Pressure Detection: Improving Prosthetics Efficacy

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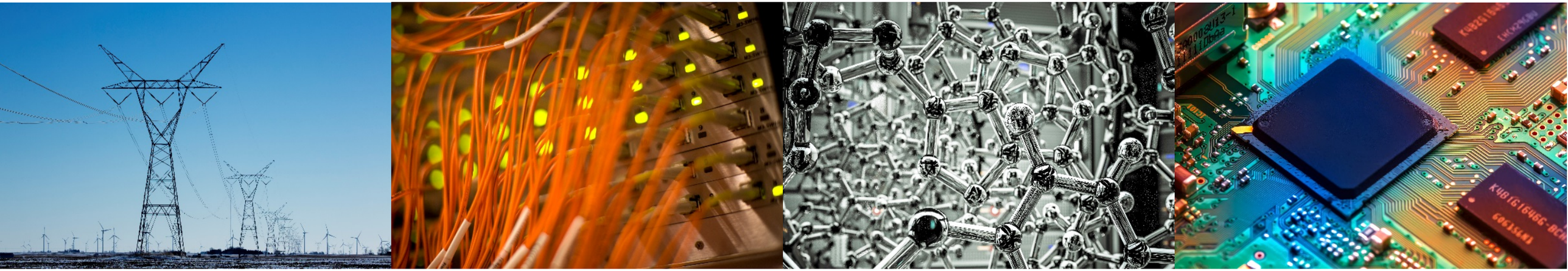
ECE 445 Group 21



Introduction

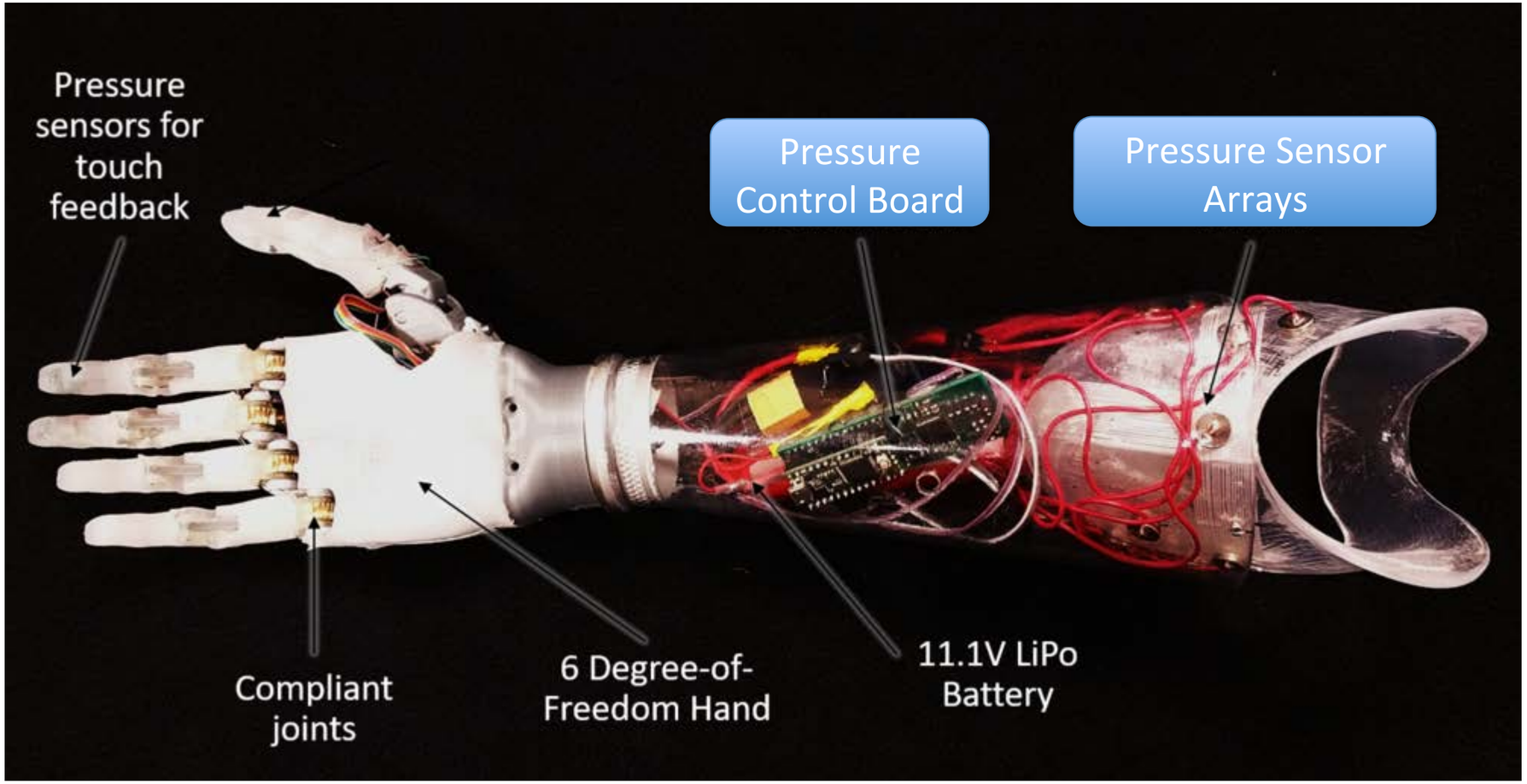
PSYONIC

- a low cost bionic arm solution

Why?

“A part of [me] has come back”

[courtesy of Psyonic]



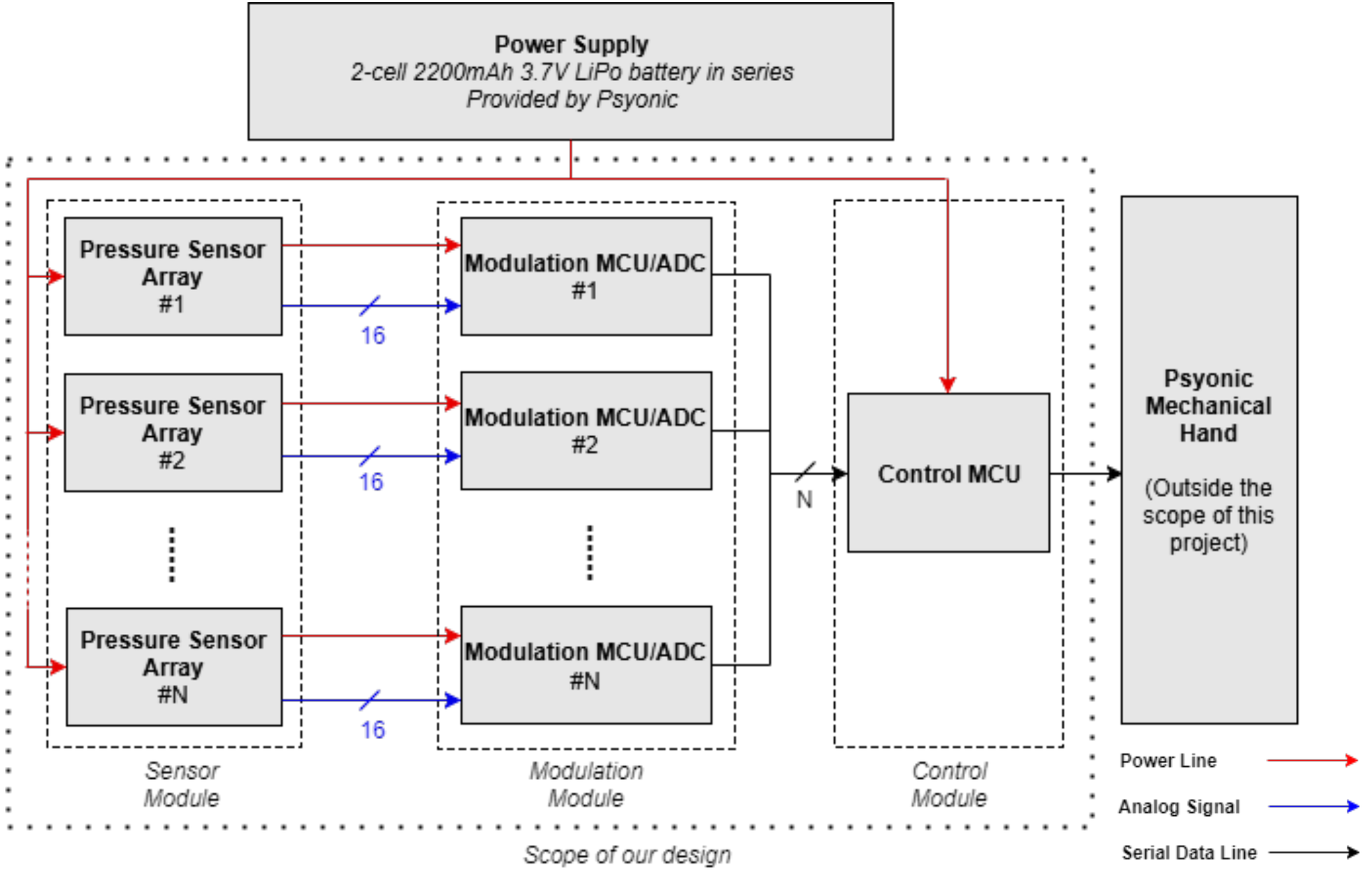
[courtesy of Psyonic]

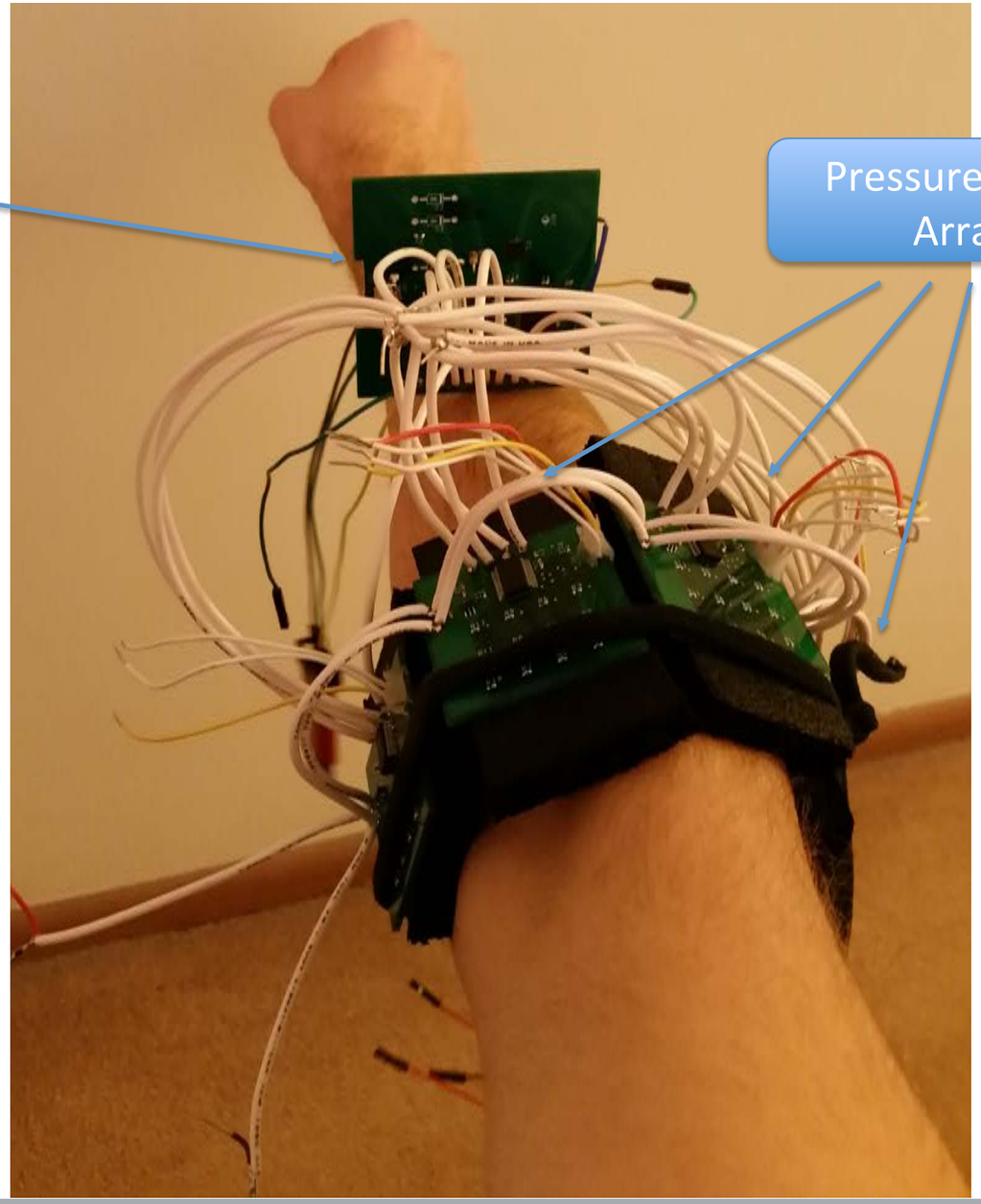
Goals

- To replace the current EMG system with a TMG system
  - Higher accuracy
  - Faster training time
- To fit the current enclosing

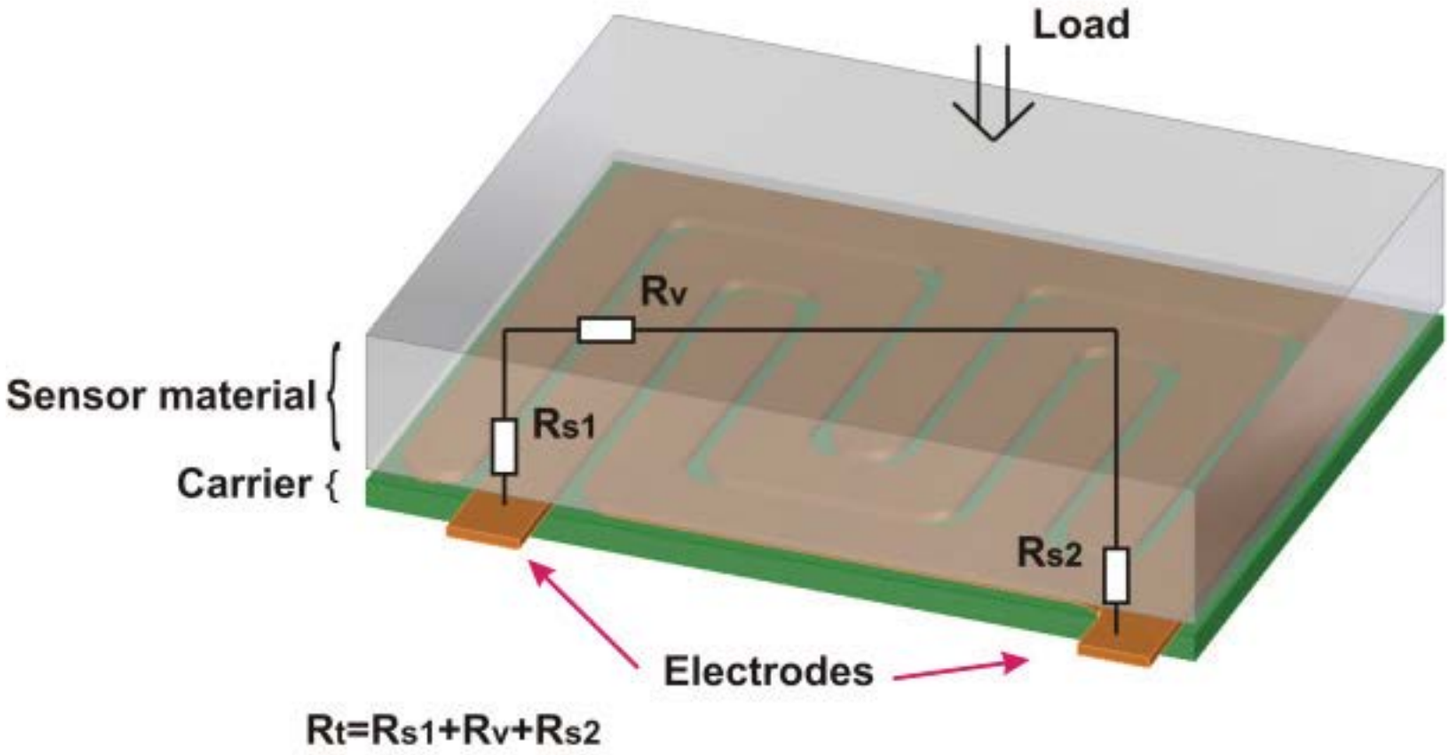
The Components

- Hardware:
  - Pressure sensors, modulation PIC, control MCU, CP2012x UART serial com
- Software:
  - Classification algorithm

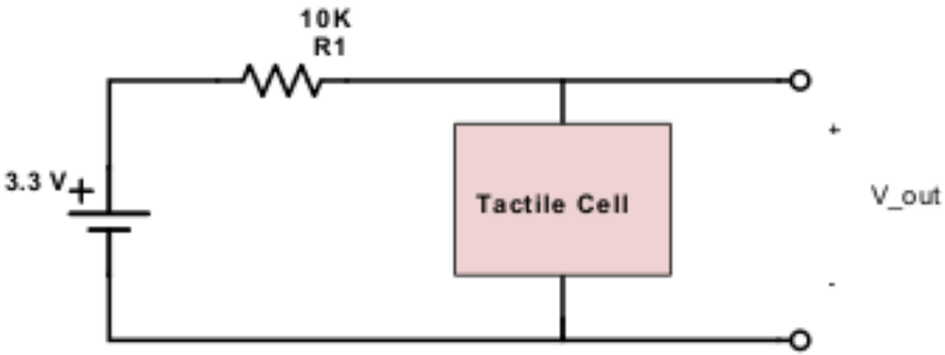

Power Supply
2-cell 2200mAh 3.7V LiPo battery in series
Provided by Psyonic
Pressure Sensor Array #1
Pressure Sensor Array #2
Pressure Sensor Array #N
16
16
16
Modulation MCU/ADC #1
Modulation MCU/ADC #2
Modulation MCU/ADC #N
N
Control MCU
Psyonic Mechanical Hand
(Outside the scope of this project)
Sensor Module
Modulation Module
Control Module
Scope of our design
Power Line
Analog Signal
Serial Data Line


Pressure Control Board
Pressure Sensor Arrays

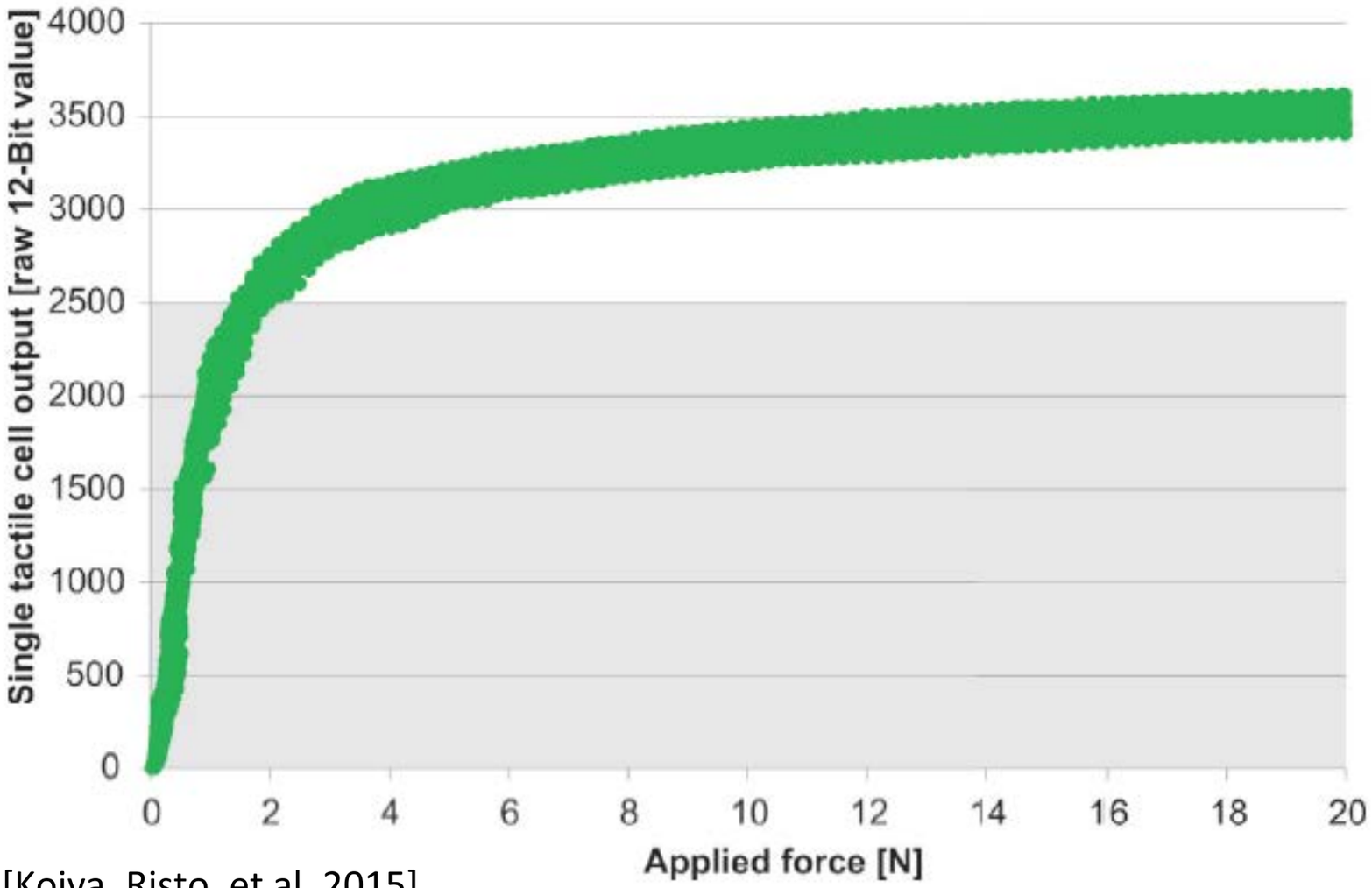
Pressure Sensor



$$V_{out} = 3.3\,V * \frac{R_t}{10K\Omega + R_t}$$

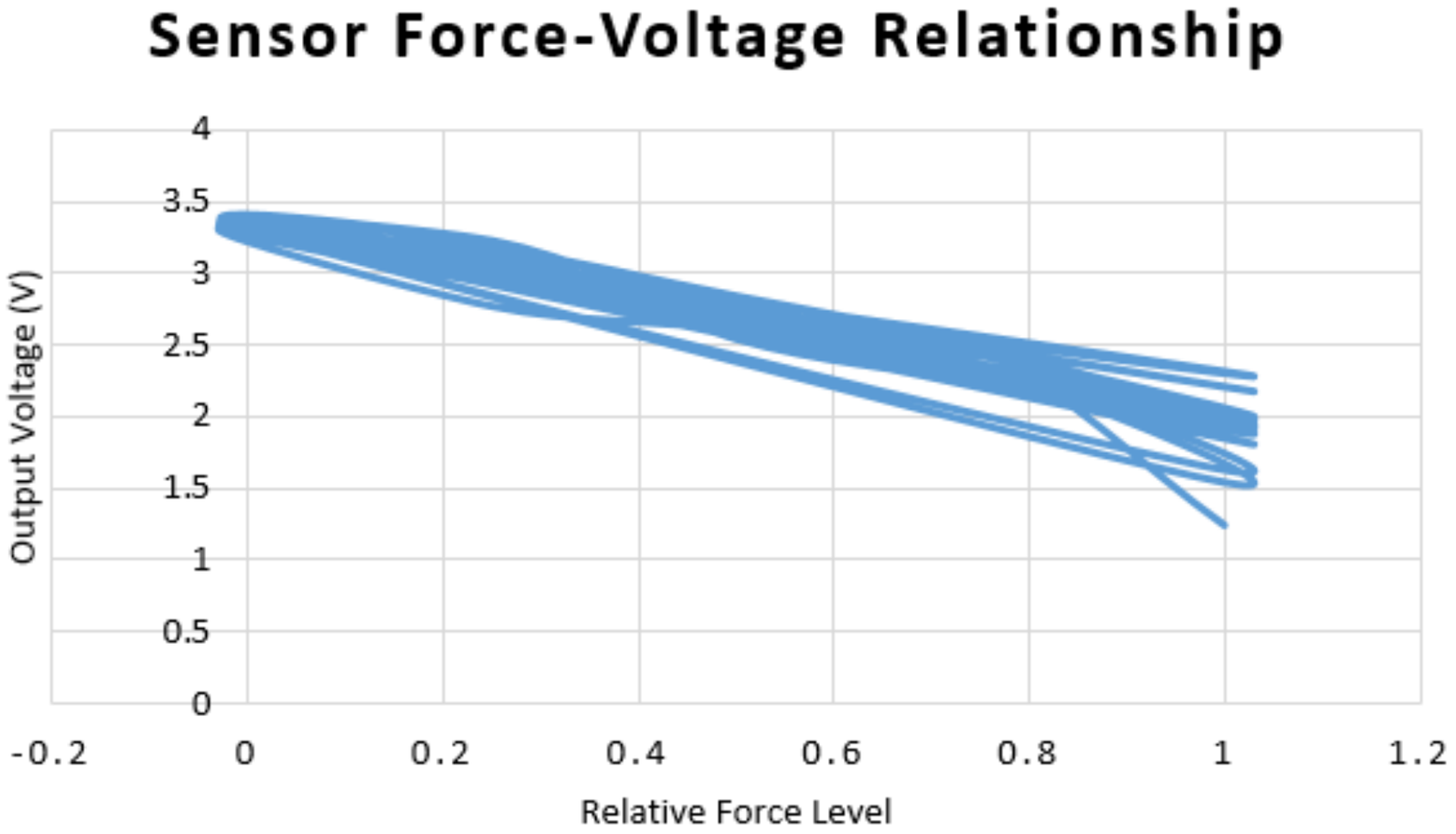


[Koiva, Risto, et al. “Shape Conformable High Spatial Resolution Tactile Bracelet for Detecting Hand and Wrist Activity.”]



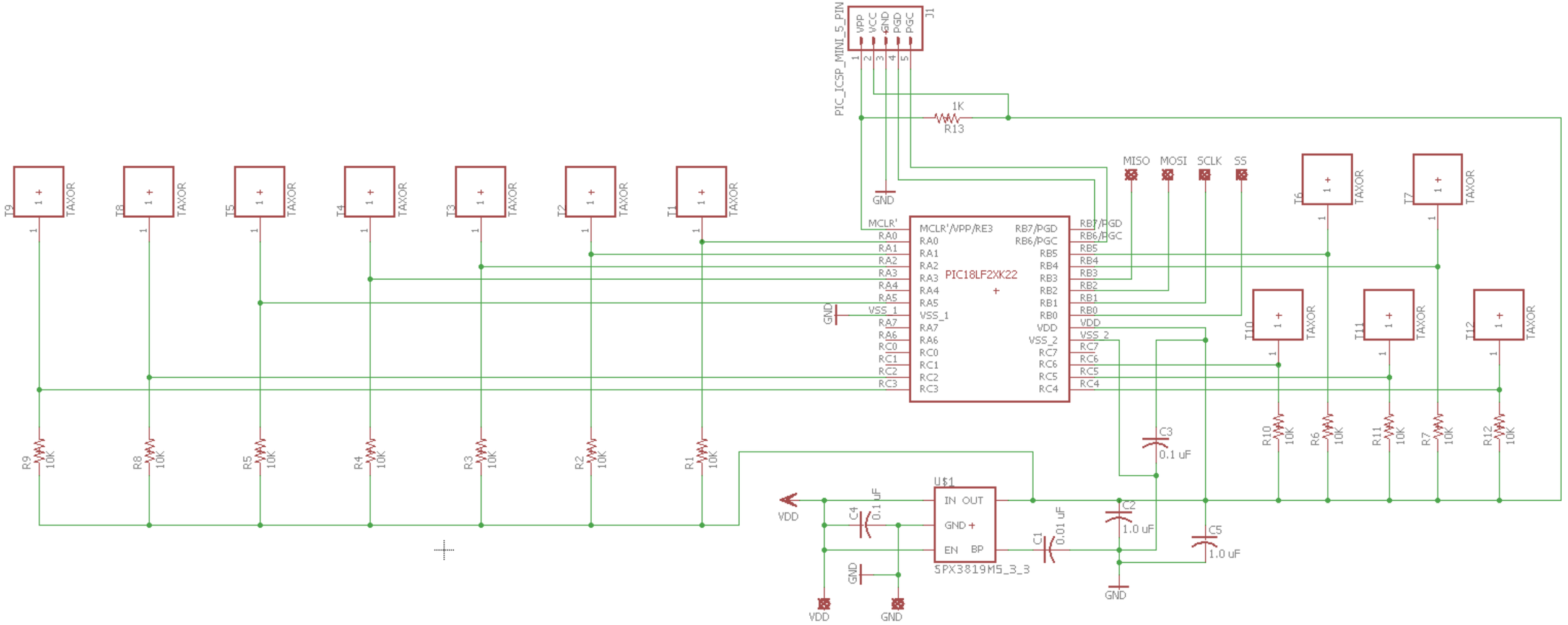
[Koiva, Risto, et al. 2015]

Pressure Sensor – Our Results

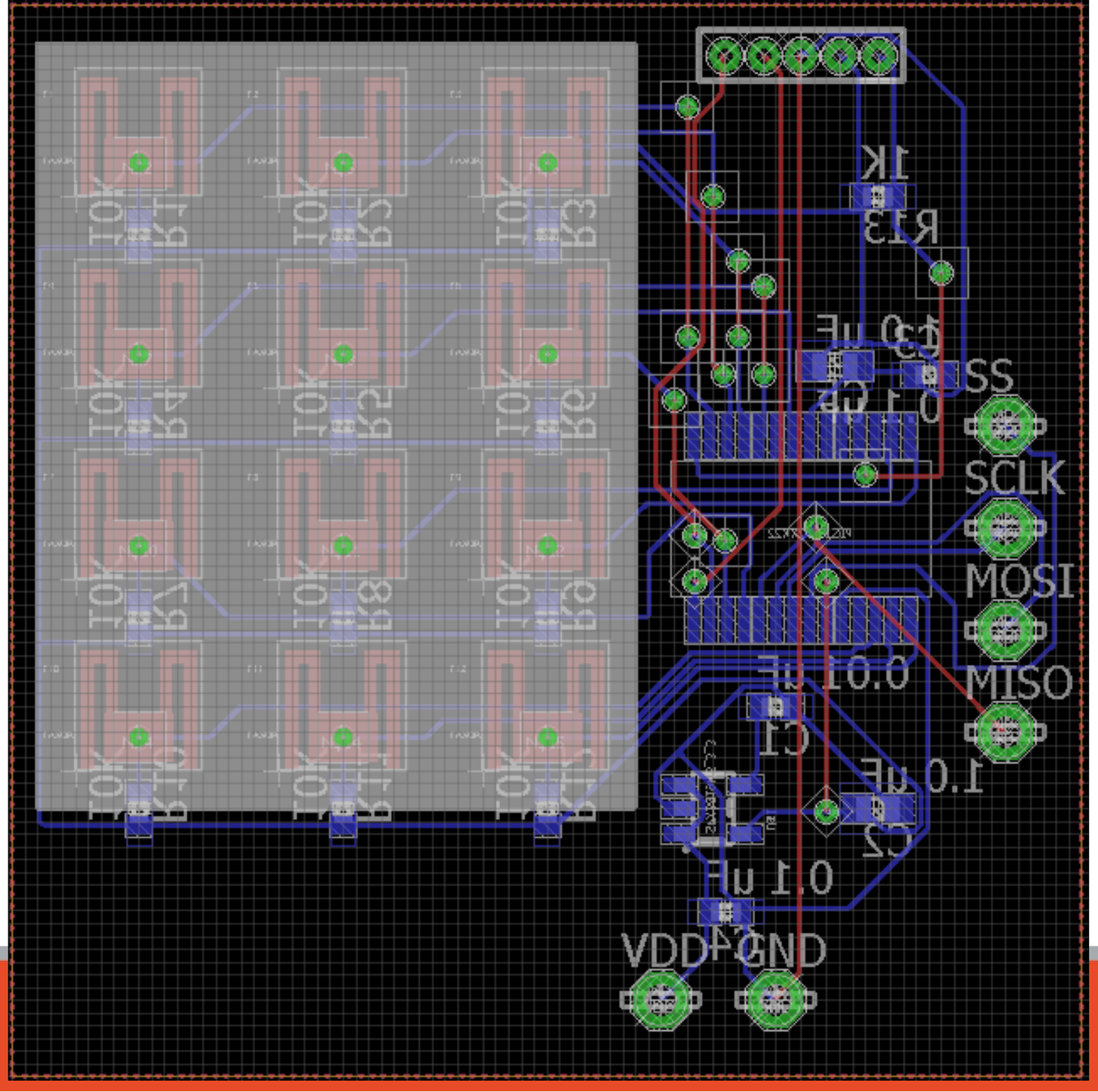


Pressure Sensor Board

- PIC microprocessor
- Access data from pressure sensor array
- Sends data to control board

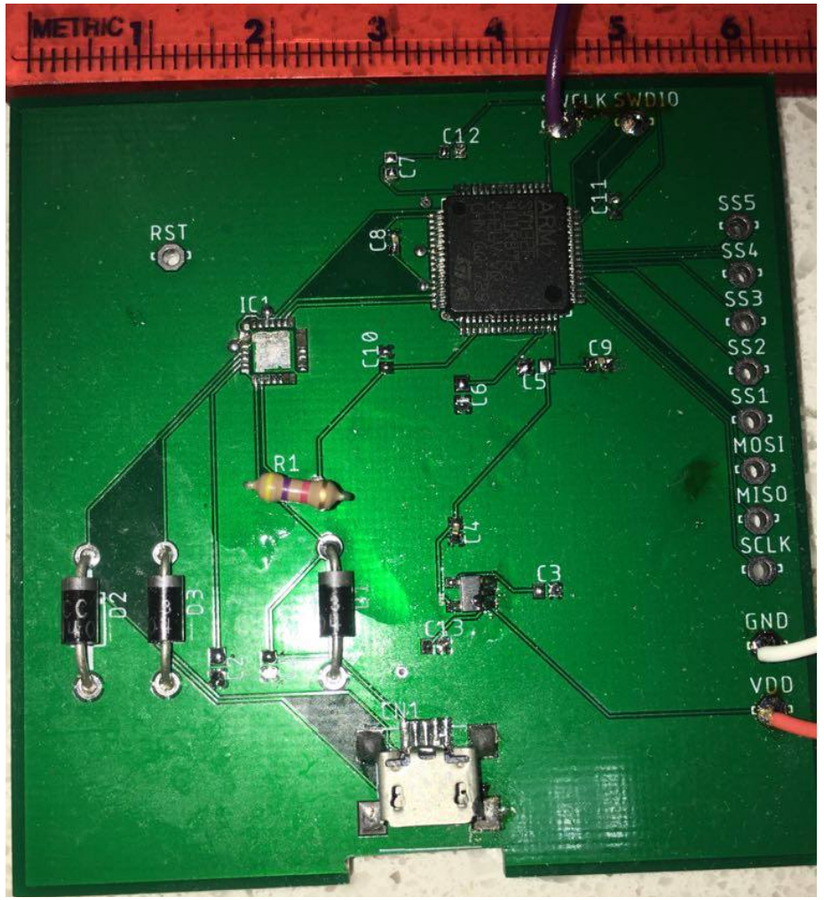

PIC_ICSP_MINI_5_PIN
VPP
VCC
GND
PGD
PGC
J1
1K
R13
GND
MISO
MOSI
SCLK
SS
MCLR'/VPP/RE3
RA0
RA1
RA2
RA3
RA4
RA5
VSS_1
RA7
RA6
RC0
RC1
RC2
RC3
PIC18LF2XK22
RB7/PGD
RB6/PGC
RB5
RB4
RB3
RB2
RB1
RB0
VDD
VSS_2
RC7
RC6
RC5
RC4
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
TAXOR
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
10K
C1
0.01 uF
C2
1.0 uF
C3
0.1 uF
C4
0.1 uF
C5
1.0 uF
U$1
IN
OUT
GND
EN
BP
SPX3819M5_3_3
VDD

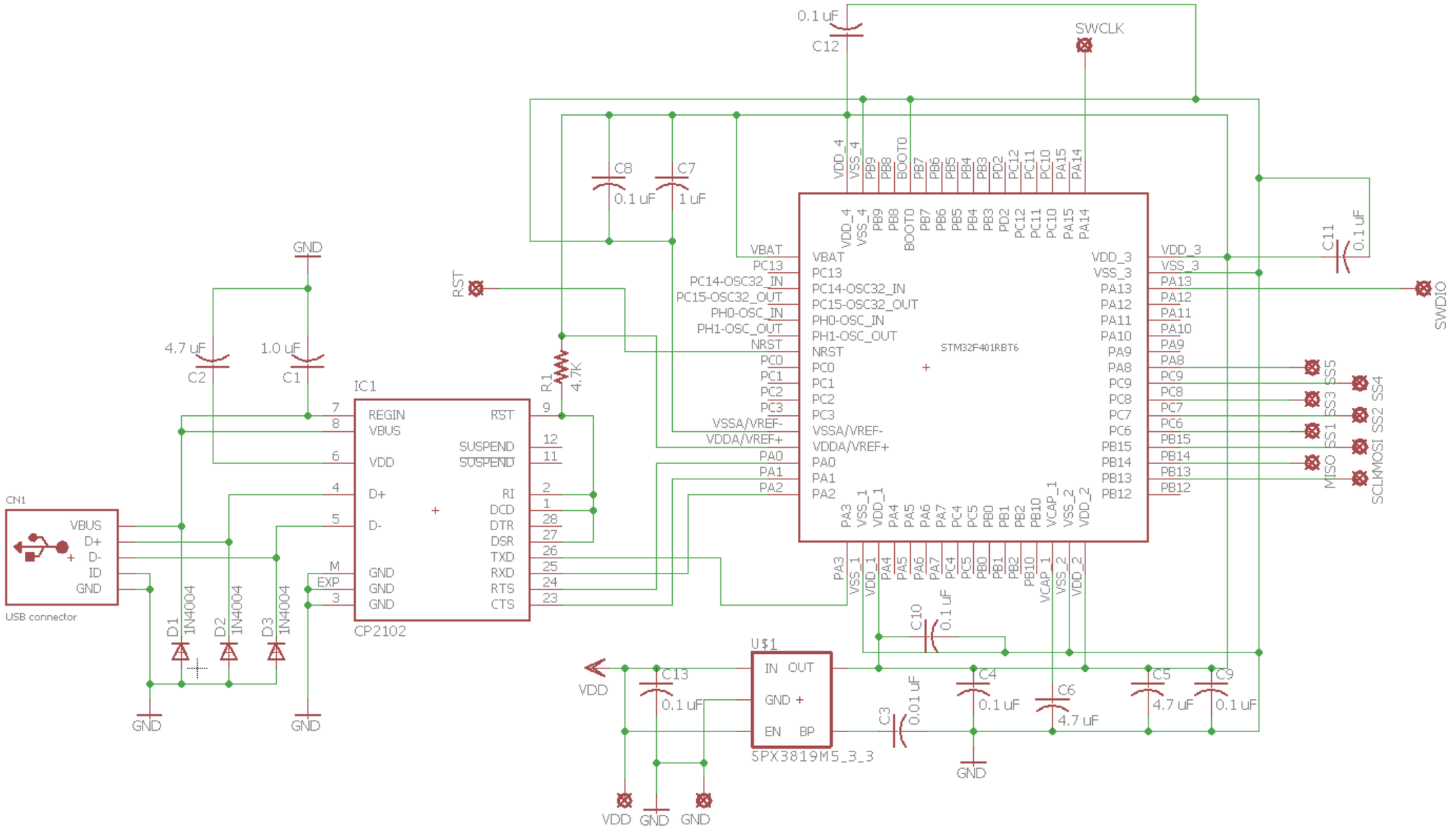
ILLINOIS

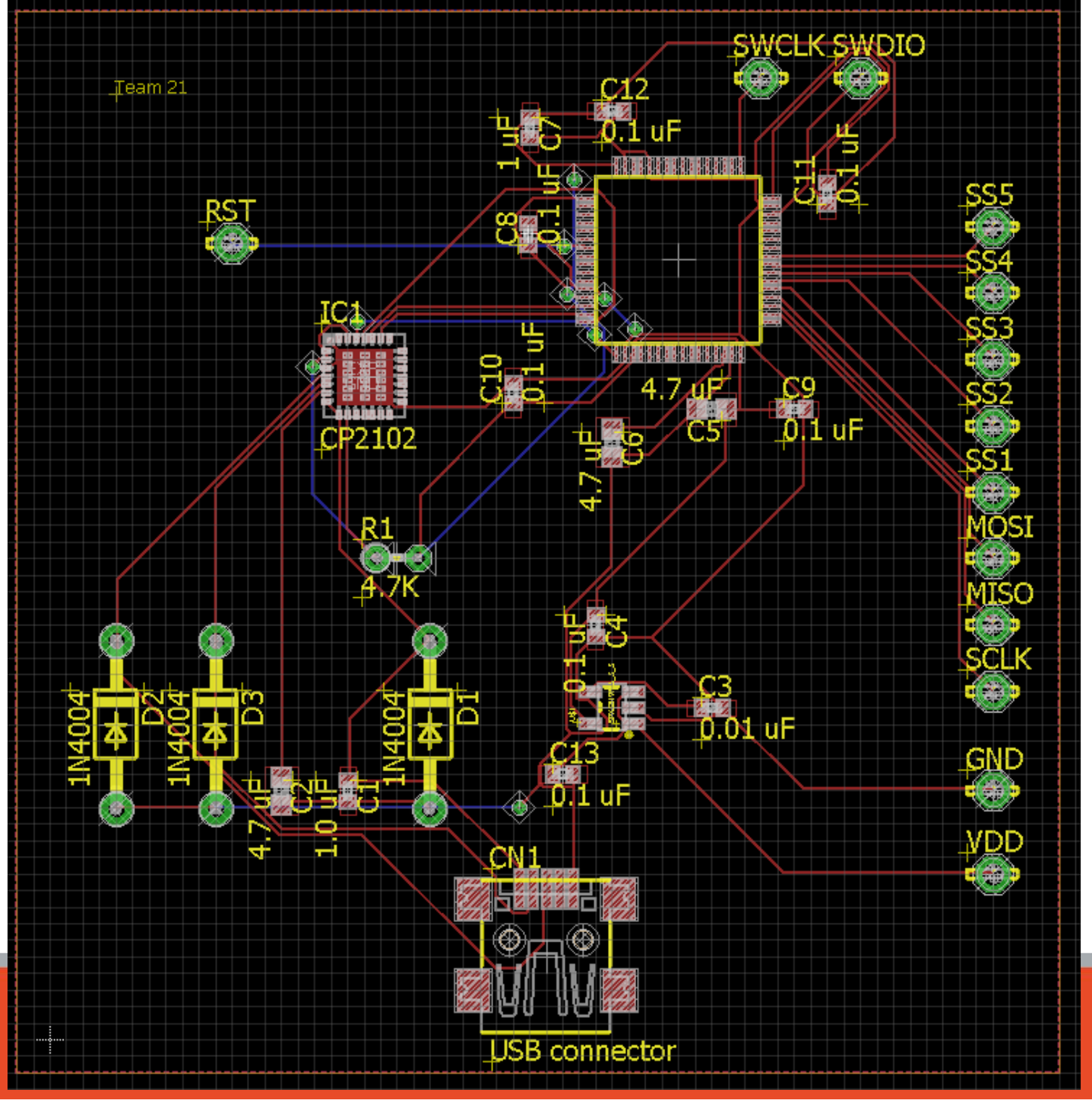

10K
R13
1K
SS
SCLK
MOSI
MISO
VDD
GND

Control Board

- STM32 ARM processor
- Reads data from pressure boards
- Runs classification algorithm



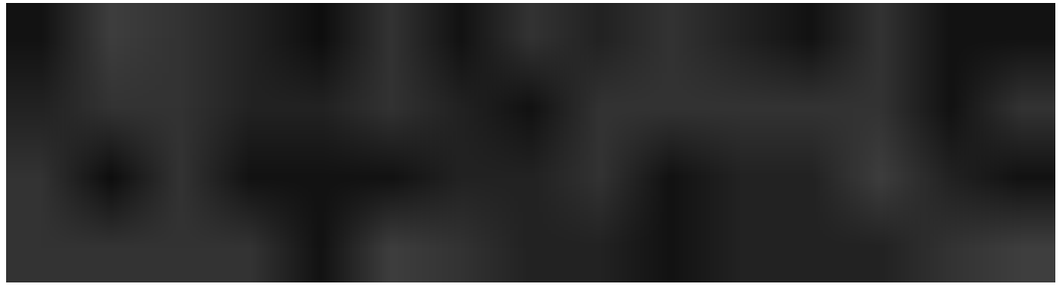

0.1 uF
C12
SWCLK
C8
0.1 uF
C7
1 uF
C11
0.1 uF
SWDIO
RST
R1
4.7K
GND
4.7 uF
C2
1.0 uF
C1
IC1
REGIN
VBUS
VDD
D+
D-
GND
RST
SUSPEND
SUSPEND
RI
DCD
DTR
DSR
TXD
RXD
RTS
CTS
CP2102
CN1
VBUS
D+
D-
ID
GND
USB connector
D1
IN4004
D2
IN4004
D3
IN4004
STM32F401RBT6
VBAT
PC13
PC14-OSC32_IN
PC15-OSC32_OUT
PH0-OSC_IN
PH1-OSC_OUT
NRST
PC0
PC1
PC2
PC3
VSSA/VREF-
VDDA/VREF+
PA0
PA1
PA2
VDD_3
VSS_3
PA13
PA12
PA11
PA10
PA9
PA8
PC9
PC8
PC7
PC6
PB15
PB14
PB13
PB12
MISO SS1 SS3 SS5
SCLK MOSI SS2 SS4
U$1
IN OUT
GND
EN BP
SPX3819M5_3_3
VDD
C13
0.1 uF
C3
0.01 uF
C4
0.1 uF
C6
4.7 uF
C5
4.7 uF
C9
0.1 uF
C10
0.1 uF


Team 21
SWCLK
SWDIO
C12
0.1 uF
1 uF
C7
C11
0.1 uF
RST
C8
0.1 uF
SS5
SS4
SS3
SS2
SS1
MOSI
MISO
SCLK
GND
VDD
IC1
CP2102
C10
0.1 uF
4.7 uF
C5
C9
0.1 uF
4.7 uF
C6
R1
4.7K
1N4004
D2
1N4004
D3
1N4004
D1
0.1 uF
C4
C3
0.01 uF
C13
0.1 uF
4.7 uF
C2
1.0 uF
C1
CN1
USB connector

Data Description

- 6 Classes + 1 “No Movement”
- Data Simulation

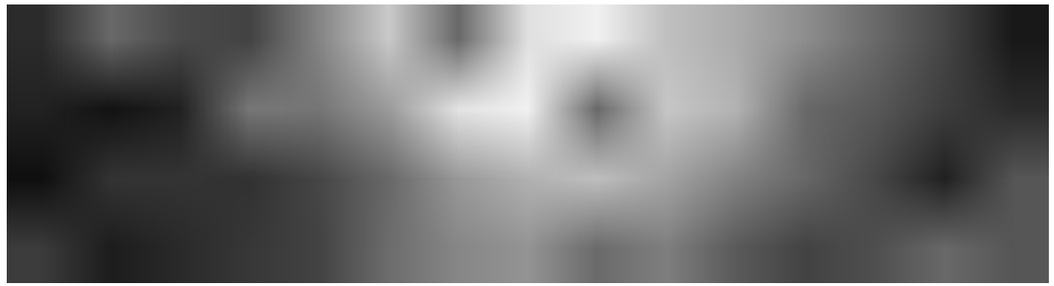
No Movement



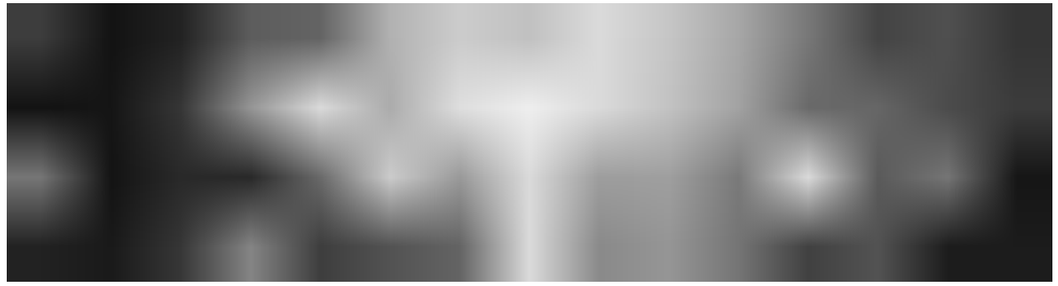
Min. Force Detected

Max. Force Detected

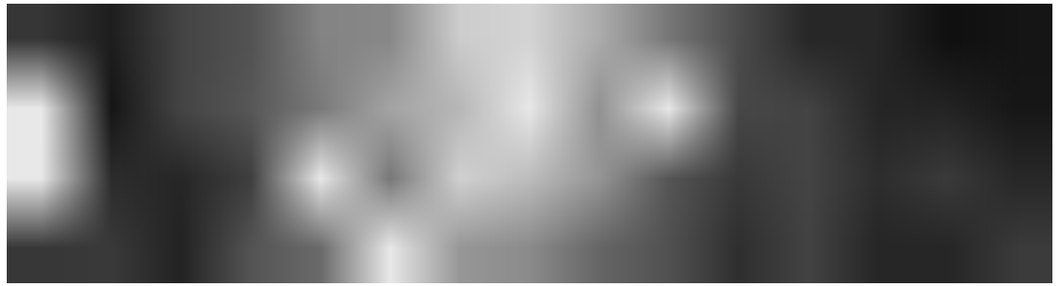
Little Finger Flexion



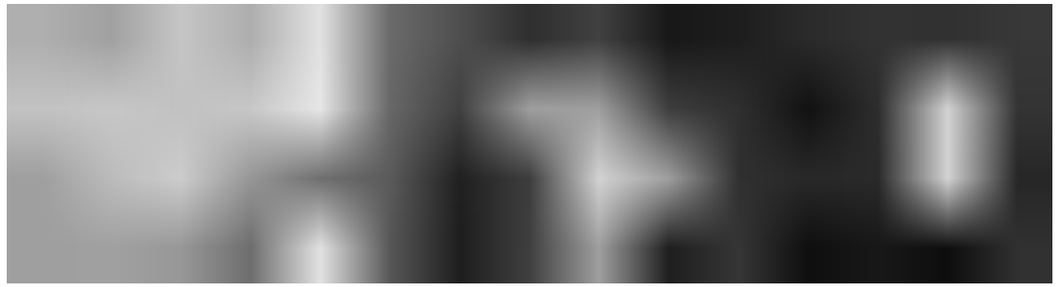
Index Finger Flexion



Thumb Rotation

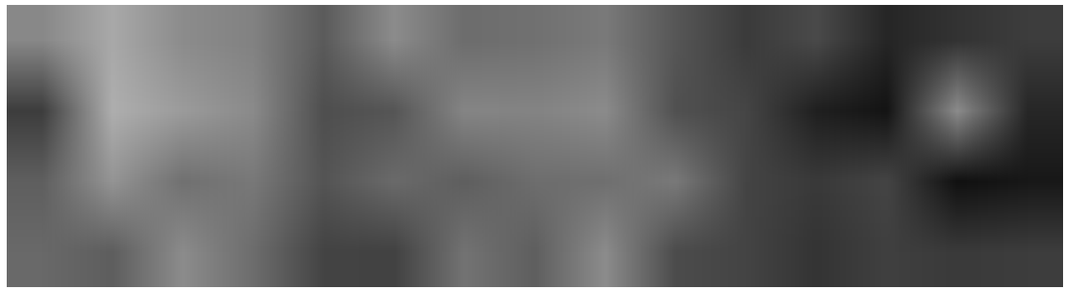


Wrist Flexion



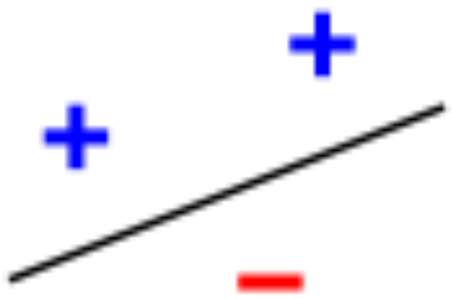
Wrist Extension

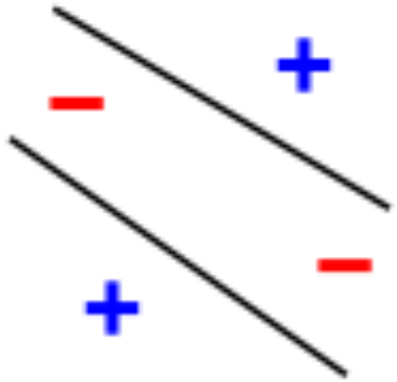
Wrist Supination



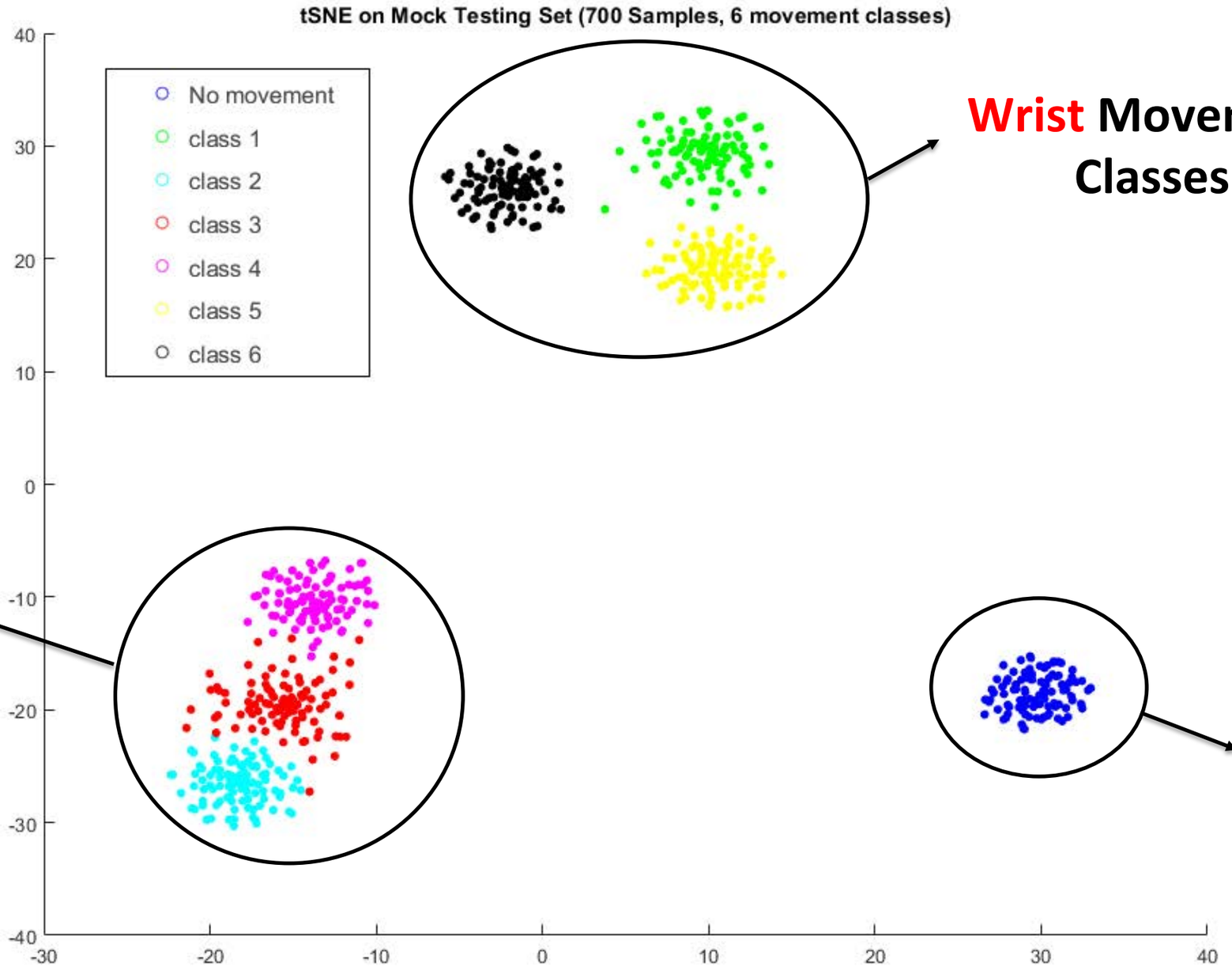
Classification Algorithm

- Choice of Algorithm
- Criteria: “Linear Separability”





“Linear separability,” *Wikipedia*, 11-Sep-2017. [Online].
Available: https://en.wikipedia.org/wiki/Linear_separability. [Accessed: 12-Dec-2017].



Wrist Movement Classes

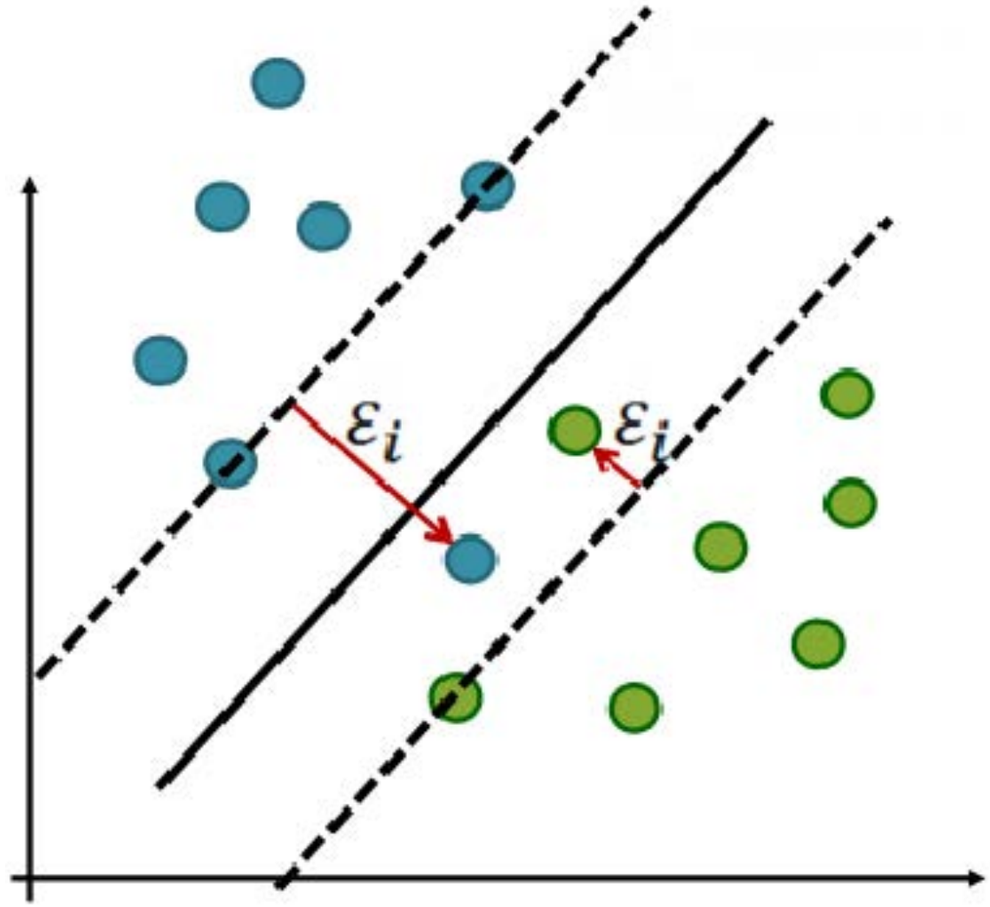
Finger Movement Classes

No Movement

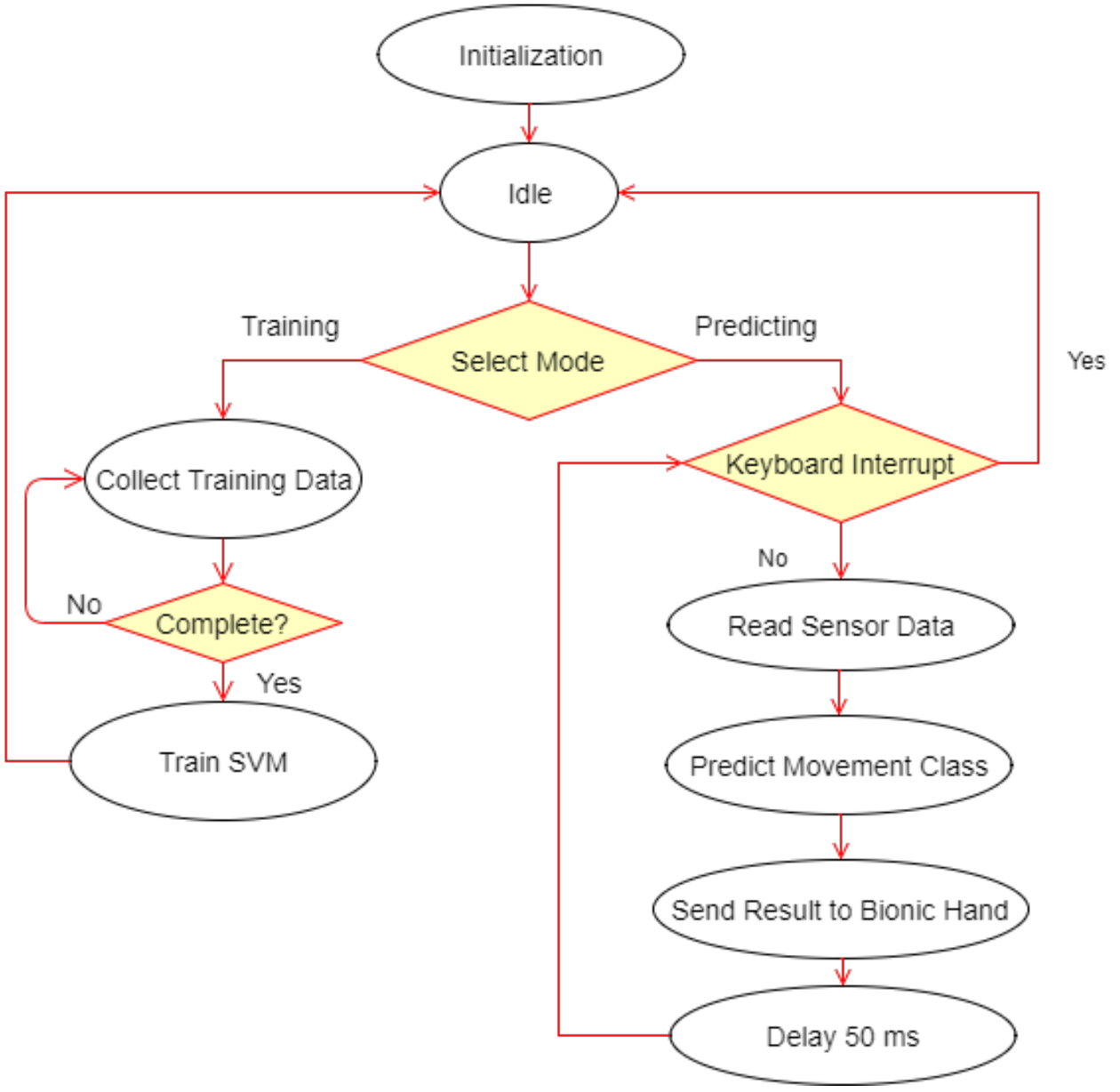
Our Choice – Soft Margin L-1 Loss SVM

"Slack" Penalty Term

$$argmin_w \frac{1}{2}||w||^2 + C\sum_{k=1}^{m} \max\{0, 1 - w \cdot x_k \cdot y_k\}$$



C. Moreira, P. Calado, and B. Martins, "Learning to rank academic experts in the DBLP dataset," *Expert Systems*, vol. 32, no. 4, pp. 477–493, 2013.


Initialization
Idle
Training
Select Mode
Predicting
Yes
Collect Training Data
Keyboard Interrupt
No
Complete?
No
Read Sensor Data
Yes
Train SVM
Predict Movement Class
Send Result to Bionic Hand
Delay 50 ms

Classification Algorithm – Our Results

- Training on **70** samples takes ~6.2 seconds on Control MCU
- Testing on **700** samples
- Result by F1 score
  - Training set: 1.0
  - Testing set: 0.9427

Strength & Weakness

Strengths	Weaknesses
• ML training under 10 sec • Resilient to sweat	• Foam availability • SPI debug
Opportunities	**Threats**
• 350,000+ amputated • 15,000 per year	• Many other low cost prosthetic arm startups

Conclusion

- Pressure sensor verified and integrated with ADC
- Highly accurate ML algorithm and can run efficiently on our ARM chip
- Prototype proof of concept successful

Future Development Considerations

- Develop synchronization logic to enable SPI
- Revise the pressure board to use a gold etched t-stop layer
- Collect a larger set of samples to analyze confidence interval of our classification result
- Expand functionality to support more movement classes

Acknowledgements

- Professor Can Bayram
- TA: Yuchen He
- Psyonic (Jesse Cornman, Dr. Aadeel Akhtar)

Thank you!
Questions?