I²C-Bus Temperature Sensors

Small, accurate, low-cost sensors for advanced temperature regulation
NXP temperature sensors use the familiar I²C-bus/SMBus format* to deliver highly accurate temperature monitoring with low power consumption in a wide variety of applications. Each device is pin-for-pin compatible with industry-standard sensors and combines a high level of precision with programmable features that help increase design flexibility.

LOCAL-ONLY TEMPERATURE SENSORS
Our local-only temperature sensors produce highly accurate digital readings of the ambient temperature and can be used to trigger interrupt, shut-down, or overtemperature alarms. They are suited for use in industrial process control, notebook computers, servers, and office electronics.

- The LM75B is a local temperature sensor and thermal watchdog with an accuracy of ±2 °C
- The PCT2075, a more accurate version of the LM75B, delivers superior performance in temperature-sensitive applications
- The SE98A, designed for applications that use DDR3 RDIMM memory, complies with JEDEC JC42.4, supports SMBus Timeout and Alert, and has security lock bits
- The SE97B brings the SE98A and a 2 Kbit EEPROM serial presence detect (SPD) together in a single device

REMOTE AND LOCAL TEMPERATURE SENSORS
Our combination remote/local sensors can monitor the temperature of the thermal diode inside the CPU or the diode connected to PNP or NPN transistors, and can trigger an interrupt or alert output.

- The SA56004 sensor, designed for handheld and portable applications, includes an offset register for system calibration, dual outputs for fan control and an interrupt, built-in diode fault detection, and one-shot conversion with power optimization in shutdown mode. It is available in a small, 8-pin package with three possible pre-configured slave device addresses.

APPLICATIONS
- System thermal management
- Office electronics
- Personal computer
- Microprocessor
- Communications equipment
- Power supply
- Industrial process control
- Laptop
- Servers
- DDR3 RDIMM (SE97B and SE98A only)

*For more on the I²C-bus and SMBus, see Overview on page 9.

NXP I²C-BUS/SMBUS TEMPERATURE SENSORS

<table>
<thead>
<tr>
<th>Feature</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wide supply range (1.7 to 5.5 V)</td>
<td>Suitable for 3.3- or 5-V systems</td>
</tr>
<tr>
<td>Wide temperature operating range (-55 to 125 °C)</td>
<td>Suitable for all system thermal management</td>
</tr>
<tr>
<td>Low operating and standby power</td>
<td>Suitable for all applications, including battery management</td>
</tr>
<tr>
<td>Programmable temperature set points</td>
<td>Temperature thresholds are easy to change</td>
</tr>
<tr>
<td>Standby mode and one-shot conversion</td>
<td>Suitable for power-sensitive applications like laptops and handhelds</td>
</tr>
<tr>
<td>Programmable fault queue</td>
<td>Prevents noise-triggered temperature trips</td>
</tr>
</tbody>
</table>

FAMILY OVERVIEW

<table>
<thead>
<tr>
<th>Local Channels</th>
<th>Remote Channels</th>
<th>Remote Channels*</th>
<th>FAN Control (Output)*</th>
<th>Temp Range</th>
<th>Frequency</th>
<th>Accuracy (Local Sensing - typ)</th>
<th>Accuracy (Remote Sensing - typ)</th>
<th>A/D Resolution (°C/# Bits)</th>
<th>Supply Range (V)</th>
<th>Supply Current (μA - typ)</th>
<th>Package(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>-55 to +125 °C</td>
<td>400 kHz</td>
<td>±1 °C</td>
<td>0.125/11</td>
<td>2.8-5.5</td>
<td>100</td>
<td>0.2</td>
<td>SO8, MSOP8, XSON8(U) and HWSON8</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>-55 to +125 °C</td>
<td>1000 kHz</td>
<td>±1 °C</td>
<td>0.125/11</td>
<td>2.7-5.5</td>
<td>125</td>
<td>&lt;0.1</td>
<td>SO8, TSSOP8, HWSON8 and TSOP6</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>-40 to +125 °C</td>
<td>400 kHz</td>
<td>±1 °C</td>
<td>0.125/11</td>
<td>3.0-3.6</td>
<td>500</td>
<td>10</td>
<td>SO8, MSOP8 and HVSON8</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>-40 to +125 °C</td>
<td>400 kHz</td>
<td>±0.5 °C</td>
<td>0.125/11</td>
<td>3.0-3.6</td>
<td>210</td>
<td>0.1</td>
<td>HWSON8</td>
</tr>
</tbody>
</table>

* Open-drain output
LOCAL TEMPERATURE SENSOR AND THERMAL WATCHDOG PCT2075 WITH ACCURACY OF ±1 °C

Features:
- On-chip thermal diode
- Bus: two-wire I2C-bus (1MHz Fast Mode Plus)
- Accuracy (max): ±1 °C (from -25 to 100 °C)
- Resolution: 11-bit (0.125 °C)
- Open-drain interrupt or comparator/thermostat output
- Shutdown mode and one-shot conversion capability
- Programmable temperature conversion rate (0.125 to 30 Hz)
- Shutdown/operating current (max): <0.1/400 µA
- Power-supply range: 2.7 to 5.5 V
- Temperature range: -55 to 125 °C
- Package: TSSOP(MSOP)8, SO8, XSON8U and HWSON8
- Drop-in replacement for: National LM75, Microchip TCN75, Maxim DS75, TI TMP75, Analog Devices AD7416

LOCAL TEMPERATURE SENSOR AND THERMAL WATCHDOG LM75B WITH ACCURACY OF ±2 °C

Same as PCT2075, with the following differences:
- Accuracy (max): ±2 °C (from -25 to 100 °C)
- Shutdown/operating current (max): 1.0/300 µA
- Bus: two-wire I2C-bus (400 kHz Fast Mode)

FEATURES ADVANTAGES
- Higher accuracy improves thermal guard-banding
- One-shot conversion helps improve performance in power-sensitive applications
- Programmable conversion helps enable more flexible system applications
- Programmable fault queue prevents false temperature trips

PCT2075/LM75B APPLICATION DIAGRAM
LOCAL-Temperature Sensors, Cont.

LOCAL TEMPERATURE SENSOR SE98A FOR DDR3 RDIMM WITH ACCURACY OF ±1 °C

Features:
- Complies with JEDEC JC42.4
- Bus: two-wire SMBus or \( ^{2} \)C-bus (standard/fast-mode compatible)
- Accuracy (max): ±1 °C (from 75 to 90 °C)
- Resolution: 11-bit (0.125 °C)
- Minimum conversion rate: 8 Hz
- Programmable hysteresis threshold: 0, 1.5, 3, or 6 °C
- EVENT output associated with three alarms: upper, lower, and critical
- Programmable SMBus alert response and timeout
- Security lock bit for data protection
- Maximum operating current: 100 µA
- \( ^{2} \)C address: 0011A2A1A0 (up to 8 devices on same bus)
- Operating-voltage range: 1.7 to 3.6 V
- Operating temperature: -40 to +125 °C
- Packages: HWSON8 package

Benefits:
- SMBus timeout prevents system bus hang-ups
- SMBus alert response enables system polling
- Over-, under-, and critical-temperature status and alarm output
- Security lock bit for data protection

SE97B/98A APPLICATION DIAGRAM

LOCAL TEMPERATURE SENSOR SE97B FOR DDR3 RDIMM WITH INTEGRATED SPD

Same as SE98, with the following differences:
- Adds integrated 2-Kbit EEPROM for Serial Presence Detect
- EEPROM \( ^{2} \)C-bus address 1010A2A1A0
- Operating-voltage range: 3.0 to 3.6V

SE98A AND SE97B THERMAL RESPONSE

Temperature Accuracy (Max)
REMOTE AND LOCAL TEMPERATURE SENSOR

REMOTE AND LOCAL TEMPERATURE SENSOR SA56004
WITH FAN CONTROL AND ACCURACY OF ±1 °C

Features:
- Bus: two-wire SMBus or I²C-bus (standard/fast-mode compatible)
- Accuracy (remote sensing) (Max): ±1 °C (from 60 to 100 °C)
- Accuracy: (local sensing) (Max): ±2 °C (from 60 to 100 °C)
- Resolution: 11-bit (0.125 °C)
- Shutdown/operating current (typ): 10/500 µA
- Shutdown mode and one-shot conversion for power savings
- Offset registers for system calibration
- ALERT/T_CRIT output for interrupt/fan control (on/off)
- Supports SMBus alert response and timeout
- Fault queue prevents noise-triggered temperature trips
- Supports diode-fault detection
- Three device addresses for server applications ("E" most commonly used - also A and C)
- Temperature range: -55 to 125 °C
- Power-supply range: 3.0 to 3.6 V
- Packages: TSSOP(MSOP)8, SO8 and HVSON8
- Drop-in replacement for National LM86, Maxim MAX6657/8, Analog Devices ADM1032

Benefits:
- SMBus timeout prevents system bus hang-ups
- SMBus alert response enables system polling
- Fault queue prevents false temperature trips
- Programmable conversion rate for system flexibility
<table>
<thead>
<tr>
<th>Part Number</th>
<th>Package</th>
<th>Order Information</th>
<th>PC/SMBus Speed (kHz)</th>
<th>Temperature Range (°C)</th>
<th>Power Supply Range (V)</th>
<th>Max AC Resolution (°C/# bits)</th>
<th>Accuracy (°C)</th>
<th>Max Supply Current (µA)</th>
<th>Max Operating Shutdown</th>
<th>Channels</th>
<th>Local Remote</th>
<th>Fan-Control Output (Open Drain)</th>
<th>Thermal-Alarm Output (Open Drain)</th>
<th>Local Remote and</th>
<th>Local</th>
<th>Remote</th>
<th>Channels</th>
<th>Channels</th>
</tr>
</thead>
<tbody>
<tr>
<td>LM75B</td>
<td>XSON8U, HWSON8, HVSON8</td>
<td>LM75B0G, LM75BT, SA5604X*</td>
<td>400</td>
<td>-25 to 100, -55 to 125</td>
<td>2.8 to 5.5</td>
<td>2</td>
<td>N/A</td>
<td>0.125/11</td>
<td>300</td>
<td>1.0</td>
<td>1</td>
<td>N/A</td>
<td>1 --</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCT2075</td>
<td>SO8, MSOP8, HWSON8, TSO86</td>
<td>PCT2075D, PCT2075DP, PCT2075TP, PCT2075GP</td>
<td>1000</td>
<td>-25 to 100 °C, -55 to 125 °C</td>
<td>2.7 - 5.5</td>
<td>1</td>
<td>N/A</td>
<td>0.125/11</td>
<td>400</td>
<td>20 (125 °C)</td>
<td>1</td>
<td>N/A</td>
<td>1 --</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SE978</td>
<td>WSON8</td>
<td>SE978P</td>
<td>400</td>
<td>75 to 95, 40 to 125, -40 to 125</td>
<td>3.0 to 3.6</td>
<td>1</td>
<td>N/A</td>
<td>0.125/11</td>
<td>400</td>
<td>10</td>
<td>1 with EEPROM</td>
<td>N/A</td>
<td>1 --</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SE98A</td>
<td>WSON8</td>
<td>SE98AP</td>
<td>400</td>
<td>75 to 95, 40 to 125, -40 to 125</td>
<td>1.7 to 3.6</td>
<td>1</td>
<td>N/A</td>
<td>0.125/11</td>
<td>400</td>
<td>5</td>
<td>1</td>
<td>N/A</td>
<td>1 --</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAS6004</td>
<td>SO8, MSOP8</td>
<td>SAS6004X*, SAS6004XP*</td>
<td>400</td>
<td>-25 to 100, -55 to 125</td>
<td>3.0 to 3.6</td>
<td>2</td>
<td>0.125/11</td>
<td>500 (typ)</td>
<td>10 (typ)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* “X” is the version, with “A”, “C” and “E” available and “E” the most commonly used.

**SELECTION GUIDE AND CROSS REFERENCE**

**Selection guide**

**CROSS-REFERENCE CHART**

<table>
<thead>
<tr>
<th>Package</th>
<th>NXP</th>
<th>National</th>
<th>Analog Devices</th>
<th>Maxim</th>
<th>Texas Instruments</th>
<th>Microchip</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO8</td>
<td>LM75BD</td>
<td>LM75BLM</td>
<td>AD7416AR</td>
<td>DS75S</td>
<td>TMP75AID</td>
<td>TCN75-3.3MOA TCN75-5.0MOA</td>
</tr>
<tr>
<td>TSSOP8</td>
<td>LM75BDP</td>
<td>LM75BMM</td>
<td>AD7416ARM</td>
<td></td>
<td></td>
<td>TCN75-3.3MA TCN75-5.0MA</td>
</tr>
<tr>
<td>SO8</td>
<td>SAS6004ED</td>
<td>LM86CIM</td>
<td>ADM1032AR</td>
<td>MAX6657MSA</td>
<td>MAX6658MSA</td>
<td></td>
</tr>
<tr>
<td>TSSOP8</td>
<td>SAS6004EDP</td>
<td>LM86CIMM</td>
<td>ADM1032ARM</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The Inter-IC bus, commonly known as the I²C-bus (“eye-squared-see bus”), is a simple, two-wire serial interface that provides the communications link between integrated circuits in a system. Developed by Philips in the early 1980s, the I²C-bus has become the de facto worldwide standard for system control and today can be found in everything from temperature sensors to EEPROMs, general-purpose I/O, A/D and D/A converters, CODECs, and microprocessors of all kinds.

LOW-COST SERIAL INTERFACE
The two-wire, serial structure of the I²C-bus lets it deliver the same functionality as a larger, more expensive parallel interface, but with far fewer pins. The data wire (SDA) carries data, while the clock wire (SCL) synchronizes data transfers.

MASTER-SLAVE HIERARCHY
I²C-bus devices are classified as master or slave. Masters initiate a message and slaves respond to a message. A master can have multiple slaves and any device can be master-only, slave-only, or switch between master and slave, as the application requires.

MULTIPLE DEVICES
The I²C-bus is designed to support multiple devices. Each I²C-bus slave device has a unique slave address. When a master sends a message, it includes the slave address at the beginning of the message. All devices on the bus hear the message, but only the addressed slave responds to it.

MULTI-MASTER SUPPORT
There can be more than one master on the bus at a time—the I²C-bus software uses arbitration and synchronization to prevent collisions and data loss. A master that detects arbitration loss terminates its use of the bus, allowing the message generated by another master to use the bus without interference.
I²C-BUS AND SMBUS: AN OVERVIEW

I²C-BUS VS. SMBUS

The system management bus, also known as the SMBus, was developed by Intel in the mid-1990s. It is a popular derivative of the I²C-bus that is, in most cases, compatible with I²C-bus formats. Both buses use a two-wire, master/slave communication scheme and have addressable slaves. The SMBus is limited to a maximum data transfer rate of only 100 kbit/s, so it requires special handling in systems that use the higher transfer rates available with the I²C-bus. Other differences include the maximum timeout period, minimum clock speed, voltage levels, pull-up resistors values and current levels.

<table>
<thead>
<tr>
<th>Feature</th>
<th>I²C-Bus</th>
<th>SMBus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slave interface reset</td>
<td>Master sends clock pulses until slave data goes high (typically nine clocks) or hardware reset</td>
<td>Master holds clock low for maximum 35 ms (time-out period)</td>
</tr>
<tr>
<td>Clock speed (min/max)</td>
<td>0 to 3.4 MHz</td>
<td>10 to 100 kHz</td>
</tr>
<tr>
<td>SMBus alert</td>
<td>No</td>
<td>Optional</td>
</tr>
<tr>
<td>VILmax</td>
<td>0.3 V&lt;sub&gt;DD&lt;/sub&gt; (or fixed 1.5 V)</td>
<td>0.8 V</td>
</tr>
<tr>
<td>VIHmin</td>
<td>0.7 V&lt;sub&gt;DD&lt;/sub&gt; (or fixed 3.0 V)</td>
<td>2.1 V</td>
</tr>
<tr>
<td>Low power (Version 1.1)</td>
<td>High power (Version 2.0)</td>
<td></td>
</tr>
<tr>
<td>IPULLUP</td>
<td>3 mA</td>
<td>350 μA</td>
</tr>
<tr>
<td>Pull-up resistor1 for V&lt;sub&gt;DD&lt;/sub&gt; = 3.3 V (≥10%)</td>
<td>&gt; 0.8 kW</td>
<td>&gt; 7.4 kW</td>
</tr>
<tr>
<td>Pull-up resistor1 for V&lt;sub&gt;DD&lt;/sub&gt; = 5.0 V (≥10%)</td>
<td>&gt; 1.6 kW</td>
<td>&gt; 13.2 kW</td>
</tr>
<tr>
<td>Data hold time</td>
<td>Performed internally</td>
<td>300 ns (externally)</td>
</tr>
</tbody>
</table>

1 Pull-up resistor value calculation based on V<sub>DD</sub> = V<sub>DD</sub> min

MIXING I²C-BUS AND SMBUS MASTER AND SLAVE DEVICES

Although there are minor differences between the various I²C-bus and SMBus standards, it’s possible to mix master and slave devices from different versions. Two factors need to be considered. First, the SMBus timeout maximum of 35 ms can restrict the performance of an I²C-bus master, but the timeout feature in most SMBus slaves can be programmed on or off. Second, the SMBus data hold time of 300 ns can also restrict I²C-bus performance, but many SMBus devices (including those from NXP) can stretch the internal data-hold time.

<table>
<thead>
<tr>
<th>I²C-Bus Slave</th>
<th>SMBus Slave</th>
</tr>
</thead>
<tbody>
<tr>
<td>I²C-bus master OK</td>
<td>OK, but ensure clock speed is greater than 10 kHz and check for data potential hold-time violations when the slave is receiving.*</td>
</tr>
<tr>
<td>SMBus master OK</td>
<td>OK</td>
</tr>
</tbody>
</table>

* All NXP temperature sensors with an SMBus interface have internal holdtime without hold-time violations.

For current information about NXP products and documentation, please visit [www.nxp.com/i2c](http://www.nxp.com/i2c).

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Document number: 9397 750 15693A4 REV 1