User Manual for TeraRanger Tower Evo

Hardware revision 1.0
Firmware revision 1.1.1

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1. Introduction

The purpose of this document is to give guidelines for use and integration of the TeraRanger Tower Evo using USB and UART communication interfaces.

2. Mechanical integration

2.1. Mechanical design

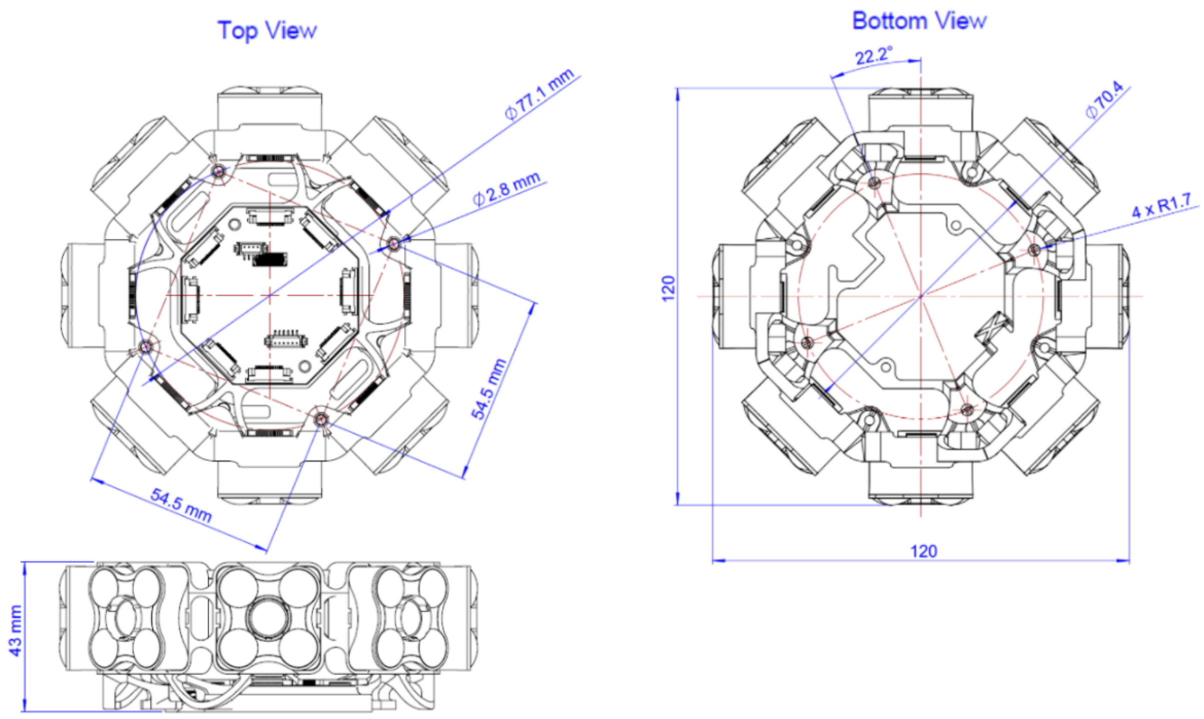


Figure 1. TeraRanger Tower Evo external dimensions

TeraRanger Tower Evo external dimensions are illustrated in Figure 1. The frame provides four mounting holes on the bottom side, all designed for M3 screws. The straight distance between mounting holes is 49.8 mm.

When choosing a place for mounting, please consider the following recommendations:

- Choose a place which is in accordance with the optical constraints listed below
- Mounting close to sources of heat or strong electromagnetic fields can decrease the sensing performance
- Do not mount anything directly in front of the sensors or in a cone of approximately +/-15° around the central optical axis of the sensor

- Within the first meter from the sensors, during operation avoid objects with high surface reflectivity in a cone of approximately +/-45° around the central optical axis of the sensor
- It is better to avoid having other sources of Continuous Wave or modulated IR light close to the sensor
- Please consider that dust, dirt and condensation can affect the sensor performance
- It is not advised to add an additional cover in front of the sensors
- Drone rotor blades, or other environments with flickering (‘chopped’) ambient light in the field of view can affect sensors’ readings

For drone use. If you are mounting the Tower Evo on a drone, please see our Pixhawk Connection Instructions document which contains important information about the orientation of the Tower.

2.2. Compatibility with TeraRanger Evo distance sensors

Kindly note that TeraRanger Tower Evo uses the Hub Evo board to provide compatibility with single point Evo distance sensors. The following table sums up Tower Evo compatibility with TeraRanger Evo distance sensors.

Name	**Visual**
TeraRanger Evo 60m	

TeraRanger Evo 60m provides longer range measurements with increased accuracy for a broader range of applications, including mapping and navigation tasks. Also, please be aware that Tower Evo is sold in versions with 4 or 8 TeraRanger Evo distance sensors.

Please note that we **do not recommend disassembly of the Evo sensors from the Tower frame** for use in configurations other than the Tower. If you wish to build custom sensor arrays, please purchase the TeraRanger Hub Evo board separately, along with suitable TeraRanger Evo distance sensors.

2.3. Electrical characteristics

DC electrical characteristics

TeraRanger Tower Evo is powered by an external power source, and can not be directly powered by USB. The following table describes the current and voltage requirements to make the TeraRanger Tower Evo work correctly. Unless otherwise specified, typical data as listed in the table below, is based on an ambient temperature value of 25°C TA = 25°C, and supply voltage of 12 V.

Please note that in rare cases (for example where the Evo sensors are pointing out to "infinity" with nothing in range) a 30 to 40 second delay in start-up can occur. No performance or functionality is affected by this, but for a faster start-up please ensure that each sensor has a target surface within its field of view.

Symbol	Ratings	Minimum	Typical	Maximum	Unit
V_{in}	External main supply voltage	12	-	24	V
V_{out}	Output voltage on LED connector	4.75	5	5.25	
$I_{Vin\ typical}$	Total current on Vin TR Tower Evo 60m, 4 sensors	170(*)	-	650(**)	mA
	Total current on Vin TR Tower Evo 60m, 8 sensors	230(*)	-	1100(**)	
	Total current on Vin TR Tower Evo 600Hz, 4 sensors	170(*)	-	480(**)	
	Total current on Vin TR Tower Evo 600Hz, 8 sensors	230(*)	-	840(**)	
I_{Vout}	Total current on Vin Visual signalization module	4	68	200	

**Maximum current consumption with eight TeraRanger Evo sensors connected and looking at long-range/low reflectivity targets or infinity in simultaneous mode. Drops significantly in sequential mode and varies with target reflectivity and distance.
* Standby values (The sensor is not actively emitting light).

Stresses above the absolute maximum ratings may cause permanent damage to the device. Exposure to maximum rating conditions for extended periods may affect product reliability.

3. USB interface

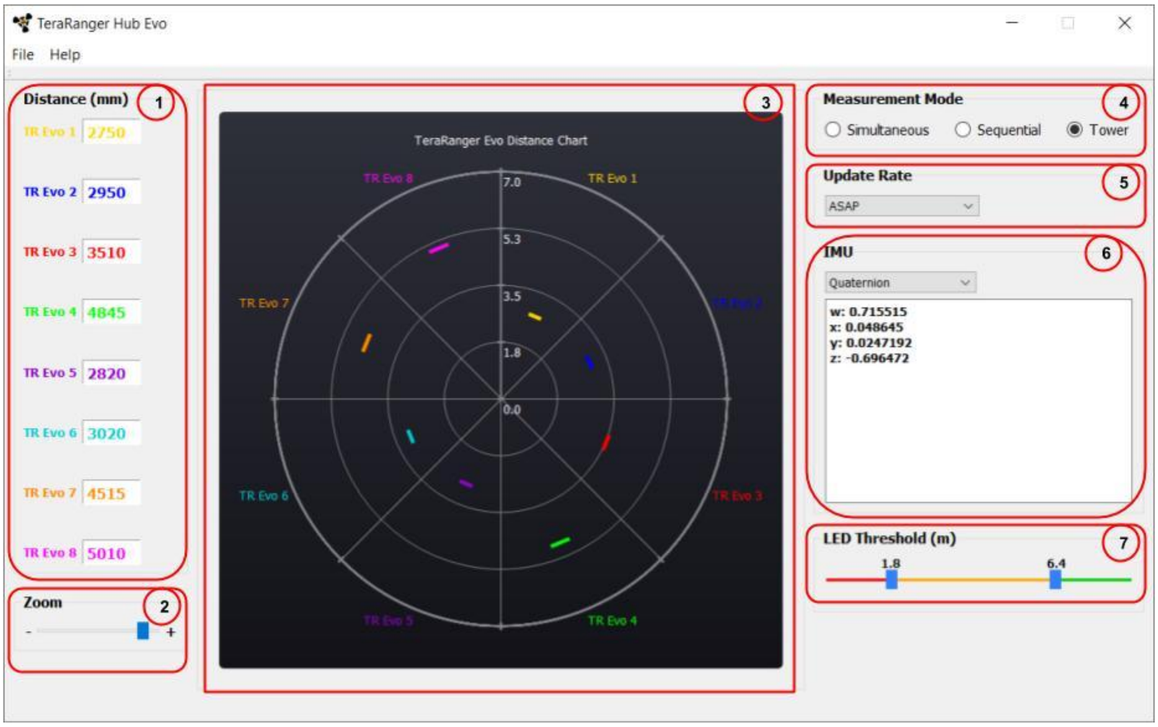
3.1. Graphical User Interface

A free graphical user interface is available for Windows, providing an easy way to visualize the data from TeraRanger Tower Evo. This is useful for demonstration, testing purposes and setting some of the basic parameters of the sensors, including operating and update rate modes. It also provides a way to easily upgrade the firmware running on the device, should it be required.

Please note that the same GUI is used for both TeraRanger Tower Evo and Hub Evo products. The GUI is available for download from the TeraRanger Tower Evo page (Downloads section) of the Terabee website. Please ensure you are using GUI version 1.0.5 or later.

3.1.1. Basic operation

Connect the TeraRanger Tower Evo to a USB port on your computer and to a suitable power supply. Select File > Connect. You should immediately see distance readings of TeraRanger Evo sensors displayed on the main chart. See example in Figure 2. The following table summarizes functionality of the graphical user interface.



Distance (mm)

TR Evo 1	2750
TR Evo 2	2950
TR Evo 3	3510
TR Evo 4	4845
TR Evo 5	2820
TR Evo 6	3020
TR Evo 7	4515
TR Evo 8	5010

Measurement Mode

○ Simultaneous ○ Sequential ● Tower

Update Rate

ASAP

IMU

Quaternion

w: 0.715515
x: 0.048645
y: 0.0247192
z: -0.696472

Figure 2. Graphical user interface

Terabee, 90 rue Henri Fabre
01630 Saint-Genis-Pouilly, France (next to CERN)

#	Display	Description
1	Measurement	Provides 4 or 8 distance values in millimeters. Sensors are numbered as per the Hub Evo board. Example: TR Evo 4 will stream distance data connected to connector Nr 4 on Hub Evo. In case “-1” value is received, no sensor is connected or not able to measure. In case “+Inf” is received, the measurement is out of range. In case “-Inf” is received, the measurement is below minimum range.
2	Zoom	Modify scale of the main chart (#3) by dragging the cursor to the left or right. The zoom range is [2.00m ; 60.0m].
3	Main chart	Provides real-time preview of distance measurements streamed from connected Evo sensors. The distance reading is visually represented on the chart by a small segment.
4	Measurement mode	Switch between, Simultaneous, Sequential and Tower mode (learn more about operating modes in section 5).
5	Update rate	Select between six options of sensor measurement update rates from a drop-down menu. Choose between Fixed (F) 50Hz, F 100Hz, F 250Hz, F 500Hz, F 600Hz or ASAP (As Soon As Possible).
6	IMU	Enable or disable the option for Inertial Measurement Unit readings. Three IMU modes are available for preview: Euler mode, Quaternion mode, Quaternion and Linear Acceleration mode.
7	LED thresholds	Adjust between three levels of visual signalization provided to discriminate three different ranges. These values can span from 0.5m to 8m with a granularity of 0.1m. Please see section 4.3 for details.

3.1.2. Firmware upgrade

The current firmware version on your TeraRanger Tower Evo can be found by selecting *Help* > *About* in the GUI. It is possible to upgrade the firmware running on your device if a new firmware version is made available by Terabee. **Only update your firmware if a new firmware version has been provided!**

Please note the Upgrade Firmware feature is only supported on Windows 7, 8 and 10. **Please follow carefully the steps outlined below to avoid permanently disabling your device.**

- Select *File* > *Upgrade Firmware*
- You will be presented with a dialog window asking you to confirm your choice **Beyond this point, if you press 'Yes' it will not be possible to revert to the firmware currently running on your TeraRanger Tower Evo!** Press 'No' to cancel and keep the current firmware or 'Yes' to continue. **Only continue if you have an updated firmware file to install!**
- Read the instructions in the dialog window that opens
- Press 'Select FW' and select the new firmware file with Windows File Explorer
- Press 'Upgrade' and wait until the operation finishes
- Close the Upgrade dialog window

3.2. Connecting the TeraRanger Tower Evo to a Host Computer

TeraRanger Tower Evo can be easily connected to a Host Computer via a micro USB cable. The TeraRanger Tower Evo can interact as a virtual COM port, and data can be streamed directly to terminal emulation software (Terabee advises using HTerm for Windows and CoolTerm for MacOS).

3.2.1. Prerequisites

For usage on Windows (7, 8) operating system, please download the Virtual COM Port driver from http://www.st.com/en/development-tools/stsw-stm32102.html and **follow the "ReadMe file" instructions given by the installer**. After successful installation, unplug the interface for a few seconds, and plug it back in. The virtual COM port should now be available on your PC. Users of Windows 10 do not need to download this driver as the built in Windows driver is recommended.

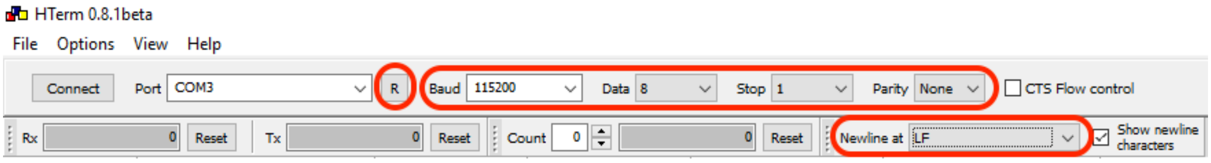
3.2.2. Terminal Emulation Software (H-Term)

In Windows you can also use any terminal emulation software of your choosing, however we suggest you use HTerm (http://www.der-hammer.info/terminal/). Extract the downloaded zip file to the folder of your choice, open it and double click on the "HTerm.exe" document.

Connect the TeraRanger Tower Evo to your computer via a micro USB cable and select the corresponding USB port (click “R” button to refresh the port list). Select values for the following fields:

- Baud rate: 115200;
- Data Bits: 8;
- Parity: None;
- Stop Bits: 1.

For easier readings, select the “LF” option for “Newline at” tab. See Figure 3 for visual instructions.



Port COM3

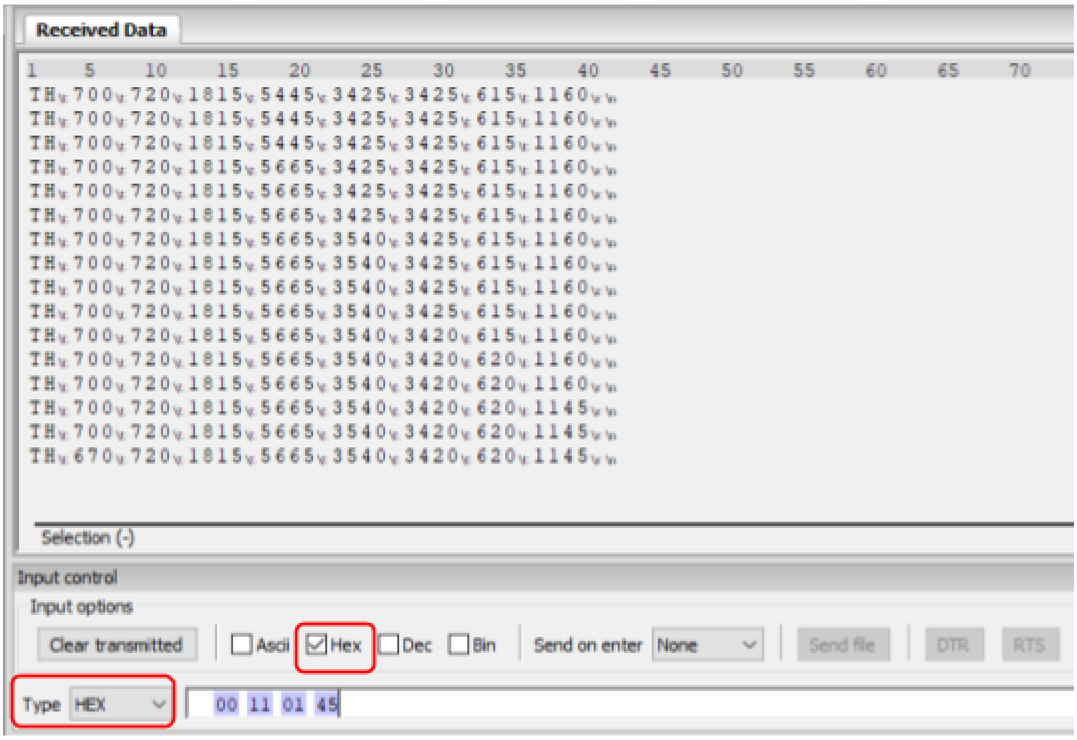
Baud 115200 Data 8 Stop 1 Parity None □ CTS Flow control

Rx 0 Tx 0 Count 0 0

Newline at LF ☑ Show newline characters

Figure 3. H-Term parameters

Once you have selected the USB port and required values, click on the “Connect” button.



```
1    5    10   15   20   25   30   35   40   45   50   55   60   65   70
TH 700 720 1815 5445 3425 3425 615 1160
TH 700 720 1815 5445 3425 3425 615 1160
TH 700 720 1815 5445 3425 3425 615 1160
TH 700 720 1815 5665 3425 3425 615 1160
TH 700 720 1815 5665 3425 3425 615 1160
TH 700 720 1815 5665 3425 3425 615 1160
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TH 700 720 1815 5665 3540 3420 620 1160
TH 700 720 1815 5665 3540 3420 620 1160
TH 700 720 1815 5665 3540 3420 620 1145
TH 700 720 1815 5665 3540 3420 620 1145
TH 670 720 1815 5665 3540 3420 620 1145
```

□ Ascii ☑ Hex □ Dec □ Bin Send on enter None

Type HEX 00 11 01 45

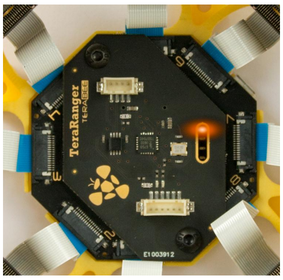
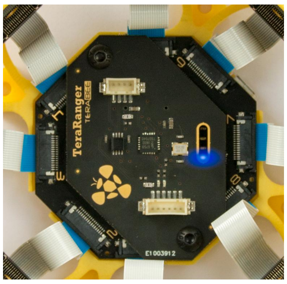
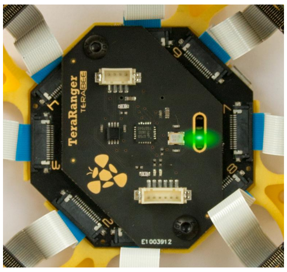
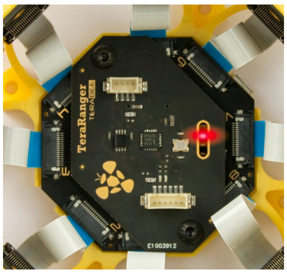
Figure 4. Distance data stream using H-Term

To communicate with the distance sensors connected to Tower Evo via the terminal emulation software, you need to send a command in hexadecimal via the “Type” box.

For this, select the “HEX” Type as illustrated in the figure above. Figure 4 shows an example of the command which allows data to be shown in TEXT mode. All commands are detailed in Section 5.

3.3. LEDs

In total, four LEDs are mounted on TeraRanger Hub Evo to give visual feedback on the sensor performance. The following table lists the functionality of each LED.

LED color	Description	Hub Evo Visual
PWR (orange)	LED continuously on whenever connected to a power supply.	
LED 0 (blue)	One blink for each TeraRanger Evo sensor detected by the Hub Evo. Example: if 8 sensors are connected, the blue LED will blink 8 times before sending distance data.	
LED 1 (green)	Continuous blinking indicates that distance values are being sent. The blink rates will be slower or faster, depending on the output rate selected. See section 5.4 for details.	
LED 2 (red)	Continuous blinking indicates an error.	

4. UART interface

4.1. Pinout information

The TeraRanger Tower Evo can be controlled through the UART interface. This is possible thanks to a "UART for Hub Evo" board - an accessory already installed on the Tower Evo (Figure 5). We strongly advise not to disassemble the Tower Evo product, including the UART for Hub Evo board, as it might result in damaging the system due to inappropriate handling.

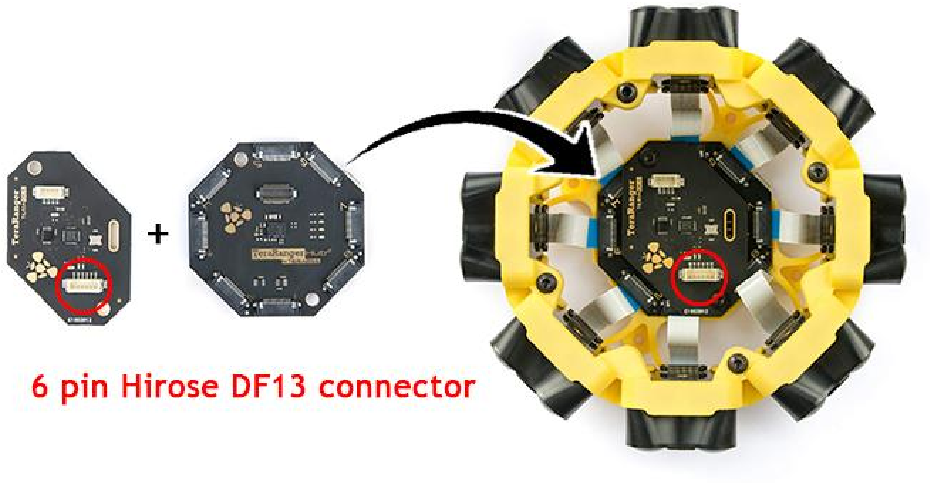


Figure 5. UART for Hub Evo board

The UART for Hub Evo board uses a single 6 pin Hirose DF13 connector for interfacing to the host system. The mating connector is a Hirose DF13-6S-1.25C with crimping contacts DF13-2630SCF (tin) or DF13-2630SCFA (gold). Please consider the mechanical stability of the mated connectors and avoid any kind of excess force on the connector (during installation and once integrated) and follow the recommendations in the Hirose DF13 series datasheet (available here: https://www.hirose.com/product/en/products/DF13) to ensure a reliable connection.

The table below provides an overview of the pin out for the DF13 connector:

Pin out and description (According to DF13 datasheet)

Pin	Designator	Description
1	NC	Not Connected
2	Rx(in)	UART receive input. 3.3V logic

3	Tx(out)	UART transmit output. 3.3V logic
4	NC	Not Connected
5	NC	Not Connected
6	GND	Interface ground

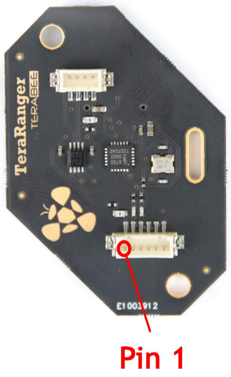


Figure 6. Pinout layout for UART

4.2. UART protocol information

The UART communication for the TeraRanger Tower Evo uses a simple Modbus-like protocol. The communication parameters are:

Baud Rate: 921600 baud
Data Bits: 8
Stop Bit(s): 1
Parity: None
HW Flow Control: None

4.3. Interface for visual signalization

Tower Evo provides an interface to control an intelligent LED light source compatible with WS2812B serial communication protocol. It allows you to drive up to four RGB LEDs through a single wire provided that the LEDs sink current is kept within the power budget indicated in the manual (see Section 2.3.).

Three levels of signalization are provided to discriminate three different ranges (set with a default value during manufacturing) as shown in the table below:

Detection	Distance	Color
No obstacle in range	Out of range	None
Obstacle detected in the range	> 4 m	Green
Obstacle detected in the range	2 m to 4 m	Orange
Close obstacle	0.5 m to 2 m	Red

New values can be programmed through the UART interface, offering the possibility of customizing the LED triggering thresholds within the valid range of the Tower. These values can span from 0.5 m to 8 m in 0.1 m increments. The upper value of the threshold range cannot be higher than the lower value of the adjacent threshold range. Overlaps between threshold ranges are checked by the Tower and, if found, the Tower responds with a ‘Nack’ (Not acknowledged) signal. Once the thresholds system is operating, if all sensors are detecting “out of range”, then all LEDs will be off. Whenever a threshold is reached by one of the sensors, the LEDs will switch to the appropriate color and stay continuously ‘on’ until a different threshold is activated.

Important Note: The LED signalization feature only provides an indicative proximity status based on the Tower Evo sensor closest to an obstacle or hazard and is provided as a useful aid rather than a guaranteed fail-safe solution. **You use this feature at your own risk.**

Below 1 meter, some target surfaces (transparent or with low light reflectivity) can potentially introduce false readings which could mean that the LED signalization is not based on the closest sensor to an obstacle. However, this will only affect the LED signalization and not the distance sensing capability.

Connector type and name:

Pin	Designator	Description
1	5 V	+5 V supply output
2	RFU	Do not connect, reserved for future use
3	DOUT	Control data output to drive four WS2812B Leds
4	GND	Power supply and interface ground

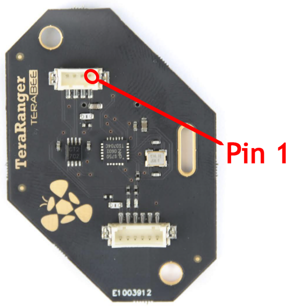


Figure 7. WS2812B serial communication, pinout layout

5. Communication and modes

The current Tower Evo firmware (1.1.1) provides four parameters for optimization of Tower Evo performance. The following parameters can be configured:

1. Printout modes
2. Operating modes
3. Update rate modes
4. IMU modes

Figure 8 illustrates the logic of available parameters on Tower Evo. Please note all commands to be sent via terminal emulation software are in hexadecimal format.

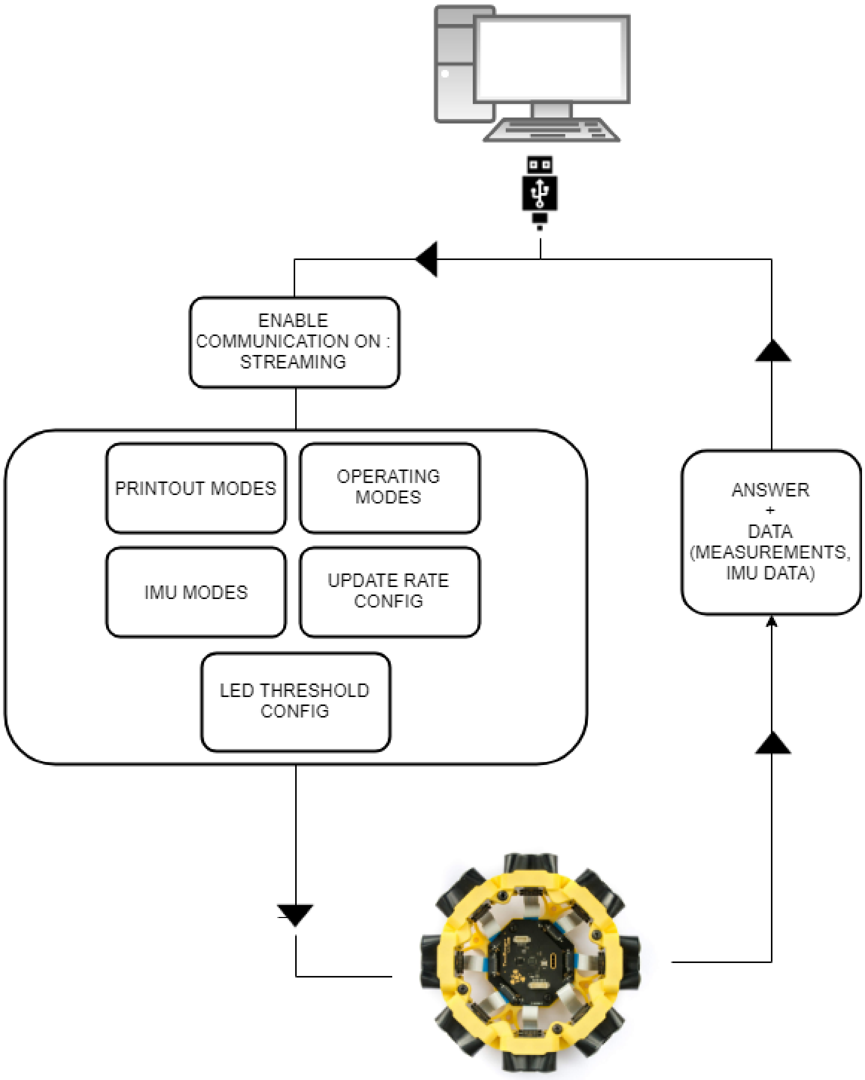


Figure 8. TeraRanger Tower Evo modes

For each command sent, a response is generated to inform the user whether the command has been validated. Command responses consist of four bytes and is a hexadecimal value. Please note that it is crucial to receive an answer to a command, before communicating the next one. For more information on response values, please see Section 5.6.

5.1. Enable / Disable Tower Evo communication

In order to enable communication with Tower Evo and send commands to modify system performance, first please make sure streaming is enabled.

5.1.1. Commands

Action Type	Mode name	Hex Command
Enable/disable communication	Activate streaming	**00 52 02 01 DF**
	Deactivate streaming	**00 52 02 00 D8**

5.2. Printout modes

The current Hub Evo firmware supports two display modes, available via terminal emulation software: (1) Text and (2) Binary.

5.2.1. Commands

Action Type	Mode name	Hex Command
Modify printout mode	TEXT (only available via USB)	**00 11 01 45**
	BINARY (default)	**00 11 02 4C**

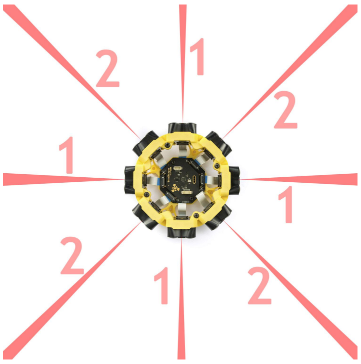
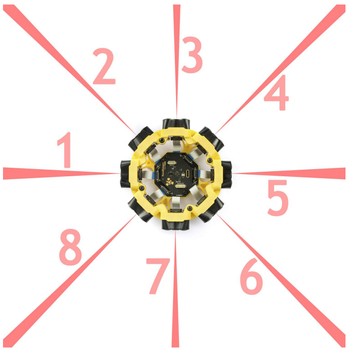
5.2.2. Output format

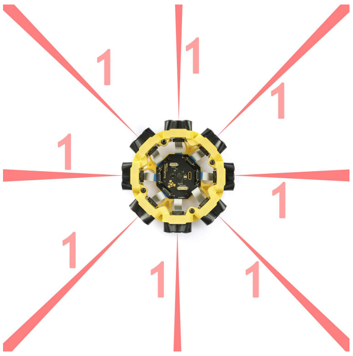
Text mode	Data output: TH\txxxx\txxxx\txxxx\txxxx\txxxx\txxxx\txxxx\txxxx\r\n - Header (two characters): T (84 decimal / 0x54 hex) and H (72 decimal / 0x48 hex) - Tabulation: \t (9 decimal / 0x09 hex) - Distance reading in millimeters** (maximum 5 bytes per sensor): xxxx - Carriage return character: \r (13 decimal / 0x0D hex) - New line character: \n (10 decimal / 0x0A hex) **if a sensor is not connected or the TeraRanger Hub Evo is unable to obtain the distance measurement from the TeraRanger Evo sensor, the associated distance value is replaced by the hexadecimal value "-1". If the target is too close to the TeraRanger Evo sensor (below the minimum distance), the associated distance value is replaced by "-Inf". If the target is too far from the TeraRanger Evo sensor (above the maximum distance), the associated distance value is replaced by "+Inf".
Binary mode	Data output (20 bytes message): TH XXXXXXXXXXXXXXXX M CRC8 - Header (two characters): T (84 decimal / 0x54 hex) and H (72 decimal / 0x48 hex) - Distance reading in millimeters** (2 bytes per sensor): XX - Mask (1 byte) Each bit of this byte correspond to one sensor connected to the hub.It gives an indication if the distance corresponding to the sensor is new (bit at 1) or old (bit at 0):M - Checksum (1 byte) of previous 19 bytes: CRC8 **if a sensor is not connected or the TeraRanger Hub Evo is unable to obtain the distance measurement from the TeraRanger Evo sensor, the associated distance value is replaced by the hexadecimal value 0x0001.

	If the target is too close to the TeraRanger Evo sensor (below the minimum distance), the associated distance value is replaced by the hexadecimal value 0x0000. If the target is too far from the TeraRanger Evo sensor (above the maximum distance), the associated distance value is replaced by the hexadecimal value 0xFFFF.

5.3. Operating modes

The current Tower Evo firmware provides three operating modes: **(1) Simultaneous mode, (2) Sequential mode and (3) Tower mode**. The following table provides a description of the functionality for each.

Operating mode	**Description**	**Visual illustration**
Tower mode	Enables crosstalk avoidance between sensors. Especially well suited for the circular configuration of Tower Evo. In Tower mode sensors connected to Hub Evo simultaneously measure distances from 4 sensors with a 90 degree angle between each. When Tower Evo, 4 sensors is used the highest possible update rates are achieved.	
Sequential mode (default)	Ensures that sensors connected to Hub Evo are synchronized in a sequential manner (1-2-3-4-5-6-7-8), receiving a single distance measurement at a time. This helps to avoid any cross-talk between sensors. Sequential mode provides more freedom for the physical placement of sensors but can result in a decrease in overall measurement repetition rates.	

Simultaneous mode	Supports simultaneous sensor operation, enabling the highest possible sampling rates. Please note that using Tower Evo with 8 distance sensors in simultaneous mode can result in sensor crosstalk. When using a Tower Evo with 4 sensors and a 90 degree angle between each, crosstalk is highly unlikely to occur.cross-talk.	

5.3.1. Commands

Action Type	Mode name	Hex Command
Modify operating modes	Tower mode	**00 31 03 E5**
	Sequential mode (default)	**00 31 02 E2**
	Simultaneous mode	**00 31 01 EB**

IMPORTANT: Sequential mode is set as the default mode. When powering and connecting Tower Evo to a host computer for the first time, please activate Tower mode by sending a corresponding command (00 31 03 E5) via terminal emulation software.

Tower Evo firmware saves the last operating mode used and auto-selects that mode the next time the system is powered up. Therefore there is no need to change the operating mode, until a different mode is required.

5.4. Output-rate modes

Tower Evo provides the option to modify the measurement sampling rates of the connected sensors. Users can select between six output-rate modes. ASAP, meaning 'as soon as possible' is, by definition, a variable rate and is dependent on how quickly the Hub receives an update from the last sensor in the chain. The other rates are fixed at 50Hz, 100Hz, 250Hz, 500Hz, 600Hz.

The output rates can be selected using the following Hex commands:

5.4.1. Commands

Action Type	Update rate	Hex Command
Modify update rate	ASAP (default)	**00 52 03 01 CA**
	50 Hz	**00 52 03 02 C3**
	100 Hz	**00 52 03 03 C4**
	250 Hz	**00 52 03 04 D1**
	500 Hz	**00 52 03 05 D6**
	600 Hz	**00 52 03 06 DF**

5.5. Visual signalization

The Tower Evo is shipped with default pre-programed thresholds, but you can set your own by using the command below:

Action Type	Hex Command
Set visual signalization threshold	**00 53 01 UU LL CRC8**

The command is a six byte command. UU is the byte that represents the upper threshold in decimeter and LL the lower one. The range of the threshold is 5 to 80 decimeter and the value of the upper one should not be less than the value of the lower one. The CRC need to be calculated using the five first bytes of the command.

5.6. Internal Measurement Unit (IMU) options

TeraRanger Hub Evo provides an onboard IMU, supporting users with spatial orientation data. By default the IMU is disabled. Three modes are available:

1. Euler mode
2. Quaternion mode
3. Quaternion and Linear Acceleration mode

Magnetic fields and vibration can disrupt IMU calibration. In order to force a self-calibration of the IMU, move the TeraRanger Hub Evo in ways that use the full range of each axis.

Here is a non-exhaustive list of motions that help with calibration:

1. For magnetometer and gyroscope: (1) draw a figure of eight into the air, (2) make a full turn in the two directions of each axis (6 rotations in total)
2. For accelerometer: Hold the Hub Evo for a few seconds in each of the following positions; left side, right side, front side, back side, up side, down side

For further explanation about the IMU orientation calibration, please refer to the following link: https://www.youtube.com/watch?v=Bw0WuAyGsnY

5.6.1. Euler mode

Euler mode provides three classic Euler angles: heading (aka yaw), roll and pitch. Please see Figure 9 for heading, roll and pitch directions on your Hub Evo.

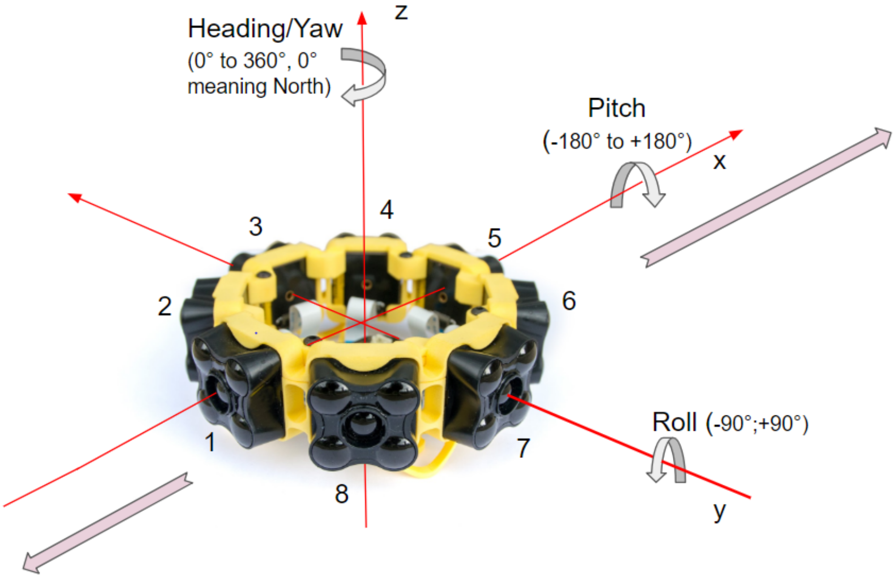


Figure 9. Roll, pitch, heading (aka yaw)

When enabling Euler mode, the displayed values are in degrees. Please see below the corresponding scaling for each of the axes:

1. Heading angle (around Z axis) goes from 0° to 360°, 0° meaning North
2. Pitch rotates from -180° to +180° around x axis
3. Roll values are in the interval [-90°;+90° around y axis] and will loop twice

Please note that 0° for pitch and roll angle means that the TeraRanger Tower Evo is horizontal.

5.6.2. Quaternion mode

To deal with matrix rotation in space, the quaternion approach simplifies the heavy math related to trigonometry and reduces the processing power requirements and optimizes the speed of operations. The Hub Evo can provide this kind of information through internal pre-processing and data fusion. For further explanation about the quaternion and the spatial rotation matrix, please refer to the following link:

https://en.wikipedia.org/wiki/Rotation_matrix#Quaternion

5.6.3. Quaternions and linear acceleration

Quaternions and linear acceleration mode displays the same coefficient as the quaternion mode, however it also gives the linear acceleration of the IMU in milli-g. Please refer to Figure 9.

- x acceleration refers to the x axis
- y acceleration refers to the y axis
- z acceleration refers to the z axis

Note: To convert those values to m.s-2 the conversion factor is **0.00980665**

It is important to know that there might be a constant offset (this can be visualized when the TeraRanger Hub Evo is not moving) on the acceleration values, that can be corrected by calibrating the IMU (see Section 5.6.).

5.6.4. Commands

Action Type	Mode name	Hex Command
Modify IMU mode	Activate Quaternion mode	**00 41 02 40**
	Activate Euler mode	**00 41 03 47**
	Activate Quaternion & Linear acceleration mode	**00 41 04 52**
	Deactivate IMU (default)	**00 41 01 49**

5.6.5. Output format

Printout mode	IMU mode	Description
Binary	Quaternion	Data output (12 bytes message): IM 0x01 WW XX YY ZZ CRC8 - Header (two characters): I (73 decimal / 0x49 hex) and M (77 decimal / 0x4D hex) - Mode (1 byte) This byte indicate in which IMU mode you are. For quaternion this byte is equal to 0x01 - Orientation data in quaternion format (2 bytes per coordinate), each two bytes represent a signed 16 bit value. You need to divide those four values by 2^14. - Checksum (1 byte) of previous 11 bytes: CRC8
	Euler	Data output (10 bytes message): IM 0x02 HH RR PP CRC8 - Header (two characters): I (73 decimal / 0x49 hex) and M (77 decimal / 0x4D hex) - Mode (1 byte) This byte indicate in which IMU mode you are. For euler this byte is equal to 0x02 - Euler angles (2 bytes per angle), each two bytes represent a signed 16 bit value. You need to divide those three values by 16 to convert them in degree. - Checksum (1 byte) of previous 9 bytes: CRC8
	Quaternion and Linear acceleration	Data output (18 bytes message): IM 0x03 WW XX YY ZZ XX YY ZZ CRC8 - Header (two characters): I (73 decimal / 0x49 hex) and M (77 decimal / 0x4D hex) - Mode (1 byte) This byte indicates in which IMU mode you are. For quaternion and linear acceleration this byte is equal to 0x03

		- Orientation data in quaternion format (2 bytes per coordinate), each two bytes represent a signed 16 bit value. You need to divide those four values by 2^14. - Linear acceleration (2 bytes per axis), each two bytes represent a signed 16 bit value. Those value are expressed in mg. - Checksum (1 byte) of previous 17 bytes: CRC8

Printout mode	IMU mode	Description
Text	**Euler**	Data output: IM\t hhh\trrr\tppp\r\n - Header (two characters): I (73 decimal / 0x49 hex) and M (77 decimal / 0x4D hex) - Tabulation: \t (9 decimal / 0x09 hex) - Euler angles. You need to divide those three values by 16 to convert them in degree. - Carriage return character: \r (13 decimal / 0x0D hex) - New line character: \n (10 decimal / 0x0A hex)
	Quaternion	Data output: IM\t www\txxx\tyyy\tzzz\r\n - Header (two characters): I (73 decimal / 0x49 hex) and M (77 decimal / 0x4D hex) - Tabulation: \t (9 decimal / 0x09 hex) - Orientation data in quaternion format.You need to divide those four values by 2^14. - Carriage return character: \r (13 decimal / 0x0D hex) - New line character: \n (10 decimal / 0x0A hex)

	Quaternion and Linear acceleration	Data output: IM\t www\txxx\tyyy\tzzz\txxx\tyyy\tzzz\r\n - Header (two characters): I (73 decimal / 0x49 hex) and M (77 decimal / 0x4D hex) - Tabulation: \t (9 decimal / 0x09 hex) - Orientation data in quaternion format.You need to divide those four values by 2^14. - Linear acceleration. Those value are expressed in mg. - Carriage return character: \r (13 decimal / 0x0D hex) - New line character: \n (10 decimal / 0x0A hex)

5.7. Command validation

For each command sent, a response is generated to inform the user whether the command has been validated. It is important to receive a response value before proceeding with the next command. Sending commands too early may discard the one still processing. Response commands consist of four bytes and are a hexadecimal value. They contain (in order):

- a header (0x30)
- the CMD code which corresponds to the first four most significant bits of the second byte of the send command (for example for the command 0x00110145 it will be 0x01)
- an ACK (0x00) or a NACK (0xFF)
- a CRC-8 checksum of the message contents

Example:

Hex Command: **00 11 01 45**
Hex Answer: **30 01 00 F4**

To calculate the CRC-8 checksum byte, we advise you to use an online CRC-8 calculator. Here is one: http://www.sunshine2k.de/coding/javascript/crc/crc_js.html

The following table sums-up the expected responses to all the commands described in the document.

Action Type	Valid responses
Enable/disable communication	**30 05 00 A0**
Modify printout mode	**30 01 00 F4**
Modify operating modes	**30 03 00 DE**
Modify update rate	**30 05 00 A0**
Modify IMU mode	**30 04 00 B5**
Modify LED threshold	**30 05 00 A0**