



The OSLRF-01 is an open source laser range sensor that works on the time-of-flight principle. It includes a laser, detector, optics and sequential-equivalent-time-sampling (SETS) circuits.

Designed as a bare-metal front end for a laser rangefinder system, the OSLRF-01 is a high quality sensor that can interface directly to the ADC channels of a microcontroller.

The OSLRF-01 is ideal for obstacle detection, distance measurement and laser rangefinder research.

#### Features:

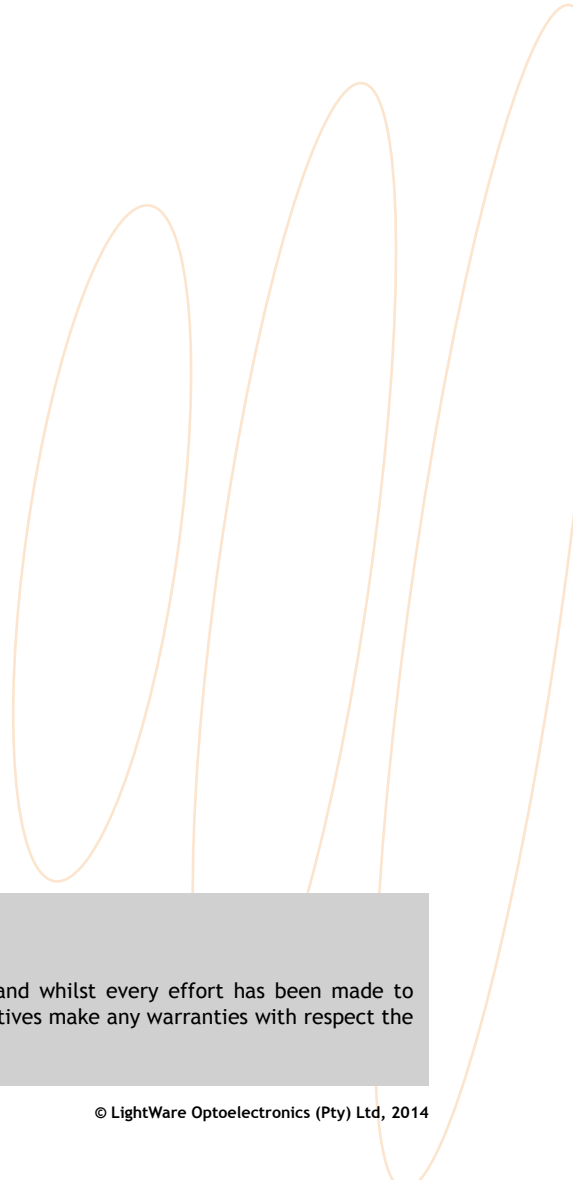
- *A laser-based time-of-flight sensor that can be incorporated into a microcontroller based laser rangefinder.*
- *SETS circuits permit direct interfacing with the ADC channels of a microcontroller.*
- *Detects surfaces and objects up to a distance of 9 meters away.*
- *Adjustable update rate and resolution.*
- *A direct replacement for ultrasonic sensors in applications where higher performance and a narrower beam are required.*
- *Affordable for the student or hobbyist.*

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### Disclaimer

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## 1. Introduction :: Open Source, Laser Rangefinder Type 01

The OSLRF-01 is a time-of-flight, “bare-metal” sensor that forms the front end of a laser rangefinder system. It runs autonomously when power is applied and produces electrical signals that can be analysed to determine the time it takes for a laser pulse to travel from the unit, to a surface and back again.

The OSLRF-01 solves the most critical engineering problems that designers face when making a time-of-flight laser rangefinder. These are:

1. The laser needs to be “fired” using a very short current pulse of tens of amps. The high speed driver components must be shielded to prevent optical and electronic leakage which would otherwise interfere with the detector and mask the return signal.
2. The detector needs to pick up the very weak return signal and amplify it to a level well above any background noise. This amplification is done using high speed amplifiers that are expensive and consume a lot of power.
3. The time between the outgoing laser pulse and the return signal needs to be measured with very high precision in order to calculate the distance. Clocking speeds of 15GHz would be needed in a timer capable of 1cm resolution and this is impractical.
4. Collimating optics for the outgoing laser beam and collection optics for the return signal are needed to make the system work over a reasonable range. These can be expensive components.

The OSLRF-01 consists of a laser, photodiode, optics, amplifiers and sequential-equivalent-timebase-sampling (SETS) circuits. These components work together to create signals that are easy to analyse, having been amplified and slowed down to a manageable speed. The output signals from the OSLRF-01 include the outgoing laser pulse, the return signal and various timing references.

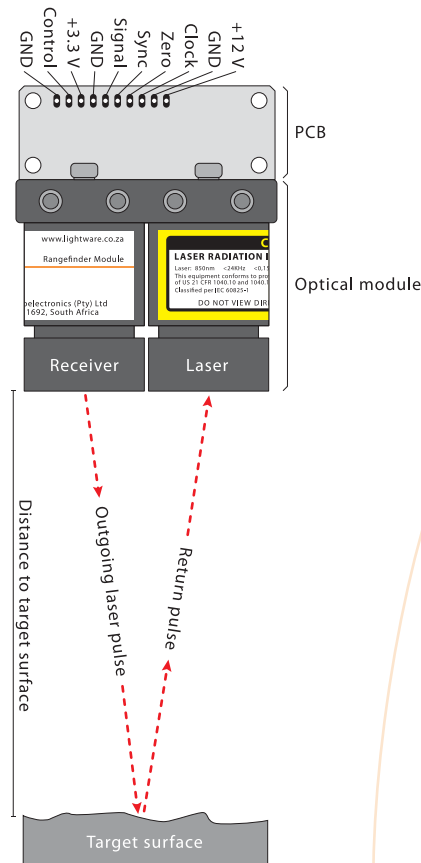


Figure 1 :: The main features of the OSLRF-01

### Important notice

This product is not a complete laser rangefinder. It requires further electronics and software to convert the signals into a distance measurement. Knowledge of basic electronics, microcontrollers and software is needed to complete an LRF design using the OSLRF-01.

## 2. Overview

The block diagram below shows the main functions inside the OSLRF-01. The laser is fired by the control logic and the outgoing laser pulse is sampled using sequential-equivalent-time-sampling (SETS). This process converts the high speed signal onto a slower timebase and this slowed down signal is visible on the “Zero” output pin. The optical output of the laser is collimated into a narrow beam by a lens and the laser flash is projected onto a target surface some distance in front of the OSLRF-01.

The laser flash travels at the speed of light to the surface and some of it reflects back to the receiver lens which focusses the light onto a photodiode. A very brief current pulse is produced by the photodiode that needs to be amplified before it can be used for timing purposes. The first stage of amplification is done by a transimpedance amplifier (TIA) that turns the current signal into a voltage. This voltage then undergoes SETS in the same way as the outgoing laser pulse, and the result is a very small but slowed down version of the return signal. This signal is then amplified and made available on the “Signal” output pin.

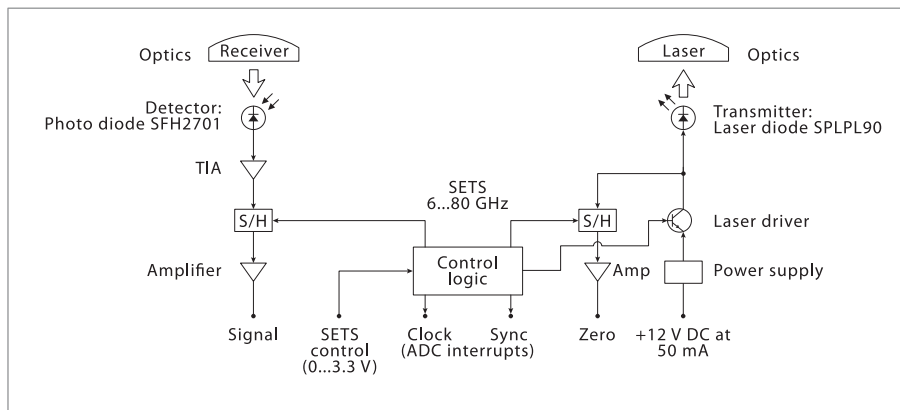


Figure 2 :: Block diagram

### 2.1 Timing references

Real-time signals inside the OSLRF-01 cannot be seen without the use of expensive equipment, but the SETS circuit slows down these signals so that they can be viewed on an inexpensive oscilloscope or captured by the ADC inputs on a microcontroller. Slowed down signals are operating on an expanded timebase that is more than 100 000 times slower than the real-time signals.

In order to know when the zero and full scale times of the expanded timebase are, a Sync reference is produced by the Control logic. The falling edge of this reference is linked to the moment when the Control logic triggers the laser driver and this is defined as the “zero\_time”. It takes a few nanoseconds before the laser actually starts producing light so there is a noticeable delay on the expanded timebase between the zero\_time and moment when the outgoing laser pulse is seen on the Zero output.

The laser flash hits a target surface sometime after the Zero signal and then the return signal can be seen on the Signal output. The return Signal and the Zero pulse are on exactly the same expanded timebase. The next falling edge of the Sync reference marks the “full\_scale\_time” and the end of a measuring cycle. The period of the Sync reference represents exactly 18.33m of distance and the distance to the laser Zero and the return Signal are measured as a proportion of this Sync distance.

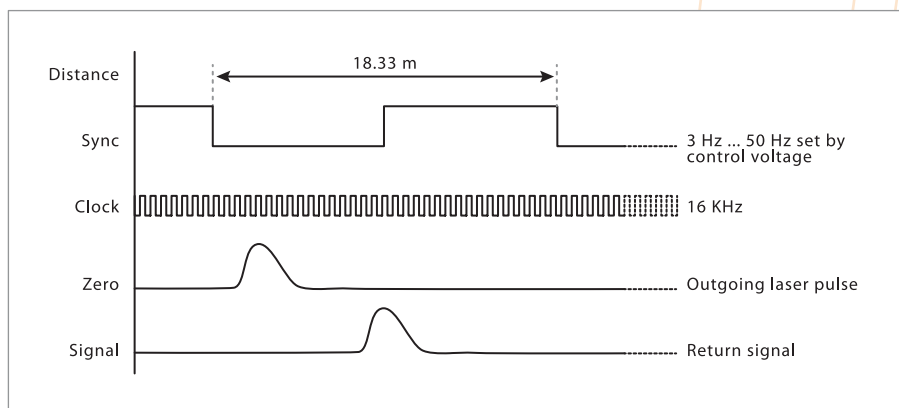


Figure 3 :: Timing signals

The period of the Sync reference can be changed by the Control voltage input. This alters the SETS circuit resulting in a faster or slower expanded timebase and therefore changing the full\_scale\_time. However, the period of the Sync reference always remains equal to 18.33m.

Calculating the distance to a signal on the expanded timebase is done as follows:

1. Measure the period of the Sync reference between successive falling edges (Sp).
2. Measure the time to the Zero signal from the falling edge of the Sync reference (Zt).
3. Measure the time to the return Signal from the falling edge of the Sync reference (Rt).
4. The distance to the return signal is given by the equation:

$$D = ((Rt - Zt) / Sp) * 18.33 \text{ m}$$

For example:

We can define the falling edge of the Sync reference to be at 0.00s on the expanded timebase (zero-time).  
The period of the Sync reference (Sp) is measured at 0.15s.  
The time to the Zero signal (Zt) is measured at 0.02s.  
The time to the return Signal (Rt) is found at 0.08s.  
Using the above equation:

$$\begin{aligned} D &= ((Rt - Zt) / Sp) * 18.33 \text{ m} \\ &= ((0.08 - 0.02) / 0.15) * 18.33 \\ &= 7.33\text{m} \end{aligned}$$

In addition to the Sync reference, there is a Clock reference that can be used to trigger successive ADC conversions on a host controller. This Clock signal is synchronous with the SETS circuit and will reduce the noise in the digitised signals when compared with an ADC performing conversions at a different rate.

## 2.2 Signal timing strategies

Once the Zero (outgoing laser pulse) and Signal (return signal) have been captured using ADC conversion, the digital representation can be analysed using various software algorithms. Each algorithm embodies a timing strategy that has benefits and limitations depending upon the final application.

The simplest timing strategy is to define a threshold voltage in software and count the number of ADC samples between the rising edge of the Zero and rising edge of the return Signal that reach this threshold. Each count equates to the “tick” of a virtual clock, and counting these ticks gives the time on an expanded timebase. Knowing the number of ticks to the full\_scale\_time of the Sync reference means that the distance can be calculated as follows:

$$\text{distance\_to\_target} = ((\text{ticks\_to\_signal} - \text{ticks\_to\_zero}) / \text{ticks\_to\_full\_scale\_time}) * 18.33\text{m}$$

A limitation of this approach is that the digitised Signal will change size as the strength of the return signal is affected by different reflective properties of the target surface. These changes will alter the height of the digitised signal and therefore the point at which the leading edge crosses the threshold. One way of handling this would be to make a dynamic threshold that is set at a fixed proportion of the height of the return Signal.

An alternative strategy is to use “constant fraction discrimination” (CFD). In this method both the front and the rear of the return Signal are timed as they cross a fixed threshold. The true position of the return Signal is defined to be midway between these points. This method cancels out some of the effects of changes in signal strength.

## 2.3 Controlling the timebase

The expanded timebase applies to the Zero, Signal and Sync outputs and can be adjusted by applying a voltage to the Control input pin. This pin will accept voltages from 0 to 3.3V or pulse-width-modulated signals directly from a port pin on a microcontroller. When left unconnected, the Sync reference has a period of about 40ms. Increasing the voltage on the Control input expands the timebase and slows down the signals. Reducing the voltage makes the timebase shorter and the signals faster.

If an exact timebase is required then a software control loop can be created that measures the period of the Sync reference and adjusts the Control voltage until the required timebase is achieved.

### 2.4 Converting the speed of light into the speed of sound

The speed of light is 299792458 m/s and the speed of sound (at sea level) is 340.29 m/s. Slowing down signals travelling at the speed of light by a factor of 881000 times makes them appear to be travelling at the speed of sound. This can be done using the OSLRF-01 by adjusting the voltage on the Control input until the period of the Sync reference is exactly 107.7ms. This is the time it would take a sound wave to travel to a target 18.33m away and return to the sensor.

Using the OSLRF-01 as a speed-of-light to speed-of-sound converter means that the signals measured by the host controller are identical to those that would be found from an ultrasonic sensor. This means that existing ultrasonic algorithms can be applied to these signals in order to calculate the distance.

If faster measurements are needed, the speed of sound may be a little too slow. Decreasing the voltage on the Control input speeds up the signals and makes them appear to be travelling faster than the speed of sound. The same measuring algorithms can be used but the speed of sound constant would be different.

### 3. Instructions for safe use

The OSLRF-01 is a laser rangefinder that emits ionizing laser radiation. The level of the laser emission is Class 1M which indicates that the laser beam is safe to look at with the unaided eye but must not be viewed using binoculars or other optical devices at a distance of less than 15 meters. Notwithstanding the safety rating, avoid looking into the beam and switch the unit off when working in the area.

CAUTION -- The use of optical instruments with this product will increase eye hazard.

The OSLRF-01 should not be disassembled or modified in any way. The laser eye safety rating depends on the mechanical integrity of the optics and electronics so if these are damaged do not continue using the OSLRF-01. There are no user serviceable parts and maintenance or repair must only be carried out by the manufacturer or a qualified service agent.

No regular maintenance is required for the OSLRF-01 but if the lenses start to collect dust then they may be wiped with suitable lens cleaning materials. Make sure that the OSLRF-01 is switched OFF before looking into the lenses.

The OSLRF-01 should be mounted using the four holes provided in the circuit board. Do not hold or clamp the lens tubes as this may cause damage and adversely affect the laser safety rating.

### Laser radiation information and labels

Specification	Value / AEL	Notes
Laser wavelength	850 nm	
Pulse width	< 30 ns	
Pulse frequency	< 16 kHz	
Peak power	< 10 W / 15.96 W	50 mm aperture at 2 m
Average power	<0.6 mW / 0.78 mW	7 mm aperture
Average energy per pulse	<0.15 nj / 200 nj	
NOHD	<15 m	Distance beyond which binoculars with may be used safely



Figure 4 :: Product identification and safety labels

Appendix A :: Specifications

OSLRF-01	
Range	0.5 ... 9 m
Resolution	Adjustable
Update rate	Adjustable: 3 ... 50 readings per second
Accuracy	Adjustable
Power supply voltage	12 V (10 ... 16 V)
Power supply current	50 mA
Outputs & interfaces	Timing & laser signal outputs
Dimensions	27 x 56 x 65 mm
Weight	57 g
Mounting	4 x M3 (3.2 mm diameter) mounting holes
Connection	0.1 in. pitch header
Optical aperture	53 mm
Laser power	14 W (peak), 6 mW (average), Class 1M
Operating temperature	- 20°C ... + 60°C

Appendix B :: Dimensions

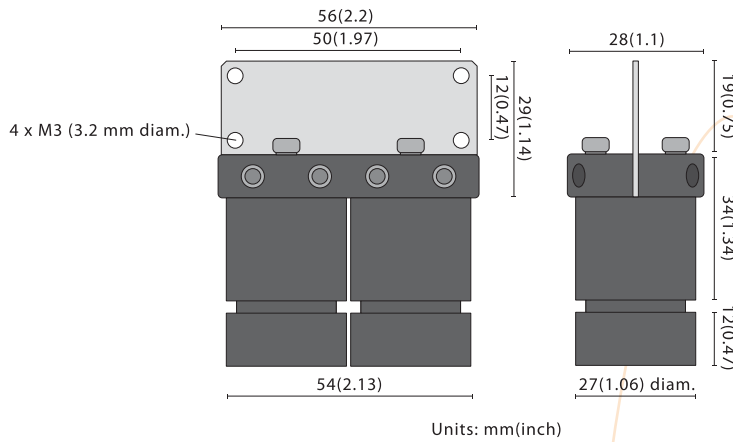


Figure 5 :: Dimension drawings

Appendix C :: Connections

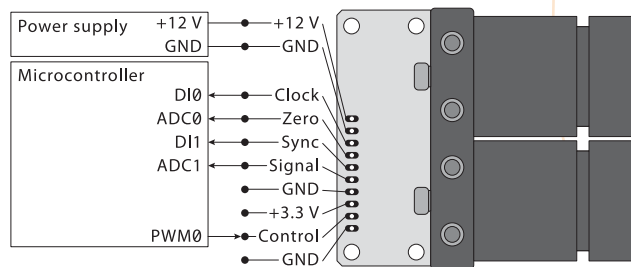


Figure 6 :: Connection diagram









### Revision history

Version	Date	Authors	Comments
Rev 0	2014/02/05	JEP	First edition

