KING'S College LONDON

FlexPulse Pro

PHYSIOLOGICAL MONITORING SYSTEM (DOCUMENTATION)

6CCYB080: MECHATRONICS

JANUARY 2024

[redacted]

Purpose of the ‘FlexPulse Pro’.

With the recent advancements in wearable technology, there is a growing interest within the realms of kinesiology and physiotherapy to leverage such innovations for the development of devices tailored to assist patients recovering from joint surgery, individuals with mobility disorders, and those pursuing general wellness goals.

Traditional gait analysis, a cornerstone in physiological assessments, is undergoing transformation through the integration of technology, providing a departure from subjective standard observation analysis towards the acquisition of quantitative data. This shift enables more objective measurements which would therefore foster a more comprehensive understanding of disease progression and thereby inform rehabilitation practice.

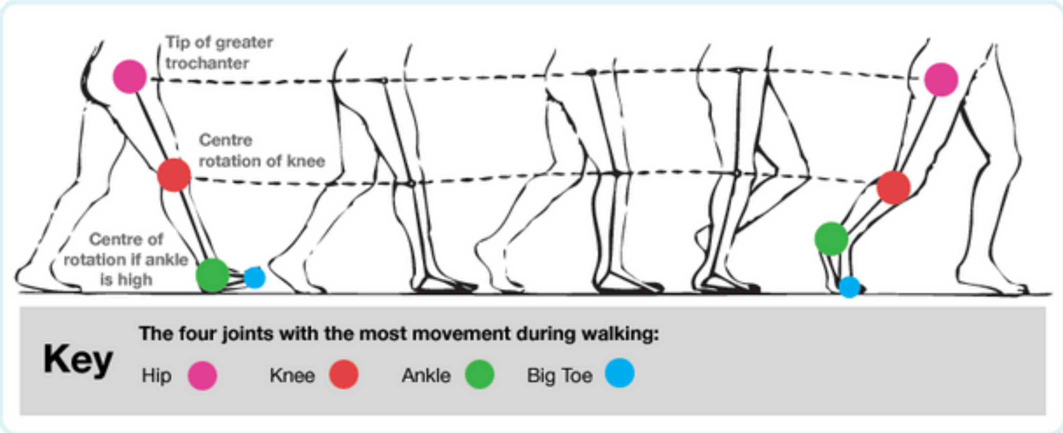


Figure 1: Human gait cycle assessed by observation analysis.

Key among the reported outcome measures in this context are knee flexion angle and heart rate during movement. For example, if a patient is recovering from ACL reconstruction surgery, they will be required to attend physiotherapy sessions. The flexion angle can be used to monitor how well they’re regaining mobility in the knee, and a high heart rate measurement would indicate that an exercise is perhaps too strenuous.

Recognizing the significance of these parameters, this documentation details the design and implementation of a wearable monitoring system – the FlexPulse Pro. This device is engineered to measure knee flexion angle and heart rate. The patient puts on a knee sleeve containing the monitor, after which acquired data can be continuously transmitted to healthcare professionals, caregivers, or even the patients themselves via Bluetooth connectivity. The monitoring system's user-friendly interface, accessible on both iOS and Android smartphones, empowers users to interact with and interpret the physiological measurements effectively, thereby fostering a holistic approach to healthcare monitoring.

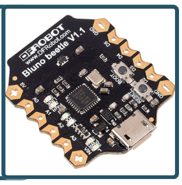
Inclusive Design

The design of the FlexPulse Pro prioritizes inclusivity by considering the diverse needs of users across different health conditions and backgrounds. It took into account the specific requirements of patients with physical disabilities or long-term conditions, ensuring relevance and effectiveness in diverse rehabilitation and wellness scenarios. The device is comfortable and adjustments to it (including sizing of the knee sleeve) can be easily made, therefore making it comfortable for any age group.

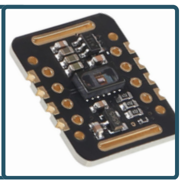
Additionally, we specifically chose the app LightBlue to display data to the user due to its intuitive interface, ensuring that individuals of varying backgrounds can easily navigate and interpret the physiological data. Contrasting colours have been strategically employed in the app's design to enhance visibility and legibility, particularly for users with visual impairments or those who may face challenges in distinguishing certain colour combinations.

Component Information

Microcontroller Board with BLE Module:
- Bluno Beetle
- DFRobot
- £12.28



Oximeter and Heart Rate Sensor:
- AEDIKO MAX30102
- AEDIKO Via Amazon
- £3.00 (Link)

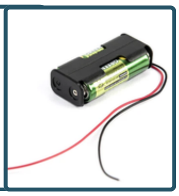


Flex Sensor:
- Thin Film Pressure Sensor
- Fafeicy via Amazon
- £6.99 (Link)

Neo G Open Knee Support
- Neo G via Boots
- £19.50 (Link)

MAX30102 Sensor Library
- SparkFun Via Arduino IDE
- Free

Power Supply
- 2 x 1.5V AA Rechargeable Batteries
- Battery Holder with leads
- Via EW3, KCL



Wires
- From ELEGOO Starter Kit

Resistor
- 10K Ohms
- From ELEGOO Starter Kit

Bluetooth LE App:
- LightBlue®
- Apple App Store
- Free

Total Spent = £41.77

Circuit Diagram

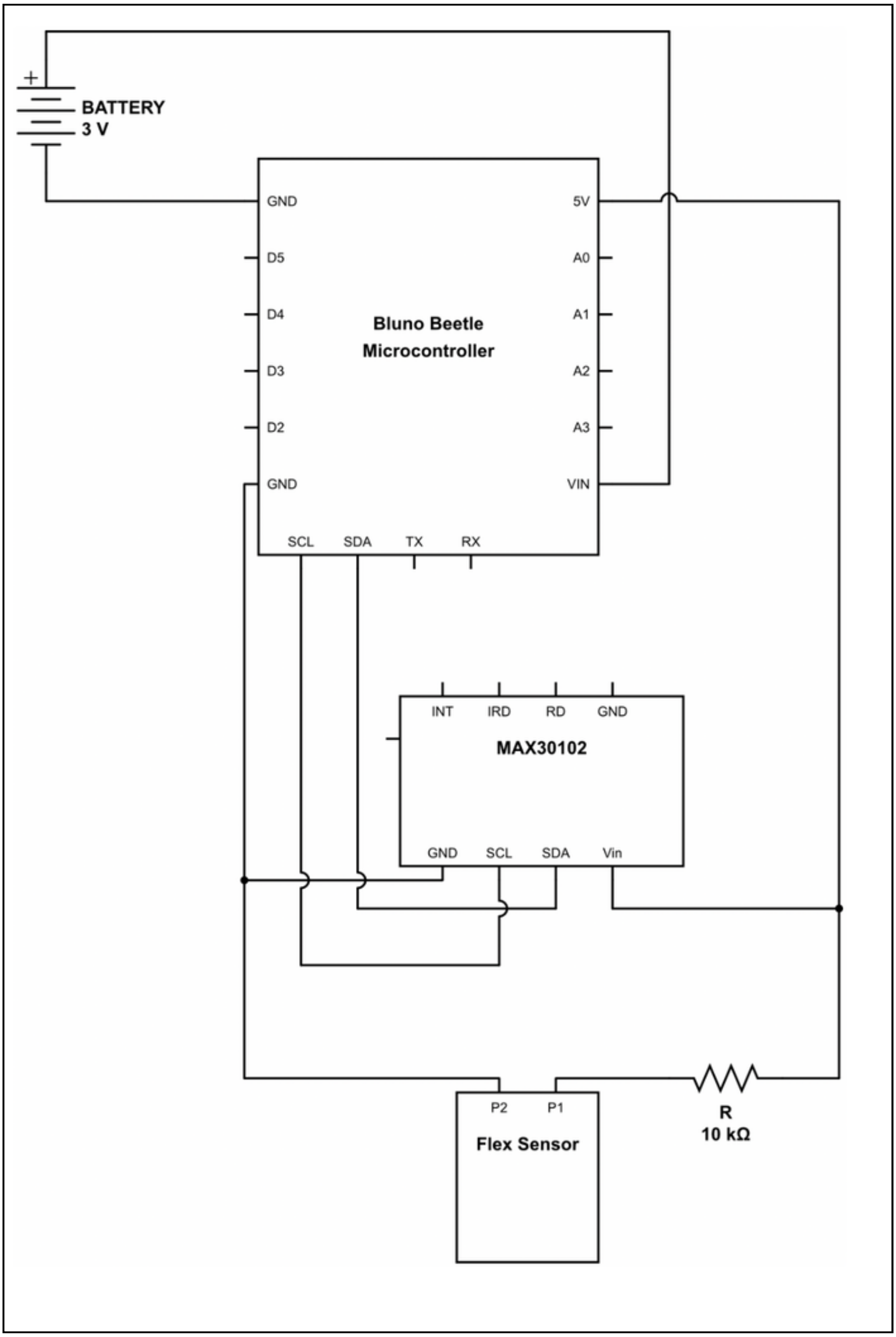


Figure 2: Circuit diagram for FlexPulse Pro system.

Wiring Diagram

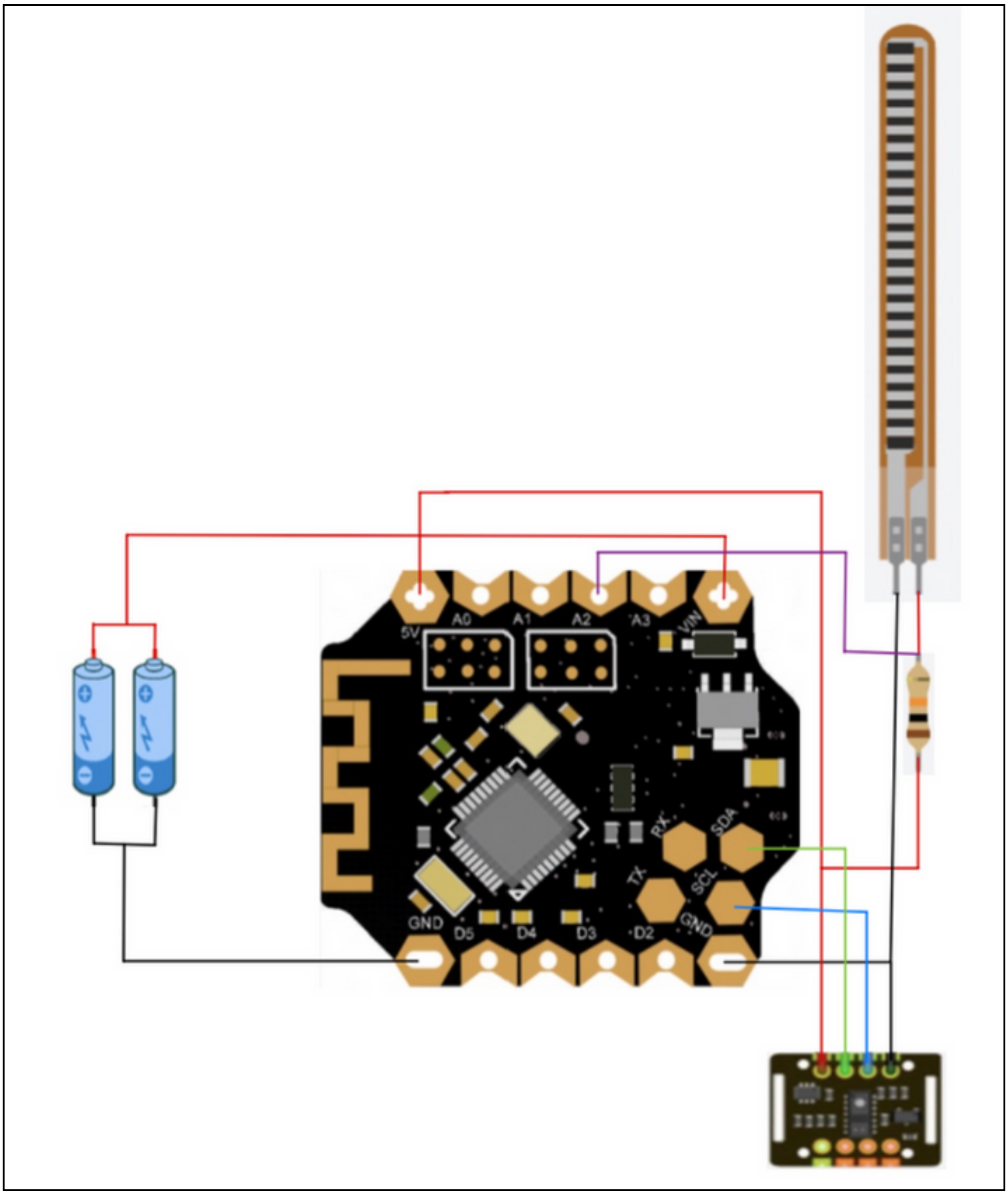


Figure 3: Wiring diagram for FelxPulse Pro system.

Block Diagram & System Operation

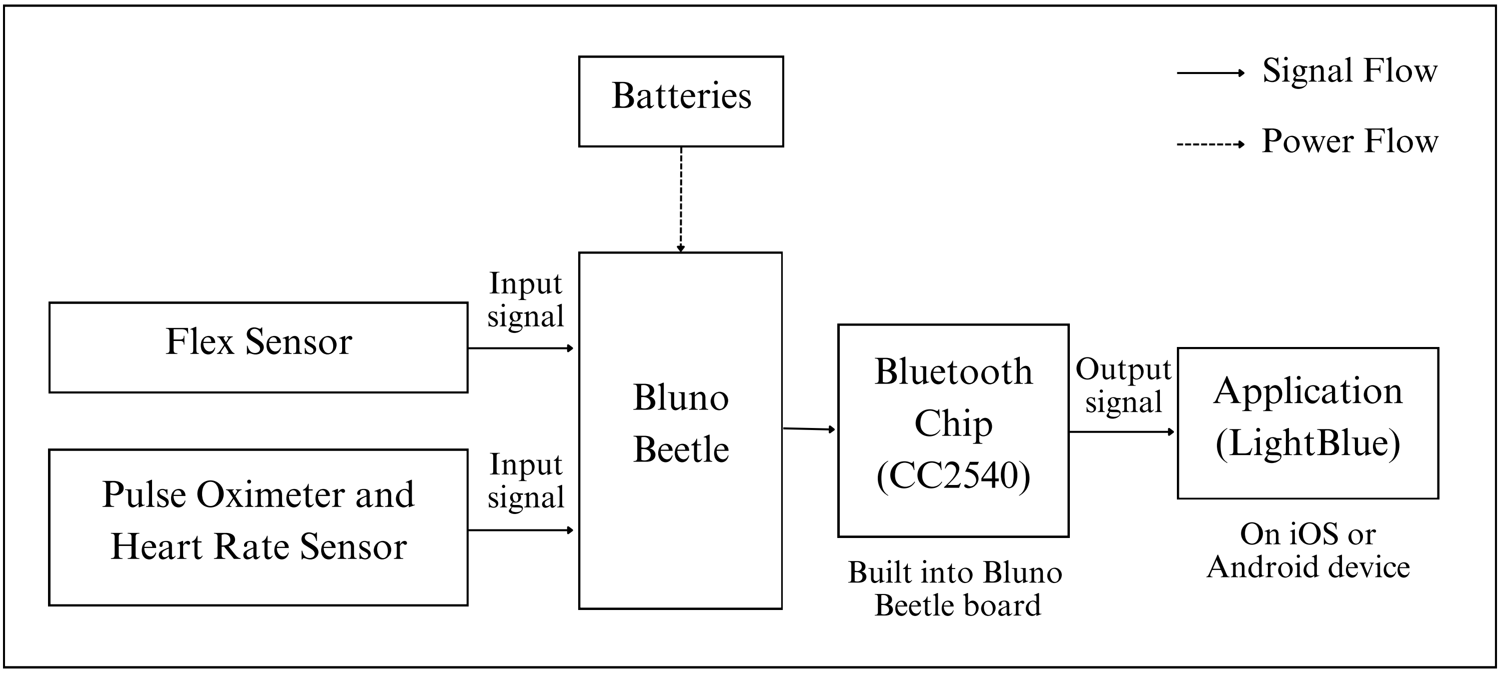


Figure 4: Block diagram for FlexPulse Pro system.

The flex sensor and pulse oximeter/heart rate sensor first measure the desired quantities (flex angle of the knee, oxygen saturation of the blood, and heart rate, respectively). The Bluno Beetle is an Arduino board with an ATmega328P microcontroller and a CC2540 Bluetooth chip, programmed using C++. It reads in the analogue signals from the sensors and performs signal conditioning to convert them to digital signals that are suitable for the output.

These output signals are stored into variables within the Arduino IDE program's code and are continuously transmitted via the Bluetooth chip on the board using Bluetooth Low Energy (BLE), so long as the monitor remains connected to a device with compatible Bluetooth capabilities. The measured physiological parameters are then displayed on the interface of the LightBlue application that has been downloaded to an iOS or Android device.

Instruction for Operation

1. Power Supply:

- Charge two 1.5V AA batteries.
- Connect the power supply to device by adding batteries to battery holder.

2. Patient puts on Knee Sleeve

- Locate the open panel at the back of the knee sleeve, where the MAX30102 sensor is.
- Ensure sensor is placed firmly against main artery behind knee (known as the popliteal artery).

3. Initialise main interface:

- Install LightBlue app via App Store (iOS devices) or Google Play Store (Android devices).
- Allow app to access Bluetooth permissions.
- Locate Bluetooth device titled 'FlexPulse Pro' in main menu.
- Scroll through the device Services and choose the Serial Monitor - it will appear as type 'Read/Write/Notify'.
- Select 'Listen for Notifications' option.
- Data comes through to the app in hexadecimal format. In order for the user to read the data, choose data type UFT-8 in the app.
- Real-time log of data is ready for viewing.

4. Analysis of patient physiological parameters using sensors:

- **How the pulse oximeter works:** The haemoglobin in the blood helps carry oxygen throughout the body. The oxygen has the characteristic of absorbing Infrared (IR) light. As blood oxygen concentration increases (after each pump of the heart), the blood becomes a more intense red and can absorb more IR light. The MAX30102 has both a red and IR LED, and a photodetector. As the IR light is shone at the skin, the photodetector receives the unabsorbed, reflected light. An oscillating waveform is produced as the amount of reflected light varies as blood flows through the finger veins. We can determine the heartbeat by measuring this wave.

- **How the Flex sensor works:** This sensor is a type of variable resistor that measures the amount of deflection it experiences when bent. It is made of a thin material coated with conductive ink which, when the sensor is bent, is what changes its resistance. When the sensor lies flat, its resistance is at its minimum. As the sensor begins to bend, its resistance gradually rises. The resistance is at its peak when the sensor is bent at 90 degrees. The change in resistance is therefore proportional to the degree of bend, and can be measured using a voltage divider circuit. By measuring the voltage across the sensor, one can determine

5. **Using the Light Blue App:**
    - If the sensor is connected properly, three values will appear in the app. First, the flexion angle of the knee in degrees, followed by the current heartbeat level in beats per minute, and finally the average heart rate calculated over the last 4 measurements.
    - If no heartbeat is detected by the sensor, the app will display a '0' warning.

6. **Data Analysis:**
    - Export the log of data for post processing.
    - Data will be exported to .csv file, which can be opened in Excel.
    - In Excel, the data is visualised using appropriate line graphs.

Example Graphs of Captured Data

Time (GMT)	Flex Angle (°)	Heart Rate (BPM)	Avg. HR
18:11	180	70	70
18:11	180	67	71
18:11	180	74	72
18:12	180	67	70
18:12	180	74	70
18:12	180	70	70
18:12	180	70	70
18:12	20	67	70
18:12	20	74	70
18:12	20	70	70
18:12	20	67	69
18:12	20	74	71
18:12	70	67	69
18:12	180	67	70
18:12	180	70	70
18:12	180	70	70
18:12	180	70	70
18:12	50	74	70
18:12	50	74	70
18:12	20	67	69
18:12	20	74	73
18:12	70	70	68
18:12	50	67	68
18:13	50	74	72
18:13	20	74	70
18:13	20	67	69
18:13	50	67	71
18:13	180	78	70
18:13	20	70	70
18:13	180	70	70
18:13	180	70	70
18:13	180	74	71
18:13	70	70	70
18:13	180	70	71
18:13	20	74	70
18:13	20	67	68
18:13	50	74	70
18:13	50	70	71
18:13	110	74	71
18:13	110	70	70

Figure 5: Excel table of Captured data

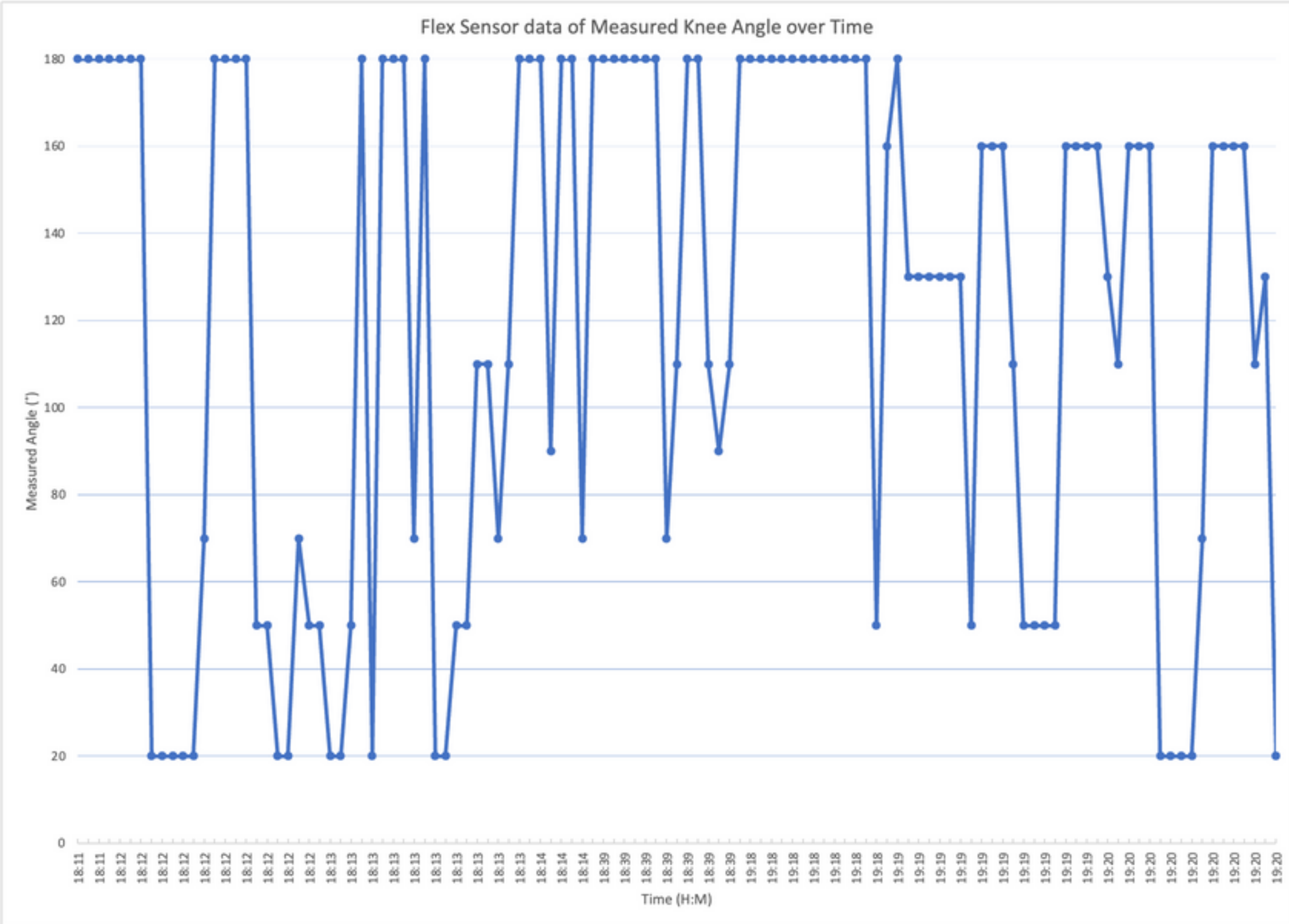


Figure 6: Graph of flex Sensor data of Measured Knee Angle from captured data

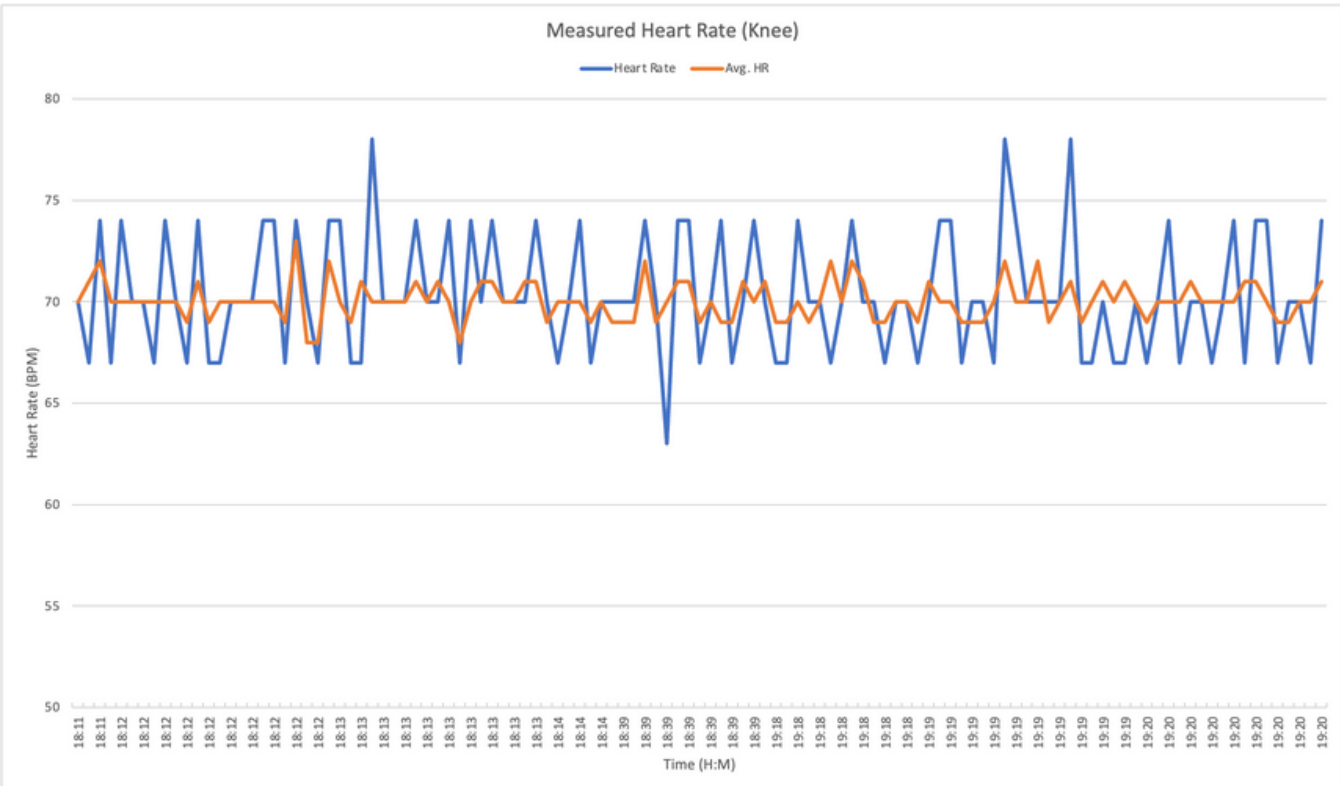


Figure 7: Graph of measured Heart Rate and average Heart rate from captured data

Source Code

Access Source Code via GitHub:
https://github.com/avanya23/FlexPulse-Pro-Public-.git

Code Included:
- *Flex & Heart Rate Sensor:* main script for microcontroller to process raw sensor data.
- *Import csv:* code to convert logged data into Excel compatible .csv file.

Contribution Acknowledgements

[redacted] **–** My main role in this project was working with the MAX30102 pulse oximeter & heart rate sensor, developing code to calculate the heart rate and how to integrate it into our device. I also worked on the circuit and block diagrams, and contributed to the Systems Operations section. I also soldered the components together.

[redacted] **–** My role in the project involved working with the Flex sensor, including its programming. I integrated the components into the knee sleeve, transforming it into a wearable device. Additionally, I was responsible for creating the wiring diagram and compiling information about the components for the project documentation.

[redacted] – My focus for this project was to find and solder a suitable power source, work on the function microcontroller, and combine the components with their code. In the project documentation, I researched and devised the Purpose of the System, Inclusive Design, and Instructions for Use sections.

[redacted] – In this project, my main focus was working with the microcontroller. In order to make the collection of our data wireless, I set up the Bluetooth component and the accompanying Light Blue app to receive the data. I also worked on the code to import the raw data into a .csv and produce the graphs.

References

- Zad, n, & Ahmed. (2022, May 12). *Max30102 pulse oximeter and heart rate sensor with Arduino*. Microcontrollers Lab. https://microcontrollerslab.com/max30102-pulse-oximeter-heart-rate-sensor-arduino/
- Das, D. (2022) How Does a Flex Sensor Work and how to Interface it with Arduino? Available at: https://circuitdigest.com/microcontroller-projects/interfacing-flex-sensor-with-arduino#:~:text=A%20flex%20sensor%20is%20a,at%20a%2090%2Ddegree%20angle
- Gait Analysis Explained Runners Need. https://www.runnersneed.com/expert-advice/gear-guides/gait-analysis.html

Video Link

https://youtu.be/jyxjG-EONRU