Day 3

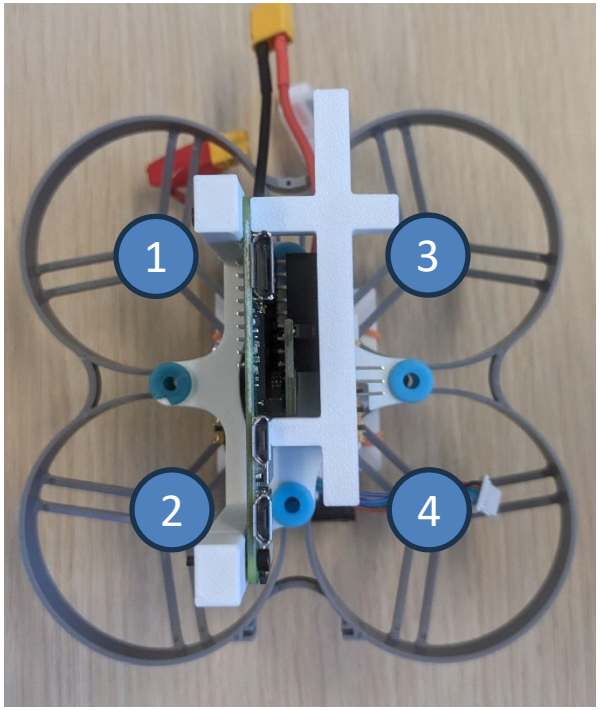
Joystick Desired thrust, pitch
P control (pitch)
D control (pitch)
I control (pitch)
PID (pitch)

Administration

- Make sure you include all requested info in reports.
  - Graphs from class should be in reports
  - Label graphs!
  - Submit code as .cpp and report as .pdf
- Practice flying!
- Team should work together on same tasks, not divide and conquer
- Submit report on time, no late submissions allowed

Motors

- 4 motors with independent speed control
- Speed between 0 and 2000
- Create an array for motor commands:
  - Int motor_commands[4];
- And then set motors with a function:
  - void set_motors()



Thrust

- Moves robot up and down vertically without effecting any other tilt.
- Motor1=Thrust
- Motor2=Thrust
- Motor3=Thrust
- Motor4=Thrust
- Thrust minimum = 0
- Thrust maximum = 2000
- Variables:
  - Thrust_neutral
  - Thrust_amplitude

Thrust joystick

- When Joystick is highest
  - Thrust=Thrust_neutral+Thrust_amplitude
- When Joystick is middle
  - Thrust=Thrust_neutral
- When Joystick is lowest
  - Thrust=Thrust_neutral-Thrust_amplitude
- Linear between these points

Pitch error

- Pitch error= desired pitch - measured pitch
  - Measured pitch from complimentary filter
  - Desired pitch from joystick
- Goal of robot controller is to have no pitch error

Joystick desired pitch

- Variables:
  - Pitch_amplitude (degrees)
- When Joystick is highest
  - Pitch_desired=-pitch_amplitude
- When Joystick is middle
  - Pitch_desired=0
- When Joystick is lowest
  - Pitch_desired=pitch_amplitude
- Linear between these points

Pitch proportional control

- More the robot tilts away from desired pitch, the stronger it torques to the desired pitch.
- Pitch torque $\propto$ pitch error
- Motor command=thrust $\pm$ P_{gain}*P_{error}
  - $\pm$ means 2 motors are +, two are -
- Try a value of P_{gain} of 10

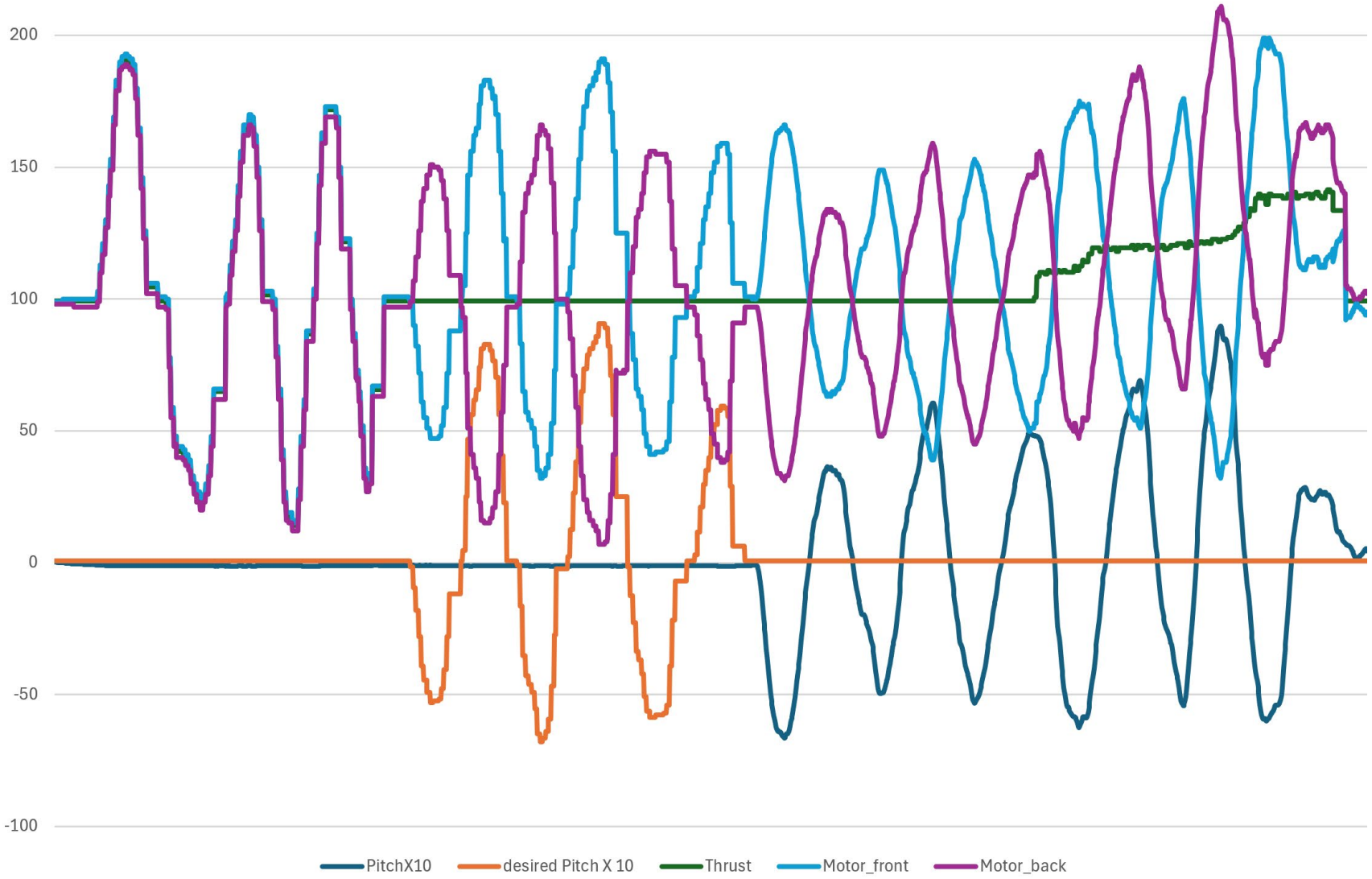
Pitch proportional control

- Motor1=thrust ± P_{gain}*P_{error}
- Motor2=thrust ± P_{gain}*P_{error}
- Motor3=thrust ± P_{gain}*P_{error}
- Motor4=thrust ± P_{gain}*P_{error}
  - ± means 2 motors are +, two are -
- Try a value of P_{gain} of 10

Milestone 1

1. P (proportional) controller, including safety
   - Control+C, Gyro limit, roll/pitch limit, joystick kill.. All kill motors (set to 0) with explanation and exits program
   - Plot the following on one graph
     - Motor speeds, desired thrust, desired pitch, measured pitch (from comp filter)
     - Show on level ground with thrust changes
     - Show on level ground with desired pitch changes
     - Show moving the imu with hands off joystick
     - Show moving the imu with joystick thrust commands~150
   - Set the following values (for nicer graphs, plot pitch*10,desired_pitch*10):
     - pitch_amplitude=10
     - Thrust_neutral=100
     - Thrust_amplitude=100

Milestone 1


200
150
100
50
0
-50
-100
PitchX10
desired Pitch X 10
Thrust
Motor_front
Motor_back

Pitch derivative control

- Keeps the robot from moving too quickly in pitch.
- The faster robot rotates in pitch, the stronger it torques to slow down the pitch speed.
- Pitch torque $\propto$ pitch velocity
- Motor command=thrust $\pm$ D_{gain}*$Pitch_{speed}$
- How to measure pitch speed?

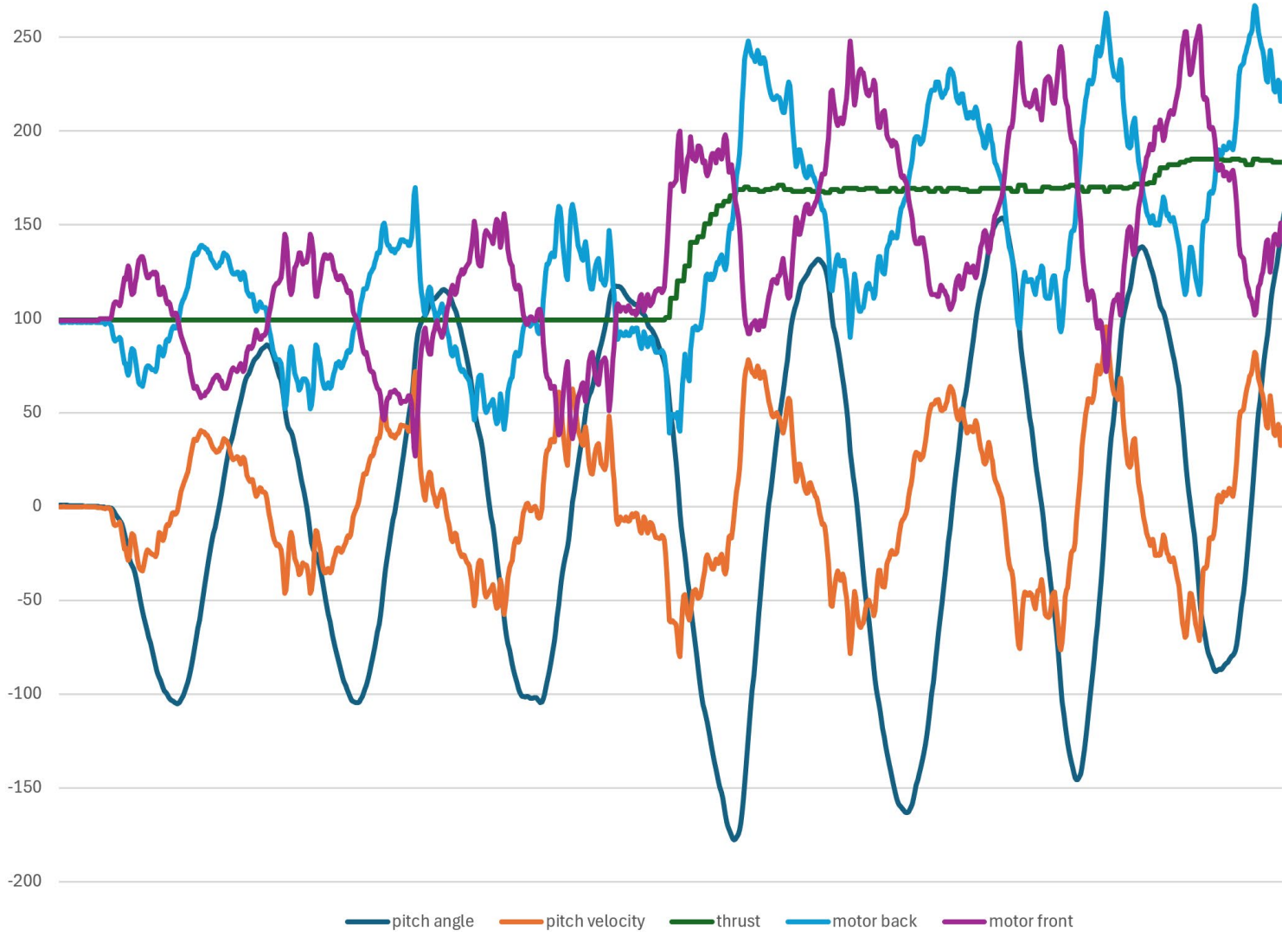
Pitch derivative control

- Motor1=thrust ± D_{gain}*$Pitch_{speed}$
- Motor2=thrust ± D_{gain}*$Pitch_{speed}$
- Motor3=thrust ± D_{gain}*$Pitch_{speed}$
- Motor4=thrust ± D_{gain}*$Pitch_{speed}$
  - ± means 2 motors are +, two are
- Try a value of D_{gain} of 1.0

Milestone 2

1. D (derivative) controller, including safety
   - Control+C, Gyro limit, roll/pitch limit, joystick kill.. All kill motors (set to 0) with explanation and exits program
   - Plot the following on one graph
     - Motor speeds, measured pitch (from comp filter), pitch velocity (from gyro)
     - Show moving the imu with hands off joystick
     - Show moving the imu with joystick thrust commands ~150
   - Set the following values (for nicer graphs, plot pitch*10):
     - Thrust_neutral=100
     - Thrust_amplitude=100

Milestone 2


250
200
150
100
50
0
-50
-100
-150
-200
pitch angle
pitch velocity
thrust
motor back
motor front

Pitch Integral control

- The longer the pitch has error, the stronger it torques to the desired pitch (up to a limit).
- Pitch torque $\propto \int$pitch error
- Every control loop:

  $Integral_{pitch} \mathrel{+}= I_{gain} * P_{error}$

  $Integral_{pitch}$ should be limited to $\pm I_{saturate}$
- Motor command=thrust $\pm Integral_{pitch}$
  - $\pm$ means 2 motors are +, two are -

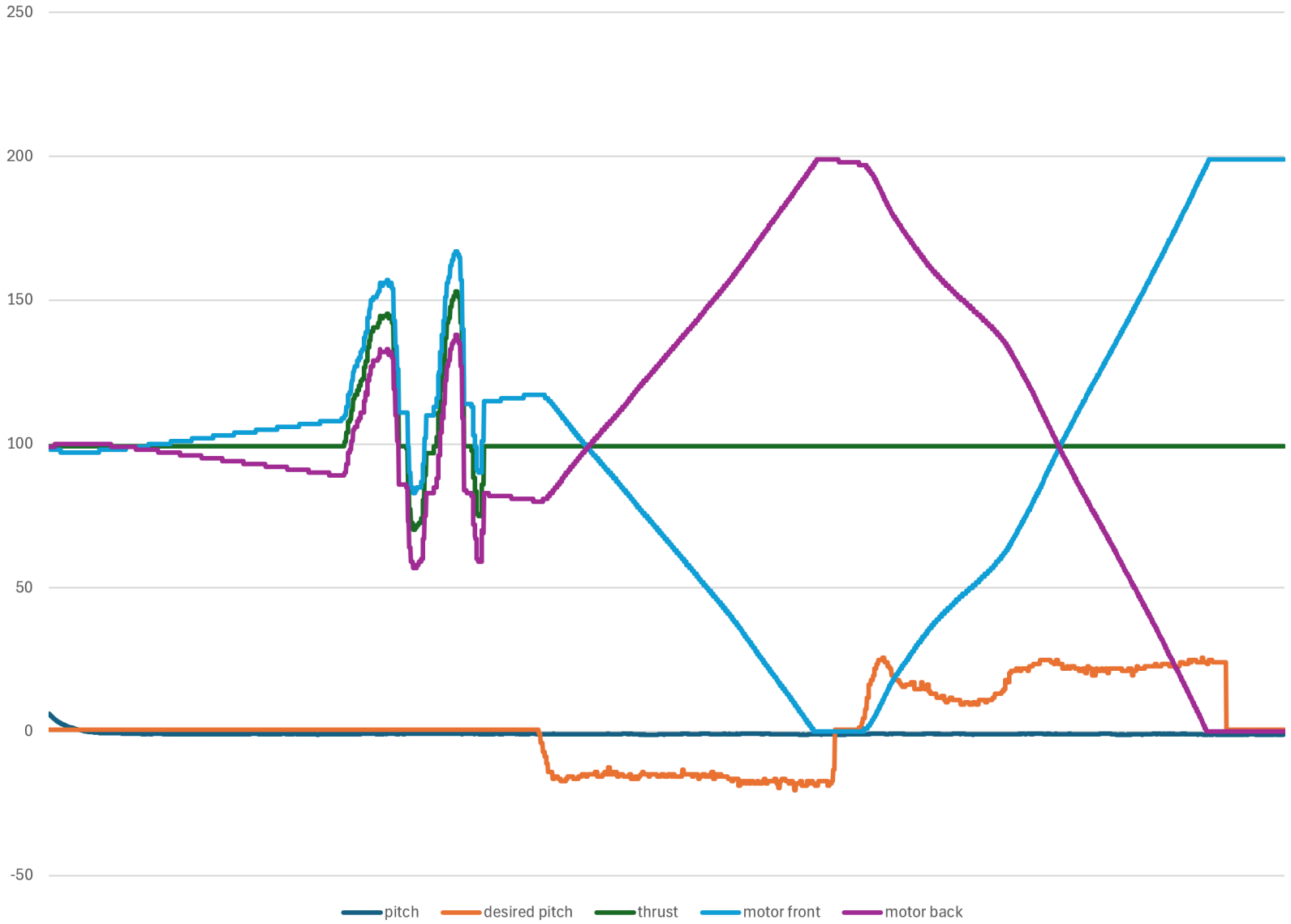
Pitch Integral control

- Motor1=thrust ± $Integral_{pitch}$
- Motor2=thrust ± $Integral_{pitch}$
- Motor3=thrust ± $Integral_{pitch}$
- Motor4=thrust ± $Integral_{pitch}$
  - ± means 2 motors are +, two are -
- Try a value of I_{gain} of .1

Milestone 3

1. I (Integral) controller, including safety
   - Control+C, Gyro limit, roll/pitch limit, joystick kill.. All kill motors (set to 0) with explanation and exits program
   - Plot the following on one graph
     - Motor speeds, thrust, desired pitch, measured pitch (from comp filter)
     - Show on level ground with hands off joystick
     - Show on level ground with joystick thrust commands~150
     - Show on level ground with desired pitch changes of a ~15 degrees until saturation.
   - Set the following values (for nicer graphs, plot pitch*10,desired_pitch*10):
     - $I_{saturate}$ =100
     - Thrust_neutral=100
     - Thrust_amplitude=100

Milestone 3


250
200
150
100
50
0
-50
pitch
desired pitch
thrust
motor front
motor back

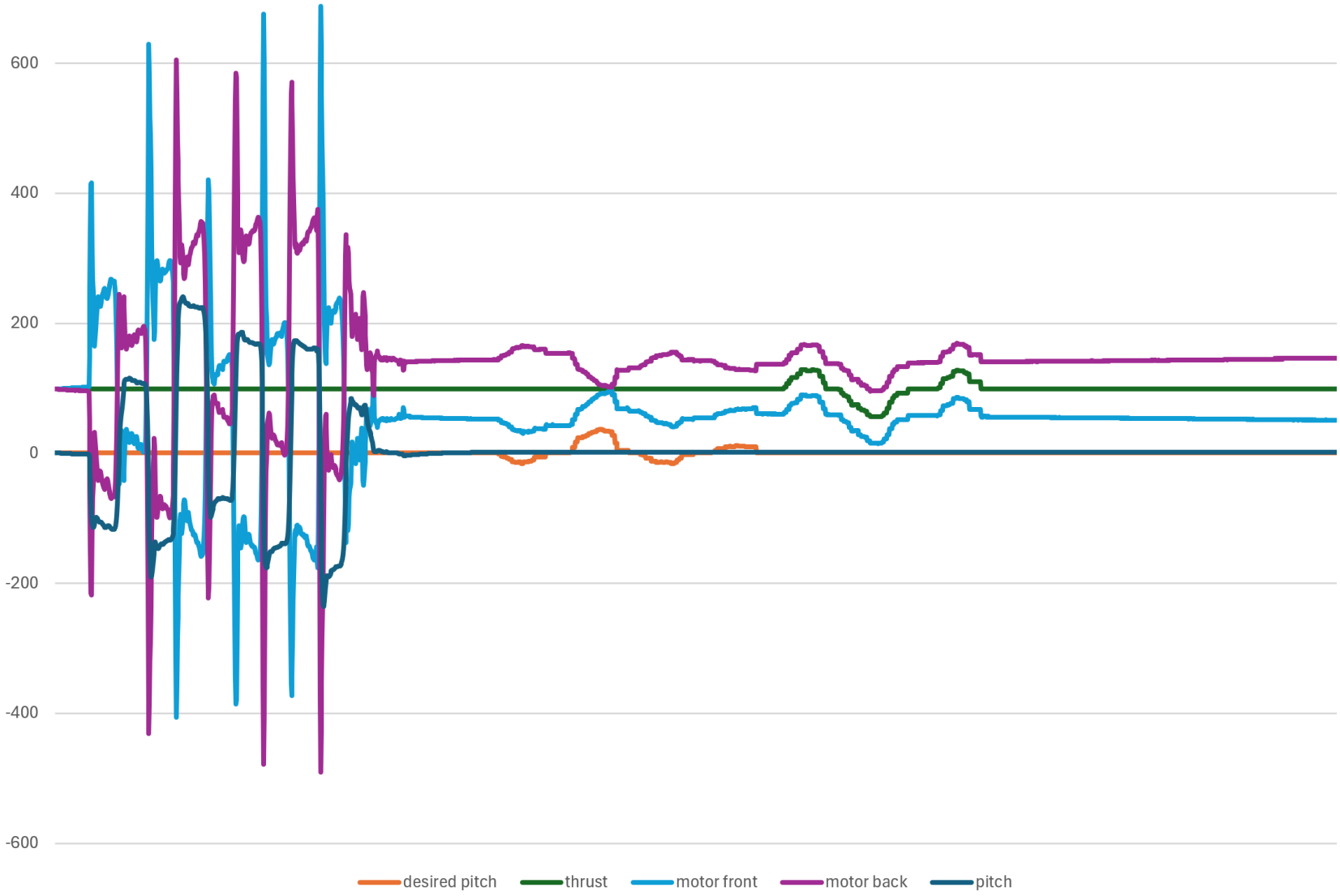
Putting it all together (for pitch)

- Combine proportional (P), Integral (I), Derivative (D)
  - PID control
- Motor1=thrust $\pm P_{gain}*P_{error} \pm D_{gain}*D_{error} \pm Integral_{pitch}$
- Motor2=thrust $\pm P_{gain}*P_{error} \pm D_{gain}*D_{error} \pm Integral_{pitch}$
- Motor3=thrust $\pm P_{gain}*P_{error} \pm D_{gain}*D_{error} \pm Integral_{pitch}$
- Motor4=thrust $\pm P_{gain}*P_{error} \pm D_{gain}*D_{error} \pm Integral_{pitch}$

Milestone 4

1. PID controller, including safety
   - Control+C, Gyro limit, roll/pitch limit, joystick kill.. All kill motors (set to 0) with explanation and exits program
   - Plot the following on one graph
     - Motor speeds,thrust, desired pitch, measured pitch (from comp filter)
     - Show moving the imu in back and forth between +- 5 degrees in quick steps.
     - Show on level ground with small, slow desired pitch changes
     - Show on level ground with small slow thrust changes.
     - Show on level ground with hands off joystick

Milestone 4


600
400
200
0
-200
-400
-600
desired pitch
thrust
motor front
motor back
pitch