

SiPM dToF LiDAR Platform User Guide

SECO-RANGEFINDER-GEVK

Description

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).

Features

- Direct ToF Operation for a Single Point
- > 0.11 m to 23 m Distance
- 650–1050 nm BK7 Plano-convex Lenses to Maximize Distance Measurement
- Out-of-the Box Operation with Dedicated GUI
- FDA Certified
- Single Power Supply
(either from USB = 5 V or PMOD Connector = 3.3 V)
- FPGA-based Time-to-Digital Convertor (TDC)
- Single Power Supply
(either from USB = 5 V or PMOD Connector = 3.3 V)
- Optimized System Cost
- Extendable System with the Bluetooth® Development Kit (BDK-GEVK) and Other Various Sensors and Actuators

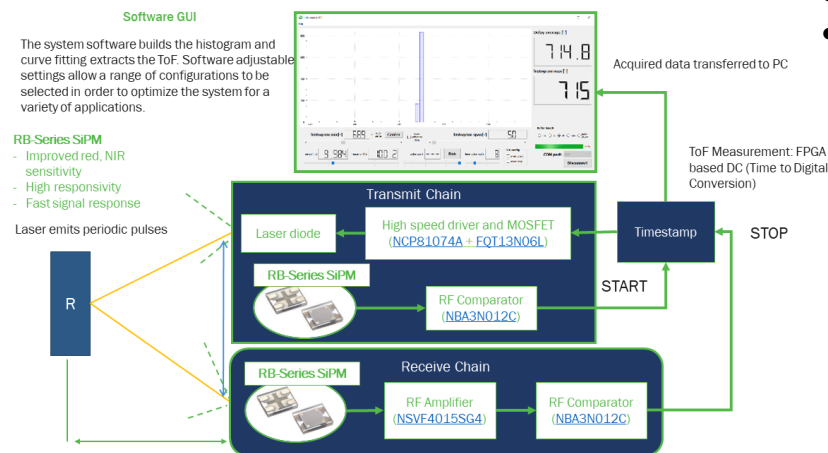


Figure 2. Block Diagram



ON Semiconductor®

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USER MANUAL

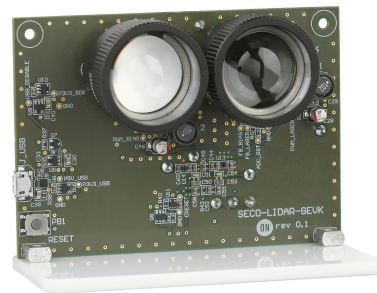


Figure 1. SECO-RANGEFINDER-GEVK

Applications

- Indoor Navigation and Rangefinding
- Collision Detection
- 3D Mapping

Collateral (See More Information on Page 54)

- [SECO-RANGEFINDER-GEVK](#)
- [MICRORB-10010-MLP](#) – SiPM Photodiode (RB Series)
- [NSVF4015SG4](#) – RF Transistor
- [NBA3N012C](#) – Discriminator (RF Comparator)
- [NCP81074A](#) – High Speed MOSFET Driver
- [FQT13N06L](#) – Logic Level MOSFET for Laser Diode

SECO-RANGEFINDER-GEVK

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.

Any modifications to the product, including but not limited to change of electronic components, optics, or FPGA code 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.



Scope and Purpose

This user guide provides practical guidelines for using dToF platform SECO-RANGEFINDER-GEVK and describes in details the overall functionality of the board. It 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

SECO-RANGEFINDER-GEVK

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.

Prerequisites

- SECO-RANGEFINDER-GEVK is delivered preprogrammed and with USB cable, enabling plug and play functionality.
- GUI PC application Range_Finder_1.0 available at www.onsemi.com/lidarrangefinder.

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INTRODUCTION

Within the Internet of Things (IoT), there are an increasing number of ranging and sensing applications looking to benefit from low-power, high performance SiPM technology. In particular, LiDAR (light detection and ranging) applications that use eye-safe near infrared (NIR) wavelengths such as Automotive ADAS (Advanced Driver Assistance Systems), 3D depth maps, mobile, consumer and industrial ranging.

In order to take advantage of the SiPM sensor's high gain and high bandwidth, the use of direct time-of-flight (dToF) can be used to provide accurate ranging with the lowest power budget. The high sensitivity of ON Semiconductor's SiPM allows the use of low power lasers for increased eye-safety. ON Semiconductor have created a software model that allows for accurate determination of system performance for a wide range of input conditions, as well as a hardware ranging platform incorporating a SiPM sensor.

The Direct Time of Flight (dToF) SiPM LiDAR demonstrates a complete rangefinding application and helps developers becoming familiar with the underlying technologies and all necessary building blocks. Furthermore, the kit helps in evaluating the core components of the system, such as the SiPM sensor. Via test points provisioned on the hardware and a variety of functionalities and configurable parameters on the GUI developers will find a fast and user-friendly way to evaluate the kit and get up to speed with the application.

Features

- Direct ToF operation for a single point
- Target Distance: > 0.11 m to 23 m

- 650-1050 nm coated BK7 Plano-convex lenses to maximize distance measurement
- 905 \pm 5 nm Band pass optical filter (FWHM: 30 \pm 5 nm) for receiving SiPM diode and getting the highest sensitivity in selected spectrum
- 905 nm laser diode transmitter
- RB-Series SiPM detector
- FPGA-based Time-to-Digital Convertor (TDC), readout, communication interface and control of two regulated bias supplies
- Out-of-the box operation with dedicated PC application (GUI)
- Single power supply (either from USB = 5 V or PMOD connector = 3.3 V)
- 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 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
- Optimized system cost
- Software adjustable settings for variety of industrial and IoT applications
- Extensible Platform - can connect to Bluetooth Development Kit ([BDK-GEVK](#)) and other various sensors and actuators

Application Capabilities

1. Auto calibration upon app launch, 'SW RESET' or manual with 'TDC calibration'
2. Test rangefinding 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

SECO-RANGEFINDER-GEVK

SPECIFICATION

This development board offers plug and play functionality based on the dToF single point measurement for ranging and sensing applications. It consists of the Silicon Photomultiplier (SiPM) that is

a single-photosensitive, high performance, solid-state sensor.

The foremost advantages that this development board brings are summarized in Table 1.

Table 1. SUMMARY OF KEY DTOF RANGEFINDER BOARD FEATURES

Key Attributes of dToF Rangefinder	dToF Optics Architecture	Biaxial
	Minimum Distance [m]	0.11 m
	Maximum Distance [m]	23 m
	Accuracy	Refer to section Measurement Error (Figure 44)
Laser Diode	Type	SPL PL 90_3 (905 nm/75 W peak radial laser diode)
	Laser Voltage [V]	15 V (Fixed)
	Optical Pulse Width [ns]	18 ns
	Laser Repetition Rate [Hz]	1042 Hz
FoV (Field of View)	Horizontal Beam Divergence	2.26°
	Vertical Beam Divergence	0.74°
Reference Diode (START Signal)	Type	MICRORB-10010-MLP
Receiving Diode (STOP Signal)	Type	MICRORB-10010-MLP
DCDC Step Down Converter for Laser Diode	Control	Digital (FPGA), regulated, OCP protection
	Output Voltage [V]	15 V (Fixed)
	Output Current Limit [mA]	42 mA
DCDC Inverting Converter for Receiving and Reference SiPM	Control	Digital (FPGA), regulated, OCP protection
	Output Voltage [V]	Regulated -32 V down to -45 V over PC application
	Output Current Limit [mA]	3.9 mA (@ -45 V) to 5.8 mA (@ -32 V)
System Supply Voltage	USB Cable [V]	5 V
	PMOD Connector [V]	3.3 V
	Voltage Selection between USB/PMOD	Automatic (PMOD has a priority)
Communication Interface	Type	UART
Time to Digital Converter	Type	FPGA based – binning TDC
	Bin Width [ps]	~85 ps
	TDC Calibration	Automatic – FPGA reference clock source (crystal)
	Number of FPGA Bins	>1800
Optics	Type	Plano-convex spherical lens, glass N-BK7
	AR Coating [nm]	650-1050 nm
	Diameter [mm]	25.4 mm (1")
	Design Wavelength [nm]	587.6 nm
Band Pass Optical Filter	CWL [nm]	905 ±5 nm
	FWHM [nm]	30 ±5 nm
Laser Safety	Limits and Single Laser Diode Fault Compliance	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 standard IEC/EN 60825-1:2014 and 21 CFR 1040.10 and 1040.11 except for deviations pursuant to Laser Notice No. 56

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SYSTEM OVERVIEW

Figure 3 depicts the operational principle of the dToF SECO-RANGEFINDER-GEVK. It consists of these main system blocks:

- FPGA (ice40)

- DCDC converters circuit
- Laser and Reference circuit (Tx)
- Receiving circuit (Rx)
- Supply management circuitry and UART control logic

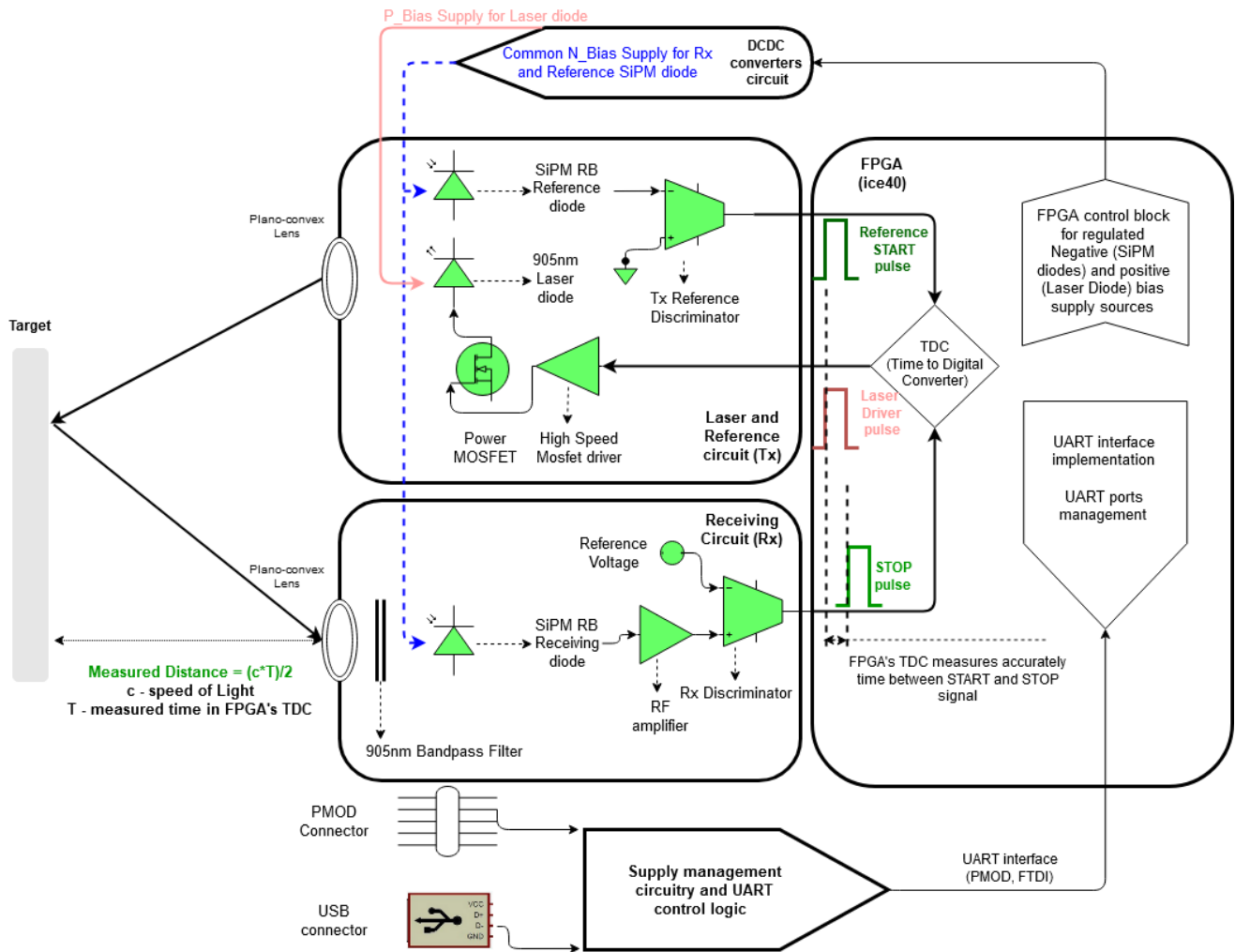


Figure 3. Operation Principle of SECO-RANGEFINDER-GEVK

FPGA (ice40)

The core logic device in the SECO-RANGEFINDER-GEVK is the FPGA that handles all necessary operations needed for seamless dToF measurements. It's a master device and in the following sections are explained key features of its functionality.

TDC (Time to Digital Converter)

In this paragraph we explain the principle of dToF measurement. In the direct ToF measurement technique the time between emission and reception of a laser pulse is measured by a high precision electronic stopwatch as shown in Figure 3. On-chip time measurement can be performed by time-to-digital (TDC) or time-to-analog converters. Usually the time measurement starts with the emission of the laser pulse and stops at the first detected photon. Since the

received optical power of the reflected laser signal scales inversely quadratic with the distance, highly sensitive photodetectors are required for long range and low emission power applications. SECO-RANGEFINDER-GEVK features digital TDC implementation in FPGA.

It serves for precise speed of light measurement, when Laser diode emits short pulse starting the TDC and highly sensitive SiPM detector stops its operation. Time of flight T between the start and stop pulse is then converted into measured distance according to the following formula, where c is the speed of light:

$$\text{Measured Distance [m]} = \frac{cT}{2} \quad (\text{eq. 1})$$

TDC functions in binning mode, where FPGA calculates propagation delay across the string of delay lines. This type

SECO-RANGEFINDER-GEVK

of measurement is highly dependent on core logic's supply voltage and varies with temperature. In order to compensate these unwanted effects, TDC is calibrated automatically by application or upon user's request. Figure 4 shows the basic principle of TDC measurement implemented in the evaluation board.

The binning line is constructed with >1800 bins, where each bin width is ~85 ps.

Minimum measurable range was observed to be 11 cm (0.11 m). This is determined by physical optics and not expected to vary significantly for different configurations.

Maximum measurable range exceeds the size of the testing space. At max tested distance (18 m), strong photon return is observed. It is expected that the maximum measurable range will be determined by TDC limit and not by photon budget. Assuming 1800 total bins in histogram with ~85 ps bin width:

$$\text{Max Range} = 1800 \cdot 85 \text{ ps} \cdot c_{\text{light}} \cdot 0.5 = 22.95 \text{ m} \quad (\text{eq. 2})$$

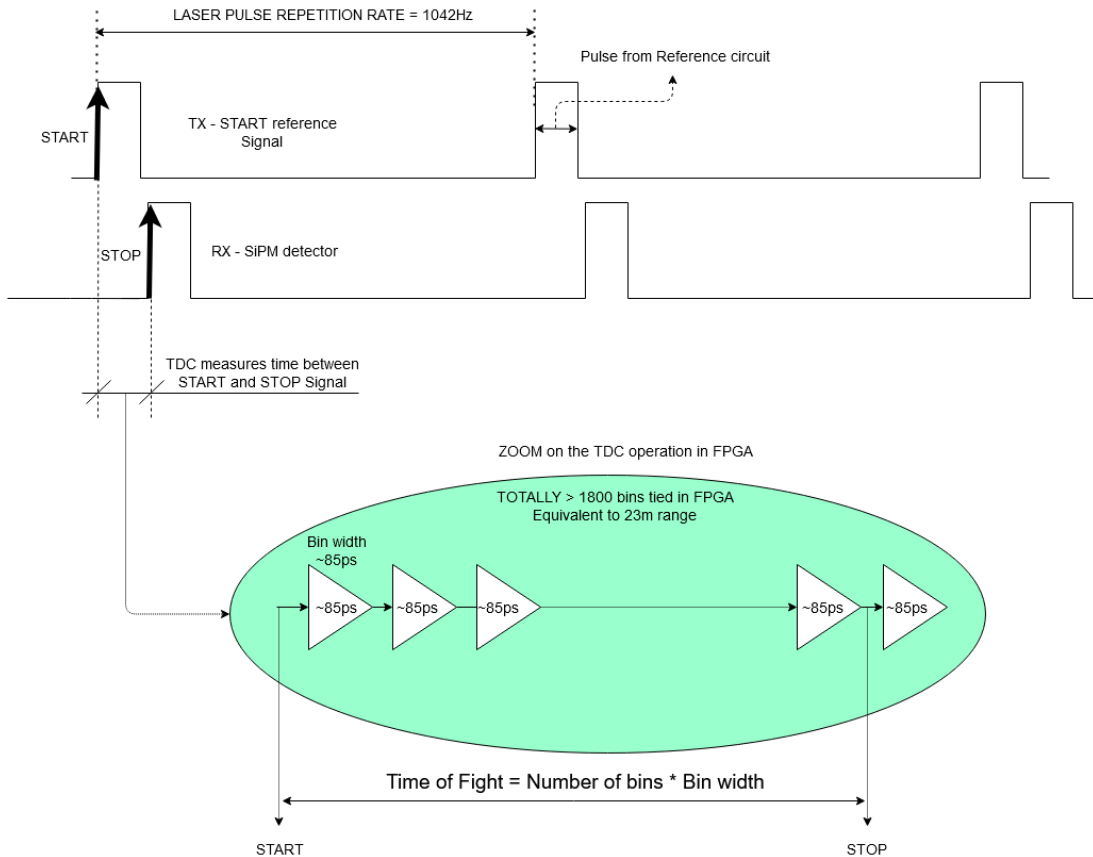


Figure 4. TDC Principle of Operation

DCDC Converters Circuit

Transmitting and receiving circuit of the SECO-RANGEFINDER-GEVK requires for its operation regulated power supply to bias SiPM receiving and reference sensors. The bias voltage is common for both SiPMs and fully controlled by FPGA. Simple dedicated inverting converter ensures negative bias presence on both diodes. Settable voltage range defined by the user is within -32 V down to -45 V, depending on the environmental conditions (indoor/outdoor application).

Transmitting circuit features dedicated boost converter for Laser diode reference voltage that is fixed to 15 V. This value was selected upon the thorough measurements to meet class 1 laser safety requirements defined by the standard.

Laser and Reference Circuit (Tx)

In order to fire 905 nm laser pulse in sufficiently short time and to maximize the optical power that meets in the given system class1 laser safety requirements, it is necessary to utilize a high-speed MOSFET driver and MOSFET transistor. ON Semiconductor's high-speed, high-current [NCP81074A](#) fulfills the bandwidth requirements for such dToF applications. Its input is fed by the FPGA's pulses and the dedicated high current output drives logic level MOSFET [FQT13N06L](#), acting as power switch for the Laser diode.

Reference circuit consists of SiPM photo sensor and is physically placed next to the 905 nm laser diode in transmitting optics holder. It functions as START signal of

SECO-RANGEFINDER-GEVK

TDC (Figure 4) and it's not the pulse coming to the [NCP81074A](#) driver from FPGA's digital pin. The main reason of this architecture is suppressing the propagation delay of the high speed MOSEFT driver itself that varies normally between 15–27 ns and is temperature dependent. Although the compensation of this propagation delay in

FPGA is possible, but driver-to-driver variation and temperature dependency would deform the overall measurement precision. Thus START Signal is taken from the reference SiPM sensor that is timing wise aligned with optical pulse out of laser diode. Figure 5 illustrates this dependency.

NCP81074A, NCP81074B

Table 2. ELECTRICAL CHARACTERISTICS (Note 1) (Typical values: $V_{DD}=12V$, $1\mu F$ from V_{DD} to GND , $T_A = T_J = -40^{\circ}C$ to $140^{\circ}C$, typical at $T_{AMB} = 25^{\circ}C$, unless otherwise specified)

Parameter	SYMBOL	Test Conditions	MIN	TYP	MAX	Unit
SWITCHING CHARACTERISTICS						
Propagation Delay Time Low to High, IN Rising (IN to OUT) (Note 2)	t_{d1}	$C_{Load} = 1.8\text{ nF}$		15	27	ns
Propagation Delay Time High to Low, IN Falling (IN to OUT) (Note 2)	t_{d2}	$C_{Load} = 1.8\text{ nF}$		15	27	ns
Rise Time (Note 2)	t_r	$C_{Load} = 1.8\text{ nF}$		4	7	ns
Fall Time (Note 2)	t_f	$C_{Load} = 1.8\text{ nF}$		4	7	ns

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

- All Limits are 100% tested at $T_{AMB} = 25^{\circ}C$ and guaranteed across temperature by design and statistical analysis.
- Guaranteed by characterization. *See timing Waveforms.

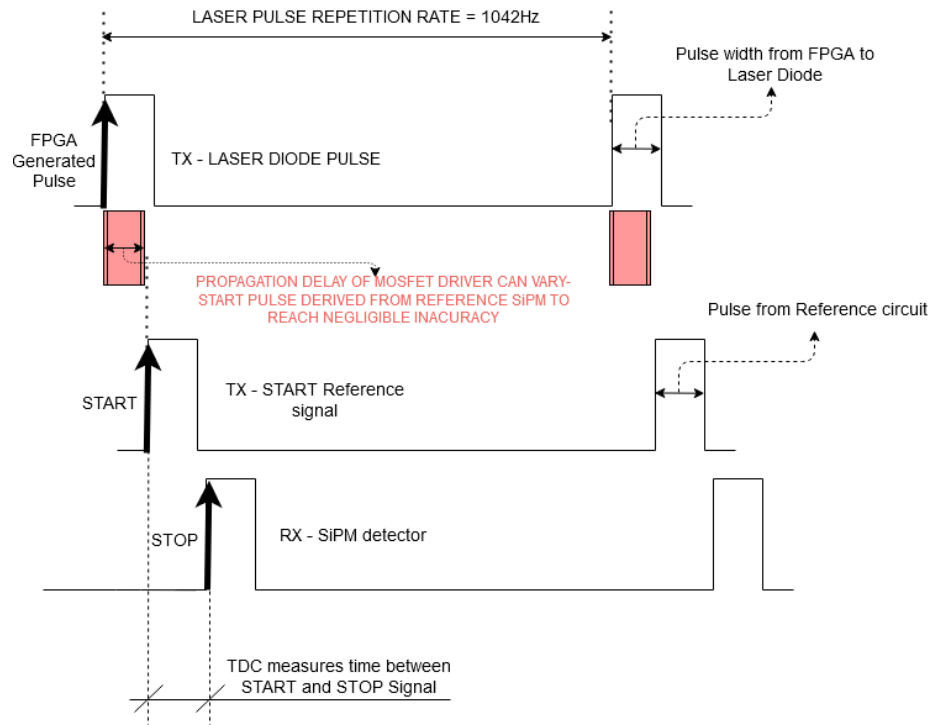


Figure 5. Propagation Delay Variation Impact of NCP81074A

Output of the Reference SiPM photodetector does not require any additional amplification due to close proximity to the laser diode – both components encapsulated in a single optical holder. Thus, the output of the SiPM is directly tied to the input of discriminator circuit (high-speed comparator) and provides sufficiently enough voltage level. [NBA3N012C](#) serves as high frequency discrimination circuit and delivers filtered logic level START signal towards input of the FPGA.

Receiving Circuit (Rx)

It functions as the main detector of the reflected signal from the object and provides STOP pulse to calculate time of flight. It sits alone in the second optical holder equipped with a 905 nm custom band pass filter to receive the narrow spectrum of the 905 nm laser diode. SiPM receiving diode outputs the signal with far lower intensity due to measurement of the reflected light from the target and distance. In order to achieve quality logic levels signal to

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STOP TDC, amplification ensures [NSVF4015SG4](#) – RF transistor followed by [NBA3N012C](#) – discriminator (RF comparator). The discriminator IC has a second input tied to the reference, so that we obtain glitch free and filtered signal inputting FPGA.

Supply Management Circuitry and UART Control Logic

SECO-RANGEFINDER-GEVK is the lower power device and can be supplied over:

- USB – direct connection to computer
- PMOD – connector present in ON Semiconductor Bluetooth IoT platform kit ([BDK-GEVK](#)) with 3.3 V available directly from BDK-GEVK PMOD interface.

Rangefinder’s electronic automatically switches between USB or PMOD supply source, where priority is given to PMOD interface.

The main communication interface with outside world is UART. Along with the automatic supply selection, FPGA controls also UART interface selection – either UART from USB or UART from PMOD.



Figure 6. SECO-RANGEFINDER-GEVK Delivery

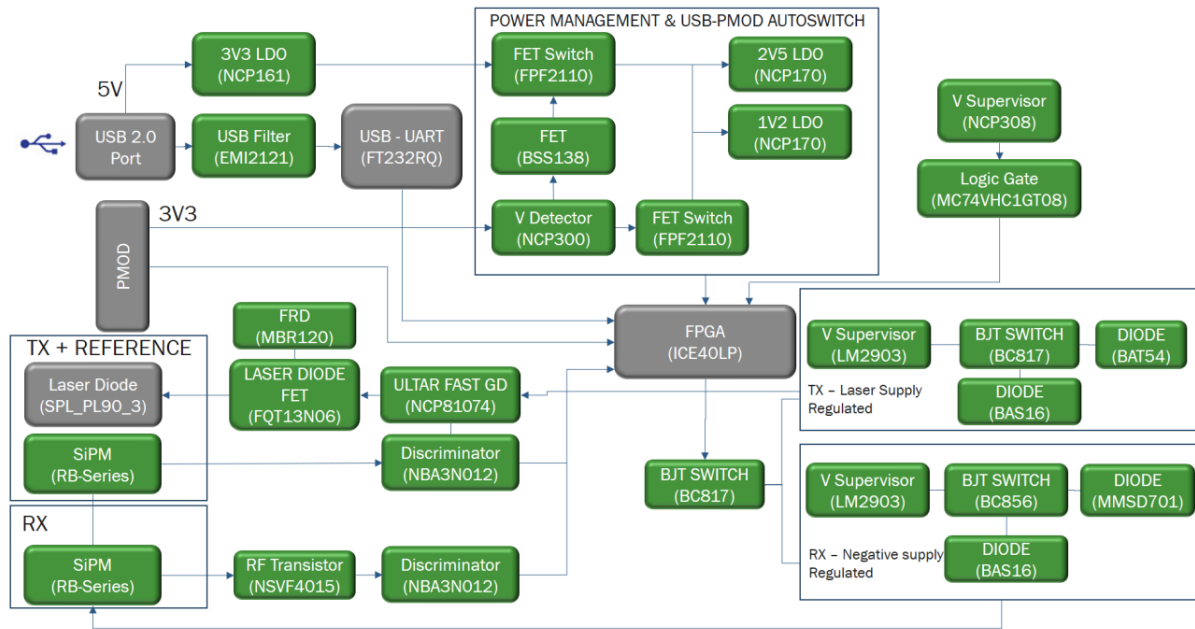


Figure 7. Detailed Block Diagram of SECO-RANGEFINDER-GEVK

DETAILED BLOCK DIAGRAM

Figure 7 shows the detailed block diagram of the system equipped with ON Semiconductor components.

SECO-RANGEFINDER-GEVK Delivery

Board itself is preprogrammed and delivered with USB cable and enabled plug and play functionality. See Figure 6 after unboxing the platform.

PC APPLICATION (GUI)

In the following chapter, we will guide you through the operation of the GUI and its features.

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 rangefinding 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

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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

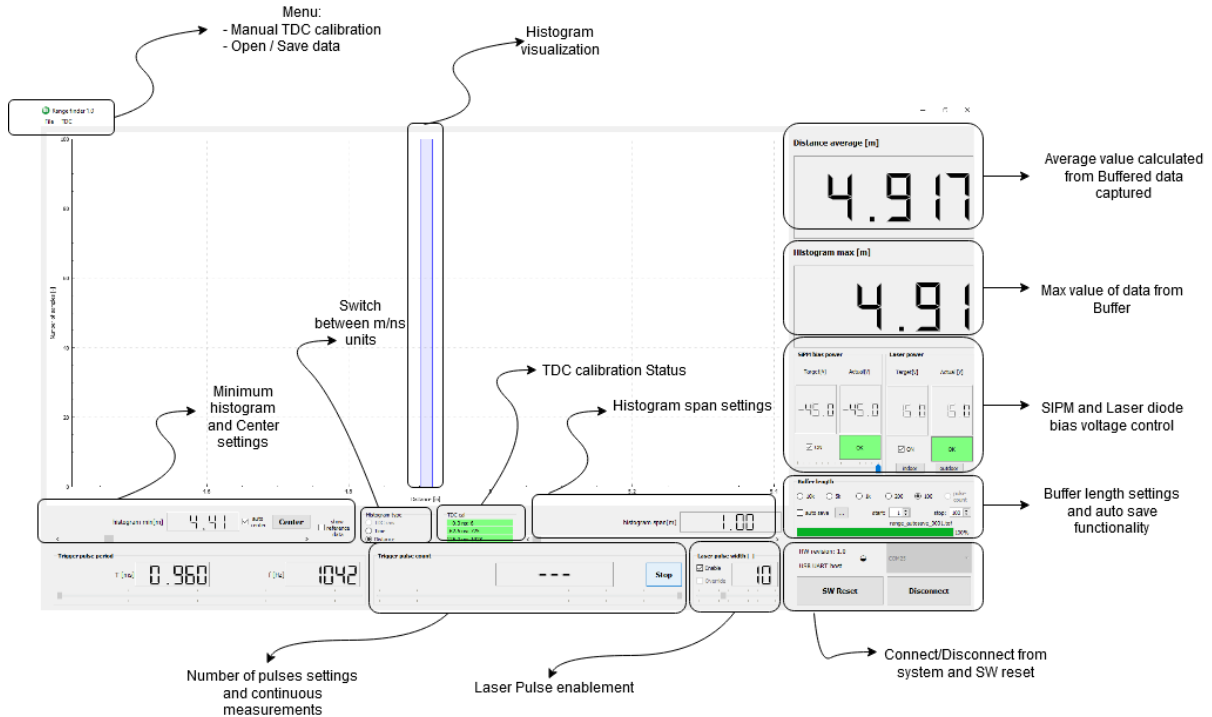


Figure 8. High Level Description of GUI Functionalities

PC Connection

The SECO-RANGEFINDER-GEVK is delivered with the USB cable (Figure 9).



Figure 9. Connection to the PC

GUI Application

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

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

- Connect the SECO-RANGEFINDER-GEVK to the PC using the USB cable as illustrated in Figure 9.

- Once the device is connected, double click on the executable file range_finder to launch the application.

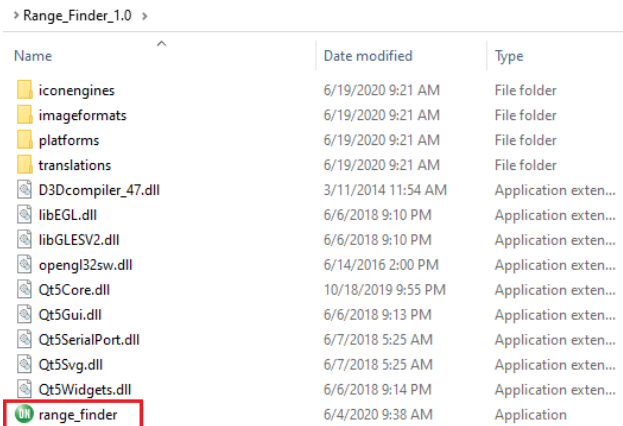


Figure 10. Range Finder 1.0 GUI Package

- Click on *Select port* combo box on the right bottom side of the application and select communication port the board is connected to (Figure 11).

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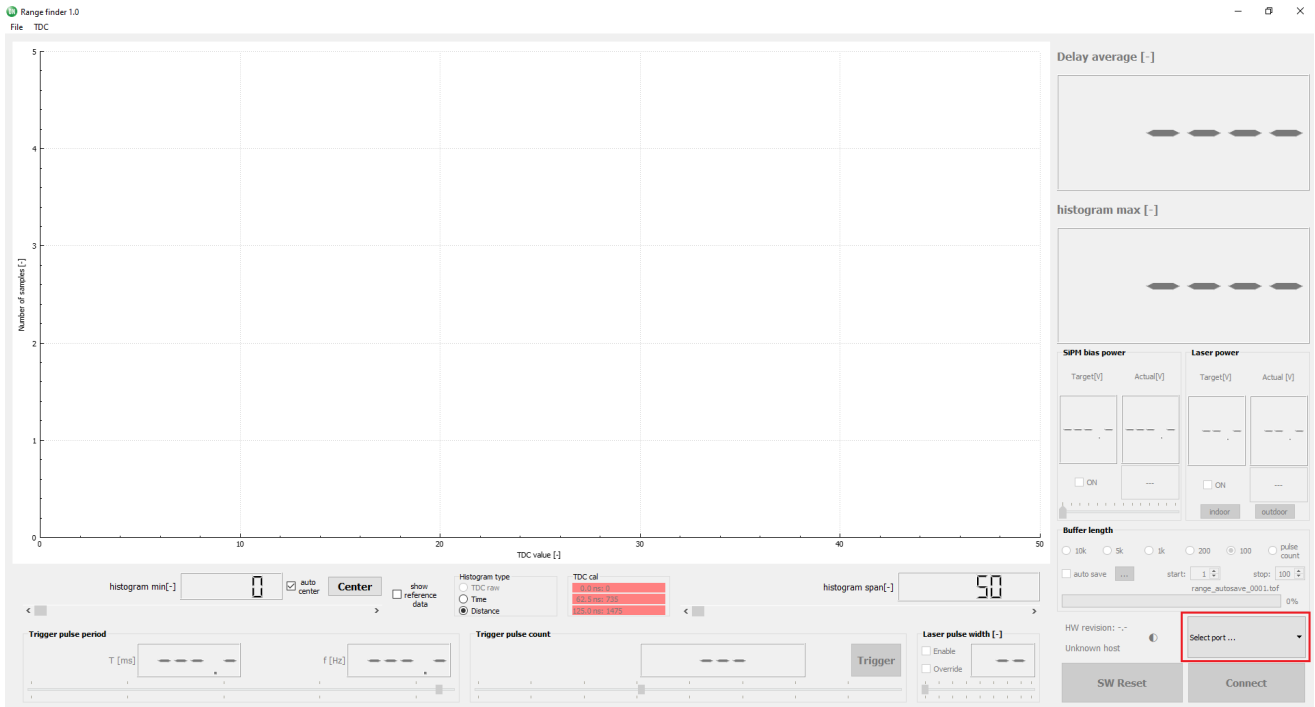


Figure 11. Select Port – Enabling the GUI Application

- Click on *Connect* button. Application connects to the board and gather its current configuration. TDC calibration routine starts automatically and it is indicated

by new TDC calibration values with green background if successful. Additionally, black semi-circle close to Disconnect button should rotate slowly.



Figure 12. TDC Calibrated Automatically and Application Connected to Rangefinder Board

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- Finally, range finding functionality can be tested:
 - Select the *SiPM bias power ON* () as well as *Laser power ON* () checkboxes as shown in Figure 13. 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 deselecting *SiPM bias power ON* () checkbox before SiPM bias power is turned on again (Figures 13, 14).
 - Select also *Enable* () checkbox in *Laser pulse width* box to enable laser pulse generation.
 - Click *Trigger* button, and the distance between the SECO-RANGEFINDER-GEVK and the selected target object (e.g. room wall) will be measured and shown in histogram as well as in the big LCD displays. (Figure 15).

NOTE: The valid measuring range is approximately from 0.3 m up to 23 m (Figure 15). Under certain conditions of use, the actual values shown by the SECO-RANGEFINDER-GEVK might differ from the actual distance by a few centimeters. Refer to section Measurement Error (Figure 44) for further details.

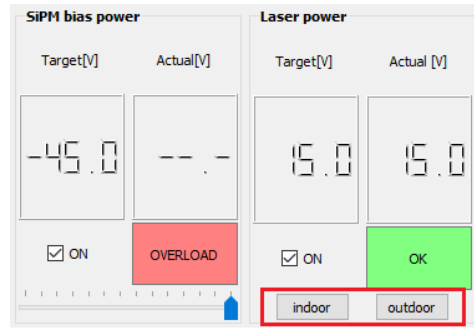


Figure 13. Overload Condition for Reference SiPM at High Ambient Illumination (Outdoor)



Figure 14. SiPM Bias Voltage Reduction (Clicking *Outdoor* Button or Using the *Slider*) Helps to Achieve OK Status at High Ambient Illumination

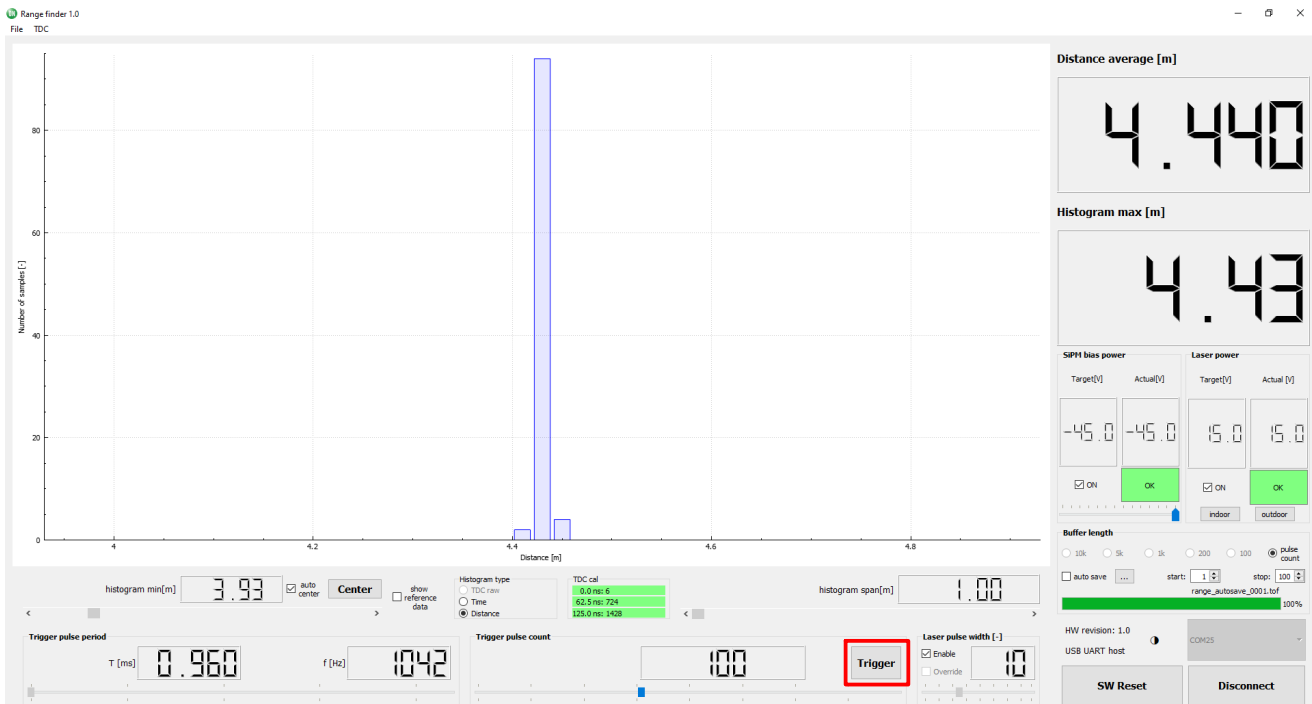


Figure 15. Rangefinder in Action

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Advanced Features of Range_Finder_1.0 PC Application

- Rangefinder's GUI 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* (Figure 16). ToF data is then visualized in [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 1024 Hz. 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]* (Figure 17).

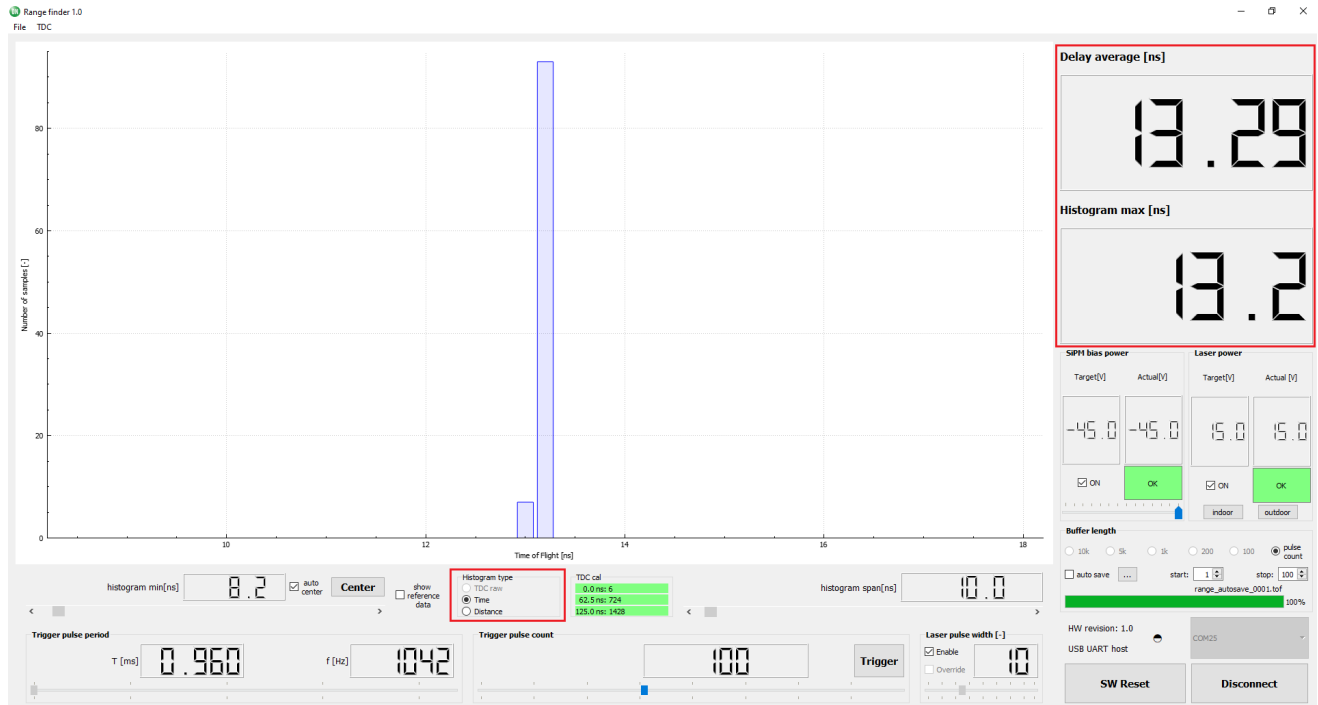


Figure 16. Switching from Distance to Time of Flight Measurement [ns]

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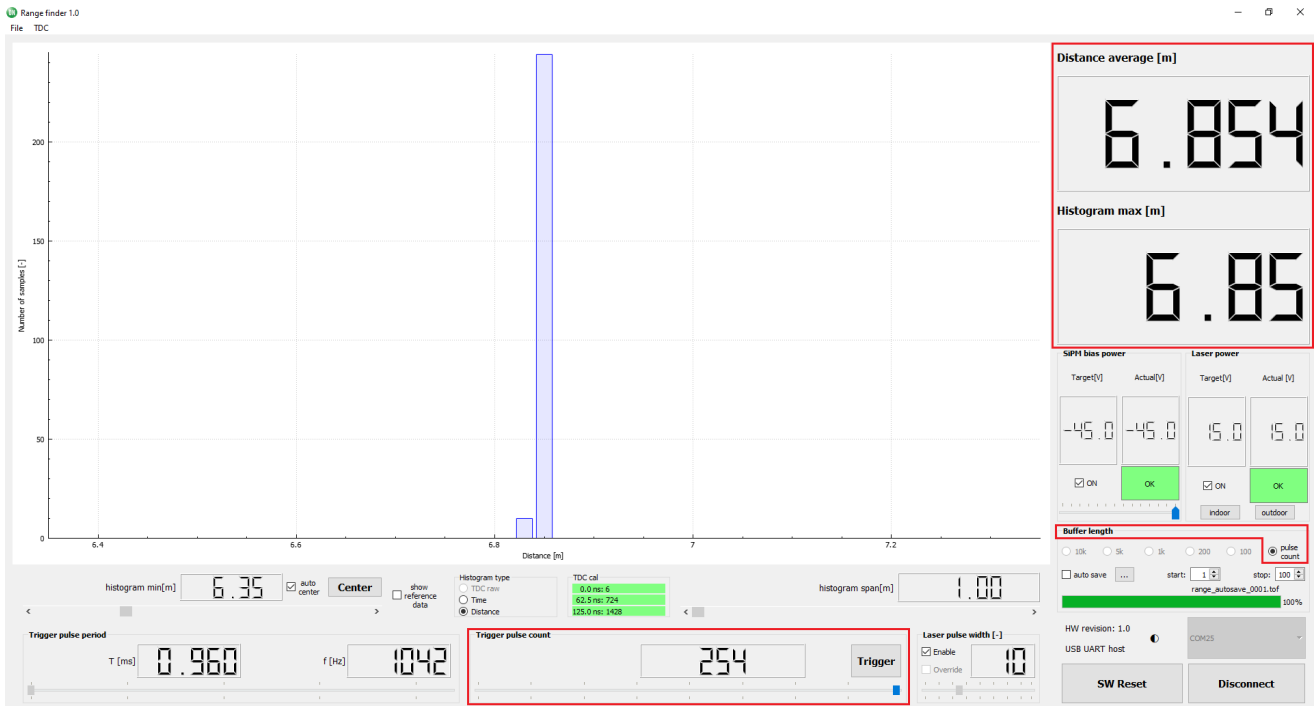
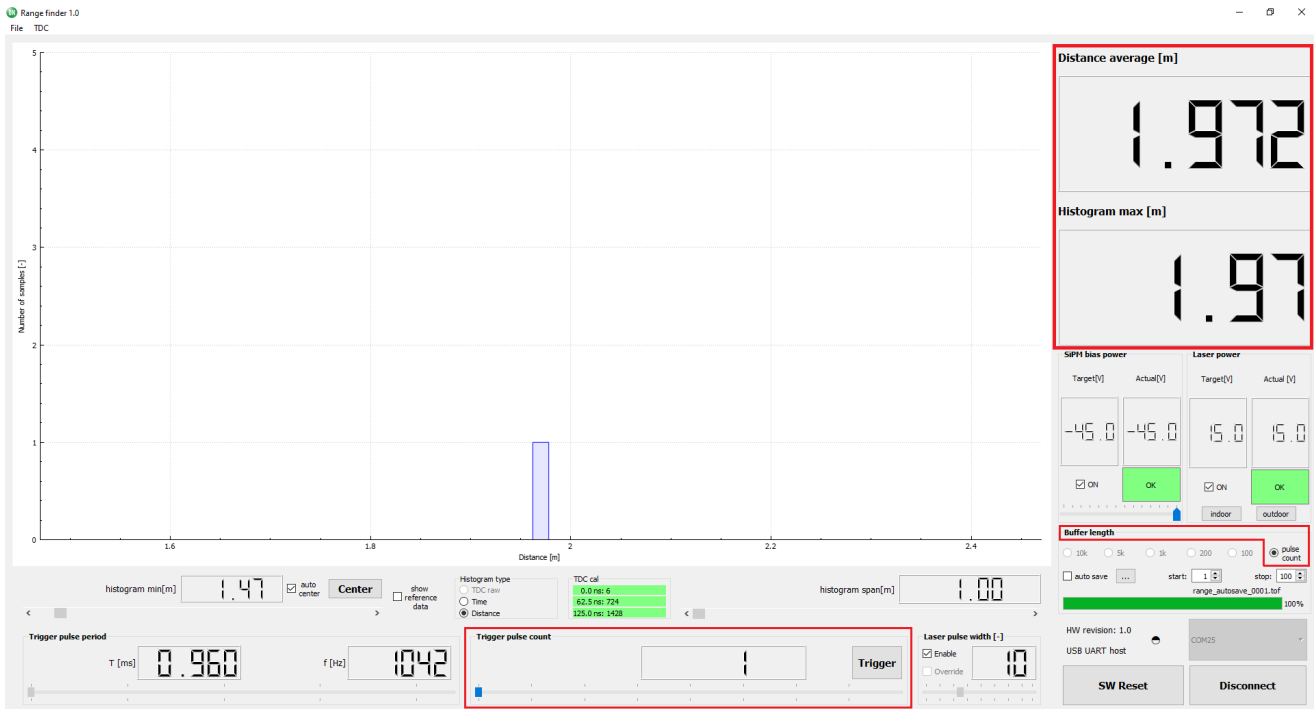


Figure 17. Trigger Pulse Count can be Adjusted between 1–254 Pulses

- **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]* (Figure 18).

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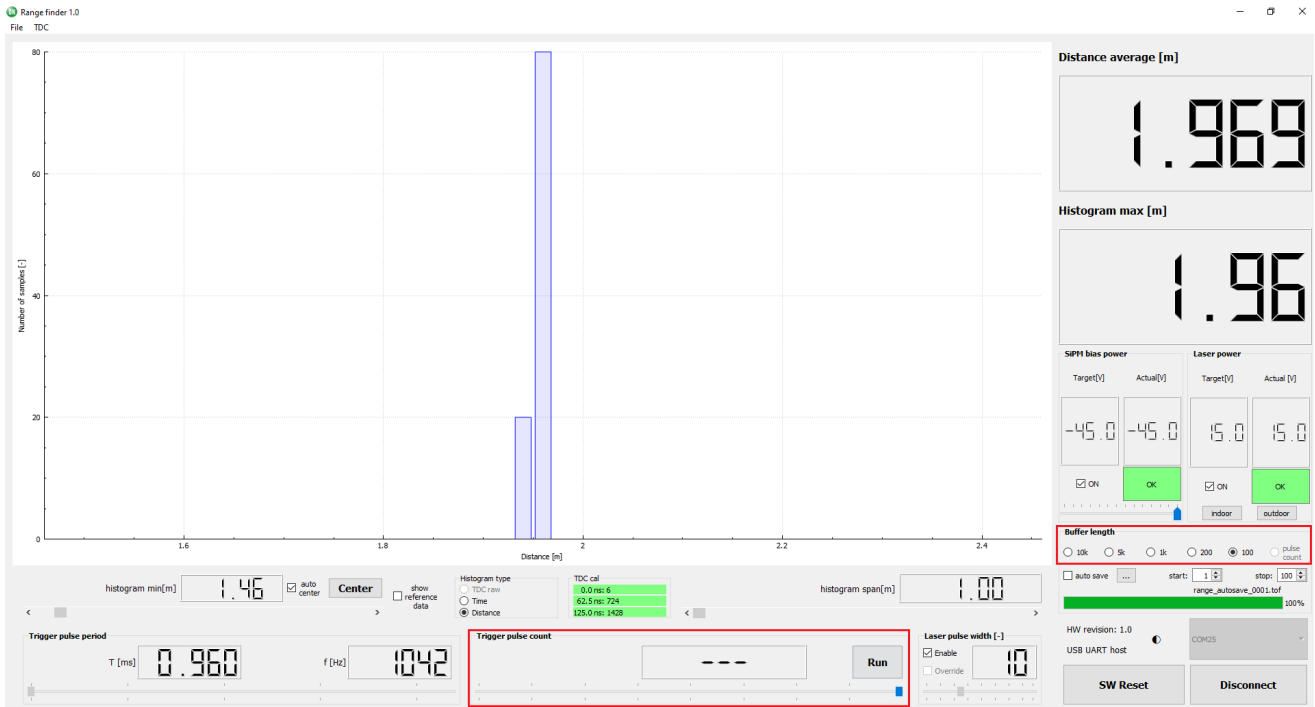


Figure 18. Rangefinder Set in RUN Mode with Adjustable Buffer Length

- The most critical part of any ToF measurement is storing the measured data for further processing, characterization etc. Range finder PC application enables storing the ToF data seamlessly and in various modes:
 1. **TRIGGER MODE – AUTOSAVE** (automated ToF file generation under fixed storage destination):
 In Trigger mode, user can automatically save ToF data from preset number of measurements. Number of measurements stored equal to number set by slider under *Trigger pulse count* control box. For instance, if user adjust 20 measurements, 20 ToF data is stored. As previously mentioned, Trigger Pulse

count scale is from 1–254.

In auto 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 19 depicts the settings visually.

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Figure 19. Auto Saving of 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 suffix .tof and can be opened in any text file (Figures 20, 21).

Figure 21 shows 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.

User can access any time the stored data and load them into the GUI directly from menu *File* → *Load ToF data*. Simply open the .tof file you want to load the ToF data from, click OK. The GUI shows them accordingly. Please follow the steps depicted in Figure 22.

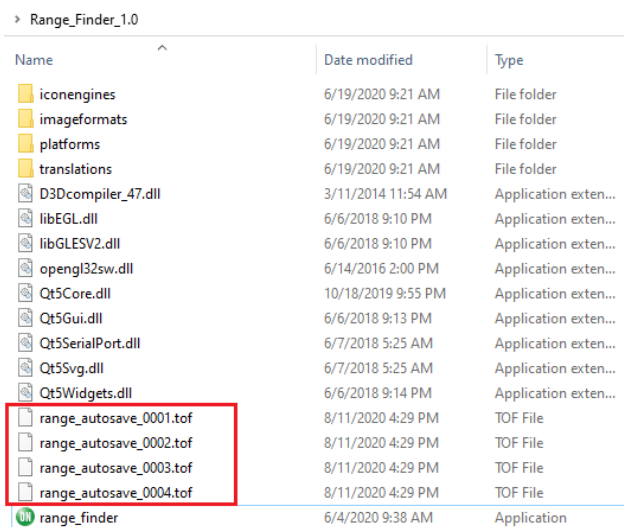


Figure 20. Trigger Mode – Auto Save Data Storage Folder

SECO-RANGEFINDER-GEVK

```

range_autosave_0002.tof x
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 21. Example of Stored Data after .tof File Opening in Text Editor

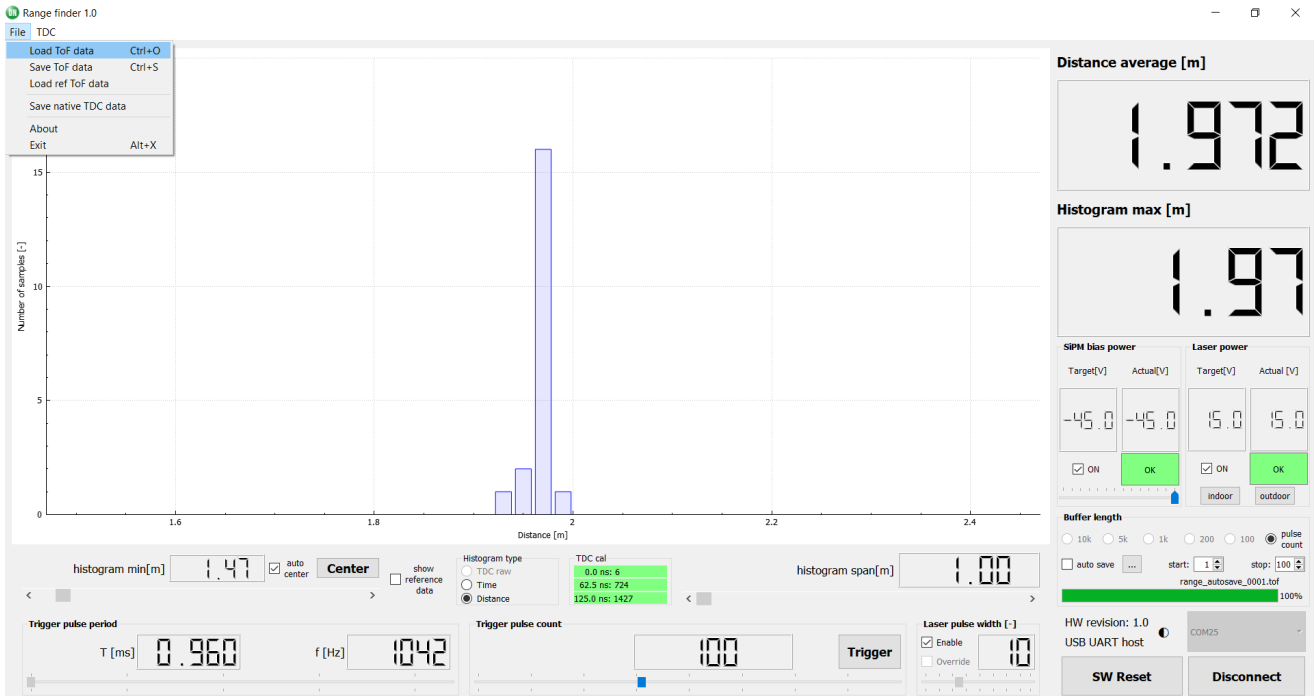


Figure 22. Loading Already Stored ToF Data from the File Out of the GUI Menu (Part 1/2)

SECO-RANGEFINDER-GEVK

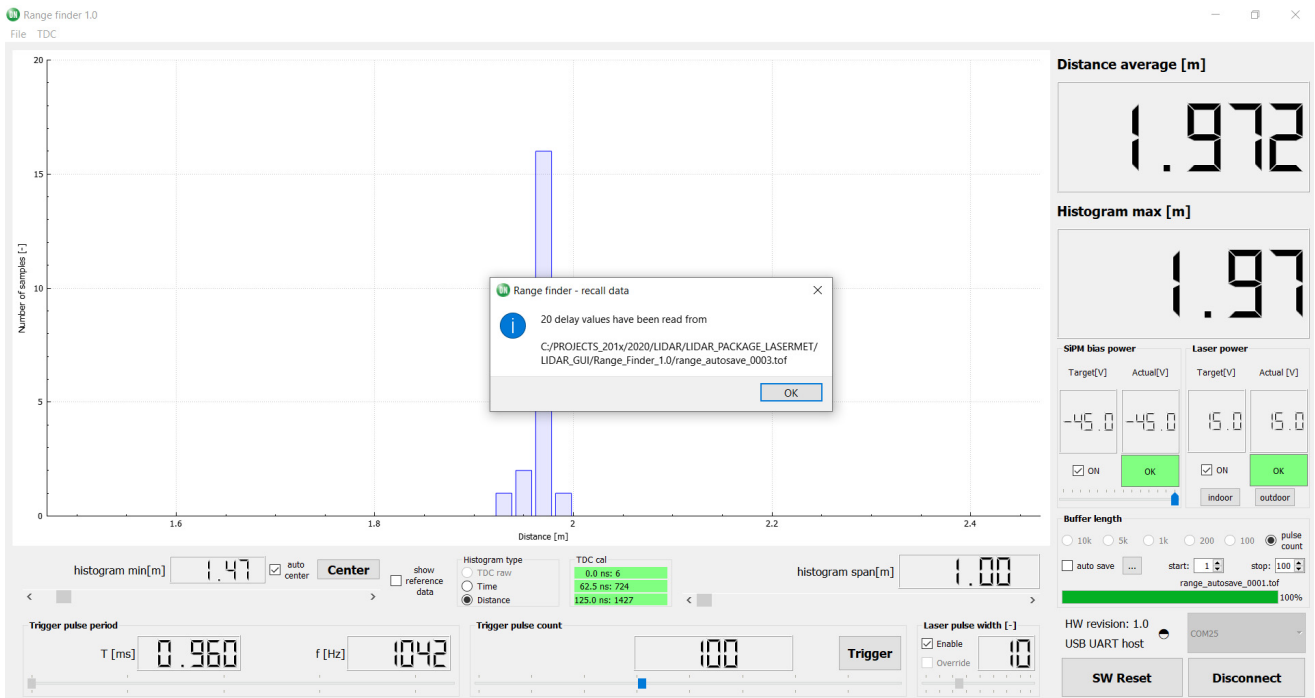
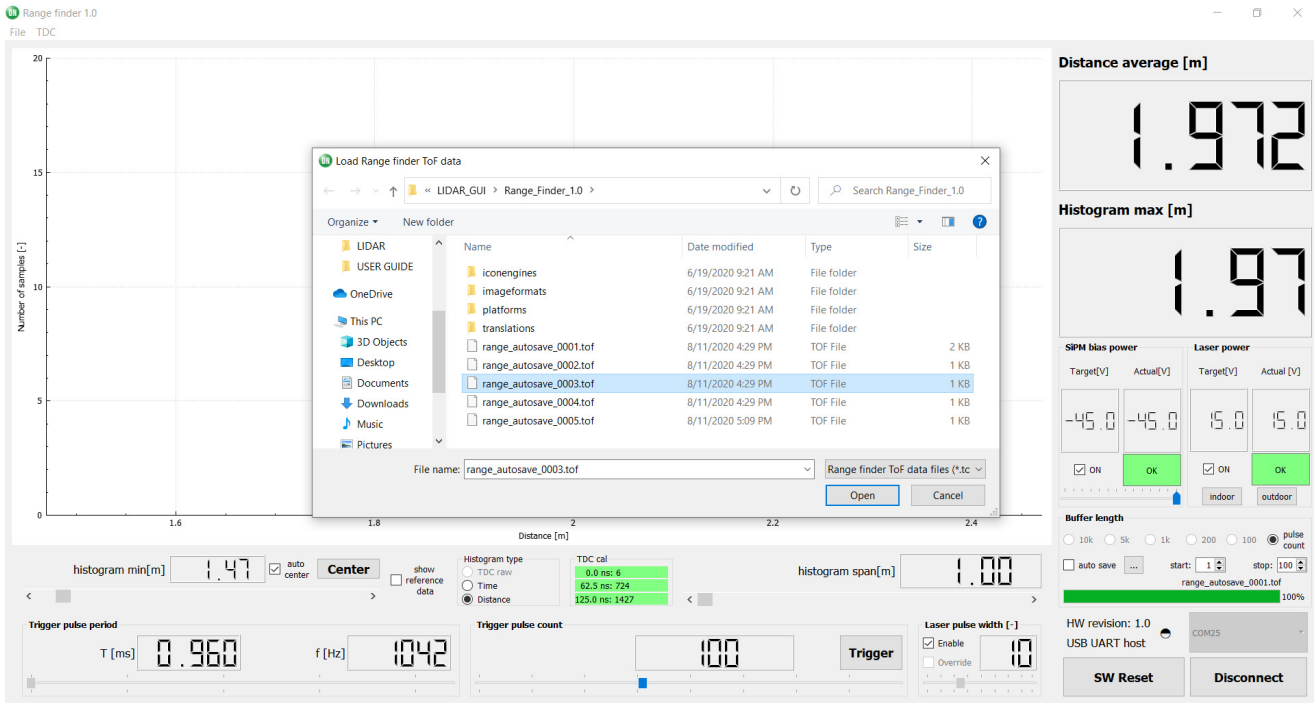


Figure 22. Loading Already Stored ToF Data from the File Out of the GUI Menu (Part 2/2)

SECO-RANGEFINDER-GEVK

2. TRIGGER MODE – AUTOSAVE

(custom ToF file name and storage destination):

This mode offers the same functionality as discussed under 1., however user may utilize its own naming convention for .tof files and have the freedom regarding the storage place, GUI offers this option as well. 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.

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 23 shows the complete flow described above.

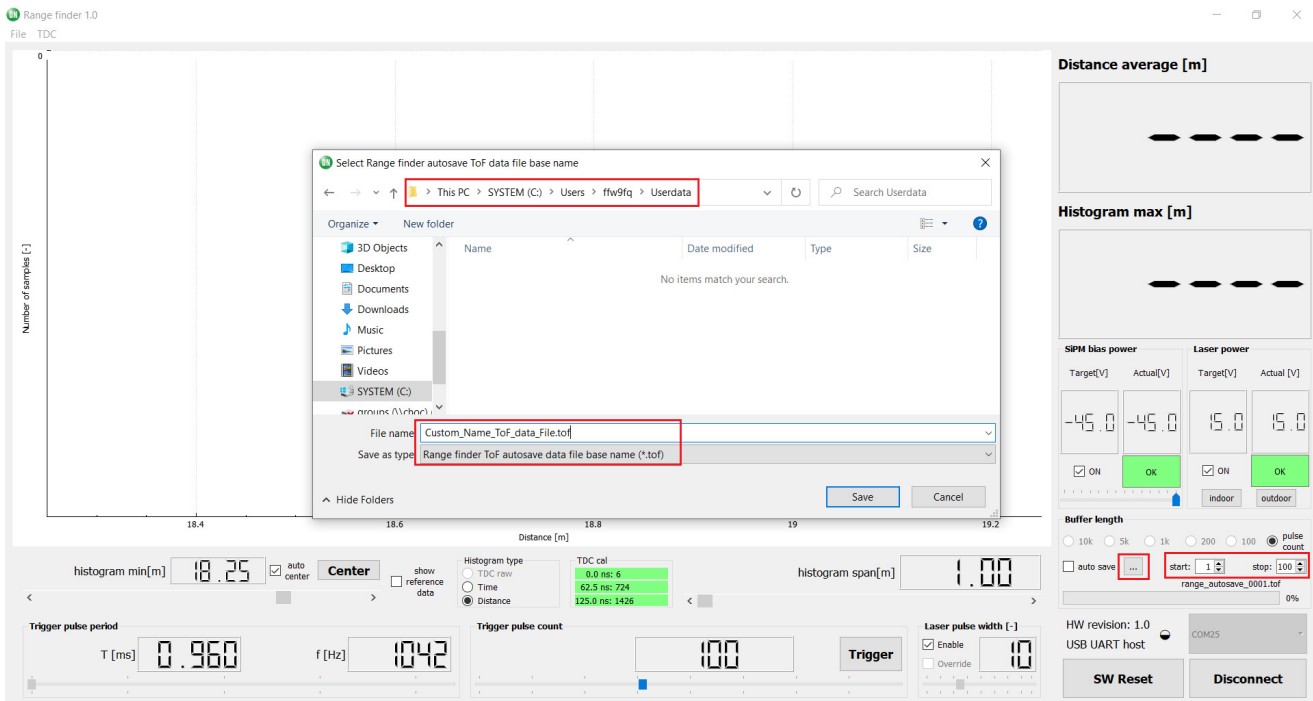


Figure 23. AutoSaving of Measured Data in Trigger Mode for Custom ToF File Name and Storage Destination (Part 1/3)

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Figure 23. AutoSaving of Measured Data in Trigger Mode for Custom ToF File Name and Storage Destination (Part 2/3)

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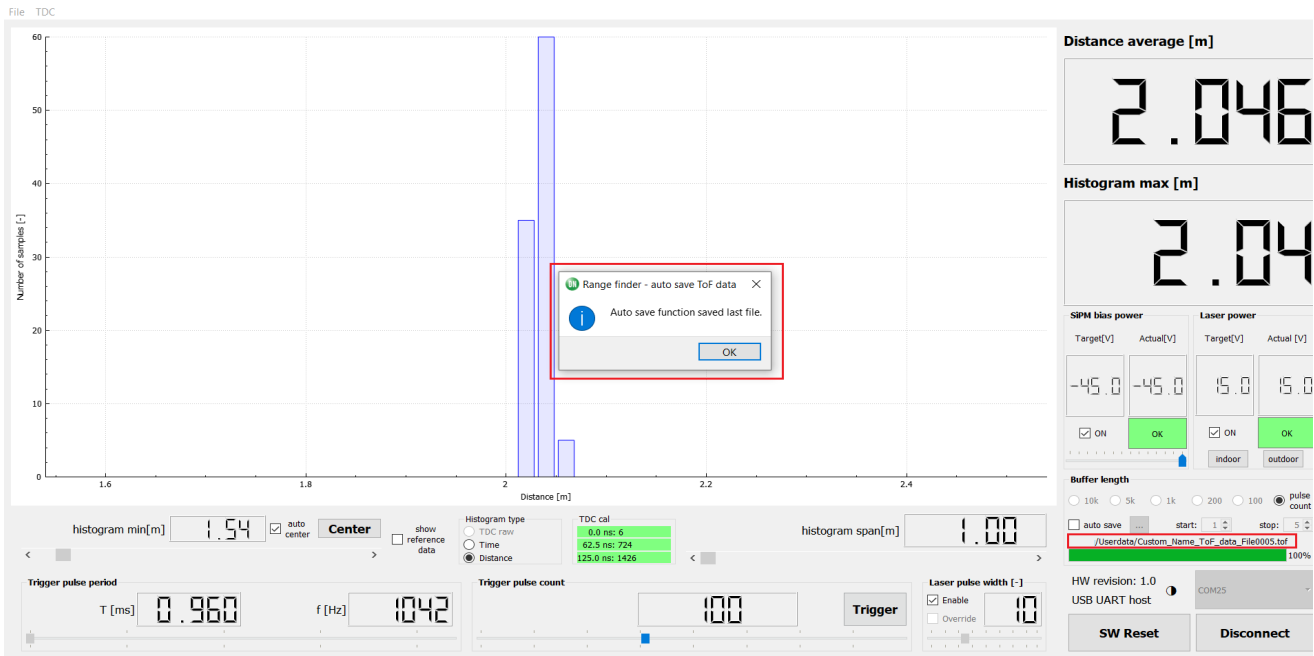


Figure 23. AutoSaving of Measured Data in Trigger Mode for Custom ToF File Name and Storage Destination (Part 3/3)

3. TRIGGER MODE – Manual Save:

If user wants to utilize its own naming convention for .tof files without incrementing and have the freedom regarding the storage place, GUI offers it. In manual save mode, *auto save* checkbox must be unchecked. Figure 24 shows the procedure on how to store the measured data into custom named file and by user selected storage place in the computer (to compare to Auto Save mode, where storage folder is

fixed – under the main GUI folder Range_Finder_1.0, where you unpacked the PC application). 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. The GUI writes the measured data accordingly. In the Trigger mode – Manual save, only one .tof data file can be stored.

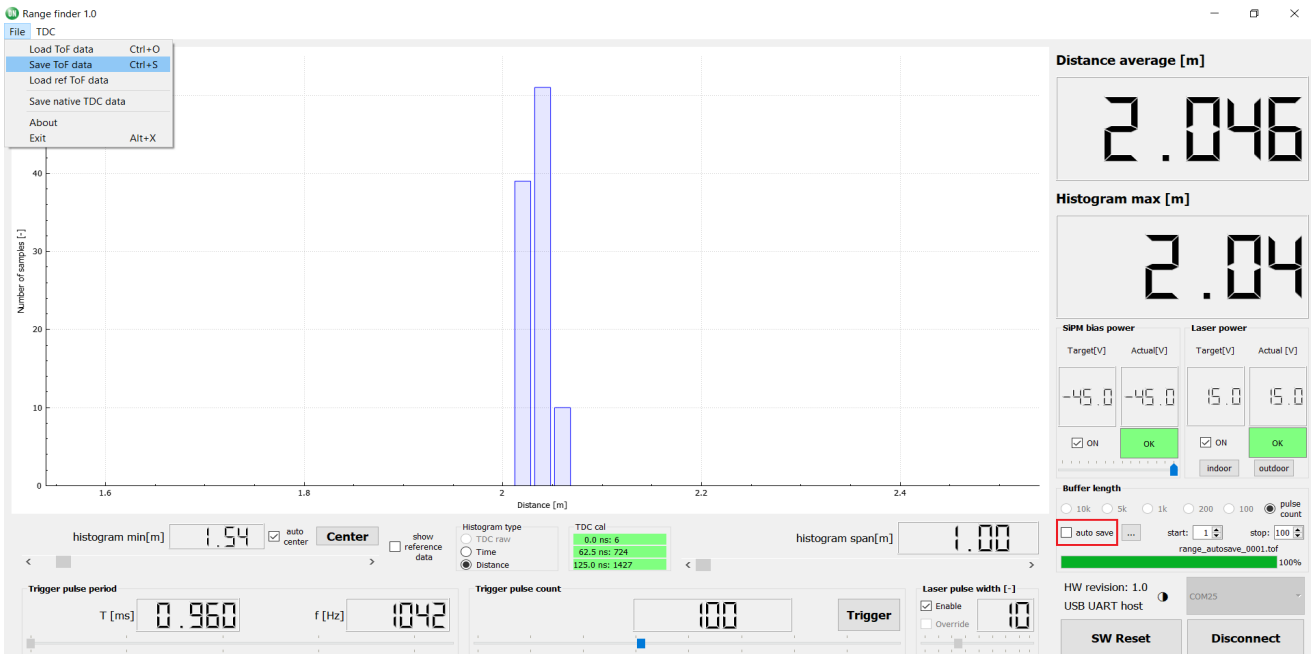


Figure 24. Custom File Name Creation and ToF Data Storage (Part 1/2)

SECO-RANGEFINDER-GEVK

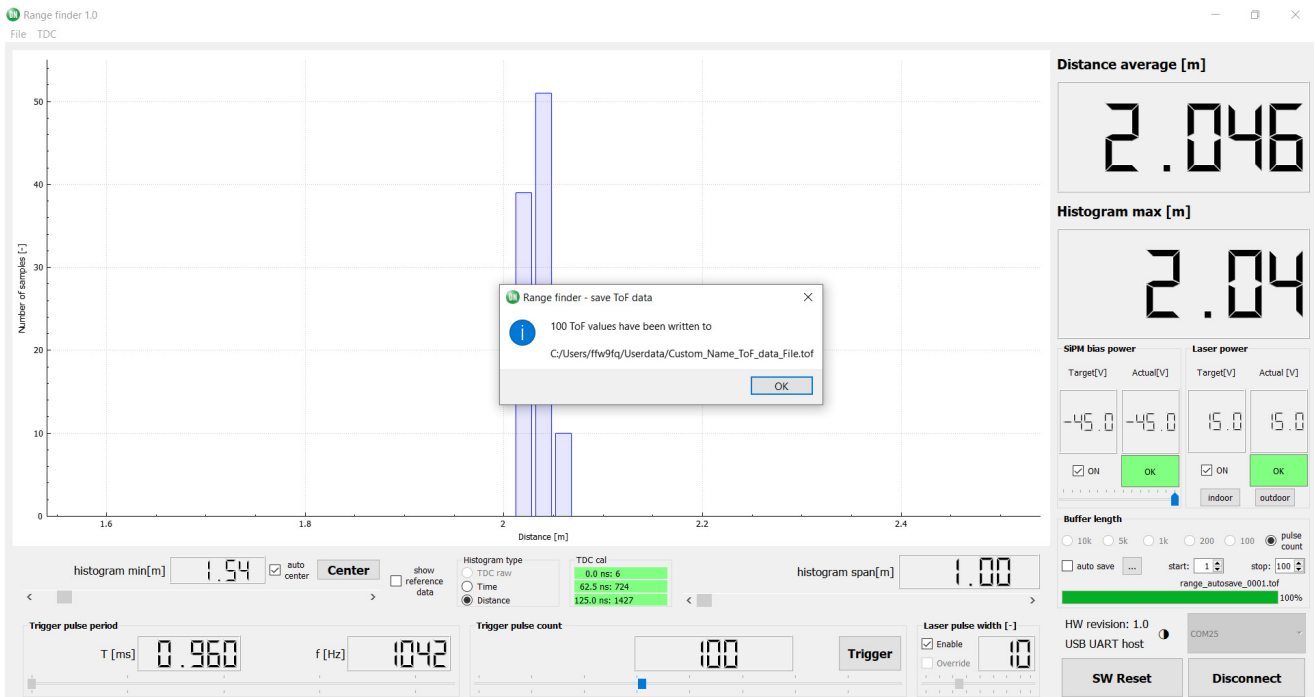
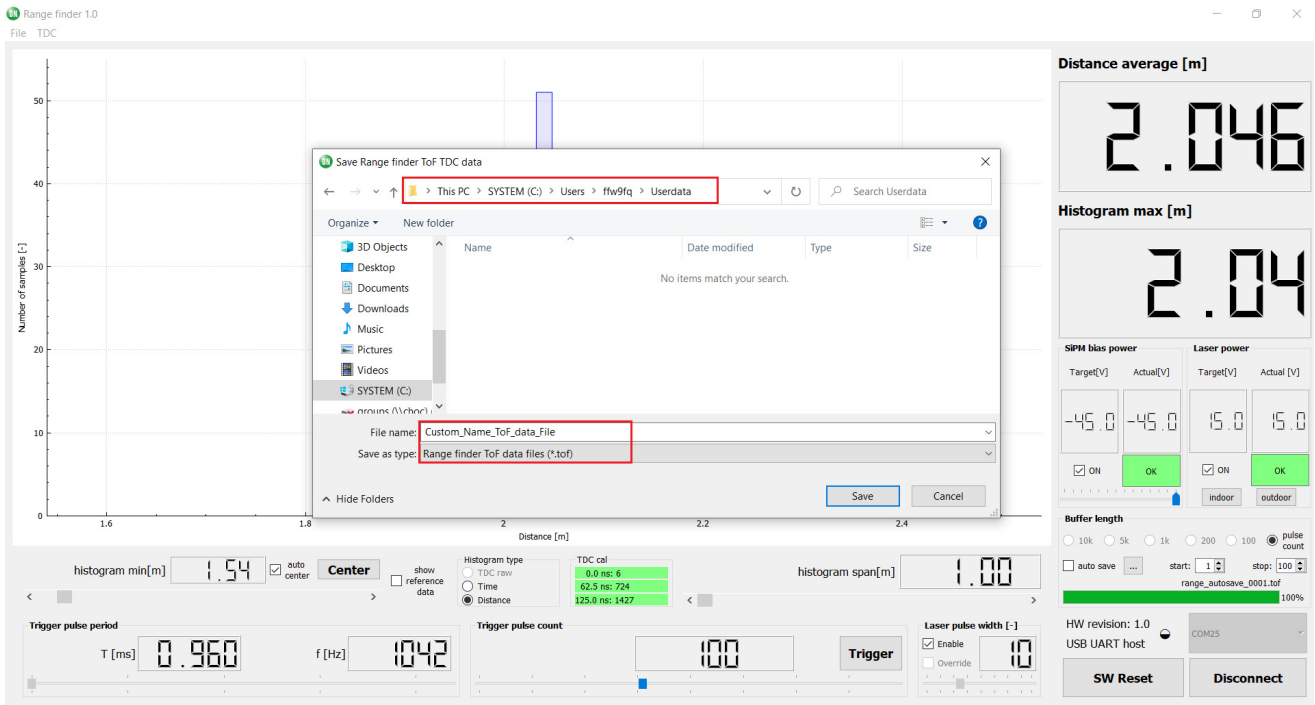


Figure 24. Custom File Name Creation and ToF Data Storage (Part 2/2)

4. *RUN MODE – AUTOSAVE (automated ToF file generation under fixed storage destination):*
 In *Run* mode, 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. Figure 25 depicts the actual implementation with 5k buffer length.

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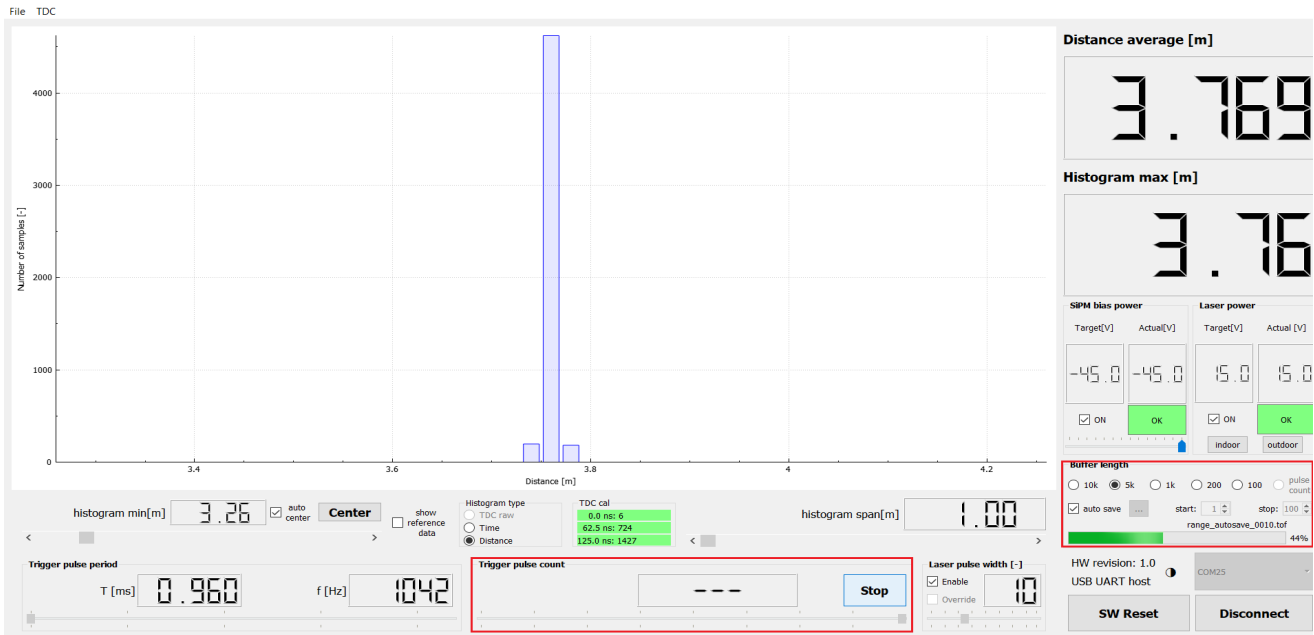


Figure 25. AutoSaving of Measured Data in RUN Mode

5. RUN MODE – AUTOSAVE (custom ToF file name and storage destination):

In *Run* mode, GUI automatically saves ToF data into user selected file name and destination location as described in bullet 2. 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

custom named files to set location with suffix given by the *start:* and *stop:* fields and data length preset under *Buffer length* control box.

Maximum number of files stored is 100. Figure 26 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*).

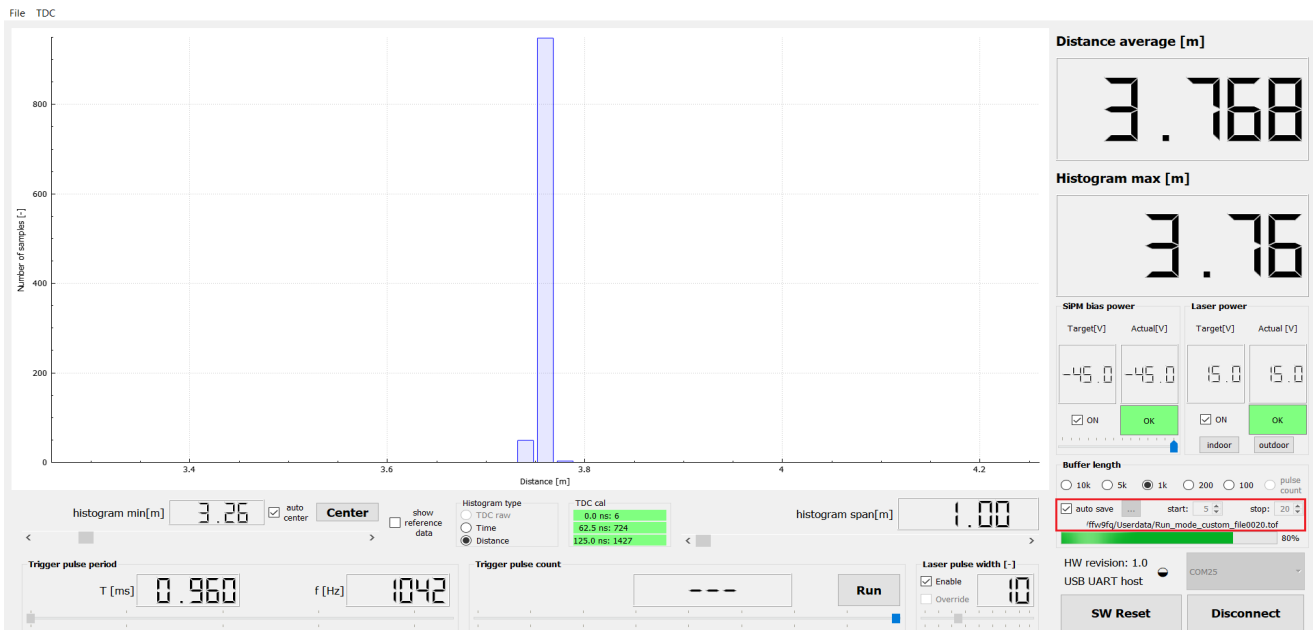


Figure 26. RUN MODE – AUTOSAVE Custom ToF File Name and Storage Destination

SECO-RANGEFINDER-GEVK

- One of the perks of the GUI 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

(Figure 27). This arrangement can be useful if user wants to visually assess e.g. the same distance and target at different number (stored vs. real-time) of samples and ambient illumination.

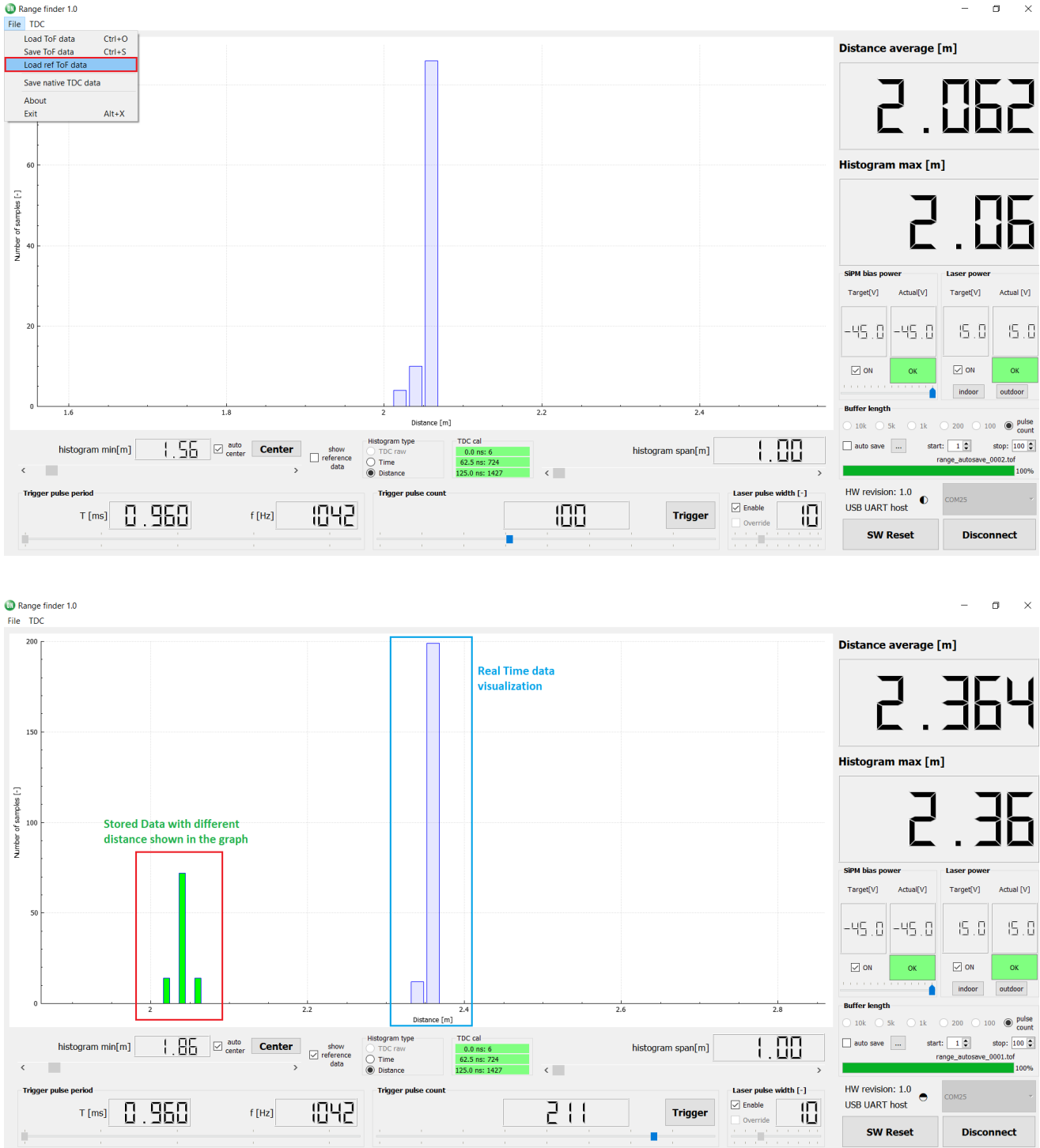


Figure 27. Loading the Stored ToF Data and Comparing to Real-time Measurement

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- The GUI is able to save Native TDC data. It represents the number of bins that correspond to measured distance, multiplied by propagation delay of single bin – please refer to Figure 3 of this document. Figure 28 shows the

procedure 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. Suffix of the File is .tdc.

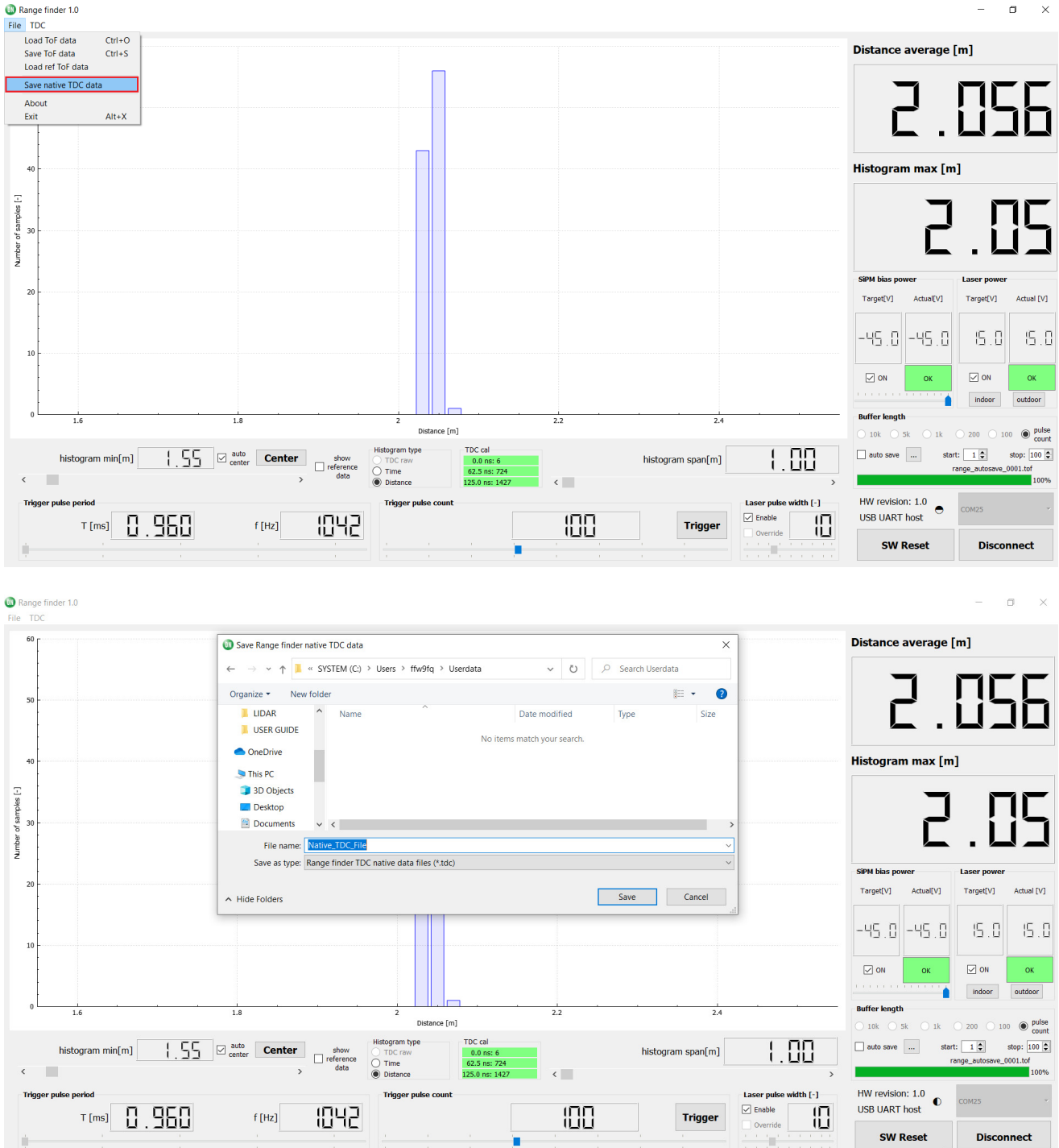
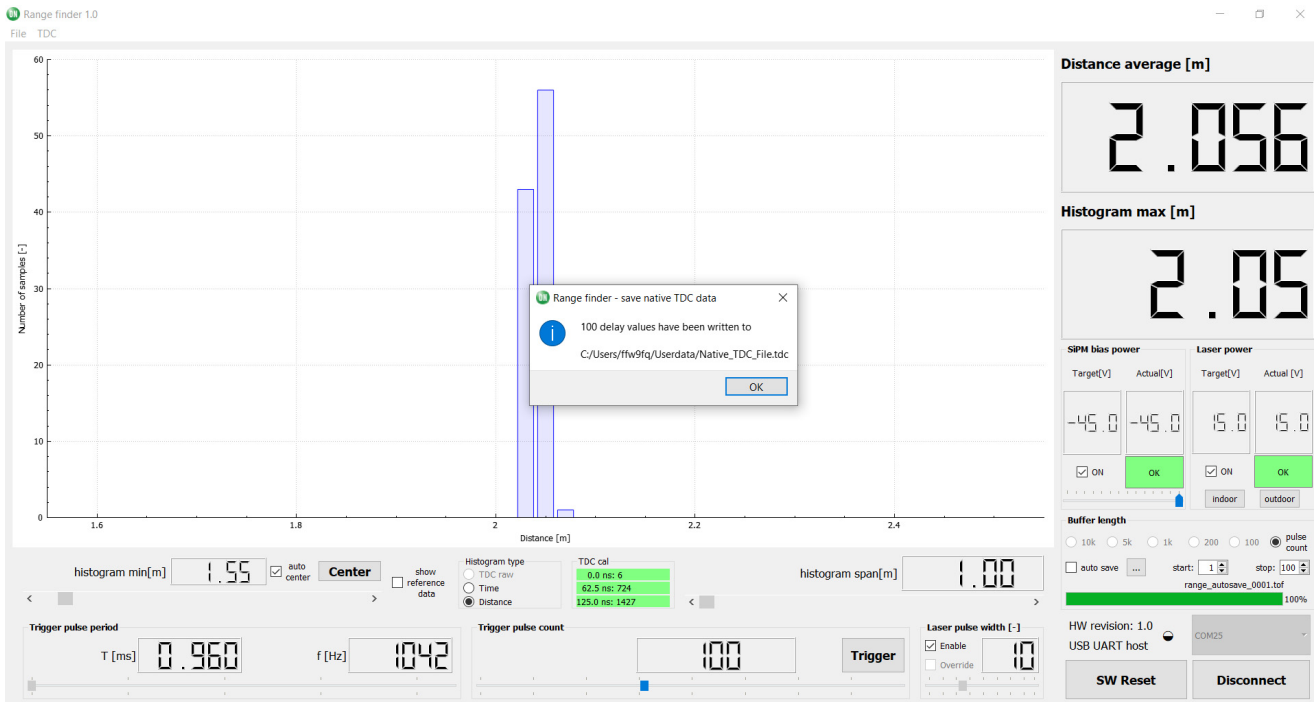


Figure 28. Saving of the Native TDC Data (Part 1/2)

SECO-RANGEFINDER-GEVK



```
Native_TDC_File.tdc x
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 28. Saving of the Native TDC Data (Part 2/2)

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- The Rangefinder system can be RESET anytime by pressing the *SW Reset* button. After this action, start-up of the system occurs with automatic launch of TDC

calibration (Figure 29). The SW RESET function will momentarily cut out the power to the electronic components.

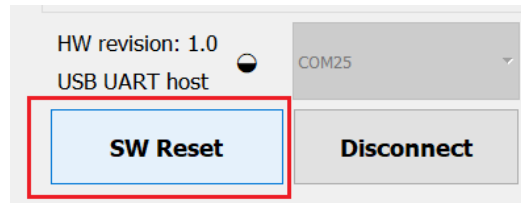


Figure 29. SW System RESET

- 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 pushing the Calibrate button under the menu as shown in Figure 30.

This function can be useful when environmental conditions like temperature changes and user needs to achieve the highest accuracy of measured data.

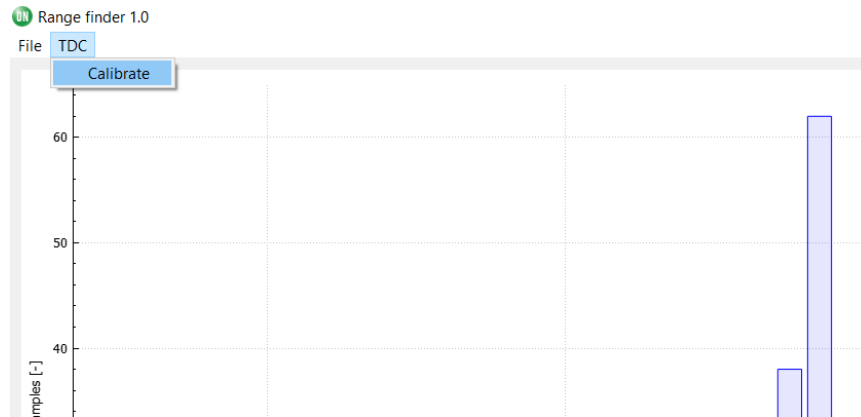


Figure 30. TDC Calibration Activation

- When user finishes the work with GUI, it's recommended to safely disconnect the Rangefinder device from

communication port. Dedicated Disconnect button serves to this purpose (Figure 31).

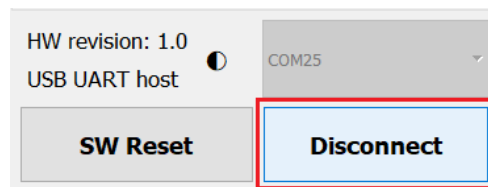


Figure 31. Disconnect Button to Deactivate Communication Interface

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OPTICAL COMPONENTS DESCRIPTION AND CHARACTERIZATION

SECO-RANGEFINDER-GEVK features biaxial optics architecture, thus it has separated transmitting and receiving

optical assembly (holder, lens ...). For both Tx and Rx side, the same holder and lens is utilized in the system. Table 2 summarizes the lens parameters and manufacturer.

Table 2. SUMMARY OF KEY LENS PARAMETERS USED IN THE RANGEFINDER

Lens Manufacturer, OPN and Available Cross References	Bohr Optics Co.,Ltd (OPN: BR25ONBK7) / Changchun Realpoo Photoelectric Co.,Ltd (OPN: RP25ONBK7) / Thorlabs (LA1951B)
Lens Shape	Plano-Convex
Substrate Material	N-BK7 (Grade A)
AR Coating Range	650-1050 nm (B Coating)
Reflectance over Coating, Range (Avg.) @ 0° AOI	< 0.50%
DIAMETER	Ø1" = 25.4 mm
EFFECTIVE FOCAL LENGTH	25.3 mm ±1%
BACK FOCAL LENGTH:	17.6 mm
Design Wavelength	587.6 nm
Index of Refraction @ 633 nm	1.515
Surface Flatness (Plano Side)	$\lambda/2$
Spherical Surface Power (Convex Side)	$3\lambda/2$
Surface Irregularity (Peak to Valley)	$\lambda/4$
Surface Quality	40-20 Scratch-Dig
Thickness Tolerance	±0.1 mm
Diameter Tolerance	+0.0/-0.1 mm
Centration	< 3 arcmin
Damage Threshold	7.5 J/cm ²
Abbe Number	$v_d = 64.17$
Clear Aperture	90% of Diameter
Focal Length Tolerance	±1%

Receiving Optics

Receiving optics consists of the Lens holder with N-BK7 plano-convex lens and a 905 nm band pass filter with precisely aligned focal point towards the SiPM photodetector. It serves as a receiving detector of reflected signal from the target. Figure 32 depicts core components of the receiving optics.

Core device in this assembly is SiPM RB series of photodetector (OPN: [MICRORB-10010-MLP](#)). It functions in Geiger mode where negative bias is applied to reach the proper function. Key information about Silicon

Photo multiplier technology can be found at ON Semiconductor webpage:

[MICRORB-10010-MLP Datasheet](#)

[Biasing and Readout of ON Semiconductor SiPM Sensors](#)
[A Brief Introduction to Silicon Photomultiplier \(SiPM\) Sensors](#)

[Introduction to the Silicon Photomultiplier \(SiPM\)](#)

[Reference Designs for the SMA and SMTPA MLP-Packaged SiPM Evaluation Boards](#)

SECO-RANGEFINDER-GEVK

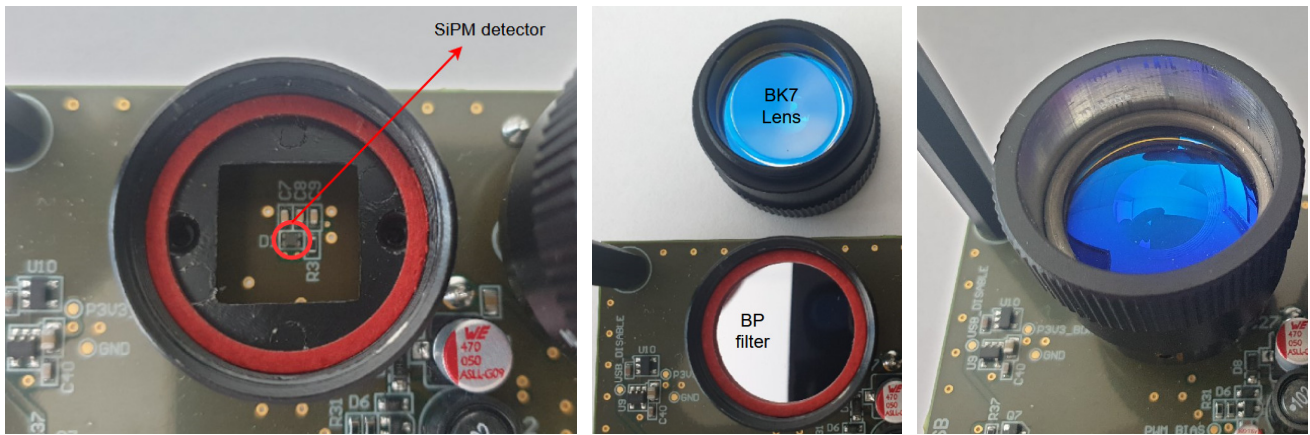


Figure 32. Receiving Optics Assembly

Band Pass Filter

Band pass filter sits on top of SiPM detector and the specification is provided in Table 3 with measured spectral response.

Below depicted bandpass filter spectral response of BP905/30 nm is measured with the following equipment and test setup:

Shimadzu spectrometer UV3150–test spectrum wavelength
 Spectrophotometer: Transmittance test + Blocking deep test
 Parallel light pipe: Comprehensive products index assess
 Goniometer: Angle error inspection

Table 3. BAND PASS FILTER SPEC

Manufacturer, OPN	Optolong Optics Co.,Ltd (OPN: BP905/30 nm)
AOI	0°
CWL	905 ±5 nm
FWHM	30.5 nm
Tp	> 85%
OD	> 2 @ 200~1100 nm
Scratch-Dig	80/50
Size	Diameter 24 mm × 1.1 mm/1.0 mm ±0.1 mm

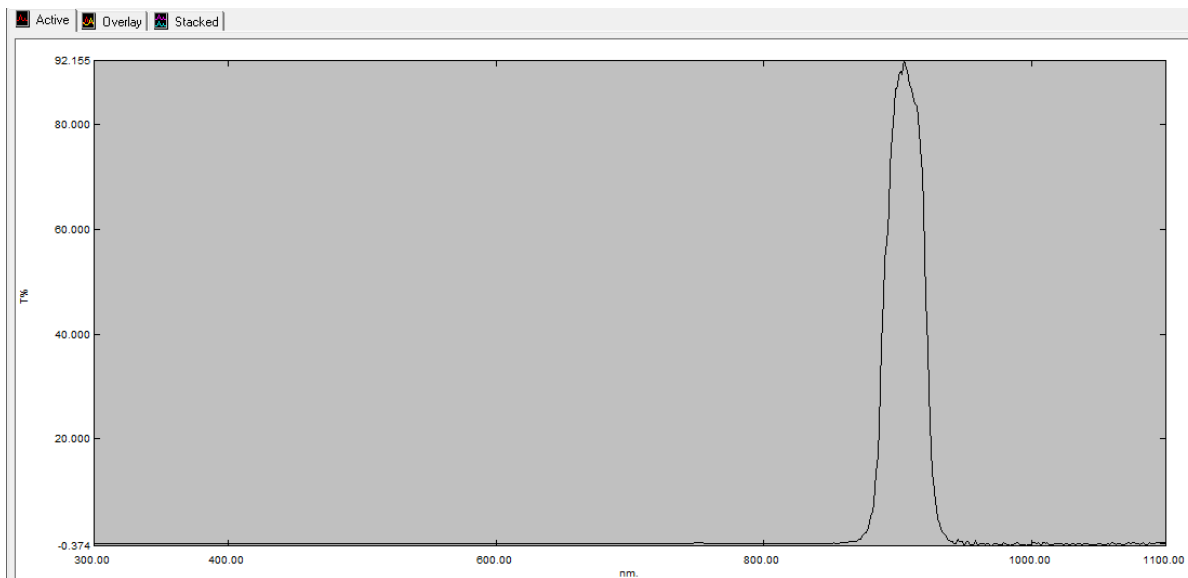


Figure 33.

Transmitting Optics

In order to capture the reflected signal from the target and filtered by receiving optics and electronics, short pulses needs to be generated to comply with laser safety class1. As

discussed in *Laser and Reference circuit (Tx)* chapter earlier, transmitting optics provides this functionality. Figure 34 shows the assembly of Tx optical holder and key components inside it.

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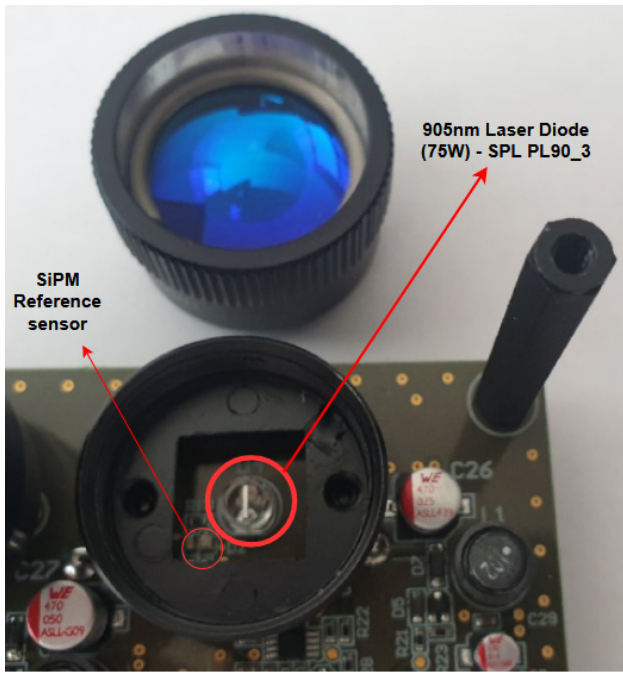


Figure 34. Transmitting Optics Assembly with SiPM Reference Diode

Laser Safety

SECO-RANGEFINDER-GEVK complies with class 1 laser safety standard and holds FDA approval for distribution towards ON Semiconductor customers.

Standard Compliance

Rangefinder board complies with standard IEC/EN 60825-1:2014 and 21 CFR 1040.10 and 1040.11 except for

deviations pursuant to Laser Notice No. 56. Each board is equipped with Laser Notice 56 label according to standard requirements (Figure 35)

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

Figure 35. Laser Notice 56 Label as Part of the SECO-RANGEFINDER-GEVK

Single Laser Diode Failure Compliance and Emission Limits

Important laser safety requirement defined by above standard, is also the Single Fault failure (e.g. once MOSFET driving the laser diode is shorted), where emission limits always must stay within standard definition.

Rangefinder board consists of the power MOSFET, functioning as a switch for laser diode. Positive bias (15 V, terminal P_LASER) from FPGA regulated DCDC boost converter is the actual Laser diode's power source. Output of the Boost converter charges the MLCC bank capacitors C17 and C18. Once the driving pulse out of the FPGA is generated through the driver chain – as soon as MOSFET opens – Laser diode emits for a short period of time. C17 and C18 discharges into the diode (Figure 36).

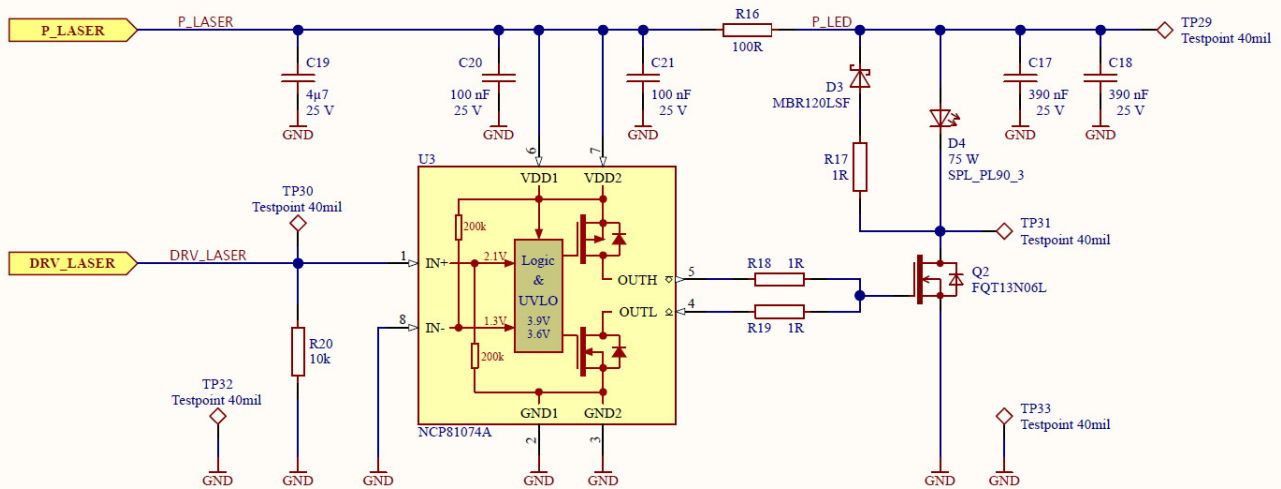


Figure 36. Laser Driver Circuit Supplied from 15 V (P_LASER)

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DCDC design, sizing the bank capacitors must be done carefully and return robust P_LASER disconnect, once MOSFET driving the laser diode is shorted. Converter must react very quickly to this overcurrent event so that Emission limits of the single fault event are never above class 1.

Rangefinder's DCDC boost is prepared to cope with this situation and OCP is continuously monitored by FPGA. Figure 37 depicts laser power supply current limit. For 15 V, laser power is disconnected whenever the current drawn reaches 42 mA.

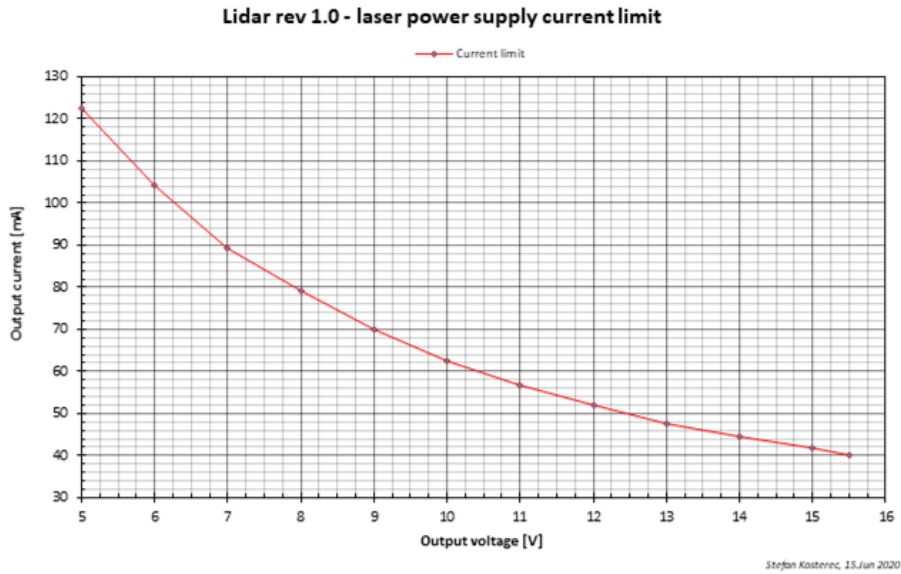


Figure 37. Laser Power Supply Current Limitation

If a such occurrence happens, GUI indicates that under *Laser power* control box – see Figure 38. You can restart to normal operation by unchecking the *ON* box before it is checked again.

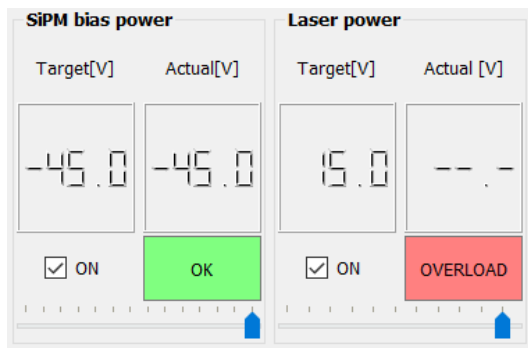


Figure 38. Overload of Laser Power is Indicated (e.g. at Single Fault Event)

Figure 39 shows the Laser optical power over time when FET Q2 is shorted. Laser optical power output is monitored before and after fault is implemented.

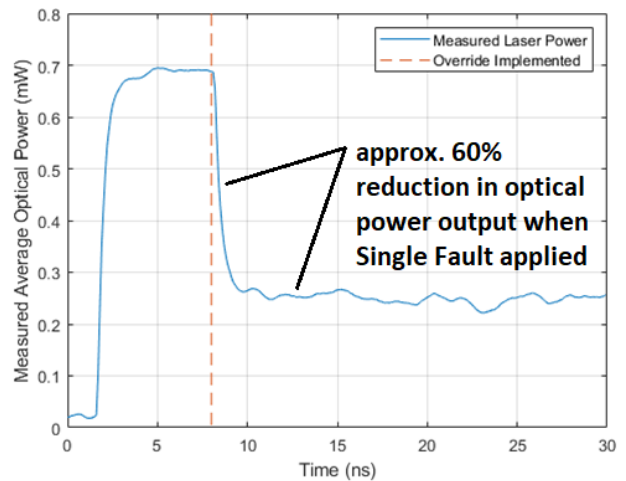


Figure 39. Laser Optical Power over Time when Single Fault Failure Happens

Typical Laser Optical Pulse Shape

Laser Optical Pulse shape was found to be dependent on laser pulse width setting and laser voltage setting. To meet class 1 requirements, laser voltage was determined to be 15 V, repetition rate of pulsing 1024 Hz. In this configuration, returned optical laser pulse width is ~18 ns.

Figure 40 depicts actual measurements (Green trace: Laser clock, Yellow Trace: Laser Optical Pulse shape from DET08C/M detector)

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Figure 40. Typical Laser Optical Pulse Shape

Ambient Light Rejection

Figure 13 in the previous chapter discusses about Overload Condition for Reference SiPM at high ambient illumination (e.g. outdoor applications). SiPM photomultiplier present at Transmitting optics (Tx) – reference and Receiving optics (Rx) – receiver, is negatively biased from the common regulated DCDC inverting converter, driven by FPGA. At high ambient illumination, reference SiPM in Tx could saturate due to direct exposure towards ambient light (only spectrum’s barrier creates Tx lens).

On the contrary, the SiPM in Rx optics does not suffer such phenomenon due to presence of highly selective band pass filter.

In order to prevent saturation and potential malfunction of SiPM reference diode (Tx), FPGA continuously monitors maximum current out of the inverting DCDC converter (Figure 41). As the negative bias is regulated directly in the GUI, current limit value varies as well.

The addition of a second band pass optical filter in place of the transmitting optics would increase the overall cost of the solution. SiPM Bias supply was overloaded above -37.5 V with high ambient light level (Figure 42 showing the test setup). By thorough measurements it has been determined that for outdoor applications SiPM $N_{\text{bias}} = -35\text{ V}$ (enabled over slider or dedicated *outdoor* button in GUI). For indoor applications SiPM $N_{\text{bias}} = -45\text{ V}$ (enabled over slider or dedicated *indoor* button in GUI).

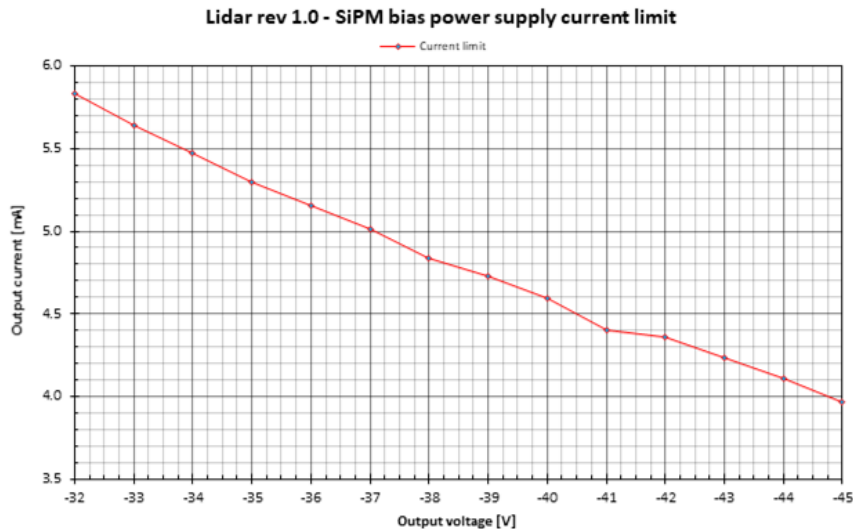
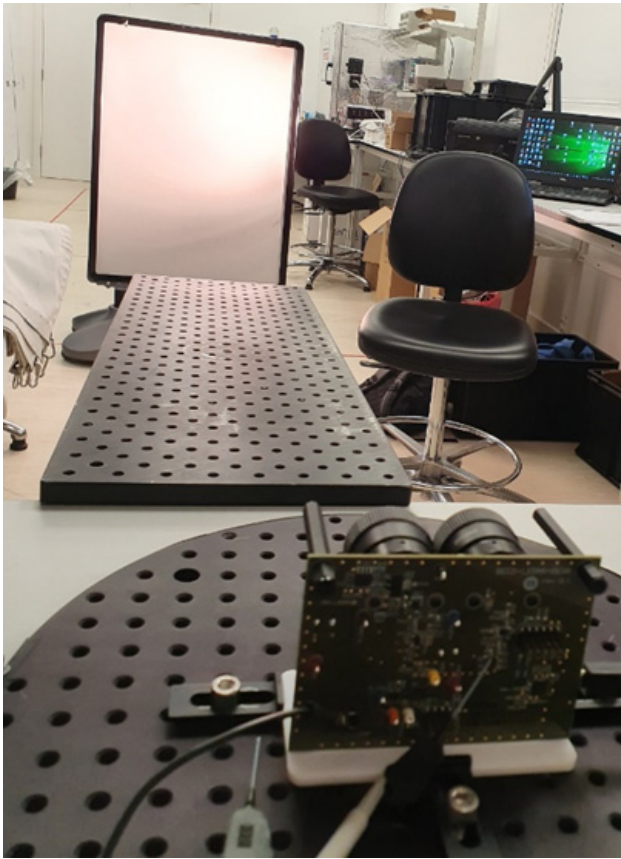


Figure 41. SiPM Bias Power Supply Limit

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Configuration Used:

Laser Repetition Rate	1042	Hz
Laser Pulse Width	31	-
Trigger Pulse Count	200	-
Laser Voltage Supply	15	V
SiPM Bias Voltage	35	V
Target	White Card	-
Distance to Target	3.5	m

Figure 42. Photo of Setup with High Ambient Light

Optics Comparison

Rx and Tx side of optics is equipped with the same lens type. Lenses from *Bohr* and *RealPoo* manufacturers has been measured and either can be used in the Rangefinder (Figure 43). Results are the following:

- Similar transmission between Bohr Optics and Realpoo Optics
- Plot shown has y-axis normalised
 - ◆ Shows relative transmission of each option, not absolute transmission
- Recommend either Bohr Optics or Realpoo Optics
 - ◆ There will be negligible difference in ranging performance due to small transmission differences

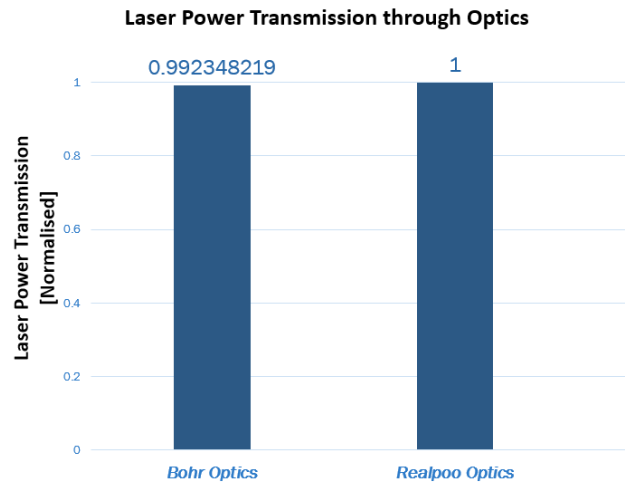


Figure 43. Laser Power Transmission between Bohr and Realpoo Lens

Measurement Error – Varying SiPM Bias Voltage

Measurement Error is defined as: Median Measured Range – Expected Range. *SiPM Bias Voltage* = -45 V gives lowest measurement error at all distances (error 10 mm at distance 10 m) – see Figure 44.

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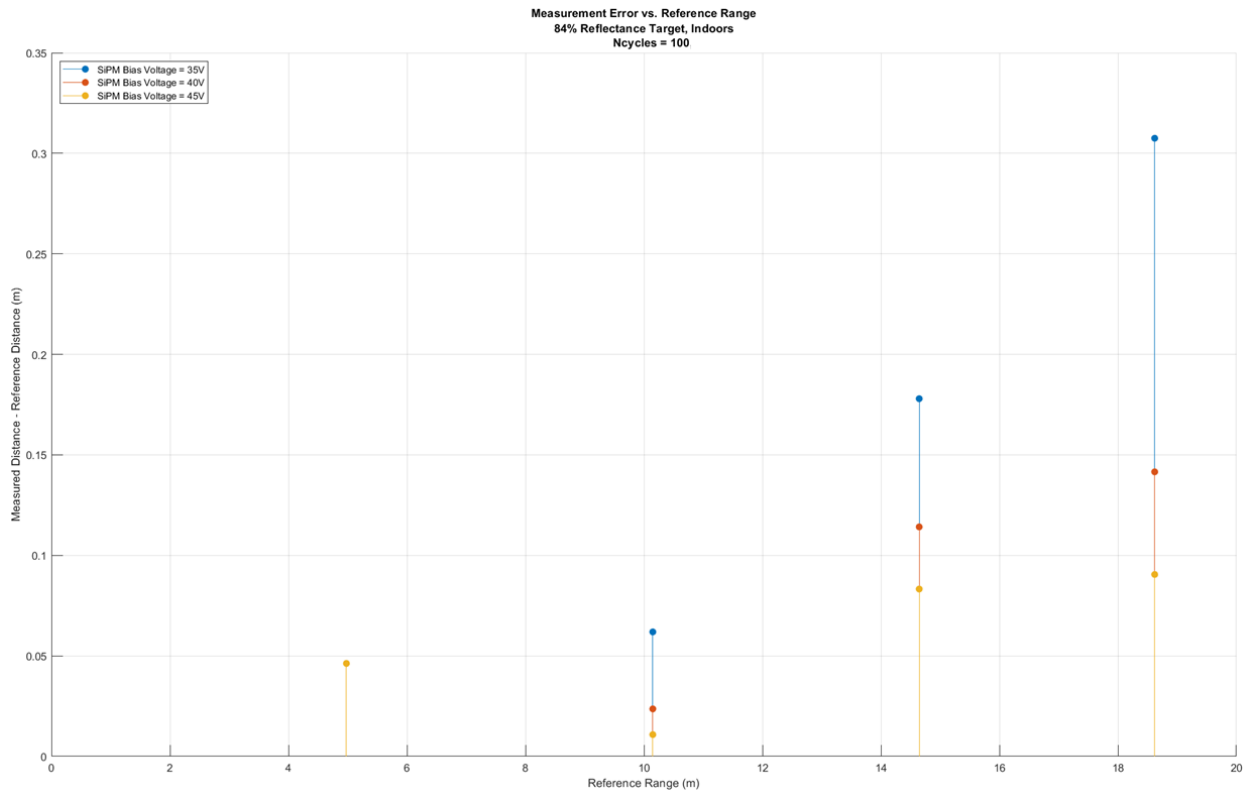


Figure 44. Measurement Error vs. Reference Range (Trigger Pulse Count = 100)

Timewalk

Timewalk can occur when a high threshold is used with a relatively weak return signal. Can lead to false increase in measured range. Discriminator (LVDS comparator) in range

finder has threshold level set low enough, in order to eliminate imprecision caused by low level signal from far distance measurement. Figure 46 reveals high return signal at 15 V laser bias.

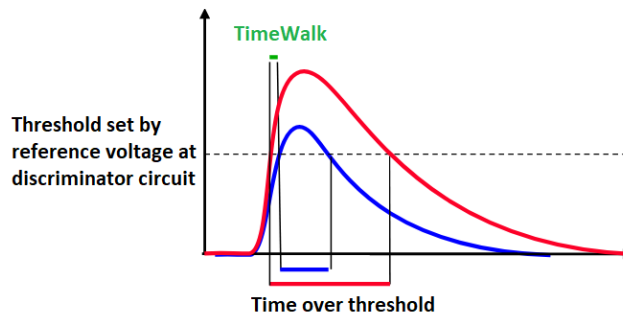
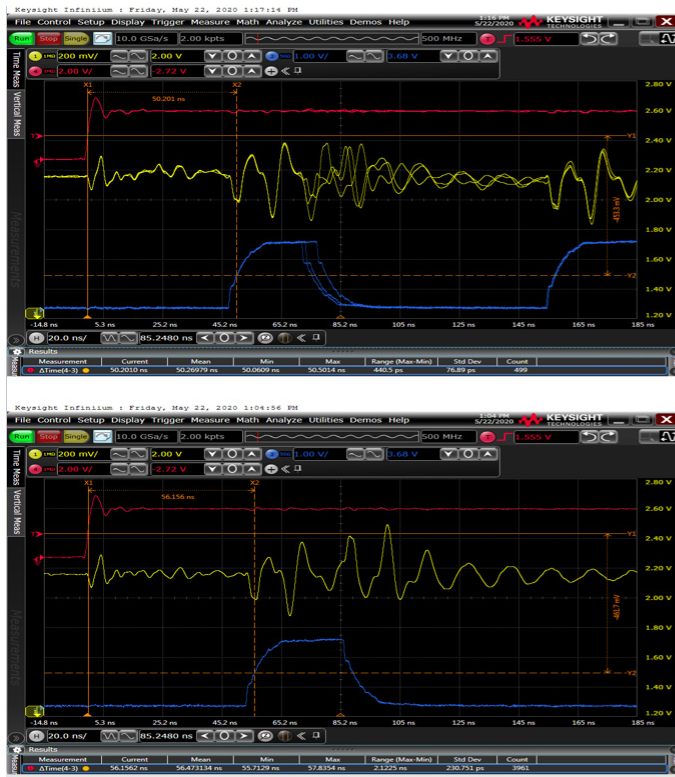


Figure 45. Time Walk Varies with Threshold Reference at LVDS Discriminator Circuit

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Scope:

Red Trace: Laser CLK

Yellow Trace: LVDS Comparator Inverted Input

Blue Trace: LVDS Comparator Output

High return signal (15V laser bias):

$\Delta t = 50.2\text{ns}$

Low return signal (5V laser bias):

$\Delta t = 56.2\text{ns}$

Figure 46. Actual Measurements of Discriminator Circuit at 5 V and 15 V Laser Bias

SECO-RANGEFINDER-GEVK

INTERFACING WITH BLUETOOTH DEVELOPMENT KIT

SECO-RANGEFINDER-GEVK was designed the way it can interface directly with Bluetooth® development kit (BDK-GEVK). From a mechanical concept, the Rangefinder perfectly aligns with the BDK-GEVK.

As mentioned in chapter *Supply management circuitry and UART control logic*, Rangefinder is prepared to operate with platform BDK-GEVK for customers to make the compelling use cases. In a such configuration (Figure 47), Rangefinder's PMOD (male) is connected to

BDK-GEVK's PMOD (female). Supply source for Rangefinder board as well as UART communication is managed fully over PMOD.

In this case, BDK-GEVK has to be connected over USB cable. FPGA and HW of Rangefinder automatically switches to PMOD once PMOD supply is detected out of BDK-GEVK. Priority set in Rangefinder is on PMOD – both supply and UART Communication port.

For more information on UART communication protocol specification (Rangefinder FPGA host controller), please contact ON Semiconductor.

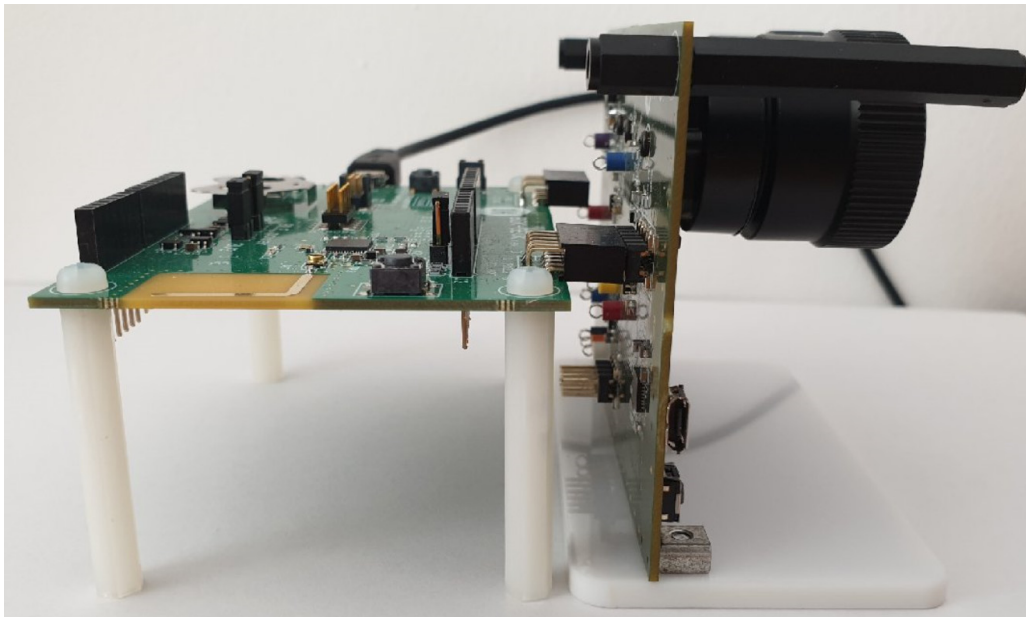
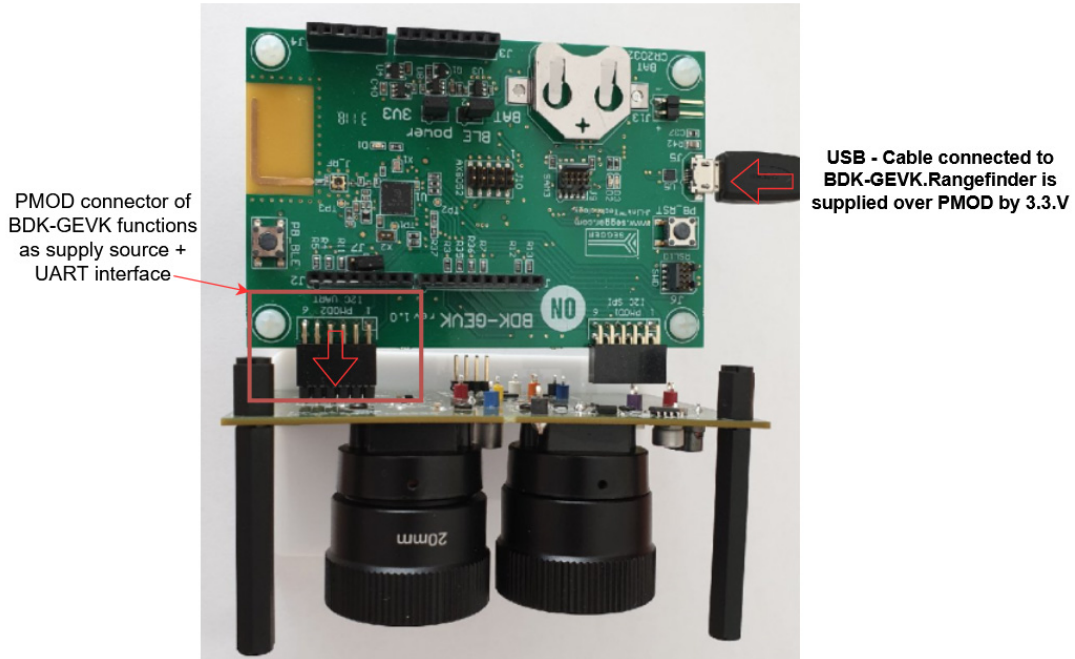


Figure 47. Connection of Rangefinder over PMOD (BDK-GEVK)

SECO-RANGEFINDER-GEVK

HW TESTING POINTS

Rangefinder board is equipped with all necessary test points for customers to measure high frequency and power management circuitry. Figure 48 shows the summary of test points. Customers can probe them directly.

- P3V3 – 3.3 V system source for DCDC converters and FPGA
- P2V5 – 2.5 V for FPGA

- P1V2 – 1.2 V for FPGA
- GND – Ground node
- P_LASER – positive laser voltage probe (15 V)
- N_BIAS – common negative voltage bias for SiPM reference and receiving photomultipliers
- CLK16M – output clock of the FPGA's Crystal

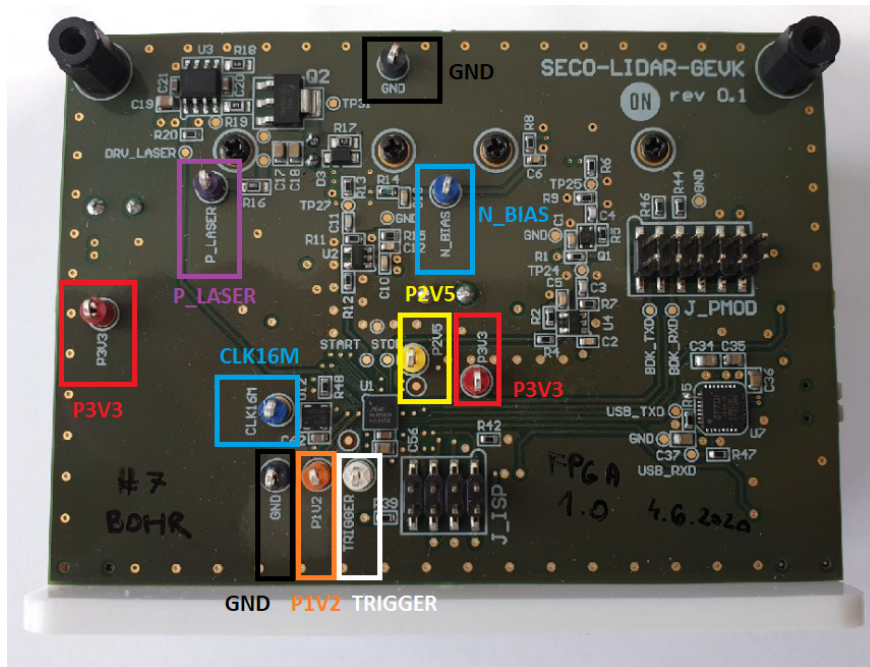
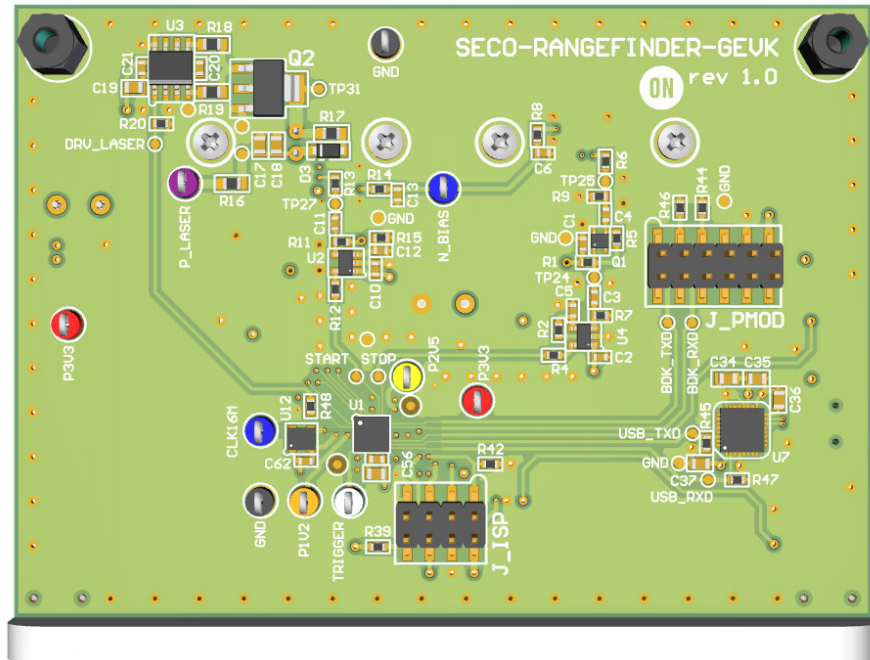


Figure 48. Key Testing Points Available for on the SECO-RANGEFINDER-GEVK

SECO-RANGEFINDER-GEVK

HARDWARE FILES

All the HW related files (schematic, layout, BOM, mechanical, gerber data) are uploaded on www.onsemi.com webpage as well.

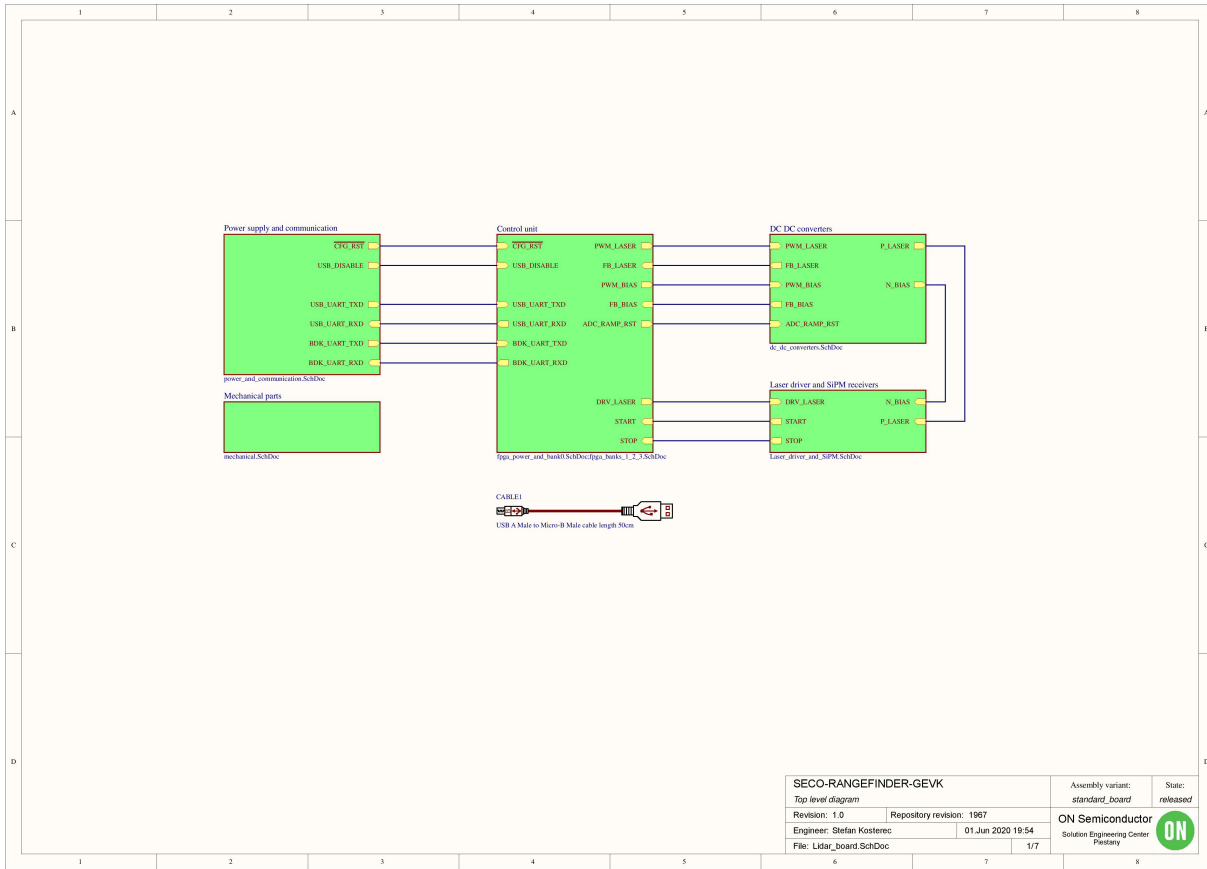
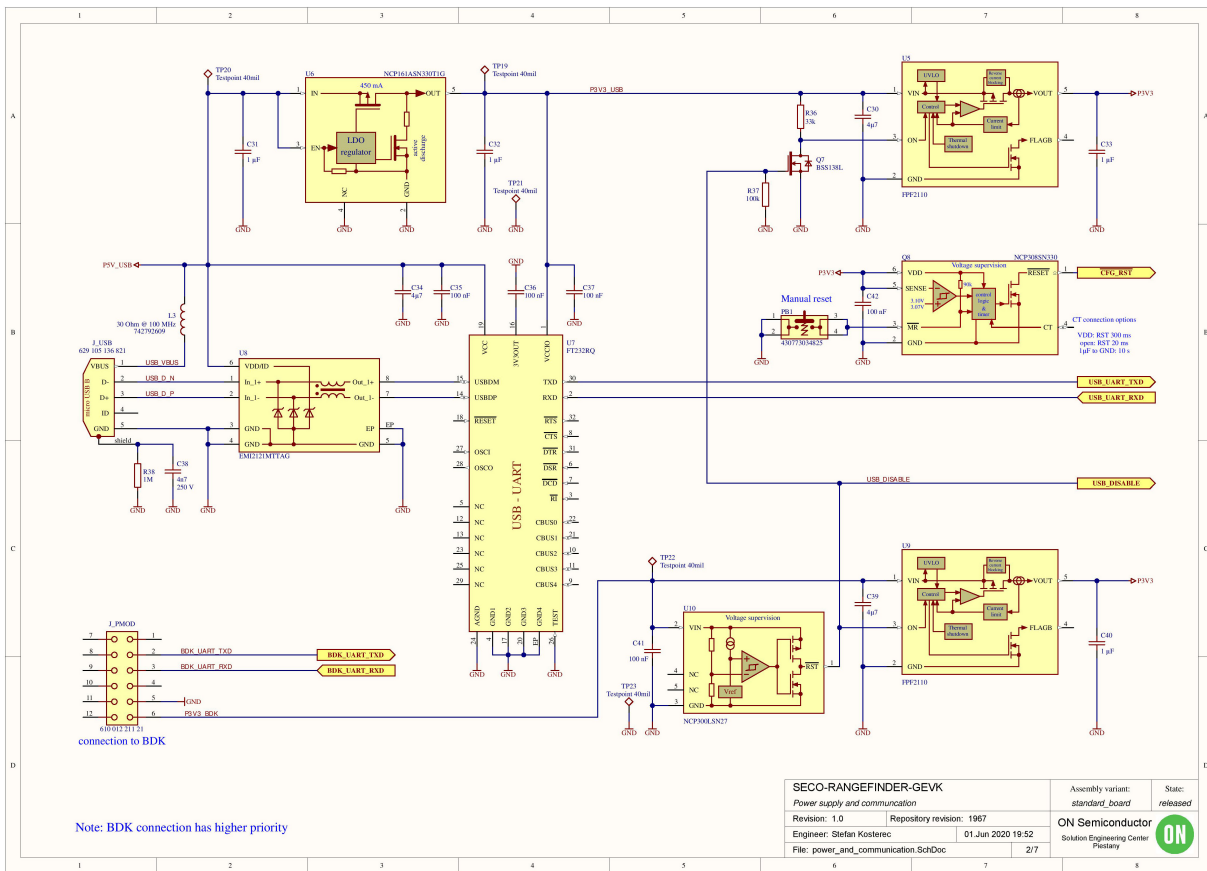


Figure 49. Rangefinder Board Circuit Diagrams (Part 1/4)



Note: BDK connection has higher priority

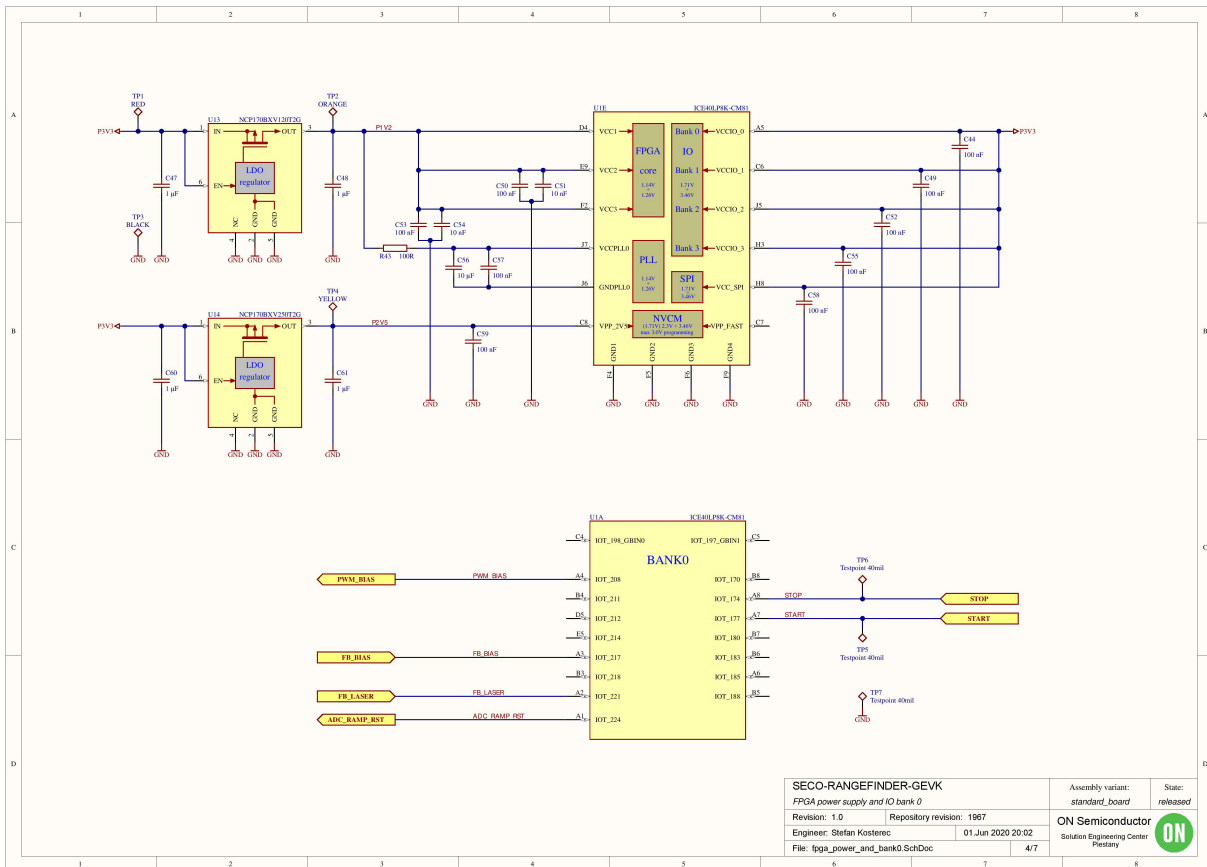


Figure 49. Rangefinder Board Circuit Diagrams (Part 2/4)

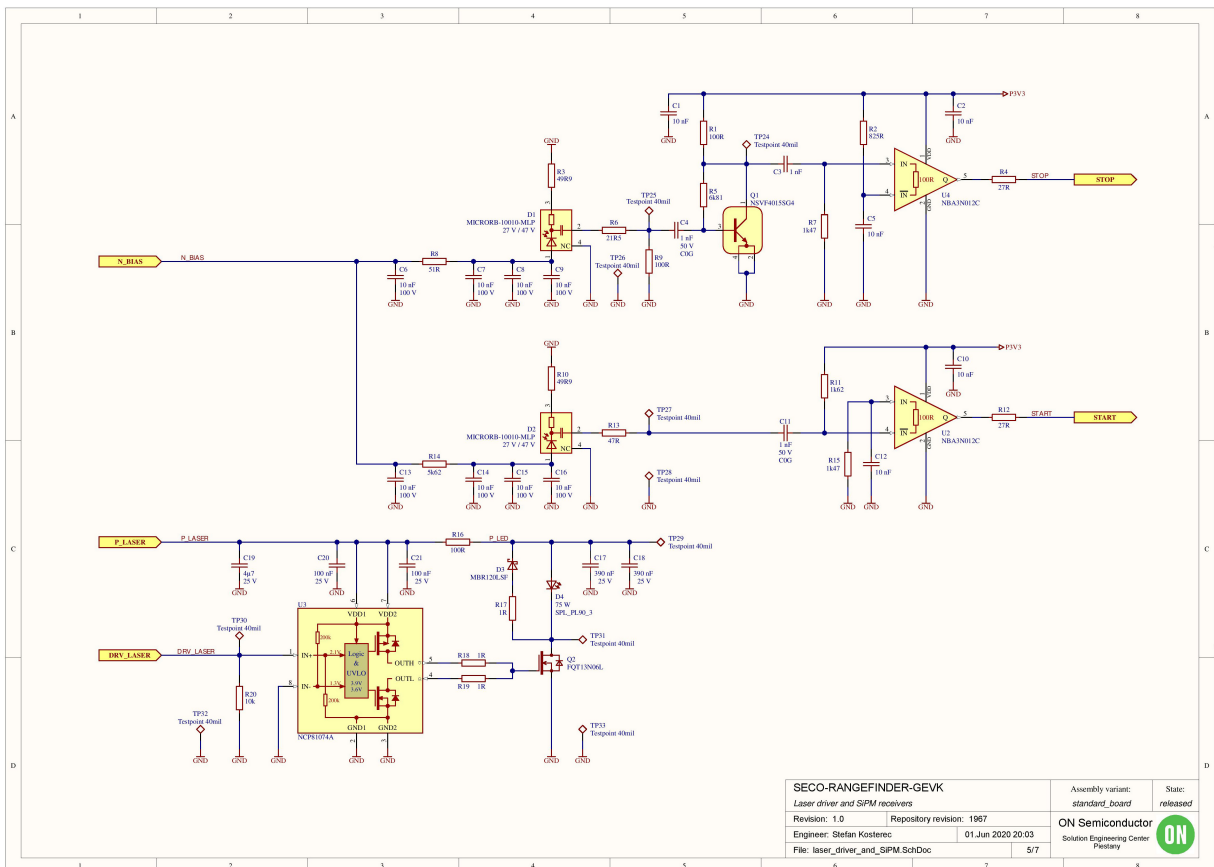
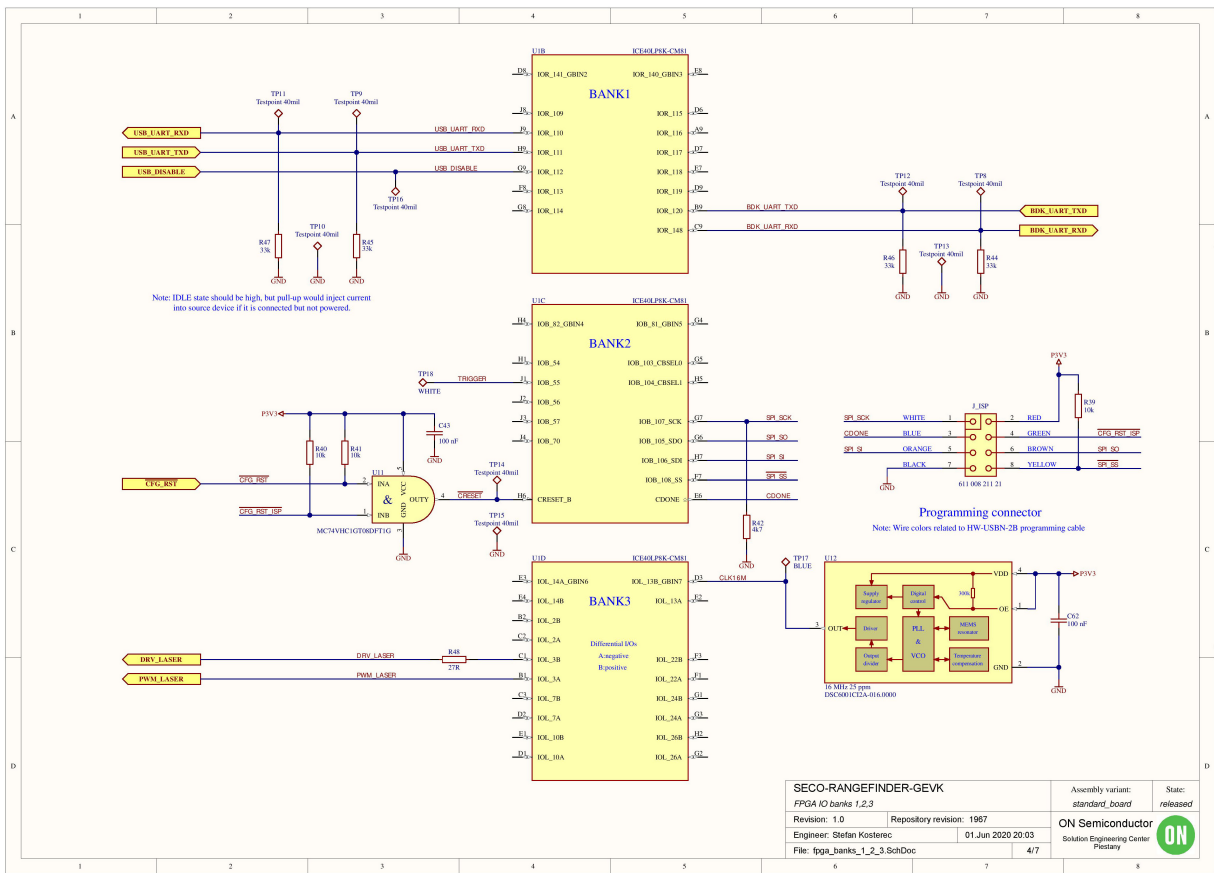


Figure 49. Rangefinder Board Circuit Diagrams (Part 3/4)

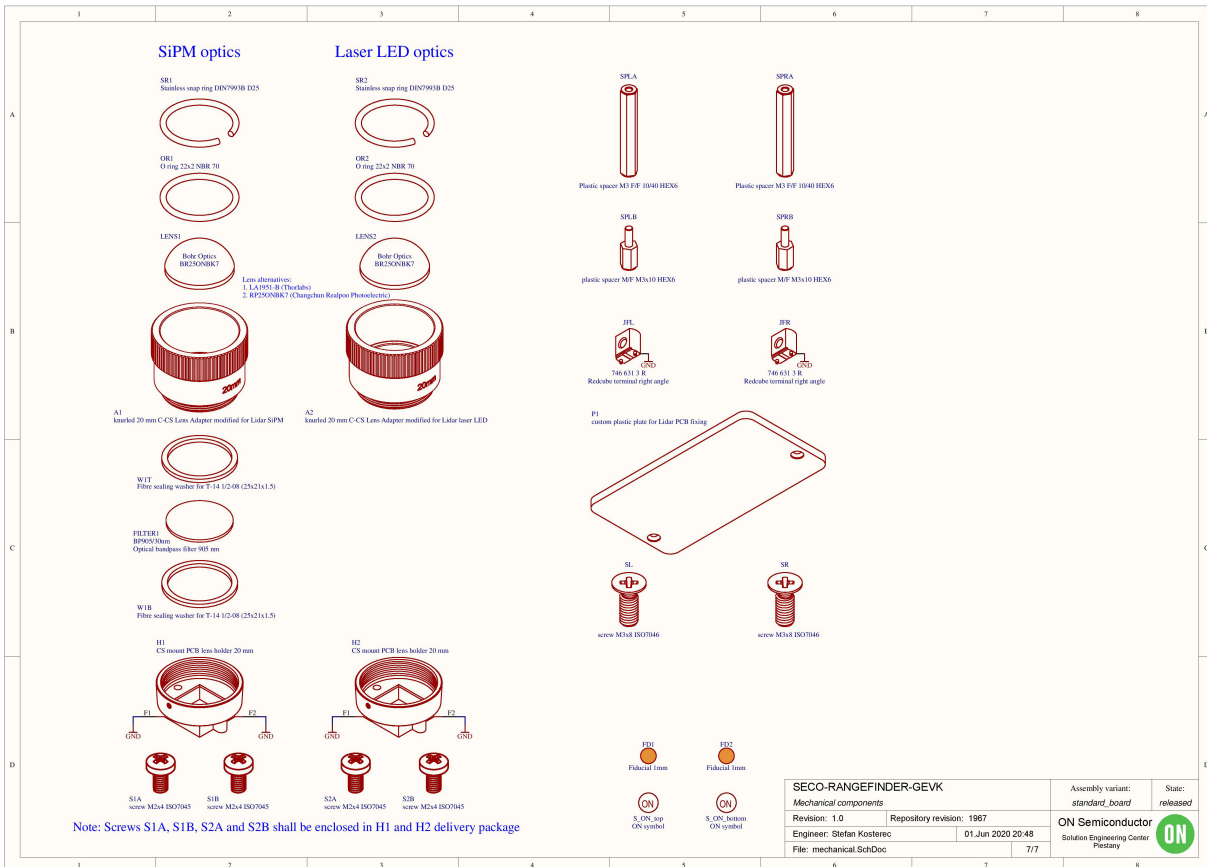
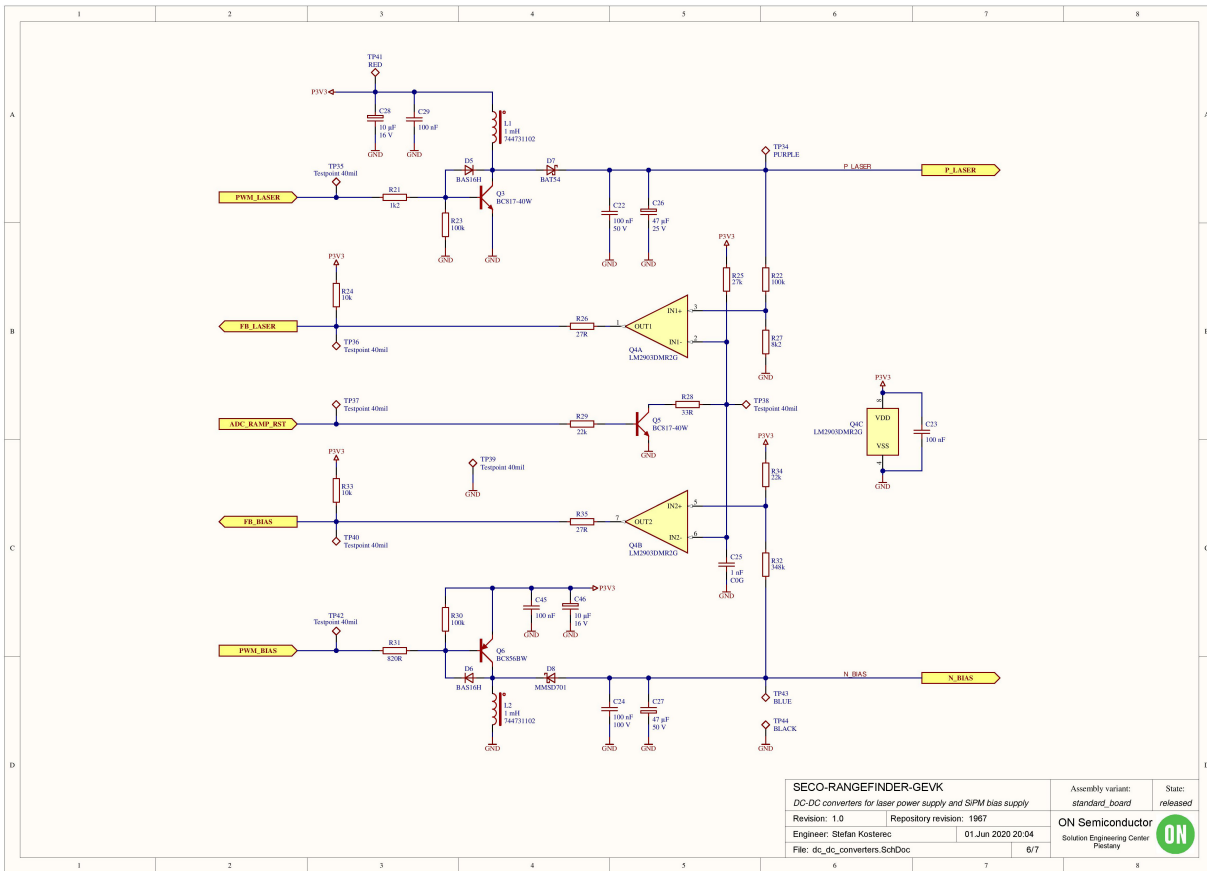


Figure 49. Rangefinder Board Circuit Diagrams (Part 4/4)

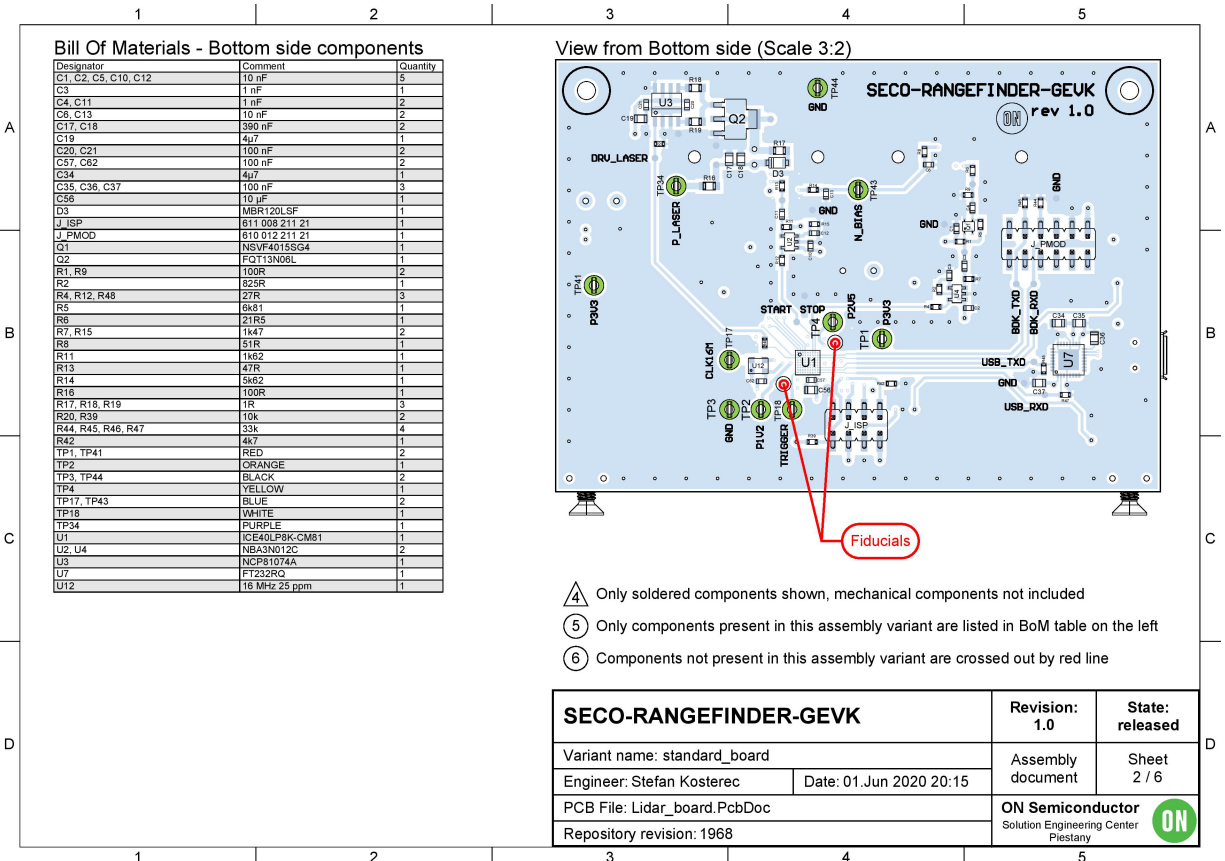
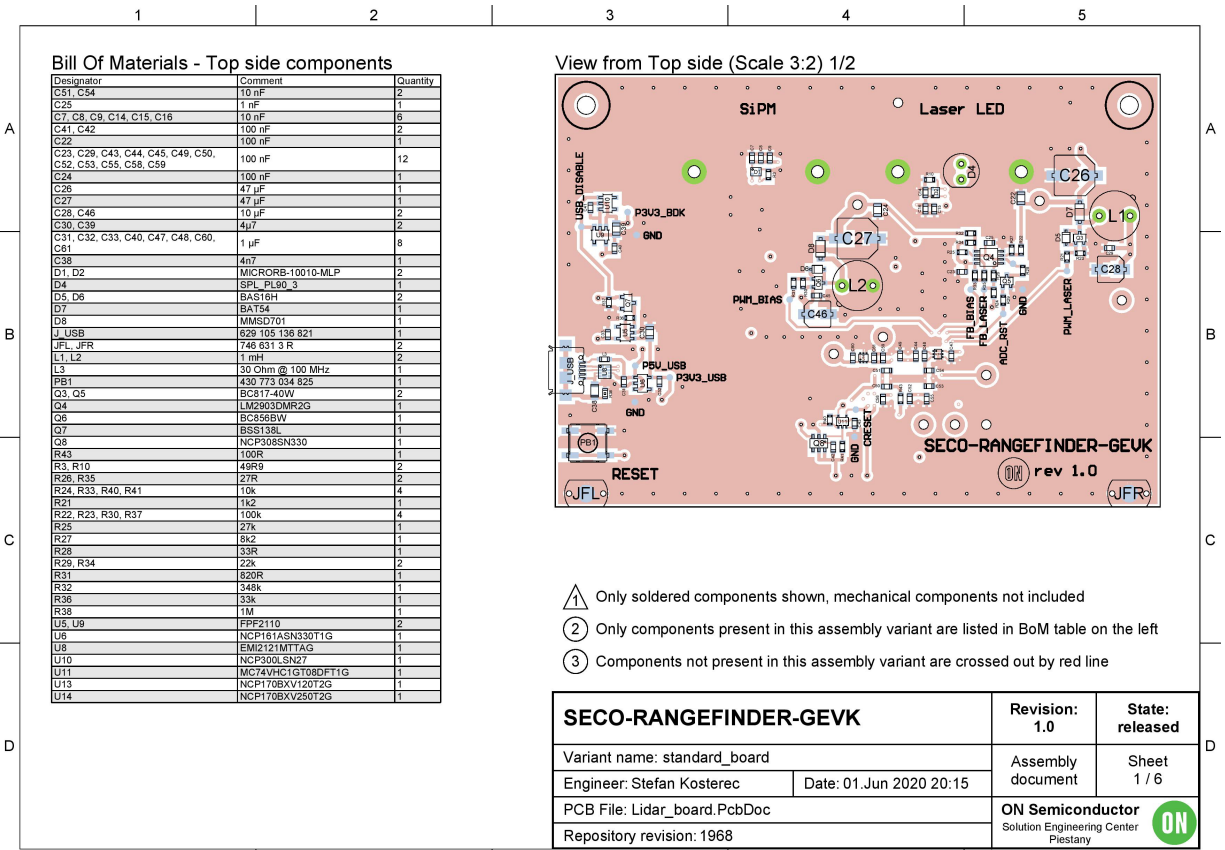


Figure 50. Rangefinder Board Assembly and BOM

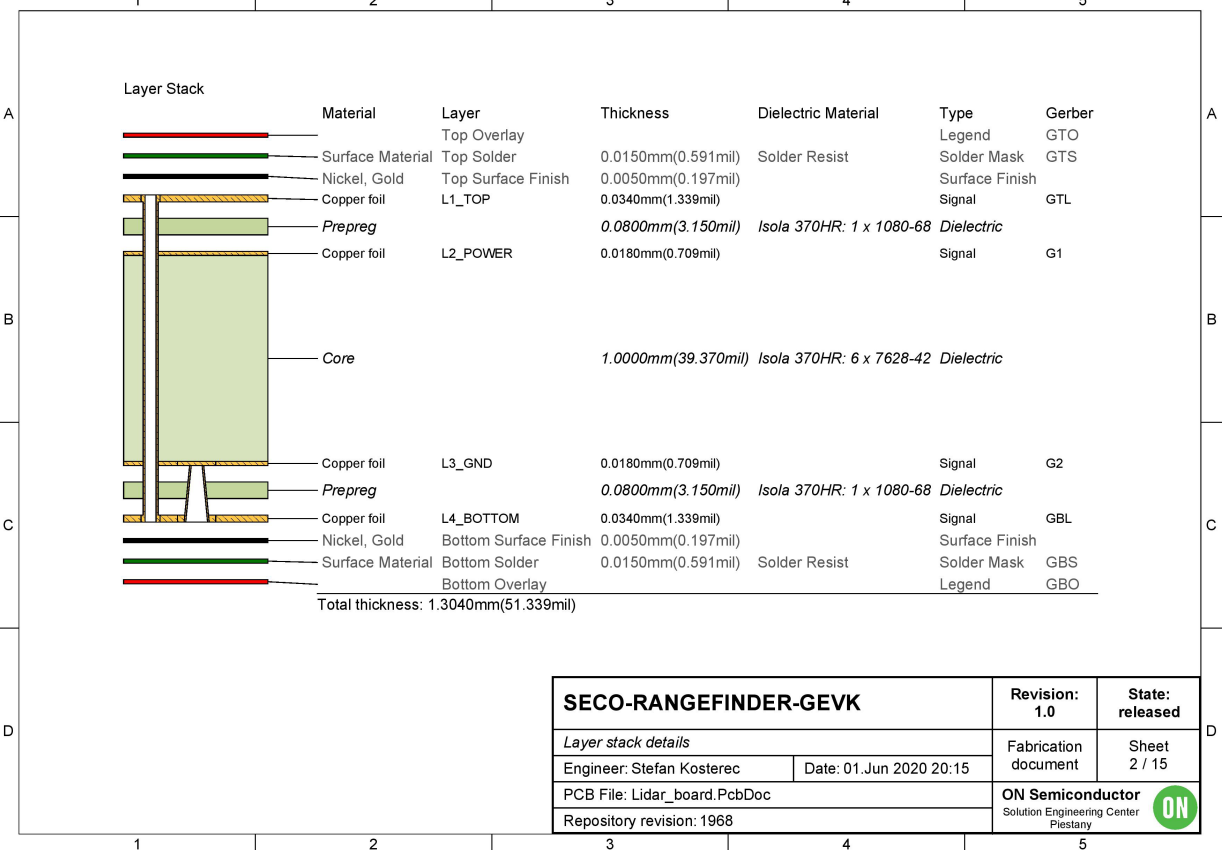
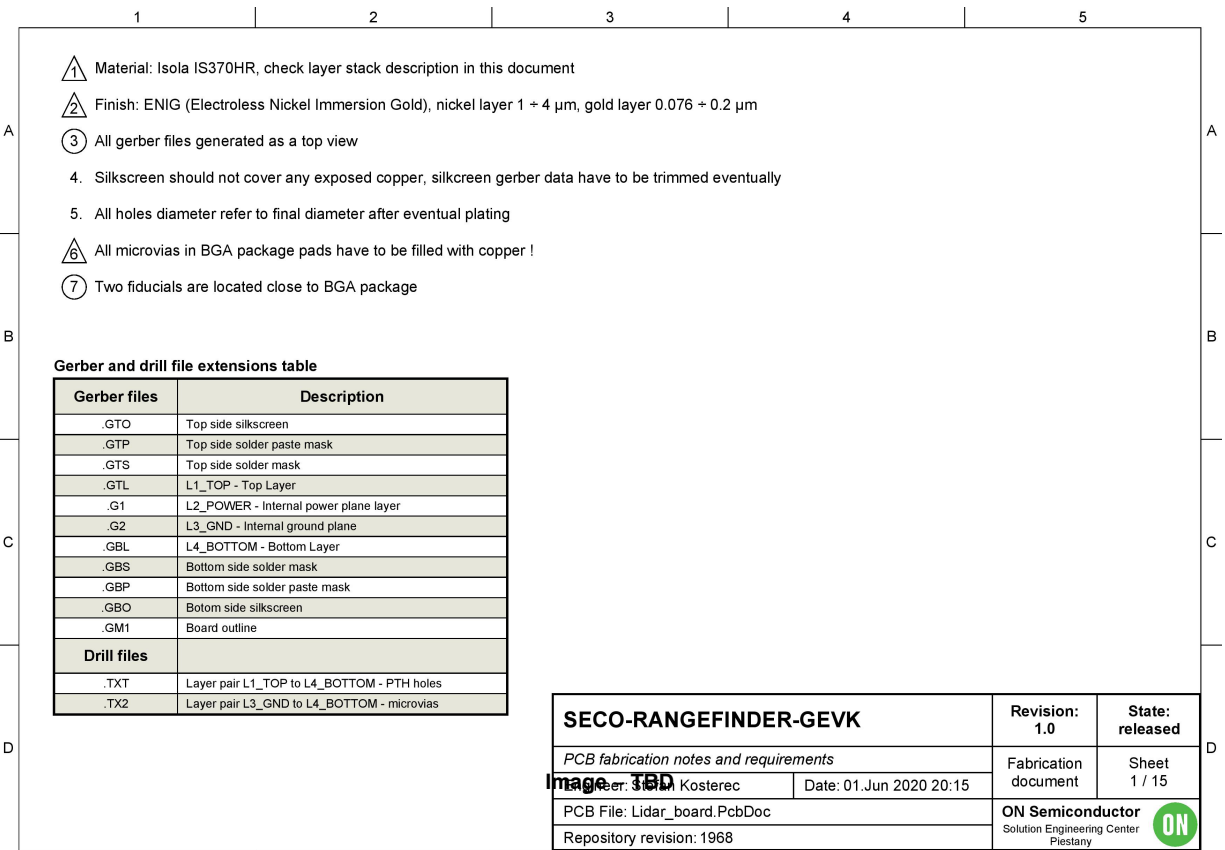


Figure 51. Rangefinder PCB Layout and Components Assembly (Part 1/8)

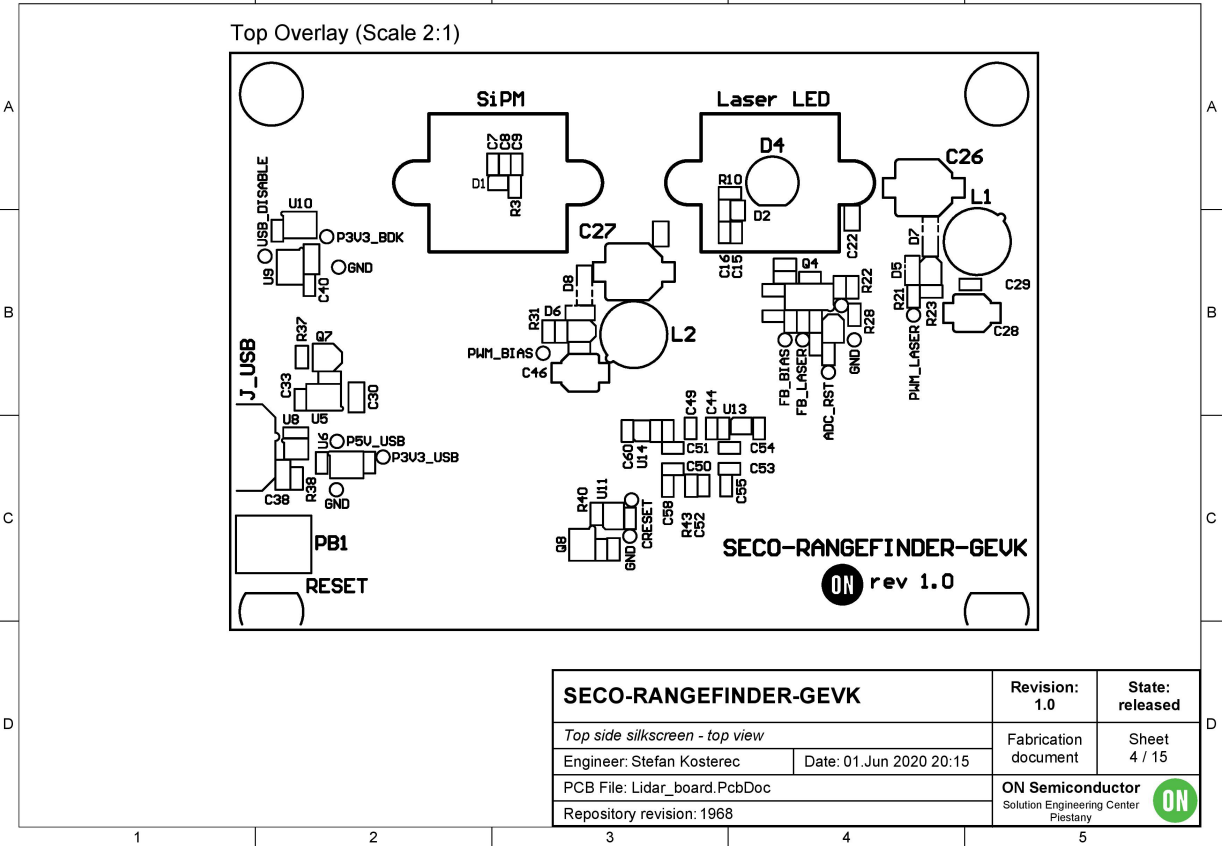
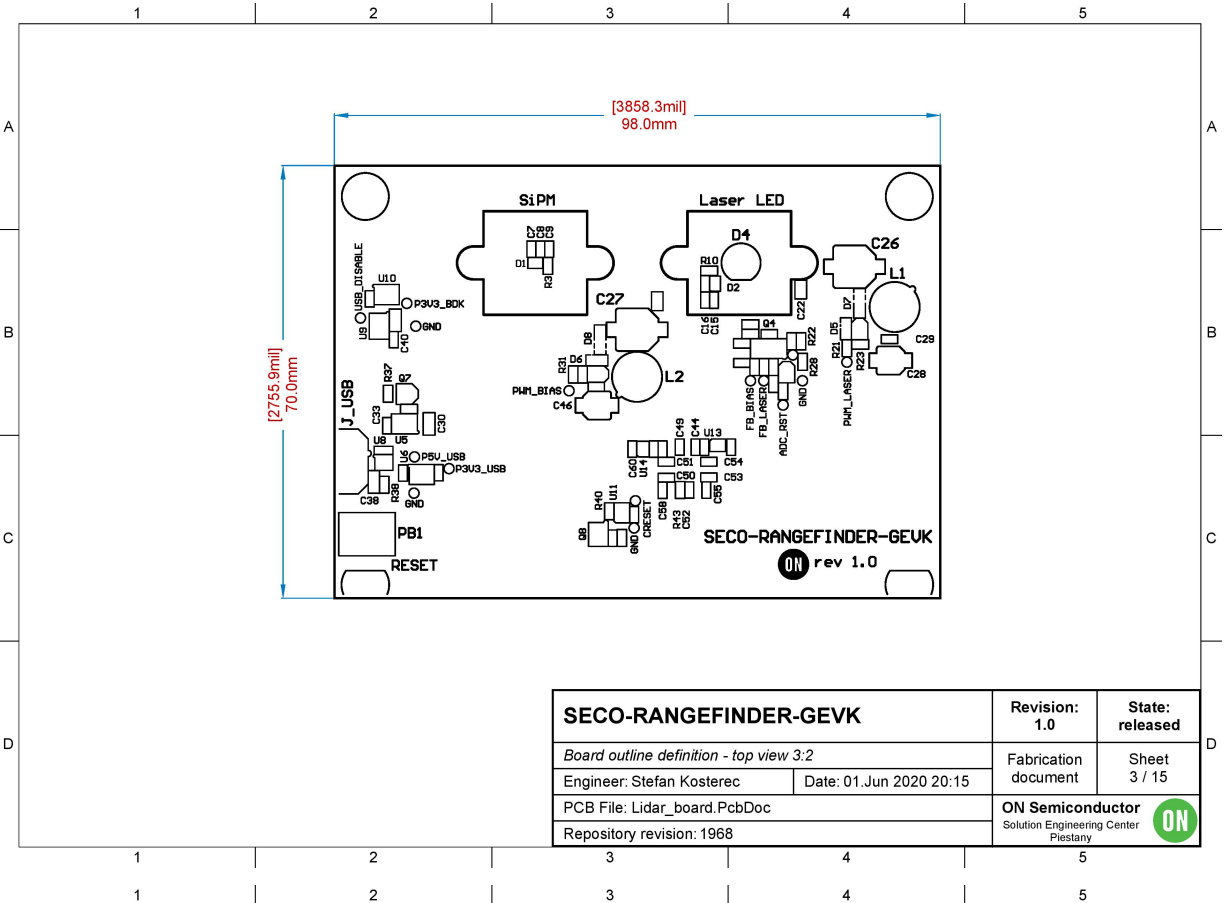


Figure 51. Rangefinder PCB Layout and Components Assembly (Part 2/8)

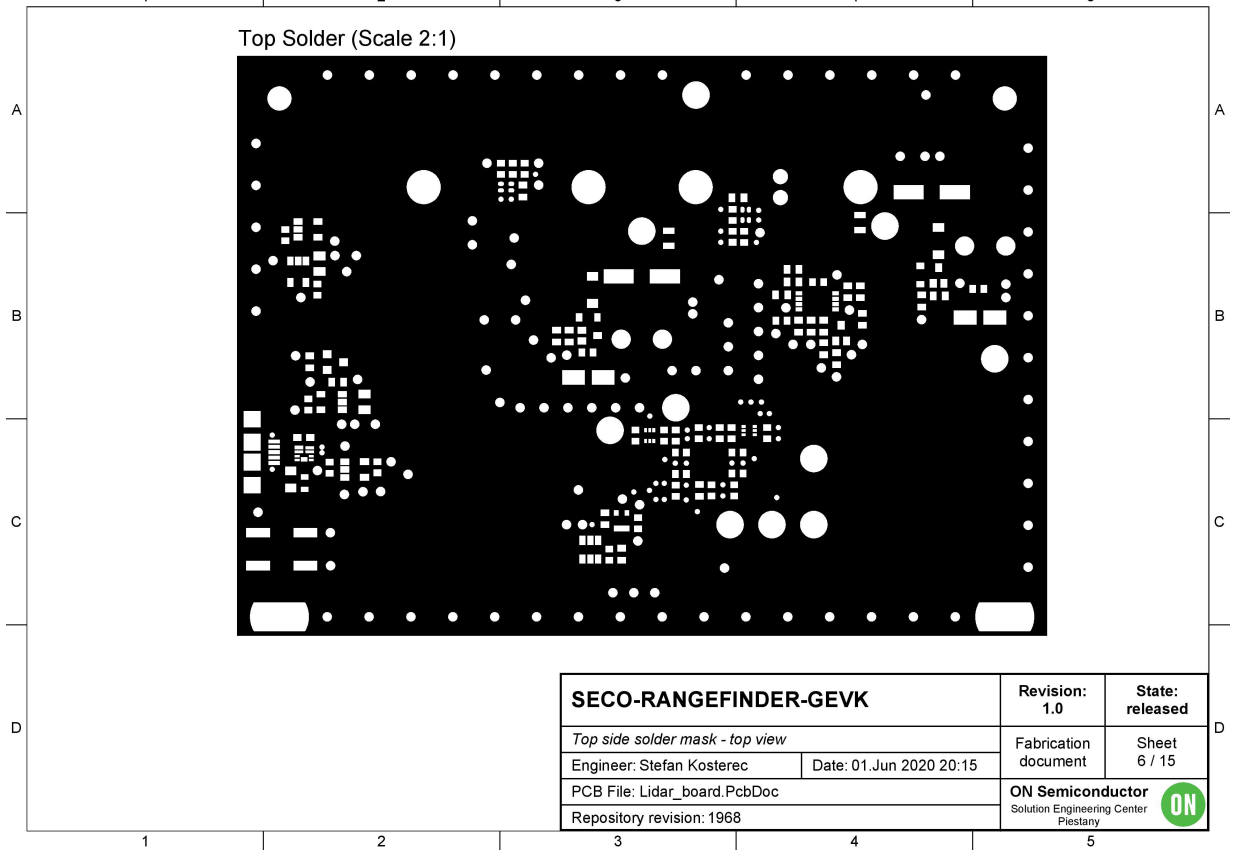
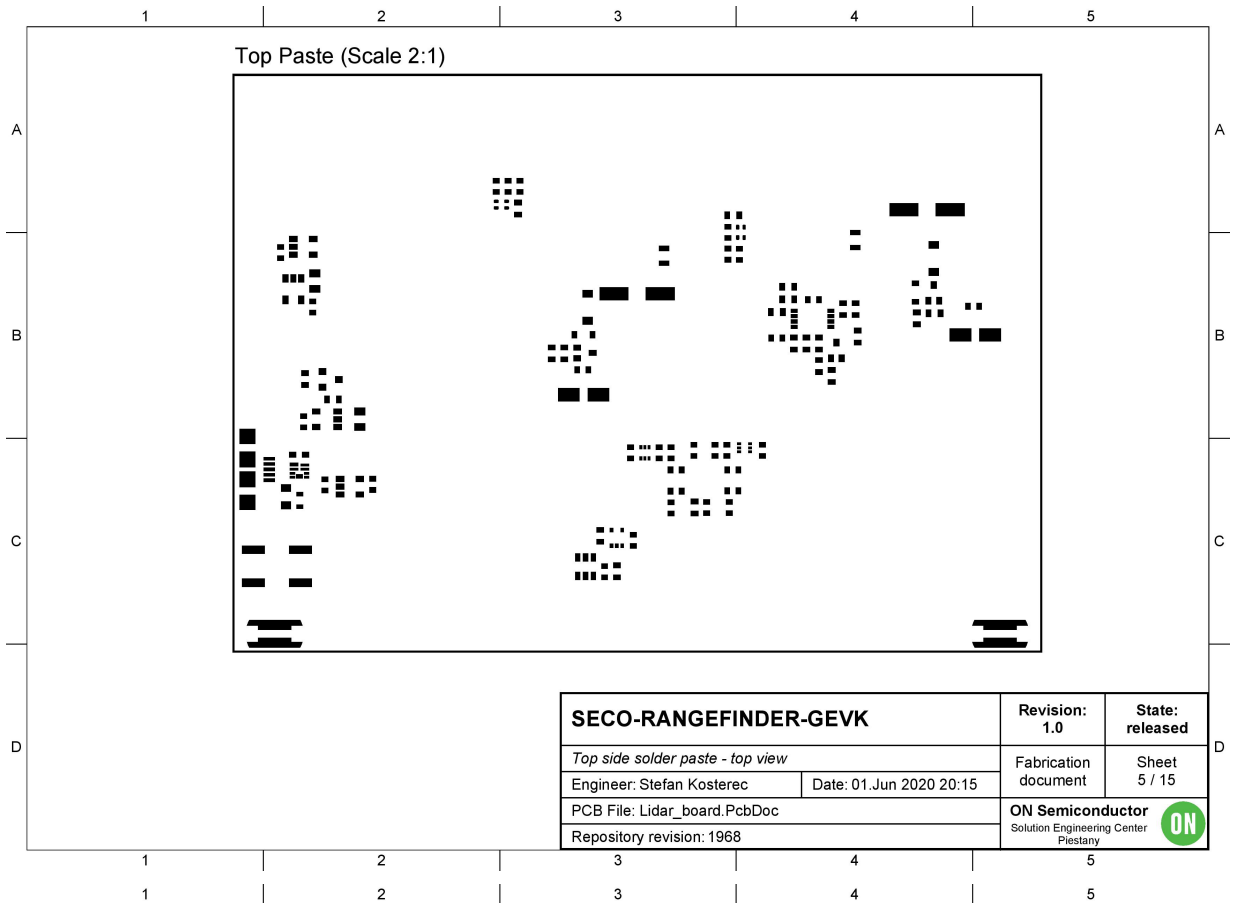


Figure 51. Rangefinder PCB Layout and Components Assembly (Part 3/8)

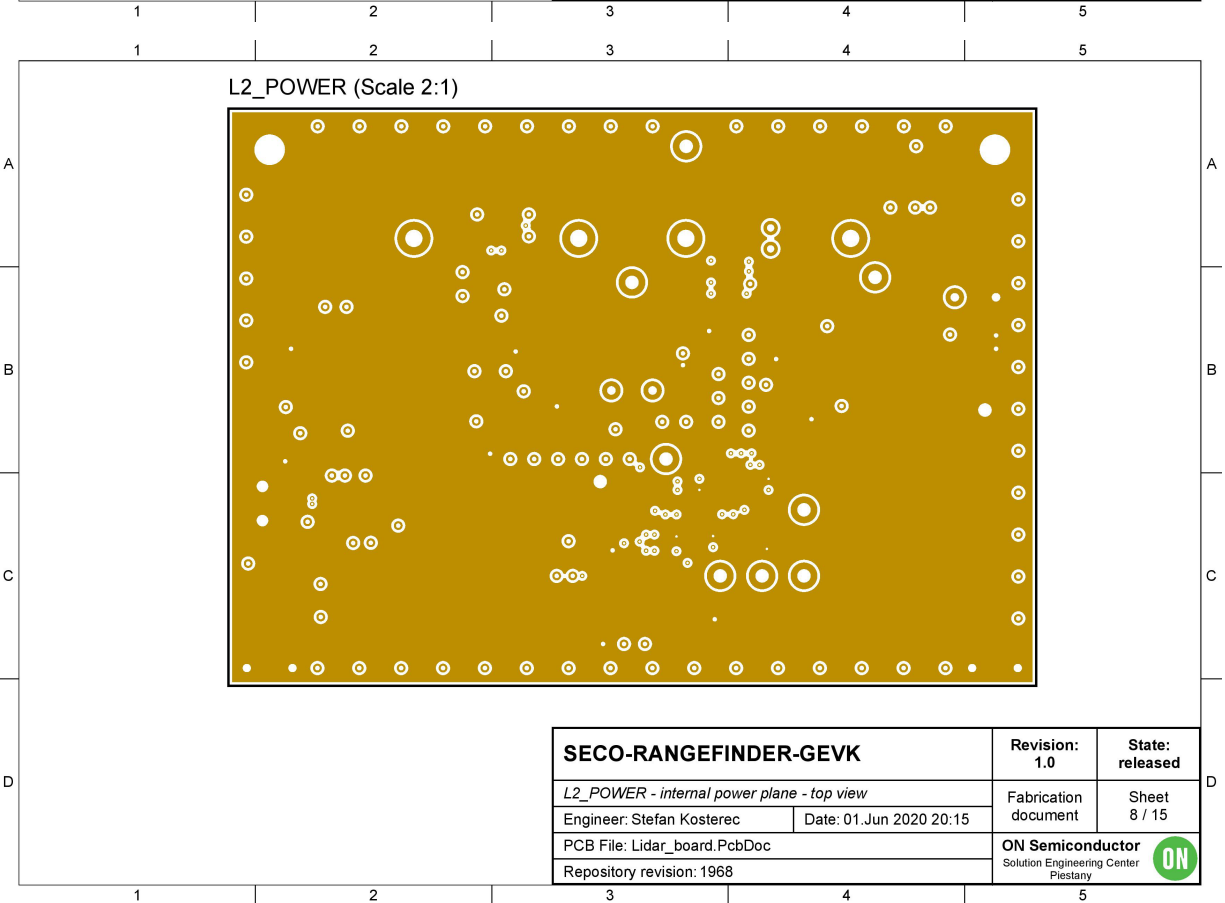
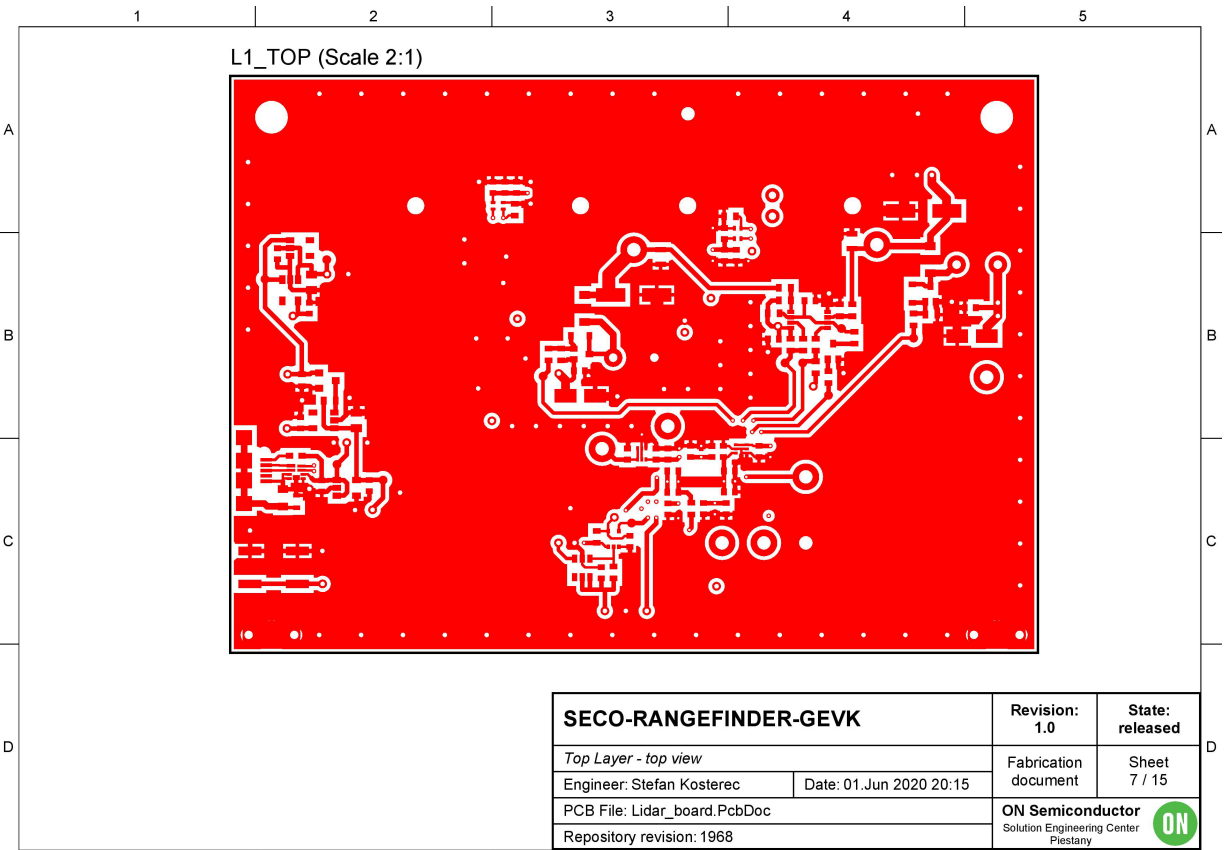


Figure 51. Rangefinder PCB Layout and Components Assembly (Part 4/8)

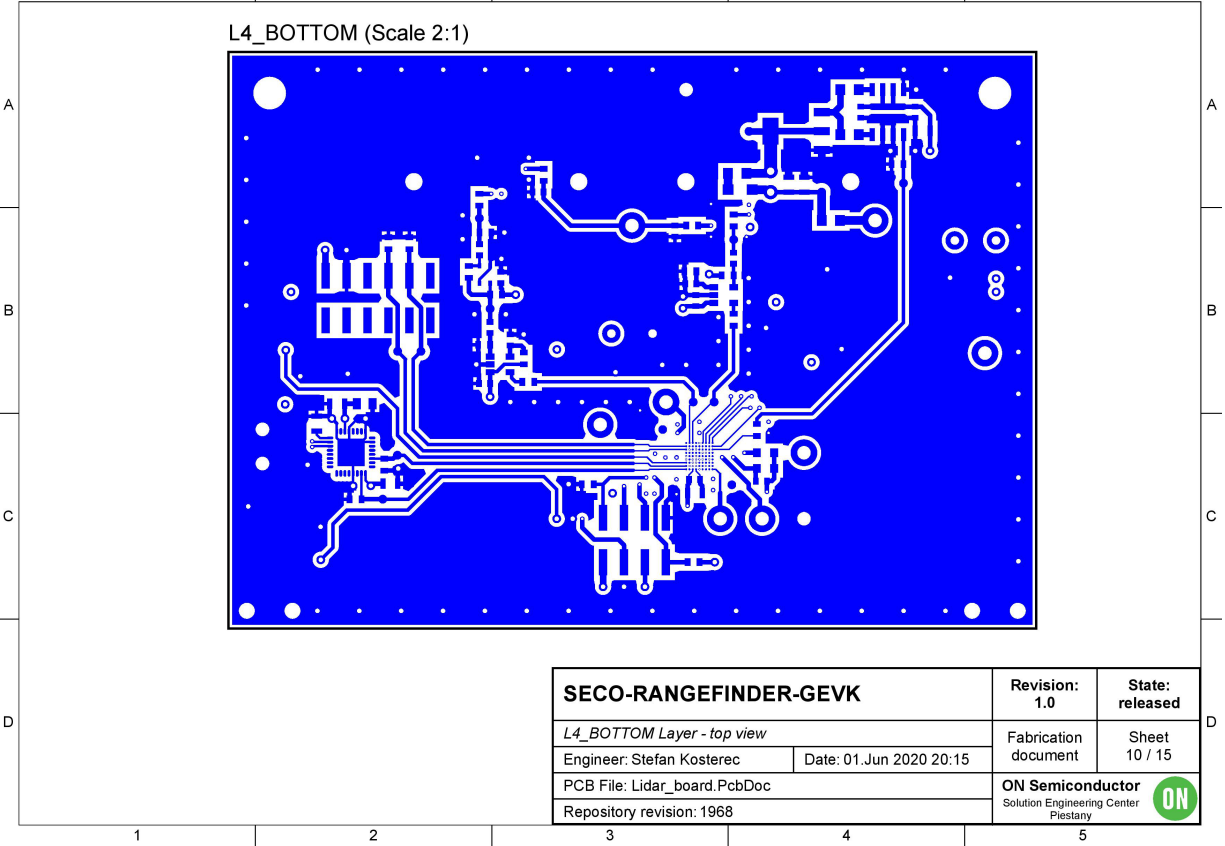
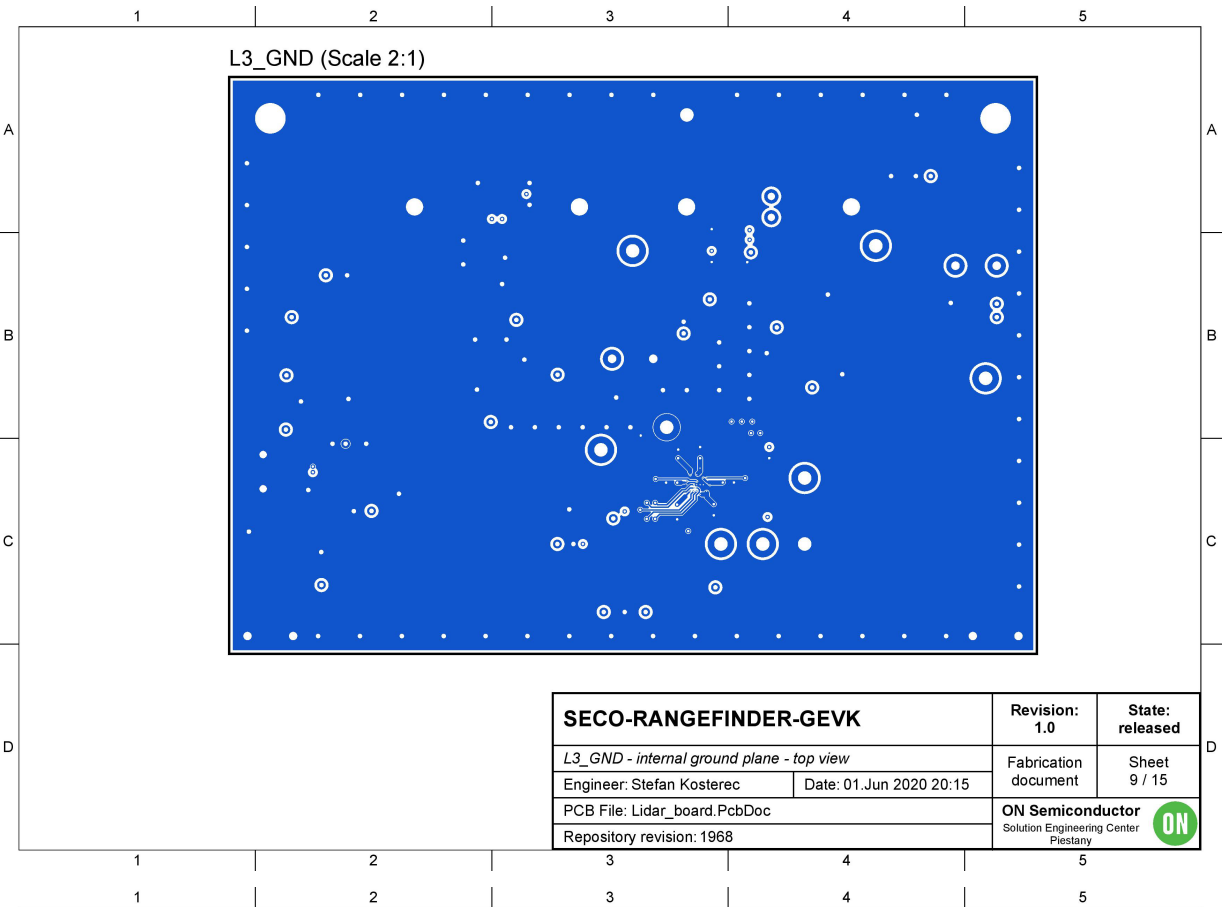


Figure 51. Rangefinder PCB Layout and Components Assembly (Part 5/8)

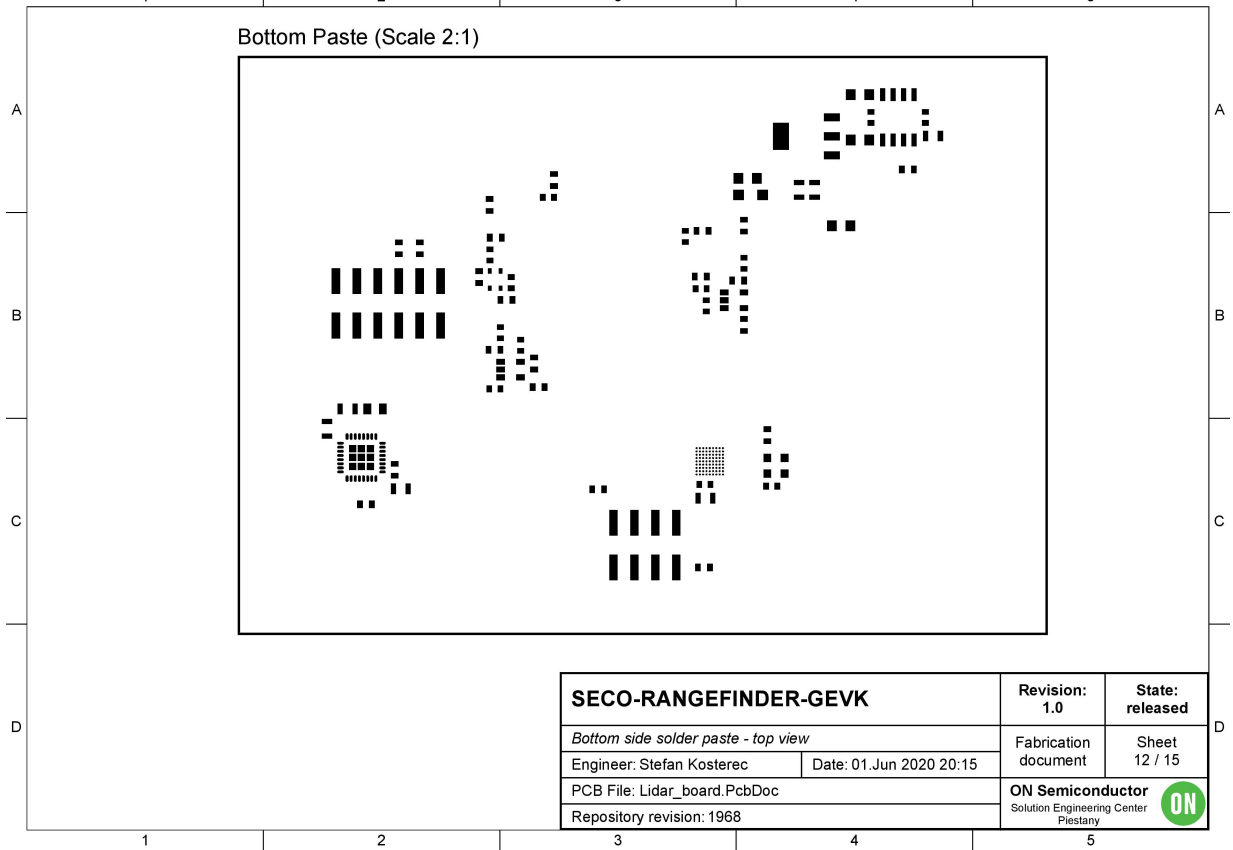
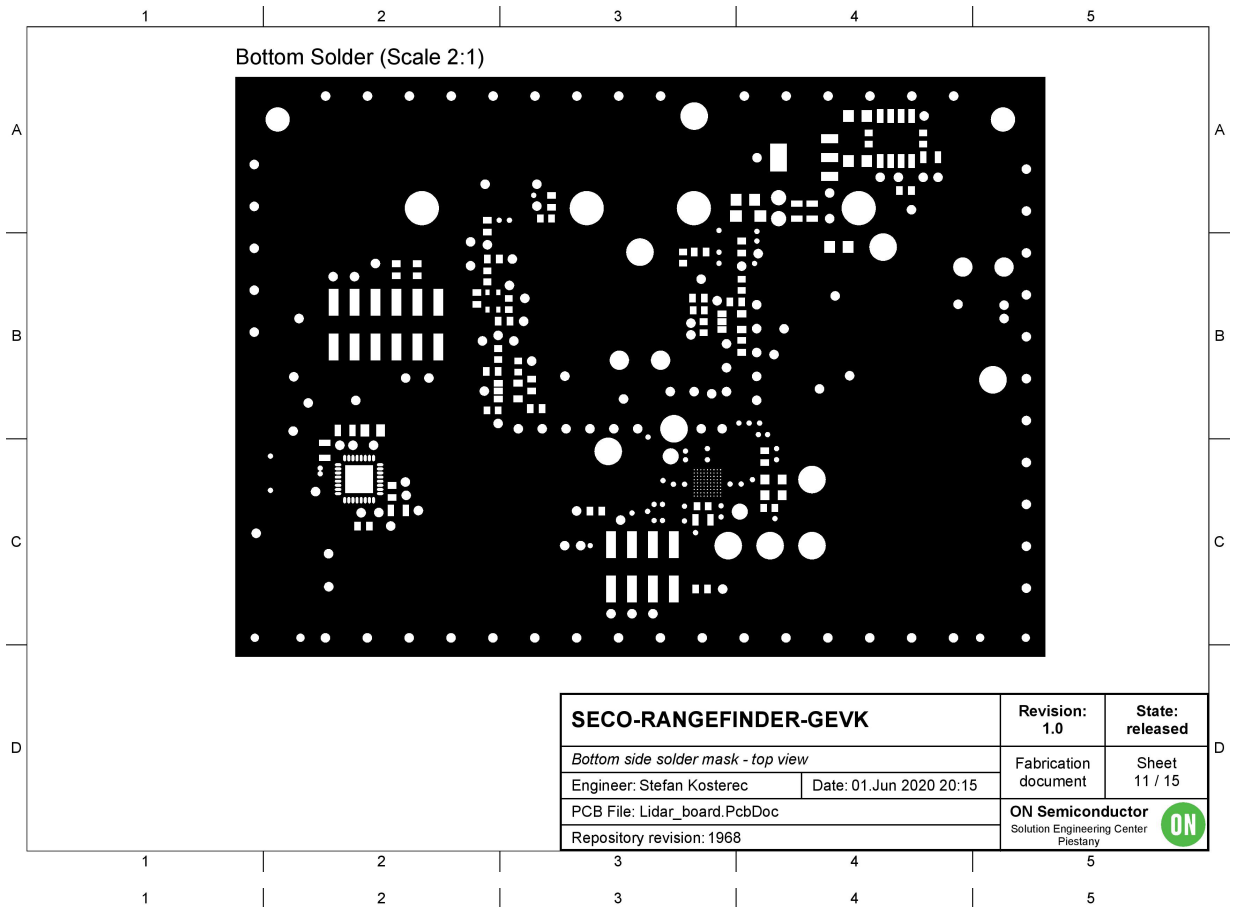


Figure 51. Rangefinder PCB Layout and Components Assembly (Part 6/8)

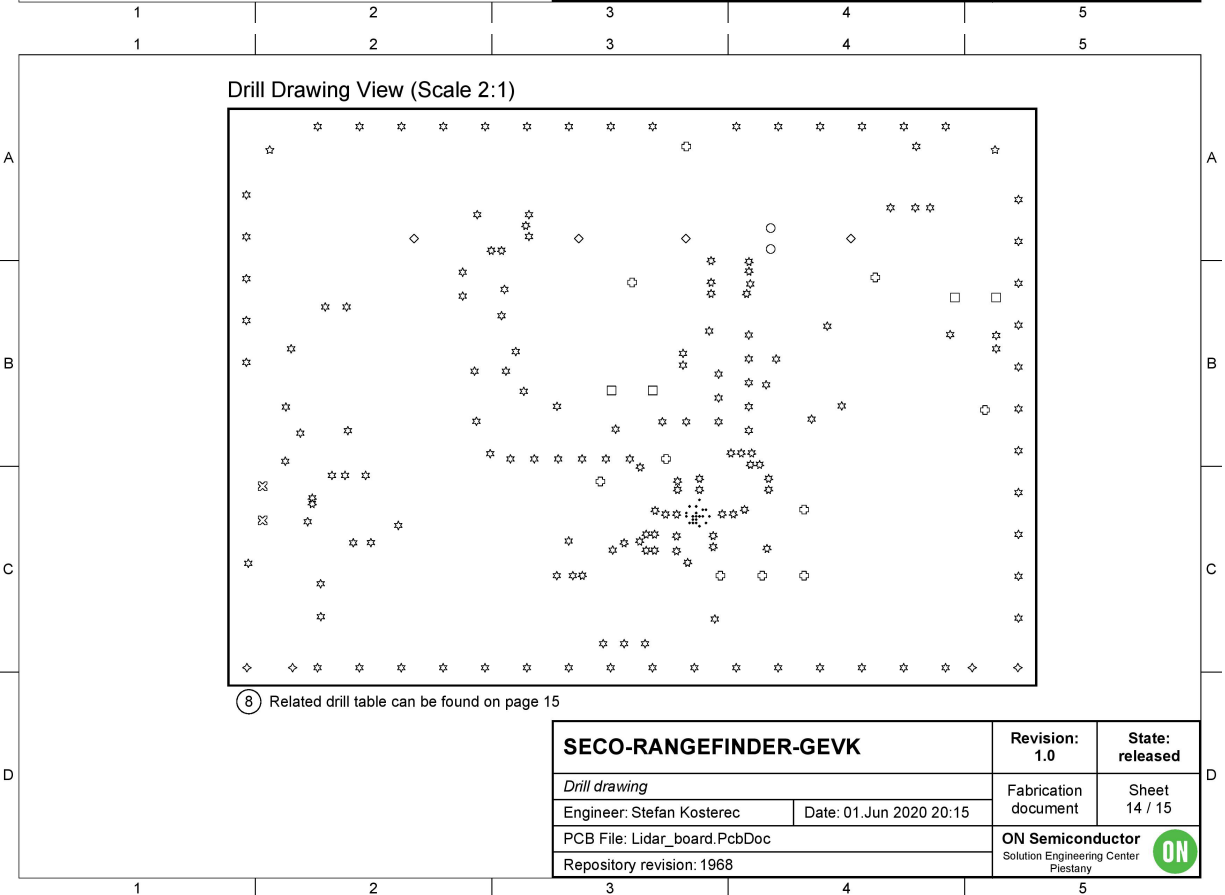
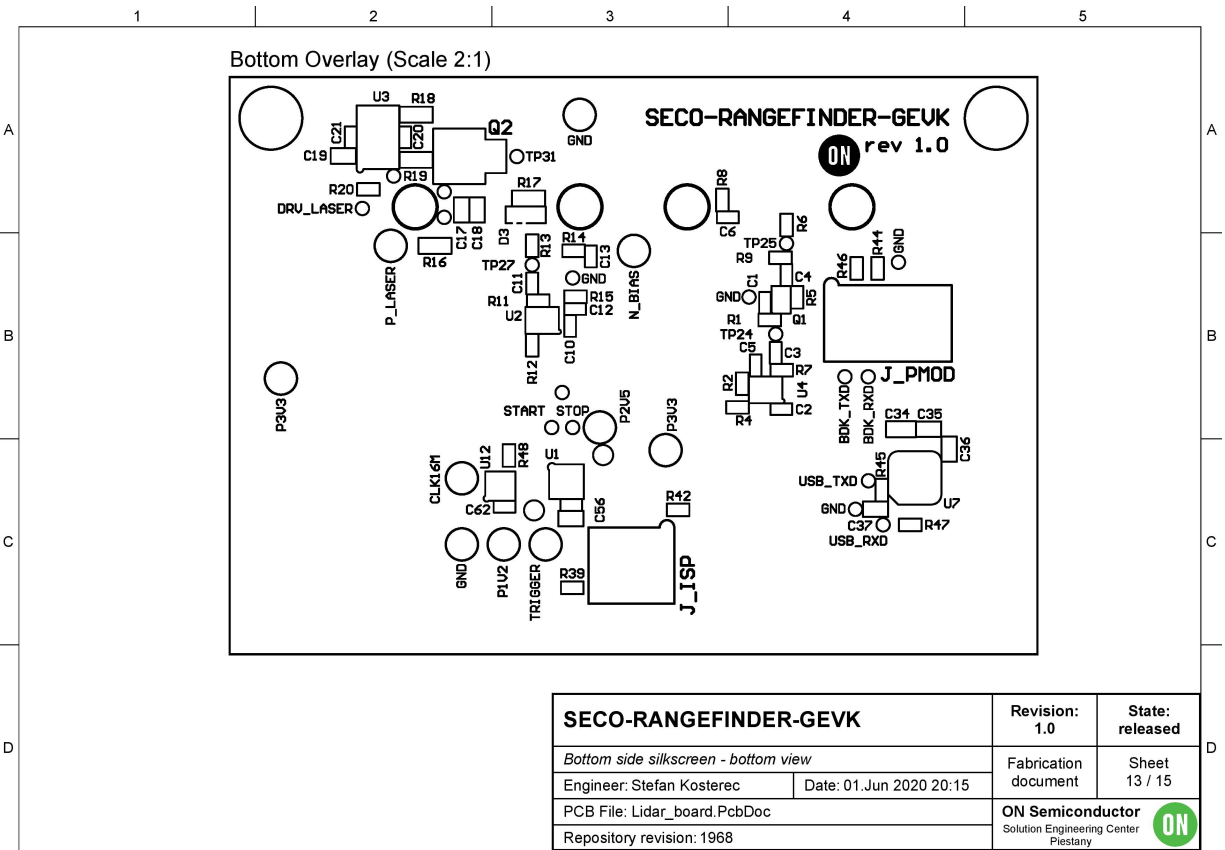


Figure 51. Rangefinder PCB Layout and Components Assembly (Part 7/8)

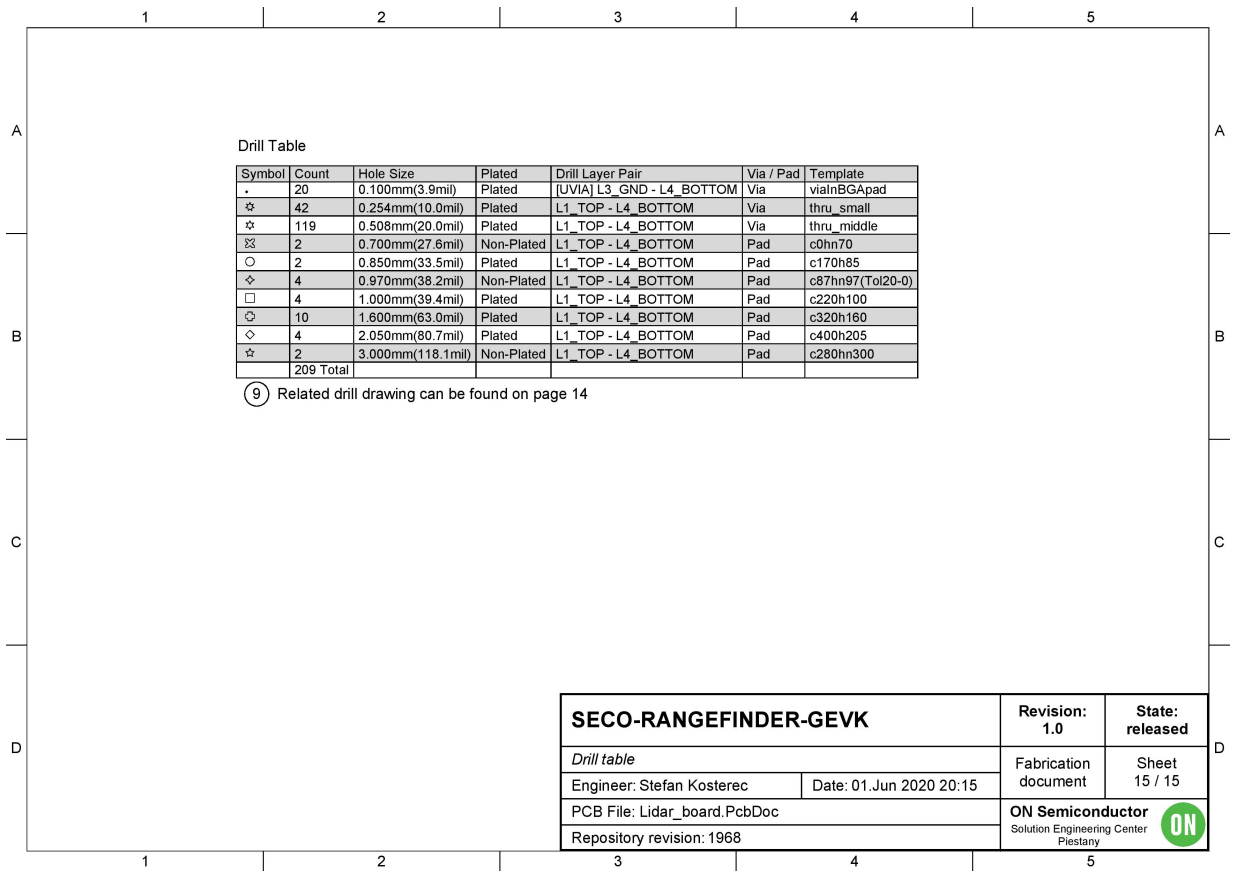


Figure 51. Rangefinder PCB Layout and Components Assembly (Part 8/8)

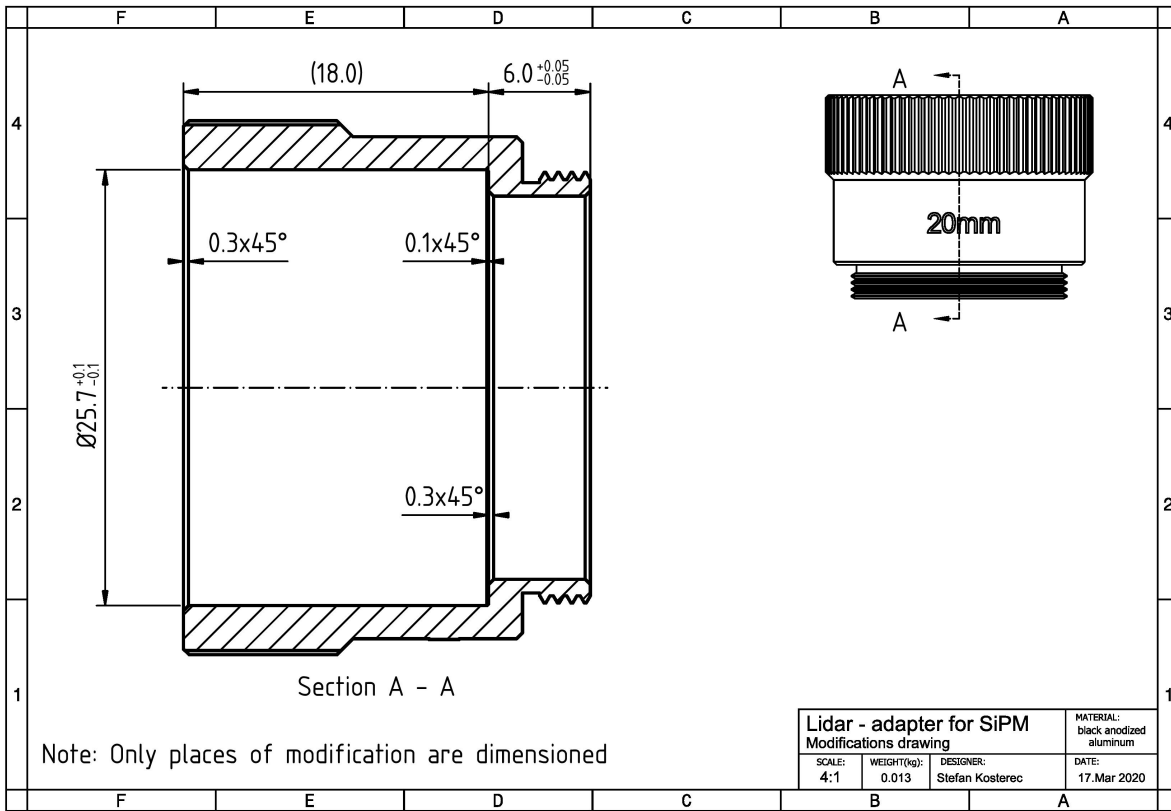


Figure 52. Custom Adapter 20 mm for SiPM

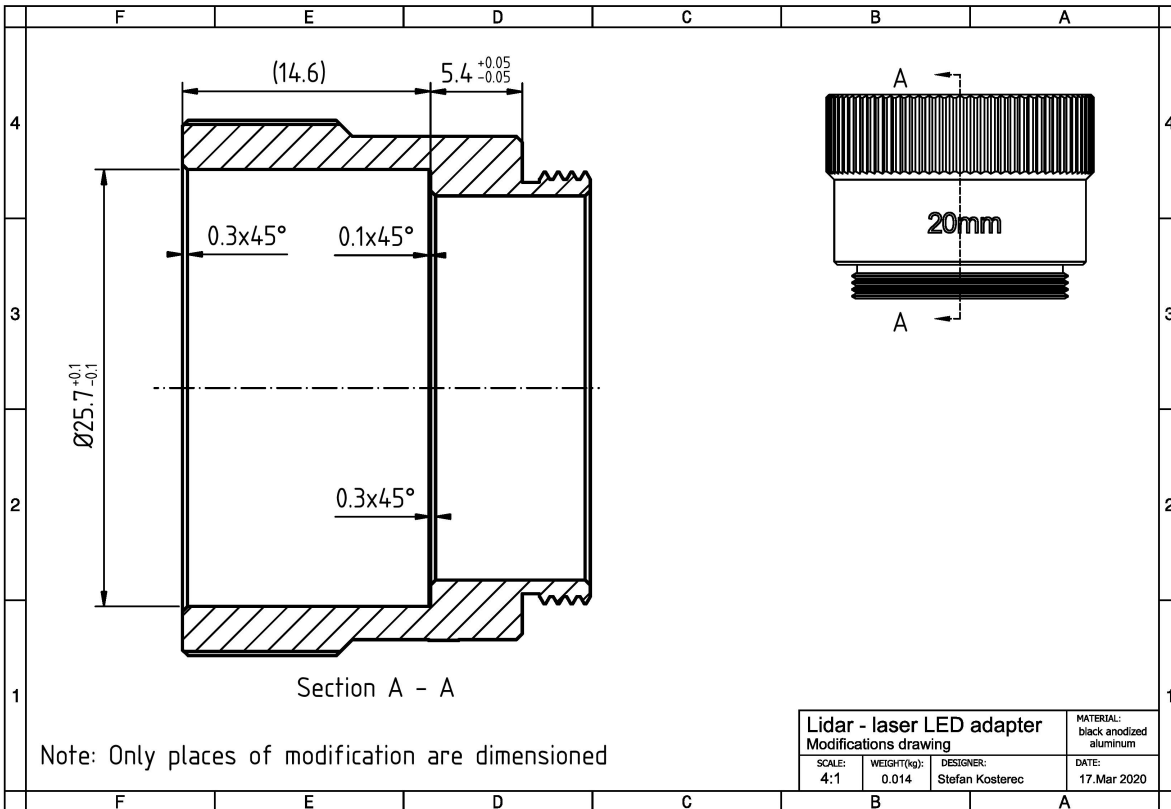


Figure 53. Custom Adapter 20 mm for Laser Diode

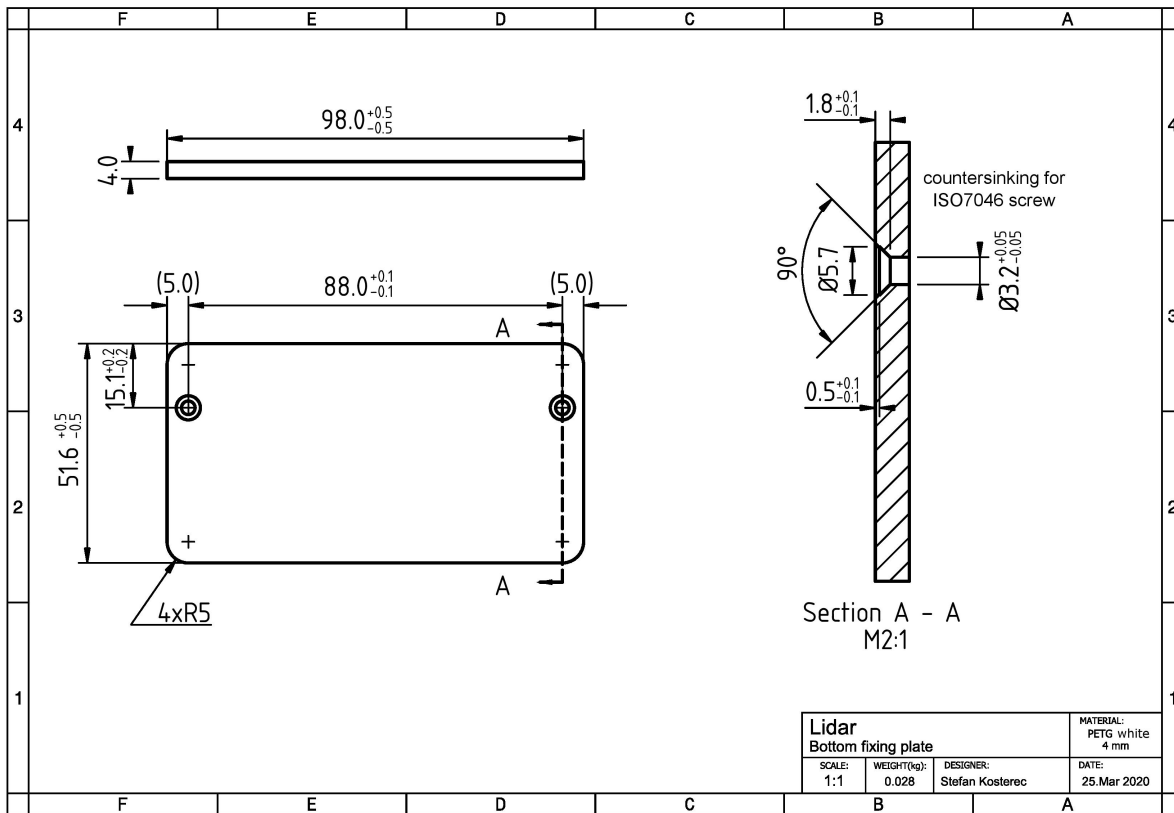


Figure 54. Custom Plexi Bottom Plate

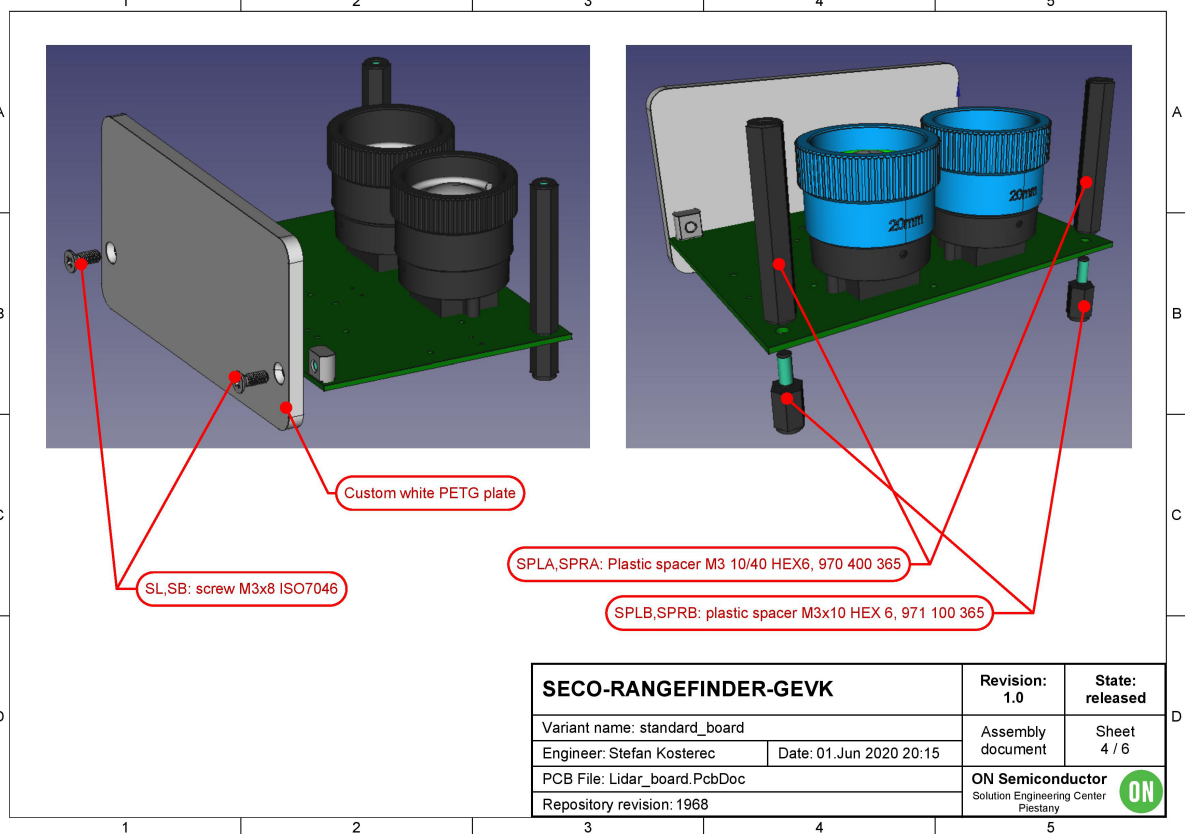
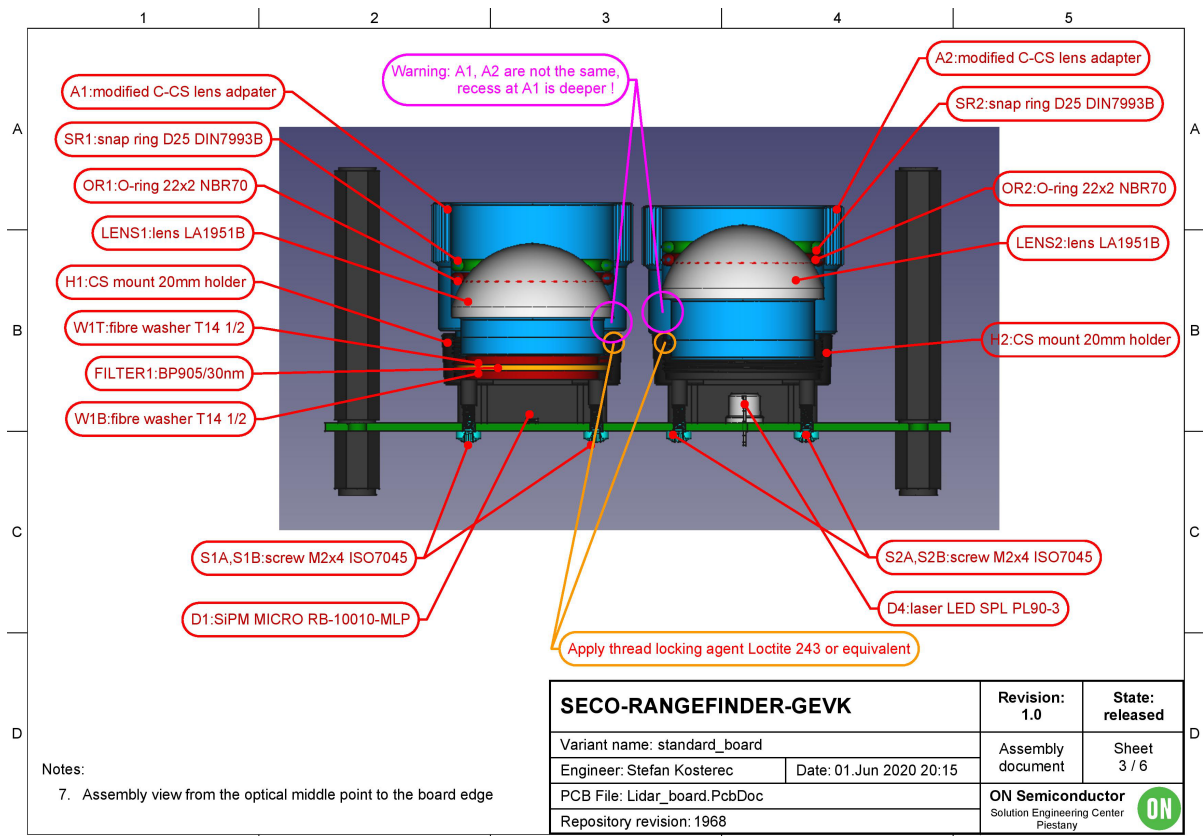


Figure 55. Optical Components Assembly and Mechanical (Part 1/2)

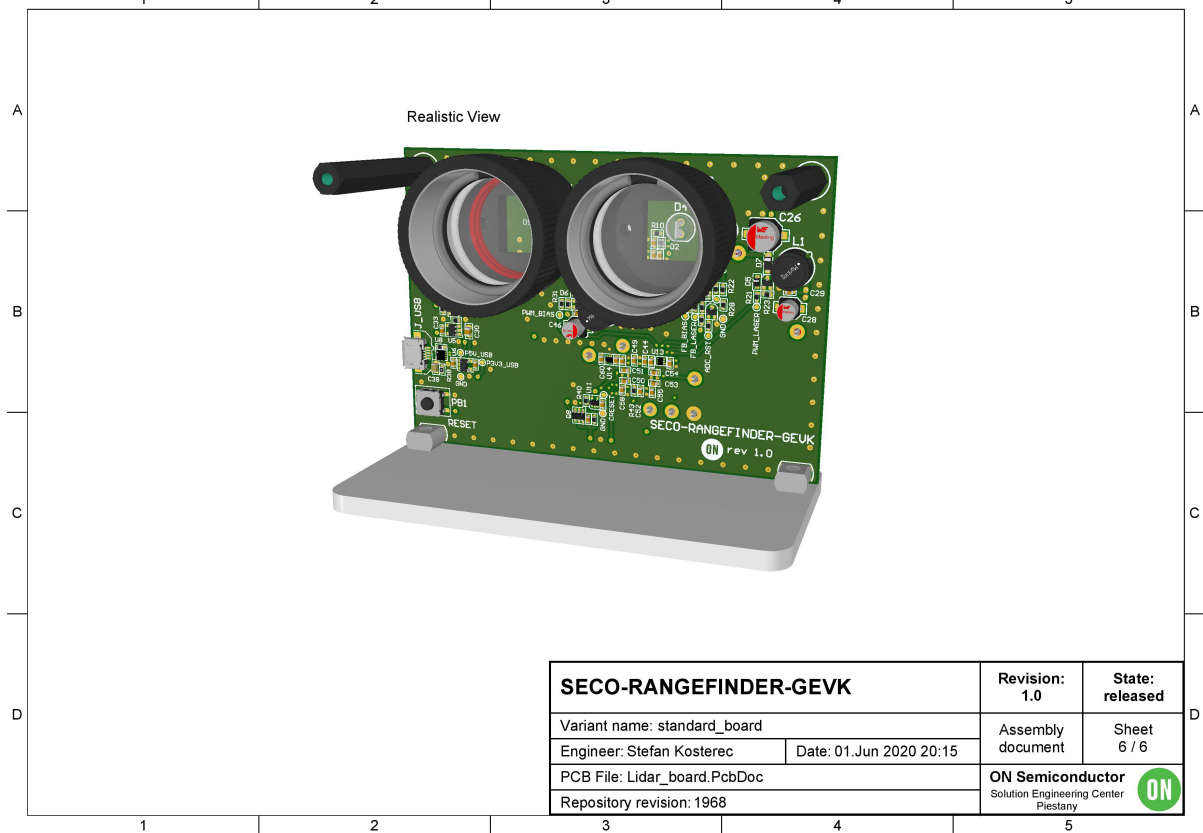
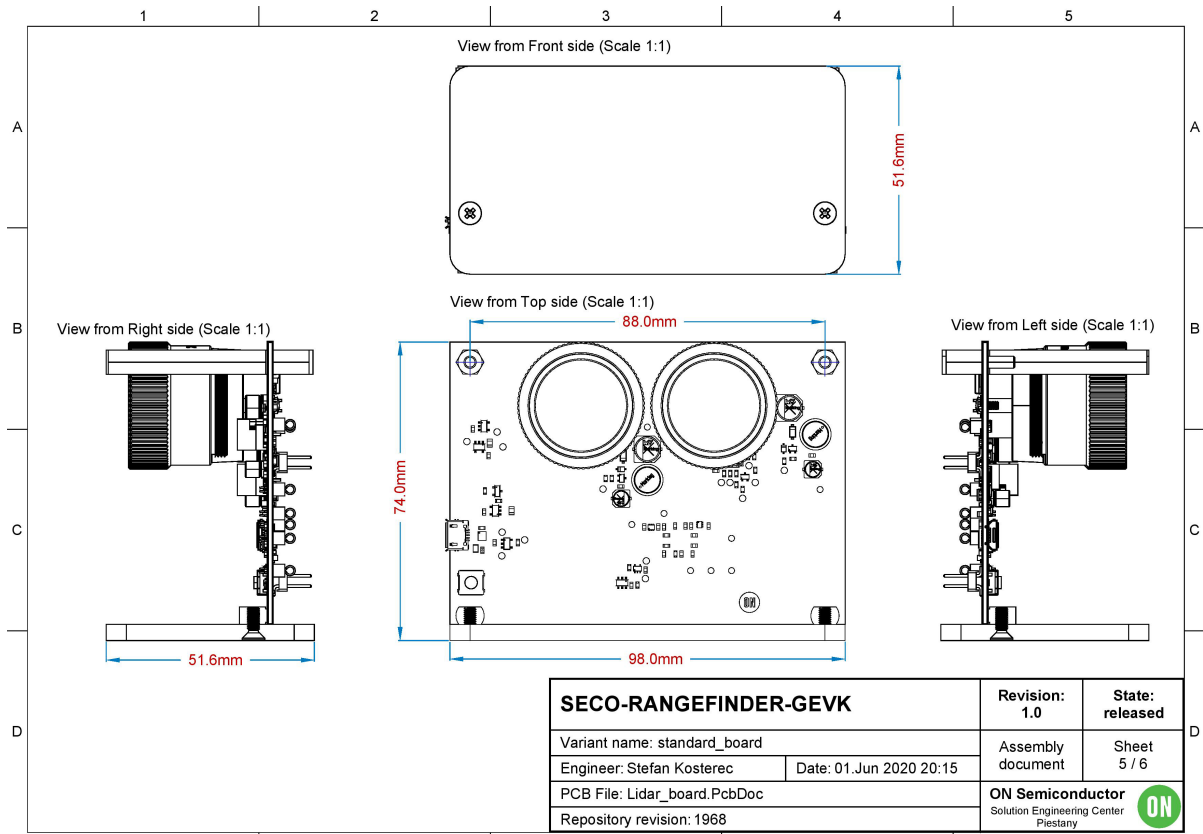


Figure 55. Optical Components Assembly and Mechanical (Part 2/2)

COLLATERAL

Receiving (RX) Circuit:

- [MICROB-10010-MLP](#) – Receiving SiPM photodiode (RB series)
- [NSVF4015SG4](#) – RF transistor
- [NBA3N012C](#) – discriminator (RF comparator)

Transmitting (TX) Circuit:

- [MICROB-10010-MLP](#) – Reference SiPM photodiode (RB series)
- [NBA3N012C](#) – reference circuit discriminator (RF comparator)
- [NCP81074A](#) – high speed MOSFET driver
- [FOT13N06L](#) – Logic level MOSFET for laser diode drive
- [MBR120LSF](#) – Schottky power diode for laser clamp
- [SPL PL90_3](#) – 905 nm/75 W peak radial laser diode

DCDC Inverting and Boost Converter Circuit:

- [BC817-40W](#) – NPN bipolar transistor
- [BC856BW](#) – PNP bipolar transistor
- [BC817-40W](#) – NPN bipolar transistor (ADC ramp reset)
- [BAS16H](#) – Switching diode
- [BAT54T](#) – Schottky diode
- [MMSD701](#) – Schottky diode UHF
- [LM2903DMR2G](#) – comparator

Power Management Circuit:


- [NCP161ASN330T1G](#) – 5 V to 3.3 V LDO
- [NCP170BXV120T2G](#) – 1.2 V LDO regulator for FPGA
- [NCP170BXV250T2G](#) – 2.5 V LDO regulator for FPGA
- [FPF2110](#) – load switch with reverse current blocking (automatic switch logic)
- [NCP308SN330](#) – voltage supervisor (automatic switch logic)
- [NCP300LSN27](#) – voltage supervisor (automatic switch logic)
- [BSS138L](#) – N channel logic level MOSFET (automatic switch logic)

Signal Management and Core Logic Circuit:

- [EMI2121MTTAG](#) – USB EMI filter
- [MC74VHC1GT08](#) – AND gate for FPGA reset circuitry
- [FT232RQ](#) – USB to UART IC
- [ICE40LP8K-CM81](#) – ice40 family FPGA

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