this protocol, it immediately begins execution of the received command after detecting the STOP condition.

The device supports the PAGE command and uses it to select which individual channel to access. When a data word is transmitted, the lower order byte is sent first and the higher order byte is sent last. Within any byte, the (MSB is sent first and the LSB is sent last.

PMBus Protocol Support

The device supports a subset of the commands defined in the PMBus Power System Management Protocol Specification Part II - Command Language Revision 1.1. For detailed specifications and the complete list of PMBus commands, refer to Part II of the PMBus specification available at www.PMBus.org. The supported PMBus commands and the corresponding device behavior are described in this document. All data values are represented in DIRECT format, unless otherwise stated. Whenever the PMBus specification refers to the PMBus device, it is referring to the device operating in conjunction with a power supply. While the command can call for turning on or off the PMBus device, the device always remains on to continue communicating with the PMBus master and the device transfers the command to the power supply accordingly.

Data Format

Voltage data for commanding or reading the output voltage or related parameters (such as the overvoltage threshold) are presented in DIRECT format. DIRECT format data is a 2-byte, two's complement binary value. DIRECT format data can be used with any command that sends or reads a parametric value. The DIRECT format uses an equation and defined coefficients to calculate the desired values. Table 3 lists coefficients used by the device.

Interpreting Received DIRECT Format Values

The host system uses the following equation to convert the value received from the PMBus device—in this case, the MAX34460—into a reading of volts, degrees Celsius, or other units as appropriate:

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

where X is the calculated, real-world value in the appropriate units (i.e., V, °C, etc.); m is the slope coefficient; Y is the 2-byte, two's complement integer received from the PMBus device; b is the offset; and R is the exponent.

Table 3. PMBus Command Code Coefficients

PARAMETER	COMMANDS	UNITS	RESOLUTION	MAXIMUM	m	b	R
Voltage	VOUT_MARGIN_HIGH VOUT_MARGIN_LOW VOUT_OV_FAULT_LIMIT VOUT_OV_WARN_LIMIT VOUT_UV_WARN_LIMIT VOUT_UV_FAULT_LIMIT POWER_GOOD_ON POWER_GOOD_OFF READ_VOUT MFR_VOUT_PEAK MFR_VOUT_MIN	mV	1	32,767	1	0	0
Voltage Scaling	VOUT_SCALE_MONITOR	—	1/32,767	1	32,767	0	0
Temperature	OT_FAULT_LIMIT OT_WARN_LIMIT READ_TEMPERATURE_1 MFR_TEMPERATURE_PEAK MFR_TEMPERATURE_AVG	°C	0.01	327.67	1	0	2
Timing	TON_DELAY TON_MAX_FAULT_LIMIT TOFF_DELAY MFR_FAULT_RETRY MFR_PG_DELAY	ms	0.2	6553.4	5	0	0

Table 4. Coefficients for DIRECT Format Value

COMMAND CODE	COMMAND NAME	m	b	R
25h	VOUT_MARGIN_HIGH	1	0	0
8Bh	READ_VOUT	1	0	0

Sending a DIRECT Format Value

To send a value, the host must use the following equation to solve for Y:

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

where Y is the 2-byte, two's complement integer to be sent to the unit; m is the slope coefficient; X is the real-world value, in units such as volts, to be converted for transmission; b is the offset; and R is the exponent.

The following example demonstrates how the host can send and retrieve values from the device. Table 4 lists the coefficients used in the following parameters.

If a host wants to set the device to change the power-supply output voltage to 3.465V (or 3465mV), the corresponding VOUT_MARGIN_HIGH value is:

$Y = (1 \times 3465 + 0) \times 10^{0} = 3465$ (decimal) = 0D89h (hex)

Conversely, if the host received a value of 0D89h on a READ_VOUT command, this is equivalent to:

$X = (1/1) \times (0D89h \times 10^{-(-0)} - 0) = 3465mV = 3.465V$

Power supplies and power converters generally have no way of knowing how their outputs are connected to ground. Within the power supply, all output voltages are most commonly treated as positive. Accordingly, all output voltages and output voltage-related parameters of PMBus devices are commanded and reported as positive values. It is up to the system to know that a particular output is negative if that is of interest to the system. All output-voltage-related commands use 2 data bytes.

Fault Management and Reporting

For reporting faults/warnings to the host on a real-time basis, the device asserts the open-drain $\overline{ALERT}$ pin (if enabled in MFR_MODE) and sets the appropriate bit in the various status registers. On recognition of the $\overline{ALERT}$ assertion, the host or system manager is expected to poll the I^2C bus to determine the device asserting $\overline{ALERT}$. The host sends the SMBus ARA (0001 100). The device ACKs the SMBus ARA, transmits its slave address, and deasserts $\overline{ALERT}$. The system controller then communicates with PMBus commands to retrieve the fault/warning status information from the device.

See the individual command sections for more details. Faults and warnings that are latched in the status registers are cleared when any one of the following conditions occurs:

- A CLEAR_FAULTS command is received.
- The $\overline{RST}$ pin is toggled or a soft-reset is issued.
- Bias power to the device is removed and then reapplied.

One or more latched-off power supplies are only restarted when one of the following conditions occurs:

- The OPERATION commands are received that turn off and on the power supplies or the CONTROL pin is toggled to turn off and then turn on the power supplies.
- The $\overline{RST}$ pin is toggled or a soft-reset is issued.
- Bias power to the device is removed and then reapplied.

A power supply is not allowed to turn on if any faults the supply responds to are detected. Only after the faults clear is the power supply allowed to turn on. When GLOBAL supplies are being sequenced on, a fault on any of the supplies keeps all GLOBAL supplies from being turned on.

Upon a system-wide power-up (OPERATION command is received to turn the supplies on when PAGE is 255 or the CONTROL pin is toggled to turn on the supplies), all enabled GLOBAL power supplies with their overvoltage- or overtemperature-fault responses enabled with the MFR_FAULT_RESPONSE command are only allowed to power up if neither the overvoltage or overtemperature fault exists.

The device responds to fault conditions according to the manufacturer fault response command (MFR_FAULT_RESPONSE). This command byte determines how the device should respond to each particular fault.

Password Protection

The device can be password protected by using the LOCK bit in the MFR_MODE command. Once the device is locked, only certain PMBus commands can be accessed with the serial port. See Table 1 for a complete list. Commands that have password protection return all ones (FFh), with the proper number of data bytes when read. When the device is locked, only the PAGE, OPERATION, CLEAR_FAULTS, and MFR_SERIAL commands can be written; all other written commands are ignored. When MFR_SERIAL is written and the upper 4 bytes match the internally flash-stored value, the device unlocks and remains unlocked until the LOCK bit in MFR_MODE is activated once again. The LOCK status bit in STATUS_MFR_SPECIFIC is always available to indicate whether the device is locked or unlocked.

Sequencing

The device implements both PMBus-defined time-based sequencing and timeslot-defined event-based sequencing. The SEQ bit in MFR_MODE determines which sequencing profile is used. With PMBus-defined sequencing, the activation of all power-supply channels (even across multiple devices) is timed from a common START signal that can be either the CONTROL pin or the OPERATION command. With timeslot sequencing, each power-supply channel is assigned to a particular timeslot and each power supply waits until the preceding power supply is active before it is turned on. The power-down sequencing of both the PMBus and the timeslot arrangements is the same. When the power supplies are instructed to turn off, all supplies can be switched off immediately, or they can be shut down in any order according to the TOFF_DELAY command setting.