Derivative Action and PID Control

Learn in This Section

- Essential Elements of the PID Controller
- Derivative on Measurement is Used in Practice
- PV Noise Degrades Derivative Action
- Case Study to Design and Apply a PID Controller

The PID Controller

- "Ideal" form of the PID Controller

$$CO = CO_{bias} + Kc \cdot e(t) + \frac{Kc}{\tau_I} \int e(t)dt + Kc \cdot \tau_D \frac{de(t)}{dt}$$

where:

CO	=	controller output signal
CO_{bias}	=	controller bias or null value
PV	=	measured process variable
SP	=	set point
$e(t)$	=	controller error = $SP - PV$
Kc	=	controller gain (a tuning parameter)
τ_I	=	controller reset time (a tuning parameter)
τ_D	=	controller derivative time (a tuning parameter)

The PID Controller

- Ideal PID Controller

$$CO = CO_{bias} + Kc \cdot e(t) + \frac{Kc}{\tau_I} \int e(t)dt + Kc \cdot \tau_D \frac{de(t)}{dt}$$

- A derivative is a slope or rate of change
- τ_D provides a separate weight to the derivative (or rate of change) of error, e(t) = SP – PV, as it changes over time
- τ_D has units of time so it is always positive
- Larger values of τ_D increase influence of the derivative term

Function of the Derivative Term

- Proportional term considers ***how far*** PV is from SP at any instant in time and adds or subtracts from CO_{bias} accordingly (recall e(t) = SP – PV)
- Integral term addresses ***how long*** and how far PV has been from SP by continually summing e(t) over time
- Derivative term considers ***how fast*** e(t) is changing at any instant using the rate of change or slope of the error curve

rapidly changing e(t) = large derivative = large impact on CO

- Derivative doesn't consider if e(t) is positive, negative or how much time has passed, just how fast e(t) is changing

Derivative on Measurement

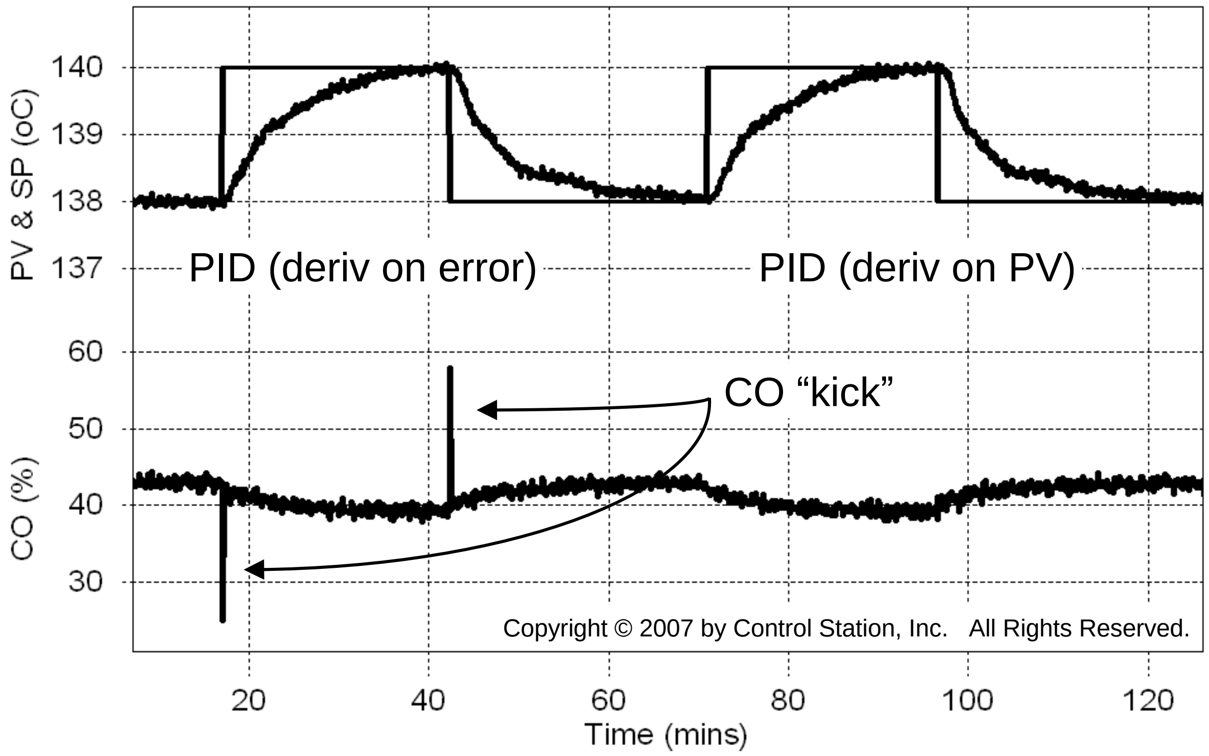
Consider that if the set point (SP) is constant, then:

$$\frac{de(t)}{dt} = \frac{d\left(\cancelto{0}{SP} - PV\right)}{dt} = -\frac{dPV}{dt}$$

That is, as long as SP is constant, then:

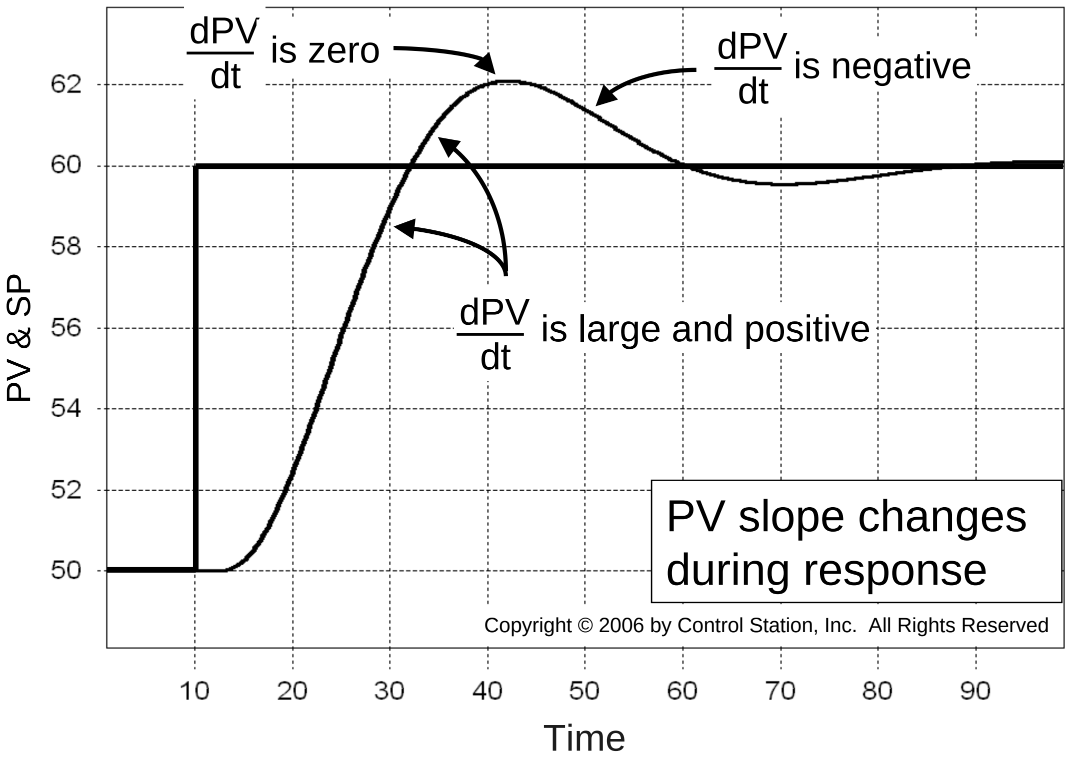
deriv on error = **−** deriv on measurement

Derivative on PV Does Not "Kick"



- Heat Exchanger under PID control shows CO kick with derivative on e(t)
- Impact of CO kick on PV performance depends on sample time (T) relative to τ_p (fast/small sample time gives little chance for impact)
- But potential for wear on mechanical FCE (e.g., valve) is always a concern

Understanding Derivative Action



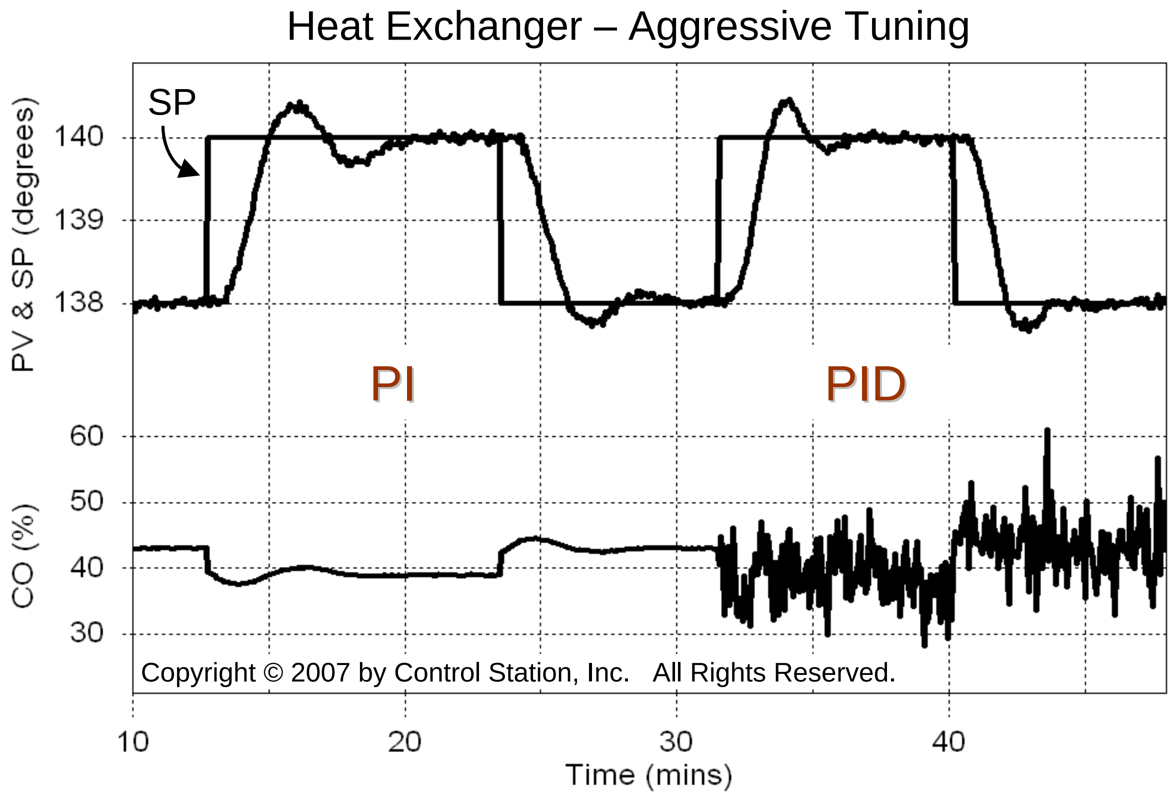
- Assuming Kc and τ_D are positive and appropriate size:
  - when dPV/dt (the slope) is positive, the derivative contribution works to decrease CO from its current value
  - when dPV/dt is negative, derivative contribution increases CO

PID Controllers Work in Harmony

- Proportional term provides a rapid response to controller error
- Integral term eliminates offset but increases the oscillatory or rolling behavior of the PV
- Derivative term works to *decrease oscillations* in the PV because its largest influence is when PV is rapidly changing

PID Set Point Tracking

- PID shows decreased oscillations compared to PI performance



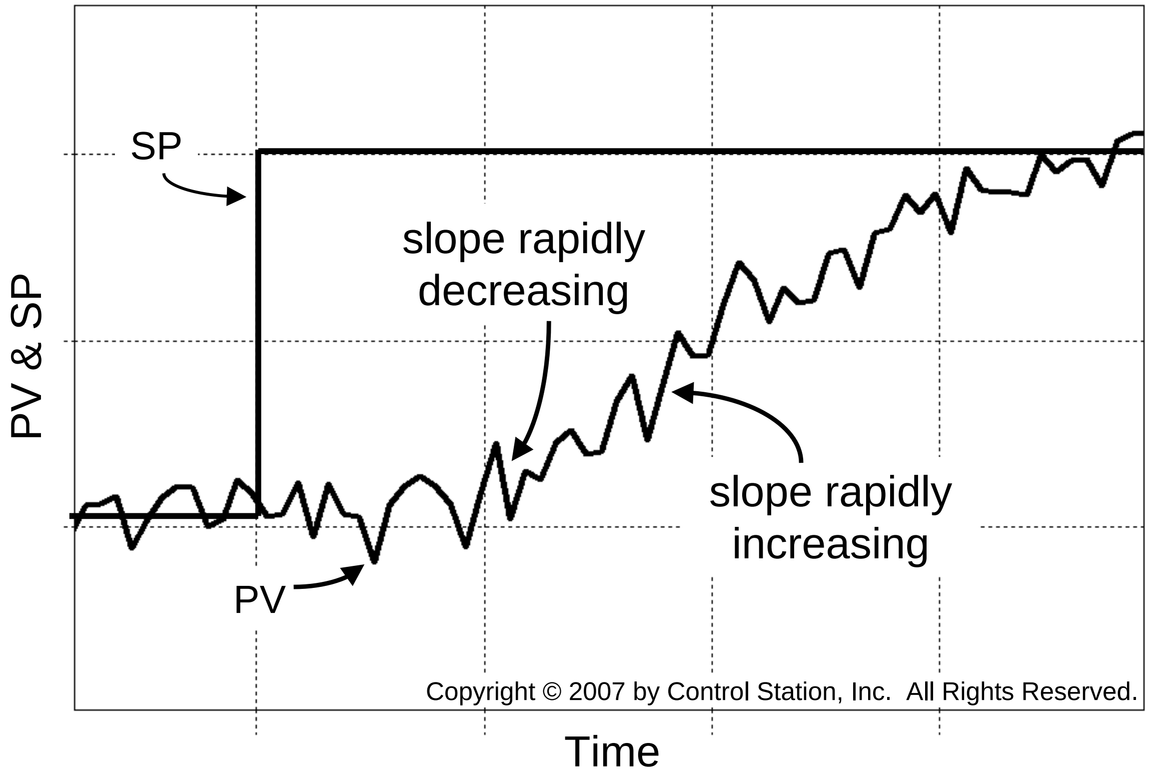
PID has somewhat:

- shorter rise time
- faster settling time
- smaller overshoot

Disadvantages of Derivative

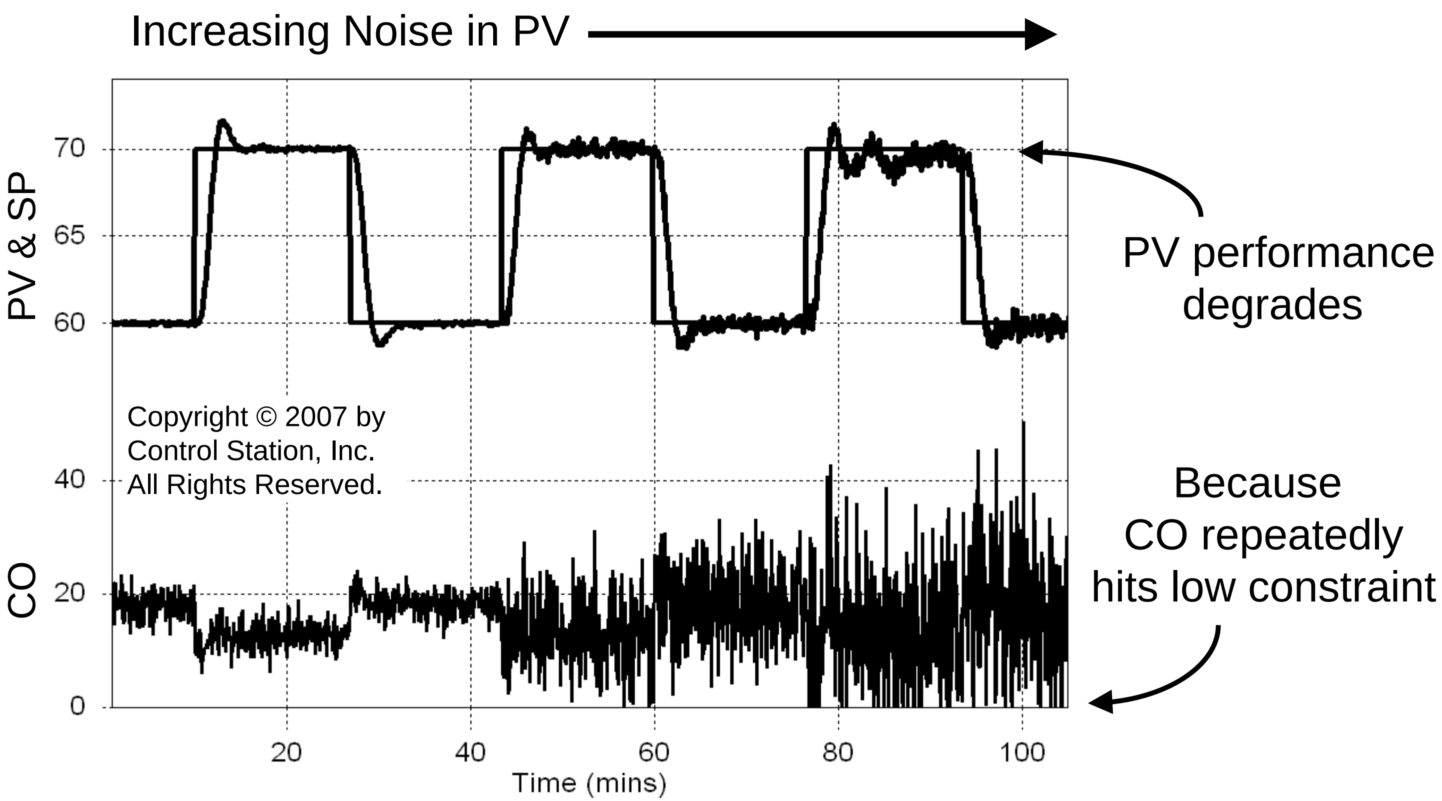
- Measurement Noise is a Problem:
  - Derivative action loses its benefits when there is random error (noise) in the measured PV – a common occurrence
  - The derivative action causes PV measurement noise to be amplified and reflected in the CO signal
  - This is because a noisy PV signal has changing derivatives as the slope switches direction at every sample

Noise Degrades Derivative Action



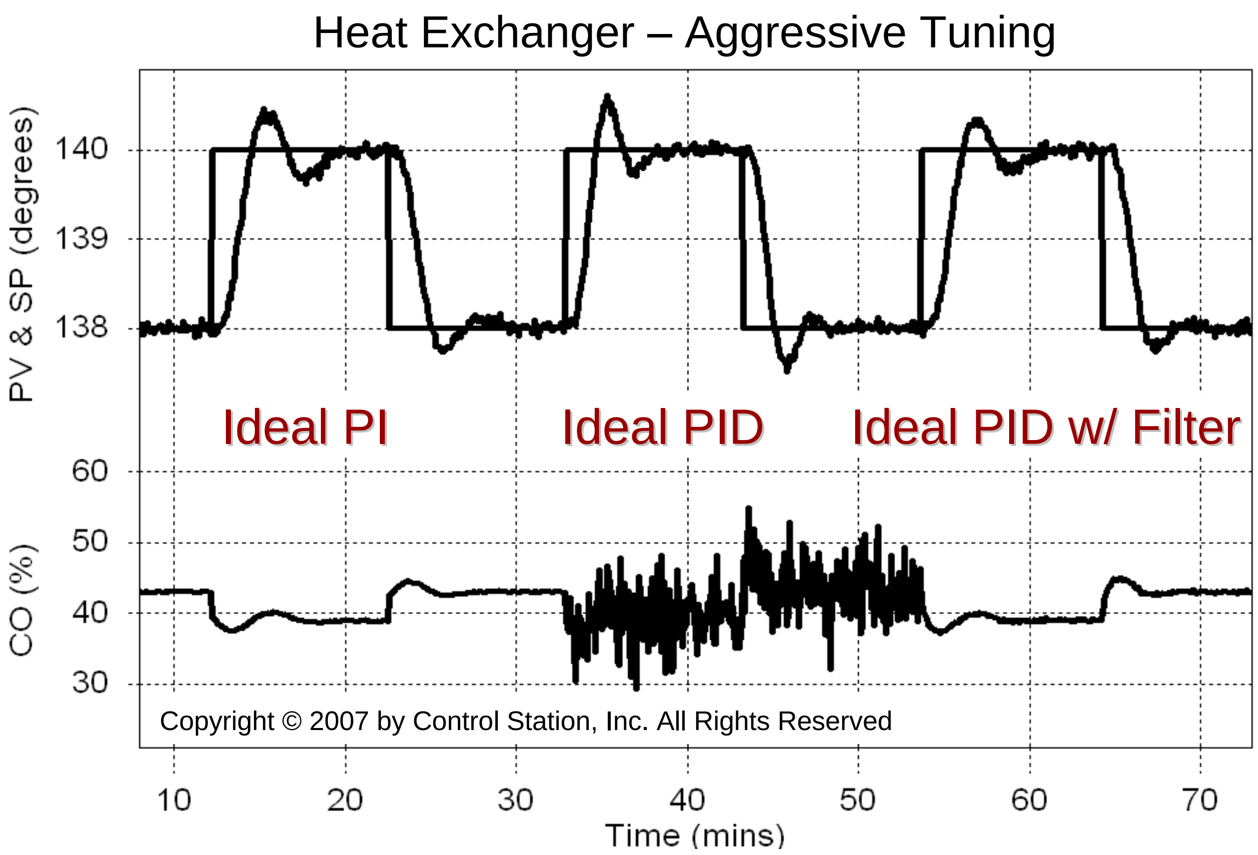
- Slope (derivative) switches direction every sample
- This produces alternating CO actions (called “chatter”) from the PID algorithm
- The CO chatter is amplified based on the size of τ_D

Noise Degrades Derivative Action



- As noise level increases, its impact on CO chatter is apparent
- If CO hits a constraint, lack of “symmetry in randomness” can impact PV

Comparing Controller Performance



- IMC tuned ideal algorithm: PI vs PID vs PID w/ CO Filter