University of British Columbia
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ELEC 391
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Ball Hopper: Gripper Robot

Group 18 - Portugal

Requirements

- Must be able to pick a standard tennis ball
- Must carry the balls for at least a distance of 2 meters
- Must be compatible with the given interface unit

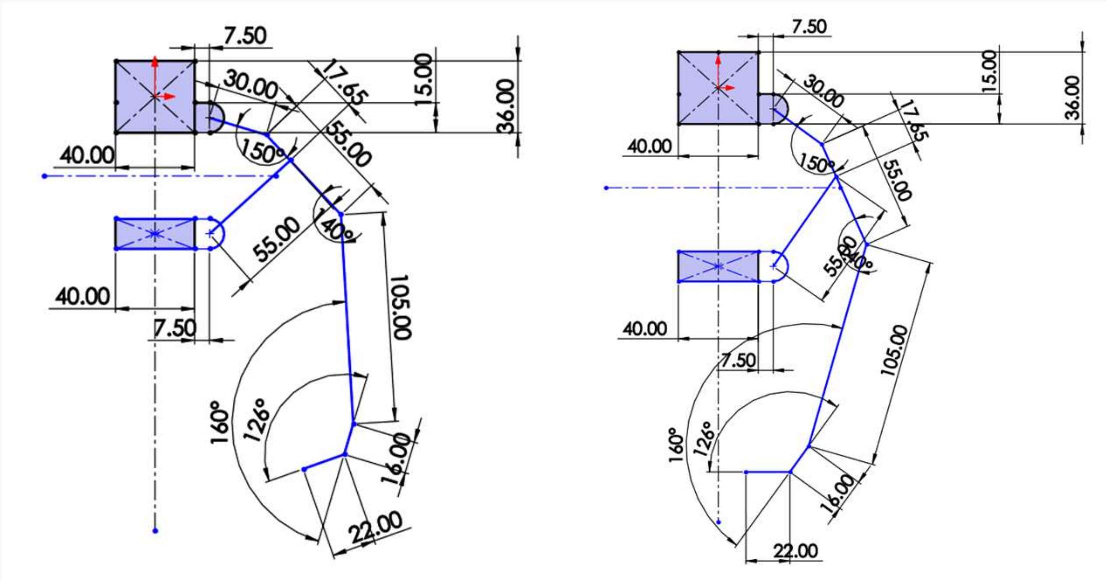
Constraints

- Cannot operate without a permanent magnet in the destination

Goals

- Maximize the distance balls can be carried
- Minimize the operation time

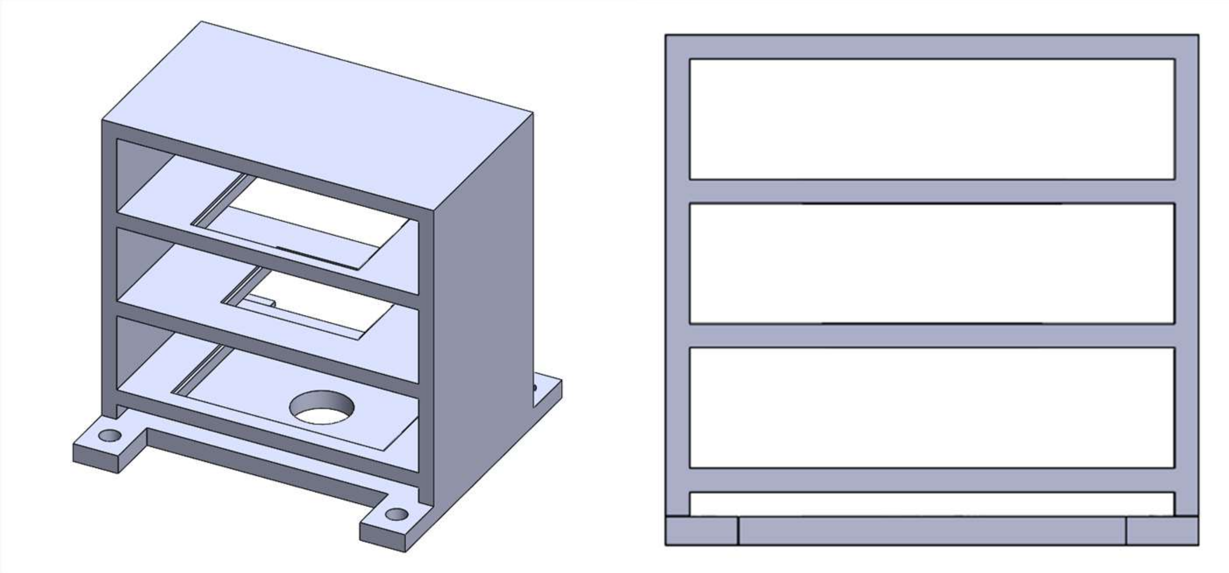
System ID – Range of Motion



Inverse Kinematics for our Gripper

- An undefined sketch was drawn to characterize the range of motion and orientation for the gripper
- This allows us to perform motion planning more efficiently than doing calculations by hand
- Only the "open" and "close" states are shown here since these are the most important to consider

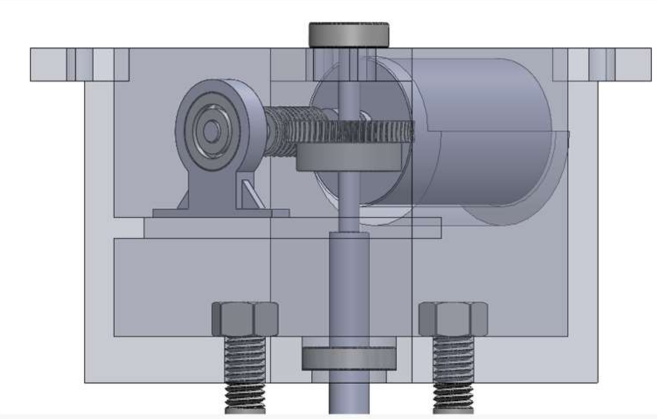
System ID - Lid

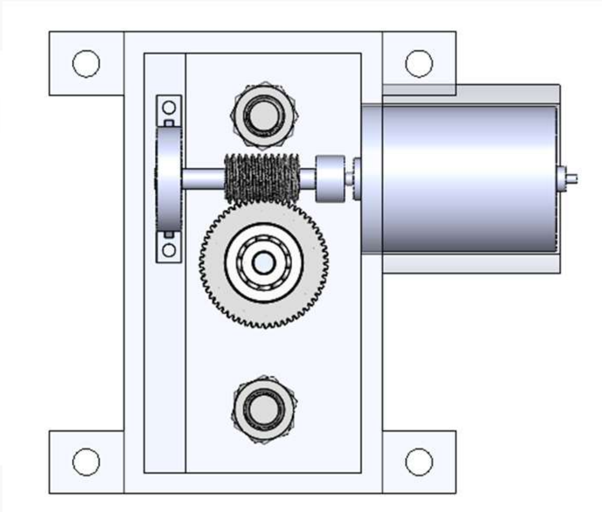


Multipurpose Lid

- Our mechanical interface is mounted at the top of the lid
- The tabs on each of the four corners of the lid are used to mount the rest of the assembly
- The shelves are used to house our Motor Driver, Pulse Counter & Motherboard PCBs
- A guiding bearing is also press fit into the bottom layer as shown in the left diagram

System ID - Gearbox

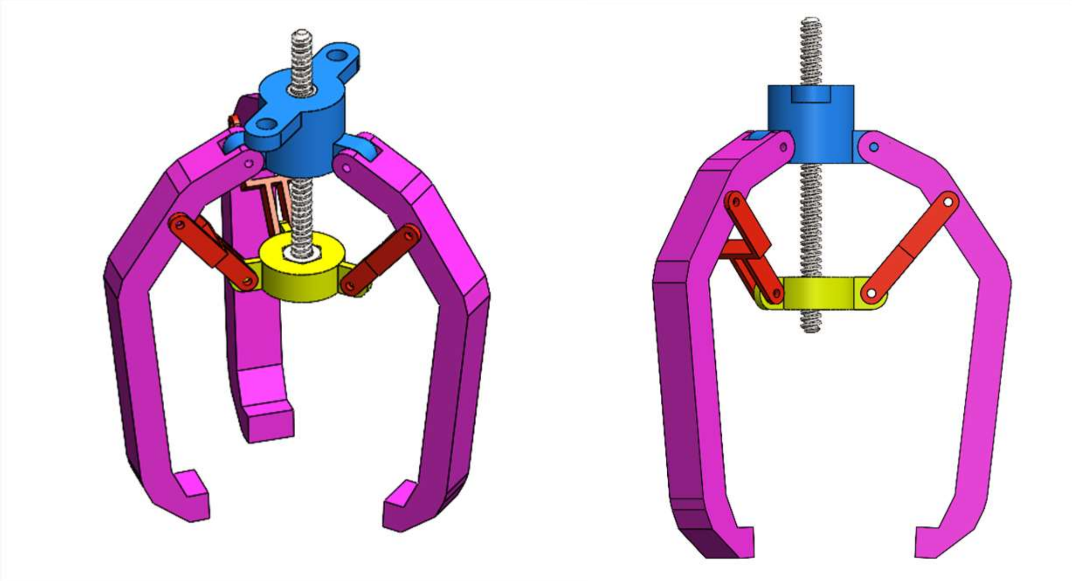




Gearbox Assembly

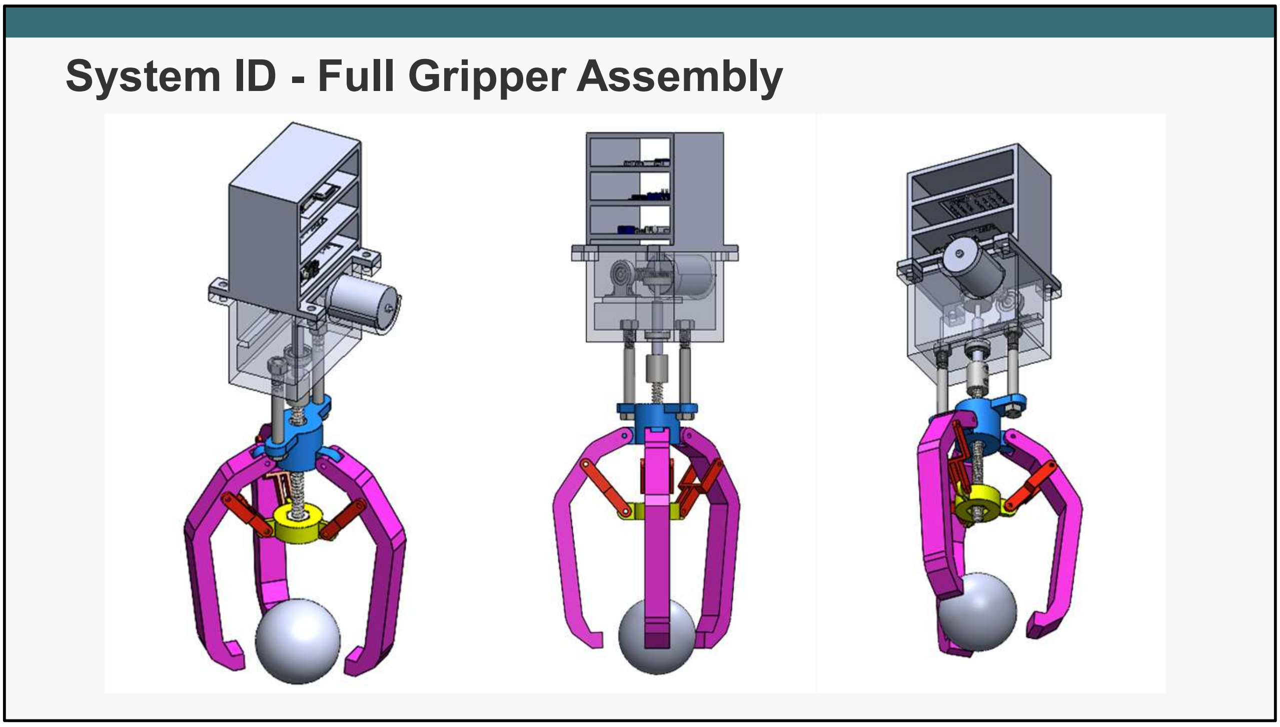
- It features a worm gear assembly with a 60:1 gear reduction, multiplying the motor's torque sufficiently
- The bearings are used to reduce rotational friction and ensure smooth rotation of the driving and driven
- Tabs at the four upper corners are used to connect the gearbox and the rest of the claw assembly to the lid
- A support was placed at the side of the gearbox to mount the motor and correctly align it with the driver shaft

System ID - Claw



Claw Assembly

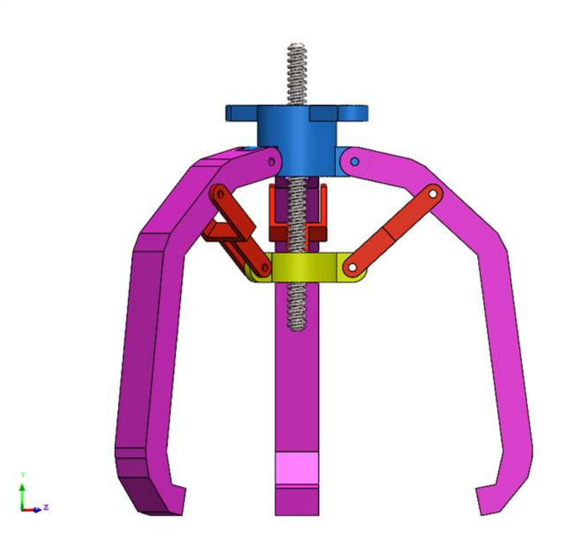
- The claw itself features three arms, three connecting rods, a lead screw and two hubs
- The upper hub in blue is used to mount the claw to the gearbox
- The lead screw transforms the rotational motion of the motor to the translational motion of the lower hub
- It lowers and raises the hub which in turn moves the fingers using the attached connecting rods
- The hub moves a distance of 0.125 inches per revolution of the lead screw

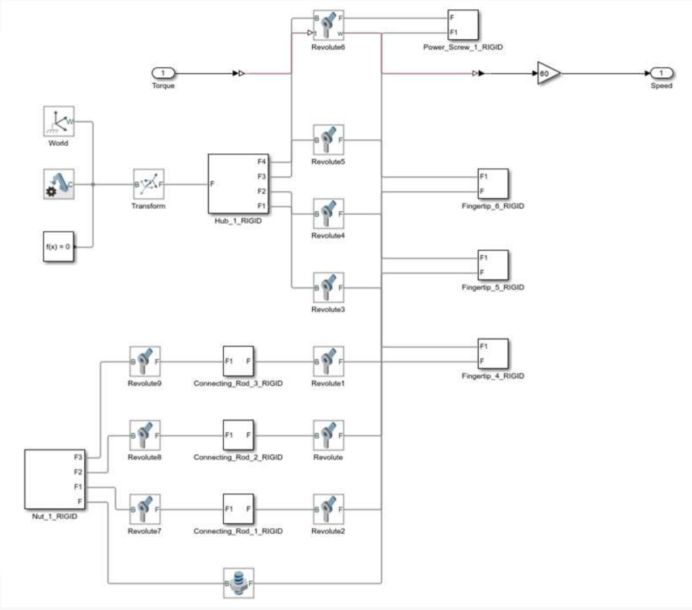


Complete Gripper Assembly

- The components from the previous slides have been integrated together
- There are a few additional components including
  - PCBs which have been placed inside of the lid
  - The model for the tennis ball to be picked up
  - The shaft collar that connects the lead screw to the driven shaft
  - Claw bolt supports between the gearbox and upper hub

System ID - Simscape Model

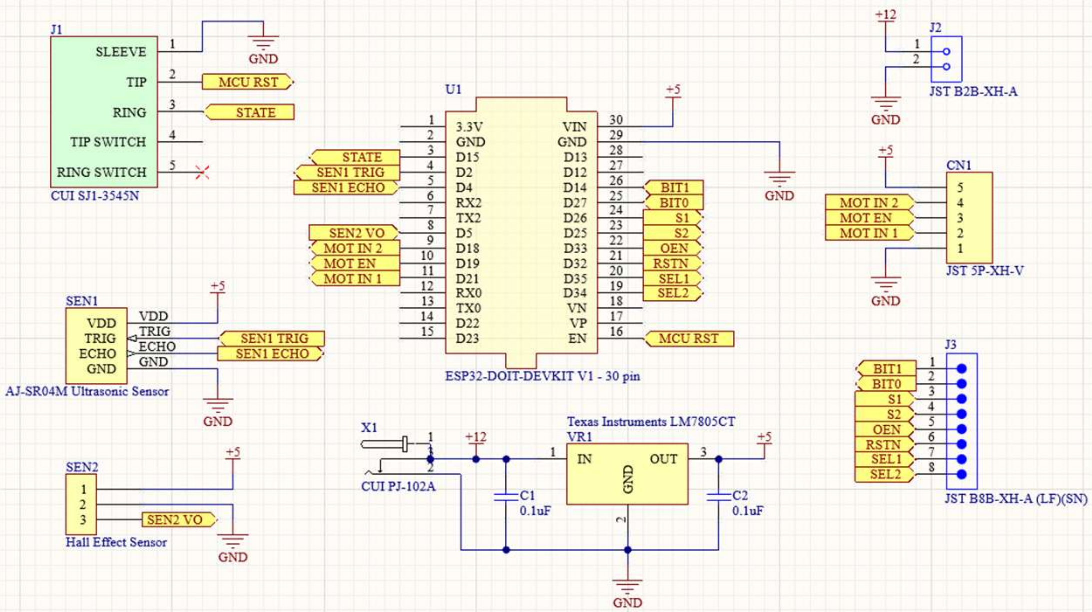




Simscape Simulation

- The Simscape model for the claw assembly is shown on the right while the model within the Simscape simulation environment is shown on the left
- Most of the model blocks are connected via revolute joints which represent rotational motion about the hinges of the claw assembly
- There is also a lead screw joint between the power screw and the lower hub to simulate the transformation from rotational motion to translational motion
- This subsystem was incorporated into our complete system model as a mechanical admittance

Analog Electronics - Motherboard Schematic

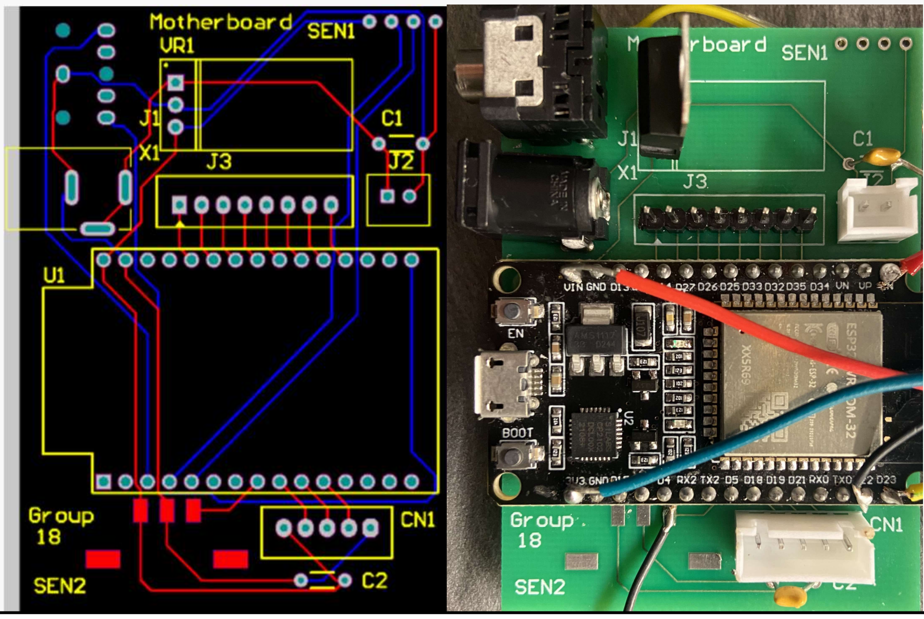


Motherboard PCB Schematic

- Esp32 devboard is used as the microcontroller as it provides enough pins and timers
- Ultrasonic sensor is used to detect the tennis ball to be picked up
- Hall effect sensor is used to detect the destination marker
- Predefined power and digital interface units are used

  - On the PCB assembly MCU RST and STATE signals have been reworked to match the crossover in the given electrical interface

Analog Electronics - Motherboard



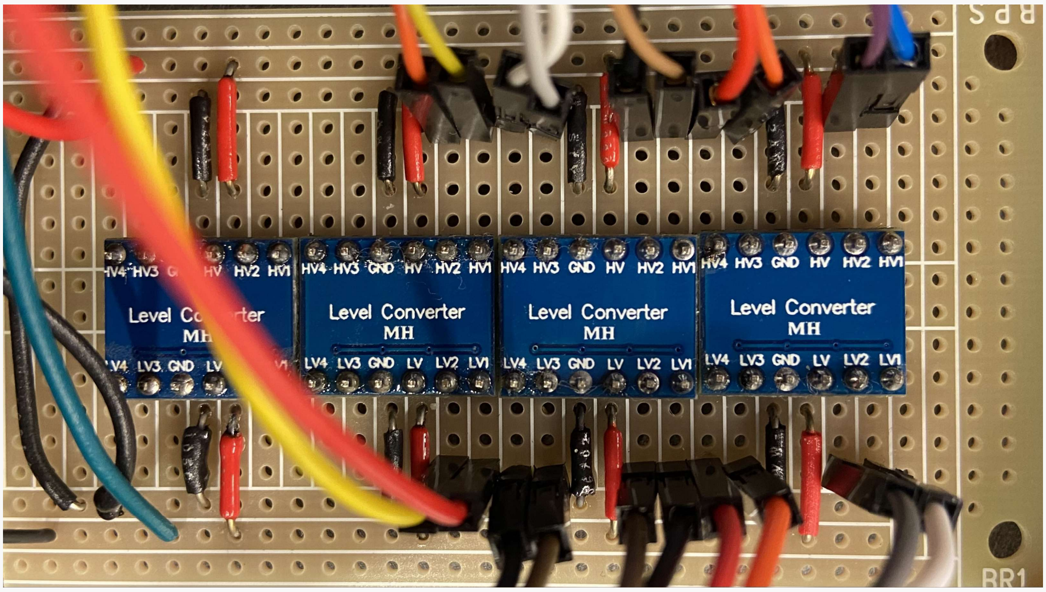
PCB Routing for the Motherboard

- A two-layer PCB is designed for the Motherboard circuit
- All the peripherals are oriented towards the left side for easy access
- Red wires show the wiring on the top layer, while the blue wires show the wiring on the bottom layer

Photo of the Assembled PCB

- A Voltage regulator is used to supply regulated 5 V to necessary pins
- J2: It is the connector for the power of the Motor Driver
- J3: It is the connector for the control signals of the Pulse Counter
- CN1: It is the connector for the control signals of the Motor Driver

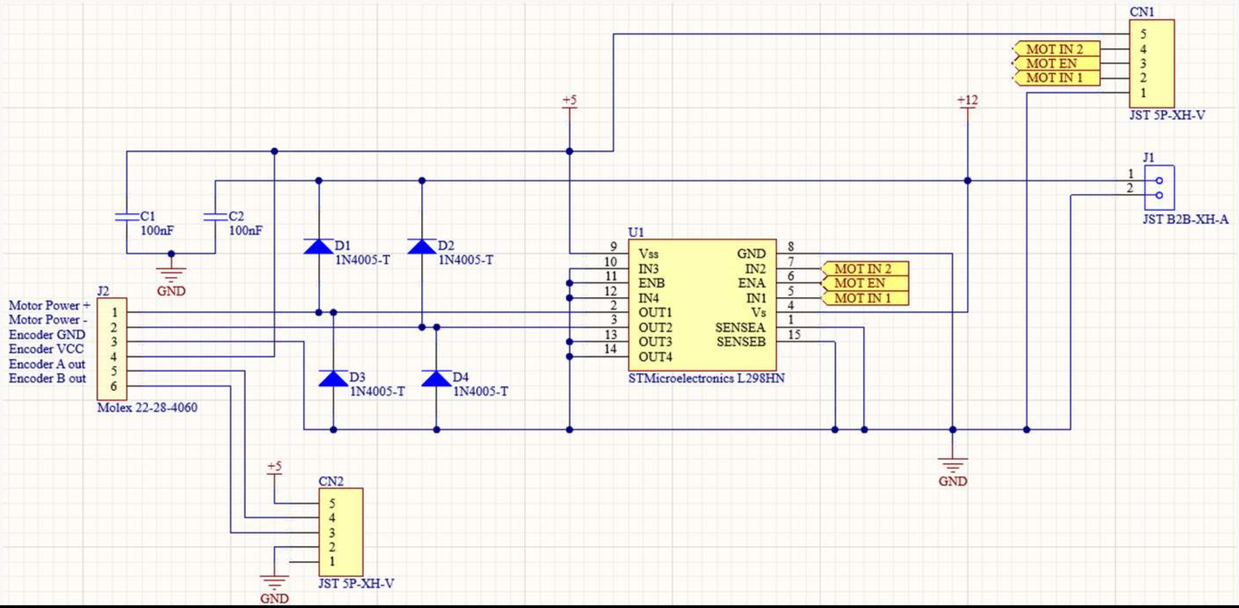
Analog Electronics – Level Shifter



Rework on a Perf Board

- Level shifters are used to convert 3.3 V signals of the microcontroller to 5 V signals for the Pulse Counter
- The level shifters are also bidirectional, allowing us to both read and write signals when necessary

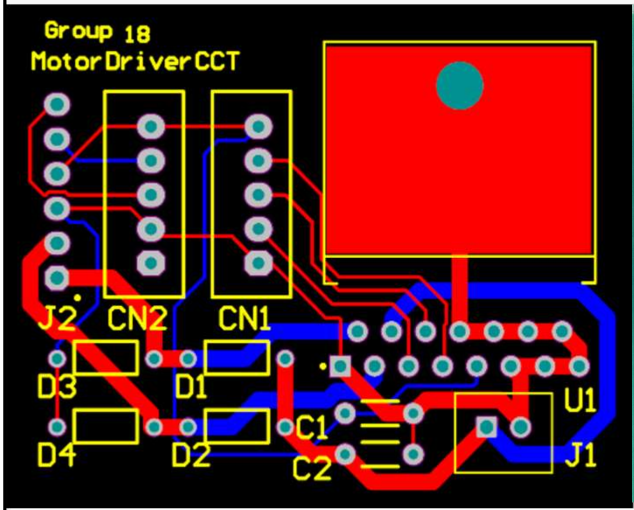
Analog Electronics - Motor Driver Schematic

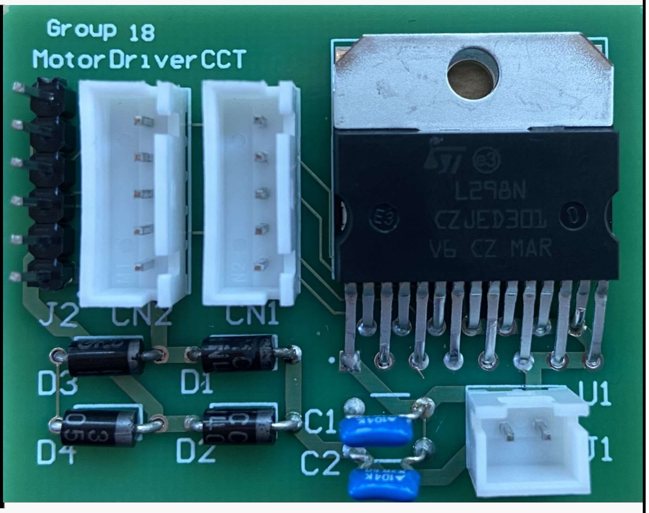


Motor Driver PCB Schematic

- L298 IC is used as the Motor Driver
- 4 fly back diodes are used to provide a path for the current to dissipate when the motor switches from on to off
- MOTIN1 and MOTIN2 signals are used to control the direction and speed of the motor

Analog Electronics - Motor Driver





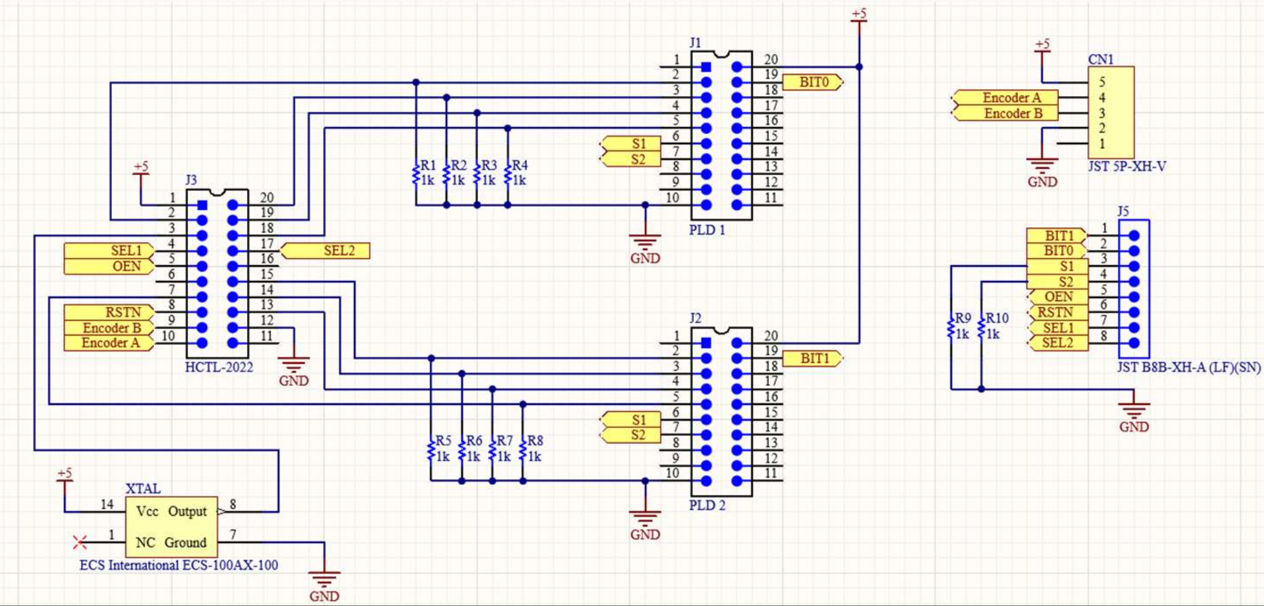
PCB Routing for the Motor Driver

- A two-layer PCB is designed for the Motherboard circuit
- 1.2 mm width traces were used to carry current to the motor because they can withstand around 3 Amps, which was the max current rating we expected
- Control and motor power signals were separated onto different parts of the board as much as possible to reduce risk of cross talk

Photo of the Assembled PCB

- Connectors from left to right are: the motor, Pulse Counter board and Motherboard
- The connector on the bottom right is for powering up the Motor Driver

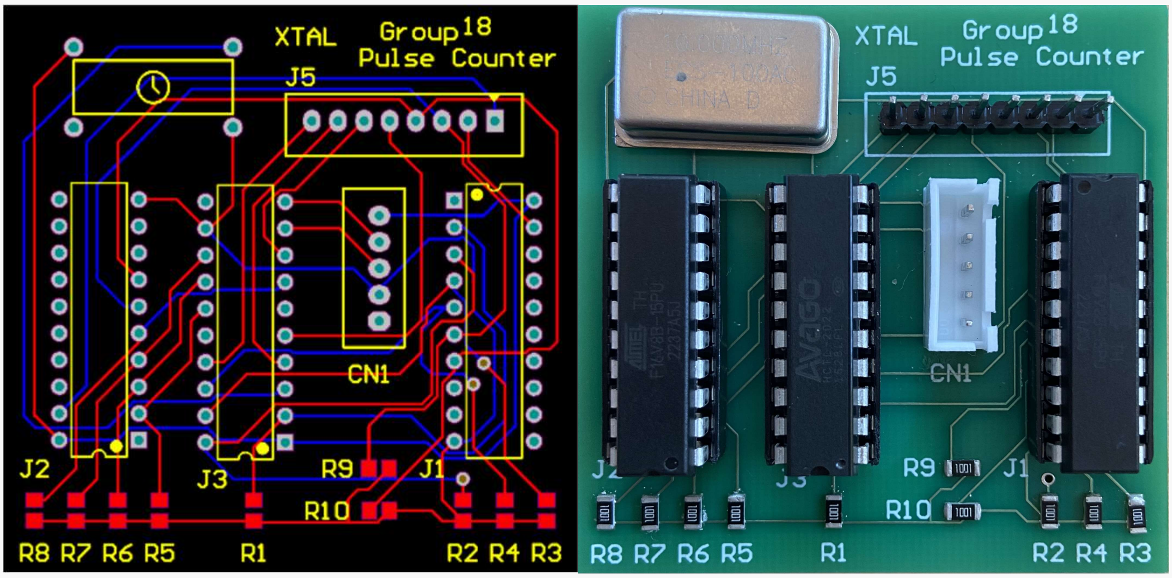
Digital Electronics - Pulse Counter Schematic



Pulse Counter PCB Schematic

- 3 20-pin DIP Sockets are used to mount HCTL-2022 and PLDs
- Crystal (XTAL) is used to provide necessary clock signal to HCTL-2022
- 1k Ohm pull-down resistors are used to ensure signals become low voltage properly and reduce noise
- External connectors are used to wire between boards

Digital Electronics - Pulse Counter



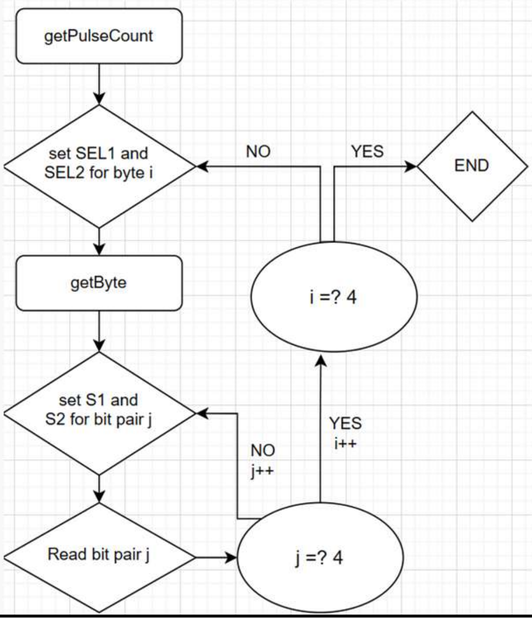
PCB Routing for the Pulse Counter

- A two-layer PCB is designed for the Pulse Counter circuit
- DIP Sockets are used to provide easy access to ICs if needed to take apart
- SMD resistors are used to minimize the occupied space

Photo of the Assembled PCB

- ICs from left to right are as follows: PLD (4-1 MUX) / HCTL-2022 / PLD (4-1 MUX)
- J5: It is the connector for Control and Output signals of HCTL-2022 and MUXs
- CN1: It is the connector for Encoder A/B Signals coming from the Motor Driver board

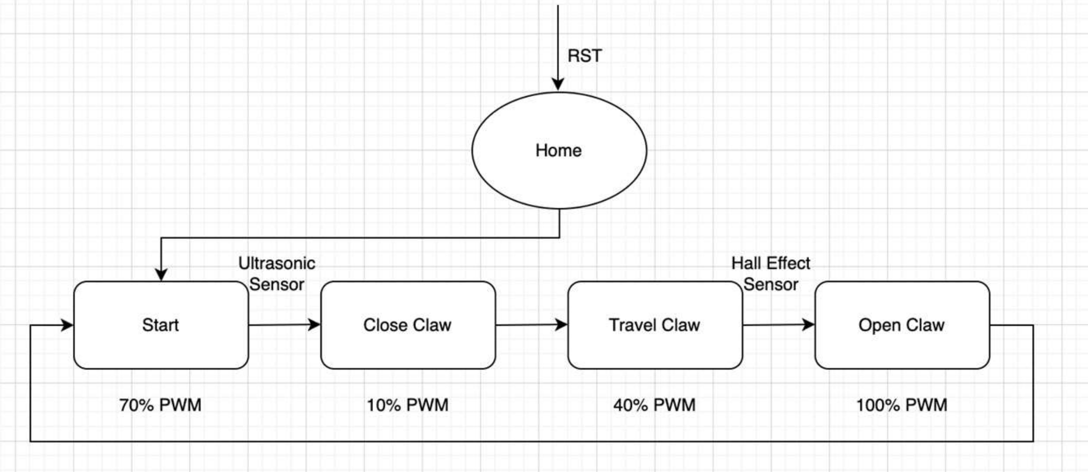
Digital Electronics - Pulse to Angle Conversion



Algorithm to Read and Convert Pulse Count to Degrees

- getPulseCount function sets SEL1 and SEL2 signals to read byte number "i"
- getByte function sets S1 and S2 signals to read a bit pair "j"
- 1 byte = 8 bits -> getByte loops 4 times
- Pulse Count is 32-bit value, 32 bits = 4 bytes -> getPulseCount loops 4 times

Optimal Control – Software Implementation



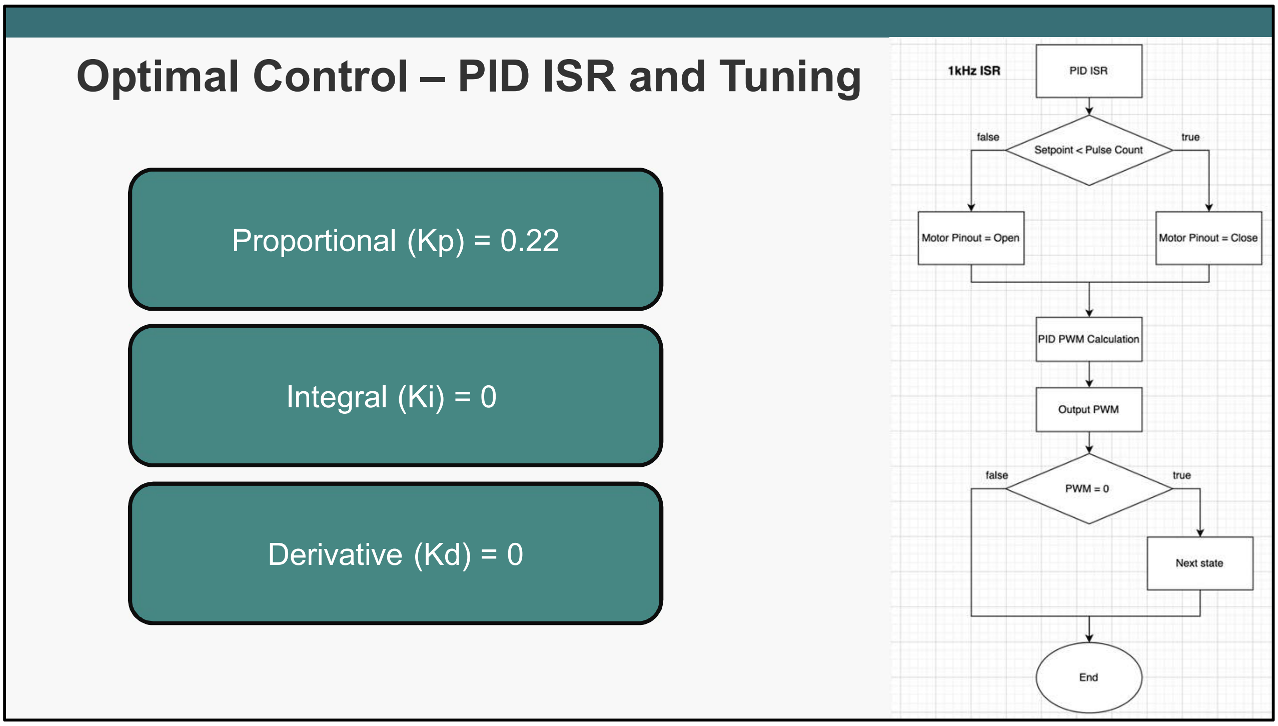
ESP32-Dev  Ultrasonic Sensor  Hall Effect Sensor 

ESP32

- All the pins give flexibility to use PWM, 32 pin layout
- PWM easy to configure frequency and resolution to blink state
- Fit requirement for ISR timer at frequency that we're using

State

- Homing and then 4 different states
- "Close" + "Open" claw use PID tuning
- Sensors used to move between states
- PID also used to move between states



P-Controller

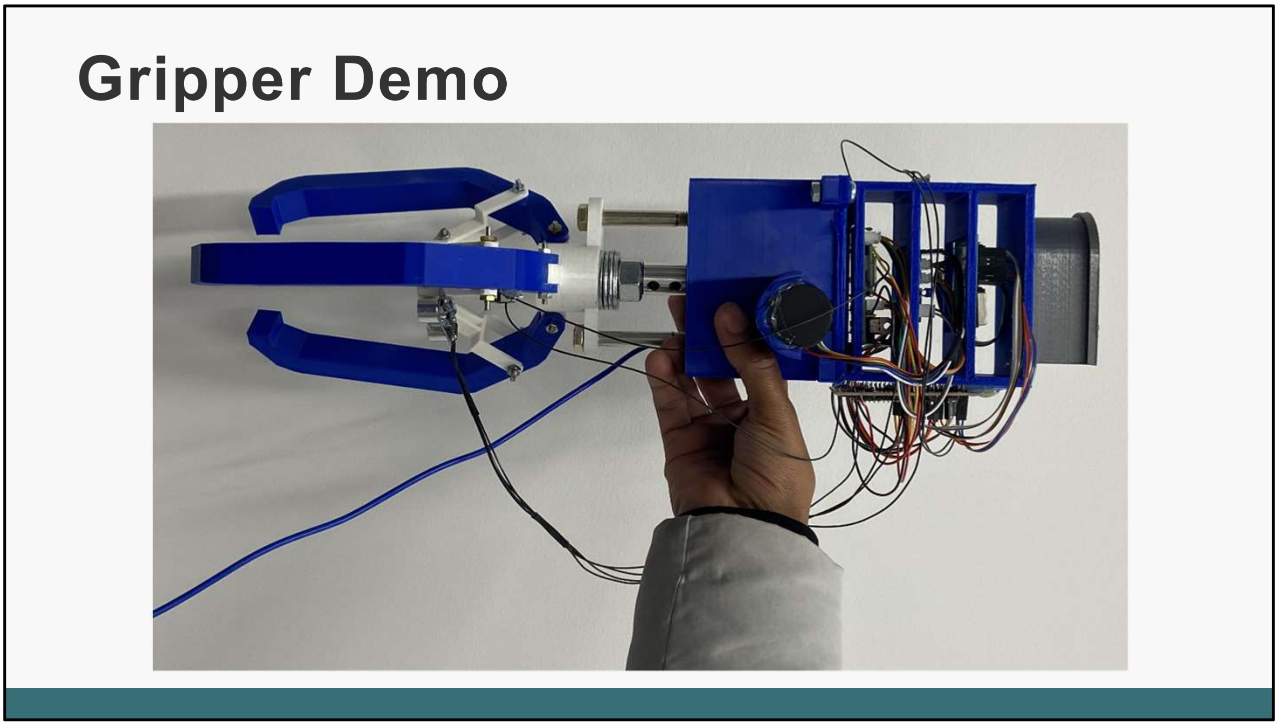
- Helps increase to set point
- Increase until oscillates, decrease rising time

I-Controller

- Helps decrease offset
- Could cause overshoot if increased too much

D-Controller

- Decrease overshoot / damping



Videos for the Project

- Motor moving the fingers: https://drive.google.com/file/d/1yS_-Fr6xO_KhF4LMuMfDDbp4060NnIY1/view?usp=sharing
- The control system working before integration, with sensors: https://drive.google.com/file/d/1pgXOPBrIMusSZi8hItNfwTtvf7tGX0xt/view?usp=sharing

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Thank you for listening!

Any questions?