SE-T-01

IQRF temperature sensor

User's guide

Preliminary

Smarter Wireless. Simply.

Description

SE-T -01 is a compact digital high-accuracy temperature sensor unit in the metallic case. It is intended for usage with a control unit connected via the I²C serial bus via the 1.5 m cable, e.g. with IQD-SE03-03 by MICRORISC which supports connectivity within the IQRF wireless Mesh network. The temperature is measured and handled in the format conforming to the IQRF Interoperable standard for sensors. The sensor unit is calibrated independently on the control device and allows recalibration by the user.

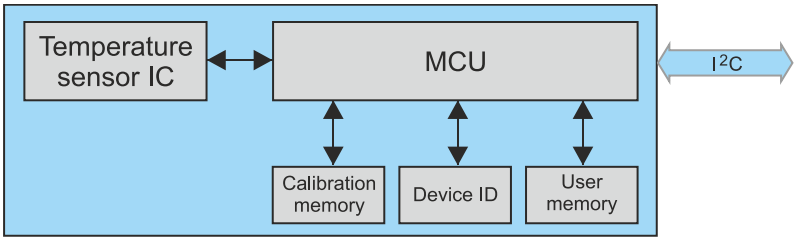
Key features

- Temperature range from -20 °C to 85 °C or from -40 °C to 85 °C
- Resolution 0.0625 °C, accuracy ±0.2 °C
- Factory calibrated, one point recalibration possible at the user
- Internal memory to store calibration parameters. No pairing with the control unit for calibration purposes is required.
- High reliability and long-term stability
- Unique device identification and unique device type identification
- MCU and user generic-purpose non-volatile memory
- I²C serial communication with the control unit
- Device address configurable from the factory on request
- Fast start-up and measurement time
- Extra-low power, battery lifetime for years even for a small cell
- Supporting data formats according to the IQRF Standard specification for sensors
- Stainless steel enclosure, water-resistant, IP67
- Plug & play compatible with IQRF wireless control unit IQD-SE03-03

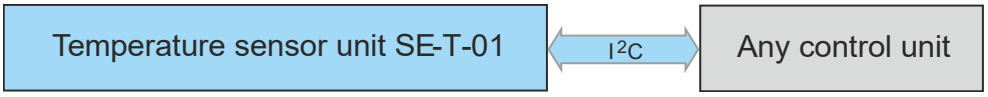
Applications

- Thermometers and thermoregulators
- Telemetry
- IQRF Beaming sensors
- Battery operated applications
- Medicine, storage monitoring, food processing industry etc.
- IQRF interoperable devices
- Smart house
- Internet of Things

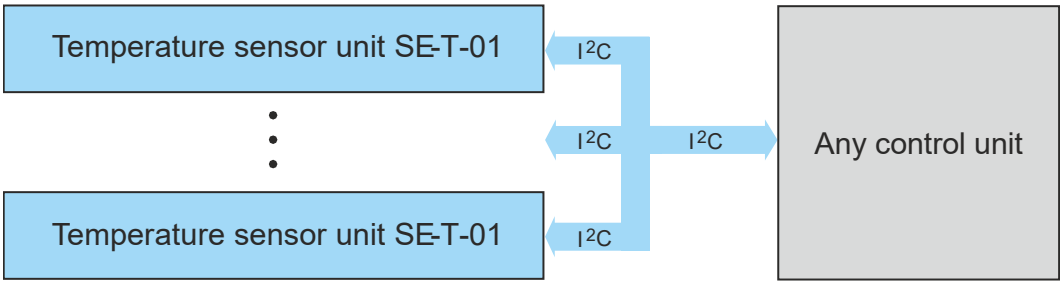
Block diagram



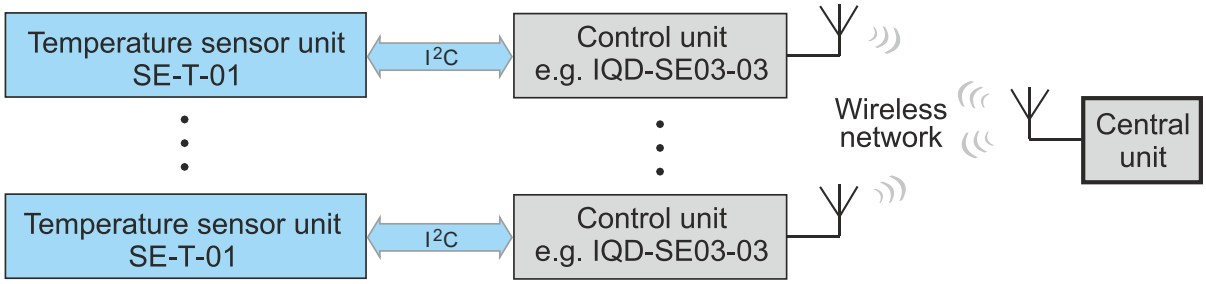
Typical usage



SE-T-01 sensor unit connected to any control unit with I²C Master.



More SE-T-01 sensor units (with different I²C addresses) connected to any control unit via a single I²C bus.



More control units IQD-SE03-03, each with sensor unit SE-T-01 connected, within an IQRF wireless network, possibly utilizing Beaming.

Technical specifications

***Typical** values (until otherwise specified)*

Power supply	From 2.5 V to 3.6 V DC, stabilized
Supply current	
Quiescent	Less than 100 nA (No operation, e.g. after the Stop condition on I²C bus)
Operating	See table Power consumption and command duration.
Temperature measurement	
Range	From -20 °C to 85 °C
Resolution	0.0625 °C
Accuracy	±0.2 °C. See diagram *Temperature accuracy.*
Long-term drift	0.03 °C / year max.
Temperature sensor IC	STS31-DIS by Sensirion
Timing	
Power-up	0.25 ms
Performing commands	See table Power consumption and command duration.
Memory	Endurance 10 000 write cycles min. User memory 32 B
Ambient temperature	
Operating	
Fixed cable installation	-40 °C to +85 °C
Flexible cable installation	-20 °C to +85 °C
Storage	-20 °C to +85 °C
Ambient environment	With a common level of electromagnetic noise
Enclosure	Stainless steel DIN 1.4571, diameter 5.0 mm, length 50 mm, protected by Polyolefin heat-shrink tube
Cable	4-wire, not shielded, PVC sheathed, diameter 5 mm, length 1.5 m
Ingress protection	IP67
Weight	53 g
I²C communication interface	
Voltage levels	2.5 V to 3.6 V, according to the actual power supply
Internal pull-up resistor on SCL and SDA lines	25 kΩ
Mode	I²C Slave
Bus clock frequency	100 kHz max.
Delay between some I²C sequences	10 µs
Address	Configurable from the factory on request. Default 0x1A

Absolute maximum ratings

Stresses beyond those values may cause permanent damage to the device. Exposure to maximum rating conditions for extended periods may affect device reliability.

Supply voltage (V_{DD})	-0.3 V to 4.0 V DC
Voltage on pins 2 (SCL) and 1 (SDA) vs. GND	-0.3 V to V_{DD} + 0.3
Ambient temperature	
Under bias	
Fixed cable installation	-40 °C to +85 °C
Flexible cable installation	-20 °C to +85 °C
Storage	
Fixed cable storage	-40 °C to +85 °C
Flexible cable storage	-20 °C to +85 °C

Hardware

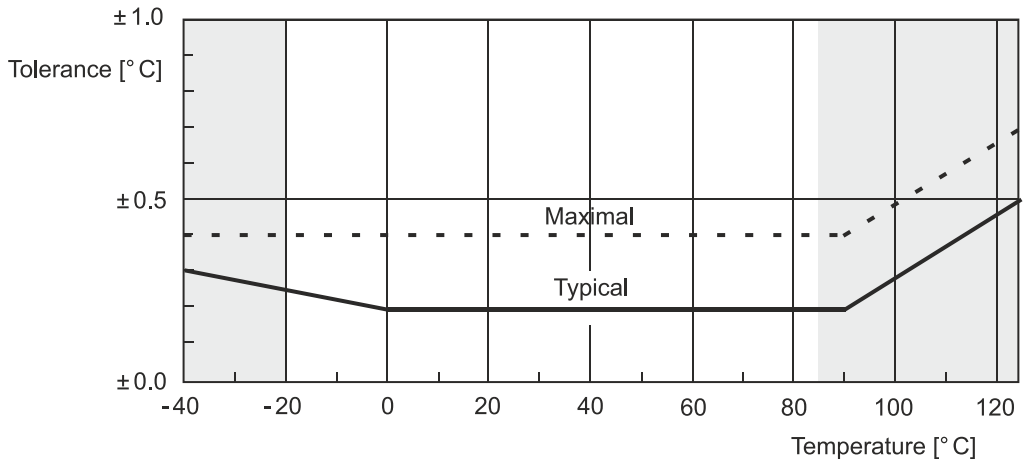
Power supply

The thermometer must be supplied by DC voltage stabilized on the control unit side. No internal LDO voltage regulator is equipped.

It is recommended to supply the thermometer from a 3.6 V battery, e.g. a Lithium Thionyl Chloride (Li-$SOCl_2$) cell and use a linear voltage regulator to maintain a steady 3.0 V output voltage.

Temperature sensor IC

Digital temperature sensor IC is used.



Temperature accuracy. The shaded areas are out of the allowed temperature range.

MCU

Internal control (including calibration) and external interfacing is ensured by an MCU inside the SE-T-01 enclosure.

Memory

Non-volatile (Flash) memory is intended as storage for calibration (and possibly other configuration parameters), device identification, and user general-purpose memory. The number of write cycles is limited.

I²C bus

The interface on the control unit side must properly be designed with respect to requirements for digital signals transferring via the cable at the given communication speed in the given environment (equipped with diodes, transils etc.).

I²C bus requires pull-up resistors on both communication lines. Weak pull-up resistors about 25 kΩ are provided internally inside the thermometer. For higher communication speed, harsh environment, etc., stronger pull-ups (e.g. 10 kΩ) can be connected on the control device side.

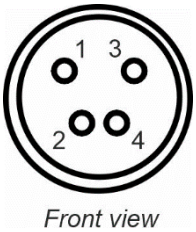
The recommended I²C bus speed is up to **100 kHz**.

Connector

The cable with female connector MA08FAHD04ST-1.5M by FINEcables is used.

Pin assignment

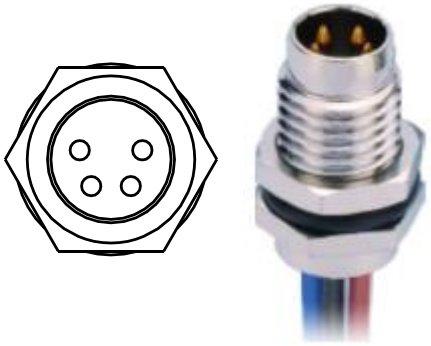
Pin	Name	Description
1	SDA	I^2C serial bus data, input / output
2	SCL	I^2C serial bus clock, input / output (for clock stretching only)
3	GND	Ground
4	VCC	Power supply



Front view

Fitting counterpart

The control unit must be equipped with a fitting counterpart panel mount male connector, e.g. MB08MSAFI04ST-W5 by FINEcables.



Operation

The functionality of the thermometer SE-T-01 should completely be managed from the control unit attached. The communication passes via a proprietary SE-T-01 protocol over the underlying I²C layer.

The sensor unit SE-T-01 spends all the time in quiescent mode except for short periods when is responding to incoming commands. The wake-up is initiated by starting I²C communication. After performing the given task the unit goes to quiescent mode again.

Power consumption and command duration

The following table shows the power consumption and execution times for a single command to read the temperature (at 100 kHz bus clock).

Supply voltage	Pull-ups	Max. standby current	Temperature reading			
			Max. current	Average current	Total consumption	Duration
3.3 V	10 kΩ	100 nA	2.6 mA	1.9 mA	34.0 nWh	19.3 ms
3.0 V	10 kΩ	100 nA	2.4 mA	1.8 mA	28.8 nWh	19.3 ms
3.3 V	5 kΩ	100 nA	3.2 mA	2.5 mA	44.1 nWh	19.3 ms
3.0 V	5 kΩ	100 nA	3.0 mA	2.3 mA	37.1 nWh	19.3 ms

Calibration

The temperature measurement is factory calibrated, linearized, and compensated for supply voltage dependencies.

Moreover, the temperature measurement can be recalibrated anytime later on by the user. The one-point calibration is used. The measured value provided by the sensor IC is corrected by the addition of the calibration value stored in the Configuration memory of the sensor unit. The format of the calibration value is also in IQRF Standard sensor format.

For recalibration, compare the measurement results with those from a calibration standard, determine the new calibration value (the old calibration value used during calibration measurement must be taken into account), and write it into the Configuration memory using the *Write memory* command.

Memory

The thermometer contains MCU with persistent Flash memory partially available for data storing (read / write). The memory consists of 14-bit words. Total memory capacity is 2K (2048) words.

When the word is read or written, the least significant byte of the word (bits 0-7 of the word) comes first, and then the most significant byte (bits 8-13 of the word mapped to bits 0-5 of the byte) follows. Bits 6-7 of the most significant byte are ignored during the writing and zeroed during a valid memory reading.

Memory map

Address [hex]	Content	Read / Write
000 – 39B	*Undocumented*	–
39C – 39F	Firmware ID	R
3A0 – 3AF	Device ID	R
3B0 – 3BF	Device Type	R
3C0 – 3DF	Configuration memory	R/W
3E0 – 3FF	User memory	R/W
400 – 7FF	*Undocumented*	–

Firmware ID

Address [hex]	Content
39C	FW major version (stored at LSB of the word)
39D	FW minor version (stored at LSB of the word)
39E – 39F	Reserved

Device ID

Address [hex]	Content
3A0 – 3A3	Unique 4-byte device ID value encoded in little-endian style (stored at LSBs of the words)
3A4	7-bit I²C device address stored in the LSB. If equals 0xFF (legacy value) then the address is default 0x1A.
3A5 – 3AF	Reserved

Device Type

Address [hex]	Content
3B0 – 3B1	Unique 2-byte device type value encoded in little-endian style (stored at LSBs of the words) 0xFFFF SE-T -01 sensor type Other values *Reserved*
3B2 – 3BF	Reserved

Configuration memory

Address [hex]	Content
3C0	LSB of the 16-bit temperature calibration value (stored at LSB of the word) in 1/16 °C units. Two's complement format is used.
3C1	MSB of the 16-bit temperature calibration value (stored at LSB of the word) in 1/16 °C units. Two's complement format is used.
3C2 – 3DF	Reserved

User memory

The User memory is freely available for storing arbitrary user data.

I²C protocol

The SE-T-01 thermometer works as a Slave on the I²C bus. The I²C protocol is standard, therefore it is not fully described in this document.

At least 10 µs **delay** is necessary between the following I²C protocol sequences: I²C-Start, I²C-Address, and I²C-DataByte.

The I2Cmaster.c library implementing I²C Master in C language is available. It is intended for Custom DPA Handler (thus for the PIC microcontroller inside the IQRF transceiver module).

Clock stretching

The thermometer extensively uses I²C clock stretching according to I²C standard to get time to execute temperature measurement or data processing.

I²C address

The 7-bit I²C device address of the sensor unit is configurable to allow connecting more devices to a single I²C bus. This configuration must be done at the factory on request. The default value is 0x**1A**.

The default I²C address is used in the examples in this document although the actual address might differ. E.g. for 0x1A, the 8-bit value 0x**34** must be sent to the I²C bus for writing and 0x**35** for reading, following the I²C Start Condition.

SE-T-01 protocol

Additionally, SE-T -01 also utilizes another protocol above I²C. It works with temperature formats (including the calibration values) according to the IQRF Sensor Standard defined in the `IQRF-StandardSensor-Vxxx.PDF` specification. This also includes a so-called FRC format optimized for very fast data collection from sensors in the IQRF wireless networks.

Data verification

To detect possible communication failure (especially in a harsh environment), the data transferred via the cable should be verified and the command repeated if failed. E.g., Read Temperature can be verified by CRC. Read Memory and Write memory can be verified by subsequent reading and comparing the data. Note that Memory Write must not be called in a simple infinite loop without avoiding possible Flash memory degradation due to limited endurance.

Standby

The sensor unit spends all the time in very low power standby mode except for short periods when communicating or executing a command. It wakes up automatically when the Start Condition is detected and falls asleep after the Stop Condition again. For higher reliability (especially in a harsh environment), the Stop Condition can be repeated more than once.

Power off

Zero consumption can be reached by disconnecting the sensor unit from power at all. The power-up time is very short.

Read Temperature

Protocol

1. <Start Condition>
2. Write the device address for writing – 0x34.
3. Write “Temperature register” address – 0x00.
4. <Stop Condition> (optional)
5. <Start Condition>
6. Write the device address for reading – 0x35.
7. Read calibrated LSB temperature value in the IQRF Standard temperature format.
8. Read calibrated MSB temperature value in the IQRF Standard temperature format.
9. Read calibrated temperature value in IQRF Standard Temperature 1-byte FRC format.
10. Read LSB temperature calibration value (stored in the Configuration memory) in the IQRF Standard temperature format.
11. Read MSB temperature calibration value (stored in the Configuration memory) in the IQRF Standard temperature format.
12. Read temperature calibration value in IQRF Standard Temperature 1-byte FRC format.
13. Read CRC computed from bytes 7.-12. CRC is compatible with 1-Wire CRC with initial value 0xFF and polynomial $x^8+x^5+x^4+1$.
14. <Stop Condition>

Notes

- The actual temperature value measured by the internal temperature sensor is adjusted by the calibration value (the calibration value is added to the raw value).
- All read bytes except the last one must be I²C acknowledged.
- Not all bytes at points 7.-13. must be read. E.g., if the calibration values should not be read, steps 10 to 13 can be omitted.
- CRC should be verified on the control device (if all bytes at points 7. to 13. are read). Recommended online CRC calculator for testing is the CRC8 Calculator.
- More erroneously read bytes after step 15. are undefined.

Example

Reading the calibrated temperature value +20.3125 °C (0x0145) and the calibration value +0.25 °C (0x0004).

	Item	Acknowledgment	Description
1.	<Start Condition>		
2.	Write 0x34	ACK	I²C address of the device for writing
3.	Write 0x00	ACK	“Temperature register” value
4.	<Stop Condition>		Optional
5.	<Start Condition>		
6.	Write 0x35	ACK	I²C address of the device for reading
7.	Read 0x45	ACK	LSB of the calibrated temperature value
8.	Read 0x01	ACK	MSB of the calibrated temperature value
9.	Read 0x55	ACK	1-byte FRC calibrated temperature value (+20.5 °C)
10.	Read 0x04	ACK	LSB of the temperature calibration value
11.	Read 0x00	ACK	MSB of the temperature calibration value
12.	Read 0x2D	ACK	1-byte FRC temperature calibration value (+0.5 °C)
13.	Read 0x1C	–	CRC value
14.	<Stop Condition>		

Read Memory

Protocol

1. <Start Condition>
2. Write the device address for writing – 0x34.
3. Write the “memory register” address – 0x01.
4. Write the LSB of the memory address.
5. Write the MSB of the memory address.
6. <Stop Condition> (optional)
7. <Start Condition>
8. Write the device address for reading – 0x35.
9. Read LSB of the 1st read memory word.
10. Read MSB of the 1st read memory word.
11. … (optionally read words from the following memory addresses)
12. <Stop Condition>

Notes

- All read bytes except the last one must be I²C acknowledged.
- Reading memory out of the available range for reading returns the word 0xEeEe.

Example

Reading the device ID (the value 0x12345678) from address 0x3A0.

	Item	Acknowledgment	Description
1.	<Start Condition>		
2.	Write 0x34	ACK	I²C address of the device for writing
3.	Write 0x01	ACK	“Memory register” value
4.	Write 0xA0	ACK	LSB of the memory address 0x3A0
5.	Write 0x03	ACK	MSB of the memory address 0x3A0
6.	<Stop Condition>		Optional
7.	<Start Condition>		
8.	Write 0x35	ACK	I²C address of the device for reading
9.	Read 0x78	ACK	LSB of the word @ 0x3A0 = LSB of the device ID
10.	Read [undefined value]	ACK	MSB of the word @ 0x3A0 = Don’t care value
11.	Read 0x56	ACK	LSB of the word @ 0x3A1 = next device ID byte
12.	Read [undefined value]	ACK	MSB of the word @ 0x3A1 = Don’t care value
13.	Read 0x34	ACK	LSB of the word @ 0x3A2 = next device ID byte
14.	Read [undefined value]	ACK	MSB of the word @ 0x3A2 = Don’t care value
15.	Read 0x12	ACK	LSB of the word @ 0x3A3 = MSB of the device ID
16.	Read [undefined value]	–	MSB of the word @ 0x3A3 = Don’t care value
17.	<Stop Condition>		

Write Memory

Protocol

1. <Start Condition>
2. Write the device address for writing – 0x34.
3. Write the “Memory register” address – 0x01.
4. Write the LSB of the memory address.
5. Write the MSB of the memory address.
6. Write 0x55 (required fixed value for security; another value disables writing to the memory).
7. Write 0xAA (required fixed value for security; another value disables writing to the memory).
8. Write LSB of the 1st of the word to be written.
9. Write MSB of the 1st of the word to be written.
10. … *optionally:* Write LSB of the next word to be written (to the following memory address)
11. Write MSB of the next word to be written etc.
12. <Stop Condition>

Notes

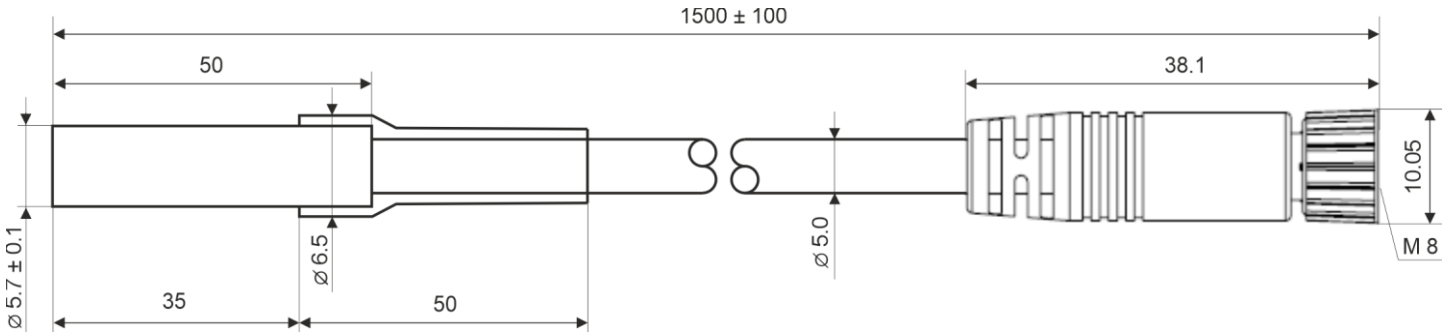
- Writing to the unavailable memory region disables further writing of the current I²C command.
- If the MSB of the last written word is omitted in the command then the last written memory row (32-word wide) is not written at all.

Example

Writing temperature calibration value +0.25 °C (0x0004) to the Configuration memory (address 0x3C0).

	Item	Acknowledgment	Description
1.	<Start Condition>		
2.	Write 0x34	ACK	I²C address of the device for writing
3.	Write 0x01	ACK	“Memory register” value
4.	Write 0xC0	ACK	LSB of the memory address 0x3C0
5.	Write 0x03	ACK	MSB of the memory address 0x3C0
6.	Write 0x55	ACK	Required Unlock memory sequence
7.	Write 0xAA	ACK	Required Unlock memory sequence
8.	Write 0x04	ACK	LSB of the calibration value written to LSB at address 0x3C0
9.	Write [any value]	ACK	Don’t care value written to MSB at address 0x3C0
10.	Write 0x00	ACK	MSB of the calibration value written to LSB at address 0x3C1
11.	Write [any value]	ACK	Don’t care value written to MSB at address 0x3C1
12.	<Stop Condition>		

Mechanical drawings



Dimensions: mm

Product information

Ordering code

SE-T-01	Thermometer sensor unit.

Supplied contents

SE-T-01	Thermometer sensor unit, with I²C device address 0x**1A**.

Recommended options

Custom I²C address	A value different from 0x1A is available on request.
MB08MSAFI04ST-W5	Counterpart connector (male). Panel mount, with 5 cm wires.
IQD-SE03-03	Control device by MICRORISC with wireless IQRF network connectivity, Beaming supported.

Document history

210303	First release

Sales and Service

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Partners and distribution

www.iqrf.org/partners

Quality management

ISO 9001 : 2009 certified

Complies with directives 2011/65/EU (RoHS) and 2012/19/EU (WEEE).

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