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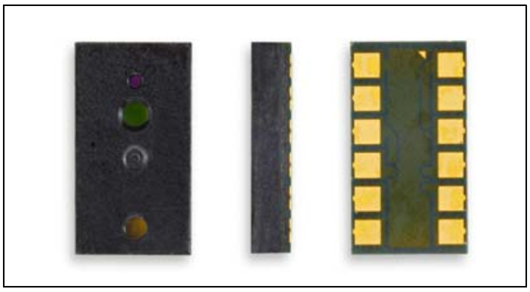
VL6180X

Proximity and ambient light sensing (ALS) module

Datasheet - production data



Features

- Three-in-one smart optical module
  - Proximity sensor
  - Ambient Light Sensor
  - VCSEL light source
- Fast, accurate distance ranging
  - Measures absolute range from 0 to above 10 cm (ranging beyond 10cm is dependent on conditions)
  - Independent of object reflectance
  - Ambient light rejection
  - Cross-talk compensation for cover glass
- Gesture recognition
  - Distance and signal level can be used by host system to implement gesture recognition
  - Demo system available: P-NUCLEO-6180X1 evaluation board
- Ambient light sensor
  - High dynamic range
  - Accurate/sensitive in ultra-low light
  - Calibrated output value in lux
- Easy integration
  - Single reflowable component
  - No additional optics
  - Single power supply
  - I^2C interface for device control and data
  - Provided with a documented C portable API (Application Programming Interface)
- Two programmable GPIO
  - Window and thresholding functions for both ranging and ALS

Applications

- Smartphones/portable touchscreen devices
- Tablet/laptop/gaming devices
- Domestic appliances/industrial devices

Description

The VL6180X is the latest product based on ST's patented F**light**Sense™ technology. This is a ground-breaking technology allowing absolute distance to be measured independent of target reflectance. Instead of estimating the distance by measuring the amount of light reflected back from the object (which is significantly influenced by color and surface), the VL6180X precisely measures the time the light takes to travel to the nearest object and reflect back to the sensor (Time-of-Flight).

Combining an IR emitter, a range sensor and an ambient light sensor in a three-in-one ready-to-use reflowable package, the VL6180X is easy to integrate and saves the end-product maker long and costly optical and mechanical design optimizations.

The module is designed for low power operation. Ranging and ALS measurements can be automatically performed at user defined intervals. Multiple threshold and interrupt schemes are supported to minimize host operations.

Host control and result reading is performed using an I^2C interface. Optional additional functions, such as measurement ready and threshold interrupts, are provided by two programmable GPIO pins.

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1 Overview

This datasheet is applicable to the final VL6180X ROM code revision.

1.1 Technical specification

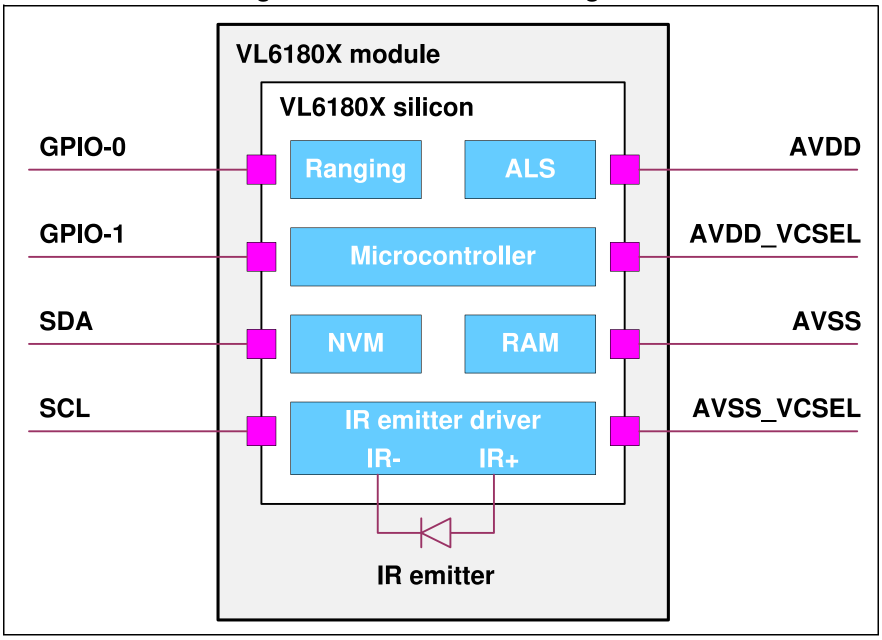
Table 1. Technical specification

Feature	Detail
Package	Optical LGA12
Size	4.8 x 2.8 x 1.0 mm
Ranging	0 to 100 mm(1)
Ambient light sensor	< 1 Lux up to 100 kLux(2) 16-bit output(3) 8 manual gain settings
Operating voltage: • Functional range • Optimum range(4)	 2.6 to 3.0 V 2.7 to 2.9 V
Operating temperature: • Functional range • Optimum range(4)	 -20 to 70°C -10 to 60°C
Typical power consumption	Hardware standby (GPIO0 = 0): < 1 µA(5) Software standby: < 1 µA(5.) ALS: 300 µA Ranging: 1.7 mA (typical average)(6)
IR emitter	850 nm
I^2C	400 kHz serial bus Address: 0x29 (7-bit)

1. Ranging beyond 100mm is dependent on target reflectance and external conditions (ambient light level, temperature, voltage)
2. When used under a cover glass with 10% transmission in the visible spectrum
3. Digital output easily converted to Lux
4. Please refer to *Table 18.: Ranging specification*
5. GPIO0, GPIO1, SCL and SDA are pulled up to AVDD (2.8V)
6. Assumes 10 Hz sampling rate, 17% reflective target at 50 mm

1.2 System block diagram

Figure 1. VL6180X block diagram



1.3 Device pinout

Figure 2 shows the pinout of the VL6180X.

Figure 2. VL6180X pinout

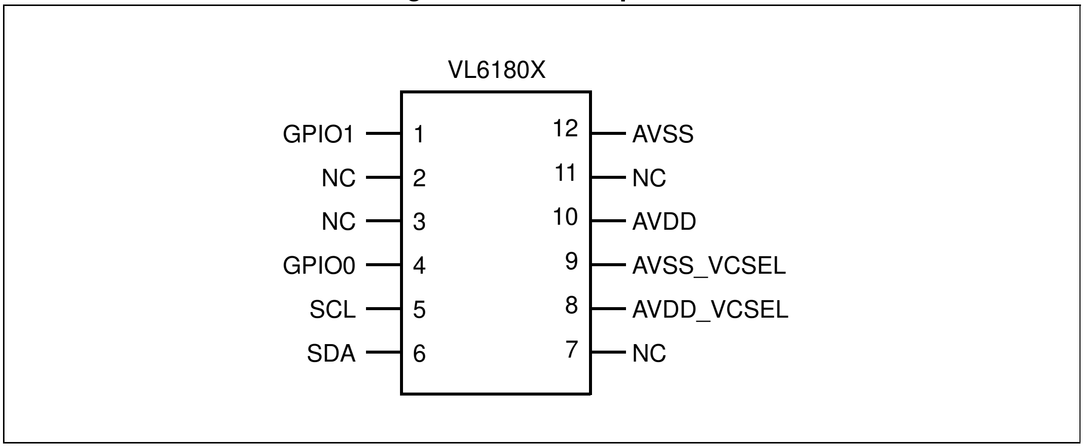


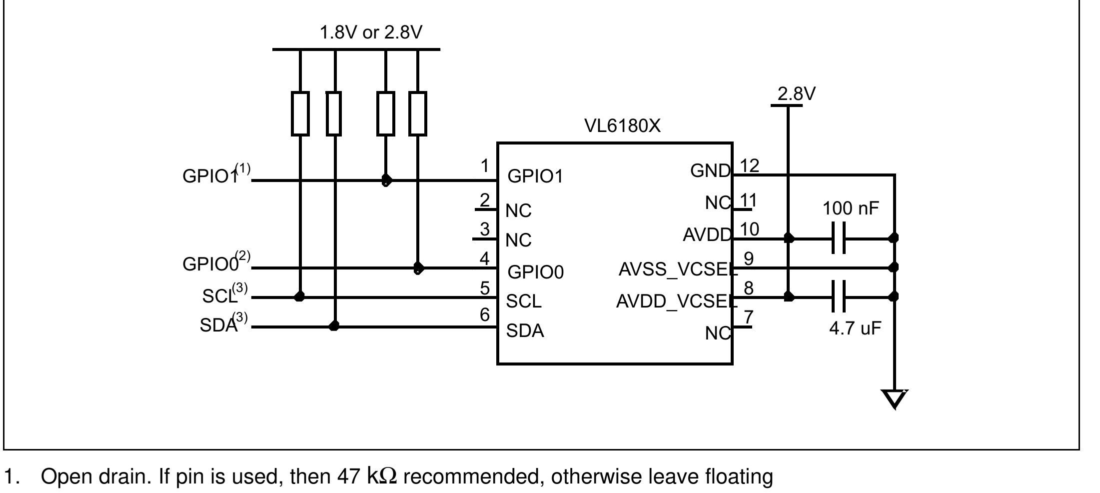
Table 2. VL6180X pin numbers and signal descriptions

Pin number	Signal name	Signal type	Signal description
1	GPIO1	Digital I/O	Interrupt output. Open-drain. If used, it should be pulled high with 47 kΩ resistor, otherwise left unconnected.
2	NC		No connect
3	NC		No connect
4	GPIO0/CE	Digital I/O	Power-up default is chip enable (CE). It should be pulled high with a 47 kΩ resistor.
5	SCL	Digital input	I^2C serial clock
6	SDA	Digital I/O	I^2C serial data
7	NC		No connect
8	AVDD_VCSEL	Supply	VCSEL power supply 2.6 to 3.0 V
9	AVSS_VCSEL	Ground	VCSEL ground
10	AVDD	Supply	Digital/analog power supply 2.6 to 3.0 V
11	NC		No connect
12	AVSS	Ground	Digital/analog ground

1.4 Typical application schematic

Figure 3 shows a typical application schematic of the VL6180X.

Figure 3. Root part number 1 schematic

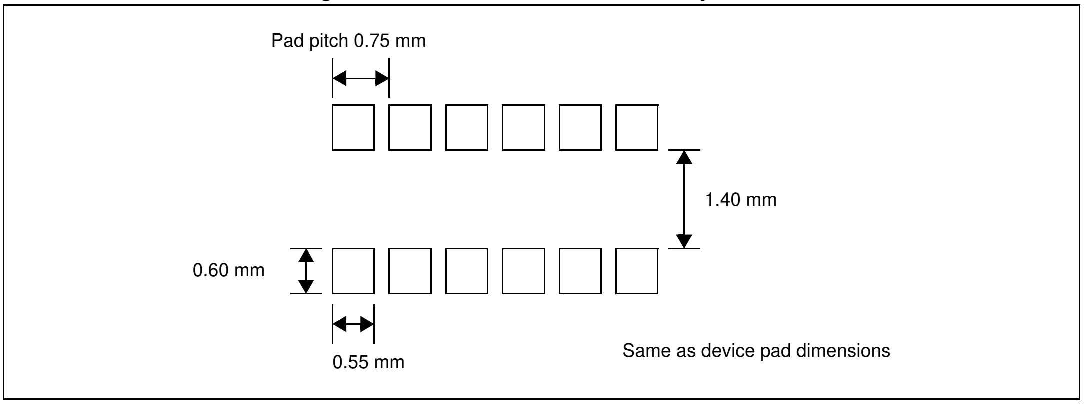


1. Open drain. If pin is used, then 47 kΩ recommended, otherwise leave floating
2. Open drain, 47 kΩ recommended
3. Open drain. Pull up resistors typically fitted once per I^2C bus at host

Note: Capacitors on AVDD and AVDD_VCSEL should be placed as close as possible to the supply pads.

1.5 Recommended solder pad dimensions

Figure 4. Recommended solder pattern



1.6 Recommended reflow profile

The recommend reflow profile is shown in *Figure 5* and *Table 3*.

Figure 5. Recommended reflow profile

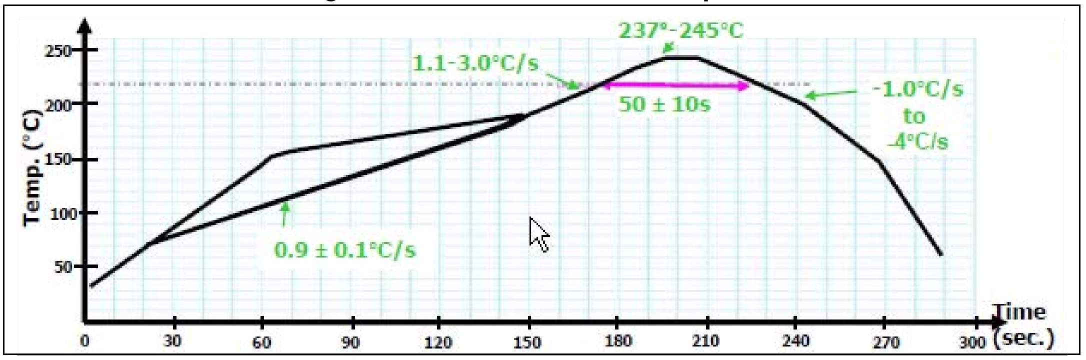


Table 3. Recommended reflow profile

Profile	Ramp to strike	
Temperature gradient in preheat	(T= 70 - 180°C):	0.9 +/- 0.1°C/s
Temperature gradient	(T= 200 - 225°C):	1.1 - 3.0°C/s
Peak temperature in reflow	237°C - 245°C	
Time above 220°C	50 +/- 10 seconds	
Temperature gradient in cooling	-1 to -4 °C/s (-6°C/s maximum)	
Time from 50 to 220°C	160 to 220 seconds	

Note: As the VL6180X package is not sealed, only a dry re-flow process should be used (such as convection re-flow). Vapor phase re-flow is not suitable for this type of optical component.

The VL6180X is an optical component and as such, it should be treated carefully. This would typically include using a 'no-wash' assembly process.

2 Functional description

This section gives an overview of the key features of the VL6180X and describes the different modes of operation of the ALS and proximity sensor.

A complete API is also associated to the device which consists of a set of C functions controlling the VL6180X to enable fast development of end-user applications. This API is structured in a way that it can be complied on any kind of platform through a well isolated platform layer (mainly for low level I^2C access). It is available for download from www.st.com.

It is assumed in the rest of the document that the host application is controlling the VL6180X device through its C API.

For a more detailed explanation of the API functions please refer to the documentation that is supplied with the API.

Typical ranging performance of the VL6180X is shown in *Figure 6*. This demonstrates the reflectance independence and range accuracy of the VL6180X from 0 to 100 mm for 3%, 5%, 17% and 88% reflective targets. The example shown here is with ST cover glass and a 1.0 mm air gap.

Figure 7 shows typical ALS linearity vs gain over a wide dynamic range. More details about the ambient light sensor can be found in *Section 2.10*.

Figure 6. Typical ranging performance

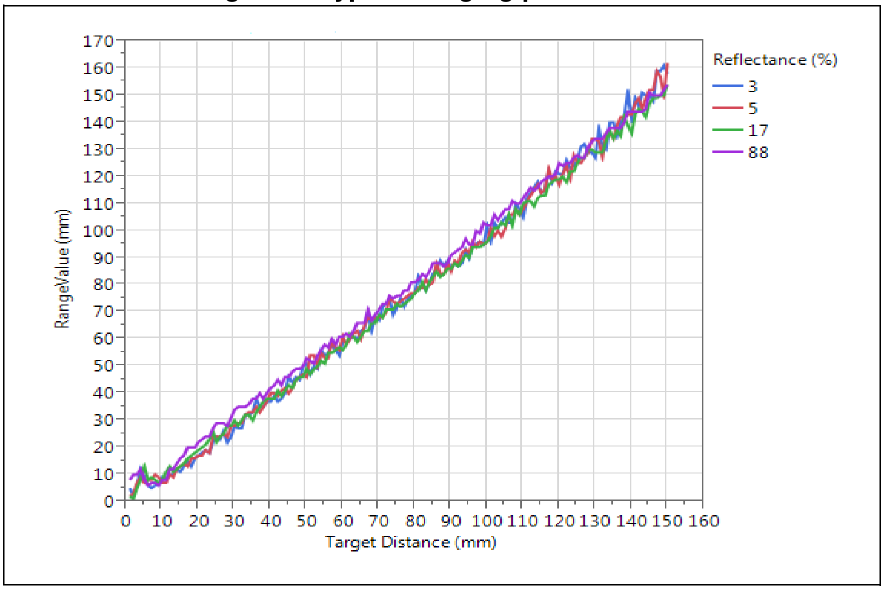
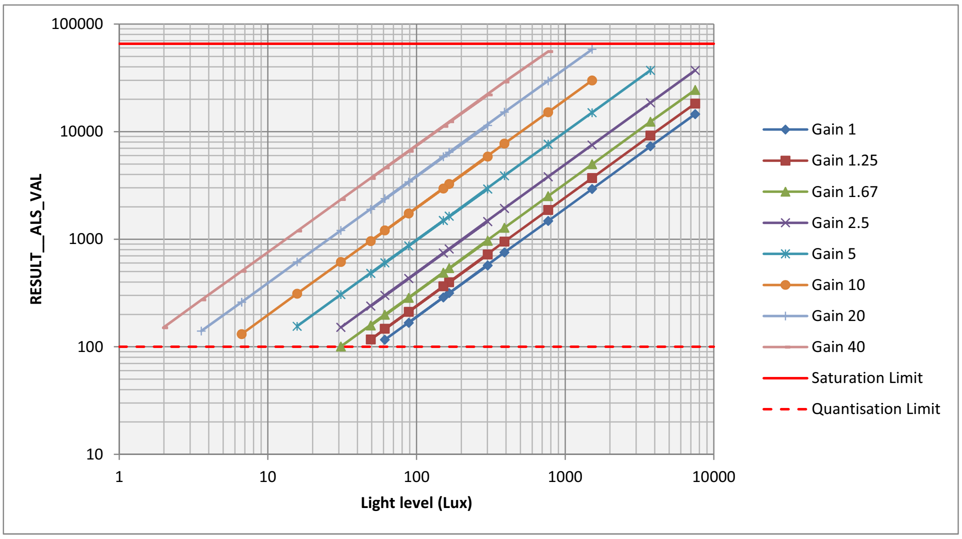


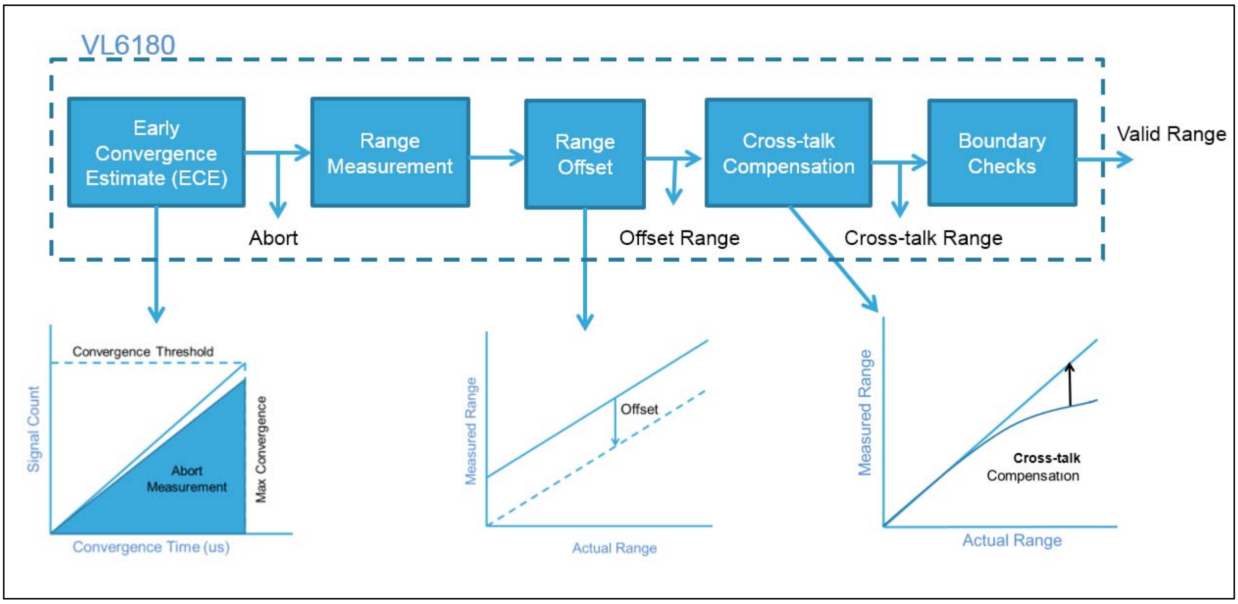
Figure 7. ALS linearity



2.1 Ranging pipe

The VL6180X uses a simple architecture to achieve range measurement.

Figure 8. Ranging pipe architecture



2.2 System state diagram

Figure 9 describes the main operating states of the VL6180X. Hardware standby is the reset state (GPIO0=0)[a]. The device is held in reset until GPIO0 is de-asserted. Note that the device will not respond to I^2C communication in this mode. When GPIO0=1, the device enters software standby after the internal MCU boot sequence has completed.

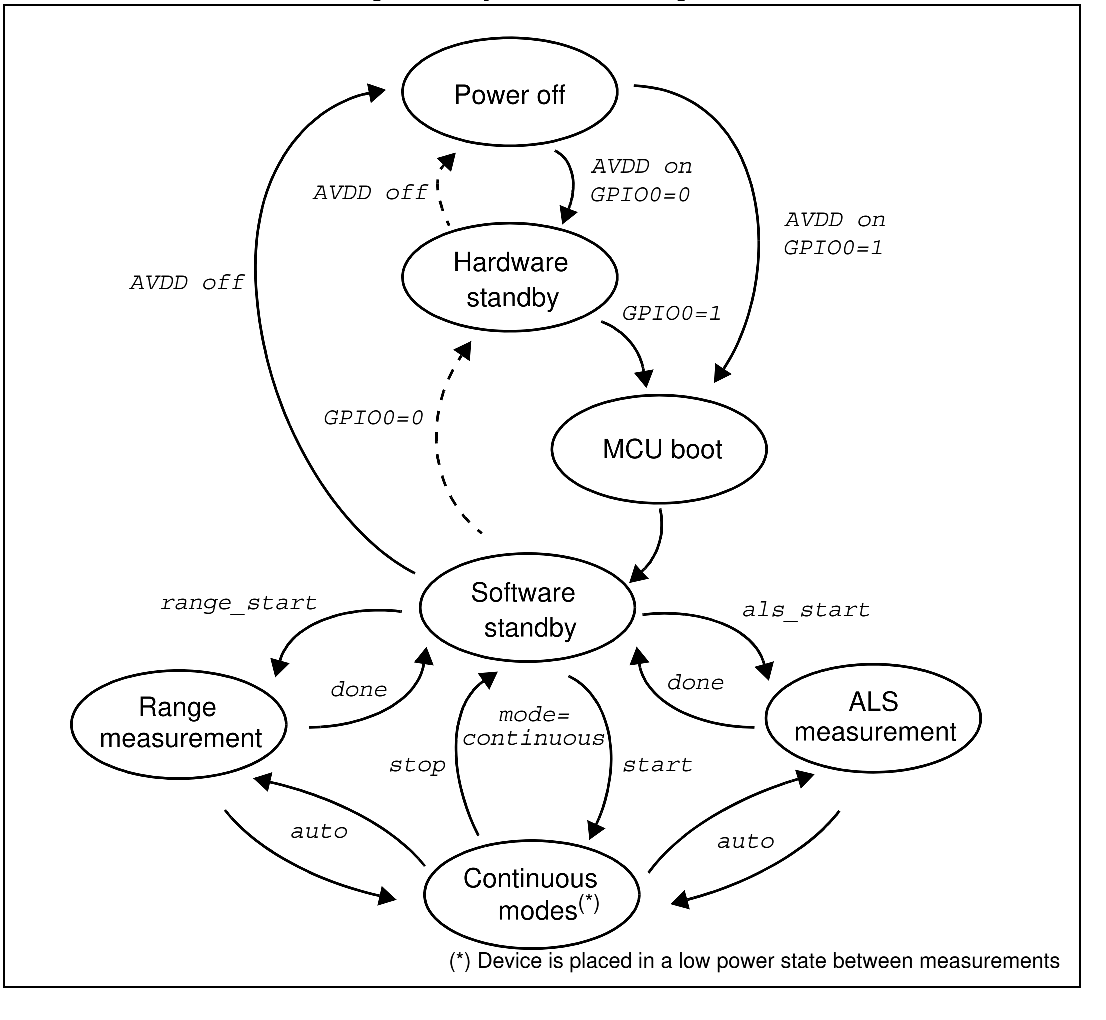
From customer application point of view, the following sequence must be followed at the power-up stage

- Set GPIO0 to 0
- Set GPIO0 to 1
- Wait for a minimum of 400µs
- Call **VL6180x_WaitDeviceBooted()**[b] API function (or wait for 1ms to ensure device is ready).

Then, at this stage, through API functions calls, it is possible to:

1. Configure the device to start single-shot ranging or ALS measurements.
2. Configure the device into continuous mode where the device uses an internal timer to schedule range/ALS measurements at specified intervals. See *Section 2.5.4: Interleaved mode*.

Figure 9. System state diagram



a. Use of GPIO0 is optional

b. Warning: The **VL6180x_WaitDeviceBooted()** function expects the device to be fresh out of reset. Calling this function when the device is not fresh out of reset will result in an infinite loop.

2.3 Timing diagram

Figure 10 and *Table 4*.show the Root part number 1 power-up timing constraints.

- AVDD_VCSEL must be applied before or at the same time as AVDD.
- GPIO0 defaults to an active low shutdown input. When GPIO0 = 0, the device is in hardware standby. If GPIO0 is not used it should be connected to AVDD.
- The internal microprocessor (MCU) boot sequence commences when AVDD is up and GPIO0 is high whichever is the later.
- GPIO1 power-up default is output low. It is tri-stated during the MCU boot sequence.

Note: In hardware standby, GPIO1 is output low and will sink current through any pull-up resistor. This leakage can be minimized by increasing the value of the pull-up resistor.

- After the MCU boot sequence the device enters software standby. Host initialization can commence immediately after entering software standby.

Figure 10. Power-up timing

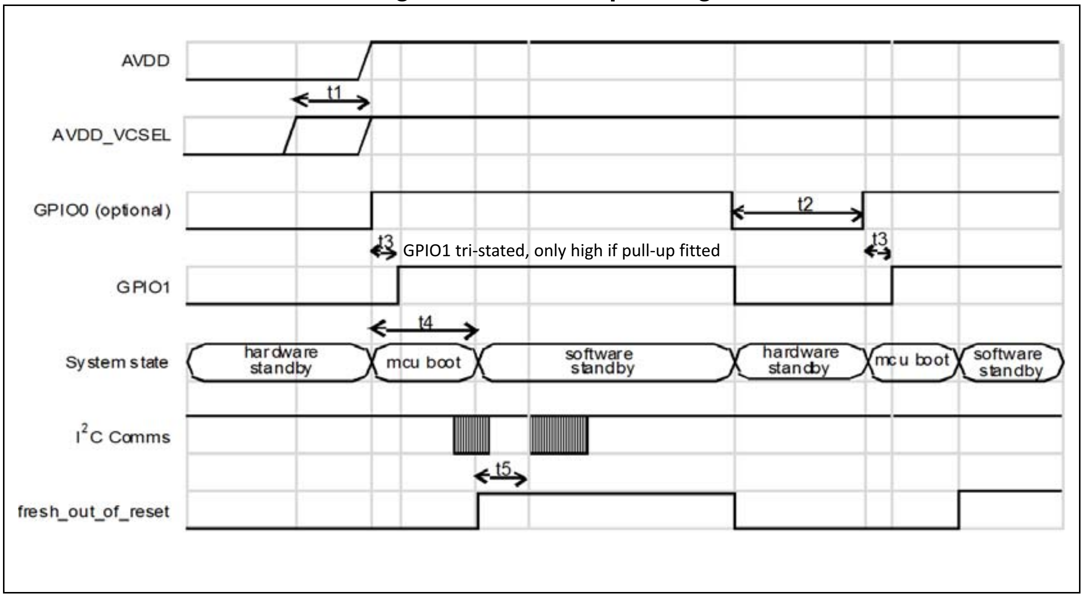


Table 4. Power-up timing constraints

Symbol	Parameter	Min	Max	Unit
t1	AVDD_VCSEL power applied after AVDD	-	0	ms
t2	Minimum reset on GPIO0	100	-	ns
t3	GPIO1 output low after hardware standby	-	400	µs
t4	MCU boot	-	1	ms
t5	Software standby to host initialization	-	0	ms

2.4 Software overview

Figure 11 shows a simple start-up routine from initialization to completing an ALS measurement while *Figure 12* shows a simple start-up routine from initialization to completing a range measurement.

Figure 11. Simple ALS routine

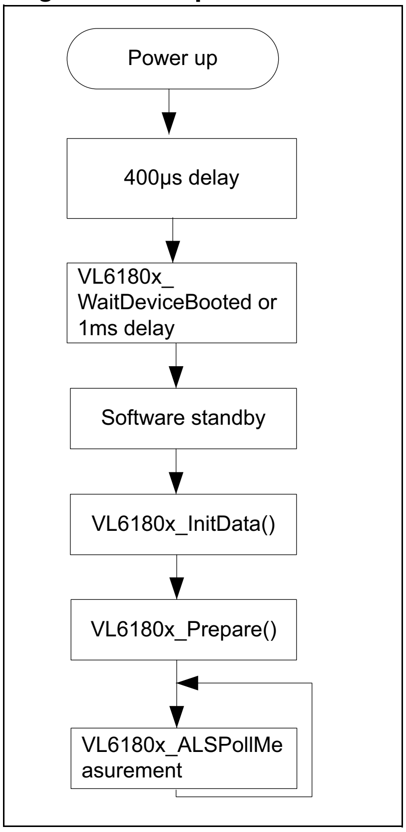
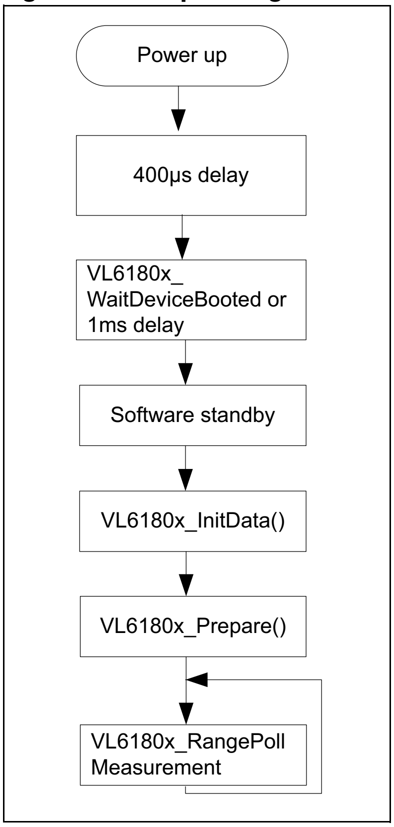


Figure 12. Simple range routine



2.5 Operating modes

The VL6180X device can operate in 2 different modes:

Single-shot measurement or Continuous measurement for both ranging and ALS.

From these 2 device modes, the Vl6180X API enables 3 different typical operating range modes: Polling, interrupt or asynchronous. And 3 different ALS modes: Polling, interrupt and interleaved.

Table 5. describes the operating modes of this device supported by the API.

- Modes 1 and 2 are single-shot range and ALS measurements.
- Modes 3 and 4 are continuous range and ALS operation.
- Mode 5 allows both ALS and range measurements to be scheduled at regular intervals. The ALS measurement is completed first immediately followed by a range measurement. Interleaved mode is described in more detail in *Section 2.5.4*.

Table 5. API supported operating modes

Mode	Function	Range		ALS		Priority
		Single	Continuous	Single	Continuous	
1	Range single-shot	•				Range
2	ALS single-shot			•		ALS
3	Range continuous		•			Range
4	ALS continuous				•	ALS
5	Interleaved mode: Range Continuous and ALS Continuous		•		•	-

Note: Single-shot ALS and range operations cannot be performed simultaneously. Only one of these operations should be performed at any one time and once started must be allowed to complete before another measurement is started. This is because any current operation will be aborted if another is started.

Wrap Around Filter is not available in Continuous range measurement mode.

Table 6. VL6180X range operating modes

API operating mode	Description	API functions	VL6180X mode	Comments
Polling	Host requests single shot measurement and waits for the result	VL6180x_RangePollMeasurement	Single shot	Recommended for first API porting or debug
Interrupt	Ranging results are retrieved from interrupts	VL6180x_RangeSetInterMeasPeriod VL6180x_SetupGPIO1 VL6180x_RangeConfigInterrupt (VL6180x_RangeSetThreshold) VL6180x_RangeStartContinuousMode VL6180x_RangeGetMeasurement VL6180x_ClearAllInterrupt	Continuous	Recommended for User Detection applications where CPU is interrupted by VL6180X so can be asleep when no target is detected (power saving)
Asynchronous	Host requests a single shot measurement and regularly checks to see if result is ready or not	VL6180x_RangeStartSingleShot VL6180x_RangeGetMeasurementIfReady	Single shot	Recommended for AF-Assist applications, Android OS-based system where CPU is synchronized by EOF/SOF from camera or by a timer so that top application controls measurement periods

Table 7. VL6180X ALS operating modes

API operating mode	Description	API functions	VL6180X mode	Comments
Polling	Host requests single shot measurement and waits for the result	VL6180x_ALSPollMeasurement	Single shot	Recommended for first API porting or debug
Interrupt	ALS results are retrieved from interrupts	VL6180x_SetupGPIO1 VL6180x_AlsConfigInterrupt (VL6180x_AlsSetThresholds) VL6180x_AlsSetSystemMode(Mode_SingleShot) VL6180x_AlsGetMeasurement VL6180x_ClearAllInterrupt	Single shot	Recommended for AF-Assist applications, where it is used along side ranging.
Interrupt	ALS results are retrieved from interrupts	VL6180x_AlsSetInterMeasurementPeriod VL6180x_SetupGPIO1 VL6180x_AlsConfigInterrupt (VL6180x_AlsSetThresholds) VL6180x_AlsStartContinuousMode VL6180x_AlsGetMeasurement VL6180x_ClearAllInterrupt	Continuous	New ALS value available once per inter-measurement period as defined by user
Interleaved	ALS and ranging results are retrieved from interrupts	VL6180x_AlsConfigInterrupt VL6180x_AlsSetInterMeasurementPeriod VL6180x_StartInterleavedMode (calls VL6180x_AlsStartContinuousMode) VL6180x_AlsGetMeasurement VL6180x_RangeGetMeasurement VL6180x_AlsStopInterleavedMode (calls VL6180x_AlsStopContinuousMode)	Continuous	New ALS and Range values available once per inter-measurement period as defined by user. See *Figure 9*

Although not supported by the API, it is possible to do a mix of continuous Range and single shot ALS measurements or continuous ALS and single shot Range measurements, as shown below.

- Mode 6 is mixed continuous range and single-shot ALS operation where regular ranging measurements are required with only the occasional ALS measurement.
- Mode 7 is mixed continuous ALS and single-shot range operation where regular ALS measurements are required with only the occasional range measurement.

Table 8. Non API operating modes

Mode	Function	Range		ALS		Priority
		Single	Continuous	Single	Continuous	
6	Range continuous and ALS single-shot		•	•		ALS
7	ALS continuous and Range single-shot	•			•	Range

In modes 6 and 7, single-shot operation takes the priority i.e. if a scheduled measurement is in progress when the host requests a single-shot measurement, the scheduled measurement will be aborted and will resume on the next available time slot.

2.5.1 Polling mode - single shot range/ALS measurement

Host calls a blocking API function that requests a single shot measurement and waits for the result. CPU is blocked during this measurement request.

Figure 13. Range polling mode

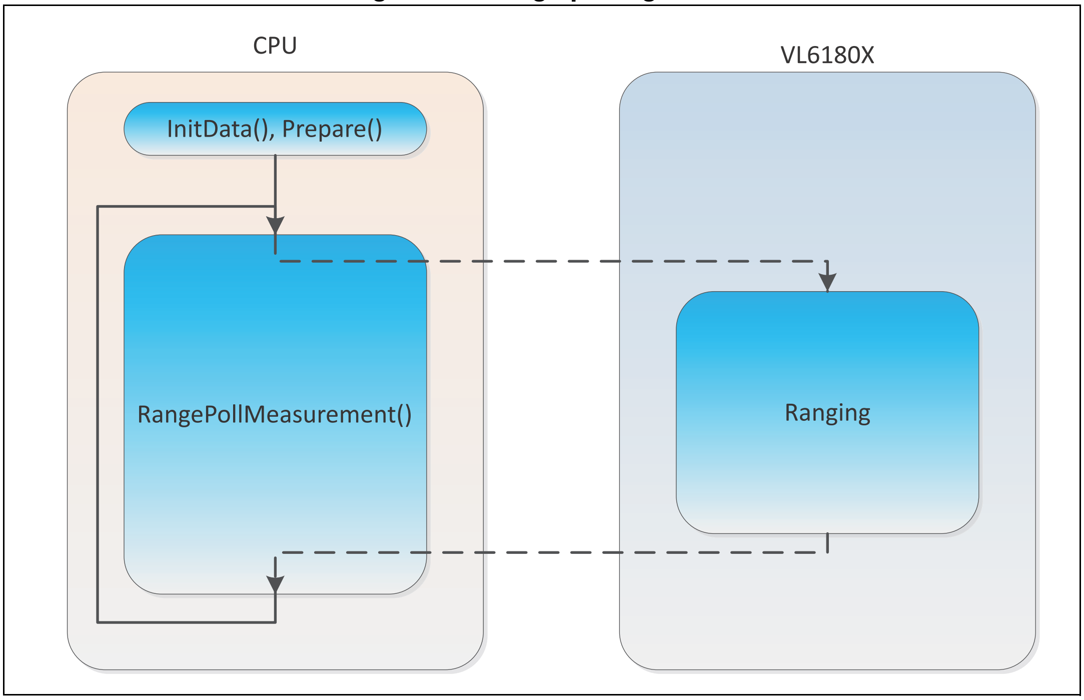
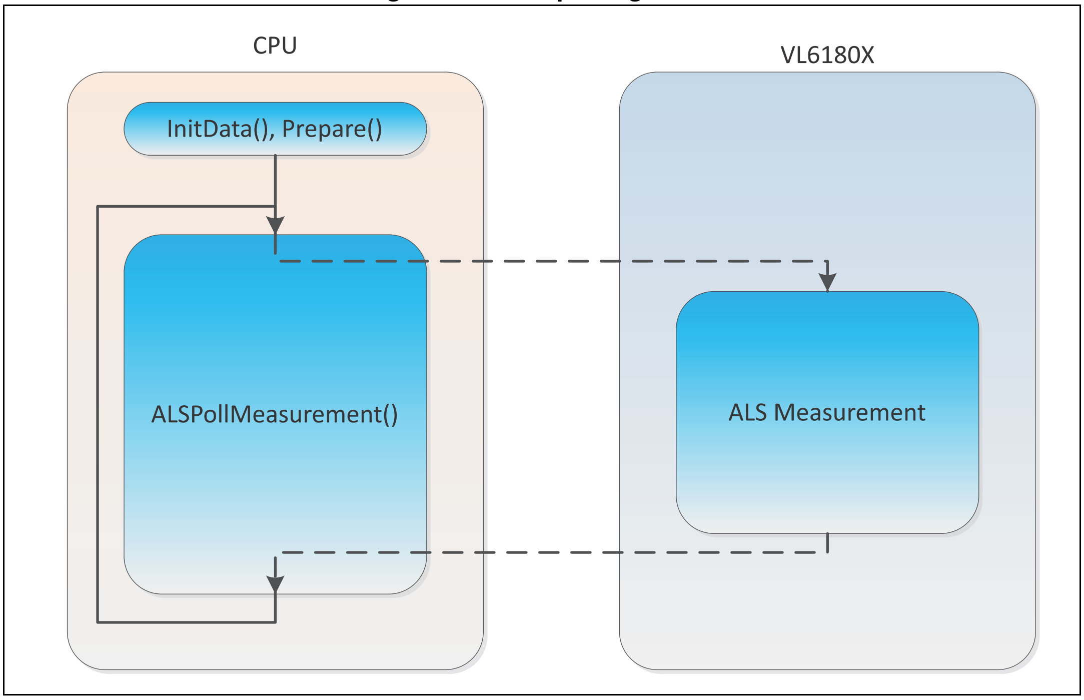


Figure 14. ALS polling mode



2.5.2 Interrupt mode

The host programs the device in continuous mode and ranging or ALS results are retrieved from interrupts.

Figure 15. Range Interrupt mode

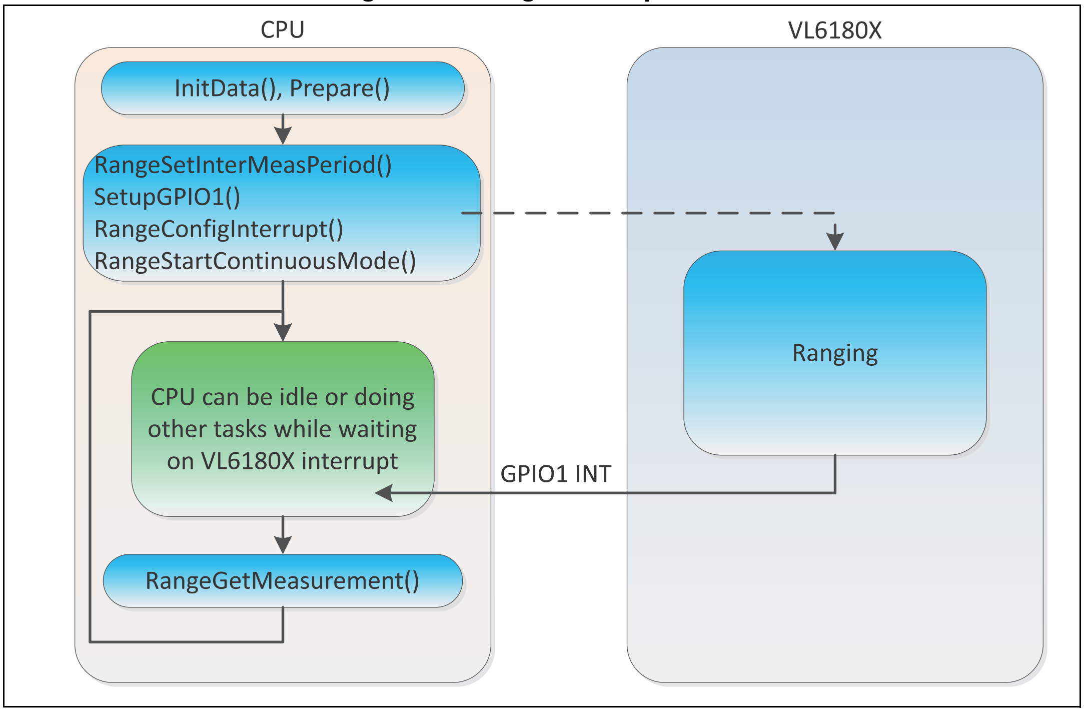
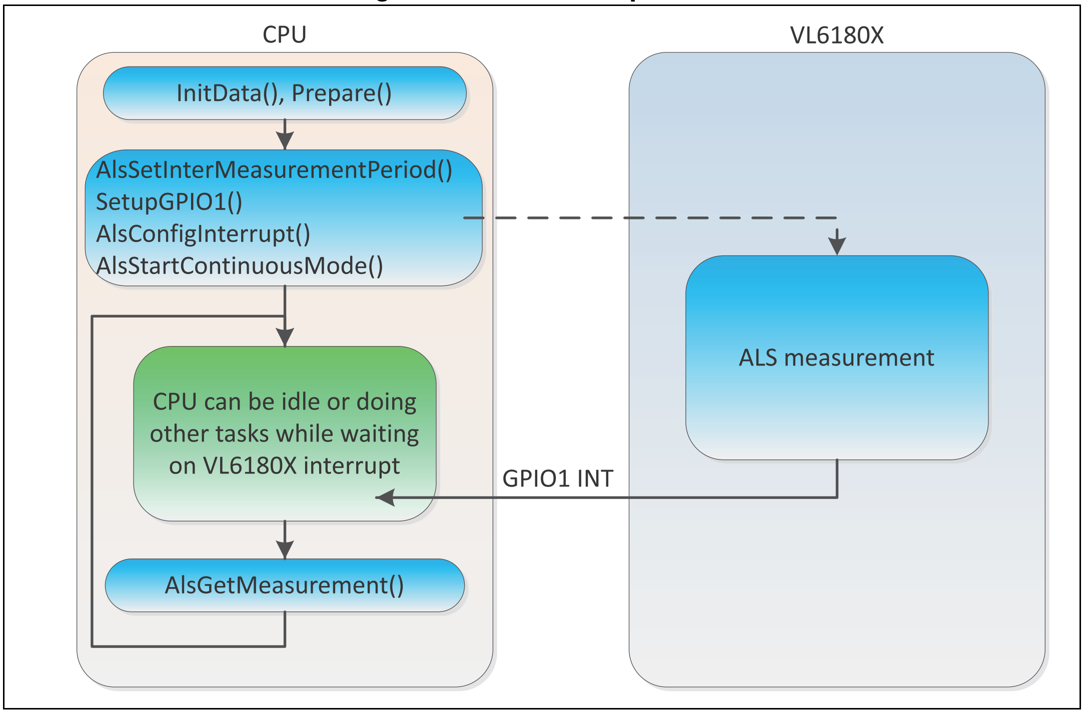


Figure 16. ALS Interrupt mode



It is not recommended to run range and ALS continuous modes simultaneously (i.e. asynchronously). Instead, mode 7 'interleaved mode' in *Table 5.* should be used.
In 'interleaved mode', scheduled range and ALS measurements operate off a single timer with a range measurement proceeding immediately after every ALS measurement.

VL6180x_RangeConfigInterrupt() or VL6180x_AlsConfigInterrupt()

The VL6180X can be configured to generate a range or ALS interrupt flag under any of the following conditions:

- New sample ready
- Level low (range/ALS value < low threshold)
- Level high (range/ALS value > high threshold)
- Out of window (range/ALS value < low threshold) OR (range/ALS value > high threshold)

In new sample ready mode (continuous mode - WAF disabled), an interrupt flag will be raised at the end of every measurement irrespective of whether the measurement is valid or if an error has occurred.
In level interrupt mode the system will raise an interrupt flag if either a low or high programmable threshold has been crossed.
Out of window interrupt mode activates both high and low level thresholds allowing a window of operation to be specified.

Range interrupt modes are selected via **VL6180x_RangeConfigInterrupt()** with **VL6180x_RangeSetThresholds()** used to set thresholds. Use **VL6180x_RangeGetInterruptStatus()** to return the ranging interrupt status.

ALS interrupt modes are selected via **VL6180x_AlsConfigInterrupt()** with **VL6180x_AlsSetThresholds()** used to set thresholds. Use **VL6180x_AlsGetInterruptStatus()** to return the ALS interrupt status.

Note: In level or window interrupt modes range errors will only trigger an interrupt if the logical conditions described above are met.

Continuous mode limits

To take account of oscillator tolerances and internal processing overheads it is necessary to place the following constraints on continuous mode operations. The following equations define the minimum inter-measurement period to ensure correct operation:

Continuous range:

VL6180x_RangeSetMaxConvergenceTime() + 5 ≤
VL6180x_RangeSetInterMeasPeriod() * 0.9

Continuous ALS:

VL6180x_AlsSetIntegrationPeriod() * 1.1 ≤
VL6180x_AlsSetInterMeasurementPeriod() * 0.9

Interleaved mode:

(**VL6180x_RangeSetMaxConvergenceTime()** + 5) +
(**VL6180x_AlsSetIntegrationPeriod()** * 1.1) ≤
VL6180x_AlsSetInterMeasurementPeriod() * 0.9

Table 9. gives an example how to apply these limits in continuous interleaved mode operating at a sampling rate of 10 Hz.

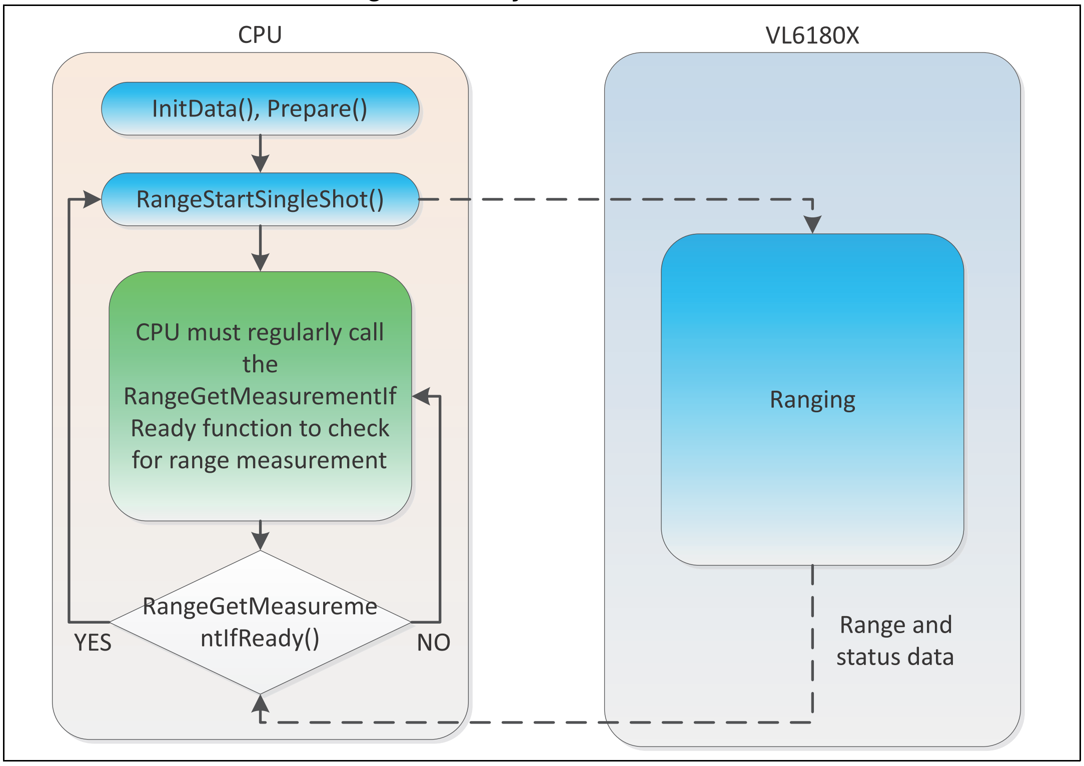
Table 9. Interleaved mode limits (10 Hz operation)

Parameter	Period (ms)
VL6180x_AlsSetInterMeasurementPeriod()	100
Effective ALS INTERMEASUREMENT PERIOD	**90**
VL6180x_RangeSetMaxConvergenceTime()	30
Total RANGE EXECUTION TIME	**35**
VL6180x_AlsSetIntegrationPeriod()	50
Total ALS INTEGRATION TIME	**55**
TOTAL EXECUTION TIME	**90**

2.5.3 Asynchronous mode - single shot range measurement

Host requests a single shot measurement and can either check regularly to see if result is ready or wait for an interrupt then call **RangeGetMeasurementIfReady()**.

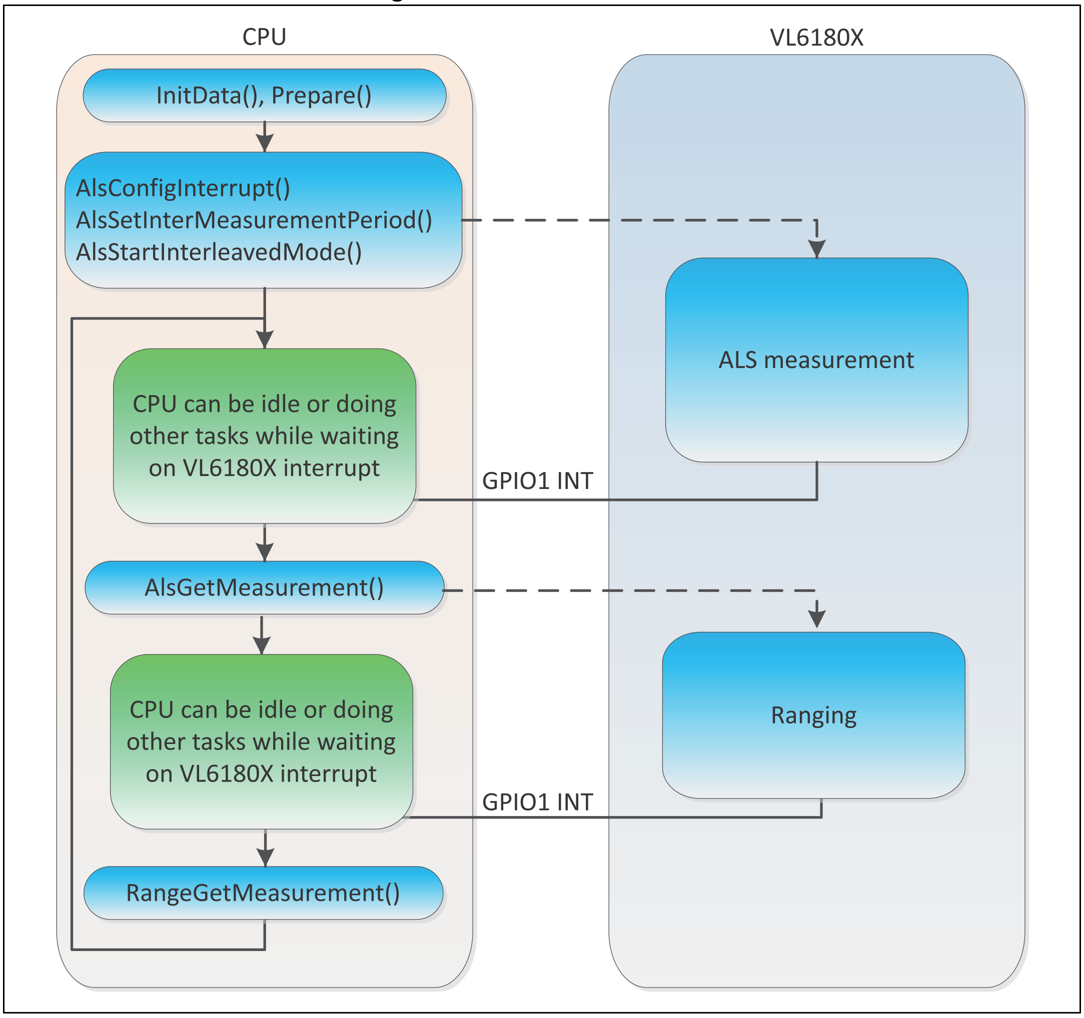
Figure 17. Asynchronous mode



2.5.4 Interleaved mode

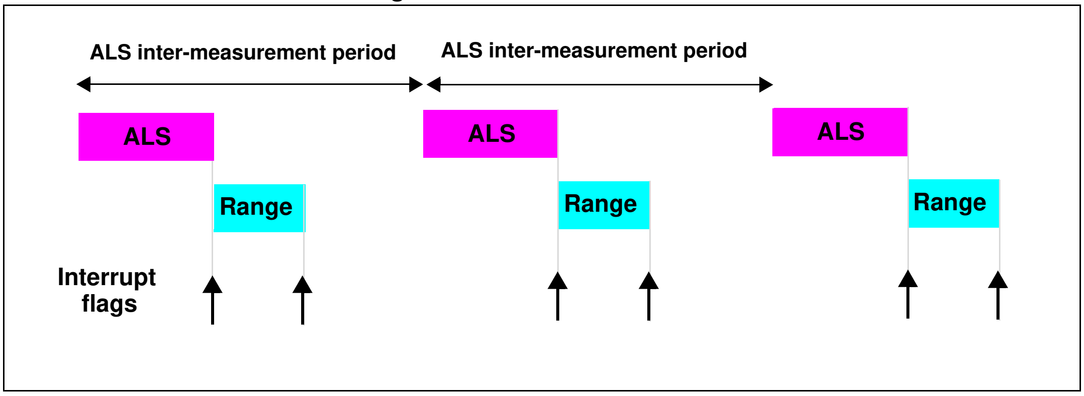
Figure 19. describes the continuous interleaved mode of operation where an ALS measurement is immediately followed by a range measurement and repeated after an interval specified by the ALS inter-measurement period.

Figure 18. Interleaved mode



Note: Continuous range settings have no effect in this mode.

Figure 19. Interleaved mode



Note: To ensure correct operation in any of the continuous modes, the user must ensure that the inter-measurement period is sufficient for the operation to be completed within the inter-measurement period. Failure to do so could result in unpredictable behavior.

2.6 History buffer

History buffer not yet implemented in API.

The history buffer is a 8 x 16-bit memory which can be used to store the last 16 range measurements (8-bit) or 8 ALS samples (16-bit). Use of the history buffer is controlled via register `SYSTEM__HISTORY_CTRL{0x12}`. There are 3 basic functions:

- enable
- range or ALS selection
- clear buffer

The buffer is read via eight 16-bit registers (`RESULT__HISTORY_BUFFER_0{0x52}` to `RESULT__HISTORY_BUFFER_7{0x60})`. The buffer holds the last 16 x 8-bit range or 8 x 16-bit ALS results as shown in *Table 10*.

Table 10. History buffer

History buffer	Range		ALS
	(High byte)	(Low byte)	(Word)
0	Range [15] (newest)	Range [14]	ALS [7] (newest)
1	Range [13]	Range [12]	ALS [6]
2	Range [11]	Range [10]	ALS [5]
3	Range [9]	Range [8]	ALS [4]
4	Range [7]	Range [6]	ALS [3]
5	Range [5]	Range [4]	ALS [2]
6	Range [3]	Range [2	ALS [1]
7	Range [1]	Range [0] (oldest)	ALS [0] (oldest)