AND9792/D

Performance Measurement and Model Validation of the ON Semiconductor Gen3 Scanning LiDAR Demonstrator

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APPLICATION NOTE

OVERVIEW

ON Semiconductor is a market leader in Silicon Photomultiplier (SiPM) and SPAD (single photon avalanche diodes) sensor technology. These sensors are now at the forefront of the most innovative developments for LiDAR applications in ADAS (Advanced Driver Assistance Systems) and autonomous vehicles. Due to its high internal gain, the SPAD−based SiPM can overcome the low−noise limitation of the amplification stage that is required for use with linear avalanche photodiode (APD) and PIN diode sensors. Therefore, for ranging beyond a few meters, the SiPM can achieve significantly higher signal−to−noise ratio (SNR) than other sensors.

ON Semiconductor has created two tools to assist in the development of SiPM−based LiDAR systems: A Matlab LiDAR model and a hardware scanning LiDAR demonstrator system. Measurements from the system have been used to validate the model. The validated model can then be used to evaluate the performance of any given system configuration without it having to be built, thus enabling customers to shorten their time to market with SiPM sensor technology.

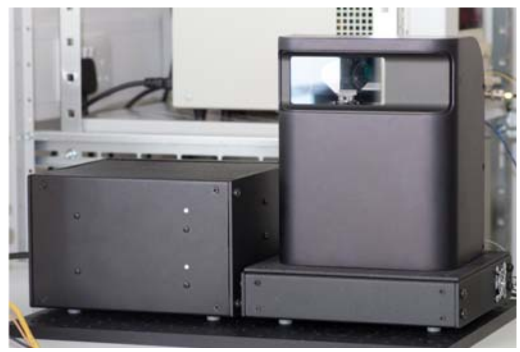

Figure 1. The ON Semiconductor Gen3 LiDAR Demonstrator

MATLAB LIDAR MODEL

A MATLAB model to simulate a time−of−flight LiDAR system has been created by ON Semiconductor. The purpose of the model is to predict the overall performance of a system given a set of system parameters.

The first step in the modelling process consists of analytically calculating the light levels at the sensor (both ambient and laser light) given a chosen optical scenario which can be varied by changing the corresponding system parameters. By comparing the calculated light levels to the saturation limit of the sensor, the chosen setup can be validated as suitable for ranging. In the event that the particular setup is not suitable for ranging, improvements on the setup itself can be evaluated by varying the system parameters, such as filters, optics or angle of view.

The second part of the model consists of a Monte Carlo simulator where the stochastic properties of the sensor, mainly the photon detection efficiency (PDE) and the timing jitter, are reproduced. This step allows a realistic output of the sensor to be obtained by simulation. In contrast to the analytic part, this step takes into account timing information such as the acquisition time, the repetition rate of the laser and the laser pulse width. The outcome of the Monte Carlo simulation is passed to a read−out model, typically a discriminator followed by a TDC (Time−to−Digital Converter), which produces a histogram of timestamps from which a range measurement can be extracted.

The Matlab model is described in more detail in a white paper that can be requested by contacting ON Semiconductor sales.

ON SEMICONDUCTOR SCANNING LIDAR DEMONSTRATOR SYSTEM

ON Semiconductor has designed and built a long−range LiDAR demonstrator system that is based on a monolithic 1 x 16 SiPM array as receiver. This is the third in a series of LiDAR demonstrators and is therefore referred to as the “Gen3” system. This Gen3 system is intended to demonstrate the capabilities of the ON Semiconductor SiPM sensors for ToF−LiDAR systems and validate the model. The system uses a 1D array of sensors to sample multiple vertical points simultaneously and by combining this with single−axis (horizontal) scanning, a complete image of the field of view can be obtained.

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The Gen3 system is comprised of 16 eye−safe 905 nm laser diodes, an electro−mechanical rotating mirror for beam steering, collection options, the ON Semiconductor monolithic SiPM sensor array and processing electronics. The diagram in Figure 2 illustrates the system architecture of the Gen3 system. The sensor is a 1 x 16 SiPM array (ArrayMC−0116A20−DFN) that has been developed by ON Semiconductor for the Gen3 demonstrator, specifically taking into account the requirements of dynamic range in bright, 100 klux ambient light conditions and the use of simple, off−the−shelf optics.

The Gen3 LiDAR system is shown in action in this video.

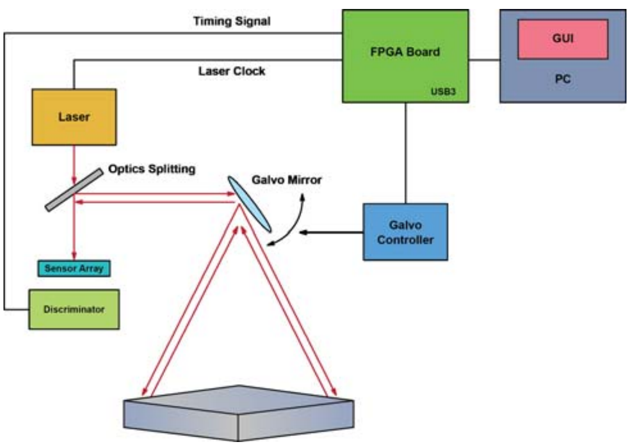

Figure 2. Gen3 LiDAR demonstrator system architecture

VERIFYING THE MODEL WITH GEN3 MEASUREMENT DATA

The Matlab LiDAR model was set up with the parameters corresponding to the Gen3 LiDAR demonstrator system, taking into account the system noise floor, the return signal level and the ambient light level. These factors were used to determine the ranging probability of the target as a function of the target distance and reflectivity. During modelling, two types of target reflectivities were considered: a low reflective target made of neoprene (~3% reflective at 905 nm) and a highly reflective target of dry pine wood (~95% reflective at 905 nm). An indoor testing environment was chosen for the verification of the model as the ambient light level can be well controlled.

Each range measurement is obtained from a histogram that is comprised of data from a fixed number of laser cycles, to get a corresponding number of ToF values. This mode of operation is commonly known as multishot mode, which is explained in more detail in this video. To enrich the quantity of acquired data, range values were determined from histograms with either 20 or 200 laser cycles. This allowed for a better comparison between data and modelled results. By acquiring multiple histograms at each range, the probability of achieving the correct ranging value can be determined and plotted as a function of the ranging distance.

The results of the modelling are summarized in Table 1, and show the maximum range (range at which the ranging probability is 95%), for different situations. The results show that the Gen3 system is able to range up to more than 200 m with a highly reflective target, to several tens of meters for a very low reflective target.

Table 1. Summary of the simulated maximum range for different target reflectivities and numbers of laser cycles, as obtained by the model.

Target Reflectivity	Laser Cycles	Maximum Range
95%	20	126 m
	200	205 m
3%	20	22 m
	200	37 m

The Gen3 demonstration system was then set up to make measurements in the same configuration as the model, to verify the maximum ranges from Table 1. Due to space limitations of ~100 m in our indoor testing environment, testing was focused on the 3% reflectivity target testing (neoprene). To fully validate the data for a high reflectivity target, a much larger space would be required (>200 m).

The ambient light illumination of the indoor testing environment was constant at < 500 lux. The testing results for the Gen3 system with the 3% reflective target, are shown in Figure 3. It shows the excellent agreement between the model (continuous line plots) and the Gen3 system measurements (individual data points).

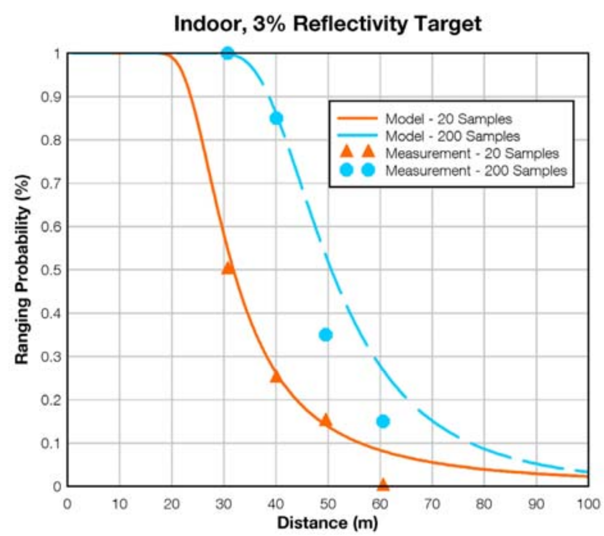

Figure 3. Model and measurement results for a 3% reflectivity target

We conclude that the model is well matched to the experimental data, validating our model.

IMAGING WITH THE GEN3

Future work will repeat this testing outdoors, in ambient solar light conditions. In the meantime, to have a sense of the working capabilities of the ranging demonstrator outdoors, an initial image of a building at around 50 m was taken, as shown in Figure 4 below. This 3D image is obtained with 20 samples per point (simulating a 30 frame per second operation) and the resulting image of the building can be seen with good accuracy and resolution. The latter can be appreciated by looking at the shape of the corner of the building. The image also shows closer obstacles such a car and hedge.

Further imaging experiments with the Gen3 system can be seen in our video. A still from the video is shown in Figure 5, showing the 2D, 3D and live action video view that is possible when imaging with the Gen3 system.

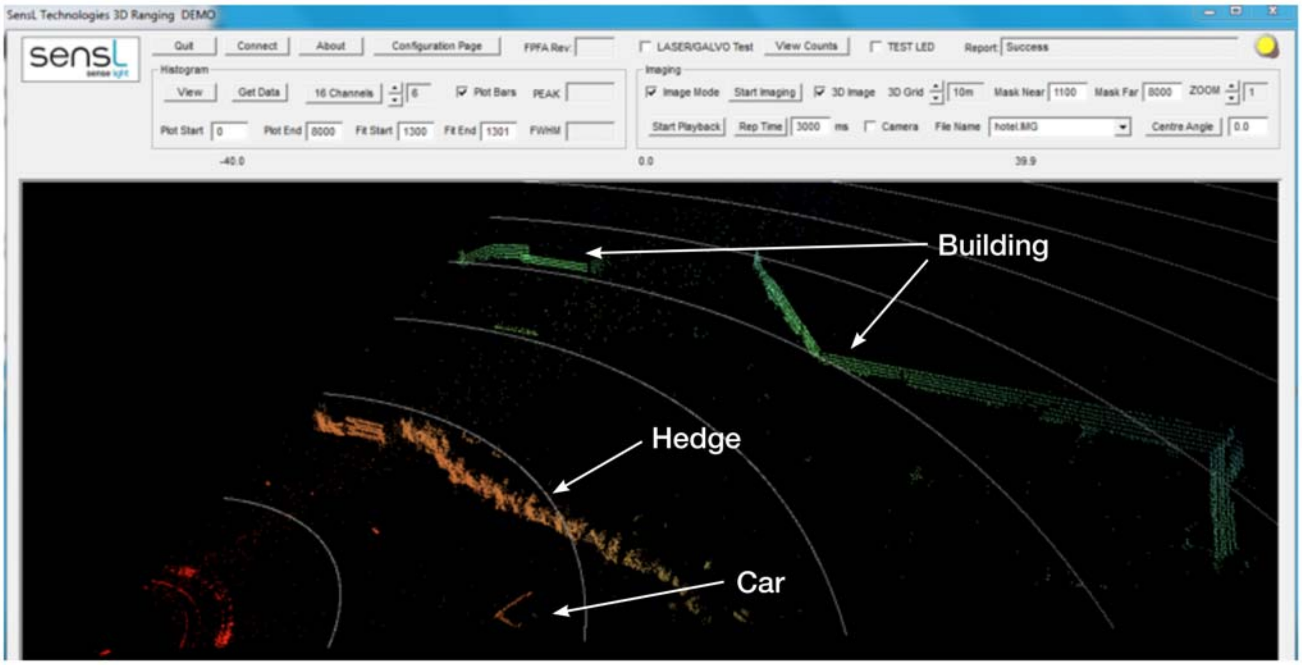

Figure 4. Outdoor imaging of building and surroundings.

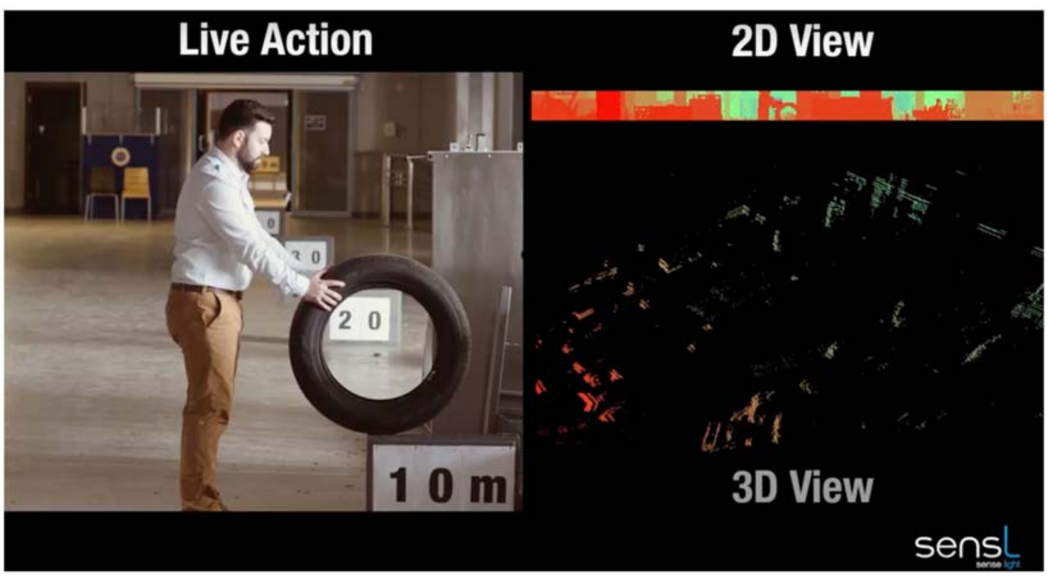

Figure 5. A still from the Gen3 LiDAR demo video

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