DESIGN REVIEW 1.2 - Notorious EMG

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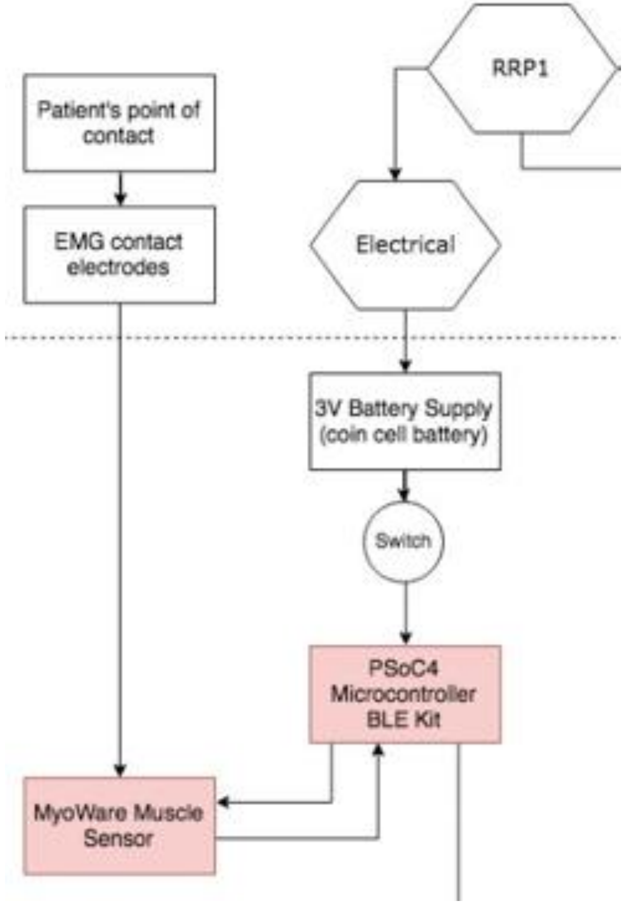
PROPOSED CRITICAL PATH DEVICE 1

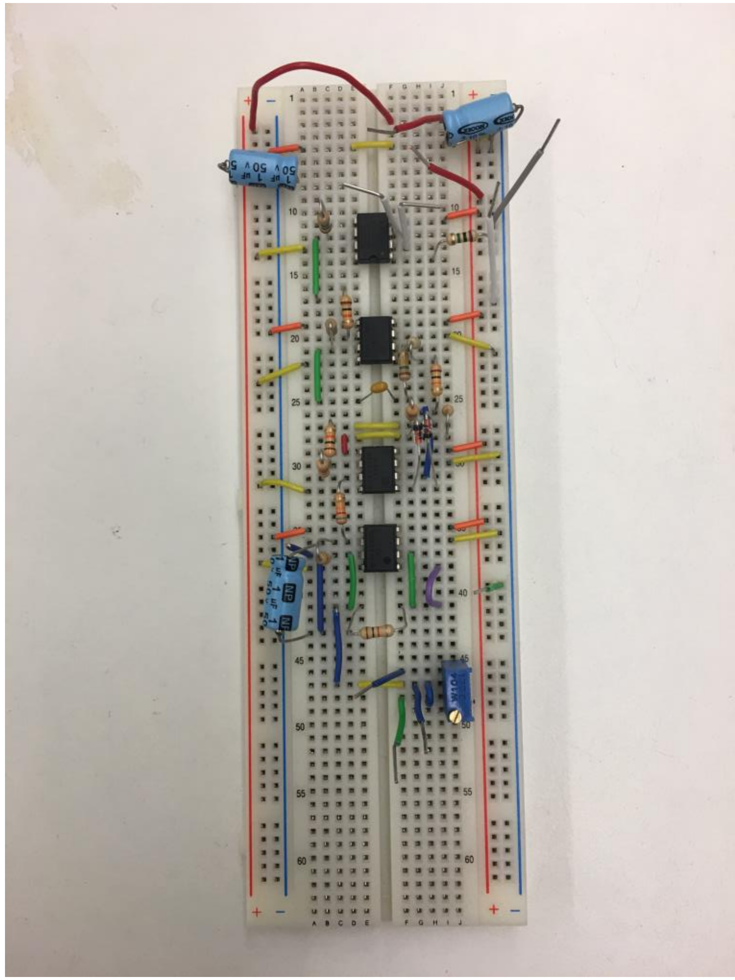
- MyoWare Muscle Sensor interfacing with Bluetooth embedded PSoC4 MCU
- Transmit muscle data wireless via Bluetooth to an output terminal

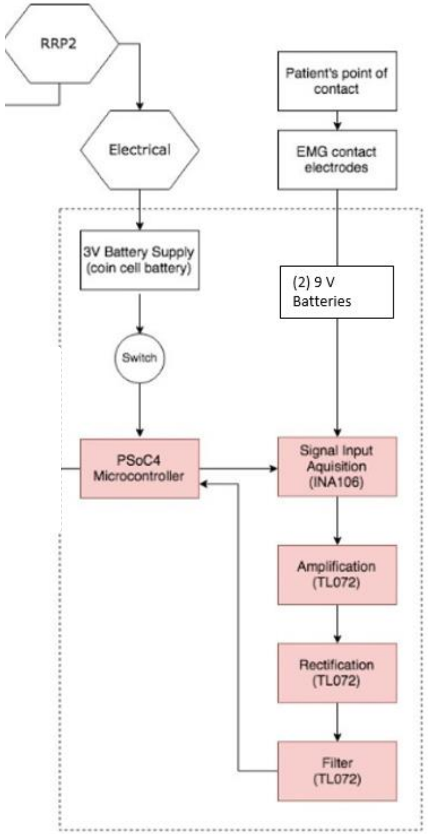


PROPOSED CRITICAL PATH DEVICE 2

- Signal Conditioning Unit (SCU) to replicate MyoWare Muscle Sensor

- Signal Acquisition
- Amplification
- Rectification
- Smoothing & Final Amplification

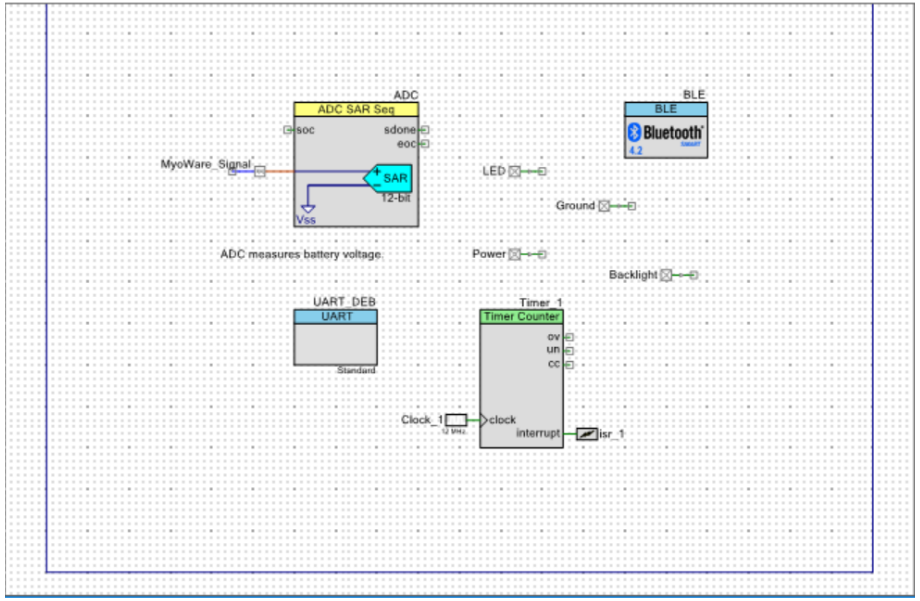


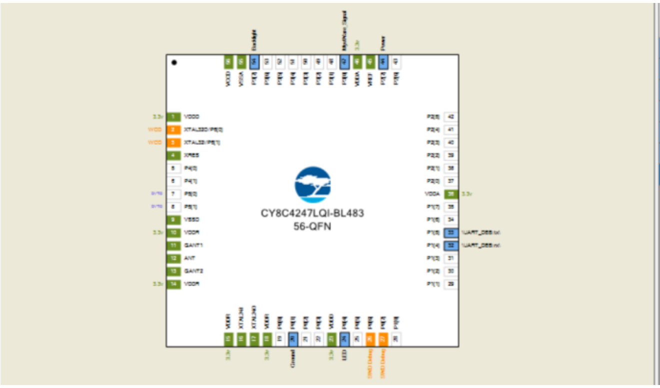


RISK REDUCTION PROTOTYPE 1

Start Page | *main.c | TopDesign.cysch | Interrupt_A.c | Interrupt_A.h | MiniScope.cydwr

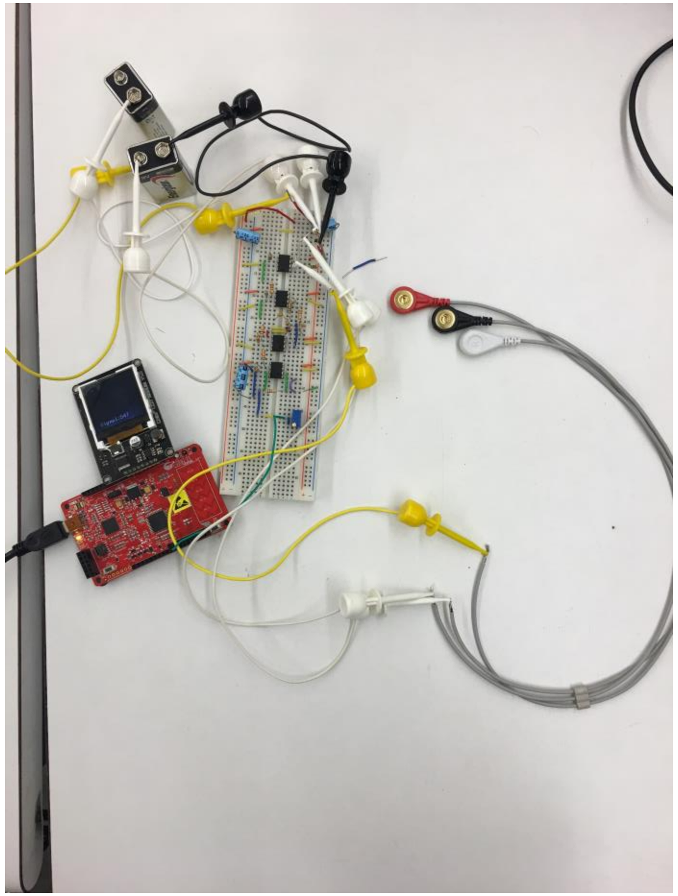
```c
Timer_Start();
Interrupt_A_Start();
ADC_Start();
ADC_StartConvert();

int timerPeriod= 0; //variable for writing period
char digits[20]; //char array to hold frequency value
int ADC_Voltage = 0; //initial muscle voltage
    for(;;)
    {
        CyGlobalIntDisable; //disable interrupts
        if(ADC_IsEndConversion(ADC_RETURN_STATUS)) //check the ADC to see if done converting
        {
            ADC_Voltage = (ADC_GetResult16(0))*(5.0/1023.0);
                Timer_WritePeriod(timerPeriod);
                sprintf(digits, "Signal:%d ", ADC_Voltage);
                GLCD_PrintString(digits, 105, 10, GLCD_WHITE, GLCD_BLACK);//display muscle signal to screen
                Timer_ClearInterrupt(Timer_GetInterruptSource());//make way for next interrupt
                CyDelay(150);
            }
        }
        CyGlobalIntEnable;//reenable interrupts

    }
```



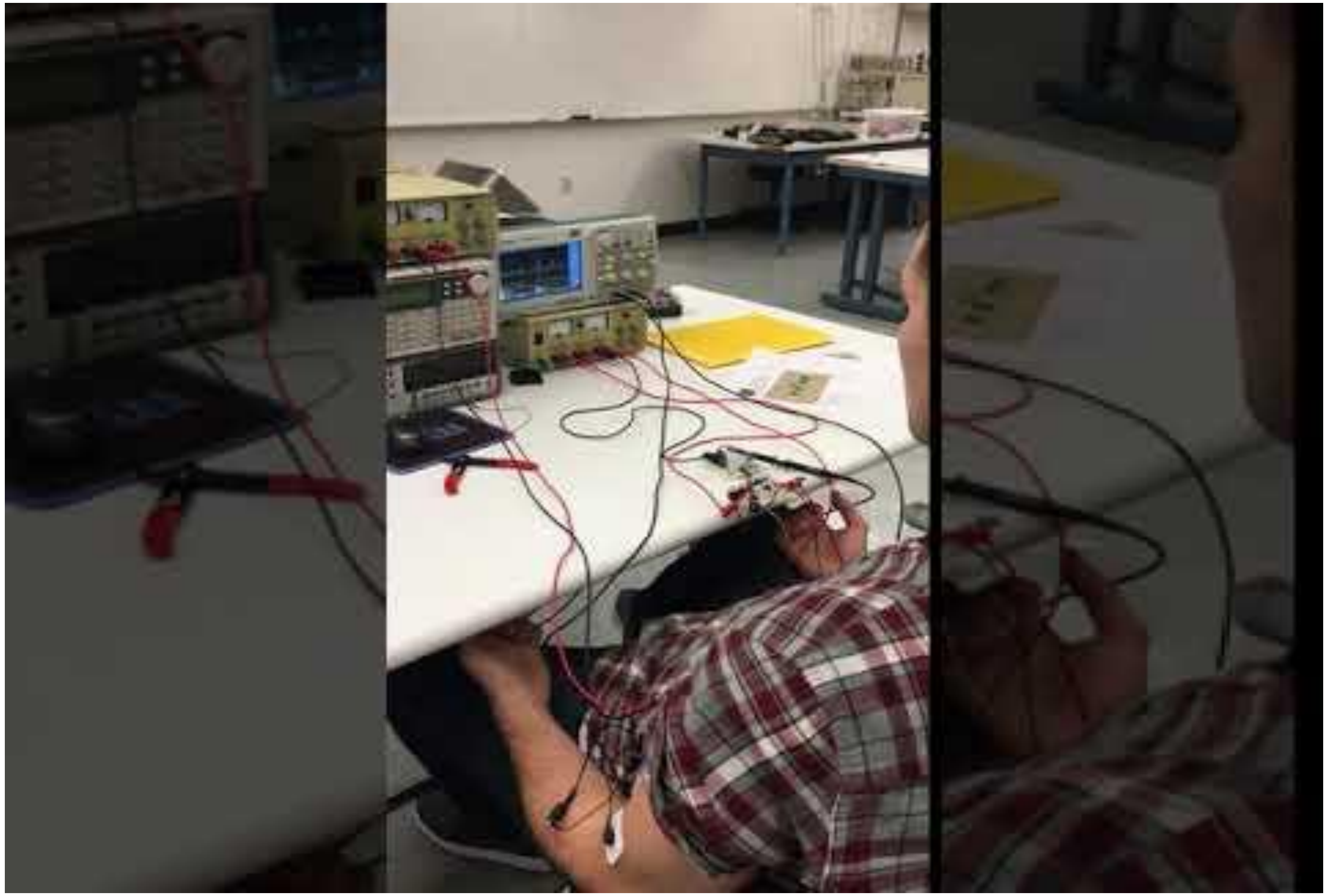


Name	Port	Pin	Lock
\UART_DEB:rx\	P1[4]	32	☑
\UART_DEB:tx\	P1[5]	33	☑
Backlight	P3[7]	54	☑
Ground	P0[1]	20	☑
LED	P0[4]	24	☑
MyoWare_Signal	P3[0]	47	☑
Power	P2[7]	44	☑

RISK REDUCTION PROTOTYPE 2



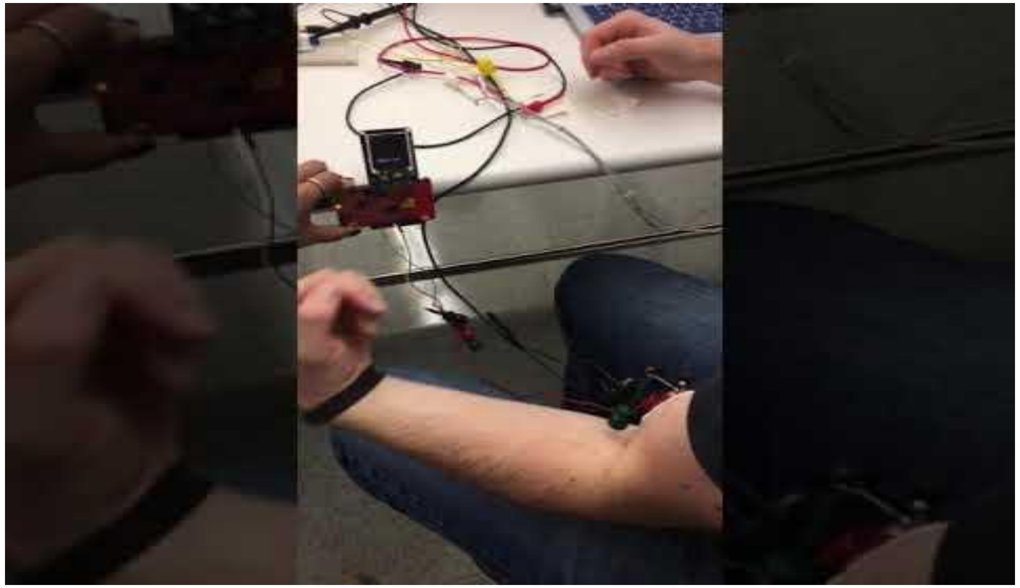
Final SCU integrated with PSoC4, output to EMG electrodes, and powers by (2) 9V batteries



Output signal of SCU compared to MyoWare Muscle Sensor output

RRP1 Specification Demonstration

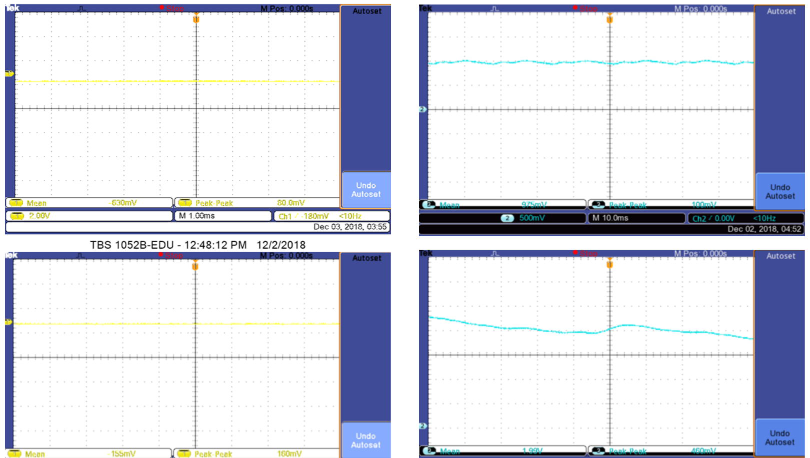
ID	Threshold	Objective	Observed
EMG001 – EMG Integration	Integrated with PSOC4	N/A	Displayed difference: ~980 Relax: ~-540 Contract: ~440
EMG002 – Wireless Data Acquistion	20 feet	30 feet	



EMG001 - Detects when muscles contracted. Observed through value increase read on GLCD screen

RRP1 Specification Demonstration

ID	Threshold	Objective	Observed
EMG003 – Data Processing & Reporting	Accurate set of data output	N/A	MyoWare & SCU avg. voltage - 53% difference
EMG004 – Wireless Data Rate	Compliant with Bluetooth 4.1	Compliant with Bluetooth 4.2	Datasheet maximum throughput: 950kbps



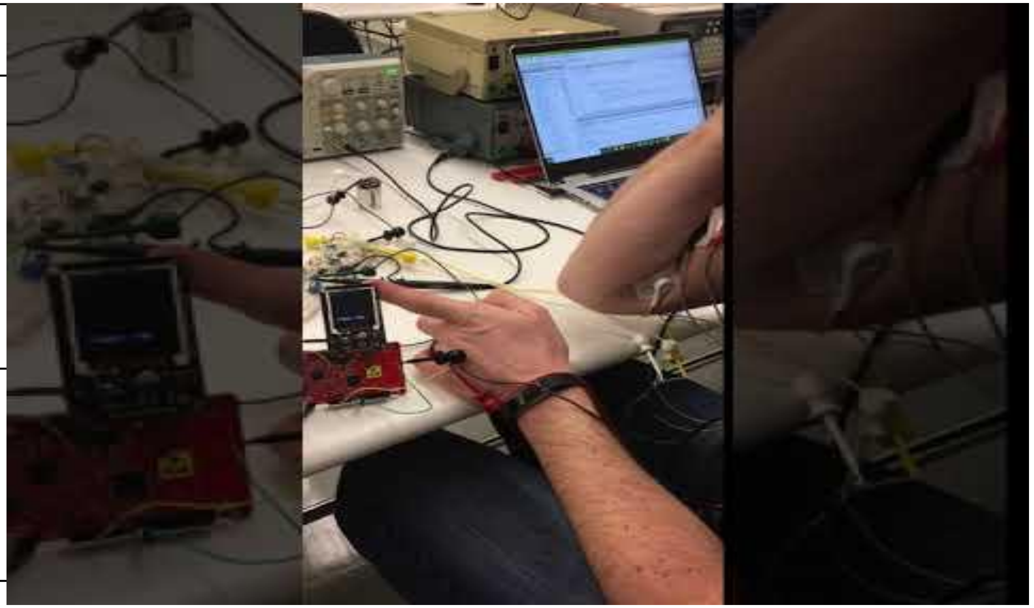
EMG004 -
Resting mean voltage (SCU): 630mV
Contracting mean voltage (SCU): 155mV
Voltage difference: 475mV

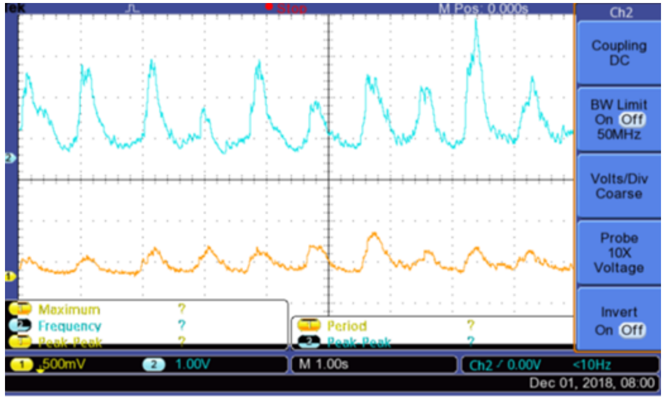
Resting mean voltage (MyoWare): 975mV
Contracting mean voltage (MyoWare): 1.99V
Voltage difference: =1.015V

Because the gain of the SCU is half the MyoWare, the desirable percent difference is doubled. Corresponding to the amplitude discrepancy, the data output still yields accurate results

RRP2 Specification Demonstration

ID	Threshold	Objective	Observed
CU001 – EMG Integration	Integrated with PSOC4	N/A	Displayed difference: ~300 Relax: ~-500 Contract: ~-800
CU002 - SCU	Within 5% peak voltage	N/A	Half amplitude



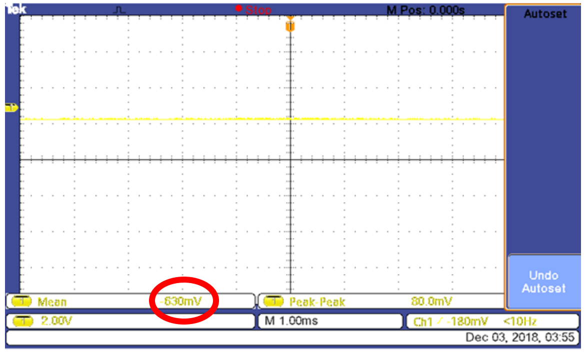


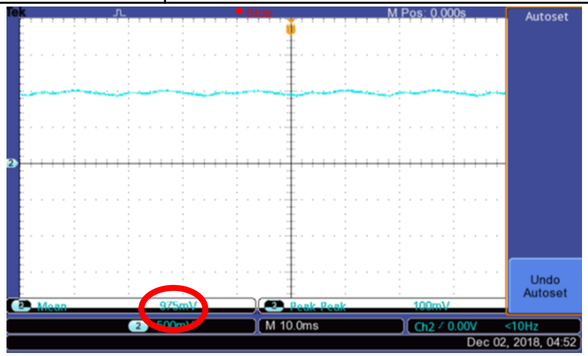
CU002 – Successfully recifies, filters, and amplifies raw EMG signal. Spec not fully met due to smaller amplitude compared to MyoWare Muscle Sensor

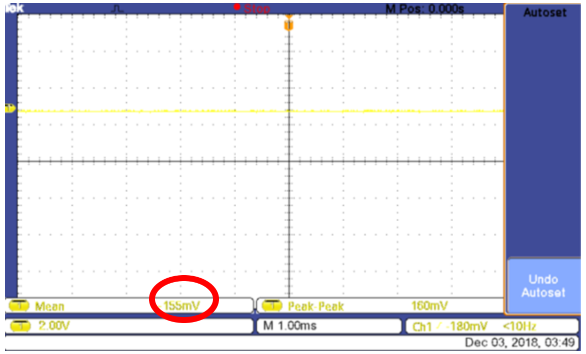
CU001 - Detects when muscles contracted. Observed through value increase read on GLCD screen

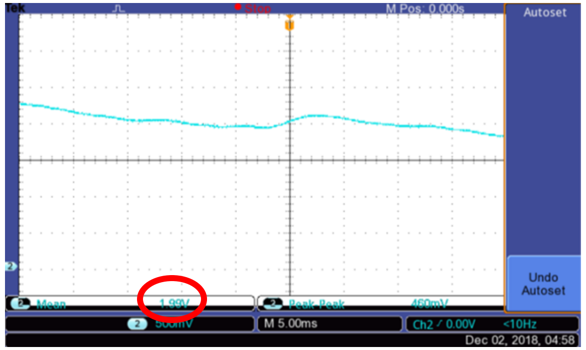
RRP2 Specification Demonstration

ID	Threshold	Objective	Observed
CU003 – Data Processing & Reporting	Accurate set of data output	N/A	MyoWare & SCU mean voltage - 53% difference









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CRITICAL DESIGN SPECIFICATIONS 1

ID	Threshold	Objective	Verification	Met?
EMG001: EMG Integration	Integrated with PSOC4	N/A	Oscilloscope	Yes
EMG002: Wireless Data Acquisition	20 feet	30 feet	Varying distances	No
EMG003: Data Processing & Reporting	Accurate set of data output	Linear correlation between MyoWare and SCU voltage values	MyoWare comparison	Yes
EMG004: Wireless Data Rate	Bluetooth 4.1 compliant	Bluetooth 4.2 compliant	Datasheet	Yes

CRITICAL DESIGN SPECIFICATIONS 2

ID	Threshold	Objective	Verification	Met?
CU001: EMG Integration	Integrated with PSOC4	N/A	Oscilloscope	Yes
CU002: Signal Conditioning Unit	5% within MyoWare peak voltage	N/A	MyoWare Comparison	No
CU003: Data Processing & Reporting	Accurate set of data output	N/A	MyoWare Comparison	Yes

ENGINEERING ANALYSES

Mechanical Analyses

- **Heat Dissipation:** Calculate heat transfer to determine possible heat sink implementation
- **Safety Analysis:** The device must avoid the risk of shocking the patient. FDA Compliance to ensure the amount of contact the user has with electrical current is safe and allowed
- **Weight & Size Analysis:** Ensure this device does not hinder user's exercise. The vision for this device is to be to the size and weight of cell phone

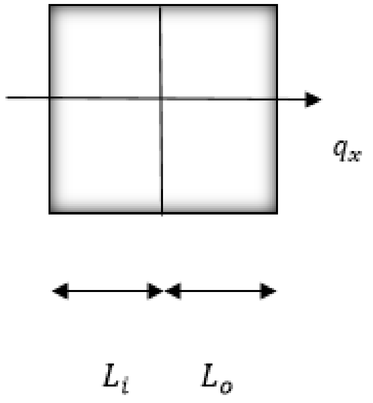
Electrical Analyses

- **Power Consumption:** Yield the smallest power source needed for the device to function over long periods of time and portable for the user
- **Data Rate Analysis:** The data sampled by the EMG electrodes must report accurate data in real-time successfully store and trigger the alert system
- **Data Storage Analysis:** The data sampled must store directly to the MCU. The amount of RAM on the MCU will need to accommodate the amount of data sampled and stored

Engineering Analyses – Heat Dissipation

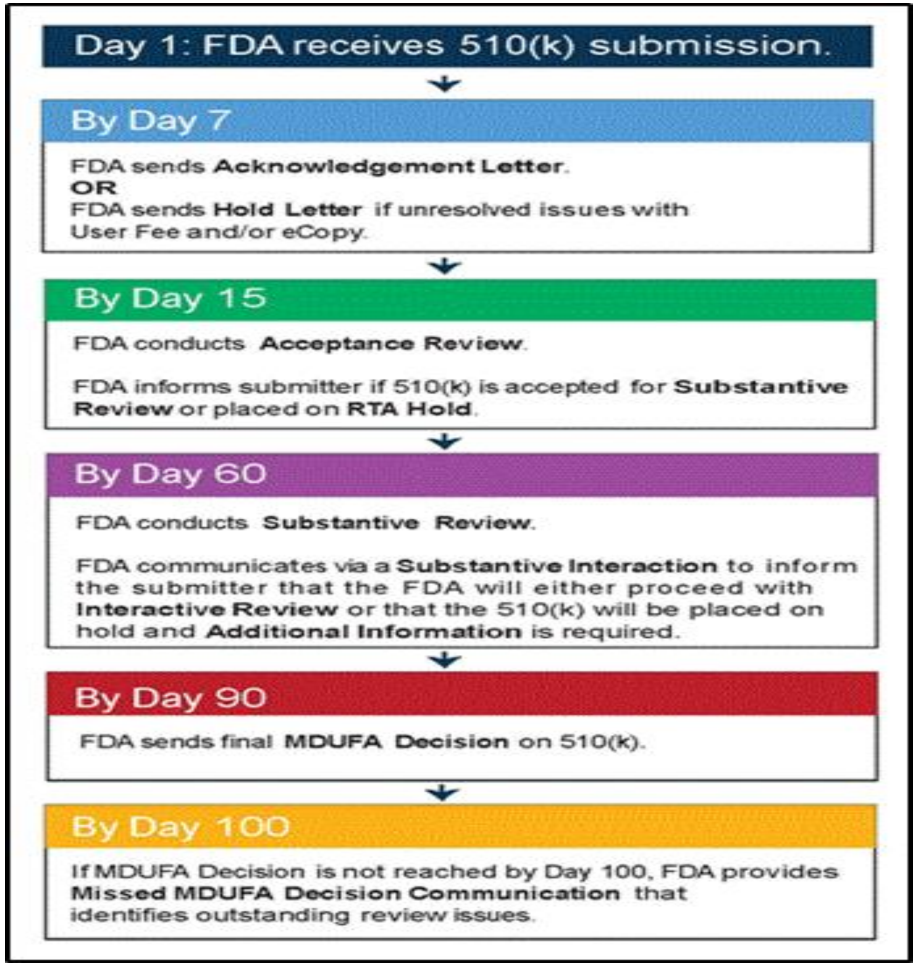
- Using the heat equation coupled with the lumped capacitance method, we compute the heat flux through the walls
- Conduction and convection coefficients can be applied once material choice is decided upon
- Since our electronics operate at low current and energy levels, heat transfer analysis concludes no need for a heat sink

1. $\rho c_p \frac{\partial T}{\partial t} = \frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right) + \frac{\partial}{\partial y}\left(k\frac{\partial T}{\partial y}\right) + \frac{\partial}{\partial z}\left(k\frac{\partial T}{\partial z}\right) + \dot{q}$ Where, k=constant
2. $0 = \frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right)$ We can solve this given two boundary conditions. T(x=0)=T_1 ; T(x=L)=T_2
3. $\int \frac{d^2T}{dx}dx = \int 0\, dx \longrightarrow \int \frac{dT}{dx}dx = \int c_1 dx$
4. T(x) = $c_1 x + c_2 \longrightarrow T(x = 0) = c_2 \longrightarrow T_1 = c_2$
5. $T(x = L) = c_1 L + T_1 \longrightarrow T(x) = \frac{T_2 - T_1}{L}x + T_1$
6. And $T_1 > T_2 \longrightarrow q_x'' = -k\frac{\partial T}{\partial x} = -k\frac{d}{dx}\left(\frac{T_2-T_1}{L}x + T_1\right) = k\frac{T_1 - T_2}{L} = \frac{T_1 - T_2}{\frac{L}{k}}$
7. Even further.... $q_x = q_x'' A = \frac{T_1 - T_2}{\frac{L}{k}}A = \frac{T_1 - T_2}{\frac{L}{kA}}$
8. $R_{eff} = \frac{1}{h_i A} + \frac{L_i}{k_i A} + \frac{L_o}{k_o A} + \frac{1}{h_o A}$ Units: $\frac{K}{W}$
9. $q_x = \frac{T_{\infty,i} - T_{\infty,o}}{R_{eff}}$
10. $q_x'' = \frac{q_x}{A_x}$



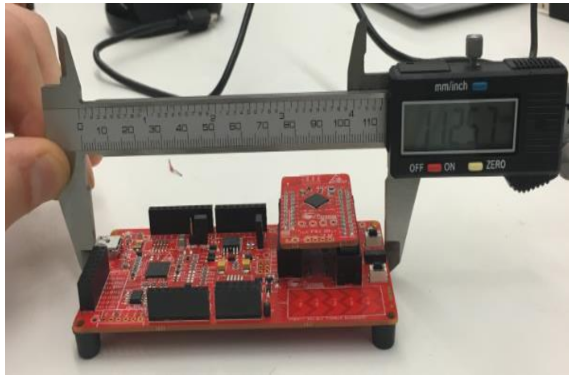
Engineering Analyses – Safety and FDA Compliance

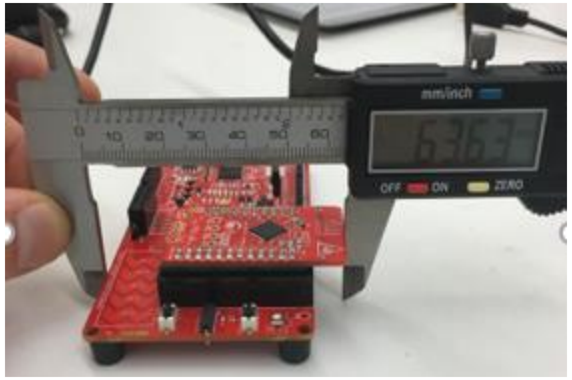
- Surface electromyography (SEMG) devices approved by the U.S. Food and Drug Administration (FDA) include those that use a single electrode or a fixed array or multiple surface electrodes
- A 510(k) form must be submitted to the FDA for review (Goal: marketing clearance)
- 3 mA is the threshold of sensation, severe shock at 50 mA, and death at 100 mA



Engineering Analyses – Size & Weight

- A size and weight analysis for RRP1 versus RRP2 was conducted. Results show RRP1 is preferred since mass and size are half RRP2's.
- Objective is to minimize mass while providing enough stiffness to withstand abuse
- Priorities: Safety, ease of use, and effectiveness





	Quantity	Weight (g)	Dimensions (mm)
MyoWare Sensor	1	7.8	53 x 22 x 5
PSOC4 BLE	1	87.7	113 x 64 x 23
Coin Cell Battery (3V)	1	3.0	20 (dia.) x 3 (t)
Total	3	98.5	Area = 117,983 mm^3

Engineering Analyses – Power Consumption

- Using a coin cell battery for RRP1 that provides up to 235 mAh, with an average current draw of 14.02 mA in total, there is an expected lifespan of 16.76 hours for RRP1
- For RRP 2, 9 V batteries provide 8.75 hours on a 50 mA draw, and the SCU consumes a total of 298.52 mW

Component	Volts (V)	Current (A)	Power Consumed (W)
1NA106	18	2.00E-03	0.036
R1- 1M Ω	2.18E-03	2.18E-09	4.73498E-12
R6 – 150 Ω	1.59E-02	1.05E-07	1.64065E-09
R7 - 10 kΩ	2.11E-06	3.04E-10	6.40385E-16
R8 - 10 kΩ	2.11E-06	3.04E-10	6.40385E-16
D1 - Signal Diode	1.51E-05	2.07E-09	3.13191E-14
D2 - Signal Diode	1.07E-05	7.57E-10	8.10204E-15
R9 - 10 k Ω	6.55E-06	9.43E-10	6.17744E-15
R16 - 585 Ω	8.93E-05	6.12E-03	5.46516E-07
100 kΩ Pot	2.80E-06	3.14E-09	8.792E-15
R5 - 150 kΩ	2.35E-06	1.57E-11	3.6895E-17
R14 - 1 kΩ	7.79E-06	1.12E-04	8.68585E-10
R13 - 80.5 kΩ	7.80E-06	9.65E-11	7.527E-16
C3 - 1 µF	7.78E-06	9.66E-11	7.51548E-16
C4 - 0.01 µF	1.57E-02	1.05E-07	1.64065E-09
R12 - 80.6 kΩ	1.26E-05	1.56E-10	1.96812E-15
R11 - 10 kΩ	6.98E-06	6.98E-10	4.87064E-15
R10 - 10 kΩ	6.53E-06	6.53E-10	4.26278E-15
C2 - 1 µF	0	0	0
R3 - 10 kΩ	1.05E-03	8.88E-05	9.31875E-08
R2 - 1 MΩ	1.23E-03	1.24E-08	1.525E-11
R4 -150 kΩ	1.57E-02	1.05E-07	1.64065E-09
Total		8.32E-03	0.0360

Engineering Analyses – Data Rate

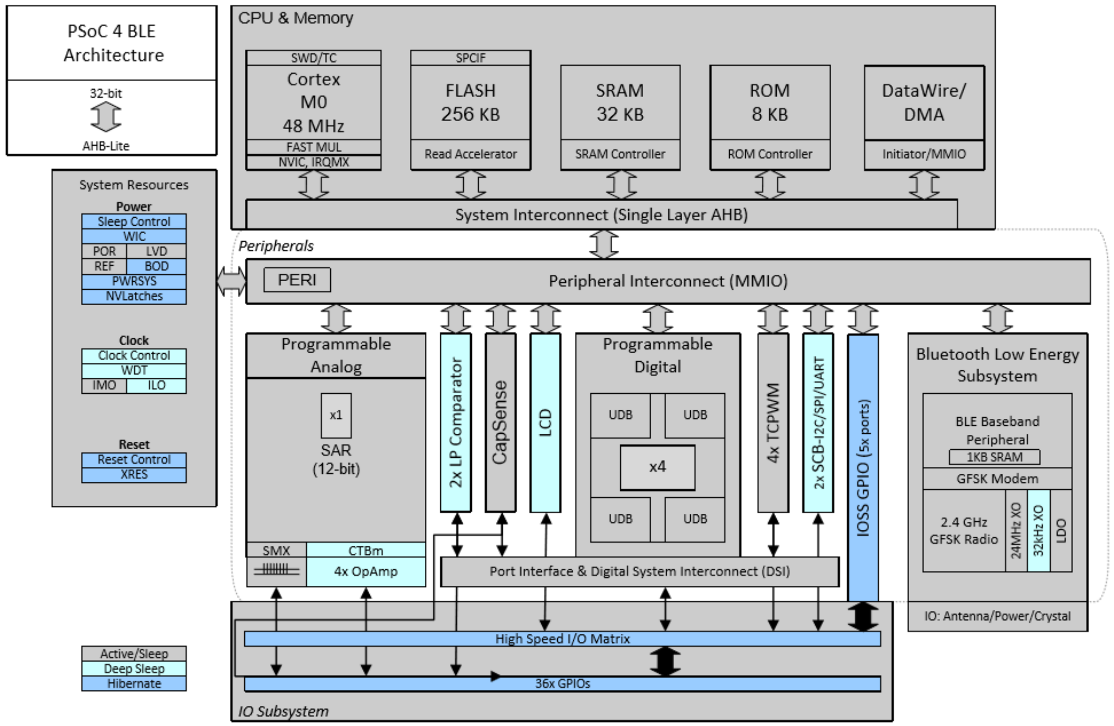
- From datasheet, maximum internal clock speed is 48 MHz (1 command / 21 ns)
- For purpose of "real-time," 21 ns per command is satisfactory
- The throughput is around 950 kbps for RRP1

$$\text{Throughput} = \frac{payload\ size\ (bytes)}{transaction\ time\ (seconds)}$$

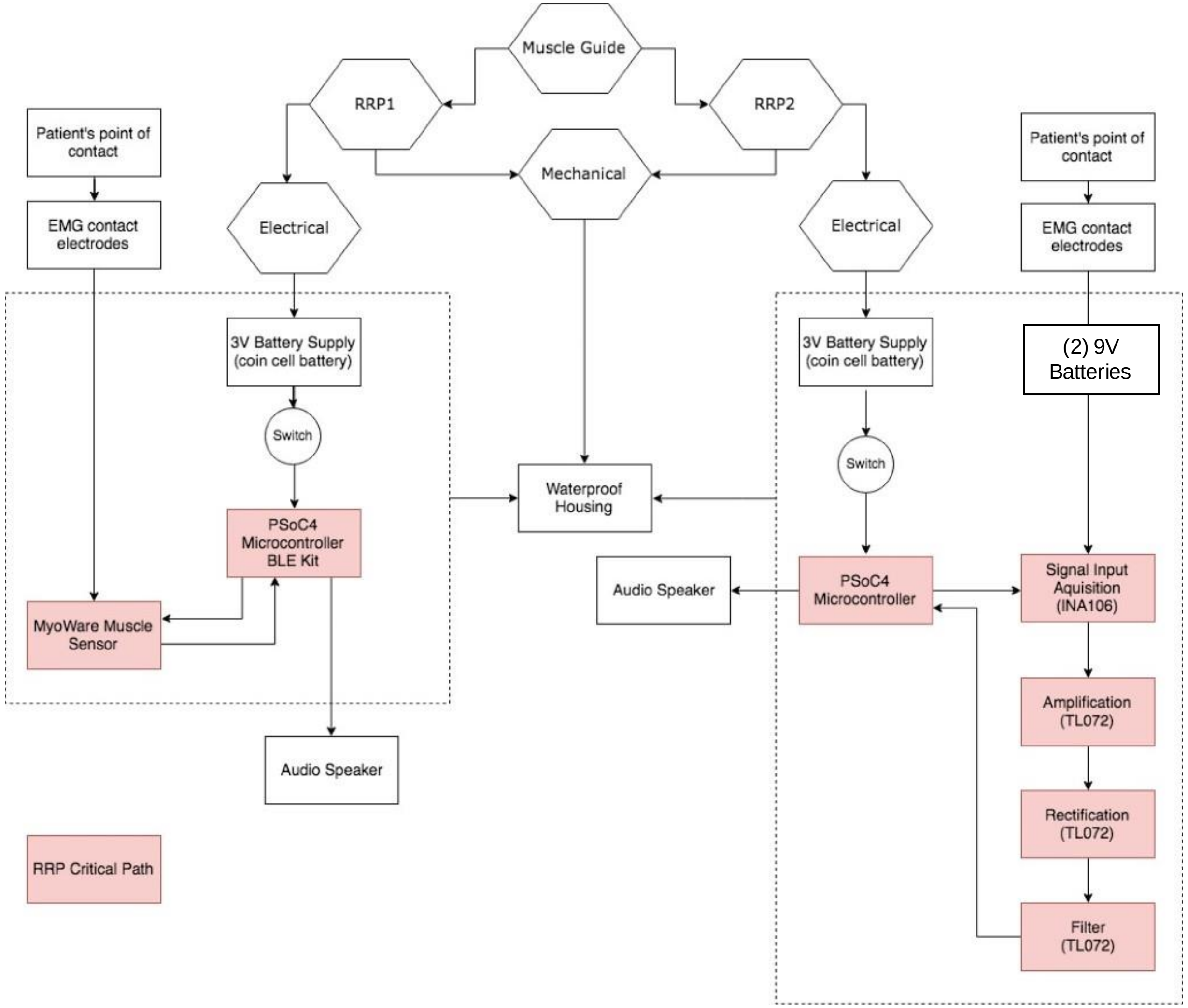
Engineering Analyses – Data Storage

- 256 kB flash
- Up to 32 kB SRAM
- 32-Bit MCU
- Flash for sorting through data, SRAM for storing
- Values determined from PSoC4 datasheet
- Approx. 12 kB SRAM used in writing program of 16.3 free kB

Figure 4. PSoC 4 BLE Architecture (CY8C4248-BL)



CONCEPT REVIEW – SYSTEM BLOCK DIAGRAM



WINTER SCHEDULE

Winter Break:

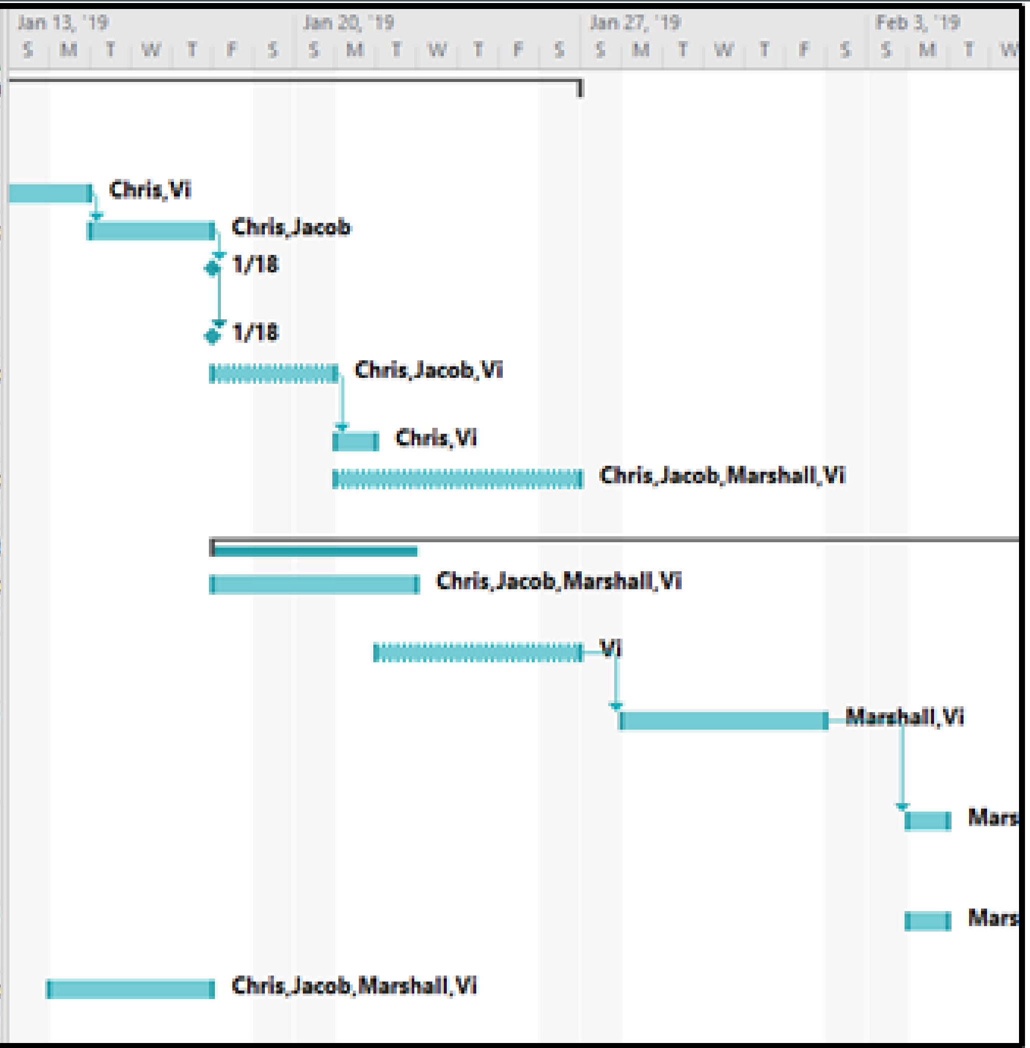
- Discuss project scope change – PT vs. Athletes

Immediate Tasks (First Week):

- PCB Signal Conditioning Unit
- Determine data destination
- Meet with Excel-o-meter alums

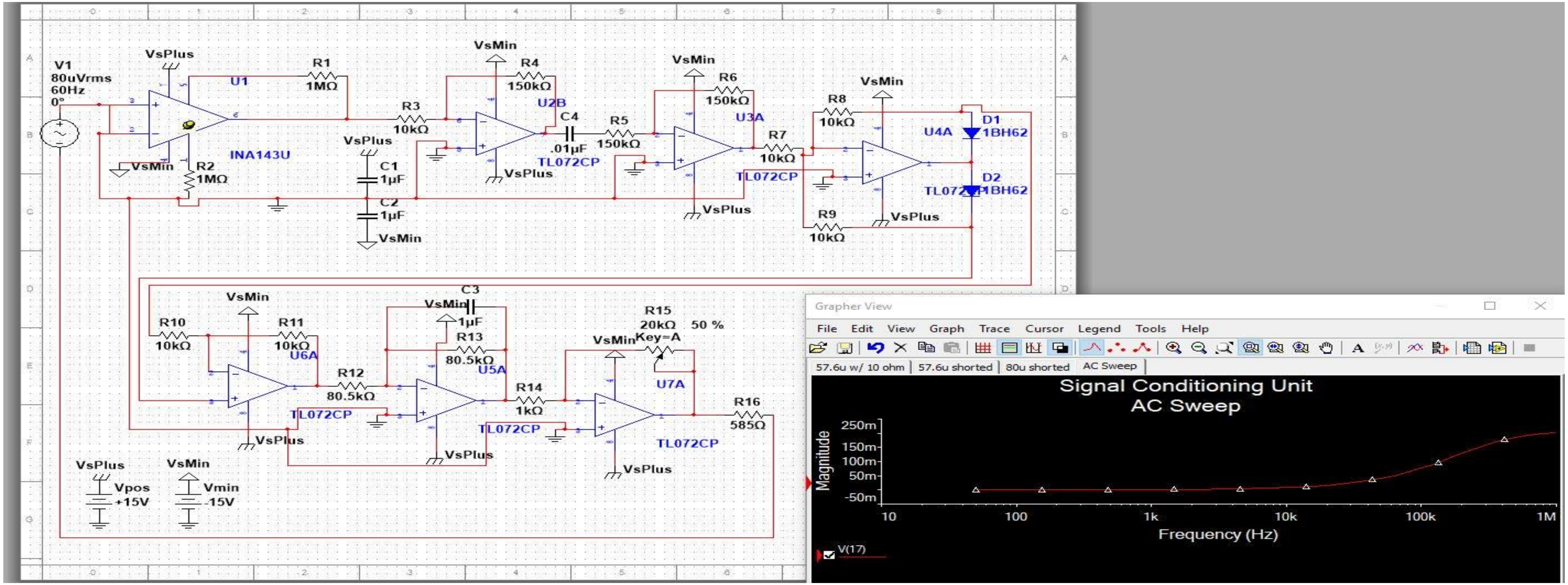
WINTER SCHEDULE

Task Name	Duration	Start	Finish		Resource Names
BLE and PCB Group	18 days	Wed 1/2/19	Sat 1/26/19		Vi, Chris, Ja
Write and Finish BLE Code	5 days	Wed 1/2/19	Tue 1/8/19		Vi
Test BLE Code	4 days	Wed 1/9/19	Mon 1/14/1	2	Chris,Vi
Design SCU PCB	3 days	Tue 1/15/19	Thu 1/17/19	3	Chris,Jacob
Order New MyoWare Sensor	0 days	Fri 1/18/19	Fri 1/18/19	4	Vi
Order PCB	0 days	Fri 1/18/19	Fri 1/18/19	5	Chris,Vi
Determine Speaker	2 days	Fri 1/18/19	Sun 1/20/19		Chris,Jacob
Order Speaker	1 day	Mon 1/21/1	Mon 1/21/1	7	Chris,Vi
Integrate PCB SCU with Bluetooth	6 days	Mon 1/21/19	Sat 1/26/19		Chris,Jacob Marshall,V
Generals	15 days	Fri 1/18/19	Thu 2/7/19		Chris, Jacol
Determine Final Target Audience	3 days	Fri 1/18/19	Tue 1/22/19		Chris,Jacob Marshall,V
Determine Data Destination Location	5 days	Tue 1/22/19	Sat 1/26/19		Vi
Recruit CSE Student for Application Build (TBD)	5 days	Mon 1/28/19	Fri 2/1/19	12	Marshall,V
Meeting with "Sock Guys" from UW (TBD)	1 day	Mon 2/4/19	Mon 2/4/19	13	Marshall
Reach out to a PT (Date TBD)	1 day	Mon 2/4/19	Mon 2/4/19		Marshall,V
Meet with Samuel & Colin (Date TBD)	4 days	Mon 1/14/19	Thu 1/17/19		Chris,Jacob Marshall,V



Questions?

Spare slides



Signal Conditioning Unit Multisim simulation

References

Holland, Taylor Mallory. The Next Step in Remote Patient Monitoring: Virtual Physical Therapy. *Samsung Business Insights*, 17 Jan. 2017, insights.samsung.com/2017/01/17/next-step-for-remote-patient-monitoring-virtual-physical-therapy/.

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