



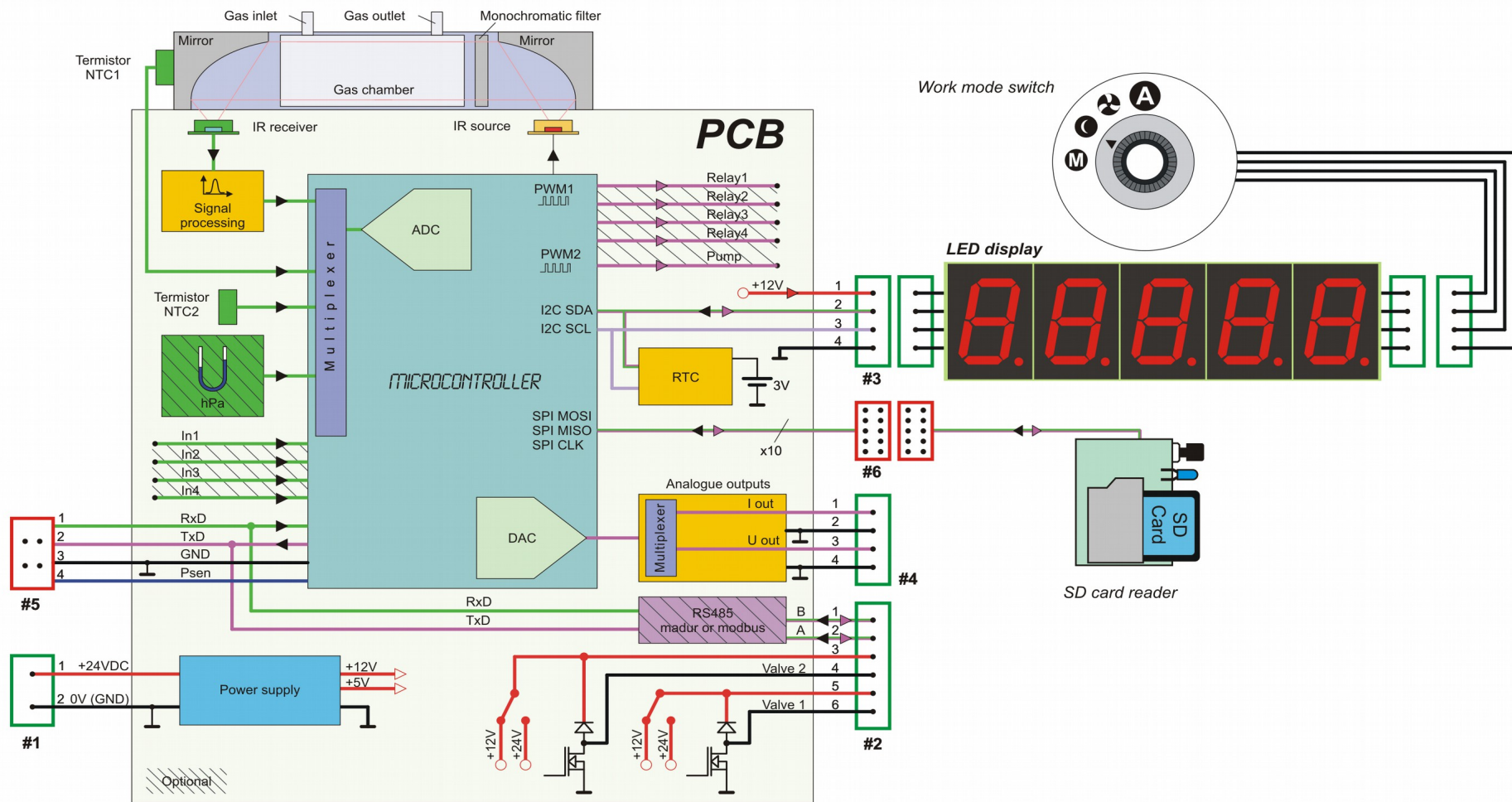
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## 1. BASIC CHARACTERISTICS OF IRMA SENSOR

- IRma is an optical sensor for gas detection.
- It has a wide work autonomy. It has implemented few automatic measurement modes that allows to adjust how the sensor works to owns requirements.
- IRma is an infra-red sensor – it incorporates a monochromatic spectral line from the near infra-red part of spectrum.
- It is produced as one channel sensor. Optionally it can be prepared in two-channel version.
- It is factory calibrated – multipoint calibration with reference gases – what provides high accuracy of measurement results.
- It has built-in temperature sensor. It is also thermally calibrated (also multipoint temperature calibration) what provides precise compensation for thermal drift.
- It can optionally be equipped with atmospheric pressure sensor that provides compensation for the changes of pressure.
- It has one current analogue output (0/4÷20mA) and one voltage analogue output (0÷5/10V). Output's resolution is 12bits.
- It has two strong “open-drain” type outputs that allows to steer external loads like pumps, valves, relays, etc.
- It requires +24VDC supply. It accepts supply in range 14÷40VDC
- It has four digital inputs that allows to control the sensor's work
- It has four digital outputs that can signalise the current measurement status and/or control external devices.
- It has PWM output with TTL signal levels that can be used for e.g. steering the internal gas pump
- It has a built-in RTC clock with calendar. RTC has a replaceable battery that provides clock's uninterrupted work even at power decay.
- It has built-in serial interface with TTL signal levels that allows to read the results in digital form and/or to adjust sensor's settings from madur.exe PC program and to upgrade sensor's firmware.
- Optionally it can be equipped with RS485 level interface and MODBUS communication that allows to simultaneously connect several sensors to a common communication bus.
- It allows to connect data-logger for constant storage of measurement results. This optional data-logger incorporates full size SD cards.
- It has 4-pin connector to connect external devices with I<sup>2</sup>C bus.
- It can be optionally be equipped with 4.5 digit LCD without display (digit height 12mm) and/or with red LED display (with digit height 25mm – visible from long distances). Display is connected via I<sup>2</sup>C bus. Displays are optional equipment.
- It can be quipped with optional work mode knob that allows to manually select the work phase (manual override over programmed modes)

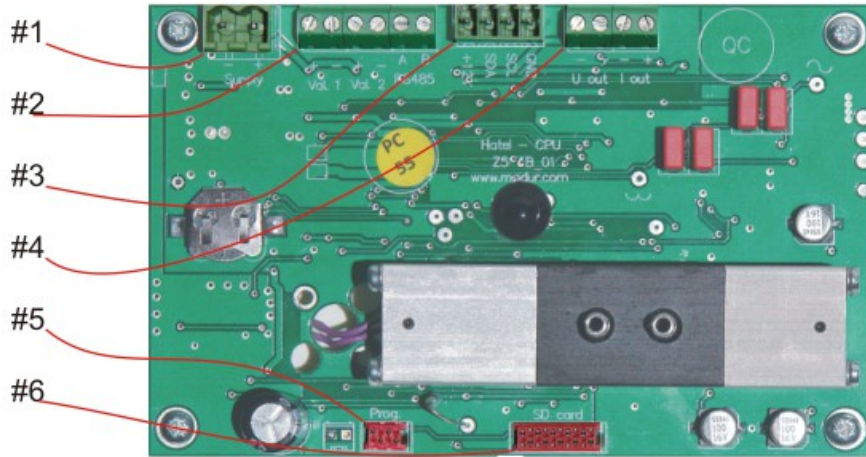


Drawing 1. Block diagram of IRma sensor

## 1.1. Sensor's connectors

Layout of all the connectors of IRma sensor, CHF3 version are showed in Drawing 1.

Pins layout is presented in the Table 1.



*Drawing 2. Connectors on IRma board*

Signatures on the drawing

1. Power connector (#1)
2. Valves and RS485 connector (#2)
3. I2C connector (#3)
4. Analogue outputs connector (#4)
5. Serial interface TTL connector (#5)
6. Data-logger connector (#6)

### 1.1.1. Power connector (#1)

This is where external +24VDC power supply is connected. IRma sensor accepts supply in range 14÷40VDC. It is advised to use nominal supply. Power connector is separable. IRma is provided with matching plug where supply cables can be connected. Sensor's circuit is protected against reverse polarity with a diode.

Sensor's power consumption (without the additional equipment), at +24VDC supply voltage does not exceed 100mA.

It is advised to use stabilised power supplies with power efficiency not lower than 2000mA.

### 1.1.2. Valves and RS485 connector (#2)

Valves connector allows to connect external devices of higher power consumption, i.e. electromagnetic valves. This connector also allows to connect RS-485 communication interface.

Below we present a diagram of control circuit of valves connected to connector (#2). Steering transistors work in "open drain" mode. Connector's terminals also contains supply (+12V or +24VDC), that can be incorporated to power the connected valves. Supply connectors are, by default, set to +12VDC. Suppression diodes allow to connect inductive loads.

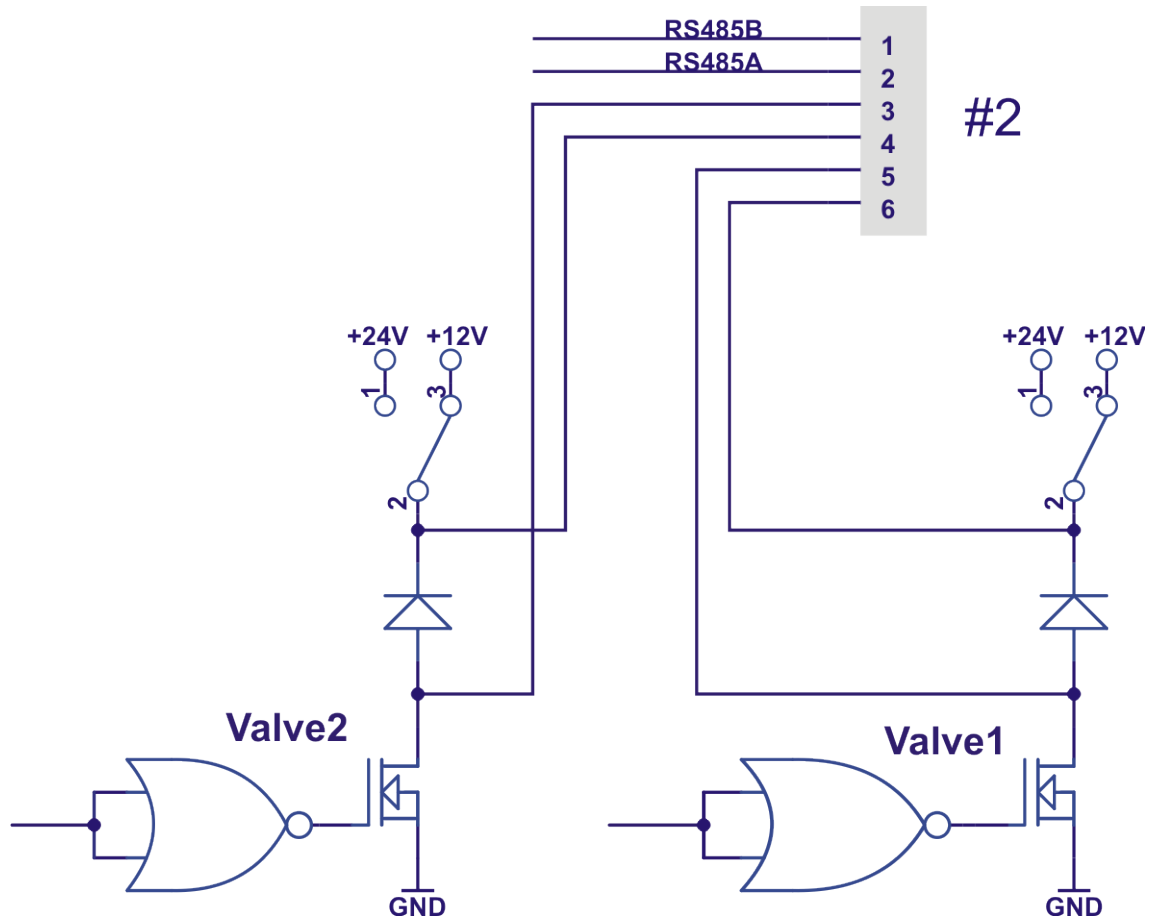
The maximal current that can be consumed from valve connector (+12V or +24V pins) is 500mA (in total for both supply pins).

The maximal current that the control transistors accept is 1A (for each transistor).

The maximal voltage that control transistors turns off is 30V.

If the connected load is inductive and does not incorporate supply +12V/+24V it is necessary to provide external suppression diodes or/and suppression capacitors.

Pin 1 and 2 of the same connector are used for RS485 communication interface – this interface is an optional equipment.



Drawing 3. Valves' control circuit incorporated in IRma sensor

### 1.1.3. I<sup>2</sup>C connector (#3)

I<sup>2</sup>C connector allows to connect external equipment to the sensor that is controlled via I<sup>2</sup>C bus, i.e. LED display or/and LCD display or/and work knob. Description of the additional equipment can be found in the annexes to this manual. Connector allows to connect up to 4 additional equipments. Connector along the I<sup>2</sup>C bus provides +12V supply for the connected modules.

The following modules are connected parallel to connector #3.

The maximal current that can consumed from I<sup>2</sup>C connector (from +12V pin) is 500mA.

#### 1.1.4. Analogue outputs connector (#4)

Analogue outputs connector provides both channels of analogue outputs, i.e. current output and voltage one. Analogue output's GND is at the same potential as supply's GND.

The minimal resistance that can load the voltage output U1 is 1.000  $\Omega$  (for range 0÷5V) or 10.000  $\Omega$  (for range 0÷10V).

The maximal resistance that can load the current output I1 is 300  $\Omega$ .

#### 1.1.5. Serial interface TTL connector (#5)

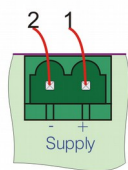
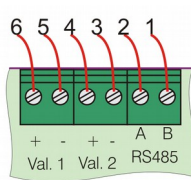
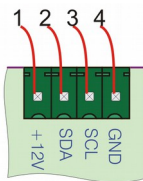
Serial interface connector allows to communicate with sensor in digital form (with help of madur.exe PC program) but also allows to program microprocessor's memory (firmware upgrade). Communication is performed at TTL levels. To connect sensor to PC a special adapter is required (available from madur). Connector provides #PSEN terminal that allows to set micro-controller in the programmable mode – this pin should be short-circuit to GND when sensor is powered on.

Detailed instructions on firmware upgrade is provided in the chapter *Loading new firmware to sensor's memory*.

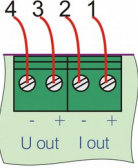
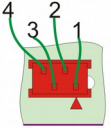
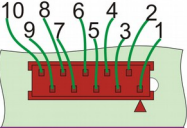
#### 1.1.6. Data-logger connector (#6)

Connector allows to connect optional data-logger module available from madur. Connector provides all the signals required by data-logger including +5V supply. Data-logger is delivered with ribbon cable and a plug matching connector #6.

Table 1. Pin layout for each connector.

#	Drawing	Pin layout	Connector type
1		<ol style="list-style-type: none"> <li>1. +24VDC – supply (input)</li> <li>2. GND – supply ground</li> </ol>	Phoenix Contact: MSTBVA 2,5/2-G-5,08 MSTB 2,5/ 2-ST-5,08
2		<ol style="list-style-type: none"> <li>1. RS485 A</li> <li>2. RS485 B</li> <li>3. Valve 2 “-” – open drain output</li> <li>4. +12VDC (or +24VDC) – output</li> <li>5. Valve 1 “-” – open drain output</li> <li>6. +12VDC (or +24VDC) – output</li> </ol>	Phoenix Contact: 3 x MKDS 1/ 2-3,81
3		<ol style="list-style-type: none"> <li>1. +12V – output</li> <li>2. SDA – I<sup>2</sup>C</li> <li>3. SCL – I<sup>2</sup>C</li> <li>4. GND</li> </ol>	Phoenix Contact: MCV 1,5/ 4-G-3,5



4		<ol style="list-style-type: none"> <li>1. I1 "+" – I1 analogue output</li> <li>2. GND</li> <li>3. U1 "+" – U1 analogue output</li> <li>4. GND</li> </ol>	Phoenix Contact: 2 x MKDS 1/ 2-3,81
5		<ol style="list-style-type: none"> <li>1. RxD TTL – data input</li> <li>2. TxD TTL – data output</li> <li>3. GND</li> <li>4. #PSEN</li> </ol>	Micromatch 4
6		<ol style="list-style-type: none"> <li>1. MOSI</li> <li>2. VCC (+5V)</li> <li>3. MISO</li> <li>4. LEDMMC</li> <li>5. SCLOCK</li> <li>6. SWITCHMMC</li> <li>7. CSLOG</li> <li>8. ISLOG</li> <li>9. GND</li> <li>10. GND</li> </ol>	Micromatch 10

### 1.2. *madur.exe* PC program

madur.exe is PC program that works in Microsoft Windows operating systems. It is provided by madur, free-of-charge with every delivered sensor. Program is not essential to work with the sensor after its installation, but it helps in comfortable adjustment of sensor's settings or in diagnosing of sensor's status. Detailed description of program's functions can be found in a separate manual.

### 1.3. *Zeroing of IRma sensor*

As any other electronic measurement device, IRma sensor is a subject to a various drifts – mainly thermal and time drifts. Sensor is equipped with temperature sensor that allows to compensate the effect of temperature changes to the measurements. Time drifts derive mainly from the physical changes of the sensor's optical system. Time drifts are removed with the zeroing process.

Zeroing consists in thorough ventilation of sensor's gas path with neutral gas (clean ambient air, nitrogen, etc.) and later in noting the signal level to the corresponding measured zero gas. It is advised to ventilate the sensor for at least 5 minutes.

To minimise the time drift effect it is advised to zero the sensor as often as possible.



## 1.4. IRma work phases

These are the work phases IRma sensor can be in:

1. Initial phases, occur just one time, after the sensor is powered on:
  - “Warming” phase – initial warming up of sensor's electronics
  - “FirstZeroing” phase – the initial zeroing of sensor
2. Essential phases, occur in all work cycles:
  - “Ventilation” phase – zeroing sensor with the neutral gas
  - “Measurement” phase – actual measurements
  - “Standby” phase – sensor resting

### 1.4.1. Initial phases – Warming

“Warming” phase occurs right after sensor is powered on. Sensor performs initial tests of its status and waits for the system temperature to stabilise. During this phase no usable measurements are performed. Time for “Warming” phase is adjustable from the PC program. Madur sets this time to 30 minutes.

Display, on each segment, perform test and then for short period shows the firmware version of the sensor in format x.y.z. During the rest of the “Warming” display segments shows dashes.

Valves, pump control and analogue outputs act as they were programmed to behave during “Warming” phase in PC program.

**REMARK:** User can change the time for the “Warming” phase via madur.exe program. However it is not advised as it can disturb sensor's thermal compensation and in consequence, demote measurement quality.

### 1.4.2. Initial phases – FirstZeroing

“FirstZeroing” phase occurs directly after “Warming”. During this phase sensor must be provided with neutral gas as it performs zeroing. During this phase no usable measurements are performed, but sensor measures and shows the results on the display. Values on display flash. Time of “FirstZeroing” phase is the same as for “Ventilation” phase and it is adjustable from the PC program. Madur sets this time to 15 minutes.

Valves, pump control and analogue outputs act as they were programmed to behave during “Ventilation” phase in PC program.

Storage to SD card is performed, if this option is enabled.

**REMARK:** User can change the time of “FirstZeroing” phase by changing the length of the “Ventilation” phase in the PC program. It is advised not to shorten this time below 5 minutes – in case there is a substantial dead volume connected to the sensor that may not be ventilated properly, and in consequence may cause inaccurate measurements.

### **1.4.3. Essential phases – Ventilation**

“Ventilation” phase starts each measurement cycle. During “Ventilation” sensor is provided with neutral gas and performs zeroing. During this phase no usable measurements are performed, but sensor measures and shows the results on the display. “Ventilation” time is set in the PC program madur.exe. By default it is set to 15 minutes. It is advised not to set it below 5 min.

Valves, pump control and analogue outputs act as they were programmed to behave during “Ventilation” phase in PC program.

**REMARK:** The first work cycle that occurs after the initial phases (after sensor is powered on) does not start with “Ventilation” phase but at once with the “Measurement” phase. It is because zeroing of sensor was just performed during the “FirstZeroing” phase.

### **1.4.4. Essential phase – Infusion**

The “Infusion” phase precedes directly the “Measurements”. During infusion the sensor is supplied with measurement gas and performs measurements but due to the delay caused by the gas course and the sensor's reaction time the measurement results can be underrated. Display behaviour is identical to “Ventilation” phase. Duration of infusion is constant and equals 1 minute.

### **1.4.5. Essential phases – Measurement**

“Measurement” is the main phase for every work cycle. It occurs right after the “Ventilation”. During this phase, sensor is provided with the measured gas and performs usable measurements. Results are presented on display. Time of the “Measurement” phase depends on the selected work mode and can last from a dozen of minutes up to 31 days. This time is adjustable from madur.exe PC program. By default it is set to 6 hours.

Valves, pump control and analogue outputs act as they were programmed to behave during “Measurement” phase in PC program.

Storage to SD card is performed, if this option is enabled.

### **1.4.6. Essential phases – Prestandby and Standby**

“Prestandby” and a follow-up “Standby” phases occur after every “Measurement” phase if the “Measurement” phase has finished, but a new work cycle has not yet started. Those phases may not occur at all. Purpose of “Prestandby” phase is to ventilate gas channel and remove any residues of measure gas. This phase last for two minutes and is not adjustable.

“Standby” occurs directly after “Prestandby” and is when sensor simply rest. “Standby” time is not defined, sensor stays in this phase until a new work cycle begins.

During these phases no usable measurements are performed, display shows a single dash.

Valves, pump control and analogue outputs act as they were programmed to behave individually during “Standby” and “Prestandby” phases.

Storage to SD card is performed, if this option is enabled.

## 1.5. IRma work modes

IRma sensor can work according to several predefined programs. Those automatic programs are called work modes. There are available:

- Cyclic measurements
- Measurements according to scheduler
- Measurements triggered by a digital input
- Monthly-cyclic mode
- Monthly-cyclic mode with adjustable length (1-30 days)

### 1.5.1. Work cycle

Every work mode is divided into work cycles. Work cycle starts with "Ventilation" phase and after that with "Measurement" phase. After "Measurement", if it is not yet a time to start a new work cycle, sensor goes to "Prestandby" and then to "Standby" phase. Sensor stays in "Standby" until a new work cycle begins.

### 1.5.2. Cyclic measurements

Cyclic mode is a simple-one-day mode, i.e. it occurs identically each day and consists of the consequent same work cycles. Cyclic measurements mode has the following parameters (every of those is adjustable from the madur.exe PC program):

- Moment of the first zeroing H1- this is when the first work cycle starts. This is set with 1s accuracy.
- Time of the "Ventilation" phase TV
- Time of the "Measurement" phase TM
- Time of the entire work cycle TC

Madur delivers sensors in cyclic mode with the following default settings:

H1	00:00:00	the first cycle starts each day at midnight
TV	00:15:00	(15 minutes)
TM	06:00:00	(6 hours)
TC	06:00:00	(6 hours)

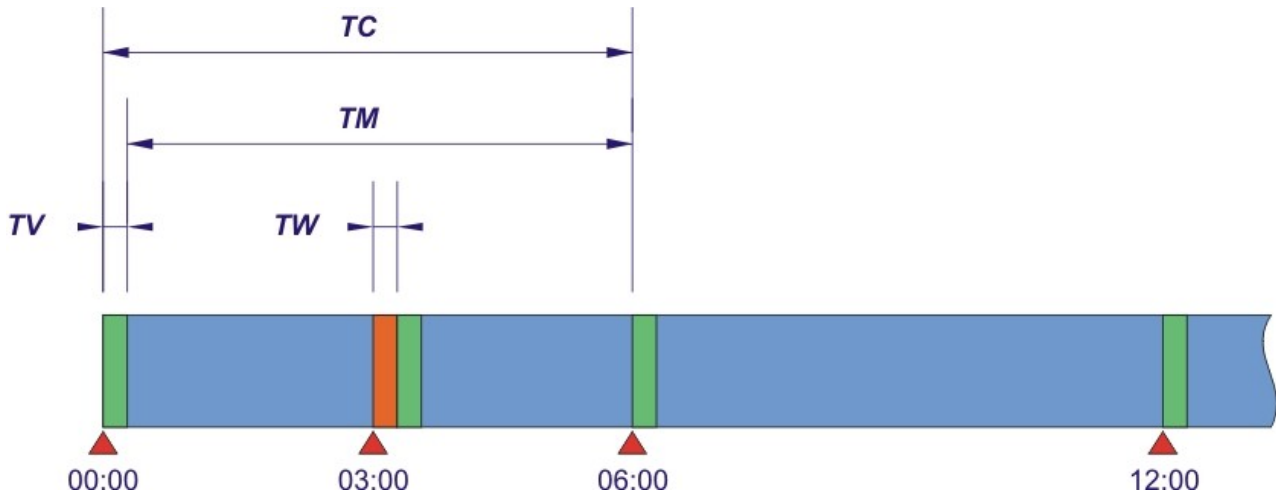
H1 and TC parameters set the beginning time for each cycle during the day. By default there are 4 cycles a day starting at the following times:

H1	00:00:00	the first cycle starts each day at midnight
H2	06:00:00	the second cycle
H3	12:00:00	the third cycle
H4	18:00:00	the fourth cycle
H1	00:00:00	the first cycle the next day
.....		

As shown above, by default, the Standby phase does not occur.

**REMARK:** the beginning of the new cycle has a higher priority than any current cycle phase. This means that if the beginning of the new cycle occurs before the current cycle finishes the current phase will be interrupted and the device will start a new cycle.

Below, we show the examples of what the measurements will look like through the day for the default and some other example settings.



Drawing 4. Cyclic mode

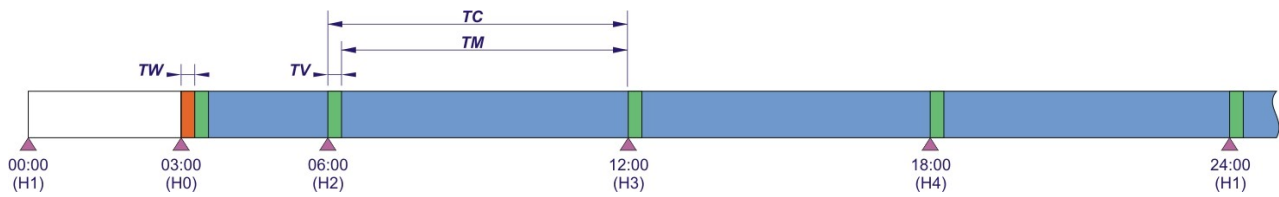
TC – cycle time  
TM – measurement time  
TW – warming time  
TV – ventilation time

Warming  
Ventilation  
Measurement  
Stand by

#### 1.5.2.1. Cyclic mode (regular) – behaviour of the unit after turning on

The device set in the regular cyclic mode executes the initial phases - “Warming” and “FirstZeroing” - and then proceeds directly to the “Measurements”. As can be seen below, duration of the first cycle is asynchronous to all the following, normally planned cycles. The synchronization starts with the second cycle.

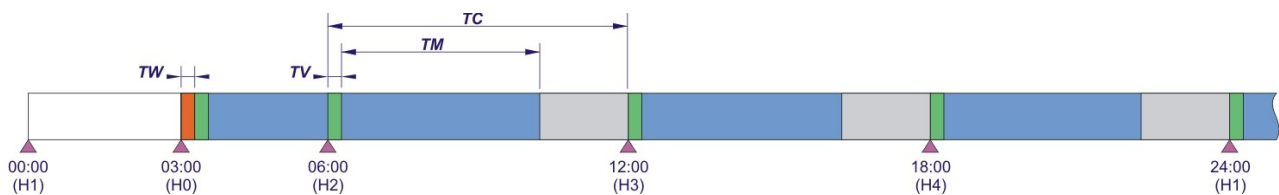
See what the work cycles looks like if the sensor with default settings is turned on at 3 o'clock (H0). The measurements are interrupted with the next, planned cycle H2 (starting with ventilation phase). Then it works as planned: →H3→H4→H1→H2...



**Drawing 5. Regular cyclic mode – sensor turned on at 3.00AM,  $TM + TV > TC$**

TC – cycle time  
 TM – measurement time  
 TW – warming time  
 TV – ventilation time  
 H0 – moment when sensor was powered on  
 H1÷H4 – beginning of the following work cycles

Warming  
 Ventilation  
 Measurement  
 Stand by



**Drawing 6. Regular cyclic mode – sensor turned on at 3.00AM,  $TM + TV < TC$**

The measurements together with the ventilation phase are shorter than a single cycle length. The sensor awaits the following cycle in Standby phase.

### 1.5.2.2. Cyclic mode (regular) – unit's behaviour at midnight

The lasting cycle will not be interrupted at midnight. The current cycle will normally be finished and the device will move on to the “Standby” phase awaiting the H1 moment. If the H1 (first zeroing) moment comes while the previous cycle lasts, the current cycle will be interrupted and a new cycle will begin.

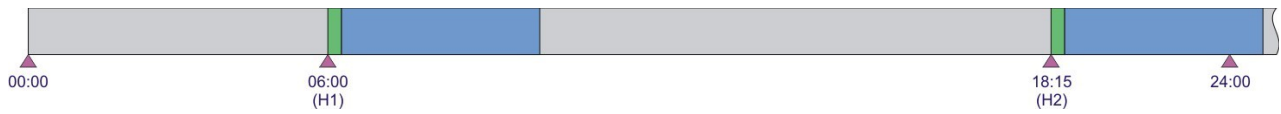
### 1.5.3. Measurements according to scheduler

Measurements according to scheduler is also a 24-hour mode (repeats every 24-hours) and contains of the maximum of 24 measurement cycles. Each of the cycle's beginning point is defined individually. Measurements according to scheduler are defined by the below parameters (they can be set via madur.exe program):

- Cycle activation table – informs which of the cycles (H1..H24) are to be performed
- Table of the beginning points for all cycles H1..H24 – informs what time every day the specific measurement cycle starts
- The length of the “Ventilation” phase TV
- The length of the „Measurement” phase TM
- The length of the whole cycle TC
- H0 – moment when sensor is powered on

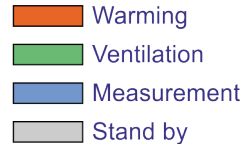
**REMARK:** the beginning of a new cycle has a higher priority than any current cycle phase. This means that if the beginning of the new cycle occurs before the current cycle finishes the current phase will be interrupted and the device will start the new cycle.

Below we show measurement cycles of the 24-hour period for the example settings of the measurements according to scheduler mode.



Drawing 7. Measurements according to scheduler mode

In the example above there are two work phases set during the day: H1 begins at 6:00, H2 begins at 18:15. Because  $TC < TV + TM$  sensor goes into standby mode in between cycles.



#### 1.5.3.1. Measurements according to scheduler – behaviour of unit after turning on

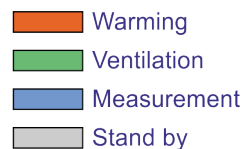
After the device set to *Measurements according to scheduler* mode is turned on, it performs the initial phases, that is „Warming” and „FirstZeroing” and then proceeds directly to „Measurement”. As shown below the first cycle duration is asynchronous to all the following, normally planned cycles. The synchronization starts with the second cycle.

See the work cycles if the sensor has been turned on at 6 o'clock (H0)



Drawing 8. Measurements according to scheduler mode – sensor turned on at 6.00AM

In the example above, sensor is turned on H0, in between scheduled cycles H1 and H2. Sensor begins its work with the initial phases (Warming and FirstZeroing) and then proceeds with the measurements. Sensor synchronise its work (to the scheduler) with the beginning of the first programmed work cycle (H2).



#### 1.5.3.2. Measurements according to scheduler – behaviour of unit at midnight

The lasting cycle will not be interrupted at midnight. The current cycle will normally be finished and the device will move on to the “Standby” phase awaiting the first planned cycle (H1 or next if H1 is inactive). If the H1 (or next if H1 is inactive) moment comes while the previous cycle lasts, the current cycle will be interrupted and a new cycle will begin.

#### 1.5.4. Measurements triggered by a digital input

For the measurements triggered by a digital input there are no predefined beginning points of the cycles. The beginning of each of the cycles is triggered from the outside with help of any of the digital inputs In1..In4.

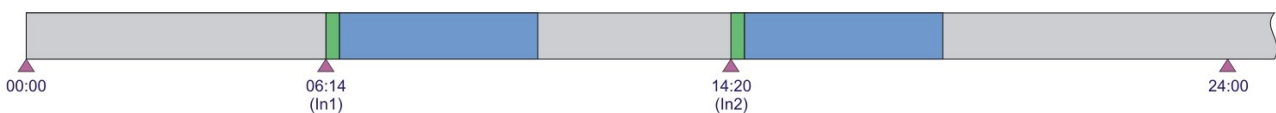
The rising slope appearing on the active input is the trigger. The disconnected (floating) input is treated as remaining in a high state.

Measurements triggered by a digital input has following parameters (all the parameters can be set via madur.exe program):

- Activation of triggering inputs – defines which of these inputs (In1..In4) can trigger the measurement cycle
- The length of the „Ventilation” phase TV
- The length of the „Measurement” phase TM
- The length of the whole cycle TC
- H0 – moment when sensor is powered on

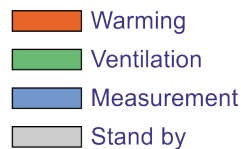
**RAMARK:** triggering signal coming from any of the active input has a higher priority than the current cycle phase. This means that each time a triggering slope appears it interrupts the current phase and the device starts the new cycle.

An example of the cycles for the 24-hour period in a triggered mode (for a specific settings) is shown below.



*Drawing 9. Measurements triggered by a digital input,  $TV + TM < TC$*

In the above example two cycles were evoked. At 6:14 (In1) and 14:20 (In2). After the In1 measurement cycle has finished the sensor moved on to Standby phase awaiting the In2 signal which triggers another measurement cycle beginning.



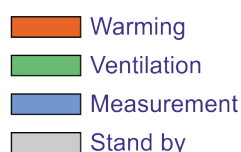
#### 1.5.4.1. Measurements triggered by a digital input – behaviour of unit after turning on

After the device, set to *Measurements triggered by a digital input* mode, is turned on it performs the initial phases, that is „Warming” and „FirstZeroing” and then proceeds directly to „Measurement”. As shown below the first cycle after the start-up is performed even though there was no triggering signal. After the first cycle has finished the device moves on to “Standby” phase and awaits for the triggering signal.



*Drawing 10. Measurements triggered by a digital input,  $TV + TM > TC$*

In the above example the beginning of the new cycle has been triggered at 7:10 (In1) and 8:25 (In2). The first cycle (after the turn on) has been interrupted by a signal from In1. In1 cycle has been discontinued as signal from In2 appeared.





#### **1.5.4.2. Measurements triggered by a digital input – behaviour of unit at midnight**

Midnight does not interrupt the current cycle. The current cycle is normally finished and the device proceeds to “Standby” phase awaiting the triggering signal from any of the active inputs.

#### **1.5.5. Monthly-cyclic mode**

Monthly-cyclic mode has a length of the cycle equal to the length of the calendar month. This means the sensor is zeroed once a month, and then a continuous measurement proceeds (until the next zeroing).

Monthly-cyclic mode has the below parameters (all of them set via madur.exe program):

- First zeroing date (DD/MM/YY) – defines the calendar date the first zeroing is to be performed. The date indicates the number of day when the monthly zeroing is to be performed.
- First zeroing moment – it is the exact hour (with the accuracy of 1s – hh:mm:ss) the monthly zeroing is to be performed
- The length of the “Ventilation” phase TV

##### **1.5.5.1. Monthly-cyclic mode – behaviour of unit after turning on**

After the device set to Monthly mode is turned on it performs the initial phases, that is „Warming” and „FirstZeroing” and then proceeds directly to „Measurement”. It remains in the measurement phase until the another zeroing comes.

##### **1.5.5.2. Monthly-cyclic mode – behaviour of unit in the different-length months**

The date of the first zeroing indicates when exactly (the day of the month) the zeroing is to be performed. If the number of the days in a month is smaller than the number of the day the zeroing is to be performed on, the zeroing will be performed on the last day of the month. That means, that whenever the date of the first zeroing is set to the 30<sup>th</sup> of January, the zeroing in February will be performed on the 28<sup>th</sup>.

#### **1.5.6. Monthly-cyclic mode with adjustable length (1-30 days)**

The *Monthly-cyclic mode with adjustable length* is similar to monthly-cyclic mode, however the cycle length does not equal the calendar month length but it is a set number of days (1..30).

Monthly-cyclic mode with adjustable length has the below parameters (all of them set via madur.exe program):

- First zeroing date (DD/MM/YY) – defines the calendar date the first zeroing is to be performed. From that day on the other zeroings are being set.
- First zeroing moment – it is the exact hour (with the accuracy of 1s – hh:mm:ss) the cyclic zeroing is to be performed
- The length of the cycle – number of days (1..30)
- The length of the “Ventilation” phase TV

Example:

The sensor works in the adjustable monthly mode. The date/hour of the first zeroing is 4:00, the 1<sup>st</sup> of September. The cycle length is 7 days. As the 1<sup>st</sup> of November 2014 was Monday the sensor will perform zeroing each Monday at 4:00.

#### ***1.5.6.1. Monthly-cyclic mode with adjustable length – behaviour of unit after turning on***

After the device set to Monthly adjustable mode is turned on it performs the initial phases, that is „Warming” and „FirstZeroing” and then proceeds directly to „Measurement”. It remains in the measurement phase until the another zeroing comes.

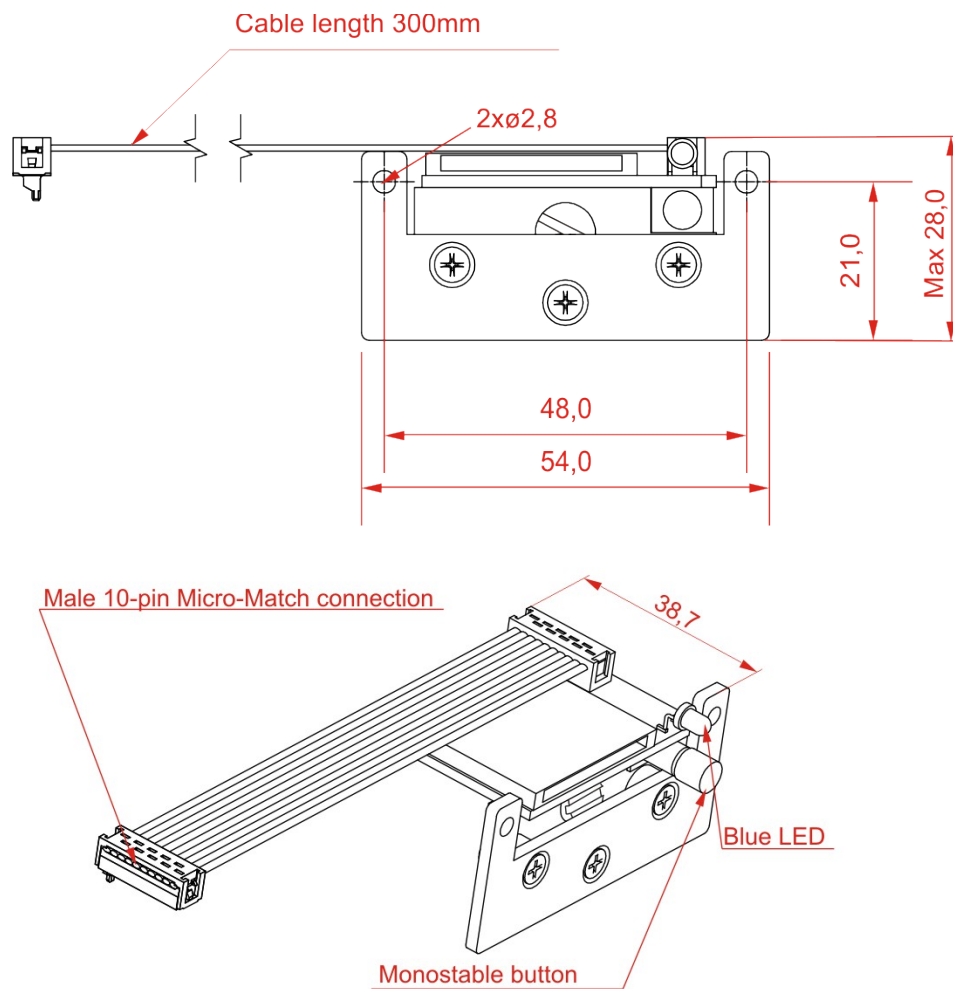
### ***1.6. Restrictions when using long-term work modes***

Long-term work modes, especially with long cycle times, result in long between-zeroing times. That can lower the measurements accuracy. In order to obtain high measurement accuracy it is advised to avoid long-term work modes.

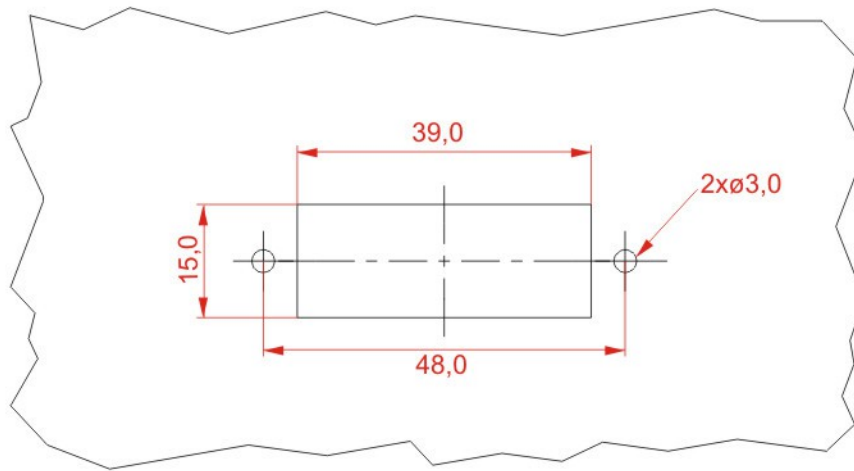
## 2. ADDITIONAL EQUIPMENT OF IRMA SENSOR

### 2.1. Data-logger

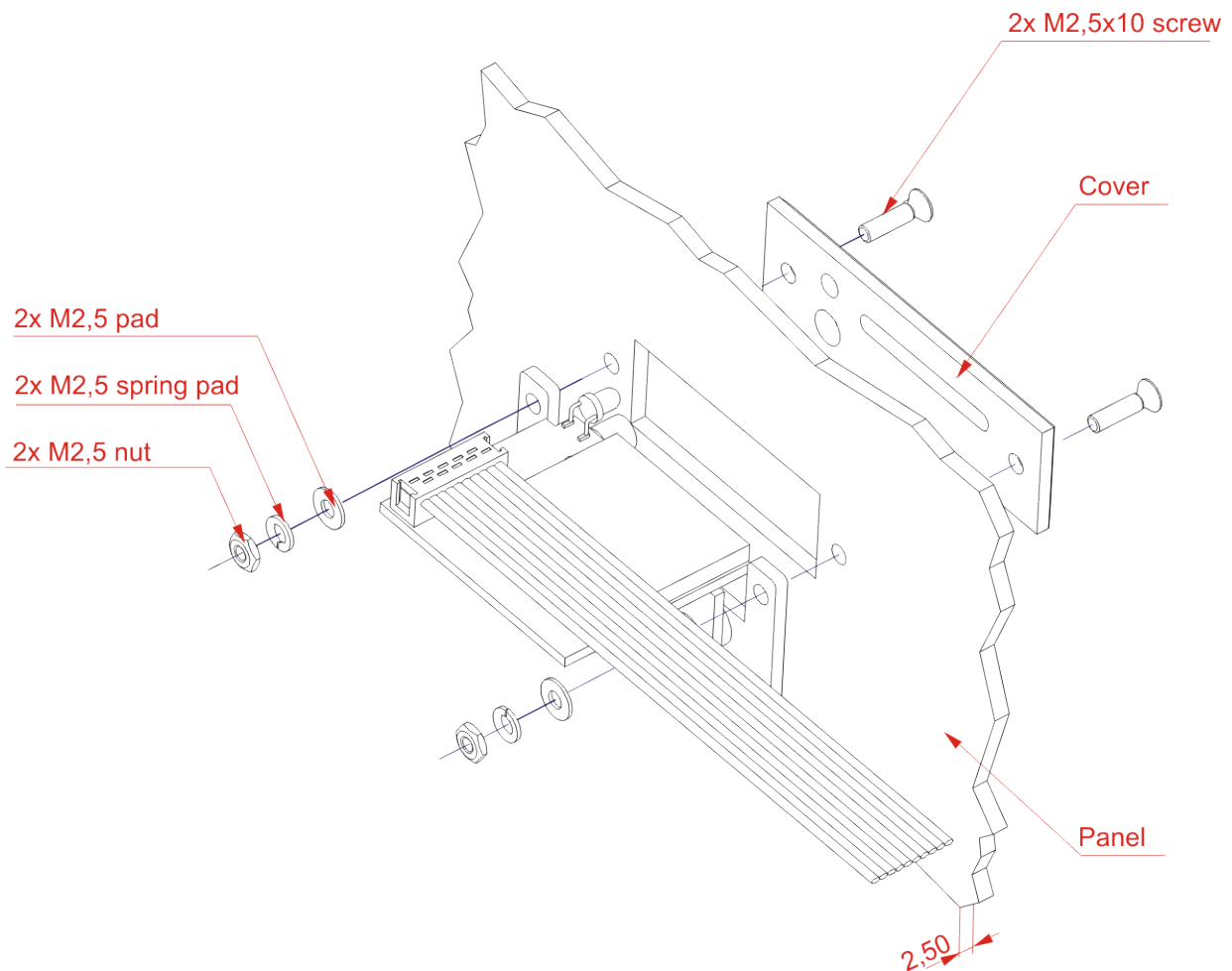
Data-logger module is presented in the picture below. It is connected to the Micro-Match 10-pin male connector. Data-logger stores measured results onto full size SD card. It is equipped with blue LED and monostable button.



Drawing 11. SD card data-logger



Drawing 12. Mounting openings in the panel



Drawing 13. Data-logger mounting

### **2.1.1.1. Type of acceptable SD cards**

Data-logger accepts full size SD and SDHC cards, MMC cards as well. It is possible to use both mini and micro SD cards along with a suitable full size adapter. Card's speed class is not critical.

Madur has successfully tested SD cards produced by Kingston and SanDisk, capacities 265MB ÷ 2GB. And SDHC cards of the same manufacturers: 4GB, 8GB, 16GB.

Sensors are delivered with (usually) 4GB Kingston SDHC card with USB adapter.

### **2.1.1.2. Card's file system and maximum memory capacity**

FAT16 file system is applied with maximal cluster size = 64kB. For this reason the card's maximum capacity is 4GB.

**REMARK:** It is possible to use SD cards larger than 4GB, but then such cards must be formatted in IRma sensor. Sensor formats >4GB cards using FAT16 file system. The area above 4GB stays unused.

### **2.1.1.3. Starting/stopping storage to SD card.**

Storage to SD card may be turned on or off. Turning the storage on/off can be performed from the PC program madur.exe when sensor is connected via serial interface. From this PC program it is possible to set the interval between the following storages. The sensor is delivered with the storage turned on and the storage interval set to 10s. If the storage is turned on, the sensor will save results to SD card always when the SD card is inserted into data-logger.

Blue LED informs about the storage status:

- LED lights constantly when SD card is in data-logger – storages are ON.
- LED is turned off when SD card is in data-logger – storages are OFF.

Turning the sensor OFF/ON does not change the status of the SD card storages.

### **2.1.1.4. Inserting SD card into data-logger**

Card should be inserted into data-logger without pushing the button. After the card is injected, it is verified and initialised. Card's initialisation lasts dozens of seconds, during this time the blue LED flashes rapidly. There are three possible statuses after the initialisation:

1. Blue LED lights constantly – initialisation went well, storages are ON, saving to SD card is started.
2. Diode dims – initialisation went well, but storages are set OFF. To be able to save results, one must turn the storages ON in the madur.exe PC program.
3. Diode flashes slowly – initialisation was failed, card should be removed from data-logger. Such status may be a consequence of a card's incorrect file type (incorrect format), but also it can indicate that the card is full or card's main folder is full.

### **2.1.1.5. Ejecting the SD card from data-logger**

Card should not be removed when the savings are in progress (blue LED flashes constantly). If the card is removed during on-going storage, data on SD card may be irreversibly corrupted! To eject the card, savings must

be interrupted – data-logger's button must be pressed shortly. Afterwards, the blue LED flashes rapidly for few seconds (this is when savings are stopped and all files are closed) and then it dims. On the display (if sensor is equipped with one), a sing PULL is showed. Then it is save to remove the card from data-logger. If the card is not removed within 10 seconds, sensor will reinitialise the card and resume the savings.

**REMARK:** if the storages are turned off (LED off) or card's initialisation failed (LED flashes slowly) it is save to remove the card at any time without any additional procedures.

#### **2.1.1.6. Powering down the sensor when storage is in progress**

**It is advised AGAINST to power the sensor down when the storages are in progress** (diode lights constantly). Data-logger is equipped with a capacitor that should provide collision-less storage interruption at a sudden power-down. Due to card's different power requirements it may occur that storage is not finished properly and that data is corrupted. For safety reasons it is advised to either disable the storage from PC program or to remove the SD card from the data-logger according to the procedure described above and only then to power down the sensor.

#### **2.1.1.7. Turning on the sensor with the SD card in data-logger**

There are no contradictions to power on the sensor if the card is already in the data-logger. Few seconds after the sensor is powered on, the card is normally initialised.

#### **2.1.1.8. Formatting a SD card in the IRma sensor**

To format a SD card:

1. When data-logger is vacant, press and hold the data-logger button
2. Insert the SD card to data-logger, keep the button pressed
3. Hold the button until the blue LED flashes twice
4. Release the button
5. Blue LED will now flash in doubles for several seconds – this means the card is being formatted.
6. When formatting is complete, the card will be initialised – rapid flashing
7. Afterwards, sensor begins to save results – LED lights constantly.
8. If, for any reason, formatting fails, data-logger LED flashes in slow rhythm – a different SD card should be used.

#### **2.1.1.9. Storing measurement data on SD card**

Data is stored on SD card as binary file. The files format and their content is presented in the manual „IRMA saving measurement data on SD card”.

### 2.1.1.10. Possible flash sequences in data-logger module

Table 2. Messages presented by different flashing modes of the data-logger blue LED.

Diode behaviour	Is SD in slot?	Description
A single blink every 3 seconds	Yes	Card initialised successfully, storage off
Turned on permanently	Yes	Card initialised successfully, storage on
Double blinking	Yes	Formatting SD card
Quick blinking	Yes	Initialising SD card
Slow blinking	Yes	Failed to initialise the card
Turned off	No	No SD card present

### 2.1.1.11. SD card errors

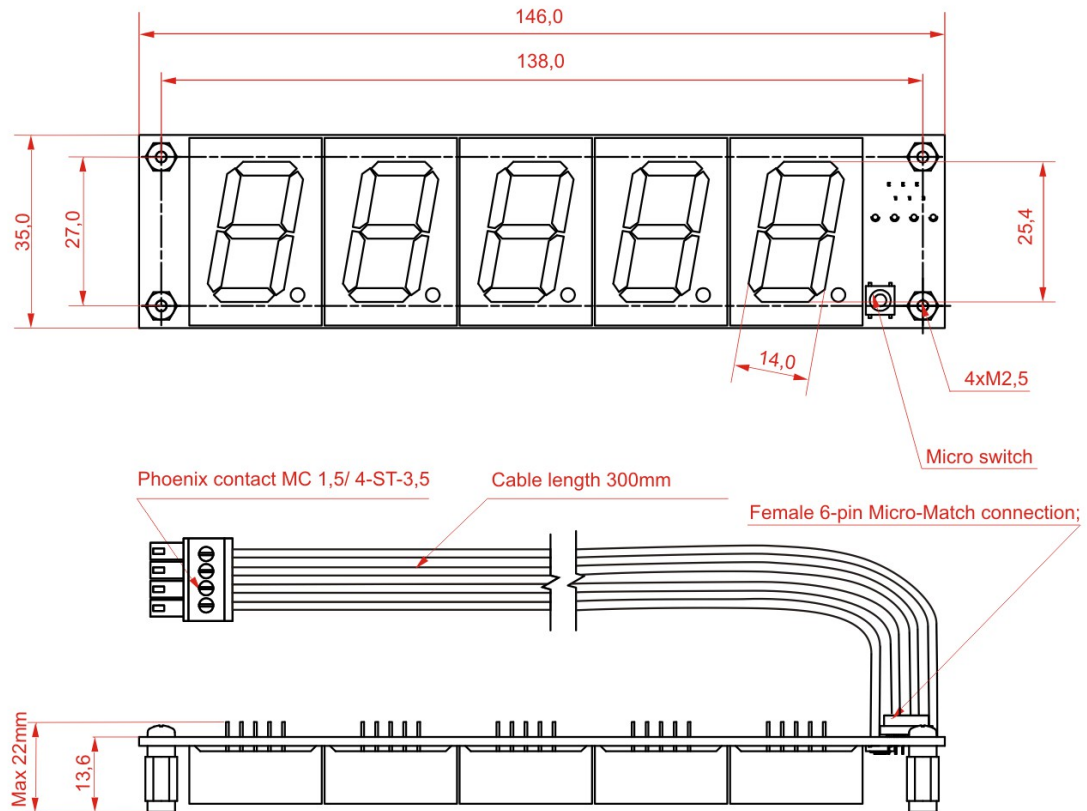
Table 3. SD card initialisation failures.

Source of the problem	Solution
Incorrect file system	Format the SD card to FAT16 file system (preferably format the card directly in the sensor)
File system corrupted	Format the SD card (preferably format the card directly in the sensor)
No free memory on SD card	Remove the redundant files or format the card
No free memory in file allocation table (>512 files stored in main folder)	Remove the redundant files (or move them to sub-folders) → lower the amount of files in the main folder
Incompatible SD card type	Use different card

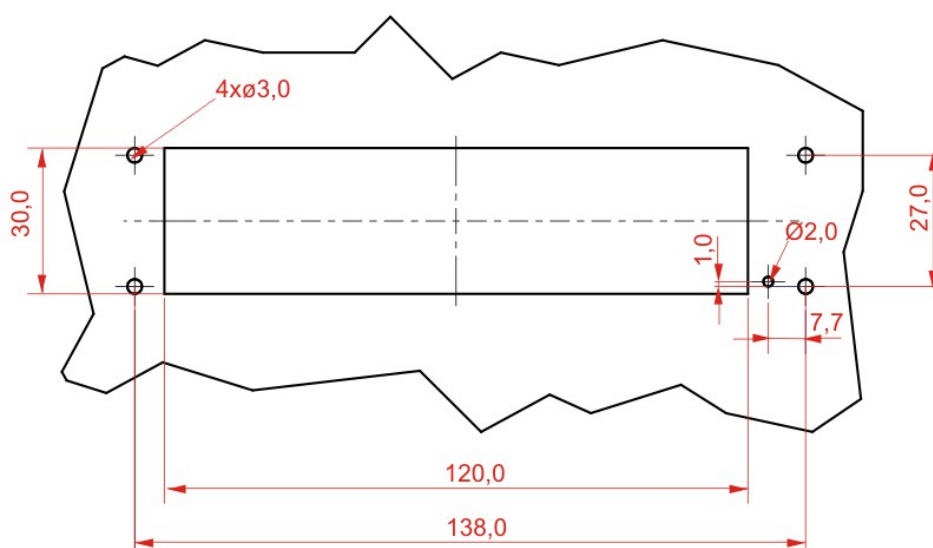


## 2.2. LED display

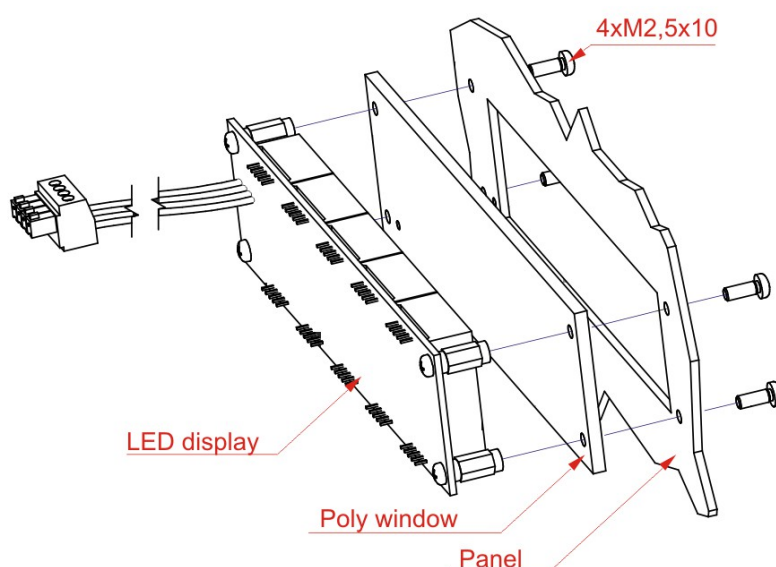
The used LED display is 5-position, 7-segment red display. It has a cable with a plug matching the I<sup>2</sup>C connector (connector #3). Display is used for results and presentation of the sensor's cycle phase.



Drawing 14. LED display – front and top views



Drawing 15. LED display – mounting openings in the panel



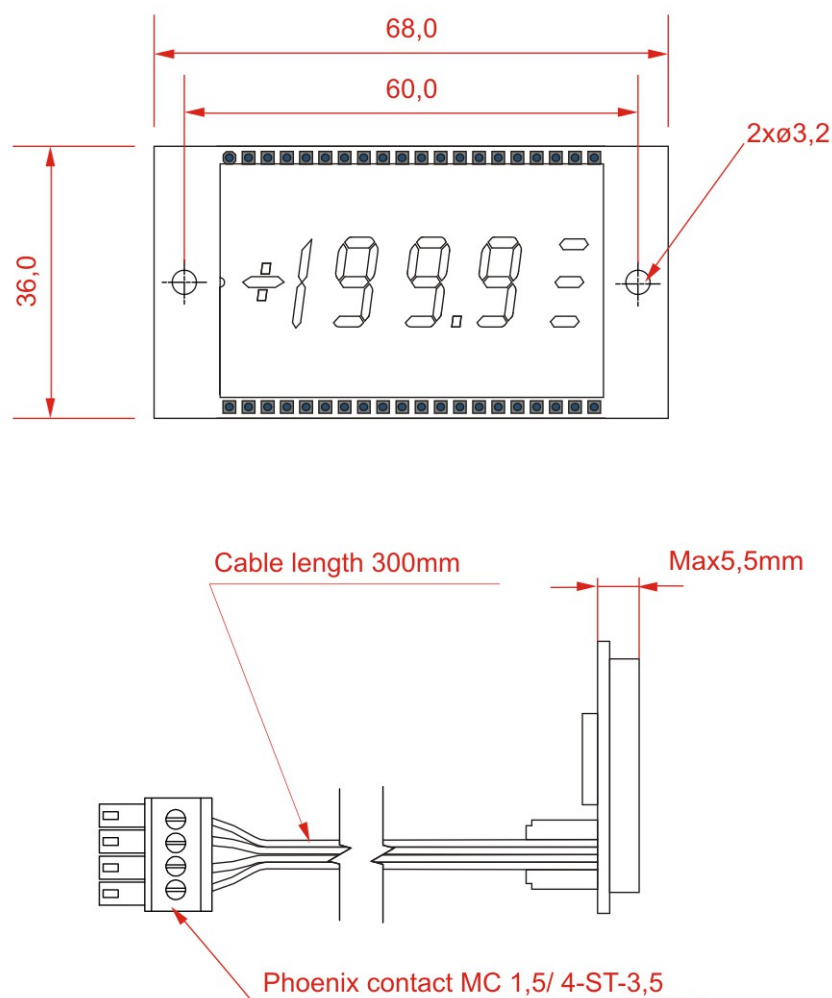
Drawing 16. LED display – mounting

The height of a single digit is 25mm which makes the displayed value legible from a long distance. Along with the display we provide you with a red PMMA glass improving the display contrast.

The power consumption by the LED module (with +12V supply) with all the segments on does not exceed 100mA.

### 2.3. LCD

The used LCD is 4.5-position, 7-segment display with no backlight. The display has a cable with a connector matching I<sup>2</sup>C connector (connector #3). Display is used for results and sensor's cycle phase presentation.



*Drawing 17. LCD – front view*

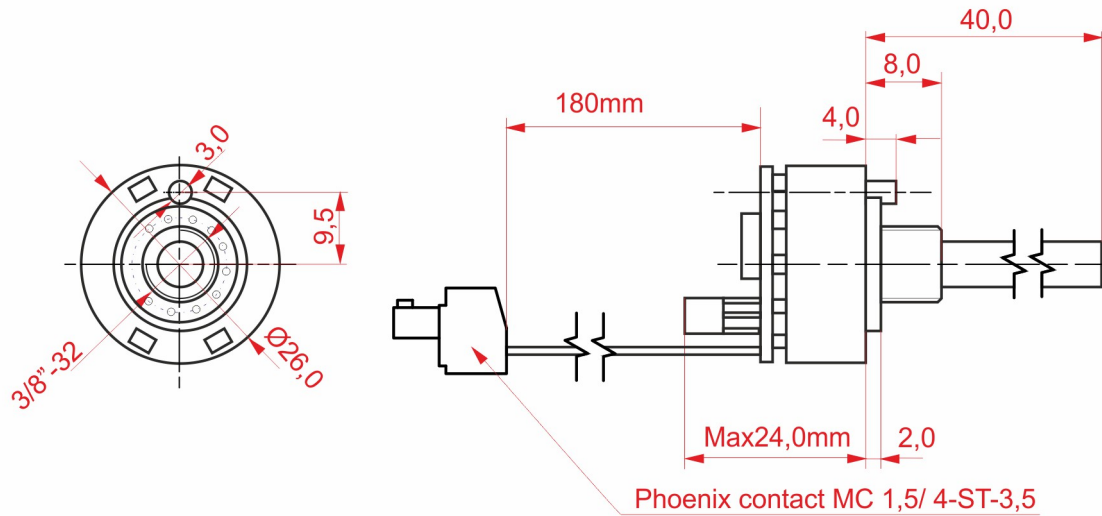
The height of the digit is 12mm.

The power consumption by the LCD module (with +12V supply) does not exceed 10mA.

## **2.4. Work knob**

Work knob is connected to the I<sup>2</sup>C connector (connector #3). It has a cable with a plug. Knob allows to put the sensor into specific work mode without the use of PC program madur.exe.

With the knob, user can decide when to zero the sensor and how long the measurements should last. It is always possible to return to the automatic mode programmed in the sensor.



*Drawing 18. Work knob – front and side view*

The power consumption by the work knob (with +12V supply) does not exceed 10mA. The knob has four positions described below.

#### **2.4.1.1. Position “Ventilation”**

Setting the knob to “Ventilation” puts the sensor into manual mode and automatically change the work phase to “Ventilation”. Sensor stays in this phase as long the work knob remains.

Solenoid valve, gas pump and analogue outputs behave as they were programmed to behave during ventilation.

During “Ventilation” phase sensor performs gas measurements. Display flashes and shows the measured result.

In the “Ventilation” phase sensor performs zeroing in the 10<sup>th</sup> second, and then every minute after, and also at the end of this phase.

Results are stored to SD card (if this option is enabled).

#### **2.4.1.2. Position “Standby”**

Setting the knob to “Standby” puts the sensor into manual mode and automatically change the work phase to “Standby”. Sensor stays in this phase as long the work knob remains.

Solenoid valve, gas pump and analogue outputs behave as they were programmed to behave during standby.

During “Ventilation” phase sensor does not perform gas measurements. Display shows dash “—” in the lowest digit.

Results are stored to SD card (if this option is enabled).

#### **2.4.1.3. Position “Measurement”**

Setting the knob to “Measurement” puts the sensor into manual mode and automatically change the work phase to “Measurement”. Sensor stays in this phase as long the work knob remains.

Solenoid valve, gas pump and analogue outputs behave as they were programmed to behave during measurements.

During “Measurement” phase sensor performs gas measurements. Display shows the measured result.

Results are stored to SD card (if this option is enabled).

**REMARK:** If the knob is switched to “Ventilation” directly from the “Measurement” the knob will perform the 1-minute “Infusion” phase first and then move on to “Measurement”.

#### **2.4.1.4. Position “Auto”**

Setting the knob to “Auto” puts the sensor into automatic mode (one that is set in the sensor's memory) and automatically change the work phase to “Ventilation”. Sensor stays in this phase for the programmed time.

Solenoid valve, gas pump and analogue outputs behave as they were programmed to behave during ventilation.

During “Ventilation” phase sensor performs gas measurements. Display flashes and shows the measured result.

Results are stored to SD card (if this option is enabled).

After “Ventilation” phase is finished, sensor enters “Measurement” phase and then continues actions specific for an on-going phase.

#### **2.4.1.5. Sensor's behaviour with work knob after power up.**

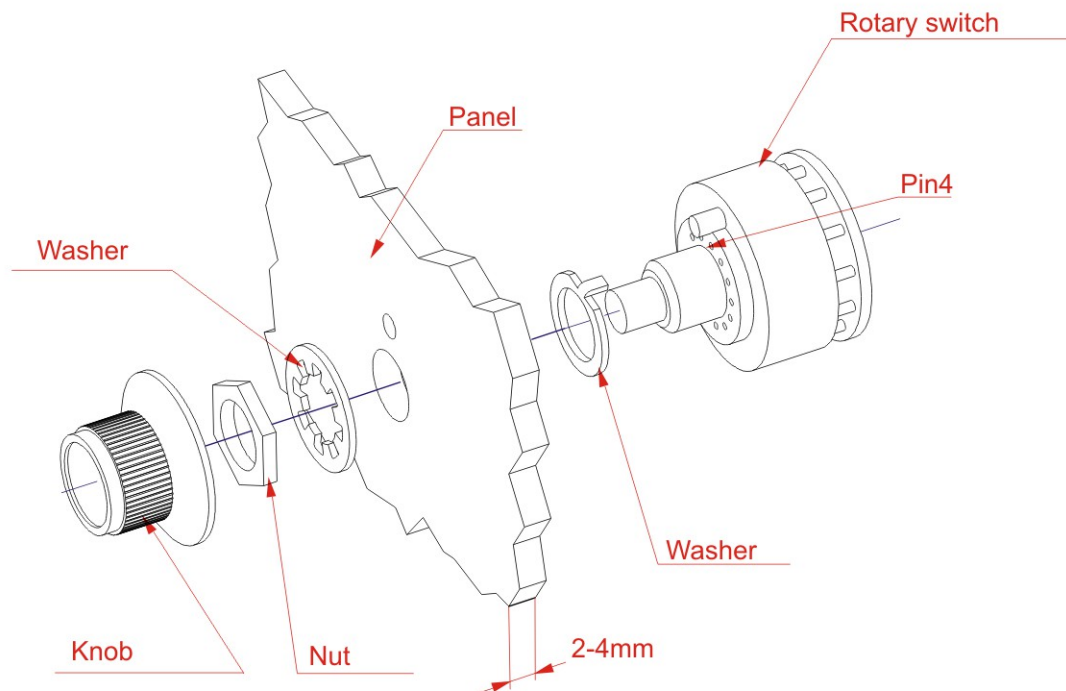
After starting the sensor, during the initial phases, sensor **does not mind the setting of the work knob**. It means that the sensor's initial phases are performed exactly the same in case of sensor without / with the work knob, regardless the knob's position.

Initial phases are: “Warming” and “FirstZeroing”. Right after the sensor is powered on, it waits the “Warming” phase, and then goes into “FirstZeroing” (sensor behaves like in during the “Ventilation” phase). Only after the “FirstZeroing” phase, the sensor considers the work knob setting and works according to the selected position.

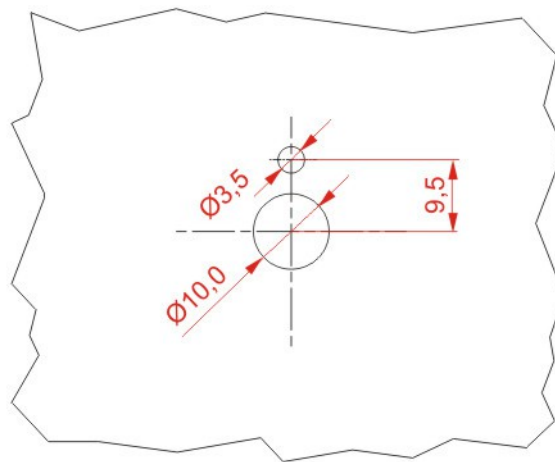
#### **2.4.1.6. Changing the knob's position**

To avoid sensor's unwanted behaviour, due to accidental change of work knob or due to transitive status (between the positions), a 3 second delay of the knob setting was introduced. This means that sensor reacts to knob selection and behaves accordingly, only after the knob is in a given position for more than 3 seconds. Temporary change of the knob's position and an immediate return to the previous setting will not effect in change of sensor's behaviour.

#### 2.4.1.7. Work knob montage

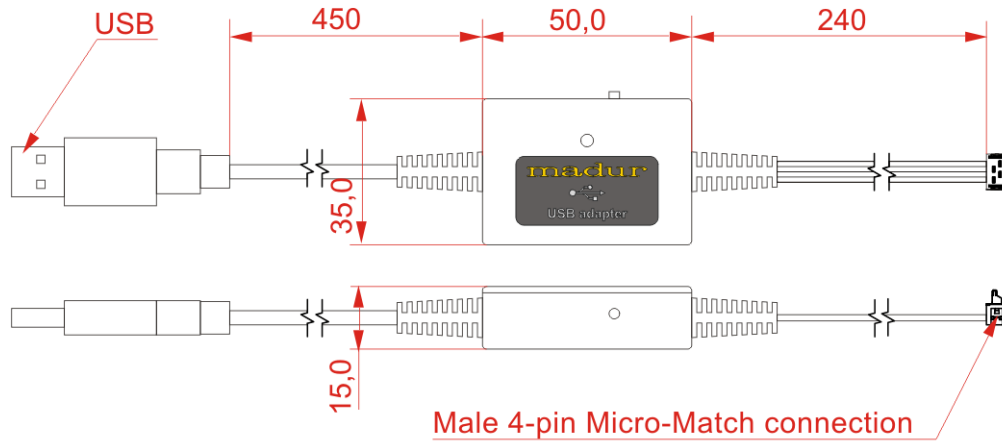


Drawing 19. Work knob – mounting



Drawing 20. Work knob – mounting openings

## 2.5. Adapter USB↔serial TTL to program sensor's processor



Drawing 21. Adapter USB – serial TTL – front and side view

Adapter allows to communicate with sensor from madur.exe program, but also to program the micro-controller to exchange the sensor's firmware. The adapter should be connected to the sensor's TTL serial interface (connector #5). In order to do so, it has been equipped with a ribbon cable with micro-match plug matching the connector #5. The converter is connected to the computer with a standard USB-A plug. It does not require any additional power supply. To make it possible to use the converter with Windows system it is necessary to install the appropriate driver supplied by madur.

The converter is equipped with double (red/green) LED diode and a button. Green diode indicates that bytes are being sent from the computer to the outer device. Red – the other way round.

The button enables the user to switch the sensor into micro-controller programming mode. To evoke the programming mode hold the converter button while turning the sensor on.

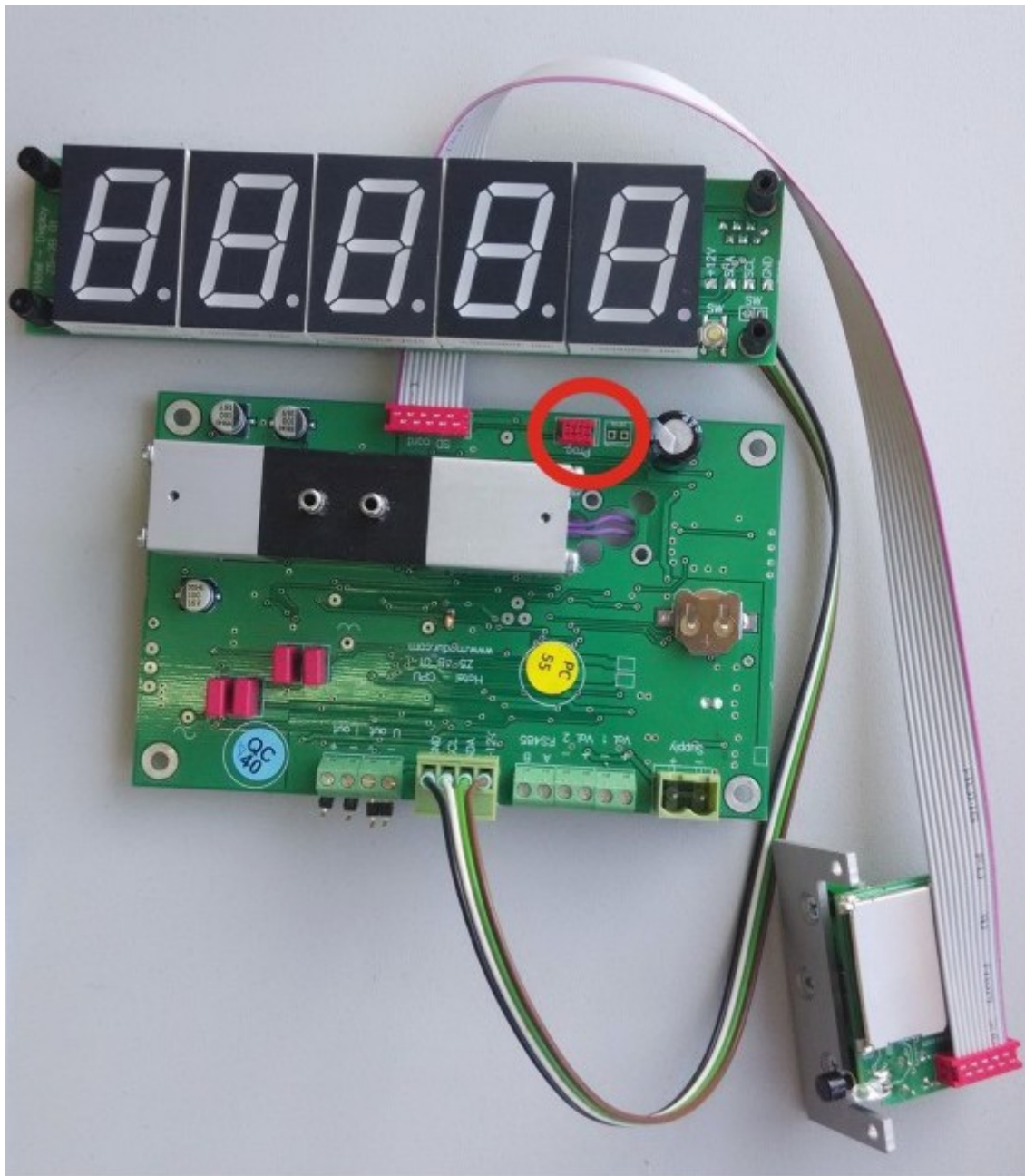
## 3. LOADING NEW FIRMWARE TO SENSOR'S MEMORY

To save new software to the sensor:

1. Install WSD program on the computer. Program can be downloaded from [here](#).
2. Connect the madur installation cable to the computer and let it be installed  
Drivers are available [here](#).
3. Connect the turned-off sensor to the madur installation cable

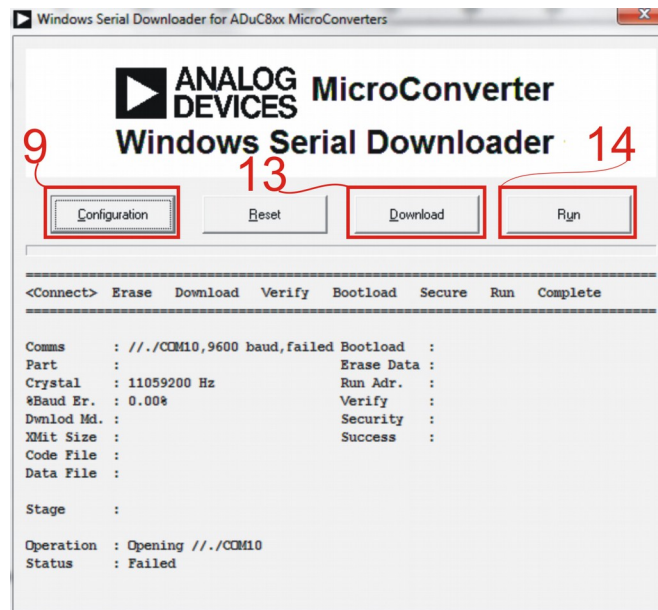
**REMARK:** the connector is polarised and can only be connected in one correct way.





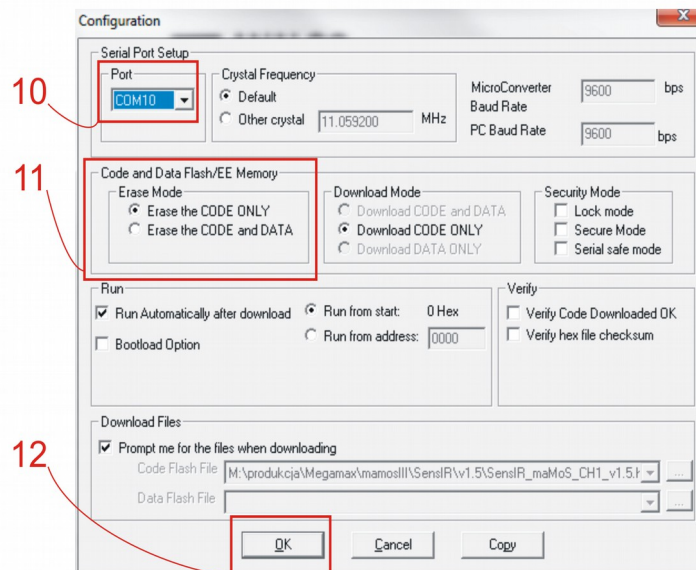
*Drawing 22. Programming connector*

4. Press and hold the button on the casing of the installation cable.
5. While observing the diode on the installation cable, connect the power supply to the sensor.
6. The button can be released when the diode on the installation cable blinks (usually right after the sensor is power on).
7. In Windows device manager (in port section) verify what COM port has been assigned to the installation cable.
8. Start the WSD program.
9. Press Configuration button.



Drawing 23. The main window of WSD program – the following steps of the manual have been marked

10. In Configuration menu choose the appropriate COM (verified in the point 7).



Drawing 24. The Configuration window of WSD program – the following steps have been marked

11. **REMARK:** make sure the option *Erase CODE ONLY* is selected (otherwise all the sensor's setting will be irreversibly removed and the device will have to be repaired at madur's).
12. Confirm the chosen settings with OK button.
13. In the *DOWNLOAD* menu indicate the version of the firmware which is to be installed in the sensor.
14. Press the *RUN* button and let the program save the new firmware version in the sensor's memory.