# I²C-bus temperature sensors

Small, accurate, low-cost sensors
for advanced temperature regulation

NXP founded by Philips

# Accurate performance in a proven format

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 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 over-temperature alarms. They are ideally suited for use in industrial process control, notebook computers, servers, and office electronics.

- The LM75A is a local temperature sensor and watchdog timer™ with an accuracy of ±2 °C.
- The SE95, a more accurate version of the LM75A, delivers superior performance in power-sensitive applications.
- The SE98, designed for applications that use SO-DIMM memory, complies with JEDEC JC42.4, supports SMBus Timeout and Alert, and has security lock bits.
- The SE97 brings the SE98 and a 2-Kbit EEPROM Serial Presence Detect (SPD) together in a single device

### Remote and local temperature sensors

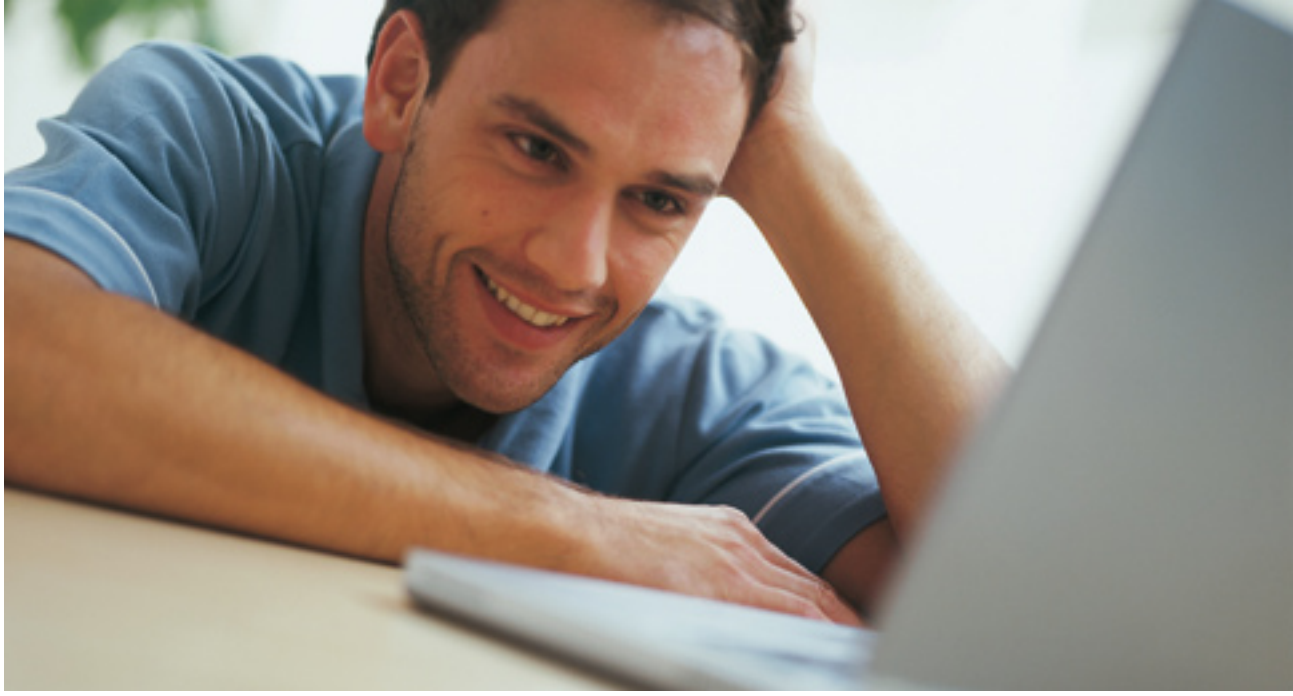
Our combination remote/local sensors can monitor the temperature of the thermal diode inside the CPU or the diode connected to PNP or NPN transistors, and can trigger an interrupt or alert output. To save power in laptop applications, the standby pin ($\overline{\text{STBY}}$) can be tied to the battery's "suspend" output.

- The NE1617A has two tri-level hardware slave address pins that let up to nine slave devices coexist on the same bus.
- The NE1619 has an integrated voltage monitor that can track five input power-supply voltages in the range of 0 to 12 V with a full-scale accuracy of ±2%.
- The SA56004, 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 eight possible pre-configured slave device addresses.

### Applications

| | |
|---|---|
| System thermal management | Office electronics |
| Personal computer | Microprocessor |
| Communications equipment | Power supply |
| Industrial process control | Laptop |
| Servers | SO-DIMM (SE97 and SE98 only) |

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



## NXP I²C-bus/SMBus temperature sensors

| Feature | Benefit |
|---|---|
| Wide supply range (2.8 to 5.5 V) | Suitable for 3.3- or 5-V systems |
| Wide temperature operating range (-55 to 125 °C) | Suitable for all system thermal management |
| Low operating and standby power | Suitable for all applications, including battery management |
| Integrated A/D for input-voltage monitor in the range of 0 to 12 V | Suitable for virtually all power-supply output monitors |
| Programmable temperature set points | Temperature thresholds are easy to change |
| Standby mode and one-shot conversion | Suitable for power-sensitive applications like laptops and handhelds |
| Programmable fault queue | Prevents noise-triggered temperature trips |

## Family overview

| | Local channels | Remote channels | Thermal-alarm output* | Fan-control output* | 0- to 12-V input voltage monitor | Accuracy (local sensing) | Accuracy (remote sensing) | A/D resolution (°C / # bits) | Supply range (V) | Supply current operating (µA) | Supply current shutdown (µA) | Package(s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LM75A | 1 | 1 | 1 | | | ±2 °C | | 0.125/11 | 2.8-5.5 | 1000 | 3.5 | SO8<br>MSOP8 |
| NE1617A | 1 | 1 | 1 | | | ±2 °C | ±3 °C | 1.0/8 | 3.0-5.5 | 70 | 3.0 | QSOP16 |
| NE1619 | 1 | 1 | | | 5 | ±3 °C | ±5 °C | 1.0/8 | 2.8-5.5 | 500 | 100 | QSOP16 |
| SA56004 | 1 | 1 | 1 | 1 | | ±2 °C | ±1 °C | 0.125/11 | 3.0-3.6 | 500 | 10 | SO8<br>MSOP8 |
| SE95 | 1 | | 1 | | | ±1 °C | | 0.03125/13 | 2.8-5.5 | 1000 | 7.5 | SO8<br>MSOP8 |
| SE97 | 1 with SPD | | | | | ±2 °C | | 0.125/11 | 3.0-3.6 | TBD | TBD | HVSON8<br>TSSOP8 |
| SE98 | 1 | | | | | ±2 °C | | 0.125/11 | 3.0-3.6 | 250 | 15 | HVSON8<br>TSSOP8 |

* Open-drain output

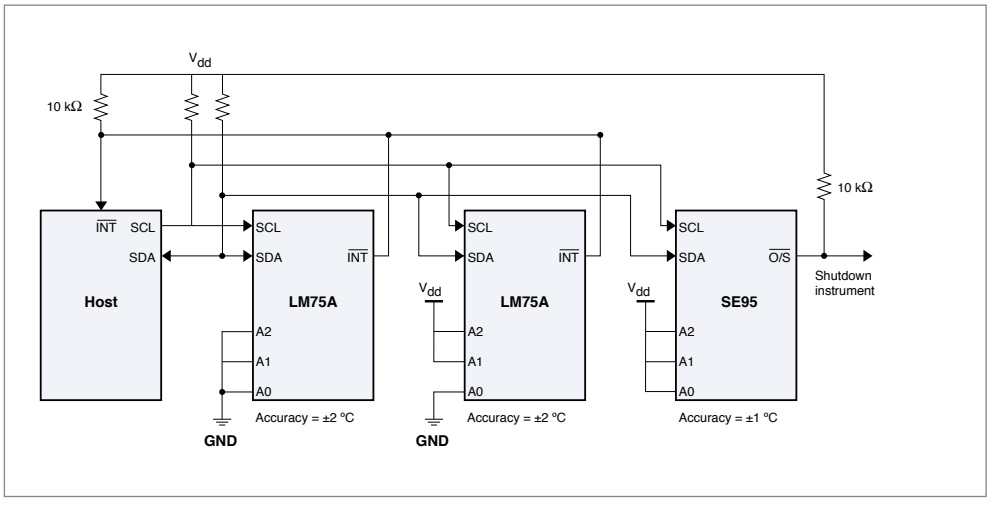
# Local-only temperature sensors

## Local temperature sensor and thermal watchdog LM75A with accuracy of ±2 °C

**Features:**

- On-chip thermal diode
- Bus: two-wire I²C-bus (standard/fast-mode compatible)
- Accuracy: ±2 °C (-25 to 100 °C)
- Resolution: 9-bit (0.25 °C) or 11-bit (0.125 °C)
- Open-drain interrupt or comparator/thermostat output
- Shutdown/operating current: 3.5/1000 µA
- Power-supply range: 2.8 to 5.5 V
- Temperature range: -55 to 125 °C
- Package: TSSOP(MSOP)8, SO8
- Drop-in replacement for: National LM75, Microchip TCN75, Maxim DS75, TI TMP75, Analog Devices AD7416

## LM75A/SE95 application diagram



## Local temperature sensor and thermal watchdog SE95 with accuracy of ±1 °C

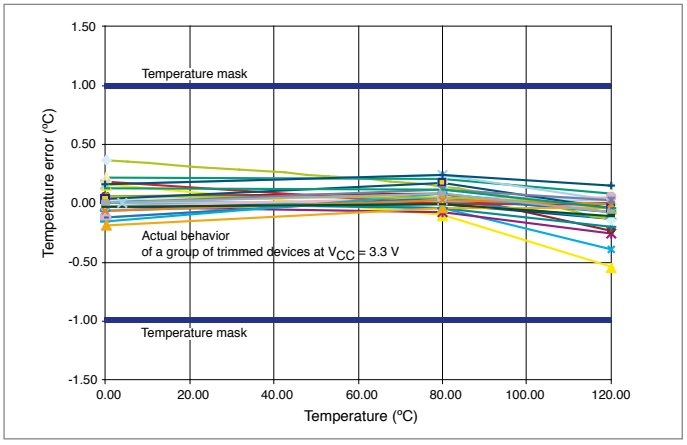
### Same as LM75A, with the following differences:

- Accuracy: ±1 °C (-25 to 100 °C)
- Resolution: 13-bit (0.03125 °C)
- Shutdown/operating current: 7.5/1000 µA
- Shutdown mode and one-shot conversion capability
- Programmable temperature conversion rate (0.125 to 30 Hz)

### Advantages over LM75A:

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

## SE95 test results




## Local temperature sensor SE98 for SO-DIMM with accuracy of ±2 °C

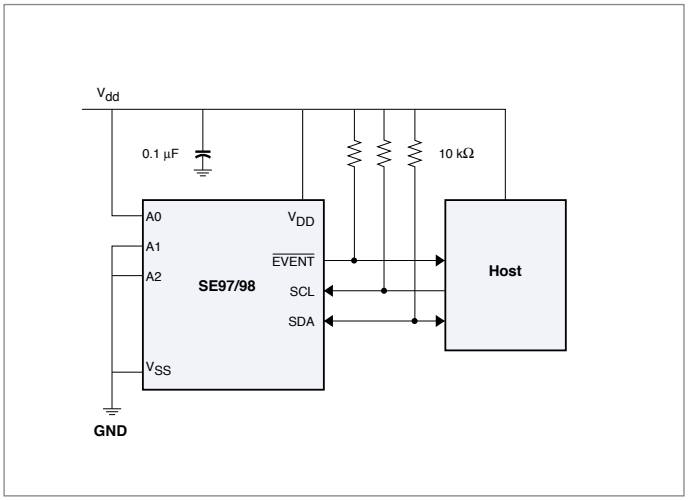
**Features:**

- Complies with JEDEC JC42.4
- Bus: two-wire SMBus or I²C-bus (standard/fast-mode compatible)
- Accuracy: ±2 °C (75 to 90 °C – SE98), or ±1 °C (75 to 90 °C – SE98/01)
- Resolution: 11-bit (0.125 °C)
- Minimum conversion rate: 8 Hz
- Programmable hysteresis threshold: 0, 1.5, 3, or 6 °C
- $\overline{\text{EVENT}}$ 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
- I²C address: 0011A2A1A0 (up to 8 devices on same bus)
- Operating-voltage range: 3.0 to 3.6 V
- Operating temperature: -20 to +125 °C
- Packages: TSSOP8, HVSON8 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

## SE97/98 application diagram



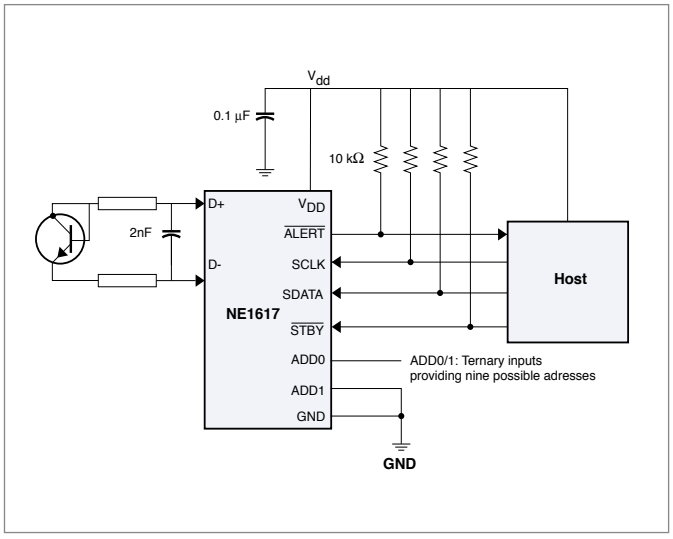

## Local temperature sensor SE97 for SO-DIMM with integrated SPD

### Same as SE98, with the following differences:

- Adds integrated 2-Kbit EEPROM for Serial Presence Detect
- EEPROM I²C-bus address 1010A2A1A0

# Remote and local temperature sensors

## NE1617A application diagram

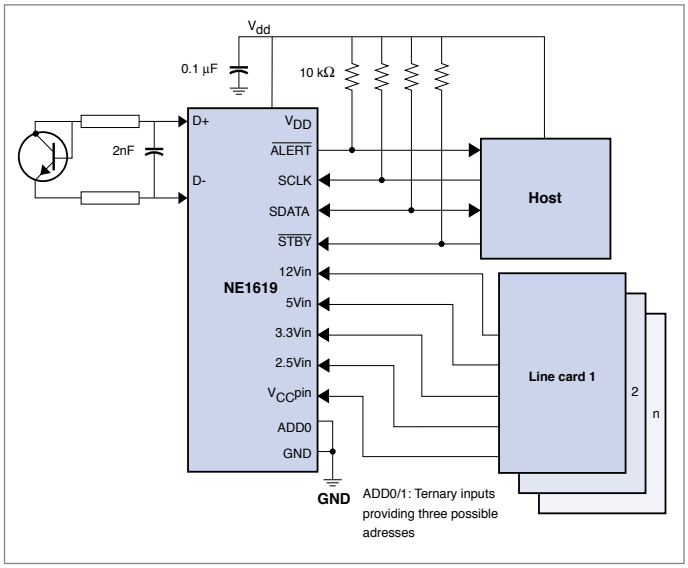



## Remote and local temperature sensor NE1617A with accuracy of ±3 °C

**Features:**

- Bus: two-wire SMBus or I²C-bus (standard-mode compatible)
- Accuracy (remote and loc al sensing): ±3 °C (60 to 100 °C)
- Resolution: 8-bit ADC (1 °C)
- Standby/operating current: 3/70 µA
- Open-drain $\overline{\text{ALERT}}$ output
- Temperature range: 0 to 125 °C
- Power-supply range: 3.0 to 5.5 V
- Package: QSOP16
- Drop-in replacement for Maxim NE1617 and Analog Devices AD1021 or AD1021A

## NE1619 application diagram




## Remote and local temperature sensor NE1619 with voltage monitor and ±3 °C accuracy

**Features:**

- Monitors five inputs from power-supply voltages of 0 to 12 V
- Bus: two-wire SMBus or I²C-bus (standard/fast-mode compatible)
- Accuracy (remote sensing): ±3 °C (0 to 120 °C)
- Accuracy (local sensing): ±5 °C (0 to 120 °C)
- ±2% of full-scale input voltage accuracy
- Resolution: 8-bit ADC (1 °C)
- Standby/operating current: 3/80 µA
- Temperatures range: -55 to 125 °C
- Power-supply range: 3.0 to 3.6 V
- Package: QSOP16

## Remote and local temperature sensor SA56004 with fan control and accuracy of ±1 °C

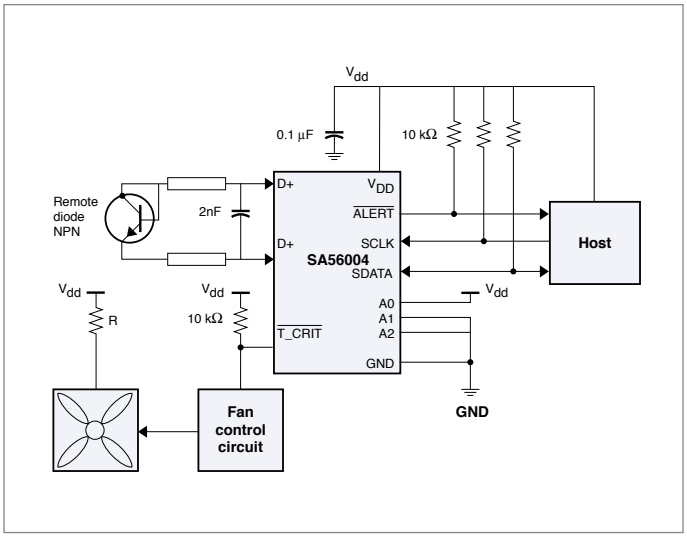
**Features:**

- Bus: two-wire SMBus or I²C-bus (standard/fast-mode compatible)
- Accuracy (remote sensing): ±1 °C (25 to 85 °C)
- Accuracy: (local sensing): ±2 °C (60 to 100 °C)
- Resolution: 11-bit (0.125 °C)
- Shutdown/operating current: 10/500 µA
- Shutdown mode and one-shot conversion for power savings
- Offset registers for system calibration
- $\overline{\text{ALERT}}$ / $\overline{\text{T\_CRIT}}$ output for interrupt/fan control (on/off)
- Supports SMBus alert response and timeout
- Fault queue prevents noise-triggered temperature trips
- Supports diode-fault detection
- Eight device addresses for server applications ("E" most commonly used)
- Temperature range: -55 to 125 °C
- Power-supply range: 3.0 to 3.6 V
- Packages: TSSOP(MSOP)8, SO8
- Drop-in replacement for National LM86, Maxim MAX6657/8, Analog Devices ADM1032

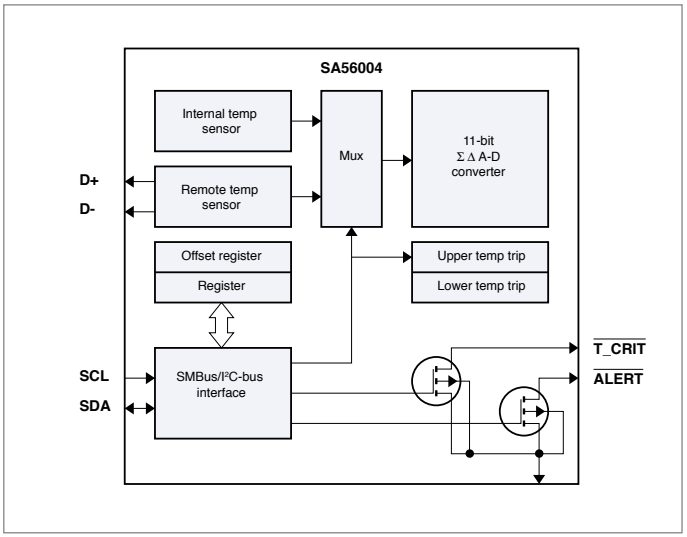
**Benefits:**

- 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

## SA56004 application diagram




## SA56004 block diagram



# Selection guide and cross reference

## Selection guide

| | Part number | Package | Order information | I²C/SMBus speed (kHz) | Temperature range (°C) | Power-supply range (V) | Accuracy (±°C) | | A/D resolution (°C / # bits) | Supply current (µA) | | Channels | | Thermal-alarm output (open drain) | Fan-control output (open drain) | Voltage monitoring (0-12 input) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Local | Remote | | Operating | Shutdown | Local | Remote | | | |
| Local | LM75A | SO8 | LM75AD | 400 | -25 to 100 | 2.8 to 5.5 | 2 | N/A | 0.125/11 | 1000 | 3.5 | 1 | N/A | 1 | -- | -- |
| | | MSOP8 | LM75ADP | | -55 to 125 | | 3 | | | | | | | | | |
| | SE95 | SO8 | SE95D | 400 | -25 to 100 | 2.8 to 3.6 | 1 | N/A | 0.03125/13 | 1000 | 7.5 | 1 | N/A | 1 | -- | -- |
| | | | | | | 3.6 to 5.5 | 2 | | | | | | | | | |
| | | MSOP8 | SE95DP | | -55 to 125 | 2.8 to 3.6 | 2 | | | | | | | | | |
| | | | | | | 3.6 to 5.5 | 3 | | | | | | | | | |
| | SE97 | HVSON8 | SE97TK | 400 | 75 to 95 | 3.0 to 3.6 | 2 | N/A | 0.125/11 | TBD | TBD | 1 with EEPROM | N/A | 1 | -- | -- |
| | | | | | 40 to 125 | | 3 | | | | | | | | | |
| | | TSSOP8 | SE97DP | | -20 to 125 | | 4 | | | | | | | | | |
| | SE98 | HVSON8 | SE98TK | 400 | 75 to 95 | 3.0 to 3.6 | 2 | N/A | 0.125/11 | 250 | 15 | 1 | N/A | 1 | -- | -- |
| | | | | | 40 to 125 | | 3 | | | | | | | | | |
| | | TSSOP8 | SE98DP | | -20 to 125 | | 4 | | | | | | | | | |
| Remote and local | SA56004 | SO8 | SA56004XD* | 400 | 60 to 100 | 3.0 to 3.6 | 2 | | 0.125/11 | 500 | 10 | 1 | 1 | 1 | 1 | -- |
| | | | | | 25 to 85 | | | 1 | | | | | | | | |
| | | MSOP8 | SA56004XDP* | | 0 to 85 | | | 2 | | | | | | | | |
| | | | | | 0 to 125 | | 3 | | | | | | | | | |
| | NE1617A | QSOP16 | NE1617ADS | 100 | 60 to 100 | 3.0 to 5.5 | 2 | 3 | 1.0/8 | 70 | 3 | 1 | 1 | 1 | -- | -- |
| | | | | | 0 to 125 | | 3 | 5 | | | | | | | | |
| Rem / loc V monitor | NE1619 | QSOP16 | NE1619DS | 400 | -55 to 125 | 2.8 to 5.5 | 5 | 3 | 1.0/8 | 500 | 100 | 1 | 1 | 1 | -- | 5 |

* "X" is the version, with "A" through "H" available and "E" the most commonly used.

## Cross-reference chart

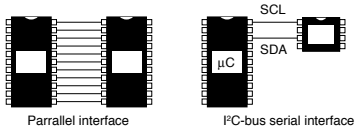
| Package | NXP | National | Analog Devices | Maxim | Texas Instruments | Microchip |
|---|---|---|---|---|---|---|
| SO8 | LM75AD | LM75BIM | AD7416AR | DS75S | TMP75AID | TCN75-3.3MOA |
| | | LM75CIM | | | | TCN75-5.0MOA |
| TSSOP8 | LM75ADP | LM75BIMM | AD7416ARM | | | TCN75-3.3MUA |
| | | LM75CIMM | | | | TCN75-5.0MUA |
| SO8 | SE95D | LM75BIM | AD7416AR | DS75S | TMP75AID | TCN75-3.3MOA |
| | | LM75CIM | | | | TCN75-5.0MOA |
| | | | | | | TCN75-5.0MOA |
| TSSOP8 | SE95DP | LM75BIMM | AD7416ARM | | | TCN75-3.3MUA |
| | | LM75CIMM | | | | TCN75-5.0MUA |
| SO8 | SA56004ED | LM86CIM | ADM1032AR | MAX6657MSA | | |
| | | | | MAX6658MSA | | |
| TSSOP8 | SA56004EDP | LM86CIMM | ADM1032ARM | | | |
| SSOP16 | NE1617ADS | | AD1021ARQ | NE1617S | | |
| | NE1618DS | | AD1021AARQ | | | |

# I²C-bus and SMBus: an overview

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.

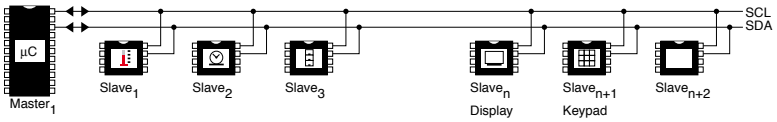
## Low-cost serial interface

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.



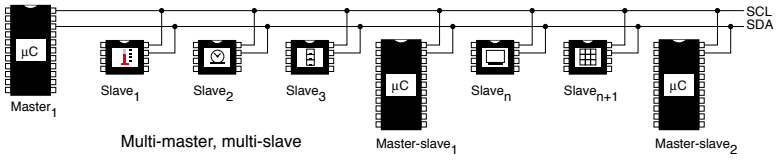

One I²C-bus master, multiple slaves

## 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.




Multi-master, multi-slave

### 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 kbps, 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.

| Feature | I²C-bus | SMBus | |
|---|---|---|---|
| Slave interface reset | Master sends clock pulses until slave data goes high (typically nine clocks) or hardware reset | Master holds clock low for maximum 35 ms (time-out period) | |
| Clock speed (min/max) | 0 to 3.4 MHz | 10 to 100 kHz | |
| SMBus alert | No | Optional | |
| $VIL_{max}$ | 0.3 $V_{DD}$ (or fixed 1.5 V) | 0.8 V | |
| $VIH_{min}$ | 0.7 $V_{DD}$ (or fixed 3.0 V) | 2.1 V | |
| | | Low power (Version 1.1) | High power (Version 2.0) |
| $I_{PULLUP}$ | 3 mA | 350 µA | 4 mA |
| Pull-up resistor[1] for $V_{DD}$ = 3.3 V (±10%) | > 0.8 kΩ | > 7.4 kΩ | > 0.65 kΩ |
| Pull-up resistor[1] for $V_{DD}$ = 5.0 V (±10%) | > 1.6 kΩ | > 13.2 kΩ | > 1.2 kΩ |
| Data hold time | Performed internally | 300 ns (externally) | |

[1] Pull-up resistor value calculation based on $V_{DD} = V_{DD\_min}$

| | I²C-bus slave | SMBus slave |
|---|---|---|
| I²C-bus master | OK | OK, but ensure clock speed is greater than 10 kHz and check for data potential hold-time violations when the slave is receiving.* |
| SMBus master | OK | OK |

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

### 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.

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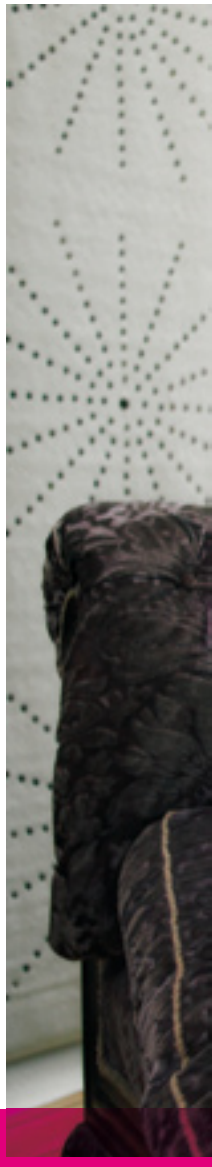

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