

Infrared Sensors



Operators manual
thermoMETER CTratio
Fiber Optics Ratio Thermometer

CE-Conformity



The product complies with the following standards:

EMC:	EN 61326-1: 2006 (Basic requirements)
	EN 61326-2-3: 2006
Safety:	EN 61010-1: 2001
Laser Safety:	EN 60825-1: 2007

The product accomplishes the requirements of the EMC Directive 2004/108/EG and of the Low Voltage Directive 2006/95/EG.

Read the manual carefully before the initial start-up. The producer reserves the right to change the herein described specifications in case of technical advance of the product. References to other chapters are marked as [▶ ...].

Warranty

All components of the device have been checked and tested for perfect function in the factory. In the unlikely event that errors should occur despite our thorough quality control, this should be reported immediately to MICRO-EPSILON. The warranty period lasts 12 months following the day of shipment. Defective parts, except wear parts, will be repaired or replaced free of charge within this period if you return the device free of cost to MICRO-EPSILON.

This warranty does not apply to damage resulting from abuse of the equipment and devices, from forceful handling or installation of the devices or from repair or modifications performed by third parties. No other claims, except as warranted, are accepted. The terms of the purchasing contract apply in full. MICRO-EPSILON will specifically not be responsible for eventual consequential damages.

MICRO-EPSILON always strives to supply the customers with the finest and most advanced equipment. Development and refinement is therefore performed continuously and the right to design changes without prior notice is accordingly reserved. For translations in other languages, the data and statements in the German language operation manual are to be taken as authoritative.

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Description

1 Description

The sensors of the CTratio series are noncontact infrared temperature sensors.

They calculate the surface temperature based on the emitted infrared energy of objects. The CTratio can work in the 1-color-mode as well as in the ratio- or 2-color-mode **[► Basics of Infrared Thermometry]**. The sensor of the CTratio is made of stainless steel (IP 65/ NEMA-4 rating) and is connected via a rugged fiber optics, which is protected by a stainless steel armour, with the controller (die casting zinc box).

1.1 1-Color-Mode [1C]

The 1-color-mode is best for measuring the temperature of objects in areas where no sighting obstructions (solid, gases or dust) exist. The measurement object must fill completely the measurement spot, if the 1-color-mode is used.

1.2 2-Color-Mode [2C]

In this mode the object temperature will be determined from the ratio of the signal of two separate and overlapping infrared bands. The 2-color-mode is best for measuring the temperature of objects which are partially obscured by other objects, openings or viewing windows that reduce energy and by dirt, smoke or steam in the atmosphere. Another benefit of the 2-color-mode is that the measurement object can be smaller than the measurement spot, provided the background is cooler than the target **[► The Ratio Principle]**.

Description

The CTratio sensor is a sensitive optical system. Please use only the thread for mechanical installation. Avoid mechanical violence on the head – this may destroy the system (expiry of warranty).

1.3 Scope of Supply

- CTratio sensor with fiber connection cable and controller
- 2 mounting nuts
- Mounting bracket, adjustable in one axis
- Operators manual

1.4 Maintenance

Lens cleaning: Blow off loose particles using clean compressed air. The lens surface can be cleaned with a soft, humid tissue moistened with water or a water based glass cleaner.

PLEASE NOTE: Never use cleaning compounds which contain solvents (neither for the lens nor for the housing).

Description

1.5 Safety Note

WARNING!

This sensor contains an internal **High-power laser** which is used for spot size illumination via the fiber optics cable.

Before you open the controller, remove the fiber optical cable from the controller or disassemble the sensor the sensor must be switched off and disconnected from the power supply and USB interface!

The laser power at properly usage of the sensor (fiber optical cable incl. sensor connected) is $< 1 \text{ mW}$ and fulfils laser class 2 according IEC 825 (1994).



1.6 Cautions

Avoid static electricity. The fiber optical cable has a minimum bending radius of **40 mm**.

In case of problems or questions which may arise when you use the CTratio, please contact our service department.

Read the manual carefully before the initial start-up. The producer reserves the right to change the herein described specifications in case of technical advance of the product.

Description

1.7 Factory Default Settings

The unit has the following presetting at time of delivery:

Signal output object temperature	0-5 V
Emissivity	1.000
Slope	1.000
Averaging (AVG)	inactive
Smart Averaging	inactive
Peak hold	inactive
Valley hold	inactive
Output channel 1	T 2C (2C temperature)
Lower limit temperature range [°C]	700
Upper limit temperature range [°C]	1800
Lower limit signal output	0 V
Upper limit signal output	5 V
Max. attenuation	95 %
Temperature unit	°C
Baud rate [kBaud]	115

Smart Averaging means a **dynamic average adaptation** at high signal edges [activation via software only].

► **Appendix C**

2 Technical Data

2.1 General Specifications

	Sensor	Controller
Environmental rating	IP 65 (NEMA-4)	IP 65 (NEMA-4)
Ambient Temperature	-20 ... 250 °C	0 ... 85 °C (70 °C with Laser ON)
Storage temperature	-40 ... 250 °C	-40 ... 85 °C
Relative humidity	10 ... 95 %, non condensing	10 ... 95 %, non condensing
Material	stainless steel	die casting zinc
Dimensions	length: 78.1 mm (SF sensor) 82.6 mm (CF sensor) thread: M18x1	89 mm x 70 mm x 30 mm
Weight	375 g (incl. fiber optics 3 m)	420 g
Fiber optics	multimode fiber, stainless steel armour	
Fiber optics length	3 m (standard), 6 m, 10 m, 15 m, 22 m	
Vibration	IEC 68-2-6: 3 G, 11 – 200 Hz, any axis	
Shock	IEC 68-2-27: 50 G, 11 ms, any axis	
Software (optional)	CompactConnect	

Technical Data

2.2 Electrical Specifications

Power supply	8–36 VDC
Current draw	max. 200 mA
Aiming laser	650 nm, 1 mW, On/ Off via programming keys or software
Outputs/ analog	selectable: 0/ 4–20 mA, 0–5/ 10 V
Digital I/O pins	2 programmable in-/ outputs, usable as: <ul style="list-style-type: none">▪ Alarm output (open collector output [24 V/ 1 A])▪ Digital input for triggered signal output and peak hold function
Output impedances	
mA	max. loop resistance 500 Ω (at 8-36 VDC)
mV	min. 100 K Ω load impedance
Digital interfaces	USB, RS232, RS485, CAN, Profibus DP, Ethernet (optional plug-in modules)
Relay outputs	2 x 60 VDC/ 42 VAC _{RMS} , 0.4 A; optically isolated (optional plug-in module)

Technical Data

2.3 Measurement Specifications

Temperature range (scalable)	700 ... 1800 °C
Spectral range	0.7...1.1 μm
Optical resolution	40:1 (SF optics) 40:1 (CF2 optics)
System accuracy ¹⁾	±(0.5 % of reading + 1 °C) ²⁾
Repeatability ¹⁾	±(0.1 % of reading + 1 °C) ²⁾
Temperature resolution (>900 °C)	0.1 K
Response time (95 % signal)	5 ms ...10 s ³⁾
Emissivity/ Gain	0.100 ...1.100 (adjustable via programming keys or software)
Slope	0.800 ...1.200 (adjustable via programming keys or software)
Signal processing	One-color-, Two-color-mode, Attenuation monitoring, Alarm, Average, Peak hold, Valley hold, Advanced peak hold with threshold and hysteresis, (adjustable via programming keys or software)

¹⁾ at ambient temperature 23 ±5 °C

²⁾ ε = 1/ Response time 1 s

³⁾ with dynamic adaptation at low signal levels

Technical Data

2.4 Optics

The CTratio is available in two focus versions:

SF optics: 41 mm@ 1524 mm (D:S = 40:1)
CF2 optics: 7.7 mm@ 305 mm (D:S = 40:1)

The following optical charts show the diameter of the measuring spot in dependence on the distance between measuring object and sensor. The spot size refers to **95 % of the radiation energy**. The distance is always measured from the front edge of the sensor.

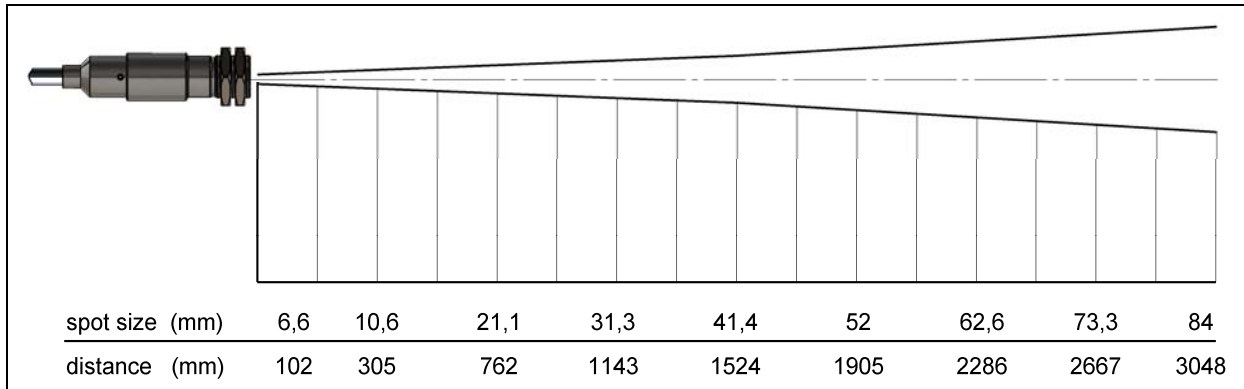


Fig. 2.1: SF optics

Technical Data

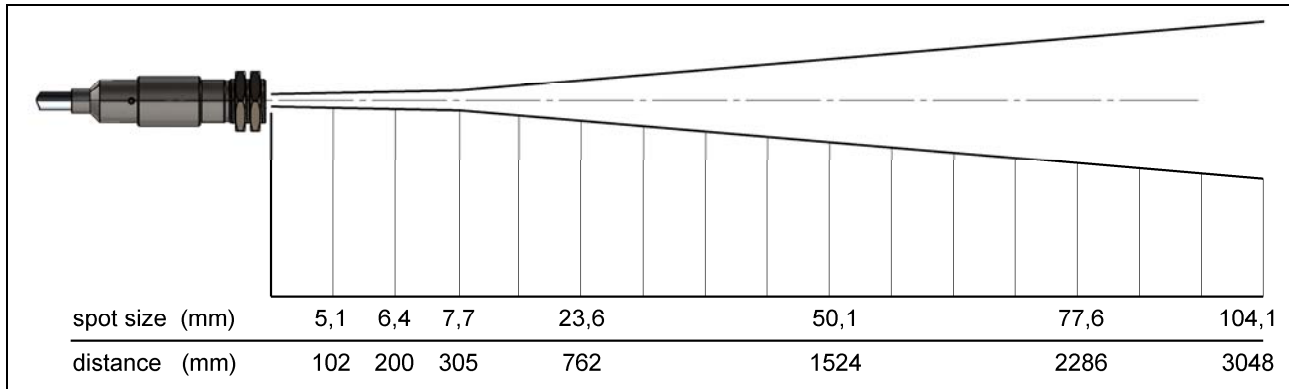


Fig. 2.2: CF2 optics

The D:S ratio is valid for the focus point.

2.5 Sensor Placement [1C Mode]

The size of the measuring object and the optical resolution of the infrared thermometer determine the maximum distance between sensor and measuring object. In order to prevent measuring errors the object should fill out the field of view of the optics completely. Consequently, the spot should at all times have at least **the same size** like the object or should be **smaller than** that.

2.6 Sensor Placement [2C Mode]

In the 2-color-mode the sensor can be placed under various conditions, like:

- Measurement through holes smaller than the spot size
- Measurement through dust, smoke or steam in the atmosphere
- Measurement of objects smaller than the measurement spot
- Measurement through a dirty lens or dirty sighting window

[► The Ratio Principle]

Please note that the sensor accuracy is not guaranteed for signal reductions of more than 95 %.

3 Mechanical Installation

The CTratio sensors are equipped with a metrical M18x1-thread and can be installed either directly via the sensor thread or with help of the hex nuts (2 pieces included in scope of supply) to the mounting bracket available. Various mounting brackets, which make the adjustment of the sensor easier, can be additionally ordered as accessories.

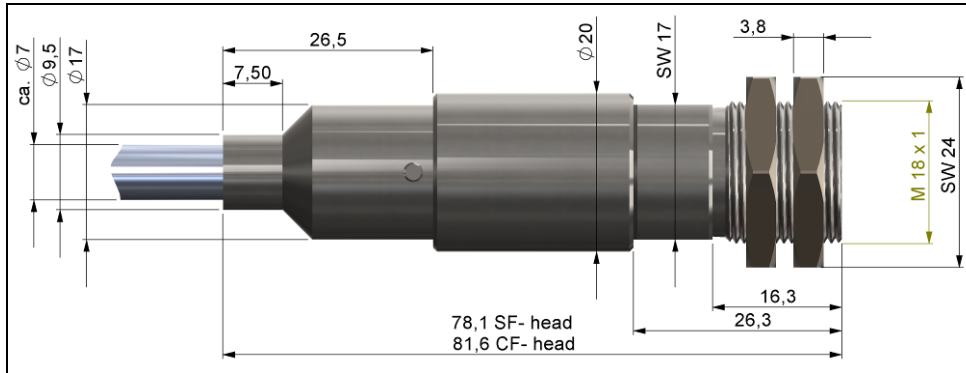


Fig. 3.1: Sensor CTratio

Please make sure that the minimum bending radius of the fiber optics of **40 mm** will be considered during installation.

Mechanical Installation

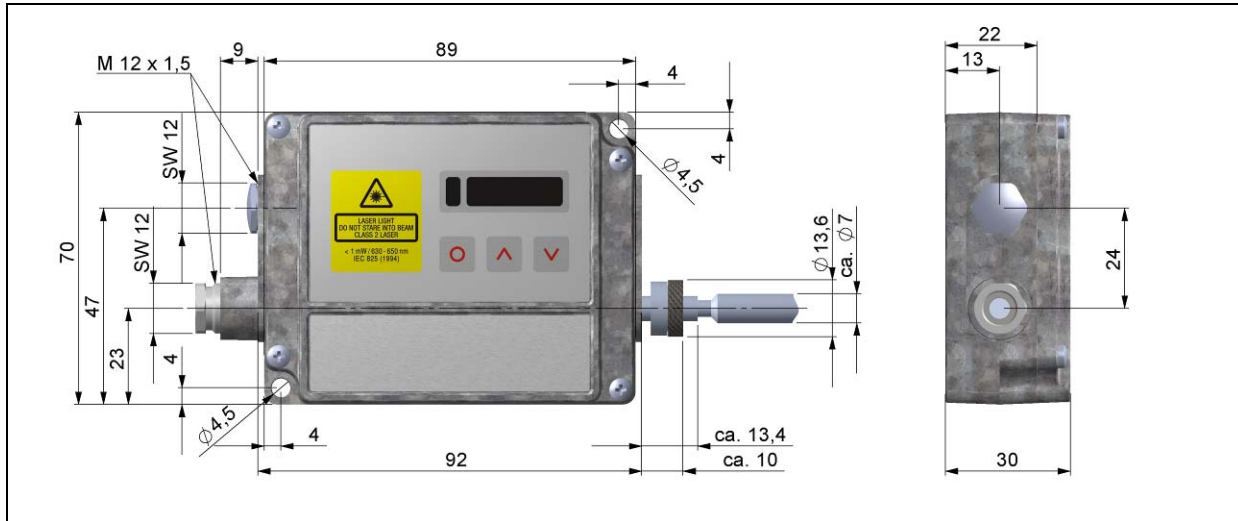


Fig. 3.2: Controller

The controller is also available with closed cover (display and programming keys with no access from outside) **[TM-COV-CT]**.



Mechanical Installation

3.1 Accessories

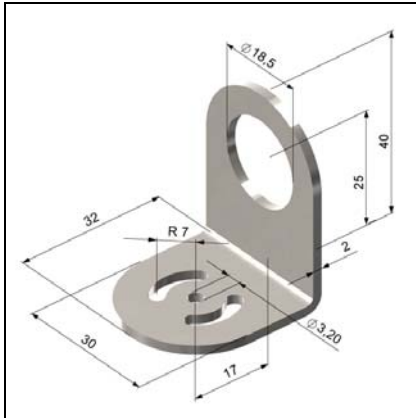


Fig. 3.3: Mounting bracket, adjustable in one axis [TM-FB-CTR]

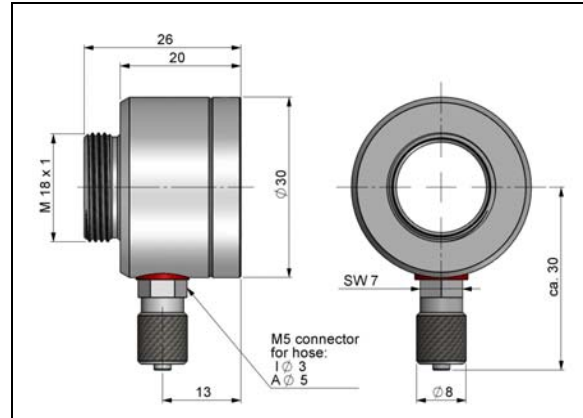


Fig. 3.4: Air purge collar [TM-AP-CTR]

The lens must be kept clean at all times from dust, smoke, fumes and other contaminants in order to avoid reading errors (in the 1-color-mode). These effects can be reduced by using an **air purge collar**. Make sure to use oil-free, technically clean air, only.

The needed amount of air (approx. 2 ... 10 l/ min.) depends on the application and the installation conditions on-site.

Mechanical Installation

3.2 Rail Mount Adapter for Controller

With the rail mount adapter the CTratio controller can be mounted easily on a DIN rail (TS35) according EN50022.

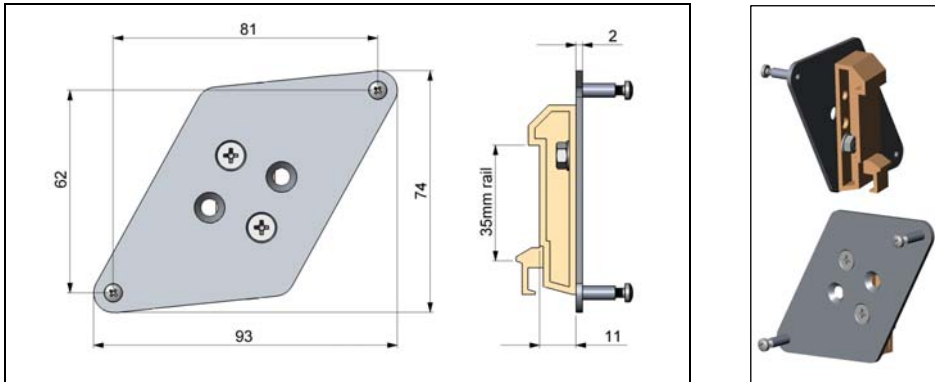


Fig. 3.5: [TM-RAIL-CT]

Mechanical Installation

3.3 Laser Sighting

The integrated laser sighting supports the alignment and focusing of the optics. The size of the laser dot is equal to the real measurement spot size at any distance.

If the laser is activated the temperature measurement is not possible!

The laser can be activated/ deactivated via the programming keys on the unit or via the software. If the laser is activated a yellow LED will shine (beside temperature display).

[► Electrical Installation/ Operating]

At ambient temperatures > 70 °C on the controller the laser will switch off automatically.



WARNING: Do not point the laser directly at the eyes of persons or animals! Do not stare into the laser beam. Avoid indirect exposure via reflective surfaces!

WARNING: Inside the controller a **High-power laser** is located. The laser light is coupled into the fiber optics. On the outlet at the sensor the laser power is < 1 mW and fulfils laser class 2 according IEC 825 (1994).

Before you open the controller, remove the fiber optical cable from the controller or disassemble the sensor the sensor must be switched off and disconnected from the power supply and USB interface!

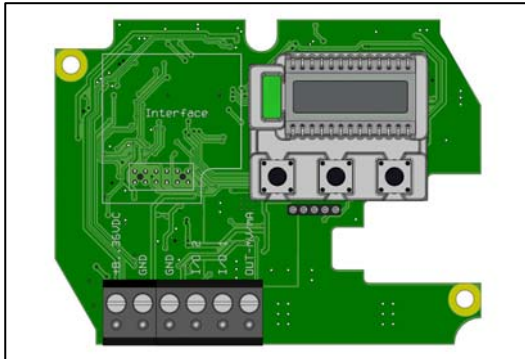
SAFETY SWITCH: If the fiber optical cable will be removed from the controller, the laser will be switched off automatically. Any manipulation at this safety switch is prohibited.

4 Electrical Installation

4.1 Cable Connections

For the electrical installation of the CTratio please open at first the cover of the controller (4 screws). Below the display are the screw terminals for the cable connection.

4.1.1 Designation



+8... 36 VDC	Power supply
GND	Ground (0V) of power supply
GND	Ground (0V) of in- and outputs
I/O 2	I/O pin 2 (digital In- /Output)
I/O 1	I/O pin 1 (digital In-/ Output)
OUT-mV/mA	Analog output object temperature (mV or mA)

Fig. 4.1: Opened controller with terminal connections

CAUTION: Please do never connect a supply voltage to the analog outputs as this will destroy the output!
The CTratio ist not a 2-wire sensor!

Electrical Installation

4.1.2 Power Supply

Please use a power supply unit with an output voltage of 8–36 VDC which can supply 200 mA.

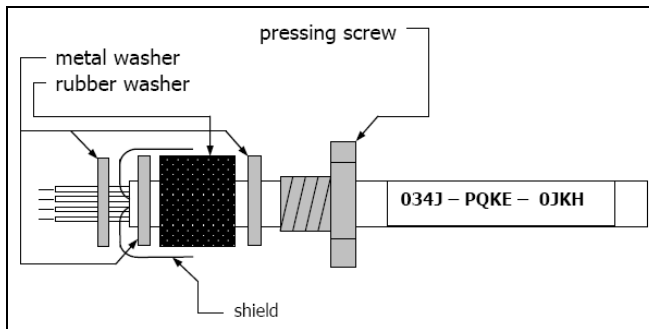
4.1.3 Cable Assembling

The cable gland M12x1,5 allows the use of cables with a diameter of 3 to 5 mm.

Remove the isolation from the cable (40 mm power supply, 50 mm signal outputs, 60 mm functional inputs). Cut the shield down to approximately 5 mm and spread the strands out. Extract about 4 mm of the wire isolation and tin the wire ends.

Place the pressing screw, the rubber washer and the metal washers of the cable gland one after the other onto the prepared cable end. Spread the strands and fix the shield between two of the metal washers. Insert the cable into the cable gland until the limit stop. Screw the cap tight.

Every single wire may be connected to the according screw clamps according to their colors.

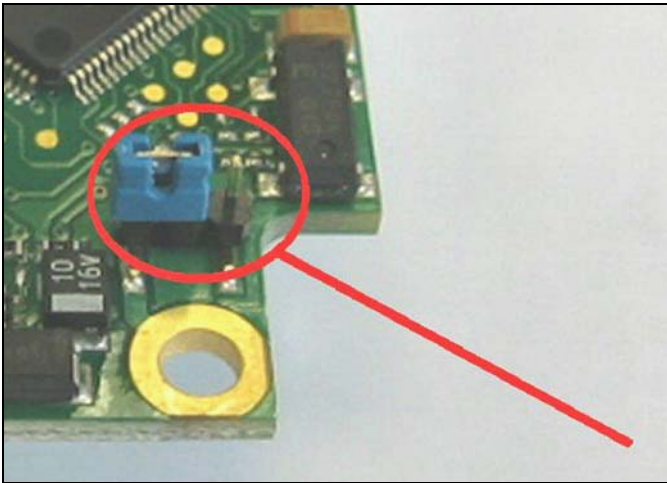


Use shielded cables only. The sensor shield has to be grounded.

Electrical Installation

4.2 Ground Connection

At the bottom side of the mainboard PCB you will find a connector (jumper) which has been placed from factory side as shown in the picture [**left** and **middle pin** connected]. In this position the ground connections (GND power supply/ outputs) are connected with the ground of the controller housing. To avoid ground loops and related signal interferences in industrial environments it might be necessary to interrupt this connection. To do this please put the jumper in the other position [**middle** and **right pin** connected].



Electrical Installation

4.3 Outputs and Inputs

The CTratio has an analog output and two digital I/O pins (programmable as in- or output).

4.3.1 Analog Output

The selection of the signal on output channel 1 can be done via the programming keys [**► Operating**].

The following output signals can be selected:

0-5 V

0-10 V

0-20 mA

4-20 mA

CAUTION: Please do never connect a supply voltage to the analog outputs as this will destroy the output.
The CTratio is not a 2-wire sensor!

The following signal sources can be selected for output channel 1:

T 2C 2C temperature



T 1C 1C temperature

Attenuation Signal attenuation in %

Electrical Installation

4.3.2 Digital I/O pins

The CTratio has two digital pins which can be programmed as in- or outputs using the CompactConnect software. The following options are available:

Function	I/O pin acts as	Description
Digital Alarm	output	Open collector output/ definition as HIGH- or LOW alarm via norm. open/ norm. close options in software dialog.
Valid LO	input	The output follows the object temperature as long as there is a Low level at the I/O pin. After discontinuation of the Low level the last value will be held.
Valid HI	input	The output follows the object temperature as long as there is a High level at the I/O pin. After discontinuation of the High level the last value will be held.
Hold 	input	The last value will be held if there is a signal with a rising edge on the I/O pin.
Hold 	input	The last value will be held if there is a signal with a falling edge on the I/O pin.

High-Pegel: $\geq 0.8 \text{ V}$

Low-Pegel: $\leq 0.8 \text{ V}$

Electrical Installation

4.3.3 Digital Interfaces

CTratio sensors can be optionally equipped with an USB-, RS232-, RS485-, CAN Bus-, Profibus DP- or Ethernet-interface. If you want to install an interface, plug the interface board into the place provided, which is located beside the display. In the correct position the holes of the interface match with the thread holes of the controller. Now press the board down to connect it and use both M3x5 screws for fixing it. Plug the preassembled interface cable with the terminal block into the male connector of the interface board.



The Ethernet interface requires at minimum 12 V supply voltage.

If the USB interface is used the sensor is powered by the computer. If you use the laser and/ or display backlight we recommend an additional power supply.

Please pay attention to the notes on the according interface manuals.

Electrical Installation

4.3.4 Relay Outputs

The CTratio can be optionally equipped with a relay output [TM-RI-CT].

The relay board will be installed the same way as the digital interfaces. **A simultaneous installation of a digital interface and the relay outputs is not possible.** The relay board provides two fully isolated switches, which have the capability to switch max. 60 VDC/ 42 VAC_{RMS}, 0.4 A DC/AC. A red LED shows the closed switch.

The switching thresholds are in accordance with the values for the visual alarms (LCD backlight). To set the alarm values a digital interface (USB, RS232 e.g.) and the software is needed.



Electrical Installation

4.4 Alarms

The CTratio has the following Alarm features:

All alarms have a fixed **hysteresis** of 2 K.

4.4.1 Visual Alarms

These alarms will cause a change of the color of the LCD display and will also change the status of the optional relays interface.

4.4.2 Digital Alarm 1 and 2

Both of the I/O pins can be programmed as alarm output. In this case the pin acts as an open collector output (24 V/ 1A).

The following signal sources can be selected:

T 2C/ T 1C/ Attenuation/ TBox/ TProcess (Temperature signal which has been selected for the analog output)

For a setup of the alarm values, selection of the signal sources and definition as high or low alarm (via change of normally open/ closed) a digital interface (e.g. USB, RS232) including the software CompactConnect is needed.

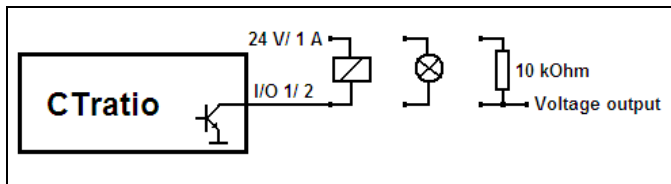


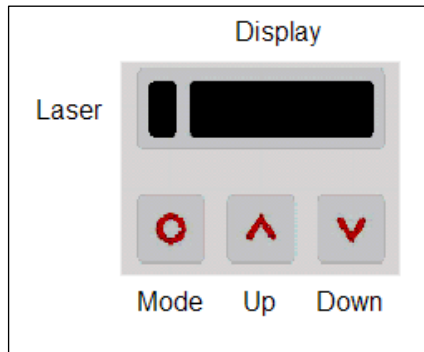
Fig. 4.2: Different wirings of the open collector output

5 Operating

After power up the unit the sensor starts an initializing routine for some seconds. During this time the display will show **INIT**. After this procedure the object temperature is shown in the display. The display backlight color changes according to the alarm settings [**► Alarms/ Visual Alarms**].

5.1 Sensor Setup

The programming keys **Mode**, **Up** and **Down** enable the user to set the sensor on-site. The current measuring value or the chosen feature is displayed. With **Mode** the operator obtains the chosen feature, with **Up** and **Down** the functional parameters can be selected – a change of parameters will have immediate effect. If no key is pressed for more than 10 seconds the display automatically shows the calculated object temperature (according to the signal processing).



Factory Default Setting

To set the CTRatio back to the factory default settings, please press at first the **Down**-key and then the **Mode**-key and keep both pressed for approx. 3 seconds. The display will show RESET for confirmation.

Pressing the Mode button again recalls the last called function on the display. The signal processing features **Peak hold** and **Valley hold** cannot be selected simultaneously.

Operating

Display	Mode [Sample]	Adjustment Range
S ON	Laser Sighting [On]	ON/ OFF
700.0 	Current 2C temperature [700.0 °C]	fixed
600.0 	Current 1C temperature [600.0 °C]	fixed
65.0 %	Current attenuation [65.0 %]	fixed
23.3 CB	Box temperature [23.3 °C]	fixed
<input type="checkbox"/> MV5	Signal output channel 1 [0-5 V]	<input type="checkbox"/> 0-20 = 0–20 mA/ <input type="checkbox"/> 4-20 = 4–20 mA/ <input type="checkbox"/> MV5 = 0–5 V/ <input type="checkbox"/> MV10 = 0-10 V
R 1.000	Slope [1.000]	0.800 ... 1.200
E 0.970	Emissivity [0.970]	0.050 ... 1.000
D 95.0	Max. attenuation [95.0 %]	-50.0 ... 99.C260
MD 2C	Main display (on electronic box) [2C temperature value]	2C = 2C temperature/ 1C = 1C temperature/ AT = attenuation
A 0.2	Signal output Average [0.2 s]	A---- = inactive/ 0.1 ... 999.9 s
P----	Signal output Peak hold [inactive]	P---- = inactive/ 0.1 ... 999.9 s / P oo oo oo oo = infinite
V----	Signal output Valley hold [inactive]	V---- = inactive/ 0.1 ... 999.9 s / V oo oo oo oo = infinite
u 700.0	Lower limit temperature range [700 °C]	depending on model
n 1500	Upper limit temperature range [1500 °C]	depending on model
[0.00	Lower limit signal output [0 V]	according to the range of the selected output signal
] 5.00	Upper limit signal output [5 V]	according to the range of the selected output signal
U °C	Temperature unit [°C]	°C/ °F
M 01	Multidrop adress [1] (only with RS485 interface)	01 ... 32
B 115	Baud rate in kBaud [115]	9.6/ 19.2/ 38.4/ 57.6/ 115.2 kBaud

Operating

S ON

Activating (ON) and Deactivating (OFF) of the integrated Sighting Laser
By pressing **Up** or **Down** the laser will be switched on or off. If the laser is activated a measurement cannot be done.

□ MV5

Selection of the Output signal. By pressing **Up** or **Down** the different output signals can be selected [**► Outputs and Inputs**].

R 1.000

Setup of Slope. Pressing **Up** increases the value, **Down** decreases the value (also valid for all further functions). The slope is the quotient of the emissivities of both of the overlapping wavelengths and therewith the deciding parameter for measurements in 2-color mode.

[**► Characteristic Slope Values**]

E 0.970

Setup of Emissivity. The emissivity is a material constant factor to describe the ability of the body to emit infrared energy. The emissivity only affects measurements in the 1-color mode.
[**► Emissivity**]

D 95.0

Setup of the allowed Attenuation. The temperature measurement will stop if the attenuation exceeds this limit [**► Attenuation**].

MD 2C

Setup of the Main display on the controller. By pressing **Up** or **Down** you can select if the 2C temperature, 1C temperature or attenuation should be displayed (independent from the selected output signal).

A 0.2

Setup of Average time. If the value is set to **0.0** the display will show --- (function deactivated). In this mode an arithmetic algorithm will be performed to smoothen the signal. The set time is the time constant. This function can be combined with all other post processing functions.

Operating

P----

Setup of Peak hold. If the value is set to **0.0** the display will show --- (function deactivated). In this mode the sensor is waiting for descending signals. If the signal descends the algorithm maintains the previous signal peak for the specified time. After the hold time the signal will drop down to the second highest value or will descend by 1/8 of the difference between the previous peak and the minimum value during the hold time. This value will be held again for the specified time. After this the signal will drop down with slow time constant and will follow the current object temperature.

V----

Setup of Valley hold. If the value is set to **0.0** the display will show --- (function deactivated). In this mode the sensor waits for ascending signals. The definition of the algorithm is according to the peak hold algorithm (inverted).

u 700.0

Setup of the **Lower limit of temperature range**. The minimum difference between lower and upper limit is **20 K**. If you set the lower limit to a value \geq upper limit the upper limit will be adjusted to **[lower limit + 20 K]** automatically.

n 1800

Setup of the **Upper limit of the temperature range**. The minimum difference between upper and lower limit is **20 K**. The upper limit can only be set to a value = lower limit + 20 K.

[0.00
certain

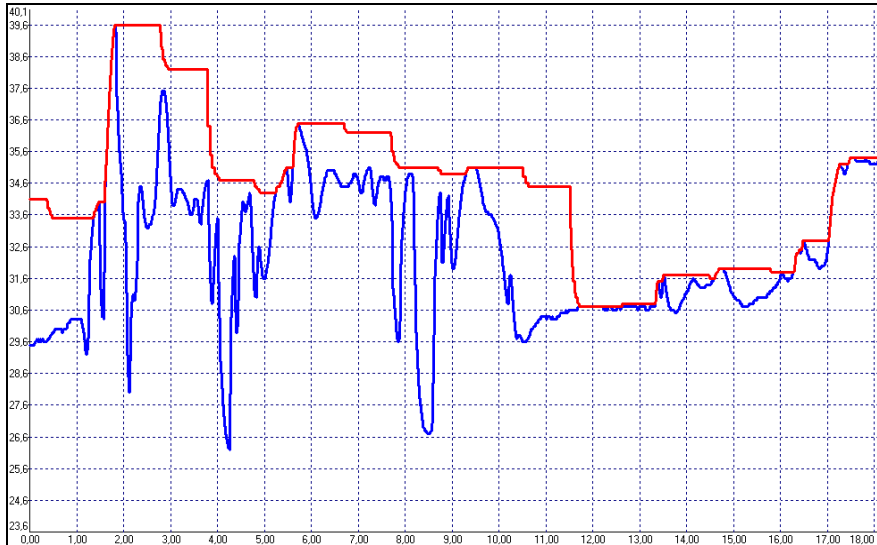
Setup of the **Lower limit of the signal output**. This setting allows an assignment of a signal output level to the lower limit of the temperature range. The adjustment range corresponds to the selected output mode (e.g. 0-5 V).

] 5.00

Setup of the **Upper limit of the signal output**. This setting allows an assignment of a certain signal output level to the upper limit of the temperature range. The adjustment range corresponds to the selected output mode (e.g. 0-5 V).

Operating

Signal graph with P----



— TProcess with Peak Hold (Hold time = 1 s)

— TActual without post processing

Operating

U °C

Setup of the **Temperature unit** [°C or °F].

M 01

Setup of the **Multidrop address**. In a RS485 network each sensor will need a specific address. This menu item will only be shown if a RS485 interface board is plugged in.

B 115k

Setup of the **Baud rate** for digital data transfer.

6 Software CompactConnect

6.1 Installation

Insert the installation CD into the according drive on your computer. If the autorun option is activated the installation wizard will start automatically.

Otherwise please start **setup.exe** from the CD-ROM. Follow the instructions of the wizard until the installation is finished.

The installation wizard will place a launch icon on the desktop and in the start menu:

[Start]\Programs\CompactConnect.

If you want to uninstall the software from your system please use the **uninstall icon** in the start menu.

You will find a detailed software manual on the CD.

6.2 Min. System Requirements

- Windows XP, Vista, 7
- USB interface
- Hard disc with at least 30 MByte free space
- At least 128 MByte RAM
- CD-ROM drive

6.3 Main Features

- Graphic display for temperature trends and automatic data logging for analysis and documentation
- Complete sensor setup and remote controlling
- Adjustment of signal processing functions
- Programming of outputs and functional inputs

6.4 Communication Settings

Serial Interface

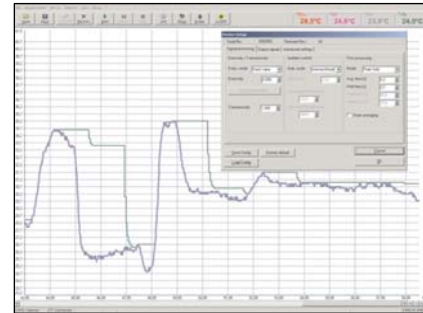
Baud rate: 9.6 ... 115.2 kBaud (adjustable on the unit or via software)
Data bits: 8
Parity: none
Stop bits: 1
Flow control: off

Protocol

All sensors of the CTratio series are using a binary protocol.

Saving of parameter settings

After power on of the CTratio sensor the flash mode is active. It means, changed parameter settings will be saved in the internal Flash-EEPROM and will be kept also after the sensor is switched off.



Software CompactConnect

In case settings should be changed quite often or continuously the flash mode can be switched off by using the following command:

Decimal: 112
HEX: 0x70
Data, Answer: byte 1
Result: 1 – Data will not be written into the flash memory
2 – Data will be written into the flash memory

If the flash mode is deactivated, all settings will only be kept as long as the unit is powered. If the unit is switched off and powered on again all previous settings are lost.
The command 0x71 will poll the current status.

You will find a detailed protocol and command description on the software CD CompactConnect in the directory: \Commands.

7 Basics of Infrared Thermometry

Depending on the temperature each object emits a certain amount of infrared radiation. A change in the temperature of the object is accompanied by a change in the intensity of the radiation. For the measurement of “thermal radiation” infrared thermometry uses a wave-length ranging between 1 μ and 20 μm . The intensity of the emitted radiation depends on the material. This material contingent constant is described with the help of the emissivity which is a known value for most materials (see enclosed table emissivity).

Infrared thermometers are optoelectronic sensors. They calculate the surface temperature on the basis of the emitted infrared radiation from an object. The most important feature of infrared thermometers is that they enable the user to measure objects contactless. Consequently, these products help to measure the temperature of inaccessible or moving objects without difficulties. Infrared thermometers basically consist of the following components:

- lens
- spectral filter
- detector
- electronics (amplifier/ linearization/ signal processing)

The specifications of the lens decisively determine the optical path of the infrared thermometer, which is characterized by the ratio **D**istance to **S**pot size.

The spectral filter selects the wavelength range, which is relevant for the temperature measurement. The detector in cooperation with the processing electronics transforms the emitted infrared radiation into electrical signals.

7.1 The Ratio Principle

The 2-color ratio technology makes possible accurate and repeatable temperature measurements that are free from dependence on absolute radiated energy values. In use, a 2-color sensor determines temperature from the ratio of the radiated energies in two separate wavelength bands (colors). The benefits of 2-color sensors are that accurate measurements can be made under the following conditions:

- ▶ When the field of view to the target is partially blocked or obscured.
- ▶ When the target is smaller than the sensor's field of view.
- ▶ When target emissivities are low or changing by the same factor in both wavelength bands.

Another benefit is that 2-color sensors measure closer to the highest temperature within the measured spot (spatial peak picking) instead of an average temperature. A 2-color sensor can be mounted farther away, even if the target does not fill the resulting spot size. The convenience is that you are not forced to install the sensor at some specific distance based upon target size and the sensor's optical resolution.

7.1.1 Partially Obscured Targets

The radiated energy from a target is, in most cases, equally reduced when objects or atmospheric materials block some portion of the optical field of view. It follows that the ratio of the energies is unaffected, and thus the measured temperatures remain accurate. A 2-color sensor is better than a 1-color sensor in the following conditions:

- ▶ Sighting paths are partially blocked (either intermittently or permanently).
- ▶ Dirt, smoke, or steam is in the atmosphere between the sensor and target.
- ▶ Measurements are made through items or areas that reduce emitted energy, such as grills, screens, channels or small openings
- ▶ Measurements are made through a viewing window that has unpredictable and changing infrared transmission due to accumulating dirt and/or moisture on the window surface.

Basics of Infrared Thermometry

- ▶ The sensor itself is subject to dirt and/or moisture accumulating on the lens surface.

1-color sensors see polluted atmosphere and dirty windows and lenses as a reduction in energy and give much lower than actual temperature readings.

7.1.2 Targets Smaller Than Field of View

When a target is not large enough to fill the field of view, or if the target is moving within the field of view, radiated energies are equally reduced, but the ratio of the energies is unaffected and measured temperatures remain accurate. This remains true as long as the background temperature is much lower than the target temperature.

Example:

- ▶ Measuring of wire or rod — often too narrow for field of view or moving or vibrating unpredictably. It is much easier to obtain accurate results because sighting is less critical with 2-color sensors.

7.1.3 Low or Changing Emissivities

If the emissivities in both wavelengths (colors) were the same, as they would be for any blackbody (emissivity = 1.0) or greybody (emissivity < 1.0 but constant), then their ratio would be 1, and target emissivity would not be an influence. However, in nature there is no such thing as a greybody. The emissivity of all real objects changes with wavelength and temperature, at varying degrees, depending on the material. When emissivity is uncertain or changing, a 2-color sensor can be more accurate than a 1-color instrument as long as the emissivity changes by the same factor in both wavelength bands. Note, however, that accurate measurement results are dependent on the application and the type of material being measured. To determine how to use 2-color sensors with your application when uncertain or changing emissivities are a factor, please contact your sales representative.

8 Emissivity

8.1 Definition

The intensity of infrared radiation, which is emitted by each body, depends on the temperature as well as on the radiation features of the surface material of the measuring object. The emissivity (ϵ – Epsilon) is used as a material constant factor to describe the ability of the body to emit infrared energy. It can range between 0 and 100 %. A “blackbody” is the ideal radiation source with an emissivity of 1.0 whereas a mirror shows an emissivity of 0.1.

If the emissivity chosen is too high, the infrared thermometer may display a temperature value which is much lower than the real temperature – assuming the measuring object is warmer than its surroundings. A low emissivity (reflective surfaces) carries the risk of inaccurate measuring results by interfering infrared radiation emitted by background objects (flames, heating systems, chamottes). To minimize measuring errors in such cases, the handling should be performed very carefully and the unit should be protected against reflecting radiation sources.

8.2 Determination of Unknown Emissivities

- ▶ First, determine the actual temperature of the measuring object with a thermocouple or contact sensor. Second, measure the temperature with the infrared thermometer and modify the emissivity until the displayed result corresponds to the actual temperature.

Emissivity

- ▶ If you monitor temperatures of up to 380 °C you may place a special plastic sticker (emissivity dots – part number: TM-ED-LS) onto the measuring object, which covers it completely. Now set the emissivity to 0.95 and take the temperature of the sticker. Afterwards, determine the temperature of the adjacent area on the measuring object and adjust the emissivity according to the value of the temperature of the sticker.
- ▶ Cover a part of the surface of the measuring object with a black, flat paint with an emissivity of 0.98. Adjust the emissivity of your infrared thermometer to 0.98 and take the temperature of the colored surface. Afterwards, determine the temperature of a directly adjacent area and modify the emissivity until the measured value corresponds to the temperature of the colored surface.

CAUTION: On all three methods the object temperature must be different from ambient temperature.

8.3 Characteristic Emissivities

In case none of the methods mentioned above help to determine the emissivity you may use the emissivity tables ▶ **Appendix A and B**. These are average values, only. The actual emissivity of a material depends on the following factors:

- temperature
- measuring angle
- geometry of the surface
- thickness of the material
- constitution of the surface (polished, oxidized, rough, sandblast)
- spectral range of the measurement
- transmissivity (e.g. with thin films)

Emissivity

8.4 Characteristic Slope Values

The slope is the quotient of the emissivities of both of the overlapping wavelength bands. The factory default value for the slope is 1.000. The following slopes are typical reference values. The real slope can vary depending on the metal alloy and surface finish.

Cobalt, Iron, Nickel, Stainless steel, Steel	▶ oxidized surfaces	Slope: 1.000
Cobalt, Iron (solid, molten), Molybdenum, Nickel, Platinum, Rhodium, Stainless steel, Steel, Tantalum, Tungsten, Wolfram	▶ unoxidized surfaces	Slope: 1.060

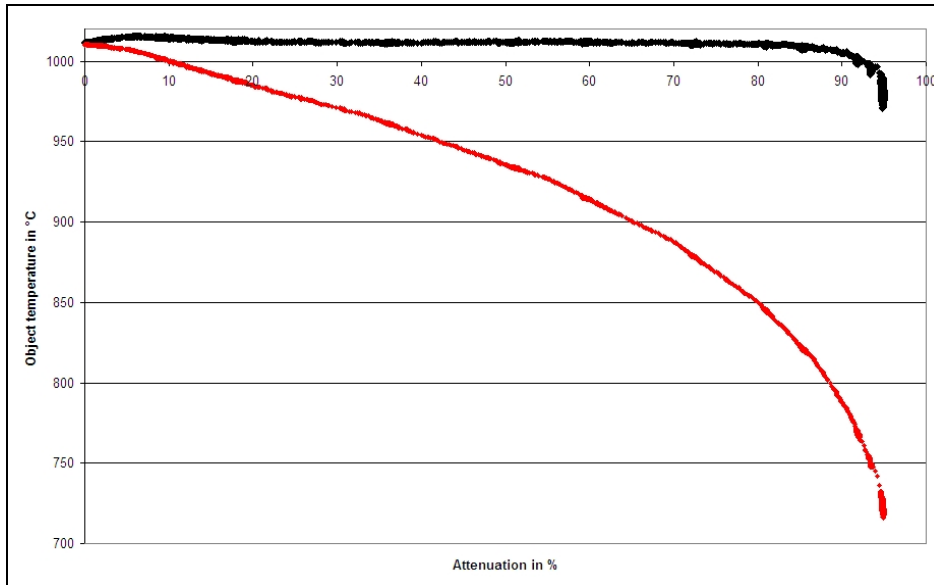
8.5 Determination of Unknown Slope Values

Basically you can use the same methods to determine an unknown slope as described under
▶ **Determination of unknown Emissivities.** As the CTratio is dedicated for high temperature applications, only the first method may be practically applicable (use of a t/c or other contact probe).

8.6 Attenuation

The CTratio is able to measure the temperature of targets smaller than the field of view (FOV). If the target size is smaller than the FOV (and thus attenuating the signal) this may cause a small inaccuracy of the reading. The inaccuracy is dependent on the object temperature and value of attenuation. The higher the object temperature and attenuation the higher the inaccuracy of the sensor.

Emissivity



This figure is showing the typical temperature reading of a ratio thermometer CT ratio in both the 1-color- and the 2-color-mode in addition of increasing contamination of the optical transmission path in-between the target and the ratio thermometer. Due to the ratio principle the 2 channel signal (upper curve) stays very stable over a wide range of attenuation up to over 90 %. The signal of the 1 channel mode (lower curve), acting like in a standard pyrometer with one measuring wavelength only, is decreasing rapidly with the contamination of the transmission path.

Appendix A – Emissivity Table Metals

Appendix A – Emissivity Table Metals

Material		typical Emissivity			
		1,0 μm	1,6 μm	5,1 μm	8-14 μm
Aluminium	non oxidized	0,1-0,2	0,02-0,2	0,02-0,2	0,02-0,1
	polished	0,1-0,2	0,02-0,1	0,02-0,1	0,02-0,1
	roughened	0,2-0,8	0,2-0,6	0,1-0,4	0,1-0,3
	oxidized	0,4	0,4	0,2-0,4	0,2-0,4
Brass	polished	0,35	0,01-0,05	0,01-0,05	0,01-0,05
	roughened	0,65	0,4	0,3	0,3
	oxidized	0,6	0,6	0,5	0,5
Copper	polished	0,05	0,03	0,03	0,03
	roughened	0,05-0,2	0,05-0,2	0,05-0,15	0,05-0,1
	oxidized	0,2-0,8	0,2-0,9	0,5-0,8	0,4-0,8
Chrome		0,4	0,4	0,03-0,3	0,02-0,2
Gold		0,3	0,01-0,1	0,01-0,1	0,01-0,1
Haynes	alloy	0,5-0,9	0,6-0,9	0,3-0,8	0,3-0,8
Inconel	electro polished	0,2-0,5	0,25	0,15	0,15
	sandblast	0,3-0,4	0,3-0,6	0,3-0,6	0,3-0,6
	oxidized	0,4-0,9	0,6-0,9	0,6-0,9	0,7-0,95
Iron	non oxidized	0,35	0,1-0,3	0,05-0,25	0,05-0,2
	rusted		0,6-0,9	0,5-0,8	0,5-0,7
	oxidized	0,7-0,9	0,5-0,9	0,6-0,9	0,5-0,9
	forged, blunt	0,9	0,9	0,9	0,9
	molten	0,35	0,4-0,6		
Iron, casted	non oxidized	0,35	0,3	0,25	0,2
	oxidized	0,9	0,7-0,9	0,65-0,95	0,6-0,95

Appendix A – Emissivity Table Metals

Material		typical Emissivity			
Spectral response		1,0 μm	1,6 μm	5,1 μm	8-14 μm
Lead	polished	0,35	0,05-0,2	0,05-0,2	0,05-0,1
	roughened	0,65	0,6	0,4	0,4
	oxidized		0,3-0,7	0,2-0,7	0,2-0,6
Magnesium		0,3-0,8	0,05-0,3	0,03-0,15	0,02-0,1
Mercury			0,05-0,15	0,05-0,15	0,05-0,15
Molybdenum	non oxidized	0,25-0,35	0,1-0,3	0,1-0,15	0,1
	oxidized	0,5-0,9	0,4-0,9	0,3-0,7	0,2-0,6
Monel (Ni-Cu)		0,3	0,2-0,6	0,1-0,5	0,1-0,14
Nickel	electrolytic	0,2-0,4	0,1-0,3	0,1-0,15	0,05-0,15
	oxidized	0,8-0,9	0,4-0,7	0,3-0,6	0,2-0,5
Platinum	black		0,95	0,9	0,9
Silver		0,04	0,02	0,02	0,02
Steel	polished plate	0,35	0,25	0,1	0,1
	rustless	0,35	0,2-0,9	0,15-0,8	0,1-0,8
	heavy plate			0,5-0,7	0,4-0,6
	cold-rolled	0,8-0,9	0,8-0,9	0,8-0,9	0,7-0,9
	oxidized	0,8-0,9	0,8-0,9	0,7-0,9	0,7-0,9
Tin	non oxidized	0,25	0,1-0,3	0,05	0,05
Titanium	polished	0,5-0,75	0,3-0,5	0,1-0,3	0,05-0,2
	oxidized		0,6-0,8	0,5-0,7	0,5-0,6
Wolfram	polished	0,35-0,4	0,1-0,3	0,05-0,25	0,03-0,1
Zinc	polished	0,5	0,05	0,03	0,02
	oxidized	0,6	0,15	0,1	0,1

Appendix B – Emissivity Table Non Metals

Appendix B – Emissivity Table Non Metals

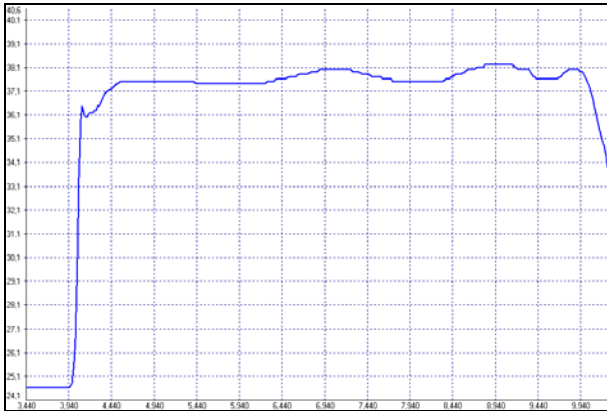
Material	typical Emissivity			
	1,0 μm	2,2 μm	5,1 μm	8-14 μm
Asbestos	0,9	0,8	0,9	0,95
Asphalt			0,95	0,95
Basalt			0,7	0,7
Carbon non oxidized graphite		0,8-0,9	0,8-0,9	0,8-0,9
		0,8-0,9	0,7-0,9	0,7-0,8
Carborundum		0,95	0,9	0,9
Ceramic	0,4	0,8-0,95	0,8-0,95	0,95
Concrete	0,65	0,9	0,9	0,95
Glass plate melt		0,2	0,98	0,85
		0,4-0,9	0,9	
Grit			0,95	0,95
Gypsum			0,4-0,97	0,8-0,95
Ice				0,98
Limestone			0,4-0,98	0,98
Paint non alkaline				0,9-0,95
Paper any color			0,95	0,95
Plastic >50 μm non transparent			0,95	0,95
Rubber			0,9	0,95
Sand			0,9	0,9
Snow				0,9
Soil				0,9-0,98
Textiles			0,95	0,95
Water				0,93
Wood natural			0,9-0,95	0,9-0,95

Appendix C – Smart Averaging

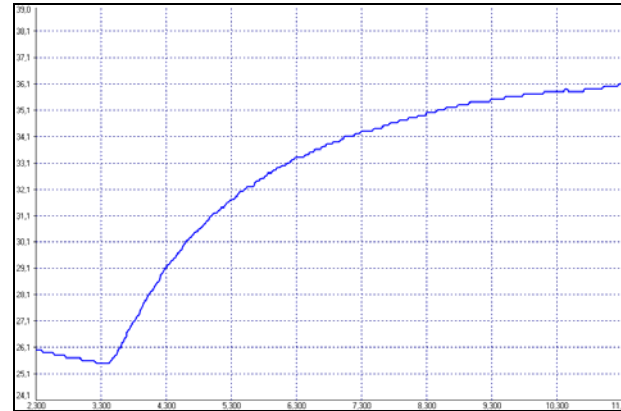
Appendix C – Smart Averaging

The average function is generally used to smoothen the output signal. With the adjustable parameter time this function can be optimal adjusted to the respective application. One disadvantage of the average function is that fast temperature peaks which are caused by dynamic events are subjected to the same averaging time. Therefore those peaks can only be seen with a delay on the signal output.

The function **Smart Averaging** eliminates this disadvantage by passing those fast events without averaging directly through to the signal output.



Signal graph with Smart Averaging function



Signal graph without Smart Averaging function



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