Electrical and Computer Engineering Department
University of Puerto Rico, Mayagüez Campus
Mayaguez, PR 00681-9042

Progress Report: Wireless Electro-cardiogram Monitor

Submitted as a partial requirement
for the course ICOM5047: Section 030
Design Course for B.S. in Computer Engineering Department
University of Puerto Rico at Mayagüez, PR

Students:

Bermudez Soto, Wilfredo

Ortiz Perez, Alexis M.

Vega Diaz, Rafael

Rivera Suarez, Melvin

Faculty Advisors:

José Fernando Vega, PhD
Associate Professor

Nayda G. Santiago Santiago, PhD
Associate Professor

Kejie Lu, PhD
Assistant Professor

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1. Executive Summary

This project is for the Capstone Course ICOM 5047. WARM is a group of Computer Engineering Senior students that proposed the creation of the Wireless ECG

Currently the WARM group is working hard on the Wireless ECG project. The Wireless ECG project is approximately at a 50% of development. Analyzing the Gantt chart reveals that there is a delay of more or less a week. Despite this fact, the project has gotten some results. Already the Cell Phone component has the capacity of sending SMS messages by the application entirely automatic and also can make use of some Bluetooth features by the application. Also, the Analog Circuit is working and there is communication between the Microprocessor and the Bluetooth module.

Although no deliverable is finished at the moment, the development of each individual deliverable has advanced. The Analog Circuit is already assembled and is being tested. Some errors regarding the Analog Circuit where found and solved. For the Microprocessor deliverable's hardware component, the interconnection with the Bluetooth module has been completed. The interconnection with the Analog Circuit task is still not finished. For the Microprocessor Software component the tasks in progress are the initialization of the Bluetooth module and storing data in the Microprocessor memory. For the Bluetooth module deliverable, the tasks completed are making a PCB for the module and interconnecting the module with a TTL cable. For the Cell Phone Software the tasks done are setting the phone programming environment, sending the SMS messages, and the design of the Graphical User Interfaces (GUIs) for the Cell Phone. The interfacing with Bluetooth task is in progress and the Communication Protocols task is not done.

In terms of budget, we spent less money than what we expected at the moment. Although there were some changes in cost of some of the components (some components cost more than expected and some cost less than expected), when we added and subtracted we arrived to total smaller than expected at the time. Another fact that contributed to our spending is the fact that the hours worked was also lesser than expected. The total estimated cost for the project at this stage was $21,968.10, and so far the cost is $17,802.70. The difference is $4,165.32 below the estimated.

2. Introduction

The purpose of this project is to satisfy this need and give patients the alternative to monitor their heart in all places and time without limiting their daily activities. The product we propose has the advantages of being wireless, portable, and that it monitors the heart continuously and at every time. The product also displays ECG data accessible to the patient and the doctor indicating the current patient's heart health. The product is easily configurable and provides several options for software installation offering the most convenient one for the customer. The goal is to provide early detection of any cardiovascular anomaly, so that the patient will be given medical attention within the first few critical hours, thus greatly improving his chances of survival. The design tries to achieve this without compromising the patient's ability to move or restraining the patient to a hospital.

3. Progress Report

The current status of the project compared with the one proposed in the calendar reflects a one-week delays. This delay is the product of several factors that will be detailed below.

3.1. Analog Circuit

Noise detected in the output of the analog circuit raised concerns about if the signal was useful enough to be processed by the microcontroller. After working with the problem we determined that the noise was being introduced by the signal generator and that after amplification and filtering the noise wasn't significant enough to distort the signal.

While working with the circuit the opto-coupler was malfunctioning. This prevented the signal to go through the filter and no to be seen at the output of the circuit. The part was replaced with a new one and as a contingency measure 2 spare opto-couplers were bought to prevent any backlog in the detection circuit.

Currently the task is to create an attenuator circuit for testing a differential signal with smaller amplitude.

3.2. Bluetooth module

Several delays were encountered with the purchase of the Bluetooth module. All the Bluetooth modules that met the requirement for our project were rarely available. The proposed module to be used, KC-21, either was not available to the U.S. nor to P.R. or out of stock. The WT12 from Bluegiga was selected to replace the KC-21 due to its similar characteristics. The module was ordered through Digi-key but it never arrived. After complaining with the USPS and Digikey we were informed that the only solution was to wait another 4 weeks for a replacement from Digi-key. We managed to acquire the module through a different supplier receiving the module on October 7. This situation caused a delay of 13 days with the tasks related to the Bluetooth module.

Upon arrival of the module we encounter further delays with the module. The module needed to be soldered to a Printed Circuit Board in order to interconnect it with the microprocessor. This task was delegated to Rafael Vega and Melvin Rivera requiring additional resources. Melvin Rivera made the PCB layout and Rafael Vega soldered the module.

The Bluetooth module is already connected through a TTL cable to a PC and we are testing its functionalities. We have achieved connecting the module to a cell phone and are testing data transmission.

3.3. Microcontroller

Due to the dependencies of the microcontroller with the analog circuit and the Bluetooth module some of its tasks were delayed. Still the UART initialization routines to connect the Bluetooth module are completed. The routines related to the analog to digital converter are done including receiving the data and saving it in the microprocessor. We still need to set the real sampling rate of the ADC.

3.4. Cell Phone

The tasks related to the cell phone software were divided in five different modules. The five modules were the Bluetooth connection, the graphical interface of the program, the text message alert, the communication protocol between the monitor and the cell phone, and requesting data from the microcontroller. Next we discuss each module.

3.4.1. Bluetooth

Several algorithm and examples on how to enable and use the Bluetooth device of the mobile device were used unsuccessfully. While they worked fine in simulation with the real device the code was non-operational causing crashes. This caused a delay with the task related to the cell phone software and as contingency the Bluetooth development was solely assigned to Alexis Ortiz while Wilfredo Bermudez continued with the rest of the tasks. Upon a deeper analysis of the situation it was found that the mobile phone that was being used to test the program was the source of the problem. While the phone does have Bluetooth the firmware was blocking it to the java virtual machine. Two different phones have been tested and the program seems to be working. Further testing is being done for data transmission.

3.4.2. Graphical Interface

The user graphical interface can be considered almost done. In the first draft of the GUI we faced a problem with the in screen buttons not working and not doing their commands. A working prototype was done were the software was able to function through a menu accessible through one the buttons of the cell phone. This delayed the completion of the cell phone software task but with a minimal impact with the other tasks. The problem has been already solve and the in screen buttons already work properly. While the GUI is functional the help documentation and the Bluetooth settings still need to be done. The help documentation is being left as the last task of the software design to have a complete view of all the features that need to be documented in the help. The Bluetooth settings depend on the Bluetooth module of the cell phone software, in order to finish this feature the Bluetooth module has to be finished first.

3.4.3. Alert Message

When implementing this function we encountered that sending the message directly through the phones SMS system was not ideal. When the program tries to access the phone's SMS system the firmware of the phone as a security measure halts the program and asks the user if he wants to allow access of said feature to the program. In case of emergency the patient might not be in a position to accept or reject such a prompt. To circumvent this problem the SMS alert system was implemented using the phones network connection, sending the text message through the internet.

3.4.4. Communication Protocols & Requesting Data from the Microcontroller

These tasks depend on the microcontroller and Bluetooth module tasks, due to their delays these ones had to be delayed. In order to make an efficient communication protocol we need to know how the data is received from the microcontroller, until the task is done this one is delayed. Similarly the same happens with requesting data from the microcontroller.

3.5. Corrective Measures

Melvin Rivera was reassigned to help with the analog circuit while the Bluetooth module arrived. He was also assigned to work with the microcontroller in the initialization, data sampling, and UART communication process. Alexis Ortiz was assigned to deal with the Bluetooth in the cell phone. Due to the several delays extra hours will be assigned to the team to work in the weekends.

3.6. *Tasks Summary*

Microcontroller:

- Interconnect microcontroller with analog circuit - Delayed
- interconnect with Bluetooth - Delayed
- receiving data from analog circuit and save it - Delayed
- Bluetooth module initialization - Delayed
- Baseline training subroutine - Delayed
- Analyze Received data - Delayed
- Send data to Bluetooth module - Delayed

Bluetooth Module:

- PCB & Soldering - Done
- Interconnect with TTL Cable - Delayed & Done
- Test Module - Delayed

Cell Phone

- Interfacing with Bluetooth - Delayed
- GUI Design - Delayed & Done
- Communication Protocol - Delayed
- Data requests from micro controller - Delayed

Added Tasks:

- PCB & Soldering for the Bluetooth

4. Budget

This section describes the total actual cost of the project and compares it with the estimated.

4.1. *Total Cost at this Moment*

Table 1 describes the total cost of the analog circuit.

Analog circuit			
Part	Qty.	Unit Price ($)	Total Price ($)
AD624	1	25.02	25.02
PS 2506	2	.99	1.98
LM 741	1	1.39	1.39
R 3.5k	1	0.05	0.05
R 150	1	0.05	0.05
R 10k	1	0.05	0.05
R 4M	1	0.05	0.05
C o.1u	1	0.15	0.15
C 1u	1	0.16	0.16
Adjusted R(200k)	1	1.48	1.48
9 volts battery	2	2.50	5.00
total			35.38

Table 1 Analgo Circuit Costs

Table 2 presents the cost of the Bluetooth module. Estimated cost $49.73. The loss module cost $67.30 and the replacement module cost $59.81. Total cost of $127.11 with a difference of $77.38 above of the estimated cost.

Bluetooth module			
Part	Qty.	Unit Price ($)	Total Price ($)
Wt12	1	67.30	67.30
Wt12	1	59.81	59.81
Total			127.11

Table 2 Bluetooth module cost

Table 3 summarizes the equipment cost. The estimated cost for the electrodes was $45.00 for a box of 50 units. For reasons of availability we bought a box of 30 units at a price of $15.00.

Equipment	Cost ($)
Flash Emulator	138.24
Microprocessor	8.84
Cell phone	196
Electrodes (30)	15.00
Total	333.84

Table 3 Equipment

Table 4 summarizes the total employee cost vs. the estimated cost for that stage.

Name	Estimated hours	Estimated cost	Worked hours	Actual cost
Wilfredo Bermudez	180	3,555	150	2,962.50
Alexis Ortiz	180	3,555	150	2,962.50
Rafael Vega	180	3,450.60	150	2,875.50
Melvin Rivera	180	6,676.20	150	5,563.50
Sub total		17,236.20		14,364.00
Unemployment Insurance (1.40%)		241.31		201.09
Disability (1.1%)		188.82		158.0
S.S 5.3%		909.74		761.29
Healthcare (7.4%)		1270.21		1062.94
401K/403b (4.3%)		738.09		617.65
Consultant	10	1000	6	600.00
Total		21,513.1		17,765

Table 4 Employees

4.2. Changes Made

4.2.1. Analog circuit

The main changes were on the AD624. The estimated cost was $6.16 but it end-up being $25.02 with a difference of $18.86 above the estimated. The PS2506 suffered changes with an estimation of $3.50 and a real cost of $1.98 for two units which is $1.52 below the estimated cost. Batteries were estimated to have a cost of $4.10, their real cost was $5.00. The difference between estimated and final cost of the analog circuit is $18.24 above.

4.2.2. Bluetooth Module

Estimated cost $49.73. The loss module cost $67.30 and the other module costs $59.81. Total cost of $127.11 with a difference of $77.38 above of the estimated cost.

4.2.3. Equipment

The estimated cost for the electrodes was $45s for a box of 50 units. For reasons of availability we bought a box of 30 units at a price of $15.00. The total estimated cost for equipment was $111.60 and the final price was $81.60 with a difference of $30.00 lower than the estimated.

4.2.4. Employee Cost:

Estimated cost of employees to date was $21,513 and the actual cost is $17,765 with a difference of $3,718 below the estimated. The difference between the estimated and actual cost is due to the following:

- It was estimated a total of 28 hours of work per week. This estimate was too high considering that each member has other courses that also require time. For that reason, we reduced the number of hours per week to about 18 hours in the first 5 weeks. For the next 2 weeks we are working weekends to complete the 28 hours a week

- Estimated hours of professional consulting services was 10 hours. So far only 6 hours of consulting have been used. The difference between the estimated and the total cost is $400 below the estimated.

4.3. Project Summary

The total estimated cost for the project at this stage was $21,968.10 and so far the cost is $18,102.70. The difference is $3866.32 below the estimated.

5. Technical Plan

In the following section we intent to present progress in a more technical sense with respect to the overall project.

5.1. *Analog Circuit*

Currently, the proposed analog circuit has been assembled and is in testing stages. This circuit uses an instrumentation amplifier with programmable gain to amplify the heart signal to an appropriate level for sampling. The signal we wish to amplify has amplitude of approximately 1mV-5mV. We used the AD624 programmed with a gain of 1000, which would bring the signal up to the order of volts.

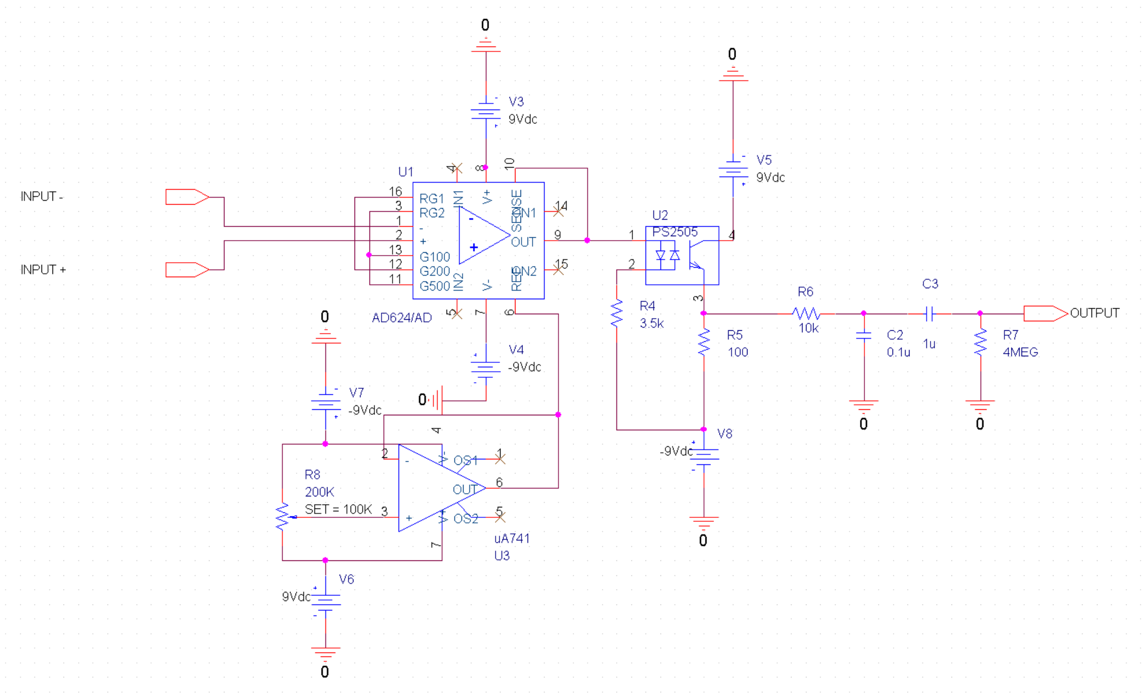
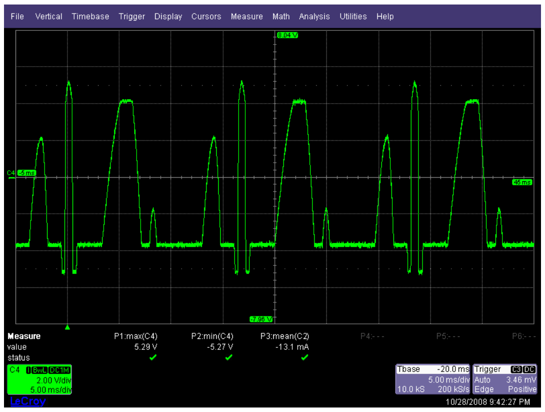


Figure 1 - Analog Circuit Schematic

The amplifier was tested by powering it with two 9V batteries then feeding it a cardiac signal generated by a function generator. With this setup, we can see that it is working correctly. However, the smallest signal that the generator can output is around 30mV, significantly bigger than the average heart signal, so part of the signal is clipped. Also, the generator only offers grounded signals, and we need a differential signal. To get around this, a testing circuit is being developed using an inverting op amp configuration with fractional gain to address the problems of signal size and differential input.


File Vertical Timebase Trigger Display Cursors Measure Math Analysis Utilities Help
-7.96 V
LeCroy

Measure	P1:max(C4)	P2:min(C4)	P3:mean(C2)	P4:- - -	P5:- - -	P6:- - -
value	5.29 V	-5.27 V	-13.1 mA			
status	✓	✓	✓			

```
C4  BwL DC1M      Tbase   -20.0 ms   Trigger  C3 DC
    2.00 V/div            5.00 ms/div Auto     3.46 mV
    5.00 ms/div   10.0 kS  200 kS/s   Edge     Positive
                                10/28/2008 9:42:27 PM
```

Figure 2 - AD624 Output

The circuit also uses a photo-coupler to protect the circuit and the patient. We used a PS2506-1. We encountered a problem during our testing stage that was determined to be a faulty PS2506. Once we changed it, the circuit worked correctly again. Another odd occurrence we encountered during our testing stages was that the photo coupler slightly amplified the P wave and the T wave. This problem has not been solved yet.

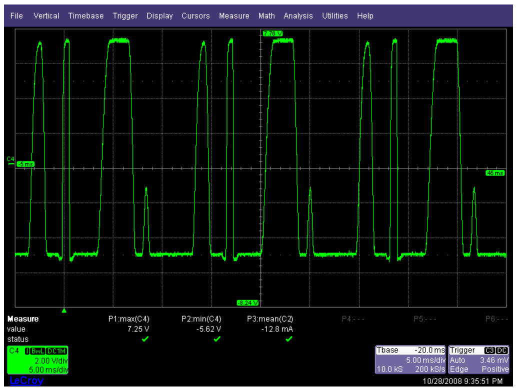


Figure 3 - PS2506 Output

The only testing stage left is the filter. During initial testing, the purposed filter, a .04Hz to 120Hz band pass filter, was filtering out the entire signal. This problem has not been solved yet. We are currently researching other types of filters and considering the prospect of reducing the bandwidth.

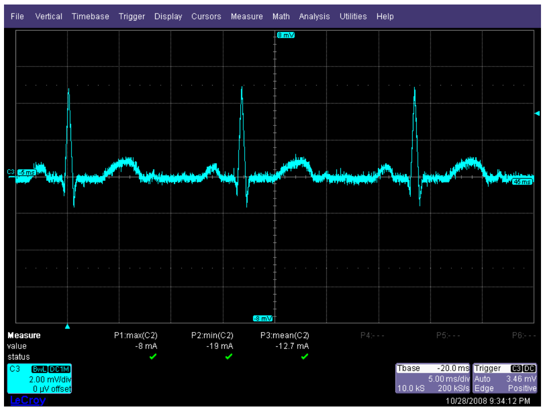


Figure 4 - Input Signal

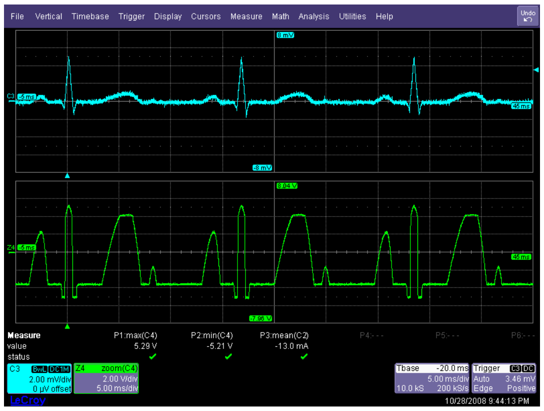


Figure 5 - Input vs. Output

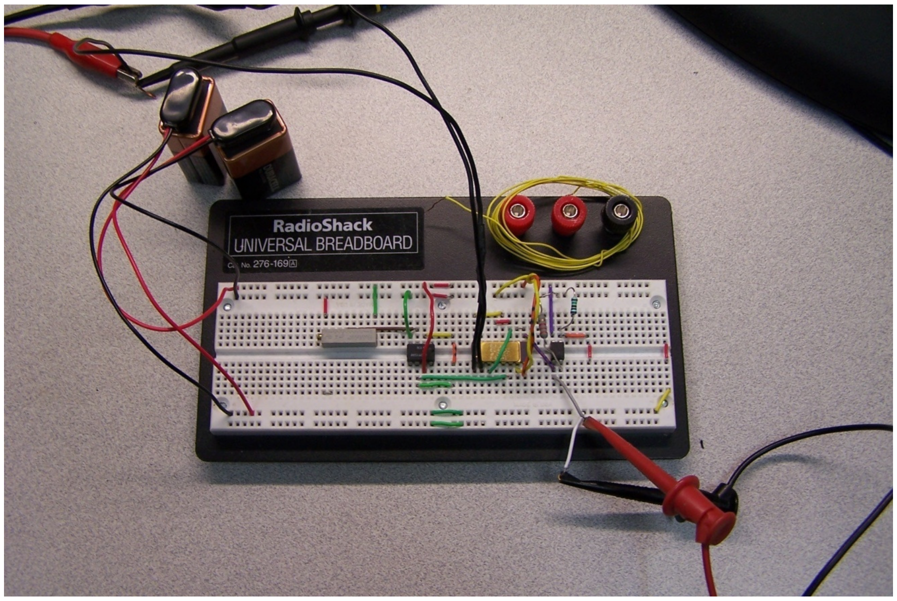


Figure 6 – Analog Circuit

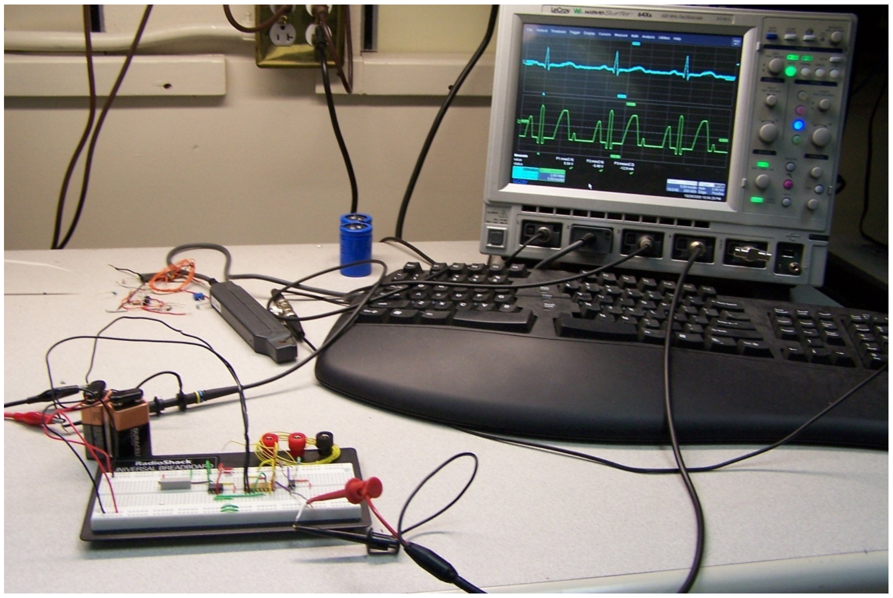


Figure 7 – Testing Environment

5.2. Microcontroller Software

5.2.1. Microcontroller Code

The code that has been already written is available in the appendix. Here I will describe the functions that have been created.

1. Set microcontroller baud rate: this function receive as parameter three hexadecimal numbers to set the UBR00 ; UBR10; UMCTL0 respectively

   void set_Baud_Rate(int,int,int);

2. Delay function: make a delay depending on the receives integer in hexadecimal

   void Delay(int);

3. UART0 rx interrupt. Manage the receives data from the uart

   __interrupt void usart0_rx (void);

4. UART Initialization; initialize the UART interface

   void UART_Initialize(void);

5. Send char function: this function send a ascii char via UART TX

   void UART0_putchar(char c);

6. Receive char function: receive a char and echo it back

   char UART0_getchar(void);

7. ADC initialization: initialize the ADC

   void ADC_Initialize(int);

8. Enable adc convertion, enable the conversion with the ADC interrupt

```
void convert_ADC_Enable(void);
```

9. Disable ADC convertion, disable the ADC conversion interrupt

```
void convert_ADC_Disable(void);
```

10. Set ports Set the ports to the input or output mode

```
void Set_Ports(void);
```

11. Request info from Bluetooth module send info command to the Bluetooth module

```
void request_INFO(void);
```

12. Change baud rate of the Bluetooth module

```
void set_Baud_Rate_19200(void);
```

5.2.2. Functions that will be Created

1- Initialize Bluetooth module
2- Connect to cell via Bluetooth
3- Send alert message to cell phone
4- Send ECG data to cell phone
5- Analyze received data

5.2.3. Bluetooth module

Bluetooth module is in testing process connected to a PC with the hyper terminal.

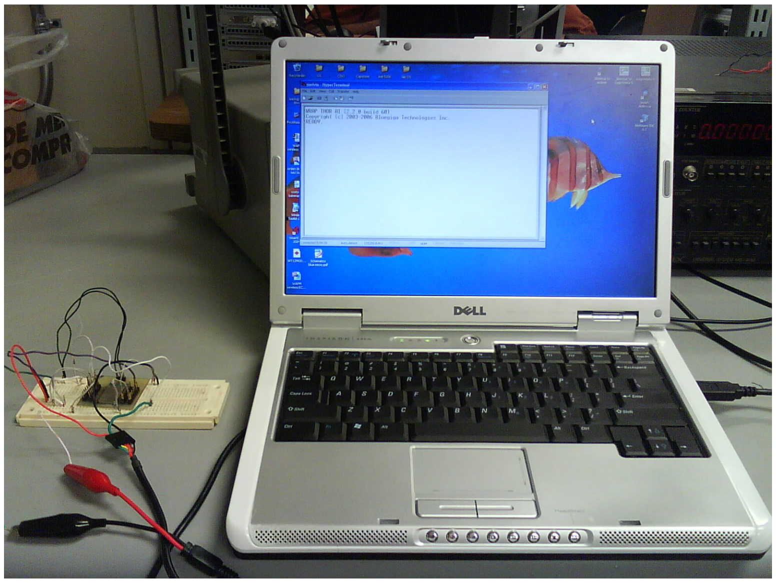
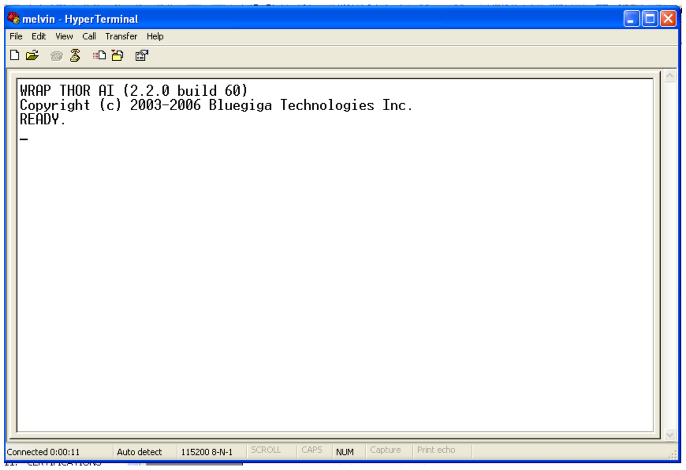


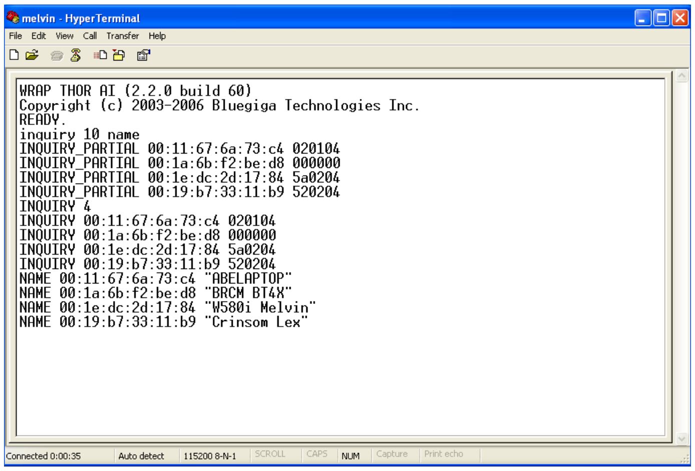
Figure 8 – Bluetooth module testing environment



```
WRAP THOR AI (2.2.0 build 60)
Copyright (c) 2003-2006 Bluegiga Technologies Inc.
READY.
_
```

Figure 9 – HyperTerminal with Bluetooth initialization

Bluetooth module is connected to the PC with the TTL cable. This is the screen that appears when the module is turn on or reset.



```
WRAP THOR AI (2.2.0 build 60)
Copyright (c) 2003-2006 Bluegiga Technologies Inc.
READY.
inquiry 10 name
INQUIRY_PARTIAL 00:11:67:6a:73:c4 020104
INQUIRY_PARTIAL 00:1a:6b:f2:be:d8 000000
INQUIRY_PARTIAL 00:1e:dc:2d:17:84 5a0204
INQUIRY_PARTIAL 00:19:b7:33:11:b9 520204
INQUIRY 4
INQUIRY 00:11:67:6a:73:c4 020104
INQUIRY 00:1a:6b:f2:be:d8 000000
INQUIRY 00:1e:dc:2d:17:84 5a0204
INQUIRY 00:19:b7:33:11:b9 520204
NAME 00:11:67:6a:73:c4 "ABELAPTOP"
NAME 00:1a:6b:f2:be:d8 "BRCM BT4X"
NAME 00:1e:dc:2d:17:84 "W580i Melvin"
NAME 00:19:b7:33:11:b9 "Crinsom Lex"
```

Figure 10 – HyperTerminal with inquiry results

Here an inquiry is made searching for the devices in range. The command used is inquiring 10 names. With this command the module does a search of devices in range and gives their address and name. The search in this case is performed in 10 seconds due to the parameter.

5.2.4. Microcontroller & Bluetooth Module Connection Schematic.

The Bluetooth module is connected to the microcontroller via UART without hand shaking. The RXD (receive) pin of the Bluetooth module is connected to the TXD (transmit) pin of microprocessor, TXD of the Bluetooth module is connected to the RXD of the microcontroller. The resistor ROSC is connected between DVcc and Rosc (pin 25) of the microprocessor this resistor is used to stabilize the UART clock. Pin number 59 is the input for the microcontroller ADC and here is connected the analog circuit.

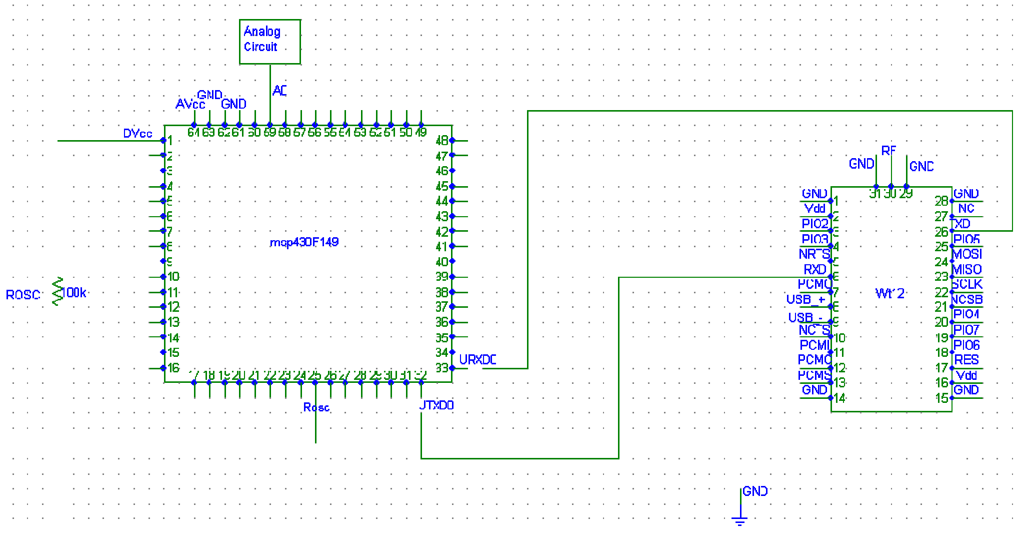


Figure 11 – Microcontroller & Bluetooth connection schematic

5.3. *Cell Phone Device*

5.3.1. Connecting to Bluetooth via Cell Phone

First of all, let's see a little overview of how the Bluetooth connection will be. The Bluetooth connection consists of 2 main "protagonists": the server and the client. The server is the device that becomes discoverable and offer services. On the other hand, the client is the device that connects to the server and asks to use a service offered by that server. In the diagram the server is offering a service named Send Data and the client is connected to the Server. The communication protocol used by them is the RFCOMM protocol, a protocol for streaming data.

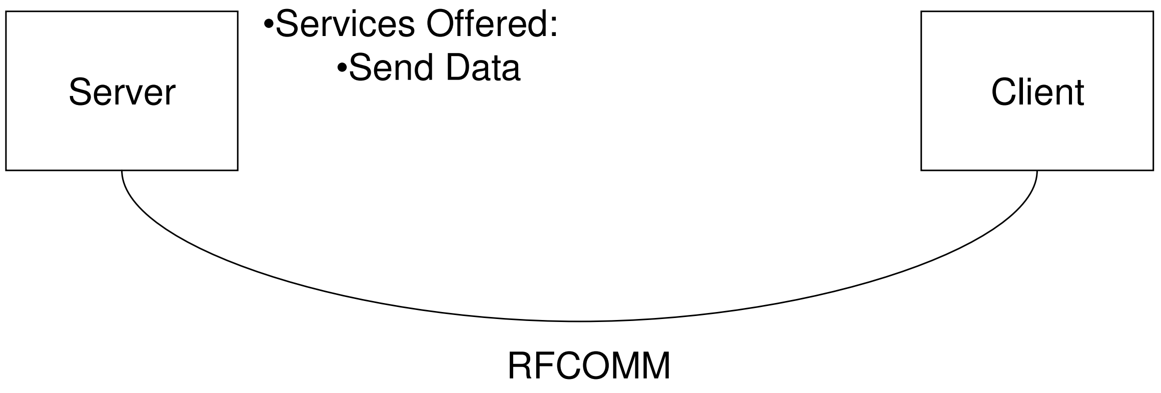


Figure 12 – Bluetooth communication model

In the case of the Wireless ECG the situation is similar. There are 2 main components: the Cell Phone and the Bluetooth module. The Cell Phone will be the server that will be discoverable by the client, in this case the Bluetooth module. When the connection is established the client will send the data to the server which will be waiting or the server will be able to request the information to the client. The communication protocol will be RFCOMM as discussed above.

We have developed a cell phone application that creates this connection. It is still in development and testing, but it is functional and demonstrates that the cell phone is connecting to the Bluetooth. This application is based on the NetBeans Mobility MIDP Sample Bluetooth Demo. This application is being tested via the NetBeans Mobility Simulator. This application tests 2 Bluetooth functionalities on the cell phone: displaying the Bluetooth friendly name and address, and establishing a RFCOMM connection.

The application is divided into 2 Midlets (that is the name of the applications for the cell phone), each one testing one of the functionalities mentioned above. The first one is called TestMidlet (source code is in the Appendix). This Midlet makes the cell phone display its friendly name an Bluetooth address, this may seem silly but it is important for the cell phone to recognize its friendly name and Bluetooth address (this one is the most important) and other's as well.

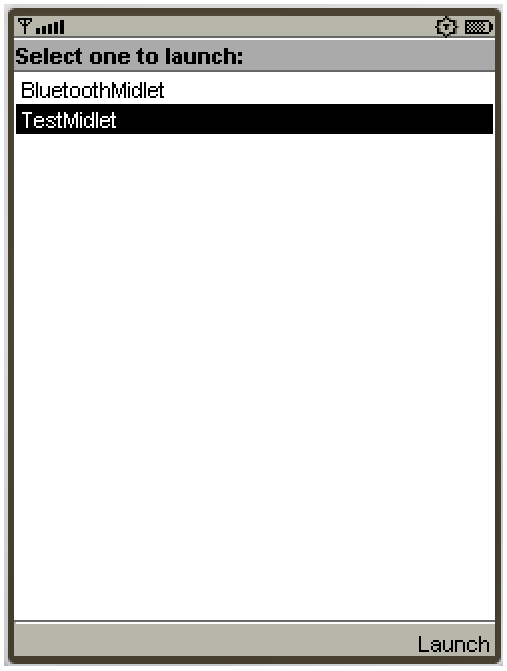
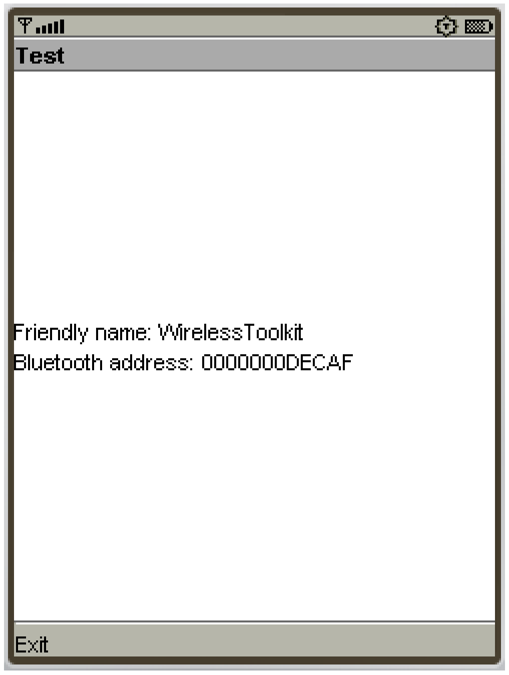


Figure 13 - Selecting TestMidlet



Friendly name: WirelessToolkit
Bluetooth address: 0000000DECAF

Figure 14 - Showing the Friendly name and Bluetooth address

The second Midlet, called BluetoothMidlet, is the one that demonstrate the capacity of connecting via Bluetooth. The Midlet lets the user select if the device is a server or a client. When there is a server and also a client the connection is created. The client sends a message to the server and the server answers the message back with another server. This interaction right now is not shown in the devices' screens but on the simulators output terminal, but it will be shown in the screens.

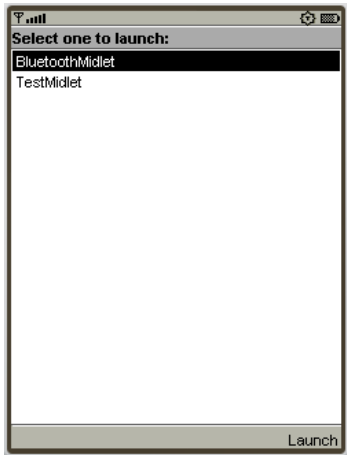


Figure 15 - Selecting Bluetooth Midlet

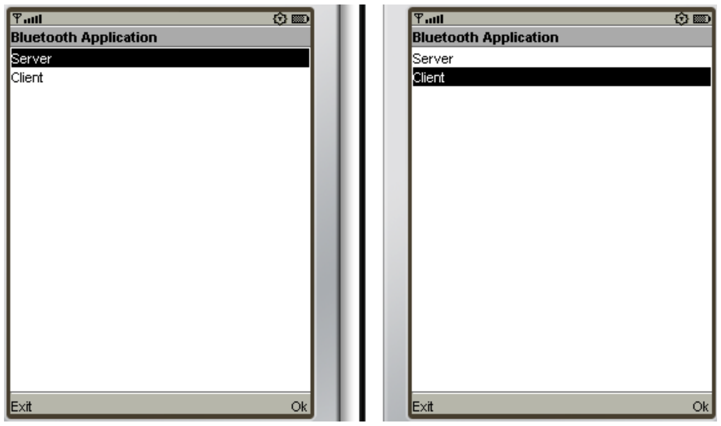
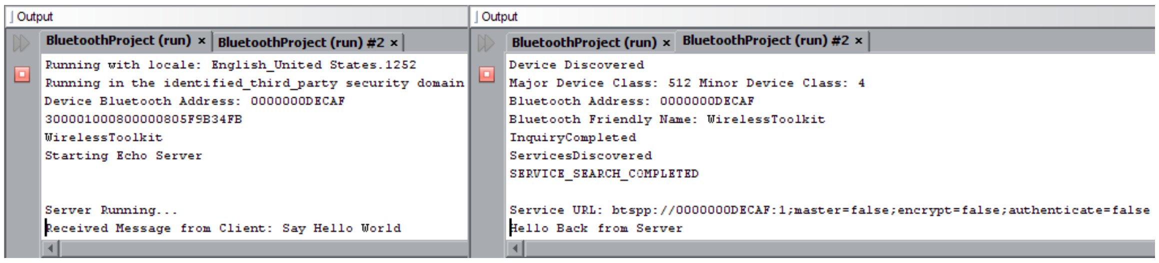


Figure 16 - One device being server and the other one being client

In figure Figure 17 - Output for the server (left) and the client (right)it is shown what happened in the interaction between the server and the client. In the left image is read "Server Running…", this means that the server is visible right now so that any client can connect to it. In the right is read "Device Discovered" meaning that now the client discovered the server. After that in the terminal is printed some information of the device discovered, and then it appears "ServiceDiscovered" and "SERVICE_SEARCH_COMPLETED" meaning that the client found a service and connected to it. Then it is shown the url of the server where it is connected. Not shown is that the client sent a message to the server. This is noticed on the left terminal where it is read "Received Message from Client: Say Hello World". The Server then sends a message to the client as shown in the right terminal "Hello Back from Server".



```
Running with locale: English_United States.1252
Running in the identified_third_party security domain
Device Bluetooth Address: 0000000DECAF
3000010008000000805F9B34FB
WirelessToolkit
Starting Echo Server


Server Running...
Received Message from Client: Say Hello World
```

```
Device Discovered
Major Device Class: 512 Minor Device Class: 4
Bluetooth Address: 0000000DECAF
Bluetooth Friendly Name: WirelessToolkit
InquiryCompleted
ServicesDiscovered
SERVICE_SEARCH_COMPLETED

Service URL: btspp://0000000DECAF:1;master=false;encrypt=false;authenticate=false
Hello Back from Server
```

Figure 17 - Output for the server (left) and the client (right)

The TestMidlet has been tested in real cell phones and worked fine. The BluetoothMidlet works fine in the simulator but in real cell phones it needs a little more work.

5.3.2. Graphical Interface

The user interface was designed as a button driven GUI where all the features of the program can accessed through them.

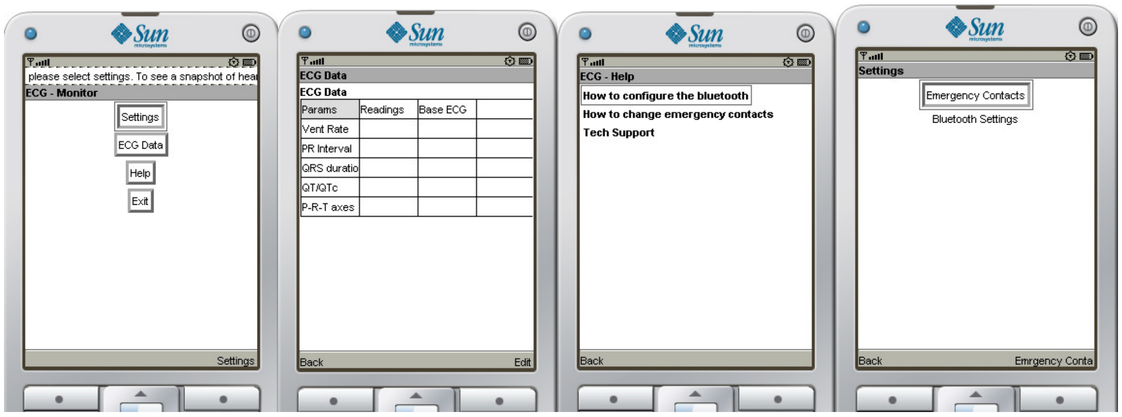
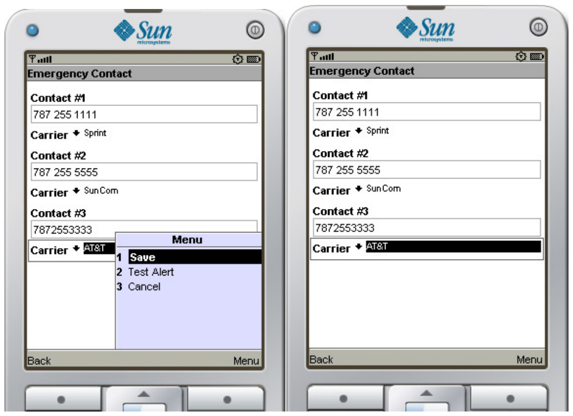


Figure 18 – (from left to right) a) Main menu b) ECG Data Table c) Help Menu d) Settings Menu

In Figure 18 – (from left to right) a) Main menu b) ECG Data Table c) Help Menu d) Settings Menuthe various interfaces the user has access to are shown. In the main menu the user access to the ECG Data, Settings and Help. The ECG Data displays a table with relevant parameters of the patient's heart. In a same manner the in the help menu the user can access documentation with relevant information of the ECG Monitor system.



Emergency Contact

Contact #1
787 255 1111
Carrier Sprint
Contact #2
787 255 5555
Carrier SunCom
Contact #3
7872553333
Carrier AT&T

Emergency Contact

Contact #1
787 255 1111
Carrier Sprint
Contact #2
787 255 5555
Carrier SunCom
Contact #3
7872553333
Carrier AT&T

Figure 19 Emergency Contact Menu

In the settings menu the user can setup the emergency contacts and the Bluetooth settings. In we can see the menu where the user can setup up to three emergency contacts. The required data are the cell phone number and the carrier, after entering the data the user can proceed to save it, test the emergency contacts which will send test alert to all the contacts or cancel discarding any data entered.

5.3.3. Emergency Alert & Settings Data

In case of emergency the system is configured to send and emergency alert in the form of a SMS text message that is sent through the internet. The messages sent to the emergency contacts in case of alert and in case of test alert are different. The exact content of the real emergency alert hasn't been yet decided due to the sensitive aspect of it.

In order to save the settings and pertinent data needed by the software the RMS database provided by J2ME was used. The first approach was to use xml files but these files only allowed to read data and not to write data to the xml file. Settings that are going to be saved in this database are SMS configuration for each carrier, emergency contacts number and carrier, and the Bluetooth settings.

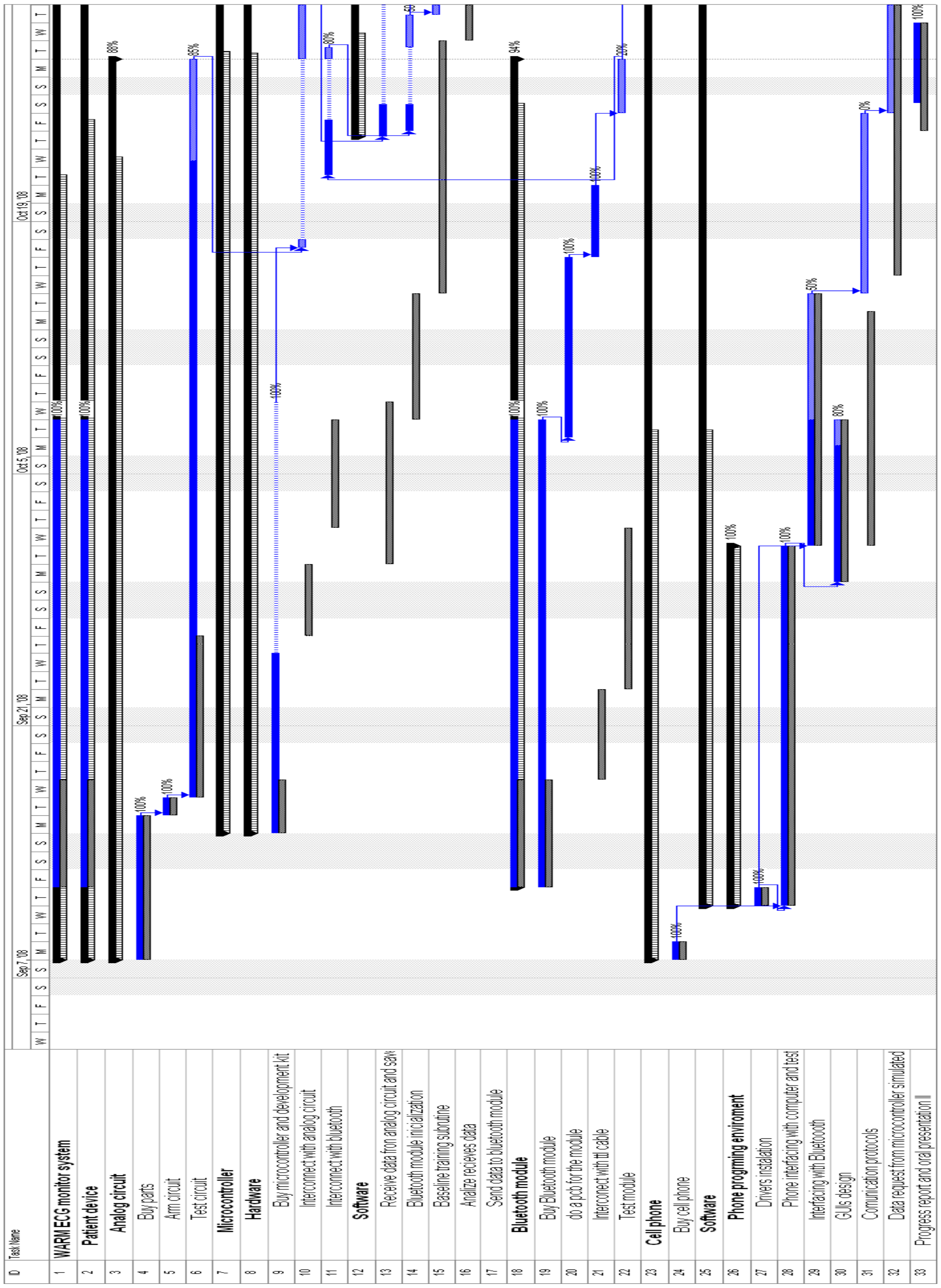
6. Future Works

- Data Sampling - Receive data from analog circuit and save it
- Bluetooth module initialization
- Baseline training subroutine – Train the microprocessor with the baseline signal
- Analyze data – interpret data received from analog circuit
- Send data from microprocessor to Bluetooth module
- Test Bluetooth module
- Interface cell phone with Bluetooth
- Communication protocols – Design communication protocols between cell phone and Bluetooth.
- Data request from microcontroller simulated with PC – Display data received from PC (simulates microprocessor)

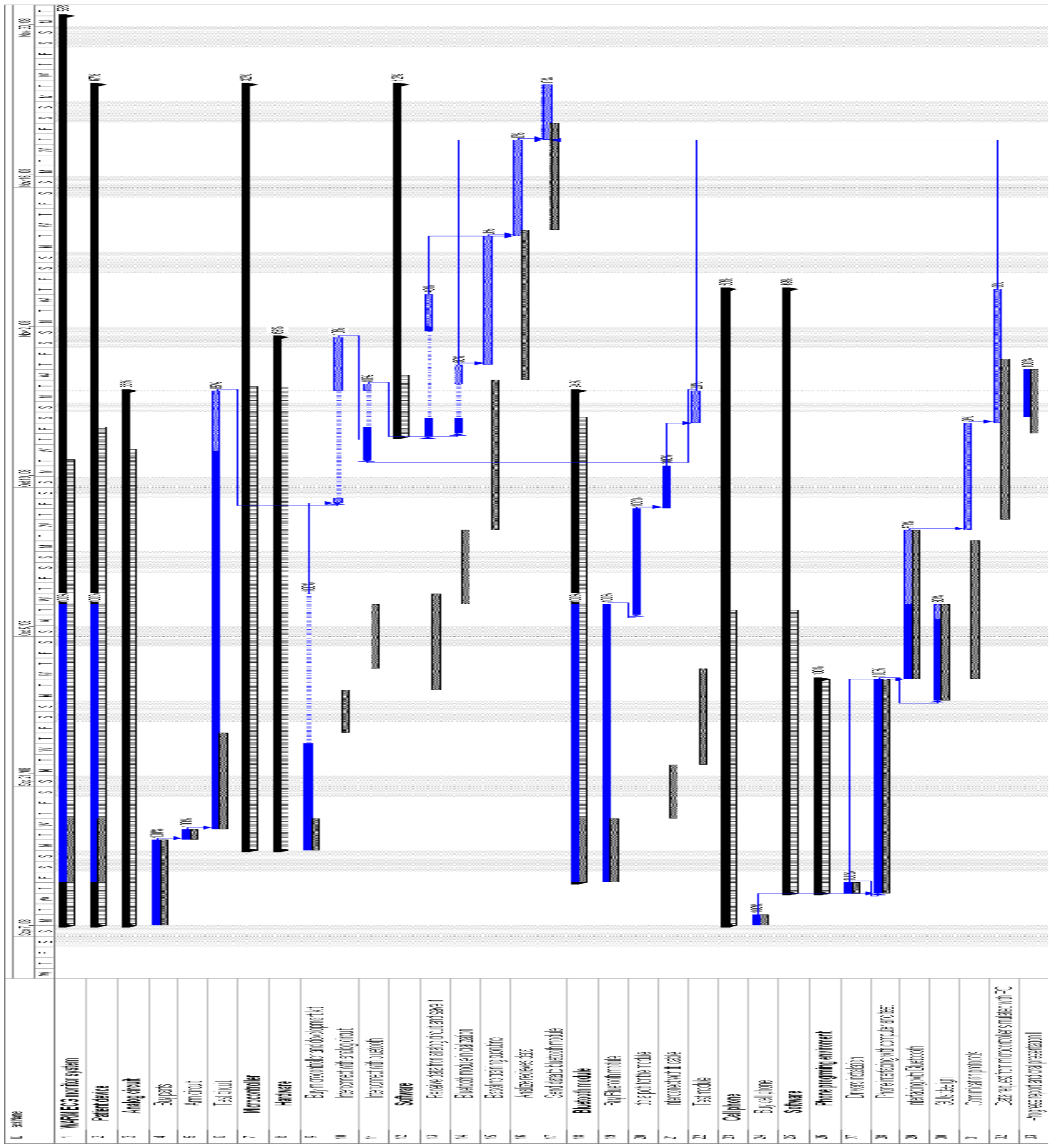
Bibliographic References

Webster, J. John Wiley& Sons. (2002). Medical Instrumentation Application and Design (3rd ed.). Asia : Pte. Ltd.

Apendix A: Gantt Chart



Gant chart of the project up to October 30, 2008


Full Gantt Chart

Apendix B: Microprocessor Code

```
#include "msp430x14x.h"


unsigned char recieved_char;        /* hold char from UART RX*/
#define   Num_of_Results   200  number of data to store
static unsigned int results[Num_of_Results];  // global array for adc results


 // FUNCTIONS
// set microcontroller baud rate
void set_Baud_Rate(int,int,int);
//delay function
void Delay(int);
// UART0 rx interrupt.
__interrupt void usart0_rx (void);
// UART Initializaion
void UART_Initialize(void);
//send char function
void UART0_putchar(char c);
//receive char function
char UART0_getchar(void);
// ADC initialization
void ADC_Initialize(int);
// enable adc convertion
void convert_ADC_Enable(void);
// Disable ADC convertion
void convert_ADC_Disable(void);
// set ports
void Set_Ports(void);
```

```
/*++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

   Bluetooth module

++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++*/

// request info from bluetooth module

void request_INFO(void);

// change baud rate

void set_Baud_Rate_19200(void);


void main(void)  {

  WDTCTL = WDTPW + WDTHOLD;              // Stop watchdog timer

  Set_Ports();                           // set the  ports

  UART_Initialize();                     // initialize uart


  _EINT();       // enable global interrupts

    set_Baud_Rate_19200();                      // set bluetooth baud rate

    set_Baud_Rate(0xBD,0x01,0x04);              // 8.547MHz 19200 microcontroller

   request_INFO();                          // send information request to bluetooth

   request_INFO();

   ADC_Initialize(10);

   _BIS_SR(LPM0_bits + GIE);                // Enter LPM0 wait for  interrupt

}


/*|||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||

         Interrupt rx

|||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||*/

#pragma vector=USART0RX_VECTOR

__interrupt void usart0_rx (void)

{
  while (!(IFG1 & UTXIFG0));              // USART0 TX buffer ready?
  {
  recieved_char = UART0_getchar() ;        // RXBUF0 to recieved_char
   UART0_putchar(recieved_char);
  }
}
/* ||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||
      Interrupt ADC
 |||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||*/
#pragma vector=ADC12_VECTOR
__interrupt void ADC12ISR (void)
{
  static unsigned int index = 0;
  /*
  results[index] = ADC12MEM0;              // Move results
  index = (index+1)%Num_of_Results;        // Increment results index, modulo
  if (index==Num_of_Results){
   convert_ADC_Disable();
  }
  */
  results[index] = ADC12MEM0;              // Move results
  if (index < Num_of_Results)
  index = (index+1);        // Increment results index, modulo

}
/*==============================================================
Delay function
==============================================================*/
```

```
void Delay(int time) // time in hexadecimal

{

  volatile unsigned int delay_count = time;

  for(;delay_count!=0;delay_count--);

}

/* ============================================================

         set the ports nedded

============================================================*/


void Set_Ports(void){

  P3DIR |= 0xff;                    // set all pins as output

  //P2DIR |= 0xff;                   //set all pins as out

  //P5DIR |= 0xff;                   // set all pins as output

  P3SEL |= 0x30;                     // bits 4-5 are for special function UART0

  P2SEL = 0x60;                     // bit 5-6 for special function ROSC, ADC12CLK

  P5SEL |= 0x30;                     //output mclk & smclk

  P6SEL |= 0x01;                     // bit 0 port 6 for analog imput ADC


}


/*============================================================

     ADC Initialization

============================================================*/

void ADC_Initialize(int count)

{

  P6SEL |= 0x01;                     // bit 0 port 6 for analog imput ADC

  _BIS_SR(SREF1);                      // enable internal references

  _BIC_SR(SREF0 + SREF2);                 // 2.5 V+ and 0 V-
  ADC12CTL0 = REFON + REF2_5V;          // enable internal reference 2.5V

  ADC12CTL0  =  ADC12ON  +  SHT0_10+MSC;          //  Turn  on  ADC12,  set  sampling  time,  start                    .
with     SHI     riding     esdge     signal     and     then     .                                                     .
continue taking samples

  ADC12CTL1  =  ADC12SSEL_3  +  SHS_0;                                   //  set  internal  SMCLK  clock                .
source

  ADC12CTL1   =   SHP+CONSEQ_2;                                   //   Use   sampling   timer   to   take   samples,   set  .
mode to repest single channel (0x10)

  ADC12IE = 0x01;                       // Enable ADC12IFG.0

  ADC12CTL0 |= ENC;                         // enable conversion

  ADC12CTL0 |= ADC12SC;                     // Start conversion

 _BIS_SR(LPM0_bits + GIE);               // Enter LPM0,Enable interrupts


  // para prueba

  /**ADC12CTL0 = ADC12ON+SHT0_8+MSC;          // Turn on ADC12, set sampling time

  ADC12CTL1 = SHP+CONSEQ_2;               // Use sampling timer, set mode

  ADC12IE = 0x01;                        // Enable ADC12IFG.0

  ADC12CTL0 |= ENC;                      // Enable conversions

  ADC12CTL0 |= ADC12SC;                    // Start conversion

  _BIS_SR(LPM0_bits + GIE);               // Enter LPM0,Enable interrupts

  */

}

/*=============================================================

     enable conversion

=============================================================*/

void convert_ADC_Enable(void)

{

  _BIS_SR (ENC);                      //activate adc

  _BIS_SR (ADC12ON);

                                  // enable convertion

}
```

```
/*============================================================
    disable convertion
============================================================*/
void convert_ADC_Disable(void){
  _BIC_SR (ENC);
}
/*=============================================================
     UART0 Initialization
/=============================================================*/


void UART_Initialize(void)
{
 /* the minimun baud rate to wt12 is 19200 baud rate*/
// UART0 - 19200 bps
// for 8MHZ clock rate
   //P3DIR |= 0xff;
 // P3SEL |= 0x38;                        // bits 4-5 are for special function UART0
 // P2SEL |= 0x20;                        // bit 5 for special function
  //P2DIR |= 0x20;
 // P5SEL |= 0x30;                        //output mclk & smclk
  //P5DIR |= 0xff;                      // set all pins as output
   BCSCTL2 |= DCOR;                        // Rosc
  _BIS_SR(OSCOFF);                         // XTAL not used
  ME1 |= UTXE0 + URXE0;                     // Enabled USART0 TXD/RXD
  UCTL0 |= CHAR;                          // 8-bit character
  UTCTL0  |=  SSEL1;                                                 //  UCLK  =  SMCLKset_Baud_Rate(0x4A,  0x00,  . . . .
0x84);
                                          //      8.547MHz      115200,      UBR00=0x4A;      UBR10=0x00;                         .
UMCTL0=0x84
  UCTL0 &= ~SWRST;                        // Initialize USART state machine
  IE1 |= URXIE0;                    // Enable USART0 RX interrupt

}

/*=============================================================

set baud rate

=============================================================*/

void set_Baud_Rate(int ubr00, int ubr10, int umctl0)

{

  _BIC_SR(GIE);             // disable all interrups

  UBR00 = ubr00;

  UBR10 = ubr10;

  UMCTL0 = umctl0;

  Delay(0xff8);

  _BIS_SR(GIE);             // Enabled all interrupts

}

/*============================================================

 send a char via UART0

=============================================================*/

void UART0_putchar(char c)

{

  // wait for other character to transmit

  while (!(IFG1 & UTXIFG0));

  U0TXBUF = c;

}

/* ============================================================

recieve a char via UART0

 =============================================================*/

char UART0_getchar(void)

{

  for (;;)
 {
  // if (U0RCTL & RXERR)
  // {
     // if you want to answer receive errors, do it here.
    // U0RCTL &= ~(FE+PE+OE+BRK+RXERR);
  // }
  // else
  // {
   //  if (IFG1 & URXIFG0)
    // {  // we've received a character
       return U0RXBUF;
     }
   }
 //}
//}
/*=============================================================
 INFO displays information about iWRAP version and features.
==============================================================*/
void request_INFO(void)
{
 UART0_putchar('I');
 UART0_putchar('N');
 UART0_putchar('F');
 UART0_putchar('O');
}
/* =============================================================
   wt12 control functions set baud rate 19200
==============================================================*/
```

```
// set baud rate 19200, 8 bit no parity, one stop bit bluetooth module
void set_Baud_Rate_19200(void)
  {
  UART0_putchar('S');
  UART0_putchar('E');
  UART0_putchar('T');
  UART0_putchar(' ');
  UART0_putchar('C');
  UART0_putchar('O');
  UART0_putchar('N');
  UART0_putchar('T');
  UART0_putchar('R');
  UART0_putchar('O');
  UART0_putchar('L');
  UART0_putchar(' ');
  UART0_putchar('B');
  UART0_putchar('A');
  UART0_putchar('U');
  UART0_putchar('D');
  UART0_putchar(' ');
  UART0_putchar('1');
  UART0_putchar('9');
  UART0_putchar('2');
  UART0_putchar('0');
  UART0_putchar('0');
  UART0_putchar('N');
  UART0_putchar(',');
  UART0_putchar('8');
  UART0_putchar('N');
  UART0_putchar('1');
}
```

Appendix V

```
//BluetoothMidlet.java
package capstone;

import java.io.IOException;
import java.io.InputStream;
import javax.bluetooth.UUID;
import javax.microedition.io.StreamConnection;
import javax.microedition.lcdui.Command;
import javax.microedition.lcdui.CommandListener;
import javax.microedition.lcdui.Display;
import javax.microedition.lcdui.Displayable;
import javax.microedition.lcdui.List;
import javax.microedition.midlet.MIDlet;

/**This Midlet is in charge of selecting if the device will be
 * server or client
 */
public final class BluetoothMidlet extends MIDlet implements CommandListener {
    // Shared UUID by server and client, RFCOMM UUID
    public static final UUID RFCOMM_UUID = new UUID(0x0003);

    /** The messages are shown this amount of time. */
    static final int ALERT_TIMEOUT = 2000;
    /** A list of menu items */
    private static final String[] elements = { "Server", "Client" };
    /** Soft button for exiting the demo. */
    private final Command EXIT_CMD = new Command("Exit", Command.EXIT, 2);
```

```
/** Soft button for launching a client or sever. */
private final Command OK_CMD = new Command("Ok", Command.SCREEN, 1);
/** A menu list instance */
private final List menu = new List("Bluetooth Application", List.IMPLICIT, elements, null);
/** A GUI part of server*/
private GUIServer server;
/** A GUI part of client*/
private GUIClient client;
/** value is true after creating the server/client */
private boolean isInit = false;
/**
 * Constructs main screen of the MIDlet.
 */
public BluetoothMidlet() {
   menu.addCommand(EXIT_CMD);
   menu.addCommand(OK_CMD);
   menu.setCommandListener(this);
   System.out.println(RFCOMM_UUID.toString());   //debug purposes
}
/**
 * Creates the demo view and action buttons.
 */
public void startApp() {
   if (!isInit) {
      show();
   }   }
/**
 * Destroys the application.
 */
protected void destroyApp(boolean unconditional) {
    if (server != null) {
        server.destroy();
    }
    if (client != null) {
        client.destroy();
    }   }
/**
 * Does nothing. Redefinition is required by MIDlet class.
 */
protected void pauseApp() {
}
/**
 * Responds to commands issued on "client or server" form.
 *
 * @param c command object source of action
 * @param d screen object containing the item action was performed on
 */
public void commandAction(Command c, Displayable d) {
    if (c == EXIT_CMD) {
        destroyApp(true);
        notifyDestroyed();
        return;
    }
    switch (menu.getSelectedIndex()) {
    case 0:
        server = new GUIServer(this);
        break;
    case 1:
        client = new GUIClient(this);


        break;
    default:
        System.err.println("Unexpected choice...");
        break;
    }
    isInit = true;
}
/** Shows main menu of MIDlet on the screen. */
void show() {
    Display.getDisplay(this).setCurrent(menu);
}
/**
 * Returns the displayable object of this screen -
 * it is required for Alert construction for the error
 * cases.
 */
Displayable getDisplayable() {
    return menu;
}
/**
 * Reads data from the connection and returns it as a
 * String.
 */
public final static String readData(StreamConnection conn) {
InputStream input = null;
byte[] data = null;
```

```
    try {
      input = conn.openInputStream();
      // Probably want to throw an exception if length is not greater then 0
      int length = input.read();
      data= new byte[length];
      length = 0;
      // Assemble data
      while (length != data.length) {
        int ch = input.read(data, length, data.length - length);
        if (ch == -1) {
          throw new IOException("Can't read data");
        }
        length += ch;
      }
    } catch (IOException e) {
      System.err.println(e);
    } finally {
      // close input stream
      if (input != null) {
        try {
          input.close();
        } catch (IOException e) {
        }    }    }
    return new String(data);
  }  }

//GuiServer.java
package capstone;
import javax.microedition.lcdui.Command;
import javax.microedition.lcdui.CommandListener;
import javax.microedition.lcdui.Displayable;



/**This class will hold the GUI of the server*/
final class GUIServer implements CommandListener {
    /** Keeps the parent MIDlet reference to process specific actions. */
    private BluetoothMidlet parent;
    /** This object handles the real transmission. */
    private BluetoothServer bt_server;
    /** Constructs server GUI. */
    GUIServer(BluetoothMidlet parent) {
        this.parent = parent;
        bt_server = new BluetoothServer();//this);
    }
    /**
     * Process the command event.
     *
     * @param c - the issued command.
     * @param d - the screen object the command was issued for.
     */
    public void commandAction(Command c, Displayable d) {
    }
    /**
     * We have to provide this method due to "do not do network
     * operation in command listener method" restriction, which
     * is caused by crooked midp design.
     *
     * This method is called by BTImageServer after it is done
     * with bluetooth initialization and next screen is ready
     * to appear.
     */
    void completeInitialization(boolean isBTReady) {
    }
    /** Destroys this component. */
    void destroy() {
    }
}

//GuiClient.java
package capstone;
import javax.microedition.lcdui.Command;
import javax.microedition.lcdui.CommandListener;
import javax.microedition.lcdui.Displayable;
/**This class will hold the GUI of the client*/
final class GUIClient implements CommandListener {
    /** Keeps the parent MIDlet reference to process specific actions. */
    private BluetoothMidlet parent;
    /** This object handles the real transmission. */
    private BluetoothClient bt_client;
    /** Constructs client GUI. */
    GUIClient(BluetoothMidlet parent) {
        this.parent = parent;
        bt_client = new BluetoothClient();//(this);
    }
    /**
     * Process the command events.
     *
     * @param c - the issued command.
     * @param d - the screen object the command was issued for.
     */
    public void commandAction(Command c, Displayable d) {
    }

    /**
     * We have to provide this method due to "do not do network
     * operation in command listener method" restriction, which
     * is caused by crooked midp design.
     *
     * This method is called by BTImageClient after it is done
     * with bluetooth initialization and next screen is ready
     * to appear.
     */
    void completeInitialization(boolean isBTReady) {
    }
    /** Destroys this component. */
    void destroy() {
    }}

//BluetoothServer.java
package capstone;
import javax.bluetooth.*;
import javax.microedition.io.*;
import java.io.*;
/**Class that represents a Bluetooth Server*/
public class BluetoothServer implements Runnable {
```

```
StreamConnectionNotifier notifier;
StreamConnection conn;
LocalDevice localDevice;
ServiceRecord serviceRecord;
InputStream input;
OutputStream output;
private boolean isInit;
private static String serverUrl = "btspp://localhost:" + BluetoothMidlet.RFCOMM_UUID + ";name=rfcommtest;authorize=false";
  /**
 * Default constructor.
 */
public BluetoothServer() {
  isInit = false;
  Thread thread = new Thread(this);
  thread.start();
}
public void run() {
  if (!isInit) {
    // Initialization is done in the thread to avoid dead lock 'isInit' ensures it is done once only
    try {
      conn = null;
      localDevice = LocalDevice.getLocalDevice();
      System.out.println(localDevice.getFriendlyName());//Testing purposes
      localDevice.setDiscoverable( DiscoveryAgent.GIAC );
      notifier = (StreamConnectionNotifier)Connector.open(serverUrl);
    } catch (BluetoothStateException e) {
      System.err.println( "BluetoothStateException: " + e.getMessage() );
    } catch (IOException e) {
      System.err.println( "IOException: " + e.getMessage() );
```

```
     }
     isInit=true;
     System.out.println( "Starting Echo Server" );
   }
   //
   try {
     System.out.println("\n\nServer Running...");
     // Pauses thread until Transmission occurs
     conn = notifier.acceptAndOpen();

     // Read Data Transmission
     String msg = BluetoothMidlet.readData(conn);
     System.out.println("Received Message from Client: " + msg);
     // Send Back a Message
     msg = "Hello Back from Server";
     output = conn.openOutputStream();
     output.write(msg.length()); // length is 1 byte
     output.write(msg.getBytes());
     output.close();
   } catch (Exception ex) {
     System.err.println("Bluetooth Server Running Error: " + ex);
   }     }}

//BluetoothClient.java
package capstone;
import javax.bluetooth.*;
import javax.microedition.io.*;
import java.io.*;
/**
```

```
 * Class that represents a Bluetooth Client
 *
 */
class BluetoothClient implements DiscoveryListener {
  private DiscoveryAgent discoveryAgent;
  private RemoteDevice[] remoteDevices;
  private UUID[] uuidSet;
  private String serviceUrl;
  /**
   * Default constructor.
   */
  public BluetoothClient() {
    try {
      LocalDevice localDevice = LocalDevice.getLocalDevice();
      discoveryAgent = localDevice.getDiscoveryAgent();
      discoveryAgent.startInquiry(DiscoveryAgent.GIAC, this);
    } catch (Exception e) {
      System.out.println(e);
    }  }
  /**
   * Method called when a device is discovered
   * @param btDevice
   * @param cod
   */
  public void deviceDiscovered(RemoteDevice btDevice, DeviceClass cod) {
    try {
      // Get Device Info
      System.out.println("Device Discovered");
      System.out.println("Major Device Class: " + cod.getMajorDeviceClass() + " Minor Device Class: " +
cod.getMinorDeviceClass());
```

```
    System.out.println("Bluetooth Address: " + btDevice.getBluetoothAddress());
    System.out.println("Bluetooth Friendly Name: " + btDevice.getFriendlyName(true));
    // Search for Services
    uuidSet = new UUID[1];
    uuidSet[0] = BluetoothMidlet.RFCOMM_UUID;
    int searchID = discoveryAgent.searchServices(null,uuidSet,btDevice,this);
  } catch (Exception e) {
    System.out.println("Device Discovered Error: " + e);
  }  }
/**
 * Method called when the inquiry is completed
 * @param discType
 */
public void inquiryCompleted(int discType) {
  System.out.println("InquiryCompleted");
}
/**
 * Method called when a service is discovered
 * @param transID
 * @param servRecord
 */
public void servicesDiscovered(int transID, ServiceRecord[] servRecord) {
  System.out.println("ServicesDiscovered");

  // in this example there is only one service
  for(int i=0;i<servRecord.length;i++) {
     serviceUrl = servRecord[i].getConnectionURL(0,false);
  }     }
/**
```

```
 * Method that is called when the service search is completed
 * @param transID
 * @param responseCode
 */
public void serviceSearchCompleted(int transID, int responseCode) {
  if(responseCode == SERVICE_SEARCH_ERROR)
    System.out.println("SERVICE_SEARCH_ERROR\n");
  if(responseCode == SERVICE_SEARCH_COMPLETED) {
    System.out.println("SERVICE_SEARCH_COMPLETED\n");
    System.out.println("Service URL: " + serviceUrl);
    StreamConnection conn = null;
    try {
          String msg = "Say Hello World";
      conn = (StreamConnection)Connector.open(serviceUrl);
      OutputStream output = conn.openOutputStream();
      output.write(msg.length());
      output.write(msg.getBytes());
      output.close();
       System.out.println(BluetoothMidlet.readData(conn));
       } catch (Exception ex) {
          System.out.println(ex);
    } finally {
          try {
            conn.close();
          } catch (IOException ioe) {
            System.out.println("Error Closing connection " + ioe);
      }     }   }
  if(responseCode == SERVICE_SEARCH_TERMINATED)
    System.out.println("SERVICE_SEARCH_TERMINATED\n");
    if(responseCode == SERVICE_SEARCH_NO_RECORDS)
      System.out.println("SERVICE_SEARCH_NO_RECORDS\n");
    if(responseCode == SERVICE_SEARCH_DEVICE_NOT_REACHABLE)
      System.out.println("SERVICE_SEARCH_DEVICE_NOT_REACHABLE\n");
  } }

//TestMidlet.java
package test;
import javax.bluetooth.LocalDevice;
import javax.microedition.midlet.*;
import javax.microedition.lcdui.*;
/**
 * This Midlet tests the capacity of the device to identify
 * its friendly name and bluetooth address
 */
public class TestMidlet extends MIDlet implements CommandListener {
    private Alert display;
    private LocalDevice localDevice;
    private final Command exit = new Command("Exit", Command.EXIT, 1);
    /**Public constructor*/
    public TestMidlet()
    {
        /*We try to get the LocalDevice instance representing the
         * device so that we can operate on it*/
        try
        {
            localDevice = LocalDevice.getLocalDevice();
        }
        catch(Exception e)
    {
        System.out.println(e);
    }
    /*This text contains the friendly name and bluetooth address
     * of the device*/
    String text = "Friendly name: " + localDevice.getFriendlyName() +
                "\nBluetooth address: " + localDevice.getBluetoothAddress();
    display = new Alert("Test");
    display.addCommand(exit);
    display.setType(AlertType.INFO);
    display.setTimeout(Alert.FOREVER);
    display.setString(text);
    display.setCommandListener(this);
}
public void startApp() {
    Display.getDisplay(this).setCurrent(display);
}
public void pauseApp() {
}
public void destroyApp(boolean unconditional) {
}
public void commandAction(Command c, Displayable d) {
    if (c == exit) {
        destroyApp(true);
        notifyDestroyed();
        return;       }   }}
```