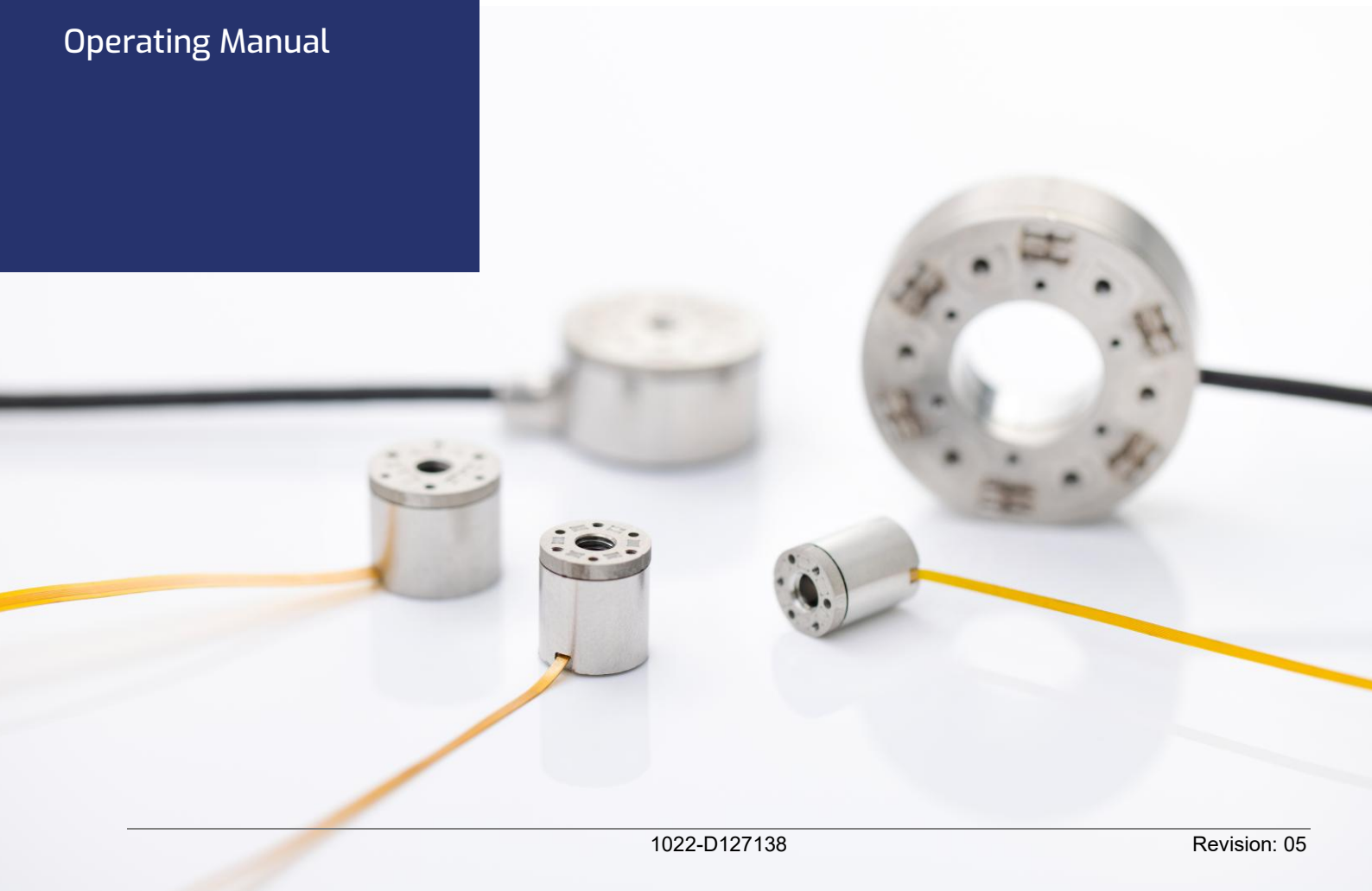
Resense
A Sense of Touch

Operating Manual

Functional Prototype
6-Axis Force/Torque Sensor with Miniature Evaluation Electronics



Technical support

If there are any questions about customer service or repairs service, please contact us.

Resense GmbH
Alexander-Wiegand-Str. 30
D-63911 Klingenberg

Phone: +49 9372 132-0

Email: info@resense.io

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	The products offered are **functional prototypes**. A functional prototype is only intended for laboratory and test operation and is not suitable for long-term testing. The actual technical data of your individual prototype may differ from the technical data within the technical documentation.

	⚠ CAUTION Resense Force/Torque (F/T) sensors are delicate objects. Pay particular attention to the inner components and disconnection due to handling of flex cable. Before installing and using this product, please carefully read chapter 5 “Assembly” and chapter 6 “Startup and operation” in this document. Otherwise, incorrect installation and handling may cause damage to this product.

Contents

1 About this manual

This operating manual contains necessary information to safely operate the **6-axis force/torque sensor prototype with evaluation electronics**, in the following called **F/T sensor**.

The operator must ensure that all persons assigned to install and operate the F/T sensor have read and understood these instructions in full.

Store these instructions within reach of the F/T sensor.

1.1 Signal words

The following signal words are used to indicate hazards, things that are forbidden and important information:

	⚠ WARNING **This signal word indicates a potential hazard that could cause serious injuries.**

	⚠ CAUTION **This signal word indicates a potential hazard that could cause minor or serious injuries.**

	NOTICE **This signal word indicates a potential hazard that could lead to material damage.**

	A note without a signal word indicates application hints **or especially important information for working with the F/T sensor.**

1.2 Safety symbols

The following safety symbols are used to indicate possible hazards, prohibitions, and important information:

	
General danger	Electric voltage

1.3 Design of the safety instructions

The safety instructions of these instructions are designed according to the following pattern:

	**⚠ CAUTION** **Explanatory text shows the consequences of disregarding this information.** • Instructive text uses direct address to indicate what to do.

1.4 Information symbols

The following information symbols are used:

- • Indicates an action to be performed
- ➲ Indicates the results of an action
- ⓘ Provides additional handling information

2 Safety

This operating manual, especially the safety instructions and the rules and regulations valid for the operating site, must be observed by all persons working with the F/T sensor.

In addition to the safety instructions in this manual, also observe any (legal and otherwise) applicable environmental and accident prevention rules and regulations (e.g. personal safety equipment).

2.1 EU/EC Low Voltage Directive

Since the F/T sensor is in functional prototype status, EU/EC conformity cannot be certified. Accordingly, the F/T sensor is not provided with a CE mark.

The electrical installation is to be carried out in accordance with the relevant provisions (e.g. wire cross-sections, protection).

Compliance with the requirements for the entire system (where F/T Sensor is part of) is the responsibility of the manufacturer of this system.

2.2 Dangers

To avoid danger to the operator or damage to the machine, the F/T sensor may be put to use only for its intended use (see chapter 2.4 “Intended use”) and in a technically flawless and safe state.
Read the general safety instructions before beginning work (see chapter 2.7 “General safety instructions”).

2.3 Personnel

Only technicians who have read and understood this operating manual may perform work on the F/T sensor. Based on their training and experience, technicians must be able to evaluate the tasks assigned to them, in order to recognize and avoid risks.

2.4 Intended use

The current functional prototypes of F/T sensor can only be used for verification of functional principles, i.e. measurement of forces and torques in the three spatial dimensions. Furthermore, it is only intended for laboratory and test operation and is not suitable for long-term productive operations. The functional samples may neither be placed on the market nor sold to third parties.

The F/T sensor must not be used in applications with special environmental conditions e.g. vacuum, potentially explosive atmospheres, clean rooms or areas with radioactive contamination.

The F/T sensor has a protection rating of IP20. This rating indicates protection against solid foreign objects ≥ 12.5 mm, but no protection against water ingress. Consequently, the sensor must not be operated in environments with elevated humidity.

It must be ensured that the F/T sensor is only used up to its specified nominal load.

⚠ CAUTION

Under continuous load, the component may break and damage the operating equipment.

- The F/T sensor has not been subjected to an endurance test. Information on the fatigue strength of the F/T sensor is not available at the time of delivery.

2.5 Reasonably foreseeable misuse

Any use that deviates from the approved technical data (e.g. nominal force, nominal torque, temperature) is not permitted.

2.6 Guarantee and liability

Guarantee and liability claims are excluded for personal injury and material damage in case of

- Ignoring the information on transport and storage
- Improper use (misuse)
- Improper or neglected maintenance and repair
- Modifications or reconstructions that have been carried out without the approval of **Resense GmbH**.

The warranty claims for functional prototypes become time-barred within 12 months after the transfer of risk as detailed in section 4 of the general sales and delivery condition.

2.7 General safety instructions

⚠ CAUTION

Faulty electrical connections or the installation of unapproved current-carrying components may result in short circuits, polarity errors, or damage to cables.

- Have all electrical connection work performed by qualified technicians only.
- Immediately replace damaged cables or plugs.

3 Product description

The F/T sensor kit prototype consists of following components:

1. 6-axis F/T sensor,
2. miniature evaluation electronics,
3. application software *F/T Explorer* (For MS Windows or Linux).

The following picture shows all three compontents in an exemplary setup scenario.

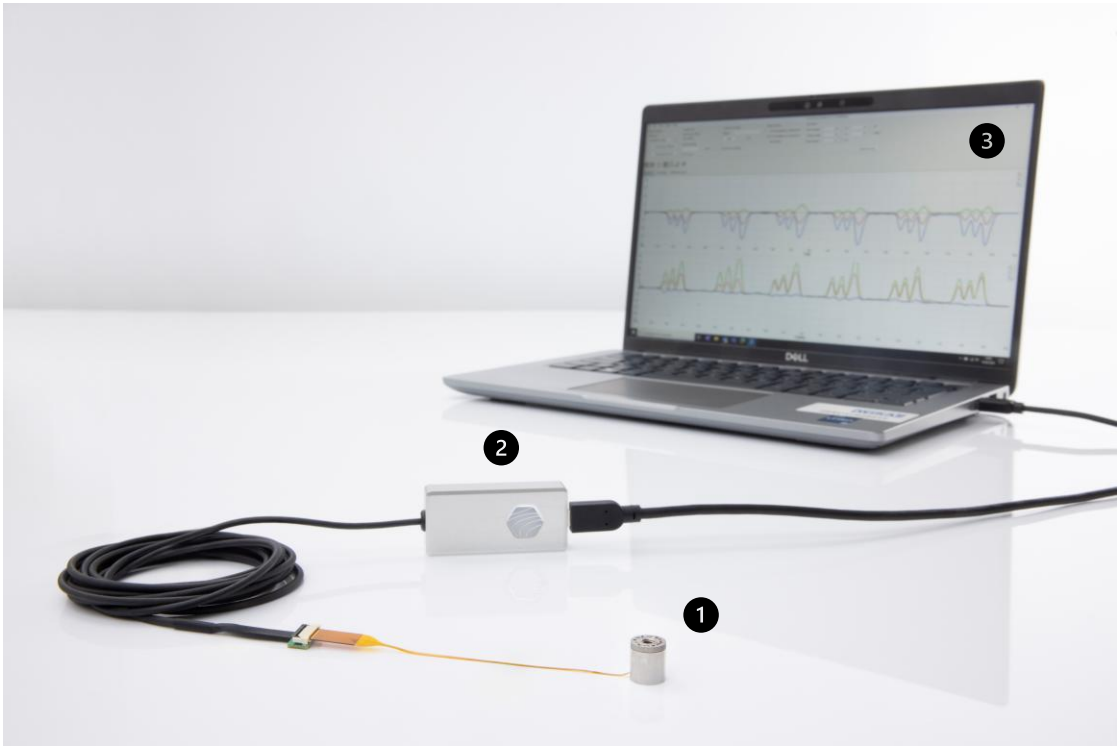


Figure 1 *Sensor-Kit Setup of F/T sensor (1), miniature evaluation electronics (2) and F/T Explorer software application (3)*

3.1 Sensor-Kit package

The Sensor-Kit includes the following components:

1. F/T sensor: The core sensing unit for measuring forces and torques along all six axes.
2. Miniature evaluation electronics: Handles signal conditioning, data processing, and communication.
3. Mounting screws and tools: For securely attaching the sensor to your chosen mechanical structure.
4. Micro-SD-Card with adapter: Preloaded with the F/T Explorer software, operating manual and sensor-specific information.
5. USB-C cable: Connects the miniature evaluation electronics box to a PC or compatible device for data transfer and power.

Figure 2 shows the sensor kit as delivered.

Figure 2 *Detailed overview of sensor-kit with all components as delivered*

3.2 Sensor

The F/T sensor is a compact sensor which can measure forces and torques in all three spatial directions. Strain gauges arranged in a hexapod structure are used as (piezzo)-resistive measurement elements to convert sensor deformation into electric voltage signals.

3.2.1 3D geometry & cables

The sensor 3D geometry of the available sensors HEX8, HEX10, HEX12, HEX21 and HEX32 can be found in chapter 10.2 “Application interface”. The smaller sensors (HEX8, HEX10 and HEX12) are connected to the miniature evaluation electronics via a round cable and a flex cable. The bigger ones (HEX21 and HEX32) are connected with a round cable only.

The round/flex cable lengths are as shown in the figure below:

- Round cable length: 110 – 140 cm
- Flex cable length (HEX8, HEX10 and HEX12 only): approx. 11.5 cm

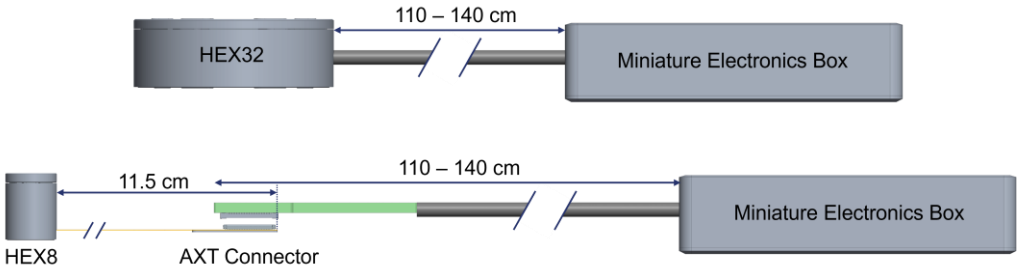


Figure 3 *Cable lengths of F/T Sensors*

3.2.2 Application interface

Dimensions of the top and bottom cover as application interfaces for the five available sensor versions HEX8, HEX10, HEX12, HEX21 and HEX32 can be found in chapter 10.2 “Application interface”.

3.2.3 Performance data

Technical details, including load ratings and maximum permissible forces and torques can be found in chapter 10.1 “Technical data”.

3.3 Miniature Evaluation Electronics

The F/T sensor prototype contains the sensor itself as well as the corresponding miniature evaluation electronics.

The electronics digitizes the analog voltage signals of strain gauges and calculates the prevailing forces and torques with the aid of a calibration matrix. This data is then transferred to the computer and is visualized by the application software.

Information about operation and the configuartion of the electronics box can be found in chapter 6.5 “Operation and configuration of the miniature evaluation electronics”.

3.4 Application software F/T Explorer

The F/T sensor prototype also includes a software application. It visualizes the force and torque values as time series on the computer. Available functions are described in chapter 6.6 “Operation and functions of the application software”.

3.5 EtherCAT shield

The EtherCAT shield is an optional accessory in prototype status and must be purchased separately. Further documentation is provided on request.

3.6 Customized Sensors

For customized sensors, separate drawings, datasheets, and manuals are provided with the delivery.

If you are using a standard sensor and are interested in an OEM or customized version, please contact your sales representative.

4 Transport and storage

4.1 Scope of delivery

- Check completeness of delivery against the delivery note.
- If there are any missing or damaged parts, please notify the carrier, the insurance company or **Resense GmbH** immediately in writing.

4.2 Packaging

The F/T sensor is delivered in sheet metal boxes.

- Dispose of the packaging materials at the recycling sites intended for this purpose. Observe the applicable national regulations concerning disposal.

4.3 Transport

NOTICE

Hard knocks, especiall because of falling or hard dropping, can damage the F/T sensor

- Never exceed the maximum permissible load for equipment.
- Lower the functional prototype F/T sensor in a controlled and steady manner.

4.4 Storage

Store the F/T sensor in dry environment at a temperature of 0° C to + 30° C in the original packaging.

Make sure that sensor is always stored in an unloaded state to avoid damage and deformation of sensor.

5 Assembly

Read the general safety instructions before beginning work (see Chapter 2.7 “General safety instructions”) and follow the (safety) guidelines specified in this document.

5.1 Preparations

- Clean/de-grease the sensor with a clean, lint-free cloth moistened with a suitable grease-dissolving but non-aggressive cleaning agent.

- Dry all fitting surfaces to neighboring components in order to achieve the proper friction of screw connections.
- Check fitting surfaces additionally for damage and impurities.

⚠ CAUTION

Electrical work in humid conditions can result in electric shocks that can cause injury.

Therefore, clean sensor (please also see chapter 7.1.3) and the associated electronics only when switched off and with power supply deactivated.

5.2 Install F/T sensor in an application

The F/T sensor itself must be installed in an application according to existing drilling pattern.

- Pay attention to tapped holes and any existing fits.
- Dimensions can be found in chapter 10.1 “Technical data” or in the customer drawing / customer-specific performance data.
- In case of deviations between technical documentation and your hardware product, please contact your sales representative immediately before starting installation.

ⓘ We recommend metal adapter parts when interfacing with the top and bottom platforms to ensure good signal quality.

NOTICE

Tightening fastening screws too firmly can lead to sensor damage.

- When tightening screws, make sure that the tightening torques do not exceed the nominal torque of the sensor.

Example: Tightening torque for M1.2 screws is 1.2 Nm and nominal torque of HEX8 sensor is only 0.1 Nm.

For further information, see the rest of this chapter

NOTICE

Using too long fastening screws can damage the sensor.

When screwing in screws, please note that they must not protrude more than 1.5 mm into the sensor structure. Screws that are too long can damage the sensor or lead to bad measurements

- If using the screws provided, the adapter part should ideally be thicker than 1.5 mm.

For further information, see the rest of this chapter

NOTICE

Loose or overloaded screw connections can damage the sensor.

- Always use a calibrated torque wrench to tighten and check all screw connections for which a tightening torque has been specified.

5.2.1 Precautions for sensor handle: Screws

A certain quantity of screws (specified in the following table) should be used for installation on both the top and the bottom surfaces. Length of screws inserted in the installation holes of both surfaces should be according to specification in the following Table 1.

Sensor	HEX8	HEX10	HEX12	HEX21	HEX32
Size	M1.2	M1.4	M1.4	M1.4	M2
Screw-in depth (mm)	1.5	1.5	1.5	1.5	3
Quantity per Sensor	6	6	6	12	12

Table 1 *Screw specifications*

NOTICE

Attention: Never screw in screws deeper than the specified screw-in depth; otherwise, the internal structure or the sensor's FPC will be damaged.

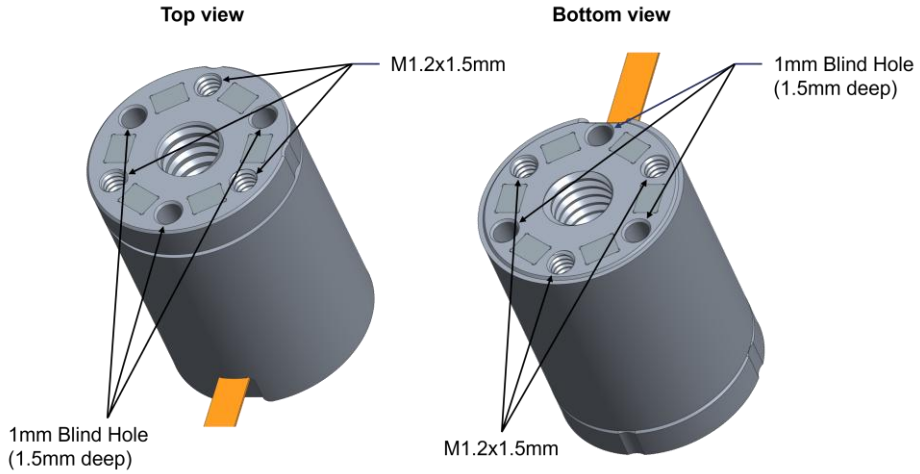


Figure 4 *Top and bottom view of F/T sensor incl. screw and blind holes (example HEX8)*

⚠ CAUTION

Do not fully tighten one screw first. This creates an uneven preload and mechanically distorts the sensing structure. As a result, the sensor may output incorrect force/torque values or even suffer permanent damage.

- Tighten all screws lightly first, then increase the torque step-by-step in a cross-pattern until the recommended tightening torque is reached.

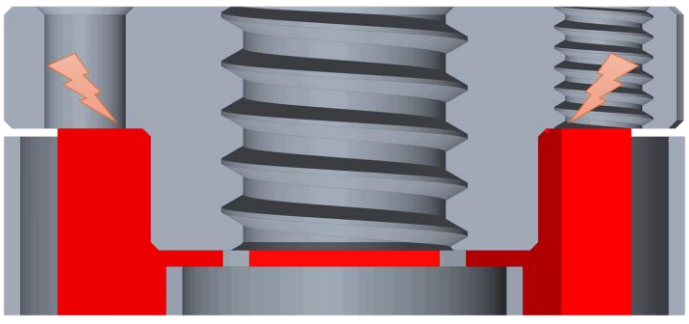


Figure 5 *Explanatory view of the sensor structure with marked critical elements for proper mechanical integration*

Recommended tightening torque:

Size	Strength Class	Dry (unlubricated)	Slotted (≈ 15%)
M1.2 (HEX8)	8.8	0.08 Nm	0.05 Nm
	10.9	0.10 Nm	0.07 Nm
	12.9	0.12 Nm	0.08 Nm
M1.4 (HEX10, HEX12, HEX21)	8.8	0.12 Nm	0.08 Nm
	10.9	0.15 Nm	0.10 Nm
	12.9	0.18 Nm	0.11 Nm
M2 (HEX32)	8.8	0.35 Nm	0.22 Nm
	10.9	0.49 Nm	0.31 Nm
	12.9	0.59 Nm	0.37 Nm

Table 2 *Recommended tightening torque specifications for ISO metric screws*

5.2.2 Precautions for sensor handle: Sensor contact surface

For sensor handle please also take the sensor contact surface into account.

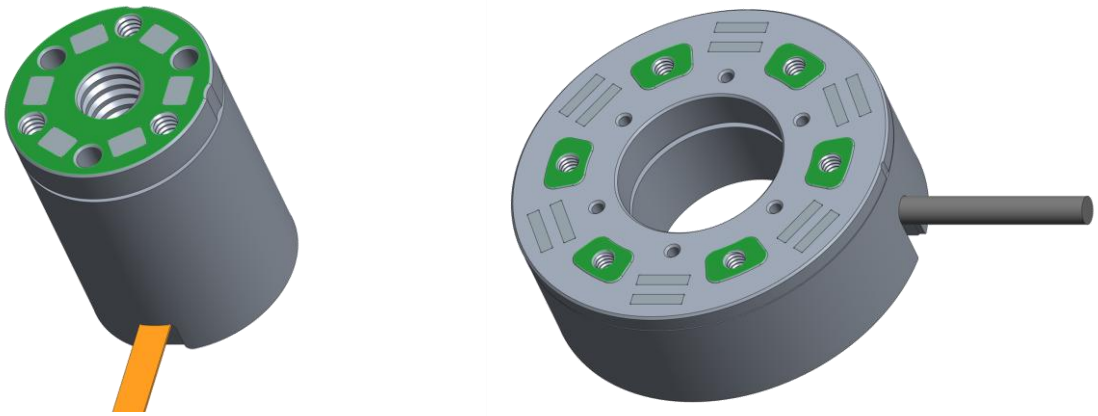
NOTICE

All **contact surfaces** on both the sensor side and the installation side are manufactured with a **flatness of 0.03 mm**. The top and bottom plates are sanded to be planar and co-planar, with a typical flatness of 0.03 mm.

Any level differences resulting from insufficient flatness may lead to incorrect force and moment measurements; therefore, the installation structure must provide sufficient rigidity under load.

Do not mount the sensor on plastic bodies, as this can lead to signal creep.

The following figure shows the sensor-side contact surface of HEX8 and HEX32 as an example.



green: defined contact area (HEX8)

green: specified contact points (HEX32)

Figure 6 *Sensor-side contact surfaces of HEX8 (left) and HEX32 (right).*

For the other sensor types HEX10, HEX12 and HEX21 the contact surface is the same as for HEX8.

5.2.3 Precautions for sensor handle: Handling of sensor FPC

When handling the sensor, plase take into account that the sensors FPC is a delicate component.

NOTICE

The FPC must not be strongly pulled in a lateral or the upper direction while the sonsor body is fixed with screws. Otherwise, the load is applied to the base os the FPC, and the wiring on the FPC might snap. Also, do not mount the product on moving parts that are bent repeatedly.

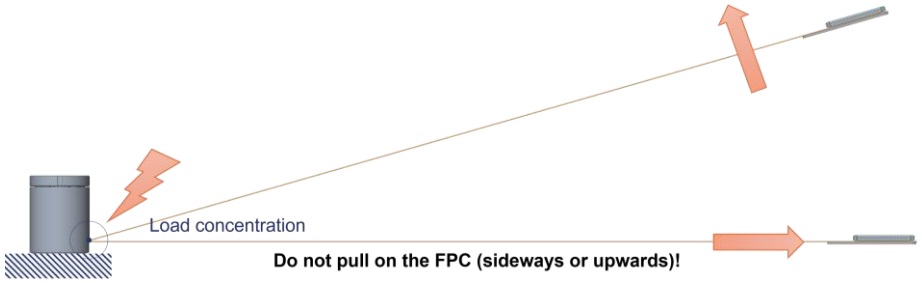


Figure 7 *Precautions of handling sensor FPC*

5.3 Install electrical connections

⚠ CAUTION

Electrically live components may result in electric shocks if touched and can cause injuries.

- Observe the five safety rules of electrical engineering before starting electrical installation work:
  - Disconnect.
  - Secure against being switched on again.
  - Check that there is no voltage.
  - Ground and short-circuit.
  - Cover neighboring and electrified parts.
- Check that protective caps are on the plugs. If protective caps are missing, check the plugs for damage and soiling.

⚠ CAUTION

Electric operation in moist areas may result in electric shocks and can cause injuries.

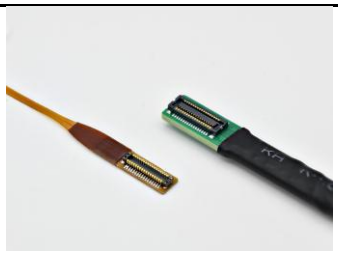
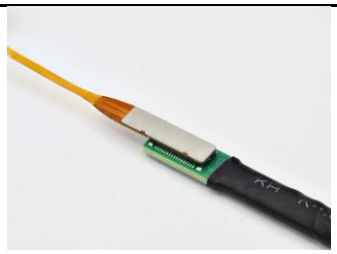
- Carry out electrical assembly only in dry areas.

The cables of all F/T sensor prototypes need to be laid out in such a way that a minimum bending radius of 10 x diameter is kept. The cables may be twisted by a maximum of ± 30° over a length of 1 m.

Torsional load of the cables should be avoided.

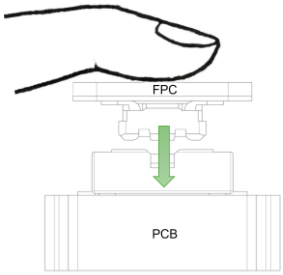
NOTICE

Note on AXT connection: For sensors with AXT connector, please make sure that the flex cable is connected properly to the round cable via the AXT connector. Please see pictures below:

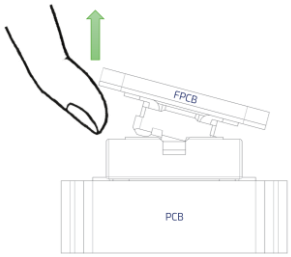
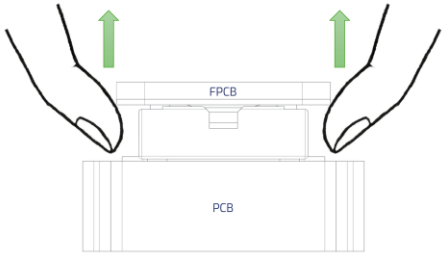
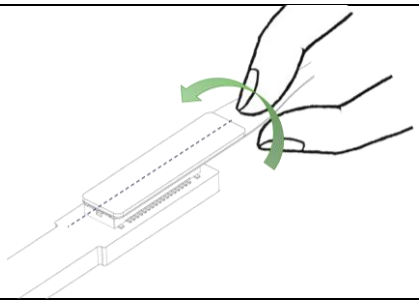
5.3.1 Precautions for sensor handle: Connect the sensor AXT connector

When connecting and and deconnecting the sensor AXT connector, please make sure to follow the guideline in the follwing as the AXT connector is a senstive part.

	• Make sure both connectors (header and socket) are aligned with each other and not tilted. • Press the header (FPC side) carefully into the socket until a “click” sound can be heard.

5.3.2 Precautions for sensor handle: Unmate the sensor AXT connector

AXT Connectors are sensitive parts. To avoid any damage to connector or its contacts, please unmate connectors using one of the three following methods (A-C):

A		While holding the PCB firmly, pull one side of the FPC up to unmate it. Make sure the force applied is vertical.
B		Grab the FPC on each side and unmate the connector by pulling it up. Make sure the force applied stays vertical.
C		Pinch the stiffened part (dark orange) of the FPC with two fingers while firmly holding the PCB. Rotate the FPC around the longitudinal axis to unmate.

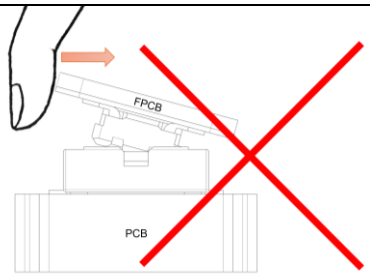
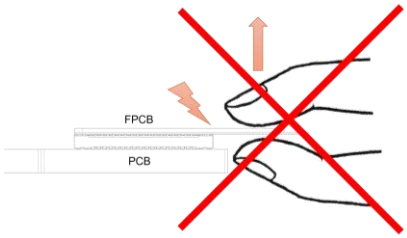
		Make sure the force applied is vertical and not horizontal. Otherwise, AXT contacts could be damaged.
		Never pinch the FPC and lift it up. This would result in a load concentration on the soldered parts of the AXT and damage it.

Table 3 *How to unmate the AXT conntector*

5.3.3 AXT Connector pin configuration and measurement principle

The following figure illustrates the AXT Connector layout and the basic structure of the measurement points.

Each measurement channel (CH1–CH6) is implemented as a Wheatstone full-bridge consisting of four strain gauges. The connector provides two pins for each signal (Px/Mx, VP/VM, T), which improves signal stability. The temperature channel uses an NTC resistor in a separate measurement bridge to compensate thermal drift of the strain-gauge signals.

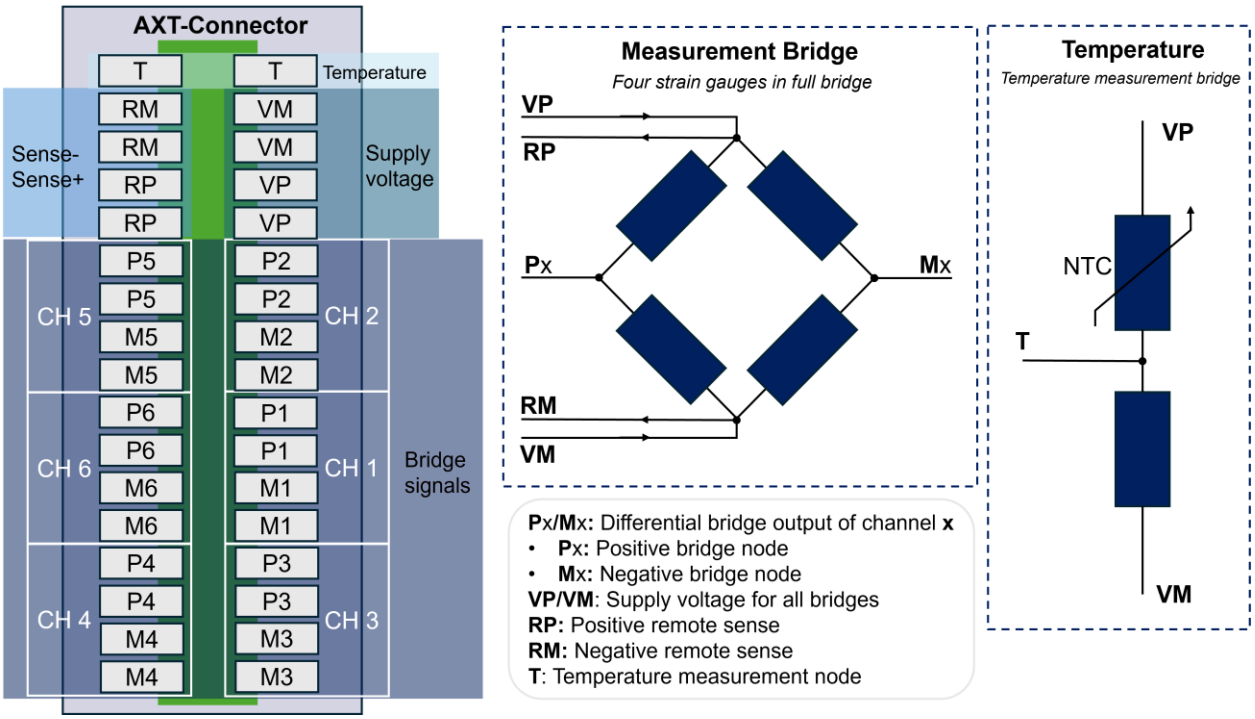


Figure 8 *AXT Connector layout and principle sensor bridges*

6 Startup and operation

6.1 Safety instructions and operating conditions

- Read general safety instructions before beginning work (see chapter 2.7 "General safety instructions").

  Improper use can cause damage to the sensor.

- F/T sensor is not a series product and can only be used in laboratory-like conditions.

- Make sure that the ambient temperature is within the permissible range (see chapter 10.1 “Technical data”)
- Use F/T sensor only up to its maximum limit values (see chapter 10.1 “Technical data”). For other application conditions, please contact our sales department (always quote the serial number).
- Operate F/T sensor only if it is permanently mounted.
- Make sure that the sensor housing is grounded during commissioning.

6.2 Operation description

6.2.1 Sensor Kit operation

Step by step setup of the sensor kit:

- Connect the USB connector of the sensor cable to the miniature evaluation electronics input.
- Connect the miniature evaluation electronics to your desktop PC via the USB-C cable. The miniature evaluation electronics is switched on automatically (see Figure 1).
- Insert the provided SD card into your PC. Directly start the software application from the storage device by double-clicking the shortcut F/T Explorer (software used to display, record and save sensor data).

6.2.2 Embedded Software Operation

The miniature evaluation electronics can acquire data following the operation flow shown in Figure 9. Correction coefficients used in the matrix operations are stored in the flash memory (Non-Volatile Memory).

ADC data of each axis is acquired. Offset output may occur even under ‘no load’ conditions after the sensor is attached to the system with mounting screws. Correct the offset with the ‘tare’ function (see chapter 6.5.1 “Description of control panel”).

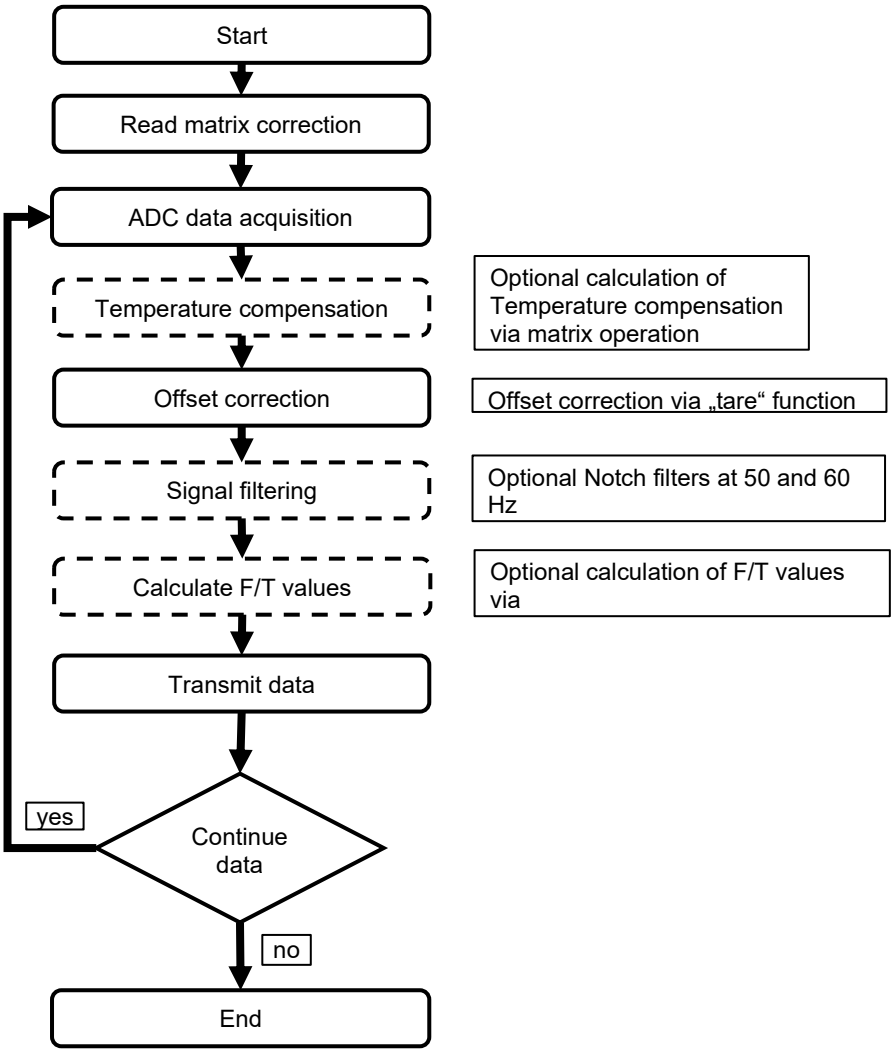


Figure 9 *Operation flow of miniature evaluation electronics firmware*

6.3 Data for electrical setup

There are no voltages higher than 10 V (low voltage range). F/T sensor does not have a 230 V main plug.

6.4 Coordinate axes definition of the sensor

The coordinate axes of the sensors can be found in chapter 10.2 „Application interface“.

6.5 Operation and configuration of the miniature evaluation electronics

Please refer to the following figures and tables for the key assignment and further functional description of the miniature evaluation electronics.

6.5.1 Description of control panel

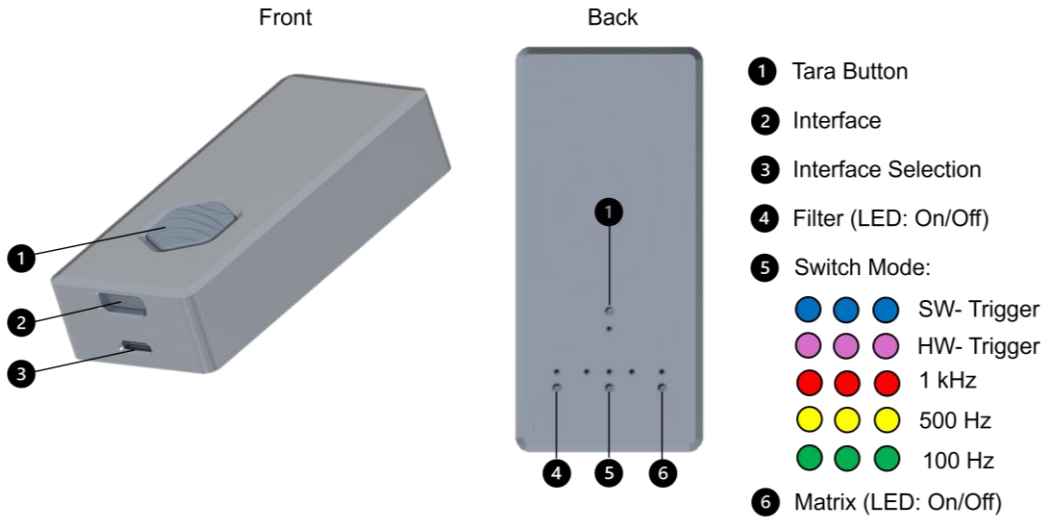


Figure 10 *Control panel of the miniature evaluation electronics*

ID	Function	Description
1	Tara	**Tare:** After pressing the tara button for more than 100 ms, the mini electronic will perform a tare operation (offset correction). The device collects one second of sampling data and calculates a tare value based on this input. **Diagnostics:** After holding the tara button for more than 15 s, the mini electronic will enter diagnostic mode and perform internal checks, capture operational parameters and detect existing fault conditions. Upon finishing diagnostic mode the device will enumerate as USB mass storage (MSC) device. The diagnostic data is stored is “DIAG.TXT” file and can be accessed directly via standard file explorer interfaces (e.g. Windows Explorer) **Bootloader:** After holding tara button for more than 30 sec., the mini electronics will switch to bootloader mode and appear as usb storage on normal computer. New firmware can be flashed by drag and drop our supplied .uf2 file. After a power cycle the new firmware runs on the box.
2	Interface	**USB:** The native USB interface from the internal Raspberry Pico micro controller is used to connect the electronics board with a desktop PC (12 MBit). The electronic is supplied with 5V from the USB interface. **UART:** The UART interface is used to communicate with an external micro controller (2 MBit). The respective pin assignment is shown below (chapter 0 “Interfaces”).
3	Interface Selection	This switch allows to select USB or UART as the currently used interface. • Switch position left: **USB** • Switch position rigt: **UART**
4	Filter	This LED shows the status of the filtering:

		• **LED on**: Filter on • **LED off**: Filter off
5	Switch Mode	**Green**: 100 Hz sampling rate **Yellow**: 500 Hz sampling rate **Red**: 1 kHz sampling rate **Magenta**: Hardware Trigger mode **Blue**: Software Trigger mode For pressing the buttons on the back control panel the supplied sim card tool can be used.
6	Matrix	This LED displays whetether the calibration matrix is enabled. • **LED on**: Output data is forces and torques in the three cartesian axes in SI units (newtons and millinewton-meters). • **LED off**: Output data is raw signals from each axis, which do not directly correspond to the forces and torques in the cartesian axes.

Table 4 *Description of miniature electronics' control panel functions*

6.5.2 Interfaces

The configurations of the Serial interface is shown in the following figure and tables.

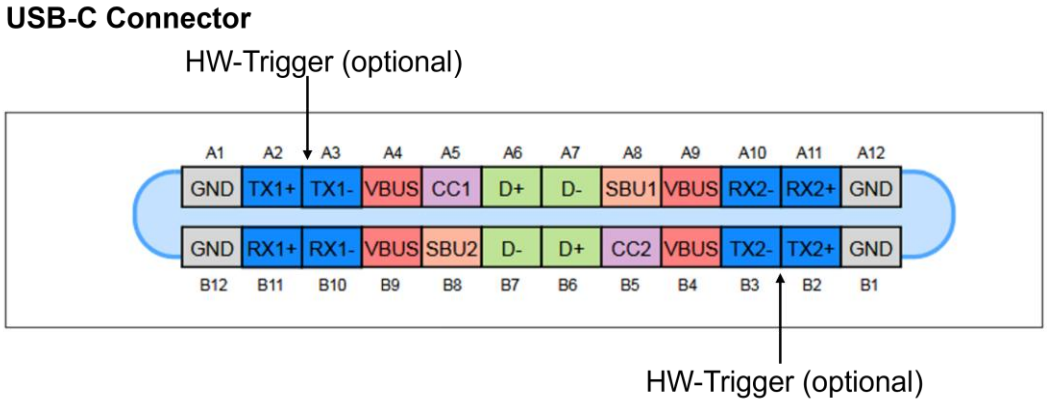


Figure 11 *USB-C Connector Configuration*

Pin	USB-C	USB	UART	SPI
VBUS	A4, A9, B4, B9	5 V	5 V	5 V
D+	A6, B6	Data+	RX (3.3 V)	SPI-TX
D-	A7, B7	Data-	TX (3.3V)	SPI-RX
GND	A1, A12, B1, B12	Ground	Ground	Ground
RX(1|2)+	B11, A11			SPI-CS
TX(1|2)+	A2, B2			SPI-CLK
TX(1|2)-	A3, B3	HW-Trigger	HW-Trigger	HW-Trigger

Table 5 *Interface pin configurations*

Baud rate	Word length	Parity	Stop
2,000,000 bit/s	8 bit	None	1 bit

Table 6 *UART interface configurations*

6.5.3 Available Modes

NOTICE

Most operating modes can be selected either via the hardware button or through software commands.

However, the **mV/V** and **Config** modes are available exclusively via software commands and do not appear in the button cycle.

Mode	Description
100 Hz	Sampling with 100 Hz data rate
500 Hz	Sampling with 500 Hz data rate
1 kHz	Sampling with 1 kHz data rate
Software Trigger	Sample only on request via protocol (Request command)
Hardware Trigger	Sample only on HIGH-Signal on HW-Trigger pad | TX- Pin on USB-C (A3 & B3)
F/T	Force/Torque mode. Configurated Matrix is applied to raw signal values.
mV/V	Output sensor values as $\frac{\mathrm{mV}}{V}$ (Only when not in F/T mode)
Config	No sampling of data

Table 7 *Mode descriptions of miniature evaluation electronics*

6.5.4 Communication Protocol

The following messages can be sent to the device. Each message is processed as a string and must be terminated with a newline character ('\n').

Message	Description
R	Read command (Software Trigger mode)
SET MODE [value]	**0** – 100 Hz Sampling mode **1** – 500 Hz Sampling mode **2** – 1 kHz Sampling mode **3** – Hardware Trigger mode **4** – Software Trigger mode
BOOT	Switch to Bootloader mode
TARA	Perform tare calculation
GET DIAGNOSTICS	Perform Diagnostics mode. Use this mode in case of support cases to report the current issues (see chapter 0 "**Support**")
GET ELECTRONICS_ID	Returns configured Electronics ID
GET SENSOR_ID	Returns configured Sensor ID
SET FILTER [value]	**1** – Enable Filter **0** – Disable Filter
SET CONFIG_MODE [value]	**1** – Enable Config mode **0** – Disable Config mode
SET BAUD [value]	Set Baudrate to desired value and reset serial communication interface (1200 < value < 20000000)
SET MVpV	**1** – Enable mVpV mode (Millivolts per Volt) **0** – Disable mVpV mode
GET ERROR	Get the latest error, if one is present

GET ERROR_LOG	Get the full error log
SET MATRIX_CALC	**1** – Set mode to F/T **0** – Set mode to raw
GET CONFIG	Returns device configurations
SET TCOMPENSATION	**1** – Enable Temperature compensation **0** – Disable Temperature compensation

Table 8 *Messages for communication protocol*

ⓘ **USB Communication Best Practice**

- ⓘ Minimum Command Size: Always send at least 8 bytes per command to ensure proper device recognition.
- ⓘ Chunking Large Commands: If your command is longer than 28 bytes, split it into 28-byte chunks before sending.
- ⓘ Why it matters: Following these limits helps prevent data loss, ensures compatibility, and keeps communication stable.

6.5.5 Data format of the serial interface

The electronics sends data via a serial interface via USB to the COM port of the PC or via the UART interface.

Binary protocol: The data is transmitted in little endian.

Data structure

Start	Header	Payload	CRC
1 Byte	4 Bytes	N Bytes	2 Bytes

Byte Layout

Field	Size	Description
Start	1	Frame-Marker (0x7E)
Header	4	Version, Type, Value
Payload	N	Values
CRC	2	CRC16-CCITT

Header

Byte	Name	Description
0	**HDR0**	Version (4bit) + Flags (4bit)
1	**HDR1**	Message type
2	**HDR2**	Number of payload values
3	**HDR3**	Counter

HDR0

Value	Description
Bit 7 - 4	Version (0-15)
Bit 3 - 0	Flags

HDR1

Value	Description
0x00	Measurement data
0x01	Configuration

HDR2 (depending of message type)

HDR1	Value	Description
0x00	N	Number of float32 (4 byte) values in payload
0x01	S	Number of bytes in payload formated as string

HDR3

Value	Description
0x00 .. 0xFF	Number of message

Example

Start	HDR0	HDR1	HDR2	HDR3	Payload	CRC
0x7E	0x10	0x00	0x06	0x00	$F_x, F_y, F_z, M_x, M_y, M_z$	

Table 9 *Binary protocol format description*

Deprecated legacy protocol:

First the three force and then three torque values are sent before the temperature value follows. These are 32-bit floating point numbers (float32).

F_x^{FT}	F_y^{FT}	F_z^{FT}	M_x^{FT}	M_y^{FT}	M_z^{FT}	Temp
4 Bytes	4 Bytes	4 Bytes	4 Bytes	4 Bytes	4 Bytes	4 Bytes

Table 10 *Legacy protocol format description*

Please see a simple Python example to convert the byte stream to floating point numbers:

[CH2, CH1, CH4, CH3, CH6, CH5, temp] = struct.unpack('fffffff', serial_line[0:28]).

NOTICE

The output values depend on the active measurement mode. In **F/T** mode the device outputs force and torque values.

In **mV/V** mode, the output is given in $\frac{mV}{V}$.

If neither mode is active, the device provides the **raw** ADC values.

For more details about the protocol see ***Force/Torque Explorer*** manual.

6.5.6 Matrix operation (F/T)

The evaluation electronics directly outputs the force/torque (F/T) data. A matrix operation is used to convert the raw ADC values into calibrated F/T values. The calculation follows:

$$x = \begin{bmatrix} F_x^{ADC} \\ F_y^{ADC} \\ F_z^{ADC} \\ M_x^{ADC} \\ M_y^{ADC} \\ M_z^{ADC} \end{bmatrix} \qquad y = \begin{bmatrix} F_x^{FT} \\ F_y^{FT} \\ F_z^{FT} \\ M_x^{FT} \\ M_y^{FT} \\ M_z^{FT} \end{bmatrix} \qquad y = Ax \qquad y_i = \sum_{j=1}^{6} a_{ij} x_j \,, \;\; i = 1, \ldots, 6$$

Component-wise expansion

$$F_x^{FT} = a_{11}F_x^{ADC} + a_{12}F_y^{ADC} + a_{13}F_z^{ADC} + a_{14}M_x^{ADC} + a_{15}M_y^{ADC} + a_{16}M_z^{ADC}$$

$$\vdots$$

$$M_z^{FT} = a_{61}F_x^{ADC} + a_{62}F_y^{ADC} + a_{63}F_z^{ADC} + a_{64}M_x^{ADC} + a_{65}M_y^{ADC} + a_{66}M_z^{ADC}$$

Data and coefficient definitions

$a_{11} \sim a_{66}$: Matrix operation corection coefficients (4 bytes)

$F_x^{ADC} \sim M_z^{ADC}$: ADC Data (3 bytes / 24 bits)

$F_x^{FT} \sim M_z^{FT}$: Matrix operation data (4 bytes)

6.5.7 Documents

The SD card provides documentation such as operating manual, quick start guide and product data sheets as well as sensor-specific documents like the calibration matrix. The software package for the F/T explorer (see chapter 3.4 “Application software F/T Explorer”) can also be found on the SD card.

6.6 Operation and functions of the application software

The supplied Force/Torque (F/T) Explorer software is used to display, record and save sensor measurement values.

6.6.1 Software installation and start

F/T Explorer software can be found on the SD card provided with every delivery. You unpack the data on your Windows or Linux computer with 64bit processor architecture. Other operating systems and 32 bit environments are not supported.

In a Windows environment start the application by double-clicking the executable file ForceTorqueExplorer.exe. A Java environment is required and is included in the delivery.

After starting the software, the serial port where your sensor is connected is automatically selected (HEX 6-axis F/T sensor). The user interface of the Force/Torque Explorer is shown in Figure 12.

6.6.2 Software function overview

Please refer to the following table for available functions of the software application.

ID	Function	Description
A	Live view	After starting the software, the live view appears. This can be opened at any time using the "Open Live View" button in the upper "Live View" control panel. Here the received sensor data is displayed live. The value ranges of the diagrams can be set in the upper control panel "Live view".
B	Sample rate	By default the software receives and processes all data sent by the electronics. The frequency can be adjusted in the upper control panel "Sample rate" and down-sampling can be realized.
C	Start/stop recordings	In the upper control panel "Recording" a new recording can be started with the button "Start". Before that a name can be assigned. With the button "Stop" in the same control panel the recording is stopped.
D	View/edit/export recordings	In the tab "Recordings" all previous recordings are listed. These can be viewed, renamed, deleted and exported using the available control panels. Furthermore, previously exported recordings can be imported (supported file formats see chapter 6.6.3). When viewing recordings, the diagram can be moved with the left mouse button pressed down and zoomed with the mouse wheel.
E1	Calibration matrix	In the tab "Calibration matrix" the calibration matrix for the conversion of raw values into force/torque values can be imported, exported, transposed and edited. You will receive the calibration matrix for your sensor with the delivery.
E2	Calibration matrix further information	The calibration matrix is also implemented on the sensor electronics. The matrix calculation can be done both in the electronics and in the software application.

Table 11 *Function overview of the software application F/T Explorer*

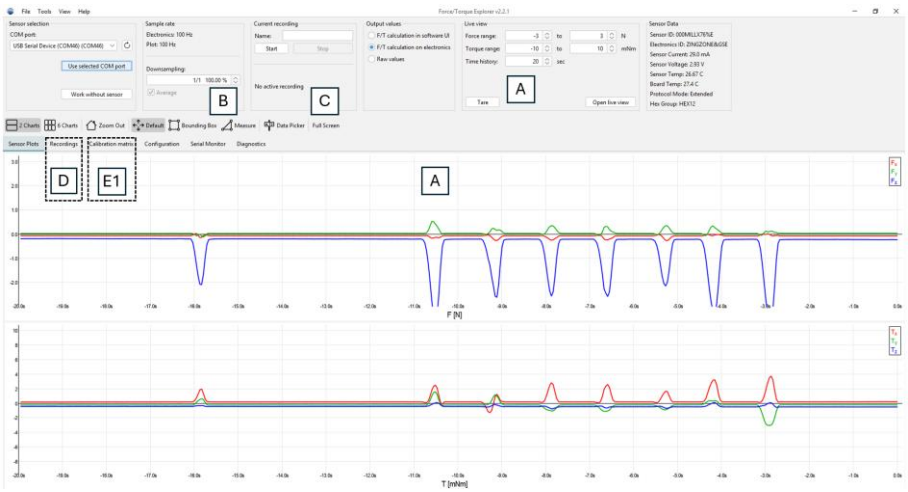


Figure 12 *Main window of the F/T Explorer*

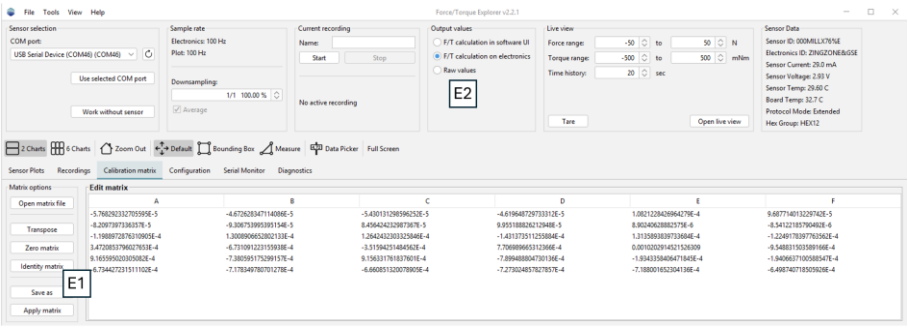


Figure 13 *How to use the calibration matrix in F/T Explorer*

6.6.3 Supported file formats for recordings

The interface allows data to be recorded and exported in various file formats for further processing. Due to the small data size, we recommend exporting in binary format. Further available file formats are listed in the following table.

Format		Note	F/T Explorer supports	
			Import	Export
Binary file	.dat	Recommended file format. Smallest file size.	X	X
JavaScript Object Notation	.json	Import not supported. File size reduced to minimum.		X
Comma Separated Values	.csv	Standard CSV with separator [,] and decimal mark [.]. Further format for directly importing into Excel with separator [;] and decimal mark [,].	X[a)]	X
Python Pickle	.pkl	Binary format for import into Python. Sample script provided in the "Scripts" folder in the program directory.	X	X

Table 12 *Overview of supported file formats*

[a)] Import is only supported for standard format, not for Excel format.

7 Maintenance and disposal

Read the general safety instructions before beginning work (see chapter 2.7 "General safety instructions").

7.1 Maintenance work

7.1.1 Visual inspection

Check the entire F/T sensor prototype and all cables for exterior damage.

7.1.2 Checking the tightening torques

- Check the tightening torque of the fastening screws on the F/T sensor before you start the measuring process.
- When tighthening the screws, make sure that the tightening torques do not exceed the nominal torque of the sensor (see chapter 5.2.1 “Precautions for sensor handle: Screws”).

7.1.3 Cleaning

NOTICE

Pressurized air can damage the F/T sensor.

Do not use pressurized air to clean the F/T sensor.

- Clean the F/T sensor using a clean, lint-free cloth.
- If necessary, use a suitable fat dissolving but non-aggressive cleaning agent.
- Apply cleaning agents sparingly. Excess liquid may enter the sensor housing and cause damage, as the device is rated IP20 and offers no protection against moisture ingress.
- Dry all contact surfaces to adjacent components to obtain the correct coefficients of friction of the screw connections.
- Check all contact surfaces for damage and foreign bodies.

7.2 Maintenance

Perform a visual inspection of F/T sensor before each commissioning.

- Check sensor for obvious damage.
- Check cables for damages.
- Check evaluation electronics for obvious damages.
- Check sensor and evaluation electronics for dirt and remove it if necessary according to the cleaning instructions in chapter 7.1.3 "Cleaning".

⚠ CAUTION

Touching live parts or damaged cables can result in short circuits, polarity errors, or injuries.

- Check F/T sensor for damaged cables and plugs before each use.
- Also check evaluation electronics for damage before each comissioning.

7.3 Disposal

Consult our customer service department for supplementary information on disassembly and disposal of the F/T sensor.

ⓘ Dispose of F/T sensor at recycling sites intended for this purpose.

ⓘ Observe the locally valid regulations for disposals.

8 Malfunctions

NOTICE

Changed operational behavior can be an indication of existing damage or cause damage to F/T sensor.

Do not put F/T sensor back into operation until the cause of malfunction has been rectified.

Rectifying of malfunctions may only be done by specially trained technicians.

Fault	Possible cause	Solution
No measurements are displayed	Sensor plug not plugged into electronics	Insert sensor plug into evaluation electronics.
	Electronics switched off	Switch on evaluation electronics using power switch.
	Electronics not connected to power supply	Connect evaluation electronics to power supply via USB plug.
	Cable breakage	Please contact our customer service.
Displaying incorrect measurement values	Incorrect calibration	Please contact our customer service.
	Overload of the sensor and plastic deformation of the elementary cells	In case of plastic deformation of elementary cells, sensor was irreparably damaged due to improper loading or overloading.
	Overload of the sensor and breakage of the bond or the elementary cells	In case of breakage of adhesive bond or elementary cells, sensor was irreparably damaged due to improper loading or overloading.
	Sensor not zeroed correctly	Zero sensor by means of the „Tara“ function.
	Double activation of matrix calculation in electronics and software application	Matrix calculation is activated only once.
	Sensor signals creep strongly	Mount sensor on a rigid base (steel, no polymers) and fix it with steel screws.

	Flex cable is not connected properly to the round cable via FPC connector	For HEX10 and HEX12 sensors: Flex wires must face up in the direction of the closing lid. Like shown in chapter 5.3 “Install electrical connections”.
Sporadic failure	Cable not connected properly	Please contact our customer service.

Table 13 *List of possible Malfunctions*

9 Support

If the information in this manual does not resolve the issue and you suspect a sensor malfunction, please collect the following details before contacting Resense Support. Providing a complete set of information will help us diagnose the problem and support you efficiently:

- **Perform initial checks**
  - Ensure the sensor has completed the required 30-minute warm-up period.
  - Grounding: If using a laptop, make sure it is connected to its power supply to ensure proper grounding.
- **Gather Setup Information**
  - PC type and power source.
  - Environmental conditions.
  - A short log or screenshot showing the error behavior.
  - A picture of the complete setup.
  - Application details (brief description of how the sensor is being used).
- **Provide sensor identification**
  - Provide the serial number or OA number of the sensor.
- **Run diagnostics**
  - Execute GET DIAGNOSTICS as described in Chapter 6.5.4 “Communication Protocol” and include the output in your report.
- **Send complete information**
  - Compile all the above details and send them to your Sales Responsible or designated Resense contact.

10 Appendix

10.1 Technical data

Please note that in exceptional cases the F/T sensor prototype may deviate from the given technical data.

10.1.1 Technical data – HEX8/10/12/21/32

NOTICE

The **HEX10** sensor is **deprecated** and no longer manufactured. It employs a foil strain-gauge technology that differs from the sensing principle used in current models.

SENSOR	HEX8	HEX10	HEX12	HEX21	HEX32
Dimensions					
Diameter [a)]	8.4 mm	10.0 mm	12.5 mm	21.0 mm	32.0 mm
Height	10.9 mm				11.1 mm
Weight	1.4 g	2.0 g	3.3 g	9.9 g	50.0 g
Nominal measurement range					
F_x, F_y	± 25 N	± 25 N	± 25 N	± 50 N	± 250 N
F_z	± 35 N	± 25 N	± 100 N	± 100 N	± 600 N
M_x, M_y,	± 100 mNm	± 125 mNm	±125 mNm	±500 mNm	±1.8 Nm
M_z	± 140 mNm	± 125 mNm	±150 mNm	±850 mNm	±4 Nm
Technical specifications					
Accuracy[b)]	1 %				
Crosstalk	3 %				
Overload capacity	300 %				
Product features					
Material	Titanium Grade 5				
Protection class	IP20				
Temperature range	0 – 50 °C				
Cable	Flex cable with axial/radial cable outlet and AXT connector (HEX10 with FPC connector)			Round cable directly connected to evaluation electronics	

[a)] Diameter excludes any connector or cable features.

[b)] Accuracy means the maximum measurement deviation relative to the full-scale value.

Table 14 *Technical data of F/T sensors*

Additional definitions:

- Latency: The time from inputting to outputting the force is calculated by adding physical response and digital processing.
  - ⓘ The latency/responsiveness is the same as sampling rate: 1kHz = 1ms.
- Resolution: The smallest change in the measurement signal that the sensor can detect and digitize.

The operating ranges of Resense miniature F/T sensors are described in following figure:

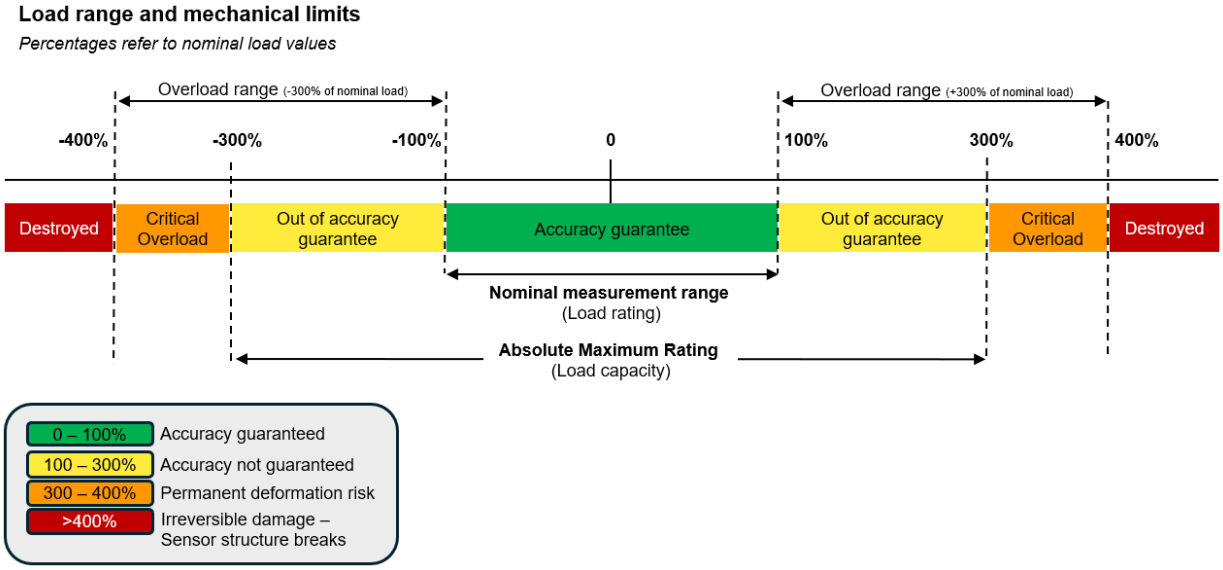


Figure 13 *Operating force and torque ranges*

⚠ CAUTION

Loads between **300 %** and **400 %** of the nominal rating may cause **permanent deformation**. Short transient shocks in this range can be tolerated, but continuous operation **must be avoided**. Loads above **400 %** will lead to irreversible sensor damage.

Noise characteristics of the Resense miniature F/T sensors:

All values denote peak-to-peak noise of the respective force and torque channels, measured under default configuration settings.

100 Hz Mode						
	Fx [mN]	Fy [mN]	Fz [mN]	Mx [µNm]	My [µNm]	Mz [µNm]
HEX8	1	2	3	10	7	13
HEX10	5	4	13	22	31	24
HEX12	3	1	3	7	7	13
HEX21	4	4	6	47	34	35
HEX32	8	10	25	121	263	191

1 kHz Mode						
	Fx [mN]	Fy [mN]	Fz [mN]	Mx [µNm]	My [µNm]	Mz [µNm]
HEX8	2	4	7	19	12	30
HEX10	13	8	41	49	89	51
HEX12	5	2	5	11	11	6
HEX21	6	9	13	55	47	77
HEX32	13	14	39	223	346	305

Table 15 *Noise tables for all available HEX sensor types*

10.1.2 Technical data – Miniature Evaluation Electronics

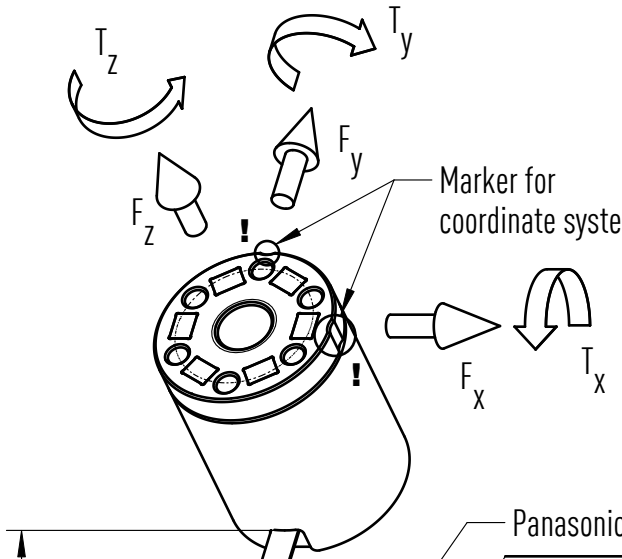
Product features	
Dimensions	13 x 25 x 54 mm
Weight	28 g
Supply Voltage	5 V
Power Consumption	544 mW
Interface	UART up to 7.2 Mbit/s (3.3V), USB 1.1 (12Mbit/s Full-Speed)
Conversion Time	500 µs
Sampling Rate (continuous)	100 Hz, 500 Hz, 1 kHz
Trigger Modes	Hardware, Software
Resolution (ADC)	24 bit

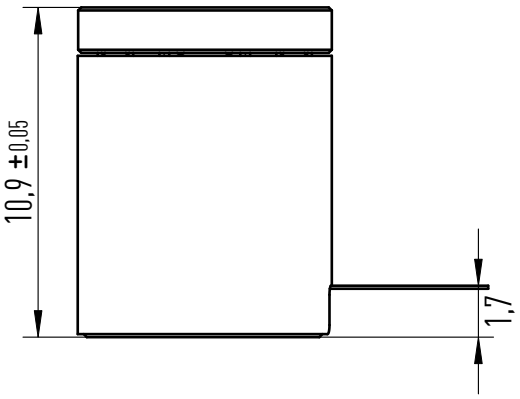
Table 16 *Technical data of miniature evaluation electronics*

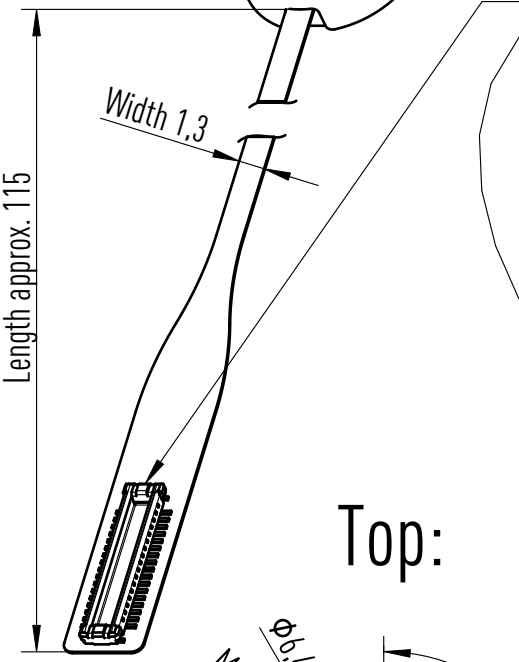
10.2 Application interface

The dimensions of the top and bottom cover which serve as the application interface for the available sensor versions HEX8, HEX10, HEX12, HEX21 and HEX32 as well as of the miniature evaluation electronics can be found in the following drawings.

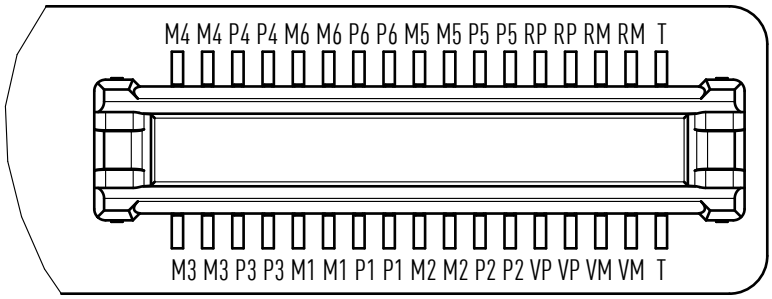
All dimensions in mm





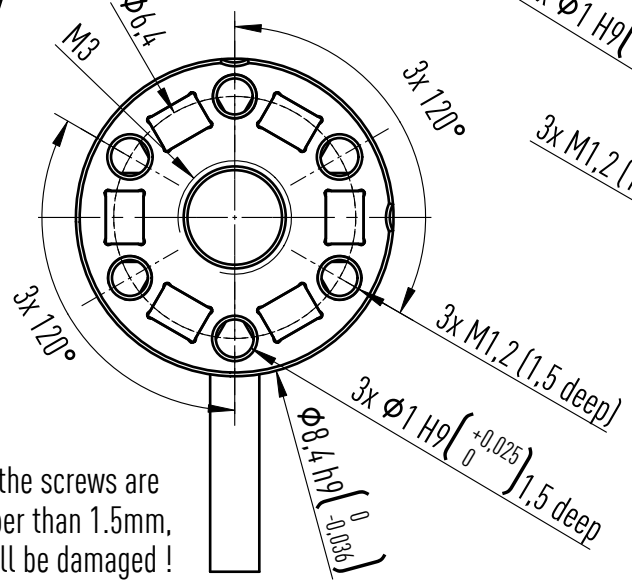


Panasonic AXT634124

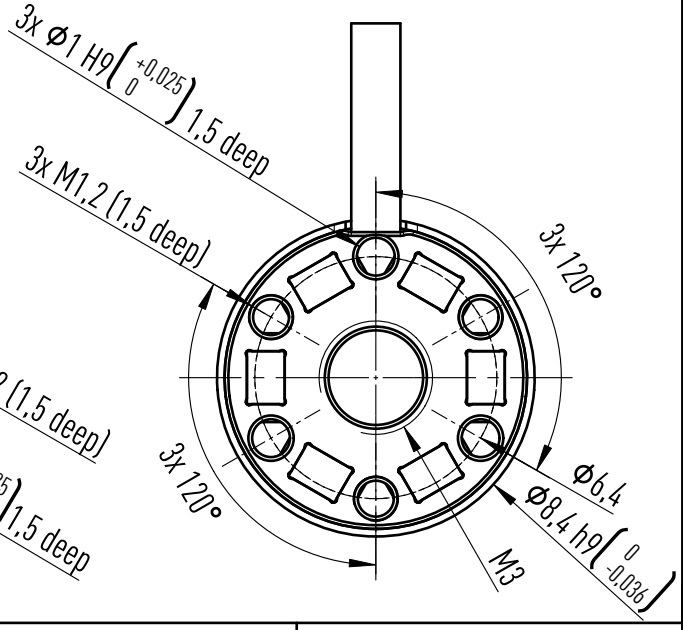


! Warning: do not supply the sensor with more than 10V !
For pin description and wiring diagramm, see manual

Top:



Bottom:



! Warning: if the screws are screwed deeper than 1.5mm, the sensor will be damaged !

Workflow working-85

REVISION	
01	

first created DILLYA 11.12.2025

Assembly HEX8

drawing number RES_111225131803.00

material	scale	modified	13.01.26	DILLYA	reference
Titanium Grade V	1:1	released			DR 85 sheets 1 / 1
raw part / nominal size					comments: Current design stage - final product may differ

Surface texture						Tol. ISO 2768 - mK			
ISO 21920						0,5 ...6	>6 ...30	>30 ...120	>120 ...400
Rz in µm	-	63	16	4	1	±0,1	±0,2	±0,3	±0,5

Check indicator | language GER/ENG | SIZE ISO 14405 GG | ISO 8015 | units mm [inch]

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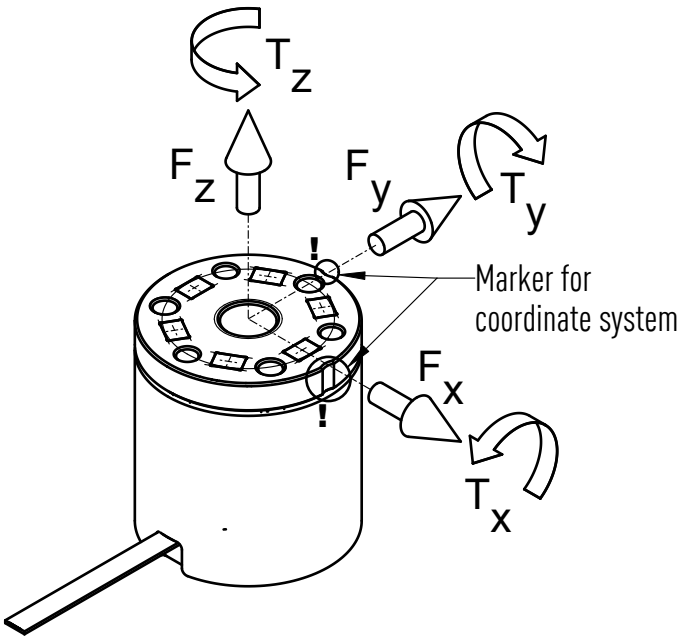
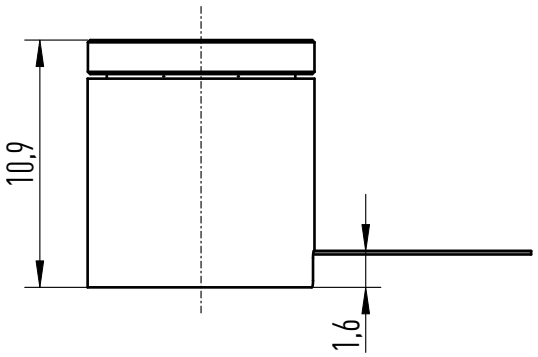
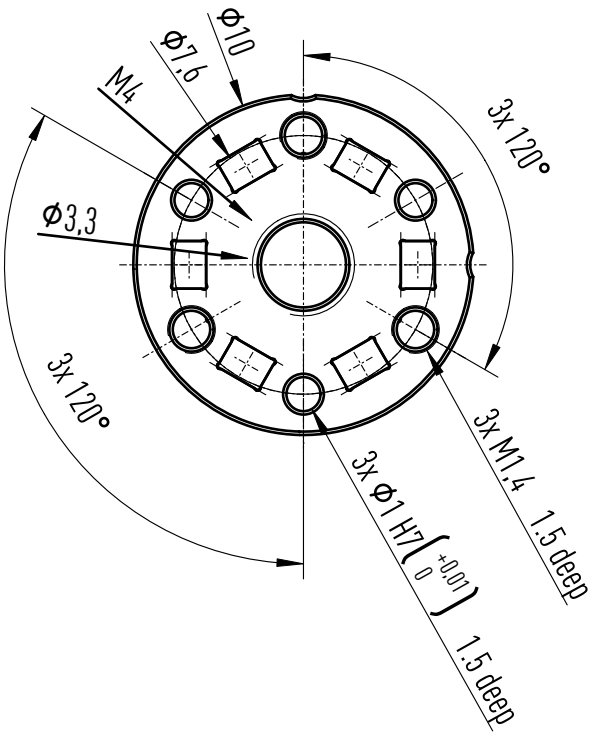
Alexander-Wiegand-Str. 30
63911 Klingenberg - GERMANY

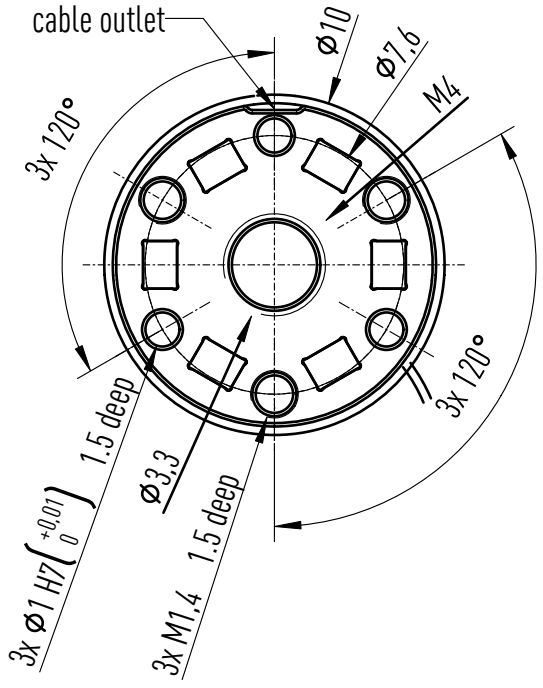




Top:



Bottom:



Workflow
working-85

REVISION	
01	

first created
RADULOS
18.03.2025
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Assembly HEX10

drawing number
RES_261023113247.00

material	scale	modified	24.02.26	RADULOS	reference
Titanium Grade V	2:1	released			DR 85 sheets 1 / 5
raw part / nominal size					comments

Surface texture						Tol. ISO 2768 - mK				Check indicator	SIZE ISO 14405 (GG)	units
ISO 1302:2002	▽	√	x √	y √	z √	0,5 ...6	>6 ...30	>30 ...120	>120 ...400			mm [inch]
R_z in µm	-	63	16	4	1	±0,1	±0,2	±0,3	±0,5	language GER/ENG	ISO 8015	

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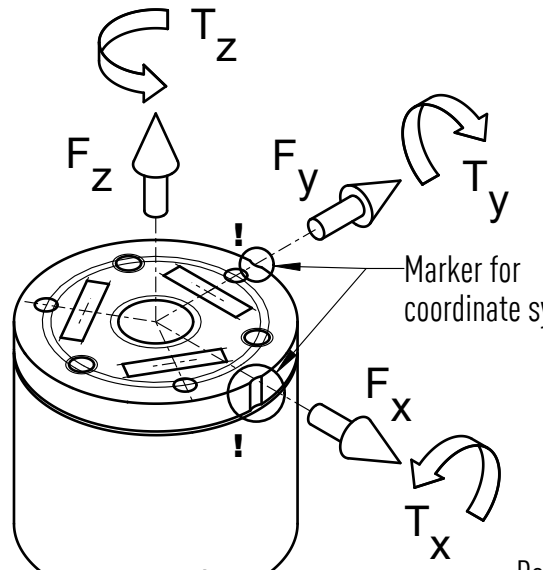
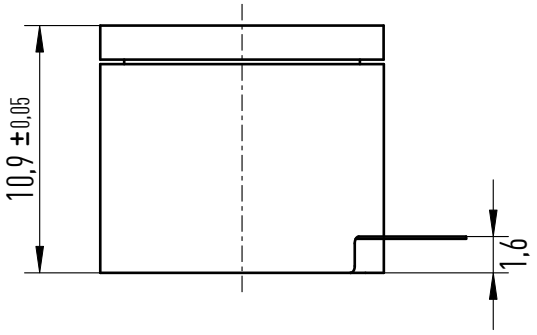
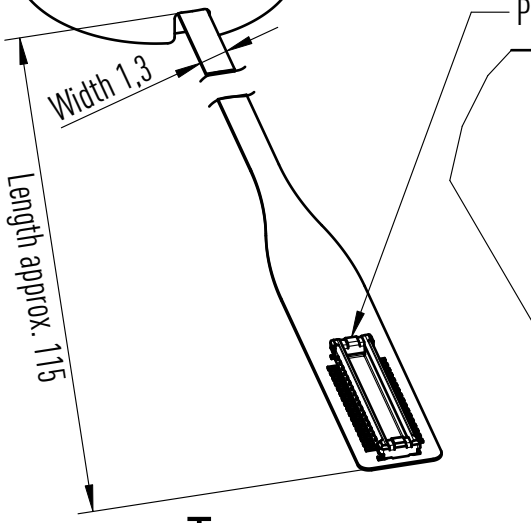
DEKLI6_EN_A4M_T01_MP 23.01.2025

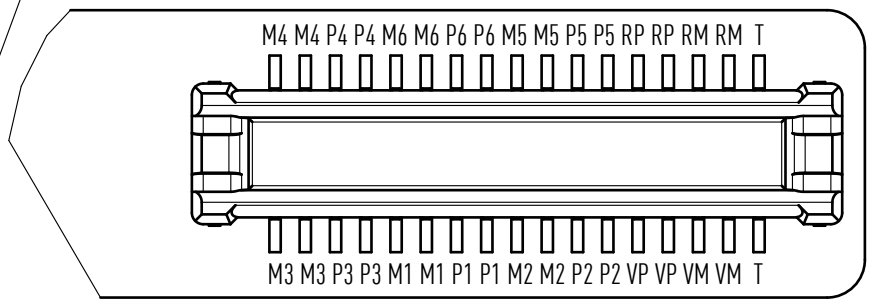
All dimensions in mm





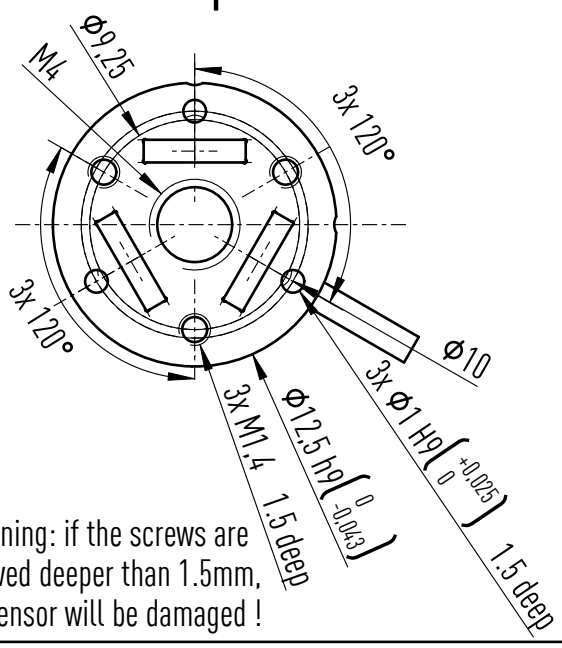


Panasonic AXT634124



! Warning: do not supply the sensor with more than 10V !
For pin description and wiring diagramm, see manual

Top:



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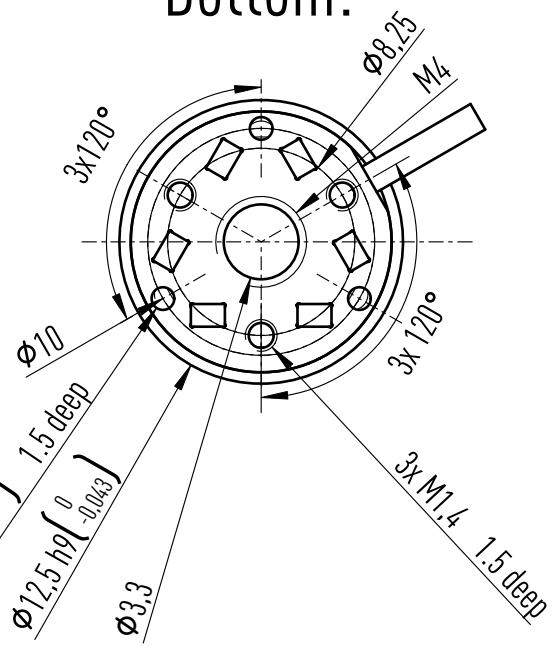

! Warning: if the screws are screwed deeper than 1.5mm, the sensor will be damaged !

Workflow working-85

REVISION	
01	

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Assembly HEX12

drawing number
RES_261023112745.00

material	scale	modified	13.01.26	DILLYA	reference
Titanium Grade V	1:1	released			DR 85 sheets 1 / 1
raw part / nominal size					comments: Current design stage - final product may differ

Surface texture						Tol. ISO 2768 - mK			
ISO 1302:2002		x	y	z	0,5 ...6	>6 ...30	>30 ...120	>120 ...400
R_z in µm	-	63	16	4	1	±0,1	±0,2	±0,3	±0,5

Check indicator
language GER/ENG
SIZE ISO 14405 (GG)
ISO 8015
units mm [inch]

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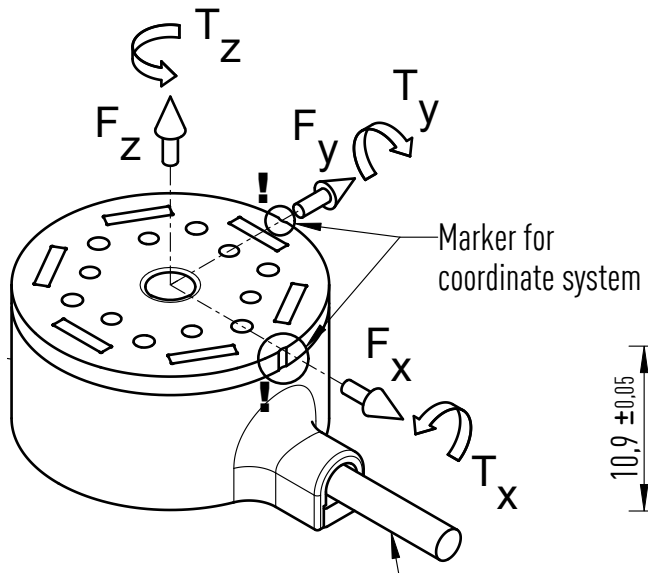
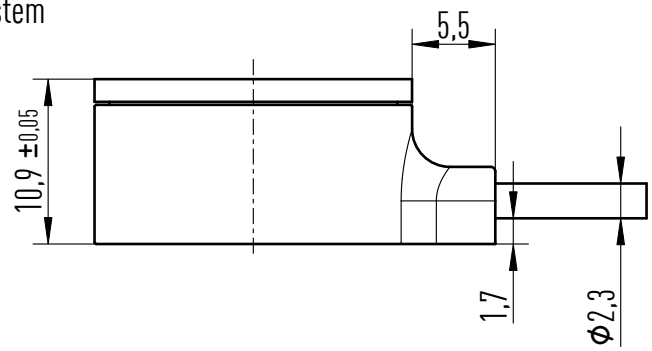
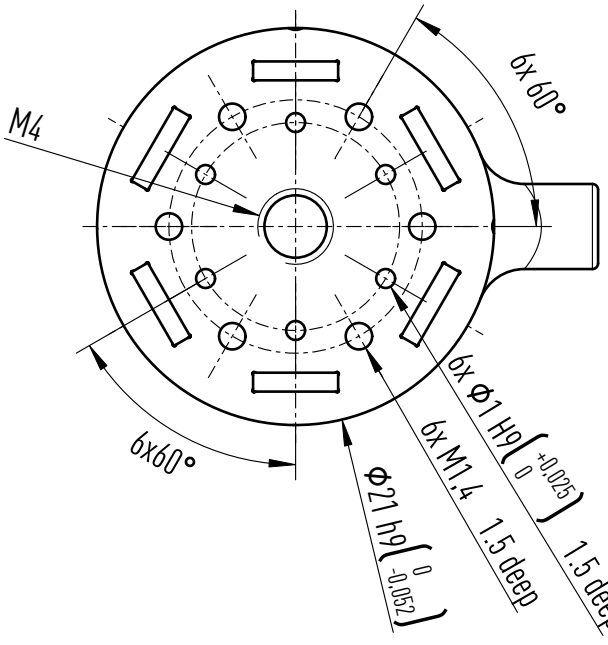
All dimensions in mm



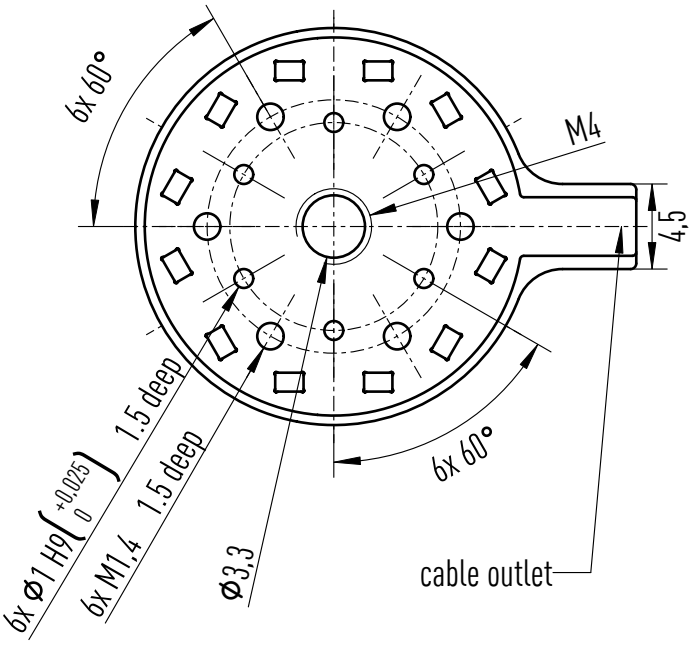


Cable length to electronics 1,1 - 1,4m

Top:



Bottom:



Sensor design is being revised. For detailed information and roadmap, please contact a sale representative.

Workflow working-85

REVISION	
01	

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18.03.2025
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Surface texture							Tol. ISO 2768 - mK				Check indicator	SIZE ISO 14405 (GG)		units
ISO 1302:2002			x	y	z		0,5 ...6	>6 ...30	>30 ...120	>120 ...400				mm [inch]
R_z in µm	-	63	16	4	1		±0,1	±0,2	±0,3	±0,5	language GER/ENG	ISO 8015		

Assembly HEX21					drawing number RES_261023103852.00
material Titanium Grade V	scale 1:1	modified	13.01.26	DILLYA	reference
		released			DR 85 sheets 1 / 1
raw part / nominal size					comments Current design stage - final product may differ

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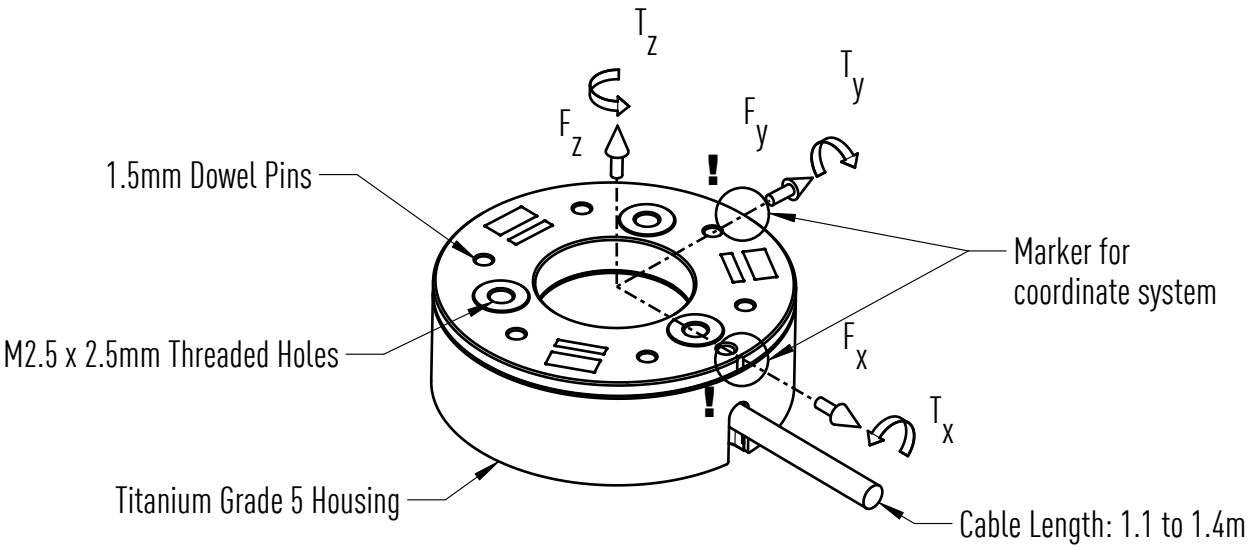
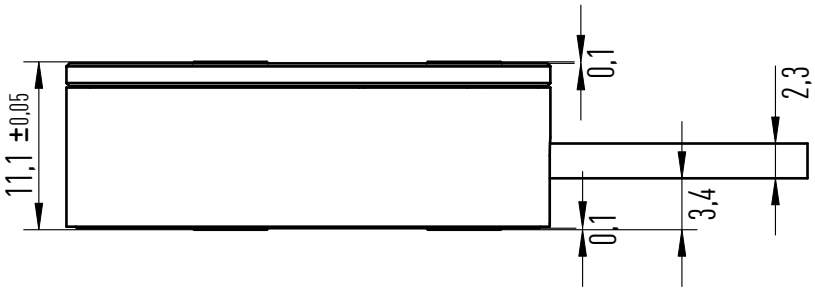
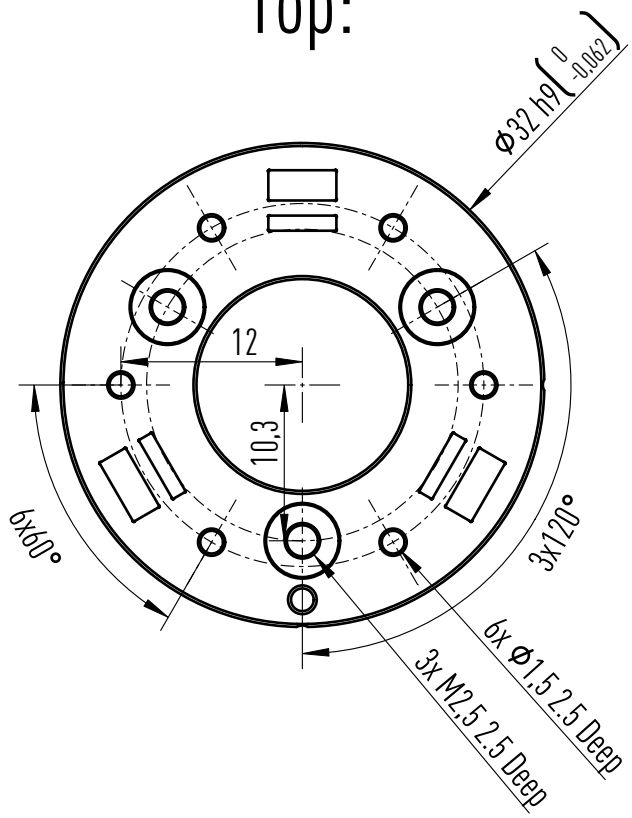
DEKLI6_EN_A4M_T01_MP 23.01.2025

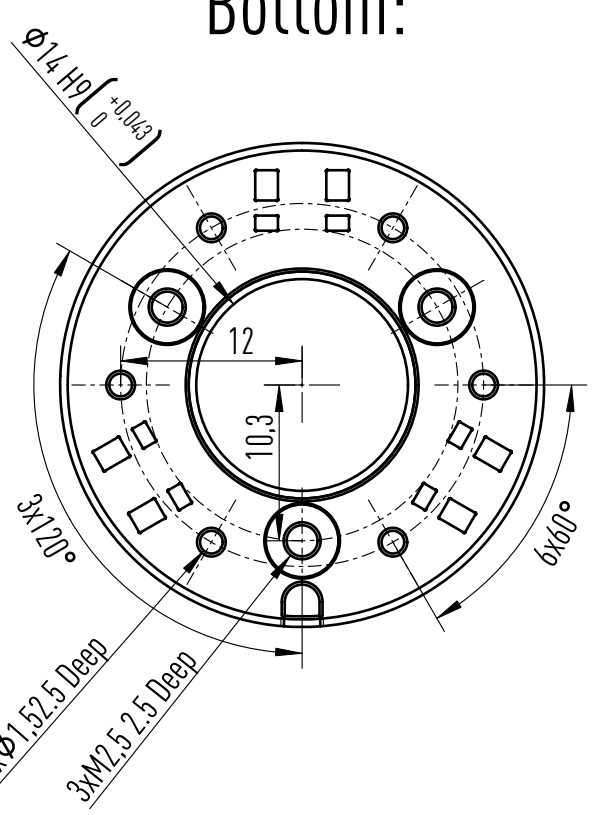




Top:



Bottom:



Workflow working-85

REVISION	
01	

first created DILLYA 25.03.2026

Assembly HEX32 v9

drawing number: RES_250326141703.00

material	scale	modified	01.04.26	DILLYA	reference
Titanium Grade V	1:4	released			DR 85 sheets 1 / 1
raw part / nominal size					comments

Surface texture						Tol. ISO 2768 - mK				Check indicator	SIZE ISO 14405 (GG)	units
ISO 21920						0,5 ...6	>6 ...30	>30 ...120	>120 ...400			mm [inch]
Rz in µm	-	63	16	4	1	±0,1	±0,2	±0,3	±0,5	language GER/ENG	ISO 8015	

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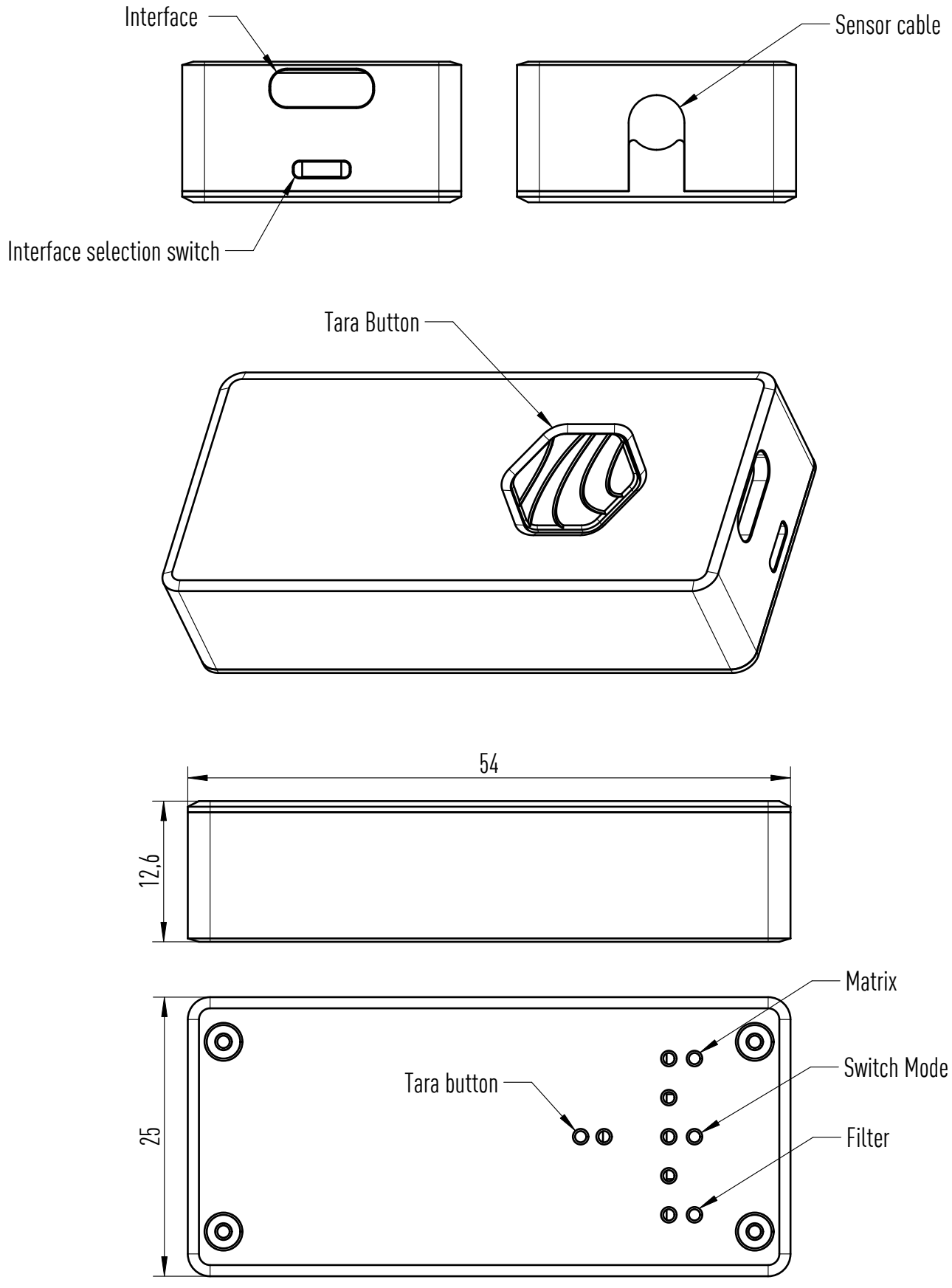
DEKLI6_EN_A4M_T01 27.01.2025



Workflow working-85

REVISION	
01	

first created
DILLYA
10.02.2026
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Resense Mini Electronics

drawing number
RES_220126092103.00

material	scale	modified	10.02.26	DILLYA	reference
Aluminium	1:1	released			DR 85 sheets 1 / 1
raw part / nominal size					comments

Surface texture						Tol. ISO 2768 - mK			
ISO 21920						0,5 ...6	>6 ...30	>30 ...120	>120 ...400
Rz in µm	-	63	16	4	1	±0,1	±0,2	±0,3	±0,5

Check indicator
language GER/ENG

SIZE ISO 14405 (GG)
ISO 8015

units mm [inch]

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