

User Manual

Document revision	1.9
Document release date	January 2024
Document number	BST-DHW-AN013
Technical reference code(s)	n.a.
Notes	Data and descriptions in this document are subject to change without notice. Product photos and pictures are for illustration purposes only and may differ from the real product appearance.

Contents

1 Introduction	6
2 Introduction to COINES SDK	8
3 COINES SDK usage	8
4 Installation	8
4.1 Installation (Windows)	9
4.1.1 System requirements	9
4.1.2 Installation of COINES SDK	9
4.1.3 Installation of compiler environment	10
4.2 Installation (Linux/MacOS)	13
4.2.1 System requirements	13
4.2.2 Installation of COINES SDK	13
4.2.3 Installation of compiler environment	14
5 Using COINES SDK to access the sensor on Engineering Board	14
5.1 Running examples on the MCU of the Application Board	14
5.1.1 Working principle	14
5.1.2 Getting started	15
5.1.3 Interfacing via BLE	16
5.1.4 Cross compiling	16
5.1.5 Viewing the results	16
5.1.6 Data logging	17
5.2 Running examples on the PC side	17
5.2.1 Working principle	17
5.2.2 PC side implementation	17
5.2.3 Getting started	18
5.2.4 Interfacing via BLE	18
5.2.5 Compiling	18
5.2.6 Viewing the results	18
5.2.7 Data logging	18
5.3 Project Cleanup	18
6 Using COINESPY to access the sensor on the Engineering Board	19
6.1 Introduction to the COINESPY library	19
6.2 Installation	19
7 Using SensorAPI with COINES SDK	20
7.1 SensorAPI	20
7.2 Downloading SensorAPI	20
7.3 Running example on MCU side	20
7.4 Running example on MCU side via BLE	22
7.5 Running example on the PC side	24
7.6 Running example on the PC side via BLE	25

8 Examples on how to use COINES SDK	27
8.1 C examples	27
8.1.1 Establishing communication	27
8.1.2 Getting board info	27
8.1.3 I2C config and read	28
8.1.4 SPI config and read	29
8.1.5 Configure VDD and VDDIO	31
8.1.6 Led and button control	31
8.1.7 File listing in External memory	32
8.1.8 Temperature measurement	33
8.1.9 Battery level measurement	33
8.1.10 Configure BLE communication	34
8.1.11 Configure Serial communication	35
8.2 Python examples	36
8.2.1 Getting board info	36
8.2.2 I2C config and read	37
8.2.3 SPI config and read	38
9 Debugging via VS code	40
10 Media Transfer Protocol (MTP) firmware for APP3.X	41
10.1 Copying the files using MTP	43
11 USB/BLE DFU bootloader	44
11.1 Key Features	44
11.1.1 USB DFU	44
11.1.2 BLE DFU	44
11.2 Invoking the Bootloader	44
11.3 Using the Bootloader via USB	45
11.4 Using the Bootloader via BLE	45
12 Switching to Operating Modes	47
12.1 APP2.0 (or) APP3.X	47
12.2 Nicla Sense ME board	47
13 Updating firmware using COINES SDK	47
14 FAQs	48
15 Annexure	50
15.1 GPIO mapping	50
15.1.1 GPIO mapping of APP2.0 shuttle board pins	50
15.1.2 GPIO mapping of APP3.X shuttle board pins	50
15.2 COINES SDK C functions	52
15.2.1 coinesAPI calls: Interface and board information	52
15.2.2 coinesAPI calls: GPIO oriented calls	53
15.2.3 coinesAPI calls: Sensor communication	53
15.2.4 coinesAPI calls: Streaming feature	57
15.2.5 coinesAPI calls: Other useful APIs	60
15.3 COINES SDK Python functions	67
15.3.1 coinespy API calls: Interface and board information	67
15.3.2 coinespy API calls: GPIO oriented calls	68
15.3.3 coinespy API calls: Sensor communication	69
15.3.4 coinespy API calls: Streaming feature	70

15.3.5 coinespy API calls: Other useful APIs	73
15.3.6 Definition of constants	74
15.4 Error Codes	78
15.5 COINES SDK structure	79

Acronyms and abbreviations

APP2.0	Application Board 2.0
APP3.X	Application Board 3.0 and Application Board 3.1
BLE	Bluetooth Low Energy
COINES	COmmunication with Inertial and Environmental Sensors
SDK	Software Development Kit
DFU	Device Firmware Upgrade
DTR	Data Terminal Ready
MCU	Microcontroller Unit
MEMS	Micro-Electro-Mechanical Systems
USB	Universal Serial Bus

1 Introduction

Bosch Sensortec offers a toolkit for evaluation of it's sensor products. The toolkit consists of 3 elements:

- 1. Engineering Board:** [Application board](#) named APP2.0 and APP3.X in this document, serves as interface translator from the sensor interface (I^2C or SPI) to a USB interface, allowing PC software to communicate with the sensor on the shuttle board. [Nicla Sense ME](#) board combines four state-of-the-art sensors from Bosch Sensortec (BHI260AP, BMP390, BMM150 and BME688) in the Arduino ecosystem.

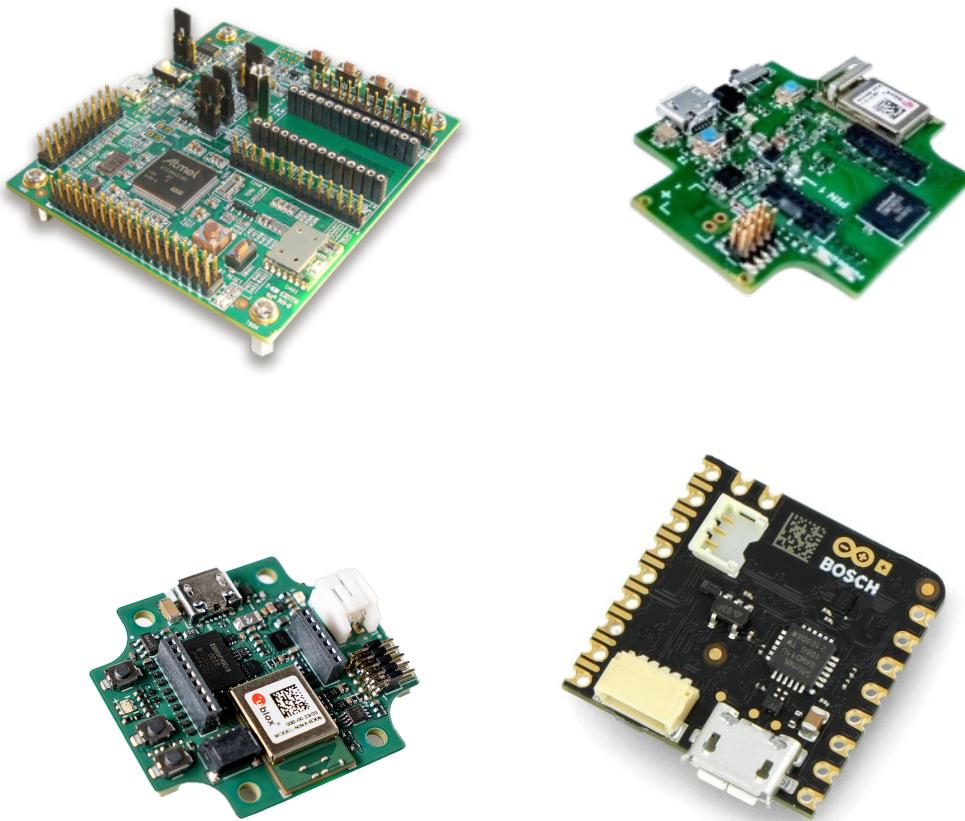


Fig. 1: Application Board 2.0/3.0/3.1/Nicla Sense ME

- 2. Sensor Shuttle board:** A sensor specific shuttle board also known as breakout board is a PCB with the sensor mounted on it. The shuttle board allows easy access to the sensor pins via a simple socket and can be directly plugged into the Bosch Sensortec's Application Boards. APP3.X shuttle boards also known as mini shuttle boards have smaller form factor when compared with APP2.0 shuttle board.



Fig. 2: APP2.0/3.X sensor shuttle board

3. **COINES SDK:** COINES SDK provides a low-level interface for communication with Bosch Sensortec's Engineering Boards enabling access to their MEMS sensors through sample applications and SensorAPI. For a detailed description, refer to the following sections.

2 Introduction to COINES SDK

COmunication with **I**Nertial and **E**nvironmental **S**ensors (COINES) is an SDK (Software Development Kit), implemented in C as a programming language that provides a low-level interface to Bosch Sensortec's Engineering Boards. The user can access Bosch Sensortec's MEMS sensors through this C interface. COINES SDK can be used with SensorAPI of the sensor which is available at <https://github.com/BoschSensortec>. The user can modify, compile and run the sample applications in COINES SDK and SensorAPI.

The working environment consists of the following:

- A Bosch Sensortec MEMS sensor on a shuttle board mounted on the socket of Bosch Sensortec's Application Board (APP2.0/APP3.X).
- Windows, Linux or Mac PC to which the Engineering Board is connected via USB or BLE.
- The release of the COINES SDK is available at <https://www.bosch-sensortec.com/software-tools/tools/coines/>
- C compiler is also required (for details, see sections below)

3 COINES SDK usage

The following diagram represents COINES SDK usage.

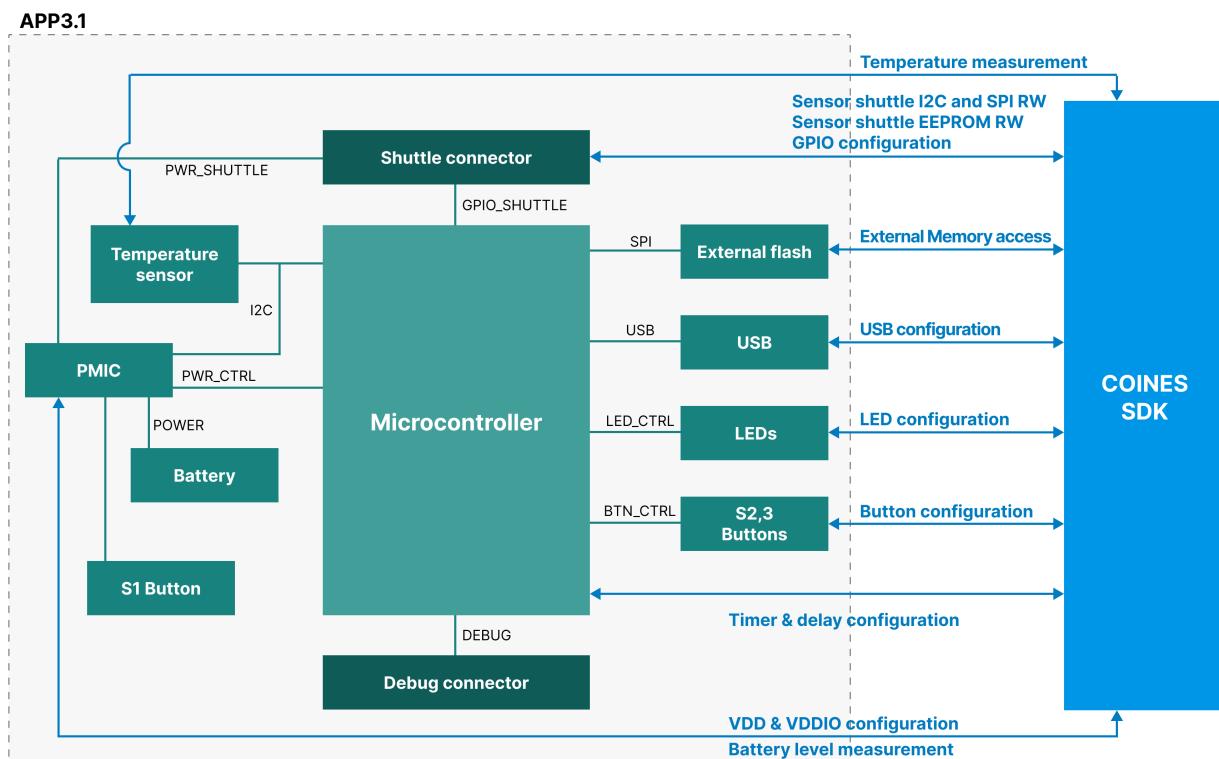


Fig. 3: COINES SDK usage with APP3.1

4 Installation

COINES SDK can be used on any recent PC or laptop system. The hardware must provide a USB interface.

COINES SDK runs on recent versions of Windows, Linux, and Mac Operating systems.

4.1 Installation (Windows)

4.1.1 System requirements

The supported OS versions are Windows 10 and 11.

4.1.2 Installation of COINES SDK

Follow the steps below to install COINES SDK:

1. Download the latest version of COINES SDK from [Bosch Sensortec website](#).
2. Run the Installer
3. Accept the End User License Agreement and click **Next**

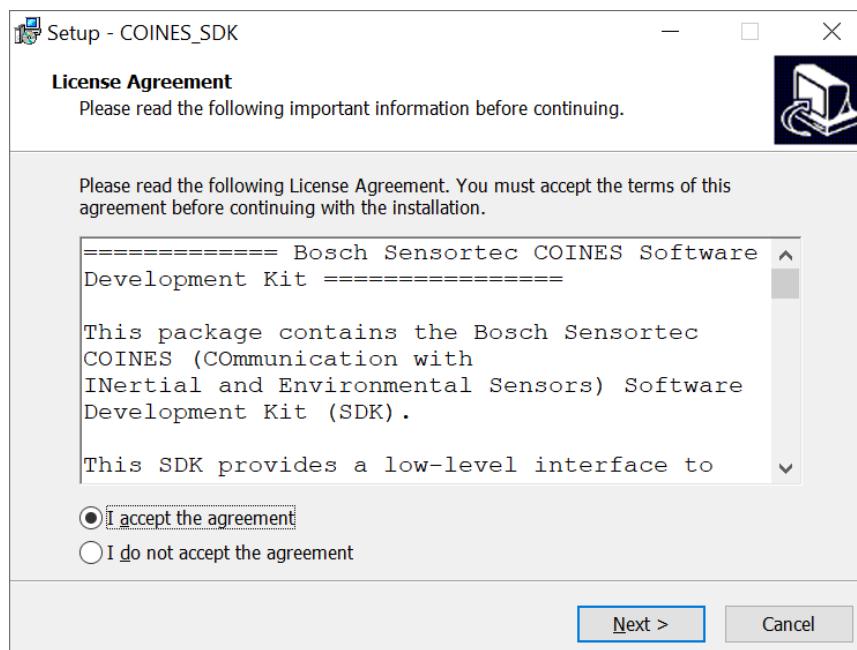


Fig. 4: Windows installer end user agreement dialog

4. Click **Install** to start the Installation.

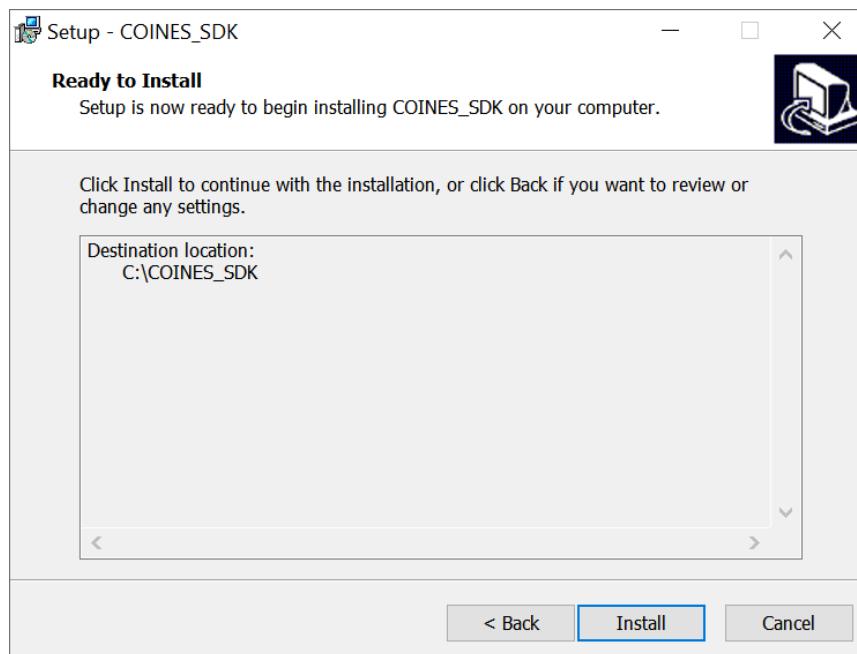


Fig. 5: Windows install dialog

4.1.3 Installation of compiler environment

COINES SDK examples can be built using GNU C compiler (GCC). There are various distributions of GCC. TDM-GCC is easy to install and therefore preferred for COINES SDK. TDM GCC is based on MinGW GCC.

If you have already installed GCC (MinGW/Cygwin/MSYS2 GCC) and added it to the 'PATH' environmental variable, you can skip the compiler installation.

The steps to the install the compiler environment are as follows:

1. Download the TDM32/TDM64 bundle ([link](#)). **Use TDM32 bundle if your Windows OS is 32-bit and TDM64 bundle if 64-bit.**
2. Start the Installer. Ensure that the option **Check for updated files on the TDM GCC server** is deselected. Click **Create** and proceed with the installation.
3. If you intend to run the COINES SDK example on the Application Board's microcontroller, install the latest version of the [GNU Embedded Toolchain for ARM](#) for Windows. Make sure you have selected **Add to PATH**.
4. Click **Install**.
5. Click **Finish**.

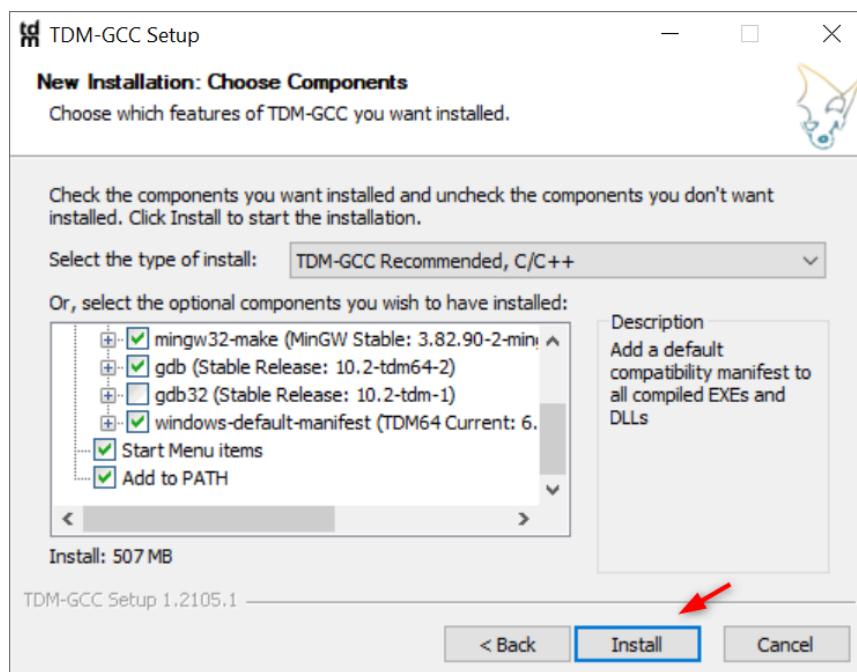
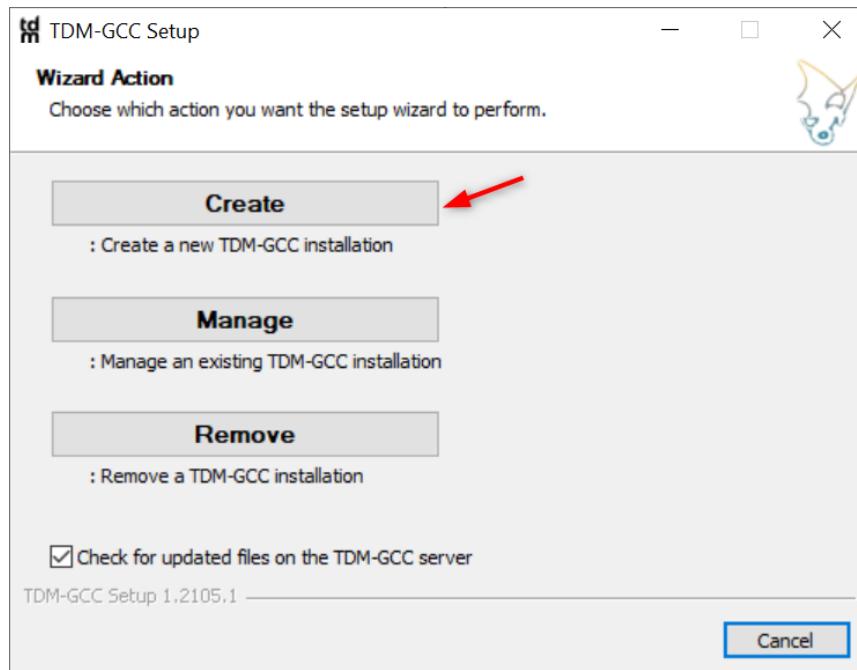


Fig. 6: TDM-GCC installation dialog

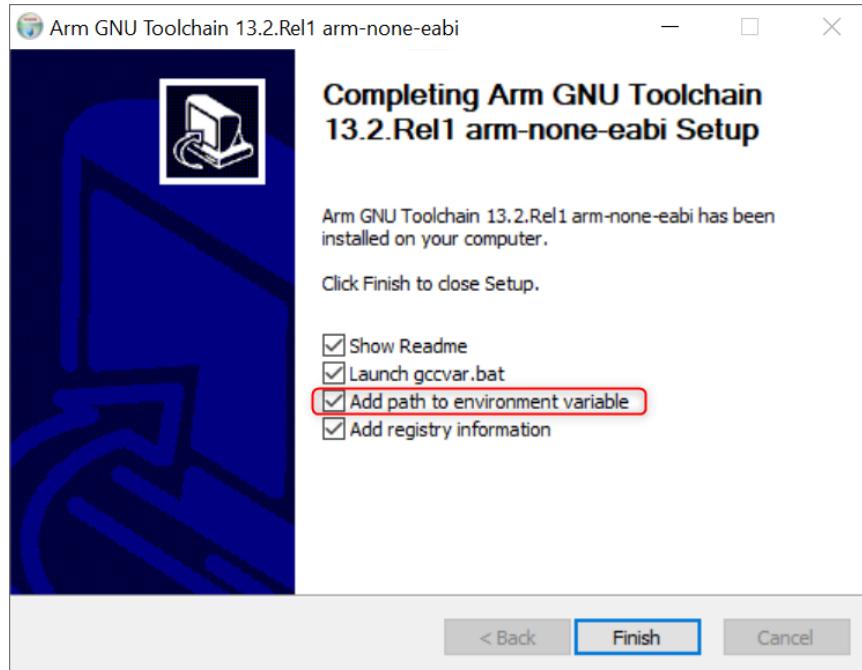


Fig. 7: GNU ARM Toolchain installation

4.2 Installation (Linux/MacOS)

4.2.1 System requirements

- The supported Linux OS versions are Debian based - Ubuntu 18.04 and 22.04.
- The supported macOS versions are MacOS 13 Ventura (13.4.1 and 13.5.2) and MacOS 14 Sonoma (14.3.1).

4.2.2 Installation of COINES SDK

Follow the steps below to install COINES SDK:

1. Download the installer.
 2. Use the command cd to go to the directory where the installer is located and make the installer executable:
- ```
$ chmod +x COINES_SDK_vX.Y.sh
```
3. Ensure that you are connected to the Internet before running the installer:
- ```
$ ./COINES_SDK_vX.Y.sh
```
4. Accept the End User License agreement.

```
:~/Downloads/coines_installer_linux$ ./COINES_SDK_External.sh
Copyright (c) 2024 Bosch Sensortec GmbH. All rights reserved.

Subject to the compliance with these terms, the User may use COINES software development kit and any derivatives exclusively with Bosch Sensortec GmbH hardware products.
It is the User responsibility to comply with third party license terms applicable to the use of third-party software (including open-source software) that may accompany COINES software development kit.

The User of this SDK must be aware that the use of this SDK may be subject to import/export restrictions. In particular there may be approval requirements, or use of this SDK and related technologies may be subject to restrictions/limitations in foreign countries.

The User of this SDK shall comply with any applicable national and international import/export control regulations, in particular Federal Republic of Germany, the European Union and the United States of America.

This license agreement shall not apply if and as far as it now or in future violates mandatory law applicable for the User and/or Bosch Sensortec GmbH, in parti
--More--
```

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lar foreign trade/export control law,
e.g. the EU Directive 833/2014 (consolidated version as of October 1, 2023 available here: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02014R0833-20231001#M25-1%20).
In case according to foreign trade/export control law, Bosch Sensortec GmbH is obliged to prevent that the User provides
Licensed Products to specific persons or legal entities or exports Licensed Products to specific countries,
the User of this SDK shall comply with a respective order by Bosch Sensortec GmbH.

Currently, according to EU Directive 833/2014 the User of this SDK shall not export Licensed Products to Russia.
Furthermore, if and to the extent that rights of use are granted or transferred under this Agreement, this shall in any event not apply to any Russian and/or Belarusian intellectual property right or trade secret protected in said states.
The Bosch Sensortec GmbH fulfilment of these Terms & Conditions is subject to such fulfilment not being opposed by impediments due to national or international import/export regulations or by any other statutory provisions.

Do you agree to the above license terms? [yes or no]yes
```

Fig. 8: Linux installer end user agreement

5. The installer will prompt you if the required dependencies/packages are not installed. (This step requires root privileges.)

4.2.3 Installation of compiler environment

On a Debian or Redhat based Linux distro, the installer prompts for installation of missing dependencies, gcc, make, and libusb-dev packages. If the installation fails, the user can manually install the dependencies.

- Debian based distros - gcc, make, libusb-1.0-0-dev, dfu-util , libdbus-1-dev
- Redhat based distros - gcc, make, libusb-devel, dfu-util, dbus-devel
- MacOS - libusb, dfu-util

If you intend to run the COINES SDK example on the Application Board's microcontroller, download the latest version of [GNU Embedded Toolchain for ARM](#) for Linux and extract the package. Add the compiler to the PATH variable by editing \$HOME/.bashrc or a similar file like /etc/profile or /etc/environment.

5 Using COINES SDK to access the sensor on Engineering Board

5.1 Running examples on the MCU of the Application Board

5.1.1 Working principle

The COINES SDK can be cross-compiled on the PC and then downloaded into the memory of the Application Board and executed there. The user has the option to download the generated binary either into the flash memory or the RAM memory.

Downloading the COINES SDK example to APP3.X flash memory will overwrite the default firmware. To update the firmware again, refer to section [13](#).

In this configuration, the COINES SDK layer provides a simple abstraction on top of the MCU BSP (i.e. board level support layer of the microcontroller). Any printf command will now not output to the console, but rather to the USB connection, which appears as a virtual COM port on the PC side.

This mode facilitates the execution of many time-critical operations on the sensor, such as fast reading of FIFO content at high data rates.

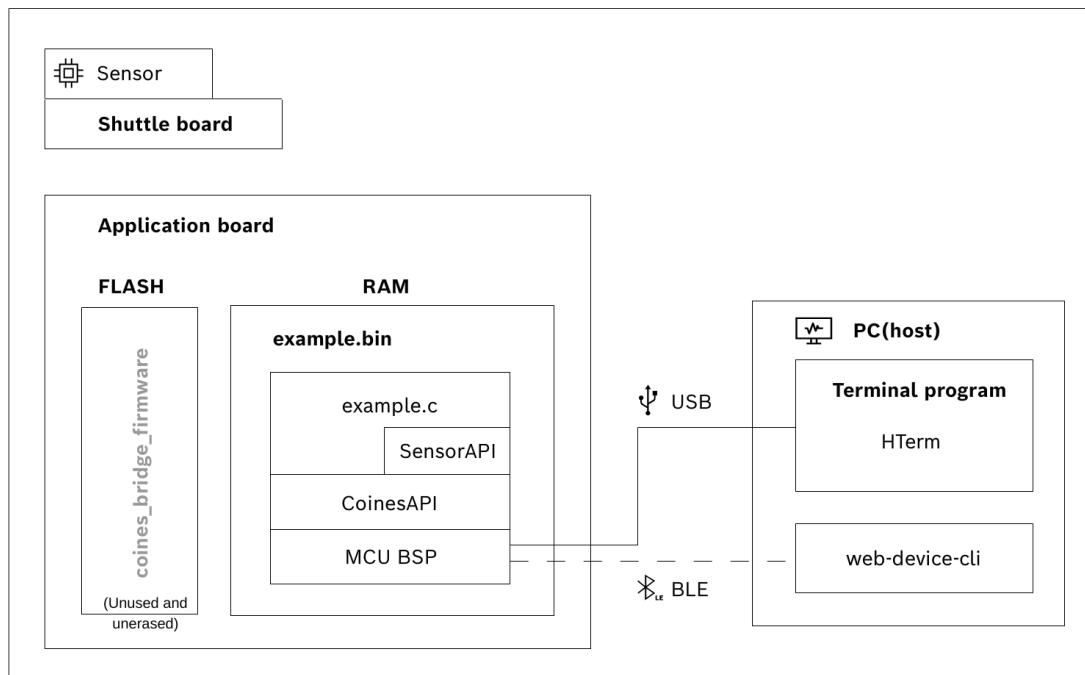


Fig. 9: Working principle: Running example on the MCU of the Application Board at LOCATION=RAM

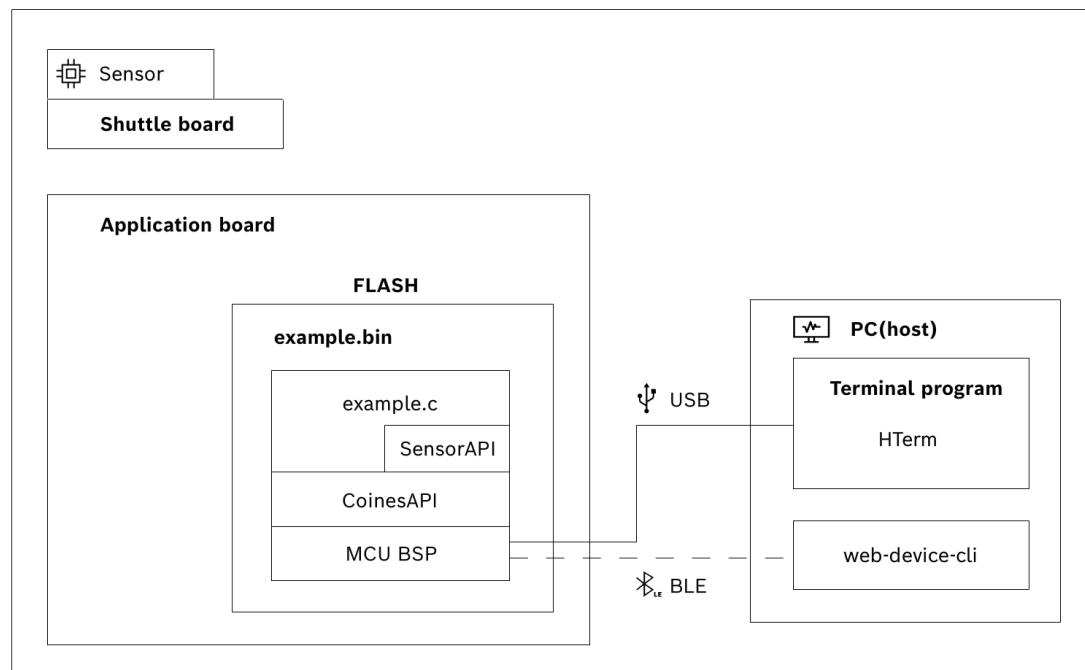


Fig. 10: Working principle: Running example on the MCU of the Application Board at LOCATION=FLASH

5.1.2 Getting started

To get started with the example execution, follow these steps:

1. Make sure the [GNU Embedded Toolchain for ARM](#) is installed on your PC and added to the environmental variable PATH.
2. Connect the Application Board via USB, with the sensor shuttle board mounted.
3. Open the command prompt or the terminal.

4. Use the command cd to go to the directory where the example to be built is located.

5.1.3 Interfacing via BLE

The procedure to interface via BLE involves these steps:

1. Open the script to be executed (in case of SensorAPI - common.c file in the selected example folder) in your IDE.
2. Change COINES_COMM_INTF_USB to COINES_COMM_INTF_BLE
3. Change all print statements:
`printf(...)` to `fprintf(bt_w,...)`
4. Now follow the steps from 1 - 4 in the section [5.1.2](#).

5.1.4 Cross compiling

To compile and download an example to the Engineering Board's microcontroller, type any of the build commands below based on available Engineering Board type and target memory location. Use 'mingw32-make' (TDM-GCC/MinGW) or 'make' (Linux/Cygwin/MSYS2/MacOS) for compilation.

Function	Command
Download example to APP2.0 MCU RAM	<code>mingw32-make LOCATION=RAM TARGET=MCU_APP20 download</code>
Download example to APP2.0 MCU FLASH	<code>mingw32-make LOCATION=FLASH TARGET=MCU_APP20 download</code>
Download example to APP3.0 MCU RAM	<code>mingw32-make LOCATION=RAM TARGET=MCU_APP30 download</code>
Download example to APP3.0 MCU FLASH	<code>mingw32-make LOCATION=FLASH TARGET=MCU_APP30 download</code>
Download example to APP3.1 MCU RAM	<code>mingw32-make LOCATION=RAM TARGET=MCU_APP31 download</code>
Download example to APP3.1 MCU FLASH	<code>mingw32-make LOCATION=FLASH TARGET=MCU_APP31 download</code>
Run an example already residing in APP2.0 flash memory	<code>mingw32-make run</code>

Note: Nicla board programs can only be executed as PC target at this moment.

5.1.5 Viewing the results

The ways to view the execution results are outlined as follows:

1. Use a Serial Terminal application to view output.
 - Windows - PuTTY, HTerm, etc.,
 - Linux - cat command. Eg: `cat /dev/ttyACM0`
 - macOS - screen command. Eg: `screen /dev/ttymodem9F31`

Note: The binary on the MCU will be executed once the serial port is opened. The port must be opened including the DTR signal set, otherwise the binary will not be executed. Some terminal programs such as HTerm allow explicit setting of the DTR signal.
2. For bluetooth communication, connect the Application Board to another power source and keep it within the BLE range. Use any of the below tools to view the output:
 - Android app - [Serial Bluetooth terminal](#)
 - Website - [Web Device CLI](#)
 - Python script - `\tools\ble-nus-term\ble-nus-term.py`

5.1.6 Data logging

The user can use any serial terminal program to access and store the provided data via a virtual COM port, e.g., HTerm, which has a "Save output" option to store logs.

5.2 Running examples on the PC side

5.2.1 Working principle

When compiling the COINES SDK for PC side, the COINES SDK layer provides an abstraction of the embedded environment on the host side. COINES SDK library provides read and write functions for I²C and SPI on PC side. These functions receive the arguments of the user input (i.e. what register address to read from) and tunnels them through the USB connection to the Application Board, where they are fed into the embedded I²C and SPI functions and are executed to access the sensor. Any result or response from those functions is tunneled back to the PC side and provided to the example application.

This approach allows easy and flexible programming and allows integrating the example code into other applications or adding advanced logging options. The drawback is that the code is not executed in real-time in this mode, as it runs on a multitasking operating system. The examples can also be run on the MCU side (see section 5.1) to overcome this drawback.

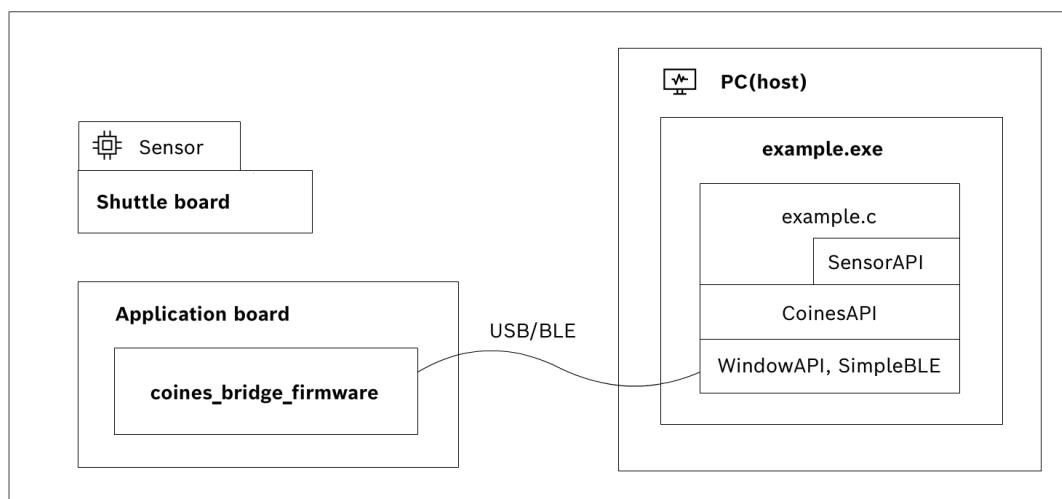


Fig. 11: Working principle: Running example on PC side

5.2.2 PC side implementation

This setup has the challenge of lacking the real-time capabilities known from a pure microcontroller environment. To overcome this, the coinesAPI offers streaming functions, which allow the user to schedule data readout directly on the microcontroller, either based on a data interrupt coming from the sensors or the microcontroller's timer. The scheduler waits for the configured interrupt (sensor interrupt or timer interrupt) and reads out areas of the register map, which the user can configure.

As an example, the user could choose to read out the 6 bytes from the register map of a certain inertial sensor, containing the sensor data of three axis (2 bytes per axis). If the user would configure e.g., a readout once per milliseconds, the result would be a data stream of three-axis sensor data at a rate of 1 kHz.

5.2.3 Getting started

To get started with example execution, follow these steps:

1. Connect the Application Board via USB, with the sensor shuttle board mounted.
2. Refer to section [13](#) and update the COINES Bridge firmware to the board.
3. Open the command prompt or the terminal.
4. Use the command cd to go to the directory where the example that is to be built is located.

Note: Some examples may not compile for both PC and MCU targets. Refer to the example documentation or simply the example name (e.g., examples that can only be compiled for the PC are named with a following '_pc').

5.2.4 Interfacing via BLE

The procedure to interface via BLE involves these steps:

1. Open the script to be executed (in case of SensorAPI - common.c file in the selected example folder) in your IDE.
2. Change COINES_COMM_INTF_USB to COINES_COMM_INTF_BLE.
3. Follow steps 1 to 4 in section [5.2.3](#).

5.2.5 Compiling

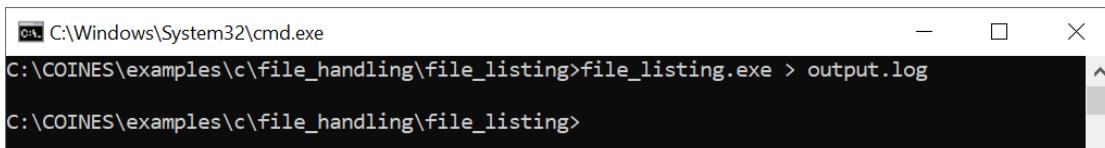
To compile an example on the PC side, execute the command "mingw32-make TARGET=PC". Use 'mingw32-make' (TDM-GCC/MinGW) or 'make' (Linux/Cygwin/MSYS2/MacOS) for compilation.

5.2.6 Viewing the results

The user can view the results after running the output executable from the PC command prompt. To view the ouput via BLE, connect the Application Board to another power source and keep it within the BLE range and run the executable on the PC.

5.2.7 Data logging

The user can use the terminal's output redirection command to store the result of a command/executable in a file, as demonstrated below.



```
C:\Windows\System32\cmd.exe
C:\COINES\examples\c\file_handling\file_listing>file_listing.exe > output.log
C:\COINES\examples\c\file_handling\file_listing>
```

5.3 Project Cleanup

The commands to clean build files are listed below:

- "mingw32-make clean" or "make clean" - Removes the compilation artifacts specific to the current project.
- "mingw32-make clean-all" or "make clean" - Removes both the project-specific compilation artifacts and artifacts associated with the COINES SDK itself, including backend, BSP, etc.

6 Using COINESPY to access the sensor on the Engineering Board

6.1 Introduction to the COINESPY library

The COINESPY library provides a Python interface for interacting with Bosch Sensortec's Engineering Boards.

The library offers the following range of functionalities:

- Control VDD and VDDIO of sensor
- Configure SPI and I²C bus parameters
- Read and write into registers of sensors from Bosch Sensortec via SPI and I²C
- Read and write digital pins of the Application Board

6.2 Installation

The COINESPY module can be installed using pip:

```
pip install coinespy
```

The module can be found at <https://pypi.org/project/coinespy/>. It is highly recommended to test the following script examples\python\coinespy_test.py in the COINES SDK installation or Refer to [8.2.1](#) to check if the installation was successful.

7 Using SensorAPI with COINES SDK

7.1 SensorAPI

Bosch Sensortec recommends using SensorAPI to communicate with the sensors. A SensorAPI, an abstraction layer written in C, makes it much more convenient for the user to access the register map of the sensor, configure certain functionality, and obtain certain information from it.

To make use of SensorAPI, some function pointers must be set to the appropriate read/write functions of the selected bus on the system (either I²C or SPI), as well as one function pointer to a system's function causing delays in milliseconds.

To execute C code using SensorAPI, the COINES SDK API provides the read, write and delay functions. These functions are wrapper functions, embedding the actual SensorAPI payloads into a transport package and sending this via USB or BLE to the Engineering Board, where the payload is translated into corresponding SPI or I²C messages and sent to the sensor on the shuttle board. The mapping would look similar to the one below.

```
#include "coines.h"
#include "bst_sensor.h"

struct bst_sensor_dev sensordev;
.....
.....
sensordev.intf = BST_SENSOR_I2C_INTF; // SPI - BST_SENSOR_SPI_INTF
sensordev.read = coines_read_i2c; // coines_read_spi
sensordev.write = coines_write_i2c; // coines_write_spi
sensordev.delay_ms = coines_delay_usec;
```

For the description of COINES SDK functions used, refer to [15.2](#).

7.2 Downloading SensorAPI

In order to download SensorAPI, follow the steps below:

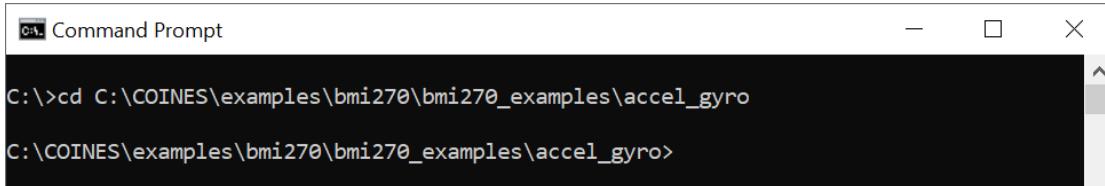
- Download SensorAPI repo using the Download zip option for selected sensors from the BoschSensortec GitHub <https://github.com/BoschSensortec>.
- Unzip the downloaded SensorAPI repo to \examples.
- Rename the unzipped folder to the sensor name, e.g., \examples\bmi270, and change the directory to an example folder to execute it.

7.3 Running example on MCU side

Here are the requirements and instructions to run examples on the MCU side:

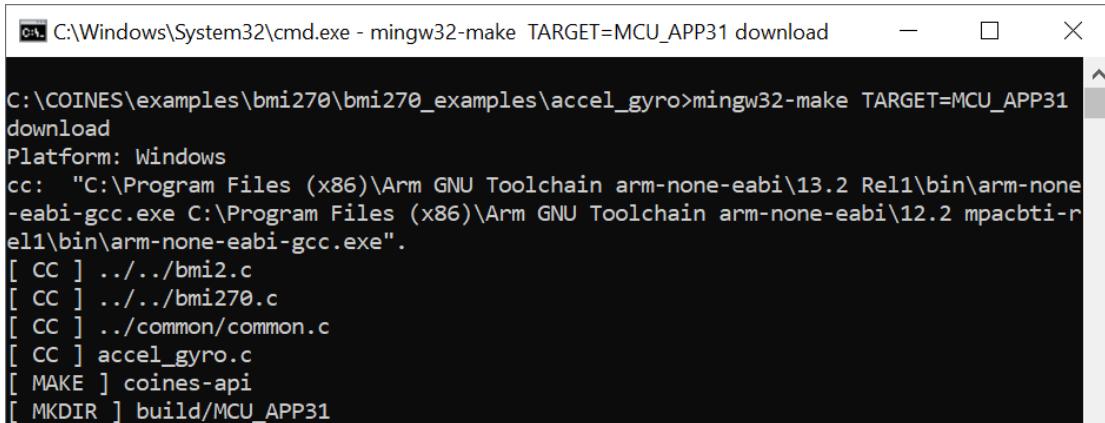
- Selected Platform: Windows
 - Board: APP3.1
 - Sensor shuttle: BMI270
 - Example: \examples\bmi270\bmi270_examples\accel_gyro
1. Connect the Application Board via USB, with the sensor shuttle board mounted.
 2. Open the command prompt or the terminal.

3. Use the command cd to go to the directory where the example that is to be built is located.

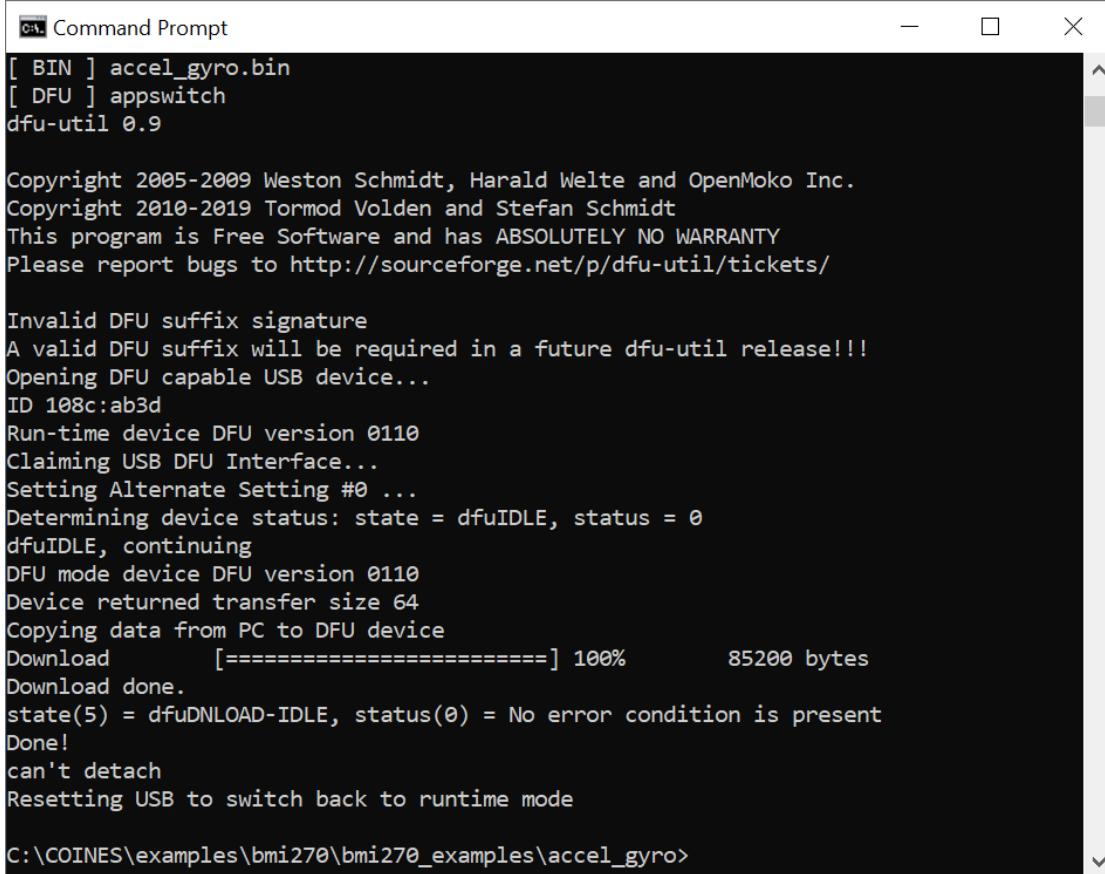


```
C:\>cd C:\COINES\examples\bmi270\bmi270_examples\accel_gyro
C:\COINES\examples\bmi270\bmi270_examples\accel_gyro>
```

4. Ensure the LEDs on the Application Board are turned on for proper connection and then execute the command "mingw32-make TARGET=MCU_APP31 download".



```
C:\COINES\examples\bmi270\bmi270_examples\accel_gyro>mingw32-make TARGET=MCU_APP31 download
Platform: Windows
cc: "C:\Program Files (x86)\Arm GNU Toolchain arm-none-eabi\13.2 Rel1\bin\arm-none-eabi-gcc.exe C:\Program Files (x86)\Arm GNU Toolchain arm-none-eabi\12.2 mpacbtি-re1\bin\arm-none-eabi-gcc.exe".
[ CC ] ../../bmi2.c
[ CC ] ../../bmi270.c
[ CC ] ./common/common.c
[ CC ] accel_gyro.c
[ MAKE ] coines-api
[ MKDIR ] build/MCU_APP31
```



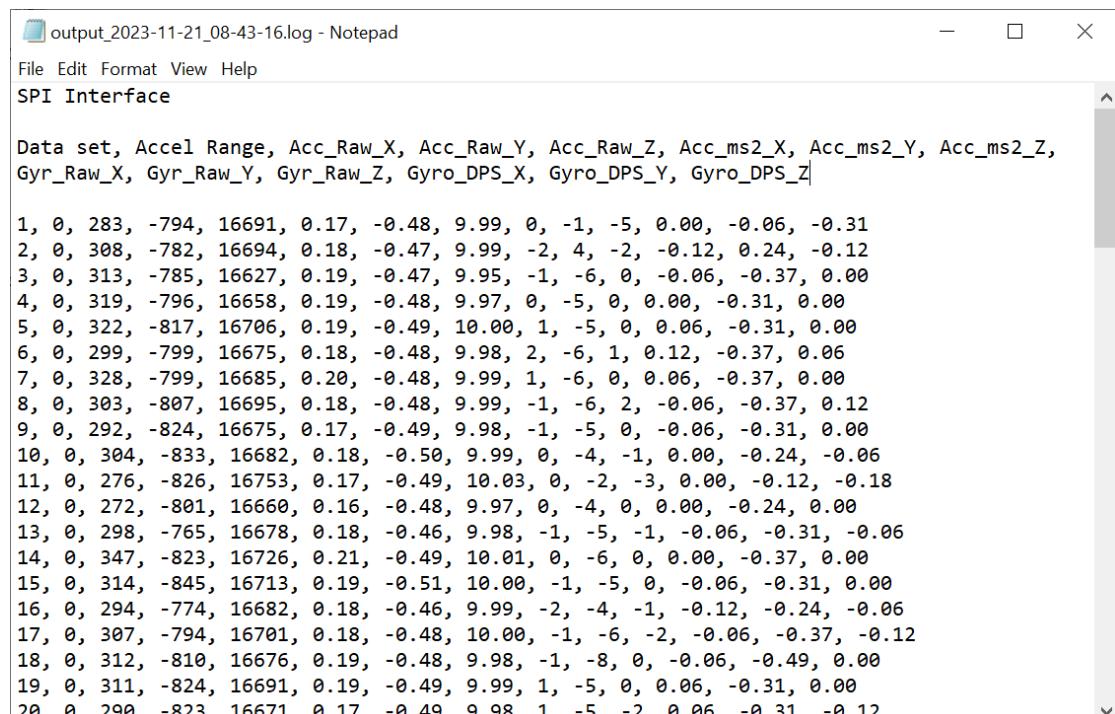
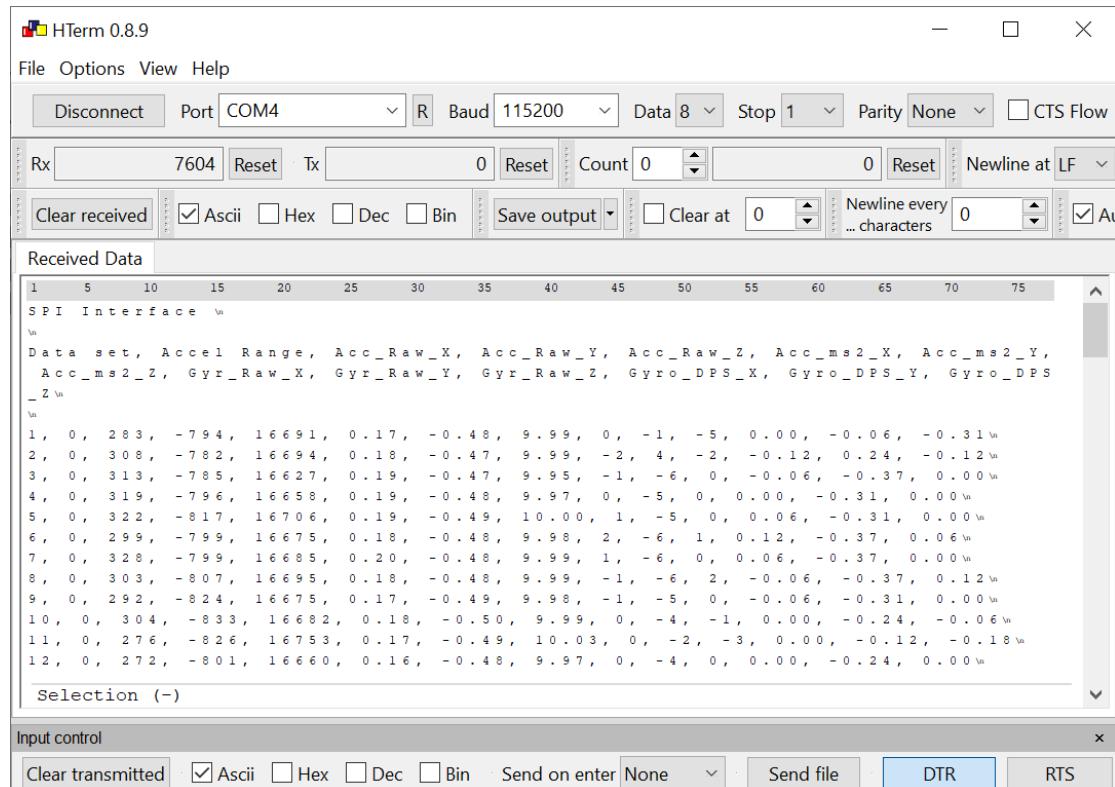
```
[ BIN ] accel_gyro.bin
[ DFU ] appswitch
dfu-util 0.9

Copyright 2005-2009 Weston Schmidt, Harald Welte and OpenMoko Inc.
Copyright 2010-2019 Tormod Volden and Stefan Schmidt
This program is Free Software and has ABSOLUTELY NO WARRANTY
Please report bugs to http://sourceforge.net/p/dfu-util/tickets/

Invalid DFU suffix signature
A valid DFU suffix will be required in a future dfu-util release!!!
Opening DFU capable USB device...
ID 108c:ab3d
Run-time device DFU version 0110
Claiming USB DFU Interface...
Setting Alternate Setting #0 ...
Determining device status: state = dfuIDLE, status = 0
dfuIDLE, continuing
DFU mode device DFU version 0110
Device returned transfer size 64
Copying data from PC to DFU device
Download      [=====] 100%          85200 bytes
Download done.
state(5) = dfuDNLOAD-IDLE, status(0) = No error condition is present
Done!
can't detach
Resetting USB to switch back to runtime mode

C:\COINES\examples\bmi270\bmi270_examples\accel_gyro>
```

5. View the output in a serial terminal application like HTerm.



7.4 Running example on MCU side via BLE

To interface via BLE, follow the steps below:

1. Go to the examples folder in file explorer.

2. Open the common.c file in the selected example folder in your IDE.
3. Change COINES_COMM_INTF_USB to COINES_COMM_INTF_BLE



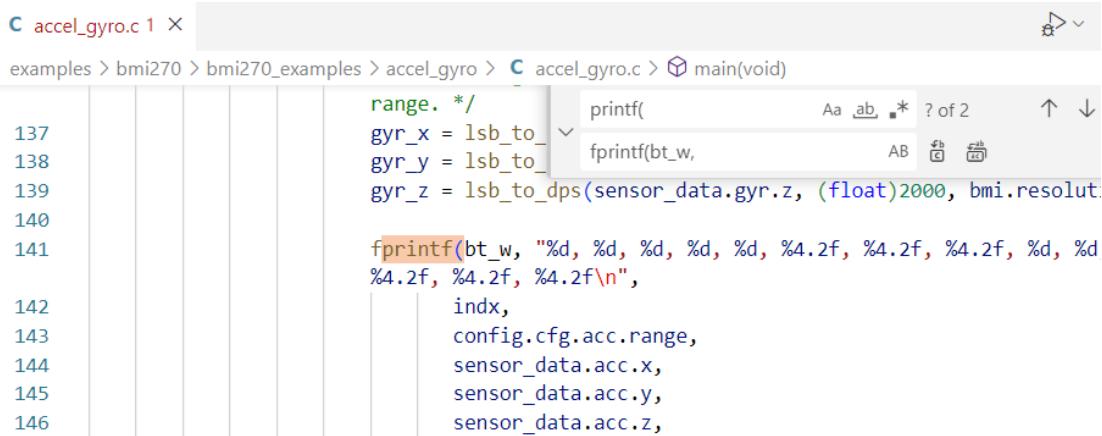
```

C common.c ×
examples > bmi270 > bmi270_examples > common > C common.c > bmi2_interface_init(bmi2_dev *, uint8_t)
133     int8_t bmi2_interface_init(struct bmi2_dev *bmi, uint8_t intf)
134     {
135         int8_t rslt = BMI2_OK;
136
137         if (bmi != NULL)
138         {
139             int16_t result = coines_board_init(COINES_COMM_INTF_BLE, true);

```

4. Open the example script and change the

`printf(...)` to `fprintf(bt_w,...)`

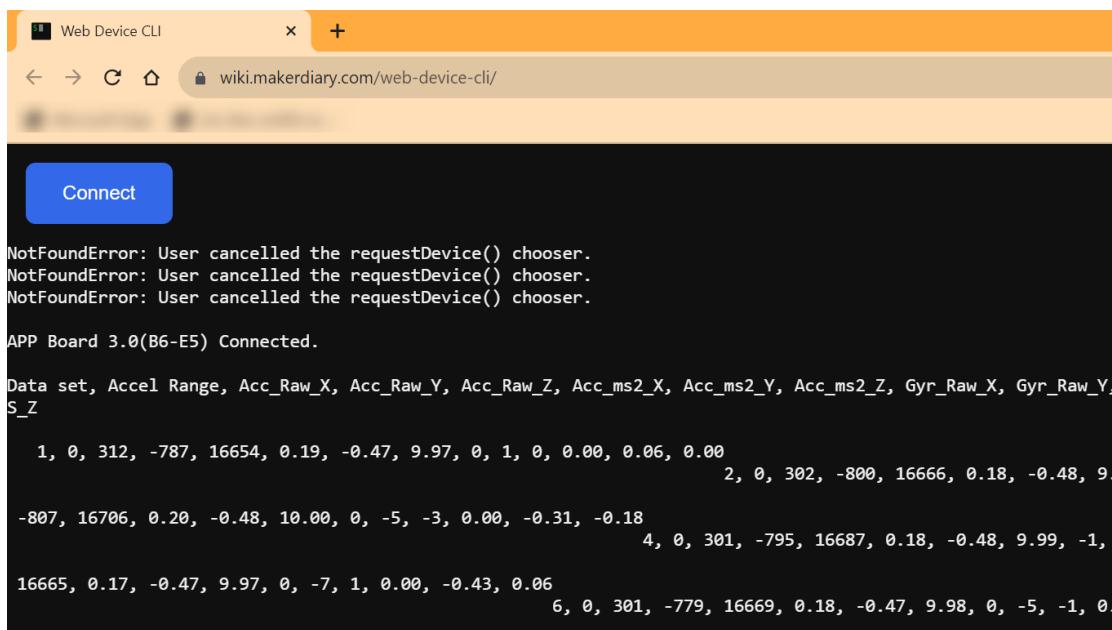
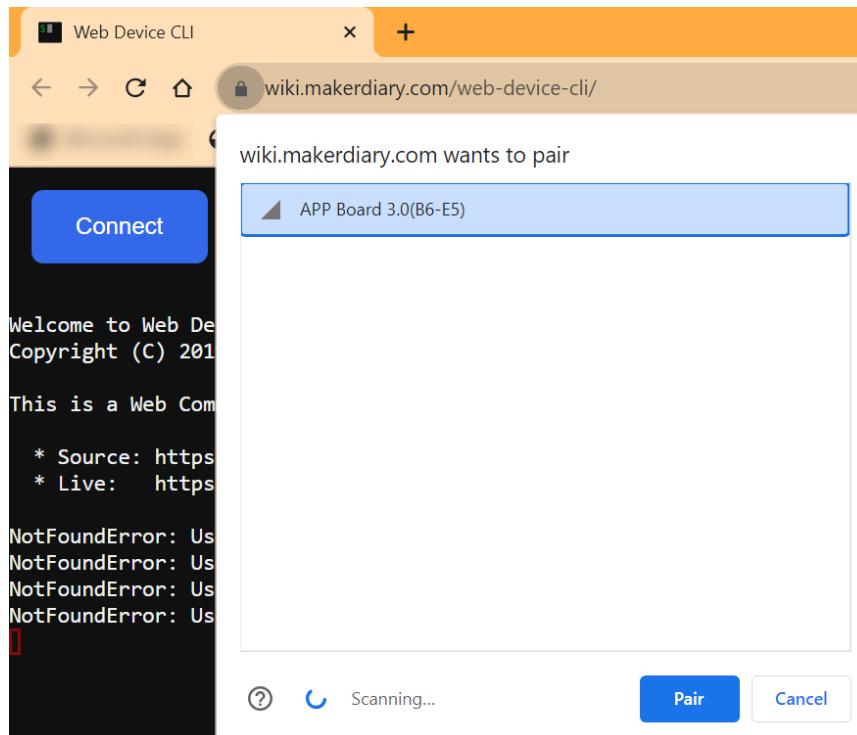


```

C accel_gyro.c 1 ×
examples > bmi270 > bmi270_examples > accel_gyro > C accel_gyro.c > main(void)
137     range. */
138     gyr_x = lsb_to_
139     gyr_y = lsb_to_
140     gyr_z = lsb_to_dps(sensor_data.gyr.z, (float)2000, bmi.resolut.
141
142     fprintf(bt_w, "%d, %d, %d, %d, %d, %4.2f, %4.2f, %4.2f, %d,
143             %4.2f, %4.2f, %4.2f\n",
144             indx,
145             config.cfg.acc.range,
146             sensor_data.acc.x,
147             sensor_data.acc.y,
148             sensor_data.acc.z,

```

5. Now follow the same steps from 1 - 4 in the [7.3](#).
6. Connect the Application Board to another power source and keep it within the BLE range.
7. View the output in the [Web Device CLI](#) site in your browser by connecting to board via BLE and by clicking **Pair**.



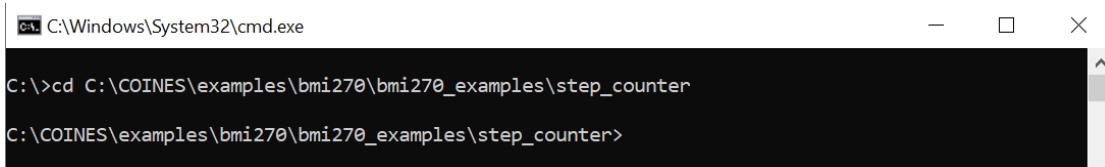
7.5 Running example on the PC side

Here are the requirements and instructions to run examples on PC side:

- Selected Platform: Windows
- Board: APP3.1
- Sensor shuttle: BMI270
- Example: \examples\bmi270\bmi270_examples\step_counter

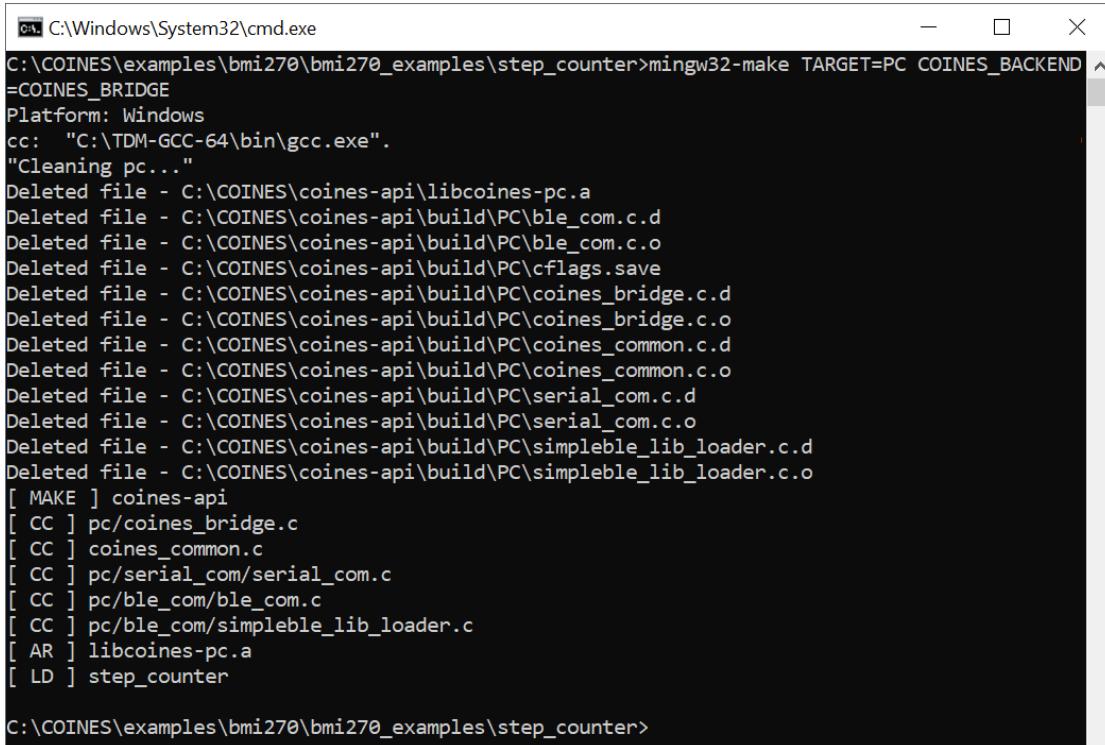
1. Connect the Application Board via USB, with the sensor shuttle board mounted.

2. Refer to section 13 and update the COINES Bridge firmware to the board.
3. Open the command prompt or the terminal.
4. Use the command cd to go to the directory where the example to be built is located.



```
C:\Windows\System32\cmd.exe
C:>cd C:\COINES\examples\bmi270\bmi270_examples\step_counter
C:\COINES\examples\bmi270\bmi270_examples\step_counter>
```

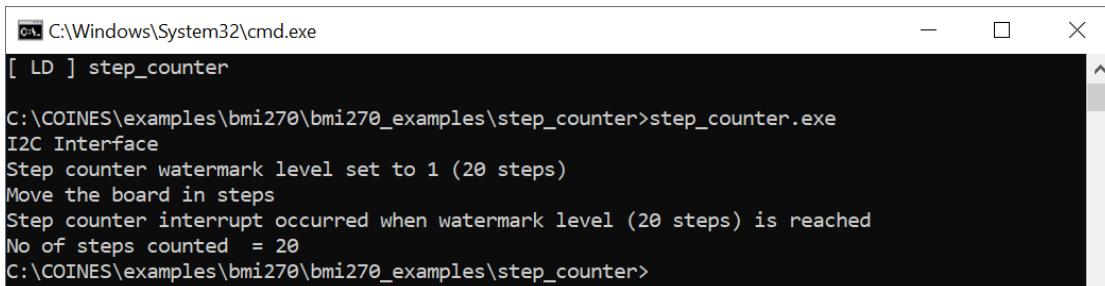
5. Execute the command "mingw32-make TARGET=PC COINES_BACKEND=COINES_BRIDGE"



```
C:\Windows\System32\cmd.exe
C:\COINES\examples\bmi270\bmi270_examples\step_counter>mingw32-make TARGET=PC COINES_BACKEND=COINES_BRIDGE
Platform: Windows
cc: "C:\TDM-GCC-64\bin\gcc.exe".
"Cleaning pc...""
Deleted file - C:\COINES\coines-api\libcoines-pc.a
Deleted file - C:\COINES\coines-api\build\PC\ble_com.c.d
Deleted file - C:\COINES\coines-api\build\PC\ble_com.c.o
Deleted file - C:\COINES\coines-api\build\PC\cflags.save
Deleted file - C:\COINES\coines-api\build\PC\coines_bridge.c.d
Deleted file - C:\COINES\coines-api\build\PC\coines_bridge.c.o
Deleted file - C:\COINES\coines-api\build\PC\coines_common.c.d
Deleted file - C:\COINES\coines-api\build\PC\coines_common.c.o
Deleted file - C:\COINES\coines-api\build\PC\serial_com.c.d
Deleted file - C:\COINES\coines-api\build\PC\serial_com.c.o
Deleted file - C:\COINES\coines-api\build\PC\simpleble_lib_loader.c.d
Deleted file - C:\COINES\coines-api\build\PC\simpleble_lib_loader.c.o
[ MAKE ] coines-api
[ CC ] pc/coines_bridge.c
[ CC ] coines_common.c
[ CC ] pc/serial_com/serial_com.c
[ CC ] pc/ble_com/ble_com.c
[ CC ] pc/ble_com/simpleble_lib_loader.c
[ AR ] libcoines-pc.a
[ LD ] step_counter

C:\COINES\examples\bmi270\bmi270_examples\step_counter>
```

6. View the output in the command prompt by running the example executable.



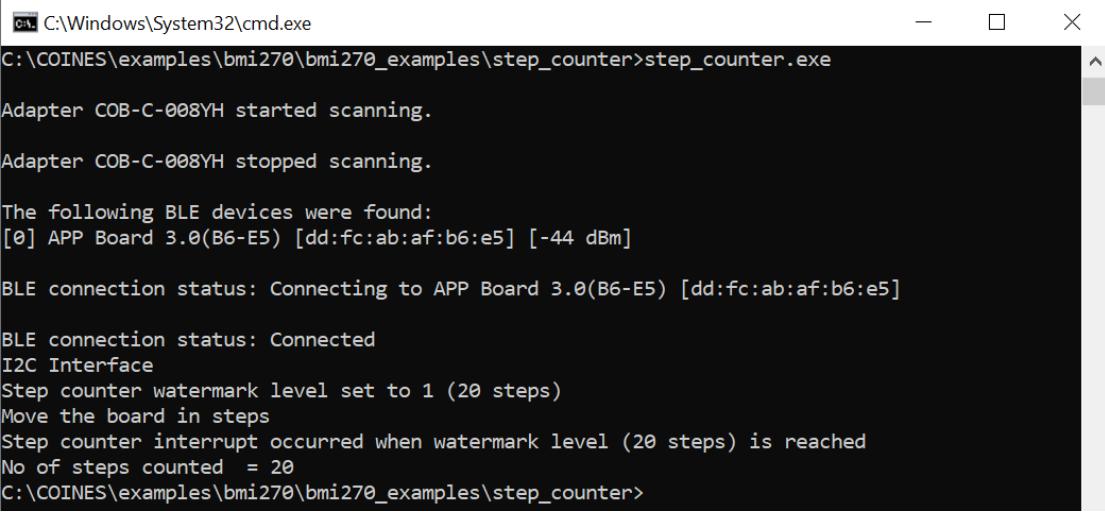
```
C:\Windows\System32\cmd.exe
[ LD ] step_counter
C:\COINES\examples\bmi270\bmi270_examples\step_counter>step_counter.exe
I2C Interface
Step counter watermark level set to 1 (20 steps)
Move the board in steps
Step counter interrupt occurred when watermark level (20 steps) is reached
No of steps counted = 20
C:\COINES\examples\bmi270\bmi270_examples\step_counter>
```

7.6 Running example on the PC side via BLE

To interface via BLE, follow the steps below:

1. Go to the examples folder in file explorer.

2. Open the common.c file in the selected example folder in your IDE.
3. Change COINES_COMM_INTF_USB to COINES_COMM_INTF_BLE.
4. Connect the Application Board to another power source and keep it within the BLE range.
5. Follow the steps 3 - 6 in the section [7.5](#).



```
C:\Windows\System32\cmd.exe
C:\COINES\examples\bmi270\bmi270_examples\step_counter>step_counter.exe

Adapter COB-C-008YH started scanning.

Adapter COB-C-008YH stopped scanning.

The following BLE devices were found:
[0] APP Board 3.0(B6-E5) [dd:fc:ab:af:b6:e5] [-44 dBm]

BLE connection status: Connecting to APP Board 3.0(B6-E5) [dd:fc:ab:af:b6:e5]

BLE connection status: Connected
I2C Interface
Step counter watermark level set to 1 (20 steps)
Move the board in steps
Step counter interrupt occurred when watermark level (20 steps) is reached
No of steps counted = 20
C:\COINES\examples\bmi270\bmi270_examples\step_counter>
```

8 Examples on how to use COINES SDK

8.1 C examples

8.1.1 Establishing communication

The following code snippet shows how to set up a connection with the board.

```
#include <stdio.h>
#include <stdlib.h>

#include "coines.h"

int main(void)
{
    int8_t error_code;
    enum coines_comm_intf comm_intf = COINES_COMM_INTF_USB;

    error_code = coines_open_comm_intf(comm_intf, NULL);
    if (error_code == COINES_SUCCESS)
    {
        printf("\nSuccessfully connected to board!\n");
    }
    else
    {
        printf("\nUnable to connect with board!\n");
        exit(error_code);
    }

    coines_close_comm_intf(comm_intf, NULL);

    return 0;
}
```

The APIs below can be used for the board interface.

- `coines_open_comm_intf`
- `coines_close_comm_intf`

8.1.2 Getting board info

The following code snippet shows how to get board information.

```
#include <stdio.h>
#include <stdlib.h>

#include "coines.h"

int main(void)
{
    int8_t error_code;
    struct coines_board_info board_info;
    enum coines_comm_intf comm_intf = COINES_COMM_INTF_USB;

    error_code = coines_open_comm_intf(comm_intf, NULL);
    if (error_code < COINES_SUCCESS)
    {
        printf("\nUnable to connect with board!\n");
    }
```

```

    exit(error_code);
}

error_code = coines_get_board_info(&board_info);
if (error_code == COINES_SUCCESS)
{
    printf("\nBoard Info:");
    printf("\n\tboard_info.board:0x%02X", board_info.board);
    printf("\n\tboard_info.hardware_id:0x%02X", board_info.hardware_id);
    printf("\n\tboard_info.shuttle_id:0x%02X", board_info.shuttle_id);
    printf("\n\tboard_info.software_id:0x%02X", board_info.software_id);
}

coines_close_comm_intf(comm_intf, NULL);

return 0;
}

```

8.1.3 I2C config and read

This basic program shows how to configure and perform I2C read.
Sensor: BMI270

```

#include <stdio.h>
#include <stdlib.h>

#include "coines.h"

#define BMI2_I2C_PRIM_ADDR 0x68

int main(void)
{
    int8_t error_code;
    uint8_t chip_id;
    uint8_t reg_addr = 0x0;
    enum coines_comm_intf comm_intf = COINES_COMM_INTF_USB;

    error_code = coines_open_comm_intf(comm_intf, NULL);
    if (error_code == COINES_SUCCESS)
    {
        printf("\nSuccessfully connected to board!\n");
    }
    else
    {
        printf("\nUnable to connect with board!\n");
        exit(error_code);
    }

    /* Power up the board */
    (void)coines_set_shuttleboard_vdd_vddio_config(3300, 3300);
    coines_delay_usecs(200);

    /* Make CSB pin HIGH */
    coines_set_pin_config(COINES_SHUTTLE_PIN_21, COINES_PIN_DIRECTION_OUT,
                         COINES_PIN_VALUE_HIGH);
    coines_delay_msec(100);

    /* SDO pin is made low */

```

```

coines_set_pin_config(COINES_SHUTTLE_PIN_SDO, COINES_PIN_DIRECTION_OUT,
COINES_PIN_VALUE_LOW);

/* I2C config */
coines_config_i2c_bus(COINES_I2C_BUS_0, COINES_I2C_STANDARD_MODE);

/* I2C read */
(void)coines_read_i2c(COINES_I2C_BUS_0, BMI2_I2C_PRIM_ADDR, reg_addr, &chip_id, 1);

printf("I2C read: Sensor chip ID - 0x%xx\n", chip_id);

(void)coines_set_shuttleboard_vdd_vddio_config(0, 0);
coines_delay_msec(100);

/* Coines interface reset */
coines_soft_reset();
coines_delay_msec(100);

coines_close_comm_intf(comm_intf, NULL);

return 0;
}

```

The user must pass GPIO pin numbers, the read register address, and the I2C device address for sensors based on the selected sensor shuttle board. I2C communication requires the proper setting of VDD and VDDIO using `coines_set_shuttleboard_vdd_vddio_config`. The APIs below can be used for I2C configure/read/write.

- `coines_config_i2c_bus`
- `coines_read_i2c`
- `coines_write_i2c`

8.1.4 SPI config and read

This basic program shows how to configure and perform SPI read.

Sensor: BMI270

```

#include <stdio.h>
#include <stdlib.h>

#include "coines.h"

#define BMI2_SPI_RD_MASK 0x80

int main(void)
{
    int8_t error_code;
    uint8_t chip_id[2], dummy_byte;

    /* An extra dummy byte is read during SPI read */
    uint8_t dummy_byte_len = 1;
    uint8_t reg_addr = 0x0;
    enum coines_comm_intf comm_intf = COINES_COMM_INTF_USB;

    error_code = coines_open_comm_intf(comm_intf, NULL);
    if (error_code == COINES_SUCCESS)
    {

```

```

        printf("\nSuccessfully connected to board!\n");
    }
    else
    {
        printf("\nUnable to connect with board!\n");
        exit(error_code);
    }

    /* Power up the board */
    coines_set_shuttleboard_vdd_vddio_config(3300, 3300);
    coines_delay_msec(200);

    /* SPI config */
    (void)coines_config_spi_bus(COINES_SPI_BUS_0, COINES_SPI_SPEED_5_MHZ,
                                COINES_SPI_MODE3);

    /* Pin config */
    coines_set_pin_config(COINES_SHUTTLE_PIN_21, COINES_PIN_DIRECTION_OUT,
                          COINES_PIN_VALUE_HIGH);

    /* Mask read register address for SPI */
    reg_addr = (reg_addr | BMI2_SPI_RD_MASK);

    /* Dummy read for SPI init*/
    (void)coines_read_spi(COINES_SPI_BUS_0, COINES_MINI_SHUTTLE_PIN_2_1, reg_addr,
                          &dummy_byte, 1);
    coines_delay_usec(450);

    /* SPI read */
    (void)coines_read_spi(COINES_SPI_BUS_0, COINES_MINI_SHUTTLE_PIN_2_1, reg_addr,
                          chip_id, 1 + dummy_byte_len);
    coines_delay_usec(450);

    printf("SPI read: Sensor chip ID - 0x%x\n", chip_id[dummy_byte_len]);

    (void)coines_set_shuttleboard_vdd_vddio_config(0, 0);
    coines_delay_msec(100);

    /* Coines interface reset */
    coines_soft_reset();
    coines_delay_msec(100);

    coines_close_comm_intf(comm_intf, NULL);

    return 0;
}

```

The user must pass GPIO pin numbers, the read register, and the SPI CS pins for sensors based on the selected sensor shuttle board. SPI communication requires the proper setting of VDD and VDDIO using `coines_set_shuttleboard_vdd_vddio_config`. The APIs below can be used for SPI configure/read/write.

- `coines_config_spi_bus`
- `coines_read_spi`
- `coines_write_spi`

8.1.5 Configure VDD and VDDIO

This program shows how to set custom VDD and VDDIO voltages.

Sensor: BMI270

Target board: APP31

```
#include <stdio.h>
#include <stdbool.h>

#include "coines.h"

#define BMI2_I2C_PRIM_ADDR 0x68

int main(void)
{
    uint8_t chip_id;
    uint16_t no_of_bytes = 1;
    uint8_t reg_addr = 0x0;
    uint16_t vdd_millivolt = 1800;
    uint16_t vddio_millivolt = 1800;

    coines_open_comm_intf(COINES_COMM_INTF_USB, NULL);

    /* Customized VDD and VDDIO - 1.8V */
    printf("Configuring VDD: %.1fV\n", vdd_millivolt / 1000.00);
    printf("Configuring VDDIO: %.1fV\n", vddio_millivolt / 1000.00);
    coines_set_shuttleboard_vdd_vddio_config(vdd_millivolt, vddio_millivolt);
    coines_delay_msec(200);

    /* I2C config & I2C read */
    coines_config_i2c_bus(COINES_I2C_BUS_0, COINES_I2C_STANDARD_MODE);
    (void)coines_read_i2c(COINES_I2C_BUS_0, BMI2_I2C_PRIM_ADDR, reg_addr, &chip_id,
                          no_of_bytes);
    printf("I2C read: Sensor chip ID - 0x%02x\n", chip_id);

    /* Device reset - 0V */
    (void)coines_set_shuttleboard_vdd_vddio_config(0, 0);
    coines_delay_msec(100);

    coines_close_comm_intf(COINES_COMM_INTF_USB, NULL);

    return 0;
}
```

In this example, the voltage levels for VDD and VDDIO are configured according to the typical values specified in the BMI270 datasheet. Within the specified operating range, users can customize the voltage levels applied to the VDD and VDDIO pins according to their requirements. APP3.0 supports only two voltage levels for VDD, which are 1.8V and 2.8V, and a single voltage level of 1.8V for VDDIO. However, in APP3.1, it is possible to configure custom voltage levels for both VDD and VDDIO.

8.1.6 Led and button control

The example program below controls LEDs and buttons on the board.

Target: MCU

Target board: APP31

```
#include <stdio.h>
#include <stdbool.h>
#include "coines.h"

/* Callback for button 3 interrupt */
static void button3CB(uint32_t param1, uint32_t param2);

/*Callback for button 3 event */
void button3CB(uint32_t param1, uint32_t param2)
{
    (void)param1;
    (void)param2;

    coines_set_led(COINES_LED_RED, COINES_LED_STATE_ON);
    coines_set_led(COINES_LED_GREEN, COINES_LED_STATE_OFF);
    coines_set_led(COINES_LED_BLUE, COINES_LED_STATE_ON);
}

int main(void)
{
    coines_open_comm_intf(COINES_COMM_INTF_USB, NULL);

    coines_set_pin_config(COINES_APP31_BUTTON_3, COINES_PIN_DIRECTION_IN,
        COINES_PIN_VALUE_HIGH);
    coines_attach_interrupt(COINES_APP31_BUTTON_3, button3CB,
        COINES_PIN_INTERRUPT_FALLING_EDGE);

    coines_close_comm_intf(COINES_COMM_INTF_USB, NULL);

    return 0;
}
```

8.1.7 File listing in External memory

The snippet below can be used to list the files in the external memory.

Target: MCU

```
#include <stdio.h>
#include "coines.h"

int main(void)
{
    coines_open_comm_intf(COINES_COMM_INTF_USB, NULL);
    DIR *directory;
    struct dirent *dir;
    directory = opendir(".");
    if (directory)
    {
        while ((dir = readdir(directory)) != NULL)
        {
            printf("%s\n", dir->d_name);
        }
        closedir(directory);
    }

    coines_close_comm_intf(COINES_COMM_INTF_USB, NULL);
}
```

```
    return 0;
}
```

8.1.8 Temperature measurement

This program demonstrates how to measure the temperature of the board.

Target: MCU

```
#include <stdio.h>
#include <stdlib.h>

#include "coines.h"

int main(void)
{
    int8_t error_code;
    float temp_data = 0;
    enum coines_comm_intf comm_intf = COINES_COMM_INTF_USB;

    error_code = coines_open_comm_intf(comm_intf, NULL);
    if (error_code == COINES_SUCCESS)
    {
        printf("\nSuccessfully connected to board!\n");
    }
    else
    {
        printf("\nUnable to connect with board!\n");
        exit(error_code);
    }

    /* Power up the board */
    coines_set_shuttleboard_vdd_vddio_config(1800, 1800);
    coines_delay_msec(200);

    /* Read temperature data */
    coines_read_temp_data(&temp_data);
    printf("\nTemperature data = %f in degC", temp_data);

    coines_set_shuttleboard_vdd_vddio_config(0, 0);
    coines_delay_msec(100);

    coines_close_comm_intf(comm_intf, NULL);

    return 0;
}
```

8.1.9 Battery level measurement

This program demonstrates how to measure battery level when a battery is connected to the board.

Target: MCU

```
#include <stdio.h>
#include <stdlib.h>

#include "coines.h"
```

```

int main(void)
{
    int8_t error_code;
    uint8_t batt_status_percentage = 0;
    uint16_t batt_status_in_milli_volts = 0;
    enum coines_comm_intf comm_intf = COINES_COMM_INTF_BLE;

    error_code = coines_open_comm_intf(comm_intf, NULL);
    if (error_code == COINES_SUCCESS)
    {
        printf("\nSuccessfully connected to board!\n");
    }
    else
    {
        printf("\nUnable to connect with board!\n");
        exit(error_code);
    }

    /* Read battery level */
    coines_read_bat_status(&batt_status_in_milli_volts, &batt_status_percentage);
    fprintf(bt_w, "Battery level in percentage = %d %% \r\n", batt_status_percentage);
    fprintf(bt_w, "Battery level in millivolts = %d mV \r\n",
            batt_status_in_milli_volts);

    coines_close_comm_intf(comm_intf, NULL);

    return 0;
}

```

8.1.10 Configure BLE communication

This example shows how to configure the BLE connection.

Target: PC

```

#include <stdio.h>
#include <string.h>
#include <stdlib.h>

#include "coines.h"

/*! Macros to hold the BLE peripheral name and address to be connected */
/*! Please change the name and address with BLE name of the Application Board under
     test */
#define BLE_NAME "APP Board 3.1(B6-E5)"
#define BLE_ADDR "dd:fc:ab:af:b6:e5"

/*! Variable to hold the communication interface type */
const enum coines_comm_intf comm_intf = COINES_COMM_INTF_BLE;

int main(void)
{
    struct ble_peripheral_info ble_config = { BLE_ADDR, "" }; /* Connection using BLE
        address */
    /*struct ble_peripheral_info ble_config = { "", BLE_NAME }; // Connection using BLE
        name */
    struct ble_peripheral_info ble_info[40];
    uint8_t peripheral_count, i;

```

```

int8_t result;

/* Get the BLE peripheral list */
result = coines_scan_ble_devices(ble_info, &peripheral_count, 7000);
if (result != COINES_SUCCESS)
{
    const char *err_str = get_coines_error_str(result);
    printf("\n%s", err_str);
    exit(result);
}

/* Print the BLE peripheral list */
printf("\nBLE devices found:");
for (i = 0; i < peripheral_count; i++)
{
    printf("\n[%d] %s [%s]", i, ble_info[i].ble_identifier, ble_info[i].ble_address);
}

/* Open BLE connection */
result = coines_open_comm_intf(comm_intf, &ble_config);
if (result == COINES_SUCCESS)
{
    printf("\nSuccessfully connected to board!\n");
}
else
{
    printf("\nUnable to connect with board!\n");
    exit(result);
}

/* Close BLE connection */
coines_set_shuttleboard_vdd_vddio_config(0, 0);
coines_delay_msec(100);

coines_soft_reset();
coines_delay_msec(100);

coines_close_comm_intf(comm_intf, NULL);

return 0;
}

```

The user must modify BLE settings like MAC address and APP3.X BLE name before executing this example.

8.1.11 Configure Serial communication

This example shows how to configure the Serial COM connection.

Target: PC

Target board: APP31

```

#include <stdio.h>
#include <string.h>
#include <stdlib.h>

#include "coines.h"

#define ROBERT_BOSCH_USB_VID (0x108C)

```

```
#define BST_APP31_CDC_USB_PID (0xAB38)

/*! Variable to hold the communication interface type */
const enum coines_comm_intf comm_intf = COINES_COMM_INTF_USB;

int main(void)
{
    int16_t result;
    struct coines_serial_com_config scom_config;

    scom_config.baud_rate = 38400;
    scom_config.vendor_id = ROBERT_BOSCH_USB_VID;
    scom_config.product_id = BST_APP31_CDC_USB_PID;
    scom_config.com_port_name = "COM4";

    /* Serial com for Linux */
    /*scom_config.com_port_name = "/dev/ttyACM0"; */

    /* Serial com for Mac */
    /*scom_config.com_port_name = "/dev/cu.usbmodemD0F684FC766C1"; */

    scom_config.rx_buffer_size = 2048;

    /* Open serial connection */
    result = coines_open_comm_intf(comm_intf, &scom_config);
    if (result == COINES_SUCCESS)
    {
        printf("\nSuccessfully connected to board!\n");
    }
    else
    {
        printf("\nUnable to connect with board!\n");
        exit(result);
    }

    /* Close serial connection */
    coines_soft_reset();
    coines_delay_msec(100);

    coines_close_comm_intf(comm_intf, NULL);

    return 0;
}
```

The user must modify Serial COM settings like vendor ID, product ID, and COM port name before executing this example.

8.2 Python examples

8.2.1 Getting board info

The following code snippet shows how to get board information.

```
import coinespy as cpy
from coinespy import ErrorCodes

COM_INTF = cpy.CommInterface.USB
```

```

if __name__ == "__main__":
    board = cpy.CoinesBoard()
    print('COINESPY version - %s' % cpy.__version__)
    board.open_comm_interface(COM_INTF)
    if board.error_code != ErrorCodes.COINES_SUCCESS:
        print(f'Could not connect to board: {board.error_code}')
    else:
        b_info = board.get_board_info()
        print(f"COINES SDK version: {b_info.lib_version}")
        print(
            f'BoardInfo: HW/SW ID: {hex(b_info.HardwareId)}/{hex(b_info.SoftwareId)}')
    board.close_comm_interface()

```

8.2.2 I2C config and read

This program shows how to configure and perform I2C read.

Sensor: BMI270

```

import sys
import coinespy as cpy
from coinespy import ErrorCodes

COM_INTF = cpy.CommInterface.USB

if __name__ == "__main__":
    BMI2_I2C_PRIM_ADDR = 0x68
    BMI2_CHIP_ID_ADDR = 0x00
    BOARD = cpy.CoinesBoard()

    BOARD.open_comm_interface(COM_INTF)
    if BOARD.error_code == ErrorCodes.COINES_SUCCESS:
        print("Successfully connected to board!")
    else:
        print(f"Open Communication interface: {BOARD.error_code}")
        sys.exit()

    # Power up the board
    BOARD.set_shuttleboard_vdd_vddio_config(vdd_val=3.3, vddio_val=3.3)
    BOARD.delay_milli_sec(200)

    # Pin config
    # Make CSB pin HIGH
    BOARD.set_pin_config(
        cpy.MultiIOPin.SHUTTLE_PIN_21, cpy.PinDirection.OUTPUT, cpy.PinValue.HIGH
    )
    # SDO pin is made low
    BOARD.set_pin_config(
        cpy.MultiIOPin.SHUTTLE_PIN_SDO, cpy.PinDirection.OUTPUT, cpy.PinValue.LOW
    )

    # I2C config
    BOARD.config_i2c_bus(
        cpy.I2CBus.BUS_I2C_0, BMI2_I2C_PRIM_ADDR, cpy.I2CMode.STANDARD_MODE
    )

    # I2C read
    accel_chip_id = BOARD.read_i2c(
        cpy.I2CBus.BUS_I2C_0, BMI2_CHIP_ID_ADDR, 1, BMI2_I2C_PRIM_ADDR

```

```
)
print(f"I2C read: Sensor chip ID - {hex(accel_chip_id[0])}")

# Deinit board
BOARD.set_shuttleboard_vdd_vddio_config(vdd_val=0, vddio_val=0)
BOARD.soft_reset()

BOARD.close_comm_interface()
```

The user must pass GPIO pin numbers, the read register address, and the I2C device address for sensors based on the selected sensor shuttle board. I2C communication requires the proper setting of VDD and VDDIO using `set_shuttleboard_vdd_vddio_config`.

8.2.3 SPI config and read

This program shows how to configure and perform SPI read.

Sensor: BMI270

```
import sys
import coinespy as cpy
from coinespy import ErrorCodes

COM_INTF = cpy.CommInterface.USB

if __name__ == "__main__":
    BMI2_CHIP_ID_ADDR = 0x00
    DUMMY_BYTES = 1
    BOARD = cpy.CoinesBoard()

    BOARD.open_comm_interface(COM_INTF)
    if BOARD.error_code == ErrorCodes.COINES_SUCCESS:
        print("Successfully connected to board!")
    else:
        print(f"Open Communication interface: {BOARD.error_code}")
        sys.exit()

    # Power up the board
    BOARD.set_shuttleboard_vdd_vddio_config(vdd_val=3.3, vddio_val=3.3)
    BOARD.delay_milli_sec(200)

    # SPI config
    BOARD.config_spi_bus(
        cpy.SPIBus.BUS_SPI_0,
        cpy.MultiIOPin.MINI_SHUTTLE_PIN_2_1,
        cpy.SPISpeed.SPI_5_MHZ,
        cpy.SPIMode.MODE3,
    )

    # Pin config
    BOARD.set_pin_config(
        cpy.MultiIOPin.SHUTTLE_PIN_21, cpy.PinDirection.OUTPUT, cpy.PinValue.HIGH
    )

    # Initialize SPI by dummy read
    BOARD.read_spi(cpy.SPIBus.BUS_SPI_0, BMI2_CHIP_ID_ADDR, 1)
    BOARD.delay_micro_sec(450)
```

```
# SPI read
chip_id = BOARD.read_spi(
    cpy.SPIBus.BUS_SPI_0,
    BMI2_CHIP_ID_ADDR,
    1 + DUMMY_BYTES,
    cpy.MultiIOPin.MINI_SHUTTLE_PIN_2_1,
)
BOARD.delay_micro_sec(450)

print(f"SPI read: Sensor chip ID - {hex(chip_id[1])}")

# Deinit board
BOARD.set_shuttleboard_vdd_vddio_config(vdd_val=0, vddio_val=0)
BOARD.soft_reset()

BOARD.close_comm_interface()
```

The user must pass GPIO pin numbers, the read register address, and the SPI CS pins for sensors based on the selected sensor shuttle board. SPI communication requires the proper setting of VDD and VDDIO using `set_shuttleboard_vdd_vddio_config`.

9 Debugging via VS code

Follow these steps to debug programs via VS code:

- Download Segger software from <https://www.segger.com/downloads/jlink/>.
- Refer to https://wiki.segger.com/J-Link_Visual_Studio_Code for using J-link with VS code.
- Download the NRF5 .svd file from Nordic Semiconductor GitHub.
- Connect J-link to the SWD debugger connector.

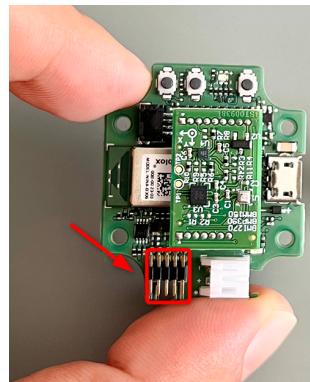


Fig. 12: APP3.1 Debugger connector

- Below is the sample launch.json config for VS code debug.

```
{
  "version": "0.2.0",
  "configurations": [
    {
      "type": "cortex-debug",
      "request": "launch",
      "name": "Debug J-Link",
      "cwd": "${workspaceRoot}",
      "executable": "/examples/c/coines_bridge_firmware/coines_bridge_firmware.elf",
      "serverpath": "C:/Program Files/SEGGER/JLink/JLinkGDBServerCL.exe",
      "servertype": "jlink",
      "armToolchainPath": "C:/Program Files (x86)/Arm GNU Toolchain arm-none-eabi/12.2 mpacbtirelli/bin",
      "device": "nRF52840_XXAA",
      "interface": "swd",
      "showDevDebugOutput": "raw",
      "svdFile": "/nRF52840.svd"
    }
  ]
}
```

Fig. 13: VS code debug launch.json

10 Media Transfer Protocol (MTP) firmware for APP3.X

The external memory chip W25M02/W25N02 on APP3.X is based on NAND flash.

FAT filesystem on NAND flash memory results in a complicated solution using a lot of RAM. Moreover, using FAT without a Flash Translation Layer (to save RAM) wears out NAND flash with frequent usage. Therefore, [FlogFS](#), a filesystem optimized for use with NAND flash, was chosen.

Using 'FlogFS' presents a new problem: 'Filesystem access from the PC via USB'. The use of 'FlogFS' with the USB Mass Storage protocol is impossible because the operating system can't recognize 'FlogFS' as a valid file system.

Using a custom protocol for filesystem operations would mean re-inventing the wheel and a lot of effort. Users also would have a different experience than with USB Mass Storage.

The solution is to use the "Media Transfer Protocol" developed initially by Microsoft for portable devices like MP3 players. Starting from Android Kitkat (v4.4), MTP is the only way to access files on an Android device since the whole flash memory (including user storage space) uses filesystems like ext4, YAFFS, F2FS, etc.

Files in APP3.X's NAND flash memory can be viewed using the USB MTP firmware.

Supported on Windows, Linux, macOS, and Android (via USB OTG).

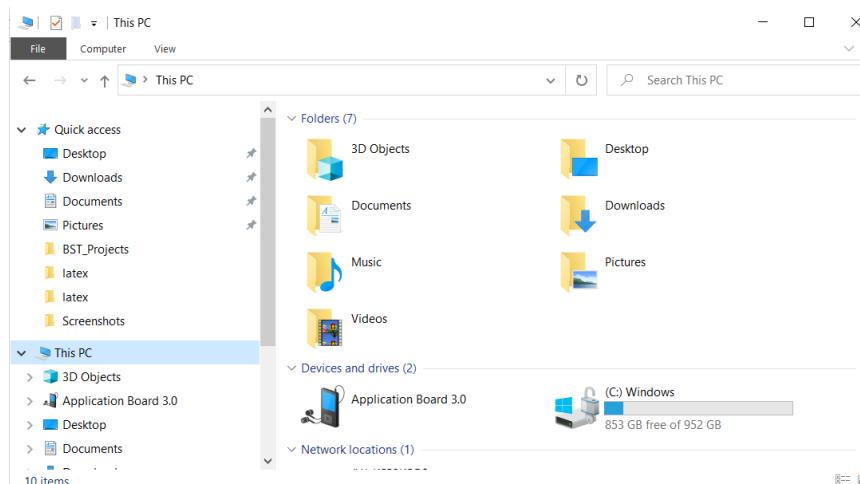


Fig. 14: APP3.X in MTP mode on Windows

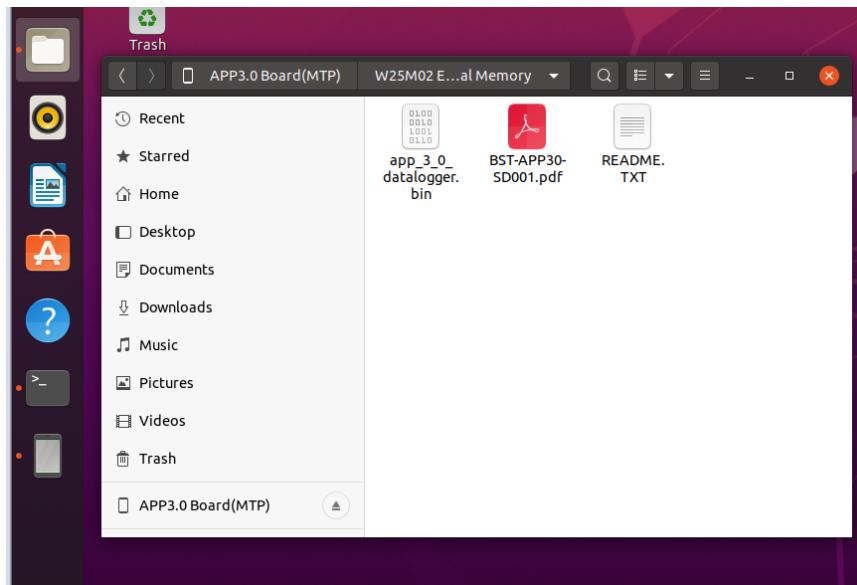


Fig. 15: APP3.X in MTP mode on Linux

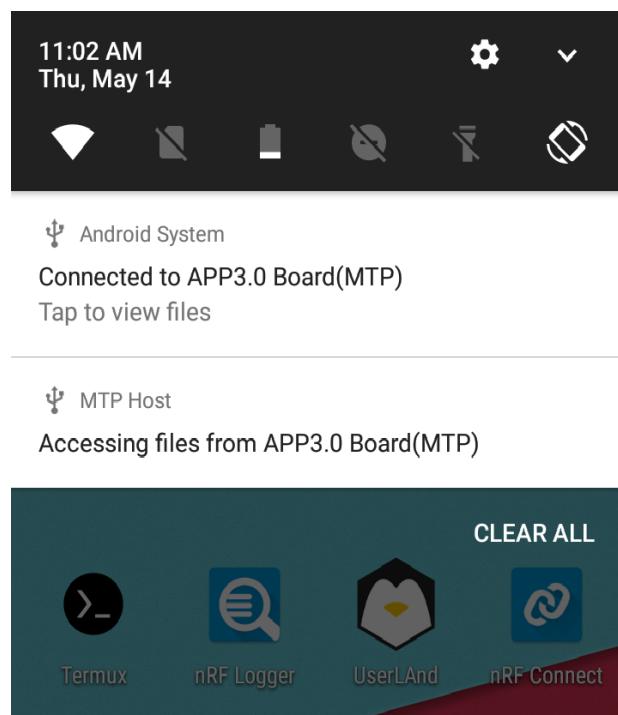


Fig. 16: APP3.X in MTP mode on Andriod

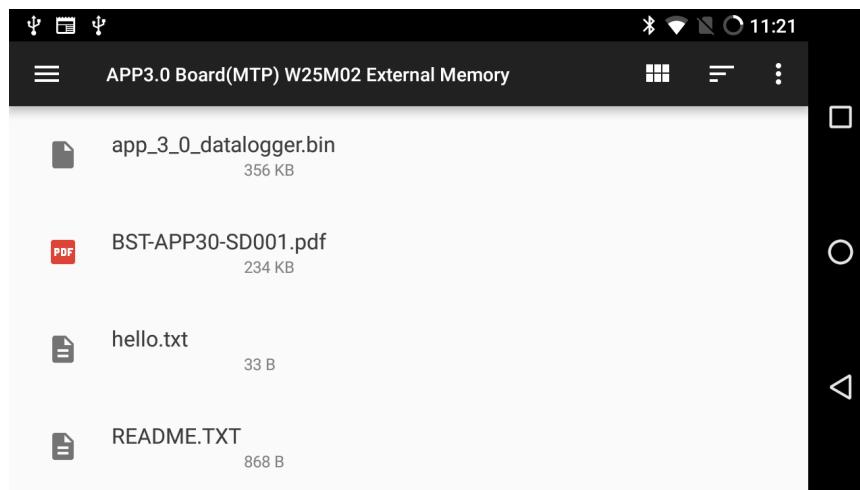


Fig. 17: Files in external memory listed on Andriod device

10.1 Copying the files using MTP

Procedure needs the following steps:

- APP3.X comes with the preloaded MTP firmware update package.
- Refer to section [Switching to Operating Modes](#) to switch to MTP mode
- The device will enumerate as an MTP device with the name "Application Board 3.X". Click it and select the "W25M02 External Memory". The device will list all the available files and all required files can be copied.

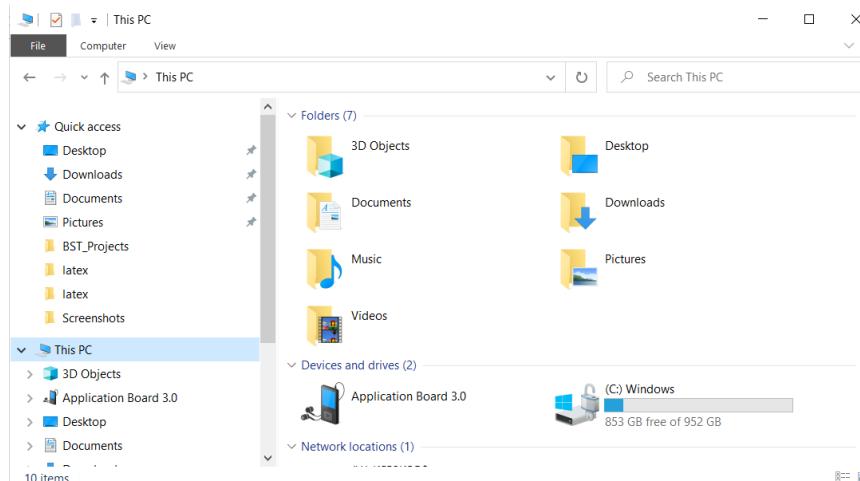


Fig. 18: Copy data log files to the PC over USB MTP

11 USB/BLE DFU bootloader

A USB/BLE Bootloader for APP3.X/nRF52840 and a Nicla Sense ME/nRF52832 chip comply with the https://www.usb.org/sites/default/files/DFU_1.1.pdf.

11.1 Key Features

11.1.1 USB DFU

The key features of USB DFU are as follows:

- Code download to RAM or FLASH
- Code read back (upload) from RAM or FLASH (useful for taking firmware backups)
- Works with Windows, Linux, macOS and Android.

11.1.2 BLE DFU

The key features of BLE DFU are as follows:

- Code download to FLASH
- Works with PC and mobile devices with iOS/Android

The bootloader was written taking into account the following aspects:

- Usability
 1. No special driver installation or admin rights should be required.
 2. The update process should be straight forward.
- Maintainability
 1. It's an open source community that takes care of the tools on the PC side. For example, dfu-util is a cross platform tool.
 2. Uses Google Chrome's WebUSB to update firmware. Sample implementation <https://devanlai.github.io/webdfu/dfu-util/>
- Size
- COINES SDK on MCU

11.2 Invoking the Bootloader

To invoke Bootloader from hardware, switch the board to bootloader mode (refer to section 12).

To invoke Bootloader from software, use the snippets below in your program based on the board selected.

- APP3.X
 1. Write 0x4E494F43 ('N','I','O','C') to MAGIC_LOCATION (0x2003FFF4)
 2. Write 0x0 or 0xF0000 to APP_START_ADDR (0x2003FFF8)
 3. Call NVIC_SystemReset()

```
#define MAGIC_LOCATION (0x2003FFF4)
#define APP_START_ADDR (*(uint32_t *) (MAGIC_LOCATION+4))

*((uint32_t *)MAGIC_LOCATION) == 0x4E494F43;
```

```
APP_START_ADDR = 0xF0000;
//APP_START_ADDR = 0x0;
NVIC_SystemReset();
```

- Nicla Sense ME Board

1. Write 0x544F4F42 ('T','O','O','B') to MAGIC_LOCATION (0x2000F804)
 2. Call NVIC_SystemReset()
-

```
#define MAGIC_LOCATION (0x2000F804)
#define APP_START_ADDR (*(uint32_t *) (MAGIC_LOCATION+4))

*((uint32_t *)MAGIC_LOCATION) == 0x544F4F42;
NVIC_SystemReset();
```

Note: The same feature can also be used to perform application switches (two or more applications can reside in the same flash memory at different address locations). Write the application start address to APP_START_ADDR instead of the bootloader address.

11.3 Using the Bootloader via USB

The commands below demonstrate how to use dfu-util for different scenarios:

- Path to dfu-util: \tools\usb-dfu

Write firmware to flash memory using the following command:

- dfu-util -a FLASH -D <firmware>.bin -R

Write firmware to RAM memory using the following command:

- dfu-util -a RAM -D <firmware>.bin -R

Read firmware from flash memory using the following command:

- dfu-util -a FLASH -U <firmware>.bin

Read firmware from RAM memory using the following command:

- dfu-util -a RAM -U <firmware>.bin

Read device serial number/ BLE MAC address using the following command:

- dfu-util -l

Note: Not applicable for Nicla Sense ME board

11.4 Using the Bootloader via BLE

To update the bootloader firmware via BLE, use the following procedure:

- PC (Windows, Linux or macOS)

Python script present in following path \tools\app30-ble-dfu can use the binary file directly.

1. Refer to section [12](#) to switch to Bootloader mode.

2. Run the command:

- pip install -r requirements.txt

3. Scan for devices to find BLE MAC address using below the command:

- python app30-ble-dfu.py -l

4. Update firmware by using the MAC address obtained in the previous step and firmware BIN file:
 - `python app30-ble-dfu.py -d D7:A3:CE:8E:36:14 -f <firmware>.bin`

- Android devices

1. Generate the ZIP package using <https://pypi.org/project/adafruit-nrfutil/> before using nRF ToolBox for BLE or nRF connect for mobile:

- `adafruit-nrfutil dfu genpkg -dev-type 0x0052 -application <firmware>.bin dfu-package.zip`

Note: Not applicable for Nicla Sense ME board

12 Switching to Operating Modes

12.1 APP2.0 (or) APP3.X

The process for switching modes for the Application Board involves these steps:

- Bootloader mode - Turn OFF and ON the board with T2 pressed, the blue LED glows indicating that the board switched to bootloader mode.
- MTP mode - Turn OFF and ON the board with T1 pressed, the green LED glows indicating that the board switched to MTP mode.

12.2 Nicla Sense ME board

The process for switching modes for the Nicla Sense ME board involves these steps:

- Bootloader mode - Press the reset button three times, the blue LED glows indicating that the board switched to bootloader mode.
- Application Mode - Press the reset button three times to switch to application mode.

13 Updating firmware using COINES SDK

To update the firmware, follow these steps:

1. Connect the Engineering Board using USB cable to PC.
2. These boards come preloaded with a bootloader update package.

Run the required .bat/.sh scripts inside \firmware\ based on the board chosen.

Function	Script
Nicla Sense ME Board - Prepare board	prepare_nicla.bat
Bootloader update	\bootloader_update\update_bootloader.bat
MTP firmware update	\mtp_fw_update\update_mtp_fw.bat
COINES Bridge firmware targetted for RAM memory	\coines_bridge\update_coines_bridge_ram_fw.bat
COINES Bridge firmware targetted for FLASH memory	\coines_bridge\update_coines_bridge_flash_fw.bat

14 FAQs

1. What to do in case of a communication or initialization failure while running examples?

Resetting or rebooting the board will help solve such issues.

2. Why is there no output in my terminal application after cross-compiling and download-ing an example on the MCU?

The code example on the MCU waits until the serial port of the board is opened. However, opening the port is not enough, the user has to ensure that also the DTR signal is set (this is required due to higher compatibility among different terminal applications).

3. How to fix libusb not found issue on macOS (arm64)?

Try the steps below to fix the issue:

- a. Install libusb: Libusb will be automatically installed as part of the COINES SDK installation. However, If it's not installed automatically, you can use Homebrew to install it:

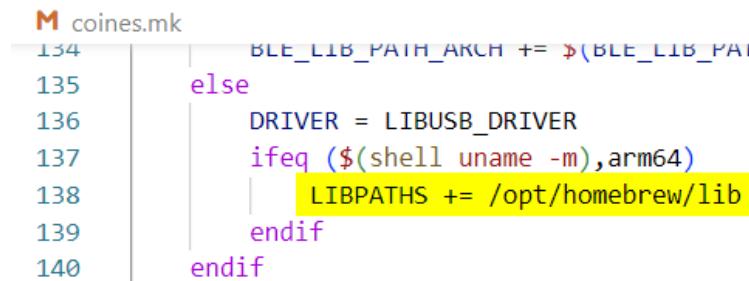
```
brew install libusb
```

After running the above command, libusb should be installed on your system.

On Intel Mac: /usr/local/lib

On M1 Mac: /opt/homebrew/lib

- b. Add the path in <installed_COINES_SDK_location>/coines.mk



```

M coines.mk
134
135     else
136         DRIVER = LIBUSB_DRIVER
137         ifeq ($($shell uname -m), arm64)
138             LIBPATHS += /opt/homebrew/lib
139         endif
140     endif

```

Fig. 19: COINES SDK file structure

4. How do I recover the original program when bootloader was erased accidentally on Application Board 3.X?

Refer to the section 9 to setup Segger and connect JLink with APP3.X. Follow the steps below to reprogram the APP3.X.

- Open SEGGER J-Flash lite tool and click 'OK' after verifying the target device.

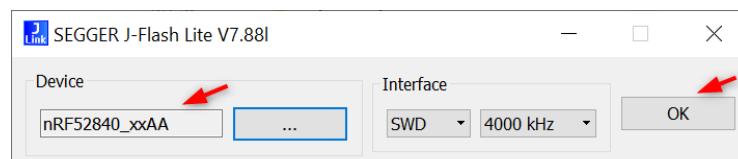


Fig. 20: SEGGER J-Flash Target selection

- Load <installed_COINES_SDK_location>/firmware/app3.X/bootloader_update/usb_ble_dfu_bootloader.hex and click 'Program Device'.

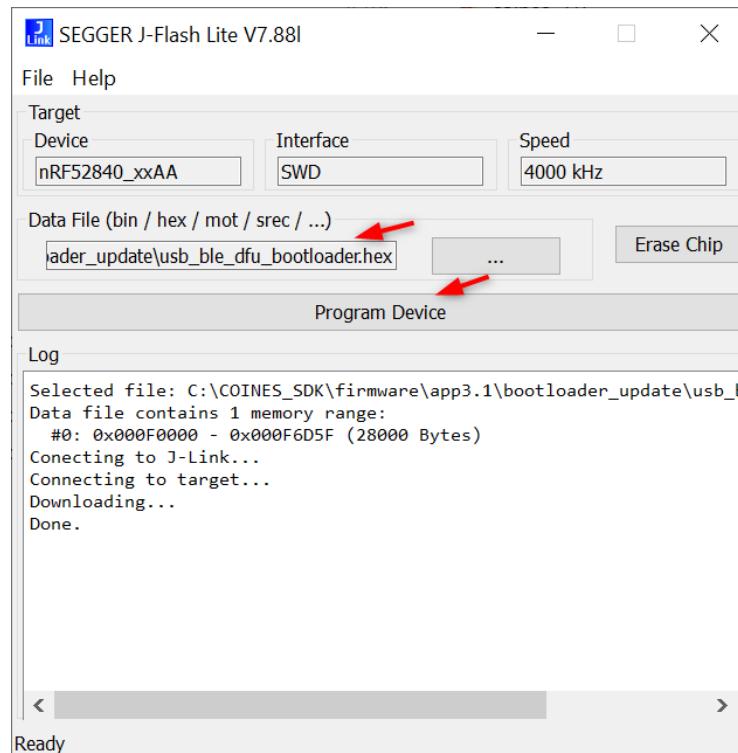


Fig. 21: SEGGER J-Flash Program Device

5. How do I run multiple application boards using COINES SDK in a single computer?

When multiple USB devices are connected to a PC, by configuring Serial COM settings for a script, the user can communicate with them separately. Refer to [8.1.11](#) for implementation.

For more FAQs, visit [Bosch Sensortec MEMS sensors forum](#).

15 Annexure

15.1 GPIO mapping

15.1.1 GPIO mapping of APP2.0 shuttle board pins

The APP2.0 shuttle board has a total of 28 pins; some have a predefined functionality, and some can be used as GPIO by the user.

The shuttle board connector details are given in the table below.

Pin number on shuttle board	Name / function	Pin number on shuttle board	Name / function
1	VDD (3.3V)	28	SHTLE_COD #4
2	VDDIO (3.3V)	27	SHTLE_COD #3
3	GND	26	SHTLE_COD #2
4	SPI MISO	25	SHTLE_COD #1
5	SPI: MOSI / I ² C: SDA	24	SHTLE_COD #0
6	SPI: SCK / I ² C: SCL	23	SHTLE_COD_GND
7	SPI: CS	22	IO_4 (GPIO #4)
8	IO_5 (GPIO #5)	21	IO_7 (GPIO #7)
9	IO_0 (GPIO #0)	20	IO_6 (GPIO #6)
10	SHTLE_COD #5	19	IO_8 (GPIO #8)
11	SHTLE_COD #6	18	SCL (see note)
12	SHTLE_COD #7	17	SDA (see note)
13	SHTLE_COD #8	16	IO_3 (GPIO #3)
14	IO_1 (GPIO #1)	15	IO_2 (GPIO #2)

Table 1: Overview of APP2.0 shuttle board pins and their functions

Note:

- In COINES SDK functions, the pins are addressed using the same numbers as on the shuttle board. For example, the GPIO #5 has the pin number 8.
- In some cases (depending on the sensor), the I²C lines are shuttle board pin 6 for the clock signal SCL and shuttle board pin 5 for the data line SDA. In such cases, pins 17 and 18 may not be connected. Carefully read the shuttle board documentation.

15.1.2 GPIO mapping of APP3.X shuttle board pins

The APP3.X shuttle board has 16 pins, seven on the left and nine on the right (with shuttle board pins facing downwards).

Note:

- In COINES SDK functions, the pins are addressed as on the APP3.X shuttle board. For example, the GPIO #5 is addressed as COINES_MINI_SHUTTLE_PIN_2_6.
- Supported VDD voltages on APP3.X are 0, 1.8V, and 2.8V
- Supported VDDIO voltage on APP3.X is 1.8V

Pin number on shuttle board	Name / function	Pin number on shuttle board	Name / function
1_1	VDD (1.8/2.8V)	2_1	SPI_CS
1_2	VDDIO (1.8)	2_2	SPI: SCK / I ² C: SCL
1_3	GND	2_3	SPI: MISO
1_4	GPIO0	2_4	SPI: MOSI / I ² C: SDA
1_5	GPIO1	2_5	GPIO4*
1_6	GPIO2	2_6	GPIO5*
1_7	GPIO3	2_7	IOXP_INT*
		2_8	PlugDet*
		2_9	EEPROM_RW

*SPI pins for secondary interface - CS:GPIO4, SCK:GPIO5, MISO:IOXP_INT, MOSI:PlugDet

Table 2: Overview of APP3.X shuttle board pins and their functions

15.2 COINES SDK C functions

15.2.1 coinesAPI calls: Interface and board information

15.2.1.1 coines_open_comm_intf

Opens the communication interface

```
int16_t coines_open_comm_intf(enum coines_comm_intf intf_type, void *arg);
```

In the case of an MCU target, the API waits indefinitely for a serial port or BLE connection (MCU_APP30 target and MCU_APP31 target).

In the case of a PC target, the user can configure communication settings either by passing the address of coines_serial_com_config or ble_peripheral_info to *arg.

Serial com configuration:

If *arg is NULL for COINES_COMM_INTF_USB, the first com port enumerated will be used for communication. The serial com configuration structure contains the following items. Refer to [8.1.11](#) for its implementation.

```
struct coines_serial_com_config
{
    uint32_t baud_rate; /*< Baud rate */
    uint16_t vendor_id; /*< vendor Id */
    uint16_t product_id; /*< Product Id */
    char* com_port_name; /*< serial com port name */
    uint16_t rx_buffer_size; /*< RX response buffer size */
};
```

BLE com configuration:

If *arg is NULL for COINES_COMM_INTF_BLE, the nearest Application board for the host BLE will be used for communication. The ble com configuration structure contains the following items. Refer to [8.1.10](#) for its implementation.

```
struct ble_peripheral_info
{
    char ble_address[COINES_CHAR_MAX_LEN]; /*< BLE device address */
    char ble_identifier[COINES_CHAR_MAX_LEN]; /*< BLE device identifier */
};
```

15.2.1.2 coines_close_comm_intf

Closes the communication interface

```
int16_t coines_close_comm_intf(enum coines_comm_intf intf_type, void *arg);
```

15.2.1.3 coines_get_board_info

Gets the board information

```
int16_t coines_get_board_info(struct coines_board_info *data);
```

The data structure contains the following items:

```
struct coines_board_info {
    /*!Board hardware ID */
    uint16_t hardware_id;
    /*!Board software ID */
    uint16_t software_id;
    /*!Type of the board like APP2.0, Arduino Due*/
    uint8_t board;
    /*!Shuttle ID of the sensor connected*/
    uint16_t shuttle_id;
};
```

15.2.2 coinesAPI calls: GPIO oriented calls

15.2.2.1 coines_set_pin_config

Sets the pin direction and the state

```
int16_t coines_set_pin_config(enum coines_multi_io_pin pin_number, enum
    coines_pin_direction direction, enum coines_pin_value pin_value);
```

15.2.2.2 coines_get_pin_config

Gets the pin configuration

```
int16_t coines_get_pin_config(enum coines_multi_io_pin pin_number, enum
    coines_pin_direction *pin_direction, enum coines_pin_value *pin_value);
```

15.2.2.3 coines_set_shuttleboard_vdd_vddio_config

This API configures the VDD and VDDIO of the sensor. For APP2.0, a voltage level of 0 or 3300 mV is supported. Any values above 0 will default to 3300 mV.

```
int16_t coines_set_shuttleboard_vdd_vddio_config(uint16_t vdd_millivolt, uint16_t
    vddio_millivolt);
```

15.2.3 coinesAPI calls: Sensor communication

15.2.3.1 coines_config_i2c_bus

Configures the I²C bus

```
int16_t coines_config_i2c_bus(enum coines_i2c_bus bus, enum coines_i2c_mode i2c_mode);
```

The first argument refers to the bus on the board. Currently, on APP2.0, there is only one bus available, so the argument is always COINES_I2C_BUS_0.

The following I²C modes are available:

COINES_I2C_STANDARD_MODE
COINES_I2C_FAST_MODE
COINES_I2C_SPEED_3_4_MHZ
COINES_I2C_SPEED_1_7_MHZ

15.2.3.2 coines_config_spi_bus

This API configures the SPI bus of the board. The argument `coines_spi_bus` refers to the bus on the board. On APP2.0, only one bus is available, so the user should only use `COINES_SPI_BUS_0`. The SPI speed can be chosen in various discrete steps, as defined in `enum coines_spi_speed` in `coines.h`. (For example, `COINES_SPI_SPEED_2_MHZ` sets the SPI speed to 2 MHz.)

```
int16_t coines_config_spi_bus(enum coines_spi_bus bus, uint32_t spi_speed, enum
                           coines_spi_mode spi_mode);
```

15.2.3.3 coines_config_i2s_bus

This API is used to configure the I²S bus to match the TDM configuration.

```
int16_t coines_config_i2s_bus(uint16_t data_words, coines_tdm_callback callback);
```

Arguments:

- `data_words`: The number of words to use in the buffer. Max is set at `COINES_TDM_BUFFER_SIZE_WORDS`.
- `callback`: register a callback to be called to process and copy the data

15.2.3.4 coines_deconfig_spi_bus

This API is used to de-configure the SPI bus.

```
int16_t coines_deconfig_spi_bus(enum coines_spi_bus bus);
```

15.2.3.5 coines_deconfig_i2c_bus

This API is used to de-configure the I²C bus.

```
int16_t coines_deconfig_i2c_bus(enum coines_i2c_bus bus);
```

15.2.3.6 coines_deconfig_i2s_bus

This API is used to stop the I²S/TDM interface from reading data from the sensor.

```
void coines_deconfig_i2s_bus(void);
```

15.2.3.7 coines_write_i2c

This API writes 8-bit register data to the I²C device at COINES_I2C_BUS_0.

```
int8_t coines_write_i2c(enum coines_i2c_bus bus, uint8_t dev_addr, uint8_t reg_addr,
    uint8_t *reg_data, uint16_t count);
```

Arguments:

- bus: I²C bus to be used
- dev_addr: I²C device address
- reg_addr: Starting address for writing the data
- reg_data: Data to be written
- count: Number of bytes to write

15.2.3.8 coines_read_i2c

This API reads 8-bit register data from the I²C device at COINES_I2C_BUS_0.

```
int8_t coines_read_i2c(enum coines_i2c_bus bus, uint8_t dev_addr, uint8_t reg_addr,
    uint8_t *reg_data, uint16_t count);
```

Arguments:

- bus: I²C bus to be used
- dev_addr: I²C device address
- reg_addr: Starting address for reading the data
- reg_data: Buffer to take up the read data
- count: Number of bytes to read

15.2.3.9 coines_i2c_set

This API is used to write the data in I2C communication.

```
int8_t coines_i2c_set(enum coines_i2c_bus bus, uint8_t dev_addr, uint8_t *data, uint8_t
    count);
```

Arguments:

- bus: I²C bus to be used
- dev_addr: I²C device address
- data: Data to be written
- count: Number of bytes to write

15.2.3.10 coines_i2c_get

This API is used to read the data in I2C communication.

```
int8_t coines_i2c_get(enum coines_i2c_bus bus, uint8_t dev_addr, uint8_t *data, uint8_t
    count);
```

Arguments:

- bus: I²C bus to be used
- dev_addr: I²C device address
- data: Data read from the sensor
- count: Number of bytes to read

15.2.3.11 coines_write_spi

This API writes 8-bit register data to the SPI device at COINES_SPI_BUS_0.

```
int8_t coines_write_spi(enum coines_spi_bus bus, uint8_t dev_addr, uint8_t reg_addr,
                      uint8_t *reg_data, uint16_t count);
```

Arguments:

- bus: SPI bus to be used
- dev_addr: Chip select pin number
- reg_addr: Starting address for writing the data
- reg_data: Data to be written.
- count: Number of bytes to write

15.2.3.12 coines_read_spi

This API reads 8-bit register data from the SPI device at COINES_SPI_BUS_0.

```
int8_t coines_read_spi(enum coines_spi_bus bus, uint8_t dev_addr, uint8_t reg_addr,
                      uint8_t *reg_data, uint16_t count);
```

Arguments:

- bus: SPI bus to be used
- dev_addr: Chip select pin number
- reg_addr: Starting address for reading the data
- reg_data: Buffer to take up the read data
- count: Number of bytes to read

15.2.3.13 coines_delay_msec

This API introduces the delay in milliseconds.

```
void coines_delay_msec(uint32_t delay_ms);
```

15.2.3.14 coines_delay_usec

This API introduces the delay in microseconds.

```
void coines_delay_usec(uint32_t delay_us);
```

15.2.3.15 coines_uart_init

This API is used to initialize the UART communication.

```
int8_t coines_uart_init(enum coines_uart_instance uart_instance, enum
    coines_uart_parity parity, enum coines_uart_flow_control flow_control, uint32_t
    baud_rate);
```

Arguments:

- **uart_instance**: Specifies the UART instance
- **parity**: UART parity
- **flow_control**: UART flow control mode
- **baud_rate**: UART baud rate

15.2.3.16 coines_uart_read

This API is used to read the data in UART communication.

```
uint16_t coines_uart_read(enum coines_uart_instance uart_instance, uint8_t *buffer,
    uint16_t length);
```

Arguments:

- **uart_instance**: Specifies the UART instance
- **buffer**: Pointer to the buffer to store the data
- **length**: Length of the buffer

15.2.3.17 coines_uart_write

This API is used to write the data in UART communication.

```
int8_t coines_uart_write(enum coines_uart_instance uart_instance, uint8_t *buffer,
    uint16_t length);
```

Arguments:

- **uart_instance**: Specifies the UART instance
- **buffer**: Pointer to the data buffer that need to be written
- **length**: Length of the buffer

15.2.4 coinesAPI calls: Streaming feature

Note:

1. The APIs below are supported only on a PC Target.
2. A simpler approach to using `coines_attach_interrupt()` API is available for MCU.

15.2.4.1 coines_config_streaming

This API sets the configuration for streaming sensor data.

```
int16_t coines_config_streaming(uint8_t channel_id, struct coines_streaming_config
    *stream_config, struct coines_streaming_blocks *data_blocks);
```

Arguments:

- **channel_id**: An integer number that can be used as an identifier/index to the sensor data that is streamed for this setting.
- **stream_config**: Contains information regarding interface settings and streaming configuration.
- **coines_streaming_blocks**: Contains information regarding the numbers of blocks to read, register address, and size for each block

Note:

The parameters below should always be set:

- **data_block.no_of_blocks**: The number of blocks to stream (must at least be one)
- For each block b:
 - **data_block.reg_start_addr[b]**: start address of the block in the register map
 - **stream_block.no_of_data_bytes[b]**: number of bytes to read, starting from the start address

For reading data from the I²C bus, set the parameters below:

- **stream_config.intf** = COINES_SENSOR_INTF_I2C;
- **stream_config.i2c_bus**: I²C bus (in case of APP2.0, this is always COINES_I2C_BUS_0)
- **stream_config.dev_addr**: I²C address of the sensor

For reading data from the SPI bus, set the parameters below:

- **stream_config.intf** = COINES_SENSOR_INTF_SPI;
- **stream_config.spi_bus**: SPI bus (in case of APP2.0, this is always COINES_SPI_BUS_0)
- **stream_config.cs_pin**: The CS pin of the sensor. Information can be obtained from the shuttle board documentation for the sensor.

When polling mode is requested, set the parameters below:

- **stream_config.sampling_units**: either milliseconds (COINES_SAMPLING_TIME_IN_MILLI_SEC) or microseconds (COINES_SAMPLING_TIME_IN_MICRO_SEC)
- **stream_config.sampling_time**: sampling period in the unit as defined in **stream_config.sampling_units**

When interrupt mode is requested, set the parameters below:

- **stream_config.int_pin**: The interrupt pin that triggers the sensor read-out. If the interrupt output of the sensor is used, the required information about the pin number can be obtained from the shuttle board documentation for the sensor.
- **stream_config.int_timestamp**: It can be configured if the sensor data is tagged with a timestamp (COINES_TIMESTAMP_ENABLE) or not (COINES_TIMESTAMP_DISABLE).

15.2.4.2 coines_start_stop_streaming

This API starts or stops sensor data streaming.

```
int16_t coines_start_stop_streaming(enum coines_streaming_mode stream_mode, uint8_t start_stop);
```

Arguments:

- **stream_mode:** streaming mode (either COINES_STREAMING_MODE_POLLING or COINES_STREAMING_MODE_INTERRUPT)
- **start_stop:** flag to either start (COINES_STREAMING_START) or stop (COINES_STREAMING_STOP) the streaming

15.2.4.3 coines_read_stream_sensor_data

This API reads the data streamed from the sensor.

```
int16_t coines_read_stream_sensor_data(uint8_t sensor_id, uint32_t number_of_samples,
                                       uint8_t *data, uint32_t *valid_samples_count);
```

Arguments:

- **sensor_id:** id of the sensor
- **number_of_samples:** number of samples the user wishes to read (not implemented)
- **data:** data buffer
 - Interrupt streaming - Packet counter + Register data + Timestamp
 - Polling streaming - Register data
- **valid_samples_count:** number of samples the user has actually received (may be less than number_of_samples)

Example of a packet:

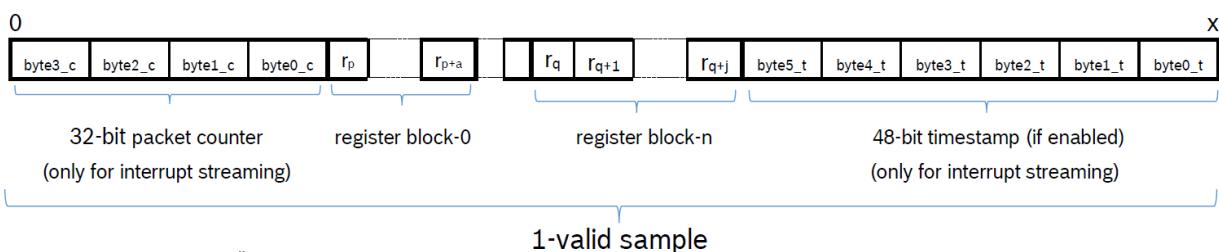


Fig. 22: Format of streaming packages

The following definitions are for the abbreviations in Figure 22:

- **r_p:** Value at register address p
- **a:** Size of register block-0
- **r_{p+a}:** Value at register address p

In the same manner, definitions are applicable to r_q, j and r_{q+j}. See the `coines_streaming_blocks` structure for information regarding register blocks.

Determine the packet counter and timestamp as follows:

```
packet_counter = (byte3_c << 24) | (byte2_c << 16) | (byte1_c << 8) | (byte0_c)
```

```
timestamp = (byte5_t << 40) | (byte4_t << 32) | (byte3_t << 24) | (byte2_t << 16) |
           (byte1_t << 8) | (byte0_t)
```

The 48-bit timestamp is enabled by using

```
coines_trigger_timer(COINES_TIMER_START, COINES_TIMESTAMP_ENABLE);
```

Determine the Timestamp in microseconds using the formula below:

$$\text{Timestamp } (\mu\text{s}) = \frac{48\text{bit_timestamp}}{30}$$

15.2.4.4 coines_trigger_timer

This API triggers the firmware timer and enables or disables the time stamp feature.

```
int16_t coines_trigger_timer(enum coines_timer_config tmr_cfg, enum
                           coines_time_stamp_config ts_cfg);
```

Arguments:

- tmr_cfg: start, stop or reset the timer (COINES_TIMER_START, COINES_TIMER_STOP or COINES_TIMER_RESET)
- ts_cfg: Enables/disables the microcontroller timestamp (COINES_TIMESTAMP_ENABLE or COINES_TIMESTAMP_DISABLE)

15.2.5 coinesAPI calls: Other useful APIs

15.2.5.1 coines_get_millis

This API returns the number of milliseconds passed since the program started.

```
uint32_t coines_get_millis();
```

15.2.5.2 coines_get_micro_sec

Returns the number of microseconds passed since the program started

```
uint64_t coines_get_micro_sec();
```

15.2.5.3 coines_attach_interrupt

This API attaches an interrupt to a Multi-IO pin. It only works on an MCU target.

```
void coines_attach_interrupt(enum coines_multi_io_pin pin_number, void
                           (*callback)(uint32_t, uint32_t), enum coines_pin_interrupt_mode int_mode);
```

Arguments:

- pin_number: Multi-IO pin
- callback: Name of the function to be called on interrupt detection
- int_mode: Trigger modes - change (COINES_PIN_INTERRUPT_CHANGE), rising edge (COINES_PIN_INTERRUPT_RISING_EDGE), falling edge (COINES_PIN_INTERRUPT_FALLING_EDGE)

15.2.5.4 coines_detach_interrupt

This API detaches interrupt from a Multi-IO pin. It only works on an MCU target.

```
void coines_detach_interrupt(enum coines_multi_io_pin pin_number);
```

Arguments:

- **pin_number:** Multi-IO pin

15.2.5.5 coines_intf_available

Return the number of bytes available in the read buffer of the interface. It only works on an APP3.x MCU target.

```
uint16_t coines_intf_available(enum coines_comm_intf intf);
```

Arguments:

- **intf:** Type of interface (USB, COM, or BLE)

15.2.5.6 coines_intf_connected

This API checks if the interface is connected. It only works on an APP3.x MCU target.

```
bool coines_intf_connected(enum coines_comm_intf intf);
```

Arguments:

- **intf:** Type of interface (USB, COM, or BLE)

15.2.5.7 coines_flush_intf

This API flushes the write buffer. It only works on an APP3.x MCU target.

```
void coines_flush_intf(enum coines_comm_intf intf);
```

Arguments:

- **intf:** Type of interface (USB, COM, or BLE)

15.2.5.8 coines_read_intf

This API reads data over the specified interface. It only works on an APP3.x MCU target.

```
uint16_t coines_read_intf(enum coines_comm_intf intf, void *buffer, uint16_t len);
```

Arguments:

- **intf:** Type of interface (USB, COM, or BLE)
- **buffer:** Pointer to the buffer to store the data
- **len:** Length of the buffer

15.2.5.9 coines_write_intf

This API writes data over the specified interface. It only works on an APP3.x MCU target.

```
uint16_t coines_write_intf(enum coines_comm_intf intf, void *buffer, uint16_t len);
```

Arguments:

- **intf**: Type of interface (USB, COM, or BLE)
- **buffer**: Pointer to the buffer storing the data
- **len**: Length of the buffer

15.2.5.10 coines_get_version

Returns pointer to COINES version string

```
char* coines_get_version(void);
```

15.2.5.11 coines_soft_reset

Resets the device. After the device is reset, it opens to the address specified in makefile (APP_START_ADDRESS).

```
void coines_soft_reset(void);
```

15.2.5.12 coines_read_temp_data

This API is used to read the temperature sensor data.

```
int16_t coines_read_temp_data(float *temp_data);
```

Arguments:

- **temp_data**: Buffer to retrieve the sensor data in degree Celsius.

15.2.5.13 coines_read_bat_status

This API is used to read the battery status.

```
int16_t coines_read_bat_status(uint16_t *bat_status_mv, uint8_t *bat_status_percent);
```

Arguments:

- **bat_status_mv**: Buffer to retrieve the battery status in millivolt.
- **bat_status_percent**: Buffer to retrieve the battery status in .

15.2.5.14 coines_ble_config

This API is used to configure BLE name and power. Call this API before calling coines_open_comm_intf API.

```
int16_t coines_ble_config(struct coines_ble_config *ble_config);
```

Arguments:

- **ble_config**: structure holding the ble name and power details

15.2.5.15 coines_set_led

This API is used to set the led state (on or off).

```
int16_t coines_set_led(enum coines_led led, enum coines_led_state led_state);
```

Arguments:

- **led**: led to which the state has to be set
- **led_state**: state to be set to the given led

15.2.5.16 coines_timer_config

This API is used to configure the hardware timer.

```
int16_t coines_timer_config(enum coines_timer_instance instance, void* handler);
```

Arguments:

- **instance**: timer instance
- **handler**: callback to be called when timer expires

15.2.5.17 coines_timer_deconfig

This API is used to de-configure the hardware timer.

```
int16_t coines_timer_deconfig(enum coines_timer_instance instance);
```

Arguments:

- **instance**: timer instance

15.2.5.18 coines_timer_start

This API is used to start the configured hardware timer.

```
int16_t coines_timer_start(enum coines_timer_instance instance, uint32_t timeout);
```

Arguments:

- **instance**: timer instance
- **timeout**: timeout in microseconds

15.2.5.19 coines_timer_stop

This API is used to stop the hardware timer.

```
int16_t coines_timer_stop(enum coines_timer_instance instance);
```

Arguments:

- **instance:** timer instance

15.2.5.20 coines_get_realtime_usec

This API is used to get the current counter (RTC) reference time in usec.

```
uint32_t coines_get_realtime_usec(void);
```

15.2.5.21 coines_delay_realtime_usec

This API is used to introduce delay based on high precision RTC (LFCLK crystal) with the resolution of 30.517 usec.

```
void coines_delay_realtime_usec(uint32_t period);
```

Arguments:

- **period:** required delay in microseconds

15.2.5.22 coines_attach_timed_interrupt

This API Attaches a timed interrupt to a Multi-IO pin.

```
int16_t coines_attach_timed_interrupt(enum coines_multi_io_pin pin_number, void
(*timed_interrupt_cb)(uint64_t, uint32_t, uint32_t), enum coines_pin_interrupt_mode
int_mode);
```

Arguments:

- **pin_number:** Multi-IO pin.
- **timed_interrupt_cb:** Name of the function to be called on detection of interrupt.
- **int_mode:** Trigger modes - change, rising edge, falling edge.

15.2.5.23 coines_detach_timed_interrupt

Detaches a timed interrupt from a Multi-IO pin.

```
int16_t coines_detach_timed_interrupt(enum coines_multi_io_pin pin_number);
```

Arguments:

- **pin_number:** Multi-IO pin

15.2.5.24 coines_echo_test

This API is used to test the communication.

```
int16_t coines_echo_test(uint8_t *data, uint16_t length);
```

Arguments:

- **data**: Data to be sent for testing
- **length**: Length of the data

15.2.5.25 coines_shuttle_eeprom_write

This API is used to write the content into shuttle eeprom.

```
int16_t coines_shuttle_eeprom_write(uint16_t start_addr, uint8_t *buffer, uint16_t length);
```

Arguments:

- **start_addr**: EEPROM write address
- **buffer**: Pointer to the buffer
- **length**: Length of the buffer

15.2.5.26 coines_shuttle_eeprom_read

This API is used to read the content from shuttle eeprom.

```
int16_t coines_shuttle_eeprom_read(uint16_t start_addr, uint8_t *buffer, uint16_t length);
```

Arguments:

- **start_addr**: EEPROM read address
- **buffer**: Pointer to the buffer
- **length**: Length of the buffer

15.2.5.27 coines_yield

This API can be defined to perform a task when yielded from an ongoing blocking call.

```
void coines_yield(void);
```

15.2.5.28 coines_execute_critical_region

This API is used to execute the function inside a critical region.

```
void coines_execute_critical_region(coines_critical_callback callback);
```

Arguments:

- **callback**: Function to execute

15.2.5.29 coines_scan_ble_devices

This API is used to connect to the BLE Adapter and return a list of BLE peripherals found during the BLE scan.

```
int16_t coines_scan_ble_devices(struct ble_peripheral_info *ble_info, uint8_t
                                *peripheral_count, size_t scan_timeout_ms)
```

Arguments:

- **ble_info:** an array of structs with information regarding detected BLE peripheral devices
- **peripheral_count:** The number of BLE peripherals found
- **scan_timeout_ms:** timeout for BLE scan

15.3 COINES SDK Python functions

As coinespy is only a wrapper on top of coinesAPI, the following API documentation is limited to the wrapper only. Details about the meaning of variables and functionality can be found in the corresponding coinesAPI documentation in the chapter above. The following function calls

are defined within the class CoinesBoard. Therefore, to access the functions, the user must first create an object of that class.

```
import coinespy as cpy
coinesboard = cpy.CoinesBoard()
```

15.3.1 coinespy API calls: Interface and board information

15.3.1.1 open_comm_interface

Sets the communication interface between the board and PC to USB, Serial or BLE

```
coinesboard.open_comm_interface(interface=CommInterface.USB, serial_com_config:
    SerialComConfig = None,
    ble_com_config: BleComConfig = None) -> ErrorCodes
```

For the definition of CommInterface, refer to [15.3.6.3](#).

15.3.1.2 close_comm_interface

Disposes the resources used by the USB/serial/BLE communication

```
coinesboard.close_comm_interface(arg=None) -> ErrorCodes
```

15.3.1.3 get_board_info

Obtains board-specific information

```
BoardInfo = coinesboard.get_board_info()

# Return:
BoardInfo.HardwareId # Hardware ID
BoardInfo.SoftwareId # Firmware version information
BoardInfo.Board      # Board type
BoardInfo.ShuttleID # ID of shuttle, in case a shuttle is detected
```

15.3.1.4 scan_ble_devices

This API connects to the BLE Adapter and returns a list of BLE peripherals found during the BLE scan.

```
ble_info, peripheral_count = coinesboard.scan_ble_devices(scan_timeout_ms=0) ->
    Tuple[list, int]
```

For the definition of parameters, refer to [15.2.5.29](#).

15.3.1.5 echo_test

This API is used to test the communication.

```
coinesboard.echo_test(data: List[int]) -> ErrorCodes
```

Arguments:

- data: Data to be sent for testing.

15.3.2 coinespy API calls: GPIO oriented calls

15.3.2.1 set_pin_config

Configures the state, level, and direction of a GPIO pin

```
coinesboard.set_pin_config(pin_number: MultiIOPin, direction: PinDirection,
                           output_state: PinValue) -> ErrorCodes
```

For the definition of MultiIOPin, refer to [15.3.6.8](#). For the definition of PinDirection, refer to [15.3.6.1](#). For PinValue, refer to [15.3.6.2](#).

15.3.2.2 get_pin_config

Obtains information regarding the Pin's state, level, and direction

```
PinConfigInfo = coinesboard.get_pin_config(pin_number: MultiIOPin)
```

```
# Return:
PinConfigInfo.direction    # 0: INPUT, 1: OUTPUT
PinConfigInfo.switch_state # 0: OFF, 1: ON
PinConfigInfo.level        # 1: HIGH, 0: LOW
```

15.3.2.3 set_shuttleboard_vdd_vddio_config

Sets the VDD and VDDIO voltage level

```
coinesboard.set_shuttleboard_vdd_vddio_config(vdd_val: float = None, vddio_val: float =
                                              None) -> ErrorCodes
```

```
# Example: coinesboard.set_shuttleboard_vdd_vddio_config(3.3, 3.3)
```

15.3.2.4 set_vdd

Sets the VDD voltage level

```
coinesboard.set_vdd(vdd_val: float = None) -> ErrorCodes
```

```
# Example: coinesboard.set_vdd(3.3)
```

15.3.2.5 set_vddio

Sets the VDDIO voltage level

```
coinesboard.set_vddio(vdd_val: float = None) -> ErrorCodes
```

```
# Example: coinesboard.set_vddio(3.3)
```

15.3.3 coinespy API calls: Sensor communication

For the definition of SPIBus, refer to [15.3.6.11](#). For the definition of I2CBus, refer to [15.3.6.10](#).

15.3.3.1 config_i2c_bus

Configures the I²C bus

```
coinesboard.config_i2c_bus(bus: I2CBus, i2c_address: int, i2c_mode: I2CMode) -> ErrorCodes
```

For the definition of I2CMode, refer to [15.3.6.4](#).

15.3.3.2 config_spi_bus

Configures the SPI bus of the board

```
coinesboard.config_spi_bus(bus: SPIBus, cs_pin: MultiIOPin, spi_speed=SPISpeed, spi_mode=SPIMode) -> ErrorCodes
```

For the definition of MultiIOPin, refer to [15.3.6.8](#). For the definition of SPISpeed, refer to [15.3.6.5](#).
For the definition of SPIMode, refer to [15.3.6.7](#).

15.3.3.3 deconfig_i2c_bus

This API is used to de-configure the I²C bus.

```
coinesboard.deconfig_i2c_bus(bus: I2CBus) -> ErrorCodes
```

15.3.3.4 deconfig_spi_bus

This API is used to de-configure the SPI bus.

```
coinesboard.deconfig_spi_bus(bus: SPIBus) -> ErrorCodes
```

15.3.3.5 write_i2c

Writes 8-bit register data to the I²C

```
coinesboard.write_i2c(bus: I2CBus, register_address: int, register_value: int, sensor_interface_detail: int = None) -> ErrorCodes
```

For the definition of parameters, refer to [15.2.3.7](#).

15.3.3.6 `read_i2c`

Reads 8-bit register data from the I²C

```
register_data = coinesboard.read_i2c(bus: I2CBus, register_address: int,
                                     number_of_reads=1, sensor_interface_detail: int = None)
```

For the definition of parameters, refer to [15.2.3.8](#).

15.3.3.7 `write_spi`

Writes 8-bit register data to the SPI device

```
coinesboard.write_spi(bus: SPIBus, register_address: int, register_value: int,
                      sensor_interface_detail: int = None) -> ErrorCodes
```

For the definition of parameters, refer to [15.2.3.11](#).

15.3.3.8 `read_spi`

Reads 8-bit register data from the SPI device.

```
register_data = coinesboard.read_spi(bus: SPIBus, register_address: int,
                                      number_of_reads=1, sensor_interface_detail: int = None)
```

For the definition of parameters, refer to [15.2.3.12](#).

15.3.3.9 `delay_milli_sec`

Introduces delay in millisecond.

```
coinesboard.delay_milli_sec(time_in_milli_sec=100)
```

15.3.3.10 `delay_micro_sec`

Introduces delay in microsecond.

```
coinesboard.delay_micro_sec(time_in_micro_sec=1)
```

15.3.4 `coinespy` API calls: Streaming feature

15.3.4.1 `config_streaming`

Sets the configuration for streaming sensor data.

```
coinesboard.config_streaming(sensor_id: int,
                             stream_config: StreamingConfig, data_blocks: StreamingBlocks) -> ErrorCodes
```

Arguments:

- **sensor_id**: An integer number that can be used as an identifier/index to the sensor data that will be streamed for this setting.
- **stream_config**: Contains information regarding interface settings and streaming configuration
- **data_blocks**: Contains information regarding numbers of blocks to read, register address, and size for each block

The parameters below should always be set:

- **data_blocks.NoOfBlocks**: number of blocks to stream (must at least be one)
- For each block b:
 - **data_blocks.RegStartAddr[b]**: start address of the block in the register map
 - **data_blocks.NoOfDataBytes[b]**: number of bytes to read, starting from the start address

For reading data from the I²C bus, set the parameters below:

- **stream_config.Intf** = `cpy.SensorInterface.I2C.value`
- **stream_config.I2CBus**: I²C bus (in case of APP2.0 and APP3.x, this is always `cpy.I2CBus.BUS_I2C_0.value`)
- **stream_config.DevAddr**: I²C address of the sensor

For reading data from the SPI bus, set the parameters below:

- **stream_config.Intf** = `cpy.SensorInterface.SPI.value`;
- **stream_config.SPIBus**: SPI bus (in case of APP2.0 and APP3.x, this is always `cpy.SPIBus.BUS_SPI_0.value`)
- **stream_config.CSPin**: CS pin of the sensor, information can be obtained from the shuttle board documentation for the sensor.
- **stream_config.SPIType**: 0 : 8-bit SPI; 1 : 16-bit SPI

When polling mode is requested, set the parameters below:

- **stream_config.SamplingUnits**: Either milliseconds or microseconds. Refer to [15.3.6.15](#).
- **stream_config.SamplingTime**: sampling period in the unit as defined in **stream_config.SamplingUnits**

When interrupt mode is requested, set the parameters below:

- **stream_config.IntPin**: Pin of the interrupt, which triggers the sensor read-out. If the interrupt output of the sensor is used, the required information about the pin number can be obtained from the shuttle board documentation for the sensor.
- **stream_config.IntTimeStamp**: It can be configured if the sensor data is tagged with a timestamp - 1 or not - 0.
- **stream_config.HwPinState**: State of the hardware pin connected to the interrupt line - 0/1: Low/high

The parameters below are common for both streaming types:

- **stream_config.IntlineCount**: Number of interrupt lines to be used for monitoring interrupts.
- **stream_config.IntlineInfo**: List of pin numbers that correspond to interrupt lines being used for interrupt monitoring.

- stream_config.ClearOnWrite: 0/1 : Disable/enable "clear on write" feature

The parameters below should only be set when stream_config.ClearOnWrite = 1:

- stream_config.ClearOnWriteConfig.StartAddress: Address of the sensor register at which the process of clearOnWrite should initiate.
- stream_config.ClearOnWriteConfig.DummyByte: Number of padding bytes that must be added before clearing the bytes starting from the designated address.
- stream_config.ClearOnWriteConfig.NumBytesToClear: Number of bytes that need to be cleared.

Below is the Python code snippet for interrupt streaming.

```
# Store streaming settings in local variables
accel_stream_settings = dict(
    I2C_ADDR_PRIMARY=0x18,
    NO_OF_BLOCKS = 2,
    REG_X_LSB= [0x12, 0x00],
    NO_OF_DATA_BYTES= [6, 1],
    CHANNEL_ID=1,
    CS_PIN=cpy.MultiIOPin.SHUTTLE_PIN_8.value,
    INT_PIN=cpy.MultiIOPin.SHUTTLE_PIN_21.value,
    INT_TIME_STAMP=1,
)
gyro_stream_settings = dict(
    I2C_ADDR_PRIMARY=0x68,
    NO_OF_BLOCKS = 2,
    REG_X_LSB= [0x02,0x00],
    NO_OF_DATA_BYTES = [6, 1],
    CHANNEL_ID=2,
    CS_PIN=cpy.MultiIOPin.SHUTTLE_PIN_14.value,
    INT_PIN=cpy.MultiIOPin.SHUTTLE_PIN_22.value,
    INT_TIME_STAMP=1,
)

# set the config_streaming parameters
stream_config = cpy.StreamingConfig()
data_blocks = cpy.StreamingBlocks()
if self.interface == cpy.SensorInterface.I2C:
    stream_config.Intf = cpy.SensorInterface.I2C.value
    stream_config.I2CBus = cpy.I2CBus.BUS_I2C_0.value
    stream_config.DevAddr = sensor["I2C_ADDR_PRIMARY"]

elif self.interface == cpy.SensorInterface.SPI:
    stream_config.Intf = cpy.SensorInterface.SPI.value
    stream_config.SPIBus = cpy.SPIBus.BUS_SPI_0.value
    stream_config.CSPin = sensor["CS_PIN"]

if sensor_type == bmi08x.SensorType.ACCEL and self.interface == cpy.SensorInterface.SPI:
    # extra dummy byte for SPI
    dummy_byte_offset = 1
else:
    dummy_byte_offset = 0

data_blocks.NoOfBlocks = sensor["NO_OF_BLOCKS"]
for i in range(0, data_blocks.NoOfBlocks):
    data_blocks.RegStartAddr[i] = sensor["REG_X_LSB"][i]
```

```

data_blocks.NoOfDataBytes[i] = sensor["NO_OF_DATA_BYTES"][i] + dummy_byte_offset

stream_config.IntTimeStamp = sensor["INT_TIME_STAMP"]
stream_config.IntPin = sensor["INT_PIN"]

# call config_streaming API for each sensor to configure the streaming settings
ret = coinesboard.config_streaming(
    accel_sensor_id, self.accel_stream_config, self.accel_data_blocks)
ret = coinesboard.config_streaming(
    gyro_sensor_id, self.accel_stream_config, self.accel_data_blocks)

```

15.3.4.2 start_stop_streaming

Starts or stops sensor data streaming.

```
coinesboard.start_stop_streaming(stream_mode: StreamingMode, start_stop:
    StreamingState) -> ErrorCodes
```

For the definition of StreamingMode, refer to [15.3.6.13](#). For the definition of StreamingState, refer to [15.3.6.14](#).

15.3.4.3 read_stream_sensor_data

Reads the data streamed from the sensor.

```
coinesboard.read_stream_sensor_data(sensor_id: int, number_of_samples: int,
    buffer_size=STREAM_RSP_BUF_SIZE) -> Tuple[ErrorCodes, list, int]
```

Return:

Tuple of ErrorCodes, data and valid_samples_count

For the detailed definition of parameters, refer to [15.2.4.3](#).

15.3.5 coinespy API calls: Other useful APIs

15.3.5.1 flush_interface

Flush the write buffer.

```
coinesboard.flush_interface()
```

15.3.5.2 soft_reset

Resets the device.

```
coinesboard.soft_reset()
```

15.3.6 Definition of constants

15.3.6.1 PinDirection

Pin mode definitions

```
class PinDirection:
    INPUT = 0 # COINES_PIN_DIRECTION_IN = 0
    OUTPUT = 1
```

15.3.6.2 PinValue

Pin level definitions

```
class PinValue:
    LOW = 0 # COINES_PIN_VALUE_LOW = 0
    HIGH = 1
```

15.3.6.3 CommInterface

Definition of the Communication interface

```
class CommInterface:
    USB = 0
    SERIAL = 1
    BLE = 2
```

15.3.6.4 I2CMode

Definition of the I2C bus speed

```
class I2CMode:
    STANDARD_MODE = 0 # Standard mode - 100kHz
    FAST_MODE = 1 # Fast mode - 400kHz
    SPEED_3_4_MHZ = 2 # High Speed mode - 3.4 MHz
    SPEED_1_7_MHZ = 3 # High Speed mode 2 - 1.7 MHz
```

15.3.6.5 SPISpeed

Definition of the SPI bus speed

```
class SPISpeed:
    SPI_10_MHZ = 6
    SPI_7_5_MHZ = 8
    SPI_6_MHZ = 10
    SPI_5_MHZ = 12
    SPI_3_75_MHZ = 16
    SPI_3_MHZ = 20
    SPI_2_5_MHZ = 24
    SPI_2_MHZ = 30
    SPI_1_5_MHZ = 40
```

```
SPI_1_25_MHZ = 48
SPI_1_2_MHZ = 50
SPI_1_MHZ = 60
SPI_750_KHZ = 80
SPI_600_KHZ = 100
SPI_500_KHZ = 120
SPI_400_KHZ = 150
SPI_300_KHZ = 200
SPI_250_KHZ = 240
```

15.3.6.6 SPITransferBits

Definition of the SPI bits

```
class SPITransferBits:
    SPI8BIT = 8 # 8 bit register read/write
    SPI16BIT = 16 # 16 bit register read/write
```

15.3.6.7 SPIMode

Definition of the SPI mode

```
class SPIMode:
    MODE0 = 0x00 # SPI Mode 0: CPOL=0; CPHA=0
    MODE1 = 0x01 # SPI Mode 1: CPOL=0; CPHA=1
    MODE2 = 0x02 # SPI Mode 2: CPOL=1; CPHA=0
    MODE3 = 0x03 # SPI Mode 3: CPOL=1; CPHA=1
```

15.3.6.8 MultiIOPin

Definition of the shuttle board pin(s)

```
class MultiIOPin(Enum):
    SHUTTLE_PIN_7 = 0x09 # CS pin
    SHUTTLE_PIN_8 = 0x05 # Multi-IO 5
    SHUTTLE_PIN_9 = 0x00 # Multi-IO 0
    SHUTTLE_PIN_14 = 0x01 # Multi-IO 1
    SHUTTLE_PIN_15 = 0x02 # Multi-IO 2
    SHUTTLE_PIN_16 = 0x03 # Multi-IO 3
    SHUTTLE_PIN_19 = 0x08 # Multi-IO 8
    SHUTTLE_PIN_20 = 0x06 # Multi-IO 6
    SHUTTLE_PIN_21 = 0x07 # Multi-IO 7
    SHUTTLE_PIN_22 = 0x04 # Multi-IO 4
    SHUTTLE_PIN_SDO = 0x1F

    # APP3.x pins
    MINI_SHUTTLE_PIN_1_4 = 0x10 # GPIO0
    MINI_SHUTTLE_PIN_1_5 = 0x11 # GPIO1
    MINI_SHUTTLE_PIN_1_6 = 0x12 # GPIO2/INT1
    MINI_SHUTTLE_PIN_1_7 = 0x13 # GPIO3/INT2
    MINI_SHUTTLE_PIN_2_5 = 0x14 # GPIO4
    MINI_SHUTTLE_PIN_2_6 = 0x15 # GPIO5
    MINI_SHUTTLE_PIN_2_1 = 0x16 # CS
```

```
MINI_SHUTTLE_PIN_2_3 = 0x17 # SDO
MINI_SHUTTLE_PIN_2_7 = 0x1D # GPIO6
MINI_SHUTTLE_PIN_2_8 = 0x1E # GPIO7
```

15.3.6.9 SensorInterface

Used to define the sensor interface

```
class SensorInterface(Enum):
    SPI = 0
    I2C = 1
```

15.3.6.10 I2CBus

Used to define the I2C type

```
class I2CBus(Enum):
    BUS_I2C_0 = 0
    BUS_I2C_1 = 1
    BUS_I2C_MAX = 2
```

15.3.6.11 SPIBus

Used to define the SPI type.

```
class SPIBus(Enum):
    BUS_SPI_0 = 0
    BUS_SPI_1 = 1
    BUS_SPI_MAX = 2
```

15.3.6.12 PinInterruptMode

Used to define pin interrupt modes

```
class PinInterruptMode(Enum):
    # Trigger interrupt on pin state change
    PIN_INTERRUPT_CHANGE = 0
    # Trigger interrupt when pin changes from low to high
    PIN_INTERRUPT_RISING_EDGE = 1
    # Trigger interrupt when pin changes from high to low
    PIN_INTERRUPT_FALLING_EDGE = 2
    PIN_INTERRUPT_MODE_MAXIMUM = 4
```

15.3.6.13 StreamingMode

Streaming mode definitions

```
class StreamingMode:  
    STREAMING_MODE_POLLING = 0 # Polling mode streaming  
    STREAMING_MODE_INTERRUPT = 1 # Interrupt mode streaming
```

15.3.6.14 StreamingState

Streaming state definitions

```
class StreamingState:  
    STREAMING_START = 1  
    STREAMING_STOP = 0
```

15.3.6.15 SamplingUnits

Sampling Unit definitions

```
class SamplingUnits:  
    SAMPLING_TIME_IN_MICRO_SEC = 0x01 # sampling unit in micro second  
    SAMPLING_TIME_IN_MILLI_SEC = 0x02 # sampling unit in milli second
```

15.4 Error Codes

Error codes are not always returned by the different function calls. Internally, an `error_code` variable is maintained and updated after the function call. It can be read out and checked by the user afterwards.

C Example

```
#include <stdio.h>
#include <stdlib.h>

#include "coines.h"

int main(void)
{
    int16_t error_code = coines_open_comm_intf(COINES_COMM_INTF_USB, NULL);
    if (error_code != COINES_SUCCESS)
    {
        const char *err_str = get_coines_error_str(error_code);
        printf("\n%s", err_str);
        exit(error_code);
    }

    coines_close_comm_intf(COINES_COMM_INTF_USB, NULL);
    return 0;
}
```

Python Example

```
import coinespy as cpy
board = cpy.CoinesBoard()
try:
    board.open_comm_interface(cpy.CommInterface.USB)
    board.close_comm_interface()
except:
    print(f'Could not connect to board: {board.error_code}')
    exit(board.error_code)
```

Error code definitions

```
COINES_SUCCESS = 0
COINES_E_FAILURE = -1
COINES_E_COMM_IO_ERROR = -2
COINES_E_COMM_INIT_FAILED = -3
COINES_E_UNABLE_OPEN_DEVICE = -4
COINES_E_DEVICE_NOT_FOUND = -5
COINES_E_UNABLE_CLAIM_INTERFACE = -6
COINES_E_MEMORY_ALLOCATION = -7
COINES_E_NOT_SUPPORTED = -8
COINES_E_NULL_PTR = -9
COINES_E_COMM_WRONG_RESPONSE = -10
COINES_E_SPI16BIT_NOT_CONFIGURED = -11
COINES_E_SPI_INVALID_BUS_INTERFACE = -12
COINES_E_SPI_CONFIG_EXIST = -13
COINES_E_SPI_BUS_NOT_ENABLED = -14
COINES_E_SPI_CONFIG_FAILED = -15
COINES_E_I2C_INVALID_BUS_INTERFACE = -16
COINES_E_I2C_BUS_NOT_ENABLED = -17
COINES_E_I2C_CONFIG_FAILED = -18
```

```

COINES_E_I2C_CONFIG_EXIST = -19
COINES_E_TIMER_INIT_FAILED = -20
COINES_E_TIMER_INVALID_INSTANCE = -21
COINES_E_TIMER_CC_CHANNEL_NOT_AVAILABLE = -22
COINES_E EEPROM_RESET_FAILED = -23
COINES_E EEPROM_READ_FAILED = -24
COINES_E INIT_FAILED = -25
COINES_E STREAM_NOT_CONFIGURED = -26
COINES_E STREAM_INVALID_BLOCK_SIZE = -27
COINES_E STREAM_SENSOR_ALREADY_CONFIGURED = -28
COINES_E STREAM_CONFIG_MEMORY_FULL = -29
COINES_E INVALID_PAYLOAD_LEN = -30
COINES_E CHANNEL_ALLOCATION_FAILED = -31
COINES_E CHANNEL_DE_ALLOCATION_FAILED = -32
COINES_E CHANNEL_ASSIGN_FAILED = -33
COINES_E CHANNEL_ENABLE_FAILED = -34
COINES_E CHANNEL_DISABLE_FAILED = -35
COINES_E INVALID_PIN_NUMBER = -36
COINES_E MAX_SENSOR_COUNT_REACHED = -37
COINES_E EEPROM_WRITE_FAILED = -38
COINES_E INVALID_EEPROM_RW_LENGTH = -39
COINES_E INVALID_SCOM_CONFIG = -40
COINES_E INVALID_BLE_CONFIG = -41
COINES_E SCOM_PORT_IN_USE = -42
COINES_E UART_INIT_FAILED = -43
COINES_E UART_WRITE_FAILED = -44
COINES_E UART_INSTANCE_NOT_SUPPORT = -45
COINES_E BLE_ADAPTER_NOT_FOUND = -46
COINES_E ADAPTER_BLUETOOTH_NOT_ENABLED = -47
COINES_E BLE_PERIPHERAL_NOT_FOUND = -48
COINES_E BLE_LIBRARY_NOT_LOADED = -49
COINES_E APP_BOARD_BLE_NOT_FOUND = -50
COINES_E BLE_COMM_FAILED = -51
COINES_E INCOMPATIBLE_FIRMWARE = -52
COINES_E UNDEFINED_CODE = -100

```

15.5 COINES SDK structure

- coines-api - Contains the source code for low-level interface to Bosch Sensortec's Engineering Boards
- doc - Contains the COINES SDK user manual
- driver - Contains the USB driver for Application Boards
- examples - Contains C and python examples
- installer_scripts - Contains the Windows batch files used internally for install and uninstall functionalities.
- libraries and thirdparty - Contains libraries and SDKs used for communication APIs.
- tools - Contains tools for the Application switch, firmware update, and BLE connect

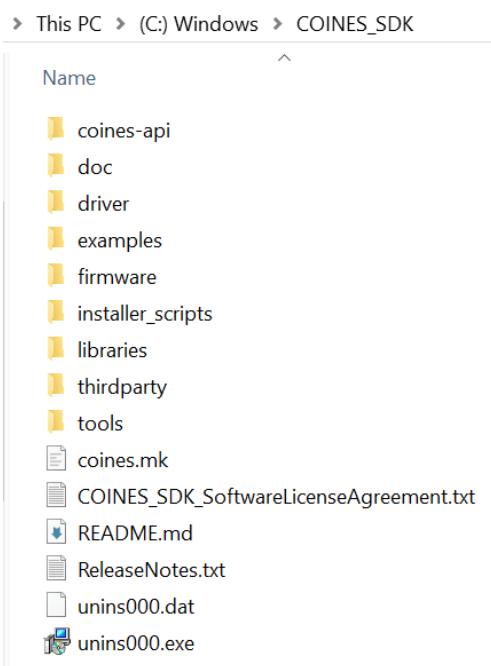


Fig. 23: COINES SDK file structure

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Modifications reserved | Printed in Germany
Preliminary - specifications subject to change without notice
Document number: BST-DHW-AN013
Revision 1.9