PID Control

CEG3H3

Randy E. Saputra, ST. MT.

Objectives

- Understand the concepts and characteristics of PID control
- Explain the circuit operation of an analog controller
- Explain the principles of operation of a digital controller, including programming concepts and sample rate
- Understand the concept of stability

PID Control

- Proportional Control
  - As the basic foundation of the control system
- Integral Control
  - Provides a means to eliminate steady-state error but may increase overshoot
- Derivative Control
  - Getting sluggish systems moving faster and reduces the tendency to overshoot

PID Control

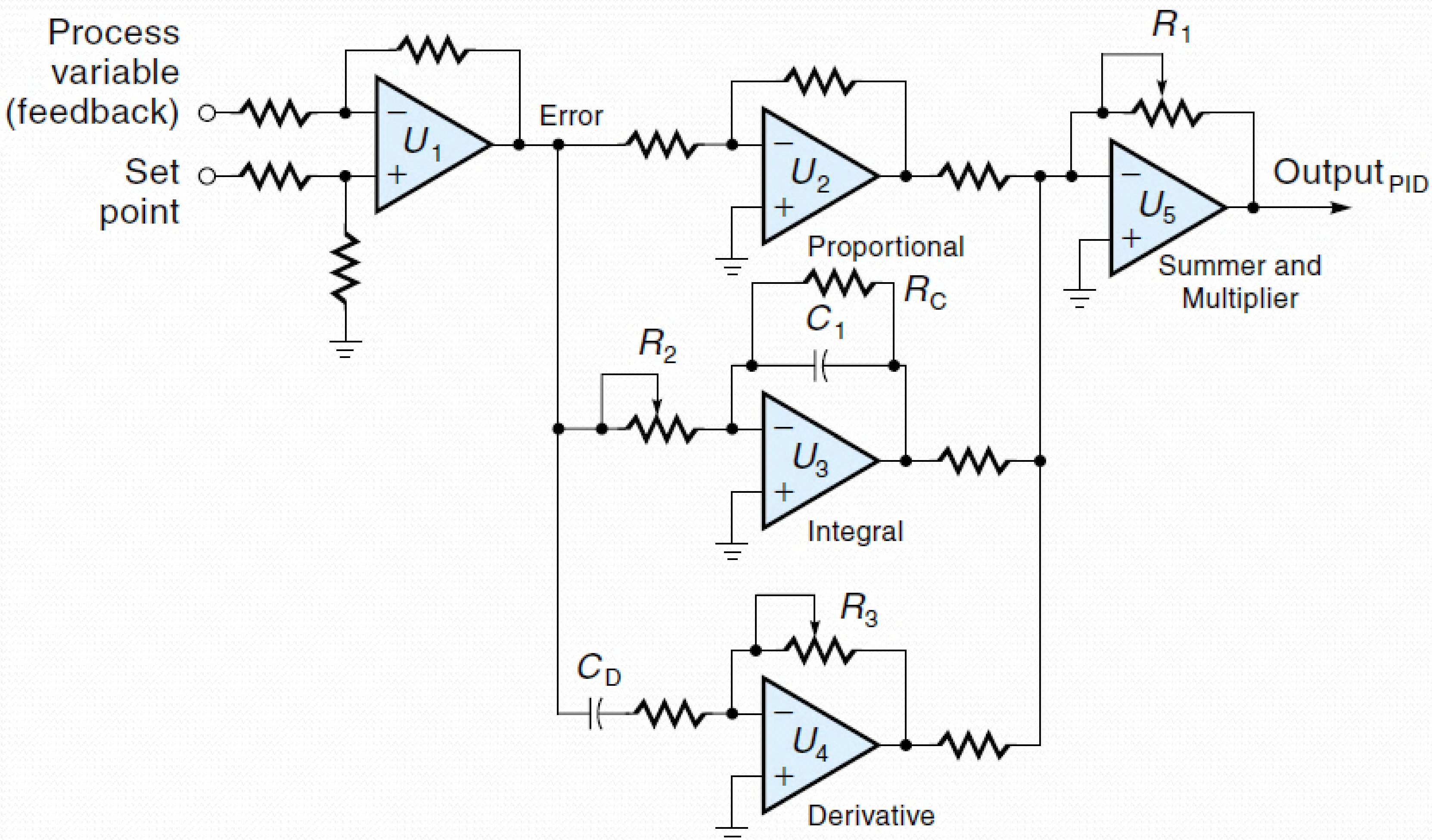
$$\text{Output}_{\text{PID}} = K_P E + K_I K_p \Sigma(E\Delta t) + K_D K_p \frac{\Delta E}{\Delta t}$$

OR

$$\text{Output}_{\text{PID}} = K_p[E + K_I \Sigma E\Delta t + K_D \frac{\Delta E}{\Delta t}$$

$\text{Output}_{\text{PID}}$ = output of the PID controller
K_P = proportional control gain
K_I = integral control gain (often seen as $1/T_I$)
K_D = derivative control gain (often seen as T_D)
E = error (deviation from the set point)
$\Sigma(E\Delta t)$ = sum of all past errors (area under the error · time curve)
$\Delta E/\Delta t$ = rate of change of error (slope of the error curve)

Analog PID Controler



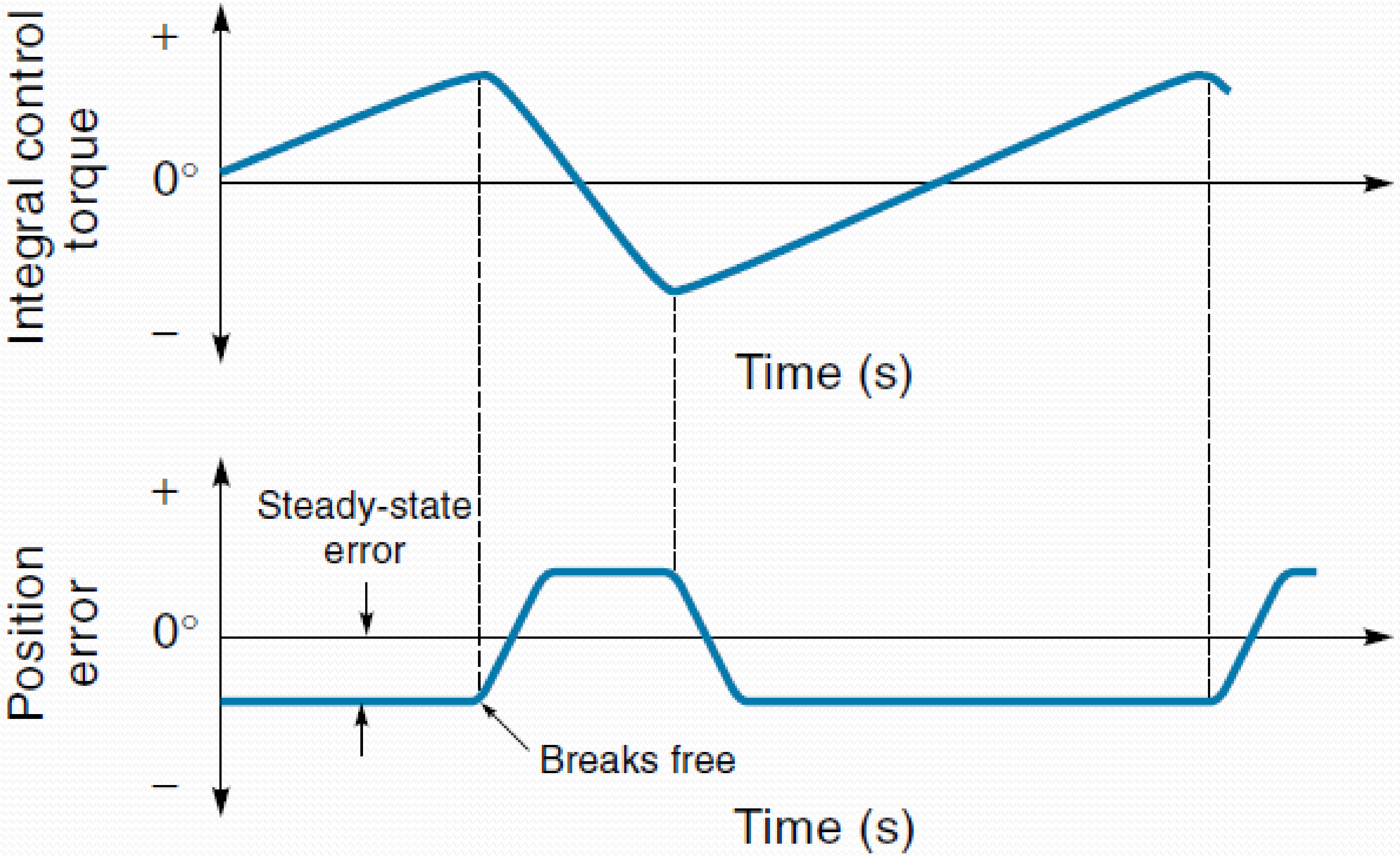
Analog PID Controler

- Op-amp U1 subtracts the feedback from the set point to produce the error signal, Op-amps U2, U3, and U4 are configured to be unit gain, integrator, and differentiator amplifiers, respectively

Integrator's Problem

- Windup
  - Occurs when a system is subjected to a large disturbance, and the proportional controller (or actuator) in its attempt to correct the problem saturates "full on"
  - A true integrator will sum all the error · time area (since the beginning of time)

Integrator's Problem



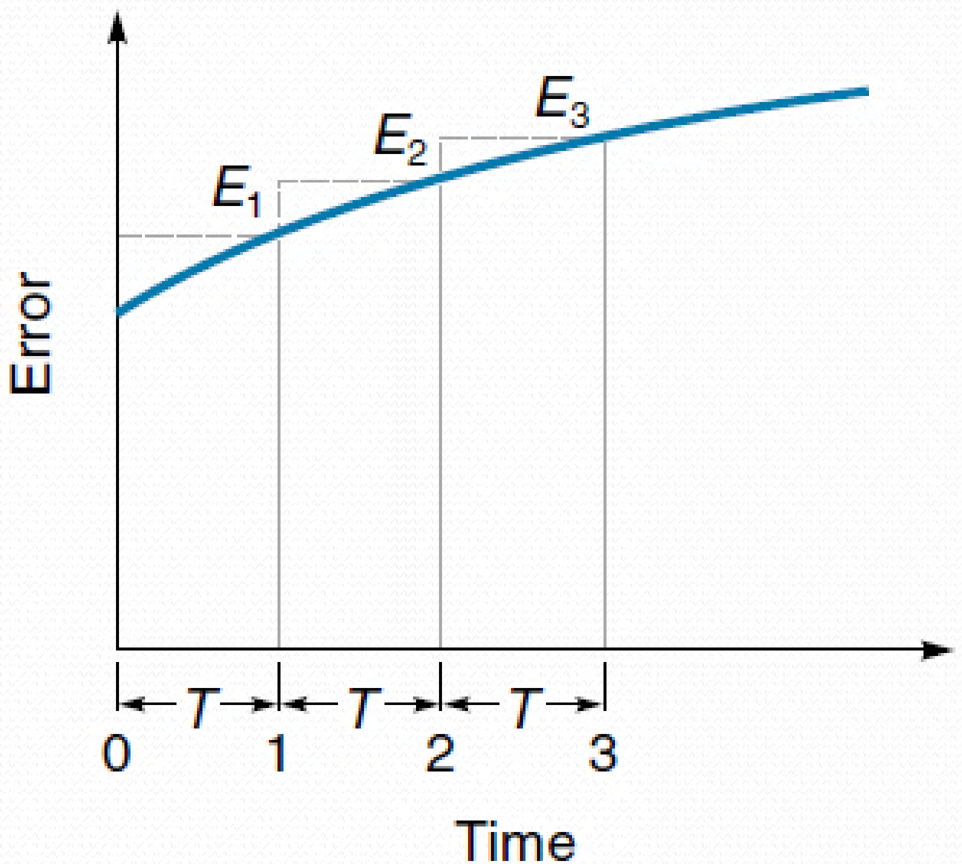
Derivative's Problem

- In a real control system, the set point is usually stepped up or down in discrete steps (step change has an infinitely positive slope, which will saturate the derivative function)
  - Solution is to base the derivative control on the feedback signal alone (PV) instead of the error because the controlled variable (be it temperature, position, or the like) can never actually change instantaneously

$$\text{Output}_{\text{PID}} = K_P[E + K_I \Sigma(E\Delta t) + K_D \frac{\Delta PV}{\Delta t}]$$

Digital PID

- Sampling



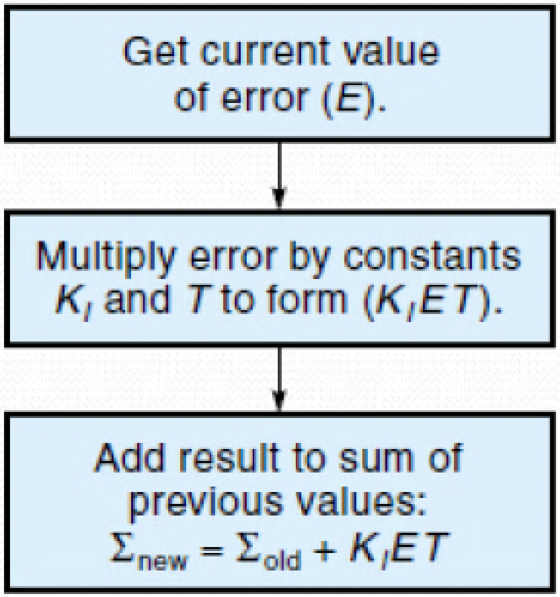
Digital PID

- Integral

$$K_I\sum(E\Delta t) = K_I E_1 T + K_I E_2 T + K_I E_3 T$$

where

K_I = integral gain
E_1 = error at time 1
E_2 = error at time 2, and so on
T = time between the samples

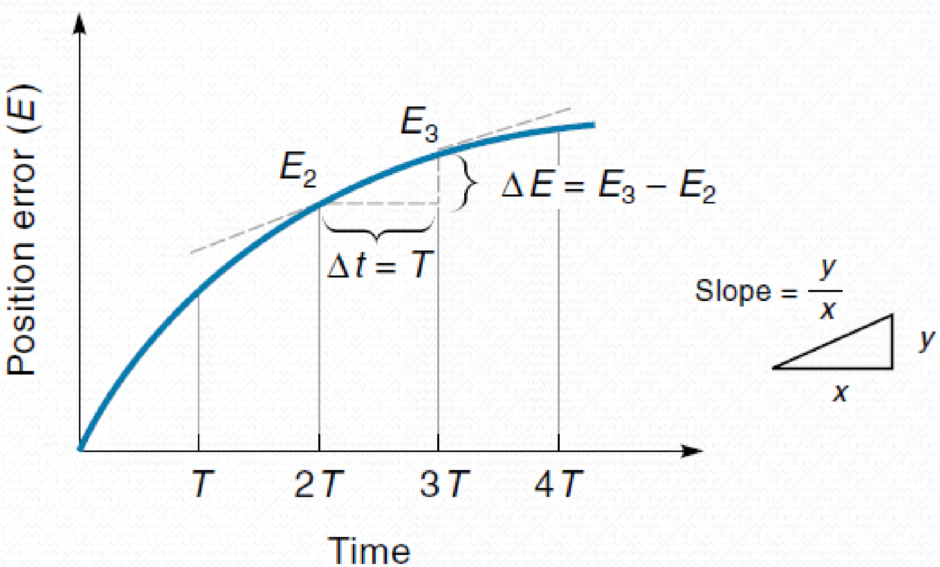


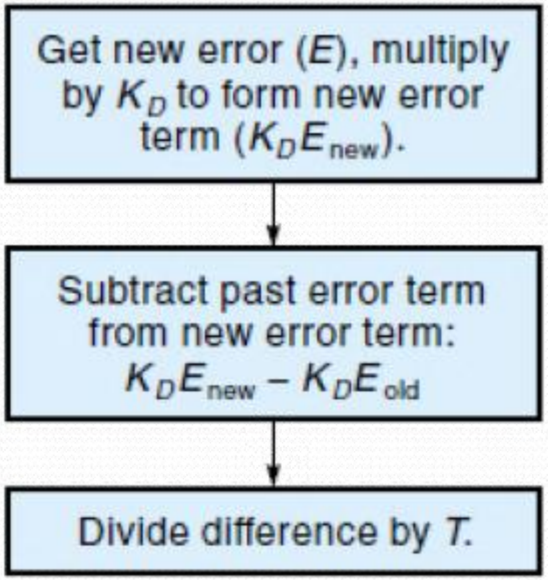
Digital PID

- Derivative

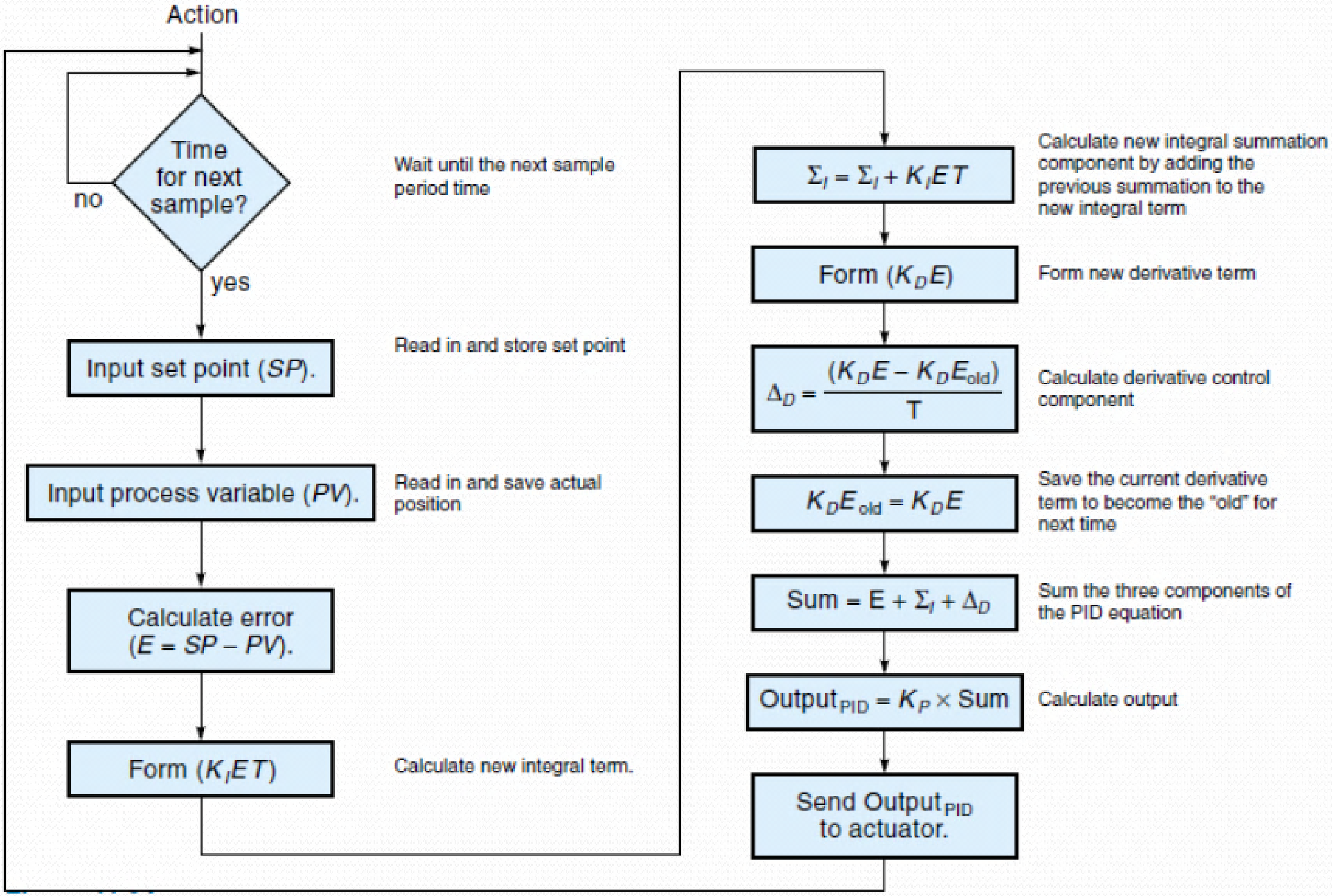
$$\text{Slope} = \frac{\Delta E}{\Delta t} = \frac{(E_3 - E_2)}{T}$$

$$K_D \frac{\Delta E}{\Delta T} = \frac{(K_D E_3 - K_D E_2)}{T}$$





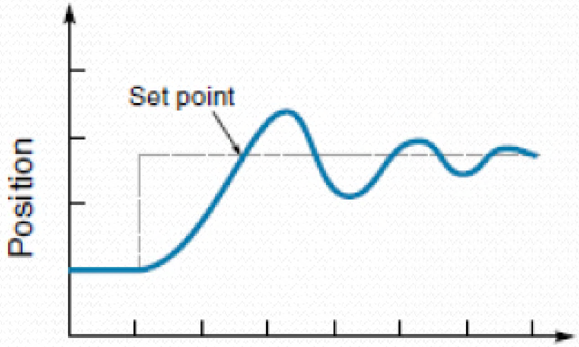
Digital PID



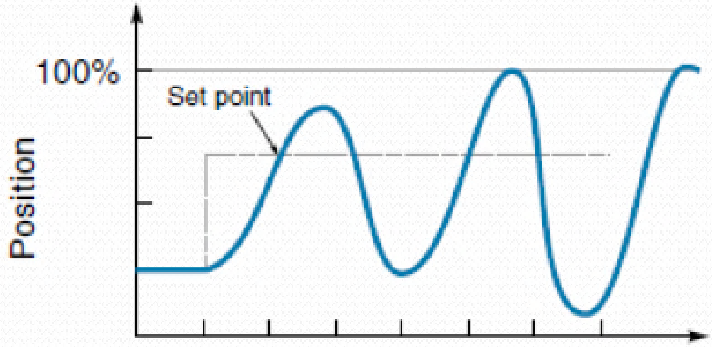
Action
Time for next sample?
no
yes
Wait until the next sample period time
Input set point (SP).
Read in and store set point
Input process variable (PV).
Read in and save actual position
Calculate error (E = SP – PV).
Form (K_I ET)
Calculate new integral term.
Σ_I = Σ_I + K_I ET
Calculate new integral summation component by adding the previous summation to the new integral term
Form (K_D E)
Form new derivative term
Δ_D = (K_D E – K_D E_old) / T
Calculate derivative control component
K_D E_old = K_D E
Save the current derivative term to become the "old" for next time
Sum = E + Σ_I + Δ_D
Sum the three components of the PID equation
Output_PID = K_P × Sum
Calculate output
Send Output_PID to actuator.

Stability

- A stable system is one where the controlled variable will always settle out at or near the set point
- An unstable system is one where, under some conditions, the controlled variable drifts away from the set point or breaks into oscillations that get larger and larger until the system saturates on each side



(a) Stable system



(b) Unstable system

Objectives Completed

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