Proof of Concept For Range Sensing Using Laser SPL PL 90_3

Here you learn how to set up a range finder yourself. A 905nm pulsed laser from OSRAM is used with a sensor to determine the distance to an object by measuring the traveling Time Of Flight (TOF) of the pulse to reach the object and hit the sensor. All components can be bought from online vendors. The presented system is the barebones of many popular (and more complex) 3D LIDAR systems and can be used to explore the details of precision and range distance as well as to implement your own code.

OSRAM SPL PL 90_3

PLASTIC PACKAGE FOR HIGH VOLUME APPLICATIONS

UP TO 75W 100NS PULSE

905 NM

-40°C – 85°C

LiDAR/ToF/SLR/Ranging

Lidar (Light Detection and Ranging) is a 3D sensing system based on either the TOF principle or on light phase shift measurement. These type of systems are the benchmark for performance by combining accuracy and operating range in 3D sensing. In this application note from OSRAM Opto Semiconductors we are exploring time of flight and single pixel LiDAR via a cost effective pathway. Many applications could benefit from the proposed systems in which they could be easily implemented:

- Industrial robot movement
- Height / Distance detection for drones and vehicles
- Liquid level sensors such as tank levels of chemical additives
- Material level sensing
- People counting in rooms
- Parking lot occupation sensor
- Traffic control (speed meters)

There also have also been interesting developments in 3D-imaging utilizing single-pixel analog detectors to record the full temporal form of back scattered light by incorporating a digital micro mirror device (DLP, Texas Instruments). The DLP "upgrade" turns the here discussed single point TOF sensor into a 3D depth sensing device but will be discussed in another paper.

The Lidar principle can be used to measure distances to any object capable of reflecting light (Fig.1). Photons can be scattered back off of many different things, such as other particles (aerosols or molecules) in the atmosphere; but it is usually solid objects that are detected. There are many different ways to use

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the signal that is collected by the sensor. Some of these uses include: detecting aerosols (pollution, dust, trace gas concentrations, etc.) in the atmosphere, detecting water vapor content in the atmosphere, measuring pressure, temperature or winds as well as many other applications. For those applications very powerful lasers are typically used that reach up to the stratosphere. The typical use of the OSRAM pulsed laser SPL PL90_3 is to measure the distance from the laser to a solid object within a couple of hundred meters/yards. With additions, a 3D rendering of the objects can be rendered.

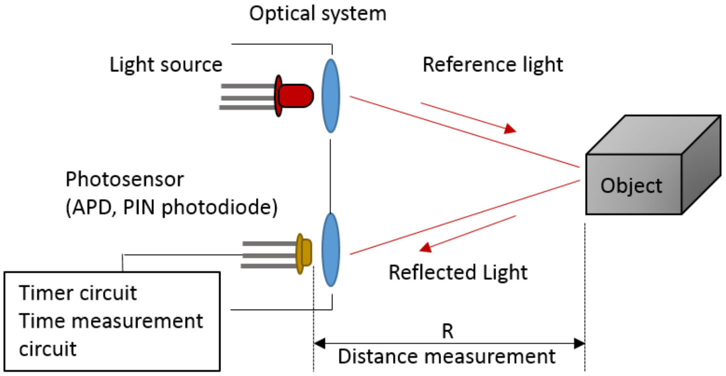


Fig. 1: Basic TOF diagram.

Typical setup

A LIDAR or ranging set-up essentially consists of four core components:

- Laser,
- Suited optics to collect the back scattered photons,
- Single photon sensitive detector,
- Timing electronics with a suited temporal resolution.

Basically, a laser pulse is sent out of a transmitter and the photons are scattered back and are collected with e.g. a telescope/lens and counted as a function of time in relation to the laser pulse. Since we know the speed of light it is then possible to calculate how far the photons have travelled round trip.

Limitations

The depth resolution and range that can be achieved with such a set-up depends on several factors, including the instrumental timing response of the detector, the laser and the temporal resolution of the timing electronics. These parameters are mentioned in this application note and it is highly encouraged to try out different settings and optics as described.

Bill of Materials / Shopping Basket

We have used these parts to build one system as well as several others. Additions and options will be added as we collect your feedback and make more experiments ourselves. We recommend this circuit for ease of use and to limit hardware development during initial investigation. This design works in indoor ambient light conditions and requires no special filters or expensive optical components.

	Single Pixel TOF	Digikey PN	
Laser Driver Board	**EPC EPC9126HC (-80VDC Bias)**	**917-1162-ND**	
D3 **Laser**	**OSRAM** **SPL PL90_3**	**475-3533-ND**	
D1 (sensor)	**MTAPD-06-016** **Silicon APD**	**1125-1301-ND**	
R1 (sensor)	**1 k 1/4W resistor**	**CF14JT1K00CT-ND**	
R2 (sensor)	**47 Ohm 2 W resistor**	**47ZCT-ND**	
C1 (sensor)	**0.1 uF 50 V axial capacitor**	**399-4610-ND**	
DB1 (sensor)	**Sparkfun BOB-09816**	**1568-1278-ND**	**Amplifier Evaluation Board**
Optics	**Edmund 6X DCX lens**	**N/A**	**Available at edmund.com** **https://www.edmundoptics.com/optics/optical-lenses/double-convex-dcx-spherical-singlet-lenses/6-x-23mm-fl-grade-2-double-convex-lens/#!**
Measurement	**Texas Instruments**	**750 MHz oscilloscope**	**Including oscilloscope cables**

Operation		**DC Power Supplies (<160, 64, and 10 VDC)**	**Including cables/mounting hardware**
Operation		**Frequency generator, 20-80 MHz**	**Including cables/mounting hardware**
Operation	**Edmund IR Card**	**N/A**	**https://www.edmundoptics.com/lasers/laser-measurement/infrared-ir-ultraviolet-uv-viewers/Laser-Detection-Card-IR/**
Setup	**Solderless breadboard**	**922327-ND**	

Table 1: The components used in this OSRAM TOF demo.

Laser SPL PL 90_3

The laser is first set up using the EPC EPC9126HC laser driver board, which is a development board primarily intended to drive laser diodes with high current pulses with total pulse widths as low as 5 ns (10% of peak). It is perfectly suited to drive the SPL PL 90_3. The discharging capacitor drive was used (see Fig. 2, top left) in this example where a square waveform from a function generator was used to trigger a high amperage path to ground through Q1, which is a high powered GaN-FET.

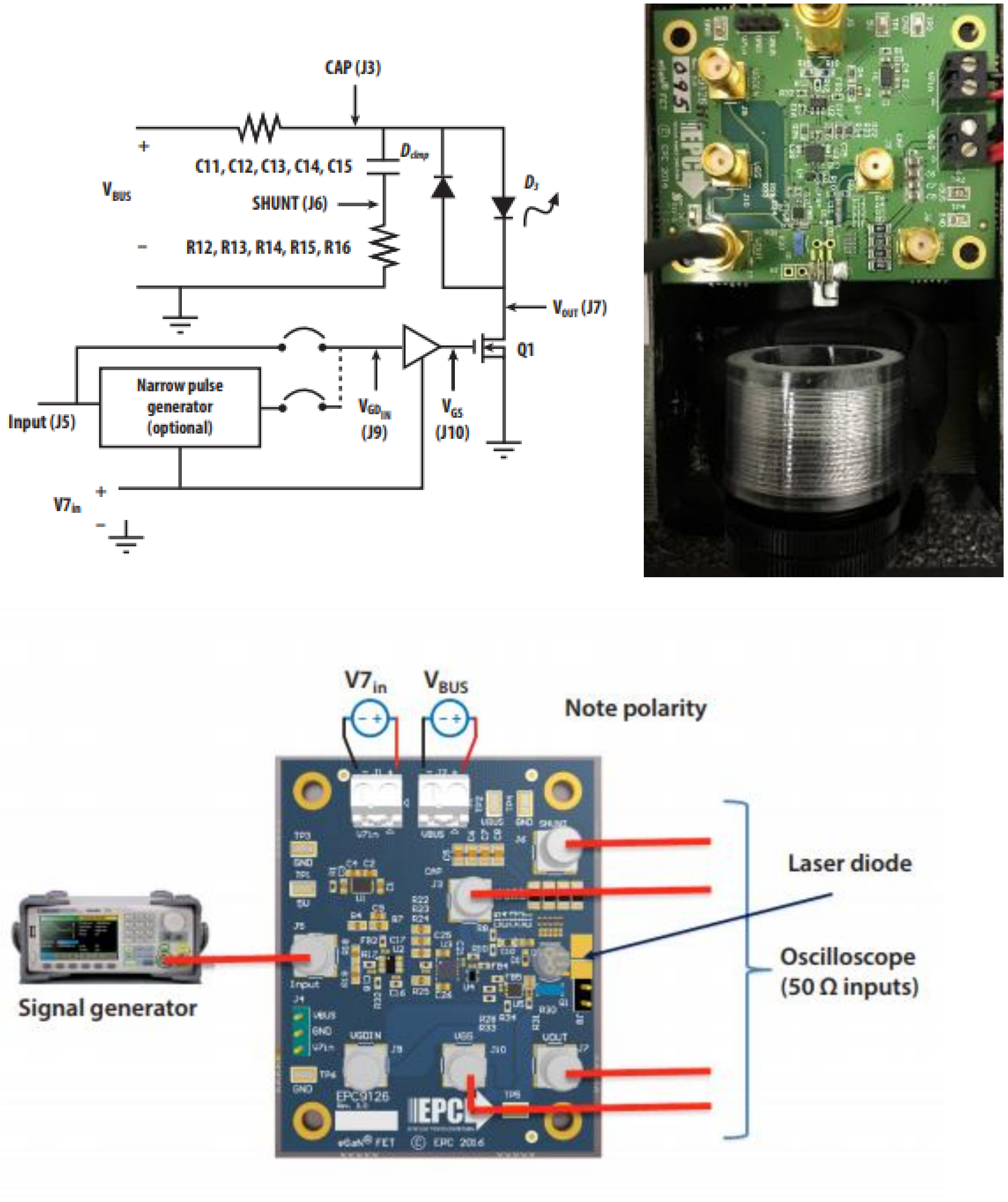
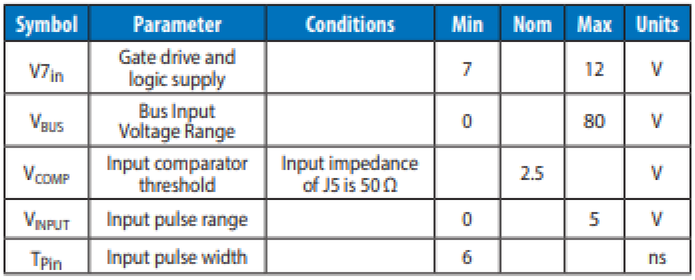


Fig. 2: The EPC9126HC drive schematic (top left – image credit of Efficient Power Conversion Inc.) and the setup driver board plus focusing lens (top right**)**. Pictorial representation of inputs, outputs and monitoring (bottom – image credit of Efficient Power Conversion Inc.).



Symbol	Parameter	Conditions	Min	Nom	Max	Units
$V7_{in}$	Gate drive and logic supply		7		12	V
V_{BUS}	Bus Input Voltage Range		0		80	V
V_{COMP}	Input comparator threshold	Input impedance of J5 is 50 Ω		2.5		V
V_{INPUT}	Input pulse range		0		5	V
T_{Pin}	Input pulse width		6			ns

Table 2: The voltage input ranges allowed by the EPC9126HC (image credit of Efficient Power Conversion Inc.).

The development board EPC9126HC is easy to set up as a laser driver. First refer to Table 2 for recommended ranges and measurement setup. Be sure to review laser safety considerations. Observe all necessary laser safety requirements including the use of personal protection equipment (PPE) as required. Refer to qualified safety personnel as necessary. Prior to connection to a power source, the laser diode (D3) must be installed using a soldering iron with the correct polarity (the correct polarity for SPL PL90_3 can be seen in Fig. 2, top right). With power off, connect the input power supply bus to +VBUS (J2) and ground / return to –VBUS (J2). With power off, connect the logic supply (7-12 V VDC) to +V7in (J1) and ground return to –V7in (J1). 5. With power off, connect the signal pulse generator to the input J5 which is terminated with 50 Ω on the EPC9126HC. The signal input can handle up to 0.25 W RMS. Connect the remaining measurement SMA outputs to an oscilloscope, using 50 Ω cables and with the scope inputs set to 50 Ω impedance.

DO NOT LOOK DIRECTLY INTO THE LASER. USE APPROPRIATE SAFETY MEASURES. ANY SURFACE CAN DIVERT THE LASER LIGHT UNPREDICTABLY.

Turn on the logic supply voltage to the required value (7-12 Volts DC), the high voltage bus (<80VDC), and finally the frequency generator (5 Vpp, 0 offset, ~50 ns, 20% duty cycle is a good starting point). Turn on the pulse source and observe switching operation via the outputs and any additional desired probing (looking at J7 = Vout is particularly helpful). Laser diode output may be visually observed with an IR card or IR sensitive camera. You may need to adjust the pulse width and duty cycle for easy alignment while observing the thermal limitations of the SPL PL90_3. An oscilloscope is connected to the trigger/frequency generator (J5) and Vout (J7) as seen in Figure 3. The input square wave is heavily distorted due to input impedance between the generator and board while attempting nanoscale pulses. Grounded coaxial cable was used in this example with the shortest leads possible – it is to be expected to observe some distortion as the pulse widths fall below 50 ns. When shutting down, turn off the frequency generator first, then the bus (high VDC), and finally V7in.

Fig. 3: The frequency generator (yellow/top trace) is shown from frequency generator/J5 while the current pulse which is pulsed across the laser shown in the pink/middle trace (J7). The bottom trace which is discussed later, is the output of a detector.

Setting up the optics for the laser

The divergent laser beam will be focused using a lens. The lens choice has a great influence in the range but a higher directionality makes it harder to align with the sensor as well. Our recommendation worked fine for indoor rooms typical ranges in ambient light.

It is recommended to focus the beam at the desired measurement point on a solid object located at that distance. In this example, short ranges were considered of <20 feet (6 meters). The most economical approach to imaging the focusing the laser beam (it will be easier to align if you can see the beam somehow) is to use a camera with the IR filter removed (some android smartphones work) or an IR card (Fig. 4). If the fluorescing glow in the infrared card is not visible, increase the duty cycle or the frequency of pulse repetition into the MHz on the frequency generator.

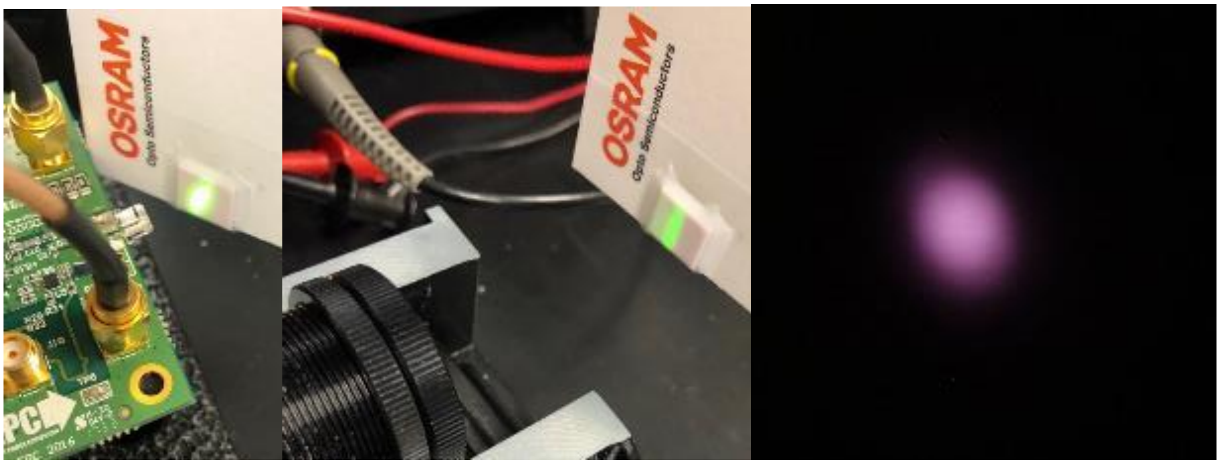


Fig. 4: Ensure that the frequency of the pulses are high enough that the laser can be observed using an infrared detector card (left) without the lens. Now focus the laser through the lens on the IR card as shown

(middle). Alternatively, an IR sensitive camera image of the focused beam (right) obtained by focusing the beam on the wall or sheet of white paper and taking images without a flash while in a darkened room.

Place the Edmund 6X DCX lens in front of the laser as shown in Figure 2 (top right). Focus the lens as shown in Fig. 4 (middle and right). If an infrared sensitive camera is used, the focused beam should look like that as shown on the Fig. 4, right, with a diameter of ~6 mm.

Setting Up the Detector (APD)

We used the Marktech avalanche photodiode (APD) MTAPD-06-016 (Fig. 5) but also the Thorlabs FDS100 and Sensl MicroRA-SMA-10020 worked in different configurations, all with good success. This particular APD requires a biasing circuit and a filter (R1, C1). The components used are listed in Table 1.

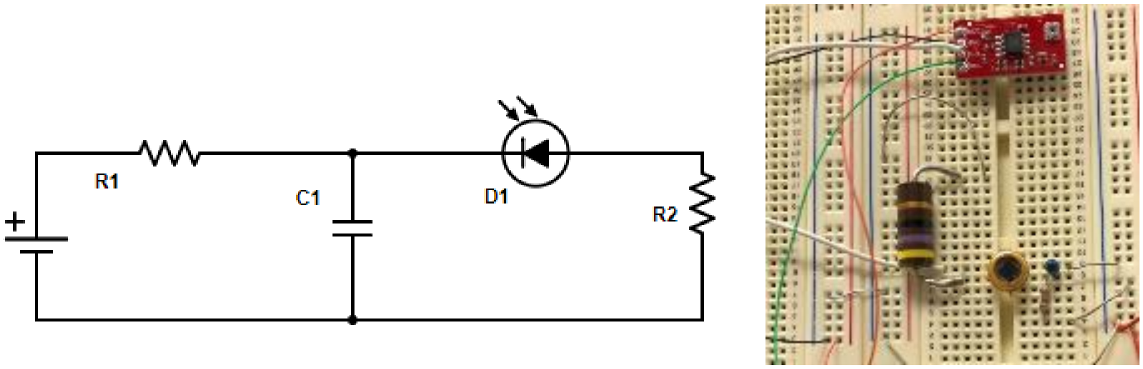


Figure 5: The Marktech APD is preceded by an RC filter and the output is measured across a low impedance, high wattage 47 Ohm resistor.

Construct the circuit shown in Figure 5 (left), taking great care when using the VDC power supply as the significant potential can destroy the sensor (do not exceed 1 mA of forward current). A breadboard eases setup as shown in Fig. 5 (right) but a circuit can be designed instead as well. To test the sensor, it is easiest to actually focus the laser into the sensor by placing the laser and the sensor face to face. The previously focused point of the laser should be used from the previous section; place the APD plus the sensor network in that same location to test the APD as shown in Fig. 6 and 7.

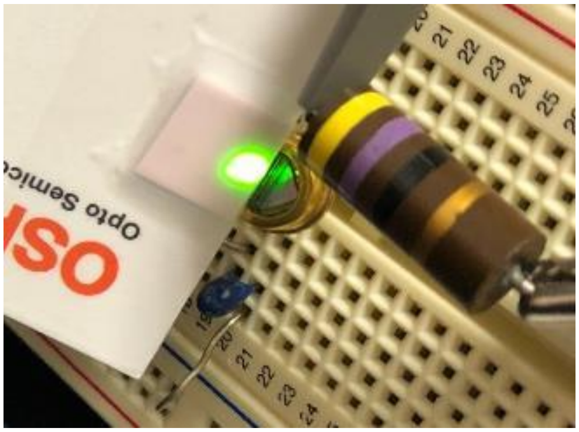


Figure 6: The sensor should be placed in the focused laser beam region.

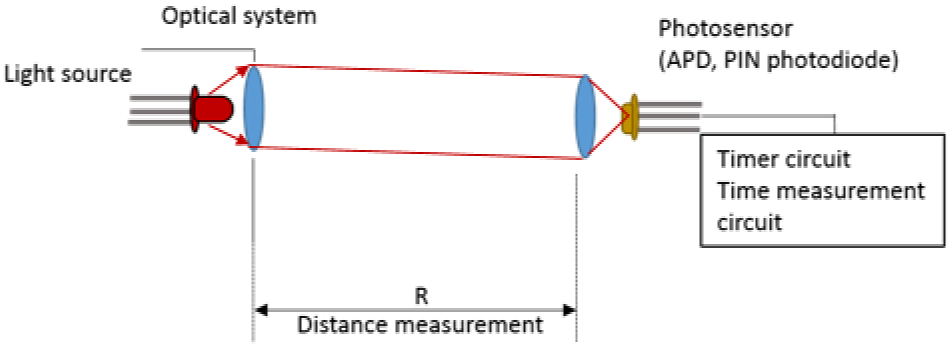


Figure 7: Focusing the laser on the detector to ensure proper operation prior for the actual ToF setup.

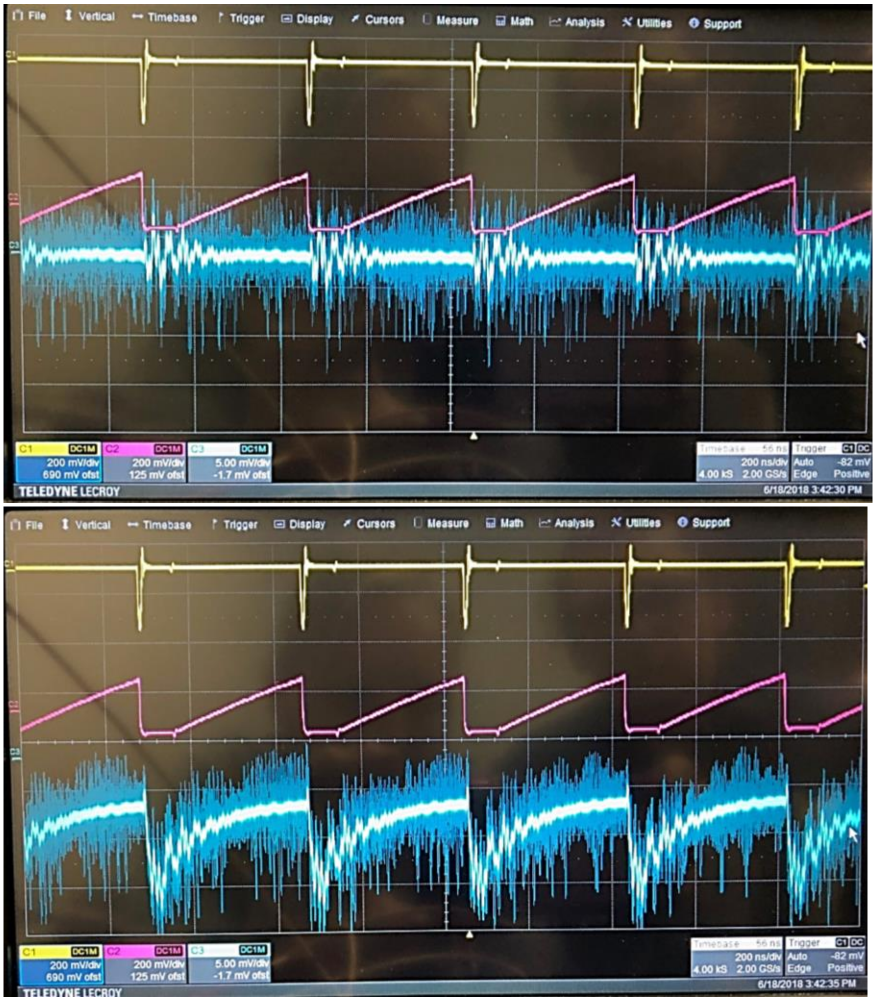


Figure 8: The top panel of the oscilloscope shows the cross talk which may be observed on the APD (blue). The bottom panel shows the APD with the laser focused on the detector region (blue).

Attach a 50 Ohm impedance scope probe between D1 and R2 while attaching the grounding portion to earth ground. There will likely see a significant amount of crosstalk as seen in Figure 8 (top panel, blue trace). If the laser board is operating in the 10's of MHz, it is to be expected in the initial setup and RC filters will need to be introduced during the refinement phase of circuit design and board layout. If good focus on the sensor has been achieved, a signal such as that seen in Figure 8 (blue trace, bottom) will be observed.

In both images of Figure 8, the yellow trace is the output from the frequency generator into the laser driver board which begins the sequence of firing the laser driver and laser. We can think of this as t= minus 0, meaning before the time of flight will be measured. Next, looking at the pink (middle) trace which is the signal showing the discharge across the laser, electrical energy is converted into photons. This is t=0, the point at which the time of flight will begin measurement. Lastly, looking at the blue trace which represents the photons collected by the APD, converting the received light into electrical pulses. It is now possible to calculate the time of flight. In this case, the laser has been directed into the sensor, as shown in Figure 7. The path is a line straight line (instead of a round trip) therefore the time of flight would be found using: $d = \frac{t*c}{1}$ where c is the speed of light, 2.99x10^8 m/s. It will also be desirable to limit the pulses or duty cycle prior to having good heat sinking which is absent on a bread board setup. The example given will quickly warm the sensor during continuous illumination and the gain will be reduced. Good heat sinking on this sensor will be necessary during board fabrication.

The gain of the APD is 50 V/A. It is common to feed the output of the APD into a transimpedance amplifier (TIA) as shown in Figure 5 (right) and 9. The circuit used for the TIA portion is available as a ready-made circuit and provides a gain of 100 (Figure 9).

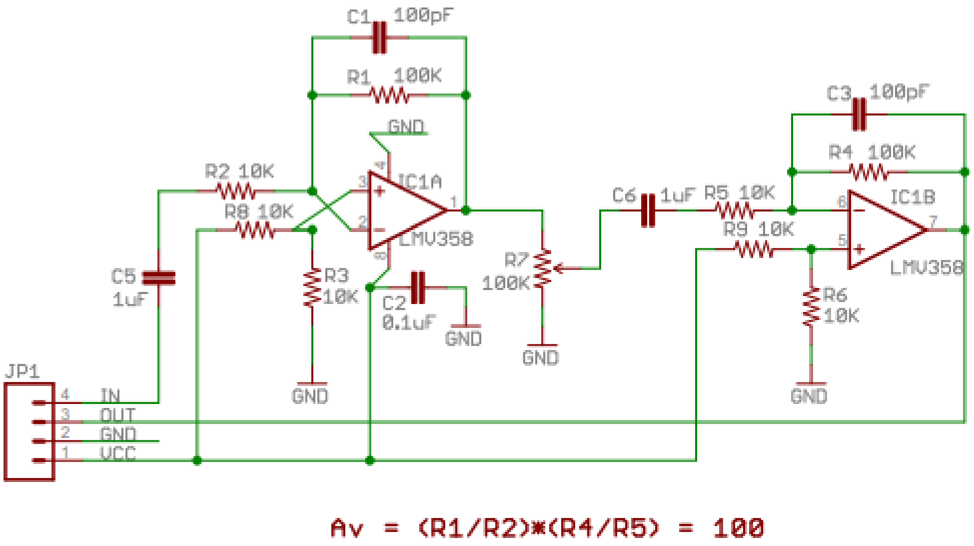


Figure 9: The TIA circuit which provides gain up to 100 (image credit - Sparkfun).

The measurement point between D1 and R2 as shown in Figure 5 (left) can now fed into the pin 4 of the daughter board (DB1) from Table 1. The output of the transimpedance amplifier (TIA) is now the new signal which is amplified by 100. The approach is similar to alignment where the signal will be monitored for maximum amplitude, indicating optimum performance. The GND pin (2) as shown in Figure 9 is attached to the same ground as that used in Figure 5. VCC is 5 VDC. This simple circuit uses a two stage amplifier.

Integration and Set Up of actual Time-Of-Flight Measurement

It is now time to incorporate the emitter and sensor together side by side, which will be on the same parallel plane and optically isolated using a metal plate between them as shown in Figure 10 (to avoid crosstalk). The second Edmund DCX 6 lens should now be placed in front of the APD. This may require some optimization of the alignment which is achieved by monitoring the output of the TIA using an oscilloscope while monitoring pin 3 (OUT) of the daughter board. Improved alignment improves the amplitude of the signal seen on the oscilloscope. A goniometer stage may be helpful but is not required, 3D printed parts are an acceptable substitute.

It is now possible to use a reflecting surface such as a piece of white board in the focusing path of the laser beam and watch the signal reflect back as the laser beam bounces off the board and back to the sensor. It is also possible now to calculate the time of flight (TOF) as in the examples in Figure 11.

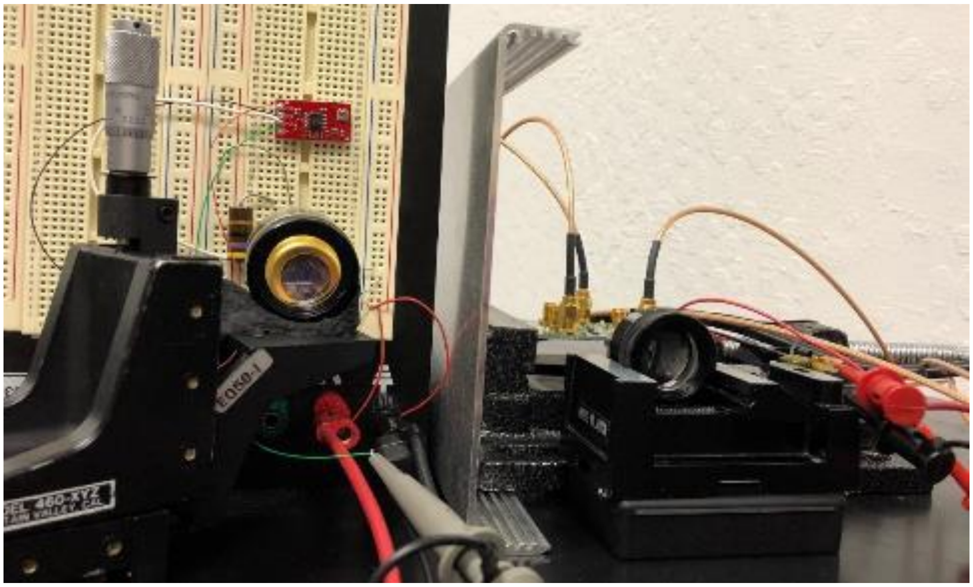
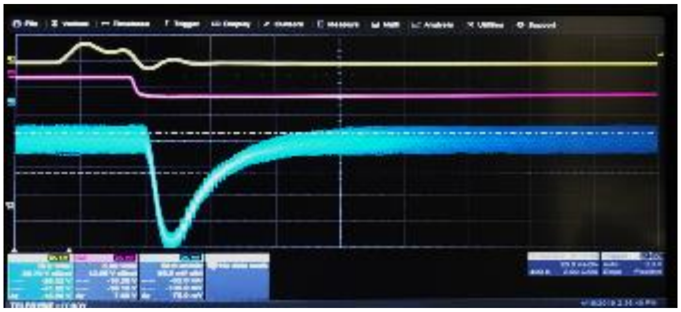


Figure 10: The laser emitter and sensor plus TIA circuit are now placed side by side. Note the metal plate which separates the two – this prevents unwanted optical crosstalk.

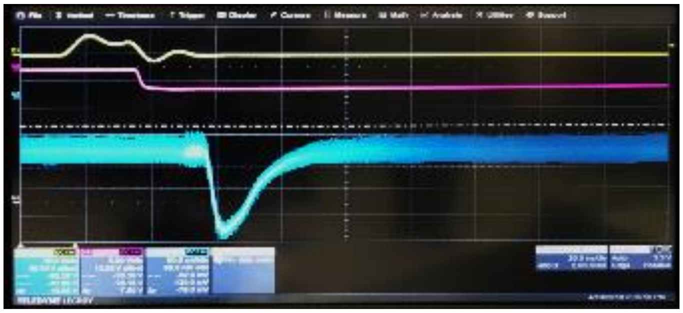
Target 12" (0.31m) from laser

$$d = \frac{t * c}{2} = \frac{5x10^{-9}s * 3x10^{8}\frac{m}{s}}{2} = 0.38\,m$$



Target 10' (3.1m) from laser

$$d = \frac{t * c}{2} = \frac{25x10^{-9}s * 3x10^{8}\frac{m}{s}}{2} = 3.8\,m$$



Target 18' (5.4m) from laser

$$d = \frac{t * c}{2} = \frac{38x10^{-9}s * 3x10^{8}\frac{m}{s}}{2} = 5.7\,m$$

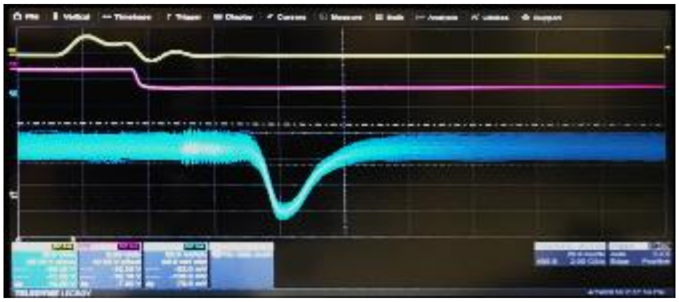


Figure 11: Three TOF flight measurements. The top panel shows a target 12" from the laser reflecting back into the sensor. The middle shows the laser reflecting from a target.

In this example, the laser has been reflected off a white, reflective surface back into a sensor, therefore the time of flight would be found using: $d = \frac{t*c}{2}$ where c is the speed of light, 2.99x10^{8} m/s. The speed of light is being used to calculate the distance of travel. Once again, the pink traces in Figure 11 represent the laser emitting photons which begin their journey. As the sensor measurement is detected later, it is then possible to quantify the amount of time from the laser emission and the received sensor pulse. It is also seen that as the distance increased, the amplitude of the pulse decreases.

Conclusion

We look forward to answering your technical questions and are open to suggestions. Has this proof of concept helped you? Are you struggling with some step or component? Please reach out to support@osram-os.com. Or visit our homepage www.osram.com/os

DISCLAIMER

Depending on the mode of operation, these laser devices emit highly concentrated visible and non visible light which can be hazardous to the human eye. Products which incorporate these devices have to follow the safety precautions given in IEC 60825-1.

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