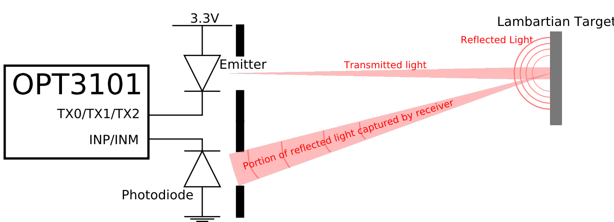
Extending the Range of OPT3101 Systems

OPT3101 is a Time-of-flight (ToF) based optical proximity sensor and range sensor AFE. This versatile AFE is compatible with a wide variety of emitters and photo diodes — some of them with integrated lens and some without integrated lens. The range and performance of the system is determined by the choice of these components and the optical assembly.

The *OPT3101 Evaluation Module* (EVM) is an example of such implementation where through hole components with integrated lenses have been used. The system level performance for the EVM can be found as part of the *this* application note. For certain applications, users may want to extend the range or to improve the performance beyond what is offered by the OPT3101 EVM. This document shows a few methods that could help achieve the same. It is important to understand that OPT3101 is an active sensing system where an emitter directs modulated light to the target. A portion of the reflected light is captured by the photodiode. The received signal is typically a very small fraction of the emitted power, this is mainly due to the physical properties of the target (see Figure 1).

Figure 1.



Most targets in real life are lambartian, reflecting the incident power in all directions with only a small fraction captured by the receiver. Hence, the captured power diminishes as an inverse square of the distance to the target. The noise and accuracy of the detected distance is a strong function of the received signal which limits the detection range based on the desired accuracy and the noise.

NOTE: It is very important to appreciate that better range and better noise performance can be achieved by only collecting more of the reflected signal from the target.

The following lists a few ways this can be achieved:

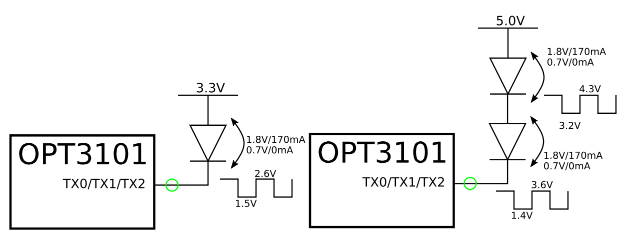
- Use a high efficiency emitter. Laser or VCSEL are a few examples.
- Stack multiple emitters.
- Use larger aperture receiver optics.

With this tech note, we assume that you are familiar with the OPT3101 device and have read *this* user's guide prior to reading this tech note.

OPT3101 has an internal driver capable of driving up to a maximum of about 170mA. This maximum limit value is critical in identifying which components emit the highest optical power for the given current. The efficiency of the emitters are typically between the range of 30% to 50%, based on the type of emitter. LEDs are lower in efficiency, but are inexpensive and are less stringent with eye safety specification requirements. LEDs are extremely hard to collimate lower than ±3º. Even under such collimated cases, there is a stray light emitted beyond the field of view. This results in wasting optical power that surpasses the region of interest. On the other hand, **higher efficiency emitters like VCSELs and lasers** help improve performance by not only by being more efficient, but also by being capable of collimating to a very small degree (up to a few milli-radians). Unlike LEDs, VCSELS and lasers are more stringent with eye safety classification and certification.

Stack two or more of the emitters with together to improve the performance (see Figure 2).

Figure 2.



To ensure the voltage levels on TX0/TX1/TX2 pins are appropriate, the high side of the voltage swing should not exceed the reliability limit. The lower side of the voltage swing should not drop below 0.7 V which then limits the 170mA current and causes non-linearity problems.With these specified constraints, the stacking options are limited to only a few topologies. For example, stacking N emitters improves the noise performance by a factor of N and also improves the range for a given noise by a factor of $\sqrt{N}$.

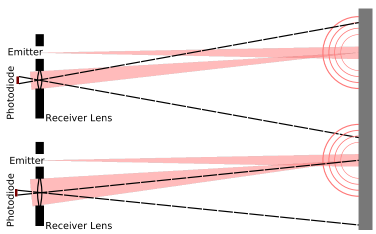
The following lists how challenging stacking can be along with how stacking can be accounted for:

- The optical alignment of N emitters should ensure the emitters' combined field of view is within the receiver optics' field of view
- Layout placement and routing becomes more stringent with more switching emitter terminals and

larger current loops. The utmost care needs to be taken to shield the switching nets and loops.

When **using custom lens on a photodiode with no integrated optics**, users are able choose lenses with a **large aperture** to collect more light. Ideally, as shown below, a larger aperture results in a larger fraction of the target's reflected light that is collected which improves the performance. Increasing aperture by a factor of N improves performance by a factor of N^2 and improves the corresponding range by a factor of N. However, in reality, an aperture increase comes with a proportional focal length increase. This is a fundamental limitation related to optics and refractive indices of a commonly available material of which lenses are made of.

Figure 3.



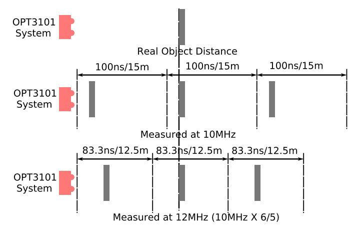
As focal length increases for a given photodiode size, the field of view (FoV) of the receiving system reduces. As long as the receiver FoV engulfs the emitter FoV, then there is no signal and performance loss. LED based systems tend to have a wider emitter field of view which limits the choice in wide aperture and focal length lenses. The maximum limit of the aperture is typically at the point of which the receiver field of view is equivalent to the emitter field of view. An aperture increase that surpasses the maximum limit yields marginal improvement or no improvement because the emitted and reflect light are not all captured by the receiving chain.

In a laser or VCSEL based system, the ability to collimate the emitter beam to a small degree leads to the possibility of the receiver aperture being larger in size in comparison to the LED based system. Even this tends to hit a practical factory alignment limit between the transmitting and receiving optics. With an extremely narrow field of view for both the emitter and receiver optics, even small change in component mounting angles, the position significantly affect the captured signal which makes the system very sensitive to factory calibration. Using a photodiode that is larger in size widens the field of view for larger aperture lenses, but OPT3101 has a maximum photodiode capacitance limit of 6 pF at 1 V bias which limits the choice as well.

In some applications that have a defined target, the retro reflector being used on the target would significantly improve noise performance and range. Unlike lambartian reflectors, the retro reflectors reflect a significant fraction of the incident light back in the same direction of the source with a very narrow dispersion. With such a reflection profile, the signal received by the receive chain is several folds higher when compared to a lambartian target which significantly improves performance. Based on the emitter field of view, the larger the size of retro reflector, the more signal gain the retro reflector provides.

OPT3101 has an un-aliased range of up to 15m. The AFE measures the phase delay between the continuous emitted and received wave, but the AFE is incapable of determining the actual phase delay between emitted and received signals. For example, targets at 1 m, 16 m, 31 m and so on would result in the same phase measurement.However, OPT3101 has a feature where the AFE measures the target at two different frequencies which helps to narrow down the real distance by utilizing measurements from both the frequencies (as shown in the illustration below). **This method is called de-aliasing and extends the range by several folds** based on the frequencies that are chosen. Refer to the *OPT3101 ToF-Based Long-Range Proximity and Distance Sensor AFE* data sheet for more information.

Figure 4.



To summarize, the three major methods, each with their own merits and limitations, to improve the performance and the range of OPT3101 based systems are explained in this tech note. Based on the application requirements, one or more of the illustrated methods can be applied to achieve the desired performance. Additionally, the OPT3101 System Estimator tool is a great way to perform what-if analyses and performance tradeoffs in advance before choosing the components to build the hardware.

1 Related Documentation

- Texas Instruments, *OPT3101 ToF-Based Long-Range Proximity and Distance Sensor AFE* data sheet
- Texas Instruments, *Introduction to Time-of-Flight Long Range Proximity and Distance Sensor System Design* user's guide
- Texas Instruments, OPT3101 System Estimator tool
- Texas Instruments, *Application of OPT3101 in Precise Distance Measurement and Ranging Applications* application report