DATA SHEET

I²C
BUS

SA56004X

±1 °C accurate, SMBus-compatible, 8-pin, remote/local digital temperature sensor with over temperature alarms

Philips
Semiconductors

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±1 °C accurate, SMBus-compatible, 8-pin, remote/local digital temperature sensor with over temperature alarms

SA56004X

GENERAL DESCRIPTION

The Philips SA56004X is an SMBus compatible, 11-bit remote/local digital temperature sensor with over temperature alarms. The remote channel of the SA56004 monitors a diode junction, such as a substrate PNP of a microprocessor or a diode connected transistor such as the 2N3904 (NPN) or 2N3906 (PNP). With factory trimming, remote sensor accuracy of ±1°C is achieved.

Under and over temperature alert thresholds can be programmed to cause the $\overline{\text{ALERT}}$ output to indicate when the on-chip or remote temperature is out of range. This output may be used as a system interrupt or SMBus alert. The $\overline{\text{T\_CRIT}}$ output is activated when the on-chip or remote temperature measurement rises above the programmed T_CRIT threshold register value. This output may be used to activate a cooling fan, send a warning or trigger a system shutdown. To further enhance system reliability, the SA56004X employs an SMBus time-out protocol. The SA56004X has a unique device architecture which is patented (U.S. patent #6542020).

The SA56004X is available in the SO8 and TSSOP8 packages. SA56004X has 8 factory-programmed, device address options. The SA56004X is pin-compatible with the LM86, MAX6657/8, and ADM1032.

Patents

Notice is herewith given that the subject device uses one or more of the following patents and that each of these patents may have corresponding patents in other jurisdictions:

Patent No. US 6,542,020 B2 — owned by Koninklijke Philips Electronics N.V., Eindhoven (NL).

FEATURES

- Accurately senses temperature of remote microprocessor thermal diodes or diode connected transistors within ±1 °C
- On-chip local temperature sensing
- 11-bit, 0.125 °C resolution
- 8 different device addresses are available for server applications. The SA56004ED/EDP which marking code ARW is address compatible with the National LM86, the MAX6657/8 and the ADM1032.
- Offset registers available for adjusting the remote temperature accuracy
- Programmable under/overtemperature alarms: $\overline{\text{ALERT}}$ and $\overline{\text{T\_CRIT}}$
- SMBus 2.0 compatible interface, supports TIMEOUT

SO8   **TSSOP8**
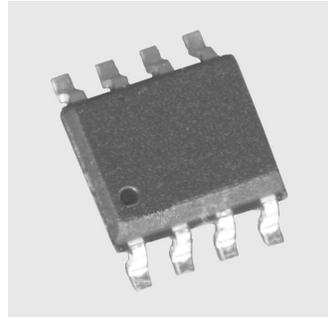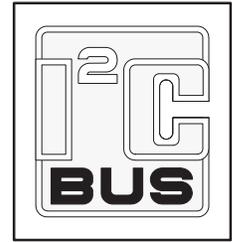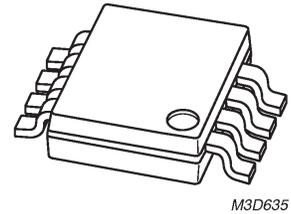
M3D635

- I^{2}C-bus standard and fast mode compatible
- TSSOP8 and SO8 packages
- Programmable conversion rate (0.0625 to 26 Hz)
- Undervoltage lockout prevents erroneous temperature readings

APPLICATIONS

- System thermal management in laptops, desktops, servers and workstations
- Computers and office electronic equipment
- Electronic test equipment & instrumentation
- HVAC
- Industrial controllers and embedded systems

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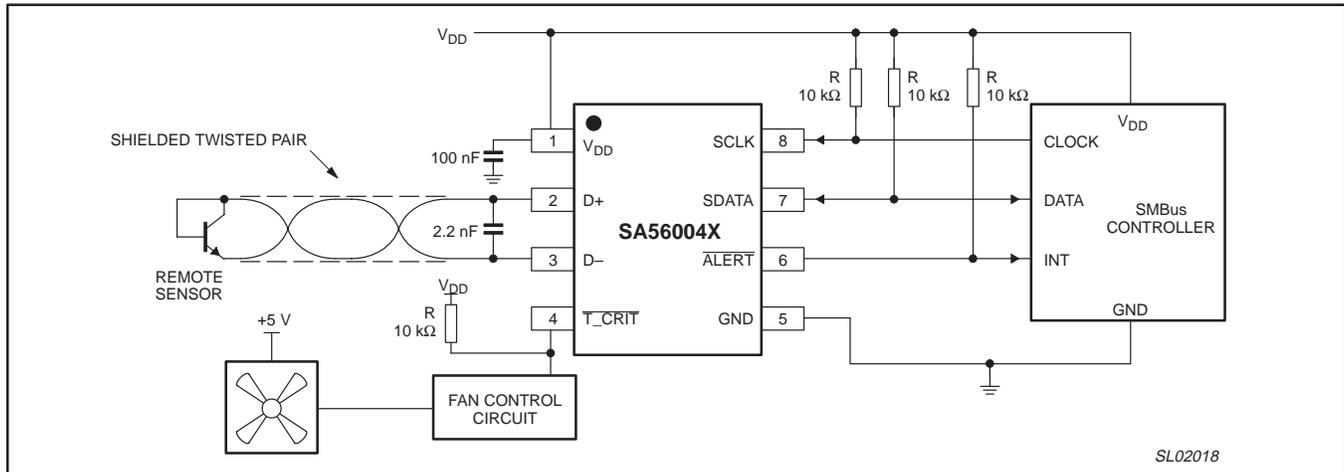
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SIMPLIFIED SYSTEM DIAGRAM

Figure 1. Simplified system diagram.

ORDERING INFORMATION

TYPE NUMBER	PACKAGE			VERSION	TEMPERATURE RANGE
	NAME	DESCRIPTION			
SA56004**X**D	SO8	plastic small outline package; 8 leads; body width 3.9 mm		SOT96-1	0 °C to +125 °C
SA56004**X**DP	TSSOP8	plastic thin shrink small outline package; 8 leads; body width 3 mm		SOT505-1	0 °C to +125 °C

NOTE:
There are 8 device slave address options (indicated by '**X**' in the Type Number, and described in Table 1).

Table 1. Device slave address options

Part number	Device slave address[1]	Part number	Device slave address[1]
SA56004AD SA56004ADP	1001000	SA56004ED[2] SA56004EDP[2]	1001100
SA56004BD SA56004BDP	1001001	SA56004FD SA56004FDP	1001101
SA56004CD SA56004CDP	1001010	SA56004GD SA56004GDP	1001110
SA56004DD SA56004DDP	1001011	SA56004HD SA56004HDP	1001111

NOTES:
1. The device slave address is factory-programmed in OTP device address register.
2. The SA56004ED/EDP has the bus address of the National LM86, MAX6657/8 and the ADM1032.

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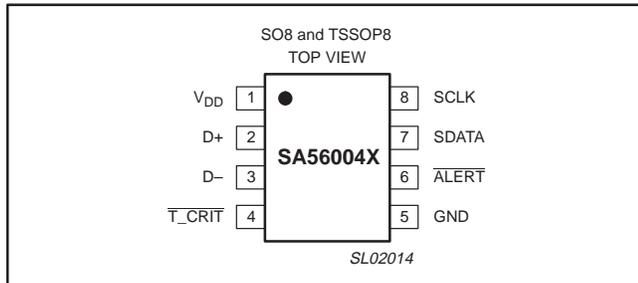
SA56004X

PIN CONFIGURATION

SO8 and TSSOP8
TOP VIEW

V_{DD}	1	8	SCLK
D+	2	7	SDATA
D−	3	6	$\overline{ALERT}$
$\overline{T\_CRIT}$	4	5	GND

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Figure 2. Pin configuration.

PIN DESCRIPTION

PIN	SYMBOL	DESCRIPTION
1	V_{DD}	Positive supply voltage. DC voltage from 3.0 V to 5.5 V.
2	D+	Diode current source (anode).
3	D−	Diode sink current (cathode).
4	$\overline{T\_CRIT}$	$\overline{T\_CRIT}$ alarm is open drain, active-LOW output which requires an external pull-up resistor. It functions as a system interrupt or power shutdown.
5	GND	Power supply ground.
6	$\overline{ALERT}$	$\overline{ALERT}$ alarm is an open drain, active-LOW output which requires an external pull-up resistor. It functions as an interrupt indicating that the temperature of the on-chip or remote diode is above or below programmed over temperature or under temperature thresholds.
7	SDATA	SMBus/I²C-bus bi-directional data line. This is an open drain output which requires an external pull-up resistor.
8	SCLK	SMBus/I²C-bus clock input which requires an external pull-up resistor.

MAXIMUM RATINGS

All voltages are referenced to GND.

SYMBOL	PARAMETER		MIN.	MAX.	UNIT
V_{DD}	Supply voltage		−0.3	+6	V
	Voltage at SDATA, SCLK, $\overline{ALERT}$, $\overline{T\_CRIT}$		−0.3	+6	V
V_{D+}	Voltage at Positive diode input		−0.3	V_{DD} + 0.3	V
$V_{D−}$	Voltage at Negative diode input		−0.3	+0.8	V
	Sink current at SDATA, SCLK, $\overline{ALERT}$, $\overline{T\_CRIT}$		−1	50	mA
I_{D+}	D+ input current		−1	1	mA
P_D	Power dissipation	SO8 package (derate 5.9 mW/°C above T_{amb} = 70 °C)	−	471	mW
		TSSOP8 package (derate 8.3 mW/°C above T_{amb} = 70 °C)	−	664	mW
$T_{j(max)}$	Maximum junction temperature		−	+150	°C
T_{stg}	Storage temperature range		−65	+165	°C

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ELECTRICAL CHARACTERISTICS

$T_{amb} = 25\ °C$, $V_{DD} = 3.0\ V$ to $3.6\ V$, unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
T_{ERRL}	Local temperature error	$T_{amb} = 60\ °C$ to $+100\ °C$	−2	± 1	+2	°C
		$T_{amb} = 0\ °C$ to $+125\ °C$	−3	−	+3	°C
T_{ERRR}	Remote temperature error	$T_{amb} = +25\ °C$ to $+85\ °C$; $T_{RD} = +60\ °C$ to $+100\ °C$	−1	−	+1	°C
		$T_{amb} = 0\ °C$ to $+85\ °C$; $T_{RD} = 0\ °C$ to $+125\ °C$	−3	−	+3	°C
T_{RESR}	Remote temperature resolution		−	11	−	bits
			−	0.125	−	°C
T_{RESL}	Local temperature resolution		−	11	−	bits
			−	0.125	−	°C
t_{CONV}	Conversion time		−	38	−	ms
V_{DD}	Supply voltage[1]		3.0	−	5.5	V
I_{DD}	Quiescent current	During conversion, 26 Hz conversion rate	−	500	−	µA
	Shutdown current	SMBus inactive	−	10	−	µA
I_{RD}	Remote diode source current	High setting: D+ − D− = +0.65 V	−	160	−	µA
		Low setting	−	10	−	µA
UVL	Undervoltage lockout (UVL) threshold voltage[2]	V_{DD} input disables A/D conversion[3]	2.6	−	2.95	V
	Power-on-Reset (POR) threshold voltage	V_{DD}, input falling edge[4]	1.8	−	2.4	V
	Local and Remote $\overline{ALERT}$ HIGH default temperature settings	Default values set at power-up	−	+70	−	°C
	Local and Remote $\overline{ALERT}$ LOW default temperature settings	Default values set at power-up	−	0	−	°C
	Local and Remote $\overline{T\_CRIT}$ default temperature settings	Default values set at power-up	−	+85	−	°C
	Hystersis ($\overline{T\_CRIT}$)	Default value set at power-up	−	+10	−	°C
	$\overline{ALERT}$ and $\overline{T\_CRIT}$ output saturation voltage	$I_{OUT} = 6.0\ mA$	−	−	0.4	V

NOTES:
1. The SA56004X is optimized for 3.3 V_{DD} operation.
2. Definition of Under Voltage Lockout (UVL): The value of V_{DD} below which the internal A/D converter is disabled. This is designed to be a minimum of 200 mV above the power-on-reset. During the time that it is disabled, the temperature that is in the "read temperature registers" will remain at the value that it was before the A/D was disabled. This is done to eliminate the possibility of reading unexpected false temperatures due to the A/D converter not working correctly due to low voltage. In case of power-up (rising V_{DD}), the reading that is stored in the "read temperature registers" will be the default value of 0 °C. V_{DD} will rise to the value of the UVL, at which point the A/D will function correctly and the normal temperature will be read.
3. V_{DD} (rising edge) voltage below which the A/D converter is disabled.
4. V_{DD} (falling edge) voltage below which the logic is reset.

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SMBus INTERFACE AC ELECTRICAL CHARACTERISTICS

V_{DD} = 3.0 V to 3.6 V; T_{amb} = 0 °C to +125 °C; unless otherwise noted.
These specifications are guaranteed by design and not tested in production.

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
V_{IH}	Logic input HIGH voltage for SCLK, SDATA	V_{DD} = 2.7 V to 5.5 V	2.2	–	–	V
V_{IL}	Logic input LOW voltage for SCLK, SDATA	V_{DD} = 2.7 V to 5.5 V	–	–	0.8	V
I_{OL}	Logic output LOW sink current	$\overline{ALERT}$, $\overline{T\_CRIT}$; V_{OL} = 0.4 V	1.0	–	–	mA
		SDATA; V_{OL} = 0.6 V	6.0	–	–	mA
I_{OH}	Logic output high leakage current	V_{OH} = V_{DD}	–	–	1.0	µA
I_{IH}, I_{IL}	Logic input currents	V_{IN} = V_{DD} or GND	–1.0	–	1.0	µA
C_i	SMBus input capacitance for SCLK, SDATA		–	5	–	pF

SMBus digital switching characteristics
The switching characteristics of the SA56004X fully meet or exceed all parameters specified in SMBus version 2.0. The following parameters specify the timing between the SCLK and SDATA signals in the SA56004X. They adhere to, but are not necessarily specified as the SMBus specifications.

|						
f_{SCLK}	SCLK operating frequency		–	–	400	kHz
t_{LOW}	SCLK LOW time	10% to 10%	4.7	5.0	–	µs
t_{HIGH}	SCLK HIGH time	90% to 90%	4.0	5.0	–	µs
t_{BUF}	SMBus free time. Delay from SDATA stop to SDATA start		4.7	–	–	µs
$t_{HD:STA}$	Hold time of start condition. Delay from SDATA start to first SCLK H-L	10% of SDATA to 90% of SCLK	4.0	–	–	µs
$t_{HD:DAT}$	Hold time of data. Delay from SCLK H-L to SDATA edges		–	300	–	ns
$t_{SU:DAT}$	Set-up time of data in. Delay from SDATA edges to SCLK L-H		250	–	–	ns
$t_{SU:STA}$	Set-up time of repeat start condition. Delay from SCLK L-H to restart SDATA	90% to to 90%	250	–	–	ns
$t_{SU:STO}$	Set-up time of stop condition. Delay from SCLK H-L to SDATA stop	90% of SCLK to 90% of SDATA	4.0	–	–	µs
t_R	Rise time of SCLK and SDATA		–	–	1	µs
t_F	Fall time of SCLK and SDATA		–	–	300	ns
t_{OF}	Output fall time	C_L = 400 pF; I_O = 3 mA	–	–	250	ns
$t_{TIMEOUT}$	SMBus TIMEOUT. Low period for reset of SMBus		25	–	35	ms
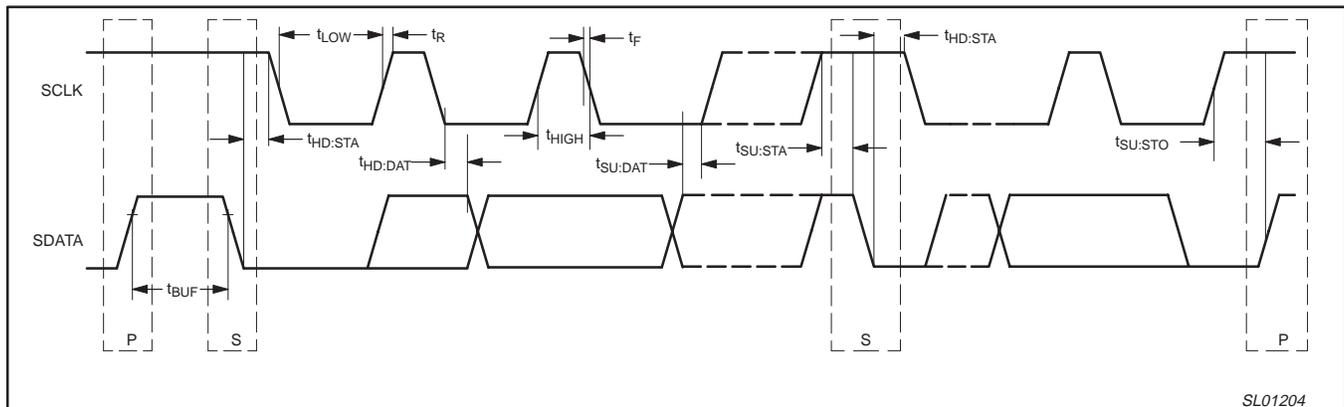
Figure 3. Timing measurements.

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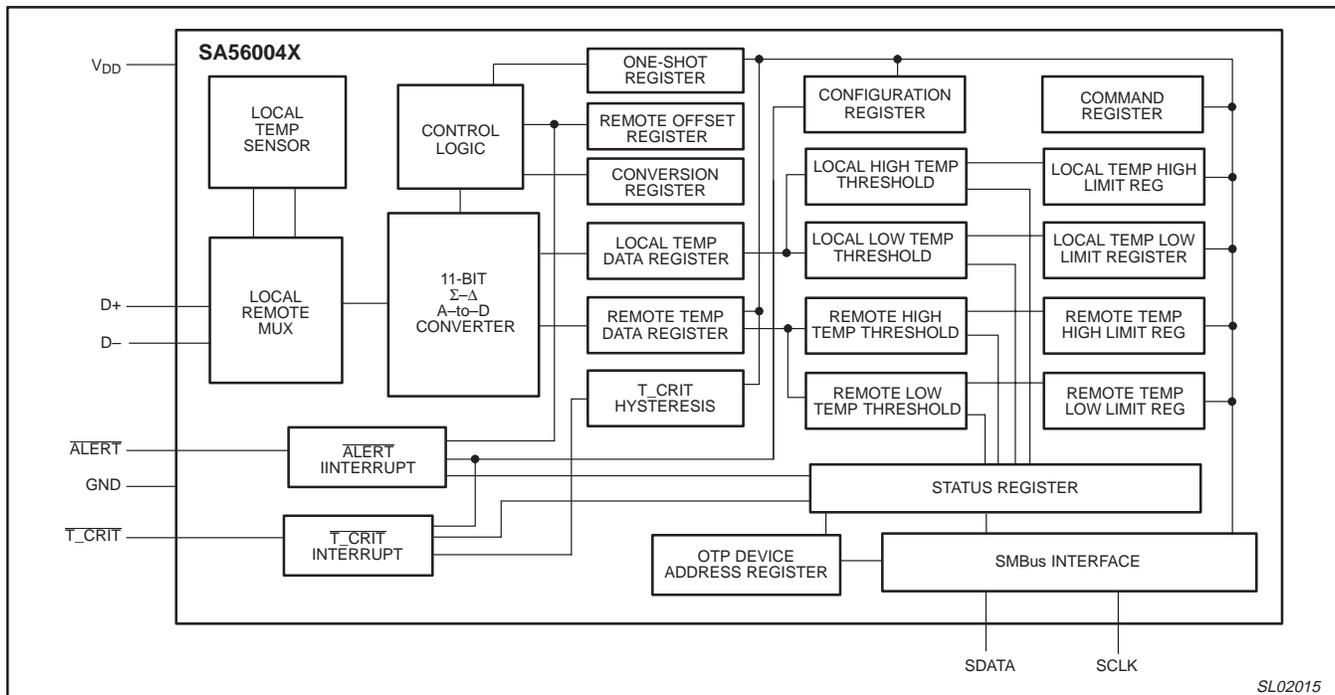SA56004X

TECHNICAL DESCRIPTION

General discussion

Figure 4. Functional diagram.

FUNCTIONAL DESCRIPTION

Serial bus interface

The SA56004X should be connected to a compatible two-wire serial interface System Management Bus (SMBus) as a slave device using the two device terminals SCLK and SDATA. The $\overline{ALERT}$ pin can optionally be used with the SMBus protocol to implement the ARA response. The controller will provide a clock signal to the device SCLK pin and write/read data to/from the device through the device SDATA pin. External pull-up resistors, about 10 kΩ each, are needed for these device pins due to open drain circuitry.

Data of 8-bit digital byte or word are used for communication between the controller and the device using SMBus 2.0 protocols which are described more in the 'SMBus Interface' section on page 14. The operation of the device to the bus is described with details in the following sections.

Slave address

The SA56004X has a 7-bit slave address register which is factory programmed in OTP memory. Eight unique devices are available with different slave addresses as defined in the 'Ordering information' section in Table 1, 'Device slave address options'. Up to eight devices can reside on the same SMBus without conflict, provided that their addresses are unique.

Register overview

The SA56004X contains three types of SMBus addressable registers. These are read only (R), write only (W), and read-write (R/W). Attempting to write to any R-only register or read data from any W-only register will produce an invalid result. Some of the R/W registers have separate addresses for reading and writing operations.

The registers of the SA56004X serve four purposes:
- Control and configuration of the SA56004X
- Status reporting
- Temperature measurement storage
- ID and manufacturer test registers.

Table 2 describes the names, addresses, power-on-reset (POR), and functions of each register. The data of the temperature-related registers is in 2's complement format in which the MSB is the sign bit. The 8-bit data of other registers is in 8-bit straight format.

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Table 2. Register assignments

REGISTER NAME	COMMAND BYTE		POR STATE	FUNCTION	BITS	ACCESSIBILITY
	READ ADDRESS	WRITE ADDRESS				
LTHB	00h	NA	0000 0000	Local Temperature HIGH Byte	8	R
RTHB	01h	NA	0000 0000	Remote Temperature HIGH Byte	8	R
SR	02h	NA	0000 0000	Status Register	8	R
CON	03h	09h	0000 0000	Configuration Register	8	R/W
CR	04h	0Ah	1000	Conversion Rate	4	R/W
LHS	05h	0Bh	0100 0110	Local HIGH Setpoint	8	R/W
LLS	06h	0Ch	0000 0000	Local LOW Setpoint	8	R/W
RHSHB	07h	0Dh	0100 0110	Remote HIGH Setpoint High Byte	8	R/W
RLSHB	08h	0Eh	0000 0000	Remote LOW Setpoint High Byte	8	R/W
One Shot	NA	0Fh		Writing register initiate a one shot conversion	0	W
RTLB	10h	NA	0000 00	Remote Temperature LOW Byte	6(MSBs)	R
RTOHB	11h	11h	0000 0000	Remote Temperature Offset High Byte	8	R/W
RTOLB	12h	12h	000	Remote Temperature Offset Low Byte	3(MSBs)	R/W
RHSLB	13h	13h	000	Remote HIGH Setpoint Low Byte	3(MSBs)	R/W
RLSLB	14h	14h	000	Remote LOW Setpoint Low Byte	3(MSBs)	R/W
RCS	19h	19h	0101 0101	Remote T_CRIT Setpoint	8	R/W
LCS	20h	20h	0101 0101	RLocal T_CRIT Setpoint	8	R/W
TH	21h	21h	0 1010	T_CRIT Hysteresis	5	R/W
LTLB	22h	NA	0000 0000	Local Temperature Low Byte	3(MSBs)	R
AM	BFh	BFh	0	Alert Mode	1	R/W
RMID	FEh	NA	1010 0001	Read Manufacturer's ID	8	R
RDR	FFh	NA	0000 0000	Read Stepping or Die Revision	8	R

Power-on-reset (POR)

When power is applied to the SA56004X, the device will enter into its power-on-reset state and its registers are reset to their default values. The configuration, status, and temperature-reading registers remain in these states until after the first conversion. As shown in Table 2, this results in:

1. Command register set to 00h.

2. Local Temperature register (LTHB and LTLB) set to 0 °C.

3. Remote Diode Temperature register (RTHB and RTLB) set to 0 °C until the end of the first conversion.

4. Status register (SR) set to 00h.

5. Configuration register (CON) set to 00h; Interrupt latches are cleared, the ALERT and T_CRIT output drivers are off and the ALERT and T_CRIT pins are pulled HIGH by the external pull-up resistors.

6. Local T_CRIT temperature setpoints (LCS) and Remote T_CRIT temperature setpoints (RCS) at 85 °C.

7. Local HIGH setpoint (LHS) and remote HIGH temperature setpoint (RHSHB) at 70 °C.

8. Local LOW setpoint (LLS) and Remote LOW temperature setpoints (RLSHB) at 0 °C.

9. Conversion Rate register (CR) is set to 8h; the default value of about 16 conversions/s.

Starting conversion

Upon POR, the RUN/STOP bit 6 of the configuration register is zero (default condition), then, the device will enter into its free-running operation mode in which the device A/D converter is enabled and the measurement function is activated. In this mode, the device cycles the measurements of the local and remote temperature automatically and periodically. The conversion rate is defined by the programmable conversion rate stored in the conversion rate register. It also performs comparison between readings and limits of the temperature in order to set the flags and interruption accordingly at the end of every conversion. Measured values are stored in the temp registers, results of the limit comparisons are reflected by the status of the flag bits in the status register and the interruption is reflected by the logical level of the ALERT and T_CRIT output. If the power-on temperature limit is not suitable, the temp limit values could be written into the limit registers during the busy-conversion duration of about 38 ms of the first conversion after power-up. Otherwise, the status register must be read and the configuration bit 7 must be reset in order to recover the device from interruption caused by the undesired temp limits.

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Low power software standby mode

The device can be placed in a software standby mode by setting the RUN/STOP bit 6 in the configuration register HIGH (to 1). In standby, the free-running oscillator is stopped, the supply current is less than 10 µA if there is no SMBus activity, all data in the registers is retained. However, the SMBus is still active and reading and writing registers can still be performed. A one-shot command will initiate a single conversion which has the same effect as any conversion that occurs when the device is in its free-running mode. To restore the device to free running mode, set the RUN/STOP bit 6 LOW (to 0).

Temperature data format

The temperature data can only be read from the Local and Remote Temperature registers; the setpoint registers (e.g. T_CRIT, LOW, HIGH) are read/write.

Both local and remote temperature reading data is represented by an 11-bit, 2's complement word with the LSB (Least Significant Bit) = 0.125 °C. The temperature setpoint data for the remote channel is also represented by an 11-bit, 2's complement word with the LSB = 0.125 °C. The temperature setpoint data for both the local channel and the T_CRIT setpoints are represented by 8-bit, 2's complement words with the LSB = 1.0 °C. For 11-bit temp data, the data format is a left justified, 16-bit word available in two 8-bit registers (high byte and low byte). For 8-bit temp data, the data is available in a single 8-bit register (high byte only).

Table 3. Temperature data format

TEMPERATURE	DIGITAL OUTPUT	
	BINARY	HEX
+125 °C	0111 1101 0000 0000	7D00h
+25 °C	0001 1001 0000 0000	1900h
+1 °C	0000 0001 0000 0000	0100h
+0.125 °C	0000 0000 0010 0000	0020h
0 °C	0000 0000 0000 0000	0000h
−0.125 °C	1111 1111 1110 0000	FFE0h
−1 °C	1111 1111 0000 0000	FF00h
−25 °C	1110 0111 0000 0000	E700h
−55 °C	1100 1001 0000 0000	C900h

SA56004 SMBus REGISTERS

Command Register

The command register selects which register will be read or written to. Data for this register should be transmitted during the Command Byte of the SMBus write communication.

Local and Remote Temperature registers (LTHB, LTLB, RTHB, RTLB)

Table 4. Local and Remote Temperature registers bit assignment

High Byte (Read only address 00h, 01h)

Bit	D7	D6	D5	D4	D3	D2	D1	D0
Value	Sign	64	32	16	8	4	2	1

Low Byte (Read only address 10h)

Bit	D7	D6	D5	D4	D3	D2	D1	D0
Value	0.5	0.25	0.125	0	0	0	0	0

Configuration register

The configuration register is an 8-bit register with read address 03h and write address 09h. Table 5 shows how the bits in this register are used.

Table 5. Configuration Register (CR) bit assignments

Bit	Name/Function	POR state
7 (MSB)	ALERT mask The ALERT interrupt is enabled when this bit is LOW. The ALERT interrupt is disabled (masked) when this bit is HIGH.	0
6	RUN/STOP Standby or run mode control: Running mode is enabled when this bit is LOW. The SA56004X is in standby mode when this bit is HIGH.	0
5	Not defined. Defaults to "0" (zero).	0
4	Remote T_CRIT mask The T_CRIT output will be activated by a remote temperature that exceeds the remote T_CRIT setpoint when this bit is LOW. The T_CRIT output will not be activated under this condition when this bit is HIGH.	0
3	Not defined. Defaults to "0" (zero).	0
2	Local T_CRIT mask The T_CRIT output will be activated by a local temperature that exceeds the local T_CRIT setpoint when this bit is LOW. The T_CRIT output will not be activated under this condition when this bit is HIGH.	0
1	Not defined. Defaults to "0" (zero).	0
0	Fault Queue A single remote temperature measurement outside the HIGH, LOW or T_CRIT setpoints will trigger an outside limit condition resulting in setting the status bits and associated output pins when this bit is LOW. Three consecutive measurements outside of one of these setpoints are required to trigger an outside of limit condition when this bit is HIGH.	0

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Status register

The contents of the status register reflects condition status resulting from all activities: comparison between temperature measurements and temperature limits, the status of A/D conversion, and the hardware condition of external diode to the device. Bit assignments are listed in Table 6. This register is read only and its address is 02h. Upon POR, all bits are set to zero.

Note: any one of the fault conditions, with the exceptions of Diode OPEN and A/D BUSY, introduces an Alert interrupt (see Alert interrupt section on page 11). Also, whenever a one-shot command is executed, the status byte should be read after the conversion is completed, which is about 38 ms (1 conversion time period) after the one-shot command is sent.

Table 6. Status Register (SR) bit assignment
Read only address 02h

Bit	Name/Function	POR state
7	BUSY When '1' A/D is busy converting.	n/a
6	LHIGH When '1' indicates Local HIGH temperature alarm.	0
5	LLOW When '1' indicates a Local LOW temperature alarm.	0
4	RHIGH When '1' indicates a Remote Diode HIGH temperature alarm.	0
3	RLOW When '1' indicates a Remote Diode LOW temperature alarm.	0
2	OPEN When '1' indicates a Remote Diode disconnect.	0
1	RCRIT When '1' indicates a Remote Diode Critical Temperature alarm.	0
0	LCRIT When '1' indicates a Local Critical Temperature alarm.	0

Conversion rate register

The conversion rate register is used to store programmable conversion data, which defines the time interval between conversions in the standard free-running auto convert mode. Table 7 shows all applicable data values and rates for the SA56004X. Only the 4 LSBs of the register are used and the other bits are reserved for future use. The register is R/W using the read address 04h and write address 0Ah. The POR default conversion data is 08h.

Table 7. Conversion rate control byte (CR)

Data value	Conversion rate (Hz)
00h	0.06
01h	0.12
02h	0.25
03h	0.50
04h	1.0
05h	2
06h	4
07h	8
08h	16
09h	32
0Ah to FFh	n/a

Temperature limit registers

Table 8. Local and Remote HIGH Setpoint registers (LHS, RHSHB, and RHSLB)
High Byte (Read only address 05h, 07h / Write address 0Bh, 0Dh)

Bit	D7	D6	D5	D4	D3	D2	D1	D0
Value	Sign	64	32	16	8	4	2	1

POR default = LHS = RHSHV = 46h (70 °C).

Low Byte (Read/Write address 13h)

Bit	D7	D6	D5	D4	D3	D2	D1	D0
Value	0.5	0.25	0.125	0	0	0	0	0

POR default RHSLB = 00h.

Table 9. Local and Remote LOW Setpoint registers (LLS, RLSHB, and RLSLB)
High Byte (Read address 06h, 08h / Write address 0Ch, 0Eh)

Bit	D7	D6	D5	D4	D3	D2	D1	D0
Value	Sign	64	32	16	8	4	2	1

POR default LLS = RLSHB = 00h.

Low Byte (Read/Write address 14h)

Bit	D7	D6	D5	D4	D3	D2	D1	D0
Value	0.5	0.25	0.125	0	0	0	0	0

POR default RLSLB = 00h (0 °C).

Table 10. Local and Remote T_CRIT registers (LCS and RCS)
Single High Byte (Read/Write address 20h, 19h)

Bit	D7	D6	D5	D4	D3	D2	D1	D0
Value	Sign	64	32	16	8	4	2	1

POR default LCS = RCS = 55h (85 °C).

Table 11. T_CRIT Hysteresis register (TH)
Single High Byte (Read and Write address 21h)

Bit	D7	D6	D5	D4	D3	D2	D1	D0
Value	–	–	–	16	8	4	2	1

POR default TH = 0Ah (10 °C).

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Customer programmable offset register (remote only)

Table 12. Remote Temperature Offset registers (RTOHB and RTOLB)

High Byte (Read/Write address 11h)

Bit	D7	D6	D5	D4	D3	D2	D1	D0
Value	Sign	64	32	16	8	4	2	1

POR default RTOHB = RTOLB = 00h.

Low Byte (Read/Write address 12h)

Bit	D7	D6	D5	D4	D3	D2	D1	D0
Value	0.5	0.25	0.125	0	0	0	0	0

POR default RTOLB = 00h.

ALERT mode register

Table 13. ALERT mode register (AM)

(Read and Write address BFh)

Bit	D7	D6	D5	D4	D3	D2	D1	D0
Value	0	0	0	0	0	0	0	$\overline{ALERT}$ mode

D7-D1: is not defined and defaults to '0'.
D0: The $\overline{ALERT}$ output is in Interrupt mode when this bit is LOW.
The $\overline{ALERT}$ output is in comparator mode when this bit is HIGH.

Other registers

The **Manufacturers ID** register has a default value A1h (1010 0001) and a read address FEh.

The **Die Revision Code** register has a default value 00h (0000 0000) and read address FFh. This register will increment by 1 every time there is a revision to the die.

One-shot register

The one-shot register is used to initiate a single conversion and comparison cycle when the device is in the standby mode; upon completion of the single conversion cycle the device returns to the standby mode. It is not a data register; it is the write operation that causes the one-shot conversion. The data written to this register is not stored; a FF value will always be read from this register. To initiate an one-shot operation, send a standard write command with the command byte of 0Fh (One-Shot Write Address).

INTERRUPTION LOGIC FUNCTIONAL DESCRIPTION

$\overline{ALERT}$ output

The $\overline{ALERT}$ output is used to signal Alert interruptions from the device to the SMBus or other system interrupt handler and it is active LOW. Because this is an open drain output, a pull-up resistor (typically 10 kΩ) to V_{DD} is required. Several slave devices can share a common interrupt line on the same SMBus.

The $\overline{ALERT}$ function is very versatile and accommodates three separate operating modes: 1) a temperature comparator, 2) a system interrupt based on temperature, and 3) an SMBus Alert Response Address (ARA) response. The ARA and interrupt modes are different only in how the user interacts with the SA56004X.

At the end of every temperature reading, digital comparators determine if the readings are above the HIGH or T_CRIT setpoint or below the LOW setpoint register values. If so, the corresponding bit

in the Status register is set. If the $\overline{ALERT}$ mask bit 7 of the Configuration register is not HIGH, then, any bit set in the Status register, other than the BUSY (D7) and OPEN (D2), will cause the $\overline{ALERT}$ output pin to be active-LOW. An alert will be triggered after any conversion cycle that finds the temperature is out of the limits defined by the setpoint registers. In order to trigger an ALERT in all alert modes, the $\overline{ALERT}$ mask bit 7 of the Configuration register must be cleared (not HIGH).

$\overline{ALERT}$ output in Comparator Mode

When operating the SA56004X in a system that utilizes a SMBus controller not having an interrupt, the $\overline{ALERT}$ output may be operated as a temperature comparator. In this mode, when the condition that triggered the ALERT to be asserted is no longer present, the $\overline{ALERT}$ output is released as it goes HIGH. In order to use the $\overline{ALERT}$ output as a temperature comparator, bit D0, the ALERT configure bit, in the ALERT Mode (AM) register must be set HIGH. This is not the POR default.

$\overline{ALERT}$ output in Interrupt Mode

In the interrupt mode, the ALERT output is used to provide an interrupt signal that remains asserted until the interrupt service routine has elapsed. In the interrupt operating mode, a read of the Status register will set the $\overline{ALERT}$ mask bit 7 of the Configuration register if any of the temperature alarm bits of the status register is set with exception of BUSY (D7) and OPEN (D2). This protocol prevents further $\overline{ALERT}$ output triggering until the master device has reset the $\overline{ALERT}$ mask bit at the end of the interrupt service routine. The Status register bits are cleared only upon a read of the status register by the serial bus master (See Figure 5). In order for the $\overline{ALERT}$ output to be used as an interrupt, the ALERT Configure bit D0 of the ALERT Mode (AM) register must be set LOW. Note, this is the POR default.
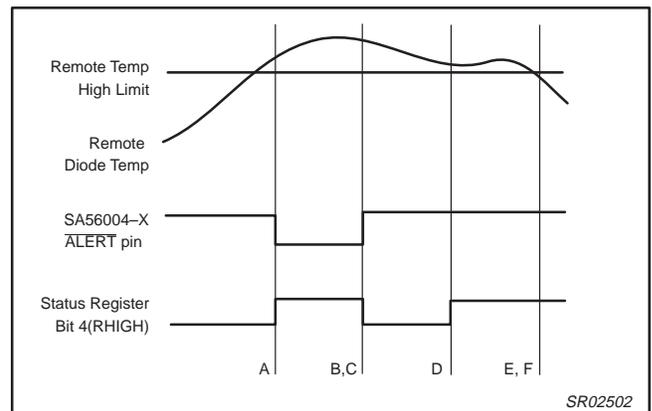
Figure 5. $\overline{ALERT}$ output in Interrupt Mode

The following events summarizes the $\overline{ALERT}$ output interrupt mode of operation:

Event A: Master senses $\overline{ALERT}$ output being active-LOW.

Event B: Master reads the SA56004X Status register to determine what cause the $\overline{ALERT}$ interrupt.

Event C: SA56004X clears the Status register, resets the $\overline{ALERT}$ output HIGH, and sets the $\overline{ALERT}$ mask bit 7 in the Configuration register.

Event D: A new conversion result indicates the temperature is still above the high limit, however the $\overline{ALERT}$ pin is not activated due to the ALERT mask.

Event E: Master should correct the conditions that caused the $\overline{\text{ALERT}}$ output to be triggered. For instance, the fan is started, setpoint levels are adjusted.

Event F: Master resets the $\overline{\text{ALERT}}$ mask bit 7 in the Configuration register.

$\overline{\text{ALERT}}$ output in SMBus alert mode
When several slave devices share a common interrupt line, an SMBus alert line is implemented. The SA56004X is designed to accommodate the Alert interrupt detection capability of the SMBus 2.0 Alert Response Address (ARA) protocol, defined in *SMBus specification 2.0*. This procedure is designed to assist the master in resolving which slave device generated the interrupt and in servicing the interrupt while minimizing the time to restore the system to its proper operation. Basically, the SMBus provides Alert response interrupt pointers in order to identify slave devices which have caused the Alert interrupt. When the ARA command is received by all devices on the SMBus, the devices pulling the SMBus alert line LOW send their device addresses to the master; await an acknowledgement and then release the alert line. This requirement to disengage the SMBus alert line prevents locking up the alert line. The SA56004X complies with this ARA disengagement protocol by setting the $\overline{\text{ALERT}}$ mask bit 7 in the Configuration register at address 09h after successfully sending out its address in response to an ARA command and releasing the $\overline{\text{ALERT}}$ output. Once the mask bit is activated, the $\overline{\text{ALERT}}$ output will be disabled until enabled by software. In order to enable the $\overline{\text{ALERT}}$ the master must read the Status register, at address 02h, during the interrupt service routine and then reset the $\overline{\text{ALERT}}$ mask bit 7 in the Configuration register to '0' at the end of the interrupt service routine (See Figure 6).

In order for the SA56004X to respond to the ARA command, the bit D0 in the $\overline{\text{ALERT}}$ mode register must be set LOW.

ALERT mask bit 7 and the $\overline{\text{ALERT}}$ mode bit D0 are both LOW for the POR default.

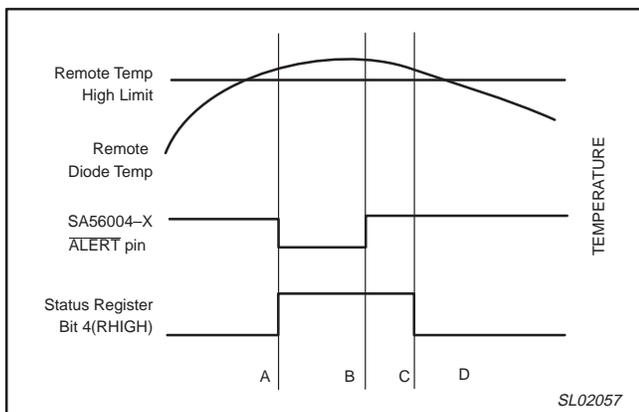The following events summarize the $\overline{\text{ALERT}}$ output interrupt operation in the SMBus alert mode:

Event A: Master senses the $\overline{\text{ALERT}}$ line being LOW.

Event A to B: Master sends a read command using the common 7-bit Alert Response Address (ARA) of 0001 100.

Event A to B: Alerting device(s) return ACK signal and their addresses using the I²C Arbitration (the device with the lowest address value sends its address first. The master can repeat the alert reading process and work up through all the interrupts).

Event B: Upon the successful completion of returning address, the SA56004X resets its $\overline{\text{ALERT}}$ output (to OFF) and sets the Alert Mask bit 7 in its configuration register.

Event C: Master should read the device status register to identify and correct the conditions that caused the Alert interruption. The status register is reset.

Event D: Master resets the Alert Mask bit 7 in the configuration register to enable the device Alert output interruption.

Note: The bit assignment of the returned data from the ARA reading is listed in Table 14. If none of the device on the bus is alerted then the returned data from ARA reading will be FFh (1111 1111).

Table 14. $\overline{\text{ALERT}}$ response bit assignment

Alert response bit	Device address bit	Function
7 (MSB)	ADD6	Address bit 6 (MSB) of alerted device
6	ADD5	Address bit 5 of alerted device
5	ADD4	Address bit 4 of alerted device
4	ADD3	Address bit 3 of alerted device
3	ADD2	Address bit 2 of alerted device
2	ADD1	Address bit 1 of alerted device
1	ADD0	Address bit 0 of alerted device
0	1	Always '1'

Figure 6. $\overline{\text{ALERT}}$ pin in SMBus Alert mode

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T_CRIT output

The T_CRIT output is LOW when any temperature reading is greater than the preset limit in the corresponding critical temperature setpoint register. When one of the T_CRIT setpoint temperatures is exceeded, the appropriate status register bit, 1 (RCRIT) or 0 (LCRIT), is set.

After every local and remote temperature conversion the Status register flags and the T_CRIT output are updated. Figure 7 is a timing diagram showing the relationship of T_CRIT output, Status bit 1 (RCRIT) and the remote critical temperature setpoint (RCS), and critical temperature hysteresis (TH) with remote temperature changes. Note that the T_CRIT output is de-activated only after the remote temperature is below the remote temperature setpoint, RCS minus the Hysteresis, TH. In the interrupt mode only, the Status register flags are reset after the Status register is read.
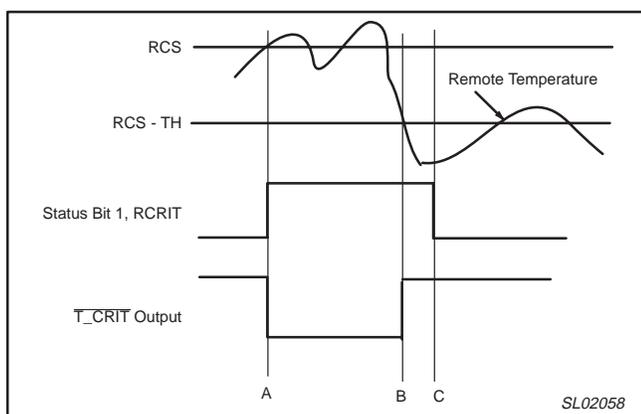


Figure 7. T_CRIT temperature response timing diagram

Event A: T_CRIT goes LOW and Status bit 1, RCRIT is set HIGH when Remote Temperature exceeds RCS, Remote T_CRIT Setpoint.

Event B: Remote Temperature goes below RCS-TH. T_CRIT is deactivated, but Status Register remains unchanged.

Event C: The Status Register Bit 1, RCRIT is reset by a read of the Status Register (in the interrupt mode).

Fault Queue

To suppress erroneous ALERT or T_CRIT triggering, the SA56004X implements a Fault Queue for both local and remote channel. The Fault Queue insures a temperature measurement is genuinely beyond a HIGH, LOW or T_CRIT setpoint by not triggering until three consecutive out-of-limit measurements have been made. The fault queue defaults off upon POR and may be activated by setting bit 0 in the Configuration register (address 09h) to '1'.
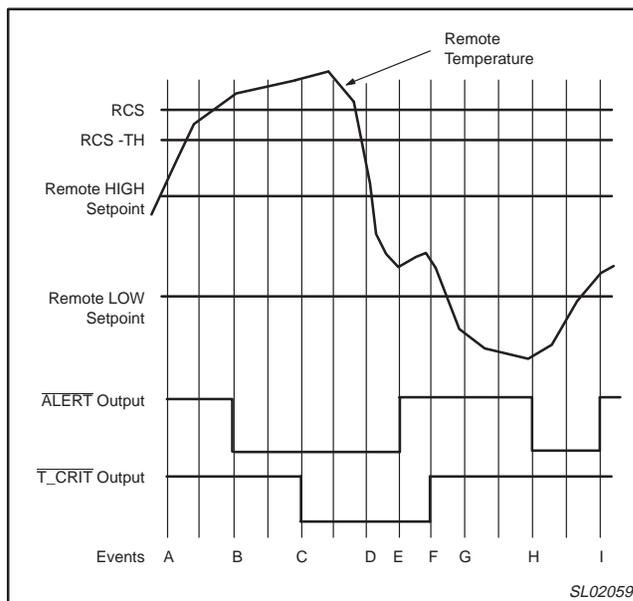
NOTE: All events indicate the compeltion of a conversion.

Figure 8. Fault Queue Remote High and Low and T_CRIT, T_CRIT Hysteresis setpoint response (Comparator mode)

At Event A: The remote temperature has exceeded the Remote HIGH setpoint.

At Event B: Three consecutive over limit measurements have been made exceeding the Remote HIGH setpoint; the ALERT output is activated (goes LOW).

By now, the remote temp has exceeded the Remote T_CRIT setpoint (RCS).

At Event C: Three consecutive over limit measurements have been made exceeding RCS; the T_CRIT output is activated (goes LOW).

At Event D: The remote temperature falls below the RCS–TH setpoint.

At Event E: The ALERT output is de-activated (goes HIGH) after a below_high_limit temperature measurement is completed.

At Event F: Three consecutive measurements have been made with the remote temperature below the RCS–TH threshold; the T_CRIT output is de-activated (goes HIGH).

At Event G: The remote temp falls below the Remote LOW setpoint.

At Event H: Three consecutive measurements are made with the temp below the Remote LOW setpoint; ALERT output is activated (goes LOW).

At Event I: The ALERT output is de-activated (goes HIGH) after a above_low_limit temperature measurement is completed.

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Diode fault detection

The SA56004X is designed with circuitry to detect the fault conditions of the remote diode. When the D+ pin is shorted to V_{DD} or floating, the Remote Temperature High Byte (RTHB) register is loaded with +127 °C, the Remote Temperature Low Byte (RTLB) register is loaded with 0 °C, and the OPEN bit (bit 2 of the Status register) is set. Under the above conditions of D+ shorted to V_{DD} or floating, if the Remote $\overline{T\_CRIT}$ setpoint is set less than +127 °C, and T_CRIT Mask are disabled, then, the $\overline{T\_CRIT}$ output pins will be pulled LOW. Furthermore, if the Remote HIGH Setpoint High Byte (RHSHB) register is set to a value less than +127 °C and the Alert Mask is disabled, then the $\overline{ALERT}$ output will be pulled LOW. Note: the OPEN bit itself will not trigger an ALERT.

When the D+ pin is shorted to ground or to D–, the Remote Temperature High Byte (RTHB) register is loaded with –128 °C (1000 0000) and the OPEN (bit 2 in the Status register) will not be set. Since operating the SA56004X is beyond its normal limits, this temperature reading represents this shorted fault condition. If the value in the Remote Low Setpoint High Byte (RLSHB) register is more than –128 °C and the Alert Mask is disabled, the $\overline{ALERT}$ output will be pulled LOW.

SMBus INTERFACE

The device can communicate over a standard two-wire serial interface System Management Bus (SMBus) or compatible I²C-bus using SCLK and SDATA. The device employs four standard SMBus protocols: Write Byte, Read Byte, Receive Byte, and Send Byte. Data formats of four protocols are shown in Figure 9. The following key points of protocol are important:

1. The SMBus master initiates data transfer by establishing a START condition (S) and terminates data transfer by generating a STOP condition (P).

2. Data is sent over the serial bus in sequences of 9 clock pulses according to each 8-bit data byte followed by 1-bit status of device acknowledgement (A).

3. The 7-bit slave address is equivalent to factory-programmed address of the device.

4. The command byte is equivalent to the address of the selected device register.

5. The receive byte format is used for quicker transfer data from a device reading register which was previously selected.

Serial interface reset

If the SMBus master attempts to reset the SA56004X while the SA56004X is controlling the data line and transmitting on the data line, the SA56004X must be returned to a known state in the communication protocol. This may be accomplished in two ways:

1. When the SDATA is LOW, the SA56004X SMBus state machine resets to the SMBus idle state if SCLK is held LOW for more than 35 ms (maximum TIMEOUT period). According to *SMBus specification 2.0*, all devices are required to time-out when the SCLK line is held LOW for 25 to 35 ms. Therefore, to insure a time-out of all devices on the bus, the SCLK line must be held LOW for at least 35 ms.

2. When the SDATA is HIGH, the master initiates an SMBus start. The SA56004X will respond properly to a SMBus start condition only during the data retrieving cycle. After the start, the SA56004X will expect a SMBus Address byte.

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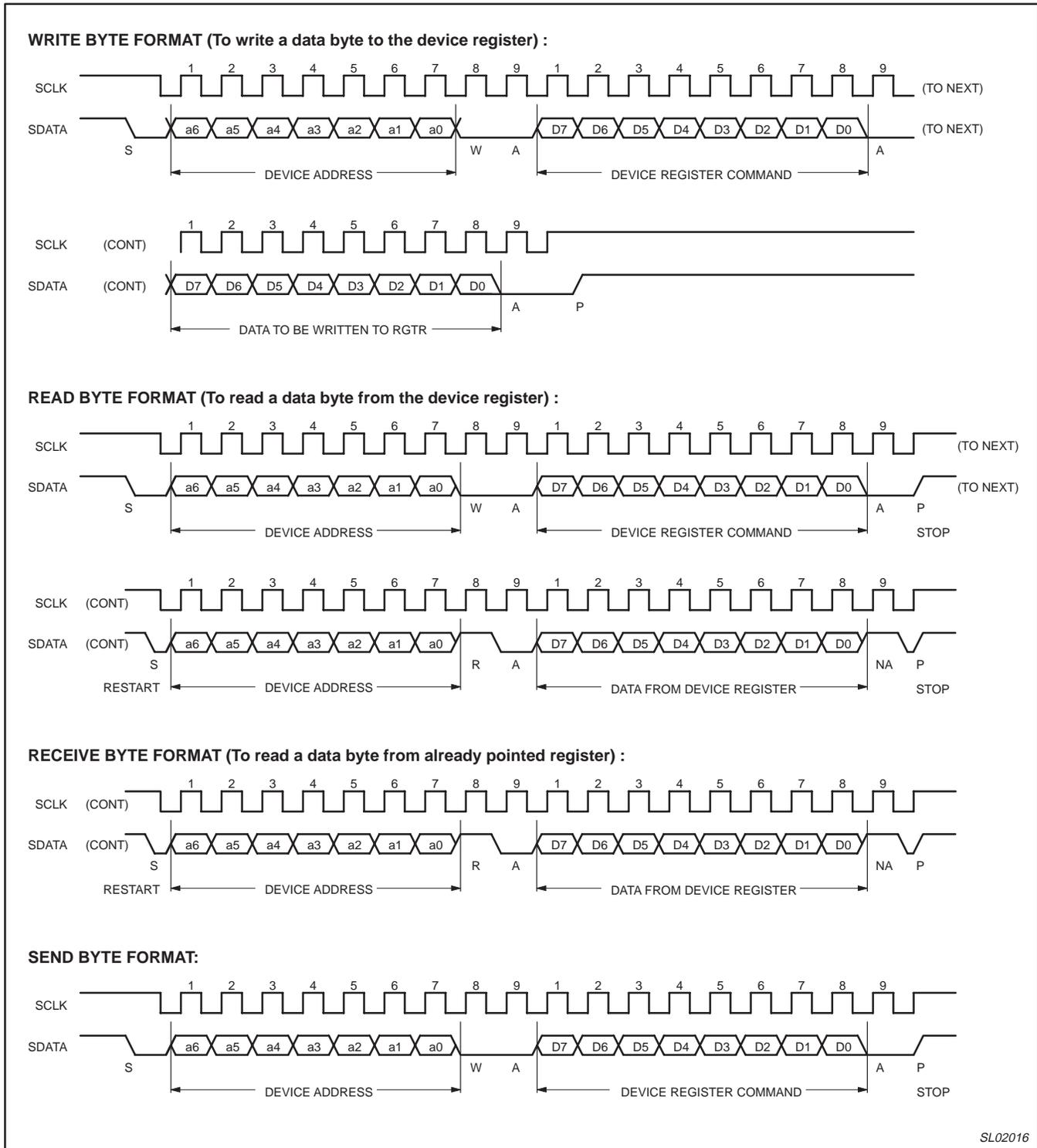**WRITE BYTE FORMAT (To write a data byte to the device register) :**

READ BYTE FORMAT (To read a data byte from the device register) :

RECEIVE BYTE FORMAT (To read a data byte from already pointed register) :

SEND BYTE FORMAT:

SL02016

Figure 9. SMBus interface protocols.

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Printed Circuit Board layout considerations

Care must be taken in PCB layout to minimize noise induced at the remote temperature sensor inputs, especially in extremely noisy environments, such as a computer motherboard. Noise induced in the traces running between the device sensor inputs and the remote diode can cause temperature conversion errors. Typical sensor signal levels to the SA56004X is a few microvolts. The following guidelines are recommended:

1. Place the SA56004X as close as possible to the remote sensor. It can be from 4 to 8 inches, as long as the worst noise sources such as clock generator, data and address buses, CRTs are avoided.

2. Route the D+ and D– lines parallel and close together with ground guards enclosing them (see 'Ideal diode trace layout', Figure 10).

3. Leakage currents due to PC board contamination must be considered. Error can be introduced by these leakage currents.

4. Use wide traces to reduce inductance and noise pickup. Narrow traces more readily pickup noise. The minimum width of 10 mil and space of 10 mil are recommended.

5. Place a bypass capacitor of 10 nF close to the V_{DD} pin and an input filter capacitor of 2200 pF close to the D+ and D– pins.

6. A shielded twisted pair is recommended for a long distance remote sensor. Connect the shield of the cable at the device side to the SA56004X GND pin and leave the shield at the remote end unconnected to avoid ground loop currents. Also notice that the series resistance of the cable may introduce measurement error; 1 Ω can introduce about 0.5 °C.
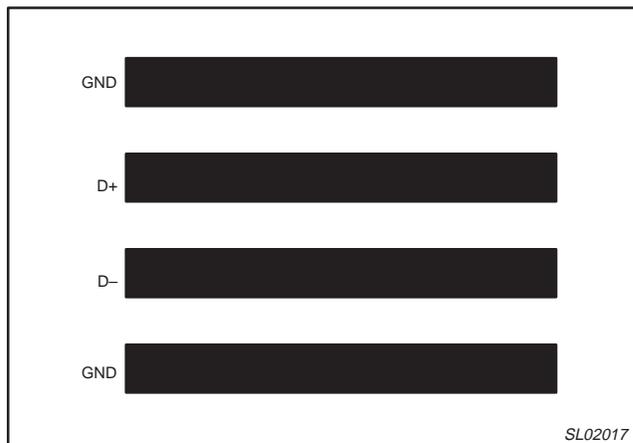

Figure 10. Ideal diode trace layout.

PACKING METHOD

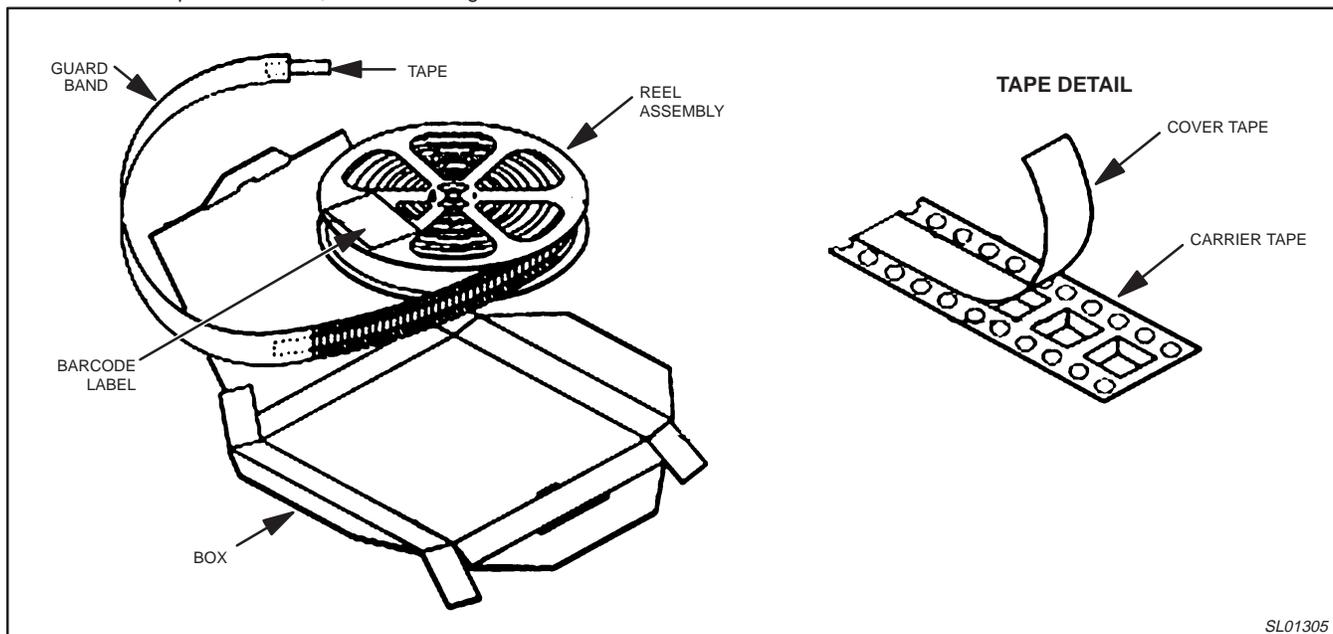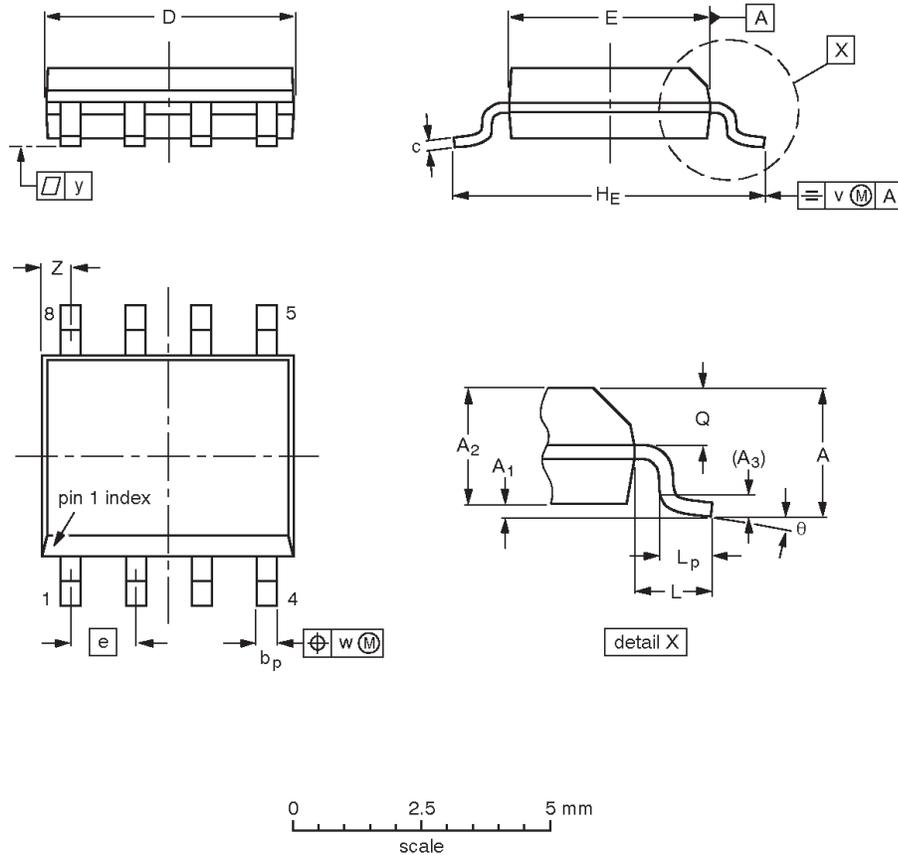The SA56004X is packed in reels, as shown in Figure 11.

Figure 11. Tape and reel packing method

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SO8: plastic small outline package; 8 leads; body width 3.9 mm

SOT96-1

scale: 0   2.5   5 mm

DIMENSIONS (inch dimensions are derived from the original mm dimensions)

UNIT	A max.	A₁	A₂	A₃	bₚ	c	D[1]	E[2]	e	H_E	L	Lₚ	Q	v	w	y	Z[1]	θ
mm	1.75	0.25 0.10	1.45 1.25	0.25	0.49 0.36	0.25 0.19	5.0 4.8	4.0 3.8	1.27	6.2 5.8	1.05	1.0 0.4	0.7 0.6	0.25	0.25	0.1	0.7 0.3	8° 0°
inches	0.069	0.010 0.004	0.057 0.049	0.01	0.019 0.014	0.0100 0.0075	0.20 0.19	0.16 0.15	0.050	0.244 0.228	0.041	0.039 0.016	0.028 0.024	0.01	0.01	0.004	0.028 0.012	

Notes

1. Plastic or metal protrusions of 0.15 mm maximum per side are not included.

2. Plastic or metal protrusions of 0.25 mm maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	EIAJ			
SOT96-1	076E03	MS-012				~~97-05-22~~ 99-12-27

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SA56004X

TSSOP8: plastic thin shrink small outline package; 8 leads; body width 3 mm

SOT505-1

scale 0 ... 2.5 ... 5 mm
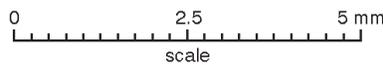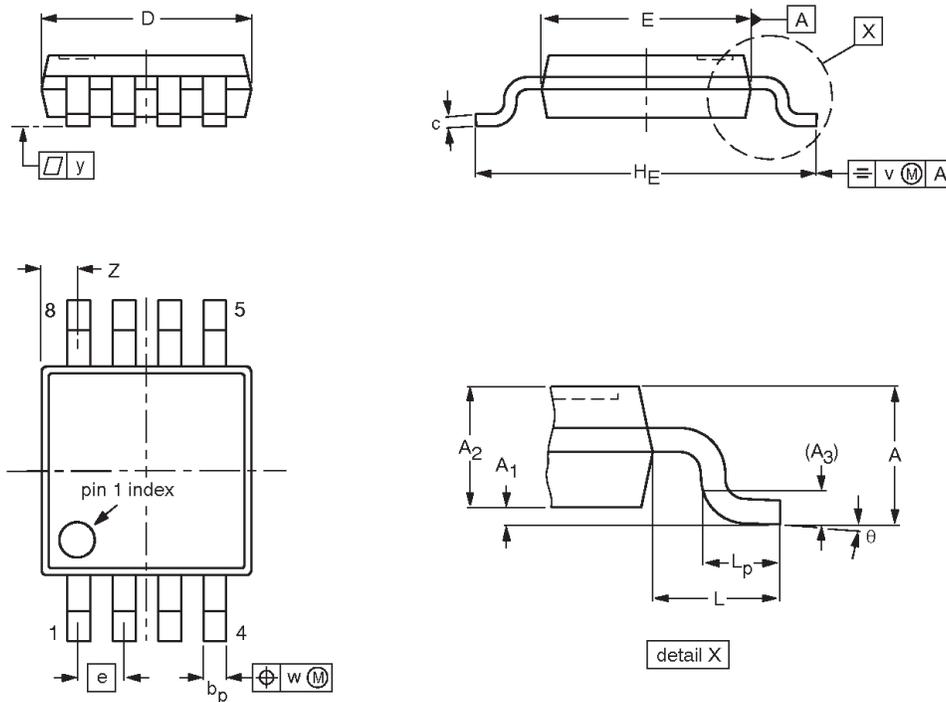
DIMENSIONS (mm are the original dimensions)

UNIT	A max.	A₁	A₂	A₃	bₚ	c	D(1)	E(2)	e	HE	L	Lₚ	v	w	y	Z(1)	θ
mm	1.10	0.15 0.05	0.95 0.80	0.25	0.45 0.25	0.28 0.15	3.10 2.90	3.10 2.90	0.65	5.10 4.70	0.94	0.70 0.40	0.1	0.1	0.1	0.70 0.35	6° 0°

Notes

1. Plastic or metal protrusions of 0.15 mm maximum per side are not included.
2. Plastic or metal protrusions of 0.25 mm maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	EIAJ			
SOT505-1						99-04-09

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REVISION HISTORY

Rev	Date	Description
_2	20030903	**Objective data (9397 750 12015). Replaces SA56004-X_1 dated 2003 Aug 19 (9397 750 10993).** Modifications: ● Part number shown on document changed from SA56004-X to SA56004X (ordering codes remain as-is). ● Added I^{2}C-bus logos.
_1	20030819	**Objective data (9397 750 10993).**

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Level	Data sheet status [1]	Product status [2] [3]	Definitions
I	Objective data	Development	This data sheet contains data from the objective specification for product development. Philips Semiconductors reserves the right to change the specification in any manner without notice.
II	Preliminary data	Qualification	This data sheet contains data from the preliminary specification. Supplementary data will be published at a later date. Philips Semiconductors reserves the right to change the specification without notice, in order to improve the design and supply the best possible product.
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[2] The product status of the device(s) described in this data sheet may have changed since this data sheet was published. The latest information is available on the Internet at URL http://www.semiconductors.philips.com.

[3] For data sheets describing multiple type numbers, the highest-level product status determines the data sheet status.

Definitions

Short-form specification — The data in a short-form specification is extracted from a full data sheet with the same type number and title. For detailed information see the relevant data sheet or data handbook.

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Date of release: 09-03

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