TEE301

Digital Temperature Sensor

The TEE301 is the next generation of the T series TEEx01. With a 16-bit unsigned integer value and a different pin assignment compared to TEE501, the TEE301 allows an easy upgrade for your existing application with minimal integration effort.

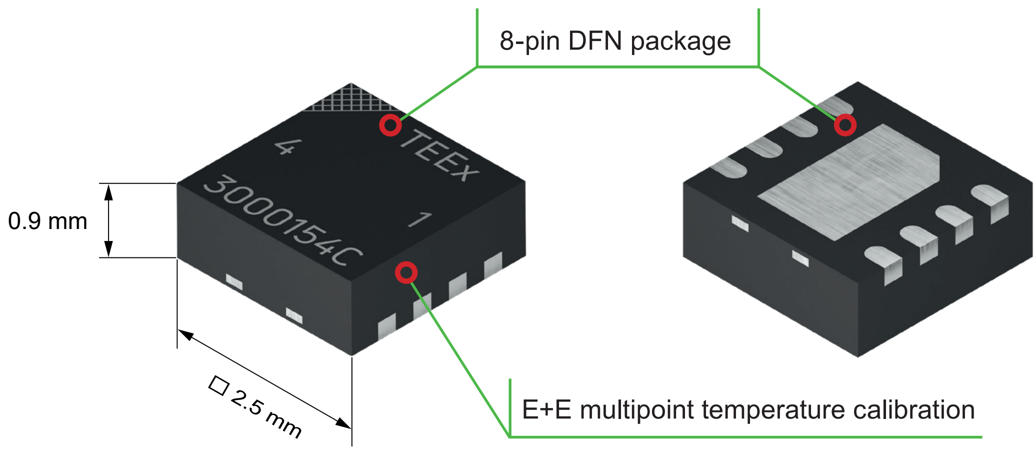
Furthermore the sensor covers a wide application range from -40 to +125 °C. Therefore the TEE301 offers a versatile measuring device for demanding tasks. With a footprint of only 2.5 x 2.5 mm, an accuracy of 0.2 °C and the expansion of up to 4 I²C addresses, it ensures outstanding performance at an excellent price-performance ratio.

Key Features

- Accuracy up to ±0.2 °C
- Supply voltage 2.35 - 3.60 V
- 8-pin DFN package
- I²C interface with pin-selectable addresses
- I²C glitch suppression
- Excellent repeatability

Typical Applications

- Building automation
- Consumer electronics
- Home appliances
- Industrial automation
- Medical devices
- Smart home
- Wearable devices
- White goods



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ACRONYM	MEANING
A	Ambient
B	Bus
CDM	Charged Device Model
ESD	Electrostatic Discharge
HBM	Human Body Model
MEAS	Measurement, Measuring
PORI	Power On Reset, Idle Mode
PORP	Power On Reset, Periodic Mode
POR	Power On Reset
PU	Pull-up
PUPE	Pull-up external
PUPI	Pull-up internal
PWRU	Power Up
T	Temperature

Table 1: List of TEEx specific acronyms

1 Pin Configuration

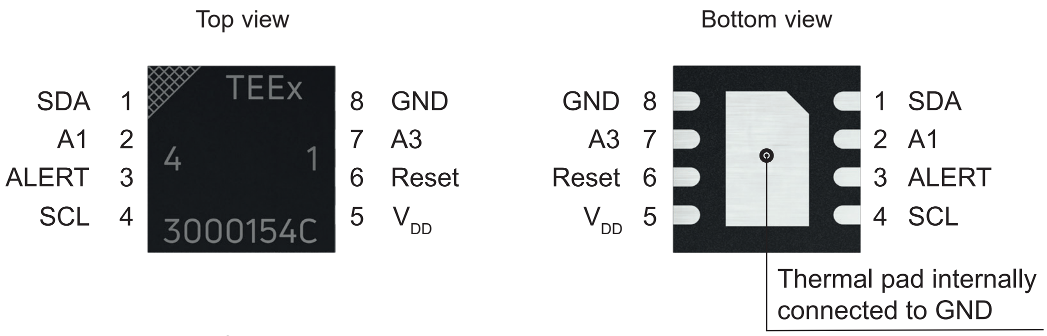


Figure 1: DFN8 pin configuration

PIN #	NAME	PIN TYPE	DESCRIPTION
1	SDA	I/O	Serial data line for I^2C communication. The external pull-up resistors (e.g. R_p = 4.7 kΩ) are required to pull the signal high.
2	A1	Input high-Z	I^2C device address pin; bit 1 of the 7-bit address; do not leave floating, to be connected to the GND for default I^2C address.
3	ALERT	Output push-pull	Indicates alarm condition; leave floating if unused.
4	SCL	I/O	Serial clock line for I^2C communication. The external pull-up resistors (e.g. R_p = 4.7 kΩ) are required to pull the signal high.
5	V_{DD}	Power	Positive supply pin
6	Reset	Inverted output with pull-up	Reset pin active low; leave floating if unused; can be connected to V_{DD} with a series resistor of R ≥ 2 kΩ.
7	A3	Input high-Z	I^2C device address pin; bit 3 of the 7-bit address; do not leave floating, to be connected to the GND for default I^2C address.
8	GND	Power	Ground (internally connected to thermal pad)

Table 2: TEE301 pin assignment

2 Typical Application

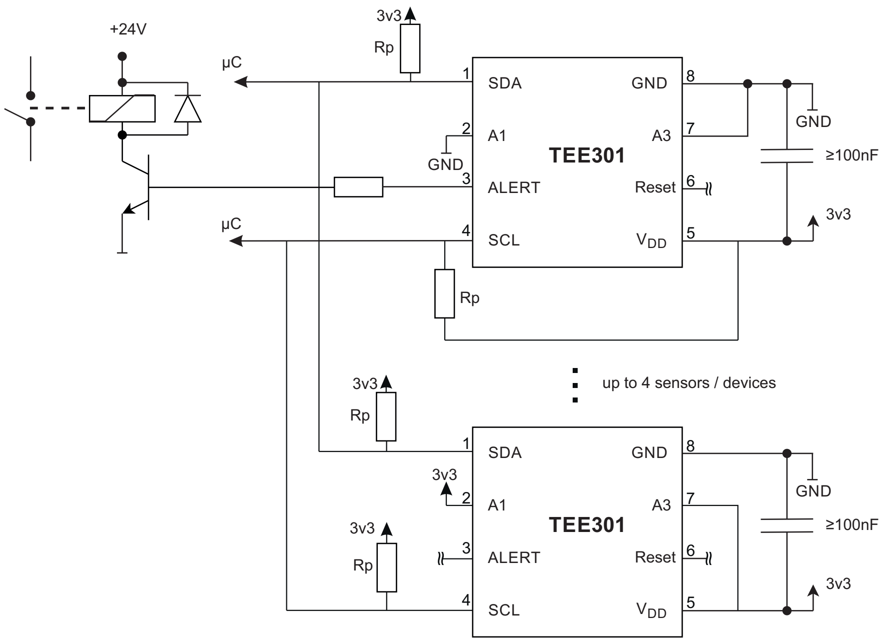


Figure 2: Typical application schematic

3 Specifications

3.1 Temperature Sensor

PARAMETER	CONDITION	MIN	TYP	MAX	UNIT
Operating Range		-40		125	°C
Accuracy			0.2	See Figure 3	°C
Resolution[1)]	high		0.01		°C
Repeatability[2)]	high		0.03		°C
Response time[3)]	τ_{63}	2			s
Long Term Drift			<0.03		°C/yr

Table 3: Temperature sensor parameters

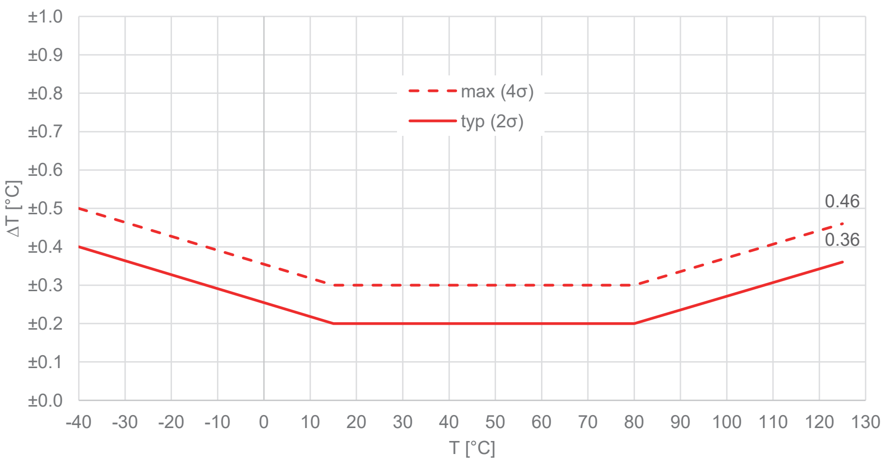


Figure 3: Temperature sensor accuracy

3.2 Recommended Operating Conditions

The TEE301 sensor can be used in the temperature range -40°C…+125°C.

1) Resolution is chosen by the corresponding measurement command.
2) The stated "Noise / Repeatability" is 3 times the standard deviation (3σ) of multiple consecutive measurement values at constant environmental conditions.
3) Time for achieving 63 % of a step function, valid at 25°C and 1m/s airflow.
The actual response time in application strongly depends on the surrounding of the sensor in the final application (heat conductivity of sensor substrate, dead volume, …).

4 Electrical Characteristics

4.1 Absolute Maximum Ratings

The absolute maximum ratings as given in Table 4 are stress ratings only and give additional information. Functional operation of the device at these conditions is not implied. Exposure to absolute maximum rating conditions for extended periods may affect the device reliability (e.g. hot carrier degradation, oxide breakdown).

PARAMETER	SYMBOL	MIN	MAX	UNIT
Power Supply	V_{DD}	-0.3	3.6	V
Digital I/O pins	V_{LOGIC}	-0.3	5.0	V
Input Current on any pin	I_{IN}	-50	50	mA
Storage Temperature	T_{STG}	-55	150	°C
ESD HBM[1)]	ESD_{HBM}	-	4	kV
ESD CDM[2)]	ESD_{CDM}	-	750	V

1) Human Body Model according to AEC-Q100-002
2) Charged Device Model according to AEC-Q100-011

Table 4: TEE301 absolute maximum ratings

4.2 Electrical Specification

Typical values correspond to V_{DD} = 3.3 V and T_A = 25 °C.
Min. and max. values are valid in the full temperature range -40 °C … 125 °C and at declared V_{DD} levels, unless otherwise noted.

PARAMETER	SYMBOL	CONDITION / COMMENT	MIN	TYP	MAX	UNIT
Supply Voltage	V_{DD}		2.35	3.3	3.6	V
POR voltage periodic mode	V_{PORP}	Static power supply	2.10	2.20	2.35	V
POR voltage idle mode	V_{PORI}	Static power supply		1.8		V
Supply current	I_{DD}	Single mode (idle)[1)]		6		µA
		Periodic mode[1)]		80		µA
		Measuring T, Calculation		900		µA
Thermal resistance	R_{TH}	Dependent on PCB layout and enviromental conditions		150		K/W

1) Without I²C communication and when not measuring

Table 5: General operation

PARAMETER	SYMBOL	CONDITION / COMMENT	MIN	TYP	MAX	UNIT
Input voltage	V_{IL}	Low level			$0.3*V_{DD}$	V
	V_{IH}	High level	$0.7*V_{DD}$		V_{DD}	V
Output voltage	V_{OL}	Current into pin: I_{OL}= 4.0 mA	0	0.25	0.40	V
	V_{OH}	High level → open drain				
Internal pull-up resistor	R_{PUPI}	V_{DD}=3.60 V & pin voltage = $0.7*V_{DD}$		25		kΩ
		V_{DD}=3.30 V & pin voltage = $0.7*V_{DD}$		27		kΩ
		V_{DD}=3.00 V & pin voltage = $0.7*V_{DD}$		30		kΩ
		V_{DD}=2.35 V & pin voltage = $0.7*V_{DD}$		34		kΩ
External pull-up resistor	R_{PUPE}	At I²C lines, pull-up current ≤4.0 mA @ 3.3 V	0.725	4.7		kΩ
Capacitive bus load	C_B	Standard			400	pF
		Fast mode			400	pF
		Fast mode plus			177	pF

1) Characterized but not tested.

Table 6: I²C communication pins SCL & SDA

PARAMETER	SYMBOL	CONDITION / COMMENT	MIN	TYP	MAX	UNIT
Input voltage	V_{IL}	Low level			$0.3*V_{DD}$	V
	V_{IH}	High level, 5V tolerant input	$0.7*V_{DD}$	V_{DD}	5.0	V
Input leakage current	I_{VDD}	Voltage @pin = 0…V_{DD}	-10	0	+10	μA
	I_{I5V}	Voltage @pin = V_{DD}…5 V		TBD		μA
Output resistance	R_{OH}	Voltage @pin = V_{DD}-0.4 V		116		Ω
	R_{OL}	Voltage @pin = 0.4 V		100		Ω

Table 7: I/O pins

PARAMETER	SYMBOL	CONDITION / COMMENT	TYP	UNIT
Power-up time	t_{PWRU}	After V_{DD} > V_{PORP}, exclude measurement at power-up	1.1	ms
Reset time	t_{RESET}	Any reset except power-up	0.9	ms
T Measurement	t_T	Low repeatability	1.7	ms
		Medium repeatability	3.3	ms
		High repeatability	13.0	ms
Measurement calculation	t_{CALC}	After every measurement	1.2	ms
SCL SDA input filter	t_{spike}	Short voltage spikes are ignored	25	ns

Table 8: General timing

Subsequently, the typical measurement time with high repeatability is $t_{MEAS} = t_T + t_{CALC}$
$= 13 + 1.2$
$= 14.2$ ms.

	TEMPERATURE
Repeatability	Resolution [°C]
High	0.01
Medium	0.06
Low	0.11

Table 9: Measurement resolution

5 Interface

5.1 Supply Pins (V_{DD}, GND)

The supply pins must be equipped with a bypass ceramic capacitor of at least 100 nF.

Sensor Power-up
As soon as V_{DD} exceeds the POR voltage V_{PORP}, the device gets initialized. After t_{PWRU}, the initialization procedure is completed.

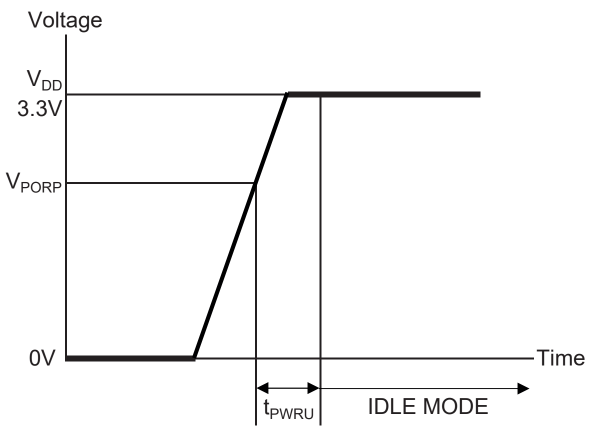


Figure 4: Sensor behaviour at power-up

5.2 I²C Communication

The I²C communication is based on the NXP UM10204 I²C bus specification and user manual[1).]
The TEE301 supports the modes “standard“ (100 kHz), “fast mode“(400 kHz) and “fast mode plus” (1 000 kHz).
The sensor works as SLAVE and needs to be queried by a MASTER.

1) Revision 7, 1 October 2021, download from https://www.nxp.com/webapp/Download?colCode=UM10204&location=null.
The document is located behind a login access barrier.

5.3 I²C Address Pins (2, 7)

The sensor's I²C base address is 0x4A (without R/$\overline{W}$ bit). Pins A1...A3 define the I²C base address.

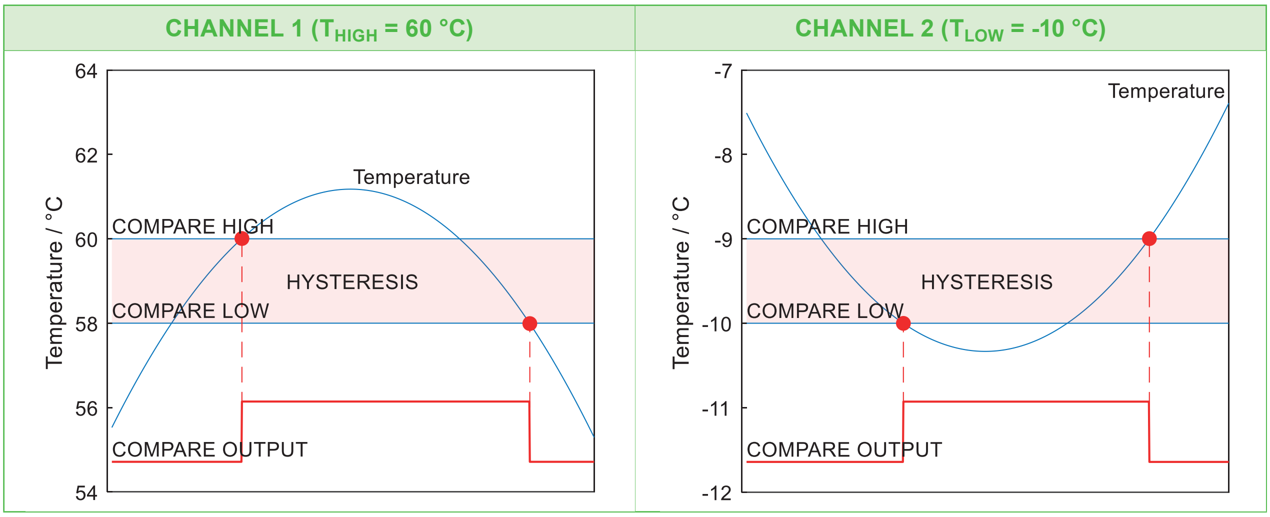
					PIN 7		PIN2				
					A3		A1	R/W	SLAVE Address (unshifted)	SLAVE Address (with $\overline{W}$)	SLAVE Address (with R)
bit #	7	6	5	4	3	2	1	0			
	1	0	0	1	0	1	0	1/0	0x4A	0x94	0x95
	1	0	0	1	0	1	1	1/0	0x4B	0x96	0x97
	1	0	0	1	1	1	0	1/0	0x4E	0x9C	0x9D
	1	0	0	1	1	1	1	1/0	0x4F	0x9E	0x9F

5.4 ALERT Pin (3)

The ALERT pin indicates low when the temperature is in the range:

- T = [T_{LOW}, T_{HIGH}] = [-10 °C, +60 °C]

If a temperature measurement values goes outside this range the ALERT pin will output high, which will remain high as long as the corresponding value will go back inside the given temperature range including the hysteresis as shown in the plots below



5.5 Reset Pin (6)

As soon as the falling edge on the reset pin is in the logic "0" blue area (low signal), as shown in the diagram below, the device goes into the reset and remains in this state as along as the voltage on the reset pin remains in the logic "0" area. In particular, during this phase, the device is in the cycle of being powered-up and reset immediately after power-up, thus the current consumption corresponds to the power-up current, approximately 1 mA. During the reset time, the device will not respond to any request on the I²C interface and set all digital outputs into a tristate mode.

As soon as the voltage rising edge reaches the logic "1" green area (high signal), the devices will be powered-up properly. The default (non-reset) pin state is high (typically 3.3 V). If unused, the reset pin can be connected to the V_{DD}.

Already small voltage drops (100 ns) on the reset pin will lead to the reset state. Thus, it is recommended to use an appropriate capacitor to avoid unwanted resets.

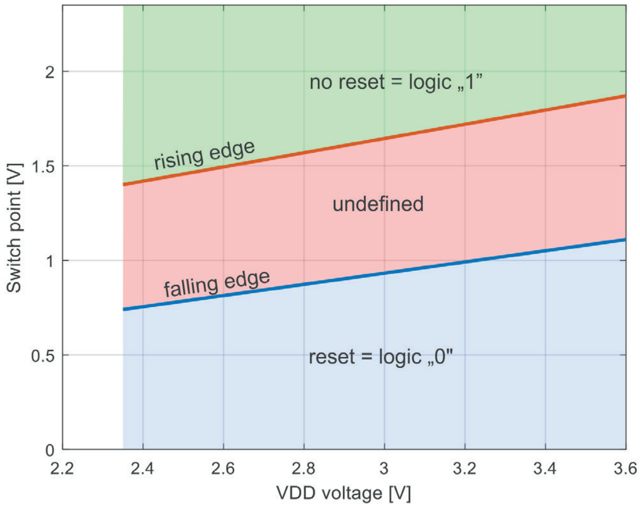


Figure 5: I/O input reset pin behavior versus the V_{DD} voltage

6 Sensor Communication

6.1 Command Overview

Measurement commands

Measurement mode	Description	CMD Hex Code		Repeatability
	I²C clock stretching	MSB	LSB	
Single-shot	enabled	0x2C	06	High
			0D	Medium
			10	Low
	disabled	0x24	00	High
			0B	Medium
			16	Low
	Measurement interval	MSB	LSB	
Periodic	0.5 mps	0x20	32	High
			24	Medium
			2F	Low
	1 mps	0x21	30	High
			26	Medium
			2D	Low
	2 mps	0x22	36	High
			20	Medium
			2B	Low
	4 mps	0x23	34	High
			22	Medium
			29	Low
	10 mps	0x27	37	High
			21	Medium
			2A	Low

Further commands

CMD Hex Code	Description
0xE000	Fetch periodic measurement data
0x30A2	Soft Reset
0x3093	Break
0x306D	Heater ON
0x3066	Heater OFF
0x3041	Clear status register
0xF32D	Readout of status register
0x06	I^2C Reset at general call address 0x0

6.2 Measured Data Format

Temperature [°C] = -45 + 175 · (Temperature MSB * 256 + Temperature LSB) / $(2^{16}-1)$

6.3 Measurement Modes

There are two different operation modes to communicate with the sensor:

1. Single Shot Measurement

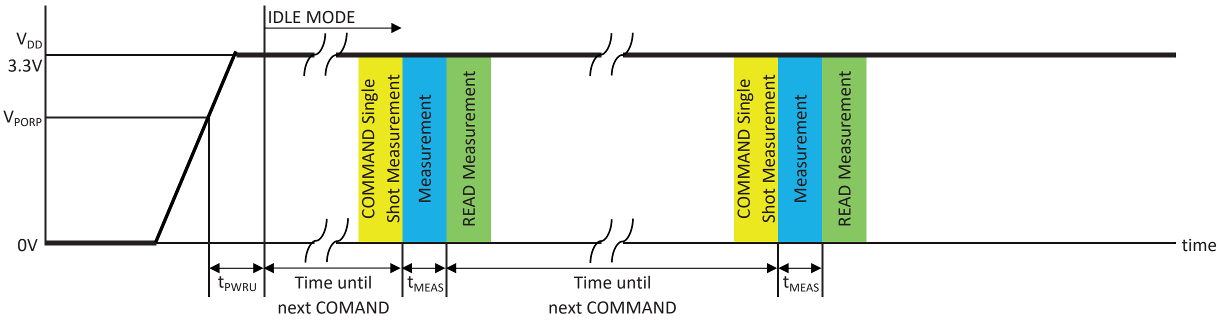


Figure 6: Single shot measurement

2. Periodic Measurement

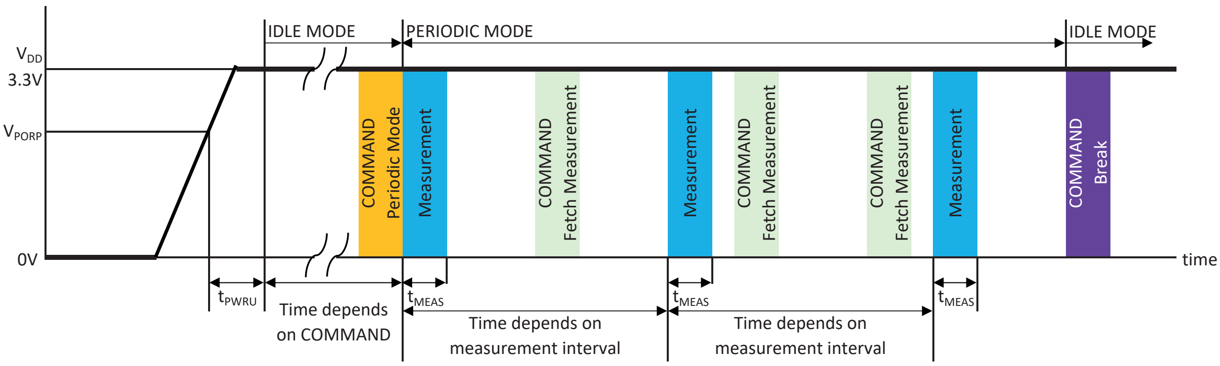


Figure 7: Periodic measurement

6.4 Single Shot Measurement

The command initiates a single measurement, the measured data is available for query after t_{MEAS}.
I²C clock stretching enabled: waiting for the end of the measurement during command execution.

Condition	CMD Hex Code		Repeatability
I²C clock stretching	MSB	LSB	
Enabled	0x2C	06	High
		0D	Medium
		10	Low
Disabled	0x24	00	High
		0B	Medium
		16	Low

A single-shot measurement is started after the command has been received successfully. The readout of the calculated T value is started by sending the I²C address again in read mode:

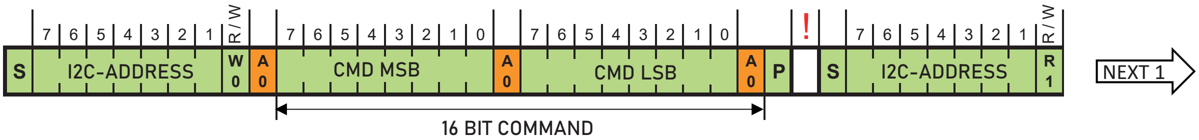


Figure 8: Start single-shot measurement readout

In case a command with clock stretching enabled has been issued, the slave holds SCL low until the calculation has been finished:

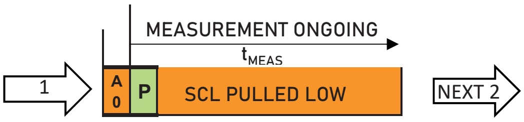


Figure 9: Clock stretching during measurement

In case a command without clock stretching has been issued, the slave does not acknowledge (NACK) a read header as long as the calculation has not been finished:

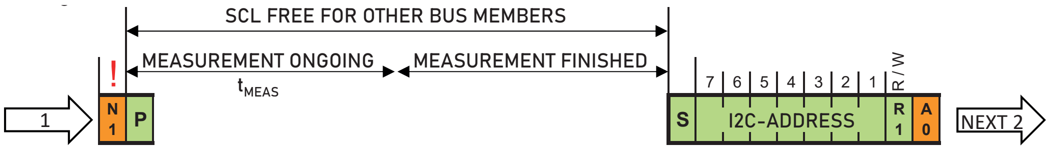


Figure 10: Poll for meauring values until ACK

After the calculation is finished, the slave responds to a read header with a pair of data words, each of them is followed by an 8 bit checksum (CRC8). The data word contains the temperature value. The master has to acknowledge each single data byte by an acknowledge (ACK), otherwise the slave will stop sending any further data and wait for a stop condition (P):

Data Bit From Master to Slave
Data Bit From Slave to Master

! = Note the deviation!

S = Start condition
P = Stop condition

R = Read Bit
W = Write Bit

A = Acknowledge (SDA low)
N = Not Acknowledge (SDA high)

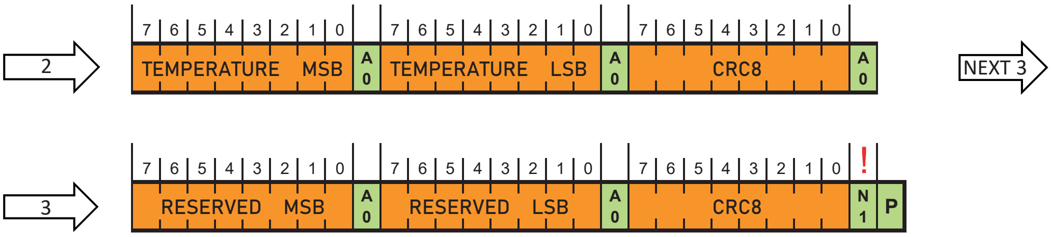


Figure 11: Measured value readout

6.5 Periodic Measurement

Once issued, measurements and calculations are started automatically with a given measuring interval and resolution.
This mode does not support clock stretching.

Condition	CMD Hex Code		Repeatability
Measurement interval	MSB	LSB	
0.5 mps	0x20	32	High
		24	Medium
		2F	Low
1 mps	0x21	30	High
		26	Medium
		2D	Low
2 mps	0x22	36	High
		20	Medium
		2B	Low
4 mps	0x23	34	High
		22	Medium
		29	Low
10 mps	0x27	37	High
		21	Medium
		2A	Low

> **Please note:** A short measurement interval can influence the power consumption and therefore the self-heating of the sensor.

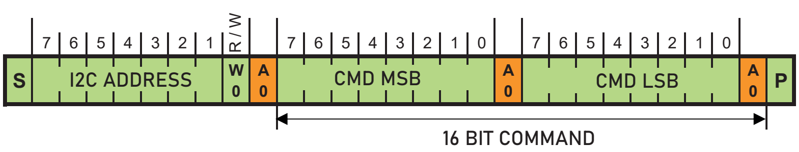


Figure 12: Periodic measurement commands

A periodic measurement command with a different measurement interval / resolution can be issued at any time, but the calculated value will be updated according the new settings earliest after a measurement with the new settings has been performed.

6.6 Fetch Periodic T Measurement Results (0xE000)

Readout of calculation results in periodic measurement mode can be performed using the fetch command. This is similar to the readout of measurement results in single-shot mode, except that clock stretching is always disabled. The slave will answer with NACK if no measurement results are available.

Command	CMD Hex Code
Fetch data	0xE000

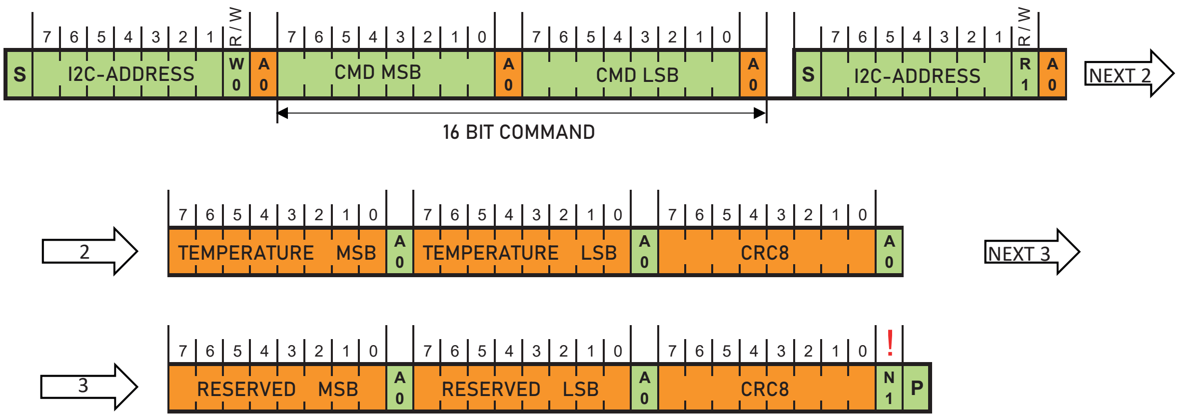


Figure 13: Fetch command

This command is also suitable to retrieve the measured data generated by the power-up procedure.

6.7 Break Command (0x3093)

The periodic measurement mode can be stopped using the break command. After finishing an ongoing measurement, the sensor will enter the idle mode. An ongoing measurement can delay the transition into the idle mode.

Command	CMD Hex Code
Break	0x3093

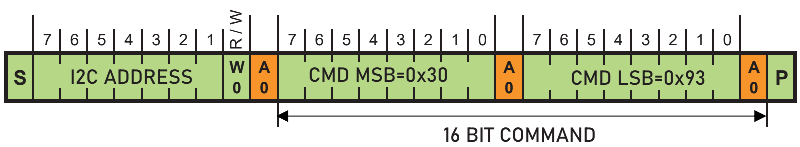


Figure 14: Break command

A single measurement (command) or a reset (command or power-up) both stop the periodic measurement, too.

6.8 Reset Commands (0x30A2, 0x06)

The slave supports multiple commands to reset the device. Once a reset command is received, the device is completely reset, like a reset during power-up. During the reset time, the device will not respond to any request on the I^{2}C interface.
In order to execute the reset on a specific device, the command “Soft Reset” can be used. This forces the system to execute the startup procedure without the need to remove the power supply. The protection will be re-established with the “Soft Reset”.

Command	CMD Hex Code
Soft reset	0x30A2

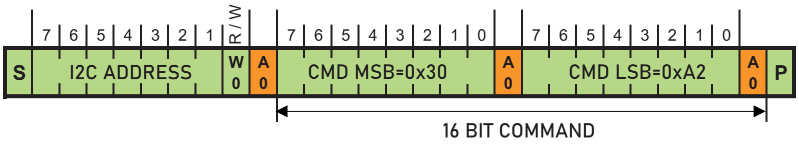


Figure 15: Soft reset

In order to reset all devices on the bus, the master can use the “General call” mode. This generates a reset (system startup) in all devices on the bus which support this function. The effect is the same as for the “Soft Reset” command.

Command	Hex Code
Address byte	0x00
Second byte	0x06

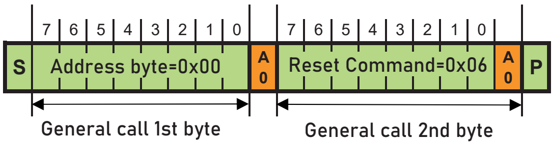


Figure 16: Reset through general call

In order to reset the I²C interface only, keep SDA high while toggling SCL nine times or more. This must be followed by a start condition preceding the next command. This sequence does not affect any configuration, status register or system status.

6.9 Status Register (0xF32D)

The sensor implements a 16 bit status register.
Its contents can be read using the following commands:

Command	CMD Hex Code	
	MSB	LSB
Read out Status Register	0xF3	0x2D

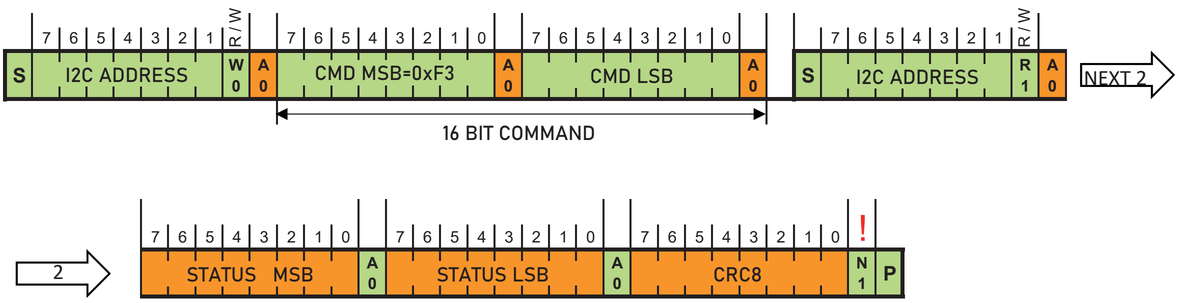


Figure 17: Read out status register

Upon receipt of the following clear command, bits 15, 4 and 3 are cleared in the status register. All other bits remain unaffected:

Command	CMD Hex Code
Clear Status Register	0x3041

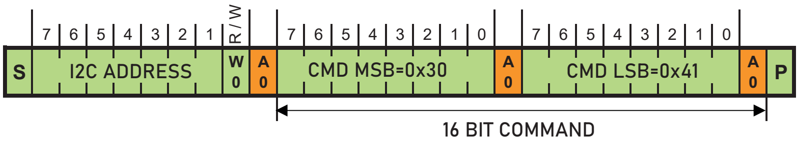


Figure 18: Clear status register

BIT	NAME	DESCRIPTION
15	OVERALL_ERROR	0: none of bits [11:0] set 1: at least one of bits [11:0] set This bit is cleared upon the Clear Status Register command
14	Reserved	-
13	Reserved	
12	Reserved	-
11	Reserved	-
10	T out of RANGE	0: no alert 1: alert (see ALERT pin)
9	Reserved	
8	Reserved	-
7	Reserved	-
6	$T > T_{HIGH}$	These bits are cleared upon “Clear status register 1” command
5	$T < T_{LOW}$	
4	System Reset	0: no reset since status 1 clear 1: POR or I^2C reset This bit is cleared upon the Clear Status Register command
3	POR	0: no POR since status 1 clear 1: POR occurred This bit is cleared upon the Clear Status Register command
2	Reserved	-
1	Reserved	-
0	CRC	1: checksum of the latest write transfer failed

Table 10: Status Register

6.10 CRC Calculation

Response data words/memory write data are protected by a CRC8 checksum:

Property	Value
Name	CRC8
Width	8 bit
Polynomial	0x31 (x8 + x5 + x4 + 1)
XOR input	0xFF
Reflect input	False
Reflect output	False
XOR output	0x00

Figure 19: CRC8 properties

6.11 Package / Dimensions

The TEE301 sensor is provided as a DFN (= Dual Flat No Leads) package.

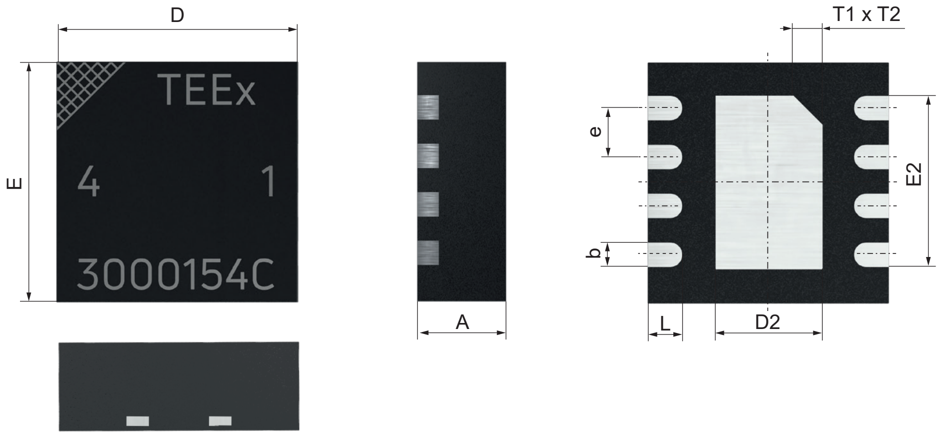


Figure 20: Package layout

PARAMETER	SYMBOL	MIN.	NOM.	MAX.	UNIT	COMMENT
Package width	D	2.40	2.50	2.60	mm	
Package length	E	2.40	2.50	2.60	mm	
Package height	A	0.80	0.90	1.00	mm	
Leadframe height	A3		0.20		mm	Not shown in the drawing
Pad pitch	e		0.50		mm	
Pad width	b	0.20	0.25	0.30	mm	
Pad length	L	0.30	0.35	0.40	mm	
Thermal pad length	D2	1.00	1.10	1.20	mm	
Thermal pad width	E2	1.70	1.80	1.90	mm	
Thermal pad marking	T1xT2		0.30 x 0.30		mm	Indicates pin 1

Table 11: Package dimensions

6.12 Tape and Reel Packaging

The TEE301 has a Moisture Sensitivity Level (MSL) of 1, according to IPC/JEDEC J-STD-020. It is recommended to further process the TEE301 sensors within 1 year after date of delivery.

Dimensions T&R in mm:

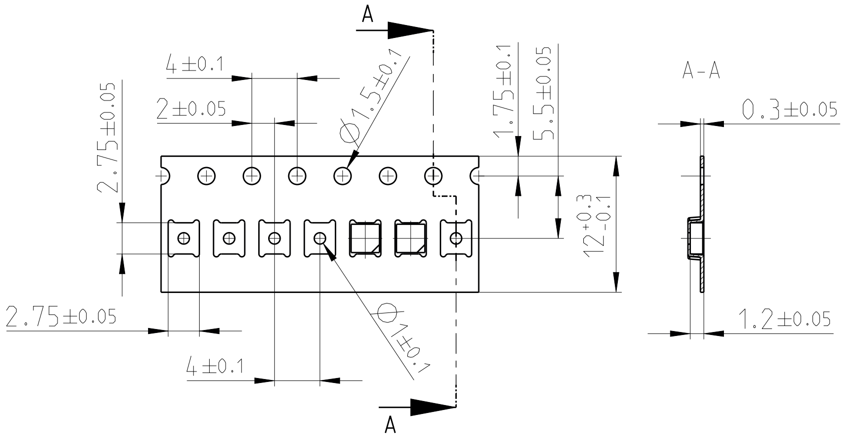


Figure 21: Tape layout

Reel size 330.2 mm (13"), Leader 520 mm (20.5"), Trailer 1240 mm (48.8").

Orientation on the tape:

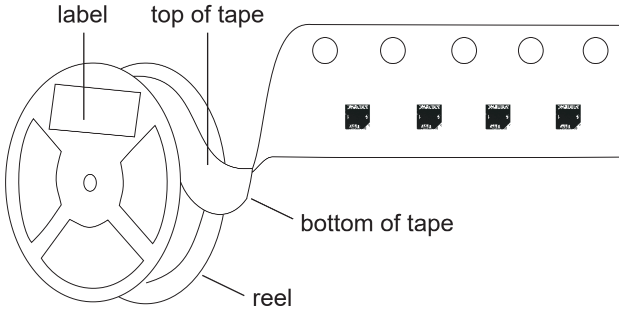


Figure 22: Orientation on the tape

6.13 Traceability

The laser marking upon the sensor's top side can be used for sensor identification / traceability.

A triangular mark at the top left indicates pin 1.

The upper line represents the designation of the component and consists of up to 6 characters. The "x" is a placeholder for the exact type, e.g. 301.

The remaining characters are a tracking code and are used by the manufacturer for identification.

Figure 23: TEEx laser marking

6.14 Ordering Information

TYPE		TAPE AND REEL PACKAGING	
TEE301	TEE301	2500 sensors	TR2,5

Ordering example:

TEE301-TR2,5

Type: TEE301
Packaging: 2500 sensors

6.15 Recommended Layout

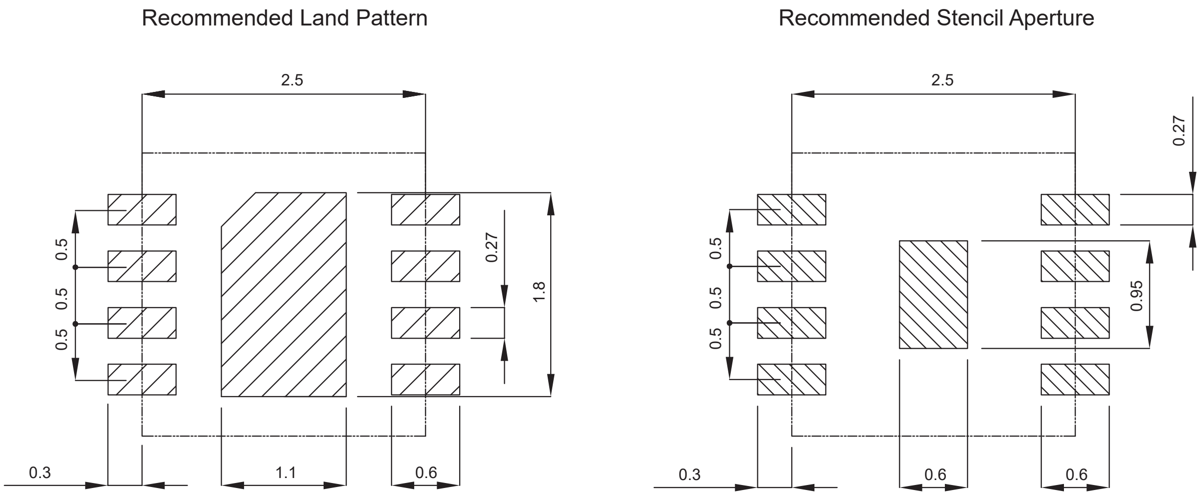


Figure 24: Recommended land pattern and stencil aperture

7 Quality

The TEEx qualification is performed based on the JEDEC JESD47 qualification test method.
The device is fully RoHs and WEEE compliant.

8 Additional Documentation

DOCUMENT	DESCRIPTION	LINK
TEE301 Handling Instructions		www.epluse.com/tee301
TEE301 CRC8 Code Example	Code samples for Arduino and Raspberry PI	https://github.com/EplusE

Table 12: Applicable documentation

9 Revision History

DATE	VERSION	PAGE(S)	CHANGES
June 2022	1.0	1-20	Initial release
December 2022	1.1	1-20	Chapter 6.14 Ordering Information updated Fig. 21: ASIC orientation on tape corrected

Table 13: Revision history