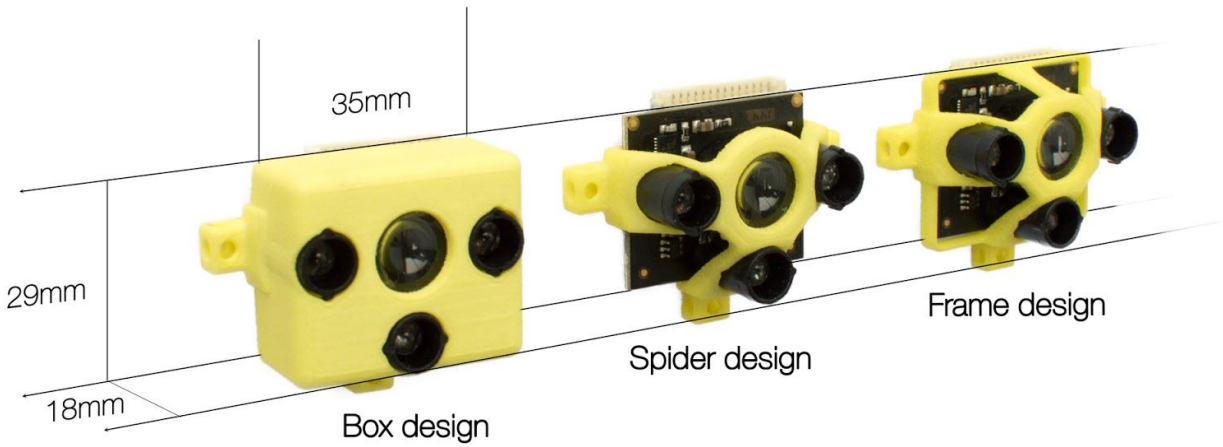
TeraRanger One

by TERABEE

Installation and Operation Manual

Version 1.0.0, June 2016
Firmware 5.0.1



Technical Specifications:

Principle:	Infrared Time-of-Flight (ToF)
Range:	Up to 14m indoors (At least 5 to 6m in sunlight)
Update rate:	1000Hz in fast mode (Up to 600Hz in precision mode)
Range resolution:	0.5cm
Accuracy:	± 4cm in precision mode
Field of view:	3°
Supply voltage:	10V DC recommended (10 to 20V DC accepted)
Supply current:	50mA average (110mA peak @12V)
Interfaces:	1.UART (+5V level, up to 115200,8,N,1)
	2.TWI (I2C compatible, +5V level, up to 400kHz, configurable address)
Connector:	15 pin DF13 (open-ended, 1.27mm pitch flat ribbon cable provided)
Designs:	Box, Spider, Frame
Weight:	8g (Spider, Frame) or 10g (Box)
Sensor types:	Type A (Box, Spider) and Type B (Box, Frame)

Safety Notes

The TeraRanger One is eye-safe in all conditions, including system failure. However, please keep a minimum of 20cm distance from your eyes when handling the sensor under power and do not look into the LEDs with any kind of optical instruments.

Table of Contents

1 About the TeraRanger One
- 1.1 Inside the Package
- 1.2 USB adapter
- 1.3 Dimensions and Mounting
- 1.4 About the Connector
- 1.5 UART Data Interface
- 1.6 TWI (I2C) Data Interface
- 1.7 USB Interface
- 1.8 Details on Supply Voltage

2 Connecting the TeraRanger One Using a Computer With a Serial Console
- 2.1 Windows
- 2.2 MacOS
- 2.3 Linux

3 Running the TeraRanger One in ROS

5 Protocol description
- 5.1 UART interface
- 5.2 I2C interface

6 How to connect to Pixhawk autopilot

7 How to calculate the CRC8 checksum

8 Understanding the field of view

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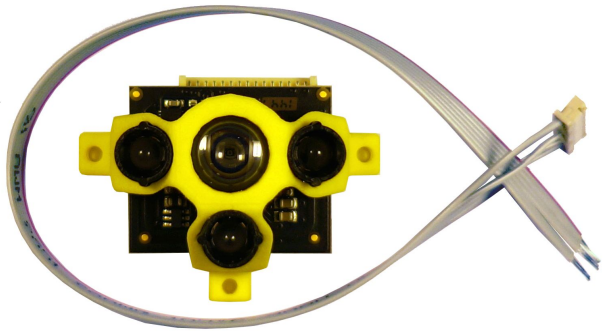
1 About the TeraRanger One

1.1 Inside the Package

You will receive the following items when purchasing a TeraRanger One:

- a fully assembled and calibrated sensor
- a connector cable with open ends that can be soldered to your device



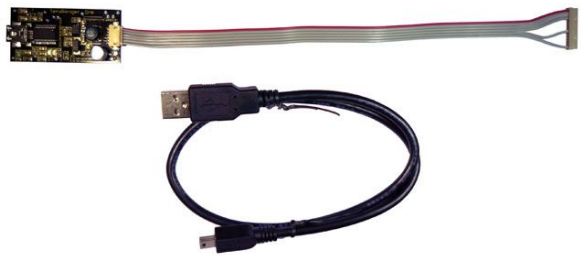
1.2 USB adapter

An optional USB adapter is available for simple plug & play connection to a PC or Mac. The USB adapter provides power to the sensor and data transfer to and from the sensor. It is ideal for evaluation and testing and for making firmware updates to the sensor, and it is also an essential item in case you need post-sales technical support.

The USB adapter can be purchased at:
http://www.teraranger.com/product/teraranger-usb-adapter/

If you have purchased a USB adapter in addition to your TeraRanger One, you will also receive the following items:

- the USB adapter board
- a connector cable that connects your USB adapter board to your TeraRanger One
- a Mini-USB cable that connects the USB adapter board to your computer



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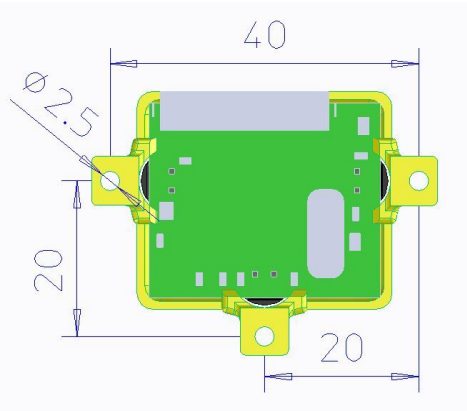
1.3 Dimensions and Mounting

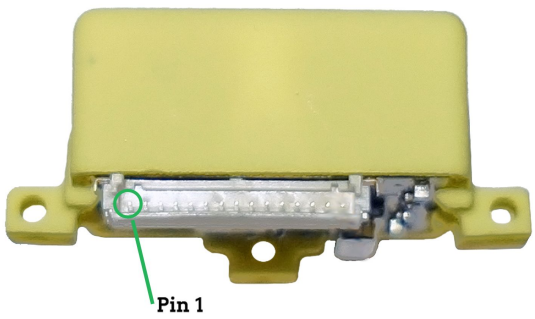
The TeraRanger One provides three mounting holes, which are designed for M2.5 screws. The individual distances between the holes are shown in the following figure which is valid for all designs of the yellow outer plastic part. Moreover, the following aspects should be taken into consideration when mounting the TeraRanger One:



- Do not remove the plastic cover as this will misalign the optics and degrade the sensor's performance
- Mount the TeraRanger One in a well ventilated location
- Take the usual precautions for sensitive electronics such as maintaining a suitable distance to strong electric and magnetic fields, strong radio emitters, strong heat sources, etc.

1.4 About the Connector

The TeraRanger One connects to your equipment using a 15 pin connector of the Hirose DF13 series. (The part number of the corresponding female connector is DF13-15S-1.25C.) The cable assembly delivered with the TeraRanger One comes with six wires installed: Ground (GND, pin 1 and 15), positive supply voltage (Vcc, pin 14), UART receive (RXD, pin 12)*, UART transmit (TXD, pin 13)* and reset (pin 7) . Please use the following image (valid for all yellow outer part designs) and table to identify the pins:



Pin	Function
15	GND
14	Vcc (10V, accepts 10-20V)
13	Serial out (TXD), 5V level
12	Serial in (RXD), 5V level
11	TWI** SDA
10	TWI** SCL
9	User I/O 1
8	User I/O 2
7	Arduino compatible reset in (to DTR)
6	Reset in (pull to GND to reset)
5	MOSI (for SPI or flashing)
4	MISO (for SPI or flashing)
3	SCLK (for SPI or flashing)
2	+5V out (use only to provide voltage levels to programming devices, max. 10mA!)
1	GND

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Note:

- Once connected, DF13 connectors are very reliable and are perfect for robotics and drone environments where vibrations are common. However, these connectors are not made for infinite plugging and unplugging. If you need to plug and unplug the sensors frequently, consider adding a more suitable connector in-line.
- Please do not apply shear forces to the connector when pushing it in the socket. Ideally, press the socket down to the PCB with your thumb and push the connector in with your other hand. Do not use tools like pliers etc.! You can find good instruction videos on DF13 plugging and unplugging on YouTube.
- Additional cables can be purchased from the TeraRanger website or your preferred TeraRanger reseller.
- Please follow basic rules on ESD** safety when connecting and touching the TeraRanger One!
- Do not apply force to the TeraRanger One PCB while handling and installing it.
- Do not plug or unplug the sensor under power. Hot plugging and unplugging may damage the sensor.

* UART is the default interface
** See for example http://en.wikipedia.org/wiki/Electrostatic_discharge

1.5 UART Data Interface

The default interface is UART on pins 12 and 13. It needs an input voltage level of 5V (logic high) to run reliably, the output voltage level is 5V. Please use a serial to USB interface (e.g. such as the TeraRanger USB adapter) to connect the TeraRanger One to your PC. DO NOT connect the TeraRanger One to a real RS-232 port of a PC, the voltage levels are different and might destroy the sensor's electronics.

The UART is configured to send and receive at 115200 bit/s, 8 data bits, no parity bit and one stop bit (115200-8N1).

1.6 TWI (I2C) Data Interface

Another way to connect to your TeraRanger One is the TWI (or better known as NXP's I2C) interface. Using this interface, you can connect multiple TeraRanger Ones to a TWI master on the same bus. Please refer to the protocol description (chapter 5) to see how the bus address of each TeraRanger One can be changed individually to avoid collisions on the bus. Please keep in mind that the TeraRanger One has a relatively narrow field of view. Hence, multiple TeraRanger Ones looking into opposite or perpendicular directions can be triggered at the same time, allowing a significantly increased readout speed!

Please refer to chapter 1.4 for the the electrical connections to be made for using TWI. The signal levels are 5V, the maximum bus speed is 400kHz and the pull-up resistors (10kOhms) are already integrated in the TeraRanger One. If you want to connect to an I2C bus with

3.3V voltage levels, you need to use a voltage level translator. An I2C adapter for reliable voltage-level-translation is available from our website at: http://www.teraranger.com/product/teraranger-i2c-adapter/.

In addition you have the option to purchase the TeraRanger Hub. This accessory board allows you to connect up to eight TeraRanger One sensors and read the data from the sensors via a single serial or USB link. See more at: http://www.teraranger.com/products/teraranger-hub/

1.7 USB Interface

If you have purchased the TeraRanger One USB adapter, you can directly connect the TeraRanger One to your PC without the need of any additional power supply. In most modern operating systems, a driver for this interface is already present and the interface will appear as an FTDI virtual COM port to which you can connect using the settings that were previously mentioned in the UART Data Interface section.

In case your computer asks you to provide a driver, please download the driver for your operating system from http://www.ftdichip.com/Drivers/VCP.htm and follow the installer. After successful installation, unplug the interface for a moment and plug it back in. The virtual COM port should now be available on your PC.

Note: Do not plug/unplug the TeraRanger One from the USB adapter while the device is powered, disconnect the USB plug from the PC first!

1.8 Details on Supply Voltage

TeraRanger One works with clean, spike and interruption free voltages ranging from 10V to 20V and has an internal voltage regulator for optimal performance. However, to minimise unnecessary heating, we advise the use of a preregulator down to 12V, and ideally 10V. For optimal efficiency, this should be a switching regulator (either buck or boost, depending on the supply voltage available on your system) with a large output capacitor and good filtering.

TeraRanger One is equipped with a safety shutdown to prevent damage from excessive currents or board temperatures arising from eventual internal failures due to incorrect mounting, misuse or externally provoked short-circuits. In case of shutdown triggering, the sensor resets automatically after reaching normal working conditions and a power cycle of the external power supply.

2 Connecting the TeraRanger One Using a Computer With a Serial Console

Your TeraRanger One can interact with any serial console using the following configuration: 115200 bit/s, 8 data bits, no parity bit and one stop bit.

2.1 Windows

In Windows you can use terminal emulation software like HTerm. If you do not already have terminal software you can download HTerm from this link:
http://www.der-hammer.info/terminal

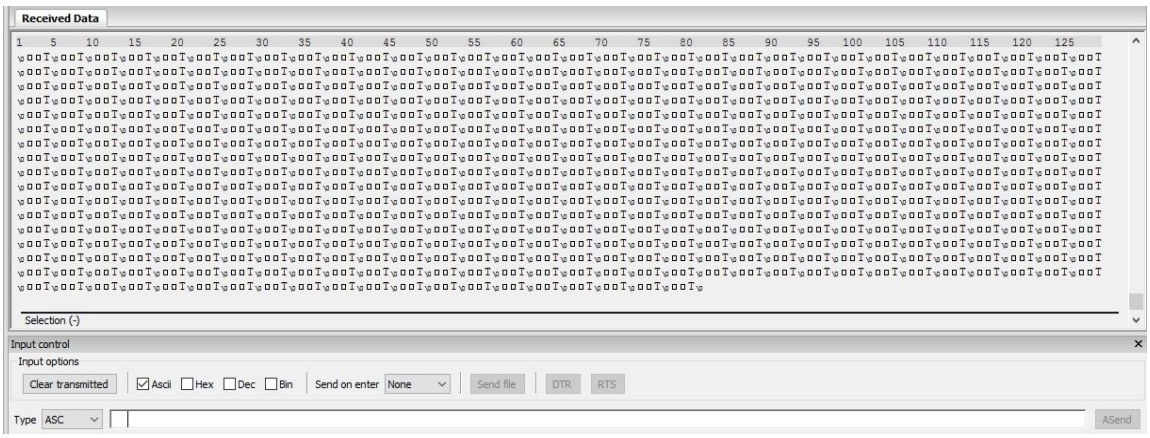
Make sure you download it before plugging the TeraRanger One into your USB port via the TeraRanger USB adapter!

Extract the downloaded zip file to the folder of your choice, open it and double click on the "HTerm.exe" file.

Now connect the TeraRanger One to your computer via the USB adapter. In order to select the USB port on which the TeraRanger One is plugged, refresh the port list by clicking on the "R" button as shown on the following image:

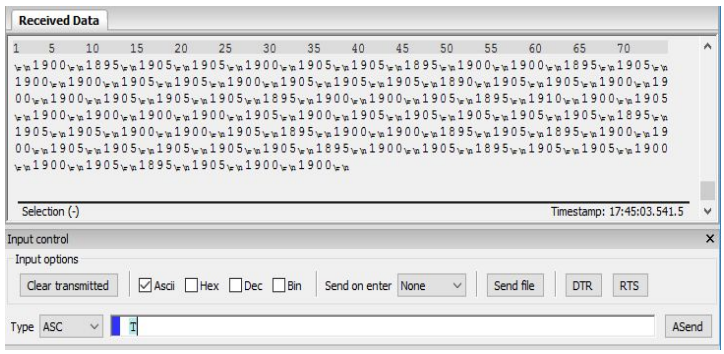
Once you have selected the port, click on the "Connect" button.

The data will now appear in the "Received data" box in "Binary" mode:



To convert the data to a human readable output, simply type "T" in the "Type" box to display the data in "Text" mode, as shown in the picture below. In this example, you can see that the measurement is around 1900mm. You can return to "Binary" mode by typing "B" in the

“Type” box.



If you want to change the sensor’s measurement mode, type “F” in the type box to select the “Fast” mode; type “P” for the “Precision” mode or type “O” for the “Optimal” mode (refer to section 5.1 for the description of the modes). In order to stop measurements simply press the disconnect button in HTerm and then unplug the USB cable.

2.2 MacOS

With MacOS, when you connect the TeraRanger One to your computer through the USB adaptor, you will be able to use it through your computer’s “Terminal” Application.

To find this application go to:

Applications > Utilities > Terminal

You can now click on the item to enter the terminal and set the appropriate reading settings by copy and pasting this first command to the page:

ls /dev/tty.*

This command will tell the terminal to show the USB device’s name that will be used to acquire distance data from your TeraRangerOne.

Example:

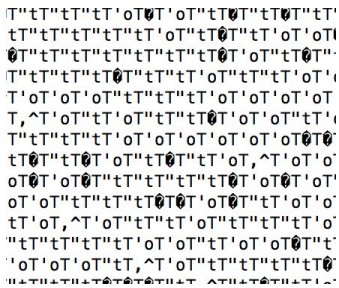
/dev/cu.usbserial-XXXXXXXXX (The X’s will have your USB port’s name)

Once you have found this, enter the following code to the next line:

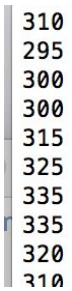
screen /dev/cu.usbserial-XXXXXXXX 115200 (Replace the X’s with your USB port’s

name)

The distance data will now appear on the terminal in “Binary” mode and will look like this:



Press the commands Shift+T to switch from binary mode to “Text” mode. This will display the distance values in millimeters, as follows:



To change the sensor from its fast mode to its precision mode, press:

Shift+F for “Fast” mode
Shift+P for “Precision” mode
Shift+O for “Optimal” mode

To stop the data measurement, press:

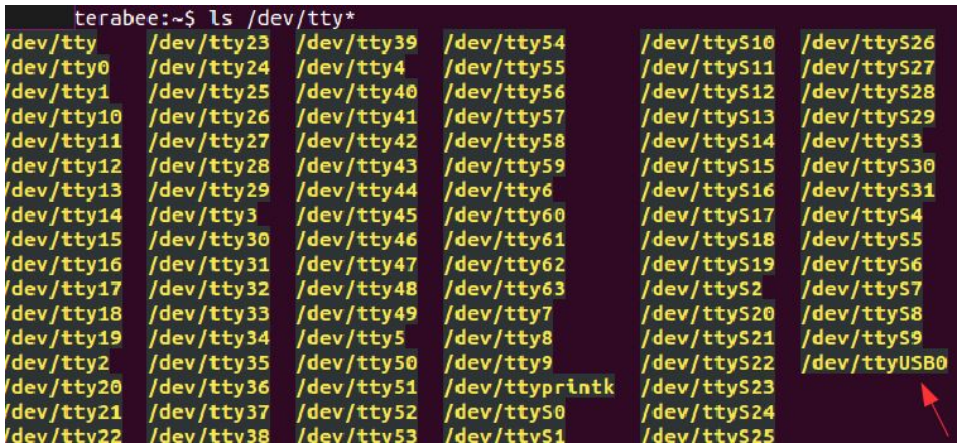
Ctrl+A then K

2.3 Linux

Linux is very similar to MacOS and also works with a terminal.

Open a terminal (shortcut: ctrl+alt+t):

type: ls /dev/tty*



Usually the name is /dev/ttyUSB0 but it can also be ttyUSB1, ttyUSB2, etc…

In order to view the data stream from the teraranger, type* the following:

> screen /dev/ttyXXX 115200 (replace ttyXXX with the correct serial device like ttyUSB0)

To see different operating modes, refer to the Mac OS section. The commands are the same.

*Be aware that *screen* might not be installed in your Linux operating system, so you might need to install it. Please follow the installation procedure recommended for your Linux distribution.

3 Running the TeraRanger One in ROS

We provide a ROS (Robot Operating System, http://www.ros.org) node which provides a topic to access the TeraRanger One data stream. Please note that the *sensor has to be configured to work in Binary mode before you can start using it with ROS*. You can download the ROS node from: https://github.com/Terabee/terarangerone-ros

To use the ROS node you need to:

1. Create a ROS Workspace
2. Copy the node terarangerone package into the workspace src directory
3. Compile using: catkin_make
4. Setup environment: source devel/setup.sh
5. Run** using: rosrun terarangerone terarangerone_node _portname:=/dev/ttyUSB0

If you want to change the operating mode, run**:

- rosrun rqt_reconfigure rqt_reconfigure

** Remember to execute the daemon roscore before running the rosrun command and change the USB port to the appropriate one.

5 Protocol description

The TeraRanger One can be read out and controlled via either UART or I2C. Even though both interfaces are activated in parallel, we recommend the use of only one interface at a time. Usage in parallel can lead to erroneous behaviour and is not supported by us. If you want to switch from one interface to the other, please power cycle the sensor in between the switch.

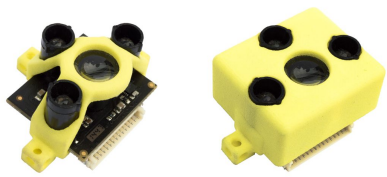
5.1 UART interface

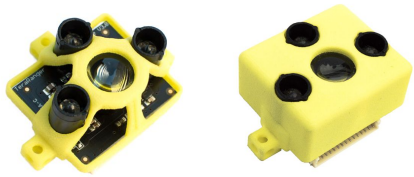
The UART is configured to send and receive at 115200 bit/s, 8 data bits, no parity bit and one stop bit (115200-8N1). Please consult section 2 to see how you can connect the TeraRanger One to your PC running Windows, Linux or MacOS.

UART commands and output format

In all UART modes, the sensor is free running, that means you do not need to send anything to start a measurement. Once a measurement in the mode you selected is finished, the sensor will send the data in the format you selected and immediately start a new measurement.

Two operating modes can be selected for either type A and type B sensors by sending the corresponding uppercase character to the TeraRanger One via the serial port:

Sensor type A 		
P	**Precise mode**	The TeraRanger One adapts its internal parameters to provide the best available accuracy. This improved accuracy results in a decrease of the measurement repetition rates, and therefore in increased reaction times. The delay between two measurements is variable and depends on the target distance and properties. **This mode offers an optimized performance in indoor environments.**

F	**Fast mode**	This mode ensures fixed measurement repetition rates and reaction times. This improvement comes at the expense of the reading accuracy and maximum range which is limited to 4.5m in this mode. The delay between two readings is 1ms.
Sensor type B 		
O	**Optimal (Precise mode for B type)**	The TeraRanger One adapts its internal parameters to provide the best available accuracy in sunlight conditions while providing high repetition rates. The delay between two measurements is variable and depends on the target distance and properties. **This mode offers an optimized performance in outdoor environments.**
F	**Fast mode**	This mode ensures fixed measurement repetition rates and reaction times. This improvement comes at the expense of the reading accuracy and maximum range which is limited to 4.5m in this mode. The delay between two readings is 1ms.

You can also set the output format by sending the corresponding uppercase character to the TeraRanger One via the serial port:

T	**Text output**	Data output in human readable form (5 - 7 bytes message): xxxxx\r\n - Distance reading in millimeters* (maximum 5 bytes per sensor): xxxxx - Carriage return character: \r (13 decimal / 0x0D hex) - New line character: \n (10 decimal / 0x0A hex) *please be aware that there is no zero-padding for leading zeros! If the TeraRanger One is unable to measure a distance, it will output -1\r\n as an error message. Valid measurements are decimal and between 200\r\n and 14000\r\n. Measurements at distances below 20cm or beyond 14m will display the 200\r\n or 14000\r\n limits.

		Note: measurements beyond 4.5m in fast mode and text output might be unreliable; the use of "Precise" or "Optimal" modes, depending on the environment, is advised for these measurement ranges
B	**Binary output**	Data output (4 bytes message): TXXCRC8 - Header: T (84 decimal / 0x54 hex) - Distance reading in millimeters** (2 bytes): XX - Checksum (1 byte) of previous 3 bytes: CRC8 **The TeraRanger One will output T00CRC (both distance bytes set to zero) as an error message in the following situations: - It is unable to measure a distance - The target distance is below 20cm or beyond 14m Valid outputs are from 200 decimal to 14,000 decimal.

Please note that the default modes when shipped are "Precise" with "Binary" output for sensor type A and "Optimal" with "Binary" output for sensor type B. The modes you select are kept in volatile memory by the sensor and have to be set after each power cycle.

5.2 I2C interface

An alternative way to read out the TeraRanger One is via its TWI bus (also known as I2C). Please refer to chapter 1.4 for the the electrical connections to be made for using TWI. The signal levels are 5V, the maximum bus speed is 400kHz and the pull-up resistors (10kOhms) are already integrated in the TeraRanger One. If you want to connect to an I2C bus with 3.3V voltage levels, you need to use a voltage level translator. An I2C adapter for reliable voltage-level-translation is available from our website at: http://www.teraranger.com/product/teraranger-i2c-adapter/.

I2C commands and output format

The TeraRanger One comes by default with I2C base address (7 bit) 0x30 and is therefore ready to be directly connected to the Pixhawk autopilot via the TeraRanger I2C adapter without any user modifications being necessary.

Like in UART mode, the TeraRanger One is free running, that means it will restart a new measurement as soon as the last one is finished. The data you read via I2C is always updated at the end of a measurement, but you can read at any time.

Reading the distance is done by sending 0x61 (this is the 7 bit address 0x30 followed by the read bit '1') followed by three byte read operations. The first two bytes you receive are a 16 bit word containing the latest measurement in mm, the third byte is the CRC8 checksum.

Writing commands to the TeraRanger One:

1. Send the address byte consisting of a 7 bit base address and the last bit indicating write (‘0’), e.g. 0x60 for base address 0x30. All commands listed in the table below are write operations, the answer will be in the next read operation for which you have to send the 7 bit address with the read bit set.
2. Send the desired command listed in the table below.
3. In case the command creates an answer, read it back immediately.

Reading data from the TeraRanger One:

1. Send the address byte consisting of 7 bit base address and the last bit indicating read (‘1’), e.g. 0x61 for base address 0x30.
2. Read back the the number of bytes imposed by the command, e.g. three bytes for a distance reading.

Command in hexadecimal	Command name	Command explanation
0x01	WHO_AM_I	Write this value to TROne via I2C and the next distance reading will contain 0xA1 in the first byte (ignore others). You can use this function to uniquely identify a TeraRanger One on the I2C bus.
0xA2	CHANGE_BASE_ADDR	Command to change base address of the TeraRanger One. Write this value followed by new address to set, e.g. send 0x42 if you want base address 0x42, ignore read/write bits. After sending this command, power cycle the device. Afterwards it will join the I2C bus as a slave on the new address.

Please note that the default modes when shipped are “Precise” with “Binary” output for sensor type A and “Optimal” with “Binary” output for sensor type B (refer to section 5.1 for the description of the modes). The operating modes for the I2C interface are set by default.

6 How to connect to Pixhawk autopilot

In its default state, the TeraRanger One can be connected to the Pixhawk autopilot using the TeraRanger I2C adapter. Currently, Ardupilot firmware from 3.3.3 supports the TeraRanger One as a precision altimeter. You can find details on how to connect the TeraRanger One to your Pixhawk on http://ardupilot.org/copter/docs/common-teraranger-one-rangefinder.html. Important: When the Pixhawk boots, the TeraRanger One needs to already be powered on, or at least be powered on at the same time as the Pixhawk. If you power the TeraRanger One after the Pixhawk has booted, it will not be recognised!

7 How to calculate the CRC8 checksum

All data telegrams in UART binary and I2C output are ending with a CRC8 checksum of the previous bytes including the header byte 'T'. Please find below an example function you can use to calculate this checksum from the received bytes which you can then compare to the received checksum to figure out if transmission errors occurred.

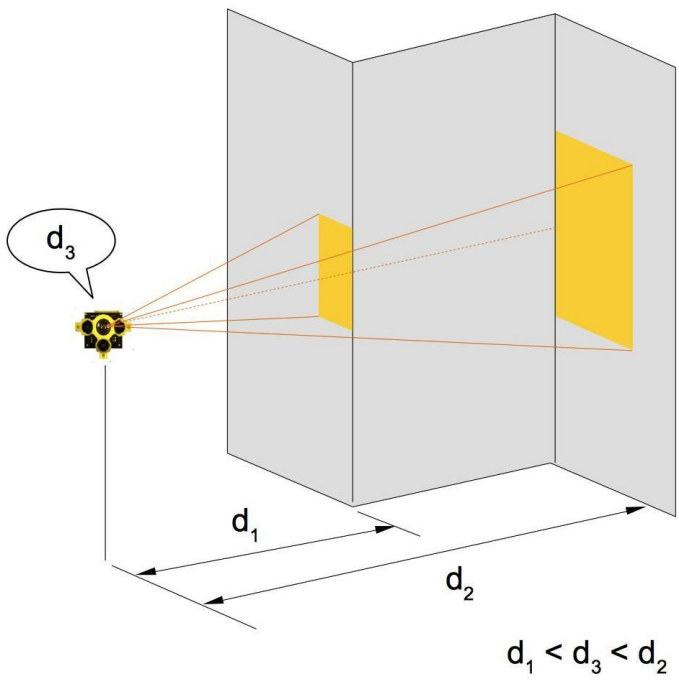
```
uint8_t crc8(uint8_t *p, uint8_t len){
// p is a buffer of type uint8_t and of length len
        uint16_t i;
        uint16_t crc = 0x0;
        while (len--) {
                i = (crc ^ *p++) & 0xFF;
                crc = (crc_table[i] ^ (crc << 8)) & 0xFF;
        }
        return crc & 0xFF;
}


static const uint8_t crc_table[] = {
// This table is used by the CRC8 calculation function
    0x00, 0x07, 0x0e, 0x09, 0x1c, 0x1b, 0x12, 0x15, 0x38, 0x3f, 0x36, 0x31,
    0x24, 0x23, 0x2a, 0x2d, 0x70, 0x77, 0x7e, 0x79, 0x6c, 0x6b, 0x62, 0x65,
    0x48, 0x4f, 0x46, 0x41, 0x54, 0x53, 0x5a, 0x5d, 0xe0, 0xe7, 0xee, 0xe9,
    0xfc, 0xfb, 0xf2, 0xf5, 0xd8, 0xdf, 0xd6, 0xd1, 0xc4, 0xc3, 0xca, 0xcd,
    0x90, 0x97, 0x9e, 0x99, 0x8c, 0x8b, 0x82, 0x85, 0xa8, 0xaf, 0xa6, 0xa1,
    0xb4, 0xb3, 0xba, 0xbd, 0xc7, 0xc0, 0xc9, 0xce, 0xdb, 0xdc, 0xd5, 0xd2,
    0xff, 0xf8, 0xf1, 0xf6, 0xe3, 0xe4, 0xed, 0xea, 0xb7, 0xb0, 0xb9, 0xbe,
    0xab, 0xac, 0xa5, 0xa2, 0x8f, 0x88, 0x81, 0x86, 0x93, 0x94, 0x9d, 0x9a,
    0x27, 0x20, 0x29, 0x2e, 0x3b, 0x3c, 0x35, 0x32, 0x1f, 0x18, 0x11, 0x16,
    0x03, 0x04, 0x0d, 0x0a, 0x57, 0x50, 0x59, 0x5e, 0x4b, 0x4c, 0x45, 0x42,
    0x6f, 0x68, 0x61, 0x66, 0x73, 0x74, 0x7d, 0x7a, 0x89, 0x8e, 0x87, 0x80,
    0x95, 0x92, 0x9b, 0x9c, 0xb1, 0xb6, 0xbf, 0xb8, 0xad, 0xaa, 0xa3, 0xa4,
    0xf9, 0xfe, 0xf7, 0xf0, 0xe5, 0xe2, 0xeb, 0xec, 0xc1, 0xc6, 0xcf, 0xc8,
    0xdd, 0xda, 0xd3, 0xd4, 0x69, 0x6e, 0x67, 0x60, 0x75, 0x72, 0x7b, 0x7c,
    0x51, 0x56, 0x5f, 0x58, 0x4d, 0x4a, 0x43, 0x44, 0x19, 0x1e, 0x17, 0x10,
    0x05, 0x02, 0x0b, 0x0c, 0x21, 0x26, 0x2f, 0x28, 0x3d, 0x3a, 0x33, 0x34,
```

```
    0x4e, 0x49, 0x40, 0x47, 0x52, 0x55, 0x5c, 0x5b, 0x76, 0x71, 0x78, 0x7f,
    0x6a, 0x6d, 0x64, 0x63, 0x3e, 0x39, 0x30, 0x37, 0x22, 0x25, 0x2c, 0x2b,
    0x06, 0x01, 0x08, 0x0f, 0x1a, 0x1d, 0x14, 0x13, 0xae, 0xa9, 0xa0, 0xa7,
    0xb2, 0xb5, 0xbc, 0xbb, 0x96, 0x91, 0x98, 0x9f, 0x8a, 0x8d, 0x84, 0x83,
    0xde, 0xd9, 0xd0, 0xd7, 0xc2, 0xc5, 0xcc, 0xcb, 0xe6, 0xe1, 0xe8, 0xef,
    0xfa, 0xfd, 0xf4, 0xf3
};
```

8 Understanding the field of view

TeraRanger One distance measurements are based on an infrared time-of-flight principle: the sensor emits an infrared signal and calculates the distance to the target based on the time it takes for the reflected signal to be detected. The system is optical and measured within a specific field of view, which is 3 degrees.

This field of view corresponds to a detection window of 4.5cm x 4.5cm at a distance of 1m, and this window size scales linearly with distance. If multiple targets are placed in the field of view of the sensor, a distance averaging effect will occur. This is represented in the following picture, whose dimensions have been exaggerated for clarity (note that the actual field of view is 3 degrees!):



Should you need to mount your TeraRanger One sensors behind or within a protective screen, such as glass or plastic, please contact support@teraranger.com so that we can give you some best practice advice.

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