Trigno™ Wireless System SDK

Specifications and procedures outlined in this document are subject to change without notice.

MAN-025-2-0

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Important Information

Intended Use

The Trigno SDK is a software development tool to be used in conjunction with the Trigno Wireless EMG biofeedback system. The SDK alone does not perform any therapeutic or diagnostic function. It is intended to be used as a software component of a parent software package. The function of the SDK is to manage the transfer of data from the Trigno System to the parent software, and is designed to work exclusively with the Trigno System.

Technical Service and Support

For information and assistance visit our web site at:
www.delsys.com

Contact us at:
E-mail: support@delsys.com
Telephone: (508) 545 8200

Device Information

Please see the Trigno Wireless EMG System User Guide for information on the EMG Device.

System Requirements

Trigno Wireless EMG System
Windows 7 or newer, 64-bit or 32-bit operating systems supported
One USB 2.0 port
2.0 GHz processor clock speed (minimum)
2 GB system memory (minimum)
1 GB hard disk storage (minimum)

Trigno Wireless System SDK Overview

The Trigno Wireless System SDK is a software package designed to allow programmers to interact with the Delsys Hardware. The SDK runs as a TCP/IP server with the Trigno Control Utility.
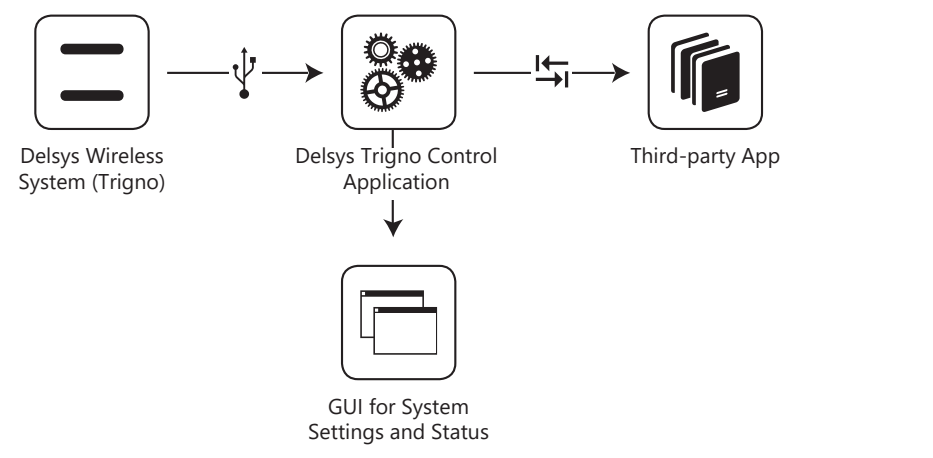

Figure 1. Data flow and SDK sub-system components.

Getting Started with the SDK

To use the SDK – install the software on a PC meeting the minimum requirements (listed above), and connect a Trigno Base Station (part of the Trigno Wireless EMG System) to the PC.

Use the Trigno Control Utility to pair sensors to desired slots (see the Trigno Wireless EMG System User Guide for help with pairing).

While the Trigno Control Utility is running, any other software can connect to the command port and instruct the base to begin streaming data. The command port is port 50040 on the host (running the Trigno Control Utility) computer.

To receive data, connect to the appropriate ports:

IM Sensor EMG Data (1 Channel)	Port 50043
IM Sensor AUX Data (9 Channels, 4 if Orientation Filter is enabled)	Port 50044
Hybrid or Other Sensors EMG Data (1 Channel)	Port 50041
Hybrid or Other Sensors AUX Data (3 Channels)	Port 50042

All data values are IEEE floats containing 4 bytes each. If multiple channels are being streamed over a port, the data are multiplexed. For example, in normal operation on port 50042 the first three samples received will be sample number 1 from each of the 3 AUX data channels.

Using the SDK

Please read the Trigno Wireless EMG System User Guide for information about using the Trigno hardware.

To use the SDK, a parent software application must perform the following tasks:

- Connect to the Trigno SDK Server via TCP/IP
- Configure the hardware (pair sensors, etc.). Please see the next section "Configuring the Trigno Hardware" for information on this.
- Start the system
- Send the command "START" over the command port (50040)
- Trigger the system (optional). Send a start trigger to the Trigno Base Station. For more information on this please see the Trigno Wireless EMG System User Guide.
- Receive Data
- Process the data streams that are being sent over the data ports. For synchronization purposes, always process bytes in segments determined by multiples of the following factor:
- (16 Sensors) * (Number of channels on port) * (4 bytes/sample)

Configuring the Trigno Hardware

The Trigno Base Station can have up to 16 sensors paired at once. To pair a sensor via the SDK, turn the sensor on, and use the command "SENSOR *n* PAIR". This will initiate the pair process. Once the process is initiated, the user must press and

hold the sensor button until the pair complete message is received.

Each Trigno Wireless sensor has a configurable digital setting which controls gains and accelerometer ranges (dependent on sensor type). For more information about sensor settings, please see the Trigno Wireless EMG System User Guide.

To configure the sensor via the SDK, use the command "SENSOR *n* SETMODE x". This will set the sensor paired to slot *n* to mode *x*. For example, "SENSOR 1 SETMODE 3" will set Sensor 1 to Mode 3.

Technical Specifications

Data Ports

The command interface is implemented on a single port 50040. This port both receives commands and sends replies.

The EMG data are streamed (output only) on port 50041.

The Accelerometer data are streamed (output only) on port 50042.

The IM type sensors' EMG data are streamed (output only) on port 50043.

The IM type sensors' other data channel (ACC, GYRO, MAG) are streamed on port 50044.

The Trigno Control application listens for incoming connections in the background on these ports, and handles data routing to any applications that connect.

Packet Structure

The TCP stream is broken into packets for commands and packetized data transfer. Each command is terminated with <CR><LF>. The end of a command packet is terminated by two consecutive <CR><LF> pairs, and the server will process all command received to this point when a two <CR><LF> pairs are received.

Control commands and replies are human-readable ASCII text, so telnet (or Hy-

perterminal) can be used to test communication with the server.

Control Commands

Protocol Version
Trigno SDK Server responds to an incoming connection by returning its version.

Triggers
Use query "TRIGGER?" return the state of the input and output triggers.

Use command "TRIGGER [START/STOP] [ON/OFF]" to arm or disarm start or stop input triggers.

Sampling Rate
Use query "RATE?" to query the currently set sampling rate.

Trigno systems use a 2000 Hz sampling rate for EMG channels and a 148.(148)‾ Hz sampling rate for accelerometer channels when accessed through the SDK.

This command has been deprecated in version 2.0. See UPSAMPLE command and query.

Upsampling
Use query "UPSAMPLING?" to query the upsampling flag. Indicates if upsampling is turned on or off. When upsampling is turned on, all high frequency channels will be sampled at 2000Hz. If off, sensors will be sampled at their native rates.

Use command "UPSAMPLE [ON/OFF]" to set the upsampling flag.

Sensor Type
Use query "SENSOR n TYPE?" to query the type of a given sensor.

Sensor Serial
Use query "SENSOR n SERIAL?" to query the serial number of a given sensor.

Sensor Firmware
Use query "SENSOR n FIRMWARE?" to query the firmware version of a given sensor.

Sensor Pair Status
Use query "SENSOR n PAIRED?" to query the state of a given sensor. Will indicate "YES" for a paired and active sensor, and "NO for a unpaired, or currently off sensor.

Use command "SENSOR n PAIR" to pair a sensor.

Sensor Channels
Use query "SENSOR n CHANNEL-COUNT?" to query the number of channels in use on a given sensor.

Sensor Gain
Use query "SENSOR n CHANNEL m GAIN?" to query the gain of a given channel on a given sensor.

Sensor Units
Use query "SENSOR n CHANNEL m UNITS?" to query the gain of a given channel on a given sensor.

Sensor Mode
Use query "SENSOR n MODE?" to query to current mode of a given sensor. This is the configurable mode of the sensor, most often the Accelerometer gain setting.
Use command "SENSOR n SETMODE y" to set the mode the given sensor. Mode can be set to modes 1-4.

Base Serial
Use query "BASE SERIAL?" to query the serial number of the connected base station.

Base Firmware
Use query "BASE FIRMWARE?" to query the firmware version of the connected base.

Data Format
Use query "ENDIANNESS?" to query the currently set endianness for the returned data.

Use command "ENDIAN BIG" to set the returned data format to big-endian.

Use command "ENDIAN LITTLE" to set the returned data format to little-endian (the default).

Data Collection
Use command "START" to start data collection.

Use command "STOP" to stop data collection.

Trigger Stop
When a stop trigger is received, the server will output the command "STOPPED".

Disconnection
Use command "QUIT" to stop data collection and close the server session.

Version
Use query "VERSION?" to get the current version of the Trigno SDK

Orientation Filter
Use query "ORIENTATION FILTER?" to determine if the real time orientation filter is currently turned on or off.

Use command "ORIENTATION FILTER ON" to turn the real time orientation filter for IM data on.

Use command "ORIENTATION FILTER OFF" to turn the real time orientation filter for IM data off.

Use query "ORIENTATION DATA FORMAT?" to determine the output format of the orientation filter. This will either be "PRY" or "QUAT"

Use command "ORIENTATION DATA QUAT" to set the output format of the orientation filter to quaternions.

Use command "ORIENTATION DATA PRY" to set the output format of the orientation filter to Pitch/Roll/Yaw

Use command "ORIENTATION FILTER ZERO" to line up sensors with respect to a common reference frame.

Use command "ORIENTATION FILTER CALIBRATE" to load the calibration program for paired sensors

Use command "ORIENTATION PATH 'pathname' " to specify the path to the current calibration file. Use the pathname (note the single quotes) parameter to indicate the path.

Use query "ORIENTATION FILTER VERSION?" to get the version number of the currently installed orientation filter.

For more details about the orientation filter please see page 11.

Master/Slave Connections
While the first connection to be created will default as the Master Connection, other connections can be made master instead.

Use query "MASTER" from a connection to make it master. Note that this command should only be sent when data collection is not running.

Control Command Replies

The server will respond "OK" to a command which is valid and has been processed.

The server will respond "INVALID COMMAND" to an unknown command or a known command with invalid data.

The server will respond "CANNOT COMPLETE" to a command which is valid, but cannot be completed due to the current state of the system (for example, a configuration command issued while data is streaming).

Data Format
Data are streamed independently for EMG channels and accelerometer channels. The sampling rate is different for EMG and accelerometer channels, so byte data will arrive at different rates on the EMG data port (50041) and the accelerometer data port (50042).

EMG Data
EMG data are returned as 16 multiplexed channels, where each sample is an IEEE float occupying 4 bytes. The byte order is controlled by the ENDIAN command.

The data will begin streaming when the first valid sample or trigger is received.

To maintain synchronization, always read or process bytes in multiples of 64 bytes. (16 channels * 4 bytes/channel = 64 bytes). 64 bytes of data will contain 1 EMG sample from each sensor.

Accelerometer Data (from non-IM sensors)

Accelerometer data are returned as 48 multiplexed channels (16 sensors * 3 axes/sensor = 48 channels), where each sample is an IEEE float occupying 4 bytes. The byte order is controlled by the ENDIAN command.

The data will begin streaming when the first valid sample or trigger is received.

To maintain synchronization, always read or process bytes in multiples of 192 bytes (48 channels * 4 bytes/channel = 192 bytes). 192 bytes of data will contain 1 accelerometer sample from each of the 48 channels.

IM Sensor Data
IM Sensor data are returned as 144 multiplexed channels (16 sensors * 3 axes/ measurement unit * 3 measurements units = 144 channels), where each sample is an IEEE float occupying 4 bytes. The byte order is controlled by the ENDIAN command.

The data will begin streaming when the first valid sample or trigger is received.

To maintain synchronization, always read or process bytes in multiples of 576 bytes (144 channels * 4 bytes/channel = 576 bytes). 576 bytes of data will contain 1 sample from each of the 144 channels.

Sensor Information and Details

Several queries above refer to sensor properties such as type, mode, or channels. The full description of each sensor type with its available channels and modes are in the table below:

TRIGNO DESCRIPTION	# TYPE	α TYPE	CHANNELS	MODES
Legacy EMG Sensor	0	A	EMG + 3 ACC	Dual Range Accelerometer (+/-1.5g, +/-6g)
Spring Contact Adapter	1	B	EMG + 3 ACC	Dual Range Accelerometer (+/-1.5g, +/-6g)
Snap Lead EMG Sensor	2	C	EMG + 3 ACC	Dual Range Accelerometer (+/-1.5g, +/-6g)
Standard EMG Sensor	3	D	EMG + 3 ACC	Quad Range Accelerometer (+/-1.5g, +/-4g, +/-6g, +/-9g)
FSR Adapter	4	E	4 Footswitch Channels	No variable mode control
EKG Biofeedback Sensor	5	F	EKG + 3 ACC	Dual Range Accelerometer (+/-1.5g, +/-6g)
Load Cell Adapter	6	G	1 Load Cell Channel	Three gain modes (506 V/V, 1015 V/V, 2025 V/V)
Goniometer Adapter	7	H	2 Goniometer Channels	Three gain modes (1813 V/V, 1413 V/V, 2221 V/V)
MiniHead Sensor	8	J	EMG + 3 ACC	Dual Range Accelerometer (+/-1.5g, +/-6g)
Analog Input Adapter	9	K	4 Analog Input Channels	No variable mode control
IM Sensor	10	L	EMG + 3 ACC + 3 GYRO + 3 MAG	Quad range IM chip (± 2g, ±250 dps), (± 4g, ±500 dps), (± 8g, ±1000 dps), (± 16g, ±2000 dps) (dps = degrees/sec)
DR Sensor	11	M	EMG	Configurable bandwidth and gain for EMG channel: (150 V/V Gain, 20-450 Hz Bandwidth), (300 V/V, 20-450Hz), (150 V/V, 10-850HZ), (300 V/V, 10-850Hz)
Trigger Adapter	12	M	Trigger Chan	No variable mode control

Real Time Orientation Filter

The real time Orientation Filter transforms the raw data from Trigno IM sensors into orientation data, which provides the orientation of each sensor in a variable format.

Data Output

When the filter is turned on, the IM data aux port (TCP/IP Port 50044) will begin transmitting either 3 or 4 channels of orientation data (depending on the format, 4 channels for QUAT or 3 channels for PRY). When the filter is off, this port transmits all 9 raw data channels from the sensor (3xACC, 3xGYRO, 3xMAG).

Quaternion (QUAT) Format

If the data format is set to QUAT, the data will be a stream containing 80 multiplexed channels ([16 sensors]*[5 values/sensor] = 80 channels), where each sample is an IEEE float occupying 4 bytes.

The 5 values per sensor are quaternions corresponding to the following:

    Channel1 = q0
    Channel2 = q1
    Channel3 = q2
    Channel4 = q3
    Channel5 = reserved

Pitch/Roll/Yaw (PRY) Format

If the data format is set to PRY, the data will be a stream containing 80 multiplexed channels ([16 sensors] * [5 values/sensor] = 80 channels), where each sample is an IEEE float occupying 4 bytes.

The first 3 values contain Pitch Roll and Yaw data, while the fourth and fifth values are currently reserved.

Quaternion to PRY formula we use:

$$\text{pitch} = \text{atan2}\left(2(q_2q_3 - q_0q_1), 2q_0^2 - 1 + 2q_3^2\right)$$

$$\text{roll} = -\arctan\left(\frac{2(q_1q_3 + q_0q_2)}{\sqrt{1 - (2q_1q_3 + 2q_0q_2)^2}}\right)$$

$$\text{yaw} = \text{atan2}\left(2(q_1q_2 - q_0q_3), 2q_0^2 - 1 + 2q_1^2\right)$$

Calibration

A calibration file is required to optimize the filter's performance. Calibration allows environment variables to be taken into account, and will help accommodate for drift in the gyroscope signal.

Generating a new calibration file

The calibration application will be run. In the current orientation filter, calibration must be run on each sensor. As long as user is in the same location, the same calibration can be used. When a user changes locations, the sensor must be recalibrated.

Clicking on the option to generate a new calibration file will guide a user through the process of calibration. This calibration will be run for ALL currently paired IM sensors. After following all steps outlined in the interactive calibration program, the user will have the option to save the calibration file.

Loading a saved calibration file

Prior to data collection, users should load a calibration file corresponding to the sensors to be used. These calibrations will then be used to optimize the orientation filter.

Trigno IM Sensor Calibration Process

When using the orientation filter, data from the Trigno IM sensor must have a calibration applied to account for distortions in the local magnetic field environment and to compensate for inherent offsets in the system. The IM Sensor Calibration application is used to generate calibration files which are used by the orientation filter. The sensor calibration application is found in the following location:

> 🔍 C:\Program Files (x86)\Delsys, Inc\Trigno Server 2.x\DelsysImuApp.exe

Once on the home screen of the Calibration app, navigate to "**File ➔ Connect**" to establish a connection between the Trigno system and PC. Select the **Calibrate** button located in the center of the screen. The magnetometer is the first component to be calibrated.

> 📌 Make sure all Trigno IM sensors are paired to desired channels and turned on before beginning calibration. This requires the Trigno Control Utility to be running.
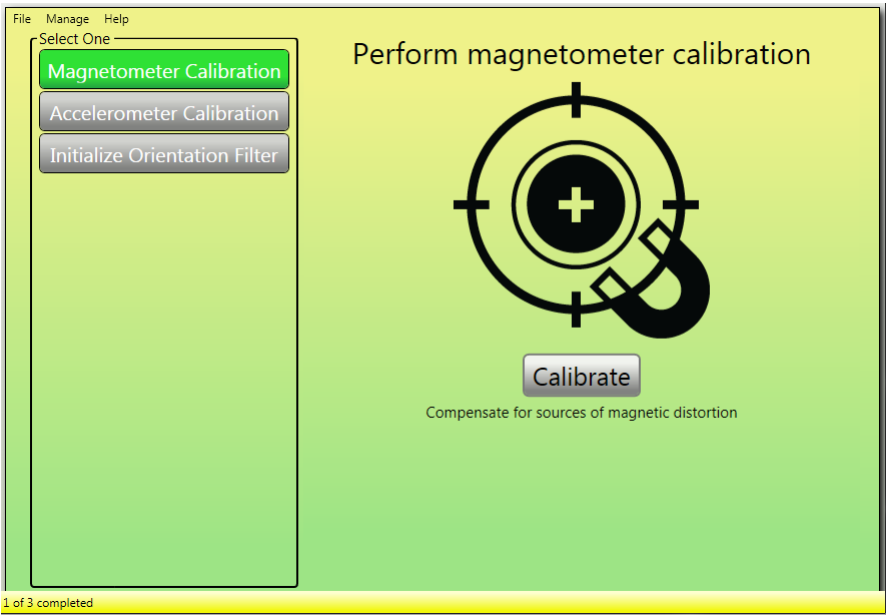

Figure 2. The Calibration Application home screen.

Magnetometer Calibration

After selecting the **Calibrate** button on the home screen, confirm the number of sensors that appear on the following screen and select **Start**.

Clicking the link will take you to an online repository of helpful documents and videos on the calibration process.

Figure 3. Calibrating the magnetometer.

A collection summary screen will appear next, begin by selecting Calibrate Sensor 1.

A figure with a set of three axes, represented as black lines, will appear. Once the calibration begins, points will be mapped to the figure as the Trigno IM sensor moves through space. The goal of the calibration is to map out a sphere centered on the origin (intersection point of the 3 axes), such that the points are spaced evenly along the surface of the sphere.

Figure 4. Data collection summary.

The Calibration app will prompt you to begin the calibration. Move the Trigno IM sensor through as many different orientations as possible. We recommend a loose "figure-8" motion while trying to keep the Delsys arrow pointed in the sensor's direction of travel. Rotating the sensor while waving will also help the calibration succeed.

📌 Rapid movement and large translations (movement side-to-side and up-and-down) are not necessary during calibration.
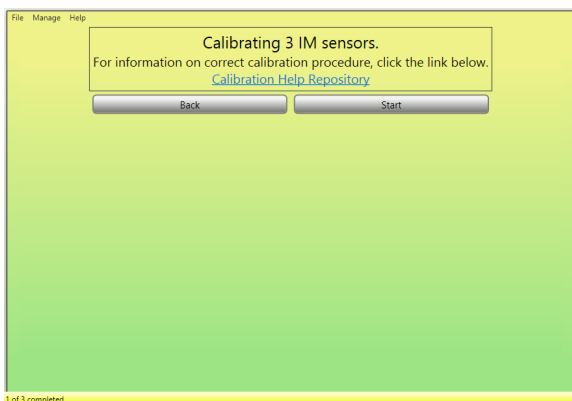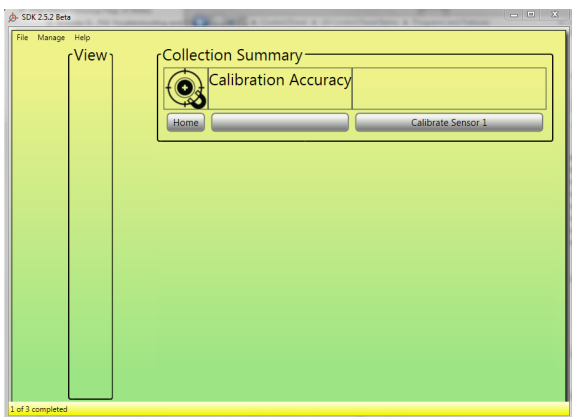
An example of a successful calibration is shown in Figure 5.

Upon completion of the calibration, you will be taken back to the summary screen and provided with the results of the collection. The percentage will be color-coded: green is good, amber is okay, and red is a bad calibration. In the case of a low scoring calibration, relevant error messages will be displayed. While a green score will represent an optimal fit, in certain environments it will be difficult to achieve. In these cases, an amber reading should be sufficient.

If unable to obtain a satisfactory calibration, one may re-calibrate by selecting the **Redo Sensor X** button. If the calibration was successful, may proceed by clicking **Calibrate Sensor 2**. Repeat this process to calibrate all paired sensors. After each calibration you will be returned to the summary screen where you can click through the results of all your magnetometer calibrations.
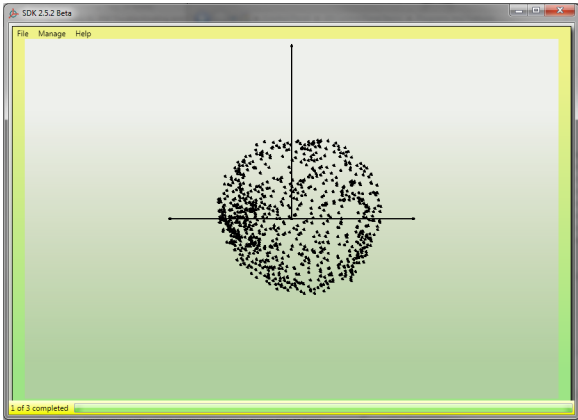
Once the task has been

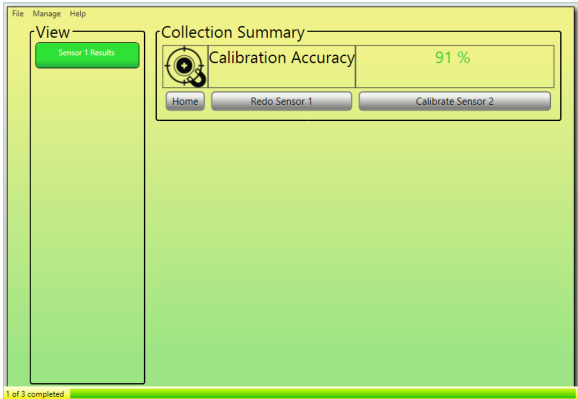**Figure 5. Example of a successful magnetometer calibration.**

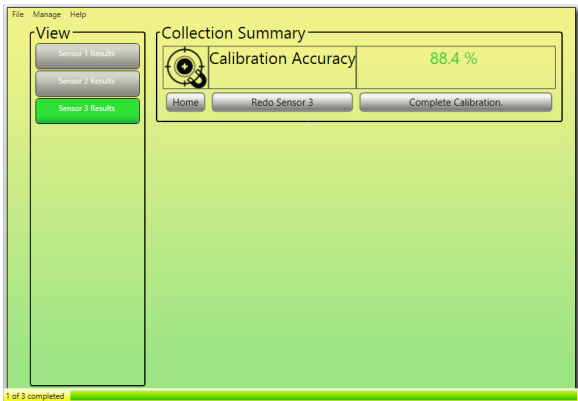
Figure 6. Calibration accuracy estimate.

Figure 7. Summary of all calibrated sensors.

completed for all sensors, return to the main screen by selecting Complete Calibration. You will be able to return to this page at any time in your session.

Accelerometer Calibration

Once back on the home screen upon completing the magnetometer calibration, make sure Accelerometer Calibration is highlighted and proceed by clicking **Calibrate** in the middle of the screen. You will then be asked to lay all Trigno IM sensors on a flat surface with silver electrodes facing down. When ready, select Start and an accelerometry plot will appear. Allow this to run in its entirety. Please note that this calibration applies to ALL sensors.

Figure 8. Running the accelerometry calibration.

You will then be brought to a screen with a Home button. Select this to proceed.

Saving the Calibration File

After returning to the home screen, save your calibration by navigating to "**File ➔ Save As…**".

This file can be loaded later to avoid unnecessarily repeating the calibration process.

> 📌 Calibration files should only be loaded if testing is being performed in the same location under similar conditions. We recommend recalibrating before the first test of each day.

Initializing Orientation Filter

The final step of the calibration procedure involves applying the calibration file to the sensors and setting up the orientation filter. To begin, make sure Initialize

Orientation Filter is selected on the home screen and click **Calibrate**. You will then be prompted to select the appropriate calibration file.

The master stream will now open and the screen will read Converged once the orientation filter has successfully initialized.
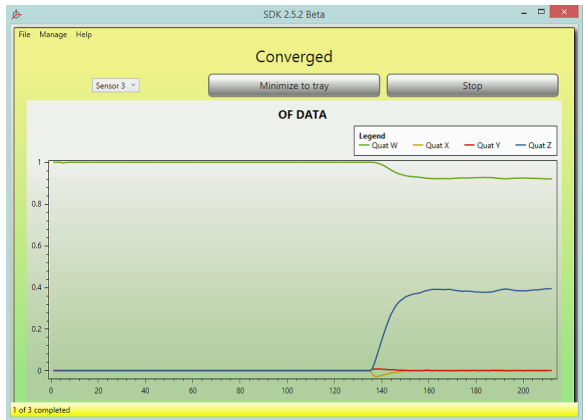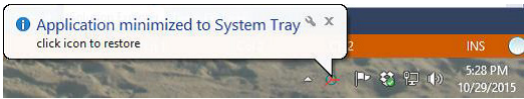

Figure 9. Filter convergence plot.

The application should remain open, as this prevents the need for re-initialization during signal acquisition. The sensors are now ready for data collection.

You should select Minimize to tray to conserve resources. The application will then appear in the Windows system tray should you need to access it afterwards.

Appendix I: Command/Query Reference Table

QUERY	DESCRIPTION	EXAMPLE	EXAMPLE REPLY
"SENSOR n TYPE?"	Returns the type of the sensor n in letter form.	"SENSOR 1 TYPE?"	"A"
"SENSOR n CHAN-NELCOUNT?"	Returns the number of active channels on sensor n	"SENSOR 1 CHAN-NELCOUNT?"	"4"
"SENSOR n MODE?"	Returns the configurable mode state of sensor n	"SENSOR 1 MODE?"	"MODE 1 (1.5g)"
"SENSOR n CHANNEL m GAIN?"	Returns the gain on channel m of sensor n	"SENSOR 1 CHAN-NEL 1 GAIN?"	"300"
"SENSOR n CHANNEL m UNITS?"	Returns the units on channel m of sensor n	"SENSOR 1 CHAN-NEL 1 UNITS?"	"Volts"
"SENSOR n FIRM-WARE?"	Returns the firmware version of sensor n	"SENSOR 1 FIRM-WARE?"	"30-06"
"SENSOR n SERIAL?"	Returns the serial number of sensor n	"SENSOR 1 SERIAL?"	"SID-1234"
"SENSOR n PAIRED?"	Returns yes or no, indicating sensor n is paired and active	"SENSOR 1 PAIRED?"	"YES"
"TRIGGER?"	Returns status of both start and stop trigger	"TRIGGER?"	"START ON STOP OFF" "START OFF STOP OFF"
"UPSAMPLING?"	Returns upsampling setting. By default upsampling is turned on and the EMG channel will be upsampled to 2000Hz for all sensors except IM.	"UPSAMPLING?"	"UPSAMPLING OFF"
"ENDIANNESS?"	Returns the currently set endianness for the streaming data. Reply indicates big endianness (data streams in big-endian format), or little endianness (data streams in little-endian format).	"ENDIANNESS?"	"LITTLE" "BIG"

QUERY	DESCRIPTION	EXAMPLE	EXAMPLE REPLY
"BASE FIRMWARE?"	Returns the firmware version of the connected Trigno Base Station	"BASE FIRMWARE?"	"Firmware: MA2902-BE1500-DS0801-US2001-DA0900"
"BASE SERIAL?"	Returns the serial number of the connected Trigno Base Station	"BASE SERIAL"	"BID: 0222"
"ORIENTATION FIL-TER?"	Returns yes or no, indicating the real time orientation filter is turned on or off.	"ORIENTATION FILTER?"	"YES"
"ORIENTATION DATA FORMAT?"	Returns the output format of the real time orientation filter. Either QUAT or PRY	"ORIENTATION DATA FORMAT?"	"QUAT" "PRY"
"ORIENTATION FILTER VERSION?"	Returns the version number of the currently installed orientation filter	"ORIENTATION FIL-TER VERSION?"	"2.5.1"
"MASTER?"	Queries whether current connection is Master	"MASTER?"	"YES"
"SLAVE"	Queries whether current connection is Slave	"SLAVE?"	"NO"

COMMAND	DESCRIPTION	EXAMPLE	EXAMPLE REPLY
"SENSOR n PAIR"	Places the requested sensor number in pair mode, allowing user to complete the pairing process by turning on a sensor and holding down the button.	"SENSOR 1 PAIR"	"PAIR INITI-ATED, PRESS AND HOLD SENSOR BUTTON TO COMPLETE PAIR" After pair is complete: "SENSOR 1 PAIR COM-PLETE"
"SENSOR n SET-MODE"	Sets the configurable mode of the currently paired sensor	"SENSOR 1 SET-MODE 2"	"Sensor 1 set to MODE 2"

COMMAND	DESCRIPTION	EXAMPLE	EXAMPLE REPLY
"TRIGGER [START/ STOP] [ON/OFF]"	Configures the triggers	"TRIGGER START ON" "TRIGGER STOP OFF"	"OK"
"UPSAMPLE [ON/ OFF]	Turns upsampling on or off for the EMG channel of all sensors except for IM sensor. By default, upsampling is turned on, and the EMG channel will be upsampled to 2000Hz.	"UPSAMPLE OFF"	
"ENDIAN [BIG/LIT- TLE]"	Sets the endianness of the streaming data.	"ENDIAN BIG" "ENDIAN LITTLE"	"OK"
"START"	Starts data collection. The SDK server will respond once communication with hard- ware is complete.	"START"	"OK"
"STOP"	Stops data collection. The SDK server will respond once communication with the hardware is com- plete.	"STOP"	"OK"
"ORIENTATION FILTER [ON/OFF]"	Turns the real time orienta- tion filter on or off	"ORIENTATION FIL- TER ON" "ORIENTATION FIL- TER OFF"	"OK"
"ORIENTATION DATA FORMAT [QUAT/ PRY]"	Sets the output format of the real time orientation filter	"ORIENTATION DATA FORMAT QUAT" "ORIENTATION DATA FORMAT PRY"	"OK"
"ORIENTATION FILTER ZERO"	Aligns sensors to a common reference frame.	"ORIENTATION FIL- TER ZERO"	"OK"
"ORIENTATION PATH 'PATH' "	Instructs the program to load a previously acquired calibra- tion file (note path in single quotes)	"ORIENTATION PATH 'C:\Users\Default\ Documents' "	"OK"
"MASTER"	Sets current connection as master, making all connec- tions slave.	"MASTER"	"NEW MAS- TER"
"QUIT"	Stops data collection and closes the server session.	"QUIT"	"BYE"

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