User's Guide
SBAU306–June 2018

OPT3101 System Estimator

The OPT3101 device is a time-of-flight (ToF) based optical proximity sensor. The *OPT3101 System Estimator* is a tool for simulating the performance of the OPT3101 AFE under various conditions. This user's guide explains the features of the *OPT3101 System Estimator* tool.

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1 Introduction

The primary purpose of this document is to explain the features of the OPT3101 system estimator tool which assists in analyzing the performance of the OPT3101 AFE under varied conditions. The document describes the various elements of the GUI. The functionality of each control of the GUI is explained with suitable examples.

2 Intended Audience

This document is intended towards developers who want to:

- Analyze the OPT3101 performance
- Incorporate OPT3101 into their solution
- Check if OPT3101 is suitable for their application

3 Prerequisite Reading

- Texas Instruments, *OPT3101 ToF-Based Long-Range Proximity and Distance Sensor AFE*
- Texas Instruments, *Introduction to Time-of-Flight Optical Proximity Sensor System Design*

4 Quick Start

4.1 Installation

Follow these steps to install the application:

1. Start the installation by running *OPT3101-System-Estimator.exe*

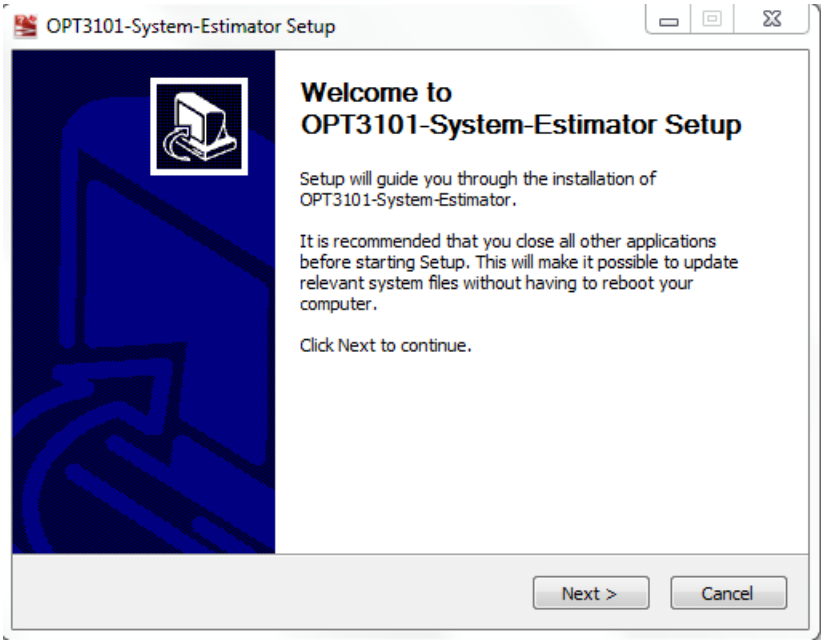

Figure 1. Installation Introduction Page

2. The welcome page is displayed. Click the *Next* button
3. Read the license agreement and click the *I Agree* button to continue

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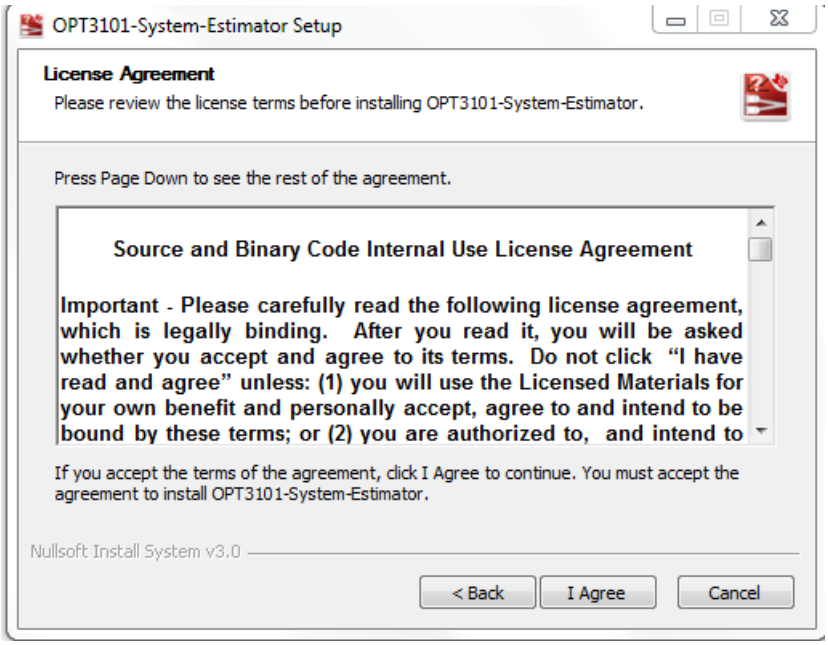

Figure 2. Installer License Page

4. Select whether a *Desktop Shortcut* or a *Start Menu* entry is needed. Click the *Next* button to continue
5. Choose the destination folder using the *Browse* button. Click the *Install* button to proceed with the installation

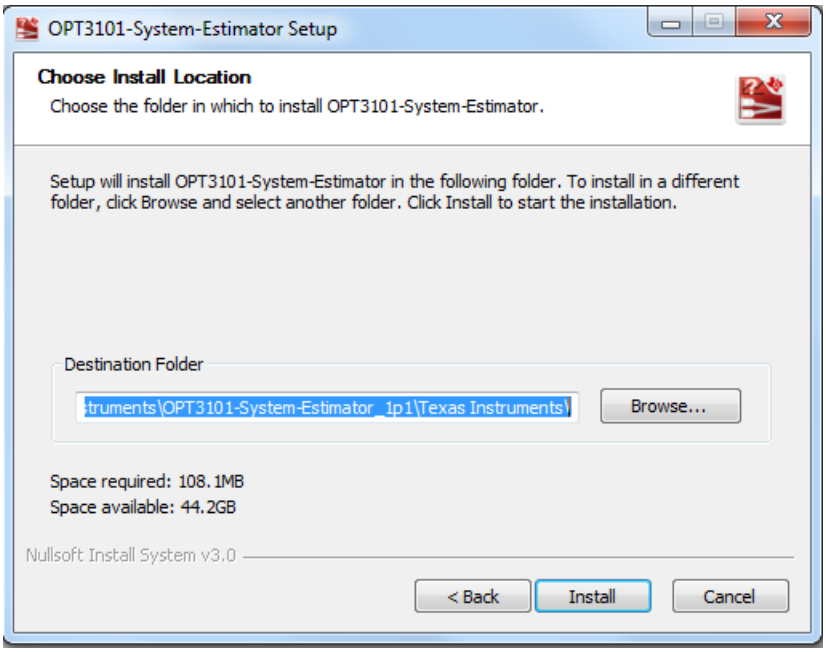

Figure 3. Installer File Location Page

6. The installer success is displayed. Click the *Finish* button to complete the installation

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4.2 Uninstallation

Follow these steps to uninstall the application:

1. Open the Uninstaller: "Start Menu -> Texas Instruments -> OPT3101-System-Estimator_*ver* -> OPT3101-System-Estimator_*ver*_Uninstall.exe", where *ver* is the version number of the application
2. The application can be uninstalled from Control Panel->Programs and Features as well
3. The welcome page is displayed. Click the *Next* button to continue
4. A confirmation is asked for uninstallation. Click on the *Uninstall* button to continue
5. Once the uninstallation finishes, click the *Finish* button to complete the process

4.3 Starting the Application

Follow these steps to start the application:

1. Open the application OPT3101-System-Estimator_*ver* from the installation folder, start menu, or desktop shortcut
2. The application should look like Figure 4:

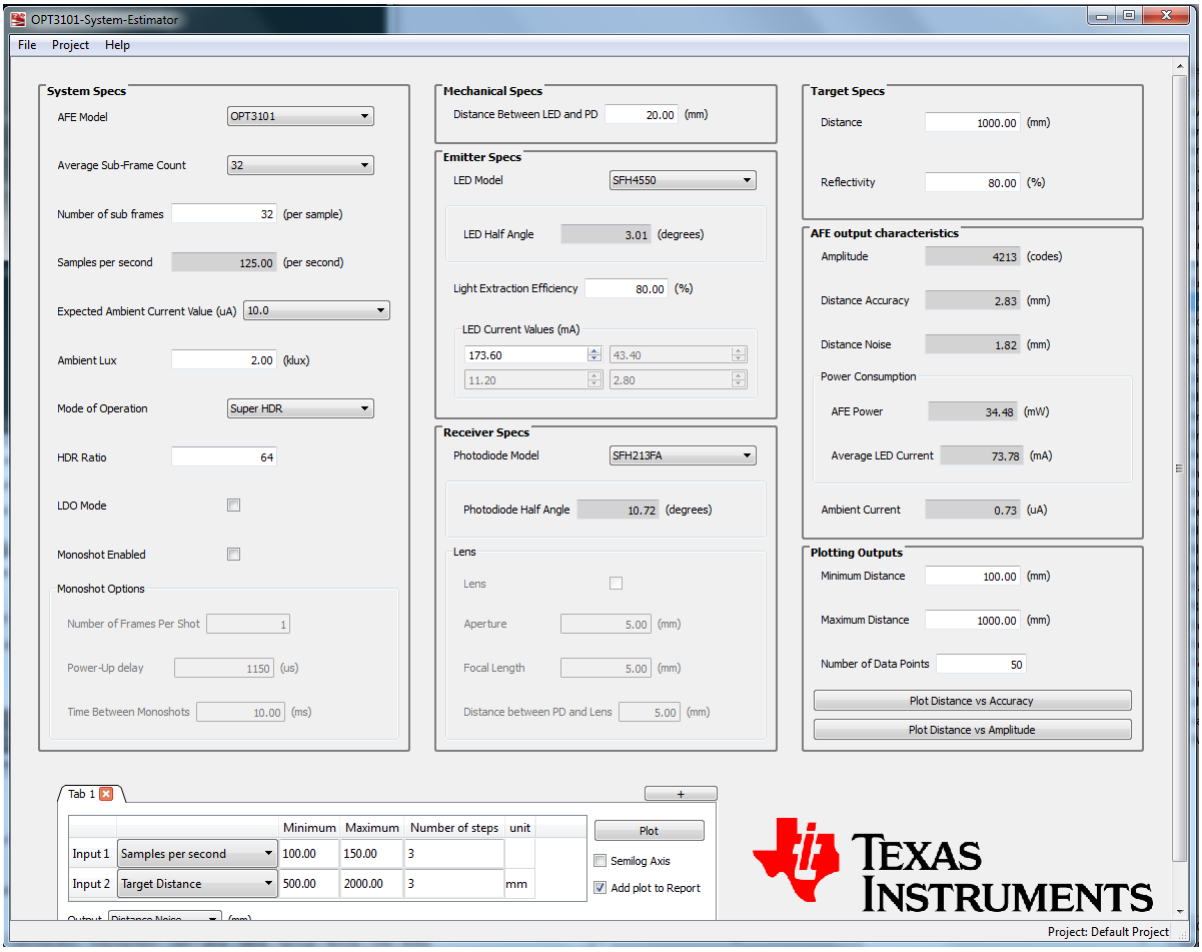

Figure 4. OPT3101 System Estimator New Window

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5 GUI Structure

The GUI includes the following sections:

- Menu Bar
  - **File**
    - **New Project:** Creates a new project
    - **Open Project:** Opens an existing project
    - **Save Project:** Saves the current project
    - **Save Project As:** Saves the current project as a different project
    - **Exit:** Closes the application
  - **Project**
    - **Generate Report:** Generate a report consisting of different project parameters and plots
    - **Manage LEDs:** View default LEDs and add custom LEDs
    - **Manage Photodiodes:** View default photodiodes and add custom photodiodes
  - **Help**
    - **About:** Version info of the current application
    - **Help:** Opens the user guide in the default browser
- **System Specs:** Contains parameters pertaining to the system - AFE model, sub-frames to average, number of sub-frames, samples per second, ambient lux, Monoshot Options, and so forth
- **Mechanical Specs:** Specifications related to the mechanical design - the distance and the angle between LED and photodiode.
- **Emitter Specs:** Specifications related to the emitter - the model of the LED used, half-angle of the LED, and LED current values
- **Receiver Specs** Specifications related to the receiver - the model of the photodiode, half angle of the photodiode, and lens options, if the photodiode does not have a built-in lens.
- **Target Specs:** Includes the target requirements - reflectivity and the target distance.
- **AFE output characteristics:** These are the output parameters of the AFE. This includes distance accuracy, distance noise, the amplitude of the received signal at the target distance, power consumption details, and the ambient current received by the AFE.
- **Plotting Tabs** Gives a sweep across one or two different input parameters in a specified range for either output power or depth resolution. Multiple tabs can be present for a particular project.
- **Distance vs Accuracy and Distance vs Amplitude:** These push buttons give options to plot the amplitude, accuracy, and noise response across various distances.
- **Status Bar:** Gives information of the project name and the information about saving and opening a file. It also provides information about parameters which should be changed if the output goes beyond the upper or lower limits.

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6 Menu Bar

6.1 File

Projects are saved as SDX files and contain data pertaining to the inputs and plotting tab parameters for each configuration. Projects can be managed using the file menu options like “New Project”, “Save Project”, “Save Project As” and “Open Project”. The application can be closed by choosing the “Exit” option.

6.2 Project

6.2.1 Generate Report

A report is a PDF file containing data and plots pertaining to the project. Each plotting tab can be added to a report by selecting the “Add Plot to Report” check box. The report consists of:

1. Project Name
2. Specifications (Inputs)
3. AFE output characteristics
4. Graphs for distance noise versus distance, distance accuracy versus distance, and amplitude versus distance
5. Selected tabs:
   - Tab parameters: One or two inputs with their minimum, maximum and number of steps and the output
   - Plots: Can be either log or semi-log according to whether the “Semilog” check box is checked

6.2.2 Manage LEDs

This option shows the illumination sources which are available with the tool. Illumination sources can be viewed, added, and modified from this dialog box.

The illumination parameters include the radiant intensity, forward current, spectral emission, as well as the field of view (FoV). There are a few default illumination sources included with the application.

Parameters for the default sources cannot be modified by the user. If a new illumination source is required, add it using the *Add* button. These can be renamed by double-clicking and typing the new name. Deletion is also possible for only the custom-added light sources. There is an option to copy LED parameters. By default, on adding a new LED, the parameters from the first LED are copied.

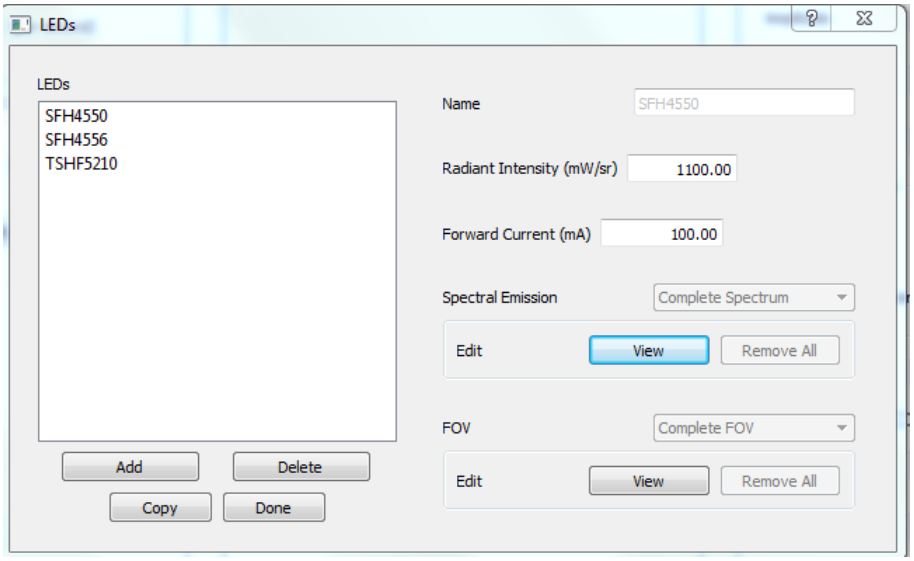

Figure 5. Manage LEDs Page

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For a new light source, the spectral emission can be provided in two ways:

1. **Single Value:** In case of a *Single Value*, the tool models a band of wavelengths. This means that a wavelength falling within the range is given a relative power emission value of 1, and any wavelength falling outside this range is given a relative power emission value of 0. Once a single value is added, the new value of the spectral emission curve can be seen using the "View and Edit" option
2. **Complete Spectrum:** When the *Complete Spectrum* is selected, the tool expects a table containing wavelengths and intensity values. These can be imported from a CSV file. The relative power emission is a fraction of the total power emitted at that wavelength. This is a value less than or equal to 1.

Similar to the spectral emission, there is an option to add the FoV curve. This takes the incident angle as well as the intensity as parameters. The single-value for an FoV is modeled using Equation 1. The complete FoV curve expects the incident angle and intensity values. There is an option to import from CSV files.

Once this window is closed or the *Done* button is clicked, the new and default illumination sources are added to the LEDs drop-down menu. Once a new LED is saved, it can be used for any new project.

6.2.3 Manage Photodiodes

The photodiode is the receiver which collects the light reflected by the target. This option allows the user to add, delete, and modify photodiodes to be used with the tool.

The parameters for the photodiode include spectral sensitivity, capacitance, area, photocurrent, irradiance at which the photocurrent is specified, spectral response, and the field of view (FoV). Just like LEDs, there are a few default photodiodes present with the tool, which cannot be modified.

Spectral sensitivity of the photodiode should be entered in A/W. The capacitance should be entered in picofarads (pF). The spectral response as well as the FoV should be entered in the same way as they are entered for the LEDs. If there is an built-in lens with the photodiode, photocurrent and irradiance are also required as parameters.

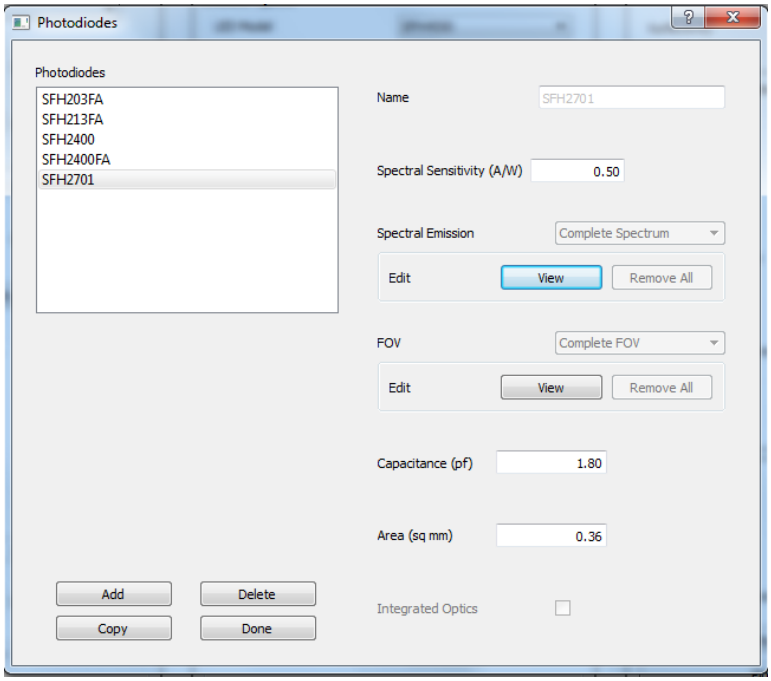

Figure 6. Manage Photodiodes Page

6.3 Help

Help consists of two options: *About* and *User Guide*. *About* displays version information about the application and *User Guide* opens this user guide for reference.

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7 Specifications

For calculation of accuracy and noise numbers, the application requires various inputs. The following sections describe these inputs in detail.

7.1 System Specifications

System specifications include the following:

1. **AFE Model:** The AFE that is being used. Currently, only one option (OPT3101) is present, and selected by default.
2. **Average sub-frame count:** This indicates the number of sub-frames which are averaged. Changing this changes the number of samples per second. Averaging sub-frames leads to a reduction in noise.
3. **Number of sub-frames:** Indicates the number of sub-frames which will be present in each frame. Increasing the sub-frame count reduces the number of samples captured per second.
4. **Samples per second:** This is a read-only parameter which indicates the sampling rate of the AFE.
5. **Expected Ambient Current Value:** This is an indicative parameter asking for the expected value of the ambient current generated by the AFE in micro-amperes (µA). Changing this changes the ambient noise factor. If the calculated ambient current is more than this value, it automatically changes to next supported max ambient range.
6. **Ambient Lux:** Indicates the light intensity in klux
7. **Mode of operation:** Indicative of the mode the AFE is operating in. There are three possible modes:
    1. **Normal:** A single current is used for illumination
    2. **HDR:** In this mode, the dynamic range is increased by using two different LED currents depending on the received signal from the target.
    3. **Super HDR:** In this mode, the dynamic range is further increased by using four different LED currents
8. **HDR Ratio:** Indicates the ratio of the LED currents being used. Only applicable in HDR and Super HDR modes. In case of Super HDR mode, this indicates the ratio between the highest and the lowest LED currents.
9. **LDO Mode:** Indicates if the LDO mode is turned on or off. In LDO mode only 3.3-V external supply is used and 1.8-V supply required for the device is generated using the on-chip LDO. LDO mode is useful for computing the AFE output power
10. **Monoshot Enabled:** Indicates if the monoshot mode is turned on. Useful for computing the AFE output power. Enabling monoshot mode adds more parameters:
    1. **Number of frames per shot:** The number of samples being captured with each shot
    2. **Power-up delay** Indicates the delay from the monoshot trigger to the sample start
    3. **Time between monoshots:** The time between two triggers

7.2 Mechanical Specifications

These include the following:

1. **Distance between LED and photodiode:** Indicates the distance between the LED and the photodiode in milimeters (mm).

7.3 Emitter Specifications

This includes the specifications related to the emitter. These are:

1. **LED Model:** Indicates the model of the LED being used. The LEDs are modeled using the parameters entered in the "Manage LEDs" section.
   There is an option to select a simple model as well. The simple model calculations are explained in Section 8.1
2. **LED Half Angle:** Indicates the half-angle of the LED.
3. **Light Extraction Efficiency:** Indicates the light-extraction efficiency of the emitter.

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4. **LED Current Values:** The output current from the LED. There are four possible LED currents in the Super HDR mode, two currents in the HDR mode, and only one possible current in the Normal mode.

7.4 Receiver Specifications

This includes the specification of the receiver. These are:

1. **Photodiode Model:** Indicates the model of the photodiode being used.
   There is an option to select simple model. These are explained in Section 8.2
2. **Photodiode Half angle:** Indicates the half-angle of the photodiode
3. **Lens:** Indicates if a lens is used with the photodiode. If the PD comes with an integrated lens, this parameter is disabled. The following parameters are required for the lens (if available):
   1. **Aperture:** The aperture of the lens
   2. **Focal Length:** The focal length of the lens
   3. **Distance between Diode and Lens:** The distance between the photodiode and the lens

7.5 Target Specifications

These are the target specifications. These include the target distance (in mm) and reflectivity (in %).

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8 Simple Model

This section explains the calculations done for modeling a simple model for the LED and the Photodiode.

8.1 Simple Model for the LED

LED simple model is generated using the half angle, LED efficiency, and the center wavelength as inputs. All other inputs stay the same. Figure 7 shows the inputs in case the "Simple Model" is selected.

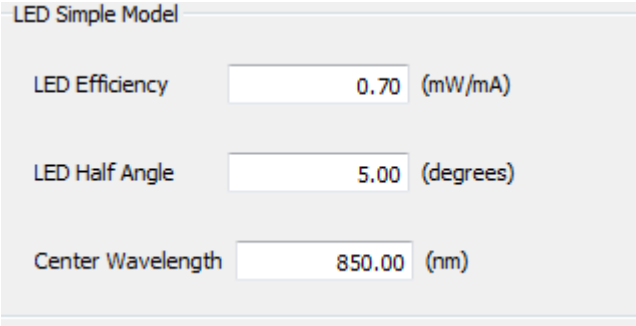

Figure 7. LED Simple Model Parameters

The half angle is used to model the LED field of view curve using the following equation:

$$\cos^{\alpha}(\theta) = 0.5 \quad (1)$$

where

- θ is the half-angle of the LED

This gives the calculation of alpha as:

$$\alpha = \frac{\log(0.5)}{\log(\cos(\theta))} \quad (2)$$

LED efficiency is entered in watt per ampere. (W/A). The center wavelength gives the amount of light falling for a certain wavelength of the LED, and is used for calculating the losses in wavelength between the LED and the photodiode.

8.2 Simple Model for the Photodiode

Similar to the LED simple model, the photodiode simple model is generated using the half-angle of the photodiode. The half angle equations remain the same as Equation 1 and Equation 2. Other parameters are the spectral sensitivity of the photodiode, photodiode area, capacitance of the photodiode, and the center wavelength. Figure 8 shows the required parameters.

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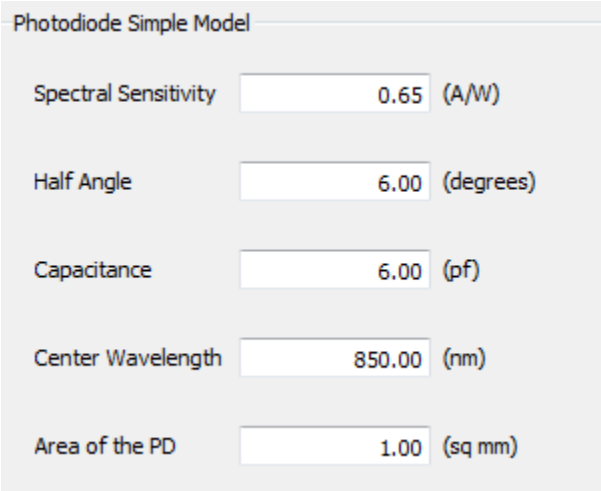

Figure 8. Photodiode Simple Model Parameters

The spectral response of the simple photodiode is considered to be a band-pass filter of 200-nm bandwidth.

By default, a simple photodiode does not come with integrated optics. For adding a custom photodiode with integrated optics, use the "Manage Photodiodes" option.

9 Output Characteristics

The output characteristics of the AFE are the calculated parameters based on the inputs provided. These include:

1. **Amplitude:** This gives the return amplitude at the target distance
2. **Distance accuracy:** This gives the accuracy at the given target distance.
3. **Distance noise:** The noise expected at the target distance
4. **Power Consumption:** Power consumed by the system. This has two parts:
    1. **AFE Power:** The total power consumed by the AFE
    2. **Average LED current:** This is the average LED current.
5. **Ambient Current:** Ambient current output

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10 Plotting

The two types of plots are explained in Section 10.1 and Section 10.2.

10.1 Plot Push-Buttons

Two plot buttons are provided to show the performance at various distances. These are "Plot Distance v/s Accuracy and "Plot Distance v/s Amplitude. These plots give an indication of the performance of the system with respect to the distance of the target, at the given reflectivity. It also shows the LED current values for the given distances. The plots are added below, for reference:

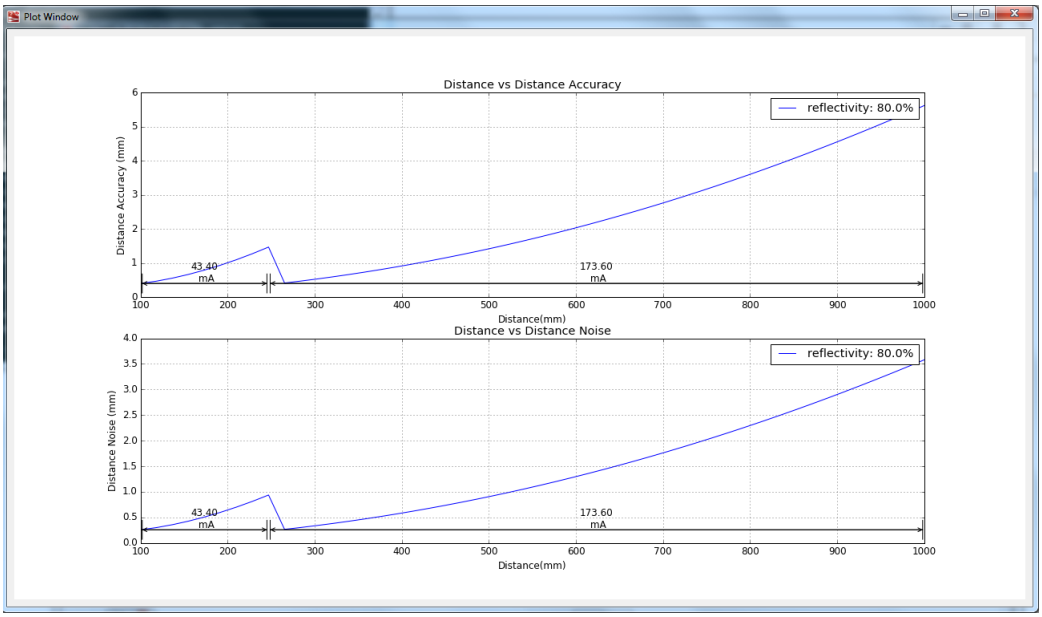

Figure 9. Typical "Distance vs Accuracy" Plot

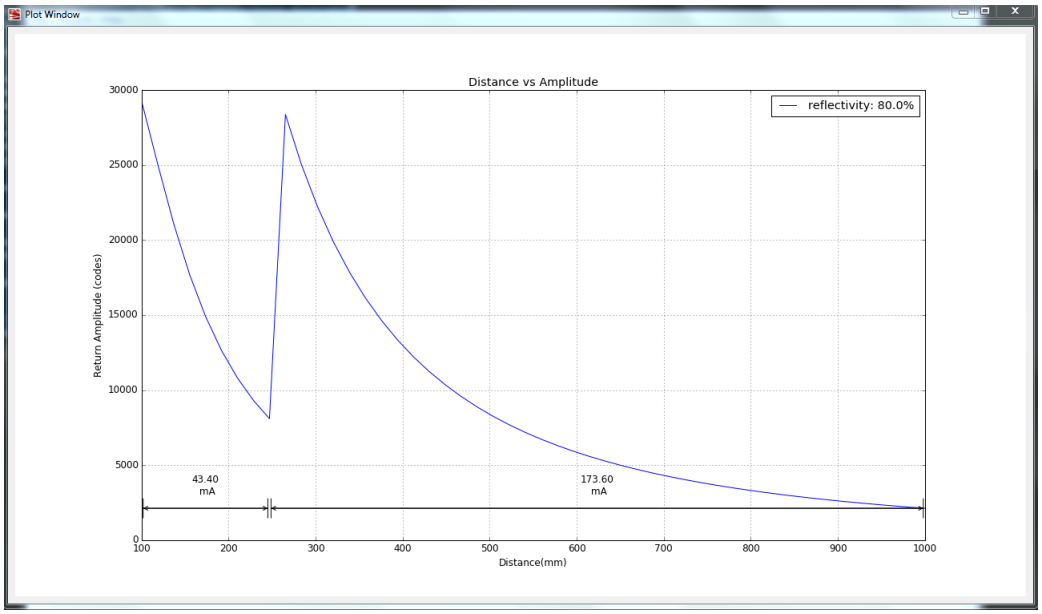

Figure 10. Typical "Distance vs Amplitude" Plot

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10.2 Plot Tab

The plotting tab gives further options to compare between parameters. The output options are distance noise and distance accuracy. Plots can be generated for varying inputs. Two inputs can be provided and the output will be calculated for both. There is an option to add a semilog axis to the y-axis. If one of the inputs is "None", it results in a single line-plot. With two inputs, we get a plot with varying inputs. Figure 11 and Figure 12 illustrate two example plots.

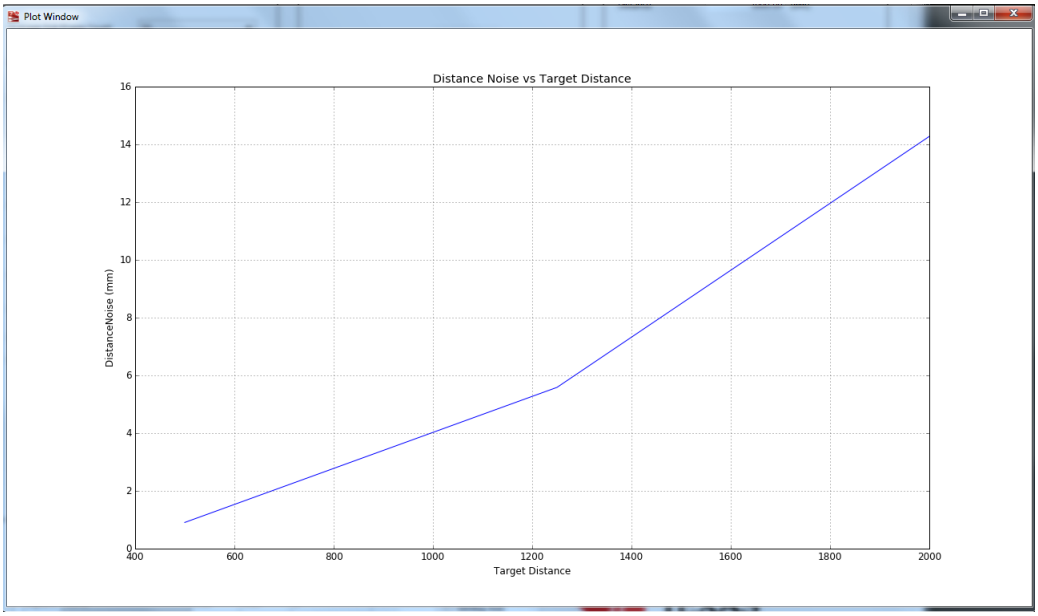

Figure 11. Tab Plot With a Single Input (Input 2 = "None")

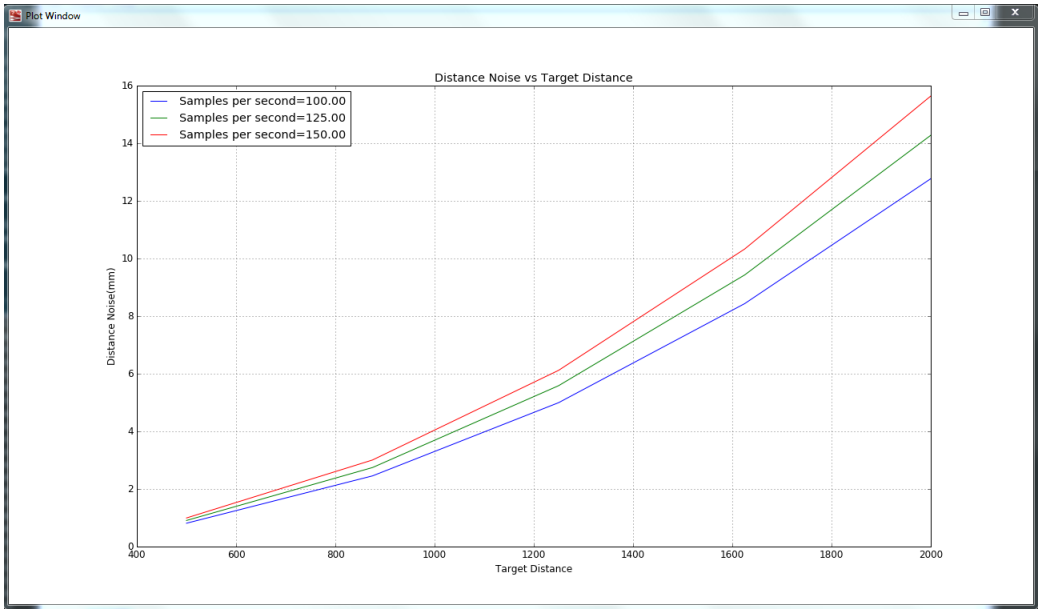

Figure 12. Tab Plot With Two Inputs

11 Input Controls

The application has many input text box controls. Some of the inputs have a tool tip giving more information about the input. The input is limited between a minimum and maximum value. Table 1 indicates the default, minimum, and maximum values of all the input parameters.

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Table 1. Input Parameter Properties

Parameter	Units	Default	Minimum	Maximum
Number of sub-frames[1]	sub-frames/sample	32	1	4000
Ambient Lux	klux	2	0	200
HDR Ratio[2]	-	64	2 (8)	128 (80)
Number of frames per shot	-	1	1	63
Power-up delay	micro-seconds (us)	1150	1150	26212
Time between monoshots	milliseconds (ms)	33.24	33.24	10000
Distance between LED and photodiode	millimeters (mm)	20	1	500
LED efficiency	milliwatts per milliampere (mW/mA)	0.7	0.01	1.2
LED half-angle	degrees	3	0	60
Center wavelength (led)	nm	850	300	1500
Light extraction efficiency	%	80	0	100
LED current values[3]	milliamperes (mA)	173.6	1.4	173.6
Photodiode half-angle	degrees	10	0	60
Spectral sensitivity	ampere per watt (A/W)	0.65	0.01	1
Capacitance	picofarad (pf)	6	1	6
Center wavelength (photodiode)	nanometers (nm)	850	300	1500
Lens aperture	millimeters (mm)	5	1	100
Focal length[4]	millimeters (mm)	5	1	100
Distance between diode and lens	millimeters (mm)	5	1	100
Distance	millimeters (mm)	1000	1	30000
Reflectivity	%	80	0	10000
Minimum distance	millimeters (mm)	100	1	30000
Maximum distance	millimeters (mm)	1000	1	30000
Number of data points	-	50	50	1000

(1) The number of sub-frames cannot be lower than the *"average sub-frame count"* option. Minimum and maximum change depending on the average sub-frame count.
(2) The ratio changes on switching between HDR and super HDR modes. The values in parenthesis are for the super HDR mode.
(3) Based on the setting, up to four LED currents are possible. The application lets the user set the highest LED current. Other values are calculated according to the HDR ratio.
(4) The minimum focal length to be entered depends on the lens aperture. The focal length cannot be less than 0.7*(lens aperture)

12 Status Bar

The status bar is split into two. The right half always displays the project name. If the current project name is "Default Project", this means that the project needs to be saved first. The application prompts for a suitable project name.

The left half gives status information about whether a file has been saved with the “File has been Saved” message and whether a report has been generated with the “Report Generated” message. These messages are temporary.

The status bar also gives suggestions when requirements go beyond limits. If the return signal is saturated, the status bar prompts the user to reduce LED current or enable the HDR modes.

13 Notes

These results are based on simulations. Actual measurements may not match the results exactly. Assumptions such as reflectivity, ambient light, lens transmittivity, sensor configuration, and so forth, may be different in the actual system and hence the results may vary. The results are not final numbers. They are approximate indicators of the system performance for an example use-case. Further optimization may be possible through rigorous design specifically for the application.

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