Multi-Channel Acquisition Module for EMG Signals

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Schedule

Overview

Overview

Motivation

- Electromyography - means of human-computer interaction
- Surface EMG - Easy to implement
- 2 types of sensors tested
- Custom Acquisition Module vs Commercial Device

The EMG Signal

EMG Signal Properties

Typical Characteristics

- Random nature [1];
- Max peak-to-peak amplitude: 10mV [2];
- Bandwidth: [50 - 150] Hz;
- Minimum Sampling Rate: 250 Sa/s [2];
- Subjective [1];
- Noise Sensitive;

Types of EMG Sensors

- Invasive - (not covered);
- Non-Invasive, based on:
  - Gel Electrodes;
  - Dry Electrodes;

The Acquisition System

The Acquisition Chain

It is based on:

1. Dry EMG Sensors
2. Acquisition Module
3. Wireless Adapter
4. PC Software

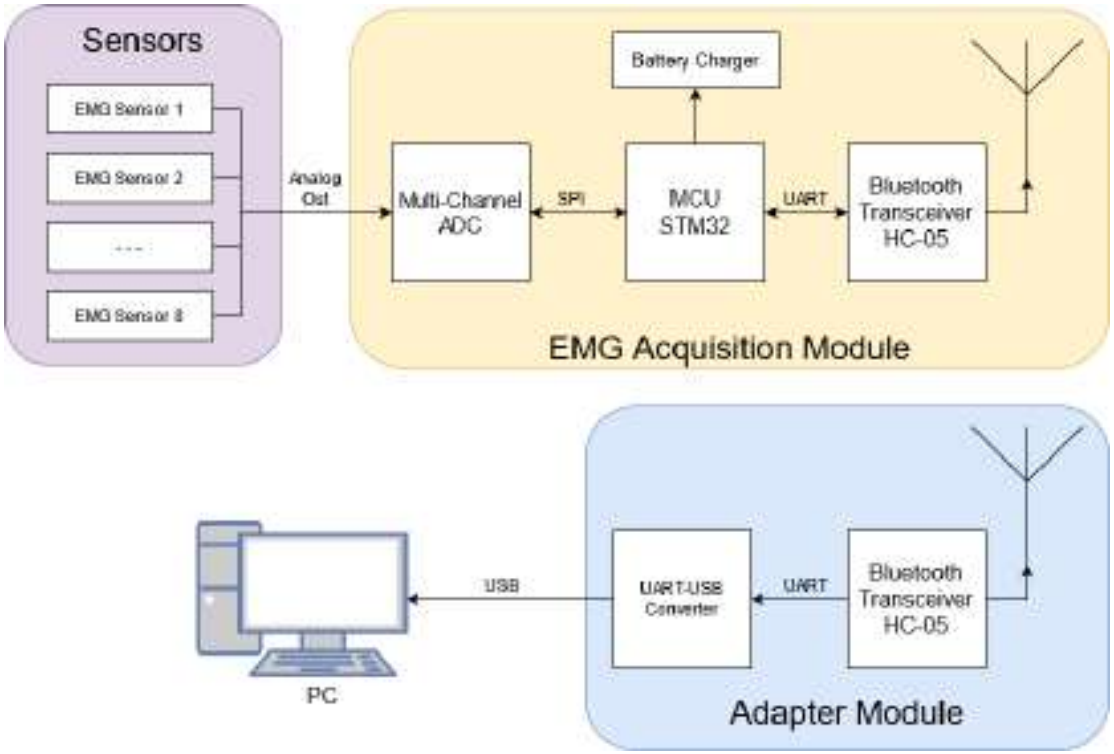

Figure: 1. The Complete Acquisition Chain

Dry EMG Sensors

OyMotion Gravity [3]:

- Metal Dry Electrode;
- Preamplifier Circuit Included;
- Detection Range: +/– 1.5mV;
- Gain: 1000;
- Signal Level: 0 – 3V;
- Signal Offset: 1.5V;
- Typical Bandwidth: 20 – 300Hz;
- Working DC Voltage: 3.3 – 5V;
- Working DC Curent: 0.5mA;

Figure: 2. Gravity EMG Sensor (Source: DFRobot).

The Acquisition Module

The Prototype:

1. A/D Converter
2. Microcontroller
3. Transceiver

The Acquisition Module

A/D Converter - AD7124-8 [4]

- Sigma Delta Architecture;
- Max 19200Sa/s;
- 24 bit Conversion (16 bit Used);
- Up to 8 Channels (4 used);
- Sequential Converter;
- Input CrossBar Multiplexer;
- Internal 2.5v Reference;
- 3.3V Digital I/O Operation;
- 0 - 2.5V Analog Input Range;
- SPI Mode 3.
- 1 MHz SPI Clock (For Lower Latency).

Figure: 3. The A/D Converter (Source: Analog Devices).

The Acquisition Module

Microcontroller - STM32 [5]

- 32 bit ARM Cortex M4;
- Optimized for Low Power;
- 256kB Flash/ 64kB RAM;
- 26 I/O, 5V tolerant;
- 3.3V Device;
- High Speed Internal (HSI) 32MHz Clock;

Figure: 4. The Microcontroller (CubeMX Utility View).

The Acquisition Module

Bluetooth Transceiver – HC-05 [6]

- Bluetooth 2.0 Technology;
- 3.5 - 5V Supply;
- Curent Draw: 35 – 40mA;
- Transparent Communication via UART;
- Configurable in AT Mode;
- Max UART Baud Rate: 921600bps ;
- 8 Data Bits, 1 Stop Bit, No parity

Figure: 5. HC-05 Module (Source: components101.com).

Figure: 6. Sample Stream through UART.

The Adapter

Adapter consists of:

1. Bluetooth Transceiver
2. UART-USB Converter

Figure: 7. Adapter Module

The Electrical Diagram

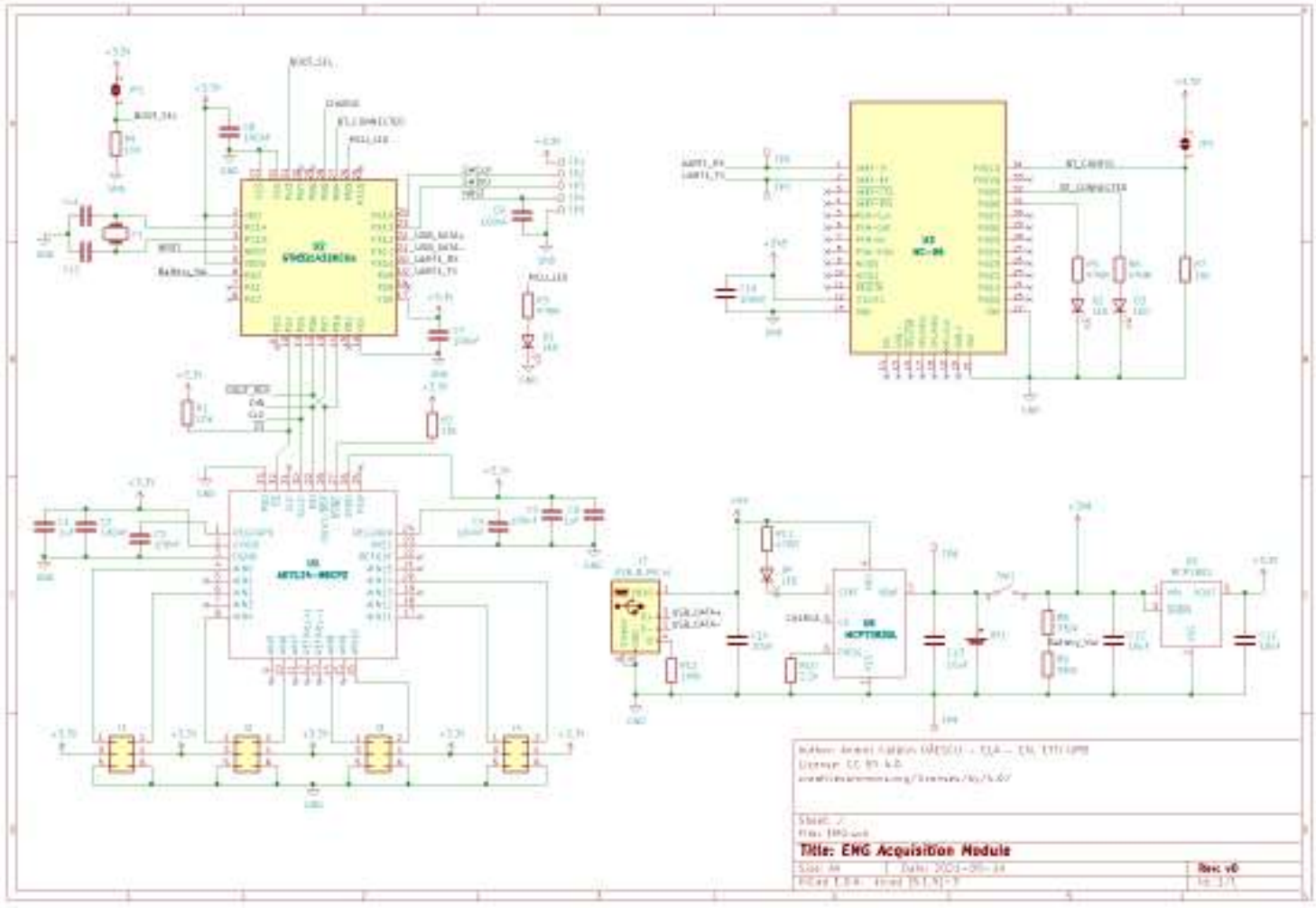

Figure: 8. Complete Electrical Diagram

The PCB

PCB Characteristics:

- Dimensions: 62 × 22 mm;
- FR4 Substrate, 0.8mm Thickness;
- 2 oz Copper, 2 Layers;
- ENIG Copper Finish;

Figure: 9. 3D Model of Prototype

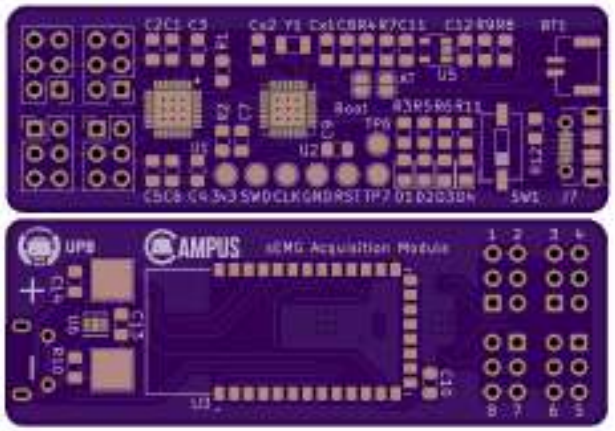

Figure: 10. OSHPark PCB

Figure: 11. Assembled Prototype

The Software

The Firmware

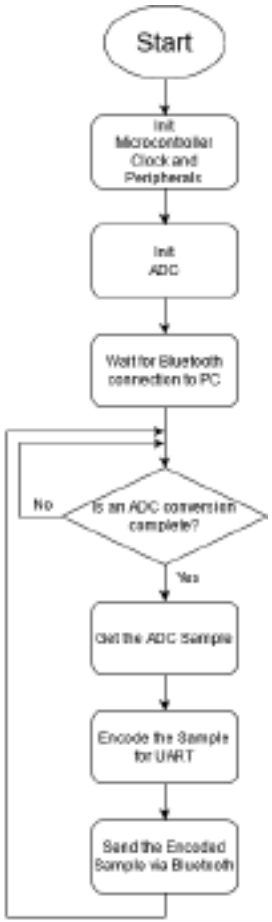

Figure: 12. Software Execution Flowchart

Firmware Characteristics:

- Embedded C;
- Low Level Framework used;
- 7.21 kB Flash with CMSIS;
- 1.53 kB RAM

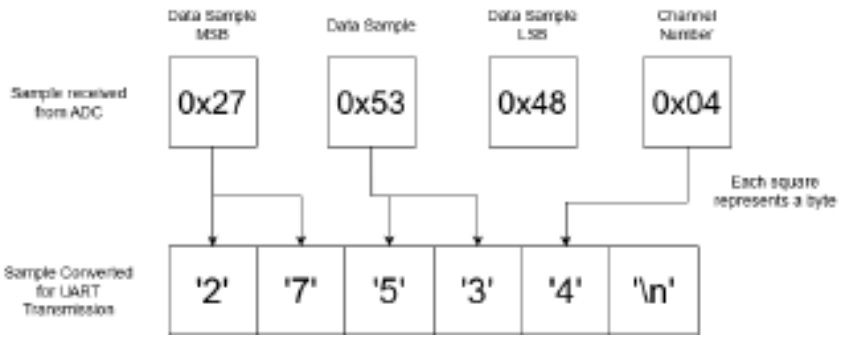

Figure: 13. UART Sample Encoding

[1] CMSIS = Common Microcontroller Software Interface Standard

The PC Program

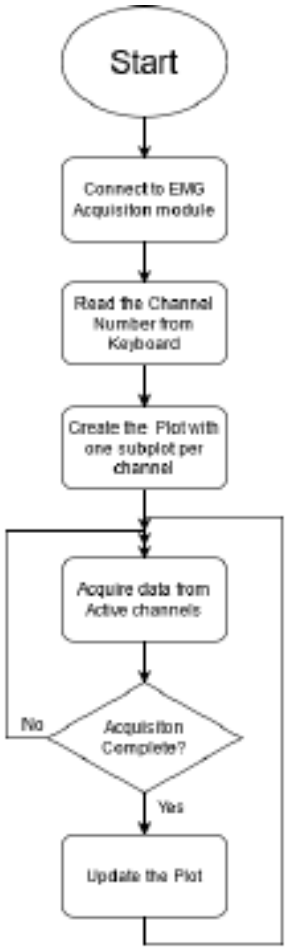

Figure: 14. Software Execution Flowchart

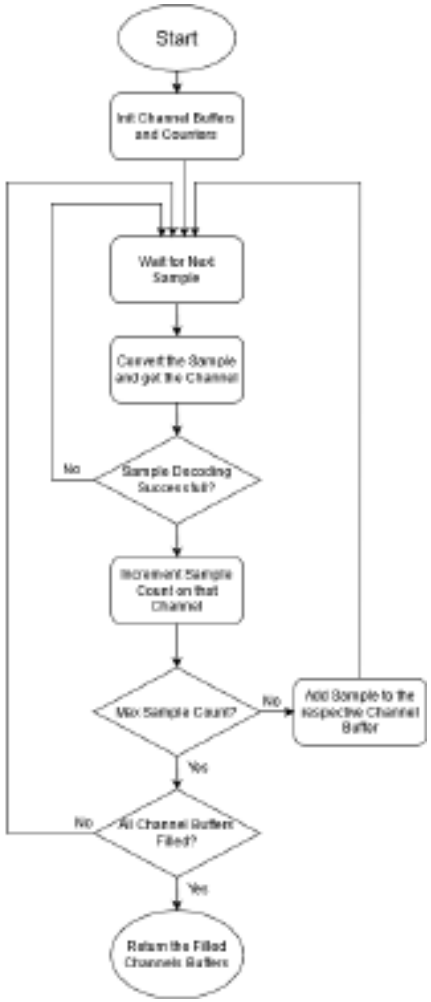

Figure: 15. Reception and Decoding Subroutine

Experimental Setup

OpenBCI

Characteristics		
Device	OpenBCI Cyton [7]	Prototype
Biopotential type	EEG, EMG, ECG	EMG
No. of Channels used	4	4
ADC Type	Sigma Delta	Sigma Delta
Precision (bits)	24	16
Conversion Type	Simultaneous	Sequential
Sample Rate (Sa/s)	250	360
Wireless	Yes	Yes
Easy to equip	No	Yes

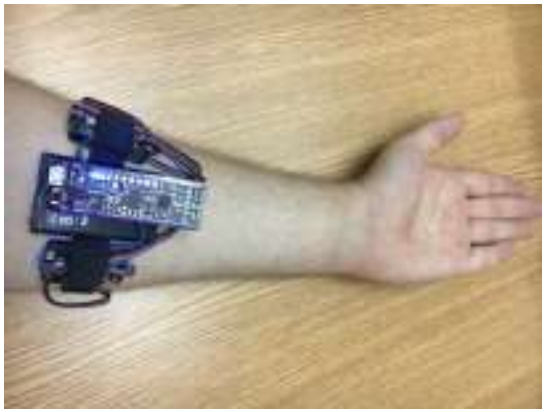

Figure: 16. Prototype Setup

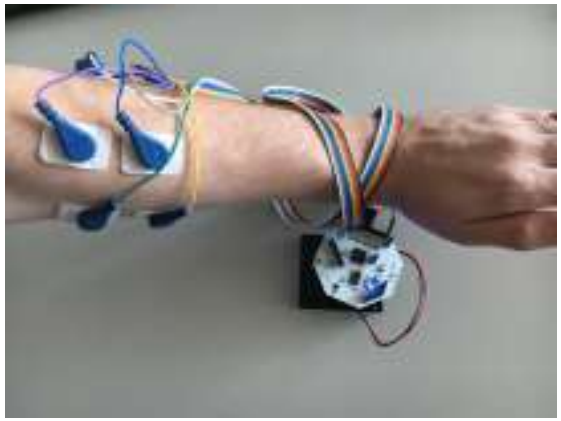

Figure: 17. OpenBCI Setup

Hand Gestures

Figure: 18. Resting Hand

Figure: 29. Wrist Extension

Figure: 20. Wrist Flexion

Figure: 21. Open Hand

Figure: 22. Fist

Figure: 23. Pronation

Figure: 24. Supination

Experimental Results

Time Domain Waveforms

Resting Hand

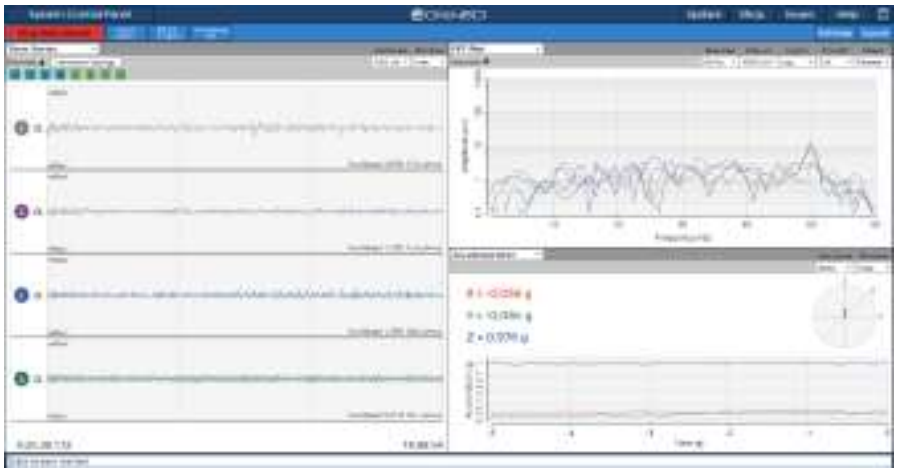

Figure: 25. Cyton Plot

Sampling Rate: 250Sa/s
Amplitude Scale: +/– 400uV
Time Scale: 5s
Noise Level: 17.7uVrms

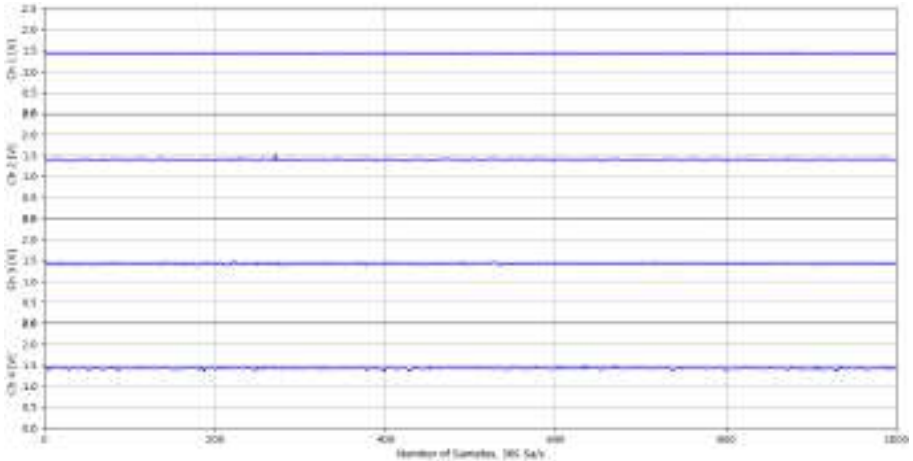

Figure: 26. Prototype Plot

Sampling Rate: 360Sa/s
Amplitude Scale: 0 – 2.5V
Time Scale: 2.5s
Noise Level: 17.7uVrms (x1000 Gain)

Time Domain Waveforms

Wrist Extension

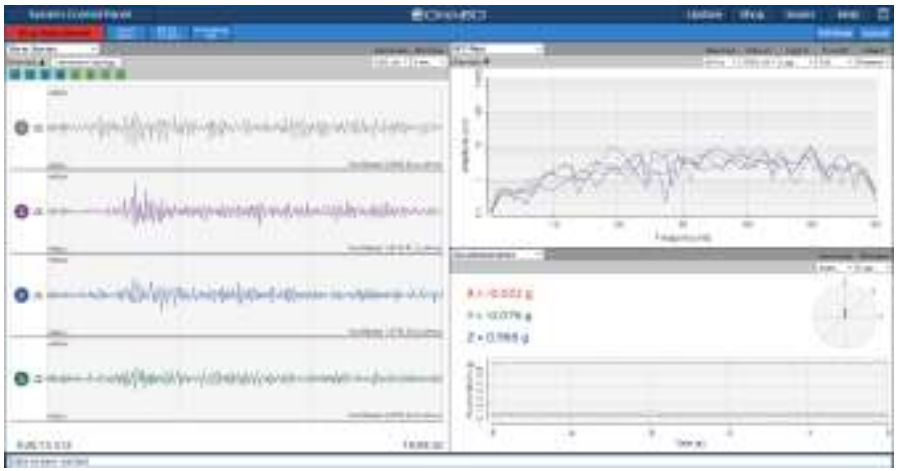

Figure: 27. Cyton Plot

Sampling Rate: 250Sa/s
Amplitude Scale: +/– 400uV
Time Scale: 5s
Noise Level: 17.7uVrms

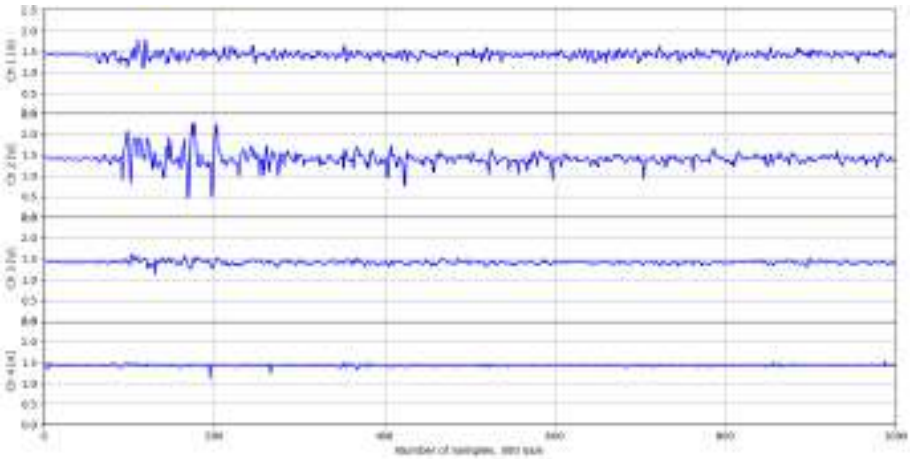

Figure: 28. Prototype Plot

Sampling Rate: 360Sa/s
Amplitude Scale: 0 – 2.5V
Time Scale: 2.5s
Noise Level: 17.7uVrms (x1000 Gain)

Time Domain Waveforms

Wrist Flexion

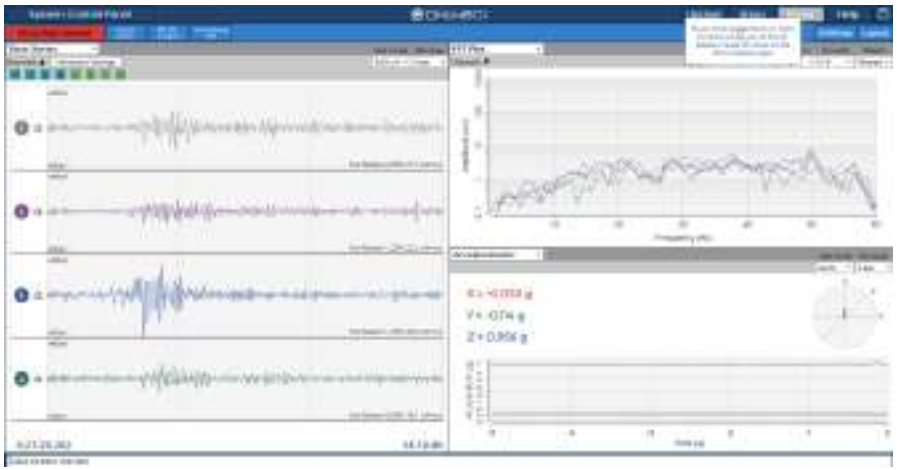

Figure: 29. Cyton Plot

Sampling Rate: 250Sa/s
Amplitude Scale: +/– 400uV
Time Scale: 5s
Noise Level: 17.7uVrms

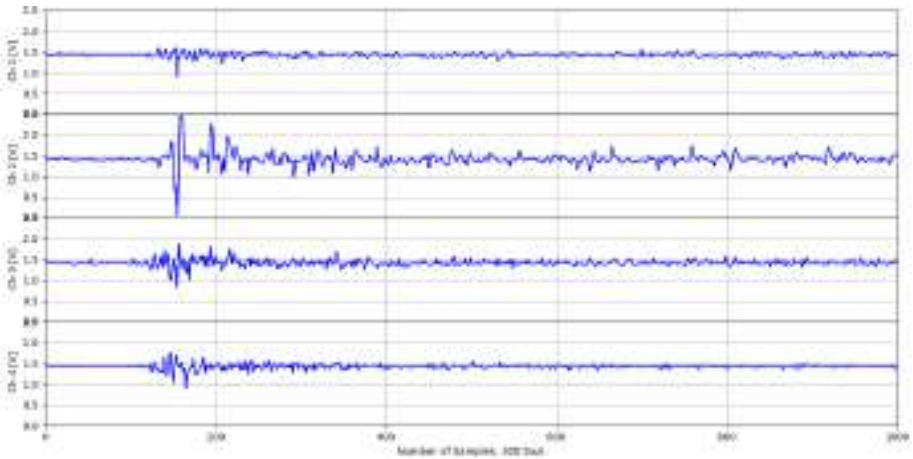

Figure: 30. Prototype Plot

Sampling Rate: 360Sa/s
Amplitude Scale: 0 – 2.5V
Time Scale: 2.5s
Noise Level: 17.7uVrms (x1000 Gain)

Time Domain Waveforms

Open Hand

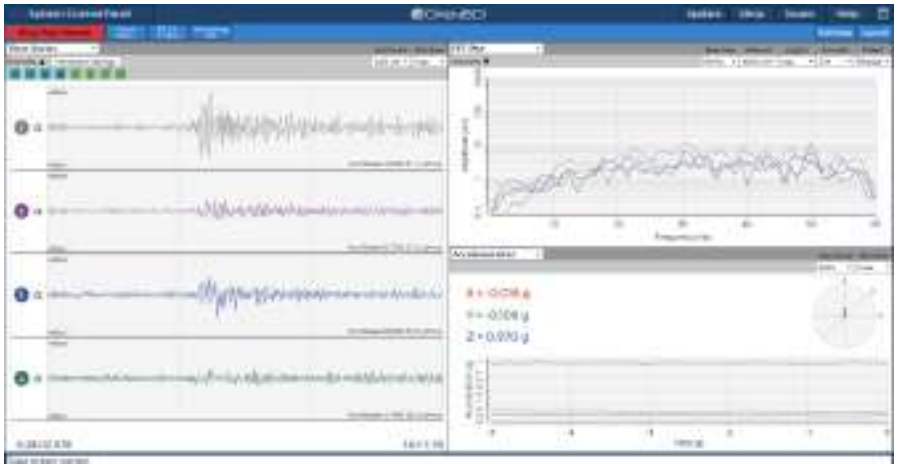

Figure: 31. Cyton Plot

Sampling Rate: 250Sa/s
Amplitude Scale: +/– 400uV
Time Scale: 5s
Noise Level: 17.7uVrms

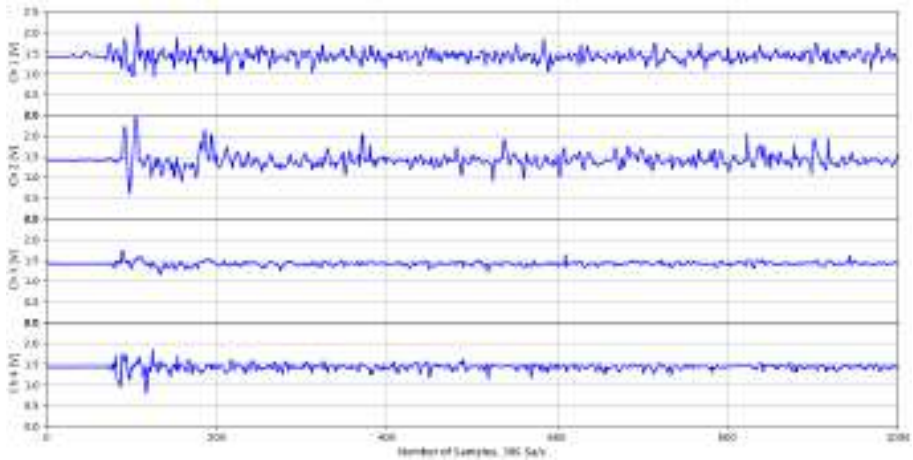

Figure: 32. Prototype Plot

Sampling Rate: 360Sa/s
Amplitude Scale: 0 – 2.5V
Time Scale: 2.5s
Noise Level: 17.7uVrms (x1000 Gain)

Time Domain Waveforms

Fist

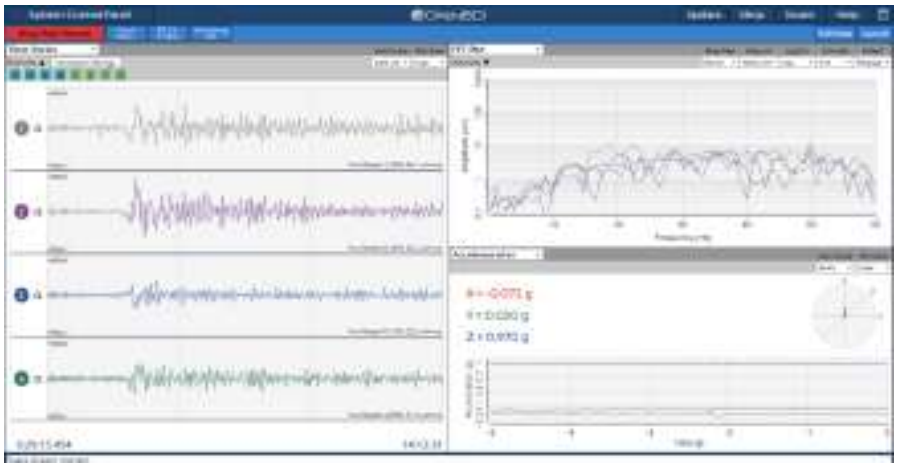

Figure: 33. Cyton Plot

Sampling Rate: 250Sa/s
Amplitude Scale: +/– 400uV
Time Scale: 5s
Noise Level: 17.7uVrms

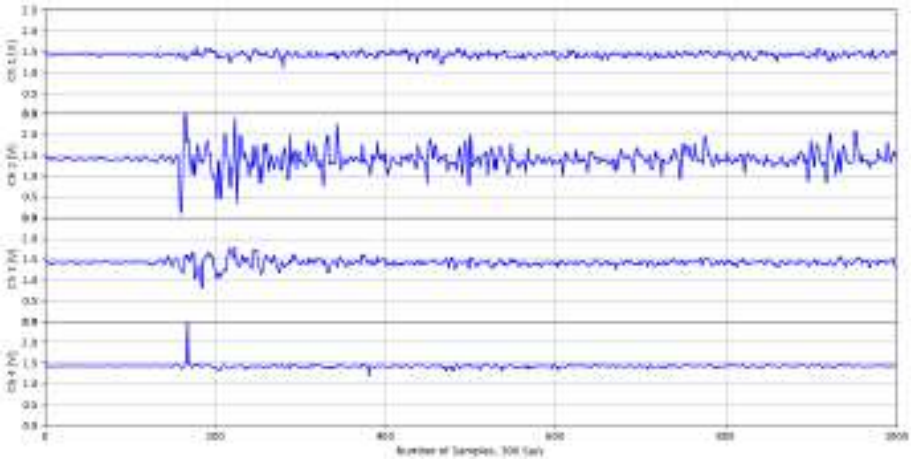

Figure: 34. Prototype Plot

Sampling Rate: 360Sa/s
Amplitude Scale: 0 – 2.5V
Time Scale: 2.5s
Noise Level: 17.7uVrms (x1000 Gain)

Time Domain Waveforms

Pronation

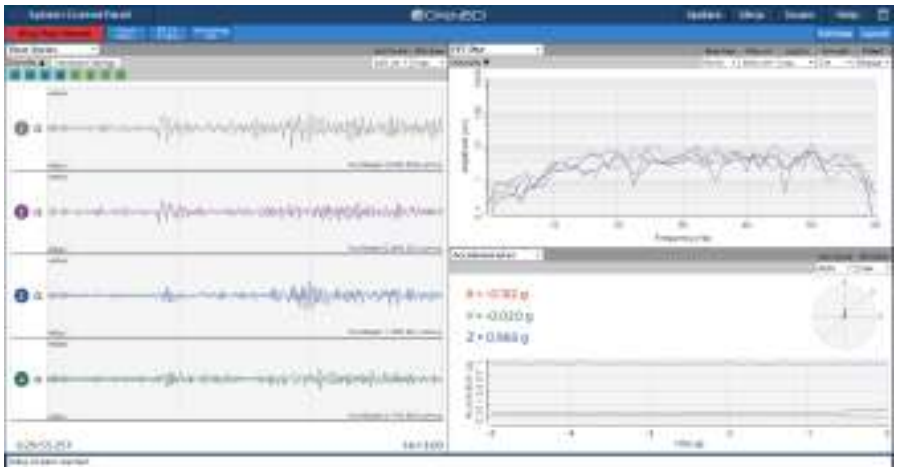

Figure: 35. Cyton Plot

Sampling Rate: 250Sa/s
Amplitude Scale: +/– 400uV
Time Scale: 5s
Noise Level: 17.7uVrms

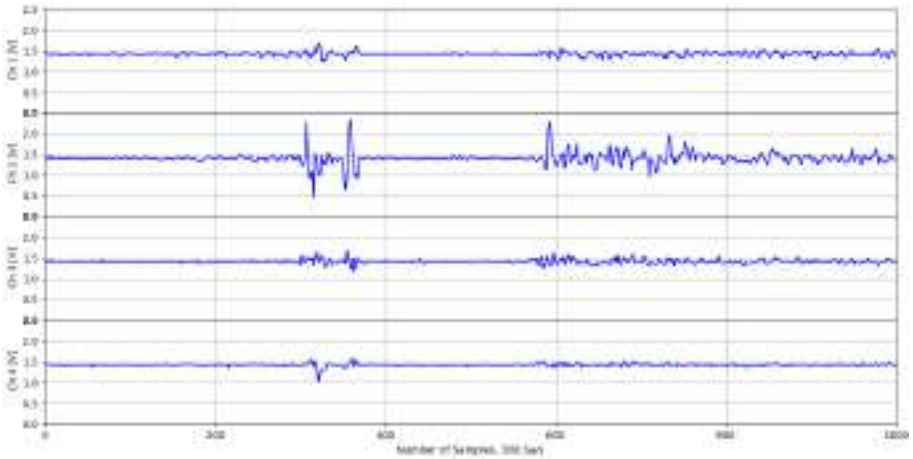

Figure: 36. Prototype Plot

Sampling Rate: 360Sa/s
Amplitude Scale: 0 – 2.5V
Time Scale: 2.5s
Noise Level: 17.7uVrms (x1000 Gain)

Time Domain Waveforms

Supination

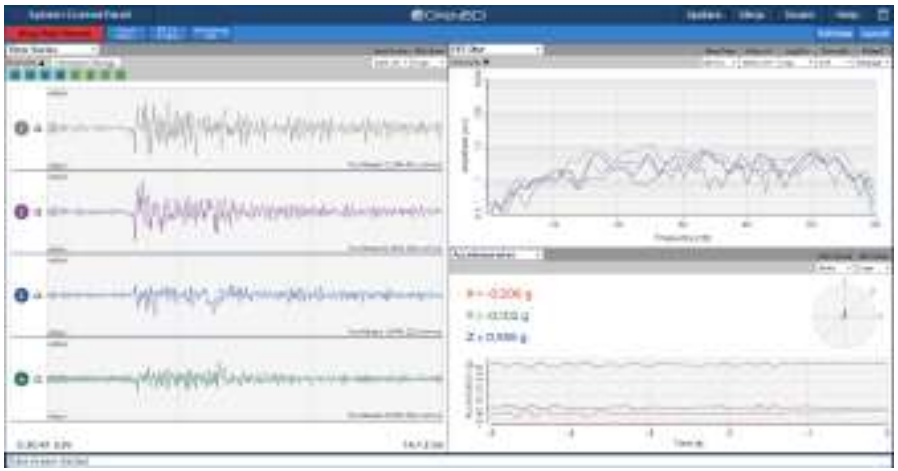

Figure: 37. Cyton Plot

Sampling Rate: 250Sa/s
Amplitude Scale: +/– 400uV
Time Scale: 5s
Noise Level: 17.7uVrms

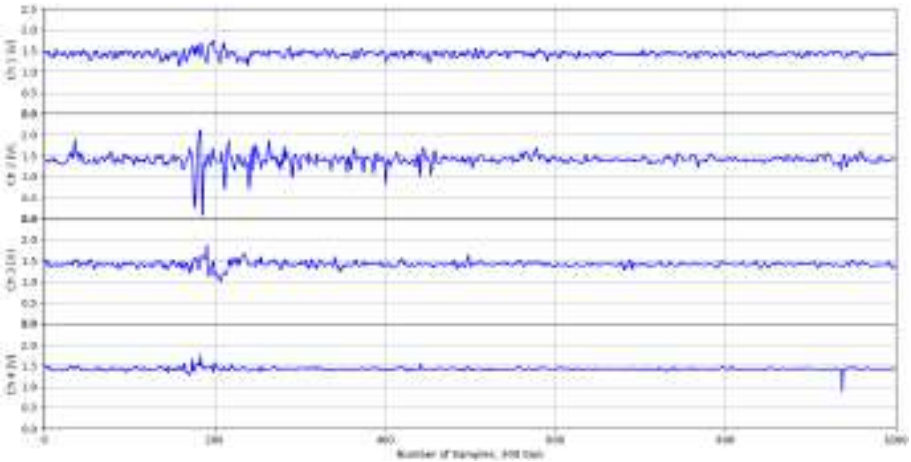

Figure: 38. Prototype Plot

Sampling Rate: 360Sa/s
Amplitude Scale: 0 – 2.5V
Time Scale: 2.5s
Noise Level: 17.7uVrms (x1000 Gain)

Conclusions

Conclusions

Project Conclusions

- Gestures are difficult to replicate;
- Sensor Positioning in Critical;
- Dry Sensors are comparable to Gelled Equivalent;

Contributions

- Designing and building the acquisition chain;
- Designing a wearable module;
- Comparing the types of sensors;

Further Improvements

- Replace MCU and Bluetooth with Wireless SoC;
- DMA communication on Acquisition Device;
- Multiprocessing in PC program;

References

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Thank You for Attention!
Questions?