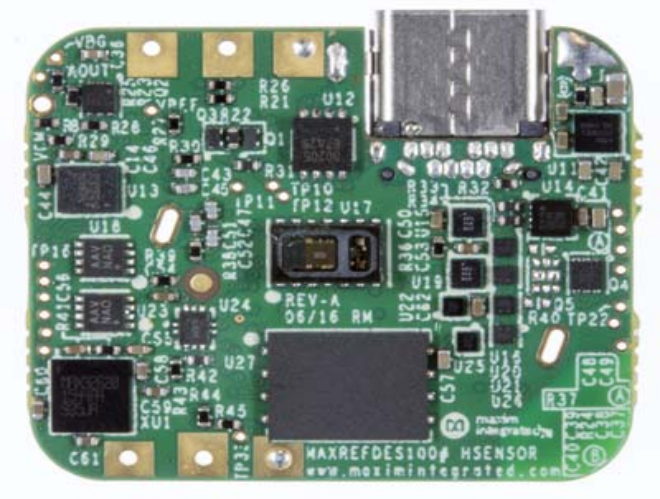
System Board 6312

MAXREFDES100# Health Sensor Platform



Maxim MAXREFDES100# health sensor platform is an integrated sensor platform that helps customers evaluate Maxim's complex and innovative medical and high-end fitness solutions. The platform integrates one biopotential analog front-end solution (MAX30003), one pulse oximeter and heart-rate sensor (MAX30101), two human body temperature sensors (MAX30205), one 3-axis accelerometer, one 3D accelerometer and 3D gyroscope, and one absolute barometric pressure sensor.

PC and Android applications are provided on the Design Resources tab to help you get up and running quickly. The PC application provides a graphical user interface (GUI) allowing you to configure and interact with all the sensors over a USB connection. The Android application provides the ability to monitor sensor data over BLE. Instructions for installing and running the applications are found on the details tab.

The ARM mbed development environment is supported for developers who want to customize the operation of the platform. The companion MAXREFDES100HDK# programming adapter that ships with the platform provides driverless drag-and-drop programming for firmware updates as well as a virtual UART interface and CMSIS-DAP compatible debugger. For more details on firmware development and source code examples visit the MAX32620HSP platform page on the ARM mbed developer site.

Features

- Skin temperature
- Heart rate
- Biopotential measurement (ECG)
- Motion
- Rotation
- Barometric pressure

Applications

- Fitness devices
- Clinical devices
- Wearable devices

Maxim builds complex and innovative solutions for medical and high-end fitness applications. These solutions are primarily stemming from multiple product lines within Maxim. In order to help customers evaluate the features of these solutions quickly and enable them with their designs, Maxim developed an integrated sensor platform called "hSensor" Platform. With this platform, customers can evaluate our portfolio faster and more easily for multiple use cases. The hSensor platform is also flexible to accommodate our newer solutions in design, or on the roadmap.

The hSensor platform supports the measurement of motion, precision skin temperature, and a variety of biopotential measurements, including electrocardiography (ECG), electromyography (EMG), and electroencephalography (EEG). In addition, the hSensor platform also supports a variety of reflective photo plethysmography measurements including pulse oximetry and heart-rate (HR) detection at three wavelengths, 880nm (infrared, IR), 660nm (red) and 537nm (green).

The platform supports GUI applications on Windows®-based PCs and Android®-based devices for simple data collection and visualization. Both direct USB connection (through a USB type C connector) and Bluetooth® low energy (BLE) radio are supported for configuration and data collections.

A direct-to-flash memory mode is supported for data collection. Flash memory read using a USB connection is also implemented.

The microcontroller of the platform is programmed with firmware that manages the system, controls the registers of all the devices on the platform, and communicates with the PC GUI. For users who want to customize the firmware for the microcontroller, refer to the firmware development guide for details: mbed (referenced as MAX32620HSP).

The following items are included in the reference design box:

- MAXREFDES100# board: the health-sensor board
- MAXREFDES100HDK# board: the development board for the MAXREFDES100# sensor board
- Battery holder: for the installation of CR2032-type coin-cell battery if a USB cable is not used
- Two ECG cables: users can solder these two ECG cables to the board for ECG measurements
- USB type-C cable: for the connection between a PC and the MAXREFDES100# board
- Micro-USB cable: for the connection between a PC and the MAXREFDES100HDK# board

The following use cases can be evaluated using this platform:

1. Fitness Applications

- Chest-based applications
  - Chest straps with HR
  - Chest straps with HR & ECG
- Wrist-based applications
  - Smart watches with Optical HR
- Ear-based applications
  - Headphones with Optical HR

2. Clinical applications

- Chest-based applications
  - 1 lead-ECG patch for Arrhythmia detection (ECG & HR only)
  - Skin temperature measurements
- Finger-based applications
  - Optical SpO2 measurement
- Ear-based applications
  - Optical HR & SpO2
- Head-based applications
  - Optical HR & SpO2
- Arm-based applications
  - Arm bands with ECG

As with all Maxim reference designs, the bill of materials (BOM), schematics, layout files, Gerber files, firmware, and software are all available online.

System Diagram

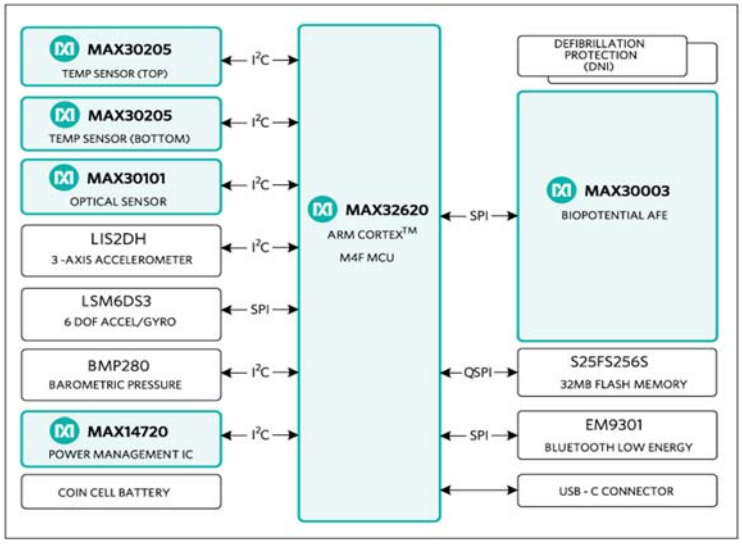


Figure 1. The MAXREFDES100# Reference Design Block Diagram.

Detailed Hardware Description

The MAX32620 microcontroller lies at the center of the hSensor. The following sensors are installed: MAX30003 biopotential analog front-end (AFE), MAX30205 human body temperature sensor, MAX30101 pulse oximeter and heart-rate sensor, LIS2DH 3-axis accelerometer, LSM6DS3 3D accelerometer and 3D gyroscope, and BMP280 absolute barometric pressure sensor.

Power Supplies

The hSensor platform can be powered by a USB connection or by a CR2032-type coin cell battery. When both USB and coin cell are attached the power is drawn from the USB due to MOSFET / Schottky diode at Q4. If a coin cell is attached without USB the coin cell is used to power the hSensor platform.

The hSensor platform uses a MAX14720 PMIC for the majority of the power management. The PMIC has internal programming such that a 3-second button press at SW1 turns the device on. A 20-second press at SW2 turns the PMIC off.

The PMIC has a power-on configuration that provides 1.2V, 1.8V and VSYS voltages. Here VSYS comes from SWOUT, which in turn comes from the battery or USB through the PMIC pin SWIN. After power-up, the microcontroller configures the PMIC for a boost voltage of 3.3V, which appears at the HVOUT pin.

While the PMIC provides the majority of power management there are some additional power supply chips. The temperature sensors are powered by a MAX8880 LDO, which is powered by HVOUT (3.3V) and regulates this down to 2.5V. The PMIC itself is fed by a MAX8881 3.3V LDO when the hSensor is attached to USB.

ESD protection is provided by the MAX3205, which attaches to all of the USB signals except for DP/DM, which have ESD protection provided by the MAX32620.

Mode selection signals

The hSensor platform uses the USB type C connector for debug (programming) and accessory signals. In some circumstances, these signals would contend with a USB host, so there is circuity to isolate these signals as needed.

The isolation is done with MAX4741 low-voltage analog switches. These switches are controlled by a combination of logic gates and MAX9064 single comparators.

The MAX9064 has an internal comparison voltage of 0.2V and two of them are used to monitor the USB pins A5 and B5 (typically designated as CC/V_{CONN}). The USB A5 and B5 pins have 5.1kΩ pulldowns on the HSP board, a USB cable has a 56kΩ pullup on only pin A5 and a debug adapter board has 56kΩ pullups on both pin A5 and B5.

The following table indicates how the hSensor platform self-configures based on the USB A5 and B5 pins.

USB Pin A5	USB Pin B5	Mode	Connection
Low	Low	Accessory	VIO and UART enabled by micro
Low	High	USB Cable	All accessory signals isolated
High	Low		
High	High	Debug	SWD, RST, VIO and UART enabled

MAX32620 Microcontroller

The MAX32620 is a 32-bit ARM® Cortex®-M4F (M4 plus floating point unit) microcontroller, suited for emerging medical and fitness applications. The architecture combines high-efficiency, signal-processing functionality with low cost, and ease of use. The device features 4 powerful and flexible power modes. Built-in dynamic clock gating and firmware controlled power gating minimize power consumption for any application. Multiple SPI, UART, and I^2C serial interfaces, as well as a 1-Wire® master and USB, allow for interconnection to a wide variety of external sensors. A four-input, 10-bit ADC with selectable reference is provided.

Refer to the MAX32620 data sheet for details and design resources including evaluation kit, developing tools & user guides.

MAX30003 Biopotential AFE

The MAX30003 is a complete, biopotential AFE solution for wearable applications. It offers high performance for clinical and fitness applications, with ultra-low power for long battery life. The MAX30003 is a single biopotential channel providing ECG waveforms and heart-rate detection.

The biopotential channel has ESD protection, EMI filtering, internal lead biasing, DC leads-off detection, ultra-low power leads-on detection during standby mode, and extensive calibration voltages for built-in self-test. Soft power-up sequencing ensures no large transients are injected into the electrodes. The biopotential channel also has high-input impedance, low noise, high CMRR, programmable gain, various low-pass and high-pass filter options, and a high resolution analog-to-digital converter (ADC). The biopotential channel is DC coupled, can handle large electrode voltage offsets, and has a fast recovery mode to quickly recover from overdrive conditions, such as defibrillation and electrosurgery.

The MAX30003 interface is compatible with SPI/QSPI™/Micro-wire/DSP. In the hSensor platform, the MAX30003 communicates with the MAX32620 microcontroller through an SPI bus.

The MAX30003 is available in a 28-pin TQFN and 30-bump wafer-level package (WLP), operating over the 0°C to +70°C commercial temperature range.

For users who want to connect the ECG cables for measurement, remove R6, R21, R44, and R45 on the sensor board. Solder ECG cables on ECGP and ECGN pads on the sensor board.

Refer to the MAX30003 data sheet for details.

MAX30205 Human Body Temperature Sensor

The hSensor board has two MAX30205 installed, one on the top side and one on the bottom side.

The MAX30205 temperature sensor accurately measures temperature and provides an overtemperature alarm/interrupt/shutdown output. This device converts the temperature measurements to digital form using a high-resolution, sigma-delta ADC. The accuracy of the MAX30205 meets the clinical thermometry specification of the ASTM E1112 when soldered on the final PCB. Communication is through an I^2C-compatible, 2-wire serial interface.

The I^2C serial interface accepts standard write byte, read byte, send byte, and receive byte commands to read the temperature data and configure the behavior of the open-drain overtemperature shutdown output.

The MAX30205 features three address select lines with a total of 32 available addresses. The sensor has a 2.7V to 3.3V supply-voltage range, low-600µA supply current, and a lockup-protected I2C-compatible interface that make it ideal for wearable fitness and medical applications.

In the hSensor platform, the top side MAX30205 (U2) I2C address is 0b1001-001x, the bottom side MAX30205 (U12) I2C address is 0b1001-000x.

This device is available in an 8-pin TDFN package and operates over the 0°C to +50°C temperature range.

Refer to the MAX30205 data sheet for details.

Quick Start Guide for PC Application

Download the latest MAXREFDES100# PC GUI program MAXREFDES100SWxxx.zip and serial driver MAXREFDES100SerialDriverxxxx.zip located at the MAXREFDES100# web page.

Required equipment:

MAXREFDES100# board
A PC with a spare USB port
One USB type A to C cable

Procedure

The MAXREFDES100# board is fully assembled and tested. Use the following steps below to verify proper board operation.

1. Unzip the hSensor serial port driver **MAXREFDES100SerialPortDriverxxxx.zip** to a local folder. **MAXREFDES100SerialPortDriverxxxx.zip** to a local folder.

2. Unzip the PC GUI program **MAXREFDES100SWxxx.zip** to a local folder and run **MAXREFDES100SWxxx.exe** to install the program on the PC.

3. Run the GUI program and ignore the following pop up window. Click **OK** to continue.

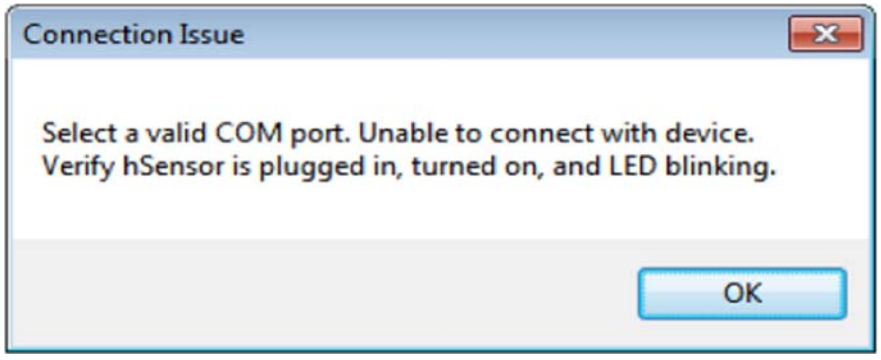


Figure 2. Connection Issue window.

4. Click **Cancel** button on the following pop up window:

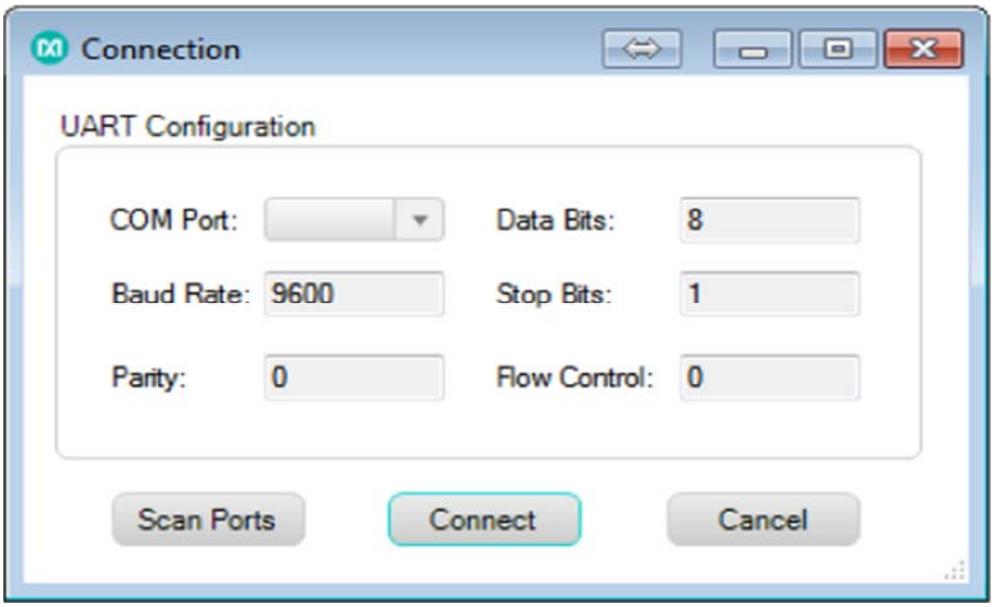


Figure 3. Connection window 1.

5. The GUI program should appear as follow:

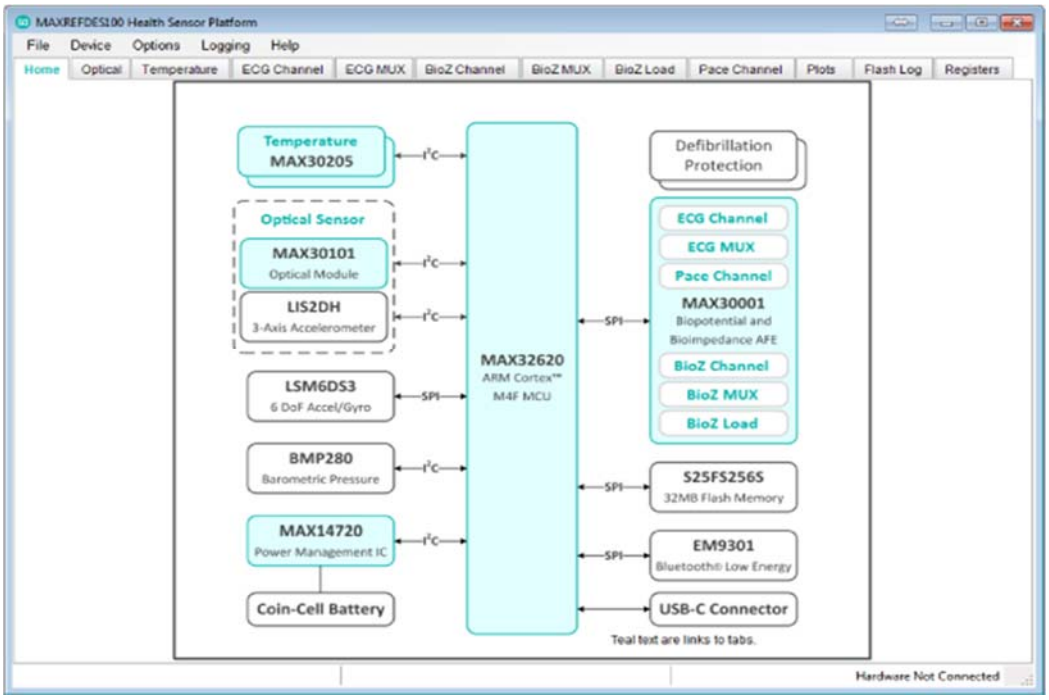


Figure 4. Hardware Not Connected window.

6. Connect the hSensor board to the PC with the USB A to C cable.

7. Press and hold the SW1 switch on the hSensor board for 3 seconds and then release. During this time, the PC looks for the device driver for the hSensor if the Maxim hSensor serial driver has not been installed on this computer.

8. Open the **Device Manager** window, the hSensor is enumerated as **CDC Device** as shown in the following window:

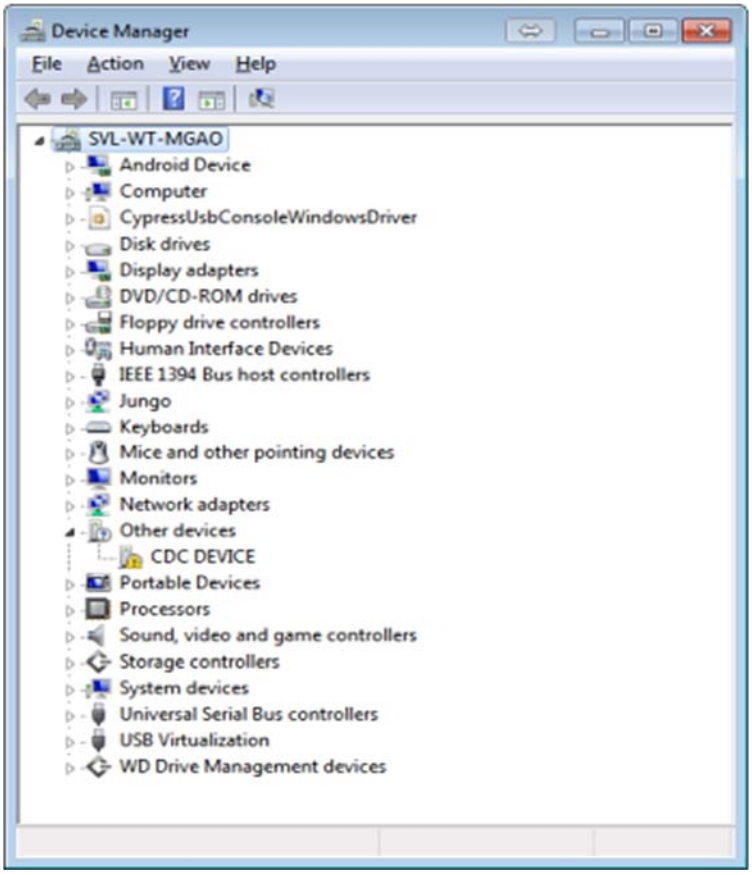


Figure 5. Device Manager window 1.

9. Right click **CDC DEVICE** and then click **Update Driver Software...** to finish the driver installation. The driver is located where MAXREFDES100SerialPortDriverxxxx.zip was unzipped.

10. After the driver installation is done, the hSensor is enumerated as a serial port and the **Device Manager** should display as below:

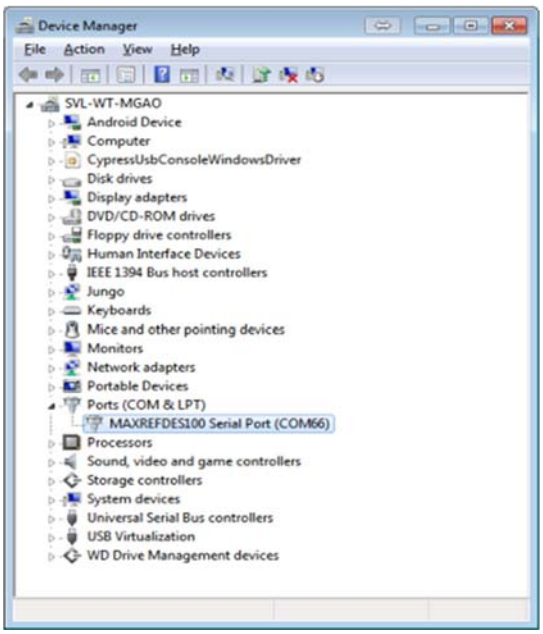


Figure 6. Device Manager window 2.

11. Go back to the hSensor GUI program, click **Device** menu, and then click **Connect** menu item, the GUI program should be connecting to the hSensor hardware. The following window should appear. Check the status bar, verify the hardware is connected.

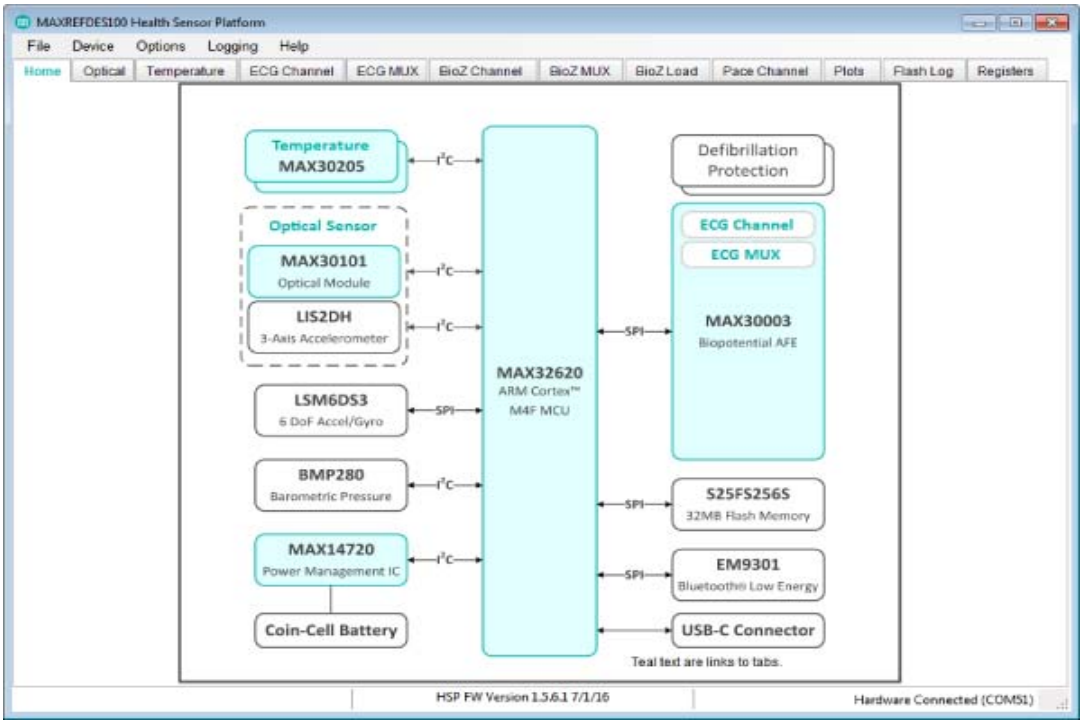


Figure 7. Home tab.

12. In the future sessions, launch the GUI program by clicking the **Start**menu and selecting the **Maxim Integrated** folder and then selecting **Health Sensor Platform** software icon. The GUI should automatically connect to the sensor board. If a connection screen pops up, select the right serial port number and click the **Connect** button as shown below:

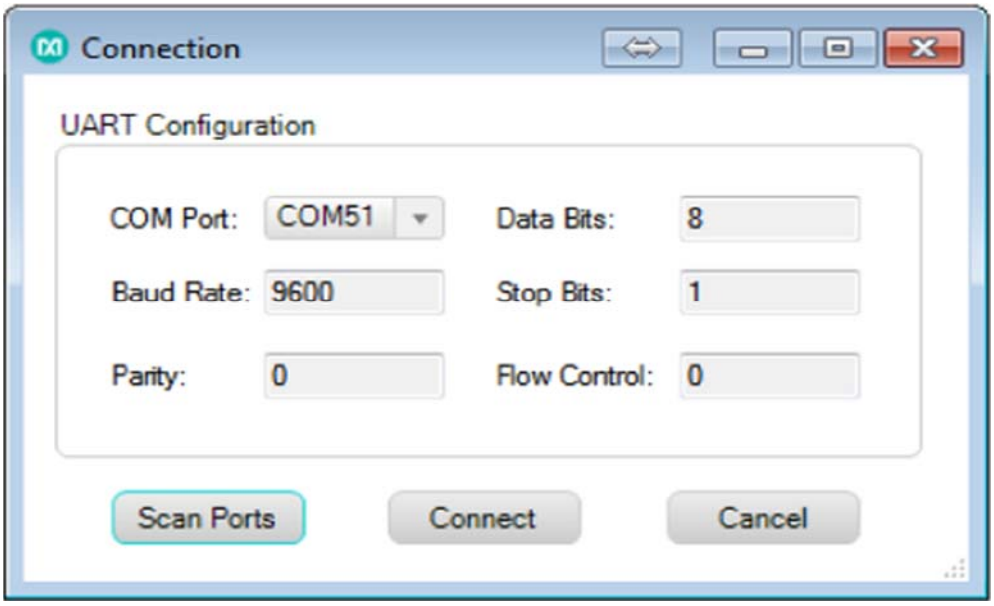


Figure 8. Connection window 2.

Detailed Software Description

The GUI program enables users to quickly configure and evaluate the sensors' features. It also provide intuitive graphs for data collection and visualization.

The **File** menu lets a user exit the application.

The **Device** menu lets a user connect and disconnect the hSensor hardware from the GUI program.

The **Options** menu lets a user show or hide the MAX30003 register names on the GUI, load or save device register settings, and enable or disable **Advanced** tab.

The **Logging** menu lets a user log ECG, R-to-R, optical, and accelerometer sensor data in a CSV file format.

The **Help** menu shows the program information.

Home Tab

The**Home** tab sheet (**Figure 7**) displays the block diagram of the hSensor platform hardware, it also provides quick links to navigate to other tab sheets.

Optical Tab

The **Optical** tab sheet (**Figure 9**) is used to configure the MAX30101 optical sensor parameters. It includes the sensor mode configuration, sensor ADC configurations, and LED settings. It also has graphs to show ADC codes and the LIS2DH accelerometer measurements. Click Start Monitor button to plot optical and acceleration measurements. Click **Stop Monitor** button to stop the measurements. . Click Start Monitor button to plot optical and acceleration measurements. Click **Stop Monitor button** to stop the measurements.

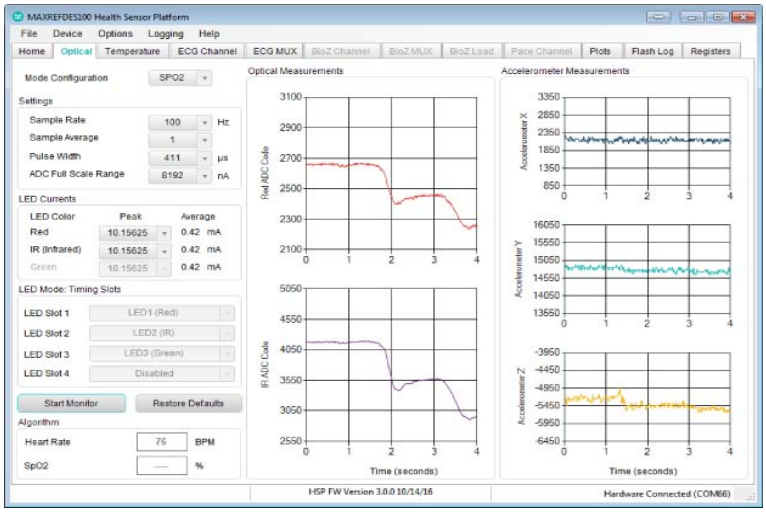


Figure 9. Optical tab.

Temperature Tab

The **Temperature** tab sheet (**Figure 10**) controls the two MAX30205 temperature sensors on the top and bottom sides of the hSensor board.

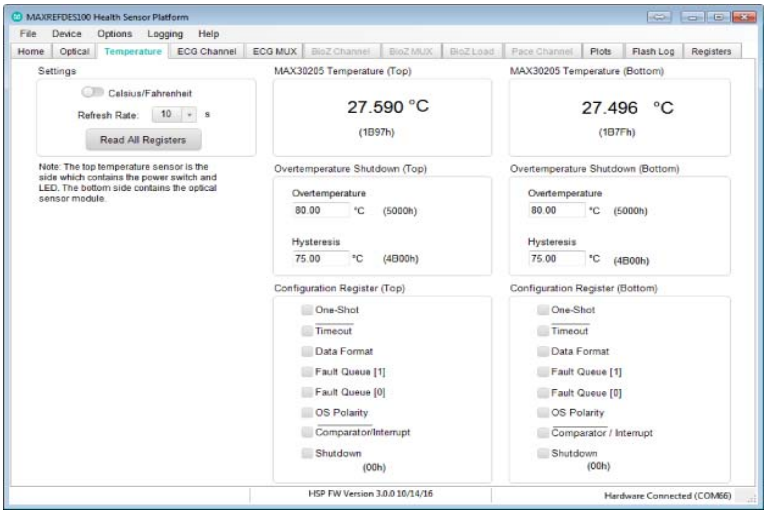


Figure 10. Temperature tab.

ECG Channel Tab

The **ECG Channel** tab sheet (**Figure 11**) controls the MAX30003 ECG channel and R-to-R settings.

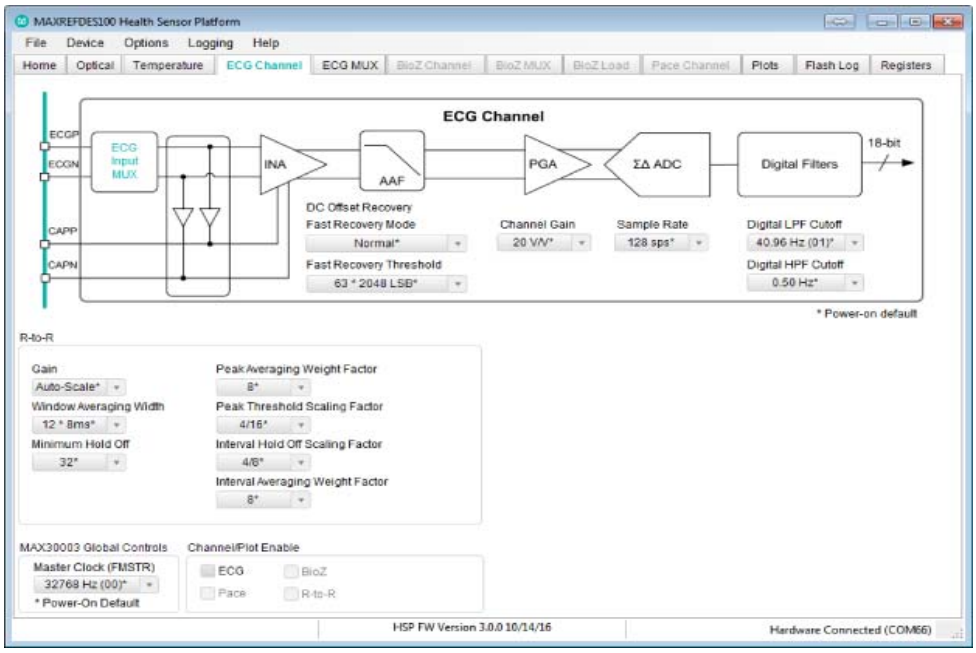


Figure 11. ECG Channel tab.

ECG MUX Tab

The **ECG MUX** tab sheet (**Figure 12**) controls the MAX30003 input multiplexers' settings. A typical setting is shown below:

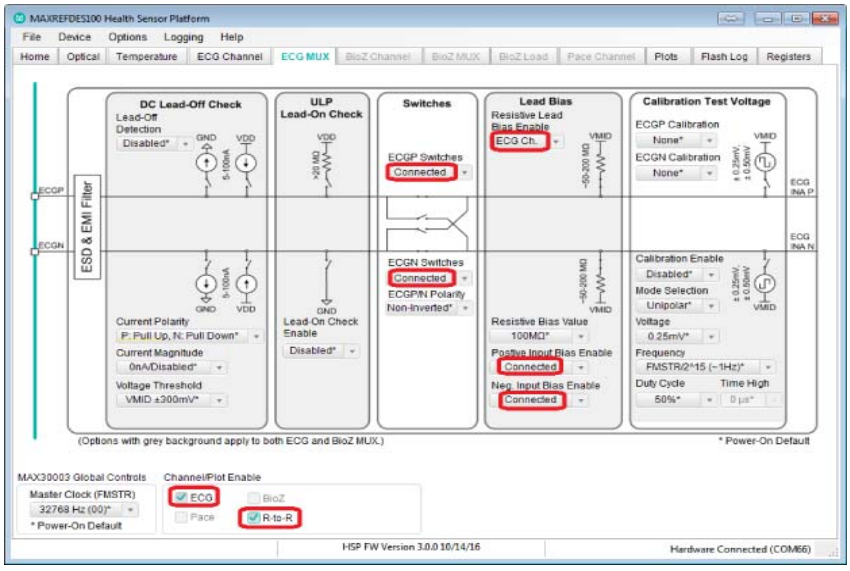


Figure 12. ECG MUX tab.

Plots Tab

The **Plots** tab sheet (**Figure 13**) displays MAX30003 ECG measurement values and input MUX status.

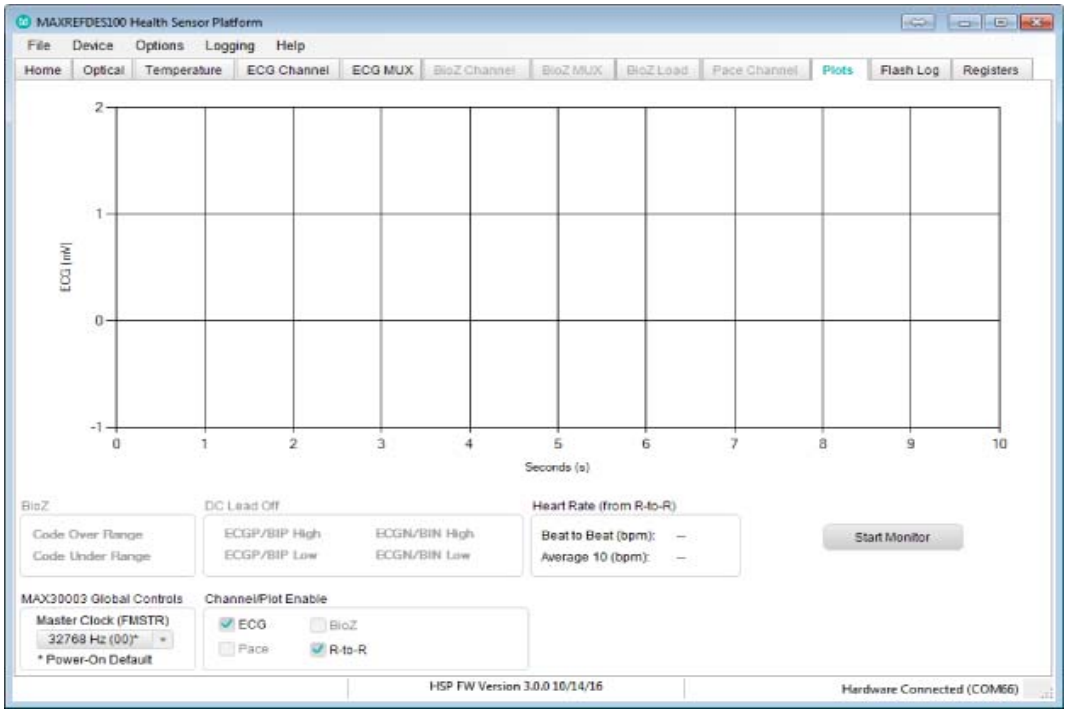


Figure 13. Plots tab.

Flash Log Tab

The **Flash Log** tab sheet (**Figure 14**) allows users to configure data logging to flash memory. The **Read** button reads the current configured settings from flash memory and applies it to the UI. The **Erase** button clears the data-logging settings. The **Write** button commits the data log settings to flash memory by selecting the desired logging channels and parameters on this tab. This also clears any data values stored on the flash memory. For optical, and MAX30003 settings, use the drop-down options on their respective tabs. The **Advanced** button shows the raw command parameters from the UI or settings read from flash memory. The **Prefix** and **Suffix** fields allow users to execute custom commands. The **Save to File** button downloads the data from the flash memory to one or more CSV files. The **Write** button and **Save to File** button operations may require a long period of time to complete depending upon the amount of data stored on the flash memory.

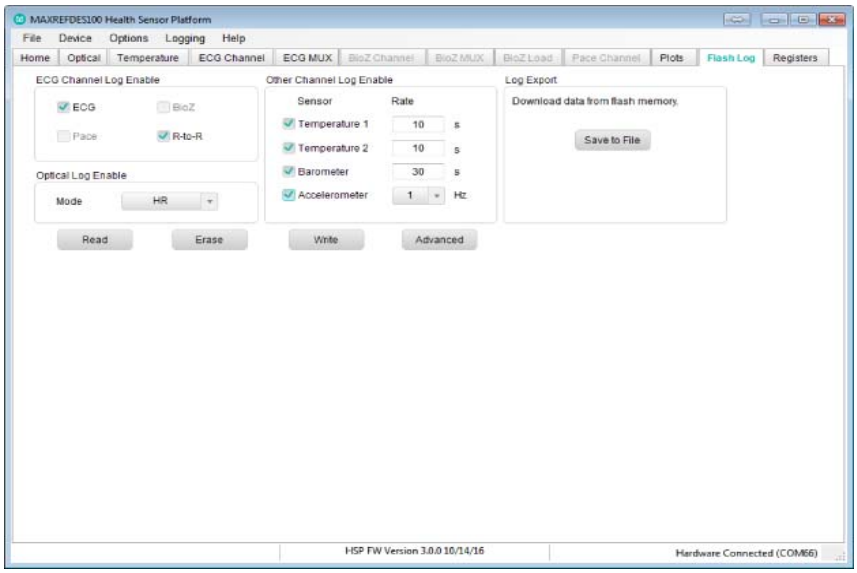


Figure 14. Flash Log tab.

Registers Tab

The **Registers** tab sheet (**Figure 15**) lists all the registers for the MAX30101, MAX30205 (top), MAX30205 (bottom), MAX30003, MAX14720, and the LIS2DH. A user can directly read or write the registers.

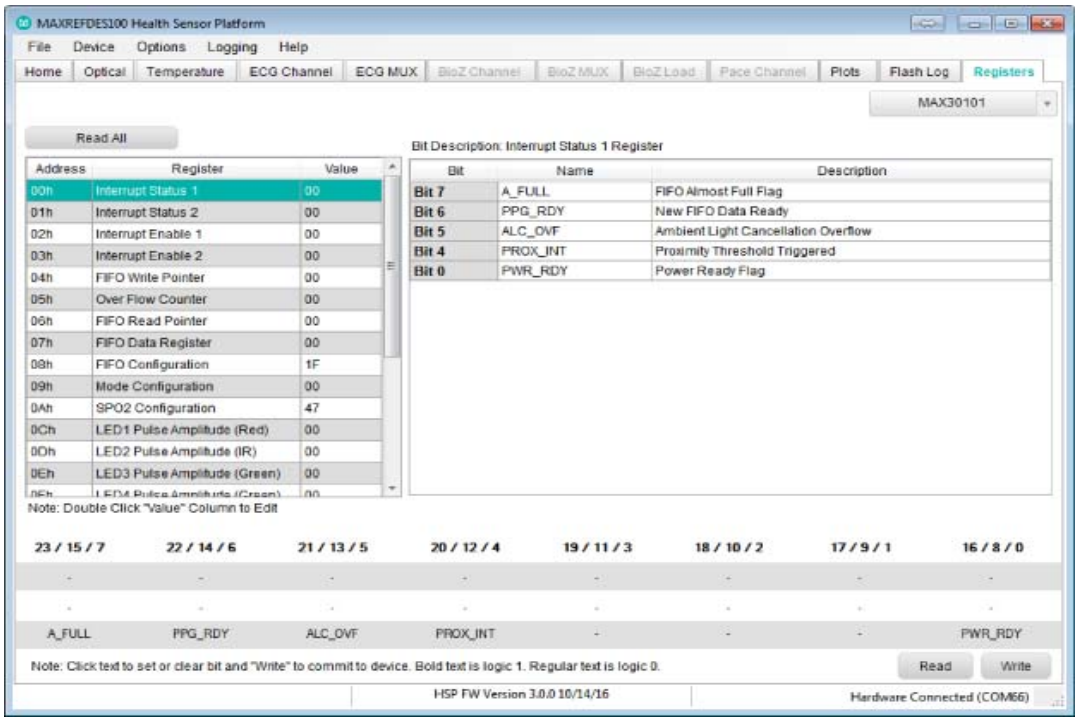


Figure 15. Registers tab.

Quick Start Guide for Android Application

The hSensor Android App is a GUI program running on an Android device. The program collects hSensor data and graphically displays it on the device screen. The program communicates with the hSensor hardware through Bluetooth 4.0 Low Energy radio.

Required Equipment:

MAXREFDES100# board
Android device running at least version 4.4
Android device with Bluetooth 4.0 support
One CR2032 coin cell battery (optional)
A PC with a spare USB port (optional if battery powered)
One USB type A to C cable (optional if battery powered)

Procedure

1. Insert the CR2032 battery into the battery holder B1.
2. If no battery is available, connect the hSensor platform hardware to a PC or Mac though a USB type C connector.
3. Press and release SW1 switch on the board. The red LED beside the switch should flash.
4. Download the latest MAXREFDES100# Android app **MAXREFDES100_Androidxxx.zip** located at the MAXREFDES100# web page. Unzip it and install it on the device. The app requires Android 4.4 or later.
5. Tap the **MAXREFDES100** icon to start the hSensor Android App.

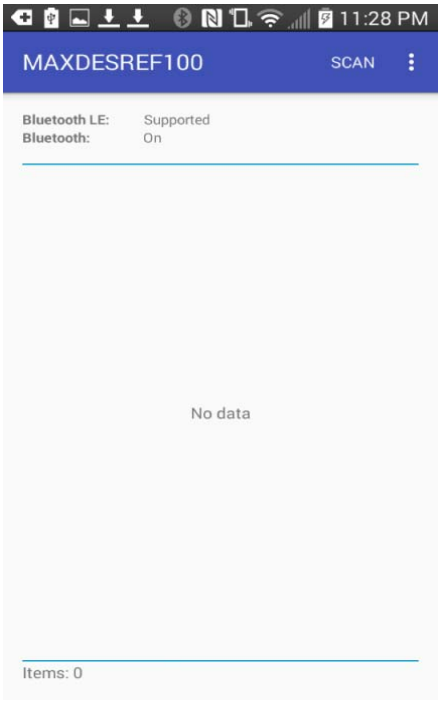


Figure 16. Android Application Screenshot 1.

6. Tap the **Scan** button at the bottom of the screen. The scan lists all of the devices currently advertising using Bluetooth 4.0.

7. Tap the **MAXREFDES100** device in the list to connect to the hSensor platform hardware.



Figure 17. Android Application Screenshot 2.

8. The following screen shows up.

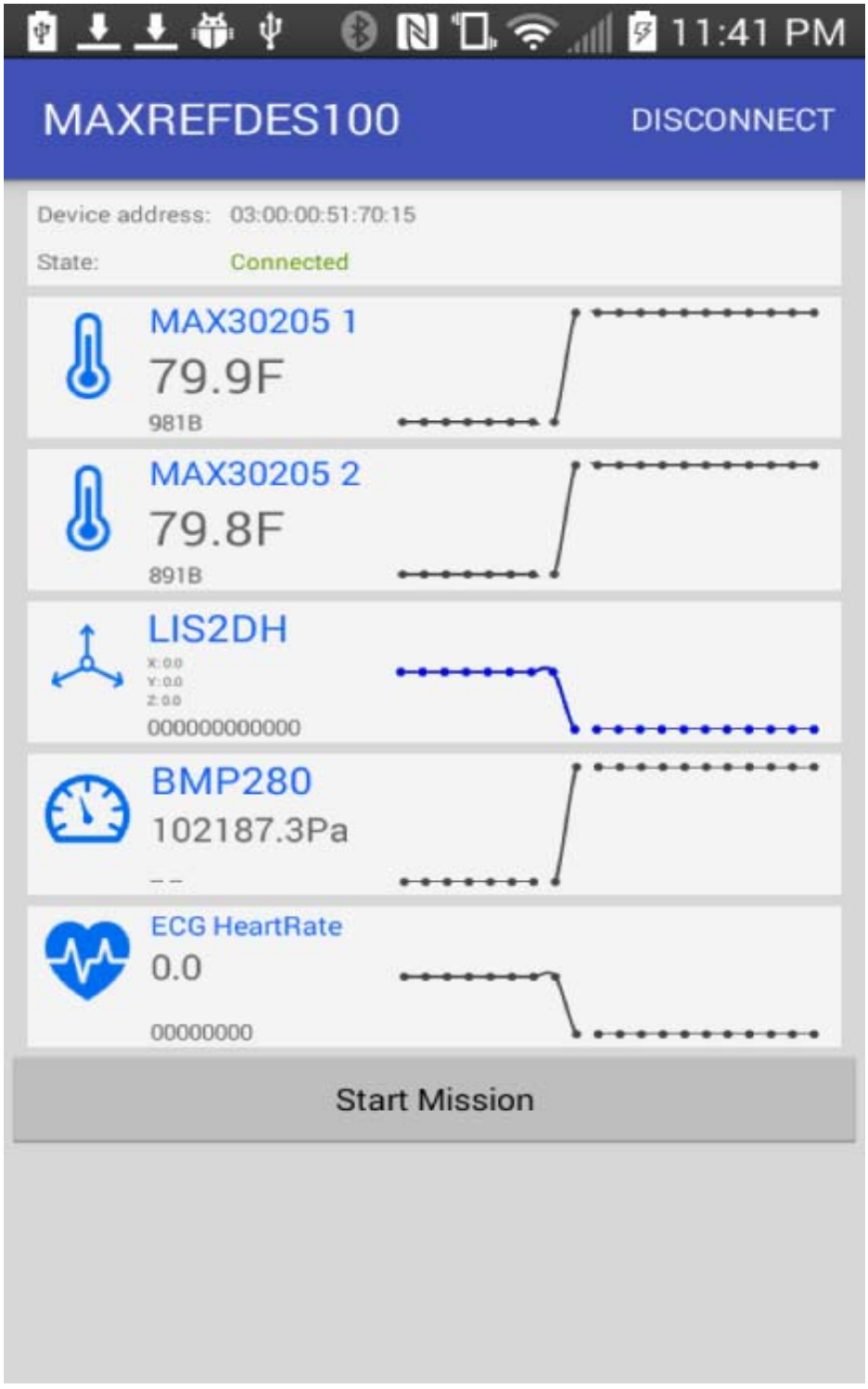


Figure 18. Android Application Screenshot8.

hSensor Interaction:

The hSensor platform sensors are listed when the device is connected. Temperature, accelerometer and pressure are shown. Heart-rate information can be shown from the MAX30003 ECG device. ECG leads must be connected to the hSensor platform in order to show a correct reading. After connecting the leads, click the **Start** button on the screen. The platform starts sampling ECG R-to-R information and displays the resulting heart rate on the screen.

Disconnecting

The hSensor device may be disconnected by pressing the **DISCONNECT** button found at the top of the screen.

Firmware Description

The MAXREFDES100# firmware is based on an interrupt-driven design model. After power-up, the microcontroller configures the power management device and sensors to their default settings. The microcontroller then waits for remote procedure calls (RPC) from GUI or Android application.

The following is the simplified firmware flowchart:

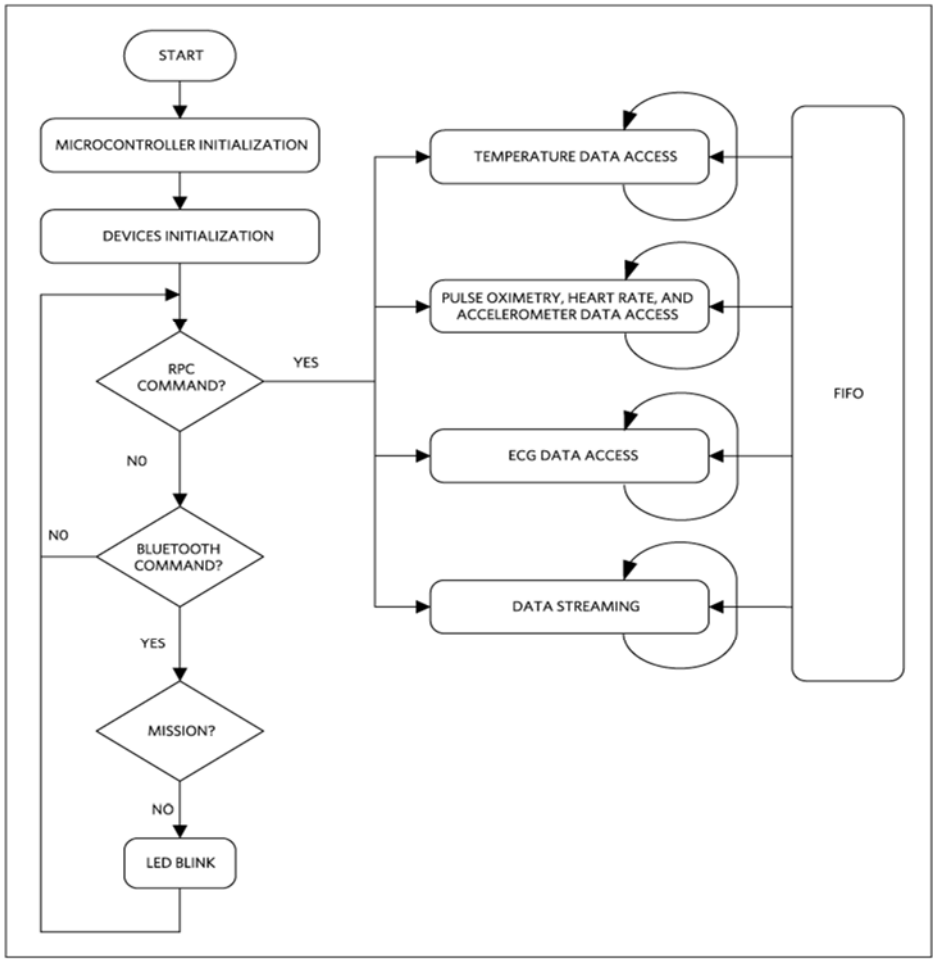


Figure 19. Firmware Flowchart V10.

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