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**Fuel level sensor
ETS.RS**

User manual

Hornelectronics Ltd

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1 Application

Fuel level sensor with interface output ETS.RS (hereinafter ETS.RS) is designed to measure the level of fuel and lubricants (FOL); it can be used on vehicles and fuel depots, in the systems of measuring and controlling FOL products amount: gasoline, diesel fuel, oil.

ETS.RS functions are determining the level of the fuel and conversion level to volume (in the absence of allocation tables sensor measured value is proportional to the level of fuel), transfer values measured by sensor via RS-232/RS-485 interface and Modbus/Omnicomm protocol.

ETS.RS can be used in a system with display devices or programmable controllers with the characteristics of the input electrical signals corresponding ETS.RS specifications.



Figure 1 – ETS.RS layout

To improve the reliability and performance of ETS.RS the following technical solutions and functions were laid in it:

- ✓ Sensor electronic circuit was immersed with elastic compound that provides maximum protection and reliability in all operating conditions. Measuring tubes are made of material that does not react chemically with the fuel components.
- ✓ Sensor contains an embedded voltage regulator, and its output is not affected by fluctuations in the supply voltage.
- ✓ Value averaging algorithm is integrated in sensor; this allows averaging values at a given time interval.
- ✓ Sensor has a built-in troubleshooting system.

2 Specifications

Name	Value
<i>Power supply</i>	
Supply voltage, V	10...30
Current consumption, mA	20
<i>Interfaces RS-232 (RS-485)</i>	
Data transfer protocol	Modbus, Omnicomm
Data transfer rate, default bit/s	19200
Supported data transfer rate bit/s	9600, 14440, 19200 38400, 57600, 115200
Parity	no
Stop bit	1
<i>Level measurement</i>	
Lower limit value of the controlled level of fuel from the tank bottom, mm	from 20
The upper limit of the measurement mm	from 200 to 4000
Basic level measurement reduced error % sensor length	± 1
Additional reduced error on the temperature,% *	No more than ± 1
<i>General characteristics</i>	
Overall dimensions, mm	L x 70 x 70
Weight, kg	from 0.3 to 3
Continuous operation time	unlimited
Operating temperature range, °C	from -40 to +70
Relative environment humidity at a temperature of no more than +40 °C, %	No more than 95

*Additional reduced error considers the impact of air temperature from - 40 °C to +70 °C.

3 Delivery package

Name	Quantity
ETS.RS	1 pc.
Extension Cable	1 pc.
Stopwater	1 pc.
Screws for mounting in a regular hole	1 pc.
Operation Manual (passport data, warranty coupon)	1 pc.
Packing box	1 pc.

* The sensor is available in the following sizes according to the heights of the tanks of vehicles: 700, 500, 350, 300, 180 mm, and the great lengths under personal order.

4 Design and operation

The measuring principle of the sensor is a capacitive one. Sensor sensing element is a cylindrical capacitor formed by two concentric tubes which capacitance varies with the level of tubes immersed in fuel.

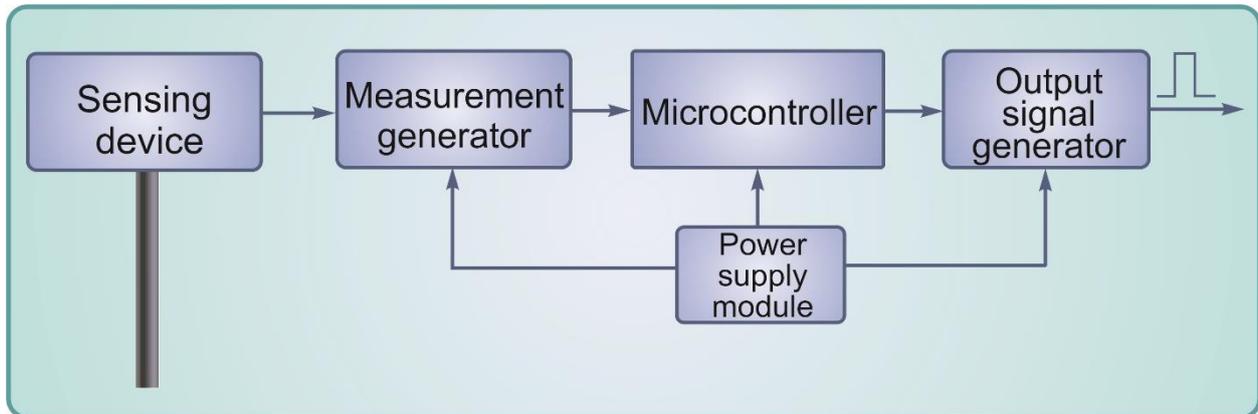


Figure 2 - ETS.RS Block diagram

This capacitor is connected to the drive circuit of the measuring generator, therefore, the measuring signal period outputted from the generator depends on sensing element capacitance, and accordingly on the level of immersion of the sensing tube into the fuel element. According to the embedded program, microcontroller measures the signal period output from the measuring generator performs its processing which includes checking for valid of measured value, averaging and temperature compensation. It calculates the values of output parameters, i.e. level of immersion, the corresponding amount of fuel, the value of Omnicomm protocol N , F , T parameters and generates diagnostic codes. Upon request (see chapter 6.3, 6.4 - "Omnicomm Protocol Description", "MODBUS Protocol Description") all calculated and measured parameters can be read along the lines of the interface RS-232/RS-485.

Power module (Fig. 2) is used for the formation of sensor components stable voltage from the onboard network input voltage; protection the sensor from surges of TV onboard network and polarity reversal to the supply lines and interference.

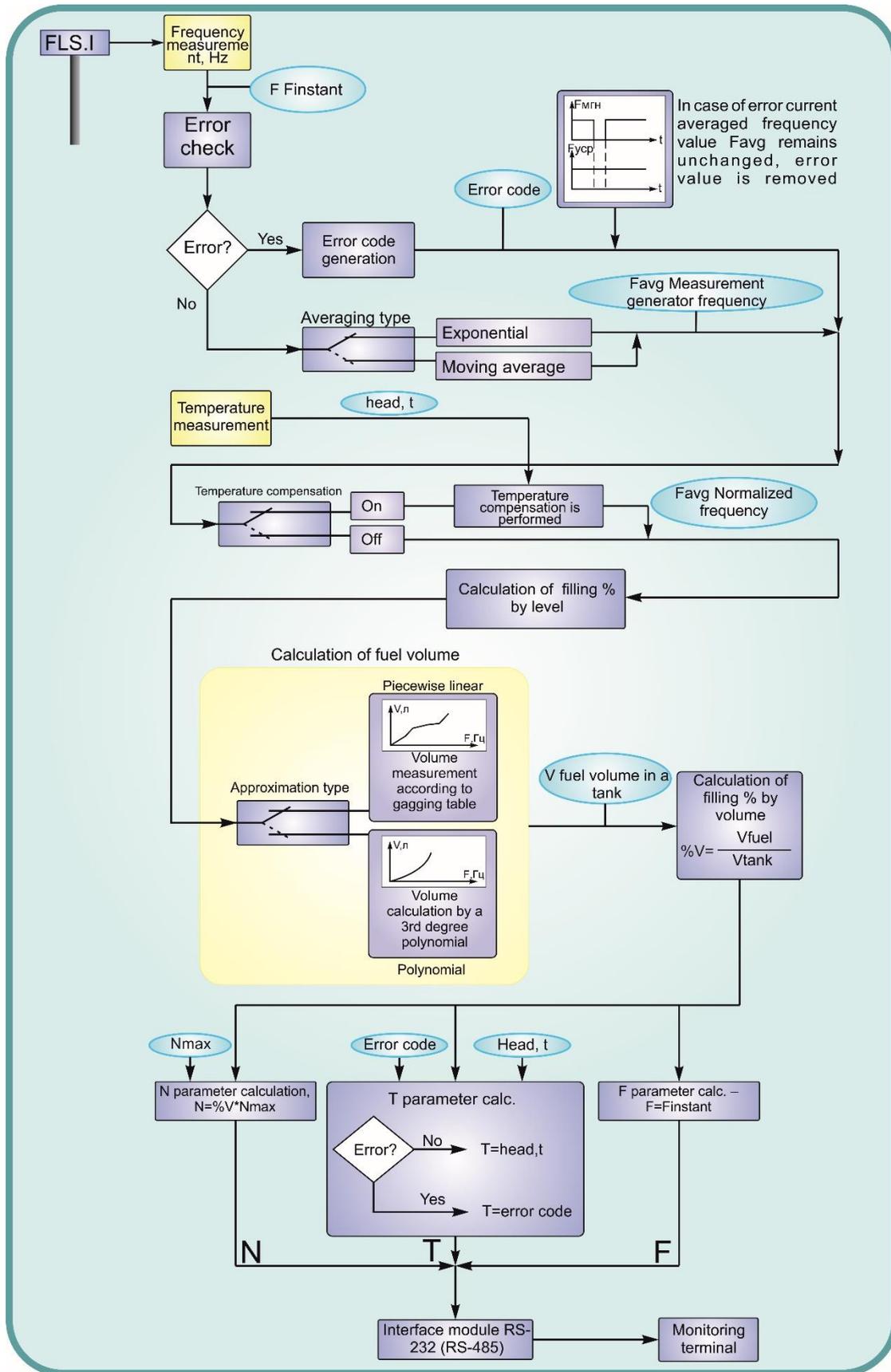


Figure 3 – ETS.RS operation algorithm

⚠ WARNING! It should be remembered that prolonged exposure of limit (and especially above the limit) values to a switch in the feed network can lead to irreversible consequences in the circuits cell protection due to overheating or breakdown. This in turn can lead to malfunction of the device. Operating range of supply voltages is given in "Specifications."

Description of ETS.RS algorithm (Figure 3):

1. The first stage performs a frequency measurement ($F_{instant}$) in the sensor if there are no errors in this case, then the value averaging according to a predetermined in the software type of averaging occurs:

⚠ WARNING! When power is on, averaging module is initialized so that for any type of averaging F_{avg} is assumed to be equal to the first measured value of the instantaneous frequency.

Moving average

Simple Moving Average (SMA) is the arithmetic mean value of n values obtained for the period of time t

(Fig. 4):

$$SMA(n) = \frac{\sum_{i=1}^n F_i}{n},$$

where F_i is the instantaneous frequency, Hz.

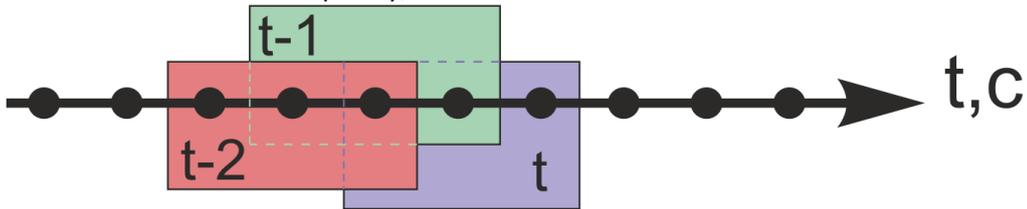
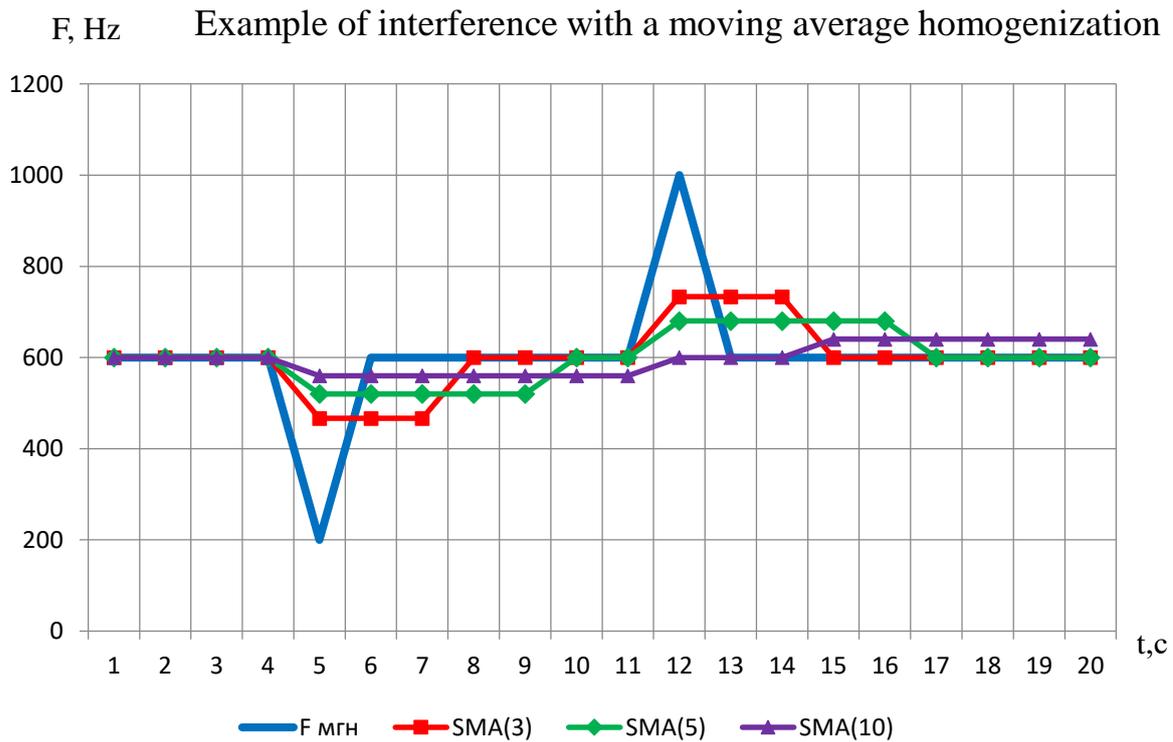
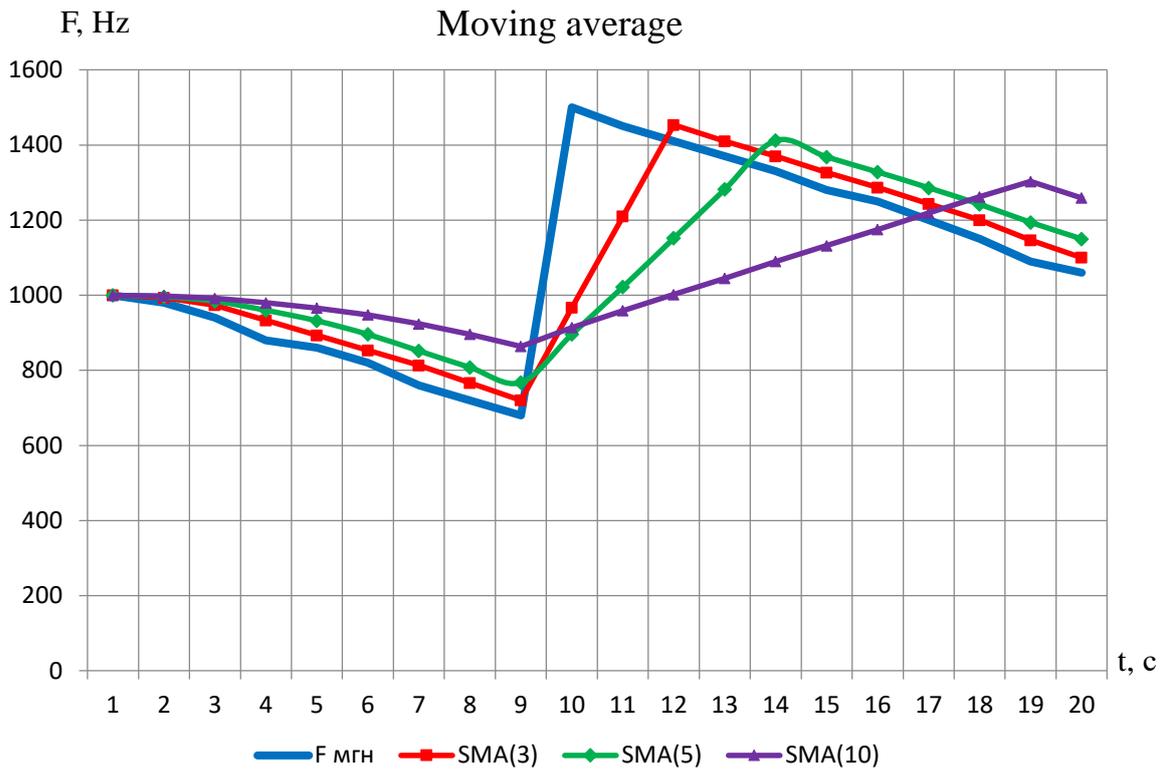


Figure 4 – Moving average of 3 values.

Below are graphs in which:

- blue line is the curve of instantaneous frequency values change
- red line is the curve averaging of 3 recent values
- green line is the curve averaging of 5 recent values
- purple line is the curve averaging of 10 recent values



Exponential average

Exponential moving average (EMA) considers more recent data as more important. Consequently, this type of moving average reacts faster to changes in its values.

Calculation of the exponential moving average for the averaging interval t is calculated as:

$$Y_i = Y_{i-1} + \alpha(X - Y_{i-1}), \text{ where}$$

Y_i is EMA at the point corresponding to a particular point in time

Y_{i-1} is EMA at a point preceding the selected time

X - the current frequency, Hz

$\alpha = \frac{3,5}{t}$ is smoothing coefficient that takes values from 0 to 1

t is the averaging interval (s), the minimum allowable t value = 5 s.

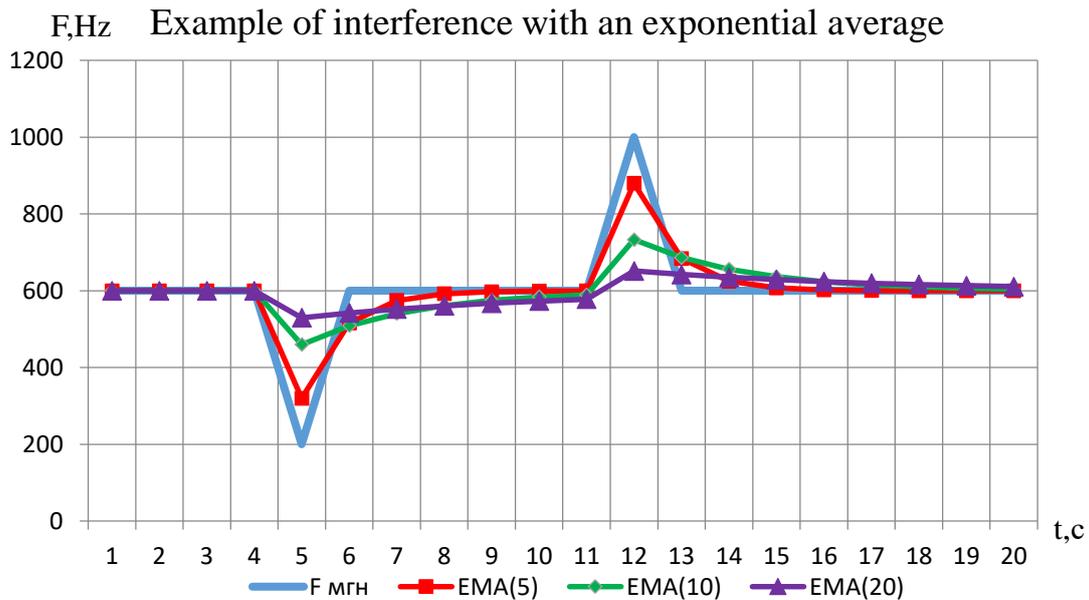
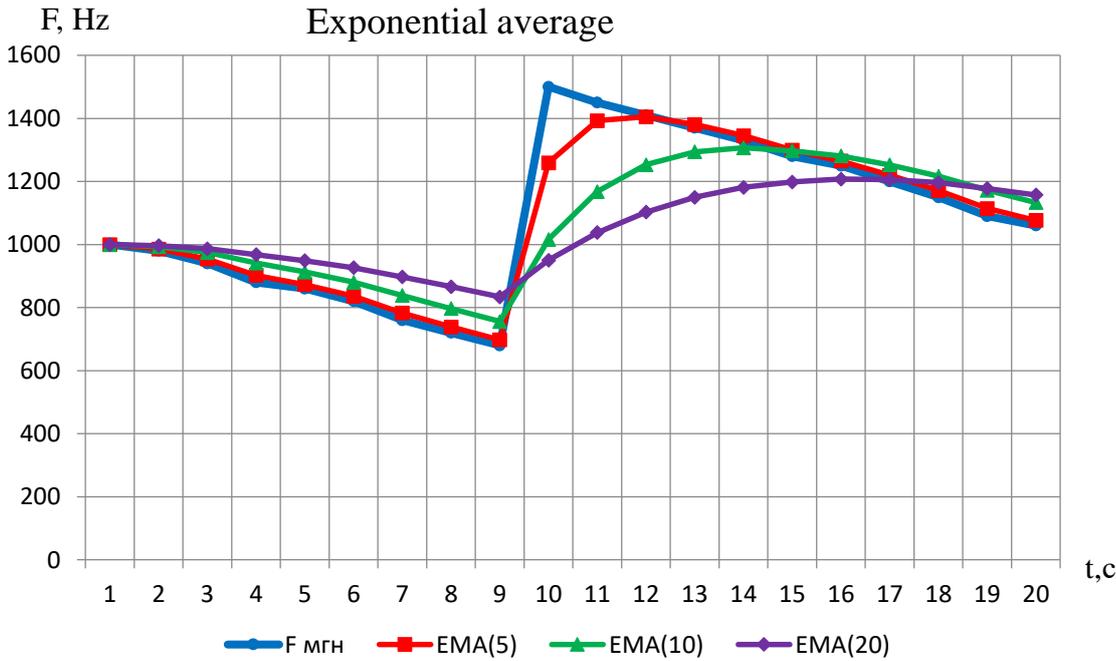
Below are graphs in which:

blue line is the curve of variation of the instantaneous frequency values;

red line is the average curve at $t = 5$ sec;

green line is average curve at $t = 10$ sec;

purple line is average curve at $t = 20$ sec;



⚠ WARNING! If there is an error in a measurement of the instantaneous frequency, then formation of fixed error code occurs, the current average frequency value F_{avg} remains unchanged, and an erroneous value is discarded (Fig. 5).

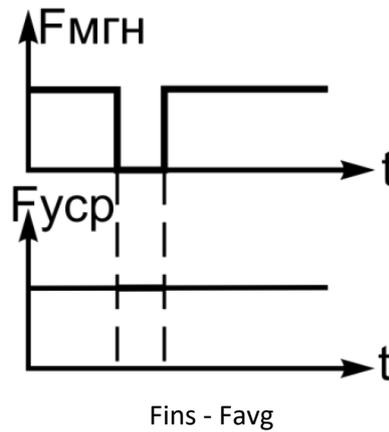


Figure 5 – Error code generation

2. If Temperature compensation option is enabled in the sensor, then temperature compensation is performed in accordance with the measured value of the temperature of the head; if the temperature compensation function is disabled, then averaged frequency value remains unchanged.

⚠ WARNING! Currently, the use of temperature compensation is not necessary since additional error on the temperature is less than 1%. All factory coefficients are equal to 1.

3. Calculation of sensor immersion in fuel percent is performed on level.

4. Based on the calculated immersion percent on level amount of fuel according to the selected type of approximation is calculated:

Piecewise linear approximation - this partition of a complex curved depending on the level of the amount of fuel at a number of parts with subsequent replacement of these parts of the curve segments of a straight line.

Piecewise linear approximation is best suited for complex-shaped tanks in which the dependence of the level is linear in certain areas (Fig. 6).

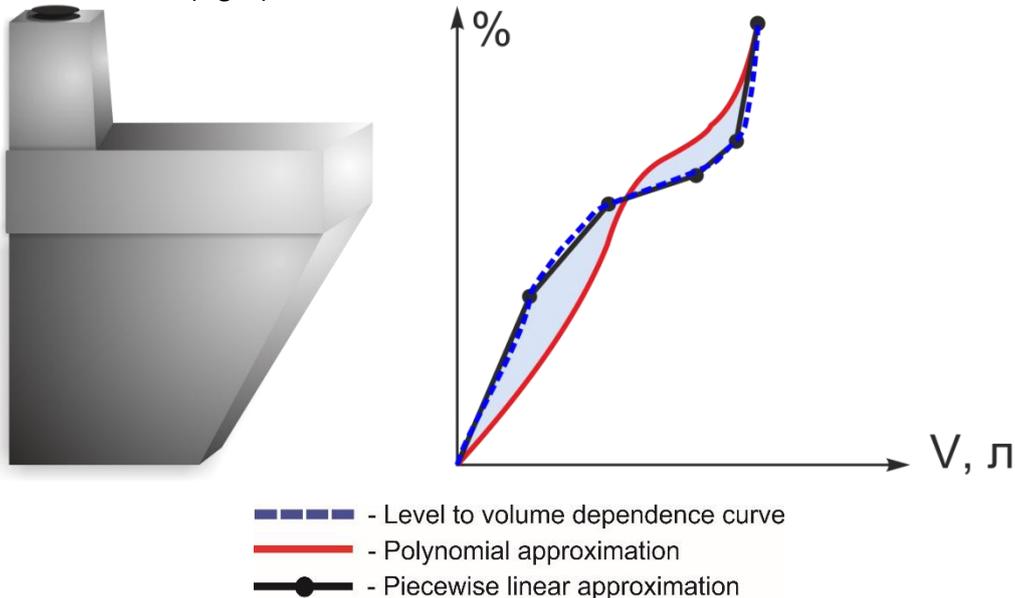


Figure 6 - The advantage of a piecewise linear approximation for the complex shape of tanks

Polynomial approximation is a replacement of complex third-degree polynomial functions that approximate the original function:

$$V(\%level) = A * \%_{level}^3 + B * \%_{level}^2 + C * \%_{level} + D$$

Where A, B, C, D are polynomial coefficients calculated with ETSConfig configuration software program on the basis of data spilling tank.

Polynomial approximation is best suited for tanks cylindrical shape (Fig. 7)

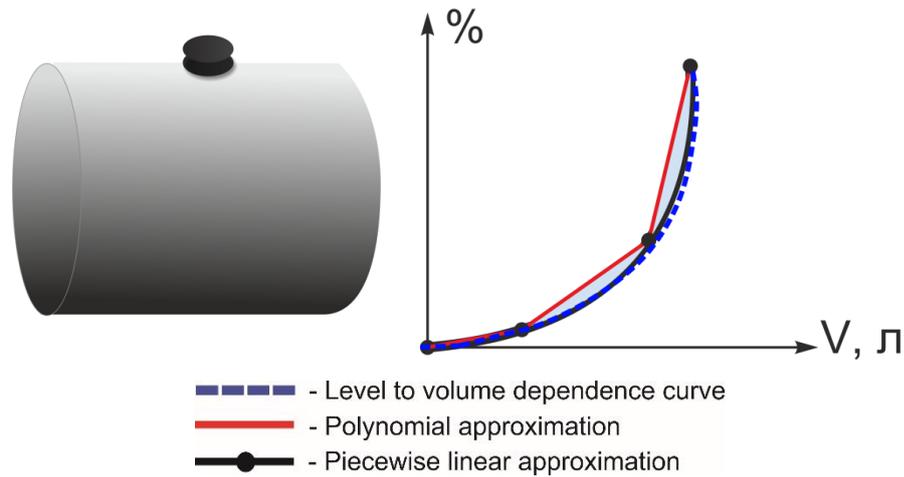


Figure 7 - The advantage of polynomial approximation for tanks of cylindrical shape

5. A percentage calculation of filling a tank by volume is performed: $V_{\%} = \frac{V_{fuel}}{V_{tank}}$.

6. Omnicomm *N*, *T* and *F* protocol parameters calculation is performed:

- Calculation of the parameters *N*: $N = V_{\%} \cdot N_{max}$, where N_{max} is the maximum *N* value, is given in the software ETS.RSConfig.
- Calculation of *T* parameter: if there is no error, then $T = t$ of the head; if there is an error $T = \text{error code}$ (see table "Diagnostic error codes ETS.RS transmitted in the *T* field).
- Calculation of the parameter *F*: $F = F_{instant}$.

7. Calculated parameters *N*, *T* and *F* can be read by the MODBUS or Omnicomm protocols by interface lines RS-232/RS-485. MODBUS protocol also allows reading the other calculated sensor parameters (see Section 6.4).

<i>Diagnostic ETS.RS error codes transmitted in the T field</i>	
Code, <i>T</i> field of Omnicomm protocol*	Error description
-100; 156 (-1; 255)	The sensor is not calibrated, both on bottom and top
-101; 155 (-2; 254)	The sensor is not calibrated on top
-102; 154 (-3; 253)	Generator frequency is 0
-103; 153 (-4; 252)	Dividing by zero, the sensor is calibrated in the same point
-104; 152 (-5; 251)	EEPROM reading error
-105; 151 (-6; 250)	Out of range, top $F > (F_{max} + 10\%)$
-106; 150 (-7; 249)	Out of range, bottom $F < (F_{min} - 10\%)$

* In brackets error codes for the sensors with the firmware to 5112010 are given

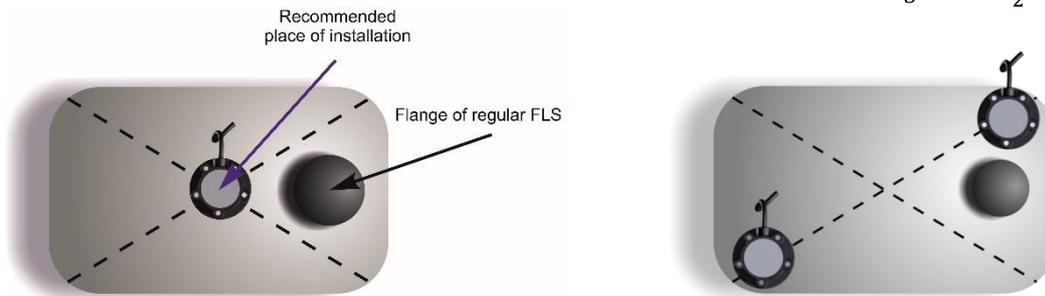
5 Operating rules

5.1 Requirements for the sensor operation

- Before putting into operation, the sensor must hold its external examination; in case of presence of mechanical damage (cracks, chips, dents, etc.) sensor operation is not permitted;
- After mounting the sensor on the vehicle it is recommended to seal all electrical connections;
- Sensor repair should be performed in certified service centers;
- Sensor operations must be performed by personnel who examined the device, its operation principle and all instructions in this manual;
- The dielectric constant of the medium must be constant. Failure to do so results in an increase in measuring errors.

5.2 General information on installation

Installation of the sensor can be made on the place of regular fuel level sensor or by cutting it in the tank. It is recommended to install it as close as possible to the geometric center of the tank (Fig. 8a), in order to avoid the influence of vehicle inclination on sensor readings. If the sensor is installed on a two-tank vehicle 1 sensor is installed on each tank. In some cases (when operating vehicles on rough terrain) it is recommended to install two sensors on a single tank (Fig. 8b). In this case, they must be positioned in the same diagonal from opposite side walls of the tanks and to calculate the total value output by the formula: $N_{gen} = \frac{N_1 + N_2}{2}$



a) closer to the geometric center of the tank; b) two sensors on one tank

Figure 8 - Selecting a sensor location

5.3 Connection diagram

Pin assignment			
Pin No.	Assignment	Wire color	
1	Power supply «-»	Brown	
2	Power supply «+»	Red	
3	A/Rx	Green	
4	B/Tx	Yellow	

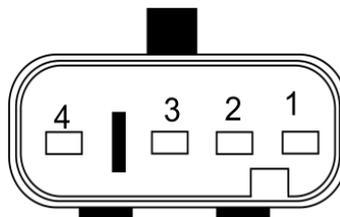
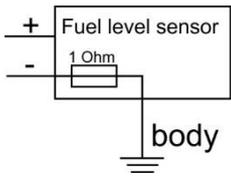
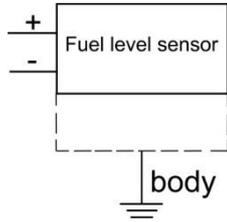


Figure 9 - ETS.RS connector

To implement different ETS.RS connections on TV two types of sensors are issued:



Type 1. Sensor with aluminum body. Designed to connect the sensors to the onboard vehicle network breaker after mass. Wire power "-" associated with the sensor body (minus the resistance between the wire and the body less than 1 Ohm).



Type 2. RM. Sensor with a carbon-fiber body. Designed to connect sensors directly to the battery and on-board network.

Legend

A

Connection point of "+" power supply



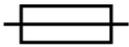
B

Connection point of "-" power supply



FA

Fuse of "+" power supply



Sensor power supply: max 20 mA

Recorder power supply: acc. to passport

DC-DC

Power supply source with isolated inputs - outputs



Variant 1

Provides the system operation ONLY WHEN MASS BREAKER IS ON (CONNECTION AFTER MASS BREAKER) - a simple option.

⚠ **WARNING!** According to this scheme, sensors can be connected with both aluminum and carbon-fiber body.

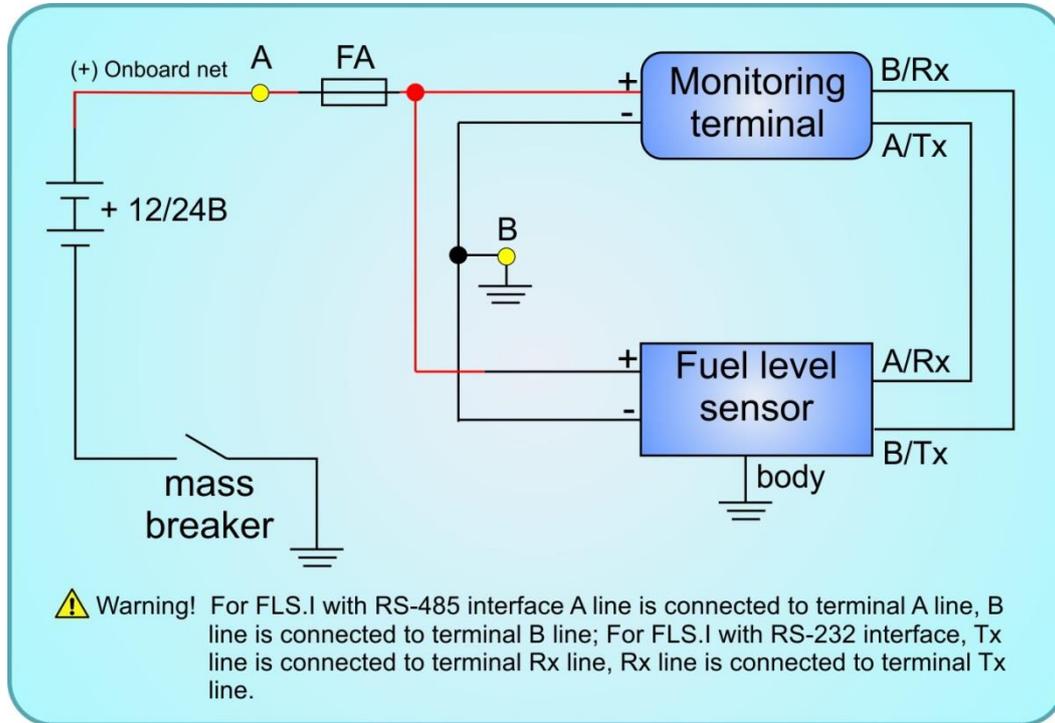


Figure 10 – Connection diagram before mass breaker

- ⚠ FA fuse must be installed as close to the point of connection " + power " as possible to protect the vehicle wiring line monitoring system power short-circuit.
- ⚠ Point A is connected in the presence of (+) board network with the ignition is off. It is recommended to connect to an established fuse to prevent them from burning due to the additional load. One of the best places is front red wire ignition .
Point B is taken on the machine body under the dashboard.

⚠ **WARNING! Connect the minus and terminal of the sensor is necessary to be taken from one point!**

Advantages:

- ✓ Reliability
- ✓ Simple to use

Disadvantages:

- ✓ Does not provide continuous monitoring

Variant 2

Provides system CONTINUOUS OPERATION (CONNECTION TO MASS BREAKER). Applied in the case when you need 24-hours monitoring of the vehicle. Sensor and monitoring terminal must be powered directly from the battery.

⚠ WARNING! Under this scheme only sensors with carbon-fiber body can connect.

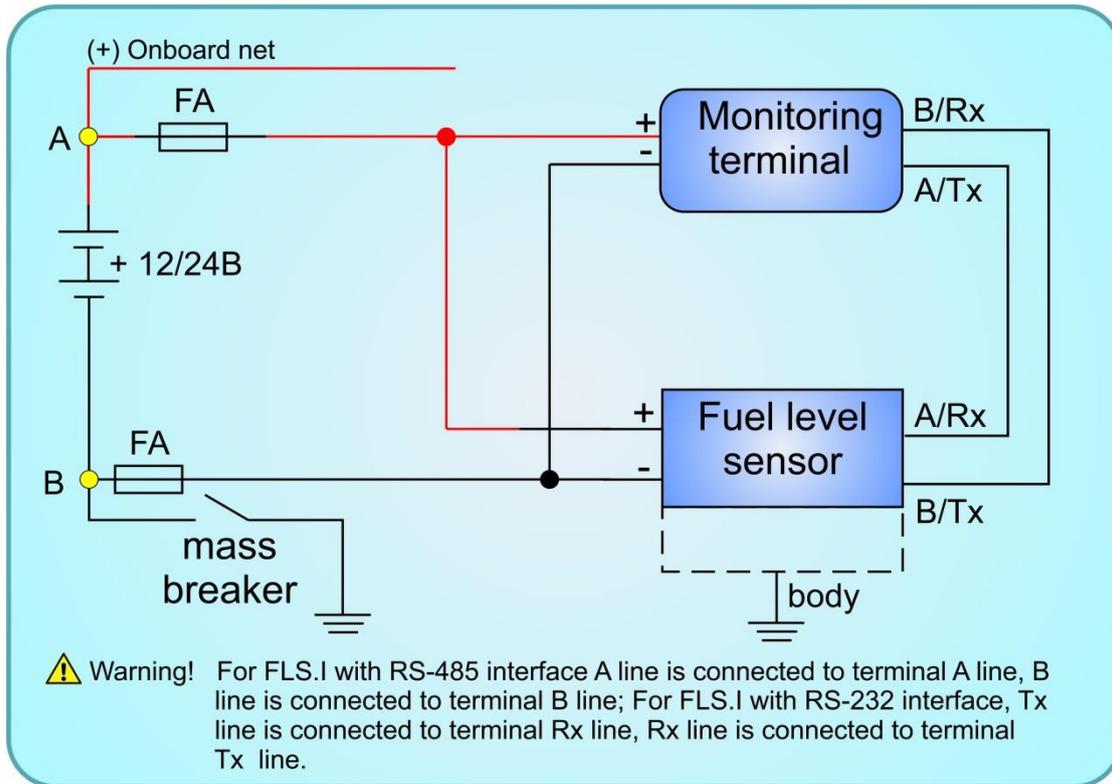


Figure 11 - Wiring after mass breaker

FA fuse must be installed as close to the point of connection " + power " as possible to protect the vehicle wiring line monitoring system power short-circuit.

- ⚠** Points A and B are connected to the junction terminals "+" and "-" of the battery.
- ⚠ WARNING!** DO NOT use this scheme on the fuel tanks of vehicles with gasoline engines.
- ⚠ WARNING!** By connecting under this variant you must verify the absence of contact between the outer tube and the casing of the tank or fuel level sensors staff.
- ⚠ WARNING!** FA2 fuse installing is obligatory. If during operation with open "mass breaker" a contact between the ETS.RS outer tube and the tank housing or ETS.RS will occur, FA2 protect your wiring system from burnout.

Advantages:

- ✓ Easy
- ✓ Provides clock control

Disadvantages:

- ✓ Unreliable if 100% protection against contact with the body of the outer tube of the tank or regular fuel level sensor is not provided.
- ✓ Do not use for petrol car fuel tanks

⚠ Variant 3

⚠ WARNING! Under this scheme sensor with RS-232 interface can only be connected.

Ensures CONTINUOUS OPERATION - the best option possible.

To ensure the galvanic isolation of ETS.RS for signal circuits and power lines electrical isolation module produced by our company are used.

⚠ WARNING! According to this scheme, sensors with aluminum and carbon-fiber body can be connected.

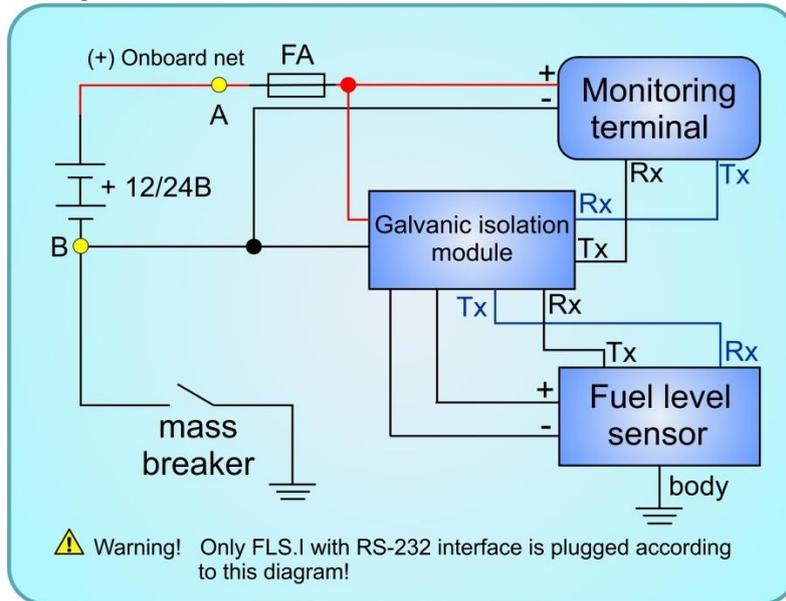


Figure 12 – Connection diagram with galvanic isolation module circuit.

⚠ FA fuse must be installed as close to the point of connection " + power " as possible to protect the vehicle wiring line monitoring system power short-circuit.

⚠ Points A and B are connected to the junction terminals "+" and "-" of the battery.

⚠ Electrical isolation module is installed in the cockpit, next to the terminal.

Advantages:

- ✓ Easy
- ✓ Provides clock control

Disadvantages:

- ✓ More expensive than variant No.2.

⚠ WARNING! According to this scheme, sensors with aluminum and carbon-fiber body can be connected.

Variant 4

Ensures CONTINUOUS OPERATION - the most reliable option.

The system uses a power supply with isolated inputs-outputs. Parameters of the power supply should be selected based on the technical data specified in the data sheets on the ETS.RS terminal monitoring, etc., with a 20% margin.

ETS.RS voltage: 10-33 V.

ETS.RS supply current: max 20 mA.

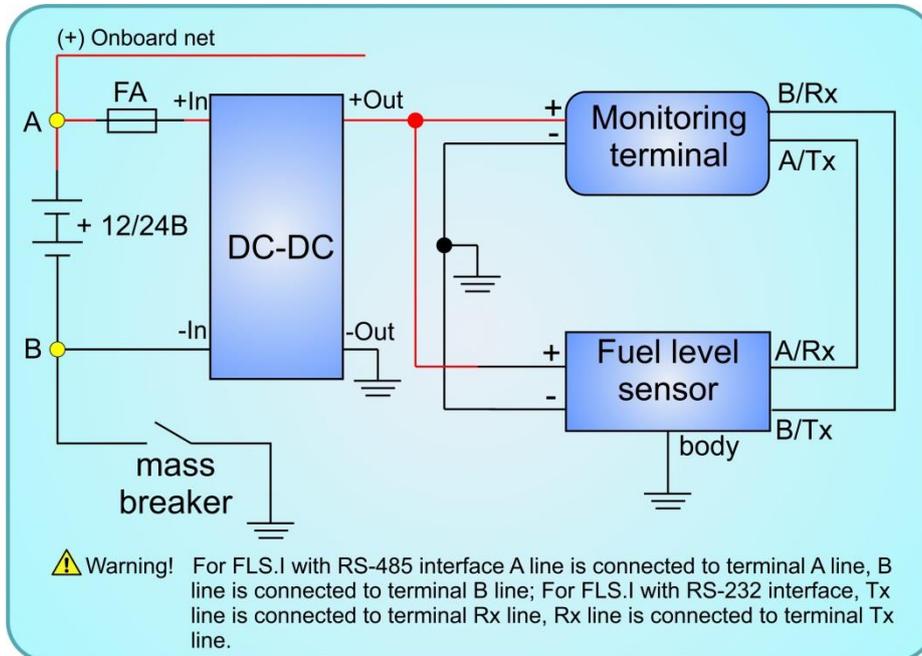


Figure 13 - Connection diagram with optional DC-DC converter

- ⚠ FA fuse must be installed as close to the point of connection " + power " as possible to protect the vehicle wiring line monitoring system power short-circuit.
- ⚠ Points A and B are connected to the junction terminals "+" and "-" of the battery.

Advantages:

- ✓ Reliability, DC-DC provides protection for both the sensor and the terminal.
- ✓ Provides clock control

Disadvantages:

- ✓ Price

5.4 . Installation procedure

1. Drill a central hole (Fig. 14) for mounting the sensor. To install the sensor bimetallic crown with diameter of 35 mm is necessary. Insert the sensor and mark the holes for attaching the sensor to the tank. Hole pattern for fixing elements is shown in Fig. 14.

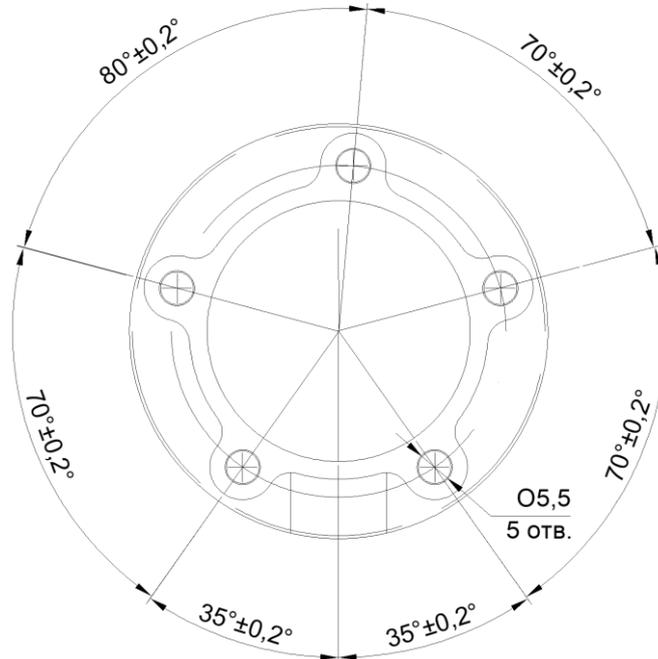


Figure 14 - Arrangement of holes for fasteners

- ⚠ **WARNING!** 1. Before drilling the fuel tank with diesel fuel must be completely filled to avoid vapor explosion! The gasoline engine fuel tank must completely be filled with water. Otherwise evaporate and remove remaining fuel.
- 2. Trim the sensor to the desired height - see Fig. 15. Use hacksaw to saw off the aluminum tube to the height of the tank, leaving not less than 20 mm between the end of the sensor and the bottom of the tank for accumulation of water and dirt. Thoroughly clean aluminum shavings between handsets. Remove bevel from the tubes.
- 3. Insert lock-pin into the end of the tubes. It is supplied with the sensor (lock-pin design - see paragraph 5.5).
- ⚠ **WARNING!** Using sensors without locking it is strictly prohibited and may result in sensor damage or failure due to loosening of the tubes during operation.

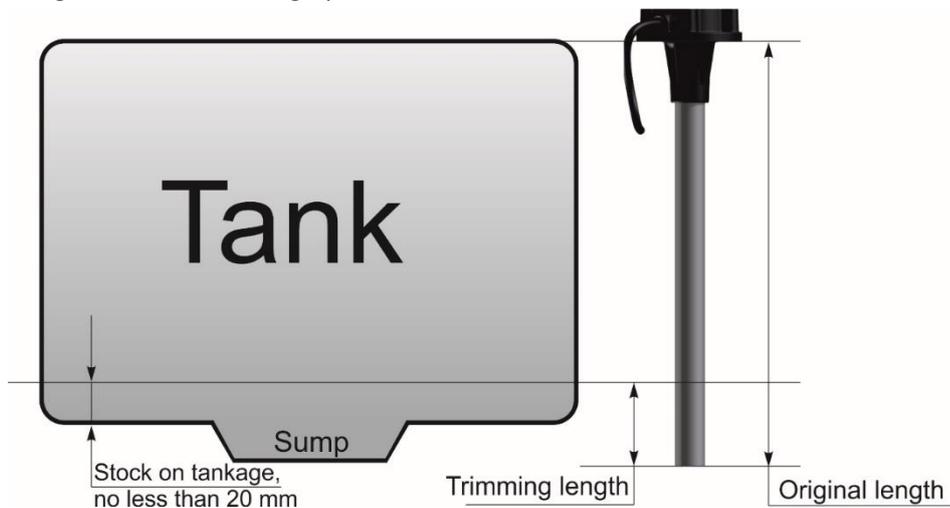


Figure 15 - Diagram of the sensor cutting

1. Route the cable to connect the ETS.RS, make all connections in accordance with the selected connection diagram (see section 5.3).
2. Check operation of ETS.RS (see paragraph 6.5).
3. Disable ETS.RS.
4. Install the sensor and assemble it with self-driving screws (or screws when installing on staffing fixation).
5. Connect ETS.RS

⚠ **WARNING!** Do not get wires crossed, incorrect connection may damage sensor!

⚠ **WARNING!** Do not apply voltage exceeding 30 V.

5.5 Lock-pin mechanism

After sensors' cutting you must always insert lock-pin supplied with the sensor into the end of the tube.

⚠ **WARNING!** Using sensors without lock-pins is strictly prohibited and may result in sensor damage due to loosening of the tubes during operation.

Lock-pin has three positions:

Position 1

Before inserting lock-pin into the sensor you should extend inner rod from a lock-pin by pushing it until it stops (Fig. 16).

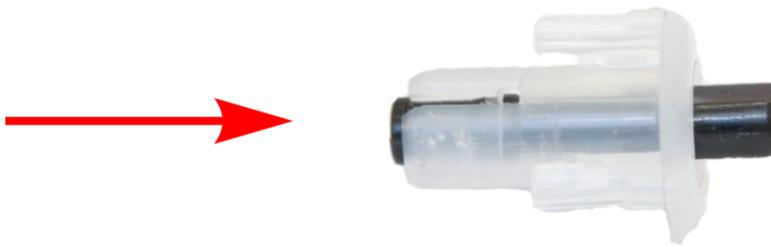


Figure 16 - Lock-pin look in position 1

Position 2

After inserting the lock-pin inside the sensor, press the inner locking rod and insert it into the lock-pin on one level with ETS.RS. In this lock-pin is wedged and thus it is fixed in the sensor tube (Fig. 17).



Figure 17 - Lock-pin look in position 2

Position 3

To get the lock-pin from the sensor, press the inner locking rod and push it deep into the lock-pin. Then wedging is removed and lock-pin can be easily removed from the sensor (Fig. 18).



Figure 18 - Lock-pin look in position 3

6 ETS.RS Customization and Configuration

To configure ETS.RS it is necessary to:

1. Download the software archive **ETSTConfig** from www.ets-by.ru website, install the **ETSTConfig** software.
2. Connect the sensor to the PC as shown in Fig. 19.

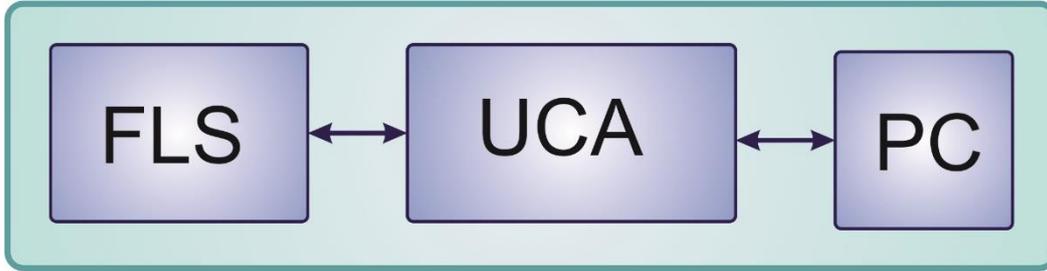


Figure 19 - Connection ETS.RS to PC

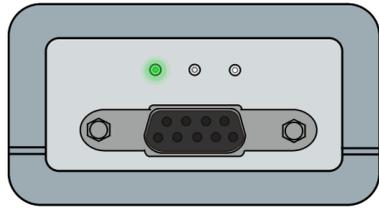
As a device for connecting a sensor to the PC you must use a universal service adapter UCA 2.2 (Fig. 20), produced by our company (for connection / cable required calibration ETS.RS UCA - ETS.RS 4-pin).



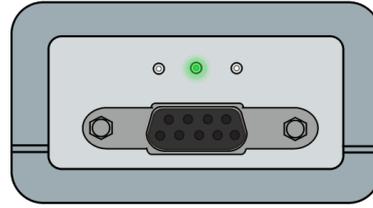
Figure 20 - UCA look

<i>UCA to ETS.RS RS-485 connection diagram</i>					
DRB-9F			ETS.RS RS-485		
Pin socket	Contact purpose		Pin socket	Contact purpose	Wire color
2	General	—	1	Power supply «-»	Brown
1	+12 V	—	2	Power supply «+»	Red
9	A	—	3	A	Green
5	V	—	4	V	Yellow
<i>UCA to ETS.RS RS-232 connection diagram</i>					
DRB-9F			ETS.RS RS-232		
Pin socket	Contact purpose		Pin socket	Contact purpose	Wire color
2	General	—	1	Power supply «-»	Brown
1	+12V	—	2	Power supply «+»	Red
9	Tx	—	3	Rx	Green
5	Rx	—	4	Tx	Yellow

3. In UCA you should select the RS-232 mode, TTL UART (first LED is lit, fig. 21a) or RS-485, TTL UART (center LED is lit, fig. 21b).



a) RS-232 Mode



b) RS-485 mode

Figure 21 - Indication of UCA operation

4. Run **ETSConfig** software. In the window opened (Figure 22), select the sensor type: Interface.

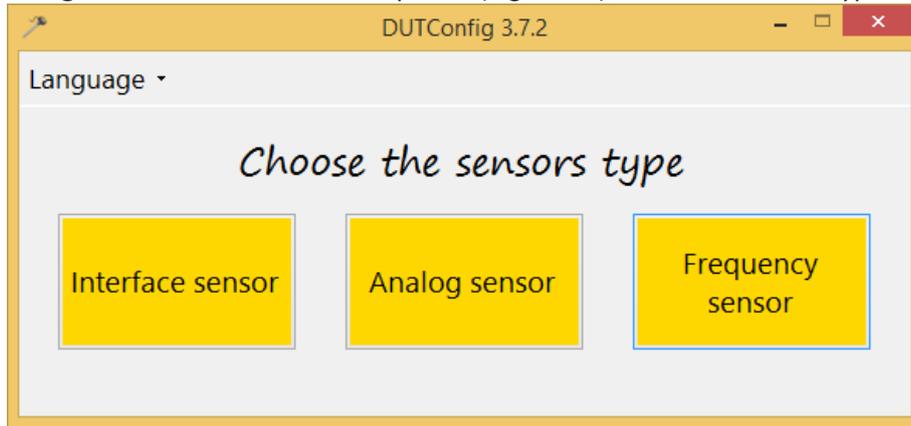


Figure 2 – Sensor selection

5. In the opened window choose:

- Port connection (Fig. 23.1), its number can be found in Windows Device Manager, where it was listed as driver UCA;
- Baud rate (standard sensor speed - 19200) (Fig. 23.2);

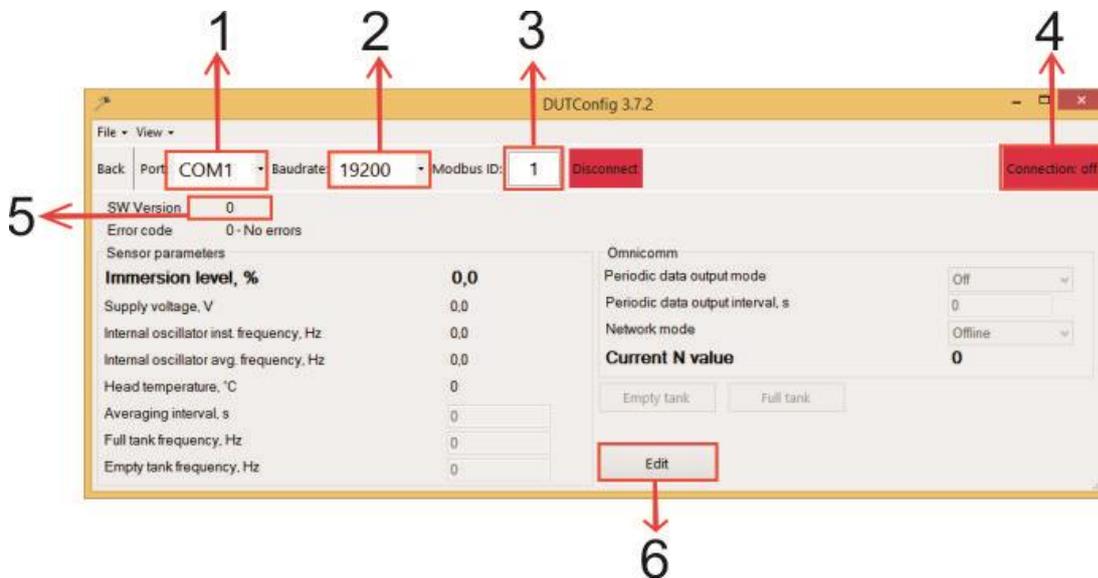


Figure 23 - Connecting ETS.RS

6. Press [Connect], make sure that the connection with the sensor is established (Fig. 23.4). In case of a successful connection the main window will show the software version (Fig. 23.5) and the sensor ID (Fig. 23.3).

⚠ WARNING! If DEVICES DIDN'T CONNECT AUTOMATICALLY, in the enter 0 in "Modbus ID" field and click [Connect].

- ⚠ **WARNING!** THE INICIAL ID NUMBER FOR ALL DEVICES - 1.
- ⚠ **WARNING!** To change the baud rate and the device ID (in any mode) you must:
 1. Press [Connect]
 2. Press [Reset] (Fig. 23.6)
 3. Set the desired baud rate and enter a new ID
 4. Press [OK] button in the main window

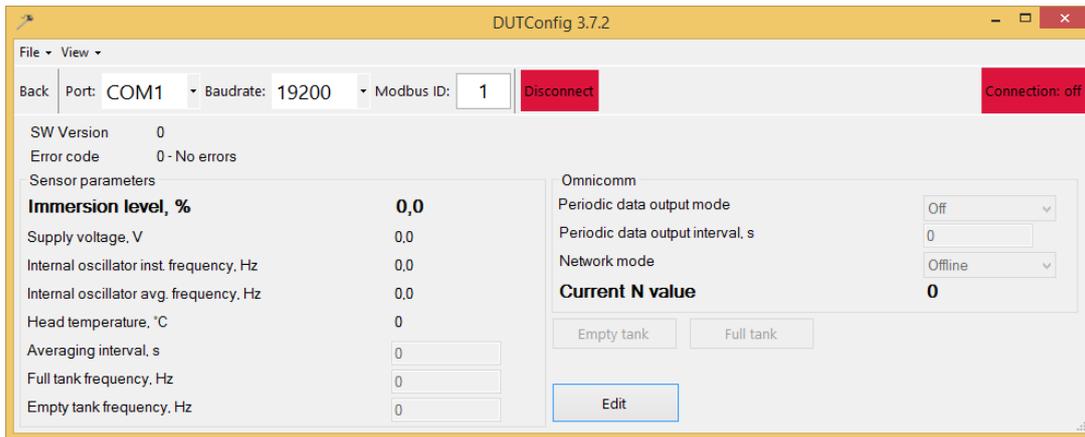


Figure 24 - The process of changing the values of ID and baud rate

6.1 Configuring the ETS.RS in standard mode

In standard mode the following parameters are configured:

1. Sensor calibration
2. Averaging interval setting
3. Parameters of the sensor operation under Omnicomm protocol are set

To configure ETS.RS in standard mode, you should:

1. Press [Reset] (Fig. 23.6).
2. Input the required parameters
3. Save your settings in the sensor by clicking [OK].

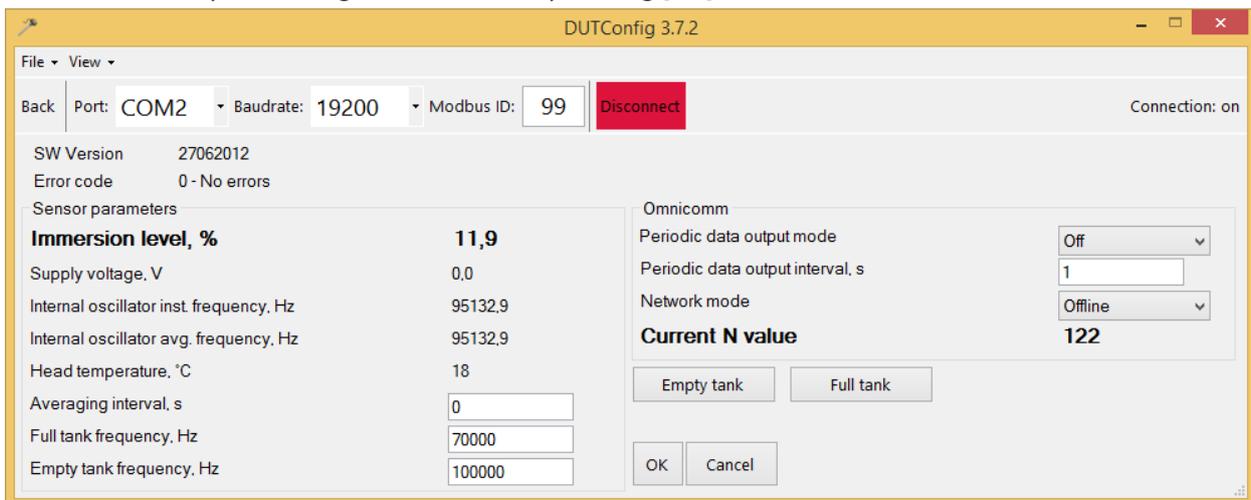


Figure 25 - ETS.RS standard mode settings

6.1.1 Sensor Calibration

To calibrate the sensor you should:

1. Fully immerse the sensor in the fuel
2. Press [Full tank]
3. Get the sensor out of fuel and dry it for 2-3 minutes
4. Press [Empty tank]

If the frequency of dry and fully immersed in the fuel sensor is known, they can be imputed manually:

1. In the "frequency for a full tank, Hz" field, input the frequency corresponding to the full tank.
2. In the "frequency for the empty tank Hz" field, input the frequency corresponding to the empty tank.

6.1.2 Setting the averaging interval

Averaging interval is the period in which the averaging of the measured values of the measuring frequency generator is done. To set the averaging interval it is necessary to input the number of seconds in the "averaging interval, s."

 **WARNING!** Possible averaging interval: 0 – 90 s; recommended averaging interval 8 – 30 s.

 **WARNING!** The default method of averaging is running average. Another method of averaging can be selected in the advanced mode (see chapter 6.2).

6.1.3 Setting the ETS.RS parameters via Omnicomm protocol

To configure the Omnicomm protocol settings you should:

1. Choose the mode of sending data to the ETS.RS terminal. To do this in the "Data auto output Flag" field select:

- Off when the terminal itself interrogates the sensor. ETS.RS transmits the data in response to requests from the terminal.
- Binary if ETS.RS itself transfers data in binary format at a time interval specified in the software in the "Period of data output, s" field.
- Text if the ETS.RS itself transfers data in character format at a time interval specified in the software in the "Period of data output, s" field.

2. Specify the period of data output (only if "Data auto output Flag" field value is other than "Off"). To do this in the "Period of data output, s" field, enter the time interval in seconds that will be sending data packets to the ETS.RS terminal.

3. Set network mode. To do this, indicate in the "network mode" field:

- Stand-alone, if the terminal is connected to one ETS.RS232 or one ETS.RS485. In this mode responds to any of ETS.RS ID.
- Network, if one terminal simultaneously connects several sensors (only for ETS.RS485). In this mode, the ETS.RS responds only to its ID and ID=255.

6.2 ETS.RS configuration in advanced mode

 **WARNING!** To setup and configure of the sensor in the advanced mode of the program menu select Mode → Advanced in the main window.

In advanced mode the following parameters are configured:

1. Sensor calibration;
2. Switch on/off temperature compensation
3. The level to volume conversion (ETS.RS gaging) is set
4. The type and the averaging interval are set
5. Parameters of the sensor operation under Omnicomm protocol are set

To configure the ETS.RS in the advanced mode, you should:

1. Press [Set] (Fig. 23.6)
2. Select tab Mode → Advanced in the main window
3. Set the required settings
4. Save your settings in the sensor, for this click [OK].

6.2.1 Sensor calibration

Sensor calibration in advanced mode is similar to calibration in standard mode (see paragraph 6.1.1).

6.2.2 Temperature compensation setting

Temperature compensation is a feature that allows you to remove the dependence of the ETS.RS operation from the temperature change.

To set the temperature compensation it is necessary to select On/Off in the "Temperature compensation" field.

⚠ WARNING! Currently, the use of temperature compensation is not necessary since additional reduced error on the temperature is less than 1%. All factory coefficients are equal to 1.

6.2.3 Level to volume calibration (ETS.RS gagging)

1. In the "Approximation type" field, indicate its type:
2. Fill in the gagging table:

A piecewise-linear approximation type is used for tanks of complex shape

A polynomial approximation type is used for tanks of cylindrical and elliptical shape (fuel trucks, tanks).

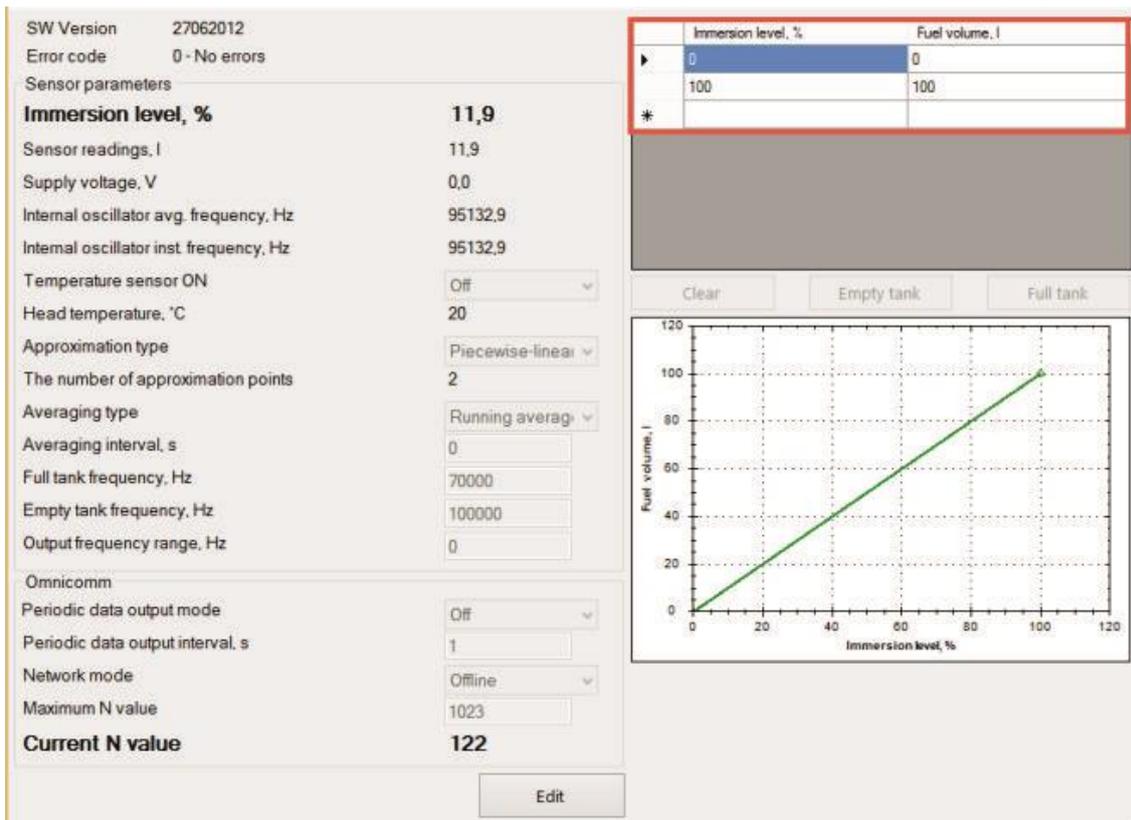


Figure 26 - The piecewise linear approximation

- For the piecewise linear approximation type (Fig. 26), enter the following lines in the calibration table: level of immersion in % and the corresponding value of the amount of fuel in liters. You allocate any strings (not necessarily strictly ascending or descending). Mistakenly entered lines can be removed.

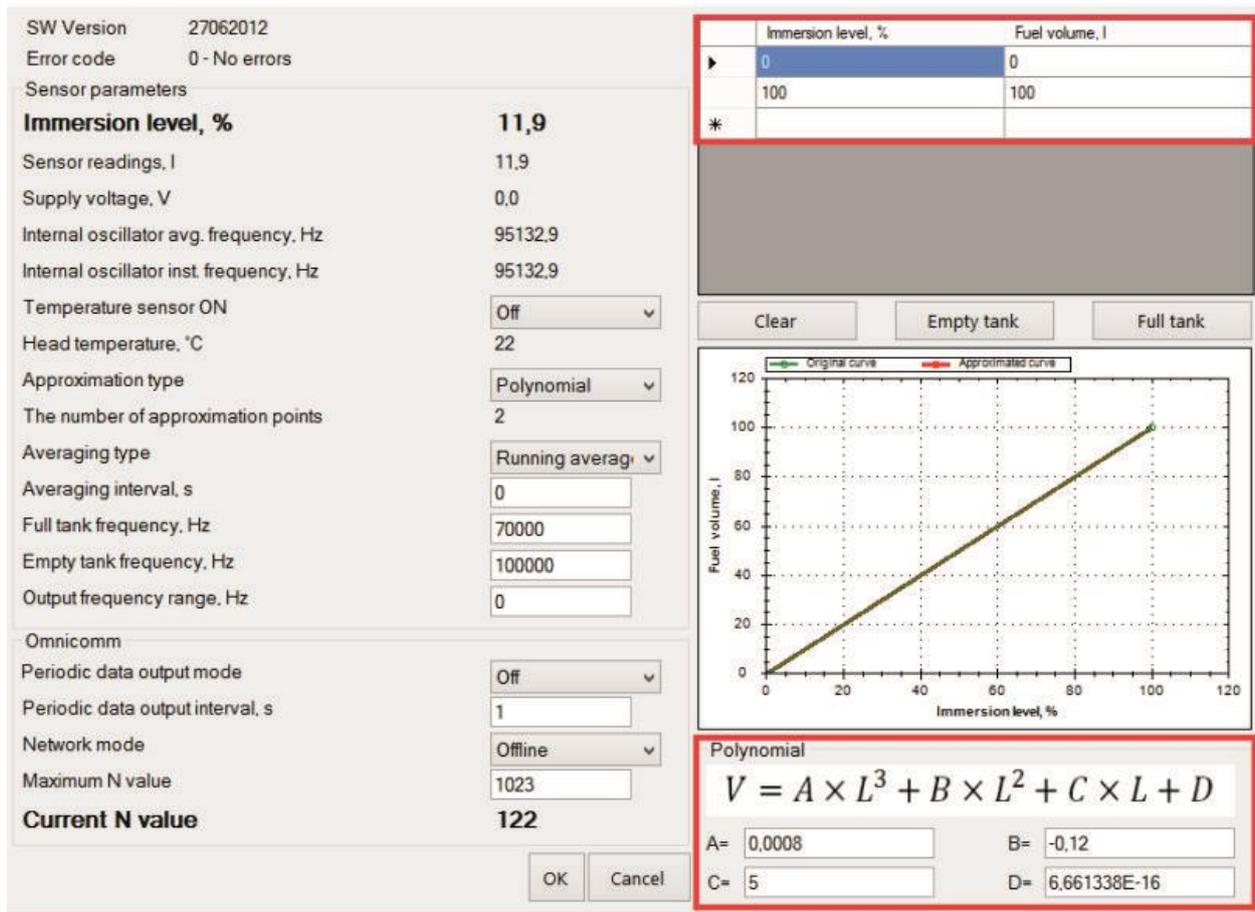


Figure 27 - The polynomial approximation

- To a polynomial type of approximation (Fig. 27) in the calibration table it is also necessary to input string raw data: % of a level of immersion and the corresponding value of the fuel volume in liters. Polynomial coefficients A, B, C, D will be automatically calculated and will appear in the "Polynomial" field.

6.2.4 Averaging type and interval setting

To adjust the averaging it is necessary to:

- In the "Averaging Type" field specify the type of averaging:
 - Exponential, the averaging interval is set to 5 seconds.
 - Moving average, the averaging interval is set in the range from 0 to 90 s.
- Set the averaging interval. To do this in the "averaging interval ,s." field input the value of the averaging time in seconds.

⚠ WARNING! Adaptive type of averaging in the testing phase and is currently not recommended for use.

6.2.5 Setting of ETS.RS operating parameters via Omnicomm protocol

Setting of the sensor under Omnicomm protocol is performed similarly to setting in standard mode (see paragraph 6.1.3). Additionally, in Advanced mode you can set the maximum value of the parameter N (from 0 to 65535). To do this, you must set it in the "Maximum N" field.

6.2.6 Firmware upgrade

To upgrade the firmware you should:

1. In Advanced mode, select the "Upgrade firmware" menu (Fig. 28).



Figure 28 - Firmware upgrade

2. In the window that opened (Figure 29), press the [Open firmware file].

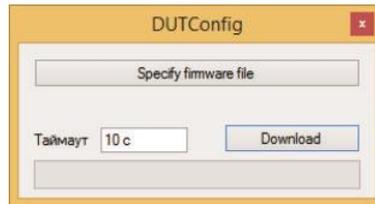


Figure 29 - Open the firmware file

3. Choose the firmware file and click [Upgrade].

6.3 Omnicomm protocol description

ETS.RS supports commands of Omnicomm protocol open part. Open part supports two types of transfer protocols: binary (HEX) or in symbolic form (transfer ASCII-sequences).

6.3.1 Description of commands for symbolic transfer protocol

Transfer via the symbolic protocol is receiving and sending the sequence of ASCII characters which are perceived as the command and response queries.

Command "DO" (0x44 0x4F) - data reading

Response line: F=xxxx t=xx N=xxxx.0 (CR) (LF)

This command is used to read the current data: F is the current value of the instantaneous (not averaged) frequency of measurement generator, t is the current temperature in Celsius or error code (see Chapter 4), N is level (volume) value (see Chapter 4). After receiving the command «DO» program will response as a sequence of ASCII characters, such as :

F=0AF9 t=1A N=03FF.0 <CR><LF>,

All data are transferred in hexadecimal.

Command "DP" (0x44 0x50) - periodic data output

Response line: F=xxxx t= xx N=xxxx.0 (CR)(LF)

Command enables periodic output data. After processing the command sensor produces periodic issuance in symbolic form (ASCII codes) of parameter F, t, N (similar to the answer to the command DO).

These data are issued periodically at intervals specified when configuring the ETS.RS in software ETSTConfig.

- ⚠ **WARNING!** In the case of the data output interval set to zero, data output will not be performed.
- ⚠ **WARNING!** Temporary (until power off) off the periodic data delivery in character format done after the receiving of any valid Omnicomm protocol command.
- ⚠ **WARNING!** Shutting down the periodic delivery of data in character format occurs after receiving the command «DO» or after changing the settings in the ETSTConfig program.

6.3.2 Description of the commands in the binary protocol

Data between the sensor and the external device are sent as messages with the format presented by the table "ETS.RS command format").

ETS.RS commands format		
Field	Field size, byte	Value
Prefix	1	0x31 for query, 0x3E for response
Network address	1	0x00...0xFF
Operation code	1	0x06, 0x07
Options	from 0 to 8 depends on operation code	Look command description
Hash sum	1	Calculated for each command field. Initialization=0. Polynomial: $a^8+a^5+a^4+1$.

CRC algorithm

To calculate CRC polynomial $a^8+a^5+a^4+1$ you can use the following algorithm (C language):

- ```

U8 CRC8(U8 data, U8 crc)
{
 U8 i = data ^ crc;
 crc = 0;
 if(i & 0x01) crc ^= 0x5e;
 if(i & 0x02) crc ^= 0xbc;
 if(i & 0x04) crc ^= 0x61;
 if(i & 0x08) crc ^= 0xc2;
 if(i & 0x10) crc ^= 0x9d;
 if(i & 0x20) crc ^= 0x23;
 if(i & 0x40) crc ^= 0x46;
 if(i & 0x80) crc ^= 0x8c;
 return crc;
}

```
- ```

U8 CRC8 (U8 b, U8 crc)
{
    U8 i = 8;
    do {
        if ( (b ^ crc) & 0x01) {
            crc = ( (crc ^ 0x18) >> 1 ) | 0x80;
        } else {
            crc >>= 1;
        }
        b >>= 1;
    } while (--i);
    return crc;
}

```

6.3.3 0x06 command (single data reading)

Function code	Description
0x06	DATA_READ (get current data, once)

This command is used to read the current data: F is the current value of the instantaneous (not averaged) frequency of measurement generator, t is the current temperature in Celsius or error code (see Chapter 4), N is level (volume) value (see chapter 4).

Data is transferred with low byte forward.

Example - function code for Omnicomm - 0x06 (DATA_READ).

Query		Response	
Field	(HEX)	Field	(HEX)
Prefix	31	Prefix	3E
Network address	00...FF	Network address	00...FF
Operation code	06	Operation code	06
Hash sum	00...FF	t, °C	-128...127
		N	0000...FFFF
		F	0000...FFFF
		Hash sum	00...FF

6.3.4 0x07 command (periodic data output)

Function code	Description
0x07	DATA_CONTIN (enable continuous data output)

Command enables periodic output data .

After processing, the command sensor begins to produce periodic data output: F, t, N (similar to the answer to the 0x06 command), with a time interval specified when configuring the ETS.RS in ETSSConfig software. At a zero value of output interval data are not provided.

Disabling periodic data output is done after the receiving any valid command, reset, or after voltage is switched off, if you configure the ETS.RS in ETSSConfig software was not set to data auto-output.

Data is transferred with low byte forward.

Example - function code for Omnicomm - 0x07 (DATA_CONTIN).

Query		Response	
Field	(HEX)	Field	(HEX)
Prefix	31	Prefix	3E
Network address	00...FF	Network address	00...FF
Operation code	07	Operation code	07
Hash sum	00...FF	Command executed successfully	00
		Command cannot be executed	01
		Hash sum	00...FF

Periodic data output format:

Response	
Field	(HEX)
Prefix	3E
Network address	00...FF
Operation code	07
Temperature, °C	-128...127
Relative level	0000...FFFF
Frequency value	0000...FFFF
Hash sum	00...FF

6.4 Modbus protocol description

ETS.RS is designed for use with display devices and programmable controllers, which support connection via RS-232 (only one sensor on the line), RS-485 (multiple sensors on the line + increase communication range) and work under the MODBUS protocol (www.modbus.org).

6.4.1 MODBUS protocol supported functions

Function code	Description
0x04	Read Input Registers (reading the register values from a certain address)
0x06	Write Single Register (register value record)

6.4.2 Description of the registers used in ETS.RS.

Addressing in MODBUS occurs through a 16-bit registers. To use a float type a pair of two registers is used.

Name	Address	Size/Mode	Description
liter	0 (0x00)	Float/ro	Sensor readings, L (if V specified - sensor volume)
prosent_L	2 (0x02)	Float/ro	Sensor readings % of the length
DOT_frequency	4 (0x04)	Float/ro	Internal generator frequency
DOT_frequency core	6 (0x06)	Float/ro	Internal generator frequency, not normalized
DOT_period	8 (0x08)	Float/ro	Internal generator period
DOT_period_core	10 (0x0A)	Float/ro	Internal generator period, not normalized
U_t	12 (0x0C)	Float/ro	Temperature sensor voltage
t	14 (0x0E)	signed short/ro	Head temperature
Fl_termo	15 (0x0F)	unsigned short/ro	Temperature sensor availability flag (0 - No)
type_appr	16 (0x10)	unsigned short/rw	Approximation type
deltaU_pow	17 (0x11)	unsigned short/rw	Sensor voltage differential – to determine the state of the engine on / off, mV
EngineState	18 (0x12)	unsigned short/rw	Engine condition: 0 – stalled, not 0 – running
version_po	19 (0x13)	unsigned long/ro	Software version

type_average	21 (0x15)	unsigned short/rw	Averaging type: 0 - exponential, 1 – moving average
Time	22 (0x16)	unsigned short/rw	Moving average averaging time, sec
Alfa	23 (0x17)	Float/rw	Exponential average alpha coefficient
fl_auto_send	25 (0x19)	unsigned short/rw	Omniconn protocol data auto-output flag: 0 – no output, 1 – output
period_auto	26 (0x1A)	unsigned short/rw	Omniconn protocol data output period in auto-output mode
omni_net_mode	27 (0x1B)	unsigned short/rw	Omniconn networking operation mode
Omni_error	28 (0x1C)	unsigned short/ro	Error code that will be provided in the Omniconn protocol temperature field
max_N	29 (0x1D)	unsigned short/rw	Maximum output value of Omniconn protocol
N_point	30 (0x1E)	unsigned short/ro	Approximation points number
dev_id	31 (0x1F)	unsigned short/rw	Modbus address
Boudrate	32 (0x20)	unsigned long/rw	Uart data transfer speed
error	34 (0x22)	unsigned short/ro	Error code
Password	35 (0x23)	unsigned short/rw	Password to change settings
F_min	36 (0x24)	Float/rw	Frequency of complete sensor
F_max	38 (0x26)	Float/rw	Frequency of an empty sensor
*U_pow	40 (0x28)	unsigned short/ro	Sensor voltage, mV
*time_average_window_stop	41 (0x29)	unsigned short/rw	Moving average averaging time at an adaptive filtering and stalled engine, sec
*deltaFout	42 (0x2a)	unsigned short/rw	Frequency generation range at frequency output
reservID	43 (0x2b)	unsigned short/rw	Reserved for future use
fl_termo_correct	44 (0x2c)	unsigned short/ro	Temperature compensation usage flag
polinom_termo_correct	45 (0x2d)	Float[5]/rw	Temperature correction polynomial
polinom_t	55 (0x37)	Float[4]/rw	Temperature sensor polynomial

* Given registers are only available in firmware versions released after 22/11/2012.

6.4.3 Data Format

Unsigned short (16 bit)

Number 0x1234 - 0x12 byte is sent first followed by 0x34.

Float inverse (32 bit)

Number 0h12345678 - consists of two 16-bit registers 0x1234 and 0x5678. The first register addresses 0x1234, the second 0x5678. Registers transfer is done as unsigned short (see above).

Example - reading the sensor parameters.

Function code for MODBUS - 0x04 (READ_INPUT_REGISTERS).

Example - Reading tank filling per cent:

Query		Response	
Field	(HEX)	Field	(HEX)
Function code	04	Function code	04
Hi address	00	Number of bytes	02
Lo address	02	Hi 0 register	12
Hi registers quantity	00	Lo 0 register	34
Lo registers quantity	02	Hi 1 register	56
		Lo 1 register	78

Example - record the sensor parameters

Function code for MODBUS - 0x06 (WRITE_SINGLE_REGISTER).

Example - recording of the dry sensor frequency (recording is made of two packets)

Packet No.1

Query		Response	
Field	(HEX)	Поле	(HEX)
Function code	06	Field	06
Hi address	00	Function code	00
Lo address	26	Hi address	26
Hi register value	12	Hi register value	12
Lo register value	34	Lo register value	34

Packet No.2

Query		Response	
Field	(HEX)	Field	(HEX)
Function code	06	Function code	06
Hi address	00	Hi address	00
Lo address	27	Lo address	27
Hi register value	56	Hi register value	56
Lo register value	78	Lo register value	78

6.5 Functional test

1. Connect ETS.RS to PC.
2. Determine the amount of fuel doped into the vehicle tank.
3. In BridgeToolBox software click [Read all from the device].
4. The total volume that is displayed in the program window must match fuel volume doped in tanks.

7 Maintenance

Product needs no maintenance.

<i>Typical problems and troubleshooting</i>		
Error	Problem description	Troubleshooting
Generator frequency is 0 Code: -102; 154 (-3; 253)	<p>Description: generator stopped – sensor doesn't measure the level of fuel.</p> <p>Character: bug is sporadic* (water circuit when driving) or permanent (for mechanical shorting) character. When troubleshooting the cause the sensor switches to operating mode.</p> <p>Reason: sensor tube Sensing device is shorted - water in fuel, manual shorted.</p>	<ol style="list-style-type: none"> 1. Dry sensor, drain water from tank; 2. Remove the mechanical short circuit. Test to measure the resistance between the sensing device tubes. Resistance value should be greater than 460 kilohms.
Reading error EEPROM Code: -104; 152 (-5; 251)	<p>Description: Stitched sensor calibration parameters got off.</p> <p>Reason: Possible damage from static electricity when gagging the sensor.</p>	<ol style="list-style-type: none"> 1. Perform ETS.RS reconfiguration (see Chapter 6). Turn off-turn on the power. 2. Refer to the manufacturer.
Out of top range $F > F_{max} + 10\%$ Code: -105; 151 (-6; 250)	<p>Description: At low fuel level sensor freezes at zero, and then exposes error.</p> <p>Character: Error occurs on the "dry" sensor. By immersing the sensor in the fuel, after passing the dead zone sensor is working properly.</p> <p>Reason: The sensor is not properly calibrated. It may also be caused by damage to the sensor electrodes.</p>	<ol style="list-style-type: none"> 1. Calibrate sensor. If the problem persists please contact the manufacturer.
Out of bottom range $F < F_{min} - 10\%$ Code: -106; 150 (-7; 249)	<p>Description: fuel level above the actual sensor periodically exposes error.</p> <p>Character: error occurs when immersed sensor close to the maximum level or at any level in the water circuit. If the error is replaced by the error "The oscillator frequency is equal to 0", the reason for the presence of water in the fuel.</p> <p>Reason: The sensor is not properly calibrated; circuit element measuring water or mud in the tank.</p>	<ol style="list-style-type: none"> 1. Error occurs at any level and periodically error code changes to -102; 154 (-3, 253) (The oscillator frequency is equal to 0), you must follow the recommendations listed for error code -102; 154 (-3, 253). 2. Error occurs on the same level, it is necessary to calibrate the sensor. If the problem persists please contact the manufacturer.

* Sporadic – from time to time

8 Marking

ETS.RS is manufactured in four versions. The information for the order is given below.

Name	Body	Trimming degree
ETS.RSM	Metal	50%
ETS.RSY	Carbon fiber	50%

Each sensor has a marked code consisting of 10 characters applied with shock-point method:

Code example	3	3	L	3	4	1	8	5	3	2
A character from code ordinal number	1	2	3	4	5	6	7	8	9	10
Symbol meaning	ETS.RS type	Length code	Code type*	Date						
Interpretation	Interface 232	700 mm	Always «L» for ETS.RS	17:00 09.07.2012						

“Code type” – always “L” for ETS.RS

Sensor type	
3	Interface 232
4	Interface 485

Length code	
1	350 mm
2	500 mm
3	700 mm
4	1000 mm
5	1400 mm
6	265 mm
7	680 mm
8	730 mm
9	750 mm
A	Custom length

"Date" - the date of ETS.RS manufacture, encoding - UNIX time, without the first and last two characters.

UNIX time			
1	Date of marking	0	0

UNIX time can be deciphered here - http://www.onlineconversion.com/unix_time.htm

Example. ETS.RS with code 42L3655169.

Explanation:

4 - ETS.RS interface 485;

2 - length 500 mm;

L - code type;

3655169 - encrypted date:

- We have 3655169;
- Add 1 from front and two 0 at the end → 1365516900;
- On site http://www.onlineconversion.com/unix_time.htm in “Unix timestamp” field register the resulting combination, click [Submit] - manufacture date will appear below - Tue, 09 Apr 2013 14:15:00 GMT .

Convert Unix timestamp to Readable Date/time
(based on seconds since standard epoch of 1/1/1970)
UNIX TimeStamp:

Figure 30 - Date explanation

9 Transportation and Storage

Transportation

Transportation of equipment in a package is subject to the following conditions:

- Air temperature from -40 °C to +80 °C;
- Relative humidity less than 95% at 40 °C;
- Transportation is allowed with all kinds of enclosed transport.

Storage

Device storage in the package is subject to the following conditions:

- Air temperature from -40 °C to +80 °C;
- Relative humidity less than 95% at 40 °C.