PID Control & Tuning Controllers

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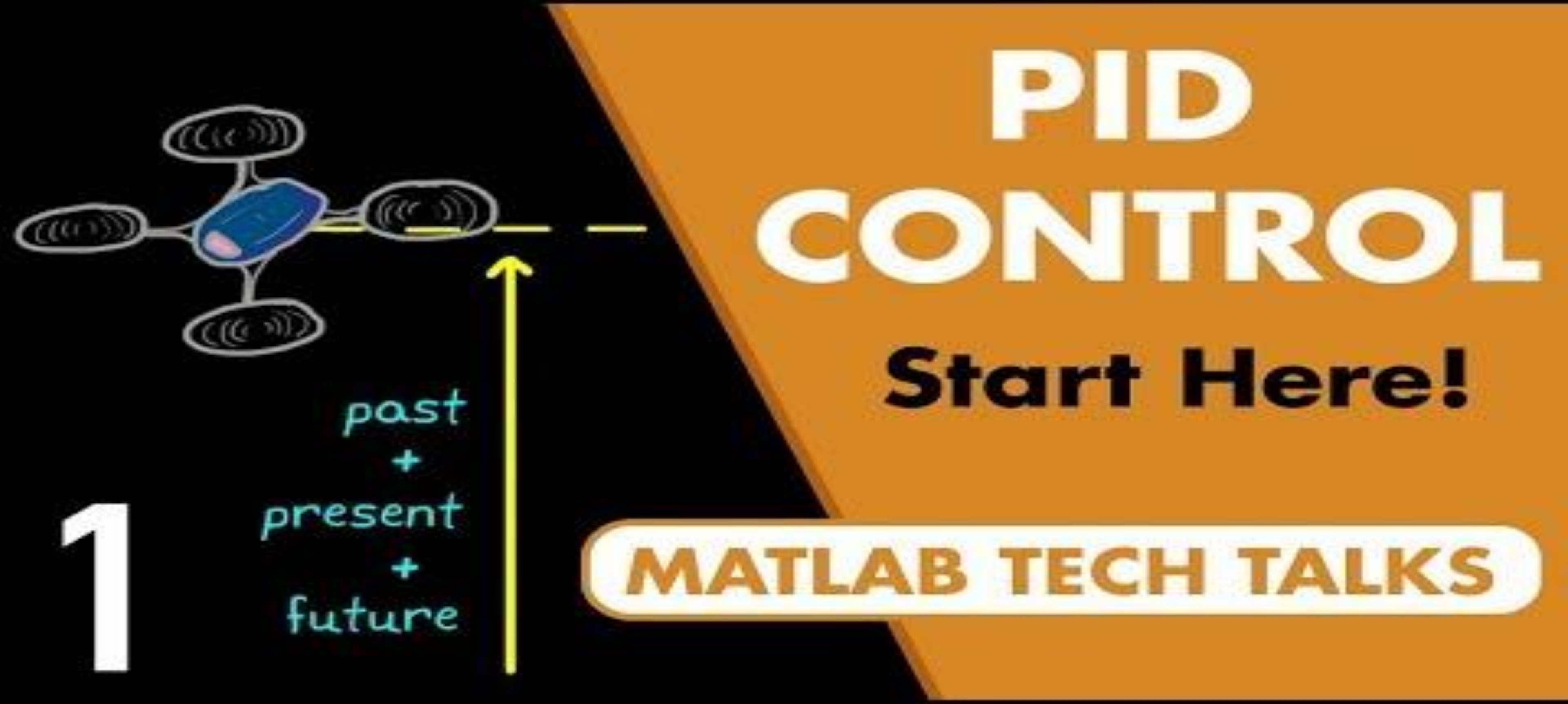
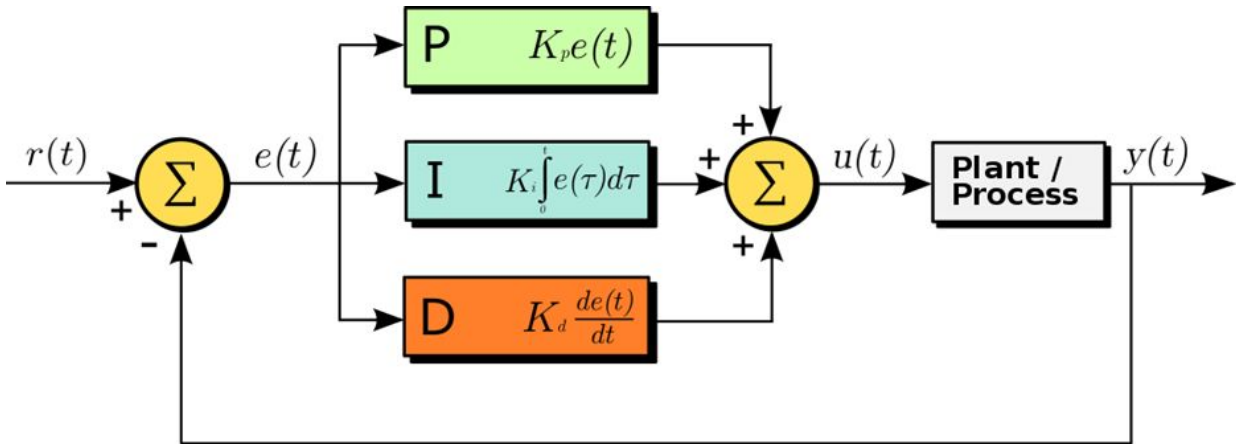


https://www.youtube.com/watch?v=wkfEZmsQqiA

PID Control

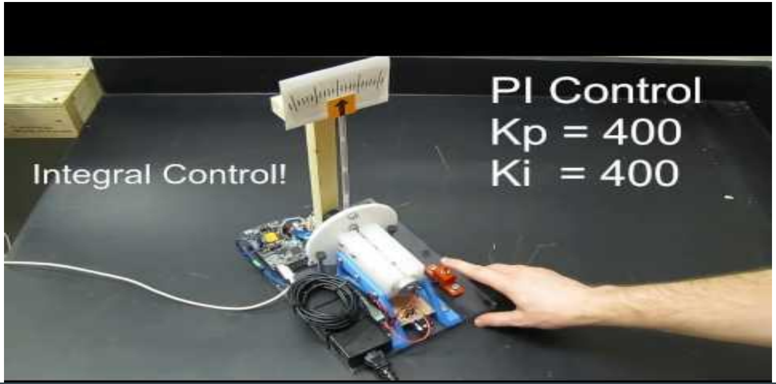
$$u(t) = K_p\, e(t) + K_i \int e(t) + K_d\, e(t)/dt$$

- $u(t)$ - control input
- $e(t)$ - error
- K_p - proportional gain
- K_i - integral gain
- K_d - derivative gain



PID Control

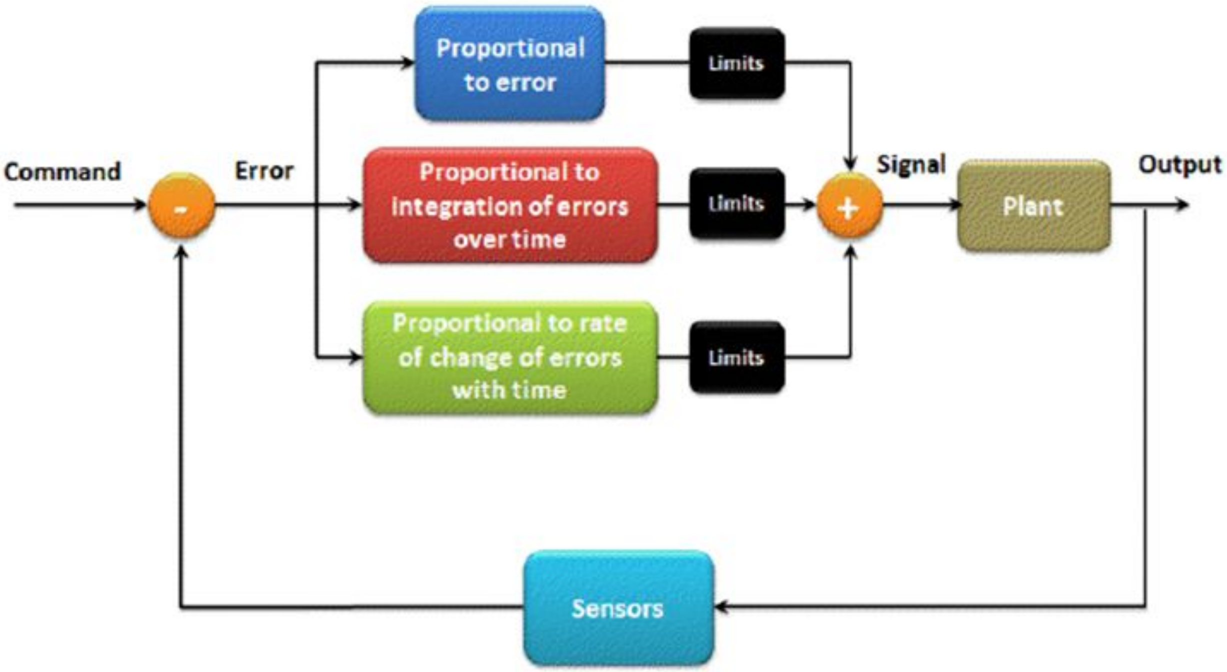
Parameters	Advantage	Limitation
K_p	Adjustment of Controller output	May cause instability
K_i	Produces zero steady state error	Slow dynamic Response and Instability
K_d	Provides rapid system response	Sensitive to Noise and non-zero offset



https://www.youtube.com/watch?v=fusr9eTceEo

PID Control

- P-I-D can be independently applied based on the nature of controller
  - P controller
  - PI controller
  - PD controller
  - PID controller



Proportional (P) Controller

- Multiplies the error by the proportional gain value K_p to get the controller output
- Advantages
  - Easy to implement
  - Less computation needed
- Disadvantages
  - Oscillations in output may be present
  - Increases maximum overshoot

Proportional Integral (PI) Controller

- Multiplies the error by the proportional gain value K_p and adds the integral of error to the proportional term.
- Advantages
  - Integral term makes sure steady state error is zero
  - Can return the controlled variable back to the exact set point
- Disadvantages
  - Requires timer to keep track of time
  - Responds slowly towards the produced error

Proportional Derivative (PD) Controller

- Multiplies the error by the proportional gain value *K_p* and adds the derivative of error to the proportional term.
- Advantages
    - Minimises the maximum overshoot
    - Fast response, improves the transient response of the system
- Disadvantages
    - Steady state error cannot be guaranteed to be zero
    - Amplifies the noise signals produced in the system

Proportional Integral Derivative (PID) Controller

- Combines the advantages of all of P-I-D
- Advantages
  - No steady state error
  - Low maximum overshoot
- Disadvantages
  - Difficult to implement
  - Gain tuning is a difficult task

Characteristics of P, I, and D Controllers

- Note that these correlations may not be exactly accurate, because Kp, Ki, and Kd are dependent of each other. In fact, changing one of these variables can change the effect of the other two. For this reason, the table should only be used as a reference when you are determining the values for Ki, Kp and Kd.

Response	Rise Time	Overshoot	Settling Time	SS Error
K_P	Decrease	Increase	Small Change	Decrease
K_I	Decrease	Increase	Increase	Eliminate
K_D	Small Change	Decrease	Decrease	Small Change

Tuning of Controllers

- Tuning is part of loop design, usually required if the system oscillates too much, responds too slowly, has steady-state error, or is unstable.
- Stability (no unbounded oscillation) is a basic requirement.
- Tuning a control loop is the adjustment of its control parameters to optimum values for a target response.
- There are several methods for tuning a PID loop. Manual tuning methods can be relatively time consuming, particularly for systems with long loop times.

- https://www.youtube.com/watch?v=sFOEsA0Irjs

Tuning a PID Controller

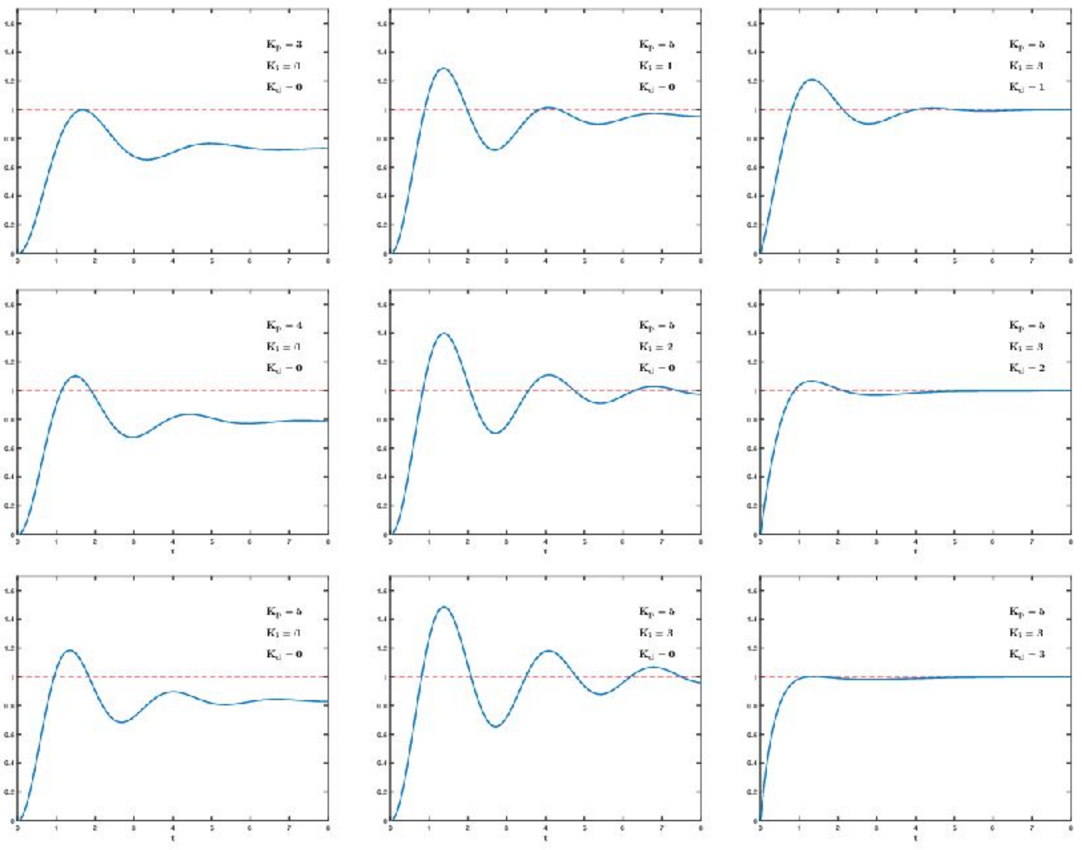
Heuristic procedure #1:

1. Set K_p to small value, K_d and K_i to 0
2. Increase K_d until oscillation, then decrease by factor of 2-4
3. Increase K_p until oscillation or overshoot, decrease by factor of 2-4
4. Increase K_i until oscillation or overshoot
5. Iterate

Tuning a PID Controller

Other methods:

- Ziegler–Nichols
- Tyreus Luyben
- Cohen–Coon
- Åström-Hägglund



Tuning a PID Controller

Heuristic procedure #2:

1. Set K_d and K_i to 0
2. Increase K_p until oscillation, then decrease by factor of 2-4
3. Increase K_i until loss of stability, then back off
4. Increase K_d to increase performance in response to disturbance
5. Iterate

PID Tuning Software

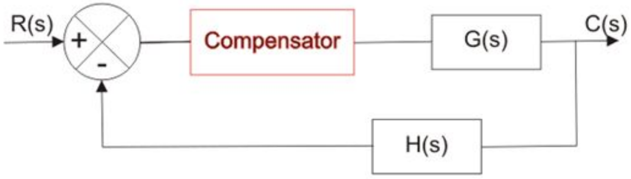
- Modern industrial systems use tuning software instead of manual tuning or calculation methods.
- These software packages will gather the data, develop process models, and suggest optimal tuning.
- With advanced PID tuning software PID loops can also be tuned in a dynamic or non-steady state (NSS) scenario.
- In such cases, the software will model the dynamics of a process, through a disturbance, and calculate PID control parameters in response.

Further Learning (PID)

- Reading:
  - http://www.pacontrol.com/download/Proportional-Integral-Derivative-PID-Controls.pdf
  - http://www.ece.uvic.ca/~agullive/trans/D_p1-20.pdf
- Videos:
  - https://www.youtube.com/watch?v=UR0hOmjaHp0 (Intro)
  - https://www.youtube.com/watch?v=XfAt6hNV8XM (Examples)
  - https://www.youtube.com/watch?v=wkfEZmsQqiA (Fundamentals)
  - https://www.youtube.com/playlist?list=PLn8PRpmsu08pQBgjxYFXSsODEF3Jqmm-y
- Math
  - https://www.youtube.com/watch?v=JEpWlTl95Tw
- Demo:
  - https://www.youtube.com/watch?v=fusr9eTceEo
  - https://sites.google.com/site/fpgaandco/pid

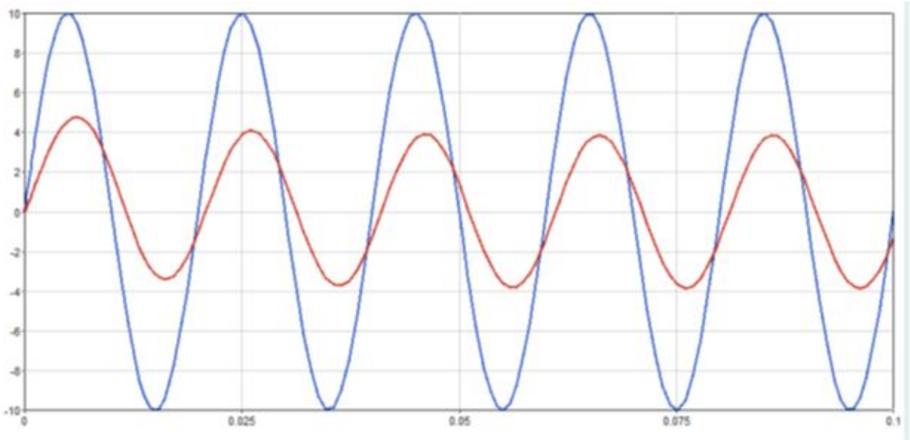
Lead–lag Compensator

- Lead-lag compensators come from the days when control engineers cared about constructing controllers from networks of op amps using frequency-phase methods.
  - ***These days pretty much everybody uses PID, but you should at least know what the heck they are in case someone asks.***
- Compensating networks are applied to the system in the form of feed forward path gain adjustment.
  - Compensate an unstable system to make it stable
  - Used to minimise overshoot
  - Increase the steady state accuracy of the system

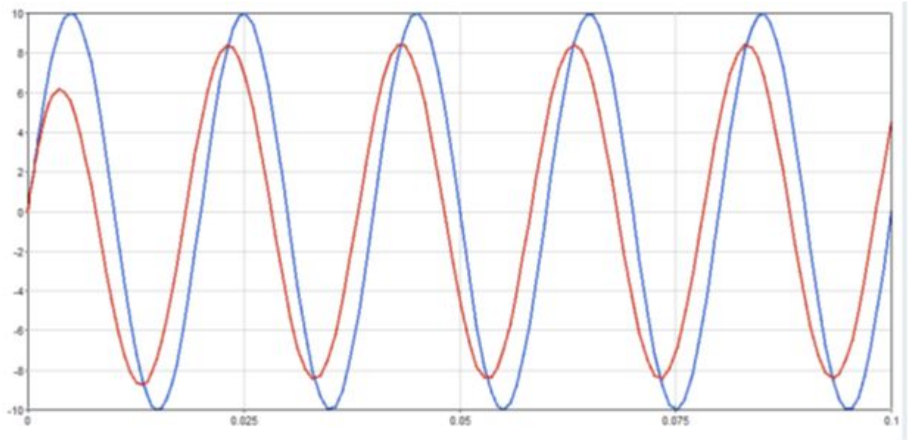


Lead–lag Compensator

Lead



Lag



https://youtu.be/xLhvil5sDcU?t=168

Summary

- PID Control
- Proportional Integral Derivative (PID) Controller
- Lead–lag Compensator

Project Updates...