Control Systems

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Unit-III

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Lecture 9

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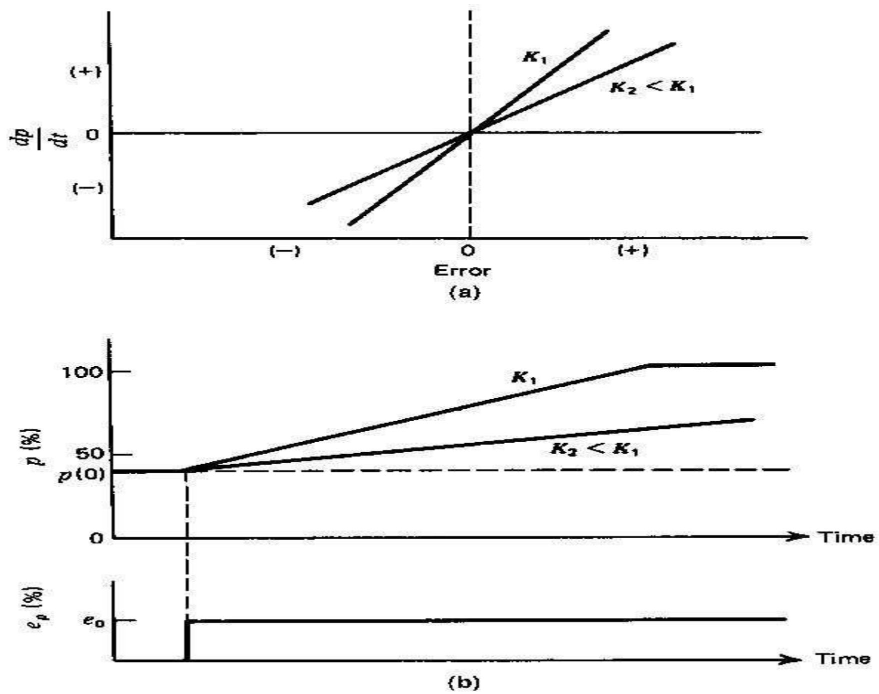
Characteristics Integral Control Action

- ✓ If error is zero, the output is a constant equal to p0.
- ✓ If there is an error, for every 1% of error, a correction of K*I* percent is added to or subtracted from p0 depending the sign of the error.

Integral mode controller action: (a) The rate of output change depends on error, and (b) an illustration of integral mode output and error.

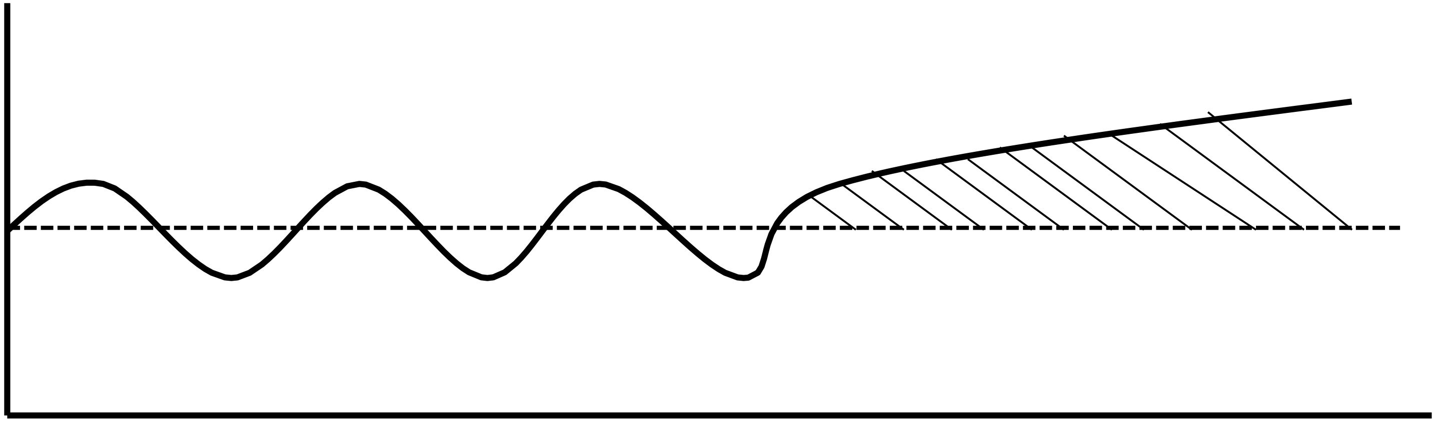


Why not "Integral"?

Integral Windup:

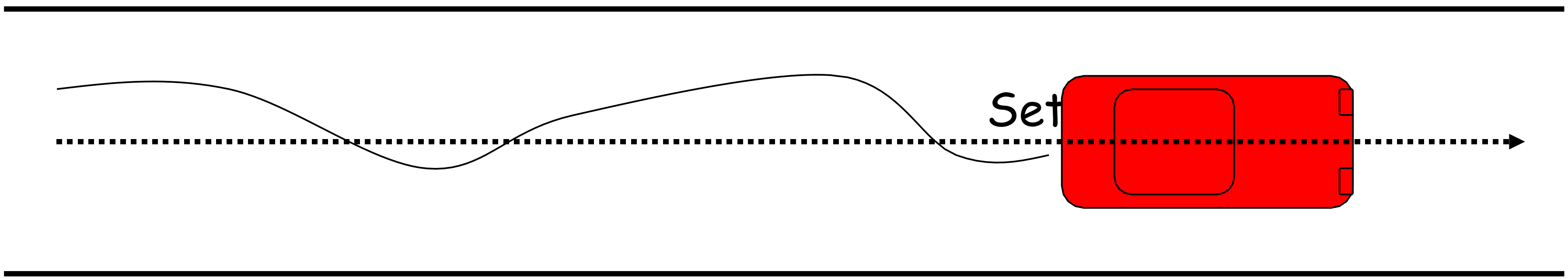
- The problem for integral controller is that, if there is a zero change in slope, the controller output holds to a constant value. This is called integral windup. The only way to cut the wind up is to put a negative error

Integration of a curve → area under the curve



Integrated input signal is multiplied by a factor, K_i

Integral Controller

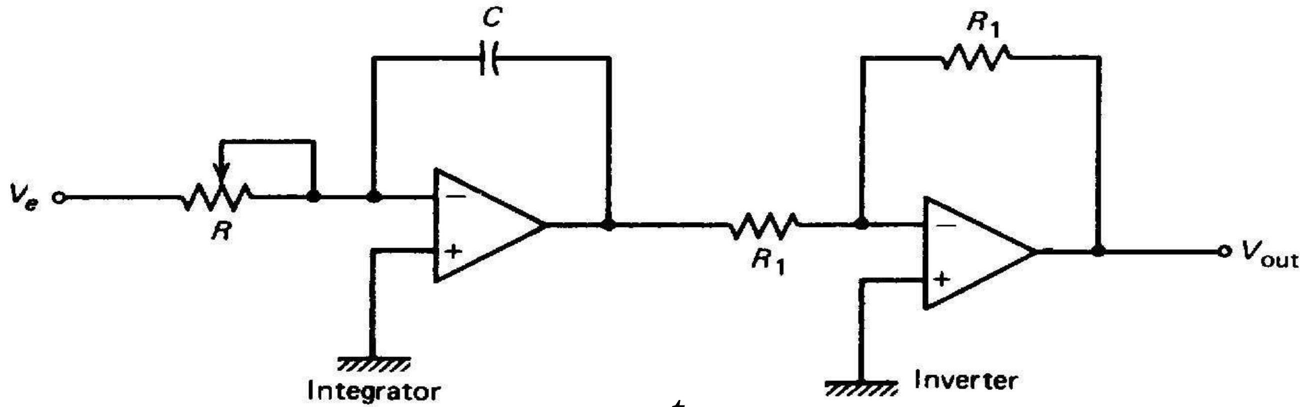


Car steering analogy:
Look out through the back window and keep track of
•how long the car has been out of desired position and
•by how much.
How long (sec) * how much (m) is the integral (sec*m).
The longer the car was positioned away from the set point the stronger the signal Good to correct for long term and only slight deviation from set point.

Integral Controller

- ✓ A purely integrating controller is slow and
- ✓ Error takes long time to build up
- ✓ Action can become too strong → overshooting
- ✓ Int controller is unaware of current position → Generally used combined with P control (looking at current position)
  – **PI control**

Electronic Integral Controller



$$Vout = G_I \int_0^t V_e dt + Vout(0)$$

Where, Vout= output voltage

$$G_I = \frac{1}{RC} \text{ =integration gain}$$

Ve = error voltage

Vout(0) = initial output voltage

Advantages of Integral Controller

- ✓ It reduces steady state error i.e. effect of offset.
- ✓ It provides high controlled output at a particular time after the error generated is for high value of KI.
- ✓ It responds to the continued existence of deviation.

Disadvantages of Integral Controller

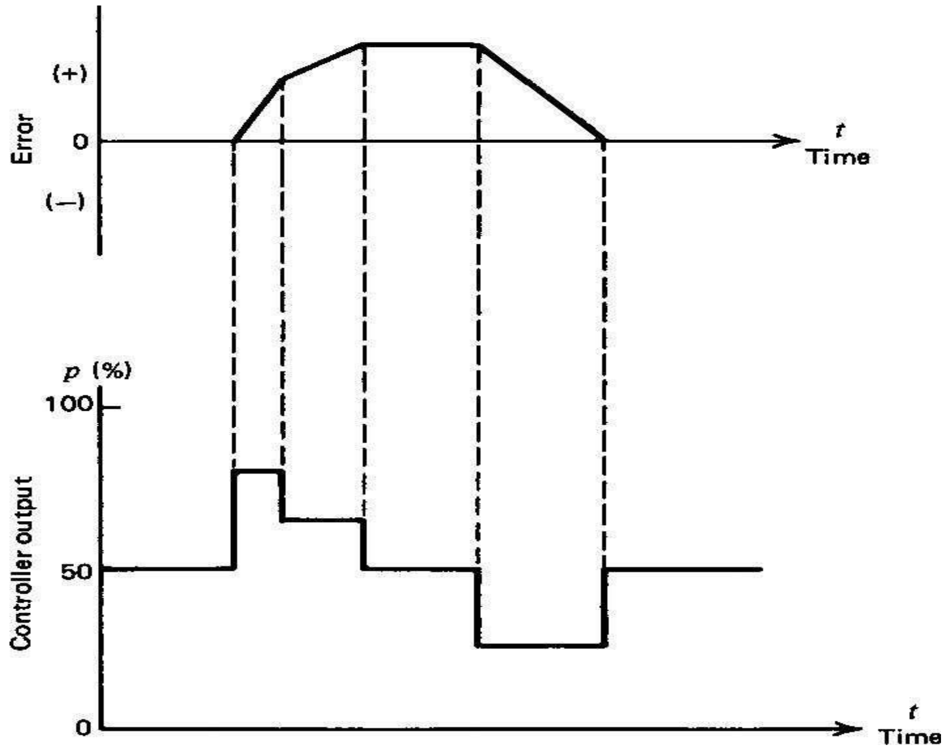
- ✓ It is never used alone.
- ✓ It makes the system unstable for oscillatory response.
- ✓ It introduces hunting in the system response about its steady state condition.

Derivative Control Action

- In a derivative control mode, the controller output is proportional to the derivative of the error. So the output can be expressed as:

$$p = K_D \frac{de_p}{dt}$$

Derivative mode controller action changes depending on the rate of error.



Characteristics Derivative Control Action

- ✓ If error is zero or the error is constant in time, the mode provides no output.
- ✓ If there is an error, for every 1% -per-second rate of change of error, the mode contributes an output of KD percent.
- ✓ For direct action, a positive rate of change of error produces a positive derivative mode output.

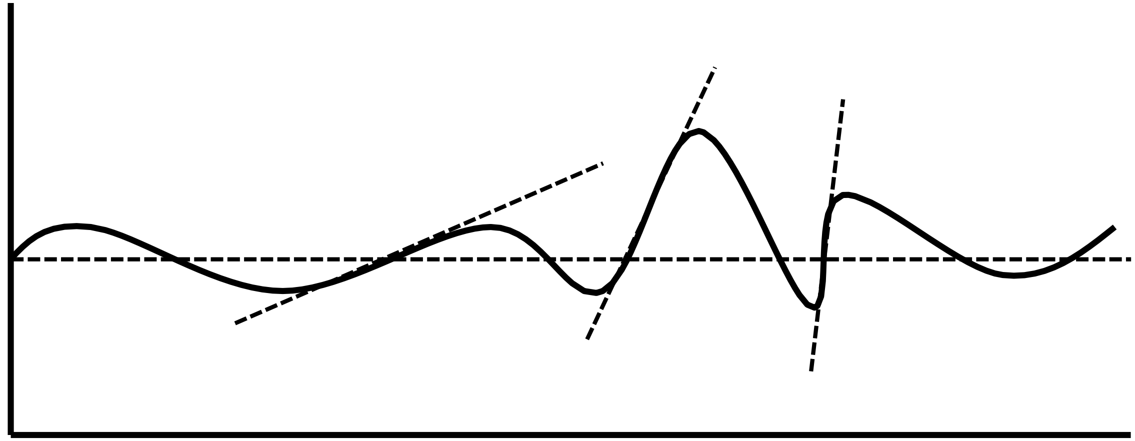
Why not “Derivative”?

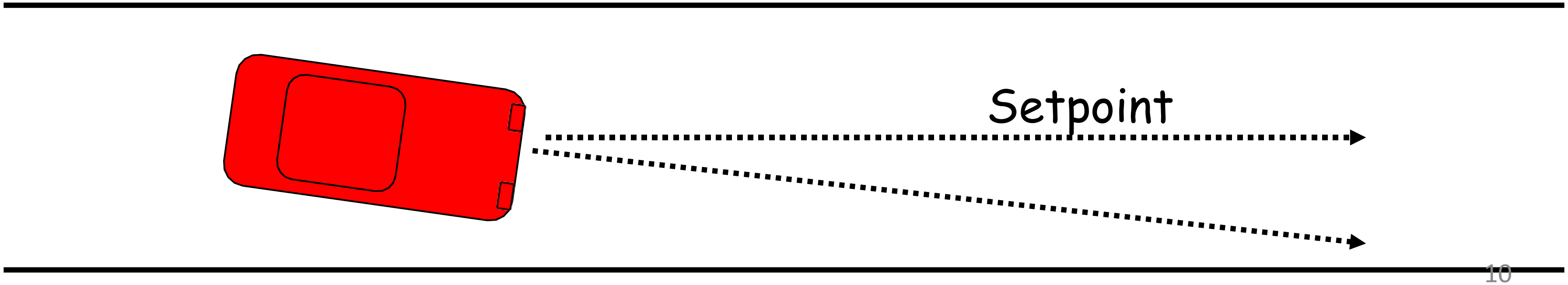
Derivative Overrun:

- ➢ A step change in set point causes a false step error for the derivative controller. This step change causes the derivative part of the controller to saturate the overall controller output. This ultimately forces the final control element to go to hard Off mode. This is called derivative overrun. The solution to this problem is to feed the derivative controller with process variable (PV) instead of error

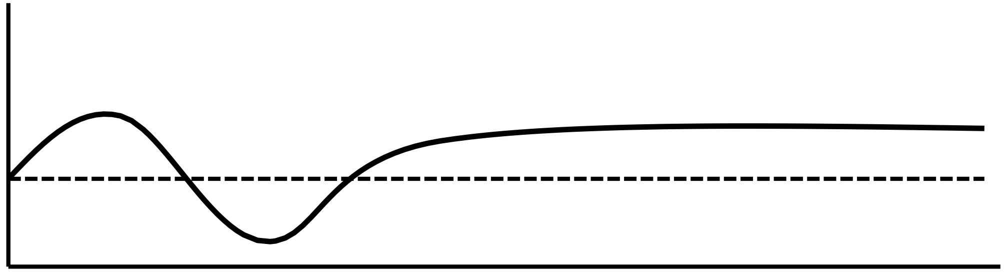
Derivative Controller

- ✓ Examines the rate of change of the output of the process
- ✓ The faster the change, the stronger the action
- ✓ The derivative of the output (slope) is multiplied by a constant, K_d



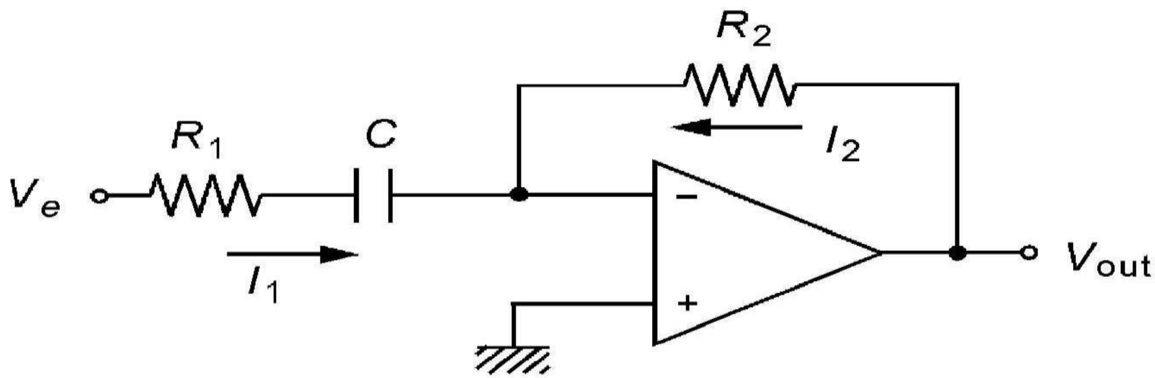


- ✓ Differential control is insensitive to slow changes
- ✓ If the variable is parallel to the setpoint, no change is made (slope = 0)



- ✓ Differential control is very useful when combined with P and I control → PID control

Electronic Derivative Controller



$$Vout + R_1 C \frac{dVout}{dt} = -R_2 C \frac{dVe}{dt}$$

Advantages of Derivative Controller

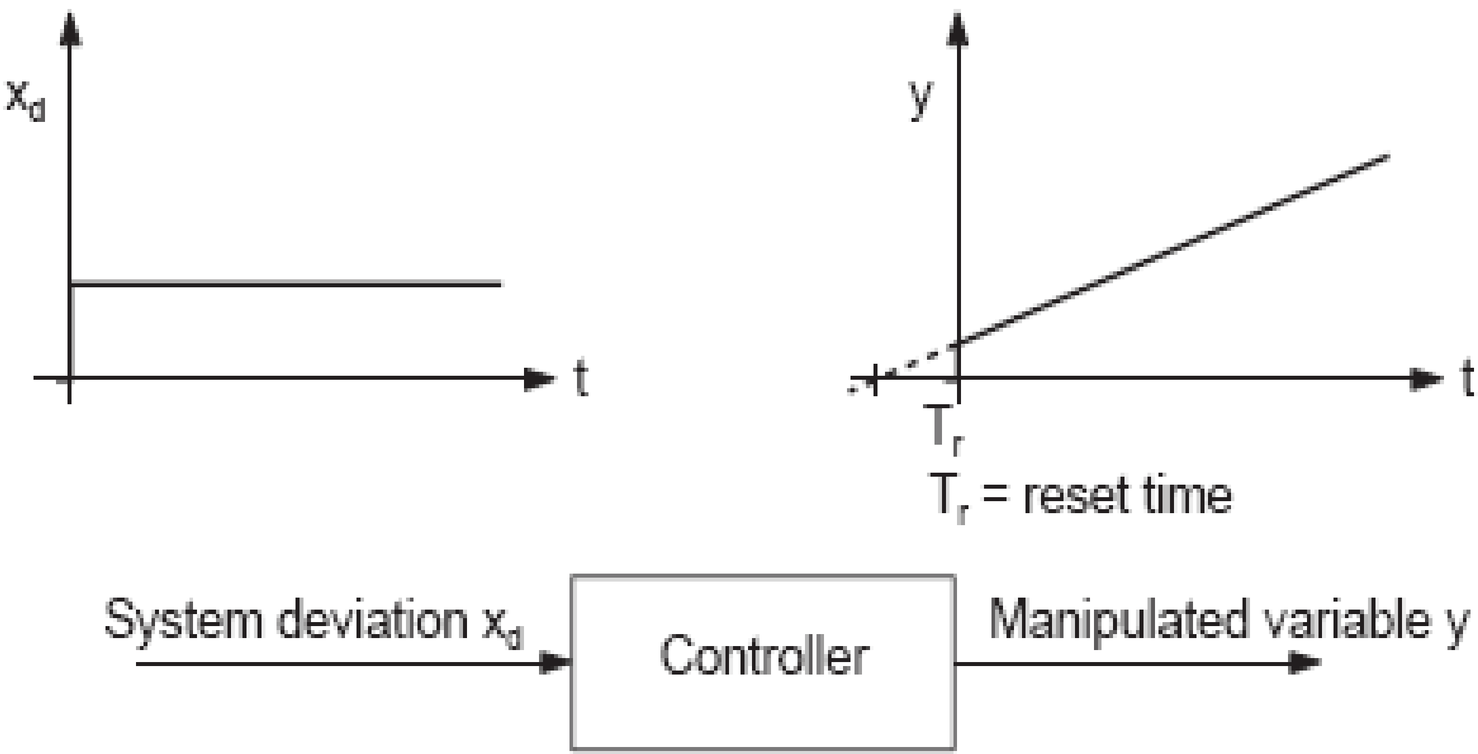
- ✓ It can overcome the overshoot and severe cycling.
- ✓ It has a rapid response to counter the effect of rapidly changing errors.
- ✓ It responds to the changes of the speed and direction to the deviation.
- ✓ It does not affect the steady state error directly, but anticipates the error.
- ✓ It increases the stability of the system by initiating an early corrective action

Disadvantages of Derivative Controller

- ✓ It cannot be used alone, since it cannot give any output for zero or constant error.
- ✓ It is ineffective for slowly changing error and hence causes the drift.
- ✓ It amplifies the noise signal and causes a saturation effect on the system.
- ✓ It does not eliminate the steady state error (offset)

PI-Controller

- ✓ The PI controller combines the behaviour of the I controller and P controller.
- ✓ This allows the advantages of both controller types to be combined: fast reaction and compensation of remaining system deviation.
- ✓ For this reason, the PI controller can be used for a large number of controlled systems.
- ✓ In addition to proportional gain, the PI controller has a further characteristic value that indicates the behaviour of the I component: the reset time (integral- action time).



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PI-Controller

- This control mode results from a combination of the proportional mode and the integral mode. The output can be expressed as:

$$p(t) = K_P e_p + K_P K_I \int_0 e_p dt + p_I(0)$$

$where,\ p_I(0)$= integral term value at t=0 (initial value)

✓ **Proportional-integral (PI) action showing the reset action of the integral contribution**