Getting started with the X-CUBE-53L1A2 Time-of-Flight ranging sensor with advanced multizone and multi-object detection expansion software for STM32Cube

Introduction

This document describes how to get started with the X-CUBE-53L1A2 software expansion for STM32Cube.

The VL53L1 is a state of the art Time-of-Flight (ToF) laser-ranging miniature sensor, enhancing the ST Flight Sense product family. Housed in a miniature and reflowable package, it integrates a single photon avalanche diode (SPAD) array, physical infrared filters and optics to achieve the best ranging performance in various ambient lighting conditions, with range of cover glass options.

Unlike conventional IR sensors, VL53L1 uses ST's latest generation direct ToF technology which allows absolute distance measurement whatever the target color and reflectance. It provides accurate ranging up to 8 m and can work at fast speed (60 Hz), which makes it the fastest miniature ToF sensor on the market.

With patented algorithms and ingenious module construction, VL53L1 is also able to detect different objects within the field of view (FoV) with depth information (histogram) at 60 Hz.

X-CUBE-53L1A2 provides a complete software for STM32 to build applications using the VL53L1 ToF sensor.

It is easily portable across different MCU families thanks to STM32Cube. This package contains a sample application to transmit the ranging data to a PC.

The software provides an implementation example for STM32 Nucleo platforms equipped with the X-NUCLEO-53L1A2 expansion board, featuring the distance ranging sensor.

The software is based on STM32Cube technology and expands STM32Cube based packages.

1 Acronyms and abbreviations

Acronym	Definition
BSP	board support package
GUI	graphical user interface
HAL	hardware abstration layer
I2C	inter-integrated circuit
MCU	microcontroller unit
SDK	software development kit
SPAD	single photon avalanche diode
ToF	Time-of-Flight

2 What is STM32Cube?

2.1 STM32Cube overview

STMCube was originated by STMicroelectronics to ease developers' life by reducing development effort, time and cost. STM32Cube covers the STM32 portfolio.

STM32Cube includes:

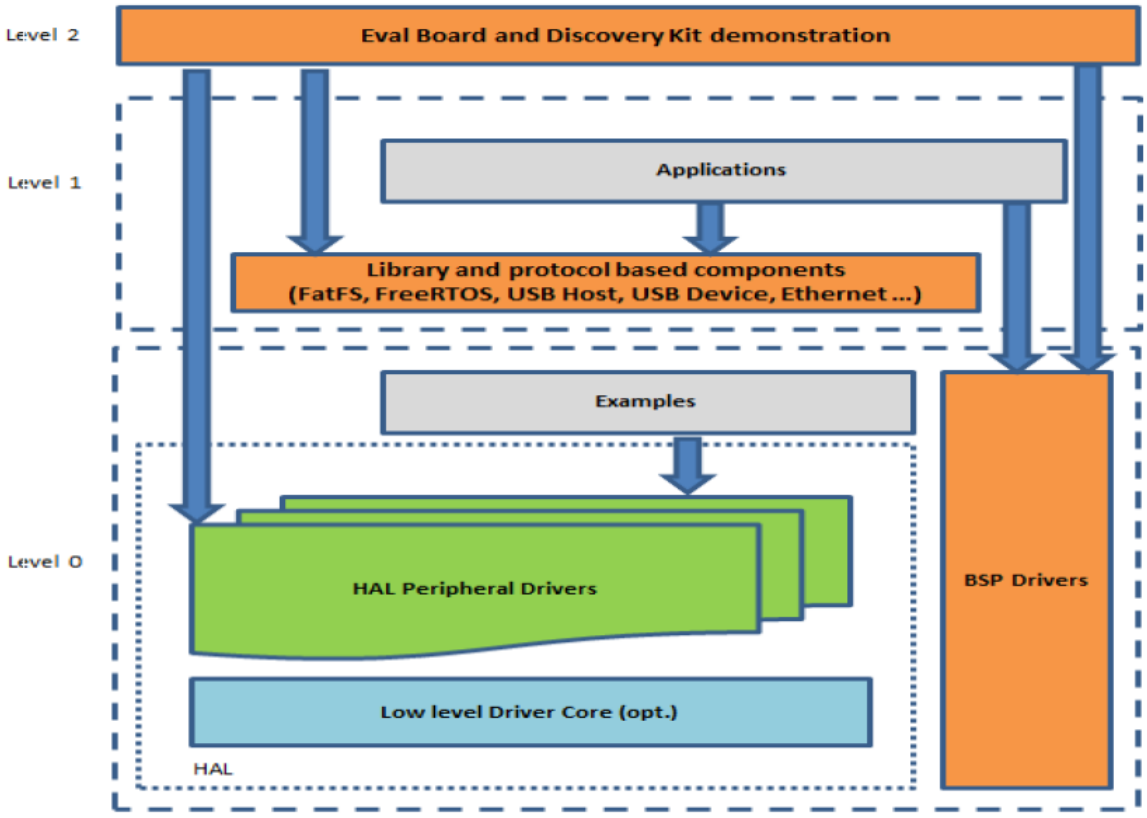
- The STM32CubeMX, a graphical software configuration tool that allows to generate C initialization code using graphical wizards.
- A comprehensive embedded software platform, delivered per series (such as STM32CubeF4 for STM32F4 series)
- The STM32Cube HAL, an STM32 abstraction layer embedded software, ensuring maximized portability across STM32 portfolio
- A consistent set of middleware components such as RTOS, USB, TCP/IP, graphics
- A full set of examples for all embedded software utilities

Information about STM32Cube are available on www.st.com at: http://www.st.com/stm32cube

2.2 STM32Cube architecture

The STM32Cube firmware solution is built around three independent levels that can easily interact with each other as illustrated in the figure below:

Figure 1. Firmware architecture



Level 0

This level is divided into three sublayers:

- **Board Support Package (BSP)**: this layer offers a set of APIs relative to the hardware components in the hardware boards (Audio codec, IO expander, Touchscreen, SRAM driver, LCD drivers. etc…) and composed of two parts:
  - Component: is the driver relative to the external device on the board and not related to the STM32, the component driver provide specific APIs to the BSP driver external components and could be portable on any other board.
  - BSP driver: it permits to link the component driver to a specific board and provides a set of friendly used APIs. The APIs naming rule is BSP_FUNCT_Action(): e.g. BSP_LED_Init(),BSP_LED_On()

    It's based on modular architecture allowing to port it easily on any hardware by justimplementing the low level routines.
- **Hardware Abstraction Layer (HAL)**: this layer provides the low level drivers and the hardware interfacing methods to interact with the upper layers (application, libraries and stacks). It provides a generic, multi instance and functionality oriented APIs which permit to offload the user application implementation by providing ready to use process. For example, for the communication peripherals (I2S, UART…) it provides APIs allowing to initialize and configure the peripheral, manage data transfer based on polling, interrupt or DMA process, and manage communication errors that may raise during communication. The HAL drivers APIs are split in two categories:
  - generic APIs which provide common and generic functions to all the STM32 series
  - extension APIs which provide specific and customized functions for a specific family or a specific part number
- **Basic peripheral usage examples**: this layer encloses the examples build over the STM32 peripheral using only the HAL and BSP resources.

Level 1

This level is divided into two sublayers:

- **Middleware components**: set of libraries covering USB host and device libraries, STemWin, FreeRTOS, FatFS, LwIP, and PolarSSL. Horizontal interactions between the components of this layer is done directly by calling the feature APIs, while the vertical interaction with the low level drivers is done through specific callbacks and static macros implemented in the library system call interface. For example, the FatFs implements the disk I/O driver to access microSD drive or the USB mass storage class.
- **Examples** based on the middleware components: each middleware component comes with one or more example (called also applications) showing how to use it. Integration examples that use several middleware components are provided as well.

Level 2

This level is composed of a single layer which is global real-time and graphical demonstration based on the middleware service layer, the low level abstraction layer and the basic peripheral usage applications for board based functionalities.

3 X-CUBE-53L1A2 expansion software for STM32Cube

3.1 Overview

X-CUBE-53L1A2 is a software package that expands the functionality provided by STM32Cube.

The key features of the package are:

- Complete software set to build the applications using the VL53L1 ToF ranging sensor
- Easy portability across different MCU families
- Sample application to transmit real time sensor ranging data to a serial terminal
- Free user friendly license terms
- An implementation example available for the X-NUCLEO-53L1 running with a NUCLEOF401RE or NUCLEO-L476RG

This software enables the ranging operation, running on STM32.

The package includes a sample application that the developer can use to start experimenting with the code. The sample application performs the ranging operation and sends the ranging data to a PC.

3.2 Architecture

This software is an expansion for STM32Cube, as such it fully complies with the architecture of STM32Cube and it expands it in order to enable development of applications using ToF sensor. Refer to Section 2.2 STM32Cube architecture for information regarding the STM32Cube architecture.

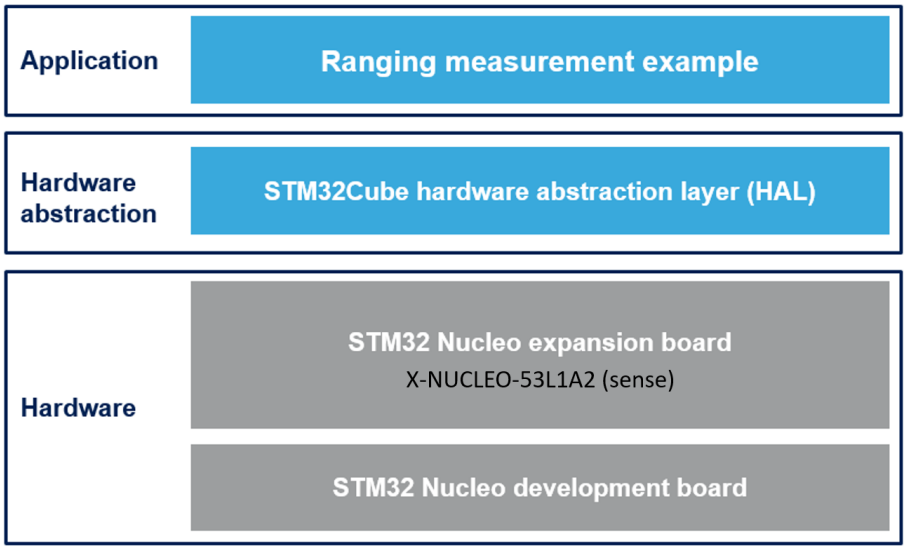
The software is based on the STM32CubeHAL, the hardware abstraction layer for the STM32 microcontroller. The package extends STM32Cube by providing a Board Support Package (BSP) for the sensors expansion board and some middleware components for serial communication with a PC.

The software layers used by the application software to access and use the sensors expansion board are the following:

- STM32Cube HAL layer: The HAL driver layer provides a generic multi instance simple set of APIs (application programming interfaces) to interact with the upper layers (application, libraries and stacks). It is composed of generic and extension APIs. It is directly built around a generic architecture and allows the layers that are built upon, such as the middleware layer, to implement their functionalities without dependencies on the specific hardware configuration for a given microcontroller unit (MCU). This structure improves the library code reusability and guarantees an easy portability on other devices.
- BSP layer: The software package needs to support the peripherals on the STM32 nucleo board apart from the MCU. This software is included in the board support package (BSP). This is a limited set of APIs which provides a programming interface for certain board specific peripherals, e.g. the LED, the user button etc. This interface also helps identify the specific board version.

The following figure outlines the software architecture of the package:

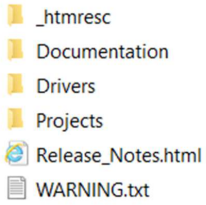
Figure 2. **X-CUBE-53L1A2 software architecture**



3.3 Folder structure

This section provides an overview of the package folders structure.
The next figure illustrates the architecture of the package

Figure 3. **X-CUBE-53L1A2 package folder structure**



The following folders are included in the software package:

- Documentation: this folder contains a compiled HTML file generated from the source code and documentating in details the software components and APIs.
- Drivers: this folder contains the HAL drivers, the board specific drivers for each supported board or hardware platform, including the on board components ones and the CMSIS layer which is a vendor independent hardware abstraction layer for the Cortex-M processor series.
- Projects: this folder contains a sample application used to access sensors data, provided for the NUCLEO-F401RE and NUCLEO-L476RG platforms with three development environments (IAR, Keil and STM32CubeIDE).

3.4 APIs

Detailed technical information about the APIs available to the user can be found in a compiled HTML file located inside the Documentation folder of the software package where all the functions and parameters are fully described.

3.5 Sample application description

There are two examples in the main.c file. One ranging example (RangingLoop()) and one multizone (Multizones()) ranging example.

The examples running on the X-NUCLEO-53L1A2 expansion board with either NUCLEO-F401RE or NUCLEO-L476RG boards is provided in the “Projects” directory. Ready to be built projects are available for the three IDEs (IAR, Keil, and STM32CubeIDE).

RangingLoop example

In the following sample application, real-time sensor ranging data is transmitted to a PC via serial port, using the HAL_UART_Transmit() system call. Transmitted sensor data can be viewed using the Tera Term.

Figure 4. RangingLoop example

```
Count=  128, #Objs=2 status=0, D=  117mm, Signal=117.53 Mcps, Ambient=5.92
                     status=0, D= 1025mm, Signal=1.30 Mcps, Ambient=5.92 Mc
Count=  129, #Objs=2 status=0, D=  117mm, Signal=115.96 Mcps, Ambient=5.92
                     status=0, D= 1037mm, Signal=1.15 Mcps, Ambient=5.92 Mc
```

In the sample return above:

- Count = 128 is the ranging number
- #Objs = is the number of detected objets (in this case 2)
- status=0 indicates there are no errors
- D=117 mm is the distance of the first detected object
- D=1025 mm is the distance of the second detected objet

Multizone example

In the following example, the SPAD receiver is divided into zones or ROIs of 8x16, RoiNumber0 and RoiNumber1. RoiNumber0 sees two objets one at 101mm and another one at 1534mm.

RoiNumber1 sees one objet at 111mm

Figure 5. Multizone example

```
Count=  130, RoiNumber0, RoiStatus=1, #Objs=2, status=0, D=  101mm, Signal=3.08 Mcps, Ambient=0.30 Mcps
                                               status=0, D= 1534mm, Signal=0.23 Mcps, Ambient=0.30 Mcps
Count=  131, RoiNumber1, RoiStatus=2, #Objs=1, status=0, D=  111mm, Signal=9.16 Mcps, Ambient=0.20 Mcps
Count=  132, RoiNumber0, RoiStatus=1, #Objs=2, status=0, D=  105mm, Signal=3.23 Mcps, Ambient=0.26 Mcps
                                               status=0, D= 1529mm, Signal=0.32 Mcps, Ambient=0.26 Mcps
Count=  133, RoiNumber1, RoiStatus=2, #Objs=1, status=0, D=  103mm, Signal=9.08 Mcps, Ambient=0.24 Mcps
Count=  134, RoiNumber0, RoiStatus=1, #Objs=2, status=0, D=  105mm, Signal=3.30 Mcps, Ambient=0.26 Mcps
                                               status=0, D= 1485mm, Signal=0.28 Mcps, Ambient=0.26 Mcps
```

4 System setup

4.1 Hardware description

This section describes the hardware components needed for developing a sensors based application.

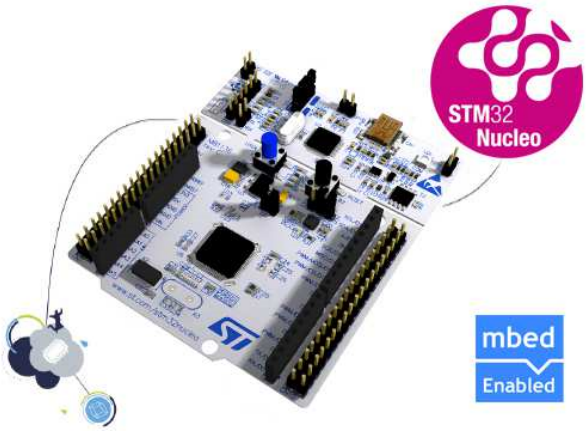
The following sections describe the individual components.

4.1.1 STM32 Nucleo platform

The STM32 Nucleo boards provide an affordable and flexible way for users to try out new ideas and build prototypes with any STM32 microcontroller lines. The Arduino® connectivity support and ST morpho headers make it easy to expand the functionality of the STM32 Nucleo open development platform with a wide choice of specialized expansion boards. The STM32 Nucleo board does not require any separate probe as it integrates the ST-LINK/V2-1 debugger/programmer. The STM32 Nucleo board comes with the STM32 comprehensive software HAL library together with various packaged software examples.

Information about the STM32 Nucleo boards is available on www.st.com at http://www.st.com/stm32nucleo

Figure 6. STM32 Nucleo board



4.1.2 X-Nucleo-53L1A2 expansion board

The X-NUCLEO-53L1A2 is a ToF ranging sensor expansion board usable with a STM32 Nucleo development board. It is also compatible with Arduino UNO R3 connector layout. The X-NUCLEO-53L1A2 interfaces with the STM32 MCU via I2C.

Information about the X-NUCLEO-53L1A2 expansion board is available on www.st.com at http://www.st.com/x-nucleo

Figure 7. **X-NUCLEO-53L1A2 expansion board**

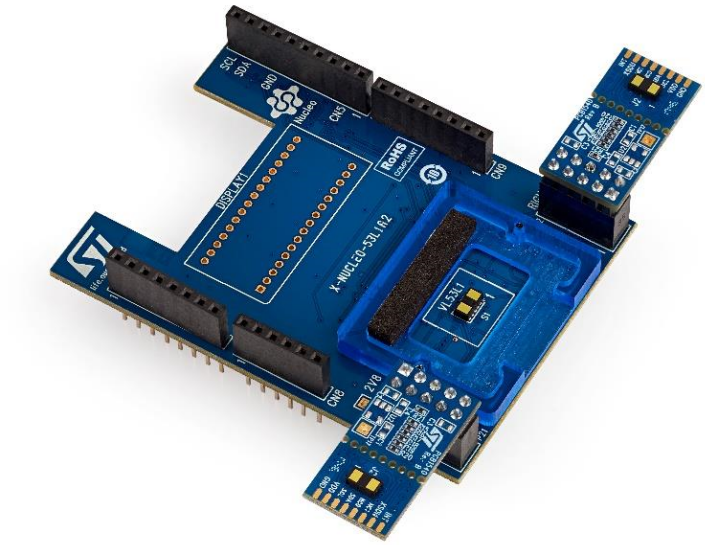
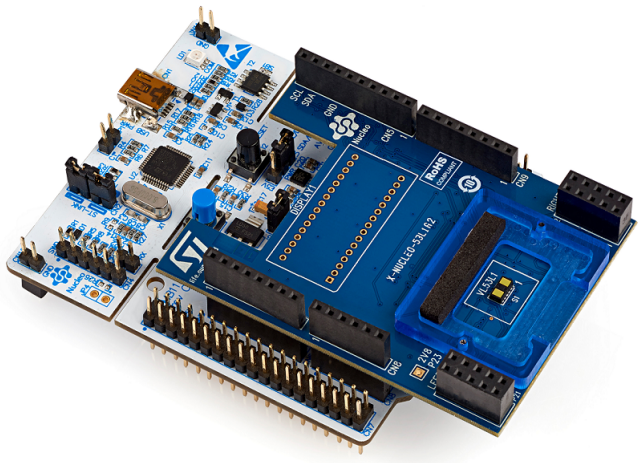


Figure 8. **X-NUCLEO-53L1A2 expansion board connected to STM32 Nucleo board**



4.2 Software description

The following software components are required in order to setup the suitable development environment to create the applications running on the STM32 Nucleo and the ToF sensor expansion board:

- X-CUBE-53L1A2: a software expansion for STM32Cube dedicated to sensors applications development. The X-CUBE-53L1A2 firmware and related documentation is available on st.com.
- Development tool chain and compiler: The STM32Cube expansion software supports the three following environments:
  - IAR + ST-Link
  - KEIL + ST-LINK
  - STM32CubeIDE + ST-LINK

4.3 Hardware and software setup

This section describes the hardware and software setup procedures. It also describes the system setup needed for the above.

4.3.1 Hardware setup

The following hardware components are needed:

- a STM32 Nucleo development platform (suggested order code: either NUCLEOF401RE or NUCLEO-L053R8)
- a sensor expansion board (order code: X-NUCLEO-53L1A2)
- a USB type A to Mini-B USB cable to connect the STM32 Nucleo to the PC

4.3.2 Software setup

This section lists the minimum requirements for the developer to setup the SDK, run the sample testing scenario based on the GUI utility and customize applications.

4.3.2.1 Development tool chain and compiler

Select one of the Integrated Development Environments supported by the STM32Cube expansion software.

Read the system requirements and setup information provided by the selected IDE provider.

4.3.2.2 PC utility

The Sensors_DataLog utility for PC has the following minimum requirements:

- PC with Intel or AMD processor running one of following Microsoft operating system:
  - Windows 10
  - Windows 7
- At least 128 MBs of RAM
- Two USB ports
- 40 MB of hard disk space

4.4 STM32 Nucleo and sensor expansion board setup

The STM32 Nucleo board integrates the ST-LINK/V2-1 debugger/programmer.

If Windows cannot install automatically the STLINK driver, the developer can download the ST-LINK/V2-1 USB driver by looking at the STSW-LINK009 software on www.st.com.

The developer needs to unzip the file and run the "stlink_winusb_install.bat" to install the STLINK driver.

The sensors expansion board X-NUCLEO-53L1A2 can be easily connected to the STM32 Nucleo motherboard through the Arduino UNO R3 extension connector, see Figure 8. X-NUCLEO-53L1A2 expansion board connected to STM32 Nucleo board. The sensor expansion board is capable of interfacing with the external STM32 microcontroller on STM32 Nucleo using inter-integrated circuit (I2C) transport layer.

Revision history

Table 1. **Document revision history**

Date	Version	Changes
08-Jan-2021	1	Initial release

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