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EMC1701

High-Side Current-Sense and Internal 1°C Temperature Monitor

PRODUCT FEATURES

Datasheet

General Description

The EMC1701 is a combination high-side current sensing device with precision temperature measurement. It measures the voltage developed across an external sense resistor to represent the high-side current of a battery or voltage regulator. The EMC1701 also measures the source voltage and uses these measured values to present a proportional power calculation. The EMC1701 contains additional bi-directional peak detection circuitry to flag instantaneous current spikes with programmable time duration and magnitude threshold. Finally, the EMC1701 includes an internal diode channel for ambient temperature measurement.

Both current sensing and temperature monitoring include two tiers of protection: one that can be masked and causes the ALERT pin to be asserted, and the other that cannot be masked and causes the THERM pin to be asserted.

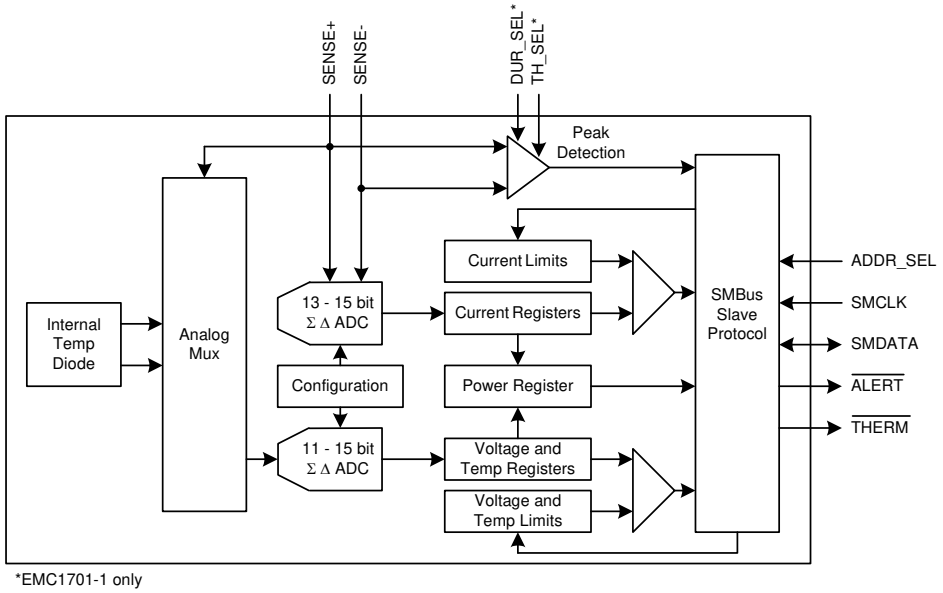
Applications

- Notebook and Desktop Computers
- Industrial
- Power Management Systems
- Embedded Applications

Features

- High-side current sensor
  - Bi-directional current measurement
  - Measures source voltage and indicates power ratio
  - 1% current measurement accuracy
  - Integrated over 82ms to 2.6sec with 11-bit resolution
  - 3V to 24V bus voltage range
- Independent hardware set instantaneous current peak detector (EMC1701-1 only)
  - Software controls to program time duration and magnitude threshold
- Power supply options
  - Bus or separately powered for low voltage operation
- Wide temperature operating range: -40°C to +85°C
- Internal temperature monitor
  - ±1°C accuracy (-5°C < T_A < 85°C)
- ALERT and THERM outputs for temperature, voltage, and out-of-current limit reporting
- SMBus 2.0 interface
  - Pin-selectable SMBus Address
  - Block Read and Write
- Available in a 12-pin 4mm x 4mm QFN RoHS Compliant Package (EMC1701-1)
- Available in a 10-pin MSOP RoHS Compliant Package (EMC1701-2)

Block Diagram



*EMC1701-1 only

Ordering Information:

ORDERING NUMBER	PACKAGE	FEATURES
EMC1701-1-KP-TR	12-pin 4mm x 4mm QFN (Lead-free RoHS compliant)	Internal diode, current sensor, hardware set peak detector
EMC1701-2-AIZL-TR	10-pin MSOP (Lead-free RoHS compliant)	Internal diode, current sensor

REEL SIZE IS 4,000 PIECES

This product meets the halogen maximum concentration values per IEC61249-2-21

For RoHS compliance and environmental information, please visit www.smsc.com/rohs

80 ARKAY DRIVE, HAUPPAUGE, NY 11788 (631) 435-6000, FAX (631) 273-3123

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Chapter 1 Pin Description

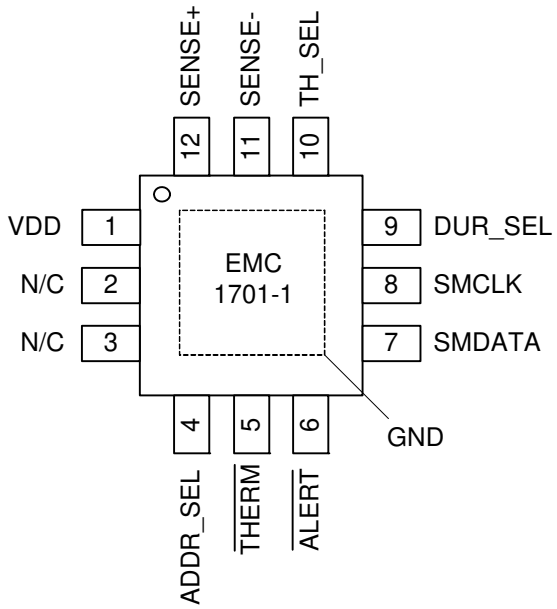


Figure 1.1 EMC1701 Pin Diagram 12-Pin QFN 4mm x 4mm

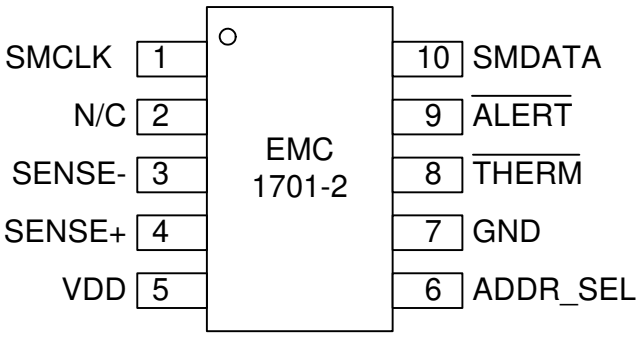


Figure 1.2 EMC1701 Pin Diagram 10-Pin MSOP

Table 1.1 Pin Description for EMC1701

PIN NUMBER EMC1701-1	PIN NUMBER EMC1701-2	PIN NAME	PIN FUNCTION	PIN TYPE
1	5	VDD	Positive power supply voltage	Power (24V)
2	2	N/C	Not internally connected	n/a
3	N/A	N/C	Not internally connected	n/a
4	6	ADDR_SEL	Selects SMBus Address	AI
5	8	$\overline{\text{THERM}}$	Active low output - requires pull-up resistor	OD (5V)
6	9	$\overline{\text{ALERT}}$	Active low output - requires pull-up resistor	OD (5V)
7	10	SMDATA	SMBus data input/output - requires external pull-up resistor	DIOD (5V)
8	1	SMCLK	SMBus clock input - requires external pull-up resistor	DI (5V)
9	N/A	DUR_SEL	Selects peak detector duration	AI
10	N/A	TH_SEL	Selects peak detector threshold	AI
11	3	SENSE-	Negative current sense measurement point	AI (24V)
12	4	SENSE+	Positive current sense measurement point	AI (24V)
Bottom Pad	7	GND	Ground	Power

The pin types are described in Table 1.2. All pins labeled with (5V) are 5V tolerant. All pins labeled with (24V) are 24V tolerant.

Table 1.2 Pin Types

PIN TYPE	DESCRIPTION
Power	This pin is used to supply power or ground to the device.
AI	Analog Input - this pin is used as an input for analog signals.
OD	Open Drain Digital Output - this pin is used as a digital output. It is open drain and requires a pull-up resistor. This pin is 5V tolerant.
DI	Digital Input - this pin is used for digital inputs. This pin is 5V tolerant.
DIOD	Open Drain Digital Input / Output - this pin is bi-directional. It is open drain and requires a pull-up resistor. This pin is 5V tolerant.

Chapter 2 Electrical Characteristics

Table 2.1 Absolute Maximum Ratings

Voltage on 5V tolerant pins	-0.3 to 5.5	V
Voltage on 2V tolerant pins	-0.3 to 2	V
Voltage on VDD, SENSE- and SENSE+ pins	-0.3 to 26	V
Voltage on any other pin to GND	-0.3 to 4	V
Voltage between Sense pins (|(SENSE+ - SENSE-)|)	< 6	V
Package Power Dissipation	0.5W up to T_A = 85°C	W
Junction to Ambient (θ_{JA}) (QFN12 package)	58	°C/W
Junction to Ambient (θ_{JA}) (MSOP10 package)	128	°C/W
Operating Ambient Temperature Range	-40 to 85	°C
Storage Temperature Range	-55 to 150	°C
ESD Rating - SMCLK, SMDATA, $\overline{\text{ALERT}}$, $\overline{\text{THERM}}$ pins - HBM	4000	V
ESD Rating - All other pins - HBM	2000	V

Note 2.1 Stresses at or above those values listed could cause permanent damage to the device. This is a stress rating only, and functional operation of the device at any other condition above those indicated in the operation sections of this specification is not implied. Prolonged stresses above the stated operating levels and below the Absolute Maximum Ratings may degrade device performance and lead to permanent damage.

Note 2.2 All voltages are relative to ground.

Note 2.3 The Package Power Dissipation specification assumes a thermal via design with the thermal landing be soldered to the PCB ground plane with four 12 mil vias (where applicable).

Note 2.4 Junction to Ambient (θ_{JA}) is dependent on the design of the thermal vias. Without thermal vias and a thermal landing, the θ_{JA} is approximately 60°C/W (EMC1701-1) including localized PCB temperature increase.

2.1 Electrical Specifications

Table 2.2 Electrical Specifications

V_{DD} = V_{BUS} = 3V TO 24V, V_{PULLUP} = 3V TO 5.5V, T_A = -40°C TO 85°C, ALL TYPICAL VALUES AT V_{DD} = V_{PULLUP} = 3.3V, V_{BUS} = 12V, AND T_A = 27°C UNLESS OTHERWISE NOTED.						
CHARACTERISTIC	**SYMBOL**	**MIN**	**TYP**	**MAX**	**UNIT**	**CONDITIONS**
DC POWER						
Supply Voltage	V_{DD}	3		24	V	
VDD Pin Supply Current	I_{DD}		610	750	uA	Temp conversions at 0.0625 conversions / second, dynamic averaging disabled current sense active
			650	950	uA	Temp conversions at 4 conversions / second, dynamic averaging disabled current sense active
			950	1100	uA	Temp conversions at 8 conversions / second, dynamic averaging enabled current sense active
VDD Pin Supply Current	$I_{DD\_T\_STANDBY}$			750	uA	Temp conversions disabled (TMEAS / STOP = '1') current sense active
VDD Pin Supply Current	$I_{DD\_ALL\_STANDBY}$			300	uA	Temp conversions disabled (TMEAS / STOP = '1') Current sense disabled (IMEAS / STOP = '1')
SENSE+ Pin Bias Current	I_{SENSE+}		90		uA	V_{SENSE} = 0V, V_{DD} = 3V to 24V, Current sense active
			15		uA	V_{SENSE} = 0V, V_{DD} = 3V to 24V, current sense disabled
			10	20	uA	V_{DD} = 0V
SENSE- Pin Bias Current	I_{SENSE-}		10		uA	V_{SENSE} = 0V, V_{DD} = 3V to 24V, Current sense active
			10		uA	V_{SENSE} = 0V, VDD = 3V to 24V, current sense disabled
			0		uA	V_{DD} = 0V
Pull-up Voltage	V_{PULLUP}	3		5.5	V	Pull-up voltage for SMBus, $\overline{\text{ALERT}}$, and $\overline{\text{THERM}}$ pins
Leakage Current (±)	I_{LEAK}			5	uA	$\overline{\text{ALERT}}$ and $\overline{\text{THERM}}$ pins, SMDATA and SMCLK pins powered or unpowered, T_A < 85°C

Table 2.2 Electrical Specifications (continued)

V_{DD} = V_{BUS} = 3V TO 24V, V_{PULLUP} = 3V TO 5.5V, T_A = -40°C TO 85°C, ALL TYPICAL VALUES AT V_{DD} = V_{PULLUP} = 3.3V, V_{BUS} = 12V, AND T_A = 27°C UNLESS OTHERWISE NOTED.						
CHARACTERISTIC	**SYMBOL**	**MIN**	**TYP**	**MAX**	**UNIT**	**CONDITIONS**
CURRENT SENSE						
Common Mode Voltage	V_{CM}	3		24	V	Voltage on SENSE+ and/or SENSE- pins, referenced to Ground
Differential Mode Voltage	V_{DIFF}	-6		+6	V	Voltage between SENSE+ and SENSE- pins
Full Scale Range (±) (see Section 5.16)	FSR	0		10	mV	1 LSB = 4.885uV
		0		20	mV	1 LSB = 9.77uV
		0		40	mV	1 LSB = 19.54uV
		0		80	mV	1 LSB = 39.08uV
Total Measurement Error (±)	V_{SENSE_ERR}		0.5	1	%	Total Error, FSR = 80mV
				3	%	Total Error, FSR = 10mV to 40mV
Offset Error (±)	V_{SENSE_OFF}			3	LSB	Offset Error, FSR = 80mV
Power Supply Rejection	V_{SENSE_PSR}		-120		dB	FSR = 10mV to 80mV, 3V < V_{DD} < 24V
Common Mode Rejection	V_{SENSE_CMR}		-110		dB	FSR = 10mV to 80mV, 3V < V_{BUS} < 24V
SOURCE VOLTAGE						
Full Scale Voltage	FSV	3		23.9883	V	Voltage on SENSE+ pin
Total Measurement Error (±) (see Section 4.1.2)	V_{SOURCE_ERR}		0.2	0.5	%	
POWER RATIO						
Full Scale Range		0		100	%	1 LSB = 1.53m%
Total Measurement Error (±)	P_{RATIO_ERR}			1.6	%	FSR = 80mV
				3	%	FSR = 10mV to 40mV
CURRENT SENSE PEAK DETECTION						
Peak Detector Threshold Range	V_{TH}	10		85	mV	Programmable via TH_SEL pin (EMC1701-1 only)
Peak Detector Duration Range	T_{DUR}	1		4096	ms	Programmable via DUR_SEL pin (EMC1701-1 only)
V_{SENSE} Peak Detection	t_{FILTER}		5		us	

Table 2.2 Electrical Specifications (continued)

V_{DD} = V_{BUS} = 3V TO 24V, V_{PULLUP} = 3V TO 5.5V, T_A = -40°C TO 85°C, ALL TYPICAL VALUES AT V_{DD} = V_{PULLUP} = 3.3V, V_{BUS} = 12V, AND T_A = 27°C UNLESS OTHERWISE NOTED.						
CHARACTERISTIC	**SYMBOL**	**MIN**	**TYP**	**MAX**	**UNIT**	**CONDITIONS**
Threshold Accuracy (±)	V_{TH_ERR}		2	5	%	V_{TH} = 80mV
INTERNAL TEMPERATURE MONITOR						
Temperature Accuracy (±)			0.25	1	°C	-5°C < T_A < 85°C
				2	°C	-40°C < T_A < 85°C
Temperature Resolution			0.125		°C	
CONVERSION TIMES						
First Conversion Ready	t_{CONV_T}		180	300	ms	Time after power up before temperature and voltage measurements updated and P_{RATIO} updated
SMBus Delay	t_{SMB_D}			25	ms	Time before SMBus communications should be sent by host
DIGITAL I/O PINS (SMCLK, SMDATA, $\overline{\text{THERM}}$, $\overline{\text{ALERT}}$)						
Input High Voltage	V_{IH}	2.0			V	SMCLK, SMDATA OD pins pulled up to V_{PULLUP}
Input Low Voltage	V_{IL}			0.8	V	
Output Low Voltage	V_{OL}			0.4	V	OD pin pulled to V_{PULLUP} 4 mA current sink

APPLICATION NOTE: The EMC1701 is trimmed at the 80mV range for best accuracy.

2.2 SMBus Electrical Specifications

Table 2.3 SMBus Electrical Specifications

V_{DD}= V_{BUS} = 3V to 24V, V_{PULLUP} = 3V to 5.5V, T_A = -40°C to 85°C Typical values are at T_A = 27°C unless otherwise noted.						
CHARACTERISTIC	**SYMBOL**	**MIN**	**TYP**	**MAX**	**UNITS**	**CONDITIONS**
SMBUS INTERFACE						
Input Capacitance	C_{IN}		4	10	pF	
SMBUS TIMING						
Clock Frequency	f_{SMB}	10		400	kHz	
Spike Suppression	t_{SP}			50	ns	

Table 2.3 SMBus Electrical Specifications (continued)

V_{DD}= V_{BUS} = 3V to 24V, V_{PULLUP} = 3V to 5.5V, T_A = -40°C to 85°C Typical values are at T_A = 27°C unless otherwise noted.						
CHARACTERISTIC	**SYMBOL**	**MIN**	**TYP**	**MAX**	**UNITS**	**CONDITIONS**
Bus Free Time Start to Stop	t_{BUF}	1.3			us	
Setup Time: Start	$t_{SU:STA}$	0.6			us	
Setup Time: Stop	$t_{SU:STO}$	0.6			us	
Data Hold Time	$t_{HD:DAT}$	0			us	
Data Setup Time	$t_{SU:DAT}$	0.6			us	
Clock Low Period	t_{LOW}	1.3			us	
Clock High Period	t_{HIGH}	0.6			us	
Clock/Data Fall time	t_{FALL}			300	ns	Min = $20+0.1C_{LOAD}$ ns
Clock/Data Rise time	t_{RISE}			300	ns	Min = $20+0.1C_{LOAD}$ ns
Capacitive Load	C_{LOAD}			400	pF	Total per bus line

Chapter 3 Communications

3.1 System Management Bus Interface Protocol

The EMC1701 communicates with a host controller, such as an SMSC SIO, through the SMBus. The SMBus is a two-wire serial communication protocol between a computer host and its peripheral devices. A detailed timing diagram is shown in Figure 3.1. Stretching of the SMCLK signal is supported; however, the EMC1701 will not stretch the clock signal.

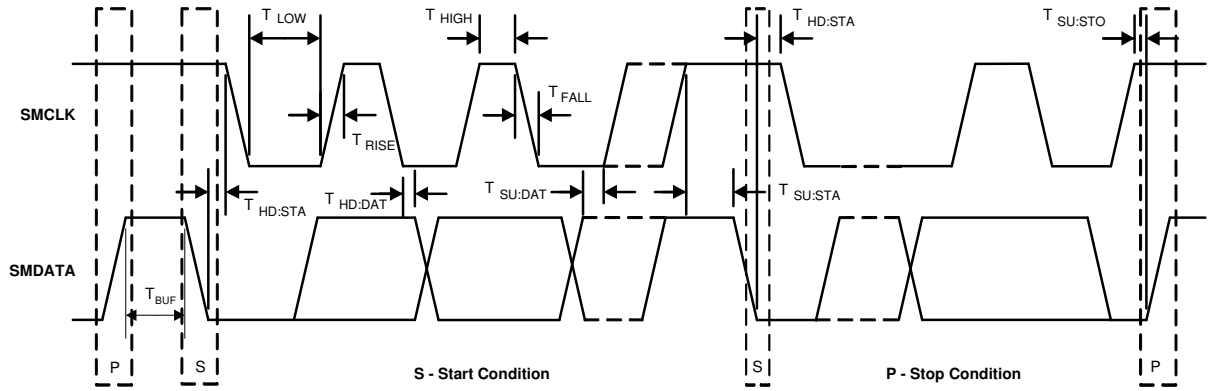


Figure 3.1 SMBus Timing Diagram

3.1.1 SMBus Start Bit

The SMBus Start bit is defined as a transition of the SMBus Data line from a logic ‘1’ state to a logic ‘0’ state while the SMBus Clock line is in a logic ‘1’ state.

3.1.2 SMBus Address and RD / $\overline{WR}$ Bit

The SMBus Address Byte consists of the 7-bit client address followed by a 1-bit RD / $\overline{WR}$ indicator. If this RD / $\overline{WR}$ bit is a logic ‘0’, the SMBus host is writing data to the client device. If this RD / $\overline{WR}$ bit is a logic ‘1’, the SMBus host is reading data from the client device.

The EMC1701 SMBus address is determined by a single resistor connected between ground and the ADDR_SEL pin as shown in Table 3.1.

Table 3.1 ADDR_SEL Resistor Setting

RESISTOR (5%)	SMBUS ADDRESS	RESISTOR (5%)	SMBUS ADDRESS
0	1001_100(r/w)	1600	0101_000(r/w)
100	1001_101(r/w)	2000	0101_001(r/w)
180	1001_110(r/w)	2700	0101_010(r/w)
300	1001_111(r/w)	3600	0101_011(r/w)
430	1001_000(r/w)	5600	0101_100(r/w)

Table 3.1 ADDR_SEL Resistor Setting (continued)

RESISTOR (5%)	SMBUS ADDRESS	RESISTOR (5%)	SMBUS ADDRESS
560	1001_001(r/w)	9100	0101_100(r/w)
750	1001_010(r/w)	20000	0101_101(r/w)
1270	1001_011(r/w)	Open	0011_000(r/w)

All SMBus Data bytes are sent most significant bit first and composed of 8-bits of information.

3.1.3 SMBus ACK and NACK Bits

The SMBus client will acknowledge all data bytes that it receives (as well as the client address if it matches and the ARA address if the $\overline{\text{ALERT}}$ pin is asserted). This is done by the client device pulling the SMBus Data line low after the 8th bit of each byte that is transmitted.

The host will NACK (not acknowledge) the data received from the client by holding the SMBus data line high after the 8th data bit has been sent.

3.1.4 SMBus Stop Bit

The SMBus Stop bit is defined as a transition of the SMBus Data line from a logic ‘0’ state to a logic ‘1’ state while the SMBus clock line is in a logic ‘1’ state. When the EMC1701 detects an SMBus Stop bit, and it has been communicating with the SMBus protocol, it will reset its client interface and prepare to receive further communications.

3.1.5 SMBus Time-out

The EMC1701 includes an SMBus time-out feature. Following a 30ms period of inactivity on the SMBus, the device will time-out and reset the SMBus interface.

The time-out functionality defaults to disabled and can be enabled by writing to the TIMEOUT bit (see Section 5.11).

3.1.6 SMBus and I^2C Compliance

The major differences between SMBus and I^2C devices are highlighted here. For complete compliance information, refer to the SMBus 2.0 specification.

1. Minimum frequency for SMBus communications is 10kHz.
2. The client protocol will reset if the clock is held at a logic ‘0’ for longer than 30ms. This time-out functionality is disabled by default.
3. The client protocol will reset if both the clock and data lines are held at a logic ‘1’ for longer than 150us. This function is disabled by default.
4. I^2C devices do not support the Alert Response Address functionality (which is optional for SMBus).

3.2 SMBus Protocols

The EMC1701 is SMBus 2.0 compatible and supports Send Byte, Read Byte, Receive Byte, Write Byte, Block Read, and Block Write as valid protocols. It will respond to the Alert Response Address protocol but is not in full compliance.

All of the protocols listed below use the convention in Table 3.2.

Table 3.2 Protocol Format

DATA SENT TO DEVICE	DATA SENT TO THE HOST
# of bits sent	# of bits sent

3.2.1 Write Byte

The Write Byte is used to write one byte of data to the registers, as shown in Table 3.3:

Table 3.3 Write Byte Protocol

START	SLAVE ADDRESS	WR	ACK	REGISTER ADDRESS	ACK	REGISTER DATA	ACK	STOP
1 -> 0	YYYY_YYY	0	0	XXh	0	XXh	0	0 -> 1

3.2.2 Read Byte

The Read Byte protocol is used to read one byte of data from the registers, as shown in Table 3.4.

Table 3.4 Read Byte Protocol

START	SLAVE ADDRESS	WR	ACK	Register Address	ACK	START	Slave Address	RD	ACK	Register Data	NACK	STOP
1 -> 0	YYYY_YYY	0	0	XXh	0	0 -> 1	YYYY_YYY	1	0	XXh	1	0 -> 1

3.2.3 Send Byte

The Send Byte protocol is used to set the internal address register pointer to the correct address location. No data is transferred during the Send Byte protocol, as shown in Table 3.5.

Table 3.5 Send Byte Protocol

START	SLAVE ADDRESS	WR	ACK	REGISTER ADDRESS	ACK	STOP
1 -> 0	YYYY_YYY	0	0	XXh	0	0 -> 1

3.2.4 Receive Byte

The Receive Byte protocol is used to read data from a register when the internal register address pointer is known to be at the right location (e.g. set via Send Byte). This is used for consecutive reads of the same register, as shown in Table 3.6.

Table 3.6 Receive Byte Protocol

START	SLAVE ADDRESS	RD	ACK	REGISTER DATA	NACK	STOP
1 -> 0	YYYY_YYY	1	0	XXh	1	0 -> 1

3.2.5 Block Write

The Block Write is used to write multiple data bytes to a group of contiguous registers, as shown in Table 3.7. It is an extension of the Write Byte Protocol.

Table 3.7 Block Write Protocol

START	SLAVE ADDRESS	WR	ACK	REGISTER ADDRESS	ACK	REGISTER DATA	ACK
1 ->0	YYYY_YYY	0	0	XXh	0	XXh	0
REGISTER DATA	**ACK**	**REGISTER DATA**	**ACK**	**. . .**	**REGISTER DATA**	**ACK**	**STOP**
XXh	0	XXh	0	. . .	XXh	0	0 -> 1

3.2.6 Block Read

The Block Read is used to read multiple data bytes from a group of contiguous registers, as shown in Table 3.8. It is an extension of the Read Byte Protocol.

Table 3.8 Block Read Protocol

START	SLAVE ADDRESS	WR	ACK	REGISTER ADDRESS	ACK	START	SLAVE ADDRESS	RD	ACK	REGISTER DATA
1->0	YYYY_YYY	0	0	XXh	0	1 ->0	YYYY_YYY	1	0	XXh
ACK	**REGISTER DATA**	**ACK**	**REGISTER DATA**	**ACK**	**REGISTER DATA**	**ACK**	**. . .**	**REGISTER DATA**	**NACK**	**STOP**
0	XXh	0	XXh	0	XXh	0	. . .	XXh	1	0 -> 1

3.2.7 Alert Response Address

The $\overline{\text{ALERT}}$ output can be used as a processor interrupt or as an SMBus Alert when configured to operate as an interrupt.

When it detects that the $\overline{\text{ALERT}}$ pin is asserted, the host will send the Alert Response Address (ARA) to the general address of 0001_100xb. All devices with active interrupts will respond with their client address, as shown in Table 3.9.

Table 3.9 Alert Response Address Protocol

START	ALERT RESPONSE ADDRESS	RD	ACK	DEVICE ADDRESS	NACK	STOP
1 -> 0	0001_100	1	0	YYYY_YYY	1	0 -> 1

The EMC1701 will respond to the ARA in the following way if the $\overline{\text{ALERT}}$ pin is asserted.

1. Send Slave Address and verify that full slave address was sent (i.e. the SMBus communication from the device was not prematurely stopped due to a bus contention event).
2. Set the MASK bit to clear the $\overline{\text{ALERT}}$ pin.

Chapter 4 General Description

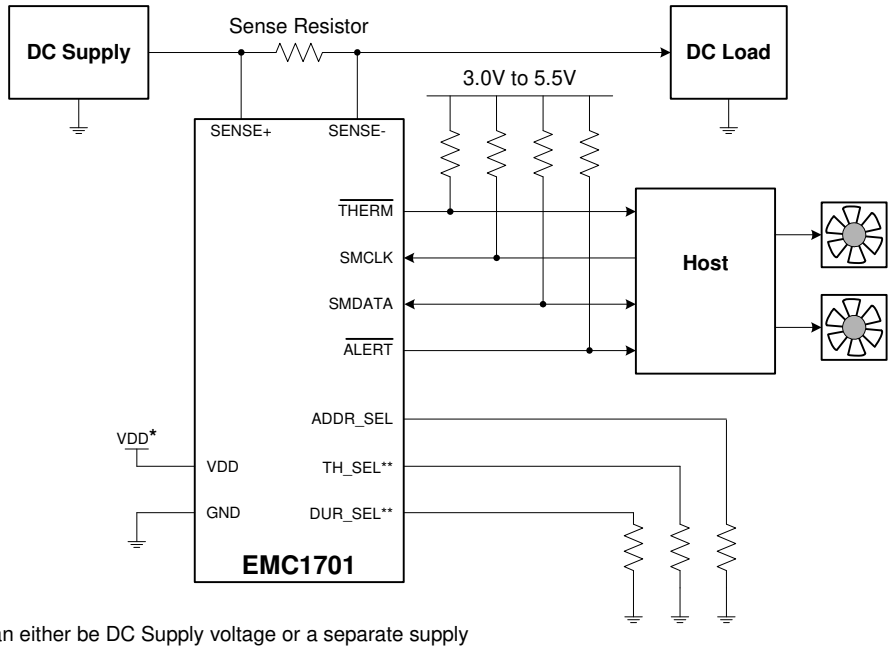
The EMC1701 is a combination high-side current sensing device with precision voltage and temperature measurement capabilities. It measures the voltage developed across an external sense resistor to represent the high-side current of a battery or voltage regulator. The EMC1701 also measures the source voltage and uses these measured values to present a proportional power calculation. The EMC1701 contains additional bi-directional peak detection circuitry to flag instantaneous current spikes with programmable time duration and magnitude threshold. Finally, the EMC1701 includes an internal diode channel for ambient temperature measurement.

The EMC1701 current-sense measurement converts differential input voltage measured across an external sense resistor to a proportional output voltage. This voltage is digitized using a variable resolution (13-bit to 15-bit) Sigma-Delta ADC and transmitted via the SMBus or I^2C protocol. The current range allows for large variations in measured current with high accuracy and low voltage drop across the resistor.

The supply voltage is also measured and stored. When combined with the sense resistor voltage measurement the power provided from the source can be determined. Programmable limits on both voltage and current levels are used to generate an interrupt.

The EMC1701 has two levels of monitoring. The first provides a maskable $\overline{\text{ALERT}}$ signal to the host when the measured temperatures or voltages meet or exceed user programmable limits. This allows the EMC1701 to be used as an independent thermal watchdog to warn the host of temperature hot spots without direct control by the host. The second level of monitoring provides a non maskable interrupt on the $\overline{\text{THERM}}$ pin if the measured values meet or exceed a second programmable limit.

A system diagram is shown in Figure 4.1.



* Can either be DC Supply voltage or a separate supply

**EMC1701-1 only

Figure 4.1 EMC1701 System Diagram

4.1 Source Monitoring

The EMC1701 includes circuitry for both source current sensing and source voltage measurement. From these measurements, a ratiometric value corresponding to the power delivered at the SENSE+ pin is provided.

4.1.1 Current Measurement

The EMC1701 includes a high-side current sensing circuit. This circuit measures the voltage, V_{SENSE}, induced across a fixed external current sense resistor, R_{SENSE}, and stores a representative voltage as a signed 11-bit number in the Sense Voltage Registers (see Section 5.18).

This circuitry is able to measure the direction of current flow (from SENSE+ to SENSE- or from SENSE- to SENSE+). Current flowing from SENSE+ to SENSE- is defined as positive current. Current flowing from SENSE- to SENSE+ is defined as negative.

The EMC1701 contains user programmable bipolar Full Scale Sense Ranges (FSSR) of ±10mV, ±20mV, ±40mV, or ±80mV (see Section 5.16). The default for this setting is ±80mV.

Each V_{SENSE} measurement is averaged over a user programmable time (see Section 5.16). It is compared against programmable high and low limits (see Section 5.21). If V_{SENSE} exceeds (or drops below) the respective limits, the $\overline{ALERT}$ pin may be asserted (the default operation is to enable current sense interrupts on the $\overline{ALERT}$ pin).

The EMC1701 also contains user programmable current peak detection circuitry (see Section 4.1.4) that will assert the $\overline{THERM}$ pin if a current spike is detected larger than the programmed threshold and of longer duration than the programmed time. This circuitry is independent of V_{SENSE}.

Full Scale Current (FSC) can be calculated from:

$FSC = \frac{FSR}{R_{SENSE}}$	where:	**[1]**
	FSC is the Full-Scale Current	
	FSR, the Full Scale Range, is either 10mV, 20mV, 40mV or 80mV (see Section 5.16)	
	R_{SENSE} is the external sense resistor value	

Actual source current through R_{SENSE} can then be calculated using:

$I_{SOURCE} = FSC \times \frac{V_{SENSE}}{2,047}$	where:	**[2]**
	I_{SOURCE} is the actual source current	
	FSC is the Full-Scale Current value (from Equation [1])	
	V_{SENSE} is the value read from the Sense Voltage Registers, ignoring the four lowest bits which are always zero (see Section 5.18)	

For example: Suppose the system is drawing 1.65A through a 10mΩ resistor and the FSR is set for 20mV. Therefore, by Equation [1], the FSC is 2A.

For a positive voltage the Sense Voltage Registers are read, ignoring the lower four bits since they are always zero, as 69_8h (0110_1001_1000b or 1688d) which is 82.5% of the full scale source current. This results in a calculated source current of 1.649A using Equation [2].

For a negative voltage the Sense Voltage Registers are read as 96_8h, also ignoring the lower four bits since they are always zero. To calculate source current the binary value is first converted from two's complement by inverting the bits and adding one:

96_8h = 1001_0110_1000b. Inverting equals 0110_1001_0111b (69_7h) and adding one gives 0110_1001_1000b (69_8h).

This results in the same calculated value as in the positive voltage case.

4.1.2 Voltage Measurement

Source voltage is measured on the supply side of the R_{SENSE} resistor (SENSE+) and stored as an unsigned 11-bit number in the Source Voltage Registers as V_{SOURCE} (see Section 5.19).

Each V_{SOURCE} measurement is averaged over a user programmable time (see Section 5.6 and Section 5.15). The measurement is delayed by the programmed conversion rate. V_{SOURCE} is compared against programmable high, low, and critical limits (see Section 5.12, Section 5.13, and Section 5.14). If the value meets or exceeds the high limits or drops below the low limits, the $\overline{ALERT}$ pin may be asserted (default is to enable this function). If the value meets or exceeds the critical limit, the $\overline{THERM}$ pin will be asserted (see Section 5.23).

Full Scale Voltage (FSV) is given by the maximum value of the Source Voltage Registers:

$FSV = 23.9883\,V$	where:	**[3]**
	FSV is the Full-Scale Voltage (a constant)	

Actual source voltage at the SENSE+ pin can be calculated using:

$Source\ Voltage = FSV \times \frac{V_{SOURCE}}{4,094}$	where:	**[4]**
	Source Voltage is the voltage at the SENSE+ pin	
	FSV is the Full-Scale Voltage (from Equation [3])	
	V_{SOURCE} is the digital value read from the Source Voltage Registers. Note that the lowest five bits are always zero (see Section 5.19)	

For example: Suppose that the actual source voltage is 10.65V. The Source Voltage Registers are read as V_{SOURCE} = 71_Ah (0111_0001_1010b or 1818d) which is 44.4% of the full scale source voltage. This results in a calculated source voltage of 10.65V using Equation [4].

Note that the actual source voltage may also be determined by scaling each bit set by the indicated bit weighting as described in Section 5.19.

4.1.3 Power Calculation

The EMC1701 may be used to determine the average power provided at the source side of R_{SENSE} (SENSE+) using the value, P_{RATIO}, contained in the Power Ratio Registers (see Section 5.20). The value represents the % of maximum calculable power.

P_{RATIO} is mathematically generated by multiplying the absolute values of V_{SENSE} and V_{SOURCE} (see Section 4.1.1 and Section 4.1.2) and stored as a shifted 16-bit unsigned number. P_{RATIO} is updated whenever either V_{SENSE} or V_{SOURCE} is updated.

Full Scale Power can be calculated from:

$FSP = FSC \times FSV$	where: FSP is the Full-Scale Power FSC is the Full-Scale Current (from Equation [1]) FSV is the Full-Scale Voltage (from Equation [3])	**[5]**

Actual power drawn from the source can be calculated using:

$P_{SOURCE} = FSP \times \frac{P_{RATIO}}{65,535}$	where: P_{SOURCE} is the actual power provided by the source measured at SENSE+ FSP is the Full-Scale Power (from Equation [5]) P_{RATIO} is the value read from the Power Ratio Registers (see Section 5.20)	**[6]**

For example: Suppose that the actual source voltage is 10.65V and the source current through a 10mΩ resistor is 1.65A. The FSC value is 2A per Equation [1]; thus, the expected power is 17.573W which is 36.6% of the FSP value.

Reading the Power Ratio Registers will report P_{RATIO} as 24,003d (0101_1101_1100_0011b or 5D_C3h), which is 36.6% of the full scale source power. This results in a calculated source power of 17.6W.

4.1.4 Current Peak Detection

The EMC1701-1 includes a hardware set instantaneous current peak detector (this circuitry is also available in the EMC1701-2 but must be configured via SMBus). The peak detector threshold and duration values may also be set via the SMBus.

The peak detector supports detection of current spikes that occur faster than the minimum current sensing conversion time. This allows quick reaction to events requiring system-level response. The circuitry compares the measured current against a user-defined threshold value and user-defined time duration. If the measured current exceeds the threshold, an internal timer is started. If the timer reaches the programmed duration, the $\overline{\text{THERM}}$ pin is asserted (see Figure 4.2 for an example of peak current detection) and the PEAK status bit set.

The $\overline{\text{THERM}}$ pin will remain asserted until the Peak is no longer detected at which point it will be released. The PEAK status bit will likewise be cleared.

The Peak Detection circuitry may also assert the $\overline{\text{ALERT}}$ pin. In this case, the $\overline{\text{ALERT}}$ pin must be configured to operate in Comparator mode. If the $\overline{\text{ALERT}}$ pin is configured to operate in Interrupt mode, the Peak Detection circuitry will not cause the $\overline{\text{ALERT}}$ pin to be asserted.

The Peak Detection circuitry includes filtering (t_{FILTER}). When the instantaneous current exceeds the threshold, it must drop below the threshold for a period of time greater than t_{FILTER} before the timer is reset. The Peak Detection circuitry works for current flowing in either direction through the sense resistor (R_{SENSE}).

APPLICATION NOTE: The Peak Detector circuitry works independently of the current measurement integration.

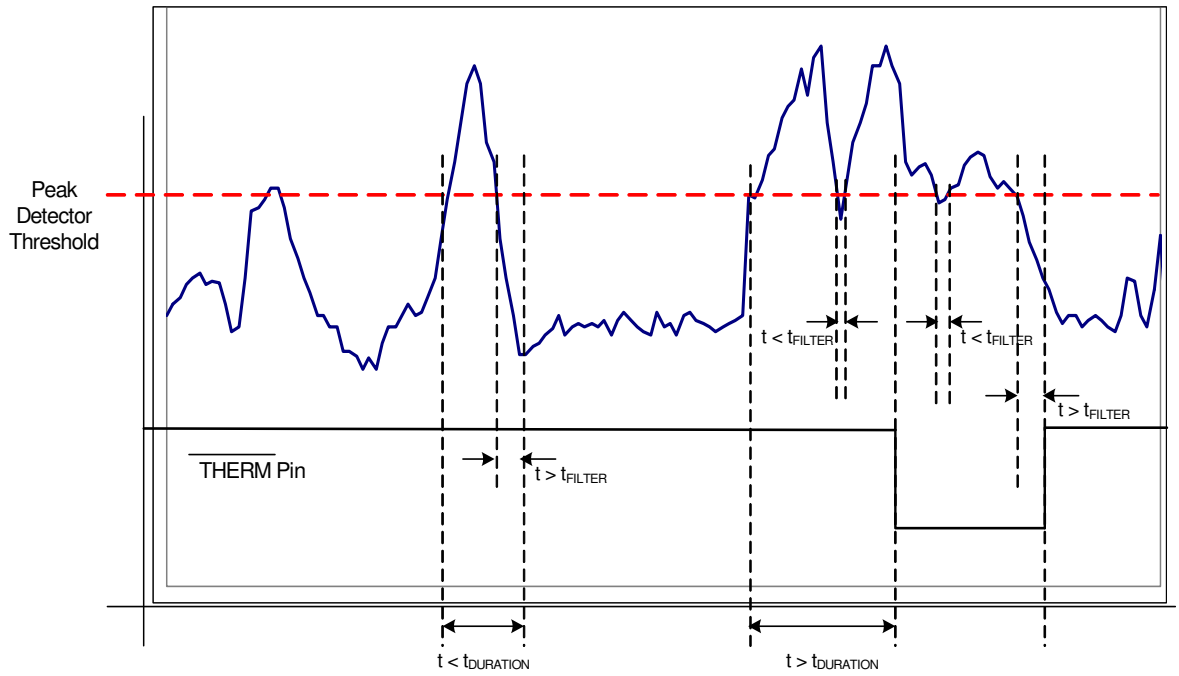


Figure 4.2 Peak Detection Example

The peak detector threshold is determined upon device power up by the value of the resistor connected between the TH_SEL pin and ground (for EMC1701-1 only) or via the SMBus (see Section 5.17). The resistor selects one of 16 different V_{SENSE} measurement limits (from 10mV to 85mV) as shown in Table 4.1.

Table 4.1 TH_SEL Resistor Setting (EMC1701-1 only)

RESISTOR (5%)	PEAK DETECTION THRESHOLD	RESISTOR (5%)	PEAK DETECTION THRESHOLD
0	10mV	1600	50mV
100	15mV	2000	55mV
180	20mV	2700	60mV
300	25mV	3600	65mV
430	30mV	5600	70mV
560	35mV	9100	75mV
750	40mV	20000	80mV
1270	45mV	Open	85mV

The peak detector duration is determined upon device power up by the value of the resistor between the DUR_SEL pin and ground (for EMC1701-1 only) or via the SMBus (see Section 5.17). The resistor selects one of 16 different time durations from 1 ms to 4.096s as shown in Table 4.2.

Table 4.2 DUR_SEL Resistor Setting (EMC1701-1 only)

RESISTOR (5%)	PEAK DETECTION MINIMUM DURATION ($T_{DURATION}$)	RESISTOR (5%)	PEAK DETECTION MINIMUM DURATION ($T_{DURATION}$)
0	1ms	1600	384ms
100	5ms	2000	512ms
180	26 ms	2700	768ms
300	51 ms	3600	1024ms
430	77 ms	5600	1536ms
560	102ms	9100	2048ms
750	128ms	20000	3072ms
1270	256ms	Open	4096ms

4.2 VDD Biasing Options

The wide device operating voltage range allows the EMC1701 to be powered from either the source voltage or an external supply. The EMC1701 contains circuitry to detect the voltage supply level on the VDD pin and enable an internal regulator as necessary.

4.3 Modes of Operation

The EMC1701 has multiple modes of operation as described here:

- Fully Active - In this mode of operation, the device is measuring the temperature channel, source voltage, and sense voltage. All data is updated at the end of the respective conversion and the limits are checked. Writing to the One-Shot register will have no effect.
- Current Sense only - In this mode of operation, the device is measuring source voltage and sense voltage only. The temperature data is not updated. V_{SOURCE} and V_{SENSE} data are updated at the end of the respective conversion and the limits are checked. Writing to the One-Shot register will update the temperature measurements. This one-shot measurement may cause the $\overline{ALERT}$ or $\overline{THERM}$ pins to be asserted if the measured temperature violates the respective limits.
- Temperature only - In this mode of operation, the device is measuring the temperature channels only. V_{SOURCE} and V_{SENSE} data are not updated. The temperature data is updated at the end of the conversion and the limits are checked. Writing to the One-Shot register will update V_{SOURCE} and V_{SENSE}. This one-shot measurement may cause the $\overline{ALERT}$ or $\overline{THERM}$ pins to be asserted if the measured voltage or current sense readings meet or exceed the respective limits.
- Standby (Stop) - In this mode of operation, the majority of circuitry is powered down to reduce supply current. The temperature, source voltage, and sense voltage measurements are not updated and the limits are not checked. In this mode of operation, the SMBus is fully active and the part will return requested data. Writing to the One-Shot register (see Section 5.8) will enable the device to update all measurement channels (temperature, V_{SOURCE}, and V_{SENSE}). This one-shot measurement may cause the $\overline{ALERT}$ or $\overline{THERM}$ pins to be asserted if any of the measured values violate their respective limits. Once all the channels are updated, the device will return to the Standby mode.