Electrocardiography (ECG)

REPORT

Project 1: ECG Monitor System

Experiment 1: Background Noise Observation

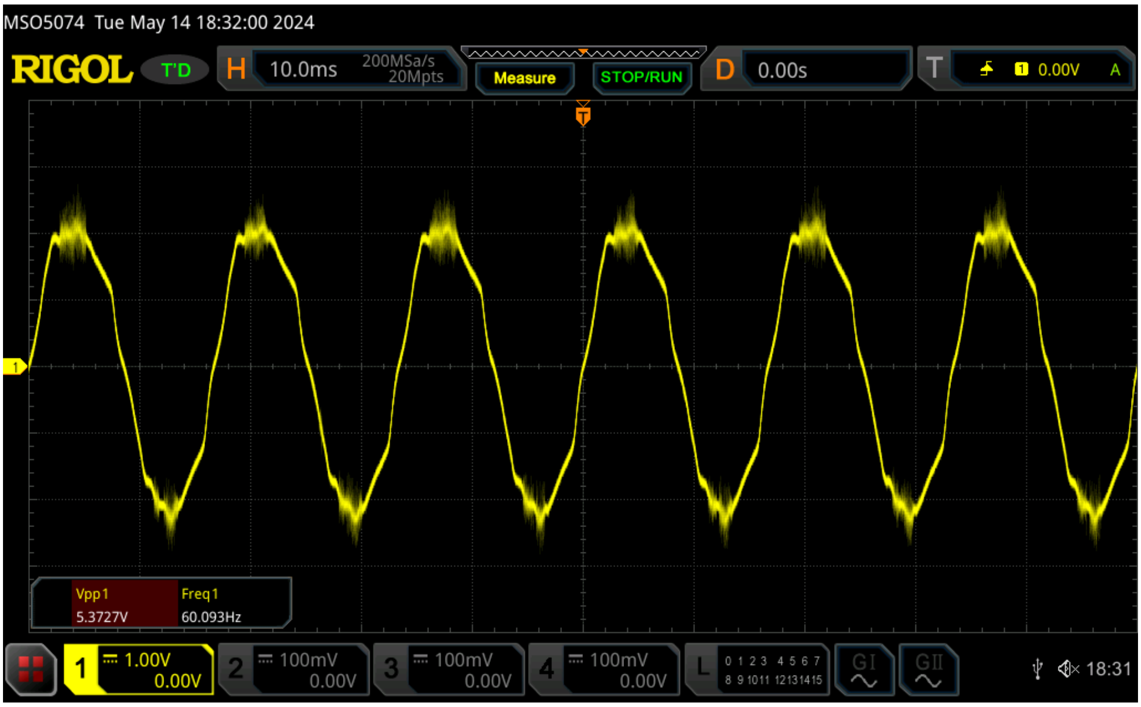

Fig 1. Wave Result with Ground Clip Grounded & Signal Clip Floating

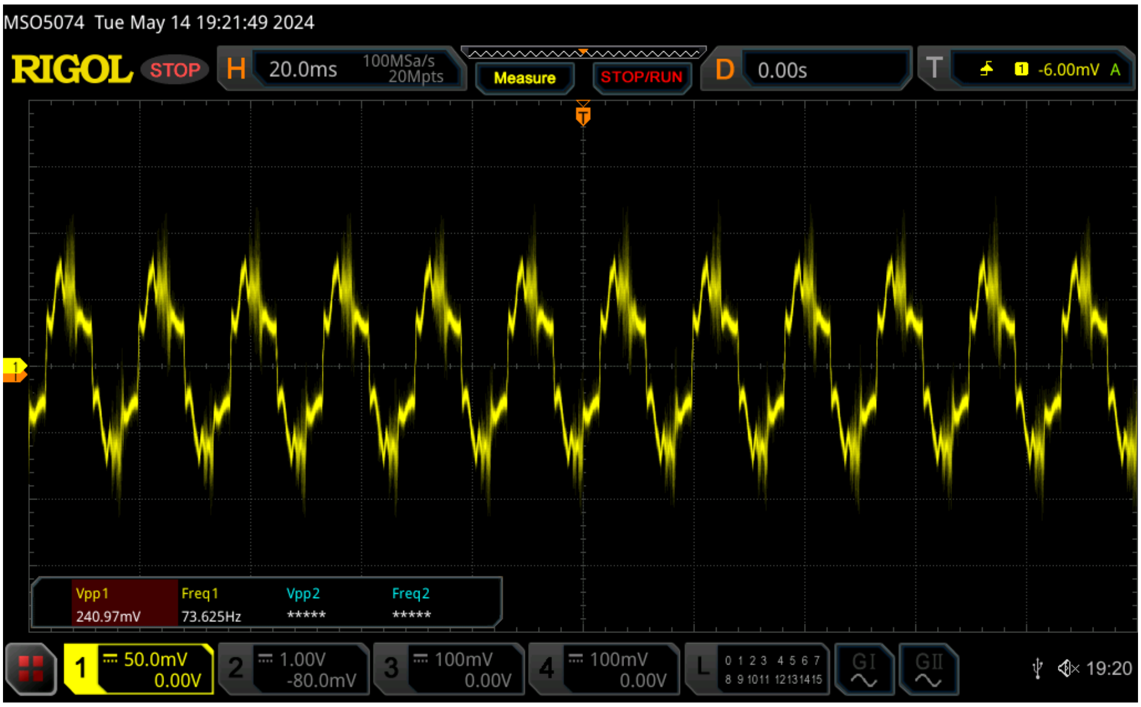

Fig 2. Wave Result with Ground Clip Grounded & Signal Clip in Hand

Power Line Noise:

The AC power in our power lines supplied by the TPC(台電) has a fundamental frequency of 60Hz. The point of experiment 1 is to let us observe and identify this noise. To acquire an accurate measurement of our heart rate, we must attenuate this disruption through a filter, which we constructed in Lab10.

Why does the oscilloscope detect a signal when I touch the signal pin with my hand?
My body can act as an antenna, picking up electromagnetic interference (EMI) from various sources, such as power lines, electrical appliances, or radio frequencies. This EMI can also be coupled to the oscilloscope's input and displayed as noise or interference on the signal.

Experiment 2: Simulated Heartbeat Measurement

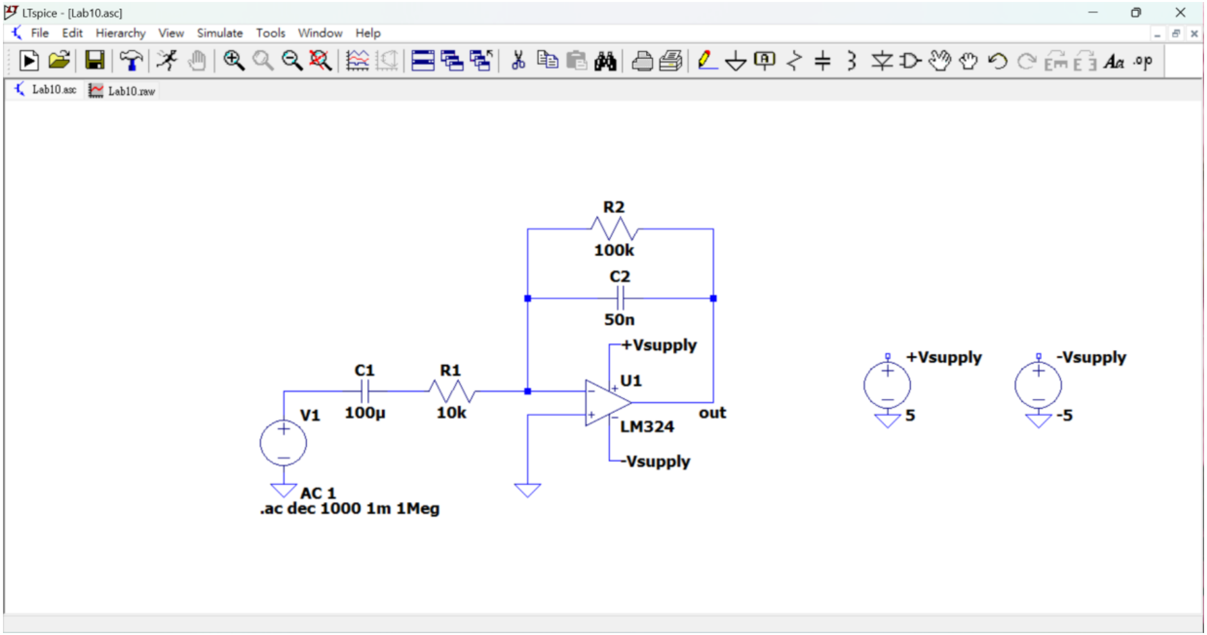

Fig 3. Bandpass Filter in LTspice

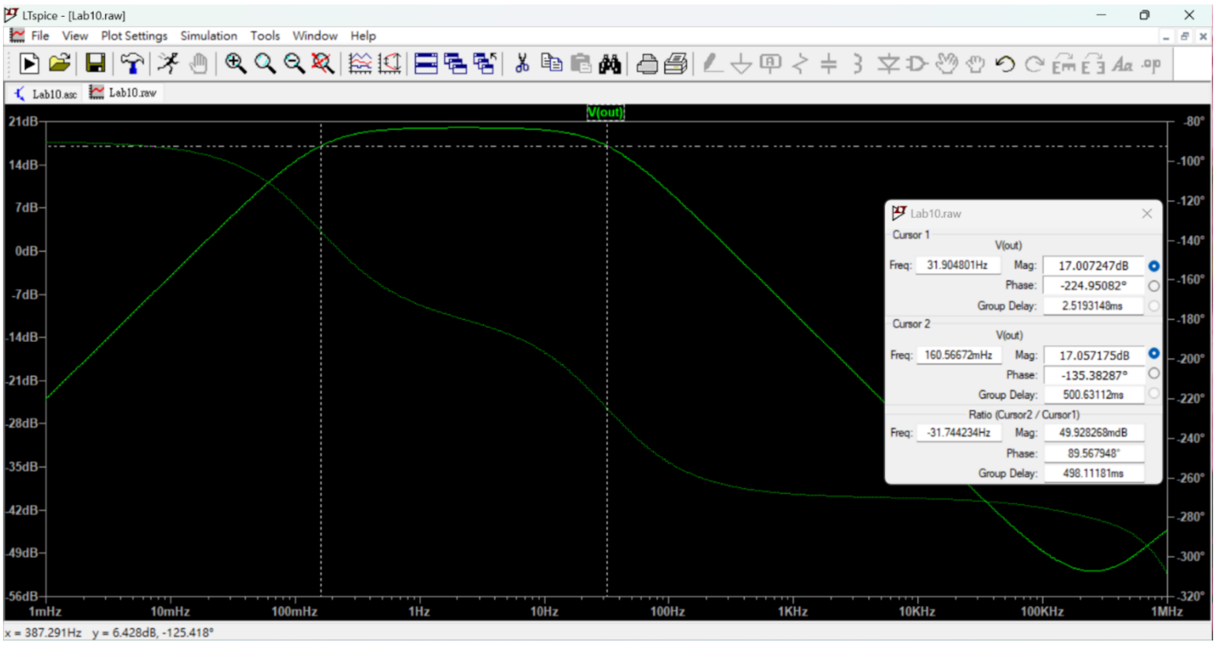

Fig 4. Bandpass Filter Frequency Sweep

$$f_{3dB\ L} = \frac{1}{2\pi \times 10k \times 100\mu} = 0.16Hz$$
$$f_{3dB\ H} = \frac{1}{2\pi \times 100k \times 50n} = 31.83Hz$$

This aligns with our need because a human's heart rate is 1Hz ~ 2Hz. This filter can amplify the heart beat signal while attenuating the power line noise.

Fig 5. Wave Result of Simulated Heart Beat Modulated with 60Hz Sine Wave

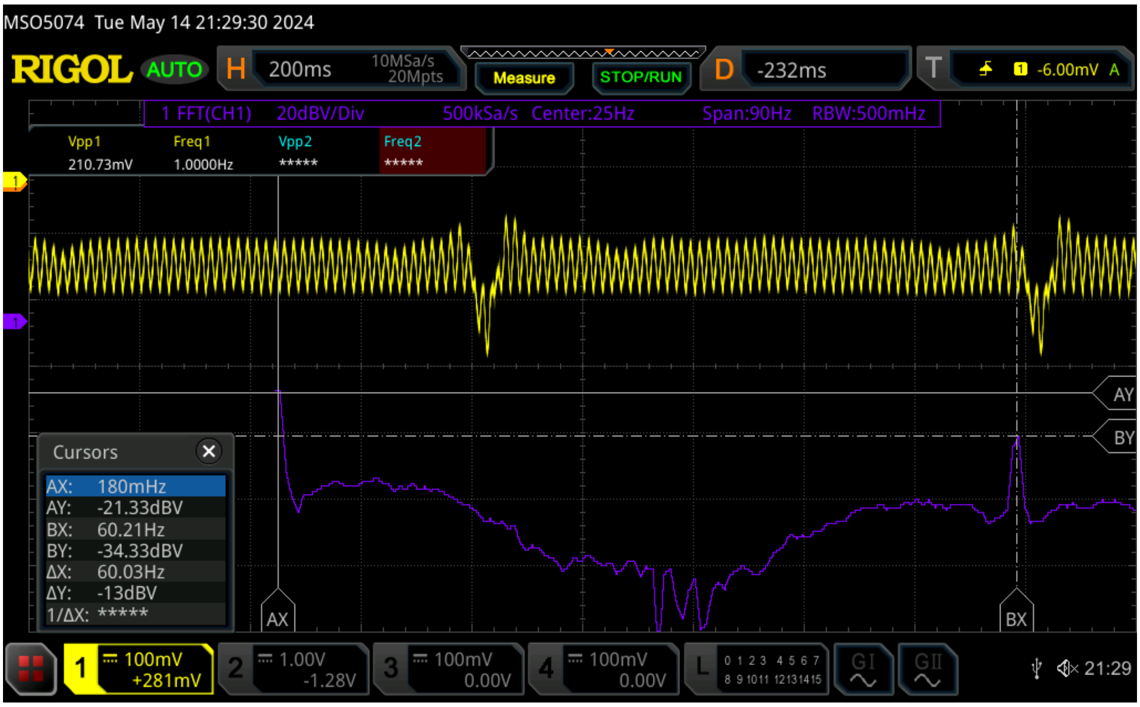

Fig 6. FFT of Simulated Heart Beat Signal at Instrumentation Amp Output

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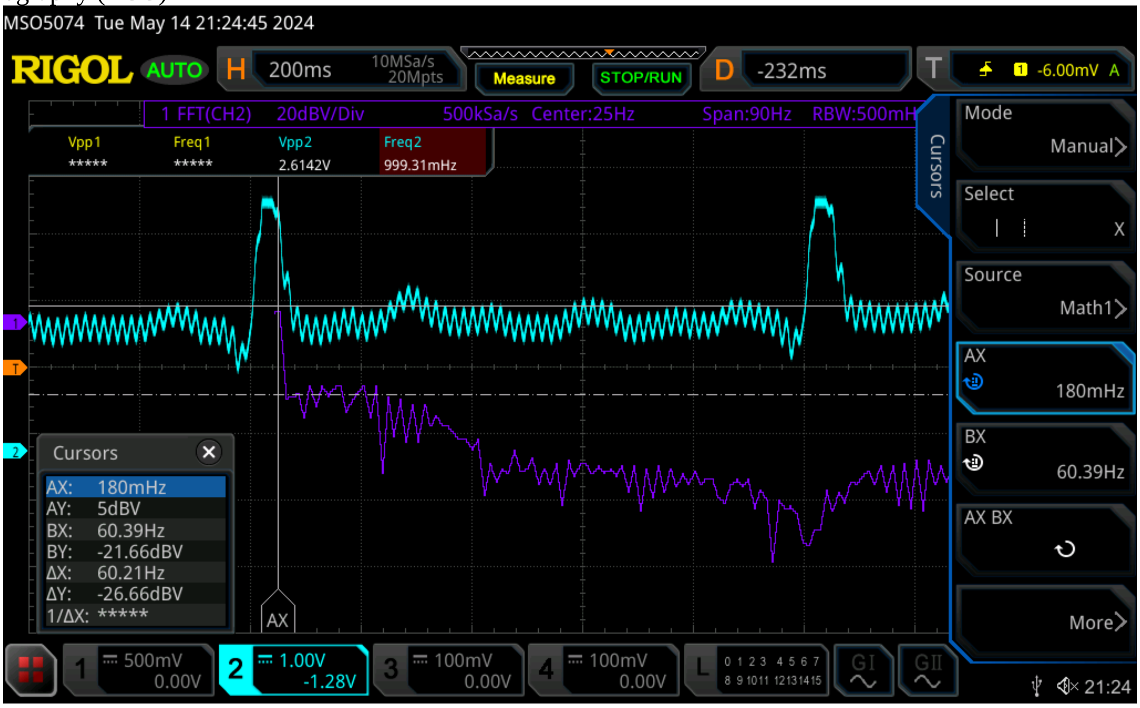

Fig 7. FFT of Simulated Heart Beat Signal at Filter Output

In this experiment, we generated a heart beat signal modulated with a 60Hz sine wave(mimic power line noise) on the function generator. Since the passband of the filter is approximately 16Hz ~ 32Hz. The power line noise is attenuated and the 1 Hz heart beat is amplified as shown on screen.

	0.2Hz	60Hz
Before Filter	-21.33 dB	-34.33 dB
After Filter	5 dB	-21.66 dB
Difference	+26.33 dB	+12.67 dB

We notice that the magnitude of both the heart beat signal and 60Hz noise are amplified. However, the heart beat signal is amplified by 26.33dB, while the power line noise is only amplified by 12.67dB. This effectively makes the heart beat signal much larger compared to the rest of the wave.

Experiment 3: Human Testing

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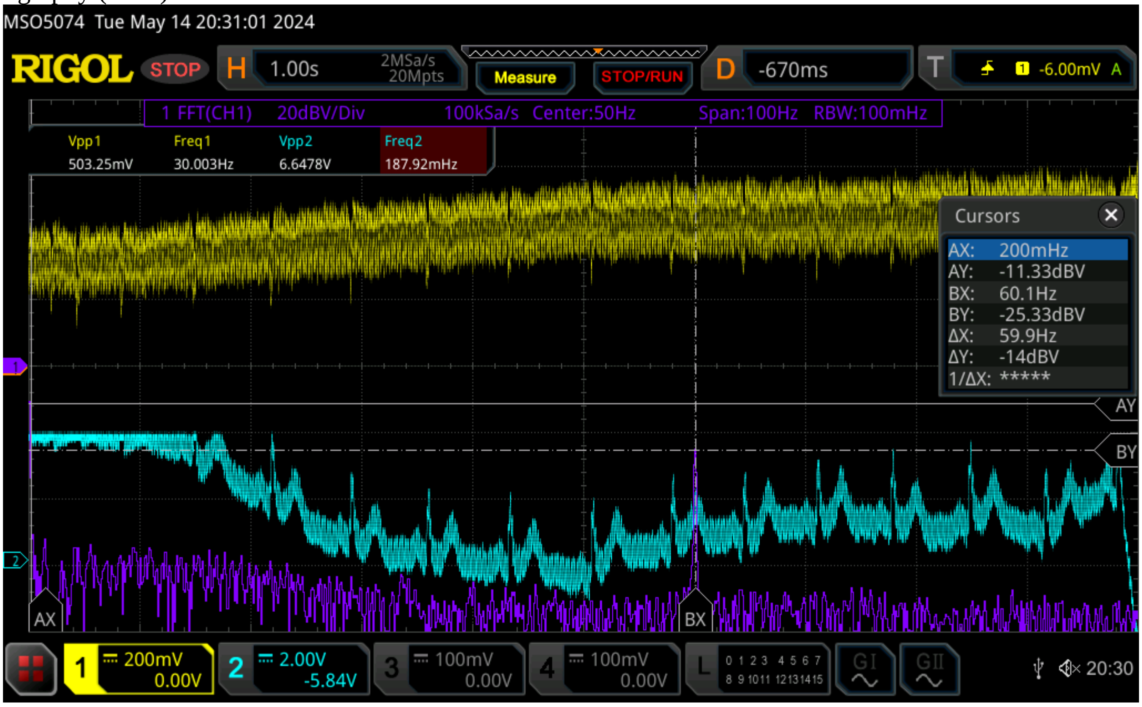

Fig 8. Wave Result of my Heart Beat Measured with AgCl Electrode

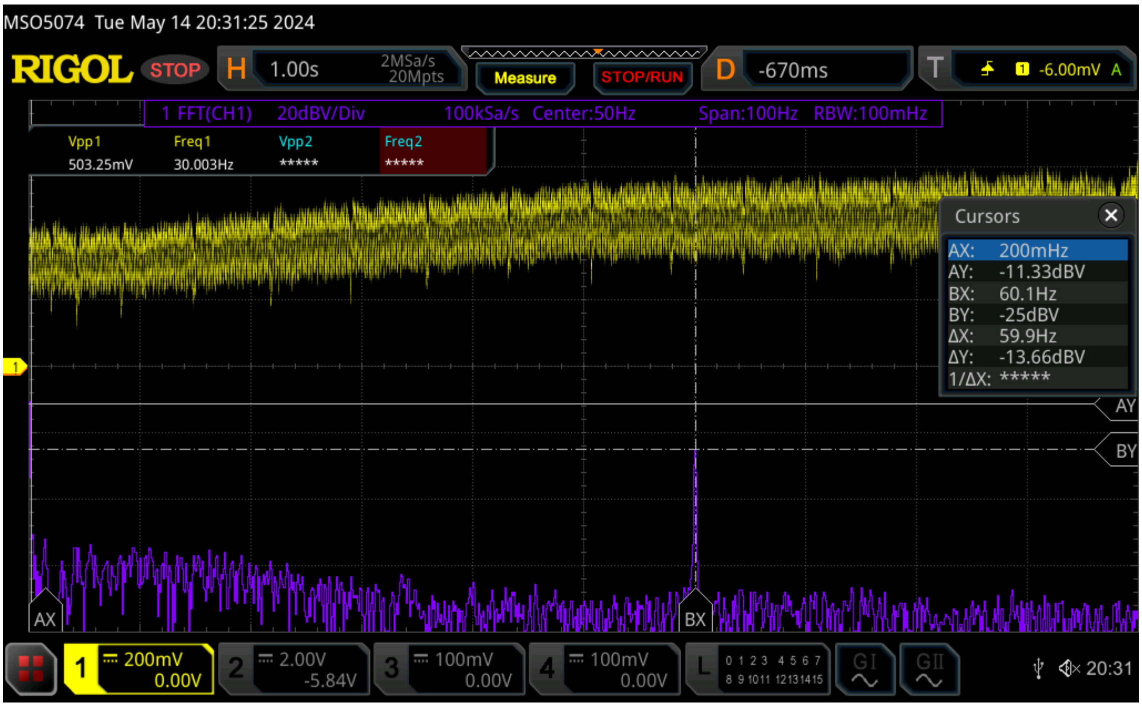

Fig 9. FFT of my Heart Beat Signal at Instrumentation Amp Output

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Fig 10. FFT of my Heart Beat Signal at Filter Output

Fig 11. Heart Rate Measured Using Cursor

The filter's effect is much more noticeable here. The signal amplified through the instrumentation amp is still very fuzzy. However, after passing through the filter, the heartbeat's peak becomes much more visible.

What is my heart rate?

Using the oscilloscopes marker, my heart rate was measured to be around 1.449 Hz. Multiply this by 60 and we get approximately 87 BPM.

Why do we use AgCl electrodes for ECG(electrocardiography) ?

1. Stable half-cell potential: This means that the voltage across the electrode-electrolyte interface remains relatively constant. This stability is crucial for accurately measuring the small potential differences of heart signals.
2. Biocompatibility: Silver and silver chloride are relatively biocompatible materials, making them suitable for direct contact with the skin in wearable devices or medical applications.

What can the ECG signal of a person tell us?

ECG is a noninvasive way for medical personnel to monitor the condition of a patient. Here's what an ECG signal can tell us:

1. Heart Rate and Rhythm:

   - ✧ Heart Rate: An ECG can measure the heart rate, determining if it's within the normal range (typically 60-100 beats per minute for adults).
   - ✧ Heart Rhythm: It helps identify if the heart rhythm is regular or irregular. Common rhythm disorders detected include atrial fibrillation, atrial flutter, and ventricular tachycardia.

2. Heart Size and Position:

   - ✧ Chamber Enlargement: An ECG can suggest enlargement of the heart's chambers (e.g., left atrial enlargement, right ventricular hypertrophy), which can be caused by conditions like hypertension or heart valve disease.
   - ✧ Position of the Heart: Abnormalities in the ECG waveforms can indicate changes in the position of the heart within the chest.

3. Electrical Conduction:

   - ✧ Conduction Abnormalities: It can identify issues with the heart's electrical conduction system, such as bundle branch blocks or atrioventricular (AV) blocks.
   - ✧ Wolff-Parkinson-White Syndrome (WPW): A specific conduction abnormality where an extra electrical pathway causes a rapid heartbeat.

4. Ischemia and Infarction:

   - ✧ Myocardial Ischemia: Changes in the ST segment and T wave can indicate reduced blood flow to the heart muscle, suggesting ischemia.
   - ✧ Myocardial Infarction (Heart Attack): Specific patterns like ST elevation, pathological Q waves, and T wave inversions are indicative of a heart attack.

5. Electrolyte Imbalances:

   - ✧ Hyperkalemia or Hypokalemia: Abnormal potassium levels can cause characteristic changes in the ECG, such as peaked T waves in hyperkalemia or flattened T waves in hypokalemia.
   - ✧ Calcium Imbalances: Hypercalcemia and hypocalcemia can affect the duration of the QT interval.

6. Drug Effects and Toxicity:

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- Medication Impact: Certain medications (e.g., digoxin, antiarrhythmics) produce specific ECG changes, which can help monitor therapeutic levels and detect toxicity.
- Toxic Substances: Effects of toxic substances or overdoses, such as from tricyclic antidepressants, can also be detected.

Experiment 4: Heart Beat Visualized

Demo Video: https://youtu.be/3JR1nX7CJEg

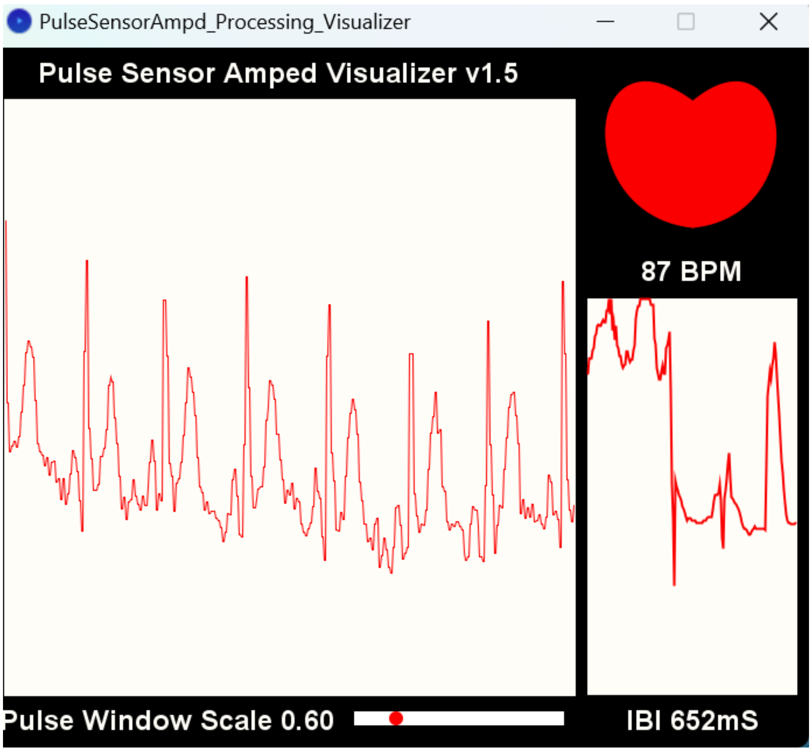

Fig 12. Heart Rate Measured on Processing 4

My heart rate measured on my laptop through Processing 4 is 87 BPM. This aligns perfectly with the result in experiment 3 (87 BPM).

My Takeaway:

This experiment has demonstrated to me the practical applications of what I learned in microelectronics. By combining different configurations of an op amp, we have created something that is actually fun and useful. Being able to put what we learned in class to use is a fascinating opportunity. This kind of hands-on experience motivates me to study microelectronics even harder because it shows me why we are learning the things in our textbook.

Project 2: Multi-function Arduino Sensor System

Demo Video: https://youtu.be/YvOr2ZIsMm4

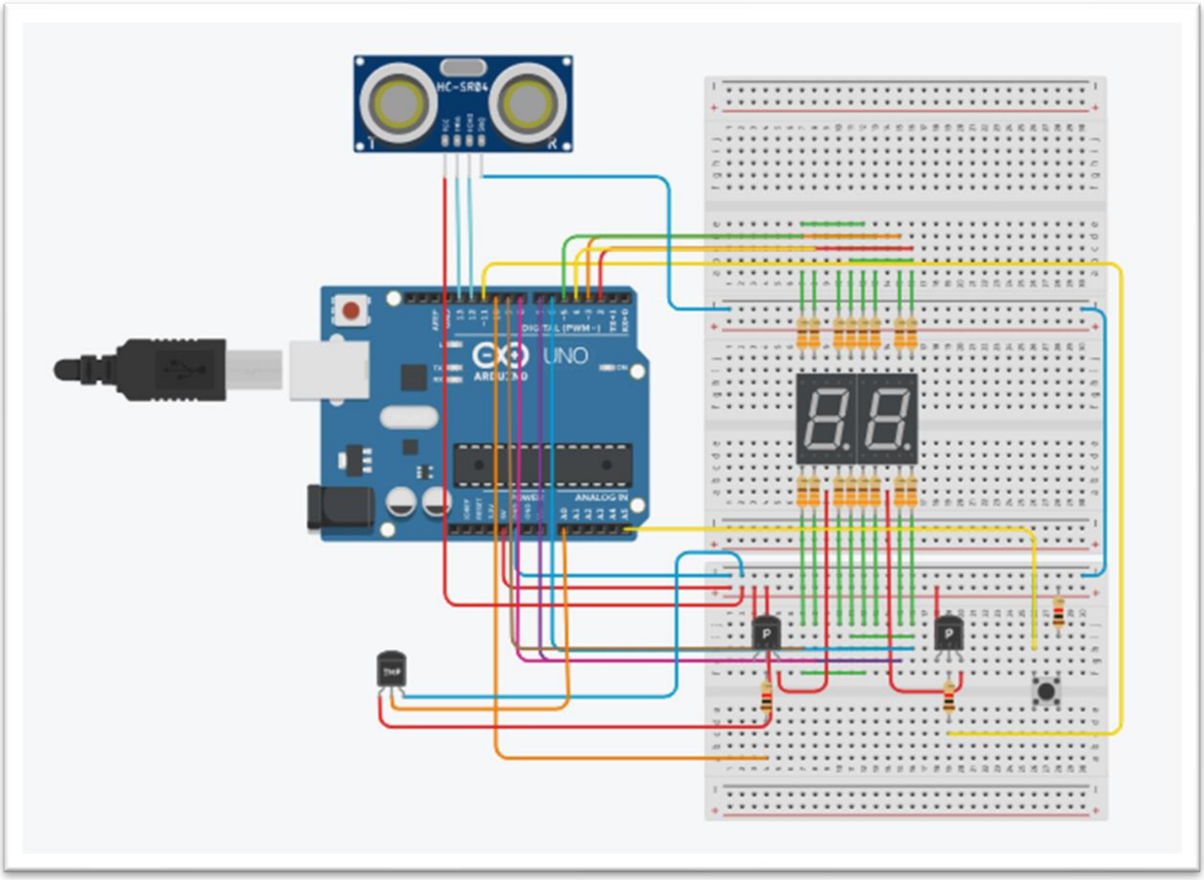

Fig 13. Arduino Circuit

```
void loop() {
  // put your main code here, to run repeatedly:
  //Debounce
  if (digitalRead(A5) == HIGH){
    delay(100);
    if(digitalRead(A5) == LOW)
      mode = !mode;
      Serial.println(mode);
  }

  if(mode  == 0 && i == 0)Save_dist();
  else if (i == 0)Save_temp();

  if(mode  == 0)Marquee(distarr,6);
  else Marquee(temparr,7);

  Dist();
  Temp();
}
```

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This is the loop() function. It contains several subfunctions that I have divided into 3 parts:

1. Distance
2. Temperature
3. Display

The explanations are as follow.

Part 1: Ultrasonic Sensor Control (Distance)

```
void Dist()
{
  digitalWrite(trigPin, LOW);
  delayMicroseconds(5);
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);
  pinMode(echoPin, INPUT);
  duration = pulseIn(echoPin, HIGH);
  cm = (duration/2) / 29.1;
}

void Save_dist(){
  distarr[0] = cm /100;
  cm = cm - 100 * distarr[0];
  distarr[1] = cm / 10;
  distarr[2] = cm % 10;
  if (distarr[0] == 0) distarr[0] = 0;
}
```

The “Dist()” function controls the HC-SR04 ultrasonic sensor and converts the measurement to centimeter. The “Save_dist()” function converts the int to an array holding each element we wish to display on the seven seg.

Part 2: LM35 Control (Temperature)

```
void Temp(){
  int interval = 400;
  if (i == 0){//(millis() - previousMillis_temp >= interval) {
    // save the last time you blinked the LED
    temp = analogRead(A0);
    temp = (temp * 500)/1024;
    previousMillis_temp = millis();
    Serial.println(temp);
    Serial.println("\n");
  }
}

void Save_temp(){
  int cast_to_int = temp * 10;
  Serial.println(cast_to_int);
    Serial.println("\n");
```

```
  temparr[0] = cast_to_int/100;
  cast_to_int = cast_to_int - 100 * temparr[0];
  temparr[1] = cast_to_int / 10;
  temparr[3] = cast_to_int % 10;
}
```
The “Temp()” function takes the measurements from the LM35 and converts it to a one-decimal-place float. The “Save_temp()” function converts the float to an array holding each element we wish to display on the seven seg.

Part 3: Seven Seg Control (Display)

```
void Marquee(int arr[], int arr_size){
   int interval = 500;
   if ( i == arr_size - 1) refresh_seven_seg(arr[i], arr[0]);
   else refresh_seven_seg(arr[i], arr[i+1]);
   if (millis() - previousMillis_display >= interval) {
    previousMillis_display = millis();
    if (i == arr_size - 1) i = 0;
    else i = i + 1;
  }
}

void refresh_seven_seg(int left_val, int right_val){
    displayDigit(right_val); //上 02
    digitalWrite(left,LOW);
    digitalWrite(right,HIGH);
    delay(3);
    displayDigit(left_val); //下 01
    digitalWrite(left,HIGH);
    digitalWrite(right,LOW);
    delay(3);
}
```
The “Marquee()” function allows us to pass in what we want to display as an array and repeatedly iterate through each element and calls “refresh_seven_seg()”. The “refresh_seven_seg()” function rapidly switches the two BJT on and off, toggling between the 2 seven segs. There is a 3rd function, “displayDigit()”. The code is not attached here due to its simplicity. It converts the numbers & characters we wish to display into seven seg characters by controlling the 8 pins. Combined, these three functions form the marquee.

My Takeaway:

This Arduino projects combines what we’ve learned in the previous experiments into one. Since this is a very basic application, it is but a tip of the iceberg of what can be done with a microcontroller. No wonder it’s so popular across the world! If I had more free time, I would be inclined to check out some of the other more intricate designs using Arduino.

References:

1. *Fundamentals of Microelectronics* (Behzad Razavi)
2. *Microelectronic Circuits* (Adel S. Sedra, Kenneth C. Smith)

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3. Texas Instrument: https://www.ti.com/document-viewer/lit/html/SSZT428
4. https://www.mayoclinic.org/healthy-lifestyle/fitness/expert-answers/heart-rate/faq-20057979