

BME 363 Lab Manual

Biomedical Instrumentation Design Laboratory
Department of Electrical, Computer, and Biomedical Engineering
<http://www.ele.uri.edu/courses/bme363/>
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Preface

Biomedical Instrumentation is vital to studying our human biology and physiology. This can be used for diagnostic, control, or therapy purposes. Some examples are ECG systems, pacemakers, medical imaging systems, just to name a few. One example we will be focusing on is PPG, or photoplethysmogram, an optically measured signal correlating to blood flow volume, which can be used to calculate heart rate, pulse oximetry (oxygen saturation), and even respiration. While much of this technology has been around for centuries, many diagnostic tools and treatments involve lengthy and extremely costly visits to the hospital. Supplementary portably systems can be a great way to monitor day-to-day improvements, provide greater independence, and alert users and/or medical professionals when certain medical conditions occur.

This laboratory will be a continuation of BME 361 Biomeasurement Lab, where we will investigate of how signals can be acquired from the human body, how these can be amplified, processed, interpreted, and we will incorporate modern drive for portable immediate accessibility by introducing Android Development Applications. The Android development will consist of data transmission through the use of Bluetooth, data display, signal processing algorithms, and some imaging which will briefly introduce BME 464, Medical Imaging. An important skill set that this lab course will provide is the development of Android app's using the Java language.

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Relevant Links

Course webpage – <http://www.ele.uri.edu/courses/bme363>

MPLAB X – <http://www.microchip.com/pagehandler/en-us/family/mplabx/>

Android Studio – <http://developer.android.com/sdk/installing/index.html?pkg=studio>

PPG example – <http://www.radiolocman.com/shem/schematics.html?di=144220>

Serial Communication – <https://learn.sparkfun.com/tutorials/serial-communication>

LAB 1: PIC18F4525 BREADBOARD UPGRADE

PURPOSE: The purpose of this lab is to bring the BME 361 PIC breadboard circuit to a higher standard such that it will provide a reliable platform for adding and integrating sensors and actuators for various projects including the senior-year capstone design projects. All components including the LCD display and the USB charger must be tightly secured to the base of the breadboard.

GOALS:

- Improve the PIC breadboard circuit from BME 361 with all wires laid down on the breadboard surface;
- Add a push-button on/off switch;
- Ground the base of the breadboard with a screw and a nut;
- Custom-make two brackets to bolt down the LCD display;
- Custom-make a clip from a section of a 3/4" PVC pipe for securing the portable USB charger;
- Add a waveform generator with simulated 60 Hz noise (LM556);
- Add an analog ECG simulator (LM555);
- Add an on-board ECG amplifier or use the ECG PCB from BME 361.
- Make sure the PIC breadboard is bug-free and everything works flawlessly.

PROCEDURE:

Hardware

1. Using your breadboard, implement the circuit seen above in Figure 1.1. You should already have the majority of it complete from BME 361.
2. Be sure you have all the necessary components, and that they are oriented correctly. (Note: if you do not know/remember the pin assignment for a certain component, look up the data-sheet and use it as a reference.)
3. Make sure everything is neat and COMPACT. You will need to have room on your breadboard for the following labs. See the layout of the demonstration in Figure 1.2.
4. Secure all components to the metal base of the breadboard, including the USB charger, the power on/off switch, and the LCD Display. Customize the necessary mechanical parts for fastening the components. See Figure 1.3.

Software

1. Open MPLAB on either a desktop computer in the lab, or your own laptop.
2. Go to <<http://www.ele.uri.edu/courses/bme363/>> to download the PIC demo code.
3. Compile and upload the code to your PIC processor.

TASKS:

1. Use an oscilloscope to ensure everything works properly. The Waveform Generator circuit replaces the need for a function generator, and allows you to create a waveform to 'test' all your states. The Analog ECG simulator has a similar function, and allows you demonstrate the HR meter without having to attach yourself to the ECG amplifier. You should have 10 states, as listed below:

01 – Binary counter	02 – ECG simulation	03 – Echo (A/D -D/A)	04 – Echo @ fs Hz
05 – Derivative	05 – Low-pass filter	06 – Hi-Freq enhance	07 – 60Hz notch filtr
08 – Median Filter	09 – HR = bpm	10 – PhotoplethysmoG	-- reserved for future

2. If you are having issues with any of the hardware, use an oscilloscope or multimeter to troubleshoot.
 - a. Test all your voltage busses to make sure you are indeed getting +5V and -5V.
 - b. Use the continuity setting on a multimeter (beep test) to make sure you have no shorts.
 - c. Test each individual part of the circuit to determine in what section the issue originates from.
3. In the lab report, document your modifications and show evidences of functionality. Include photos.

MATERIALS & TOOLS:

BME 361 Lab circuit

Building materials including sheet metal , PVC pipe, screws and nuts

Shrink tubes, double-sided foam tape

Super glue, contact cement (polychloroprene)

Soldering iron, sheet metal cutter, heat gun

Oscilloscope, multimeter

BREADBOARD LAYOUT:

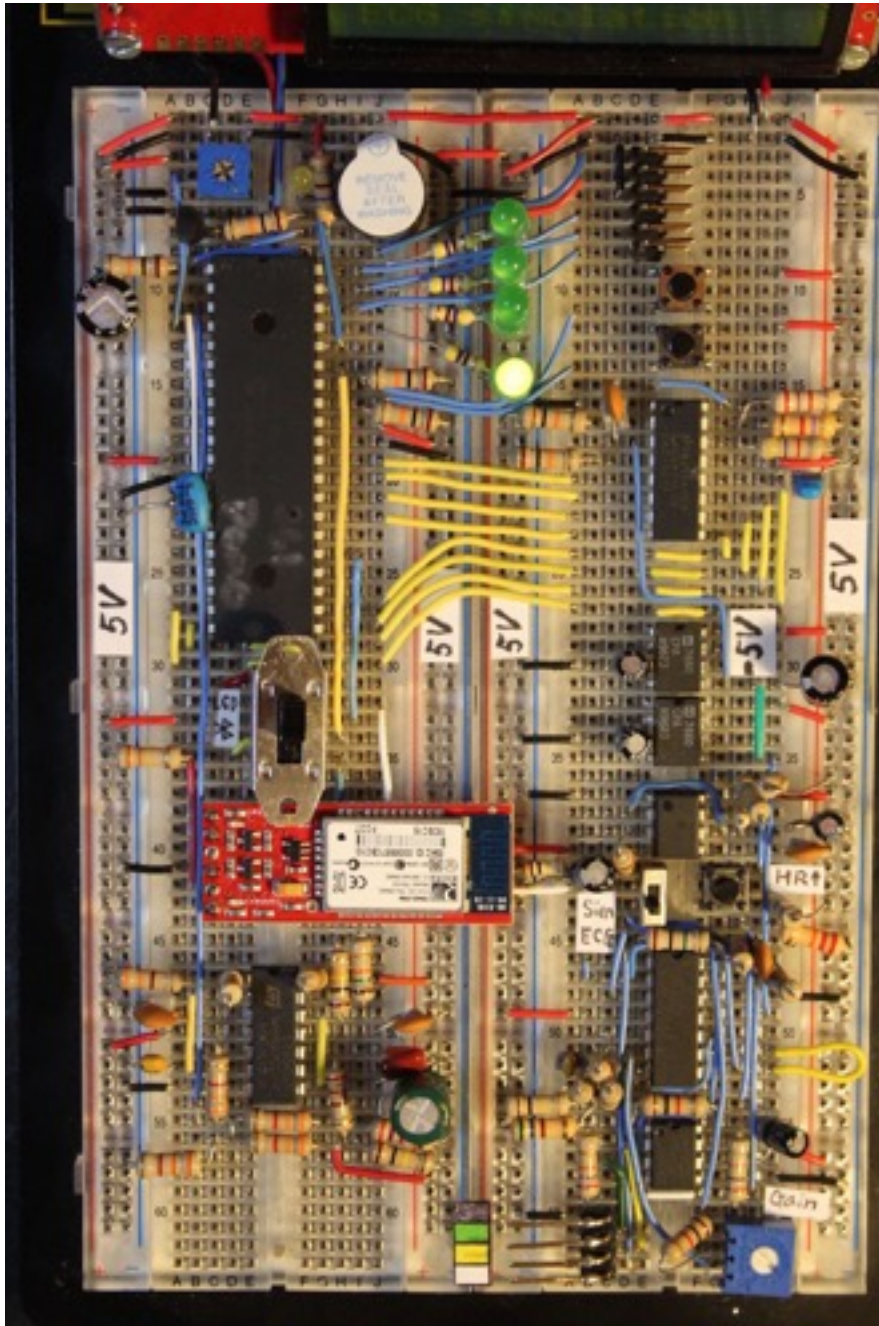


Figure 1.2. Demonstration Breadboard

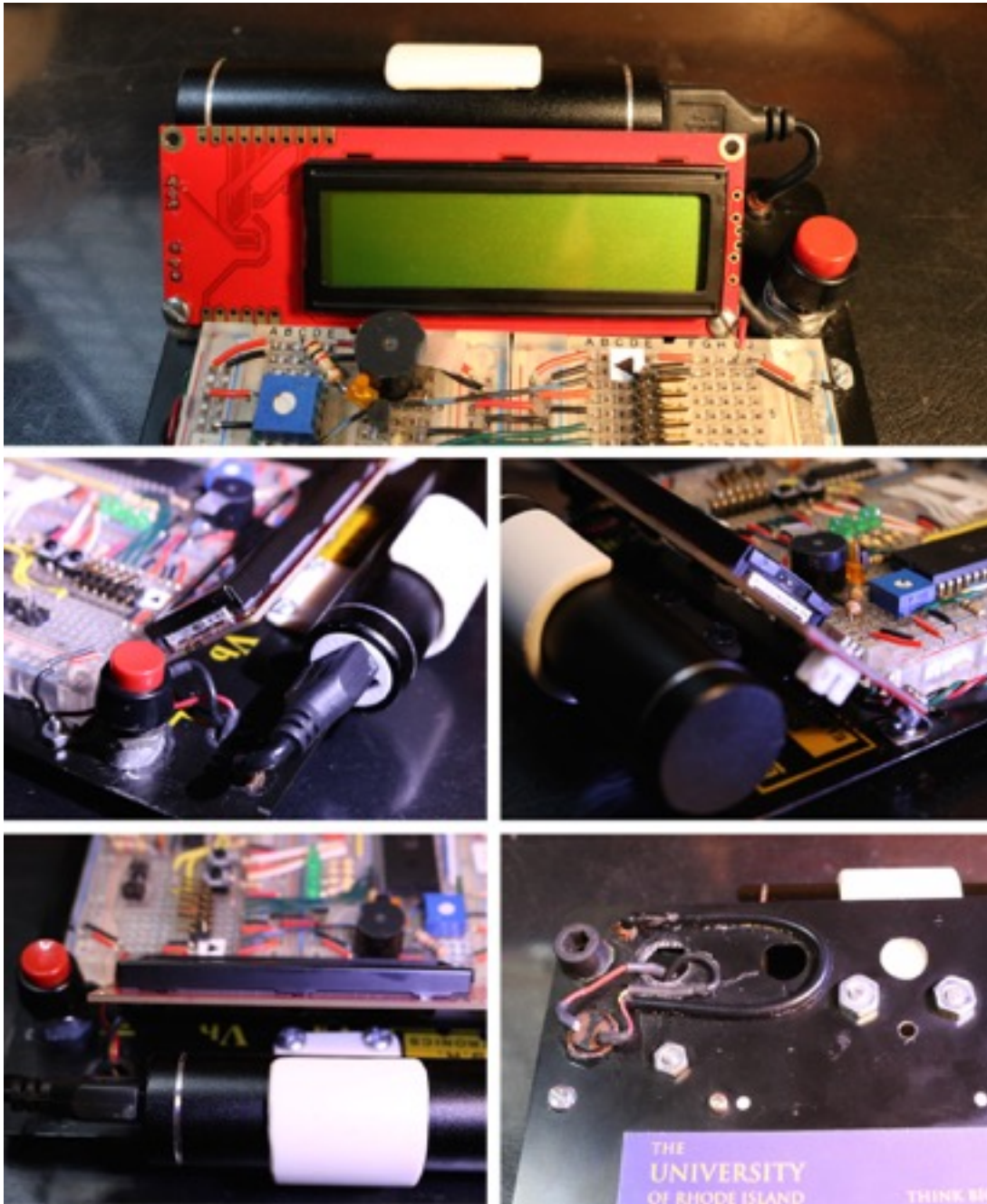
MECHANICAL MODIFICATIONS:

Figure 1.3. Breadboard Hardware Modifications

PROCEDURE:Hardware

1. Connect the bluetooth modem as seen in figure 2.1 above. The SPI transmit line (TX) of the PIC (pin 25) is connected to the receive line (RX) of either the LCD display or the Bluetooth modem. A single-pole double-throw (SPDT) switch is used to make the selection. The switch is also used to provide the 5V power to either the LCD display or the Bluetooth modem. A logic signal is send to RB2 of the PIC (pin 35) that tells the software which device is selected. The variable in the PIC associated with this is called "enableBT."

Software

1. Download Android Studio. Instructions are listed in Appendix A.
2. Go to <<http://www.ele.uri.edu/courses/bme363/>> to download the Android code ZIP file.
3. Unzip the file and put the folder in an appropriate place (desktop or a subfolder, but not too deep).
4. Open Android Studio and select 'import project, to select your downloaded file.
5. A screenshot of the Android Studio is shown on next page.

TASKS:

1. If you are connected to an android device via USB, it will automatically prompt you to use the device. Otherwise, it will prompt you to run it on the emulator. When the USB cable is initially connected, the Android device is usually on the "USB for charging" mode. Swap down from the top to show the notifications and select "Transfer files (MTP)".
2. You may also need to enable Setup —> Developer option —> USB debugging.
3. You may now go ahead and "run the app", the green play button.
4. If this bluetooth modem and the Android device are used for the first time, "pairing" needs to be done. This is accomplished by running "Setup" on Android. Select bluetooth and use "1234" as the pairing code.
5. If all is done correctly, your new app (PICscope) should be created and open on your device. You may now connect to bluetooth and see the waveform sent through the PIC.
6. If you have Bluetooth connection issues, go to Appendix B for additional steps.
7. In Android studio, familiarize yourself with the application, and layout options. Under Project > Android> PICscope > Java> edu.uri.egr.bme363lab> ui > main activity you will find your MainActivity.java file. This is the backbone of the application, and is what goes on behind the scenes of your application. See next page.
8. Next, find the activity_main.xml to see the code for layout. This is where you create your GUI layout, which is the front end of your application.

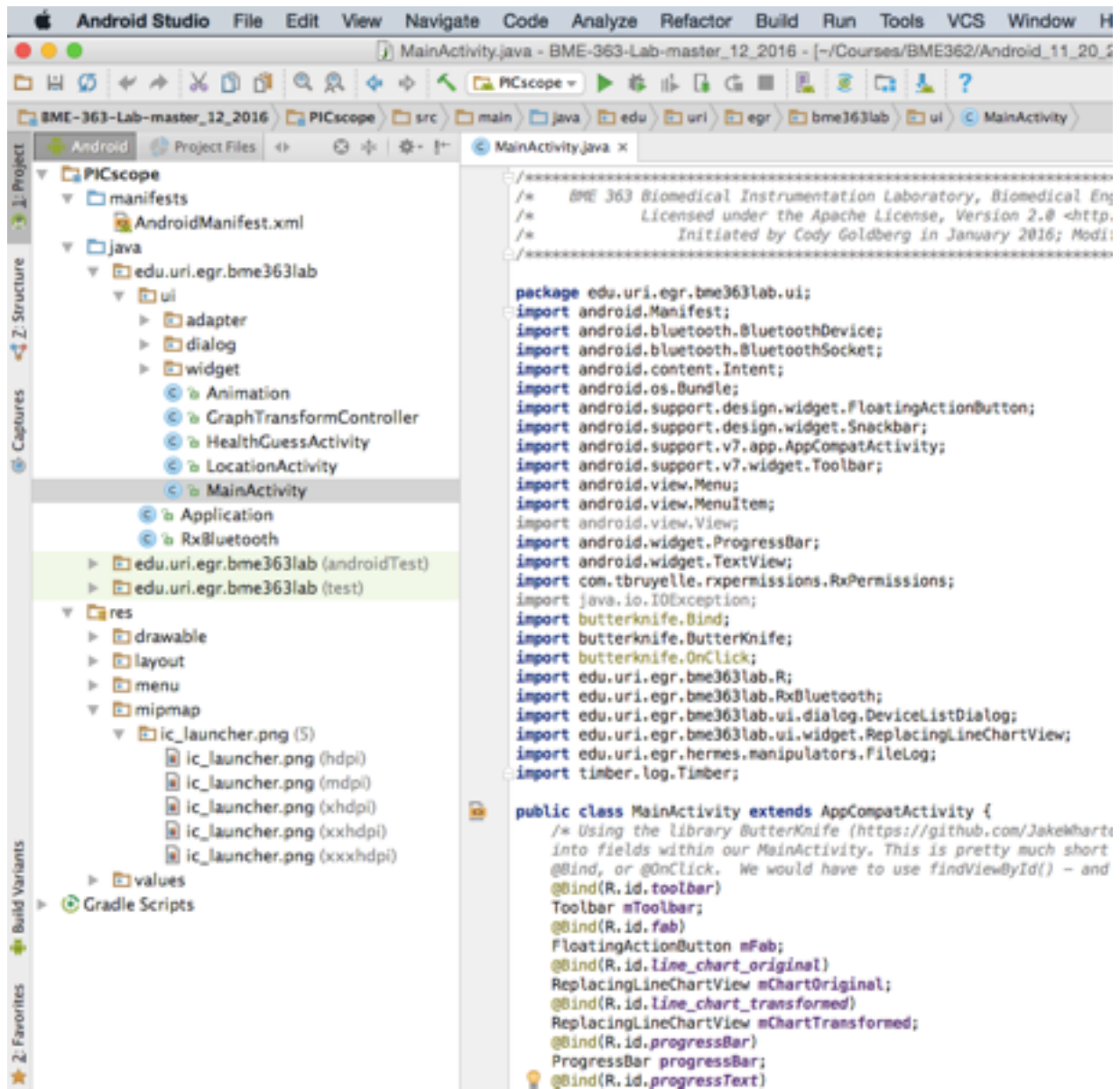


Figure 2.2. Android Studio screenshot

LAB 3: PHOTOPLETHYSMOGRAM (PPG) CIRCUIT

PURPOSE: A Photoplethysmogram (PPG) is a method that uses light absorption to measure blood volume change, and can be used to determine the heart rate. Using two diodes, one to transmit light, and one to read the absorbed light, we can obtain an analog signal that corresponds to the pulsatile blood flows in an artery. The two methods this is done are through transmission and reflectance. Transmission involves light passing through the tissue, and being detected at the other side. Reflectance is used when light cannot be transmitted all the way through the tissue, such as when the tested area is too thick, has bone, or other interference such as nail polish.

GOAL: This lab aims at building a PPG circuit. You will learn 1) the principle of photoplethysmogram, 2) the op amp circuitry, 3) the operations of modulation and demodulation.

MATERIALS:

(2) IR or red LED's	39K
LED (any color)	330K
LM 324 Op Amp	2.2M
820	(2) 4.7M
1K	(2) 0.01 μ F
2.2K	0.1 μ F
(4) 10 K	(2) 2.2 μ F
15K	

PROCEDURE:

Hardware

1. Implement the circuit on the breadboard according to the schematic in Figure 3.1. Using infrared LED's, you won't be able to see light emitted, but depending if you have an IR filter on your phone, you may be able to see light using your phone camera (most likely not). However, using an Oscilloscope, you should be able to see changes on the output when you wave the emitting diode in front of the receiving diode. As an alternative, you can use red LED's.
2. Test the PPG circuit by inserting your thumb or index finger between the LED transmitter and the LED detector. You should see something that looks like a saw tooth waveform in Figure 3.2. You may even be able to see your respiratory rate from the variability in baseline.
3. If it doesn't work the first time, measure voltages at the test points (A-D as shown) and debug the circuit.
4. Try using both the reflection and transmission method to obtain a PPG signal.
5. Study the operation of the light detection and demodulation by observing the signal waveforms through various stages of the circuit with an oscilloscope.

Software

1. Study the sample code that provides a 1 KHz square wave to drive the LED under the PPG mode (function 10).
2. Display the PPG waveform on the Android device.

SCHEMATIC:

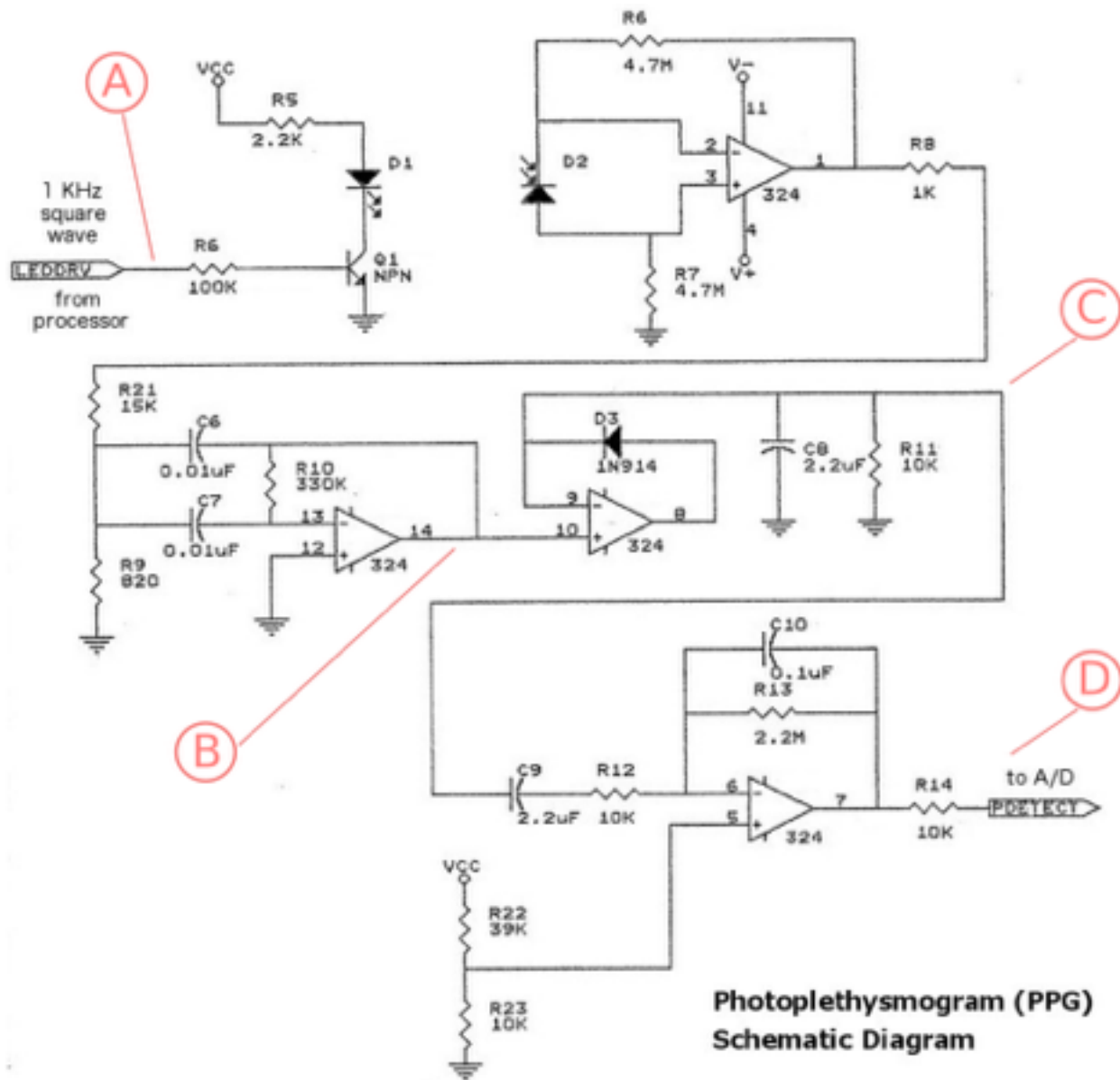


Figure 3.1. Schematic for PPG

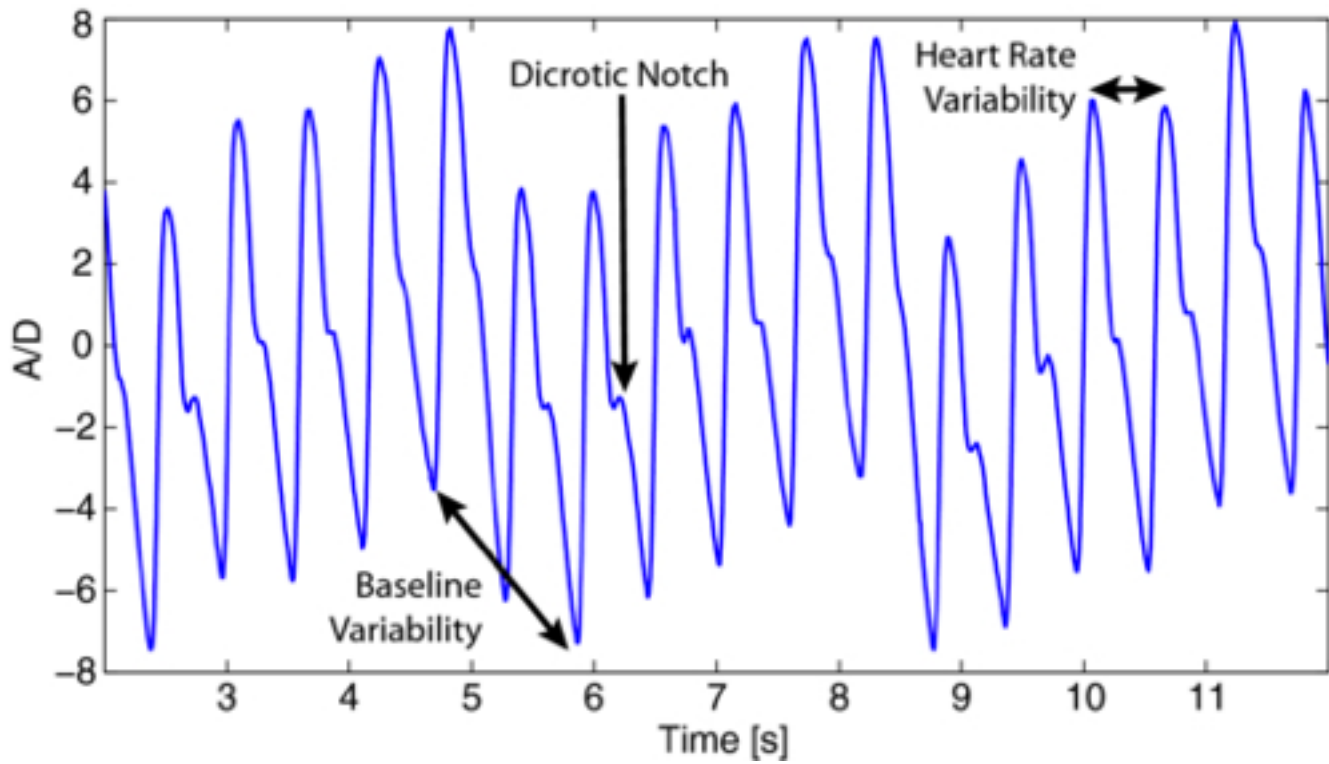


Figure 3.2. PPG signal

LAB 4: BMI CALCULATION

PURPOSE: The purpose of this lab is to study fluctuations in heart rate linked to age, sex, BMI, exercise/stress and generate an algorithm to provide an educated guess of your heart health. During this process you will also learn how to map out a layout, and use different user controls, and link these values to be used in your algorithm.

GOAL: You will be creating a screen on the Android device that will ask you a series of questions, including age, sex, height, weight, and fitness level, and match that against your heart rate to estimate your heart health. You may also want to add additional criteria, such as smoker/nonsmoker, stress levels, heart health, or even ambient temperature to increase accuracy.

MATERIALS:

- PIC board with ECG circuit
- Android Studio and a smartphone or tablet

PROCEDURE:

Hardware

1. Using your ECG circuit, measure your resting heart rate. You can take your pulse, or use a finger PPG to compare.

Software

1. Use Android Studio to create a GUI. The GUI will utilize different input methods such as a radio button for Male or Female, a spinner drop down for fitness level, and a text field for your height, weight, and age. You will also create a **Calculate** button to calculate BMI and guess heart rate.
2. Using the BMI formula listed below, as well as Figure 4.1, create a lookup table to determine heart health. For example, an average fitness female of age 30 should have a heart rate in the range of 73-76 BPM

Men							Women						
Age	18-25	26-35	36-45	46-55	56-65	65+	Age	18-25	26-35	36-45	46-55	56-65	65+
Athlete	49-55	49-54	50-56	50-57	51-56	50-55	Athlete	54-60	54-59	54-59	54-60	54-59	54-59
Excellent	56-61	55-61	57-62	58-63	57-61	56-61	Excellent	61-65	60-64	60-64	61-65	60-64	60-64
Good	62-65	62-65	63-66	64-67	62-67	62-65	Good	66-69	65-68	65-69	66-69	65-68	65-68
Above Average	66-69	66-70	67-70	68-71	68-71	66-69	Above Average	70-73	69-72	70-73	70-73	69-73	69-72
Average	70-73	71-74	71-75	72-76	72-75	70-73	Average	74-78	73-76	74-78	74-77	74-77	73-76
Below Average	74-81	75-81	76-82	77-83	76-81	74-79	Below Average	79-84	77-82	79-84	78-83	78-83	77-84
Poor	82+	82+	83+	84+	82+	80+	Poor	85+	83+	85+	84+	84+	84+

Figure 4.1. Heart health vs age chart

$$BMI = \text{Weight} * 703 / \text{Height}^2$$

Weight in pounds, and height in inches

LAB 5: MODE CHANGE BUTTON ON ANDROID

PURPOSE: The purpose of this lab is to implement a button to control the “function” mode on the PIC board.

GOAL: 1) Complete the two-way communication between the PIC board and the Android device. 2) Add a button on the Android waveform screen to send a signal back to the PIC to advance the “function” mode.

MATERIALS:

PIC board

Android Studio and a smartphone or tablet

PROCEDURE:

Hardware

1. Add a wire on the PIC board that connects the TX-O line of the Bluetooth modem to the RX line (pin 26) of the PIC18F4525.

Software

1. Use Android Studio to create the code to send a message back to the PIC when the “function” icon is touched.
2. Use MPLAB X to program the PIC to receive the message from the Android device and advance the “function” accordingly.

LAB 6: BEAT-TO-BEAT HEART RATE FROM PPG

PURPOSE: The purpose of this lab is to implement a beat-to-beat heart rate detector using the PPG signal, and 2) to study fluctuations in heart rate linked to age, sex, BMI, exercise/stress. During this process you will also learn how to map out a layout, and use different user controls, and link these values to be used in your algorithm.

GOAL: 1) Design a peak-and-valley detection algorithm to measure the beat-to-beat heart rate from PPG; Implement the algorithm in Java on the Android device. 2) Study the sample code provided for a dialog box that will ask you a series of questions, including age, sex, height, weight, and fitness level, and match that against your heart rate to estimate your heart health. You may also want to add additional criteria, such as smoker/nonsmoker, stress levels, heart health, or even ambient temperature to increase accuracy.

MATERIALS:

PIC board and PPG circuit from Lab 3
Android Studio and a smartphone or tablet

PROCEDURE:

Hardware

1. From lab 3, measure your PPG and send the waveform to the Android device for display and processing.

Software

1. Use Android Studio to create an algorithm to perform beat-to-beat heart rate detection.
2. Display the heart rate on the waveform screen and update the heart rate every beat.

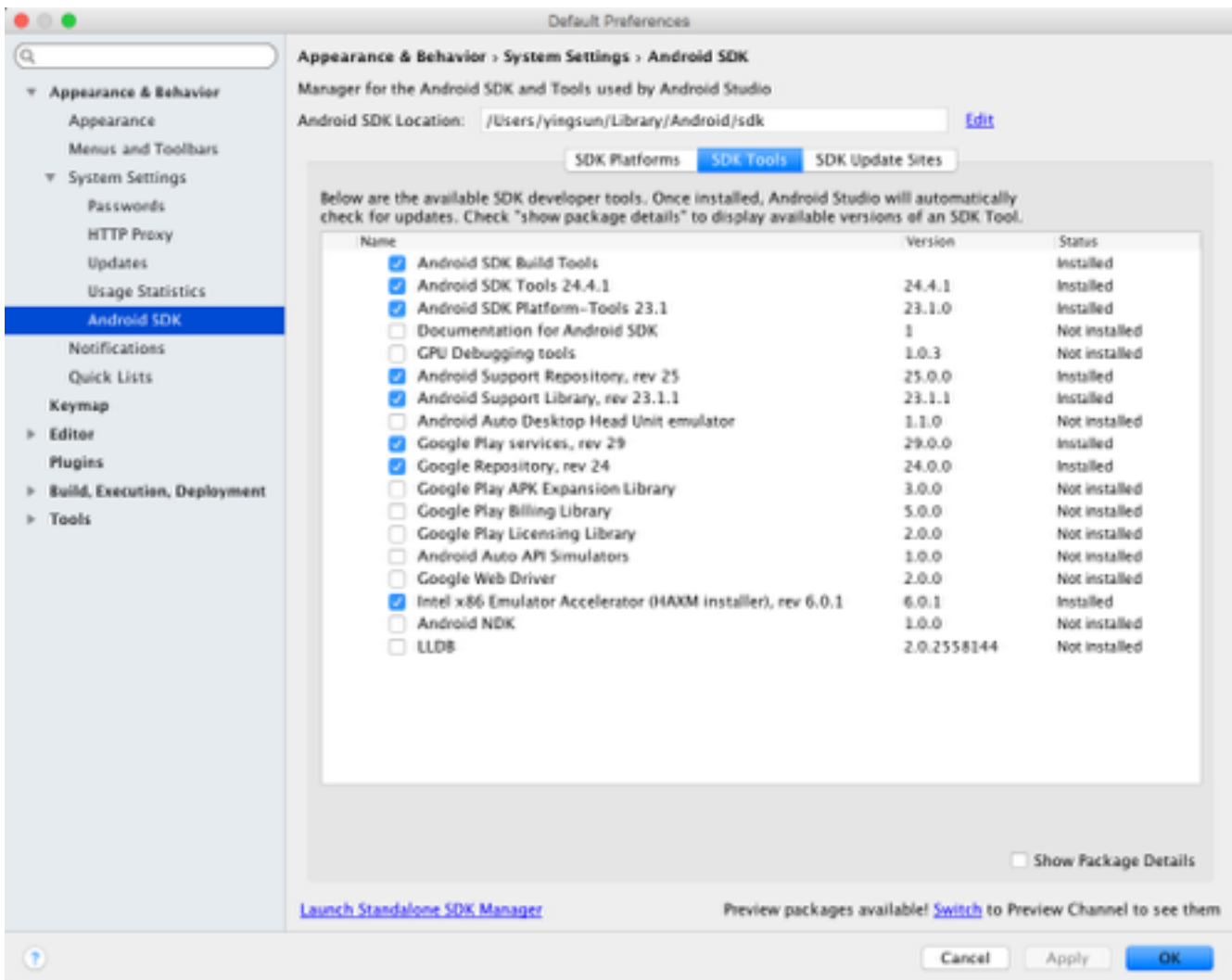
APPENDIX

A. MPLAB® X IDE installation, OSX

1. Download and install “mplabc18-v3.40.dmg”
2. Download and install “xc8-v1.35-full-install-osx-installer.dmg” at <http://www.microchip.com/pagehandler/en-us/family/mplabx/>
3. Either import the existing MPLAB project, or create new.

B. Install Android Studio

1. <http://developer.android.com/sdk/installing/index.html?pkg=studio>
2. Download & install java SDK if needed
3. Install android studio following directions
4. Add SDK packages as instructed



Developing for Android:

1. Install “jdk-8u65-macosx-x64.dmg”
2. Install “android-studio-ide-141.2343393-mac.dmg”
3. Either import the Android project, or create new.
4. If you receive compile errors related to “lambda/java8/syntax” you will have to modify the project to point to the JDK 8 installed previously.
 - a. To do that, right click on the module (normally named “app”) on the left project explorer window, and select “Open Module Settings”
 - b. On the left, click on “SDK Location”, and replace JDK location with “/Library/Java/JavaVirtualMachines/jdk1.8.0_40.jdk/Contents/Home”
 - c. The above is the default JDK location, however, it might be different. You may have to go searching.

C. Bluetooth Configuration to set BAUD rate

Power up the Bluetooth modem but disconnect the PIC TX line to it. Pair the laptop with the Bluetooth modem. Open a terminal window.

```
screen //dev/tty.RN <tab> ..... it responds with the full code
screen //dev/tty.RNXXX-XXX 115200 ..... type 115200 and enter
$$$ ..... it responds with CMD
su,96 ..... it responds with AOK
sq,16 ..... it responds with AOK
r,1 ..... it responds with Reboot!
```