4-Channel PMBus Power System Manager Featuring Accurate Input Current and Energy Measurement

FEATURES

- **Sequence, Trim, Margin and Supervise Four Power Supplies**
- **Manage Faults, Monitor Telemetry and Create Fault Logs**
- **PMBus™ Compliant Command Set**
- **Supported by LTpowerPlay® GUI**
- **Margin or Trim Supplies to Within 0.25% of Target**
- **Monitor Input Current (±1%) and Accumulate Energy**
- **Fast OV/UV and OC Supervisors Per Channel**
- **Coordinate Sequencing and Fault Management Across Multiple LTC PSM Devices**
- **Automatic Fault Logging to Internal EEPROM**
- **Operate Autonomously Without Additional Software**
- External Temperature and Input Voltage Supervisors
- Accurate Monitoring of Four Output Voltages, Four Output Currents, Four External Temperatures, Input Voltage and Current, and Internal Die Temperature
- I^2C/SMBus Serial Interface
- Can Be Powered from 3.3V, or 4.5V to 15V
- Pin-Compatible to the LTC2974
- Available in 64-Lead 9mm × 9mm QFN Package

APPLICATIONS

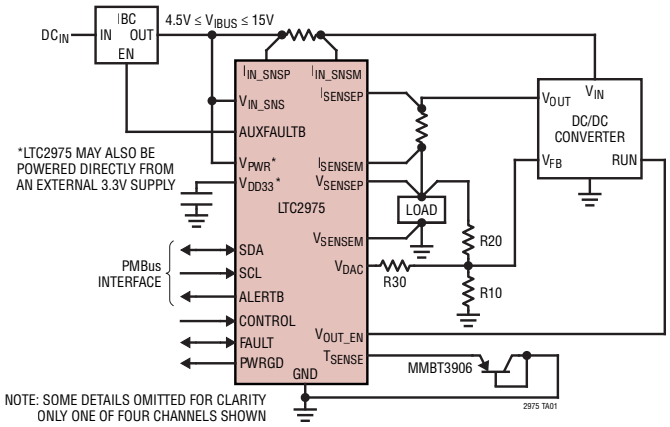
- Computers and Network Servers
- Industrial Test and Measurement
- High Reliability Systems
- Video and Medical Imaging

DESCRIPTION

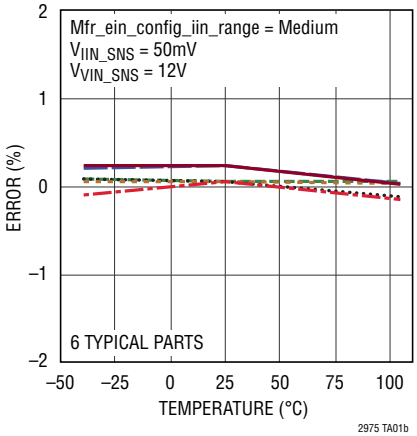
The LTC®2975 is a 4-channel Power System Manager used to sequence, trim (servo), margin, supervise, manage faults, provide telemetry and create fault logs. PMBus commands support power supply sequencing, precision point-of-load voltage adjustment and margining. DACs use a proprietary soft-connect algorithm to minimize supply disturbances. Supervisory functions include over and under current, voltage and temperature threshold limits for four power supply output channels as well as over and under voltage threshold limits for a single power supply input channel. Programmable fault responses can disable the power supplies with optional retry after a fault is detected. Faults that disable a power supply can automatically trigger black box EEPROM storage of fault status and associated telemetry. An internal 16-bit ADC monitors four output voltages, four output currents, four external temperatures, input voltage and current, and die temperature. Input power, energy, and output power is also calculated. A programmable watchdog timer monitors microprocessor activity for a stalled condition and resets the microprocessor if necessary. A single wire bus synchronizes power supplies across multiple LTC Power System Management (PSM) devices. Configuration EEPROM with ECC supports autonomous operation without additional software.

TYPICAL APPLICATION

4-Channel PMBus Power System Manager with Input Energy Metering



Power Measurement Error



ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_J = 25°C. V_{PWR} = V_{IN_SNS} = 12V, V_{DD33}, V_{DD25}, REFP and REFM pins floating, unless otherwise indicated. C_{VDD33} = 100nF, C_{VDD25} = 100nF, $C_{VIN\_SNS\_CAP}$ = 10nF and C_{REF} = 100nF.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
f_{IN_ADC}	Input Sampling Frequency				62.5		kHz
Sense Input Current Characteristics (Note 12)							
I_{IN_VSENSE}	Input Current	$V_{SENSEP}n$ and $V_{SENSEM}n$ Inputs	●			±15	µA
	Differential Input Current	$V_{SENSEP}n$ and $V_{SENSEM}n$ Inputs, V_{IN_DIFF} = 6V	●			±30	µA
I_{IN_ISENSE}	Input Current	$I_{SENSEP}n$ and $I_{SENSEM}n$ Inputs	●			±3	µA
	Differential Input Current	$I_{SENSEP}n$ and $I_{SENSEM}n$ Inputs, $\lvert V_{IN\_DIFF}\rvert$ = 0.17V	●			±5	µA
DAC Output Characteristics							
N_V_{DAC}	Resolution				10		Bits
V_{FS_VDAC}	Full-Scale Output Voltage (Programmable)	DAC Code = 0x3FF, DAC Polarity = 1, Buffer Gain Setting_0	●	1.3	1.38	1.44	V
		DAC Code = 0x3FF, DAC Polarity = 1, Buffer Gain Setting_1	●	2.5	2.65	2.77	V
INL_V_{DAC}	Integral Nonlinearity	(Note 6)	●			±2	LSB
DNL_V_{DAC}	Differential Nonlinearity	(Note 6)	●			±2.4	LSB
V_{OS_VDAC}	Offset Voltage	(Note 6)	●			±15	mV
V_{DAC}	Load Regulation	$V_{DAC}n$ = 2.65V, $I_{VDAC}n$ Sourcing = 2mA			100		ppm/mA
		$V_{DAC}n$ = 0.1V, $I_{VDAC}n$ Sinking = 2mA			100		ppm/mA
	PSRR	DC: 3.13V ≤ V_{DD33} ≤ 3.47V, V_{PWR} = V_{DD33}			60		dB
	Leakage Current	$V_{DAC}n$ Hi-Z, 0V ≤ $V_{DAC}n$ ≤ 6V	●			±100	nA
	Short-Circuit Current Low	$V_{DAC}n$ Shorted to GND	●	–12		–4	mA
	Short-Circuit Current High	$V_{DAC}n$ Shorted to V_{DD33}	●	4		12	mA
C_{OUT}	Output Capacitance	$V_{DAC}n$ Hi-Z			10		pF
t_{S_VDAC}	DAC Output Update Rate	Fast Servo Mode			~~250~~ 500		µs
Voltage Supervisor Characteristics							
V_{IN_VS}	Input Voltage Range (Programmable)	V_{IN_VS} = ($V_{SENSEP}n$ – $V_{SENSEM}n$), Low Resolution Mode	●	0		6	V
		V_{IN_VS} = ($V_{SENSEP}n$ – $V_{SENSEM}n$), High Resolution Mode	●	0		3.8	V
		Single-Ended Voltage: $V_{SENSEM}n$	●	–0.1		0.1	V
N_VS	Voltage Sensing Resolution	0V to 3.8V Range: High Resolution Mode			4		mV/LSB
		0V to 6V Range: Low Resolution Mode			8		mV/LSB
TUE_VS	Total Unadjusted Error	2V ≤ V_{IN_VS} ≤ 6V, Low Resolution Mode	●			±1.25	% of Reading
		1.5V < V_{IN_VS} ≤ 3.8V, High Resolution Mode	●			±1.0	% of Reading
		0.8V ≤ V_{IN_VS} ≤ 1.5V, High Resolution Mode	●			±1.5	% of Reading
t_{S_VS}	Update Period				12.21		µs
Current Supervisor Characteristics							
V_{IN_CS}	Current Sense Input Range	Single-Ended Voltage: $I_{SENSEP}n$, $I_{SENSEM}n$	●	–0.1		6	V
		Differential Voltage: V_{IN_CS} = ($I_{SENSEP}n$ – $I_{SENSEM}n$)	●	–170		170	mV
N_CS	Current Sense Resolution	IOUT_OC_FAULT_LIMIT • IOUT_CAL_GAIN IOUT_UC_FAULT_LIMIT • IOUT_CAL_GAIN			400		µV/LSB
TUE_CS	Total Unadjusted Error	50mV ≤ $\lvert V_{IN\_CS}\rvert$ ≤ 170mV	●			±3	% of Reading
		$\lvert V_{IN\_CS}\rvert$ < 50mV	●			±1.5	mV
V_{OS_CS}	Offset Error	V_{IN_CS} = 0	●			±600	µV
t_{S_CS}	Update Period				12.21		µs

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_J = 25°C. V_{PWR} = V_{IN_SNS} = 12V, V_{DD33}, V_{DD25}, REFP and REFM pins floating, unless otherwise indicated. C_{VDD33} = 100nF, C_{VDD25} = 100nF, $C_{VIN\_SNS\_CAP}$ = 10nF and C_{REF} = 100nF. (Note 2)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{OUT} Enable Output ($V_{OUT\_EN\ [3:0]}$) Characteristics							
V_{VOUT_ENn}	Output High Voltage	I_{VOUT_ENn} = –5µA, V_{DD33} = 3.13V	●	10	13	14.7	V
I_{VOUT_ENn}	Output Sourcing Current	V_{VOUT_ENn} Pull-Up Enabled, V_{VOUT_ENn} = 1V	●	–5	–7	–9	µA
	Output Sinking Current	Strong Pull-Down Enabled, V_{VOUT_ENn} = 0.4V	●	2.5	5	8	mA
		Weak Pull-Down Enabled, V_{VOUT_ENn} = 0.4V	●	33	50	65	µA
Added	Output Leakage Current	Internal Pull-Up Disabled, 0V ≤ V_{VOUT_ENn} ≤ 15V	●			±1	µA
V_{VOUT_VALID}	Minimum V_{DD33} when V_{OUT_ENn} Valid	V_{VOUT_ENn} ≤ 0.4V	●			1.1	V
General Purpose Output (AUXFAULTB) Characteristics							
$V_{AUXFAULTB}$	Output High Voltage	$I_{AUXFAULTB}$ = –5µA, V_{DD33} = 3.13V	●	10	13	14.7	V
$I_{AUXFAULTB}$	Output Sourcing Current	AUXFAULTB Pull-Up Enabled, $V_{AUXFAULTB}$ = 1V	●	–5	–7	–9	µA
	Output Sinking Current	Strong Pull-Down Enabled, $V_{AUXFAULTB}$ = 0.4V	●	2.5	5	8	mA
	Output Leakage Current	Internal Pull-Up Disabled, 0V ≤ $V_{AUXFAULTB}$ ≤ 15V	●			±1	µA
Energy Meter Characteristics							
TUE_ETB	Energy Meter Time-Base Error		●			±1.5	% of Reading
TUE_PIN	READ_PIN Total Unadjusted Error	V_{IIN_SNSP} – V_{IIN_SNSM} = 50mV, Medium Range	●			±1	% of Reading
TUE_EIN	Energy Meter Total Unadjusted Error	V_{IIN_SNSP} – V_{IIN_SNSM} = 50mV, Medium Range	●			±2.5	% of Reading
EEPROM Characteristics							
Endurance	(Notes 8, 11)	0°C < T_J < 85°C During EEPROM Write Operations	●	10,000			Cycles
Retention	(Notes 8, 11)	T_J < 105°C	●	20			Years
t_{MASS_WRITE}	Mass Write Operation Time (Note 9)	STORE_USER_ALL, 0°C < T_J < 85°C During EEPROM Write Operations	●		440	4100	ms
Digital Inputs SCL, SDA, CONTROL0, CONTROL1, CONTROL2, CONTROL3, WDI/RESETB, FAULTB0, FAULTB1, WP							
V_{IH}	High Level Input Voltage	FAULTB0, FAULTB1, SDA, SCL, WDI/RESETB, WP	●	2.1			V
		CONTROL*n* Only	●	1.85			V
V_{IL}	Low Level Input Voltage	FAULTB0, FAULTB1, SDA, SCL, WDI/RESETB, WP	●			1.5	V
		CONTROL*n* Only	●			1.6	V
V_{HYST}	Input Hysteresis				20		mV
I_{LEAK}	Input Leakage Current	0V ≤ V_{PIN} ≤ 3.6V	●			±2	µA
t_{SP}	Pulse Width of Spike Suppressed	FAULTB0, FAULTB1, CONTROL*n*			10		µs
		SDA, SCL			98		ns
t_{FAULT_MIN}	Minimum Low Pulse Width for Externally Generated Faults			180			ms
t_{RESETB}	Pulse Width to Assert Reset	$V_{WDI/RESETB}$ ≤ 1.5V	●	300			µs
t_{WDI}	Pulse Width to Reset Watchdog Timer	$V_{WDI/RESETB}$ ≤ 1.5V	●	0.3		200	µs
f_{WDI}	Watchdog Timer Interrupt Input Frequency		●			1	MHz
C_{IN}	Input Capacitance				10		pF
Digital Input SHARE_CLK							
V_{IH}	High Level Input Voltage		●	1.6			V
V_{IL}	Low Level Input Voltage		●			0.8	V
$f_{SHARE\_CLK\_IN}$	Input Frequency Operating Range		●	90		110	kHz

OPERATION

LTC2975 OPERATION OVERVIEW

The LTC2975 is a PMBus programmable power supply controller, monitor, sequencer and voltage and current supervisor that can perform the following operations:

- Accept PMBus compatible programming commands.
- Provide DC/DC converter input voltage, output voltage, output current, output temperature, and LTC2975 internal temperature readback through the PMBus interface.
- Control the output of DC/DC converters that set the output voltage with a trim pin or DC/DC converters that set the output voltage using an external resistor feedback network.
- Sequence the startup of DC/DC converters via PMBus programming and the CONTROL input pins. The LTC2975 supports time-based sequencing and tracking sequencing. Cascade sequence on with time based sequence off is also supported.
- Trim the DC/DC converter output voltage (typically in 0.02% steps), in closed-loop servo operating mode, autonomously or through PMBus programming.
- Margin the DC/DC converter output voltage to PMBus programmed limits.
- Trim or margin the DC/DC converter output voltage with direct access to the margin DAC.
- Supervise the DC/DC converter input voltage, output voltage, load current and the inductor temperatures for overvalue/undervalue conditions with respect to PMBus programmed limits and generate appropriate faults and warnings.
- Accurately handle inductor self-heating transients using a proprietary algorithm. These self-heating effects are combined with external temperature sensor readings to improve accuracy of current supervisors and ADC current measurement.
- Respond to a fault condition by continuing operation indefinitely, latching-off after a programmable deglitch period, latching-off immediately or sequencing off after TOFF_DELAY. Use retry mode to automatically recover from a latched-off condition. With retry enabled, MFR_RETRY_COUNT programs the number of retries (0 to 6 or infinite) for all pages.
- Optionally stop trimming the DC/DC converter output voltage after it reaches the initial margin or nominal target. Optionally allow trimming restart if target drifts outside of V_{OUT} warning limits.
- Store command register contents to EEPROM with CRC and ECC through PMBus programming.
- Restore EEPROM contents through PMBus programming or when V_{DD33} is applied on power-up.
- Report the DC/DC converter output voltage status through the power good output.
- Generate interrupt requests by asserting the ALERTB pin in response to supported PMBus faults and warnings.
- Coordinate system wide fault responses for all DC/DC converters connected to the LTC2975 FAULTB0 and FAULTB1 pins.
- Synchronize sequencing delays or shutdown for multiple devices using the SHARE_CLK pin.
- Software and hardware write protect the command registers.
- Disable the input voltage to the supervised DC/DC converters in response to output OV, UV, OC and UC faults.
- Log telemetry and status data to EEPROM in response to a faulted-off condition.
- Supervise an external microcontroller's activity for a stalled condition with a programmable watchdog timer and reset it if necessary.
- Prevent a DC/DC converter from re-entering the on state after a power cycle until a programmable interval (MFR_RESTART_DELAY) has elapsed and its output has decayed below a programmable threshold voltage (MFR_VOUT_DISCHARGE_THRESHOLD).
- Read high side input current, input voltage, input power, and accumulated input energy.
- Record minimum and maximum input voltage, input current, input power, output voltages, output currents and output temperatures.
- Access user EEPROM data directly, without altering RAM space (Mfr_ee_unlock, Mfr_ee_erase, and Mfr_ee_data). Facilitates in-house bulk programming.
- Accommodate multiple hosts with Command Plus.

OPERATION

EEPROM

The LTC2975 contains internal EEPROM (Non-Volatile Memory) with error-correcting code (ECC) to store configuration settings and fault log information. EEPROM endurance, retention and mass write operation time are specified over the operating temperature range. See Electrical Characteristics and Absolute Maximum Ratings sections.

Non destructive operation above T_J = 105°C is possible although the Electrical Characteristics are not guaranteed and the EEPROM will be degraded.

Operating the EEPROM above 105°C may result in a degradation of retention characteristics. The fault logging function, which is useful in debugging system problems that may occur at high temperatures, only writes to fault log EEPROM locations. If occasional writes to these registers occur above 105°C, a slight degradation in the data retention characteristics of the fault log may occur.

It is recommended that the EEPROM not be written using STORE_USER_ALL or bulk programming when T_J > 85°C.

The degradation in EEPROM retention for temperatures >105°C can be approximated by calculating the dimensionless acceleration factor using the following equation.

$$AF = e^{\left[\left(\frac{Ea}{k}\right)\bullet\left(\frac{1}{T_{USE}+273}-\frac{1}{T_{STRESS}+273}\right)\right]}$$

where:

AF = acceleration factor

Ea = activation energy = 1.4eV

k = 8.617 • 10^{-5} eV/°K

T_{USE} = 105°C specified junction temperature

T_{STRESS} = actual junction temperature °C

Example: Calculate the effect on retention when operating at a junction temperature of 125°C for 10 hours.

T_{STRESS} = 125°C

T_{USE} = 105°C

AF = 8.65

Equivalent operating time at 105°C = 86.5 hours.

So the overall retention of the EEPROM was degraded by an additional 76.5 hours as a result of operation at a junction temperature of 125°C for 10 hours. Note that the effect of this overstress is negligible when compared to the overall EEPROM retention rating of 175,200 hours at a junction temperature of 105°C.

AUXFAULTB

The AUXFAULTB pin can be configured to indicate when some fault conditions have been detected. See Figure 1 for a conceptual view of this multiplexing.

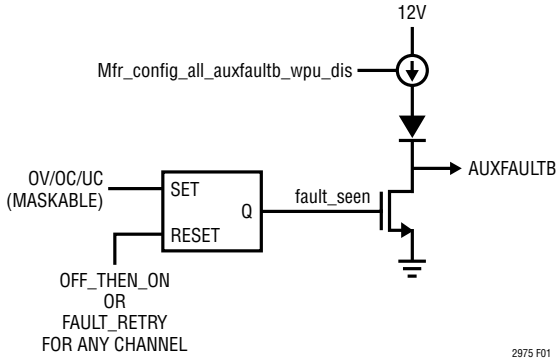


Figure 1. AUXFAULTB MUX

The MFR_CONFIG2_LTC2975 and MFR_CONFIG3_LTC2975 commands can be used on a per channel basis to select which, if any, fault conditions will cause the AUXFAULTB pin to be driven low. The only fault types which can be propagated to the AUXFAULTB pin are overvoltage faults and overcurrent/undercurrent faults.

Mfr_config_all_auxfaultb_wpu selects whether the AUXFAULTB pin is in the hi-Z state, or weakly pulled-up to approximately 12V, using a 5µA current. As shown in Figure 1, the pull-down to GND overrides if any enabled faults are detected.

PMBUS COMMAND SUMMARY

Summary Table

COMMAND NAME	CMD CODE	DESCRIPTION	TYPE	PAGED	DATA FORMAT	UNITS	EEPROM	DEFAULT VALUE: FLOAT HEX	REF PAGE
TON_RISE	0x61	Time from when the $V_{OUT\_EN}n$ pin goes high until the LTC2975 optionally soft-connects its DAC and begins to servo the output voltage to the desired value.	R/W Word	Y	L11	ms	Y	10.0 0xD280	57
TON_MAX_FAULT_LIMIT	0x62	Maximum time from $V_{OUT\_EN}n$ = ON assertion that an UV condition will be tolerated before a TON_MAX_FAULT condition results.	R/W Word	Y	L11	ms	Y	15.0 0xD3C0	57
TON_MAX_FAULT_RESPONSE	0x63	Action to be taken by the device when a TON_MAX_FAULT event is detected.	R/W Byte	Y	Reg		Y	0xB8	60
TOFF_DELAY	0x64	Time from CONTROL pin and/or OPERATION command = OFF to $V_{OUT\_EN}n$ pin = OFF.	R/W Word	Y	L11	ms	Y	1.0 0xBA00	57
STATUS_BYTE	0x78	One byte summary of the unit's fault condition.	R Byte	Y	Reg			NA	65
STATUS_WORD	0x79	Two byte summary of the unit's fault condition.	R Word	Y	Reg			NA	65
STATUS_VOUT	0x7A	Output voltage fault and warning status.	R Byte	Y	Reg			NA	65
STATUS_IOUT	0x7B	Output current fault and warning status.	R Byte	Y	Reg			NA	65
STATUS_INPUT	0x7C	Input supply fault and warning status.	R Byte	N	Reg			NA	65
STATUS_TEMPERATURE	0x7D	External temperature fault and warning status for READ_TEMPERATURE_1.	R Byte	Y	Reg			NA	65
STATUS_CML	0x7E	Communication and memory fault and warning status.	R Byte	N	Reg			NA	65
STATUS_MFR_SPECIFIC	0x80	Manufacturer specific fault and state information.	R Byte	Y	Reg			NA	65
READ_VIN	0x88	Input supply voltage.	R Word	N	L11	V		NA	71
READ_IIN	0x89	DC/DC converter input current.	R Word	N	L11	A		NA	71
READ_VOUT	0x8B	DC/DC converter output voltage.	R Word	Y	L16	V		NA	71
READ_IOUT	0x8C	DC/DC converter output current.	R Word	Y	L11	A		NA	71
READ_TEMPERATURE_1	0x8D	External diode junction temperature. This is the value used for all temperature related processing, including IOUT_CAL_GAIN.	R Word	Y	L11	°C		NA	71
READ_TEMPERATURE_2	0x8E	Internal junction temperature.	R Word	N	L11	°C		NA	71
READ_POUT	0x96	DC/DC converter output power.	R Word	Y	L11	W		NA	71
READ_PIN	0x97	DC/DC converter input power.	R Word	N	L11	W		NA	71
PMBUS_REVISION	0x98	PMBus revision supported by this device. Current revision is 1.1.	R Byte	N	Reg			0x11	83
USER_DATA_00	0xB0	Manufacturer reserved for LTpowerPlay.	R/W Word	N	Reg		Y	NA	84
USER_DATA_01	0xB1	Manufacturer reserved for LTpowerPlay.	R/W Word	Y	Reg		Y	NA	84
USER_DATA_02	0xB2	OEM Reserved.	R/W Word	N	Reg		Y	NA	84
USER_DATA_03	0xB3	Scratchpad location.	R/W Word	Y	Reg		Y	0x0000	84
USER_DATA_04	0xB4	Scratchpad location.	R/W Word	N	Reg		Y	0x0000	84
MFR_LTC_RESERVED_1	0xB5	Manufacturer reserved.	R/W Word	Y	Reg		Y	NA	84
MFR_INFO	0xB6	Manufacturer specific information.	R Word	N	Reg			NA	83

Added

PMBUS COMMAND SUMMARY

Summary Table

COMMAND NAME	CMD CODE	DESCRIPTION	TYPE	PAGED	DATA FORMAT	UNITS	EEPROM	DEFAULT VALUE: FLOAT HEX	REF PAGE
MFR_T_SELF_HEAT	0xB8	Calculated temperature rise due to self-heating of output current sense device above value measured by external temperature sensor.	R Word	Y	L11	°C		NA	54
MFR_IOUT_CAL_GAIN_TAU_INV	0xB9	Inverse of time constant for Mfr_t_self_heat changes scaled by 4 • t_{CONV_SENSE}.	R/W Word	Y	L11		Y	0.0 0x8000	54
MFR_IOUT_CAL_GAIN_THETA	0xBA	Thermal resistance from inductor core to point measured by external temperature sensor.	R/W Word	Y	L11	°C/W	Y	0.0 0x8000	54
MFR_READ_IOUT	0xBB	Alternate data format for READ_IOUT. One LSB = 2.5mA.	R Word	Y	CF	2.5mA		NA	71
MFR_LTC_RESERVED_2	0xBC	Manufacturer reserved.	R/W Word	Y	Reg			NA	84
MFR_EE_UNLOCK	0xBD	Unlock user EEPROM for access by MFR_EE_ERASE and MFR_EE_DATA commands.	R/W Byte	N	Reg			NA	46
MFR_EE_ERASE	0xBE	Initialize user EEPROM for bulk programming by MFR_EE_DATA.	R/W Byte	N	Reg			NA	46
MFR_EE_DATA	0xBF	Data transferred to and from EEPROM using sequential PMBus word reads or writes. Supports bulk programming.	R/W Word	N	Reg			NA	46
MFR_EIN	0xC0	Input Energy data bytes.	R Block	N	Reg			NA	49
MFR_EIN_CONFIG	0xC1	Configuration register for energy and input current.	R/W Byte	N	Reg		Y	0x00	49
MFR_SPECIAL_LOT	0xC2	Customer dependent codes that identify the factory programmed user configuration stored in EEPROM. Contact factory for default value.	R Byte	Y	Reg		Y	NA	83
MFR_IIN_CAL_GAIN_TC	0xC3	Temperature coefficient applied to IIN_CAL_GAIN.	R/W Word	N	CF	ppm	Y	0x0000	49
MFR_IIN_PEAK	0xC4	Maximum measured value of READ_IIN	R Word	N	L11	A		NA	71
MFR_IIN_MIN	0xC5	Minimum measured value of READ_IIN.	R Word	N	L11	A		NA	71
MFR_PIN_PEAK	0xC6	Maximum measured value of READ_PIN.	R Word	N	L11	W		NA	71
MFR_PIN_MIN	0xC7	Minimum measured value of READ_PIN.	R Word	N	L11	W		NA	71
MFR_COMMAND_PLUS	0xC8	Alternate access to block read and other data. Commands for all additional hosts.	R/W Word	N	Reg				30
Added MFR_CLEAR_ENERGY	0xCC	Clear MFR_EIN time and energy values	Send Byte	N				NA	
MFR_DATA_PLUS0	0xC9	Alternate access to block read and other data. Data for additional host 0.	R/W Word	N	Reg				30
MFR_DATA_PLUS1	0xCA	Alternate access to block read and other data. Data for additional host 1.	R/W Word	N	Reg				30
MFR_CONFIG_LTC2975	0xD0	Configuration bits that are channel specific.	R/W Word	Y	Reg		Y	0x0080	35
MFR_CONFIG_ALL_LTC2975	0xD1	Configuration bits that are common to all pages.	R/W Word	N	Reg		Y	0x0F7B	35
MFR_FAULTB0_PROPAGATE	0xD2	Configuration that determines if a channel's faulted off state is propagated to the FAULTB0 pin.	R/W Byte	Y	Reg		Y	0x00	64
MFR_FAULTB1_PROPAGATE	0xD3	Configuration that determines if a channel's faulted off state is propagated to the FAULTB1 pin.	R/W Byte	Y	Reg		Y	0x00	64

PMBUS COMMAND SUMMARY

Summary Table

COMMAND NAME	CMD CODE	DESCRIPTION	TYPE	PAGED	DATA FORMAT	UNITS	EEPROM	DEFAULT VALUE: FLOAT HEX	REF PAGE
MFR_PWRGD_EN	0xD4	Configuration that maps WDI/RESETB status and individual channel power good to the PWRGD pin.	R/W Word	N	Reg		Y	0x0000	58
MFR_FAULTB0_RESPONSE	0xD5	Action to be taken by the device when the FAULTB0 pin is asserted low.	R/W Byte	N	Reg		Y	0x00	64
MFR_FAULTB1_RESPONSE	0xD6	Action to be taken by the device when the FAULTB1 pin is asserted low.	R/W Byte	N	Reg		Y	0x00	64
MFR_IOUT_PEAK	0xD7	Maximum measured value of READ_IOUT.	R Word	Y	L11	A		NA	71
MFR_IOUT_MIN	0xD8	Minimum measured value of READ_IOUT.	R Word	Y	L11	A		NA	71
MFR_CONFIG2_LTC2975	0xD9	Configuration bits that are channel specific	R/W Byte	N	Reg		Y	0x00	35
MFR_CONFIG3_LTC2975	0xDA	Configuration bits that are channel specific	R/W Byte	N	Reg		Y	0x00	35
MFR_RETRY_DELAY	0xDB	Retry interval during FAULT retry mode.	R/W Word	N	L11	ms	Y	200 0xF320	60
MFR_RESTART_DELAY	0xDC	Delay from actual CONTROL active edge to virtual CONTROL active edge.	R/W Word	N	L11	ms	Y	400 0xFB20	57
MFR_VOUT_PEAK	0xDD	Maximum measured value of READ_VOUT.	R Word	Y	L16	V		NA	71
MFR_VIN_PEAK	0xDE	Maximum measured value of READ_VIN.	R Word	N	L11	V		NA	71
MFR_TEMPERATURE_1_PEAK	0xDF	Maximum measured value of READ_ TEMPERATURE_1.	R Word	Y	L11	°C		NA	71
MFR_DAC	0xE0	The code of the 10-bit DAC.	R/W Word	Y	Reg			0x0000	51
MFR_POWERGOOD_ ASSERTION_DELAY	0xE1	Power-good output assertion delay.	R/W Word	N	L11	ms	Y	100 0xEB20	58
MFR_WATCHDOG_T_FIRST	0xE2	First watchdog timer interval.	R/W Word	N	L11	ms	Y	0 0x8000	58
MFR_WATCHDOG_T	0xE3	Watchdog timer interval.	R/W Word	N	L11	ms	Y	0 0x8000	58
MFR_PAGE_FF_MASK	0xE4	Configuration defining which channels respond to global page commands (PAGE=0xFF).	R/W Byte	N	Reg		Y	0x0F	30
MFR_PADS	0xE5	Current state of selected digital I/O pads.	R/W Word	N	Reg			NA	65
MFR_I2C_BASE_ADDRESS	0xE6	Base value of the I^2C/SMBus address byte.	R/W Byte	N	Reg		Y	0x5C	30
MFR_SPECIAL_ID	0xE7	Manufacturer code for identifying the LTC2975.	R Word	N	Reg		Y	~~0x0224~~	83
MFR_IIN_CAL_GAIN	0xE8	The nominal resistance of the input current sense element in mΩ.	R/W Word	N	L11	mΩ	Y	1.0 0xBA00	49
MFR_VOUT_DISCHARGE_ THRESHOLD	0xE9	Coefficient used to multiply VOUT_ COMMAND in order to determine V_{OUT} off threshold voltage.	R/W Word	Y	L11		Y	2.0 0xC200	51
MFR_FAULT_LOG_STORE	0xEA	Command a transfer of the fault log from RAM to EEPROM.	Send Byte	N				NA	75
MFR_FAULT_LOG_RESTORE	0xEB	Command a transfer of the fault log previously stored in EEPROM back to RAM.	Send Byte	N				NA	75
MFR_FAULT_LOG_CLEAR	0xEC	Initialize the EEPROM block reserved for fault logging and clear any previous fault logging locks.	Send Byte	N				NA	71
MFR_FAULT_LOG_STATUS	0xED	Fault logging status.	R Byte	N	Reg		Y	NA	75

0x0226

PMBUS COMMAND DESCRIPTION

WRITE_PROTECT

The WRITE_PROTECT command provides protection against accidental programming of the LTC2975 command registers. All supported commands may have their parameters read, regardless of the WRITE_PROTECT setting, and the EEPROM contents can also be read regardless of the WRITE_PROTECT settings.

There are two levels of protection:

- Level 1: Nothing can be changed except the level of write protection itself. Values can be read from all pages. This setting can be stored to EEPROM.
- Level 2: Nothing can be changed except for the level of protection, channel on/off state, and clearing of faults. Values can be read from all pages. This setting can be stored to EEPROM.

WRITE_PROTECT Data Contents

BIT(S)	SYMBOL	OPERATION
b[7:0]	Write_protect[7:0]	1000_0000b: Level 1 Protection - Disable all writes except to the WRITE_PROTECT, PAGE, MFR_EE_UNLOCK, STORE_USER_ALL commands. 0100_0000b: Level 2 Protection – Disable all writes except to the WRITE_PROTECT, PAGE, MFR_EE_UNLOCK, STORE_USER_ALL, OPERATION, MFR_COMMAND_PLUS, MFR_PAGE_FF_MASK and CLEAR_FAULTS commands. 0000_0000b: Enable writes to all commands. xxxx_xxxxb: All other values reserved.

MFR_CLEAR_ENERGY

Write Protect Pin

The WP pin allows the user to write-protect the LTC2975's configuration registers. The WP, MFR_CLEAR_ENERGY asserted it provides Level 2 protection: all writes are disabled except to the WRITE_PROTECT, PAGE, MFR_EE_UNLOCK, STORE_USER_ALL, OPERATION, MFR_COMMAND_PLUS, MFR_PAGE_FF_MASK and CLEAR_FAULTS commands. The most restrictive setting between the WP pin and WRITE_PROTECT command will override.

WP PIN STATE	WRITE_PROTECT COMMAND VALUE	WRITE PROTECT LEVEL
Low	0x00	No write protection
	0x40	Level 2
	0x80	Level 1
High	0x00	Level 2
	0x40	Level 2
	0x80	Level 1

MFR_PAGE_FF_MASK

The MFR_PAGE_FF_MASK command is used to select which channels respond when the global page command (PAGE = 0xFF) is in use.

MFR_PAGE_FF_MASK Data Contents

BIT(S)	SYMBOL	OPERATION
b[7:4]	Reserved	Always returns 0000b
b[3]	Mfr_page_ff_mask_chan3	Channel 3 masking of global page command (PAGE=0xFF) accesses 0 = ignore global page command accesses 1 = fully respond to global page command accesses

PMBUS COMMAND DESCRIPTION

INPUT CURRENT AND ENERGY

COMMAND NAME		DESCRIPTION	TYPE	PAGED	DATA FORMAT	UNITS	EEPROM	DEFAULT VALUE	REF PAGE
MFR_EIN	0xC0	Input Energy data bytes.	R Block	N	Reg			NA	49
MFR_EIN_CONFIG	0xC1	Configuration register for energy and input current.	R/W Byte	N	Reg		Y	0x00	50
MFR_CLEAR_ENERGY	0xCC	Clear MFR_EIN time and energy values	Send Byte	N				NA	51
MFR_IIN_CAL_GAIN	0xE8	The nominal resistance of the input current sense element in mΩ.	R/W Word	N	L11	mΩ	Y	1.0 0xBA00	50

Energy Measurement and Reporting

Input energy measurement and monitoring supports the following:

- Input energy derived from the accumulated product of READ_VIN and READ_IIN.
- Reporting input energy value as a 48-bit integer in mJ. Returning value in Joules eliminates the need for the host to manage time.
- Reporting input energy time as a 48-bit integer in ms, where input energy ~~tim~~ or MFR_CLEAR_ENERGY monitoring was last reset.
- Resetting time and energy accumulators whenever MFR_EIN_CONFIG is written.
- Wrapping of time and energy accumulators when full.
- An optional HD mode allowing the user to give priority to energy measurement by forcing the ADC to measure READ_VIN and READ_IIN between every other ADC measurement.
- Reporting energy and time values coherently.
- Ability to decrement energy to prevent rectification and accumulation of noise when the channel is off. Energy is not allowed to decrement below zero.

MFR_EIN

Read only. This 12 byte data block returns the input energy value and time. Once the block read starts, MFR_EIN updates are suspended until the block read completes. However, energy and time continue to accumulate internally during block reads.

Table 2. MFR_EIN Data Block Contents

DATA	BYTE*	DESCRIPTION
Energy_value [7:0]	0	Energy Value in mJ. This is the accumulated energy since Mfr_ein_config was last written. or MFR_CLEAR_ENERGY was last written
Energy_value [15:8]	1	
Energy_value [23:16]	2	
Energy_value [31:24]	3	
Energy_value [39:32]	4	
Energy_value [47:40]	5	
Energy_time [7:0]	6	Energy Time in ms. This is the elapsed time since Mfr_ein_config was last written. or MFR_CLEAR_ENERGY
Energy_time [15:8]	7	
Energy_time [23:16]	8	
Energy_time [31:24]	9	
Energy_time [39:32]	10	
Energy_time [47:40]	11	

PMBUS COMMAND DESCRIPTION

MFR_IIN_CAL_GAIN_TC

The MFR_IIN_CAL_GAIN_TC sets the temperature coefficient of the MFR_IIN_CAL_GAIN register value in ppm/°C. This command uses the internal die temperature.

Refer to MFR_IIN_CAL_GAIN for details on proper usage.

MFR_IOUT_CAL_GAIN_TC Data Contents

BIT(S)	SYMBOL	OPERATION
b[15:0]	Mfr_iin_cal_gain_tc	16-bit twos complement integer representing the temperature coefficient. Value = Y where Y = b[15:0] is a twos complement number. Example: Mfr_iin_cal_gain_tc = 3900ppm For b[15:0] = 0x0F3C Value = 3900

MFR_CLEAR_ENERGY

This send byte command clears the accumulated energy and time value in MFR_EIN and can be written even when the LTC2975 is write-protected with level 2 protection. The LTC2975 may internally delay the application of this command by up to t_{UPDATE_ADC} in order to avoid corrupting an ongoing energy calculation.

VOUT_MODE	0x20	Output voltage data format and mantissa exponent (2^{-13}).	R Byte	Y	Reg			0x13	52
VOUT_COMMAND	0x21	Servo target. Nominal DC/DC converter output voltage setpoint.	R/W Word	Y	L16	V	Y	1.0 0x2000	52
VOUT_MAX	0x24	Upper limit on the output voltage the unit can command regardless of any other commands.	R/W Word	Y	L16	V	Y	4.0 0x8000	52
VOUT_MARGIN_HIGH	0x25	Margin high DC/DC converter output voltage setting.	R/W Word	Y	L16	V	Y	1.05 0x219A	52
VOUT_MARGIN_LOW	0x26	Margin low DC/DC converter output voltage setting.	R/W Word	Y	L16	V	Y	0.95 0x1E66	52
VOUT_OV_FAULT_LIMIT	0x40	Output overvoltage fault limit.	R/W Word	Y	L16	V	Y	1.1 0x2333	52
VOUT_OV_WARN_LIMIT	0x42	Output overvoltage warning limit.	R/W Word	Y	L16	V	Y	1.075 0x2266	52
VOUT_UV_WARN_LIMIT	0x43	Output undervoltage warning limit.	R/W Word	Y	L16	V	Y	0.925 0x1D9A	52
VOUT_UV_FAULT_LIMIT	0x44	Output undervoltage fault limit. Used for Ton_max_fault and power good de-assertion.	R/W Word	Y	L16	V	Y	0.9 0x1CCD	52
POWER_GOOD_ON	0x5E	Output voltage at or above which a power good should be asserted.	R/W Word	Y	L16	V	Y	0.96 0x1EB8	52
POWER_GOOD_OFF	0x5F	Output voltage at or below which a power good should be de-asserted when Mfr_config_all_pwrgd_off_uses_uv is clear.	R/W Word	Y	L16	V	Y	0.94 0x1E14	52
MFR_VOUT_DISCHARGE_THRESHOLD	0xE9	Coefficient used to multiply VOUT_COMMAND in order to determine V_{OUT} off threshold voltage.	R/W Word	Y	L11		Y	2.0 0xC200	52
MFR_DAC	0xE0	The code of the 10-bit DAC.	R/W Word	Y	Reg			0x0000	52

PMBUS COMMAND DESCRIPTION

CYCLICAL MUX LOOP DATA

BYTE NUMBER DECIMAL	BYTE NUMBER HEX	LOOP BYTE NUMBER DECIMAL	MUX LOOP 3	54 BYTES PER LOOP
226	E2	40	Status_ temperature2[7:0]	
227	E3	39	Read_ temperature_1_2[15:8]	
228	E4	38	Read_ temperature_1_2[7:0]	
229	E5	37	Status_mfr_ specific2[7:0]	
230	E6	36	Status_vout2[7:0]	
231	E7	35	Read_vout2[15:8]	
232	E8	34	Read_vout2[7:0]	
233	E9	33	Read_pout1[15:8]	
234	EA	32	Read_pout1[7:0]	
235	EB	31	Read_iout1[15:8]	
236	EC	30	Read_iout1[7:0]	
237	ED	29	Status_iout1[7:0]	Last valid fault log byte
238	EE		0x00	Bytes EE - FE return 0x00
239	EF		0x00	

CYCLICAL MUX LOOP DATA

BYTE NUMBER DECIMAL	BYTE NUMBER HEX	LOOP BYTE NUMBER DECIMAL	MUX LOOP 3	54 BYTES PER LOOP
240	F0		0x00	
241	F1		0x00	
242	F2		0x00	
243	F3		0x00	
244	F4		0x00	
245	F5		0x00	
246	F6		0x00	
247	F7		0x00	
248	F8		0x00	
249	F9		0x00	
250	FA		0x00	
251	FB		0x00	
252	FC		0x00	
253	FD		0x00	
254	FE		0x00	This is PMBUS byte 255. It must be read to clear Mfr_fault_log_ status_ram.

IDENTIFICATION/INFORMATION

COMMAND NAME	CMD CODE	DESCRIPTION	TYPE	PAGED	DATA FORMAT	UNITS	EEPROM	DEFAULT VALUE	REF PAGE
CAPABILITY	0x19	Summary of PMBus optional communication protocols supported by this device.	R Byte	N	Reg			0xB0	83
PMBUS_REVISION	0x98	PMBus revision supported by this device. Current revision is 1.1.	R Byte	N	Reg			0x11	84
MFR_SPECIAL_ID	0xE7	Manufacturer code for identifying the LTC2975.	R Word	N	Reg		Y	~~0x0224~~ 0x0226	84
MFR_SPECIAL_LOT	0xC2	Customer dependent codes that identify the factory programmed user configuration stored in EEPROM. Contact factory for default value.	R Byte	Y	Reg		Y	NA	84
MFR_INFO	0xB6	Manufacturer specific information.	R Word	N	Reg			NA	84

Added

CAPABILITY

The CAPABILITY command provides a way for a host system to determine some key capabilities of the LTC2975.

CAPABILITY Data Contents

BIT(S)	SYMBOL	OPERATION
b[7]	Capability_pec	Hard coded to 1 indicating Packet Error Checking is supported. Reading the Mfr_config_all_pec_en bit will indicate whether PEC is currently required.
b[6:5]	Capability_scl_max	Hard coded to 01b indicating the maximum supported bus speed is 400kHz.
b[4]	Capability_smb_alert	Hard coded to 1 indicating this device does have an ALERTB pin and does support the SMBus Alert Response Protocol.
b[3:0]	Reserved	Always returns 0.

PMBUS COMMAND DESCRIPTION

PMBUS_REVISION

PMBUS_REVISION Data Contents

BIT(S)	SYMBOL	OPERATION
b[7:0]	PMBus_rev	Reports the PMBus standard revision compliance. This is hard-coded to 0x11 for revision 1.1.

MFR_SPECIAL_ID

0x0226

This register contains the manufacturer ID for the LTC2975. Always returns ~~0x0224.~~

MFR_SPECIAL_LOT

These paged registers contain information that identifies the user configuration that was programmed at the factory. Contact the factory to request a custom factory programmed user configuration and special lot number.

Added

MFR_INFO

The MFR_INFO register contains manufacturer specific information and is updated after a power-on reset, a RESTORE_USER_ALL command, or an EEPROM bulk read operation.

MFR_INFO Data Contents

BIT(S)	SYMBOL	OPERATION
b[15:6]	Reserved	Reserved.
b[5]	Mfr_info_ecc_user	EEPROM ECC status. 0: Corrections made in the EEPROM user space. 1: No corrections made in the EEPROM user space.
b[4:0]	Reserved	Reserved.

USER SCRATCHPAD

COMMAND NAME	CMD CODE	DESCRIPTION	TYPE	PAGED	DATA FORMAT	UNITS	EEPROM	DEFAULT VALUE	REF PAGE
USER_DATA_00	0xB0	Manufacturer reserved for LTpowerPlay.	R/W Word	N	Reg		Y	NA	84
USER_DATA_01	0xB1	Manufacturer reserved for LTpowerPlay.	R/W Word	Y	Reg		Y	NA	84
USER_DATA_02	0xB2	OEM Reserved.	R/W Word	N	Reg		Y	NA	84
USER_DATA_03	0xB3	Scratchpad location.	R/W Word	Y	Reg		Y	0x0000	84
USER_DATA_04	0xB4	Scratchpad location.	R/W Word	N	Reg		Y	0x0000	84
MFR_LTC_RESERVED_1	0xB5	Manufacturer reserved.	R/W Word	Y	Reg		Y	NA	84
MFR_LTC_RESERVED_2	0xBC	Manufacturer reserved.	R/W Word	Y	Reg			NA	84

USER_DATA_00, USER_DATA_01, USER_DATA_02, USER_DATA_03, USER_DATA_04, MFR_LTC_RESERVED_1 and MFR_LTC_RESERVED_2

These registers are provided as user scratchpad and additional manufacturer reserved locations.

USER_DATA_03 and USER_DATA_04 are available for user scratchpad use. These 10 bytes (1 unpaged word plus 4paged words) might be used for traceability or revision information such as serial number, board model number, assembly location, or assembly date.