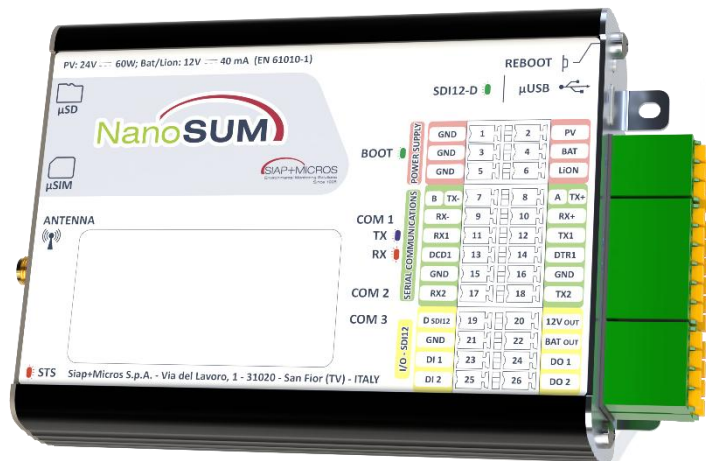


e016 NanoSUM

Data acquisition unit



User Manual
 Firmware Version 1.3.1

SIAP+MICROS

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1. Precautions and safety

NanoSUM is a compact measuring instrument for the acquisition, processing, storage and transmission of digital sensor measurements in various communication protocols. This equipment complies with the requirements of the Low Voltage Directive (LVD) 2014/35/EU, the Electromagnetic Compatibility Directive (EMC) 2014/30/EU and the Radio Equipment Directive (RED) 2014/53/EU.

Please pay particular attention to the meaning of the following symbols that may be encountered in this manual and in product documentation (labels, technical specifications, brochures, etc.).



General warning / danger symbol. Indicates a potential hazard that can cause injury or damage. Pay particular attention when you encounter the symbol.



Disposal of the product that must NOT be disposed of as municipal waste but rather in accordance with the European Waste of Electrical and Electronic Equipment (WEEE) Directive 2012/19/EU.



DC voltage and current symbol.

For the safety of the operator, it is necessary to follow the procedures described in this manual and read all the notes with particular attention.

1.1 Intended use

The control unit pertaining to the NanoSUM series is a local management device for environmental and weather-climate monitoring stations capable of directly interfacing weather sensors, analyzers, chemical-physical probes, actuators, etc. that have a serial output in MODBUS protocol or in SDI – 12. It is also able to directly acquire up to a maximum of two frequency or pulse digital inputs. It has been designed to meet various data acquisition, processing and transmission needs, from the simplest, for single stations, to the most complex, for networks of various kinds of stations managed by remote control centers.

Keep this manual carefully and always keep a copy available to the operators. For technical and commercial information and support, please refer to the manufacturer's contacts.

SIAP+MICROS S.p.a.

Via del Lavoro 1,

31020 – San Fior (TV) - Italia

<https://www.siapmicros.com/>

<https://www.siapmicros.com/en/contatti/>

For detailed technical specification, please refer to product page.

https://www.siapmicros.com/en/data_acquisition/datalogger/

1.2 Warnings

NanoSUM is a device designed to be used by trained personnel. The manufacturer declines all responsibility in the event of failures due non-compliance with observing the instructions, tampering, uses not foreseen in this manual, improper use of the appliance, use by untrained operators. Only authorized and trained personnel must have access to the work area for normal use and maintenance operations.

General safety rules

- Handle the instrument only with perfectly dry hands..
- The instrument must not operate in the presence of flammable gases, fumes or in any environment at risk of explosion.
- Do not remove, replace or modify any electrical or mechanical part without authorization.
- Maintenance operations, replacement of components and interventions inside the appliance must be carried out only by SIAP+MICROS specialized technical personnel or by SIAP+MICROS trained personnel.
- Pay attention to any warning labels against potentially dangerous practices.

1.3 Displacement

To avoid damage to the equipment, use caution during transportation.

1.4 Unpacking

Before unpacking and installing the instrument, make sure you have taken the following precautions:

- Use suitable gloves to protect against possible abrasions etc.
- If any damage caused by the transport carried out at the supplier's expense is found, return the instrument to the supplier.
- Once removed from the packaging, place the instrument and its component parts on a flat surface.
- Pay attention to the connectors on the side of the instrument container during the operation.

Before installing the instrument check that:

- The mains voltage of the installation area complies with the operating conditions of the instrument.
- Avoid turning on the instrument before carefully following the installation and start-up instructions in this manual.

1.5 Correct start-up procedure

The following procedure allows the correct power supply of the NanoSUM control unit with a lead acid battery and a solar panel.

1. Connect the battery to the power supply connector at pins BAT – GND (see chapter 2).

2. Pay attention to the polarity of the battery: BAT must be connected to the positive terminal and GND to the negative¹.
3. Connect the solar panel to the power supply connector at pins PV – GND (see chapter 2).
4. Pay attention to the polarity of the solar panel: PV must be connected to the positive terminal and GND to the negative.
5. If not already done, insert the connector into the terminal block.

NanoSUM can also be powered by a non-rechargeable Li-ion battery or a nominal 12VDC power supply. In this case, connect the lithium battery or the power supply to the power supply connector at the LiON – GND pins, making sure that the LiON pin is positive and GND is negative.

It is possible for both types of power to coexist, i.e. lead-acid battery with solar panel and lithium battery on LiON connector. The solar panel will only charge the lead battery. The actual power source of the data logger will be the one with the highest voltage. For example, if you have a 12V lead acid battery and a 7V lithium battery, the lead acid battery will be used. Conversely, if you have a 12V lead acid battery and a 13.8V power supply connected to LiON, the power supply will be used for the entire data logger and in this case the battery will be a form of back-up power in case of mains voltage power failure for the main power supply.

If using external power supplies connected to the electricity distribution network, pay particular attention to the selection of the power supply device, isolation and network filtering.

Pay attention to the green led named **BOOT**²: this has to blink to indicate the module is starting properly. If not, press and hold the **REBOOT**² button for 3 seconds and release it as soon as the **BOOT** led starts flashing. Do not overextend the pressure.

Correct power on of the module is indicated by the red **CONNECTION STATUS LED** which, after a boot delay of about twenty seconds, starts flashing.

1.6 Diagnostic start procedure

As will be explained in detail in paragraph 3.13, the control unit can operate in a particular operating mode, called diagnostic mode, which is the factory-set mode for the first start-up of the data logger, and is very useful both during initial installation and during maintenance. This particular mode can be activated both via software and through the REBOOT power button.

The activation of the diagnostic mode is obtained by pressing and holding down the REBOOT button for at least six seconds. The green **BOOT** LED will start flashing after the third second of pressing, do not release it but continue until at least six seconds. For safety, you can count up to a maximum of eight seconds and then release. The ECU will start in diagnostic mode.

Correct power on of the module is indicated by the red **CONNECTION STATUS LED** which, after a boot delay of about twenty seconds, starts flashing.

¹ NanoSUM is equipped with reverse polarity protection devices. It is however good to pay attention to the connections.

² Consider Chapter 2 for hardware description

1.7 Restart procedure

To restart in normal mode a NanoSUM that is currently ON, press and hold the REBOOT button for at least three seconds and release it as soon as the BOOT LED starts flashing. Do not press for more than five seconds.

To restart in diagnostic mode a NanoSUM that is currently ON, press and hold the REBOOT button for at least 10 seconds and then release it.

Correct power on of the module is indicated by the red **CONNECTION STATUS LED** which, after a boot delay of about twenty seconds, starts flashing.

1.8 In operation

During operation, avoid intervening on the electrical connections: completely disconnect the power supply before making any modifications.

1.9 Storage

If you do not plan to use the equipment for an extended period of time (at least one year) disconnect all cables from the equipment, place it in a clear plastic bag along with a bag of desiccant salts and seal the bag with tape. Put appropriate indication on the bag of the contents and weight of the equipment by inserting the wording "HANDLE WITH CARE".

Store the instrument in an environment with a temperature between 0°C and 60°C with a humidity not exceeding 80%. Make sure that the instrument is stored in a stable position and that it cannot be damaged or moved by inexperience or carelessness. Do not stack other tools or weights. Do not place the instrument on top of other instruments and in any case ensure the solidity and stability of the underlying support.

1.10 Maintenance

1.10.1 Cleaning

Disconnect all connecting cables before cleaning the device. For cleaning, use a soft, dry cloth. Never use damp cloths, solvents, water or other liquids. Compressed air can be used to eliminate any dusty residues.

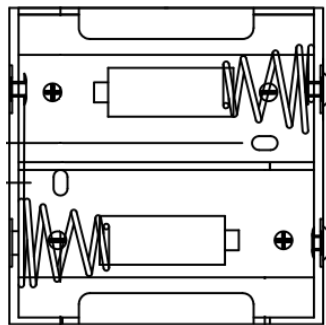
1.10.2 Electric lines protection

The product is equipped with protection devices against electrostatic discharges. The power supplies are also provided with circuitry against polarity reversals. There are no overcurrent protection fuses therefore pay particular attention to the connections and always refer to the technical specifications of the instrument for the applicability limits. See Chapter 2 for more details.

1.10.3 Battery replacement (IP68 Version)

The product is available in a version with an IP68 sealed box equipped with batteries³. When replacing the batteries, keep in mind that:

- The battery pack contains 2 batteries: always replace both batteries even if only one is exhausted.
- The batteries must be of the ER34615M type, i.e. Li-SOCl₂ lithium batteries.
- Batteries must be capable of delivering 2000mA continuous current.
- Batteries must be capable of delivering a pulse current up to 3000mA.
- Pay attention to the correct polarity of the battery indicated in the battery holder itself.



- Replace the batteries with the data logger disconnected.
- Do not tamper with the battery pack in any way.

If in doubt, contact SIAP+MICROS for assistance.

1.11 Disposing



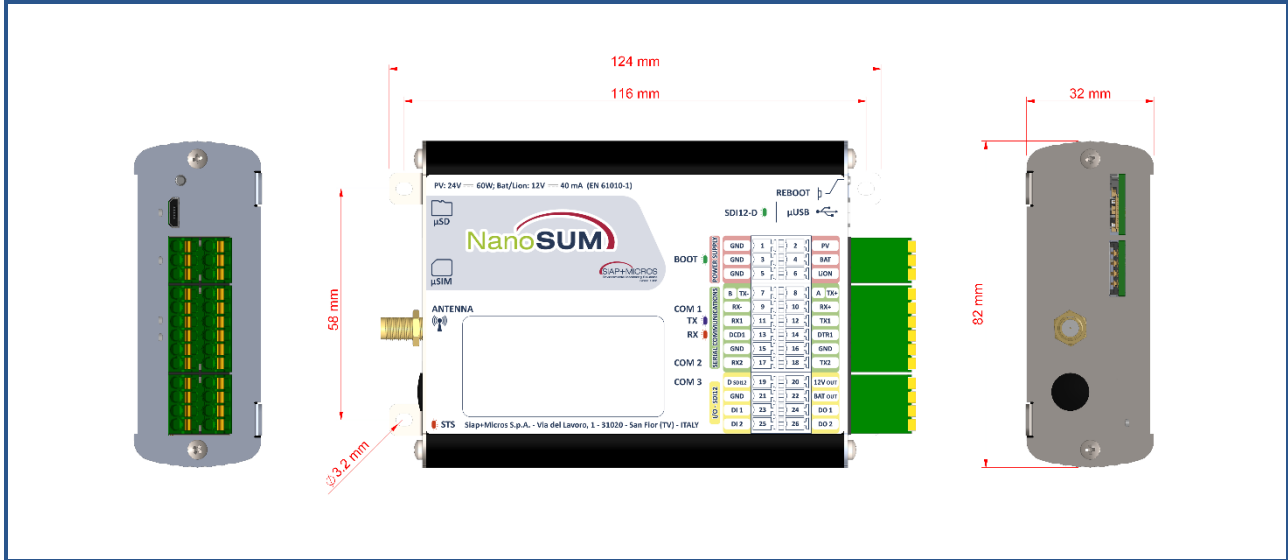
In compliance with the European Union directive 2012/19/EU on Waste Electrical and Electronic Equipment, this product must be disposed of by taking it to a designated collection point for the recycling of electrical and electronic equipment.

For more information regarding your nearest recycling center, contact your local authority office.

³ More details in Hardware and connections chapter.

2. Hardware and connections

2.1 Terminal blocks and connections



Terminal block and connections

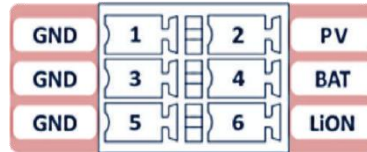
Ground	GND	1	2	PV	Solar panel input
Ground	GND	3	4	BAT	Lead acid battery input
Ground	GND	5	6	LiON	Input in DC or lithium battery
B(-) RS-485 / TX- RS-422 COM1	B TX-	7	8	A TX+	COM1 A(+) RS-485 / TX+ RS-422
RX- RS-422 COM1	RX-	9	10	RX+	COM1 RX+ RS-422
RX RS-232 COM1	RX1	11	12	TX1	COM1 TX RS-232
DCD RS-232 COM1	DCD1	13	14	DTR1	COM1 DTR RS-232
Ground RS-232 COM2	GND	15	16	GND	COM1 ground RS-232
RX RS-232 COM2	RX2	17	18	TX2	COM2 TX RS-232
Data line SDI-12 COM3	D SDI12	19	20	12V OUT	12V / 100mA output
Ground	GND	21	22	BAT OUT	Battery voltage output
Digital input 1	DI 1	23	24	DO 1	Digital output 1
Digital input 2	DI 2	25	26	DO 2	Digital output 2

The NanoSUM datalogger is equipped with:

- **Connection terminal board.** Compact terminal block with spring contacts housing:
 - **Power connectors.** Highlighted in pink in the figure on the previous page, they include the connections of the solar panel (PV – GND), rechargeable lead battery (BAT – GND), DC input (LiON – GND)
 - **COM1 communication device.** It is an acquisition communication port towards sensors in MODBUS protocol which can be used alternatively as RS – 485 (A, B), RS – 232 (RX1, TX1, DTR1, DCD1, GND) or as RS – 422 (TX+, TX-, RX+, RX-)
 - **COM2 communication device.** It is an RS – 232 (RX2, TX2, GND) communication port for acquisition towards sensors in MODBUS protocol.
 - **COM3 communication device.** It is a standard communication port to SDI – 12 sensors, data line on pin 19 of the terminal block, indicated as D_{SDI12}.
 - **Output sensors power supply:** 12V_{OUT}: 12V / 100mA, BAT_{OUT}: voltage equal to the supply voltage, DO1, DO2: open drain outputs for enabling relays or external power supplies.
 - **Digital inputs:** there are two digital inputs DI1 and DI2, both referred to the common ground GND, capable of acquiring both open drain signals and active signals (maximum 24V) for measuring frequency, period, pulse count, cumulative pulse counter.
- **Type B μUSB connector.** Configuration and advanced debugging connector.
- **Reset button.** If you press and hold the button next to the μUSB for more than three seconds, the data logger restarts.
- **μSIM connector.** For normal data logger operation, a valid M2M μSIM must be inserted. Contact your cellular network service provider for more information.
- **μSD card connector.** There is a μSD card connector for data backup storage.
- **Main antenna connector.** The main antenna connector is of the female SMA type capable of housing a 50Ω impedance antenna. The antenna bands must fall between the module bands. Refer to the detailed technical specifications for more information.
- **Optional provision for GNSS.** Next to the antenna, a black cap covers the predisposition for the GNSS satellite positioning system. Contact SIAP+MICROS S.p.a. for further information regarding the possibility of purchasing this option.
- **Signaling LEDs.** NanoSUM is equipped with five signaling LEDs:
 - **CONNECTION STATUS:** red LED whose flashing indicates the status of the connection.
 - **BOOT:** Flashing green LED when starting or restarting the data logger; in these phases the flashing is of one second ON and one second OFF alternately. The LED turns on during the acquisition phases to indicate the correct functioning of the module.
 - **COM1 TX:** Blue LED indicating transmission from the data logger to a sensor on COM1.
 - **COM1 RX:** Red LED indicating reception from a sensor to the data logger on COM1.
 - **SDI12-D:** Green LED indicating data exchange on the SDI – 12 interface.

2.2 Power Supply

The power supply section includes the connector called POWER SUPPLY and highlighted in pink on the data logger label.



NanoSUM is able to manage two possible power modes:

1. Solar panel and nominal 12V rechargeable lead battery at the PV – GND and BAT – GND pairs, i.e. pins 2, 1 and 4, 3.
2. Non-rechargeable battery or 12V_{DC} power supply to LiON – GND pair, pins 6 and 5.

2.2.1 Photovoltaic panels and battery power supply

NanoSUM is equipped with an autonomous battery charger capable of managing a solar panel and the charge of a nominal 12V lead-acid battery. Special features of the battery charger are:

- 3-phase charging algorithm: bulk (constant current), absorb (constant voltage), float (maintenance)
- Input power self-limitation: 3.2 A maximum current, 60W.
- Battery current self-limitation at 3.2 A.
- Dynamic tracking algorithm of the solar panel working point to obtain the maximum available power (MPPT, Maximum Power Point Tracking).
- Correction of the charging voltage according to the temperature to preserve the battery.
- Diagnostic measurements of battery voltage and solar panel voltage.

Refer to the technical specifications for the detailed electrical characteristics of the battery charger, solar panels and compatible batteries.

The solar panel input is marked by the **PV** (positive, pin 2) and **GND** (negative, pin 1) terminals and has the main function of maintaining the charge on the lead battery. Solar panels are supported for charging 12V batteries, with a maximum permitted voltage of 28V_{DC}, of any power, this being self-limited to approximately 60W. In conditions of solar radiation, the battery charging circuit adapts the operating point of the panel to obtain maximum power and is able to deliver up to 3.2A on the battery.

The panel input is equipped with:

- Protection circuit against reverse polarity
- Low pass filtering
- Filtering to limit insertion spikes
- Protection circuit against electrostatic discharges up to 18 kV qualified for standards:
 - IEC 61000-4-2, level 4
 - IEC 61000-4-5 (surge); peak current 3 A at 8/20 μs
 - AEC-Q101

The battery input is marked by the **BAT** (positive, pin 4) and **GND** (negative, pin 3) terminals and has the function of main power supply of the data logger. A lead battery with a nominal voltage of 12V can be connected to these terminals. The battery input is also equipped with:

- Protection circuit against reverse polarity
- 18V voltage limiter
- Protection circuit against electrostatic discharges up to 18 kV qualified for standards:
 - IEC 61000-4-2, level 4
 - IEC 61000-4-5 (surge); peak current 3 A at 8/20 μ s
 - AEC-Q101




The battery charger is also equipped with a special algorithm to preserve the lead battery from deep discharge conditions; in particular, if the battery voltage drops below 10.5V, the algorithm completely shuts down the data logger to protect the battery from deep discharge. In any case, the battery charger continues to function, therefore in the presence of solar radiation it will resume charging the battery. At this point, when the battery voltage has risen above 11.5V, the algorithm re-powers the data logger and provides for a clean start of the module. The algorithm, as will be seen later, can be disabled by configuration key.

2.2.2 Non-rechargeable battery and 12V_{DC} power supply

The input marked by the **LiON** (positive, pin 6) and **GND** (negative, pin 5) terminals can house an independent power source such as a power supply with a nominal voltage of 12V_{DC} or a non-rechargeable battery, typically lithium-ion. The input is equipped with a protection diode against reverse polarity. In case of power supply from a non-rechargeable lithium battery, it is necessary to disable the battery protection algorithm to allow operation at voltages up to the minimum limit of 6V⁴.

When using the LiON power input, do not use the battery and solar panel input. The two power systems are mutually exclusive.

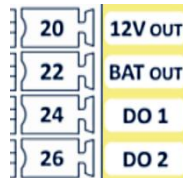
2.2.3 Power supplies summary table

Power Supply Input	Name	Pin
Photovoltaic Panel 24V _{MAX}  60W _{MAX}	PV – GND	Positive input: pin 2 Negative input: pin 1
Rechargeable lead-acid battery 12V 	BAT – GND	Positive input: pin 4 Negative input: pin 3
Auxiliary input 6V ÷ 15V 	LiON – GND	Positive input: pin 6 Negative input: pin 5

⁴ For further information, please refer to paragraphs 3.10 BMS: battery management system and 4.1: General parameters.

2.3 Power supply of connected devices

The NanoSUM data logger can power the sensors connected to it through four possible outputs with different electrical characteristics. The output power supplies are part of the I/O – SDI12 connector, colored yellow on the label, as shown below.



The four outputs, all referred to the ground of the board (GND), have the following characteristics:

1. **12V_{OUT}**: pin 20 of the terminal board, 12V regulated with maximum current of 100mA. Optionally it is possible to request a 5V power supply with the same current limitations⁵. The output, normally off, can be configured normally on or with a preliminary switching time for scheduled acquisitions. Refer to the following chapters for more details.
2. **BAT_{OUT}**: pin 22 of the terminal block, provides the input power supply voltage to the output. The output, normally off, can be configured normally on or with a preliminary switching time for scheduled acquisitions. Refer to the following chapters for more details.
3. **DO1**: pin 24 of the terminal block, open drain output useful for activating relays or enabling pins for external power supplies. The output, normally off, can be configured normally on or with a preliminary switching time for scheduled acquisitions. Refer to the following chapters for more details.
4. **DO2**: pin 26 of the terminal board, open drain output useful for activating relays or enabling pins for external power supplies. The output, normally off, can be configured normally on or with a preliminary switching time for scheduled acquisitions. Refer to the following chapters for more details.

The two open drain outputs DO1 and DO2 are also equipped with an electrostatic discharge protection circuit with the following characteristics:

- ESD protection up to 30 kV according to the IEC 61000-4-2 standard
- ESD protection up to 30 kV according to ISO 10605; C = 330pF, R = 330Ω
- ISO 7637-3: a pulse: VS = -150 V / b pulse: VS = +100 V
- AEC-Q101 qualified

⁵ The option must be agreed at the time of the commercial offer.

2.4 Digital inputs

On the same I/O – SDI12 connector there are two digital inputs DI1, pin 23, and DI2, pin 25, also these refer to the GDN common ground of the board.



Peculiar characteristics of these inputs are:

- Ability to acquire square wave pulses with variable duty cycle from open drain or open emitter signals as they are equipped with internal pull up and level shifters.
- Ability to acquire square wave pulses with variable duty cycle from active signals as they are equipped with limiting circuitry and internal level shifters.
- Channel acquisition must be enabled in the configuration in which case, these are acquired every second to measure:
 - Frequency
 - Count
 - Logical state
 - Time interval in a logical state

Digital inputs are also equipped with an electrostatic discharge protection circuit with the following characteristics:

- ESD protection up to 30 kV according to the IEC 61000-4-2 standard
- ESD protection up to 30 kV according to ISO 10605; C = 330pF, R = 330Ω
- ISO 7637-3: a pulse: VS = -150 V / b pulse: VS= +100 V
- AEC-Q101 qualified

2.5 Serial communications

NanoSUM has various communication interfaces: towards the sensors and diagnostics / configuration communication connectors which will be analyzed in the next paragraphs.

The interfaces to the sensors are mainly located on the connector marked SERIAL COMMUNICATIONS, green on the label, and on pin 19 of the terminal block as shown in the next figure.



A μ USB B interface is added, for diagnostics and module configuration.

This chapter will also describe the hardware that implements radio frequency connectivity.

2.5.1 COM1 RS – 485 / RS – 232 / RS – 422 multi serial interface

COM1 is a multi-serial interface in the sense that it can be used alternatively as RS – 485, as RS – 232 or as RS – 422; it therefore allows great versatility in the connection of serial sensors. On this interface, sensors in standard MODBUS protocol can be connected. The baud rate can be selected from 1200, 2400, 4800, 9600, 19200, 38400, 57600 bps for the RS – 485 and RS – 422. The RS – 232 allows instead to reach even 115200 bps. Below are the characteristics of the various interfaces available:

- **RS – 485**

It is characterized by terminals **A** (positive, pin 8) and **B** (negative, pin 7); the interface is equipped with:

- 4.7 k Ω pull up resistor to 3.8V on positive pin A
- 4.7 k Ω pull down resistor to ground on negative pin B
- Low pass filter circuit, on both lines, with cutoff frequency of 7.2 MHz
- Electrostatic discharge protection circuit with the characteristics:
 - Compliance with IEC61000-4-2 (ESD) \pm 15kV (air), \pm 8kV (contacted)
 - Compliance with IEC61000-4-4 (EFT) 40A (5/50ns)
 - Compliance with the IEC61000-4-5 standard (Lightning strike) 12A (8/20 μ s)

- **RS – 232**

It is characterized by the **RX1** (receive, pin 11), **TX1** (transmit, pin 12), **DCD1** (DCD, pin 13), **DTR1** (DTR, pin 14) and **GND** (ground, pin 16) terminals. The interface is equipped with:

- Low pass filter circuit, on all RX1, TX1, DCD1, DTR1 lines, with cutoff frequency of 7.2 MHz

- Protection against electrostatic discharges up to ± 15 kV according to the IEC61000 standard
- **RS – 422**
It is characterized by terminals **RX-** (negative reception, pin 9), **RX+** (positive reception, pin 10), **TX-** (negative transmission, pin 7), **TX+** (positive transmission, pin 8). The interface is equipped with:
 - 4.7 k Ω pull up resistor to 3.8V on positive pin A
 - 4.7 k Ω pull down resistor to ground on negative pin B
 - Low pass filter circuit, on both lines, with cutoff frequency of 7.2 MHz
 - Electrostatic discharge protection circuit with the characteristics:
 - Compliance with IEC61000-4-2 (ESD) ± 15 kV (air), ± 8 kV (contacted)
 - Compliance with IEC61000-4-4 (EFT) 40A (5/50ns)
 - Compliance with the IEC61000-4-5 standard (Lightning strike) 12A (8/20 μ s)

2.5.2 COM2 RS – 232 serial interface

COM2 is an RS – 232 serial interface for acquiring sensors in standard MODBUS protocol. The baud rate can be selected from 1200, 2400, 4800, 9600, 19200, 38400, 57600 and 115200 bps. COM2 has the following characteristics:

- **RS – 232**
It is characterized by the **RX2** (reception, pin 17), **TX2** (transmission, pin 18) and **GND** (ground, pin 15) terminals. The interface is equipped with:
 - Low pass filter circuit, on lines RX2 and TX2 with cutoff frequency of 7.2 MHz
 - Protection against electrostatic discharges up to ± 15 kV according to the IEC61000 standard

2.5.3 COM3 SDI – 12 interface

COM3 is an interface for acquiring SDI – 12 sensors characterized by the **D_{SDI12}** terminal (bidirectional data line, pin 19) with the following characteristics:

- SDI – 12 standard data line at 5V with 360 k Ω pull down resistor to ground.
- Low pass filter circuit with cutoff frequency of 128 kHz
- Electrostatic discharge protection circuit with the following characteristics:
 - ESD immunity in accordance with the IEC 61000-4-2 standard
 - ± 30 kV contact discharge
 - ± 30 kV discharge in air
 - ESD capability according to the AEC-Q101 standard:
 - human body model class H3B: > 8 kV

2.5.4 μ USB interface

NanoSUM is equipped with a slave μ USB type B interface mainly used for module configuration and for diagnostics or firmware updates operated by qualified personnel of SIAP+MICROS⁶.

To use this interface, available only in the Windows environment, it is necessary to install appropriate drivers at the end of which NanoSUM exposes two modem COM ports and a diagnostic COM port.

The interface features:

- Common mode choke, 0.5 A maximum, impedance of 90 Ω at 100MHz
- Specific EMI filter for USB ports
- Electrostatic discharge suppressor circuit with the characteristics:
 - IEC 61000-4-2 level 4 on external pins:
 - 15 kV for air discharge
 - 8 kV for contact discharge
 - IEC 61000-4-2 level 1 on internal pins:
 - 2 kV for air discharge
 - 2 kV for contact discharge
- Circuit for separation and filtering of the ground of the connecting cable

2.5.5 Radio connectivity

NanoSUM is a global 4G module available in two different versions:

- Category M1 and NB1 with support and automatic fallback to 2G network.
- Category 1 with support and automatic fallback to 3G and 2G network.

The 4G technology with 2G fall back makes it possible to considerably reduce consumption, compared to a 3G module, while still maintaining a data exchange speed that is fully adequate for the functions and expected purposes for the data logger. NanoSUM can operate on a very large number of RF bands which ensure global network coverage. The supported bands are shown below.

Category M1 and NB1 data logger with 2G fall back

Technology	Supported bands
2G	B2 (1900), B3 (1800), B5 (850), B8 (900)
4G cat M1/NB1	B1 (2100), B2 (1900), B3 (1800), B4 (AWS 1700), B5 (850), B8 (900), B12 (700), B13 (700), B18 (800), B19 (800), B20 (800), B26 (850), B28 (700)

⁶ It is always possible, and advisable, to use the FTP function to update the configuration or firmware of the module in the field, as will be explained later.

Category 1 data logger with 3G and 2G fall back

Technology	Supported bands
2G	B2 (1900), B3 (1800), B5 (850), B8 (900)
3G	B1 (2100), B2 (1900), B4 (AWS 1700), B5 (850), B6 (850), B8 (900), B19 (800)
4G cat 1	B1 (2100), B2 (1900), B3 (1800), B4 (AWS 1700), B5 (850), B8 (900), B8 US, B9 (1800), B12 (700), B13 (700), B14 (700), B18 (800), B19 (800), B20 (800), B25(1900), B26 (850), B28 (700)

The radio frequency interface is via:

- **50 Ω adapted multiband antenna**

To make the most of the bands made available, we recommend multiband antennas in the range 600 MHz ÷ 3 GHz. The antenna connects to a female SMA connector marked on the label as "ANTENNA". Inside the module there is a notch type filtering circuitry to suppress any out-of-band disturbances.

- **μ SIM enabled for M2M data traffic**

Make use of **Machine To Machine (M2M)** type data SIM. The module does not have an automatic SIM presence detection function. Pay close attention to the direction of insertion of the SIM shown on the label. The μ SIM connector is not push pull, therefore do not force or push the SIM once inserted. Pay particular attention when inserting it. The interface with the SIM is characterized by:

- Bidirectional EMI filter circuit
- ESD protection circuit in accordance with the IEC 61000-4-2 level 4 standard
 - ± 15 kV for air discharge
 - ± 8 kV for contact discharge
 - 5V overvoltage limitation circuit

2.6 Other characteristics

In the normal use of NanoSUM, the data collected is stored in a circular archive file in the internal memory of the device (non-volatile Flash memory) and periodically transferred to one or more FTP servers. However, it is possible to make a copy of the data on a removable external storage medium. Next to the μ SIM connector, there is in fact a push-pull connector capable of housing a μ SD card for data backup. The only functionality of this storage is to save copies of archive data in daily files within monthly folders. NanoSUM supports μ SD cards up to specification 2 of the standard, formatted in either FAT or FAT32 or extFAT. The data on both memories, as will be described in detail later, are both in the dynamic SIAP+MICROS format, a proprietary plain text format that is easy to read.

Near the μ USB connector there is a button which, if held down for more than three seconds, starts the module reboot procedure. At the start of the reboot procedure you will notice that the green "BOOT" LED will start flashing as in the boot phase.

2.7 General requirements

The data logger operates according to EN 61010-1. NanoSUM is designed to operate under the following conditions.

- The IP protection level of the data logger is IPX0, therefore it is only permitted for indoor or outdoor use only inside a box with an adequate IP protection level. In the case of boxes with an IP protection level higher than IP66, ensure ventilation of the external box with suitable sealed vents.
- Temperature range -40°C – +80°C.



Be very careful when operating at ambient temperatures above 60°C. Use appropriate personal protective equipment to handle the device in such environments.

- Relative humidity range: 0% – 100% non-condensing.
- Maximum operating altitude greater than 5000 m.
- The applied supply voltages must remain within the limits detailed in the previous paragraphs and in the technical specifications. The internal regulators provide stabilization of the power supply. However, the use of unstable or noisy power supplies is not recommended.
- Overvoltage category II.

In the wiring of the input power supplies (PV, BAT and LiON), preferably use AWG16 cables or, in any case, with a cross-section greater than 1 mm² and with a built-in 5 A fuse.

In the wiring of the BAT_{OUT} output power supply, preferably use AWG16 cables or, in any case, with a cross-section greater than 1 mm² and with a built-in 5 A fuse.

In the wiring of the 12V_{OUT} output power supply, rated at 100 mA, it is possible to use AWG24 cables or with a greater cross-section. It is recommended to protect the output with a 100 mA fuse.

In the wiring of the other signal lines, it is possible to use AWG24 cables or with a greater cross-section.

It can be used a maximum cables cross-section of 1.5 mm².

The data logger connectors are push-on: the cable is inserted after pressing, with a flat-head screwdriver, the orange groove at the insertion point. The connectors accept both cables with ferrules and bare cables. Please note that to reach the maximum permitted cable section of 1.5 mm², it is necessary to use bare cables or cables with ferrules but without plastic protection. For cables terminated with ferrules and plastic protection, the maximum section is lowered to 0.75 mm².

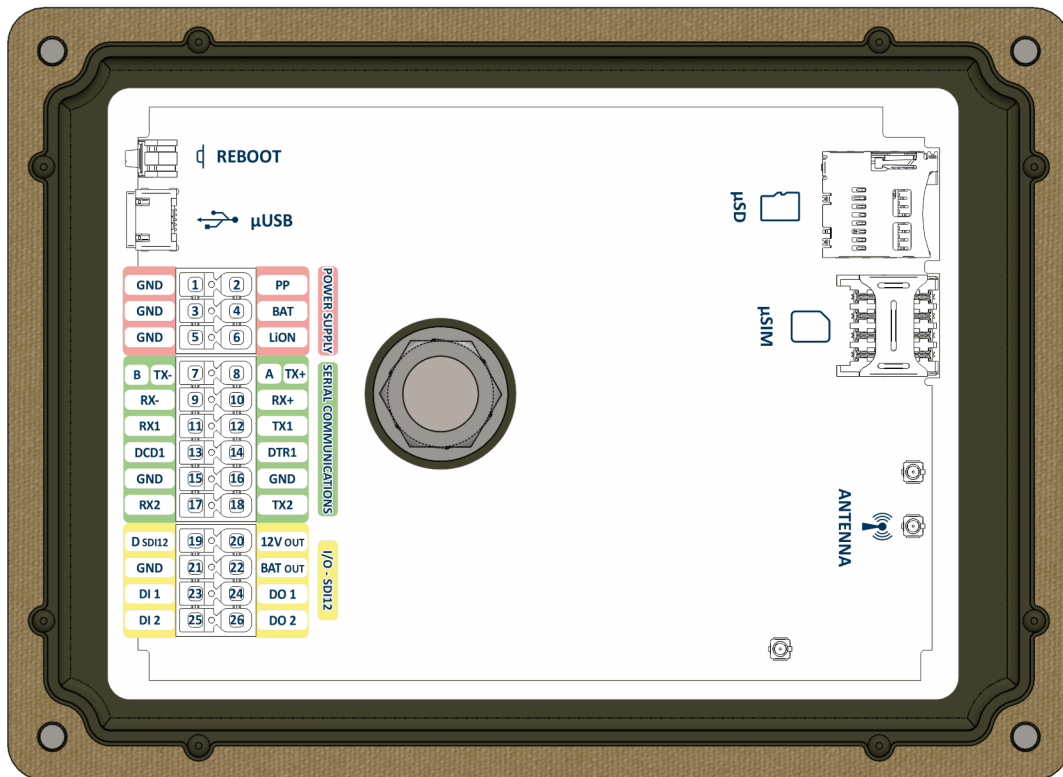
2.8 NanoSUM IP68 version

NanoSUM is also available in the IP68 version, i.e. with its operating circuit inside an IP68 class watertight container as shown in the next figure.



Figure 1 NanoSUM IP68

The NanoSUM circuit is housed inside the container, with a terminal board identical to the one described, and the power supply battery pack.



Refer to paragraph 2.1 for the meaning of the connections.

Outside the box there are:

- Two PG9 IP68 cable glands for the passage of the power cables and connection of the various sensors.
- An IP68 box pressure compensating blower. To ensure the IP68 seal, this must be tightened to the box with a torque of 0.7 ± 0.1 Nm.
- An IP68 omnidirectional antenna.

The box is equipped with four convenient fixing holes and four screws ensure the correct closure of the lid. A gasket ensures the tightness of the box. The gasket normally used is in carbon-reinforced black silicone; in this case the locking screws must be tightened with a tightening torque of 1.0 Nm; do not exceed this torque in order not to damage the gasket. In some cases you may find a creamy white silicone gasket. In this case, the tightening torque of the box screws must be 0.7 Nm.

During ordinary maintenance it is advisable to replace the gasket; refer to SIAP+MICROS for any spare parts.

NanoSUM IP68 is typically used for groundwater monitoring, directly in situ inside measurement and control wells.

3. User guide and programming

NanoSUM is a device that allows you to acquire measurements from sensors with serial output in different protocols, or from digital sensors. The measurements are then processed and stored, at scheduled time, in a circular file, for a limited period of time dictated by the storage frequency, and periodically transmitted to one or more FTP servers via 4G connection in category 1 or, in the absence of such networks, in 3G or 2G. There is also a category M1 / NB1 version with 2G fallback. The device can also function as an automatic alert station, managing the routing of alarm messages of different priorities to designated recipients, based on acquired data and configurable thresholds. The various aspects of the functions can be configured both locally, via the USB interface made available, and remotely, via files on FTP servers or SMS configuration messages.

This chapter will detail the various aspects of using and configuring NanoSUM.

3.1 General characteristics

All NanoSUM functions are made available by the operating program binary file *anylog.bin* and its configuration file *config.ini*: in the absence of even just one of these files, the device cannot function. In the following, *anylog.bin* will be referred to as the program file or firmware file; *config.ini* will be referred to as the configuration file. The operating program takes advantage of the potential made available by the processor with which the module is equipped, and in particular the possibility of dividing the elementary operations into several separate jobs, *tasks* within the operating system, which are performed in a concurrent manner. In particular, the program develops in four distinct and concurrent tasks:

- **Main Task**

The main task, as the name implies, is the fundamental task of the operating program on which the core functionalities of the system depends. It is in charge of:

- Manage the power supplies to the sensors
- Manage the acquisition of sensor measurements and their statistical processing
- Manage the storage of acquired data on circular archive files
- Manage any alarm status and their forwarding
- Prepare the newly stored data for transmission

- **Service Tasks**

- The service task is a fundamental accessory task that is in charge of:
- Manage system initializations
- Manage program file and configuration file updates
- Manage date and time synchronization
- Manage storage of backup data archive⁷

⁷ If configured.

- Manage operations in low power consumption

- **FTP Task**

The FTP task manages all those aspects related to the possibility of spontaneously connecting to one or more FTP servers and makes the following operations possible:

- Management of data upload on configured FTP servers
- Management of the download of new firmware versions (anylog.bin) and notification to the service task for the finalization of the firmware update
- Management of the download of new versions of the configuration file (config.ini) and notification to the service task for the finalization of the configuration update
- Management of command execution file download, command execution, response upload⁸
- System log file upload management

- **SMS Tasks**

The SMS task manages the exchange of SMS messages between NanoSUM and any remote terminal. In particular, NanoSUM can receive commands via SMS or send alarm notifications via SMS. These aspects will be discussed in detail later in the text.

A peculiar aspect of NanoSUM is the possibility of operating in two different modes, according to a compromise between consumption and performance:

- **Active operation**

This is the normal operation mode of the data logger in which the device is at full power even if, thanks to the dynamic management of the internal frequencies, it manages to obtain very low consumption. In this operating mode the module can be pushed to very low acquisition times with the maximum computational power available⁹.

- **Shutdown operation**

It is an operating mode suitable for sporadic acquisitions over time: between one scheduled operation and another, the system completely shuts down the main core and the peripherals connected to it, keeping only the secondary core active. This strategy makes it possible to further reduce consumption. In order for shutdown operation to be used, the shortest scheduled time must be greater than 120 seconds. More details on this operating mode will be given in the dedicated paragraph.

⁸ Refer to paragraph *Transmission, FTP data sending and advanced features*

⁹ NanoSUM could theoretically arrive at an acquisition every second. However, this time is limited by the communication delays on the serial sensor chain, which therefore limits its effective performance.

3.2 Sensors and measures

The primary function of NanoSUM is to acquire measurements from the sensors connected to it in a cadenced and regular manner. The sensors are treated as logical entities made up of measurements: at least one measurement must be associated with each sensor and the same sensor can be made up of several measurements, with some limits which will be explored in the chapter on instrument configuration. Here we will describe the aspects of cadence and synchronization and the various types of sensors that can be acquired.

3.2.1 Measurement intervals in normal operating status

In a normal operating state, or with the alarms disabled, the acquisition, processing, storage and transmission of measurement data takes place at pre-established and configurable intervals. In particular, it will be necessary to define three different intervals:

- **Acquisition interval [s]**

It identifies every how many seconds the operating cycle will acquire the measurements of the various configured sensors and progressively carry out the necessary processing.

- **Recording interval [s]**

It identifies every how many seconds the operating cycle will finalize the processing and store the processed measurements of the various configured sensors.

- **Transmission interval [s]**

Identifies every how many seconds the operating cycle will fetch the new stored data and prepare them for transmission by the independent FTP task.

These three intervals in turn can be global intervals or detailed intervals:

- **Global intervals**

The global intervals are specified with a global parameter on the configuration file and apply, in the absence of detailed intervals, to all the configured sensors. The definition of these intervals is in any case mandatory even in the case of definition of detailed intervals.

- **Detailed intervals**

If necessary, a particular acquisition interval and a particular memorization interval can be configured for each sensor; the transmission rate instead remains global.

This flexibility allows you to create very complex and varied configurations. The fact that the definition of sensor is an abstract entity composed of one or more measures, then allows to make the intervals independent even within the same physical sensor. Let's take for example a combined temperature and humidity sensor for which we want, for example, to measure the temperature every minute and the humidity every 10 minutes. Just configure two logical sensors that refer to the same physical sensor. In the logical temperature sensor, the acquisition time can be detailed to one minute; in the humidity logic sensor, the acquisition time can be detailed to 10 minutes.

An entire paragraph will be dedicated to the operating of NanoSUM as an automatic alarm control unit and to the management of alarms. In the next paragraph instead we will describe how alarm states can alter the intervals.

3.2.2 Measurement intervals in alarm operating status

When alarm management is enabled, the program associates a status to the data logger as a result of comparing the alarm status of the individual sensors: the data logger status is the most severe of all the sensors in alarm. Three different alarm states with increasing severity are possible:

- Warning or yellow alert status
- Pre-alarm or orange alert status
- Alarm or red alert status

If you enable alarm management, global intervals must be defined for each of these states. Indeed, NanoSUM can adjust the intervals according to the type of alarm, for example by making them more frequent in more severe conditions. As for the normal operating state, it is possible to define the detailed intervals in the three altered states of warning, pre-alarm and alarm. In the absence of detailed intervals, the interval change occurs with the global intervals.

3.2.3 Acquirable sensors types

It is possible to connect sensors of the following types to NanoSUM:

- Serial sensors, RS – 485¹⁰, RS – 232¹¹ or RS – 422¹⁰ in MODBUS protocol on COM1 and COM2
- Sensors in SDI – 12 protocol on COM3
- Digital sensors (contacts, frequency signals, pulses, etc.) on the digital input terminals

In addition to these, there are internal diagnostic measures that can be seen in all respects as a single local sensor or as several local sensors, according to the configuration needs.

3.2.3.1 MODBUS sensors

NanoSUM supports the MODBUS standard for reading sensor measurements. The implemented functions are:

- 1: read coils
- 2: read discrete inputs
- 3: read holding registers
- 4: read input registers

¹⁰ In case two or more sensors are connected on the same RS – 485 or RS – 422, it is necessary to pay attention that they have different addresses.

¹¹ Only one sensor per interface is allowed in the RS – 232 connection.

Supported data types are: 16-bit unsigned integer, float, "swapped" float, 32-bit unsigned integer, 32-bit unsigned "swapped" integer, 16-bit signed integer, 32-bit signed integer, 32-bit signed "swapped" integer. The "swapped" data types defined in the standard appear, in the data stream, inverted with respect to the "normal" data.

In particular, indicating the single bytes of a 32bit data with the letters A, B, C and D:

- The float data is represented by the sequence ABCD
- Swapped float data is represented by the sequence CDAB
- The 32bit integer data is represented by the sequence ABCD
- Swapped 32bit integer data is represented by the sequence CDAB

The standard MODBUS functions allow to acquire a certain number of consecutive registers. Therefore, if a physical MODBUS sensor has measurements in non-consecutive registers, it is necessary to define two or more logical sensors, which refer to the same physical sensor, in order to be able to acquire the measurements correctly.

A MODBUS sensor in NanoSUM is characterized by the following parameters:

- Name: any label of up to 32 characters
- MODBUS address: the address of the sensor
- Communication port: choice between COM1 and COM2
- Baud rate: selectable from 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200¹² bps
- Other features: no parity check, 8 data bits and 1 stop bit
- Acquisition function
- Start address
- Number of consecutive registers starting from the starting address
- Response timeout, in milliseconds. There are three communication attempts each with the specified timeout.

Each measurement of a MODBUS sensor is characterized by:

- Numerical identifier
- Name: any label of up to 20 characters
- Register: MODBUS address of the starting register of the measurement data
- Data type of the measure
- Number of decimals for rounding

¹² Only for RS – 232

3.2.3.2 SDI – 12 sensors

NanoSUM supports some acquisition functions of the SDI – 12 standard for reading sensor measurements in this protocol on the dedicated COM3 communication interface. The implemented functions are:

- Measurement execution command: M, M1, ..., M9
- Concurrent measurement execution command: C, C1, ..., C9
- Request data command: D0, ..., D9

Refer to the SDI – 12 standard for the operating details of these commands. Here it is useful to describe how the acquisition of one or more SDI – 12 sensors takes place on COM3. First, however, it must be considered that an SDI – 12 sensor in NanoSUM is characterized by the following parameters:

- Name: any label of up to 32 characters
- SDI – 12 address: the address of the sensor
- Measurement execution command (M, M1, ..., M9, C, C1, ..., C9)
- Response timeout, in milliseconds. There are three communication attempts each with the specified timeout.

Each measurement of an SDI – 12 sensor is characterized by:

- Numerical identifier
- Name: any label of up to 20 characters
- Measurement data request command (D0, ..., D9)
- Data position, starting from position number 1
- Number of rounding decimals

Now lets assume that you have an SDI – 12 sensor connected to COM3 and the data logger is configured with commands M for start measuring and D0 for data request. Assume also that the sensor responds to M indicating that the response will be ready after 3 seconds. The NanoSUM operating flow at the acquisition interval will be:

- M command and response interpretation. Extraction of number of measures and extraction of delay which, in the example, is three seconds.
- Waiting for the delay (three seconds in the example).
- D0 command and recovery of the configured measurements.

Concurrent C commands (C, ..., C9) are treated in the same way as M commands (M, ..., M9). If there was another SDI – 12 sensor configured, necessarily with a different address from the first, this would be acquired only at the end of the first one. The delays of the SDI – 12 sensors are blocking therefore it is necessary to take them into account in the station design.

3.2.3.3 Digital sensors

NanoSUM can acquire up to two sensors with switched contact or square wave digital output for frequency, pulse count and time period measurements.

A digital sensor is characterized by the following parameters:

- Name: any label of up to 32 characters
- Response timeout, in milliseconds. There are three communication attempts each with the specified timeout.

Each measurement of a digital sensor type is characterized by:

- Numerical identifier
- Name: any label of up to 20 characters
- Physical address of the digital channel on the terminal block
- Data type of the measurement which can be:
 - Frequency.
 - Logical state [0, 1].
 - Cumulative count (number of closures of a contact or falling edges of a square wave). The value is a counter that goes from 0 to 2^{32} and resets either upon reaching overflow or after the data logger is powered off.
 - Contact closing timer: count of seconds, between one acquisition and another, in which a contact is closed.
 - Instant contact closing time. It is similar to the previous one: if a contact is closed upon acquisition, it accumulates in the measure a time equal to the current acquisition time.
 - Rain gauge: total rainfall. The instantaneous measurement, the average value, and the maximum all represent the same total accumulated rainfall from the moment the NanoSUM is powered on. The minimum value is the accumulated rainfall from the previous interval. To obtain the accumulated rainfall in mm, the measurement must be scaled using the rain gauge constant through the corrective formula.
 - Rain gauge: rainfall during the storage period. The instantaneous measurement, the average value, and the maximum all represent the same accumulated rainfall during the storage period, i.e., between two consecutive records. To obtain the accumulated rainfall in mm, the measurement must be scaled using the rain gauge constant through the corrective formula.
- Number of rounding decimals

3.2.3.4 Local sensors

NanoSUM provides internal diagnostic measurements that can be configured as local sensors. In particular, a local type sensor is characterized by the following parameters:

- Name: any label of up to 32 characters

- Response timeout, in milliseconds. There are three communication attempts each with the specified timeout.

Each measurement of a local type sensor is characterized by:

- Numerical identifier
- Name: any label of up to 20 characters
- Physical address of the local channel which allows one of the following quantities to be selected:
 - Supply voltage in V
 - Quality level of the received radio signal in dBm (RSSI)
 - Internal temperature in °C
 - Relative humidity of the PCB in %
 - Solar panel voltage in V
- Number of decimals for rounding.

3.2.4 Measures common characteristics

Some configurable characteristics of the measurements are transversal to the type of sensor. In particular, as you will see in detail in the configuration chapter, you can specify:

- A polynomial corrective formula up to the third degree
- An additional offset on the measurement
- A validation on the physical minimum and maximum of the measure
- Processing filters to select the types of processing to be performed on the data collected between one storage and another
- Code letter and detailed identification for processing
- Possibility of specifying a different measure identifier for each type of processing rather than for a single measure
- Definition of detailed intervals of acquisition and storage
- Enabling of alarm management and definition of the thresholds relating to the measures

We will return to these aspects in detail later in the document.

3.3 Acquisitions

The acquisition of the sensor measurements are always sequential: the sensors with the lowest index in the configuration are acquired first. The acquisition deadline is synchronized with the system clock; for example if a sensor must be acquired every minute, the acquisition will start at the 0 second of every minute. If, on the other hand, there is an acquisition every 20 seconds, this will start at seconds 0, 20 and 40 of each minute. An acquisition every 3 minutes will take place at minutes 0, 3, 6, 9, 12, 15 ..., 51, 54, 57 of each hour. Synchronization remains operational even if you configure sensors with different intervals. Each start of acquisition will be properly synchronized.

To make the acquisition process more robust and reliable, triple call repetition is implemented: NanoSUM try to call the sensor up to a maximum of three consecutive times each separated by a configurable timeout.

3.3.1 Power supply sensors management

In all those cases where consumption needs particular attention, it is possible to manage the power supplies to the sensors so that they normally remain off and are activated a certain number of seconds before the acquisition rate. It is a configurable parameter. The switchable power supplies are 12V_{OUT}, BAT_{OUT}, DO1 and DO2. There are therefore four independent lines with which to manage the data acquisition aimed to reach the lowest consumption.

3.4 Processing of the acquired data

The acquired measurements undergo various processing, some instantaneous, aimed at correcting or normalizing the data, others statistical and progressive, in view of storing the statistical values of the data.

3.4.1 Instantaneous measures elaborations

Instantaneous processing are operations on the instantaneous value acquired of a measurement, useful for applying correction curves or measurement offsets. The elaborations are performed sequentially and are:

1. Polynomial correction formula

It is possible to specify a polynomial up to the third degree of the form $y = a \cdot x^3 + b \cdot x^2 + c \cdot x + d$ in which x refers to the current instantaneous data and y is the result of the processing. For example, consider an anemometer with natural frequency output whose manufacturer supplies a correction curve to obtain the measurement in m/s starting from the measured Hz. This curve can and should be specified as a corrective polynomial.

2. Offset

It is possible to specify a correction offset which is added to the result of the previous polynomial correction, if present, or to the instantaneous data in the absence of polynomial correction, which we can summarize in the formula $z = y + o$. Consider, for example, an ultrasonic snow level sensor which, after installation, measures a residual level of 30 cm in the absence of snow. You can use the offset to easily zeroing the measurement.

3. Validation

Finally, it is possible to specify minimum and maximum physical validation limits for each measurement: if this exceeds the limits, it is rejected. The operation follows the application of the polynomial and the offset, if configured. For example, consider a relative humidity sensor; validation limits of e.g. -1% and 101% can be specified to ensure that valid data is always within the physically correct operating range.

All these processes are optional and must be enabled and configured. There may be therefore cases in which none is enabled or perhaps only the offset or only the validation. NanoSUM offers total freedom in this regard. If all the instantaneous processings are configured, it must always be remembered that the polynomial correction will be performed first, to the result of which the offset will be added and, only on this definitive data, will the validation be made.

3.4.2 Statistical elaborations

The statistical elaborations are progressive elaborations which have as input the result of the instantaneous elaborations and as output the progressive statistical averages of such data between one storage and another. Typically, in fact, the interval between the memorizations is usually a multiple of the acquisition intervals so that between each memorization a statistical sample of measurements is created which can be processed to obtain different parameters:

- The average value
- The minimum value
- The maximum value
- The standard deviation
- The minute to which the minimum refers
- The minute to which the maximum refers
- The counter of valid data, i.e. of those data that become part of the statistics

When the instantaneous data are of trigonometric quantities, as happens for example for the wind direction, it is possible to specify that also the statistical elaborations are trigonometric.

When the instantaneous data are of accumulation quantities, as occurs for example in the case of accumulated rainfall, it is possible to specify a particular type of processing in which the average data is replaced by the accumulation data.

When instantaneous data is expected to vary gradually and continuously, it can be specified a statistical filtering processing, which is useful for filtering out any spurious peaks.

3.5 Main data storage and backup

When the storage interval expires, the program finalizes the progressive averages and stores the data in an internal circular archive file. This file is populated until the maximum capacity is reached, after which the new data take the place of the older data in a FIFO type structure. It is possible to memorize:

- The instantaneous value of the last measurement
- The average value of the instantaneous measurement population
- The minimum value of the instantaneous measurement population
- The maximum value of the instantaneous measurement population
- The standard deviation of instantaneous measurements population
- The minute to which the minimum refers
- The minute to which the maximum refers
- The counter of valid data that enters in to averaging process

The file is a set of data records in clear ASCII format called dynamic SIAP+MICROS record layout. The details of the record are given in the appendix. For the moment it is underlined that normally:

- Each processing has the same numerical identifier as the measure to which it refers
- Each elaboration is marked by a unique letter which establishes its type: for example 'A' for the instantaneous, 'B' for the average, 'C' for the minimum, 'D' for the maximum, etc¹³.

To increase flexibility and compatibility with the most various SCADA systems, NanoSUM offers the possibility of:

- Customize the numerical identifier of each processing by unlinking it from the measure identifier
- Personalize the distinctive coding letter

The circular archive file has the name *dataRecord.dat* at the path *mod/Archive* and has a maximum size that can be configured up to 4MB, with a default of 2MB. The minimum size allowed is 100kB.

It is possible to enable a data backup on an external µSD card storage unit. In this case the dynamic SIAP+MICROS record is stored in daily files with name *yyyymmdd.dat* in monthly folders with the name *yyyymm*. In these names *yyyy* is the four-digit year, *mm* the two-digit month, *dd* the two-digit day.

3.6 Transmission, FTP data sending and advanced FTP features

At the transmission interval, the main task prepares the data stored in the archive for transmission. Only the data that has not yet been transmitted, i.e. the data accumulated between the last successful transmission to the FTP server and the current one, are prepared for sending. The preparation process consists in copying the new data into pre-established folders, one for each configured FTP server, so that the FTP task can fetch them concurrently and securely with respect to the operations of the main cycle.

It is possible to configure up to a maximum of 20 different FTP sites for data delivery and it is necessary to configure at least one of them. The operating program uses separate folders for each configured FTP server; these folders have the prefix FTP followed by a progressive identification number of the corresponding server for example FTP0, FTP1 etc¹⁴. Each server maintains independence from the others regarding transmission operations. This strategy allows you to always have updated data on all configured servers and to compensate for any blackouts of some servers without affecting the others. Every minute the FTP task checks all the FTP folders for new data to transfer. If there are data, the task transfers it:

- The task connect to the FTP server.
- The correct presence on the server of the paths necessary for the data and remote management of the data logger is checked¹⁵ and, if not present, all the necessary resources are created¹⁶.
- The file is uploaded to the server with a temporary extension.
- A check is made that the process has actually been successful.

¹³ See appendix for more details

¹⁴ See the paragraph on NanoSUM configuration for more details.

¹⁵ See advanced FTP functionalities.

¹⁶ The account on the server must have read, write and creation rights enabled.

- If the process is successful, the file on the server is renamed with a .DAT extension and the local temporary file inside the FTP<X> folder is deleted.
- If the process fails there will be another transmission attempt at the following minute and the temporary file will remain in the FTP<X> folder which will not be populated with new data until the current ones are transferred.
- Before disconnecting, the server is checked for updates or commands.

Particularly:

- Check for new firmware versions
- Check for a new configuration
- Check for the presence of a command file

The details of these advanced features will be described in the dedicated paragraph.

- The task log out of the server.

Files on the server are normally uploaded in dynamic SIAP+MICROS format. Alternatively, a configuration key allows the data to be loaded into a simplified alternative ASCII layout. Please refer to the appendix for a description of the two formats.

The maximum size of the data file in the sending folders is configurable and has a maximum value of 64kB, which is also the default, and a minimum size of 5kB.

It is possible to enable a data sending watchdog function that monitors the FTP sending functionality over time. If, for some reason, data fails to upload for longer than the user-configured watchdog interval, the entire NanoSUM is physically restarted with a full power off, delay, clean power up procedure.

As mentioned, unless otherwise specified, each configured FTP site is enabled to perform advanced functions such as remote firmware and configuration updates or the execution of commands. However, it is possible to disable support for these features in the configuration.

3.6.1 *FTPS: FTP over TLS / SSL*

It is possible to enable each FTP site to support FTPS (FTP over TLS/SSL) protocol. The FTPS protocol is a special implementation of the FTP protocol in which commands, exchanged on the control port, and data, exchanged on the data port, are protected by encryption suites agreed upon in advance between server and data logger, according to the TLS transport protocol.

NanoSUM supports TLS versions 1.0, 1.1, 1.2 and 1.3 and more than 50 different encryption suites. Selection is fully automatic and transparent to the user. The negotiation of the protocol version and the particular cipher suite to be used is done during the preliminary connection phase in which NanoSUM explicitly requests a secure connection to the server on the control port. Once this phase, called handshaking, is completed, the connection is secured on the control port where commands are exchanged between the data logger and the server. In the case of a data exchange, another handshaking is performed on a data port communicated by the server so that this exchange is also protected.

When configuring the server for FTPS support, special attention should be paid to the fact that NanoSUM does not support some features:

- TLS session resumption is not supported: NanoSUM cannot reuse session data for the data port but needs a new session. Therefore, the server must be configured not to require TLS session resumption.
- Dual authentication is not supported i.e., the server cannot request a certificate from the data logger to authenticate it. The only authentication supported is server authentication.
- Only the explicit FTPS protocol is supported as recommended by the RFC 4217 standard.

3.6.2 *Advanced features: firmware update*

It is possible to update the anylog.bin operating program remotely via FTP. For this purpose it will be necessary to:

- Rename the new firmware binary to **anylog.new**.
- Create an **anylog.md5** control file that contains the MD5 hash code of anylog.new represented with 32 hexadecimal digits.
- Upload the two files **anylog.new** and **anylog.md5** to the remote path of the server **CONFIG/ST0<id>**, where <id> is the NanoSUM identifier.

The FTP task, on each connection, checks the remote CONFIG/ST0<id> path for the binary file anylog.new and its MD5 control file, anylog.md5. If both files are not found, the download process will be aborted. If both files are present, they will be downloaded to the module and a file will also be saved containing the index of the FTP site from which the firmware was taken and the connection parameters for validating the firmware itself. The task deletes the remote anylog.new file but leaves the anylog.md5 file on the server for later checking.

At this point it is the services task that manages the finalization of the update. In particular, having verified the correctness of the control code, it will restart the module for the start of the new firmware. After the restart, an internal check of the functions will be performed including, among other things, also the connection test to the server from which the firmware itself was downloaded for the deletion of the residual remote anylog.md5 file. NanoSUM will attempt the operation every minute for up to 15 minutes.

If all the control operations are successful, the firmware is definitively validated and updated and both uploaded files will have been deleted on the server.

If at least one of the operations fails, NanoSUM rolls back to the previous firmware version to still ensure operation in the event of an error on loading or critical bugs on the new program. This can be seen from the fact that the anylog.md5 file is still present on the server after more than 15 minutes and is not deleted.

The function described can be implemented on any server enabled for advanced features and is very practical for remote management of the data logger.

3.6.3 Advanced features: configuration update

It is possible to update the configuration config.ini of the operating program remotely via FTP. For this purpose it will be necessary:

- Rename the new configuration file to **config.new**.
- Upload the **config.new** file to the remote path of the **CONFIG/ST0<id>** server, where <id> is the NanoSUM identifier.

The FTP task, at each connection, checks the CONFIG/ST0<id> remote path looking for the config.new file. If this is present it will be downloaded to the module and its remote version will be deleted. The module will then restart to complete the configuration update.

Upon restart, internal diagnostic tests are performed to evaluate the new configuration. If even one of these fails, the module rolls back to the old configuration. If successful, the configuration is uploaded as a backup copy to all servers configured in the **config.bck** file.

The function described can be implemented on any server enabled for advanced features and is very practical for remote management of the data logger.

3.6.4 Advanced features: FTP commands

It is possible to send commands remotely to NanoSUM by writing them as single lines of a **commands.txt** file in the remote path of the server **CONFIG/ST0<id>**, where <id> is the NanoSUM identifier. Each line represents a command that will be executed by the data logger and the result of the execution will be written on a **performed.txt** file that will be uploaded to the server. Instead, the commands.txt file will be deleted from the server.

The commands that require a restart of the module are executed only at the end of all the programmed operations on the FTP servers; NanoSUM will then complete the various data uploads before restarting.

The commands are case insensitive and can therefore also be written in lower case. Pay particular attention, however, to respect the separation spaces. Only one space must be placed between the words of a command, as well as between the command and the following parameters.

All FTP commands are also available via SMS as you will see in the next paragraph.

The table on the following page shows the supported commands.

Command	Meaning
!FW	Operating program version request.
GET FW	As previous.
GET BUILD	Operating program build date request.
GET SW	Module software version request.
GET IMEI	Module IMEI request.

Command	Meaning
GET ICCID	SIM ICCID request.
GET MEM	Query the amount of HEAP and RAM memory in use.
GET FS	Returns the list of files and folders of the root directory and the bytes of memory still available.
!TW	Hardware restart with power off. This command is executed after all the others because it requires restarting the module.
RESET	Software reset without power off. This command is executed at the end of all the others because it requires the operating program to be restarted.
REBOOT	As previous.
CLK	Reading system clock.
!IM <n> <start>	Reading of <n> consecutive instantaneous measurements starting from index <start>. The measurements are indexed sequentially: the first one written in the configuration file will have index 1 and the following ones have an incremental index.
STATUS LAST	Reading of all instantaneous data with the date to which the measurements refer.
STATUS DELTAT [<i>]	Reading global acquisition, storage and transmission intervals in the current operating state. If index <i> is present, the intervals of the sensor indexed by <i> are returned. Pay attention to place a space between STATUS and DELTAT and a space between DELTAT and index <i>.
STATUS DELTATN [<i>]	Reading global acquisition, storage and transmission intervals in normal operating status. If index <i> is present, the intervals of the sensor indexed by <i> are returned. Pay attention to place a space between STATUS and DELTATN and a space between DELTATN and index <i>.
STATUS DELTATW [<i>]	Reading global acquisition, storage and transmission intervals in the warning operating state. If index <i> is present, the intervals of the sensor indexed by <i> are returned. Pay attention to put a space between STATUS and DELTATW and a space between DELTATW and index <i>.
STATUS DELTATP [<i>]	Reading global acquisition, storage and transmission intervals in the pre-alarm operating state. If index <i> is present, the intervals of the sensor indexed by <i> are returned. Pay attention to put a space between STATUS and DELTATP and a space between DELTATP and index <i>.
STATUS DELTATA [<i>]	Reading global acquisition, storage and transmission intervals in the alarm operating state. If index <i> is present, the intervals of the sensor indexed by <i> are returned. Pay attention to place a space between STATUS and DELTATA and a space between DELTATA and the index <i>.
GET CONFIG <key>	Reading configuration key. If <key> is omitted the command is discarded.
GET ROWS <n> <start>	Reading <n> configuration keys starting from line number <start>. The first line of the configuration corresponds to index 1. If <start> and <n> are omitted, it returns the total number of lines in the configuration file.

Command	Meaning
SEND CONFIG	Request to send the config.bck configuration backup file to all FTP sites enabled for advanced features.
STATUS ARCHIVE	Archive file occupation request.
DELETE ARCHIVE	Delete the archive file and FTP folders for a clean reboot.
!PR 0 <yyyy> <mm> <dd> <hh> <nn> <ss>	Relocation of FTP uploads. It is a command that allows you to force the upload of archive data that has already been uploaded. You must specify a date with <yyyy> which is the 4-digit year, <mm> the two-digit month, <dd> the two-digit day, <hh> the two-digit hour, <nn> the minute in two digits, <ss> the seconds in two digits. The program will reposition itself to the closest date in the archive.
GET LOG	The operating program stores daily LOG files in case of errors or particular events. The command uploads all the LOG files to the station service folder (CONFIG/ST0<id>) of each server configured and enabled for advanced features.
STATUS LOG	Returns the list of LOG files present in the NanoSUM LOG folder.
DELETE LOG [<name>]	Delete the LOG file named <name>. If <name> is omitted all files are deleted.
DISABLE SHDN [<min>]	Disable shutdown (low power operation) for <min> minutes. $1 \leq \text{mins} \leq 1440$.
NTP SYNCH	Force a synchronization of the system clock with NTP server.
GET DIAG	It reads the diagnostic parameters: battery voltage [V], RSSI radio signal quality [dBm], internal temperature [°C] and humidity [%], solar panel voltage [V] if present.
GET MEAS	Performs all configured measurements. The results of the operation do not enter the averages.
GET BMS	Returns current BMS (battery management system) settings.
RST BMS	Restores the default values of the BMS (battery management system).
GO DIAG	The command restarts the module in diagnostic operating mode for a maximum of four hours or until a command to return to normal mode.
GO NORM	The command restarts the module in normal operating mode.
GET OPER	The command returns the operating mode of the logger. It can be normal or diagnostic.
SMS TO <ce1_num>	The command sends an introductory SMS to the phone number <ce1_num> which must always start with the + of the international prefix. For example SMS TO +390123456789 sends a welcome message to the Italian number (+39) 0123456789..
GET LIST	The command returns the list of supported commands.

An example of commands.txt file could be the following.

```
GET FW
GET BUILD
GET MEM
GET FS
CLK
STATUS LAST
```

An example of answer is the following.

```
*****
GET FW
Firmware version 1.3.1 C1 SW6 - FW STM32 1.2.0
*****

*****
GET BUILD
Built on Jun  3 2025 08:33:26
*****

*****
GET MEM
HEAP memory 304.0 kB of 8243.9 kB - peak 314.7 kB
RAM memory 8848.0 kB of 16984.0 kB
*****

*****
GET FS
.
..
Archive
FTP0
FTP1
FTP2
FTP3
LOG
anylog.bin
appcfg.ini
calib.dat
commands.txt
config.ini
normal.opr
performed.txt
Free size: 3774464

*****

*****
CLK
Time: 2025/05/19 - 09:11:39 - TZ 0 - DST 0

*****

*****
STATUS LAST
ST02 09:11:40 19/05/2025
ID1 Dist RDR (m) = -0.0471
ID2 QoM RDR (dB) = 3
ID3 Tilt RDR (g) = 4.0
ID4 Alim RDR (V) = 13.18
ID5 Temp RDR (gC) = 21.51
ID6 RH RDR (%) = 64.1
ID7 Dist RDR FILT(m) = -0.0471
```

ID15 Alim RDR FILT(V) = 13.18
ID16 Temp RDR FILT(gC) = 21.51
ID17 RH RDR FILT(%) = 64.1
ID10 Alim (V) = 13.2
ID11 Vsolar (V) = 20.6
ID12 RSSI (dBm) = -82.0
ID13 Temp (gC) = 26.5
ID14 RH (%) = 59.0

3.7 SMS commands

All the commands seen in the previous paragraph can also be transmitted via SMS text messages, one command per message. Two commands are added to the previous commands: one allows you to modify, create or delete individual configuration keys, the other to send AT commands to the internal modem.

Command	Meaning
CHANGE CONFIG <key>=[<value>]	Change or delete configuration key. If <value> is omitted, the <key> is deleted, otherwise modified. If <key> does not exist, it is created. The command generates an immediate soft restart. It is important to highlight that: <ul style="list-style-type: none"> • There must be only one space between CHANGE and CONFIG. • There must be only one space between CHANGE CONFIG and <key> • The separator between <key> and <value> must necessarily be the character "=" • The command can be written in uppercase or lowercase however it must be written in full with a single space between CHANGE and CONFIG and a single space between the command and <key>. • <key> is case sensitive so pay particular attention to correctly write the value of the key.
ATCOM [AT command]	It execute the single AT command passed as an argument and return the response.
CHECK FTP	Instantly connect to FTP servers to run advanced features.
GET ARCHIVE	Upload the entire archive file to any FTP server enabled for advanced features.

To make SMS commands more robust and secure, the possibility of configuring an access password of maximum 32 characters has been introduced¹⁷. Default password is "1234". An SMS command is therefore composed by the password, a separating space and the command text itself:

<password><space><command>

For example if the password is "1234" and the command STATUS LAST, the SMS should be written: 1234 STATUS LAST. When the module receives the message, it manages it and replies via SMS to the sender. In case of responses longer than 160 characters, NanoSUM sends all the sequential messages necessary for the delivery of the entire response.

Since network operators are responsible for the delivery of the SMS, neither the sequentiality of the messages, nor the actual delivery times, nor the correct delivery by the network is guaranteed. In other words, internally, the commands are managed from the one that arrives first to the one that arrives last but this order may not coincide with the order in which the messages are sent. Furthermore, it is not guaranteed that an SMS message will arrive or arrive in a certain time interval. Given the unmanageable limitations set out above, the use of FTP commands is strongly recommended, especially in diagnostic mode.

¹⁷ See chapter regarding datalogger configuration.

3.8 System date and time management

The system date and time are fundamental aspects for all NanoSUM functions; in fact, without a valid date and time, a timestamp could not be assigned to the database records, effectively making the acquisitions unusable. For this reason, the data logger is equipped with two clocks with date:

- **Main system RTC**

It is the actual system clock, kept periodically aligned and synchronized. In the event of an invalid date and temporary impossibility to synchronize the time using the cellular network, it uses the emergency clock to realign the time.

- **Secondary emergency RTC**

It is a clock kept constantly aligned with the main clock, equipped with time retention supercap, and performs the function of a backup clock in cases where the main clock has synchronization problems.

The system clock is always set to solar time and automatic change to daylight saving time is disabled. The time zones are managed with a 15-minute resolution with the possibility of setting an offset of up to 48 positive quarters of an hour (+12 hours) and 48 negative quarters of an hour (-12 hours) with respect to UTC time to cover the whole globe. The management of the quarters of an hour allows you to manage some countries that adopt these time lags¹⁸:

- Lord Howe Island (Australia) UTC + 10:30
- Broken Hill (Australia) UTC + 9:30
- Eucla (Australia) UTC + 8:45
- Cocos Islands (Australia), Myanmar UTC + 6:30
- Nepal UTC + 5:45
- India, Sri Lanka UTC + 5:30
- Afghanistan UTC + 4:30
- Iran UTC + 3:30
- Newfoundland (Canada) UTC - 3:30
- Marquesas Islands UTC - 9.30am

A map of world time zones is shown on the following page, which better highlights the advantages of flexible management based on time zones of 15-minute intervals.

¹⁸ Chatam Island (New Zealand) with UTC + 13:45 is excluded

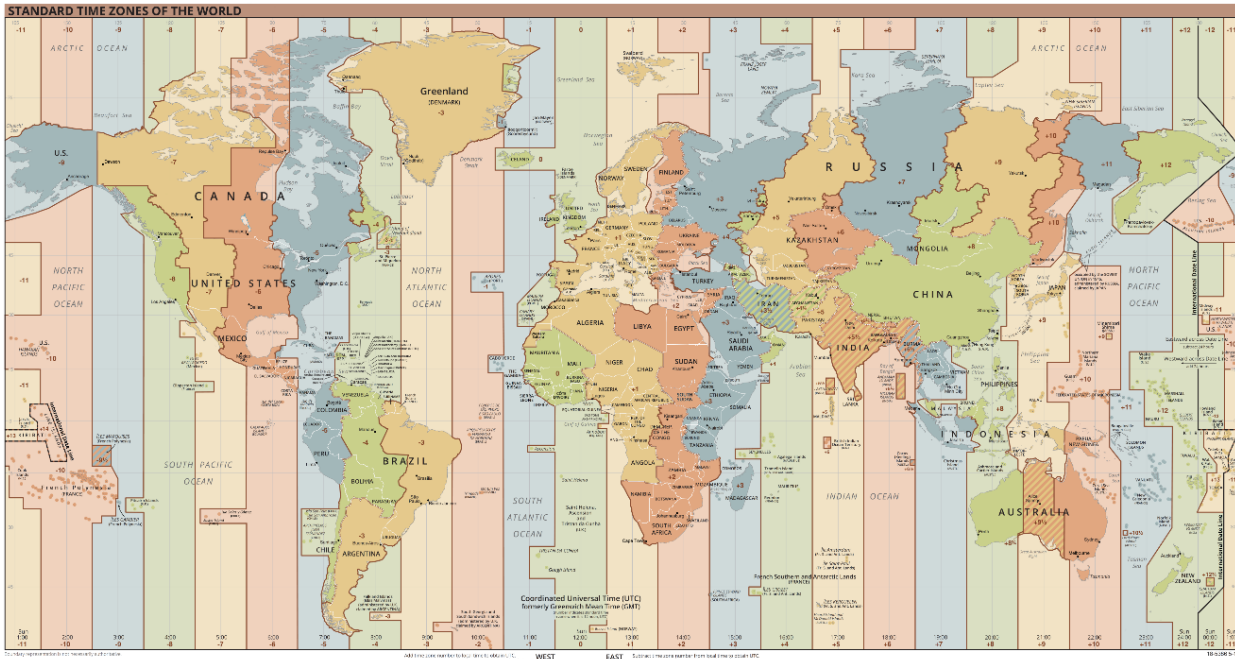


Figure 2: Time zones

The time synchronization strategy develops on three different levels:

1. Synchronization via NTP server

This is the privileged mode for time synchronization: the module connects to an NTP server specified in the configuration. If the server is not present in the configuration, NanoSUM will use the default **0.pool.ntp.org**. On successful synchronization, the time is used to synchronize both the main and emergency clocks. If instead the synchronization fails for some reason (NTP site not available, connection problems, etc.), the synchronization strategy is described in the second point.

2. Synchronization by time of the cell where the modem is registered

When the modem is registered, the cell generally makes the time and date available, which can differ by a few seconds from the exact time, but which is still usable and stable. If the cell time is read successfully, it is used to synchronize both the main clock and the emergency clock. If instead the synchronization fails for some reason (for example modem not registered on the network), the synchronization strategy is described in the third point.

3. Synchronization with emergency clock

NanoSUM uses the backup time of the emergency clock to synchronize the main system clock.

Now let's see some particular cases in which the strategy is declined:

- **First start ever: both clocks have no valid time**

This is the typical case that occurs upon first installation or in any case in the event that the data logger has been disconnected from the power supply for a sufficient period of time to discharge the time retention supercap and cause the main and emergency clocks to lose time. The state is therefore characterized by the absence of valid time on both clocks. In this case, NanoSUM will proceed as follows: attempt to synchronize the time via NTP server or cell, as described above, up to a maximum of 10 times. As soon as the time is recovered, both clocks are synchronized and the operating program

continues normally. If, on the other hand, all 10 attempts fail, the data logger is restarted at low level, i.e. completely switched off and switched on again after about a minute's delay.

- **Continuous operation with valid time on both clocks**

In this case, the system is always on and a periodic NTP synchronization is performed, every 24 hours, to limit the drifts of the main RTC. In particular, NanoSUM proceeds as follows:

- After the first synchronization, a 24-hour timer starts on start-up.
- When the timer expires, it synchronizes to the next useful time exactly halfway between one memorization and another.
- Halfway between one memorization and the next, the main clock is synchronized, exclusively via NTP.
 - If the attempt is successful, the emergency clock is also synchronized and the successful synchronization of the clocks is written in the log file. The next synchronization timer is set to 24 hours.
 - If the attempt fails, nothing is done as the main clock already has a correct time. The synchronization error is written in the log file and the synchronization timer is reset for a next attempt after 4 hours.

- **Starting from operation in shutdown**

As will be seen in a subsequent paragraph, shutdown operation is aimed at maximum energy savings and every detail of operation, including time synchronization, is optimized for this purpose. In this context, it is necessary to anticipate that this operation provides for a complete shutdown of the module which is only switched on again at some deadline such as an acquisition, storage or transmission. The module, then, shuts down and starts up continuously and, since the synchronization with NTP servers is expensive both in terms of time and in terms of energy, the synchronization procedure at startup is modified in this sense:

- On startup the main clock receives the time from the backup clock
- In the event that the backup clock does not have a valid date, an attempt is made to recover the cell time from the cellular network by making up to a maximum of 10 attempts spaced two seconds apart from each other without a connection to an NTP server.
- If the previous procedure fails, an NTP connection will be made for time synchronization; if this should fail, the data logger is restarted at low level, i.e. completely switched off and switched on again after about a minute's delay.

In any case, in the normal operating cycle, after 7 FTP transmissions a synchronization of the time via NTP is made, with updating of both clocks, to precisely realign the dates.

3.9 Alarm management

NanoSUM can be used as an automatic alert station; its operation is based on a four-state alarm threshold system:

- Normal identified by the GREEN color code
- Warning identified by the YELLOW color code
- Pre-alarm identified by the ORANGE color code
- Alarm identified by the RED color code

The color code system adopted reflects the typical color codes of the Italian civil protection system and is fully compatible with this system. The same color codes are found on the proprietary SIAP+MICROS Polaris SCADA.

Any alarm status is actually a general operating status of the data logger regulated by the crossing of configurable thresholds for each individual measurement. It is possible to associate up to a maximum of six different thresholds, three higher and three lower, to each measure for which particular attention is to be paid. These thresholds delimits the operation, with respect to that given measurement, in seven areas:

- Area above upper alarm threshold (alarm, red zone)
- Area between the upper pre-alarm threshold and the upper alarm threshold (pre-alarm, orange zone)
- Area between the upper warning threshold and the upper pre-alarm threshold (warning, yellow area)
- Area between the lower warning threshold and the upper warning threshold (normal, green zone)
- Area between the lower warning threshold and the lower pre-alarm threshold (warning, yellow zone)
- Area between the lower pre-alarm threshold and lower alarm threshold (pre-alarm, orange zone)
- Area below the lower alarm threshold (alarm, red zone)

Just some of these thresholds can be configured for each measure, effectively expanding the operating areas. Measures are individually evaluated and their alarm status is associated with the alarm status of the entire sensor to which the measures belong and contributes to forming the data logger alarm status. If several measures are in different alarm states, the data logger will be in the most serious alarm state.

The transition from an alarm state to a more serious one can only take place if the measure persists above the threshold for a given persistence value that can be configured. The same applies for returning from an alert state to a less serious one to which an hysteresis is added: it is not enough for the measure to be below the threshold for a given persistence, but it must be below the threshold minus a configurable hysteresis value.

It is possible to choose whether the evaluation is made on the instantaneous data or on the average data.

The change of state of one or more measures generates a change of state of the data logger: NanoSUM will assume the operating state of the most severe alarm state among those of all the measures. For example, if one measure is in warning and one in pre-alarm, the data logger status will be that of pre-alarm.

It is possible to configure the data logger to modify its intervals based on the alarm status.

The next figure illustrates the concepts of operating areas, thresholds and return hysteresis and provides an example to illustrate the transition between the various operating conditions.

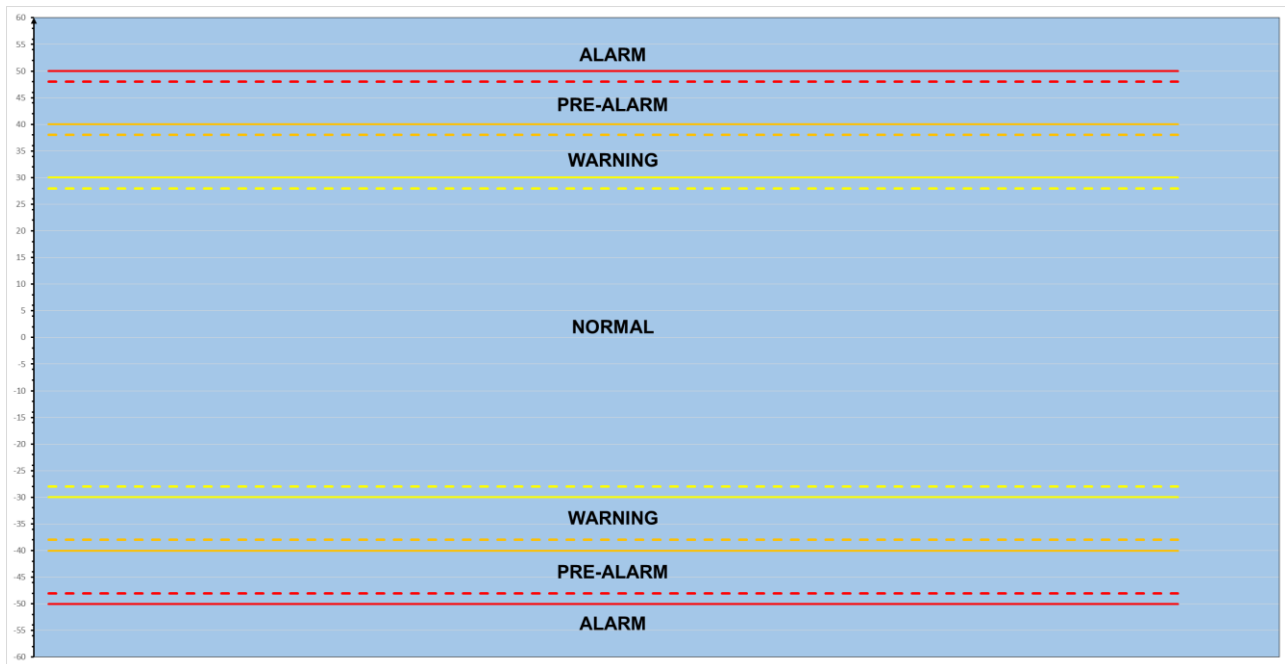


Figure 3: Operating areas

For example, suppose a temperature measurement acquired every 10 seconds. The image shows an example of alarm thresholds with hysteresis of 2°C (dashed lines). Assume also a persistence equal to 6 times on the instantaneous data, i.e. for an equivalent time of $6 * 10$ seconds, 1 minute. The thresholds are defined respectively:

- Upper alarm: 50°C
- Upper pre-alarm: 40°C
- Upper warning: 30°C
- Lower warning: -30°C
- Lower pre-alarm: -40°C
- Lower alarm: -50°C

In the temperature range between -30°C and 30°C it is in the normal operating state.

In normal operating state, if the temperature were to rise to 32°C for 30 seconds and then drop below 30°C, there would be no change in status because persistence would not be satisfied. If, on the other hand, it rise to 32°C for more than a minute, there would be a change of state.

In the same way, suppose you are in pre-alarm at 44°C, to return to the warning condition you need to drop steadily below 38°C, equal to the threshold minus the hysteresis, for a time longer than the persistence.

It is noted that the upper thresholds have a hysteresis which is subtracted from the threshold value and is lower while, the lower thresholds, have a hysteresis which is added to the threshold value and is higher. This is always valid. The hysteresis can also be seen as a threshold change induced by the operating state altered by the alarm: the thresholds, in the event of a state other than normal, become more stringent for the return. The persistence and hysteresis mechanism allows to avoid situations of false alarms or returns in the event that the value of the measure varies between the defined alarm threshold.

Exceeding an alarm threshold or returning to a less serious alarm state, generates well-defined actions aimed to manage the situation:

- Evaluation of the change of state of the measures.

Each measure has an alarm status which therefore indicates the status of the measurement at that given moment, relative to its configured thresholds. At the end of all the instantaneous acquisitions, the status of each given measure is checked and updated. In the presence of a configuration that explicitly indicates control over the average measurement, the status will be evaluated when processing on the average data is closed and the persistence will refer to the memorization time instead of the acquisition time. The measure alarm status will be used for all subsequent operations.

- Evaluation of the change of state of the data logger.

The current state of the data logger is evaluated based on the alarm states of the single measures: the state of the data logger is that of the measure in the most critical alarm state.

- Writing an alarm record, if enabled.

If any measure causes a change in the alarm status, and the writing of an alarm record is enabled in the configuration, a particular record will be generated in the data record which will report the alarm and contain the measures that have changed status, the thresholds exceeded, the current status of the measures. For details of the record, see Appendix A.

- The change of intervals of acquisition and storage of sensors in an alert state according to their configuration.
- Transmission interval change according to the status of the data logger and its configuration.
- Send SMS messages informing the measure alarm status and data logger alarm status to the appropriate recipients.

To reduce the number of SMS and give a general overview of the system status, NanoSUM composes a single message containing:

- a. Overall status of the data logger
- b. Identifier of the measure in alarm with instantaneous value and threshold exceeded for each measure in a state other than normal.

To give an example, suppose a data logger with battery voltage of 12.5V, a temperature of 35°C, with measurement ID equal to 3, which enters a state of warning when the threshold of 30°C is exceeded, a hydrometric level, with measurement ID equal to 4, with a value of 305cm already in pre-alarm with a threshold of 300cm and measurement ID 4. The event of temperature status change generates the writing of the alarm record and the SMS report with the text:

ST0<ID> <logger name> status: PREALARM

ID 3 temperature: WARNING, meas 35, thr 30

ID 4 level: PREALARM, meas 305, thr 300

In addition to what has been seen, as you will see in the chapter on configuration, it is possible to configure:

- Disabling of alarm storage record

By means of a global configuration parameter it is possible to disable the storage of the alarm record. The SMS service remains active. The parameter is at data logger level.

- Associating type of measure to alarms

It is possible to specify whether the quantity on which to check the alarm status is the instantaneous or the average. The parameter refers to a single measure.

- Personalization of SMS delivery

From the configuration, it is possible to disable the sending of alarm messages to certain recipients or to limit the types of alarm that can be reported to some supervisors rather than others.

- Signaling of alarm return on record at start up

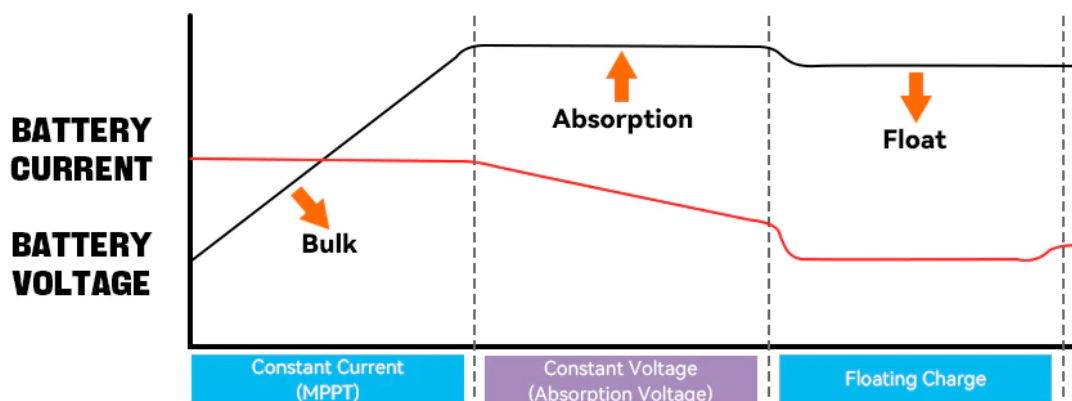
When starting the data logger, if alarm trace storage is enabled and the measures are in the normal state, it is possible to enable the writing of a record signaling the normality of all the measures.

3.10 BMS: battery management system

NanoSUM has an internal battery management system whose purpose is to maximize the useful life of lead-acid batteries, minimizing the degradation of the overall capacity that would occur in deep discharge situations. The battery monitor, which is normally always enabled, takes care of completely cutting off power to the main core and to the connected peripherals and sensors, when the battery voltage drops below 10.5V and restores it when it rises above 11.5V unless otherwise indicated in configuration.

It is possible to disable the battery monitor using a special configuration key. This is necessary when primary lithium batteries, which must be brought to a complete discharge, are used.

However, the NanoSUM's BMS also offers the possibility of customizing the battery protection thresholds and the parameters that define the charging curve thus giving the possibility, if deemed appropriate, to adapt the charging algorithm to the data sheet of the battery used. As mentioned, the NanoSUM is equipped with a 3-stage battery charger.



The configurable parameters are:

- Absorption voltage (absorption phase), default 14.4V at 25°C. The value should be between 12.5V and 16.5V.
- Float voltage, default 13.2V at 25°C. The value should be between 12.5V and 16.5V and in any case lower than the absorption voltage.
- Low voltage disconnect (LVD), which is the voltage at which the load is disconnected to preserve the battery from deep discharge. Default of 10.5V with return hysteresis of 1V¹⁹. The value should be between 10.0V and 12.5V.
- Chemistry type between lead acid and lithium iron phosphate (LiFePO₄) batteries. The type of chemistry chosen is reflected in the temperature correction of the charging curve. Temperature correction of the charging curve is always present for lead acid batteries while it is disabled for LiFePO₄ batteries. The default value is set to lead – acid batteries.
- Minimum operating temperature: the temperature below which the battery charger is disabled. This temperature threshold is disabled by default. The value should be between -60°C and 80°C.
- Maximum operating temperature: the temperature above which the battery charger is disabled. This temperature threshold is disabled by default. The value should be between -60°C and 80°C and above the minimum operating temperature.

3.11 Watchdog

NanoSUM has two system watchdogs that controls its operation:

- Watchdog on the data logger operating cycle

This watchdog is used to check the correct operation of the main cycle of the operating program. Based on the configured intervals, a convenient timeout is automatically set which must be reset by the operating program before it expires. If this does not happen, due to some program block for example, the second core, which operates at a lower level, completely shuts down the main core and restarts it. In turn, the lower level core is controlled by an independent hardware watchdog. The main control system cannot be disabled.

- Watchdog that checks the correct delivery of data to FTP servers

This watchdog takes care of monitoring the correct upload of data files to the FTP servers configured. If, for some reason, data fails to be delivered for an interval that exceeds the time configured for the watchdog, NanoSUM is restarted. This type of control can be disabled by a dedicated configuration key.

¹⁹ The voltage must exceed $10.5V + 1V = 11.5V$ for the datalogger to be reactivated.

3.12 Operation in low power consumption: shutdown

In order to minimize current consumption, in case of sporadic acquisitions or in any case with long time intervals, NanoSUM can be placed in a particular operating mode which will be indicated with **shutdown**.

When this mode is enabled, between one interval and the next, the entire main core is shut down, the power supply is removed from core as well as from the main peripherals. The power supplies to the sensors are also powered off, except for those configured to remain active even during shutdown²⁰. The only parts that remain powered and fully operational are the power management system and the secondary core, which will also take care of powering up the main core, sensors and peripherals in view of a scheduled deadline.

Shutdown operation can be enabled provided that the minimum interval is greater than two minutes. The average current absorbed by the data logger decreases with the increases of time between intervals towards an asymptotic value which is the residual power supply of the supervision and control parts that we have highlighted.

In the shutdown operating mode, all the module functions remain operational, the only difference from normal operation being the different synchronization strategy, already discussed in the relative paragraph, aimed at further minimizing consumption²¹.

3.13 Diagnostics mode

The diagnostic mode is a particular temporary operating mode of the data logger which enables a series of aspects that make it easier:

- Understand if the data logger started correctly.
- Check that the sensor connections are good.
- Verify that the sensors are working properly.
- Check the quality of the radio signal and the operating diagnostic parameters even if not explicitly configured.
- Check quickly that data are correctly stored.
- Verify that the archive files are correctly delivered to the various configured FTP sites.

This mode is particularly useful both in the initial installation phase and in the maintenance phase of a field control unit. Indeed, NanoSUM does not have a display and could sometimes be configured with very high acquisition, storage and transmission times which would make it difficult to verify correct operation in the field. These aspects become even more critical in case of operation in shutdown as the module power on time is reduced to the minimum necessary to save energy.

²⁰ Useful function for sensors that must always be power for their correct operation.

²¹ See the technical specifications for details on consumption in some particular cases.

The diagnostic mode tries to overcome these limitations and exploit the potentials that the module makes available for dialogue with the operator and the verification of correct operation. In particular, the verification can be done both through FTP commands and through SMS commands.

In diagnostic mode NanoSUM reads all parameters of the loaded configuration but:

- **Ignores shutdown mode and keeps the module powered on all the time**

Keeping the module always on allows a more reliable verification through SMS commands or direct connection of the module to the USB for direct operations on the file system²² if it should become necessary. For testing are very useful these FTP commands:

- **STATUS LAST** to read the last instantaneous data acquired
- **GET DIAG** for measuring and reading diagnostic data
- **GET MEAS** for measuring and reading sensor data
- **GET LOG** for uploading LOG files to FTP servers enabled for advanced functions

- **Enable continuous diagnostic log on USB**

This aspect allows for in-depth diagnostics of the control unit.

- **Performs a time synchronization via NTP server on startup**

Time synchronization allows both to verify the connection and to have a correct start date. Synchronization can be forced at any time with the **NTP SYNCH** command.

- **Sensors are acquired every 30 seconds regardless of what has been configured.**

The acquisitions are dense to quickly check the connections and the response of the sensors and configure any additional parameters such as, for example, any offsets.

- **Measurements are stored every 60 seconds regardless of what has been configured.**

The memorizations can be verified in a short time allowing to check and correct any errors, for example on the identifiers of the measures.

- **Transmission occurs every 60 seconds regardless of what has been configured**

The very frequent data upload to FTP servers allows on one hand to verify the correct connection and upload of data to the configured servers and, on the other hand, makes it possible to operate quickly with FTP commands instead of SMS commands.

- **Supplies with pre-ignition times longer than 20 seconds are always on**

- **Alarm management is disabled**

In diagnostic mode, all checks can be performed directly by the technician in the field with the use of a smartphone that can send text messages and connect to the internet. With SMS you can send commands to the data logger, which is always on, and with FTP client applications you can access the configured servers directly from the phone and also take advantage of the FTP commands.

²² For more details, refers to appendix B.

The use of the FTP commands is preferred and recommended essentially because the timing and the correct delivery of the SMS messages depends on the network operator of the SIMs involved and are not guaranteed. With the diagnostic mode, instead, the FTP commands are processed every minute on the enabled servers. Another advantage of FTP commands is the possibility of processing several commands at a time, obtaining a general picture of the situation very quickly. It is also an essential operating mode both for any changes to the configuration file and for updating the operating program.

The diagnostic mode is the first boot mode of each NanoSUM. However, the mode can be enabled at any time in various alternative ways:

- By FTP **GO DIAG** command on any of the command-enabled FTP servers.
- Via SMS command **GO DIAG**. If the module is in shutdown, send the SMS and turn on the module with the REBOOT button.
- By holding down the REBOOT button as explained in paragraph 1.6.
- Deleting the **normal.opr** file from the internal memory (module root folder)²².

Similarly, the exit from the diagnostic mode and the return to the normal operating mode can be implemented in various alternative ways:

- By FTP **GO NORM** command on any of the command-enabled FTP servers.
- Via SMS command **GO NORM**.
- Due to timeout: four hours after starting up in diagnostic mode, the module automatically returns to normal operating mode.
- Writing the **normal.opr** file in the internal memory (module root folder)²². The file must contain the word "NORMAL".

4. Configuration

The NanoSUM configuration is contained in a text file named **config.ini** stored in the root folder of the internal file system. It is an ASCII file organized in lines terminated by <CR><LF>, each line has a key-value structure:

<Key>=<Value>, <Value>, <Value>... <CR><LF>

The key uniquely identifies the parameter and the values that follow depends on it. The values are separated from each other by the character ',' while, between the key and the series of values, it is necessary to use the character '='.

Some parameters are general to the station, others are specific to the sensors and we will describe them in detail in the next paragraphs. Note that although the order of the keys in the file is not important, to have a readable configuration it is advisable to sort it into sections:

- General parameters
- Sensors and measurements
- FTP data delivery server
- SMS recipients

The '#' character at the beginning of a line identifies that line as a comment. It is always advisable to have an initial comment line or lines identifying the configuration and any changes. The maximum line length is **160** characters including <CR><LF>. The maximum number of lines that can compose the file is **2048**.

Since version 1.1.1 of the operating program, the ability to be able to configure the device via DAK configuration software version 3.6.0 has been introduced. The DAK is a proprietary SIAP+MICROS software for configuration of its data loggers and currently supports configuration for DA18K, DA22K, NanoSUM, MicroSUM, MegaSUM. The software has a very intuitive tree structure divided into sections that allows for entry of initial notes, general station parameters, sensor-by-sensor acquisitions, FTP transmissions, and SMS alarm transmissions. Its structure mirrors the setting of the textual configuration file, and for this reason, the manual writing of the configuration file will be described in detail in the following while we refer to the DAK manual, and the DAK itself, for the details of configuration through the software. An important note to keep in mind is that, in order to make the configurations DAK compatible, the following line should be inserted in the config.ini file immediately after the initial comment, if any, and before the list of configuration keys:

[CONFIG]

This indicates the actual beginning of the configuration parameters that the operating program will use for its operation. An example of manually writing a configuration will be given later in the manual.

Some configuration keys are necessary for NanoSUM to work correctly and cannot be omitted, while other keys can be omitted and are loaded with default values. For example, it is always necessary to specify at least one valid FTP server with the FTP0 key since there must always be at least one server on which to deliver data. In the same way, an APN must always be specified for correct connection to the network.

In the following paragraphs, all the configuration parameters will be described, dividing the discussion into general parameters and sensor parameters.

When writing the configuration file, the allowed characters are:

@	Δ	SP	0	i	P	¿	p
£	_	!	1	A	Q	a	q
\$	Φ	"	2	B	R	b	r
¥	Γ	#	3	C	S	c	s
è	Λ	π	4	D	T	d	t
é	Ω	%	5	E	U	e	u
ù	Π	&	6	F	V	f	v
ì	Ψ	'	7	G	W	g	w
ò	Σ	(8	H	X	h	x
Ç	Θ)	9	I	Y	i	y
LF	≡	*	:	J	Z	j	z
Ø	ESC	+	;	K	Ä	k	ä
ø	Æ	,	<	L	Ö	l	ö
CR	æ	-	=	M	Ñ	m	ñ
Á	ß	.	>	N	Ü	n	ü
á	É	/	?	O	Ş	o	à

4.1 General parameters

The following table lists the general parameters of each station, which will be described in detail.

Parameter	Mandatory	Default
SITE=<spID>,<name>	YES	9999,Test station
APN=<name>	YES	---
IPV=<IPversion>	NO	IPV4
NTP=<ntp_server>,<offset>	NO	0.pool.ntp.org,0
EXTRA=<atcommand>	NO	No commands
PASSWORD=<password>	NO	1234
VERBOSE=<n>	NO	2
ENABLE_SHUTDOWN=<mask>	NO	0
MAX_DISK=<kmax>	NO	2048
MAX_FTP=<kmax>	NO	64
BACKUP_EN=<en>	NO	0
LI_BATT=<en>	NO	0
CUSTOM_BMS=<en>,<Vabs>,<Vfloat>,<LVD>,<chem>,<LTD>,<HTD>	NO	0
STEP_NORMAL=<dt_acq>,<dt_mem>,<dt_ftp>	YES	600,3600,14400
STEP_WARNING=<dt_acq>,<dt_mem>,<dt_ftp>	YES	600,3600,14400
STEP_PREALARM=<dt_acq>,<dt_mem>,<dt_ftp>	YES	600,3600,14400
STEP_ALARM=<dt_acq>,<dt_mem>,<dt_ftp>	YES	600,3600,14400
ALA_REC_EN=<recEn>,<type>	NO	1,0
ALA_CTIME_EN=<en>	NO	0
BOOST_ON_TIME=<seconds>	NO	0
BAT_ON_TIME=<seconds>	NO	0
OD1_ON_TIME=<seconds>	NO	0

Parameter	Mandatory	Default
OD2_ON_TIME=<seconds>	NO	0
WDFTP=<minWD>	NO	1440
FTPx=<ipDest>,<user>,<path>,<disableExtra>	YES at least FTP0	---
FTPxPSW=<passwd>	YES at least FTP0	---
FTPxREC=<rec_type>	NO	S+M dynamic
FTPxTLS=<en_tls>,<ftp_verbose>	NO	0,0
SMSy=<number>,<flag>	NO	No SMS

The **x** indicator can be a number between 0 and 19 for FTP keys as up to 20 FTP sites are allowed. The **y** indicator can be a number between 0 and 31 for SMS keys as up to 32 SMS recipients are allowed for alarms.

There are some parameters that absolutely must be present and are mandatory in a configuration. The lack of even just one of these parameters causes the loading of the configuration to fail; it will be written a LOG file containing the error and the module will be restarted. The error of one of these parameters is therefore critical. Therefore, particular attention must be paid to the definition of the configuration.

Below is a description of the keys.

SITE: description of the station

SITE=<spID>,<site_name>	
<spID>	Station identification number (31 bit integer number, default 9999).
<site_name>	Location or product name (default Test station) up to 32 characters.

APN: access point name for the connection

APN=<name>	
<name>	Name of the ACCESS POINT (example internet.it). Maximum 32 characters.

IPV: selection of the IP protocol

IPV=<IPversion>	
<IPversion>	IP protocol type. 0 for IPV4, 1 for IPV6, 2 for IPV4V6. Defaults: 0.

NTP: configuration of parameters for time synchronization

NTP=<ntp_server>,<offset>	
<ntp_server>	NTP server name (example: 0.pool.ntp.org).
<offset>	Offset with respect to Greenwich Mean Time in quarters of an hour: 1 = +0.25h; 4 = +1h; -4 = -1h.

EXTRA: series of AT commands at module startup

EXTRA=<at_command>	
<at_command>	Semicolon-separated string of AT commands

With this key it is possible to enter one or more AT commands separated by “;” which are executed when the module is started. On the EXTRA line it is possible to insert commands up to a maximum of 100 characters. For example: EXTRA=AT;ATE0;AT&W;

PASSWORD: password for managing SMS commands

PASSWORD=<password>	
<password>	Alphanumeric password to be used for authentication of SMS sent to NanoSUM. Maximum length of 32 characters. Defaults 1234.

VERBOSE: enable verbose log on USB

VERBOSE=<n>	
<n>	USB log enable 0 = disabled 1 = only errors 2 = errors and detailed information on operating cycle (default) 3 = errors, detailed information on operating cycle and advanced debug

ENABLE_SHUTDOWN: enable energy saving

ENABLE_SHUTDOWN=<pwmode>	
< pwmode>	Enabling energy saving management with bit mask.

This key allows NanoSUM to switch off between one interval and another. This only occurs for idle intervals greater than 2 minutes. The <pwmode> bitmask allows you to select several options:

- 0: always on (default), shutdown disabled
- 1: shutdown with automatic programmed restart
- 2: BAT_{OUT} holding flag; NanoSUM turns off but BAT_{OUT} is kept active
- 4: 12V_{OUT} holding flag; NanoSUM turns off but 12V_{OUT} is kept on
- 8: OD1 holding flag; NanoSUM turns off but OD1 is kept on
- 16: OD2 hold flag; NanoSUM turns off but OD2 is kept on

The individual bits adds up to give different combinations, for example:

- <pwmode> = 3 indicates shutdown is enabled but BAT_{OUT} power from the battery (1 + 2) must be kept active.
- <pwmode> = 13 indicates that shutdown is enabled but the 12V_{OUT} power supply and the digital output OD1 (1 + 4 + 8) must be kept active.

MAX_DISK: maximum size of the internal data memory

MAX_DISK=<kmax>	
<kmax>	Maximum archive file size in KB (default=2048, max=4096).

MAX_FTP: maximum FTP upload file size for single site

MAX_FTP=<kmax>	
<kmax>	Maximum size in KB of the temporary delivery file (default=64, max=64).

BACKUP_EN: enable backup storage on µSD card

BACKUP_EN=<en>	
<en>	If <en>=1 it enables data backup on SD card (default 0).

LI_BATT: disabling battery control algorithm

LI_BATT=<en>	
<en>	If <en>=1 it informs the data logger that there is a lithium battery on the LiON connector as power source and the battery monitor is disabled. The calibration offset is also used to correct the battery voltage measurement.

CUSTOM_BMS: customization of battery management parameters

CUSTOM_BMS=<en>,<Vabs>,<Vfloat>,<LVD>,<chem>,<LTD>,<HTD>	
<en>	<en>=1 enables the customization of battery management parameters
<Vabs>	Absorption voltage. One decimal; * to disable the field, default 14.4. Limits $12.5 \leq Vabs \leq 16.5$.
<Vfloat>	Float voltage. One decimal; * to disable the field, default 13.2. Limits $12.5 \leq Vfloat \leq 16.5$.
<LVD>	Voltage at which to turn off the data logger to protect the battery from over-discharge. The turn-on hysteresis is 1V. One decimal; * to disable the field, default 10.5. Limits $10.0 \leq LVD \leq 12.5$.
<chem>	<chem>=0 for lead acid batteries, <chem>=1 for LiFePO4 batteries. (* to disable the field, default 0)
<LTD>	Low temperature at which charging is stopped to preserve the battery. One decimal; * to disable the field. Disabled by default. Limits $-60.0 \leq LTD \leq 80.0$.
<HTD>	High temperature at which charging is stopped to preserve the battery. One decimal; * to disable the field. Disabled by default. Limiti $-60.0 \leq HTD \leq 80.0$.

STEP_NORMAL: definition of global intervals in normal state

STEP_NORMAL=<dt_acq>,<dt_mem>,<dt ftp>	
<dt_acq>	Acquisition rate, in seconds, in NORMAL (GREEN) state.
<dt_mem>	Storage rate, in seconds, in NORMAL (GREEN) state.
<dt ftp>	Transmission rate, in seconds, in NORMAL (GREEN) state.

STEP_WARNING: definition of global intervals in warning state

STEP_WARNING=<dt_acq>,<dt_mem>,<dt ftp>	
<dt_acq>	Acquisition rate, in seconds, in WARNING (YELLOW) state.
<dt_mem>	Storage rate, in seconds, in WARNING (YELLOW) state.
<dt ftp>	Transmission rate, in seconds, in WARNING (YELLOW) state.

STEP_PREALARM: definition of global intervals in pre-alarm state

STEP_PREALARM=<dt_acq>,<dt_mem>,<dt ftp>	
<dt_acq>	Acquisition rate, in seconds, in PREALARM (ORANGE) state.
<dt_mem>	Recording frequency, in seconds, in PREALARM (ORANGE) state.
<dt ftp>	Transmission rate, in seconds, in PREALARM (ORANGE) state.

STEP_ALARM: definition of global intervals in alarm state

STEP_ALARM=<dt_acq>,<dt_mem>,<dt ftp>	
<dt_acq>	Acquisition rate, in seconds, in ALARM (RED) state.
<dt_mem>	Recording rate, in seconds, in ALARM (RED) state.
<dt ftp>	Transmission rate, in seconds, in ALARM (RED) state.

ALA_REC_EN: alarm record configuration

ALA_REC_EN=<recEn>,<type>	
<recEn>	recEn = 0 disables storage of the alarm record.
<type>	<type> indicates the type of alarm record: 0 record with 3 thresholds, otherwise with 2 thresholds

ALA_CTIME_EN: enabling interval change on alarm

ALA_CTIME_EN=<en>	
<en>	Enabling interval change on alarm: en=0 disable (default), en=1 enable.

BOOST_ON_TIME: 12V_{OUT} power supply configuration

BOOST_ON_TIME=<seconds>	
<seconds>	Pre-ignition time in seconds, with respect to acquisition, of the 12V _{OUT} power supply: 0=off, 1=always on, >1=pre-ignition seconds.

BAT_ON_TIME: BAT_{OUT} power supply configuration

BAT_ON_TIME=<seconds>	
<seconds>	Time in seconds of pre-ignition, with respect to acquisition, of the BAT _{OUT} power supply: 0=off, 1=always on, >1=seconds of pre-ignition.

OD1_ON_TIME: OD1 power supply configuration

OD1_ON_TIME=<seconds>	
<seconds>	Pre-ignition time in seconds, with respect to acquisition, of the OD1 digital output: 0=off, 1=always on, >1=pre-ignition seconds.

OD2_ON_TIME OD2 power supply configuration

OD2_ON_TIME=<seconds>	
<seconds>	Pre-ignition time in seconds, with respect to acquisition, of digital output OD2: 0=off, 1=always on, >1=pre-ignition seconds.

WDFTP: FTP watchdog configuration

WDFTP=<minWD>	
<minWD>	Timeout minutes of the watchdog that controls the FTP upload. 10 <= minWD <= 2880. To disable, set to 0. Default is 10 minutes.

FTP_x: FTP_x server configuration parameters

FTP_x=<ipDest>,<user>,<path>,<disableExtra>	
<ipDest>	IP address of the FTP server with index x with $0 \leq x \leq 19$. 64 character maximum length. It can be in the form <IP address>:<port> or <URL>:<port>. The port can be omitted if the server uses the port 21.
<user>	Username of the FTP server of index x with $0 \leq x \leq 19$. 32 character maximum length.
<path>	FTP data upload path. If you want to save in the root folder, set to "/". 64 character maximum length.
<disableExtra>	Flag which set to 1 disables the advanced features of firmware, update, configuration and remote commands. If absent or other than 1, the FTP site is enabled for advanced management operations.

FTP_xPSW: password for authentication on the FTP_x server

FTP_xPSW=<passwd>	
<passwd>	Password for the FTP server of index x with $0 \leq x \leq 19$.

FTP_xREC: Enabling simplified ASCII record on the FTP_x server

FTP_xREC=<rec_type>	
<rec_type>	<rec_type>=ASCII for simplified ASCII record, <rec_type>=MICROS for dynamic SIAP+MICROS record. Record type for the FTP server of index x with $0 \leq x \leq 19$.

FTPxTLS: FTPS enabling or disabling and log level of FTPx server

FTPxTLS= <en_tls>,<ftp_verbose>	
< en_tls >	< en_tls >=0 FTP protocol. < en_tls >=1 FTPS protocol.
<ftp_verbose>	USB log enable for each FTP server 0 = disabled 1 = only errors 2 = errors and detailed information on operating cycle (default) 3 = errors, detailed information on operating cycle and advanced debug

It is important to remember that FTP sites must necessarily be defined with progressive numbers starting from 0. It is not possible to put random numbers but the continuity of the indexes must be ensured. There must always be at least FTPO.

Each FTP server can have a different log level based on how much detail the operator needs to analyze. These log levels, set in the FTPxTLS key, are independent of the operating program log level, set with the VERBOSE key, and add up to it.

In order to use the FTPS protocol, special care must be taken to configure the server so that it supports FTPS but does not require TLS session resumption nor client authentication. Only explicit FTPS is supported as recommended by the RFC 4217 standard.

SMSy: definition of the recipients of the SMS alarms

SMSy=<number>,<flag>	
<number>	Telephone number of an SMS recipient for receiving alarms. The number must necessarily begin with the "+" character followed by the two digits of the international prefix. For example, for Italy, +391234567890.
<flag>	Alarm reception filter: 0: No alarms are delivered to the current recipient 1: All alarms are delivered to the current recipient 2: only the pre-alarms and alarms are delivered but not the warnings 3 or higher: only the alarms are delivered but not the warnings and pre-alarms

In this key, the index y assumes values between 0 and 31.

4.2 Sensors parameters configurations

The configuration of each logical sensor consists of a first key that identifies its general parameters, followed by the keys that describe its measurements. Each logical sensor can be associated with several logical measures, each with its own configuration parameters, corrective formula, type of storage and alarm data. Two or more logical sensors can then refer to the same physical sensor. The sensor configuration keys are summarized in the table below.

Parameter	Mandatory
SENSxCFG=<type>, <name>,...	YES
SENSxNIC=<nac>	NO
SENSxDTN=<dt_acq>, <dt_mem>	NO
SENSxDTW=<dt_acq>, <dt_mem>	NO
SENSxDTP=<dt_acq>, <dt_mem>	NO
SENSxDTA=<dt_acq>, <dt_mem>	NO
SENSxMEASyCFG=<memID>, <name>...	YES
SENSxMEASyFRM=<multiply_3>, <multiply_2>, <multiply_1>, < multiply_0>	NO
SENSxMEASyOFF=<Offset>	NO
SENSxMEASyELA=[<Elabo>], [<memo>], [<minValid>], [<maxValid>]	NO
SENSxMEASyCOD=<last>, <avg>, <min>, <max>, <dev>, <minMin>, <minMax>	NO
SENSxMEASyIDM=<last>, <avg>, <min>, <max>, <dev>, <minMin>, <minMax>	NO
SENSxMEASyALL=<Hyst>, <pers>, <type>, <valWSup>, <valWInf>, <valPSup>, <valPInf>, <valASup>, <valAInf>	NO

In the table, x is a progressive number that uniquely identifies the logical sensor and can assume values between 0 and 49 for a maximum of 50 logical sensors. In the same way y is a progressive number which uniquely identifies the measurement inside sensor x and can assume values between 0 and 19 for a maximum of 20 measures per sensor. It is important to remember that the sensors and measurements must necessarily be defined with progressive numbers starting from 0. It is not possible to put random numbers but the continuity of the indexes must be ensured. There should always be a SENS0CFG key followed by SENS0MEAS0CFG.

As seen in the sensors paragraph, the types of sensors allowed are: MODBUS, SDI – 12, digital sensors and local diagnostic data. For each type we will explain the configuration parameters. In the following, we will show the basic (mandatory) configuration parameters of sensors and measures and then, in a single paragraph, the additional (optional) parameters of the measures such as corrective formulas, offsets, processing, alarms, etc.

4.2.1 MODBUS sensors

SENSxCFG=MODBUS,<name>,<idx>,<com>,<bps>,<ctrl>,<fn>,<start>,<nreg>,<timeout>	
<name>	Sensor name, up to 32 characters.
<idx>	MODBUS address.
<com>	Communication port: 1 COM1 (default), 2 (COM2).
<bps>	Port Speed: 0=1200, 1=2400, 2=4800, 3=9600, 4=19200, 5=38400, 6=57600, 7=115200 (only COM2 or COM1 only on RS – 232).
<ctrl>	<p>8N1. At present the configuration is fixed at 8 data bits, 1 stop bit and no parity. The field is ignored. In the future it could indicate the characteristics of the port expressed in the form klm where</p> <p>k are the data bits: 5, 6, 7 or 8</p> <p>l is parity: N=none, E=even, O=odd, S=space</p> <p>m the stop bits: 1=1, 2=2, 3=1.5, 4=0.5.</p>
<fn>	MODBUS function code: 1 = Read Coils, 2 = Read Discrete Inputs, 3 = Read Multiple Holding Registers 4 = Read Input Registers
<start>	Starting address of registers to read (minimum allowed 1).
<nreg>	Number of consecutive registers to read.
<timeout>	Response timeout in milliseconds.

SENSxMEASyCFG=<memID>,<name>,<idx>,<dataType>,<ndec>	
<memID>	Measure storage numerical identifier.
<name>	Measure name, up to 20 characters.
<idx>	MODBUS address of the data.
<dataType>	Data type: 1=16 bit unsigned int, 2=float, 3=swapped float, 4=32 bit unsigned int, 5=32 bit swapped unsigned int, 6=16 bit unsigned int, 7=32 bit unsigned int, 8=32 bit swapped unsigned int.
<ndec>	Number of decimals for rounding

4.2.2 SD-I12 sensors

SENSxCFG=SDI12,<name>,<idx>,<EXEcom>,<timeout>	
<name>	Sensor name, up to 32 characters.
<idx>	SDI – 12 address.
< EXEcom >	Measurement execution command: M, M1, ..., M9 or C, C1, ..., C9 .
<timeout>	Response timeout in milliseconds.

SENSxMEASyCFG=<memID>,<name>,<RQScm>,<idx>,<ndec>	
<memID>	Measure storage numerical identifier.
<name>	Measure name, up to 20 characters.
<RQScm>	Request command: D0, ..., D9 .
<idx>	Data position starting from 1.
<ndec>	Number of decimals for rounding.

4.2.3 Digital sensors

SENSxCFG=DIGITAL,<name>,<timeout>	
<name>	Sensor name, up to 32 characters.
<timeout>	Response timeout in milliseconds.

SENSxMEASyCFG=<memID>,<name>,<idx>,<dataType>,<ndec>	
<memID>	Measure storage numerical identifier.
<name>	Measure name, up to 20 characters.
<idx>	Digital channel address 1=channel DI1, 2=channel DI2.
<dataType>	Type of digital measurement: 1 = frequency in Hz (resolution 0.1 Hz) 2 = logic state [0, 1] 3 = count (number of closures of a contact). In the record, instead of the average, you will have the accumulated value. 4 = logic status timer (checks for how many seconds between one acquisition and another a contact is closed, i.e. the status is at 1)

	<p>5 = if upon acquisition the logic status of the digital input is at 1, i.e. the contact is closed, accumulates in the measure a time equal to the current acquisition time.</p> <p>6 = rain gauge with total cumulated rainfall. The measurement is the total accumulation of rainfall (infinite counter). The rainfall constant must be defined in the configuration as a gain factor.</p> <p>7 = rain gauge with cumulated rainfall in the storage period. The measurement is the accumulation of rainfall in the period between two consecutive records. The rainfall constant must be defined in the configuration as a gain factor.</p>
<ndec>	Number of decimals for rounding.

4.2.4 Local diagnostic sensors

SENSxCFG=LOCAL,<name>,<timeout>	
<name>	Sensor name, up to 32 characters.
<timeout>	Response timeout in milliseconds.

SENSxMEASyCFG=<memID>,<name>,<idx>,<ndec>	
<memID>	Measure storage numerical identifier.
<name>	Measure name, up to 20 characters.
<idx>	<p>Internal address</p> <p>0: Supply voltage in V</p> <p>1: RSSI signal quality in dBm</p> <p>2: Internal temperature in °C</p> <p>3: Internal relative humidity in %</p> <p>4: Solar panel voltage in V</p>
<ndec>	Number of decimals for rounding.

4.2.5 Additional sensors parameters

SENSxDTN: Specifies detailed intervals in normal state

SENSxDTN=<dt_acq>,<dt_mem>	
<dt_acq>	Acquisition rate, in seconds, in NORMAL (GREEN) state.
<dt_mem>	Storage rate, in seconds, in NORMAL (GREEN) state.

This parameter allows you to specify particular acquisition and storage intervals for each sensor. If omitted, global times are used. It is not possible to specify the transmission interval, which is always global.

SENSxDTW: Specifies detailed intervals in warning state

SENSxDTW=<dt_acq>,<dt_mem>	
<dt_acq>	Acquisition rate, in seconds, in WARNING (YELLOW) state.
<dt_mem>	Storage rate, in seconds, in WARNING (YELLOW) state.

This parameter allows you to specify particular acquisition and storage intervals for each sensor. If omitted, global times are used. It is not possible to specify the transmission interval, which is always global.

SENSxDTP: Specifies detailed intervals in pre-alarm state

SENSxDTP=<dt_acq>,<dt_mem>	
<dt_acq>	Acquisition rate, in seconds, in PREALARM (ORANGE) state.
<dt_mem>	Recording frequency, in seconds, in PREALARM (ORANGE) state.

This parameter allows you to specify particular acquisition and storage intervals for each sensor. If omitted, global times are used. It is not possible to specify the transmission interval, which is always global.

SENSxDTA: Specifies detailed intervals in alarm state

SENSxDTA=<dt_acq>,<dt_mem>	
<dt_acq>	Acquisition rate, in seconds, in ALARM (RED) state.
<dt_mem>	Recording rate, in seconds, in ALARM (RED) state.

This parameter allows you to specify particular acquisition and storage intervals for each sensor. If omitted, global times are used. It is not possible to specify the transmission interval, which is always global.

SENSxNIC: Sensor x out of cycle: allows to not acquiring a sensor in configuration

SENSxNIC=<nic>	
<nic>	If the key is present and <nic> is equal to 1, sensor x is excluded from the acquisition therefore, it will be memorized with * (invalid data) but will not be acquired and will not generate LOG warnings.

SENSxMEASyFRM: corrective formula up to the third degree $y = a \cdot x^3 + b \cdot x^2 + c \cdot x + d$.

SENSxMEASyFRM=<a>,,<c>,<d>	
<a>	Third order multiplicative factor (* to disable the field).
	Second order multiplicative factor (* to disable the field).
<c>	First order multiplicative factor (* to disable the field).
<d>	Offset factor (* to disable the field).

SENSxMEASyOFF: measure offset

SENSxMEASyOFF=<offset>	
<offset>	Offset value that will be added to the measure after the corrective formula

SENSxMEASyELA: measure processing and validation

SENSxMEASyELA=<Elabo>,<memo>,<minEN>,<minValid>,<maxEN>,<maxValid>	
<Elabo>	Processing type: 1=normal, 2=vectorial, 3=accumulation data, 4=statistical filter.
<memo>	Bit mask that define the storage type.
<minValid>	Minimum of validation (* to disable the field).
<maxValid>	Maximum of validation (* to disable the field).

If the key is absent, the measurement is assigned a normal processing by default with storage of instantaneous data and average data without validation limits.

The normal processing type performs arithmetic averages on the instantaneous data.

The vector processing, instead, means that the average data are calculated with trigonometric functions assuming an amplitude vector of unitary modulus. This is useful, and must be used, in the case of wind direction measurements for example.

The type of data processing indicated with accumulation indicates that the value returned by the sensor is an infinite counter, therefore the instantaneous value is simply copied onto the average.

The type of data processing indicated with statistical filter, uses the calculated statistics from the previous storage to filter the data that will enter the current average calculation.

The <memo> bit mask allows you to choose, among all the processed data, which one to store:

- 1: last instantaneous data (LAST) (standard coding A)
- 2: average value (standard coding B)
- 4: minimum value (standard coding C)
- 8: maximum value (standard D coding)
- 16: standard deviation (standard F coding)
- 32: minute of minimum (standard code L)
- 64: minute of maximum (standard coding M)
- 128: valid data counter (standard coding E)

The individual bits add up to give different combinations, for example:

- <memo> = 3 indicates that the memorization of the last instantaneous (1) and of the average value (2) storage is enabled (1 + 2 = 3).
- <memo> = 15 indicates that instantaneous (1), average (2), minimum (4) and maximum (8) value storage is enabled (1 + 2 + 4 + 8 = 15).

SENSxMEASyCOD: detailed coding of the character for each statistical data

SENSxMEASyCOD=<last>,<avg>,<min>,<max>,<dev>,<minMin>,<minMax>,<counter>	
<last>	Instantaneous data code character
<avg>	Average data code character
<min>	Minimum data code character
<max>	Maximum data code character
<dev>	Standard deviation data code character
<minMin>	Minute of the minimum code character
<minMax>	Minute of the maximum code character
<counter>	Data valid counter code character

You must specify the parameters up to the last one you want to customize. For example, the line SENSxMEASyCOD=B,Z encodes the instantaneous with the letter B and the average with the letter Z while the other parameters are left at default. If you want to specify a particular parameter that is not the first and leave the others at default, you must use the * character to indicate that you want to leave out the key. For example, the line SENSxMEASyCOD=*,*,*,P encodes only the standard deviation with the letter P. The first

four are not modified due to the presence of the * character and the last three are not modified because they are not present.

SENSxMEASyIDM: detailed storage ID coding for each statistical data

SENSxMEASyIDM=<last>,<avg>,<min>,<max>,<dev>,<minMin>,<minMax>,<counter>	
<last>	Instantaneous data coding integer
<avg>	Average data coding integer
<min>	Minimum data coding integer
<max>	Maximum data coding integer
<dev>	Standard deviation data coding integer
<minMin>	Minute of the minimum data coding integer
<minMax>	Minute of the maximum data coding integer
<counter>	Data valid counter coding integer

If this key is used, all parameters must be specified. Any unspecified parameters, indicated with the character *, will not be stored in the record. It is also required that all custom IDs are different, otherwise the default for all measurements will be automatically set, i.e. the key will be disabled. Let us clarify with some examples.

Measure ID 10; processing mask 255 (all processing); SENSxMEASyIDM=1,2,3,4

In this case, the instantaneous data is stored with ID 1, the average with ID 2, the minimum with ID 3 and the maximum with ID 4. The other configured processings will not be included in the record because they are absent in the key.

Measure ID 10; processing mask 255 (all processing); SENSxMEASyIDM=1,1,3,4

In this case, since there are two equal IDs, the key is ignored. All the measurements configured in the bitmask will be stored with ID 10.

Measure ID 10; processing mask 255 (all processing); SENSxMEASyIDM=1,*,3

In this case, the instantaneous data will be stored with ID 1 and the minimum with ID 3. The other configured processings will not be entered in the record because they are absent in the key.

Measure ID 10; processing mask 14 (average, minimum and maximum); SENSxMEASyIDM=1,2,3,4

In this case, the instantaneous data is not memorized because it is not in the memorization mask; the average is memorized with ID 2, the minimum with ID 3 and the maximum with ID 4.

Measure ID 10; processing mask 14 (average, minimum and maximum); SENSxMEASyIDM=*,*,*,1,2

In this case, the configuration is clearly wrong since the coding key excludes what was configured for storage. No data will be stored.

SENSxMEASyALL: measurement alarm management

SENSxMEASyALL=<Hyst>,<pers>,<type>,<valWSup>,<valWInf>,<valPSup>,<valPInf>,<valASup>,<valAInf>	
<Hyst>	Hysteresis value for each threshold expressed in the unit of measure of the data.
<pers>	Persistence value in over threshold state expressed in multiples of the monitoring time. (default 3)
<type>	Type of measure for evaluating the alarm status. 0 = instantaneous (default), 1 = average.
<valASup>	Higher alarm threshold value (RED).
<valPSup>	Higher pre-alarm threshold value (ORANGE).
<valWSup>	Higher warning threshold value (YELLOW).
<valWInf>	Lower warning threshold value (YELLOW).
<valPInf>	Lower pre-alarm threshold value (ORANGE).
<valAInf>	Lower alarm threshold value (RED).

The first three fields are mandatory. In particular, the first, hysteresis, is necessary while persistence and type can be replaced with * in which case NanoSUM will assume the default values, i.e. 3 for persistence and 0 (instantaneous data) for the type. For alarm thresholds there must be at least one; in other words, you can choose how many and which thresholds to insert. To disable a type of alarm, enter the * character as key.

Some examples of a temperature measurement in degrees Celsius:

SENS0MEAS0ALL=1,5,0,60,*,*,*,*-20

Hysteresis of 1°C, persistence 5 times of acquisition and evaluation on instantaneous data. Upper alarm threshold of 60°C and lower alarm threshold of -20°C.

SENS0MEAS0ALL=2,0,1,60,40

Hysteresis of 2°C, zero persistence (single evaluation) and evaluation on average data. Upper alarm threshold of 60°C and upper pre-alarm threshold of 40°C.

SENS0MEAS0ALL=1,*,*,*,40,20,-10,-20

Hysteresis of 1°C, evaluation persistence at default value of 3 and instantaneous data. Upper pre-alarm threshold of 40°C, upper warning threshold of 20°C, lower warning threshold of -10°C and lower pre-alarm threshold of -20°C.

It is emphasized that the thresholds must be chosen with criteria and the condition that must be verified is:

Upper ALARM > Upper PREALARM > Upper WARNING > Lower WARNING > Lower PREALARM > Lower ALARM

4.3 Configuration example

Below we give an example of configuration file so that it can clarify the above aspects. The global specifications of the station are as follows:

- Station identifier 10, name Test NanoSUM, with APN internet.it, and IPV4 support.
- Server for NTP time synchronization 0.pool.ntp.org with Rome time zone, UTC+1.
- SMS password customization: new password “qwerty”
- USB diagnostics enabled
- Shutdown disabled
- Maximum archive file size of 4MB and maximum FTP file size of 32kB
- Intervals in normal state equal to 1 minute of acquisition, 10 minutes of storage, 10 minutes of transmission
- Intervals in warning state equal to 1 minute of acquisition, 5 minutes of memorization, 10 minutes of transmission
- Intervals in pre-alarm state equal to 30 seconds of acquisition, 2 minutes of storage, 5 minutes of transmission
- Intervals in alarm state equal to 30 seconds of acquisition, 30 seconds of storage, 1 minute of transmission
- Enabling of writing of 3-threshold type alarm records
- Enabling interval change in case of alarm
- Regarding power supplies: 12V_{OUT} off with 10 second pre power on, BAT_{OUT} always on, OD1 and OD2 always off.
- Watchdog on FTP enabled and equal to 1 hour, data backup on SD card enabled

The connected sensors are:

- **Local diagnostic sensor** with the following measures enabled:
 - Battery voltage with ID 1, 1 decimal rounding and storage of instantaneous, average, minimum and maximum.
 - RSSI with ID 2, no rounding decimal and storage of instantaneous, average, minimum and maximum
 - Internal temperature with ID 3, 1 decimal rounding and storage of instantaneous, average, minimum and maximum
 - Internal humidity with ID 4, no rounding decimals and storage of instantaneous, average, minimum and maximum
 - Solar panel voltage with ID 5, 1 decimal rounding and storage of instantaneous, average, minimum and maximum

For this sensor, the acquisition and storage times are redefined bringing them to 10 seconds and 60 seconds respectively, for all the operating states of the data logger.

- **MODBUS pyranometer** with identifier 7 connected on COM1 at 9600 bps, 8 data bits, no parity and 1 stop bit. The acquisition function is the 3 read holding registers, and 2 registers are read starting from register 1, timeout of 1 second. We have a single measure:
 - Solar radiation with ID 6 in register 1, data type swapped float, 1 decimal rounding and storage of instantaneous, average, minimum and maximum
- **Combined MODBUS temperature and humidity sensor** with identifier 3 connected to COM1 at 9600 bps, 8 data bits, no parity and 1 stop bit. The acquisition function is the 3 read holding registers, and 4 registers are read starting from register 1, timeout of 1 second. There are two measures:
 - Temperature with ID 7 in register 1, data type swapped float, 1 decimal rounding and storage of instantaneous, average, minimum and maximum. This measure is associated with an alarm evaluation on the instantaneous data with persistence of four measurements and hysteresis of 2°C. The lower warning thresholds of 0°C, the lower pre-alarm of -10°C and the lower alarm of -20°C are defined.
 - Humidity with ID 8 in register 3, swapped float data type, no rounding decimals and storage of instantaneous, average, minimum and maximum
- **MODBUS barometer** with identifier 5 connected on COM1 at 9600 bps, 8 data bits, no parity and 1 stop bit. The acquisition function is the 3 read holding registers, and 4 registers are read starting from register 5, timeout of 1 second. There are two measures:
 - Pressure with ID 9 in register 5, data type swapped float, 2 decimals for rounding and storage of instantaneous, average, minimum and maximum
 - Internal temperature with ID 90 in register 7, data type swapped float, 2 decimals rounding and storage of instantaneous, average, minimum and maximum
- **MODBUS radar level sensor** with identification 246 connected on COM1 at 9600 bps, 8 data bits, no parity and 1 stop bit. The acquisition function is the 3 read holding registers. The measures to be acquired are not all consecutive and two logic sensors will be instantiated.

The first reads 10 registers starting from register 111, 1 second timeout. There are three measures:

- Distance in mm with ID 10 in register 111, data type swapped float, 1 decimal rounding and storage of instantaneous, average, minimum and maximum. This measure is associated with an alarm evaluation on the average data with persistence of two measures and hysteresis of 20cm. Alarm threshold higher than 7 meters, pre-alarm higher than 5 meters and warning higher than 3 meters.
- Internal temperature with ID 11 in register 119, data type swapped float, 1 decimal rounding and storage of instantaneous, average, minimum and maximum.
- Signal quality with ID 12 in register 115, data type swapped float, 1 decimal rounding and storage of instantaneous, average, minimum and maximum.

The second logic sensor reads 2 registers starting from register 2301 and has a measure:

- Sensor status with ID 13 in register 2301, 32-bit integer data type, no rounding decimal and instantaneous, minimum and maximum data storage with change of the record instantaneous data coding character to "B".
- **SDI – 12 sonic anemometer** with identifier 1. The anemometer have various measures in different commands of the SDI – 12 protocol and is divided into three logical sensors.

The first reads 4 measures with start measure command M, data request D0, timeout 2 seconds:

- Wind speed with ID 14, position 1, 1 decimal rounding and storage of instantaneous, average, minimum and maximum
- Wind direction with ID 15, position 2, 1 decimal rounding, trigonometric averages and storage of instantaneous, average, minimum and maximum
- Internal compass with ID 16, position 3, 1 decimal rounding, trigonometric averages and storage of instantaneous, average, minimum and maximum
- Status of the sensor with ID 17, position 4, no rounding decimal and storage of the instantaneous, minimum and maximum data with modification of the coding character of the instantaneous data of the record to "B".

The second reads 3 measures with start measure command M4, data request D4, timeout 2 seconds:

- WMO wind speed with ID 18, position 1, 1 decimal rounding and storage of instantaneous, average, minimum and maximum
- Minimum WMO wind speed with ID 19, position 2, 1 decimal rounding and storage of instantaneous, average, minimum and maximum
- WMO wind speed gust with ID 20, position 3, 1 decimal rounding and storage of instantaneous, average, minimum and maximum

The third reads 3 measures with start measure command M5, data request D5, timeout 2 seconds:

- WMO wind direction with ID 21, position 1, 1 decimal rounding, trigonometric averages and storage of instantaneous, average, minimum and maximum
- Minimum WMO wind direction with ID 22, position 2, 1 decimal rounding, trigonometric averages and storage of instantaneous, average, minimum and maximum
- Maximum WMO wind direction with ID 23, position 1, 1 decimal rounding, trigonometric averages and storage of instantaneous, average, minimum and maximum
- **Natural rain gauge** which measures the total cumulative rainfall, with ID 24, on digital input 1 (DI1) configured as cumulative count with 1 decimal rounding. It is specified a correction formula that multiplies the count value by the rain gauge constant equal to 0.2 mm. The accumulation, the minimum and the maximum are stored. The accumulation, in the position of the instantaneous data, is coded with the character "B" in the record instead of the default one.

Data are uploaded to two FTP sites:

- IP address **1.2.3.4**, user **NanoSUM**, password **p4ssw0rd**, data subfolder **/Data**, enabled for advanced features

- IP address **2.3.4.5**, user **NanoSUM**, password **pa55word**, root data folder, disable advanced features, simplified ASCII record layout

Four recipients responsible for alarm SMS are configured:

- Number +391234567890 with delivery not enabled
- Number +392345678901 with delivery of all warning, pre-alarm and alarm messages
- Number +393456789012 with delivery of pre-alarm and alarm messages only
- Number +394567890123 with delivery of alarm messages only

The configuration described translates into the following config.ini file.

```

#NanoSUM test configuration
[CONFIG]
SITE=10,Test NanoSUM
APN=internet.it
EXTRA=AT;ATE0;AT&Y1;AT&P1;AT&W1;
NTP=0.pool.ntp.org,4
IPV=0
PASSWORD=qwerty
VERBOSE=1
ENABLE_SHUTDOWN=0
MAX_DISK=4096
MAX_FTP=32
STEP_NORMAL=60,600,600
STEP_WARNING=60,300,600
STEP_PREALARM=30,120,300
STEP_ALARM=30,30,60
ALA_REC_EN=1,0
ALA_CTIME_EN=1
BOOST_ON_TIME=10
BAT_ON_TIME=1
OD1_ON_TIME=0
OD2_ON_TIME=0
WDFTP=60
BACKUP_EN=1
#Local diagnostic measures
SENS0CFG=LOCAL,Diagnostic,1000
SENS0NIC=0
SENS0DTN=10,60
SENS0DTW=10,60
SENS0DTP=10,60
SENS0DTA=10,60
SENS0MEAS0CFG=1,Vbat(V),0,1
SENS0MEAS0ELA=1,15
SENS0MEAS1CFG=2,RSSI(dBm),1,0
SENS0MEAS1ELA=1,15
SENS0MEAS2CFG=3,Int. Temp(gC),2,1
SENS0MEAS2ELA=1,15
SENS0MEAS3CFG=4,Int. RH(%),3,0
SENS0MEAS3ELA=1,15
SENS0MEAS4CFG=5,Vps (V),4,1
SENS0MEAS4ELA=1,15
#SIAP+MICROS t055-TPIR pyranometer
SENS1CFG=MODBUS,TPIR,7,1,3,8N1,3,1,2,1000
SENS1NIC=0
SENS1MEAS0CFG=6,Solar rad.(Wm-2),1,3,1
SENS1MEAS0ELA=1,15
#SIAP+MICROS t026-TTEPRH Temp. RH
  
```

```

SENS2CFG=MODBUS,TTEP-RH,3,1,3,8N1,3,1,4,1000
SENS2NIC=0
SENS2MEAS0CFG=7,Air Temp.(gC),1,3,1
SENS2MEAS0ELA=1,15
SENS2MEAS0ALL=2,4,0,*,*,*,0,-10,-20
SENS2MEAS1CFG=8,Air RH(%),3,3,1
SENS2MEAS1ELA=1,15
#SIAP+MICROS t011-TBAR barometric pressure
SENS3CFG=MODBUS,TBAR,5,1,3,8N1,3,5,4,1000
SENS3NIC=0
SENS3MEAS0CFG=9,Air Press.(mBar),5,3,2
SENS3MEAS0ELA=1,15
SENS3MEAS1CFG=90,Temp Press.(gC),7,3,2
SENS3MEAS1ELA=1,15
#VEGA 80GHz radar level measure
SENS4CFG=MODBUS,VEGA C 23,246,1,3,8N1,4,111,10,1000
SENS4NIC=0
SENS4MEAS0CFG=10,Dist Vega(mm),111,3,1
SENS4MEAS0ELA=1,15
SENS4MEAS0ALL=200,2,1,7000,5000,3000,*,*,*
SENS4MEAS1CFG=11,Temp Vega(gC),119,3,1
SENS4MEAS1ELA=1,15
SENS4MEAS2CFG=12,Sig Vega(dB),115,3,1
SENS4MEAS2ELA=1,15
#VEGA 80GHz radar level status
SENS5CFG=MODBUS,VEGA C 23,246,1,3,8N1,4,2301,2,1000
SENS5NIC=0
SENS5MEAS0CFG=13,Status Vega,2301,4,0
SENS5MEAS0ELA=1,13
SENS5MEAS0COD=B
#SIAP+MICROS Winson ultrasonic anemometer
SENS6CFG=SDI12,Winson,1,M,2000
SENS6NIC=0
SENS6MEAS0CFG=14,Win Speed(m/s),D0,1,1
SENS6MEAS0ELA=1,15
SENS6MEAS1CFG=15,Win Dir(gN),D0,2,1
SENS6MEAS1ELA=2,15
SENS6MEAS2CFG=16,Win magneto(gN),D0,3,1
SENS6MEAS2ELA=2,15
SENS6MEAS3CFG=17,Win Status,D0,4,0
SENS6MEAS3ELA=1,13
SENS6MEAS3COD=B
#SIAP+MICROS Winson ultrasonic anemometer
SENS7CFG=SDI12,Winson,1,M4,2000
SENS7NIC=0
SENS7MEAS0CFG=18,Win Speed WMO(m/s),D4,1,1
SENS7MEAS0ELA=1,15
SENS7MEAS1CFG=19,Win Min WMO(m/s),D4,2,1
SENS7MEAS1ELA=1,15
SENS7MEAS2CFG=20,Win Gust WMO(m/s),D4,3,1
SENS7MEAS2ELA=1,15
#SIAP+MICROS Winson ultrasonic anemometer
SENS8CFG=SDI12,Winson,1,M5,2000
SENS8NIC=0
SENS8MEAS0CFG=21,Dir WMO(gN),D5,1,1
SENS8MEAS0ELA=2,15
SENS8MEAS1CFG=22,Dir Min WMO(gN),D5,2,1
SENS8MEAS1ELA=2,15
SENS8MEAS2CFG=23,Dir Max WMO(gN),D5,3,1
SENS8MEAS2ELA=2,15
#SIAP+MICROS t043-TPUW-52NN30 rain gauge
SENS9CFG=DIGITAL,TP500 UNI,1000
SENS9NIC=0
SENS9MEAS0CFG=24,Total rain(mm),1,3,1
  
```

```
SENS9MEAS0FRM=0,0,0.2,0  
SENS9MEAS0ELA=1,13  
SENS9MEAS0COD=B  
#FTP section  
FTP0=1.2.3.4,NanoSUM,/Data  
FTP0PSW=p4ssw0rd  
FTP0REC=MICROS  
FTP1=2.3.4.5,NanoSUM/,1  
FTP1PSW=pa55word  
FTP1REC=ASCII  
#SMS section  
SMS0=+391234567890,0  
SMS1=+392345678901,1  
SMS2=+393456789012,2  
SMS3=+394567890123,3
```

It should be noted that all the sensors are provided with the key SENSxNIC=0 to be able to exclude them from the acquisition cycle at any time and in a very simple way, by changing this key to 1. The FTP0PSW=MICROS key is not necessary since, if omitted, the record on the FTP server is in dynamic SIAP+MICROS. Making it explicit, especially when you have some servers with ASCII layout as happens in the example for FTP1, increases the readability of the configuration.

4.4 Loading configuration from the terminal

The config.ini configuration file described in the previous paragraph must be copied to the root folder of the module. We have already illustrated how an FTP server can be used to update the file; here we will describe how to proceed for the update from a PC. It's important to note that:

- A Windows operating system is required
- It is necessary to install the device driver package first²³
- You need a terminal capable of sending entire ASCII files in response to a prompt. A possible terminal with this feature is TeraTerm®.

Once the drivers have been installed, connecting the NanoSUM USB port creates two virtual modem-type, COM ports and a diagnostic port. For direct access to the file system, one of the two modem-type ports must be used. It should be noted that, if the VERBOSE=1 key is present in the currently loaded configuration, one of the two communication ports is used by the operating program for writing diagnostic strings, therefore the other must be used.

Suppose initially that NanoSUM is not running in shutdown. Having identified the correct port, you need to:

- Turn on NanoSUM
- Open the COM port identified on the terminal. Any port parameter is fine.
- Type the **AT#M2MLIST<CRLF>** command

It is the file and folder list command to which NanoSUM will reply with the list of files and directories of the startup folder. You recognize that you are in the right folder by the presence of the appcfg.ini file, an internal file that must not be modified or deleted in any way.

- If the config.ini file is present, delete it with the command **AT#M2MDEL=config.ini<CRLF>**
- Type the write command **AT#M2MWRITE=config.ini,<filelen><CRLF>**.

The write command specifies the file name and its length **<filelen>** in bytes. The module will respond to this command with the characters >>>.

- Load from the terminal **<filelen>** bytes that make up the config.ini file. When **<filelen>** is passed, the module responds with OK and the loading procedure is completed.
- To make the configuration operational, the module must be restarted with the **AT#REBOOT<CRLF>** command.

As an example, suppose you want to load a configuration of 842 bytes. The steps in the terminal will be as follows (in blue the commands, in red the response from NanoSUM):

²³ File Telit_Windows_10_WHQL_Drivers_Installer_2.18.0000 and Telit_Windows_11_WHQL_Drivers_Installer_11.00.0000.zip

AT#M2MLIST

```
#M2MLIST: <.>
#M2MLIST: <..>
#M2MLIST: <Archive>
#M2MLIST: <FTP0>
#M2MLIST: <LOG>
#M2MLIST: "anylog.bin",334224
#M2MLIST: "appcfg.ini",94
#M2MLIST: "config.ini",842
#M2MLIST: free bytes: 6166528
```

OK

AT#M2MDEL=config.ini

OK

AT#M2MLIST

```
#M2MLIST: <.>
#M2MLIST: <..>
#M2MLIST: <Archive>
#M2MLIST: <FTP0>
#M2MLIST: <LOG>
#M2MLIST: "anylog.bin",334224
#M2MLIST: "appcfg.ini",94
#M2MLIST: free bytes: 6168576
```

OK

AT#M2MWRITE=config.ini,842

```
>>>SITE=1000,Test NanoSUM
APN=internet.it
EXTRA=AT;ATE0;AT&Y1;AT&P1;AT&W1;
NTP=0.pool.ntp.org,4
IPV=0
...
...
#SMS section
SMS0=+391234567890,1
```

OK

AT#REBOOT

Although the configuration change can be done with the operating program running, there is a particular case that requires the temporary disabling of the operating program and that is when the module is configured in shutdown. In this case, in fact, the module is configured to switch off and remain off until the next configured interval. Furthermore, the power-on time is kept as short as possible and therefore it is difficult to do any file operations. The procedure will modify like this:

- Turn on NanoSUM
- As soon as the red CONNECTION STATUS LED starts flashing, open the COM port identified on the terminal and give the command **AT+M2M=0<CRLF>**. This disables the execution of the operating program and causes a restart of the module.
- Proceed with the procedure as in the previous points.
- Give the command **AT+M2M=1<CRLF>**. This causes a restart of the module and re-enables the execution of the operating program. For the operation of NanoSUM it is essential to remember this step.

4.5 Loading operating program from the terminal

The anylog.bin operating program file must be copied to the root folder of the module and enabled to run at startup. We have already illustrated how an FTP server can be used to update the file; here we will describe how to proceed for the update from a PC. The same recommendations as in the previous paragraph apply:

- A Windows operating system is required.
- It is necessary to first install the device driver package²³.
- A terminal capable of sending entire binary ASCII files at a module response prompt is required. A possible terminal with this feature is TeraTerm®.
- You must ensure that NanoSUM has a valid configuration before uploading.

The USB port of the data logger is used in the same way. Suppose initially that NanoSUM is not running in shutdown. Having identified the correct port, you need to:

- Turn on NanoSUM
- Open the COM port identified on the terminal. Any port parameter is fine.
- Type the **AT#M2MLIST<CRLF>** command
- If the anylog.bin file is present, delete it with the command **AT#M2MDEL=anylog.bin<CRLF>**
- Type the write command **AT#M2MWRITE=anylog.bin,<filelen><CRLF>**.

The write command specifies the file name and its length <filelen> in bytes. The module will respond to this command with the characters >>>.

- Load from the terminal <filelen> bytes that make up the anylog.bin file. When <filelen> is passed, the module responds with OK and the loading procedure is completed.
- If the operating program was running correctly, to make the new program operative it is simply necessary to restart the module with the **AT#REBOOT<CRLF>** command.
- If, on the other hand, it is a first installation or the operating program is disabled, it must be enabled with the command **AT#M2MRUN=2,anylog.bin<CRLF>** and run it with the command **AT+M2M=1<CRLF>**. The last command will generate a restart of the module.

If instead NanoSUM were in shutdown, the procedure will change as follows:

- Turn on NanoSUM
- As soon as the red CONNECTION STATUS LED starts flashing, open the COM port identified on the terminal and give the command **AT+M2M=0<CRLF>**. This disables the execution of the operating program and causes a restart of the module.
- Proceed with the procedure as in the previous points concluding with the two commands **AT#M2MRUN=2,anylog.bin<CRLF>** and **AT+M2M=1<CRLF>**.

The last command causes a restart of the module and re-enables the execution of the operating program. For the operation of NanoSUM it is essential to remember this step.

5. Regulation

5.1 Safety regulations

The detailed examination of the project and of the execution methods has made it possible to establish what are the risks that the product may present during its entire life, if used correctly, and therefore to define the essential requirements that are applicable to it. These requirements may be contained in one or more directives and all must be met regardless of which directive they belong to. Two conditions are therefore necessary for the application of a directive to a product:

- The product is within its scope
- The product presents risks to which the essential requirements of the directive refer.

From the risk analysis carried out, described in the following pages, it emerged that the European directives applicable to the product in question are the following:

European Directive	Title	Reference transposition law in Italy
2014/35/EU	Low Voltage Directive (LVD)	Legislative Decree No. 86 of 19 May 2016
2014/30/EU	Electromagnetic Compatibility Directive (EMC)	Legislative Decree No. 80 of 18 May 2016
2014/53/EU	Radio Equipment Directive (RED)	Legislative Decree No. 128 of 22 June 2016

The product in question falls within the scope of the Low Voltage Directive 2014/35/EU implemented in Italy with Legislative Decree number 86 of 19 May 2016, the Electromagnetic Compatibility Directive 2014/30/EU implemented in Italy with Legislative Decree number 80 of 18 May 2016 and the Radio Equipment Directive 2014/53/EU implemented in Italy with Legislative Decree number 128 of 22 June 2016.

5.2 EMC

This equipment has been designed in compliance with the requirements of the directives indicated in the CE declaration enclosed with the product.

6. Compliant use of the equipment

The equipment has been designed to be used according to the specifications indicated in the following table:

INTENDED USE AND LIMITATIONS OF EQUIPMENT	DATA / INFORMATION AVAILABLE
Intended use	The intended use includes only acquisition, transmission and processing of physical and chemical parameter measurements for meteorology, agrometeorology, hydrometry, environmental and climatic monitoring, remote control and automation of aqueducts, water purifiers, sewers, etc., distributed logic control and automation systems, special applications for landslide control, microbiological processes, chemicals, etc.
Reasonably foreseeable misuses and contraindications for use	Use in a home or hobby environment is improper; use by unqualified and/or inadequately trained persons.
Usage environment	Not intended for use in environments with explosive, corrosive and flammable gases or vapors.
Any critical environmental factors	The environmental conditions for correct use are: <ul style="list-style-type: none"> • Reference temperature: +20 °C • Operating temperature: -40 ÷ +80 °C • Maximum permissible relative humidity: 100% non-condensing • Storage temperature: 0 ÷ +60 °C • Storage humidity: 80% maximum • Maximum altitude: 5000 m • Pollution degree: 2
Professionalism or experience required of operators	Personnel must be qualified or properly trained and educated about the risks involved.

NOTES

- Periodic updates are made to the information contained in this document. These are inserted in new editions of the document.
- The manufacturer may make modifications and/or changes to the product described in this document at any time and without notice.
- Rights reserved. It is not permitted to reproduce or duplicate all or part of this document without the authorization of the manufacturer.

7. History of the revisions

The following table shows the description of the changes made to this document.

Version	Date	Updates
00	05/23/2022	First version of the document.
01	07/27/2022	Added battery voltage measurement calibration offset if you enable the LI_BATT parameter
02	12/22/2022	Added new graphics to the document
03	04/14/2023	Update to firmware version 1.0.3
04	11/30/2023	<p>Updated to firmware version 1.1.1.</p> <p>Updated "6. Environmental conditions of use" in "6. Compliant use of the equipment". Also updated the contents of the table.</p> <p>Updated references to regulations in Chapters 1 and 5.</p> <p>Inserted paragraph "2.2.3 Power supplies summary table".</p> <p>Added the possibility of configuration with DAK 3.6.0.</p>
05	05/01/2024	<p>Updated to firmware version 1.2.0.</p> <p>Added global category 1 module support.</p> <p>Added FTPS support.</p> <p>New log levels: VERBOSE configuration key.</p> <p>New BMS (battery management system) functionality.</p> <p>Updated FTP and SMS commands.</p>
06	09/01/2024	<p>Updated to firmware version 1.2.1.</p> <p>Added digital measurements of total rainfall and rainfall during the period.</p>
07	06/03/2025	<p>Updated to firmware version 1.3.1.</p> <p>New <i>CHECK FTP</i> and <i>GET ARCHIVE</i> SMS commands.</p> <p>Minor changes to <i>GET MEM</i> command.</p> <p>New average processing with statistical data filtering.</p> <p>New type of stored data: valid data counter.</p> <p>Support for signed integer data types in MODBUS protocol.</p> <p>Added document symbol legend.</p> <p>Added new chapter <i>General requirements</i>.</p>

8. Declaration of Conformity



MD 751.1 rev. 03

EU Declaration of Conformity (DoC)

Manufacturer: SIAP+MICROS S.p.A.
 Via del Lavoro, 1 – 31020 S. Fior (TV) – Italy
<https://www.siapmicros.com/en/>

This declaration of conformity is issued under the sole responsibility of the manufacturer.

Object of the declaration:

Description	Product Code/Model
NanoSUM NanoSum Datalogger is a global 4G module in category M1 and NB1, serial interface, digital input and microUSB and standard configuration	PEM-E016C-NANO

The object of the declaration described above is in conformity with the relevant Union harmonization legislation:

- **2014/53/EU** The Radio Equipment Directive (RED)
- **2011/65/EU** The Restriction of Hazardous Substances Directive (RoHSD)

The following harmonised standards and technical specifications have been applied:

RED references:

ELECTROMAGNETIC COMPATIBILITY (Article 3.1b):

EN 61326-1 2021-06	Electrical equipment for measurement, control and laboratory use - EMC requirements - General requirements
EN 301 489-1 V2.2.3:2019	ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 1: Common technical requirements; Harmonised Standard for ElectroMagnetic Compatibility
EN 301 489-52 V1.2.1:2021-11	ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 52: Specific conditions for Cellular Communication User Equipment (UE) radio and ancillary equipment; Harmonised Standard for ElectroMagnetic Compatibility

EFFECTIVE AND EFFICIENT USE OF RADIO SPECTRUM (Article 3.2):

EN 301 511 V12.5.1:2017-03	Global System for Mobile communications (GSM); Mobile Stations (MS) equipment; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU
EN 301 908-1 V13.1.1:2019-11	IMT cellular networks; Harmonised Standard for access to radio spectrum; Part 1: Introduction and common requirements
EN 301 908-13 V13.1.1:2019-11	IMT cellular networks; Harmonised Standard for access to radio spectrum; Part 13: Evolved Universal Terrestrial Radio Access (E-UTRA) User Equipment (UE)



MD 751.1 rev. 03

HEALTH & SAFETY (Article 3.1a):

EN 61010-1 2010+A1:2021-11	Safety requirements for electrical equipment for measurement, control and laboratory use Part 1: General requirements
EN 62311 2019	Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz to 300 GHz)

RoHSD references:

EN 63000 2016+AMD1:2022	Technical documentation for the assessment of electrical and electronic products with respect to the restriction of hazardous substances
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Date
31-01-2023

CEO
Alex Stevanin

Appendix A: data record formats

A.1 SIAP+MICROS dynamic data record format

Internally to NanoSUM, the data is stored in a clear ASCII file; this ASCII file is structured in lines, each line is a storage record in an encoded form called dynamic SIAP+MICROS record layout. The length of the record layout varies according to the number and type of data contained therefore, in situations where the data to be inserted in the layout are minimal, the length of the layout itself and, consequently, the space occupied by the data, will be very low. The record may contain both instantaneous and statistical data, as well as alarm data. This type of record is also the normal way in which data is delivered to the configured FTP servers.

Each record is made up of three distinct parts called respectively:

- Head
- Body
- Terminator

Each of these parts of the record is subdivided internally into fields separated from each other by the character ",", (ASCII 44).

Header

The header of the record layout contains the general information that allows the identification of the record on the basis of the time event and the station to which it belongs. In detail, its format is as follows:

ST0<station_id>,<const>,hh.nn.ss,dd,mm,yy,<type>,<Mnum_input> ,

The meaning of the various fields is as follows:

- **ST0<station_id>**. Header that identifies the beginning of the head of the record. It consists of the characters "ST0" plus a number indicating the numerical code (ID) of the station. For example, header ST01 identifies the record of Station 1.
- **<const>**. Constant code identifying the type of record layout. It is 6 for the dynamic layout.
- **hh.nn.ss**. Hour, minute and second of the storage event for each field.
- **dd** Day of the record storage event.
- **mm**. Month of the record storage event
- **yy**. Year of the record storage event
- **<type>**. Constant code identifying the type of record. It is 0 for the type of statistical data record layout (instantaneous and processing). We will see that it could be 2 for the 2-threshold alarm record and 7 for the 3-threshold alarm record.
- **<Mnum_input>**. Field made up of the character "M" followed by a number indicating the total number of parameters contained in the Body of the record layout. For example, M9 indicates a total of 9 parameters, while M50 indicates a total of 50 parameters.

The head therefore uniquely identifies the station, the instant in time to which the data refer, the number and type of data that will follow in the body.

Body

The body of the record layout contains the statistical data (instantaneous, average, minimum, maximum, standard deviation, etc.) relating to each measurement parameter. It consists of the repetition of blocks of information repeated as many times as there are parameters to be represented.

In particular, the format of the body looks like this:

BODY RECORD = block_1 + “,” + block_2 + “,” + block_3 +

Each block is made up of several sections which together constitute the registry of the parameter represented. The block has a dynamic structure, therefore there can be multiple sections to represent it. In the specific case of statistical data, there is no fixed number of sections, but these can vary on the basis of specific needs. In detail, each block is structured as follows:

block_n = <id> + “,” + section_1 + “,” + section_2 + “,” + ... + “,” + section_n

In each block <id> is the numerical identifier of the measurement, as per configuration, while the various sections are in turn divided into two fields which together contribute to give a single piece of information regarding the measurement:

section_N = <constant> + “,” + <value>

In details:

- <constant> is an ASCII character (from ASCII 65 to ASCII 90) which expresses the meaning of the next "value" field. NanoSUM supports the following codes:
 - **A** INSTANTANEOUS VALUE of the parameter (at the instant of memorization of the record).
 - **B** AVERAGE VALUE of the parameter.
 - **C** MINIMUM VALUE of the parameter.
 - **D** MAXIMUM VALUE of the parameter.
 - **F** STANDARD DEVIATION of the parameter.
 - **L** MINUTE OF MINIMUM (expressed as minutes from midnight).
 - **M** MINUTE OF MAXIMUM (expressed as minutes from midnight).
 - **E** VALID DATA COUNTER (samples that forms statistical averages).
- <value> is a numeric value that represents the measurement value, a particular code, a particular state, etc. It should be noted that the <value> field takes on different meanings depending on the <constant> field that precedes it.

To clarify better, a block capable of representing a measurement parameter could be structured as follows:

<id> + “,” + B + “,” + <average_value> + “,” + C + “,” + <minimum_value> + D + “,” + <maximum_value>

The sections represented are not necessarily positional in the sense that it is not necessary to respect a precise order, furthermore their number can vary according to the information to be provided for the represented parameter. It is therefore possible to provide only the average statistical data for one parameter, while for

another the average, minimum and maximum statistical data. The parameters to be memorized remain defined in the configuration.

In situations where the <value> field of any section is not a valid numeric value, it is replaced with a specific character which is "*" (ASCII 42).

NanoSUM makes available two particular aspects that are explained in the paragraph concerning the configuration:

- It is possible to modify the letters of the <constant> field with letters from the configuration
- It is possible to specify different <id> for statistical parameters referring to the same physical measurement

Terminator

The terminator is a field that indicates the end of the record layout. The terminator consists of the character "#" (ASCII 35) + a number indicating the total fields of the record between the start of the header, "ST0", and the terminator "#" included. For example, #50 indicates that the record is made up of a total of 50 fields with header "ST0" and terminator "#" included.

The last character of the record will be the carriage return <CRLF>.

Example of a record

Monitoring station number 100 which on 20 March 2022 at 14.00.00 memorized a record layout of statistical data relating to

- Temperature with identifier 1 with average, minimum and maximum values
- Humidity with identifier 7 with instantaneous and average value

ST0100,6,14.00.00,20,03,2022,0,M5,1,B,18.5,C,18.3,D,18.7,7,A,65,B,63,#21<CRLF>

Record modification for alarm records

NanoSUM supports the writing of 4-state alarm records (3 upper thresholds and 3 lower thresholds) as described in the alarm management paragraph. It can also be configured to support 3-state alarm records (2 upper thresholds and 2 lower thresholds). These records maintain a very similar structure to the one explained and differ in the following aspects:

- **Header**

In the header, the <type> field varies. This assumes the value 7 for the NanoSUM 3-threshold alarm record. Assumes the value 2 for the 2-threshold alarm record.

- **Sections**

Sections still take the form <constant> + <value> but with different letters and meanings:

- <constant> = **T**, <value> is always constant and equal to 0 in NanoSUM.
- <constant> = **W**, indicates that the following <value> is the type of alarm which can assume the following meanings.

For the 3-threshold system:

- <value> = 0, normal state
- <value> = 1, higher warning status
- <value> = 2, higher pre-alarm status
- <value> = 3, higher alarm status
- <value> = -1, lower warning status
- <value> = -2, lower pre-alarm status
- <value> = -3, lower alarm status

For the 2-threshold system:

- <value> = 0, normal state
- <value> = 1, higher pre-alarm status
- <value> = 2, higher alarm status
- <value> = -1, lower pre-alarm status
- <value> = -2, lower alarm status
- <constant> = **A**, indicates that the following <value> is the measurement value that generated the alarm.
- <constant> = **V**, indicates that the following <value> is the reference threshold value that has been exceeded.

Therefore, a block capable of representing an alarm of a measure parameter could be structured as follows:

id + “,” + T,0 + “,” + W + “,” + value_1 + “,” + A + “,” + value_2 + “,” + V + “,” + value_3

The four sections represented are not positional, in the sense that it is not necessary that they respect a precise order, but it is good practice to represent them with the sequence described above.

Assume that a temperature with identifier 12, of station 87, on 15 July 2022 at 15:00:00, exceeds the pre-alarm threshold, of a 3-threshold record, with a value of 35°C on a threshold of 30°C. The alarm record would be structured as follows:

ST087,6,15.00.00,15,07,2022,7,M4,12,T,0,W,2,A,35,V,30,#18<CRLF>

Dynamic data record name

The dynamic SIAP+MICROS record files are uploaded to the enabled FTP servers with a file name, with the .DAT extension, which contains the measurement identifier of the station and the upload date:

ST0<ID>_yyyymmddhhnss.DAT

Let's go back to the example record of the station 100

ST0100,6,14.00.00,20,03,2022,0,M5,1,B,18.5,C,18.3,D,18.7,7,A,65,B,63,#21<CRLF>

If the upload is done at 17:30:00, we will have the file ST0100_20220320173000.DAT.

A.2 Simplified ASCII SIAP+MICROS data record format

The simplified ASCII layout is a transcode layout obtained starting from the dynamic SIAP+MICROS archive, which can be used as an alternative for uploading measurement data to FTP servers enabled for this layout. The peculiarity is that each row of the layout represents a single measure structured in five fields separated by ";". The decimal separator is the "." (point).

<date>;<identifier>;<type>;<value>;<validation><CRLF>

In this we have:

- **<date>**: date formatted as yyyy-mm-dd hh:nn:ss (e.g. 2022-03-29 09:05:00)
- **<identifier>**: numerical identifier of the measure
- **<type>**: numeric value that encodes the type of data with this correspondence:
 - 1 = instantaneous value (A)
 - 2 = average value (B)
 - 3 = minimum value (C)
 - 4 = maximum value (D)
 - 6 = standard deviation (F)
 - 10 = minute of the minimum (L)
 - 11 = minute of the maximum (M)
 - 5 = valid data counter (E)
- **<value>**: measure value.
- **<validation>**: it is set to 0 if the measure value is valid, to 1 if the data is not valid.

In case of measurement in error (character "*" in the dynamic record), the measure will be entered with <value> equal to -9999 and <validation> equal to 1.

Two special cases may arise due to the advanced configuration possibilities of NanoSUM:

- Detailed identifiers for statistical processing.

Normally the statistical elaborations of a measure take the same numerical identifier of the measure and are distinguished by the literal code in the dynamic layout. It is possible to introduce a different numerical identifier also for statistical processing and in this case this number will be used in the <identifier> field.

- Customization of code letters.

As seen, it is possible to customize the coding letters of each type of measurement statistical processing. In this case it is necessary to pay particular attention to that the letter used is a valid letter in transcoding. Valid and encoded transcoding letters are:

- A = 1
- B = 2

- C = 3
- D = 4
- E = 5
- F = 6
- G = 7
- H = 8
- I = 9
- L = 10
- M = 11
- R = 12
- J = 13

If you customize with a non-coded letter, the record will still be inserted and <type> will be a number equal to the ASCII value of the letter. For example if you encode with the letter K, <type> will be 75.

Let's go back to the example of the dynamic path from the previous paragraph

```
ST0100,6,14.00.00,20,03,2022,0,M5,1,B,18.5,C,18.3,D,18.7,7,A,65,B,63,#21<CRLF>
```

Its transcode is as follows:

```
2022-03-20 14:00:00;1;2;18.5;0<CRLF>
```

```
2022-03-20 14:00:00;1;3;18.3;0<CRLF>
```

```
2022-03-20 14:00:00;1;4;18.7;0<CRLF>
```

```
2022-03-20 14:00:00;7;1;65;0<CRLF>
```

```
2022-03-20 14:00:00;7;2;63;0<CRLF>
```

The files in simplified ASCII layout are uploaded to the enabled FTP servers with a file name, with a .TXT extension, which contains the measurement identifier of the station and the upload date:

ST0<ID>_yyyymmddhhnss.TXT

Let's go back to the example of the station record 100

```
ST0100,6,14.00.00,20,03,2022,0,M5,1,B,18.5,C,18.3,D,18.7,7,A,65,B,63,#21<CRLF>
```

If the upload is done at 17:30:00, we will have the file ST0100_20220320173000.TXT

It is important to note that this layout cannot be used to represent alarm records which will therefore be discarded.

Appendix B: 4G module commands management

B.1 AT commands for file system and operating environment management

NanoSUM can receive AT commands on the USB serial port that is not used for online diagnostics. In addition to the 3GPP TS 27.005 and 27.007 commands, there is a series of custom commands for the low-level management of the module. In particular, we want to focus here on the commands for managing the file system and the operating environment of NanoSUM.

Be very careful when using these commands.

Incorrect use can lead to blocking or malfunctioning of the data logger

In the following, it is implied that:

- A Windows operating system is required.
- It is necessary to install the device driver package first.
- Some commands require a terminal capable of sending entire binary ASCII files to a module response prompt. A possible terminal with this feature is TeraTerm®.
- Each command must be terminated by the carriage return and line feed characters, <CRLF>.

The following file system management commands are supported.

- **AT#M2MLIST** – list of directory contents

Running the command displays a list of files in the current directory. You can specify a directory other than the current one using the syntax:

AT#M2MLIST=<path>

In the command, <path> (optional) is the path. Note that:

The maximum length of a path is 128 characters.

- The maximum number of characters allowed for a folder name is 64.
- <path> is case sensitive.
- <path> may or may not be enclosed in double quotes.
- Path separator is always “/” (slash).
- Current directory after boot is “/mod”.

Let us clarify with two examples.

AT#M2MLIST

#M2MLIST: <.>

#M2MLIST: <..>

#M2MLIST: <Archive>

#M2MLIST: <FTP0>

```
#M2MLIST: <FTP1>  
#M2MLIST: <LOG>  
#M2MLIST: "anylog.bin",343520  
#M2MLIST: "appcfg.ini",94  
#M2MLIST: "config.ini",993  
#M2MLIST: free bytes: 6555648
```

OK

AT#M2MLIST=FTP0

```
#M2MLIST: <.>  
#M2MLIST: <..>  
#M2MLIST: "PTR.BIN",7  
#M2MLIST: "ST01000_20220412151500.PART",82  
#M2MLIST: free bytes: 6553600
```

OK

- **AT#M2MREAD** – reading a file

Command used to read a file. The syntax is AT#M2MREAD=<file_name>. The <file_name> field is always mandatory and can be:

- A file name in the current directory.
- A filename relative to a path.

When specifying the file name, or the path, pay attention that:

- The maximum length of a path is 128 characters.
- The maximum number of characters allowed for a folder or file name is 64.
- The maximum number of characters in a file path is given by the sum of the previous ones i.e. 192 characters.
- If <file_name> is not present, an error is reported.
- The file name and path are case sensitive.
- <file_name> may or may not be enclosed in double quotes.

- **AT#M2MWRITE** – writing a file

Command used for writing a file. The syntax is

AT#M2MWRITE=<file_name>,<size>[,<binToMod>].

In this:

- <file_name> is the filename or path in the same way as the previous command.
- <size> is the size, in bytes, of the file to write.
- <binToMod> is an optional parameter that is usually not used. If this is set to 1 and <file_name> has the "bin" extension, the system saves the file in the "/mod" directory regardless of the specified path.

After the command, NanoSUM replies with a prompt >>> waiting for a number of bytes equal to <size>. Use the characteristics of the selected terminal to be able to send the desired file to the module.

- **AT#M2MDEL** – deletion of a file

Command used to delete a file. The syntax is AT#M2MDEL= <file_name>. For the <file_name> parameter, the same applies as for the other commands.

- **AT#M2MMKDIR** – creation of a directory

Command used for creating a directory. The syntax is AT#M2MMKDIR=<directory_name>.

- **AT#M2MCHDIR** – change of current directory

Command used to change the current directory. The syntax is AT#M2MCHDIR=<path>.

- **AT#M2MRMDIR** – removal of a directory

Command used to delete a directory. The syntax is AT#M2MRMDIR=<directory_name>.

The following commands for managing the operating environment are supported.

- **AT#M2MRUN** – enable executable at startup

It is a command used to set the execution permissions of a binary file. The syntax is:

AT#M2MRUN=<mode>[,<bin_file>[,<delay>]]

- <mode> represents the execution modes.

Modes 0, 1 and 2 generate a reboot; the others are immediate.

- 0: no execute permission for all binaries in "/mod".
- 1: execute permission for all binaries in "/mod".
- 2: Exclusive execute permission for the specified <bin_file>.
- 3: Stop all running applications.
- 4: Start all applications if they are not already running.
- 5: stop all running applications except < bin_file >; starts < bin_file > if it is not already running.

It is used mode 2 for anylog.bin with the AT#M2MRUN=2,anylog.bin command.

- <bin_file> name of the binary file.
- <delay> execution delay in seconds.

NanoSUM's executable binary file is called anylog.bin and should normally be the only program running. Startup delays are already managed at program level so <delay> can be omitted or set to zero. The command normally used is therefore always **AT#M2MRUN=2,anylog.bin**. This command is given at the factory and there is no need to give it again except in the event of module memory corruption.

- **AT+M2M** – enable datalogger operating environment

The previous command is not enough to start the application: the environment must be explicitly enabled to execute binary executable files.

The AT+M2M=1 command enables the application environment to run and generates a restart. This command is given at the factory and does not need to be given again except in the case of a voluntary temporary disabling of the environment.

The AT+M2M=0 command disables the application environment from running and generates a reboot. It is a convenient command in case you need to stop the application. Always remember to restart the environment with the command AT+M2M=1.

- **AT#REBOOT** – software reboot of the data logger

The command restarts the primary core of the datalogger for a clean start of the entire operating system.

In the following paragraphs we will show some examples of use.

B.2 Manual loading of the configuration file

To manually load the config.ini configuration file, we distinguish two cases:

1. Normal operation with NanoSUM always on

The configuration can also be changed while the operating program is running with the commands:

- AT#M2MLIST
- AT#M2MDEL=config.ini
- AT#M2MWRITE=config.ini,<size>
- At the >>> prompt send the configuration with the terminal program
- At the end of the loading the module will answer with OK
- AT#REBOOT to restart the module and make the new configuration operational

2. Operation in shutdown with NanoSUM off

In case of operation in shutdown, it can be restarted in diagnostic mode by pressing the REBOOT button for more than six seconds to go back to the previous case. However, remember to put the module back in normal mode when finished.

It is also possible to proceed in another way by temporarily stopping the operating environment:

- AT+M2M=0 stops the environment and restarts the module
- Proceed as in the previous point but without issuing the AT#REBOOT command
- AT+M2M = 1 restart the environment and the module

In cases of operation in shutdown it is necessary to know in advance the number of the USB serial port to be used. The safest procedure is the one that involves putting the module in diagnostics or using FTP servers.

B.3 Manual loading of operating program

To load the anylog.bin program file manually, proceed exactly as in paragraph B.2.

B.4 Manual disable and enable of the operating environment

To disable the operating environment, send the command AT+M2M=0. Pay attention that in this case all functions of the data logger are excluded, the operating program does not go into execution, and the module is to all intents and purposes a 4G modem.

To enable the operating environment, send the command AT+M2M=1. The command will restart the module and run the binary files enabled with the command AT#M2MRUN.

B.5 Execution enabling of operating program anylog.bin

To enable the anylog.bin program to run, type the command AT#M2MRUN=2,anylog.bin and then AT+M2M=1.

B.6 Manual enable and disable of the diagnostic mode

To enable diagnostic mode:

- AT+M2M=0 stops the environment and restarts the module
- AT#M2MLIST
- AT#M2MDEL=normal.opr
- AT+M2M = 1 restarts the environment and the module

To disable diagnostic mode and enter normal mode:

- AT#M2MWRITE=normal.opr,6
- At the prompt >>> write the six bytes **NORMAL** from the terminal
- At the end the module will reply with OK.
- AT#REBOOT to restart the module and make the new mode operational