TILKOM
TRANSDUCERS & TELEMETRY

M56 6-COMPONENT WHEEL FORCE TRANSDUCER

Operating Manual

CONTENTS:

This operation manual acquaints with the structure, operating principles and terms of use of the M56 6-component Wheel Force Transducer (WFT) and verifies the parameters and technical data guaranteed by the producer.

Any person charged with Transducer installation, operation, maintenance or repair must in any case have read and understood the operating manual and the notes on safety, in particular.

NOTE!

Multicomponent sensors may only be installed by qualified personnel in compliance with the specifications and with the safety requirements and regulations of the mounting instructions.

Fig. 1. General view of the M56 WFT

1. DESCRIPTION AND SPECIFICATION

1.1 Field of application

The M56-25k-15k-5k 6-component Wheel Force Transducer (WFT) is used to measure up to 6 loads acting on a vehicle wheel, such as longitudinal Fx, vertical Fy, lateral Fz forces, bending moments Mx, My and torque Mz along three orthogonal axes X, Y, Z.

The WFT includes the transducer measuring body (M56-25K-15K-5K), M56-02 telemetry module with the mounting flange installed, M56 indicator (decoder) - provides USB2.0 interface for data recording, the software “Transducer”.

1.2 Specifications

1.2.1. The Nominal Range and maximum values of Forces and Moments

Transducer type	Measured Force, Moment	Nominal measurement value	Nominal measurement range	Maximum overload	Maximum rotation speed
M56-25k-15K-5k	$\mathbf{F_X}$ (longitudinal)	25 000N	±25 000 N	30%	2500 1/min
	$\mathbf{F_Y}$ (vertical)	25 000 N	±25 000 N		
	$\mathbf{F_Z}$ (lateral)	15 000 N	±15 000 N		
	$\mathbf{M_X}$ (bending moment)	5 000 Nm	±5 000 Nm		
	$\mathbf{M_Y}$ (bending moment)	5 000 Nm	±5 000 Nm		
	$\mathbf{M_Z}$ (torque)	5 000 Nm	±5 000 Nm		

1.2.2 Electrical and metrological parameters

Combined error, including nonlinearity and hysteresis related to the nominal measurement value	%	≤|±0.5|
Crosstalk related to the nominal measurement value	%	≤|±0.5|
Temperature effect per 10°C on the zero balance, related to the output value	%/10°C	≤|±0.2|
A/D conversion	bit	12
Sample rate	Hz	2500
Angular resolution with 1024 increments		0.35°
Nominal supply voltage	V (DC)	18…30
Power consumption	W	<10
Digital Output		
Interface		USB 2.0
Data transfer rate (Full-Speed)	Mbit/sec	12

1.2.3 Environmental Characteristics and Mechanical Resistance

Nominal temperature range	˚C	0…+60
Humidity	%	95 (+35°C)
Atmospheric pressure	kPa	84…106,7 (630…800 mm Hg)
Storage temperature range	˚C	-10…+70
Storage humidity	%	95 (+ 30°C)
Vibration resistance: Frequency range Duration Acceleration	 Hz h m/s^2	 10…55 1 40
Impact resistance: Number of impacts Duration Acceleration	 n ms m/s^2	 1000 10 400
Ingress protection rating		IP 50

1.2.4 Mechanical parameters

Stiffness, compliance of the transducer measuring body (calculated)

M56-25K-15K-5K					
		Linear displacement	Angular displacement	Stiffness	
$F_{X,Y}$	25 kN	0,152 mm		164,5	kN/mm
F_Z	15 kN	0,235 mm		63,8	kN/mm
$M_{X,Y}$	5 kN•m	1,110 mm	0,403°	12,4	kN•m/deg
M_Z	5 kN•m	0,098 mm	0,036°	138,8	kN•m/deg

Rim diameter	min 14”

Weight

M56-25K-15K-5K WFT with the telemetry module	kg	7.4

1.2.5 The software

The “Transducer” software available for Windows 10®, Windows 11® enables the acquisition of measurement data, its visualization and storage in the PC memory via the USB 2.0 interface.

1.3 The scope of supply

M56-25K-15K-5K transducer measuring body	1
M56.02 telemetry module with the mounting flange installed	1
M56 Indicator (decoder) (USB 2.0 interface)	1
Signal cable 5m length	1
USB cable 1.6m	1
Software “Transducer” for Windows 10, 8, 7, XP	1
User manual	1
Operator guide (software description on CD)	1

Overall and installation dimensions of M56-25K-15K-5K WFT are shown in Fig. 2, 3, 4.

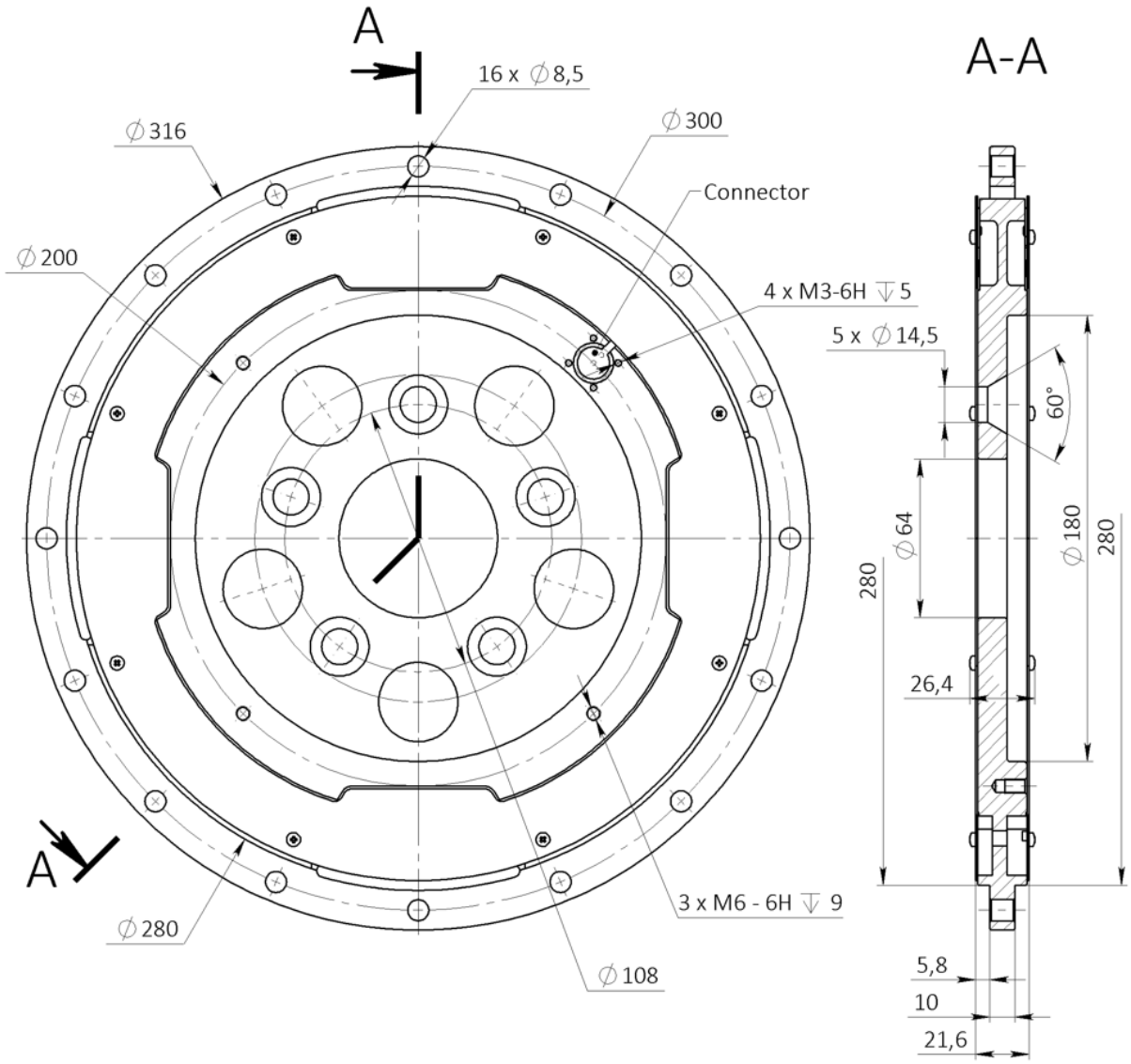


Fig.2. M56-25K-15K-5K measuring body. Overall and installation dimensions, mm.

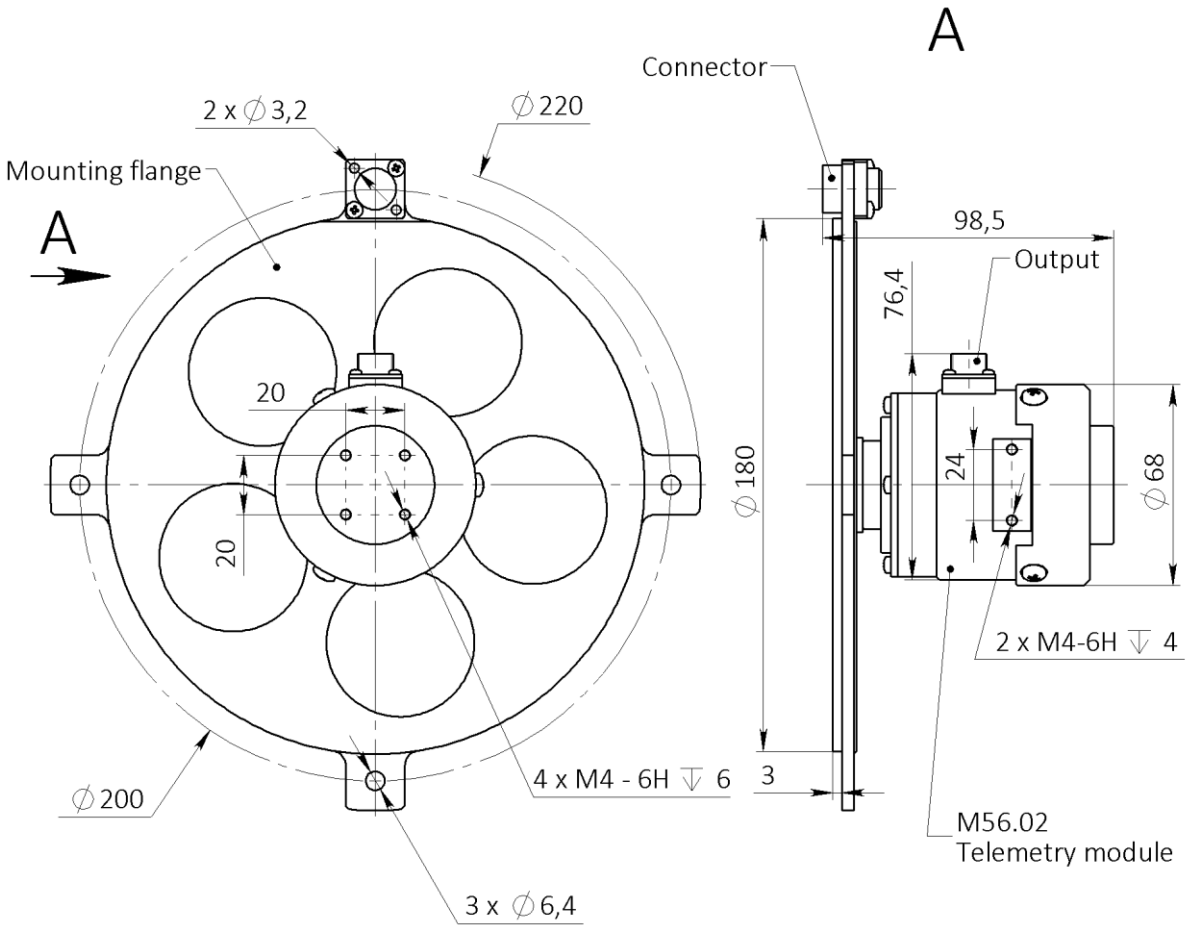
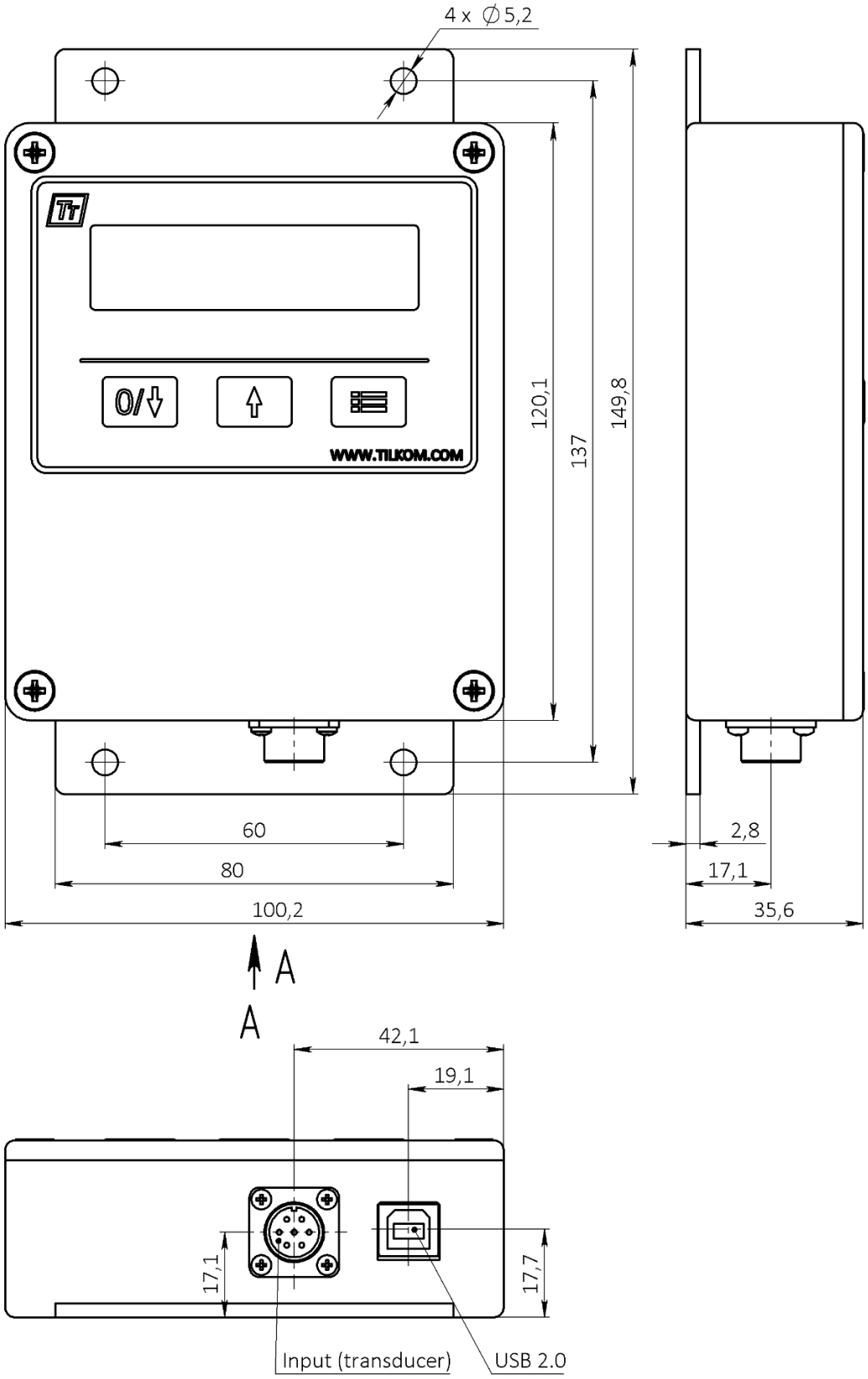


Fig.3. M56.02 telemetry module with the mounting flange. Overall and installation dimensions, mm.



Pic. 4. M56 Indicator (decoder). Overall and installation dimensions, mm.

1.4 Design and operation

1.4.1 Design

The M56-25K-15K-5K measuring body (Fig.2) is a monolithic disk (hereinafter “measuring disc”) made of alloy steel, shielded with cover plates.

The measuring disk has two rows of holes along the inner and outer diameter. The inner diameter holes are to be mounted on the steering wheel hub or on the drive axle flange of a vehicle. The outer diameter holes are to be mounted on the drive wheel disk. The drive wheel disk should be modified appropriately. The holes for the mounting flange of the telemetry module are in the center of the measuring disk.

The measuring disk has elastic elements with the strain gauges installed. The strain gages in turn are connected into strain-gage bridges. The measuring disk has an electronic plate with an amplifier-converter, which is connected to the rotor of the telemetry module. The indicator (decoder) is connected to the stator of the telemetry module via the signal cable.

The air transformer of the telemetry module powers the strain-gage bridges and the electronic plate. D.C. 18…30V through the connection in the stator housing, in turn powers the telemetry module.

The M56.02 telemetry module (see Fig. 3) consists of the rotor and the stator. The rotor is mounted in the stator on bearings. On the rotor there are spinning coils, on the stator – fixed coils of the air transformer, the electronic plate with the signal receiver, power generator and the encoder. The connection with the M56 indicator (decoder) occurs through an electrical connection on the stator housing via multicore cable.

The general view of the M56 indicator (decoder) is given in Fig. 1. Overall and installation dimensions, pin numbers of connectors are given in Fig. 4

The indicator housing is made of aluminum alloy and has mounting flanges with holes. At the top of the front panel is a digital two-row liquid crystal display. Under the display, there are three buttons to control the indicator. At the bottom of the indicator are the connector for the sensor (via the M56.02 telemetry module) and CAN, USB interface connectors.

The indicator receives data from the M56-25K-15K-5K sensor via the M56.02 telemetry module, decodes, converts and transfers the data to the PC or other controller device. The indicator is powered by the telemetry module.

1.4.2 Operation

The M56 6-component Wheel Force Transducer (WFT) is used to determine the forces and torques acting on a vehicle wheel during test drives.

The M56 wheel force transducer provides simultaneous measurement of the full 6 components of force and moment, such as longitudinal force $\mathbf{F_X}$, vertical force $\mathbf{F_Y}$, lateral (axle wheel) force $\mathbf{F_Z}$, along 3 orthogonal axis **X**, **Y**, **Z**, bending moments $\mathbf{M_X}$, $\mathbf{M_Y}$, and torsional moment $\mathbf{M_Z}$ (see Fig. 5)

When an arbitrary load acts upon the transducer, the SG bridges unbalance occurs. The GS bridges are configured so that the unbalance of each one is proportional to the corresponding $\mathbf{F_X}$, $\mathbf{F_Y}$, $\mathbf{F_Z}$ force or $\mathbf{M_X}$, $\mathbf{M_Y}$, $\mathbf{M_Z}$ moment. How the arbitrary load applied to the transducer is resolved into components see in Fig. 5.

The unbalance signals are transmitted to the amplifiers of the measuring disk, where they are amplified and converted into digital code. Then the digital encoded signal is transferred via the cable into the rotor of the telemetry module. Then through the air transformer the signal is transmitted to the electronic plate of the stator, where it is amplified and transmitted via the signal cable to the indicator (decoder). On the stator of the telemetry module the angle sensor is located. Its digital signal is also transmitted to the indicator (decoder).

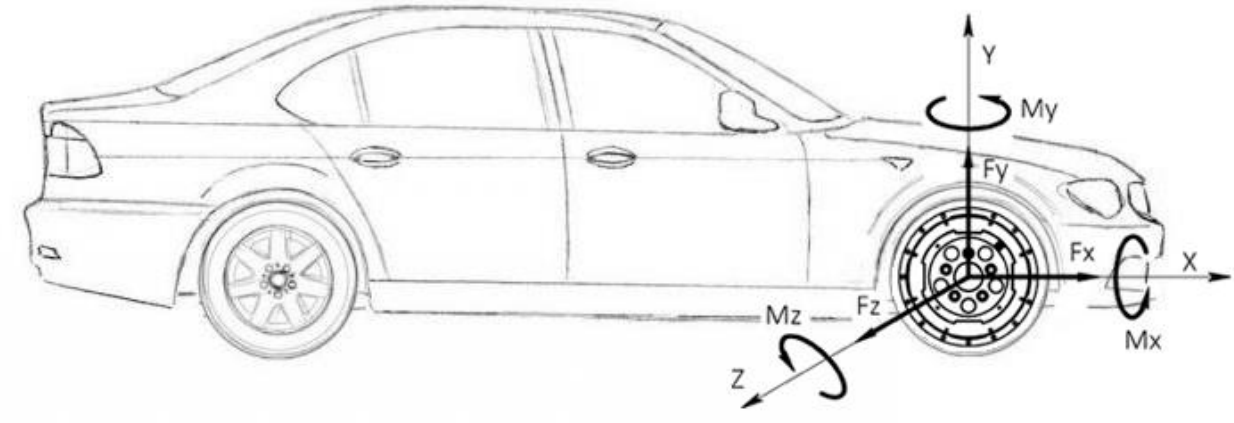


Fig.5. The scheme of forces and moments measured with the M56-25K-15K-5K WFT.

The positive direction of forces and moments on the right side of a vehicle is shown.
On the left side, the signs $\mathbf{F_X}$, $\mathbf{F_Z}$, $\mathbf{M_X}$, $\mathbf{M_Z}$ are reversed.

The indicator-decoder displays the forces and moments measured by the sensor on a digital display, and performs several transformations of the measuring signal:

1) Trigonometric transformation, i.e. conversion of rotating coordinates to stationary, depending on the angle of rotation of the wheel;
2) Data transfer to PC with Transducer Software via USB 2.0 interface.

The indicator-decoder also implements a number of functions for adjusting the measuring channels of forces, moments and angle of rotation of the wheel.

The conversion of the rotating coordinates of the wheel to the stationary coordinates of the vehicle is performed according to the formulas:

$$F_x = F_{x1}\, cos\, cos\, (\varphi) - F_{y1}\, sin\, sin\, (\varphi)$$

$$F_y = F_{y1}\, cos\, cos\, (\varphi) + F_{x1}\, sin\, sin\, (\varphi)$$

where X, Y – stationary coordinates (coordinates of the vehicle),
X_1, Y_1 – rotating coordinates of the sensor (coordinates of the wheel),
F_x, F_y – measuring signals of the sensor after the conversion of the coordinates,
F_{x1}, F_{y1} - measuring signals of the sensor before the conversion of the coordinates,
φ – rotation angle of the WFT (wheel of the vehicle) relative to stationary coordinates,

To increase the accuracy of measurements, the M56 WFT provides compensation for the cross influence of forces and moments on the strain gages (crosstalk). This phenomenon can be described as follows: when e.g. the external bending moment acting upon a transducer causes the unbalance of $\mathbf{M_X}$, $\mathbf{M_Y}$ strain gage bridges, an insignificant unbalance of other strain gage bridges (e.g. $\mathbf{F_X}$, $\mathbf{F_Y}$) may occur. That may lead to an increase in combined measurement error. The value of crosstalk unbalance is determined empirically during the calibration and is estimated by the crosstalk coefficient. Crosstalk coefficient is defined as the ratio of crosstalk unbalance to the nominal strain bridge unbalance at nominal value of external influence. In total, there can be 36 crosstalk coefficients according to the number of pairs of measured components. However, in practice, a number of crosstalk coefficients do not exceed 0.1% of the nominal measured value and therefore are not taken into account. In cases where the crosstalk exceeds 0.1%, the adjustment of measuring signals is provided according to the formulas:

$$F_{X1} = \Delta F_x K_{11} + \Delta F_y K_{12} + \Delta F_z K_{13} + \Delta M_x K_{14} + \Delta M_y K_{15} + \Delta M_z K_{16}$$
$$F_{Y1} = \Delta F_x K_{21} + \Delta F_y K_{22} + \Delta F_z K_{23} + \Delta M_x K_{24} + \Delta M_y K_{25} + \Delta M_z K_{26}$$
$$F_{Z1} = \Delta F_x K_{31} + \Delta F_y K_{32} + \Delta F_z K_{33} + \Delta M_x K_{34} + \Delta M_y K_{35} + \Delta M_z K_{36}$$
$$M_{X1} = \Delta F_x K_{41} + \Delta F_y K_{42} + \Delta F_z K_{43} + \Delta M_x K_{44} + \Delta M_y K_{45} + \Delta M_z K_{46}$$
$$M_{Y1} = \Delta F_x K_{51} + \Delta F_y K_{52} + \Delta F_z K_{53} + \Delta M_x K_{54} + \Delta M_y K_{55} + \Delta M_z K_{56}$$
$$M_{Z1} = \Delta F_x K_{61} + \Delta F_y K_{62} + \Delta F_z K_{63} + \Delta M_x K_{64} + \Delta M_y K_{65} + \Delta M_z K_{66}$$

where $\mathbf{F_{X1}}$, $\mathbf{F_{Y1}}$, $\mathbf{F_{Z1}}$, $\mathbf{M_{X1}}$, $\mathbf{M_{Y1}}$, $\mathbf{M_{Z1}}$ – corrected values of signals of measured forces and moments in wheel coordinates;

$\Delta\mathbf{F_x}$, $\Delta\mathbf{F_y}$, $\Delta\mathbf{F_z}$, $\Delta\mathbf{M_x}$, $\Delta\mathbf{M_y}$, $\Delta\mathbf{M_z}$ – unbalances of strain gage bridges corresponding to the measured forces and moments in wheel coordinates;

$\mathbf{K_{11}}$, $\mathbf{K_{22}}$, $\mathbf{K_{33}}$, $\mathbf{K_{44}}$, $\mathbf{K_{55}}$, $\mathbf{K_{66}}$ – calibration coefficients;

$\mathbf{K_{12}}$, $\mathbf{K_{13}}$ … $\mathbf{K_{64}}$, $\mathbf{K_{65}}$ – crosstalk coefficients.

This adjustment of measuring signals occurs in the microprocessor module of the M56 measuring disk. Crosstalk coefficients are determined during the calibration and saved in the microprocessor module memory.

From the output of the indicator-decoder, the digital measuring signal is sent directly to a PC via the USB 2.0 interface.

The software “Transducer”, which is supplied together with the sensor, provides visualization of measurement data in the form of numbers and graphs on the monitor screen, as well as their storage in the PC memory.

2. APPROPRIATE USE

2.1. Operating Precaution

Avoid the overload of the M56-25K-15K-5K sensors during the operation. The permissible loads are given in chapter 1.2.1. You can control and monitor the current loads and its over range on the PC monitor with the “Transducer” software.

2.2. Installation

2.2.1. General Dangers

When using the transducer, the legal and safety regulations for the respective application must be observed. The transducer supply voltage is not dangerous. The transducer does not have an adverse effect on the environment.

2.2.2. Mounting

Before installing the transducer to the vehicle, install the measuring body on the wheel rim adapter. Tighten the M8 bolts (16 pcs).

It is recommended to use the original equipment manufacturer (OEM) wheel design as the basis of the rim adapter design. An example of the design of a wheel rim adapter and hub adapter is given in Appendix 1 and Appendix 2.

The M56-25K-15K-5K WFT is to be mounted as follows (see Fig. 6):

1. Mount the wheel hub adapter on the axle flange of a vehicle. Tighten the fastening screws with the regulated tightening torque.

2. Mount the wheel rim adapter (with the tire and the transducer measuring body) on the vehicle. Tighten the fastening screws with the regulated tightening torque.

3. Mount the M56.02 telemetry module on the M56-25K-15K-5K measuring body with the corresponding mounting flange, aligning the electrical contacts of the measuring body and the flange. Fasten the flange with M6 (3 pcs) and M3 (2 pcs.) screws.
Before installing the telemetry module, it is recommended to check the functionality of the spring electrical contacts located on the flange. To do this, you need to press on the spring contact with your finger and make sure that it does not stick.

4. Fix the stator of the telemetry module with the restraint rod and arm to prevent rotation. The fastening must be rigid in the direction of rotation of the wheel and at the same time flexible in the direction of deformation of the tire (up and down).

6. Place the M56 indicator-decoder, PC and other recording equipment in the cab of a vehicle.

7. Make the electrical connections according to the scheme given in fig. 7. Use the supplied cables.

8. Provide the connection of 18…30V DC power supply and its quick disconnection. The power is connected to the red (+) and black (-) wires located in the common signal cable harness.
For power supply it is necessary to use a separate battery that is not connected to the vehicle's on-board network.

9. Perform a trial connection of the power supply; make sure that the sensors are operational - M56 indicator-decoder shows some data on display.

10. On the M56 indicator-decoder, perform configuration of the transducer in accordance with Paragraph 2.4.1 “Setting up wheel side”. **It is important to set on which side of the vehicle the transducer is installed: on the right or on the left.**

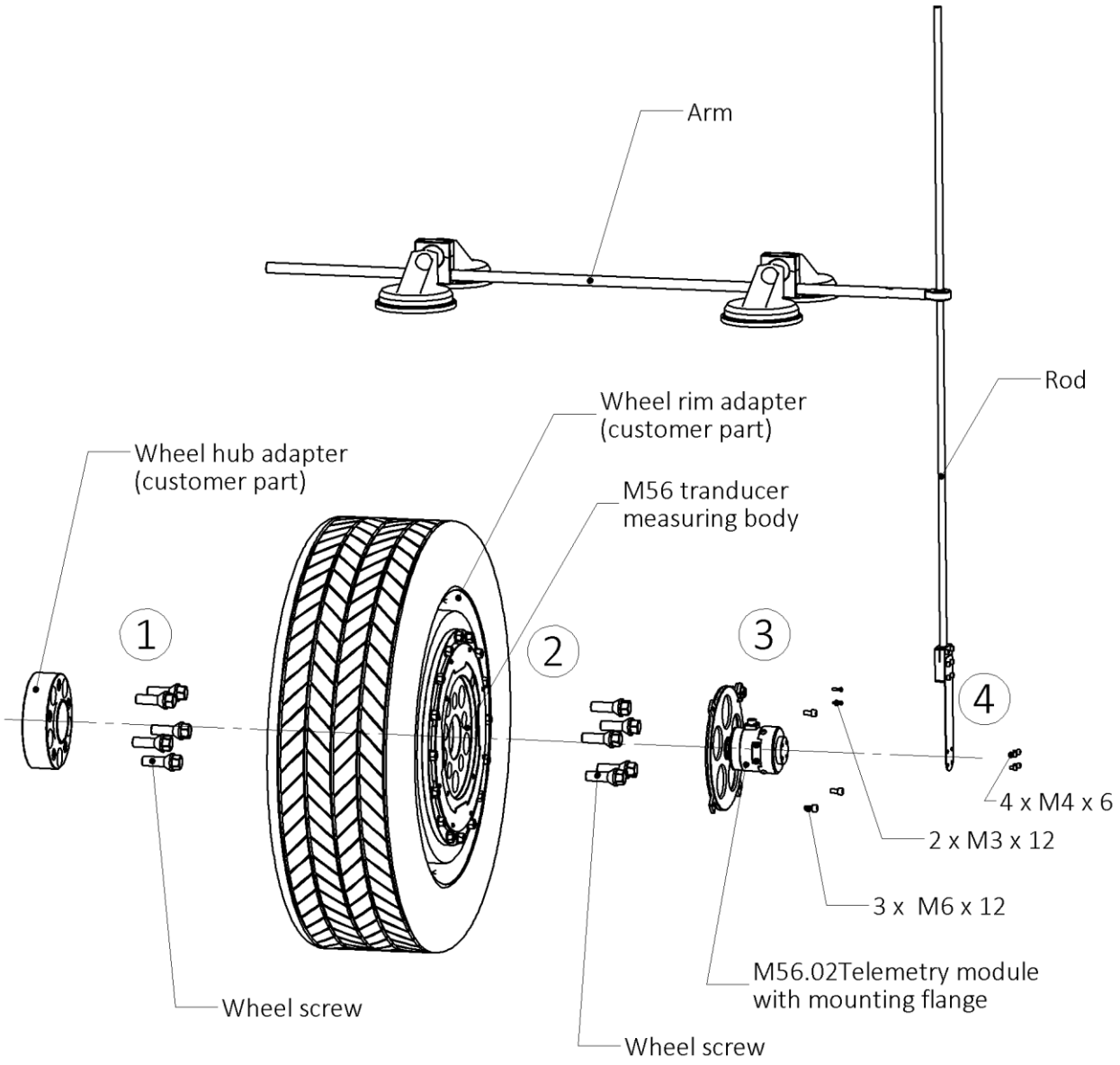


Fig.6. M56 WFT installation procedure.

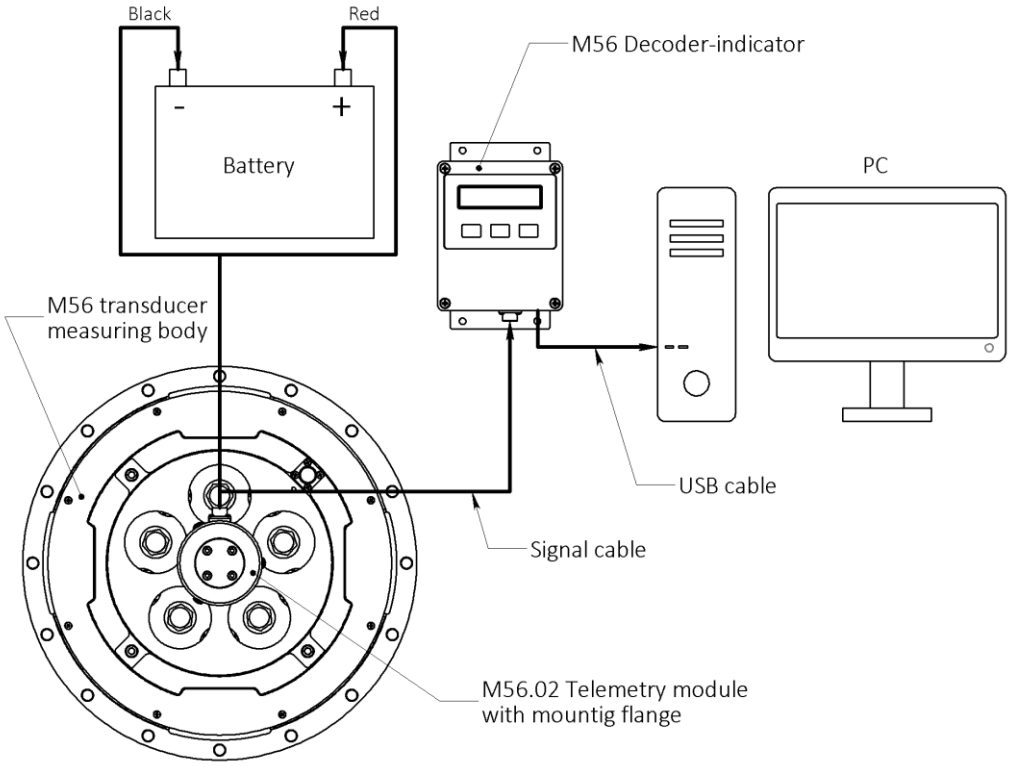


Fig.7. The scheme of electrical connections of the M56-25K-15K-5K WFT.

2.3. M56 indicator-decoder operating procedure

Indicator-decoder M56 is intended for viewing measurement data and adjusting settings. It starts operating after M56 WFT powering up.

The indicator-decoder M56 has a digital display (two lines of 16 characters each), USB 2.0 (Type B) interface for data transfer to PC and three buttons for navigation and editing settings. The appearance of the display and buttons is shown in Figure 8.

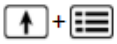
Fig.8. M56 indicator-decoder appearance

Indicator-decoder M56 has 2 main operation modes:

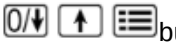
- Measurement view menu
- Edit settings menu

Measurement view menu is available immediately after the indicator is powered up and has list of display modes:

- Fx and Angle of rotation
- Fy and Angle of rotation
- Fz and Angle of rotation
- Mx and Angle of rotation
- My and Angle of rotation
- Mz and Angle of rotation
- Rotational speed and transducer temperature
- Parameters view menus (reference Information)
- Viewing menu navigation is done using  buttons. The viewing menu diagram is shown in Figure 9.

Edit settings menu is available after pressing  buttons and allow to edit list of settings:

- Corrections (zero adjusting algorithm)
- Language
- Interface options (if available)
- M56 WFT options
- Data processing options

Edit settings menu navigation is done using  buttons. The edit settings menu diagram is shown in Figure 10.

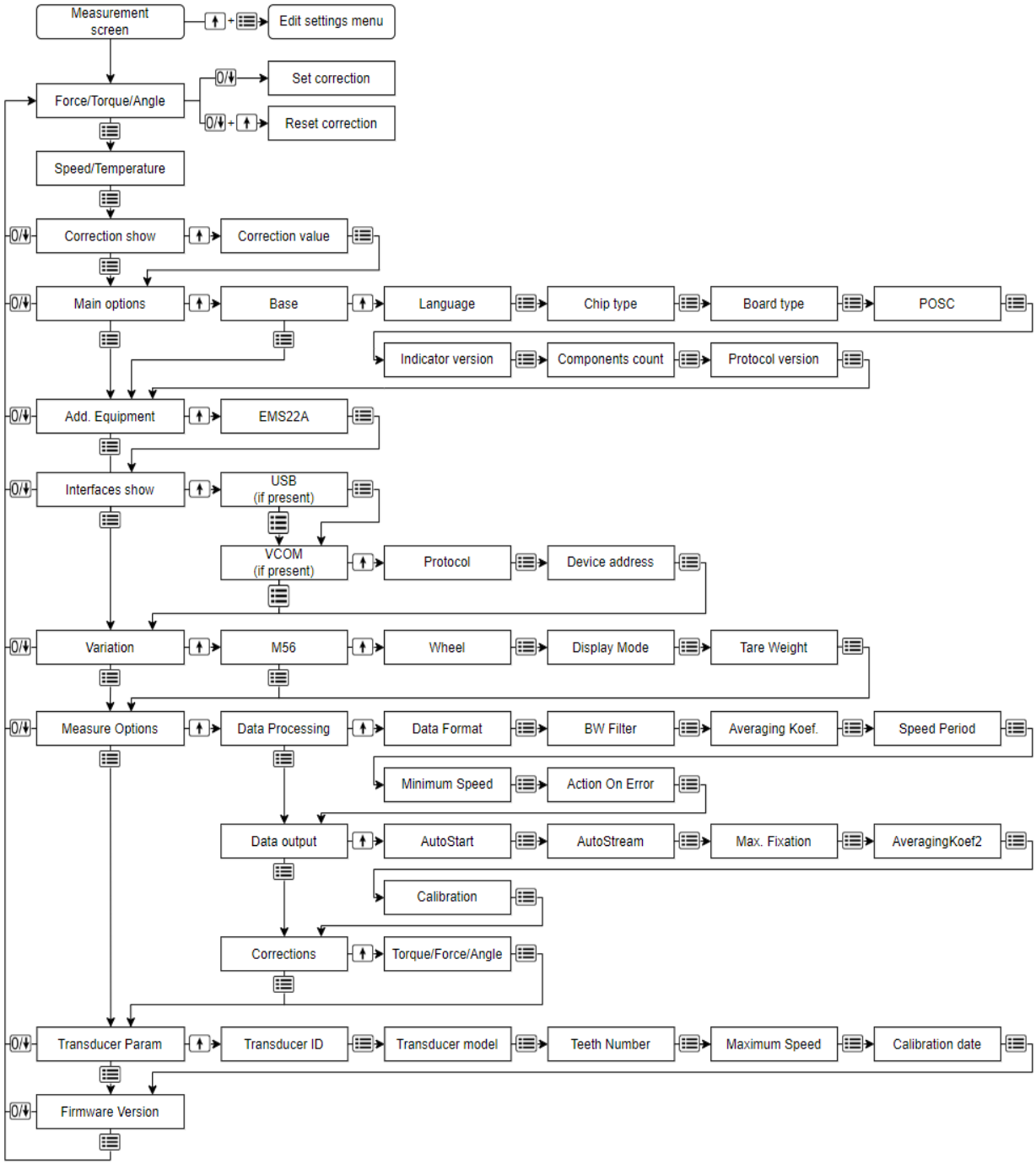


Fig.9. M56 indicator-decoder measurement view menu scheme

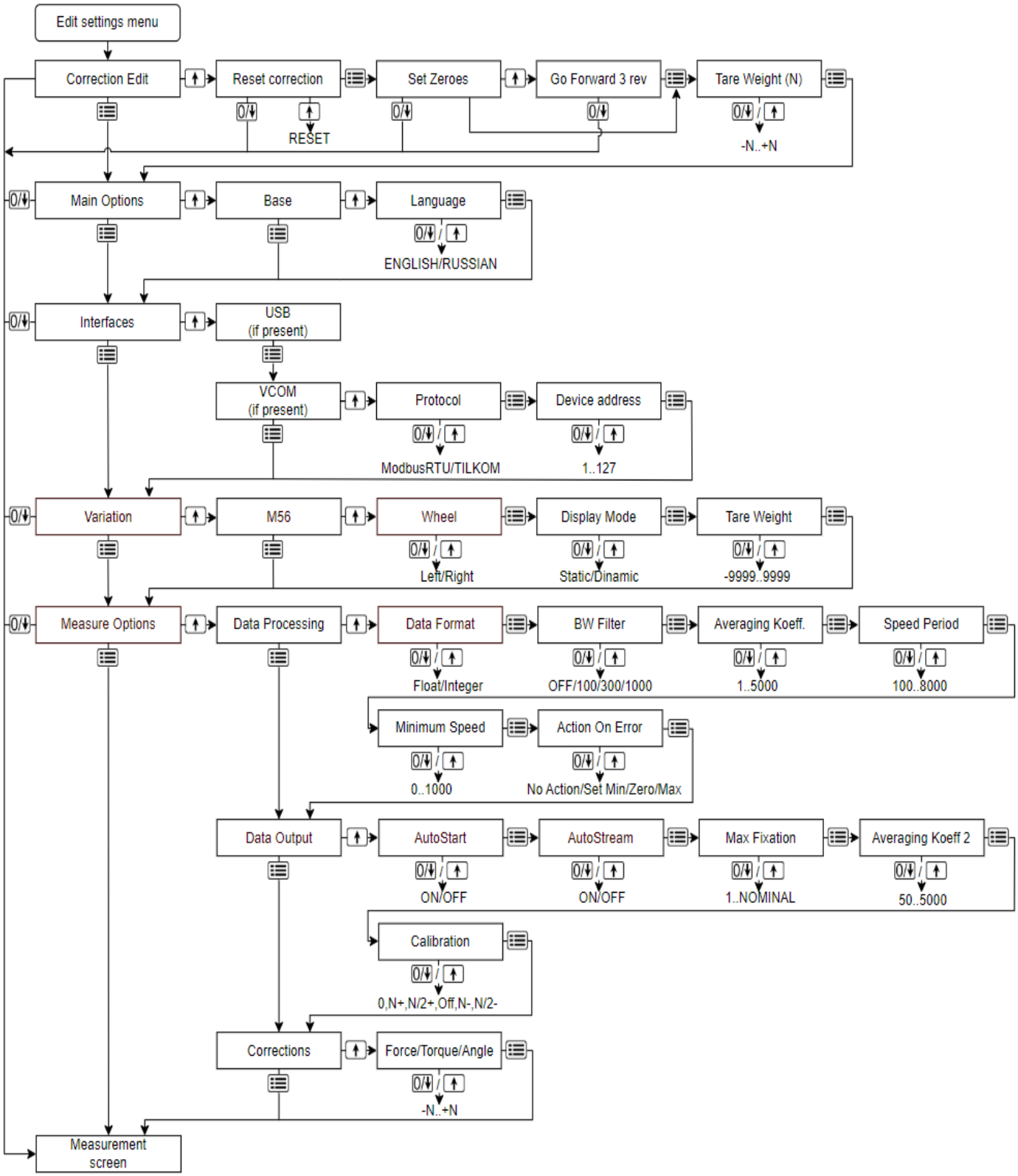


Fig.10. M56 indicator-decoder edit settings menu scheme

2.4. Measurement preparation

2.4.1 Setting up wheel side

After installing the M56 WFT on the disk and vehicle, it is necessary to configure the installation side and display mode in the indicator.

Apply power to the sensor. The M56 indicator-decoder display should turn on and show one of the active forces. After this, follow the menu items by pressing the buttons to set installation side and display mode according to figure 11.

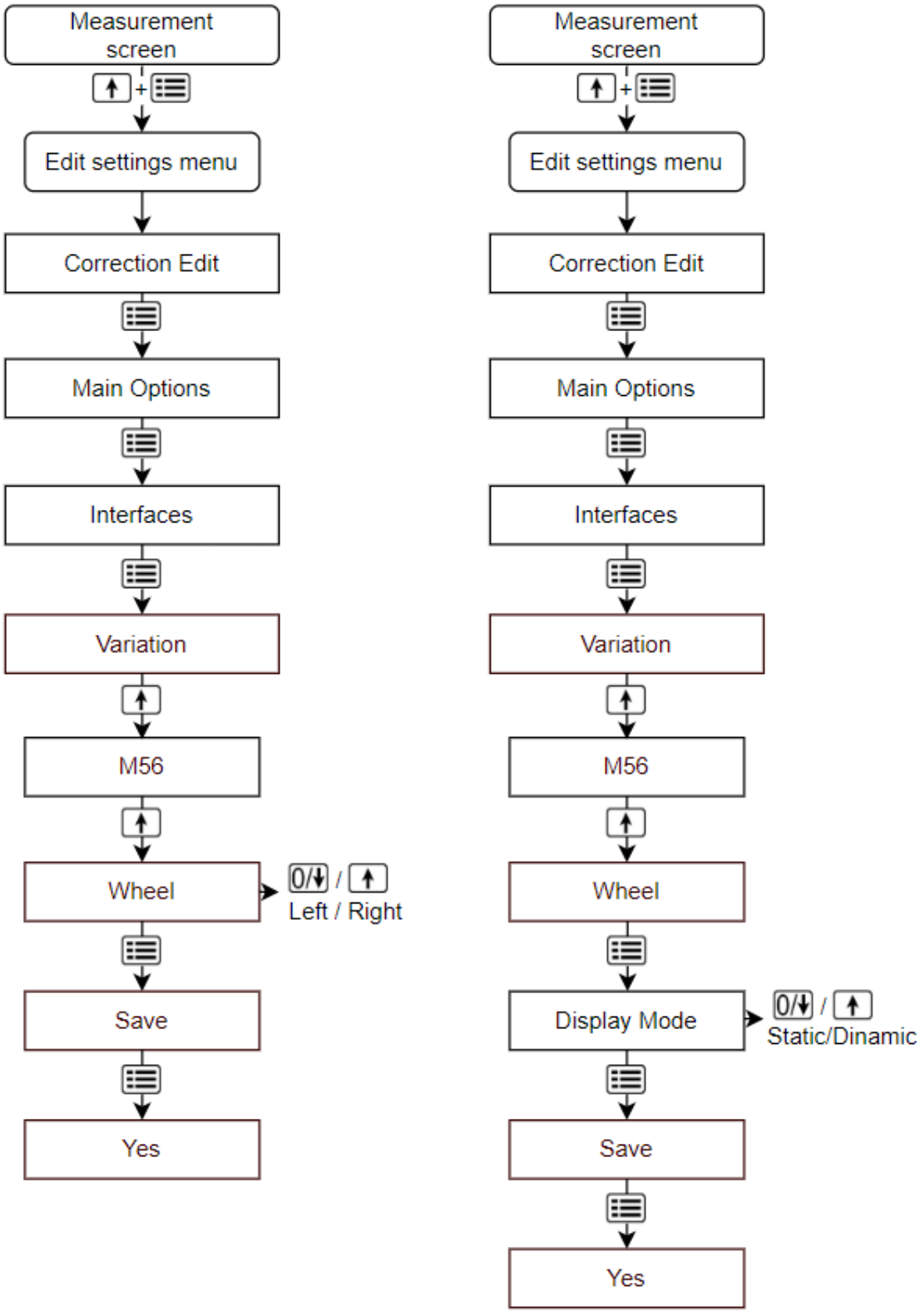


Fig.11. M56 indicator-decoder installation side and display mode setting scheme

2.4.2 Zero adjustment

When mounting the M56 sensors, the measuring body is deformed and the unbalance of the strain gauge bridges occurs, which is observed as a deviation of the indicator readings from zero values in the absence of load. In this regard, before starting the measurements, it is necessary to perform the procedure of zero adjustment for all measured components including wheel angle. This procedure has a semi-automatic mode.

To perform the zeroing procedure, it is necessary to evenly rotate the suspended wheel by performing three full turns. Also, three full turns of the wheel can be performed by rolling the vehicle on a level surface. The revolution counter is in the extreme right position of the bottom line.

To perform zeroing follow the menu items by pressing the buttons to start setting the zeroing algorithm according to figure 12.

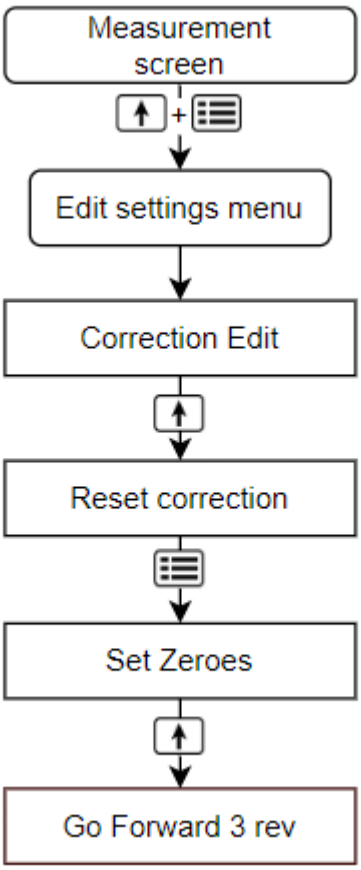


Fig.12. M56 indicator-decoder setting zeroes algorithm start procedure.

After this, the device will begin counting wheel revolutions. After three revolutions, the program will calculate corrections for all forces, moments and angle of rotation, and then display a message “SET ZEROES COMPLETED” and corrections can be saved. Saving corrections implies writing corrections to permanent memory. Therefore, after turning off and then turning on the power, the corrections will be the same.

After completing the procedure of zeroes adjustment, the force Fy equal to the weight of the wheel and the current angle value should be displayed on the indicator board. For other components, readings should be close to zero (deviations of not more than 1-2% of the nominal measured value)

After completing the zeroes adjustment, the sensor is ready for operation to measure the forces and moments acting on the wheels of the vehicle.

2.4.2 Setting up software

To visualize and record the measurement process, you must use the "Transducer" software supplied with the sensor.

“Transducer” program can be installed on Windows 10®, Windows 11® PC. After installing, you need to run the "Configurator" subprogram, set the parameters shown in Figure 15 and click "OK".

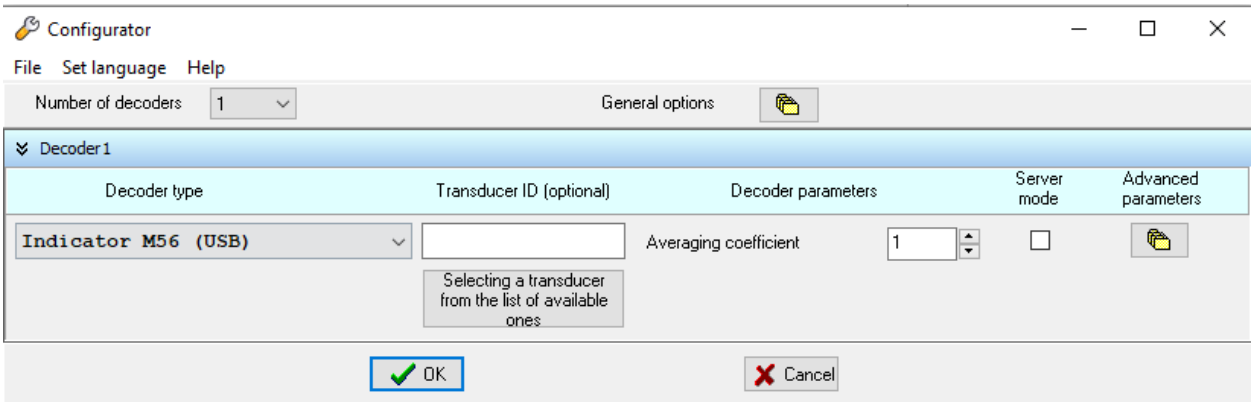


Fig.13. "Configurator" subprogram setup for M56.

After setting up "Configurator" subprogram you can connect the M56 indicator-decoder to the PC via USB cable and run "Transducer" software and press the "Play" button in the top left corner of the window and software will start getting and visualize data from sensor like shown on figure 14.

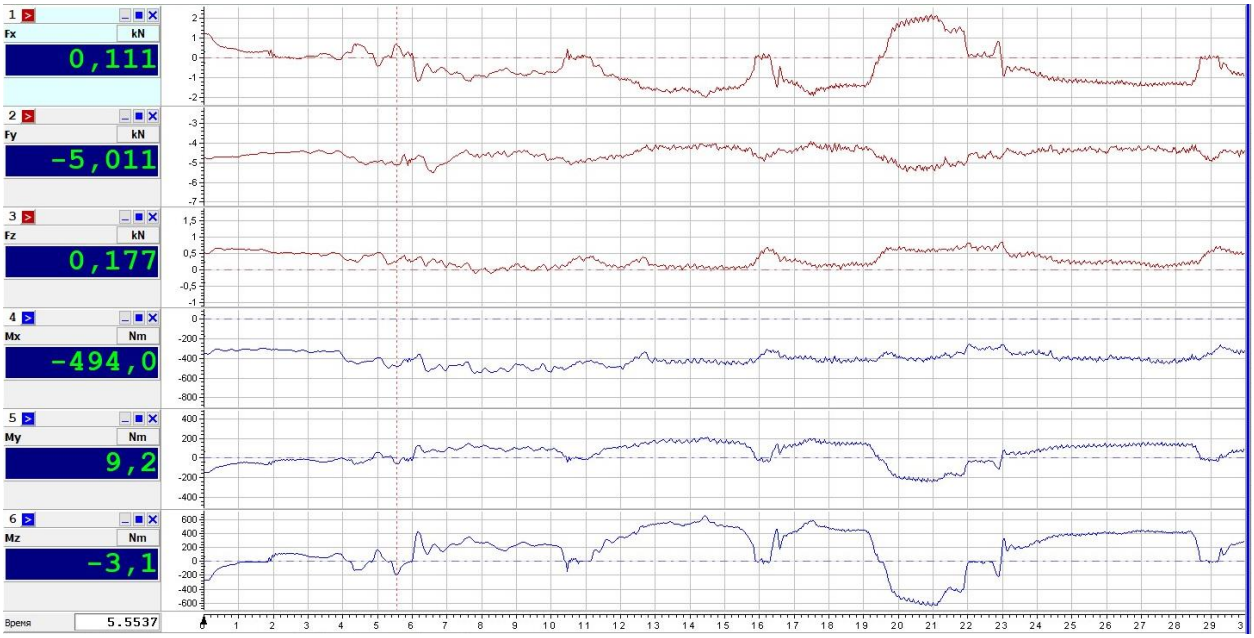


Fig.13. "Transducer" software window example.

For additional instructions refer to "Transducer" manual by pressing F1 key or Help -> Show help.

3. MAINTENANCE

The M56-25K-15K-5K WFT is maintenance-free. The calibrating is performed by the manufacturer.

4. CORRECTIVE MAINTENANCE

4.1 The corrective maintenance is performed by the manufacturer.

4.2 Possible faults that the user can troubleshoot by himself.

Possible fault	Possible cause	Troubleshooting
No transducer readout	No power supply of the transducer	Check the power connections in accordance with the scheme in Fig. 7
No transducer readout	No power supply of the transducer	Check the functionality of the spring electrical contacts located on the flange of the M56.02 telemetry module

5. STORAGE AND TRANSPORTATION

5.1. The storage of the M56 FWT must occur by the ambient temperature from + 5 to + 40°C and relative humidity up to 80% by 25°C.

There must be no dust, acid fumes, alkali, corrosive gas and other agents in the storage.

5.2. The M56 WFT can be transported by any closed vehicle in suitable packing.

For the limited climate conditions during the forwarding refer to section 1.2.3.

6. DISPOSAL

The M56-25K-15K-5K WFT does not contain life-threatening or environmentally harmful substances. Disposal is carried out in accordance with the procedure adopted at the enterprise using the sensor.

7. WARRANTY

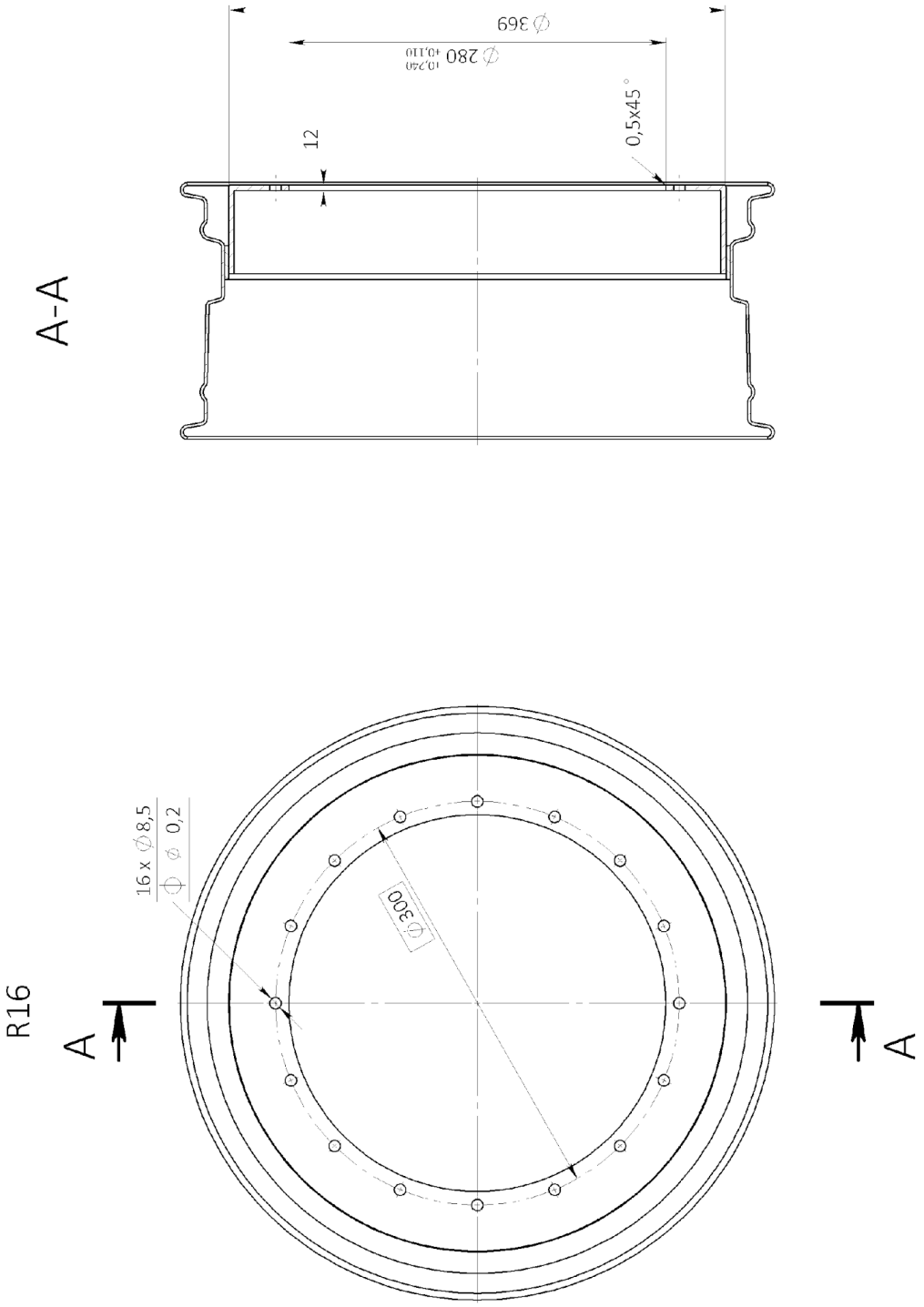
7.1. The M56 WFTs are warranted by the producer to meet the requirements mentioned in this Operating Manual, when used appropriately, stored and maintained properly.

Warranty period of operation is 12 months from the date of putting into operation.

7.2. Warranty exclusions and limitations:

- the termination of the warranty storage period, if the transducer is not put into operation;
- the termination of warranty operating period, if the transducer is put into operation;
- the warranty period is prolonged for the period from the written claim till the putting the device into operations by the manufacturer.

Appendix 1. Rim adapter based on 6.5J x 16 rim



Appendix 2. Hub adapter