Control System Design - 2

ICT 41205 Digital Control Systems

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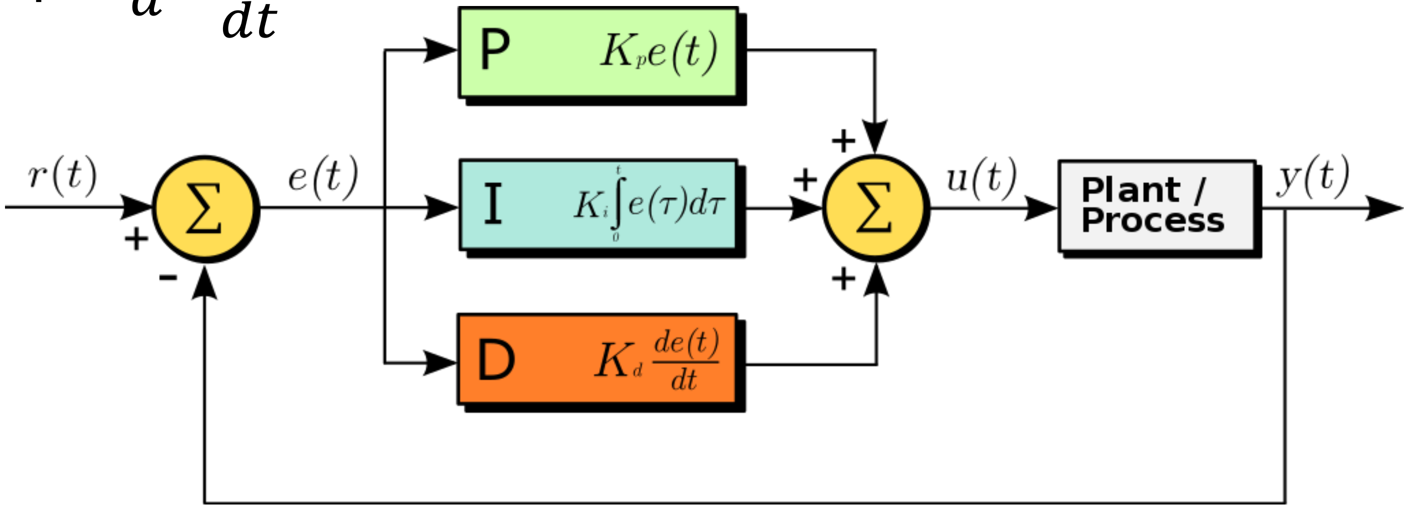
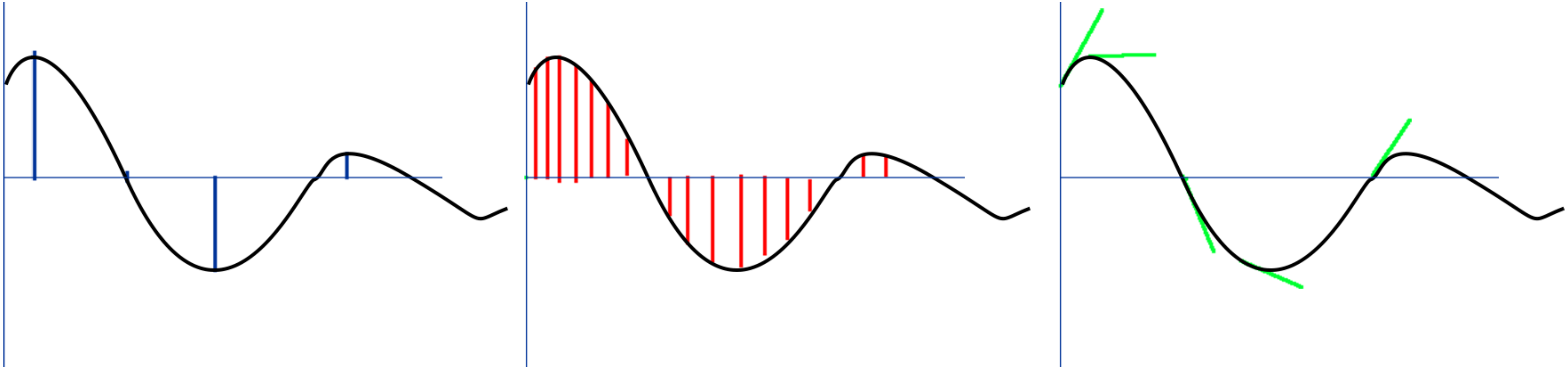
PID Control

- $u(t) = K_p e(t) + K_i \int e(\tau)\, d\tau + K_d \frac{de(t)}{dt}$
  - $u(t)$ - control input
  - $e(t)$ - error
  - K_p - proportional gain
  - K_i - integral gain
  - K_d - derivative gain

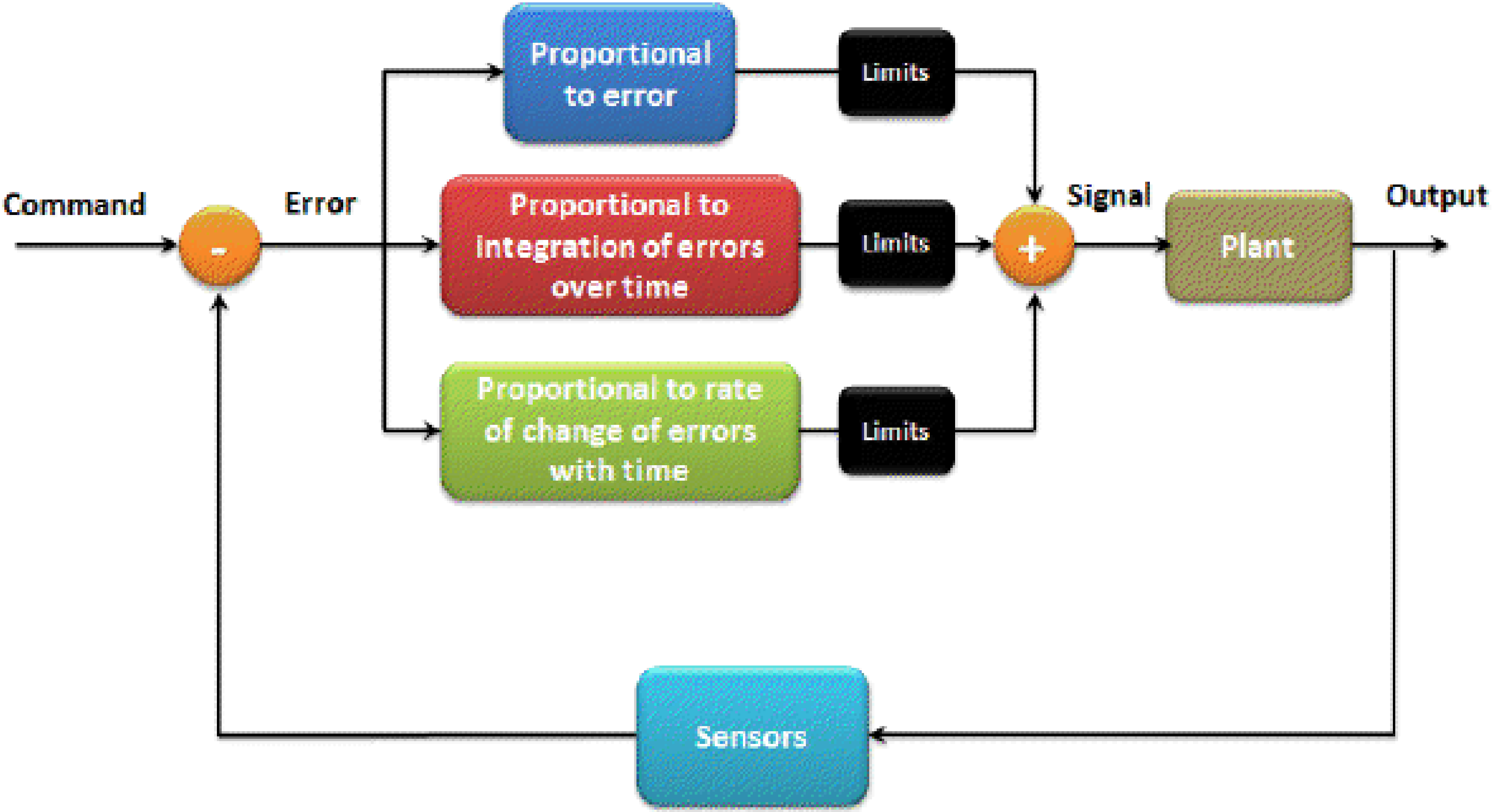


PID Control

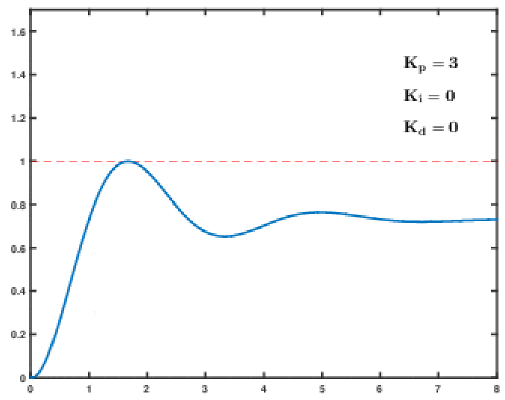
- Multiply the error by the proportional gain value K_p
- Multiply the integral of error by the integral gain value K_i
- Multiply the derivative of error by the derivative gain value K_d

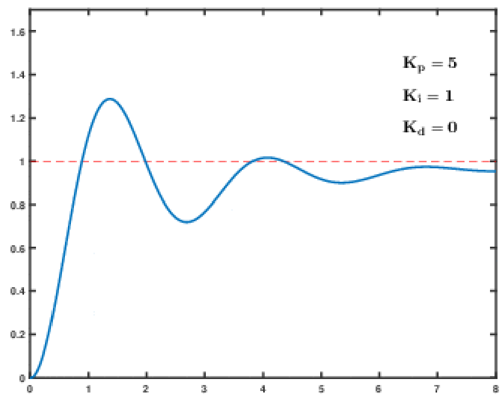


PID Control


Command
Error
Proportional to error
Proportional to integration of errors over time
Proportional to rate of change of errors with time
Limits
Limits
Limits
Signal
Plant
Output
Sensors

PID Control


$K_p = 3$
$K_i = 0$
$K_d = 0$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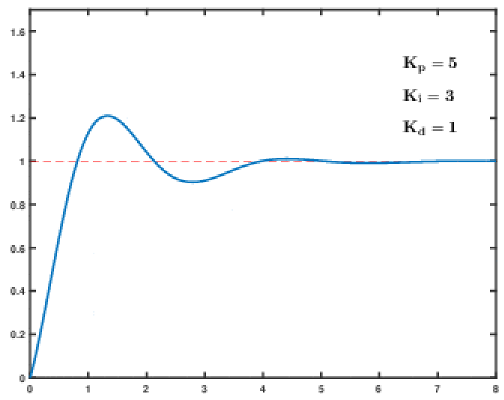
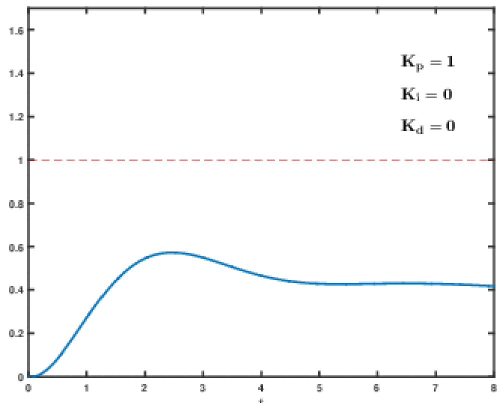
$K_i = 1$
$K_d = 0$


$K_p = 5$
$K_i = 3$
$K_d = 1$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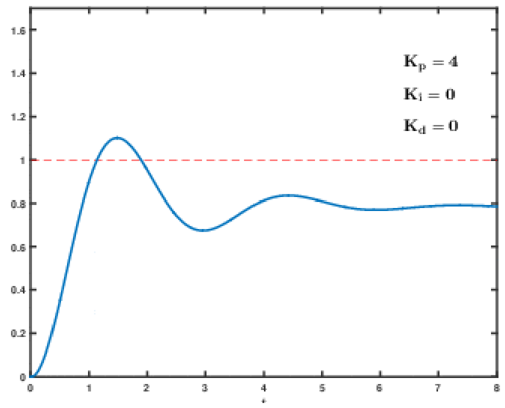
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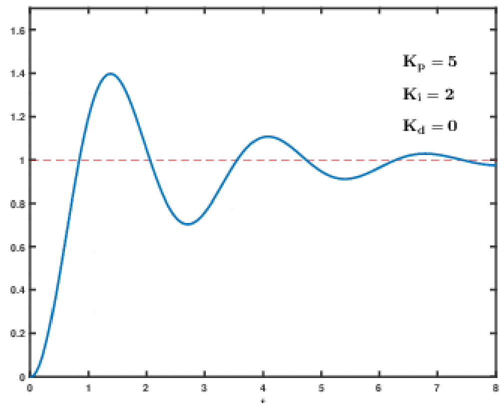
$K_d = 0$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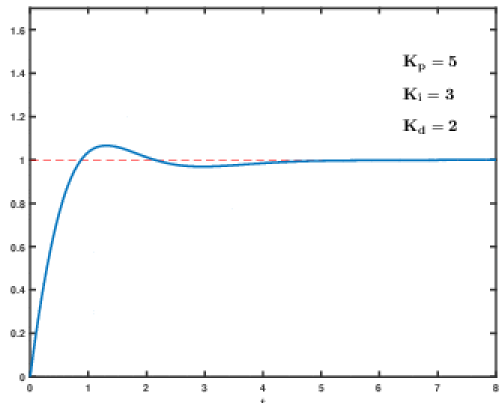
$K_d = 0$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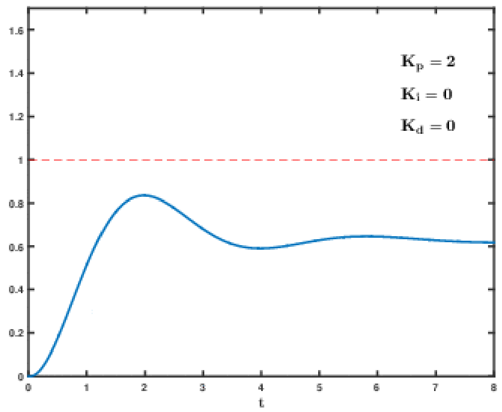
$K_d = 2$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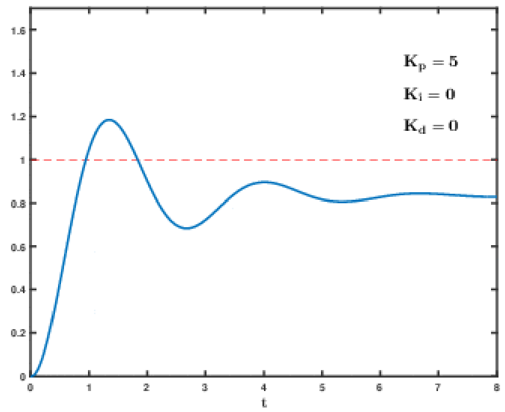
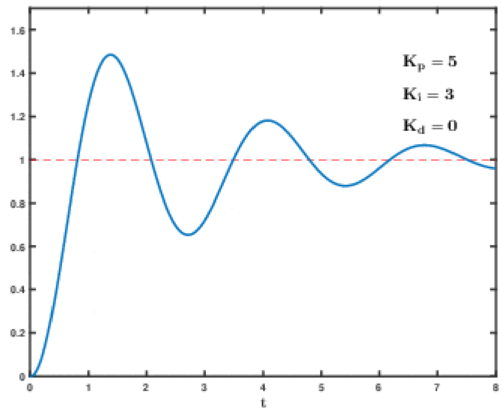
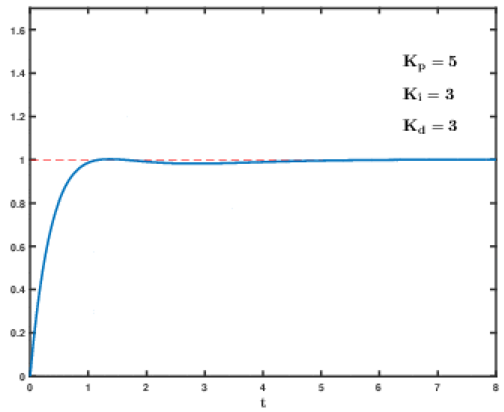
$K_i = 0$
$K_d = 0$
t


$K_p = 5$
$K_i = 0$
$K_d = 0$
t


$K_p = 5$
$K_i = 3$
$K_d = 0$
t


$K_p = 5$
$K_i = 3$
$K_d = 3$
t

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.

Tuning a PID Controller

- Heuristic procedure #1:
  - Set K_p to small value, K_d and K_i to 0
  - Increase K_d until oscillation, then decrease by factor of 2-4
  - Increase K_p until oscillation or overshoot, decrease by factor of 2-4
  - Increase K_i until oscillation or overshoot
  - Iterate

Tuning a PID Controller

- Heuristic procedure #2:
  - Set K_d and K_i to 0
  - Increase K_p until oscillation, then decrease by factor of 2-4
  - Increase K_i until loss of stability, then back off
  - Increase K_d to increase performance in response to disturbance
  - Iterate

Tuning a PID Controller

- Other methods:
  - Ziegler–Nichols
  - Tyreus Luyben
  - Cohen–Coon
  - Åström-Hägglund

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.