LiDAR in a Chip
FlightSense™
Introduction to Time of Flight

Imaging Division
Photonic Sensors Business Line
FlightSense™ Breakthrough Technology

Measurement at the speed of light!

**FlightSense™ Principle**

- **Emitter**
- **Photon**
- **Sensor**
- **Target**

**Measured distance** = \( \frac{\text{Photon travel time}}{2} \times \text{Speed of light} \)

1 cm round-trip at 67 ps!

**Key benefits:**

- **Direct distance measurement**
  Independent of target size, color & reflectance

- **Fully Integrated Time of Flight Module**
  ST #1 World Wide Supplier

- **Very fast (few ms)**

- **Low power**

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FlightSense™
Optical Time-of-Flight Product Family

ST is Worldwide #1 ToF supplier

Proven track record in manufacturing
>350Mu products shipped
300% AAGR

Single Photon Avalanche Diode
Ultra fast time resolution enabling Direct ToF processed in ST CMOS SPAD process

ST Proprietary Time-of-Flight IP
Best compromise of cost, complexity & power vs performance

Compact integrated system
Sensor, filters, optics, VCSEL and driver integrated
Fully calibrated system

Optimized and reliable supply chain
High volume & low cost

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Introducing FlightSense™ Technology

- Ranging Sensor
- Laser IR Light Source
- Ambient Light Sensor (VL6180X)

**Accurate**

**Flexible integration**

**Invisible Industrial Design**
- Easy to integrate
- Can be hidden behind cover glass

**All in one solution**

**Added value**

**Patented Technology**
- based on Time-of-Flight
<table>
<thead>
<tr>
<th>Feature</th>
<th>Capacitive</th>
<th>Ultra-Sonic</th>
<th>Conventional IR</th>
<th>ST FlightSense™</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size/Weight</td>
<td>Small/light</td>
<td>2xToF/Heavy</td>
<td>Small/Light</td>
<td>Small/Light</td>
</tr>
<tr>
<td>Mechanical integration</td>
<td>Complex (antenna)</td>
<td>Complex (large module)</td>
<td>Easy (if all-in-one)</td>
<td>Easy (all in one, reflowable)</td>
</tr>
<tr>
<td>Signal Amplitude</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Real distance output</td>
<td>No</td>
<td>No (computed)</td>
<td>No (computed)</td>
<td>Real distance in mm (readable thru i²C)</td>
</tr>
<tr>
<td>Minimum distance</td>
<td>0cm</td>
<td>10cm</td>
<td>0cm</td>
<td>0cm</td>
</tr>
<tr>
<td>Maximum distance</td>
<td>Few cms</td>
<td>Up to 1.5m</td>
<td>20cm</td>
<td>up to 4 meters (1)</td>
</tr>
<tr>
<td>Reliable (Vs objects color and reflectance)</td>
<td>No. May detect target in all directions around antenna</td>
<td>No, impacted</td>
<td>No, impacted</td>
<td>Yes even black (3%), gloves, …</td>
</tr>
<tr>
<td>Reliable (Vs material finish/roughness)</td>
<td>No. Sensitive to body or object charge</td>
<td>No. Isotropic, impacted by wide sound</td>
<td>No. Angular dependency</td>
<td>Yes, with angular dependency</td>
</tr>
<tr>
<td>Gesture control Tap vs Swipe</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
FlightSense™ Supports Gesture Recognition

Basic Movement Detection

• 4 Gestures from a single ToF sensor
• Directional swipe detection when using 2x ToF sensors

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Tap</td>
<td>Press a virtual ‘button’ on top of the sensor, once</td>
</tr>
<tr>
<td>Double Tap</td>
<td>Press a virtual ‘button’ on top of the sensor, twice</td>
</tr>
<tr>
<td>Single Swipe</td>
<td>Slide hand left to right or from right to left over the sensor</td>
</tr>
<tr>
<td>Double Swipe</td>
<td>Slide hand from left to right and back to left or from right to left and back to right over the sensor</td>
</tr>
</tbody>
</table>

• Discriminate right to left, from left to right gesture when using 2x sensors
FlightSense™ Product Longevity

7-year commitment

FlightSense™ benefits from ST Longevity Program:

- 7-year longevity from Product Introduction Date
- In place for VL6180X since January 2015, and for VL53L0X since Sept. 2016
FlightSense™ Product Descriptions
ST’s FlightSense™ Mass-Market Products

- **1st generation ST ToF sensor**
  - Main features: Proximity sensor & ALS
  - Major use cases:
    - Proximity distance measurement
    - Proximity detection
    - Lighting control
    - Basic gesture

- **2nd generation ST ToF sensor**
  - Main feature: Ranging sensor
  - Major use cases:
    - Up to 2 meters distance measurement
    - User / object detection
    - Robotics
    - Basic gesture

- **3rd generation ST ToF sensor**
  - Main feature: Long distance ranging sensor, high speed
  - Major use cases:
    - Up to 4 meters distance measurement
    - Programmable FoV
    - User / object detection
    - Robotics

**New Products**

- **VL6180X**
  - Proximity, gesture & ALS sensor
  - In Mass-production

- **VL53L0X**
  - Ranging and gesture sensor
  - In Mass-production

- **VL53L1X**
  - Long distance ranging sensor
  - In Mass-production
New generation ToF sensor with lens, for long-distance ranging and ROI selection

**Product highlights**

- **OLGA**: 4.9 x 2.5 x 1.56 mm
- **FoV**: 27°
- Compatible footprint with VL53L0X

**Enhanced performance:**

- Full FoV ranging: **400cm+** (white target, no IR)
- SPAD array zone selection (2x2; 4x4; full screen), for FoV reduction

**Cutting-edge module and silicon:**

- Fastest miniature ToF product in the market (up to 16ms ranging with full ranging spec)
- Integrated lens for longer range and better immunity to ambient light
- Programmable settings to best fit customer’s application:
  - Low power with interrupts for user / object detection
  - Long distance ranging
  - High accuracy for small movement detection

**Applications**

**Presence user detection**

- Autonomous mode with interrupts
- Low-power
- Long distance 400cm+
- PC, tablets, IoT, portable handsets, security...

**Obstacle detection:**

- Robots: Obstacle avoidance
- Vacuum cleaners: Wall following, cliff detection
- Drones: Take-off and landing, Ceiling detection

**Accurate objects distance scanning**

- Vending machines: control of objects in racks
- Coins dispensers: coins counting
- Smart shelves: Consumer scanning

**OLGA:** 4.9 x 2.5 x 1.56 mm

FoV: 27°

Compatible footprint with VL53L0X
VL53L1X System FoV (Field of View)
Compatible footprint with VL53L0X: Easy migration

- OLGA12 Package
- LxW = 4.9 x 2.5 mm
- Height: 1.56mm +/- 40um (max 1.6mm)
- Reflowable (IPC/JEDEC JSTD-020-C)

A 30° lens is added on return aperture (SPAD array) to increase the signal strength back from the target (8x more signal than VL53L0X). It increases ranging performance and accuracy.

- The VCSEL is not equipped with an emitter lens
- Emitted optical power is identical to VL53L0X
- Retain full laser class1 registration

Typical System Field of View: 27°

Exclusion cones for mechanical integration
VL53L1X Detection Cone

- VL53L0X: d=200cm, Ø = 29 cm
- VL53L1X: d=400cm, Ø = 192 cm
- VL6180: d=60cm, Ø = 96 cm
VL53L1X Allows Custom FoV Selection

Region of Interest (ROI) selection by the user

- VL53L1X as no fixed pre-defined size for the sensing array, unlike other sensors on the market, or VL53L0X
- VL53L1X sensing array is composed by 16x16 SPADs (Single Photon Avalanche Diodes) that can be selected by customer
- The sensing array is called “ROI” (Region or Interest)
- VL53L1X returns the distance to object covered by the ROI FoV
- User defines the 2 corners of the array, through SW driver (API) or through the Eval Kit GUI. It could even be rectangular. Only condition is to have a minimum of 4x4 SPADs array
- The change of ROI can be done “on the fly” by the host

Changing the ROI by software allows to virtually reduce the FoV

<table>
<thead>
<tr>
<th>ROI zone size</th>
<th>Diagonal FOV covered by the zone *</th>
</tr>
</thead>
<tbody>
<tr>
<td>4x4 spads</td>
<td>6.9° (smallest)</td>
</tr>
<tr>
<td>5x5 spads</td>
<td>8.6°</td>
</tr>
<tr>
<td>6x6 spads</td>
<td>10.3°</td>
</tr>
<tr>
<td>7x7 spads</td>
<td>12.0°</td>
</tr>
<tr>
<td>8x8 spads</td>
<td>13.7°</td>
</tr>
<tr>
<td>16x16 spads</td>
<td>27.0 (largest, full FoV)</td>
</tr>
</tbody>
</table>

* (Exact FOV per ROI size being characterized)
Adapt VL53L1X Performance to Your Application

<table>
<thead>
<tr>
<th>Target performance to best fit application</th>
<th>Autonomous low power (ALP)</th>
<th>Fast Ranging</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description</strong></td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>• Low power mode</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>• VL53L1X works as master (autonomous state machine)</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>• Sends Interrupt to host if target detected</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td><strong>Application type</strong></td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>• User / object detection</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>• Laptop and tablets, Smartphones</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>• Sanitary (smart faucets…)</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>• IoT devices</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>• Security</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td><strong>Max Ranging</strong></td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>(Typical, in the Dark, full FoV)</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>White 88% or Grey54% : 2.8m (76ms; 13Hz)</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>Grey 54%: 2.65m (30ms)</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td><strong>Accuracy</strong></td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>White: 1.5% Grey: 2.5% (offset +/-25mm)</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td><strong>Ranging under ambient light</strong></td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
</tbody>
</table>
Autonomous Low-Power User Detection

Save battery when no user detected, and easily wake-up your device for <1mW

- For user detection application, most of the time there is nobody in front of the device
- The device must be in sleep mode, waiting to be awakened by the ToF sensor
- The ToF sensor must consume as little as possible, just to detect if someone is approaching the device. When user is in front, it must wake-up the host
- VL53L1X includes an Autonomous low-power mode, specially defined for this application

Embedded low-power MCU
- Programmable thresholds and repetition rate
- Autonomous state machine in VL53L1X
- Once target detected, an interrupt is sent on GPIO1 pin to wake-up the host (no need of i2C)

Example of Energy Saving:
- VL53L1X in low-power autonomous mode : 0.9mW (1Hz, 20ms ranging operation)
- Tablet (iPAD3): Active: 40W, Sleep Mode: 0.4W
- Laptop (iMAC 27”inch): Active: 80W, Display off: 20W, Sleep mode: 1W
Example of Low-Power User Detection

“Waking-up the PC” state machine

The ToF sensor generates an interrupt when target is detected

The host wakes-up and programs ToF sensor in “Autonomous” mode, with OEM programmable RangingFreq and TimingBudget, until the target leaves the sensor FoV

ToF sensor in “Autonomous Low Power”
RangingFreq ~ 1 Hz
TimingBudget ~ 20 ms

Target Detected? (RangeStatus)

NO

YES

ToF sensor in “Autonomous”
RangingFreq ~ 1 Hz to 50Hz
TimingBudget ~ 20ms to 1sec.

There is no target in front of PC
The System is in Std-by mode

There is no target in front of PC
The System is in Std-by mode
## Customizable Thresholding

<table>
<thead>
<tr>
<th>Threshold condition set in VL53L1X</th>
<th>Human &amp; device situation and Interrupt raised by VL53L1X</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Above HIGH” (&gt; High)</td>
<td><img src="image1.png" alt="Diagram" /></td>
</tr>
<tr>
<td>“Below LOW” (&lt; Low)</td>
<td><img src="image2.png" alt="Diagram" /></td>
</tr>
<tr>
<td>“In Window” (&gt;= Low AND &lt;= High)</td>
<td><img src="image3.png" alt="Diagram" /></td>
</tr>
<tr>
<td>“Out of Window” (&gt; High OR &lt; Low)</td>
<td><img src="image4.png" alt="Diagram" /></td>
</tr>
</tbody>
</table>

- INT (Interrupt), fixed interrupt
- INT* (optional interrupt), customer choice

No target
Long-Distance Ranging Settings

• Ranging distance ~4.5m
  (White target, no CG, 60ms timing budget, no ambient IR)

• Recommended for applications requiring long distance ranging, in low IR ambient
Example of Short-Distance Ranging (5mm to 150mm) with high Xtalk cover-glass, FoV, in dark, 30ms, lite SD
Cover-Glasses and Special Module for FlightSense™ Sensors
Clipable Cover Glass by Hornix (China)
Low Xtalk CG ready to be clipped above ToF sensors, and fixed on a PCB

- Detail of Cover Glass, with a cavity underneath clipped on the ToF sensor, and a shape around the glass for insertion into a frame
- One version to be glued on PCB
- One version with holes to screw the CG on PCB

- Detail of complete module, with ToF sensor soldered on PCB, CG clipped on sensor and glued on PCB, and connector below the PCB

![Diagram of VL53L1X module with IR Cover Glass and PCB]
FlightSense™ Development Tools and Technical Support
FlightSense™ Development Tools

- Quick and easy evaluation and application development thanks to X-NUCLEO expansion boards and STM32 NUCLEO boards
- Small form factor satellites for easy integration into customers’ devices
- Basic evaluation in stand-alone USB, or advanced through GUI on PC

- Complete suite of SW tools and documentation (API, X-CUBE…)
- Code examples for plug and play application (Ranging, ALS, gesture…)
The STM32 Open Development Environment (ODE) consists of a set of stackable boards and a modular open SW environment designed around the STM32 microcontroller family.
STM32 Nucleo
Development Boards (NUCLEO)

• A comprehensive range of affordable development boards for all the STM32 microcontroller series, with unlimited unified expansion capabilities and integrated debugger/programmer functionality.

Power supply through USB or external source

Integrated debugging and programming ST-LINK probe

STM32 microcontroller

Complete product range from ultra-low power to high-performance

ST morpho extension header

Arduino™ UNO R3 extension headers

www.st.com/stm32nucleo
X-CUBE SW Package for FlightSense™ sensors

Nucleo-centric SW package following STM32Cube SW architecture
Code is structured in a way ToF sensors-based applications can be built very quickly on Nucleo platforms

Based on FlightSense™ sensor API
Sensor API appears as a BSP component

Validated on Nucleo pack
Example codes available for various NUCLEO STM32 boards (F401RE, L476RG, L053R8) plugged with ToF sensors X-NUCLEO expansion boards and satellites

Ranging, Ranging with satellites, ALS examples + Gesture detection demos
Examples: RangingAndALS (VL6180X) or RangingWithSatellites (VL6180X or VL53L0X)
1 application: GestureDetect (TAP & SWIPE)
Source code with pre-compiled binaries and Keil, IAR and STM32Workbench projects
STM32 Open Development Environment

Expansion boards can be plugged together

The building blocks

- Sense
  - Proximity, Ranging, microphone
  - Accelerometer, gyroscope
  - Inertial modules, magnetometer
  - Pressure, temperature, humidity

- Connect
  - Bluetooth LE, Sub-GHz radio
  - NFC, Wi-Fi, GNSS

- Translate
  - Audio amplifier
  - Touch controller
  - Operation Amplifier

- Move / Actuate
  - Stepper motor driver
  - DC & BLDC motor driver
  - Industrial input / output

- Power
  - Energy management & battery

- Process
  - General-purpose microcontrollers
  - Secure microcontrollers

- Software

Your need

Your need is translated into the following steps:

- COLLECT
- TRANSMIT
- ACCESS
- CREATE
- POWER
- PROCESS

Our answer

www.st.com/stm32ode
FlightSense™ Sensors Adopted by Multiple System Development Tools
“Getting Started” Video for VL53L0A1 Nucleo Expansion Board

- https://www.youtube.com/watch?v=RvUaD1A7jBs
VL53L1X Development Tools and Technical Support
VL53L1X Nucleo Expansion Board
X-NUCLEO-53L1XA1 works with STM32F401RE

Available in Q1.18

Arduino Connectors

VL53L1X
Ranging sensor

2x VL53L1X satellites
(plugged or hardwired)

Cover Glass sample
(PMMA material. Low XTalk)

Cover Glass holder
(Can hold Cover Glass and spacers)

Spacers
3 spacers 0.25/0.5/1mm to create various air gaps below CG

PC GUI interface
<table>
<thead>
<tr>
<th>Item</th>
<th>Picture</th>
<th>Commercial Product (= Order Code)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL53L1X sensor</td>
<td><img src="image1" alt="Picture" /></td>
<td>VL53L1CXV0FY/1</td>
<td>Delivery in T&amp;R MOQ: 3.6Ku With protective liner LT = 12 weeks</td>
</tr>
<tr>
<td>VL53L1X Nucleo™ Expansion board</td>
<td><img src="image2" alt="Picture" /></td>
<td>X-NUCLEO-53L1A1/</td>
<td>To go along with STM32F401 Nucleo board. Comes with cover-glass holder, 2x cover-window samples, 3x spacers, 2x 2v8 Breakout boards</td>
</tr>
<tr>
<td>Pack: VL53L1X Nucleo™ Expansion board + STM32F401 NUCLEO</td>
<td><img src="image3" alt="Picture" /></td>
<td>P-NUCLEO-53L1A1/</td>
<td>X-NUCLEO-53L1A1 expansion board delivered together with STM32F401 NUCLEO board</td>
</tr>
<tr>
<td>VL53L1X Breakout board</td>
<td><img src="image4" alt="Picture" /></td>
<td>VL53L1X-SATEL</td>
<td>Available in March18</td>
</tr>
</tbody>
</table>