Features

The MAXREFDES106# is a chest-worn device that displays and logs biometric data. The platform includes the following innovative features:

- ECG-Based Heart Rate
- Optical PPG-based SpO_2
- BioZ-Based Respiration Rate
- Skin and Ambient Temperature
- Location Finder to Determine the Best Placement Location
- Rechargeable 190mAh Battery

General Description

The MAXREFDES106# is a vital sign monitoring platform in a chest-patch form factor. The platform uses algorithms and high sensitivity photoplethysmography (PPG), electrocardiogram (ECG), bioimpedance (BioZ), and temperature biosensor measurements to calculate heart rate (HR), respiration rate (RR), and blood oxygenation (SpO_2). The vital signs data can be displayed on a Microsoft Windows® graphical user interface (GUI) in real-time and logged to a local file for further study.

The patch is designed for long-term passive monitoring with a runtime of one day on a single charge. The PPG acquisition system consists of a red and infrared (IR) light emitter source and two photodiode receivers. The MAX86178 AFE includes dual high-resolution optical readout signal-processing channels with robust ambient-light cancellation, which is ideal for SpO_2 measurement. PPG and accelerometer data are processed by the embedded algorithm inside of the MAX32674C algorithm hub (Algo Hub) to calculate SpO_2. The ECG acquisition system has three electrodes for continuous ECG, and four electrodes for BioZ monitoring. The PC GUI contains algorithms to filter the ECG and BioZ data, and to calculate heart rate, respiration rate, blood stroke volume, and cardiac output. All algorithms are not publicly available. The exception to this is the SpO_2 algorithm, which is released as an .msbl file that is flashed to the MAX32674C.

The patch also features measurements for both skin temperature and ambient temperature using two low-power consumption, highly accurate MAX30210 temperature sensors.

The real-time vital signs can be viewed and logged through Low Energy Bluetooth® communications available from the PC GUI running on a Microsoft Windows PC.

Figure 1. MAXREFDES106# Vital Sign Monitoring Patch

Contents

System Architecture

The MAX32666 host MCU is responsible for retrieving the raw ECG, BioZ, and PPG data from the MAX86178 AFE and ADXL367 accelerometer. Additionally, the host MCU collects the raw data from the MAX30210 temperature sensors. The host firmware includes the ‘Location Finder’ algorithm, which is used to find the best location and position for the MAXREFDES106# on the chest.

PPG and accelerometer data are processed by the embedded algorithm inside the MAX32674C Algo Hub to calculate SpO_2 readings. The MAX32674C has bootloader firmware, which allows the application code of the MAX32674C to be updated to the latest ADI supplied proprietary SpO_2 Algo Hub .msbl firmware.

There are three electrodes for continuous ECG measurement and four electrodes for BioZ monitoring.

The PC GUI uses the BleuIO dongle to connect to the MAXREFDES106# through wireless BLE. The PC GUI contains algorithms to filter the ECG and BioZ data, and to calculate heart rate and respiration rate. The PC GUI interface allows the user to change configuration settings and capture the data to a log file. Plots for ECG, BioZ, SpO_2 respiration rate, accelerometer, and temperatures are available.

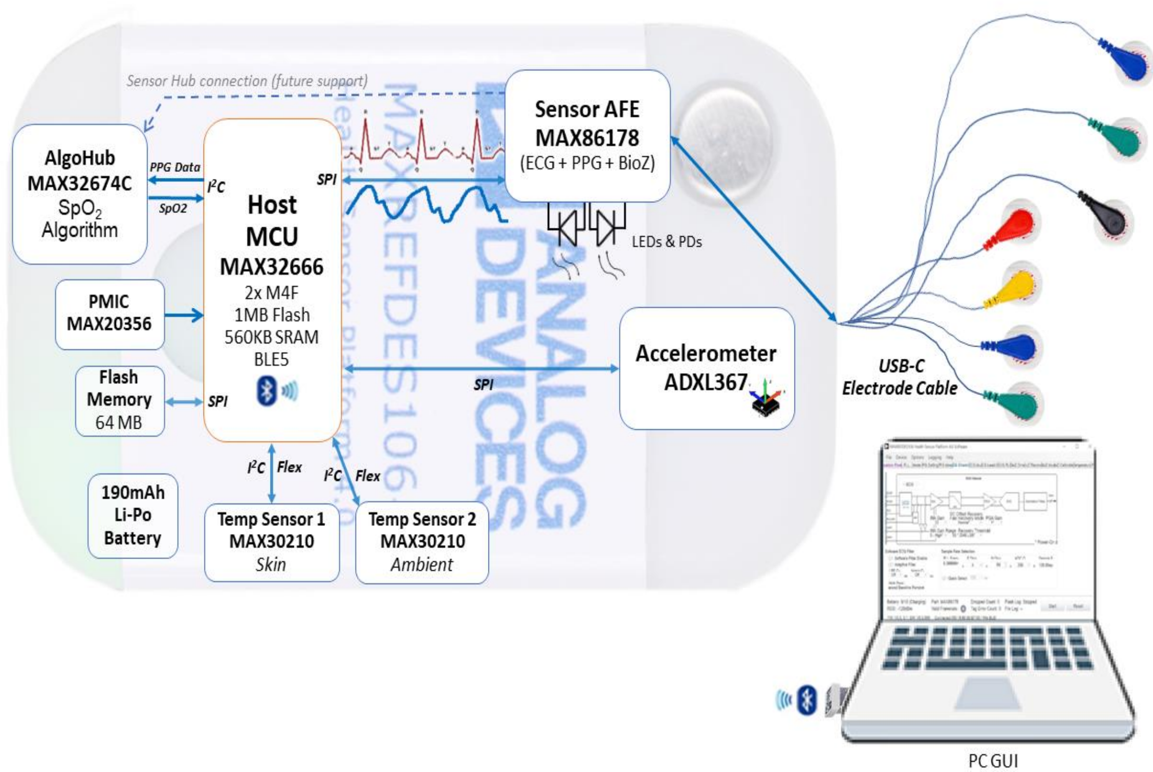


Figure 2. MAXREFDES106# System Diagram

Push Button Description

Table 1 describes the functionality of the push button. For non-power related button presses 'Status LED' activity and push button functions start two seconds after the last push button press and release (timeout for number of presses counter is 2s).

Table 1. Push Button Functionality

Push Button Action	**Status LED Activity**		**Function When Released**
	During Press	**2s After Release**	
Press for > 1 Second	Off	On with Status	Power On
Press for > 3 Seconds	No Change	Off	Power Off
Press for > 13 Seconds	No Change	Off	Force Power Off
Once Powered Up			
1 Press in 2 Seconds	No Change	Flashing Green When Successful	Start/Stop Location Finder (2s After Release)
2 Presses in 2 Seconds	No Change	Slow Blink Cyan	Start/Stop Flash Logging (2s After Release)
3 Presses in 2 Seconds	No Change	Off	Turn Off/On Status LED (2s After Release)

Color Definitions for the Status LED

Table 2 describes the state of the device for a given 'Status LED' color and blinking status. These are listed in order of priority. As an example, if a failure is detected (solid red LED), this has higher priority and is displayed instead of a yellow LED status.

Table 2. Color Definitions for Status LED (When Location Finder is Inactive) **LED Color**	**Solid (No Blinking)**	**Fast Blink**	**Slow Blink**
Green	Not Used	Location Finder Successful	Not Used
Blue	Bluetooth Connected	Not Used	GUI Logging Using BLE in Progress
Red	Failure Detected	MAX32674C Communications Failed	Battery Critically Low (<10%)
Yellow	Device is Initializing	MAX32674C Programming in Progress	Battery Low (10% to 50%)
Cyan	USB Connected	Not Used	Flash Logging in Progress
Pink	Not Used	Not Used	Battery High (>50%)

Location Quality Definitions for the Location Finder LED

The 'Location Finder' algorithm is activated when the MAXREFDES106# is turned on with a single short press of the push button. The location finder can also be started using the GUI. When started with a button press, the status LED blinks green when a good location is found. Until that time, the status LED displays the current status. See the 'Location Finder GUI' tab description for more information on patch placement and how the location finder works.

Included Components

The MAXREFDES106# platform includes the following components:

- MAXREFDES106# Board
  - MAX32674C with Embedded Heart Rate and Blood Oxygen Saturation (SpO_2) Algorithms
  - MAX32666 Host Microcontroller with Integrated BLE 5.0 and Location Finder Algorithm
  - MAX86178 PPG, ECG, and BioZ Analog Front-End (AFE)
  - Osram SFH 7015 Red, IR LED
  - Two Photodiodes (VEMD8080)
  - ADXL367 3-Axis MEMS Accelerometer
  - 256MB Flash Memory (MX66U2G45GXRI00)
  - MAX20356 Power Management IC (PMIC)
  - Two MAX30210 Temperature Sensors with ±0.1°C Accuracy from +20°C to +50°C
  - Two Aluminum Contact Disks
  - Lumex RGB Status LED
  - Push Button
- USB-C 7-Lead ECG, BioZ Snap Electrode Cable (7-Lead Electrode Cable)
- 3M Red Dot ECG Wet Electrodes (B01AME7YC0, 14 Pieces)
- Rechargeable 190mAh Li-Po Battery (HPL402323-2C)
- MAXDAP-TYPE-C Programming Adapter
- USB Type-C™ Cable (USB-C)
- USB Micro-B Cable (Micro-USB)
- BleuIO BLE 5.0 USB Dongle
- Two-Piece Snap-Fit 3D Printed Enclosure
- 3M Double-Sided Adhesive Tape (1577, 5 Pieces)

Additional Components Required

- Microsoft Windows 10+ PC
- PC GUI Software to Display/Log ECG Heart Rate, BioZ Respiration Rate, and PPG SpO_2
- MAX32666 Host Firmware (.bin)
- MAX32674C Algo Hub Firmware (.msbl)

Updating the Firmware

It is critical to update the MAXREFDES106# firmware to the latest version to ensure the device is running the latest features and interfaces with the 'Evaluation GUI' correctly.

Updating the MAX32666 Host MCU Firmware (.bin)

This section discusses updating the host firmware of the MAXREFDES106#. The host firmware is responsible for the high-level system management of the device and the .bin is flashed to the onboard flash of the MAX32666 MCU. The MAXREFDES106# host firmware is updated using the MAXDAP-TYPE-C programming adapter.

Required Equipment

All the following necessary components are included in the MAXREFDES106# package:

- MAXDAP-TYPE-C Programming Adapter
- USB-A to Micro-USB Cable
- MAXREFDES106#

Procedure

Follow this procedure to update the MAXREFDES106# device system firmware. The latest firmware file can be downloaded from the 'Design Resources' tab of the MAXREFDES106# product page.

1. Connect the Micro-USB to the MAXDAP-TYPE-C programmer and connect the other end of the cable to the PC. Connect the MAXDAP-TYPE-C programmer to the USB-C port of the MAXREFDES106#, as shown in Figure 3.
2. When the MAXDAP programmer is connected to the PC and the MAXREFDES106#, power is always provided to the MAXREFDES106#. For best programming results, do a power cycle of the MAXREFDES106#. Hold the push button down for > 3 seconds while the MAXDAP is connected. The MAXREFDES106# powers down briefly and then powers up again.

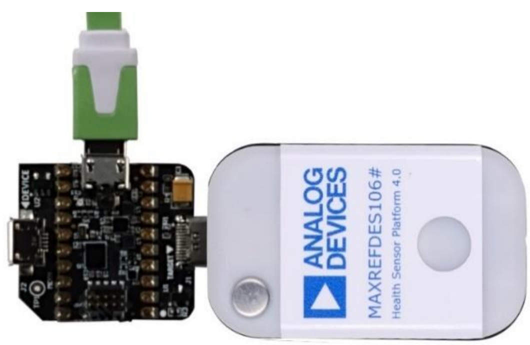


Figure 3. Micro-USB to MAXDAP-TYPE-C to MAXREFDES106#.

3. Unzip the 'MRD106_Update.zip' file. Find the 'openocd' folder and 'load_fw.bat' file. Move the 'MRD106_Host' firmware into this folder. The folder looks like Figure 4.

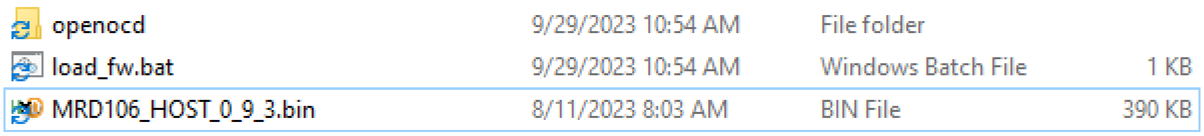


Figure 4. MRD106 Update Folder

4. Open a command prompt in this folder.
5. Load the new firmware from the command prompt. To do this, enter 'load_fw.bat MRD106_HOST_x.bin'. For 'x', use the true file name. As an example, for the folder in Figure 4, enter 'load_fw.bat MRD106_HOST_0_9_3.bin'.
6. The programming may fail the first few attempts. Run the same command again until the firmware successfully loads. Figure 5 and Figure 6 show two possibles results when the firmware has loaded properly.

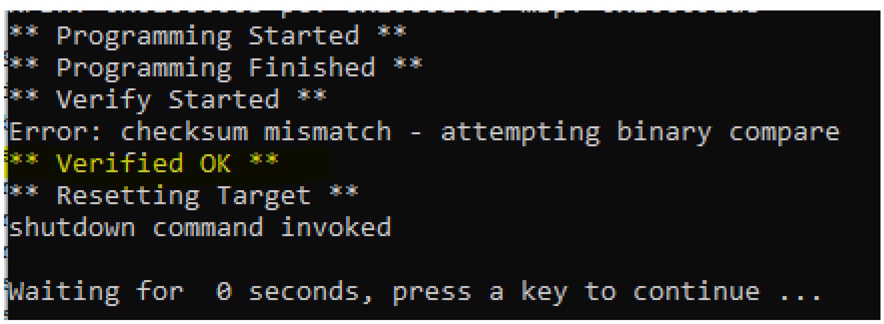


Figure 5. Successful Programming if Checksum Mismatch

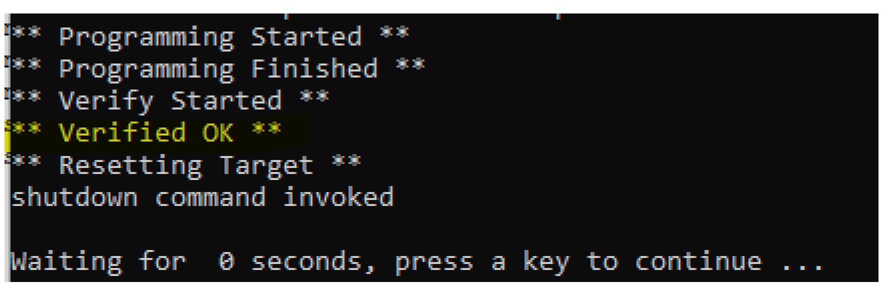


Figure 6. Successful Programming

7. After a successful programming, unplug the DAPLINK from the MAXREFDES106#. Then, hold the MAXREFDES106# push button for more than 13 seconds to force a power down.
8. The MAXREDES106# host firmware is now successfully programmed.

Updating the MAX32674C Algo Hub Microcontroller Coprocessor Firmware (.msbl)

1. Connect the USB-C cable to the MAXREFDES106# and connect the other end of the cable (USB-A end of the USB-C) to the PC USB port.

Figure 7. Connect USB-C Cable to the MAXREFDES106#

2. Open the 'Device Manager' and note the COM port associated with the MAXREFDES106#.

Figure 8. Note the USB Serial Device COM Port Number for MAXREFDES106#

3. Navigate to the MAX32674C firmware subfolder of the MAXREFDES106# software package.

4. Double click the **Flash_MAX32670_MRD106.bat** file (not the .exe file). A command prompt opens and asks for a port number. Enter the COM port number from step 3 and press **ENTER**. Only the port number is needed here (that is, for COM6, enter 6).

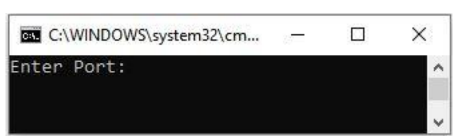
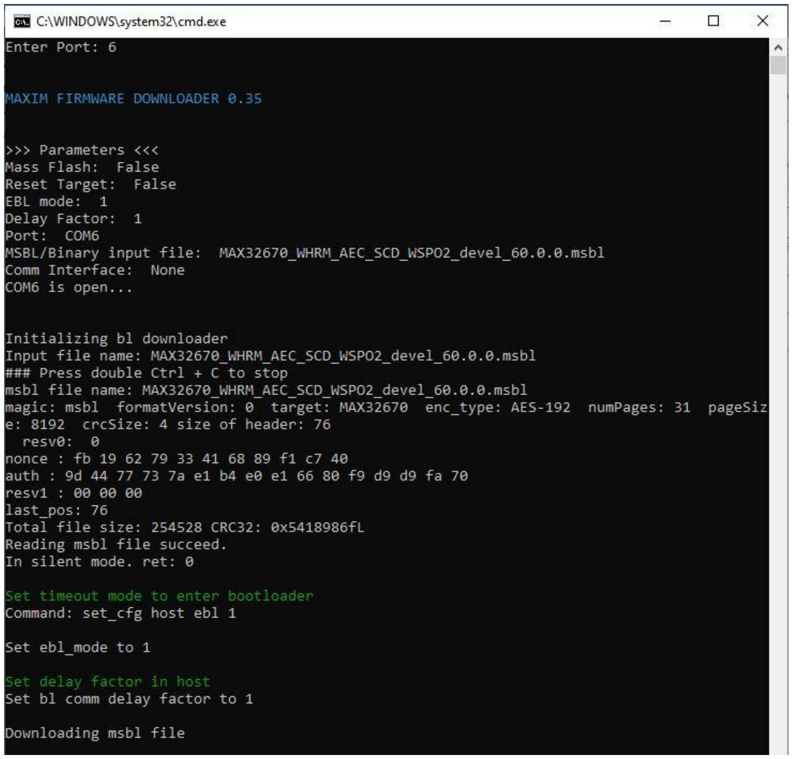
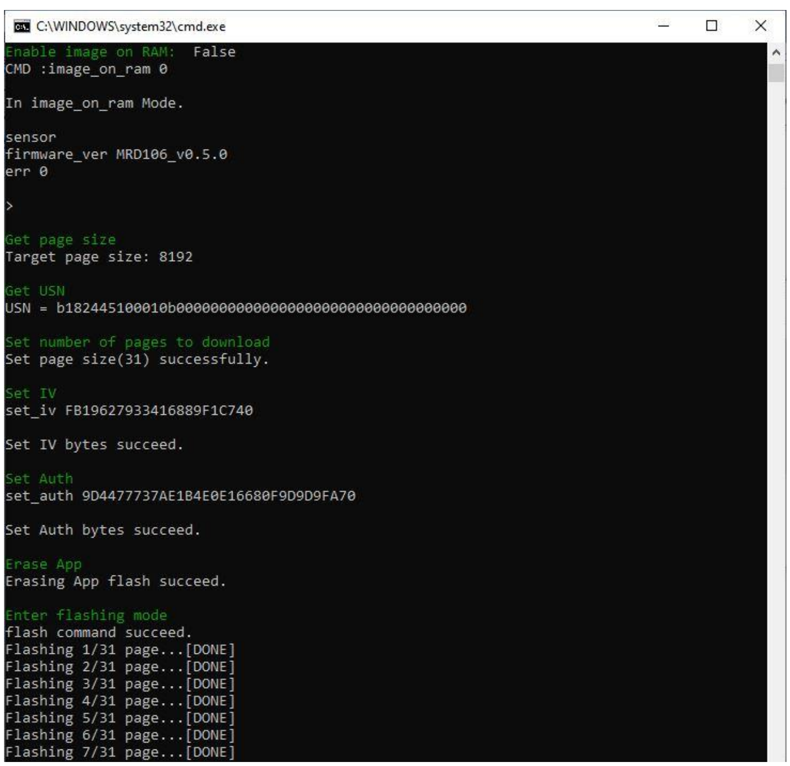


Figure 9. Note the USB Serial Device COM Port Number

5. After pressing ENTER, the program begins flashing the MAX32674C with the latest firmware. A successful flash looks like Figure 10, and 'SUCCEED…' displays near the end.



```
C:\WINDOWS\system32\cmd.exe
Enter Port: 6


MAXIM FIRMWARE DOWNLOADER 0.35


>>> Parameters <<<
Mass Flash:  False
Reset Target:  False
EBL mode:  1
Delay Factor:  1
Port:  COM6
MSBL/Binary input file:  MAX32670_WHRM_AEC_SCD_WSPO2_devel_60.0.0.msbl
Comm Interface:  None
COM6 is open...


Initializing bl downloader
Input file name: MAX32670_WHRM_AEC_SCD_WSPO2_devel_60.0.0.msbl
### Press double Ctrl + C to stop
msbl file name: MAX32670_WHRM_AEC_SCD_WSPO2_devel_60.0.0.msbl
magic: msbl  formatVersion: 0  target: MAX32670  enc_type: AES-192  numPages: 31  pageSiz
e: 8192  crcSize: 4 size of header: 76
  resv0:  0
nonce : fb 19 62 79 33 41 68 89 f1 c7 40
auth : 9d 44 77 73 7a e1 b4 e0 e1 66 80 f9 d9 d9 fa 70
resv1 : 00 00 00
last_pos: 76
Total file size: 254528 CRC32: 0x5418986fL
Reading msbl file succeed.
In silent mode. ret: 0

Set timeout mode to enter bootloader
Command: set_cfg host ebl 1

Set ebl_mode to 1

Set delay factor in host
Set bl comm delay factor to 1

Downloading msbl file
```



```
C:\WINDOWS\system32\cmd.exe
Enable image on RAM:  False
CMD :image_on_ram 0

In image_on_ram Mode.

sensor
firmware_ver MRD106_v0.5.0
err 0

>

Get page size
Target page size: 8192

Get USN
USN = b182445100010b0000000000000000000000000000000000

Set number of pages to download
Set page size(31) successfully.

Set IV
set_iv FB19627933416889F1C740

Set IV bytes succeed.

Set Auth
set_auth 9D4477737AE1B4E0E16680F9D9D9FA70

Set Auth bytes succeed.

Erase App
Erasing App flash succeed.

Enter flashing mode
flash command succeed.
Flashing 1/31 page...[DONE]
Flashing 2/31 page...[DONE]
Flashing 3/31 page...[DONE]
Flashing 4/31 page...[DONE]
Flashing 5/31 page...[DONE]
Flashing 6/31 page...[DONE]
Flashing 7/31 page...[DONE]
```

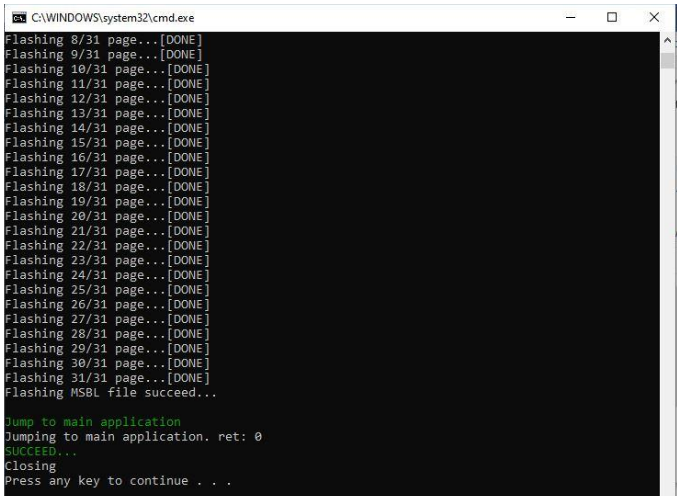


Figure 10. Flashing the .msbl to the MAX32674C

Optional: If the .msbl flashing has FAILED, then disconnect the USB-C cable and power down the device by holding the push button on the MAXREFDES106# for at least 13 seconds. Then, repeat the procedures, starting with step 1.

The MAX32674C Algo Hub Microcontroller Coprocessor is now updated to the latest firmware!

Installing the MAXREFDES106# Health Sensor Platform PC GUI

1. Uninstall any previously installed versions of the MAXREFDES106# Health Sensor Platform PC GUI.

2. Download and extract the 'Evaluation Package' from the Analog Devices website for the MAXREFDES106#.

   Note: The software package includes the latest firmware .bin, algorithm .msbl, and the corresponding PC GUI Microsoft Windows application .exe. **All three must be updated to ensure compatibility.**

3. Double click the **MAXREFDES106Setup_x.y.z.exe** file. Click **Next >** to go to the first four pop-ups.

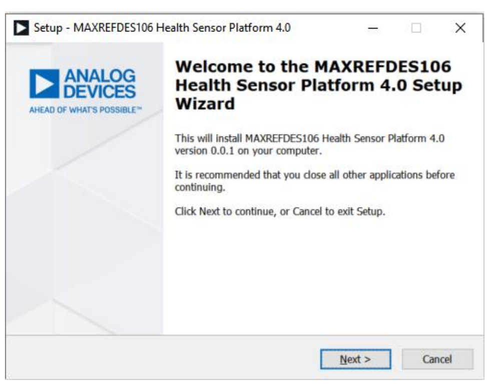


Figure 11. PC GUI Welcome

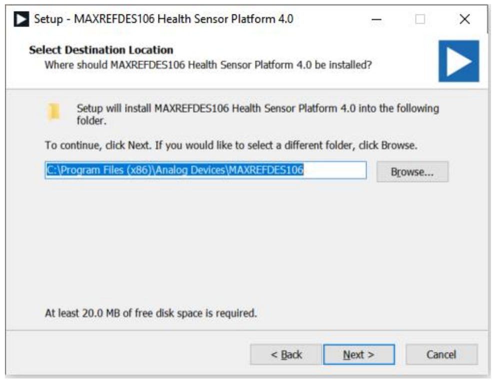


Figure 12. PC GUI Select Destination

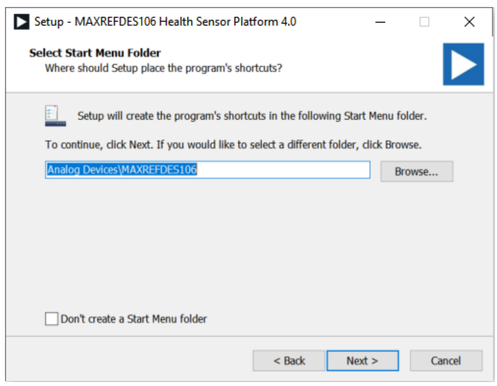


Figure 13. PC GUI Select Start Menu Folder

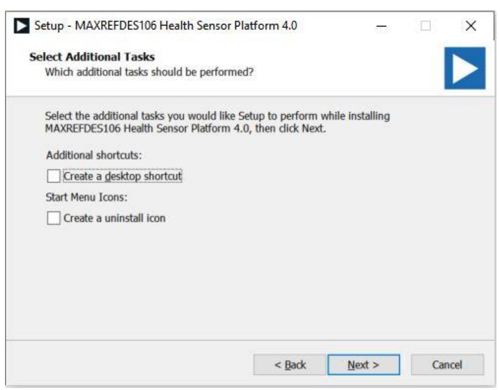


Figure 14. PC GUI Select Additional Tasks

4. Then, click **Finish** in the ‘Ready to Install’ pop-up.

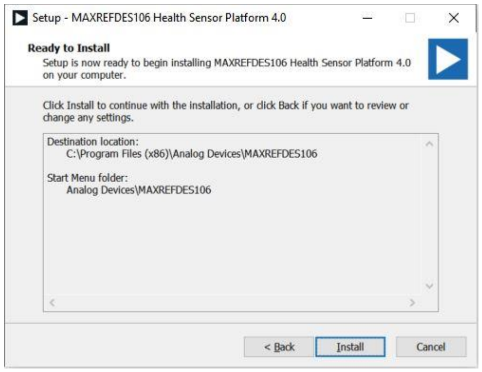


Figure 15. PC GUI Ready to Install

Charge the Device and Run the MAXREFDES106# Health Sensor Platform PC GUI

1. Unplug any devices connected to the MAXREFDES106#. **Power down the MAXREFDES106#** by holding down the push button for at least 13 seconds.
2. Connect the USB-C cable to the MAXREFDES106# and to the PC.

Figure 16. Connect USB-C Cable to the MAXREFDES106#

3. Connect the BleuIO dongle to the PC.

Figure 17. Plug the BleuIO Dongle into the PC

4. Run the MAXREFDES106# Health Sensor Platform PC GUI. Select Bleu IO in the pull-down and select MAXREFDES106. Click ‘Connect’ (wait several seconds before the Bleu IO shows up in the pull-down list).

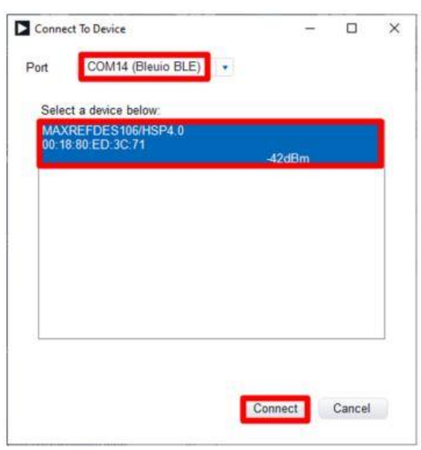


Figure 18. Connect the PC GUI BleuIO to the MAXREFDES106#

5. The battery level displays at the bottom left of the PC GUI. The host .bin, Algo Hub, and .msbl versions display at the bottom center of the PC GUI.

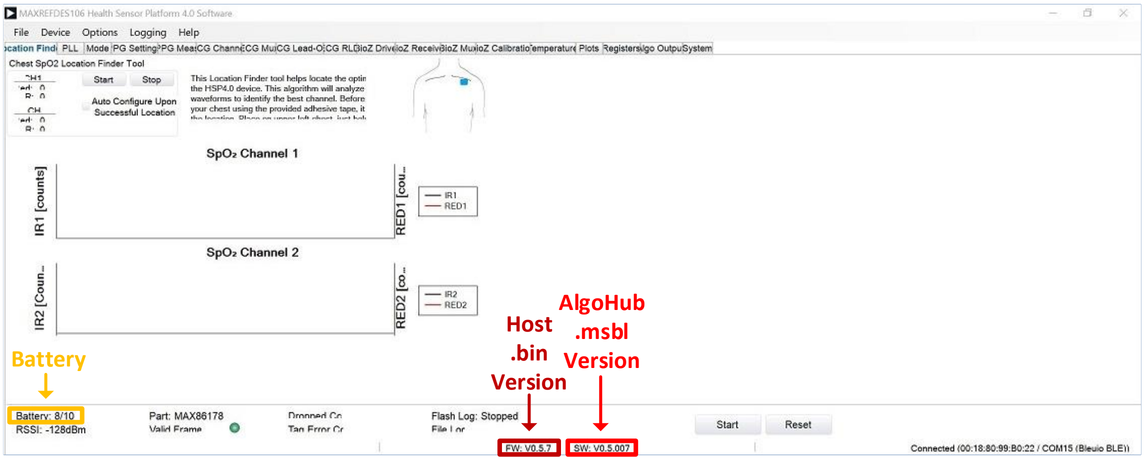


Figure 19. Battery Level, Host .bin Version, Algo Hub .msbl Version

6. The GUI version is displayed by clicking 'Help > About'.

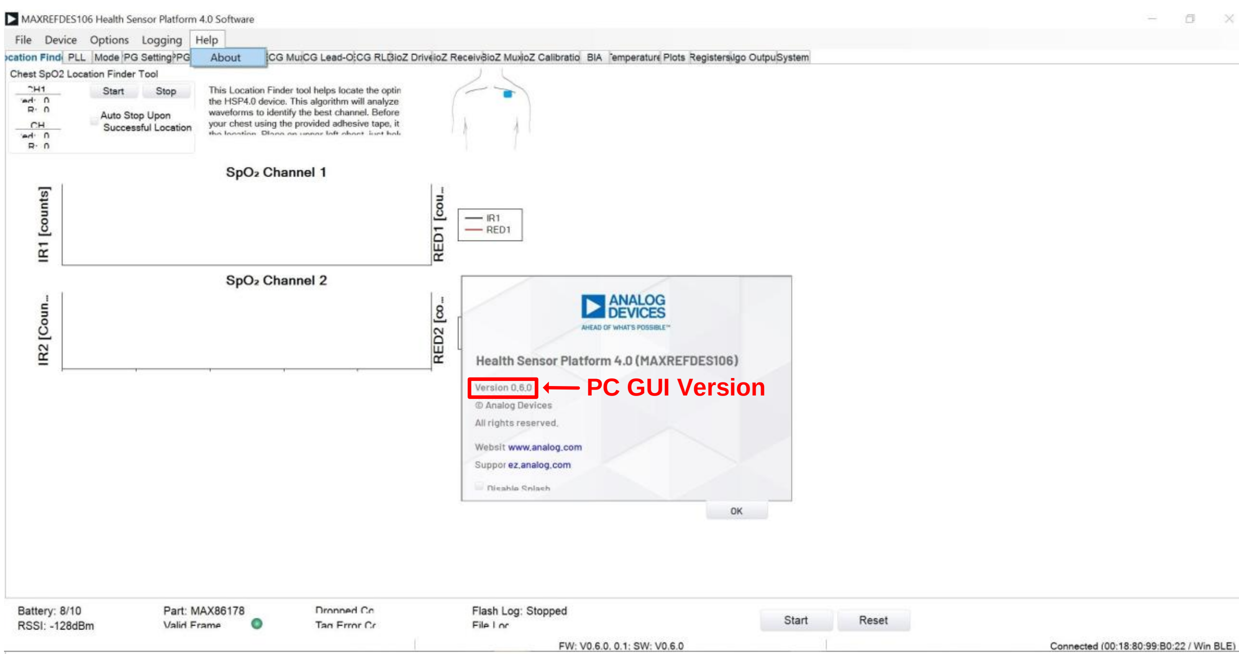


Figure 20. PC GUI Version

When using the MAXREFDES106#, update the following three firmware and software using the latest and same software release package.

Flash the host micro, MAX32666, with the **.bin** file using drag and drop to the DAPLINK folder.

Flash the algorithm **.msbl** file to MAX32674C using the .bat file.

Install the PC GUI using the **.exe** file.

Orientation of the USB-C 7-Lead Electrode Cable to the MAXREFDES106#

After the MAXREFDES106# battery is charged, disconnect the USB-C cable.

The **orientation** of the USB-C 7-electrode ECG, BioZ snap cable to the MAXREFDES106# **IS VERY IMPORTANT**. The USB symbol on the USB-C 7-lead electrode cable must be visible when viewing the MAXREFDES106# from the top. Plug the USB-C 7-lead electrode cable into the MAXREFDES106#, as shown in Figure 21.

Figure 21. Orientation of the USB-C 7-Lead Electrode to the MAXREFDES106#

Measurements

Photoplethysmogram (PPG)

The MAXREFDES106# has a highly configurable and very powerful PPG AFE with the MAX86178, which includes programming high-current LED drivers and dual high-resolution optical readout signal-processing channels with robust ambient-light cancellation. The user can quickly evaluate every aspect of this fully programmable PPG AFE with the 'Evaluation GUI'. This section discusses how to set up a basic PPG measurement and provides an overview of how the measurement is structured at a high level.

See the MAX86178 data sheet for a more detailed description of the available feature-set of the PPG AFE.

Overview

Fundamentally, a PPG measurement on the MAXREFDES106# can be broken down into **frames**. Inside a frame, the PPG AFE drives an LED sequence and measures changes in light absorption through PDs sampled by an ADC chain. Every aspect of this sequence is programmable, and each frame is organized into a sequence of **measurement** blocks.

A frame can consist of up to six sequential measurements blocks.

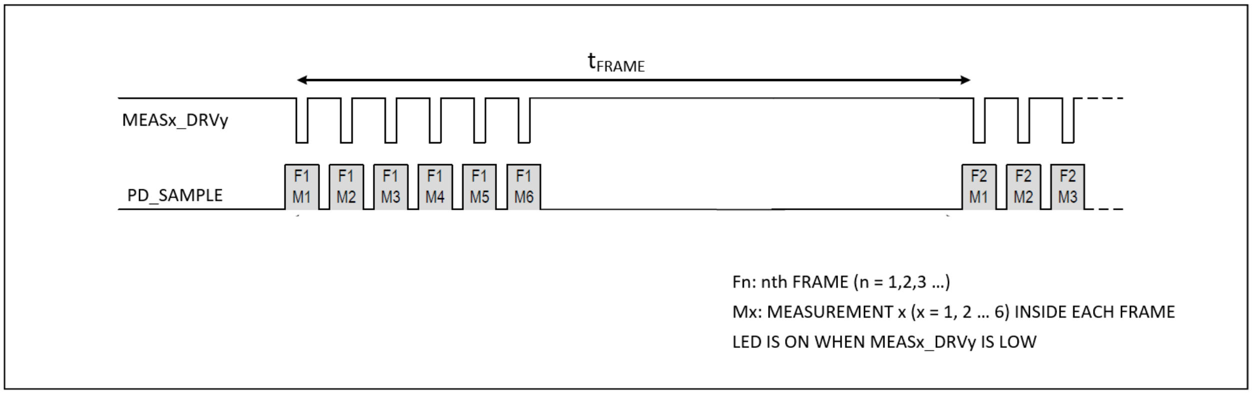


Figure 22. Frame with Six Measurements, M1 to M6

Each measurement block is essentially an exposure, like in a traditional camera. It has a certain exposure time, and up to two LEDs can be driven and two PDs sampled in each exposure. These exposures can be used separately or combined with measurement averaging. This allows a single optical AFE to support multiple optical measurements in a compact, energy-efficient design. Measurement settings can be finetuned manually in the **Raw Mode** or adjusted algorithmically by enabling the **AGC** in the **Algo Hub Mode**. See the section **PPG Mode** for details on these modes.

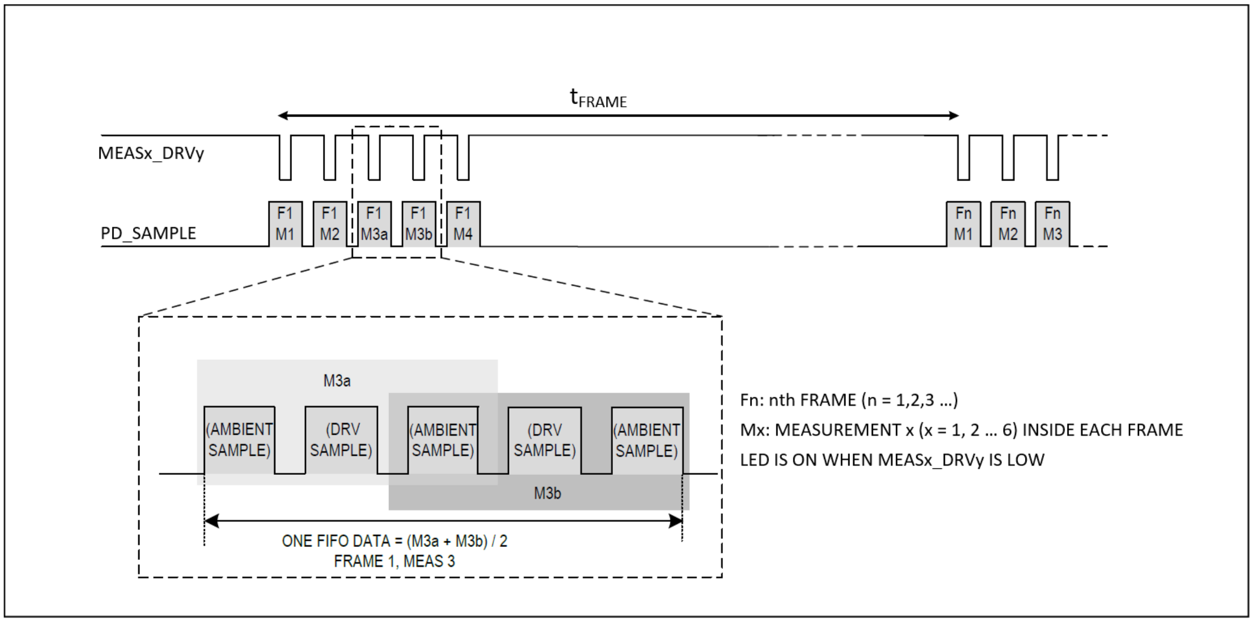


Figure 23. Frame with Measurement Averaging. MEAS3 has Two Sample Averaging, Before Being Pushed to FIFO as One Sample

For most situations, the default PPG settings are optimal for the MAXREFDES106#. When the **Algo Hub** mode is enabled for SpO_2 measurements, the device goes back to these default PPG settings.

Associated Tabs

The tabs associated with PPG measurement are the **Location Finder**, **Mode**, **PPG Settings**, and **PPG Measurement** tabs. See their associated sections in this user guide for a more detailed description of each available configuration option.

Minimum Settings

The following settings satisfy the minimum requirements for collecting a raw PPG measurement. The rest of the settings can be configured further but can be left at their default values.

- Mode: ‘Raw Mode’ selected.
- PPG Settings: ‘PPG1 Power Down’ and/or ‘PPG2 Power Down’ not checked.
- PPG Measurement: At least one measurement enabled.

Starting and Stopping a Measurement

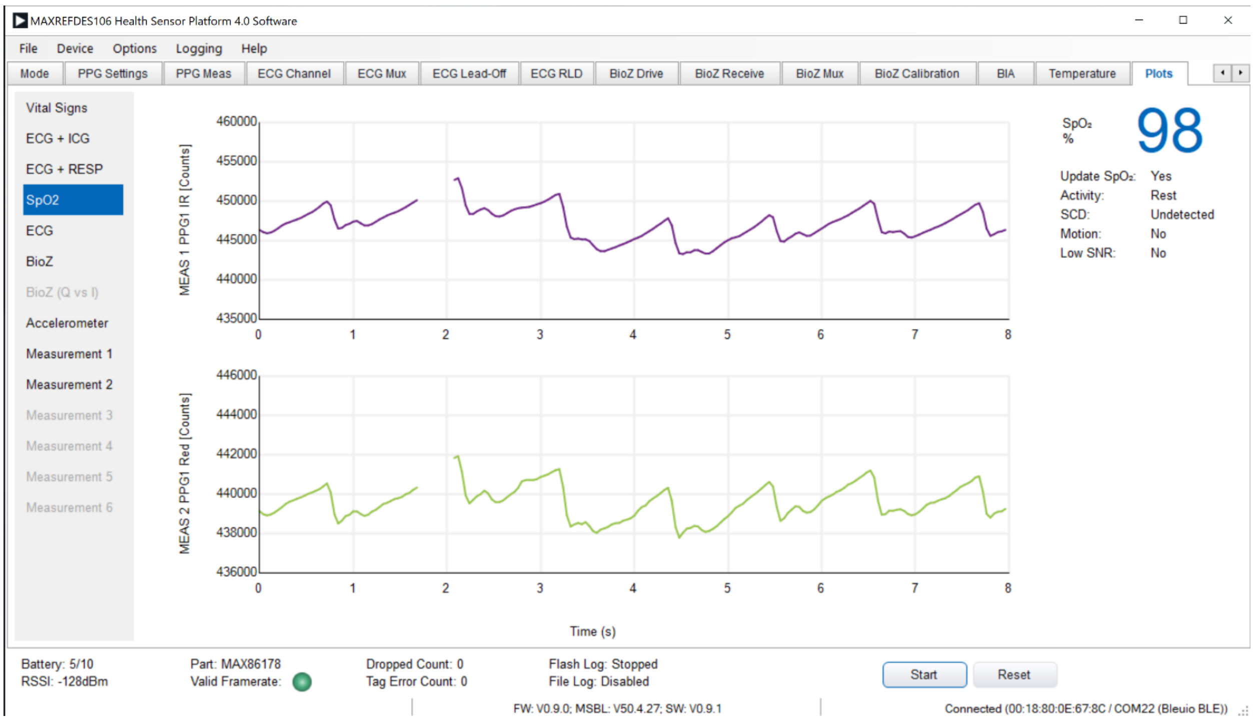


Figure 24. Example of Raw PPG Measurement Output

- Ensure the patch is placed securely on the chest, powered on, and connected to the GUI.
- Ensure the minimum settings requirements, listed above, are met.
- Start the measurement by clicking **Start**. The PPG data is drawn to the **Plots** tab. Stop an active PPG measurement by clicking **Stop**.
- PPG measurements can be simultaneously enabled alongside with ECG and Bio-Z measurements.

Electrocardiogram (ECG)

The MAXREFDES106# contains a MAX86178 complete ECG data acquisition system to collect high-fidelity ECG data using 3M Red Dot electrodes. The MAX86178 features low-noise and high-input impedance, plus an active right-led drive (RLD) circuit for excellent common-mode rejection (CMRR) and robust ECG performance. Additional features such as a wide range of configurable gain options, an automatic fast recovery mode, AC and DC lead-off detection, and an ultra-low-power (ULP) lead-on detection circuit enables uncompromised performance in demanding applications. Evaluate nearly every aspect of this powerful ECG solution with the 'Evaluation GUI'. This section discusses how to set up a basic ECG measurement and provides an overview of how the ECG measurement is structured.

See the MAX86178 data sheet for a more detailed description and available feature-set of the ECG AFE.

Overview

An electrocardiogram measures the electrical activity of the heart through conducting electrodes placed in contact with the skin. A conducting path is made through the heart and constitutes an ECG measuring from right arm (RA) to left arm (LA). The ECG signal chain then filters, amplifies, and samples these contact point voltages, and uses advanced differential signal processing techniques to derive a high-quality ECG signal. The RLD electrode is used in this differential mode processing to provide a better body bias voltage and reject common-mode noise.

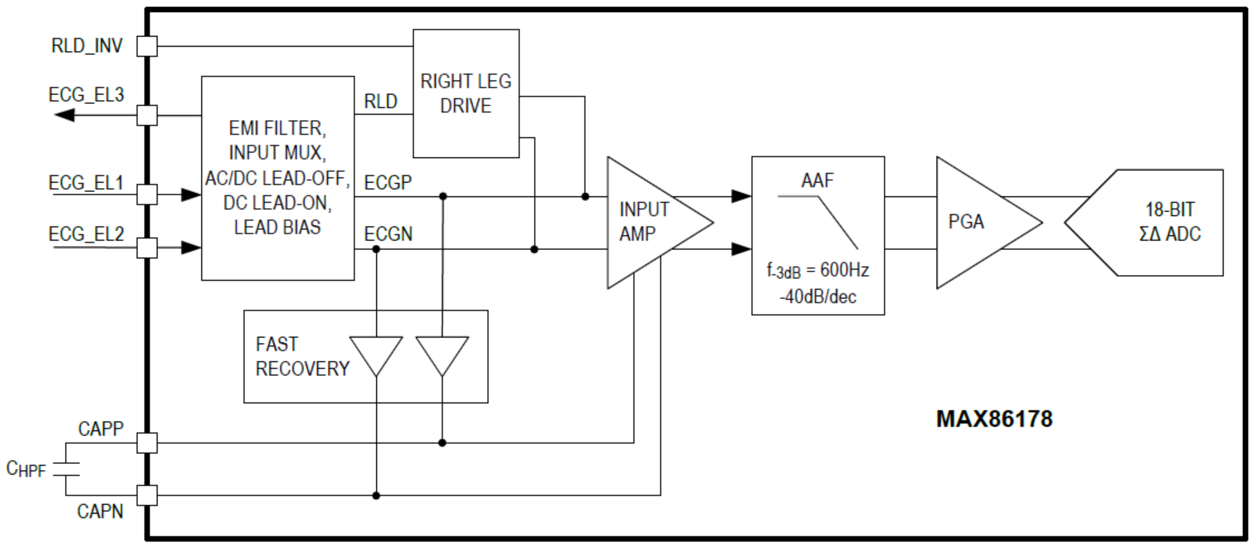


Figure 25. ECG Channel Signal Chain

The ECG signal chain, shown in Figure 25, consists of an input MUX, ESD structure, EMI filtering, and an input amplifier complete with an externally configurable HPF, fast-recovery mode, anti-aliasing filter (AAF), programmable gain amplifier (PGA), and a delta-sigma ADC.

Associated Tabs

The tabs associated with ECG measurement are the **PLL**, **ECG Channel**, **ECG Mux**, **ECG Lead Off**, and **ECG RLD** tabs. See their associated sections for a more detailed description of each available configuration option.

Minimum Settings

The following settings satisfy the minimum requirements for collecting a raw ECG measurement. The rest of the settings can be configured further but can be left at their power-on defaults.

- ECG Channel: ‘ECG Enable’ checked (checking this box on one of the tabs checks all).
- ECG MUX: Keep default settings.
- ECG Lead Off: Keep default settings.
- ECG RLD: ‘RLD Enable’ checked.

Starting and Stopping a Measurement

Figure 26. Example ECG Measurement Output

- Ensure the patch is placed securely on the chest, powered on, and connected to the GUI.
- Ensure the RA, LA, and RLD electrodes are placed securely, as shown in Figure 27.

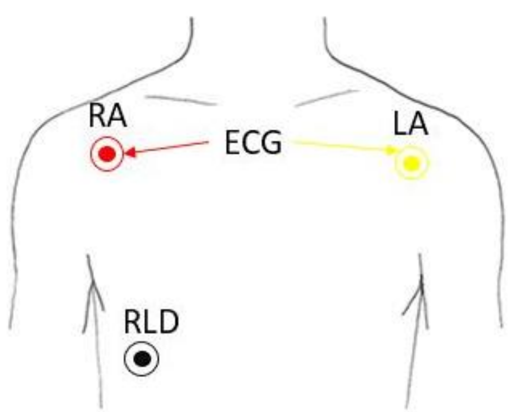


Figure 27. ECG Electrodes: RA (Red), LA (Yellow), RLD (Black)

- Ensure the minimum settings requirements, listed above, are met.
- Start a measurement by clicking **Start**. ECG data is drawn to the Plots tab. Stop an active ECG measurement by clicking **Stop**.
- ECG measurement can be simultaneously enabled alongside the PPG and Bio-Z measurements.

Bioimpedance (Bio-Z)

The MAXREFDES106# includes a high-performance BioZ data acquisition system, MAX86178. The system can measure impedance across multiple application areas with a wide range of frequencies and magnitudes.

See the MAX86178 data sheet for a more detailed description and available feature-set of the BioZ AFE.

Overview

The BioZ system primarily consists of a transmit (TX) channel, a receive (RX) channel, and an input/output MUX. The BioZ system supports calibration using internal or external calibration resistors, enabling 0.1 % accuracy in the I/Q channel. The flexible I/O MUX, lead-on and lead-off detection, adjustable amplifier bias, and lead bias allow for flexible hardware designs capable of multiple measurement types with low power consumption.

Associated Tabs

The tabs associated with BioZ measurement are the **PLL**, **BioZ Drive**, **BioZ Receive**, **BioZ Mux**, and **BioZ Calibration**. See their associated sections for a more detailed description of each available configuration option.

Minimum Settings

The following settings satisfy the minimum requirements for collecting a raw ECG measurement. The rest of the settings can be configured further but can be left at their power-on defaults.

- BioZ Drive: ‘I-Channel’ selected in ‘BioZ Enable’ (selecting this box on one of the tabs selects all).
- BioZ Receive: ‘I-Channel’ selected.
- BioZ MUX: Keep as default.
- BioZ Calibration: Before any BioZ measurement, a BioZ Calibration is required. See the **BioZ Calibration** section for details.

Starting and Stopping a Measurement

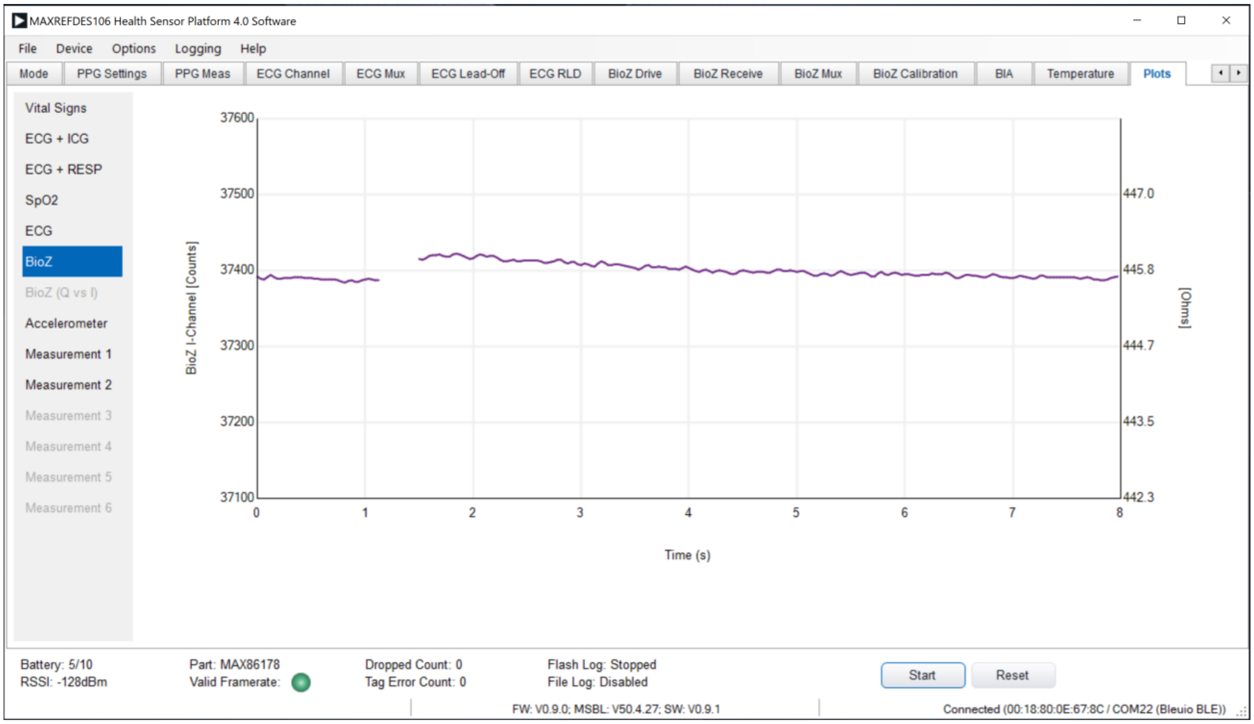


Figure 28. Example BioZ Measurement Output

- Ensure the patch is placed securely on the chest, powered on, and connected to GUI.
- Ensure the minimum settings requirements, listed above, are met.
- Start a measurement by clicking **Start**. BioZ data is drawn to the Plots tab. Stop an active BioZ measurement by clicking **Stop**.
- Ensure electrodes I+, V+, I-, V- are placed as in Figure 29.

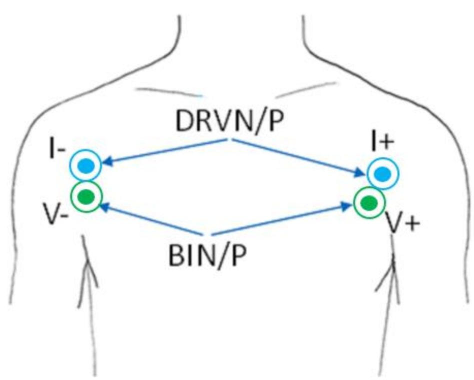


Figure 29. BioZ Electrodes: I- (Blue), I+ (Blue), V- (Green), V+ (Green)

- BioZ measurement can be simultaneously enabled alongside the PPG and ECG measurements.

Algorithms

The MAXREFDES106# includes a MAX32674C Algorithm Hub that contains Analog Devices' proprietary algorithms for deriving HR from ECG measurement, SpO_2 from PPG measurement, respiration rate from BioZ measurement, and stroke volume and cardiac output from impedance cardiography (ICG). Additional analytics such as signal confidence-level are provided to aid the user. These algorithms are continually updated and improved. So, it is best to use the latest version of the firmware (see the section **Updating the Firmware** for more details).

Algorithm Operating Modes

'Algorithm Hub Mode'

The MAX32666 host MCU firmware contains the sensor drivers to configure and manage the MAX86178 AFE sensor and ADXL367 accelerometer. The host MCU is responsible for reading the raw PPG data and sending it to the MAX32674C SpO_2 Algo Hub for processing. The AGC is handled by the host MCU firmware. Timing is more as the host MCU firmware must be able to time multiplex (interleave) tasks sequentially or run parallel processes that communicate with multiple devices simultaneously.

Impedance Cardiography (ICG)

Note: Starting in 2023, HSP4 modules are updated by adding capacitors to the pads C66 and C68 to create a 13.5kHz low-pass filter (LPF) on the ECG inputs. This LPF removes the high frequency stimulus produced by the BioZ drive circuit from reaching the ECG inputs. Older HSP4 patches do not have the added capacitors and therefore may not be able to perform the ICG measurement. To perform an ICG measurement with older HSP4s, the HSP4 enclosure can be opened and capacitors (470pF, 0201) can be soldered to the empty C66 and C68 pads.

To check the version of the patch, look at the sticker on the top of the patch. An updated patch has a 'V2' in the bottom left corner, which indicates the added LPF.

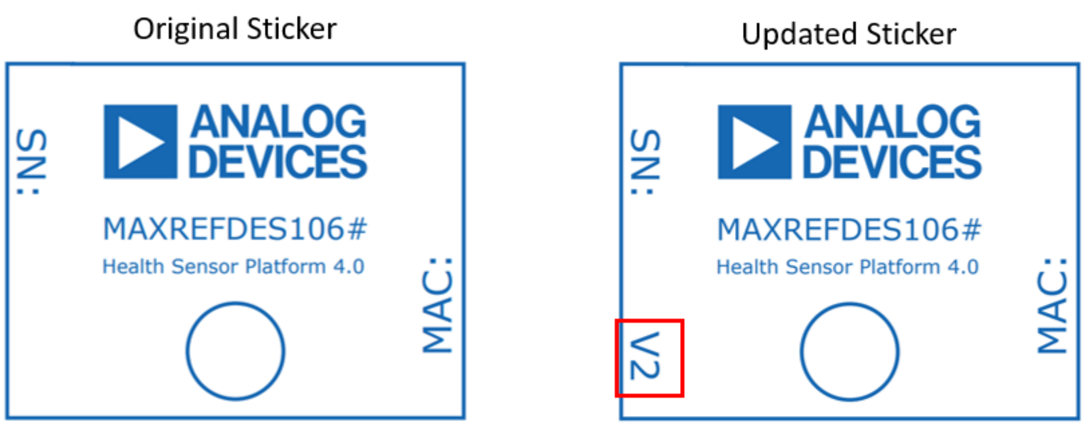


Figure 30. Comparison of Original HSP4 to Updated HSP4

The following section discusses how to enable the ICG algorithms output as well as the fundamentals of the algorithm setup.

Associated Tabs

The tabs for configuring the ICG algorithm are the **Mode, ECG Channel, ECG Mux, ECG RLD, BioZ Drive, BioZ Receive,** and **BioZ Mux** tabs. The ICG algorithms operate on BioZ and ECG input data, but only support 512Hz sampling rate from both ECG and BioZ.

Minimum Settings

The following settings satisfy the minimum requirements for collecting ICG data. The rest of the settings can be configured further but can also be left at their power-on defaults. The ICG algorithm uses these default settings.

- Mode: Select HR [ECG] + ICG [BioZ] in 'Quick Configuration' window.
- Mode: Enter the **Distance Between the V+/- Electrodes**, **Gender**, **Height**, **Weight** and **Body Build** in the 'Stroke Volume Parameters' window.

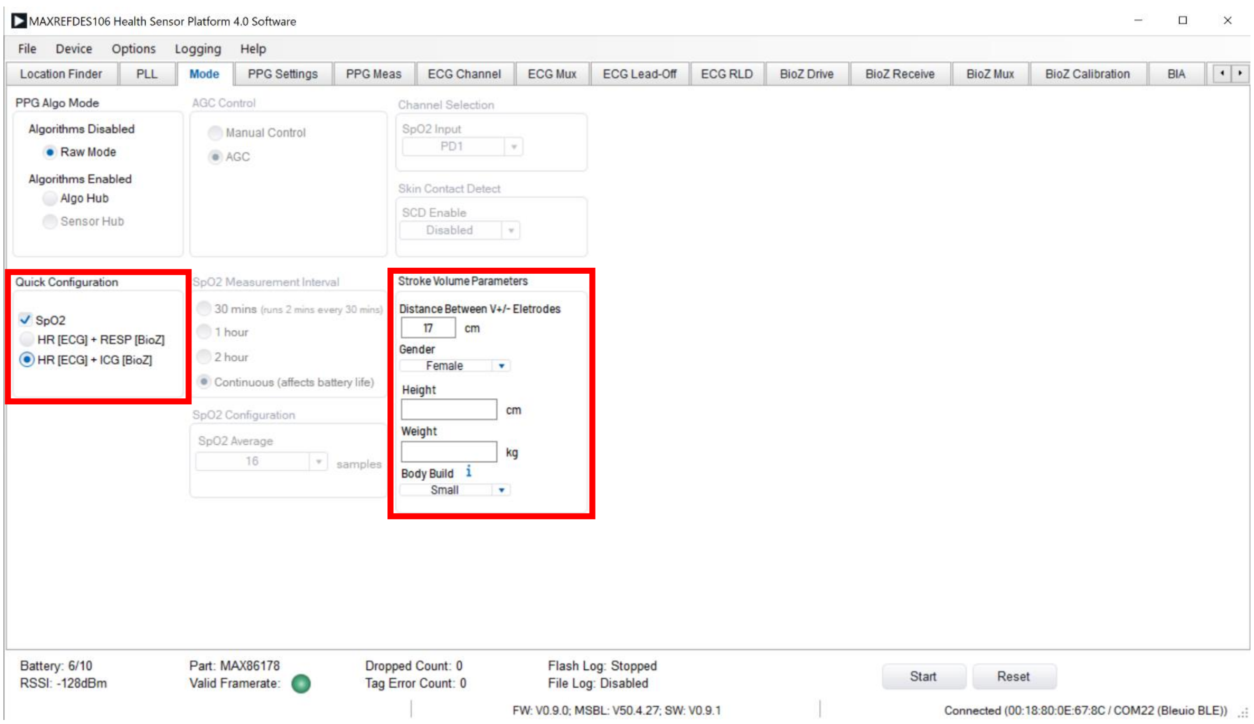


Figure 31. Mode Tab: Select HR [ECG] + ICG [BioZ] and Enter Stroke Volume Parameters

These settings satisfy the requirements to start an ICG measurement and the rest of the tabs can be left at their power-on defaults. To improve the accuracy of the measurement, a BioZ calibration should be done (see **BioZ Calibration** section for details).

- ECG Channel: Keep power-on default settings.

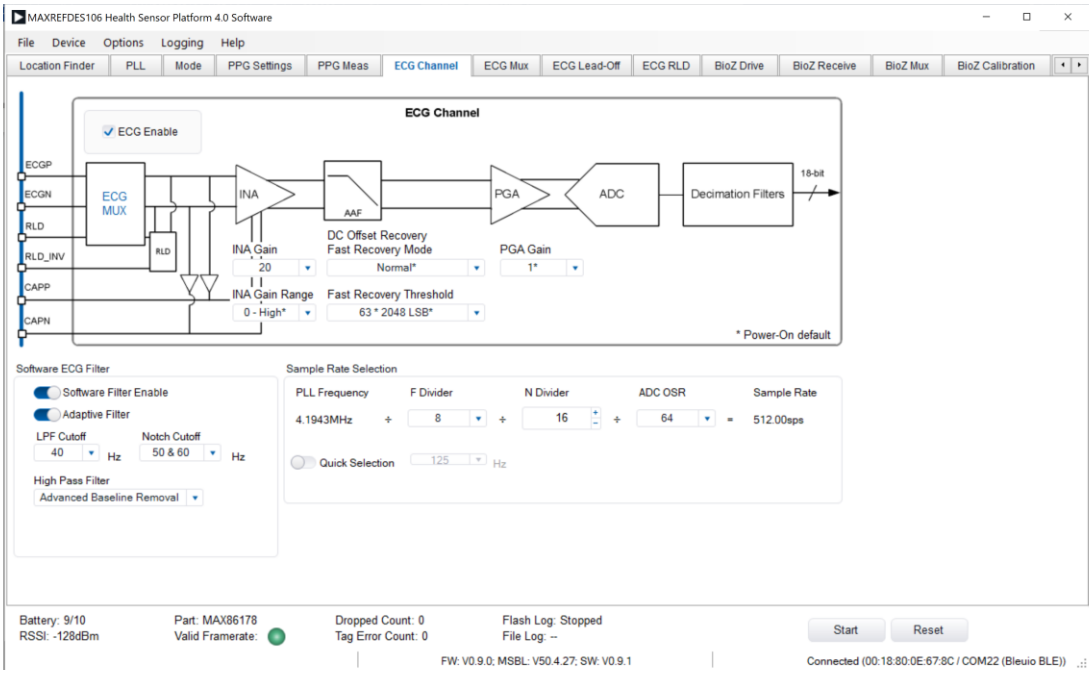


Figure 32. ECG Channel Tab: Use Power-On Default Settings

- ECG Mux: Keep power-on default settings.

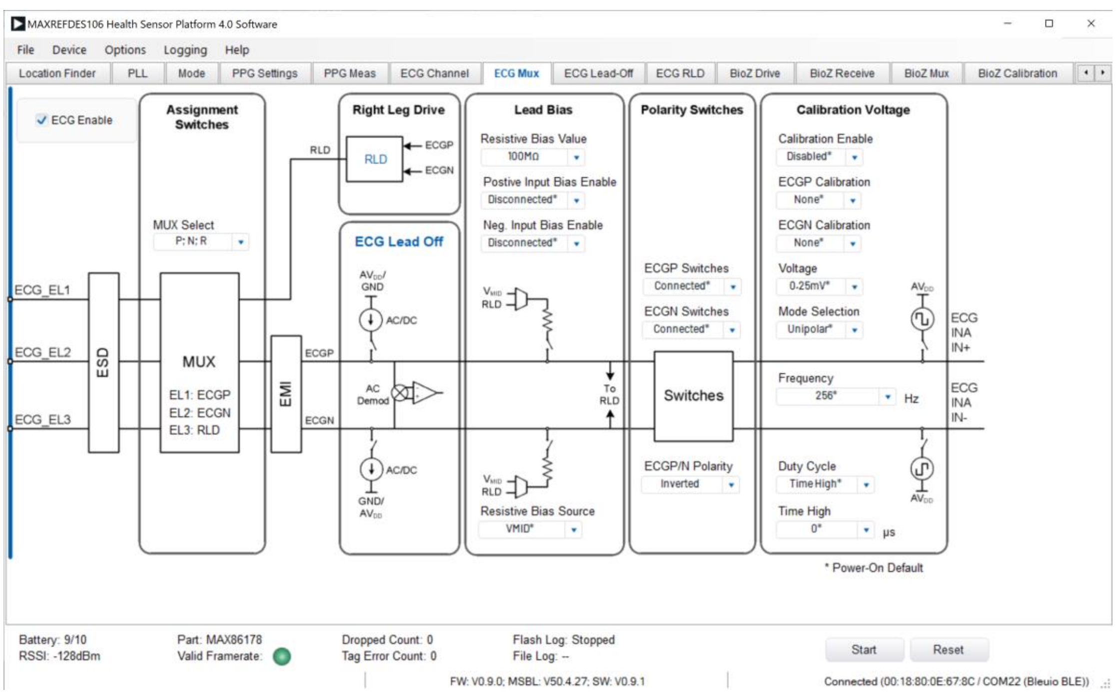


Figure 33. ECG Mux Tab: Use Power-On Default Settings

- ECG RLD: Keep power-on default settings.

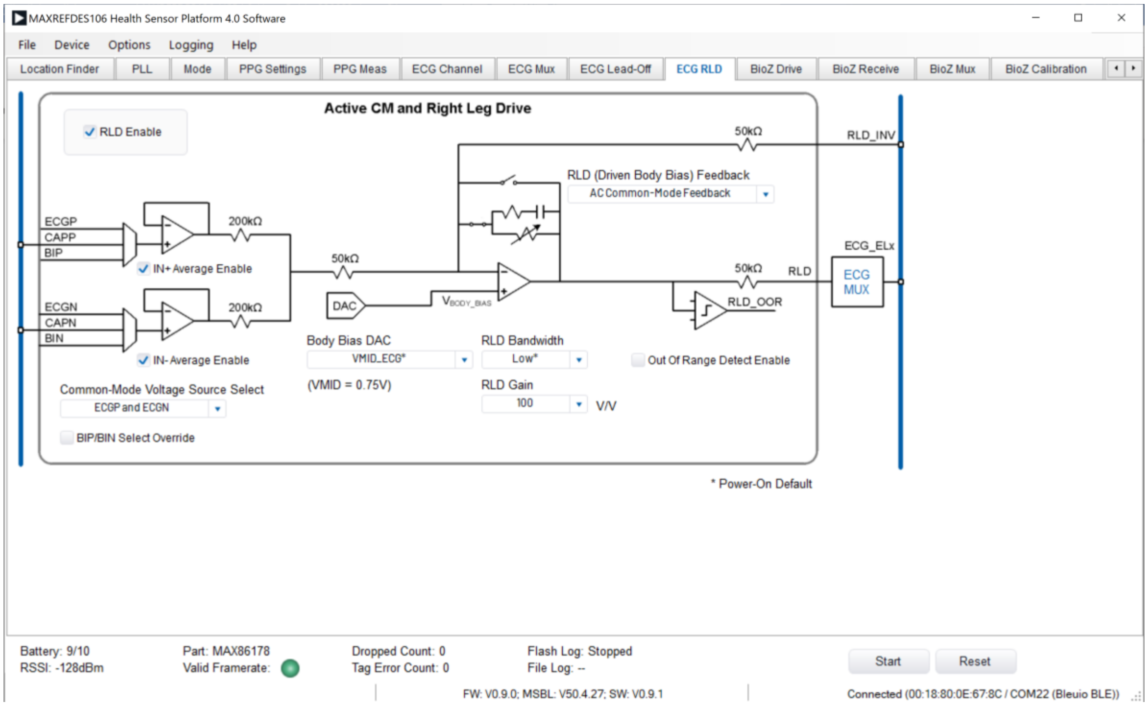


Figure 34. ECG RLD Tab: Use Power-On Default Settings

- BioZ Drive: Keep power-on default settings.

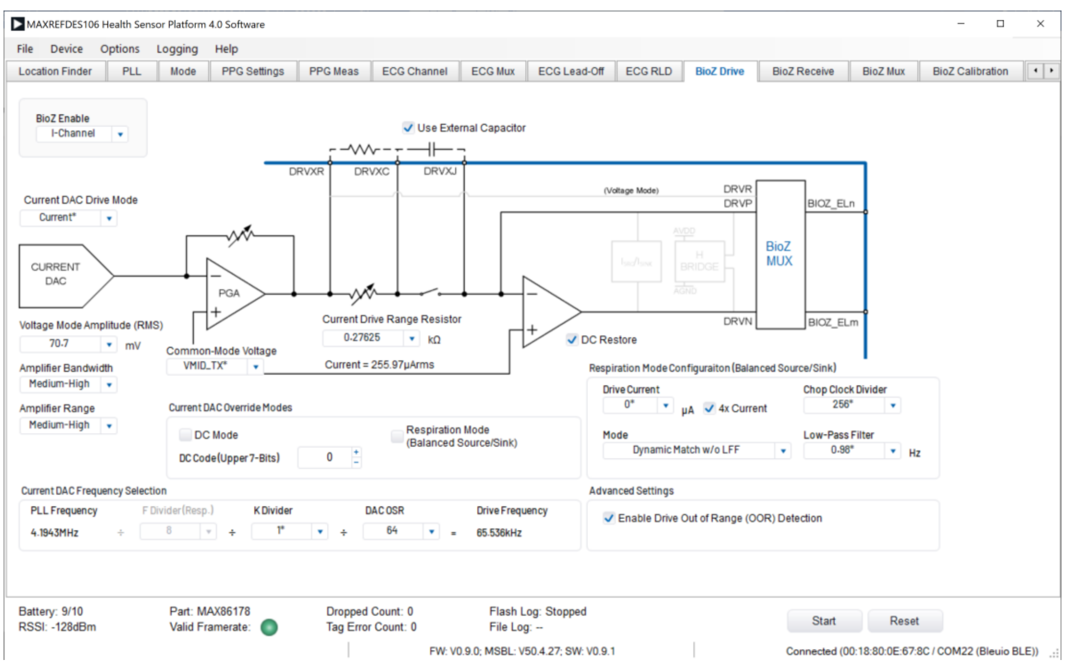


Figure 35. BioZ Drive Tab: Use Power-On Default Settings

- BioZ Receive: Keep power-on default settings.

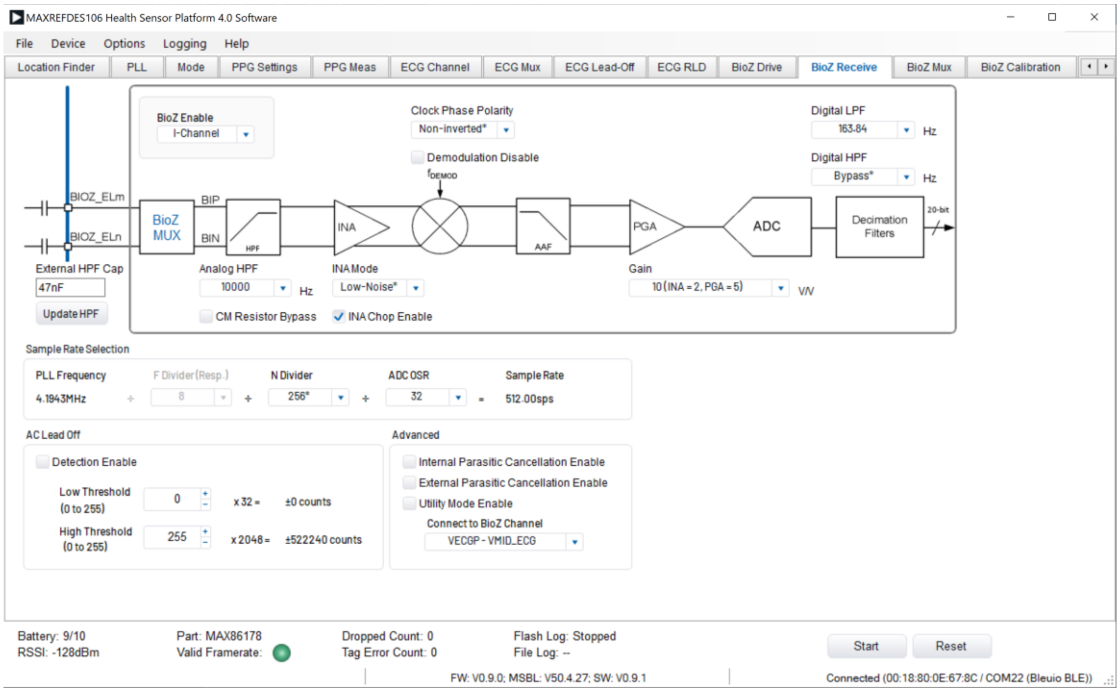


Figure 36. BioZ Receive Tab: Use Power-On Default Settings

- BioZ Mux: Keep power-on default settings.

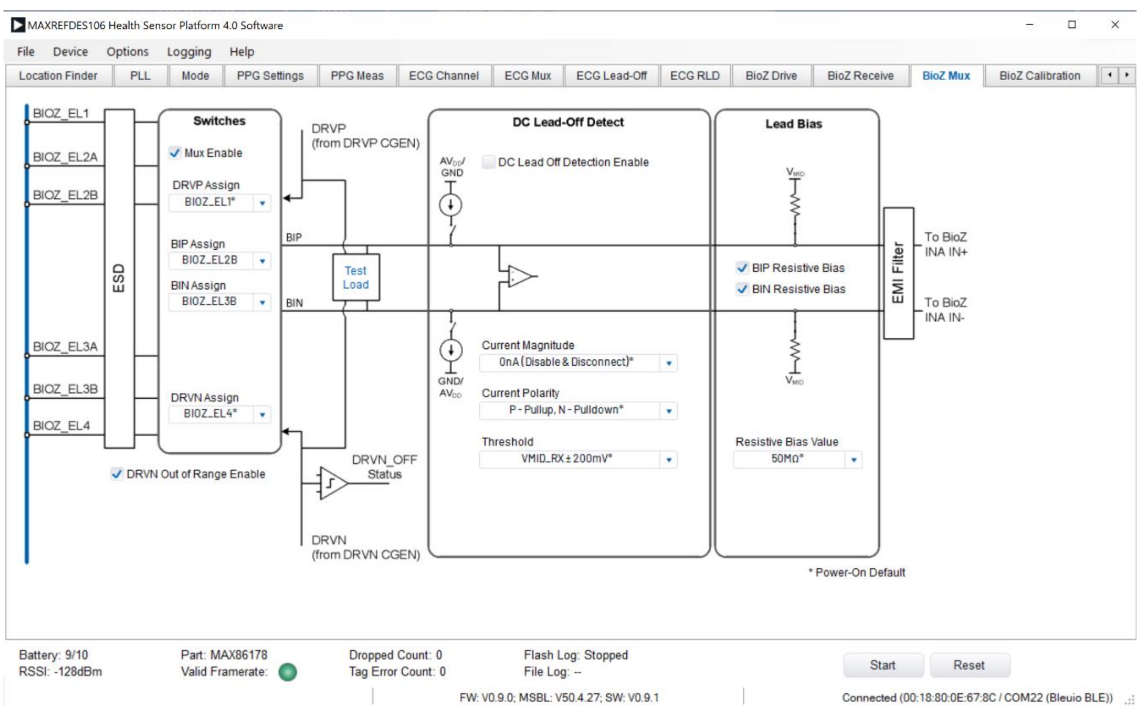


Figure 37. BioZ Mux Tab: Use Power-On Default Settings

Placing the Electrode

ICG measurement requires that all seven electrodes are used in these locations.

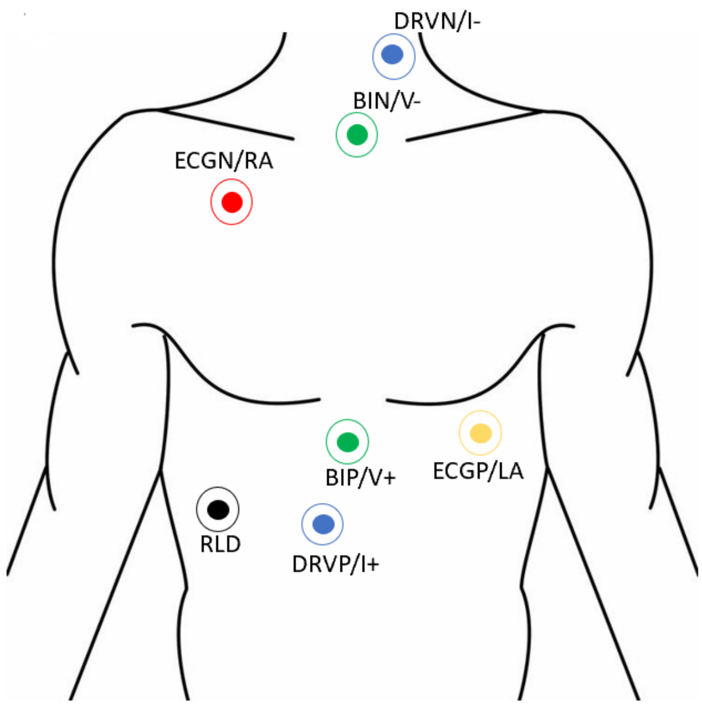


Figure 38. Placing the ICG Electrode

Starting and Stopping a Measurement

- Ensure the electrodes are attached securely on the chest (Figure 38), the patch is powered on, and connected to the GUI.
- Ensure the minimum settings requirements, listed above, are met.
- Start the measurement by clicking **Start**. ICG algorithm data is displayed to the Plots tab under ECG + ICG. Stop an active measurement by clicking **Stop**.

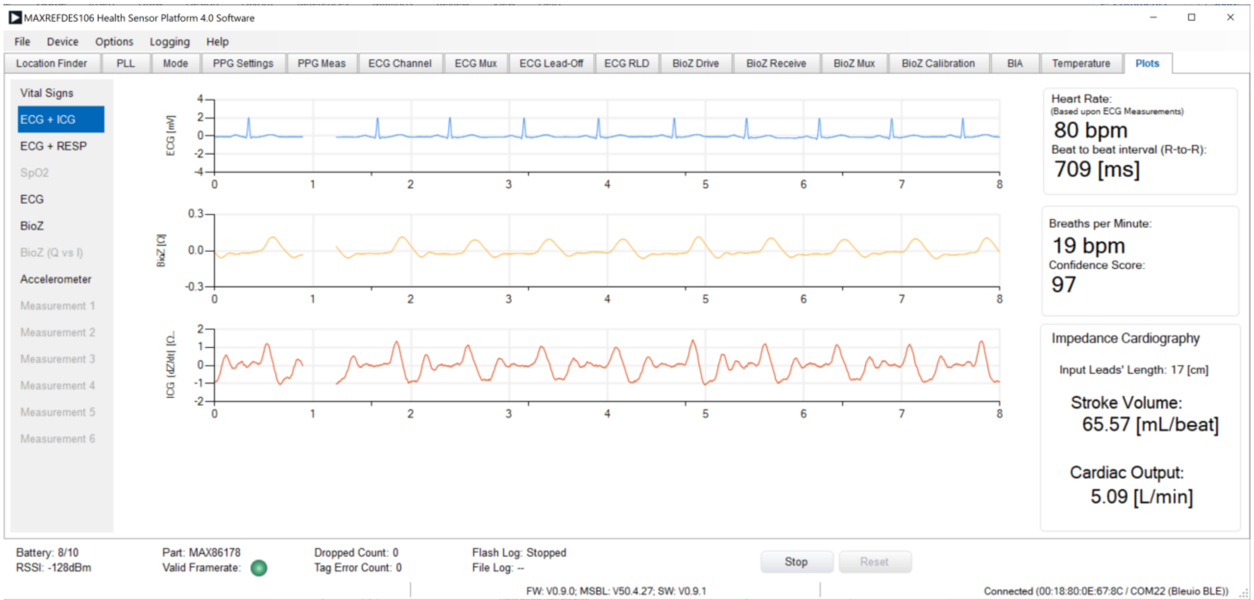


Figure 39. Example ICG Plot Tab

Bio-impedance Analysis (BIA)

The following section discusses how to enable the BIA algorithm output as well as fundamentals of the algorithm setup.

Associated Tab

The tab for configuring the BIA algorithm is the **BIA** tab.

Minimum Settings

- BIA: Go to the BIA tab and first select the type of units of measurement (metric or imperial).
  - Then, input personal information (height, weight, age, and gender) into the 'Bioelectrical Impedance Analysis Inputs' window.
  - Click 'Calibrate', and when it has finished calibrating, press 'Start Measurement' and hold still until the measurement is done.
  - BIA outputs display in the 'Bioelectrical Impedance Analysis Outputs' window.
- All other settings should be left as their power-on default settings.

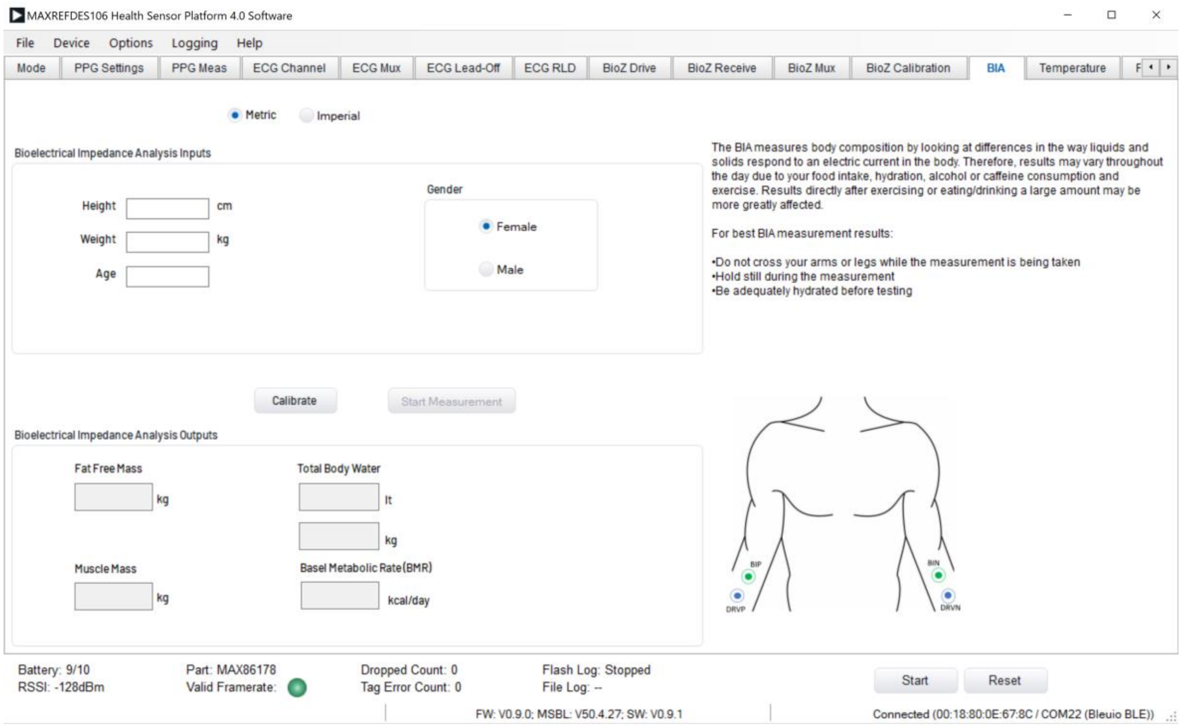


Figure 40. BIA Tab

Placing the Electrode

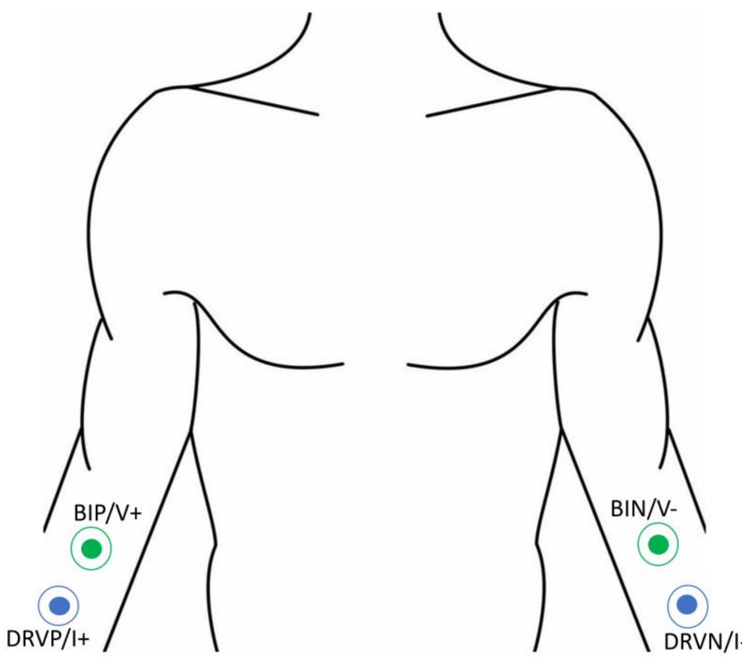


Figure 41. Placing the BIA Electrode Placement

Heart Rate (HR)

The following section discusses how to enable the HR algorithm output as well as fundamentals of the algorithm setup.

Associated Tabs

The tabs for configuring the HR algorithm are the **Mode**, **ECG Mux**, **ECG Lead-Off**, and **ECG RLD** tabs. The HR algorithm operates on ECG input data, but only supports 512Hz sampling rate.

Minimum Settings

The following settings satisfy the minimum requirements for collecting HR algorithm data. The rest of the settings can be configured further but can also be left at their power-on defaults. The HR algorithm uses the default ECG settings.

- Mode: Select ECG in ‘Quick Configuration’ window.

Once ECG in ‘Quick Configuration’ is selected, the rest of the settings can be configured at their power-on defaults.

- ECG Channel: Keep power-on default settings.

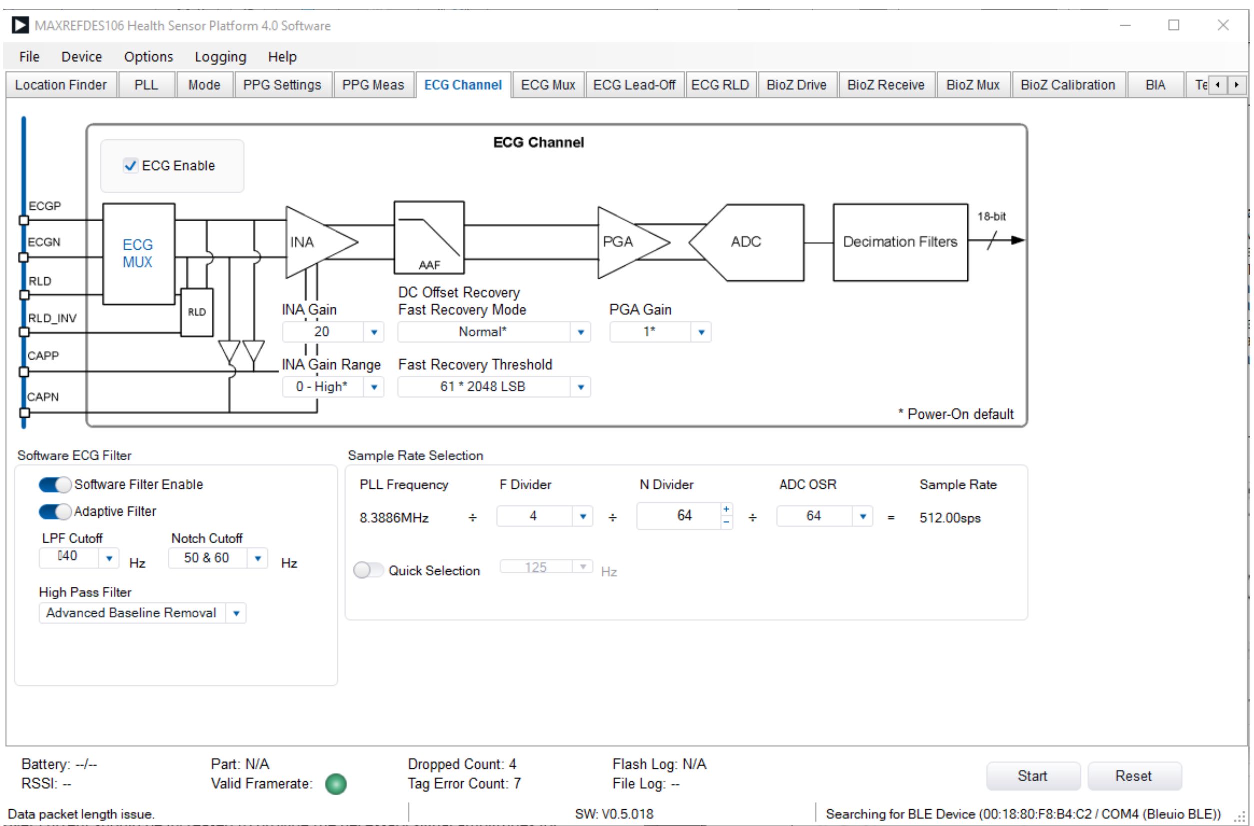


Figure 42. ECG Channel Tab: Use Power-On Default Settings

- ECG Mux: Keep power-on default settings.

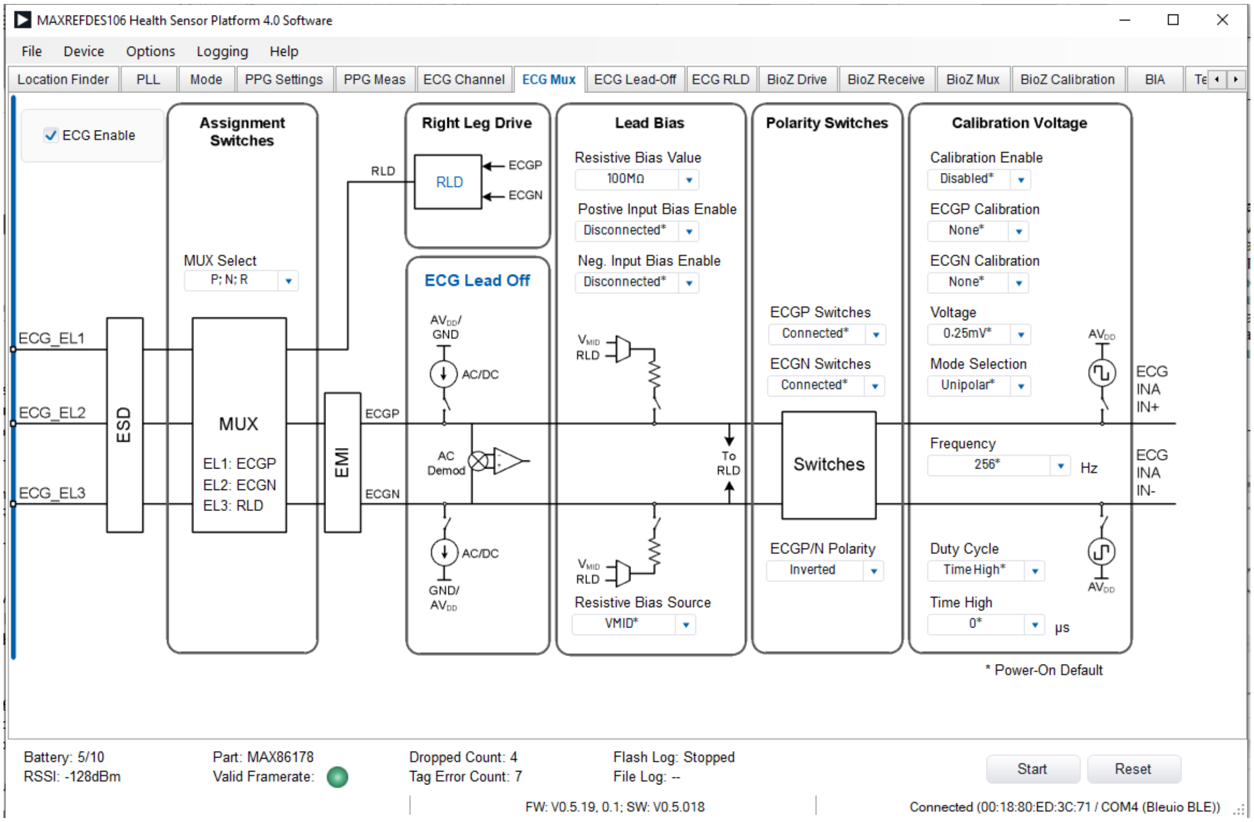


Figure 43. ECG Mux Tab: Use Power-On Default Settings

ECG Lead-Off

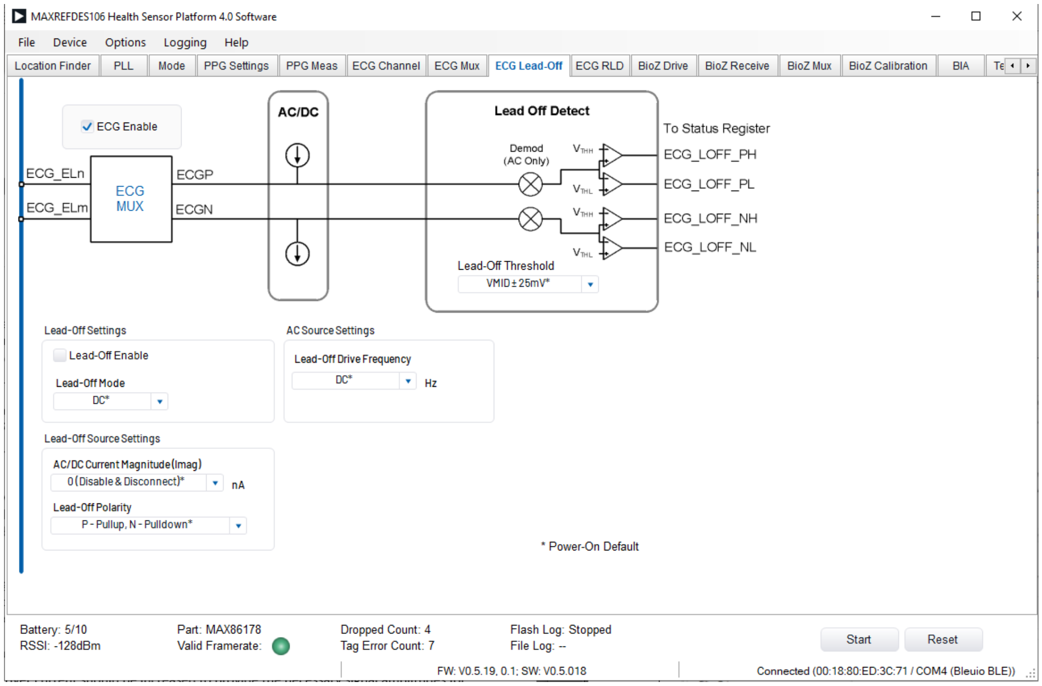


Figure 44. ECG Lead Off Tab

ECG RLD

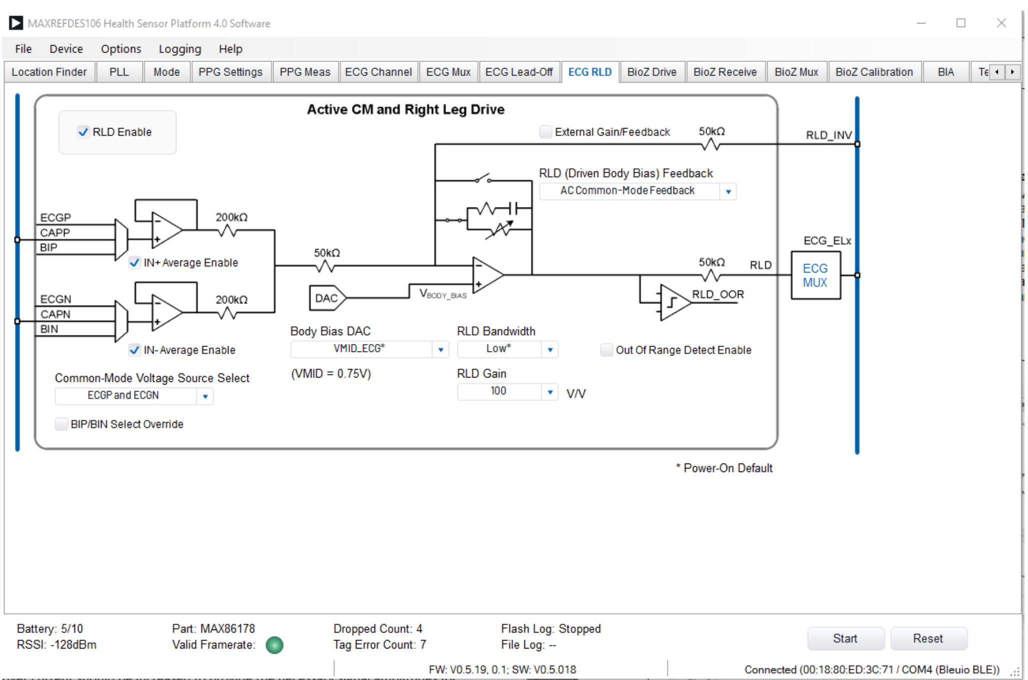


Figure 45. ECG RLD Tab

Blood Oxygen Saturation (SpO_2)

This section discusses how to enable the SpO_2 algorithm output and fundamentals of the algorithm setup. Analog Devices' proprietary algorithms for deriving clinical-grade accuracy pulse oximetry (SpO_2) measurements from Red and IR PPG signals are packaged in the .msbl file, which is flashed to the MAX32674C (the SpO_2 source code/library is not released to the public) . The default SpO_2 calibration coefficients have been generated from hypoxia lab data from a similar optical spaced device. It is provided for evaluation purposes only. The customer should use their final form factor to collect hypoxia data, which is used to generate the production SpO_2 calibration coefficients. The procedures are in the Guidelines for SpO_2 Measurement Using the Maxim MAX32664 Sensor Hub document. The MAXREFDES106# itself has not been evaluated by the US food and drug administration (FDA).

Associated Tabs

The 'Mode' tab is used to configure the PPG SpO2 mode settings. There are three modes but currently only 'Raw' and 'Algo Hub' mode are supported. 'Sensor Hub' mode will be supported later. Raw mode is used to capture raw data before any processing is done. Algo Hub mode enables the device to interact with the MAX32674C Algo Hub. The MAX32674C acts as a coprocessor, which takes raw data from the sensor and outputs the algorithm report. The default settings are recommended for 'Algo Hub' mode.

Minimum Settings

The following settings satisfy the minimum requirements for collecting SpO_2 algorithm data. The rest of the settings can be configured further but can be left at their power-on defaults. The algorithm uses the default settings for PPG measurements 1 and 2. Measurement 1 drives the IR (LEDx) LED, and Measurement 2 drives the Red (LEDx) LED. Both measurements sample the photodiode, which can provide better SpO2 (see location finder part for more details)

- Mode: Algo Hub mode selected, SpO_2 selected.

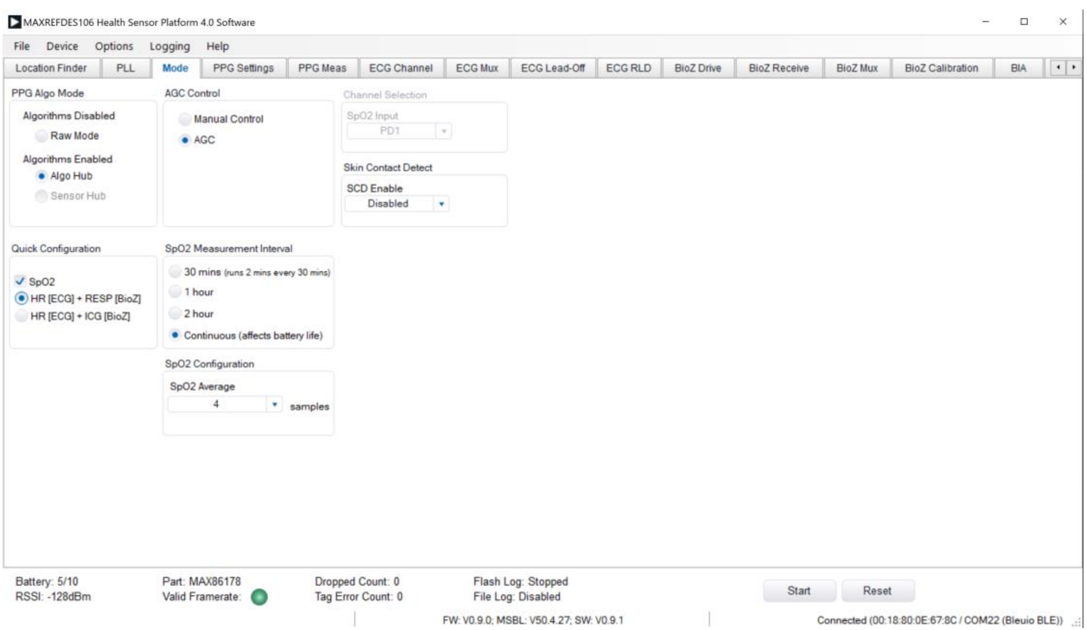


Figure 46. Mode Tab: Power-On Default Settings

Overview

Fundamentally, the SpO_2 algorithm measured the differences between the PPG waveforms captured by the Red and IR LEDs to estimate the blood oxygenation levels. The algorithm is based on PPG data so the following factors can negatively impact the SpO_2 estimation:

- Motion artifacts: Motion and movement severely impact PPG quality and the ability of the algorithm to calculate the SpO2. The SpO_2 algorithm is intended to be used at rest condition only.
- Measurement obstacles: Hair, sweat, imperfect contact, skin variations, excessive or non-periodic motion, etc., all negatively impact SpO2 performance.
- PPG settings: Improper LED/PD settings resulting in a low-quality PPG signal with negatively impacted performance.

Additionally, similar general guidelines can be followed for the measurements:

General Guidelines:

- The SpO2 algorithm needs Red and IR input PPG data. The algorithm is built upon the characteristics of these wavelengths and how they interact with the skin.
- LED driver current should be increased as much as the power consumption requirements of the application allow to get the highest amplitude signals. Typically, a DC or average level of 400k ADC counts should be the target for the IR and Red PPG signals needed for SpO2 measurements.
- Sample rate should be increased as much as power consumption requirements allow so that better sample averaging can take place, smoothing noise artifacts while increasing algorithm responsiveness.
- Motion and movements should be limited; remain as still as possible during the measurement period.

Starting and Stopping a Measurement

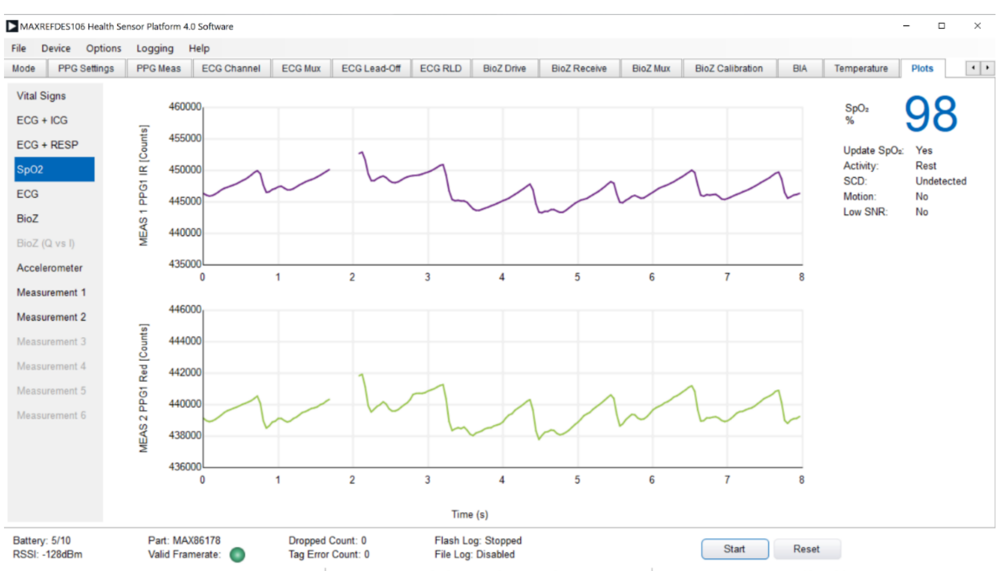


Figure 47. Example SpO_2 Algorithm Output

- Ensure the patch is placed securely on the chest, powered on, and connected to the GUI.
- Ensure the minimum settings requirements, listed above, are met.
- Start the measurement by clicking **Start**. SpO2 algorithm data is displayed to the Plots tab. Stop an active measurement by clicking **Stop**.

Temperature Sensors

The MAXREFDES106# includes two highly accurate ±0.1ºC MAX30210 temperature sensors paired with thermal contact discs on the top and bottom of the patch, respectively. These offer high-resolution skin and ambient temperature measurements. The MAXREFDES106# achieves this with an optimal thermo-mechanical configuration, limiting the thermal loss to the environment, while maximizing the thermal conductance to the temperature disc through thermally conductive epoxy and a dedicated aluminum contact disc. The design realizes the objective of maximizing area while minimizing volume, which is critical in these types of auxiliary temperature sensing applications.

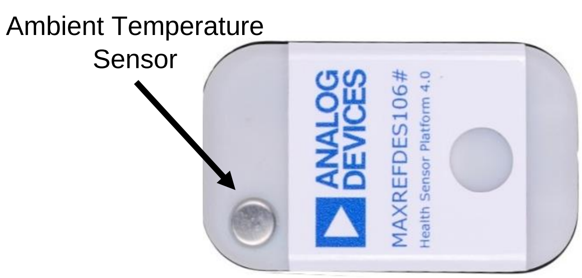


Figure 48. MAXREFDES106# Thermal Contact

Associated Tabs

The tab associated with temperature sensor measurements is the **Temperature** tab.

Starting and Stopping a Measurement

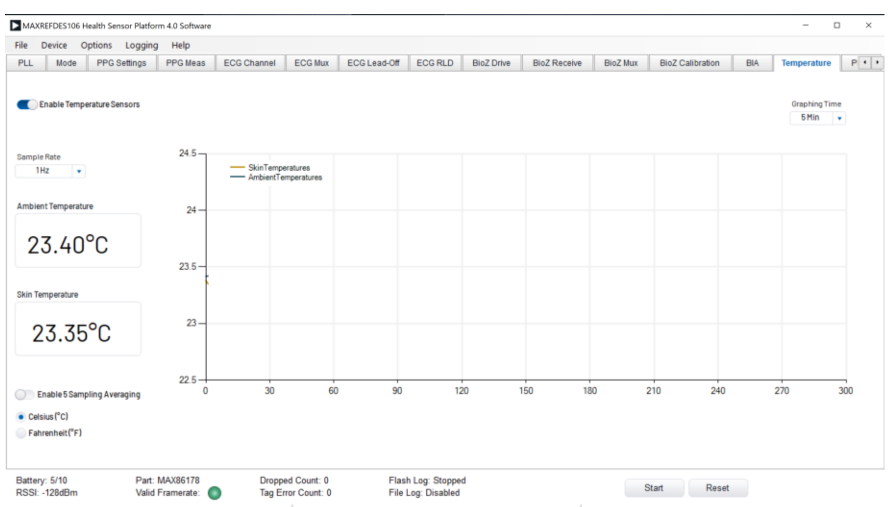


Figure 49. Example Temperature Measurement Output

- Ensure the patch is placed securely on the chest, powered on, and connect to the GUI.
- Navigate to the ‘Temperature’ tab and enable ‘Temperature Sensors’.
- To start a measurement, press **Start**. Stop an active temperature measurement by clicking **Stop**.

Temperature data is plotted on the ‘Temperature’ tab as well as in the ‘Plots’ tab under ‘Vital Signs’.

PC GUI Tabs

Location Finder Tab

This location finder tool helps locate the optimal chest location to attach the HSP4.0 patch. This algorithm analyzes the Red and IR PPG waveforms to identify the best channel. Before attaching the HSP4.0 to the chest using the provided adhesive tape, it is advised to first check the location. Place on upper left chest, below the clavicle (collar bone). See Figure 51 for details.

Directions: Move the patch to the location shown in the GUI and press **Start** in the ‘Chest SpO2 Location Finder Tool’ window. The algorithm analyzes seven seconds of data and then indicates a score on channel 1 and 2. Green is for great location, yellow is for an okay location, and red for a bad location. If the GUI shows red, move the patch to a new spot and wait for the score indicator to update. Repeat until a green location is found.

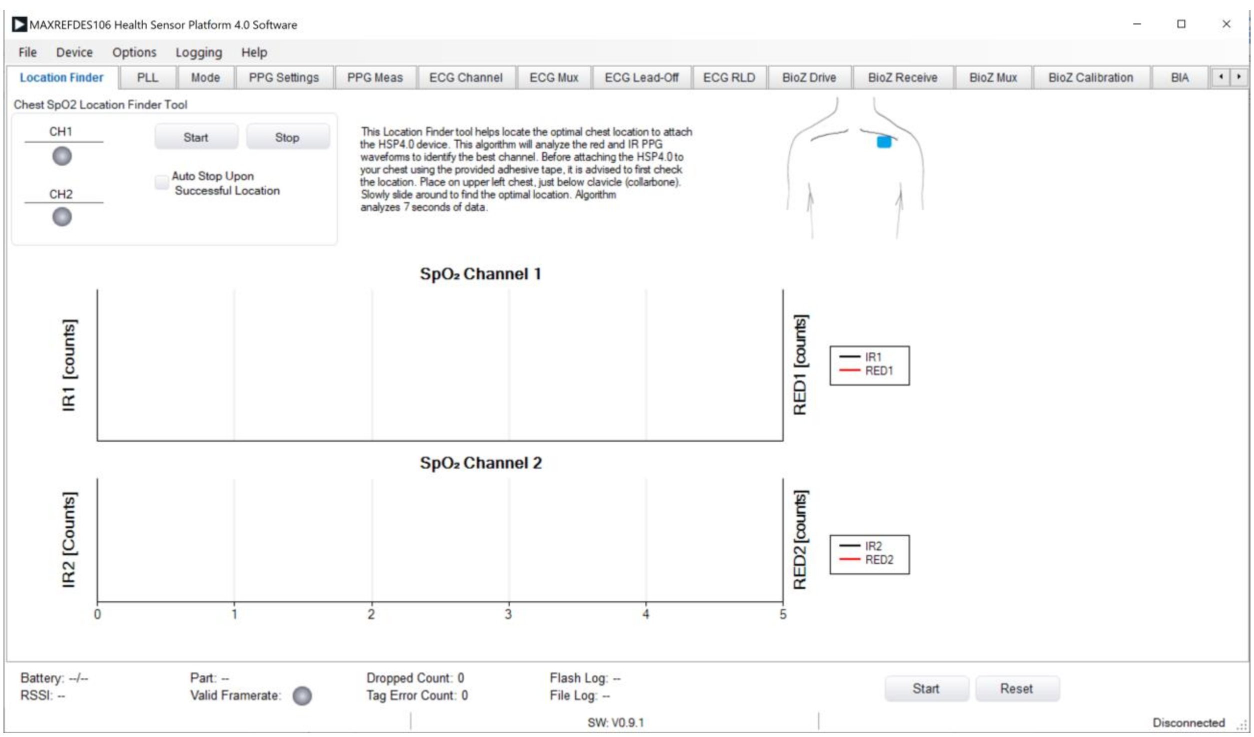


Figure 50. Location Finder Tab

Available Options

Table 2. Location Finder Configuration Options

Sub-Section	Option	Description
Chest SpO2 Location Finder Tool	CH1: Red/IR Color Indicator	MAXREFDES106# has two optical channels (Red and IR in each channel) to evaluate the optimal location on the chest. Green is for great location, yellow is for okay location, and red for poor location.
	CH2: Red/IR Color Indicator	MAXREFDES106# has two optical channels (Red and IR in each channel) to evaluate the optimal location on the chest. Green is for great location, yellow is for okay location, and red is for poor location.
	Start/Stop	Start/Stop the location finder algorithm.
	Auto Stop Upon Successful Location	Selects to automatically stop the location finder algorithm when an optimal location is found.

PLL Tab

The PLL tab allows the generation of PLL clock frequency. PLL is enabled by default. PLL frequency is generated by multiplying the **Clock Selection** frequency with the **M Divider**. PLL frequency ranges from 4MHz to 24MHz. Refer to Table 3 for more details.

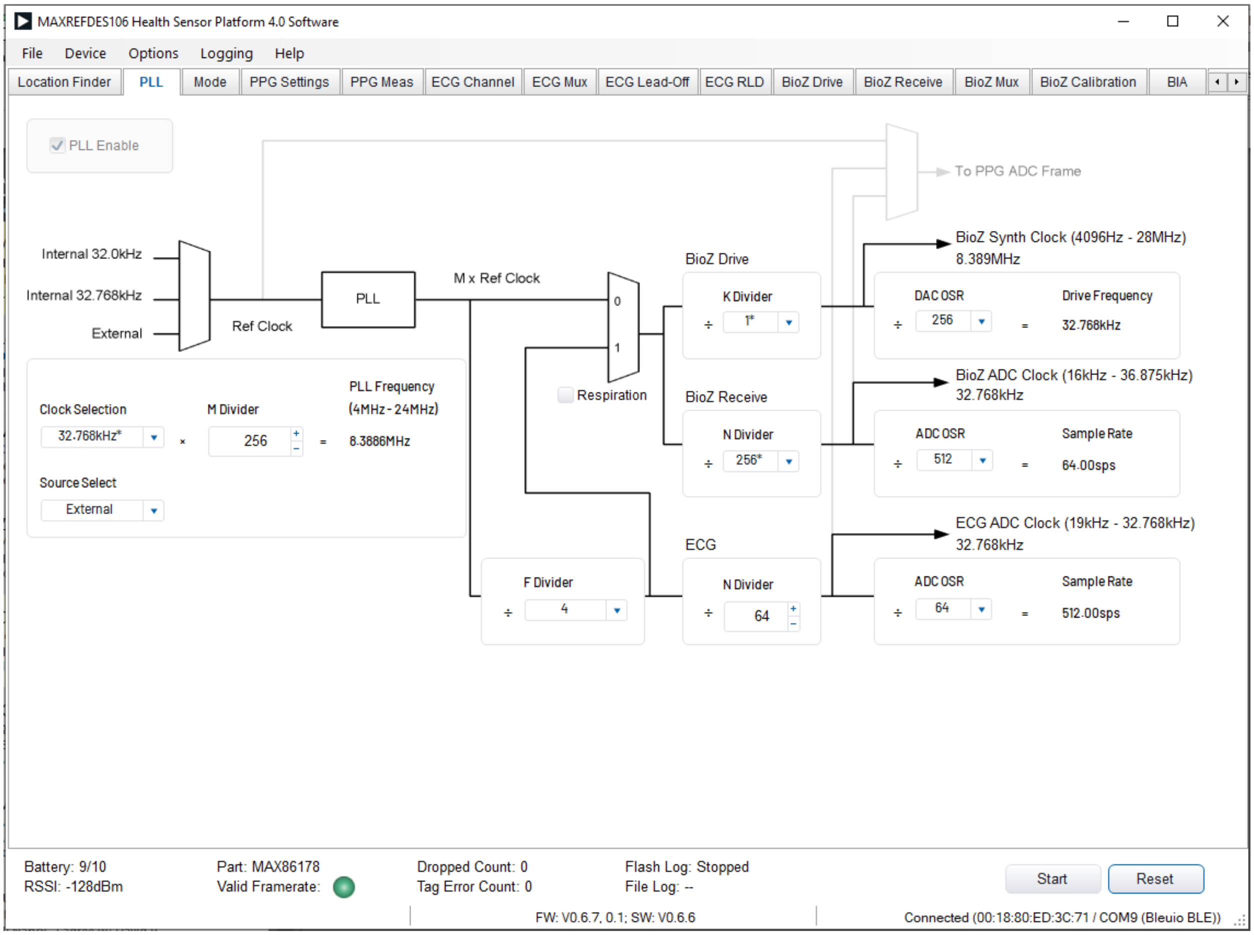


Figure 51. PLL Tab

Available Option

Table 3. PLL Configuration Options

Sub-Section	Option	Description
	Clock Selection	Selects internal oscillator between 32KHz and 32.768KHz to supply the reference clock.
	Source Select	Selects between the internal oscillator and external oscillator to supply the reference clock
	Respiration	Enabling **Respiration** causes the output of the mux to equal the PLL frequency divided by the **F Divider**. If disabled, the output of the mux is simply the PLL frequency. This functionality allows lower drive and sampling frequencies to be generated, as measuring respiration does not require high frequencies.

	BioZ Synth Clock	The BioZ drive clock is generated by dividing the output of the mux by the **K Divider**. The BioZ drive frequency is generated by dividing the output of the mux by the **K Divider** and **DAC OSR**.
	BioZ ADC Clock	The **BioZ ADC Clock** is generated by dividing the output of the mux by the **N Divider** of the **BioZ Receive**. The **BioZ ADC Clock** sample rate is generated by dividing the output of the mux by the **N Divider** and the **ADC OSR** of the **BioZ Receive**.
	ECG ADC Clock	The **ECG ADC Clock** is generated by dividing the PLL frequency by the **F Divider** and **N Divider** of the ECG. The ECG ADC sample rate is generated by dividing the PLL frequency by the **F Divider**, **N Divider**, and **ADC OSR** of the ECG.
	To PPG ADC Frame	The PPG frame rate is generated by the reference clock in the **Clock Selection** but is defined under the **PPG Settings** tab in the **Desired Frame Rate**.

PPG Mode Tab

This tab controls the operating mode of the PPG AFE at a high level, and fundamentally switches the device between two operating modes: Algorithm outputs disabled, and Algorithm outputs enabled.

- The Algorithm disabled mode is used to collect raw PPG data, and the settings are controlled manually in the PPG settings and 'PPG Measurement Settings' tabs instead.
- The Algorithm enabled modes are used to configure the device to enable HR, SpO2, RESP, and ICG estimation.

With algorithms enabled, a default PPG setup suitable for most situations is loaded and used as input to the HR, SpO2, RESP, and ICG algorithms. These defaults are intelligently selected, but the evaluation GUI offers a relatively open interface to modify the input data configuration, if necessary. However, not all possible configurations are fully supported. If the defaults are modified, ensure the modifications are properly selected.

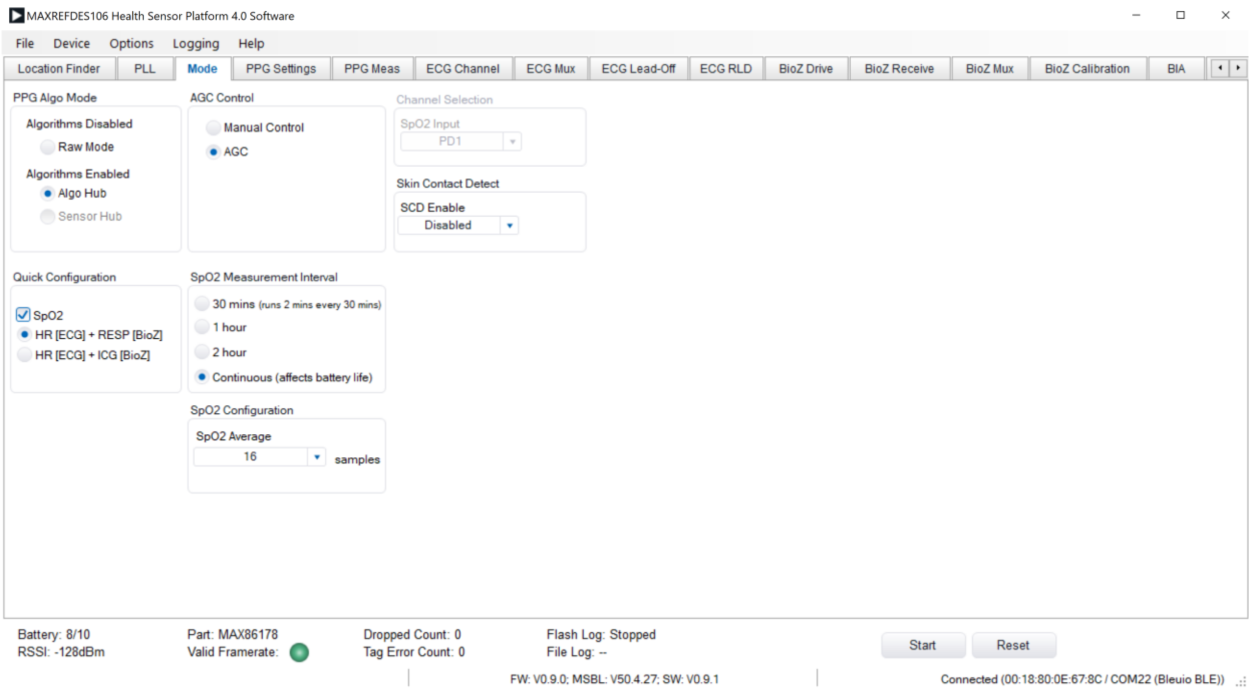


Figure 52. Mode Tab

Available Options

Table 4. PPG Mode Configuration Options

Sub-Section	Option	Description
Mode	Raw Mode	Configures PPG raw mode. HR/SpO_2 algorithm outputs are disabled. PPG settings are controlled manually through the ‘PPG Settings’ and ‘PPG Measurement Settings’ tabs.
	Algo Hub	Enables HR/SpO_2 algorithm outputs in the ‘Algorithm Hub’ operating mode. See the Algorithm Operating Modes section for more details.
AGC Control	Control Enable	Enables AGC (see ‘Control Select’).
	Control Select	Automatic gain control = AGC. This mode offers some more control than AEC. In this mode, the algorithm hub is given a target PD current, and it adapts the LED selection and driver currents based on what it predicts it needs to hit that target. Sample rate and DAC offsets can be manually set in this mode.
AGC Control Setting	Target PD Current	With AGC enabled: This is the fixed PD current target the algorithm hub always tries to hit. It adjusts LED driver currents as necessary.

SpO2 Configuration	SpO2 Average	Controls the number of samples to average for SPO2 (MEAS2 and MEAS3, example, IR and Red). The minimum is locked to four samples for this platform to ensure sufficient signal noise ratio (SNR) for algorithm performance. *Default SPO2 Integration time is 117.1µs (not shown on GUI). The SPO2 algorithm coefficients do not support adjustment of DAC offset, as this affects the R-curve and ratio-of-ratios utilized to report SPO2 values.*

PPG Settings Tab

This tab offers further configuration settings for the PPG AFE. Primarily, this tab is used to control the PPG frame rate, enable/disable PPG channels, and configure the onboard accelerometer.

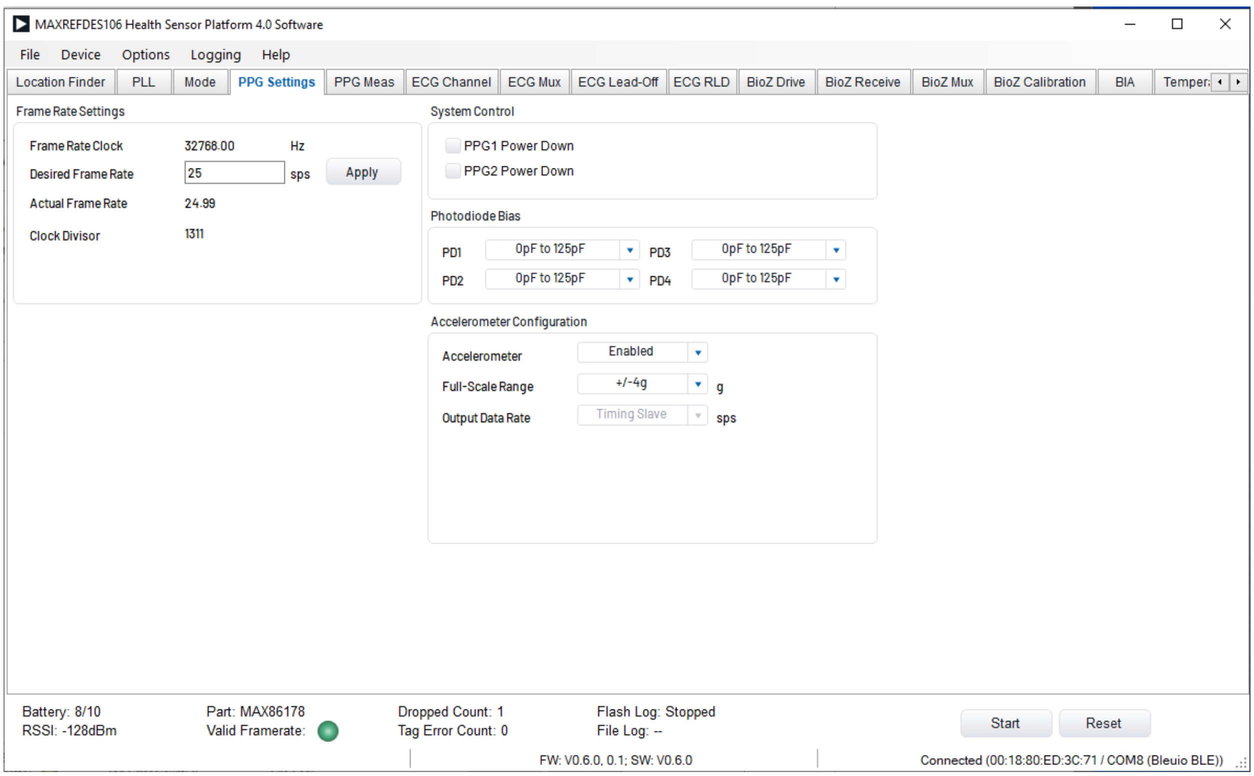


Figure 53. PPG Settings Tab

Available Options

Table 5. PPG Settings Configuration Options

Sub-Section	Option	Description
Frame Rate Settings	Frame Rate Clock	Displays the MAX86178 internal oscillator to use as the clock source for the PPG frame rate.
	Desired Frame Rate	Sets the desired frame rate of the PPG AFE. Enter a target value and then hit 'Enter' to have the GUI calculate and set the correct clock divisor for this target value. Any value up to 2048 can be set here. (Due to BLE bandwidth limitations, not all frame rates are supported.)
	Actual Frame Rate	Actual frame rate of the PPG AFE. Due to rounding from the clock divisor, 'Desired Frame Rate' and 'Actual Frame Rate' may differ slightly.
	Clock Divisor	Displays the calculated clock divisor for the 'Desired Frame Rate'.
System Control	PPG1 Power Down PPG2 Power Down	Checking this box powers down the corresponding PPG channel to save power. At least one channel should remain enabled during measurements.
Photodiode Bias	PD1/PD2/PD3/PD4	Sets the photodiode bias for each photodiode. There are three available biasing options to support a larger range of PD capacitances, allowing different PDs to be used. For the MAXREFDES106# photodiodes, the 0pF to 125pF range should be used, as the PDs used have a capacitance of 47nF typical. See the 'Photodiode Biasing' section of the MAX86180 datasheet for more details.
Accelerometer Configuration	Accelerometer	Enables or disables the onboard accelerometer. Note: When enabling the 'Algo Hub' mode, the accelerometer is automatically enabled.
	Full-Scale Range	Sets the output scale of the accelerometer data.

PPG Measurement Settings

This tab offers in-depth manual control of the PPG AFE. Individual measurement blocks can be enabled, configured, and sequenced here. The layout of the LEDs and PDs on the MAXREFDES106# is provided for reference in Figure 55.

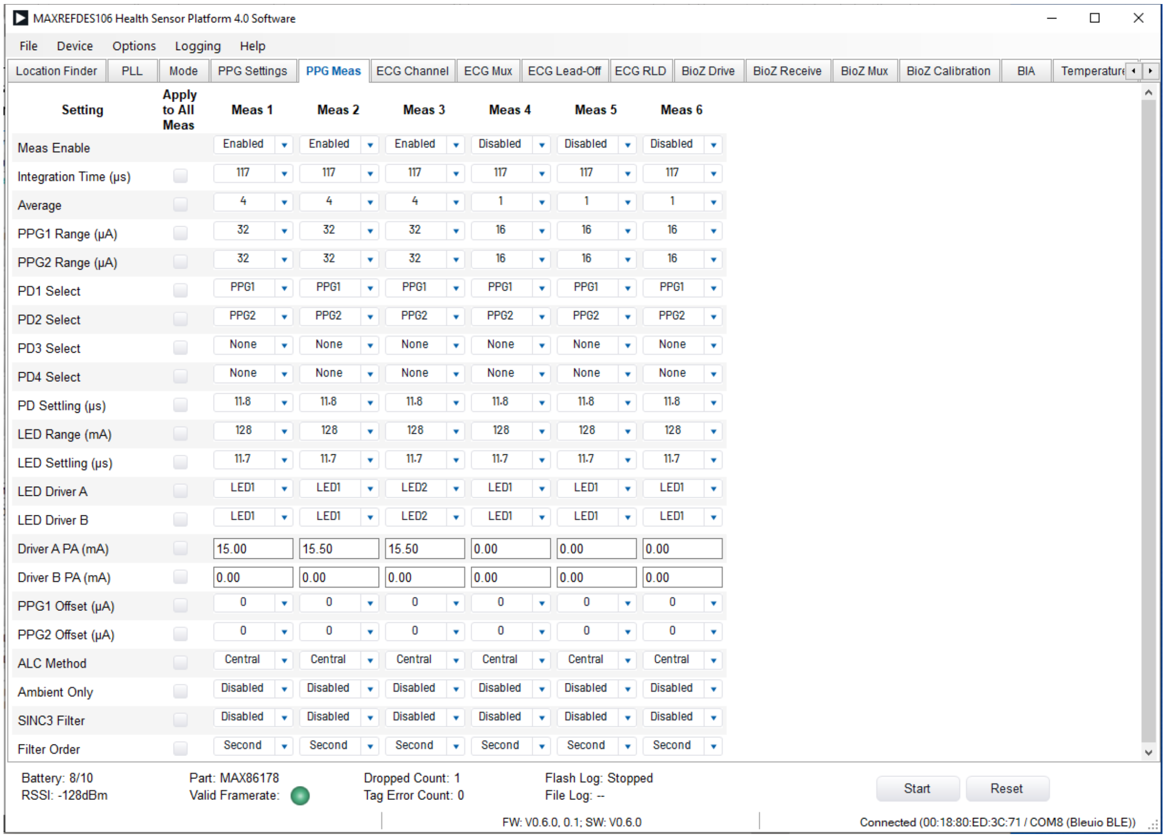


Figure 54. PPG Meas Tab: PPG Measurement Settings Tab

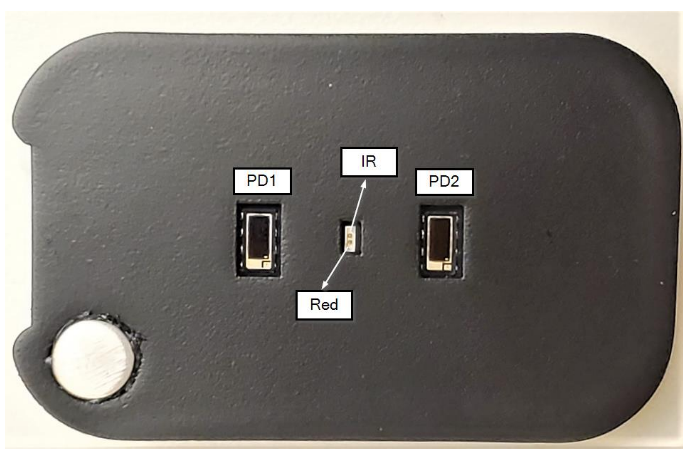


Figure 55. MAXREFDES106# LED and PD Layout, Bottom View

Available Options

Table 6. PPG Measurement Configuration Options

Sub-Section	Option	Description
Setting	Meas Enable	Enables the measurement block. Each measurement block can contain a unique LED+PD configuration, and up to nine can be enabled per frame. A measurement can be thought of as an **exposure** in a traditional camera.
	Integration Time	Sets the width of the measurement block in micro- seconds. This effectively modulates the optical-channel bandwidth, allowing for a tradeoff between the LED power consumption and PPG signal quality.
	Average	This sets the number of consecutive measurement blocks that are collected and then averaged together into one output. Refer to the MAX86176 data sheet for more information on *Burst Averaging.*
	PPG1 Range	Sets the full-scale range of the optical-signal path for the PPG1 channel in µA.
	PPG2 Range	Sets the full-scale range of the optical-signal path for the PPG2 channel in µA.
	PD1/PD2 Select	Selects the photodiode (input pin) to sample for each PPG channel. See Figure 55 for PD layout.
	PD Settling Time	Sets the settling time for the photodiode(s) in µs. This is the settling time that occurs after an ambient exposure sample has completed and before the LEDs are driven for the next exposure. Refer to the MAX86176 data sheet for more details.
	LED Range	Sets the maximum current pulse amplitude for the LED drivers in mA.
	LED Settling	Sets the settling time for the LED(s) in µs. This is the settling time that occurs before the PD can start sampling. Refer to the MAX86176 data sheet for more details.
	LED Driver A/B	Selects the LED to drive for driver A/B. The configuration of LED driver and LED mux are highly flexible, allowing for any of the six LED driver pins to sink current from one or both LED drivers. For MAXREFDES106/HSP4.0, the LEDs are connected to the following DRV pins: LED1 = IR LED2 = Red
	Driver A/B PA	Sets the LED driver current pulse amplitude in mA. This is the amount of current the driver pushes through the LED

		during the measurement. The maximum possible value is configured with the LED range setting.
	PPG1/PPG2 Offset	Sets the offset for the two-bit offset DAC in µA. This allows for extending the optical dynamic range by sourcing some of the exposure current to the offset DAC. This feature is especially useful under certain conditions that occur when attempting to limit the exposure ADC counts. For example, when avoiding saturation while increasing the exposure-signal perfusion index.
	ALC Method	Ambient Light Cancellation Method. **Central** comprises three ADC conversions: two ambient and one exposure conversions. Recommended for most use cases. **Forward** comprises two ADC conversions: one each of ambient and exposure conversions. Refer to the MAX86176 data sheet for more details on both methods.
	Ambient Only	This option configures the measurement to only collect ambient light PPG samples with the LED drivers disabled.
	SINC3 Filter	Enables the SINC3 decimation filter for the delta-sigma PPG ADC. This filter provides improved high-frequency roll-off that improves the high-frequency ambient-light rejection. By default, the device uses a third order COI3 filter. This filter is only available with an integration time setting of 117.1µs.
	Filter Order	This option configures the order of decimation filter, second and third order. This second order filter is only available when the SINC3 filter is disabled, and integration time is 117.0µs. Enabling this feature also results in an actual integration time of 118.2µs.

ECG Channel Tab

This tab offers a high-level overview of the ECG channel configuration options, and allows for configuration of the input amplifier gains, fast recovery modes, ADC samples rate, and software filters. **Software ECG Filter** is shown on ECG signals in the GUI plots as well as saved in a separate file log ending in '.ecg_filtered.csv'. See the table configuration options in Table 7 for more details.

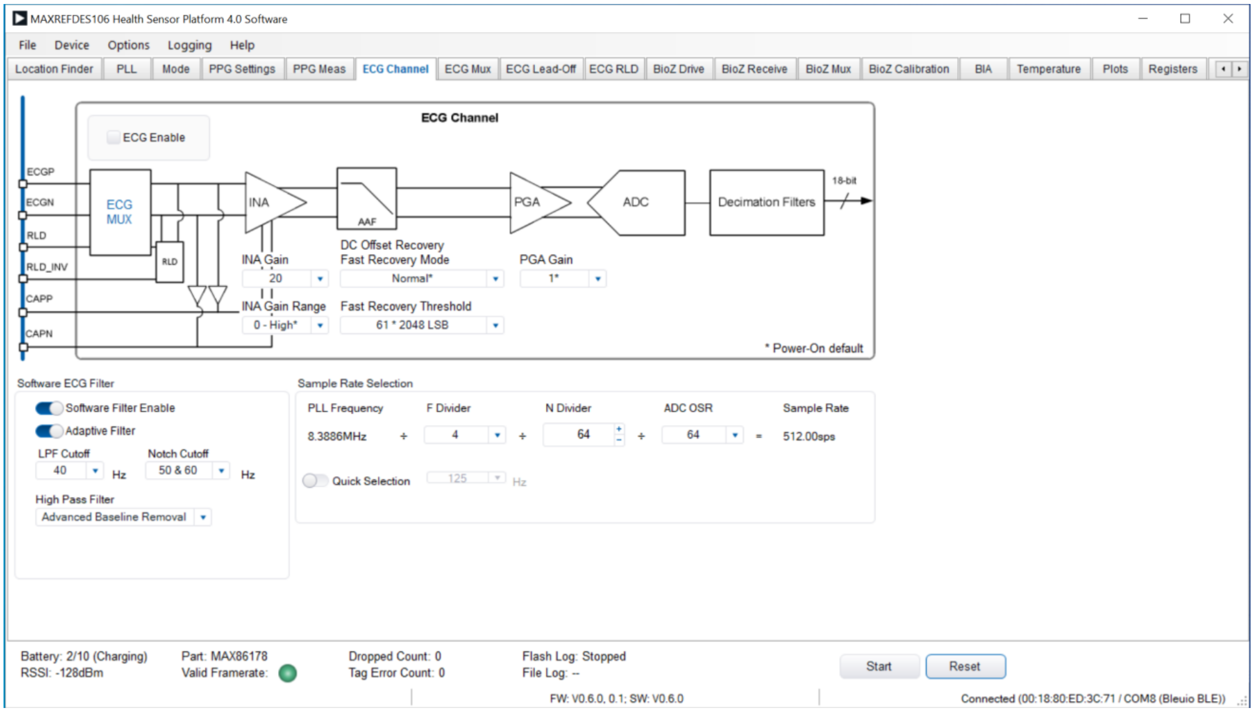


Figure 56. ECG Channel Tab

Available Options

Table 7. ECG Channel Configuration Options

ECG Channel	ECG Enable	Enables/Disables the Collection of ECG Measurements.
	INA Gain	Sets the input amplifier gain factor. DC bias of ECGP and ECGN and slow-moving DC drift signals are removed by the input amplifier, and the differential AC signal is amplified by this factor before being passed to the PGA and ADC.
	Fast Recovery Mode	The INA can rapidly recover from an overdrive event, such as a defibrillation pulse. There are two modes of fast recovery: automatic and manual. In the automatic recovery mode, the overdrive event is detected when the output of the ECG measurement exceeds the symmetric thresholds defined by ± (2048 x ECG_FAST_REC_THRESHOLD). Although the manual recovery mode is presented as an option in the GUI, it is a feature that is best deployed in end-application firmware. Refer to the 'Fast Recovery Mode' section of the MAX86178 data sheet for details.
	Fast Recovery Threshold	Sets the ECG threshold at which the fast recovery mode begins to trigger.
	PGA Gain	Sets the gain factor for the PGA. This is the final gain stage before the ECG signal is sampled by the ADC.

Software ECG Filter	Adaptive Filter	This switch toggles the adaptive nature of the 'Software ECG Filter' chain. Adaptive noise filtering can filter out remaining noise in the filter pass bands by learning the noise profile. Thus, variations in the signal pertaining to noise are removed and ECG features are displayed much more clearly. Filtered data shown in the GUI is saved to a separate .csv file ending in '.ecg_filtered.csv'.
	Baseline Removal	This switch toggles the baseline removal feature of the 'Software ECG Filter' chain. This is a Analog Devices advanced post-processing filter that tracks the baseline signal and eliminates baseline drift and motion artifacts. It can recover very fast from sudden signal level changes due to motion or other possible causes.
	LPF Cutoff	Sets the cutoff frequency of the LPF in the 'Software ECG Filter' chain. This is typically used to remove high-frequency interference noise and is a double-pole IIR Filter. Currently, only 128Hz, 256Hz, 512Hz, and 1024Hz ECG sample rates are supported up to the Nyquist frequency (example: 150Hz is not supported when ECG is set to 256Hz but is selectable when configuring ECG to 512Hz).
	Notch Cutoff	Sets the cutoff frequency of the 'Notch Filter' in the 'Software ECG Filter' chain. This is typically set to 50Hz and/or 60Hz to filter noise introduced by the AC powerline interference.
Sample Rate Selection	Sample Rate	The ECG ADC sample rate is generated by dividing PLL frequency by the **F Divider, N Divider,** and **ADC OSR.**

ECG Mux Tab

This tab offers an expanded view into the ‘ECG Input Mux’ block of the ‘ECG Channel’ tab. It is used to connect or isolate the ECGP/ECGN input pins from the rest of the signal chain, enable ‘ULP Lead-On’ checking, configure leas biases, and enable calibration signals. See the available options in Table 8 for more details.

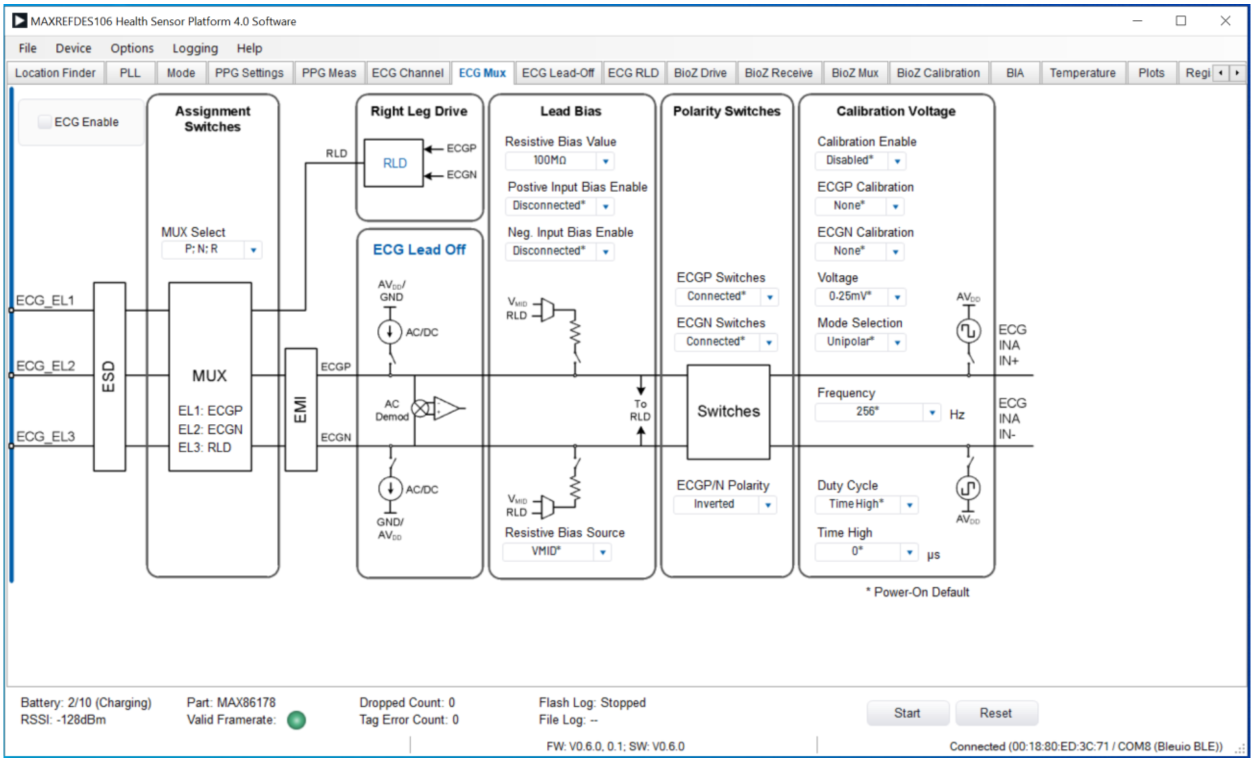


Figure 57. ECG Mux Tab

Available Options

Table 8. ECG Mux Configuration Options

Sub-Section	Option	Description
ECG Enabled		Enable/Disable ECG measurement.
Assignment Switches	MUX Select	Assign ECGP/ECGN/RLD to different electrodes.
Polarity Switches	ECGP/ECGN Switches	Connects or isolates the ECGP and ECGN pins from the internal signal path. The switches must be connected to collect an ECG signal.
	ECGP/N Polarity	Controls the polarity of the ECGP/ECGN pin connections. These are non-inverted by default. If the ECG waveform is inverted, change this value.

Lead Bias	Resistive Bias Value	Selects the internal lead biasing resistors. These are selectable resistors connected between the ECGP/ECGN input pins and V_{MID_ECG} that drive the electrodes within the input common-mode requirements of the ECG channel and can drive the connected body to the proper common-mode voltage level. For dry electrode use cases, where contact impedances can be much higher and potentially imbalanced, the use of a third electrode (RLD) is strongly advised instead of internal lead biasing.
	Positive Input Bias Enable	Enables/Disables the connection of the lead bias resistor to the ECGP source.
	Negative Input Bias Enable	Enables/Disables the connection of the lead bias resistor to the ECGN source.
Calibration Voltage	Calibration Enable	Enables/Disables the connection of the calibration PWM voltage signals to the ECGP/ECGN source. These calibration signals are available to provide rectangular pulse-train signals for internal signal-chain validation.
	ECGP/ECGN Calibration	Selects the voltage source to use for calibration of the ECGP channel. Each input can be connected to either of the two sources or V_{MID_ECG} for differential mode amplitudes between 0.25mV$_{PP}$ and 2.0mV$_{PP}$ or common-mode amplitudes between 0.25mV$_{PP}$ and 1mV$_{PP}$.
	Mode Selection	Sets the calibration voltage source for both ECGP and ECGN sources to be unipolar or bipolar with respect to V_{MID_ECG}.
	Voltage	Sets the amplitude of the calibration PWM signals.
	Frequency	Sets the frequency of the calibration PWM signals.
	Duty Cycle and Time High	Sets the pulse-width of the calibration PWM signals.

ECG Lead OFF Tab

This tab offers an expanded view of the 'ECG Lead Off' block in the 'ECG Mux' tab and is used to configure AC or DC lead-off detection. Lead-off detection is used to detect when the ECG electrodes are no longer in contact with the skin, or the electrode has deteriorated, resulting in a high electrode impedance. AC and DC leads off can be used while the ECG cannel is enabled.

Fundamentally, these lead-off detection methods involve sinking and sourcing current into the ECGP/ECGN lines and checking for a conduction path through the body by measuring differential voltage (DC) or impedance (AC). Refer to the MAX86178 data sheet for more details, and the available options in Table 9 for more details on the available configurations.

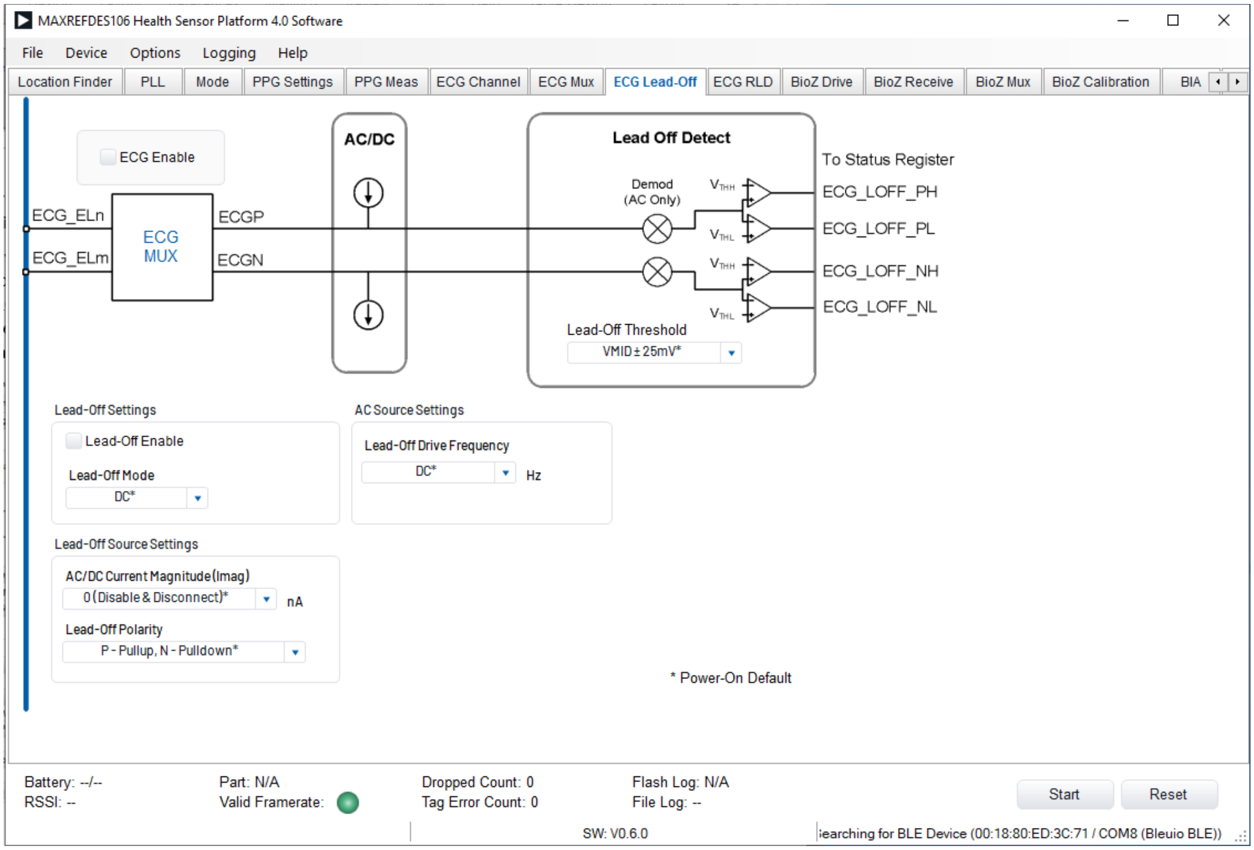


Figure 58. ECG Lead-Off Tab

Available Options

Table 9. ECG Lead Off Configuration Options

Sub-Section	Option	Description
ECG Lead Off	ECG Enable	Enables/Disables the collection of ECG measurements.
	Lead Off Settings	Enables/Disables ‘ECG Lead-Off’ detection, selecting between AC or DC. DC lead-off detection involves injecting a small DC current through the ECGP and ECGN leads, and measuring the differential voltage that develops across the leads. AC lead-off detection provides more detailed electrode contact information by performing AC-impedance measurements and can provide information about the quality of the electrode tissue interface. Pay careful attention when selecting the stimulus frequency during ECG measurements as the stimulus frequency can and will interfere with ECG signals when selected at low values. Refer to the MAX86178 data sheet for more details.

Lead-Off Source Settings	AC/DC Current Magnitude	Sets the magnitude of the current source/sinks used in the lead-off detection.
	Lead-Off Polarity	The polarity of the current sources on ECGP and ECGN can be reversed by selecting P (Pull-down), N (Pull-up). This is useful if electrode polarities are reversed.
AC Source Settings	Lead-Off Drive Frequency	When AC is selected for 'Lead-Off Mode', the AC lead-off detection uses a square-wave current source with the frequency defined in the 'Lead-Off Drive Frequency'.

ECG RLD Tab

This tab is used to enable and configure the right leg drive (RLD) circuit. The RLD circuit improves system-level common-mode rejection of signals coupled to the user from the environment, primarily 50Hz or 60Hz power-line interference. When RLD is enabled, the circuit senses the AC common-mode input signal from the input electrodes, inverts, and amplifies the signal, and drives it onto the body through a third electrode. This has the effect of attenuating the common-mode signal at the inputs and driving them toward a selectable reference voltage, typically VMID_ECG. This also ensures proper common-mode biasing of the electrodes, allowing the internal lead bias resistors to be disabled. Alternatively, the RLD circuit can also act as a DC body-bias buffer. See the available options in Table 10 for more details.

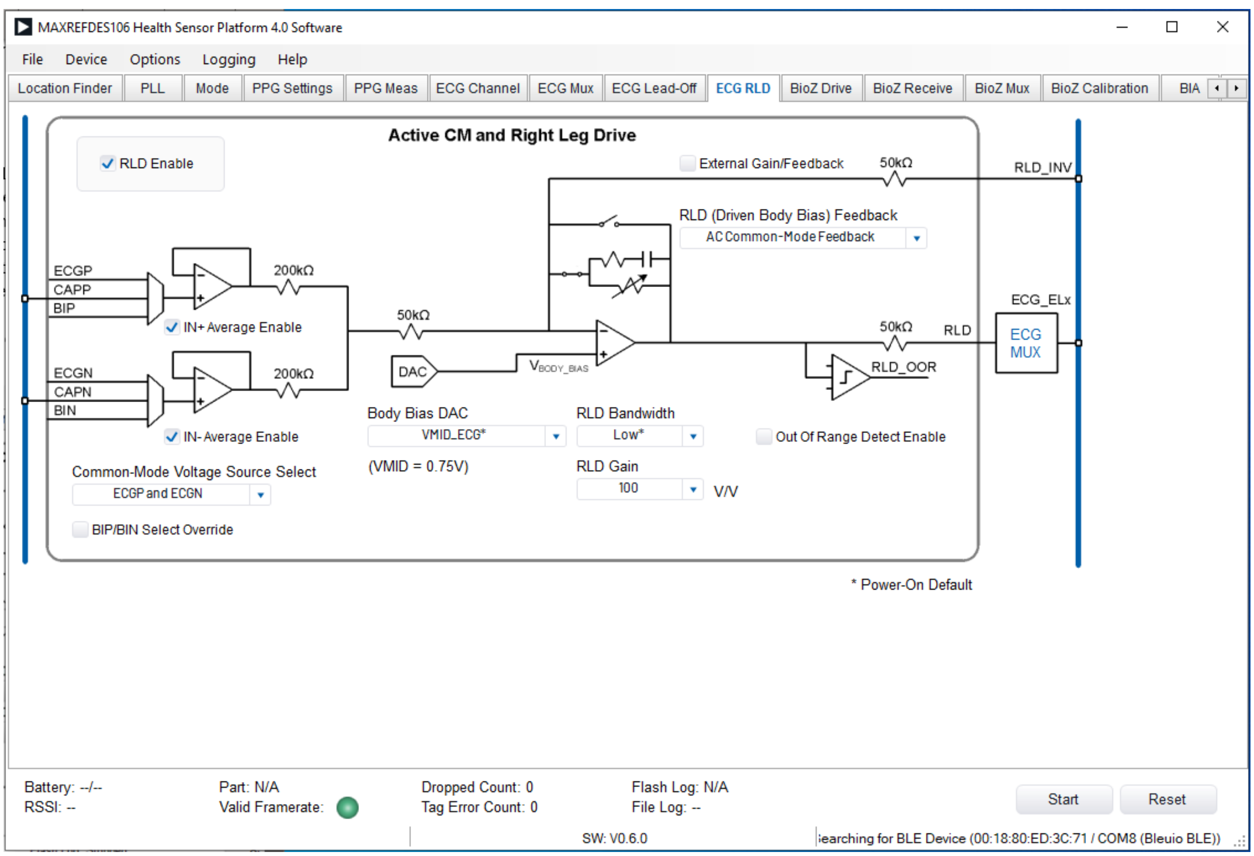


Figure 59. ECG RLD Tab

Available Options

Table 10. ECG RLD Configuration Options

ECG RLD	RLD Enable	Enables/Disables Right Leg Drive.
	RLD (Driven Body Bias) Feedback	Selects the RLD operating mode. DC Buffer Mode = The feedback network is shorted and the RLD amplifier acts as a DC buffer to bias the body to a voltage selected by the 'Body Bias DAC' option. Closed-Loop Right Leg Drive Mode = The RLD amplifier applies the inverting gain to the AC common mode input signal, forming a feedback loop through the body to bring the ECGP and ECGN inputs to the voltage selected by the 'Body Bias DAC' option.
	Common-Mode Voltage Source Select	Selects the common-mode inputs to the RLD circuit from either the filtered CAPP/CAPN pins or directly from the ECGP/ECGN pins. In general, the ECGP/ECGN pins are better at attenuating higher frequency common-mode signals such as power-line interference.
	IN+/IN- Average Enable	Selects which ECG inputs are averaged and used as an input to the RLD amplifier. For proper operation, both IN+ and IN- should be selected.
	Body Bias DAC	Configures the body bias voltage to use as input to the RLD circuit. This is V_{MID_ECG} plus or minus a configurable offset. This offset is used to compensate for electrode offset voltages.
	RLD Bandwidth	Sets the bandwidth of the inverting common-mode voltage amplifier. Higher bandwidth consumes more power, and the lowest bandwidth setting is adequate for power line frequencies.
	RLD Gain	Sets the gain factor of the inverting common-mode voltage amplifier. Higher gain settings provide the best common-mode noise rejection for electrodes with high-contact impedance, including dry electrodes.
	Out of Range Detect Enabled	Toggles whether the RLD out-of-range detector is enabled. This detects when the total impedance between the RLD electrode and input ECG electrodes is too high to maintain the feedback loop, usually because electrodes are off or have poor contact with the user.

BioZ Drive Tab

This tab can configure four types of stimuli: a balanced square-wave source/sink current, a sine-wave current, a sine-wave voltage, and an H-bridge voltage square wave. See the available options in Table 11 for more details.

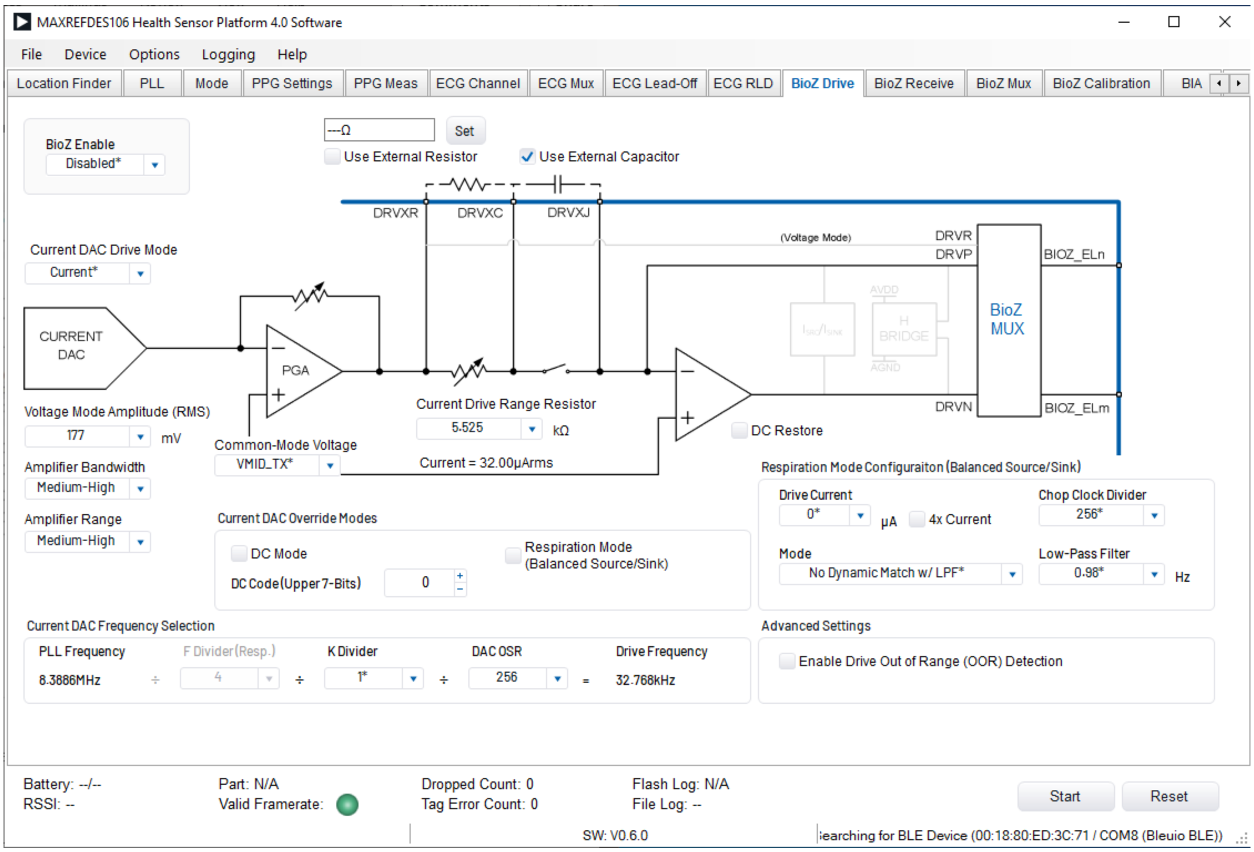


Figure 60. BioZ Drive Tab

Available Options

Table 11. BioZ Drive Configuration Options

BioZ Drive	BioZ Enable	Select I-Channel to Enable BioZ Measurement from the In-Phase Component or Q-Channel to Enable BioZ Measurement from the Quadrature-Phase Component.
	Current DAC Drive Mode	Offers several modes of stimulation that can be selected: **Current** for sine-wave current, **Voltage** for sine-wave voltage, **H-Bridge** for square wave voltage, and **Standby** for a low-power state where electrodes are driven to VMID_TX. **Standby** is useful to maintain electrode bias between measurements. Note that **Current DAC Drive Mode** is ignored when respiration is enabled.

	Voltage Mode Amplitude (RMS)	Adjust current and voltage amplitudes from the 'Current DAC'. There are four settings, 35.4mV, 70.7mV, 177mV, and 354mV. When **Voltage** is selected for **Current DAC Drive Mode**, the **Voltage Mode Amplitude** sets voltage RMS amplitude at DRVR. When **Current** is selected for **Current DAC Drive Mode**, the **Voltage Mode Amplitude** and **Current Drive Range Resistor** set the current magnitude and change the voltage amplitude at DRVR depending on the current drive range resistor used. Note that certain amplitudes are not available for certain stimulus frequencies to align with safety standards. Refer to the MAX86178 data sheet 'BioZ Transmit Channel' section for recommended settings and safety limits.
	Common-Mode Voltage	The Bioz drive channel is driven to the voltage selected in the **Common-Mode Voltage** setting. Selecting RLD enables the DRVN path to function as right led drive during BioZ measurement.
	Use External Capacitor	When sine-wave current is used for stimulation, an external capacitor must be inserted between DRVXC and DRVSJ pins on the MAX86178 to couple AC-stimulus current and prevent DC current from passing into the patient. Deselect to bypass this external capacitor.
	DC Restore	The BioZ channel drive channel contains a 10MΩ feedback resistance to the current drive amplifier to maintain DC bias of the drive electrodes during a lead-off event and reduce amplifier settling time when the lead is reconnected. Enabling the **DC Restore** applies this feedback resistance. This should be enabled if 'Cext' is used.
	Current DAC Frequency Selection	The BioZ drive frequency is generated by dividing the output of the PLL mux by **K Divider** and **DAC OSR**. Selecting respiration mode additionally divides this frequency by the **F Divider.**
Amplifier Settings	Amplifier Bandwidth	Sets the gain bandwidth of the voltage drive and current drive amplifiers. Higher bandwidth is recommended for high-frequency applications including bioimpedance analysis and impedance cardiography. Low bandwidth is recommended for low-frequency applications including galvanic skin response to reduce power consumption.
	Amplifier Range	Sets the output stage option for the voltage drive (1st) and current drive (2nd) amplifiers. Higher amplifier ranges are recommended for higher output current loading, although this consumes more power.
Current DAC Override Modes	DC Mode	The BioZ drive channel contains settings to override the default 'Current DAC' configuration and drive DC current instead of sine-wave current. Selecting **DC Mode** enables this functionality. When **DC Mode** is selected, the DC current magnitude is defined in 'DC Code' (upper 7-bits)

	Respiration Mode (Balanced Source/Sink)	Enabling **Respiration Mode** allows for balanced square wave source/sink current stimulation, and the **Current DAC Drive Mode** is ignored.
Respiration Mode Configuration (Balanced Source/Sink)	Drive Current/ 4x Current	Set the magnitude of square wave current. For safety reasons, 4x current should not be asserted unless the stimulus frequency is greater than 10kHz.
	Chop Clock Divider/Mode/Low-Pass Filter	Sets the settings for chopping BioZ measurement. Enabling chopping and CMFB with LPF reduces 1/f and 50Hz/60Hz noise. Refer to the MAX86178 data sheet 'BioZ Transmit Channel' section for details.
Advanced Settings	Enable Drive Out of Range (OOR) Detection	The sine-wave current drive has a maximum DRVN output compliance voltage of 0.2 to (V_{DD} – 0.2) volts. If 'Drive OOR' is selected, the DRVN OOR flag is asserted if the output voltage exceeds a range of 0.27 to (V_{DD} – 0.32) volts. The DRVN OOR indicator is located on the 'Plots' tab when the 'Respiration (BioZ)' plot is selected.

BioZ Receive Tab

This tab comprises an input MUX, a by-passable and programmable analog high-pass filter, an instrumentation amplifier with programmable gain, demodulator, anti-alias filter, another programmable gain amplifier, and an analog-to-digital converter (ADC). Refer to the MAX86178 data sheet for more details. See the available options in Table 12 for more details.

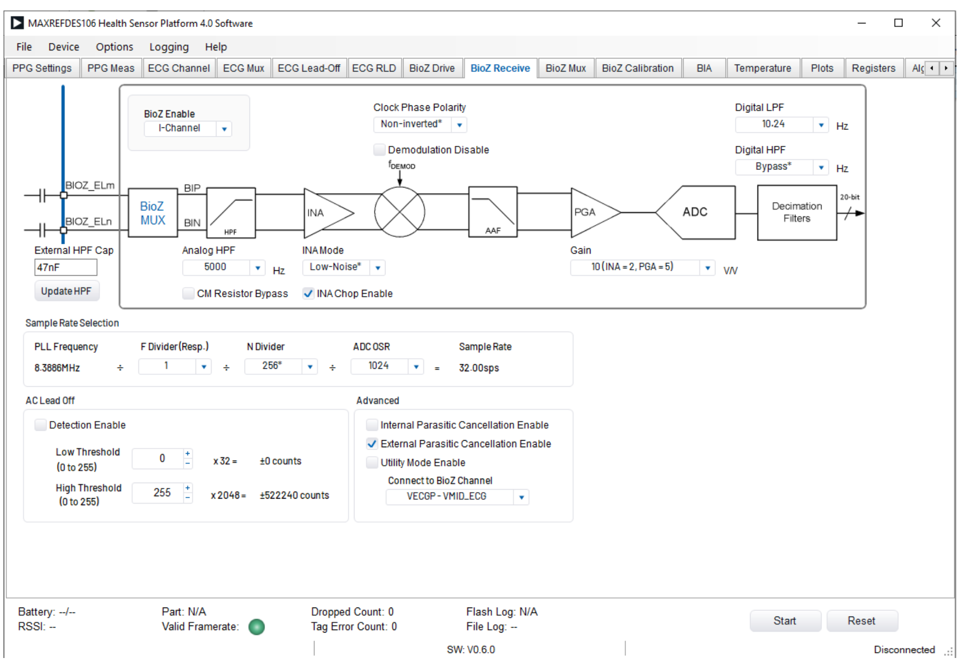


Figure 61. BioZ Receive Tab

Available Options

Table 12. BioZ Receive Configuration Options

BioZ Receive	BioZ Enable	Select I-Channel to Enable BioZ Measurement from the In-Phase Component or Q-Channel to Enable BioZ Measurement from the Quadrature-Phase Component.
	External HPF Cap	External capacitors can be connected at the MAX86178 BIP and BIN input paths for high-pass filtering. Enter the value of these capacitors in the **External HPF Capacitor** and click **Update HPF** to update. This value is required to calculate the allowable corner frequencies for **Analog HPF**.
	Analog HPF	Two filtering options. First, the MAX86178 has an internal HPF, with corner frequencies ranging from 100Hz to 10,000Hz. Second, the internal HPF can use the external HPF capacitor in place of its internal capacitor. The allowable corner frequencies are automatically calculated based on the external capacitor value. The analog HPF can be disabled by selecting the **Bypass** option. Refer to the MAX86178 data sheet 'BioZ Receive Channel' section for more details. When analog HPR is enabled, a 100MΩ resistor between the analog HPF midpoint and VMID_RX is connected by default to increase the common-mode input impedance. Select **CM Resistor Bypass** to bypass this resistor.
	INA Mode	Select **Low-Power** to reduce power consumption. Select **Low-Noise** for a lower SNR.
	Clock Phase Polarity	Allows the demodulator clock-phase polarity to be inverted. This is useful if electrodes are connected with inverted polarity. Selecting **Demodulation Disable** disables demodulation and allows a direct conversion of the differential input voltage across BIP and BIN.
	Gain	Sets BioZ receive channel gain by the combined gains of INA and PGA. There are four gain settings that are selected: 1V/V, 2V/V, 5V/V, and 10V/V.
	Digital LPF/HPF	Sets cutoff frequencies for 'Digital LPF' and 'Digital HPF' in BioZ receive channel. The cutoff frequencies for these filters are automatically calculated based on the BioZ ADC sample rate.
	INA Chop Enable	Selecting **INA Chop Enable** allows for 16kHz chopping in the INA.
Sample Rate Selection	Sample Rate	The BioZ receive channel sample rate is generated by dividing the output of the PLL mux by the **N Divider** and **ADC OSR.** Selecting respiration mode additionally divides this frequency by the **F divider**.
AC Lead Off	Detection Enable	Enable/Disable 'AC Lead Off' detection.

	Low/High Threshold	The BioZ channel can perform AC lead-off detection by comparing the BioZ ADC output to the Threshold defined in **Low Threshold** and **High Threshold**. If the output remains over the **High Threshold** or under the **Low Threshold** for over 128ms, the BIOZ_OVER or BIOZ_UNDER status bit is asserted.
Advanced	Internal/External Parasitic Cancellation Enable	Selecting 'Internal Parasitic Cancellation Enable' or 'External Parasitic Cancellation Enable' helps mitigate the effects of parasitic capacitances in the electrode-tissue interfaces to ensure phase accuracy in the BioZ measurement. When using **External Parasitic Cancellation**, internal guard amplifiers output guard signals at the MAX86178 pins BIOZ_EL2A and BIOZ_EL3A. Connect guard traces to these pins and surround the BIP and BIN nets to mitigate the effect of parasitic capacitances.
	Utility Mode Enable	Enables the BioZ ADC to measure a buffered copy of the voltage selected in **Connect to BioZ Channel**. Refer to the MAX86178 data sheet BIOZ section for more details.

BioZ Mux Tab

See the available options in Table 13 for more details.

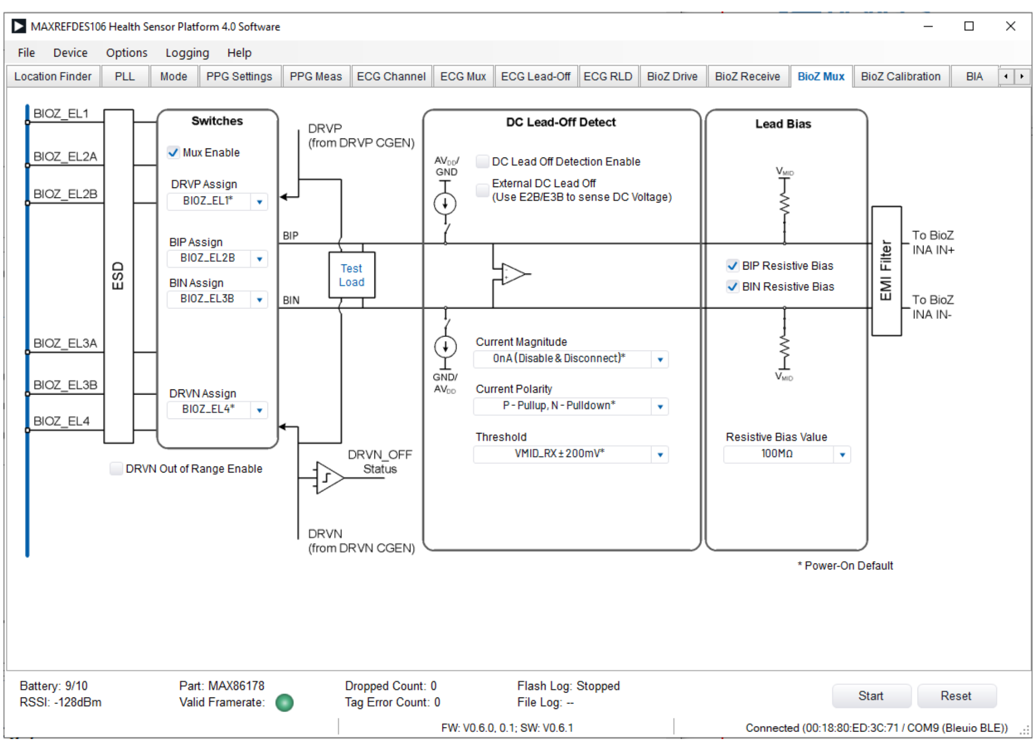


Figure 62. BioZ Mux Tab

Available Options

Table 13. BioZ Mux Configuration Options

Switches	Mux Enable/DRVP Assign/DRVN Assign/BIN Assign/DRVN Assign	Enable/Disable a Specially Programmed Mux that Assigns the IC Pins to the IC Internal Paths DRVP, BIP, BIN, and DRVN to Support Various BioZ Applications. Disabling the Mux Disconnects All Electrode and Calibration Pins. Enabling the Mux Connects Electrode Pins as Selected by the DRVP Assign, BIP Assign, BIN Assign, and DRVN Assign.
	DRVN Out of Range Enable	Enable DRVN lead-off detection.
DC Lead-Off Detect	DC Lead-Off Detection Enable	Enable/Disable the **DC Lead-Off Detection.**
	Current Magnitude/ Polarity	Define the DC source and sink currents.
	Threshold	When performing DC lead-off detection by injecting DC current and comparing the differential voltage across BIP and BIN to the voltage thresholds selected in **Threshold**.
Lead Bias	BIP/BIN Resistive Bias	Lead-biasing for the BioZ channel drives the electrodes within the input common-mode voltage requirements of the BioZ channel. It is recommended to enable both **BIP Resistive Bias** and **BIN Resistive Bias**.

BioZ Calibration Tab

This tab configures the calibration to ensure accurate impedance measurements. For proper calibration, gain and phase errors need to be calculated for each stimulus frequency. Refer to the MAX86178 data sheet ‘Calibration’ section for a full description of the calibration procedure and equations to calculate gain and phase errors.

The calibration procedure uses either internal programmable resistors or an external calibration resistor connected at the calibration pins. A default calibration file is loaded when the MAXREFDES106# GUI is opened.

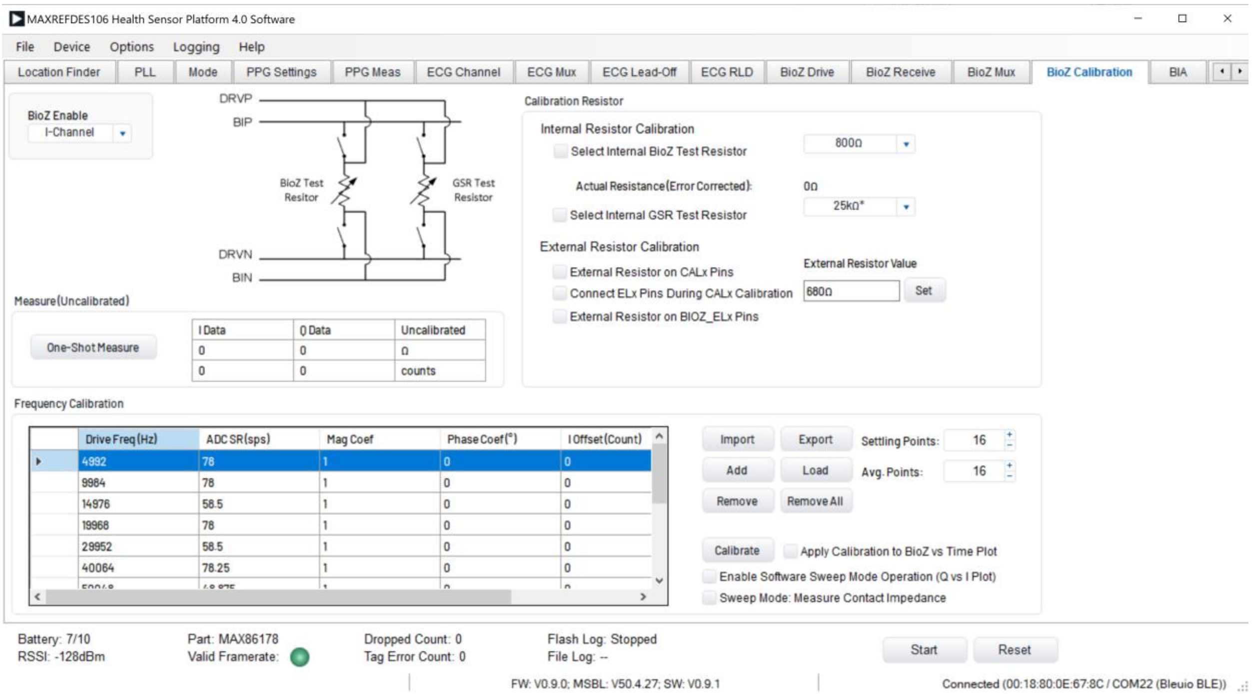


Figure 63. BioZ Calibration Tab

Available Options

Table 14. BioZ Calibration Configuration Options

BioZ Calibration	BioZ Enable	Select I-Channel to Enable BioZ Measurement from the In-Phase Component or Q-Channel to Enable BioZ Measurement from the Quadrature-Phase Component.
Measure (Uncalibrated)	One-Shot Measure	Select ‘One-Shot Measure’ to get a quick measurement of voltage and impedance using the settings defined in the **BioZ Drive**, **BioZ Receive**, and **BioZ Mux** without having to start data acquisition and having to view measurements in the ‘Plots’ tab.
Frequency Calibration		The GUI can automatically perform a calibration at multiple frequencies, allowing calibrated frequency sweeps for bioimpedance spectroscopy applications. A default calibration file is loaded when the GUI starts.
	Import/Export	After completing the calibration, selecting **Export** saves the calibration coefficients to a .csv file, which can later be reloaded by selecting **Import**.
	Add	Clicking **Add** copies the current ‘BioZ Drive Frequency’ in **PLL** tab into frequency list. Multiple frequencies can

		be added by configuring the 'BioZ Drive Frequency' in **PLL** tab to the desired settings, and then clicking **Add**.
	Load	Clicking **Load** loads the selected frequency in frequency list to 'BioZ Drive Frequency' in **PLL** tab.
	Remove/Remove All	Clicking **Remove** deletes the selected frequency from the frequency list. Clicking **Remove All** clears the frequency list.
	Calibrate	Press to start calibration with proper configuration.
	Apply Calibration to BioZ vs. Time Plot	Check **Apply Calibration to BioZ vs. Time Plot** during calibration.
	Enable Software Sweep Mode Operation (Q vs. I Plot)	After calibration, check **Enable Software Sweep Mode Operation (Q vs. I Plot)** to plot BioZ I channel vs. BioZ Q channel in **Plots** tab.
Calibration Resistor	Internal/External Resistor Calibration	Select either **Internal Resistor** or **External Resistor** for calibration.

Calibration Procedure:

1. A calibration file is loaded when the GUI starts. Desired/Undesired frequency can be added/deleted using **Add/Remove**.
2. Configure **BioZ Drive**, **BioZ Receive**, and **BioZ Mux** tabs with desired settings.
3. Calibration can be done using either **External Resistor Calibration** or **Internal Resistor Calibration**.

    a. **External Resistor Calibration**

    An external 680Ω, 0.05% precision resistor on CALx pins is included. To select the external precision resistor on the CALx pins :

    I. Select **External Resistor on CALx Pins.**

    II. The 680Ω value is the default value in the **External Resistor Value** box. If the value is changed, enter **680** in the box and press **Set** to confirm the selection. Press **Set** as typing the value in the box only **does not** properly set the resistor value.

    III. Select **Apply Calibration to BioZ vs. Time Plot** and press **Calibrate**.

    IV. As each frequency in list is calibrated, the new **Mag Coefficient** is automatically loaded into the frequency list.

    V. Uncheck **External Resistor on CALx Pins.**

    b. **Internal Resistor Calibration**

Internal resistors have an approximately 1.5% tolerance.

I. Check **Select Internal BioZ Test Resistor** and select internal resistance (5kΩ, 800Ω, 500Ω, 200Ω) according to the drive current being used for calibration. Refer to the MAX86178 data sheet for more information on setting BioZ drive current.

II. Disable **Mux Enable** in **BioZ Mux** tab.

III. Select **Apply Calibration to BioZ vs. Time Plot** and press **Calibrate**.

IV. As each frequency in list is calibrated, the new **Mag Coefficient** is automatically loaded into the frequency list.

V. Uncheck **Select Internal BioZ Test Resistor** and enable **Mux Enable** in **BioZ Mux** tab.

BIA Tab

The BIA tab is used to run the entire BIA measurement using the BioZ circuitry. See available options for BIA in the Table 15.

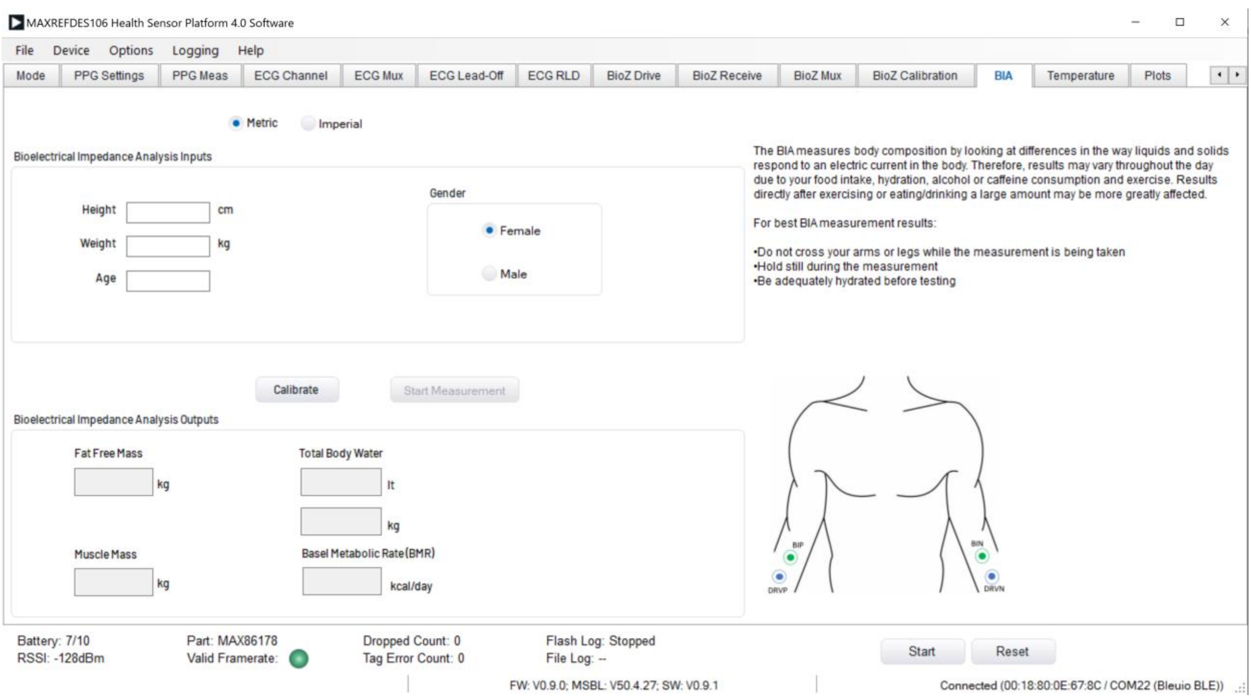


Figure 64. BIA Tab

Table 15. Options for BIA

Sub-Section	Option	Description
BIA	Units of Measurement	Select 'Metric' or 'Imperial' units when using BIA.
	Height, Weight, Age	Enter your height, weight, and age into the **Bioelectrical Impedance Inputs** window.
	Gender	Select 'Male' or 'Female' in the 'Gender' window.

Temperature Tab

The temperature tab is used to start, stop, and plot skin and ambient temperature measurements from the onboard MAX30210 clinical grade 0.1ºC accurate temperature sensor, calibrated in an oil bath. See the available options in Table 16 for more details.

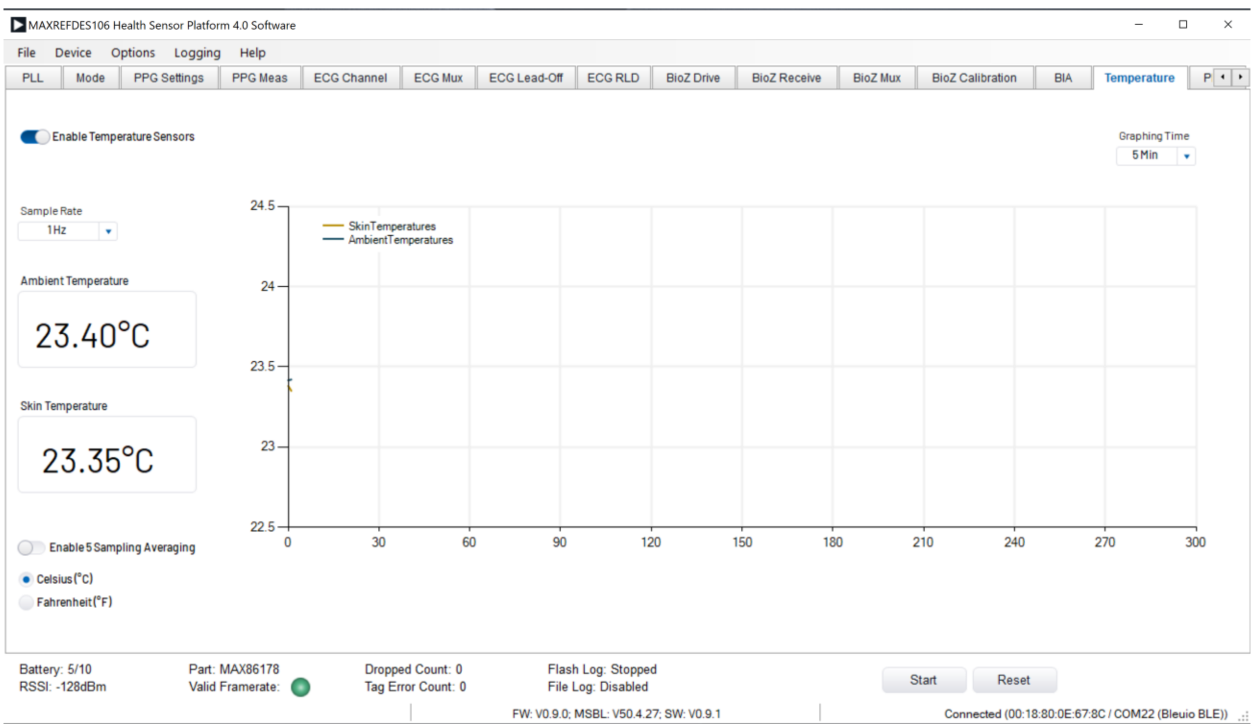


Figure 65. Temperature Tab

Available Options

Table 16. Temperature Configuration Options

Sub-Section	Option	Description
Temperature	Enable Temperature Sensors	Turns on or off the temperature sensors.
	Sample Rate	Sample Rate options: 1Hz, 2Hz, 4Hz, 8Hz, 10Hz.
	Enable 5 Sampling Averaging	Allows an average of five samples into one sample pushing to FIFO.
	Celsius/ Fahrenheit	Selects the units to display the temperature (°F or °C).
	Graphing Time	Selects X-axis time scale from 5 seconds, 10 seconds, 20 seconds, 30 seconds, 60 seconds, 2 minutes, 5 minutes, 10 minutes, and 20 minutes.

Plots Tab

The plots tab is where the output data for all measurements are displayed except for BIA having its own dedicated tab. ECG, PPG, BioZ, accelerometer signals, temperature, and HR, SpO_2, respiration algorithm can be viewed through their associated sub-sections in the left sidebar.

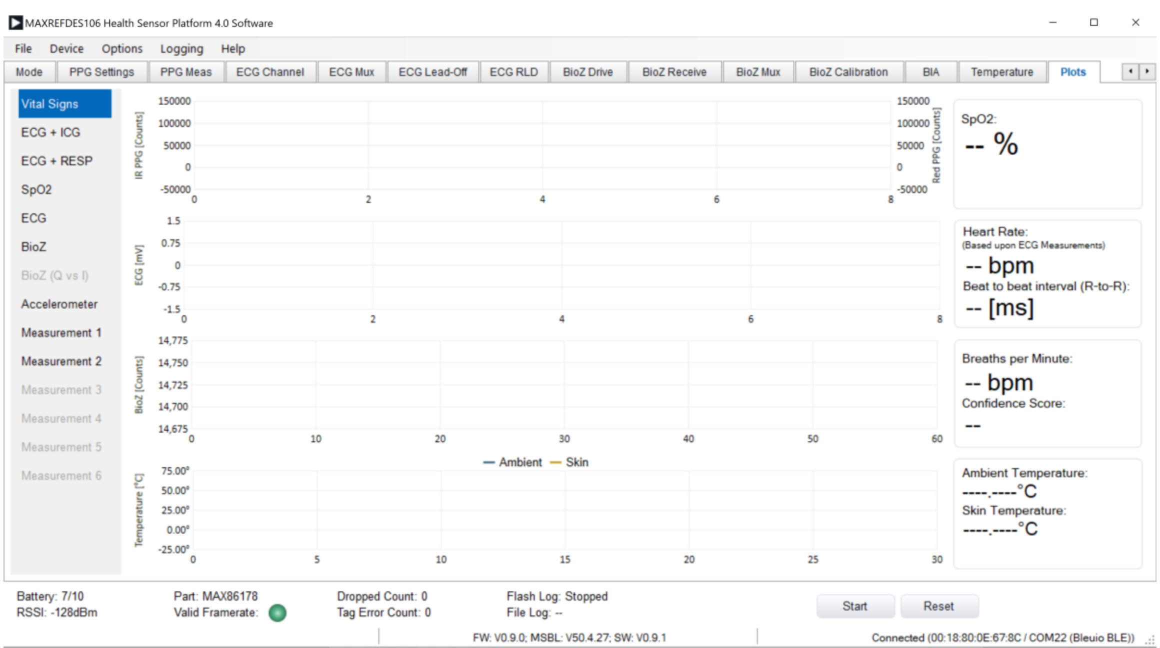


Figure 66. Plots Tab

1. **Vital Signs**

- Summary plots for PPG-SpO_2, ECG-HR, BioZ-Respiration, and Temperature (Skin/Ambient). See Figure 66 to select other combinations of signals.

2. **ECG + ICG**

- HR and ICG algorithm output and corresponding data can be viewed here.

3. **ECG + RESP**

- HR and Respiration algorithm output and corresponding data can be viewed here.

4. **SpO_2**

- SpO_2 algorithm output and PPG input data can be viewed here.

5. **ECG**

- HR algorithm output and ECG data can be viewed here.

6. **BioZ**

- Bio Impedance data can be viewed here.

7. **BioZ (Q vs. I)**

- Bioimpedance Q channel data versus I channel data can be viewed here.

8. **Accelerometer**

- Output data from the onboard accelerometer can be viewed here.

9. **Measurement 1-6**

- Raw PPG measurement data can be viewed here for enabled measurements.

Register Tab

The registers tab offers a view of the available internal registers of the onboard MAX86178, MAX30210, or ADXL367 accelerometer. Registers cannot be modified while the device is actively taking a measurement. The GUI highlights the registers being changed based on different settings. Modifying the devices at the register level can break their functionality, and extreme care should be taken when doing so.

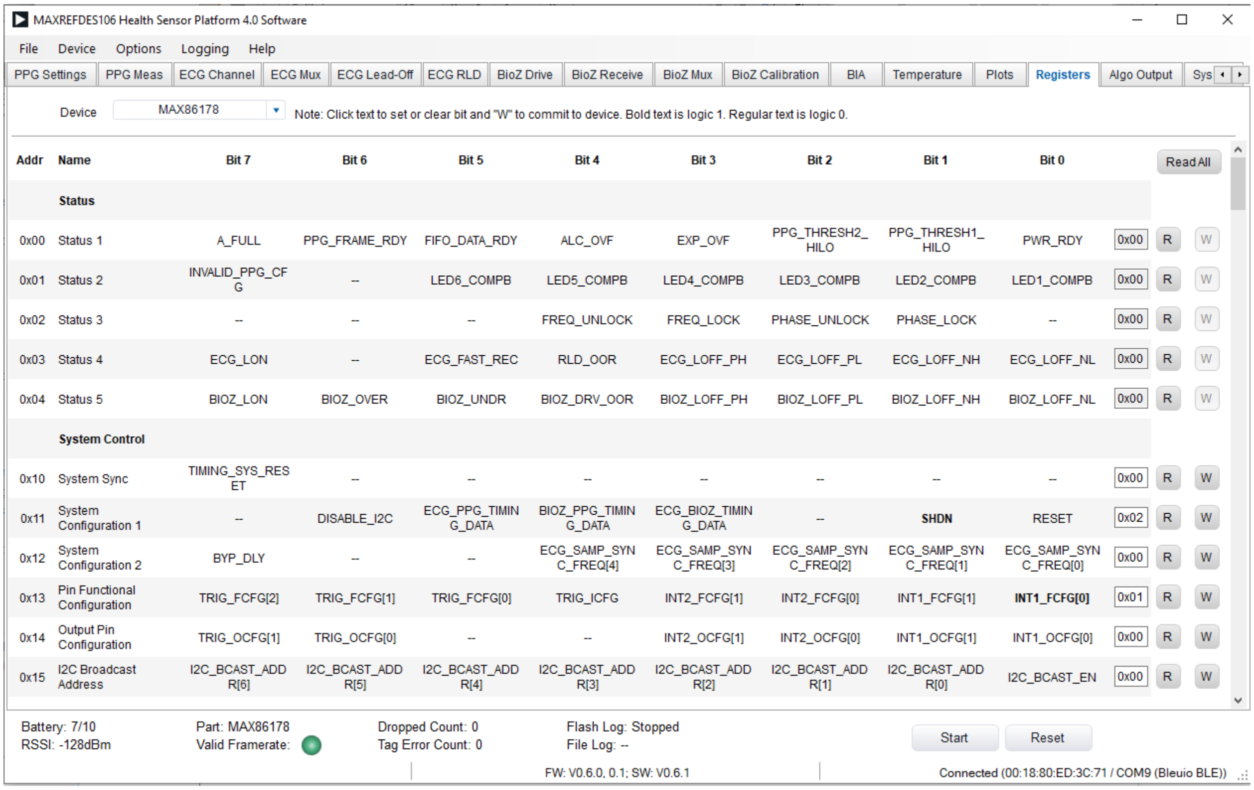


Figure 67. Registers Tab

Available Options

Table 17. Registers Configuration Options

Sub-Section	Option	Description
Registers	Device	Select the device registers to read/write to the MAX86178, MAX30210, or ADXL367.
	MAX86176	The MAX86178 is fully adjustable through software registers and the user can read/write to the register.
	MAX30210	The MAX30210 also has the flexibility to get controlled by registers and the user can read/write to the register.
	ADXL367	This is an accelerometer with certain info and control registers the user can control.

Data Logging

Logging to a File

1. To log data to the file, click the **Logging** tab of the GUI and select file logging (Figure 68)

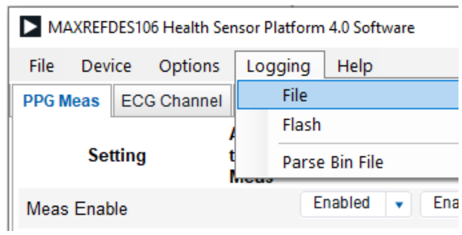


Figure 68. Data Logging to a File

2. The GUI prompts for a location to save the log file. Select an accessible location.
3. A check mark indicates that file logging is enabled. So does the **File Log : Enabled** status message in the status bar.
4. Click **Start** to begin collecting measurements and logging data to the file.
5. File logging data is saved in a .bin file and automatically parsed and processed into separate .csv files. See the section **Data Format**.
6. File logging is complete! Open the saved .csv file to view the data.

Logging to Flash Memory

Starting flash logging through the GUI is not supported currently.

1. Logging data to flash memory must be done through the push button on the MAXREFDES106#. Register settings can still be set using the GUI. However, before flash logging, the patch must be disconnected from the GUI. This can be done by selecting **Device** and then clicking **Disconnect (**Figure 69).

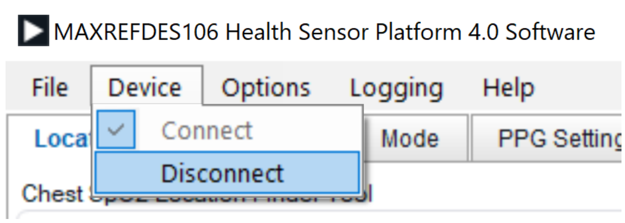


Figure 69. Disconnecting HSP4 from GUI

2. A successful disconnection shows the message 'Disconnected' in the bottom right corner of the GUI.
3. Once the patch is disconnected from the GUI, start flash logging by pressing the button on the MAXREFDES106# twice. If done correctly, a slow blinking 'Cyan LED' is seen. This indicates the patch has started measurements and is flash logging the data collected. See **Push Button Description** and **Status LED Color Definitions**.

4. To stop flash logging, press the button on the patch twice. See **Push Button Description** and **Status LED Color Definitions**.

    a. If the patch dies during flash logging, all data is safely stored and can be retrieved once powered back.

5. To recover the flashed data, connect the MAXREFDES106# to the computer using the included USB-C cable. It is detected as a mass storage device (or USB drive). Open the .bin file or copy it to the PC.

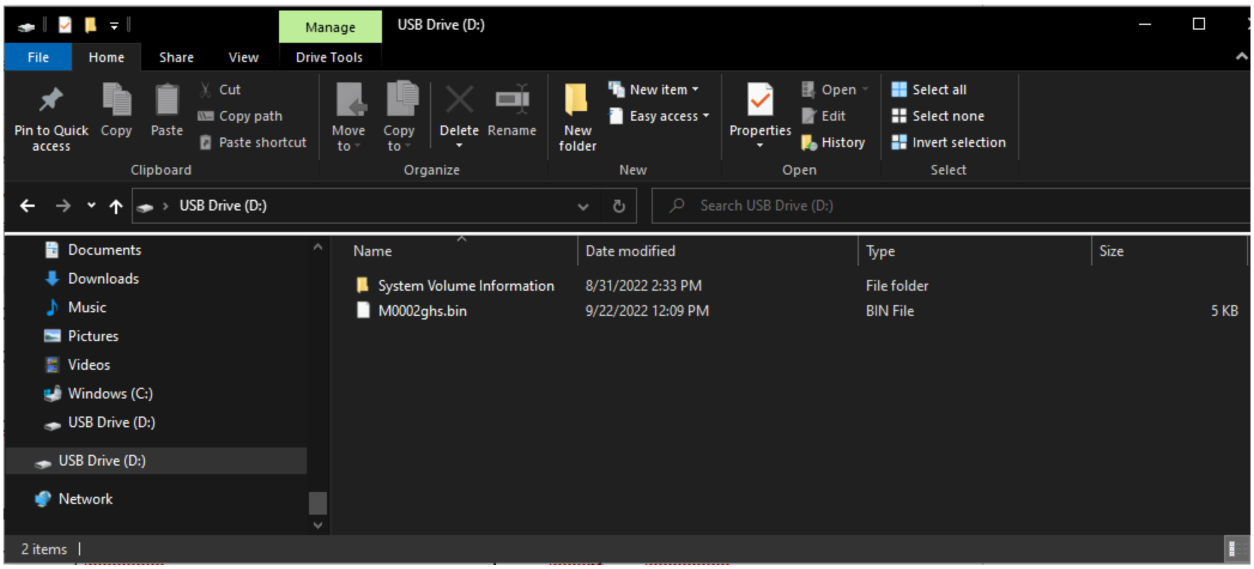


Figure 70. MAXREFDES106# Connected to a Computer, Using Included USB-C Cable, and Detected as a Mass Storage Device (USB Drive) Containing the Flash Logged .bin File

6. In the GUI, select **Logging,** then **Parse Bin File.**

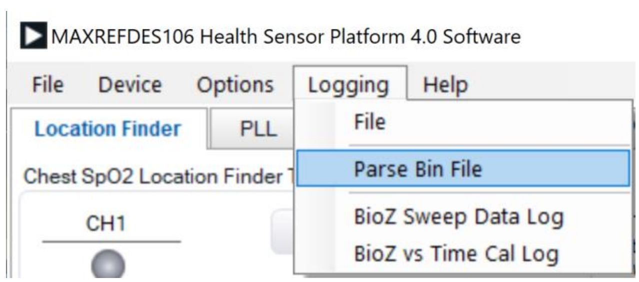


Figure 71. The Built-In Parser Processes, Converts, and Saves Flash Log Data to .csv Files

7. Select an input for the .bin file and output directory for the parsed .csv file.

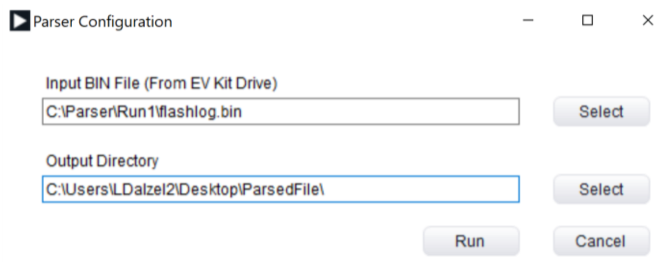


Figure 72. Parsing a Flash Log .bin File

8. Click **Run**. Once the parsing is complete, a status window displays some information about the log file and where it is saved. Long data sets may take more time.

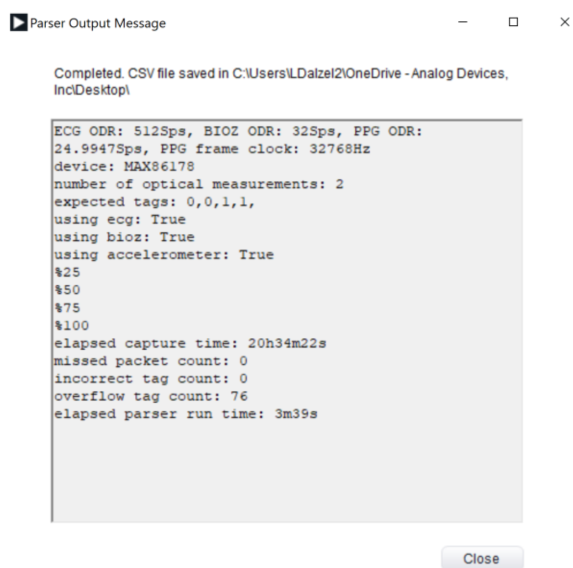


Figure 73. Completed Flash Log Parse Confirmation Window

9. Flash logging conversion is now complete! Open the saved .csv file to view the data.

Data Format for Logged Files

PPG, ECG, BioZ, accelerometer, and algorithm log files are saved in separate .csv files. PPG files are saved as **.ppg**, raw ECG files as **.ecg**, filtered ECG files as **.ecg_filtered**, BioZ logs as **.bioz**, accelerometer logs as **.acc**, and algorithm log files as **.algo**. These files can be opened with a standard .csv editor, such as Microsoft Excel. Temperature data can be logged in the **Temperature** tab.

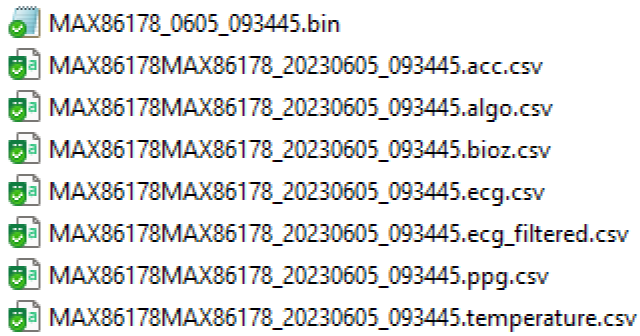


Figure 74. Log Files

Troubleshooting

USB Device Not Recognized

If the following message pops up when connecting the USB-C cable to the MAXREFDES106# to the PC, then unplug the MAXREFDES106#, and power down the MAXREFDES106# by holding down the push button for at least 13 seconds. Then, reconnect the USB-C cable to the MAXREFDES106# and PC. Allow MS Windows at least five minutes to finish initializing the COM Port driver. If this still does not remedy the issue, then retry this procedure using a different USB port on the PC that is not on an USB port extender.

Figure 75. USB Device Not Recognized

The USB Serial Device Associated with the MAXREFDES106# Does Not Show up as a COM Port in the Device Manager Ports Listing

Unplug the MAXREFDES106#, and power down the MAXREFDES106# by holding down the push button for at least 13 seconds. Then, reconnect the USB-C cable to the MAXREFDES106# and PC. Allow MS Windows at least five minutes to finish initializing the COM Port driver. If this still does not remedy the issue, then retry this procedure using a different USB port on the PC that is not on an USB port extender.

Drag and Drop Does Not Work: Updating the MAXDAP-TYPE-C Programmer

Follow these steps if the MAXDAP-TYPE-C does not show up as DAPLINK or the drag and drop into the DAPLINK fails to program the MAX32666.

The following procedure ensures that the MAXDAP-TYPE-C programmer is updated to the latest version.

Connect the MAXDAP-TYPE-C programmer to the PC with the Micro-USB cable while holding down the push button on the device. The easiest way to do this is to plug in the Micro-USB side of the cable to the programmer first, and then plug in the USB-A side of the cable to the PC while holding down the push button.

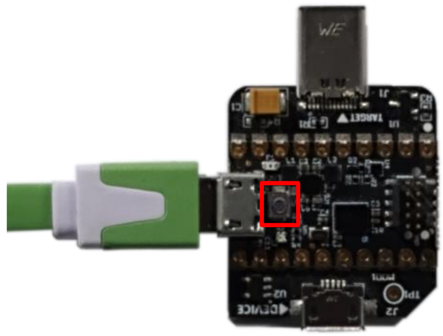


Figure 76. MAXDAP-TYPE-C Push Button

After about one second, the LED flashes and a new MAINTENANCE device appears in the list of available devices, as shown in Figure 77.

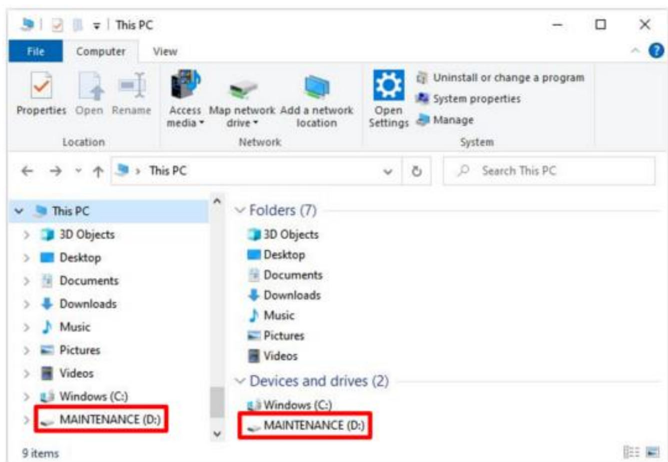


Figure 77. MAINTENANCE Drive

Drag and drop the https://github.com/MaximIntegrated/max32625pico-firmware-images/raw/master/bin/max32625_max32666hsp3_if_crc_dip_v1.0.5.bin file onto the MAINTENANCE drive. For a pop-up message up asking to copy the file without its properties, click **Yes**. The following window (Figure 78) appears while the programmer is being flashed.

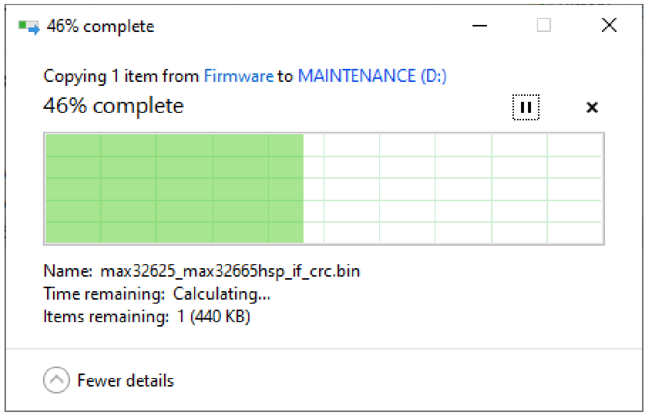


Figure 78. Wait for the Percent Complete Message to Finish and the MAXDAP-TYPE-C LED to Stop Flashing

Once the flash is complete, the MAINTENANCE drive disappears, and a new DAPLINK drive appears in a few moments. The programmer is now ready to be connected to the MAXREFDES106#.

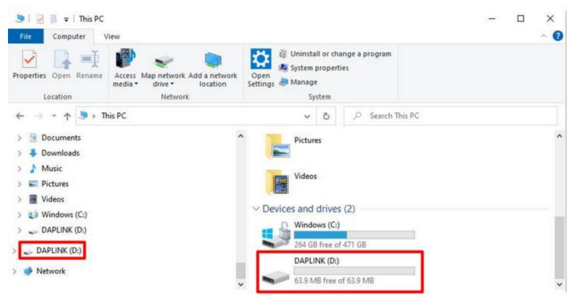


Figure 79. DAPLINK Drive

Packet Drop Counts Seen in the PC GUI

If packet drop counts are seen when using the PC GUI, then verify that the BleuIO version is 2.2.0 or higher.

Confirm that the BleuIO Dongle Firmware is Version 2.2.0+

1. The BleuIO dongle firmware must be updated to version 2.2.0 or higher. To confirm the BleuIO dongle firmware version number, plug in the BleuIO dongle and wait a few minutes for the MS Windows drivers to finish installing.

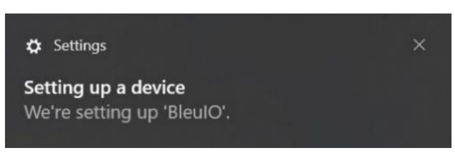


Figure 80. Wait for MS Windows to Install BleuIO Dongle Drivers

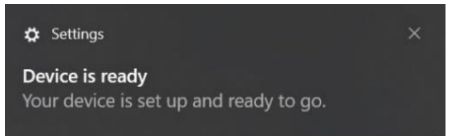


Figure 81. MS Windows Finished Installing BleuIO Dongle Drivers

2. Open the 'Device Manager' and note the COM port associated with the BleuIO dongle (the COM port number may be different from Figure 82). The COM port number for the BleuIO dongle changes to a different COM port after ten seconds after it is plugged in. To confirm the version number, note the COM port number after the BleuIO is plugged in for at least ten seconds.

Figure 82. After the BleuIO is Plugged in for at Least 10 Seconds, Note the USB Serial Device COM Port Number for the BleuIO Dongle

3. Download and install a terminal emulation software such as Tera Term software from the web: Download File List - Tera Term - OSDN.

   Run the Tera Term software and select **File**, **New connection**.

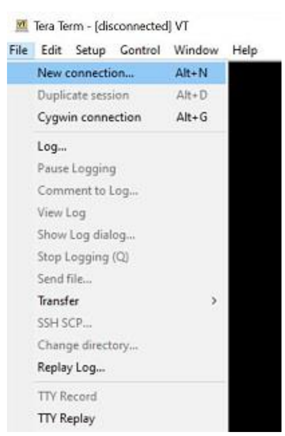


Figure 83. Tera Term: File, New Connection

Select the 'Serial' and COM port noted and click OK.

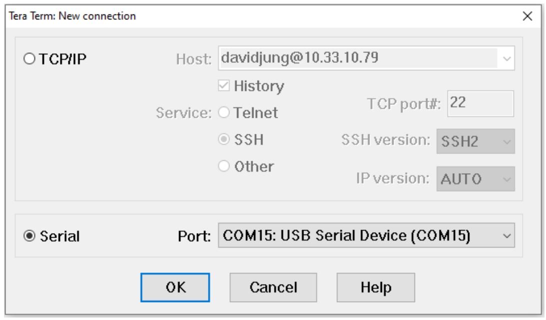


Figure 84. Tera Term: Serial, COM (Noted Port Number)

4. Enter ATI in the Tera Terminal and verify that the version is 2.2.0 or higher. If not, update the BleuIO Dongle firmware in the troubleshooting section.

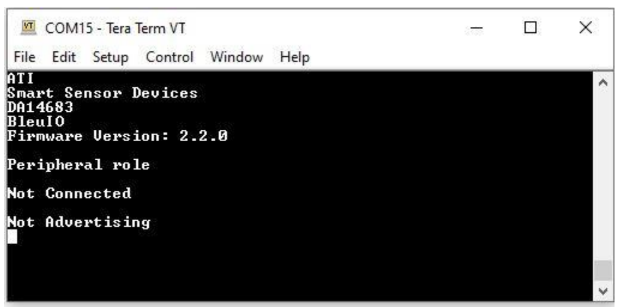


Figure 85. Tera Term: ATI Command Entered

Updating the BleuIO Dongle Firmware to 2.2.0

Update the BleuIO dongle firmware to version 2.2.0 or higher.

Open the 'Device Manager' and note the COM port associated with the BleuIO dongle (the COM port number may be different from Figure 86). The COM port number for the BleuIO dongle changes to a different COM port after ten seconds after it is plugged in. To update the BleuIO firmware, note the COM port number displayed during the first nine seconds after the BleuIO is plugged in.

Figure 86. Note the USB Serial Device COM Port Number for the BleuIO Dongle During the First Nine Seconds

The procedure to reflash the BleuIO dongle is found in the following link:

https://www.bleuio.com/getting_started/docs/firmware/

The instructions to flash the BleuIO to version 2.2.0 are summarized here.

Download the bleu.2.2.0.zip file.

https://www.bleuio.com/getting_started/docs/firmware/

Extract the **bleuio.2.2.0.img** to a folder such as c:\tmp.

Download the host_usb_updater.zip file.

https://smart-sensor-devices-ab.github.io/ssd005-manual/files/host_usb_updater.zip

Extract the **host_usb_updater.exe** to the same folder in the previous step.

Close the Tera Term window if it is running.

Open a **Command Prompt** using the administrator account login.

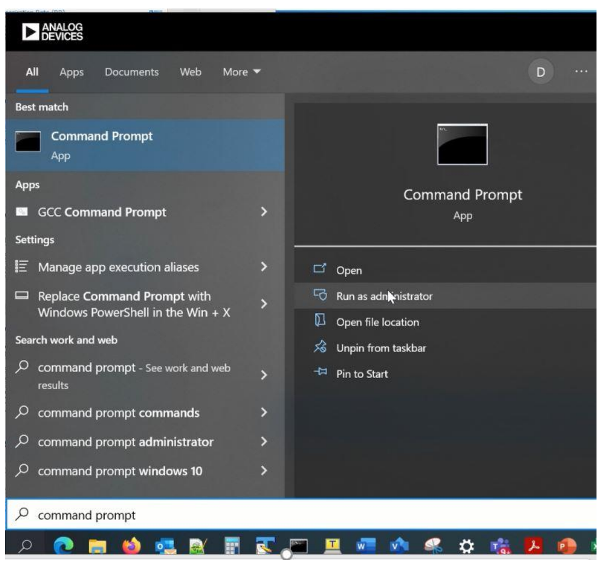


Figure 87. Run Command Prompt Using the Administrator Account

Open a **Command Prompt** window and change the directory to **c:\tmp** by entering the command **cd c:\tmp.**

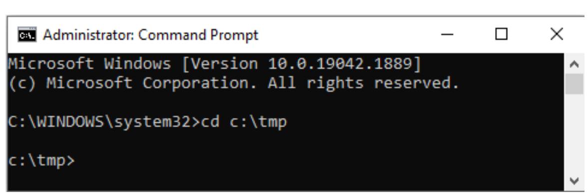


Figure 88. Change the Directory to c:\tmp

Without hitting **Enter**, type in the following command, but replace xx with the BleuIO COM port number found during the first nine seconds after the BleuIO is plugged in.

host_usb_updater xx bleuio.2.2.0.img -verbose

Unplug the BleuIO dongle, wait three seconds, and be ready to press **Enter** in the **Command Prompt** window and be ready to enter the administrator password to the PC (copy the log in ID to the paste buffer for quicker response). The update command must be initiated as soon as the BleuIO dongle is plugged in. The bootloader times out in ten seconds, and there are error messages if the flashing of the firmware is not completed within ten seconds; retry the procedures (unplug dongle, 'up arrow' the above command, plug in the dongle, press **Enter** for the command above).

```
C:\tmp>host_usb_updater 14 bleuio.2.2.0.img -verbose
HOST_USB_UPDATER_VERSION = 2
opening serial port successful
=== Try loading firmware image ===
=== Try to perform USB firmware update ===
HOST=[issue_command: INFO - sent: getsuousbbuffsz]
PASS=[OK 4096]
HOST=[issue_command: INFO - sent: alloc 2048]
PASS=[OK]
HOST=[issue_command: INFO - sent: fwupdate]
PASS=[OK]
do_firmware_update: start work
issue_command_get_ok:COMMAND: SUOUSB_WRITE_STATUS 0 2 0100

issue_command_get_ok: WAIT
issue_command_get_ok: YES, got [OK]
issue_command_get_ok:COMMAND: SUOUSB_GPIO_MAP 0 4 00050102

issue_command_get_ok: WAIT
issue_command_get_ok: YES, got [OK]
issue_command_get_ok:COMMAND: SUOUSB_PATCH_LEN 0 2 0010

issue_command_get_ok: WAIT
issue_command_get_ok: YES, got [OK]
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 0
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 4096
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 8192
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 12288
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 16384
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 20480
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 24576
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 28672
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 32768
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 36864
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 40960
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 45056
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 49152
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 53248
```

```
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 57344
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 61440
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 65536
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 69632
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 73728
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 77824
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 81920
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 86016
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 90112
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 94208
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 98304
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 102400
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 106496
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 110592
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 114688
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 118784
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 122880
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 126976
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 131072
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 135168
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 139264
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 143360
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 147456
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 151552
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 155648
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 159744
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 163840
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 167936
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 172032
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 176128
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 180224
do_firmware_update: send 4096 byte block 2 * 2048 chunks) @ 184320
do_firmware_update: end 4096 byte block processing - OK - remainder:356
do_firmware_update: set up block size 356
issue_command_get_ok:COMMAND: SUOUSB_PATCH_LEN 0 2 6401
```

```
issue_command_get_ok: WAIT
issue_command_get_ok: YES, got [OK]
do_firmware_update: set up block size 356 - OK
do_firmware_update: send 356 byte block @ 188416
do_firmware_update: end last block processing - OK - remainder:0
issue_command_get_ok:COMMAND: SUOUSB_READ_MEMINFO 0 1 00

issue_command_get_ok: WAIT
issue_command_get_ok: YES, got [OK 188772]
do_firmware_update: SUOUSB_READ_MEMINFO size ok 188772 188772 [OK 188772]
do_firmware_update: send suousb_mem_dev_end
do_firmware_update: wait SUOUSB_CMP_OK
do_firmware_update: send suousb_mem_dev_reset
do_firmware_update: STOP
Result:Pass

C:\tmp>
```

Figure 89. BleuIO Firmware Successfully Updated to Version 2.2.0