Data Acquisition Board for Stroke Rehabilitation Hand Device

Computer Integrated Surgery II

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Introduction

- Created novel data acquisition (DAQ) board for collecting and amplifying voltage readings on up to 20 independent channels with programmable amplifiers
- Created library of functions to improve the convenience of adjusting gain function when programming the amplifier units
- Providing rapid rehabilitative evaluation and training for acute stroke patients affected in the upper limbs is a key goal of neurological and rehabilitation research.
- By improving the readability of weak force signals from acute patients through signal adjustment, the DAQ board will allow for easier clinical testing and faster patient recovery.

The Problem

- Recent neurological research suggests that early rehabilitation is an effective way to treat acute stroke patients [1].
- The Amadeo by Tyromotion relies on linear motion sensing and actuation to provide rehabilitation. Limitations include lack of portability, time investment to secure wrist and fingers, and internal friction.
- Previous prototype, shown in Fig. 1, addressed portability and signal amplification using a stock NI DAQ board, but can only support up to two fingers through 8 channels.

Figure 1: Existing prototype of Stroke Rehabilitation Hand Device

The Solution

- To increase the channel count needed to support all five digits of the typical human hand, a new DAQ board needs to be fabricated from scratch
- Microprocessor (Teensy 3.5 by PJRC) digitizes and organizes analog voltage readings, has a small footprint, 23 ADC channels, and USB and I²C ports for amplifier and computer communication.
- Programmable amplifiers (PGA309 by NI) have a gain range from 2.7 to 1152 V/V, which is adjustable through independent gain and offset settings.
- Mulitplexers (TCA9548A) provide hardware-specific identifiers for Teensy to access amplifiers with during calibration.
- Prototype was wired on breadboard shown in Fig. 2; breakout boards were used for the amplifiers and multiplexers to interface; all breakout boards and Teensy required that headers be soldered to their pin pads.

$$V_{OUT} = [(V_{DIFF} + V_{COARSE\ OFFSET})(\text{Front-End PGA Gain}) + V_{ZERO\ DAC}][\text{Gain DAC}][\text{Output Amplifier Gain}]$$

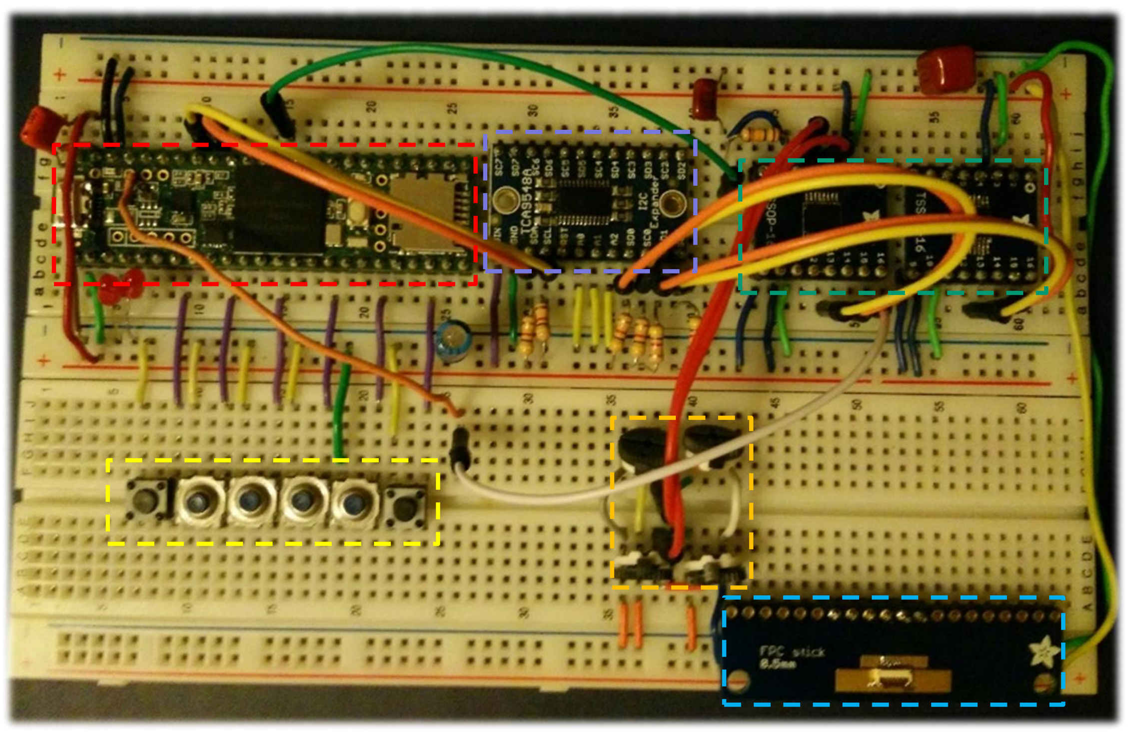

Figure 2: PGA309 Transfer Function & Breadboard Prototype Mockup of DAQ Board
(Teensy outlined in red, multiplexer in purple, amplifiers in green, test buttons in yellow, mock strain gauge in orange, finger board interface in blue)

V_{ref}	$V_{offset,fine}$	$V_{offset,coarse}$	GI	GD	GO	$V_{diff,abs}$	$V_{out,probe}$	$V_{out,ADC}$	$V_{out,calc}$	$\%error_{ADC}$	$\%error_{calc}$
3.27	0.82	0	4	0.5	2	0.29	2	2.01	1.98	0.29	-1.13
3.27	1.64	0	4	0.5	2	0.29	2.82	2.82	2.80	-0.03	-0.89
3.27	0.82	0	4	0.33	2	0.29	1.33	1.33	1.31	0.17	-1.87
3.27	0.82	0	4	1	2	0.11	2.49	2.50	2.52	0.39	1.00
3.27	0.82	-0.014	4	0.5	2	0.29	2	2.01	1.92	0.29	-3.90
3.27	0.82	0	8	0.5	2	0.26	2.75	2.75	2.90	0.16	5.36
3.27	0.82	0	4	0.5	3	0.26	2.68	2.68	2.79	0.16	3.96
3.27	0.82	0	16	0.5	2	0.07	1.89	1.90	1.94	0.32	2.51
3.27	0.82	0	4	0.5	2.4	0.07	1.33	1.31	1.32	-1.71	-0.98

Table 1: Results summary of amplifier setting change test with ADC and transfer function errors compared to probe

Outcomes and Results

- Validation test was run for verifying amplifier setting adjustment; summarized in Table 1
- Performance tests were conducted for sampling rate and noise; summarized in Table 2 and Fig. 3

Averaging Samples	Sampling Speed	Conversion Speed	Sampling Rate (kHz)	Noise (increments)
8	Medium	Medium	26.56	30
16	Medium	Medium	14.23	25
16	High	High	28.29	29
32	High	High	21.34	35

Table 2: Results summary of sampling rate and noise performance at various ADC settings

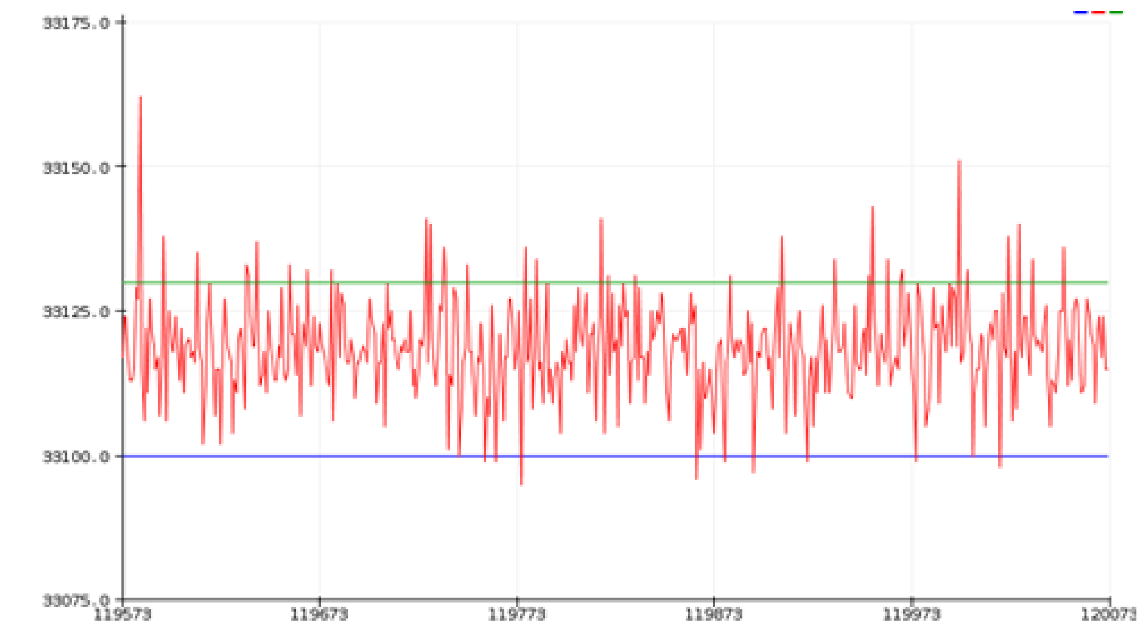

Figure 3: Digitized 16-bit voltage readings in red of third trial at last 500 samples; Upper and lower bounds used for axis scaling are in green and blue

Future Work

- Group will wrap up PCB board fabrication using the design in Fig. 4 within the next week; the physical board will be validated by hand
- A new version of the DAQ board with improvements mainly to noise reduction and other issues will be addressed over the summer

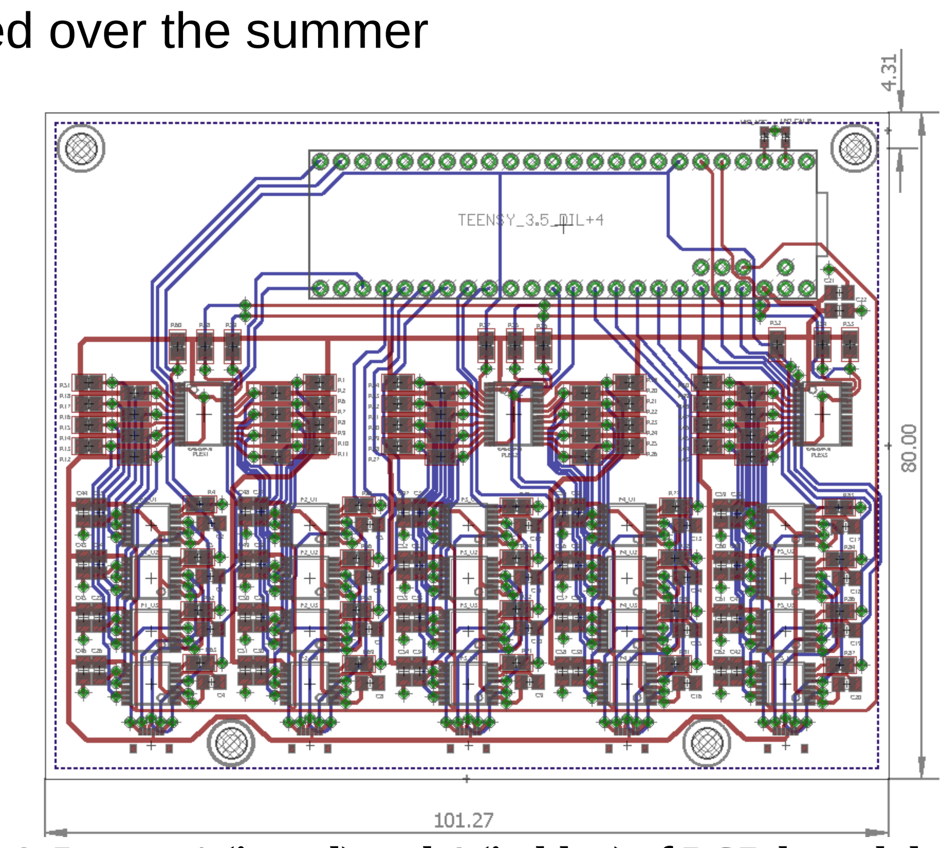

Figure 4: Layers 1 (in red) and 4 (in blue) of PCB board design

Lessons Learned

- Allocate plenty of time for PCB design and breadboard troubleshooting

Credits

- Jacob Carducci – DAQ subsystem of rehab hand device
- Kevin Olds – Mechanical features of rehab hand device

Related Publications

- [1] J. Xu et al. “Recovery of hand function after stroke: separable systems for finger strength and control,” bioRxiv, 2016.

Acknowledgements

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