MAX20860A PMBus Command Set User Guide

UG2332; Rev 0; 7/25

Abstract

This user guide lists and describes the PMBus commands implemented in the MAX20860A integrated step-down switching regulator. Standard commands from the PMBus specification are not described in detail unless there are deviations from the PMBus specification functionality. Analog Devices' manufacturer-specific commands are fully described in this document.

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Introduction

This document lists and describes the PMBus™ commands implemented in the MAX20860A integrated step-down switching regulator. The MAX20860A implements a subset of the PMBus application profile commands for DC-DC point of loads. Standard commands from the PMBus specification are not described in detail unless there are deviations from the PMBus specification functionality. Analog Devices manufacturer-specific commands are fully described in this document.

The MAX20860A's command functionality is based on revision 1.3 of the PMBus Specification, which is therefore referenced throughout this document. The PMBus specifications can be found on the PMBus and SMBus™ organization websites:

http://pmbus.org/specs.html
http://smbus.org/specs/

The commands in this document are presented in the following format:

<COMMAND_NAME>			
Reference:	<"Standard Command" or "Analog Devices Specific">	**Stored in Nonvolatile Memory:**	<"Yes" or "No">
Command Code:	<Hex value>	**Format:**	<Data format>
Data Bytes:	<Byte count>	**Units:**	<Unit of measure>
Transfer:	<SMBus transaction type>	**Factory Value:**	<Factory setting>
Output Must Be Disabled for a Write Transaction:	<"Yes" or "No">		
Description/Notes:	<Command definition if specific to Analog Devices, or notes on command functionality where it differs from the PMBus specification>		

PMBus Communication Protocol

This section describes the protocol and command packet formats required for executing PMBus transactions on the MAX20860A. This has been implemented in compliance with Revision 1.3 of the PMBus Specification Part II.

Table 1. Bit and Byte Symbols Legend

BIT/BYTE SYMBOL	NO. OF BITS	DESCRIPTION
GRAY-COLORED SYMBOL	Various	The host is controlling the SDA signal, and therefore the bit or byte is sent from the host to the MAX20860A.
BLUE-COLORED SYMBOL	Various	The MAX20860A is controlling the SDA signal, and therefore the bit or byte is sent from the MAX20860A to the host.
S	0	START condition: SCL and SDA lines are initially high; SDA transitions low while SCL is high; SCL transitions low thereafter. This indicates the start of a transaction.
S R	0	REPEATED START condition: Behaves the same as a standard START condition except that it is sent after a START condition without there being a STOP condition in between.
P	0	STOP condition: SCL and SDA lines are initially low; SCL transitions high while SDA is low; SDA transitions high thereafter. This indicates the completion of a transaction.
R	1	Read bit: logic-high
W	1	Write bit: logic-low
A	1	ACK (Acknowledge): If a byte transaction is successful, the receiver will send an ACK by pulling SDA low for the next SCL pulse.
N A	1	NACK (No Acknowledge): If the receiver sends a NACK, by leaving SDA high for the next SCL pulse, this will indicate either a failed transaction or the end of a successful read transaction.
DEVICE ADDRESS	7	Each MAX20860A device's 7-bit address can be configured using the PGM0 resistor. The host sends this address at the start of a transaction to select the device it wishes to communicate with. The device address must always be followed by either a Read or Write bit to complete the byte and indicate the type of transaction.
COMMAND CODE	8	All supported PMBus commands have an associated command code to indicate which command the host wishes to execute.
DATA BYTE	8	Depending on the command's transaction type, a varying number of data bytes may be included (Send Byte: 0, Read/Write Byte: 1, Read/Write Word: 2, Read/Write Block: 2+).

BIT/BYTE SYMBOL	NO. OF BITS	DESCRIPTION
PEC BYTE	8	Packet Error Check Byte: Optional byte that is sent at the end of the transaction to protect against data corruption; calculated using a CRC-8 checksum.

Read Transaction Protocol

The MAX20860A uses three main types of read transactions: Read Byte, Read Word, and Read Block. The command packet format for a read transaction is dependent on the specific transaction type, which varies with respect to each PMBus command. The appropriate read transaction type for each command is specified in its designated section within this document.

Use the command packet format in *Figure 1* for a **Read Byte** operation.

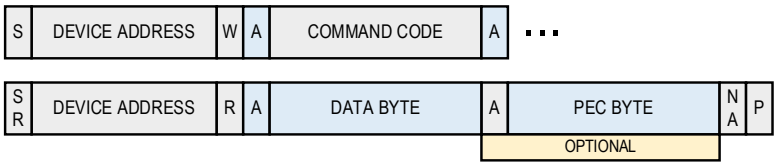

Figure 1. Read Byte Command Packet Format

Use the command packet format in *Figure 2* for a **Read Word** operation.

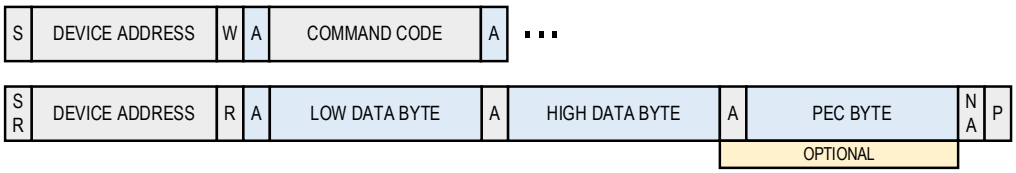

Figure 2. Read Word Command Packet Format

Use the command packet format in *Figure 3* for a **Read Block** operation.

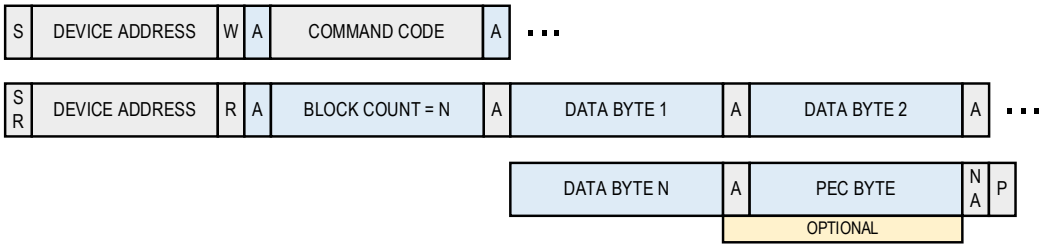

Figure 3. Read Block Command Packet Format

Write Transaction Protocol

The MAX20860 uses three main types of write transactions: Write Byte, Write Word, and Write Block. The command packet format for a write transaction is dependent on the specific transaction type, which varies with respect to each PMBus command. The appropriate write transaction type for each command is specified in its designated section within this document.

Use the command packet format in *Figure 4* for a **Write Byte** operation.

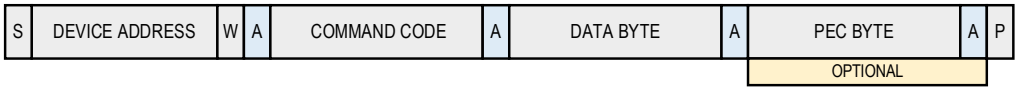

Figure 4. Write Byte Command Packet Format

Use the command packet format in *Figure 5* for a **Write Word** operation.

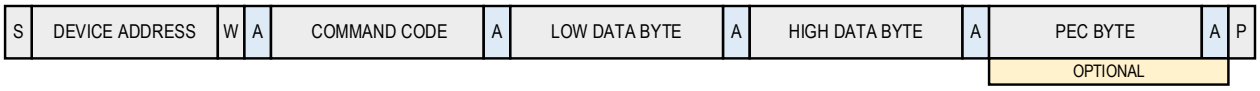

Figure 5. Write Word Command Packet Format

Use the command packet format in *Figure 6* for a **Write Block** operation.

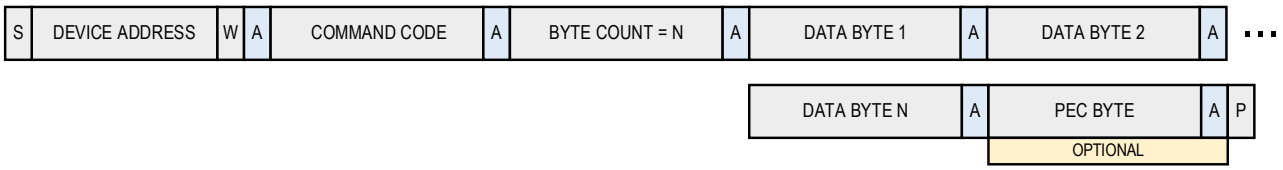

Figure 6. Write Block Command Packet Format

Send Byte Transaction Protocol

Use the command packet format in *Figure 7* for a **Send Byte** operation.

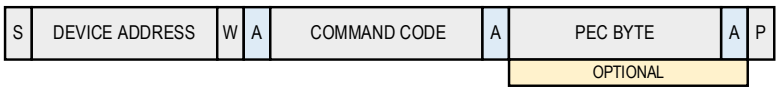

Figure 7. Send Byte Command Packet Format

PMBus Timing Diagram

The timing diagrams in *Figure 8* illustrate the transaction protocol for the two parts of a Read Byte transaction as an example – starting from the STOP condition of the previous transaction and leading up to the STOP condition of the Read Byte transaction itself.

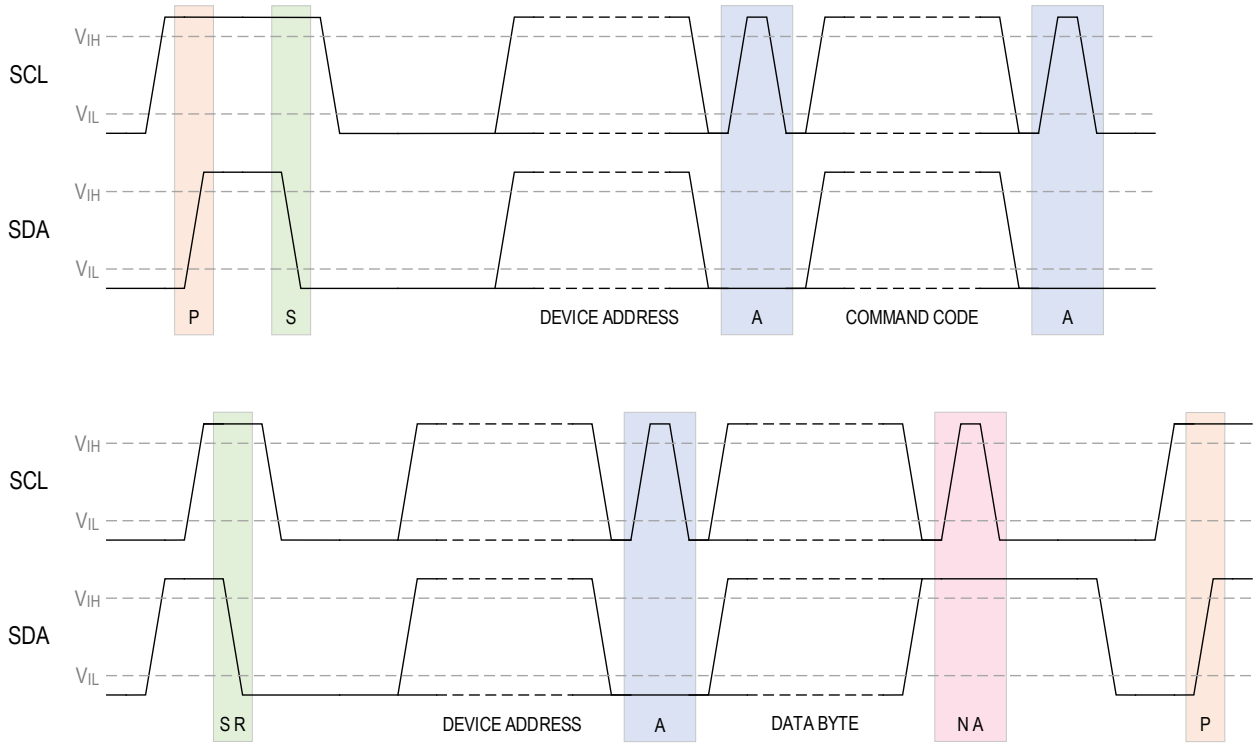

Figure 8. Read Byte Timing Diagrams

MAX20860A List of PMBus Commands

Table 2 lists the PMBus commands that are supported by the MAX20860A, providing a brief description of each command as well as its command code, transaction type, data format, factory value, and whether it can be stored in nonvolatile memory (NVM).

Table 2. List of PMBus Commands

COMMAND CODE	COMMAND NAME	DESCRIPTION	TYPE	DATA FORMAT	FACTORY VALUE	STORED IN NVM
0x01	OPERATION	Output enable/disable.	R/W Byte	Bit Field	0x8A	Yes
0x02	ON_OFF_CONFIG	EN pin and PMBus OPERATION command setting.	R/W Byte	Bit Field	0x1F	Yes
0x03	CLEAR_FAULTS	Clears any fault bits that have been set.	Send Byte	N/A	N/A	N/A
0x10	WRITE_PROTECT	Level of protection provided by the device against accidental changes.	R/W Byte	Bit Field	0x20	No
0x15	STORE_USER_ALL	Stores general user settings to PMBus nonvolatile memory.	Send Byte	N/A	N/A	N/A
0x16	RESTORE_USER_ALL	Restores to latest settings stored in the PMBus nonvolatile memory.	Send Byte	N/A	N/A	N/A
0x19	CAPABILITY	Summary of PMBus optional communication protocols supported by this device.	R Byte	Bit Field	0xD4	No
0x1B	SMBALERT_MASK	Selectively masks the assertion of the ALERTB output.	Block W -Block R Process Call/W Word	Bit Field	N/A	Yes
0x20	VOUT_MODE	Output voltage data format and mantissa exponent.	R Byte	Bit Field	0x16	No
0x21	VOUT_COMMAND	Feedback reference voltage setpoint.	R/W Word	ULINEAR 16	PGM1 Dependent	Yes
0x24	VOUT_MAX	Upper limit of reference voltage setpoint.	R/W Word	ULINEAR 16	PGM1 Dependent	No
0x27	VOUT_TRANSITION_RATE	Margin-high operation feedback reference voltage setpoint.	R/W Word	ULINEAR 16	PGM1 Dependent	Yes
0x29	VOUT_SCALE_LOOP	Margin-low operation feedback reference voltage setpoint.	R/W Word	ULINEAR 16	PGM1 Dependent	Yes
0x2B	VOUT_MIN	Lower limit of reference voltage setpoint.	R/W Word	ULINEAR 16	PGM1 Dependent	No
0x33	FREQUENCY_SWITCH	Switching frequency.	R/W Word	LINEAR11	PGM1 Dependent	Yes
0x37	INTERLEAVE	Phase shift from SYNC_IN to LX1.	R Word	Bit Field	0x0160	Yes

COMMAND CODE	COMMAND NAME	DESCRIPTION	TYPE	DATA FORMAT	FACTORY VALUE	STORED IN NVM
0x40	VOUT_UV_FAULT_LIMIT	Output/feedback overvoltage fault threshold.	R Word	ULINEAR 16	PGM1 Dependent	No
0x41	VOUT_OV_FAULT_RESPONSE	Output/feedback overvoltage fault response.	R/W Byte	Bit Field	0xB9	Yes
0x44	VOUT_UV_FAULT_LIMIT	Output/feedback undervoltage fault threshold.	R Word	ULINEAR 16	PGM1 Dependent	No
0x45	VOUT_UV_FAULT_RESPONSE	Output/feedback undervoltage fault response.	R/W Byte	Bit Field	0x39	No
0x46	IOUT_OC_FAULT_LIMIT	Positive overcurrent fault threshold.	R/W Word	LINEAR11	PGM1 Dependent	No
0x47	IOUT_OC_FAULT_RESPONSE	Positive overcurrent fault response.	R/W Byte	Bit Field	0xF9	Yes
0x4B	IOUT_UC_FAULT_LIMIT	Negative overcurrent fault threshold.	R Word	LINEAR11	PGM1 Dependent	No
0x4C	IOUT_UC_FAULT_RESPONSE	Negative overcurrent fault response.	R/W Byte	Bit Field	0xF9	No
0x4F	OT_FAULT_LIMIT	Overtemperature fault threshold.	R/W Word	LINEAR11	0xF26C	No
0x50	OT_FAULT_RESPONSE	Overtemperature fault response.	R Byte	Bit Field	0xB9	No
0x51	OT_WARN_LIMIT	Overtemperature warning threshold.	R Word	LINEAR11	0xF1A4	Yes
0x55	VIN_OV_FAULT_LIMIT	Input overvoltage fault threshold.	R Word	LINEAR11	0xDA3A	No
0x56	VIN_OV_FAULT_RESPONSE	Input overvoltage fault response.	R/W Byte	Bit Field	0x39	Yes
0x59	VIN_UV_FAULT_LIMIT	Input undervoltage fault threshold.	R Word	LINEAR11	0xD895	No
0x5A	VIN_UV_FAULT_RESPONSE	Input undervoltage fault response.	R/W Byte	Bit Field	0xB9	No
0x78	STATUS_BYTE	One byte summary of the unit's fault condition.	R Byte	Bit Field	N/A	No
0x79	STATUS_WORD	Two bytes summary of the unit's fault condition.	R Word	Bit Field	N/A	No
0x7A	STATUS_VOUT	Output voltage fault and warning status.	R/W Byte	Bit Field	N/A	No
0x7B	STATUS_IOUT	Output current fault and warning status.	R/W Byte	Bit Field	N/A	No
0x7C	STATUS_INPUT	Input voltage fault and warning status.	R/W Byte	Bit Field	N/A	No
0x7D	STATUS_TEMPERATURE	Temperature fault and warning status.	R/W Byte	Bit Field	N/A	No
0x7E	STATUS_CML	Communication fault and warning status.	R/W Byte	Bit Field	N/A	No
0x80	STATUS_MFR_SPECIFIC	Manufacturer-specific fault and warning status.	R/W Byte	Bit Field	N/A	No
0x88	READ_VIN	Input voltage telemetry.	R Word	LINEAR11	N/A	No
0x8B	READ_VOUT	Feedback voltage telemetry.	R Word	ULINEAR 16	N/A	No

COMMAND CODE	COMMAND NAME	DESCRIPTION	TYPE	DATA FORMAT	FACTORY VALUE	STORED IN NVM
0x8C	READ_IOUT	Output current telemetry.	R Word	LINEAR11	N/A	No
0x8D	READ_TEMPERATURE_1	IC junction temperature telemetry.	R Word	LINEAR11	N/A	No
0x8E	READ_TEMPERATURE_2	External power stage junction temperature telemetry.	R Word	LINEAR11	N/A	No
0x98	PMBUS_REVISION	PMBus revision compliance.	R Byte	Bit Field	0x33	No
0xAD	IC_DEVICE_ID	Device root part number.	R Block	ASCII	“MAX20860A”	No
0xAE	IC_DEVICE_REV	Device revision code.	R Block	ASCII	N/A	No
0xD4	RAMP_SLP	Slope compensation options.	R/W Byte	Bit Field	PGM1 Dependent	Yes
0xD9	EXT_SPS_FAULT_RESPONSE	External power stage fault response.	R/W Byte	Bit Field	0xF9	No
0xDB	SNSP_FAULT_RESPONSE	Feedback SNSP/SNSN pin open fault response.	R/W Byte	Bit Field	0x80	No
0xDD	REMAINING_STORES	Number of remaining units of nonvolatile memory.	R Byte	Unsigned Integer	0x12	No
0xDE	DPLL_FLAGS	Status register of frequency Synchronization.	R Byte	Bit Field	N/A	No
0xE0	STATUS_MFR_SPECIFIC_2	Manufacturer-specific fault and warning status.	R/W Byte	Bit Field	N/A	No
0xE1	STATUS_MFR_SPECIFIC_3	Manufacturer-specific fault and warning status.	R/W Byte	Bit Field	N/A	No
0xE7	RVGA_GAIN	Voltage loop gain resistance options.	R/W Byte	Bit Field	PGM1 Dependent	Yes
0xE8	ZERO_SEL	Voltage loop zero options.	R/W Byte	Bit Field	0x05	Yes
0xE9	AMS_OPT	Advanced modulation scheme options.	R/W Byte	Bit Field	PGM1 Dependent	Yes
0xEA	RESTORE_ADI_ALL	Restore all PMBus commands to their default factory and PGM1-dependent values.	Send Byte	N/A	N/A	N/A
0xF1	MFR_VIN_UV_FAULT_LIMIT_SETPOINT	Manufacturer-specific option to expand input undervoltage threshold for dual-phase operation.	R/W Byte	Bit Field	0x11	Yes

On and Off Related Commands

OPERATION

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	Yes – Bits [5:4] Only
Command Code:	0x01	**Format:**	Bit Field
Data Bytes:	1	**Units:**	N/A
Transfer:	Read/Write Byte	**Factory Value:**	0x8A
Output Must Be Disabled for a Write Transaction:	Only for Bit 6		

Description/Notes: See Section 12.1 of the PMBus Specification Part II.

The OPERATION command is used to configure the operational state of the device with regards to turning it on and off, as well as output voltage control.

Only the following bit values are supported for this command:

BIT [7]	MEANING
0x0	Output Disabled
0x1	Output Enabled

BIT [6]	MEANING
0x0	Switching stops immediately after output is disabled.
0x1	Controlled ramp-down of output upon it being disabled.

BIT [5:4]	MEANING
0x0	PMBus VOUT_COMMAND is used for output voltage control.
0x3	AVSBus Target V_{OUT} command is used for output voltage control.

BIT [3:2]	MEANING
0x2	V_{OUT} faults are active during margining.

BIT [1]	MEANING
0x1	PMBus VOUT_COMMAND is updated to the AVSBus Target V_{OUT} command value when returning to PMBus control of the output voltage.

BIT [0]	MEANING
0x0	Reserved

ON_OFF_CONFIG

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	Yes – Bits [2] and [0] Only
Command Code:	0x02	**Format:**	Bit Field
Data Bytes:	1	**Units:**	N/A
Transfer:	Read/Write Byte	**Factory Value:**	0x1F
Output Must Be Disabled for a Write Transaction:	Only for Bit 0		

Description/Notes: See Section 12.2 of the PMBus Specification Part II.

The ON_OFF_CONFIG command configures the relationship between the EN pin and the operational state of the device, specifically with respect to turning it on and off.

Supported values for the ON_OFF_CONFIG command:

DATA BYTE VALUE	MEANING
0x1A, 0x1B	Status of the EN pin is ignored.
0x1E	EN high required to enable. EN low results in output ramping down to 0V in t_{OFF_FALL} time, after a delay of t_{OFF_DELAY}.
0x1F	EN high required to enable. EN low results in immediate shutdown.

Output Voltage Related Commands

VOUT_MODE			
Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x20	**Format:**	Bit Field
Data Bytes:	1	**Units:**	N/A
Transfer:	Read Byte	**Factory Value:**	0x16
Output Must Be Disabled for a Write Transaction:	N/A		
Description/Notes:	See Section 13.1 of the PMBus Specification Part II. This device supports the PMBus ULINEAR16 format for the values of output voltage related commands. These commands will return and receive two-byte data which will serve as the integer mantissa in the ULINEAR16 format. The read-only VOUT_MODE command has a value of 0x16, which indicates a ULINEAR16 exponent of N = -10.		

VOUT_COMMAND			
Reference:	Standard Command	**Stored in Nonvolatile Memory:**	Yes
Command Code:	0x21	**Format:**	ULINEAR16
Data Bytes:	2	**Units:**	V
Transfer:	Read/Write Word	**Factory Value:**	PGM1 Dependent
Output Must Be Disabled for a Write Transaction:	No		
Description/Notes:	See Section 13.2 of the PMBus Specification Part II. When in PMBus output voltage control (OPERATION[5:4] = 00b), VOUT_COMMAND can be used for setting the regulator's target output voltage. Since this device has a ULINEAR16 exponent of -10, VOUT_COMMAND data sent to and from the device is divided by 1024 to determine the actual output voltage value, with an LSB size of 0.9765mV. VOUT_COMMAND will accept values from 0x019A (0.4004V) to 0x0A3D (2.560V). Output voltages higher than 0.7998V must be adjusted by means of an external resistive voltage divider at the SNSP and SNSN pins of the device. The resistor-divider ratio must match the setting of the VOUT_SCALE_LOOP command in order for VOUT_COMMAND to match 1:1 with the real output voltage.		

VOUT_SCALE_LOOP

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	Yes
Command Code:	0x29	**Format:**	LINEAR11
Data Bytes:	2	**Units:**	N/A
Transfer:	Read/Write Word	**Factory Value:**	N/A
Output Must Be Disabled for a Write Transaction:	Yes		

Description/Notes: See Section 13.10 of the PMBus Specification Part II.

VOUT_SCALE_LOOP is a scale factor for VOUT_COMMAND to define the V_{REF} since the V_{REF} output range is limited to [0.4V to 0.8V].

Supported values for the VOUT_SCALE_LOOP command and their respective supported output voltage ranges are summarized in the table below. When the scale factor is not set to 1.0 (0xE010), an external resistor-divider at SNSP and SNSN must be used to sense the output voltage (refer to MAX20860A IC data sheet for more details).

DATA BYTE VALUE	SCALE FACTOR	RESISTOR-DIVIDER VALUES R_FB1/R_FB2 (Ω)	V_{OUT} RANGE (V)
0xE005	0.3125	2.2k/1.0k	1.2803 to 2.5596
0xE008	0.5000	2.2k/2.2k	0.7998 to 1.5996
0xE00B	0.6875	1.0k/2.2k	0.5820 to 1.1641
0xE010	1.0000	N/A	0.4004 to 0.7998

The output voltage ranges provided above apply to both the VOUT_COMMAND and READ_VOUT commands for $V_{OUT} \leq 2.5596V$.

If a $V_{OUT} > 2.5596V$ is desired, the scale factor should be set to 1.0 (0xE010) and an external resistive voltage divider should be used to scale up the output voltage. In this case, the various output voltage related commands such as VOUT_COMMAND, VOUT_OV_FAULT_LIMIT, VOUT_UV_FAULT_LIMIT, and READ_VOUT refer to the reference voltage and must be multiplied by the voltage divider ratio to obtain the real associated output voltage value.

VOUT_MAX

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x24	**Format:**	ULINEAR16
Data Bytes:	2	**Units:**	V
Transfer:	Read Word	**Factory Value:**	PGM1 Dependent
Output Must Be Disabled for a Write Transaction:	N/A		

Description/Notes: See Section 13.5 of the PMBus Specification Part II.

VOUT_MAX defines the maximum values acceptable for VOUT_COMMAND based on the VOUT_SCALE_LOOP setting.

This command is read-only and is dependent on the VOUT_SCALE_LOOP setting as shown in the following table:

VOUT_SCALE_LOOP		**VOUT_MAX**	
DATA BYTE VALUE	**V_{OUT} SCALE RATIO**	**DATA BYTES VALUE**	**MAX V_{OUT} (V)**
0xE005	0.3125	0x0A3D	2.5596
0xE008	0.5000	0x0666	1.5996
0xE00B	0.6875	0x04A8	1.1641
0xE010	1.0000	0x0333	0.7998

VOUT_MIN

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x2B	**Format:**	ULINEAR16
Data Bytes:	2	**Units:**	V
Transfer:	Read Word	**Factory Value:**	PGM1 Dependent
Output Must Be Disabled for a Write Transaction:	N/A		

Description/Notes: See Section 13.12 of the PMBus Specification Part II.

VOUT_MIN defines the minimum values acceptable for VOUT_COMMAND based on the VOUT_SCALE_LOOP factor.

This command is read-only and is dependent on the VOUT_SCALE_LOOP setting as shown in the following table:

VOUT_SCALE_LOOP		VOUT_MIN	
DATA BYTE VALUE	**V_{OUT} SCALE RATIO**	**DATA BYTE VALUE**	**MIN V_{OUT} (V)**
0xE005	0.3125	0x051F	1.2803
0xE008	0.5000	0x0333	0.7998
0xE00B	0.6875	0x0254	0.5820
0xE010	1.0000	0x019A	0.4004

VOUT_TRANSITION_RATE

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	Yes
Command Code:	0x27	**Format:**	LINEAR11
Data Bytes:	2	**Units:**	V/ms
Transfer:	Read/Write Word	**Factory Value:**	PGM1 Dependent
Output Must Be Disabled for a Write Transaction:	No		

Description/Notes: See Section 13.8 of the PMBus Specification Part II.

The VOUT_TRANSITION_RATE command selects one of four slew-rate options for the output voltage that apply to soft-startup, soft-shutdown, and target changes in VOUT_COMMAND. The value of VOUT_TRANSITION_RATE must be scaled by the VOUT_SCALE_LOOP command's value to determine the actual output voltage slew-rate.

When the output voltage is controlled by AVSBus, the VOUT_TRANSITION_RATE command will be continuously updated with the positive voltage slew rate setting received from the AVSBus interface.

Supported values for the VOUT_TRANSITION_RATE command are as follows:

DATA BYTE VALUE	OUTPUT SLEW RATE (V/ms)
0xB856	0.168
0xB8AA	0.333
0xB900	0.500
0xBA00	1.000

Switching Frequency and Configuration Commands

FREQUENCY_SWITCH

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	Yes
Command Code:	0x33	**Format:**	LINEAR11
Data Bytes:	2	**Units:**	kHz
Transfer:	Read/Write Word	**Factory Value:**	PGM1 Dependent
Output Must Be Disabled for a Write Transaction:	Yes		

Description/Notes: See Section 14.4 of the PMBus Specification Part II.

This command sets the device's switching frequency in kHz. The switching frequency is set during initialization by the selected scenario (PGM1 resistor) unless a specific value has been written to FREQUENCY_SWITCH and saved to the nonvolatile memory using the User Store feature.

The device supports 10 fundamental switching frequencies, as follows:

DATA BYTE VALUE	SWITCHING FREQUENCY (kHz)
0x089A	308
0x08C8	400
0x08DE	444
0x08FA	500
0x091E	571
0x094E	667
0x0990	800
0x09F4	1000
0x0A9B	1333
0x0BE8	2000

In case an external power stage is detected, the acceptable switching frequency cannot exceed 1000kHz. Therefore, any selected value that is >1000kHz will be set to 1000kHz.

RAMP_SLP

Reference:	Analog Devices Specific	**Stored in Nonvolatile Memory:**	Yes
Command Code:	0xD4	**Format:**	Bit Field
Data Bytes:	1	**Units:**	N/A
Transfer:	Read/Write Byte	**Factory Value:**	PGM1 Dependent
Output Must Be Disabled for a Write Transaction:	Yes		

Description/Notes: The RAMP_SLP command is used to configure the device's slope compensation.

Inside the MAX20860A control loop, there is a compensation ramp that can be tuned to help improve stability. There are two ramp slopes: an early ramp (rmp_slp_1) and the PWM ramp (rmp_slp_2). This register defines these ramp slopes.

Supported bit values for this command are shown in the following tables:

BIT [6:4]	ramp_slp2
0x0	420nA
0x1	630nA
0x2	840nA
0x3	1050nA
0x4	1260nA
0x5	1470nA
0x6	1680nA
0x7	1890nA

BIT [0]	ramp_slp1
0x0	6µA
0x1	12µA

RVGA_GAIN

Reference:	Analog Devices Specific	**Stored in Nonvolatile Memory:**	Yes
Command Code:	0xE7	**Format:**	Bit Field
Data Bytes:	1	**Units:**	kΩ
Transfer:	Read/Write Byte	**Factory Value:**	PGM1 Dependent
Output Must Be Disabled for a Write Transaction:	Yes		

Description/Notes: The RVGA_GAIN command is used to select the RVGA value that sets the voltage loop gain (refer to the MAX20860A data sheet for more details).

The following values for RVGA are supported:

DATA BYTE VALUE	RVGA (kΩ)
0x00	10.0
0x01	11.0
0x02	15.6
0x03	22.0
0x04	27.0
0x05	31.0
0x06	37.3
0x07	44.5
0x08	52.2
0x09	62.3
0x0A	74.5
0x0B	104.4
0x0C	52.2
0x0D	74.5
0x0E	37.3
0x0F	104.4

ZERO_SEL

Reference:	Analog Devices Specific	**Stored in Nonvolatile Memory:**	Yes
Command Code:	0xE8	**Format:**	Bit Field
Data Bytes:	1	**Units:**	kHz
Transfer:	Read/Write Byte	**Factory Value:**	0x05
Output Must Be Disabled for a Write Transaction:	Yes		

Description/Notes: The ZERO_SEL command is used for configuring the MAX20860A's voltage loop zero. This relates to the time that V_{OUT} needs in order to recover when there is variation in the load.

The following configurations are supported:

DATA BYTE VALUE	f_Z (kHz)
0x00	3
0x01	5
0x02	7.5
0x03	8.75
0x04	10
0x05	12.5
0x06	15
0x07	17.5

AMS_OPT

Reference:	Analog Devices Specific	**Stored in Nonvolatile Memory:**	Yes
Command Code:	0xE9	**Format:**	Bit Field
Data Bytes:	1	**Units:**	N/A
Transfer:	Read/Write Byte	**Factory Value:**	PGM1 Dependent
Output Must Be Disabled for a Write Transaction:	Yes		

Description/Notes: This register defines the options for implementing the MAX20860A's advanced modulation scheme (AMS) algorithm. This feature can be used for increasing the control loop bandwidth and therefore improving the load-transient response (see the MAX20860A data sheet for more details).

Supported values for this command are as follows:

DATA BYTE VALUE	MEANING
0x00	AMS disabled
0x09	AMS enabled

INTERLEAVE

AMS_OPT

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	Yes
Command Code:	0x37	**Format:**	Bit Field
Data Bytes:	2	**Units:**	N/A
Transfer:	Read/Write Word	**Factory Value:**	0x0160
Output Must Be Disabled for a Write Transaction:	Yes		

Description/Notes: See Section 14.7 of the PMBus Specification Part II.

The MAX20860A supports frequency synchronization for its PWM signals. When a valid external synchronization clock is applied to the device's SYNC_IN pin, the first phase's PWM signal has its rising edge synchronized with the external clock's rising edge with a fixed minimum delay of 230ns.

The INTERLEAVE command is used to configure the additional programmable phase delay between the rising edges of the SYNC_IN external clock and the first phase's PWM signal.

Supported values for the INTERLEAVE command are as follows:

DATA BYTE VALUE	PHASE DELAY (°)
0x0180	0
0x0160	0
0x0181	45
0x0161	60
0x0182	90
0x0162	120
0x0183	135
0x0163	180

Moreover, if AMS is enabled, there is an additional 180° phase delay between the rising edges of the SYNC_IN external clock and the first phase's PWM signal.

In 2-phase operation (with no external power-stage connected), the second phase is clocked 180° out of phase with the first phase. In 3-phase operation, the second and third phases are timed 120° and 240° after the first phase, respectively. And in 4-phase operation, the second, third, and fourth phases are timed 90°, 180°, and 270° after the first phase, respectively.

Fault-Related Commands

VOUT_OV_FAULT_LIMIT			
Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x40	**Format:**	ULINEAR16
Data Bytes:	2	**Units:**	V
Transfer:	Read Word	**Factory Value:**	See Description
Output Must Be Disabled for a Write Transaction:	N/A		
Description/Notes:	See Section 15.2 of the PMBus Specification Part II. The VOUT_OV_FAULT_LIMIT command sets the output voltage measurement that causes an output overvoltage fault. Its value is divided by 1024 to determine the actual output overvoltage fault limit. VOUT_OV_FAULT_LIMIT tracks the VOUT_COMMAND value and is always set to VOUT_COMMAND x 1.13 (13% above VOUT_COMMAND).		

VOUT_OV_FAULT_RESPONSE

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	Yes – Bits [5:3] Only
Command Code:	0x41	**Format:**	Bit Field
Data Bytes:	1	**Units:**	N/A
Transfer:	Read/Write Byte	**Factory Value:**	0xB9
Output Must Be Disabled for a Write Transaction:	Yes		

Description/Notes: See Section 15.3 of the PMBus Specification Part II.

This command sets the device's response to an output overvoltage fault.

Supported bit values for this command are shown below:

BIT [7:6]	MEANING
0x0	V_{OUT} overvoltage fault condition is ignored.
0x2	V_{OUT} overvoltage fault results in immediate device shutdown.

BIT [5:3]	MEANING
0x0	Latch off – no attempt is made to restart after a fault shutdown.
0x7	Attempt to restart continuously until commanded off, or until another fault condition causes the unit to latch off completely.

BIT [2:0]	MEANING
0x1	20ms delay between retry attempts.

VOUT_UV_FAULT_LIMIT

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x44	**Format:**	ULINEAR16
Data Bytes:	2	**Units:**	V
Transfer:	Read Word	**Factory Value:**	See Description
Output Must Be Disabled for a Write Transaction:	N/A		
Description/Notes:	See Section 15.6 of the PMBus Specification Part II. The VOUT_UV_FAULT_LIMIT command sets the output voltage measurement that causes an output undervoltage fault. Its value is divided by 1024 to determine the actual output undervoltage fault limit. VOUT_UV_FAULT_LIMIT tracks the VOUT_COMMAND value and is always set to VOUT_COMMAND x 0.87 (13% below VOUT_COMMAND).		

VOUT_UV_FAULT_RESPONSE

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x45	**Format:**	Bit Field
Data Bytes:	1	**Units:**	N/A
Transfer:	Read/Write Byte	**Factory Value:**	0x39
Output Must Be Disabled for a Write Transaction:	Yes		

Description/Notes: See Section 15.7 of the PMBus Specification Part II.

This command sets the device's response to an output undervoltage fault.

Supported bit values for this command are shown below:

BIT [7:6]	MEANING
0x0	V_{OUT} undervoltage fault condition is ignored.
0x2	V_{OUT} undervoltage fault results in immediate device shutdown.

BIT [5:3]	MEANING
0x0	Latch off – no attempt is made to restart after a fault shutdown. (The user cannot select this setting.)
0x7	Attempt to restart continuously until commanded off, or until another fault condition causes the unit to latch off completely.

BIT [2:0]	MEANING
0x1	20ms delay between retry attempts.

IOUT_OC_FAULT_LIMIT

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x46	**Format:**	LINEAR11
Data Bytes:	2	**Units:**	A
Transfer:	Read/Write Word	**Factory Value:**	PGM1 Dependent
Output Must Be Disabled for a Write Transaction:	Yes		

Description/Notes: See Section 15.8 of the PMBus Specification Part II.

The IOUT_OC_FAULT_LIMIT command sets the value of the output current that causes a positive overcurrent fault to occur.

The following settings are supported:

2-phase operation:

DATA BYTE VALUE	OVERCURRENT FAULT LIMIT (A)
0xF0C8	50
0xF0F0	60
0xF118	70
0xF140	80

3-phase operation:

DATA BYTE VALUE	OVERCURRENT FAULT LIMIT (A)
0xF12C	75
0xF168	90
0xF1A4	105
0xF1E0	120

4-phase operation:

DATA BYTE VALUE	OVERCURRENT FAULT LIMIT (A)
0xF190	100
0xF1E0	120
0xF230	140
0xF280	160

IOUT_OC_FAULT_RESPONSE

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	Yes
Command Code:	0x47	**Format:**	Bit Field
Data Bytes:	1	**Units:**	N/A
Transfer:	Read/Write Byte	**Factory Value:**	0xF9
Output Must Be Disabled for a Write Transaction:	Yes		

Description/Notes: See Section 15.9 of the PMBus Specification Part II.

This command sets the device's response to an output overcurrent fault.

Supported bit values for this command:

BIT [7:6]	MEANING
0x0	Overcurrent fault condition is ignored.
0x3	Overcurrent fault results in immediate device shutdown.

BIT [5:3]	MEANING
0x0	Latch off – no attempt is made to restart after a fault shutdown.
0x7	Attempt to restart continuously until commanded off, or until another fault condition causes the unit to latch off completely.

BIT [2:0]	MEANING
0x1	20ms delay between retry attempts.

IOUT_UC_FAULT_LIMIT

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x4B	**Format:**	LINEAR11
Data Bytes:	2	**Units:**	A
Transfer:	Read Word	**Factory Value:**	PGM1 Dependent
Output Must Be Disabled for a Write Transaction:	N/A		

Description/Notes: See Section 15.13 of the PMBus Specification Part II.

The IOUT_UC_FAULT_LIMIT command sets the value of the output current that causes a negative overcurrent fault to occur. IOUT_UC_FAULT_LIMIT[10:0] can be divided by 4 to determine the actual output undercurrent fault limit.

IOUT_UC_FAULT_LIMIT tracks the IOUT_OC_FAULT_LIMIT value and is always set to IOUT_OC_FAULT_LIMIT x -0.875 (-87.5% of the positive current limit).

IOUT_UC_FAULT_RESPONSE

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x4C	**Format:**	Bit Field
Data Bytes:	1	**Units:**	N/A
Transfer:	Read/Write Byte	**Factory Value:**	0xF9
Output Must Be Disabled for a Write Transaction:	Yes		

Description/Notes: See Section 15.14 of the PMBus Specification Part II.

This command sets the device's response to a negative overcurrent fault.

Supported bit values for this command:

BIT [7:6]	MEANING
0x3	Negative overcurrent fault results in immediate device shutdown.

BIT [5:3]	MEANING
0x0	Latch off – no attempt is made to restart after a fault shutdown.
0x7	Attempt to restart continuously until commanded off, or until another fault condition causes the unit to latch off completely.

BIT [2:0]	MEANING
0x1	20ms delay between retry attempts.

OT_FAULT_LIMIT

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x4F	**Format:**	LINEAR11
Data Bytes:	2	**Units:**	°C
Transfer:	Read Word	**Factory Value:**	0xF26C
Output Must Be Disabled for a Write Transaction:	N/A		

Description/Notes: See Section 15.17 of the PMBus Specification Part II.

The OT_FAULT_LIMIT command sets the junction temperature, in degrees Celsius, at which an overtemperature fault will occur. OT_FAULT_LIMIT[10:0] can be divided by 4 to determine the actual overtemperature fault limit, T_R. The device temperature must drop below T_F for the overtemperature fault to no longer persist.

The device will be preset to one of the following four settings:

DATA BYTE VALUE	T_R (°C)	T_F (°C)
0xF250	148	127
0xF26C	155	135
0xF2AC	171	150
0xF2D8	182	160

OT_FAULT_RESPONSE

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x50	**Format:**	Bit Field
Data Bytes:	1	**Units:**	N/A
Transfer:	Read Byte	**Factory Value:**	0xB9
Output Must Be Disabled for a Write Transaction:	N/A		

Description/Notes: See Section 15.18 of the PMBus Specification Part II.

This command sets the device's response to an overtemperature fault.

Supported bit values for this command:

BIT [7:6]	MEANING
0x0	Overtemperature fault condition is ignored.
0x2	Overtemperature fault results in immediate device shutdown.

BIT [5:3]	MEANING
0x0	Latch off – no attempt is made to restart after a fault shutdown.
0x7	Attempt to restart continuously until commanded off, or until another fault condition causes the unit to latch off completely.

BIT [2:0]	MEANING
0x1	20ms delay between retry attempts.

OT_WARN_LIMIT

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	Yes
Command Code:	0x51	**Format:**	LINEAR11
Data Bytes:	2	**Units:**	°C
Transfer:	Read/Write Word	**Factory Value:**	0xF1A4
Output Must Be Disabled for a Write Transaction:	Yes		

Description/Notes: See Section 15.19 of the PMBus Specification Part II.

The OT_WARN_LIMIT command sets the junction temperature, in degrees Celsius, at which an overtemperature warning will be flagged. OT_WARN_LIMIT[10:0] can be divided by 4 to determine the actual overtemperature warning threshold.

The following two settings are supported:

DATA BYTE VALUE	OT WARNING THRESHOLD (°C)
0xF1A4	105
0xF1F4	125

VIN_OV_FAULT_LIMIT

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x55	**Format:**	LINEAR16
Data Bytes:	2	**Units:**	V
Transfer:	Read Word	**Factory Value:**	0xDA3A
Output Must Be Disabled for a Write Transaction:	N/A		

Description/Notes: See Section 15.23 of the PMBus Specification Part II.

The VIN_OV_FAULT_LIMIT command allows the user to read the value of the input voltage that causes an input overvoltage fault. This value is fixed at 17.8V (0xDA3A).

VIN_OV_FAULT_RESPONSE

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	Yes
Command Code:	0x56	**Format:**	Bit Field
Data Bytes:	1	**Units:**	N/A
Transfer:	Read/Write Byte	**Factory Value:**	0x39
Output Must Be Disabled for a Write Transaction:	Yes		

Description/Notes: See Section 15.24 of the PMBus Specification Part II.

This command sets the device's response for an input overvoltage fault.

Supported bit values for this command:

BIT [7:6]	MEANING
0x0	V_{DDH} overvoltage fault condition is ignored.
0x2	V_{DDH} overvoltage fault results in immediate device shutdown.
0x3	Inhibit operation while V_{DDH} is above overvoltage threshold. Retry immediately once condition clears.

BIT [5:3]	MEANING
0x7	Attempt to restart continuously until commanded off, or until another fault condition causes the unit to latch off completely.

BIT [2:0]	MEANING
0x1	20ms delay between retry attempts.

VIN_UV_FAULT_LIMIT

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	Yes
Command Code:	0x59	**Format:**	LINEAR16
Data Bytes:	2	**Units:**	V
Transfer:	Read Word	**Factory Value:**	0xD895
Output Must Be Disabled for a Write Transaction:	N/A		

Description/Notes: See Section 15.27 of the PMBus Specification Part II.

The VIN_UV_FAULT_LIMIT command allows the user to read the value of the V_{DDH} Undervoltage Lockout threshold – this is the value of input voltage that causes an input undervoltage fault. By default, this is preset to 4.75V.

DATA BYTE VALUE	V_{DDH} UVLO THRESHOLD (V)
0xD853	2.5
0xD895	4.75

VIN_UV_FAULT_LIMIT is a read-only command. However, the V_{DDH} UVLO threshold can still be modified using the MFR_VIN_UV_FAULT_LIMIT_SETPOINT command. This setting can subsequently be stored in the part's nonvolatile memory.

VIN_UV_FAULT_RESPONSE

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	Yes
Command Code:	0x5A	**Format:**	Bit Field
Data Bytes:	1	**Units:**	N/A
Transfer:	Read Byte	**Factory Value:**	0xB9
Output Must Be Disabled for a Write Transaction:	N/A		

Description/Notes: See Section 15.28 of the PMBus Specification Part II.

This command sets the device's response to an input undervoltage fault.

Supported bit values for this command:

BIT [7:6]	MEANING
0x2	V_{DDH} undervoltage fault results in immediate device shutdown.
0x3	Inhibit operation while V_{DDH} is below undervoltage threshold. Retry immediately once condition clears.

BIT [5:3]	MEANING
0x7	Attempt to restart continuously until commanded off, or until another fault condition causes the unit to latch off completely.

BIT [2:0]	MEANING
0x1	20ms delay between retry attempts.

EXT_SPS_FAULT_RESPONSE

Reference:	Analog Devices Specific	**Stored in Nonvolatile Memory:**	No
Command Code:	0xD9	**Format:**	Bit Field
Data Bytes:	1	**Units:**	N/A
Transfer:	Read Byte	**Factory Value:**	0xF9
Output Must Be Disabled for a Write Transaction:	N/A		

Description/Notes: This command indicates the response to a fault in an external power stage device.

Supported bit values for this command:

BIT [7:6]	MEANING
0x0	External power stage fault is ignored.
0x2	External power stage fault results in immediate device shutdown.
0x3	Inhibit operation while the fault condition persists. Retry immediately once condition clears.

BIT [5:3]	MEANING
0x0	Latch off – no attempt is made to restart after a fault shutdown.
0x7	Attempt to restart continuously until commanded off, or until another fault condition causes the unit to latch off completely.

BIT [2:0]	MEANING
0x1	20ms delay between retry attempts.

SNSP_FAULT_RESPONSE

Reference:	Analog Devices Specific	**Stored in Nonvolatile Memory:**	No
Command Code:	0xDB	**Format:**	Bit Field
Data Bytes:	1	**Units:**	N/A
Transfer:	Read Byte	**Factory Value:**	0x80
Output Must Be Disabled for a Write Transaction:	N/A		

Description/Notes: This command indicates the response to an SNSP pin fault.

Supported bit values for this command:

BIT [7:6]	MEANING
0x0	SNSP fault is ignored.
0x2	SNSP fault results in immediate device shutdown.

BIT [5:3]	MEANING
0x0	Latch off – no attempt is made to restart after a fault shutdown.

BIT [2:0]	MEANING
0x0	N/A (no autoretry option)

MFR_VIN_UV_FAULT_LIMIT_SETPOINT

Reference:	Analog Devices Specific	**Stored in Nonvolatile Memory:**	Yes
Command Code:	0xF1	**Format:**	Bit Field
Data Bytes:	1	**Units:**	N/A
Transfer:	Read/Write Byte	**Factory Value:**	0x11
Output Must Be Disabled for a Write Transaction:	Yes		

Description/Notes:

The MFR_VIN_UV_FAULT_LIMIT_SETPOINT command allows the user to set the value of the V_{DDH} undervoltage lockout (UVLO) threshold – this is the value of input voltage that causes an input undervoltage fault. Any changes to this setting are also reflected in the VIN_UV_FAULT_LIMIT register.

By default, the V_{DDH} UVLO threshold is preset to 4.75V. In order to save a modified V_{IN} UVLO threshold, the setting must be saved to the device's nonvolatile memory.

There are two values supported for this command. Unsupported values that are not listed below should not be written.

DATA BYTE VALUE	V_{DDH} UVLO THRESHOLD (V)
0x10	2.5
0x11	4.75

Note that the 2.5V V_{DDH} UVLO threshold should only be used for 2-phase operation.

Unit Status Commands

CLEAR_FAULTS			
Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x03	**Format:**	N/A
Data Bytes:	0	**Units:**	N/A
Transfer:	Send Byte	**Factory Value:**	N/A
Output Must Be Disabled for a Write Transaction:	No		
Description/Notes:	See Section 15.1 of the PMBus Specification Part II. When received, the CLEAR_FAULTS command will clear any nonpersistent fault indicators from all STATUS registers.		

SMBALERT_MASK

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	Yes
Command Code:	0x1B	**Format:**	Bit Field
Data Bytes:	1	**Units:**	N/A
Transfer:	Block Write-Block Read Process Call/Write Word	**Factory Value:**	N/A
Output Must Be Disabled for a Write Transaction:	Yes		

Description/Notes: See Section 15.38 of the PMBus Specification Part II.

The SMBALERT_MASK command may be used to prevent a status bit for a given fault or warning condition from asserting the SMBALERT# signal. See the SMBALERT# section for a description of this signal's purpose and behavior.

All MAX20860A status registers, except STATUS_BYTE, STATUS_WORD, and DPLL_FLAGS, can have their bits masked using the SMBALERT_MASK command.

Write Transactions:

The Write Word packet format in *Figure 9* is used to mask the bits of a specific status register of choice.

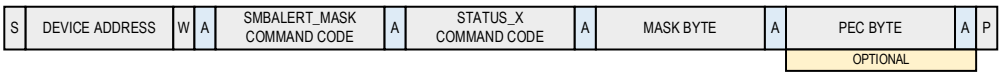

Figure 9. SMBALERT_MASK Write Transaction Command Packet Format

The 'STATUS_X Command Code' byte is used to indicate which status command SMBALERT# masking will be applied to. The 'Mask Byte' bits that are set to '1' will result in the matching bits in the chosen status register to be masked from asserting the SMBALERT# signal.

Read Transactions:

The Block Write-Block Read Process Call packet format shown in *Figure 10* is used for retrieving a specific status register's SMBALERT_MASK settings.

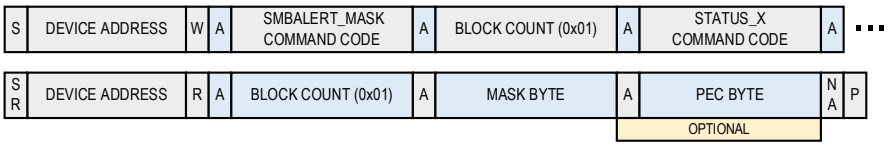

Figure 10. SMBALERT_MASK Read Transaction Command Packet Format

For all SMBALERT_MASK read transactions, 'Block Count' is always equal to '0x01'. Also, in correspondence with the write transactions, any 'Mask Byte' bits that are read as '1' indicate that the corresponding bit of the chosen status register (as per the STATUS_X Command Code byte) has been masked from asserting the SMBALERT# signal.

STATUS_BYTE

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x78	**Format:**	Bit Field
Data Bytes:	1	**Units:**	N/A
Transfer:	Read Byte	**Factory Value:**	N/A
Output Must Be Disabled for a Write Transaction:	N/A		

Description/Notes: See Section 17.1 of the PMBus Specification Part II.

The STATUS_BYTE command returns one byte of information with a summary of the most critical faults. Based on the information from this register, the host can get more precise information by reading the appropriate fault-specific status registers.

The following information can be read from the STATUS_BYTE register:

BIT	MEANING
7	Busy
6	Off
5	V_{OUT} OV Fault
4	I_{OUT} OC Fault
3	V_{IN} UV Fault
2	TEMPERATURE Fault
1	CML Fault
0	NONE OF THE ABOVE: A fault or warning not listed in bits [7:1] of STATUS_BYTE has occurred.

STATUS_WORD

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x79	**Format:**	Bit Field
Data Bytes:	2	**Units:**	N/A
Transfer:	Read Word	**Factory Value:**	N/A
Output Must Be Disabled for a Write Transaction:	N/A		

Description/Notes: See Section 17.2 of the PMBus Specification Part II.

The STATUS_WORD command returns two bytes of information with a summary of the unit's fault conditions. Based on the information from this register, the host can get more precise information by reading the appropriate fault-specific status registers.

The following information can be read from the STATUS_WORD register:

	BIT	MEANING
High Byte	15	V_{OUT} Fault or Warning
	14	I_{OUT} Fault
	13	V_{IN} Fault
	12	Manufacturer-Specific Fault or Warning
	11	POWER_GOOD# (Power-good signal is not asserted)
	10	—
	9	Other
	8	NONE OF THE ABOVE: A fault or warning not listed in bits [15:1] of STATUS_WORD has occurred.
Low Byte	7	Busy
	6	Off
	5	V_{OUT} OV Fault
	4	I_{OUT} OC Fault
	3	V_{IN} UV Fault
	2	TEMPERATURE Fault
	1	CML Fault
	0	NONE OF THE ABOVE: A fault or warning not listed in bits [7:1] of STATUS_WORD has occurred.

STATUS_VOUT

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x7A	**Format:**	Bit Field
Data Bytes:	1	**Units:**	N/A
Transfer:	Read/Write Byte	**Factory Value:**	N/A
Output Must Be Disabled for a Write Transaction:	No		

Description/Notes: See Section 17.3 of the PMBus Specification Part II.

The STATUS_VOUT command returns one data byte of information on the status of the output voltage.

The following information can be read from the STATUS_VOUT register:

BIT	MEANING
7	V_{OUT} OV Fault
6	—
5	—
4	V_{OUT} UV Fault
3	VOUT_MAX_MIN Warning
2	—
1	—
0	—

STATUS_IOUT

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x7B	**Format:**	Bit Field
Data Bytes:	1	**Units:**	N/A
Transfer:	Read/Write Byte	**Factory Value:**	N/A
Output Must Be Disabled for a Write Transaction:	No		

Description/Notes: See Section 17.4 of the PMBus Specification Part II.

The STATUS_IOUT command returns one data byte of information on the status of the output current.

The following information can be read from the STATUS_IOUT register:

BIT	NAME
7	I_{OUT} OC Fault
6	—
5	—
4	I_{OUT} UC Fault
3	—
2	—
1	—
0	—

STATUS_INPUT

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x7C	**Format:**	Bit Field
Data Bytes:	1	**Units:**	N/A
Transfer:	Read/Write Byte	**Factory Value:**	N/A
Output Must Be Disabled for a Write Transaction:	No		

Description/Notes: See Section 17.5 of the PMBus Specification Part II.

The STATUS_INPUT command returns one data byte of information on the status of the input V_{DDH} voltage.

The following information can be read from the STATUS_INPUT register:

BIT	NAME
7	V_{IN} OV Fault
6	—
5	—
4	V_{IN} UV Fault
3	—
2	—
1	—
0	—

STATUS_TEMPERATURE

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x7D	**Format:**	Bit Field
Data Bytes:	1	**Units:**	N/A
Transfer:	Read/Write Byte	**Factory Value:**	N/A
Output Must Be Disabled for a Write Transaction:	No		

Description/Notes: See Section 17.6 of the PMBus Specification Part II.

The STATUS_TEMPERATURE command returns one data byte of information on faults or warnings related to the device temperature.

The following information can be read from the STATUS_TEMPERATURE register:

BIT	MEANING
7	OT Fault
6	OT Warning
5	—
4	—
3	—
2	—
1	—
0	—

STATUS_CML

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x7E	**Format:**	Bit Field
Data Bytes:	1	**Units:**	N/A
Transfer:	Read/Write Byte	**Factory Value:**	N/A
Output Must Be Disabled for a Write Transaction:	No		

Description/Notes: See Section 17.7 of the PMBus Specification Part II.

The STATUS_CML command returns one data byte of information on communication, logic, and memory related faults.

The following information can be read from the STATUS_CML register:

BIT	MEANING
7	Invalid or Unsupported Command Received
6	Invalid or Unsupported Data Received
5	Packet Error Check Failed
4	Nonvolatile Memory Fault
3	—
2	—
1	A communication fault other than the ones listed in this table has occurred (any other SMBus error).
0	—

STATUS_MFR_SPECIFIC

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x80	**Format:**	Bit Field
Data Bytes:	1	**Units:**	N/A
Transfer:	Read/Write Byte	**Factory Value:**	N/A
Output Must Be Disabled for a Write Transaction:	No		

Description/Notes: See Section 17.9 of the PMBus Specification Part II.

The STATUS_MFR_SPECIFIC command returns one data byte of information on various manufacturer-specific faults.

The following information can be read from the STATUS_MFR_SPECIFIC register:

BIT	MEANING
7	Fast POCP Fault
6	—
5	Boost Undervoltage Fault
4	—
3	V_{CC} Undervoltage Fault
2	—
1	—
0	—

STATUS_MFR_SPECIFIC_2

Reference:	Analog Devices Specific	**Stored in Nonvolatile Memory:**	No
Command Code:	0xE0	**Format:**	Bit Field
Data Bytes:	1	**Units:**	N/A
Transfer:	Read/Write Byte	**Factory Value:**	N/A
Output Must Be Disabled for a Write Transaction:	No		

Description/Notes: See Section 17.9 of the PMBus Specification Part II.

The STATUS_MFR_SPECIFIC_2 command returns one data byte of information on various manufacturer-specific faults.

The following information can be read from the STATUS_MFR_SPECIFIC_2 register:

BIT	MEANING
7	Positive Sense Fault
6	—
5	External Power Stage Overtemperature Warning
4	AVDD Undervoltage Fault
3	DVDD Undervoltage Fault
2	Seal Ring Fault
1	External Power Stage Overtemperature Fault
0	Miscellaneous External Power Stage Fault

STATUS_MFR_SPECIFIC_3

Reference:	Analog Devices Specific	**Stored in Nonvolatile Memory:**	No
Command Code:	0xE1	**Format:**	Bit Field
Data Bytes:	1	**Units:**	N/A
Transfer:	Read/Write Byte	**Factory Value:**	N/A
Output Must Be Disabled for a Write Transaction:	No		

Description/Notes: See Section 17.9 of the PMBus Specification Part II.

The STATUS_MFR_SPECIFIC_3 command returns one data byte of information on various manufacturer-specific faults.

The following information can be read from the STATUS_MFR_SPECIFIC_3 register:

BIT	MEANING
7	Negative Sense Fault
6	—
5	PWM Open Fault (This is checked during the start-up handshake between the MAX20860A and any external power stages.)
4	TS_FAULTB Open Fault (This is checked during the start-up handshake between the MAX20860A and any external power stages.)
3	External Power Stage Population Fault
2	Boost Overvoltage Fault
1	—
0	PWM1-PWM2 Short Fault

DPLL_FLAGS

Reference:	Analog Devices Specific	**Stored in Nonvolatile Memory:**	No
Command Code:	0xDE	**Format:**	Bit Field
Data Bytes:	1	**Units:**	N/A
Transfer:	Read Byte	**Factory Value:**	N/A
Output Must Be Disabled for a Write Transaction:	N/A		

Description/Notes: The DPLL_FLAGS command returns one data byte of information with regards to the Digital Phase Lock Loop and frequency synchronization.

Note that this is not a fault status register. Therefore, even if one or more of this register's bits are asserted, this does not necessarily indicate a fault.

The following information can be read from the DPLL_FLAGS register:

BIT	MEANING
7	—
6	—
5	—
4	—
3	V_{DDH} is not high enough to perform a User Store (V_{DDH} < 10.8V)
2	SYNC_IN pin is floating/Loss of Synchronization in the DPLL
1	DPLL is Locked in Phase
0	DPLL is Locked in Frequency

Telemetry Commands

READ_VIN			
Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x88	**Format:**	LINEAR11
Data Bytes:	2	**Units:**	V
Transfer:	Read Word	**Factory Value:**	N/A
Output Must Be Disabled for a Write Transaction:	N/A		
Description/Notes:	See Section 18.1 of the PMBus Specification Part II. This register provides a readback for the input voltage telemetry. The actual value, in volts, can be determined by dividing the READ_VIN[10:0] value by 32.		

READ_VOUT			
Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x8B	**Format:**	ULINEAR16
Data Bytes:	2	**Units:**	V
Transfer:	Read Word	**Factory Value:**	N/A
Output Must Be Disabled for a Write Transaction:	N/A		
Description/Notes:	See Section 18.4 of the PMBus Specification Part II. The output voltage ADC measures the voltage between the SNSPx and SNSNx pins. The READ_VOUT command returns this measured voltage after scaling it by VOUT_SCALE_LOOP. Therefore, provided that the feedback resistors used are matched with the VOUT_SCALE_LOOP setting as per the MAX20860A data sheet guidelines, the READ_VOUT value can be interpreted as follows: Actual V_{OUT} = READ_VOUT x 2^{-10} The equation above only holds true if the VOUT_SCALE_LOOP setting (i.e., the scale factor) is equal to $R_{FB\_TOP}/(R_{FB\_TOP} + R_{FB\_BOTTOM})$. If this is not the case, the following extended equation must be used: Actual V_{OUT} = (READ_VOUT x 2^{-10}) x (scale factor) x $(R_{FB\_TOP} + R_{FB\_BOTTOM})/R_{FB\_TOP}$		

READ_IOUT			
Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x8C	**Format:**	LINEAR11
Data Bytes:	2	**Units:**	A
Transfer:	Read Word	**Factory Value:**	N/A
Output Must Be Disabled for a Write Transaction:	N/A		
Description/Notes:	See Section 18.5 of the PMBus Specification Part II. This register provides a readback for the output current telemetry. The actual value, in amps, can be determined by dividing the READ_IOUT[10:0] value by 4.		

READ_TEMPERATURE_1			
Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x8D	**Format:**	LINEAR11
Data Bytes:	2	**Units:**	°C
Transfer:	Read Word	**Factory Value:**	N/A
Output Must Be Disabled for a Write Transaction:	N/A		
Description/Notes:	See Section 18.6 of the PMBus Specification Part II. This register provides a readback for the IC junction temperature telemetry using an internal temperature sensor. The actual temperature value, in degrees Celsius, can be determined by dividing the READ_TEMPERATURE_1[10:0] value by 4.		

READ_TEMPERATURE_2			
Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x8E	**Format:**	LINEAR11
Data Bytes:	2	**Units:**	°C
Transfer:	Read Word	**Factory Value:**	N/A
Output Must Be Disabled for a Write Transaction:	N/A		
Description/Notes:	See Section 18.6 of the PMBus Specification Part II. This register provides a readback of the hottest external power-stage's junction temperature. The actual temperature value, in degrees Celsius, can be determined by dividing the READ_TEMPERATURE_2[10:0] value by 4.		

Inventory Information and Device Identification Commands

CAPABILITY

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x19	**Format:**	Bit Field
Data Bytes:	1	**Units:**	N/A
Transfer:	Read Byte	**Factory Value:**	0xD4
Output Must Be Disabled for a Write Transaction:	N/A		

Description/Notes: See Section 11.12 of the PMBus Specification Part II.

This register provides a summary of the PMBus optional communication protocols supported by this device.

The following features are supported:

- Packet error checking
- 1MHz bus speed
- SMBALERT#
- LINEAR11 numeric format
- AVSBus

PMBUS_REVISION

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x98	**Format:**	Bit Field
Data Bytes:	1	**Units:**	N/A
Transfer:	Read Byte	**Factory Value:**	0x33
Output Must be Disabled for a Write Transaction:	N/A		

Description/Notes: See Section 22.1 of the PMBus Specification Part II.

This command indicates the revisions of PMBus Specification Part I and PMBus Specification Part II that this device is compliant to.

The PMBUS_REVISION command is fixed to the following bit values:

BIT [7:4]	PMBus Specification Part I
0x3	Revision 1.3

BIT [3:0]	PMBus Specification Part II
0x3	Revision 1.3

IC_DEVICE_ID

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0xAD	**Format:**	ASCII String
Data Bytes:	9	**Units:**	N/A
Transfer:	Read Block	**Factory Value:**	See Description
Output Must Be Disabled for a Write Transaction:	N/A		
Description/Notes:	See Section 22.2.7 of the PMBus Specification Part II. IC_DEVICE_ID returns a 9-character ASCII string used to represent the part number of the IC. For this part, this command reads: “MAX20860A”.		

IC_DEVICE_REV

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0xAE	**Format:**	ASCII String
Data Bytes:	8	**Units:**	N/A
Transfer:	Read Block	**Factory Value:**	See Description
Output Must Be Disabled for a Write Transaction:	N/A		
Description/Notes:	See Section 22.2.8 of the PMBus Specification Part II. IC_DEVICE_REV returns an 8-character ASCII string used to represent the die type and revision of the IC.		

Security Commands

WRITE_PROTECT

Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x10	**Format:**	Bit Field
Data Bytes:	1	**Units:**	N/A
Transfer:	Read/Write Byte	**Factory Value:**	0x20
Output Must Be Disabled for a Write Transaction:	No		

Description/Notes: See Section 11.1 of the PMBus Specification Part II.

Only the following values of WRITE_PROTECT are supported:

DATA BYTE VALUE	MEANING
0x80	Only the following command can be written to: • WRITE_PROTECT
0x40	Only the following commands can be written to: • OPERATION • WRITE_PROTECT
0x20	Only the following commands can be written to: • OPERATION • ON_OFF_CONFIG • WRITE_PROTECT • VOUT_COMMAND
0x00	Enable writes to all commands.

Note that Send Byte transactions are also impacted by the WRITE_PROTECT setting, despite them not being categorized as write transactions. This is to extend security restrictions to highly impactful commands such as STORE_USER_ALL and RESTORE_USER_ALL.

Memory and Storage Commands

STORE_USER_ALL			
Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x15	**Format:**	N/A
Data Bytes:	0	**Units:**	N/A
Transfer:	Send Byte	**Factory Value:**	N/A
Output Must Be Disabled for a Write Transaction:	Yes		
Description/Notes:	See Section 11.6 of the PMBus Specification Part II. When the STORE_USER_ALL command is sent, the contents of the working memory (volatile RAM) are written to the device's nonvolatile memory as a "User Store". To successfully execute the STORE_USER_ALL command, there must be at least one unit of OTP memory available, as reported by the REMAINING_STORES command. If STORE_USER_ALL is sent when REMAINING_STORES = 0 (meaning all User Stores have been utilized), then the command is NACK'd. The MAX20860A supports up to 18 possible User Stores. Note that if the device starts with a REMAINING_STORES of 0x13 (19 available stores), then the first of these User Stores is a "dummy store". The user will need to exhaust this extra User Store and do a power cycle before being able to use the User Store feature.		

RESTORE_USER_ALL			
Reference:	Standard Command	**Stored in Nonvolatile Memory:**	No
Command Code:	0x16	**Format:**	N/A
Data Bytes:	0	**Units:**	N/A
Transfer:	Send Byte	**Factory Value:**	N/A
Output Must Be Disabled for a Write Transaction:	Yes		
Description/Notes:	See Section 11.7 of the PMBus Specification Part II. The RESTORE_USER_ALL command instructs the device to copy the contents of the nonvolatile memory to matching locations in the working memory. The settings stored in the most recently executed User Store are the ones that get copied. To successfully execute the RESTORE_USER_ALL command, PMBus command data must have been previously saved at least once using the STORE_USER_ALL command. If RESTORE_USER_ALL is sent when REMAINING_STORES = 18 (no PMBus data has been stored), the command is NACK'd and bit 7 of STATUS_CML is set.		

REMAINING_STORES

Reference:	Analog Devices Specific	**Stored in Nonvolatile Memory:**	No
Command Code:	0xDD	**Format:**	Unsigned Integer
Data Bytes:	0	**Units:**	N/A
Transfer:	Read Byte	**Factory Value:**	0x12
Output Must Be Disabled for a Write Transaction:	N/A		
Description/Notes:	This command returns a count of the remaining units of nonvolatile memory, where each unit can contain one User Store worth of data. Note that if the device starts with a REMAINING_STORES of 0x13 (19 available stores), then the first of these User Stores is a “dummy store”. The user will need to exhaust this extra User Store and do a power cycle before being able to use the User Store feature.		

RESTORE_ADI_ALL

Reference:	Analog Devices Specific	**Stored in Nonvolatile Memory:**	No
Command Code:	0xEA	**Format:**	N/A
Data Bytes:	0	**Units:**	N/A
Transfer:	Send Byte	**Factory Value:**	N/A
Output Must Be Disabled for a Write Transaction:	Yes		
Description/Notes:	This command restores all PMBus commands to their factory values in working memory (volatile RAM). To make the factory PMBus command values persist through a power cycle, it is necessary to follow RESTORE_ADI_ALL with the STORE_USER_ALL command.		

SMBALERT#

The MAX20860A adheres to Section A.2 of Revision 3.0 of the SMBus Specification, as well as Section 10.3 of Revision 1.3 of the PMBus Specification Part II. These outline the required behavior of the SMBALERT# signal.

The purpose of the SMBALERT# signal is to notify the user or the host device that the part wishes to communicate. If the part identifies a fault or warning, it responds by flagging the appropriate status bit and pulling the SMBALERT# signal low (provided that the status bit has not already been masked using the *SMBALERT_MASK* command). By default, all status bits in the MAX20860A are unmasked and therefore pull the SMBALERT# signal low.

Even once all unmasked fault conditions and their respective status bits have been cleared, the SMBALERT# signal will stay low until one of the following conditions is met:

- A CLEAR_FAULTS command is sent.
- The part is reenabled (after being disabled).
- An Alert Response Address has been received.

If any of the items listed above is executed before all unmasked fault conditions and their respective status bits have been cleared, the SMBALERT# signal will immediately be reasserted low.

Alert Response Address (ARA)

The SMBus Alert Response Address has a predefined value of 0001 100b. This address is reserved for the ARA and cannot be used for any other purpose.

When the host performs a read operation using the ARA, any device that has pulled SMBALERT# low will respond to the read request by sending its respective device address. Once the host acknowledges (ACKs) the device address, the device will stop asserting SMBALERT# low.

If there are multiple devices pulling SMBALERT# low, the device with the lowest device address will respond to the ARA first. The SMBALERT# signal will continue to stay low after this device has stopped asserting it due to the other devices that are asserting it too. Because SMBALERT# has stayed low at the completion of the message transfer, the host will know to read the ARA again. It will continue to do so until all device's pulling SMBALERT# low have responded, thus allowing the signal to be released high.

The ARA command packet format uses a modified Receive Byte operation, as shown in *Figure 11*.

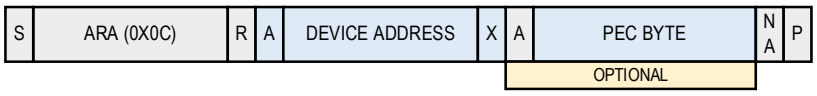

Figure 11. ARA Modified Receive Byte Format

Note that the device address can be followed by either a Read or Write bit – it is "Not Important" (X).

Memory Loading and Nonvolatile PMBus Memory

The MAX20860A allows users to store active PMBus command settings in nonvolatile memory, therefore allowing these settings to persist through device power cycling, as well as granting the ability to be recalled at demand. This feature is implemented using one-time programmable (OTP) memory. Each successful attempt to store the PMBus command data consumes 16 bytes, for a total of 18 possible stores.

Order of Memory Loading and Precedence

The MAX20860A adheres to Section 6.1 of Revision 1.3 of the PMBus Specification Part II. This outlines the order with which PMBus command parameters are set in a PMBus device.

When the MAX20860A is powered up, it performs automatic initialization of the working memory and sequentially loads settings from several sources (hard-coded logic, pin-strap settings, and field-programmable nonvolatile memory). This is done in the order outlined by the PMBus Specification. Moreover, when new settings are loaded for a command that has already been programmed from a different source, the new settings will overwrite the old values that are already in the working memory.

This is illustrated in *Figure 12*, where the numbers indicate the order with which memory is loaded upon initial power up, whereas the various PMBus memory commands shown underneath the numbers can be used to store or load memory after the part has already been initialized.

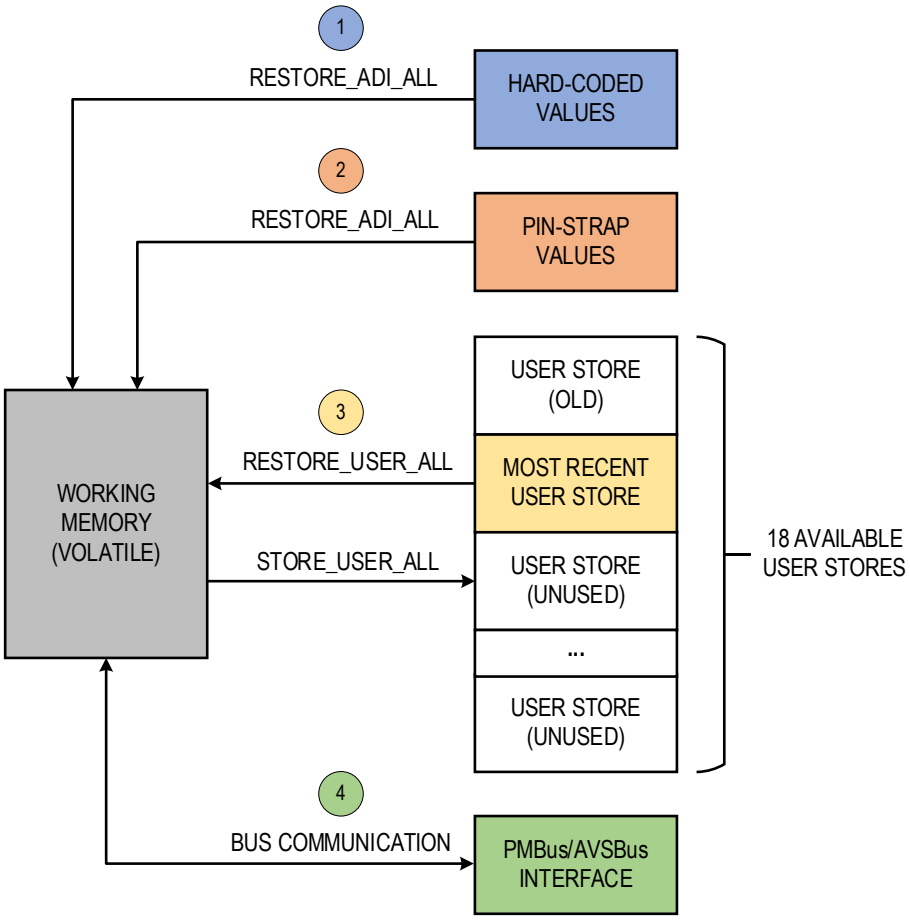

Figure 12. Memory Loading Order

As shown in *Figure 12*, upon initial power-up, the first set of values loaded into the working memory are any hard-coded “factory” values determined by the IC design.

The second set of values loaded into the working memory come from the pin-strap resistors external to the IC (R_PGM0 and R_PGM1). If any of the values programmed by the pin-strap resistors are for commands that have already been hard-coded, the pin-strap values will overwrite the previously loaded hard-coded values.

The third set of values are loaded from nonvolatile memory, provided that at least one user store has been executed. The values loaded are the settings that have been saved in the most recent User Store. If any of the values loaded from nonvolatile memory are for commands that have already either been hard-coded or been programmed using pin-strap resistors, the user store values will overwrite the previous settings.

And finally, once the device has completed its initialization by loading settings from the three prior sources, it will begin to accept commands from the PMBus and AVSBus interfaces. Provided that their specific prerequisites have been met, commands written using PMBus or AVSBus will always overwrite any prior settings.

Procedure for Executing and Restoring User Stores

To execute a User Store and save the device’s active settings in nonvolatile memory, the STORE_USER_ALL command needs to be sent through PMBus. For the store to be successful, the part must first be disabled and it must be ensured that the total available stores have not been exhausted. The remaining number of stores can be checked by reading the REMAINING_STORES command.

If multiple User Stores have been executed, only the most recent User Store settings can be recalled, which can be done by sending the RESTORE_USER_ALL command. And as described earlier, when the device first powers up, it will also initialize with the settings from the most recent User Store.

The MAX20860A also supports the manufacturer-specific RESTORE_ADI_ALL command. Sending this command causes the device to return to a “fresh” state by loading all hard-coded and pin-strap dependent command values. If the user wishes for the part to also initialize in its “fresh” state, the RESTORE_ADI_ALL command needs to be followed by a STORE_USER_ALL command.

Each of these commands is fully described in the *Memory and Storage Commands* section.

User Store Contents

Table 3 lists all the commands and their respective bits that have their active settings saved in nonvolatile memory after a User Store.

Table 3. Commands and Bits in User Store

COMMAND CODE	COMMAND NAME	BITS	DESCRIPTION
01h	OPERATION	6	Selects whether disabling regulation by setting OPERATION[7] to 0 results in a soft-shutdown or if switching stops immediately
		5:4	Selects whether to accept V_{OUT} setpoint commands from PMBus or AVSBus
02h	ON_OF_CONFIG	2	Selects whether the EN input pins are ignored or not when determining if the outputs are enabled/disabled
		0	Selects whether toggling EN to low results in a soft-shutdown or if switching stops immediately
1Bh	SMBALERT_MASK	N/A	Masks a faults ability to assert SMBALERT#
21h	VOUT_COMMAND	15:0	Selects the V_{OUT} setpoint
27h	VOUT_TRANSITION_RATE	15:0	Selects the soft-startup/shutdown slew rate
29h	VOUT_SCALE_LOOP	15:0	Selects the V_{OUT} scale factor
33h	FREQUENCY_SWITCH	15:0	Selects the switching frequency
37h	INTERLEAVE	15:0	Selects the phase delay between the rising edges of the SYNC_IN signal and the first output's first PWM signal
41h	VOUT_OV_FAULT_ RESPONSE	5:3	Selects whether the regulator attempts to restart or not after a V_{OUT} overvoltage condition
47h	IOUT_OC_FAULT_ RESPONSE	7:6	Enables/disables the response to an I_{OUT} overcurrent condition
		5:3	Selects whether the regulator attempts to restart or not after an I_{OUT} overcurrent condition
51h	OT_WARN_LIMIT	15:0	Selects the overtemperature warning threshold
56h	VIN_OV_FAULT_ RESPONSE	7:6	Configures the response to a V_{DDH} overvoltage condition
D4h	RAMP_SLP	7:0	Selects the slope values for the internal compensation ramps
E7h	RVGA_GAIN	7:0	Configures the voltage loop gain
E8h	ZERO_SEL	7:0	Configures the voltage loop zero
E9h	AMS_OPT	7:0	Enables/disables AMS
F1h	MFR_VIN_UV_FAULT_ LIMIT_SETPOINT	0	Configures the V_{DDH} UVLO threshold for dual-phase operation

All commands listed in *Table 3* are fully described in their designated sections earlier in the document.

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	7/25	Initial release	—