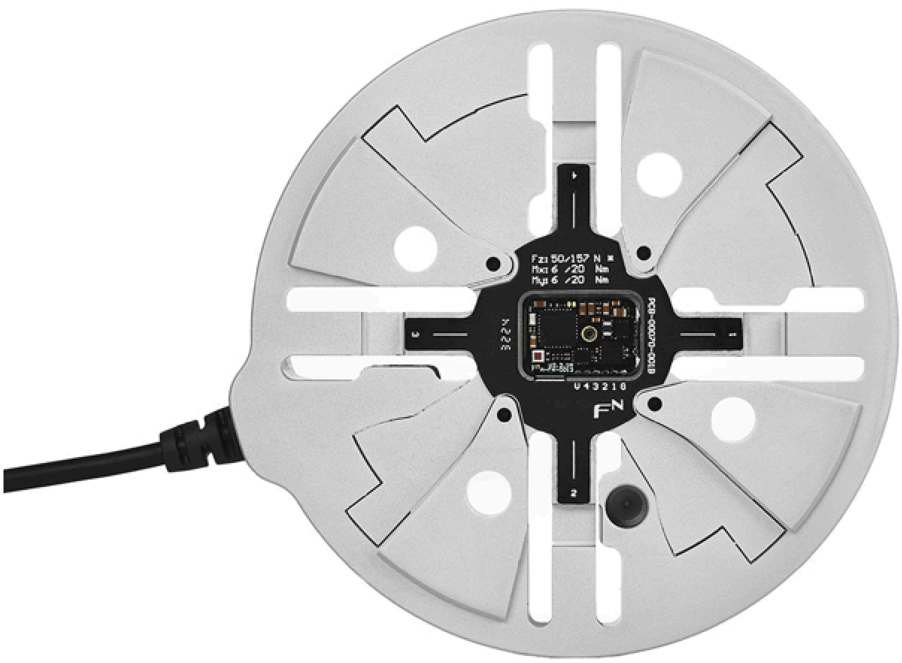

MAN-00014-001

ASY-00035-001, 3-DOF, SENSING SYSTEM

User Manual

Record Revision History

Rev.	Effective Date	Author	Change Request #	Change Summary
A	2023/09/11	Aman Ladak, Stephanie Skarica	N/A	Initial Release

Forcen Inc.

FOR EXTERNAL RELEASE

Table of Contents

1. Scope & Limitations

This document provides an overview of the ASY-00035-001 sensing system. In particular, the document outlines the technical specifications, installation instructions and a quick start guide for connecting to the sensor over USB and viewing data in the provided BonneChere software.

2. Acronyms

DOF – Degrees of Freedom

3. Referenced Documents

Document Number	Description
N/A	N/A

4. Product Overview

ASY-00035-001 is a fully integrated 3-DOF force sensing system capable of resolving axial forces and bending moment data through onboard electronics. The system has built-in overload protection which engages at the upper band of the specified sensing range, thereby being able to withstand high impact loading and continued overload without fear of permanent failure. Optional edge computing is capable of compensating for acceleration (Dynamic Weight Compensation).

For Dynamic Weight Compensation, the sensor system calculates a resolved mass value dependent on force-moment data from 4 sensing structures. The system integrates multiple technologies to provide a unique solution to weight sensing regardless of the orientation.

5. Technical Specifications

5.1. Mechanical Specifications

Table 1: Mechanical specifications of the ASY-00035-001 sensing system

Type	Description	Specification	Units	Comments
Sensing Specifications	Number of sensing elements	4	-	-
	Sensing type and axis	3-DOF: Fz, Mx, My	-	-
	Fz Full-Scale (FS) Range	50	N	-
	Fz Digital Resolution	<0.04	N	-
	Fz Accuracy	3	% FS	-
	Fz Overload Engagement (Safe Overload)	250	N	Overload values are for independent loading only.
	Mx/My FS Range	6	Nm	-
	Mx/My Digital Resolution	<0.005	Nm	-
	Mx/My Accuracy	3	% FS	-
	Mx/My Overload Engagement (Safe Overload)	30	Nm	Overload values are for independent loading only.

Type	Description	Specification	Units	Comments
Environmental Specifications	Operating Temperature Range	10 - 50	°C	Forcen's Development Kit systems are not temperature compensated. This is an additional feature that Forcen can provide at the Beta development phase for customized systems.
Physical Specifications	Sensor Body Material	7075 Aluminum	-	-
	Approximate Weight	185	g	-
	Diameter	90	mm	-
	Thickness	12.5	mm	-

5.2. Electrical Specifications

Table 2: Electrical specifications of the ASY-00035-001 sensing system

Type	Description	Specification	Units	Comments
Electrical Specifications	Power Requirements	5	V	-
	Data Rate	100	Hz	Default data rate of the sensor. Data rate can be configured from 10-2500 Hz upon request.
	Filtering	None	-	-
	Communication Type	USB/Ethernet	-	USB is standard for Development Kit. Ethernet is available with a conversion bridge. Other communications available for customized systems.
	Connector	USB-A Male/M8 Male	-	USB-A or M8 for Development Kit. Other connector types available for customized systems.

6. Operating Guide

6.1. Sensor Mounting

- The sensing system is designed to meet ISO 9409-1-50-4-M6 standard mounting requirements for easy mounting into co-bots commonly used in industry.

Mounting

- Forcen recommends mounting the sensor as per the instructions below for the most accurate results. If you plan to deviate from these specifications, please contact Forcen to ensure that the sensor will still function as expected.
- Sensor Fixed End: Mount the sensor to a plate through the 6 mm counterbore through holes.
- Sensor Sensing End: Mount the moving end to the sensor via the M6 threaded holes.

6.2. Bolt Torque

- Torque all bolts (6 mm) to 9 Nm.

6.3. Sensor Keep-Out Zones

- Do not mount anything below the keep out zone. All adapter and mounting plates must sit flush on the protruding surfaces, and cannot go below these surfaces. The sensor will not function as intended if the 1.5 mm and 1.25 mm zones are breached (Figure 1).

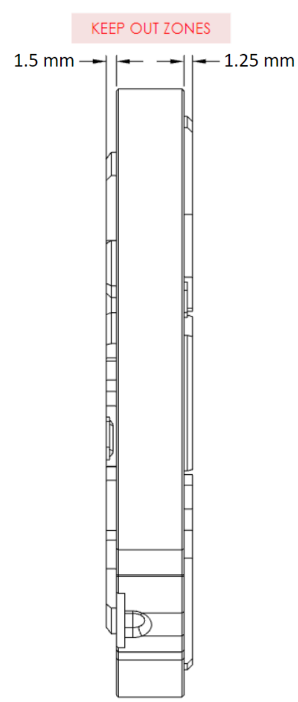

Figure 1: Sensor Keep-Out-Zones

6.4. Data Acquisition Software Operating Guide

- Forcen has developed an in-house data acquisition and visualization software, BonneChere, for use with its sensors. This software provides a plug and play experience to quickly view and log sensor data.
- The BonneChere version that is compatible with ASY-00035-001 is located in ForceN_IRIS:
  - Unzip the provided folder and run the application by double-clicking the executable named "IRIS.exe".
  - Note that an error screen may appear when opening the application for the first time, which says "Windows Protected your PC". This occurs as Windows does not recognize this as an authenticated or authorized application. To run BonneChere, click on "More Info" then "Run Anyway".
- Connecting to the Sensor with BonneChere:
  - Once BonneChere has loaded, click on "New Device" on the main screen.
  - A popup labelled "Configure Serial Connection" will appear. Click on the three horizontal lines as shown in Figure 2 below, and select the USB port the sensor is connected to.

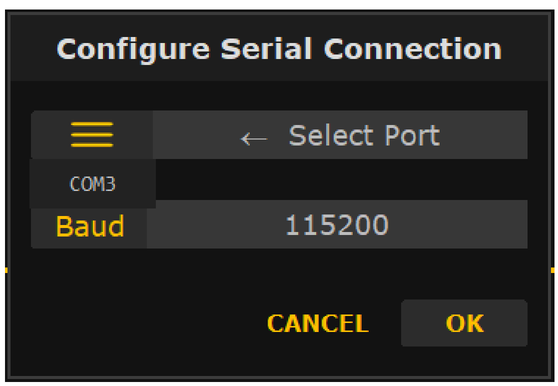

Figure 2: Loading the sensor into BonneChere

  - Press "OK" to finish adding the device.
- When the device is successfully connected, you will see the device information such as the unique identifier and firmware version added to the left side of the program as shown below in Figure 3.

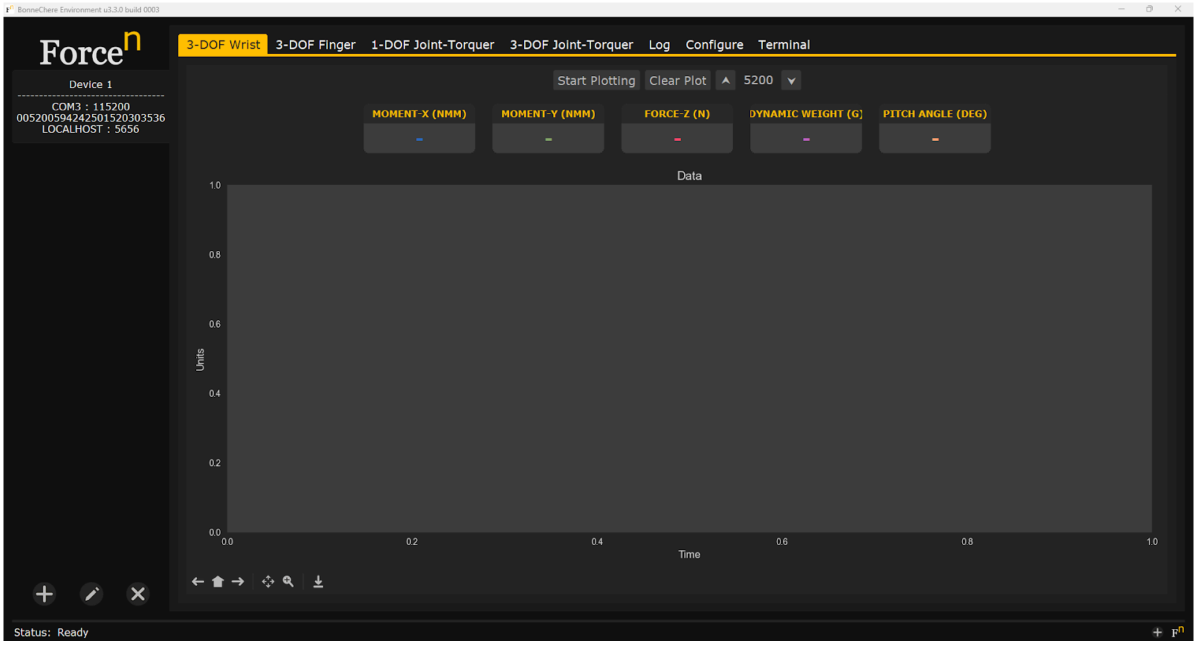

Figure 3: BonneChere environment with a successfully loaded sensor

- Through BonneChere, you can plot sensor data, read/configure device registers, log device data, tare the sensor, etc. Refer to Section 7 for more details.
- Note: if using the device for the first time, ensure that taring is completed in order to obtain accurate sensor readings. Refer to Section 9 for the taring process.

6.5. Coordinate System

- The coordinate system for the sensing system is shown below in Figure 4.

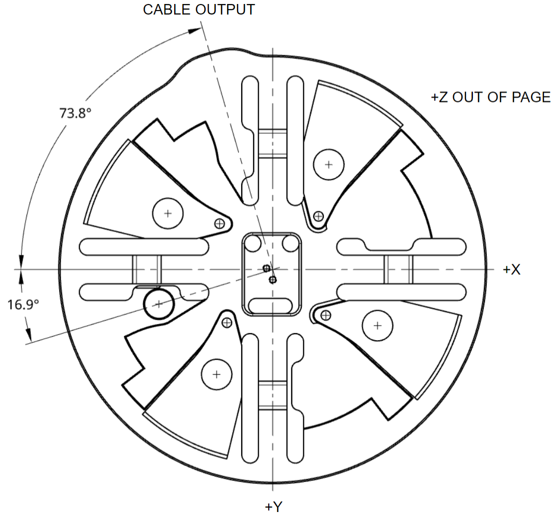

Figure 4: Coordinate system of the ASY-00035-001 sensing system

7. BonneChere Functionality

This section provides more details regarding the various functionalities of BonneChere used to configure and interact with the sensor. This section assumes the sensor has already been connected to BonneChere, as outlined in Section 6.4.

7.1. Plotting Sensor Data

- Navigate to the “3-DOF Wrist” tab.
- Click “Start Plotting” to visualize the data in Mx (Nmm), My (Nmm), and Fz (N) with respect to time in seconds. If it is a sensor system with dynamic weight compensation, Dynamic Weight (g) and Pitch Angle (deg) will also be shown. The “Start Plotting” button will automatically place the sensor into RUNNING (continuous data streaming) mode. See Figure 5 below for reference.

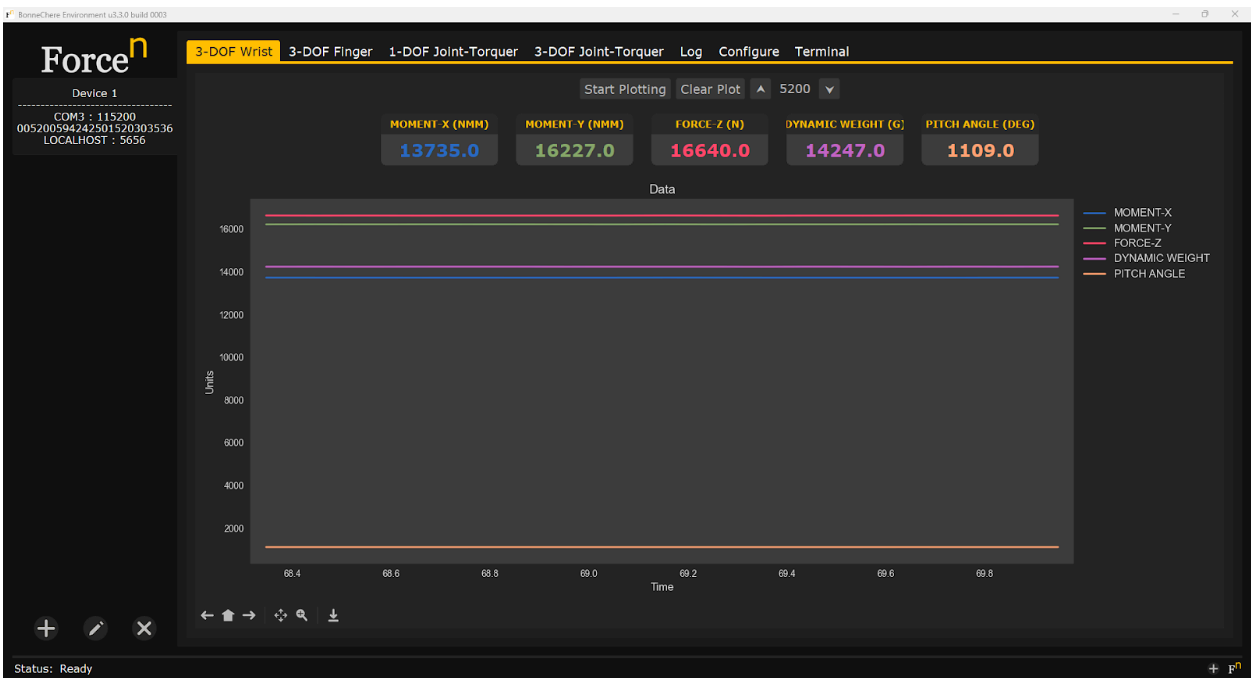

Figure 5: Plotting sensor output data in BonneChere

- To pause the plotting, click “Stop Plotting”.
- At any point of plotting, refresh the plot by clicking “Clear Plot”.
- To modify the time window being displayed on the plot, change the “5200” value seen in Figure 5.

7.2. Reading/Setting Device Registers

- Navigate to the “Terminal” tab.

- To set a register value, type <**S**xxVVVV> in the bar shown in Figure 6 below and press Enter or the click "Send" button. Note that 'xx' is the ASCII ID of the register of interest (these will be provided throughout the document) and 'VVVV' is the value to be set.

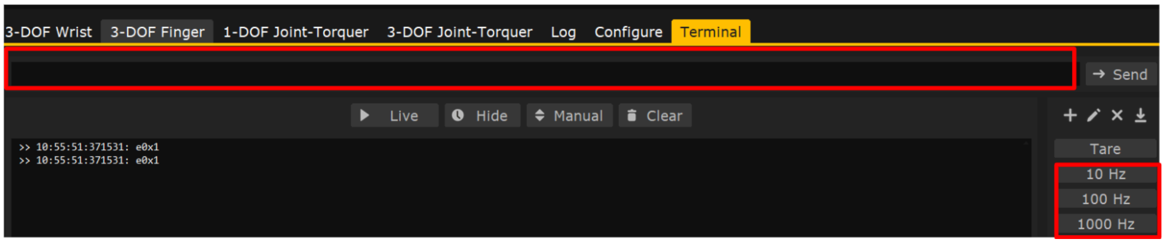

Figure 6: Terminal bar used to send commands to the connected device

- To read a register value, type <**G**xx> in the bar shown in Figure 6 and press Enter or the "Send" button. Note that 'xx' is the ASCII ID of the register of interest (these will be provided throughout the document).
- The response code of setting a register, or the requested value, will be displayed in the terminal window below the command bar. The codes are as follows:

Table 3: Return codes for register reading/writing

Code	Code Type	Description
a0x1	Acknowledgement	Write Success
e0x0	Error	Unknown error
e0x1	Error	Action unsupported
e0x2	Error	Action invalid
e0x3	Error	Address invalid
e0x4	Error	Data invalid
e0x5	Error	Data length invalid
e0x8	Error	No read access
e0x9	Error	No write access
e0xA	Error	General write error
e0xB	Error	Device mode error
rVVVV	Response code (read success)	Response to register read, where 'VVVV' is the requested value in decimal (base 10) or hex if preluded by a '0x'

- To save the value of a modified register to EEPROM, send a <CS> command. See Section 7.5 for more information about saving register values.

7.3. Setting the Sampling Rate

- Navigate to the “Terminal” tab.
- Type `<SDRxx>` in the bar shown in Figure 6, where ‘`xx`’ is the desired sampling rate in Hz.
    - For 10 Hz: Type `<SDR10>`
    - For 100 Hz: Type `<SDR100>`
    - For 1000 Hz: Type `<SDR1000>`
- The command buttons shown on the right side of Figure 6 can also be clicked to set the sampling rate to either 10, 100 or 1000 Hz. Additional command buttons can also be added by clicking on the “+” sign.
- If setting the sampling rate is successful, the return code `a0x1` will be displayed in the terminal window.

7.4. Placing the Device into RUNNING Mode

In order to automatically stream real-time data (RTD) messages from the device using a COM port, the sensor must be placed into RUNNING (continuous data streaming) mode.

- Navigate to the “Terminal” tab.
- Type `<SDM2>` in the bar shown in Figure 6.
- If setting the device mode is successful, the return code `a0x1` will be displayed in the terminal window.

The format of the RTD messages streamed from the device is explained in Section 8.1.

7.5. Saving Modified Register Values

When register values are modified, they will be applied to the current runtime data. However, they are not automatically saved to EEPROM and thus will be lost after a power cycle. To save the modified values for future use:

- Navigate to the “Terminal” tab.
- Type `<CS>` in the bar shown in Figure 6.
- If the save is successful, the response code `a0x2` will be displayed in the terminal window.
- If the save fails, the response code `e0x7` will be displayed.

7.6. Logging Data

- Navigate to the “Log” tab.
- Select the channels you want to collect data for on the right hand side under “Direct”, as shown below in Figure 7.

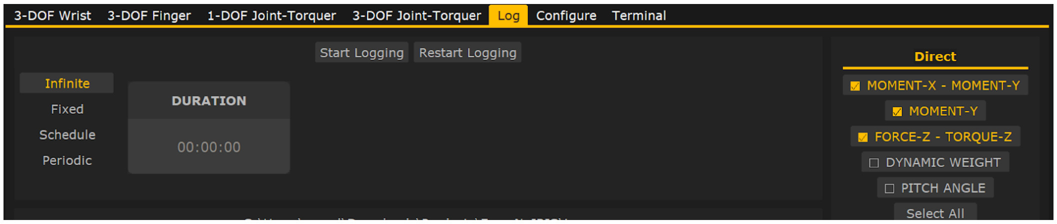

Figure 7: Logging data in BonneChere

- Use the “Start Logging” button (seen in Figure 7) to begin collecting data, and then press “Stop Logging” to stop collecting data.
- The log files will automatically be saved in the following directory:
  - ForceN_IRIS→ Logs

7.7. Notes for General Operation of the Sensor

- When fastening/unfastening the fixturing, it is recommended to unplug the sensor from the USB port.
- If fastening/unfastening the device at any time, ensure that the sensor is tared again as per Section 9.
- The sensor can be plugged and unplugged from the USB port at any time and this will not damage the sensor.

8. Firmware Details

8.1. Output Data Mapping

This section explains the mapping of the device output data while reporting real-time measurements using real-time data (RTD) messages. **Note** that in order to automatically receive these messages, the device must be in **RUNNING** (continuous data streaming) mode. To put the device into RUNNING mode, send a <SDM2> command (see Section 7.4 for more details). These messages, or frames, can then be seen in the “Terminal” tab in the terminal window by pressing “Live” as seen in Figure 8 below. They can also be seen in other COM port windows connected to the sensor.

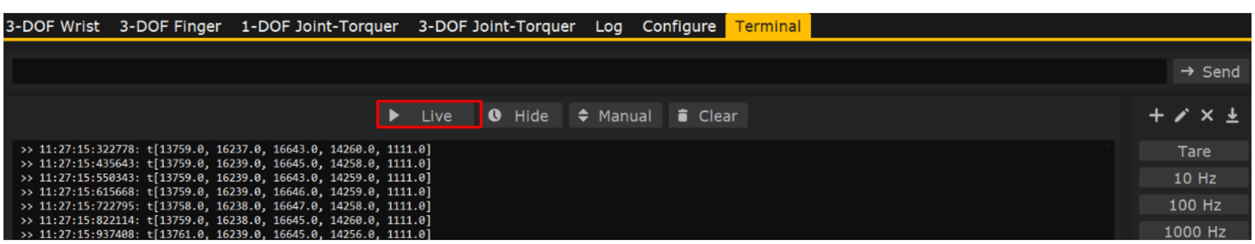

Figure 8: Viewing RTD messages in BonneChere

The output mapping of the sensor varies depending on if dynamic weight compensation is available for the sensing system. These mappings are outlined in the sub-sections below.

The RTD also gets displayed in the “3-DOF Wrist” tab as separate channel outputs, which are labeled, as shown in Figure 9. The channel outputs will update if the “Start Plotting” button is pressed, which automatically places the device into RUNNING mode.

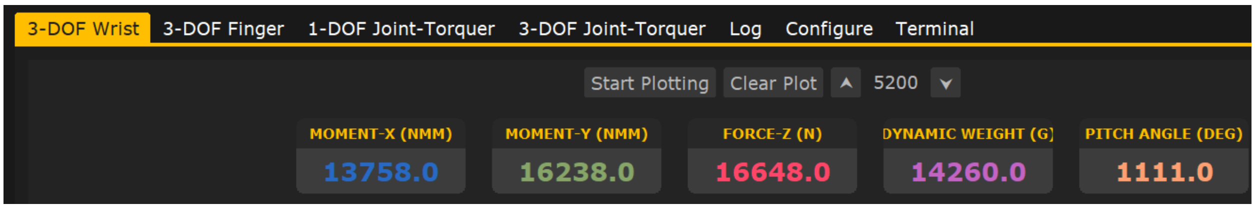

Figure 9: RTD displayed as separate channels in BonneChere

8.1.1. Output Data Mapping for System Without Dynamic Weight Compensation

The format of the RTD messages of a sensor without dynamic weight compensation is outlined below in Table 4.

Table 4: RTD message output mapping for sensor without dynamic weight compensation

SOF	Command Type	Mx	My	Fz	EOF	IFS
<	\space	[Nmm]	[Nmm]	[mN]	>	\n

8.1.2. Output Data Mapping for System With Dynamic Weight Compensation

The format of the RTD messages of a sensor with dynamic weight compensation is outlined below in Table 5.

Table 5: RTD message output mapping for sensor with dynamic weight compensation

SOF	Command Type	Mx	My	Fz	Weight	Pitch Angle	EOF	IFS
<	\space	[Nmm]	[Nmm]	[mN]	[grams]	[degrees]	>	\n

8.2. User Constant Mapping for End of Arm Tool Parameters

This section describes the measurement of the end of arm tool (EoAT) to accurately determine the arm characteristics required as user inputs within the onboard firmware model. The sensing system requires the following input parameters shown below in Table 6.

Table 6: Required EoAT parameter inputs with corresponding register

Register (ASCII ID)	Parameter	Description	Value	Units
`U0`	ARM COG X	The distance between the midplane of the sensor's sensing beams and the center of gravity of the connected arm in the x-direction of the sensor.	User Input Value	m
`U1`	ARM COG Y	The distance between the midplane of the sensor's sensing beams and the center of gravity of the connected arm in the y-direction of the sensor.	User Input Value	m
`U2`	ARM COG Z	The distance between the midplane of the sensor's sensing beams and the center of gravity of the connected arm in the z-direction of the sensor *(annotated as (d) in Figure 10)*.	User Input Value	m
`U3`	ARM WEIGHT	The **total** weight of the connected arm.	User Input Value	kg
`U4`	ARM LENGTH Z	The distance between the midplane of the sensor's sensing beams and the loading point along the z-direction of the sensor *(annotated as (e) in Figure 10)*.	User Input Value	m
`U5`	ARM WEIGHT CONFIDENCE	The confidence in the arm weight measurement; this is used to report a calibration warning if the measured arm weight is outside these confidence bounds. The value in this register should be between 0 (indicating no confidence) and 1 (indicating 100% confidence). If unsure, set it to 0.8 which is typically a good starting point.	User Input Value	Ratio

Register (ASCII ID)	Parameter	Description	Value	Units
	Sensing Beam Distance	The distance from the EoAT sensor mating surface to the midplane of the sensor's sensing beams.	0.009525	m

Note that all registers in Table 6 can be set by sending `<SxxVVVV>` to the device, where '`xx`' is the register ASCII ID and '`VVVV`' is the desired value to be set. This can be done using the "Terminal" tab in BonneChere. See Section 7.2 for more details.

Guidelines on measuring the EoAT parameters mentioned in Table 6 can be seen in Section 8.2.1 below.

8.2.1. Measuring End of Arm Tool Parameters

The ARM COG Z parameter is characterized by the combination of two dimensions. First, the distance from the sensor-EoAT mating surface to the midplane of the sensor's sensing beams, which is annotated as **(a)** in Figure 10 and value defined in Table 6 (Sensing Beam Distance). Second, the distance normal from the sensor-EoAT mating surface to the center of gravity of the EoAT, which is annotated as **(b)** in Figure 10. The final value of ARM COG Z is annotated as **(d)**, with the center of gravity of the EoAT being marked by an asterisk in Figure 10.

The ARM LENGTH Z parameter is characterized by the combination of two dimensions. First, the distance from the sensor-EoAT mating surface to the midplane of the sensor's sensing beams, which is annotated as **(a)** in Figure 10 and value defined in Table 6 (Sensing Beam Distance). Second, the distance from the sensor-EoAT mating surface to the retracted gripper, which is annotated as **(c)** in Figure 10. The final value of ARM LENGTH Z is annotated as **(e)** in Figure 10.

The ARM WEIGHT parameter is characterized by the total mass of all parts that are directly or indirectly connected to the sensing system at the sensor-EoAT mating surface. When measuring the weight, attach all components to the arm and perform the measurement immediately before mounting it with the sensor.

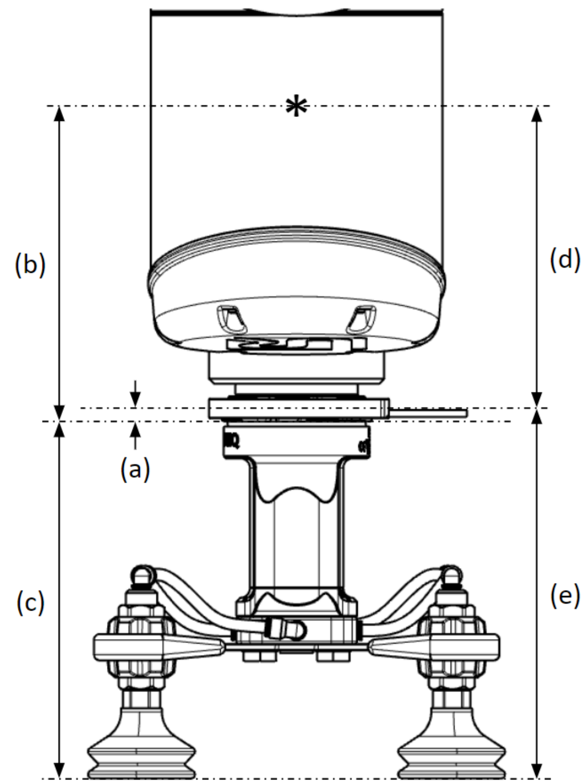

Figure 10: Representation of the required EoAT parameter measurements

9. Sensor Taring

This section explains in detail the steps required to properly tare a sensor with or without onboard dynamic weight compensation. During the taring procedure, the device automatically determines the sensor offsets to output proper moments, forces, and weight (weight only applies if dynamic weight compensation is available). The device also measures and verifies the user provided arm weight as detailed in Section 8.2.

Note that the "Tare" command button shown on the right side of Figure 6 is to be used with other Forcen Development Kit sensor systems, and is not intended to be used with the 3-DOF Wrist system. It therefore does not tare the 3-DOF Wrist sensor system when clicked.

The taring process must be repeated each time the bolts connecting directly to the sensor are fastened/unfastened. All values outlined in Table 6 should be set before attempting the sensor taring process. It is recommended to wait at least 4 minutes after boot up and before taring to ensure all internal electronics reach steady state.

The taring sequence can be triggered by setting the "DEVICE_MODE" ('`DM`') register to 5 by sending the `<SDM5>` command (see Section 7.2 for more details). Once the device receives this command, it will initiate the taring algorithm. The algorithm is composed of multiple stages; each stage is designed to resolve and validate the sensor baseline measurements. The stages of the algorithm vary depending on if the sensor system includes dynamic weight compensation. The details of each algorithm can be seen in the sub-sections below.

The taring sequence can be stopped at any time by switching the “DEVICE_MODE” (‘DM’) register to a different value. For example, sending <SDM2> will put the device into RUNNING (continuous data streaming) mode. If taring is allowed to run to completion and exit, the device will automatically revert back to the last selected mode prior to taring.

After the taring sequence is completed, internal registers are updated with the new taring values. The module will use the new values to perform any future calculations, however, these values are not saved to EEPROM by default. If desired, the user can issue a save configuration command <CS> after the taring is successfully completed to save the calculated offsets. By saving these values and assuming the sensor has not been altered during reboots, it may be possible to get properly calibrated measurements without recalibration. However, this can be affected by many factors and it is strongly recommended to always recalibrate the model after each power cycle to ensure best operation.

9.1. Sensor Taring Sequence for Systems **Without** Dynamic Weight Compensation

The stages and possible outcomes of the taring sequence for a sensor system without dynamic weight compensation are shown in Figure 11 below.

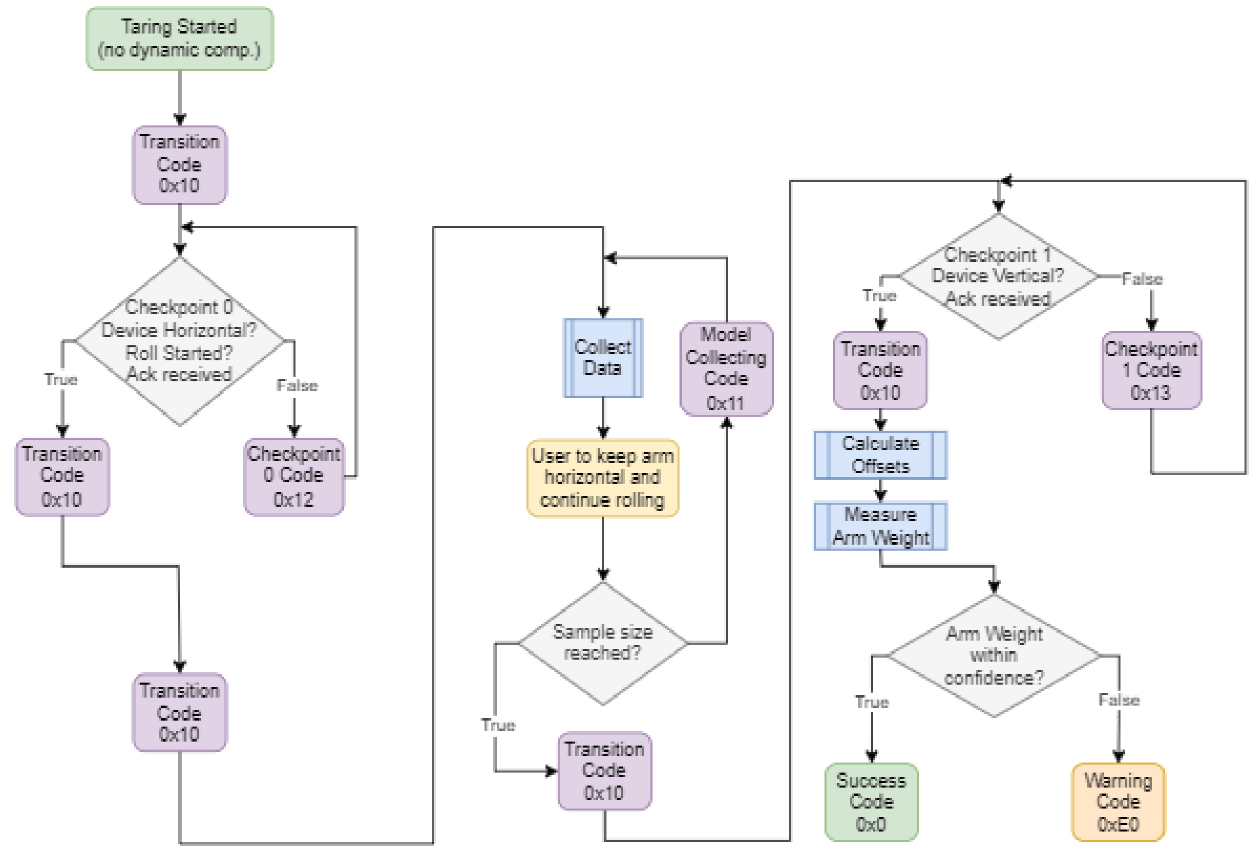

Figure 11: Taring procedure for sensor system without dynamic weight compensation

Note that since the sensor system without dynamic weight compensation does not include an IMU, the user is relied upon to have the device in the required position at all times. The taring return codes will be displayed in the terminal window of the "Terminal" tab in BonneChere.

During the taring sequence shown above in Figure 11, the user must follow certain steps to ensure that the device is tared correctly. All the steps required are summarized below:

1. Initiate taring by setting the "DEVICE_MODE" ('`DM`') register to 5 (Send `<SDM5>`).
2. Move the device to horizontal orientation as shown in Figure 13.
3. Once the device is horizontal, with rolling beginning or ready to begin, set the "TARING_CONTINUE" ('`TC`') register to 1 (send `<STC1>`).
4. Roll the device at least 360 degrees while horizontal.
    a. The amount of data collected during this step can be specified by the "TARING_TIME" ('`TT`') register (e.g. sending `<STT10>` will collect data for 10 seconds).
    b. To see the current value of the '`TT`' register, send `<GTT>`.
    c. The user is required to keep the device horizontal during this data collection stage.

5. Keep the device rolling for the time specified in the "TARE_TIME" register or until the device indicates completion (transition code `0x10` and then checkpoint code `0x13`).
6. Move the device to vertical orientation as shown in Figure 14.
7. Once the device is vertical and stationary, set the "TARING_CONTINUE" ('`TC`') register to 1 (send `<STC1>`).
8. Within one second the taring will complete.
    a. The device will calculate the taring parameters during this time.
    b. The device will measure the arm weight and compare it to the user input, taking into consideration the arm weight confidence factor.
        i. If the arm weight is within acceptable range, the taring exits with success code `0x0`.
        ii. If the arm is outside the acceptable range, the taring exits with warning code `0xE0`.

9.2. Sensor Taring Sequence for Systems **With** Dynamic Weight Compensation

The stages and possible outcomes of the taring sequence for a sensor system with dynamic weight compensation are shown in Figure 12 below.

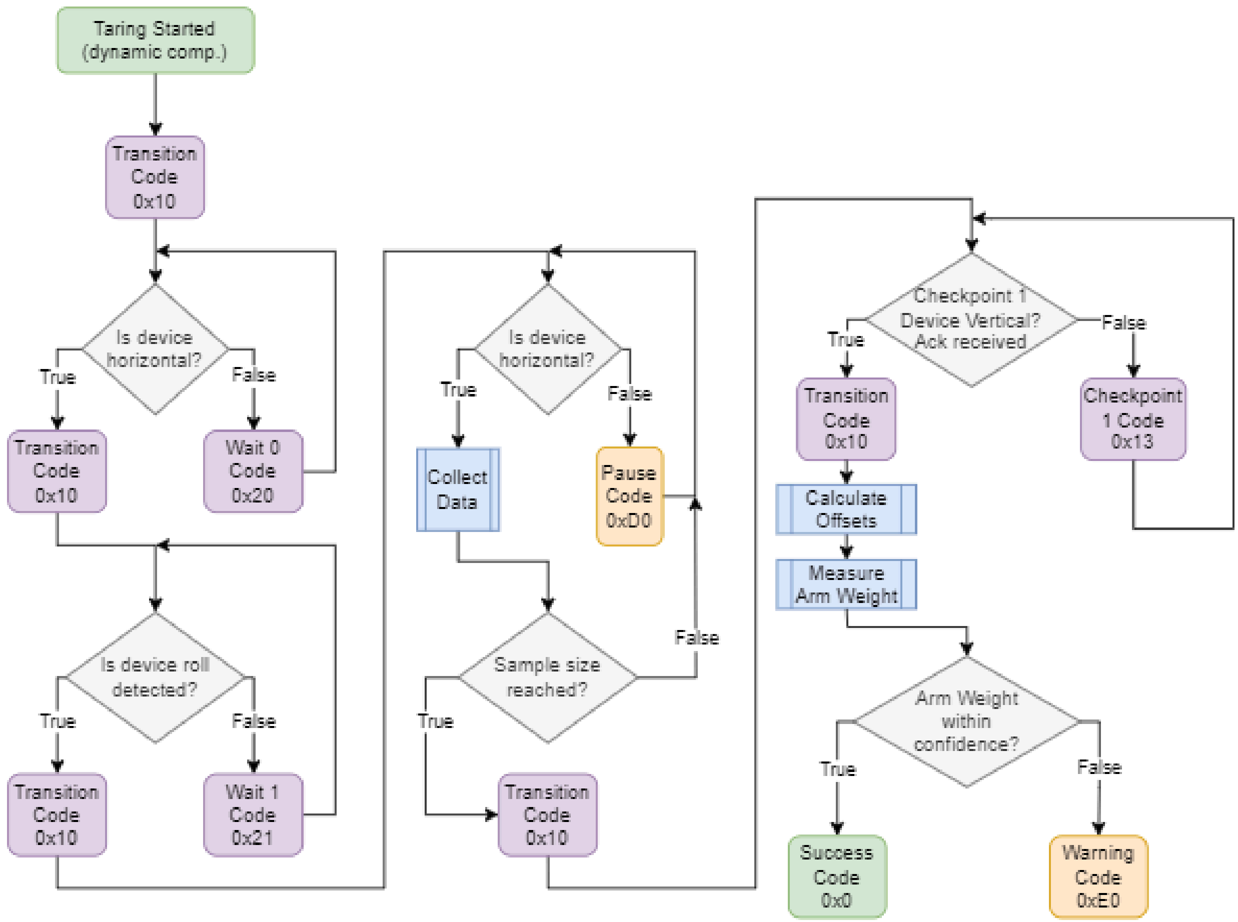

Figure 12: Taring procedure for sensor system with dynamic weight compensation

Note that the horizontal taring procedure will also take into consideration the orientation of the IMU and calibrate it accordingly. The taring return codes mentioned will be displayed in the terminal window in the “Terminal” tab of BonneChere.

During the taring sequence shown above in Figure 12, the user must follow certain steps to ensure that the device is tared correctly. All the steps required are summarized below:

1. Initiate the taring by setting the “DEVICE_MODE” (‘`DM`’) register to 5 (Send `<SDM5>`).
2. Move the device to horizontal orientation as shown in Figure 13.
3. Roll the device at least 360 degrees while horizontal.
    a. The amount of data collected during this step can be specified by the “TARING_TIME” (‘`TT`’) register (e.g. sending `<STT10>` will collect data for 10 seconds).
    b. To see the current value of the ‘`TT`’ register, send `<GTT>`.

   c. If the device is more than +/- 5 degrees from horizontal, the taring process pauses data collection (pause code `0xD0`).

4. Keep the device rolling for the time specified in the "TARE_TIME" register or until the device indicates completion (transition code `0x10` and then checkpoint code `0x13`).
5. Move the device to vertical orientation as shown in Figure 14.
6. Once the device is vertical and stationary, set the "TARING_CONTINUE" ('`TC`') register to 1 (send `<STC1>`).
7. Within one second the taring will complete.
   a. The device will calculate the taring parameters during this time.
   b. The device will measure the arm weight and compare it to the user input, taking into consideration the arm weight confidence factor.
      i. If the arm weight is within acceptable range, the taring exits with success code `0x0`.
      ii. If the arm is outside the acceptable range, the taring exits with warning code `0xE0`.

9.3. Sensor Taring Sequence - Orientation Diagrams

This section includes robot end of arm tool diagrams for visualization of the horizontal and vertical orientation for the device mentioned in Section 9.1 and Section 9.2.

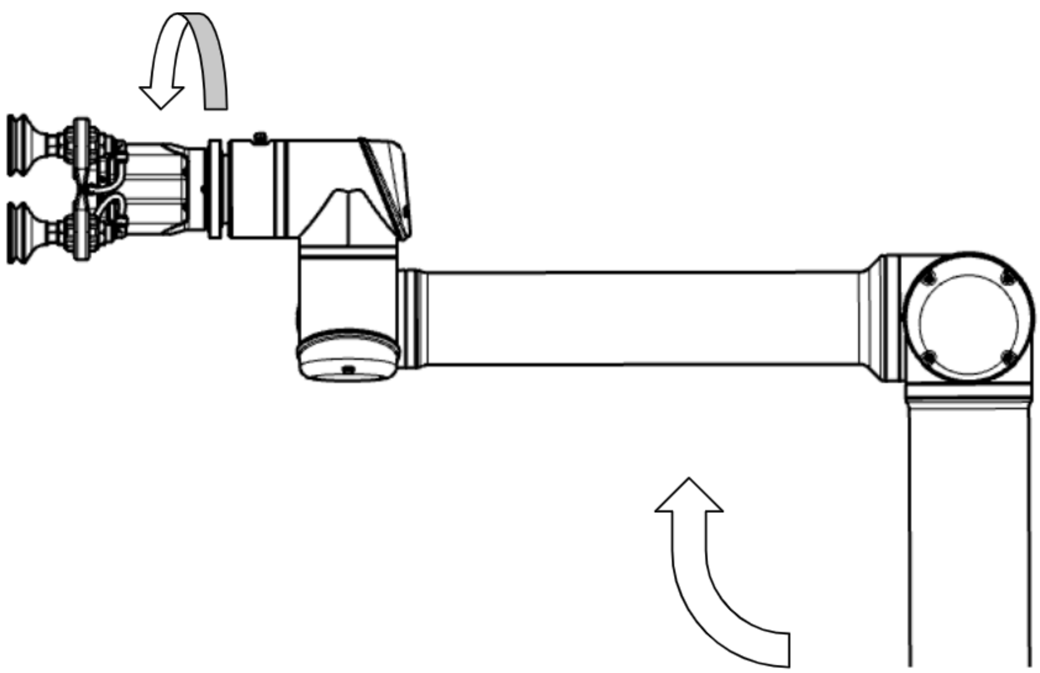

Figure 13: Device horizontal orientation with the direction of roll indicated

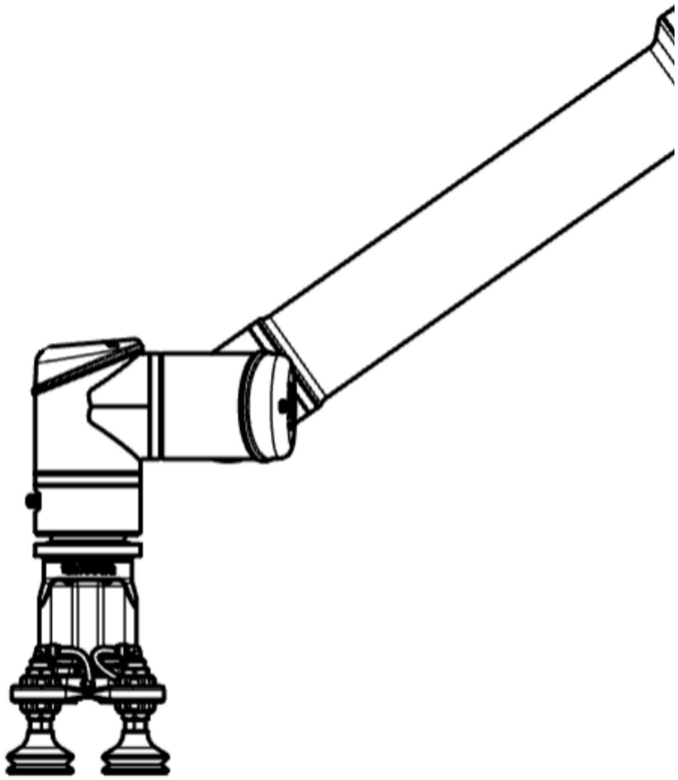

Figure 14: Device vertical orientation

9.4. Additional Taring Sequence Error Codes

In addition to the taring return codes mentioned in Section 9.1 and Section 9.2, there are some error codes that may appear. These include:

- `0xF0` -> General taring error
- `0xF9` -> Taring data filter failure

If these codes are observed, contact Forcen for further assistance.