OPTICAL SPEED AND LENGTH SENSORS

ISD-3 family

User manual

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1. Overview

The main purpose of the Sensor is high precision measurement of speed and traveling distance of the vehicle relative to ground (automotive and railroad application) and speed and length of objects moved relative to the sensor (industrial application).

Measuring principle – raster spatial filtration of an object image, technology is patent pending.

Main features of the ISD-3 family:

- High precision of measurement: 0,03 – 0,1% RMS in industrial, 0,1 – 0,2% RMS of velocity and <0,1% of distance (>100m) in automotive application.
- Reliable measurements on virtually all types of surfaces.
- Broad range of nominal working distances – from 15 cm to 160 cm and it can vary up to 2,5 times during measurements.
- Big lens aperture – geometric aperture ratio up to 1:4. As a sequence, LED IR diode of 3-5 Wt electrical power is enough for object illumination in most cases.
- Low weight aluminum housing, IP67 environmental protection.
- Low power consumption of controller module (1,5 Wt) due to last generation of ARM microcontrollers used.

Note: Sensor design and its characteristics may differ, dye to continuous efforts for further improvement.

2. Safety precautions

- Use supply voltage and interfaces indicated in the sensor specifications.
- In connection/disconnection of cables, the sensor power must be switched off.

3. Electromagnetic compatibility

The sensors have been developed for use in industry and meet the requirements of the following standards:

- EN 55022:2006 Information Technology Equipment. Radio disturbance characteristics. Limits and methods of measurement.
- EN 61000-6-2:2005 Electromagnetic compatibility (EMC). Generic standards. Immunity for industrial environments.
- EN 61326-1:2006 Electrical Equipment for Measurement, Control, and Laboratory Use. EMC Requirements. General requirements.

4. General Information

Currently ISD-3 family included 6 models with different versions with working range from 10 cm up to 80 cm (available on request) . Custom-ordered configurations are possible with parameters different from those shown below.

2-Dimentional sensors available to measure, for instance, longitudinal speed of rotating tubes in tube-rolling mill, or transversal displacement of moving objects.

4.1 Optical ISD-3 and Laser ISD-5 comparison – how to choose for the customer task

Sensorika's optical and laser sensors both can be used for road and industrial applications, preferable ones depends on the customer task. For ISD-5 details, please, refer to ISD-5_Sens_manual_en. In the table below we compare main features of the sensors:

Parameter	Optical ISD-3	Laser ISD-5	Comments
Spatial filter location	Inside the sensor	Outside (on the object)	
Spatial filter long term stability	Very stable	Stable,	But ISD-5 depends on laser wavelength stability
Sensitivity to the optical windows pollutions	Low	High	For laser beam output windows clearance is very critical to form fringe pattern on object
Lifetime for illuminator	>100000 hours for LED at 0,5 of its nominal power	>50000 hours for laser at 0,3 of its nominal power	LED and laser light source lifetime strongly depends on its nominal current (= temperature). We use 5 Wt LED at 2,5 Wt load and 200 mWt laser at 50 mWt load (18 mWt of optical power) to extend its lifetime.
Environment temperature sensitivity	Low	High	For laser, temperature stabilizer needed at T<8 ºC.
Field of view on object	20x50 mm typically	2x5 mm typically	Laser one is preferable mostly for the thin cable diameters with very low speed possible.
Working on very even and mirror-like surfaces	Low capability	High capability	
Measuring speed range	0,05 – 100 m/s	0,005 – 50 m/s	Dynamic range for both sensor is 1:1000, i.e. min speed is 1/1000 of max speed at given sensor setup.
Controller unit	Soft, controller and Firmware are the same		

Main Technical Data

Parameters	Value	Comments
Speed range	0,05 – 100 m/s	Full range. But at a time, dynamic range Vmax/Vmin is 1000 – selected by setup (see ch.5)

Speed accuracy*	<±0,1 % RMS	
Absolute distance accuracy*	<±0,03 % RMS	After calibration at S >100 m.
Measuring frequency	27 - 70 Hz	Others are user adjustable, (max 80 Hz see capt. 10.3. below for details)
Nominal distance to the road and tolerance (range of working distance)	15 – 160 cm (±25%)**	Examples: 15±3 cm; 20±7 cm; 35±13 cm, 50±20 cm, 80±25 cm. Others on request. The less nominal the better speed accuracy.
System power supply (tolerance)	12V nominal (11 – 14,5V)	Others on request
System power consumption	Sensor head: 7 Wt (with LED as illuminator) Processor unit: 1,5 Wt	
Sensor head operation temperature range	-20…+50˚C	
Weight of the sensor + mounting bracket	280g + 120g	Without cable
Weight of the processor unit	350g	
Sensor dimensions	Ø55 x 200 (230) mm + illuminator	See fig.2.
Processor unit dimensions	120 x 100 x 35 mm	Without connectors
Sensor cable length	3 m	Up to 10 m on request
System power cable length	2 m	Up to 10 m on request
Environmental sensor head protection	IP67	
Magnetic fixing tool	4 magnets x 12 Kg strength	Option, see fig.2.
Controller unit outputs:		
Analog out Freuency out Digital out	Speed, 65 mV/(m/s) 3,3V max. Length, 1000 pulses/m (=speed 1000 Hz/(m/s), meander 0 – 5 V, TTL compatible, or 0-Vcc, up to 200 KHz. Ethernet (UDP protocol): No of meas, Speed, Length, signal quality (S/N ratio) UART 3 V TTL + COM-USB converter	Typical values, user adjustable (see software description below). DAC resolution – 12 bit, frequency resolution – 32 bit Default as Main protocol Option as additional to Ethernet (data output only) or instead of Ethernet***
Physical data latency,	½ of measuring time*(No of	Stable, , without averaging.

ms	averaging)	
Base Software***	- Program to read data via Ethernet***, visualization and saving data; - Program for sensor diagnostics - Dynamic library (DLL) customer DAC software - Sensor parameters configuration via any Internet browser	See below for details. Custom software by request is possible.

* After calibration on the object to eliminate mounting axes errors.
** For typical road surface. On even and non-contrast surface actual upper limit may be less.
***Main protocol can be only one of the type – Ethernet or Serial COM-USB, because it demand different Base software for data acquisition and sensor config.

Due to our continuous efforts to improve sensors, Sensorika reserves the right to change specification without prior notice.

5. Example of the designation when ordering

ISD – 3.1 – 35cm – ET – AN(U) – PL(12V) –SM –12V - (0,5-50 m/s) - 3m -1,5m
Comments:

Symbol	Description
3.1	Basic variant.
35cm	Nominal distance to the object[1)]
ET/COM	Digital interfaces[2)] (main protocol to connect to PC): ET – Ethernet (UDP protocol, basic vriant), USB – COM-USB converter. Option: ET+UART – Ethernet as Main, UART – as data repeater[3)]
AN(U)	Analog out, voltage (U) – base - or current (I)
PL	Pulse out, 0-12V – base (0-5V, 0-24V – options) ENC (level,V) – encoder A and B (90 deg schift) [4)]
SM	Stop length measurement (=stop pulse out) function
Power Supply	12 V (10-14,5) – base, 10 – 24 V – option.
(0,5-50 m/s)	Preferable low and upper speed limit In m/s[5)]. Set real values , it is necessary for sensor parameters and electronic band optimization for customer task
3m	Cable length from sensor to controller unit
1,5 m	Power cable length
Comments	Another useful information: type of application (road/industry), environment conditions, current out level (0-20 or 4-20 mA), pulse out level (if differ from power supply) etc.

1) Choose a minimal distance fit to the task. The less distance, the better sensor accuracy.
2) Only one option can be selected, because it demands different set of program on PC.

3) Additional connector can be installed to transmit data via UART as ASCII to another controller or smart screen (data block format must be defined by customer).

4) Encoder signal emulation (not change the phase if moving direction inversion) – used if customer DAC has no single channel counter input.

5) At a time, dynamic range Vmax/Vmin is 1000.

6. System Parts and Connections

System parts and connections are shown on fig.1 below.

Pulse out

Analog out

Blocking Pulse out

Power connector

UART out (as data re-peater)

Ethernet 100 Mb/s (standard patchcord)

Sensor cable

Fig. 1. Sensor parts and connectors.

If both contacts on “Stop Pls” connected - no pulses on Pulse out. It is used when there are long stops mowing to avoid false counting in length.

7. Dimensions and mounting

7.1. Overall demands for sensor mounting

Sensor outline dimension, mounting tools and optical axe location are presented on fig 2.

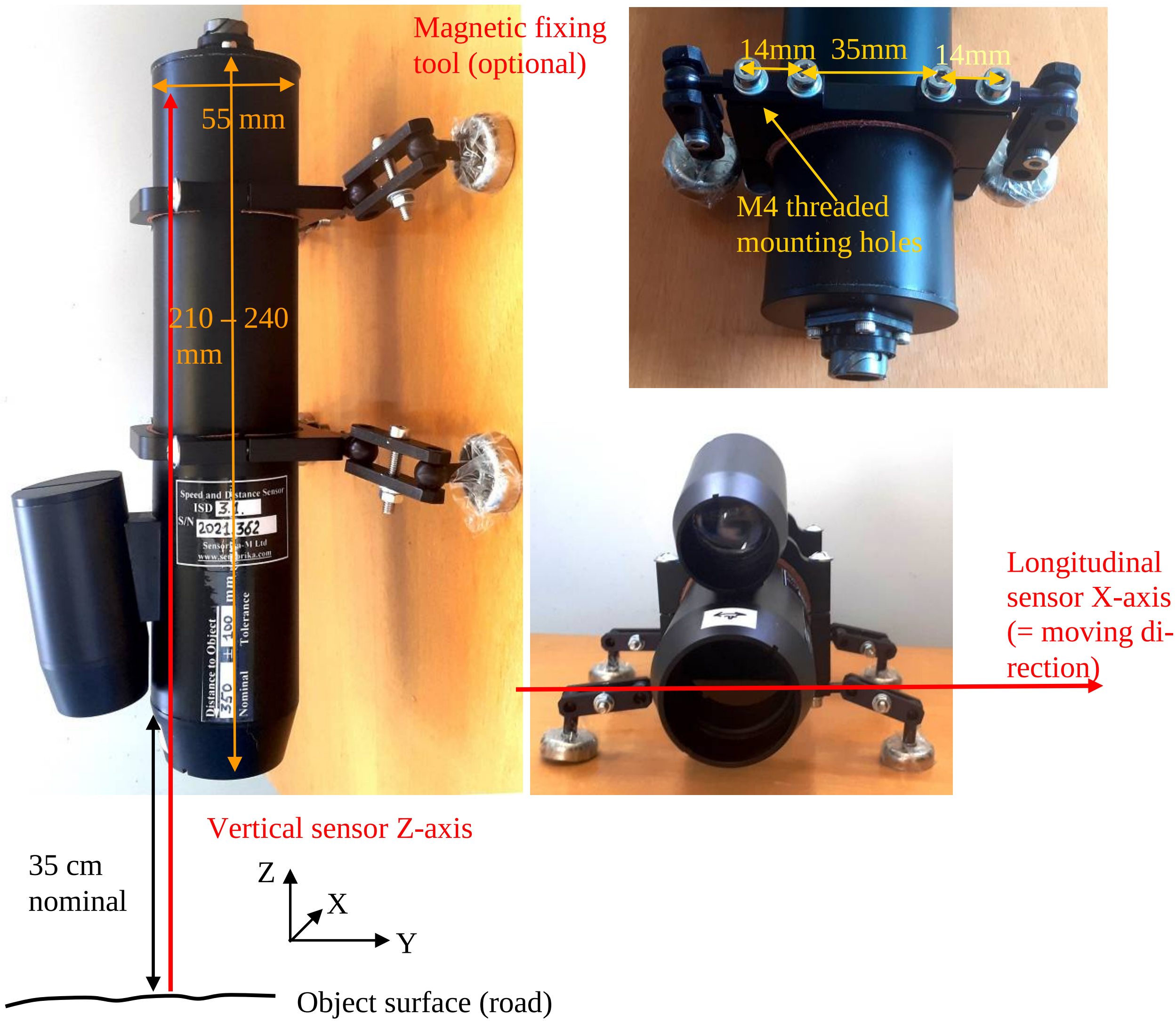


Fig. 2. Sensor position relative to the road. Moving along X-axis.

Nominal distance to the object could be measured from front plane of the sensor, as indicated.

Sensor X-axis must be perpendicular and Y-axis – parallel to object moving direction. In ZY plane (perpendicular to drawing plane) sensor Z-axis can be tilted from vertical position (for instance, to avoid the light direct reflection to sensor receiver area from glossy surface). Note: inaccuracy (non-perpendicular/parallel with angle α) in sensor X and Y axis relative to object mowing direction will lead to decreasing the measurements as sin(α). For instance, at α=4˚ measured speed will less then actual in 0,24%. That is why, the pre-calibration needed to reject the align errors to achieve the maximum accuracy.

8. Connection

8.1. Sensor cable: 7 pin FQ14-7T type to DB9.

Sensor cable

Signal description	FQ14-7T Pins	DB9M Pins	Wire
5 V Electronics	1	1	Orange
5 V LED	2	6	Brown
GND LED	3	5	Brown_White + Shield
GND Signals*	4	4	Green_W+Blue_W
GND Electronics*	5	9	Orange_W
Signal-	6	3	Green
Signal+	7	2	Blue

*Grounds joined in controller unit. Signal ground connected to the controller unit housing.

8.2. Other cables.

Power connector

Signal description	PY04-4Z Pins	Automobile plug	Comment
Power 12 V (10-14,5)	1	Brown	With wrong polarity protection (serial diode in controller box
Pulse Out	2		Parallel to BNC output
GND Power	3	Blue	
GND Pulse	4		

UART Tx out

Signal description	BNC	COM-USB converter (Prolific	Comment

		PL2303TA)	
Serial Data Transmit Tx	Center	White	3 V TTL, can be connected to customer controller Rx.
GND	Ring	Black	

9. Working with system and its software

9.1. Working with external (custom) DAQ

- Fix sensor properly relative to the object.
- Connect sensor and controller unit by cable, switch the power ON. Controller ready in 3 s.
- Connect appropriate output with the DAC input.
- If needed, correct the calibration multiplier in DAQ or controller software (see below).

Pulse output used for precise length measurement – connect it to DAC counter input. It can be used for speed measurement too via frequency input. But to measure frequency correctly measurement frequency could be at least no less then sensor update frequency.

To measure the speed via analog output is most simple, but less accurate (12 bit). The best way is using digital port (Ethernet), If possible.

9.2. Working with sensor software

The sensor can be connected to the PC via network. Sensor IP address is 192.168.0.1 by default. To establish cable connection, PC must have static address 192.168.0.XXX with 255.255.255.0 mask. Set it in TCP/IPv4 config in Alternative config tab. If needed, IP address can be changed via setup.

9.3. Configuration parameters

Open any Internet browser (Internet Explorer, Opera, Chrome …), enter controller IP as an address. Page with sensor configuration parameters appears. As an example:

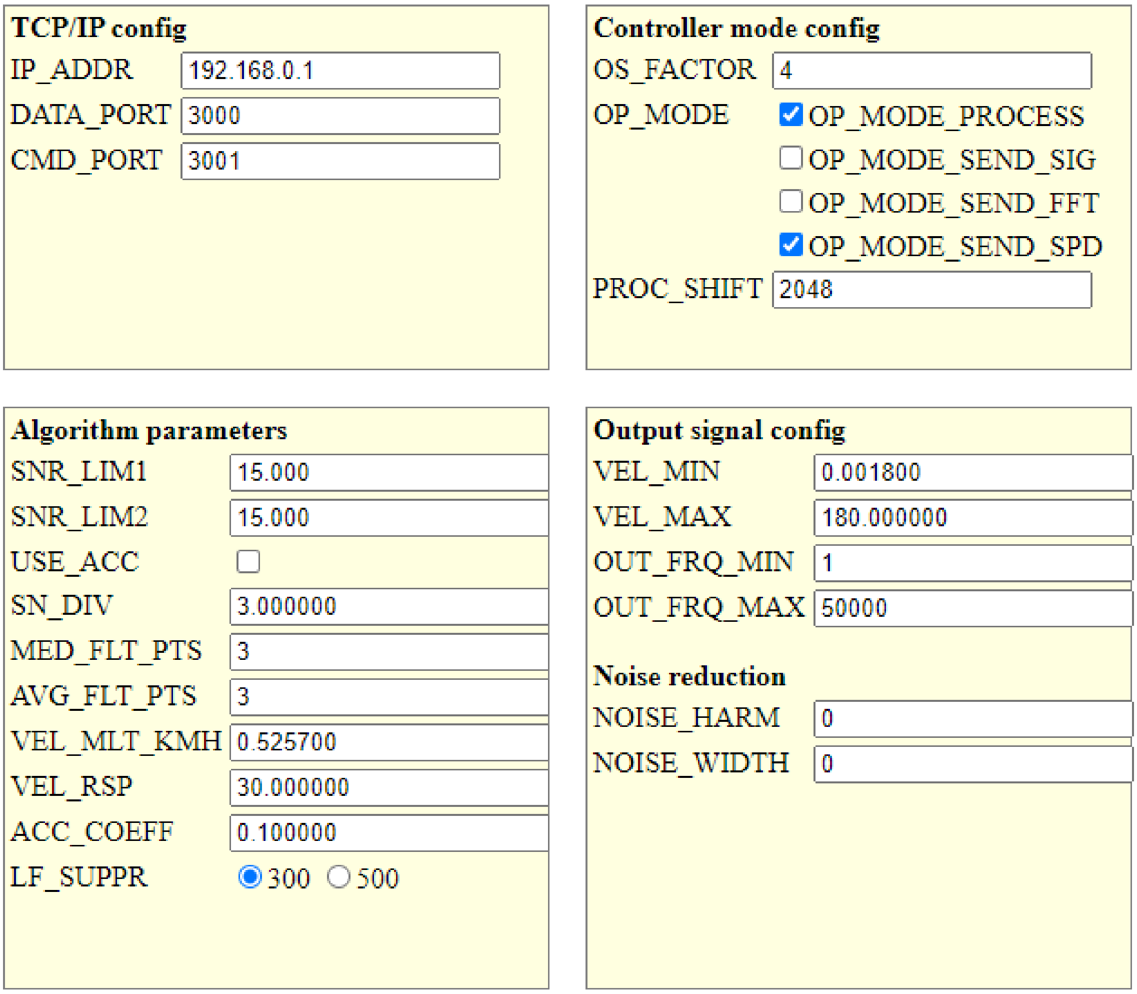


Fig. 4. Page with sensor configuration parameters.

What is opened is a content of flash memory of the controller. Parameters details:

“TCP/IP Config”:

Parameters are writes. Please, restart controller.

- IP_ADDR – Controller’s address. Non recommended to change without necessity. If changed – do not forget to enter new address in browser after controller restart.

- DATA_PORT – Port on PC where data send. The same must be used as a parameter to read data by DLL (see below).

- CMD_PORT – Controller port to writes the parameters. Do not change!

“Algorithm parameters”:

- SNR_LIM1 и SNR_LIM2 – Signal to Noise Ratio Limit – to distinguish between standstill and mowing object. If real less – speed regarded as = 0. Typical values at stand still are 2 – 6. At moving object S/N 1 (and S/N 2 at velocities > 20% of Vmax) > 100 - 1000 typically. See real S/N at stand still in the software (see below) and set it 5 - 10 times more to guarantee V=0 at stand still. But in some cases (rainy weather, vibrating grass…) – some velocity measurement at standstill can occur. In some range it can be overcome by S/N increasing. Current S/N can be observed in the program supplied (see below). At very high noises at standstill (heavy rain) – use function “Stop Count” (when frequency output used) and unblock it just before the start moving.

- USE_ACC – not used since 2019.

- S/N_DIV – Decreasing S/N at velocities > 20% of Vmax. Default is 3 (not recommended to change)/

- MED_FLT_PTS – Median filter order (points of measurements taking into account. Min. value = 0 (no filter).

- AVG_FLT_PTS – Order of data averaging filter. Min. value = 1 (no filter)

- VEL_MLT_KMH – Velocity calibration multiplier. Act to length calculation too.

- VEL_RSP – Define the maximum velocity changing between measurements at abrupt real velocity changing. The more the value, the faster sensor can react. For automotive application value 10 corresponded ab. 1 g acceleration at 34 Hz measurement. Min value = 1, maximum 2000 – fastest reaction.

- AC_COEFF – not used since 2019

- LF_SUPPR – for factory use only, do not change!

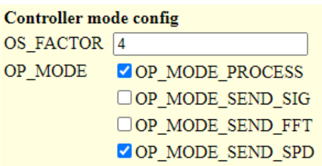
«**Controller mode config** »:

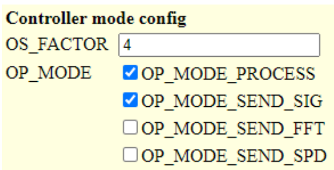
- OS_FACTOR – Divider for ADC sampling time, Values are 1, 2, 4, …, 24. Used to change speed range limits. For instance, if at OS_FACTOR=4 it was 0,5 – 180 Km/h at OS_FACTOR=2 it will be 1 – 360 Km/h, at OS_FACTOR=8 it will be 0,25 – 90 Km/h etc. But remember that electronics frequency band optimized for default speed range.

- OP_MODE – Set the controller mode (if change – Reset after Write obliged). Selected modes activates the following:

OP_MODE_PROCESS – process the data and send the result to frequency and analog output. **Must be always ON**.

OP_MODE_SEND_SIG, OP_MODE_SEND_FFT (not used since 2019, OP_MODE_SEND_SPD – Send the data via Ethernet. **Only one or no one must be selected** (No one – data not sent to Ethernet, just to Freq and An – max measuring freq possible (up to 100 Hz)).

Use OP_MODE_SEND_SPD 

to work with a visualization program supplied (see below). Use OP_MODE_SEND_SIG 

, to work with a diagnostic program supplied (see below)

- PROC_SHIFT – Allow to change measurement frequency (sliding average). Values are 4096, 2048, 1024, 512. But maximum result frequency will not exceed 80 Hz with sending data via Ethernet and 100 Hz without Ethernet.

«**Output signal config**»:

- VEL_MIN and VEL_MAX – Limits max and min velocities in Km/h which corresponds analog and frequency outputs boundaries (at VEL_MIN analog output is 0 V, at

VEL_MAX analog output is 3,2 V). Example: at VEL_MAX=180 [Km/h] = 50 [m/s] =3,2 V, i.e. 3,2V/50 = 64 mV/m/s

- OUT_FRQ_MIN and OUT_FRQ_MAX – Define min and max frequency output at VEL_MIN and VEL_MAX. To set 1000 pulses/m (=1000Hz/m/s): 1000Hz/m/s*50m/s = 50000 Hz = OUT_FRQ_MAX. At OUT_FRQ_MAX=5000 – 100 pulses/m etc.

«**Noise reduction**»:

- NOISE_HARM and NOISE_WIDTH – Allows programmatically suppress narrow-band electromagnetic noise with central frequency NOISE_HARM (in harmonics number) and ± NOISE_WIDTH (in harmonics number around the central frequency) . Noise, if present, can be seen in Contr_UDP_SIG program. See fig 8 below for details.

After changing and writing parameters, controller must be restarted. Press button “Restart” (it takes 3 sec only), then you have to reload the page, because during reset the connection with controller was lost.

9.4. Controller reset to factory settings

In case of controller firmware damage (loosing power during writing new data, writing wrong parametes etc.) it can work incorrect or loose Ethernet connections. In this case initial factory settings can be restored as following:

- Switch OFF Controller Power.
- Unplug the sensor cable from controller and connect pins 7 and 8 by wire.
- Switch ON Controller Power for 3 – 5 s. Factory settings is restored.
- Remove pins 7 and 8 connections , plug the sensor cable.
- Do not forget to write user parameters if they were differ from factory ones.

9.5. Working with sensor software

For viewing and saving the sensor data a special program supplied (LabView based). To run LV execution files an environment like Run Time Engine must be installed first. Just run setup in ISD_Installer directory. After installation, any LV .exe files can be run on this PC. **Note: only one program below can run at a time because it used the same resources**.

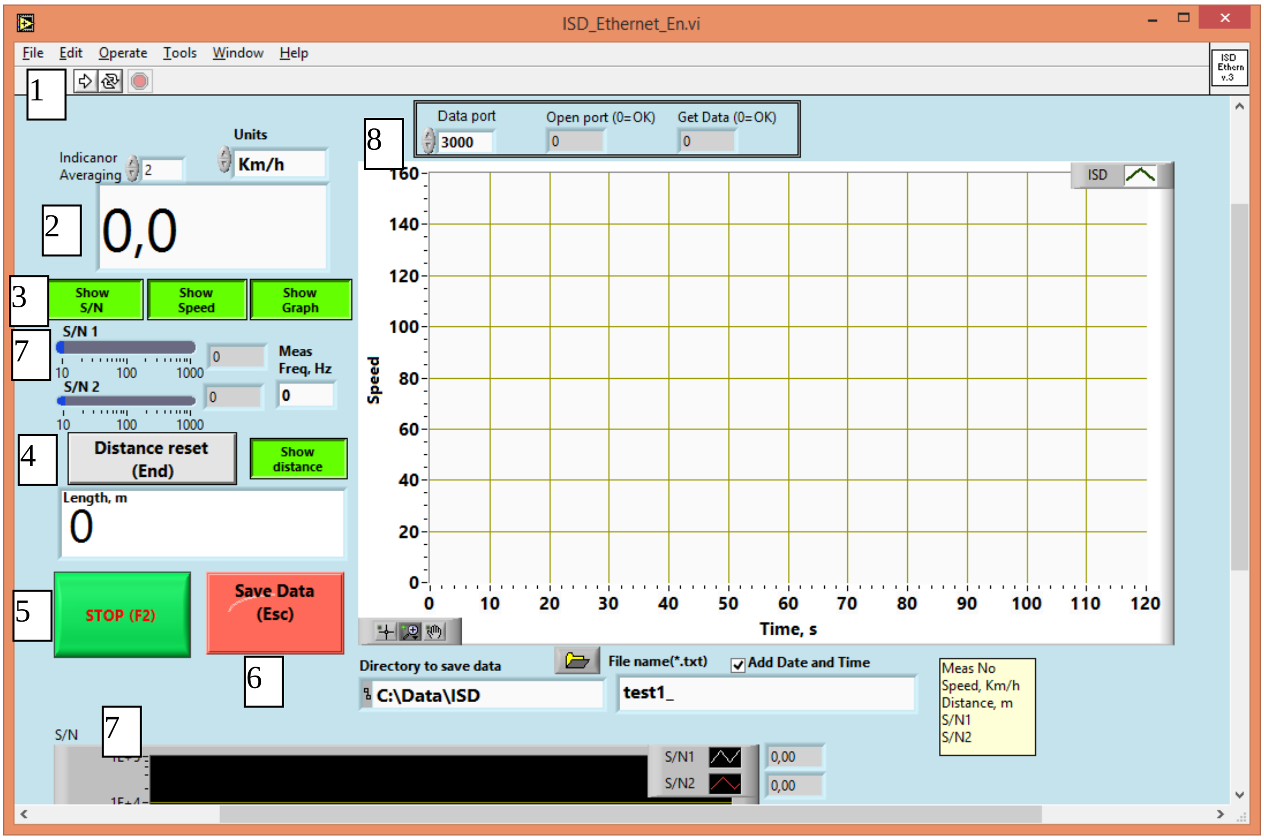
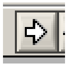


Fig.5. ISD_Ethernet_En.exe – Program to work with sensor data sended from controller to PC via Ethernet connection.

Here:

1 – Run program button  . When it runs the indicator  (abort button) becomes red.

2 – Current speed indicator in selectable units and averaging (acts to indicator and Speed Graph only, not to saving data).

3 – Visibility ON/OFF of indicators. All ON load PC more, especially at high measurement frequency.

4 – Distance indicator with button to set it to 0. Act on saving length data too. Note: controller send cumulative distance from its power ON, so use this button to set distance to 0 before start measurement (brake test for instance).

5 – Program Stop button. Use it to stop program to correct closing the PC ports and data file (see 6 below).

6 – Save Data button. When it pressed, the data writes to memory – its directory and name are editable (change it if needed before Start). Note, that the directory must exist (created in advance), file with the name will be created automatically. After test is over, use Stop program button to write the data to the file. Data saves as text file (ASCII) in 5 columns: No of measurement; Speed [Km/h]; Length [m] , S/N1, S/N2.

7 – Current S/N and measuring frequency indicators (in bar and Ghart). Normally, at standstill S/N is ab. 2 – 6. If it much more – there are some extra noises or mowing objects in the sensor view area (see 10.3 above). Try to increase S/N in “Algorithm Parameters” or use diagnostic program (see fig.6. below).

8 – Data acquisition state indicators (for diagnostic). For instance Get Data=4 means that another program running.

Diagnostic programs:

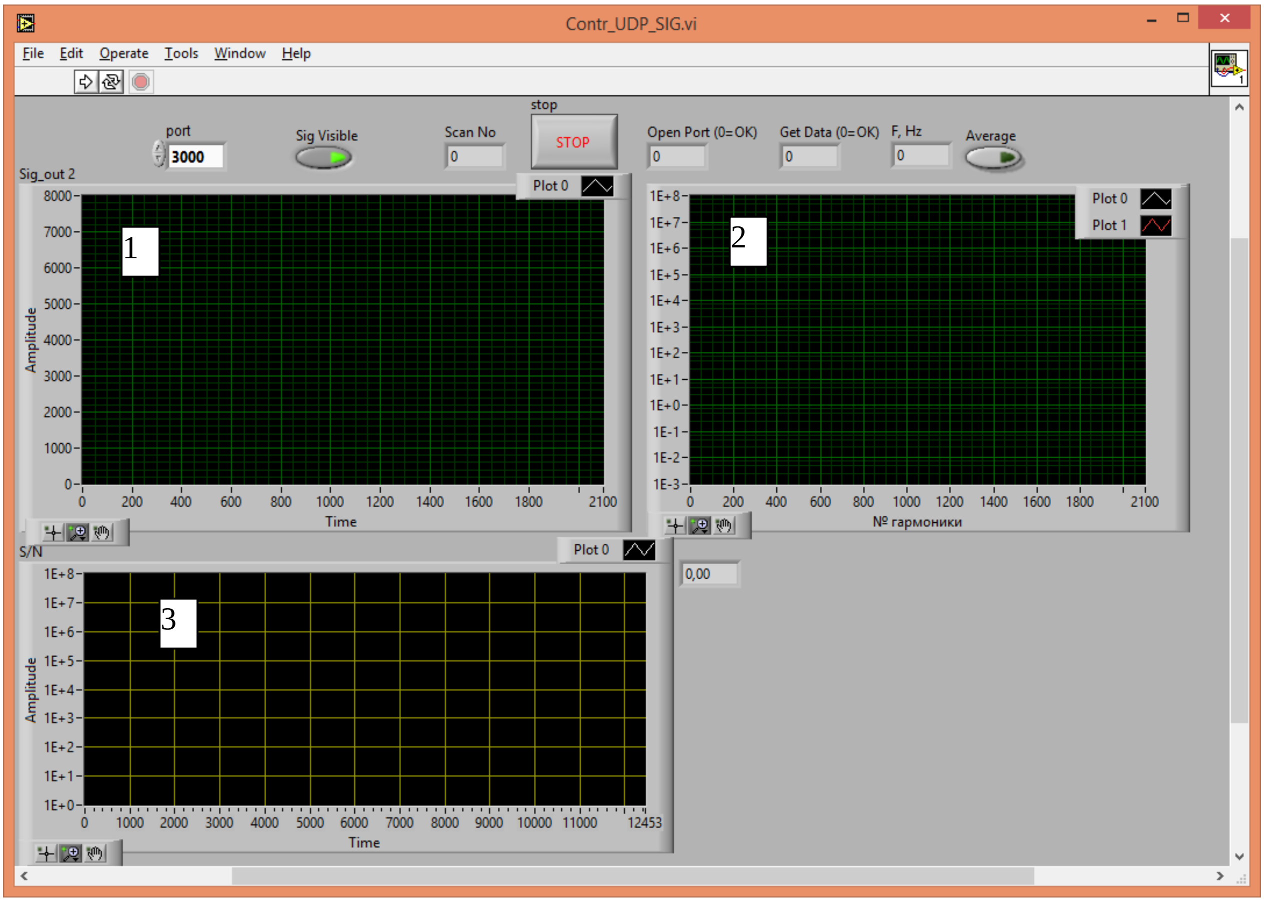
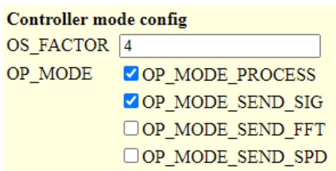


Fig.6. Contr_UDP_SIG.exe – Sensor diagnostic program.

Useful for first sensor mounting, especially working on cables – to adjust sensor position to get maximum signal (see fig.7).

To run this program, switch controller to SIG mode 

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Here:

1 – Signal oscillogram;

2 – Fourier spectrum og the signal;

3- Signal quality = Current S/N ratio.

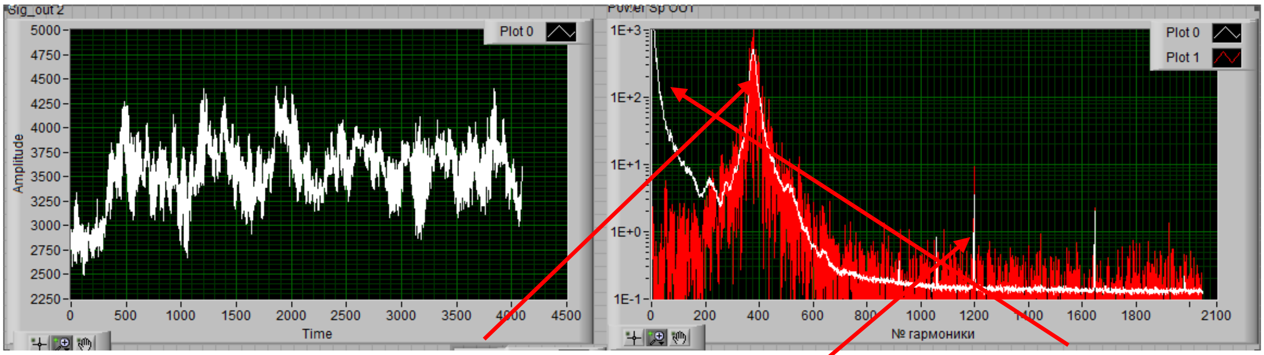


Fig.7. Typical sensor signal. Main signal (frequency proportional to speed) and parasitic low-frequency signal (dye to object brightness changing). EM noise, if it comparable with the signal amplitude can be programmatically suppressed. For this example, to suppress noise at 1200 harmonics set NOISE_HARM = 1200 and NOISE_WIDTH= 3 – 5 or more (exact noise frequency may deviate with a time). This area will be not taken into account in controller algorithm.

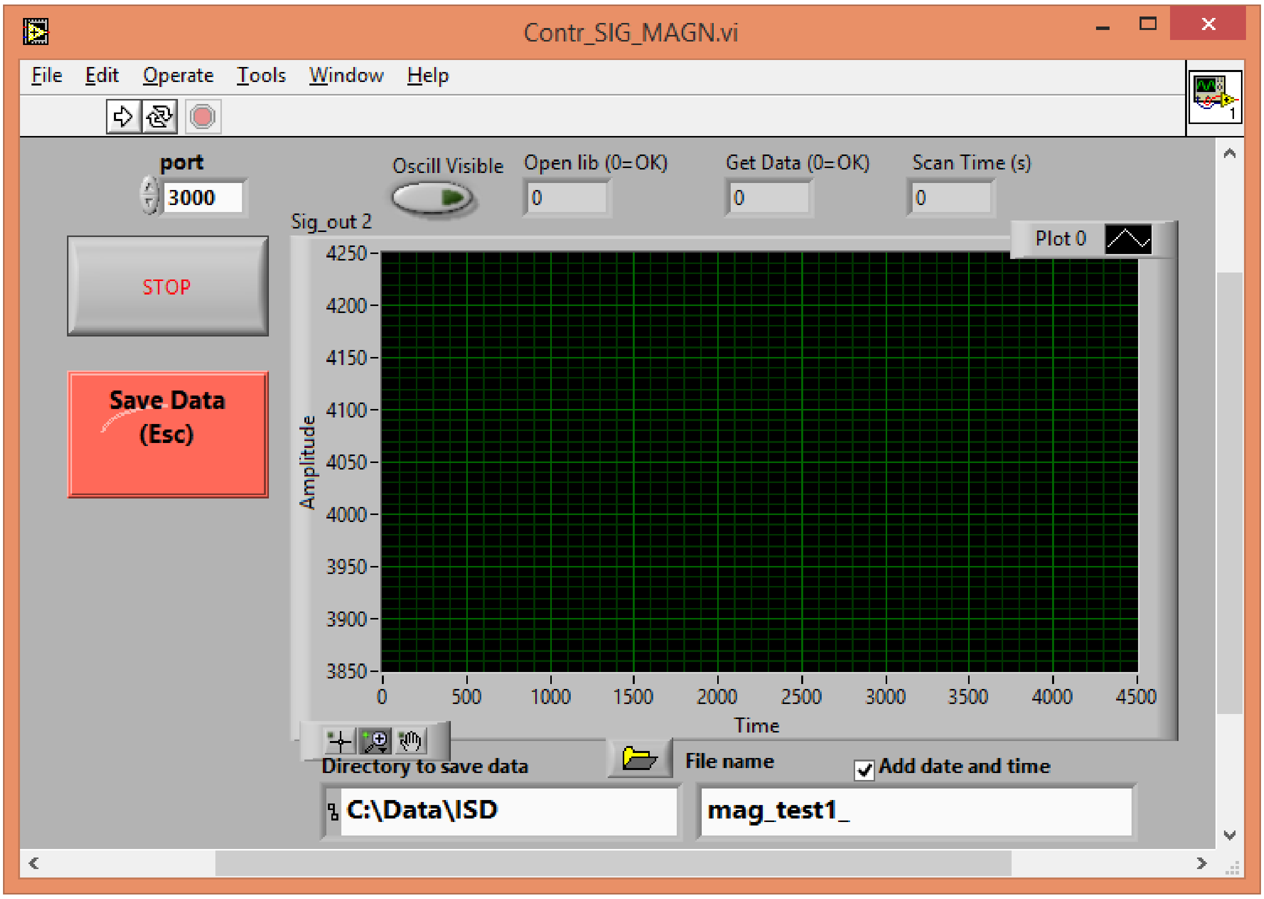


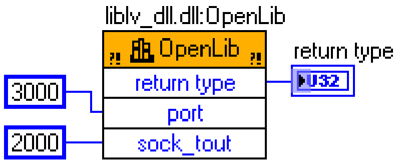
Fig.8. Contr_SIG_MAGN.exe - Program to stream write sensor signal for further diagnostic.

In mode OP_MODE_SEND_SIG writing initial sensor signal possible. Use this program if some problem occurs with sensor. Run the program, press “Save Data” – data writes to PC memory (ab. 1 Mb/s). After “Stop” it saves to file – you can zip it and send to vendor for detailed analysis.

9.6. Dynamic Link Library description

User can read the sensor data in third party software environment like C++, LabView and others. For this, liblv_dll.dll module can be used. Data format is in lv_dll.h file. To read the data via Ethernet only 3 function needed. Below are examples for LabView environment.

OpenLib :



Opens and configure PC ports to work with net UDP protocol.

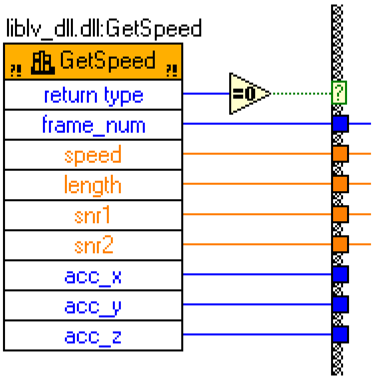
Input parameters:

- **port** - No of port to receive the data – must be the same as in controller DATA_PORT (see. 10.3).

- **sock_tout** – Timeout for data waiting in ms.

Output: **return type**, 0 = OK, or see lv_dll.h for list of errors.

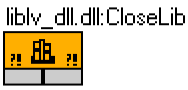
GetSpeed :



Reads the data continuosly.

- **return type**, 0 = OK;
- **frame_num** – No of measurement;
- **speed** – current speed [Km/h];
- **length** – length [m] from controller power ON;
- **snr1, snr2** – Current S/N;
- **acc_x, acc_y, acc_z** – Current accelerations [m/c^2]

CloseLib :



Close the port and releases the PC resources. It must be executed before program stops.

10. System maintenance

The sensor head and processor unit has no service points. Maintenance limited to keeping clean the sensor windows. Note: Do not use solvents for cleaning!

11. Warranty

Warranty period is 18 months after selling.

12. Troubleshooting

12.1. Some constant speed measured at standstill

There is strong electromagnetic noise on the controller ADC input. As a rule, it induced on cable signal wires from power wires, especially if pulse DC-DC converter used or some pulce power consumers (like DAQ system) feeded from the same source. Use separate power source if possible. Use diagnostic program to see the noise and to suppress it.

12.2. No speed measurement at object mowing

- Cable or electronic damage or wrong parameters in the sensor setup. Use the diagnostic program to see the signals.
- No Ethernet connection (programs does not running). Check settings for direct cable connections.
- If sensor Setup damaged, reset the controller to factory settings (see 9.3. above).

12.3. Programs not run or browther not enter to Setup

As a rule, it is dye to Windows security system (Firewall). At first opening the program system may ask to permission – allow it. Browser itself can block the IP – add it to browser exclusions.

Sensor repairing must curried out by manufacturer only.