LT7176P/LT7176P-1 PMBUS I²C Reference Manual

OVERVIEW

This reference manual describes the digital communications capabilities of the LT7176P/LT7176P-1, including the functionality of each power management bus (PMBus) command. Refer to the following specifications for more information regarding the bus protocol details:

- PMBus Specification Revision 1.3.1
- SMBus Specification Revision 3.1

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PMBus/SMBus/I²C

PMBus/SMBus/I²C Capabilities

The LT7176P/LT7176P-1 serial interface is PMBus compliant and can operate at any frequency between 10kHz and 1MHz. The device address is configurable using the nonvolatile memory (NVM). The serial interface supports the following protocols defined in the PMBus and SMBus specifications:

- Send Byte, Write Byte, Write Word, Block Write
- Read Byte, Read Word, Block Read
- Alert Response Address
- PAGE_PLUS_READ, PAGE_PLUS_WRITE
- Zone Write
- SMBALERT_MASK Read and Write

The LT7176P/LT7176P-1 pulls the $\overline{\text{ALERT}}$ pin low to indicate conditions that may require attention. See the *Status* in the *PMBus Command Details* section for more information.

Similarities Between PMBus, SMBus, and I²C 2-Wire Interface

The PMBus 2-wire interface is an incremental extension of the SMBus. The SMBus is built upon I²C with some minor differences in timing, DC parameters, and protocol. The PMBus/SMBus protocols are more robust than simple I²C byte commands because PMBus/SMBus provides timeouts to prevent persistent bus errors and optional packet error checking (PEC) to ensure data integrity. In general, a bus controller device that can be configured for I²C communication can be used for PMBus communication with little or no change to hardware or firmware. Repeat start (restart) is not supported by all I²C controllers, but is required for I²SMBus/PMBus reads. If a general-purpose I²C controller is used, check that repeat start is supported.

For a description of the minor extensions and exceptions PMBus adds to SMBus, refer to PMBus Specification Part 1 Revision 1.3.1: Section 5: Transport.

For a description of the differences between SMBus and I²C, refer to System Management Bus (SMBus) Specification Version 3.1: Appendix B—Differences Between SMBus and I²C.

Communication Protection

All read operations return a valid PEC if the PMBus controller requests it. If Bit 2 of the MFR_CONFIG_ALL_LT7176 command is set, the PMBus write operations are not acted upon until a valid PEC is received by the LT7176P/LT7176P-1. If a PEC is included in a command write, that PEC must be valid, or a PEC write error occurs, regardless of the value of Bit 2 of the MFR_CONFIG_ALL_LT7176 command.

If a PEC write error occurs, an attempt is made to access unsupported commands, or invalid data is written to supported commands, the LT7176P/LT7176P-1 ignores the command, sets the communications, memory, and logic (CML) bit in the STATUS_BYTE and STATUS_WORD commands, sets the appropriate bit in the STATUS_CML command, and pull the $\overline{\text{ALERT}}$ pin low.

ADDRESSING AND COMMUNICATIONS

Device Addressing

The LT7176P/LT7176P-1 offer addressing modes that provide flexible ways to control multiple channels at once or individually.

Device addressing is the standard way to communicate with a single instance of the LT7176P/LT7176P-1. The value of the device address is set by the MFR_ADDRESS command and the ASEL pin. Device addressing can be disabled by writing a value of 0x80 to the MFR_ADDRESS command. If MFR_ADDRESS cannot be read from NVM due to an NVM fault, the device address is set to 0x7C.

Global addressing provides a means to address all LT7176P/LT7176P-1 devices on the bus. The LT7176P/LT7176P-1 global addresses are fixed at 0x5A (7-bit notation) and 0x5B. They cannot be disabled. Do not read from global addresses because multiple devices may respond simultaneously. Other Analog Devices' device types may respond at one or both global addresses.

Rail addressing provides a means to control multiple channels simultaneously. While similar to global addressing, the rail address can be dynamically assigned with the MFR_RAIL_ADDRESS command, allowing any logical grouping of channels that may be required for reliable system control. Do not read from rail addresses because multiple devices may respond.

Zone write addressing provides a means to write to a set of channels. The set of channels can be distributed across multiple devices. Each channel is programmed to be part of a zone by programming the selected zone number to the ZONE_CONFIG command. This configuration only needs to be performed once. After zone configuration, the bus controller uses the ZONE_ACTIVE command to select the active zone. If the configured zone of a channel matches the active zone or the active zone is set to all zones, the channel responds to subsequent ZONE_WRITE operations. A ZONE_WRITE operation is started when the bus controller uses the ZONE_WRITE address (0x37, 7-bit notation) as the device address in an SMBus write command.

All means of PMBus addressing require the user to employ disciplined planning to avoid addressing conflicts. Communication to LT7176P/LT7176P-1 devices at global and rail addresses are limited to command write operations.

Communication Recommendations

If PMBus commands are received faster than they are being processed, the LT7176P/LT7176P-1 may become too busy to handle new commands. If a command is written when the LT7176P/LT7176P-1 are busy processing a command, the devices ignore that command, set Bit 7 of STATUS_BYTE, and pull the $\overline{\text{ALERT}}$ pin low. Bit 6 of MFR_COMMON sets to 1 when the LT7176P/LT7176P-1 are ready to accept commands. This bit can be polled before writing commands. Alternatively, clock stretching can be enabled. Clock stretching is enabled by setting Bit 1 of MFR_CONFIG_ALL_LT7176.

NVM commands may take longer to process, including STORE_USER_ALL and MFR_COMPARE_USER_ALL. In these cases, either poll Bit 6 of MFR_COMMON or enable clock stretching to avoid a busy condition.

PMBus COMMAND SUMMARY

Table 1 lists supported PMBus commands and manufacturer-specific commands. A complete description of the included PMBus commands is found in the PMBus Power System Management Protocol Specification. Floating point values listed in the default value column are half-precision IEEE floating point numbers. All commands from 0xC0 through 0xFF not listed in *Table 1* are implicitly reserved by the manufacturer. Users must avoid blind writes within this range of commands to avoid undesired operation of the LT7176P/LT7176P-1. All commands from 0x00 through 0xBF not listed in *Table 1* are implicitly not supported by the manufacturer. Attempting to access unsupported or reserved commands results in a CML command fault event.

The LT7176P/LT7176P-1 contains additional manufacturer-reserved commands not listed in *Table 1*. Reading these commands is harmless to the operation of the IC. However, the contents and meaning of these commands can change without notice.

Some of the unpublished commands are read-only and generate a communications, memory, and logic (CML) Bit 6 fault if written. Writing to commands not published in *Table 1* is not permitted.

Table 1. Supported PMBus and MFR Commands[1]

COMMAND NAME[2]	COMMAND CODE	DESCRIPTION	TYPE	DATA FORMAT	UNIT	NVM [3]	DEFAULT VALUE
PAGE	0x00	Provides integration with multipage PMBus devices.	R/W byte	Register		No	0x00
OPERATION	0x01	Operating mode control. On/off, margin high, and margin low.	R/W byte	Register		Yes	0x80
ON_OFF_CONFIG	0x02	RUN pin and PMBus bus on/off command configuration.	R/W byte	Register		Yes	0x1E
CLEAR_FAULTS	0x03	Clears any fault bits that are set.	Send byte				
PAGE_PLUS_WRITE	0x05	Writes a command directly to a specified page.	W block				
PAGE_PLUS_READ	0x06	Reads a command directly from a specified page.	Block R/W				
ZONE_CONFIG	0x07	Assigns the current page to the specified zone number for ZONE_WRITE operations.	R/W word	Register		Yes	0xFEFE
ZONE_ACTIVE	0x08	Selects the active zone for ZONE_WRITE operations.	R/W word	Register		No	0xFEFE
WRITE_PROTECT	0x10	Level of protection provided by the device against accidental changes.	R/W byte	Register		Yes	0x00
STORE_USER_ALL	0x15	Stores user operating memory to NVM. It can be written three times.	Send byte				

COMMAND NAME[2]	COMMAND CODE	DESCRIPTION	TYPE	DATA FORMAT	UNIT	NVM [3]	DEFAULT VALUE
RESTORE_USER_ALL	0x16	Restores user operating memory from NVM.	Send byte				
CAPABILITY	0x19	Summary of PMBus optional communication protocols supported by this device.	R byte	Register		No	0xD8
QUERY	0x1A	Asks if a given command is supported, and what data formats are supported.	Block R/W	Register		No	
SMBALERT_MASK	0x1B	Masks $\overline{\text{ALERT}}$ activity.	Block R/W	Register		Yes	
VOUT_MODE	0x20	Output voltage format and exponent.	R byte	Register		No	0x60
VOUT_COMMAND	0x21	Nominal output voltage set point.	R/W word	IEEE	V	Yes	0.3, 0x34CD
VOUT_MAX	0x24	Upper limit on the commanded output voltage.	R/W word	IEEE	V	Yes	0.323, 0x352B
VOUT_MARGIN_HIGH	0x25	Margin high output voltage set point.	R/W word	IEEE	V	Yes	0.315, 0x350A
VOUT_MARGIN_LOW	0x26	Margin low output voltage set point.	R/W word	IEEE	V	Yes	0.3, 0x34CD
VOUT_TRANSITION_RATE	0x27	Rates the output changes when V_{OUT} is commanded to a new value.	R/W word	IEEE	V/ms	Yes	0.25, 0x3400
FREQUENCY_SWITCH	0x33	Switching frequency of the regulator.	R/W word	IEEE	kHz	Yes	1000.0, 0x63D0
VIN_ON	0x35	Input voltage at which the unit must start power conversion.	R/W Word	IEEE	V	Yes	1.4, 0x3D9A
VIN_OFF	0x36	Input voltage at which the unit must stop power conversion.	R/W word	IEEE	V	Yes	1.35, 0x3D66
IOUT_CAL_OFFSET	0x39	Offset for READ_IOUT.	R/W word	IEEE	A	Yes	0.32, 0x351F
VOUT_OV_FAULT_LIMIT	0x40	Output overvoltage (OV) fault limit.	R/W word	IEEE	V	Yes	0.33, 0x3548

COMMAND NAME[2]	COMMAND CODE	DESCRIPTION	TYPE	DATA FORMAT	UNIT	NVM [3]	DEFAULT VALUE
VOUT_OV_FAULT_ RESPONSE	0x41	Action to be taken by the device when an output overvoltage fault is detected.	R/W byte	Register		Yes	0xB8
VOUT_OV_WARN_LIMIT	0x42	Output overvoltage warning limit.	R/W word	IEEE	V	Yes	0.323, 0x352B
VOUT_UV_WARN_LIMIT	0x43	Output undervoltage (UV) warning limit.	R/W word	IEEE	V	Yes	0.278, 0x3473
VOUT_UV_FAULT_LIMIT	0x44	Output undervoltage fault limit.	R/W word	IEEE	V	Yes	0.27, 0x3452
VOUT_UV_FAULT_ RESPONSE	0x45	Action to be taken by the device when an output undervoltage fault is detected.	R/W byte	Register		Yes	0x00
IOUT_OC_FAULT_ RESPONSE	0x47	Action to be taken by the device when an output overcurrent fault is detected.	R/W byte	Register		Yes	0x00
IOUT_OC_WARN_LIMIT	0x4A	Output overcurrent warning limit.	R/W word	IEEE	A	Yes	24.0, 0x4E00
OT_FAULT_LIMIT	0x4F	Internal overtemperature fault limit.	R/W word	IEEE	°C	Yes	160.0, 0x5900
OT_FAULT_RESPONSE	0x50	Action to be taken by the device when an internal overtemperature fault is detected.	R/W byte	Register		Yes	0xC0
OT_WARN_LIMIT	0x51	Internal overtemperature warning limit.	R/W word	IEEE	°C	Yes	140.0, 0x5860
VIN_OV_FAULT_ RESPONSE	0x56	Action to be taken by the device when an input overvoltage fault is detected.	R/W byte	Register		Yes	0xB8
VIN_UV_WARN_LIMIT	0x58	Input supply undervoltage warning limit.	R/W word	IEEE	V	Yes	−1.0, 0xBC00
TON_DELAY	0x60	Time from RUN and/or OPERATION onto the output rail turn-on.	R/W word	IEEE	ms	Yes	0.0, 0x0000
TON_RISE	0x61	Time from when the output starts to rise until the output voltage reaches the V_{OUT} commanded value.	R/W word	IEEE	ms	Yes	1.0, 0x3C00

COMMAND NAME[2]	COMMAND CODE	DESCRIPTION	TYPE	DATA FORMAT	UNIT	NVM [3]	DEFAULT VALUE
TON_MAX_FAULT_LIMIT	0x62	Maximum time from the start of TON_RISE for VOUT to cross the VOUT_UV_FAULT_LIMIT.	R/W word	IEEE	ms	Yes	5.0, 0x4500
TON_MAX_FAULT_ RESPONSE	0x63	Action to be taken by the device when a TON_MAX_FAULT event is detected.	R/W byte	Register		Yes	0x00
TOFF_DELAY	0x64	Time from RUN and/or OPERATION off to the start of TOFF_FALL ramp.	R/W word	IEEE	ms	Yes	0.0, 0x0000
TOFF_FALL	0x65	Time from when the output starts to fall until the output reaches zero volts.	R/W word	IEEE	ms	Yes	2.0, 0x4000
TOFF_MAX_WARN_LIMIT	0x66	Maximum allowed time, after TOFF_FALL is completed, for the unit to decay below MFR_DISCHARGE_THRESHOLD.	R/W word	IEEE	ms	Yes	0.0, 0x0000
STATUS_BYTE	0x78	One-byte summary of the unit fault condition.	R/W byte	Register		No	
STATUS_WORD	0x79	Two-byte summary of the unit fault condition.	R/W word	Register		No	
STATUS_VOUT	0x7A	Output voltage fault and warning status.	R/W byte	Register		No	
STATUS_IOUT	0x7B	Output current fault and warning status.	R/W byte	Register		No	
STATUS_INPUT	0x7C	Input supply fault and warning status.	R/W byte	Register		No	
STATUS_TEMPERATURE	0x7D	Internal temperature fault and warning status for READ_TEMPERATURE_1.	R/W byte	Register		No	
STATUS_CML	0x7E	Communication, memory fault, and warning status.	R/W byte	Register		No	
STATUS_MFR_SPECIFIC	0x80	Manufacturer-specific fault and state information.	R/W byte	Register		No	
READ_VIN	0x88	Measured input supply voltage.	R word	IEEE	V	No	
READ_VOUT	0x8B	Measured output voltage.	R word	IEEE	V	No	

COMMAND NAME[2]	COMMAND CODE	DESCRIPTION	TYPE	DATA FORMAT	UNIT	NVM [3]	DEFAULT VALUE
READ_IOUT	0x8C	Measured output current.	R word	IEEE	A	No	
READ_TEMPERATURE_1	0x8D	Measured internal temperature.	R word	IEEE	°C	No	
READ_FREQUENCY	0x95	Measured pulse width modulation (PWM) switching frequency.	R word	IEEE	kHz	No	
PMBUS_REVISION	0x98	PMBus revision supported by this device. Current revision is 1.3.	R byte	Register		No	0x33
MFR_ID	0x99	The manufacturer ID in ASCII.	R block				ADI
MFR_SERIAL	0x9E	Unique part serial number.	R block				
IC_DEVICE_ID	0xAD	Identification of the IC in ASCII.	R block				LT7176P or LT7176P-1
IC_DEVICE_REV	0xAE	Revision of the IC.	R block				
MFR_NVM_UNLOCK	0xBD	Contact the factory. Only used for MFR_NVM_DATA bulk programming.					
MFR_NVM_USER_WRITES_REMAINING	0xBE	Number of STORE_USER_ALL writes remaining.	R byte	Register		No	
MFR_NVM_DATA	0xBF	Contact the factory. Used for bulk programming. Not needed for STORE_USER_ALL.					
MFR_USER_DATA_00	0xC9	NVM word available for the user.	R/W word	Register		Yes	0x0000
MFR_USER_DATA_01	0xCA	NVM word available for the user.	R/W word	Register		Yes	0x0000
MFR_READ_EXTVCC	0xCD	Measured $EXTV_{CC}$ voltage, when enabled.	R word	IEEE	V	No	
MFR_READ_ITH	0xCE	Measured I_{TH} voltage, when enabled.	R word	IEEE	V	No	
MFR_CHAN_CONFIG_LT7176	0xD0	Configuration bits that are channel-specific.	R/W word	Register		Yes	0x02C9
MFR_CONFIG_ALL_LT7176	0xD1	General configuration bits.	R/W word	Register		Yes	0x0000

COMMAND NAME[2]	COMMAND CODE	DESCRIPTION	TYPE	DATA FORMAT	UNIT	NVM [3]	DEFAULT VALUE
MFR_FAULT_PROPAGATE_LT7176	0xD2	The configuration that determines which faults are propagated to the $\overline{\text{FAULT}}$ pin.	R/W word	Register		Yes	0xA097
MFR_READ_ASEL	0xD3	Read the ASEL pin resistor value	R word	IEEE	kΩ	No	
MFR_PWM_MODE_LT7176	0xD4	Configuration for the PWM engine.	R/W word	Register		Yes	0x0FDC
MFR_FAULT_RESPONSE	0xD5	Action to be taken when the $\overline{\text{FAULT}}$ pin is externally asserted low.	R/W byte	Register		Yes	0xC0
MFR_IOUT_PEAK	0xD7	Reports the maximum measured value of READ_IOUT since the last MFR_CLEAR_PEAKS.	R word	IEEE	A	No	
MFR_ADC_CONTROL_LT7176	0xD8	Configures the update rate for measurements taken by the analog-to-digital converter (ADC).	R/W byte	Register		Yes	0x0E
MFR_RETRY_DELAY	0xDB	Retries interval during fault retry mode.	R/W word	IEEE	ms	Yes	10.0, 0x4900
MFR_VOUT_PEAK	0xDD	Maximum measured value of READ_VOUT since last MFR_CLEAR_PEAKS.	R/W word	IEEE	V	No	
MFR_VIN_PEAK	0xDE	Maximum measured value of READ_VIN since last MFR_CLEAR_PEAKS.	R/W word	IEEE	V	No	
MFR_TEMPERATURE_1_PEAK	0xDF	Maximum measured value of internal temperature (READ_TEMPERATURE_1) since last MFR_CLEAR_PEAKS.	R/W word	IEEE	°C	No	
MFR_READ_PWM_CFG	0xE0	Measured PWM_CFG resistor value.	R word	IEEE	kΩ	No	
MFR_READ_VOUT_CFG	0xE1	Measured VOUT_CFG resistor value.	R word	IEEE	kΩ	No	
MFR_CLEAR_PEAKS	0xE3	Clears all peak values.	Send byte				
MFR_DISCHARGE_THRESHOLD	0xE4	The output voltage used to determine output has decayed sufficiently to reenable the channel.	R/W word	IEEE		Yes	0.2, 0x3266
MFR_PADS_LT7176	0xE5	Digital status of the I/O pads.	R word	Register		No	

COMMAND NAME[2]	COMMAND CODE	DESCRIPTION	TYPE	DATA FORMAT	UNIT	NVM [3]	DEFAULT VALUE
MFR_ADDRESS	0xE6	Sets the 7-bit I²C address byte.	R/W byte	Register		Yes	0x4F
MFR_SPECIAL_ID	0xE7	ID code used by the manufacturer.	R word	Register		No	0x1C1D
MFR_COMMON	0xEF	Manufacturer status bits that are common across multiple Analog Devices chips.	R byte	Register		No	
MFR_COMPARE_ USER_ALL	0xF0	Compares current command contents with NVM.	Send byte				
MFR_CHANNEL_STATE	0xF1	Returns the state of the channel.	R byte	Register		No	
MFR_PGOOD_DELAY	0xF2	The time output voltage must be between UV and OV before the PGOOD pin transitions high.	R/W word	IEEE	ms	Yes	1.0, 0x3C00
MFR_NOT_PGOOD_ DELAY	0xF3	The time output voltage must be below UV or above OV before the PGOOD pin transitions low.	R/W word	IEEE	ms	Yes	0.1, 0x2E66
MFR_PWM_PHASE_ LT7176	0xF5	Sets PWM phase.	R/W byte	Register		Yes	0x00
MFR_SYNC_CONFIG_ LT7176	0xF6	SYNC pin input/output configuration.	R/W byte	Register		Yes	0x01
MFR_PIN_CONFIG_ STATUS	0xF7	Pin configuration fault status.	R byte	Register		No	
MFR_RAIL_ADDRESS	0xFA	Common address to adjust common parameters.	R/W byte	Register		Yes	0x80
MFR_DISABLE_OUTPUT	0xFB	Disables regulator outputs until reset.	R/W byte	Register		No	0x00
MFR_NVM_USER_WP	0xFC	Disables commands that write user NVM.	R/W byte	Register		Yes	0x00
MFR_RESET	0xFD	Commanded a reset without requiring a power-down.	Send byte				

[1] Empty cells mean not applicable.

[2] Do not assume compatibility of commands between different devices based upon command names. Always refer to the manufacturer's data sheet for each device for a complete definition of the command's function. Analog Devices strives to keep command functionality compatible between all Analog Devices devices. However, differences can be introduced to address specific product requirements.

[3] Commands indicated with Y in the NVM column indicate that these commands are stored and restored using the STORE_USER_ALL and RESTORE_USER_ALL commands, respectively.

Table 2. Abbreviations of Supported Data Formats[1]

PMBus TERMINOLOGY		PMBus SPECIFICATION REFERENCE	DEFINITION	EXAMPLE
Register			Per bit meaning is defined in each command description.	PMBus STATUS_BYTE command
IEEE	IEEE 754 half-precision floating point	Rev 1.3.1 Part II 8.4.4	Floating point 16-bit data: for normal values, value = $(-1)^{S} \times 2^{N-15} \times \left(1 + \frac{M}{1024}\right)$, where S = Bit[15], N = Bits[14:10], M = Bits[9:0].	$\text{Bits}[15:0] = 0\text{x}4580 = (-1)^{0} \times 2^{17-15} \times \left(1 + \frac{384}{1024}\right) = 5.5$

[1] Empty cells are left blank intentionally.

PMBus COMMAND DETAILS

Addressing and Write Protection

Table 3. Addressing and Write Protection Commands

COMMAND NAME	CODE	DESCRIPTION	TYPE	NVM	DEFAULT VALUE[1]
PAGE	0x00	Channel (page) selected for any paged command.	R/W byte	No	0x00
PAGE_PLUS_WRITE	0x05	Writes a command directly to a specified page.	W block	No	N/A
PAGE_PLUS_READ	0x06	Reads a command directly from a specified page.	Block R/W process	No	N/A
ZONE_CONFIG	0x07	Specifies the zone number for the selected page.	R/W word	Yes	0xFEFE
ZONE_ACTIVE	0x08	Sets active zone number.	R/W word	No	0xFEFE
WRITE_PROTECT	0x10	Protects the device from unintended PMBus modifications.	R/W byte	Yes	0x00
MFR_ADDRESS	0xE6	Specifies right-justified 7-bit device address.	R/W byte	Yes	0x4F
MFR_RAIL_ADDRESS	0xFA	Specifies right-justified 7-bit address for channels to be controlled together.	R/W byte	Yes	0x80

[1] N/A means not applicable.

PAGE

The PAGE command provides the ability to configure, control, and monitor multiple channels through only one physical address, either the device address or global address 0x5B (7-bit address).

The LT7176/LT7176-1 has only one channel, and the PAGE command can only be 0x00 or 0xFF. Both values have the same effect. PAGE 0xFF is used to select all channels in multichannel devices. The PAGE command is included only for compatibility with other PMBus devices.

PAGE_PLUS_WRITE

The PAGE_PLUS_WRITE command provides a way to select the page within the LT7176/LT7176-1, sends a command, and then sends the data for the command, all in one communication packet. Commands allowed by the present write-protection level can be sent with PAGE_PLUS_WRITE.

The value stored in the PAGE command is not affected by PAGE_PLUS_WRITE. If PAGE_PLUS_WRITE is used to send a nonpaged command, the page number byte is ignored.

Note that PAGE_PLUS commands cannot be nested. A PAGE_PLUS command cannot be used to read or write another PAGE_PLUS command. If this is attempted, the LT7176/LT7176-1 refuses to acknowledge the entire PAGE_PLUS packet and issues a CML fault for invalid/unsupported data.

The PAGE_PLUS_WRITE command cannot be used to write the PAGE command.

If the PAGE_PLUS_WRITE command is sent during a ZONE_WRITE, the page field is used as the effective zone. The page field overrides the write zone of ZONE_ACTIVE for this PAGE_PLUS_WRITE only.

The LT7176/LT7176-1 has only one page, and the PAGE_PLUS_WRITE command is included only for compatibility with other PMBus devices.

PAGE_PLUS_READ

The PAGE_PLUS_READ command provides the ability to select the page within the LT7176/LT7176-1, sends a command, and then reads the data returned by the command, all in one communication packet.

The value stored in the PAGE command is not affected by PAGE_PLUS_READ. If PAGE_PLUS_READ is used to access data from a nonpaged command, the page number byte is ignored.

Note that PAGE_PLUS commands cannot be nested. A PAGE_PLUS command cannot be used to read or write another PAGE_PLUS command. If this is attempted, the LT7176/LT7176-1 refuses to acknowledge the entire PAGE_PLUS packet and issues a CML fault for invalid/unsupported data.

The PAGE_PLUS_READ command cannot be used to read the PAGE command.

The LT7176/LT7176-1 has only one page, and the PAGE_PLUS_READ command is included only for compatibility with other PMBus devices.

ZONE_CONFIG

The ZONE_CONFIG command is used to assign the currently selected channel to a specific zone number for ZONE_WRITE operations. Zone configuration only needs to be performed once, but zone numbers can be changed at any time.

The zone of the channel can be assigned to any zone number between 0x00 and 0x7F. It can also be set to 0xFE, which means no zone. Any channel programmed to a no zone ignores ZONE_WRITE operations.

The ZONE_CONFIG command uses the SMBus word write, and word read protocols.

Table 4. ZONE_CONFIG Bits and Meaning

BITS	MEANING
[15:8]	Must be 0xFE
[7:0]	Assigned zone

ZONE_ACTIVE

The ZONE_ACTIVE command sets the active zone for ZONE_WRITE operations. When ZONE_WRITE is sent by the bus controller, the active zone controls which channels are affected by that write.

The active zone can be set to any zone number between 0x00 and 0x7F. The active zone can also be set to 0xFF, which means all zones. If a ZONE_WRITE is sent while the active zone is set to all zones, any channel not programmed to no zone via ZONE_CONFIG is affected by that write.

The ZONE_ACTIVE command must be sent using the ZONE_WRITE address (0x37) as a ZONE_WRITE operation. If the ZONE_ACTIVE command is sent to the global, device, or rail addresses, the invalid command bit is set in STATUS_CML.

Table 5. ZONE_ACTIVE Bits and Meaning

BITS	MEANING
[15:8]	Must be 0xFE
[7:0]	Active zone

WRITE_PROTECT

The WRITE_PROTECT command is used to control writing to the LT7176/LT7176-1. When WRITE_PROTECT is set to 0x00, writes to all commands are enabled.

The PAGE_PLUS_WRITE command can be used to write any command that is not write protected. The PAGE_PLUS_READ command can be used to read any command.

Table 6. WRITE_PROTECT Byte and Meaning

BITS	MEANING
0x80	Disable all writes except to the WRITE_PROTECT, PAGE, MFR_NVM_UNLOCK, and STORE_USER_ALL commands.
0x40	Disable all writes except to the WRITE_PROTECT, PAGE, MFR_NVM_UNLOCK, MFR_CLEAR_PEAKS, STORE_USER_ALL, OPERATION, and CLEAR_FAULTS commands. Individual fault bits can be cleared by writing a 1 to the respective bits in the STATUS registers.
0x20	Disable all writes except to the WRITE_PROTECT, OPERATION, MFR_NVM_UNLOCK, MFR_CLEAR_PEAKS, CLEAR_FAULTS, PAGE, ON_OFF_CONFIG, VOUT_COMMAND, and STORE_USER_ALL commands. Individual fault bits can be cleared by writing a 1 to the respective bits in the STATUS registers.
0x10	Reserved, must be 0.
0x08	Reserved, must be 0.
0x04	Reserved, must be 0.
0x02	Reserved, must be 0.
0x01	Reserved, must be 0.

MFR_Address

The MFR_ADDRESS command byte and the ASEL pin set the seven bits of the PMBus device address.

Setting this command to a value of 0x80 disables device addressing. The global device addresses, Address 0x5A and Address 0x5B, cannot be deactivated.

If the ASEL pin is floating or connected to V_{DD18}, the device will use the full MFR_ADDRESS value. If a resistor is connected to the ASEL pin according to the *Table 7*. The four least significant bits (LSBs) of the device address will be determined by the ASEL resistor value.

Reading MFR_ADDRESS always returns the value loaded from NVM or written via PMBus write. The value read from MFR_ADDRESS is not affected by the ASEL pin.

LT7176/LT7176-1 does not ignore ASEL, even when bit 6 of MFR_CONFIG_ALL_LT7176 is set to ignore the other resistor configuration pins.

The three MSBs 6:4 of the device address are always determined by bits 6:4 of MFR_ADDRESS.

Table 7. LT7176/LT7176-1 Address Configuration Using ASEL Resistor

ASEL RESISTOR VALUE (±1%)	VALUE OF PMBus DEVICE ADDRESS LSBs 3:0
Floating or V_{DD18}	NVM value of MFR_ADDRESS
124kΩ	0xF
107kΩ	0xE

ASEL RESISTOR VALUE (±1%)	VALUE OF PMBus DEVICE ADDRESS LSBs 3:0
93.1kΩ	0xD
80.6kΩ	0xC
69.8kΩ	0xB
60.4kΩ	0xA
51.1kΩ	0x9
43.2kΩ	0x8
36.5kΩ	0x7
30.9kΩ	0x6
25.5kΩ	0x5
21kΩ	0x4
16.5kΩ	0x3
11.8kΩ	0x2
6.65kΩ	0x1
0 (SGND)	0x0

Table 8. Illegal Values for MFR_ADDRESS

ADDRESS	OTHER USES
0x0C	ARA protocol address
0x37	Zone write
0x5A	Global all rail address
0x5B	Global address

Attempting to set the MFR_ADDRESS command to illegal values sets a CML invalid data fault.

After changing the device address, leave at least 10µs for the new address to take effect before starting a new PMBus transaction.

The LT7176/LT7176-1 always responds to the global addresses, Address 0x5A and Address 0x5B. Writes to Address 0x5A affect all pages, and reads target Page 0, as if PAGE = 0xFF.

MFR_RAIL_Address

The MFR_RAIL_ADDRESS command enables direct device address access to the currently selected channel. Writing this command sets, the rail address for the currently selected channel. The value of this command is common to all devices attached to a single power supply rail.

Setting this command to a value of 0x80 disables rail device addressing for the selected channel.

Attempting to set MFR_RAIL_ADDRESS to an illegal address, as defined in the *MFR_Address* section, sets a CML invalid data fault.

Writing the PAGE_PLUS_READ or PAGE_PLUS_WRITE command to the rail address sets a CML invalid command fault.

Reading from the rail address results in a CML other fault.

After changing the rail address, leave at least 10µs for the new address to take effect before starting a new PMBus transaction.

General Configuration

Table 9. General Configuration Commands

COMMAND NAME	CODE	DESCRIPTION	TYPE	NVM	DEFAULT VALUE
MFR_CHAN_CONFIG_LT7176	0xD0	Configuration bits that are channel specific.	R/W word	Yes	0x02C9
MFR_CONFIG_ALL_LT7176	0xD1	Configuration bits common to all channels.	R/W word	Yes	0x0000

MFR_CHAN_CONFIG_LT7176

The MFR_CHAN_CONFIG_LT7176 command sets various per channel configuration bits.

Table 10. MFR_CHAN_CONFIG_LT7176 Bits

BITS	DEFAULT	MEANING		
[15:11]	00000	Reserved.		
10	0	Applies only to the LT7176P-1 0 = Both output Phase 0 and Phase 1 are enabled when V_{OUT} is enabled 1 = Follower phase (Phase 1) is disabled		
9	1	0 = Top switch drive strength normal. 1 = Top switch drive strength high.		
8	0	0 = Default single-phase application or polyphase leader operation. 1 = Polyphase follower mode. All but one channel in polyphase applications should be set to follower mode. Internal compensation cannot be used in polyphase operation. The channel operates in forced continuous conduction mode.		
7	1	0 = Device will not pull SHARE_CLK down due to V_{IN} voltage level. 1 = Enable SHARE_CLK pull-down until V_{IN} exceeds VIN_ON, or if V_{IN} falls below VIN_OFF.		
6	1	0 = 250Ω output V_{SENSEP} pull-down is disabled. 1 = 250Ω output V_{SENSEP} pull-down is enabled when off and during TOFF_FALL.		
[5:4]	00	Reserved.		
3	1	0 = Channel output remains active if SHARE_CLK is held low. 1 = Channel output is disabled if SHARE_CLK is held low.		
[2:1][1]	0	Output voltage range.		
		VALUE	**MAXIMUM OUTPUT VOLTAGE**	**MINIMUM RECOMMENDED OUTPUT VOLTAGE[2]**
		0	1.375V	0.3V
		1	2.75V	0.8V
		2	3.4V	1.6V
		3	Invalid; writing this causes CML invalid data	

BITS	DEFAULT	MEANING
0	1	0 = V_{OUT} must be below MFR_DISCHARGE_THRESHOLD before the output can be enabled. 1 = The output can be enabled, regardless of V_{OUT}.

[1] Bit 2 and Bit 1 cannot be set to a value that makes the value in VOUT_COMMAND, VOUT_MARGIN_HIGH, or VOUT_MARGIN_LOW become greater than the maximum value for the selected range.

[2] Setting the output voltage lower than the minimum recommended output voltage will result in reduced performance.

MFR_CONFIG_ALL_LT7176

The MFR_CONFIG_ALL_LT7176 command sets various global configuration bits.

Table 11. MFR_CONFIG_ALL_LT7176 Bits

BITS	DEFAULT	MEANING
[15:7]	000000000	Reserved.
6	0	0 = Configuration resistors are measured and used to configure the LT7176/LT7176-1 during initialization. 1 = CFG pin configuration resistors are ignored on VOUT_CFG and PWM_CFG pins.
[5:3]	000	Reserved.
2	0	0 = Valid PEC not required. 1 = Valid PEC required.
1	0	0 = Disable PMBus clock stretching. If the LT7176/LT7176-1 are too busy to process a command, the devices refuse to acknowledge the command and set Bit 7 in STATUS_BYTE and STATUS_WORD. 1 = Enable PMBus clock stretching.
0	0	Reserved.

On, Off, and Margin

Table 12. On, Off, and Margin Commands[1]

COMMAND NAME	CODE	DESCRIPTION	TYPE	NVM	DEFAULT VALUE
OPERATION	0x01	Operating mode control. On/off, margin high, and margin low.	R/W byte	Yes	0x80
ON_OFF_CONFIG	0x02	RUN pin and PMBus OPERATION command configuration.	R/W byte	Yes	0x1E
MFR_RESET	0xFD	Commanded reset.	Send byte		

[1] Empty cells are left blank intentionally.

Operation

The OPERATION command is used to turn the channel on or off in conjunction with the RUN pin, according to the configuration defined in ON_OFF_CONFIG. It is also used to set the output voltage to VOUT_MARGIN_HIGH or VOUT_MARGIN_LOW.

Disabling and then re-enabling the channel causes all latched faults and status bits to be cleared.

Table 13 lists the OPERATION values supported by the LT7176/LT7176-1.

Table 13. Operation Values

FUNCTION	VALUE
Turn off immediately	0×00
Turn on	0×80
Margin low	0×98
Margin high	0×AB
Sequence off	0×40

ON_OFF_CONFIG

The ON_OFF_CONFIG command configures the combination of the RUN pin input and serial bus commands required to turn the channel on and off.

The only bits allowed to be changed are as follows:

- Bit 3: when high, the channel only provides output power if the on/off portion of the OPERATION is set.
- Bit 2: when high, the channel only provides output power if the RUN pin is high.
- Bit 0: when high, the channel performs an immediate shutdown when the RUN pin is deasserted. Bit 0 only has an effect when Bit 2 is also set.

Bit 4 and Bit 1 must both be 1. Setting Bit 4 or Bit 1 to 0 generates a CML fault.

If Bit 2 and Bit 3 of the ON_OFF_CONFIG command are both set to 1 (which is the factory default), the channel only turns on if the RUN pin is high and the OPERATION command is set to enable (on, margin low, or margin high).

MFR_RESET

The MFR_RESET command causes the LT7176/LT7176-1 to reset.

Reading the MFR_RESET command also causes the LT7176/LT7176-1 to reset.

PWM Configuration

Table 14. PWM Configuration Commands

COMMAND NAME	CODE	DESCRIPTION	TYPE	UNIT[1]	NVM	DEFAULT VALUE
FREQUENCY_SWITCH	0x33	Controller switching frequency.	R/W word	kHz	Yes	1000.0
MFR_PWM_MODE_LT7176	0xD4	PWM configuration, including PWM mode.	R/W word	N/A	Yes	0x0FDC
MFR_PWM_PHASE_LT7176	0xF5	Sets PWM phase.	R/W byte	N/A	Yes	0x00
MFR_SYNC_CONFIG_LT7176	0xF6	SYNC pin configuration.	R/W byte	N/A	Yes	0x01

[1] N/A means not applicable.

FREQUENCY_SWITCH

The FREQUENCY_SWITCH command selects the internal oscillator frequency in 50kHz steps. The valid range is from 1MHz to 3MHz. If the commanded frequency is not a multiple of 50kHz, the nearest multiple is used.

Regardless of the value of FREQUENCY_SWITCH, if an external clock is present on the SYNC pin, the LT7176P/LT7176P-1 attempts to synchronize the PWM to the external clock, unless Bit 1 or Bit 0 in the MFR_SYNC_CONFIG_LT7176 command is set. If an external clock is to be used for synchronization, it is recommended to program FREQUENCY_SWITCH to the same frequency as the external clock.

The FREQUENCY_SWITCH command has two data bytes encoded in half-precision floating point format. When Bit 6 of the MFR_CONFIG_ALL_LT7176 command is 0, a configuration resistor on the PWM_CFG pin can override stored NVM values for the FREQUENCY_SWITCH command at power-up.

MFR_PWM_MODE_LT7176

Table 15. MFR_PWM_MODE_LT7176 Bits

BITS	DEFAULT	MEANING		
[15:11]	0b00001	Error Amplifier Transconductance (g_{MEA}), 0.3V to 1.375V V_{OUT} range: g_{MEA} = (Value + 1) × 150µS, 0.8V to 2.75V V_{OUT} range: g_{MEA} = (Value + 1) × 75µS, 1.6V to 3.4V V_{OUT} range: g_{MEA} = (Value + 1) × 37.5µS.		
[10:9]	0b11	Current-Limit Selection[1]		
		Value	**Positive Valley Current Limit, $I_{LIM-POS}$ (Typical)**	**Negative Valley Current Limit, $I_{LIM-NEG}$ (Typical)**
		3	+24A	−13.4A
		2	+19A	−11.4A
		1	+14A	−8.2A
		0	+10A	−6.8A
[8:6]	0b111	Internal Compensation Capacitor Value, C_{ITH}		
		Value		**C_{ITH} Capacitor Value**
		7		320pF
		6		280pF
		5		240pF
		4		200pF
		3		160pF
		2		120pF
		1		80pF
		0		40pF

BITS	DEFAULT	MEANING	
[5:3]	0b011	Internal Compensation Lead Resistor Value, R_{ITH}	
		Value	**R_{ITH} Resistor Value**
		7	60kΩ
		6	42kΩ
		5	29kΩ
		4	20kΩ
		3	14kΩ
		2	10kΩ
		1	7kΩ
		0	5kΩ
2	1	0 = Bit 0 is used during TOFF_FALL. 1 = Use forced continuous mode during TOFF_FALL regardless of the value of Bit 0.	
1	0	Forces the connection of the internal compensation network to I_{TH}, even if there is external compensation.	
0	0	0 = Channel operates in forced continuous conduction mode when the output is in regulation at the commanded output voltage and during TOFF_FALL 1 = Pulse skip mode is enabled.	

[1] The LT7176P-1 per-phase current limits are half of the LT7176P current limit settings. For example, for a current limit 0, the LT7176P-1 positive current limit is 5A per phase, for a total of 10A.

When Bit 6 of the MFR_CONFIG_ALL_LT7176 command is 0, configuration resistors, if populated, override stored NVM values for the MFR_PWM_MODE_LT7176 command at power-up.

MFR_PWM_PHASE_LT7176

The MFR_PWM_PHASE_LT7176 command sets the channel PWM phase.

Table 16. MFR_PWM_PHASE_LT7176 Value and Phase

VALUE	PHASE (°)
0×00	0
0×01	15
0×02	30
0×03	45
0×04	60
0×05	75
0×06	90
0×07	105

VALUE	PHASE (°)
0×08	120
0×09	135
0×0a	150
0×0b	165
0×0c	180
0×0d	195
0×0e	210
0×0f	225
0×10	240
0×11	255
0×12	270
0×13	285
0×14	300
0×15	315
0×16	330
0×17	345

When Bit 6 of the MFR_CONFIG_ALL_LT7176 command is 0, configuration resistors, if populated, override stored NVM values for the MFR_PWM_PHASE_LT7176 command at power-up.

MFR_SYNC_CONFIG_LT7176

Table 17. MFR_SYNC_CONFIG_LT7176 Bits

BITS	DEFAULT	MEANING
[7:2]	000000	Must be 0.
1	0	0 = SYNC clock input is used if applied. 1 = Ignore SYNC clock input. Note that the SYNC clock input is always ignored if the SYNC output is enabled (Bit 0 high). Note that even if Bit 1 is set, an external clock on SYNC may not be ignored during reset. If an external clock is applied to SYNC at POR and the configuration resistor function has not been disabled (that is, Bit 6 of the MFR_CONFIG_ALL_LT7176 command is set to its factory default value of 0 in NVM), the LT7176P/LT7176P-1 configure internal settings as described in the *Theory of Operation* section in the **LT7176P**data sheet.
0	1	0 = Disable SYNC output clock. 1 = Enable SYNC output clock (after V_{IN} has risen above VIN_ON for the first time after power is applied).

When Bit 6 of MFR_CONFIG_ALL_LT7176 is 0, configuration resistors may override stored NVM values for the MFR_SYNC_CONFIG_LT7176 command at power-up.

Input Voltage and Limits

Table 18. Input Voltage and Limits Commands

COMMAND NAME	CODE	DESCRIPTION	TYPE	UNIT	NVM	DEFAULT VALUE
VIN_ON	0x35	Input voltage at which the channel starts power conversion.	R/W word	V	Yes	1.4
VIN_OFF	0x36	Input voltage at which the channel stops power conversion.	R/W word	V	Yes	1.35
VIN_UV_WARN_LIMIT	0x58	Input supply undervoltage warning limit.	R/W word	V	Yes	−1.0

VIN_ON

The VIN_ON command sets the value of the V_{IN} voltage, in volts, at which the LT7176/LT7176-1 starts power conversion.

Note that the LT7176/LT7176-1 regulator does not start unless either $EXTV_{CC}$ is more than 3.0V or V_{IN} is more than 2.7V.

This command has two data bytes encoded in half-precision floating-point format.

- Maximum = 4.0V
- Minimum = 1.4V

VIN_OFF

The VIN_OFF command sets the value of the V_{IN} voltage, in volts, at which the LT7176/LT7176-1 stops power conversion.

This command has two data bytes encoded in half-precision floating-point format.

- Maximum = 4.0V
- Minimum = 1.35V

VIN_UV_WARN_LIMIT

The VIN_UV_WARN_LIMIT command sets the value of the input voltage that causes an input voltage low warning.

This alarm is masked until the input exceeds the warning limit at least once since the LT7176/LT7176-1 has been powered.

In response to the VIN_UV_WARN_LIMIT being exceeded, the device also does the following:

- Sets the NONE_OF_THE_ABOVE bit in the STATUS_BYTE command.
- Sets the INPUT bit in the STATUS_WORD command.
- Sets the V_{IN} undervoltage warning bit in the STATUS_INPUT command.
- Notifies the host by asserting the $\overline{\text{ALERT}}$ pin low, unless masked.
- Share fault by asserting the $\overline{\text{FAULT}}$ pin low, if selected by MFR_FAULT_PROPAGATE_LT7176.

This VIN_UV_WARN_LIMIT command has two data bytes encoded in half-precision floating-point format.

- Maximum = 7.0V
- Minimum = −1.0V

The low-input-voltage warning is detected by the ADC. The typical response time is less than 5ms in continuous monitor mode and less than 100ms in low-power mode. Note that this response delay occurs even when the previous ADC measurement is under the new VIN_UV_WARN_LIMIT command.

Output Voltage and Limits

Table 19. Output Voltage and Limits Commands

COMMAND NAME	CODE	DESCRIPTION	TYPE	UNIT[1]	NVM	DEFAULT VALUE
VOUT_MODE	0x20	Output voltage format and exponent.	R byte	N/A	No	0x60
VOUT_COMMAND	0x21	Nominal output voltage set point.	R/W word	V	Yes	0.3
VOUT_MAX	0x24	Upper limit on the commanded output voltage.	R/W word	V	Yes	0.323
VOUT_MARGIN_HIGH	0x25	Margin high output voltage set point.	R/W word	V	Yes	0.315
VOUT_MARGIN_LOW	0x26	Margin low output voltage set point.	R/W word	V	Yes	0.3
VOUT_OV_FAULT_LIMIT	0x40	Output overvoltage fault limit.	R/W word	V	Yes	0.33
VOUT_OV_WARN_LIMIT	0x42	Output overvoltage warning limit.	R/W word	V	Yes	0.323
VOUT_UV_WARN_LIMIT	0x43	Output undervoltage warning limit.	R/W word	V	Yes	0.278
VOUT_UV_FAULT_LIMIT	0x44	Output undervoltage fault limit.	R/W word	V	Yes	0.27
MFR_DISCHARGE_ THRESHOLD	0xE4	The voltage threshold that determines output has decayed sufficiently.	R/W word	V	Yes	0.2
MFR_PGOOD_DELAY	0xF2	Time output voltage must be between UV and OV before PGOOD transitions high.	R/W word	ms	Yes	1.0
MFR_NOT_PGOOD_DELAY	0xF3	Time output voltage must be below UV or above OV before PGOOD transitions low.	R/W word	ms	Yes	0.1

[1] N/A means not applicable.

VOUT_MODE

The read-only VOUT_MODE command returns 0x60, indicating that the output voltage commands use the IEEE half-precision floating-point format.

VOUT_COMMAND

The VOUT_COMMAND command sets the output voltage when the OPERATION command has selected VOUT_COMMAND and uses half-precision floating-point format.

If OPERATION is set to 0x80 (turn on the output with the target voltage of VOUT_COMMAND) and VOUT_COMMAND is greater than VOUT_MAX, the target output voltage is limited to VOUT_MAX. When VOUT_COMMAND is commanded to a value greater than VOUT_MAX, a VOUT_MAX warning occurs.

When Bit 6 of MFR_CONFIG_ALL_LT7176 is 0, configuration resistors may override stored NVM values for this command at power-up.

Bits[2:1] of MFR_CHAN_CONFIG_LT7176 select the output voltage range. See *Table 20* for the recommended minimum output voltage for each voltage range.

Table 20. Output Voltage Range Maximums and Minimums

1.375V V_{OUT} RANGE	2.75V V_{OUT} RANGE	3.4V V_{OUT} RANGE
1.375V maximum	2.75V maximum	3.4V maximum
0.3V minimum	0.8V minimum	1.6V minimum

VOUT_MAX

The VOUT_MAX command sets an upper limit on the commanded voltage. It applies to VOUT_COMMAND, VOUT_MARGIN_HIGH, and VOUT_MARGIN_LOW. If the output voltage is commanded to a value greater than VOUT_MAX, the target output voltage is limited to VOUT_MAX. When VOUT_MAX is lower than VOUT_COMMAND, VOUT_MARGIN_HIGH, or VOUT_MARGIN_LOW, a VOUT_MAX warning occurs.

The VOUT_MAX command uses a half-precision floating point format.

- Maximum = 5.5V
- Minimum = 0.3V

When Bit 6 of MFR_CONFIG_ALL_LT7176 is 0, configuration resistors may override stored NVM values for this command at power-up.

VOUT_MARGIN_HIGH

The VOUT_MARGIN_HIGH command loads the LT7176/LT7176-1 with the voltage to which the output is to be regulated when the OPERATION command is set to 0xA8 (margin high). When OPERATION is set to 0xA8 and VOUT_MARGIN_HIGH is greater than VOUT_MAX, the output voltage is limited to VOUT_MAX. When VOUT_MARGIN_HIGH is commanded to a value greater than VOUT_MAX, a VOUT_MAX warning occurs.

The VOUT_MARGIN_HIGH command uses half-precision floating point format.

When Bit 6 of MFR_CONFIG_ALL_LT7176 is 0, configuration resistors may override stored NVM values for the VOUT_MARGIN_HIGH command at power-up.

Bits[2:1] of MFR_CHAN_CONFIG_LT7176 select the output voltage range.

Table 21. Output Voltage Range Maximums and Minimums

1.375V V_{OUT} RANGE	2.75V V_{OUT} RANGE	3.4V V_{OUT} RANGE
1.375V maximum	2.75V maximum	3.4V maximum
0.3V minimum	0.8V minimum	1.6V minimum

VOUT_MARGIN_LOW

The VOUT_MARGIN_LOW command loads the LT7176/LT7176-1 with the voltage to which the output is to be changed when the OPERATION command is set to 0x98 (margin low). When OPERATION is set to 0x98 and VOUT_MARGIN_LOW is greater than VOUT_MAX, the output voltage is limited to VOUT_MAX. When VOUT_MARGIN_LOW is commanded to a value greater than VOUT_MAX, the VOUT_MAX_WARNING bit in VOUT_STATUS is set.

The VOUT_MARGIN_LOW command uses half-precision floating point format.

When Bit 6 of MFR_CONFIG_ALL_LT7176 is 0, configuration resistors may override stored NVM values for this command at power-up.

Bits[2:1] MFR_CHAN_CONFIG_LT7176 select the output voltage range.

Table 22. Output Voltage Range Maximums and Minimums

1.375V V_{OUT} RANGE	2.75V V_{OUT} RANGE	3.4V V_{OUT} RANGE
1.375V maximum	2.75V maximum	3.4V maximum
0.3V minimum	0.8V minimum	1.6V minimum

VOUT_OV_FAULT_LIMIT

The VOUT_OV_FAULT_LIMIT command sets the value of the output voltage measured at the VSENSE pins, which causes an output overvoltage fault.

The VOUT_OV_FAULT_LIMIT command uses a half-precision floating point format.

- Maximum = 6.0V
- Minimum = 0.3V

The value must be greater than VOUT_UV_WARN_LIMIT, VOUT_UV_FAULT_LIMIT, and MFR_DISCHARGE_THRESHOLD, or an invalid data error occurs.

When Bit 6 of MFR_CONFIG_ALL_LT7176 is 0, configuration resistors may override stored NVM values for this command at power-up.

VOUT_OV_WARN_LIMIT

The VOUT_OV_WARN_LIMIT command sets the value of the output voltage measured at the VSENSE pins, which causes an output overvoltage warning. In response to the VOUT_OV_WARN_LIMIT being exceeded, the LT7176/LT7176-1 also do the following:

- Set the NONE_OF_THE_ABOVE bit in the STATUS_BYTE command.
- Set the VOUT bit in the STATUS_WORD command.
- Set the V_{OUT} overvoltage warning bit in the STATUS_VOUT command.
- Notify the host by asserting the $\overline{\text{ALERT}}$ pin low, unless masked.
- Share fault by asserting the $\overline{\text{FAULT}}$ pin low, if selected by MFR_FAULT_PROPAGATE_LT7176.

The VOUT_OV_WARN_LIMIT command uses a half-precision floating point format.

- Maximum = 6.0V
- Minimum = 0.0V

The value must be greater than VOUT_UV_WARN_LIMIT, VOUT_UV_FAULT_LIMIT, and MFR_DISCHARGE_THRESHOLD, or an invalid data error occurs.

When Bit 6 of MFR_CONFIG_ALL_LT7176 is 0, configuration resistors may override stored NVM values for this command at power-up.

VOUT_UV_WARN_LIMIT

The VOUT_UV_WARN_LIMIT command sets the value of the output voltage measured at the VSENSE pins, which causes an output undervoltage warning.

In response to VOUT_UV_WARN_LIMIT being exceeded, the LT7176/LT7176-1 also do the following:

- Set the NONE_OF_THE_ABOVE bit in the STATUS_BYTE.
- Set the VOUT bit in the STATUS_WORD.
- Set the V_{OUT} undervoltage warning bit in the STATUS_VOUT command.
- Notify the host by asserting the $\overline{\text{ALERT}}$ pin is low, unless masked.
- Share fault by asserting the $\overline{\text{FAULT}}$ pin is low, if selected by MFR_FAULT_PROPAGATE_LT7176.

The VOUT_UV_WARN_LIMIT command uses a half-precision floating point format.

- Maximum = 5.5V
- Minimum = 0.0V

The value must be less than VOUT_OV_WARN_LIMIT and VOUT_OV_FAULT_LIMIT, or an invalid data error occurs.

When Bit 6 of MFR_CONFIG_ALL_LT7176 is 0, configuration resistors may override stored NVM values for the VOUT_UV_WARN_LIMIT command at power-up.

VOUT_UV_FAULT_LIMIT

The VOUT_UV_FAULT_LIMIT command sets the value of the output voltage measured at the VSENSE pins, which causes an output undervoltage fault.

The VOUT_UV_FAULT_LIMIT command uses a half-precision floating point format.

- Maximum = 5.5V
- Minimum = 0.27V

The value must be less than VOUT_OV_WARN_LIMIT and VOUT_OV_FAULT_LIMIT, or an invalid data error occurs.

When Bit 6 of MFR_CONFIG_ALL_LT7176 is 0, configuration resistors may override stored NVM values for the VOUT_UV_FAULT_LIMIT command at power-up.

MFR_DISCHARGE_THRESHOLD

The MFR_DISCHARGE_THRESHOLD command specifies the output voltage threshold below which the output voltage must decay to enable the channel if the discharge threshold feature is enabled (Bit 0 of MFR_CHAN_CONFIG_LT7176 is 0).

If the discharge threshold is enabled, when automatically retrying after a fault, the device also waits for V_{OUT} to be less than the discharge threshold after waiting MFR_RETRY_DELAY.

The value must be less than VOUT_OV_WARN_LIMIT and VOUT_OV_FAULT_LIMIT, or an invalid data error occurs.

This command uses a half-precision floating-point format.

- Maximum = 6V
- Minimum = 0.1V

MFR_PGOOD_DELAY

The MFR_PGOOD_DELAY command sets the time, in milliseconds, rounded to the nearest 10µs, that the output voltage must be between VOUT_OV_FAULT_LIMIT and VOUT_UV_FAULT_LIMIT before the PGOOD pin transitions high. If the output voltage moves to less than the undervoltage limit or more than the overvoltage limit before the PGOOD pin transitions high, the delay timer resets to zero. Note that PGOOD is always held low when the channel is off and during TON_RISE, regardless of whether VOUT is within the limits.

This command uses a half-precision floating-point format.

- Maximum = 64000ms
- Minimum = 0ms

MFR_NOT_PGOOD_DELAY

The MFR_NOT_PGOOD_DELAY command sets the time in milliseconds, rounded to the nearest 10 µs, that the output voltage must be between VOUT_OV_FAULT_LIMIT and VOUT_UV_FAULT_LIMIT before the PGOOD pin is pulled low. If the output voltage is between the undervoltage and overvoltage limits before PGOOD transitions low, the delay timer resets to zero. Note that the MFR_NOT_PGOOD_DELAY command only applies when the channel is enabled. If the channel is disabled by the MFR_NOT_PGOOD_DELAY command, the RUN pin, or a fault condition set to disable the output, the PGOOD pin is pulled low immediately.

This command uses a half-precision floating-point format.

- Maximum = 100ms
- Minimum = 0ms

Output Current Limits

Table 23. Output Current Limits Commands

COMMAND NAME	CODE	DESCRIPTION	TYPE	UNIT	NVM	DEFAULT
IOUT_OC_WARN_LIMIT	0x4A	Output overcurrent warning limit	R/W word	A	Yes	24.0

IOUT_OC_WARN_LIMIT

The IOUT_OC_WARN_LIMIT command sets the value of the output current that causes an output overcurrent warning in amperes. This value is the total current limit, not per phase.

In response to the IOUT_OC_WARN_LIMIT being exceeded, the LT7176/LT7176-1 do the following:

- Set the NONE_OF_THE_ABOVE bit in the STATUS_BYTE command.
- Set the IOUT bit in the STATUS_WORD command.
- Set the I_{OUT} overcurrent warning bit in the STATUS_IOUT command.
- Notify the host by asserting the $\overline{\text{ALERT}}$ pin is low, unless masked.
- Share fault by asserting the $\overline{\text{FAULT}}$ pin low, if selected by MFR_FAULT_PROPAGATE_LT7176.

The IOUT_OC_WARN_LIMIT command uses a half-precision floating point format.

- Maximum = 30A
- Minimum = 0.0A

The output overcurrent warning is detected by the ADC. Typical response time is less than 5ms in continuous-monitor mode and is less than 100ms in low-power mode.

The IOUT_OC_WARN_LIMIT command is ignored during TON_RISE.

Temperature

Table 24. Temperature Commands

COMMAND NAME	CODE	DESCRIPTION	TYPE	UNIT	NVM	DEFAULT VALUE
OT_FAULT_LIMIT	0x4F	Overtemperature fault limit	R/W word	°C	Yes	160
OT_WARN_LIMIT	0x51	Overtemperature warning limit	R/W word	°C	Yes	140

OT_FAULT_LIMIT

The OT_FAULT_LIMIT command sets the value of the internal die temperature in degrees Celsius, which causes an overtemperature fault. This command uses a half-precision floating-point format.

- Maximum = +160°C
- Minimum = −60°C

OT_WARN_LIMIT

The OT_WARN_LIMIT command sets the value of the internal die temperature in degrees Celsius, which causes an overtemperature warning. In response to the OT_WARN_LIMIT being exceeded, the LT7176/LT7176-1 use the following steps:

- Set the TEMPERATURE bit in the STATUS_BYTE command.
- Set the overtemperature warning bit in the STATUS_TEMPERATURE command.
- Notify the host by asserting the $\overline{\text{ALERT}}$ pin is low, unless masked.
- Share fault by asserting the $\overline{\text{FAULT}}$ pin low, if selected by MFR_FAULT_PROPAGATE_LT7176.

The OT_WARN_LIMIT command uses a half-precision floating point format.

- Maximum = +160°C
- Minimum = −60°C

The overtemperature warning is detected by the ADC. The typical response time is less than 5ms in continuous monitor mode and less than 100ms in low-power mode.

Timing

Sequencing On

Table 25. Sequencing On Commands

COMMAND NAME	CODE	DESCRIPTION	TYPE	UNIT	NVM	DEFAULT VALUE
VOUT_TRANSITION_RATE	0x27	Rates the output changes when commanded to a new value.	R/W word	V/ms	Yes	0.25
TON_DELAY	0x60	Time from RUN or OPERATION on to output turn-on.	R/W word	ms	Yes	0
TON_RISE	0x61	Time from output turn-on to reach the commanded value.	R/W word	ms	Yes	1.0
TON_MAX_FAULT_LIMIT	0x62	Maximum time from the start of TON_RISE for V_{OUT} to cross VOUT_UV_FAULT_LIMIT.	R/W word	ms	Yes	5.0

VOUT_TRANSITION_RATE

When a PMBus device receives either a VOUT_COMMAND, OPERATION, VOUT_MARGIN_HIGH, VOUT_MARGIN_LOW, or VOUT_MAX command that causes the output voltage to change, VOUT_TRANSITION_RATE sets the rate (in V/ms) at which the output voltage changes. This commanded rate of change does not apply when the unit is commanded on or off. Values of greater than 0.05V/ms are recommended for optimal performance. At smaller sizes, the transition-step-size quantization error may be undesirable.

The VOUT_TRANSITION_RATE command uses a half-precision floating-point format.

- Maximum = 25V/ms (While the VOUT_TRANSITION_RATE can be commanded up to 25V/ms, the actual achievable output voltage transition rate may be limited by other factors, including output capacitance, current limit, and compensation.)
- Minimum = 0.01V/ms

TON_DELAY

The TON_DELAY command sets the time, in milliseconds, from when a start condition is received until the output voltage starts to rise. The time is internally rounded down to the nearest 10µs. This command uses a half-precision floating-point format.

- Maximum = 64000ms
- Minimum = 0ms

TON_RISE

The TON_RISE command sets the time, in milliseconds, from the time the output starts to rise to the time the output enters the regulation band. The time is internally rounded to the nearest 10µs. The channel is set to pulse-skipping mode during TON_RISE events. The maximum rise rate of the digital ramp controller is 25V/ms. If the commanded output voltage divided by TON_RISE is more than 25V/ms, the digital control ramps at this rate. The minimum output voltage rise time is further limited by the analog behavior of the switcher, which is affected by several factors, including output capacitance, current-limit selection, and loop compensation.

When TON_RISE is commanded to change during the TON ramp-up, the LT7176/LT7176-1 act on the command as soon as possible. However, the new ramp rate is calculated for a full ramp from 0V. Because the output is partially ramped and time has already passed, the actual total ramp time differs from the new value for TON_RISE.

The TON_RISE command uses a half-precision floating-point format.

- Maximum = 63ms
- Minimum = 0ms

TON_MAX_FAULT_LIMIT

The TON_MAX_FAULT_LIMIT command sets the value, in milliseconds, that determines how long the LT7176/LT7176-1 can attempt to power up the output without reaching the output undervoltage fault limit. The time is internally rounded down to the nearest 10µs. A data value of 0ms means that there is no limit and that the unit can attempt to bring up the output voltage indefinitely.

The TON_MAX_FAULT_LIMIT time starts after TON_DELAY has finished, and a soft-start sequence is started. The resolution of the TON_MAX_FAULT_LIMIT is 10µs. If the VOUT_UV_FAULT_LIMIT is not reached within the TON_MAX_FAULT_LIMIT time, the response of this fault is determined of the value of the TON_MAX_FAULT_RESPONSE command value.

The TON_MAX_FAULT_LIMIT command uses a half-precision floating-point format.

- Maximum = 64000ms
- Minimum (disabled) = 0ms

Sequencing Off

Table 26. Sequencing Off Commands

COMMAND NAME	CODE	DESCRIPTION	TYPE	UNIT	NVM	DEFAULT VALUE
TOFF_DELAY	0x64	Time from RUN and/or OPERATION off to the start of TOFF_FALL	R/W word	ms	Yes	0.0
TOFF_FALL	0x65	Time from when the output starts to fall until the output reaches 0V	R/W word	ms	Yes	2.0
TOFF_MAX_WARN_LIMIT	0x66	Maximum allowed time, after TOFF_FALL is completed, for output to decay below MFR_DISCHARGE_THRESHOLD	R/W word	ms	Yes	0.0

TOFF_DELAY

The TOFF_DELAY command sets the time, in milliseconds, from when a stop condition is received until the output voltage starts to fall. The time is internally rounded down to the nearest 10µs. This command uses a half-precision floating-point format.

- Maximum = 64000ms
- Minimum = 0ms

TOFF_FALL

The TOFF_FALL command sets the time, in milliseconds, from the end of the turn-off delay time until the output voltage is commanded to zero. The time is internally rounded to the nearest 10µs. It is the ramp time of the V_{OUT} DAC.

During V_{OUT} ramp-down, the LT7176/LT7176-1 uses continuous conduction mode if either Bit 2 of MFR_PWM_MODE_LT7176 is set to 1, or Bit 0 of MFR_PWM_MODE_LT7176 is set to 0. Otherwise, V_{OUT} decays only due to the external load (and the 250Ω internal pull-down if Bit 6 of MFR_CHAN_CONFIG_LT7176 is set to 1). For defined TOFF_FALL times, it is recommended to set Bit 2 of MFR_PWM_MODE_LT7176 to 1. The maximum fall rate of the digital ramp controller is 25V/ms. If the commanded output voltage divided by TOFF_FALL is more than 25V/ms, the digital control ramps down at this rate. The minimum V_{OUT} fall time is further limited by the analog behavior of the switcher, which is affected by several factors, including output load, output capacitance, and current-limit selection. After the digital ramp-down is completed, the switching regulator is disabled. If the V_{OUT} fall rate is limited by the analog behavior, the regulator disables before the ramp-down is complete, and the output is not forced all the way to zero. Setting TOFF_FALL to 2ms or greater ensures that V_{OUT} ramps to zero during TOFF_FALL.

The TOFF_FALL command uses a half-precision floating-point format.

- Maximum = 63ms
- Minimum = 0ms

TOFF_MAX_WARN_LIMIT

The TOFF_MAX_WARN_LIMIT command sets the value, in milliseconds, that determines how long the LT7176/LT7176-1 can attempt to turn off the output until a warning is asserted. The time is internally rounded to the nearest 1ms. The output is considered off when the VOUT voltage is less than MFR_DISCHARGE_THRESHOLD. The calculation begins after TOFF_FALL is complete. TOFF_MAX_WARN is not enabled if the discharge requirement is disabled (Bit 0 of MFR_CHAN_CONFIG_LT7176 is set to 1).

In response to the TOFF_MAX_WARN_LIMIT being exceeded, the LT7176/LT7176-1 also do the following:

- Set the NONE_OF_THE_ABOVE bit in the STATUS_BYTE command.
- Set the VOUT bit in the STATUS_WORD command.
- Set the TOFF maximum warning bit in the STATUS_VOUT command.
- Notify the host by asserting the $\overline{\text{ALERT}}$ pin low, unless masked.
- Share fault by asserting the $\overline{\text{FAULT}}$ pin low, if selected by MFR_FAULT_PROPAGATE_LT7176.

The special data value of 0ms means that there is no limit and that the LT7176/LT7176-1 can attempt to turn off the output voltage indefinitely.

The TOFF_MAX_WARN_LIMIT command uses a half-precision floating-point format.

- Maximum = 64000ms
- Minimum = 10.0ms
- Disabled = 0.0ms

Fault Response

All Faults

Table 27. All Faults Commands

COMMAND NAME	CODE	DESCRIPTION	TYPE	UNIT	NVM	DEFAULT VALUE
MFR_RETRY_DELAY	0xDB	Retry interval during fault retry	R/W word	ms	Yes	10.0

MFR_RETRY_DELAY

The MFR_RETRY_DELAY command sets the time in milliseconds between restarts if the fault response is to retry the controller at specified intervals. The time is internally rounded down to the nearest 10µs. This command value is used for all fault responses that require a retry. The retry time starts when a fault has been detected by the offending channel.

Note that the retry delay time is set by either the MFR_RETRY_DELAY command or the time required for the regulated output to decay below MFR_DISCHARGE_THRESHOLD, whichever is longer. If the natural decay time of the output is too long, it is possible to remove the voltage requirement of the MFR_RETRY_DELAY command by asserting Bit 0 of MFR_CHAN_CONFIG_LT7176.

The MFR_RETRY_DELAY command uses a half-precision floating-point format.

- Maximum = 64000ms
- Minimum = 0.02ms

Input Voltage

Input-voltage faults only cause a configured fault response when the associated device is on. The $\overline{\text{FAULT}}$ pin will also only be asserted when the device is on. However, the $\overline{\text{ALERT}}$ pin is asserted low unless masked by SMBALERT_MASK.

Table 28. Input Voltage Commands

COMMAND NAME	CODE	DESCRIPTION	TYPE	NVM	DEFAULT VALUE
VIN_OV_FAULT_RESPONSE	0x56	Action to be taken when an input overvoltage fault is detected.	R/W byte	Yes	0xB8

VIN_OV_FAULT_RESPONSE

The VIN_OV_FAULT_RESPONSE command sets the action the LT7176/LT7176-1 takes in response to an input overvoltage fault.

The LT7176/LT7176-1 also does the following:

- Set the NONE_OF_THE_ABOVE bit in the STATUS_BYTE command.
- Set the INPUT bit in the upper byte of the STATUS_WORD command.
- Set the VIN_OV fault bit in the STATUS_INPUT command.
- Notify the host by asserting the $\overline{\text{ALERT}}$ pin is low, unless masked.
- Share fault by asserting the $\overline{\text{FAULT}}$ pin low, if selected by MFR_FAULT_PROPAGATE_LT7176.

Table 29. Data Byte Contents: VIN_OV_FAULT_RESPONSE

BITS	DESCRIPTION	VALUE	MEANING
[7:6]	Response. For all values of Bits[7:6], the LT7176/LT7176-1 sets the VIN_OV fault bit in the STATUS commands and pulls the $\overline{\text{ALERT}}$ pin low, unless masked.	00	Not supported. Writing this value generates a CML fault.
		01	Not supported. Writing this value generates a CML fault.
		10 (default)	The LT7176/LT7176-1 shuts down immediately (disables the output) and responds according to the retry setting in Bits[5:3].
		11	Not supported. Writing this value generates a CML fault.
[5:3]	Retry setting.	000-110	The LT7176/LT7176-1 does not attempt to restart. The output remains disabled until the devices are commanded off or bias power is removed by removing V_{IN} and $EXTV_{CC}$.
		111 (default)	The LT7176/LT7176-1 attempts to restart continuously, without limitation, until the devices are commanded off (by the RUN pin or the OPERATION command or both), bias power is removed, or another fault condition causes the unit to shut down without retry. Note that the retry interval is set by the MFR_RETRY_DELAY command.
[2:0]	Delay time.	000 (default)	Must be 0. Writing this to a nonzero generates a CML fault.

Output Voltage

Output-voltage faults only cause a configured fault response when the associated channel is on. However, the $\overline{\text{ALERT}}$ pin is asserted low unless masked by SMBALERT_MASK.

Table 30. Output Voltage Commands

COMMAND NAME	CODE	DESCRIPTION	TYPE	NVM	DEFAULT VALUE
VOUT_OV_FAULT_RESPONSE	0x41	Action to be taken when an output overvoltage fault is detected	R/W byte	Yes	0xB8
VOUT_UV_FAULT_RESPONSE	0x45	Action to be taken when an output undervoltage fault is detected	R/W byte	Yes	0x00
TON_MAX_FAULT_RESPONSE	0x63	Action to be taken when a TON_MAX_FAULT event is detected	R/W byte	Yes	0x00

VOUT_OV_FAULT_RESPONSE

The VOUT_OV_FAULT_RESPONSE command sets the action the LT7176/LT7176-1 takes in response to an output overvoltage fault. The LT7176/LT7176-1 also does the following:

- Set the VOUT_OV bit in the STATUS_BYTE.
- Set the VOUT bit in the STATUS_WORD.
- Set the VOUT_OV fault bit in the STATUS_VOUT command.
- Set the VOUT_OV warning bit in the STATUS_VOUT command.
- Notify the host by asserting the $\overline{\text{ALERT}}$ pin is low, unless masked.
- Share fault by asserting the $\overline{\text{FAULT}}$ pin low, if selected by MFR_FAULT_PROPAGATE_LT7176.

Table 31. Data Byte Contents: VOUT_OV_FAULT_RESPONSE

BITS	DESCRIPTION	VALUE	MEANING
[7:6]	Response. For all values of Bits[7:6], the LT7176/LT7176-1 sets the VOUT_OV fault and warning bits in the status commands and pulls the $\overline{\text{ALERT}}$ pin low, unless masked.	00	The LT7176/LT7176-1 operates in continuous mode while the fault is active, attempting to regulate to the programmed voltage.
		01	The LT7176/LT7176-1 continues operation for the delay time specified by Bits[2:0] and the delay time unit specified for that particular fault. If the fault condition is still present at the end of the delay time, the devices respond as programmed in the retry setting (Bits[5:3]).
		10 (default)	The LT7176/LT7176-1 shuts down immediately (disables the output) and responds according to the retry setting in Bits[5:3].
		11	Not supported. Writing this value generates a CML fault.
[5:3]	Retry setting.	000 to 110	The LT7176/LT7176-1 does not attempt to restart. The output remains disabled until the LT7176/LT7176-1 are commanded off or bias power is removed by removing V_{IN} and $EXTV_{CC}$.
		111 (default)	The LT7176/LT7176-1 attempts to restart continuously, without limitation, until the devices are commanded off (by the RUN pin or the OPERATION command or both), bias power is removed, or another fault condition causes the unit to shut down without retry. Note that the retry interval is set by the MFR_RETRY_DELAY command.
[2:0]	Delay time.	XXX[1]	The delay time is in 10µs increments. This delay time determines how long the channel continues operating after a fault is detected. 000 is the default.

[1] X = Don't care.

VOUT_UV_FAULT_RESPONSE

The VOUT_UV_FAULT_RESPONSE command sets the action the LT7176/LT7176-1 takes in response to an output undervoltage fault. The LT7176/LT7176-1 also does the following:

- Set the NONE_OF_THE_ABOVE bit in the STATUS_BYTE command.
- Set the VOUT bit in the STATUS_WORD command.
- Set the VOUT UV fault bit in the STATUS_VOUT command.
- Set the VOUT UV warning bit in the STATUS_VOUT command.
- Notify the host by asserting the $\overline{\text{ALERT}}$ pin is low, unless masked.
- Share fault by asserting the $\overline{\text{FAULT}}$ pin low, if selected by MFR_FAULT_PROPAGATE_LT7176.
- The UV fault and warning are masked until the following criteria are achieved:
- The TON_MAX_FAULT_LIMIT is reached.
- The TON_DELAY sequence completes.
- The TON_RISE sequence completes.
- The VOUT_UV_FAULT_LIMIT threshold is reached.
- The IOUT_OC_FAULT_LIMIT is not present.

The UV fault and warning are masked whenever the channel is not active. The UV fault and warning are masked during TON_RISE and TOFF_FALL sequencing.

Table 32. Data Byte Contents: VOUT_UV_FAULT_RESPONSE

BITS	DESCRIPTION	VALUE	MEANING
7:6	Response. For all values of Bits[7:6], the LT7176/LT7176-1 set the VOUT_UV fault and warning bits in the STATUS commands and pull the $\overline{\text{ALERT}}$ pin low, unless masked.	00 (default)	The LT7176/LT7176-1 continues operation without interruption.
		01	The LT7176/LT7176-1 continues operation for the delay time specified by Bits[2:0] and the delay time unit specified for that particular fault. If the fault condition is still present at the end of the delay time, the devices respond as programmed in the retry setting (Bits[5:3]).
		10	The LT7176/LT7176-1 shuts down immediately (disables the output) and responds according to the retry setting in Bits[5:3].
		11	Not supported. Writing this value generates a CML fault.
[5:3]	Retry setting.	000 (default) to 110	The LT7176/LT7176-1 does not attempt to restart. The output remains disabled until the devices are commanded off or bias power is removed by removing V_{IN} and $EXTV_{CC}$.
		111	The LT7176/LT7176-1 attempt to restart continuously, without limitation, until the devices are commanded off (by the RUN pin or OPERATION command or both), bias power is removed, or another fault condition causes the devices to shut down without retry. Note that the retry interval is set by the MFR_RETRY_DELAY command.
[2:0]	Delay time.	XXX[1]	The delay time is in 10µs increments. This delay time determines how long the channel continues operating after a fault is detected. 000 is the default.

[1] X = Don't care.

TON_MAX_FAULT_RESPONSE

The TON_MAX_FAULT_RESPONSE command sets the action the LT7176/LT7176-1 takes in response to a TON MAX fault.

The LT7176/LT7176-1 also does the following:

- Set the NONE_OF_THE_ABOVE bit in the STATUS_BYTE command.
- Set the VOUT bit in the STATUS_WORD command.
- Set the TON MAX fault bit in the STATUS_VOUT command.
- Notify the host by asserting the $\overline{\text{ALERT}}$ pin is low, unless masked.
- Share fault by asserting the $\overline{\text{FAULT}}$ pin low, if selected by MFR_FAULT_PROPAGATE_LT7176.
- A value of 0 disables the TON_MAX_FAULT_RESPONSE command. It is not recommended to use 0.

Table 33. Data Byte Contents: TON_MAX_FAULT_RESPONSE

BITS	DESCRIPTION	VALUE	MEANING
[7:6]	Response. For all values of Bits[7:6], the LT7176/LT7176-1 sets the TON MAX fault bit in the STATUS commands and pulls the $\overline{\text{ALERT}}$ pin low, unless masked.	00 (default)	The LT7176/LT7176-1 continues operation without interruption.
		01	Not supported. Writing this value generates a CML fault.
		10	The LT7176/LT7176-1 shuts down immediately (disables the output) and responds according to the retry setting in Bits[5:3].
		11	Not supported. Writing this value generates a CML fault.
[5:3]	Retry setting.	000 (default) to 110	The LT7176/LT7176-1 does not attempt to restart. The output remains disabled until the devices are commanded off or bias power is removed by removing V_{IN} and $EXTV_{CC}$.
		111	The LT7176/LT7176-1 attempt to restart continuously, without limitation, until the devices are commanded off (by the RUN pin or OPERATION command or both), the bias power is removed, or another fault condition causes the devices to shut down without retry. Note that the retry interval is set by the MFR_RETRY_DELAY command.
[2:0]	Delay time.	XXX[1]	Must be 0. Writing this to nonzero generates a CML fault. 000 is the default.

[1] X = Don't care.

Output Current

Table 34. Output Current Commands

COMMAND NAME	CODE	DESCRIPTION	TYPE	NVM	DEFAULT VALUE
IOUT_OC_FAULT_RESPONSE	0x47	Action to be taken when an output overcurrent fault is detected	R/W byte	Yes	0x00

IOUT_OC_FAULT_RESPONSE

Table 35. Data Byte Contents: IOUT_OC_FAULT_RESPONSE

BITS	DESCRIPTION	VALUE	MEANING
[7:6]	Response. For all values of Bits[7:6], the LT7176/LT7176-1 sets the IOUT OC fault bit in the status commands and pulls the $\overline{\text{ALERT}}$ pin low, unless masked.	00 (default)	The LT7176/LT7176-1 continues operation indefinitely while maintaining the output current set by MFR_PWM_MODE_LT7176, regardless of the output voltage (known as constant-current or brick-wall limiting).
		01	Not supported. Writing this value generates a CML fault.
		10	The LT7176/LT7176-1 continues operation for the delay time specified by Bits[2:0] and the delay time unit specified for that particular fault. If the fault condition is still present at the end of the delay time, the devices respond as programmed in the retry setting (Bits[5:3]).
		11	The LT7176/LT7176-1 shuts down immediately (disables the output) and responds according to the retry setting in Bits[5:3].
[5:3]	Retry setting.	000 (default) to 110	The LT7176/LT7176-1 does not attempt to restart. The output remains disabled until the devices are commanded off or bias power is removed by removing V_{IN} and $EXTV_{CC}$.
		111	The LT7176/LT7176-1 attempt to restart continuously, without limitation, until the devices are commanded off (by the RUN pin or OPERATION command or both), bias power is removed, or another fault condition causes the units to shut down without retry. Note that the retry interval is set by the MFR_RETRY_DELAY command.
[2:0]	Delay time.	XXX[1]	The delay time is in 10µs increments. This delay time determines how long the channel continues to operate after a fault is detected. 000 is the default.

[1] X = Don't care.

Temperature

Internal temperature faults only cause a configured fault response when the associated channel is on. However, the $\overline{\text{ALERT}}$ pin is asserted low unless masked by SMBALERT_MASK.

Table 36. Temperature Command

COMMAND NAME	CODE	DESCRIPTION	TYPE	NVM	DEFAULT VALUE
OT_FAULT_RESPONSE	0x50	Action to be taken when an internal overtemperature fault is detected	R/W Byte	Yes	0xC0

OT_FAULT_RESPONSE

The OT_FAULT_RESPONSE command sets the action the LT7176/LT7176-1 takes in response to an internal overtemperature fault.

The LT7176/LT7176-1 also does the following:

- Set the MFR bit in the STATUS_WORD command.
- Set the OT fault bit in the STATUS_TEMPERATURE command.
- Notify the host by asserting the $\overline{\text{ALERT}}$ pin is low, unless masked.
- Share fault by asserting the $\overline{\text{FAULT}}$ pin low, if selected by MFR_FAULT_PROPAGATE_LT7176.

Table 37. Data Byte Contents: OT_FAULT_RESPONSE

BITS	DESCRIPTION	VALUE	MEANING
[7:6]	Response. For all values of Bits[7:6], the LT7176/LT7176-1 set the OT fault bit in the STATUS commands and pull the $\overline{\text{ALERT}}$ pin low, unless masked.	00	Not supported. Writing this value generates a CML fault.
		01	Not supported. Writing this value generates a CML fault.
		10	The LT7176/LT7176-1 shuts down immediately (disables the output) and responds according to the retry setting in Bits[5:3].
		11 (default)	The output of the LT7176/LT7176-1 is disabled while the fault is present. Operation resumes, and the output is enabled when the fault condition no longer exists.
[5:3]	Retry setting.	000 (default) to 110	The LT7176/LT7176-1 does not attempt to restart. The output remains disabled until the LT7176/LT7176-1 are commanded off or bias power is removed by removing V_{IN} and $EXTV_{CC}$.
		111	Not supported. Writing this value generates a CML fault.
[2:0]	Ignored.	XXX[1]	Ignored. 000 is the default.

[1] X = Don't care.

Fault Sharing

Table 38. Fault Sharing Commands

COMMAND NAME	CODE	DESCRIPTION	TYPE	NVM	DEFAULT
MFR_FAULT_PROPAGATE_LT7176	0xD2	Determines which faults are propagated to the $\overline{\text{FAULT}}$ pin	R/W Word	Y	0xA097
MFR_FAULT_RESPONSE	0xD5	Action to be taken when the $\overline{\text{FAULT}}$ pin is asserted low	R/W Byte	Y	0xC0

MFR_FAULT_PROPAGATE_LT7176

The MFR_FAULT_PROPAGATE_LT7176 command selects the conditions that can cause the $\overline{\text{FAULT}}$ pin to be asserted low. When the $\overline{\text{FAULT}}$ pin is asserted low due to a fault condition, it will remain asserted until:

- The channel is disabled and then enabled (by RUN or OPERATION, depending on ON_OFF_CONFIG), clearing the fault condition.
- The MFR_RETRY_DELAY expires when the fault condition is no longer present for faults that are configured with a retry response.

A fault is only propagated to the $\overline{\text{FAULT}}$ pin if the corresponding fault response command is configured to disable the channel and the corresponding bit is set to 1 in MFR_FAULT_PROPAGATE_LT7176.

Table 39. Data Byte Contents: MFR_FAULT_PROPAGATE_LT7176

BITS	DEFAULT	CONDITION	DESCRIPTION
15	1	V_{OUT} turned on while discharging	Enables propagation of the VOUT discharge condition. This is used when bit 0 of MFR_CHAN_CONFIG_LT7176 is 0 (discharge requirement enabled). If V_{OUT} is turned on while V_{SENSE} is above MFR_DISCHARGE_THRESHOLD, V_{OUT} will be disabled until V_{SENSE} decays below that threshold.
14	0	Reserved	
13	1	TON max fault	
12 to 8	0	Reserved	
7	1	Overtemperature fault	
6 to 5	0	Reserved	
4	1	Input OV fault	
3	0	Reserved	
2	1	I_{OUT} OC fault	
1	1	V_{OUT} UV fault	
0	1	V_{OUT} OV fault	

MFR_FAULT_RESPONSE

This command determines the device's response to the $\overline{\text{FAULT}}$ pin being pulled low.

Table 40. MFR_FAULT_RESPONSE Command

VALUE	MEANING
0xC0	The device will stop delivering power as fast as possible in response to the $\overline{\text{FAULT}}$ pin being pulled low.
0x00	The device continues to operate without interruption.

The LT7176/LT7176-1 also does the following:

- Sets the NONE_OF_THE_ABOVE bit in the STATUS_BYTE.
- Sets the MFR bit in the STATUS_WORD.

Identification

Table 41. Identification Commands[1]

COMMAND NAME	CODE	DESCRIPTION	TYPE	NVM	DEFAULT VALUE
CAPABILITY	0x19	PMBus optional communication protocols supported.	R byte	No	0xD8
PMBUS_REVISION	0x98	PMBus revision supported, currently 1.3.	R byte	No	0x33
MFR_ID	0x99	Returns ADI.	R block	No	ADI
MFR_SERIAL	0x9E	Unit-specific unique serial number.	R block	No	N/A
IC_DEVICE_ID	0xAD	Returns LT7176P or LT7176P-1.	R block	No	LT7176P or LT7176P-1
IC_DEVICE_REV	0xAE	Manufacturer revision number.	R block	No	N/A
MFR_SPECIAL_ID	0xE7	Manufacturer code.	R word	No	0x1C1D

[1] N/A means not applicable.

Status

Figure 1 summarizes the internal LT7176/LT7176-1 status registers accessible by the PMBus command. These status registers indicate various faults, warnings, and other important operating conditions. As shown in *Figure 1*, the STATUS_BYTE and STATUS_WORD commands summarize the contents of other status registers.

The NONE_OF_THE_ABOVE bit in STATUS_BYTE indicates that one or more of the bits in the most significant nibble of STATUS_WORD are also set.

Unless masked by SMBALERT_MASK, any asserted bit in a STATUS_x register (including any fault or warning) also pulls the $\overline{\text{ALERT}}$ pin low.

With some exceptions, the SMBALERT_MASK command can be used to prevent the LT7176/LT7176-1 from pulling the $\overline{\text{ALERT}}$ pin low for bits in these registers on a bit-by-bit basis. These mask settings apply to STATUS_WORD and

STATUS_BYTE in the same fashion as the status bits themselves. For example, if $\overline{\text{ALERT}}$ is masked for all bits in Channel 0 STATUS_VOUT, $\overline{\text{ALERT}}$ is effectively masked for the VOUT bit in STATUS_WORD for Page 0.

Status information contained in MFR_COMMON and MFR_PADS can be used to debug further or clarify the contents of STATUS_BYTE or STATUS_WORD, as shown in *Figure 1*. However, the contents of MFR_COMMON and MFR_PADS do not directly affect the state of the $\overline{\text{ALERT}}$ pin.

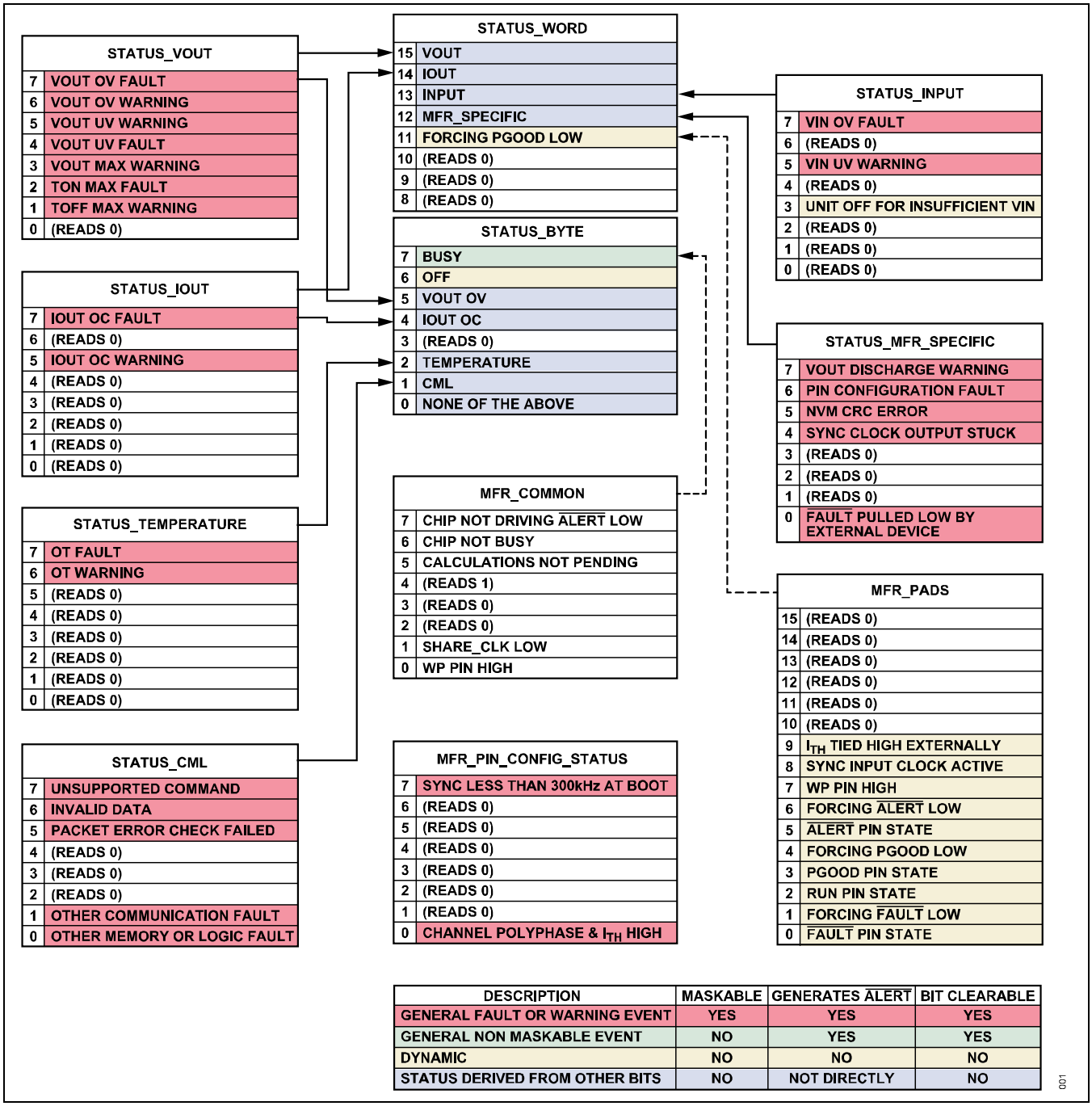

Figure 1. Status Register Summary

Table 42. Status Commands

COMMAND NAME	CODE	DESCRIPTION	TYPE	NVM
CLEAR_FAULTS	0x03	Clear all fault bits.	Send byte	No
SMBALERT_MASK	0x1B	Mask $\overline{\text{ALERT}}$ pin.	Block R/W	Yes
STATUS_BYTE	0x78	One-byte summary of the faults and warnings of the LT7176/LT7176-1.	R/W byte	No
STATUS_WORD	0x79	One-word summary of the faults and warnings of the LT7176/LT7176-1.	R/W word	No
STATUS_VOUT	0x7A	Output voltage faults and warnings.	R/W byte	No
STATUS_IOUT	0x7B	Output current faults and warnings.	R/W byte	No
STATUS_INPUT	0x7C	Input supply faults and warnings.	R/W byte	No
STATUS_TEMPERATURE	0x7D	Internal temperature faults and warnings.	R/W byte	No
STATUS_CML	0x7E	Communications, memory, and logic faults and warnings.	R/W byte	No
STATUS_MFR_SPECIFIC	0x80	Manufacturer-specific faults and warnings.	R/W byte	No
MFR_PADS_LT7176	0xE5	Digital status of I/O pads.	R word	No
MFR_COMMON	0xEF	Manufacturer status bits are common across multiple Analog Devices' devices.	R/W byte	No
MFR_CHANNEL_STATE	0xF1	Returns the state of the channel.	R byte	No
MFR_PIN_CONFIG_STATUS	0xF7	Indicates the source of the pin configuration fault.	R byte	No

CLEAR_FAULTS

The CLEAR_FAULTS command clears any fault bits that have been set. This command clears all bits in all STATUS commands simultaneously. The CLEAR_FAULTS command also deasserts the $\overline{\text{ALERT}}$ pin. If the fault is still present when the bit is cleared, the fault bit remains set, and the host is notified by asserting the $\overline{\text{ALERT}}$ pin is low.

The CLEAR_FAULTS command does not cause the LT7176/LT7176-1 that have latched off for a fault condition to restart. The LT7176/LT7176-1 devices that have shut down for a fault condition are restarted only when the following situations occur:

- The output is commanded to turn off and then to turn back on via the RUN pin and/or the OPERATION command.
- The MFR_RESET command is issued.
- The V_{IN} and $EXTV_{CC}$ bias power are removed and reapplied to the LT7176/LT7176-1.
- Reading the CLEAR_FAULTS command also clears all bits in all STATUS commands and deasserts the $\overline{\text{ALERT}}$ pin.

SMBALERT_MASK

The SMBALERT_MASK command can be used to prevent selected status bits from asserting $\overline{\text{ALERT}}$ low as they are asserted. Only supported bits can be masked.

The bits in the mask byte align with the bits in the specified status register. For example, if the STATUS_TEMPERATURE command code is sent in the first data byte and the mask byte contains 0x40, a subsequent overtemperature warning is still set, Bit 6 of STATUS_TEMPERATURE, but not assert $\overline{\text{ALERT}}$ low. All other supported STATUS_TEMPERATURE bits continue to assert $\overline{\text{ALERT}}$ low if set.

SMBALERT_MASK cannot be applied to the derived bits in STATUS_BYTE or STATUS_WORD. Bit 7, the busy fault bit, of STATUS_BYTE can be masked. The STATUS_WORD is not supported for SMBALERT_MASK.

Providing an unsupported command code to SMBALERT_MASK generates a CML for invalid and/or unsupported data.

Table 43. Factory Default SMBALERT_MASK Settings

STATUS REGISTER	MASK VALUE	MASKED BITS
STATUS_BYTE	0x00	None
STATUS_VOUT	0x00	None
STATUS_IOUT	0x80	IOUT_OC fault
STATUS_TEMPERATURE	0x00	None
STATUS_CML	0x00	None
STATUS_INPUT	0x00	None
STATUS_MFR_SPECIFIC	0x00	None

STATUS_BYTE

The STATUS_BYTE command returns a one-byte summary of the most critical faults. Bit 7 can be cleared by writing a 1 to its position.

Table 44. STATUS_BYTE Contents

BIT	NAME	DESCRIPTION
7	BUSY	A fault is declared because the LT7176/LT7176-1 fails to respond to a command.
6	OFF	This bit is set if the channel is not providing power to its output, regardless of the reason, including simply not being enabled.
5	VOUT OV	An output overvoltage fault has occurred.
4	IOUT OC	An output overcurrent fault has occurred.
3	Unsupported	Not supported (device returns 0).
2	TEMPERATURE	A temperature fault or warning has occurred.
1	CML	A communication, memory, or logic fault has occurred.
0	NONE OF THE ABOVE	A fault or warning not listed in Bits[7:1] has occurred.

STATUS_WORD

The STATUS_WORD command returns a two-byte summary of the channel fault condition. The low byte of the STATUS_WORD command is the same as the STATUS_BYTE command. Bit 7 can be cleared by writing a 1 to its position.

Table 45. STATUS_WORD Contents

BITS	NAME	DESCRIPTION
15	VOUT	An output voltage fault or warning has occurred.
14	IOUT	An output current fault or warning has occurred.
13	INPUT	An input voltage fault or warning has occurred.
12	MFR_SPECIFIC	A fault or warning specific to the LT7176/LT7176-1 has occurred.
11	POWER NOT GOOD	This bit is set when the LT7176/LT7176-1 is forcing the PGOOD pin low.
[10:8]	Unsupported	Not supported (device returns 0).

STATUS_VOUT

The STATUS_VOUT command returns one byte of V_{OUT} status information. An individual bit can be cleared by writing a 1 to its position.

Table 46. STATUS_VOUT Contents

BITS	NAME	DESCRIPTION
7	VOUT OV FAULT	V_{OUT} overvoltage fault.
6	VOUT OV WARNING	V_{OUT} overvoltage warning.
5	VOUT UV WARNING	V_{OUT} undervoltage warning.
4	VOUT UV FAULT	V_{OUT} undervoltage fault.
3	VOUT MAX WARNING	Warning that the LT7176/LT7176-1 is commanded to exceed VOUT_MAX.
2	TON MAX FAULT	TON_MAX fault.
1	TOFF MAX WARNING	TOFF_MAX warning.
0	Unsupported	Not supported (device returns 0).

STATUS_IOUT

The STATUS_IOUT command returns one byte of I_{OUT} status information. An individual bit can be cleared by writing a 1 to its position.

Table 47. STATUS_IOUT Contents

BIT	NAME	DESCRIPTION
7	IOUT OC FAULT	I_{OUT} overcurrent fault.
6	Unsupported	Not supported (device returns 0).
5	IOUT OC WARNING	I_{OUT} overcurrent warning.
[4:0]	Unsupported	Not supported (device returns 0).

STATUS_INPUT

The STATUS_INPUT command returns one byte of input voltage status information. An individual bit can be cleared by writing a 1 to its position.

Table 48. STATUS_INPUT Contents

BIT	NAME	DESCRIPTION
7	VIN OV FAULT	V_{IN} overvoltage fault.
6	Unsupported	Not supported (device returns 0).
5	VIN UV WARNING	V_{IN} undervoltage warning.
4	Unsupported	Not supported (device returns 0).
3	UNIT OFF FOR INSUFFICIENT VIN	The unit is off due to insufficient input voltage.
2	Unsupported	Not supported (device returns 0).
1	Unsupported	Not supported (device returns 0).
0	Unsupported	Not supported (device returns 0).

STATUS_TEMPERATURE

The STATUS_TEMPERATURE command returns one byte of sensed internal temperature status information. An individual bit can be cleared by writing a 1 to its position.

Table 49. STATUS_TEMPERATURE Contents

BIT	NAME	DESCRIPTION
7	OT FAULT	Internal overtemperature fault.
6	OT WARNING	Internal overtemperature warning.
[5:0]	Unsupported	Not supported (device returns 0).

STATUS_CML

The STATUS_CML command returns one byte of status information regarding PMBus communication, internal memory, and logic. An individual bit can be cleared by writing a 1 to its position.

Table 50. STATUS_CML Contents

BIT	DESCRIPTION
7	Invalid or unsupported command received.
6	Invalid or unsupported data received.
5	Packet error check failed.
4	Not supported (device returns 0).
3	Not supported (device returns 0).
2	Not supported (device returns 0).
1	Other communication fault.
0	Other memory or logic fault.

STATUS_MFR_SPECIFIC

The STATUS_MFR_SPECIFIC command returns one byte with the manufacturer-specific status information. Bit 4 and Bit 5 are not page-specific. An individual bit can be cleared by writing a 1 to its position.

Table 51. STATUS_MFR_SPECIFIC Contents

BIT	DESCRIPTION
7	V_{OUT} turned on when the output voltage was above the discharge threshold.
6	Pin configuration fault (see the *MFR_PIN_CONFIG_STATUS* section for more information).
5	NVM fault. Either the CRC does not match, or error correction indicates an uncorrectable error.
4	Sync stuck low while SYNC pin is configured as a clock output (MFR_SYNC_CONFIG_LT7176, Bit 0 is set to 1).
3	Not supported (device returns 0).
2	Not supported (device returns 0).
1	Not supported (device returns 0).
0	$\overline{\text{FAULT}}$ pin pulled low by external device.

MFR_PIN_CONFIG_STATUS

During initialization, the LT7176/LT7176-1 checks for various invalid pin configurations. If a pin configuration fault is detected, the LT7176/LT7176-1 pulls down the PGOOD pin and sets Bit 6 of STATUS_MFR_SPECIFIC. The regulator outputs are also locked off until the LT7176/LT7176-1 are reset. The MFR_PIN_CONFIG_STATUS commands return one read-only byte indicating what type of pin configuration fault has been detected.

Table 52. MFR_PIN_CONFIG_STATUS Bit Descriptions

BIT	DESCRIPTION
7	A frequency of less than 300kHz is detected on the SYNC pin during initialization. This may occur if a higher-frequency clock starts during the initialization process. If an external clock is to be applied to the SYNC pin, it must start before the LT7176/LT7176-1 initialization begins, or after initialization is complete.
[6:1]	Not supported (device returns 0).
0	The device is set for polyphase follower (MFR_CHAN_CONFIG_LT7176 bit 8 set high), while internal compensation is selected (I_{TH} pin tied high).

MFR_PADS_LT7176

The read-only MFR_PADS_LT7176 command returns the digital status of the listed pins.

Table 53. MFR_PADS_LT7176 Bit Descriptions

BIT	DESCRIPTION
[15:10]	Not supported (device returns 0).
9	I_{TH} is tied high externally.
8	Sync input clock active.
7	WP
6	Device driving $\overline{\text{ALERT}}$ low.
5	$\overline{\text{ALERT}}$
4	Device driving PGOOD low.
3	PGOOD.
2	RUN.
1	Device driving $\overline{\text{FAULT}}$ low.
0	$\overline{\text{FAULT}}$

MFR_COMMON

The MFR_COMMON command contains bits that are common to all Analog Devices digital power and telemetry products. This command cannot cause the $\overline{\text{ALERT}}$ pin to be asserted.

Table 54. MFR_COMMON Bit Description

BIT	DESCRIPTION
7	Chip is not driving $\overline{\text{ALERT}}$ low.
6	Chip is not busy.
5	Calculations not pending.
4	Reserved (device returns 1).
3	Reserved (device returns 0).
2	Reserved (device returns 0).
1	SHARE_CLK timeout.
0	WP pin status.

MFR_CHANNEL_STATE

The MFR_CHANNEL_STATE command returns the state of the channel.

Table 55. MFR_CHANNEL_STATE Values

VALUE	DESCRIPTION
0, 7	Off.
2	Waiting for TON_DELAY.
3	Power-on ramp up (TON_RISE).
4, 5	On.
6	Waiting for TOFF_DELAY.
8	Power-off ramp down (TOFF_FALL).

Telemetry

Table 56. Telemetry Commands

COMMAND NAME	CODE	DESCRIPTION	TYPE	UNIT1	NVM	DEFAULT VALUE[1]
IOUT_CAL_OFFSET	0x39	Offset for READ_IOUT.	R/W word	A	Yes	0.32
READ_VIN	0x88	Measured input supply voltage.	R word	V	No	N/A
READ_VOUT	0x8B	Measured output voltage.	R word	V	No	N/A
READ_IOUT	0x8C	Measured output current.	R word	A	No	N/A
READ_TEMPERATURE_1	0x8D	Measured internal temperature.	R word	°C	No	N/A
READ_FREQUENCY	0x95	Frequency of the top gate.	R word	kHz	No	N/A
MFR_READ_EXTVCC	0xCD	Measured $EXTV_{CC}$ pin voltage.	R word	V	No	N/A
MFR_READ_ITH	0xCE	Measured ITH pin voltage.	R word	V	No	N/A
MFR_READ_ASEL	0xD3	Read the ASEL pin resistor value.	R word	kΩ	No	N/A
MFR_IOUT_PEAK	0xD7	Maximum READ_IOUT.	R word	A	No	N/A
MFR_ADC_CONTROL_LT7176	0xD8	ADC configuration.	R/W byte	N/A	Yes	0x0E
MFR_VOUT_PEAK	0xDD	Maximum READ_VOUT.	R word	V	No	N/A
MFR_VIN_PEAK	0xDE	Maximum READ_VIN.	R word	V	No	N/A
MFR_TEMPERATURE_1_PEAK	0xDF	Maximum READ_TEMPERATURE_1.	R word	°C	No	N/A
MFR_READ_PWM_CFG	0xE0	Measured PWM_CFG resistor value.	R word	kΩ	No	N/A
MFR_READ_VOUT_CFG	0xE1	Measured VOUT_CFG resistor value.	R word	kΩ	No	N/A
MFR_CLEAR_PEAKS	0xE3	Clears all recorded peak values.	Send byte	N/A	No	N/A

[1] N/A means not applicable.

IOUT_CAL_OFFSET

The IOUT_CAL_OFFSET command sets an offset for READ_IOUT in amperes. See the *READ_IOUT* section for details. This command uses a half-precision floating-point format.

READ_VIN

The READ_VIN command returns the measured input voltage.
This command uses a half-precision floating-point format.

READ_VOUT

The READ_VOUT command returns the measured output voltage.
This command uses a half-precision floating-point format.

READ_IOUT

The READ_IOUT command returns the output current, averaged over the measurement time determined by the IOUT aperture control. See the *MFR_ADC_CONTROL_LT7176* section for details about the IOUT aperture control.

The value returned by READ_IOUT is the measured output current offset by the value of IOUT_CAL_OFFSET. A dominant source of READ_IOUT error is systematic offset, which is largely a function of switching frequency, input voltage, output voltage, and inductor selection. To improve the accuracy of READ_IOUT, record the value reported by READ_IOUT in typical application conditions at zero load with IOUT_CAL_OFFSET set to zero. Then write IOUT_CAL_OFFSET to the negation of the recorded READ_IOUT value at no load. This value of IOUT_CAL_OFFSET can be systematically stored in NVM for all devices and does not need to be calibrated for every LT7176/LT7176-1 individually.

The READ_IOUT command uses a half-precision floating point format.

READ_TEMPERATURE_1

The READ_TEMPERATURE_1 command returns the internal device temperature.
This command uses a half-precision floating-point format.

READ_FREQUENCY

The READ_FREQUENCY command returns the top switch switching frequency in kilohertz (kHz).
This command uses a half-precision floating-point format.

MFR_READ_EXTVCC

The MFR_READ_EXTVCC command returns the measured voltage on the $EXTV_{CC}$ pin.
This command is updated only when Bit 0 of MFR_ADC_CONTROL_LT7176 is set to 1 to enable debug telemetry measurements.
The MFR_READ_EXTVCC command uses a half-precision floating point format.

MFR_READ_ITH

The MFR_READ_ITH command returns the measured voltage at the switching regulator compensation point.
This command is updated only when Bit 0 of MFR_ADC_CONTROL_LT7176 is set to 1 to enable debug telemetry measurements.
The reported voltage corresponds to the valley-current operating point, scaled by the current-sense transconductance ($\Delta I_{OUT}/\Delta VI_{TH}$). Refer to the **LT7176/LT7176-1** data sheet for more information on the programmable current limit. The compensation point voltage is measured differentially with respect to the internal zero valley current reference voltage of approximately 935mV.
The MFR_READ_ITH command uses a half-precision floating point format.

MFR_READ_ASEL

The MFR_READ_ASEL command returns the measured ASEL pin resistor value.

If the ASEL pin is left floating, MFR_READ_ASEL returns a large value.

The MFR_READ_ASEL command uses a half-precision floating-point format.

MFR_IOUT_PEAK

The MFR_IOUT_PEAK command reports the highest output current measured.

This command is cleared using the MFR_CLEAR_PEAKS command.

The MFR_IOUT_PEAK command uses a half-precision floating-point format.

MFR_ADC_CONTROL_LT7176

The MFR_ADC_CONTROL_LT7176 command controls adjustable features of the telemetry loop.

Bit 4 enables the I_{OUT} scope mode, where the output current measurement is updated more frequently. The update rate for all other measurements is decreased when the I_{OUT} scope mode is enabled.

Bits[3:2] select the aperture time for the I_{OUT} measurement. A longer aperture time provides more precise output current measurements but increases the time required for the I_{OUT} measurement and the overall telemetry loop. A shorter aperture time provides a faster measurement but with less precision.

Table 57. Mode, I_{OUT} Oversample Ratio (OSR), and Update Times for MFR_ADC_CONTROL_LT7176

MODE	I_{OUT} OSR	UPDATE TIME FOR IOUT MEASUREMENT (ms)	UPDATE TIME FOR OTHER MEASUREMENTS (ms)
Standard	3	8.1	8.1
	2	6.3	6.3
	1	5.5	5.5
	0	5.1	5.1
I_{OUT} Scope	3	5	19.4
	2	3.3	12.4
	1	2.5	9
	0	2.1	7.2

Bit 1 enables lower-frequency telemetry measurements to reduce the input supply quiescent current. When this bit is set, the telemetry runs with a typical period of 110ms (compared to a typical period of 5.5ms when this bit is zero).

Bit 0 enables the debug telemetry measurements: MFR_READ_EXTVCC and MFR_READ_ITH. When this bit is 1, the other measurements update at a slower rate.

Table 58. MFR_ADC_CONTROL_LT7176 Bit Descriptions

BITS	DEFAULT VALUE	DESCRIPTION
4	0	Enable scope mode for the I_{OUT} measurement.
[3:2]	1	IOUT measurement aperture time.
1	1	Enable low-frequency telemetry (110ms typical period, 2mA typical supply current reduction).
0	0	0 = Standard telemetry measurements. 1 = Debug telemetry measurements: standard + $EXTV_{CC}$ + ITH.

MFR_VOUT_PEAK

The MFR_VOUT_PEAK command reports the highest output voltage measured.

This command is cleared using the MFR_CLEAR_PEAKS command.

The MFR_VOUT_PEAK command uses a half-precision floating-point format.

MFR_VIN_PEAK

The MFR_VIN_PEAK command reports the highest input voltage measured.

This command is cleared using the MFR_CLEAR_PEAKS command.

The MFR_VIN_PEAK command uses a half-precision floating-point format.

MFR_TEMPERATURE_1_PEAK

The MFR_TEMPERATURE_1_PEAK command reports the highest internal temperature measured.

This command is cleared using the MFR_CLEAR_PEAKS command.

The MFR_TEMPERATURE_1_PEAK command uses a half-precision floating-point format.

MFR_READ_PWM_CFG

The MFR_READ_PWM_CFG command returns the measured PWM_CFG pin resistor value.

If the PWM_CFG pin is left floating or is tied to VDD18, MFR_READ_PWM_CFG returns a large value.

If Bit 6 of MFR_CONFIG_ALL_LT7176 is set to disable the resistor configuration during initialization, MFR_READ_PWM_CFG returns 0.

The MFR_READ_PWM_CFG command uses a half-precision floating point format.

MFR_READ_VOUT_CFG

The MFR_READ_VOUT_CFG command returns the measured VOUT_CFG pin resistor value.

If the VOUT_CFG pin is left floating or is tied to VDD18, MFR_READ_VOUT_CFG returns a large value.

If Bit 6 of MFR_CONFIG_ALL_LT7176 is set to disable the resistor configuration during initialization, MFR_READ_VOUT_CFG returns 0.

The MFR_READ_VOUT_CFG command uses a half-precision floating point format.

MFR_CLEAR_PEAKS

The MFR_CLEAR_PEAKS command clears the MFR_x_PEAK data values. These values are also cleared at reset or power-up.

NVM Commands

Most NVM access commands complete in milliseconds.

Store/Restore

Table 59. Store/Restore Commands[1]

COMMAND	CODE	DESCRIPTION	TYPE	NVM	DEFAULT VALUE[1]
STORE_USER_ALL	0x15	Stores user operating memory to NVM. It can only be written three times.	Send byte	No	N/A
RESTORE_USER_ALL	0x16	Restores user operating memory from NVM.	Send byte	No	N/A
MFR_COMPARE_USER_ALL	0xF0	Compares current command contents with NVM.	Send byte	No	N/A
MFR_USER_DATA_00	0xC9	NVM word available for the user.	R/W word	Yes	0x0000
MFR_USER_DATA_01	0xCA	NVM word available for the user.	R/W word	Yes	0x0000
MFR_DISABLE_OUTPUT	0xFB	Disables regulator outputs until reset.	R/W byte	No	0x00
MFR_NVM_USER_WRITES_REMAINING	0xBE	Number of STORE_USER_ALL writes remaining.	R byte	No	N/A
MFR_NVM_USER_WP	0xFC	Disables commands that write user NVM.	R/W byte	Yes	0x00

[1] N/A means not applicable.

STORE_USER_ALL

The STORE_USER_ALL command instructs the LT7176/LT7176-1 to copy the contents of the operating memory to nonvolatile memory. All commands designated as NVM backed commands are stored in nonvolatile memory by the STORE_USER_ALL command.

STORE_USER_ALL may only be written three times during the life of the LT7176/LT7176-1.

Throughout the STORE_USER_ALL operation, the device junction temperature must be maintained between −40°C and 125°C, and $EXTV_{cc}$ must be maintained at more than 9.6V.

If a nonvolatile memory write fails, Bit 5 is set in STATUS_MFR_SPECIFIC, indicating that a nonvolatile memory fault has occurred. If the LT7176/LT7176-1 are reset or bias power is removed while a nonvolatile memory fault is present, the device address is set to 0x7C on the next power-up.

Reading the STORE_USER_ALL command also instructs the LT7176/LT7176-1 to copy the contents of the operating memory to nonvolatile memory.

RESTORE_USER_ALL

The RESTORE_USER_ALL command provides a means by which the user can perform a reset of the LT7176/LT7176-1 . Reading the RESTORE_USER_ALL command also causes the LT7176/LT7176-1 to reset.

MFR_COMPARE_USER_ALL

The MFR_COMPARE_USER_ALL command instructs the LT7176/LT7176-1 to compare the current command contents with what is stored in nonvolatile memory. If the compare operation detects differences, a CML Bit 0 fault is generated.

Reading the MFR_COMPARE_USER_ALL command also instructs the LT7176/LT7176-1 to compare the current command contents with what is stored in nonvolatile memory.

MFR_USER_DATA_00 and MFR_USER_DATA_01

The MFR_USER_DATA_xx commands can be used by the user to store any data. Each of these commands stores one 16-bit word. This data is written to the NVM when the STORE_USER_ALL command is written.

MFR_DISABLE_OUTPUT

When written to 0xFF, the MFR_DISABLE_OUTPUT command disables the regulator outputs until reset. The value of MFR_DISABLE_OUTPUT is not stored in NVM, allowing anything to be programmed into ON_OFF_CONFIG, OPERATION, and so forth, without powering up the output. MFR_DISABLE_OUTPUT also allows all NVM stored commands to be configured and written to NVM with STORE_USER_ALL without powering up the output. The MFR_DISABLE_OUTPUT command can be read to determine the state of the output disable function.

MFR_NVM_USER_WRITES_REMAINING

When read, MFR_NVM_USER_WRITES_REMAINING returns the number of times STORE_USER_ALL can be written.

MFR_NVM_USER_WP

When written to 0xFF, the MFR_NVM_USER_WP command disables the commands that can be used to write to the user NVM space: STORE_USER_ALL and MFR_NVM_DATA writes. The MFR_NVM_USER_WP command can only be written to 0xFF.

NOTES

I^2C refers to a communications protocol originally developed by Philips Semiconductors, which is now NXP Semiconductors.

REVISION HISTORY

REVISON NUMBER	REVISION DATE	DESCRIPTION	PAGE NUMBER
0	11/26	Initial release	—

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