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## mHealth Application Note: Bluetooth Enabled ECG Board

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### ***Overview***

This application note describes a Bluetooth extension of the Texas Instruments' ECG board and how it can be used to capture and display a user's ECG signal in the UAH Serial Application running on a Bluetooth-enabled workstation.

### ***Background***

An electrocardiogram (ECG) is a recording of the electrical activity on the body surface generated by the heart. This activity reflects the action of the cardiac muscle as it depolarizes and repolarizes during the cardiac cycle. The ECG represents the temporal and spatial summation of the action potentials of the myocardial fibers typically measured with body-surface electrodes. ECGs are used to diagnose arrhythmias, abnormal electrolyte (potassium) levels, and conduction abnormalities. They are also used for screening and therapy guidance for heart disease.

Figure 1 shows a typical cycle of an ECG waveform. The ECG signal is characterized by six peaks and valleys labeled with successive letters of the alphabet P, Q, R, S, T, and U. Before we analyze these characteristic peaks and valleys, let us take a quick look at the electrical system of the heart.

Figure 2 shows structures of interest for the heart's electrical system. The sinoatrial node (SA) is the pacemaker of the heart – it initiates the action potentials that cause contraction. The action potential spreads through the atria. The atrioventricular (AV) node allows the signal started by the SA to spread to the ventricles. The bundle of His (atrioventricular bundle) starts at the AV, divides into left and right branches which follow the septum and curve around to the outer

walls. Purkinje fibers extend from the bundle of His. These help spread the action potential rapidly through the ventricle.

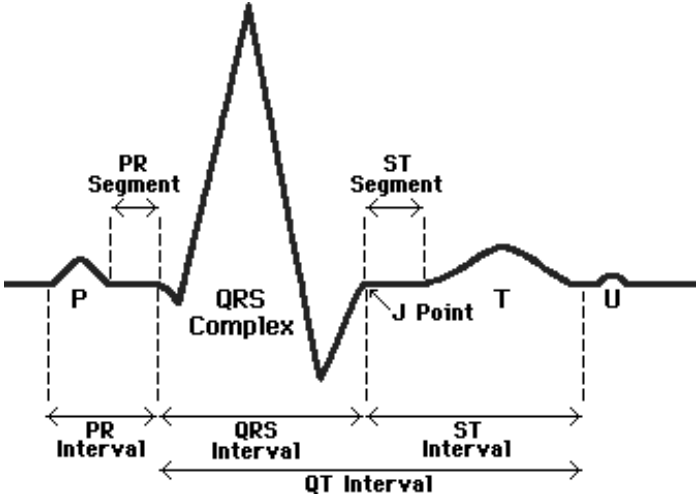


Figure 1. The EKG waveform.

**Structures of the Heart**

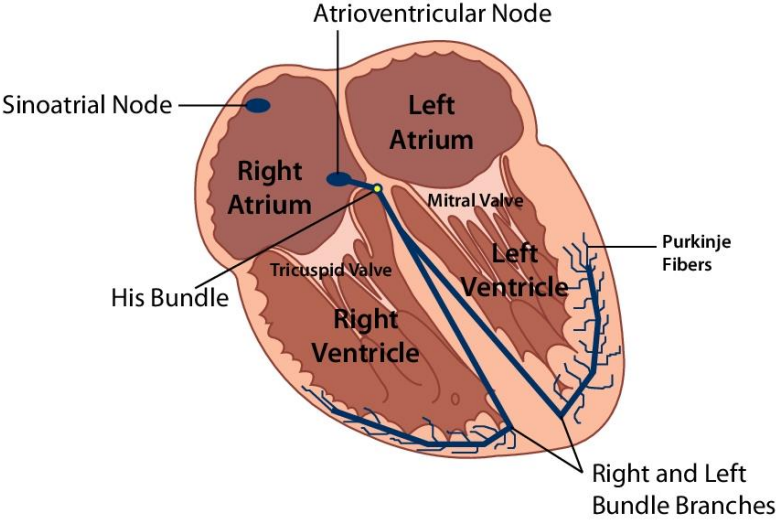


Figure 2. Electrical system of the heart.

- The **P wave** shows atrial depolarization. The P wave shows that the electrical potential has left the SA node, swept across the atria, and has initiated atria contraction. A normal P wave has duration of .04 - .1 sec. If it is greater than .11 sec it is abnormal. The P wave should always be gently rounded - never pointed or peaked. After the P wave, there is a "silent period" where nothing is happening in the ECG tracing. This quiescent period is called the PR interval.
- The **PR segment** is the transmission delay through the **atrioventricular (AV) node**, the electrical control system of the heart, to the **Purkinje fibers**, which allow for the heart contract synchronously.
- The **PR interval** is a combination of the **P wave** and the **PR segment**. It typically lasts for 0.12 to 0.20 seconds. The PR interval represents a refractory period in which the AV node captures the SA node signal and holds it for a short time. The PR interval allows the atria to contract and "top off" the ventricles with blood - an event called *atria kick*. If there was no time lag after the P wave, the ventricles would pump prematurely before being adequately filled by atria systole.
- The **QRS complex** shows ventricular depolarization. It is made up of the **Q wave** (the low point before the peak of the QRS complex), the **R wave** (the first positive deflection on the ECG electrodes), and the **S wave** (the low point at the end of the QRS complex, which may vary in intensity depending on the ECG electrodes).
- The **QRS interval**, which ends at the J point, shows the time required for depolarization of both ventricles. It typically lasts 0.04 to 0.10 seconds.
- The **ST segment** shows early ventricular repolarization. It begins at the **J point**.
- The **T wave** shows ventricular polarization. It generally is positive, rounded, and asymmetric.
- The **U wave** shows the repolarization of Purkinje fibers. Whether this is present depends on the electrodes used.
- The **QT interval** show the total time for ventricular depolarization and repolarization.

A user's heart rate can be determined using an ECG, for each heartbeat will be represented by one instance of this waveform. Noise can be present in an ECG as a result of skeletal muscle contraction, as well as ambient power line noise. This will be discussed later in the report.

## **ECG Monitor**

The ECG monitor board based on a MSP430FG439 microcontroller is shown in Figure 3. The board is powered by a coin-sized 3V lithium battery, CR2032. A detailed description of the board and its operation can be found at the following web address: <http://www.ti.com/lit/an/slaa280a/slaa280a.pdf>. PCB Gerber files, schematic, bill of materials, and firmware are provided in a zip file associated with this application report (<http://www.ti.com/general/docs/litabsmultiplefilelist.tsp?literatureNumber=sla280a>).

Two square pads, one on the top layer and the other on the bottom layer of the double sided PCB, are provided on either side of the LCD to serve as right and left hands contact electrodes. When in use the board must be held using both hands by placing the thumb and index fingers of each hand on the square pads. Care must be taken not to touch any other electrical areas of the PCB. A good way is to keep the hold towards the edges of the board. The contact resistance between the fingers and the square pads must be low for good signal quality. A little bit of moisturizer spread and rubbed over the fingers helps users with dry skin.



Figure 3. ECG monitor based on MSP430FG439 microcontroller.

The board is connected to a **BlueSMiRF** Bluetooth dongle to transmit EKG information over Bluetooth to a host computer. The dongle consists of a transmit (Tx) and receive (Rx) line which communicates serially with the MSP430 board. The Bluetooth dongle is powered from the ECG board. Because the ECG board acts as a transmitter, its port 2.5 (TX for a serial communication) is connected to the TX line on the BlueSMiRF board. This serial communication runs at a 115,200 Baud rate.

### ***Using Bluetooth-enabled ECG Monitor: A Step by Step Tutorial***

After the board is programmed you can connect it to a host computer with either native Bluetooth capability or a Bluetooth dongle. The text below describes steps taken on a Windows 7 workstation. Please note there are two versions of this application. The **ecg.c file** transmits only the ECG signal while the **ecg\_hearttrate.c** file transmits both the ECG signal and the current hearttrate. The setup will vary slightly depending on the application desired.

- 1) Go to the **Control Panel** and select **Devices and Printers**, then **Bluetooth Devices**. Then select **Add a Device**.

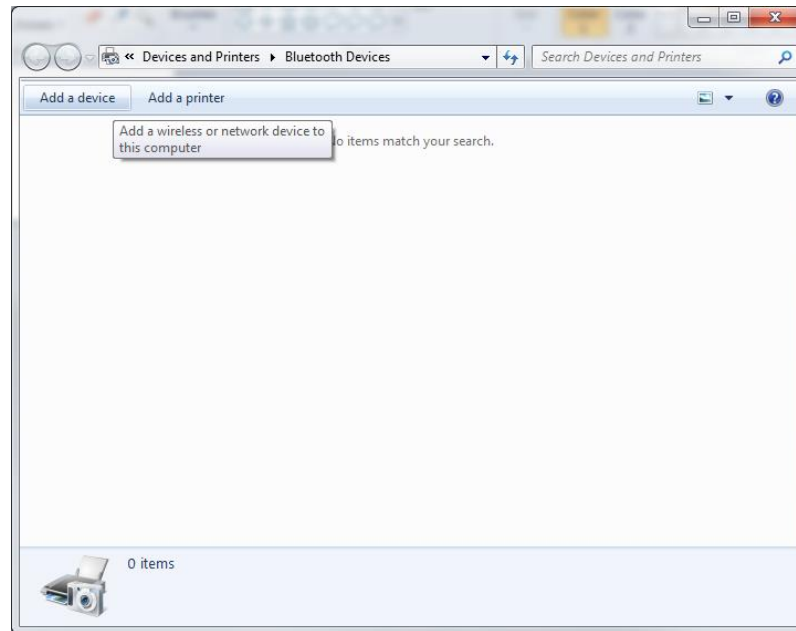


Figure 4. The Bluetooth Devices menu.

- 2) From the list of available devices, select the **RN42**.

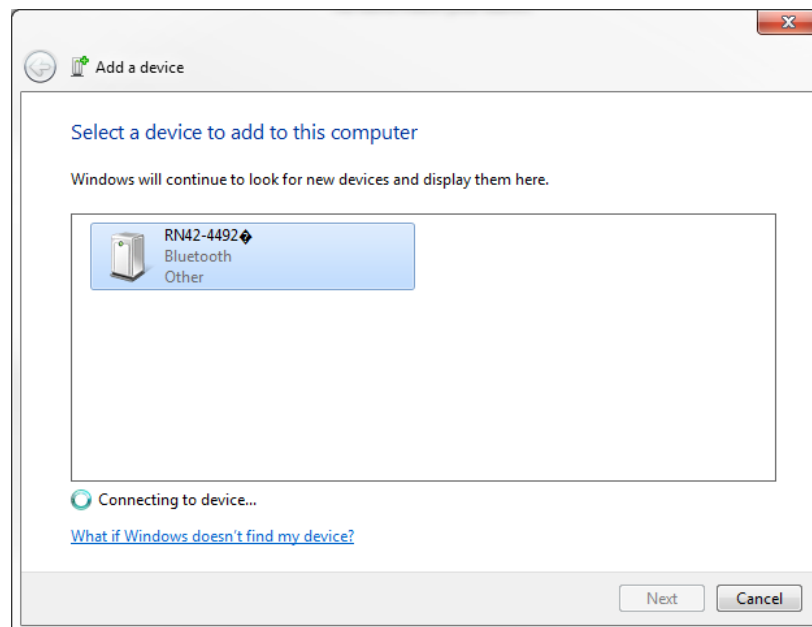


Figure 5. Selecting the RN42-4492 in the Add a device dialog box.

- 3) After the **RN42** is paired with your computer, right click on it and select **Properties** and go to the **Hardware** tab. Make note of what serial COM port it is tied to.

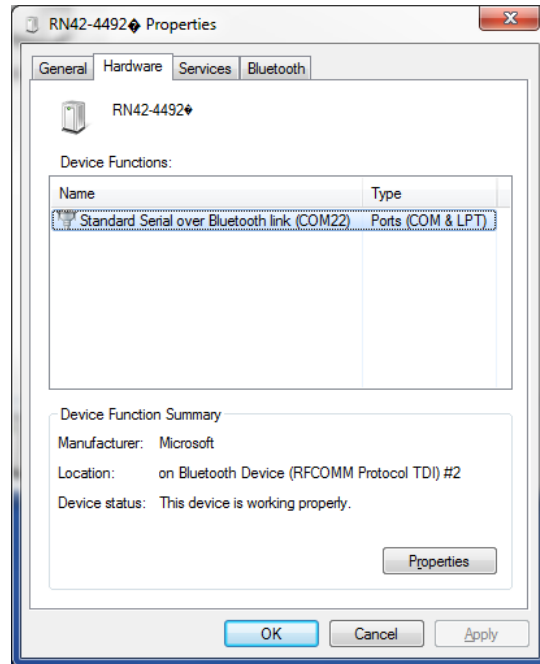


Figure 6. In this example, the RN42-4492 is tied to COM22

- 4) Open the **UAH Serial App** (available at <http://portal.mhealth.uah.edu/public/index.php/serial-port-application>). On the **Settings** tab.
- If using the **ecg.c** file, use the following settings (alternatively load the included **ecg.dat** file): **Packet size** set to **2**, **Header** set to **85**, **Number of Channels** set to **1**, and **CH 0 Type** set to **Byte 8bit**.
  - If using the **ecg\_hearttrate.c** file, use the following settings (alternatively load the included **ecg.dat** file): **Packet size** set to **3**, **Header** set to **85**, **Number of Channels** set to **2**, **CH 0 Type** set to **Byte 8bit**, and **CH 1 Type** set to **Byte 8bit**.

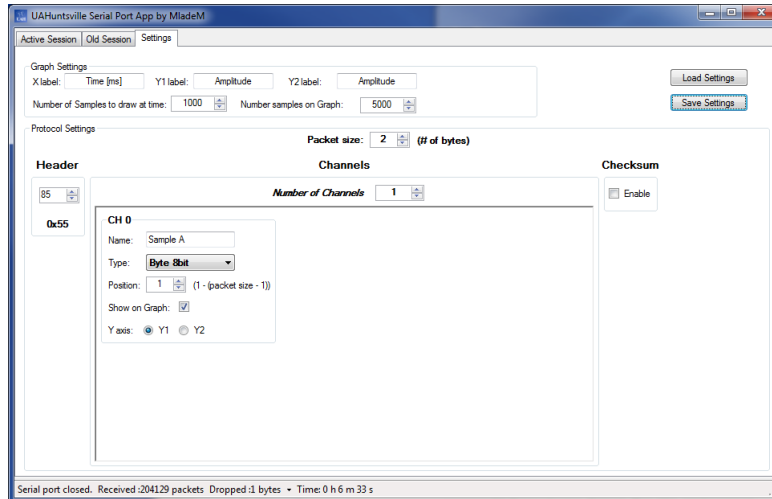


Figure 7. The settings used in communicating with the MSP430/BlueSMiRF for the **ecg.c** file.

- 5) Go back to the **Active Session** tab. Select the **COM Port** noted in step 3, set **Data Bits** to **8**, **Baud Rate** to **115200**, **Stop Bits** to **One**, **Parity** to **None**, and **Handshake** to **None**. Also, check the **Enable Chart** box. Then press the **Connect** button.

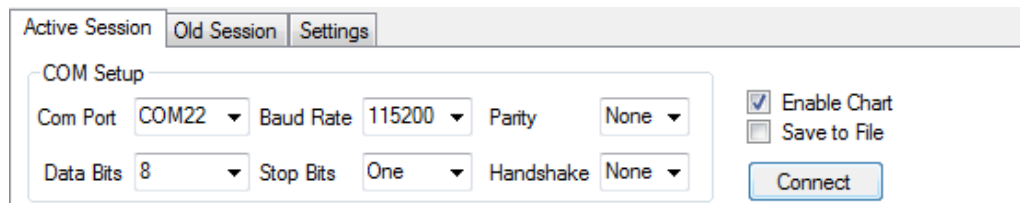


Figure 8. Setting up the Active Session.

- 6) At this point, a dialog box noting an incoming Bluetooth connection should appear above the right side of the task bar. Click on this dialog box.

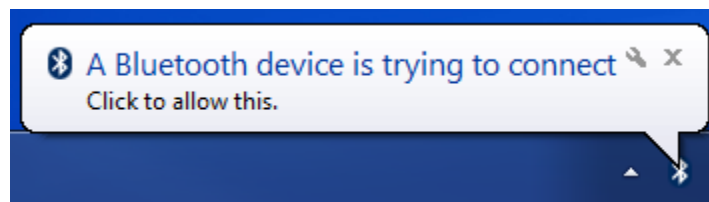


Figure 9. The Bluetooth connection dialog box.

- 7) To connect to the BlueSMiRF, a pairing code is needed. By default, this is **1234**, though it might be different depending on if you have changed settings.

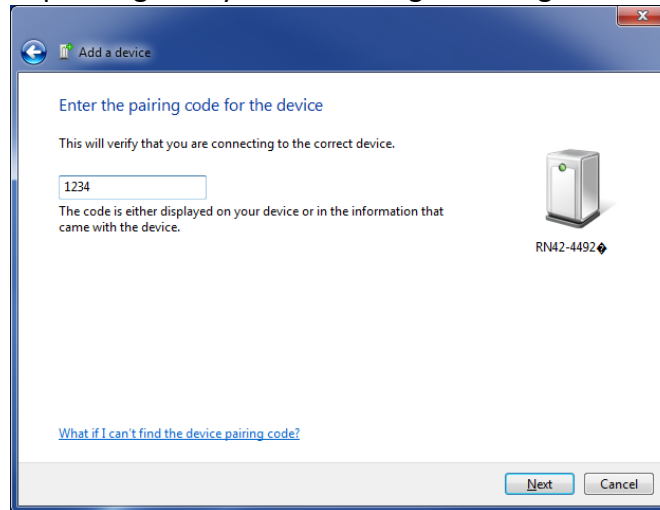


Figure 10. Entering the pairing code to connect to the BlueSMiRF

- 8) Now your computer and the MSP430 are connected serially through the BlueSMiRF. Go back to the **UAH Serial App**. You might need to attempt to connect to the device again. After the connection is made, the ECG signal will display on the graph providing you are holding the electrodes properly. Possible values range from **0** to **255**.

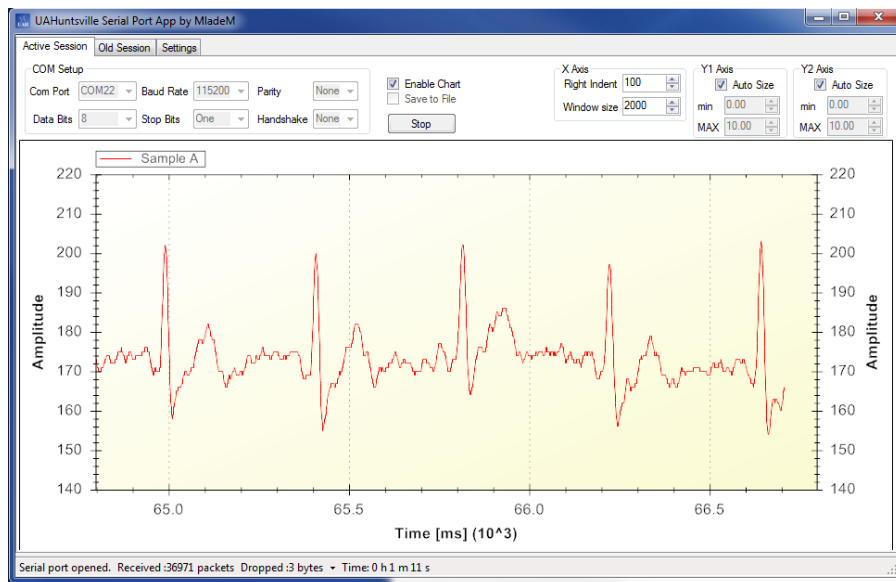


Figure 11. UAH Serial App displaying EKG data



## **Troubleshooting**

- To ensure proper connection, make sure that the BlueSMiRF is transmitting data before attempting to connect. This can be done by placing your fingers on the electrodes as shown in **Figure 3**.
- The UAH serial app might crash when attempting the first connection to the BlueSMiRF (i.e., before **Step 6** in the tutorial). If this occurs, ensure that the host computer and the BlueSMiRF are paired, then reopen the UAH serial app.
- Data will not be displayed correctly if the settings from **Step 4** and **Step 5** are not applied exactly.

## **References**

- 1) *MSP430x4xx Family User's Guide* (<http://www.ti.com/lit/ug/slau056l/slau056l.pdf>)
- 2) *UAH Serial Port Application* (<http://portal.mhealth.uah.edu/public/index.php/serial-port-application>)
- 3) *Using the BlueSMiRF* (<https://learn.sparkfun.com/tutorials/using-the-bluesmirf>)
- 4) *Heart-Rate and EKG Monitor Using the MSP430FG439* (<http://www.ti.com/lit/an/slaa280a/slaa280a.pdf>)
- 5) *Medical-Surgical Nursing, 7<sup>th</sup> Edition* (ISBN: 978-1-4377-2801-9)
- 6) *Basics of EKG Interpretation: A Programed Study* (<http://www.usfca.edu/fac-staff/ritter/ekg.htm>)