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ST Artificial Intelligence enabler multizone Time- of-Flight sensors, VL53L7CH, VL53L8CH Introduction

STMicroelectronics

남형돈 차장



FlightSense™ making light work

Time-of-Flight Principle



● ST proprietary FlightSense™ technology

● True distance measurement

● Fast and low power

● Truly invisible 940nm illumination



ST pioneer and leader in Time-of-Flight (ToF)

ST is #1 Worldwide Time-of-Flight sensor supplier

4 Generations

of all-in-one ToF solution deployed since 2014

>500 devices

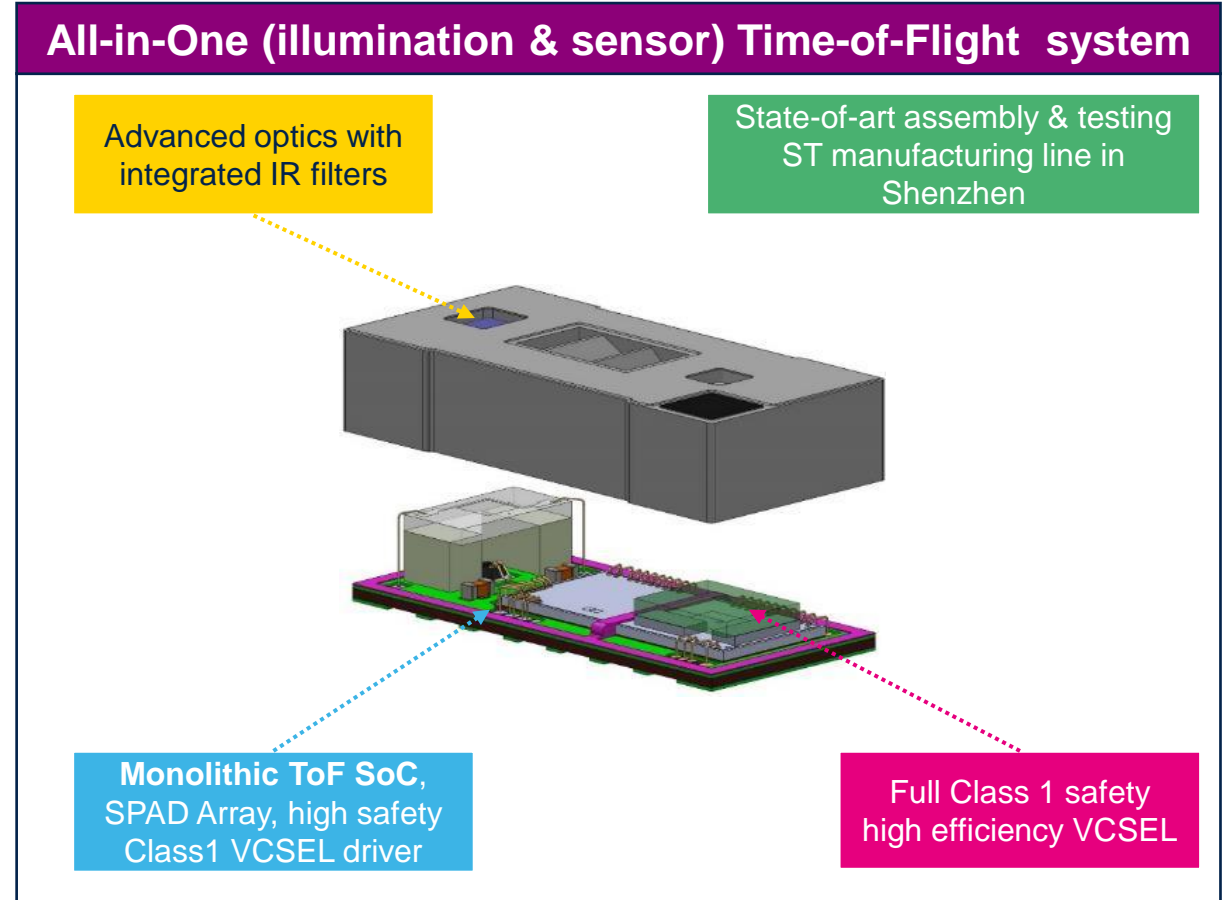
Over 200 phones with ST's Time of Flight technology
Several hundreds of non wireless end products on the market
Unlimited variety of use-cases beyond smartphones

>80,000

Evaluation kits deployed

>2 Billions

ToF units shipped. Mastering end-to-end supply chain

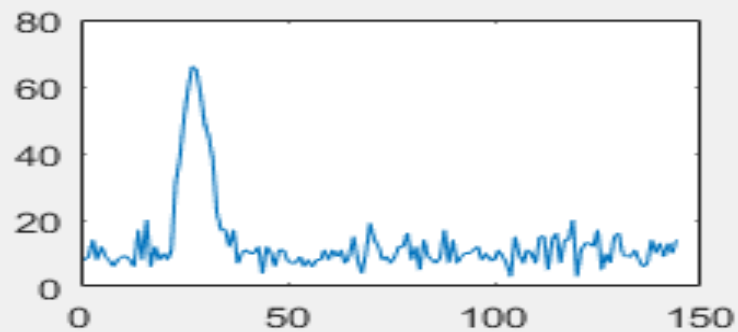


What are CNH?

Giving system host access to original sensor power to enable AI

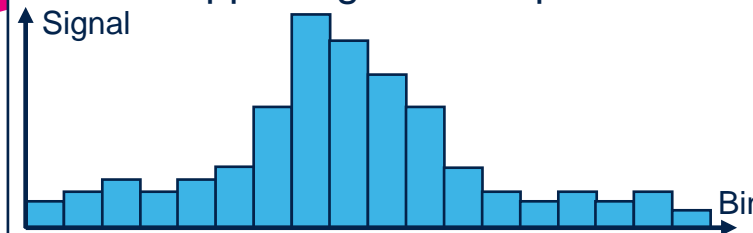
Raw histogram

- Provides histogram for each zone on 128 bins
- Bin size is exactly 37.5 mm
- Data are raw sensor output, but not accessible as is



Compact Normalized Histogram

- Up to 18 programmable bins output per zone in 8x8 mode (64 zones)
 - Up to 72 bins for 16 zones
 - Up to 128 bins for 8 zones
- The product firmware is computing raw histogram data to output CNH
- Only new LxCH sensor products are supporting CNH output data



Standard data

- Up to 5 standard data (distance, signal, ambient) output per zone, in addition to CNH data output
- The product firmware is computing raw histogram data to output standard data
- All sensor products, including new LxCH are supporting standard data output

Output data	Value
Distance	357 mm
Peak signal rate	66 kcps/spad
...	...



Standard Time-of-Flight data output

For each multizone-sensor zone, the sensor pre-processes histogram data into 5 information output

5 pre-processed histogram data

- **Distance related**



- Distance (mm)
- Distance sigma (mm)

- **Signal related**

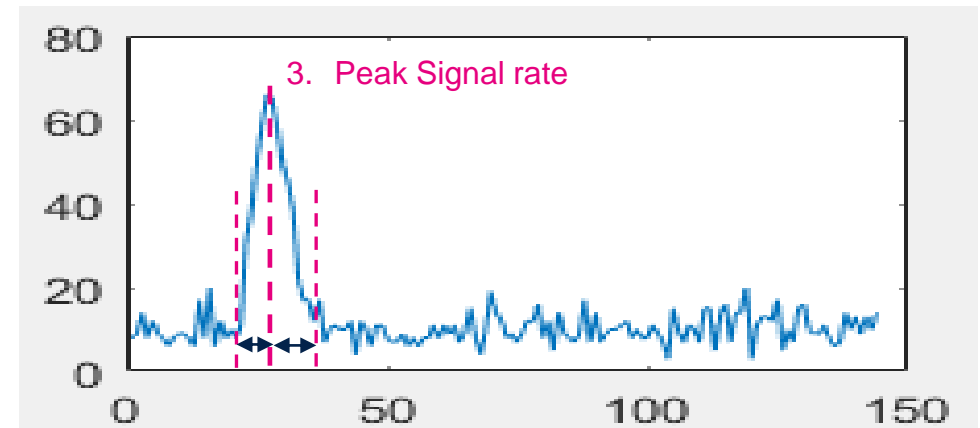
- Peak signal rate (kcps/spad)

- **Other**

- Infrared ambient level (kcps/spad)
- Reflectance (%)

From the raw histogram, extract standard data

- Computed directly in the firmware, the standard are output via I²C or SPI to the system host



1. Distance
2. Distance Sigma

Additional output data:
4. Infrared ambient level
5. Reflectance

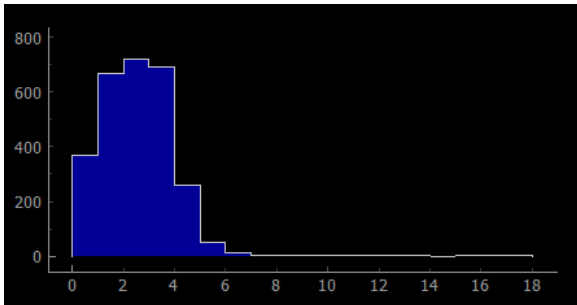


Compact Normalized Histogram

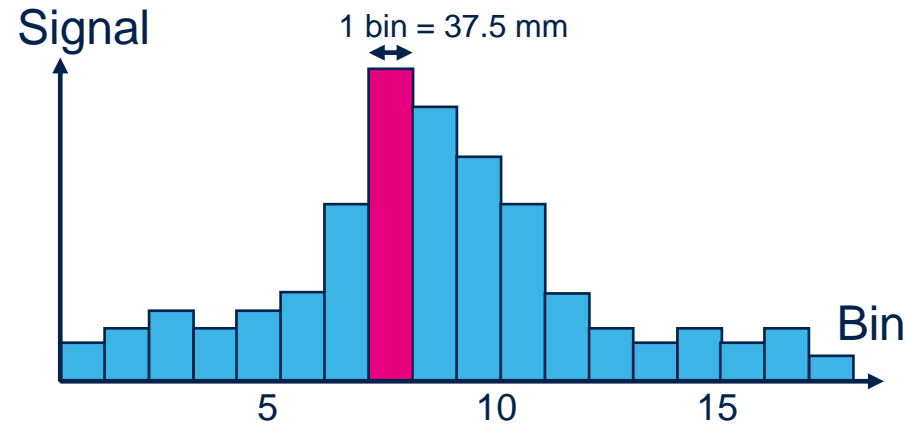
CNH resolution and data-set contains way more information than ranging distances

New data

- For each zone, the sensor provides CNH, with signal count on each bin



- X unit is bin number
- Y unit is signal count
- The measured ambient level is removed from the CNH data



Additional features

- Both standard and CNH data
- Ambient map information
- Autonomous mode available
- Both I²C and SPI* communication modes available

* VL53L8CH only

High data quantity

- 1 histogram bin = 1 data
- Up to 18 bins per zone (8x8)
 - Total of 1152 data

What means CNH?

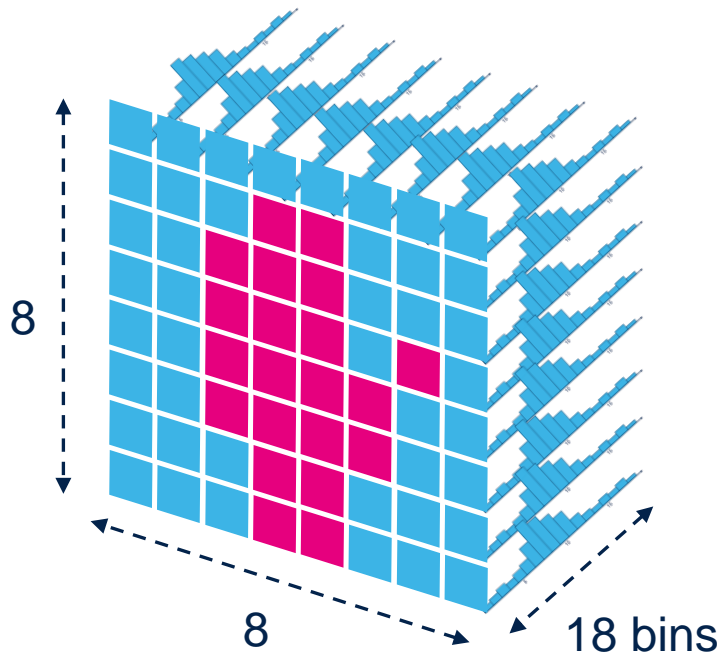
C: Compact → Options are available to reduce the amount of data compared to the native “raw” histogram data

N: Normalized → Raw data are adjusted to compensate variations caused by frame-to-frame adjustments

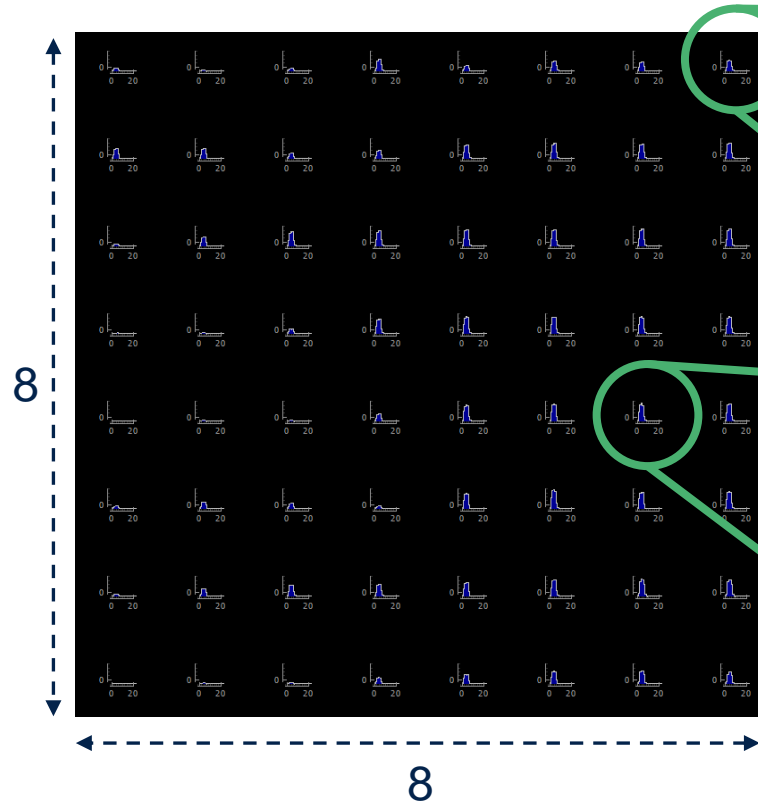
H: Histogram → Primary data is in the form of histograms recording return-signal-strength vs range

CNH resolution and data-set contains way more information than ranging distances

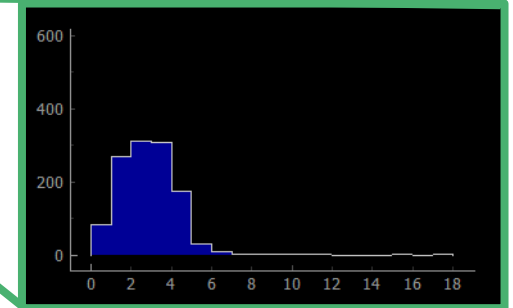
Theory



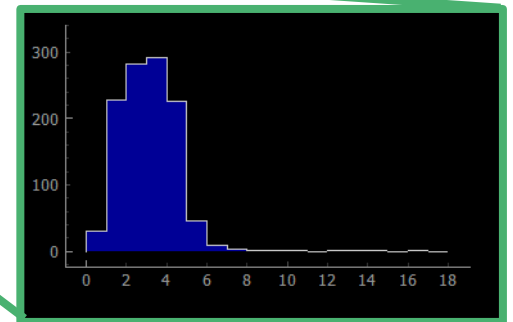
“Visible” X,Y resolution: 8x8 zones



“Hidden” Z resolution : 18 bins



18 bins

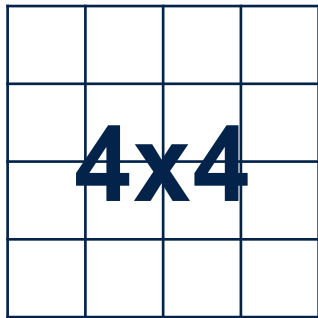


18 bins



15x more data per frame in 4x4 mode

Resolution



Standard data only

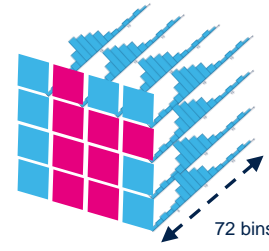
- Up to 5 data per zone
- 16 zones



- **Up to 80 data per frame**

CNH only

- Up to 72 CNH bins per zone*
- 16 zones

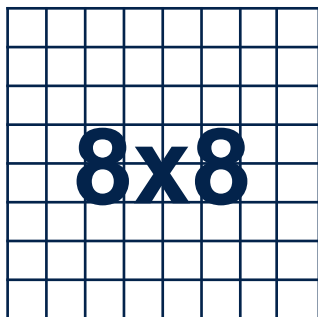


- **Up to 1152 data per frame**

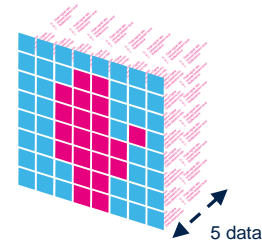
Standard data + CNH

- 5 standard data per zone
- Up to 72 CNH bins per zone*
- Total of 77 data per zone*
- 16 zones

- **Up to 1232 data per frame**

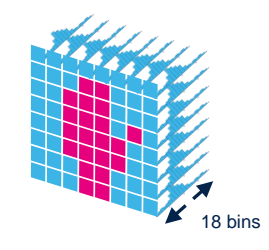


- Up to 5 data per zone
- 64 zones



- **Up to 320 data per frame**

- Up to 18 CNH bins per zone**
- 64 zones



- **Up to 1152 data per frame**

- 5 standard data per zone
- Up to 18 CNH bins per zone**
- Total of 23 data per zone**
- 64 zones

- **Up to 1472 data per frame**

CNH products



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Two products, one solution

Two products

VL53L7CH



- Up to 350 cm ranging
- 60° x 60° FoV (90° diagonal)
- I²C interface

VL53L8CH



- Up to 400 cm ranging
- 45° x 45° FoV (65° diagonal)
- High ambient light immunity
- Low power consumption
- I²C and SPI interface
- External synchronization pin

Common features

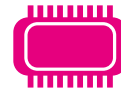
- Autonomous low power mode
- Motion Indicator

100% compatible

Single STM32 project



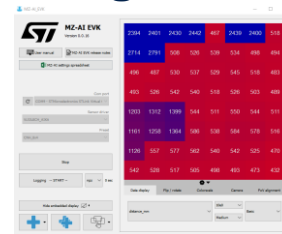
Single driver (ULD)



Single FW

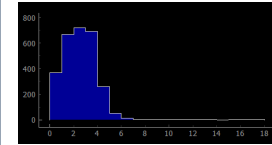


Single GUI



Output data

Compact Normalized Histogram



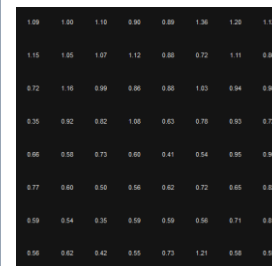
- Up to 18 bins in 8x8 at 15Hz
- Up to 72 bins in 4x4 at 15Hz

Standard data



- 2 for distance (distance, sigma)
- 1 for signal (signal peak)
- 2 additional data (ambient level and reflectance)

Ambient map



- IR ambient light level data generated





VL53L7CH and VL53L8CH selection guide

VL53L7CH



VL53L8CH



Field of view	60° x 60° (90° diagonal)	45° x 45° (65° diagonal)
Resolution	Up to 8x8 (64 zones)	
Common features	Autonomous low power mode	
Additional features		External synchronization pin
Driver	100% compatible	
Interfaces	I ² C (1 MHz)	I ² C (1 MHz) and SPI (3 MHz)
Distance ranging	Dark condition	350 cm
	Under ambient light*	65 cm
Power consumption**	4.5mW	1.6mW
Module size	6.4 x 3.0 x 1.6 mm	6.4 x 3.0 x 1.75 mm



VL53L7CH overview

An Artificial Intelligence enabler, 90° FoV 8x8 multizone Time-of-Flight sensor



Multi-zone (8x8) Package size : 6.4 x 3.0 x 1.6 mm FoV : 90° diagonal	Maximum ranging distance: 3.5 meters Ranging under ambient light (5 klux): 65 cm Close distance linearity: >2cm
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Typical use-cases

- AI applications
- Floor sensing
- Glass detection
- Gesture recognition

Applications

- Vacuum cleaners
- Smart speaker
- Home automation
- White goods
- Industrial

Highlights

- Parallel multizone ranging** output:
 - Up to **8x8 zone** separate regions of interest
- Ultra-wide field of view:** 60° x 60° (**90° diagonal**)
- Distance ranging performances:**
 - Up to **350 cm ranging** in **dark condition**
 - Up to **65 cm ranging** under **ambient light**
- Multi-target detection** and distance measurement in each zone
- Motion indicator** indicating if the target has moved
- 30 Hz** frame rate capability
- Immunity to cover glass cross-talk** beyond 60cm
- Pin-to-pin compatible** with VL53L5CX and VL53L7CX
- Software driver compatible** with VL53L8CH

90° FoV

8 x 8 64 zones

Compact Normalized Histogram (CNH)





VL53L8CH overview

An Artificial Intelligence enabler, high performance 8x8 multizone Time-of-Flight sensor



Multi-zone (8x8)

Package size :

6.4 x 3.0 x 1.75mm

FoV : 65° diagonal

Maximum ranging distance: 4 meters

Ranging under ambient light (5 klux): 285 cm

Close distance linearity: >2cm

Typical use-cases



AI applications



Rim detection



Floor sensing



Glass detection



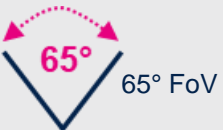
People counting



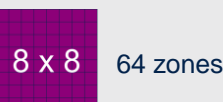
Gesture recognition



Air quality monitoring



65° FoV



8 x 8 64 zones



Perf. Under Ambient (>200cm)



Compact Normalized Histogram (CNH)

Applications



Vacuum cleaners



Smart speaker



Home Appliances



Air purifier



Industrial

Highlights

Parallel multizone ranging output:

- Up to **8x8 zones** separate regions of interest

Wide field of view: 45° x 45° (**65° diagonal**)

Distance ranging performances:

- Up to **400 cm ranging** in **dark condition**
- Up to **285 cm ranging** under **ambient light**

Multi-target detection and distance measurement in each zone

Low power consumption

Motion indicator indicating if the target has moved

30 Hz frame rate capability

Immunity to cover glass cross-talk beyond 60cm

Pin-to-pin compatible with VL53L8CX

Software driver compatible with VL53L7CH

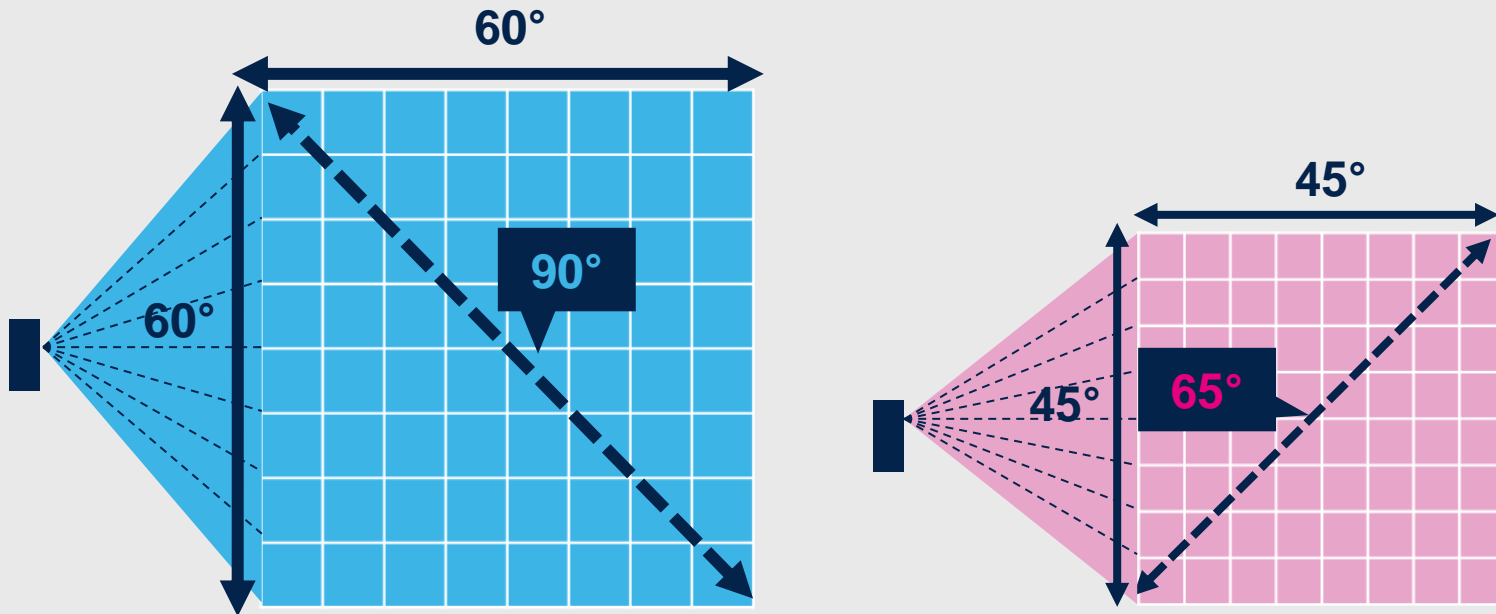




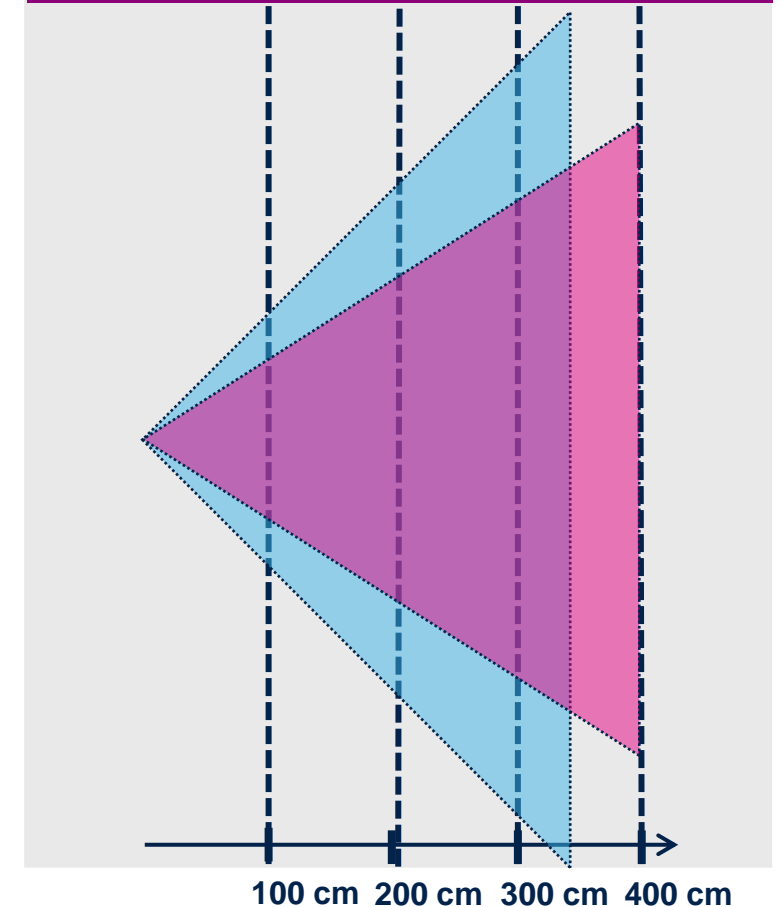
Field of view and ranging comparison

The **VL53L7CH** has a wider optical field of view, the **VL53L8CH** ranges further

Coverage zone



Maximum ranging distance
(drawing at scale)



CNH demos



Live Demo



CNH technically



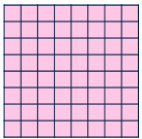


CNH data are widely parameterizable

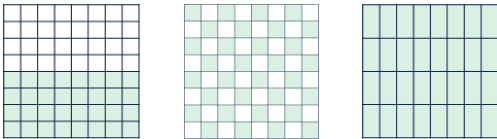
Resolution

- Set the resolution up to 64 zones
- Merge close zones into one bigger
- Reduce resolution to allow for increased number of bins and frequency

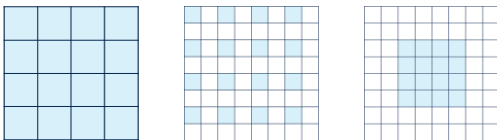
• 64 zones



• 32 zones

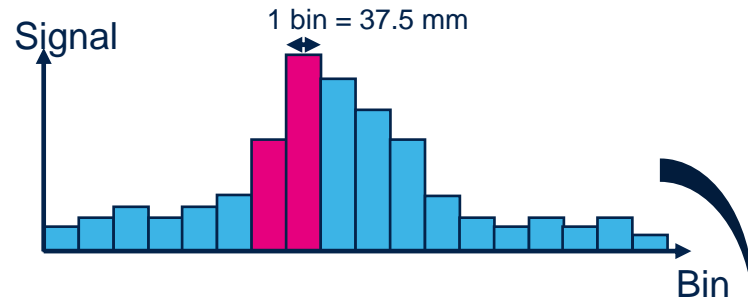


• 16 zones

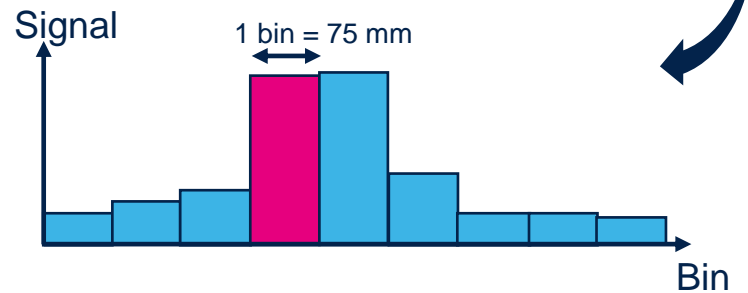


Histogram binning

- Increase the depth of the histogram by summing adjacent bins
- Bin your histogram up to 8 bins in 1

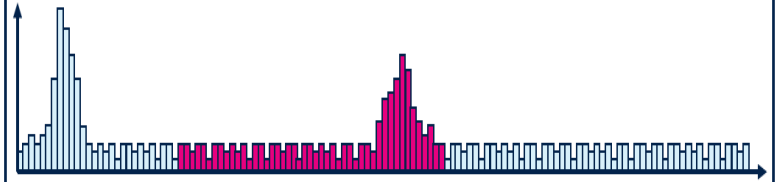


2 bins are summed to get one bin



CNH parameters

- Bin start = bin26
- Number of selected bins = 48



Configuration examples

Res.	Histo	CNH size*	Transfer time	Frame rate
8 zones	80 bins	3268 bytes	32 ms	30 fps
8 zones	128 bins	5188 bytes	48 ms	20 fps
16 zones	48 bins	3948 bytes	36 ms	25 fps
16 zones	72 bins	5868 bytes	54 ms	18 fps
32 zones	36 bins	6108 bytes	56 ms	15 fps
64 zones	18 bins	6108 bytes	56 ms	15fps

* CNH size must be <6180 bytes

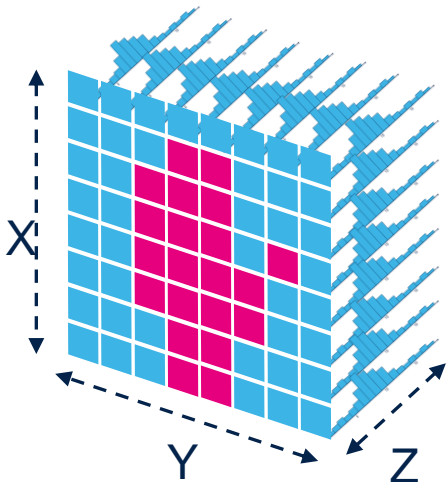


XY resolution vs Z resolution

Lower XY resolution allows higher Z resolution

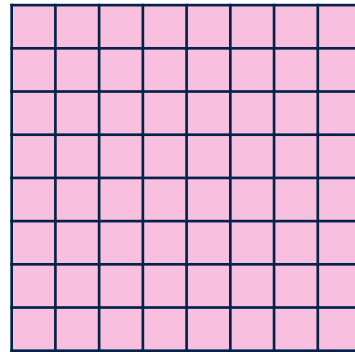
XYZ resolution

- X and Y represents the numbers of zone you can range
- Z resolution represents the number of bins



64 zones

- Outputting the 64 zones means to get the full 8x8 resolution



- Bins/Max frequency:
 - 18 bins = 15Hz
 - 12 bins = 15Hz
 - 8 bins = 15Hz

32 zones

- Choose the 32 zones
 - By selecting only few zones on an 8x8 matrix
 - By merging two close zones into one from an 8x8 matrix

- Pattern examples*:

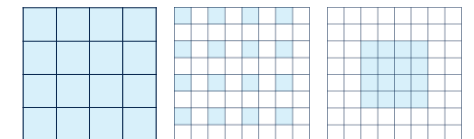


- Bins/Max frequency:
 - 36 bins = 15Hz
 - 18 bins = 15Hz
 - 12 bins = 15Hz

16 zones

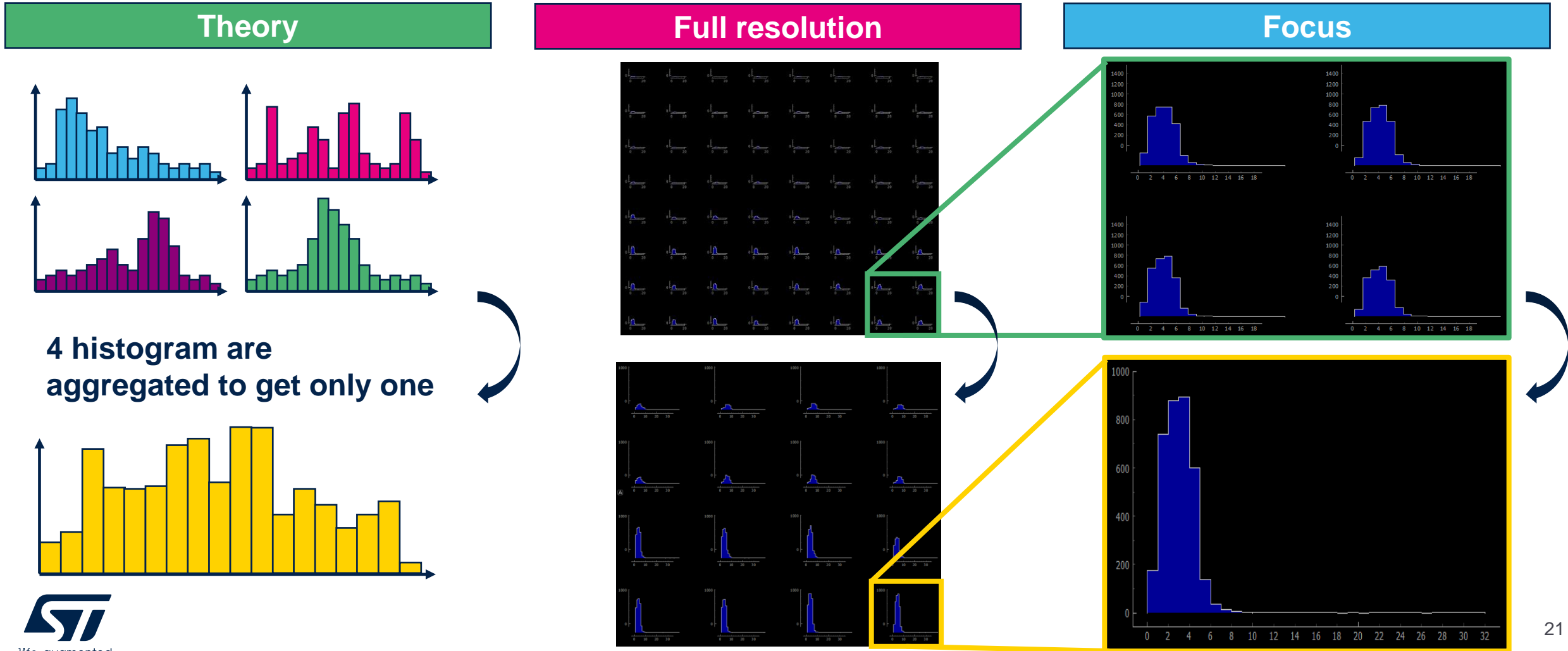
- Choose the 16 zones
 - By aggregating an 8x8 matrix in 4x4
 - By selecting only few zones on an 8x8 matrix

- Pattern examples*:



- Bins/Max frequency:
 - 72 bins = 18Hz
 - 48 bins = 25Hz
 - 28 bins = 30Hz

Bin aggregation allows deriving a single CNH





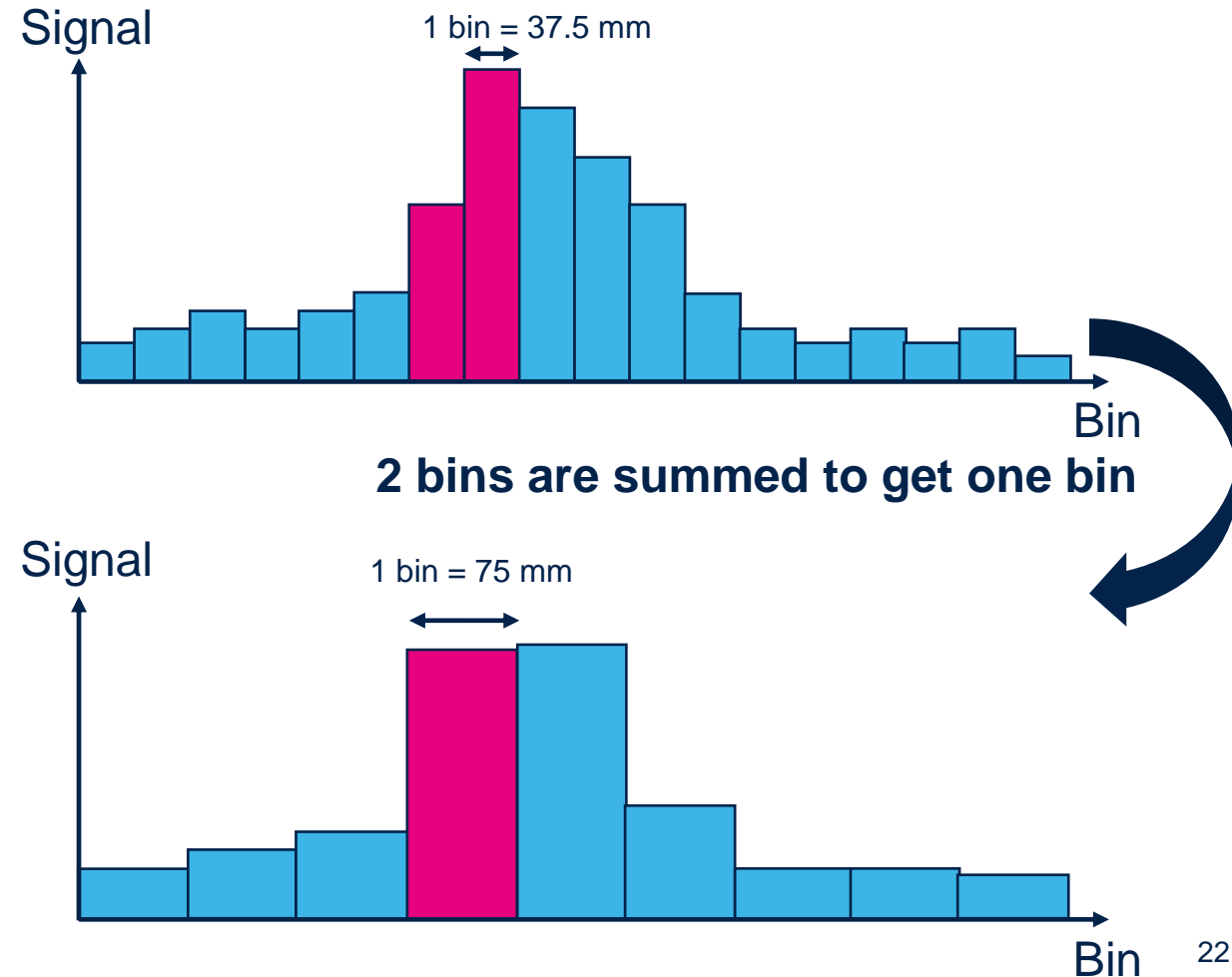
Histogram binning

Increase histogram depth by summing histogram

Binning for longer bin window

- Some applications could require covering a longer bin window
- Bin the histogram up to 8 bins in 1
 - In this case, bin now measures $37.5 \text{ mm} \times 8 = 300 \text{ mm}$
- Examples:

Binning factor	Bin size	Max window in 8x8 (18 bins @15Hz)
1	37.5 mm	675 mm
2	75 mm	1350 mm
4	150 mm	2700 mm
8	300 mm	5400 mm*



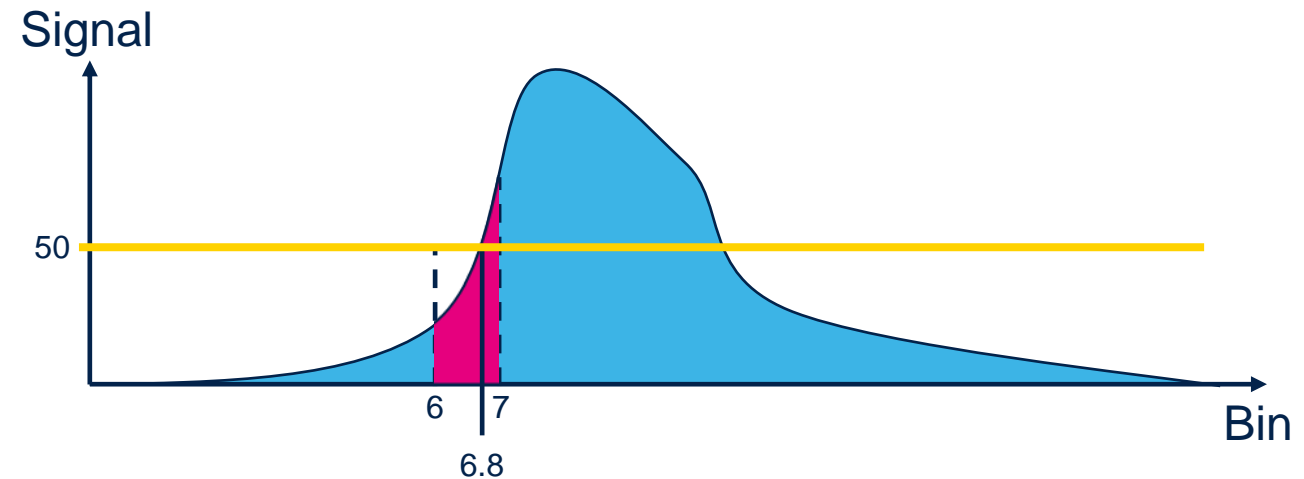
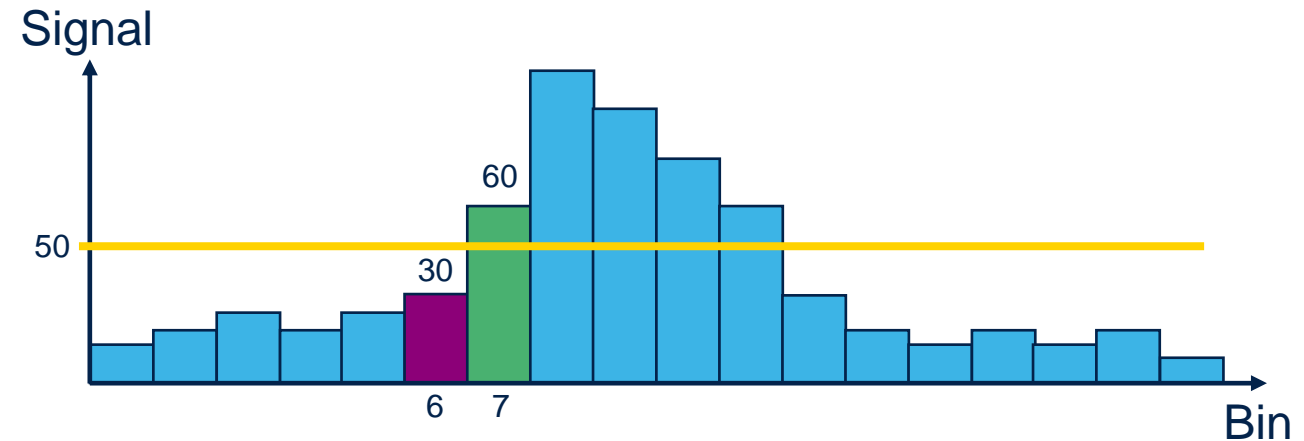


First Significant Bin (FSB)

FSB is one of the major post-processing data

First bin above the ambient light level

- The **ambient light level data** is generated for each zone
- The logic would like to take the first bin reaching this value
 - In our example: it should be the **bin7**
- Because we don't know at which moment the signal has reached threshold, we do interpolation
 - In our example: between **bin6** and **bin7**
- Based on this interpolation, we can know more precisely the moment is has been reached
 - In our example: it has been reached at **bin6.8**
- To know the distance, we just multiply the bin found by the bin size (37.5 mm*)
 - In our example: $37.5 \text{ mm}^* \times 6.8 = 25.5 \text{ cm}$










Ordering codes





Technical documentation

Complete toolset to start evaluation and integration

	VL53L7CH 	VL53L8CH 
Datasheet 	DS14309	DS14310
Software package 	STSW-IMG043	
User Manual 	UM3183	
GUI 	Integrated to the SW zip file	
Evaluation boards 	X-NUCLEO-53L7A1 P-NUCLEO-53L7A1 SATEL-VL53L7*	X-NUCLEO-53L8A1 P-NUCLEO-53L8A1 SATEL-VL53L8

Software package

www.st.com/en/embedded-software/stsw-img043

Part Number	General Description	ECCN (EU)	ECCN (US)	Supplier	Download
+ STSW-IMG043_EVK	GUI for VL53L7CH and VL53L8CH	NEC	EAR99	ST	Get latest
+ STSW-IMG043_F401	STM32F401 project source code	NEC	EAR99	ST	Get latest
+ STSW-IMG043_LNX	Linux driver based on the ULD	NEC	EAR99	ST	Get latest
+ STSW-IMG043_PY	Python scripts examples	NEC	EAR99	ST	Get latest
+ STSW-IMG043_ULD	Ultra Lite Driver source code	NEC	EAR99	ST	Get latest



* SATEL-VL53L7 boards are not yet on the market, SATEL-VL53L7CX can be used for the moment



Multi-zone AI enablers ordering codes

Go to st.com/FlightSense contact your usual distributor

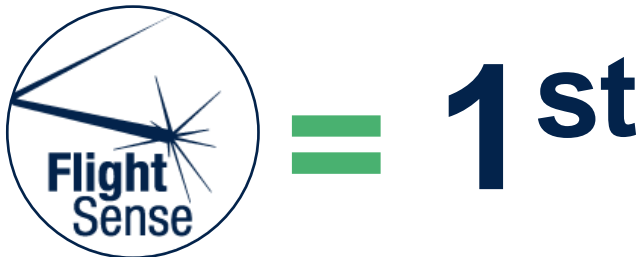
Item	Picture	Ordering Code	Comments	
VL53L7CH sensor		VL53L7CHV0GC/1	Tape & reel	MOQ= 3.6ku
			With liner	LT= 22weeks
VL53L7 Nucleo™ expansion board		X-NUCLEO-53L7A1/	<ul style="list-style-type: none"> Cover-window holder Cover-window sample 3x spacers 	
VL53L7 expansion pack		P-NUCLEO-53L7A1/	X-NUCLEO-53L7A1 + NUCLEO-F401RE	
VL53L7 Breakout boards		SATEL-VL53L7CX SATEL-VL53L7 (Q1'24)	2x Breakout boards delivered	

Item	Picture	Ordering Code	Comments	
VL53L8CH sensor		VL53L8CHV0GC/1	Tape & reel	MOQ= 3.6ku
			With liner	LT= 22weeks
VL53L8 Nucleo™ expansion board		X-NUCLEO-53L8A1/	<ul style="list-style-type: none"> Cover-window holder Cover-window sample 3x spacers 	
VL53L8 expansion pack		P-NUCLEO-53L8A1/	X-NUCLEO-53L8A1 + NUCLEO-F401RE	
VL53L8 Breakout boards		SATEL-VL53L8	2x Breakout boards delivered	

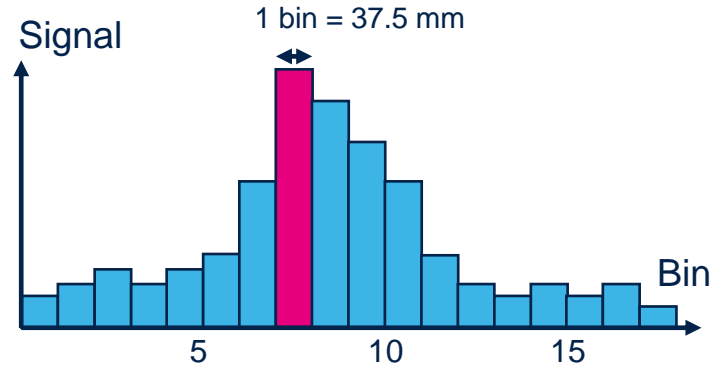


FlightSense™ Summary

Leader on Direct ToF

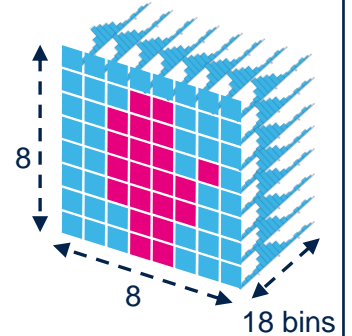


Compact Normalized Histogram



Boost your data quantity

- Up to 1.5 K data per frame
- Both standard and CNH data



Two products

- **VL53L7CH**
 - 90° FoV
 - 350 cm max distance
- **VL53L8CH**
 - 65° FoV
 - 400 cm max distance



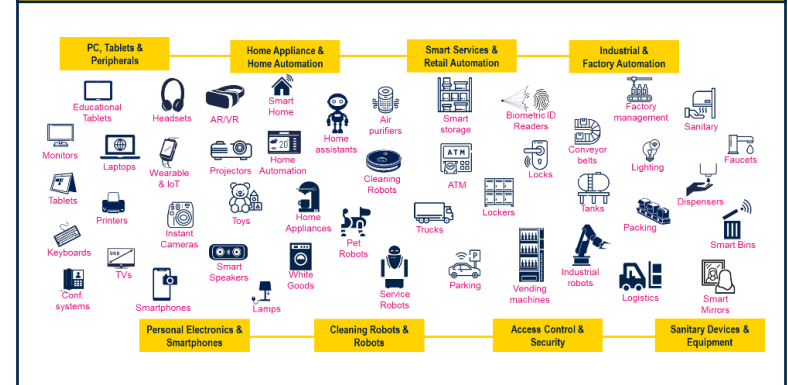
Continuous improvement

FlightSense industrial & mass market portfolio

Category	Product	Key Features
Multizone	VL53L7CH	90° FoV, 350 cm dark, 300 cm dark
	VL53L8CH	65° FoV, 400 cm dark, 300 cm dark, Low power consumption
	VL53L8CX	65° FoV, 400 cm dark, 300 cm dark
Singlezone	VL53L7CX	90° FoV, 350 cm dark, 300 cm dark
	VL53L8CX	65° FoV, 400 cm dark, 300 cm dark
	VL53L3CX	20° FoV, 200 cm dark, 150 cm dark
	VL53L4CX	30° FoV, 300 cm dark, 150 cm dark
	VL53L1CB	27° FoV, 200 cm dark, 150 cm dark, 18 mm beam
	VL53L1CX	27° FoV, 200 cm dark, 150 cm dark, 18 mm beam
	VL53L0CX	20° FoV, 200 cm dark
	VL53L4CD	30° FoV, 300 cm dark, 150 cm dark, 18 mm beam

Legend: Legacy product (blue), Special product (green), New product (red)

Unlimited markets & applications



Our technology starts with You



Find out more at www.st.com/FlightSense

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