MAX20751 PMBus APPLICATION NOTE

1.0 MAX20751 PMBus INTERFACE OVERVIEW

The MAX20751 master controller includes a serial bus (PMBus) that supports advanced regulator monitoring and control capabilities. The PMBus interface supports a subset of the PMBus 1.2 and SMBus 2.0 specifications. More information about these specifications can be found at www.pmbus.org and www.smbus.org. The following features are supported.

- Static PMBus Address programming with external resistors
- Compliant with high-power SMBus DC specification (3.1.3)
- Supported PMBus Protocols
  - Write Byte/Word (5.5.4)
  - Read Byte/Word (5.5.5)
  - Send Byte (5.5.2)
  - Block Write
  - Block Read
  - Block Write Block Read Process Call
  - Packet Error Checking Mechanism Support (5.4)
- SMBALERT# Signal via ALERTB Pin
- Clock Stretching

1.1 Monitoring Functions

The following monitoring functions are available via the MAX20751 PMBus interface.

- Various Fault Status
- Manufacturer's Device ID
- Manufacturer's Model
- Manufacturer's Revision
- Manufacturer's Serial Number
- Input Voltage
- Output Voltage
- Temperature
- Power Output
- Output Current
- System Fault Log (saves up to 5 system faults in chronological order, fault log must be cleared before other faults will be logged)
- PMBus revision

1.2 Control Functions

- Overtemperature Warning and Fault Thresholds
- Undertemperature Warning Threshold
- Input Voltage Overvoltage (OV) Warning and Fault Thresholds
- Input Voltage Undervoltage (UV) Warning and Fault Thresholds
- Output Current Warning Threshold
- Output Voltage OV Warning Threshold
- Output Voltage UV Warning and Fault Thresholds
- Output Voltage Command
- Output Voltage Margin Low and High Thresholds
- Power Good On and Off Threshold
- Operation – On and Off Configuration
- Restore/Store Default and User Settings
- Startup T_{ON} and T_{OFF} Delay Timing
- Maximum T_{ON} Fault
- Switching Frequency
- Orthogonal Current Rebalance Gain
- Output Voltage Slew Rate
- Fault Responses

1.3 Calibration Features

- Output current gain and offset
- Input voltage divider ratio and offset
- Output voltage offset

2.0 MAX20751 PMBus PROTOCOL

2.1 Write/Read Format

The MAX20751 PMBus interface supports single-byte and dual-byte (word) register read and write, block read and write, block write-block read process call, and send byte protocols. Table 1 through Table 8 show the formats used for all supported operations. Packet error checking can be used on any transaction. Table 9 shows all PMBus commands supported by the MAX20751 controller.

Table 1: Read Byte Format

# of bits	1	7	1	1	8	1	1	7	1	1	8	1	1
	S	MAX20751 PMBus Address	W	ACK	Command	ACK	S	MAX20751 PMBus Address	R	ACK	Data Byte	NACK	P

Table 2: Write Byte Format

# of bits	1	7	1	1	8	1	8	1	1
	S	MAX20751 PMBus Address	W	ACK	Command	ACK	Data Byte	ACK	P

Table 3: Read Word Format

# of bits	1	7	1	1	8	1	1	7	1	1	8	1	8	1	1
	S	MAX20751 PMBus Address	W	ACK	Command	ACK	S	MAX20751 PMBus Address	R	ACK	Data Byte Low	ACK	Data Byte High	NACK	P

Table 4: Write Word Format

# of bits	1	7	1	1	8	1	8	1	8	1	1
	S	MAX20751 PMBus Address	W	ACK	Command	ACK	Data Byte Low	ACK	Data Byte High	ACK	P

Table 5: Send Byte Format

# of bits	1	7	1	1	8	1	1
	S	MAX20751 PMBus Address	W	ACK	Data Byte	ACK	P

Table 6: Block Write Format

# of bits	1	7	1	1	8	1	8	1	8	1
	S	MAX20751 PMBus Address	W	ACK	Command	ACK	Byte Count = N	ACK	Data Byte 1	ACK
					8	1	8	1	1	
					Data Byte 2	ACK	…… Data Byte N	ACK	P	

Table 7: Block Read Format

# of bits	1	7	1	1	8	1	1	7	1	1	8	1	1
	S	MAX20751 PMBus Address	W	ACK	Command	ACK	S	MAX20751 PMBus Address	R	ACK	Byte Count = N	ACK	P
					8	1	8		1		8	1	1
					Data Byte 1	ACK	Data Byte 2		ACK	……	Data Byte N	NACK	P

Table 8: Block Write Block Read Process Call

# of bits	1	7	1	1	8	1	8	1	8	1	8	1
ACK	S	MAX20751 PMBus Address	W	ACK	Command	ACK	Byte Count = N	ACK	Data Byte 1	ACK	Data Byte 2	ACK
					8	1		1	7		1	1
				……	Data Byte N	ACK	…….	SR	MAX20751 PMBus Address		R	ACK
					8	1	8	1	8	1		
				…….	Byte Count = N	ACK	Data Byte 1	ACK	Data Byte 2	ACK		
					8	1	1					
				…….	Data Byte N	NACK	P					

Table 1–8 Legend

S = Start Condition: Clock and Data lines initially high
Data transitions low while clock is high
clock transitions low

P = Stop Condition: Clock and Data lines initially low
Clock transitions high while data is low
Data transitions high

R = Read bit (Logic High)

W = Write bit (Logic Low)

Command = Relevant MAX20751 PMBus register

ACK = Acknowledge (logic-low)

NACK = Not acknowledge (logic-high)

SR = Repeated Start condition

Note 1: Shaded areas in Tables 1–8 are driven by the MAX20751. Unshaded areas are driven by bus host.

2: Packet Error Check (PEC) can be used in conjunction with these commands.

3: The PEC is a CRC-8 error checking byte, calculated on all the message bytes.

4: Block write/block read and block write-block read process call commands support up to two data bytes.

Table 9: MAX20751 PMBus Command List

Command Code (Reg)	PMBus Command Name	Type	Units	Format	N	Two's Complement	Default	High Byte								Low Byte								Stored in NV_OTP Upon STORE_USER_ALL Command	Factory Default Stored in NV_OTP
								b7	b6	b5	b4	b3	b2	b1	b0	b7	b6	b5	b4	b3	b2	b1	b0		
01h	OPERATION	R/W Byte	—				00h									OP(7)	OP(6)	OP(5)	OP(4)	OP(3)	OP(2)	Any Value	Any Value	–	Y
02h	ON_OFF_CONFIG	R/W Byte	—				17h									0	0	0	1	Config (3)	Config (2)	1	Config (0)	Y	Y
03h	CLEAR_FAULTS	Send Byte	—				—																		–
12h	RESTORE_DEFAULT_ALL	Send Byte	—				—																	–	–
15h	STORE_USER_ALL	Send Byte	—				—																	–	–
16h	RESTORE_USER_ALL	Send Byte	—				—																	–	–
19h	CAPABILITY	R Byte	—				B0h									1	0	1	1	0	0	0	0	–	–
1Ah	QUERY	Block Write- Block Read Process Call	—				—																	–	–
1Bh	SMBALERT_MASK	W Word/ Block Write- Block Read Process Call	—				—																	–	–
20h	VOUT_MODE	R Byte	—				20h									0	0	1	0	0	0	0	0	–	–
21h	VOUT_COMMAND	R/W Word		VID		N	Table 14	0	0	0	0	0	0	0	0	VoutCmd(7)	VoutCmd(6)	VoutCmd(5)	VoutCmd(4)	VoutCmd(3)	VoutCmd(2)	VoutCmd(1)	VoutCmd(0)	Y	–
24h	VOUT_MAX	R/W Word		VID		N	00FFh (1.52V)	0	0	0	0	0	0	0	0	Vmax (7)	Vmax(6)	Vmax (5)	Vmax (4)	Vmax (3)	Vmax (2)	Vmax (1)	Vmax (0)	Y	Y
25h	VOUT_MARGIN_HIGH	R/W Word		VID		N	00FFh (1.52V)	0	0	0	0	0	0	0	0	Vhigh (7)	Vhigh (6)	Vhigh (5)	Vhigh (4)	Vhigh (3)	Vhigh (2)	Vhigh (1)	Vhigh (0)	Y	Y
26h	VOUT_MARGIN_LOW	R/W Word		VID		N	0001h (0.25V)	0	0	0	0	0	0	0	0	Vlow (7)	Vlow (6)	Vlow (5)	Vlow (4)	Vlow (3)	Vlow (2)	Vlow(1)	Vlow(0)	Y	Y
38h	IOUT_CAL_GAIN	R/W Word	Ω	Direct		Y	0000h (0Ω)	Igain (15)	Igain (14)	Igain (13)	Igain (12)	Igain (11)	Igain (10)	Igain (9)	Igain (8)	Igain (7)	Igain (6)	Igain (5)	Igain (4)	Igain (3)	Igain (2)	Igain (1)	Igain (0)	Y	Y
39h	IOUT_CAL_OFFSET	R/W Word	A	Direct		Y	0000h (0A)	Ioff (15)	Ioff (14)	Ioff (13)	Ioff (12)	Ioff (11)	Ioff(10)	Ioff(9)	Ioff(8)	Ioff(7)	Ioff(6)	Ioff(5)	Ioff(4)	Ioff(3)	Ioff(2)	Ioff(1)	Ioff(0)	Y	Y
42h	VOUT_OV_WARN_LIMIT	R/W Word	V	VID		N	Table 15	0	0	0	0	0	0	0	0	Vown (7)	Vown (6)	Vown (5)	Vown (4)	Vown (3)	Vown (2)	Vown (1)	Vown (0)	Y	-
43h	VOUT_UV_WARN_LIMIT	R/W Word	V	VID		N	Table 15	0	0	0	0	0	0	0	0	Vuwn (7)	Vuwn (6)	Vuwn (5)	Vuwn (4)	Vuwn (3)	Vuwn (2)	Vuwn (1)	Vuwn (0)	Y	-
44h	VOUT_UV_FAULT_LIMIT	R/W Word	V	VID		N	Table 15	0	0	0	0	0	0	0	0	Vuflt (7)	Vuflt (6)	Vuflt (5)	Vuflt (4)	Vuflt (3)	Vuflt (2)	Vuflt (1)	Vuflt (0)	Y	-
45h	VOUT_UV_FAULT_RESPONSE	R/W Byte	-				00h									off on Flt	0	0	0	0	0	0	0	Y	Y
47h	IOUT_OC_FAULT_RESPONSE	R/W Byte	-				B9h									1	0	1	1	1	0	0	1	Y	Y
4Ah	IOUT_OC_WARN_LIMIT	R/W Word	A	Linear	-1	N	FBFFh (511.5A)	1	1	1	1	1	0	Iwn (9)	Iwn (8)	Iwn(7)	Iwn(6)	Iwn(5)	Iwn(4)	Iwn(3)	Iwn(2)	Iwn(1)	Iwn(0)	Y	–
4Fh	OT_FAULT_LIMIT	R/W Word	°C	Linear	0	Y	0096h (150°C)	0	0	0	0	0	OTFlt (10)	OTFlt (9)	OTFlt (8)	OTFlt (7)	OTFlt (6)	OTFlt (5)	OTFlt (4)	OTFlt (3)	OTFlt (2)	OTFlt (1)	OTFlt (0)	Y	Y
50h	OT_FAULT_RESPONSE	R/W Byte	-				00h									off on Flt	0	0	0	0	0	0	0	Y	Y
51h	OT_WARN_LIMIT	R/W Word	°C	Linear	0	Y	0087h (135°C)	0	0	0	0	0	OTwn (10)	OTwn (9)	OTwn (8)	OTwn (7)	OTwn (6)	OTwn (5)	OTwn (4)	OTwn (3)	OTwn (2)	OTwn (1)	OTwn (0)	Y	Y
52h	UT_WARN_LIMIT	R/W Word	°C	Linear	0	Y	07D8h (-40°C)	0	0	0	0	0	UTwn (10)	UTwn (9)	UTwn (8)	UTwn (7)	UTwn (6)	UTwn (5)	UTwn (4)	UTwn (3)	UTwn (2)	UTwn (1)	UTwn (0)	Y	Y
55h	VIN_OV_FAULT_LIMIT	R/W Word	V	Linear	-5	N	D9E0h (15V)	1	1	0	1	1	0	OVflt (9)	OVFlt (8)	OVflt (7)	OVFlt (6)	OVFlt (5)	OVFlt (4)	OVFlt (3)	OVFlt (2)	OVFlt (1)	OVFlt (0)	Y	Y
56h	VIN_OV_FAULT_RESPONSE	R/W Byte	—				00h									off on Flt	0	0	0	0	0	0	0	Y	Y
57h	VIN_OV_WARN_LIMIT	R/W Word	V	Linear	-5	N	D9DDh (14.9V)	1	1	0	1	1	0	OVwn(9)	OVwn(8)	OVwn (7)	OVwn (6)	OVwn (5)	OVwn (4)	OVwn (3)	OVwn (2)	OVwn (1)	OVwn (0)	Y	Y

Table 9: MAX20751 PMBus Command List

Command Code (Reg)	PMBus Command Name	Type	Units	Format	N	Two's Complement	Default	High Byte								Low Byte								Stored in NV_OTP Upon STORE_USER_ALL Command	Factory Default Stored in NV_OTP
								b7	b6	b5	b4	b3	b2	b1	b0	b7	b6	b5	b4	b3	b2	b1	b0		
58h	VIN_UV_WARN_LIMIT	R/W Word	V	Linear	-5	N	D895h (4.66V)	1	1	0	1	1	0	UVwn(9)	UVwn(8)	UVwn (7)	UVwn (6)	UVwn (5)	UVwn (4)	UVwn (3)	UVwn (2)	UVwn (1)	UVwn (0)	Y	Y
59h	VIN_UV_FAULT_LIMIT	R/W Word	V	Linear	-5	N	D892h (4.56V)	1	1	0	1	1	0	UVflt(9)	UVFlt(8)	UVflt (7)	UVFlt (6)	UVFlt (5)	UVFlt (4)	UVFlt (3)	UVFlt (2)	UVFlt (1)	UVFlt (0)	Y	Y
5Ah	VIN_UV_FAULT_RESPONSE	R/W Byte	–				00h									off on Flt	0	0	0	0	0	0	0	Y	Y
5Eh	POWER_GOOD_ON	R/W Word	V	VID		N	Table 15	0	0	0	0	0	0	0	0	Pgon (7)	Pgon (6)	Pgon (5)	Pgon (4)	Pgon (3)	Pgon (2)	Pgon (1)	Pgon (0)	Y	-
5Fh	POWER_GOOD_OFF	R/W Word	V	VID		N	Table 15	0	0	0	0	0	0	0	0	Pgoff (7)	Pgoff (6)	Pgoff (5)	Pgoff (4)	Pgoff (3)	Pgoff (2)	Pgoff (1)	Pgoff (0)	Y	-
60h	TON_DELAY	R/W Word	ms	Direct		N	0800h (0ms)	Ton(15)	Ton(14)	Ton (13)	Ton (12)	Ton (11)	Ton(10)	Ton(9)	Ton(8)	Ton(7)	Ton(6)	Ton(5)	Ton(4)	Ton(3)	Ton(2)	Ton(1)	Ton(0)	Y	Y
62h	TON_MAX_FAULT_LIMIT	R/W Word	ms	Direct		N	0800h (disabled)	Ton-flt(15)	Ton-flt(14)	Ton-flt(13)	Ton-flt(12)	Ton-flt(11)	Ton-flt(10)	Ton-flt(9)	Ton-flt(8)	Tonflt (7)	Tonflt (6)	Tonflt (5)	Tonflt (4)	Tonflt (3)	Tonflt (2)	Tonflt (1)	Tonflt (0)	Y	Y
63h	TON_MAX_FAULT_RESPONSE	R/W Byte	–				00h									off on Flt	0	0	0	0	0	0	0	Y	Y
64h	TOFF_DELAY	R/W Word	ms	Direct		N	0800h	Toff(15)	Toff(14)	Toff(13)	Toff(12)	Toff(11)	Toff(10)	Toff(9)	Toff(8)	Toff(7)	Toff(6)	Toff(5)	Toff(4)	Toff(3)	Toff(2)	Toff(1)	Toff(0)	Y	Y
78h	STATUS_BYTE	R/W Byte	–				-									Busy	off	OVP	OCP	UVLO	Temp	CML	0	—	—
79h	STATUS_WORD	R/W Word	–				-	Vout	Pout	Input	Mfr_spec	PG	0	0	0	Busy	off	OVP	OCP	UVLO	Temp	CML	0	—	—
7Ah	STATUS_VOUT	R/W Byte	–				-									0	OVP_warn	UVP_warn	UVP_flt	Vout-Max	Ton_Max	0	0	—	—
7Bh	STATUS_IOUT	R/W Byte	–				-									OCP_flt	0	OCP_warn	0	0	0	0	0	—	—
7Ch	STATUS_INPUT	R/W Byte	–				-									OVLO_flt	OVLO_warn	UVLO_warn	UVLO_flt	0	0	0	0	—	—
7Dh	STATUS_TEMPERATURE	R/W Byte	–				-									OTP_flt	OTP_warn	UTP_warn	0	0	0	0	0	—	—
7Eh	STATUS_CML	R/W Byte	–				-									Invalid cmd	Invalid data	Incor-rect PEC	0	0	0	Flt_other_c	0	—	—
80h	STATUS_MFR_SPECIFIC	R/W Byte	–													Flt Config	Flt Slave	OVP_flt	OVP_Umb	0	0	0	0	—	—
88h	READ_VIN	R Word	V	Linear	-5	N	-	1	1	0	1	1	0	Vin (9)	Vin (8)	Vin (7)	Vin (6)	Vin (5)	Vin (4)	Vin (3)	Vin (2)	Vin (1)	Vin (0)	—	—
8Bh	READ_VOUT	R Word		VID		N	-	0	0	0	0	0	0	0	0	Vout (7)	Vout (6)	Vout (5)	Vout (4)	Vout (3)	Vout (2)	Vout (1)	Vout (0)	—	—
8Ch	READ_IOUT	R Word	A	Linear	-1	Y	-	1	1	1	1	1	Iout (10)	Iout (9)	Iout (8)	Iout (7)	Iout (6)	Iout (5)	Iout (4)	Iout (3)	Iout (2)	Iout (1)	Iout (0)	—	—
8Dh	READ_TEMPERATURE_1	R Word	°C	Linear	0	Y	-	0	0	0	0	0	Temp (10)	Temp (9)	Temp (8)	Temp (7)	Temp (6)	Temp (5)	Temp (4)	Temp (3)	Temp (2)	Temp (1)	Temp (0)	—	—
96h	READ_POUT	R Word	W	Linear	1	Y	-	0	0	0	0	1	Pout(10)	Pout(9)	Pout(8)	Pout (7)	Pout (6)	Pout (5)	Pout (4)	Pout (3)	Pout (2)	Pout (1)	Pout (0)	—	—
98h	PMBUS_REVISION	R Byte	–				22h									0	0	1	0	0	0	1	0	—	—
99h	MFR_ID	Block R/W	–				ascii"VT"	0	1	0	1	0	1	1	0	0	1	0	1	0	1	0	0	—	—
9Ah	MFR_MODEL	Block R/W	–				01h									0	0	0	0	0	0	0	1	Y	—
9Bh	MFR_REVISION	Block R/W	–				00h									0	0	0	0	0	0	0	0	Y	—
9Eh	MFR_SERIAL	Block R/W	–				0000h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Y	—
	Manufacturer-Specific																								
D1h	VIN_RATIO	R/W Word	–	Linear	-11	N	A88Ch	1	0	1	0	1	0	ratio (9)	ratio (8)	ratio (7)	ratio (6)	ratio (5)	ratio (4)	ratio (3)	ratio (2)	ratio (1)	ratio (0)	Y	Y
D6h	FSW	R/W Byte					Table 15									0	0	0	0	0	FSW (2)	FSW (1)	FSW (0)	Y	—
D7h	HARDWARE FLAGS	R Word	–				—								vddh_uvlob	sense_p_open_core	rref	r_mramp	wdof	slave_fault	slave_popula-tion	slave_startup	pwm_open		
DDh	STORE_USER_ALL_NUM	R Byte	–				—									0	0	0	0	0	SNo (2)	SNo (1)	SNo (0)	—	—
E2h	FAULT_LOG1	R Byte	–				—									slave_fault	wdof	ocp_core	vddh_uv	0	ovp_umb_core	0	ovp_core	—	—
E3h	FAULT_LOG2	R Byte	–				—									slave_fault	wdof	ocp_core	vddh_uv	0	ovp_umb_core	0	ovp_core	—	—
E4h	FAULT_LOG3	R Byte	–				—									slave_fault	wdof	ocp_core	vddh_uv	0	ovp_umb_core	0	ovp_core	—	—
E5h	FAULT_LOG4	R Byte	–				—									slave_fault	wdof	ocp_core	vddh_uv	0	ovp_umb_core	0	ovp_core	—	—

Table 9: MAX20751 PMBus Command List

Command Code (Reg)	PMBus Command Name	Type	Units	Format	N	Two's Complement	Default	High Byte								Low Byte								Stored in NV_OTP Upon STORE_USER_ALL Command	Factory Default Stored in NV_OTP
								b7	b6	b5	b4	b3	b2	b1	b0	b7	b6	b5	b4	b3	b2	b1	b0		
E6h	FAULT_LOG5	R Byte	–				-									slave_fault	wdof	ocp_core	vddh_uv	0	ovp_umb_core	0	ovp_core	—	—
E7h	CLEAR FAULT_LOG	W Byte	–				-									0	0	0	0	0	0	0	clear	—	—
E8h	FIRMWARE_REVISION	R Byte	–				–									Sw (7)	Sw (6)	Sw (5)	Sw (4)	Sw (3)	Sw (2)	Sw (1)	Sw (0)	—	—
ECh	VOUT_COMMAND_FINE	R/W Byte	–				03h (0mV)									0	0	0	0	0	fine (2)	fine (1)	fine (0)	Y	Y
EDh	VIN_CAL_OFFSET	R/W Word	V	Direct		Y	0000h (0V)	Vinoff (15)	Vinoff (14)	Vinoff (13)	Vinoff (12)	Vinoff (11)	Vinoff (10)	Vinoff (9)	Vinoff (8)	Vinoff (7)	Vinoff (6)	Vinoff (5)	Vinoff (4)	Vinoff (3)	Vinoff (2)	Vinoff (1)	Vinoff (0)	Y	Y
EFh	SLEW_RATE	R/W Byte	–				Table 14									0	0	0	0	0	0	Slew (1)	Slew (0)	Y	—
F1h	OCR_GAIN	R/W Byte	–				01h (4x)									0	0	0	0	0	0	OCR (1)	OCR (0)	Y	Y
F2h	OCS_TON	R/W Byte	–				01h (1.3µs)									0	0	0	0	0	0	Swch (1)	Swch (0)	Y	Y

2.2 Configuring the MAX20751 Address

MAX20751 PMBus address is set through R_SEL0 and R_SEL1. Eight unique addresses are possible as shown in Table 10.

Table 10: MAX20751 PMBus Address Format

PMBus Address (ADDR) Bit Number	Bit Value
<7>	1
<6>	1
<5>	1
<4>	0
<3>	R_SEL0 bit 4
<2>	R_SEL1 bit 4
<1>	R_SEL1 bit 3

3.0 STATUS REPORTING

MAX20751 supports the following status reporting registers, STATUS_BYTE, STATUS_WORD, STATUS_INPUT, STATUS_VOUT, STATUS_IOUT, STATUS_TEMPERATURE, STATUS_CML, and STATUS_MFR_SPECIFIC. Figure 1 contains a detailed summary of the status register contents. CLEAR_FAULT (Reg_03H) is used to clear any fault bits that have been set. At the same time, the device clears its ALERTB signal output. Sending the CLEAR_FAULT command does not cause a unit that has shut down due to a fault to restart. The OVP_FAULT, OVP_UMBRELLA, FAULT_SLAVE, FAULT_CONFIG, and WDOF faults will only be cleared by device V_{DD} or V_{DD33} power cycling. If the fault is still present, the fault bit will be set again.

STATUS_BYTE returns more critical faults. STATUS_WORD returns two bytes of fault information. The low byte of STATUS_WORD is the same register as the STATUS_BYTE command. Based on the information in these summary registers, the host can get more information by reading more specific fault status registers.

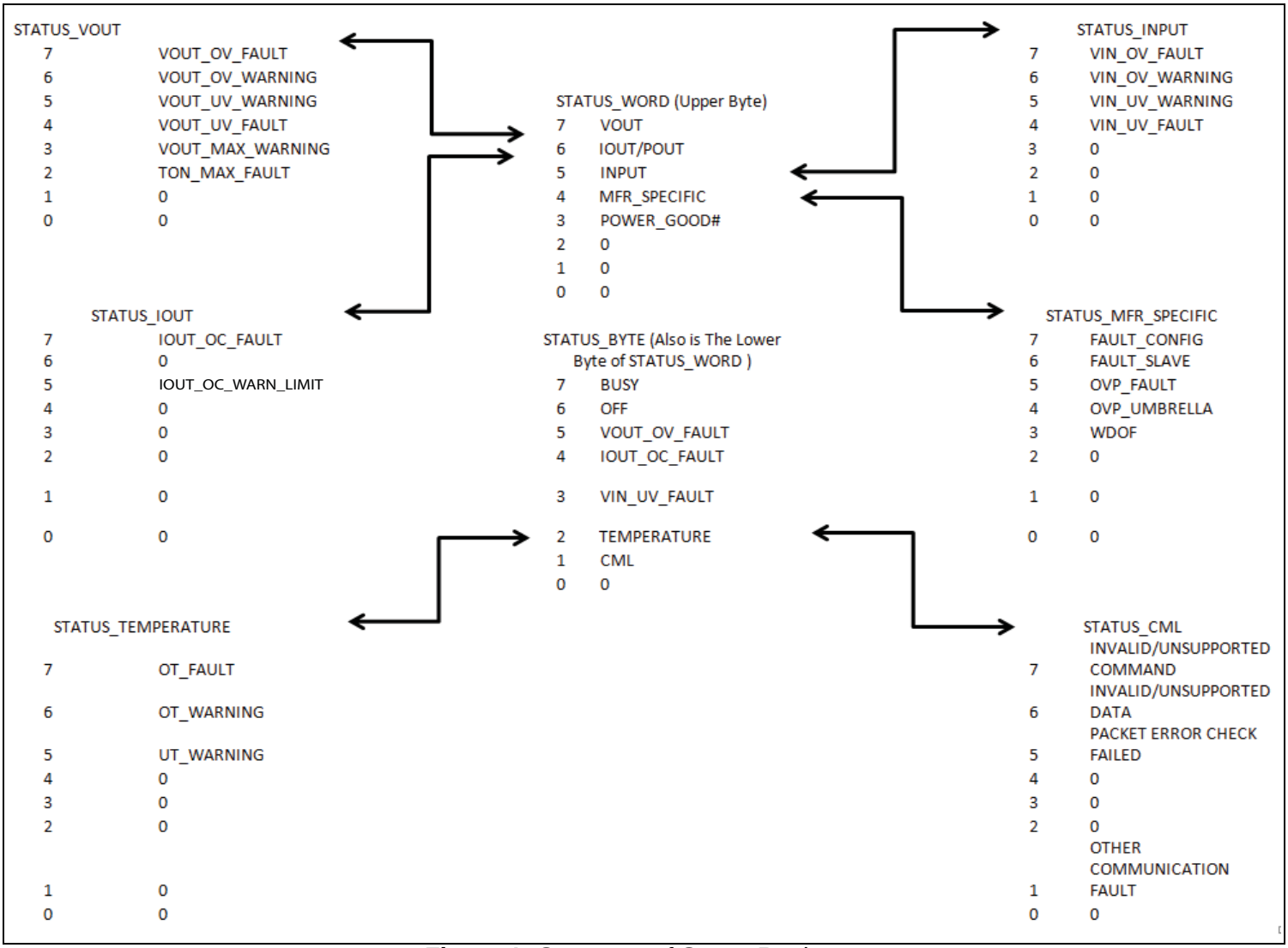

Figure 1: Summary of Status Registers

Table 11: STATUS_WORD

Byte	Bit Number	Status Bit Name	Meaning
High	7	V_{OUT}	An output voltage fault or warning has occurred.
	6	I_{OUT}/P_{OUT}	An output current fault or warning has occurred.
	5	Input	An input voltage, input current, or input power fault or warning has occurred.
	4	MFR_SPECIFIC	A manufacturer-specific fault or warning has occurred.
	3	Power_Good#	If this bit is set, power is "not good."
	2	NA	Not supported
	1	NA	Not supported
	0	NA	Not supported
Low	7	BUSY	A fault is asserted because the device was busy and unable to respond.
	6	OFF	This bit is asserted if the unit is not providing power to the output, regardless of the reason, including simply not being enabled.
	5	VOUT_OV_Fault	An output overvoltage fault has occurred.
	4	IOUT_OC_Fault	An output overcurrent fault has occurred.
	3	VIN_UV_Fault	An input under voltage fault has occurred.
	2	Temperature	A temperature fault or warning has occurred.
	1	CML	A communications, memory or logic fault has occurred.
	0	NA	Not supported

The MAX20751 has manufacturer-specific fault logs that save up to five system faults logs (Reg_E2h to Reg_E6h). Set CLEAR_FAULT_LOG (command E7h) to 1h followed by 0h clear the fault logs. Table 12 shows the fault log bit information.

Table 12: Faults Logs Bit Information

Bit #	Bit Name
7	SLAVE FAULT–OTP, Boost fault, VX short, VDDH OVLO, VDDH UVLO, VDD UVLO
6	WDOF–µC Watchdog Timer trip
5	OCP_CORE–Overcurrent Protection Fault
4	VIN_UV–Input Voltage Fault
3	0
2	OVP_UMB_CORE–Overvoltage Protection. Output voltage exceeds the maximum fixed (umbrella) level allowed.
1	0
0	OVP_CORE–Overvoltage Protection, tracking. Output voltage exceeds the overvoltage level that tracks the VOUT_COMMAND value.

Table 13: Hardware Flags

Byte	Bit Number	Hardware Flag	Meaning
Upper	7	0	None
	6	0	None
	5	0	None
	4	0	None
	3	0	None
	2	0	None
	1	0	None
	0	vddh_uvlob	A negated version of the undervoltage lockout (UVLO) of the VIN_UV pin. Low when the voltage on the VIN_UV pin is below the VIN_UV UVLO threshold.
Lower	7	sense_p_open_core	The SENSE_P pin is not connected (floating).
	6	rref	The resistor connected to R_REF pin is out of range.
	5	r_mramp	The resistor connected to MRAMP pin is out of range.
	4	wdof	Watchdog timer overflow (timeout).
	3	slave_fault	Slave IC fault (slave IC pulled TS_FAULTB pin low).
	2	slave_population	Slave ICs are not populated in the correct order.
	1	slave_startup	Slave IC fault occurred during startup of slave IC.
	0	pwm_open	A PWM pin is not connected (floating).

4.0 CONTROL

4.1 OPERATION and ON_OFF_CONFIG

The OPERATION command is used to control turn-on and turn-off in conjunction with the VR_ON pin. Exact control behavior is set by the ON_OFF_CONFIG command. The default value of the ON_OFF_CONFIG command is 17h. Bit 4 of ON_OFF_CONFIG must always be set to 1. Also note that the MAX20751 will not perform a soft-off ramp-down if ON_OFF_CONFIG is set to 1Bh and OPERATION is changed from 80h to 40h; the workaround for this is to set ON_OFF_CONFIG to 1Ah instead. Also note that only active-high VR_ON polarity is supported.

4.2 Output Voltage Control

The following registers are used for output voltage related configuration settings. All of the formats are in VID VR12.0. The output voltage mode and VID data byte format are shown in Figure 2. VOUT_COMMAND and other output voltage related commands are a 2 byte unsigned variable where the least significant bit is 5mV. If the output voltage is programmed below 0.25V, the output is disabled. The output voltage formulas are as follows:

Equation 1

$$\frac{V_{OUT}}{Volt} = \frac{(\text{VOUT\_COMMAND}[7:0] - 1)}{200} + 0.25$$

Equation 2

$$\frac{V_{OUT\ MAX}}{Volt} = \frac{(\text{VOUT\_MAX}[7:0] - 1)}{200} + 0.25$$

Example:

To set V_{OUT} = 1V, VOUT_COMMAND needs to be written 97h, which is equivalent to 151 in decimal.

Equation 3

$$\frac{V_{OUT\ \text{High Margin Setpoint}}}{Volt} = \frac{(\text{VOUT\_MARGIN\_HIGH}[7:0]-1)}{200} + 0.25$$

Equation 4

$$\frac{V_{OUT\ \text{Margin Low Setpoint}}}{Volt} = \frac{(\text{VOUT\_MARGIN\_LOW}[7:0]-1)}{200} + 0.25$$

Equation 5

$$\frac{V_{OUT\ \text{OV Warn Limit}}}{Volt} = \frac{(\text{VOUT\_OV\_WARN\_LIMIT}[7:0]-1)}{200} + 0.25$$

Equation 6

$$\frac{V_{OUT\ \text{UV Warn Limit}}}{Volt} = \frac{(\text{VOUT\_UV\_WARN\_LIMIT}[7:0]-1)}{200} + 0.25$$

Equation 7

$$\frac{V_{OUT\ \text{UV Fault Limit}}}{Volt} = \frac{(\text{VOUT\_UV\_FAULT\_LIMIT}[7:0]-1)}{200} + 0.25$$

Equation 8

$$\frac{V_{OUT\ \text{Power Good On}}}{Volt} = \frac{(\text{POWER\_GOOD\_ON}[7:0]-1)}{200} + 0.25$$

Equation 9

$$\frac{V_{OUT\ \text{Power Good Off}}}{Volt} = \frac{(\text{POWER\_GOOD\_OFF}[7:0]-1)}{200} + 0.25$$

The VOUT_UV_FAULT_RESPONSE command configures the fault response when a UVP condition occurs. A value of 00h will mean no turn-off on fault and 80h will disable the output until the fault is cleared.

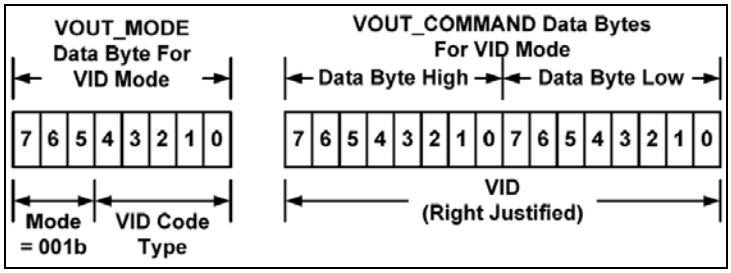

Figure 2: VID Format Data Bytes

4.3 Output Current Control

The IOUT_OC_FAULT_RESPONSE command is used to set the warning limit of output current. The data must be sent in Linear format with N = -1 and the least significant bit is 0.5A.

Equation 10

$$\text{Overcurrent Warning Limit} = \text{IOUT\_OC\_WARN\_LIMIT}[10:0] \bullet 2^{-1}$$

The IOUT_OC_WARN_LIMIT command configures the fault response when output current overcurrent condition occurs. A value of 00h configures the overcurrent mode to constant current, B9h to hiccup mode, and C0h to turn-off mode.

4.4 Temperature Control

There are four commands, OT_FAULT_LIMIT,OT_WARN_LIMIT, UT_WARN_LIMIT, and OT_FAULT_RESPONSE, that are used to control the temperature warning, fault threshold and response. The data format is in linear format with N = 0. The LSB is 1°C.

Equation 11

$$\text{Overtemperature Fault Limit} = \text{OT\_FAULT\_LIMIT}[10:0] \bullet 2^{0}$$

Equation 12

$$\text{Overtemperature Warning Limit} = \text{OT\_WARN\_LIMIT}[10:0] \bullet 2^{0}$$

Equation 13

$$\text{Undertemperature Warning Limit} = \text{UT\_WARN\_LIMIT}[10:0] \bullet 2^{0}$$

The OT_FAULT_RESPONSE command configures the fault response when an overtemperature condition occurs. Setting 00h will mean no turn-off on fault and 80h will turn off the output until the fault is cleared.

4.5 Input Voltage Control

The following commands are used to control the input voltage warning, fault thresholds and fault responses. The data format is linear format with N = -5.

Equation 14

$$\text{VIN OV Fault Limit} = \text{VIN\_OV\_FAULT\_LIMIT[10:0]} \bullet 2^{-5}$$

Equation 15

$$\text{VIN OV Warn Limit} = \text{VIN\_OV\_WARN\_LIMIT[10:0]} \bullet 2^{-5}$$

Equation 16

$$\text{VIN UV Warn Limit} = \text{VIN\_UV\_WARN\_LIMIT[10:0]} \bullet 2^{-5}$$

Equation 17

$$\text{VIN UV Fault Limit} = \text{VIN\_OV\_FAULT\_LIMIT[10:0]} \bullet 2^{-5}$$

The VIN_OV_FAULT_RESPONSE and VIN_UV_FAULT_RESPONSE commands configure the fault response when an input overvoltage or undervoltage condition occurs. A value of 00h will mean no turn-off on fault and 80h will turn off the output until the fault is cleared.

4.6 Startup and Shutdown Delay Timing

The TON_DELAY command sets the time, in milliseconds, from when a start condition is received until the output voltage starts to rise. The TOFF_DELAY command sets the time in milliseconds, from a stop condition is received until the unit stops transferring energy to the output. The TON_MAX_FAULT_LIMIT command sets an upper limit, in milliseconds, on how long the unit can attempt to power up the output without reaching the output undervoltage fault limit. If TON_MAX_FAULT_LIMIT is set for 0ms, the TON_MAX_FAULT function is disabled. The data format is direct and the least significant bit is 2ms. Do not set TON_DELAY, TON_MAX_FAULT_LIMIT, or TOFF_DELAY to less than 800h or more than BFFh. There is an exception to the startup delay timing set by TON_DELAY during a READ_TEMPERATURE_1 command transaction. See Section 7.3.

Equation 18

$$T_{ON}\ \text{Delay} = (\text{TON\_DELAY[15:0]} - 800\text{h}) \bullet 2ms$$

Equation 19

$$T_{OFF}\ \text{Delay} = (\text{TOFF\_DELAY[15:0]} - 800\text{h}) \bullet 2ms$$

Equation 20

$$T_{ON}\ \text{MAX Fault Limit} = (\text{TON\_MAX\_FAULT\_LIMIT[15:0]} - 800\text{h}) \bullet 2ms$$

5.0 OPERATING MEMORY AND NONVOLATILE STORAGE

5.1 Default/User Configurations

The MAX20751 configuration settings are stored in operating memory, which is volatile. The operating memory is loaded from one or more of the following places:

- Values hard-coded into MAX20751
- Values programmed from configuration resistor pins
- A nonvolatile memory called the default store
- A nonvolatile memory called the user store
- Communications from the PMBus

Parameters should be loaded into the operating memory in the following order:

1. Hard-coded parameters
2. Configuration resistors pins
3. Nonvolatile default values

The values of the default store are programmed by Maxim during the manufacturing process. The end user can have their own set of settings stored in the nonvolatile user store. MAX20751 supports three PMBus commands to store and restore values from nonvolatile memory, RESTORE_DEFAULT_ALL, STORE_USER_ALL and RESTORE_USER_ALL (if the RESTORE_USER_ALL command is used and no configurations have been saved by the user, the default values are used). To prevent any unpredictable and catastrophic results, these commands can only be executed when in shutdown mode. See Table 9 for a list of parameters that will be transferred when these commands are sent.

5.2 Configuration Resistors Registers

The MAX20751 PMBus interface can be used to verify and change command values that are set using configuration resistors. Table 14 shows a list of configuration resistors settings, and Table 15 shows the list of PMBus commands used to verify or change these resistor-set command values. Note that command values changed using the PMBus interface, but not saved to the user store, will revert back to resistor-set values once V_{DD} or V_{DD33} is toggled. Table 15 and Table 17 show the detailed switching frequency and slew rate command information.

Table 14: MAX20751 R_SEL Table

		R_SEL3		R_SEL2	R_SEL1		R_SEL0	
		<4:3>	<2:0>	<4:0>	<4:3>	<2:0>	<4>	<3:0>
Code	R (Ω)	V_{OUT} Slew Rate (V/ms)	Fsw (kHz)	VOUT_COMMAND[7:3] (V)[1]	ADDR[2:1]	VOUT_COMMAND [2:0][1]	ADDR[3]	R_{DES} (Ω)[2]
0	0	1.25	300		00	-0.005	0	604
1	17.8		350			0.000		549
2	33.2		400			0.005		511
3	48.7		450			0.010		464
4	64.9		500			0.015		432
5	80.6		600			0.020		412
6	95.3		700	0.49		0.025		383
7	115		800	0.53		0.030		365
8	133	2.5	300	0.57	01	-0.005		340
9	154		350	0.61		0.000		324
10	178		400	0.65		0.005		309
11	200		450	0.69		0.010		294
12	226		500	0.73		0.015		280
13	249		600	0.77		0.020		274
14	274		700	0.81		0.025		261
15	301		800	0.85		0.030		249
16	332	5	300	0.89	10	-0.005	1	604
17	365		350	0.93		0.000		549
18	402		400	0.97		0.005		511
19	432		450	1.01		0.010		464
20	464		500	1.05		0.015		432
21	499		600	1.09		0.020		412
22	536		700	1.13		0.025		383
23	576		800	1.17		0.030		365
24	619	0.5	300	1.21	11	-0.005		340
25	665		350	1.25		0.000		324
26	715		400	1.29		0.005		309
27	768		450	1.33		0.010		294
28	825		500	1.37		0.015		280
29	887		600	1.41		0.020		274
30	953		700	1.45		0.025		261
31	1020		800	1.49		0.030		249

Note 1. VOUT_COMMAND is interpreted according to the VID VR12.0 table; the least significant bit corresponds to a 5mV step.

Note 2: R_{DES} defines I_{LIM} and I_{CCMAX}.

Table 15: PMBus Commands Set by RSEL Resistors

Command Code	PMBus Command Name	Default	Default	Min	Max
D6h	Fsw	R/W Byte	Table 14	00h	07h
EFh	SLEW_RATE	R/W Byte	Table 14	00h	03h
21h	VOUT_COMMAND	R/W Word	Table 14	0000h	00FFh
42h	VOUT_OV_WARN_LIMIT	VOUT_COMMAND x 1.05	Table 14	0000h	00FFh
43h	VOUT_UV_WARN_LIMIT	VOUT_COMMAND x 0.95	Table 14	0000h	00FFh
44h	VOUT_UV_FAULT_LIMIT	VOUT_COMMAND x 0.82	Table 14	0080h	0B00h
5Eh	POWER_GOOD_ON	VOUT_COMMAND x 0.94	Table 14	0000h	00FFh
5Fh	POWER_GOOD_OFF	VOUT_COMMAND x 0.92	Table 14	0080h	00FFh

Table 16: FSW Command

Code	f_{SW} (KHz)
0	300
1	350
2	400
3	450
4	500
5	600
6	700
7	800

Table 17: SLEW_RATE Command

Code	Slew Rate (mV/µs)
0	1.25
1	2.5
2	5
3	0.5

5.3 OCS_T_ON

The on-chip switcher on time setting can be read and modified with the OCS_TON command, which is defined in Table 18.

Table 18: OCS_TON Command

Code	Switcher On Time (µs)
0	0.65
1	1.30
2	1.90
3	2.75

5.4 OCR Gain

The orthogonal current rebalance (OCR) gain setting can be read and modified with the OCR_GAIN command. (Table 19)

Table 19: OCR_GAIN Command

Code	OCR Gain
0	0
1	4
2	8
3	10

5.5 Output Voltage Fine Adjustment

The VOUT_COMMAND_FINE manufacturer-specific command is used to fine-tune the output voltage in smaller increments that is otherwise possible with the VID VR12.0 table. VOUT_COMMAND adjusts the output setpoint as shown Table 20.

Table 20: VOUT_COMMAND_FINE Command

Code	Output Voltage Fine Adjustment (mV)
0	3.75
1	2.5
2	1.25
3	0
4	-1.25
5	-2.5
6	-3.75
7	-5

6.0 DEVICE INDENTIFICATION AND CAPABILITY

The PMBus MFR_XX commands in Table 21 are used to store manufacturer data. These are manufacturer ID, model, revision, and serial number.

The PMBUS_REVISION command returns the PMBus specification revision information that is supported by the MAX20751. The CAPABILITY command, which allows the user to identify some key capabilities of MAX20751, returns B0h. This means the IC supports PEC, maximum speed of 400kHz and has an ALERTB output pin and supports the SMBus Alert Response protocol.

The QUERY command is used to ask the MAX20751 if it supports a given command. The command uses the block write-block read process call command. For the write portion of the process call, the one data byte is the command code of the command being investigated. For the read portion of the process call, the one data byte is unsigned binary integer with values defined in Table 22.

Table 21: Device Identification Commands

Command Code	PMBus Command Name	Type	Default
98h	PMBUS_REVISION	R Byte	22h
99h	MFR_ID	Block R/W	ASCII “VT”
9Ah	MFR_MODEL	Block R/W	01h
9Bh	MFR_REVISION	Block R/W	Block R/W 00h
9Eh	MFR_SERIAL	Block R/W	0000h
19h	CAPABILITY	R Byte	B0h
1Ah	QUERY	Block Write-Block Read Process Call	

Table 22: QUERY Command Return Data Byte Format

Bits	Value	Meaning
7	1	Command is supported.
	0	Command is not supported.
6	1	Command is supported for Write.
	0	Command is not supported for Write.
5	1	Command is supported for read.
	0	Command is Not supported for read.
4:2	0	Linear data format used.
	1	16-bit signed number.
	10	Reserved
	11	Direct mode format used.
	100	8-bit unsigned number.
	101	VID mode format is used.
	110	Manufacturer-specific format is used.
	111	Command does not return numeric data. This is also used for command that return blocks of data.
1:0	XX	Reserved for future use.

If bit [7] is zero, then the rest of the bits are don't care.

7.0 TELEMETRY COMMANDS

The MAX20751 provides a wide range of system parameter reporting, including input voltage, highest slave temperature, output current, output voltage, and output power.

7.1 Read Input Voltage

The READ_VIN command returns the input voltage in volts. Input voltage read back is affected by two other registers, namely VIN_RATIO and VIN_CAL_OFFSET.

The VIN_CAL_OFFSET command is a user input for input voltage reporting fine calibration. The least significant bit is 1/32V with values ranges from -4 to 3. Input voltage ratio is used to match the external input voltage ratio resistor values. The data format is linear with N = -11.

Equation 21

$$V_{IN}\ \text{Divider Ratio} = \text{VIN\_RATIO}[10:0] \bullet 2^{-11}$$

Equation 22

$$\frac{\text{VIN Calibration Offset}}{Volt} = \frac{\text{VIN\_CAL\_OFFSET}[15:0]}{32}$$

Equation 23

$$\frac{V_{IN}}{Volt} = \text{READ\_VIN}[10:0] \bullet 2^{-5}$$

7.2 Read Output Current

The READ_IOUT command returns the output current in amperes. READ_IOUT data is in linear format. IOUT_CAL_OFFSET and IOUT_CAL_GAIN are used to calibrate the output current read back value. The value of IOUT_CAL_GAIN is used to trim the apparent value of R_{DES} in the MAX20751 application circuit to provide current-sense gain calibration. The value of IOUT_CAL_OFFSET is summed with the READ_IOUT data to allow current-sense offset calibration. IOUT_CAL_OFFSET and IOUT_CAL_GAIN can accept 16-bit two's complement values from -32 to 31.

Equation 24

$$\frac{I_{OUT}\ \text{Calibration Offset}}{A} = \text{IOUT\_CAL\_OFFSET}[15:0] \bullet 2^{-1}$$

Equation 25

$$\frac{I_{OUT}\ \text{Calibration Gain}}{\Omega} = \text{IOUT\_CAL\_GAIN}[15:0] \bullet 2^{-1}$$

Equation 26

$$\frac{I_{OUT}}{\text{A}} = \text{READ\_IOUT}[15:0] \bullet 2^{-1}$$

7.3 Read Temperature

READ_TEMPERATURE_1 returns the highest slave temperature in °C. Read temperature data is in linear format. When the MAX20751 output is disabled, the READ_TEMPERATURE_1 command will take up to 6ms to complete. During this time, the device is unable to respond to a VR_ON enable signal, and startup is delayed until the READ_TEMPERATURE_1 transaction is complete. The temperature cannot be read if a STATUS_MFR_SPECIFIC fault bit is set.

Equation 27

$$\text{Highest Slave Temperature} = \text{READ\_TEMPERATURE\_1}[10:0] \bullet 2^{0}$$

7.4 Read Output Voltage

The READ_VOUT command returns the output voltage in volts. The data is in VID VR12.0 format.

Equation 28

$$\frac{V_{OUT}}{\text{V}} = \frac{(\text{READ\_VOUT}[15:0] - 1)}{200} + 0.25$$

7.5 Read P_{OUT}

READ_POUT is in linear format.

Equation 29

$$\frac{P_{OUT}}{V} = \text{READ\_POUT}[10:0] \bullet 2^{1}$$

8.0 SMBus ALERT RESPONSE PROTOCOL

The MAX20751 supports an alert response address protocol as described in the SMBus 2.0 specification. The MAX20751 implements combined alert request. Other fault or warning sources will not trigger another alert until a CLEAR fault command or VR_ON toggle and/or PMBus OPERATION command is issued. See the SMBus 2.0 specification Appendix A for more details.

8.1 PMBus Alert Pin

The ALERTB pin supports the SMBALERT# signal described in the SMBus 2.0 specification. The fault conditions that will assert the alert line low are as follows:

- Any bits different from 0 and not masked by SMBALERT_MASK command will pull the AlertB pin low in Status_CML.
- Any bits different from 0 and not masked by SMBALERT_MASK command will pull the AlertB pin low in Status_VOUT.
- Any bits different from 0 and not masked by SMBALERT_MASK command will pull the AlertB pin low in Status_IOUT.
- Any bits different from 0 and not masked by SMBALERT_MASK command will pull the AlertB pin low in Status_Temperature.
- Any bits different from 0 and not masked by SMBALERT_MASK command will pull the AlertB pin low in Status_MFR_Specific.
- Any bits different from 0 and not masked by SMBALERT_MASK command will pull the AlertB pin low in Status_Input.
- PMBus message lasts longer than expected.

The SMBALERT_MASK command is used to prevent a warning or fault condition from asserting the ALERTB signal. The command format (write word) used to block a status bit or bits from causing the ALERTB signal to be asserted is shown in Table 23. The bits in the mask byte align with the bits in the corresponding status register.

Table 23: SMBALERT_MASK Command Packet Format

# of bits	1	7	1	1	8	1	8	1	8	1	1
	S	MAX20751 PMBus Address	W	ACK	SMBALERT_MASK Command Code	ACK	Status_x Command Code	ACK	Mask Byte	ACK	P

The command format (block write-block read process call) used to determine the setting of the SMBALERT_MASK for a given status register is shown in Table 24.

Table 24: Retrieving the SMBALERT_MASK Setting for a Given Status Register

# of bits	1	7	1	1	8	1	8	1	8	1
	S	MAX20751 PMBus Address	W	ACK	SMBALERT_MASK Command Code	ACK	Byte Count = 1	ACK	Status_x Command Code	ACK
	1	**7**	**1**	**1**	**8**	**1**	**8**	**1**	**1**	
	SR	MAX20751 PMBus Address	R	ACK	Block Count = 1	ACK	Mask Byte	NACK	P	

The three ways to release the alert line are:

- CLEAR_FAULTS command: The command also enables new faults/warnings to trigger another alert.
- ARA (see the SMBUS specification 2.0): The MAX20751 will respond with its PMBus address if it has asserted ALERTB low. It follows the standard arbitration protocol to resolve multiple devices sending alert to host. If the MAX20751 wins arbitration and successfully sends its address to the master, ALERTB is released. Another alert cannot be triggered until the master sends the CLEAR_FAULTS command, toggles VR_ON, or toggles the OPERATION command.
- Toggling VR_ON and/or sending a PMBus OPERATION command has the same effect as a CLEAR_FAULTS command.

Appendix A: Known Issues

1. Does not acknowledge (ACK) the general call address (00h). Implements the command, but does not acknowledge the address.

REVISION HISTORY

Revision	Description	Date
0	Initial Application Note	N/A
1	Updated Table 9 and Section 7.4	12/16

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