Accurate distance measurements with a highly integrated ToF position sensor

Introduction

In many applications, it is not possible to measure the distance to a target by establishing a physical contact. Typical examples include measuring the presence of objects on a conveyor belt in logistic centers, ensuring safe distances around moving robot arms, and establishing the position of assets from humans or robots in a warehouse. Time of Flight (ToF) position sensors help you measure the distance by using the time it takes the light to travel back and forth to the object. The OPT3101 is a good example of a high-speed, high-resolution, AFE for continuous-wave, fully-integrated ToF-based position sensor. The sensor has 16-bit distance output at 15-m unambiguous range. For more information on the OPT3101, see *OPT3101 ToF-Based Long-Range Proximity and Distance Sensor AFE*. The most important considerations for position sensors are:

- Distance
- Accuracy
- Repeatability
- Response time

For this application, the dedicated distance range is up to 2.5 m.

Table 1. Key System Specifications

PARAMETER	SPECIFICATIONS
Distance	0.43 to 2.5 m
Accuracy	0.78% @ 1 m
Repeatability	1.02 mm @ 2 m
Response Time	0.25 ms minimum

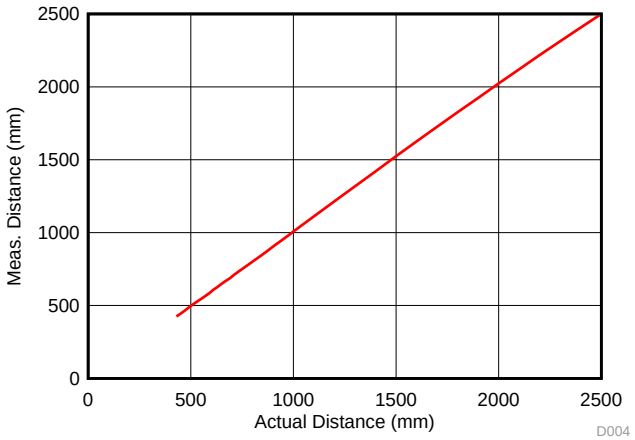
Implementation

In this application, the OPT3101 EVM measures the distance to a flat 1.5m x 2 m white wall. The wall is effective under a small (±3 degrees) Field of View (FoV). To prevent the FoV from falling to the ground, mount the OPT3101 EVM on the edge of a movable desk. Use a laser distance measurement to get the actual distance data. The OPT3101 has an internal ambient cancellation block that allows for great performance in different ambient conditions. This module uses two components to transmit and receive information, which is illumination driven by an OPT3101 internal LED driver and photodiode. The OPT3101 EVM takes the test data and the TI Latte records the distance, accuracy, and amplitude.

Test Results

The measured distance range is from 0.43 m to 2.5 m with a white wall as a target. The OPT3101's maximum sample rate is 4 kHz, resulting in the fastest response time of 1/4 kfps = 0.25 ms. This application uses 32 samples, where you achieve a 125 fps output data rate. The response time based on the data rate of 125 fps is 1/125 fps = 8 ms. Use the above set-up to measure the OPT3101's performance. Figure 1 shows the measured versus actual distance plot is linear.

Figure 1. Measured Distance



The measurement accuracy is a significant parameter for the position sensor. Figure 2 shows that the OPT3101's distance measurement error is 0.1 mm at a distance of 2.5 m.

Figure 2. Distance Measurement Error

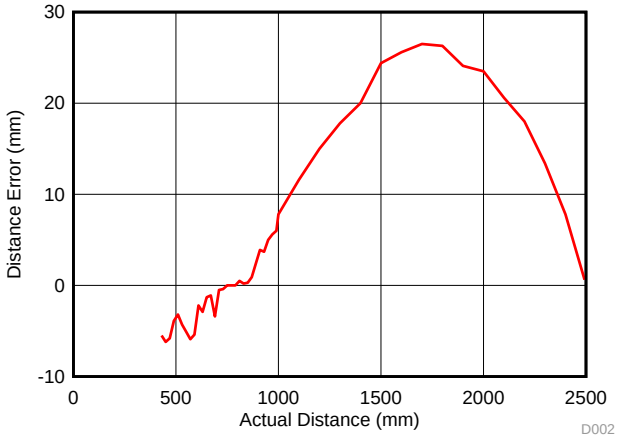


Figure 3 shows the distance measurement error percentage. The tests were completed in indoor conditions. Within 2.5 m, the distance measurement error is within 1.6% of the actual distance.

Figure 3. Distance Measurement Error %

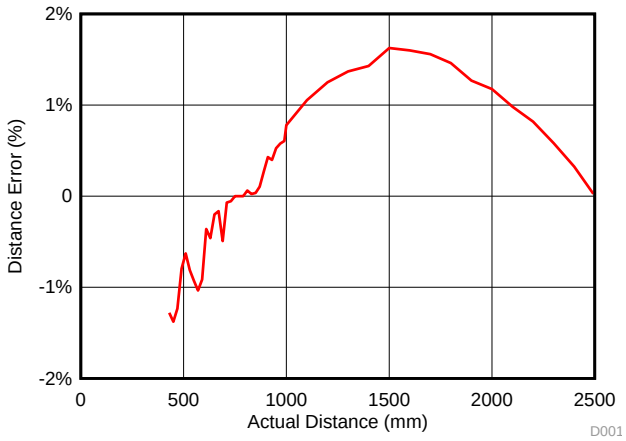
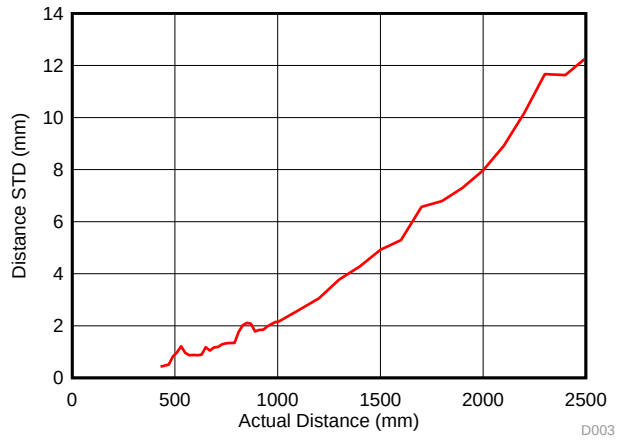


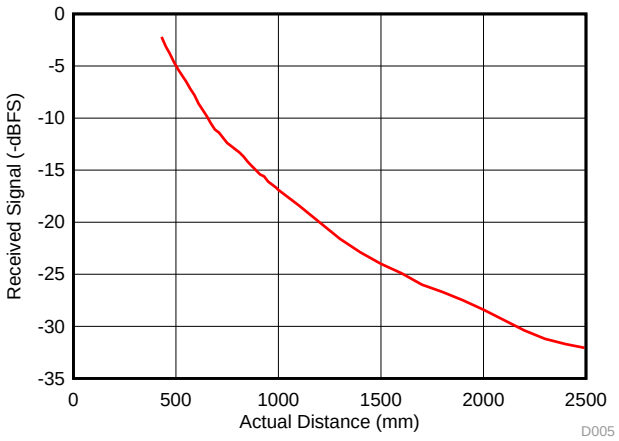
Figure 4 shows the standard deviation of the distance measurement for the 32 frames. The OPT3101 gives the flexibility to design a system with various frame options, so you can easily customize the application and the use case. An increase in average frames decreases the standard deviation in measurements while a decrease in average frames increases the data collection rate.

Figure 4. Distance Standard Deviation



The received signal is shown in Figure 5. A longer distance results in a lower received signal and more noise.

Figure 5. Received Signal



ToF technologies independently determine phase and amplitude, resulting in color independency. Color independency measures the distance independent of object color. Repeatability is the degree of consistency between measurement results by measuring the same object multiple times under the same conditions in a short time interval. To test repeatability, the OPT3101 EVM and the desk are moved back and forth to the same position in a short time interval. The results are shown in Table 2. For example, the repeatability is 1.02 mm at 2 m.

Table 2. Repeatability

Actual Distance (mm)	1 (mm)	2 (mm)	3 mm)	4 (mm)	5 (mm)	Repeatability (mm)
500	496.7	495.6	497	495.7	496.2	0.61
800	800.7	800.2	800.2	800.6	800	0.3
1200	1216.2	1216.3	1215.7	1216.7	1215.8	0.4
1500	1523.3	1523.3	1522.2	1523.9	1521.5	0.97
2000	2020.7	2020.8	2022.6	2020.4	2019.9	1.02
2500	2498	2497.6	2499.8	2498.7	2500.2	1.12

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale (www.ti.com/legal/termsofsale.html) or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265