

User Manual for Terabee IND-Thermal-90



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1.2. Technical specifications

Table 1 - Technical specifications of Terabee IND-Thermal-90

Product code	TB-IND-T90
Performance	
Detection principle	Thermopile
Sensor resolution	32 × 32 pixels
Field Of View (FOV)	90°× 90°
Frame rate	7 Hz
Measurable temperature range	-20 °C to 670 °C
Temperature accuracy ⁽¹⁾	±2 °C for targets below 100 °C, ±2% for targets above 100 °C
Thermal sensitivity <i>(At 1 Hz and 25 °C ambient temperature)</i>	329 mK
Electronics	
Supply voltage V_{DD}	12 VDC to 24 VDC
Typical current consumption <i>(Without NO/NC load, 20°C ambient temperature)</i>	38 mA <i>(at 12V DC)</i> 21 mA <i>(at 24V DC)</i>
Initialization time	< 4 s
Interfaces	
Serial (temperature measurement and remote settings)	
Type	RS485 (half-duplex, 1.2 ... 256 kbps), unprotected
Communication protocol	Modbus
Digital output (alarm)	
Type	Switching (NO/NC in PNP/NPN configuration), 0V - V_{DD}
Maximum output current	450 mA (at 24 V), unfused
Output delay	< 200 ms
Visual notification (status, communication, error)	
Type	3 x LEDs (multi-color)
Mechanics	
Dimensions	95 mm x 57 mm x 27 mm
Weight	75 g

Enclosure rating	IP65 ⁽²⁾
Housing material	Main body: ABS Backplate: Aluminium
Type of connection	M12 A-coded male connector, 5-pin
Ambient temperature operation (at $V_{DD} = 24\text{ VDC}$)	-10°C to 65°C
Mounting	4 slots for M4 screws
Conformity	
Reference Standard	CE, RoHS, Vibration & Shock

1. Reference Application 2 (see below): central 4x4 pixels and 10 frames temporal moving average. Accuracy may also vary depending on distance, target emissivity, and ambient temperature.
2. Refer to the conformity certificate in the User Manual for details.

1.3. Symbols explanation and further information

The following symbols are used within the document:



This symbol indicates specific recommendations in order to run the camera in the intended way



The device is electro-static sensitive if touched on the camera (sensor) metallic part (see Figure 2). However it automatically recovers after disturbance occurs.



Figure 2. Focus on the electro-static sensitive camera (sensor) metallic part

The bottom casing part includes four slots for mounting the camera using standard M4 screws. The following methods can be used to mount the Terabee IND-Thermal-90:

1. Front-panel mount using the long M4 screw slots (Figure 4)
2. Back-panel mount using the 2mm ledge on the front side of the camera (Figure 5)

The first solution allows for easy surface attachment and rapid evaluation of the camera. Depending on the Application requirements for connector/cable position, the camera can be mounted either horizontally or vertically. The second solution offers the possibility to mount the camera behind a surface (e.g. panel), ideally with 2 mm thickness for a more integrated look. Please note that mounting components (e.g. screws, nuts, etc.) are not included in the product packaging.



Figure 4. Front-panel mounting examples with camera in vertical position (left, connector at the bottom - considered as default in the manual) and tilted by 90 degree (right).

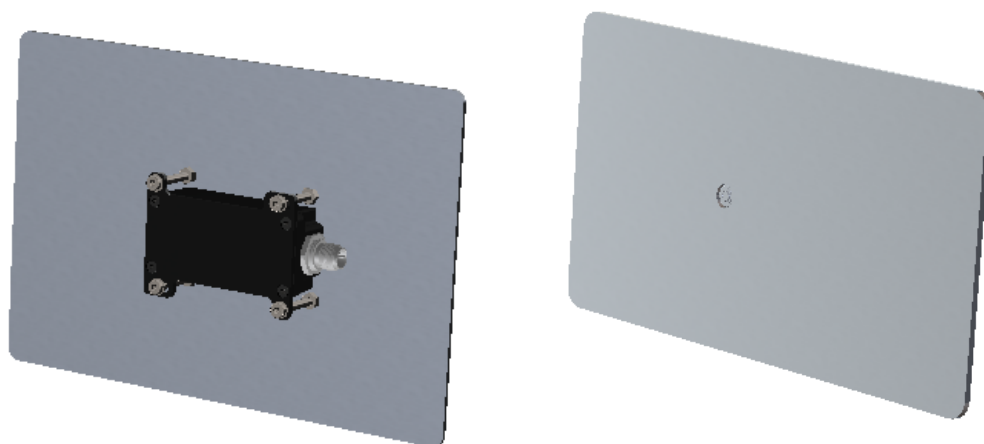


Figure 5. Back-panel mounting example: back (left) and front (right) isometric views

Optional mounting brackets for angled attachment methods to existing industrial infrastructures are also available as accessories on the [Terabee website](#).

Table 2 - Optional mounting brackets compatible with IND-Thermal-90

Accessory	Terabee SKU	Link
90 degrees mounting bracket	TB-90MB-IND-TOF-1	Link
Adjustable mounting bracket for Terabee industrial sensor	TB-AMB-IND	Link

2.3. Operating indicators

Onboard multi-color LEDs provide a visual confirmation of temperature threshold breach, camera power and connection status. Figure 6 and the corresponding Table 3 describe the connector location, and operating indicators. Table 4 shows the signalization sequence of the LEDs.

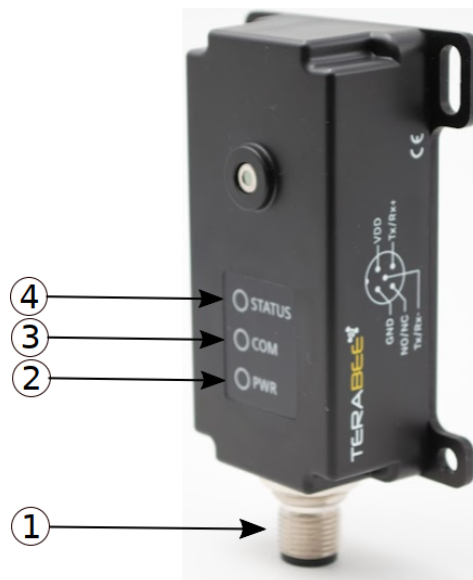


Figure 6. M12 Connector and LED indicators

Table 3 - Connector location and onboard operating buttons and indicators

No.	Category	Designator	Description
1	Connection	M12 connector	A-coded male, 5 pin
2	LED indicator	PWR	Power indicator
3	LED indicator	COM	RS485 data transmission
4	LED indicator	STATUS	Notification of alarm / error status

Table 4 - LED signalization logic

LED indicator	LED Color	Signalization logic
PWR	Green	LED continuously ON whenever connected to

		a power supply
COM	Yellow/Red	LED is connected directly to the RS485 line, signals data transmission and reception
STATUS	Green/Red	Steady green during normal operation, turns red when the NO/NC output is active. Blinking red without any green light signals an error.

2.4. M12 connector pinout

Terabee IND-Thermal-90 uses an M12 A-coded male connector, 5 pins. Figure 7 and Table5 provide an overview of the connector pinout.

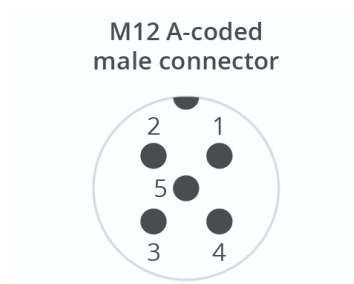


Figure 7. M12, 5-pin connector pinout layout

Table 5 - Connector pinout description

Pin	Designator	Description
1	V _{DD}	12 .. 24V DC power supply
2	GND	Ground (power supply and data)
3	NO/NC	Normally Open or Normally closed (PNP/NPN) connection
4	Tx/Rx+	RS485 differential line. High for logic 1 and low for logic 0
5	Tx/Rx-	RS485 differential line. Low for logic 1 and high for logic 0

2.5. DC Electrical characteristics

Table 6 - DC Electrical characteristics

	Parameter	Level	Level
Power supply	Voltage input DC	12 V	24 V
	Current consumption (typical)	38 mA	21mA
Digital output levels NO/NC (in PNP/NPN)	Voltage output DC	0 V	24 V
	Current consumption		450 mA ¹

¹ At $V_{DD} = 24$ V DC, unfused

3. Camera coordinate system

The Terabee 3Dcam VGA coordinate system is defined in Figure 7. The camera is always vertically mounted (M12 connector on the base), as per picture. The z-axis is to be considered as the distance from the target.

Terabee IND-Thermal-90 is a passive optical temperature measurement camera that uses thermopile principle. The camera features a 90 degree Field of View, which corresponds to a detection area of 2 m × 2 m (spot diameter in reception) at 1 m range; 6 m × 6 m (spot diameter) at 3 m range, and scales linearly with distance, i.e. as $2 \times z$ in Figure 7.

E.g. if one considers the observer to be directed from the target to the camera as per Figure 8 - left, a typical resulting heatmap is shown in Figure 8 - right. Color-code is temperature [°C] from cold to hot (black → red → orange → yellow → white).

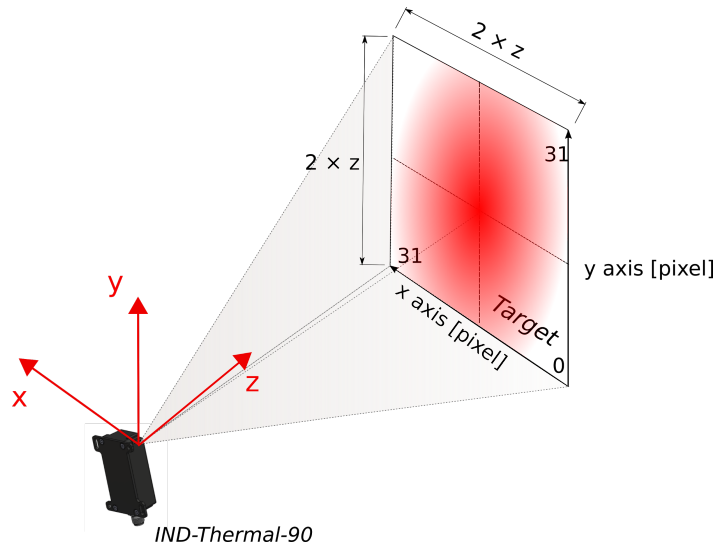


Figure 7. IND-Thermal-90 reference coordinate system and projected Field of View

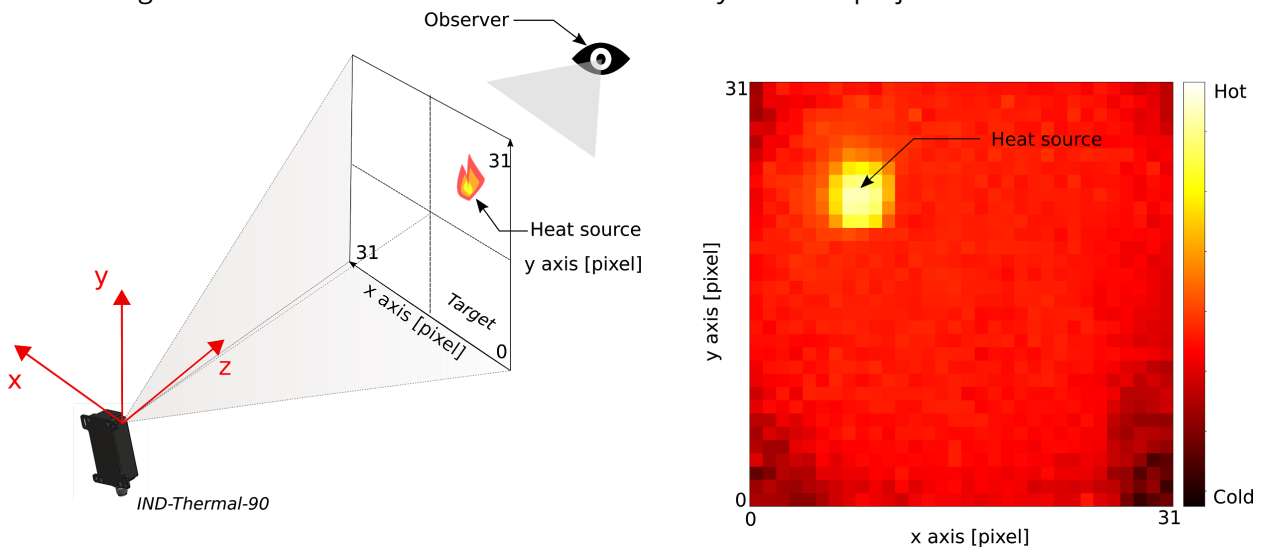


Figure 8. Typical views in color-code pictures in the manual: left- observer direction from target to camera; right - resulting heatmap (considering the registers mapping as shown in Section 7, Figure 15). Note that, given the choice of the observer, x axis direction is inverted in left and right Figures

4. Settings

4.1. Connectivity to RS485 bus

Figure 8 shows an example of connection in a Modbus of multiple (N) IND-Thermal-90 cameras.

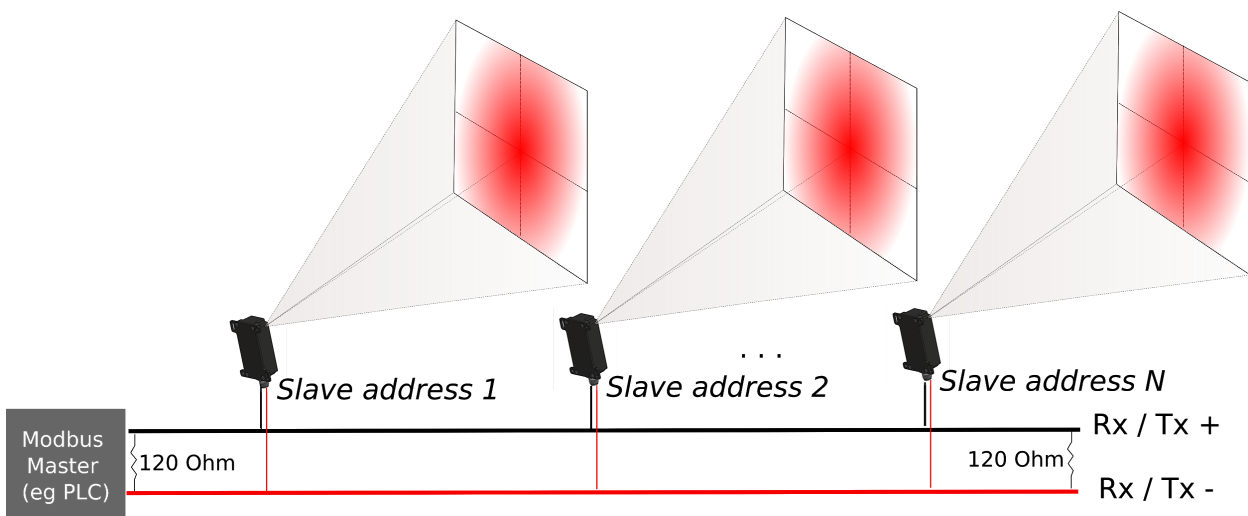


Figure 9. Connection of multiple IND-Thermal-90 cameras on RS485 network. External 120 Ohm termination resistors have to be added for signal stability at the beginning and end of the transmission line.



It is important to use 120 Ohm resistors at both terminations of the RS485 bus for proper operation.

The RS485 interface is a **half-duplex connection** with the following default parameters:

- Baud rate** : 19200
- Data bits** : 8
- Stop bits** : 1
- Parity** : Even

On top of that, a Modbus RTU protocol is in place to handle the data transfer. Detailed information about the Communication registers are in [Section 7](#). This is a master-slave type of protocol, ideal for RS485 data communications. This protocol supports up to 247 devices on the bus. The Terabee IND-Thermal-90 operates as a slave device.

Protocol	Input description
Modbus	<ul style="list-style-type: none"> Select transmission speed (1.2 to 256 kbps)
	<ul style="list-style-type: none"> Select parity bit (None, Even, Odd). If using no parity, then stop bits becomes 2
	<ul style="list-style-type: none"> Select Slave address



When the IND-Thermal-90 is connected for the first time (from default settings), it is important to match the master network speed to the camera default baud rate (19.2 kbps) and parity (even) and connect to the camera. Afterwards it is possible to update the specific camera connection parameters. After the update a restart of the camera (power off → on cycle) is suggested.

4.2. Alarm

Protocol	Input description
Modbus	<ul style="list-style-type: none"> Detection choice for hotspot: hot, cold, hot & cold for the three Applications
	<ul style="list-style-type: none"> Flag to activate alarm event electrical activation on NO/NC pin alarm
	<ul style="list-style-type: none"> Flags to activate alarm contribution, respectively, from Application 1, Application 2 and/or Application 3
	<ul style="list-style-type: none"> Setting to switch between NO and NC
	<ul style="list-style-type: none"> Setting to switch between NPN and PNP connections
	<ul style="list-style-type: none"> Setting to put the alarm timer-based or user-resettable
	<ul style="list-style-type: none"> Duration of the alarm pulse (50 ms - 2000 ms)
	<ul style="list-style-type: none"> Manual reset of the alarm

4.3. Camera settings

Protocol	Input description
Modbus	<ul style="list-style-type: none"> Sensor emissivity

5. Embedded Applications

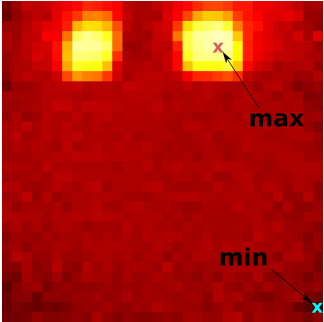
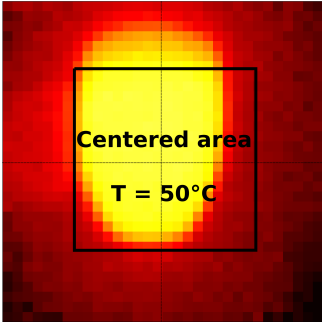
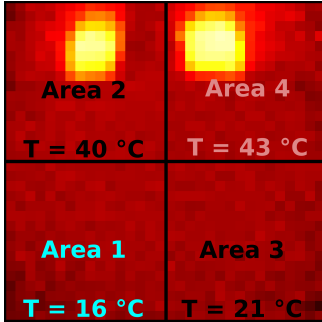
The camera features three embedded Applications (summarized in Table 6) which process camera measured temperature data and optionally raise alarms using a classic NO/NC (0- V_{DD}) switching output, according to user programmable settings. Each of the three Applications can be enabled/disabled (for alarming) by user choice; and trigger zones can be customized to meet specific Application needs. Such Applications allow, respectively, monitoring of:

1. The average and minimum/maximum temperatures over the available frame, localize hot/cold spots and optionally raise alarm, in case measured min/max temperatures exceed the (user-selectable) thresholds.
2. The average temperature of an arbitrary area (centered in the FoV) and compare it to the (user-selectable) thresholds in order to raise alarms.
3. The average temperature of user-defined regions of interest (ROI), list and count hot/cold spots (i.e. the ROIs exceeding the user-selectable thresholds) and raise alarms.

All Applications support temperature data communication via RS485 interface at all times. However the complete frame of 32 x 32 pixels requires several Modbus messages to be sent and received via the bus.

Since the camera's NO/NC switching output and RS485 temperature/settings data use distinct pins, both functions can be used either to complement each other or as separate functions. For instance, the switching output can act as a trigger for the master device, e.g. Programmable Logic Controller (PLC), to inquire about the current minimum and maximum temperatures.

Table 6 - Embedded Applications

	Application 1	Application 2	Application 3
			
Setup	Via RS485 (Modbus) or Graphical User Interface (GUI)		
Operation Sensor data	Available via RS485 (Modbus)		
Operation Switching output (NO/NC)	Temperature Threshold Alarm (triggered by min/max temperature over the available Field of View)	Threshold Alarm from the average over a Centered area (expandable to the available Field of View)	Counting and monitoring of Regions of Interest (ROI)
Application examples	Temperature control of continuous flow of extruded material Temperature monitoring of electrical cabinets	Automatic control of water spray when hot materials (e.g. bricks) pass on conveyor belts (in the center of the Field of View)	Fire and explosion prevention

5.1. Alarm logic

The alarm logic is represented in Figure 10. Modbus registers content and addresses (addr) are summarized in the [Communication Section](#) of this manual.

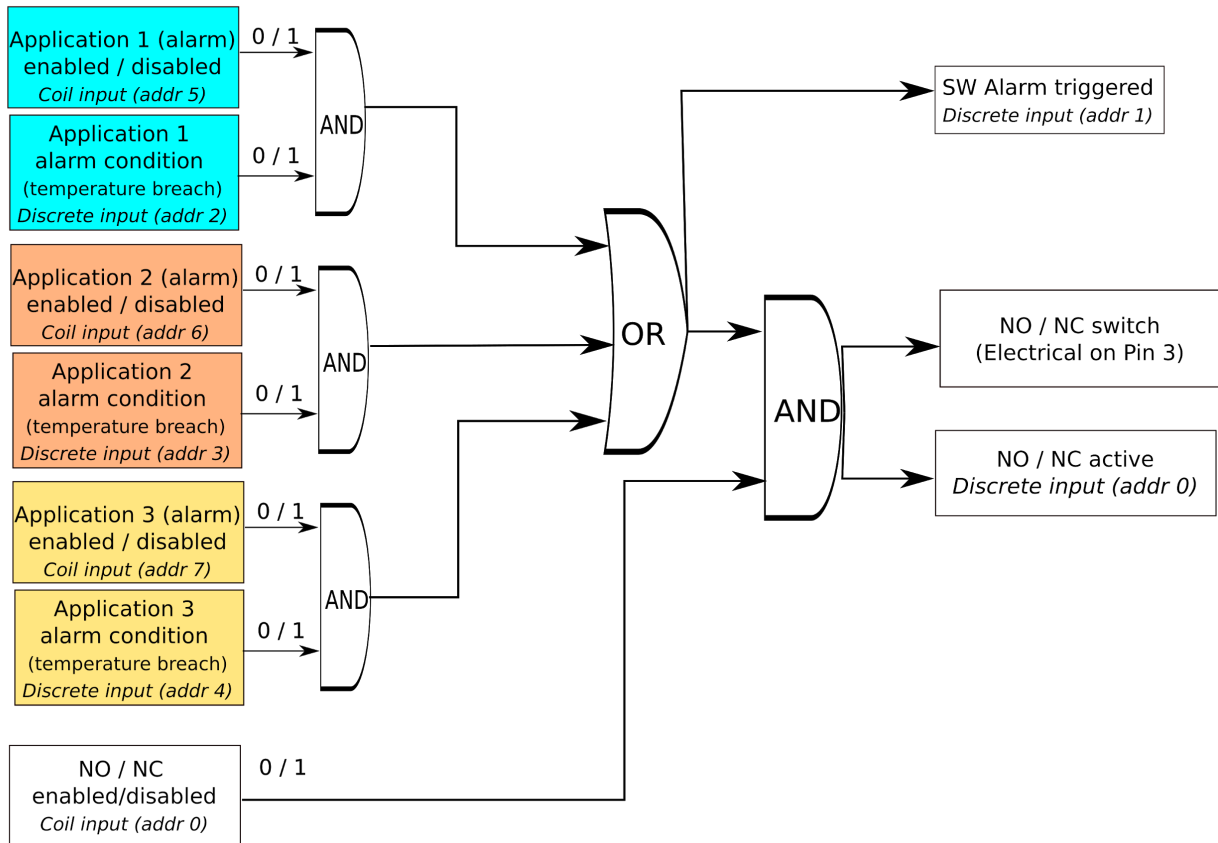


Figure 10. Logic for alarm of IND-Thermal-90.

5.2. Application 1

Description

The average temperature and minimum-maximum temperatures (and related pixel coordinates) are derived from measurements over the available frame. Such minimum and maximum measured temperature pixels are compared to user-defined min and max thresholds and can (optionally) generate an alarm (i.e. a switch) over the NO/NC output.

Figure 11 shows a centered area of 18 x 18 pixels and an example of commands to trigger alarm via Application 2 is shown in Table 7.

Inputs

Protocol	Input description
Modbus	<ul style="list-style-type: none">Minimum and maximum temperature thresholds²
	<ul style="list-style-type: none">Detection choice for hotspot: hot, cold, hot & cold
	<ul style="list-style-type: none">FoV to be considered for Application: entire (default) or central 20 × 20 pixels³
	<ul style="list-style-type: none">Option of temporal moving average (4 frames). Same setting as for App1

Outputs

Protocol	Output description
Modbus	<ul style="list-style-type: none">Measured minimum, maximum (values and pixel coordinates) and average temperatures over the available the FoV
Modbus + electric	<ul style="list-style-type: none">Optional Alarm and NO/NC flags activation in case of temperature breach

² For stable alarm readings, it is suggested to consider minimum 10 °C (190 dK) difference between minimum and maximum thresholds

³ Due to potential residual non-linearities, measurement might result slightly distorted at the corners of the FoV (lower with respect to the center for an isothermal target). Therefore it might be useful to activate the option 'limited FOV flag'=1 to shrink the minimum, maximum and average temperature calculation locally in the inner 20 × 20 pixels. N.B.: the camera will always acquire the full 32 × 32 data frame in case the customer is interested in full image reconstruction.

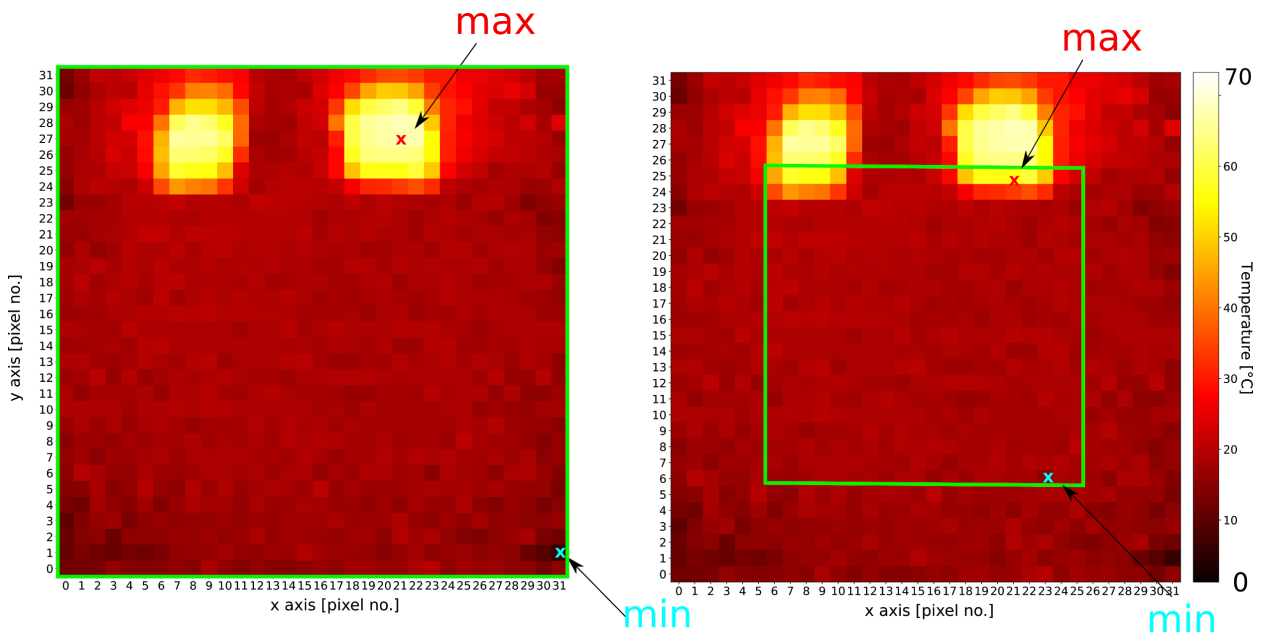


Figure 11. Application 1. Example of two similar heat sources in the camera full FoV with option:

- **Left: 'limited_FoV_flag = 0'.** Minimum (cyan 'x' marker), maximum (red 'x' marker) and average temperatures are computed in the full FoV. In this case $(x_{min}, y_{min}) = (21, 27)$ and $(x_{max}, y_{max}) = (31, 1)$ - see green rectangular contour.
- **Right: 'limited_FoV_flag = 1'.** Minimum (cyan 'x' marker), maximum (red 'x' marker) and average temperatures are computed only in the central 20×20 pixels (green rectangular contour). In this case $(x_{min}, y_{min}) = (21, 25)$ and $(x_{max}, y_{max}) = (23, 6)$ respectively.

Table 7 - Example of 'hot' NO/NC timer-based (250 ms) alarm activation for Application 1 (referring to Figure 11 - right). Text in **red** indicates alarming conditions and related outputs. Description of Modbus registers can be found in the [Communication Section](#) of this manual

Input (from user)	Modbus Register	Address	Value
Application 1 enabled/disabled	Coil input	5	1
NO / NC enabled/disabled		0	1
Limited FoV flag		11	1
NO/NC timer based		1	1 (default)
NO/NC selected		2	0 (NO)
NPN/PNP selected		3	1 (NPN)
Application 1 and 3 moving average		10	0
NO/NC ON time	Holding register	8	250 (ms)
Application 1 (cold threshold)		3	2732 dK (0.05 °C)
Application 1 (hot threshold)		2	3082 dK (35.05 °C)
Temperature choice		13	1 (hot)

Output (from camera)	Modbus Register	Address	Value
Application 1 minimum temperature	Input register	0	2881 dK (14.95 °C)
Application 1 minimum YX coordinates		1	6421 (Y = 25, X = 21)
Application 1 maximum temperature		3	3281 dK (54.95 °C)
Application 1 maximum YX coordinates		3	1559 (Y = 6, X = 23)
NO/NC active	Discrete input	0	1
Alarm triggered		1	1
Application 1 Alarm triggered		2	1

5.3. Application 2

Description

Average temperature is measured over a centered area (square shape, side length in pixel is user-selectable). This is compared to user selected min and max thresholds for alarm triggering NO/NC.

Figure 12 shows a centered area of 18 x 18 pixels and an example of commands to trigger alarm via Application 2 is shown in Table 8.

Inputs

Protocol	Input description
Modbus	<ul style="list-style-type: none">Size of centered area of interest in pixels in the 2n x 2n format: eg (2 × 2 = 4 pixels), (4 × 4 = 16 pixels), (6 × 6=36 pixels), ..., up to full FoV (32 × 32= 1024 pixels)
	<ul style="list-style-type: none">Min and max temperature thresholds⁴ for centered area
	<ul style="list-style-type: none">Moving average window size (1 to 16 reading frames – default is over 10 frames)

Outputs

Protocol	Output description
Modbus	<ul style="list-style-type: none">Average temperature of central area (also depending on moving average, if selected)
Modbus + electric	<ul style="list-style-type: none">Optional Alarm and NO/NC flags activation in case of temperature breach

⁴ For stable alarm readings, it is suggested to consider a minimum difference of 10 °C (190 dK) between minimum and maximum thresholds.

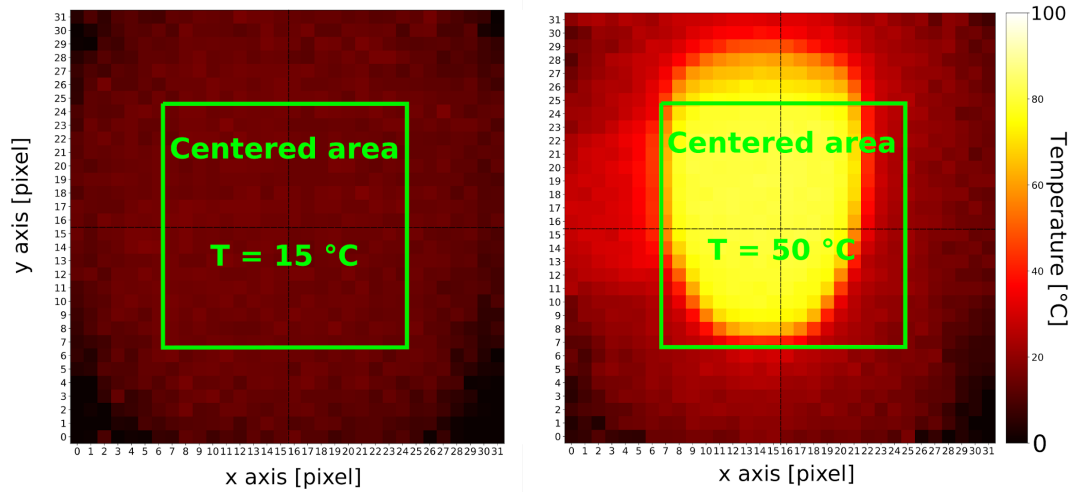


Figure 12. Application 2. Difference in reading without (left) and with (right) hotspot. Temperature values are rounded to the closest integer for illustration purposes.

Table 8 - Example of 'hot' NO/NC timer-based (250 ms) alarm activation from Application 2. (with reference to Figure 12 - right). Text in **red** indicates alarming conditions and related outputs. Description of Modbus registers can be found in the [Communication Section](#) of this manual

Input (from user)	Modbus Register	Address	Value
Application 2 enabled/disabled	Coil input	6	1
NO / NC enabled/disabled		0	1
NO/NC timer based		1	1 (default)
NO/NC selected		2	0 (NO)
NPN/PNP selected		3	1 (NPN)
NO/NC ON time	Holding register	8	250 (ms)
Application 2 (cold threshold)		5	2732 dK (0.05 °C)
Application 2 (hot threshold)		4	3082 dK (35.05 °C)
Temperature choice		13	1 (hot)
Application 2 centered area size		10	18 (18 × 18 pixels)
Output (from camera)	Modbus Register	Address	Value
Application 2 centered area temperature	Input register	24	3231dK (49.95 °C)
NO/NC active	Discrete input	0	1
Alarm triggered		1	1
Application 2 Alarm triggered		3	1

5.4. Application 3

Description

FoV is divided into squared regions of interest (ROIs, which size is user-selectable). Average temperatures of each ROI are computed and stored in Modbus registers.

A counter shows the number of ROIs breaching (user-selectable) threshold temperatures. Alarm (NO/NC) is optionally activated if one of the Grid ROIs breaches temperature threshold(s).

Figure 13 shows the criterium of ROI area selection with respect to the raw registers. Figure 14 shows a typical averaging with ROI size of 16 pixels × 16 pixels.

An example of commands to trigger alarm via Application 3 is shown in Table 9.

Inputs

Protocol	Input description
Modbus	<ul style="list-style-type: none"> Size of Grid ROIs, eg 2 × 2 (256 ROIs) or 4 × 4 (64 ROIs) or 8 × 8 (default, 16 ROIs) or 16 × 16 (4 ROIs)
	<ul style="list-style-type: none"> Minimum and maximum temperature thresholds⁵ for Grid ROIs (one threshold set for all of them)
	<ul style="list-style-type: none"> Reset of Number of cold / hot Grid ROIs counter
	<ul style="list-style-type: none"> Selection of “unidirectional” or “bi-directional” counter
	<ul style="list-style-type: none"> Option of temporal moving average (4 frames). Same setting as for App1

Outputs

Protocol	Output Description
Modbus	<ul style="list-style-type: none"> Array of 0 (normal spot) / 1 ('hotspot') ROIs for alarm areas localisation on a given frame
	<ul style="list-style-type: none"> Number of cold/hot grid ROIs <ul style="list-style-type: none"> Uni-directional counter. The counter is only incremental and is increasing in time (up to 65535) for any new ROI breaching the temperature thresholds. Then must be resetted by the customer. Bi-directional counter. The total number (per frame) of ROIs breaching the temperature thresholds is shown. Therefore the counter can increment/decrement according to the current number of hotspots. Does not require resetting.

⁵ For stable alarm readings, it is suggested to consider a minimum difference of 10 °C (190 dK) between minimum and maximum thresholds.

	<ul style="list-style-type: none"> Measured average temperatures per ROI, up to 256 values (maximum number of ROIs for ROI size of 2x2 pixels) In case of breach(es), value/coordinates of the ROI with the highest gap to threshold⁶. The coordinate is an index of the Alarm Array (see first Output)
Modbus + electric	<ul style="list-style-type: none"> Optional Alarm and NO/NC flags activation in case of temperature breach of one or more ROIs

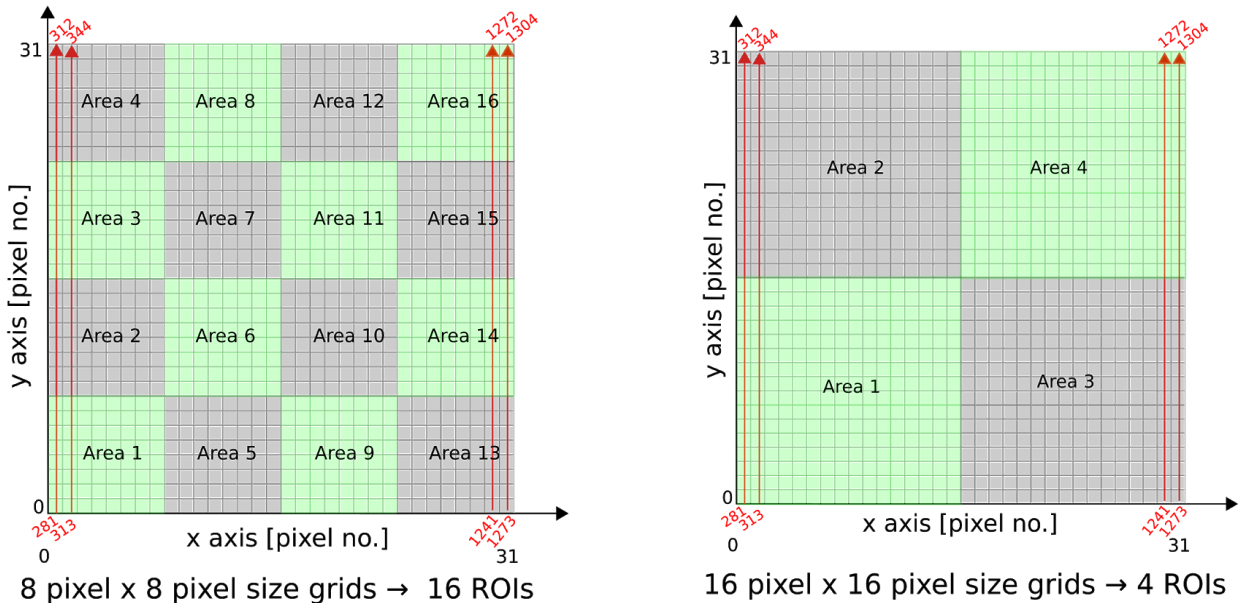


Figure 13. Application 3. Example of user selectable configuration of ROIs with different grid sizes on top of registers mapping of Figure 15.

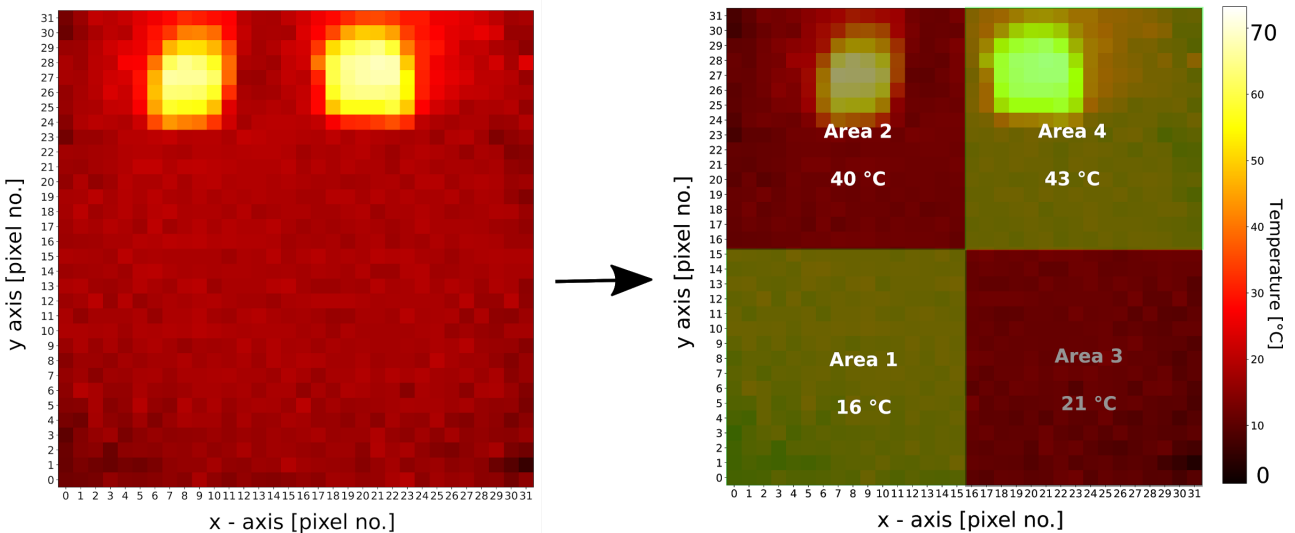


Figure 14. Application 3. Example of averaging over 4 ROIs. Temperature values are rounded to the closest integer for illustration purposes.

⁶ Example: thresholds set as minimum = 30 °C and maximum = 50 °C. At the same time: ROI measured = 56°C and ROI2 measured = 20 °C ⇒ $\Delta(\text{ROI1}) = |56-50| \text{ °C} = 6\text{°C}$, $\Delta(\text{ROI2}) = |20-30| \text{ °C} = 10\text{°C}$ ⇒ ROI2 alarm is shown and published in specific (highest delta) Modbus register (value and coordinate).

Table 9 - Example of 'hot' NO/NC alarm activation from Application 3 (referring to Figure 14 – right). Text in **red** indicates alarming conditions and related outputs. Description of Modbus registers can be found in the [Communication Section](#) of this manual

Input (from user)	Modbus Register	Address	Value
Application 3 enabled/disabled	Coil input	7	1
NO / NC enabled/disabled		0	1
Application 3 bi-directional counter		4	0
NO/NC timer based		1	1 (default)
NO/NC selected		2	0 (NO)
NPN/PNP selected		3	1 (NPN)
Application 1 and 3 moving average		10	0
NO/NC ON time	Holding register	8	250 (ms)
Application 3 (cold threshold)		5	2732 dK (0.05 °C)
Application 3 (hot threshold)		6	3082 dK (35.05 °C)
Temperature choice		13	1 (hot)
Application 3 ROI size		12	4
Output (from camera)	Modbus Register	Address	Value
Application 3 hotspot location	Input register	5	1001000000000000
		6	0000000000000000
		...	
		20	0000000000000000
Application 3 ROI temperature		25	2892 dK (16.05 °C)
		26	3131 dK (39.95 °C)
		27.	2941dK (20.95 °C)
		28	3161 dK (42.95 °C)
		...	0
Application 3 hotspot counter		23	2
Highest delta breach hotspot temperature	21	3161 dK (42.95 °C)	

Highest delta breach hotspot coordinates as expressed by registers "Application 3 hotspot location"		22	4
NO/NC active	Discrete input	0	1
Alarm triggered		1	1
Application 3 Alarm triggered		4	1

6. Measurement units

Temperatures are stored in Modbus registers in decikelvin [dK]. In order to convert to common degree Celsius [°C], the well known formula is the following:

$$\text{Temperature [°C]} = \text{Temperature [dK]} / 10 - 273.15$$



Please note that conversion from decikelvin [dK] to degrees Celsius [°C] implies the introduction of numbers of type 'float'. Given the camera accuracy (in the order of 1 °C), a rounding to integer could be suggestable for some operations.

7. Communication

7.1. Input registers (read-only)

Table 18 - Input registers (read only)

Name	Functionality	Address	Length
Application 1 minimum temperature	Retrieves the minimum temperature recorded with the measured image frame. Value in dK (decikelvin).	0	1
Application 1 minimum YX coordinates	Retrieves the minimum temperature position recorded with the measured image frame. Example: 2832 (decimal), split into two uint8_t, MSB is y, LSB is x y is 11 (2832 >> 8), x is 16 (2832 & 0xFF).	1	1
Application 1 maximum temperature	Retrieves the maximum temperature recorded with the measured image frame. Value in dK (decikelvin).	2	1
Application 1 maximum YX coordinates	Retrieves the maximum temperature position recorded with the measured image frame. Example: 2832 (decimal), split into two uint8_t, MSB is y, LSB is x y is 11 (2832 >>8), x is 16 (2832 & 0xFF).	3	1
Application 1 mean temperature	Gives the mean temperature value recorded with the measured image frame. Value in dK (decikelvin).	4	1
Application 3 Hotspot location	Displays the hotspot locations measured in the image frame for Application 3. ⁷	5-20	16

⁷ 16 registers of integers (data type 'uint16'), i.e. up to 16 x 16 (bits) = 256 bits . The content of each bit is 0 (no hotspot) or 1 (hotspot). Any bit of these registers (in binary form) is related to an area (ROI).

Such 16 registers are filled partially and in order, from register 5 to 20, if the size of ROI is larger than 2 x 2 . Examples:

- if ROI size is 16 x 16, only the first four bits of the first register will represent 'hotspot' (1) or 'no hotspot' (0) conditions for the related 4 ROIs.
- If ROI size is 2 x 2, all the 256 bits of the 16 registers will represent 'hotspot' (1) or 'no hotspot' (0) conditions for the related 256 ROIs.

Highest delta breach hotspot temperature	Gives the highest delta breach within the hotspot temperatures measured for Application 3. Value in dK (decikelvin).	21	1
Highest delta breach hotspot coordinates as expressed by registers "Application 3 hotspot location"	Gives the highest delta breach location within the hotspot temperatures which are measured for Application 3.	22	1
Application 3 Hotspot counter	Retrieves the counter value for hotspots in Application 3.	23	1
Application 2 temperature	Gives the temperature of the centered area as measured by Application 2 after the average of pixels. Value in dK (decikelvin).	24	1
Application 3 ROI temperature	Gives the average temperature values starting from the first ROI. Values in dK (decikelvin).	25-280	256
Pixel temperatures	Gives the values of pixels in the image frame starting from 0,0. Values in dK (decikelvin).	281-1304	1024

Registers mapping

Figure 15 shows the pixel mapping criterium (value in Modbus register → pixel temperature) in order to produce a heatmap (see eg Figures 11, 12, 14) in the reference coordinates frame of Figure 7.

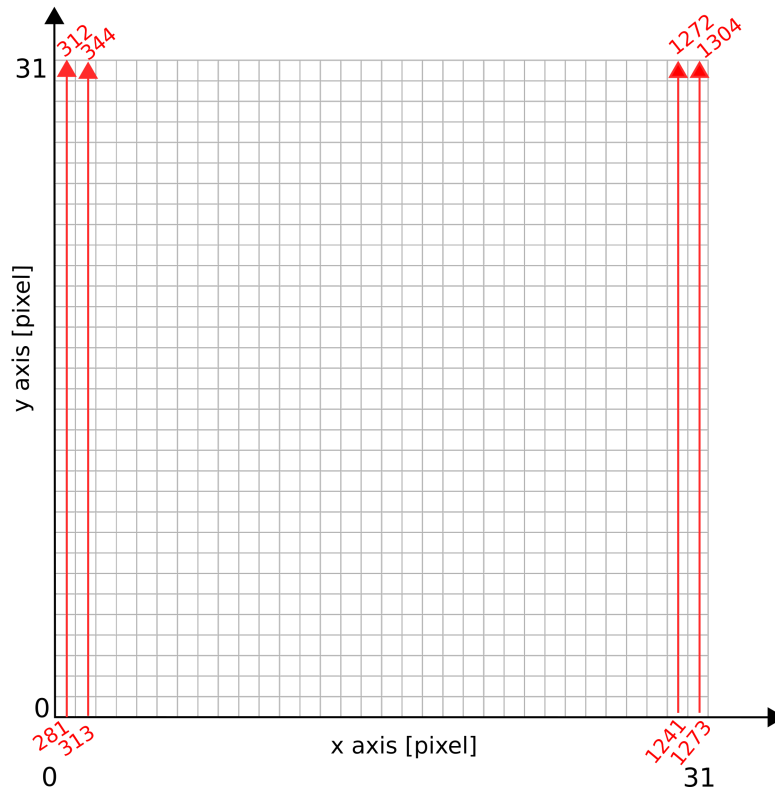


Figure 15. Mapping of content of Modbus input registers related to raw pixel temperatures (281-1304). Values in red correspond to the register number, whilst black axes are the pixel indexing in a 32 x 32 frame (eg as per Fig. 8).

7.2. Configurable camera parameters (holding registers)

The following section lists holding registers of configurable camera parameters, their functionality.



As per the Modbus standard, a slave ID of 0 means the command is a broadcast and will be acknowledged by all devices connected to the network. This is true for all commands listed here.

Example: 0x00 0x06 0x00 0x00 0x00 0x01 0x49 0xDB. This sets the address of all devices on the bus to 1. The slave can't reply to the master in broadcast mode.



Content of holding registers is kept in the camera memory after a restart (power off → power on).

Device address settings (slave address)

This parameter holds the device address. For changing this parameter, please use the following configuration:

Copyright © Terabee 2021
 Terabee, 90 Rue Henri Fabre
 01630, St Genis-Pouilly, France (next to CERN)

Slave ID : 1 to 247
Address location : 0
Value : 1 to 247 (default 1)

RS485 parameters

This parameter defines the communication parameters baud-rate and parity along with the stop bit. Once the parameters are set, the device needs to be restarted to configure the device with the updated parameters.

Baud rate	Hexa-decimal value
1200	0x00
2400	0x04
4800	0x08
9600	0x0C
14400	0x10
19200	0x14
28800	0x18
38400	0x1C
56000	0x20
57600	0x24
115200	0x28
128000	0x2C
256000	0x30

Parity	Hexa-decimal Value
None	0x00
Odd	0x01
Even	0x02

Slave ID : 1 to 247
Address location : 1
Value : (default value is 22 i.e., baud rate –19200, parity–even)

For example: For setting baud rate of 19200 with the even parity, take the hexadecimal values from the above tables and perform a logic OR operation on them and convert to decimal numbers as shown in below.

In Hexadecimal -- 0x14 | 0x02 = 0x16 (22 in Decimal).

Note: *Requires camera restart*

Application 1 hot threshold

This parameter defines the hot threshold temperature value for Application 1 which will raise an alarm when the measured pixel temperature is above the threshold value (when the **TEMPERATURE CHOICE** is selected for 1 or 3).

Slave ID : 1 to 247
Address location : 2
Value : 2531 (-20°C) to 9431 (+670°C)
value in dK (decikelvin), default 3731 (100°C)

Application 1 cold threshold

This parameter defines the cold threshold temperature value for Application 1 which will raise an alarm when the measured pixel temperature is below the threshold value (when the **TEMPERATURE CHOICE** is selected for 2 or 3).

Slave ID : 1 to 247
Address location : 3
Value : 2531 (-20°C) to 9431 (+670°C)
value in dK (decikelvin), default 2731(0°C)

Application 2 hot threshold

This parameter defines the hot threshold temperature value for Application 2 which will raise an alarm in case the average of pixels of the target spot centered exceeds the hot thresholds (when the **TEMPERATURE CHOICE** is selected for 1 or 3).

Slave ID : 1 to 247
Address location : 4
Value : 2531 (-20°C) to 9431 (+670°C)
value in dK (decikelvin), default 3731 (100°C)

Application 2 cold threshold

This parameter defines the cold threshold temperature value for Application 2 which will raise an alarm in case the average of pixels of the target spot centered falls below the cold thresholds (when the **TEMPERATURE CHOICE** is selected for 2 or 3).

Slave ID : 1 to 247
Address location : 5
Value : 2531 (-20°C) to 9431 (+670°C)
value in dK (decikelvin), default 2731 (0°C)

Application 3 hot threshold

This parameter defines the hot threshold temperature value for Application 3 which will raise an alarm when the measured temperature of the active area is above the threshold value (when the **TEMPERATURE CHOICE** is selected for 1 or 3).

Slave ID : 1 to 247
Address location : 6
Value : 2531 (-20°C) to 9431 (+670°C)
value in dK (decikelvin), default 3731 (100°C)

Application 3 cold threshold

This parameter defines the cold threshold temperature value for the Application 3 which will raise an alarm when the measured temperature of the active area is below the threshold value (when the **TEMPERATURE CHOICE** is selected for 2 or 3).

Slave ID : 1 to 247
Address location : 7
Value : 2531 (-20°C) to 9431 (+670°C)
value in dK (decikelvin), default 2731 (0°C)

NO/NC ON time

This parameter defines the amount of time the NO/NC switching output will remain triggered and will be reset after the defined time in milliseconds (when the NO/NC TIMER BASED is selected).

Slave ID : 1 to 247
Address location : 8
Value : 50 to 2000 (in milliseconds, default 250)

IND-Thermal-90 emissivity

This parameter defines the emissivity value of the camera which has the default value of 95.

Slave ID : 1 to 247
Address location : 9
Value : 1 to 100 (default 95)

Application 2 centered area size

This parameter defines the size of centered area as x*x pixels which is used in Application 2. Where x is the value in the register used.

Slave ID : 1 to 247
Address location : 10

Value : Even numbers between 2 to 32 (default value is 4)

Application 2 moving average size

This parameter defines the size of moving average value for Application 2 which averages the pixels to detect the hotspot temperature.

Slave ID : 1 to 247

Address location : 11

Value : 1 to 16 (default value is 10)

Application 3 ROI size

This parameter defines size of ROI pixels as x*x pixels for Application 3 to count the number of hotspots within the area. The below values represents the pixel size

Value	Pixel size
1	2*2
2	4*4
3	8*8
4	16*16

Slave ID : 1 to 247

Address location : 12

Value : 1 to 4 (default value is 3)

Temperature choice

This parameter defines the temperature choice to make the hot/cold thresholds active depending on the selected number.

1 = Only hot threshold, which makes only the hot threshold value to trigger the Application.

2 = Only cold threshold, which makes only the cold threshold value to trigger the Application.

3 = Both cold & hot threshold, which makes a hot/cold threshold value to trigger the Application.

Slave ID : 1 to 247

Address location : 13

Value : 1 to 3 (default 1)

7.3. Configurable Flags (Coil Inputs)

The following section lists coils of configurable flags and their functionality.



Content of Coil Input registers is kept in the camera memory after a restart (power off → power on). Exceptions to this are the following coil inputs: “master reading”, “clear no/nc” and “application 3 reset uni-directional counter”. These three registers are used as flags during runtime and will not be saved.

NO/NC enabled/disabled

This parameter defines whether the NO/NC contact must be activated or not in case of alarm incoming from the applications. **The default setting value is 0 (OFF).**

- When **NO/NC enabled/disabled** = 0 (OFF), the Applications will keep running and raise a software alarm, if there is an alarm condition. But there will be no action of NO/NC Contact.
- When **NO/NC enabled/disabled** = 1 (ON), the NO/NC logic is activated and the Applications raise the alarms with NO/NC Contact.

Slave ID : 1 to 247
Address location : 0
Value : 0 or 1 (value 0 for OFF and 1 for ON , default 0)

NO/NC timer based

This parameter defines whether the NO/NC is timer based or not. **The default setting value is 1 (ON).**

- When **NO/NC timer based** = 0 (OFF), NO/NC can only be refreshed by master action.
- When **NO/NC timer based** = 1 (ON), the NO/NC will be refreshed by a timer.⁸

Slave ID : 1 to 247
Address location : 1
Value : 0 or 1 (value 0 for OFF and 1 for ON , default 1)

NO/NC selected

This parameter defines whether the switching output is in a normally open (NO) or normally closed (NC) configuration. A value of 0 sets it to NO, while a value of 1 sets it to NC. **The default setting value is 0 (NO).**

⁸ In case of persistence of the alarm condition, the NO/NC output will switch periodically for the length of the alarm and stop for a short time (typically 50-100 ms) in between.

Slave ID : 1 to 247
Address location : 2
Value : 0 or 1 (value 0 for NO and 1 for NC, default 0)

NPN/PNP selected

This parameter defines whether the switching output is sourcing (PNP) or sinking power (NPN). A value of 0 sets it to PNP, while a value of 1 sets it to NPN. **The default setting value is 1 (NPN).**

Slave ID : 1 to 247
Address location : 3
Value : 0 or 1 (value 0 for PNP and 1 for NPN, default 1)

Note: *Requires camera restart.*

Application 3 uni-directional counter

This parameter defines the counter for Application 3, whether ROIs works as both incremental and decrement or only Increment. **The default setting value is 0 (bi-directional).**

- When **APPLICATION 3 uni-directional counter** = 0 (OFF), the counter for Application 3 works both as incremental and decremental as the area gets hotter/colder.
- When **APPLICATION 3 uni-directional counter** = 1 (ON), the counter for Application 3 works only in an incremental way (uni-directional counter).⁹

Slave ID : 1 to 247
Address location : 4
Value : 0 or 1 (value 0 for OFF and 1 for ON, default 0)

Application 1 (alarm) enabled/disabled

This parameter defines whether Application 1 can trigger the alarm and NO/NC (if No/NC is enabled) or not. **The default setting value is 0 (OFF).**

- When **APPLICATION 1 ENABLED/DISABLED** = 0 (OFF), the Application 1 cannot trigger the alarm, even if there is an alarm situation, but the data can still be displayed and sampled.

⁹ NB: the uni-directional counter will increment any time there is a new switch (0 → 1) in the bits constituting hotspot array. I.e. if a hotspot (1) persists in more than one frame, it will not be counted again, but would be counted if, e.g. due to a reading glitch, there is a temporary transition of the hotspot (1) into a coldspot (0).

- When **APPLICATION 1 ENABLED/DISABLED** = 1 (ON), the Application 1 can trigger the alarm (NO/NC).

Slave ID : 1 to 247
Address location : 5
Value : 0 or 1 (value 0 for OFF and 1 for ON , default 0)

Application 2 (alarm) enabled/disabled

This parameter defines whether Application 2 can trigger the alarm and NO/NC (if NO/NC is enabled), or not. **The default setting value is 0 (OFF).**

- When **Application 2 enabled/disabled** = 0 (OFF), the Application 2 cannot trigger the alarm, even if there is an alarm situation, but the data can still be displayed and sampled.
- When **Application 2 enabled/disabled** = 1 (ON), the Application 2 can trigger the alarm (NO/NC).

Slave ID : 1 to 247
Address location : 6
Value : 0 or 1 (value 0 for OFF and 1 for ON , default 0)

Application 3 (alarm) enabled/disabled

This parameter defines whether Application 3 can trigger the alarm and NO/NC (if No/NC is enabled), or not. **The default setting value is 0 (OFF).**

- When **Application 3 enabled/disabled** = 0 (OFF), the Application 3 cannot trigger the alarm, even if there is an alarm situation, but the data can still be displayed and sampled.
- When **Application 3 enabled/diabled** = 1 (ON), the Application 3 can trigger the alarm (NO/NC).

Slave ID : 1 to 247
Address location : 7
Value : 0 or 1 (value 0 for OFF and 1 for ON , default 0)

Master reading

This parameter defines whether the master device is going to read the frames or not reading frames. **The default setting value is 0 (OFF).**

- When **Master reading** = 0 (OFF), the pixel values coming from the sensor are continuously updated on the related Modbus registers (see last row in Table 18).

- When **Master reading** = 1 (ON), the pixel values stop being updated in the Modbus registers until the flag is again set to 0.

Asynchronous reconstruction of Frame by using 'Master reading' flag

The 'Master reading' flag is particularly important when the master wants to acquire a full frame.

In order to perform an asynchronous frame reconstruction (Get), the customer can retrieve up to 125 pixel temperatures per Modbus message, meaning that at least nine Modbus messages must be exchanged between Modbus Master (eg PLC) and Modbus Slave (IND-Thermal-90) to retrieve the full $32 \times 32 = 1024$ pixels and reconstruct constituting a heatmap image. In order to avoid update of the pixels on the Modbus during the image retrieval (with consequent image blur or corruption), the customer must place **Master reading** = 1, before starting to read all the pixel temperatures. Right after he will restore **Master reading** = 0. The flow-chart in Figure 15 shows the process.



NB IND-Thermal-90 does not feature a streaming option, thus the frame reconstruction is asynchronous only.



The three Applications will continue to run on the updated frames, even if 'Master reading' is set to 1. This implies that quantities like average and minima/maxima and related coordinates (from an immediately prior or subsequent read of the application registers) are continuously updated and thus might not precisely correspond to the ones in the reconstructed frame. With not fast thermal dynamics their values shall be fairly similar though.



It is possible to get full frame coordinates also without setting in advance the 'Master reading' flag to 1. In this case it is not guaranteed that temperature values of the full 1024 pixels will correspond to the same moment in time.

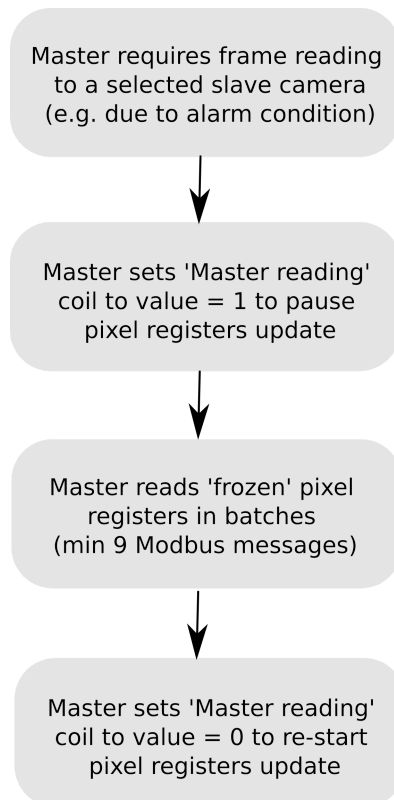


Figure 16. Flow-chart for the logic of the Asynchronous Reconstruction of frame

Slave ID : 1 to 247
Address location : 8
Value : 0 or 1 (value 0 for OFF and 1 for ON , default 0)

Application 1 limited FoV flag

This flag defines the scan area of application 1. If enabled, only the inner 20×20 pixels will be used for minimum, maximum and average calculation. Alternatively, if disabled, the entire 32×32 frame will be scanned. **The default setting value is 0 (OFF).**

Slave ID : 1 to 247
Address location : 9
Value : 0 or 1 (value 0 for OFF and 1 for ON , default 0)

Application 1 and 3 moving average

This flag applies temporal (moving) average in both Applications 1 and 3 in order to smooth out noise from the readings. If enabled, a moving average over (fixed) 4 consecutive frames is applied to such Applications. If deactivated (0), the current frame is shown and considered for calculations of alarm algorithms inside applications 1 and 3. **The default setting value is 0 (OFF).**

Slave ID : 1 to 247

Address location : 10
Value : 0 or 1 (value 0 for OFF and 1 for ON , default 0)

Clear NO/NC

This parameter will be set to ON by the Applications when there is an alarm situation and the NO/NC is triggered. If the NO/NC is based on a timer, it can be cleared when the timer expires or otherwise by setting this coil to 0. If the NO/NC is action based, then the only way to stop it is the master setting this register to 0. **The default setting value is 0 (OFF).**

Slave ID : 1 to 247
Address location : 11
Value : 0 or 1 (value 0 for OFF and 1 for ON , default 0)

Application 3 reset uni-directional counter

This parameter is defined to reset the counter to 0, when writing 1 to the coil and the coil will then reset back to 0 as soon as the counter becomes 0¹⁰. **The default setting value is 0 (OFF).**

Slave ID : 1 to 247
Address location : 12
Value : 0 or 1 (value 0 for OFF and 1 for ON , default 0)

7.4. Discrete Inputs (Read-Only)

The following section lists the indication flags and their functionality.

NO/NC active

This parameter defines if there is a normally open (NO) or normally closed (NC) output triggered from the device. If the value is 1 that indicates the NO/NC is active and output is triggered from the device, else, the NO/NC is inactive and No trigger from the device. **The default setting value is 0 (OFF).**

Slave ID : 1 to 247
Address location : 0
Value : 0 or 1 (value 0 for OFF and 1 for ON , default 0)

Alarm triggered

This parameter defines if there is an alarm triggered situation at global level, irrespective of any Application. If the value is 1 that indicates there is an alarm triggered , else, there is no alarm situation. **The default setting value is 0 (OFF).**

¹⁰ The uni-directional counter does not increment anymore when it reaches the value of 65535. Therefore, in this situation, it must be reset to restart counting (from 0).

Slave ID : 1 to 247
Address location : 1
Value : 0 or 1 (value 0 for OFF and 1 for ON , default 0)

Application 1 alarm triggered

This parameter defines if there is an alarm triggered situation for Application 1. If the value is 1 that indicates there is an alarm triggered for Application 1, else, there is no alarm situation. **The default setting value is 0 (OFF).**

Slave ID : 1 to 247
Address location : 2
Value : 0 or 1 (value 0 for OFF and 1 for ON , default 0)

Application 2 alarm triggered

This parameter defines if there is an alarm triggered situation for Application 2 . If the value is 1 that indicates there is an alarm triggered for Application 2, else, there is no alarm situation. **The default setting value is 0 (OFF).**

Slave ID : 1 to 247
Address location : 3
Value : 0 or 1 (value 0 for OFF and 1 for ON , default 0)

Application 3 alarm triggered

This parameter defines whether there is an alarm triggered situation for Application 3. If the value is 1 that indicates there is an alarm triggered for Application 3, else, there is no alarm situation. **The default setting value is 0 (OFF).**

Slave ID : 1 to 247
Address location : 4
Value : 0 or 1 (value 0 for OFF and 1 for ON , default 0)

7.5. Default factory reset

The camera can be reverted back to its default settings (configurable camera parameters) at any time. This can be done using the following Modbus-like serial command:

{Slave ID} 0xFF {CRC16-Modbus}
Example for Slave ID 1 (default): 0x01 0xFF 0x40 0x60

The camera will reply via RS485 interface, Modbus-like format (its own address + 0xFF + CRC16-Modbus) with a slave ID 1. The STATUS LED will flash 10 times alternating red/green colors as a visual confirmation.

8. Connection example: input to a PLC

8.1. PNP connection

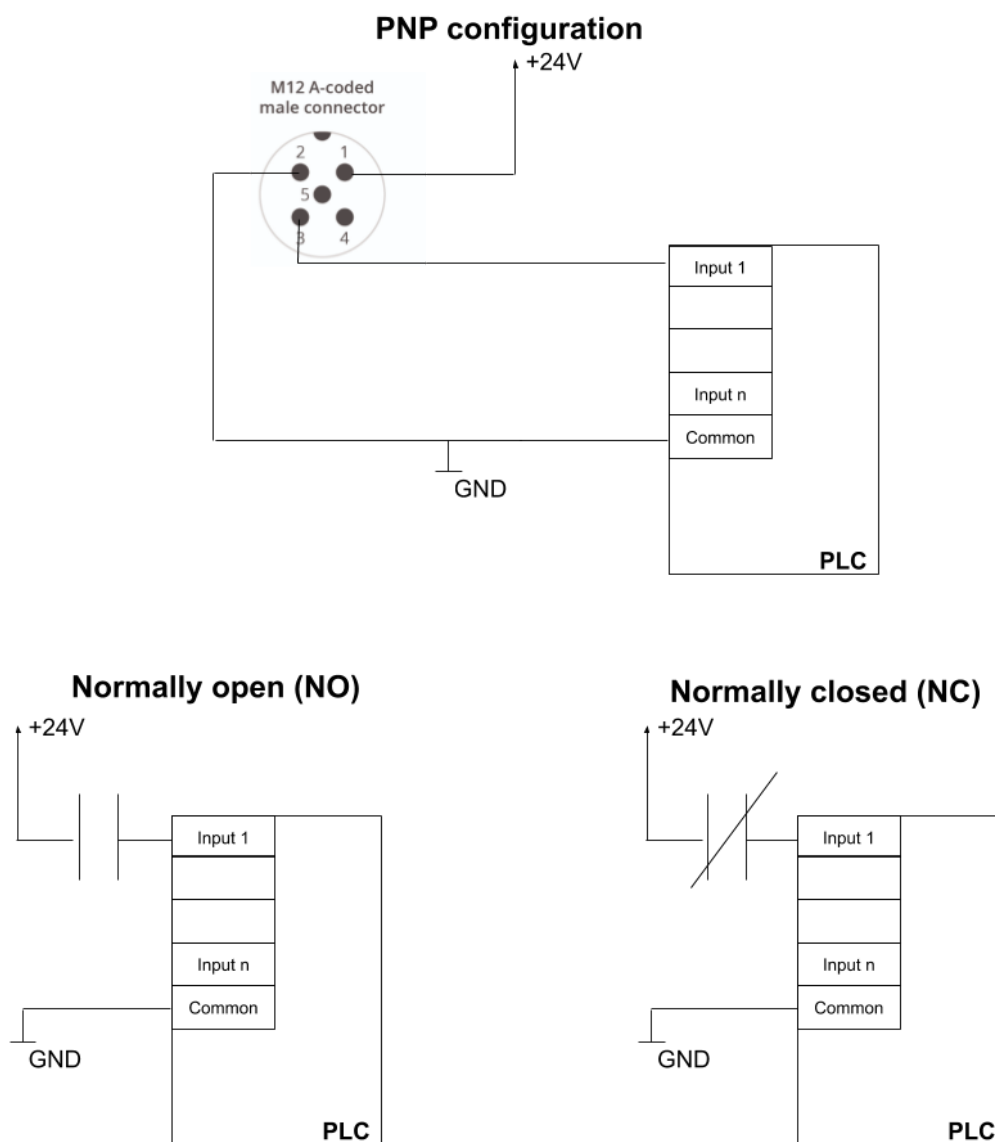


Figure 17. Example of PNP connection (top) for NO/NC schematics (bottom)

8.2. NPN connection

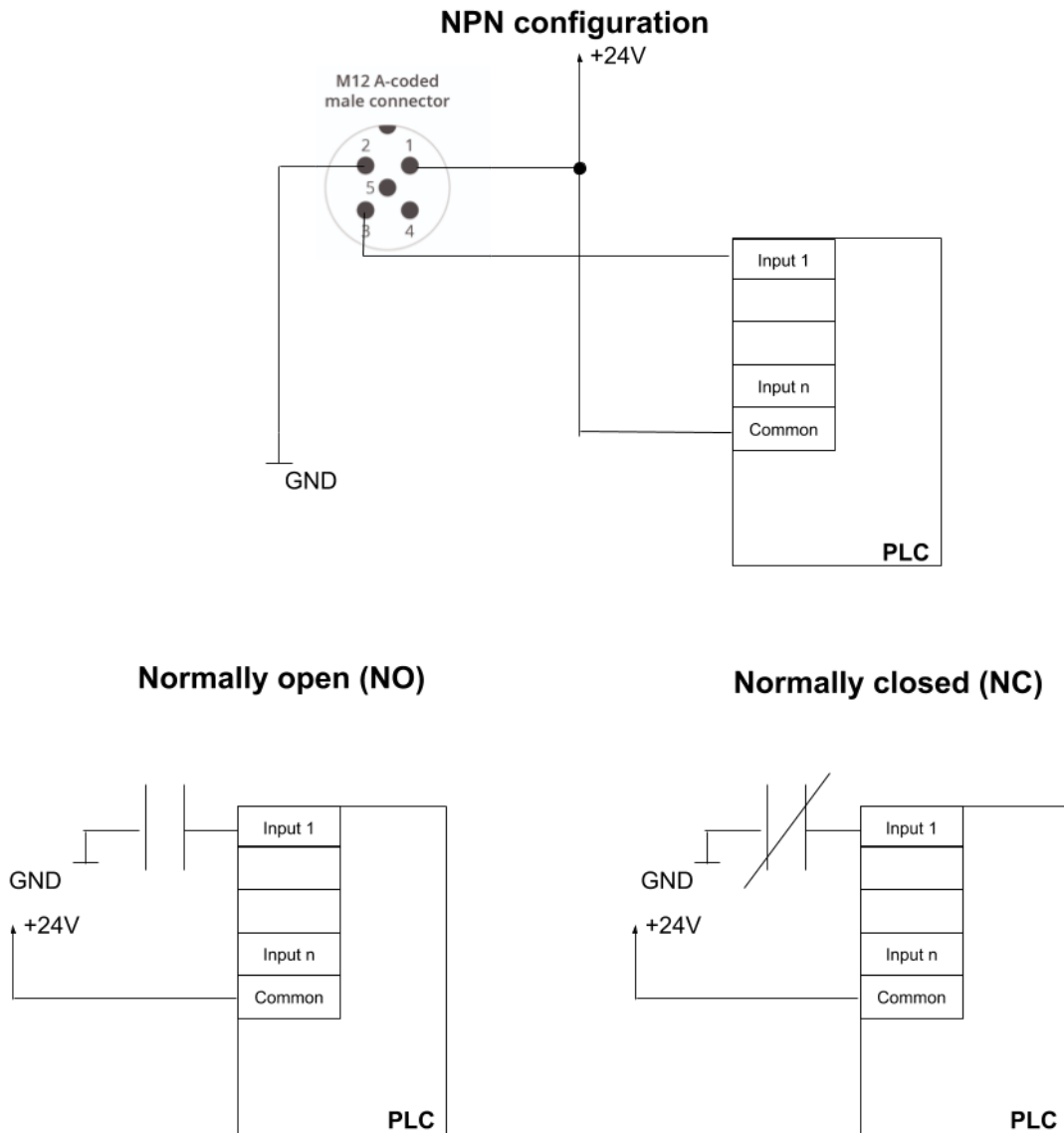


Figure 18. Example of NPN connection (top) for NO/NC schematics (bottom)

9. Connection to PC (Windows)

This section provides guidelines on connection and sensor evaluation on a PC, using Microsoft® Windows® OS. This includes instructions on hardware arrangement, software setup using MODBUS Doctor application (v2.7) and examples on executing commands for modifying some of the basic sensor parameters.

9.1. Hardware setup

Figure 19 illustrates connection logic between the IND-Thermal-90 sensor and a PC, and the following components are required for a complete setup:

- 1 × Terabee IND-Thermal-90 sensor
- 1 × Straight M12 5-pin A-coded cable of your preference (example [here](#), not provided by Terabee)
- 1 × RS485-to-USB adapter (example [here](#), not provided by Terabee)
 - (Not mandatory) 1 × USB extension cable (already available in suggested RS485-to-USB package) to connect to PC Control Unit (PC)
- 1 × Power Supply capable of supplying 12-24V DC @ >50mA

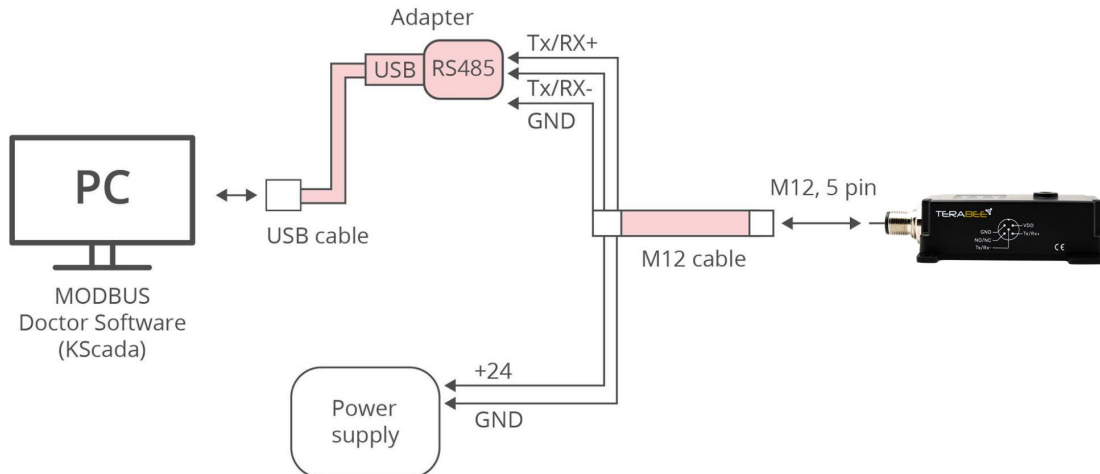


Figure 19. IND-Thermal-90 connection to PC: hardware setup diagram

The following summarizes the steps to be taken for connecting the IND-Thermal-90 camera to a PC.

Step 1

Connect the M12 cable to the sensors M12, 5-pin connector.

Step 2

Connect the data lines of the M12 cable to the RS485-to-USB adapter. See wiring instructions in Table 19.

Table 19 - Wiring connection between IND-Thermal-90 and RS485-to-USB adapter

M12 cable	Specific for RS485-to-USB adapter here
Tx/Rx+ (pin 4)	A+
Tx/Rx- (pin 5)	B-
Ground (pin 2)	GND

Step 3

Connect the power lines of the M12 cable to a power supply source. See wiring instructions in Table 20. Wire +24V (pin) and GND (pin) to the selected power supply (capable to provide 24V supply).

Table 20 - Wiring connection between IND-Thermal-90 and Power supply

M12 cable	Power supply
12V ... 24V DC power supply (pin 1)	Positive pin
GND (pin 2)	Negative pin

Step 4

Connect the RS485-to-USB adapter to the USB port of your PC. An extension USB cable (provided with the recommended adapter) from the adapter to the PC might be useful.

Step 5

Power the sensor by turning on the power source.

Step 6

The camera LED indicator PWR will now constantly stay ON (GREEN) to confirm proper voltage supply. STATUS LED will also turn green confirming normal operation¹¹.

Step 7

The hardware setup is completed and the user can now proceed to configuring basic software parameters.

i *During power up the sensor will apply the last operating parameters used or default ones if it's the first boot-up*

i *Note: The NO/NC line is not used in this setup, it can be left floating or shorted to ground*

¹¹ At camera startup, if there is already an alarm condition active and the NO/NC output is enabled, STATUS led might turn ON in GREEN color and quickly (after 1-2 seconds) switch to RED.

9.2. Software setup

As the Terabee IND-Thermal-90 camera uses the MODBUS RTU protocol for data communication via RS485 interface, for operation on PC we recommend to work with MODBUS Doctor freeware utility software (KScada). To do so, please follow the [link](#) to the official page of KScada and download the MODBUS Doctor software.

9.2.1. MODBUS Doctor software configuration

After successful download, initiate the software on your PC. Next, select **RTU** to make sure the following settings are configured accordingly:

- Baud rate: 19200
- Data bits: 8
- Stop bits: 1
- Parity: even
- Port Name: select the USB (COM) port on which the RS485-to-USB adapter is connected

For visual instructions please consult Figure 20. Once these parameters are configured, click **“Connection”**. Contact with the sensor should now be established and the Status (bottom left) should change to **“Connected”**. Figure 21 illustrates a successful connection.

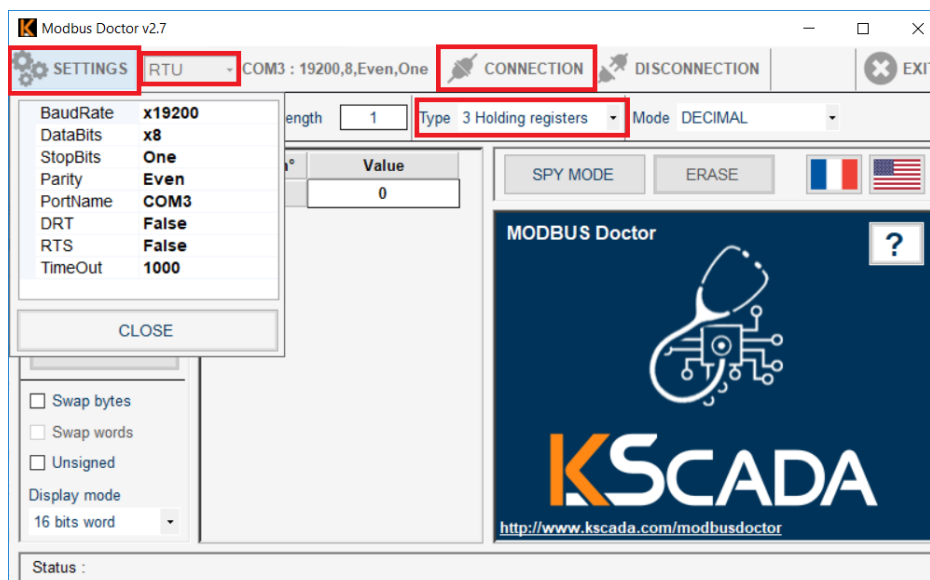


Figure 20. Setting connection parameters on MODBUS Doctor

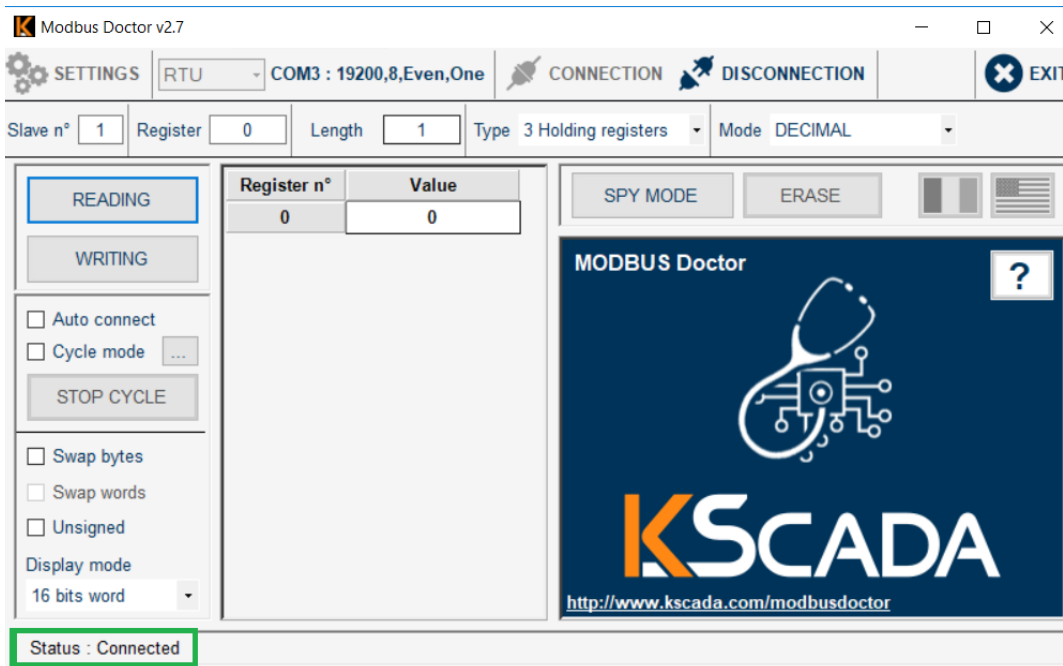


Figure 21. Status after pressing "Connection"

9.3. Basic IND-Thermal-90 camera parameter configuration

To learn more about all configurable sensor parameters (inputs/outputs), please refer to the [Communication Section](#) of this manual.

9.3.1. Read pixel temperature data example

The MODBUS protocol uses a master/slave architecture of communication where one device or process has uni-directional control over one or more devices. In order to read (inquire) live temperature data from the sensor, please execute the following READ command:

Read distance data:

- Slave ID: 1 to 247 (enter corresponding slave ID, 1 in our case)
- Type (function): 04 Input Register
- Address location: 790 - **we target the central pixels**
- Length (Quantity): 10

Click "**READING**" to execute the command. The distance data is now read from the sensor, and displayed in the "Value" field. The sensors onboard LED indicator (COM) will blink YELLOW (Rx) and RED (Tx) whenever there is data transmission via RS485. Visual instructions for executing the "read pixel temperature data" command are illustrated in Figure 22. The status indicator will also show "Request OK (1/1)". **Please note that all temperatures are represented in decikelvin.**

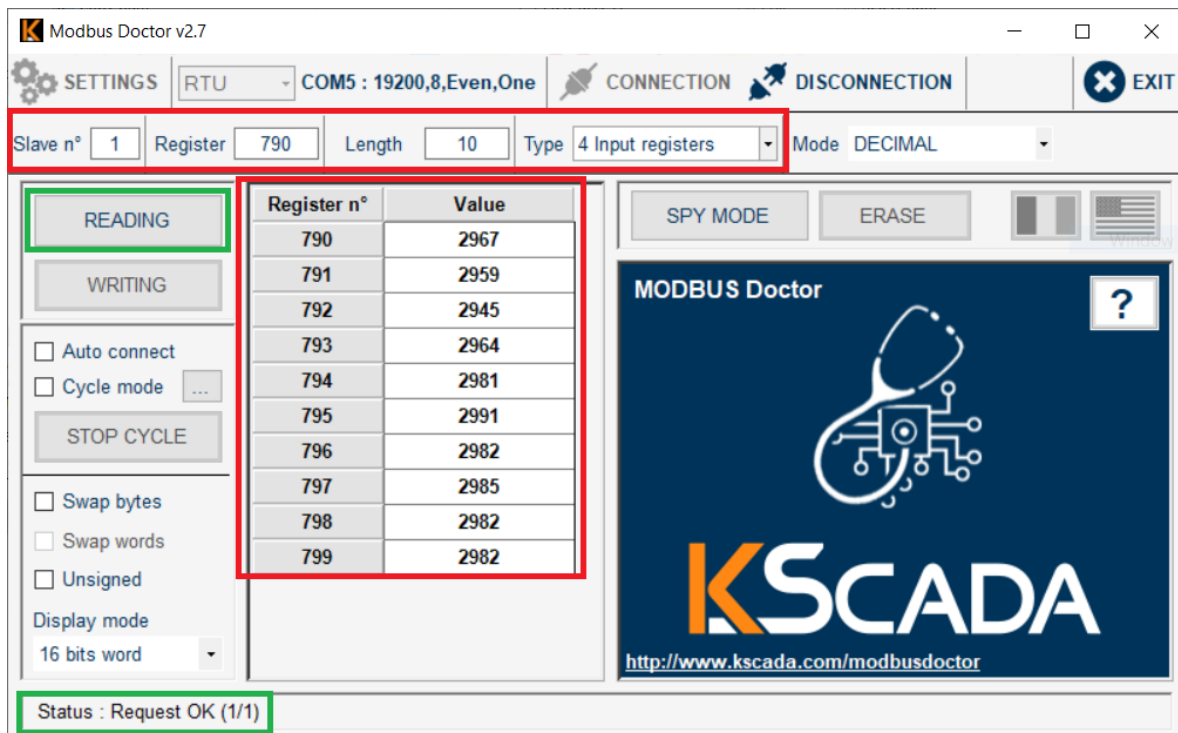


Figure 22. Read temperature data command execution example

Switching to cycle mode

To make the data acquisition automatic (see Figure 23), activate “Cycle mode” by ticking the box on the left side of the Modbus Doctor window. Then click “Reading” and the software will now acquire new data every 100 ms (default value).

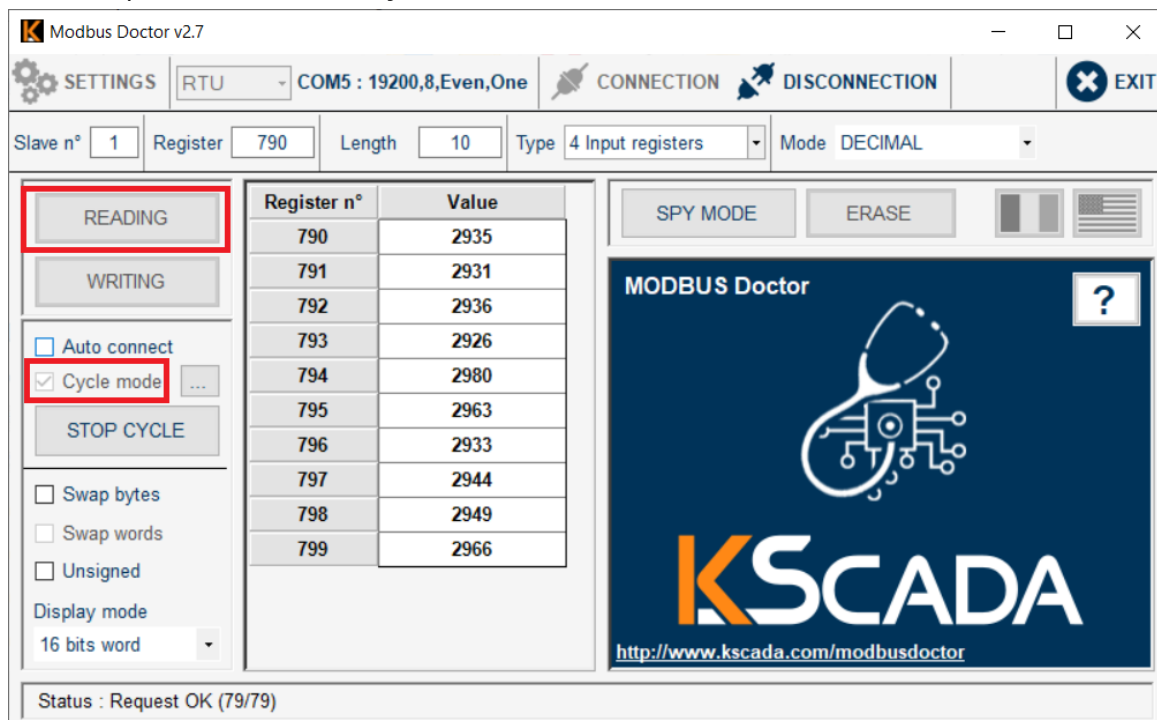


Figure 23. Read temperature data in cycle mode

10. Compliance


EU Declaration of Conformity	
<i>The manufacturer:</i>	Terabee SAS
<i>settled in:</i>	St. Genis Pouilly, France
<i>Vat Number:</i>	FR38789459179
Declares that the Appliance	
<i>Type and/or Model</i>	Terabee IND-Thermal-90 February 2021
<i>Description:</i>	Thermal camera based on thermopile principle
<i>Function:</i>	Industrial automation
<i>Provided that it is installed, maintained and used in the application for which it is made, with respect of the « profession's practices », relevant installation standards and manufacturer's instructions, is in conformity with the relevant European Union harmonisation legislation and specifically:</i>	
<i>Directives</i>	
2014/30/UE	EMC -Electro Magnetic Compatibility
2011/65/UE	RoHS
<i>Main requirements and/or reference harmonised standards used:</i>	
CEI EN 60068-2-6:2009 CEI EN 60068-2-27:2012 CEI EN 60068-2-64:2012+A1:2020 CEI EN 60529:1997+A1:2000+A2:2014 CEI EN 61000-6-1:2019 CEI EN 61000-6-2:2019 CEI EN 61000-6-3:2007+A1:2013 CEI EN 61000-6-4:2020 CEI EN 61000-4-2:2011 CEI EN 61000-4-3:2007+A1:2009 +IS12010+A2:2011 CEI EN 61000-4-4:2013 CEI EN 61000-4-5:2016+A1:2018 CEI EN 61000-4-6: 2014 CEI EN 61000-4-8: 2013 CEI EN 61000-4-20: 2013	
<i>This declaration of conformity is issued on the sole responsibility of the manufacturer.</i>	
Name, surname, Role and Signature of the person authorized to sign the declaration in the name of the manufacturer	
<i>Place and Date</i>	
St. Genis Pouilly, France (February 18, 2021)	 Massimiliano Ruffo (Terabee CEO)

Figure 24. EU Declaration of conformity with compliance to standards and used directives