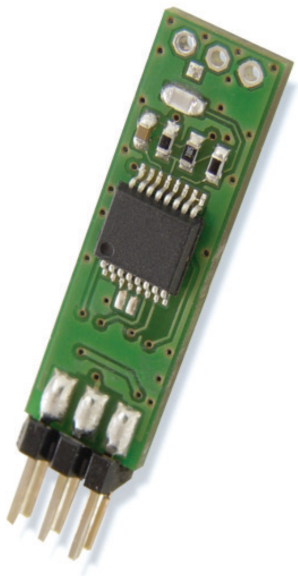
DATA SHEET

Thermocouple module with digital I²C-Interface - THMOD-I²C

Description



Characteristic features

- Industrial temperature measuring method
- Wide measuring range, -270...+1360 °C
- Digital I²C-interface
- Simple integration to micro-controller
- Scope of supply with thermocouple, Type K
- Calibrated and ready-to-use
- Miniaturised dimensions
- Optimum price performance ratio
- Customer specific product variants and OEM-models possible

Areas of application

- Micro-controller
- Instrumentation
- CONRAD C-Control
- Customer specific products

Technical data

Thermocouple module THMOD-I²C	
Measuring principle	Thermoelectric voltage measurements (Seebeck-Effect)
Signal processing	Digital in ASIC
Measuring range	type -300 -270...+300 °C
	type -800 -270…+800 °C
	type -1370 -270…+1370 °C
Resolution	T1 -300 ca. 0,1 K (Typ J) T2 -800 ca. 0,2 K (Typ J) T3 -1370 ca. 0,5 K (Typ J)
Temperature measurement-connection point	-32…+97 °C, class B
Module response time	< 30 msec.
Dimensions	9 x 46,0 x 5,0 mm
Operating voltage	6…24 V
Current consuption	< 3 mA
Model	SMD-Module
Connection	Pin strip, 6-pin, RM 2.54 mm
I²C-Interface	100 / 400 kHz, Adress 0x78
Article	**Art.-No.**
Thermocouple module type -300	THMOD-I²C-300
Thermocouple module type -800	THMOD-I²C-800
Thermocouple module type -1370	THMOD-I²C-1370

Features

Thermocouples are very widely used in industry and are considered as the standard method for measurement of temperatures over a wide measuring range. For example, with cheap NiCr-Ni thermocouples, a temperature range of -270...+1360 °C can be realised.

While using a thermocouple in combination with a micro-controller, the relatively low thermovoltage should be properly amplified. Since thermocouple measures relatively the thermoelectric voltage of the second pole, additionally absolute temperature measurement is also always required.

With the help of this thermocouple module, simple method is possible to realise a temperature measurement over a wide measuring range with a micro-controller. The module takes care of both the measurement of thermovoltage as well as determination of temperature at the connection point. A high resolution, 14 Bit A/D-converter is also already integrated in the ASIC and both measurements are made available at the I²C-interface.

Therefore, the processing in the micro-controller is limited to simple application of a calculation. Since the module is calibrated ex factory over thermo voltage, no additional calibration is required by the user.
To simplify the product-development, an USB-I²C-Adapter and a PC-Software is available for the display and data recording – please send us your enquiry!

B+B Thermo-Technik GmbH | Heinrich-Hertz-Straße 4 | D-78166 Donaueschingen
Fon +49 771 83160 | Fax +49 771 831650 | info@bb-sensors.com | bb-sensors.com

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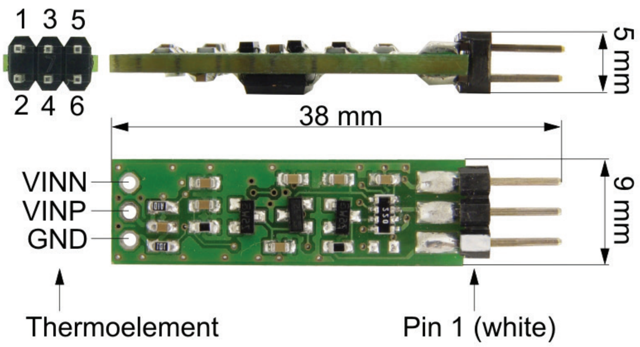
Application notes

In the scope of supply, a thermocouple type K is included for test purposes, which is suitable in the range of Teflon insulation up to approx. 250 °C. For higher application temperatures, the insulation must be removed or for example, a metal sheathed thermocouple should be used.
The operating voltage of 6 to 24 V is stabilised in the module to 5 V. The internal voltage of 5 V also serves as the reference level for the digital I²C-communication. Other options, for example, with 3.3 V or 5 V operating voltage are also available as special models.
While connecting the measuring probes over longer routes, the I²C-Bus, which is used externally out of the device, should not be used internally, in order to avoid coupling of interferences to the device internal communication. The EMV-guidelines are to be followed and application of shielded lines are to be recommended.
By short time interruption of operating voltage, a RESET of the ASIC can be caused. If there is a provision of switching off the operating voltage, then the pullup resistance of the I²C-Bus must be connected to the switched voltage.

Connection layout of the plugs

Pin	Title	Function
1 (white)	VDD	Operating voltage 6 ... 24 V
2	GND	Ground
3	SDA	Serial data I²C
4	SCL	Serial counter I²C
5	---	not used
6	---	not used



I²C-Interface

The communication corresponds to I²C protocol. The default address of the component is 0x78 and the component can always be communicated under this address. Additionally, a second address can also be programmed during configuration ex factory, through which the sensor can be addressed.

At the address 0x78, 4 Bytes can be read. The following assignment is applicable:

Data

0x78	Byte_0	MSB Thermovoltage
	Byte_1	LSB Thermovoltage
	Byte_2	MSB Connector temperature
	Byte_3	LSB Connector temperature

Scaling of measured values

Both the thermovoltage as well as the temperature of the connection point are transferred as 15 bit value (bit 0 - 14). From the 15 bit measured value, the thermovoltage is used as 14 bit resolution, the least significant bit (0, 1) can be ignored. In case of temperature connection point, the 12 bit resolution is used, the least significant bit (0-2) can be ignored. The most significant bit (15) is always 0 during normal operation and in case of error, it is set to 1.

The following scaling is applied for measured values:

Thermovoltage	Typ -300
Numeric value via I²C Interface	0x 0000...7FFF dec. 0...32767
Physical value	-12,500...20,268 mV
Measuring range	32,768 mV
Resolution	2 µV

Thermovoltage	Typ -800
Numeric value via I²C Interface	0x 0000...7FFF dec. 0...32768
Physical value	-12,500...53,036 mV
Measuring range	65,536 mV
Resolution	4 µV

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Thermovoltage	Typ -1360
Numeric value via I²C Interface	0x 0000...7FFF dec. 0...32767
Physical value	-12,500...85,804 mV
Measuring range	98,304 mV
Resolution	6 µV

Termperature channel	all models
Numeric value via I²C Interface	0x 0000 ... 7FFF dec. 0... 32767
Physical value	-32...95,996 °C
Scaling	T (°C)=V / 256 - 32

Determination of temperature

The modules are universal to use, and in principle, suitable for all thermocouples. The included thermocouple is a K type with material-combination NiCr-Ni. The following examples refer to the module -T1 and included thermocouple. The connection of the thermocouple must be done with the correct polarity, otherwise the temperature will be measured incorrectly. From the respective module variants, the usable voltage range is so selected that the specified temperature measuring range can be realised with Fe-CuNi thermocouple (type J), as well as with NiCr-Ni thermocouples (type K). Since the NiCr-Ni thermocouples produce a lower Seebeck voltage as compared to Fe-CuNi (type J) thermocouple, the measuring range is larger with NiCr-Ni thermocouples, with somewhat lower temperature resolution. Because of this, for example, the module type-800 with application of NiCr-Ni thermocouple can be used up to approx. 1200 °C. The first channel measures the thermovoltage. The scaling is defined, that 16 bit integer arithmetic can be applied for the calculations and table interpolations. The scaling of measured values depends on the used module and is linear to thermovoltage. The second channel measures the absolute temperature at the connection point with a Pt1000 resistance thermometer. The scaling is optimised on the integer processing in the micro controller and is linear to the temperature. The temperature is to be calculated mathematically. For this purpose, both channels must be calculated together. First the thermovoltage is measured, which is read over the first two bytes at address 0x78 over the I²C-Bus. The first byte is the MSB, and the second byte is the LSB. The uppermost bit is used for error detection and is not included into the calculation. Afterwards, the temperature is determined at the connection point, for which the second and third bytes are read. The second byte is the MSB, and the third byte is the LSB. The uppermost bit is used for error detection and is masked. The value corresponds to the temperature in 1/256 °C, with offset shift of -32 °C.

Corresponding to the measured temperature at the connection point and depending upon the used thermocouple, a correction value is worked out (for type K see table 1, right 3 columns). Then the correction value is added to the numeric value of the thermovoltage, so that the temperature at the connection point is added with correct sign quasi as thermovoltage on the measured thermovoltage.

With the intermediate results as shown in table 2, the temperature of the measuring point is determined through interpolation.

Example: This is for a Module -300 with NiCr-Ni Thermocouple (Type K). The 4 Byte I²C-Data at the address 0x78 in HEX is read like this:

60 85 3E 00

The thermovoltage (0x6085, dec 24709) is 12.209 mV. The temperature value of the connection point (0x3E00, dec 15872), results in a temperature value 30.0 °C (see table 1). For this temperature and the Module -300, the correction value is 1203 digits. Added to the numeric value of the thermo voltage results in 25912 digits thermovoltage. With this value, one can now interpolate in table 2 and the measured value comes out as 330 °C at the measuring point.

Correction value of connection point

Digit	Temp.	mV	-300	-800	-1360
512	-30	-1,156	-1156	-578	-385
3072	-20	-0,778	-778	-389	-259
5632	-10	-0,392	-392	-196	-131
8192	0	0	0	0	0
10752	10	0,397	397	199	132
13312	20	0,798	798	399	266
15872	30	1,203	1203	602	401
18432	40	1,612	1612	806	537
20992	50	2,023	2023	1012	674
23552	60	2,436	2436	1218	812
26112	70	2,851	2851	1426	950
28672	80	3,267	3267	1634	1089
31232	90	3,682	3682	1841	1227

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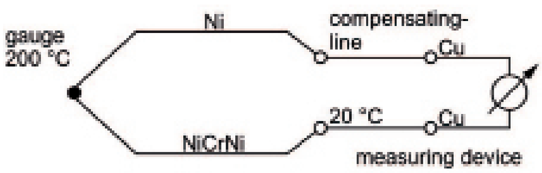
Scaling of thermo voltage

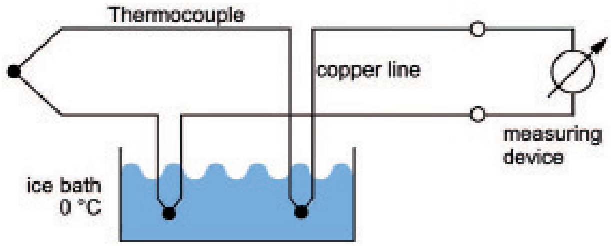
Temp.	mV	-300	-800	-1360
-200	-5,891	6609	3305	2203
-100	-3,554	8946	4473	2982
-50	-1,889	10611	5306	3537
0	0	12500	6250	4167
50	2,023	14523	7262	4841
100	4,096	16596	8298	5532
200	8,138	20638	10319	6879
300	12,209	24709	12355	8236
400	16,397	28897	14449	9632
500	20,644	-	16572	11048
600	24,905	-	18703	12468
700	29,129	-	20815	13876
800	33,275	-	22888	15258
900	37,327	-	24913	16609
1000	41,276	-	26888	17925
1100	45,119	-	28810	19206
1200	48,838	-	30669	20446
1300	52,410	-	32455	21637
1370	54,819	-	-	22440

The thermoelectric effect

The temperature measurement with thermocouples is based on the Seebeck-Effect: At the junction point of two different metals, a temperature dependent contact voltage originates.
Therefore, a thermocouple or thermopair consists of two point shaped wires of different metals or metal alloys joined together. If this junction point is heated up, a voltage can be measured at the ends.



However, in practice, now it is not possible to have only one thermopair in a current circuit. There must be at least one more point at which the ends are brought together or another metal, e.g. a modified copper spool of moving coil instruments. It contains further thermopairs from which the individual thermo voltages are added in the current circuit. In the end, the sum is the total of all thermo voltages at the instrument. Now, if one takes care that transfer at copper of the measuring system is done at a point, for which the temperature is known, the basis of temperature of „connection point“ and thermo voltage at the temperature of the thermocouple can be determined.
In laboratory applications, the connection point can be created in ice water. In this case, the measured thermovoltage corresponds to the Seebeck-voltage of the used thermocouples.



Usually the temperature connection point is determined by means of an absolute measurement method, for example with a PT 1000. Then, it is possible to mathematically compensate the temperature of the connection point.
In practice, the connection of thermocouples is done over uniform leads, which are either of the same material or with expensive inert metal elements or from an alloy which has the same thermal data.

Then the extension is normally up to the connection point, where the temperature is again compensated over an absolute temperature measurement.

As per DIN IEC 584-1 (DIN EN 60 584-1), the following thermopairs are standardised.

Identification letter	Symbol	Measuring range in °C	Thermovoltage in µV
E	NiCr-CuNi	-200...+1000	-8825...+76373
J	Fe-CuNi	-210...+1200	-8095...+69553
K	NiCr-Ni	-200...+1372	-5891...+54886
N	NiCrSi-NiSi	-200...+1300	-3990...+47513
T	Cu-CuNi	-200...+400	-5603...+20872

Without inert metal thermocouple

Identification letter	Symbol	Measuring range in °C	Thermovoltage in µV
S	Pt10 %RH-Pt	-50...+1768	-235...+18694
R	Pt13 %RH-Pt	-50...+1768	-226...+21103
B	Pt30 %RH -Pt6 %RH	+250...+1820	-291...+13820

Inert metal thermocouple

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The respective elements are not compatible among each other because these are from different alloys. The elements deliver different thermo voltages. The most frequently used thermo medium is the type “K“ that is manufactured from the NiCr-Ni metal alloy. The application temperature range of this type reaches up to 1200 °C.

Finally, thermocouples only consist of a twisted, welded conductor pair, which can be produced from thin wires as an example. Because of its low thermal mass, the response time is extremely fast.

Tolerance limits

As per IEC 584, three tolerance classes are defined, which are valid for delivery condition of thermopairs from 0.25 to 3 mm. As per material and application temperature, the thermocouples are subject to certain ageing through diffusion of foreign materials.

The characteristics of thermo voltage over the temperature is not linear and must be corrected with the subsequent electronics or software. The electronics normally also takes care of the measurement and compensation of the connection voltage.

The mechanical designs of thermocouples are very diverse. The metal sheathed thermocouples occupy a special position. The thermowires are embedded in a compact insulation of magnesium-oxide and housed in a metal sheath of stainless steel or Inconel (nickel-alloy). Metal sheath thermocouples are hermetically sealed, flexible and mechanical very robust. The compact insulation completely holds the wires so that internal short circuits are practically impossible.

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