Control Systems

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Third Year ECE

Unit-III

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Lecture 10

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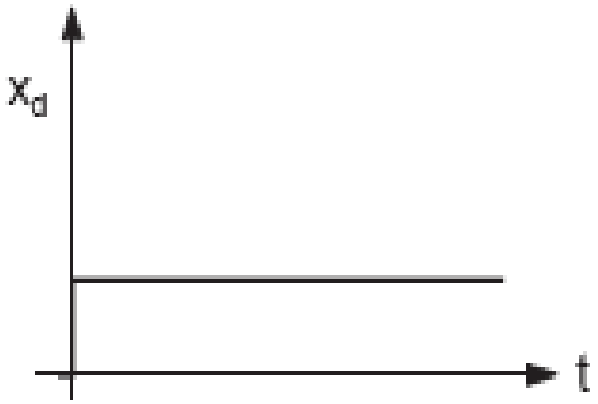
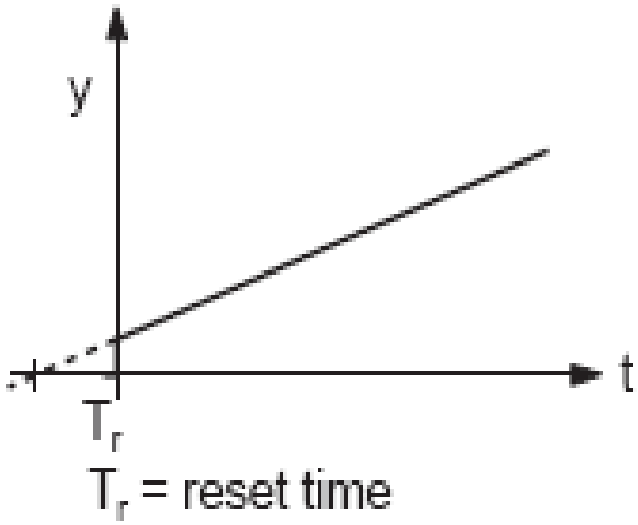
PI-Controller

- ✓ 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).





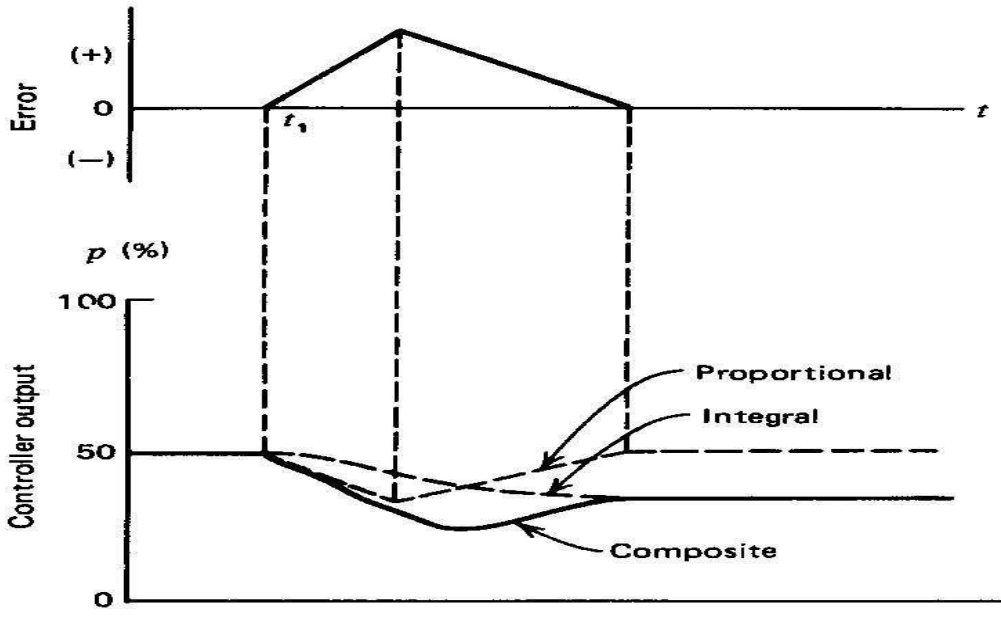
PI-Controller

- 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)

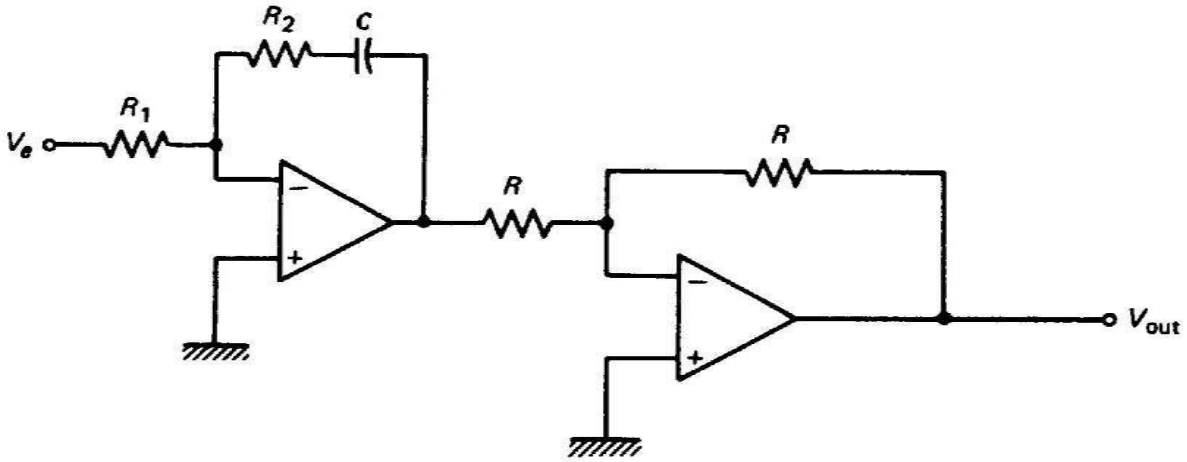
- ✓ **Proportional-integral (PI) action showing the reset action of the integral contribution**



Characteristics of PI-Controller

- ✓ When error is zero, the controller output is fixed at PI(0).
- ✓ If there is an error, the proportional term contributes a correction, and the integral term begins to increase/decrease the accumulated value [initially, pI (0)], depending on the sign of the error and the direct or reverse action.

Electronic PI Controller



$$Vout = \left(\frac{R_2}{R_1}\right)Ve + \left(\frac{R_2}{R_1}\right)\frac{1}{R_2C}\int_0^t V_e dt + Vout(0)$$

Advantages of PI Controller

- ✓ It provides better stability to the system.
- ✓ It provides simplicity and directness.
- ✓ It fully eliminates the steady state error i.e. offset.
- ✓ It has good transient response.
- ✓ It stabilizes the controller gain.

Disadvantages of PI Controller

- ✓ It takes the longer time to stabilize the controller gain than proportional controller action.
- ✓ It suffers from only oscillation induced by the integral overshoot.
- ✓ It requires excessive stabilization, when the process has many energy elements or dead time.

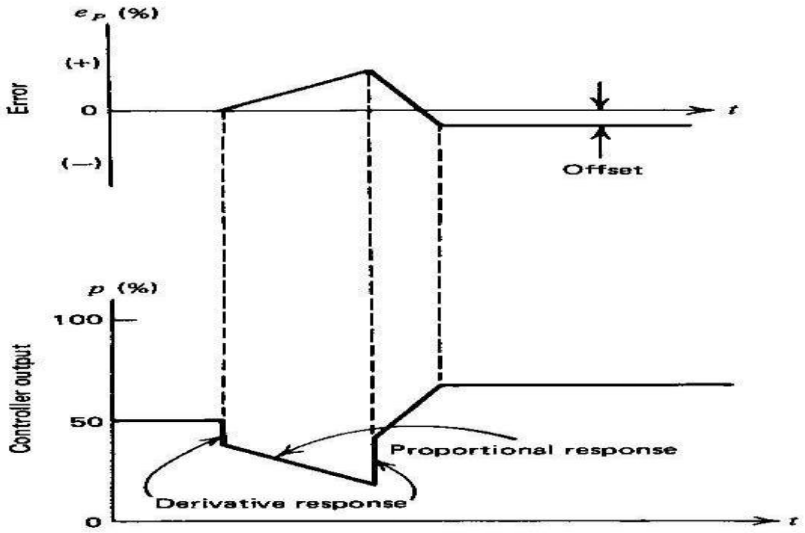
PD Controller

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

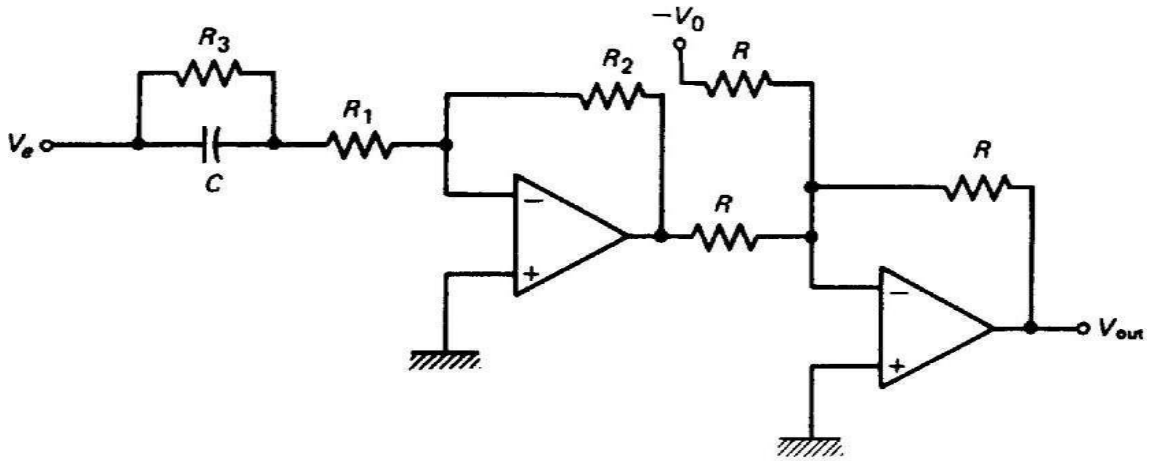
$$p = K_P e_p + K_P K_D \frac{de_p}{dt} + p_0$$

- ✓ The PD controller consists of a combination of proportional action and differential action.
- ✓ The differential action describes the rate of change of the system deviation.
- ✓ The greater this rate of change – that is the size of the system deviation over a certain period – the greater the differential component.
- ✓ In addition to the control response of the pure P controller, large system deviations are met with very short but large responses.
- ✓ This is expressed by the derivative-action time (rate time).

Proportional-derivative (PD) action showing the offset error from the proporti mode



Electronic PD Controller



$$Vout = \left(\frac{R_2}{R_1 + R_3}\right)Ve + \left(\frac{R_2}{R_1 + R_3}\right)R_3 C\frac{dVe}{dt} + Vo$$

Advantages of PD Controller

- ✓ It allows the rise of narrower proportional band with its lesser offset.
- ✓ It increases the controller gain during the error change.
- ✓ It can compensate the rapidly changing error.
- ✓ It can handle the fast process load change.
- ✓ It can compensate some of the lag in a process.

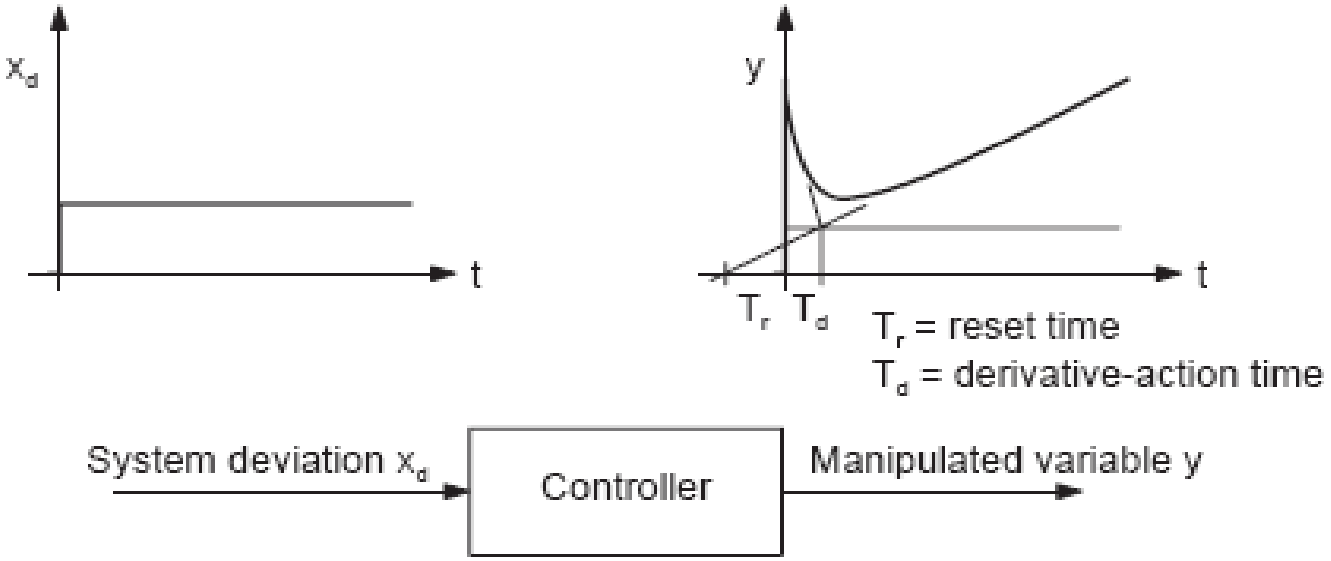
Disadvantages of PD Controller

- ✓ It cannot eliminate the offset of proportional controller.

PID- Controller

- ✓ In addition to the properties of the PI controller, the PID controller is complemented by the D component.
- ✓ This takes the rate of change of the system deviation into account.
- ✓ If the system deviation is large, the D component ensures a momentary extremely high change in the manipulated variable.
- ✓ While the influence of the D component falls of immediately, the influence of the I component increases slowly.
- ✓ If the change in system deviation is slight, the behaviour of the D component is negligible
- ✓ This behavior has the advantage of faster response and quicker compensation of system deviation in the event of changes or disturbance variables.
- ✓ The disadvantage is that the control loop is much more prone to oscillation and that setting is therefore more difficult.

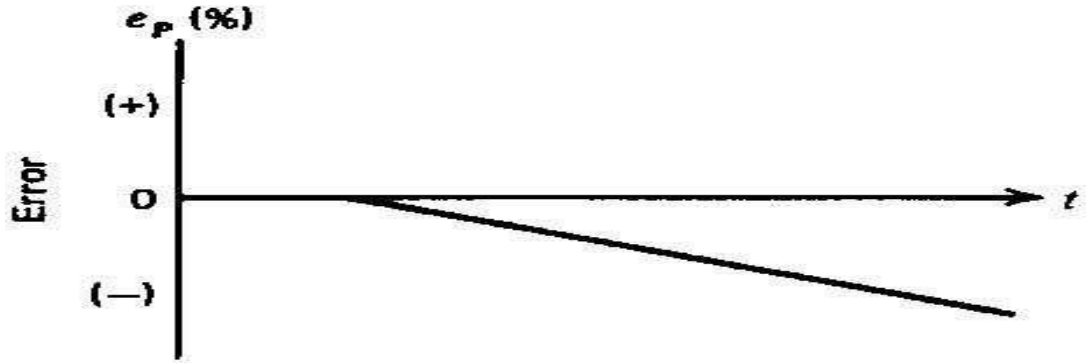
PID- Controller

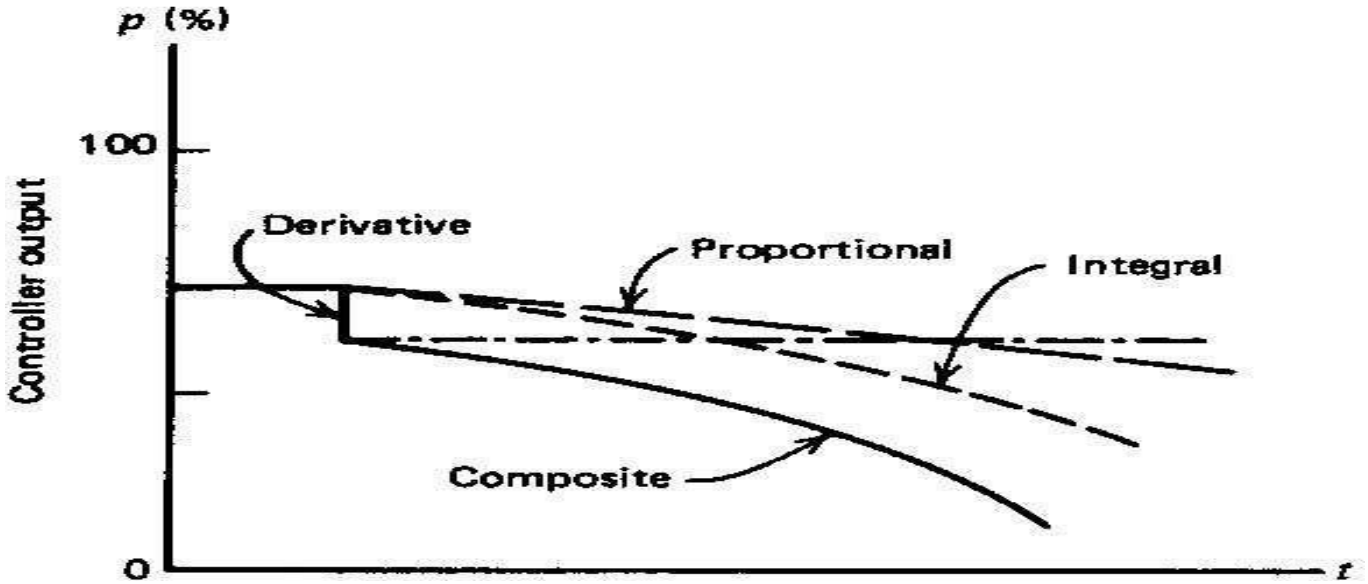


✓ This is one of the most powerful but complex controller mode operations combines the proportional, integral and derivative modes. The output for this mode can be expressed as:

$$p = K_P e_p + K_P K_I \int_0^t e_p dt + K_P K_D \frac{de_p}{dt} + p_I(0)$$

The three-mode controller action exhibits proportional, integral, a derivative action.





Time Analogy of PID Controller

- ✓ P: Present time. Only considers current position. Not aware of current direction and of error history
- ✓ I: Past time. Only compiles an error sum of the past. Not aware of current distance of signal from setpoint and of current direction.
- ✓ D: Future time. Only considers current direction (trend). Now aware of current distance of signal from setpoint and of error history.

PID Response

1. Output without control

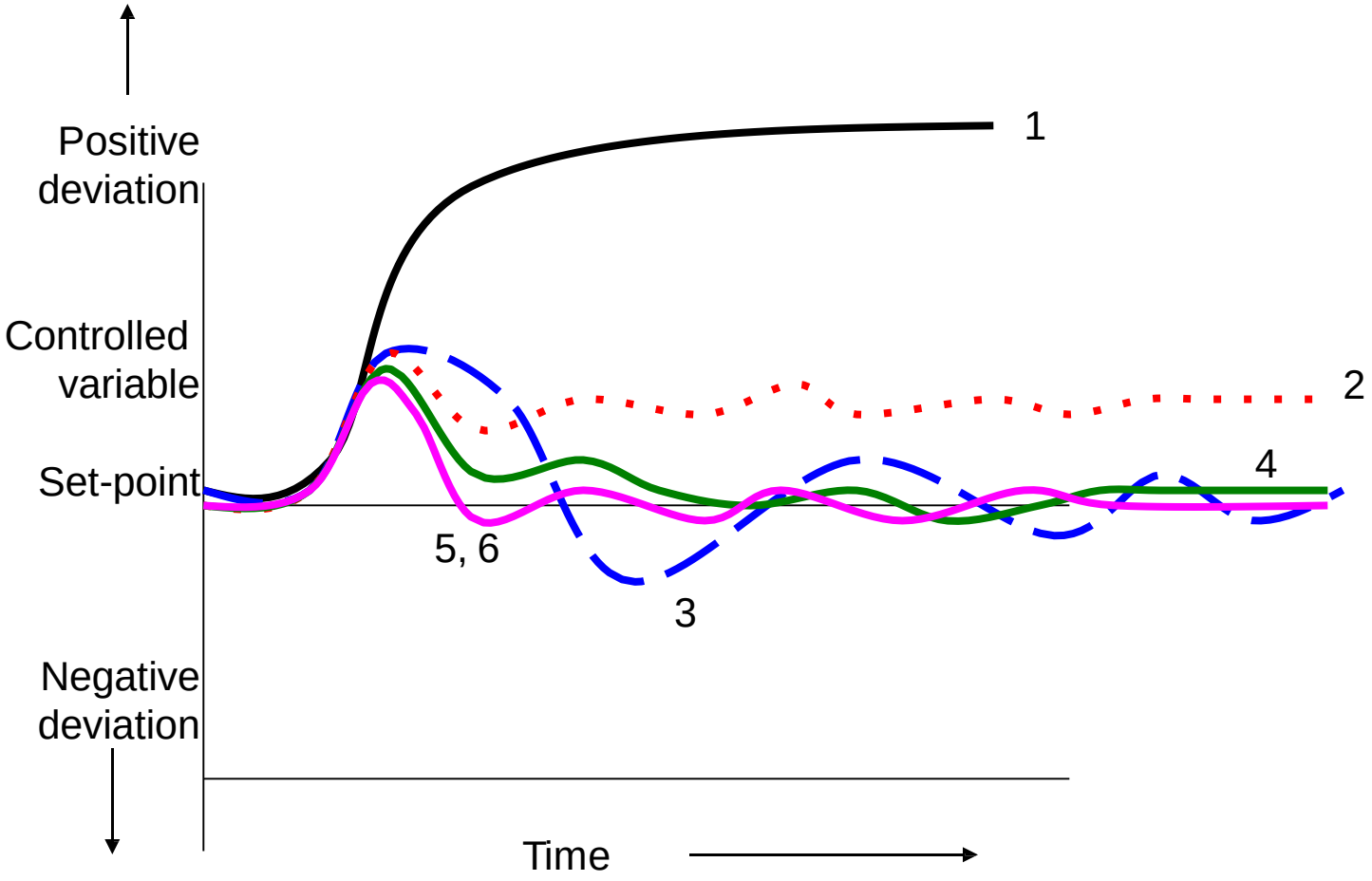
2. Proportional action

3. Integral action

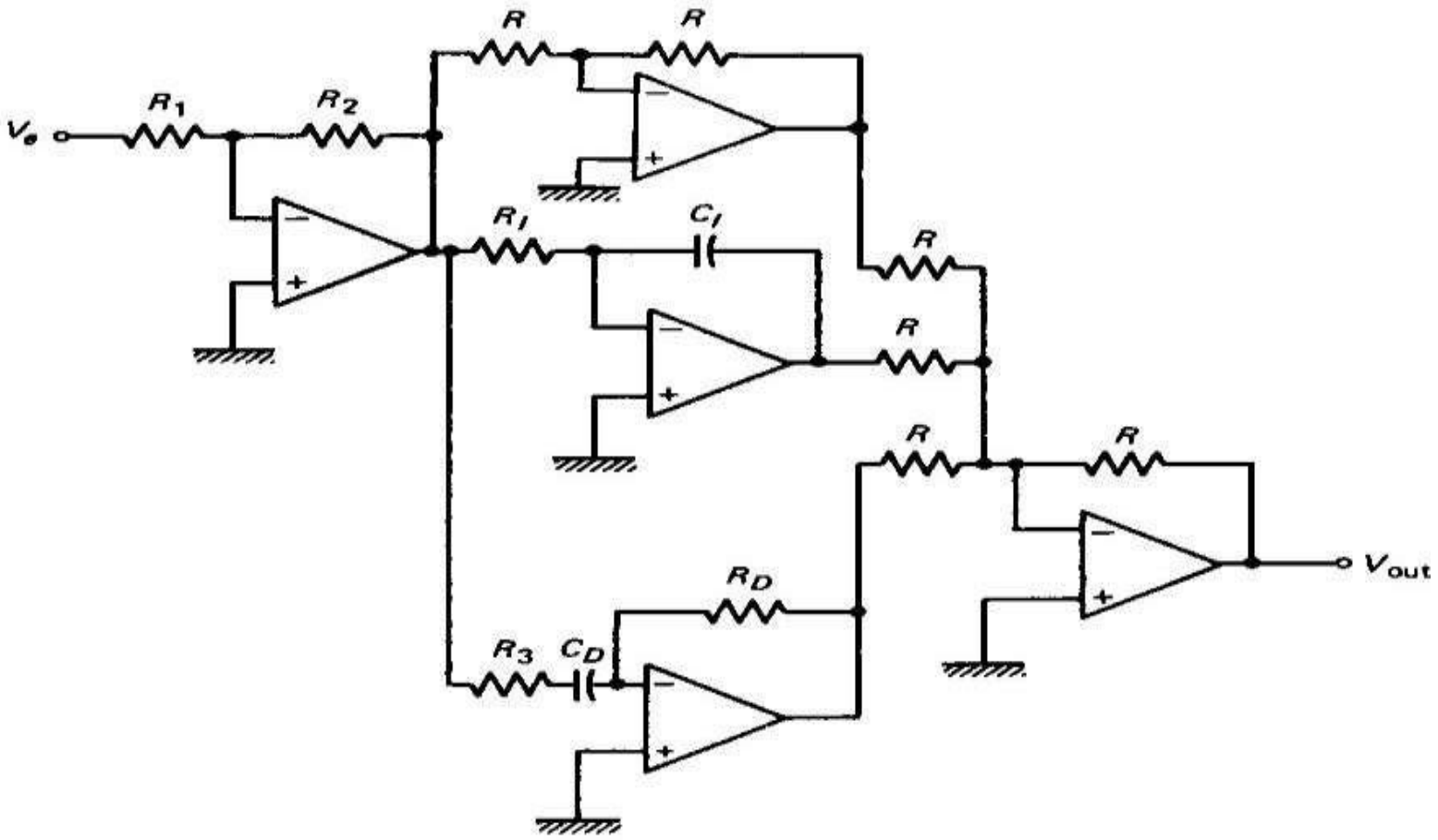
4. Proportional + integral action

5. Proportional + derivative action

6. Proportional + integral + derivative action



Electronic PID Controller



$$-Vout = \left(\frac{R_2}{R_1}\right)Ve + \left(\frac{R_2}{R_1}\right)\frac{1}{R_I C_I}\int V_e dt + \left(\frac{R_2}{R_1}\right)R_D C_D \frac{dV_e}{dt} + Vout(0)$$

Advantages of PID Controller

- ✓ It reduces the overshoot which often occurs when integral control action is added to proportional control action.
- ✓ It counteracts the lag characteristics introduced by the integral control action.
- ✓ It approaches the tendencies towards oscillations.
- ✓ It senses the rate of movement away from the set point and gives corrective action earlier than only with P or PI

Disadvantages of PID Controller

- ✓ It is more effective for control process with many energy storage element than P+I control action used alone.
- ✓ It eliminates the offset i.e. steady state error introduced by proportional control action.
- ✓ It stabilizes the gain of the controller

UNIT-III
The End
Thank You