HEART RATE MONITORING SYSTEM WITH ALARM TRIGGERS

BY: SAAD NABEEL

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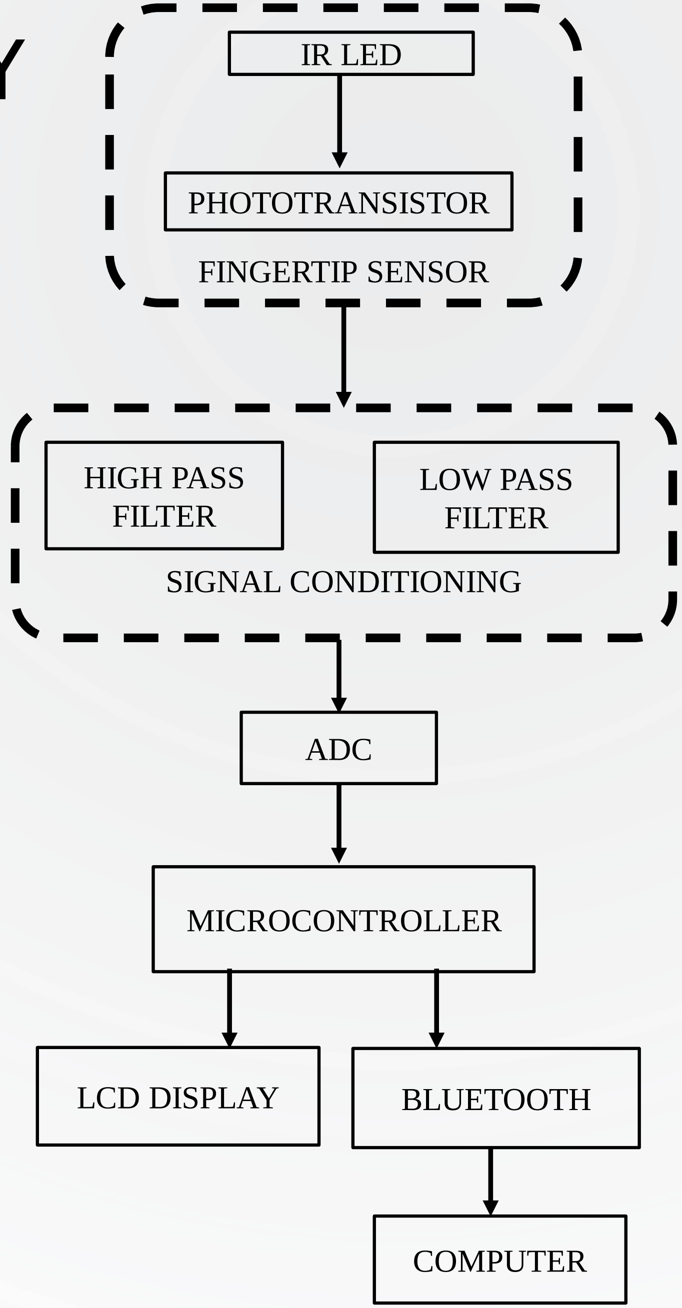
MOTIVATION

- Preventative measure for cardiac diseases
- Allows patients to monitor vital signs at their leisure
- Database records aid in detection of anomalies
- Crucial for fitness monitoring technologies

OBJECTIVES

- Measure pulse rate of an individual
- Measure body temperature of an individual
- Alert user if pulse rate anomaly detected
- Wireless transmission of data to computer
- Creation of custom database for vital signs records

METHODOLOGY



SPECIFICATIONS: OPTICAL SENSOR

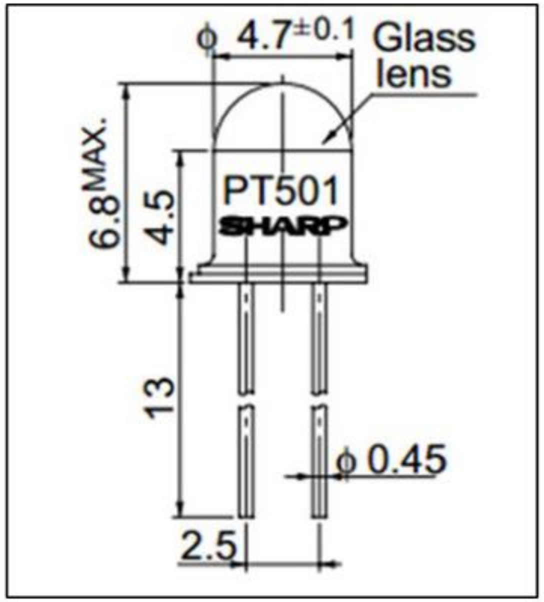


Figure 1: PT501 Phototransistor

Main components: Infrared LED & Phototransistor

- PT501
  - Used to receive the transmitted signals from the IR LED
  - Sensitivity of 800nm
- Infrared LED
  - Peak wavelength 950nm

Sensor Type	Phototransistor	Photodiode
Frequency Response	Slower response than photodiodes	Ideal for very fast signals but gives a much lower output signal
Gain	Phototransistors have a higher gain.	Photodiodes require an amplifier to use
Miscellaneous	Have an enclosure to detect light more efficiently	Do not have an enclosure.

SPECIFICATIONS: OPERATIONAL AMPLIFIER

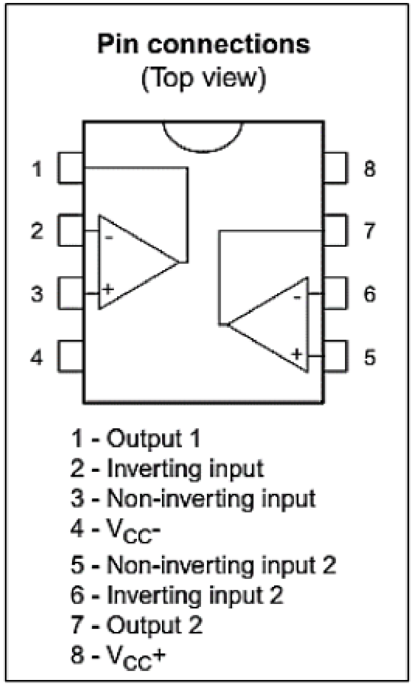


Figure 2: Pin Connections of LM358N Op Amp

- LM358N Operational Amplifier
- Changes of blood volume picked up by the IR LED & phototransistor are too small to be read by microcontroller
- Signal must be amplified in order to collect measurements

SPECIFICATIONS: WIRELESS TRANSMISSION

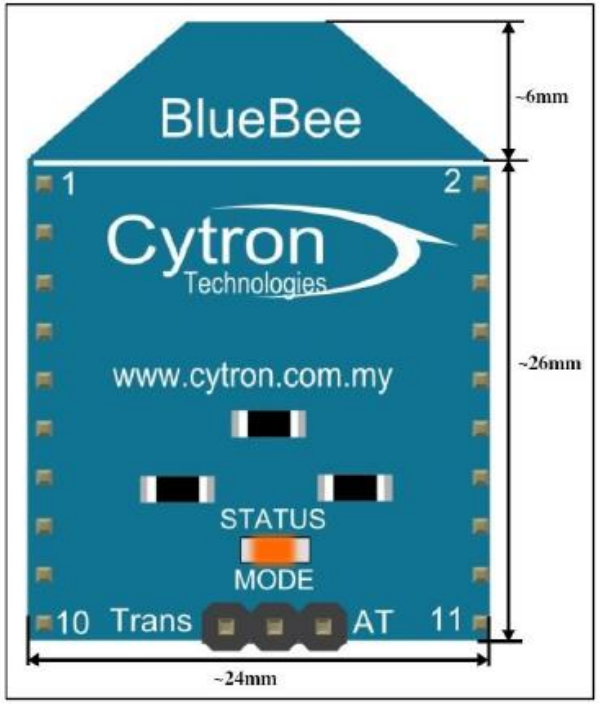


Figure 3: BlueBee module dimensions and pin layout

- Operating voltage: 3.3V
- Operating Frequency: 2.4-2.48GHz unlicensed ISM band.
- Transfer rate: The asynchronous transfer rate is 2.1Mbps (Max) / 160 kbps; the synchronous transfer rate is 1Mbps/1Mbps.
- Transmission distance: 20-30 meters in free space.

SPECIFICATIONS: TEMPERATURE IC

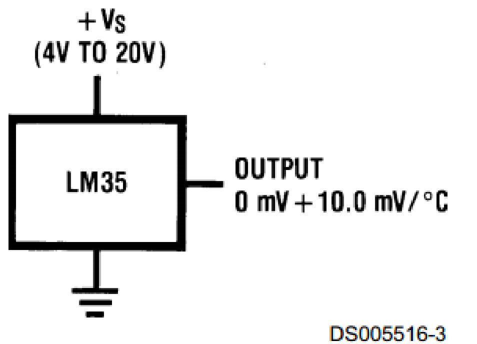


FIGURE 1. Basic Centigrade Temperature Sensor (+2°C to +150°C)

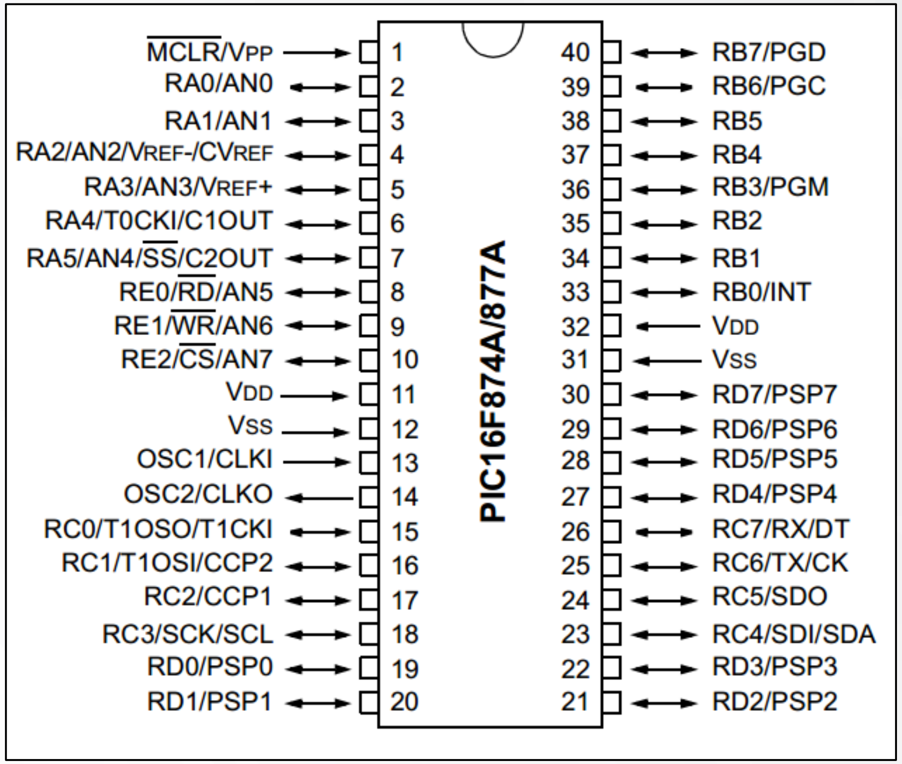
LM35DZ

The LM35 does not require any external calibration or trimming to provide typical accuracies of ±1⁄4°C at room temperature and ±3⁄4°C over a full −55 to +150°C temperature range.
This sensor directly measures temperature in degrees Celsius and does not require the microcontroller to perform any equations to acquire the temperature (aside from ADC).

Features

- Calibrated directly in ° Celsius (Centigrade)
- Linear + 10.0 mV/°C scale factor
- 0.5°C accuracy guaranteeable (at +25°C)
- Rated for full −55° to +150°C range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 4 to 30 volts
- Less than 60 μA current drain
- Nonlinearity only ±1⁄4°C typical

SPECIFICATIONS: MICROCONTROLLER

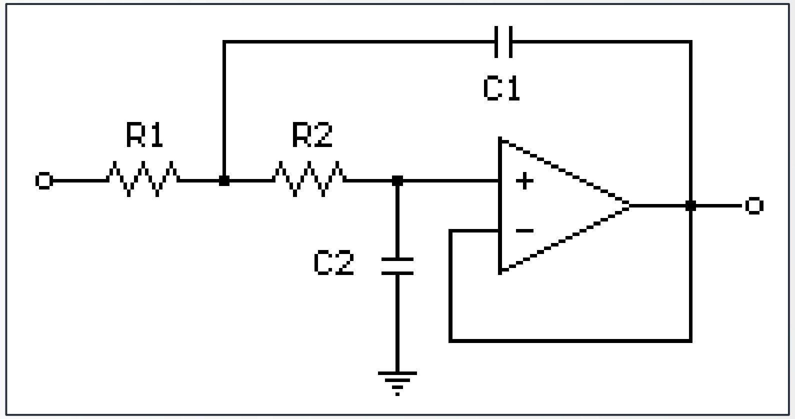


40 pin PIC16F8772A

The microcontroller is able to distinguish analogue values once they have been converted to a scale of 0V to 5V. The PIC16F877A includes a 10-bit, up to 8-channel Analog-to-Digital Converter meaning it has the capability to detect 1024 (2^{10}) discrete analogue levels.

- A wide operating voltage of 2V – 5.5V
- Low power consumption
- Analogue to digital ports

SIGNAL CONDITIONING: LOW PASS FILTER



Low Pass Filter

Allows low frequencies to pass &
Attenuates high frequencies

Low frequencies (f < fc):	$\frac{Vout}{Vin} \cong A_F$
Cut-off frequency (f = fc):	$\frac{Vout}{Vin} = \frac{A_F}{\sqrt{2}} = 0.707A_F$
High frequencies (f > fc):	$\frac{Vout}{Vin} < A_F$

Operation of Low Pass Filters

For non-inverting amplifiers, the voltage gain for the filter is given as a function of the feedback resistor (R_2) divided by the input resistor (R_1):

$$DC\ Gain = (1 + \frac{R2}{R1})$$

Hence, the gain of an active low pass filter:

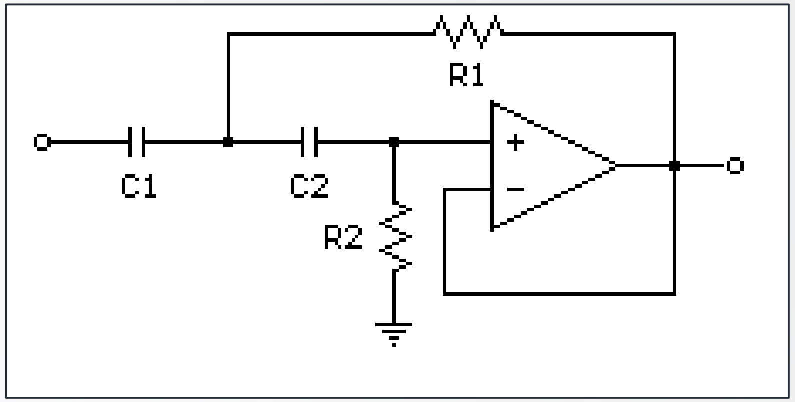
$$Voltage\ Gain, (Av) = \frac{Vout}{Vin} = \frac{A_F}{\sqrt{1 + \left(\frac{f}{fc}\right)^2}}$$

A_F = the pass band gain of the filter (1 + R2/R1)

f = the frequency of the input signal (Hz)

fc = the cut-off frequency (Hz)

SIGNAL CONDITIONING: HIGH PASS FILTER



High Pass Filter

Gain for an active high pass filter is calculated as:

$$\text{Voltage Gain (Av)} = \frac{Vin}{Vout} = \frac{Af(\frac{f}{fc})}{\sqrt{1+(\frac{f}{fc})^2}}$$

A_F = the pass band gain of the filter (1+R2/R1)

f = the input signal frequency (Hz)

fc = cut off frequency (Hz)

Allows high frequencies to pass &
Attenuates low frequencies

Low frequencies (f < fc):	$\frac{Vout}{Vin} < A_F$
Cut-off frequency (f = fc):	$\frac{Vout}{Vin} = \frac{A_F}{\sqrt{2}} = 0.707A_F$
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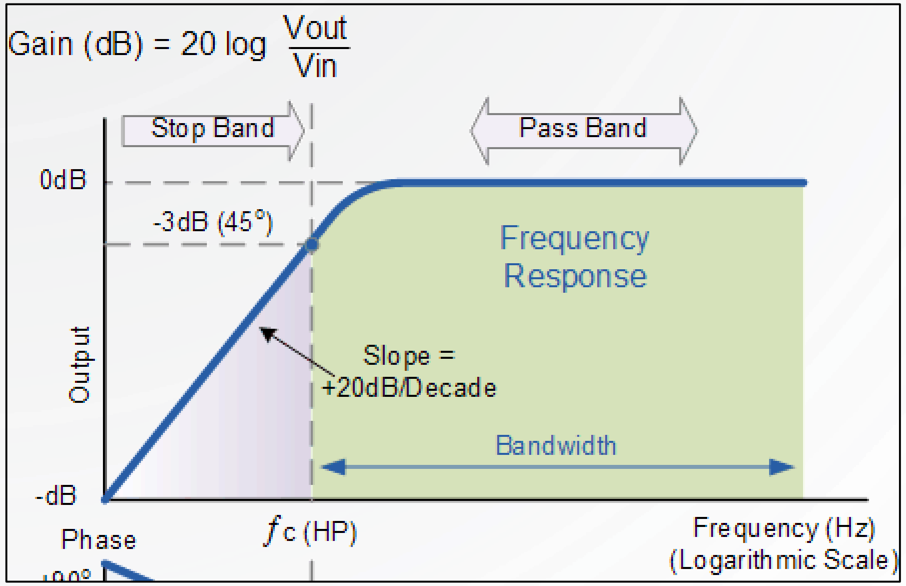
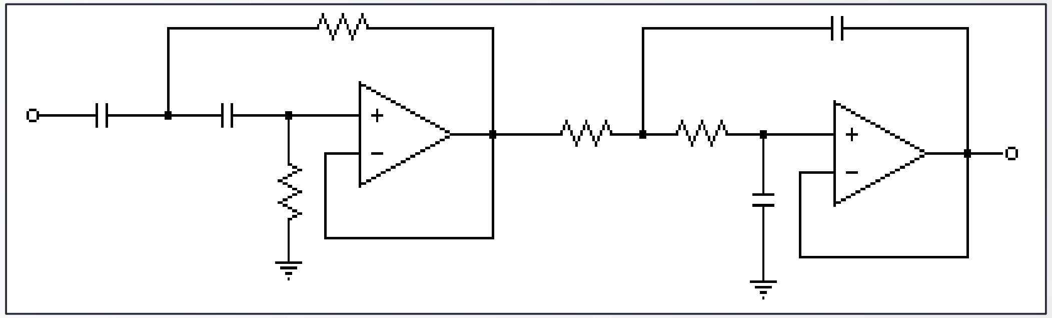
Operation of High Pass Filters



Frequency Response of HP Filters

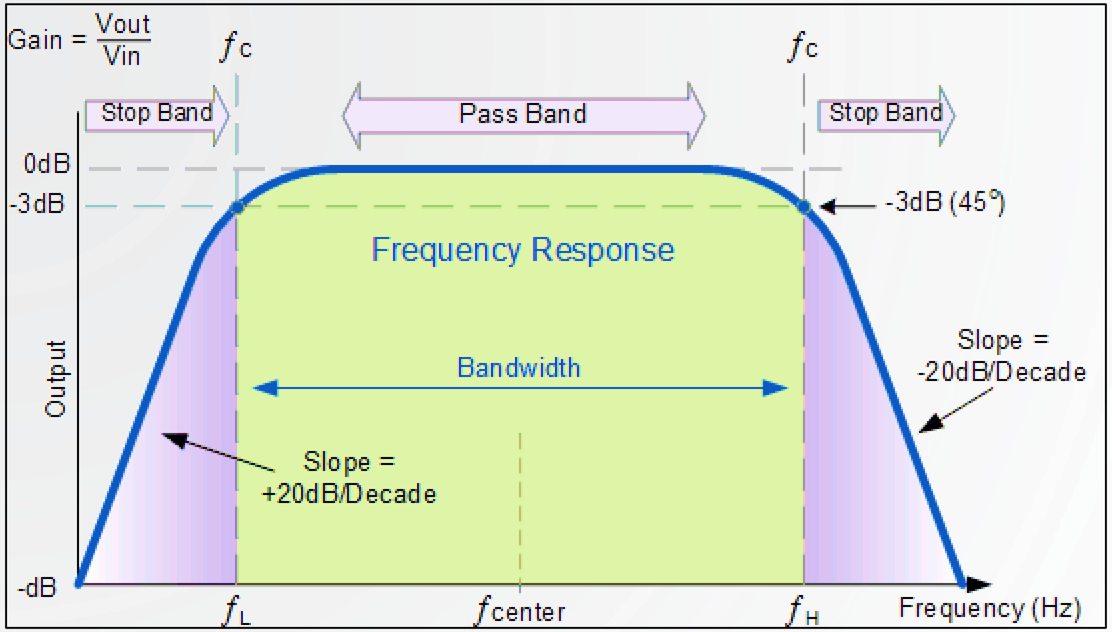
SIGNAL CONDITIONING: BAND PASS FILTER



Band Pass Filter

Band pass filters have two cut off frequency points which are the lower frequency and higher frequency and attenuate all other frequencies outside of these points

The cut off frequency of the low pass filter is greater than the cut off frequency of the high pass filter. The discrepancy between them at the -3dB point will decide the bandwidth of the band pass filter. The filter will block any signals outside these points.

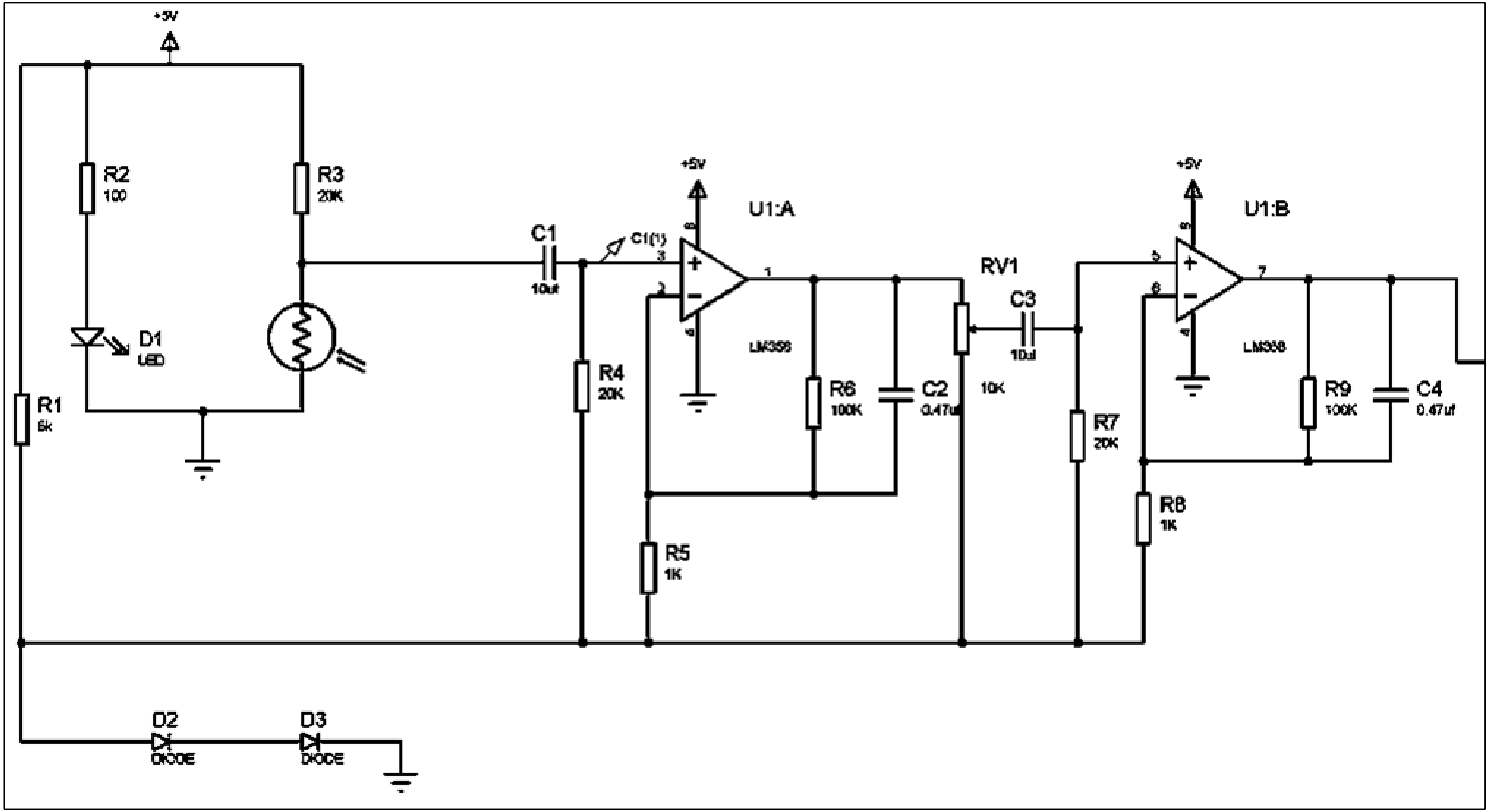


Frequency Response of a Band Pass Filter

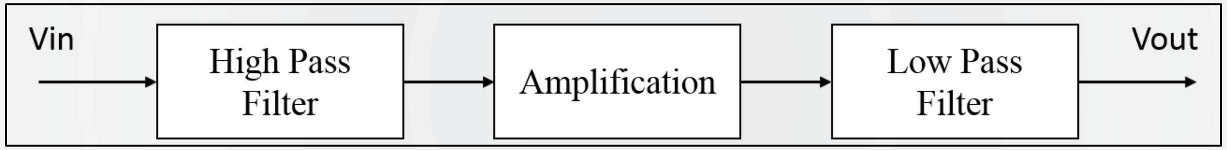
The upper and lower frequencies of a band pass filter can be found using the same formula used to calculate cut off frequencies of high pass and low pass filters:

$$fc = \frac{1}{2\pi fRC} Hz$$

SIGNAL CONDITIONING: CIRCUIT



SIGNAL CONDITIONING



<table>
<tr><th></th><th>Equation</th><th>Calculation</th></tr>
<tr><td>Gain of Non-Inverting Op Amp</td><td>$Gain\ (Av) = \frac{Rf}{R1} + 1$
Rf = 100KΩ
R1 = 1KΩ</td><td>$Av = \frac{100K\Omega}{1K\Omega} + 1 = 101$</td></tr>
<tr><td colspan="3">The cut off frequency in a low pass filter is the point where high frequencies will be attenuated and only low frequencies will be allowed to pass through. The cut off frequency of a high pass filter is the point where only high frequencies can pass. Cascading the two filters creates a band pass filter. To calculate the upper and lower cut off frequencies of a band pass filter, the following equation is used:</td></tr>
<tr><td>Cut off frequency in Hertz, fc</td><td>$fc = \frac{1}{2\pi RC} Hz$
R = 100KΩ
C = 0.47μF</td><td>$fc = \frac{1}{2\pi(100K\Omega)(0.47\mu F)}$
= 3.386 Hz</td></tr>
<tr><td>Maximum Output Gain</td><td>$fr^2 = f_{Upper} \times f_{Lower}$</td><td>$fr^2$ = 3.386 Hz x 3.386 Hz
= 11.464996 Hz</td></tr>
</table>

ANALOGUE TO DIGITAL CONVERSION (ADC)

The ADC conveys a ratio metric value, meaning the ADC fixes 5V to represent 1023 and anything less than 5V will be a ratio between 5V and 1023.

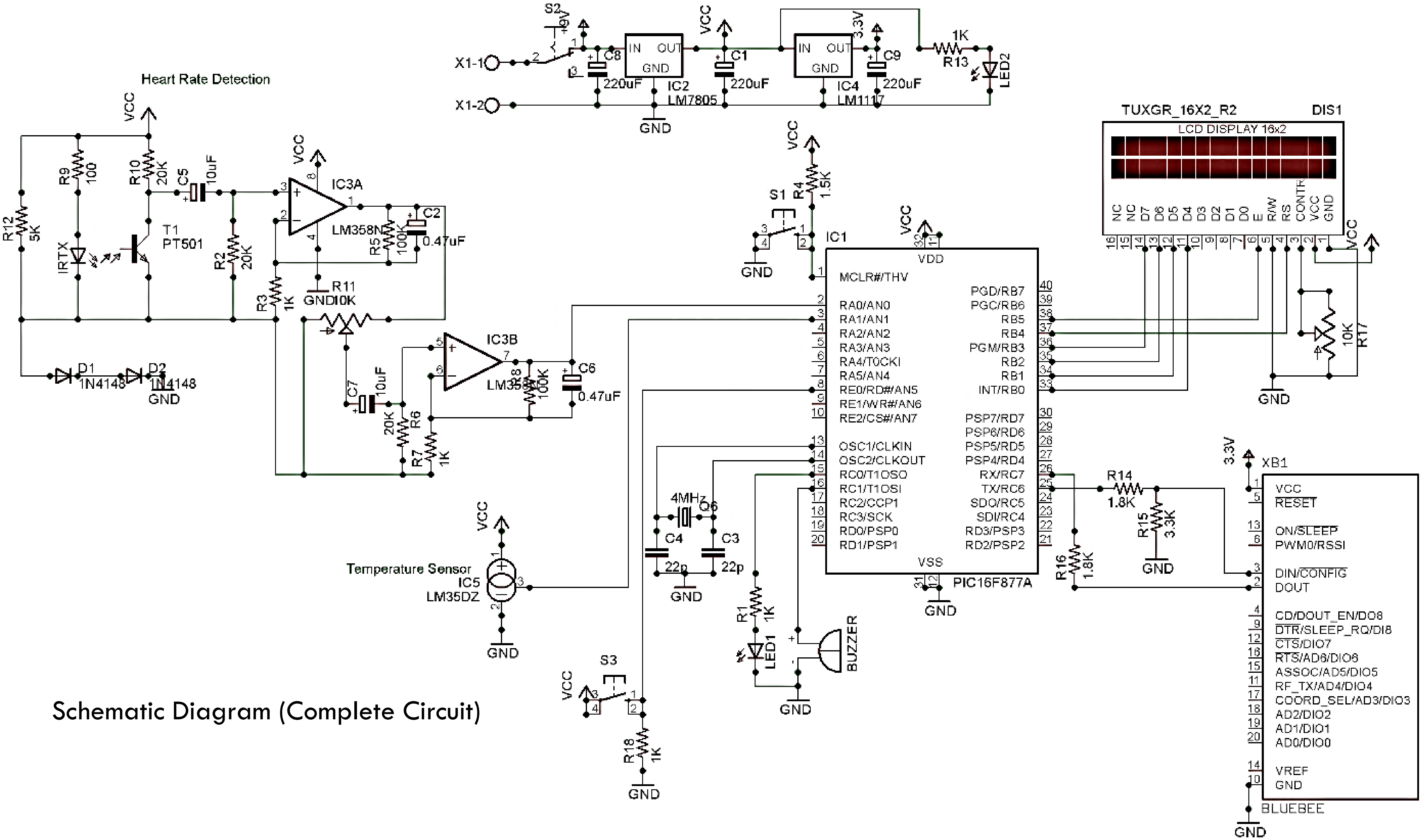
$$\frac{Resolution\ of\ the\ ADC}{System\ Voltage}$$

$$= \frac{ADC\ Reading}{Analogue\ Voltage\ Measured}$$

Since the system implemented in this project is using a 5V supply, a simple substitution can be done.

$$\frac{1023}{5V} = \frac{ADC\ Reading}{Analogue\ Voltage\ Measured}$$

	Code	Solution
Heart Rate	input1 = adc_read(0)/4; if(input1>=128)	1023/4 ≈ 255 $\frac{255}{5V} = \frac{128}{x}$ $x = 2.509\ Volts$ If input 1 >= 2.5V, then it is HIGH
	input1=adc_read(0)/4; if(input1<=45)	$\frac{255}{5V} = \frac{45}{x}$ $x = 0.88\ Volts$ If input 1 <= 45, then it is LOW



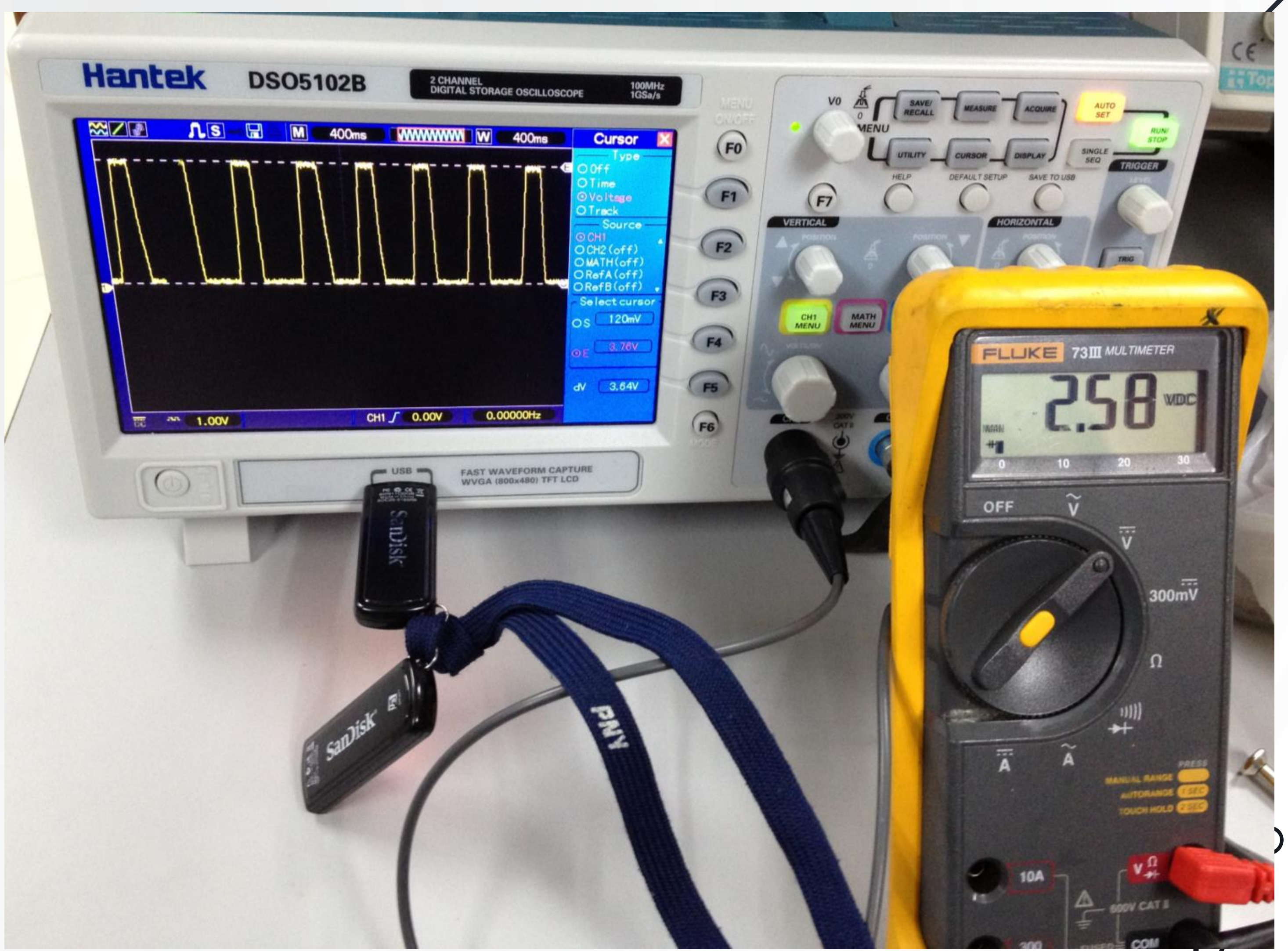
Schematic Diagram (Complete Circuit)

PIN CONNECTIONS

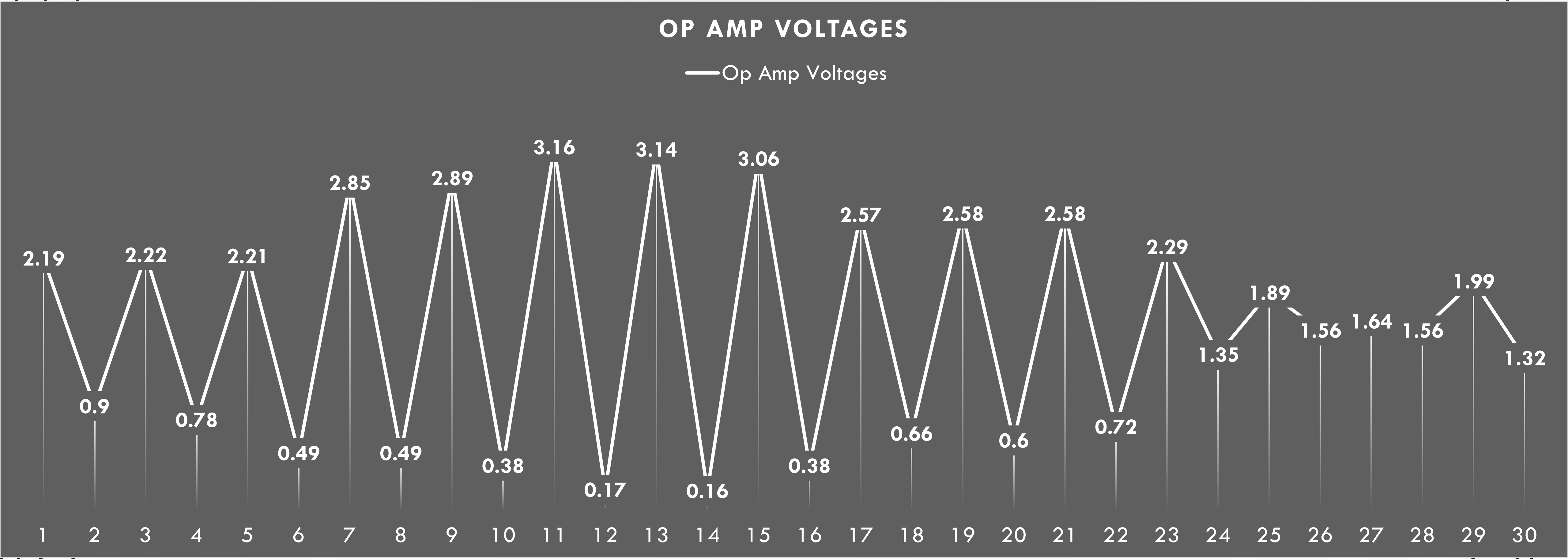
Pin #	Microcontroller Pins	Operation
1	Master Clear (MCLR)	Resets the microcontroller
2	AN0	Used to attain analogue input from heart rate detection circuit
3	AN1	Used to attain readings from temperature sensor
8	AN5	Connected as switch which initiates the program in the microcontroller
13&14	OSC1/CLKIN & OSC2/CLKOUT	Used to connect the crystal oscillator
15&16	RC0 & RC1	Used to connect the buzzer and LED
33-38	RB0 - RB5	Used to connect the LCD Display
25&26	TX/RC6 & RX/RC7	Used to connect the BlueBee module

TESTING AND RESULTS: OP-AMP

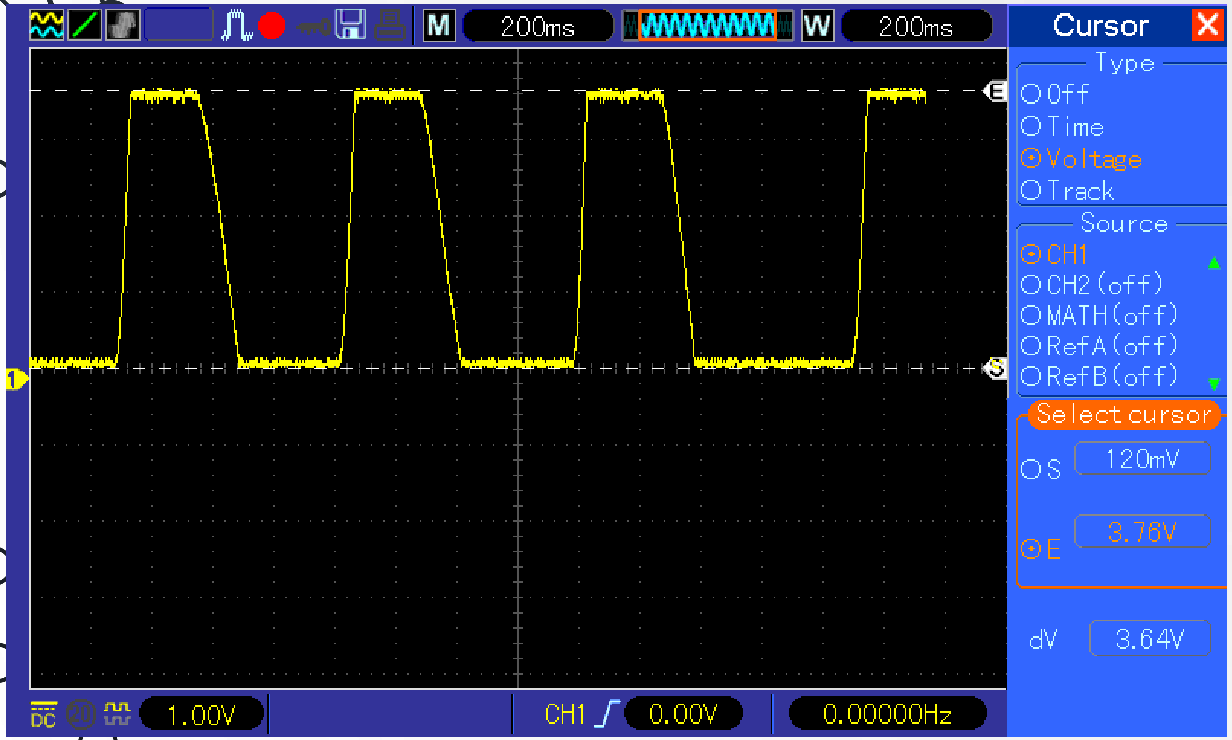
Heart Rate of Nurshahifa (Readings)	High Peak (V) from DC Multimeter	Low Peak (V) from DC Multimeter
1	2.19 V	0.90 V
2	2.22 V	0.78 V
3	2.21 V	0.49 V
4	2.85 V	0.49 V
5	2.89 V	0.38 V
6	3.16 V	0.17 V
7	3.14 V	0.16 V
8	3.06 V	0.38 V
9	2.57 V	0.66 V
10	2.58 V	0.60 V
11	2.58 V	0.72 V
12	2.29 V	1.35 V
13	1.89 V	1.56 V
14	1.64 V	1.56 V
15	1.99 V	1.32 V



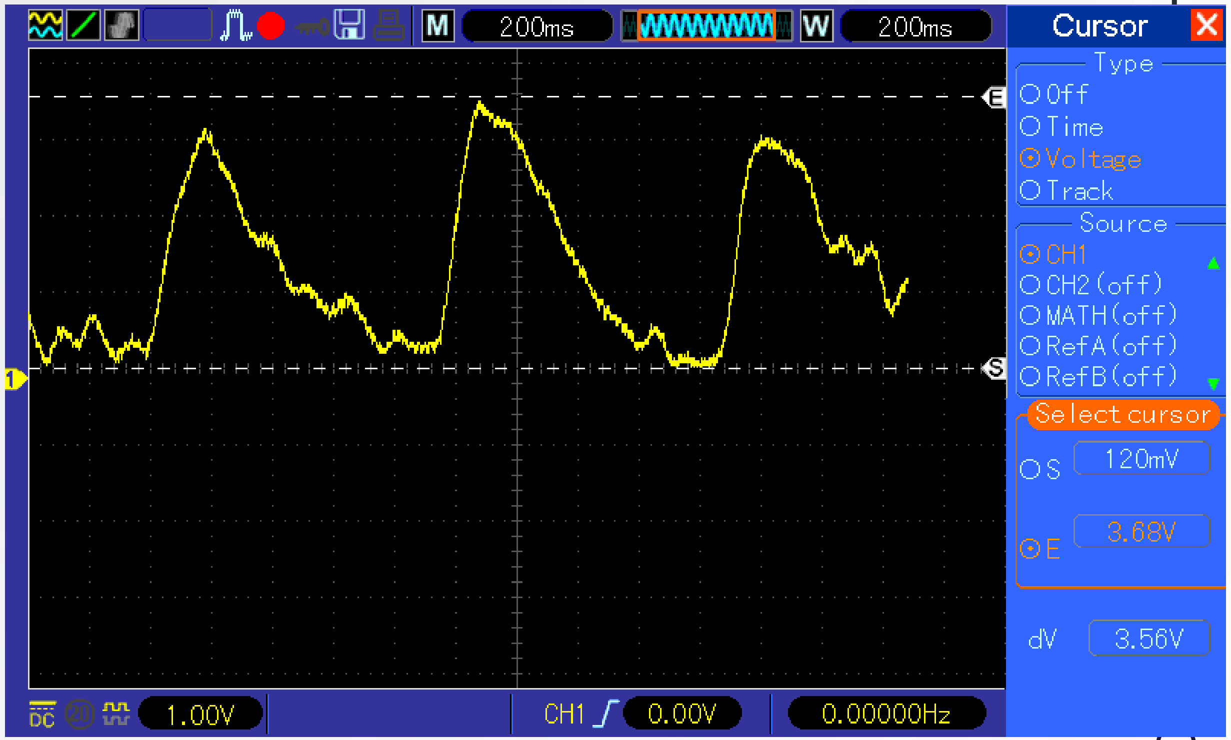
TESTING AND RESULTS: OP-AMP



TESTING AND RESULTS: PULSE DETECTION

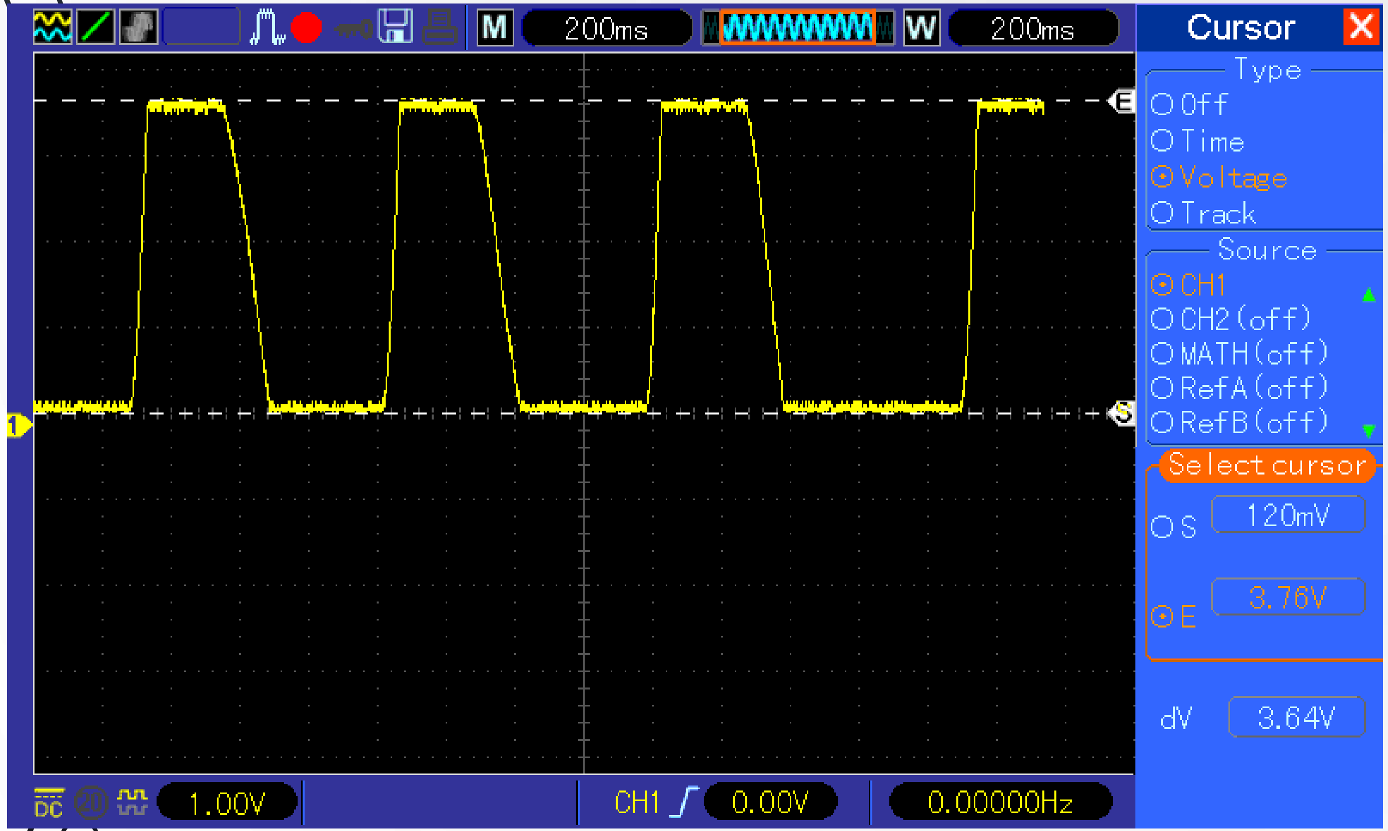


Ideal Pulse Detection



Pulse Detection with Interference

TESTING AND RESULTS: PULSE DETECTION



Ideal Pulse Detection

Each block on the plane shown represents a time of 200ms on the x axis and a value of 1 volt on the y-axis. The peak voltage achieved in the heart rate of Saad Nabeel is 3.76V – 0.120V = 3.64 Volts. From this diagram it can be seen that each cycle (beat) from a low peak to the next subsequent low peak ranges approximately 800ms. Saad Nabeel's heart rate can be calculated by:

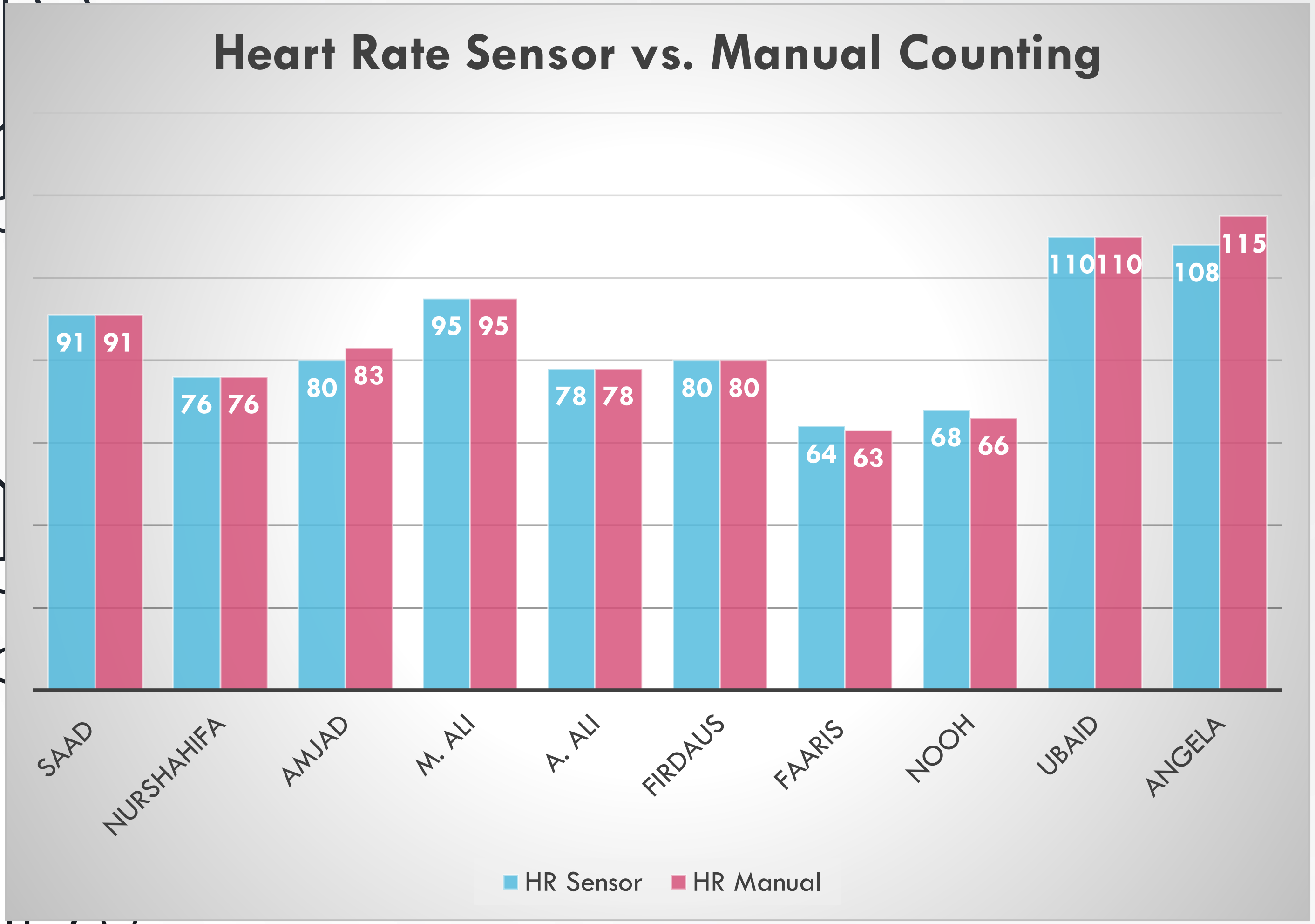
$$800ms \times 5\ cycles\ (beats) = 4\ seconds$$

$$equates\ to\ 5\ beats\ every\ 4\ seconds$$

$$\frac{5\ beats}{4\ seconds} = \frac{x}{60\ seconds}$$

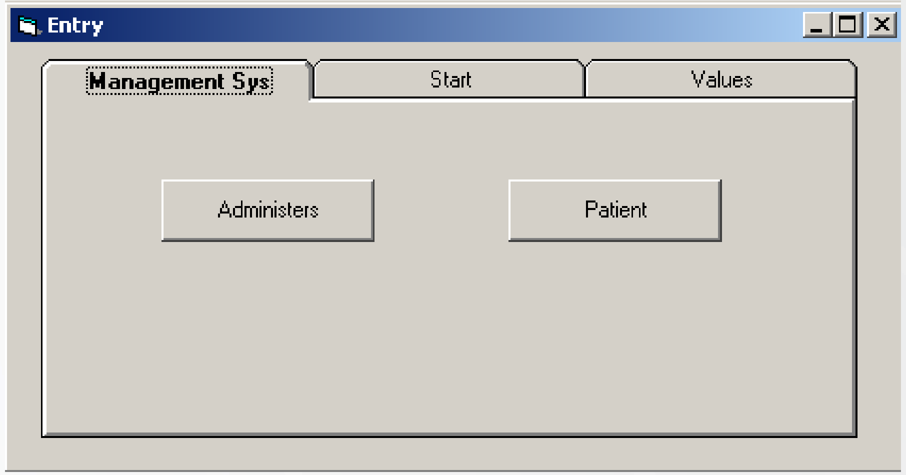
$$x = 75\ beats\ per\ minute$$

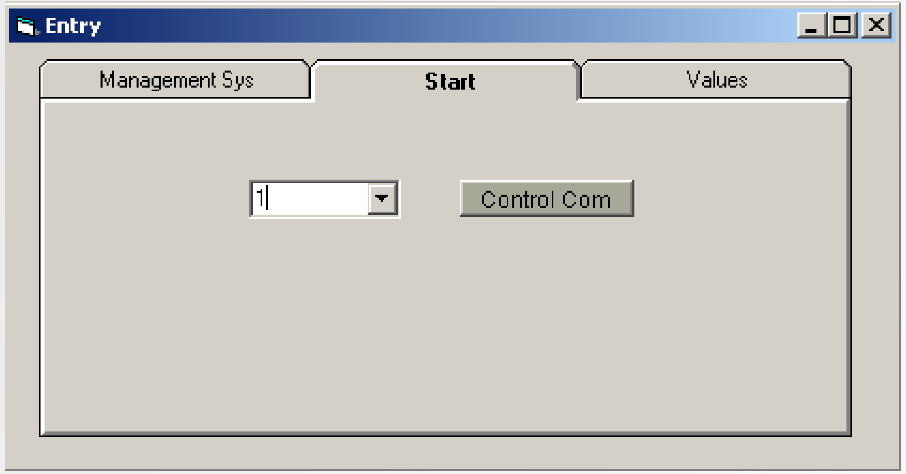
TESTING AND RESULTS: RELIABILITY

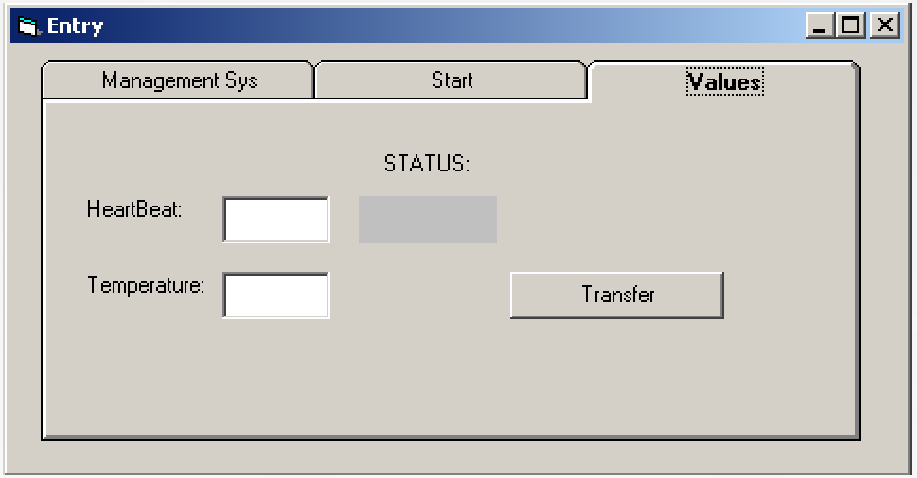


Name	Heart Rate Sensor (BPM)	Manual counting method (BPM)	Temp Sensor (°C)	Temp Thermometer (°C)
Saad N.	91	91	31	31
Nurshahifa	76	76	30	30
Amjad Elsir	80	83	27	28
Mohamed A.	95	95	26	28
Ahmad A.	78	78	27	27
Firdaus	80	80	29	29
Ahmed Faaris	64	63	31	31
Mohamed N.	68	66	32	31
Ubaid S.	110	110	35	34
Angela J.	108	115	31	31

TESTING AND RESULTS: VISUAL BASIC PROGRAM



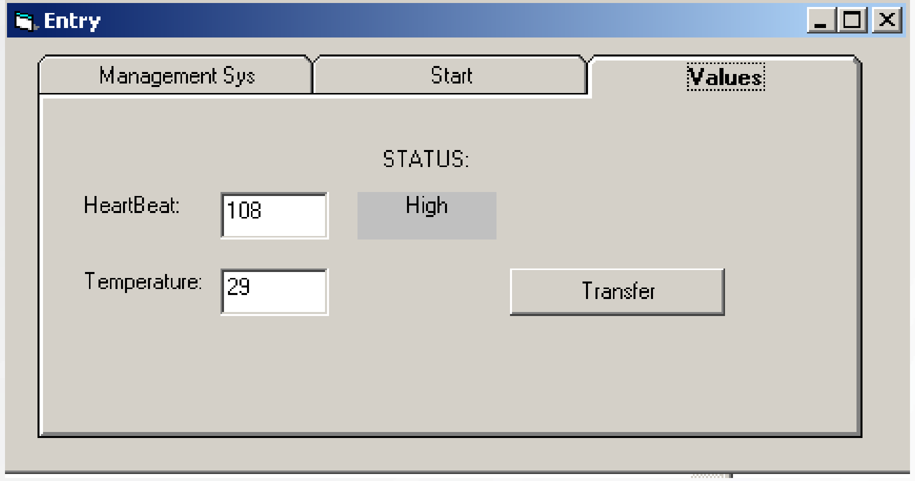




User Interface Tabs

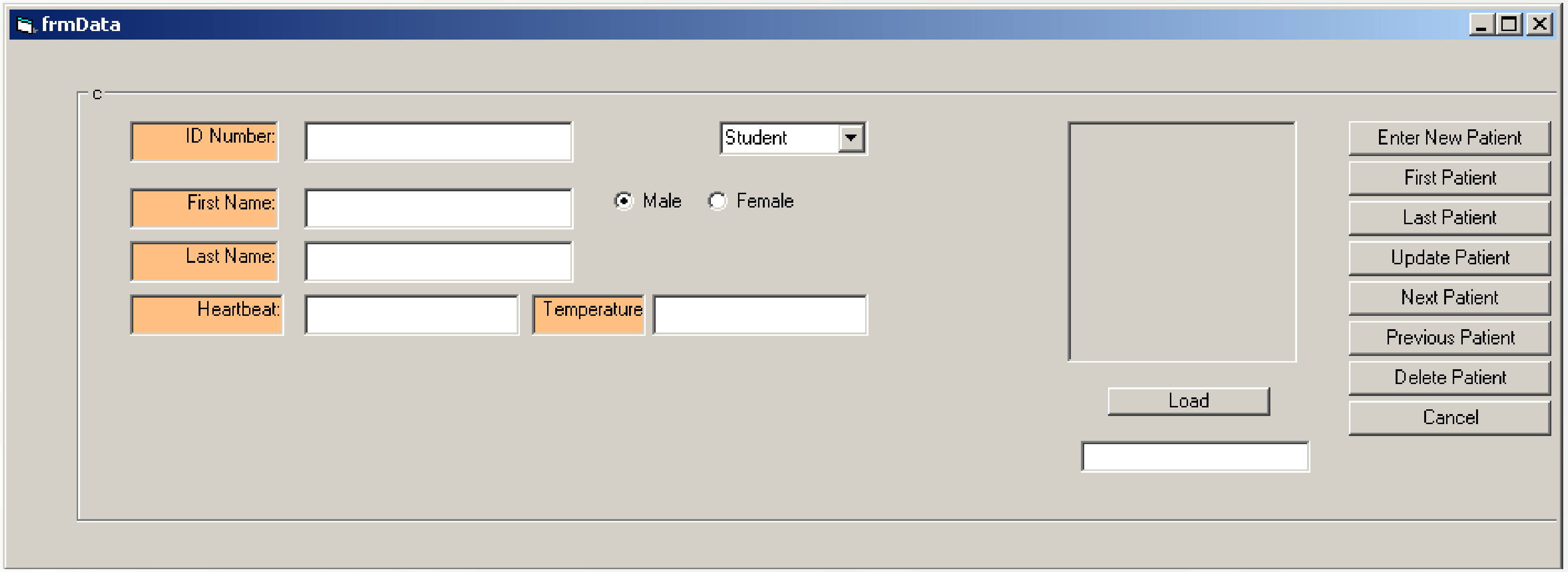
TESTING AND RESULTS: VISUAL BASIC PROGRAM

Bluetooth communication	
Usart_init(9600);	//initialize serial Bluetooth communication with a baud rate of 9600 bps //USART: Universal Synchronous Asynchronous Receiver
usart_write(pulse);	//sends the pulse rate data to Bluetooth
Usart_write(temp);	//send temperature data to Bluetooth

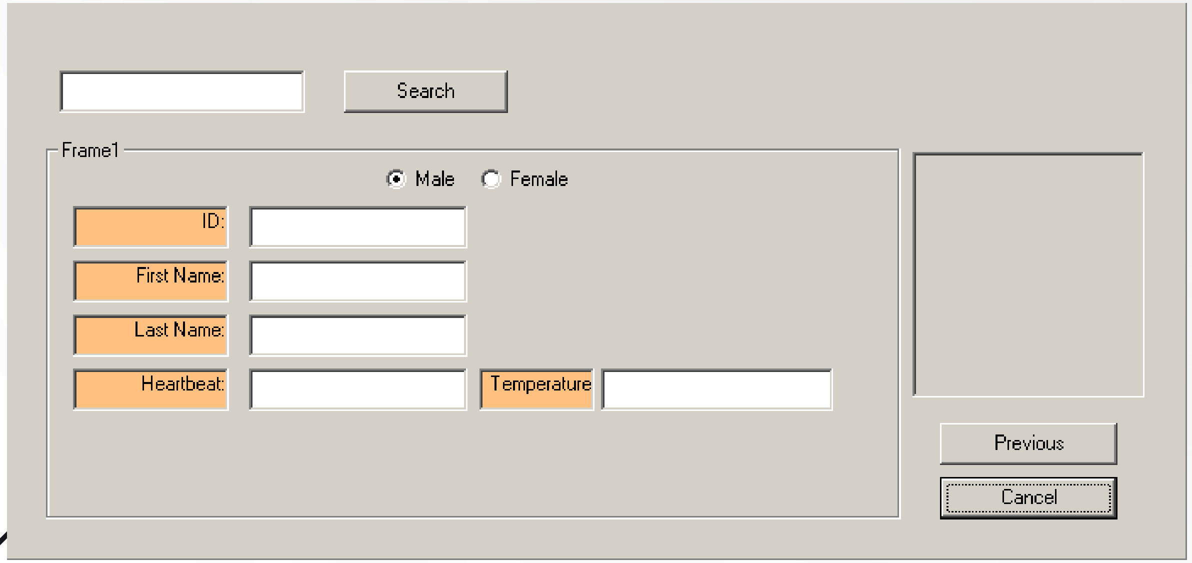


Successful Bluetooth Transfer

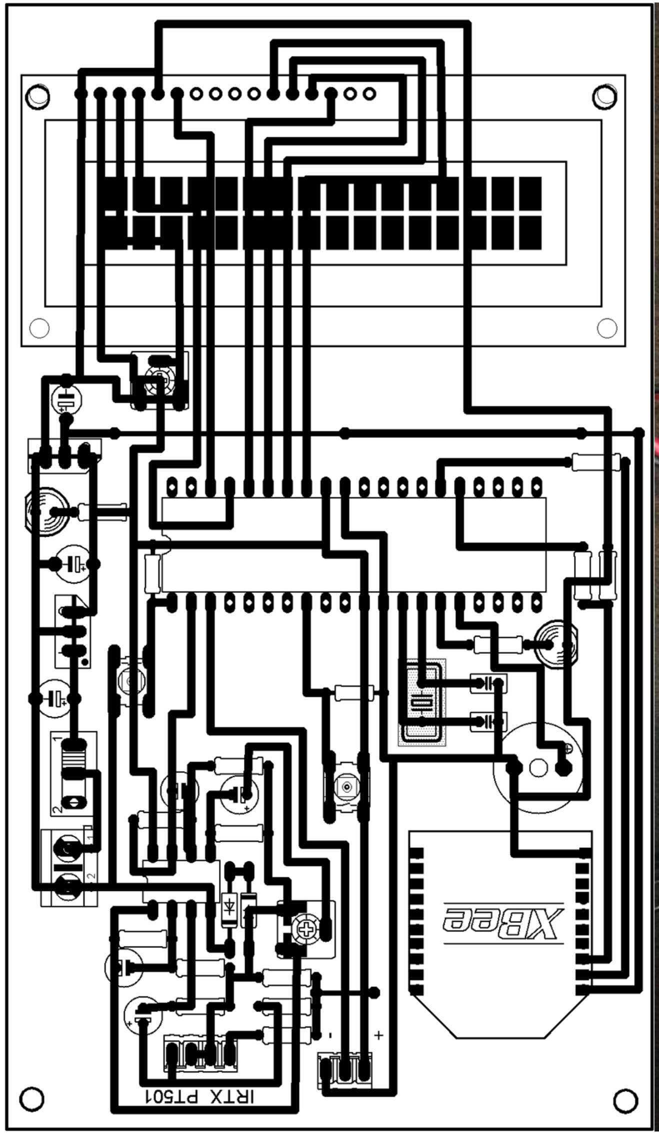
TESTING AND RESULTS: VISUAL BASIC PROGRAM

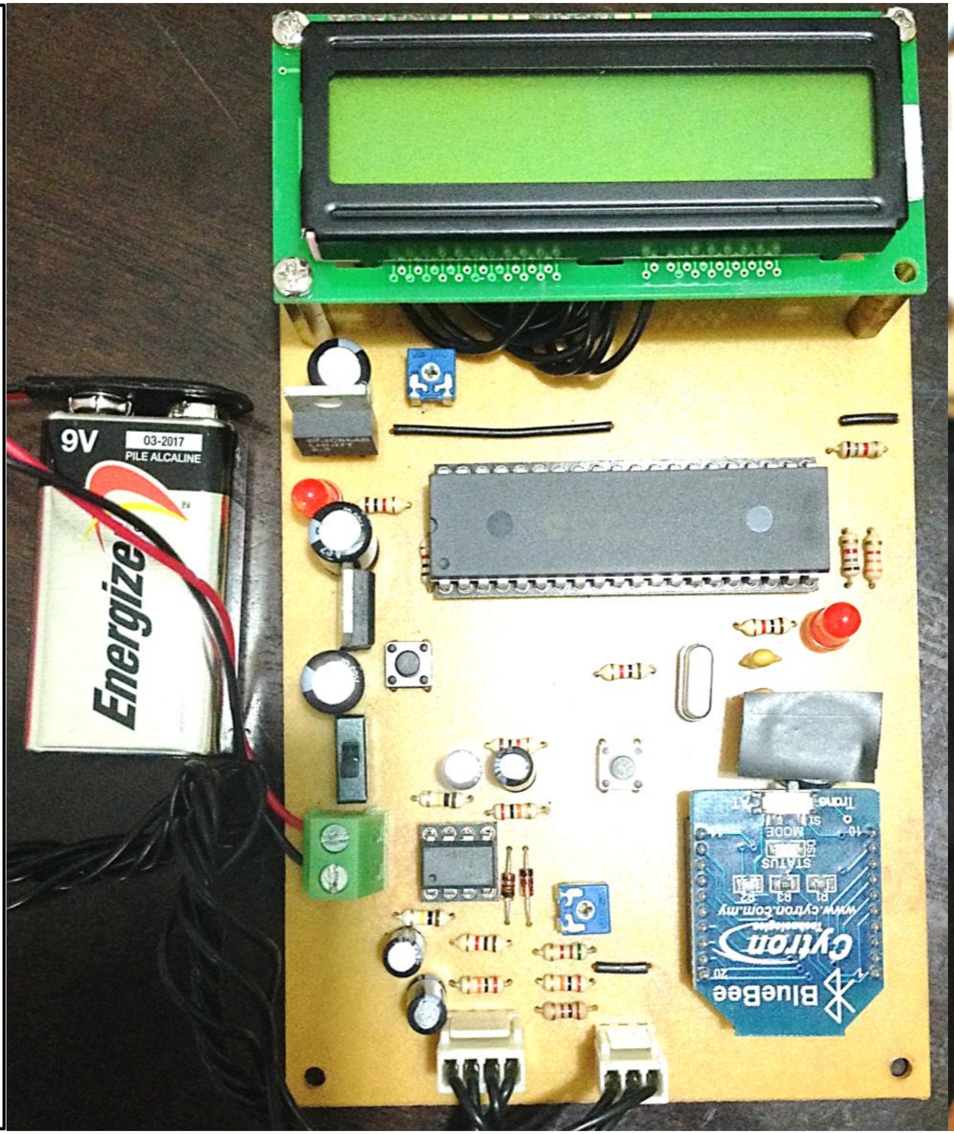


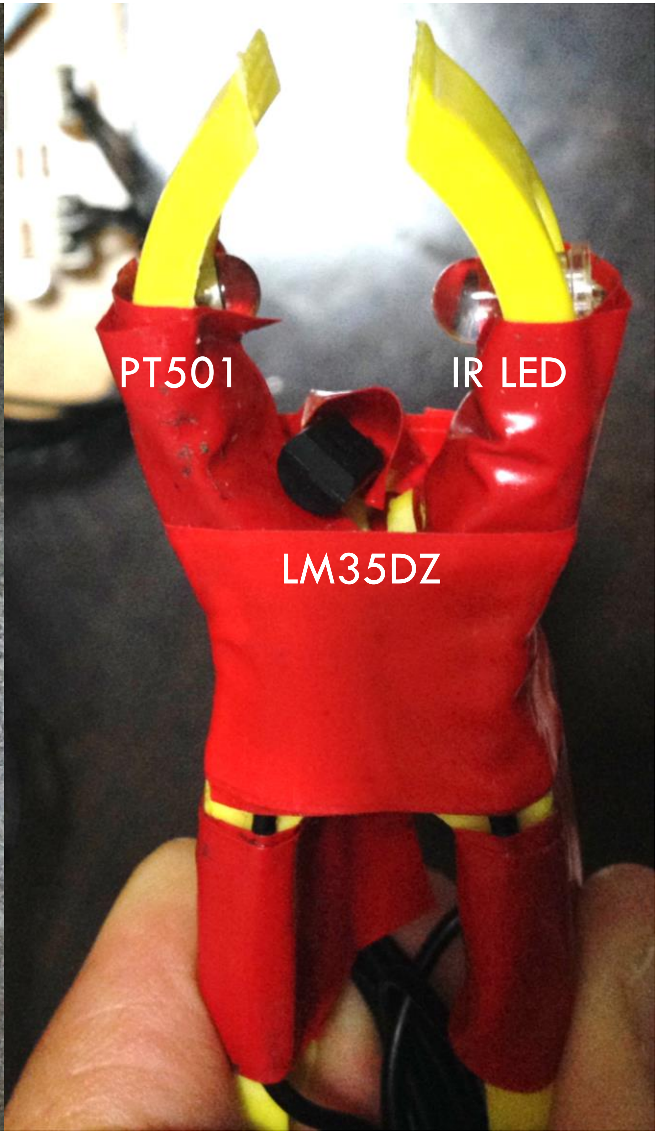
Patient Information Form



Patient Search Form







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