Product Document

Published by
ams OSRAM Group

User Guide

UG000436

AS702x

Evaluation Software

User Manual

v2-00 • 2019-Jun-06

Content Guide

1 Introduction

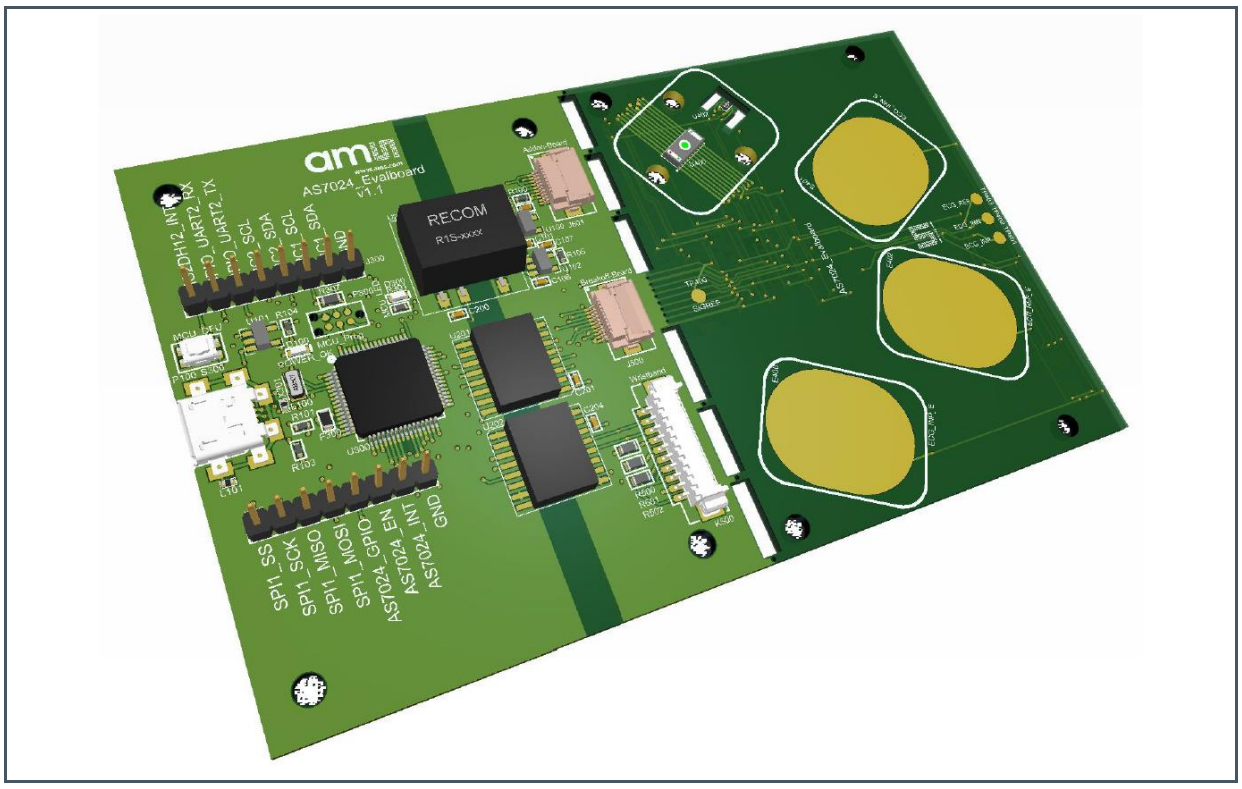
The AS702x Evaluation Kit was designed to evaluate all functions of the AS702x Vital Signs sensor and test them in various applications.

The Evaluation Kit works with USB connection to the PC and comes with a GUI, which enables the user to change AS702x register settings, see measurement results and many more.

The SDK (Software Development Kit) currently contains algorithms for HRM, HRV and BP and is supplied with the Evaluation Kit. The compiled firmware can be flashed onto the STM32 ARM Cortex-M4 low power MCU.

1.1 Kit Content

Figure 1:
The Evaluation Hardware Board



For full flexibility, the vital signs sensor (AS702x), a temperature sensor (AS6200), an accelerometer (LIS2DH12) and three electrodes are located on the break out board, which can be used in any application and re-connected to the main board via FPC cable once broken off. There is also the option to attach external electrodes.

Any signals important for development are accessible for probing at pin headers.

After breaking off the board, it is also possible to connect the AS702x Add-On Board with the FPC cable or the AS702x Wristband via the PicoBlade connector.

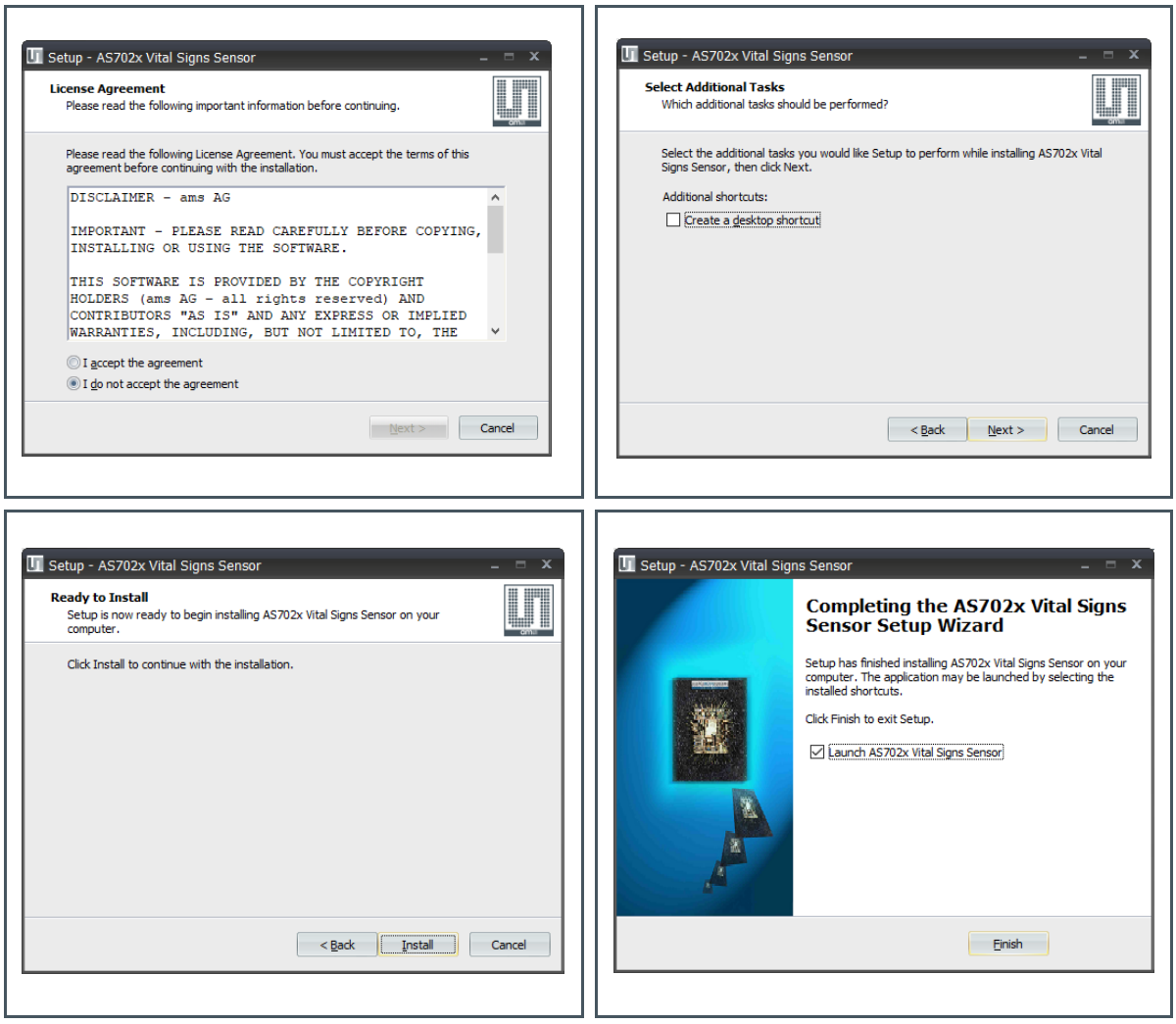
1.2 Ordering Information

Ordering Code	Description
AS7024-EVALKIT	Evaluation Kit for AS7024
AS7026GG-EVALKIT	Evaluation Kit for AS7026GG

2 Getting Started

The client software is available for download on https://download.ams.com/AS702x. To install, start the installer executable and follow the instructions as shown in Figure 2 (left to right top to bottom).

Figure 2:
AS702x Vital Signs Sensor Installation



For Windows OS versions prior to Windows® 10, the STSW-STM32102 virtual COM port driver needs to be installed as well. The driver can be found in the <drivers\STM32_vcp_driver> folder contained within the client software installation path. To install it, go to your OS version directory (Win7 or Win8, OS versions prior to Windows® 7 are compatible with the Windows® 7), then :

1. Double click on dpinst_x86.exe if you are running a 32-bits OS version
2. Double click on dpinst_amd64.exe if you are running a 64-bits OS version
3. Follow the instructions

For updating the FW on the evaluation board over USB, the DfuSe driver from STMicroelectronics has to be installed. This is available in the <drivers\DFU> folder contained within the client software installation path. To install it, go to your OS version directory (Win7, Win8 or Win8.1), then:

1. Go to [x86] directory or [x64] directory based on your OS version:
2. Double click on dpinst_x86.exe if you are running a 32-bits OS version
3. Double click on dpinst_amd64.exe if you are running a 64-bits OS version
4. Follow the instructions

Information

In some cases, it can be necessary that the driver needs to be installed even on a Windows 10 system. In this case chose the driver installer from the Win 8.1 folder and install.

3 Hardware Description

3.1 Hardware Architecture

Figure 3:
Evaluation Hardware Board - Top

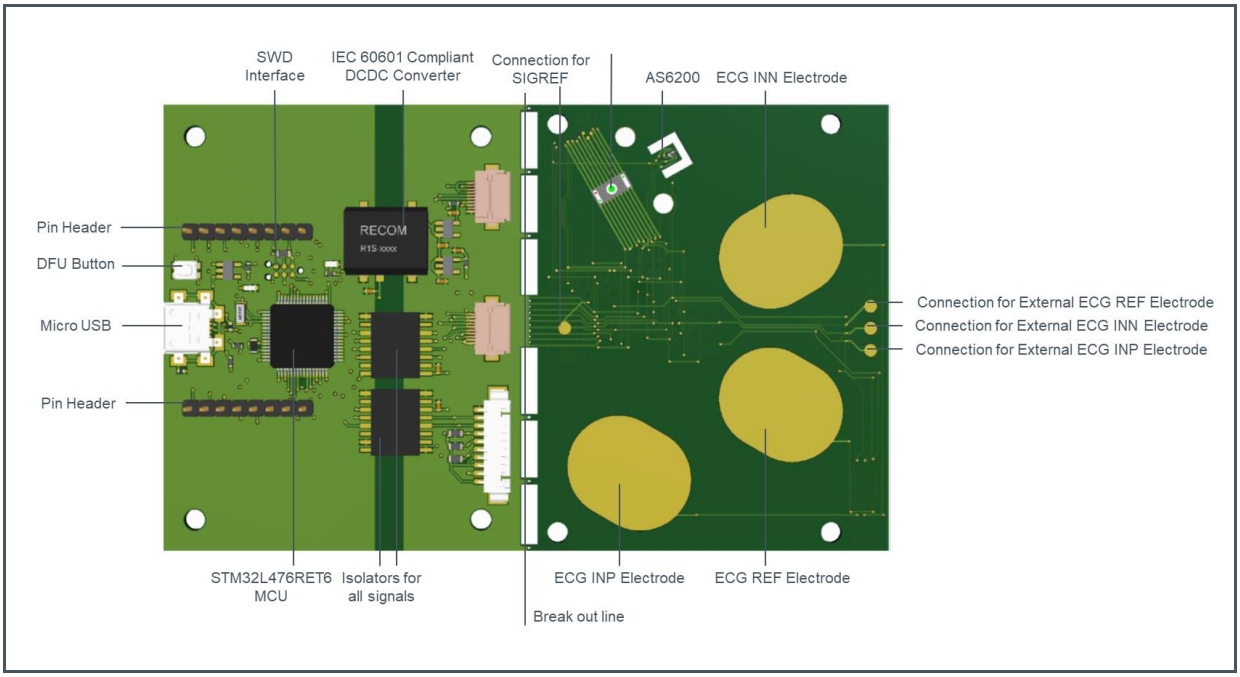
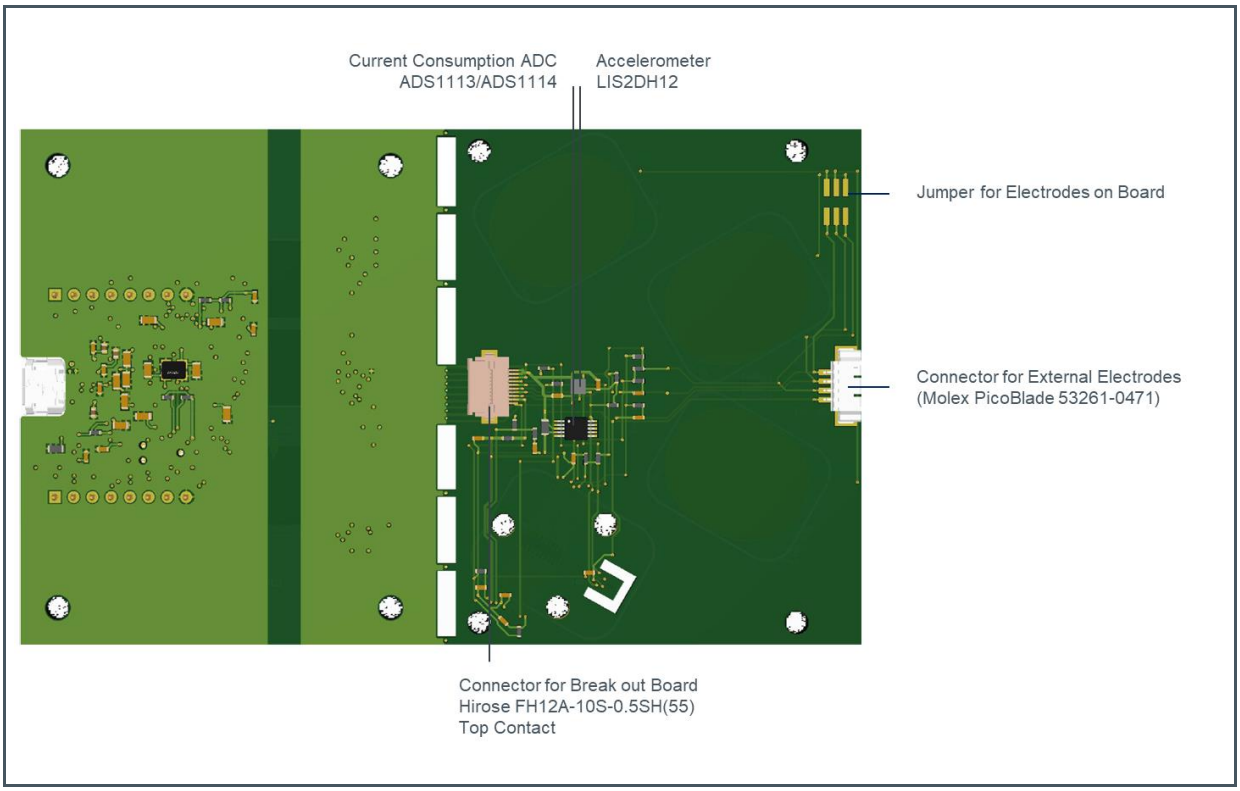
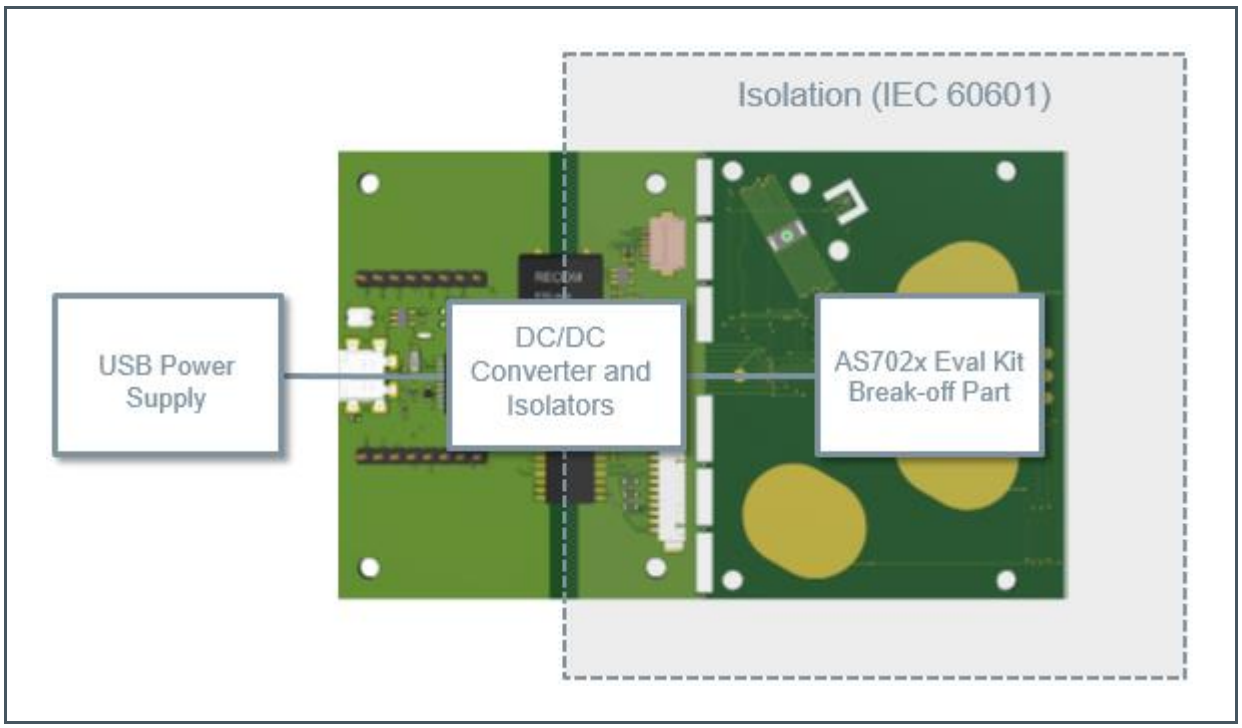


Figure 4:
Evaluation Hardware Board – Bottom



3.2 Power Supply

Figure 5:
Power Supply of AS702x Evaluation Kit



The AS702x Eval Kit is supplied by USB connection to the PC. In order to avoid a direct connection from the electrodes to the power grid, an IEC 60601 compliant RECOM DCDC converter (R0.25S-0505/H or R0.25S-0505/HP) is assembled on the board as well as isolator ICs for any other signals, which means that there is no physical connection between the break out part of the board and the power grid.

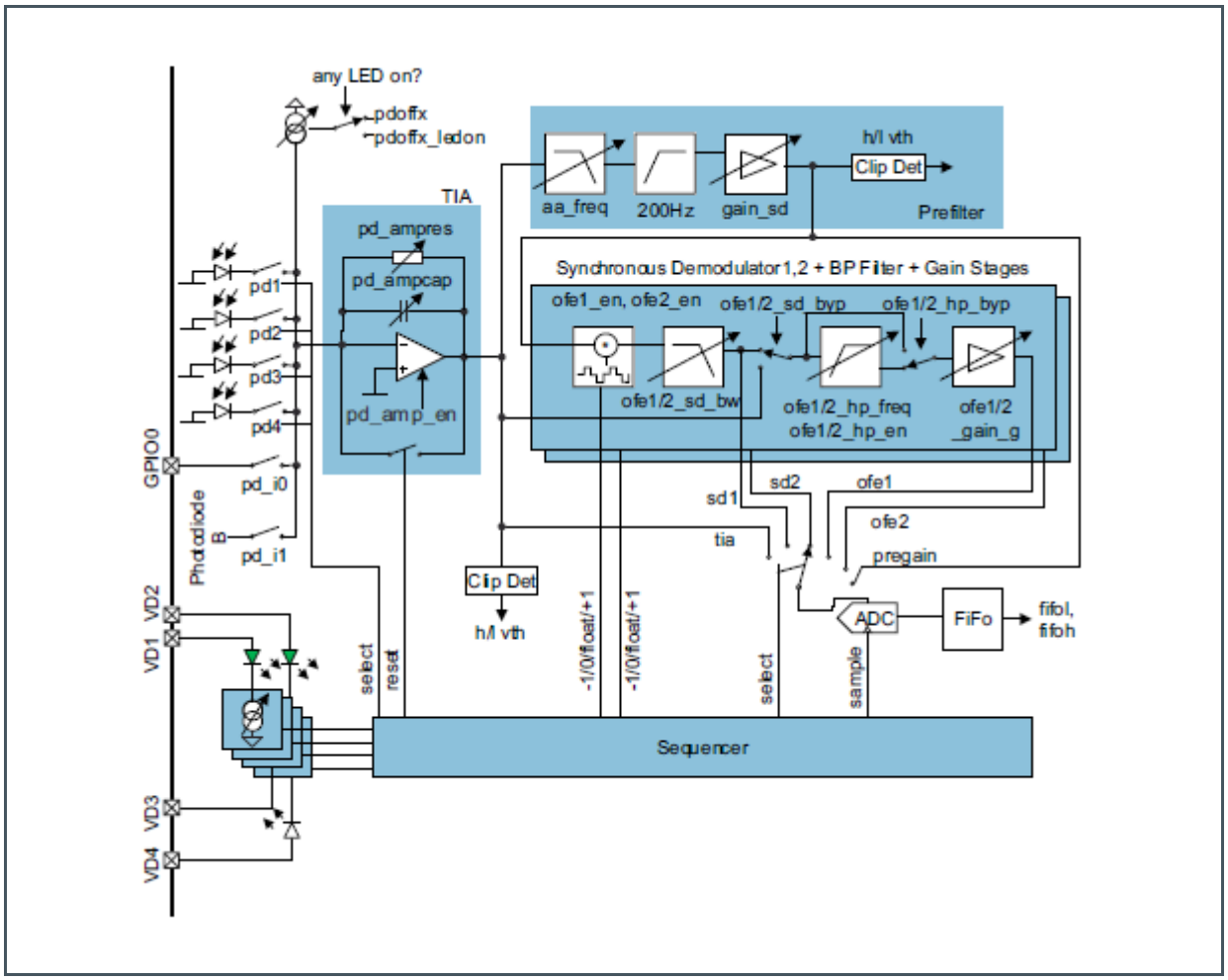
4 AS702X Overview

The AS702X is a photocurrent and voltage sensor capable of taking PPG, ECG, proximity and skin temperature/resistivity measurements. It integrates an optical front end, ECG amplifier, electrical analog front end and light to frequency (LTF) converter. Features a built in sampling sequencer, 128-byte FIFO, a 14-bit SAR ADC, four GPIO pins and an I^2C interface.

4.1.1 Optical Front End

The figure below shows the block diagram of the optical front end.

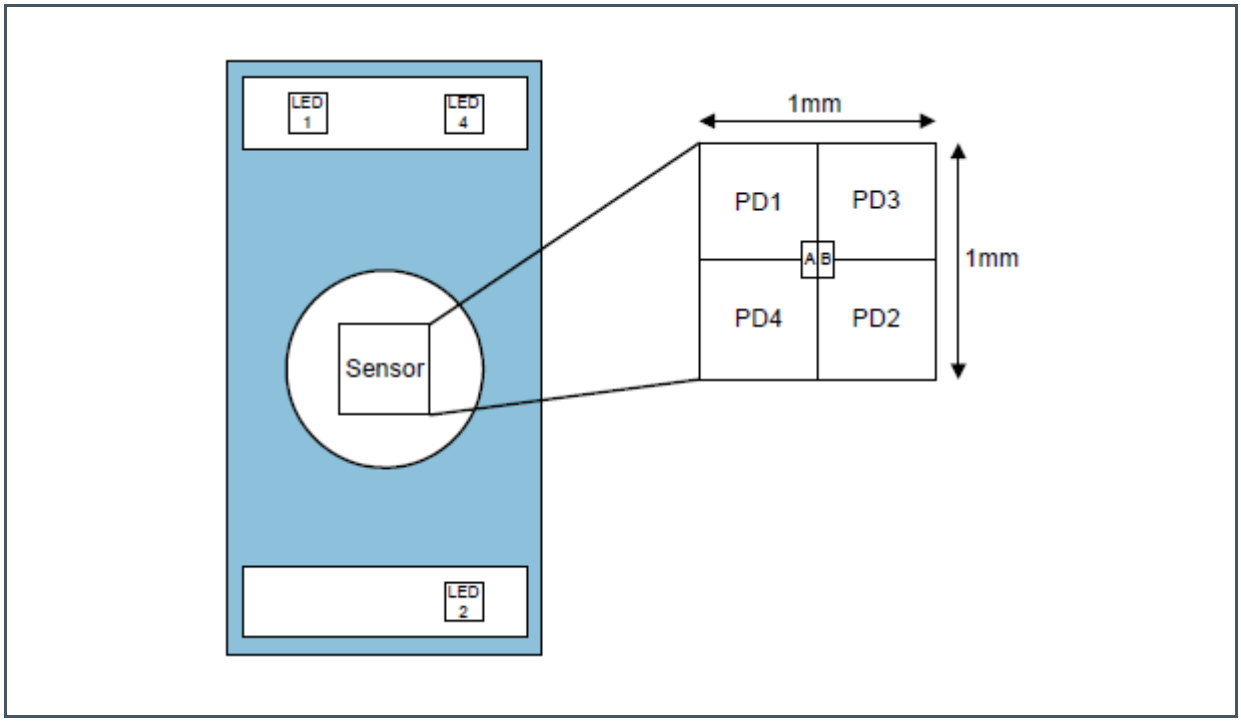
Figure 6:
Optical Front End



The optical front end consists of:

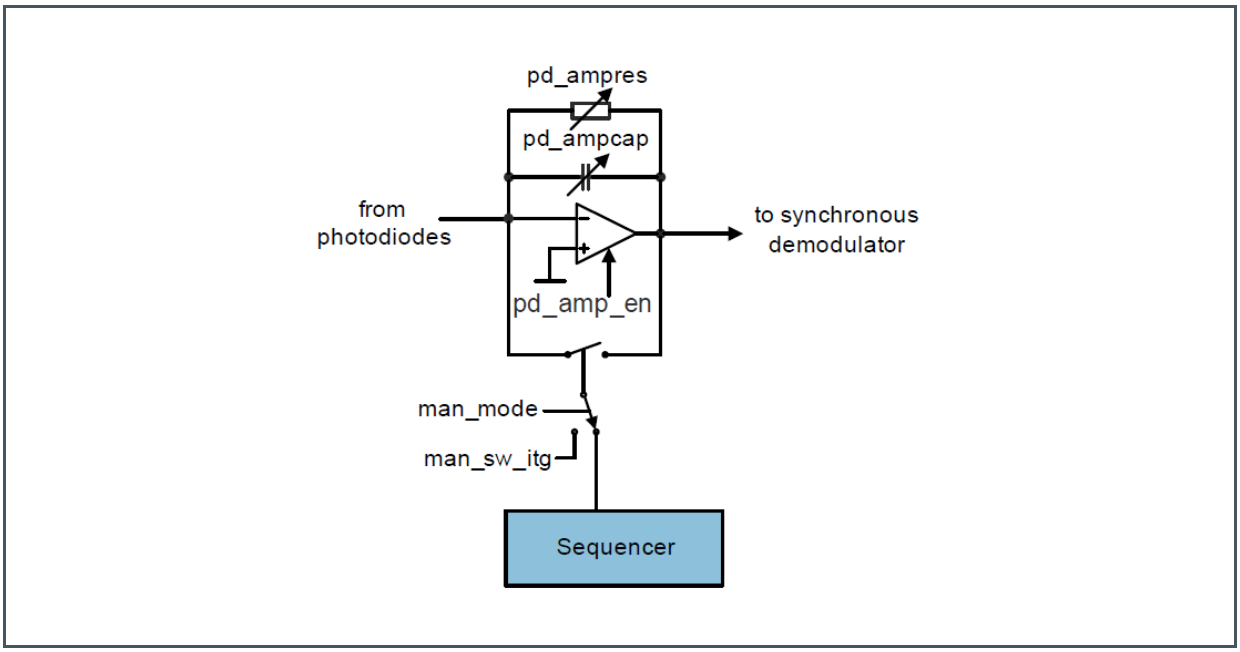
- 4 LEDs, individually configurable, operated manually or controlled by the built in sampling sequencer
  - 2 built in green LEDs (VD1 and VD2)
  - 1 built in IR LED (VD4)
  - 1 free for connecting an external LED to VD3
- 6 photodiodes
  - 4 with green filters (PD1, PD2, PD3 and PD4)
  - 1 IR (B)
  - 1 Clear (A)

Figure 7:
Photodiode Arrangement



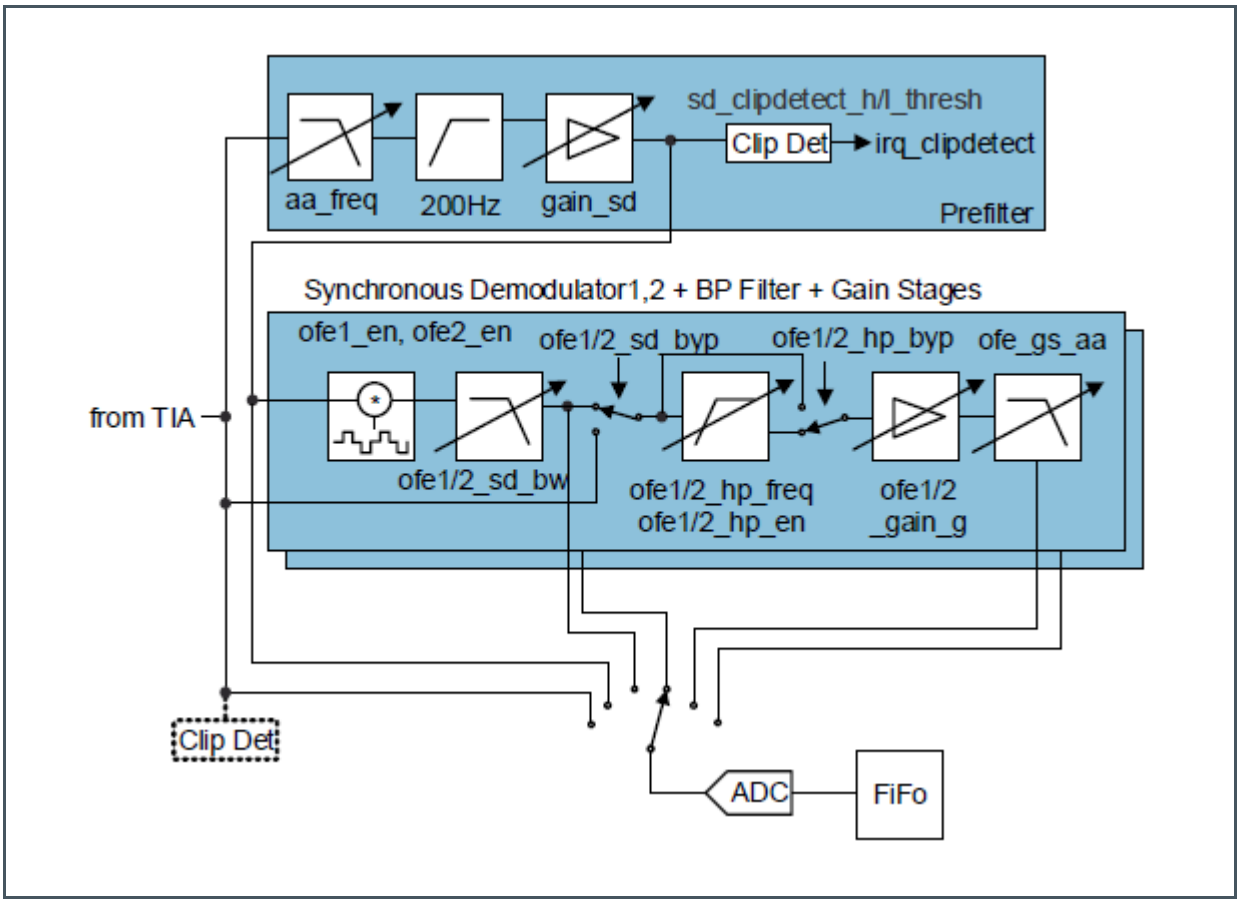
- Trans-impedance amplifier (TIA)
  - Configurable photodiode connection
  - Photodiode input current offset compensation
  - Configurable gain
  - 2 different modes of operation – photocurrent to voltage converter or photocurrent integrator
  - Clip detection

Figure 8:
TIA



- TIA output filter (Prefilter, see Figure 9)
  - Adjustable anti-aliasing low-pass filter
  - 200Hz high-pass filter to remove DC component
  - Adjustable gain stage
  - Clip detection
- 2 identical signal conditioning blocks (OFE1 and OFE2, see Figure 9)
  - Synchronous demodulator – used to extract small optical signals in noisy environment (ambient light)
  - Adjustable synchronous demodulator output low pass filter
  - Adjustable high pass filter for DC component removal
  - Adjustable output gain stage
- Adjustable low pass OFE1/2 output anti-aliasing filter (ofe_gs_aa on Figure 9)

Figure 9:
Optical Signal Conditioning

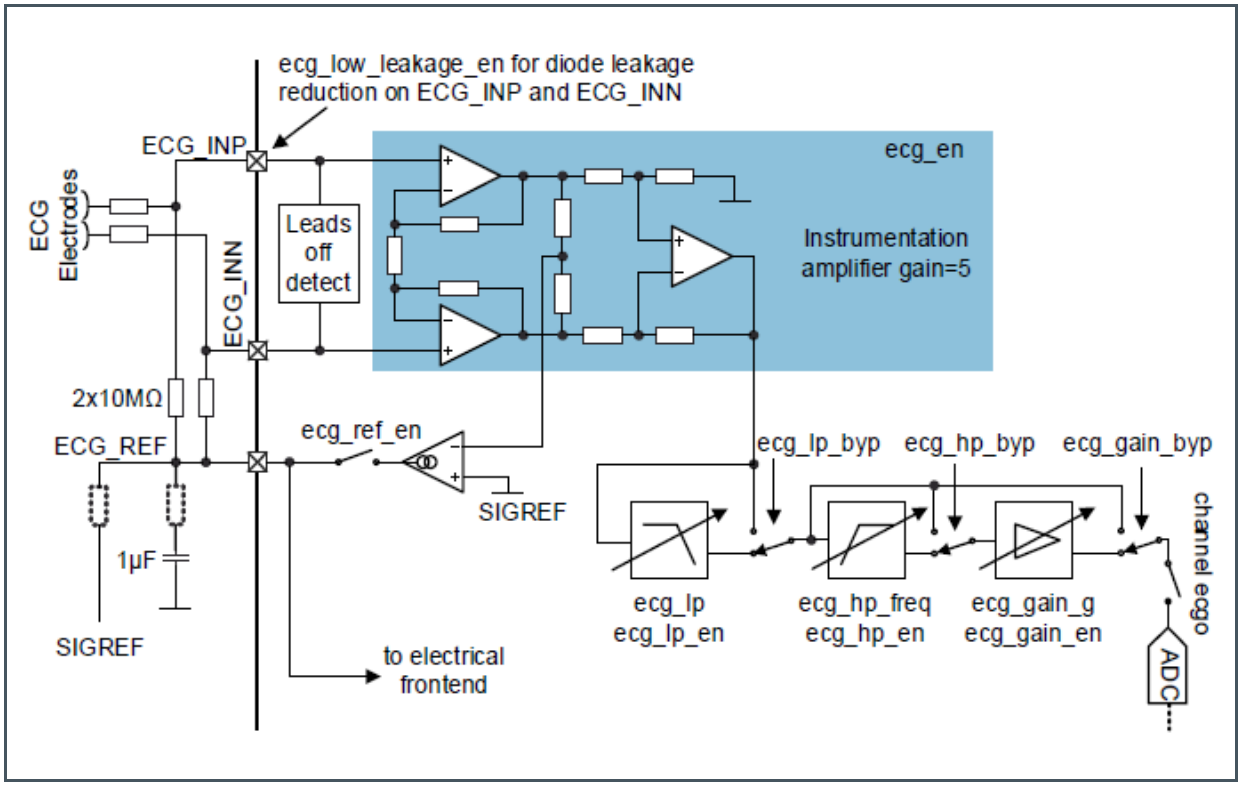


Each of the blocks depicted on Figure 9 can be individually enabled or disabled, and when enabled it is possible to be bypassed.

4.1.2 ECG Amplifier

The output signal of the ECC instrumentation amplifier is band passed with adjustable high-pass and low-pass filters and then amplified with a configurable gain stage. It features ECG lead off detection to check if the user actually touches the ECG leads. Low leakage compensation can also be enabled. The circuitry is missing a 50/60Hz notch filter; such is implemented in the evaluation software.

Figure 10:
ECG Amplifier Circuit



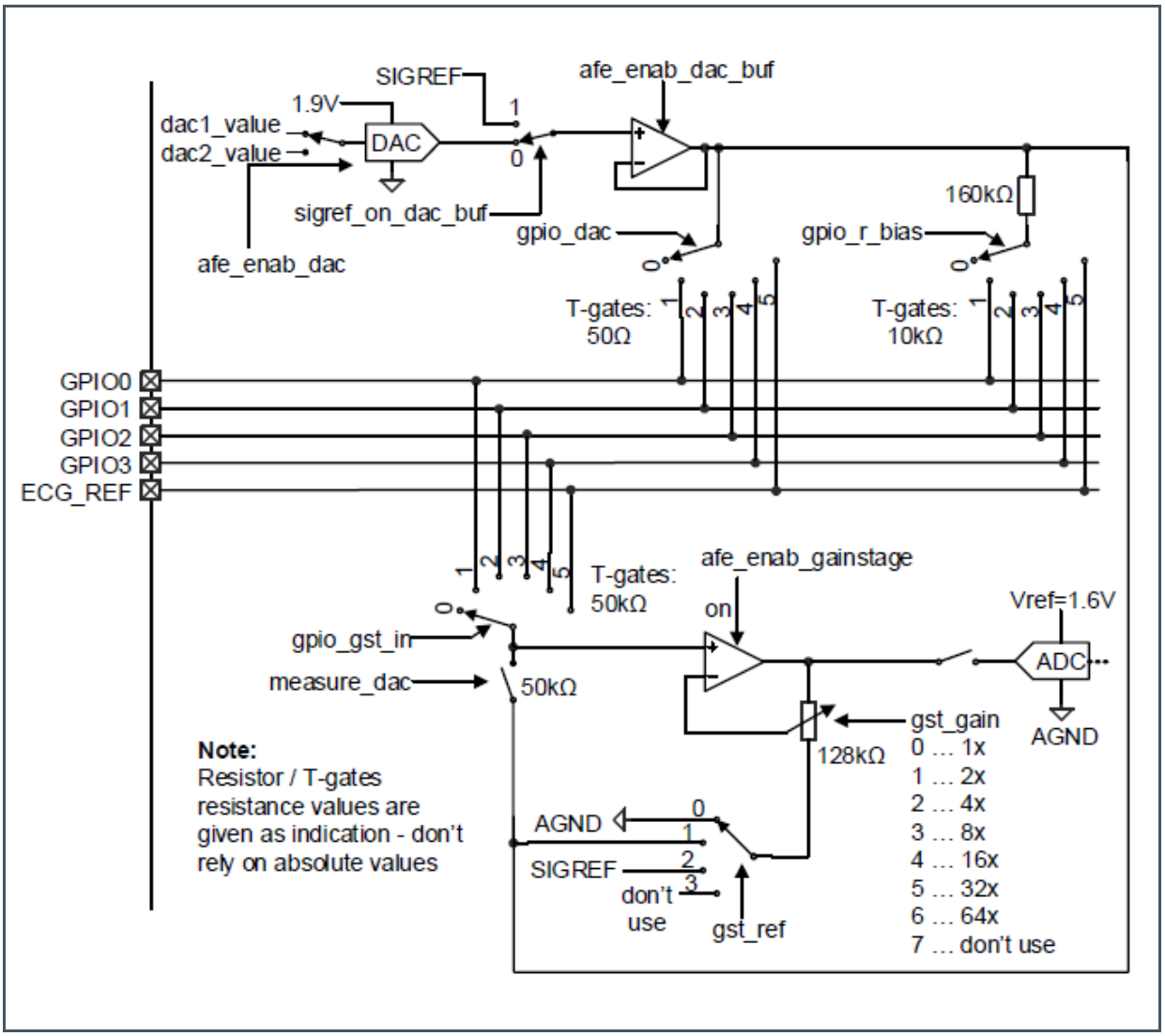
4.1.3 Electrical Analog Front End (EAFE)

The four general-purpose pins and ECG_REF can be used as analog input pins for the electrical analog front end.

The analog inputs configuration sets up different non-inverting amplifier topologies:

- with offset and input voltage divider (temperature sensor)
- with current source and offset (temperature sensor)
- with current source and reference path (temperature sensor)
- with high impedance, GND referenced
- with DC-Blocking, Referenced to V_ADCRef/2
- with DC-blocking and fast settling time, referenced to ADCRef /2

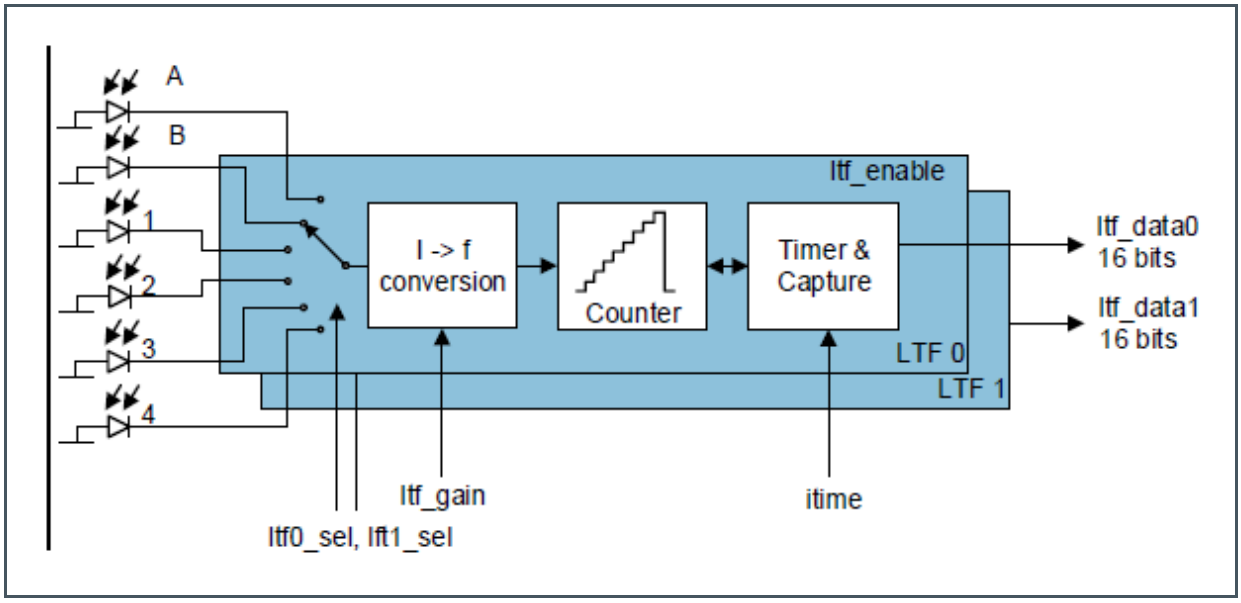
Figure 11:
Electrical Analog Front End



4.1.4 Light-to-Frequency Converter (LTF)

The LTF module can use any of the photodiodes. Photodiodes connected to the LTF cannot be used at the same time with TIA. Integration time (itime) is configured in unit steps, one unit step is 3.702ms. The unit step can be reduced by 2, 4 or 8, this is also reducing the resolution of the conversion. The LTF modulator can be set to run continuously and write the result of each integration to the FIFO.

Figure 12:
Light-to-Frequency Converter



4.1.5 ADC and FIFO

ADC

The ADC is a 14-bit successive approximation register type with input clock of 1MHz. A configurable clock divider can reduce the input clock. One conversion takes 25 clock cycles plus configurable number of ADC settling clock cycles (64 the default for ADC settling cycles). The ADC can be manually triggered by register or automatically triggered by the built in sampling sequencer. Two channel selection registers, ADC_CHANNEL_MASK_L and ADC_CHANNEL_MASK_H, define the channels the ADC will convert. The ADC will start with the channels in ADC_CHANNEL_MASK_L from the LS asserted bit to the MS asserted bit, then continue with the channels in ADC_CHANNEL_MASK_H register again from LS asserted bit to MS asserted bit LS bit. Then wraps back to the LS bit of ADC_CHANNEL_MASK_L. Thus, the ADC will go through each channel in the order shown on Figure 13 with TIA being the first (smallest index), OFE1 second, SD1 third and so on to the GPIO2 being the last.

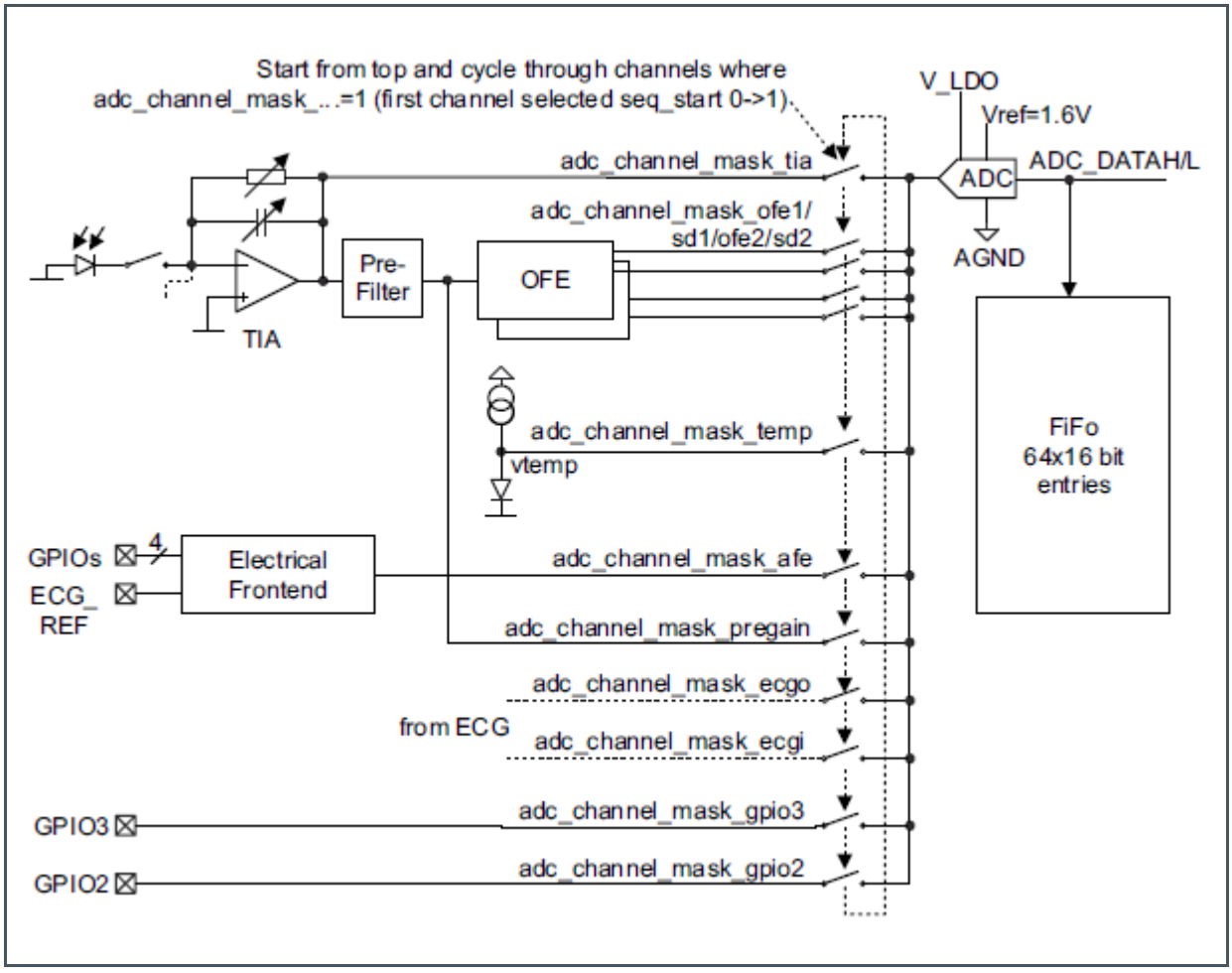
When triggered from the sequencer, the channel selection is set always to the smallest channel when the sequencer starts for the first time. When sequencer starts, then stops and starts again, channel selection will not reset, it will stay at the channel it was on when the sequencer stopped.

When triggered manually, the channel selection resets with every write to one of the channel selection registers.

After each conversion, the sample goes to the FIFO and the channel selection automatically advances to the next enabled channel. The current ADC output is also available in the ADC data register, but as there is no latch mechanism, the data from this register can be inconsistent as the ADC might be running at the time of ADC data register access.

ADC can trigger an interrupt after conversion has finished.

Figure 13:
ADC Channels



FIFO

The AS702X FIFO is 128 bytes long. ADC samples are 2 bytes each, which means, FIFO can hold up to 64 samples. There is a FIFO length register, which gives how much samples are currently available in the FIFO. The FIFO can send an interrupt when the number of available samples reaches a certain configurable threshold.

4.1.6 Digital Interface

GPIO Pins

All four GPIO pins can be digitally controlled and can have pull up/down added. Can be used as analog input pins for the EAFE, GPIO2 and GPIO3 additionally can be used with the ADC.

Interrupts

An interrupt output pin INT is used to interrupt the host. Depending on the setting in register INTENAB each of the interrupt source below can assert INT output pin (active low).

- **irq_adc:** end of ADC conversion
- **irq_sequencer:** end of sequencer sequence reached.
- **irq_ltf:** a light-to-frequency conversion is finished.
- **irq_adc_threshold:** ADC threshold triggered
- **irq_fifothreshold:** FIFO almost full (as defined in register fifo_threshold)
- **irq_fifooverflow:** FIFO overflow (error condition, data is lost)
- **irq_clipdetect:** TIA output and/or SD output exceeded threshold‑ see details in CLIPSTATUS
- **irq_led_supply_low:** led supply low comparator triggered

4.1.7 Sampling Sequencer

The sampling sequencer synchronizes the LED pulsing, the synchronous demodulator, the ADC and the integrator times. The sequencer configuration sets the LED on and off times, synchronous demodulator positive and negative multiplication times, the ADC start time and the integrator start and stop times. The sequencer generates the eight bit-timings based on the 1µs input clock. The input clock can be reduced with a configurable clock divider.

The sequencer executes measurement cycles with a period defined by Equation 1 where SEQ_PER and SEQ_DIV are registers of AS702x having values from 0 to 255 (see pages 38 and 39 in the AS7026GG datasheet):

Equation 1:

$$SEQ\_PER * (SEQ\_DIV + 1) * 1\mu s$$

SEQ_DIV holds the value of the 1µs input clock divider.

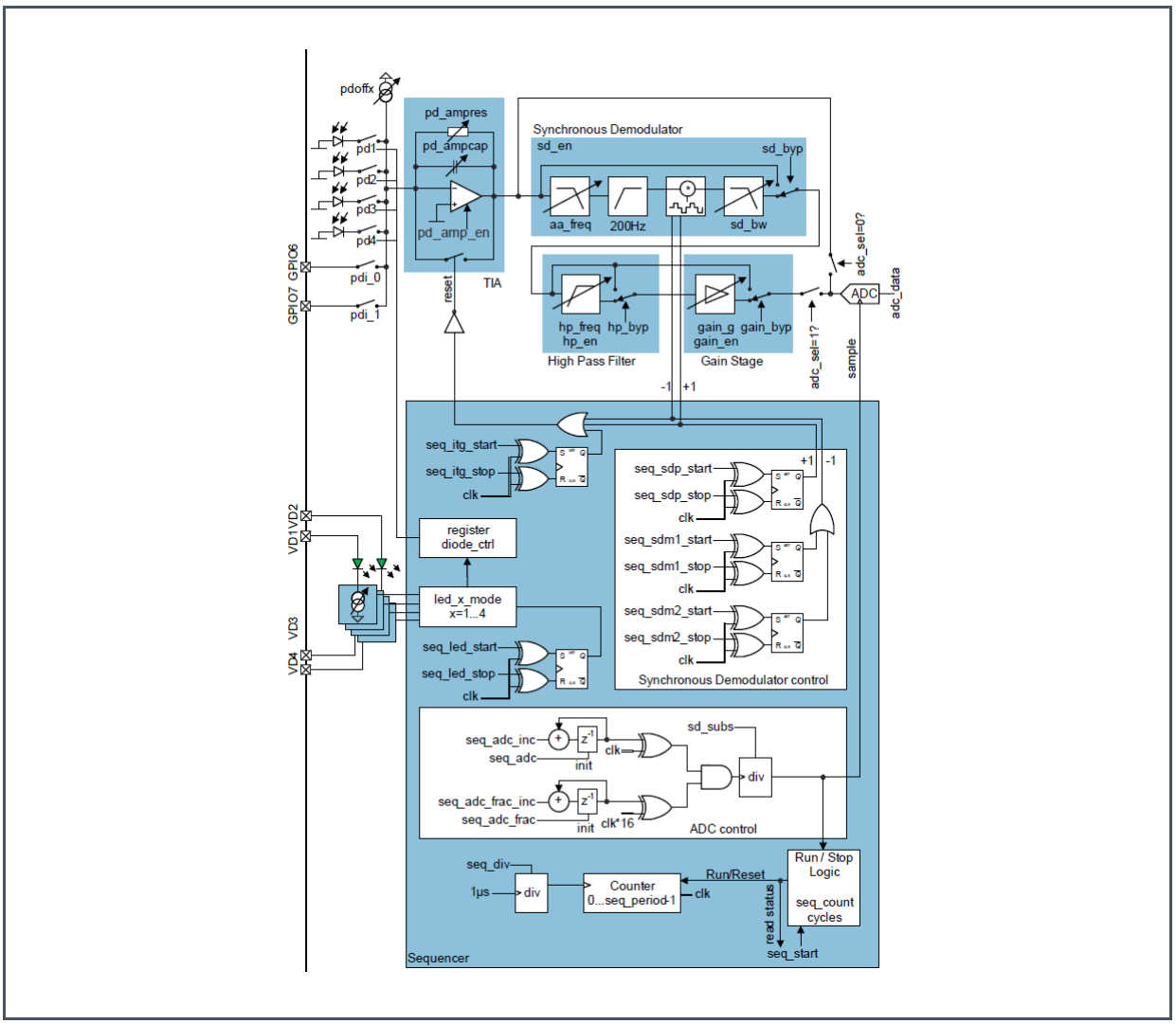
Within one sequencer cycle, the sequencer will:

- Switch the LEDs on at the specified LED start time and then switch them off at the LED stop time
- Start the positive and negative synchronous modulator multiplications at the specified start and stop times for each operation

- Trigger a conversion of the currently selected ADC channel at the time specified by the ADC start time. After the conversion has finished, ADC channel selection will advance the next enabled ADC channel, which will get measured during the next cycle. That gives one ADC channel per Sequencer cycle. For the TIA channel, two additional ADC timings can be specified. That means TIA can be measured up to 3 times within the same sequencer cycle:
  - a 2nd measurement will be done, if the value for “2nd TIA” value is specified (> 0) and is bigger than the one given in “1st” plus the time needed for the ADC to finish one conversion
  - a 3d measurement will be done, if “3d TIA” value is specified (> 0) and is bigger than the one given in “2nd TIA” plus the time needed for the ADC to finish one conversion

  In the case of more than one TIA measurement within the same sequencer cycle, it is important to make sure that the additional measurements can finish within the time of one sequencer cycle.

Figure 14:
Sequencer Block Diagram



Sampling Rate and Subsampling

Throughout this document, sampling rate refers to the rate at which the sequencer produces samples of the same ADC channel. This depends on the number of enabled ADC channels and on configuration of the subsampling feature of the sequencer.

Subsampling is used when the application requires lower sample rates than what is possible with the configured SEQ_PER and SEQ_DIV values, and with the number of enabled ADC channels. Lower sample rate can also be achieved by setting SEQ_PER and SEQ_DIV to large enough values, but this is not advisable as SEQ_DIV is multiplied to all the timings of the sequencer, thus the LED pulses will become very long, which is probably not desired. SEQ_DIV should be kept relatively small for finer resolution of the times.

The register, SEQ_CFG and SD_SUBS, configure how subsampling will be executed:

- sd_subs field in SD_SUBS register defines if subsampling is enabled; when it is 0, no subsampling is done – every sequencer cycle triggers an ADC measurement (Figure 15); setting to N>0, enables subsampling and then for N sequencer cycles the sequencer will not trigger the ADC, followed by one cycle with ADC conversion.
- sd_subs_always bit in SEQ_CFG register defines if all enabled ADC channels are subject to subsampling. Using this only makes sense for more than one enabled ADC channel.
    - sd_subs_always = 1: subsampling of all enabled ADC channels (Figure 16)
    - sd_subs_always = 0: subsampling of the first enabled ADC channel only (Figure 17)

The following three figures below show how subsampling is executed by the sequencer. In all of them ADC cycle means one ADC iteration through all the enabled channels. **Attention**: ADC cycle is not the same as sequencer cycle. ADC_SEL is the ADC channel selection; ADC_ACCESS is an ADC conversion of the currently selected ADC channel; t_{ADC} is the configured ADC start time in the sequencer configuration; t_{SUB} is the sequencer period given by Equation 1.

On Figure 15 three ADC channels are enabled - 1 (OFE1), 6 (EAFE) and 11 (GPIO2). No subsampling enabled (sd_subs=0).

On Figure 16 three ADC channels are enabled – 0 (TIA), 4 (SD2) and 8 (ECGO). Subsampling is enabled, every second sequencer cycle will trigger the ADC (sd_subs=2) and all enabled ADC channels are subsampled.

On Figure 17 three ADC channels are enabled – 0 (TIA), 4 (SD2) and 8 (ECGO). Subsampling is enabled, every third sequencer cycle will trigger ADC (sd_subs=3) and only the first enabled ADC channel is subsampled.

Figure 15:
No Subsampling (sd_subs=0)

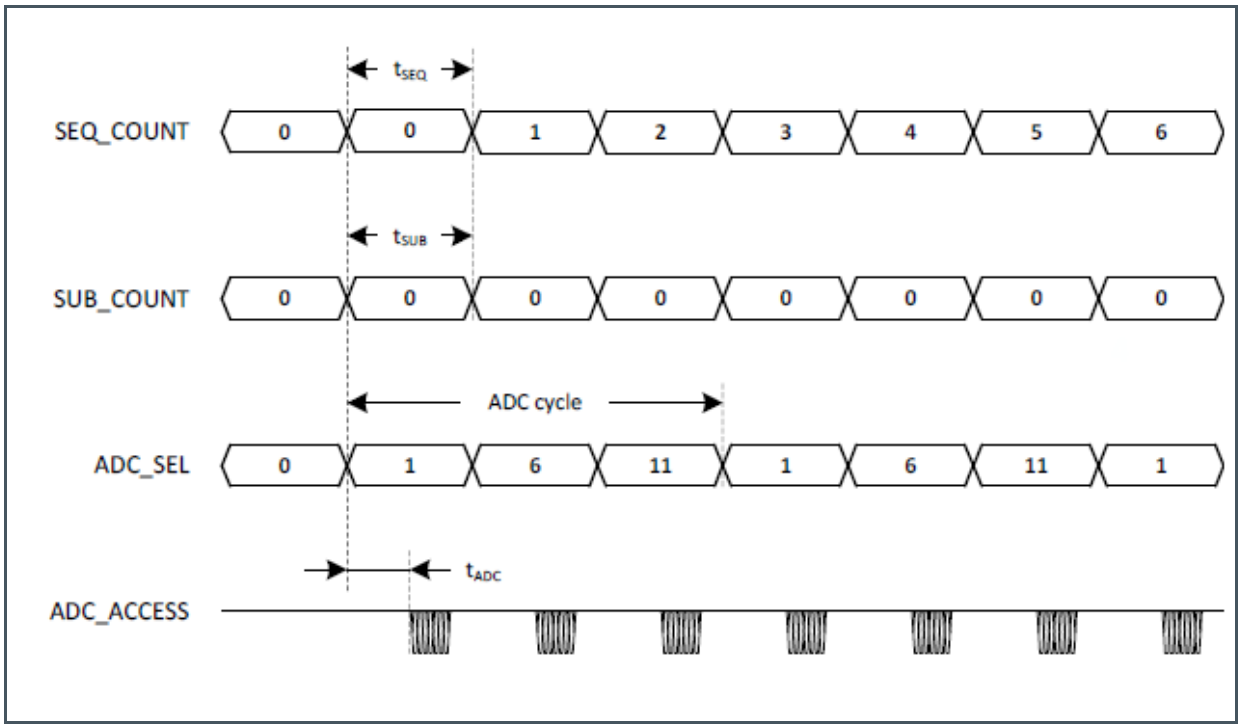


Figure 16:
Subsampling of All Enabled ADC Channels (sd_subs=2 and sd_subs_always=1)

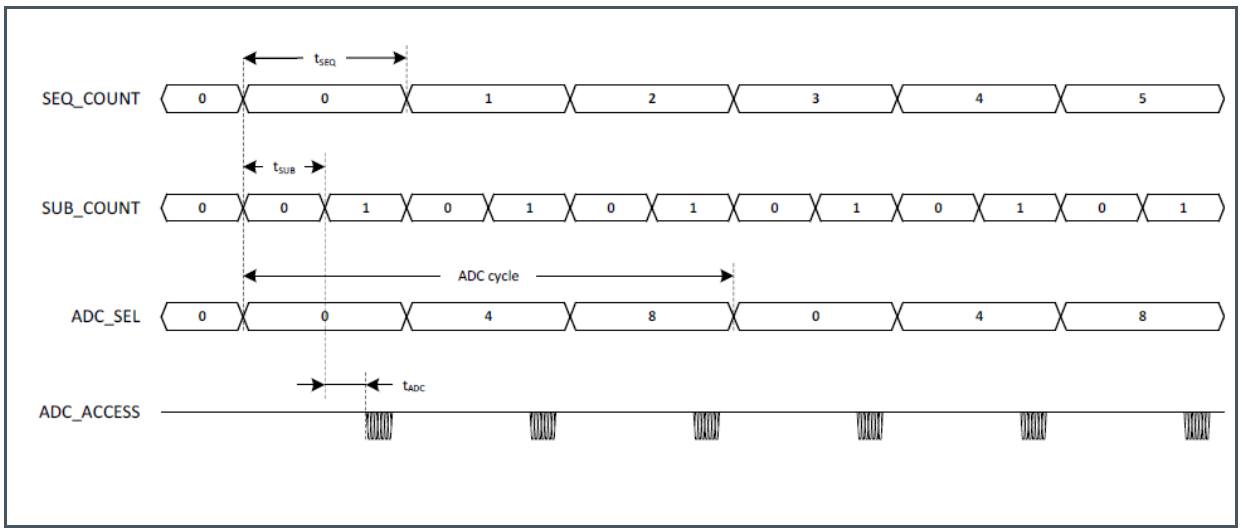
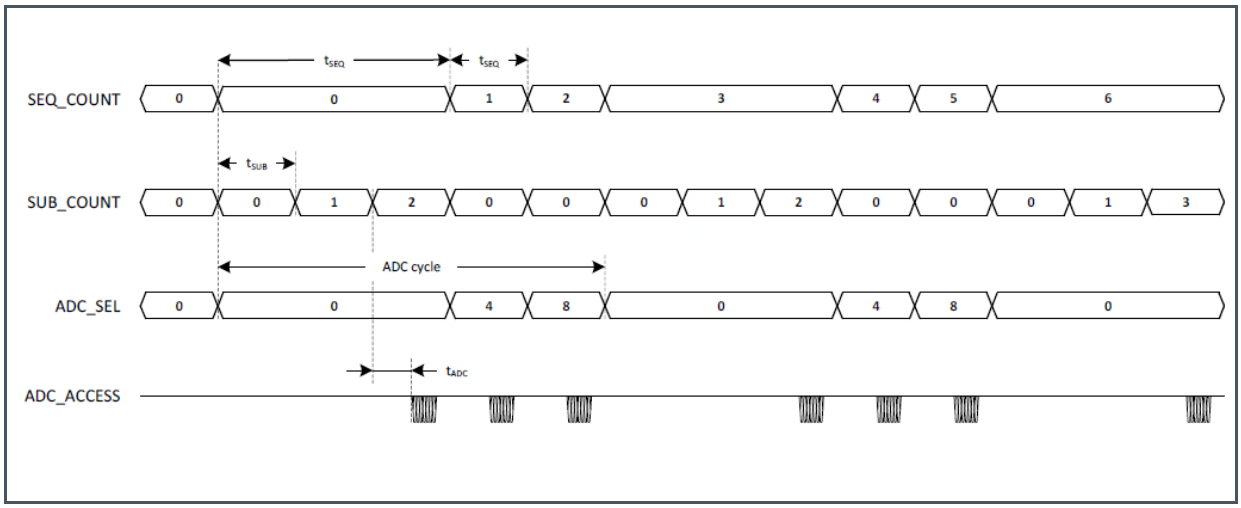


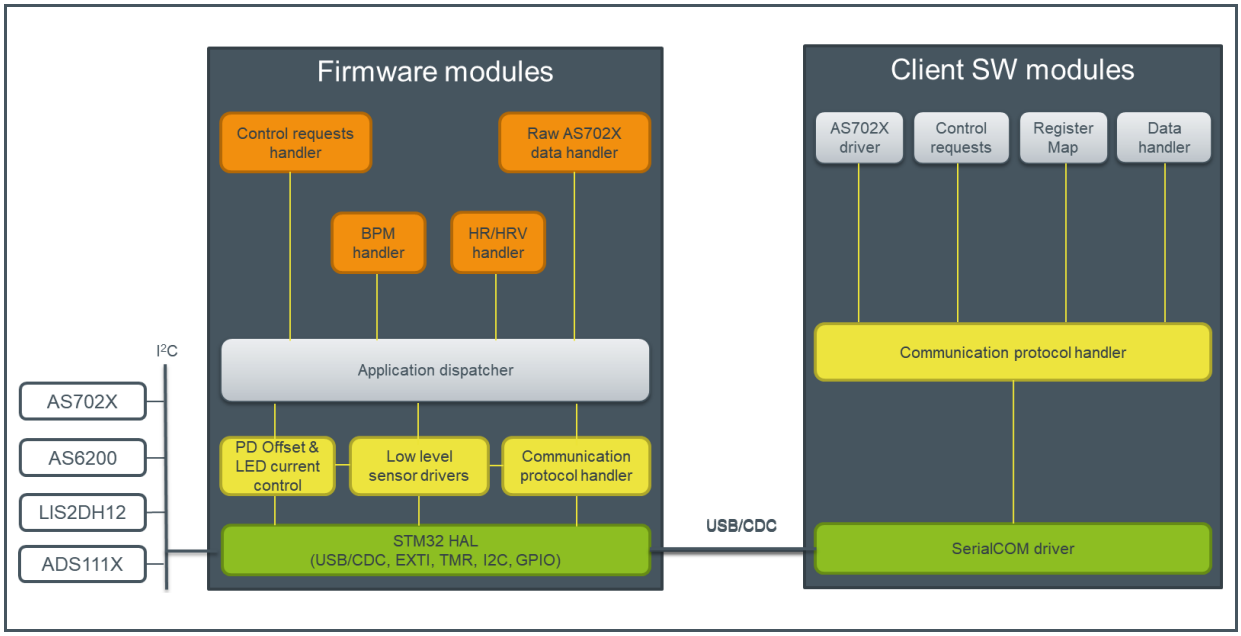
Figure 17:
Subsampling of 1st Enabled ADC Channel Only (sd_subs=3 and sd_subs_always=0)



5 Software Description

5.1 Software Architecture

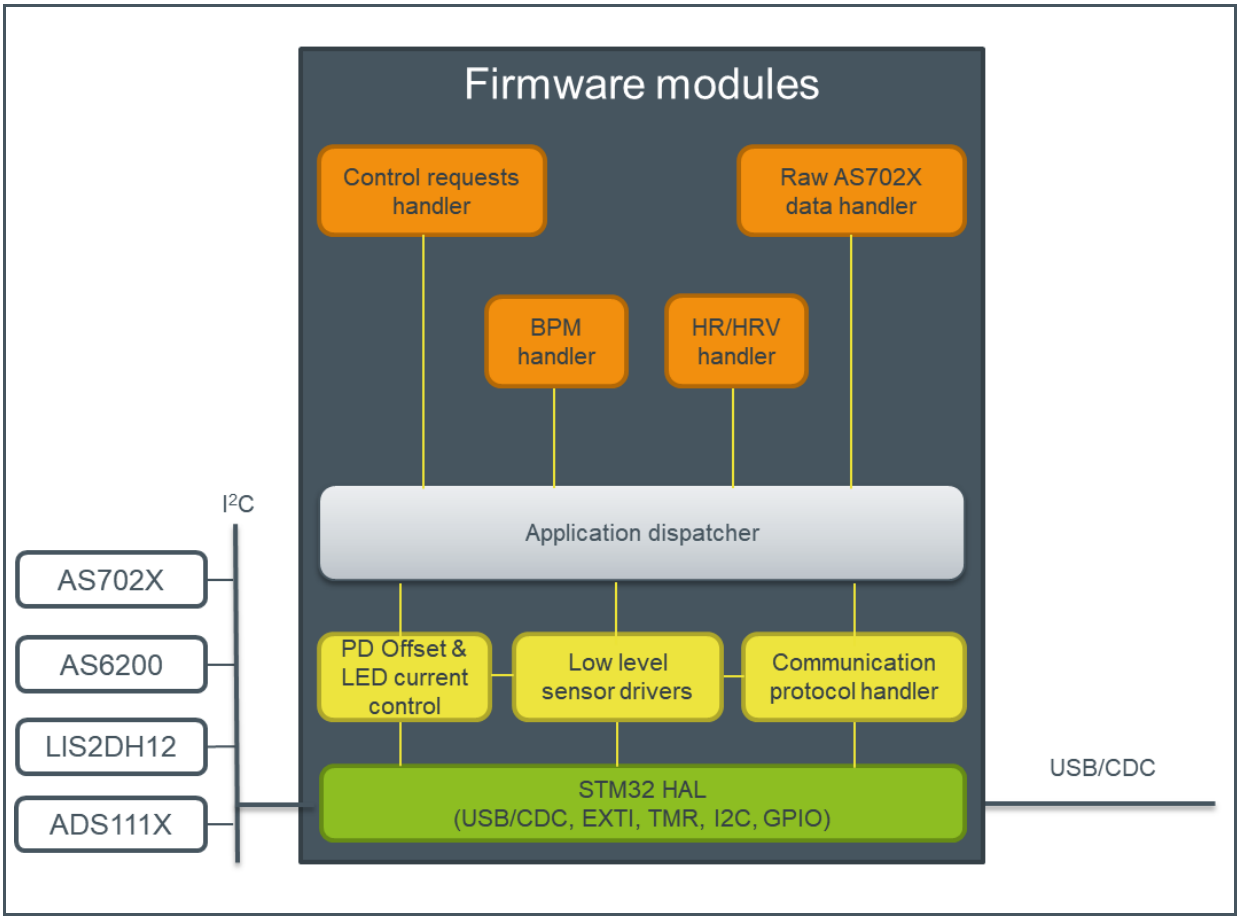
Figure 18:
SW Modules



The AS702x evaluation software consists of firmware and client software (GUI). The firmware is running on an ARM Cortex M4 MCU (STM32L476RETx), implements virtual COM port CDC interface for client communication and vital sign detection applications. The client software displays raw data, algorithm data and board data (temperature and power consumption). Raw data can be logged and exported as .csv file for further analysis.

5.1.1 Evaluation Firmware

Figure 19:
Firmware Modules



HAL Layer Code Generated by STMCubeMX

- I^2C, USB, interrupt handling

Low Level Sensor Drivers

- AS702x vital sign sensor driver
- AS6200 temperature sensor driver
- LIS2DH12 accelerometer driver for motion compensation
- ADS111X ADC for current consumption measurement

Communication Protocol Handler

Receives and parses packets coming from the UART interface and based on the protocol type forwards them to the application dispatcher or executes them immediately when packet is one of read/write AS702x register, get FW number. Packs the responses to the incoming requests (when one is expected) and sends them to the CDC interface for transmission to the host.

PD Offset and LED Current Control Algorithm

When enabled, its task is to bring the PPG signal to a certain predefined quality (expressed in minimum peak to peak value) whereby using as less LED current as possible. The algorithm uses the output of the TIA and OFE1 channels.

It will first check, if offset compensation needs to be applied by comparing the averaged TIA to a high and a low threshold (both fixed in FW, not configurable). If the value is below the low threshold, PD offset is decreased. If it is above the high threshold and if the currently configured PD offset is < 238, PD offset is increased, otherwise the LED current is decreased.

If the TIA signal is within the range defined by the low and high thresholds, the algorithm will check if the amplitude of the OFE1 signal is within certain limits defined by configurable minimum and maximum. In case the calculated OFE amplitude is outside this range, if OFE1 amplitude is below the defined minimum, LED current is increased; if it is above the maximum, LED current is decreased. The range within which the LED current is allowed to change is given by configurable minimum and maximum.

After a change in PD offset and/or LED input current, the algorithm will not do the OFE1 check for a period of 1500 milliseconds (this is the period of a 40 BPM heartrate). The current minimum and maximum values of the OFE1 signal are being reset at a configurable interval.

Refer to chapter 0 (PD Offset & LED Current Control Configuration) for details on how to configure and use it.

Application Dispatcher

The application dispatcher is responsible for sending the application requests, received from the client software to the relevant application for execution. The FW implements 3 types of applications – control requests handler, raw data handler and vital sign algorithm handlers. Implemented vital sign algorithm handlers are heart rate monitor (HRM), heart rate variability (HRV) and blood pressure monitor (BPM).

Control Requests Handler

Handles FW control requests like application selection, AGC configuration and measurement start/stop.

Raw AS702x Data Handler

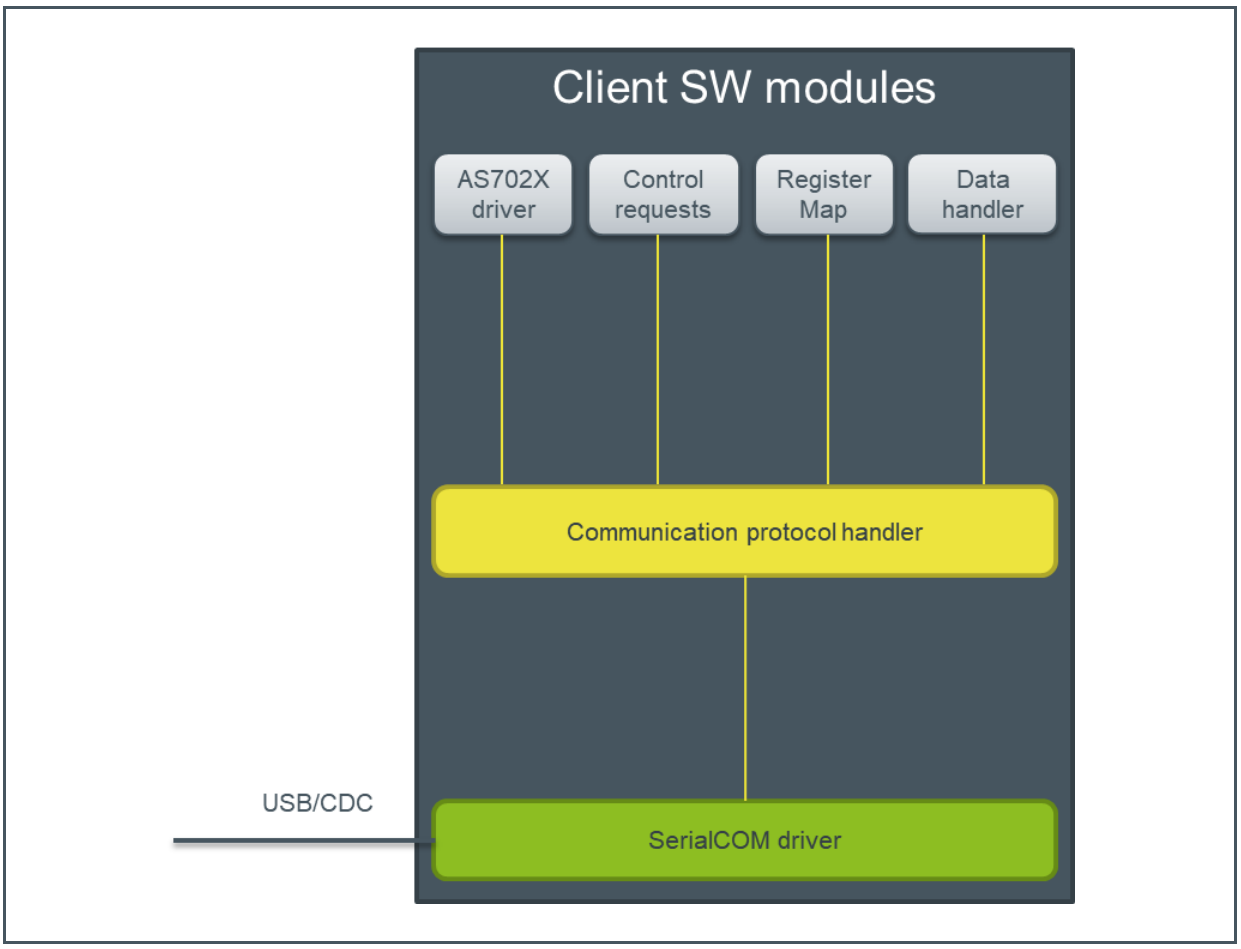
Collects and stores raw AS702x sample data in a data buffer and sends the buffered data to the client upon request.

Vital Sign Application Handlers – HRM, HRV and BP App Handlers

Aggregate data needed by the relevant algorithm, run the algorithm and handle data requests sent from the client.

5.1.2 Client Software

Figure 20:
Client Software Modules



SerialCOM Driver

Low-level UART communication driver – open/close COM port connections, send and receive byte streams to/from the UART interface.

Communication Protocol Handler

Implementation of the communication protocols exchanged between the client software and the FW.

AS702x Driver

Driver code used for AS702x configuration (register read/write).

Control Requests

FW control requests – start/stop measurements, select/deselect algorithm and AGC configuration.

Register Map

Direct access to the complete register set of the AS702x.

Data Handler

Handles incoming data – updates the relevant ADC channel plot and/or updates vital sign data fields of the GUI.

5.2 Graphical User Interface

This section describes the Graphical User Interface (GUI) of the **AS702x Vital Sign Sensor** application. The application is designed to be used with **AS702x** sensor series evaluation kits.

User Guide Version

1.0

Valid for the following software version

- AS702x Vital Sign Sensor v.7.1.8.0

Supported hardware

- AS702xAS702x_Evalboard v1.2

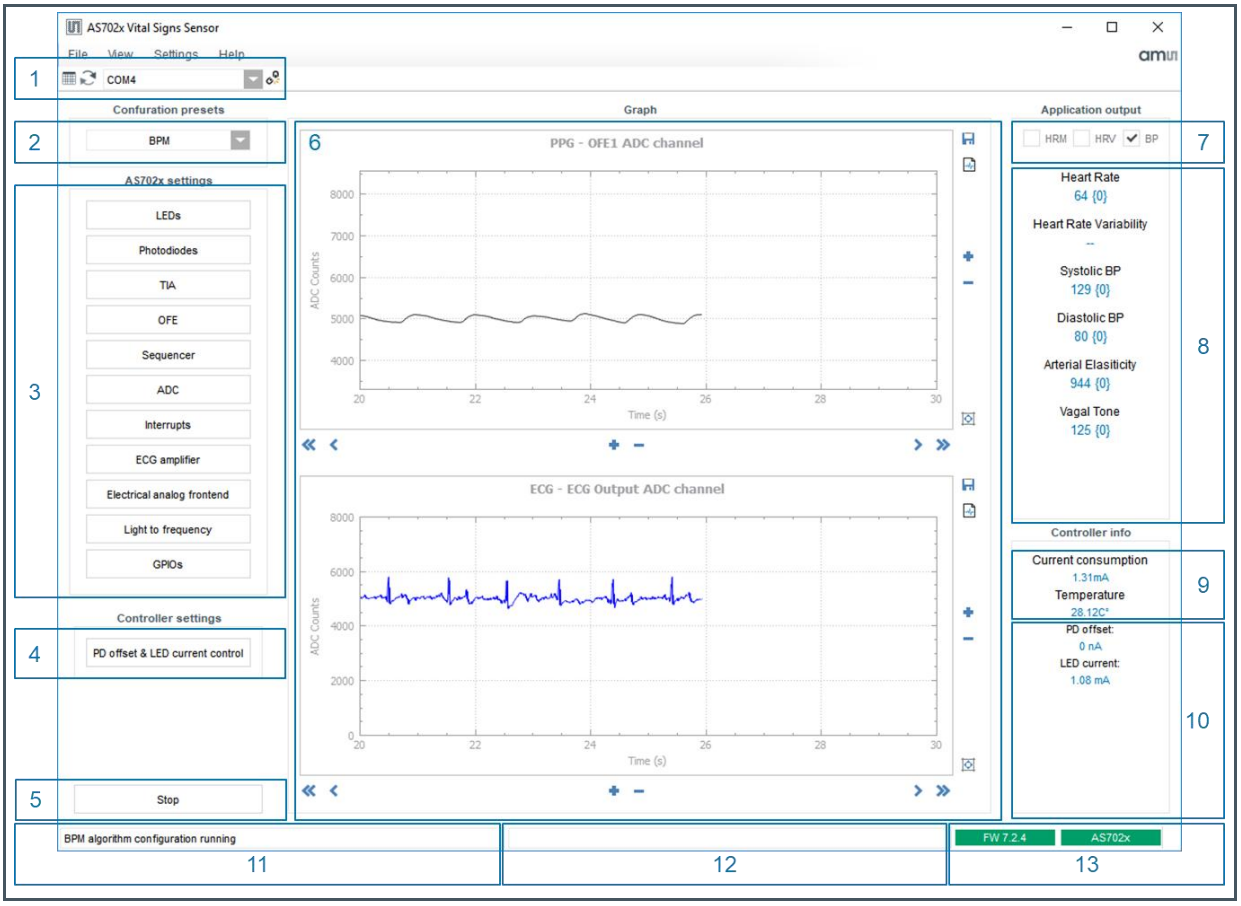
Download

Navigate to https://download.ams.com/AS702x and download the latest version.

5.2.1 Overview

Figure 21 shows the main window of the graphical user interface. To connect hardware the connection control elements are used (1). The measured data is displayed in the main section of the application (6). Additional information about current consumption and temperature is showed in (9). Calculated heart rate, calculated blood pressure, heart rate variability are displayed in (8).

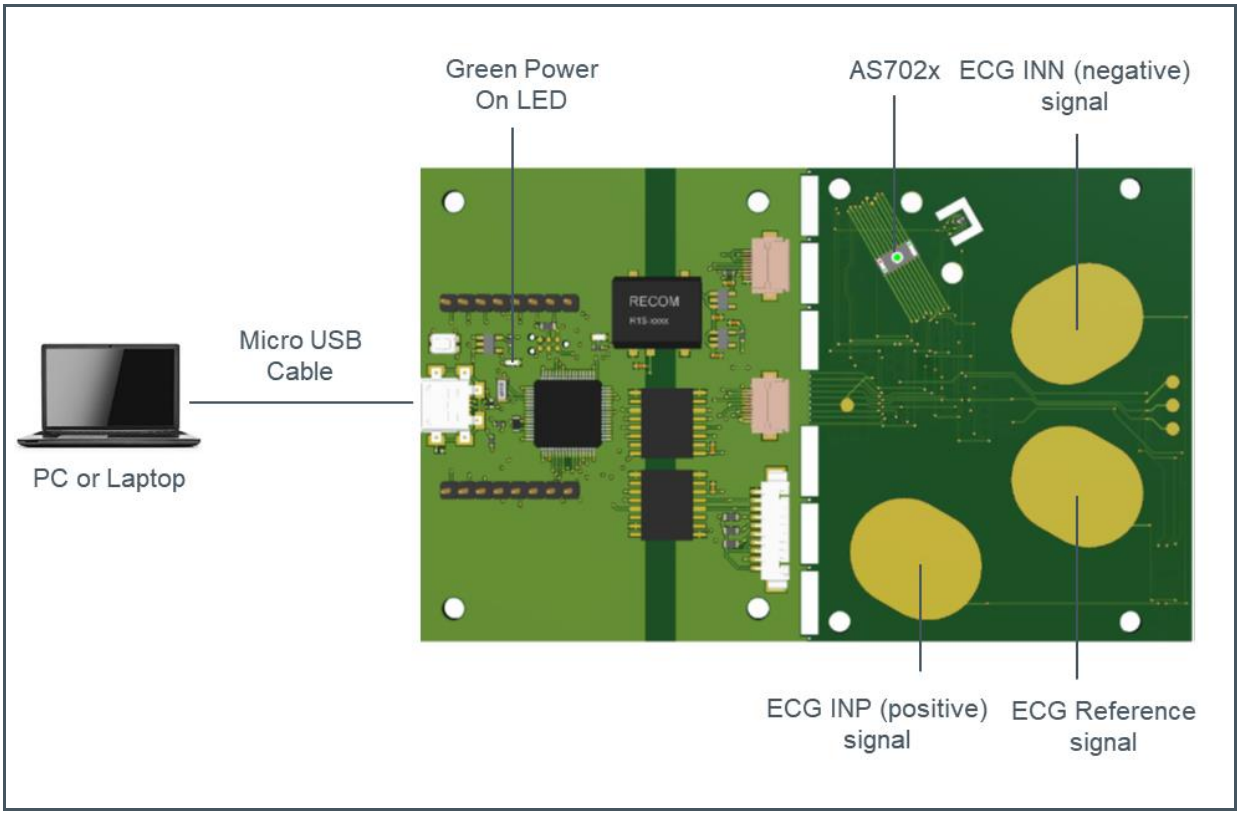
Figure 21 :
AS702x Vital Sign Sensor - Graphical User Interface



1 Connection control elements
2 Configuration presets
3 AS702x configuration settings
4 Controller configuration settings
5 Start/Stop recording
6 Graphical representation of data
7 Measurement type
8 Calculated vales based on measurement
9 Temperature (AS6200) and current consumption (AS702X) values
10 The currently configured values for PD offset and Led input current
11 Description of the current configuration
12 Status box
13 Connection status and FW version of connected hardware

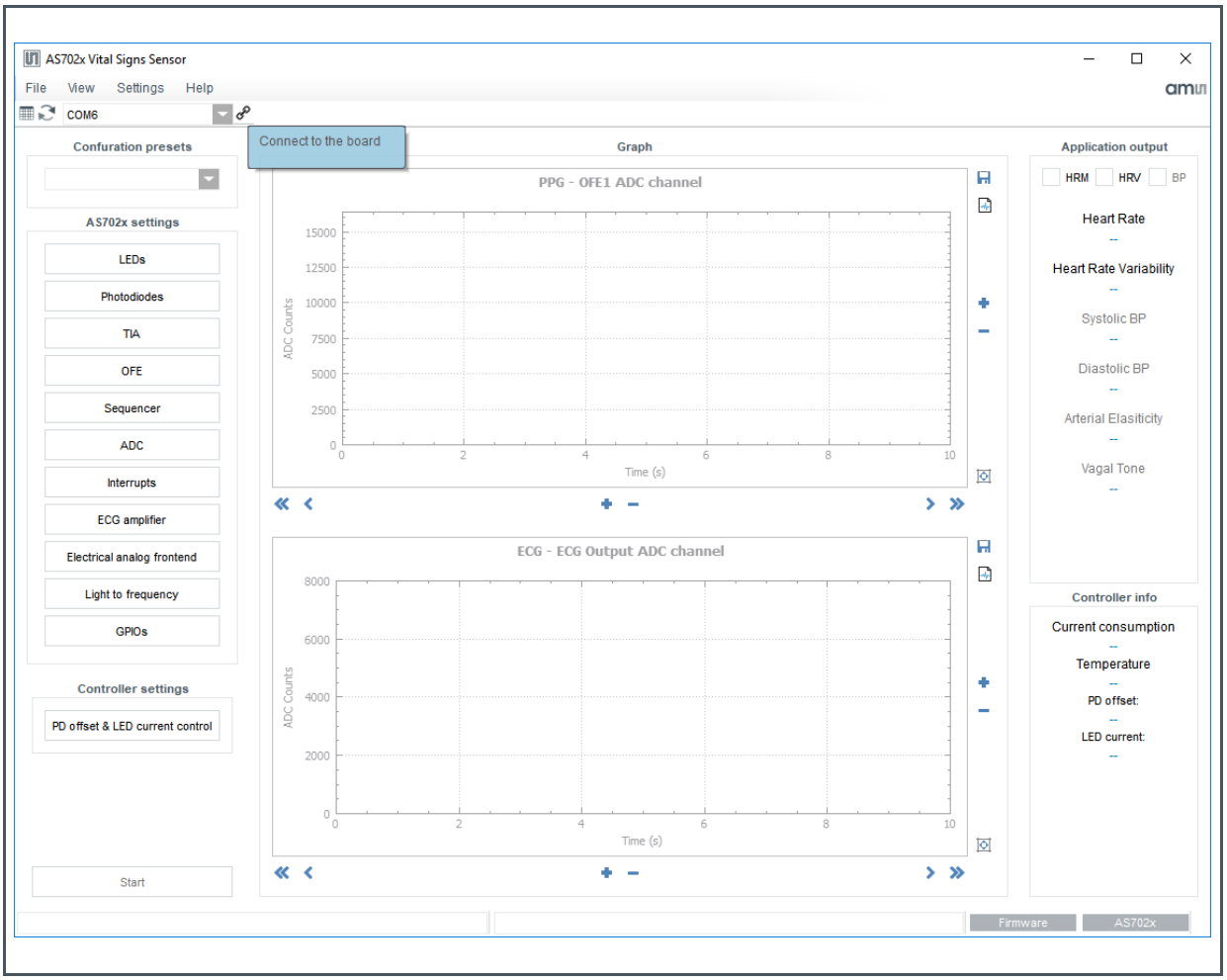
Powering Up and Starting a Measurement

Figure 22 :
Plugging in the Board (powering on)



1. Connect the Micro USB to USB cable to the Eval Kit and plug it into your computer
2. The green power LED will turn ON as soon as the board is powered
3. Start the client software

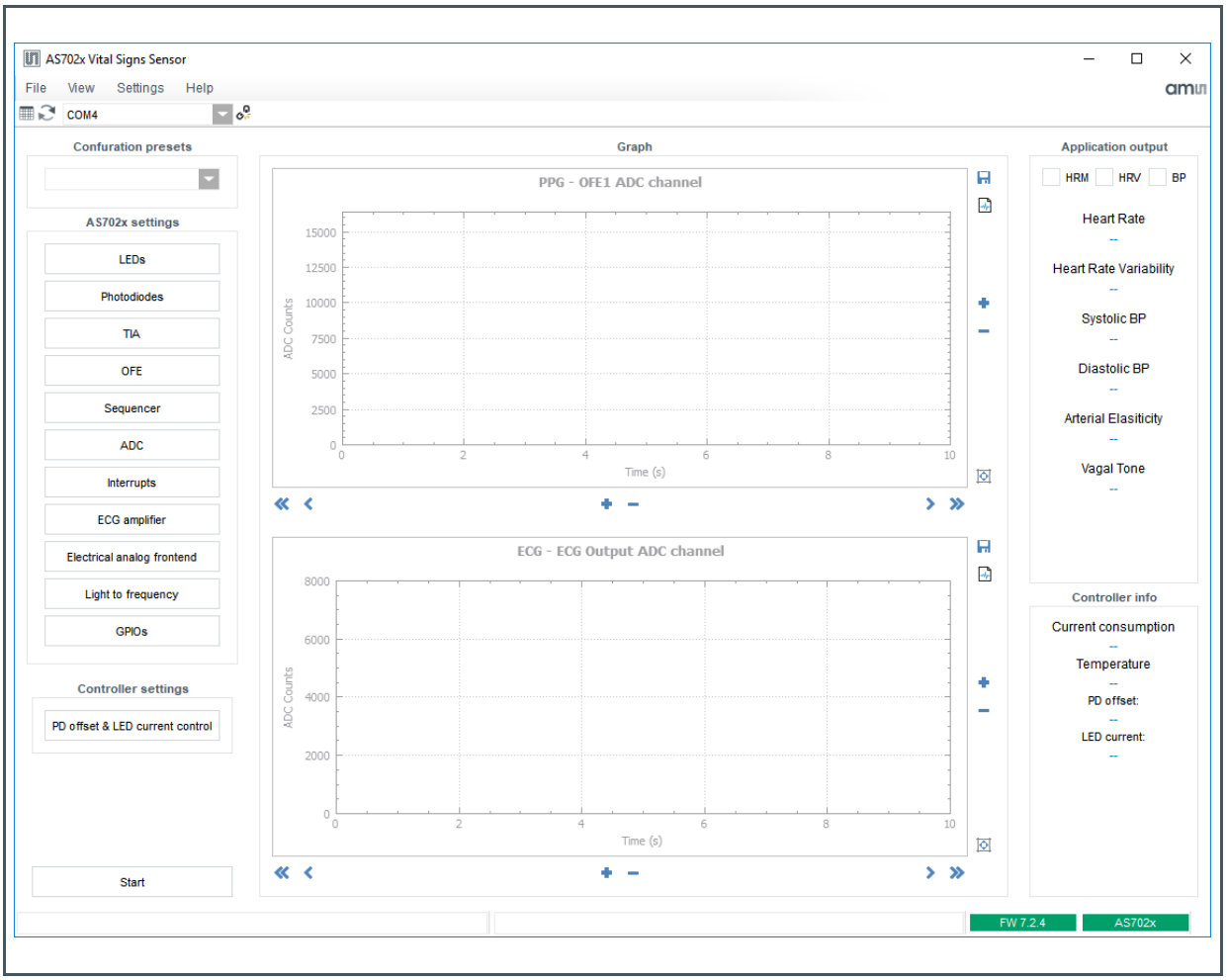
Figure 23 :
Connecting to the Board



1 Select the appropriate COM port name from the drop down box

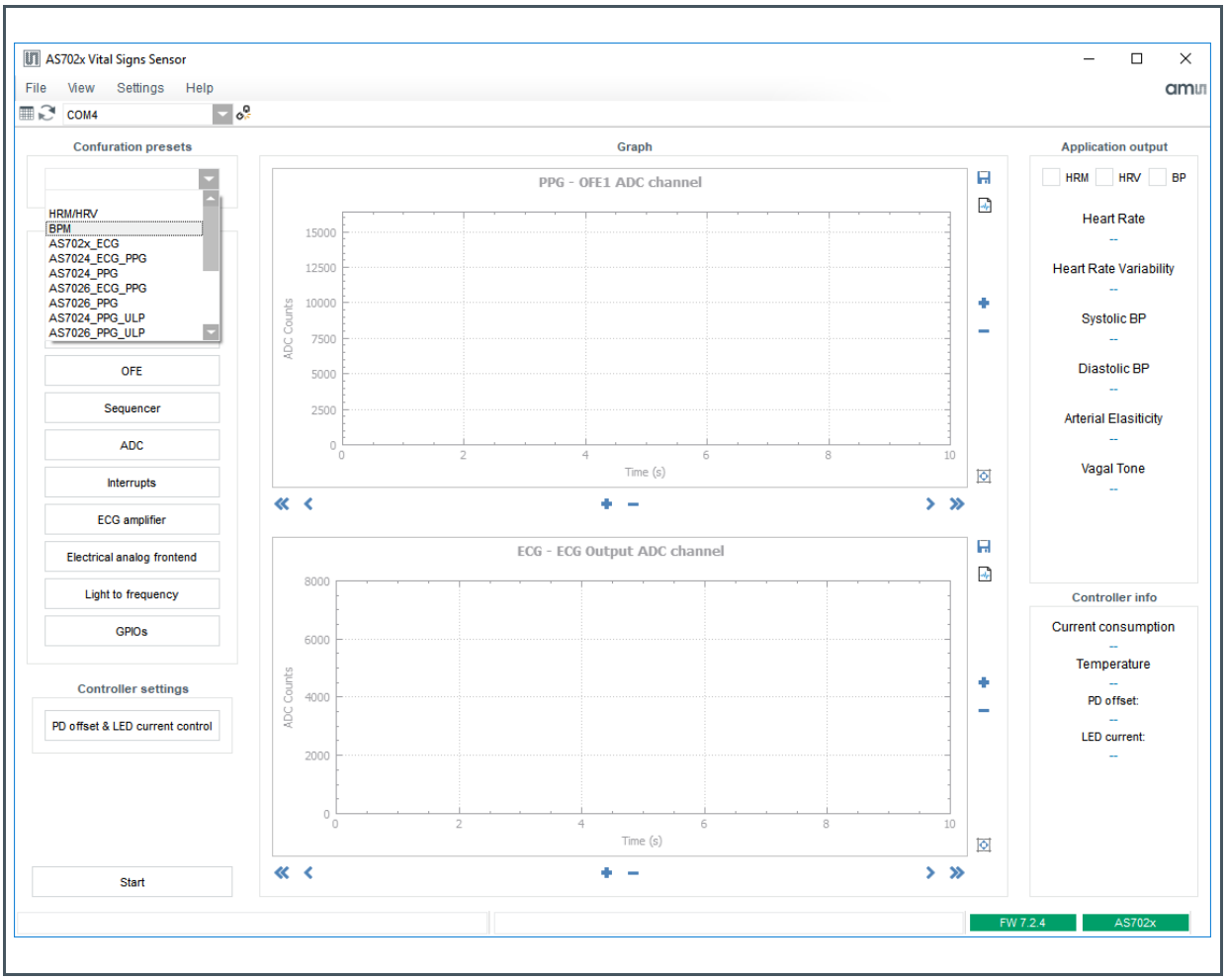
2 Click the connect button

Figure 24 :
Board Connected



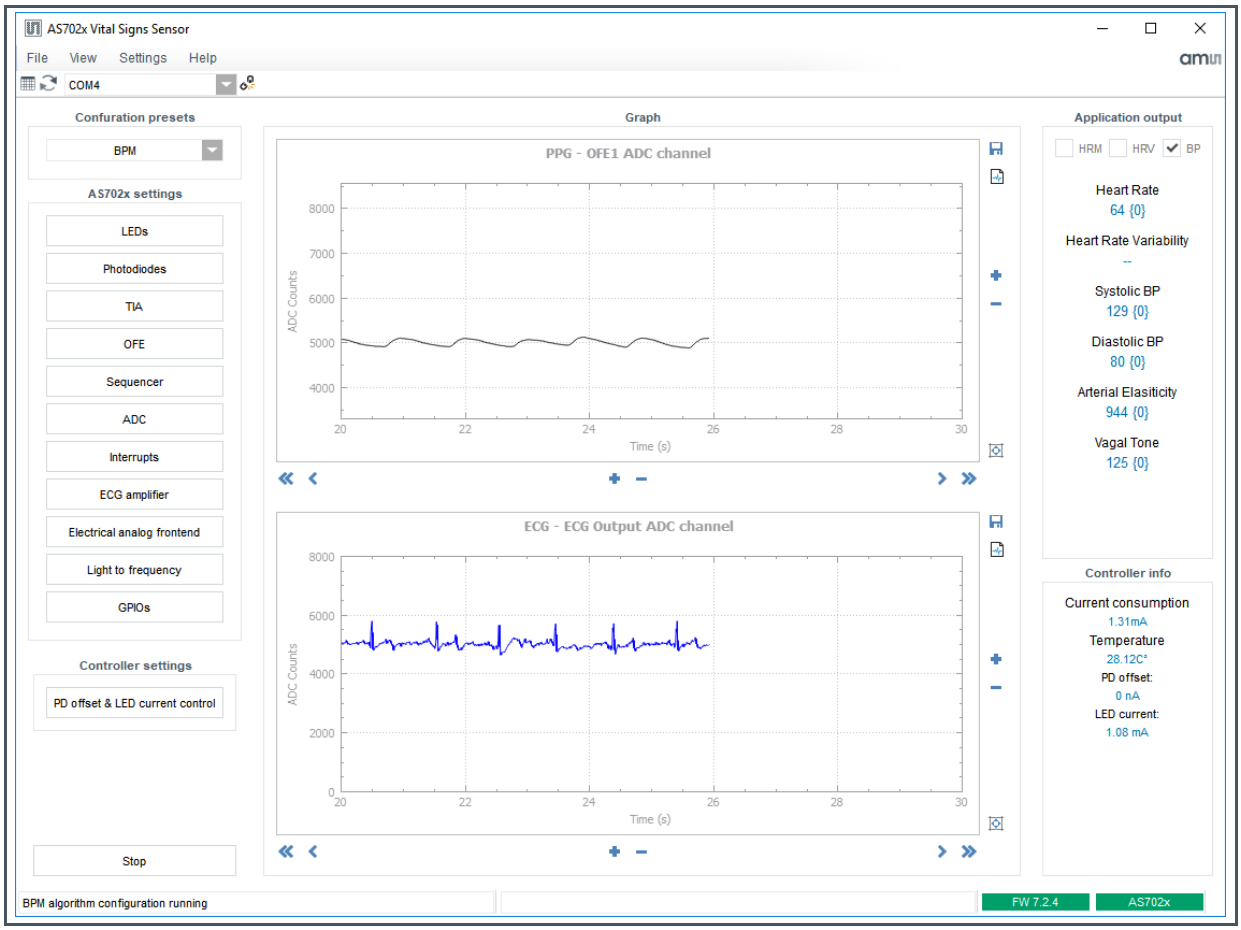
1 Connect button will change its glyph to upon successful connection
2 The two status boxes on the bottom right side will turn green and show the FW number currently flashed on the board

Figure 25 :
Starting a Measurement



1 Select one of the built in configuration presets
2 Select the measurement type – HRM/HRV/BP can be enabled. BP and HRM/HRV are mutually exclusive. HRV is only possible together with HRM.
Optionally check and change AS702X settings. On the first startup after SW installation no settings are loaded, after that the last used settings will be used.
3 To start a measurement with the current settings click on the Start button.
4 The green AS702x LEDs will turn on, Start button's caption will change to "Stop"
5 Hold the ECG INP and reference electrodes with pointer and middle finger of your left hand, put the pointer finger of your right hand on the ECG INN electrode and the middle finger of your right hand on the AS702x to measure
6 The raw pulse and ECG data will be displayed in the GUI
7 The output of the algorithm will be displayed on the right hand side of the window. The numbers in the curly brackets show how many seconds have passed since the last result different than zero was reported. After five seconds of no new result, the values will time out and the content of the fields will change to "--".

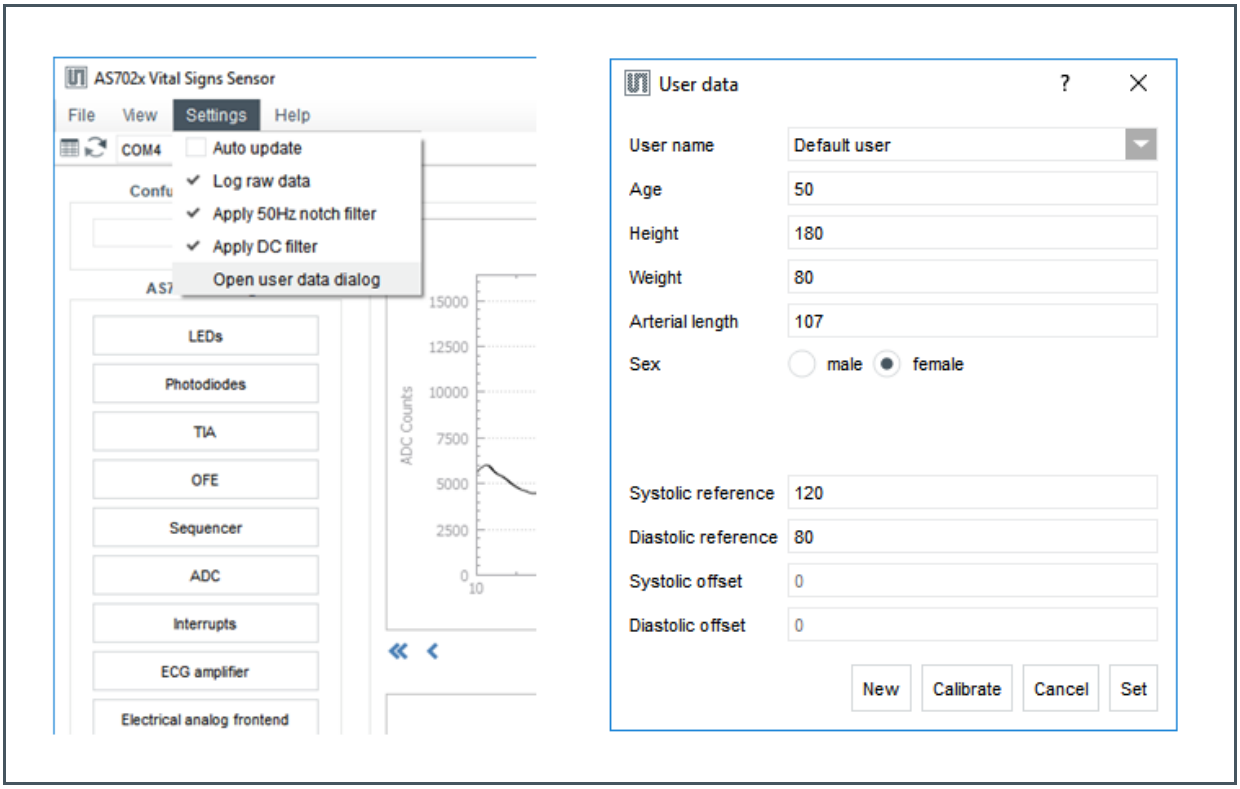
Figure 26:
Running Blood Pressure Measurement



5.2.2 Setting up for Blood Pressure Measurement

The blood pressure measurement will give most accurate results with correct user profile. A default user profile is used, if none exists. To create a new user profile, open menu Settings and select “Open user data dialog”.

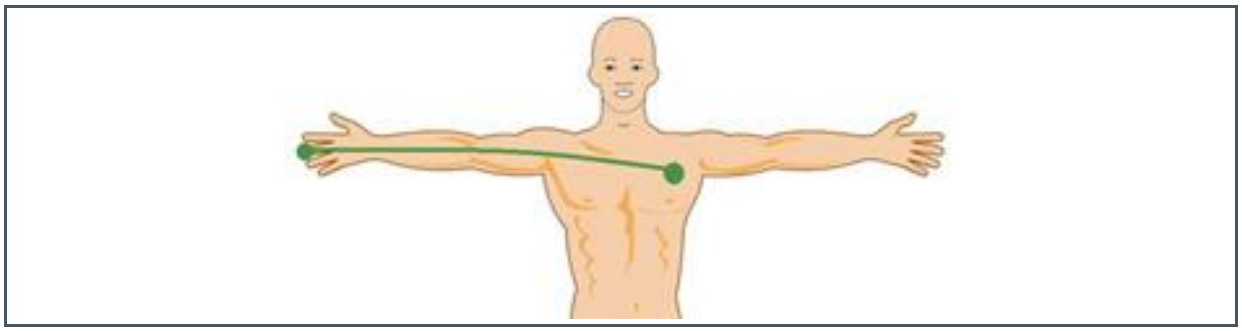
Figure 27:
User Data Window



In the “User data” window click on button “New”. The field “User name” will change to “New user” and the “New” button will change its caption to “Save”. Enter all field values:

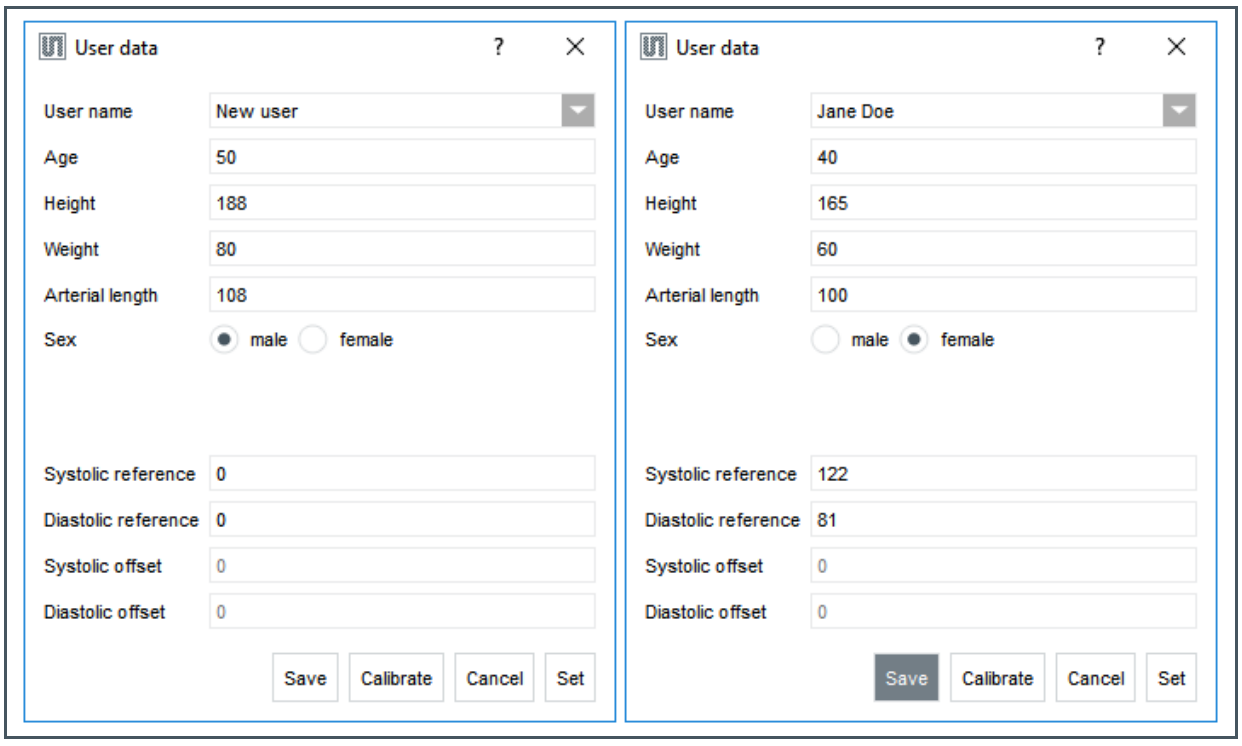
- Age – age in years
- Height – in cm
- Weight – in kg
- Arterial length – in cm (0 = unknown); to measure the arterial length, please measure the distance from the tip of your right middle finger to the middle of the line from your left nipple to the left axle as shown in Figure 28. If the field is left zero, the arterial length will be estimated based on the user’s height.
- Systolic and Diastolic reference - obtained with a reference device (e.g. a cuff device)
- Systolic offset - calculated during calibration, not enabled for user input
- Diastolic offset - calculated during calibration, not enabled for user input

Figure 28:
Measurement of the Arterial Length



Click “Save” to add the newly created user profile to the user profile database.

Figure 29:
Creating a New User

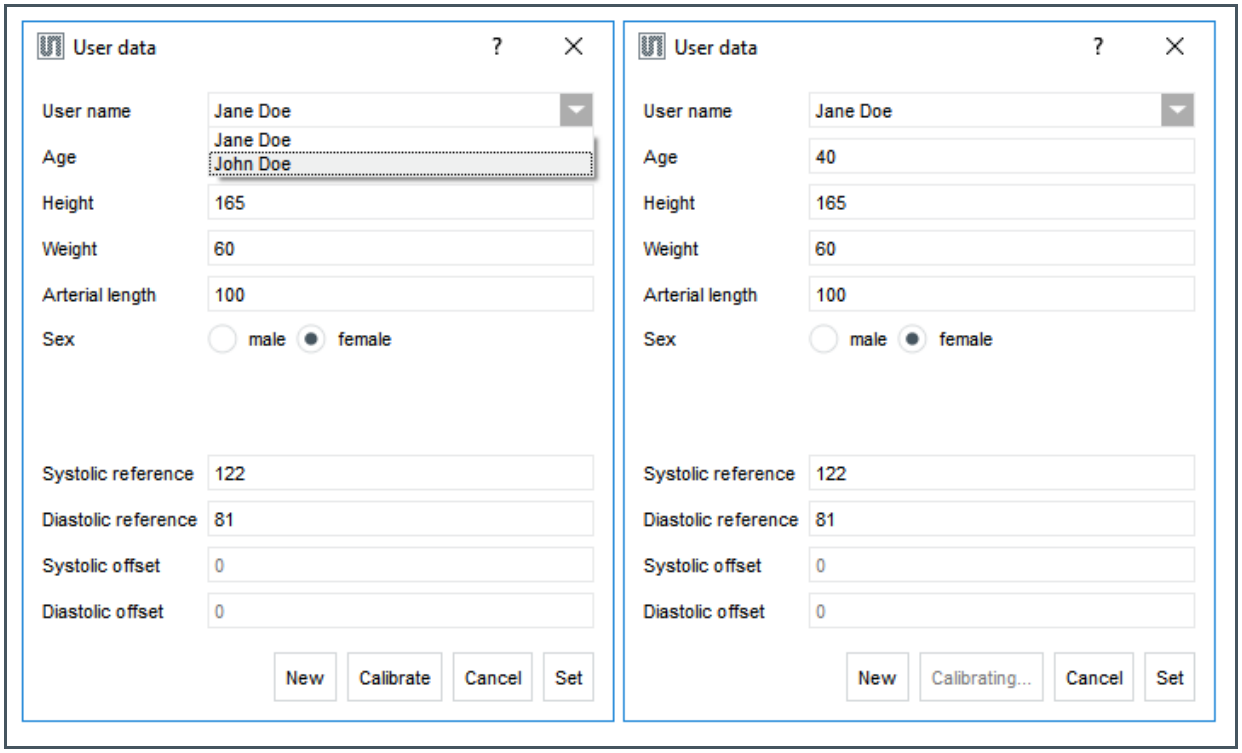


Next step is to execute the calibration procedure in order to get the values for Systolic and Diastolic offsets. This requires that the board is connected and the “BPM” configuration is selected from the configuration presets. If not, click “Set” to close the “User data” window and go back to the “Main” window (“Set” also sets the current user). Connect to the board, select the “BPM” preset and go back to the “User data” window to execute the calibration procedure.

Calibration Procedure

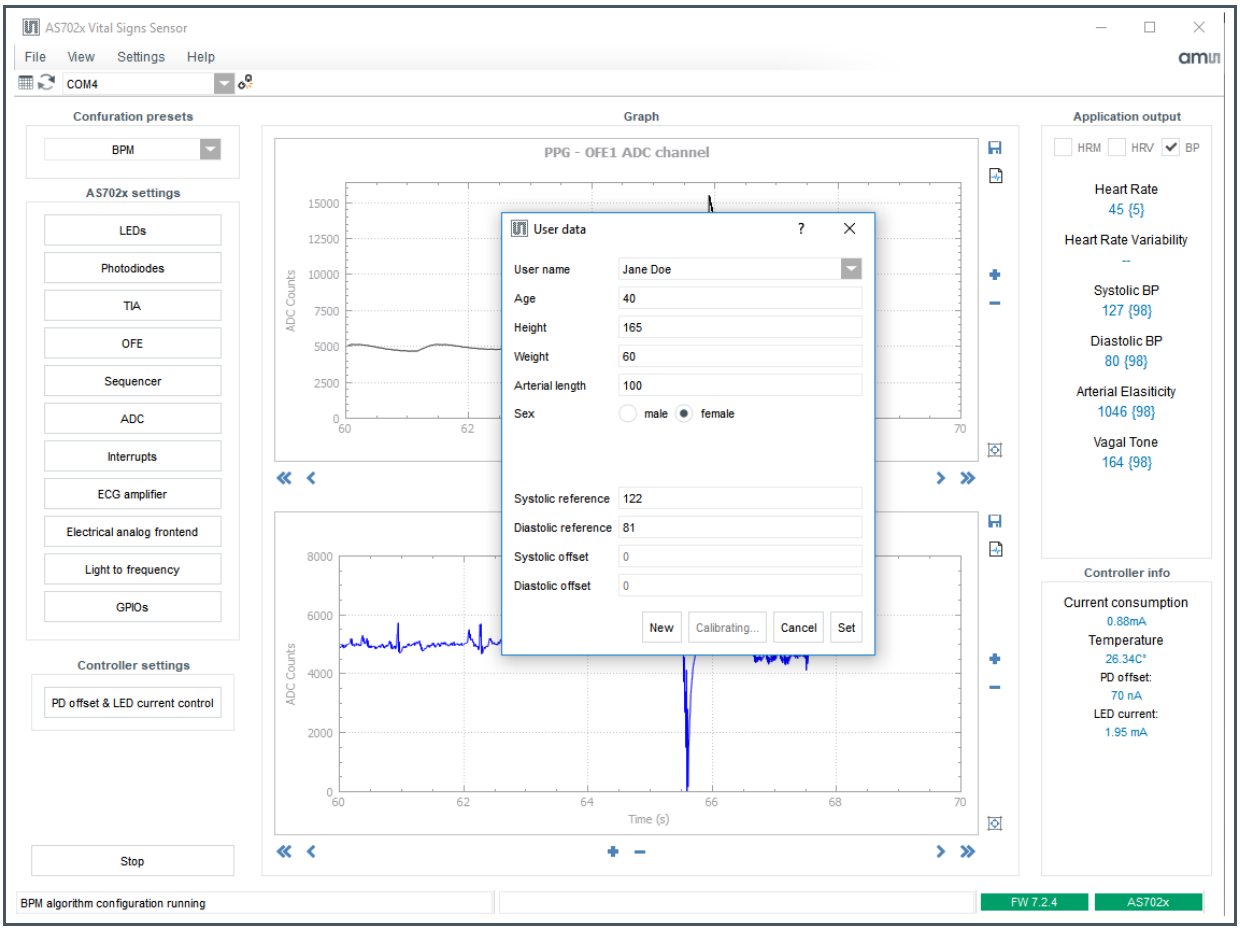
Select the user to calibrate from the “User name” combo box and click the “Calibrate” button. The caption of the “Calibrate” button will change to “Calibrating…”.

Figure 30:
User Calibration



Blood pressure measurement will start. The “Start” button will turn to “Stop”, the PPG and ECG graphs will start plotting the raw data, and blood pressure values will start displaying on the “Main” window.

Figure 31:
Calibration Ongoing



After five blood pressure values have been successfully calculated, calibration will finish, the measurement stopped and the values for “Systolic offset” and “Diastolic offset” updated.

Figure 32:
Calibration Finished

Click “Set” to save the values and close the window.

5.2.3 AS702x Configuration Settings

The AS702x configuration settings are located on the left of the evaluation software (see Figure 21). At power-up the board starts with the following default configuration:

- The two green LEDS - LED1(VD1) and LED2(VD2) are enabled, the LED current set to 50 mA
- Sequencer period set to 2000 µs
- Photodiode Trans-Impedance amplifier (TIA) is on and used
- All filters are on and used
- ADC is set to measure only the optical front end 1 after the gain stage (OFE1)

The individual settings of each of the AS702X blocks can be viewed/changed in the dedicated configuration sub menu. To enter the submenus press the corresponding button.

Figure 33:
Submenu Selection.

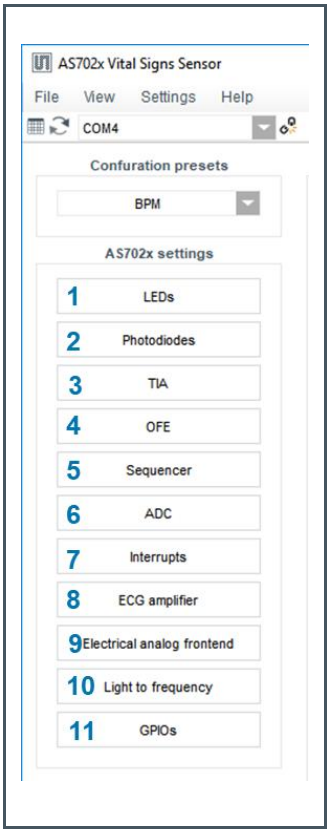
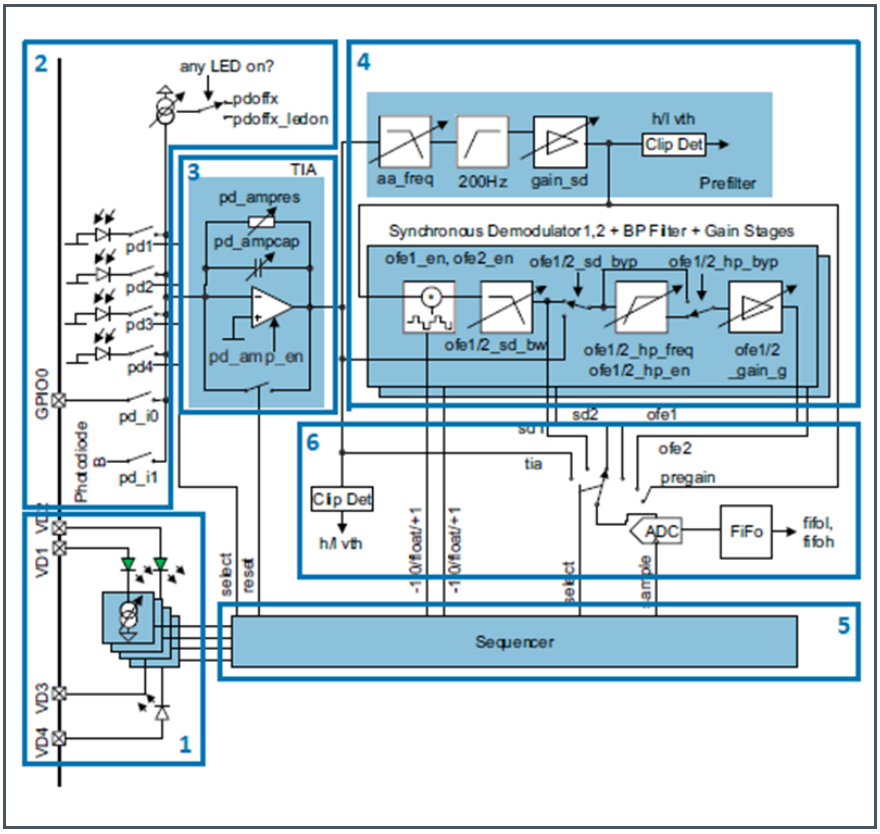


Figure 34:
AS702x Block Diagram. Highlighted Blocks Are Configured in the According Submenus.



1 LEDs -> Datasheet AS7026GG pg. 14 ff.
2 Photodiodes -> Datasheet AS7026GG pg. 24 ff.
3 TIA -> Datasheet AS7026GG pg. 29 ff.
4 OFE -> Datasheet AS7026GG pg. 34 ff.
5 Sequencer -> Datasheet AS7026GG pg. 35 ff.
6 ADC -> Datasheet AS7026GG pg. 75 ff.
7 Interrupts -> Datasheet AS7026GG pg. 84 ff.
8 ECG amplifier -> Datasheet AS7026GG pg. 70 ff.
9 Electrical analog frontend -> Datasheet AS7026GG pg. 61 ff.
10 Light to frequency -> Datasheet AS7026GG pg. 54 ff.
11 GPIOs -> Datasheet AS7026GG pg. 84 ff.

LED Configuration

Attention

LED current, LED mode and LED state can be set in the “LEDs configuration” window. It is recommended to configure the current only when the output is not active as there is no latch implemented to keep the 10 bits consistent.

Figure 35:
LED Configuration Submenu

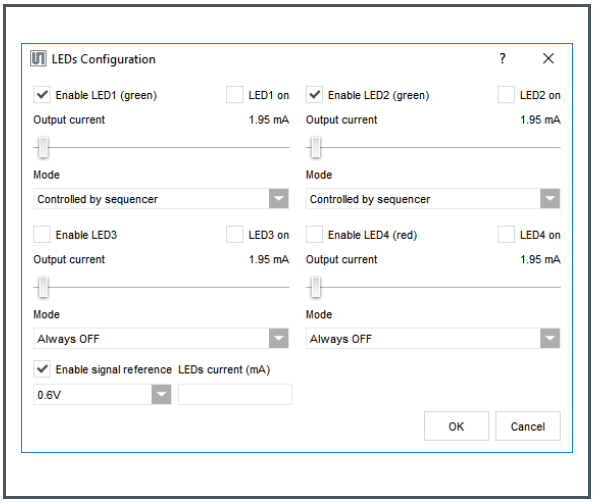
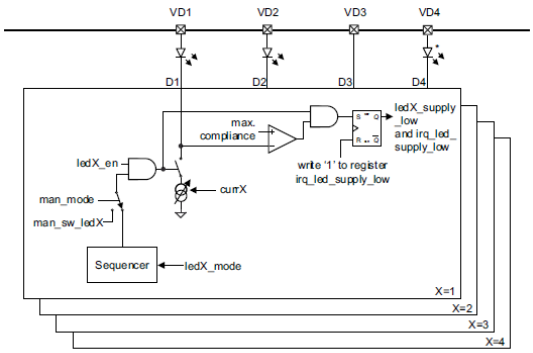


Figure 36:
LED Driver Block Diagram



For further information, please refer to the following documents:

- AS7026GG Datasheet p. 14 ff.

Photodiodes Configuration

Select the photodiodes which to connect to the TIA input. The offset current is optional, this allows cancellation of constant light sources like sunlight. Default for the input offset current is 0 for both – LEDs off and any LED on.

For an external photodiode or any other sensor with (low) current output, the pins GPIO0 and GPIO1 can be used as input.

The sequencer controls the diodes – see **DIODE_CTRL** described in register **MAN_SEQ_CFG**.

Figure 37:
Photodiode Configuration Submenu

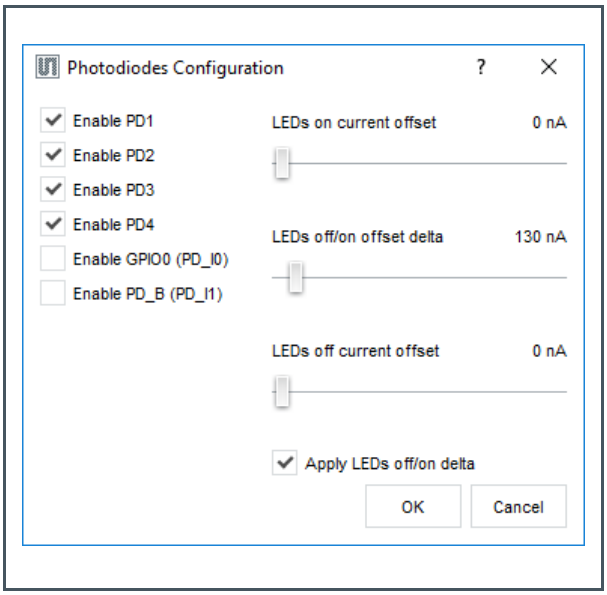
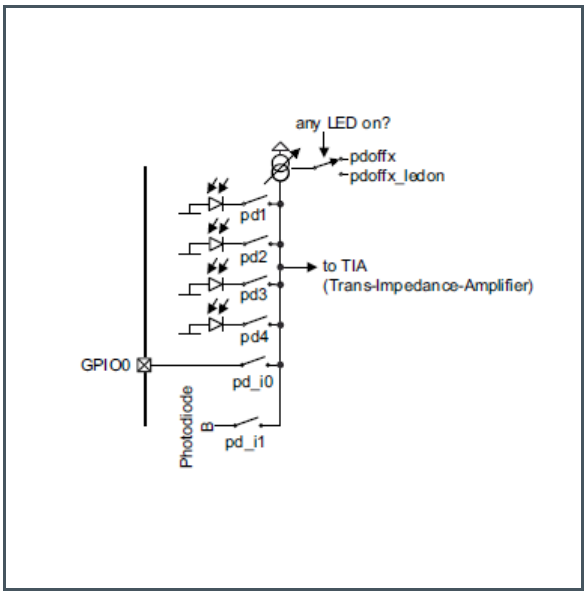


Figure 38:
Photodiode Block Diagram



For further information, please refer to the following documents:

- AS7026GG Datasheet p. 24 ff.

TIA (TransImpedance Amplifier) Configuration

The TIA has to be configured according to the information in the AS702x datasheet (table in figure 30).

It is recommended to **always** set “OpAmp Offset” to 15.

Figure 39:
TIA Configuration Submenu

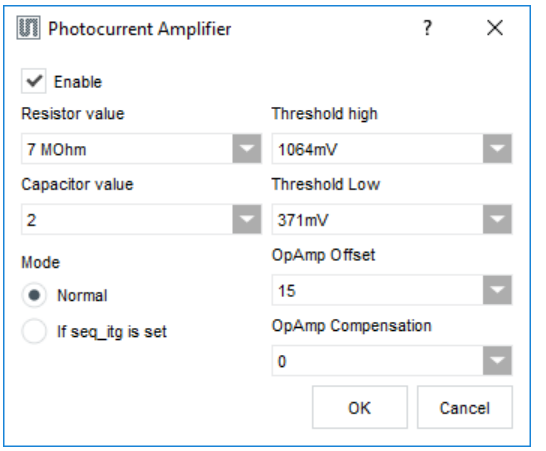
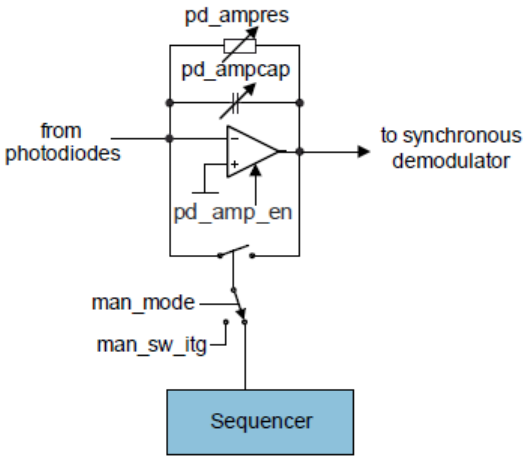


Figure 40:
TIA Block Diagram



For further information, please refer to the following documents:

- AS7026GG Datasheet p. 29 ff.

OFE (Optical Frontend) Configuration

In this window, the OFE blocks can be enabled and the filter chain configured. When the synchronous demodulator is enabled, a sampling rate (refer to Sampling Rate and Subsampling) of at least 200Hz should be configured (due to the 200Hz HP filter).

Figure 41:
OFE Configuration Submenu

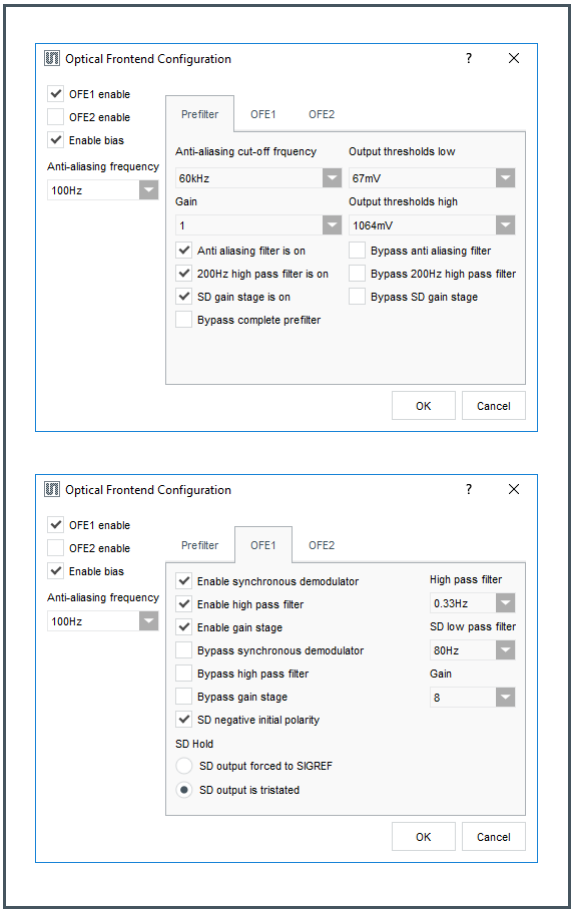
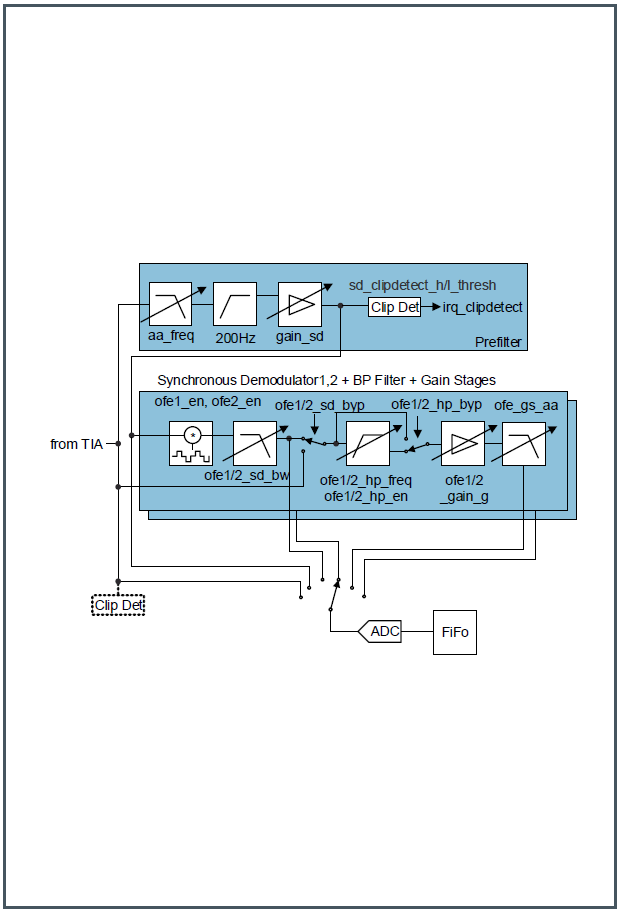


Figure 42:
OFE Block Diagram



Check OFE1 and/or OFE2 check box to enable the corresponding OFE block.

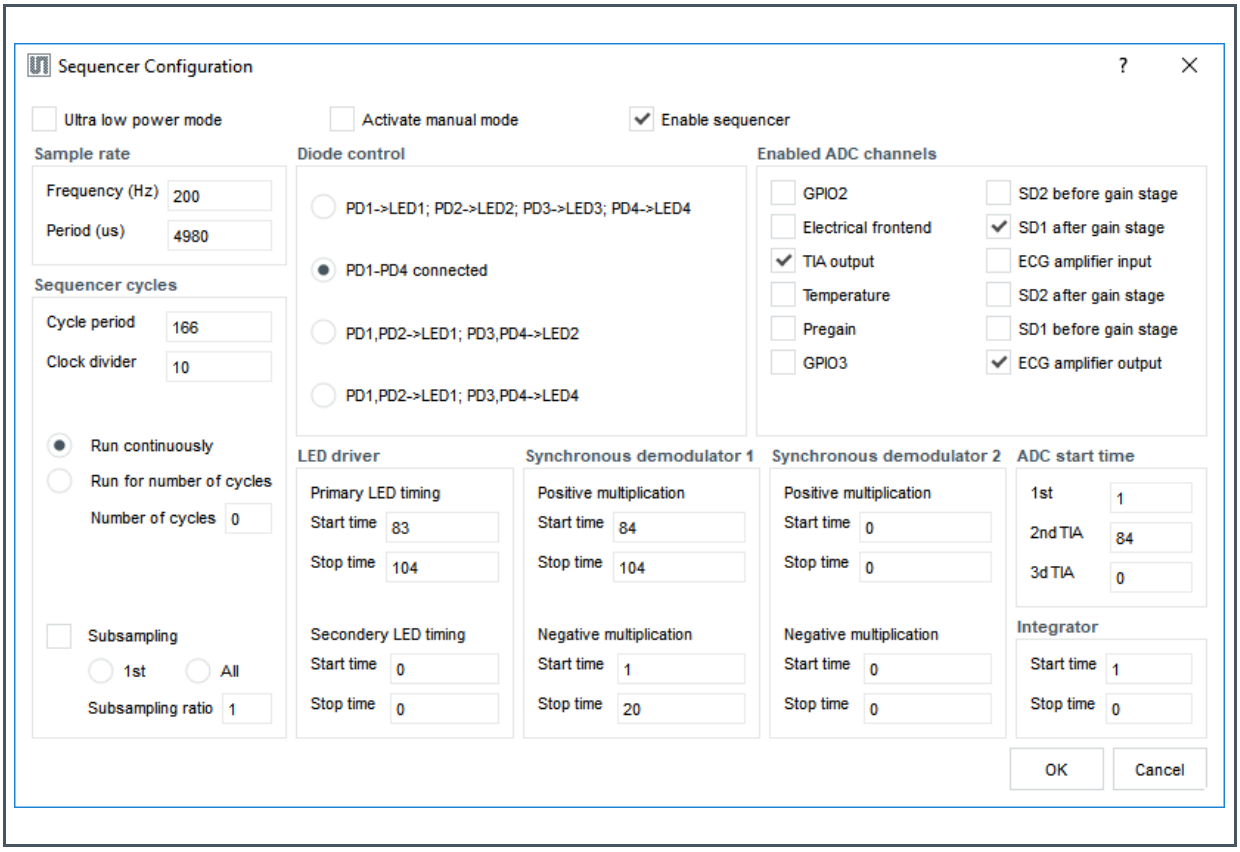
The “Prefilter” tab is setting the configuration of the input filters of the two synchronous demodulators. For reference, please see **OFE_CFGA**, **OFE_CFGB**, **OFE_CFGC** and **OFE_CFGD** register descriptions in the AS702x datasheet.

For further information, please refer to the following documents:

- AS7026GG Datasheet p. 34 ff.

Sequencer Configuration

Figure 43:
Sequencer Configuration Submenu



The “Cycle period” field of the “Sequencer configuration” window (see Figure 43) holds the value of the SEQ_PER register. The client software will automatically calculate its value from the user input for Sample frequency/period entered in the fields “Frequency (Hz)” / “Period (µs)” of the “Sequencer configuration” window (Figure 43). Sample period/frequency is the period/frequency between/of samples of the **same** ADC channel and it depends on the number of enabled ADC channels. If the calculation yields a value for the cycle period that is bigger than 255 - the maximum possible, subsampling will be enabled[1]. Please refer to Sampling Rate and Subsampling for details on sampling rate.

Use this window to enable/disable ADC channels.

[1] For example, with one ADC channel enabled and desired sample rate of 200Hz, the sequencer cycle period needs to be 5000 µs. If (SEQ_DIV+1) is 10, the SEQ_PER register should be 500, but as it is 8 bits, it cannot fit the value 500. It is also not advisable to increase the clock divider as that will affect all the other timing settings, it is better to keep that small to give finer granularity of the timing. To achieve the 200Hz sample rate, the cycle period will be set to 250 and subsampling enabled with subsampling ratio of 2 – meaning the ADC will be triggered every 2nd sequencer cycle. That will give a sample rate of 200Hz / 5000µs period.

Any change in the values of the fields for sample frequency, sample period, cycle period and in the ADC channel selection will cause a new calculation of the values for the rest of the fields.

For further information, please refer to the following documents:

- AS7026GG Datasheet p. 35 ff.

ADC Configuration

This window configures the clock divider of the 1MHz ADC input clock and the ADC settling periods. ADC channels are enabled in the Sequencer Configuration window. Here the selection is just shown.

Figure 44:
ADC Configuration Submenu

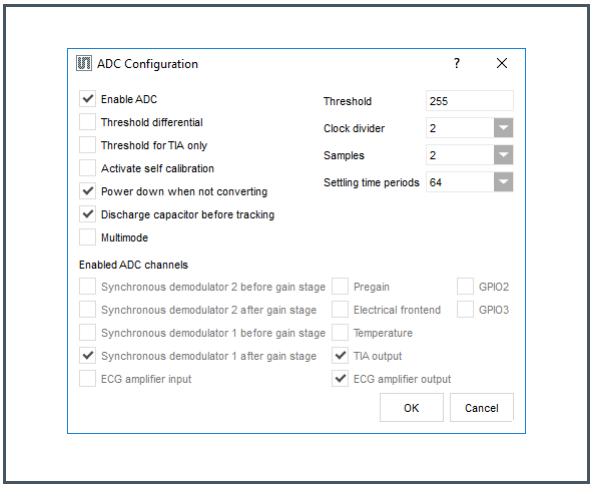
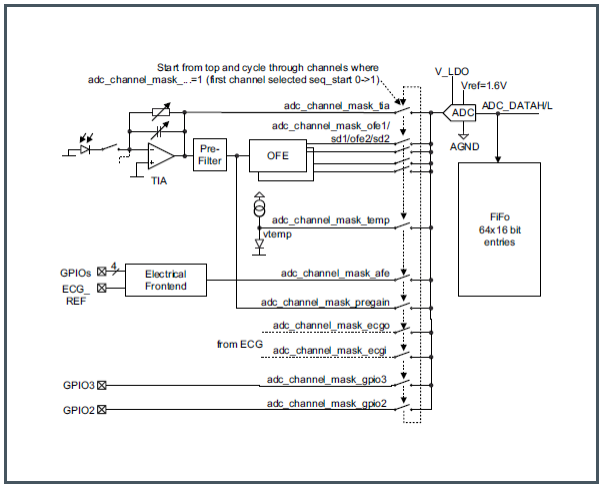


Figure 45:
ADC Block Diagram



For further information, please refer to the following documents:

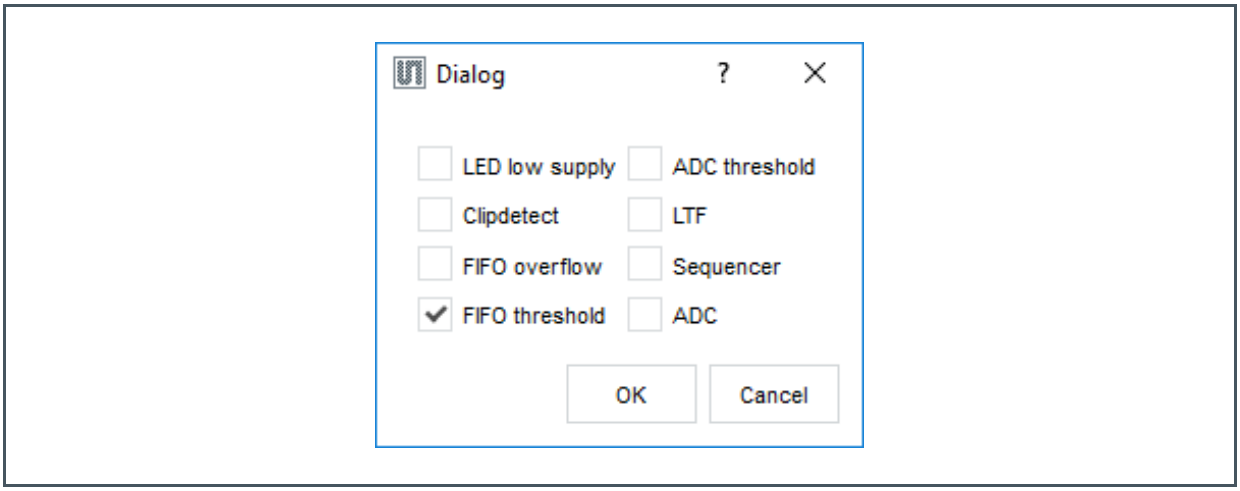
- AS7026GG Datasheet p. 75 ff.

Interrupts Configuration

Enable interrupt sources:

- ADC: End of ADC conversion
- Sequencer: End of sequencer sequence reached.
- LTF: A light-to-frequency conversion is finished.
- ADC threshold: ADC threshold triggered – see ADC threshold.
- FIFO threshold: FIFO almost full (default is each sample triggers an interrupt)
- FIFO overflow: FIFO overflow (error condition, data is lost
- Clipdetect: TIA output and/or SD output exceeded threshold– see details in CLIPSTATUS
- LED supply low: led supply low comparator triggered – see details in LEDSTATUS

Figure 46:
Interrupt Configuration Submenu



For further information, please refer to the following documents:

- AS7026GG Datasheet p. 84 ff.

ECG Amplifier Configuration

The ECG (electrocardiography) amplifier is a high impedance, low noise instrumentation amplifier with analog circuitry to band pass filter the signal and amplify it before converting it with the ADC.

The ECG signal can be used independently or together with PPG in further computation. (e.g. blood pressure)

Figure 47:
ECG Amplifier Configuration Submenu

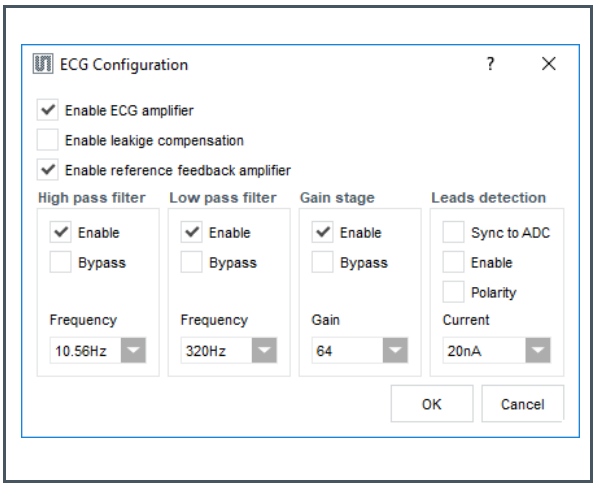
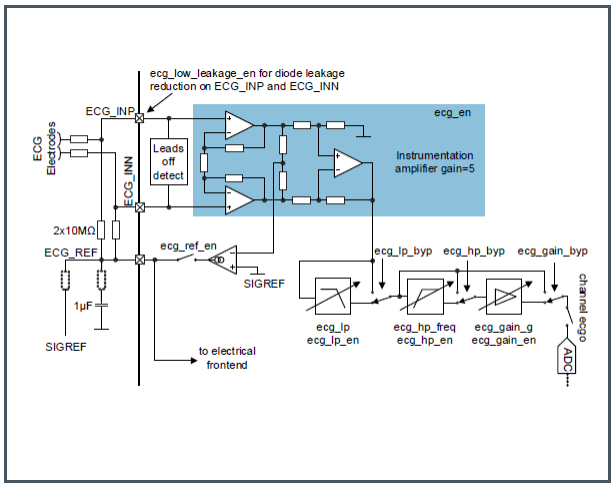


Figure 48:
ECG Amplifier Block Diagram



For further information, please refer to the following documents:

- AS7026GG Datasheet p. 70 ff.

Electrical Analog Frontend Configuration

The electrical analog front end consists of three identical signal paths with independent settings of bias condition, gain and offset.

Here the EAF_CFG, EAF_GST, EAF_BIAS, EAF_DAC and EAF_DAC_CFG registers are set.

Figure 49:
Electrical-Analog-Frontend Configuration Submenu

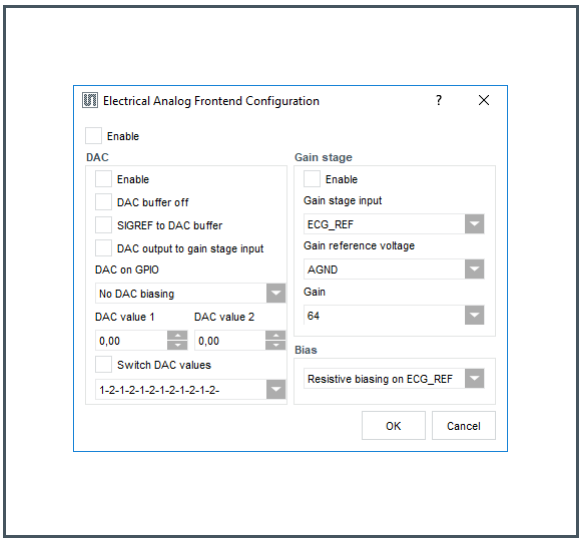
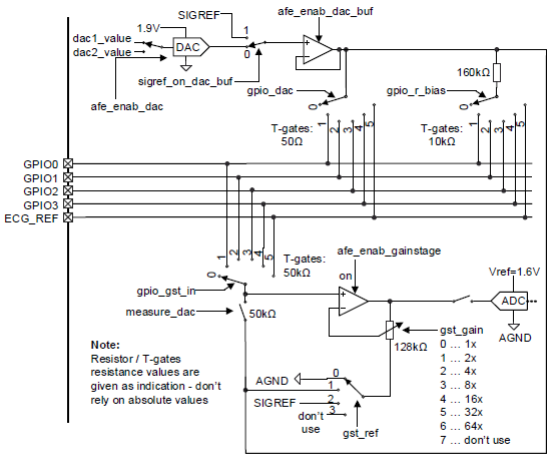


Figure 50:
Electrical-Analog-Frontend Block Diagram



For further information, please refer to the following documents:

- AS7026GG Datasheet p. 61 ff.

Light-to-Frequency Configuration

Light-to-frequency feature can be used to convert a light source into a frequency signal.

Attention

Do not use diodes that are connected to the TIA (register **PD_A, PD_B, PD1...4**) at the same time when itf_en is enabled on the same diode.

For detailed information, please refer to the AS7026GG datasheet.

Figure 51:
Light-to-Frequency Configuration Submenu

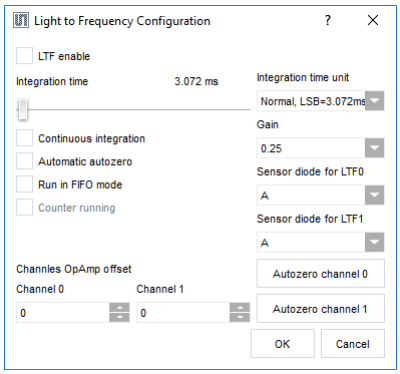
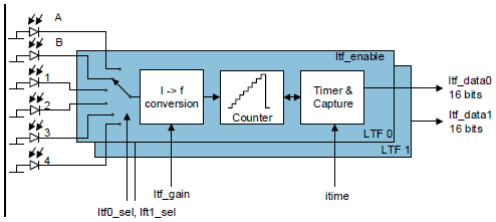


Figure 52:
Light-to-Frequency Block Diagram



The following registers can be shown/configured in the dialog: **ITIME**, **LTF_CONFIG**, **LTF_SEL** and **LTF_GAIN**.

For further information, please refer to the following documents:

- AS7026GG Datasheet p. 54 ff.

GPIOs Configuration

To set a GPIO to analog mode check the check box from the “GPIO mode” group box. If left unchecked, then the GPIO is a digital output or input, depending on the state of the “GPIOx enable output” check boxes - unchecked means the pin is digital input. If the pin is set as digital output, it’s state can be set via the corresponding check box in the “Output state” group box.

Figure 53:
GPIO Configuration Submenu

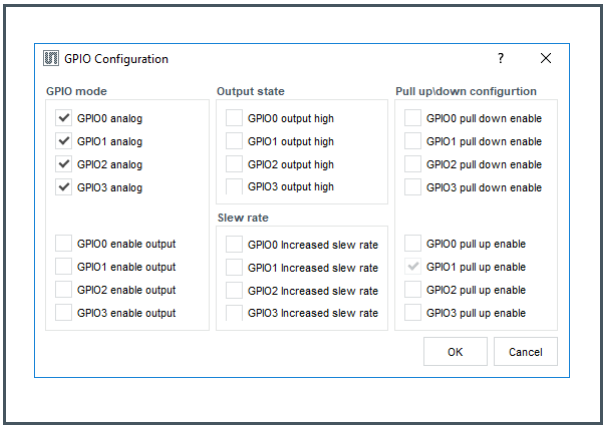
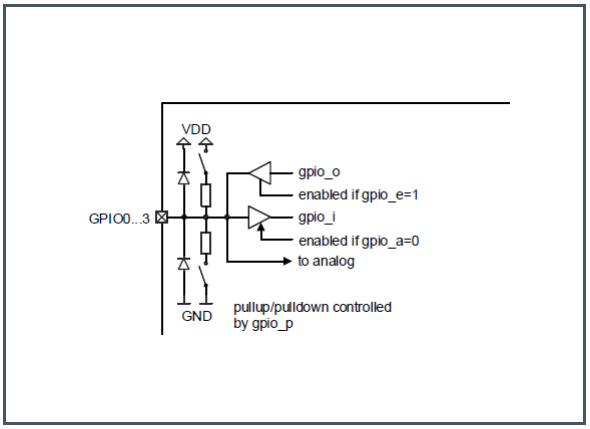


Figure 54:
GIPO Block Diagram



For further information, please refer to the following documents:

- AS7026GG Datasheet p. 84 ff.

5.2.4 Controller Configuration

This section describes the configurations of the firmware running on the microcontroller that communicates with the AS702x.

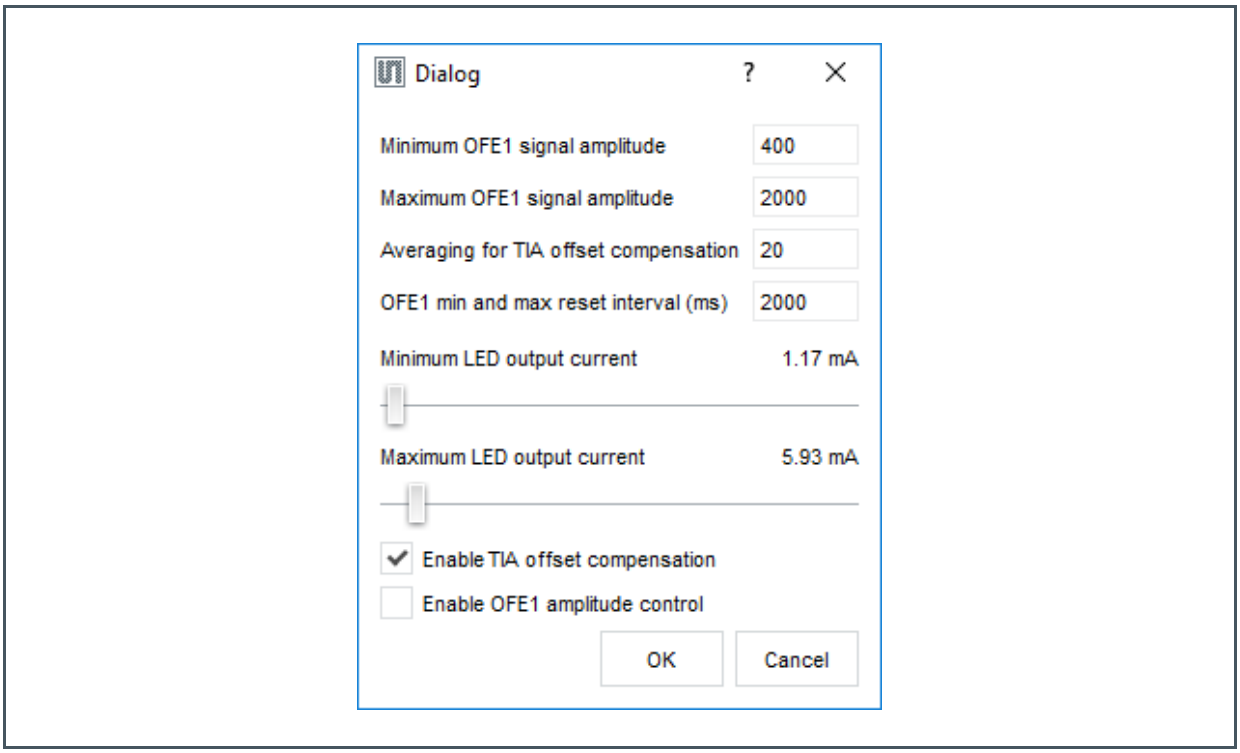
PD Offset & LED Current Control Configuration

The PD offset and LED current control is an algorithmic approach to increase signal quality of PPG signals. The algorithm continuously monitors the TIA and OFE1 outputs and if necessary reconfigures the AS702x while measuring to ensure ideal conditions.

A detailed description of the algorithm is given in section PD Offset and LED Current Control Algorithm.

Figure 55 shows the PD Offset & LED Current Control Submenu.

Figure 55:
PD Offset & LED Current Control Submenu



Minimum OFE1 signal amplitude – if the amplitude of the OFE1 signal drops below that value, LED current will be increased, if LED current control is enabled.

Maximum OFE1 signal amplitude – if the amplitude of the OFE1 signal grows above that value, LED current will be decreased, if LED current control is enabled.

Averaging for TIA offset compensation – how many samples are averaged before TIA mean value is assessed based on which PD offset is corrected.

OFE1 min and max reset interval – the interval at which the min and max values calculated over a moving average are reset in order to keep a recent history and to avoid random spikes.

Minimum and maximum LED output current – sets the range in which the LED current can move if LED current control is enabled. If LED current control is disabled the LED have constant LED current set in the LED Configuration window.

Enable TIA offset compensation and Enable OFE amplitude control check boxes define what will be controlled by the algorithm and if the algorithm is enabled. If both checkboxes are unchecked, the algorithm is disabled and there will be no correction for TIA offset and LED current control.

Enable TIA offset compensation check box, when checked, enables TIA offset compensation.

Enable OFE amplitude control check box, when checked, enables LED current control. LED current control only works together with TIA offset compensation.

5.2.5 Advanced Settings

Additional ADC Channels and Light-to-Frequency Data Display

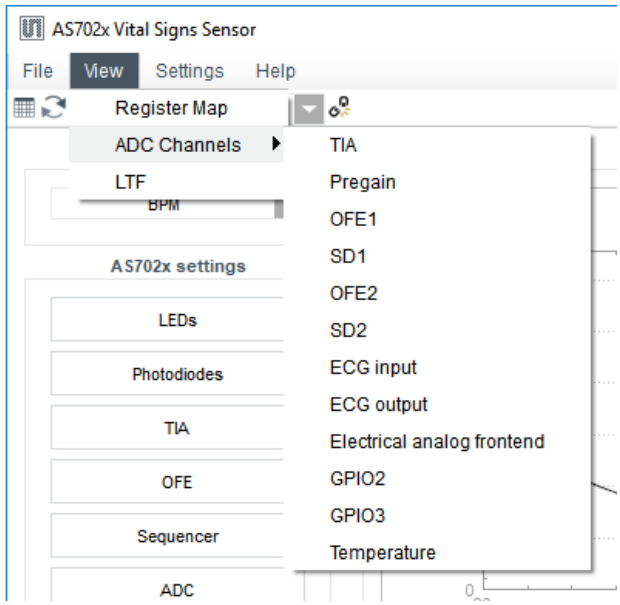
The AS702x Vital Sign Sensors evaluation software allows to display multiple channels. The PPG and ECG channels are always active in the main windows. Additional channels can be displayed via the View menu as shown in Figure 56.

To display a data plot of an ADC channel other than OFE1 and ECG Output, click on menu “View → ADC Channels” and then on the desired ADC channel.

For Light-to-Frequency data output, click on “View → LTF”.

A separate plot window will open.

Figure 56:
Additional Output Channels

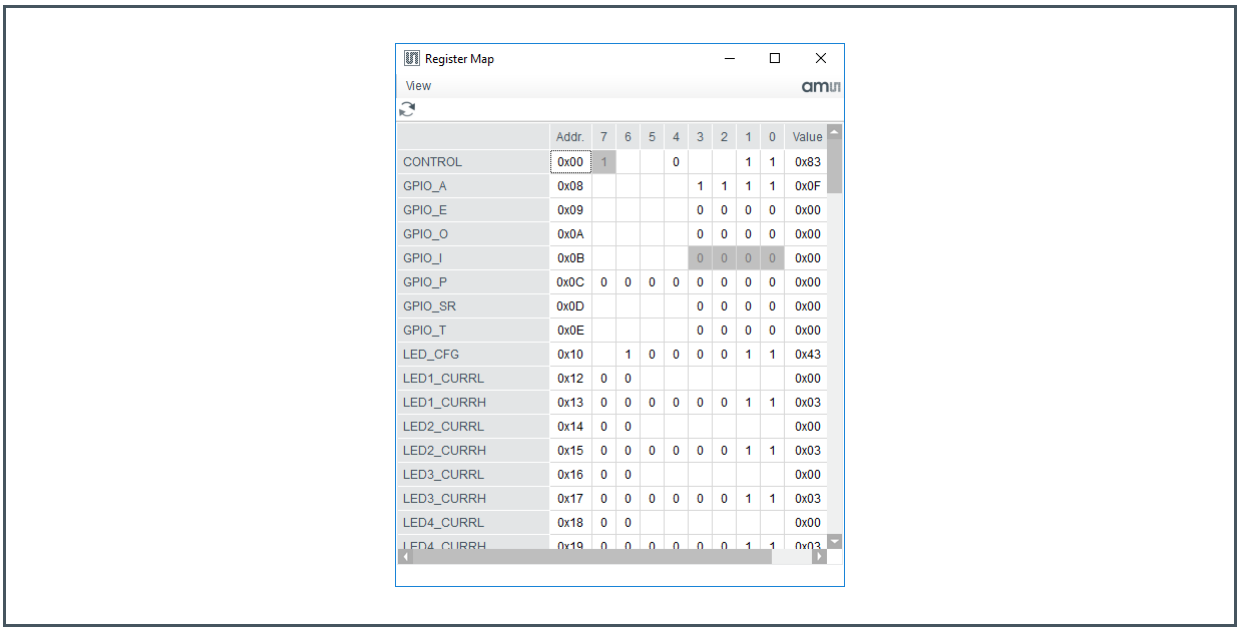


Register Map

The “Register Map” window is used to view/change the contents of the complete set of AS702x user register. To open it, click on the “View → Register Map” menu.

Changing a register value can be done either by modifying its value in the relevant “Value” field or by toggling a bit by clicking on the relevant bit cell. Changing a value in the register map will not update the current selection in the configuration windows of the GUI. Also, a change in any of the configuration windows will not trigger an automatic update of the already opened register map window. To update the values, click on the refresh button marked with the orange rounded rectangle on the “Register Map” picture on the right.

Figure 57:
Register Map Dialog



	Addr.	7	6	5	4	3	2	1	0	Value
CONTROL	0x00	1			0			1	1	0x83
GPIO_A	0x08					1	1	1	1	0x0F
GPIO_E	0x09					0	0	0	0	0x00
GPIO_O	0x0A					0	0	0	0	0x00
GPIO_I	0x0B					0	0	0	0	0x00
GPIO_P	0x0C	0	0	0	0	0	0	0	0	0x00
GPIO_SR	0x0D					0	0	0	0	0x00
GPIO_T	0x0E					0	0	0	0	0x00
LED_CFG	0x10		1	0	0	0	0	1	1	0x43
LED1_CURRL	0x12	0	0							0x00
LED1_CURRH	0x13	0	0	0	0	0	0	1	1	0x03
LED2_CURRL	0x14	0	0							0x00
LED2_CURRH	0x15	0	0	0	0	0	0	1	1	0x03
LED3_CURRL	0x16	0	0							0x00
LED3_CURRH	0x17	0	0	0	0	0	0	1	1	0x03
LED4_CURRL	0x18	0	0							0x00
LED4_CURRH	0x19	0	0	0	0	0	0	1	1	0x03

Saving Current Configuration Settings to a File

The current configuration settings can be exported to a file. To do this, click on the “File → Save Configuration” menu. This will open the “Save Configuration File” dialog box on the second picture on the right. Enter file name and choose the file location, then click “Save”.

Loading Configuration Settings from File

To load a previously exported configuration settings, click on the “File → Load Configuration” menu. This will open the “Select Configuration File” dialog box. Select the configuration file from which to load settings and click “Open” button.

The settings imported from the file can be reviewed in the relevant configuration windows.

If the GUI is connected to the board, the newly imported settings will be applied immediately, otherwise upon successful connection to the board.

Figure 58:
Safe and Load Configuration Menu Entries

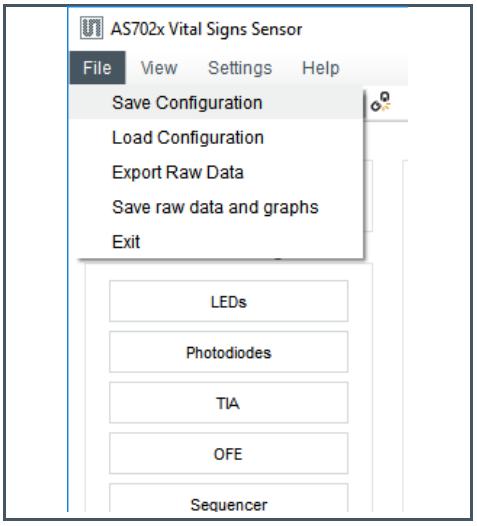
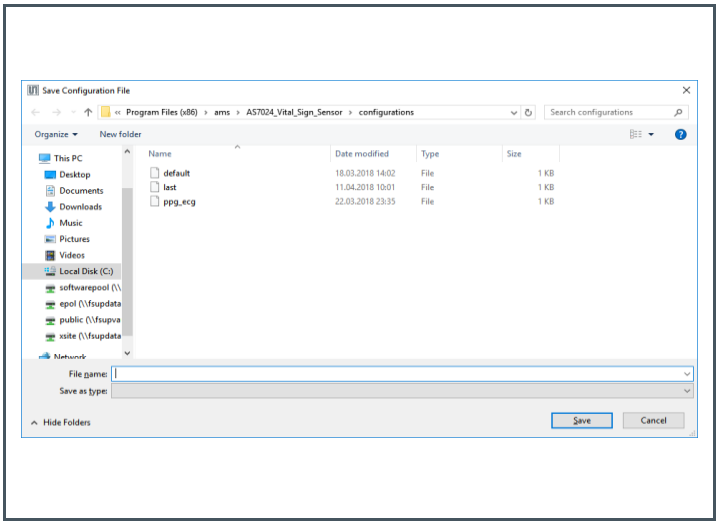


Figure 59:
Safe Configuration File Dialog



Raw Data Logging and Exporting

By default, during measurement the raw data from the AS702x is logged in memory. When a measurement is stopped, this data can be exported to a comma delimited file by clicking on the "File → Export Raw Data" menu and selecting the file location and file name in the save file dialog box.

Raw data file format:

- first raw has the column captions
- first column has the timestamp in milliseconds
- columns 2nd to the last have the data from the enabled ADC channels

Raw data logging can be disabled by unchecking the "Log raw data" check box in the "Settings" menu.

Figure 60:
Export Raw Data Menu

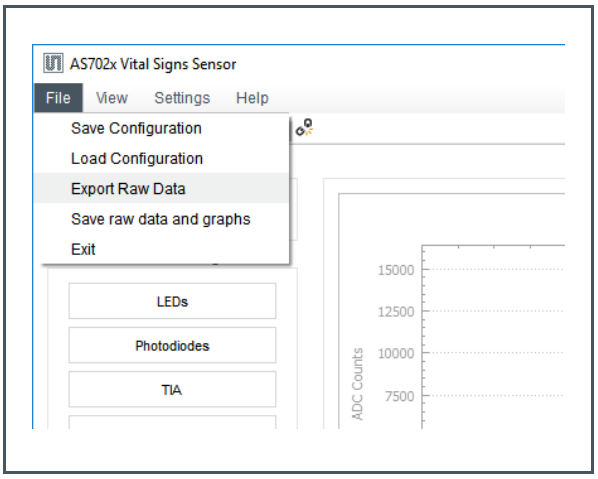
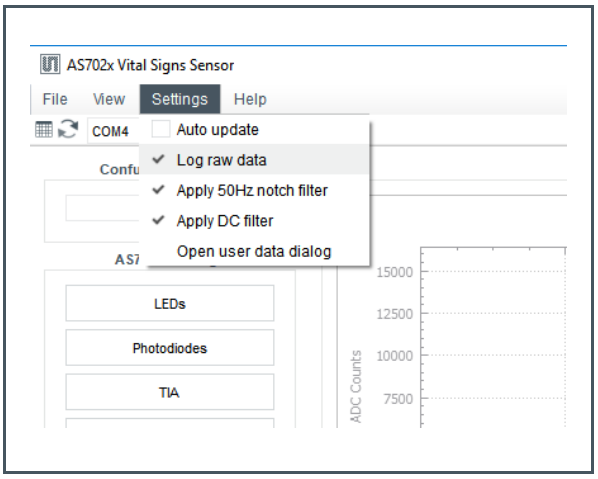


Figure 61:
Log Raw Data Menu



5.3 FW, Driver, API

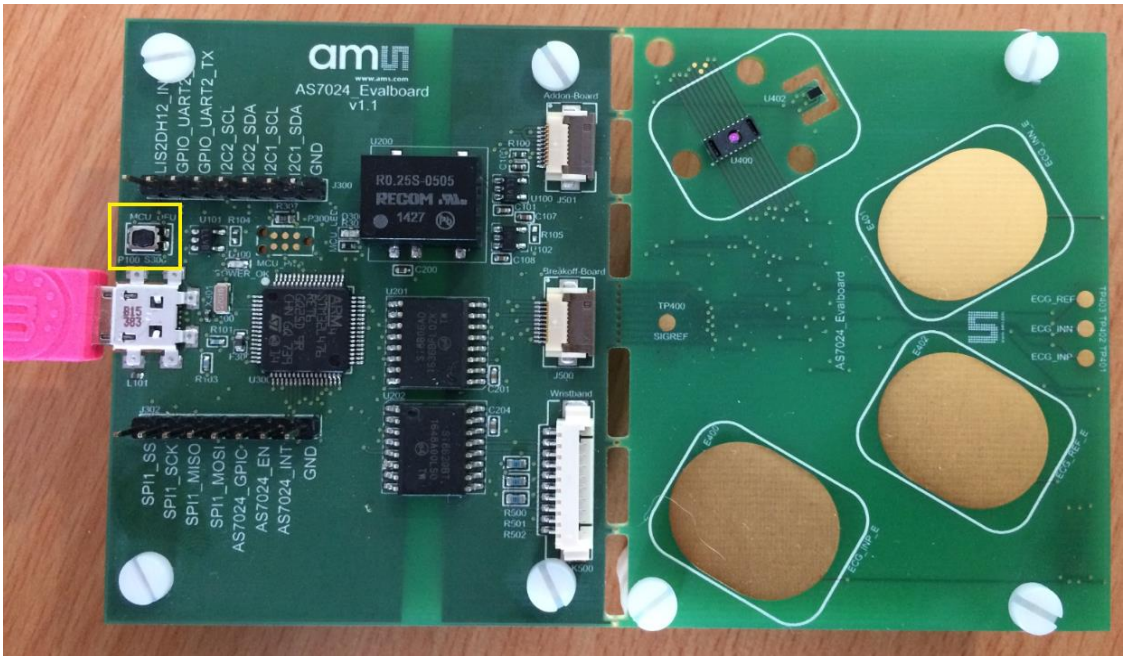
5.3.1 Controller Firmware Update over USB

Starting in DFU Mode

In order to update the FW over USB on the AS702x Evaluation Board the MCU has to be started in DFU mode. To do so follow the steps below:

1. If the board is connected to the PC, disconnect it.
2. Press the button marked with yellow on the picture below and connect the USB cable to the computer while keeping the button pressed. Release the button once the USB cable is plugged in.

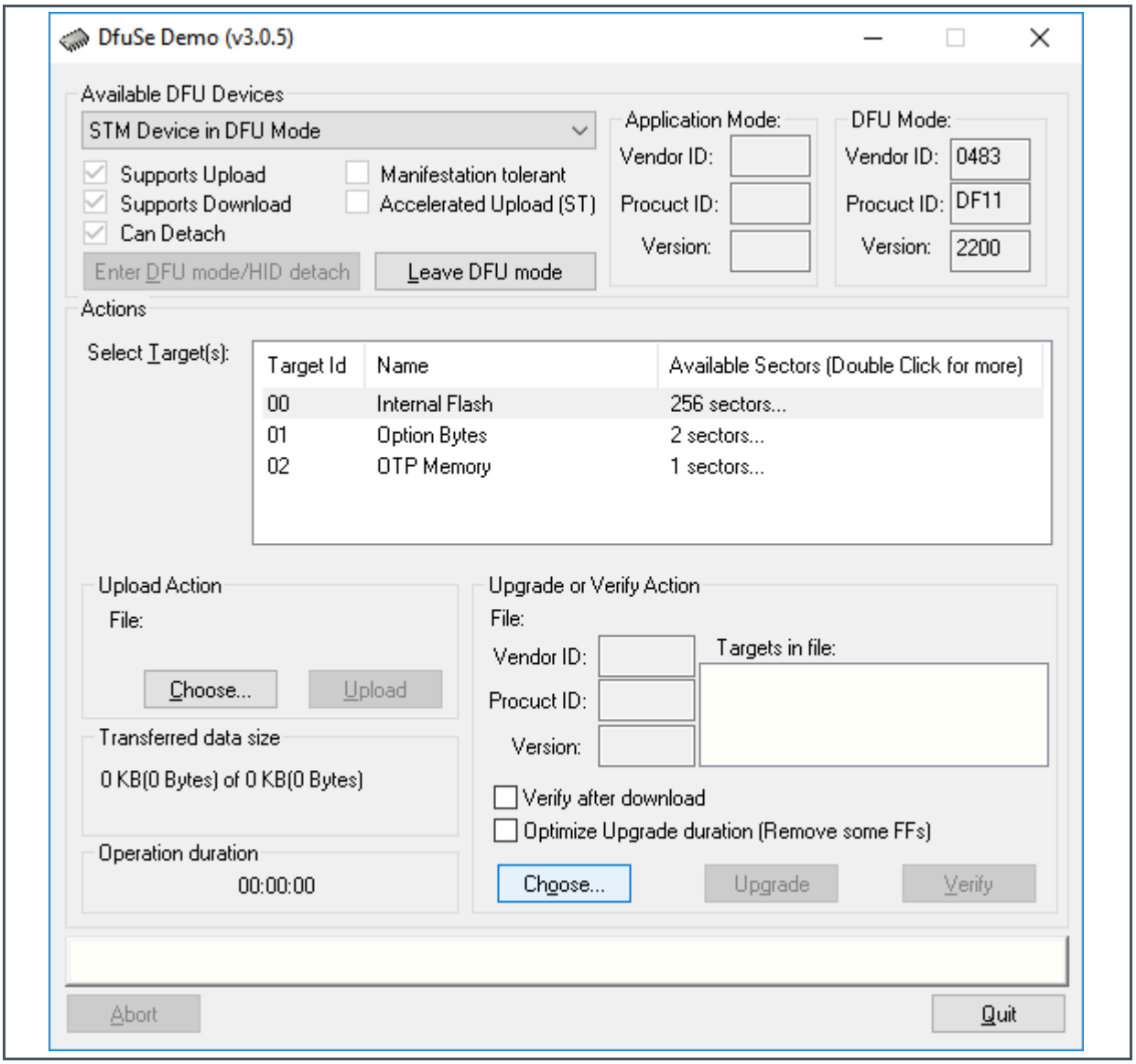
Figure 62:
Evaluation Board



(1) The button used to start into bootloader mode is highlighted.

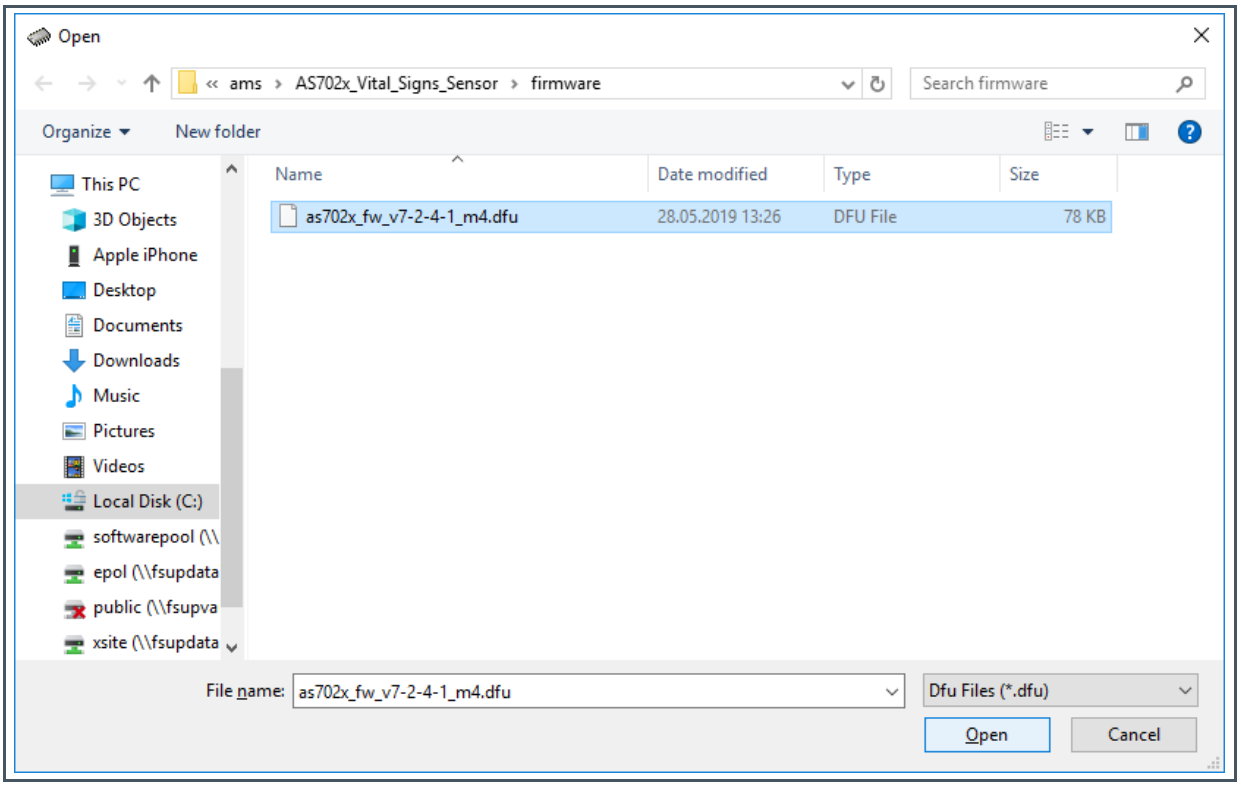
3. Start the DfuSeDemo.exe from the “extras\DFU” folder located at the installation folder of the GUI (if not changed during installation should be “\Program Files (x86)\ams\AS702x_Vital_Sign_Sensor”.

Figure 63:
DfuSeDemo Started



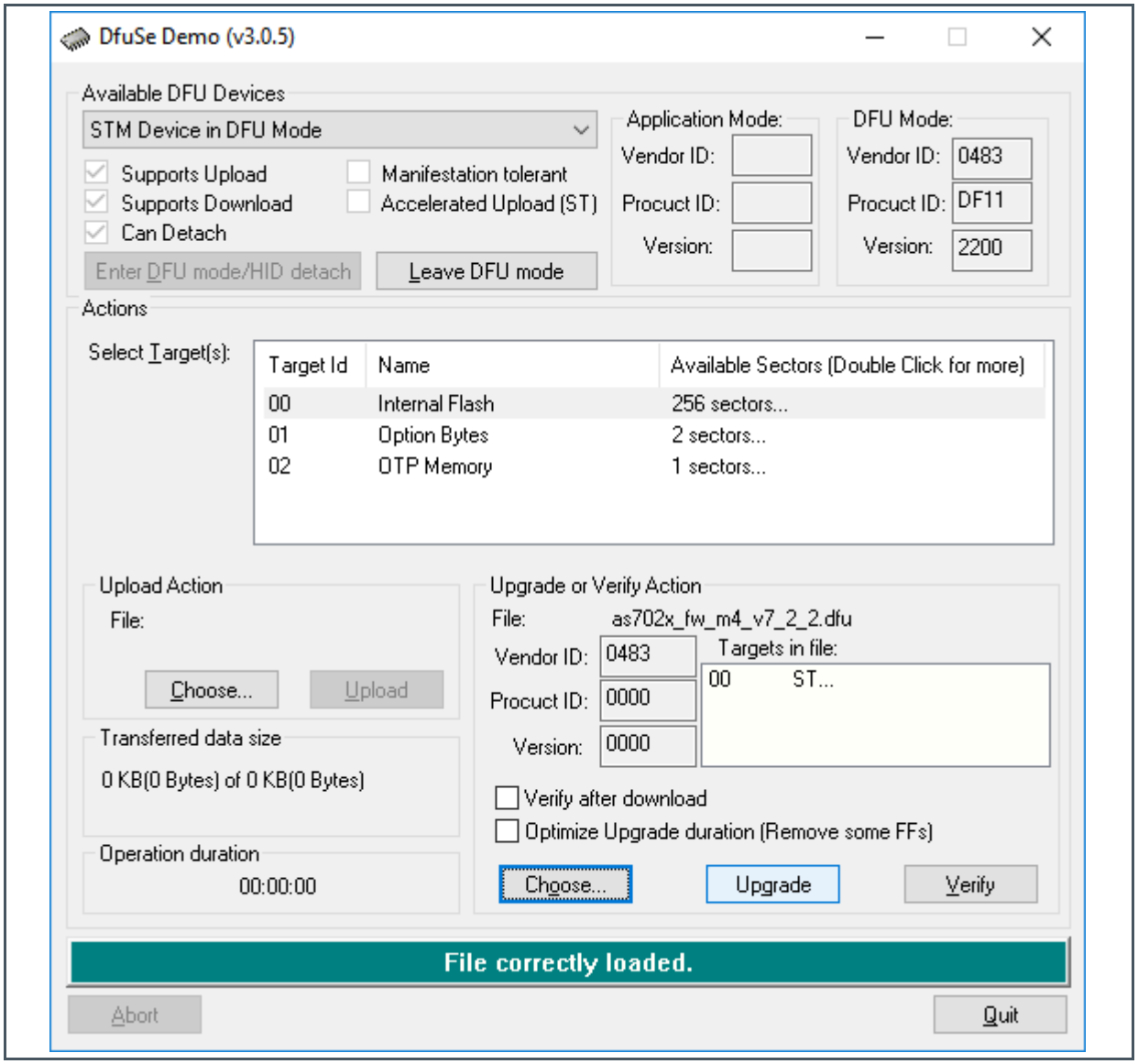
4. Click “Choose” to select the .dfu file containing the new FW and click on “Open”.

Figure 64:
Choosing firmware DFU Package



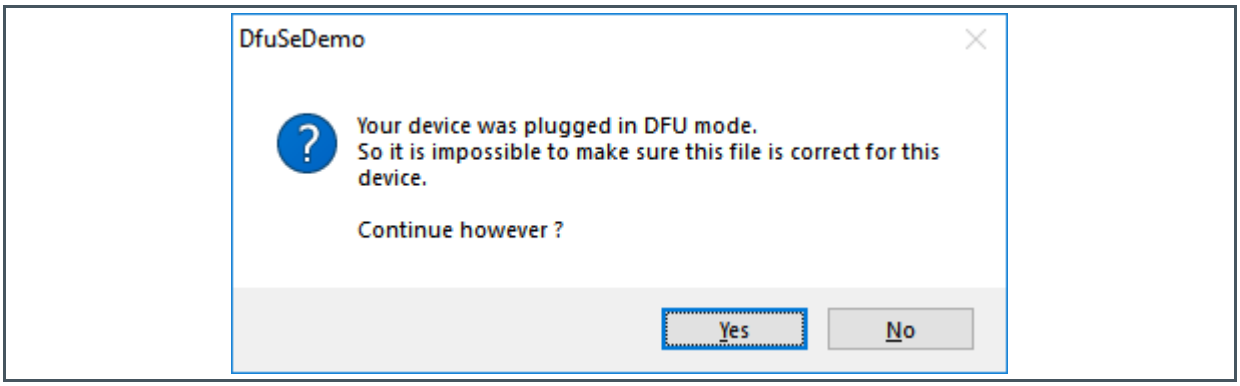
5. If the firmware was correctly loaded, the “Upgrade” button will be enabled, click on it to start the upgrade process.

Figure 65:
Firmware Correctly Loaded



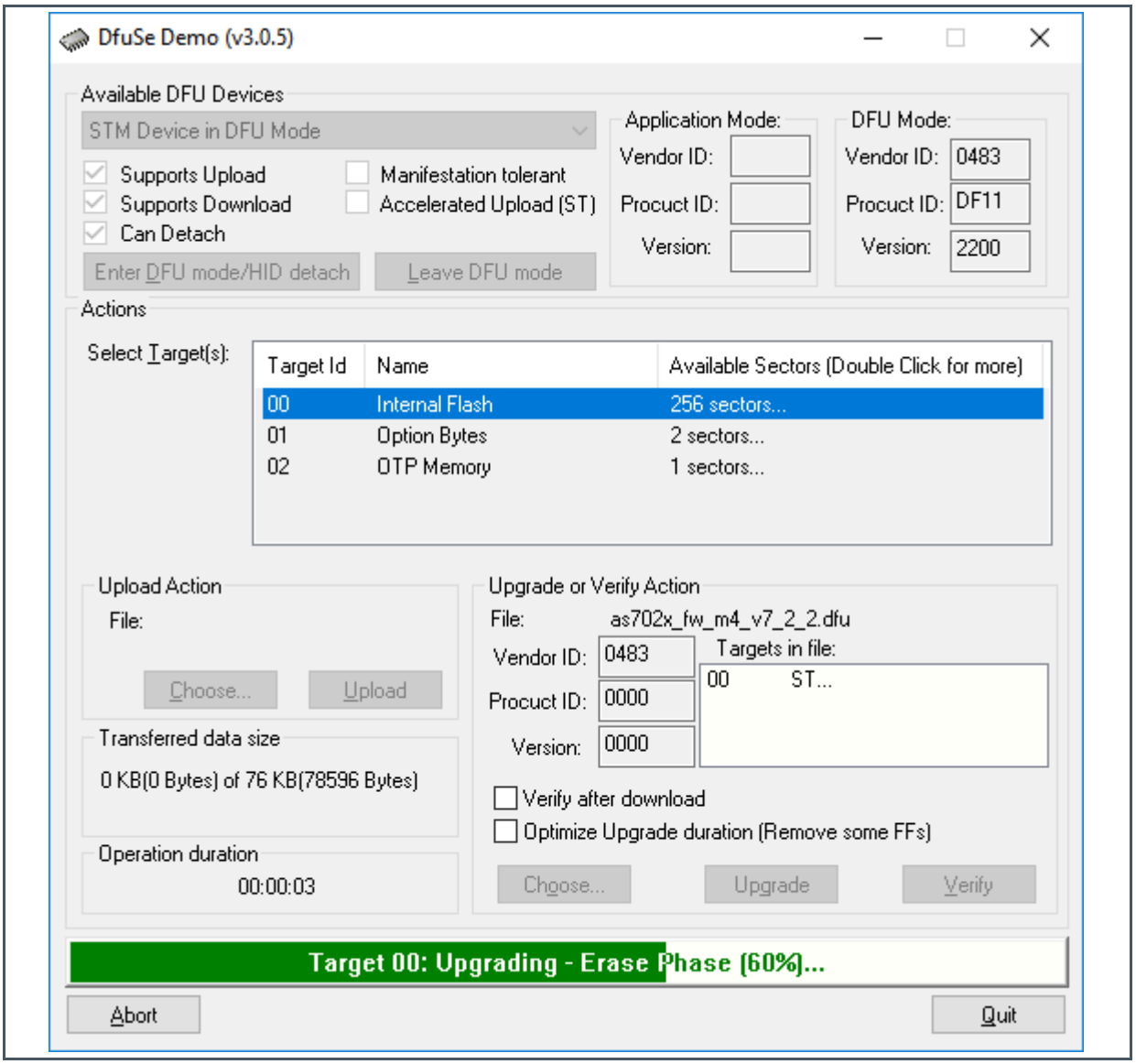
6. The pop-up window shown in the figure below will then open. Click on “Yes” to continue.

Figure 66:
Confirm Firmware Upgrade



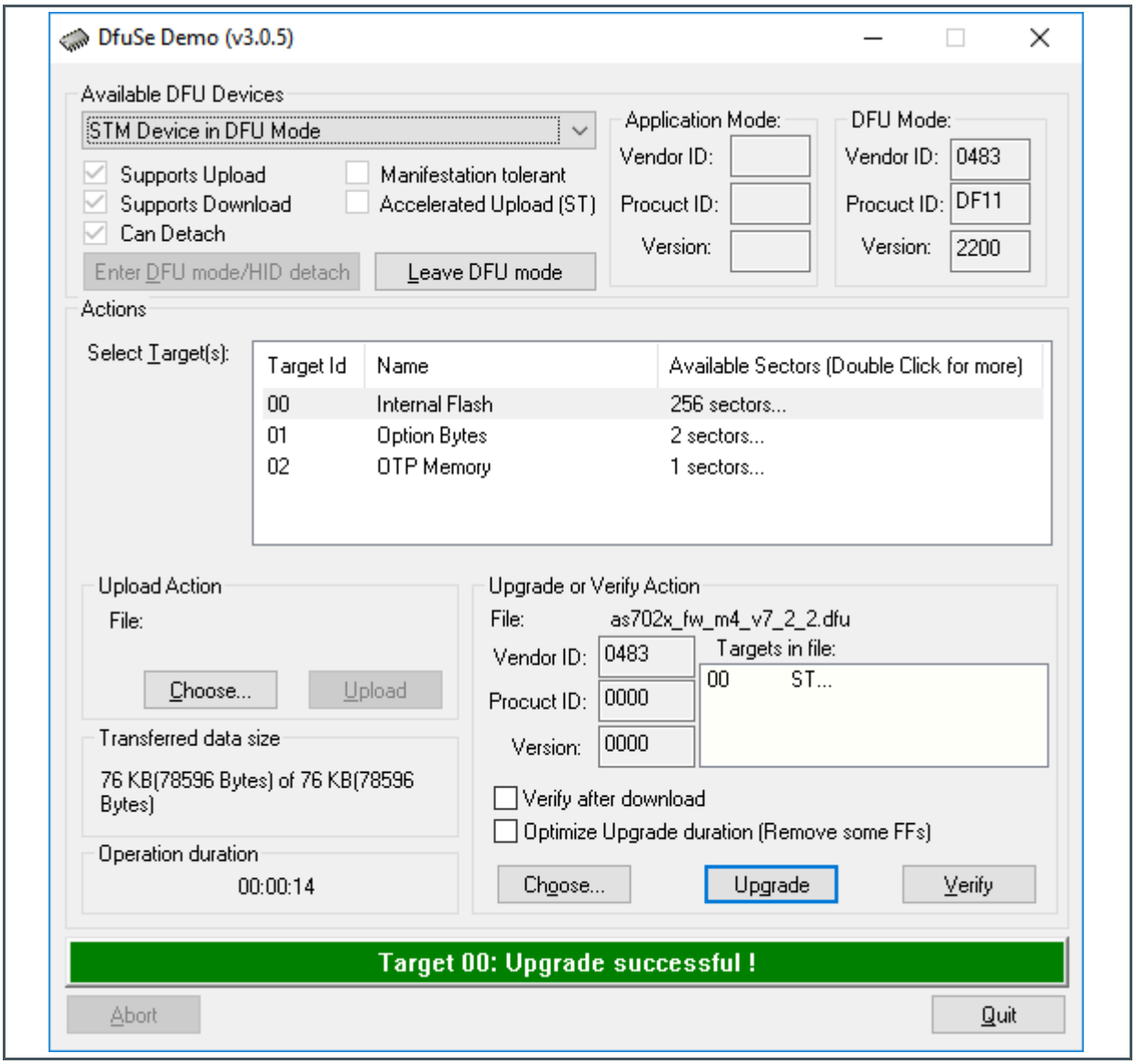
7. The upgrade process will start; upgrade status will be displayed at the bottom of the window.

Figure 67:
Firmware Upgrade Ongoing



8. After the FW upgrade finished, click on “Leave DFU mode”, then “Quit”.

Figure 68:
Firmware Upgrade Finished



9.

6 Revision Information

Changes from previous version to current revision v2-00	Page
All figures showing the Main window of the client SW exchanged	28-37
Updated LED configuration section with new figure showing the new feature - LED output state setting	40
New chapter explaining the user calibration procedure for blood pressure measurement	33-38
Firmware upgrade section modified	56-63

- Page and figure numbers for the previous version may differ from page and figure numbers in the current revision.
- Correction of typographical errors is not explicitly mentioned.

7 Legal Information

Copyrights & Disclaimer

Demo Kits, Evaluation Kits and Reference Designs are provided to recipient on an “as is” basis for demonstration and evaluation purposes only and are not considered to be finished end-products intended and fit for general consumer use, commercial applications and applications with special requirements such as but not limited to medical equipment or automotive applications. Demo Kits, Evaluation Kits and Reference Designs have not been tested for compliance with electromagnetic compatibility (EMC) standards and directives, unless otherwise specified. Demo Kits, Evaluation Kits and Reference Designs shall be used by qualified personnel only.

ams AG reserves the right to change functionality and price of Demo Kits, Evaluation Kits and Reference Designs at any time and without notice.

Any express or implied warranties, including, but not limited to the implied warranties of merchantability and fitness for a particular purpose are disclaimed. Any claims and demands and any direct, indirect, incidental, special, exemplary or consequential damages arising from the inadequacy of the provided Demo Kits, Evaluation Kits and Reference Designs or incurred losses of any kind (e.g. loss of use, data or profits or business interruption however caused) as a consequence of their use are excluded.

ams AG shall not be liable to recipient or any third party for any damages, including but not limited to personal injury, property damage, loss of profits, loss of use, interruption of business or indirect, special, incidental or consequential damages, of any kind, in connection with or arising out of the furnishing, performance or use of the technical data herein. No obligation or liability to recipient or any third party shall arise or flow out of ams AG rendering of technical or other services.

RoHS Compliant & ams Green Statement

RoHS Compliant: The term RoHS compliant means that ams AG products fully comply with current RoHS directives. Our semiconductor products do not contain any chemicals for all 6 substance categories, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, RoHS compliant products are suitable for use in specified lead-free processes.

ams Green (RoHS compliant and no Sb/Br): ams Green defines that in addition to RoHS compliance, our products are free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material).

Important Information: The information provided in this statement represents ams AG knowledge and belief as of the date that it is provided. ams AG bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. ams AG has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. ams AG and ams AG suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

Headquarters
ams AG
Tobelbader Strasse 30
8141 Premstaetten
Austria, Europe
Tel: +43 (0) 3136 500 0

Please visit our website at www.ams.com
Buy our products or get free samples online at www.ams.com/Products
Technical Support is available at www.ams.com/Technical-Support
Provide feedback about this document at www.ams.com/Document-Feedback
For sales offices, distributors and representatives go to www.ams.com/Contact
For further information and requests, e-mail us at ams_sales@ams.com