Camera Positioning System

ECE 445 Spring 2017

Team 79

TA: John Capozzo

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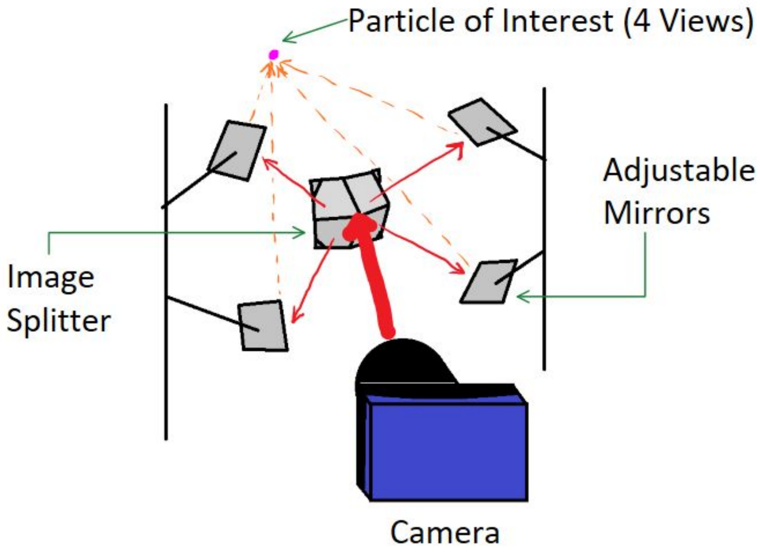
Outline

- Introduction
- Objective
- Block Diagram
- LABVIEW
- Traversing Sub-System (Stepper Motor)
- Pan & Tilt Unit (Servo Motor)
- Auto-Calibration and Closed-Loop control
- Power Unit
- Overview of the circuit
- Success and challenges
- Recommendations of future work
- Acknowledgement

Introduction - Background

- Manual camera position calibration for particle tracking research is difficult and time consuming
- Used in Renewable Energy & Turbulent Environment Research Group
- Sponsored by John Deere



Current Particle Tracking Equipment

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Introduction - Background

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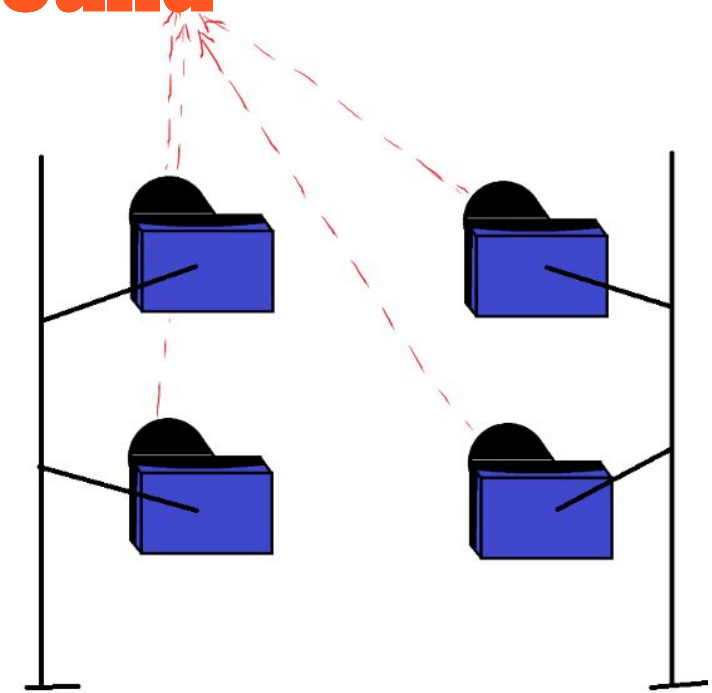

4 Independently Computer Controlled Cameras

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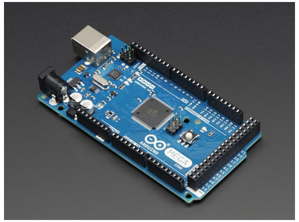
Introduction - What have been done.

- A MechSE team built the physical setup last semester.
- The frame can hold four cameras.
- It is roughly 2m by 2m tall and wide.
- Controlled by an Arduino Mega



Completed setup

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Objectives For This Semester

- Design an integrated control and processing unit on PCB
- Create a LABVIEW user interface
- Implement auto-calibration unit using snap action switches
- Implement closed-loop control for pan & tilt unit
- Investigate the feasibility of building an integrated power module

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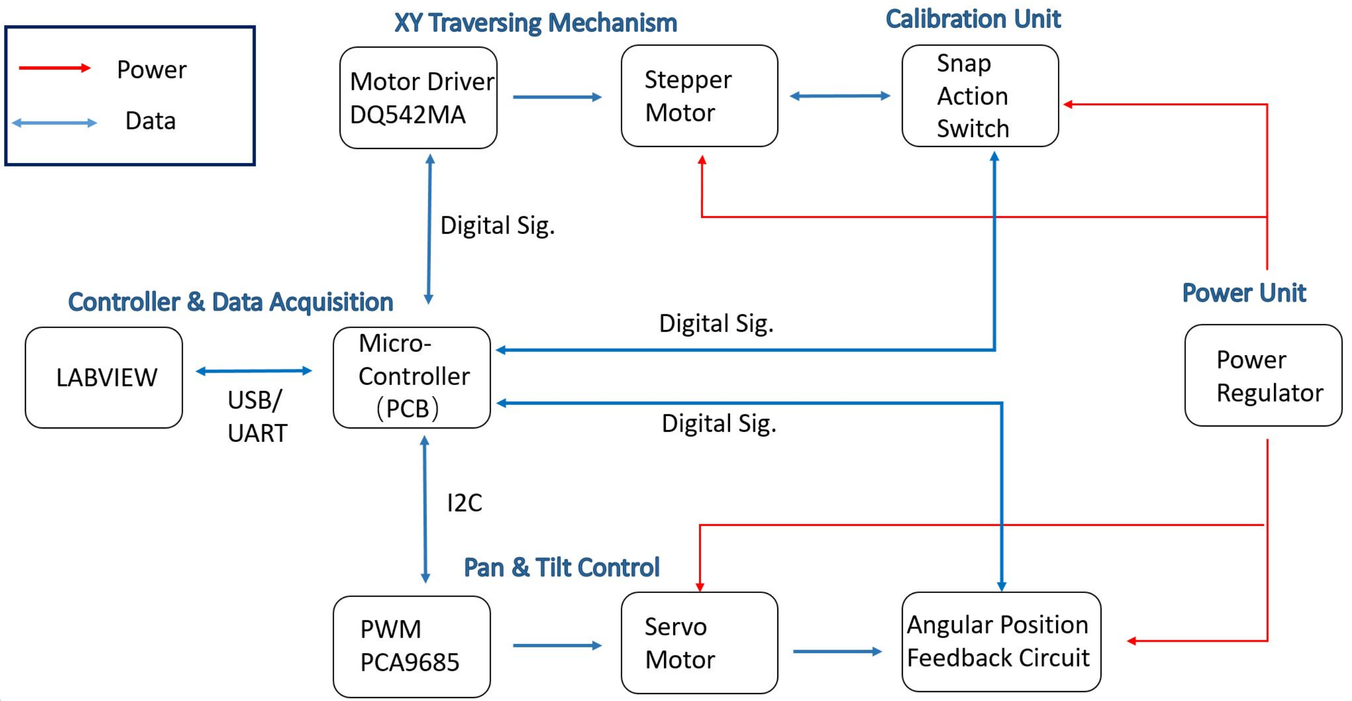
Block diagram



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LABVIEW

- LABVIEW is a widely used visual programming language
- It provides a library to communicate with ATmega328
- Pros:
  Easy to build a user interface
  Built in library for communication
- Cons:
  Slow loop rate (<30Hz)
  More difficult to express logic

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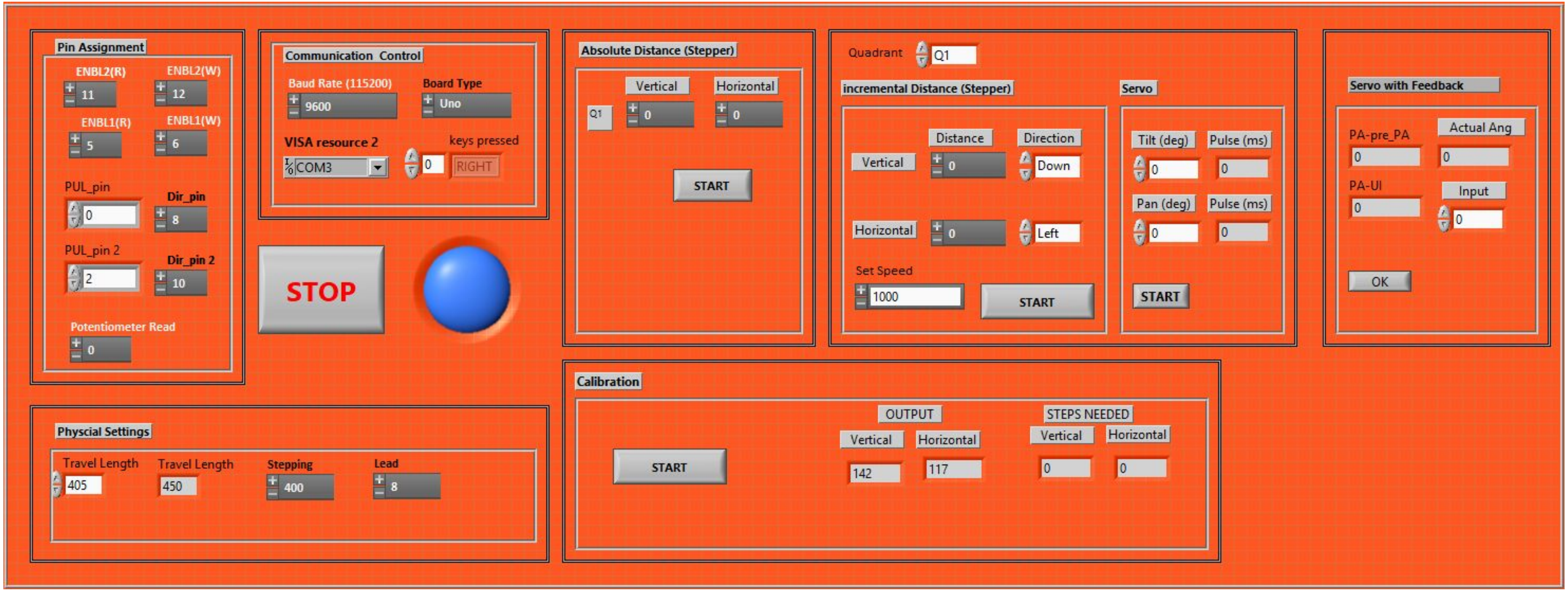
LABVIEW User Interface



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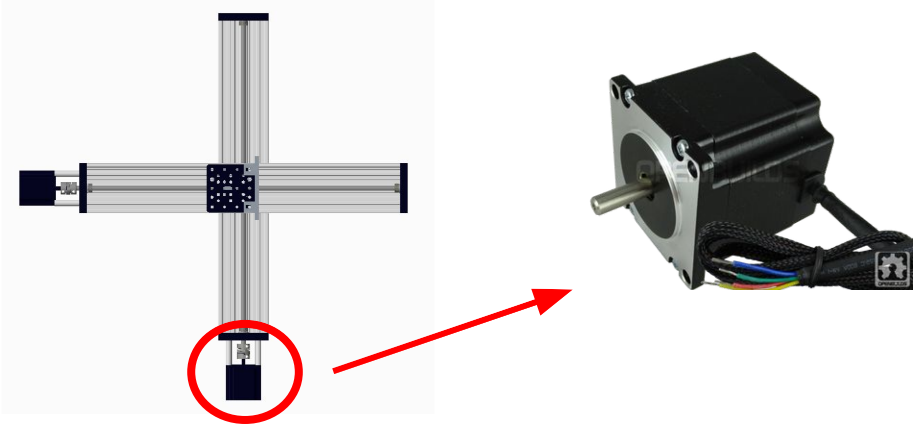
Traversing System - Stepper & Driver

- DQ542MA 2-Phase Hybrid stepper motor driver
- It provides micro-stepping options
- Overvoltage,short circuit protection
- NEMA 23 stepper motor
- 200 steps/rev native resolution



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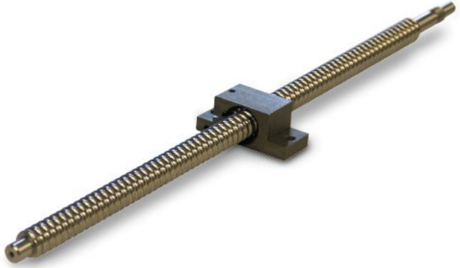
Traversing System - Step Calculation

- 400 steps/rev (motor driver)
- 8 mm travel per revolution (Leadscrew)
- 50 steps/mm
- 1 step = 1 pulse
- # of pulses = distance (mm) * 50 steps/mm



Steps/Rev	400	800	1600	3200	6400	12800	25600	1000
Steps/mm	50	100	200	400	800	1600	3200	125

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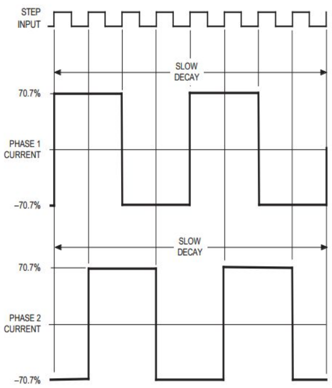
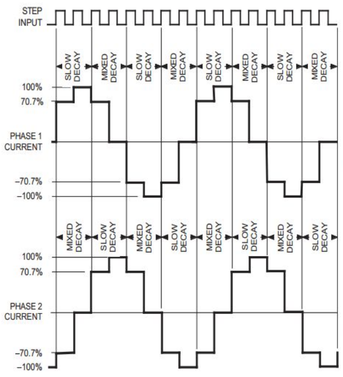
Traversing System - Stepper & Driver

- 4 wire bipolar (2 phase) stepper motor
- Rotor is axially magnetized
- Rotor teeth: 50
- Stator teeth: 48
- Microstepping improves stepping resolution

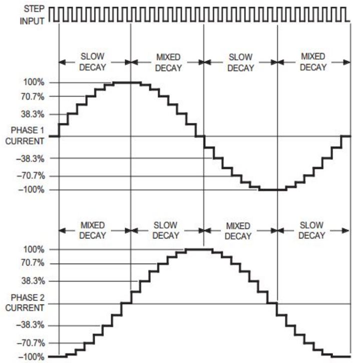
Full Step Operation

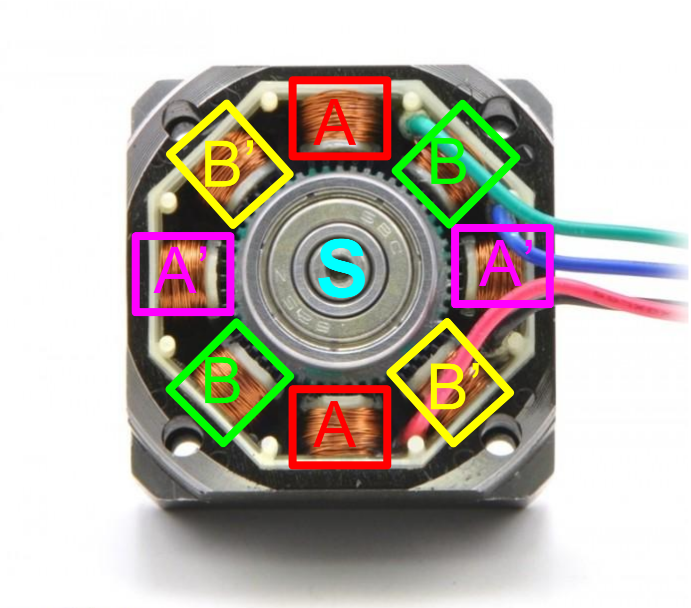


Half Step Operation



8 Microstep/Step Operation





www.pololu.com

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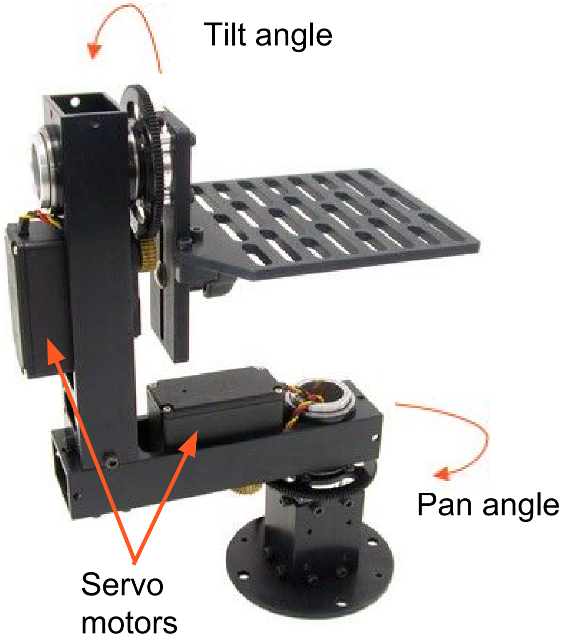
Pan & Tilt Head - Servo Motor

- Hitec HS-785HB servo
- Voltage range: 4.8V - 6V
- Torque: 183 oz/in
- 7 : 1 gear ratio



The 7:1 gear box allows for 196 degrees of rotation and better precision on each axis and 7 times the torque from the servo motors.

Purchased from ServoCity

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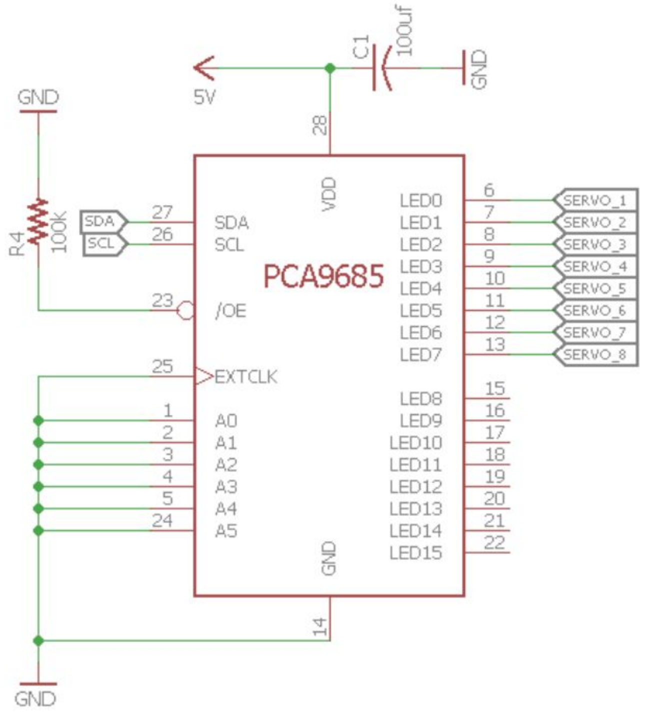
Pan & Tilt Head - Servo Driver

- Use PCA9685 chip to control the servo motors
- It communicates with ATmega328 through I2C protocol.
- The communication is implemented in LABVIEW



Schematic of PCA9685

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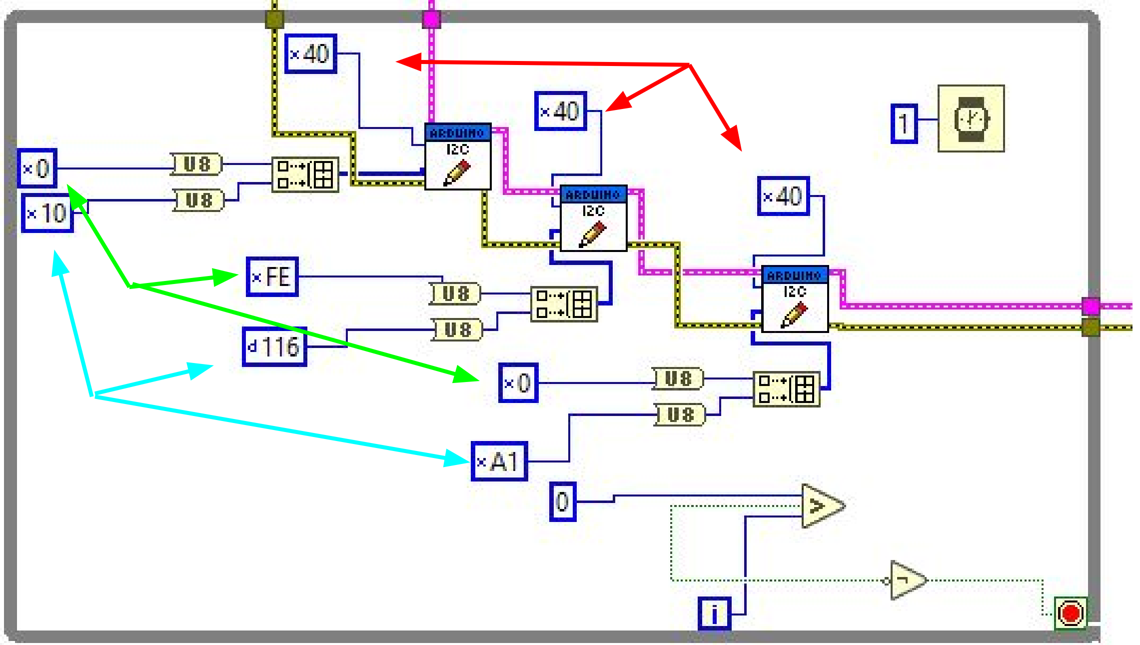
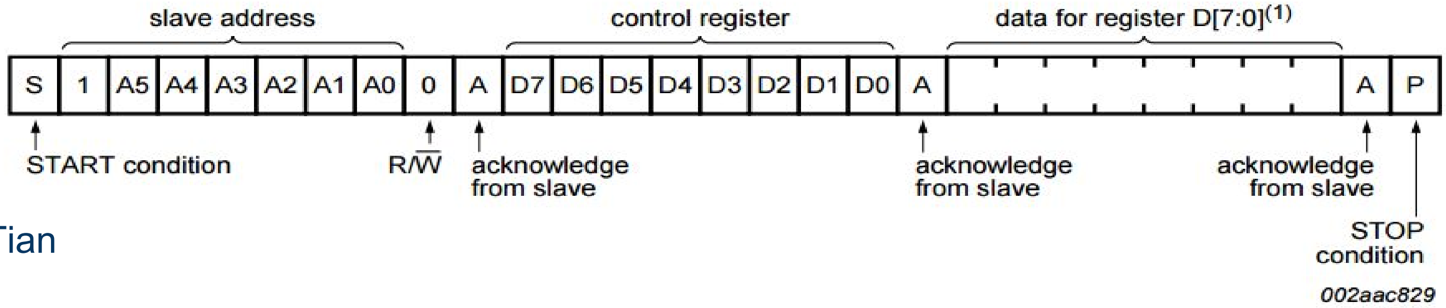
Slave address
Control register
Data



- Three consecutive I2C Write operation in LABVIEW
- Only 1 I2C slave
- Derived the settings from the datasheet



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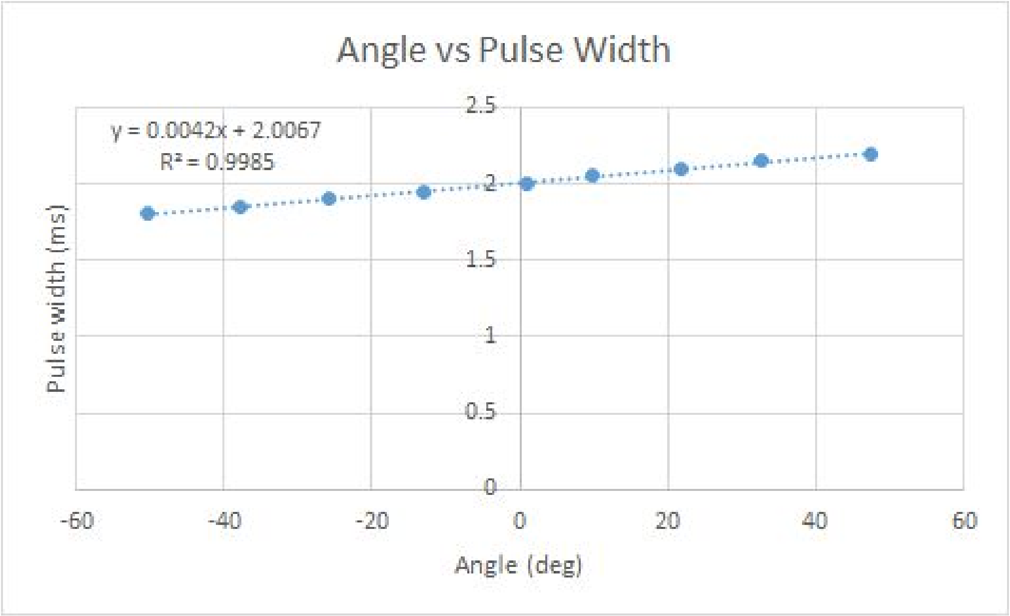
Pan & Tilt Head (Angle Mapping)

Pulse Width (ms) = 0.0042 * Angle (deg) + 2.0067



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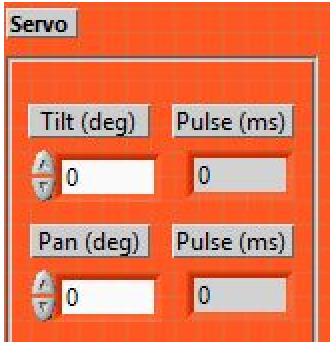
Relationship between angle and pulse width

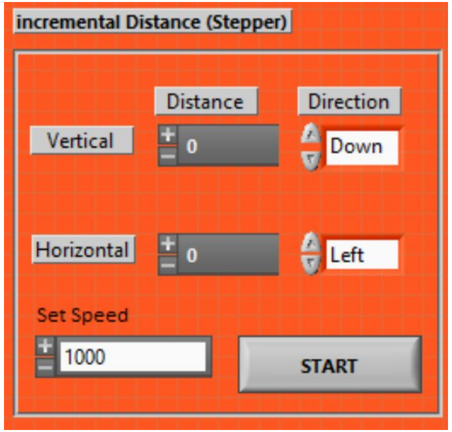
- PCA9685 accepts pulse width (ms) as input
- User enters angle (deg.) to control the pan & tilt heads
- Every servo is slightly different



Traversing Unit Functionalities

Last semester:

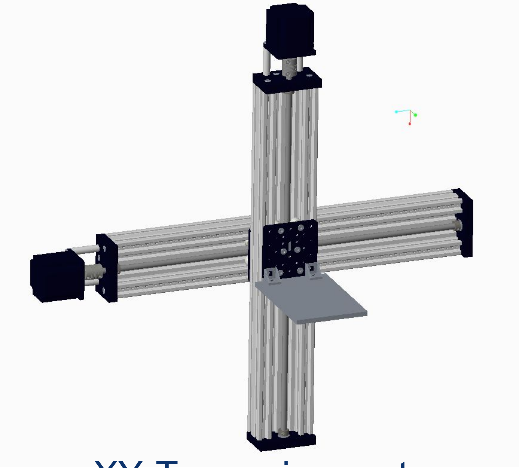
- Arrow keys control
- Need to measure the actual position of the traversing unit



Incremental distance control panel

Added functions in this semester:

- Auto-calibration
- User specified position by coordinates in mm
- User specified position by travel in mm
- Software boundaries



XY-Traversing system

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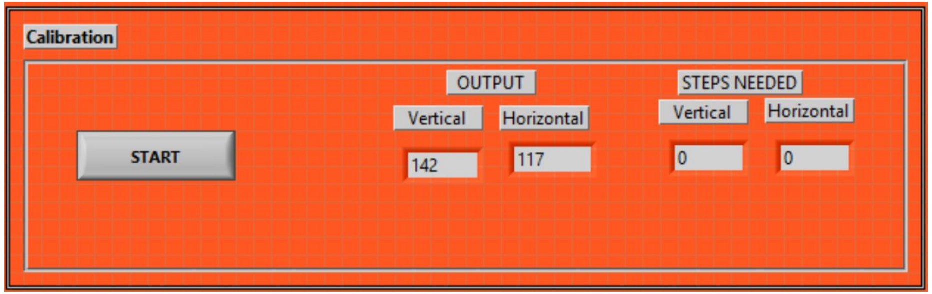
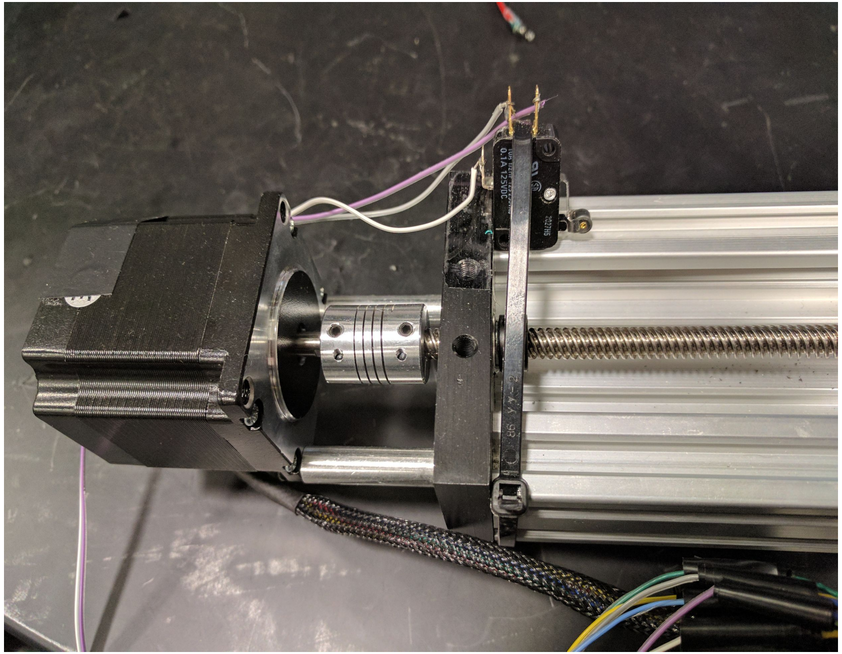
Auto-calibration

- Snap action switches
- Reset origin
- Coordinate display



Calibration control panel



Snap action switch on track boundary

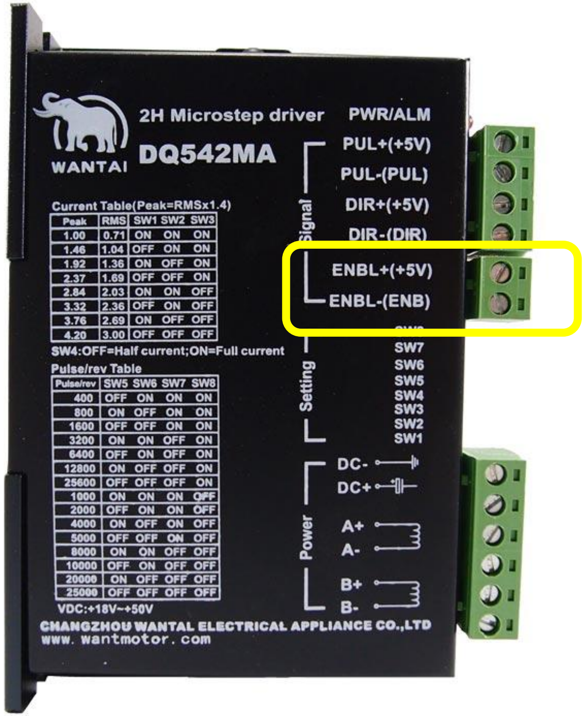
Weicheng Jiang

Auto-calibration Implementation

- LabVIEW generates short pieces of pulse trains to move the traversing unit step by step to the boundary from an unknown initial position
  - LabVIEW only allows for pulse trains with specified number of pulses

Auto-calibration Implementation

- When snap action switch closes, ENABLE on stepper motor driver is pulled high for 2s, and coordinate display is set to 0
  - ENABLE has to be pulled high for at least 1s to stop the stepper motor
- After 2s, ENABLE is pulled low again and the unit moves to the center



Stepper motor driver

Weicheng Jiang

Closed-loop Control of Pan&Tilt Head

Disadvantages without feedback and control:

- Actual angular position is unknown
- Errors due to mechanical parts such as gears and the way the servo is installed, and noise in electric signals
- Manual adjustment is imprecise and time-consuming

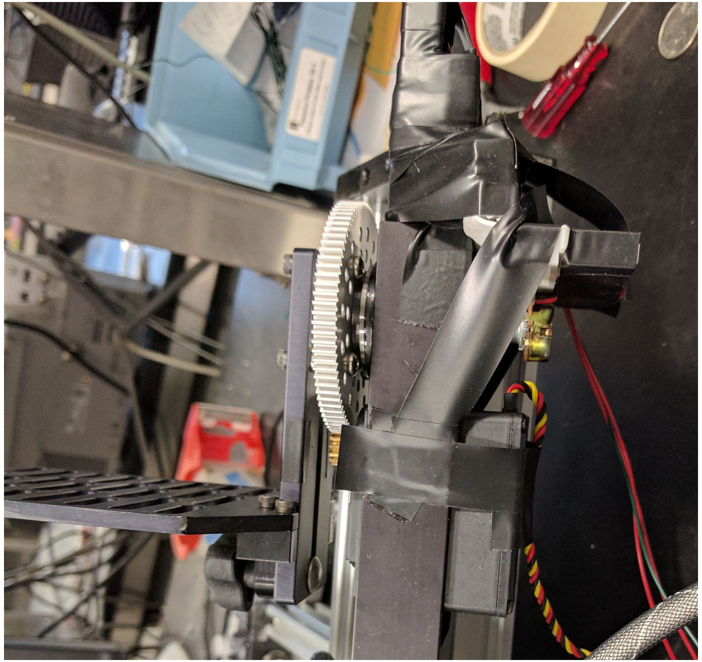
Solution: installing a potentiometer as an encoder to measure the actual angle and implement control algorithm to correct errors

Pan&Tilt head with camera

Weicheng Jiang

Power of Feedback and Closed-loop Control

- Actual angular position display
- Control algorithm ensures actual angle to be within +/- 0.5 degree of the specified angle
- Neutral position of the potentiometer must match bottom position of P&T head



Pan&Tilt head with encoder

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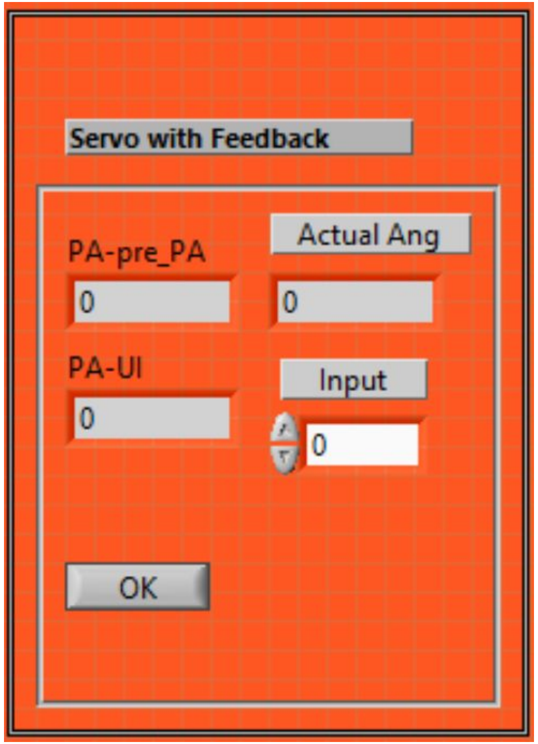
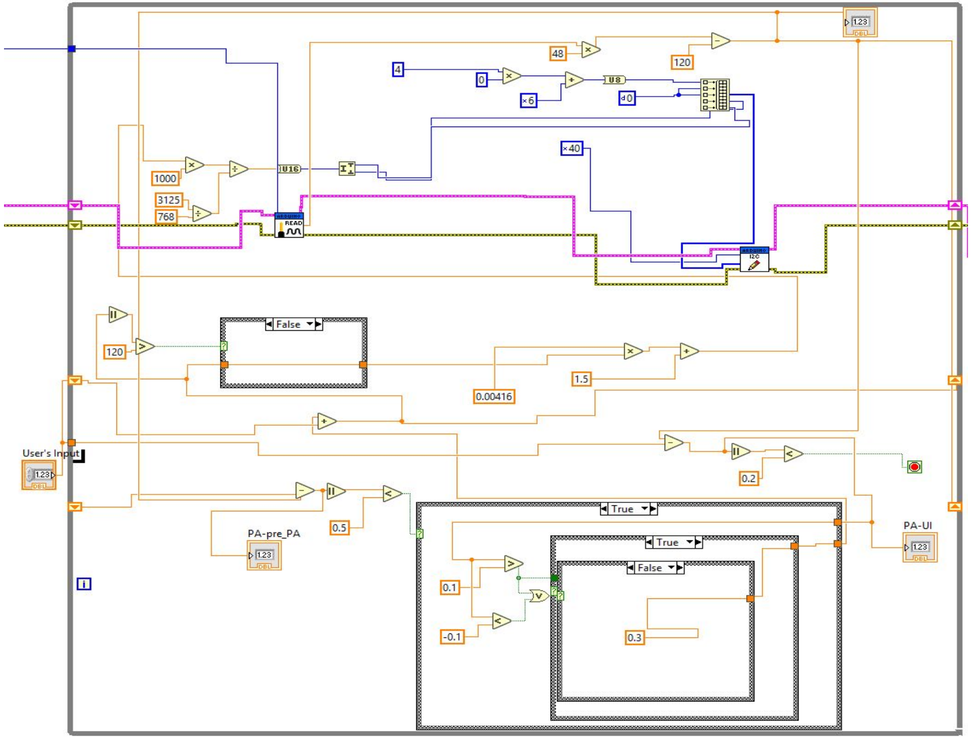
Closed-loop Control Implementation





Weicheng Jiang Closed-loop servo control panel

LabVIEW block diagram

Closed-loop Control Algorithm

Get **user specified angle**

PWM turns on

While the **actual angle** is outside the **range of tolerance**

If pan&tilt head is not moving

If **actual angle** is smaller than **specified angle** and outside **range of tolerance**

Increase **PWM** “ON” time by a small amount

If **actual angle** is larger than **specified angle** and outside **range of tolerance**

Decrease **PWM** “ON” time by a small amount

Power Specifications

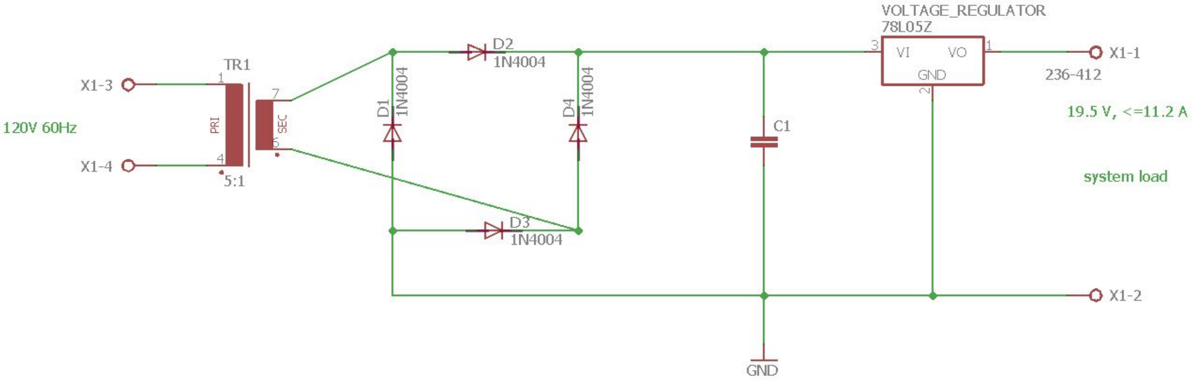
Note: these values are for one unit. There are 8 stepper motors and 8 servos.	**Acceptable Input Voltage Range**	**Chosen Input Voltage with Current Power Adaptor**	**Input Current Range (measured in field tests)**	**Current Power Adaptor Specs**
NEMA 23 Stepper Motor	12V ~ 48V	19.5V	330mA ~ 850mA	**Dell AC Adaptor** Output: 19.5V, 16.9A max, 330W max
HS-785HB Servo	4.8V ~ 6V	6V	12.5mA ~ 375mA	**ServoCity AC Adaptor** Output: 6V, 3A max, 18W max

Weicheng Jiang

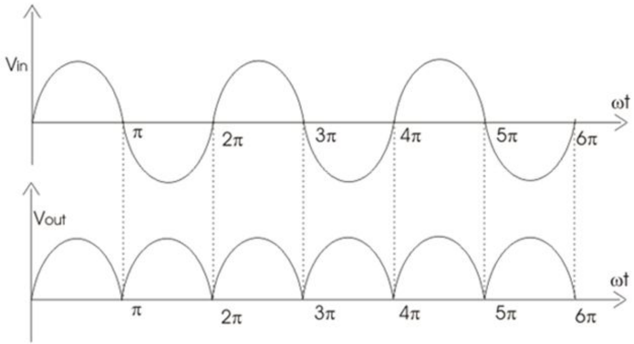
Build Our Own All-in-one Power Unit?

- Transformer
- Full-wave rectifier
- Reservoir capacitor
- Voltage regulator

Maximum system current=1*8+0.4*8=11.2A at 19.5V



Power circuit



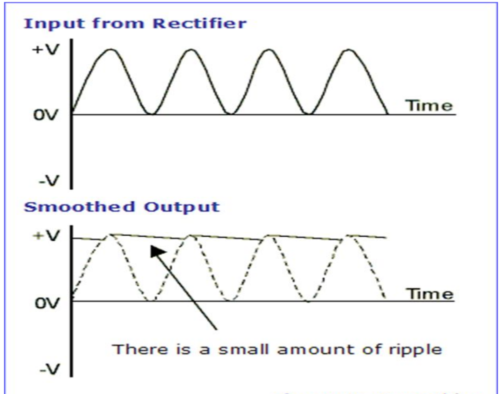


Figure 2: Smoothing

Weicheng Jiang

Stick With Existing Power Adaptors

- Could not find appropriate parts that meet the power requirements of our system
- Building a power unit with high power can be dangerous
- Existing power adaptors work quite well
- Need more time building LabVIEW-chip communication, auto-calibration of the traversing unit and closed-loop control of pan&tilt head

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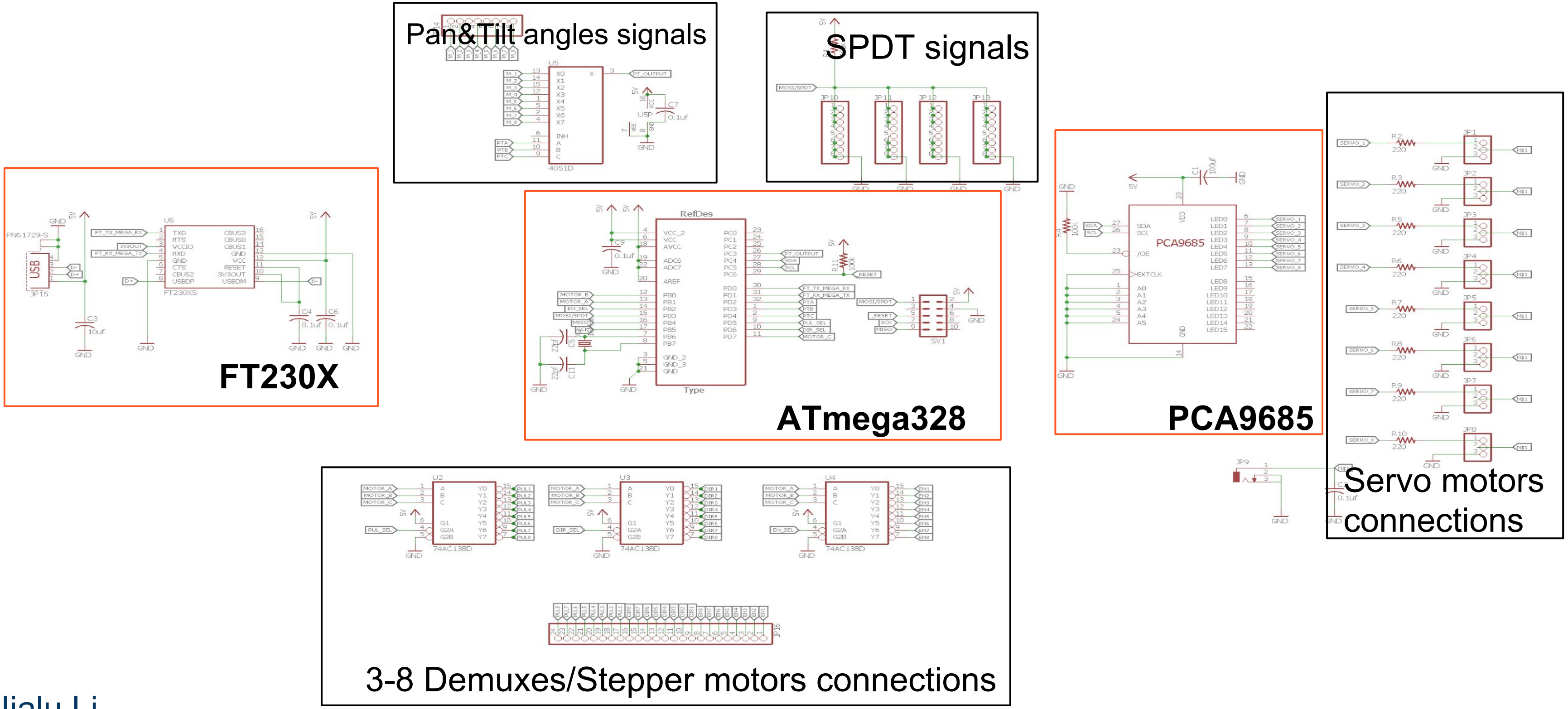
PCB design-schematic



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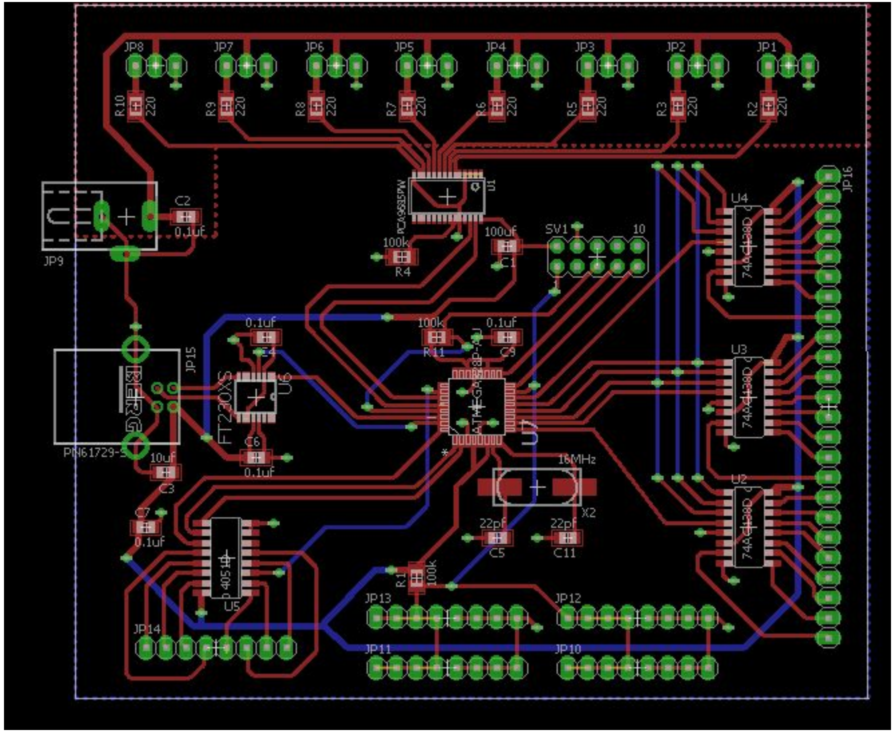
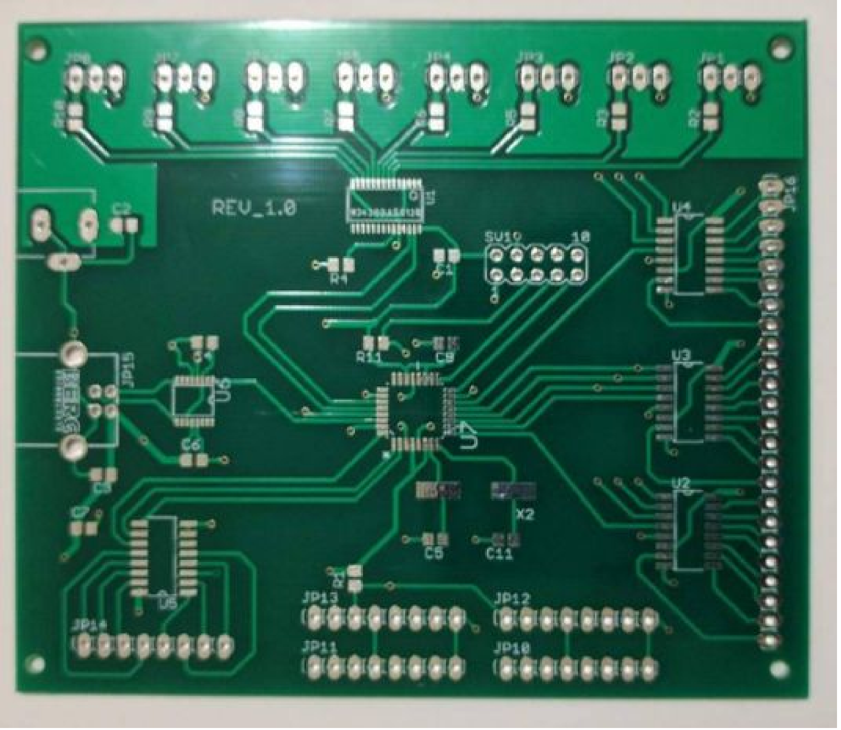
PCB design-board layout & actual board



PCB board layout



PCB actual board(front)

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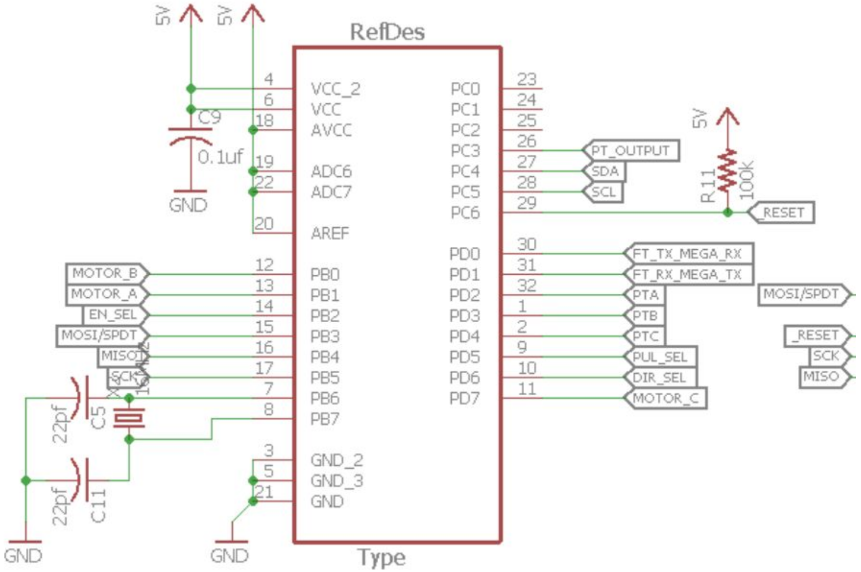
PCB design-main chips

- ATmega328 (main microprocessor)
- Requirements
  - Power supply from USB 5V+/-0.5V
  - The RESET pin works properly
  - Communicate with FT230X chip via UART signal and PCA9685 chip via I2C
  - Correct analog and digital I/O input and output
- Verifications
  - The LED connected to SCK pin blink three times
  - Stepper motor control, close-loop feedback control, and calibration unit perform as expected



Schematic of ATMega328

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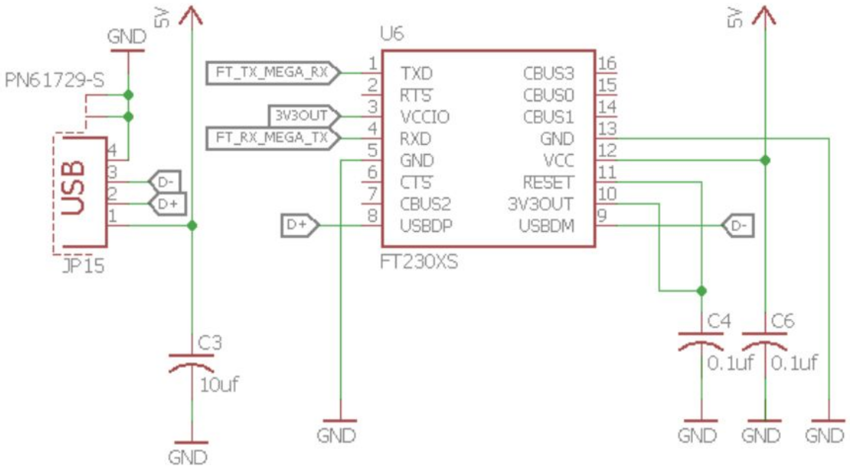
PCB design-main chips

- FT230X
- Requirements
  - The USB cable should provide a voltage from 5V+/-0.5V to the circuit board
  - Convert the USB signal to UART signal and communicate with ATmega328
  - Data transmission (baud) rate 9600 and packet size 15 byte
- Verification
  - The LABVIEW interface is able to communicate with microprocessor ATmega328



Schematic of FT230X

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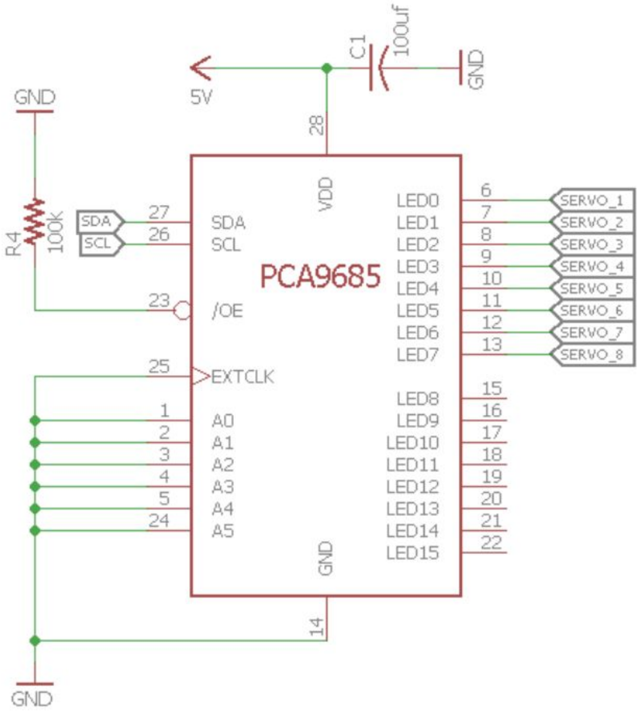
PCB design-main chips

- PCA9685
- Requirements
  - Power supply from USB 5V+/-0.5V
  - Operates between 24 Hz to 1526 Hz with adjustable duty cycle from 0% to 100%
  - Output 60 Hz signals on PWM channel 0 to 7
  - Control servo motor by changing PWM signals
- Verifications
  - Close-loop feedback control of servo motors works as expected



Schematic of PCA9685

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PCB design-other components

- Three 3-8 decoder (74AC11138)
  - Used to output correct pulse, direction and enable signals for stepper motors in four quadrants
- Snap action switch signals
  - Signals that come from snap action switches for calibration purpose
- One 3-8 multiplexer (74HC4051D)
  - Analog signals from potentiometer for servo motors in four quadrants
- Servo-motor connections
  - Each line is protected by 220 ohms resistors

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PCB design-errors and problems

- First round of PCB order was delayed
- Digikey sent wrong packages of 74AC11138, and we received 74AC138
- Decoders are no longer needed for final Demo
- Snap action switch signals need extra logic OR gate
- SDA & SCL in PCA9685 didn’t pull HIGH

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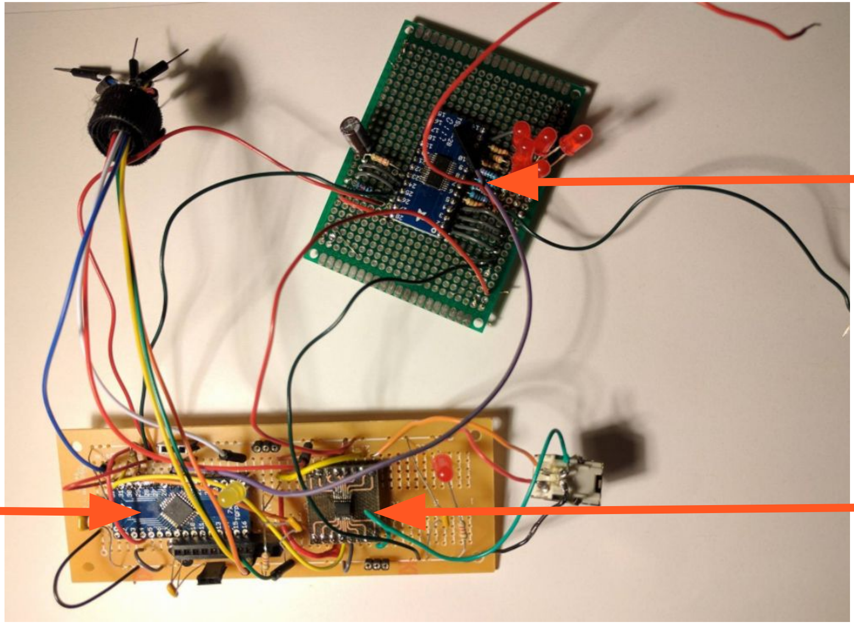
Final circuit on perfboard

- We kept three most important chips and completed functionalities for one quadrant



Circuit on perfboard

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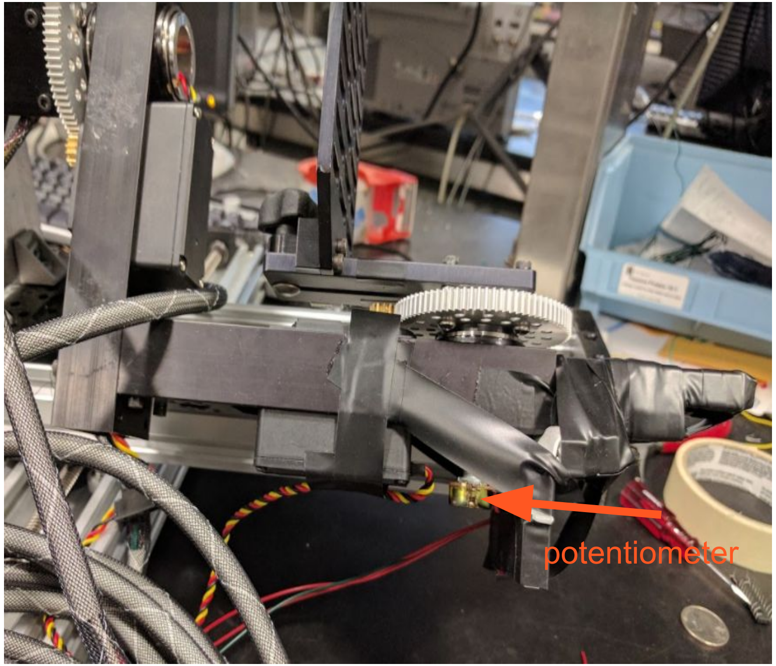
Successes and Challenges

- Successes
  - All designed units are functional
  - Designed circuit works properly
- Challenges
  - Burn Arduino Uno bootloader to brand-new ATMega328 chip with USBASP, need to figure out the ISP communication, clock setting, etc
  - Mount potentiometer to fit with the structure of the servo motor



How potentiometer installed on servo motor

Jialu Li

Recommendations for future work

- Expand calibration and servo motor close-loop feedback controls to all camera gantries
- Integrate all necessary circuit parts into one PCB unit

Jialu Li

Acknowledgement

- Prof. Chamorro in Renewable Energy & Turbulent Environment Group at the Department of Mechanical Science and Engineering
- Sponsor John Deere
- TA: John Capozzo
- Mark Smart and Skot Wiedmann in Electronics Services Shop

Thank you!
Any questions?