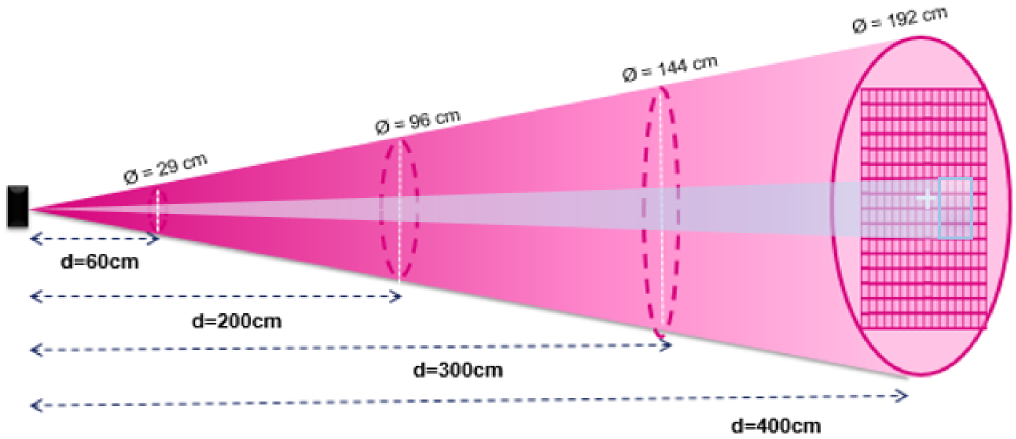
Using the programmable region of interest (ROI) with the VL53L1X

Introduction

The VL53L1X allows a region of interest (ROI) to be selected. This document explains how to reduce this ROI from its nominal 27 ° field of view (FoV) down to 15 °.

Figure 1. **VL53L1X system FoV: receiver cone at 27 °**



1 Document scope

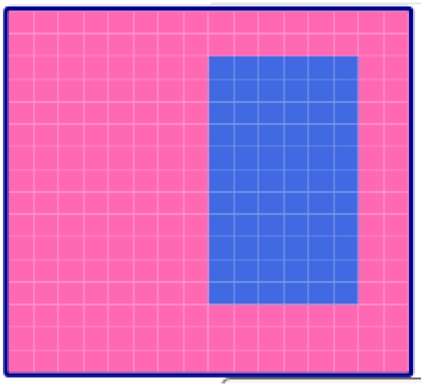
This document explains how to configure the ROI of the VL53L1X with a view to reducing the FoV of the sensing area on the receiver SPAD array. This can be achieved using the SW driver application programming interface (API) or the evaluation kit graphical user interface (GUI).

In this application note:

- "ROI selection" means positioning the reduced sensing area at a selected place on the SPAD array to detect and measure the distance of the specified area of interest of the external scene.
- "Reduced FoV" means using a reduced number of SPADs for the ROI sensing area to limit the viewing angle of the sensor device.

The selected ROI can be defined by any combination of edge co-ordinates on the X-axis and Y-axis, keeping a minimum size of 4x4.

Figure 2. **VL53L1X ROI selection with reduced sensing area (blue represents the active sensing area)**



This document also provides some recommendations for ROI selection, taking into account the ranging distance performance trade off and use case topology.

2 Time-of-Flight sensing and ROI principles

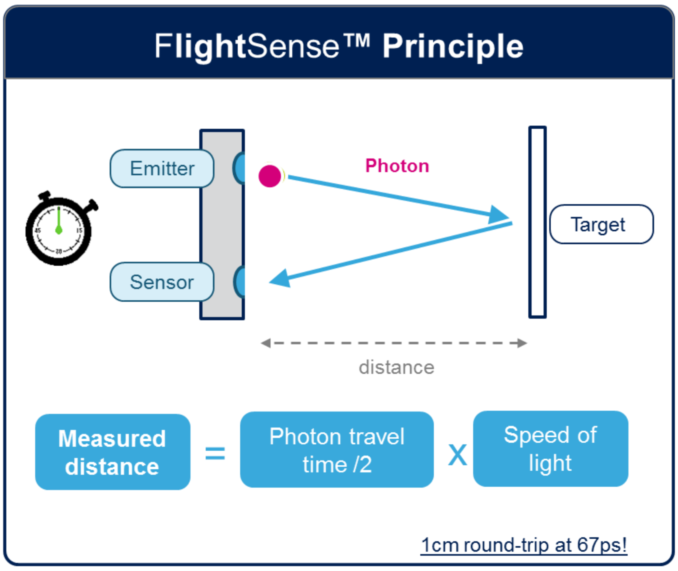
The VL53L1X device is an advanced optical device allowing distances measurements and target detection. The device incorporates the Time-of-Flight principle (ToF) which is a method for measuring the distance between a sensor and an object, based on the time difference between the emission of a VCSEL light signal and its return to the sensor, after being reflected by the object.

The VL53L1X embeds:

- The emitter, a vertical cavity surface emitting laser (VCSEL)
- The receiver, an array of single photon avalanche diodes (SPADs)

The photons emitted by the laser reflect on the target and trigger avalanches when coming back to the SPAD. The time between the emission of the photons and the avalanche (ToF) is measured and translated into a target distance in the range result register.

Figure 3. ToF principle



Although the VCSEL emitted beam is not perfectly symmetrical, it can be considered as a cone. Such a beam has 97 % of the optical power present in a cone of 27 °.

Since no optic is used in the outgoing emission path, it is the native performance of the VCSEL. The glass present on the VCSEL is a simple IR filter to reduce interference on the t0 time measurement.

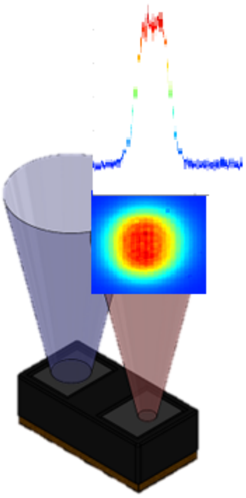


Figure 4. Emitter cone

On the receiver side, there is a SPAD array covered by a convergent lens. Consequently, the system can be seen as a camera subsystem (see figure below) with a big granularity due to the limited number of SPADs.

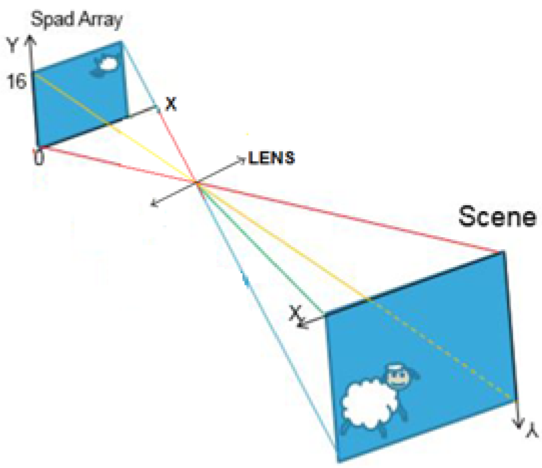


Figure 5. Lens and SPAD subsystem

The full diagonal FoV of the device receiver is 27 ° using the 16x16 SPADs.

The VL53L1X sensor architecture allows ROIs with a reduced set of SPADs to be selected, thereby reducing the sensing area and allowing the receiver FoV to be reduced. The only condition is that the ROI must have an array of at least 4x4 SPADs.

To conclude, the emitter FoV cannot be modified by the VCSEL and the system keeps sending FoVs measuring 27 °. Conversely, the receiver FoV can be reduced and it is possible to measure only a part of the scene of interest.

3 Setting the SPAD array

The SPAD array is composed of 16x16 SPADs. The minimum selectable SPAD number is 4 in each direction which have been checked by firmware (i.e if a customer program selects a 2x8 array, the VL53L1X firmware overwrites the parameters and selects a 4x8 array).

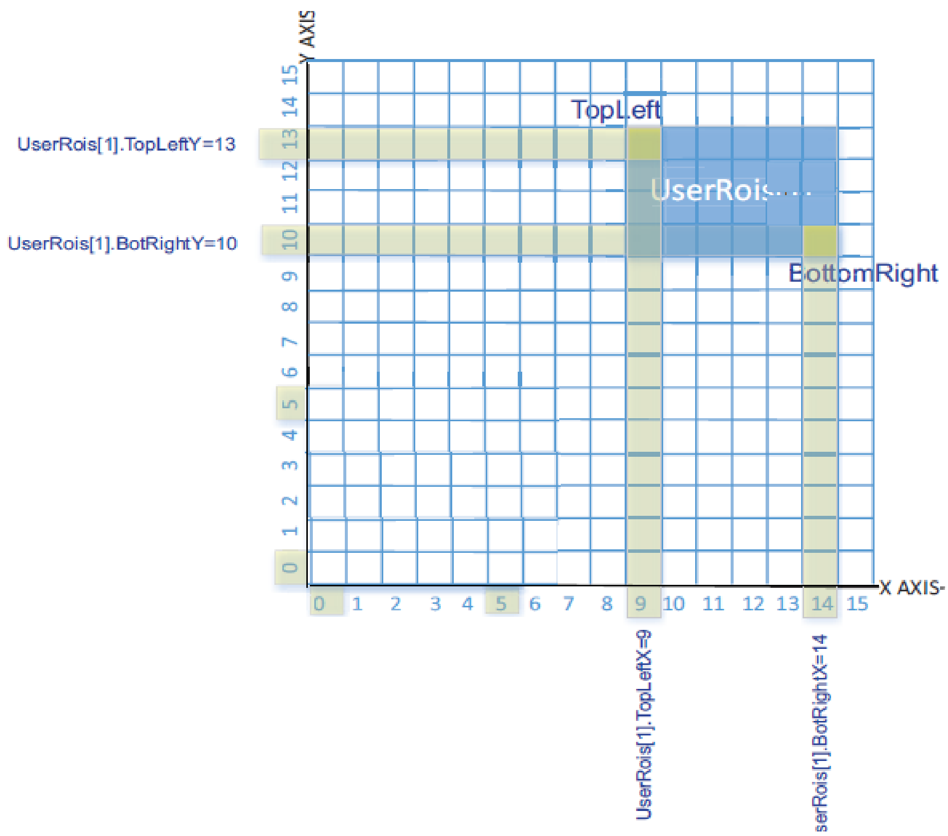
3.1 Addressing the SPAD array

The SPAD is addressed through the SW driver API (please refer to UM2356 for additional information).

To select a FoV and a ROI, the program calls the *VL53L1_SetUserROI()* routine as follows:

```
VL53L1_RoiConfig_t RoiConfig;

RoiConfig.UserRois[0].TopLeftX = 9;

RoiConfig.UserRois[0].TopLeftY = 13;

RoiConfig.UserRois[0].BotRightX = 14;

RoiConfig.UserRois[0].BotRightY = 10;

Status = VL53L1_SetUserROI(Dev, &RoiConfig);
```

Figure 6. **ROI coordinates**



3.2 Calibrating the SPAD array

The offset is ROI dependent. Hence, one offset calibration per region is required if an accuracy of <5 cm is needed.

3.3 Scanning multiple ROIs

The *VL53L1_SetUserROI()* routine must be called prior to the *VL53L1_StartMeasurement()*. It is then possible to change the ROI between two measurements using the stop function *VL53L1_StopMeasurement()*.

4 Performance and recommendations

4.1 FoV performance

The table below gives estimations of some achievable FoV's.

ROI zone size (in SPADs)	Diagonal FOV covered by the zone
4x4	15 ° (smallest)
8x8	20 °
16x16	27 ° (largest, full FoV)

4.2 Measurement performance

When the number of SPADs are reduced, the number of photons received is also reduced. Consequently, the distribution of crosstalk and the return beam are not uniform. Depending on the location of the ROI, measurement performances can differ.

The table below gives the minimum distance and ranging error of an ROI measurement in the center of the SPAD array. For this measurement:

- Ambient = dark i.e. no IR light in the 940±30 nm range
- Target = full ROI with 88 % reflectance i.e. N9.5 Munsell
- Timing budget = 30 ms
- Voltage and temperature = nominal i.e. 2.8 V and 23 °C
- Selected mode = long distance (see UM2356)

Table 1. Measurement performance table

Parameter	16x16 ROI	8x8 centered	4x4 centered
Minimum distance	3.60 m	3.1 m	1.7 m
Ranging error	±20 mm	±20 mm	±20 mm

4.3 Ranging distance performance trade off

If the ROI is reduced, the standard deviation of the mean ranging value is increased and the maximum distance is reduced compared to the full area. To improve this i.e to improve repeatability, the measurement time can be increased.

For example, the ranging time is usually 30 ms. If the measurement time is increased by two, the standard deviation is divided by the root of two.

4.4 Topology recommendation

In some applications, a reduced ROI or a variable FoV is required. For example, in the figure below, because the FoV is emitted at 27 °, part of the light is reflected on the walls which affects the distance measurement accuracy. One part of the full beam still reaches the target and is reflected back to the SPAD area. These are the photons that the ToF sensor should ideally measure.

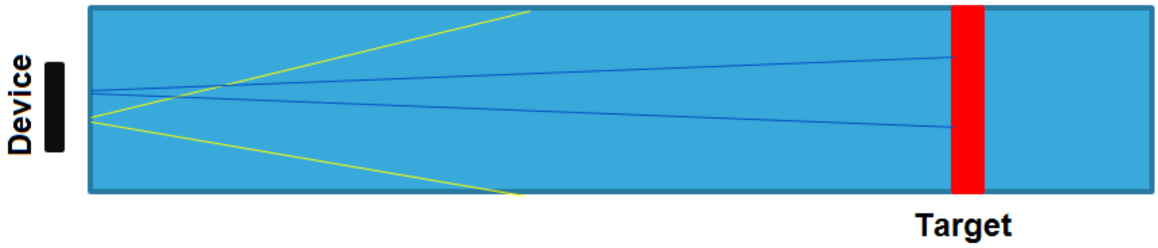
It is then mandatory to limit the reflectivity of the walls and increase the reflectivity of the target.

One solution, if possible, is to place a reflector on the target which will increase the number of photons returned directly by the target to the SPAD.

If this is not possible, a lookup table of the result can be registered to improve the accuracy.

Due to the mounting tolerance (device on PCB and PCB to equipment), a scan of the full ROI is useful to define what is the best location of the ROI to optimize the number of photons coming back from the target.

Figure 7. Target inside a tube example



Revision history

Table 2. **Document revision history**

Date	Version	Changes
30-Jul-2018	1	Initial release

Contents

1 **Document scope** **2**

2 **Time-of-Flight sensing and ROI principles** **3**

3 **Setting the SPAD array** **5**

3.1 Addressing the SPAD array 5

3.2 Calibrating the SPAD array 5

3.3 Scanning multiple ROIs 6

4 **Performance and recommendations** **7**

4.1 FoV performance 7

4.2 Measurement performance 7

4.3 Ranging distance performance trade off 7

4.4 Topology recommendation 7

Revision history **9**