TeraRanger Evo 64px

by TERABEE

User Manual for TeraRanger Evo 64px with: USB and UART backboard

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1 Introduction

The purpose of this document is to give guidelines for use and integration of the TeraRanger Evo 64px multi-pixel sensor with (a) UART backboard, and/or (b) USB backboard using these standard communication interfaces.

1.1 About TeraRanger Evo 64px

TeraRanger Evo64px is the multi-pixel Time-of-Flight sensor of the TeraRanger Evo product family. It provides a matrix of 8x8 distance readings over a 15 degrees FOV, with a maximum range up to 5m. The sensor offers two operating modes: select “Fast” mode with sampling rates as high as 130 frames per second or choose “Close-range” mode for improved minimum range, with measurements starting from 10 centimeters. Evo 64px delivers depth data in a compact form-factor, weighing as little as 12 grams. The sensor uses infrared LED technology, meaning it is fully eye-safe and also operates in low light or dark conditions without the need for external illumination.

2 Mechanical integration

The mechanical design of the main sensor module (black) allows easy assembly to its backboard (yellow) using a simple ‘clip-in’ technique. (When you clip the two together, ensure there is no visible gap between the black and yellow parts.) The yellow backboard has two mounting holes for final installation.

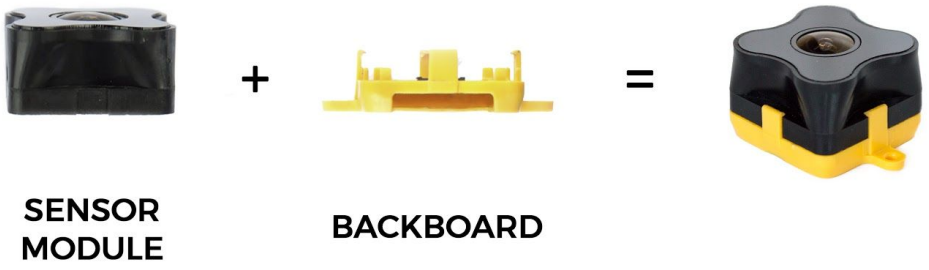

Figure 1. TeraRanger Evo two-part design

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 sensor or in a cone of approximately ±15° around the central optical axis of the sensor
- Within the first meter from the sensor, avoid objects with high surface reflectivity in a cone of approximately ±45° around the central optical axis of the sensor

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- It is advisable 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's performance
- It is not advised to add an additional cover in front of the sensor
- Drone rotor blades, or other environments with flickering ('chopped') ambient light in the field of view can affect the sensor's readings

2.1 Mechanical design

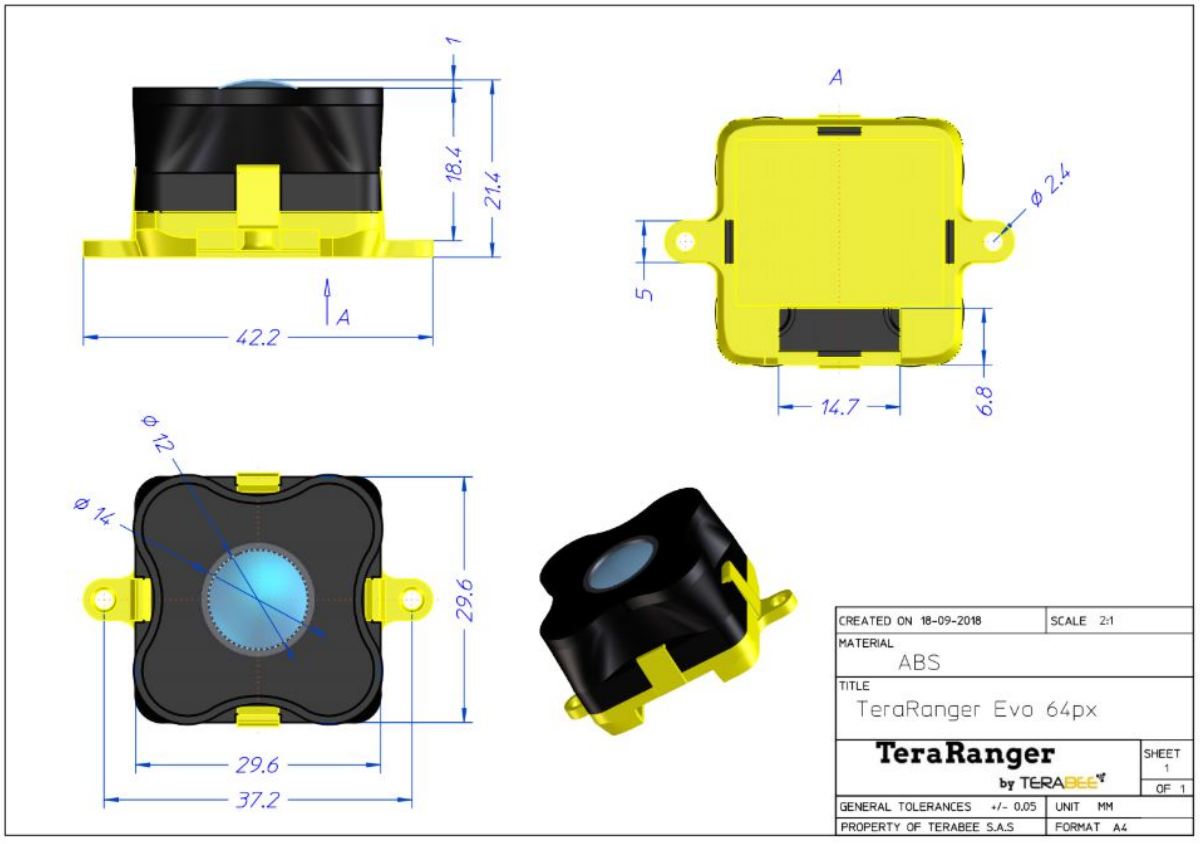

Figure 2. TeraRanger Evo 64px external dimensions

2.2 Sensor handling during system assembly

During assembly and integration, please observe all common ESD precautions. All optical surfaces (sensor front) should be kept clean and free from contact with chemicals.

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3 USB backboard use

The USB backboard comes with a standard Micro-USB connector.

3.1 Graphical User Interface

A free Graphical User Interface (GUI) is available, providing an easy way to visualize the data from your TeraRanger Evo 64px sensor. This is useful for demonstration, testing purposes and checking some of the basic parameters of the sensor. It also provides a way to easily export raw distance data and upgrade the firmware running on the device.

The GUI is available for download here: GUI Download. (See “Download” section of the TeraRanger Evo 64px product page).

3.1.1 Prerequisites

For usage on Windows 7 and Windows 8, 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.

3.1.2 Basic Operation

During installation of the GUI, you might receive a notification from Windows about an unknown application trying to start (Figure 3). In the “Windows protected your PC” screen select **More info > Run anyway** to proceed with Evo 64px GUI installation and please be advised that running this application will not put your PC at risk.

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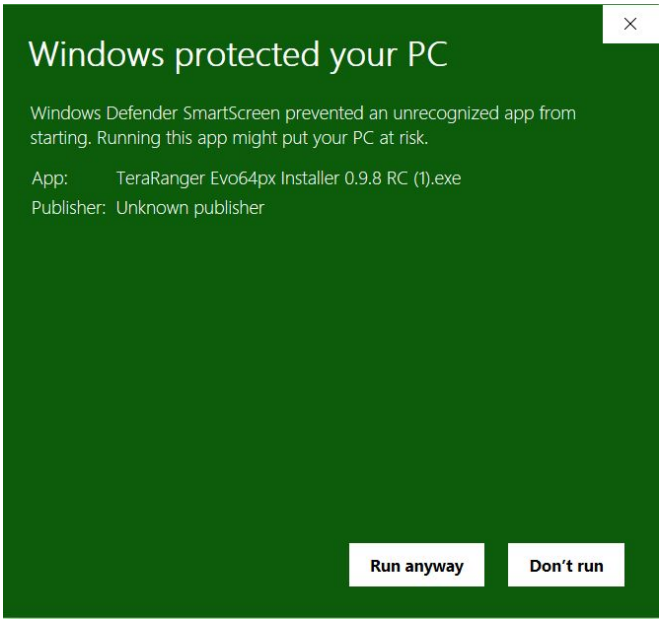

Figure 3. Windows protection screen during installation

After successful installation, make sure your TeraRanger Evo 64px is connected to a USB port on your computer. In the GUI select **File > Connect (Ctrl+O)**. You will immediately see 64 distance readings displayed in a 8x8 pixel color map, labeled Depth Map (Figure 4).

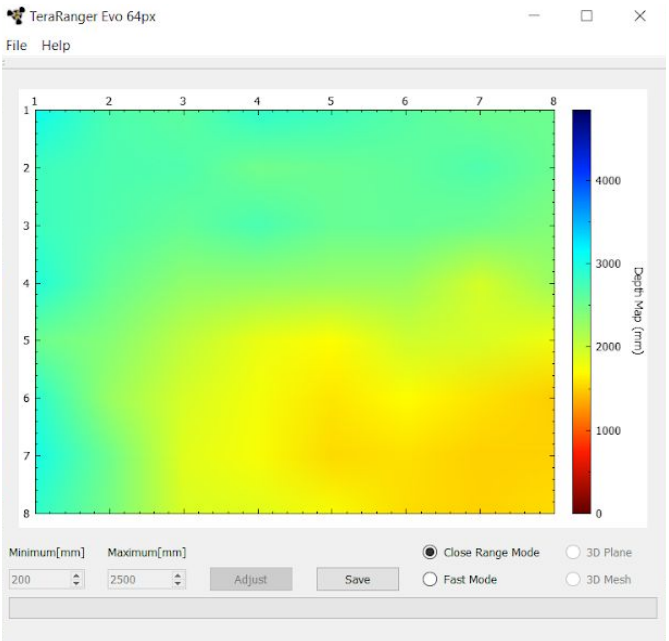

Figure 4. Graphical user interface: home screen

On the right side of the depth map you will find a color vs distance (millimeters) scale. By default the scale will automatically adjust the color code depending on the highest range detected at time of data capture and remain until a higher distance is reached. The scale will not automatically downscale in the event when the maximum distance in the pixel field reduces. In order to reset it, select **File > Reset Bounds**.

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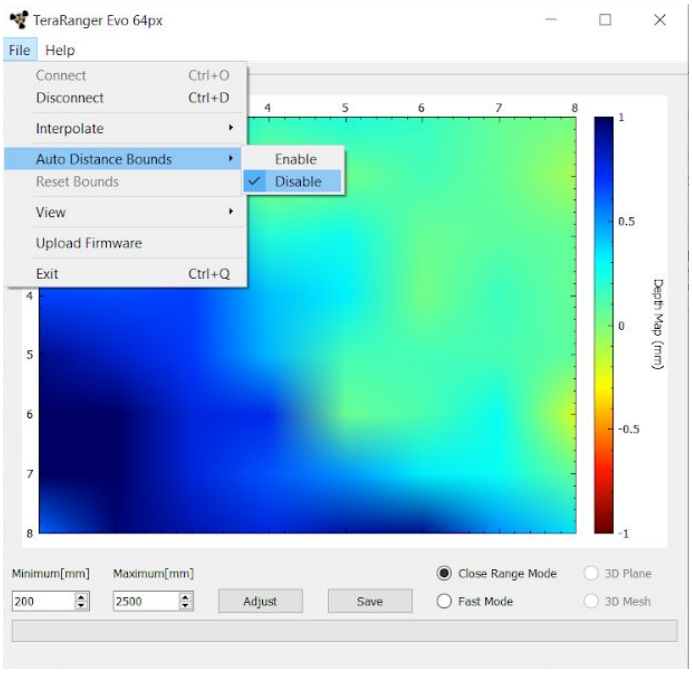

Figure 5. Auto vs manual distance bounds

To set custom distance bounds, in the GUI select **File > Auto Distance Bounds > Disable** (Figure 5). You should now be able to input minimum and maximum bounds in millimeters in the fields on the bottom left side of the screen. Select "**Adjust**" to apply changes, and your color map will adjust according to the set values.

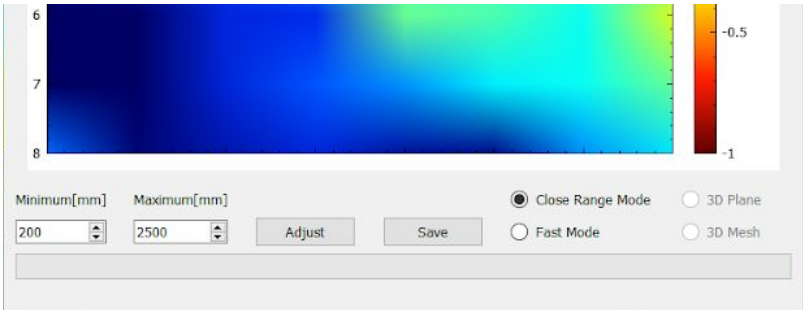

Figure 6. Fast vs Close Range mode

On the main interface, select between **Fast mode** and **Close Range mode** (Figure 6). Use "Fast" mode and achieve sampling rates as high as 130 frames per second, or select "Close Range" mode for improved minimum range, starting from 10 centimeters. For more information on the TeraRanger Evo 64px's operating modes please refer to the TeraRanger Evo 64px specification sheet.

By default, the 64 distance readings visualized on the depth map are interpolated. To disable interpolation of pixels and display values in discrete mode, select **File > Interpolate > Disable** (Figure 7).

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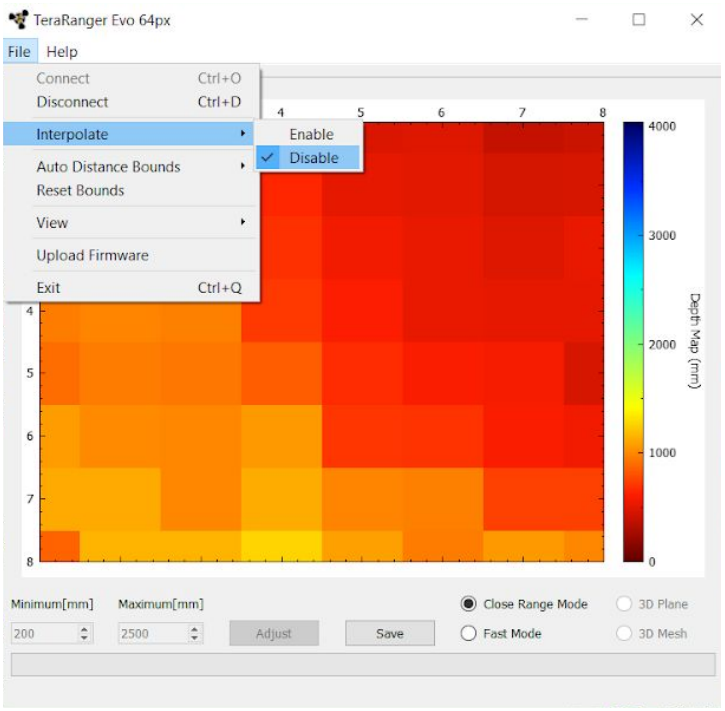

Figure 7. Interpolate vs discrete mode

The GUI also offers the option to display the distance data in a 3 dimensional map representation. Select **File > View > 3D Plot**, and a new window will now open with the 64 pixels represented in a 3D model. Choose to demonstrate the 3D model in a **Plane or Mesh view** (Figure 8), both options can be selected at the bottom of the main GUI screen.

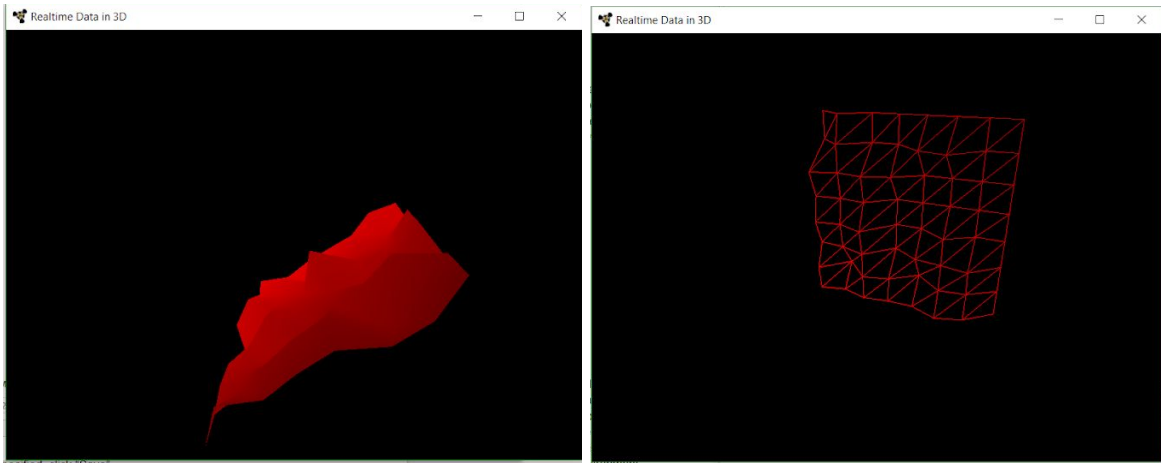

Figure 8. View data in a 3D plot: Plain vs Mesh view

Select **File > View > Pixel Data** and stream a matrix of 8x8 distance values in millimeters in real-time. The “Pixel Data” option also streams 64 values of ambient level in real-time, which is proportional to the target irradiance centered around 940nm. See Figure 9 for visual instructions.

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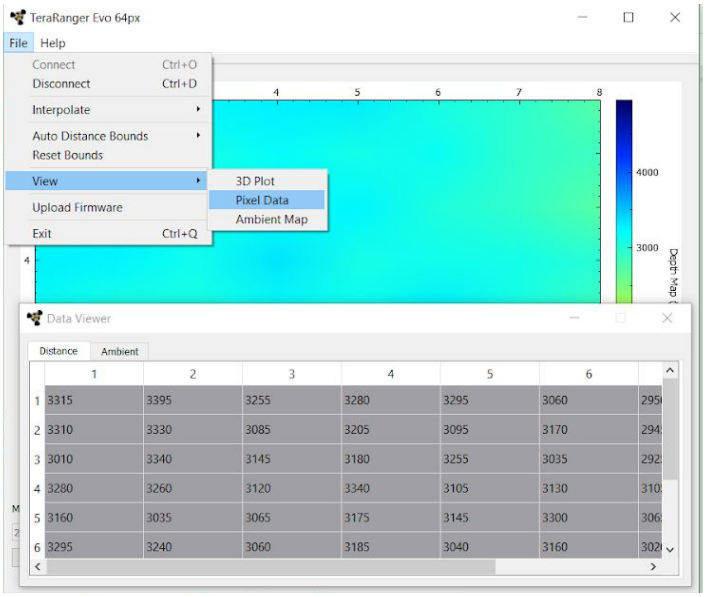

Figure 9. Stream raw distance and ambient values in real-time

You can also choose to visualize the ambient values in an 8x8 pixel grayscale map by selecting **File > View > Ambient map**. This can be useful in detecting other near-infrared sources in your environment.

You can also export raw distance and ambient data in a text-format file, by selecting "**Save**" on the main screen of the GUI. Next, you'll be asked to save the text file in a location of your preference. Afterwards a dialog window will appear offering to specify exact amount of frames to be exported. Please note that one frame equals 64 distance values and 64 ambient values. Once this is specified, click "**Save**" and your text file will be exported. See Figure 10 for visual instructions.

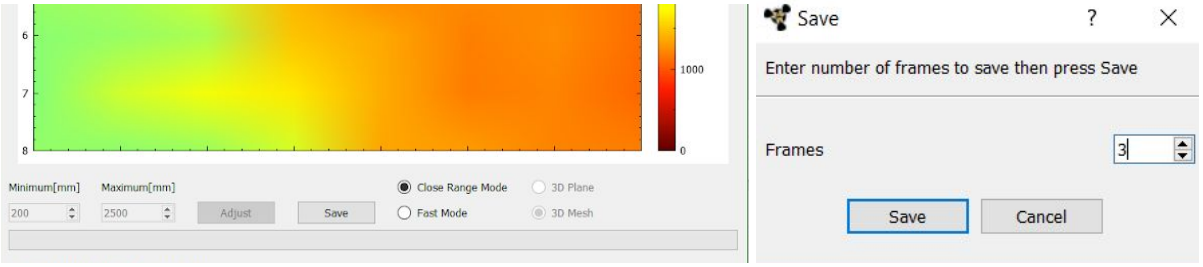

Figure 10. Export raw distance data

Figure 11 illustrates a text file of exported data with 3 frames. The first value in the row always indicates the sequential number of the frame, followed by a header; 17 for distance readings and 19 for ambient values. In the example above, the first row shows 64 distance values in millimeters and the second row shows 64 values on near-infrared ambient; both rows are part of frame number 1.

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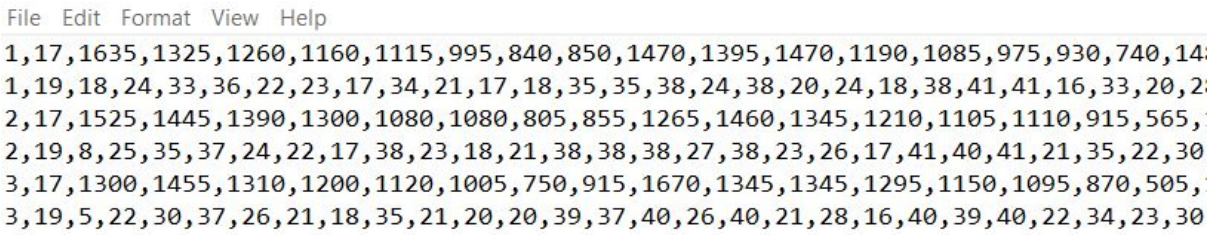


Figure 11. Text file of raw data exported from GUI

Once you are done with testing the sensor, in the GUI select **File > Disconnect (Ctrl+D)**, the GUI will terminate its VCP connection with the sensor.

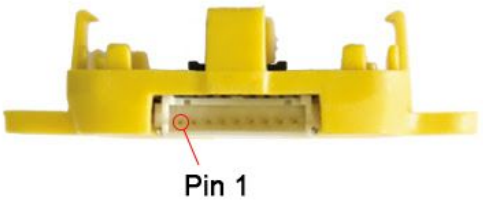
3.1.3 Firmware Upgrade

It is possible to upgrade the firmware running on your device if a new firmware version is made available on the Terabee website. The current firmware version on your TeraRanger Evo can be found by selecting *Help* > *About* in the graphical user interface.

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

- Install the latest version of the TeraRanger Evo GUI on your computer available on the “Download” section of Evo 64px product page of Terabee website.
- Download the latest firmware file from the Terabee website
- In the GUI Select **File > Connect** and then **File > Upgrade Firmware**
- You will be presented with a dialog window asking you to confirm your choice
- After confirming your choice, a new dialog window will present you with instructions on selecting the firmware file and launching the upgrade process, read the instructions carefully.
- Press **Select File** and select the new firmware file with Windows File Explorer
- Press **Upgrade** and wait until the operation finishes
- Close the Upgrade dialog box

4 UART backboard use



4.1 UART interface

The TeraRanger Evo 64px can be controlled through UART interface. It uses a single 9 pin Hirose DF13 connector for interfacing to the host system. The mating connector is a Hirose DF13-9S-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 of the DF13 connector:

Pin out and description (According to DF13 datasheet)

Pin	Designator	Description
1	Tx	UART transmit output. 3.3V logic
2	Rx	UART receive input. 3.3V logic
3	GND	Power supply and interface ground
4	rfu	RESERVED FOR FUTURE USE
5	rfu	RESERVED FOR FUTURE USE
6	rfu	RESERVED FOR FUTURE USE
7	5V	+5V supply input
8	GND	Power supply and interface ground
9	rfu	RESERVED FOR FUTURE USE

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4.2 Backboard LEDs

Five LEDs are mounted to give visual feedback on the sensor. Table below lists the functionality of each LED:

LED	**Description**
PWR (orange)	Power indicator, on when 5V connected
Rx/Tx (red/green)	UART receive and transmit indicators
LED 0 / LED 1	For internal use only

4.3 Electrical characteristics

DC electrical characteristics

	Parameter	***Minimum***	***Standard***	***Maximum***
Power supply	Voltage input	4.75 V	5V	5.25 V
	Current consumption(*)	80 mA	-	250 mA
Interface logic levels (referenced to +3V3)	LOW HIGH	- 2.3		1 -

* Values recorded while reading a target at 2m distance. NB: this value depends on ambient conditions, distance and target reflectivity

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5 Communication

5.1 UART protocol information

The UART communication for the TeraRanger Evo 64px uses a simple protocol via UART depending on the backboard used with the sensor.

The communication parameters for UART are:

Baud Rate: 3000000
Data Bits: 8
Stop Bit(s): 1
Parity: None
HW Flow Control: None

5.2 USB protocol information

The USB communication for the TeraRanger Evo 64px uses a simple protocol via USB depending on the backboard used with the sensor.The communication parameters for the USB VCP are:

Baud Rate: 115200
Data Bits: 8
Stop Bit(s): 1
Parity: None
HW Flow Control: None

5.3 Commands

The user can send commands to configure the sensor to work in a specific mode. The frame of the command is built concatenating 8 bit address of the TeraRanger Evo 64px, 4 bit Command (CMD) code, 4 bit for data count (indicating how many bytes of data will follow), N bytes of the data itself and a CRC-8 (8 bit) checksum of the entire frame in the last byte. The layout is depicted in Figure 12.

Figure 12. Frame structure for Evo 64px commands

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The table below lists the commands, including address and CRC-8, that can be sent to the sensor:

Command Name	Command Description	Command
Distance Print	The sensor outputs 64 distance values	0x00 11 02 4C
Distance Ambient Print (Default)	The sensor outputs 64 distance values and 64 ambient values	0x00 11 03 4B
Close Range Mode (Default)	The sensor takes 2 subsequent frames at different light modulation frequencies and builds the final image by picking the best pixels of the 2 frames. This provides distance readings starting from 0.1 to 5m at a reduced sampling rate.	0x00 21 01 BC
Fast Mode	If performance is driven by the reading speed, the sensor can be set to work in this mode. In Fast mode, obtain distance values from 0.5 to 5m.	0x00 21 02 B5
Deactivate VCP Output	Deactivate USB VCP Output	0x00 52 02 00 D8
Activate VCP Output	Activate USB VCP Output	0x00 52 02 01 DF

NB: ***Each command MUST be transmitted in a continuous stream ie. not byte by byte.***

The TeraRanger Evo 64px will reply to the above commands with a four byte response. The third byte of the response will contain either an ACK (0x00) or a NACK (0xFF) to indicate if the sensor has acknowledged or not acknowledged the command. In the case of the UART interface, the sensor will tolerate moderate buffer overruns but it is advisable to always wait for a command reply before sending a new command.

5.4 UART / USB output format

The TeraRanger Evo 64px by default outputs **Distance and Ambient data**. When connected via UART, the sensor will immediately start outputting data on startup. **However when connected via USB, it is necessary to send the ACTIVATE USB OUTPUT command as shown in commands table in section 5.3.**

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Depending on the mode, each frame will output one or more data packets with each packet identified by a header, for example in Distance & Ambient mode, the sensor will output two frames containing 64 distance values and 64 ambient values followed by a CRC32 to secure the data integrity on the transmission. The output format structure in Distance mode is depicted in Figure 13.

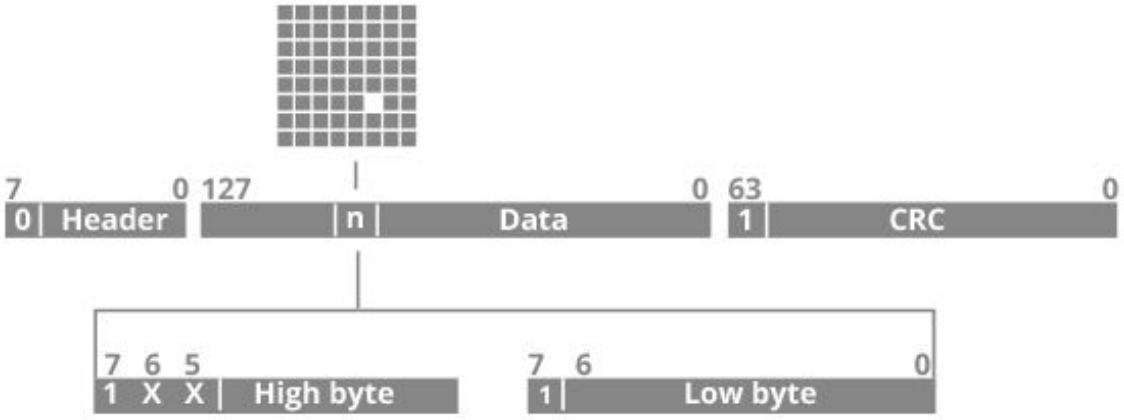

Figure 13. Evo 64px output format structure

The frame transmission ends with a New Line character (1 byte). Each byte transmitted by the sensor is categorised into two types, *data and metadata*. Data is information from the sensor itself and metadata provides information about the data eg. packet headers. In the case of Data, the most significant bit of every byte is set to 1. And in the case of metadata the most significant bit is 0.

ie. 0b1xxxxxxx ➔ this byte is a data byte
0b0xxxxxxx ➔ this byte is a metadata byte

For hardware reasons, the size of every frame transmitted by the sensor is a multiple of 4 therefore frames which are not multiples of 4 have padding appended.

Each frame has a CRC32 checksum appended to it to allow the end user to confirm data integrity. The CRC32 used is CRC-32 MPEG 2 (Polynomial 0x4C11DB7 with initial value of 0xFFFFFFFF and Final Xor Value 0x0).

Please reference Appendix section for instructions on the following topics:

- CRC validation
- reading data from Evo 64px sensor (includes sample code in python).

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For data output structure please reference table below.

Header	Description	Structure
0x11 / 0d17	**Distance:** 64 distance measurements as calculated by the sensor for each pixel after temperature, ambient light and distance correction.	**14 bit integer * 64 * 2** Each pixel distance value is transmitted as two bytes, representing the hibyte and the lobyte of the pixel value. Hibyte first and lobyte second. The MSB of each byte should be cleared to zero.
0x13 / 0d19	**Ambient[1]:** 64 ambient measurements as calculated by the sensor for each pixel after an ambient measurement cycle.	**12 bit integer * 64 * 2** Each pixel value is transmitted as two bytes, representing the hibyte and the lobyte of the pixel value. Hibyte first and lobyte second. The MSB of each byte should be cleared to zero.
N/A	**Padding if applicable**	X bytes with the value 0x80 to make the frame a multiple of a 32 bit integer.
N/A	**CRC-32**	**32 bit integer * 1** The CRC is transmitted as eight bytes with only the four lower bits containing data. The MSB of each byte should be cleared to zero.

Each frame is terminated by a newline character (0x0A) to allow the user to make use of the readline functionality of most serial port libraries.

The TeraRanger Evo outputs distance values in millimetres within a specified range depending on the measurement mode. After extraction of the data from the Evo 64px's

[1] Depending on the selected printout mode, Ambient data might or might not be output by the sensor (refer to section 5.3, Commands)

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frame, a pixel can be in one of four states. Please consult table below for possible measurement output.

Measurement status*	**Output**
Valid Measurement (equivalent to distances from 100mm to 5000mm)	0x0064 - 0x1388
Object too close (below minimum distance)	0x0000
Object too far (above maximum distance)	0x3FFF
ERROR (unable to give back value, eg. too absorbent or too reflective surface)	0x0001

*End State Pixel [x][y]

6 Compliance

Eye safety	**RoHS**	CE
Yes; compliant with IEC 62471:2006	Yes	Currently pending

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Appendix

A.1 CRC validation

When using python, you will find a dedicated module named '**crcmod**'. Please install the module using '**pip**' with the following command:

```
pip install crcmod
```

A.1.1 How to calculate CRC8 checksum for Evo 64px

After defining this function:

```
self.crc8 = crcmod.predefined.mkPredefinedCrcFun('crc-8')
```

You will be able to use the above function on any buffer, as illustrated in the code below. In this case 'ack' variable is a 4-byte buffer containing an ACK response.

```
crc = self.crc8(ack[:3])
        if crc == ord(ack[3]):  # Check that CRC's are matching
              ...
```

A.1.2 How to calculate CRC32 checksum for Evo 64px

After defining this function:

```
self.crc32 = crcmod.predefined.mkPredefinedCrcFun('crc-32-mpeg')
```

To validate the CRC checksum of a data frame for Evo 64px sensor, please use the following function.

```
def crc_check(self, frame):
      index = len(frame) - 9  # Start of CRC
      crc_value = (ord(frame[index]) & 0x0F) << 28
      crc_value |= (ord(frame[index + 1]) & 0x0F) << 24
      crc_value |= (ord(frame[index + 2]) & 0x0F) << 20
      crc_value |= (ord(frame[index + 3]) & 0x0F) << 16
      crc_value |= (ord(frame[index + 4]) & 0x0F) << 12
      crc_value |= (ord(frame[index + 5]) & 0x0F) << 8
      crc_value |= (ord(frame[index + 6]) & 0x0F) << 4
```

```
        crc_value |= (ord(frame[index + 7]) & 0x0F)
        crc_value = crc_value & 0xFFFFFFFF
        crc32 = self.crc32(frame[:index])

        if crc32 == crc_value:
                return True
        else:
                print "Discarding current buffer because of bad checksum"
                return False
```

A.2 Sample code

The python sample code provides with basic sensor functionality and communication, including activating data output, reading data, sending commands and validating CRC checksum. The python file of this sample code is available for download under "Download" section of the TeraRanger Evo 64px product page.

```
#!/usr/bin/python
# -*- coding: utf-8 -*-
import numpy as np
import serial
import crcmod.predefined
import threading


class Evo_64px(object):

        def __init__(self):
        self.portname = "/dev/ttyACM0"
        self.baudrate = 115200

        # Configure the serial connections (the parameters differs on the
device you are connecting to)
        self.port = serial.Serial(
                port=self.portname,
                baudrate=self.baudrate,
                parity=serial.PARITY_NONE,
                stopbits=serial.STOPBITS_ONE,
                bytesize=serial.EIGHTBITS
        )
        self.port.isOpen()
        self.crc32 = crcmod.predefined.mkPredefinedCrcFun('crc-32-mpeg')
        self.crc8 = crcmod.predefined.mkPredefinedCrcFun('crc-8')
        self.serial_lock = threading.Lock()
```


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```
	def get_depth_array(self):
	'''
	This function reads the data from the serial port and returns it
as
	an array of 12 bit values with the shape 8x8
	'''
	got_frame = False
	while not got_frame:
		with self.serial_lock:
			frame = self.port.readline()
		if len(frame) == 269:
			if ord(frame[0]) == 0x11 and self.crc_check(frame):  #
Check for range frame header and crc
				dec_out = []
				for i in range(1, 65):
					rng = ord(frame[2 * i - 1]) << 7
					rng = rng | (ord(frame[2 * i]) & 0x7F)
					dec_out.append(rng & 0x0FFF)
				depth_array = [dec_out[i:i + 8] for i in range(0,
len(dec_out), 8)]
				depth_array = np.array(depth_array)
				got_frame = True
		else:
			print "Invalid frame length: {}".format(len(frame))

	depth_array.astype(np.uint16)
	return depth_array

	def crc_check(self, frame):
	index = len(frame) - 9  # Start of CRC
	crc_value = (ord(frame[index]) & 0x0F) << 28
	crc_value |= (ord(frame[index + 1]) & 0x0F) << 24
	crc_value |= (ord(frame[index + 2]) & 0x0F) << 20
	crc_value |= (ord(frame[index + 3]) & 0x0F) << 16
	crc_value |= (ord(frame[index + 4]) & 0x0F) << 12
	crc_value |= (ord(frame[index + 5]) & 0x0F) << 8
	crc_value |= (ord(frame[index + 6]) & 0x0F) << 4
	crc_value |= (ord(frame[index + 7]) & 0x0F)
	crc_value = crc_value & 0xFFFFFFFF
	crc32 = self.crc32(frame[:index])

	if crc32 == crc_value:
		return True
	else:
```

```
            print "Discarding current buffer because of bad checksum"
            return False

      def send_command(self, command):
      with self.serial_lock:# This avoid concurrent writes/reads of
serial
            self.port.write(command)
            ack = self.port.read(1)
            # This loop discards buffered frames until an ACK header is
reached
            while ord(ack) != 20:
                  self.port.readline()
                  ack = self.port.read(1)
            else:
                  ack += self.port.read(3)

            # Check ACK crc8
            crc8 = self.crc8(ack[:3])
            if crc8 == ord(ack[3]):
                  # Check if ACK or NACK
                  if ord(ack[2]) == 0:
                  return True
                  else:
                  print "Command not acknowledged"
                  return False
            else:
                  print "Error in ACK checksum"
                  return False

      def start_sensor(self):
      if self.send_command("\x00\x52\x02\x01\xDF"):
            print "Sensor started successfully"

      def stop_sensor(self):
      if self.send_command("\x00\x52\x02\x00\xD8"):
            print "Sensor stopped successfully"

      def run(self):
      self.port.flushInput()
      self.start_sensor()

      depth_array = []
      while depth_array is not None:
            depth_array = self.get_depth_array()
```

```
            print depth_array
      else:
            self.stop_sensor()


if __name__ == '__main__':
      evo_64px = Evo_64px()
      evo_64px.run()
```