SiPM dToF LiDAR Platform
Getting Started Guide

SECO-RANGEFINDER-GEVK

The SiPM Direct Time of Flight (dToF) LiDAR Platform is a complete development kit for single point range-finding applications. The FDA-certified kit is based on the RB-series NIR-enhanced SiPM from ON Semiconductor, and integrates all essential system components including laser and reference circuit (Tx), receiving circuit (Rx), power management systems, and core FPGA and UART communication.

The Silicon Photomultiplier (SiPM) is a single-photosensitive, high performance, solid-state sensor. It is formed of a summed array of closely-packed Single Photon Avalanche Photodiode (SPAD) sensors with integrated quench resistors, resulting in a compact sensor that has high gain (~1x106), high detection efficiency (> 50%) and fast timing (sub-ns rise times).



Figure 1. SECO-RANGEFINDER-GEVK contents

Prerequisites

- SECO-RANGEFINDER-GEVK is delivered pre-programmed and with USB cable, enabling plug and play functionality.
- GUI PC Application Range_Finder_1.0
- SiPM dToF LiDAR platform Evaluation Board User Manual (UM70015-D)

Scope and Purpose

This Getting Started Guide provides information on how to use the SiPM Direct Time of Flight (dToF) LiDAR platform (SECO-RANGEFINDER-GEVK) together with the available graphical user interface (GUI). For complete information on the platform and system, refer to the User Manual.

The SECO-RANGEFINDER-GEVK meets the power requirements for a Class 1 Laser product to BS EN 60825-1:2014 under normal operating conditions and those of single fault failure. The design complies with laser safety standard IEC / EN 60825-1:2014 and 21 CFR 1040.10 and 1040.11 except for deviations pursuant to Laser Notice No. 56.

Read the Safety and Evaluation Board Information section before manipulating the board.

Summarized features

- Direct ToF operation for a single point
- > 0.11 m to 23 m distance
- 650-1050nm BK7 plano-convex lenses to maximize distance measurement
- Out-of-the box operation with dedicated GUI
- FDA Certified
- Single power supply (either from USB = 5V or PMOD connector = 3.3V)
- FPGA-based Time-to-Digital Convertor (TDC)

Applications

- Indoor navigation and range finding (up to 20 m)
- Collision Detection
- 3D mapping

IMPORTANT SAFETY AND EVALUATION BOARD INFORMATION

WARNING

Failure to heed the following warnings could result in an accident resulting in death or serious injury.

Laser Warning

This device requires no regular maintenance. In the event that the device becomes damaged or is inoperable, repair or service must be handled by authorized, factory-trained technicians only. Attempting to repair or service the unit on your own can result in direct exposure to laser radiation and the risk of permanent eye damage. For repair or service, contact your ON Semiconductor representative for more information. This device should not be modified or operated without its housing or optics. Operating this device without a housing and optics, or operating this device with a modified housing or optics that expose the laser source, may result in direct exposure to laser

radiation and the risk of permanent eye damage. Removal or modification of the diffuser in front of the laser optic may result in the risk of permanent eye damage.

CAUTION

Failure to heed the following cautions could result in minor or moderate injury.

Laser Caution

Caution – Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.
This device emits laser radiation. This laser product is designated Class 1 during all procedures of operation. It is advisable to avoid looking into the beam when operating the device and to turn off the module when not in use. This device must be used only according to the directions and procedures described in the Operation Manual and Technical Specifications, available at www.onsemi.com.Use of controls or adjustments, or performance of procedures other than those specified herein, may result in hazardous radiation exposure.

NOTICE

Failure to heed the following notice could result in personal or property damage, or negatively impact the device functionality.

Laser Notice
This evaluation board meets the power requirements for a Class 1 Laser product to BS EN 60825-1:2014 under normal operating conditions and those of single fault failure.

Complies with IEC / EN 60825-1:2014 and 21CFR 1040.10 and 1040.11 except for deviations pursuant to Laser Notice No.56, dated May 8th 2019.

Labelling
The following label is present on SECO-RANGEFINDER-GEVK aperture. Label shall be legible, durable and permanently attached.



Laser Notice No. 56
The following label is present on SECO-RANGEFINDER-GEVK baseplate. Label shall be legible, durable and permanently attached.

Complies with IEC / EN 60825-1:2014 and
21 CFR 1040.10 and 1040.11 except for deviations
pursuant to Laser Notice No. 56, dated May 8th 2019

Actual SECO-RANGEFINDER-GEVK board labeling
The following picture shows the actual placement of labels on the SECO-RANGEFINDER-GEVK.



1 GUI functionalities

Listed below are the functionalities of the Graphical User Interface (GUI)

1. Auto calibration upon app launch, ‘SW RESET‘ or manual with ‘TDC calibration’
2. Test range-finding capability
3. Distance or time of flight measurement
4. Operation modes:
    - Trigger: set number of laser pulses and emit them on button ‘Trigger‘
    - Run: continuously emitting pulses
5. Settable buffer length
6. Settable bias voltage for SiPM - RB photomultipliers
7. Safety:
    - Overload protection and indication on GUI for Laser and SiPM-RB bias voltages
8. Saving data:
    - Autosave / Manual save – save test data in .tof files. (Manual save only for trigger mode)
    - Formats: Time .tof (ns) /native TDC data .tdc (number of bins)
9. Loading data:
    - .tof files to the graphical. Comparisons with real-time data
10. Adjustable histogram span / automatic

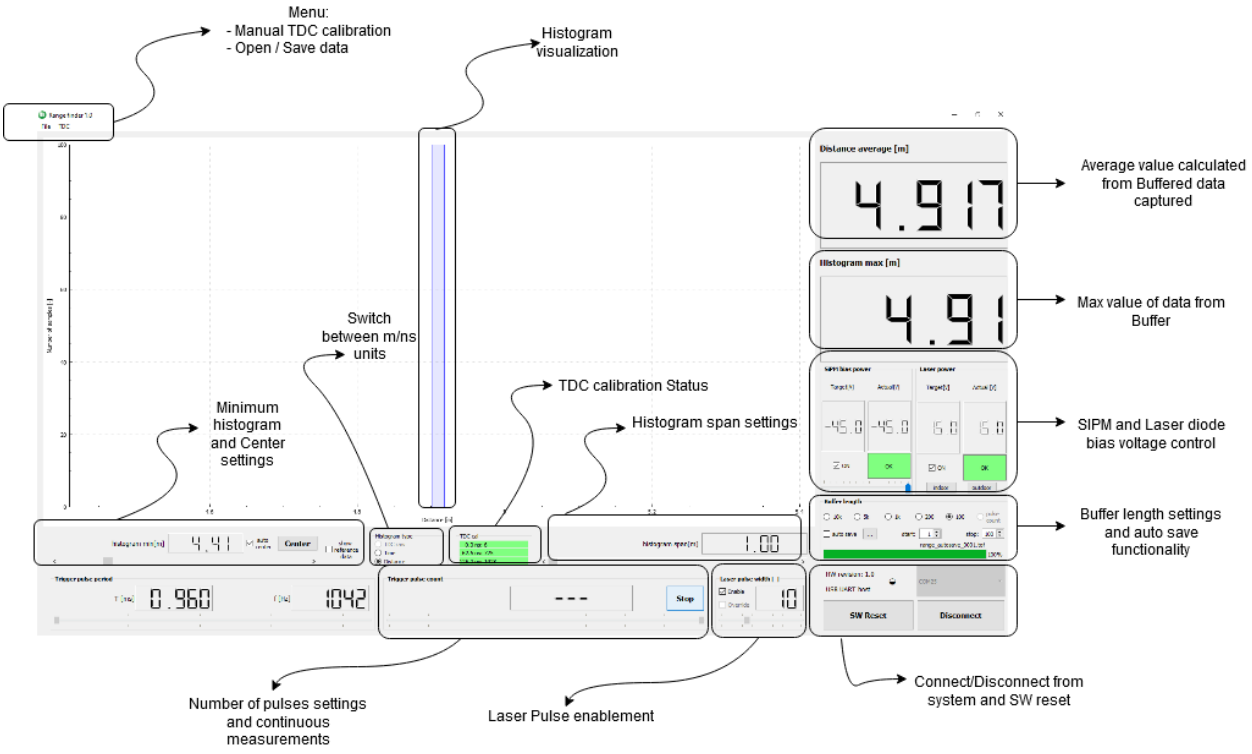


Figure 2. GUI Functionalities

2 PC Connection

The SECO-RANGEFINDER-GEVK is delivered with a USB cable. To get started, connect the USB cableto the Micro USB connector available on the board and the USB port on the computer (Fig.3).



Figure 3. Connection to the PC

3 GUI Application

Download the dedicated PC application (Range_Finder_1.0) and save it on your hard drive.

Note: The GUI application runs only on the Windows OS.

Double click on executable file range_finder to start the application.

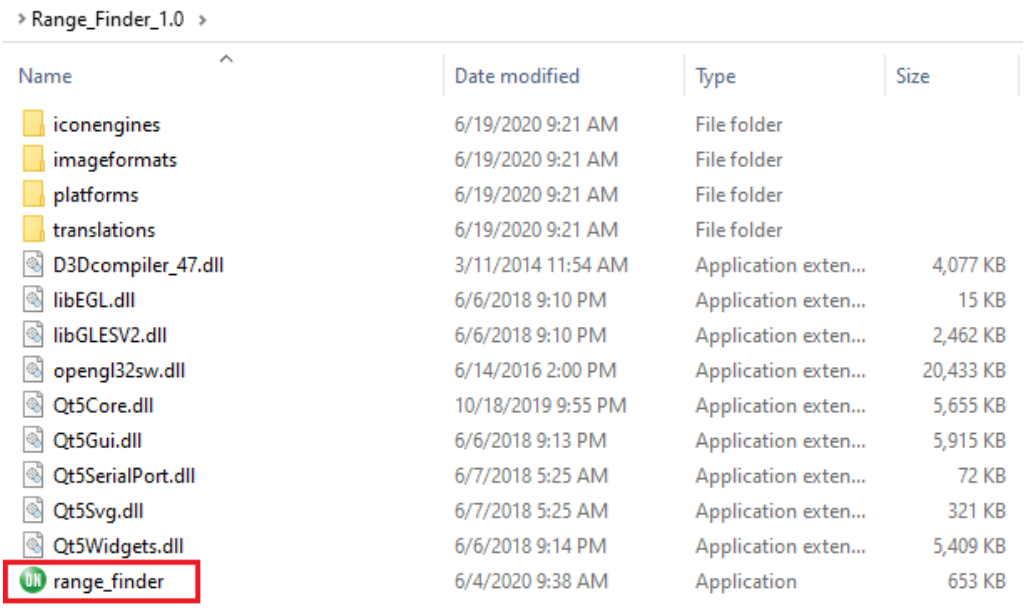


Figure 4 .*Range Finder 1.0 GUI package*

Click on ***Select port*** combo box on the right bottom side of the application and select communication port the board is connected to (Figure 5).

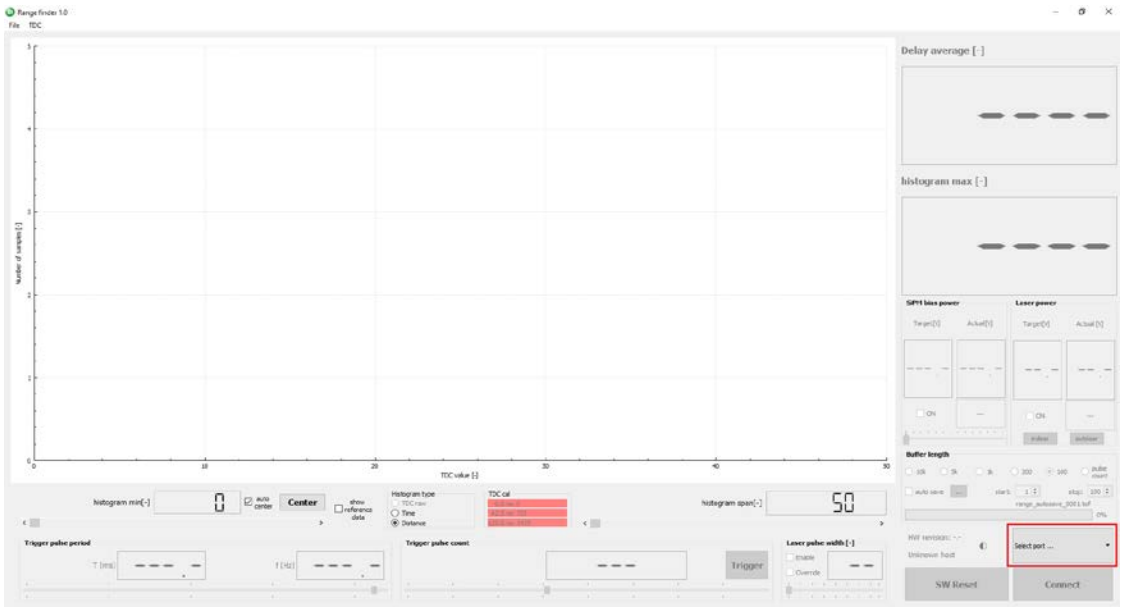


Fig.5 Select Port - Enabling the GUI application

Click on the ***Connect*** button. This will allow the application to connect to the board and gather its current configuration. The TDC calibration routine will start automatically. If the calibration is successful, new TDC calibration values will be displayed, highlighted in green. Additionally, the black semi-circle close to the Disconnect button should rotate slowly.



Figure 6. TDC calibrated automatically and application connected to LiDAR Platform

Finally, the range finding functionality can be tested:

1. Check ***SiPM bias power ON*** as well as ***Laser power ON*** checkboxes. Actual voltages shown should be within ± 0.2 V interval from target voltages. Two ***OK*** status labels with green background should be displayed. Under certain circumstances (high ambient light intensity) SiPM bias power may enter overload state indicated by red background label. If so, reduce the SiPM bias power target voltage by clicking ***outdoor*** button or using horizontal slider. The overload protection has to be cleared by unchecking ***ON*** checkbox before SiPM bias power is turned on again (Fig. 7, 8).

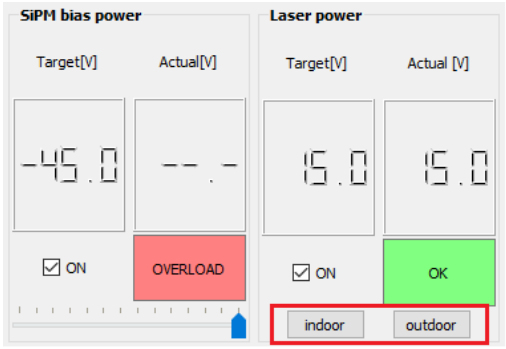


Figure 7. Overload Condition for Reference SiPM at high ambient illumination (outdoor)

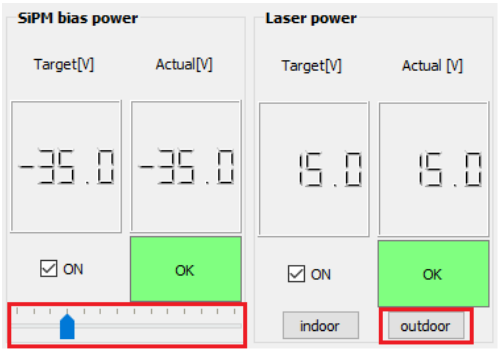


Figure 8. SiPM bias voltage reduction (clicking outdoor button or using the slider) helps to achieve OK status at high ambient illumination

2. Check also ***Enable*** checkbox in ***Laser pulse width*** box to enable laser pulse generation.
3. Click ***Trigger*** button, distance from the board and selected target (e.g. room wall) will be measured and shown in histogram as well as in big LCD displays.

   Note: the valid measuring range is approximately from 0.3 m up to 23 m (Figure 9)

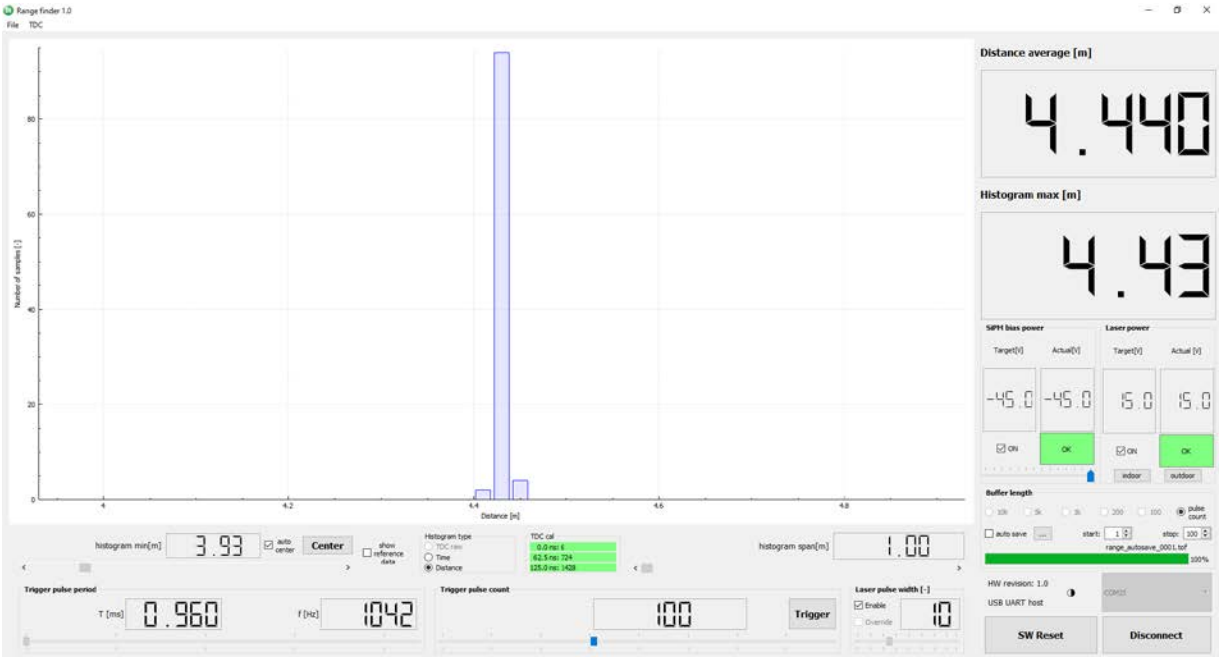


Figure 9. LiDAR Platform in Action

3.1 GUI Application Advanced Features

The LiDAR Platform's GUI application is capable of visualization Time of Flight data [ns] except default distance measurement [m]. The setting is available under ***Histogram*** type box and check ***Time*** (Fig.10). ToF data is then visualized in [ns].

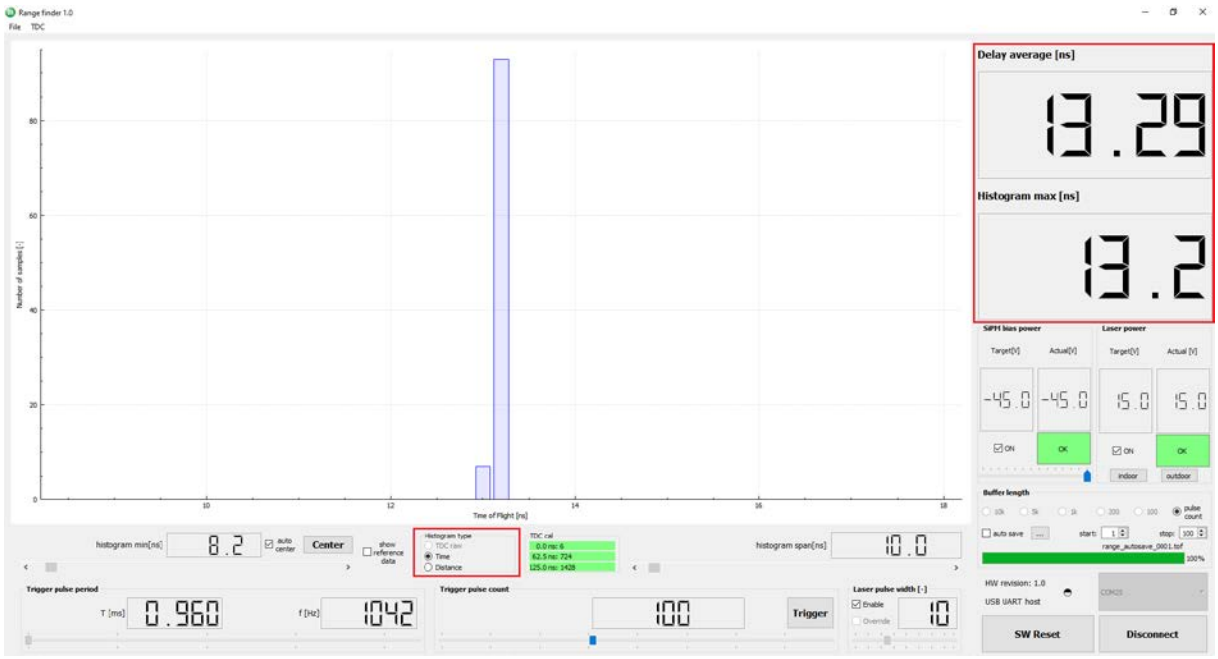


Figure 10. Switching from Distance to Time of Flight measurement [ns]

- **TRIGGER MODE**: Under the ***Trigger pulse count*** control box, user can adjust number of laser pulses emitted by Laser diode. The scale is from 1 – 254. Any number set within this range and followed by push of ***Trigger*** button, equals to number of measurements taken. Distance between the pulses is in the rhythm of 1024Hz. Thus ***Trigger pulse period*** control box is fixed to that frequency due to Laser safety compliance. For instance, setting the slider to **1** takes only single measurement, while adjustment to **100**, returns 100 measurements visualized in histogram chart with summary data depicted under ***Distance average [m]*** and ***Histogram max [m]*** (Fig. 11).



Fig.11 Trigger pulse count can be adjusted between 1 - 254 pulses

- **RUN MODE:** Under the ***Trigger pulse count*** control box, if user moves the slider to the far right end of the scale, ***Trigger*** button alters to **Run**. In this mode, Rangefinder continuously run and visualize the data. Under this operation, number of measurements taken reflects the ***Buffer length*** size.

  Rangefinder operates by default in the RUN mode with buffer length of 100. However, user can change number of measurement taken. GUI allows to buffer 100, 200, 1k, 5k or 10k data with summary calculated under ***Distance average [m]*** and ***Histogram max [m]*** (Fig. 12).

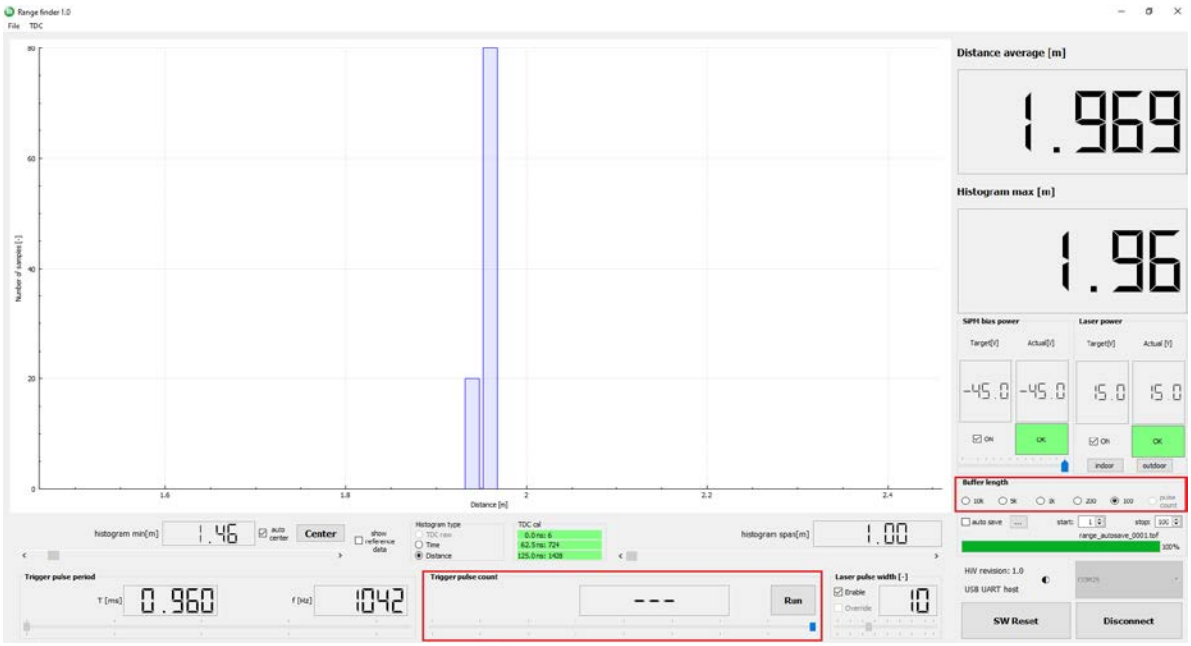


Figure 12. LiDAR Platform set in RUN mode with adjustable Buffer Length

The most critical part of any ToF measurement is storing the measured data for further processing, characterization etc. The PC application makes storing the ToF data seamlessly and in various modes:

1. **Trigger Mode- Autosave**

   In Trigger Mode, you can automatically save ToF data from a preset number of measurements. The number of measurements stored is equal to the number set by slider under ***Trigger pulse count*** control box. For instance, if you adjust 20 measurements, 20 ToF data is stored. As previously mentioned, Trigger Pulse count scale is from 1 – 254.

   In uto save mode, ***auto save*** checkbox must be checked. Once the ***Trigger pulse count*** is adjusted by slider and ***auto save*** checked, each push on ***Trigger*** button visualize and save ToF data into new file. GUI automatically creates the file name and increments its numbering whenever the ***Trigger*** button is pushed. (e.g. range_autosave_0001.tof, range_autosave_0002.tof, range_autosave_0003.tof, … range_autosave_0100.tof).

   Figure 17 depicts the settings.



Figure 13. Autosaving Measured Data in Trigger Mode

In Auto Save Mode, the particular data files are stored by default under the main GUI folder Range_Finder_1.0, where you unpacked the PC application. Each file is recognized by the .tof suffix and can be opened in any text file (Figure 14, 15).

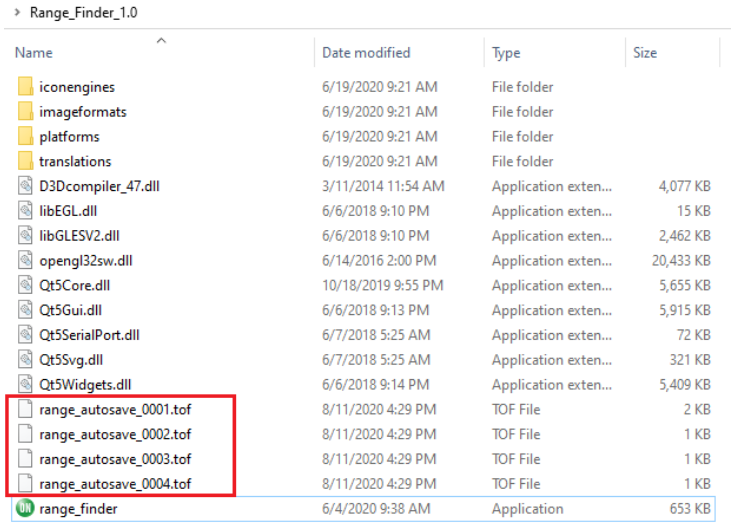


Figure 14. Trigger Mode - Auto Save Data Storage Folder

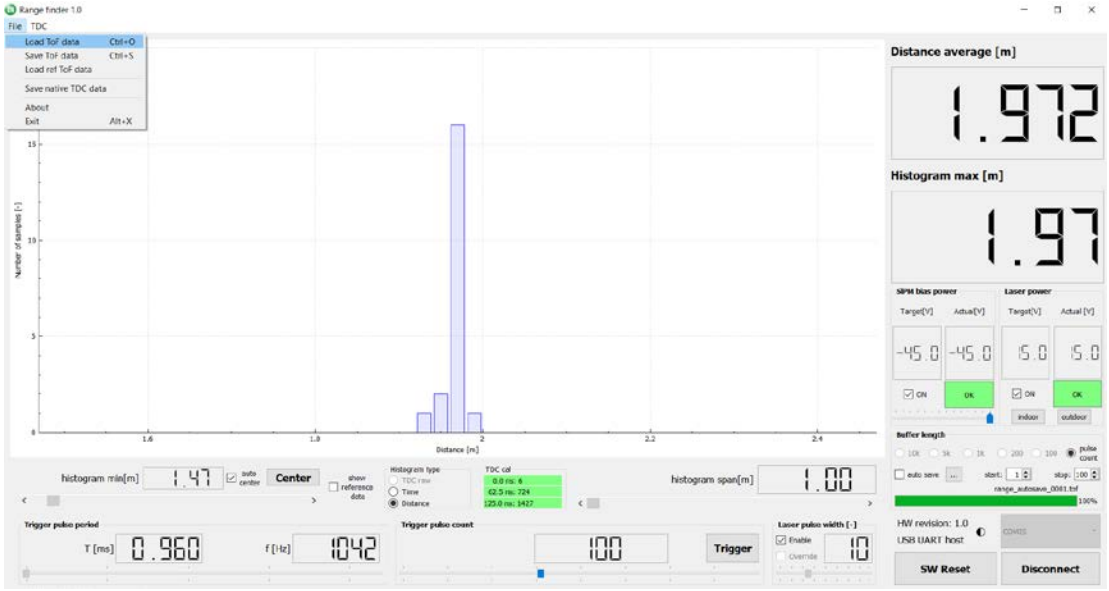
Below is shown example how the ToF data is stored for the specific case of 20 measurements (***Trigger Pulse count*** set to 20). Time of Flight data is saved in nanoseconds. Along with ToF values, Operating conditions and TDC calibration values are stored as well.

range_autosave_0002.tof

```
1  ******************************
2  TDC calibration values:
3    0.0 ns:   6    OK
4   62.5 ns:   722  OK
5  125.0 ns:   1424     OK
6  ******************************
7  Operating conditions:
8  Laser pulse width setting:  10
9  Trigger pulse period:   0.000960
10 Bias power supply voltage:  -45.0
11 Laser power supply voltage:     15.0
12 ******************************
13 Time of Flight data [ns]:
14 13.180866
15 13.180866
16 13.180866
17 13.180866
18 13.180866
19 13.180866
20 13.180866
21 13.268156
22 13.268156
23 13.180866
24 13.180866
25 13.180866
26 13.180866
27 13.180866
28 13.093575
29 13.180866
30 13.180866
31 13.268156
32 13.180866
33 13.180866
34 ******************************
35
```

Figure 15. Stored Data Example after .tof file opening in text editor

At any time, you can access the stored data and load it into the GUI directly from menu ***File*** -> ***Load ToF data***. Simply open the .tof file you want to load the ToF data from and click OK. The PC application shows them accordingly. Please follow the steps depicted in Figure 16.



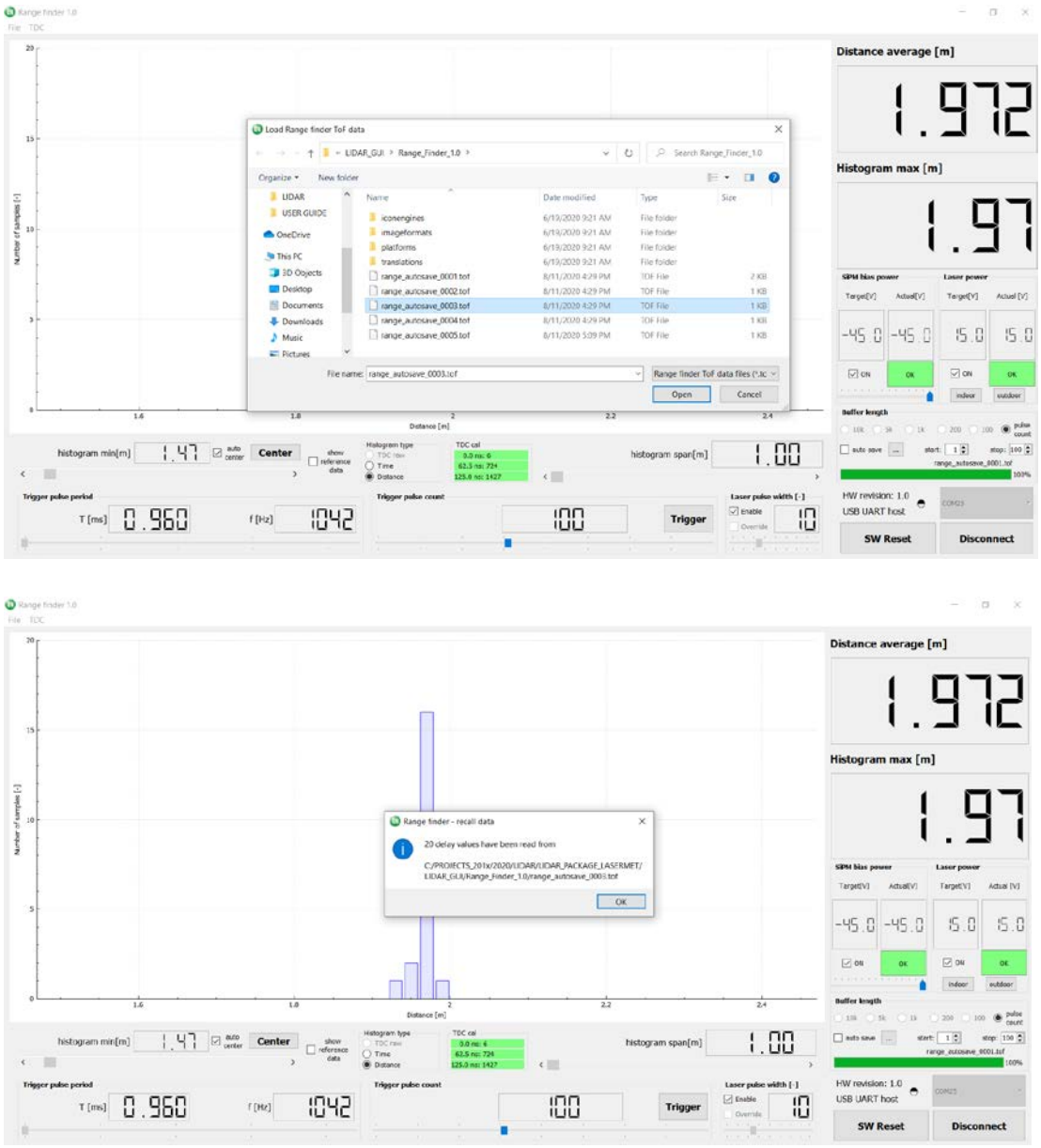


Fig.16 Loading already stored ToF data from the file out of the GUI Menu

2. **TRIGGER MODE – AUTOSAVE (custom ToF file name and storage destination):**
   This mode offers the same functionality as discussed under **1.** but allows you to set your own naming convention for .tof files and have the freedom regarding the storage place. In Auto Save Mode, first uncheck the ***auto save*** checkbox under ***Buffer length*** control box.
   Open three dots ***(…)*** box next to the ***auto save*** checkbox under ***Buffer length*** and select your own .tof file name and destination, e.g. *Custom_Name_ToF_data_File.tof*. User is also capable to set the maximum number of files, automatically generated, under ***start:*** and ***stop:*** fields within ***Buffer length*** control box.
   The maximum number of data files automatically stored is 100.
   Let's allow storage of maximum 5 files, so the setting will look like ***start:1*** and ***stop:5.***

After the destination and file name has been determined, click on the SAVE button and path with selected file name and assigned **start:** number is reflected at ***Buffer length*** control box. In our case, ***start:1*** setting generates *Custom_Name_ToF_data_File0001.tof* into selected destination.

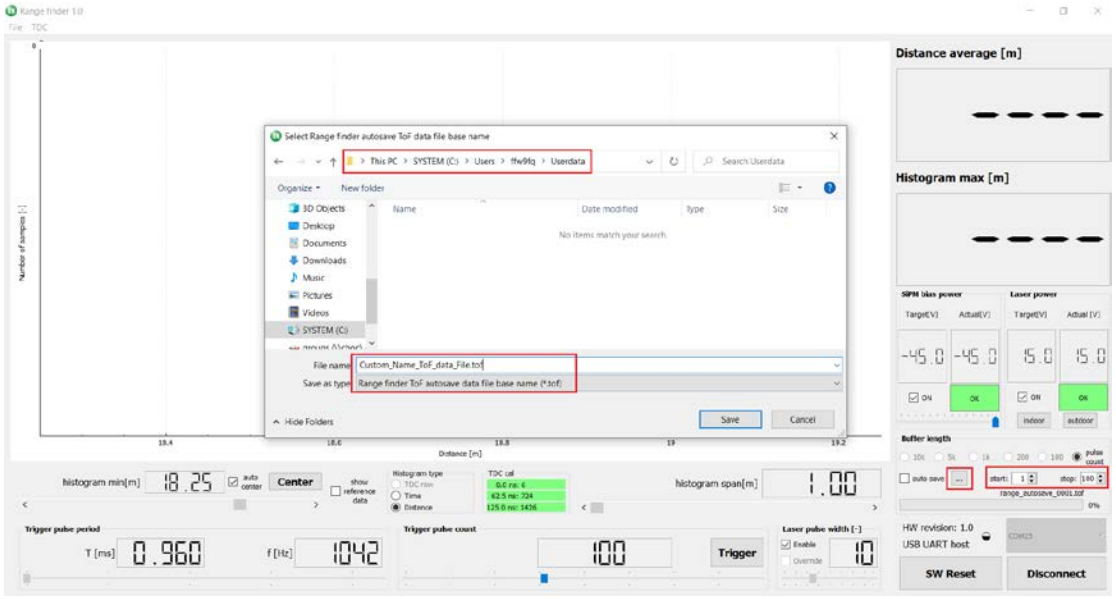
The last step is to enable ***auto save*** checkbox (***start:*** and ***stop:*** fields are shaded). Now you're ready to take and save the ToF data.

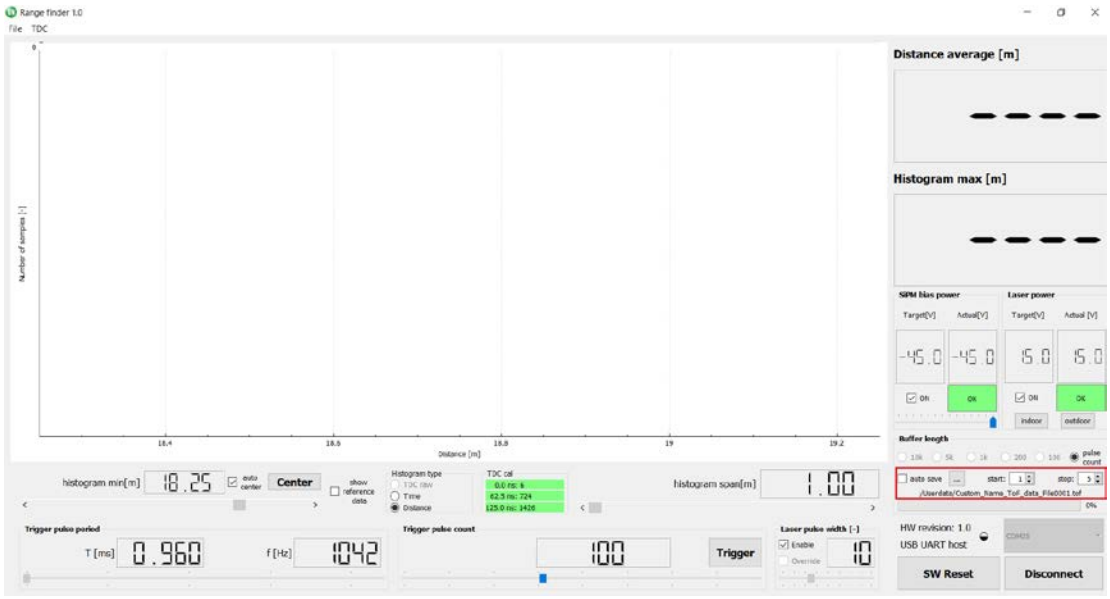
Each push on ***Trigger*** button visualize and save ToF data into new file. GUI automatically increment the file's numerical suffix whenever the ***Trigger*** button is pushed. (in our case *Custom_Name_ToF_data_File0001.tof, Custom_Name_ToF_data_File0002.tof, Custom_Name_ToF_data_File0003.tof, Custom_Name_ToF_data_File0004.tof, Custom_Name_ToF_data_File0005.tof*).

Once the ***stop:*** field reaches 5 corresponding to generation of last file (*Custom_Name_ToF_data_File0005.tof),* GUI returns the notification ''*Auto save function saved last file*''.

Data stored in these .tof files can be anytime loaded into GUI as outlined in bullet **1.**

Figure 17 shows the complete flow described above.




Range finder 1.0
File TDC
Distance average [m]
Histogram max [m]
SPM bias power
Laser power
Target[V]
Actual[V]
-45.0
-45.0
15.0
15.0
ON
OK
indoor
outdoor
Buffer length
pulse count
auto save
start:
stop:
0%
HW revision: 1.0
USB UART host
SW Reset
Disconnect
Number of samples [-]
Distance [m]
18.4
18.6
18.8
19
19.2
histogram min[m]
18.25
auto center
Center
show reference data
Histogram type
TDC raw
Time
Distance
TDC cal
0.0 ns: 0
62.5 ns: 724
125.0 ns: 1426
histogram span[m]
1.00
Trigger pulse period
T [ms]
0.960
f [Hz]
1042
Trigger pulse count
100
Trigger
Laser pulse width [-]
Enable
Override
10


Range finder 1.0
File TDC
Distance average [m]
Histogram max [m]
SPM bias power
Laser power
Target[V]
Actual[V]
-45.0
-45.0
15.0
15.0
ON
OK
indoor
outdoor
Buffer length
pulse count
auto save
start:
stop:
0%
HW revision: 1.0
USB UART host
SW Reset
Disconnect
Number of samples [-]
Distance [m]
18.4
18.6
18.8
19
19.2
histogram min[m]
18.25
auto center
Center
show reference data
Histogram type
TDC raw
Time
Distance
TDC cal
0.0 ns: 0
62.5 ns: 724
125.0 ns: 1426
histogram span[m]
1.00
Trigger pulse period
T [ms]
0.960
f [Hz]
1042
Trigger pulse count
100
Trigger
Laser pulse width [-]
Enable
Override
10

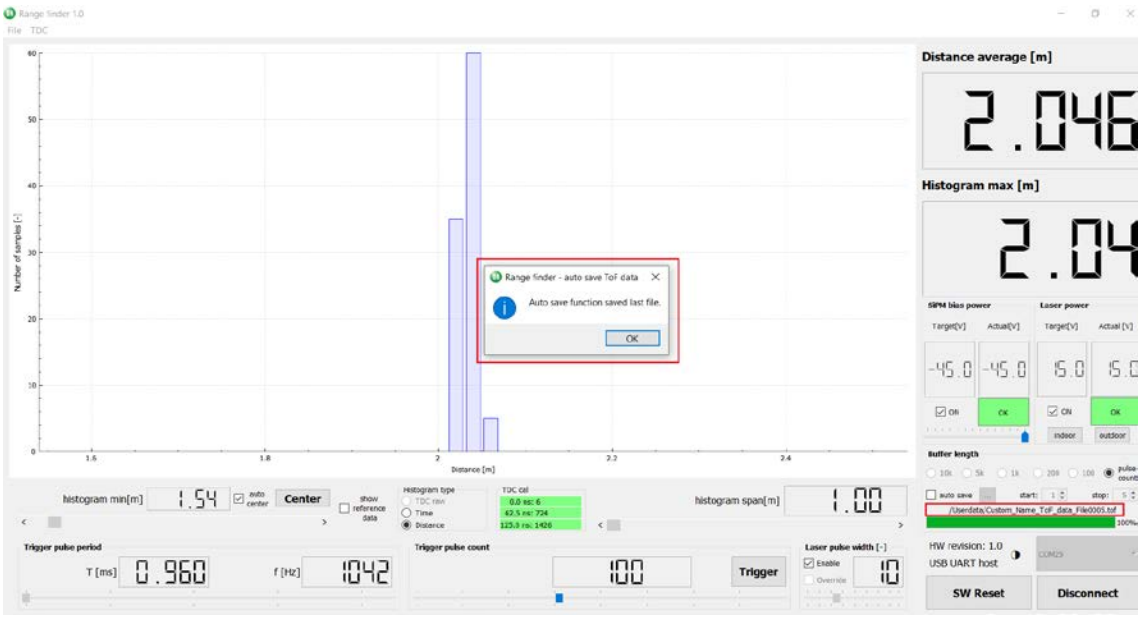
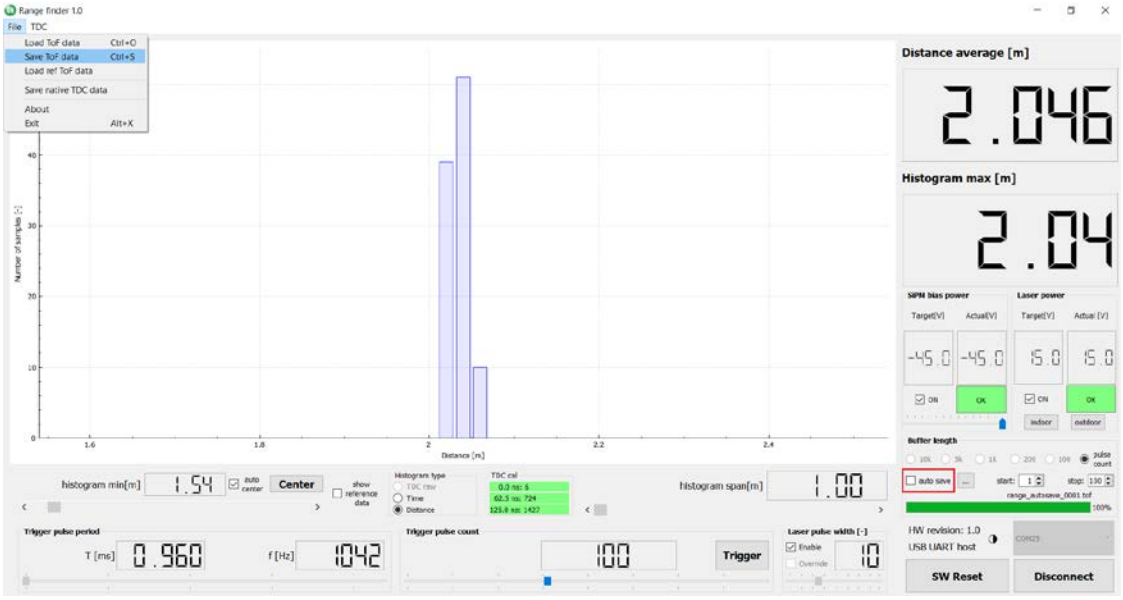


Figure 1.7 Autosaving Measured Data in Trigger Mode for Custom ToF File Names and Storage Destination

3. Trigger Mode – Manual Save

To use your own naming convention for .tof files without incrementing and for freedom of saving locations, uncheck the ***auto save*** checkbox in Manual Save Mode. This is unlike the process in Auto Save Mode where the storage folder is fixedFigure 18 shows the procedure for how to store the measured data into custom file name and location.

To save the ToF data with custom name and storage location, go to menu ***File*** -> ***Save ToF data***. Write your own file name and point to destination, where the data will be stored. Click OK. PC application writes the measured data accordingly. In the Trigger mode – Manual save, only one .tof data file can be stored.



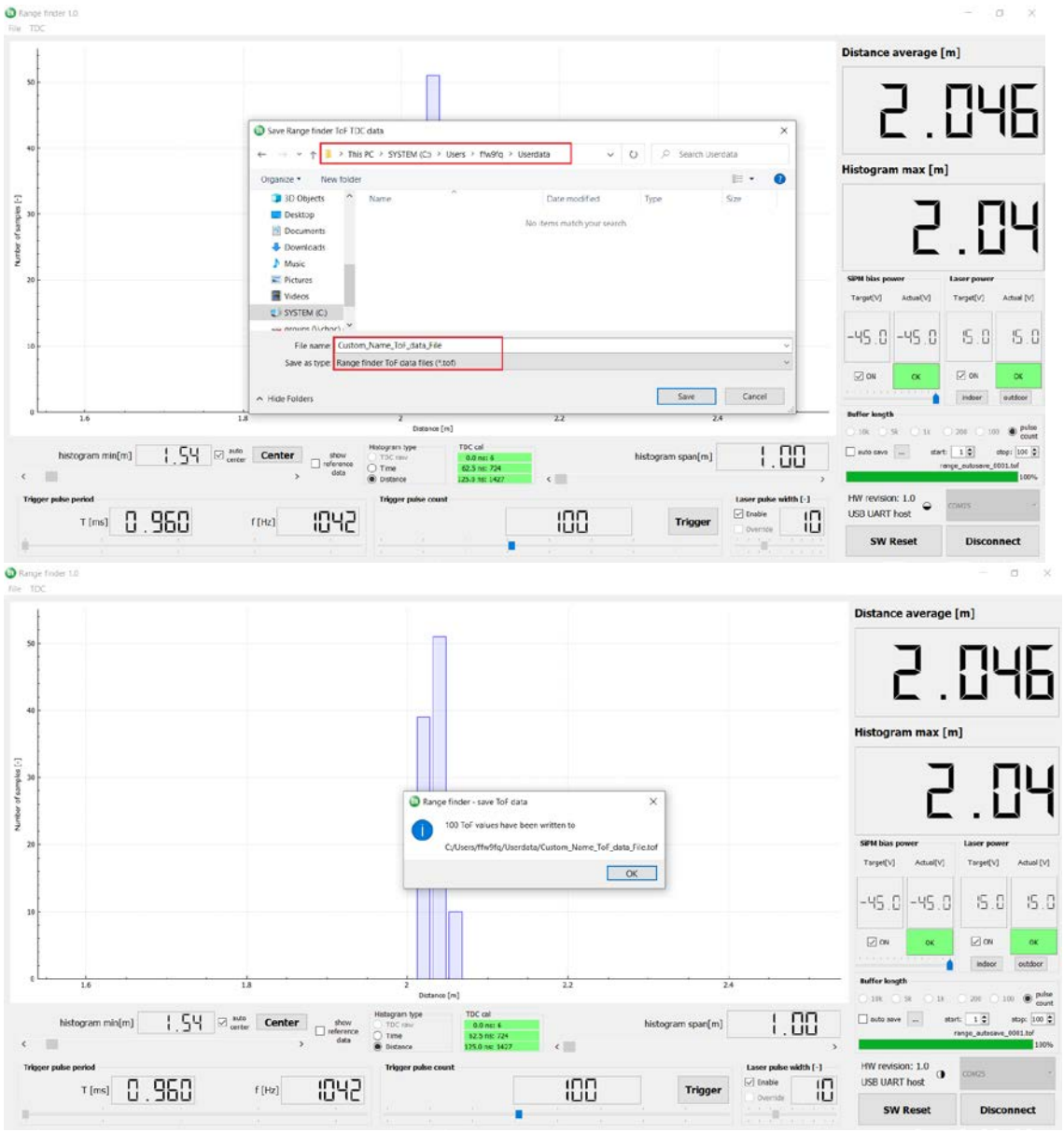


Fig.18 Custom File name creation and ToF data storage

4. Run Mode- Autosave

In ***Run*** mode, the GUI automatically saves ToF data into auto generated files and location as described in bullet **1.** Number of measurements stored in single file equal to number set by ***Buffer length*** control box (100, 200, 1k, 5k or 10k data). ***Trigger pulse count*** control box must have the slider moved to the far right end of the scale, where ***Trigger*** button alters to ***Run***. Hitting the ***Run*** button, once ***auto save*** checkbox is checked, ensures continuous measurement and consecutive auto generation of files with data length preset under ***Buffer length.***

Maximum number of files stored is 100. Fig. 19 depicts the actual implementation with 5k buffer length.

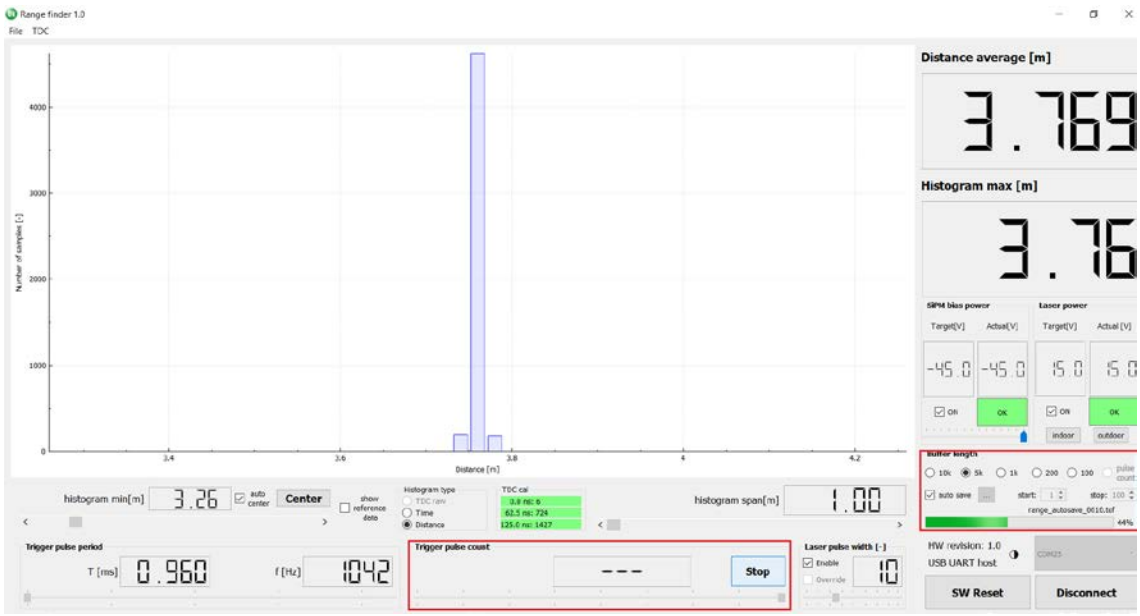


Figure 19. Auto Saving Measured Data in Run Mode

5. Run Mode – Autosave

In ***Run*** mode, the GUI automatically saves ToF data into your selected file name and destination location as described in Bullet 5**.**

The number of measurements stored in a single file is equal to the number set by ***Buffer length*** control box (100, 200, 1k, 5k or 10k data). The ***Trigger pulse count*** control box must have the slider moved to the far right end of the scale, where ***Trigger*** button alters to ***Run***. Selecting the ***Run*** button once ***auto save*** checkbox is checked, ensures continuous measurement and consecutive auto generation of custom named files to set location with suffix given by the **start:** and **stop:** fields and data length preset under ***Buffer length*** control box***.***

The maximum number of files stored is 100. Figure 20 depicts the actual implementation with ***1k*** buffer length and selected file name *Run_mode_custom_file.tof*. **start:5** and **stop:20** generates 15 files in selected destination with appropriate incremental suffix at the end of the custom file name (*Run_mode_custom_file0005.tof* to *Run_mode_custom_file0020.tof*).

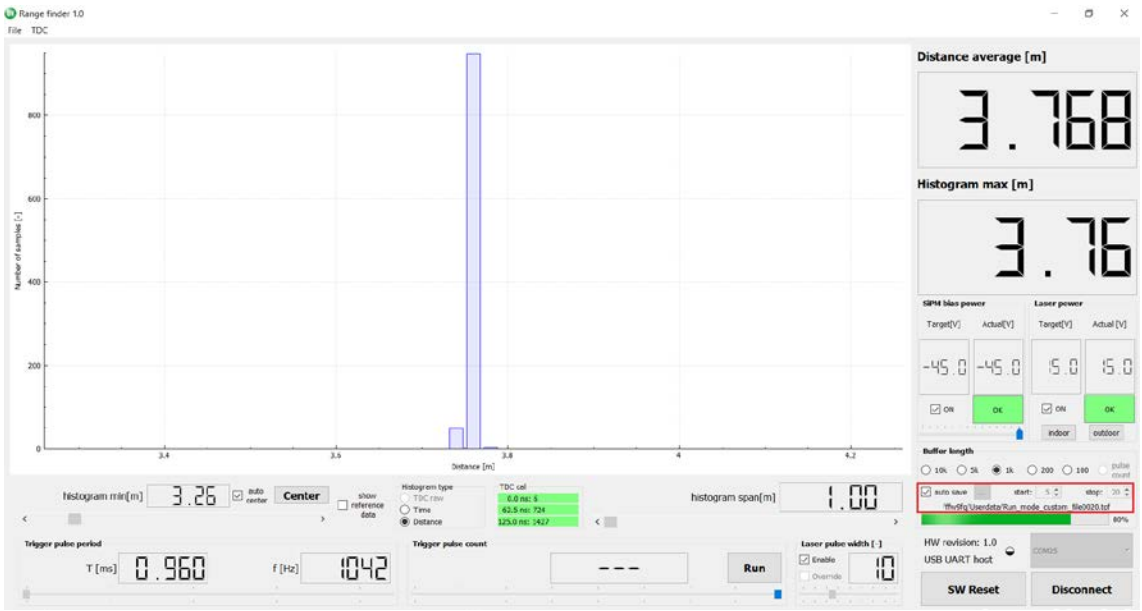
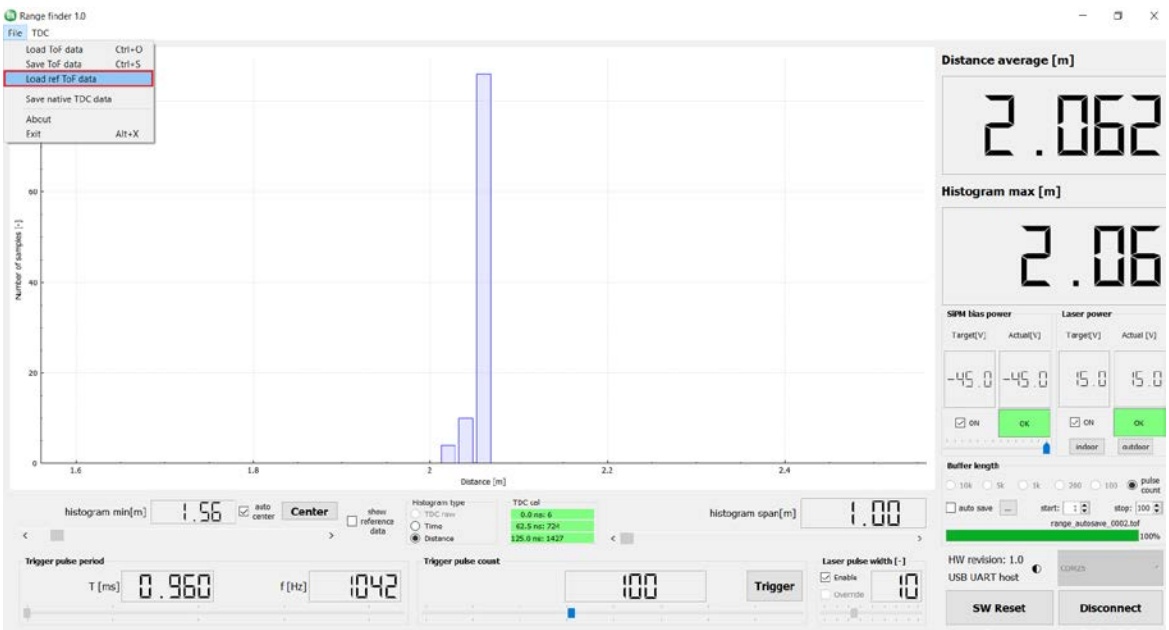


Figure 20. Run Mode – AUTOSAVE Custom ToF File Name and Storage Destination

One of the benefits of the PC application is ability to bring the store data outlined above and compare it visually with real-time data in both Trigger and Run Mode. The stored file can be brought to the GUI by menu File -> Load ref ToF data and histogram color appears in green (Fig. 21). This arrangement can be useful if user wants to visually asses e.g. the same distance and target at different number (stored vs. real-time) of samples and ambient illumination.



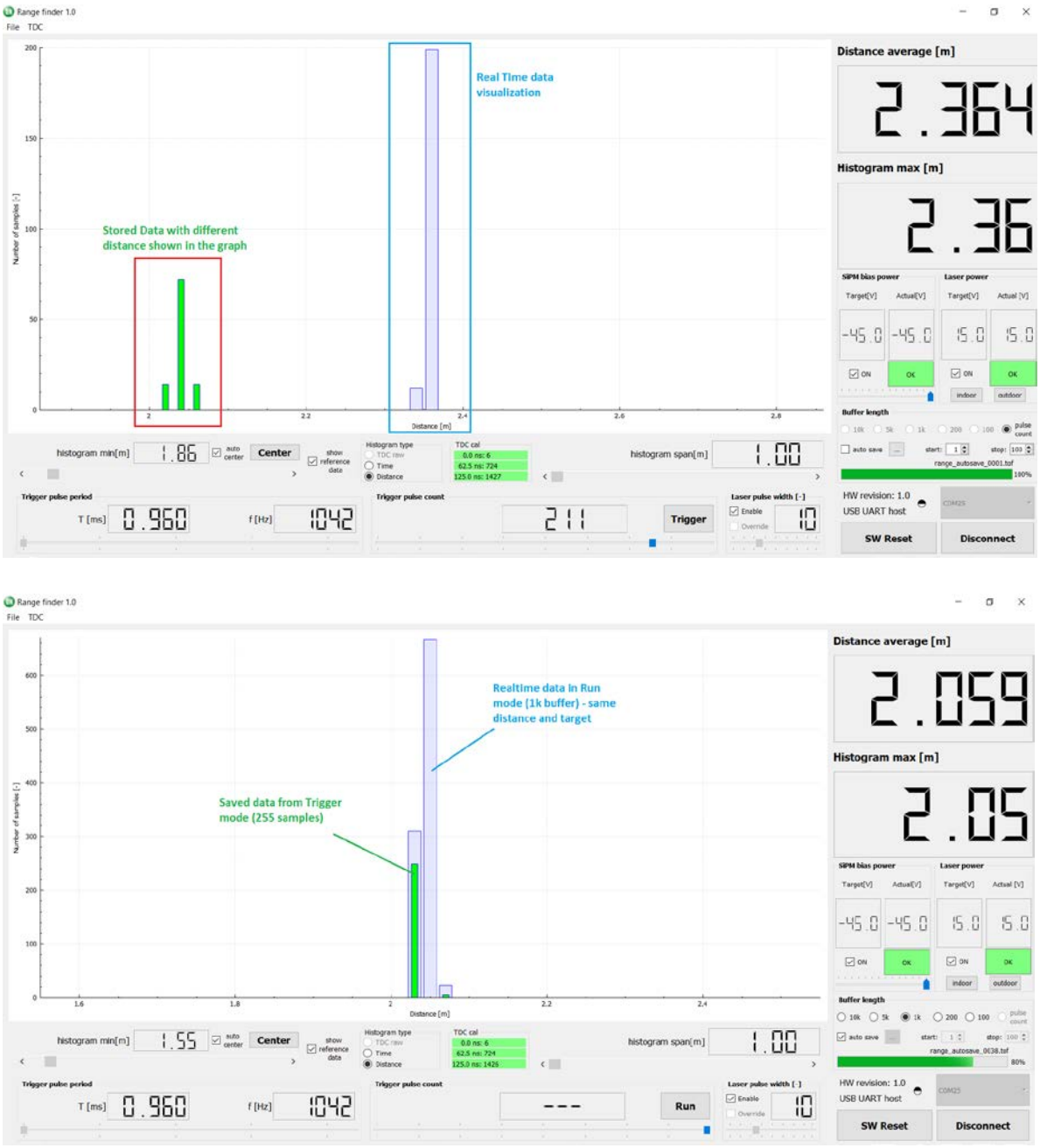
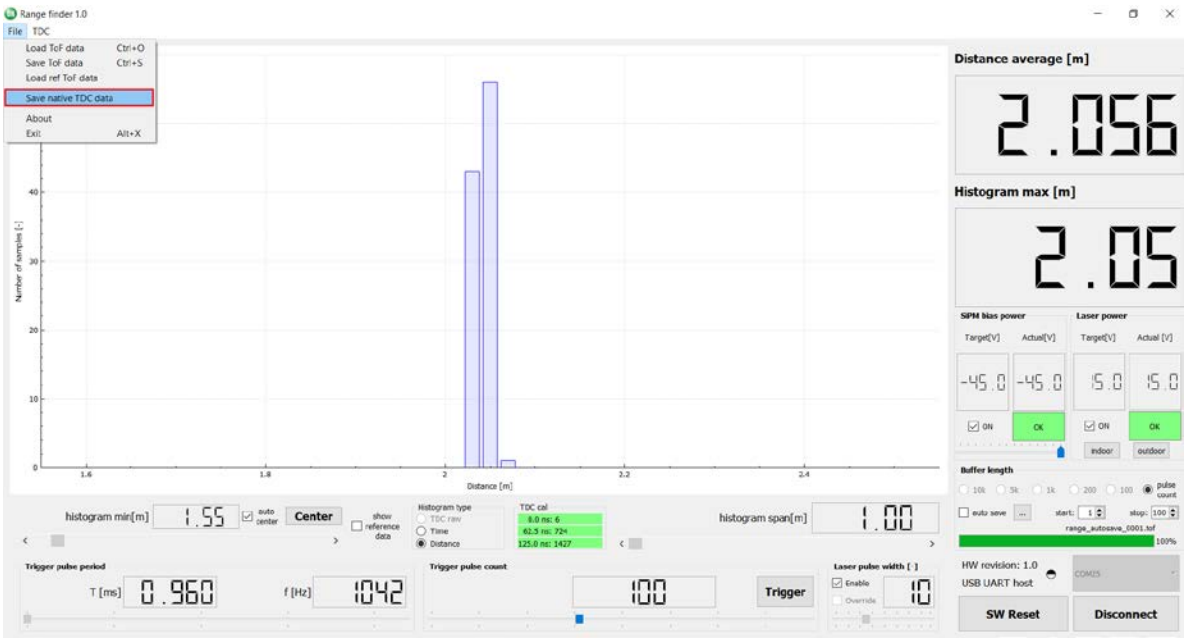
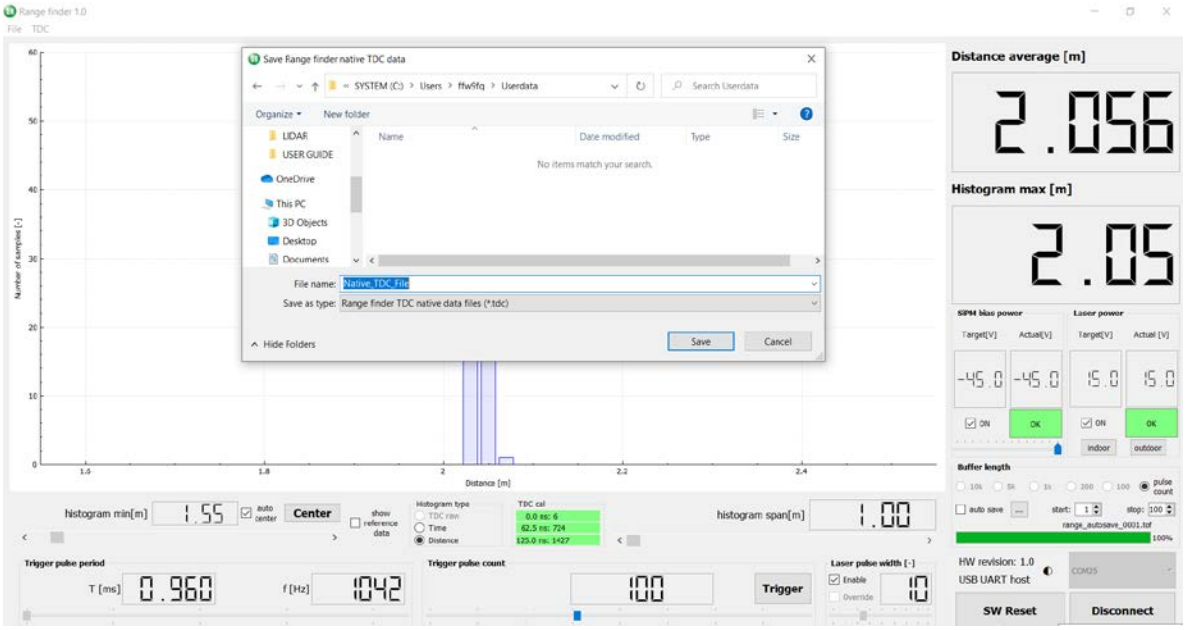
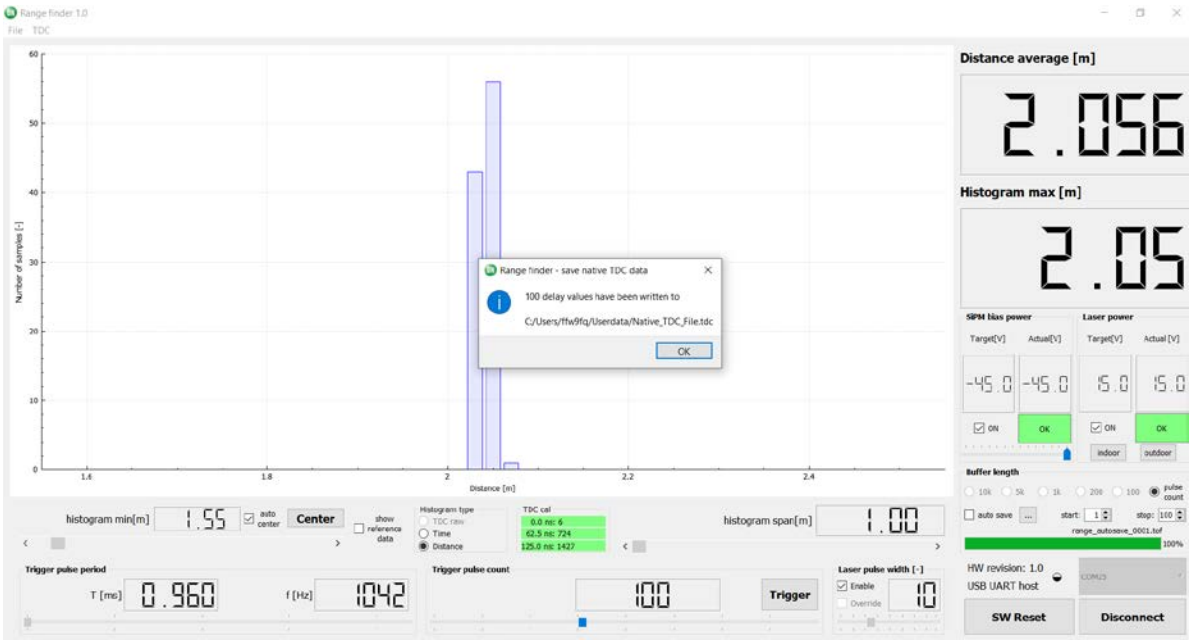


Figure 21. Loading the Stored ToF data and Comparing to Real-time Measurements

The GUI application can save Native TDC data. It represents the number of bins that correspond to measured distance, multiplied by the propagation delay of single bin. Figure 22 shows the procedure of how to capture and store the TDC bins corresponding to actual ToF and recalculated distance. It can be stored under ***File*** -> ***Save native TDC data*** and opened in any text editor. The file suffix is .tdc.


Range finder 1.0
File TDC
Load ToF data Ctrl+O
Save ToF data Ctrl+S
Load ref ToF data
Save native TDC data
About
Exit Alt+X
Number of samples [-]
Distance [m]
Distance average [m]
2.056
Histogram max [m]
2.05
SiPM bias power
Laser power
Target[V]
Actual[V]
-45.0
-45.0
15.0
15.0
ON
OK
indoor
outdoor
Buffer length
pulse count
auto save
start: 1
stop: 100
range_autosave_0001.tof
100%
HW revision: 1.0
USB UART host
COM25
SW Reset
Disconnect
histogram min[m]
1.55
auto center
Center
show reference data
Histogram type
TDC raw
Time
Distance
TDC cal
0.0 ns: 6
62.5 ns: 724
125.0 ns: 1427
histogram span[m]
1.00
Trigger pulse period
T [ms]
0.960
f [Hz]
1042
Trigger pulse count
100
Trigger
Laser pulse width [-]
Enable
Override
10


Range finder 1.0
File TDC
Save Range finder native TDC data
SYSTEM (C:) > Users > ffw9fq > Userdata
Search Userdata
Organize
New folder
LIDAR
USER GUIDE
OneDrive
This PC
3D Objects
Desktop
Documents
Name
Date modified
Type
Size
No items match your search.
File name: Native_TDC_File
Save as type: Range finder TDC native data files (*.tdc)
Hide Folders
Save
Cancel
Number of samples [-]
Distance [m]
Distance average [m]
2.056
Histogram max [m]
2.05
SiPM bias power
Laser power
Target[V]
Actual[V]
-45.0
-45.0
15.0
15.0
ON
OK
indoor
outdoor
Buffer length
pulse count
auto save
start: 1
stop: 100
range_autosave_0001.tof
100%
HW revision: 1.0
USB UART host
COM25
SW Reset
Disconnect
histogram min[m]
1.55
auto center
Center
show reference data
Histogram type
TDC raw
Time
Distance
TDC cal
0.0 ns: 6
62.5 ns: 724
125.0 ns: 1427
histogram span[m]
1.00
Trigger pulse period
T [ms]
0.960
f [Hz]
1042
Trigger pulse count
100
Trigger
Laser pulse width [-]
Enable
Override
10



Native_TDC_File.tdc

```
1  ********************************
2  TDC calibration values:
3    0.0 ns:   6    OK
4   62.5 ns:   724  OK
5  125.0 ns:   1427     OK
6  ********************************
7  Operating conditions:
8  Laser pulse width setting:  10
9  Trigger pulse period:   0.000960
10 Bias power supply voltage:  -45.0
11 Laser power supply voltage:     15.0
12 ********************************
13 Native TDC data:
14 162
15 163
16 164
17 164
18 164
19 164
20 164
21 164
22 164
23 163
24 163
25 163
26 164
```

Figure 22. Saving the Native TDC File

The LiDAR platform system can be reset at any time by pressing the ***SW Reset*** button. After this, start-up of the system occurs with automatic launch of TDC calibration (Figure.23).

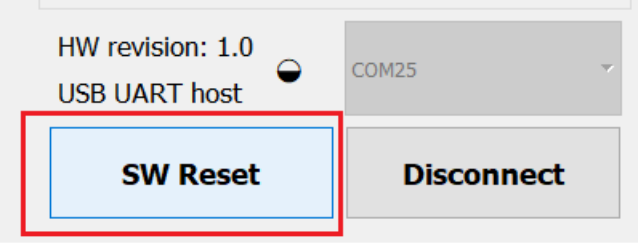


Figure 23. Software System RESET

The TDC is normally calibrated automatically once the PC application is launched or if ***SW Reset*** button is pressed. The easiest way to re-calibrate the TDC is by pushing the Calibrate button under the menu, as shown in Fig. 24. This function is useful when environmental conditions, like temperature, changes and you need to achieve the highest accuracy of measured data.

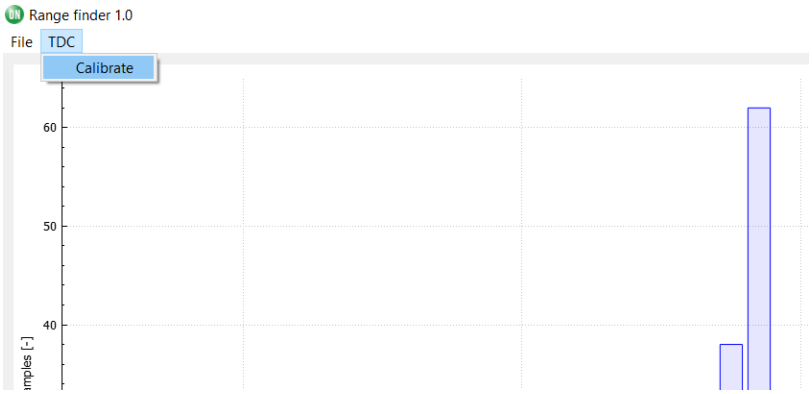


Figure 24. TDC Calibration Activation

When you are finished working with the GUI, it is recommended to safely disconnect the LiDAR platform from the communication port. The Disconnect button is used for this purpose (Figure 25).



Figure 25. Disconnect Button to Deactivate Communication Interface