



I²C-bus temperature sensors

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

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 $\pm 2\%$.
- ▶ 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 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 MSOP8
SE95	1		1			±1 °C		0.03125/13	2.8-5.5	1000	7.5	SO8 MSOP8
SE97	1 with SPD					±2 °C		0.125/11	3.0-3.6	TBD	TBD	HVSON8 TSSOP8
SE98	1					±2 °C		0.125/11	3.0-3.6	250	15	HVSON8 TSSOP8

* Open-drain output

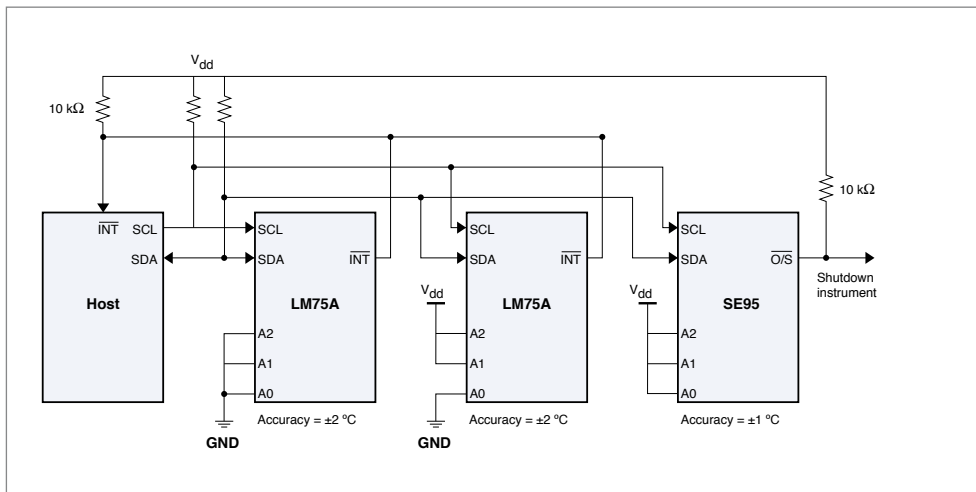
Local-only temperature sensors

Local temperature sensor and thermal watchdog LM75A with accuracy of $\pm 2^\circ\text{C}$

Features:

- ▶ On-chip thermal diode
- ▶ Bus: two-wire I²C-bus (standard/fast-mode compatible)
- ▶ Accuracy: $\pm 2^\circ\text{C}$ (-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 $\pm 1^\circ\text{C}$

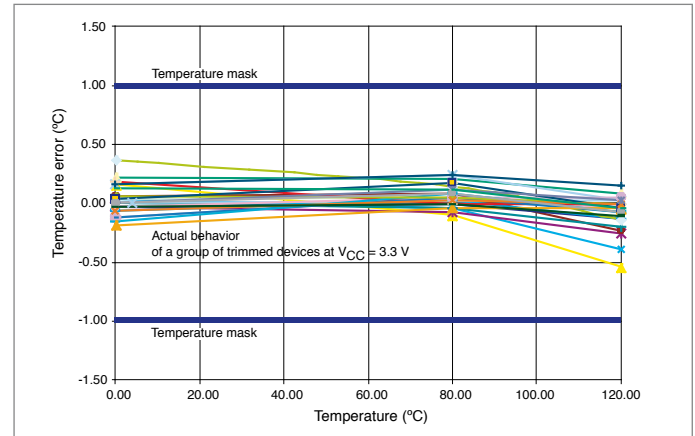
Same as LM75A, with the following differences:

- ▶ Accuracy: $\pm 1^\circ\text{C}$ (-25 to 100°C)
- ▶ Resolution: 13-bit (0.03125°C)
- ▶ Shutdown/operating current: $7.5/1000\ \mu\text{A}$
- ▶ Shutdown mode and one-shot conversion capability
- ▶ Programmable temperature conversion rate (0.125 to $30\ \text{Hz}$)

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 $\pm 2^\circ\text{C}$

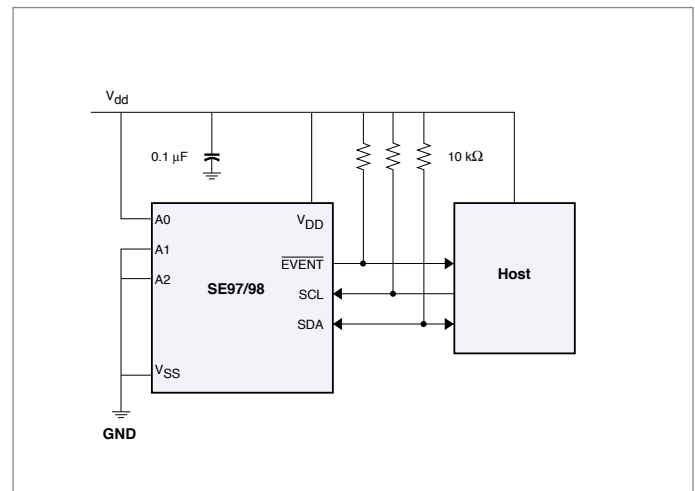
Features:

- ▶ Complies with JEDEC JC42.4
- ▶ Bus: two-wire SMBus or I²C-bus (standard/fast-mode compatible)
- ▶ Accuracy: $\pm 2^\circ\text{C}$ (75 to 90°C – SE98), or $\pm 1^\circ\text{C}$ (75 to 90°C – SE98/01)
- ▶ Resolution: 11-bit (0.125°C)
- ▶ Minimum conversion rate: $8\ \text{Hz}$
- ▶ 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: $100\ \mu\text{A}$
- ▶ I²C address: $0011\text{A}2\text{A}1\text{A}0$ (up to 8 devices on same bus)
- ▶ Operating-voltage range: 3.0 to $3.6\ \text{V}$
- ▶ Operating temperature: -20 to $+125^\circ\text{C}$
- ▶ 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



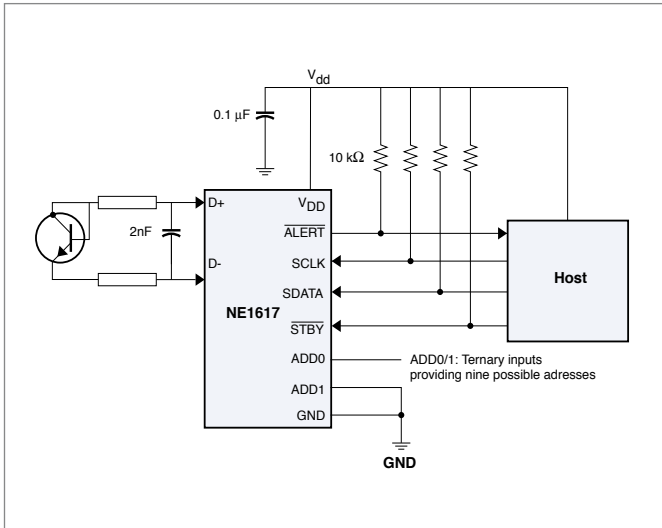
Local temperature sensor SE97 for SO-DIMM with integrated SPD

Same as SE98, with the following differences:

- ▶ Adds integrated 2-Kbit EEPROM for Serial Presence Detect
- ▶ EEPROM I²C-bus address $1010\text{A}2\text{A}1\text{A}0$

Remote and local temperature sensors

NE1617A application diagram

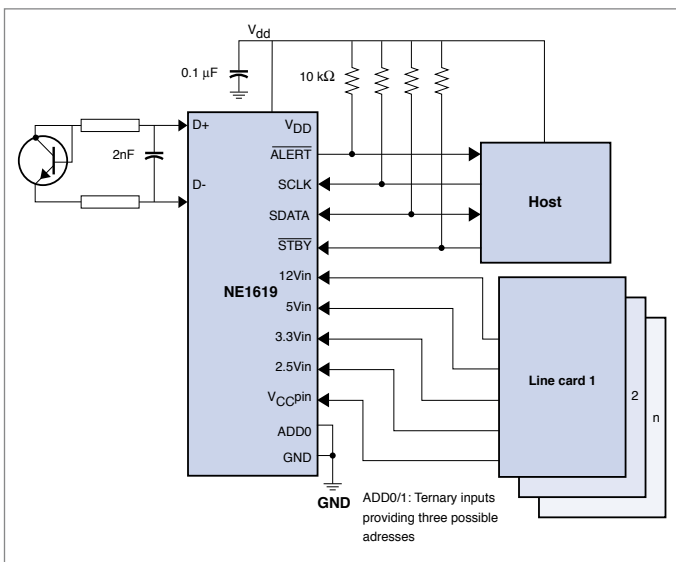


Remote and local temperature sensor NE1617A with accuracy of $\pm 3^\circ\text{C}$

Features:

- ▶ Bus: two-wire SMBus or I²C-bus (standard-mode compatible)
- ▶ Accuracy (remote and local sensing): $\pm 3^\circ\text{C}$ (60 to 100 $^\circ\text{C}$)
- ▶ Resolution: 8-bit ADC (1 $^\circ\text{C}$)
- ▶ Standby/operating current: 3/70 μA
- ▶ Open-drain $\overline{\text{ALERT}}$ output
- ▶ Temperature range: 0 to 125 $^\circ\text{C}$
- ▶ 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 $\pm 3^\circ\text{C}$ 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): $\pm 3^\circ\text{C}$ (0 to 120 $^\circ\text{C}$)
- ▶ Accuracy (local sensing): $\pm 5^\circ\text{C}$ (0 to 120 $^\circ\text{C}$)
- ▶ $\pm 2\%$ of full-scale input voltage accuracy
- ▶ Resolution: 8-bit ADC (1 $^\circ\text{C}$)
- ▶ Standby/operating current: 3/80 μA
- ▶ Temperatures range: -55 to 125 $^\circ\text{C}$
- ▶ Power-supply range: 3.0 to 3.6 V
- ▶ Package: QSOP16

Remote and local temperature sensor SA56004 with fan control and accuracy of $\pm 1^\circ\text{C}$

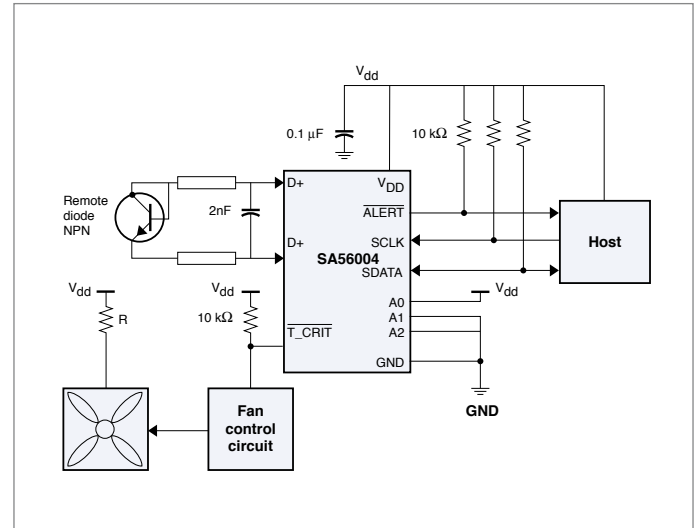
Features:

- ▶ Bus: two-wire SMBus or I²C-bus (standard/fast-mode compatible)
- ▶ Accuracy (remote sensing): $\pm 1^\circ\text{C}$ (25 to 85°C)
- ▶ Accuracy: (local sensing): $\pm 2^\circ\text{C}$ (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

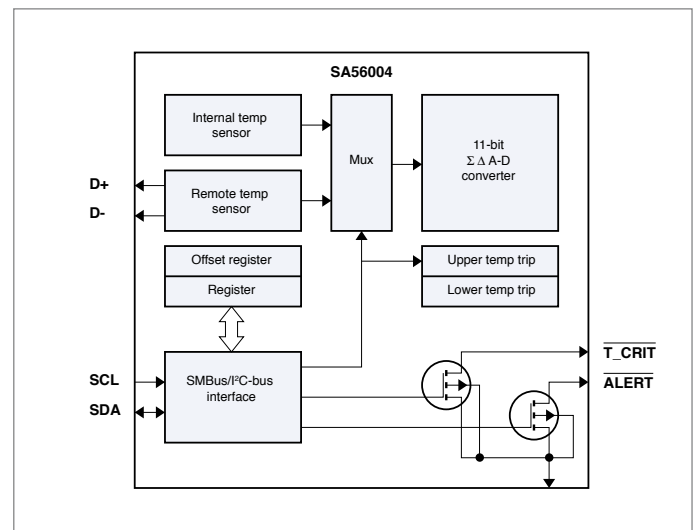
Benefits:

- ▶ 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	I ² C/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 0 to 125	3.0 to 5.5	2 3	3 5	1.0/8	70	3	1	1	1	--
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

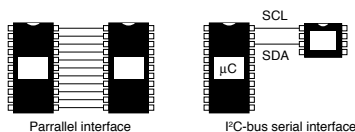
Package	NXP	National	Analog Devices	Maxim	Texas Instruments	Microchip
SO8	LM75AD	LM75BIM LM75CIM	AD7416AR	DS75S	TMP75AID	TCN75-3.3MOA TCN75-5.0MOA
TSSOP8	LM75ADP	LM75BIMM LM75CIMM	AD7416ARM			TCN75-3.3MUA TCN75-5.0MUA
SO8	SE95D	LM75BIM LM75CIM	AD7416AR	DS75S	TMP75AID	TCN75-3.3MOA TCN75-5.0MOA TCN75-5.0MOA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

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.

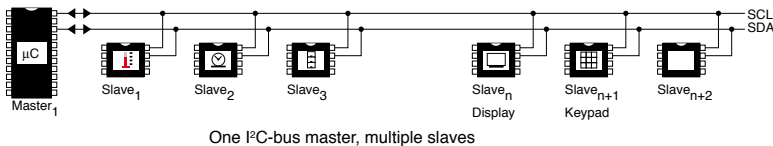
Low-cost serial interface

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.

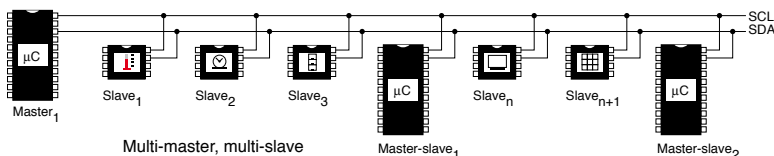


Multiple devices

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 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	I ² C-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	
V _{ILmax}	0.3 V _{DD} (or fixed 1.5 V)	0.8 V	
V _{IHmin}	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 $V_{DD} = V_{DD_min}$

	I ² C-bus slave	SMBus slave
I ² C-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

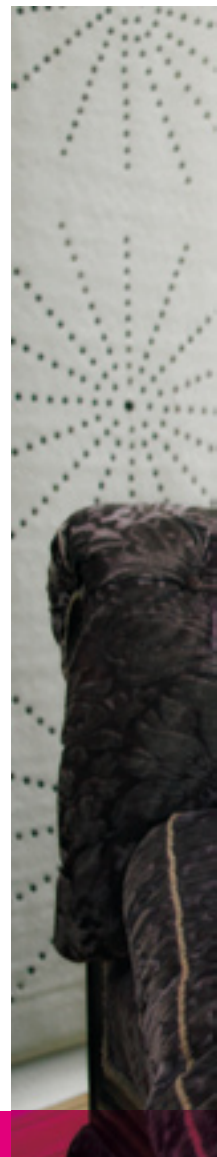
* All NXP temperature sensors with an SMBus interface have internal hold-time without hold-time violations.

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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