VL53L1X

Datasheet

A new generation, long distance ranging Time-of-Flight sensor based on ST's FlightSense technology

Product status link
VL53L1X

Features

Fully integrated miniature module

- 940 nm invisible laser emitter (Class 1)
- SPAD (single photon avalanche diode) receiving array with integrated lens
- Low power microcontroller running advanced digital firmware
- 4.9 x 2.5 x 1.56 mm

Fast, accurate distance ranging

- Fast and accurate long distance ranging
  - Up to 400 cm distance measurement
  - Up to 50 Hz ranging frequency
- Pin-to-pin compatible with the VL53L0X FlightSense ranging sensor
- 27° typical full field of view (FoV)
- Programmable region of interest (ROI) size on the receiving array allows reduction of the sensor FoV
- A programmable ROI position on the receiving array, provides multizone operation control from the host

Eye safety

- Class 1 laser device compliant with latest standard IEC 60825-1:2014 - 3rd edition

Easy integration

- Software driver and code example for turnkey ranging
- Single reflowable component
- Single power supply 2v8
- Can be hidden behind many cover glass materials
- I²C interface (up to 400 kHz)
- Shutdown and interrupt pins

Application

- User detection (autonomous low-power mode) to power on/off and lock/unlock devices like personal computers/laptops and the Internet of Things (IoT)
- Service robots and vacuum cleaners (long distance and fast obstacle detection)
- Drones (landing assistance, hovering, ceiling detection)
- Smart shelves and vending machines (goods inventory monitoring)
- Sanitary (robust user detection whatever the target reflectance)
- Smart building and smart lighting (people detection, gesture control)
- 1 D gesture recognition
- Laser assisted autofocus (AF) enhances the camera AF system's speed and robustness, especially in difficult scenes such as low light and low contrast, and provides video focus tracking assistance

Description

The VL53L1X is a state-of-the-art, Time-of-Flight (ToF) laser-ranging sensor, enhancing the ST FlightSense product family. It is the fastest miniature ToF sensor on the market with accurate ranging up to 4 m and fast ranging frequency up to 50 Hz.

Housed in a miniature and reflowable package, it integrates a SPAD receiving array, a 940 nm invisible Class 1 laser emitter, physical infrared filters, and optics to achieve the best ranging performance in various ambient lighting conditions with a range of cover glass options.

Unlike conventional IR sensors, the VL53L1X uses ST’s latest generation ToF technology, which allows absolute distance measurement whatever the target color and reflectance.

It is also possible to program the size of the ROI on the receiving array, allowing the sensor FoV to be reduced.

1 Acronyms and abbreviations

Table 1. Acronyms and abbreviations

Acronym/abbreviation	Definition
AMR	absolute maximum rating
API	application programming interface
ESD	electrostatic discharge
FoV	field of view
HW STANDBY	hardware standby
I^2C	inter-integrated circuit (serial bus)
MSB	most significant bit
PCB	printed circuit board
ROI	region of interest
SCL	serial clock line
SDA	serial data line
SW STANDBY	software standby
SPAD	single photon avalanche diode
TB	timing budget
ToF	Time-of-Flight
VCSEL	vertical-cavity surface-emitting laser

2 Product overview

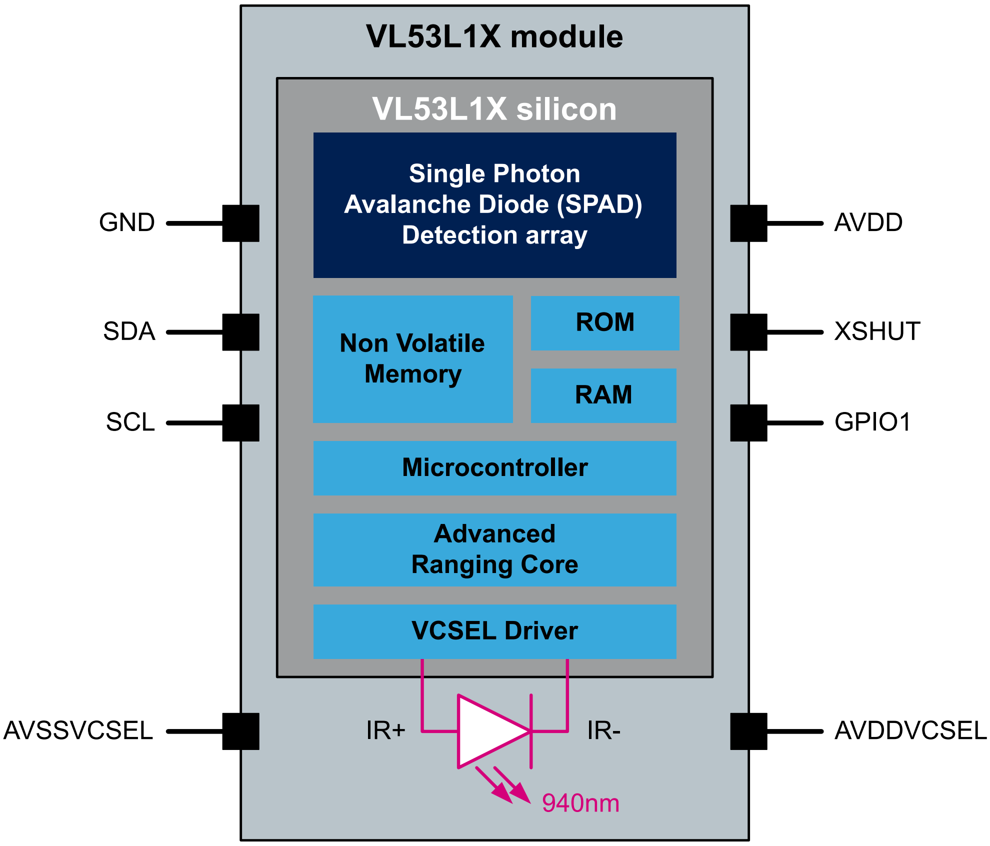
2.1 Technical specification

Table 2. **Technical specification**

Feature	Detail
Package	Optical LGA12
Size	4.4 x 2.5 x 1.56 mm
Operating voltage	2.6 to 3.5 V
Operating temperature	-20 to 85°C
Receiver FoV (diagonal FoV)	Programmable from 15 to 27 degrees
Infrared emitter	940 nm
I²C	Up to 400 kHz (fast mode) serial bus Programmable address default is 0x52

2.2 System block diagram

Figure 1. **VL53L1X block diagram**



2.3 Device pinout

The following figure shows the pinout of the VL53L1X (see also Section 8: Outline drawings).

Figure 2. VL53L1X pinout (bottom view)

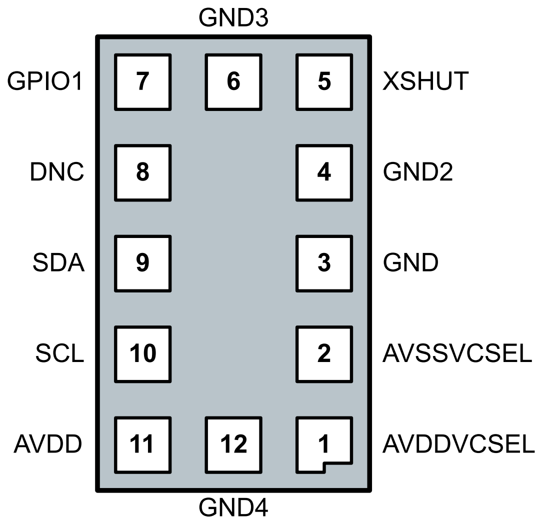


Table 3. VL53L1X pin description

Pin number	Signal name	Signal type	Signal description
1	AVDDVCSEL	Supply	VCSEL supply, connect to main supply
2	AVSSVCSEL	Ground	VCSEL ground, connect to main ground
3	GND		Connect to the main ground
4	GND2		
5	XSHUT	Digital input	Xshutdown pin, active low
6	GND3	Ground	Connect to the main ground
7	GPIO1	Digital output	Interrupt output. Open drain output
8	DNC	Digital input	Do not connect, must be left floating
9	SDA	Digital input/output	I²C serial data
10	SCL	Digital input	I²C serial clock input
11	AVDD	Supply	Supply, connect to the main supply
12	GND4	Ground	Connect to the main ground

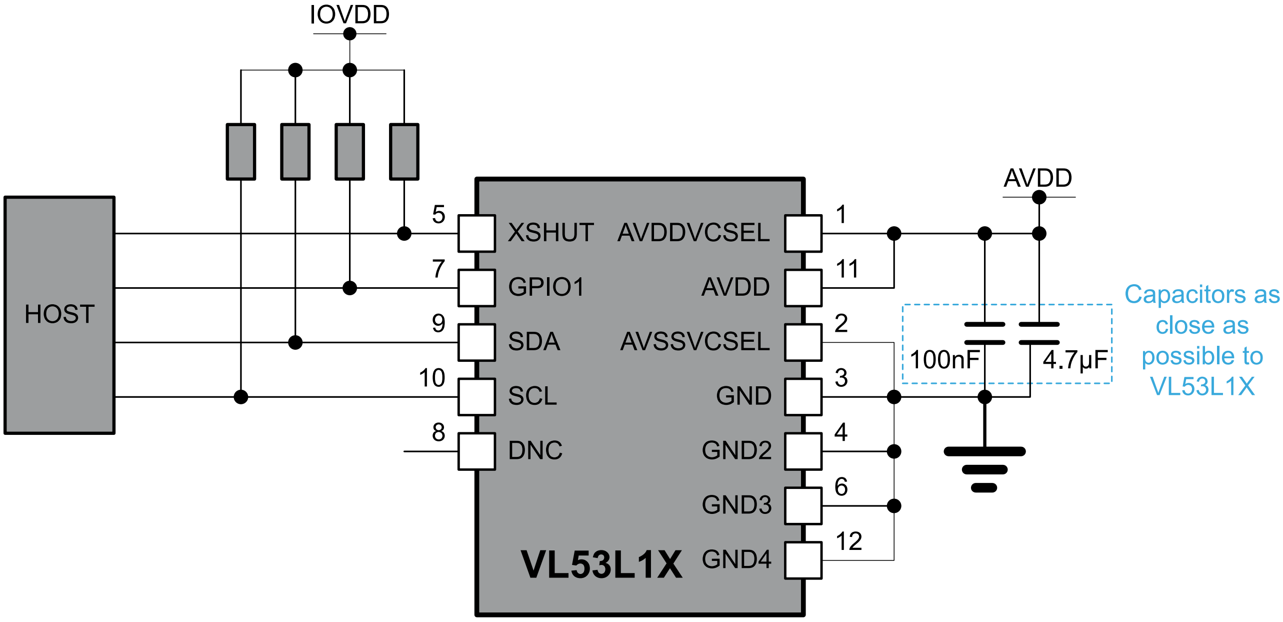
Note: AVSSVCSEL and GND are ground pins and can be connected together in the application schematics.

Note: GND2, GND3, and GND4 are standard pins that we force to the ground domain in the application schematics to avoid possible instabilities if set to other states.

2.4 Application schematic

The following figure shows the application schematic of the VL53L1X.

Figure 3. VL53L1X schematic



Note: Place the capacitors on the external supply AVDD as close as possible to the AVDDVCSEL and AVSSVCSEL module pins.

Note: The external pull-up resistor values can be found in the I²C-bus specification. Pull-ups are typically fitted only once per bus, near the host. See Table 4. Suggested pull-up and series resistors for I²C fast mode for suggested values.

Note: The XSHUT pin must always be driven to avoid leakage current. A pull-up is needed if the host state is not known. XSHUT is needed to use hardware standby mode (there is no I²C communication).

Note: The recommended value of the XSHUT and GPIO1 pull-ups is 10 kOhms.

Note: Leave the GPIO1 unconnected if not used.

Table 4 shows the recommended values for pull-up resistors for an AVDD of 1.8 V to 2.8 V in I²C fast mode (up to 400 kHz).

Table 4. Suggested pull-up and series resistors for I²C fast mode

I²C load capacitance (C_L) (1)	Pull-up resistor (Ohms)
$C_L \leq 90$ pF	3.6 k
90 pF < $C_L \leq 140$ pF	2.4 k
140 pF < $C_L \leq 270$ pF	1.2 k
270 pF < $C_L \leq 400$ pF	0.8 k

1. *For each bus line, C_L is measured in the application PCB by the customer.*

3 Functional description

3.1 System functional description

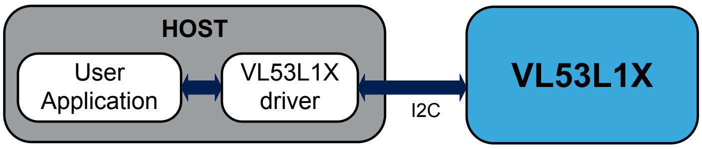
Figure 4. VL53L1X system functional description shows the system level functional description. The host customer application controls the VL53L1X device using an API (application programming interface). The API implementation is delivered to the customer as a driver (Bare C code).

The driver shares with the customer application a set of high level functions that allow control of the VL53L1X firmware. Functions include initialization, ranging start/stop, and setting the system accuracy.

The driver enables fast development of end user applications without the complication of direct multiple register access. The driver is structured in a way that it can be compiled on any kind of platform through a good hardware abstraction layer.

A detailed description of the driver is available in the VL53L1X API user manual(UM2356).

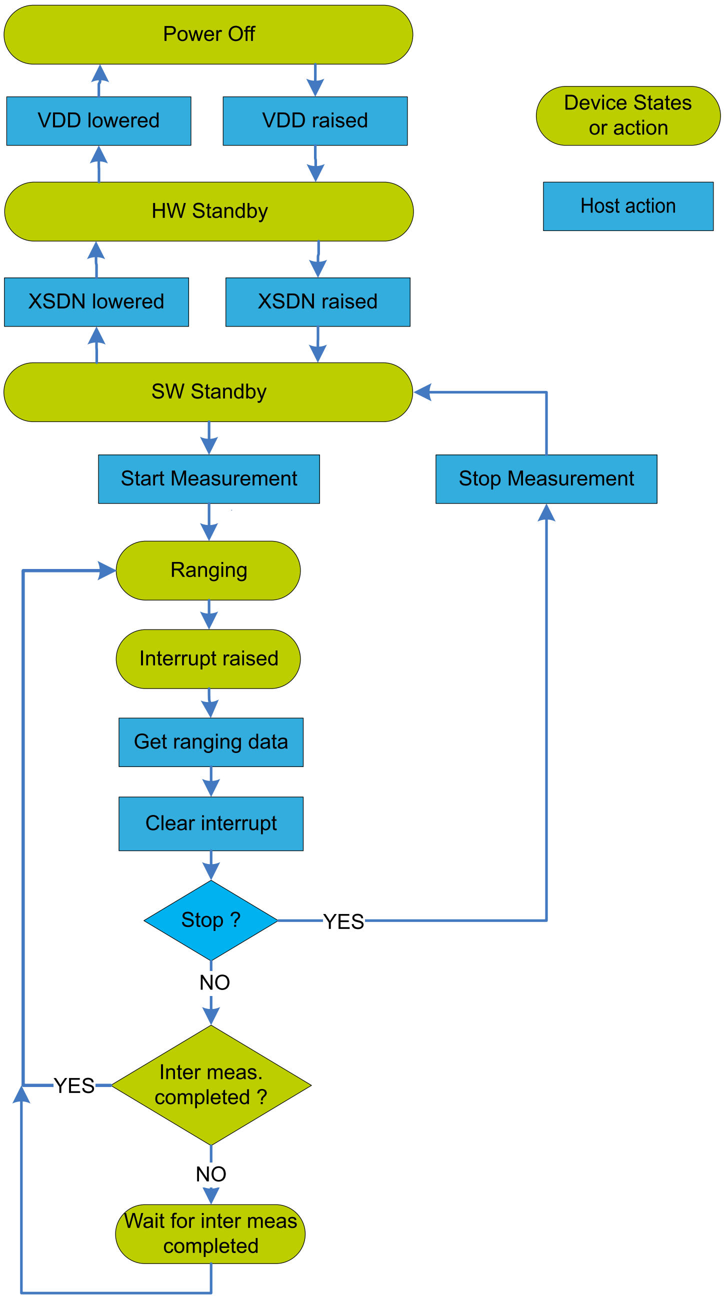
Figure 4. VL53L1X system functional description



3.2 System state machine description

The following figure shows the system state machine.

Figure 5. System state machine



3.3 Customer manufacturing calibration flow

The VL53L1X driver includes calibration functions. To benefit from device full performances, it is recommended they be run once at the customer production line.

Device calibration allows for the compensation of part-to-part parameter variations and the presence of a cover glass that may affect device performance.

Calibration data stored in the host have to be loaded into the VL53L1X at each startup using a dedicated driver function.

Three calibration steps are needed: RefSPAD, offset, and crosstalk.

RefSPAD and crosstalk calibrations have to be performed whenever the customer adds a protective cover glass on top of the VL53L1X module.

Offset calibration has to be performed in all situations. It allows reflow and cover glass effects to be compensated.

The detailed procedure is provided in the VL53L1X API user manual (UM2356).

3.4 Ranging description

The VL53L1X software driver proposes a turnkey solution to allow fast implementation and easy ranging in all customer applications.

Autonomous ranging mode is the default configuration that offers optimized functionalities of the VL53L1X.

- Ranging is continuous, with a programmable delay between two ranging operations (called an intermeasurement period). The ranging duration (timing budget) is also programmable.
- The user can set distance thresholds (below, above, inside, or outside the user-defined thresholds). An interrupt is raised only when threshold conditions are met.
- ROI size and position are programmable. The user chooses a custom FoV from 4x4 SPADs (minimum size) up to 16x16 SPADs (full FoV).
- A clear interrupt is mandatory to allow the next ranging data to be updated.

If the ranging distance cannot be measured (when there is no target or a weak signal), a corresponding range status is generated. The host can read the range status.

The VL53L1X software driver provides turnkey functions to read output results after the measurement. The main values reported are:

- Ranging distance in mm
- Return signal rate
- Ambient signal rate
- Range status

Range status and output measurement definitions are provided in the VL53L1X API user manual (UM2356).

3.5 Key parameters

3.5.1 Distance mode

The VL53L1X has three distance modes (DM): short, medium, and long.

Long distance mode allows the longest possible ranging distance of 4 m to be reached. However, this maximum ranging distance is impacted by ambient light.

Short distance mode is more immune to ambient light, but its maximum ranging distance is typically limited to 1.3 m.

Table 5. Maximum distance vs. distance mode under ambient light

Distance mode	Max. distance in the dark (cm)	Max. distance under strong ambient light (cm)
Short	136	135
Medium	290	76
Long	360	73

Test conditions

Timing budget (TB) = 100 ms, white target 88%, dark = no IR ambient, and ambient light = 200 kcps/SPAD

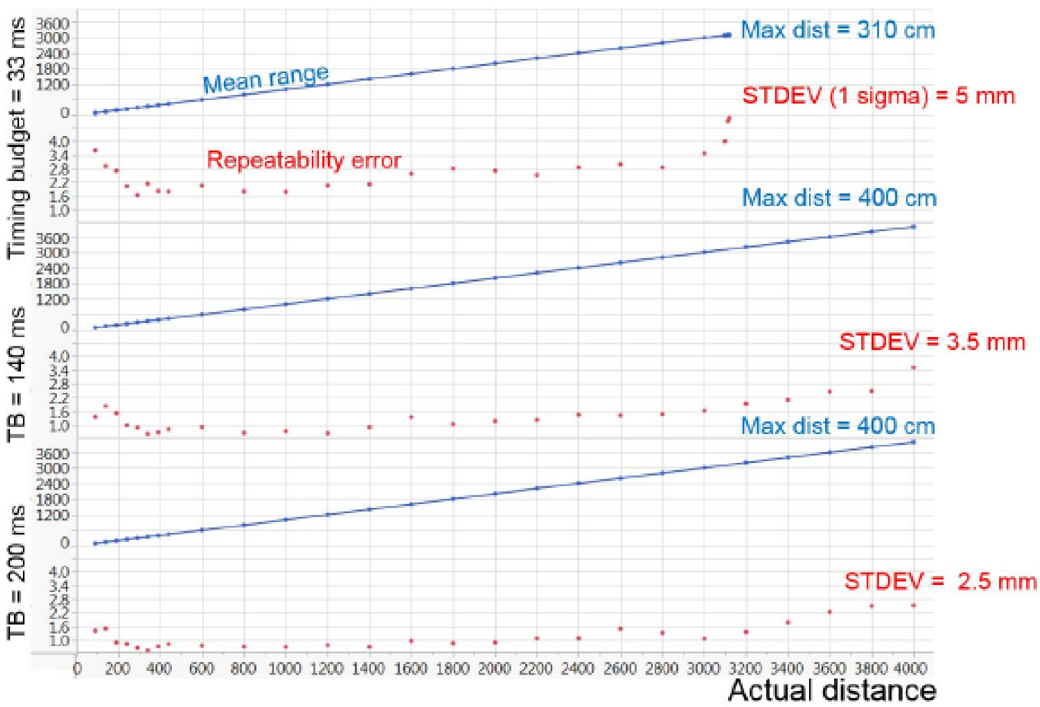
3.5.2 Timing budget

The VL53L1X timing budget can be set from 20 ms up to 1000 ms.

- 20 ms is the minimum timing budget and can be used only in short distance mode.
- 33 ms is the minimum timing budget which can work for all distance modes.
- 140 ms is the timing budget which allows the maximum distance of 4 m (in the dark on a white chart) to be reached with long distance mode

Increasing the timing budget increases the maximum distance the device can range and improves the repeatability error. However, average power consumption augments accordingly.

Figure 6. Maximum distance and repeatability error vs. timing budget



Test conditions

Timing budget = 33 ms, 40 ms, 200 ms, grey target 54%, ambient light = dark

3.6 Power up and boot sequence

Two options are available for device power-up/boot.

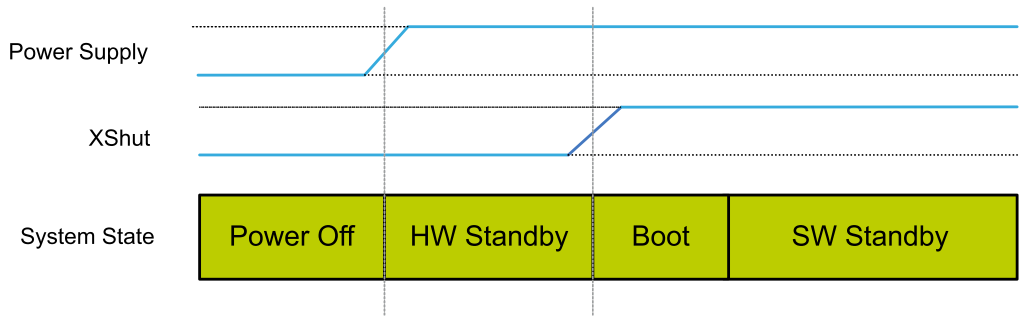
Option 1

The XSHUT pin is connected and controlled from the host.

This option optimizes power consumption. The device can be completely powered off when not used, and then woken up through the host GPIO (using the XSHUT pin).

Hardware standby mode is the period when the power supply is present and the XSHUT is low.

Figure 7. Power-up and boot sequence



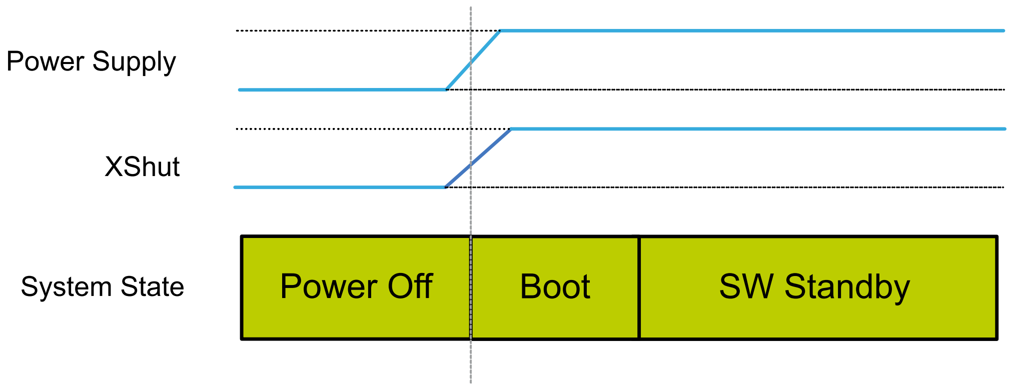
Note: The boot duration is 1.2 ms maximum.

Option 2

The host does not control the XSHUT pin. This pin is tied to the power supply value through a pull-up resistor.

When the XSHUT pin is not controlled, the power-up sequence is as shown in the following figure. In this case, the device goes automatically to software standby after boot, without entering hardware standby.

Figure 8. Power-up and boot sequence with XSHUT not controlled



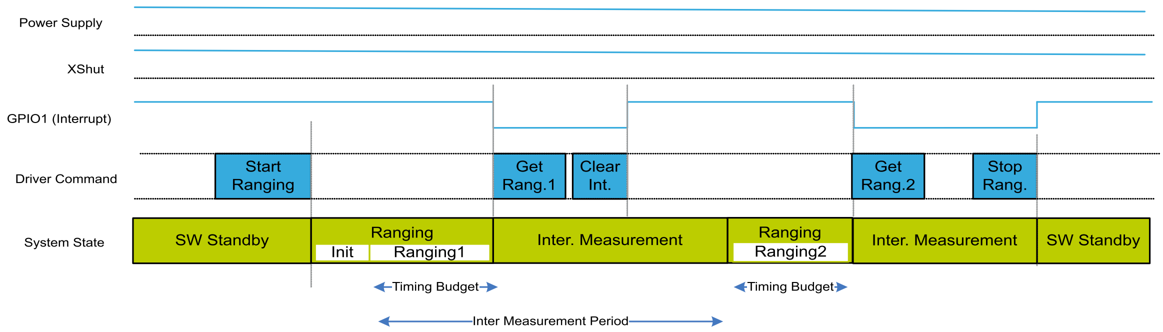
Note: The boot duration is 1.2 ms maximum.

Note: In all cases, XSHUT has to be raised only when the power supply is tied on.

3.7 Ranging sequences

The following figure shows the combination of the driver commands and the system states.

Figure 9. Autonomous sequence



Note: The user sets the timing budget and inter measurement timing parameters using a dedicated driver function.

3.8 Sensing array optical center

The VL53L1X module includes a lens that focuses the photons on the 16x16 SPAD-sensing array.

The sensing array optical center specification considers the part-to-part variation in production.

The optical center is defined by the coordinates Xo and Yo.

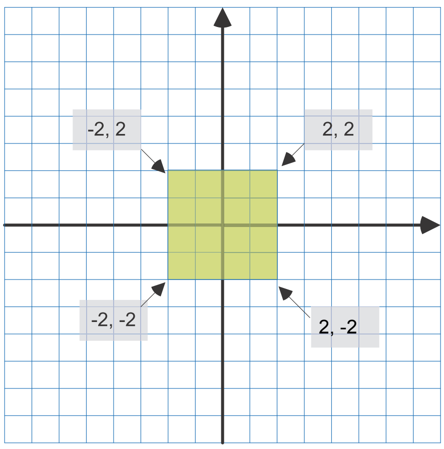
The optical center is measured for each part during a factory test at STMicroelectronics. The coordinates are stored in the VL53L1X nonvolatile memory and are readable by the customer through the software driver in the application. This helps optimize design alignment with the image sensor in the application and its ranging performance.

The green array in Figure 10. Optical center specification gives the possible location of the optical center. For more details, refer to the VL53L1X API user manual (UM2356).

Table 6. Optical center specification

Parameter	Min.	Typ.	Max.	Unit
Xo offset	-2	0	2	SPAD
Yo offset	-2	0	2	

Figure 10. Optical center specification



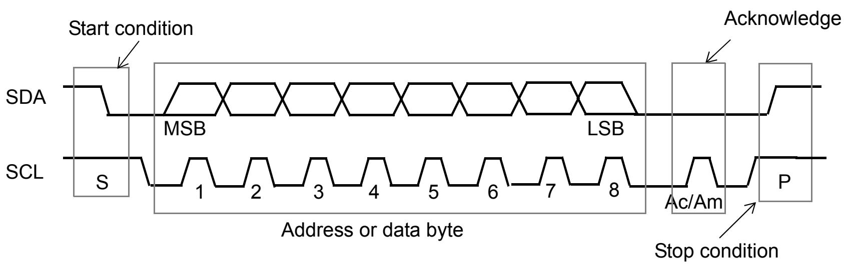
4 Control interface

This section specifies the control interface. The I²C interface uses two signals: serial data line (SDA) and serial clock line (SCL). Each device connected to the bus uses a unique address and a simple controller/target relationship exists.

Both SDA and SCL lines are connected to a positive supply voltage using pull-up resistors located on the host. Lines are only actively driven low. A high condition occurs when lines are floating and the pull-up resistors pull lines up. When no data are transmitted both lines are high.

Clock signal generation is performed by the controller device. The controller device initiates data transfer. The I²C bus on the VL53L1X has a maximum speed of 400 kbits/s and uses a default device address of 0x52.

Figure 11. Data transfer protocol



Information is packed in 8-bit packets (bytes) and is always followed by an acknowledge bit, Ac for the VL53L1X acknowledge and Am for the controller acknowledge (host bus controller). The internal data are produced by sampling SDA at a rising edge of SCL. The external data must be stable during the high period of SCL. The exceptions to this are start (S) or stop (P) conditions when SDA falls or rises respectively, while SCL is high.

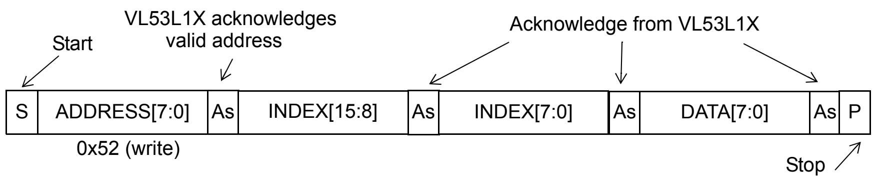
A message contains a series of bytes preceded by a start condition, and followed by either a stop or repeated start (another start condition but without a preceding stop condition), followed by another message. The first byte contains the device address (0x52) and also specifies the data direction. If the least significant bit is low (that is, 0x52) the message is a controller write-to-the-target. If the LSB is set (that is, 0x53) then the message is a controller read-from-the-target.

Figure 12. I²C device address: 0x52

MSBit							LSBit
0	1	0	1	0	0	1	R/W

All serial interface communications with the ToF sensor must begin with a start condition. The VL53L1X module acknowledges the receipt of a valid address by driving the SDA wire low. The state of the read/write bit (LSB of the address byte) is stored and the next byte of data, sampled from SDA, can be interpreted. During a write sequence, the second byte received provides a 16-bit index, which points to one of the internal 8-bit registers.

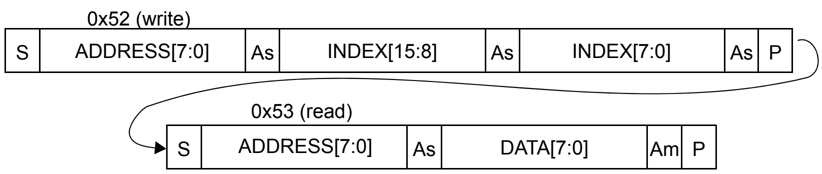
Figure 13. **Data format (write)**



As data are received by the target, they are written bit by bit to a serial/parallel register. After each data byte has been received by the target, an acknowledge is generated, the data are then stored in the internal register addressed by the current index.

During a read message, the contents of the register addressed by the current index is read out in the byte following the device address byte. The contents of this register are parallel loaded into the serial/parallel register and clocked out of the device by the falling edge of SCL.

Figure 14. **Data format (read)**



At the end of each byte, in both read and write message sequences, an acknowledge is issued by the receiving device (that is, the VL53L1X for a write, and the host for a read).

A message can only be terminated by the bus controller, either by issuing a stop condition or by a negative acknowledge (that is, not pulling the SDA line low) after reading a complete byte during a read operation.

The interface also supports auto increment indexing. After the first data byte has been transferred, the index is automatically incremented by 1. The controller can therefore send data bytes continuously to the target until the target fails to provide an acknowledge, or the controller terminates the write communication with a stop condition. If the auto increment feature is used, the controller does not have to send address indexes to accompany the data bytes.

Figure 15. **Data format (sequential write)**

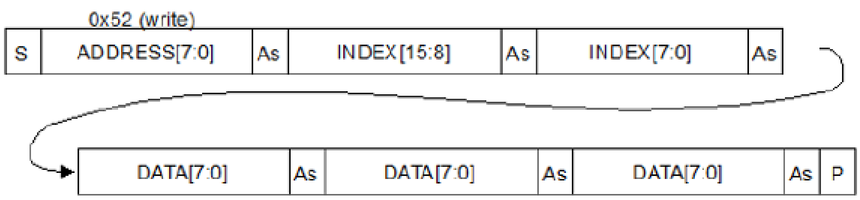
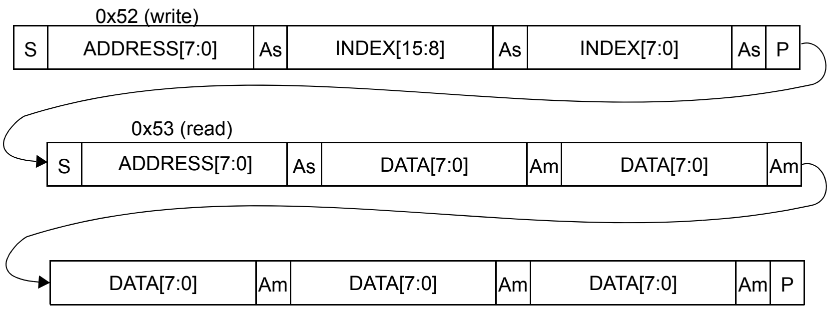


Figure 16. **Data format (sequential read)**



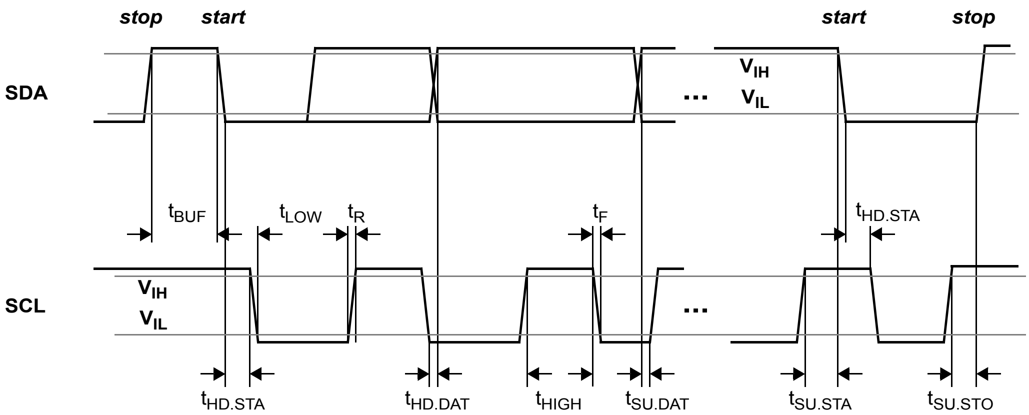
4.1 I²C interface - timing characteristics

Timing characteristics are shown in the Table 7. I²C interface - timing characteristics for fast mode (400 kHz). Refer to Figure 17. I²C timing characteristics for an explanation of the parameters used.

Table 7. **I²C interface - timing characteristics for fast mode (400 kHz)**

Symbol	Parameter	Minimum	Typical	Maximum	Unit
F_{I2C}	Operating frequency	0	—	400	kHz
t_{LOW}	Clock pulse width low	1.3	—	—	µs
t_{HIGH}	Clock pulse width high	0.6	—	—	
t_{SP}	Pulse width of spikes that are suppressed by the input filter	—	—	50	ns
t_{BUF}	Bus free time between transmissions	1.3	—	—	µs
$t_{HD.STA}$	Start hold time	0.26	—	—	µs
$t_{SU.STA}$	Start setup time	0.26	—	—	
$t_{HD.DAT}$	Data in hold time	0	—	0.9	
$t_{SU.DAT}$	Data in setup time	50	—	—	ns
t_R	SCL/SDA rise time	—	—	300	
t_F	SCL/SDA fall time	—	—	300	
$t_{SU.STO}$	Stop setup time	0.6	—	—	µs
Ci/o	Input/output capacitance (SDA)	—	—	10	pF
Cin	Input capacitance (SCL)	—	—	4	
C_L	Load capacitance	—	125	400	

Figure 17. I²C timing characteristics



All timings are measured from either V_{IL} or V_{IH}.

4.2 I²C interface - reference registers

The registers shown in the table below can be used to validate the user I²C interface.

Table 8. Reference registers

Register name	Index	After fresh reset, without the driver loaded
Model ID	0x010F	0xEA
Module type	0x0110	0xCC
Mask revision	0x0111	0x10

Note: The I²C read/writes can be 8, 16, or 32-bit. Multibyte read/writes are always addressed in ascending order with the MSB first as shown in Table 9. 32-bit register example.

The customer must use the VL53L1X software driver for easy and efficient ranging operations to match performance and accuracy criteria. Hence full register details are not exposed. The customer should refer to the VL53L1X API user manual (UM2356).

Table 9. 32-bit register example

Register address	Byte
Address	MSB
Address + 1	...
Address + 2	...
Address + 3	LSB

5 Thermal characteristics

5.1 Absolute maximum rating (TSTG)

Warning: *Stresses above those listed in the following table may cause permanent damage to the device. These are stress ratings only. Functional operation of the device is not implied at these or any other conditions above those indicated in the operational sections of the specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.*

The storage temperature (T_{STG}) is the ambient temperature at which the device can be stored with no voltage applied.

Table 10. Absolute maximum rating conditions

Parameter	Min.	Max.	Unit
Storage temperature (T_{STG})	-40	105	°C

5.2 Ambient operating temperature

The ambient operating temperature is the temperature at which the device may be powered and can operate without any damage.

Table 11. Recommended operating temperature

Parameter	Min.	Max.	Unit
Ambient operating temperature	-20	85	°C

6 Electrical characteristics

6.1 Absolute maximum ratings

Warning: *Stresses above those listed in the following table may cause permanent damage to the device. These are stress ratings only. Functional operation of the device is not implied at these or any other conditions above those indicated in the operational sections of the specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.*

Table 12. Absolute maximum ratings

Parameter	Min.	Typ.	Max.	Unit
AVDD	-0.5	—	3.6	V
SCL, SDA, XSHUT, and GPIO1				

6.2 Recommended operating conditions

Table 13. Recommended operating conditions

There are no power supply sequencing requirements. The I/Os may be high, low, or floating when AVDD is applied. The I/Os are internally failsafe with no diode connecting them to AVDD.

Parameter		Min.	Typ.	Max.	Unit
Voltage (AVDD)		2.6	2.8	3.5	V
IO (IOVDD) (1)	Standard mode	1.6	1.8	1.9	
	2V8 mode (2) (3)	2.6	2.8	3.5	

1. *XSHUT should be high only when AVDD is on.*
2. *SDA, SCL, XSHUT, and GPIO1 high levels have to be equal to AVDD in 2V8 mode.*
3. *The default driver mode is 1V8. 2V8 mode is programmable using the device settings loaded by the driver. For more details, refer to the VL53L1X API user manual (UM2356).*

6.3 Electrostatic discharge

The VL53L1X is compliant with the ESD values presented in the following table.

Table 14. ESD performances

Parameter	Specification	Conditions
Human body model	JS-001-2012	± 2 kV, 1500 ohms, 100 pF
Charged device model	JESD22-C101	± 500 V

6.4 Current consumption

Table 15. Power consumption at ambient temperature

All current consumption values include silicon process variations. Temperature and voltage are nominal conditions (23°C and 2.8 V). All values include AVDD and AVDDVCSEL.

Parameter	Min.	Typ.	Max.	Unit
HW STANDBY	3	5	7	μA
SW STANDBY (2V8 mode) (1)	4	6	9	μA
Inter measurement	—	20	—	μA
Ranging average (AVDD + AVDDVCSEL) (2) (3)	—	16	18	mA
Average power consumption at 10 Hz with 33 ms timing budget	—	—	20	mW
Average power consumption at 1 Hz with 20 ms timing budget when no target is detected	—	0.9	—	mW
Average power consumption at 1 Hz with 20 ms timing budget when the target is detected	—	1.4	—	mW

1. *In 2V8 (IOVDD) mode, pull-ups have to be modified. Then the SW STANDBY consumption is increased by 0.6 μA.*
2. *Average consumption during the ranging operation in long distance mode.*
3. *Peak current (including VCSEL) can reach 40 mA.*

6.5 Digital input and output

Table 16. Digital I/O electrical characteristics

Symbol	Parameter	Min.	Typ.	Max.	Unit
Interrupt pin (GPIO1)					
V_{IL}	Low level input voltage	—	—	0.3 IOVDD	V
V_{IH}	High level input voltage	0.7 IOVDD	—	—	V
V_{OL}	Low level output voltage (I_{OUT} = 4 mA)	—	—	0.4	V
V_{OH}	High level output voltage (I_{OUT} = 4 mA)	IOVDD-0.4	—	—	V
F_{GPIO}	Operating frequency (C_{LOAD} = 20 pF)	0	—	108	MHz
I²C interface (SDA/SCL)					
V_{IL}	Low level input voltage	-0.5	—	0.6	V
V_{IH}	High level input voltage	1.12	—	3.5	V
V_{OL}	Low level output voltage (I_{OUT} = 4 mA)	—	—	0.4	V
$I_{IL/IH}$	Leakage current (1)	—	—	10	μA
$I_{IL/IH}$	Leakage current (2)	—	—	0.15	μA

1. *AVDD = 0 V*
2. *AVDD = 2.85 V, and I/O voltage = 1.8 V*

7 Ranging performance

7.1 Test conditions

In all the measurement tables of this document, it is considered that:

1. The full FoV is covered (typically at 27°). Alternatively, a partial FoV is covered after a specific ROI definition by the user. The array size of the partial FoV is from 4x4 SPADs to 16x16 SPADs.
2. The charts used as targets are:
   – Gray with a reflectance of 17% and a Munsell of N4.74.
   – Gray with a reflectance of 54% and a Munsell of N8.25.
   – White with a reflectance of 88% and a Munsell of N9.5.
3. The nominal voltage is 2.8 V and the temperature is 23°C.
4. The detection rate is considered as 100%.
5. Unless mentioned, the device is controlled through the driver using the following default settings:
   – Distance mode is long.
   – Timing budget is 100 ms.
   – No cover glass is present.
   – Target covers the full FoV.
6. Ambient light is defined as follows:
   – Dark = no IR light in the band 940 nm ±30 nm.
   – 50 kcps/SPAD = lighting on a sunny day from behind a window.
   – 200 kcps/SPAD = lighting on a sunny day from behind a window, with direct illumination on the sensorNo cover glass is present.
   – For reference, usual office lighting is around 5 kcps/SPAD.

Note: kcps is kilo counts per second. kcps/SPAD is the return ambient rate measured by the VL53L1X.

7.2 Accuracy, repeatability, and ranging error definitions

7.2.1 Accuracy definition

Accuracy = mean distance–actual distance

- The mean distance is the average of 32 measured distances.
- The actual distance is the actual target distance.

An offset error, a temperature drift, or a voltage drift may affect the accuracy.

7.2.2 Repeatability definition

Repeatability is the standard deviation of the mean ranging value of 32 measurements. It can be improved by increasing the timing budget. A typical repeatability value for the VL53L1X ranges from ±1% to ±0.15% depending on the timing budget and the ambient light.

7.2.3 Ranging error definition

Ranging error = accuracy + repeatability error.

The ranging error value is an ST metric that is used in the performances tables below.

7.3 Minimum ranging distance

The minimum ranging distance ensured is 4 cm. Under this minimum distance, the sensor detects a target, but the measurement is not accurate.

7.4 Performance in dark conditions

Table 17. Performance in dark conditions

Parameter	Target reflectance	Min. value	Typ. value
Max. distance (cm)	White 88%	260	360 (1)
	Gray 54%	220	340
	Gray 17%	80	170
Ranging error (mm)	—	± 20	

1. *The typical value is 400 with a timing budget of 140 ms.*

Test conditions (including those described in Section 7.1: Test conditions) are:

- Ambient light = dark
- Timing budget = 100 ms unless state otherwise
- Long distance mode

7.5 Performance in ambient light conditions

7.5.1 Long distance mode

Table 18. Typical performance in ambient light with long distance mode

Parameter	Target reflectance	Dark	50 kcps/SPAD	200 kcps/SPAD
Max. distance (cm)	White 88%	360	166	73
	Gray 54%	340	154	69
	Gray 17%	170	114	68
Ranging error (mm)	—	± 20	± 25	± 25

Test conditions (including those described in Section 7.1: Test conditions) are:
- Ambient light = dark, 50 kcps/SPAD, or 200 kcps/SPAD.
- Distance mode = long

7.5.2 Short distance mode

Table 19. Typical performance in ambient light with short distance mode

Parameter	Target reflectance	Dark	200 kcps/SPAD
Max. distance (cm)	White 88%	130	130
	Gray 54%	130	130
	Gray 17%	130	120
Ranging error (mm)	—	± 20	± 25

Test conditions (including those described in Section 7.1: Test conditions) are:
- Ambient light = dark, 200 kcps/SPAD.
- Distance mode = short

7.6 Performance under partial ROI in dark conditions

Table 20. Typical performance under partial ROI in dark conditions

Parameter	Target reflectance	16x16	8x8	4x4
Max. distance (cm)	White 88%	360	308	170
	Gray 54%	340	254	143
	Gray 17%	170	119	45
Diagnol FoV (degrees)	—	27	20	15
Ranging error (mm)	—	± 20	± 20	± 20

Test conditions (including those described in Section 7.1: Test conditions) are:
- Ambient light = dark
- Target covers a partial FoV
- ROI is centered on the optical center
- Distance mode = long

8 Outline drawings

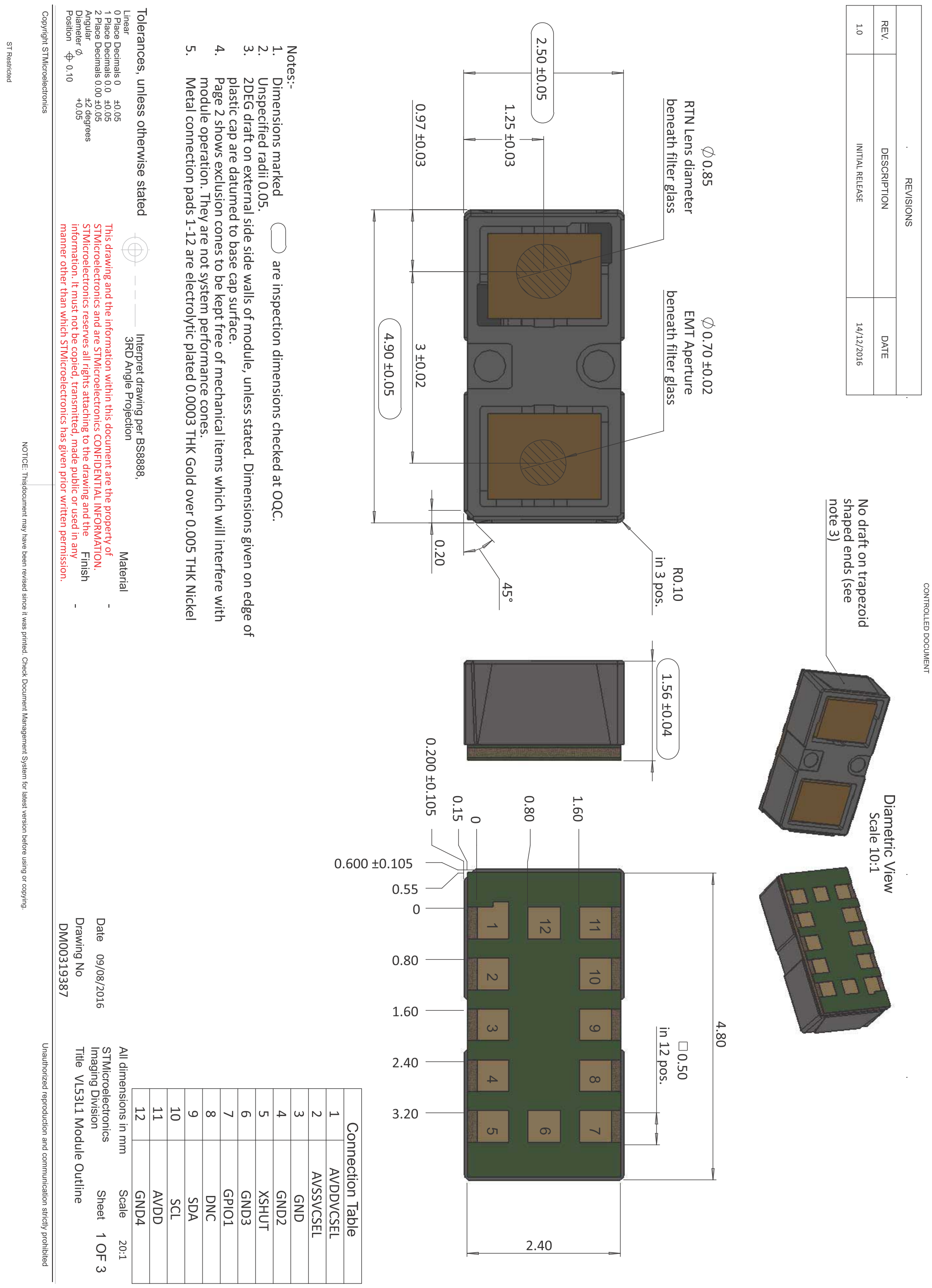


Figure 18. Outline drawing (1/3)

Figure 19. Outline drawing (2/3)

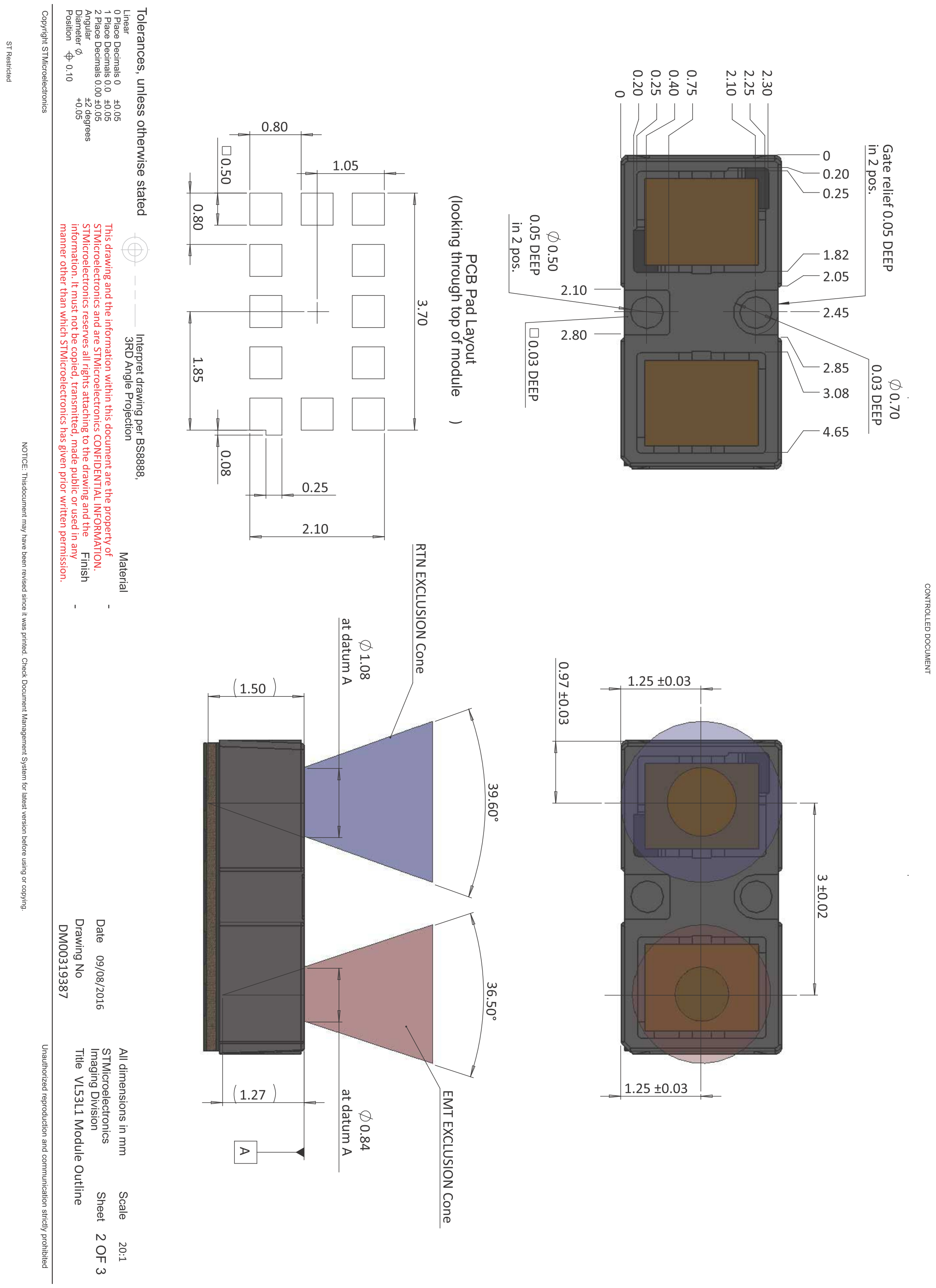
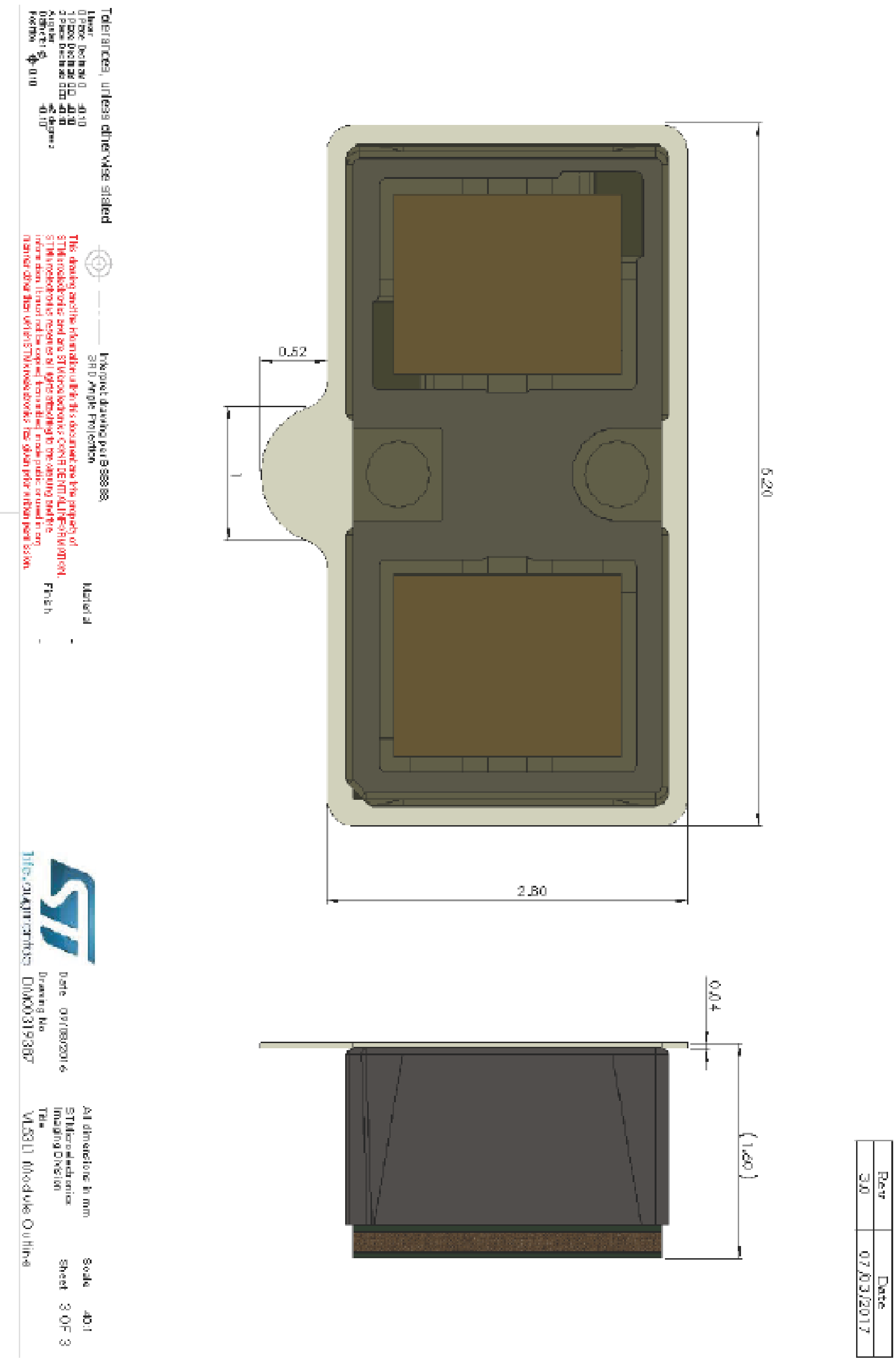


Figure 20. Outline drawing (3/3)



Caution: The VL53L1X module is delivered with a protective liner covering the top of the cap to protect the sensor from foreign material during the assembly process. It must be removed by the customer just before mounting the cover glass.

9 Laser safety

This product contains a laser emitter and corresponding drive circuitry. The laser output is designed to meet Class 1 laser safety limits under all reasonably foreseeable conditions including single faults in compliance with IEC 60825-1:2014.

Do not increase the laser output power by any means. Do not use any optics to focus the laser beam.

Caution: Use of controls or adjustments, or performance of procedures other than those specified herein may result in hazardous radiation exposure.

Figure 21. Class 1 laser label

This product complies with:

- IEC 60825-1:2014
- 21 CFR 1040.10 and 1040.11, except for conformance with IEC 60825-1:2014 as described in the laser notice number 56, dated May 8, 2019.
- EN 60825-1:2014 including EN 60825-1:2014/A11:2021
- EN 50689:2021, however STMicroelectronics does not guarantee compliance with the requirement of clause 5 from EN50689 regarding child appealing products. If designing a child appealing product, contact STMicroelectronics' technical application support.

10 Packing and labeling

10.1 Product marking

A two line product marking is applied on the backside of the module (on the substrate). The first line is the silicon product code, and the second line, the internal tracking code.

10.2 Inner box labeling

The labeling follows the STMicroelectronics' standard packing acceptance specification.

The following information is on the inner box label:

- Assembly site
- Sales type
- Quantity
- Trace code
- Marking
- Bulk ID number

10.3 Packing

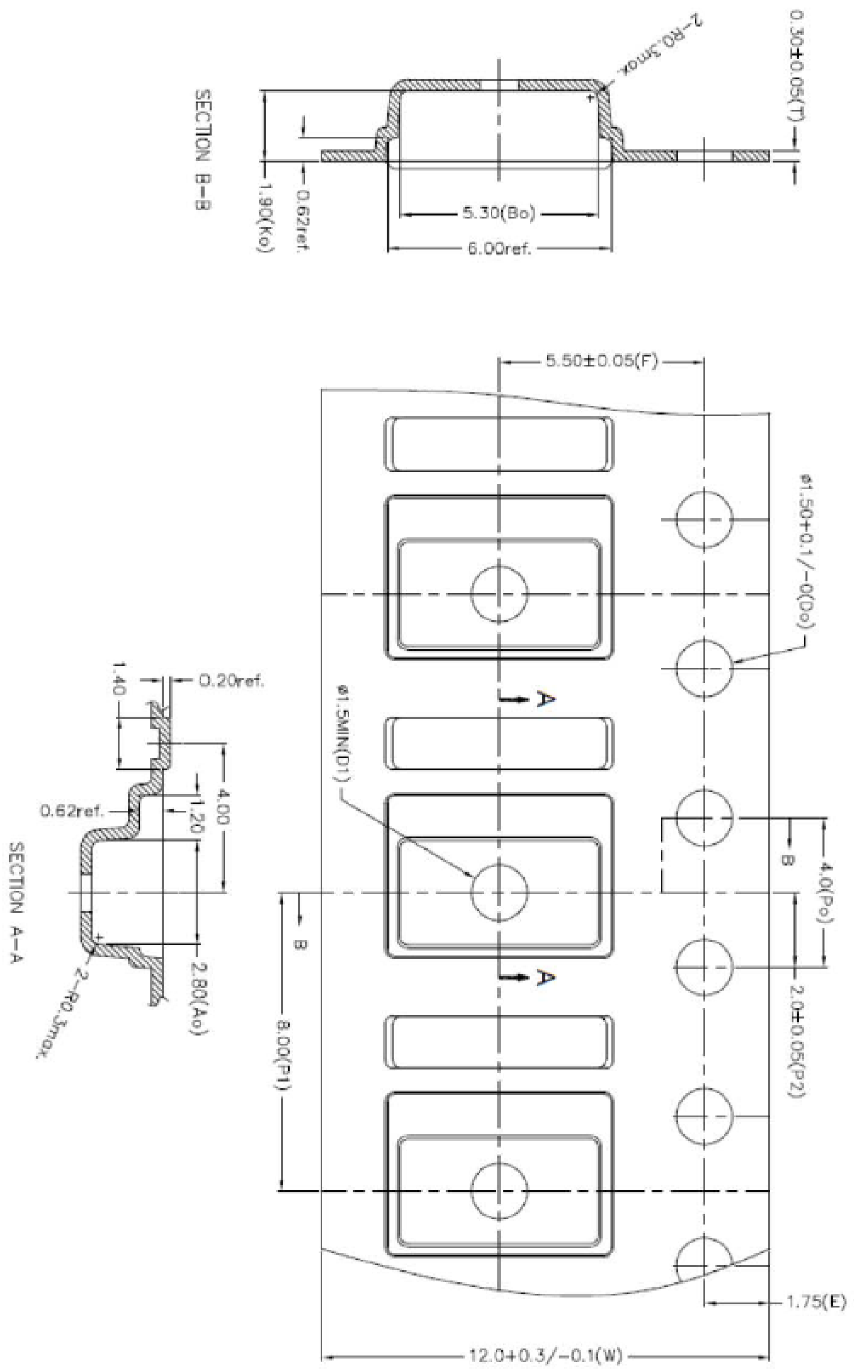
At the customer/subcontractor level, it is recommended to mount the device in a clean environment to avoid foreign material deposition.

To help avoid any foreign material contamination at product assembly level the modules are shipped in a tape and reel format with a protective liner, starting from production version (cut1.1).

The packing is vacuum-sealed and includes a desiccant.

10.4 Tape outline drawing

Figure 22. Tape outline drawing



11 Handling, moisture, and reflow precautions

11.1 Shock precaution

Sensor modules house numerous internal components that are susceptible to shock damage. If a unit is subject to excessive shock, it must be rejected even if no apparent damage is visible. For example, if it is dropped on the floor, or if a tray/reel of units is dropped on the floor.

11.2 Part handling

Handling must be done with nonmarring, ESD, safe carbon, plastic, or Teflon™ tweezers. Ranging modules are susceptible to damage or contamination. The customer is advised to use a clean assembly process after removing the tape from the parts, and until a protective cover glass is mounted.

11.3 Compression force

A maximum compressive load of 25 N should be applied on the module.

11.4 Moisture sensitivity level

Moisture sensitivity is level 3 (MSL) as described in JEDEC JSTD-020-C.

For devices that are classified to the levels defined in JEDEC JSTD-020-C, JEDEC JSTD-033-C provides:

- Manufacturers and users with standardized methods for handling, packing, and shipping.
- Standardized methods for using moisture/reflow and process sensitive devices.

11.5 Pb-free solder reflow process

Table 21. Recommended solder profile and Figure 23. Solder profile show the recommended and maximum values for the solder profile.

Customers have to tune the reflow profile depending on the PCB, solder paste, and material used. We expect customers to follow the recommended reflow profile, which is specifically tuned for the VL53L1X package.

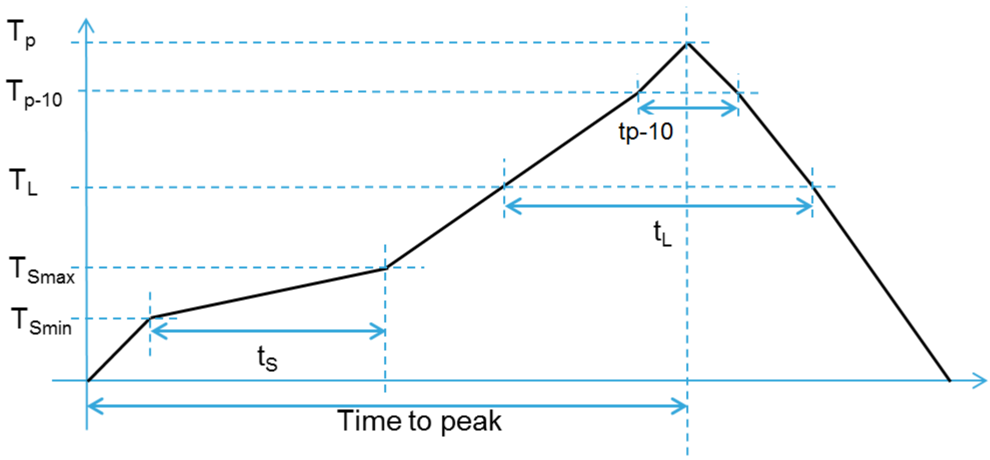
If a customer must perform a reflow profile, which is different from the recommended one, the new profile must be qualified by the customer at their own risk. This is especially true for peaks >240°C. In any case, the profile must be within the “maximum” profile limit described in JEDEC JSTD-020-C and in Table 21. Recommended solder profile.

Note: Temperatures mentioned in the table below are measured at the top of the VL53L1X package.

Table 21. Recommended solder profile

Parameters	Recommended	Maximum	Unit
Minimum temperature (T_S min)	130	150	°C
Maximum temperature (T_S max)	200	200	
Time t_s (T_S min to T_S max)	90-110	60-120	s
Temperature (T_L)	217	217	°C
Time (t_L)	55-65	55-65	s
Ramp up	2	3	°C/s
Temperature (T_{p-10})	—	250	°C
Time (t_p)		10	s
Ramp up		3	°C/s
Peak temperature (Tp)	240	245	°C
Time to peak	300	300	s
Ramp down (peak to T_L)	-4	-6	°C/s

Figure 23. Solder profile



Note: The component should be limited to a maximum of three passes through this solder profile.

Note: As the VL53L1X package is not sealed, only a dry reflow process should be used (such as convection reflow). Vapor phase reflow is not suitable for this type of optical component.

Note: The VL53L1X is an optical component and should be treated carefully. This would typically include using a ‘no-wash’ assembly process.

12 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK packages, depending on their level of environmental compliance. ECOPACK specifications, grade definitions and product status are available at: www.st.com. ECOPACK is an ST trademark.

13 Ordering information

Table 22. **Order codes**

Order codes	Package	Packing	Minimum order quantity
VL53L1CXV0FY/1	Optical LGA12 with liner	Tape and reel	3600 pcs

Revision history

Table 23. Document revision history

Date	Version	Changes
24-Jun-2022	6	Removed "™" from the document title. Updated Figure 15. Data format (sequential write)
29-Nov-2022	7	Updated Figure 18. Outline drawing (1/3), Figure 19. Outline drawing (2/3), and Figure 20. Outline drawing (3/3). Updated Figure 22. Tape outline drawing.
09-Aug-2024	8	Features section: Added "eye safety". Updated master/slave to controller/target. Added Section 5: Thermal characteristics, including a maximum AMR of 105°C. Table 13. Recommended operating conditions: Removed ambient temperature data. Section 6.5: Digital input and output: Updated maximum value of V_{IH} to 3.5 V. Updated Section 9: Laser safety. Updated Section 10: Packing and labeling. Added Section 11: Handling, moisture, and reflow precautions.

Contents