

## Arduino Based Control and Measuring ECG and PPG

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**Abstract:** This contribution describes the planning and the development of laboratory activities for an introduction to biomedical system instrumentation. Remote ECG monitoring systems are becoming commonplace medical devices for remote heart monitoring. In recent years, remote ECG monitoring systems have been applied in the monitoring of various kinds of heart diseases, and the quality of the transmission and reception of the ECG signals during remote process kept advancing. This paper tries to clarify the future developmental strategies of the three channel ECG signal remote monitoring, which can be helpful in guiding the research and development of remote ECG monitoring.

### *Chapter one*

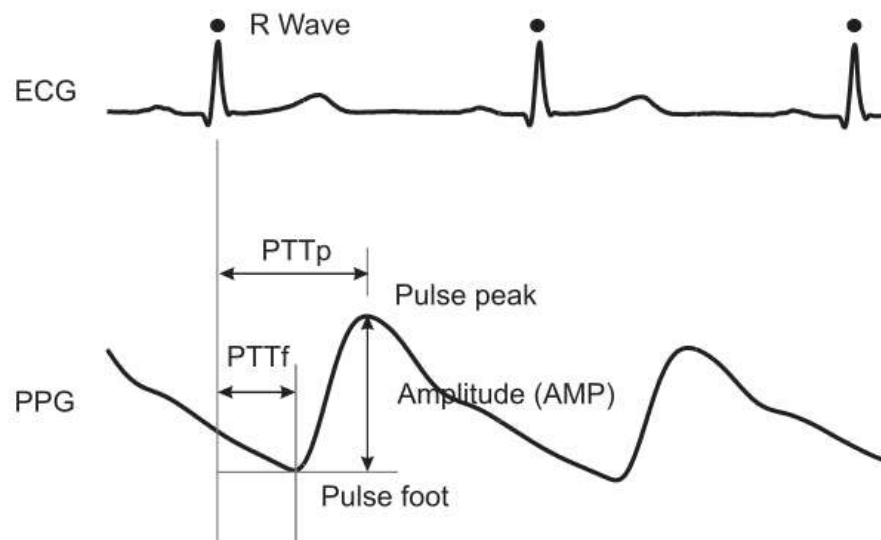
#### *Introduction*

##### **1.1 Introduction**

Measuring blood pressure traditionally involves a nurse or the doctor placing an inflatable hand cuff to somewhere above your elbow, asking you to breathe in and out. They then use a stethoscope to understand the timing of the measure. If you happen to have one of those digital Blood pressure meters at your home, you already know the poor accuracy. [1]

Cuff less BP measurement has always been a challenge. There are a wide variety of studies where several methods were developed for cuff-free BP measurement and one among them which showed great potential is PTT or Pulse Transit Time, which acts as an indicator of Blood Pressure. Pulse Transit Time in simple words is the time taken by a pulse wave to propagate from heart to the point where reading is taken, in our case the fingertip. [1]

Maxim Integrated recently released the MAX86150, a biopotential sensor which gives both Photoplethysmogram (PPG) and Electrocardiogram (ECG) simultaneously sampled. According to clinical studies, we can measure PTT (Pulse Transit Time) which is a measure of our blood pressure using ECG and PPG waveforms.



**Fig 1.1 Getting the values of pulse Transit time (PTT) of the foot of the pulse and to the peak of the pulse**

## 1.2 Aim of Project

Our project is concerned to control and measuring ECG and PPG, using the MAX86150 sensor puts ECG and SPO2 on a single chip, opening new opportunities for calculation of pulse transit time (PTT) and indirect blood pressure.

## 1.3 Proposed System

The system controlled by the Arduino Uno which takes information from the ProtoCentral (MAX86150) sensor used to measure the ECG and PPG and draw the results as figures showed the shapes of measured valued.

## 1.4 Project Organization

This project falls into five chapters as follows:

1. Chapter one presents the introduction of the project.
2. Chapter two presents the explain the system theoretical analysis and compounds like (Arduino, ECG and SPO2 sensor).
3. Chapter three describes the proposed design of the porotype device and Schematic diagram.
4. Chapter four discusses all results.
5. Chapter five introduces briefly all the conclusions that have been obtained during research and offers some suggestions for future work.

### *Chapter two*

#### 2.1 Introduction

The System Consists A Microcontroller Which Is The Arduino Uno That Responsible Of Analyzing Data We Have.

#### 2.1 Electrocardiogram (ECG/EKG)

An electrocardiogram (ECG or EKG) is a test that checks how your heart is functioning by measuring the electrical activity of the heart. With each heartbeat, an electrical impulse (or wave) travels through your heart. This wave causes the muscle to squeeze and pump blood from the heart.

An ECG measures and records the electrical activity that passes through the heart. A doctor can determine if this electrical activity is normal or irregular.

An ECG may be recommended if you are experiencing arrhythmia, chest pain, or palpitations and an abnormal ECG result can be a signal of a number of different heart conditions.

## 2.2 Pulse Transit Time

Pulse transit time (PTT) is a measurement of the time it takes for an arterial pulse wave to reach the periphery.<sup>13</sup> PTT can be calculated from the finger photoplethysmograph (PPG) of the oxygen saturation monitor and the R-wave of the electrocardiogram (ECG) during a polysomnogram (PSG). Blood pressure can be indirectly calculated by assuming that the speed of the PTT wave is inversely proportional to systolic blood pressure, for example an increase in blood pressure results in a shorter PTT and vice versa. The ECG R-wave is used to estimate the opening of the aortic valve and contraction of the left ventricle. The PPG is used to estimate the arrival of the pulse in the periphery, and from these two values the PTT is calculated. While not as accurate as the PAT, there is no inflation of the PPG finger probe, and thus the device can be worn with relative comfort during sleep. Since this method relies on the RR interval for its calculations, any arrhythmia, such as atrial fibrillation, can lead to significant artifact and invalidate PTT results.

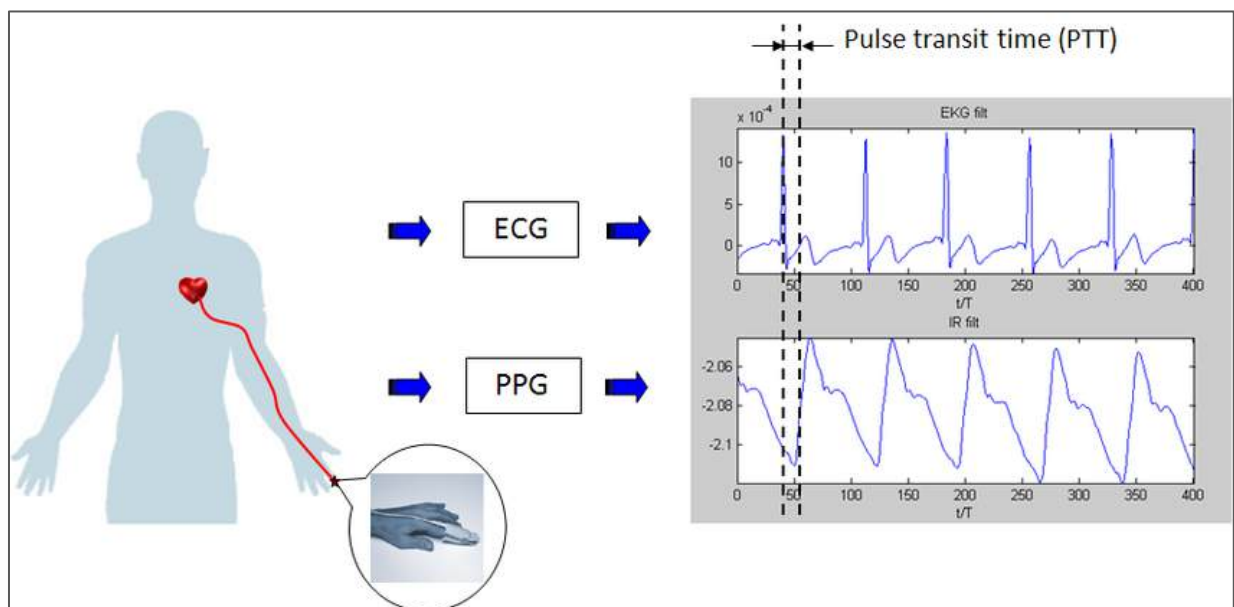


Fig 2.1 Pulse Transit Time

## 2.3 Photoplethysmography (PPG)

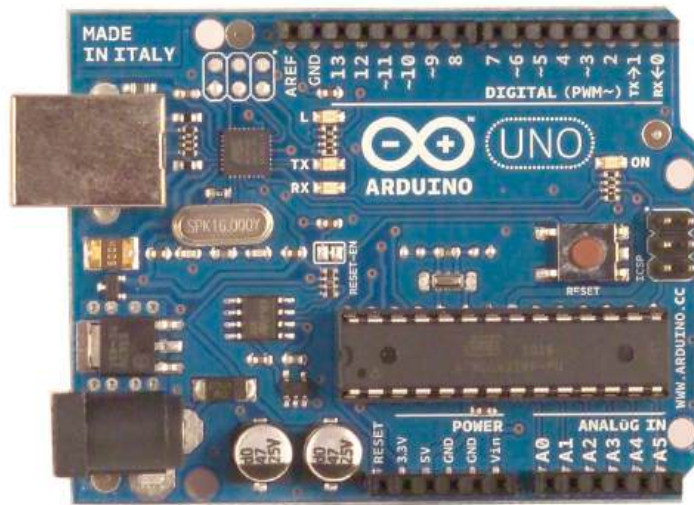
Photoplethysmography (PPG) is an examination comparable to the ankle-brachial index except that it uses a very tiny blood pressure cuff around the toe and a PPG sensor (infrared light to evaluate blood flow near the surface of the skin) to record waveforms and blood pressure measurements. These measurements are then compared to the systolic blood pressure in the arm.

## 2.4 system component

### 2.4.1 The Arduino

- The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI.
- USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter.
- "Uno" means one in Italian and is named to mark the upcoming release of Adriano 1.0. The Uno and version

- will be the reference versions of Adriano, moving forward. The Uno is the latest in a series of USB
- Adriano boards, and the reference model for the Adriano platform; for a comparison with previous versions,



**Figure 2.1 the Adriano UNO**

Microcontroller ATmega328
Operating Voltage 5V
Input Voltage (recommended) 7-12V
Input Voltage (limits) 6-20V
Digital I/O Pins 14 (of which 6 provide PWM output)
Analog Input Pins 6
DC Current per I/O Pin 40 am
DC Current for 3.3V Pin 50 am
Flash Memory 32 KB of which 0.5 KB used by boot loader
SRAM 2 KB
EEPROM 1 KB
Clock Speed 16 MHz

### Power

- The Adriano Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically.
- External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnu and Vin pin headers of the POWER connector.
- The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

- ✓ The power pins are as follows:

### 2.2.3 the pins descriptions

- ✓ Vin The input voltage to the Adriano board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin. • 5V. The regulated power supply used to power the microcontroller and other components on the board. This can come either from VIN via an on-board regulator, or be supplied by USB or another regulated 5V supply. • 3V3. A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA. • GND. Ground pins.
- ✓ The Atmega328 has 32 KB of flash memory for storing code (of which 0,5 KB is used for the boot loader); It has also 2 KB of SRAM and 1 KB of EEPROM (which can be read and written with the EEPROM library).
- ✓ Each of the 14 digital pins on the Uno can be used as an input or output, using pin Mode(), digital Write(), and digital Read() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 am and has an internal pull-up resistor (disconnected by default) of 20-50 ohms. In addition, some pins have specialized functions:
- ✓ Serial: 0 (RX) and 1 (TX). Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip . • External Interrupts: 2 and 3. These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attach Interrupt() function for details. • PWM: 3, 5, 6, 9, 10, and 11. Provide 8-bit PWM output with the analog Write() function. • SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). These pins support SPI communication, which, although provided by the underlying hardware, is not currently included in the Adriano language.
- ✓ LED: 13. There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.
- The Uno has 6 analog inputs, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and the analog Reference() function. Additionally, some pins have specialized functionality:
- ✓ I2C: 4 (SDA) and 5 (SCL). Support I2C (TWI) communication using the Wire library.
- ✓ There are a couple of other pins on the board:
- ✓ AREF. Reference voltage for the analog inputs. Used with analog Reference(). • Reset. Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.
- ✓ The Adriano Uno has a number of facilities for communicating with a computer, another Adriano, or other microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An ATmega8U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer. The '8U2 firmware uses the standard USB COM drivers, and no external driver is needed. However, on Windows, an \*.inf file is required.

### 2.4.2 Proto Central MAX86150

The new smart MAX86150 from Maxim rolls three devices into one for easy measurement of vital signs: an ECG frontend, an optical pulse oximeter and an optical heart rate sensors. This breakout board helps you unlock new applications for such devices.

This means that it integrates the photoplethysmogram(PPG) and Pulse oximeter (SPO2), Electrocardiogram (ECG) and Heart rate sensor module into the same chip. A PPG is obtained by

optically measuring the changes in the volume of blood over the skin tissue, whereas the Electrocardiogram sensor can detect the electrical activity of the heart. **The coolest feature of this chip is that the PPG and ECG are simultaneously sampled, resulting in synchronized ECG and PPG values.** This allows us to calculate the Pulse transit time (PTT) as an indirect measure of blood pressure.



**Fig 2.2 Proto Central MAX86150**



**Fig 2.3 Proto Central MAX86150 with LEDS Cable**

### 2.4.3 Spark Fun Qwiic Shield for Arduino

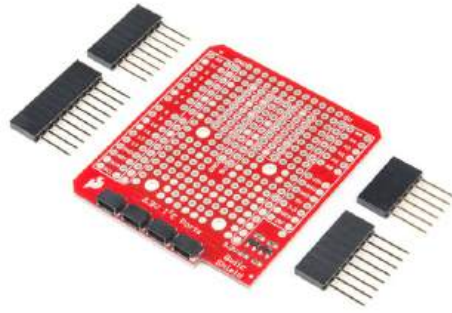
- This shield connects the I2C bus on your compatible with Arduino board to a series of SparkFun Qwiic connectors and provides the circuitry to convert the 5V given to the 3.3V required by I2C boards in our Qwiic system. A great retrofit for any Uno you may have.

As long as your devices are on different addresses, the Qwiic system allows for daisy chaining, meaning you can stack as many sensors as you'd like to create a tower of sensing power!

The Qwiic Shield has four Qwiic connection ports, all on the same I2C bus, as well as a large prototyping area to design and make your own unique circuits.

Also has a few 3-by-1 rails to help with prototyping, as well as buses for ground, 5V and even 3.3V.

- We have included four mounting ports in the same design as our Qwiic sensors, allowing you to affix your small board to the top of the shield.



### 2.4.3 Spark Fun Qwiic Shield for Arduino

### 2.4.4 USB-A to B Cable

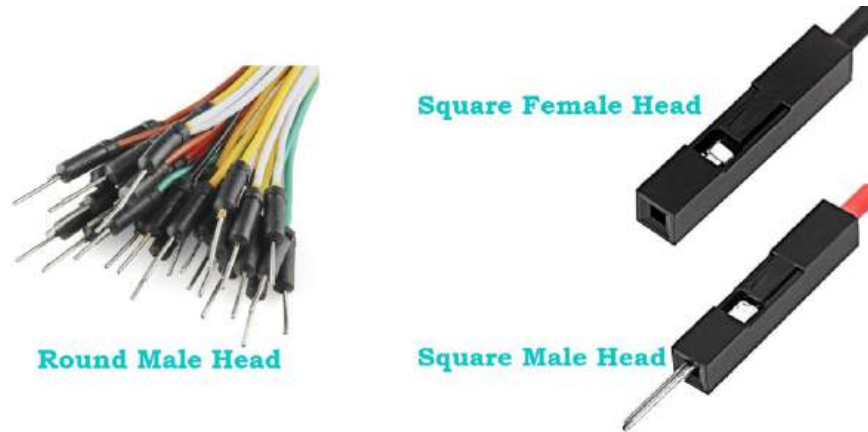
Standard USB 2.0 peripheral cables for connecting printers, scanners, USB hard drives, and other USB devices. Choose six colors including black



### 2.4.4 USB-A to B Cable

### 2.4.5 Jumper wires

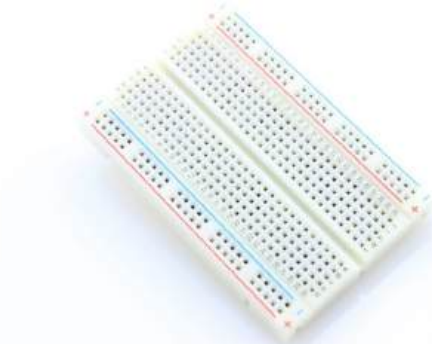
- ✓ Made from insulated 26AWG wire with crimped pin in plastic housing
- ✓ Length 150mm
- ✓ Pin size approx. 0.6mm
- ✓ Housing width 2.5mm (fits 0.1in. pitch)
- ✓ Plug pins fit connectors in breadboard without damage
- ✓ Available in male-to-male, female-to-female and male-to-female configurations
- ✓ Supplied in assorted coloured **packs of 10**



#### 2.4.5 Jumper wires

#### 2.4.6 Bread board

A **breadboard**, or protoboard, is a construction base for prototyping of electronics. Originally the word referred to a literal **bread board**



#### 2.4.7 Proto Central Electronics Proto Central Pulse Oximeter & Heart Rate Sensor Based on MAX30100

It is a multipurpose sensor used for multiple applications. It is a **heart rate monitoring** sensor along with a **pulse oximeter**. The sensor comprises two Light Emitting Diodes, a photodetector, and a series of low noise signal processing devices to detect heart rate and to perform pulse oximetry

##### Features

- ✓ Operating Voltage – 1.8V to 3.3V
- ✓ Input Current – 20mA
- ✓ Integrated Ambient Light Cancellation
- ✓ High Sample Rate Capability
- ✓ Fast Data Output Capability

##### Pin Configuration of MAX30100 Oximeter Module

Below is the pin configuration of the MAX30100 module. It is a 7 pin sensor module with an enabled I2C communication protocol to interact with the microcontroller.

Pin Type	Pin Function
VIN	Voltage Input
SCL	I2C – Serial Clock
SDA	I2C – Serial Data
INT	Active low interrupt
IRD	IR LED Cathode and LED Driver Connection Point

	(Leave floating in the circuit)
RD	Red LED Cathode and LED Driver Connection Point(Leave floating in the circuit)
GND	Ground pin

Note: There are two module versions of the MAX30100 sensor module. The one which we have showcased is the 7-pin version, whereas there is a 5-pin version as well which does not have IRQ and RD pin.

The 5-pin module is considered to be more accurate as the circuitry for the module is on the other side of the sensor.

**Alternatives for MAX30100**

Pulse 3+, Proto Central AFE4490, ROHM BH1792GLC, FSH 7060

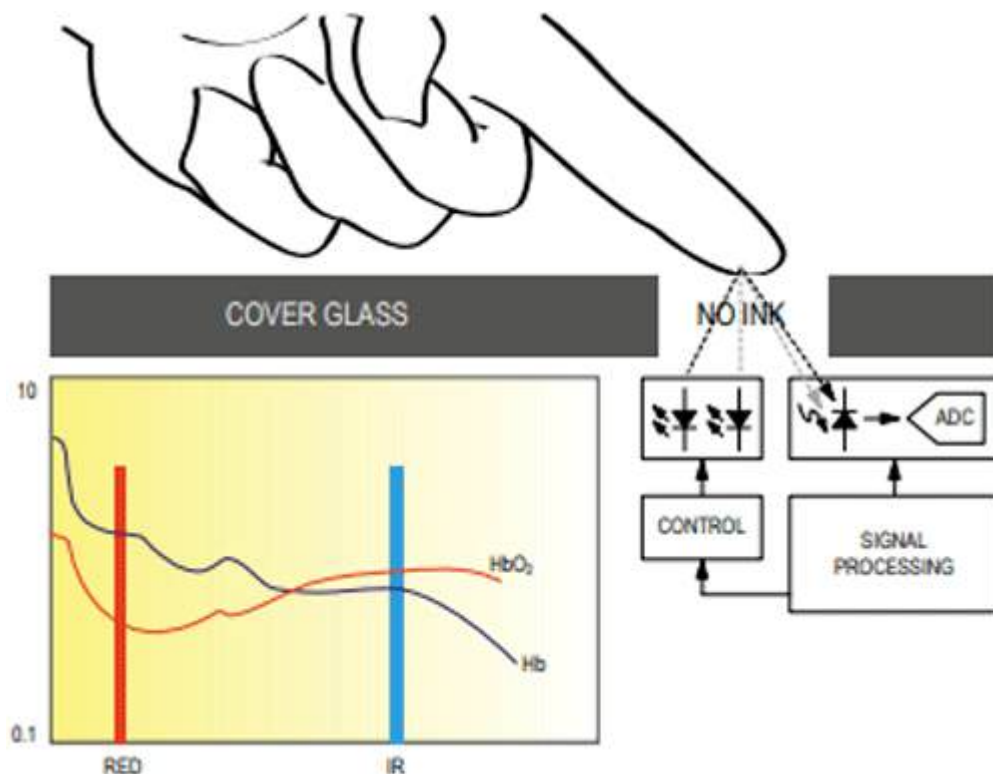
Equivalent for MAX30100

MAX30102

Working of the MAX30100 Oximeter

**Working of an oximeter:**

The sensor consists of a pair of Light-emitting diode which emits monochromatic red light at a wavelength of 660nm and infrared light at a wavelength of 940 nm. These wavelengths are particularly chosen as at this wavelength oxygenated and deoxygenated hemoglobin have very different absorption properties. As shown in the graph below, it can be seen that there is a difference between HbO<sub>2</sub>(oxygenated Hb) and Hb(deoxygenated Hb) when subjected to these specific wavelengths.



**Sensor part:**

There are two parts to the sensor, an emitting diode, and a photoreceiver. As the photodiode emits the light, it falls over the finger which has to be placed steadily. The light emitted gets absorbed by the oxygenated blood and the rest of the light is reflected through the finger and falls over the detector whose output data is then processed and read through a microcontroller.

## Applications of MAX30100

Here are some of the applications where MAX30100 can be used:

Medical Oxygen measurement devices

Wearable Devices

Fitness Assistant systems



### 2.4.7 Proto Central Electronics Proto Central Pulse Oximeter & Heart Rate Sensor Based on Max30100

#### Chapter three

#### Circuit Design

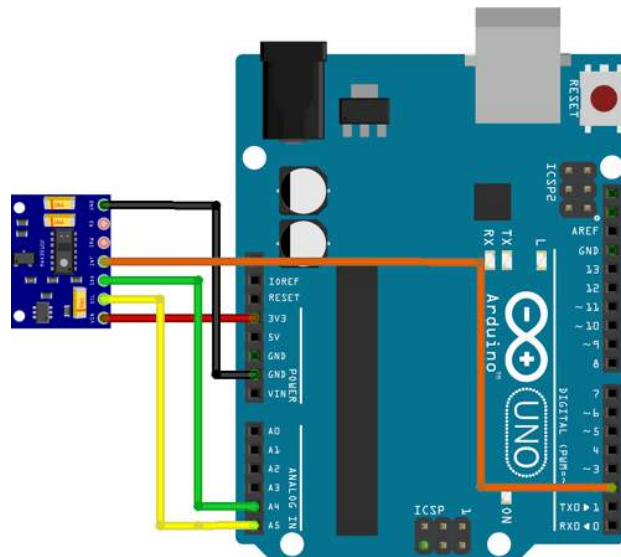
##### 3.1 Introduction

This chapter will give an explanation about the method that used in this project. It will be including the description of the design flow, design architecture and detail explanations for the software development. Based on the requirement, the design is divided into two developments; software development and hardware development. In order to confirm the system is working, the programming needs to be done correctly.

##### 3.2 System Architecture

###### 3.2.1 Connecting MAX 30100 Module to a Microcontroller

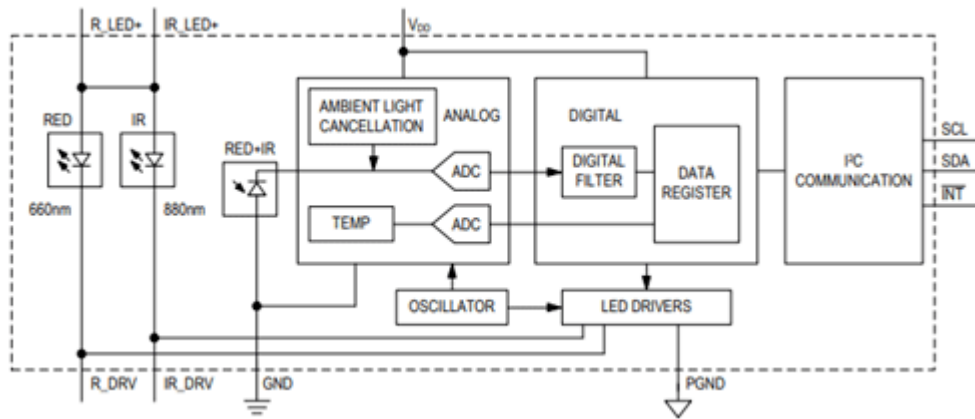
I showed the connections from MAX30100 to the Arduino microcontroller below. The pulse oximeter uses an I2C communication protocol in order to communicate with the microcontroller. The connections are pretty simple and you can easily make your own Arduino oximeter.



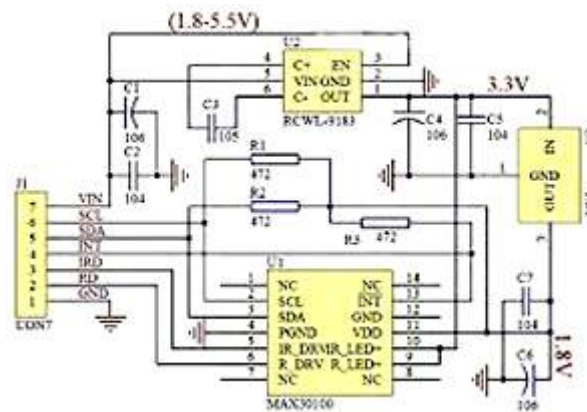
V<sub>in</sub> is connected to the 3.3V port of Arduino since the operating voltage of the module is 1.8V-3.3V. The ground terminal of the oximeter is connected to the ground of the Arduino. As part of the communication protocol, two pins which are the SCL and SDA are connected to the Arduino's A5 and A4 pins, respectively. The INT pin on the module is also connected to the microcontroller's Digital Pin 2 to check if the heartbeat is captured properly.

Functional Block and the Circuit Diagram of MAX30100 Module

Below is the functional block for the MAX30100 module. The module consists of two LEDs (IR and RED) both of specific wavelengths, along with a photodetector to detect the received light.



The output from the photodiode is sent to the analog-to-digital converter from which the digital data is sent from a filter to the digital data register. The data can be collected from the register and can be sent to the microcontroller following the I2C communication protocol.



The image above showcases the internal circuitry of the MAX30100 module and can be used as a reference circuit while designing your own custom module.

Chapter four

Results

4.1 Summary of the Results

You can either use the Arduino IDE's built-in serial plotter utility or use something like ProtoCentral OpenView to look at the ECG and PPG waveforms.

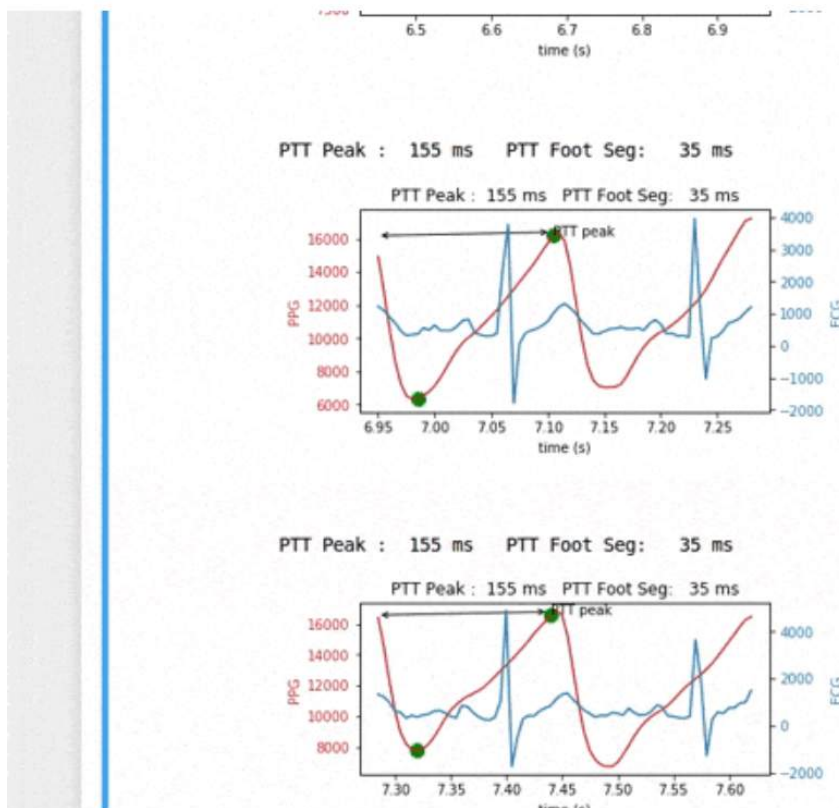


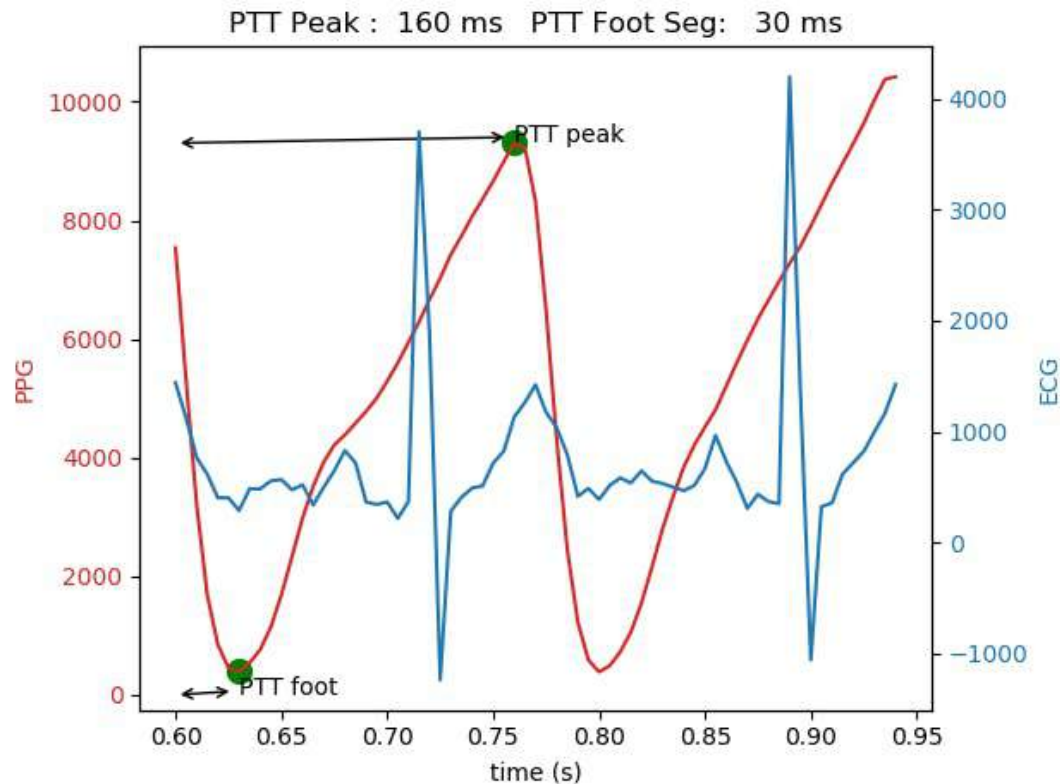
Here is the final output of the PPG and ECG in synchronous display

### Measuring PTT intervals

This functionality is not currently built into the current version of our Arduino library, but will be in the future. Meanwhile, we used Python to calculate the PTT peak and foot intervals of each segment of ECG-PPG that is measured simultaneously by the MAX86150 breakout board.

Below is quick run through of the code.





For each R peak detected, we discovered the following trench and peak of the processed PPG signal. The time intervals are obtained using the sampling frequency.

PTT is often inversely proportional to BP. Though there are several limitations of using PTT to measure ecg, this board opens a platform to work on those limitations.

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