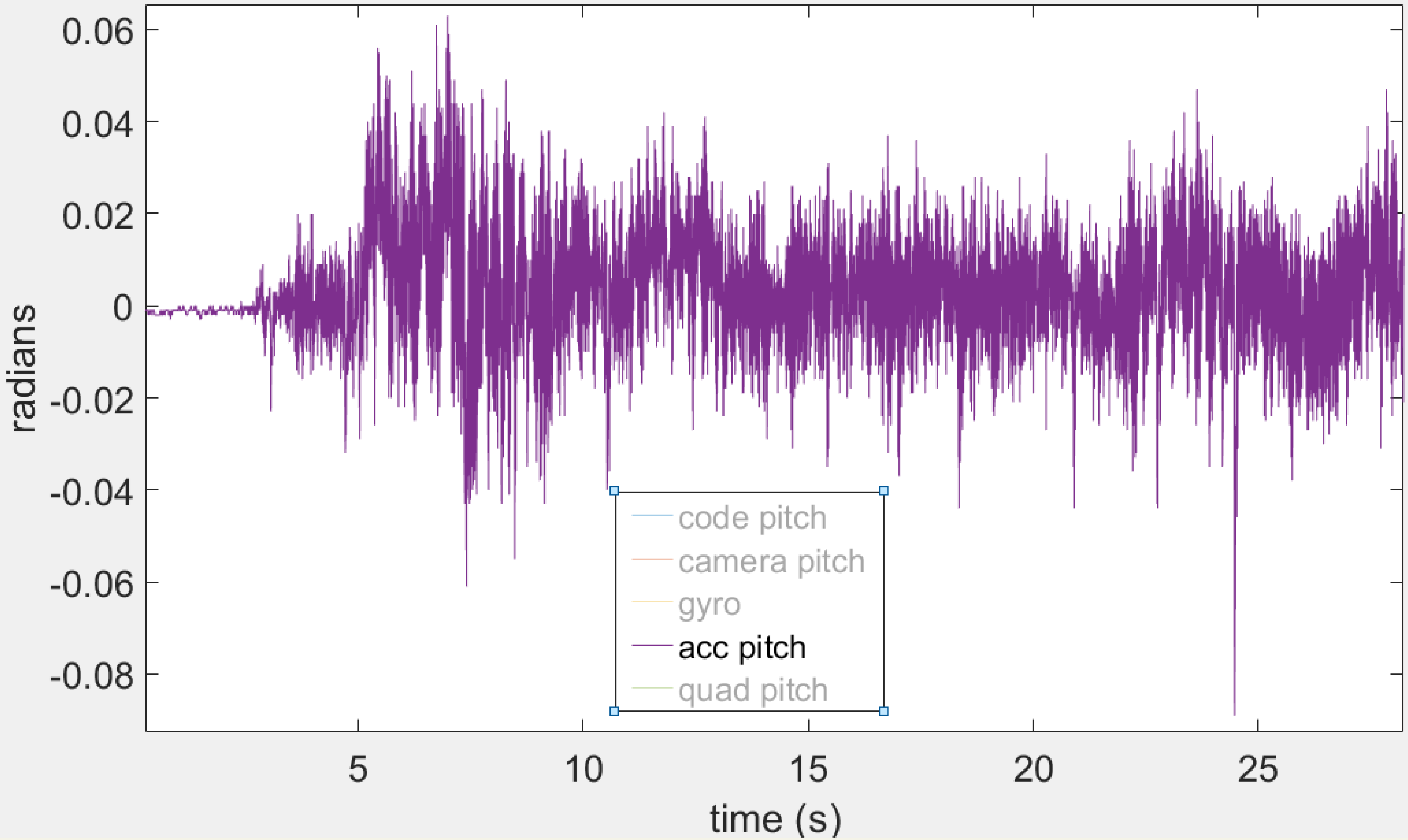
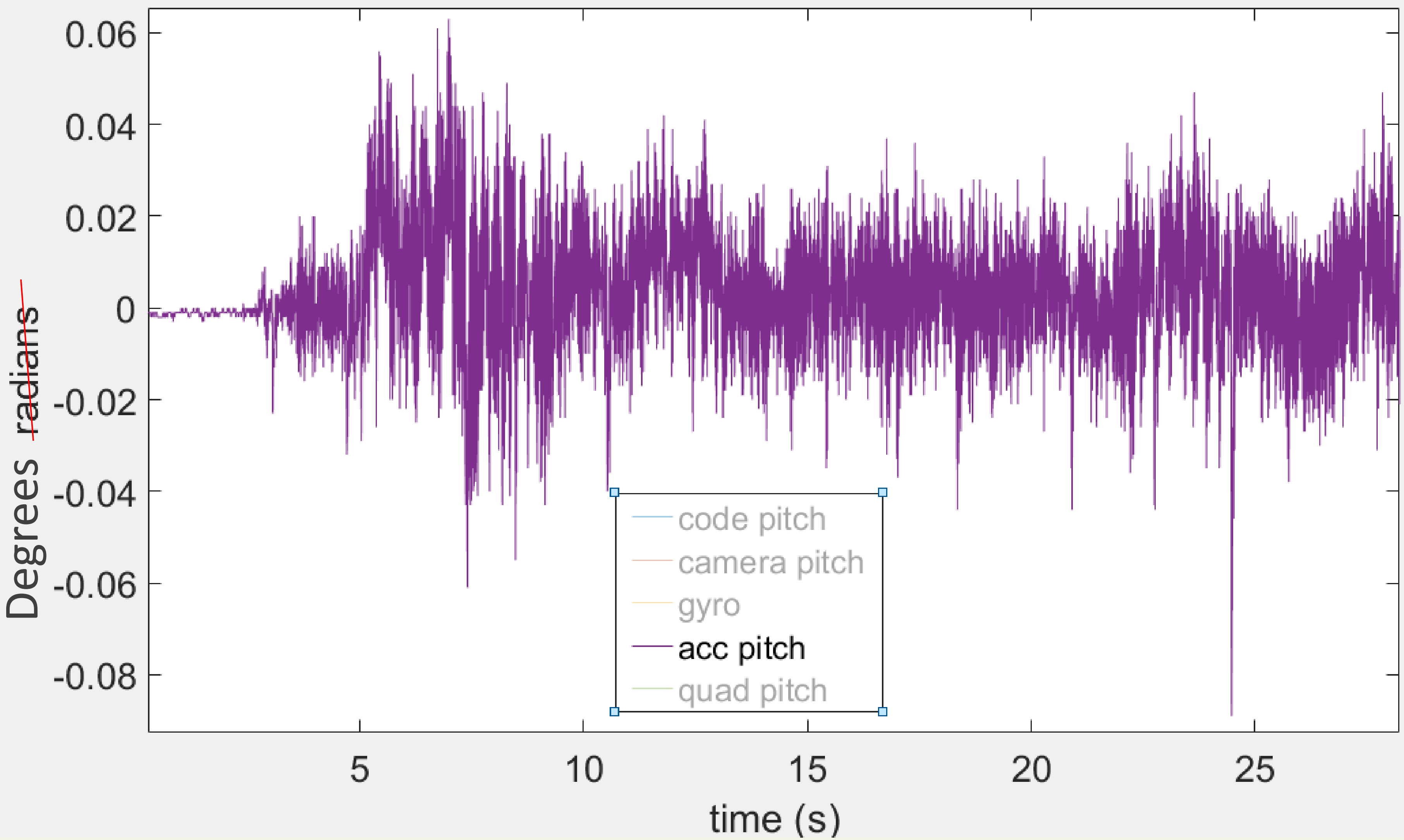
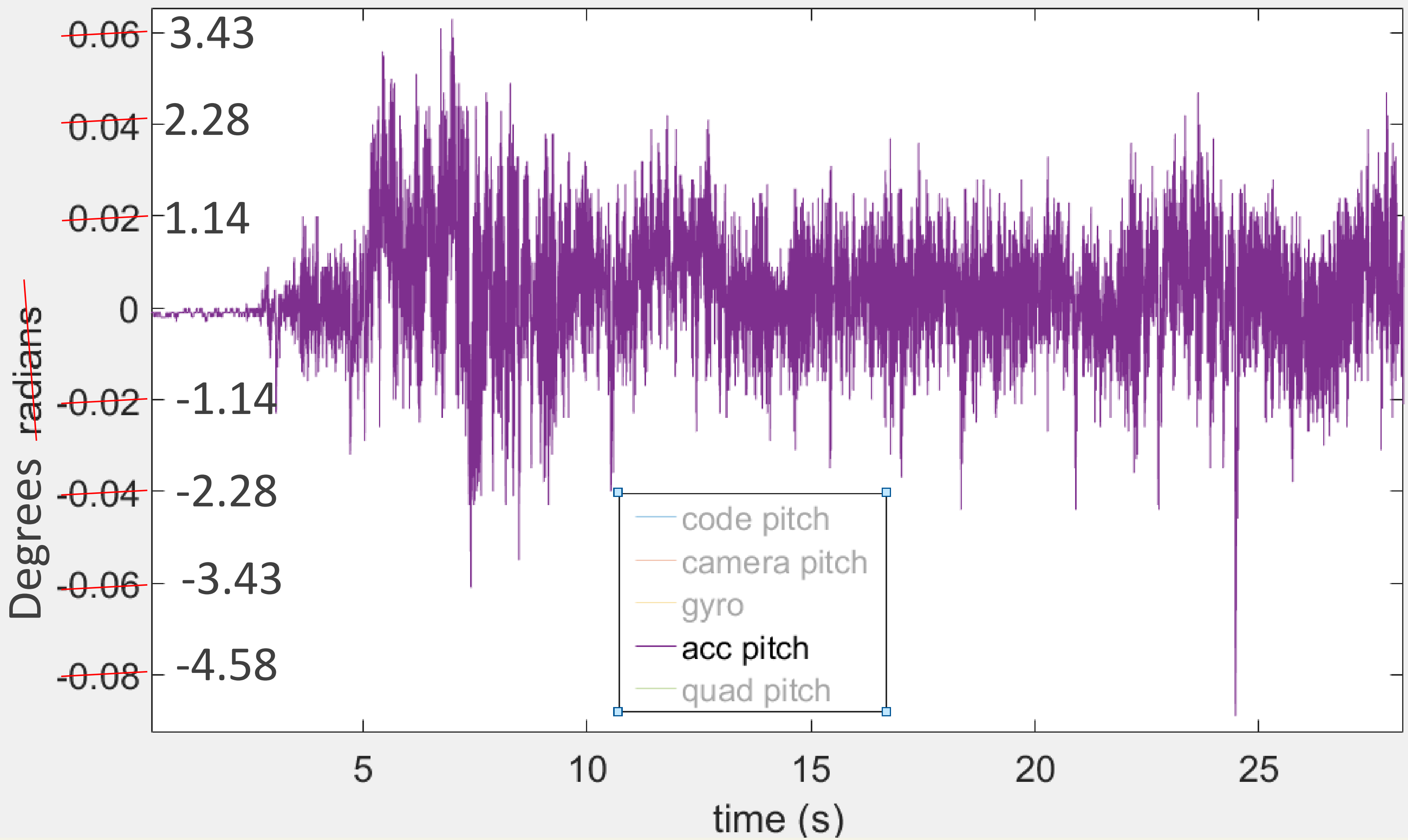


0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
radians
5
10
15
20
25
time (s)
code pitch
camera pitch
gyro
acc pitch
quad pitch



0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
Degrees radians
5
10
15
20
25
time (s)
code pitch
camera pitch
gyro
acc pitch
quad pitch



0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
3.43
2.28
1.14
-1.14
-2.28
-3.43
-4.58
Degrees radians
5
10
15
20
25
time (s)
code pitch
camera pitch
gyro
acc pitch
quad pitch

Living with Noise

Speaker:

Dr. Phillip Jones

Noise is everywhere

- Thinking about noise
- Examples
  - Sensors
  - Interfaces
  - Ground
  - Amplifiers
  - Controllers

Thinking about noise

- Realize: all applications have noise
- Important questions to ask!
  - How much noise can my application tolerate?
  - How does increasing/decreasing noise impact the performance/behavior of my system?
    - Qualitatively: from intuitive understanding of the system
    - Quantitatively: from measurements during experimentation
- Noise mitigation strategies
  - What are common noise mitigation strategies for my task?
  - What are trade-offs between mitigation options?

Sensors

- Accelerometers and Gyroscopes
- Accelerometer: “High” frequency noise (i.e. vibrations)
  - Physical mitigation technique: Dampers

- Gyroscope: “Low” frequency drift (i.e. accumulation error)
- Mitigation techniques the combinine sensor strengths:
  - Complementary filter:
    - $\Theta(t) = \alpha(\Theta(t-\Delta T) + \omega\ \Delta T) + (1- \alpha)\ \Theta_a$
    - https://www.youtube.com/watch?v=RU-g7W8mCSI
  - Kalman Filter
  - Mahony Filter

Interfaces

- Interfaces under consideration
  - Digital signals generated by mechanical means
    - Push Button
    - Toggle switch
    - Quadrature Encoder
  - Digital signals connect via an unreliable connector
    - Lose RC connector, etc.
- Mitigation approaches: http://www.labbookpages.co.uk/electronics/debounce.html
  - Analog Debounce circuit
  - Digital Debounce circuit
  - Software Debounce

Ground

- Analog / Digital / Motor (Power) grounds
  - Not caring for grounds has caused many an engineer to drop hours/days/weeks tracking down odd behavior
  - Noisy digital circuits can corrupt Analog logic, and Motors create havoc for everyone.
  - "Well Grounded, Digital Is Analog": Maxim App Note 4345
    - https://www.maximintegrated.com/en/app-notes/index.mvp/id/4345

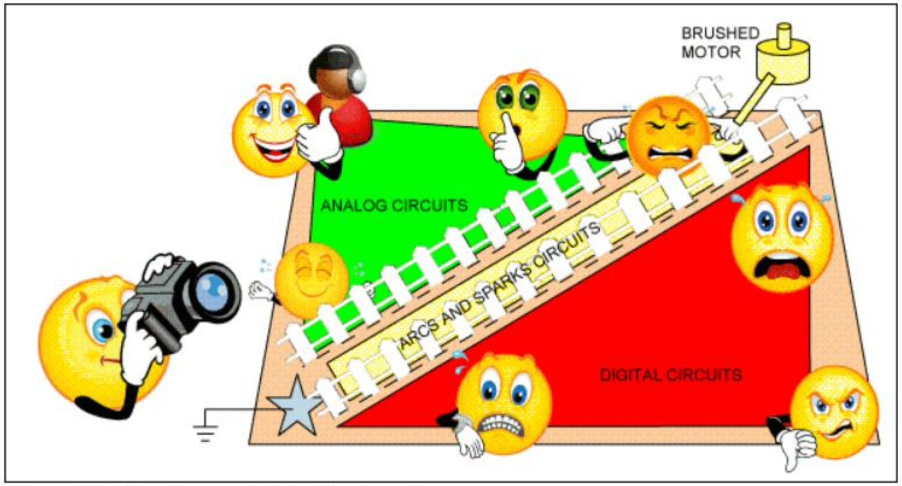


Figure 6b. Two fences isolate the circuits.

Maxim: App Note 4345

Amplifiers with unwanted oscillations

- Quote: *"If you want to build an oscillator, first build an Amplifier".*
- A result of not having well grounded/isolated circuits, Breadboards, PCBs
- Lack of isolation between Amplifier Input and Output can set up unwanted parasitic paths between the two, which in turn can cause oscillations.
- Nice write up on tracking down the causes of oscillations in Amplifiers: http://analogmodules.com/oscillation-in-amplifiers/

Controllers

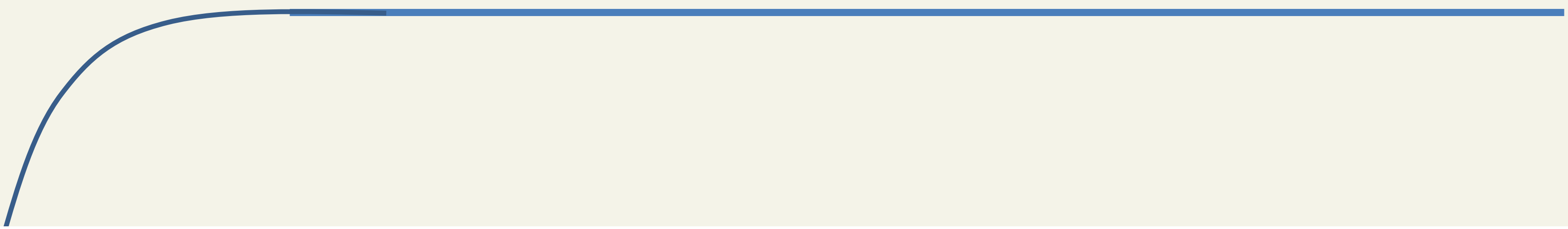
- Noise in a system increases difficulty of tuning controllers
- Lower gains must be uses to avoid pushing the system into unstable conditions.
- PID simulator: https://sites.google.com/site/fpgaandco/pid

Proportion/Integral/Derivative (PID) Controller example

$$u[n] = K_P e[n] + K_I \sum_{j=0}^{n} e[j] + K_D(e[n] - e[n-1])$$

Revisiting the D constant in PID controller

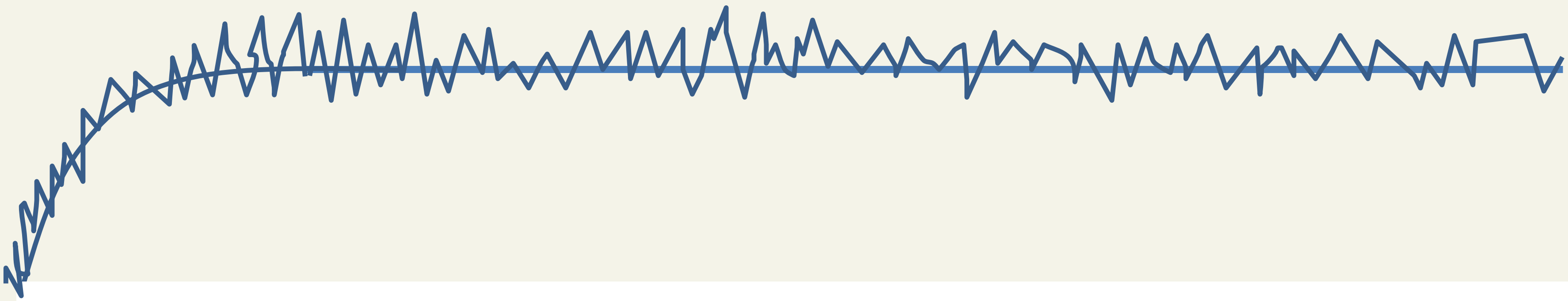
- A large D constant will dampen the system, helping to keep it stable, but causing it to be slow in reacting.
- Are there any issues we need to be concerned with in a real system for a large D constant?



$$u[n] = K_P e[n] + K_I \sum_{j=0}^{n} e[j] + K_D(e[n] - e[n-1])$$

Revisiting the D constant in PID controller

- A large D constant will dampen the system, helping to keep it stable, but causing it to be slow in reacting.
- Are there any issues we need to be concerned with in a real system for a large D constant?
- A large D constant will amplify the noise from the sensor which will case the controller to give large spikes of compensation.



$$u[n] = K_P e[n] + K_I \sum_{j=0}^{n} e[j] + K_D(e[n] - e[n-1])$$