MAXREFDES104# HEALTH SENSOR PLATFORM 3.0

User Guide

UGxxxx; Rev 1.2.0; 8/21

maxim integrated™

Abstract

This user guide provides information about preparing and running the MAXREFDES104# health sensor band. This platform uses high-sensitivity PPG, ECG, and temperature biosensors, a power-management IC (PMIC), and a microcontroller from Maxim Integrated® in a wrist-worn design to capture biometric signals important to healthcare. The platform also contains algorithms to calculate heart health and blood oxygenation based on the biosensor measurements.

Rev. 1.1.0, May 2021

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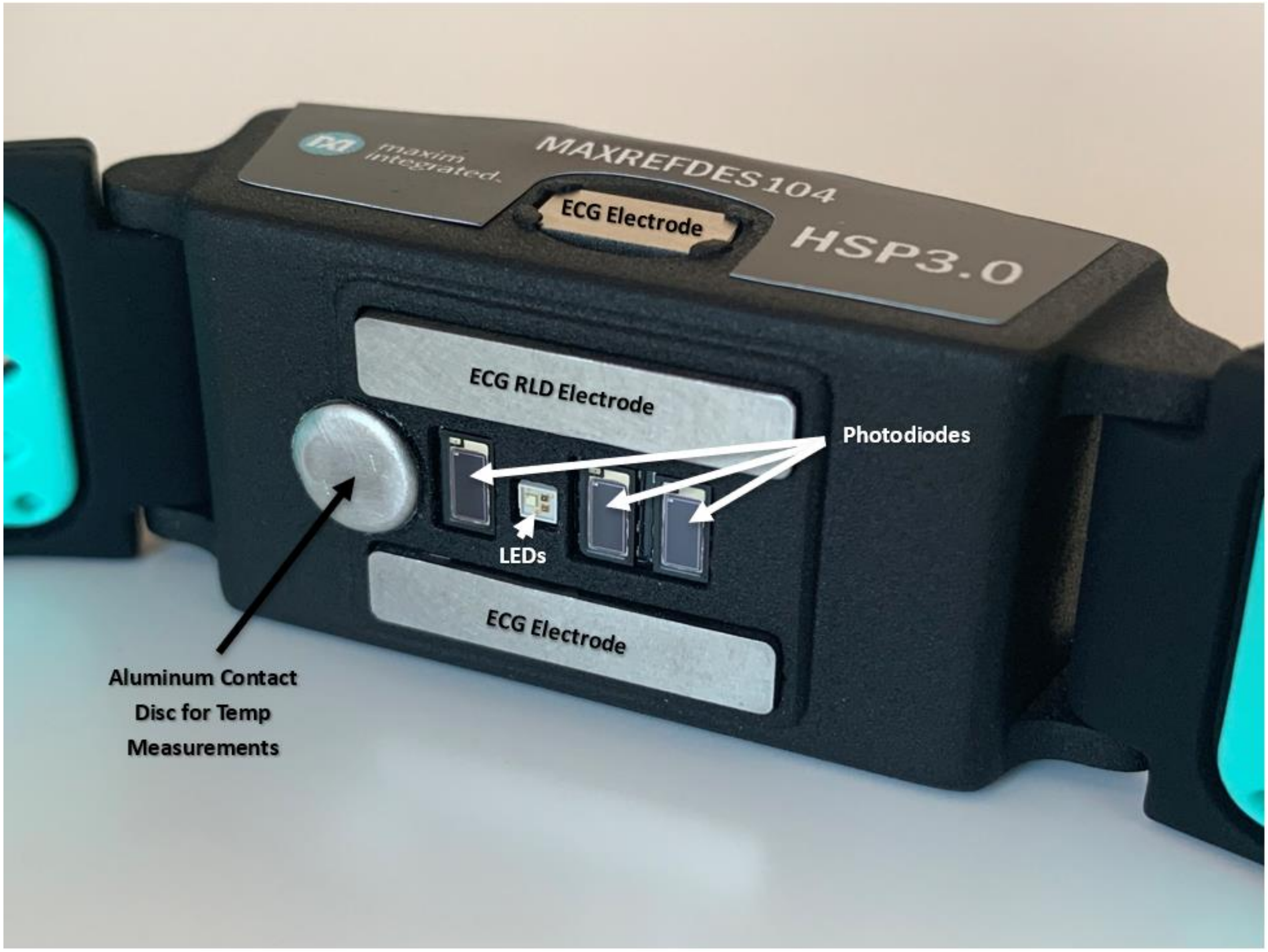


Figure 1. MAXREFDES104# bottom and side view.

Note on the enclosure:

The MAXREFDES104# Health Sensor Platform 3.0 is not waterproof or sweatproof. Keep it away from any excessive liquids including wrist perspiration, as it might damage the sensitive electronics inside by shorting out exposed pads.

Figure 2. MAXREFDES104# top view.

2 Included Components

The MAXREFDES104# platform includes the following components:

- MRD104 Micro Board
    - 32MB Flash Memory (MX25U51245GZI54)
    - MAX32670 Microcontroller and Algorithm Coprocessor (Algorithm Hub)
    - MAX20360 Power Management IC (PMIC)
    - MAX32666 Host Microcontroller (Host MCU) with Integrated BLE
    - Status LEDs
- MAX86176 Sensor Board
    - MAX86176 ECG and PPG Biosensor AFE
    - LEDs: 1 Green, 1 Red, 1 IR [OSRAM SFH7016]
    - 3 Photodiodes [Vishay VEMD8080]
    - 3-Axis Accelerometer [ST Micro LIS2DS12]
- MAX30208 Temperature Sensor connected to Aluminum contact disc
- Li-Po Battery 105mAh [Adafruit 1570]
- MAXDAP-TYPE-C Programming Adapter
- Cy Smart CY5677 BLE USB Dongle
- Stainless Steel (ANSI SS304) ECG Dry Electrodes (3 pcs.)
- 3D Printed Enclosure and Band

2.1 Additional Components Required

- PC Running Windows 10+
- Microsoft .NET framework 4.7 or later

3 System Diagram

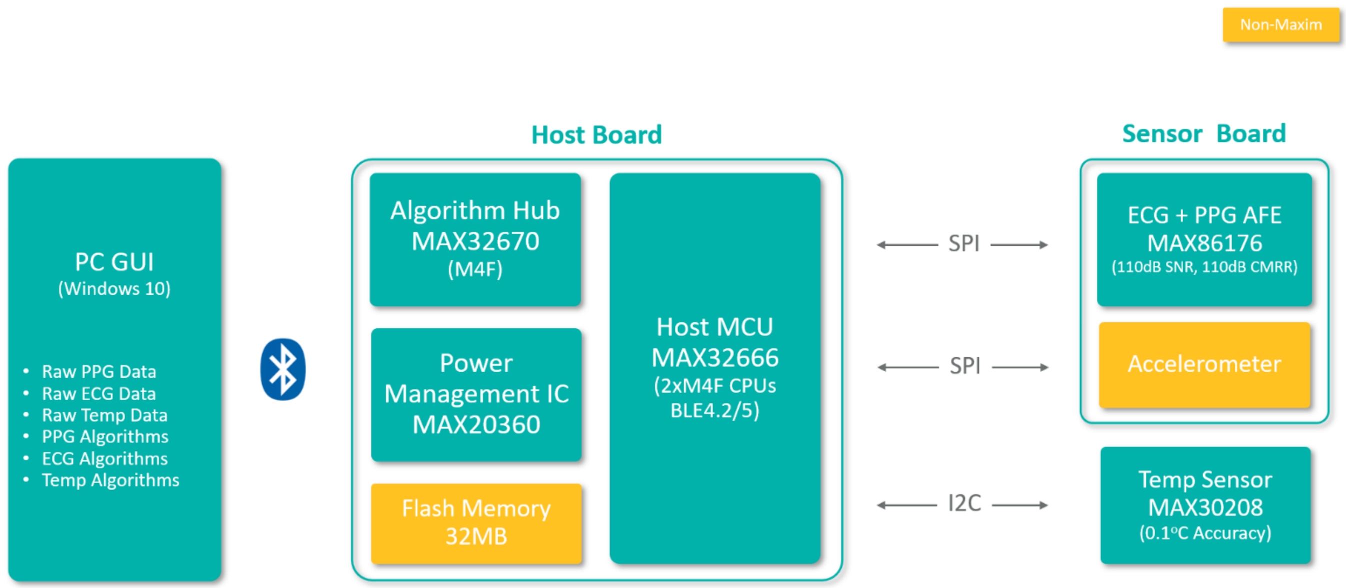


Figure 3. MAXREFDE104# system diagram.

4 Updating the Firmware

It is critical to update the MAXREFDES104# firmware to the latest version to ensure the device is running the latest features and interfaces with the Evaluation GUI correctly.

4.1 Updating the Host MCU Firmware (.bin)

This section discusses updating the system firmware of the MAXREFDES104#. This firmware is responsible for the high-level system management of the device and is flashed to the onboard MAX32666 host MCU. The MAXREFDES104# system firmware is updated using the included MAXDAP-TYPE-C Programming Adapter.

Required Equipment

All the following necessary components are included in the MAXREFDES104# package:

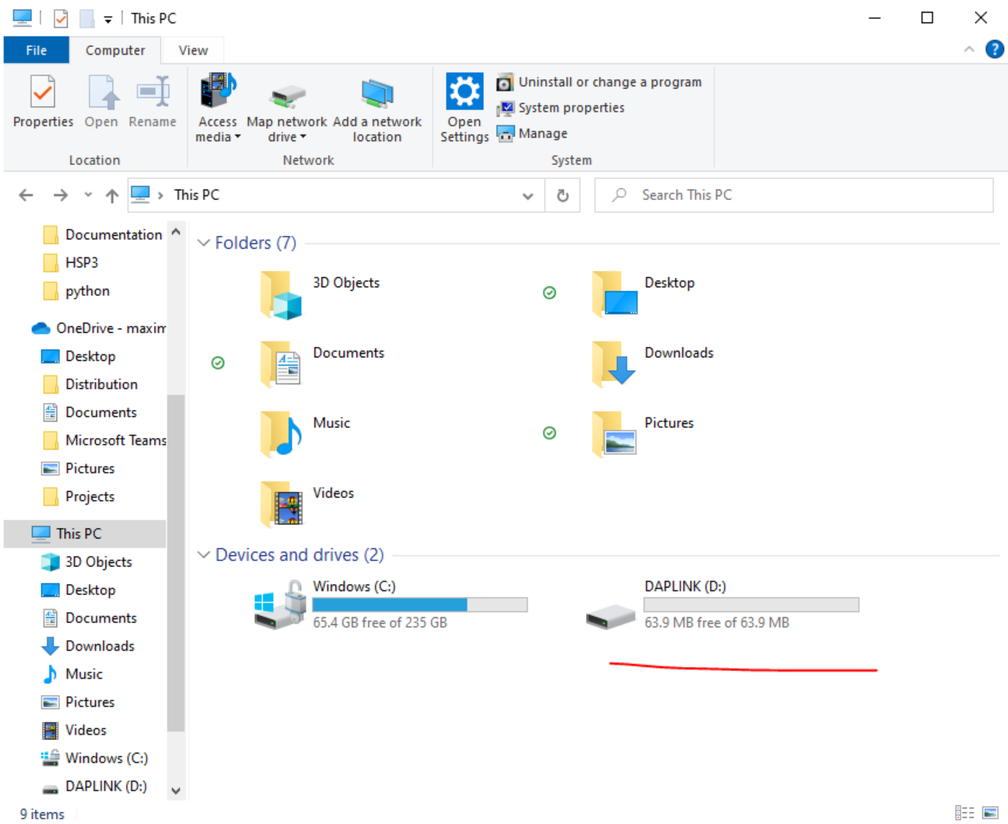
- MAXDAP-TYPE-C Programming Adapter
- USB-A to Micro-USB Cable
- MAXREFDES104#

Procedure

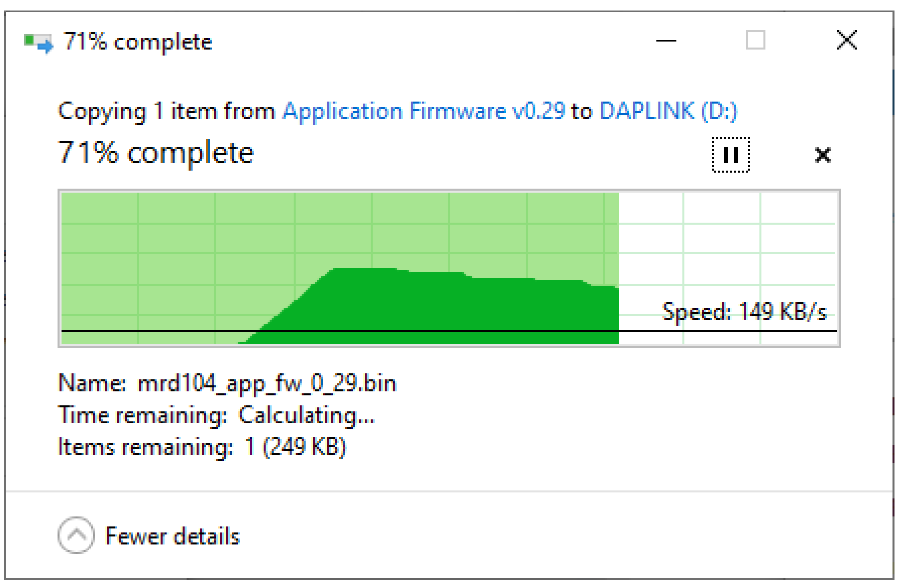
Follow this procedure to update the MAXREFDES104# device system firmware. The latest firmware file can be downloaded from the Design Resources tab of the MAXREFDES104# Product Page *here*.

1. Connect the MAXDAP-TYPE-C programmer to the USB-C port of the MAXREFDES104# as shown below:

2. The LED on the MAXDAP-TYPE-C programmer will blink, and a new DAPLINK drive will appear in the list of available devices and drives in File Explorer, as shown below:

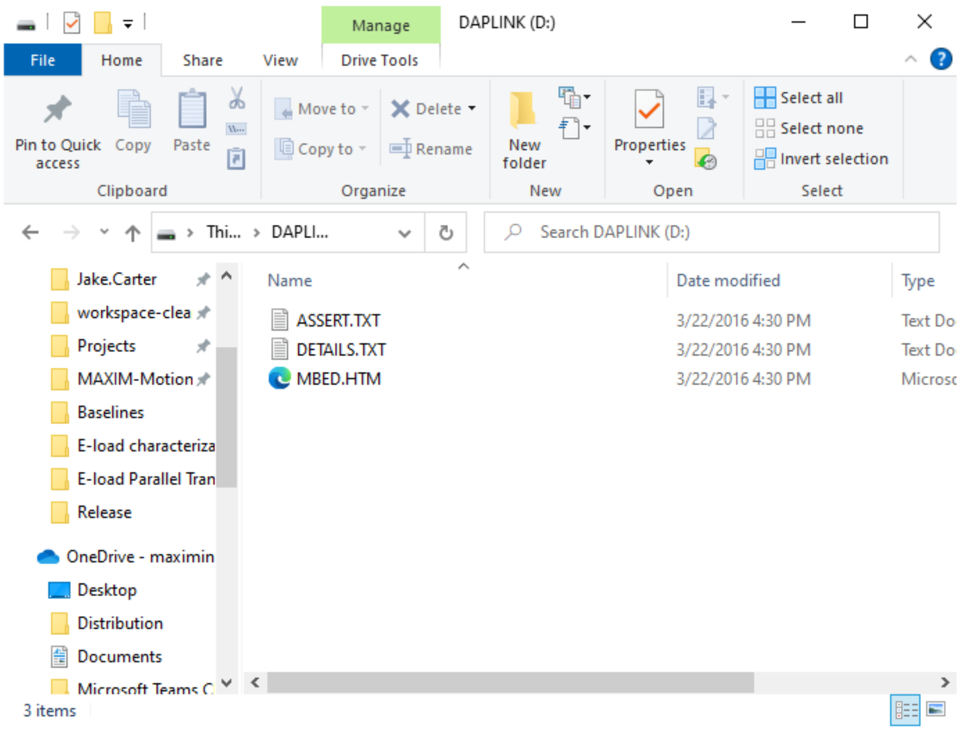


3. Drag and drop the host MCU firmware image onto the DAPLINK drive. This file has the filename **mrd104_app_fw_x_xx.bin**, where **x** indicates a version number and is located in the “MAX32666_FW” sub-folder of the MAXREFDES104 software package.



4. Once the flash is complete, open the DAPLINK drive again and verify the flash is successful by checking for the absence of a FAIL.TXT file. A successful flash will look similar to the screenshot below.

   If there is a FAIL.TXT file in the DAPLINK drive, follow the procedure in the *Section 4.3 - Updating the MAXDAP-TYPE-C Programmer* and return to step 1 afterwards.



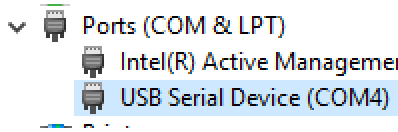
5. Unplug the MAXDAP-TYPE-C programmer and power cycle the MAXREFDES104# with the power button (12 second press). See *Section 5.1 – Button Functionality* for more details on power-cycling.

6. The MAXREFDES104# is now successfully updated to the latest firmware!

4.2 Updating the MAX32670 Algorithm Hub Microcontroller Coprocessor Firmware (.msbl)

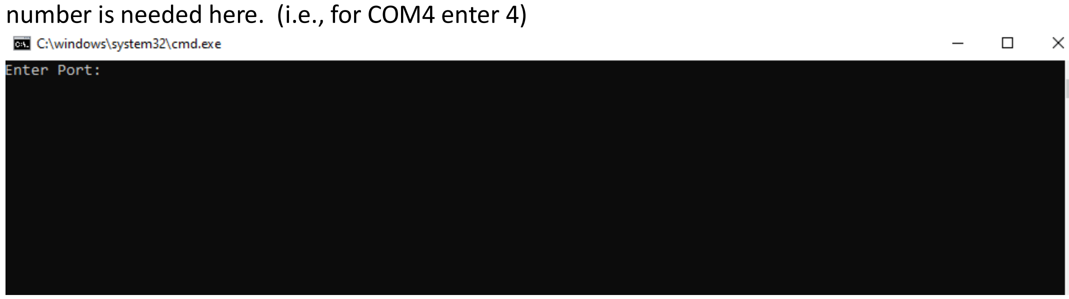
1. Connect the MAXREFDES104# to the PC with the included USB Type-C cable. **Note**: If you are continuing onto here from Section 4.1, unplug the MAXDAP-TYPE-C adapter. This connection goes directly to the MAXREFDES104# from your PC.

2. Open the Device Manager and take a note of the COM port associated with the MAXREFDES104#.

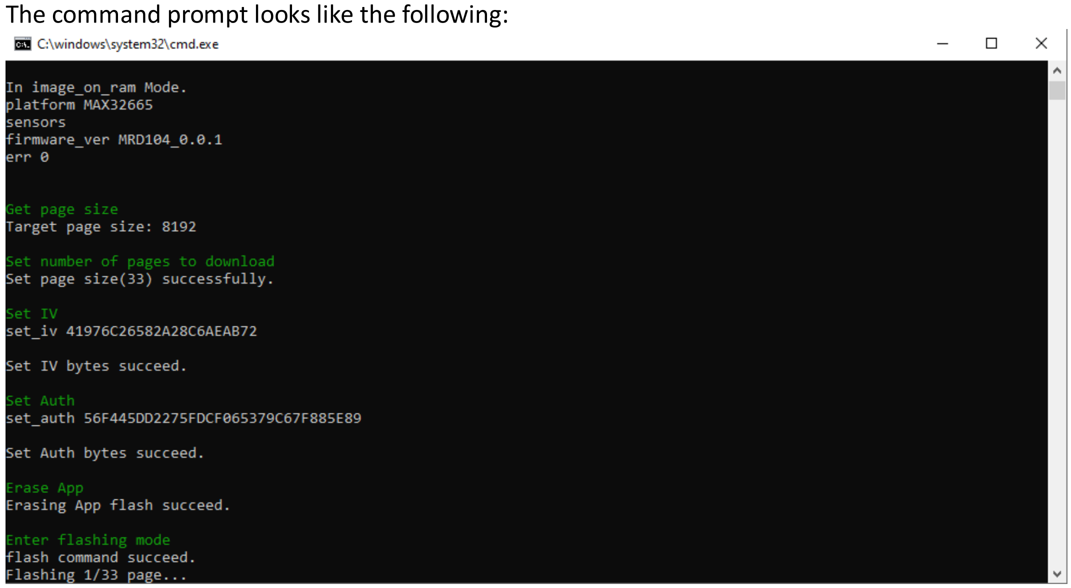


3. Navigate to the MAX32674_FW sub-folder of the MAXREFDES104# software package.

4. Double click the Flash_MAX32670_FW.bat file (not the .exe file). A command prompt opens and ask for a port number. Enter the COM port # from step 2 and press ENTER. Only the port number is needed here. (i.e., for COM4 enter 4)



5. After pressing ENTER, the program begins flashing the MAX32670 with the latest firmware. The command prompt looks like the following:



6. Monitor the output of the program for success. A successful flash looks as follows, with the **Flashing MSBL file succeed…** message.

```
Flashing 30/33 page...[DONE]
Flashing 31/33 page...[DONE]
Flashing 32/33 page...[DONE]
Flashing 33/33 page...[DONE]
Flashing MSBL file succeed...

Jump to main application
Jumping to main application. ret: 0
SUCCEED...
Closing
Press any key to continue . . .
```

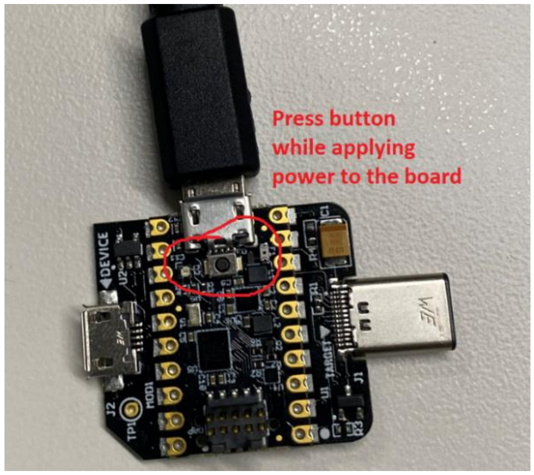
7. (Optional) If the **FAILED to jump application…** message appears, power cycle the device (12 second press) with the power button. See *Section 5.1 – Button Functionality* for more details on the power button.

8. The MAX32674 Algorithm Hub Microcontroller Coprocessor is now updated to the latest firmware!

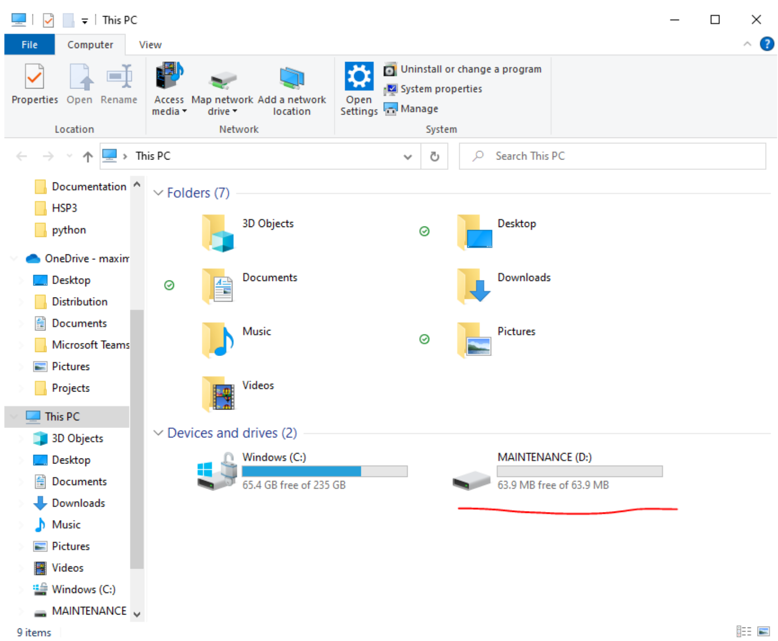
4.3 Updating the MAXDAP-TYPE-C Programmer (Optional)

Follow these steps if flashing the MAXREFDES104# fails on multiple attempts. This ensures that the MAXDAP-TYPE-C programmer is updated to the latest version.

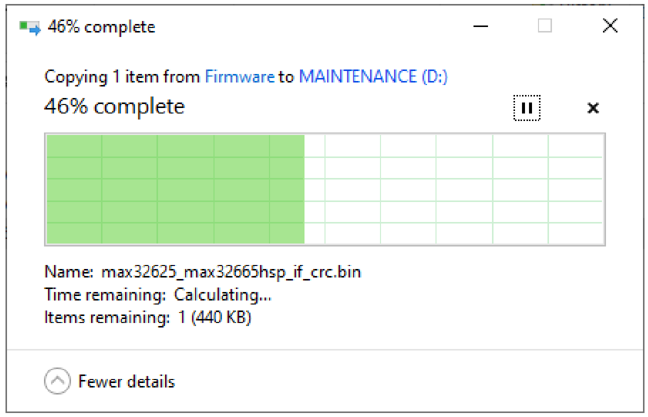
9. Connect the MAXDAP-TYPE-C programmer to the PC with the Micro-USB cable **while holding down the push button on the device**. The easiest way to do this is to plug in the Micro-USB side of the cable to the programmer first, and then plug in the USB-A side of the cable to the PC while holding down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



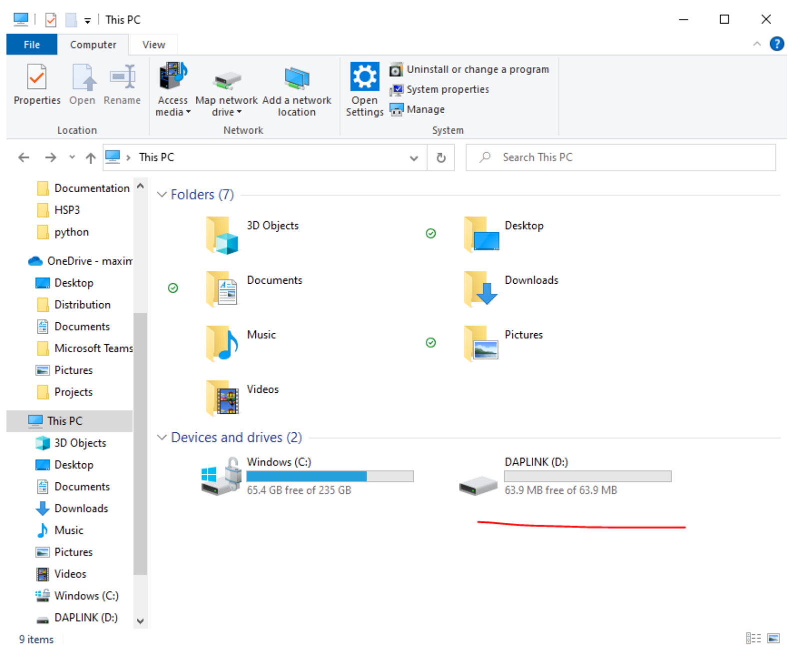
10. After about one second, the programmer lights flash and a new MAINTENANCE device appears in the list of available devices (as shown in the following figure).



11. Drag and drop the [max32625_max32665hsp_if_crc.bin]() file onto this MAINTENANCE drive. If a message pops up asking to copy the file without its properties, click yes. The following window appears as the programmer is flashed.



12. 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 MAXREFDES104#.



5 Operating the Health Sensor Band

5.1 Button Functionality

The button closest to the edge of the device is the **power button**. The only functions of this button are to power on and off the device.

- To power **on** the device, press and hold the power button for **one second** and release. The status LED turns on.
- To power **off** the device, press and hold the power button for **3 to 12 seconds**. The status LED will blink magenta and turns off upon releasing the button.
- To **hard power off** the device (if the device is unresponsive) hold the power button for **12-15 seconds** until the status LED turns off.

The other button, labelled with a bold '**F**', is aptly named the 'F button'. This function button stops flash-logging after it has been started and has no other functionality. See Section 8.2 – Logging to Flash Memory for more details.

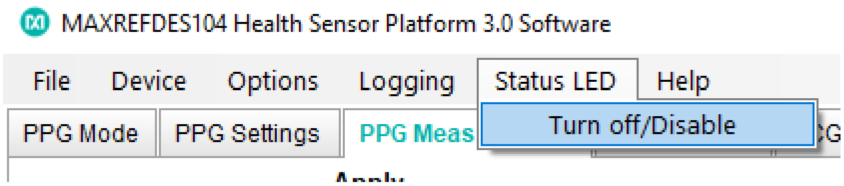
5.2 Status LED Color Definitions

Table 1. Status LED Color Definitions

LED COLOR	SOLID (NO BLINKING)	FAST BLINK	SLOW BLINK
Red	Failure detected (needs system reset)	Communications failed	Battery critically low (< 10%)
Green	USB connected (no data streaming)	Streaming USB data	Device is ready (no USB connection)
Blue	Reserved	Streaming Bluetooth LE data	Bluetooth Low Energy (Bluetooth LE or BLE) connected (no data streaming)
Magenta	Reserved	Press and hold the power button on the MAXREFDES103# until the LED status turns magenta and blinks fast to power off	Reserved
Cyan	Reserved	Flash logging active	Reserved
Yellow	System is initializing	The LED status flashes yellow for two seconds after the programming is complete	Battery low (10% to 25%)
White	Reserved	Reserved	Mass Storage Device (MSD) mode
Off	LEDs are turned off	N/A	N/A

5.3 Status LED Options

In order to save on power consumption or avoid blinking lights during sleep, the Status LED can be disabled via the Status LED > Turn off/Disable menu option, as shown below, at any time. This is helpful for overnight sleep data collection. This cannot be toggled on/off once data streaming or flash logging has begun.



5.4 How to Position the Device on the Wrist

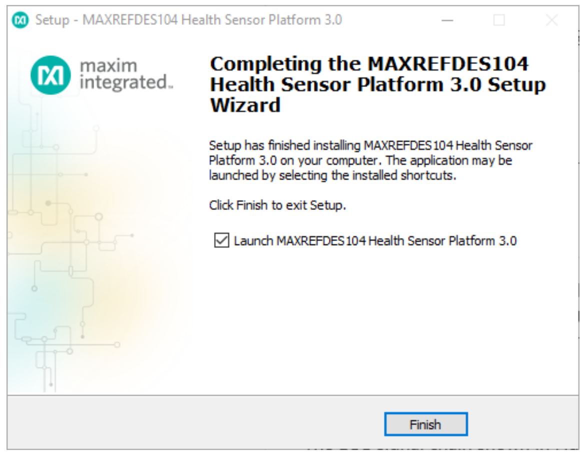
Position the health sensor band approximately two finger widths up the arm from the wrist bone. If possible, wear the health sensor band on the non-dominant hand, as this improves the quality of the data. The health sensor band should fit tightly but comfortably around the wrist. Make sure the skin has direct contact with the two parallel ECG electrode contacts on the bottom of the device, and that these electrodes both sit flush against the skin.

Figure 4. How to position the device on the wrist.

6 Evaluation GUI

6.1 Installation (Windows 10)

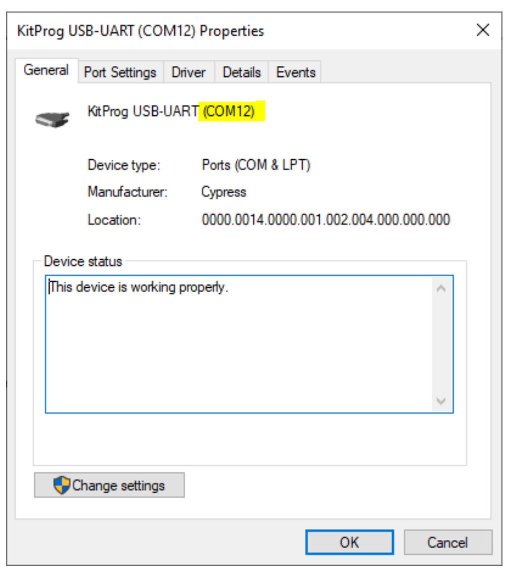
1. Download the latest GUI installer from the Design Resources tab of the MAXREFDES104 product page *here*. **Note:** All software resources are under NDA and access must be granted via the NDA request form on the product page.
2. Double click the installer executable and follow the installer instructions.
3. Select the **Launch MAXREFDES104 Health Sensor Platform 3.0** and click **Finish**.



6.2 Connecting to the Device

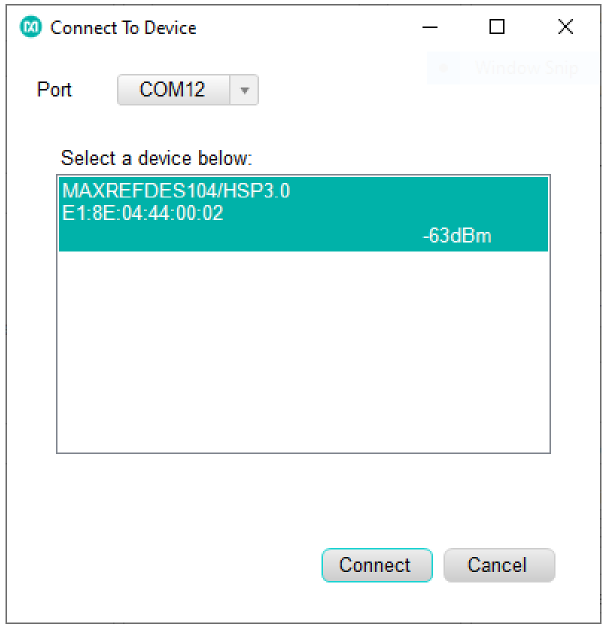
Before connecting to the device, ensure both the GUI and the device firmware are updated to the latest available version. See *Section 4 – Updating the Firmware* for details.

1. First, plug in the CY5677 BLE Dongle to a USB port on the PC. The Green and Red status LEDs on the dongle light up, and the Dongle appears in Device Manager under *Ports (COM & LPT).*

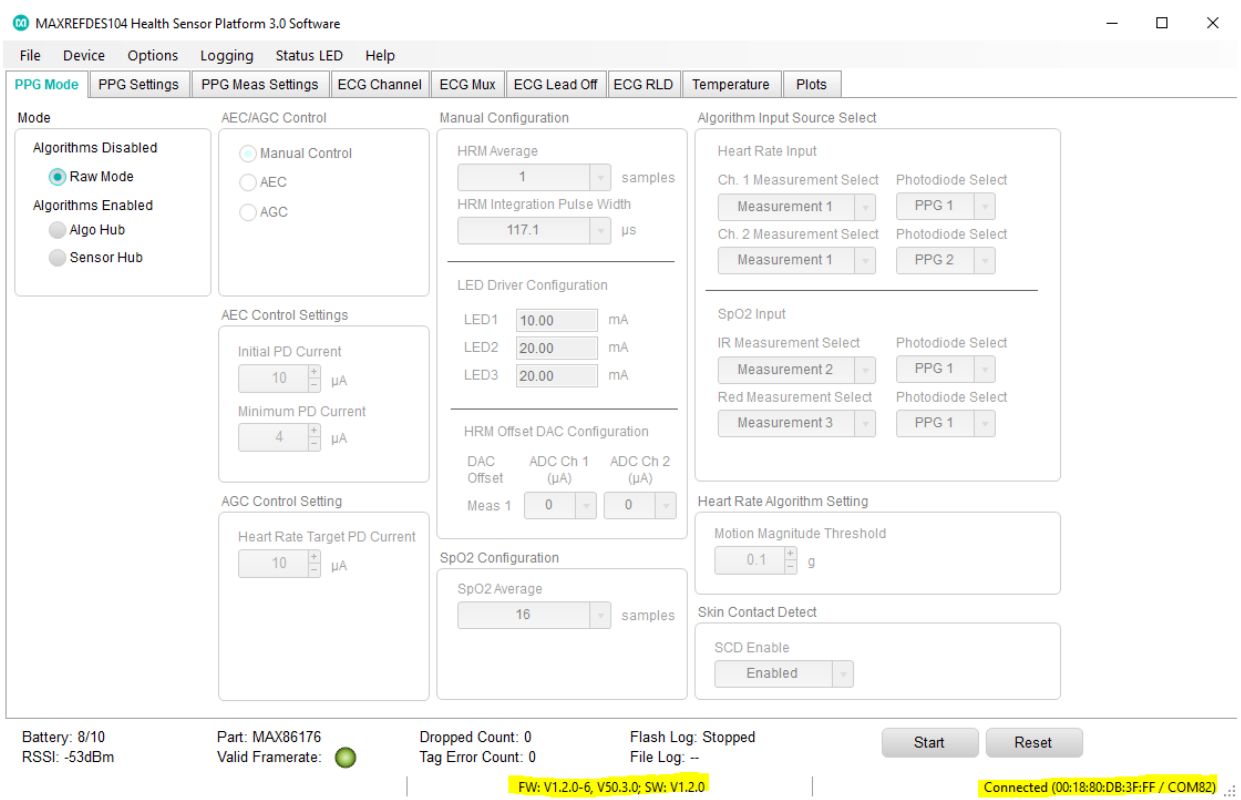


2. Power on the MAXREFDES104#.

3. Launch the **MAXREFDES104 Health Sensor Platform 3.0** software.
4. In the **Connect to Device** window, select the COM port of the CY5677 dongle from the dropdown menu.
5. Select the MAXREFDES104# from the list of available devices. Click Connect.



6. Verify the device is successfully connected. The GUI status message in the bottom right corner displays **Connected** and the device's Bluetooth MAC Address. Version numbers and MAC addresses may vary from the following image.



6.3 Measurements

6.3.1 Photoplethysmogram (PPG)

The MAXREFDES104# has a highly configurable and very powerful PPG AFE with the MAX86176, which includes programmable 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 *MAX86176 Datasheet* for a more detailed description of the available feature-set of the PPG AFE.

Overview

Fundamentally, a PPG measurement on the MAXREFDES104# 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 nine sequential measurements blocks.

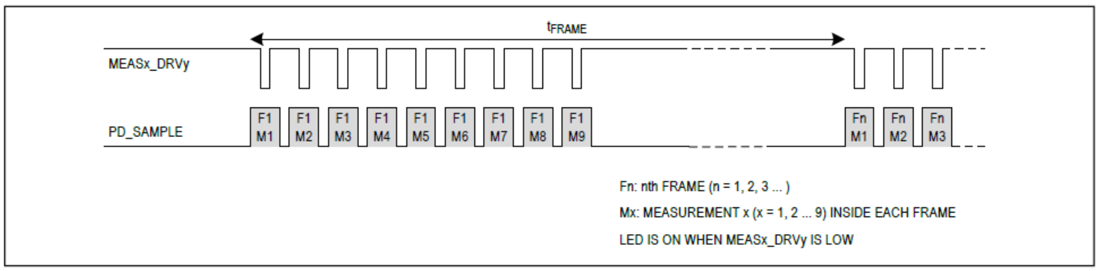


Figure 5. *Frame with nine measurements, M1 to M9.*

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 AEC or AGC in the Algo hub mode. See *Section 6.3.1 - PPG Mode* for details on these modes.

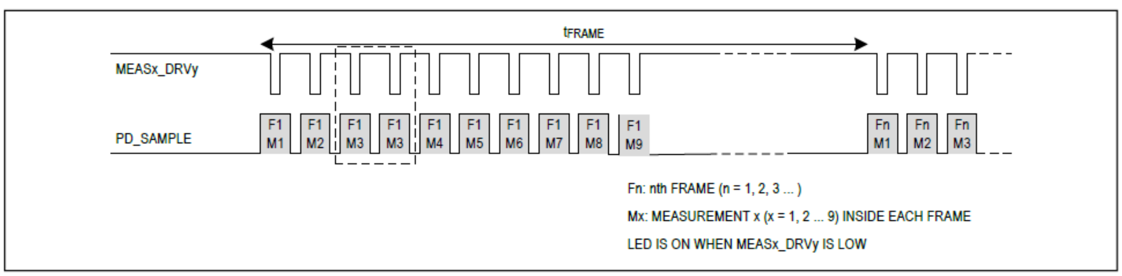


Figure 6. *Frame with measurement averaging. MEAS3 has two sample averaging, before being pushed to FIFO as one sample.*

For most situations, the default PPG settings are optimal for the MAXREFDES104#. When the Algo hub mode is enabled for *Heart Rate* and/or *SpO_2* measurements, the device goes back to these default PPG settings.

Associated Tabs

The tabs associated with PPG measurement are the *PPG Mode*, *PPG Settings*, and *PPG Measurement Settings* 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.

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

Starting/Stopping a Measurement

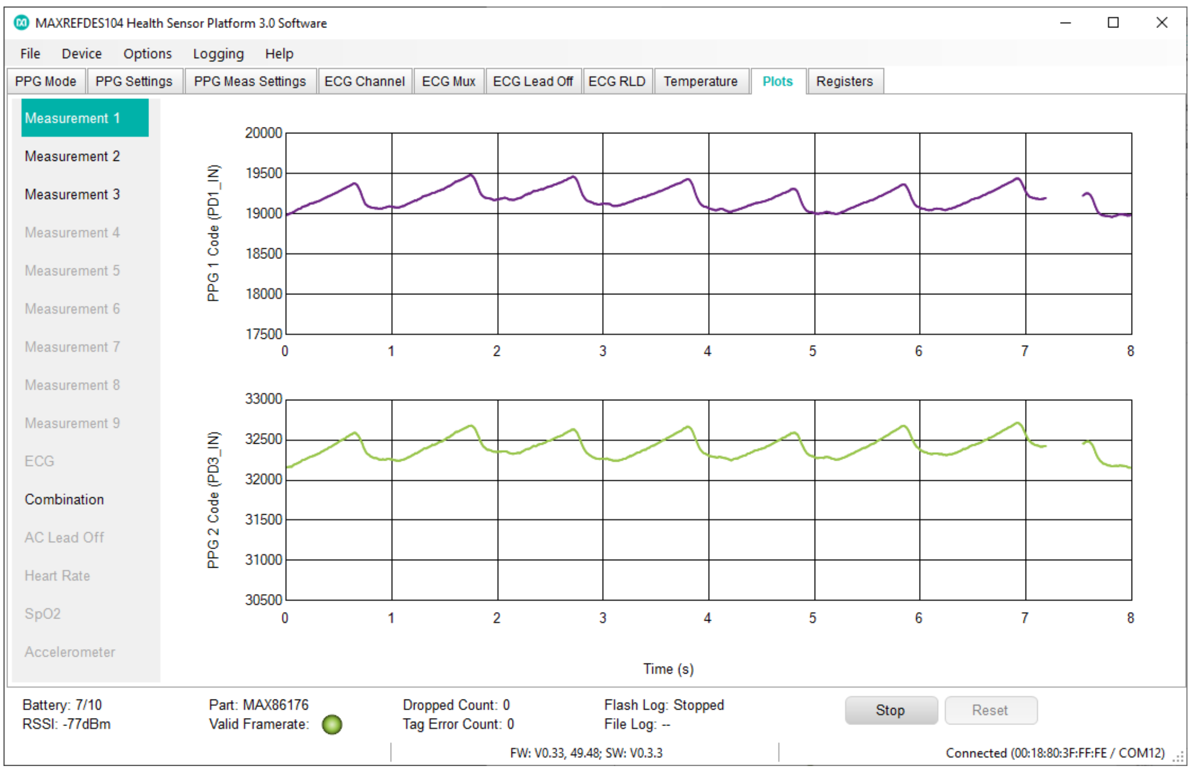


Figure 7. Example of raw PPG measurement output.

- Ensure the watch is placed securely on the wrist, powered on, and connected to the GUI.
- Ensure the minimum settings requirements, listed above, are met.
- The measurement can be started by clicking **Start**. The PPG data is drawn to the *Plots* tab. An active PPG measurement can be stopped by clicking **Stop**.
- PPG Measurements can be simultaneously enabled alongside ECG measurements.

6.3.2 Electrocardiogram (ECG)

The MAXREFDES104# contains a MAX86176 complete ECG and PPG data acquisition system to collect high-fidelity ECG data using dry electrodes. The MAX86176 features low-noise and high-input impedance, plus an active right-leg drive (RLD) circuit for excellent CMRR and robust 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 such as this wrist-worn device with dry electrodes. Nearly every aspect of this powerful ECG solution can be evaluated 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 *MAX86176 Datasheet* 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. On the MAXREFDES104#, two dry-contact electrodes are positioned on the bottom of the device, contacting the wrist, and one dry-contact electrode is positioned on the side of the device. A conducting path is made through the heart when the side ECG electrode meets the finger. This constitutes a LEAD 1 (LEAD I) 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.

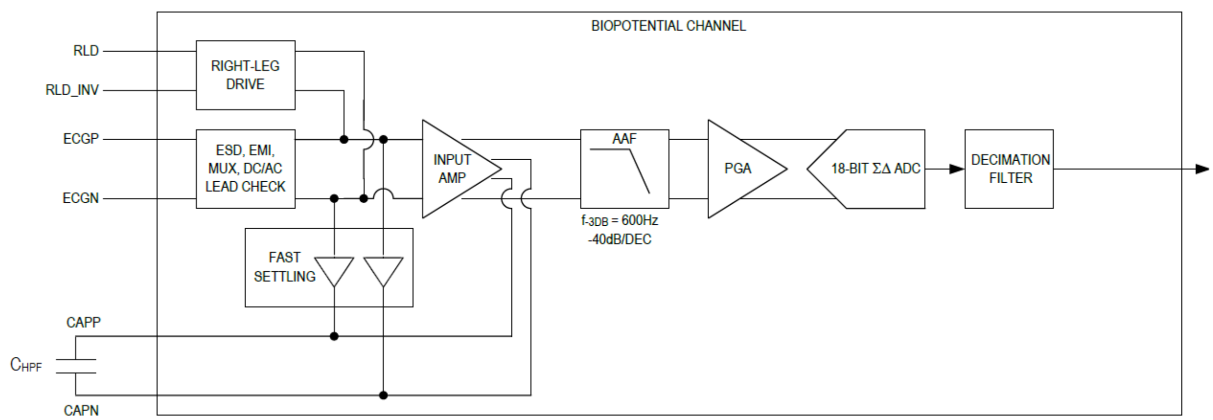


Figure 8. ECG channel signal chain.

The ECG signal chain shown in Figure 7 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), and programmable gain amplifier (PGA), and a delta-sigma ADC.

Associated Tabs

The tabs associated with ECG measurement are the *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: ECGP/N Polarity adjusted based on which wrist/finger is used (sometimes necessary to invert the signal).
- ECG RLD: Enable RLD **checked** (Right Leg Drive).

Starting and Stopping a Measurement

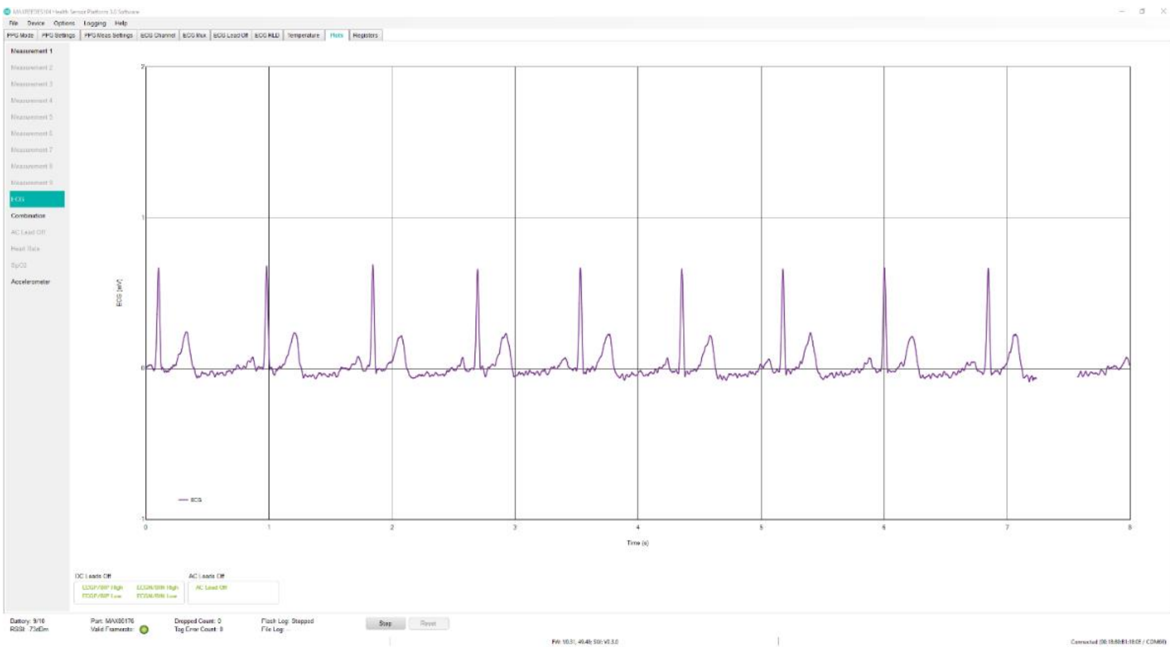


Figure 9. Example ECG measurement output.

- Ensure the watch is placed securely on the wrist, powered on, and connected to the GUI.
- Ensure the minimum settings requirements, listed above, are met.
- A measurement can be started by clicking **Start**. ECG data is drawn to the *Plots* tab. An active ECG measurement can be stopped by clicking **Stop**.
- During the ECG measurement, place the finger on the side ECG electrode of the watch. **NOTE**: Avoid touching the USB-C port with another finger during the measurement. This grounds the hand and negates the ECG body bias voltage, negatively affecting the measurement, and is easy to do when the wristband is worn upside-down. The MAXREFDES104# package optionally includes a rubber USB-C protector that is inserted into the port during measurements to prevent this grounding.

Figure 10. Touching the USB-C port, grounding the body! ***Incorrect*** *ECG/RLD bias applied. This typically occurs when the wristband is worn upside-down.*

Figure 11. Not touching USB-C port. Correct ECG/RLD bias applied, resulting in excellent ECG signal acquisition.

- ECG measurements can be simultaneously enabled alongside the PPG measurements.

6.3.3 Algorithms

The MAXREFDES104# includes a Biosensor and MAX32670 Algorithm Hub that contains Maxim's proprietary algorithms for deriving *HR* and *SpO_2* measurements from PPG signals. Additional analytics such as confidence-level are provided to aid the end user. These algorithms are continually updated and improved. So, it is best to use the latest version of the firmware (see *Section 4 – Updating the Firmware* for more details).

6.3.3.1 Algorithm Operating Modes

There are two algorithm modes available on the MAXREFDES104. Each has fundamental differences that affect the data pipeline happening inside the device. The two modes are:

- "Sensor Hub Mode"
    - The MAX32670 directly connected to accelerometer and PPG+ECG AFE, configurating them directly. Allows Host MCU to save power by offloading the command, control, and processing of raw data. AGC/AEC is handled by MAX32670. Easier and seamless effort to integrate into system.
- "Algorithm Hub Mode"
    - Configures the MAX32670 as a co-processor, with the main MAX32666 Host MCU configuring the sensors, reading the raw data, and sending it to the MAX32670 for processing. The AGC/AEC is handled by the Host MCU, in addition to the higher workload and power consumption, associated with being active more often. Timing is more critical as Host MCU must be able to time multiplex (interleave) tasks sequentially or run parallel processes that communicate with multiple devices simultaneously. Helpful for immediate bring up and system debug.

These different algorithm modes can be selected from the *PPG Mode* tab. In both modes, *HR* and *SpO_2* outputs are available. See their corresponding sections in this User Guide for more details on algorithm output-specific configuration.

6.3.3.2 Heart Rate (HR)

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

Associated Tabs

The tab for configuring the HR algorithm is the *PPG Mode* tab. The HR algorithm operates on PPG input data, but with either Algo Hub mode or Sensor Hub mode enabled, the default *PPG Measurement Settings* are loaded and used.

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 be left at their power-on defaults. The HR algorithm uses the default PPG settings for measurement 1, which drives the Green (LED1) and samples PD2 and PD3.

- PPG Mode: Algo Hub mode or Sensor Hub mode selected.
- PPG Mode: Input Source Select: Set Ch.1 Measurement Select and Ch.2 Measurement Select to an enabled measurement from the *PPG Measurement Settings* tab.
- PPG Settings: PPG1 Power Down **and/or** PPG2 Power Down **not** checked.

Overview

The HR algorithm itself uses digital signal processing techniques on incoming PPG data to provide an estimation of the user's heart rate. The algorithm outputs a Confidence Level (CL) with its prediction as well, indicating how **sure** the algorithm is of its estimation. A variety of factors can impact the quality of a PPG signal, and therefore the CL of the HR algorithm, including:

- Motion artifacts: Movement severely impacts PPG quality and HR CL.
- Measurement obstacles: Hair, sweat, imperfect contact, skin variations, etc., negatively impact HR CL.
- PPG settings: Improper LED/PD settings resulting in a low-quality PPG signal with negatively impacted HR CL.

The algorithm does have some methods for mitigating noise, motion artifacts, and general low CL readings, but in general the HR algorithm output is only as good as the PPG signal being fed to it. Some general guidelines can be followed:

General Guidelines

- The HR algorithm performs best with Green LED PPG data, due to the green LED's skin penetration depth, and arterial and skin stackup on the wrist. It penetrates the skin deep enough for capillary reflection, but not so deep that it picks up musculature reflections. Additionally, the LED used is an efficient emitter, providing large optical power given the current supplied.
- The LED driver current should be increased to provide the necessary signal amplitudes for calculating HR or SpO_2.
- The frame 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. The Maxim HRM and SpO_2 algorithms require a 25Hz effective output PPG frame rate. The support sample rates and on chip average combinations are captured on the PPG Mode tab.
- Motion and movement should be limited. Simply put, remain as still as possible.

Starting and Stopping a Measurement

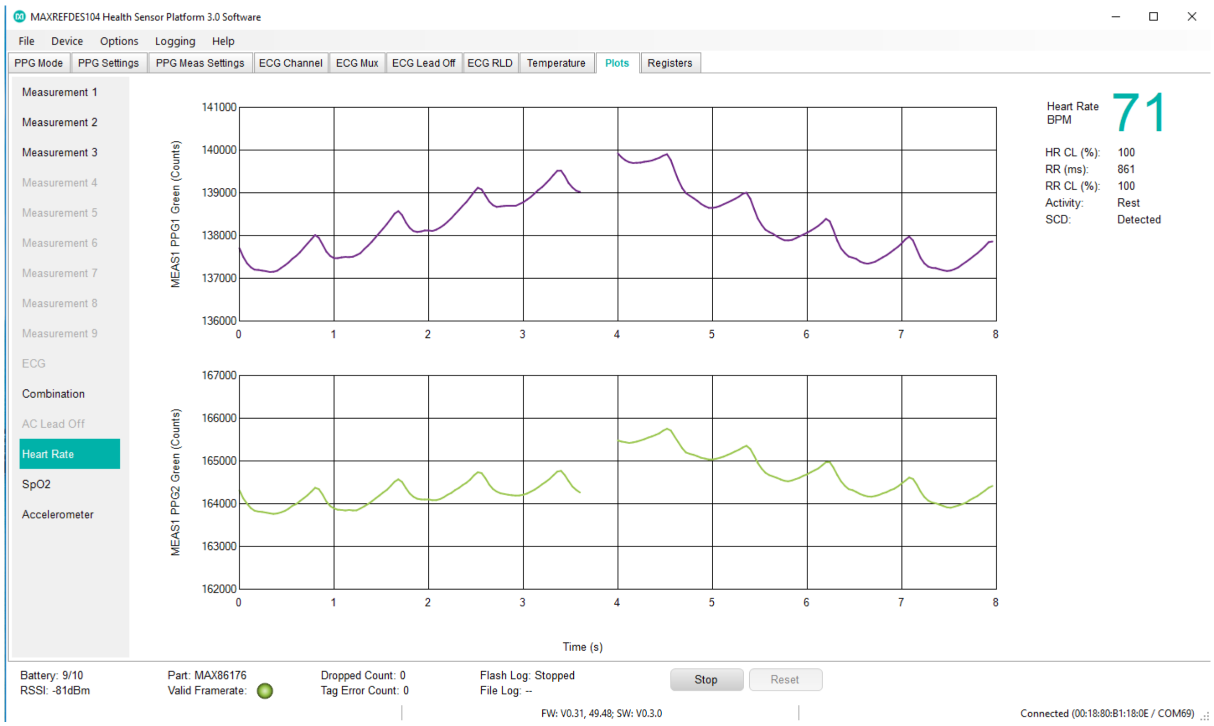


Figure 12 Example Heart Rate Algorithm Output

- Ensure the watch is placed securely on the wrist, powered on, and connected to the GUI.
- Ensure the minimum settings requirements, listed above, are met.
- The measurement can be started by clicking on **Start**. HR algorithm data is drawn to the *Plots* tab. An active measurement can be stopped by clicking **Stop**.

6.3.3.3 Blood Oxygen Saturation (SpO_2)

This section discusses how to enable the SpO_2 algorithm output and fundamentals of the algorithm setup. Maxim's proprietary algorithms for deriving clinical-grade accuracy pulse oximetry (SpO_2) measurements from Red and IR PPG signals. The coefficients are generated from a similar optical spacing at a Hypoxia lab compliant with FDA requirements. It's provided for evaluation purposes only. The MAXREFDES104 itself is not evaluated by the FDA.

Associated Tabs

The tab for configuring the SpO_2 algorithm is the *PPG Mode* tab. The SpO_2 algorithm operates on PPG input data, but with Algo Hub mode or Sensor Hub mode enabled, the default *PPG Measurement Settings* are loaded and used.

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 2 and 3. Measurement 2 drives the IR (LED2) LED, and Measurement 3 drives the Red (LED1) LED. Both measurements sample PD1.

- PPG Mode: Algo Hub mode or Sensor Hub mode selected.

- PPG Mode: Set Ch.1 Measurement Select and Ch.2 Measurement Select to an enabled measurement from the *PPG Measurement Settings* tab.
- PPG Settings: PPG1 Power Down **and/or** PPG2 Power Down **not** checked.

Overview

Fundamentally, the SpO_2 algorithm measures 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 same factors as for the HR algorithm 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 SpO_2. 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 SpO_2 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 measurement:

General Guidelines

- The SpO_2 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 SpO_2 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. Simply put: remain as still as possible during the measurement period.

Starting and Stopping a Measurement

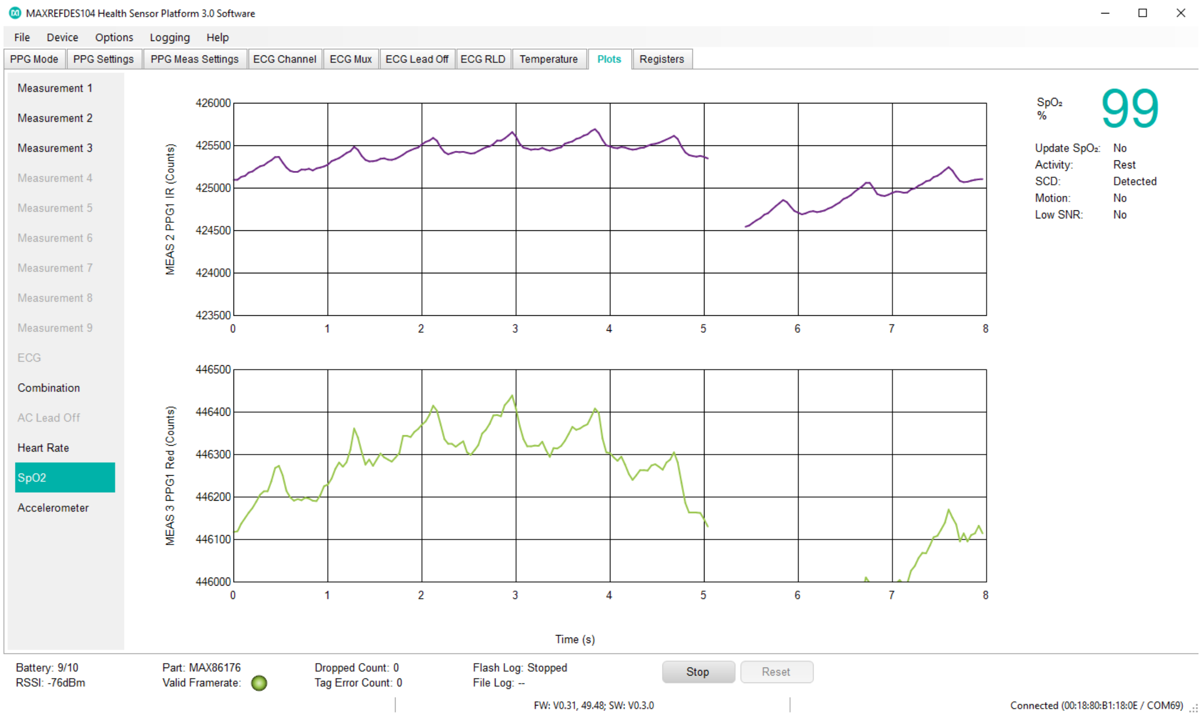


Figure 13. Example SpO_2 algorithm output.

- Ensure the watch is placed securely on the wrist, powered on, and connected to the GUI.
- Ensure the minimum settings requirements, listed above, are met.
- The measurement can be started by clicking **Start**. HR algorithm data is drawn to the *Plots* tab. An active measurement can be stopped by clicking **Stop**.

6.3.4 Skin Temperature

The MAXREFDES104# includes a highly accurate ±0.1°C MAX30208 temperature sensor paired with a thermal contact disc on the bottom of the device, offering a high-resolution skin temperature measurement. The MAXREFDES104# 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.

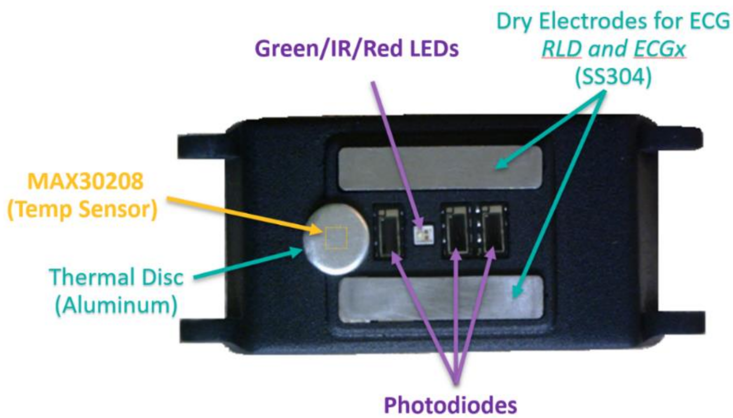


Figure 14. MAXREFDES104# electrode, thermal contact, LED, and PD positioning.

Associated Tabs

The only tab associated with temperature sensor measurements is the *Temperature* tab. Body temperature measurements do not require any configuration from the user.

Starting and Stopping a Measurement

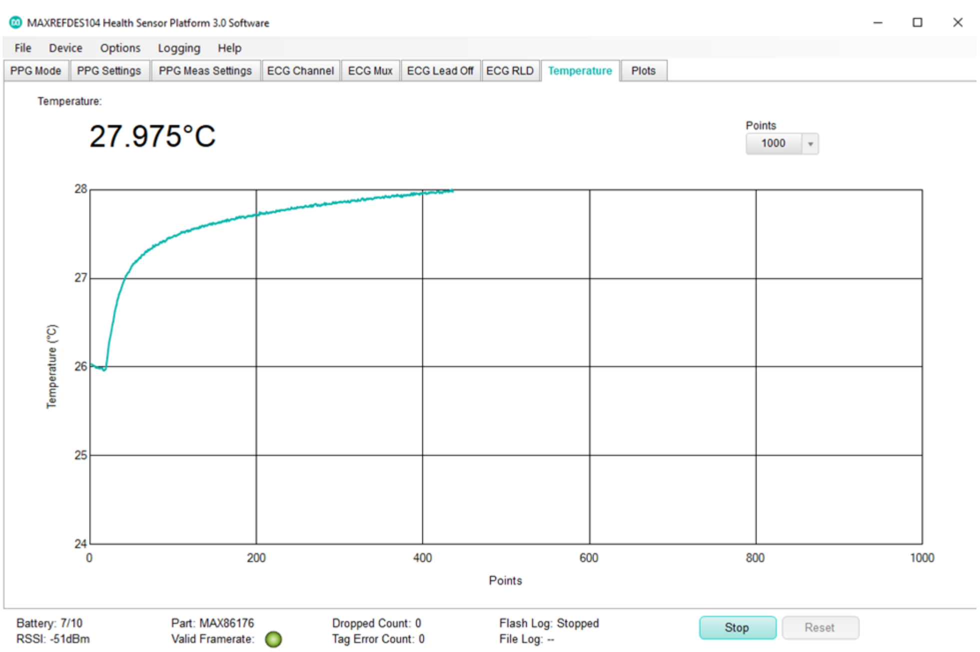


Figure 15. Example temperature measurement output.

- Ensure the watch is placed securely on the wrist, powered on, and connected to the GUI.
- Navigate to the *Temperature* tab and click **Start** to collect and plot measurements.
- An active temperature measurement can be stopped by clicking **Stop**.

7 Tabs

7.1 PPG Mode

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 Algorithms 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 Algorithms enabled modes are used to configure the device to enable HR and SpO_2 estimations, and this tab offers further configuration options in these modes.
    - The device can be set to “Algorithm Hub Mode” or “Sensor Hub Mode” here as well. See *Section 6.3.3.1 – Algorithm Operating Modes* for a more detailed description of these two different algorithm output modes.

With algorithms enabled, a default PPG setup suitable for most situations is loaded and used as input to the HR and SpO_2 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.

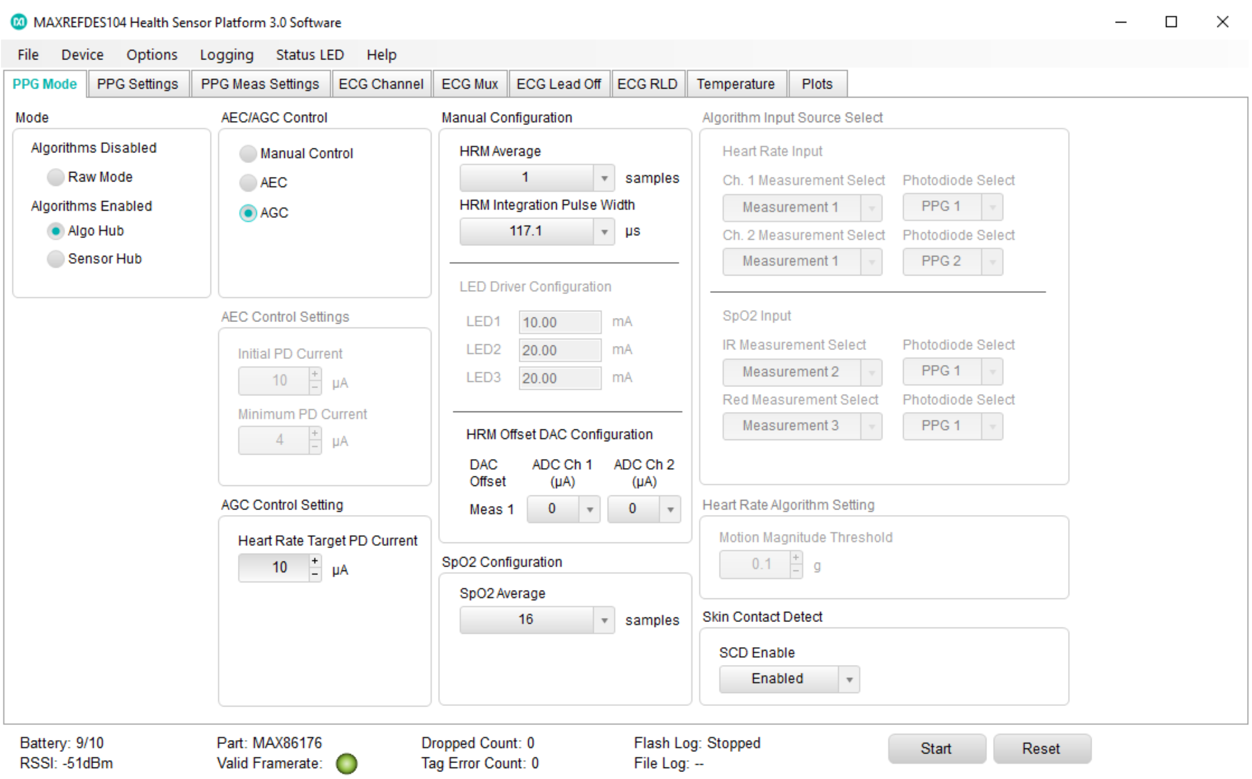


Figure 16. PPG mode GUI tab.

Available Options

Table 2. 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 *Section 6.3.3.1 – Algorithm Operating Modes* for more details.
	Sensor Hub	Enables HR/SpO_2 algorithm outputs in the "Sensor Hub" operating mode. See *Section 6.3.3.1 – Algorithm Operating Modes* for more details.
AEC/AGC Control	Control Enable	Enables AEC or AGC (see "Control Select" below)
	Control Select	AEC = Automatic Exposure Control. With this enabled, the algorithm hub is given complete control of the PPG AFE. It selects LEDs, driver currents, and sample rate based on the PD current it predicts it needs for the highest quality measurement. A starting point and minimum PD current value can be configured in the AEC Control Settings sub-section. AGC = Automatic Gain Control. This mode offers the user 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.
AEC Control Settings	Initial PD Current	With AEC enabled: This sets the initial PD current target the algorithm hub starts from. From this value, the algorithm hub may increase or decrease PD current based on its estimation of what it requires for the best measurement.
	Minimum PD Current	With AEC enabled: This sets the minimum PD current the algorithm hub can drop its target to. If the hub is getting the level of quality it needs, it drops its PD current target as low as possible to try to conserve power.
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.

Manual Configuration	HRM Average	Controls the number of samples to average for HRM (MEAS1, Green)
	HRM Integration Pulse Width	Exposure time for the HRM measurements (MEAS1). The PPG AFE integrated the light received on the photodiode for this period of time.
	LED Driver Configuration	LED driver currents for each of the three LEDs are set here. LED1 = Green LED2 = IR LED3 = Red
	HRM Offset DAC Configuration	Each optical signal path also incorporates a two-bit offset DAC for extending the optical dynamic range. There are four settings: 0µA, 8µA, 16µA, and 24µA. This allows for a larger convertible exposure range by sourcing some of the exposure current from the offset DAC.
SpO2 Configuration	SpO2 Average	Controls the number of samples to average for SPO2 (MEAS2 and MEAS3, e.g. IR and Red). The minimum is locked to 4 samples for this platform, to ensure sufficient SNR for algorithm performance. *Default SPO2 Integration time is 117.1us (not shown on GUI). The SPO2 algorithm coefficients do not support adjustment of DAC offset, as this effects the R-curve and ratio-of-ratios utilized to report SPO2 values.*
Algorithm Input Source Select	Heart Rate Input	Configures the PPG input into the HR algorithm. LED and PD settings are set in the *PPG Measurement Settings* tab. These settings are fed to the HR algorithm based on which measurement block is selected for use here.
	SpO_2 Input	Configures the PPG input into the HR algorithm. LED and PD settings are set in the *PPG Measurement Settings* tab. These settings are fed to the HR algorithm based on which measurement block is selected for use here.
Heart Rate Algorithm Setting	Motion Magnitude Threshold	Sets the magnitude of data from the accelerometer that triggers the algorithm hub's motion threshold. Above this threshold, the algorithm attempts to discard sample data.
Skin Contact Detect	SCD Enable	Enables/Disables Skin Contact Detection (SCD). The algorithm hub uses PPG data to detect if the watch is attached to the wrist or not.

7.2 PPG Settings

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.

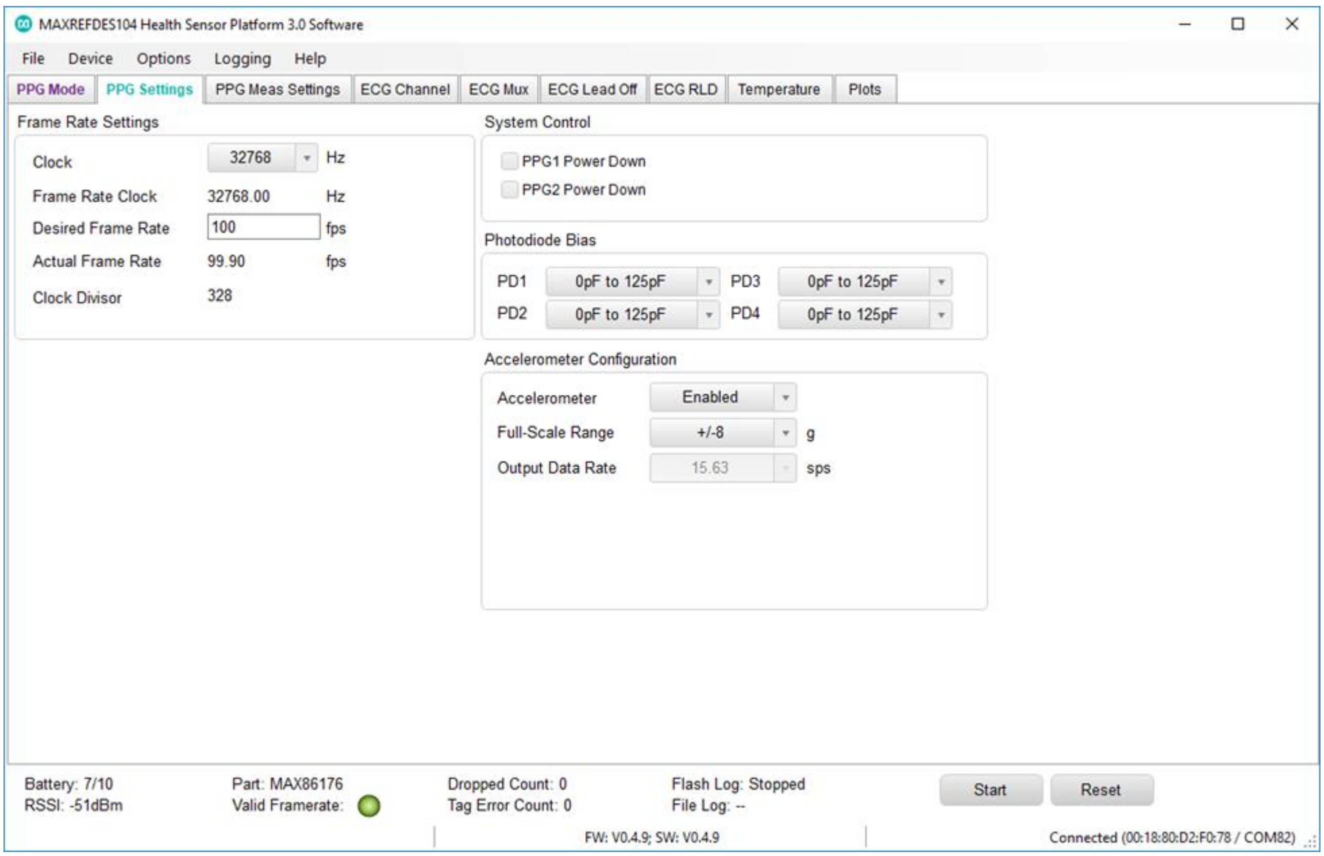


Figure 17. PPG settings GUI tab.

Available Options

Table 3. PPG Settings Configuration Options

Sub-Section	Option	Description
Frame Rate Settings	Clock	Selects one of the two MAX86176 internal oscillators to use as the clock source for the PPG frame rate.

	Frame Rate Clock	Displays the value of the PPG frame rate clock, selected above.
	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 MAXREFDES104# 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 *MAX86176 datasheet* for more details.
Accelerometer Configuration	Accelerometer	Enables or disables the onboard accelerometer. Please Note: When enabling the Algo Hub mode, the accelerometer is automatically enabled.
	Full-Scale Range	Sets the output scale of the accelerometer data.

7.3 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 MAXREFDES104# is provided for reference in Figure 8.

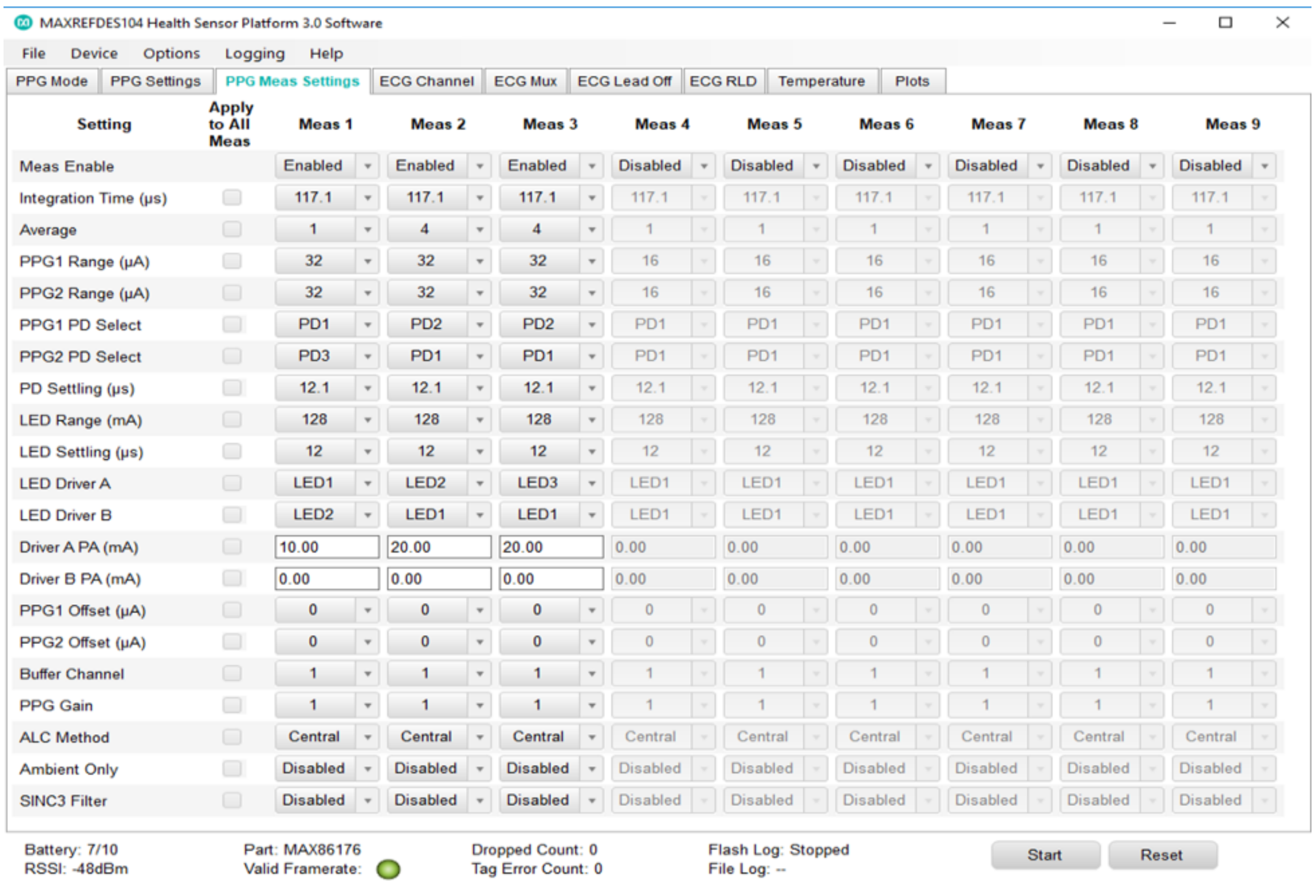


Figure 18. PPG measurement settings GUI tab.

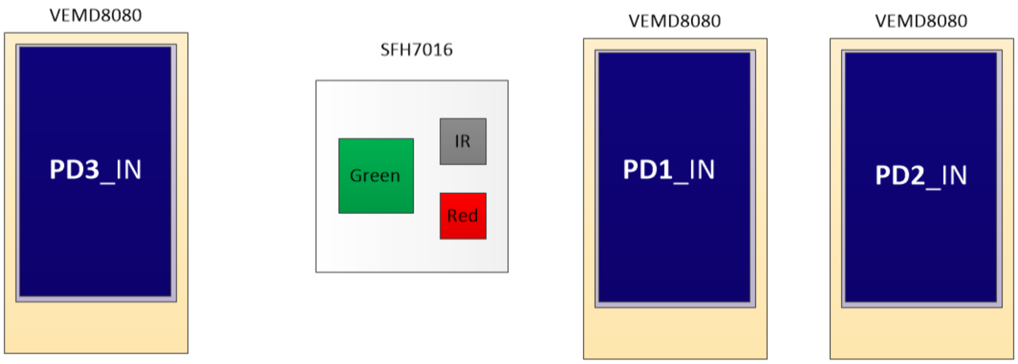


Figure 19. MAXREFDES104# LED and PD layout bottom view.

Available Options

Table 4. PPG Measurement Settings 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. See 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.
	PPG1/PPG2 PD Select	Selects the photodiode (input pin) to sample for each PPG channel. See Figure 18 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 MAXREFDES104/HSP3.0, the LEDs are connected to the following DRV pins: LED1 = Green LED2 = IR LED3 = 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.
	Buffer Channel	Sets the buffer channel for the PPG input. This allows the input from one PPG channel to feed both channels. The buffer mode is automatically enabled if PPG1 PD Select = PPG2 PD Select.
	PPG Gain	Sets the gain to be applied to the buffer channel. This reduces LED power by a factor equal to the gain setting at the cost of a slight increase in noise, resulting in a slight reduction of SNR.
	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 117.1 µs.

7.4 ECG Channel

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 sample rate, and software filters. See the available options in the following table for more details.

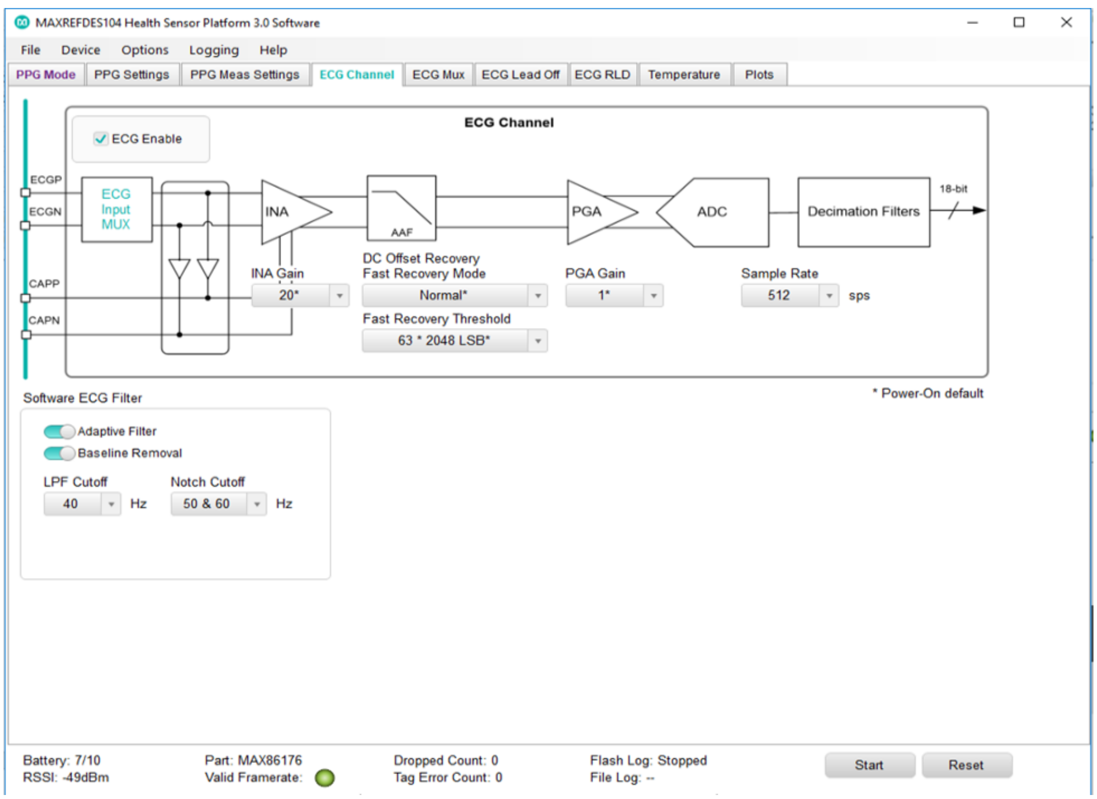


Figure 20. ECG channel GUI tab.

Available Options

Table 5. ECG Channel Configuration Options

Sub-Section	Option	Description
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 *MAX86176 data sheet* under 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 Programmable Gain Amplifier. This is the final gain stage before the ECG signal is sampled by the ADC.
	Sample Rate	Sets the sample rate of the Analog to Digital Converter that samples the ECG signal after it is passed through the input filtering and gain stages. If a sample rate is selected unsupported by the software filter library, the following Software ECG Filter options are disabled.
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.
	Baseline Removal	This switch toggles the baseline removal feature of the Software ECG Filter chain. This is a Maxim Integrated 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 Low-Pass Filter in the Software ECG Filter chain. This is typically used to remove high-frequency interference noise and is a double-pole IIR Filter. At this time only 128, 256, 512, and 1024 Hz 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 50 and/or 60 Hz to filter noise introduced by the AC powerline interference.

7.5 ECG Mux

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 lead biases, and enable calibration signals. See the available options in the following table for more details.

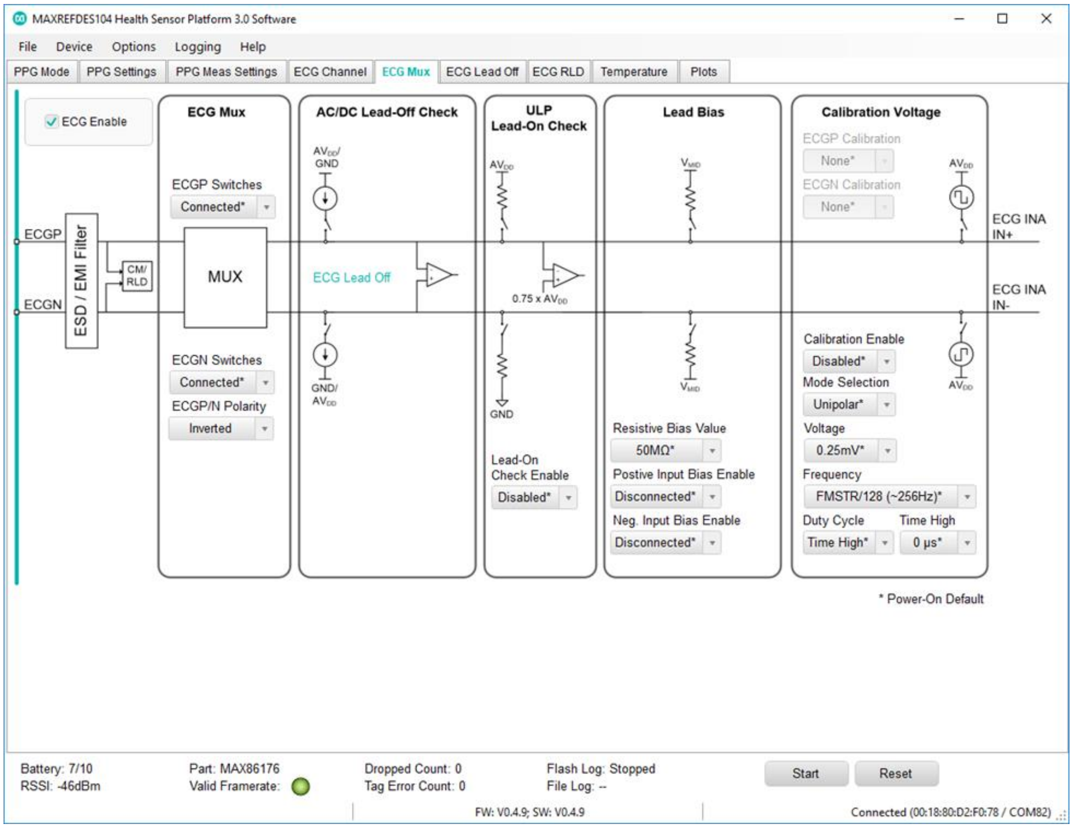


Figure 21. *ECG Mux GUI tab.*

Available Options

Table 6. ECG Mux Configuration Options

Sub-Section	Option	Description
ECG Mux	ECG Enable	Enables/Disables the collection of ECG measurements.
	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.
ULP Lead-On Check	Lead-On Check Enable	Enables/disables ultra-low-power DC lead-on detection. The ECG channel must be disabled if the ULP Lead-On Check is enabled. Refer to the *MAX86176 data sheet* for more details on this feature.

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 signal.
	Duty Cycle and Time High	Sets the pulse-width of the calibration PWM signal.

7.6 ECG Lead Off

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 dry electrodes are no longer in contact with the skin and can be used while the ECG channel is enabled. This is in contrast with the ULP lead-on detection, which cannot be used while the ECG channel is enabled. Additionally, the software currently only supports ULP lead-on detection through the manual register configuration. See the *Registers* section for more information.

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 MAX86176 data sheet for more details, and the available options in the following table for more details on the available configurations. The optimal settings are pre-configured as defaults and are loaded at time of launch.

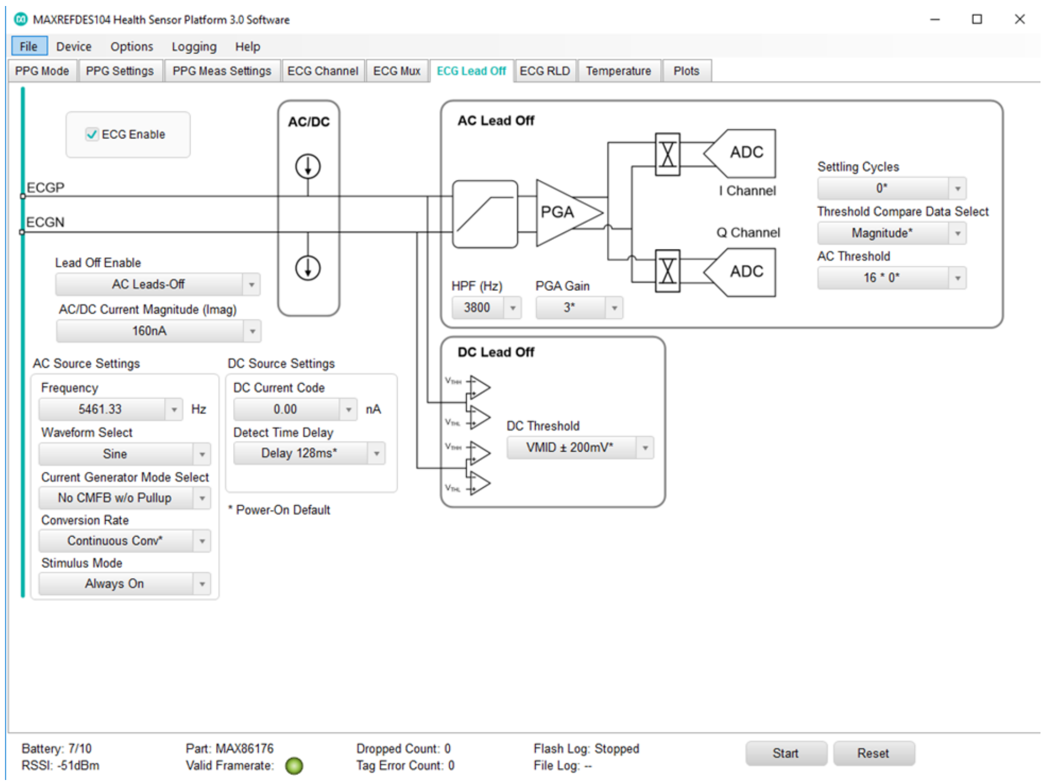


Figure 22. ECG Mux GUI tab.

Available Options

Table 7. ECG Lead Off Configuration Options

Sub-Section	Option	Description
ECG Lead Off	ECG Enable	Enables/Disables the collection of ECG measurements.
	Lead Off Enable	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 *MAX86176 data sheet* for more details.
	AC/DC Current Magnitude	Sets the magnitude of the current source/sinks used in the Lead-Off detection.
AC Source Settings	Frequency	Sets the Frequency of the AC current source waveform. If used simultaneously with ECG recording, the stimulus frequency (f_{STIM}) should be chosen to be outside of the ECG signal bandwidth so that the AC lead-off signal does not interfere with the ECG signal.
	Waveform Select	Sets the waveform type of the AC current source between a square and sine wave.
	Current Generator Mode Select	Selects the current generator mode. Abbreviations used in menu options: CMFB = Common-Mode Feedback LPF = Low-Pass Filter CMFB w/o LFP is recommended for more applications, resulting in minimal impact to the input impedance and CMRR performance.
	Conversion Rate	Sets the conversion rate of the sampling ADC used in the lead-off detection signal chain.
	Stimulus Mode	Enables/Disables turning off during ECG conversions to avoid interfering with the ECG signal. When the ECG channel is active, the Stimulus Mode should be set to continuous to avoid startup shutdown transients interfering with the ECG signal.
AC Lead Off	Settling Cycles	Selects the number of sine wave or square wave cycles needed for the AFE to settle for AC lead-off detection before the ADC conversion begins. Refer to the *MAX86176 data sheet* for more details.
	Threshold Compare Data Select	Selects the signal to compare with the comparator threshold voltage. Refer to the *MAX86176 data sheet* for more details.
	AC Threshold	Selects the threshold for AC lead-off detection. Refer to the *MAX86176 data sheet* for more details.

DC Source Settings	DC Current Code	Sets the amplitude of the DC current sources used in DC Lead-Off detection.
	Detect Time Delay	Sets the time that the measured DC Lead-Off differential voltage must exceed the DC threshold voltage to trigger the lead-off detection interrupt. Refer to the [MAX86176 data sheet]() for more details.
DC Lead Off	DC Threshold	Sets the voltage threshold that the measured DC Lead-Off differential voltage must exceed to trigger the lead-off detection interrupt. Refer to the [MAX86176 data sheet]() for a visual representation.

7.7 ECG RLD

This tab is used to enable and configure the Right Leg Drive circuit (RLD). The right leg drive (RLD) circuit enables improved 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 V_{MID_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.

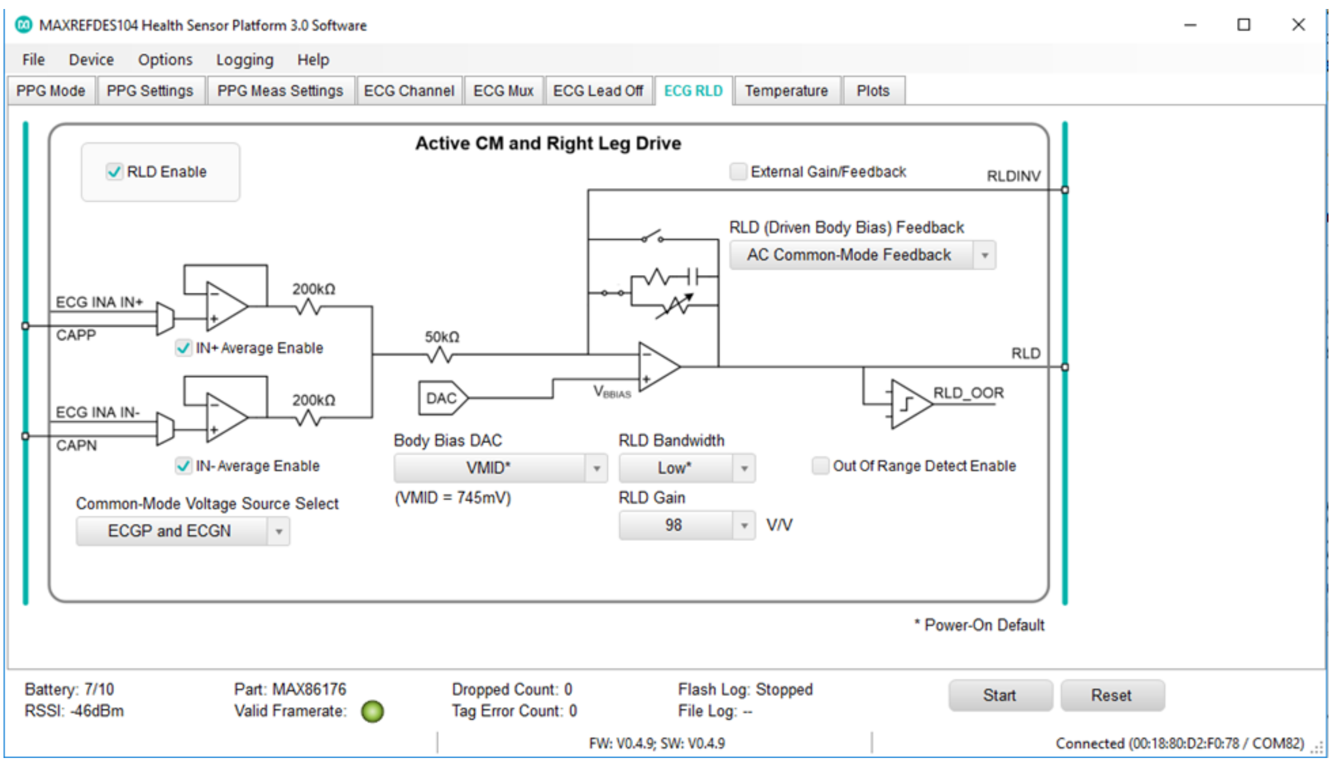


Figure 23. ECG RLD GUI tab.

Available Options

Table 8. ECG RLD Configuration Options

Sub-Section	Option	Description
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.
	External Gain/Feedback	Toggles whether the internal RLD feedback resistor should be disconnected to use solely the external gain/feedback resistor to control the gain of the inverting common-mode negative feedback amplifier.
	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	Toggles averaging on the common-mode inputs.
	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 the input ECG electrodes is too high to maintain the feedback loop, usually because electrodes are off or have poor contact with the user.

7.8 Temperature

The temperature tab is used to start, stop, and plot body temperature measurements from the onboard MAX30208 clinical grade 0.1°C accurate temperature sensor, calibrated in an oil bath. It is the simplest tab to work with. Simply select the number of plot points for the x-axis of the output plot, and use **Start** and **Stop** to collect measurements. The data is captured at approximately 10Hz.

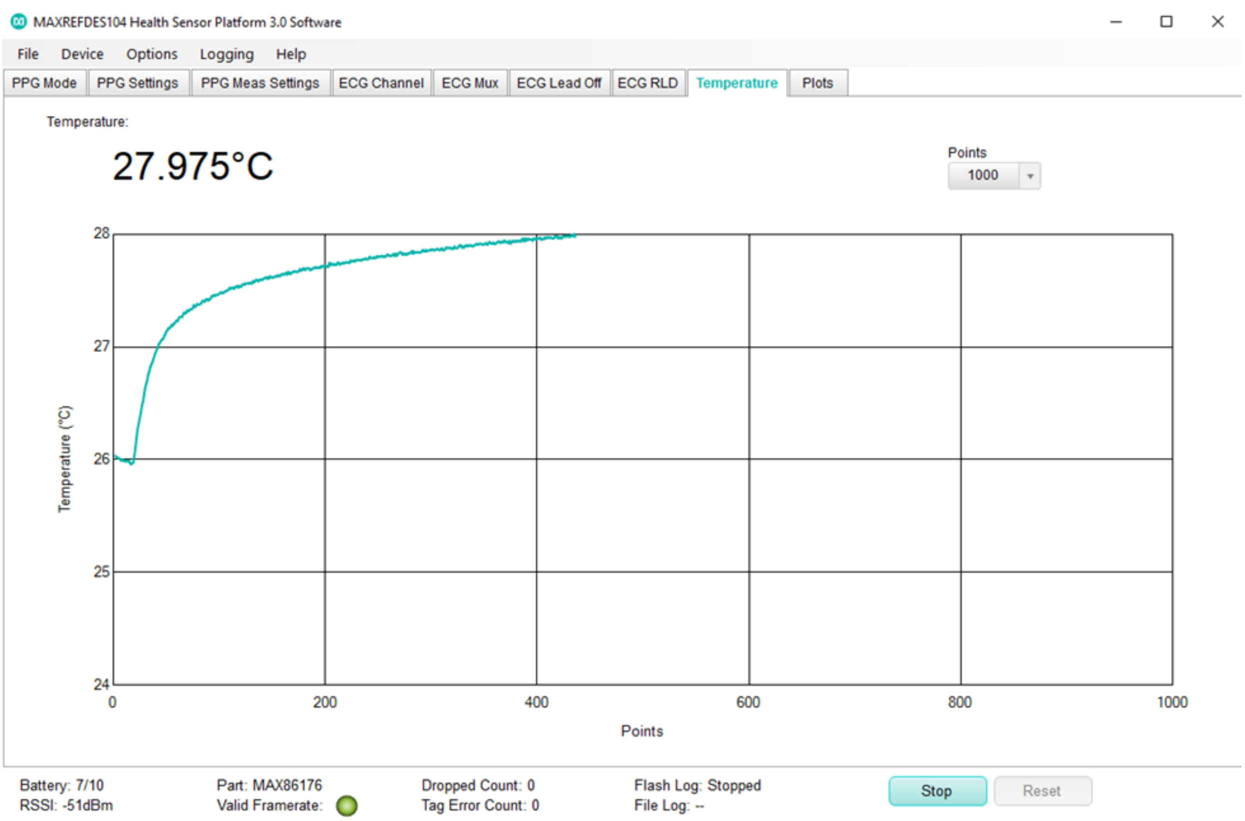


Figure 24. Temperature GUI tab.

Available Options

Table 9. Temperature Configuration Options

Sub-Section	Option	Description
Temperature	Points	Defines the number of temperature data points to plot.

7.9 Plots

The plots tab is where the output data for all measurements except body temperature are plotted. Output data from the PPG measurements 1-9, ECG, HR and SpO_2 algorithms, accelerometer, and AC Lead Off circuitry can all be viewed through their associated sub-sections. Additionally, two of any of these measurements can be viewed simultaneously with the **Combination** sub-section. See the following for more details on each section.

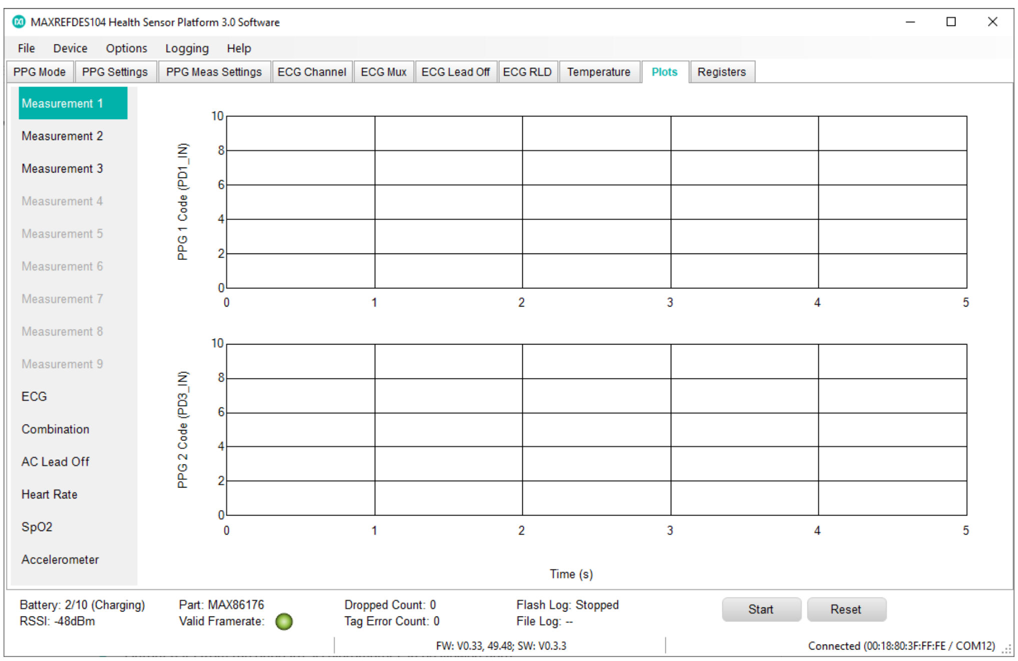


Figure 25. Plots GUI tab.

1. **Measurement X**
   - Raw PPG measurement data can be viewed here for enabled measurements.
2. **ECG**
   - Raw ECG measurement data can be viewed here when ECG measurements are enabled.

3. **Combination**

- Any two PPG measurement channels can be viewed simultaneously on this tab, as well as the ECG plot output. Use the dropdowns to select which plots are routed to this combination view.

4. **AC Lead Off**

- Output signals from the AC Lead Off circuit can be viewed here if AC Lead Off detection is enabled.

5. **Heart Rate**

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

6. **SpO2**

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

7. **Accelerometer**

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

7.9.1 Registers

The registers tab offers a view of the available internal registers of the onboard MAX86176, MAX30208, or LIS2DS12 accelerometer. Registers *cannot* be modified while the device is actively taking a measurement. The GUI highlights which registers are being changed based on different settings. Modifying the devices at the register level can break its functionality, and extreme care should be taken when doing so. The Registers tab can be accessed by the drop down *Options* then selecting *Advanced* then selecting *Register Tab Enable.* Bold indicates a logical 1, non-bold is a logical 0.

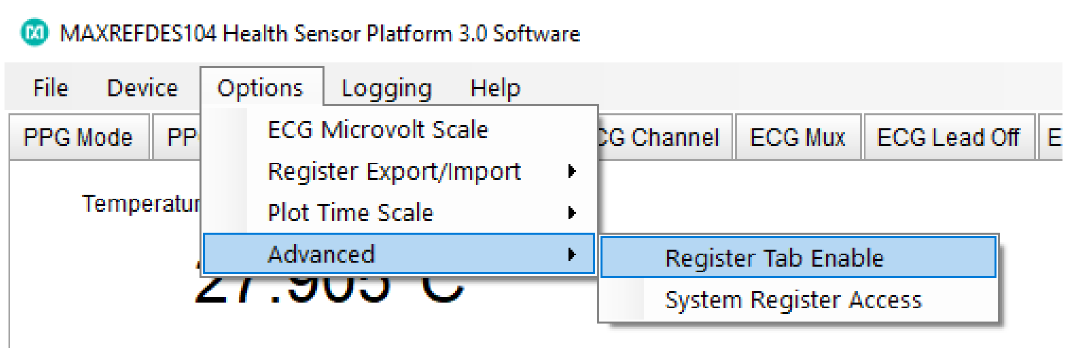


Figure 26. Enabling the Register Tab

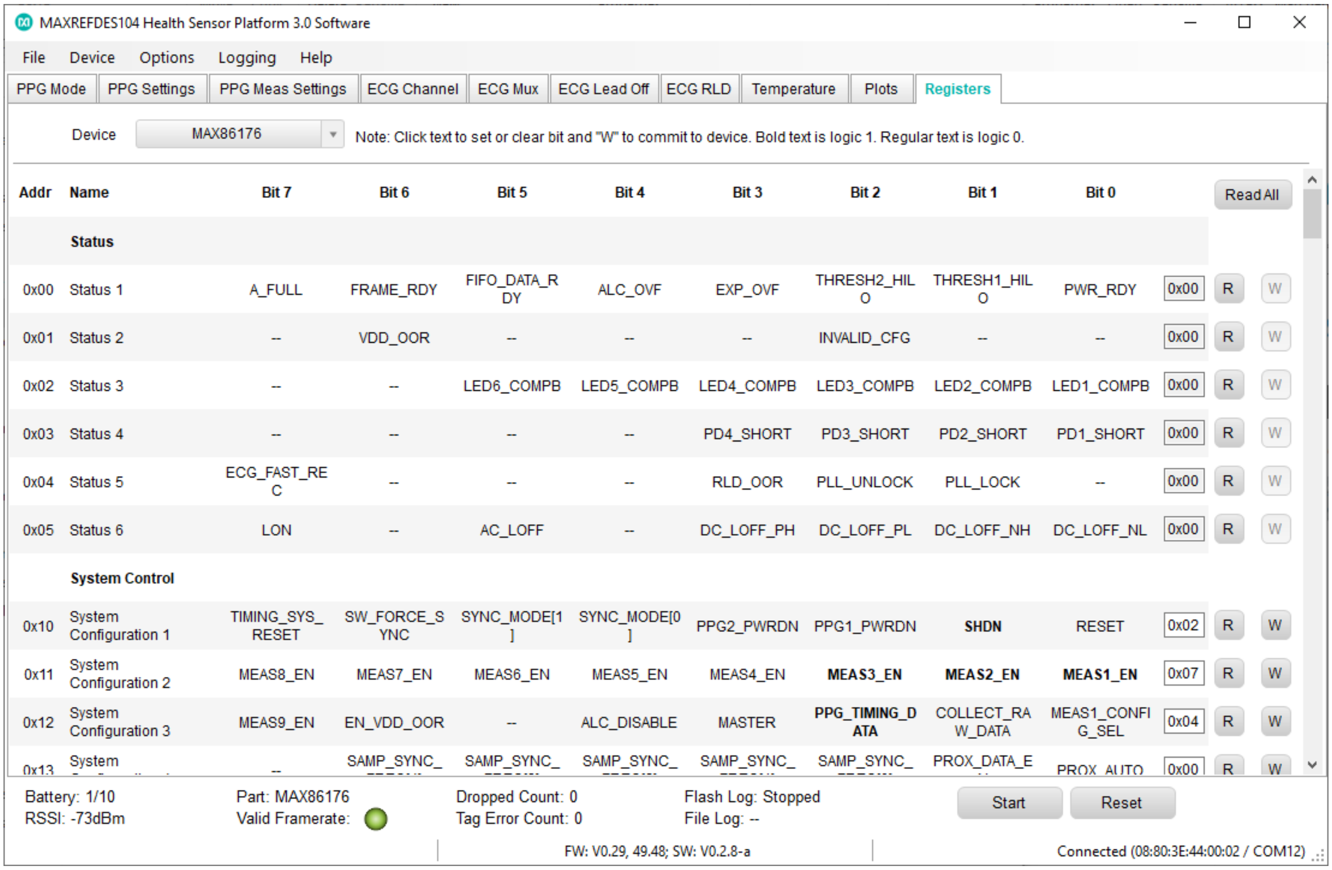


Figure 27. Registers GUI tab.

Available Options

Table 10. Device Register Configuration Options

Sub-Section	Option	Description
Registers	Device	Select in which device registers to read/write to: the MAX86176, MAX30208, or LIS2DS12.
	MAX86176	The MAX86176 is fully adjustable through software registers and the user can read/write to the register.
	MAX30208	The MAX30208 also has the flexibility to get controlled by registers and the user can read/write to the register.
	LIS2DS12	This is an accelerometer with certain info and control registers the user has control on.

8 Data Logging

8.1 Logging to a File

1. To log data to the file, click the Logging tab of the GUI and select file logging (as shown in the following figure).

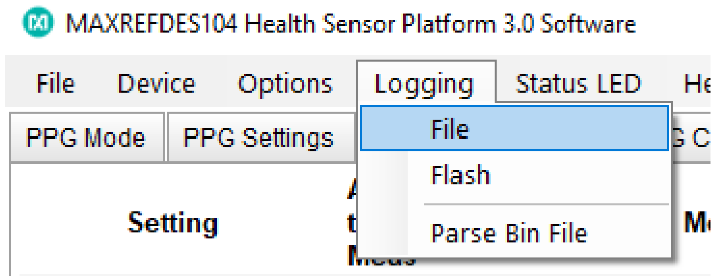


Figure 28. Enabling file logging.

2. The GUI prompts for a location to save the log file. Select an accessible location.
3. A blue check mark indicates that file logging is enabled, as well as 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 (PPG, ECG, and Temperature) are saved in a .bin file and automatically parsed and processed in up to three separate .csv files. See *Section 8.3 Data Format* section.
6. File logging is complete! Open the saved .csv file to view the data.

8.2 Logging to Flash Memory

Some combinations of features are not supported during flash logging at this time. See the *known issues* in the supporting or ancillary document (Software Release Package - Release Notes).

1. To log data to flash memory, click the Logging tab of the GUI and select “Flash”, as shown in the figure below.

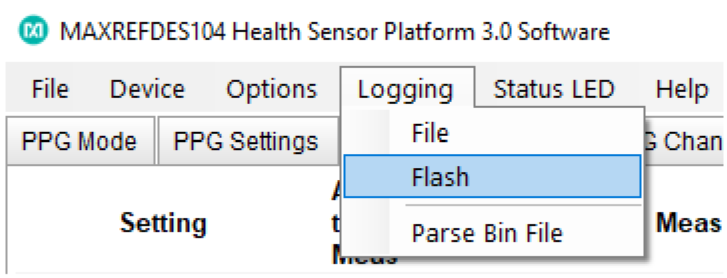


Figure 29. Enabling Flash Logging.

2. A blue check mark indicates that file logging is enabled, as well as the **Flash Log: Enabled** status message in the bottom status bar.
3. Click **Start** to begin collecting measurements and logging data to the onboard flash memory.

- The MAXREFDES104# will disconnect from Bluetooth and continue logging to the onboard flash memory, untethered from the computer.
- The status LED, if left enabled, will alert the user to the battery charge level. See 5.2 Status LED Color Definitions.

4. To stop flash logging, press the **F button** on the MAXREFDES104#.

5. To recover the data, connect the MAXREFDES104# to the computer using the included USB-C cable. It will be detected as a mass storage device (or USB Drive), which you can open and access the .bin file contained, or copy to the local machine.

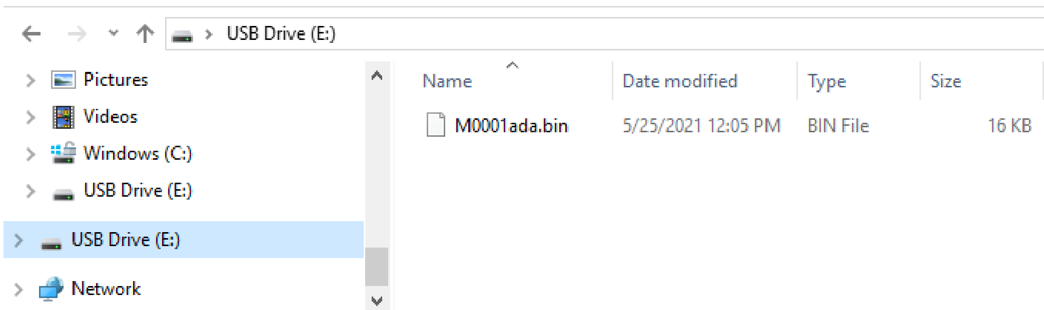


Figure 30. MAXREFES104 connected to a computer, using included USB-C cable, and detected as a mass storage device (USB Drive) containing the flash logged .bin file

6. Select **Logging,** then **Parse Bin File**.

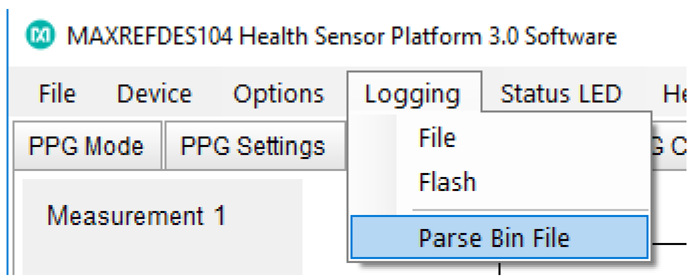


Figure 31. The built in parser processes, converts, and saves flash log data to a .csv file.

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

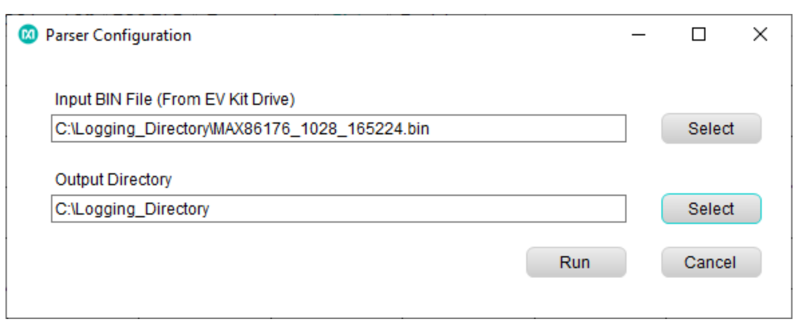


Figure 32. Parsing a Flash Log .BIN File

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 up to 1 min or more to process.

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

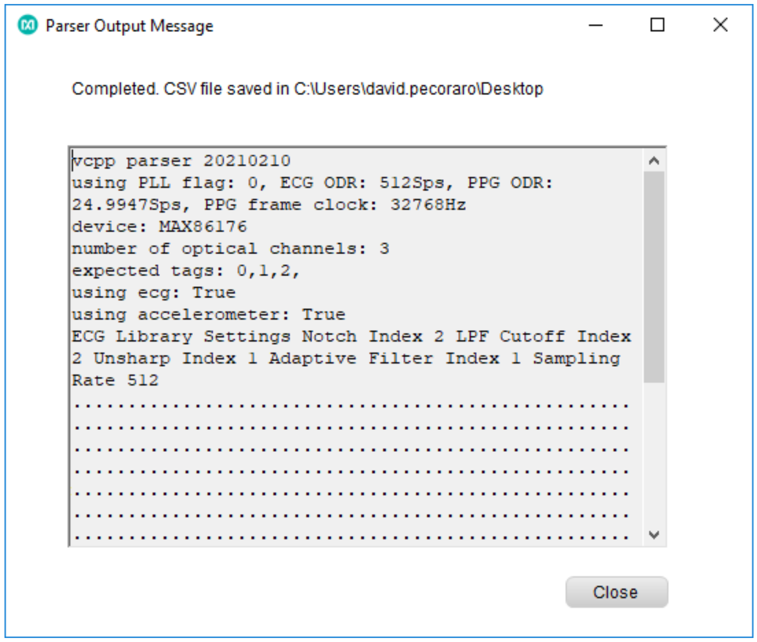


Figure 33. Completed Flash Log Parse Confirmation Window.

8.3 Data Format

PPG, ECG, and Temperature log files are saved in separate .csv files. PPG files are saved with the "_PPG" designator, ECG files are saved with "_ECG" designator, and temperature logs are saved with "_Temperature" designator. These files can be opened with a standard .csv editor, such as Microsoft Excel. Temperature is always logged. ECG and/or PPG must be enabled. PPG and ECG both cannot be disabled. If ECG *or* PPG is disabled, a .csv will not be created for the respective feature, example, PPG and Temperature are enabled, no ECG file log would be created.

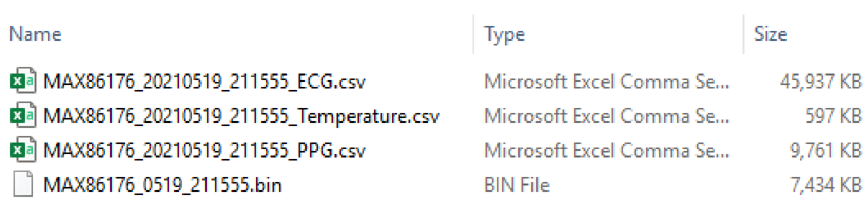


Figure 34. Data log output and naming structure.

ECG Log Files

The following describes the output file format for ECG log files, which are created when ECG measurements are enabled. If ECG is disabled, a "_ECG.csv" will not be created.

- Rows 1-14 contain register values.
- Row 15 contains the start time in milliseconds.
- Row 16 is a column header denoting the measurement timestamp, sample number, raw ECG data, and filtered ECG data.
- The rows following contain rows of data corresponding to the column headers.

- Finally, the rows following the rows of data show stop time, elapsed capture time, and missed packet count. See the following figure for an example where ECG and AC leads-off detection is enabled.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX86176reg0x26			
2	0	0	MAX8617	MAX8617	KX122reg(	KX122reg(	reg0xFF	LIS2DSreg	LIS2DSreg	accelID	fileParseI	0	0	RTCpreSca	WallClock	WallClock	WallClock	WallClock	UseAcc	WallClock	WallClock_B4
3	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	0	0	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	0	0			
4	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	0	0	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	0	0			
5	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	0	0	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	0	0			
6	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	0	0	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	0	0			
7	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	0	0	0			
8	0x02	0x07	0x04	0x00	0x55	0x80	0x9f	0x3f	0x20	0x05	0x1f	0x08	0x18	0x3f	0x50	0x08	0x14	0x00			
9	0x00	0x00	0x41	0x39	0x25	0x52	0x02	0x00	0x00	0x00	0x1f	0xd6	0x9d	0x39	0x43	0x01	0x01	0x77			
10	0x01	0x1a	0x3f	0x50	0x01	0x28	0x00	0x00	0x00	0x02	0x1a	0x3f	0x50	0x01	0x28	0x00	0x00	0x00			
11	0x00	0x18	0x3a	0x50	0x00	0x00	0x00	0x00	0x00	0x00	0x18	0x3a	0x50	0x00	0x00	0x00	0x00	0x00			
12	0x00	0x18	0x3a	0x50	0x00	0x00	0x00	0x00	0x00	0x00	0x18	0x3a	0x50	0x00	0x00	0x00	0x00	0x00			
13	0x00	0x18	0x3a	0x50	0x00	0x00	0x00	0x00	0xcb	0x00	0x18	0x3a	0x50	0x00	0x00	0x00	0x02	0x00			
14	0x82	0x00	0x3f	0x00	0x60	0x00	0x00	0x70	0x80	0x00	0x00	0x0d	0x00	0xce	0x40	0x00	0x00	0x00			
15	start time	24.02.2021 17:36:04:35																			
16	Timestam	sampleNu	ECG	Filtered_ECG																	
17	24.02.2021	1	18416	2407.61																	
18	24.02.2021	2	68369	9327.1																	
19	24.02.2021	3	81526	19196.6																	
20	24.02.2021	4	86206	28847.5																	
21	24.02.2021	5	90992	36593.9																	
22	24.02.2021	6	93378	41791.5																	
23	24.02.2021	7	91500	44109.9																	
24	24.02.2021	8	86045	43482.2																	
25	24.02.2021	9	81202	40361.2																	
26	24.02.2021	10	79249	35695																	
27	24.02.2021	11	80112	30611.4																	

Figure 355. Output CSV file example for ECG log files.

PPG Log Files

The following describes the output file format for **PPG** log files, which are created when PPG measurements are enabled. If PPG is disabled, a "_PPG.csv" will not be created.

- Rows 1-14 contain register values.
- Row 15 contains the start time in milliseconds.
- Row 16 contains expected tag values.
- Row 17 is a column header denoting the timestamp, sample number, tags for LED, PPG values for each channel, and accelerometer values.
- The rows following contain rows of data corresponding to the column headers.
- Finally, the rows following the rows of data show stop time, elapsed capture time, missed packet count, and incorrect tag count.
- See Figure 31 for an example where algo hub mode has been enabled with default settings. The column header for PPG measurements are denoted in the format LEDCn_PDm, where n corresponds to the nth-enabled measurement and m corresponds to the PPG channel 1 or 2. In this example, LEDC1_PD2 represents the first-enabled measurement and PPG channel 2 of that measurement. Note that this header format does not describe which LED or LED driver is used. When multiple measurements are enabled, the corresponding columns are added in the .csv file following this header format.
- Flash log does not use an RTC, thus only sample number and the MAX86176's timing data are captured., therefore the PPG log file might differ from the below example slightly.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX86176reg0x26			
2	0	0	MAX8617	MAX8617	KX122reg(	KX122reg(	reg0xFF	LIS2DSreg	LIS2DSreg	accelID	fileParseI	0	0	RTCpreSca	WallClock	WallClock	WallClock	WallClock	UseAcc	WallClock	WallClock_B4
3	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	0	0	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	0	0			
4	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	0	0	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	0	0			
5	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	0	0	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	0	0			
6	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	0	0	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	0	0			
7	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	MAX8617	0	0	0			
8	0x02	0x07	0x04	0x00	0x55	0x80	0x9f	0x3f	0x20	0x05	0x1f	0x08	0x18	0x3f	0x50	0x08	0x14	0x00			
9	0x00	0x00	0x41	0x39	0x25	0x52	0x02	0x00	0x00	0x00	0x1f	0xd6	0xb4	0x73	0xfb	0x01	0x01	0x77			
10	0x01	0x1a	0x3f	0x50	0x01	0x28	0x00	0x00	0x00	0x02	0x1a	0x3f	0x50	0x01	0x28	0x00	0x00	0x00			
11	0x00	0x18	0x3a	0x50	0x00	0x00	0x00	0x00	0x00	0x00	0x18	0x3a	0x50	0x00	0x00	0x00	0x00	0x00			
12	0x00	0x18	0x3a	0x50	0x00	0x00	0x00	0x00	0x00	0x00	0x18	0x3a	0x50	0x00	0x00	0x00	0x00	0x00			
13	0x00	0x18	0x3a	0x50	0x00	0x00	0x00	0x00	0x00	0x00	0x18	0x3a	0x50	0x00	0x00	0x00	0x00	0x01			
14	0x02	0x00	0x3f	0x00	0x60	0x00	0x00	0x70	0x80	0x00	0x00	0x0d	0x00	0xce	0x40	0x00	0x00	0x00			
15	start time	24.02.2021 18:01:26:395																			
16	expected	0	0	1	1	2	2														
17	Timestam	samepleN	tagLEDC1_	tagLEDC1_	tagLEDC2_	tagLEDC2_	tagLEDC3_	tagLEDC3_	LED1_PPG	LED1_PPG	LED2_PPG	LED2_PPG	LED3_PPG	LED3_PPG	ACC_X[mg	ACC_Y[mg	ACC_Z[mg]				
18	24.02.2021	1	0	0	1	11	2	11	41214	63397	145157	524287	98373	524287	-21	-252	970				
19	24.02.2021	2	0	0	1	11	2	11	41117	63288	145021	524287	98301	524287	-14	-256	978				
20	24.02.2021	3	0	0	1	11	2	11	41022	63129	144937	524287	98257	524287	-17	-256	969				
21	24.02.2021	4	0	0	1	11	2	11	40957	62876	144990	524287	98152	524287	-22	-263	952				
22	24.02.2021	5	0	0	1	11	2	11	40563	62522	144686	524287	97884	524287	-13	-244	976				
23	24.02.2021	6	0	0	1	11	2	11	40581	62405	144670	524287	97931	524287	-16	-234	962				
24	24.02.2021	7	0	0	1	11	2	11	40658	62350	144584	524287	97917	524287	-15	-253	973				
25	24.02.2021	8	0	0	1	11	2	11	40678	62322	144546	524287	97927	524287	-12	-259	974				
26	24.02.2021	9	0	0	1	11	2	11	40612	62240	144472	524287	97941	524287	-12	-259	962				
27	24.02.2021	10	0	0	1	11	2	11	40529	62161	144449	524287	97995	524287	-10	-255	970				
28	24.02.2021	11	0	0	1	11	2	11	40454	62090	144440	524287	98025	524287	-17	-253	967				
29	24.02.2021	12	0	0	1	11	2	11	40393	62016	144453	524287	98051	524287	-17	-253	967				
30	24.02.2021	13	0	0	1	11	2	11	40331	61999	144448	524287	98065	524287	-11	-257	966				
31	24.02.2021	14	0	0	1	11	2	11	40248	61920	144384	524287	98035	524287	-15	-255	967				
32	24.02.2021	15	0	0	1	11	2	11	40188	61824	144351	524287	98001	524287	-18	-251	973				
33	24.02.2021	16	0	0	1	11	2	11	40120	61767	144299	524287	97966	524287	-15	-260	973				
34	24.02.2021	17	0	0	1	11	2	11	40065	61747	144270	524287	97953	524287	-16	-252	965				

Figure 36. Output CSV file example for PPG measurements when only PPG is enabled (first few rows).

Temperature Log Files

The following describes the output file format for temperature log files.

- The first row contains the header denoting timestamp and temperature measurement columns.
- All other rows up to the last contain the collected temperature measurements.
- The last row contains the stop timestamp.

	A	B	C	D
1	Timestamp[Day.Month.Y	Temperature[C]		
2	24.02.2021 17:36:04:151	30.58		
3	24.02.2021 17:36:04:248	30.58		
4	24.02.2021 17:36:04:345	30.59		
5	24.02.2021 17:36:04:442	30.59		
6	24.02.2021 17:36:04:539	30.585		
7	24.02.2021 17:36:04:636	30.585		
8	24.02.2021 17:36:04:733	30.59		
9	24.02.2021 17:36:04:829	30.59		
10	24.02.2021 17:36:04:926	30.585		
11	24.02.2021 17:36:05:23	30.585		
12	24.02.2021 17:36:05:120	30.595		
13	24.02.2021 17:36:05:217	30.595		
14	24.02.2021 17:36:05:314	30.595		
15	24.02.2021 17:36:05:411	30.595		
16	24.02.2021 17:36:05:508	30.585		
17	24.02.2021 17:36:05:604	30.57		
18	24.02.2021 17:36:05:701	30.585		
19	24.02.2021 17:36:05:798	30.6		

Figure 377. Output CSV file example for temperature measurements

Notes

When both PPG and ECG measurements are enabled, the output .csv file format for the PPG log file is slightly different.

- Instead of timestamp, the column header in Row 17 denotes ppgDelayInFrameClocks, ppgDelayInMicroSeconds, and relativeEcgSampleNum. Note that the column header ppgDelayInMicroSeconds also contains the FCLK frequency that was used. The data corresponding to these column headers allow the user to sync the timing of PPG data with ECG data. See the following figure for an example where both PPG and ECG are enabled. See MAX86176 Datasheet for detailed timing information.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1	MAX86176reg	MAX86176reg0x1	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176reg0x26			
2	0	0	MAX86176	MAX86176	KX122reg	KX122reg	reg0xFF	LIS2DSreg	LIS2DSreg	accelID	fileParseI	0	0	RTCpreSca	WallClock	WallClock	WallClock	WallClock	UseAcc	WallClock	WallClock_B4
3	MAX86176reg	MAX86176reg0x2	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	0	0	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	0	0			
4	MAX86176reg	MAX86176reg0x3	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	0	0	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	0	0			
5	MAX86176reg	MAX86176reg0x4	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	0	0	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	0	0			
6	MAX86176reg	MAX86176reg0x5	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	0	0	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	0	0			
7	MAX86176reg	MAX86176reg0x9	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	MAX86176	0	0	0			
8	0x02	0x07	0x04	0x00	0x55	0x80	0x9f	0x3f	0x20	0x05	0x1f	0x08	0x18	0x3f	0x50	0x08	0x14	0x00			
9	0x00	0x00	0x41	0x39	0x25	0x52	0x02	0x00	0x00	0x00	0x1f	0xd6	0x9d	0x39	0x43	0x01	0x01	0x77			
10	0x01	0x1a	0x3f	0x50	0x01	0x28	0x00	0x00	0x00	0x02	0x1a	0x3f	0x50	0x01	0x28	0x00	0x00	0x00			
11	0x00	0x18	0x3a	0x50	0x00	0x00	0x00	0x00	0x00	0x00	0x18	0x3a	0x50	0x00	0x00	0x00	0x00	0x00			
12	0x00	0x18	0x3a	0x50	0x00	0x00	0x00	0x00	0x00	0x00	0x18	0x3a	0x50	0x00	0x00	0x00	0x00	0x00			
13	0x00	0x18	0x3a	0x50	0x00	0x00	0x00	0x00	0xcb	0x00	0x18	0x3a	0x50	0x00	0x00	0x00	0x02	0x00			
14	0x82	0x00	0x3f	0x00	0x60	0x00	0x00	0x70	0x80	0x00	0x00	0x0d	0x00	0xce	0x40	0x00	0x00	0x00			
15	start time	24.02.2021 17:36:04:35																			
16	expected tags	0	0	1	1	2	2														
17	PpgDelayInFra	PpgDelayInMicro	relativeEc	sampleNu	tagLEDC1_	tagLEDC1_	tagLEDC2_	tagLEDC2_	tagLEDC3_	tagLEDC3_	LED1_PPG	LED1_PPG	LED2_PPG	LED2_PPG	LED3_PPG	LED3_PPG	ACC_X[mg	ACC_Y[mg	ACC_Z[mg]		
18	33	1007.080078	13		0	0	1	11	2	11	43998	61847	182435	524287	115251	524287	180	-102	989		
19	0	0	33		0	0	1	11	2	11	43981	61857	182440	524287	115258	524287	183	-108	990		
20	31	946.044922	54		0	0	1	11	2	11	43939	61859	182506	524287	115333	524287	183	-108	990		
21	62	1892.089844	74		0	0	1	11	2	11	43928	61876	182469	524287	115280	524287	177	-112	991		
22	29	885.009766	95		0	0	1	11	2	11	43938	61925	182478	524287	115276	524287	181	-105	987		
23	60	1831.054688	115		0	0	1	11	2	11	43946	61949	182549	524287	115351	524287	176	-105	990		
24	27	823.974609	136		0	0	1	11	2	11	43941	61970	182543	524287	115348	524287	180	-106	990		
25	58	1770.019531	156		0	0	1	11	2	11	43937	61969	182511	524287	115322	524287	181	-113	987		
26	25	762.939453	177		0	0	1	11	2	11	43922	62004	182511	524287	115330	524287	181	-109	989		
27	56	1708.984375	197		0	0	1	11	2	11	43903	62014	182511	524287	115333	524287	178	-114	989		
28	23	701.904297	218		0	0	1	11	2	11	43908	62053	182489	524287	115308	524287	185	-109	988		
29	54	1647.949219	238		0	0	1	11	2	11	43877	62060	182519	524287	115347	524287	183	-107	990		
30	21	640.869141	259		0	0	1	11	2	11	43888	62108	182557	524287	115363	524287	182	-108	994		
31	52	1586.914062	279		0	0	1	11	2	11	43861	62112	182519	524287	115329	524287	185	-107	987		
32	19	579.833984	300		0	0	1	11	2	11	43855	62137	182515	524287	115327	524287	181	-114	987		
33	50	1525.878906	320		0	0	1	11	2	11	43866	62171	182523	524287	115312	524287	181	-106	991		
34	17	518.798828	341		0	0	1	11	2	11	43862	62157	182423	524287	115236	524287	181	-109	992		
35	48	1464.84375	361		0	0	1	11	2	11	43849	62177	182443	524287	115244	524287	183	-115	985		

Figure 38. Output CSV file example for PPG measurements when both PPG and ECG are enabled (first few rows and columns).

9 Notes, Troubleshooting, and FAQ

9.1 Known Issues

Please see the *Software Package Release Notes* PDF in the release package for a list of known issues and updates.

9.2 Notes on the Enclosure

The MAXREFDES104# is not an industrial-grade health band. It is intended for performance demonstration and typical design guidance. Opening and closing of the enclosure lid is not recommended for any reason. Solvents such as alcohol should not be used to clean the device since solvents can damage these items. The MAXREFDES104# is not waterproof nor sweatproof. Keep it away from any excessive liquids including wrist perspiration, as it might damage the sensitive electronics inside by shorting out exposed pads.

9.3 Note on Greyed-Out Options

Some combinations of settings are either not supported or introduce known bugs. These combinations are greyed-out in the GUI as to avoid potential issues. See the known issues text file distributed with the GUI for a list/additional information.

9.4 Troubleshooting/FAQ

Table 11. Troubleshooting Table

Symptom	Check
Cannot connect to device with GUI	Check device firmware and GUI are both updated to the latest versions.
No device found by the GUI	Ensure the CySmart CY5677 BLE dongle is plugged into the PC prior to launching the GUI, and that the correct drivers are installed for the dongle.
Connection issues: Intermittent or dropped connections	Ensure no other BLE devices or dongles are being used (minimize when possible) and use only the included CySmart CY5677 BLE dongle.
Device will not power on	Check device is charged. Plug in the device to a USB port through the included USB-C cable and attempt to power on.
PPG/ECG signal quality issues	Ensure the device has a good fit on the wrist. See *Section 5.3 – How to Position the Device on the Wrist*.

	Ensure the battery level of the device is sufficiently charged. Do not use the device while charging. Battery power is directly correlated to device performance.
ECG signal is inverted	Check the ECGP/N Polarity setting on the *ECG Mux* tab.
HR Algorithm is not working properly	Ensure sufficiently high ADC counts. Increase Sample Rate, Average, and Integration Pulse Width on the *PPG Mode* tab. Use AGC and target 5µA+ of PD current on the *PPG Mode* tab. Alternatively, disable AGC and target 400k+ ADC counts manually.
SpO_2 Algorithm is not working properly	Hold still! Ensure sufficiently high ADC counts. Increase Sample Rate, Average, and Integration Pulse Width on the *PPG Mode* tab. Use AGC and target 5µA+ of PD current on the *PPG Mode* tab. Alternatively, disable AGC and target 400k+ ADC counts manually.
ECG Signal is noisy	Ensure NOT touching the USB port on the device. This is connected to the ground and affects the body bias. Use included rubber stopper if provided with one or adjust fingers to avoid touching USB port.
The MAXREFDES104# does not show up as mass storage device	Use the included USB-C cable and try rotating the USB-C male end 180 degrees and reinsert, thus rotating the cable connection.
Device does not show up after connected to computer with USB-C cable	The MAXREFDES104# will show up as a “USB Drive” on some systems. Try **flipping** the USB-C cable that in plugged into the device. (early versions are unidirectional, later version are bi-directional)