Application note

Guidelines for tuning ranging profiles with VL53L9CX

Introduction

This document describes how to configure the VL53L9CX. This application note explains the dependencies between frame rate, exposure, power consumption, and performance.

1 Exposure

1.1 Ranging modes

Exposure is defined as the sum of all integrations required to capture one frame. The different steps allow the device to refine the distance estimation. The VL53L9CX can operate in two ranging modes: precision or ambient. Precision mode is composed of steps, while ambient mode is composed of six steps.

The table below shows the difference between the two ranging modes.

Table 1. VL53L9CX ranging modes

	Precision	Ambient
Integration steps	7	6
Min distance	50 mm	450 mm
Maximum distance	8.8 m	8.5 m
Accuracy	High	Moderate
Ranging under ambient	Moderate	High
Xtalk	Very low (1)	Immunity (2)
SNR	Moderate	High

1. *Crosstalk impact depends on the quality of the cover glass. The default settings in precision mode is not impacted by the crosstalk if the cover glass transmission and crosstalk ratios are aligned with ST guidelines (Guidelines for the cover glass of the VL53L9CX Time-of-Flight 2K zones (AN6346) for more details).*
2. *Crosstalk impact depends on the quality of the cover glass. The default setting in ambient mode is Xtalk free. However, the minimal distance for accurate return is only 450 mm; below this distance the detection is still possible but is not accurate.*

1.2 Step duration guidelines

The exposure can be adapted (so steps duration) to the near infrared ambient condition. To maintain the ranging capability in presence of 940 nm (+/-10 nm) ambient light, increase the exposure duration. Increasing the exposure duration improves the SNR and the maximum ranging distance.

1.2.1 Exposure limits

In low ambient conditions (an indoor environment for example), exposing for too long is not necessary. Overexposing may result in underestimating the target reflectance. ST recommends also keeping the exposure above 2 ms. The table below summarizes ST recommendation for the two profiles with different ambient conditions.

Table 2. Frame exposure recommendations

Ambient conditions	Precision mode			Ambient mode		
	Min	Typ	Max	Min	Typ	Max
< 1 W/m²	2 ms	4 ms	10 ms	2 ms	4 ms	8 ms
> 1 W/m²	6 ms	8 ms	16 ms	4 ms	6 ms	16 ms
> 5 W/m²	12 ms	16 ms	20 ms	10 ms	16 ms	20 ms

1.2.2 Exposure ratios

Exposure configuration is possible when the device is streaming or in standby. The configuration is possible using the NB_SHOT_STEP_n firmware registers. For a given exposure, there are seven configuration steps to set. ST recommends maintaining the ratio as defined in the following table. A good ratio between steps helps to maintain the best ranging performance.

Table 3. **Step exposure ratios**

	Precision mode	Ambient mode
NB_SHOT_STEP_1	117 * x	231 * x
NB_SHOT_STEP_2	234 * x	461 * x
NB_SHOT_STEP_3	469 * x	709 * x
NB_SHOT_STEP_4	721 * x	1419 * x
NB_SHOT_STEP_5	1443 * x	0
NB_SHOT_STEP_6	1443 * x	1418 * x
NB_SHOT_STEP_7	117 * x	231 * x

Note: x is the total exposure duration in milliseconds.

1.2.3 Metadata information

Step exposures are streamed out by VL53L9CX in the frame metadata. This information is used by the postprocessing functions to normalize the signal and estimate the pixel reflectance. Firmware provides the NB_SHOT_STEP_5 (in precision mode or NB_SHOT_STEP_4 in ambient mode), NB_SHOT_STEP_6 and NB_SHOT_STEP_7 settings.

2 Frame rate and frame period

Frame period is defined as the duration of the frame acquisition, including the interframe blanking period. The frame rate is defined as:

$$\text{Frame}_{RATE} = \frac{1}{\text{Frame}_{PERIOD}}$$

The frame period is defined as the sum of the start of frame configuration, frame integration, end of frame activity and inter frame blanking duration. A way to maximize the frame rate is to minimize the interframe blanking period.

Figure 1. Frame period decomposition

Table 4. Frame period duration in MIPI

Power mode	SOF (ms)	Integration	EOF (ms)
Regular	1	2 + Exposure (1 + 1.115 x Dithering (1))	1
Low power	3.4		1
Ultralow power	3.8		2.5

1. *Dithering: Dynamic blanking period has little impact in integration duration as shown in the table above. Dithering helps to reduce interference and wraparound. It is recommended to keep it.*

2.1 I3C/I2C readout

If the application is using the communication interface to readout the frames, the EOF is gated by the readout. Contrary to MIPI streaming, the application must explicitly acknowledge that the frame has been read to the firmware. End-of-frame period stops when the CMD_ACK_FRAME_READ is received.

Note: Do not send the acknowledge command before starting to read the data to speed up the process. The data could be overwritten before the driver has had time to read it.

The table below gives approximate read duration depending on the output interface used.

Table 5. Readout duration depending on the readout interface

Resolution	MIPI (1 Gbps)	I3C (10 Mbps)	I^2C (1 Mbps)
54x42	200 µs	11.8 ms	118 ms
24x20	< 50 µs	3 ms	30 ms
18x14	< 50 µs	1.3 ms	13 ms
12x10	< 10 µs	0.6 ms	6.2 ms
8x6	< 10 µs	0.3 ms	3.3 ms
4x4	< 10 µs	0.1 ms	0.8 ms

In autonomous mode the user can configure the Frame_{PERIOD} through the firmware UI. The firmware periodically triggers the new frame. A new frame can only start if the previous frame's acquisition is terminated. If the new frame is triggered and the device is not interframe blanking, the trigger event is ignored.

2.2 Frame rate limit

Given the relationship between frame duration, exposure and power mode, and the constraint on the new frame trigger, there is a physical limit on the frame rate. For example, streaming above 100 FPS in full resolution requires the exposure to be limited to 4.5 ms, using a MIPI interface and streaming in regular power mode.

3 Power consumption

Power consumption varies with many parameters.

3.1 IR ambient

Light around 940 nm is not filtered by the IR filter and contributes to the noise and power consumption.

3.2 Frame exposure

During frame exposure, the VCSEL driver and VCSELs are emitting light. The power consumption on Tx is proportional to exposure duration.

3.3 Frame rate

The frame rate is indirectly linked to the power consumption; the shorter the interframe duration, the higher the power consumption.

3.4 Power mode

Power mode can reduce the average power consumption during interframe blanking. ST recommends using low power and ultralow power modes with low frame rate or when the interframe blanking is long enough. For example, ST recommends using ultralow power mode when the I3C interface is used to readout the data. This configuration allows a longer readout duration, which reduces the power consumption.

4 Conclusion

Tuning profiles provide an effective way to optimize system efficiency for one of the following needs: higher frame rate, better overall performance, or reduced power consumption.

ST delivers a profile tuning tool to tune the profile for its application. Contact ST local support for access to the tuning tool. The tool can check the power consumption and performance for a given configuration.

Revision history

Table 6. **Document revision history**

Date	Version	Changes
09-Jul-2026	1	Initial release

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