Control Systems

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Unit-III

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Lecture 8

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ON-OFF Controller- 2 Position Controller

Synonyms:

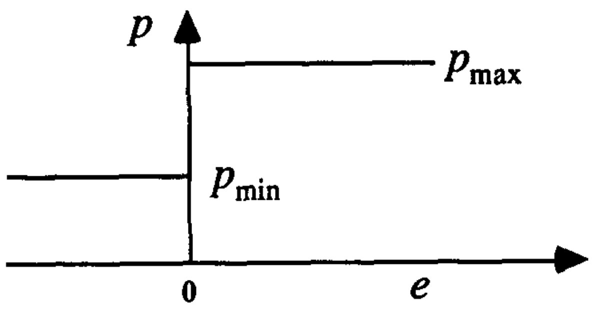
"two-position" or "bang-bang" controllers.

$$p(t) = \begin{cases} p_{\max} & if \quad e > 0 \\ p_{\min} & if \quad e < 0 \end{cases}$$

ideal case

e = error =
set point – measured variable

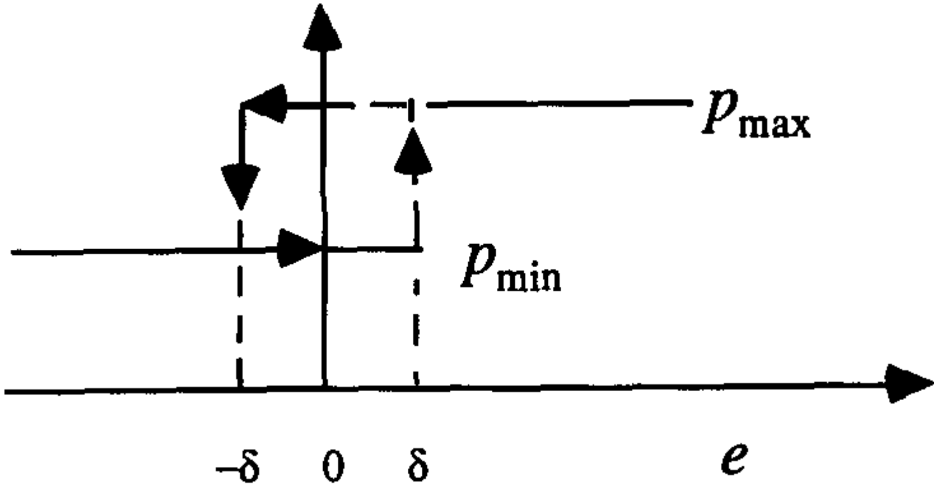
$p_{\max}$ **is the "on" value**
$p_{\min}$ **is the "off" value**



Controller output has two possible values.

Neutral Zone

Practical case (dead band)



$$p(t) = \begin{cases} P_{max} & for \quad e > \delta \\ P_{min} & for \quad e < -\delta \end{cases}$$

δ = tolerance

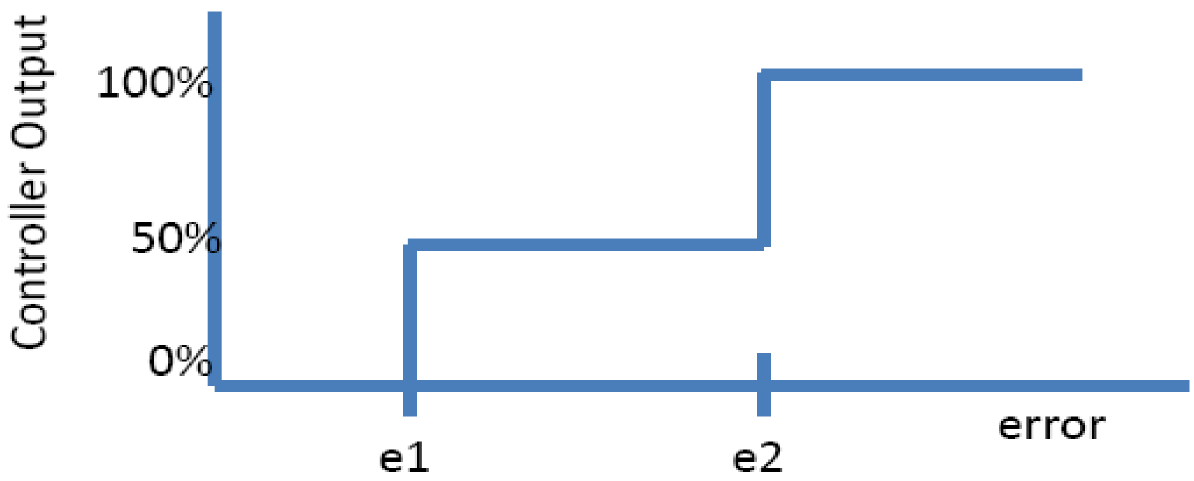
system never reaches steady-state

ON-OFF Controller-Multi position Controller

Multimode/ Multi-position Controller: Multimode controller is a logical extension of On/Off controller. It is used to provide several intermediate, rather than two, setting of the controller output. This discontinuous control is used in an attempt to reduce the cycling behavior and overshoot and undershoot inherent in the On/Off controller.

The most common example of a multimode controller can be:

$$p = \begin{cases} 100\%, & e_p > e_2 \\ 50\%, & -e_1 < e_p < e_2 \\ 0\%, & e_p < -e_1 \end{cases}$$



Floating Control Mode

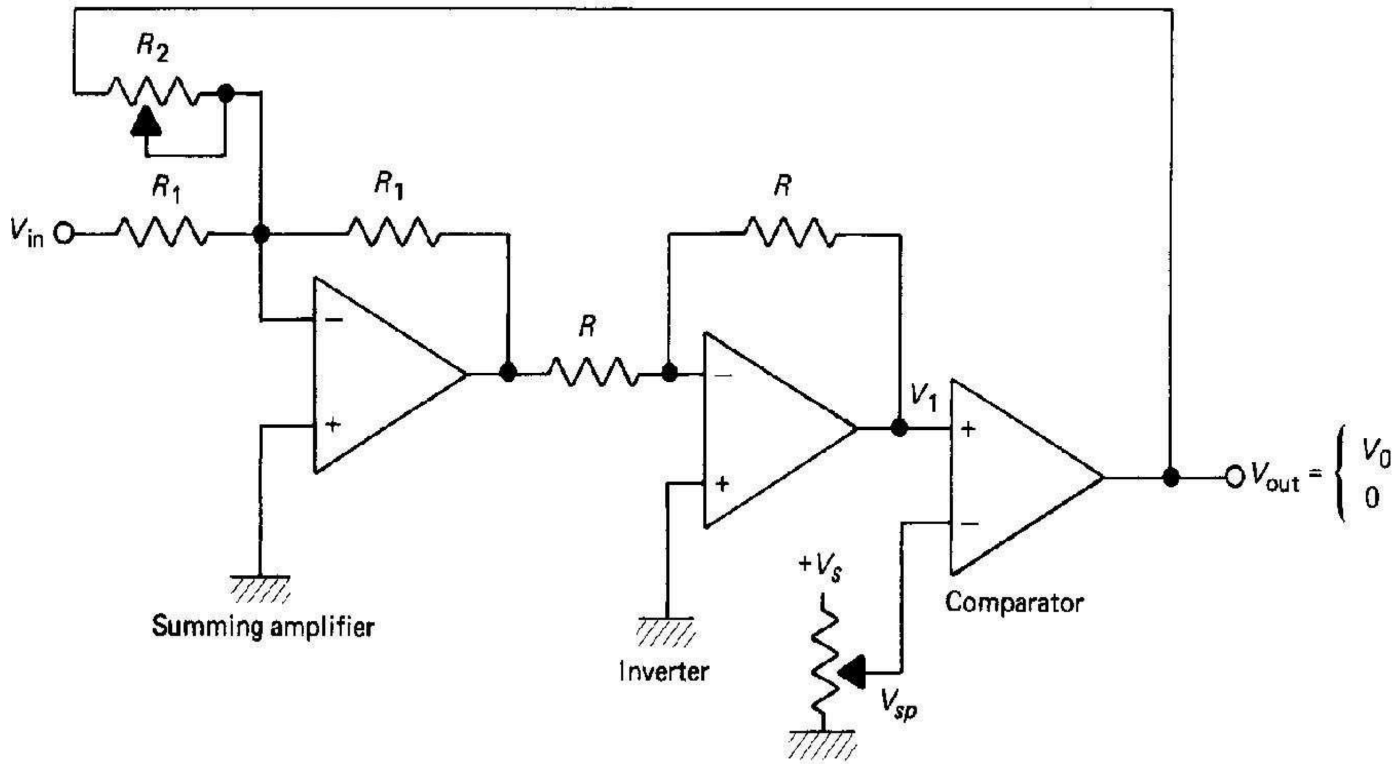
- ✓ In a floating control, the specific output of the controller is not uniquely determined by the error. If the error is zero the output does not change but remains (floats) at whatever setting it was when the error went to zero. When the error moves off zero, the controller output again begins to change

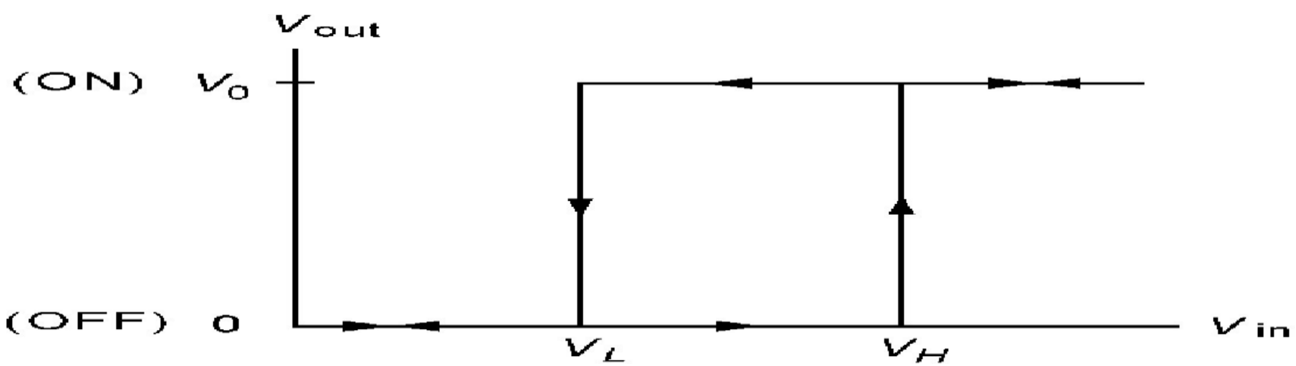
- Floating mode controller is of two types:

  - ✓ Single Speed: In the single-speed floating mode, the output of the control element changes at a fixed rate when the error exceeds the neutral zone.

  - ✓ Multi Speed: In the multi-speed floating mode, not one but several possible speeds (rates) are changed by controller output. Usually, the rate increases as the deviation exceeds certain rate.

Electronic ON-OFF Controller





Advantages of ON-OFF Controller

- ✓ Only two output states i.e. ON and OFF.
- ✓ Simple construction
- ✓ Low cost

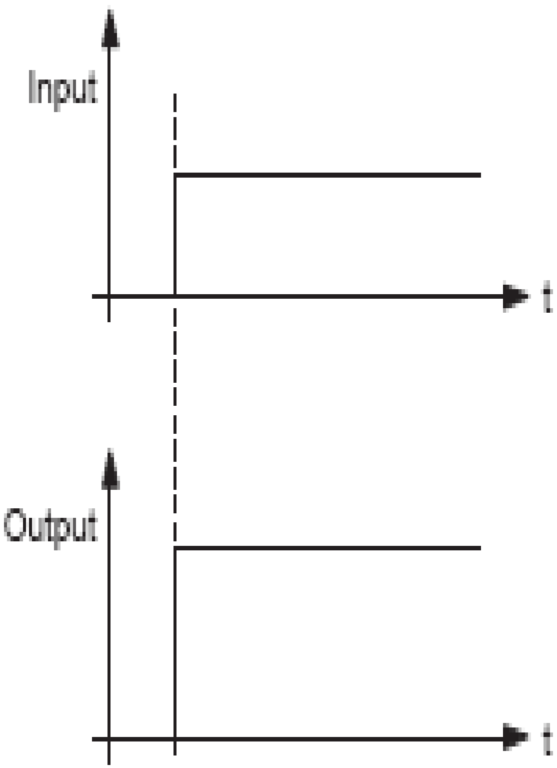
Disadvantages of ON-OFF Controller

- ✓ Response of ON-OFF controller is slow.
- ✓ Not suitable for complex system

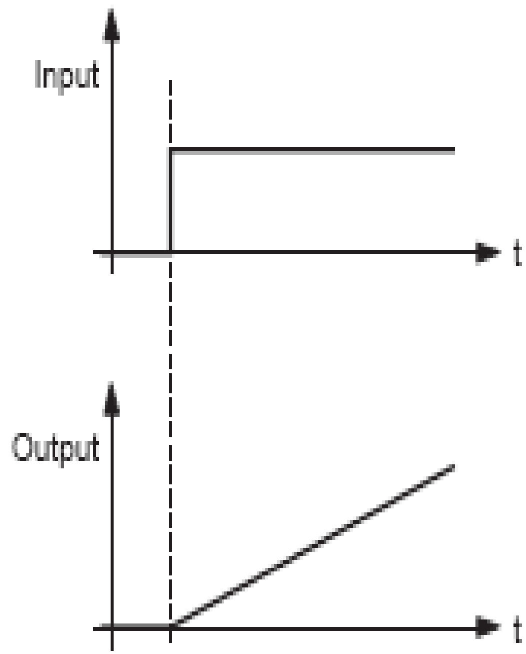
Proportional- Integral- Derivative

Output Response for Step Input Signal for:

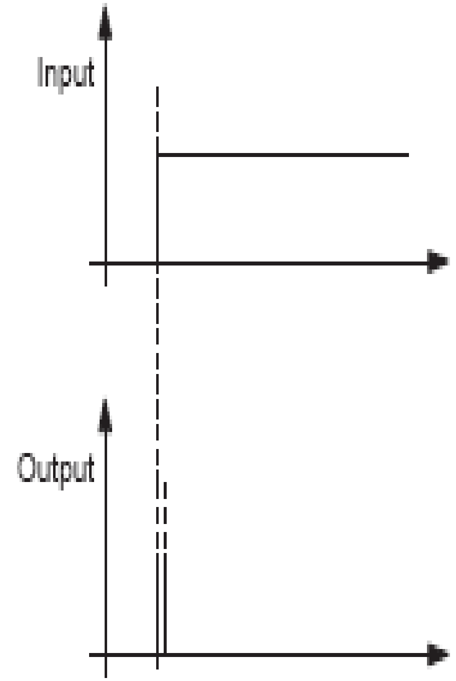
Proportional



Integral

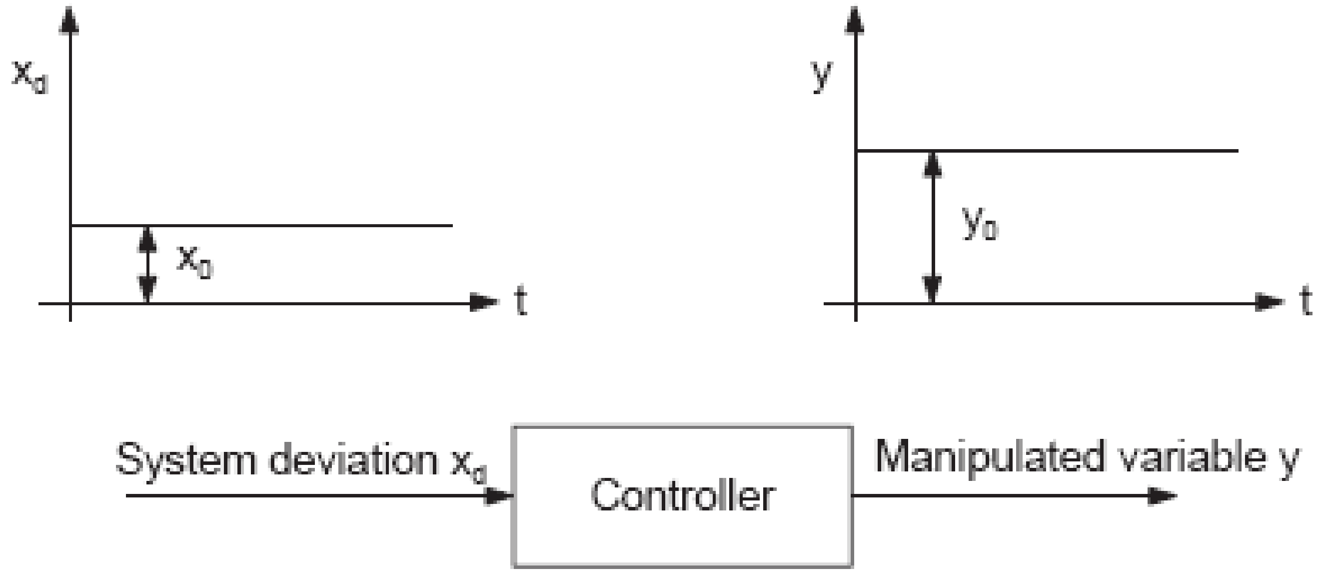


Derivative



Proportional Control Action

- ✓ In the case of the proportional controller, the actuation signal is proportional to the system deviation.
- ✓ If the system deviation is large, the value of the manipulated variable is large.
- ✓ If the system deviation is small, the value of the manipulated variable is small.
- ✓ The time response of the P controller in the ideal state is exactly the same as the input variable



Proportional Control Action

- ✓ In a proportional control mode, a smooth linear relationship exists between the controller output and the error. The range of error to cover the 0% to 100% controller output is called the proportional band, because the one-to-one correspondence exists only for errors in this range.

- ➢ The output can be expressed as:

$$p = K_p e_p + p_0$$

Where,

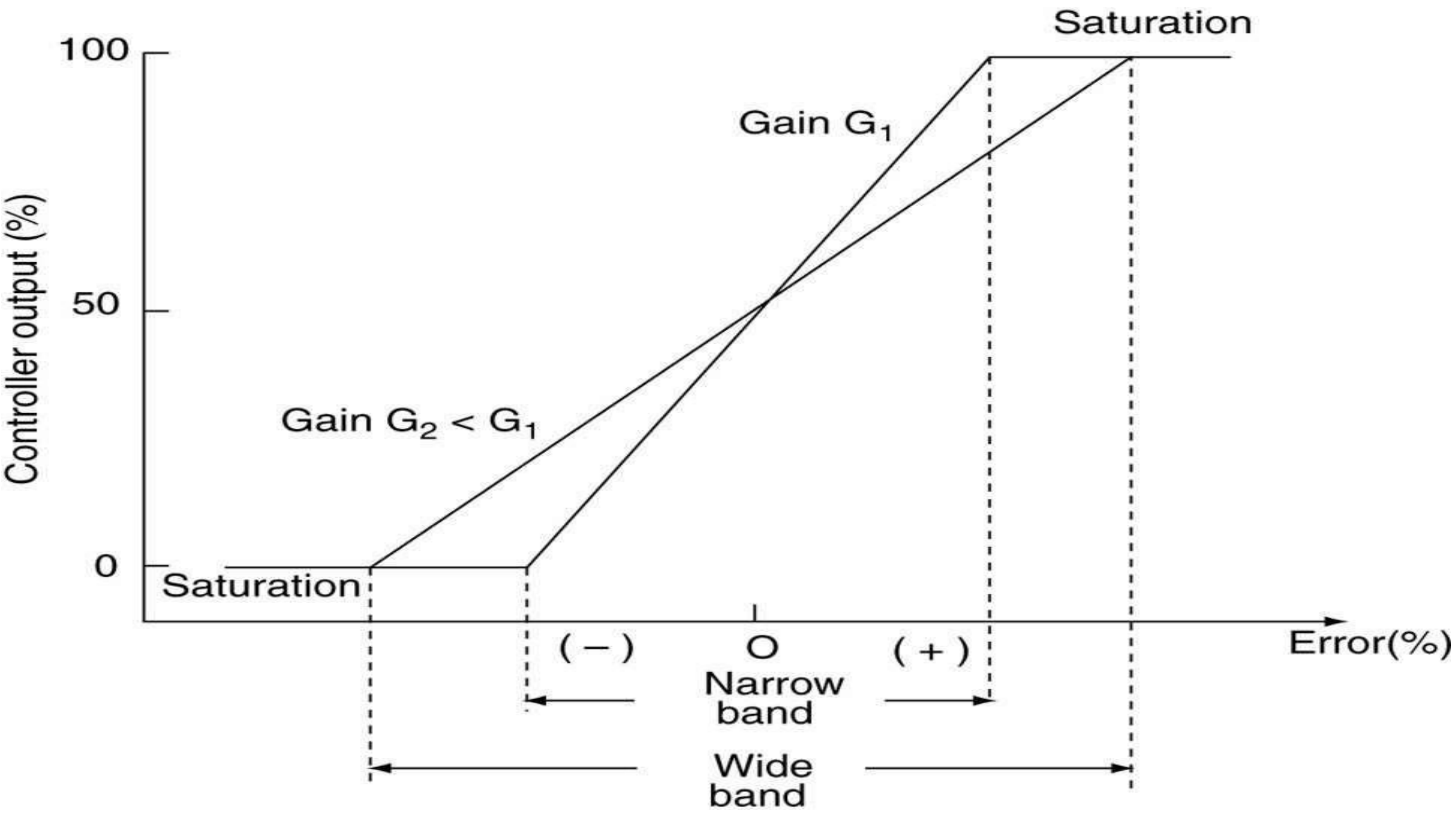
Kp = proportional gain between error and controller output

p0 = controller output with no error.

- ➢ In a proportional control mode, the proportional band is dependent on the gain and can be expressed as :

$$PB = \frac{100}{K_p}$$

The proportional band of a proportional controller depends on the inver the gain.



Characteristics of P Control mode

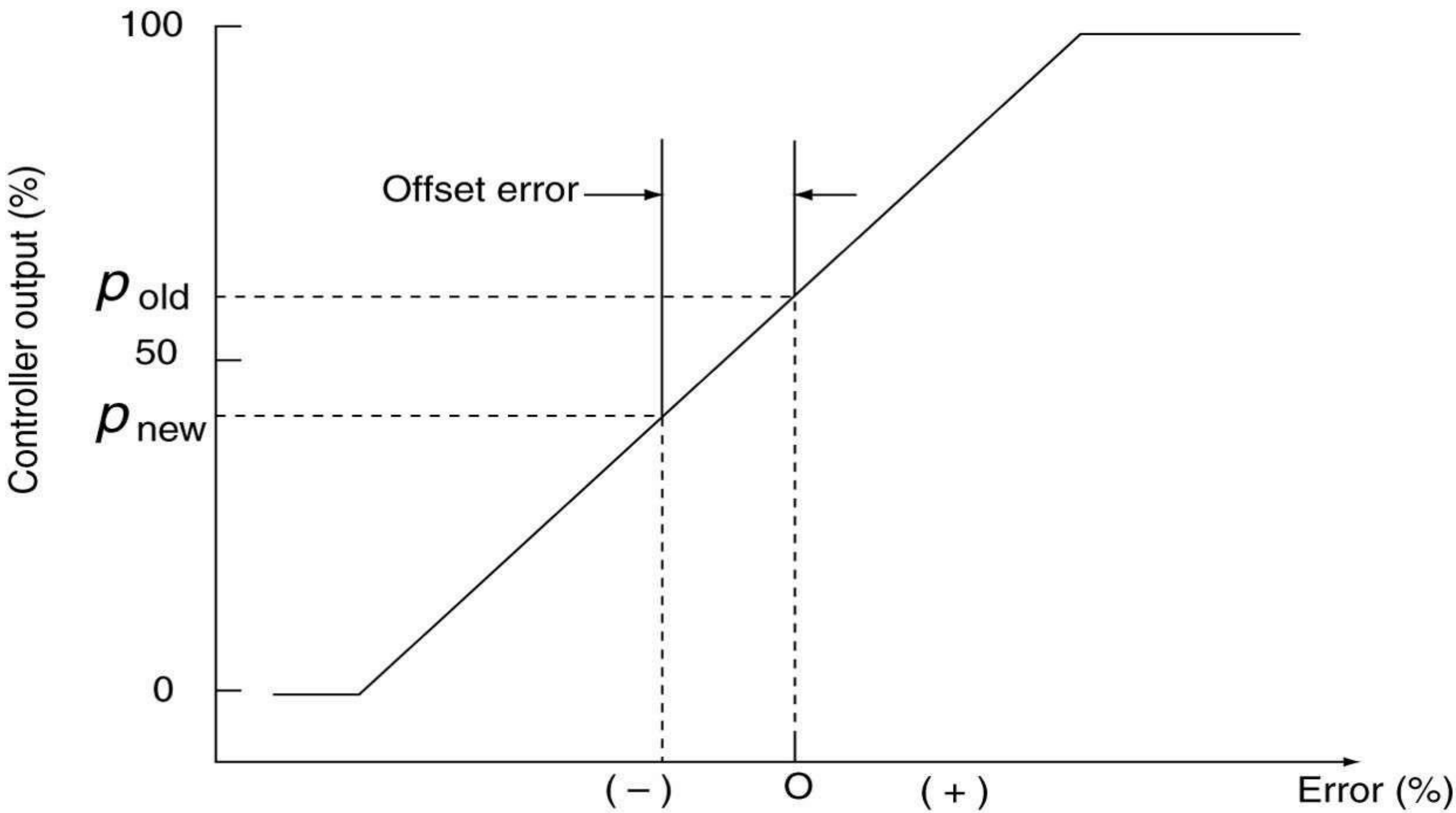
- ✓ If error is zero, the output is a constant equal to p0.
- ✓ If there is an error, for every 1% of error, a correction of Kp percent is added to or subtracted from p0 depending the sign of the error.
- ✓ There is a band of error about zero of magnitude PB with which the output is not saturated at 0% or 100%.

Why not “Proportional”?

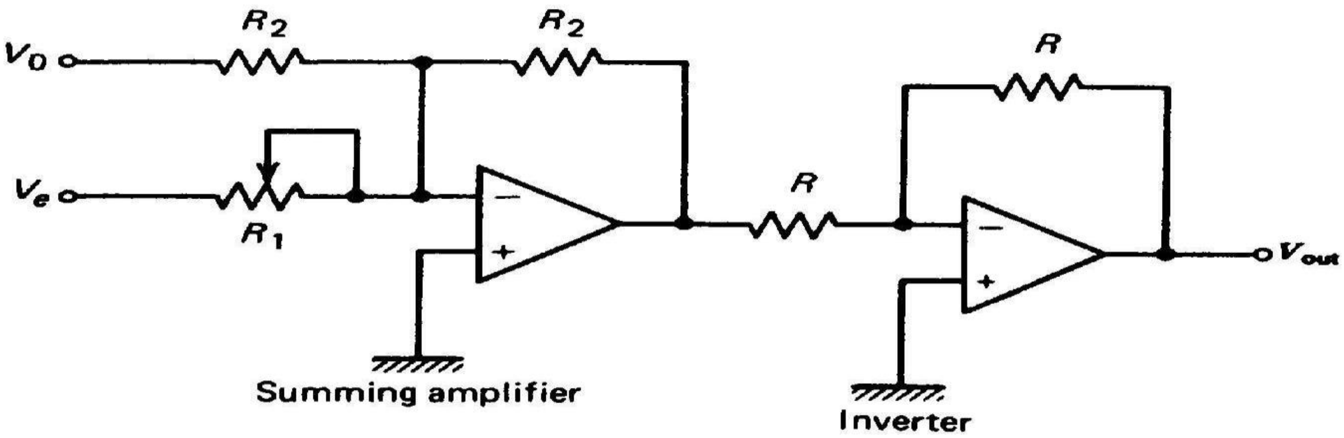
Offset:

- ➢ An important characteristics of proportional controller mode is that it produces a permanent residual error in the operating point of the controlled variable, when a change in load occurs. This error is referred to as offset. It can be minimized by a larger constant Kp which will also reduce the proportion band.

An offset error must occur if a proportional controller requires a new zero-
output following a load change



Example: # Electronic Proportional Controller



$$V_{out} = G_p V_e + V_o$$

Where, Vout= output voltage

$$G_p = \frac{R_2}{R_1} = gain$$

Ve = error voltage

Vo = output with zero error

Advantages of Proportional Controller

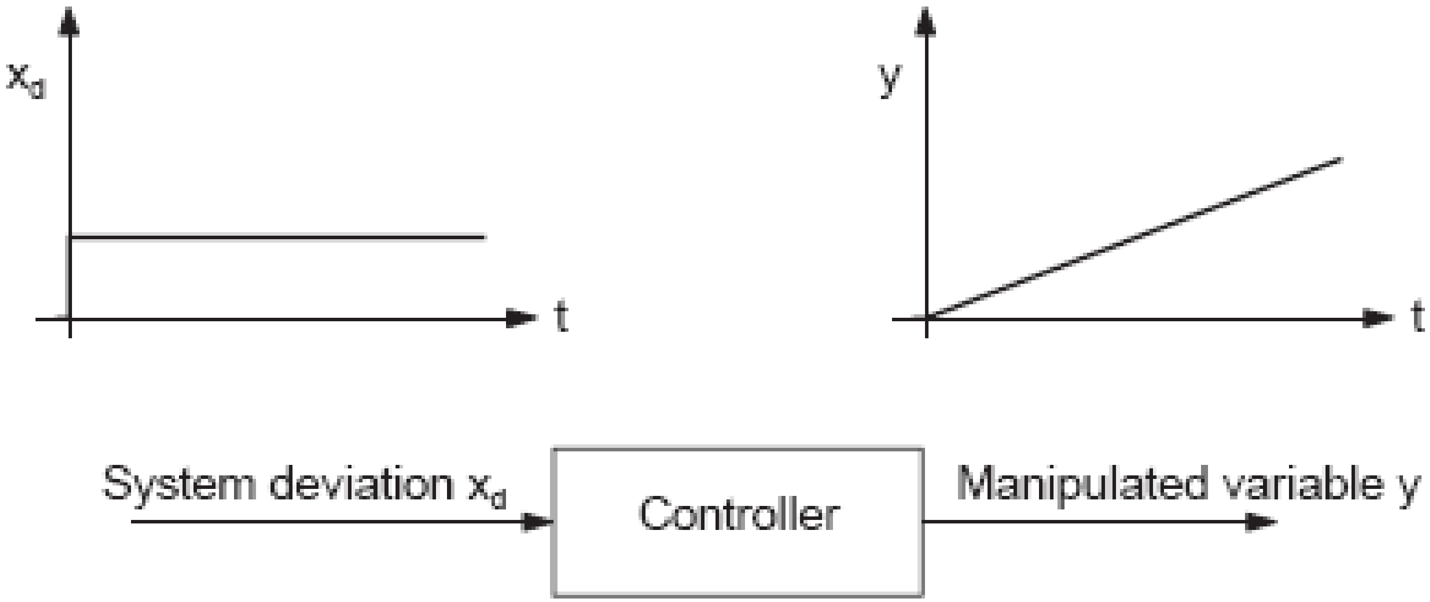
- ✓ Construction is simple
- ✓ These controllers has high loop gain
- ✓ It has steady state tracking accuracy
- ✓ It improves the disturbances signal reduction
- ✓ It stabilizes the gain and makes the system more stable

Disadvantages of Proportional Controller

- ✓ It cannot accommodate load change without sustained deviation.
- ✓ It produces the constant steady state error.
- ✓ For very large gain it leads to instability of the system
- ✓ It has a sluggish i.e. slow response for wide proportional band.
- ✓ It makes the system less sensitive to parameter variation

Integral Control Action

- ✓ The I controller adds the system deviation over time. It integrates the system deviation.
- ✓ As a result, the rate of change (and not the value) of the manipulated variable is proportional to the system deviation.
- ✓ This is demonstrated by the step response of the I controller: if the system deviation suddenly increases, the manipulated variable increases continuously.



Integral Control Action

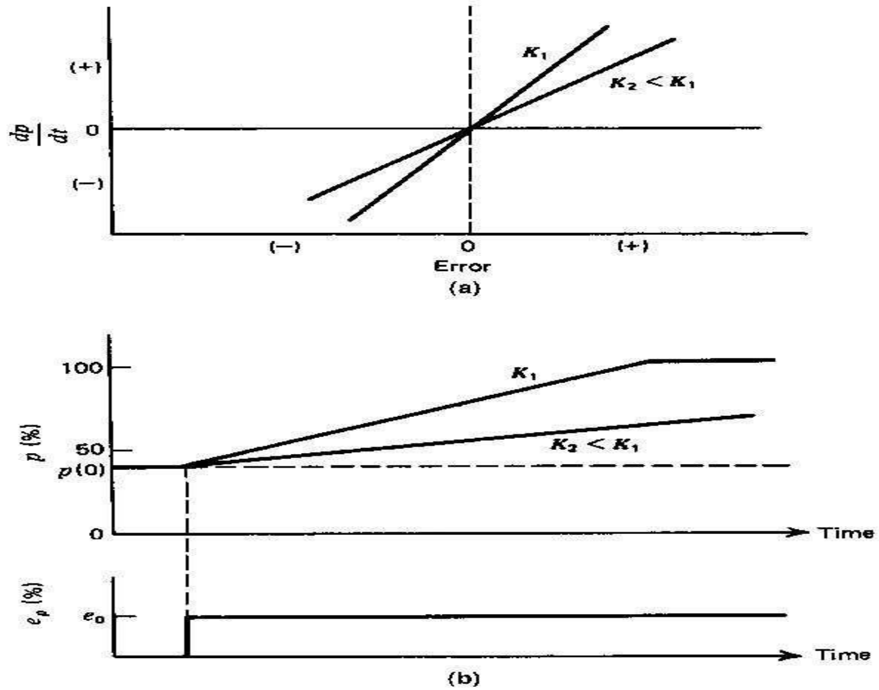
- The greater the system deviation, the steeper the increase in the manipulated variable
- For this reason the I controller is not suitable for totally compensating remaining system deviation.
- If the system deviation is large, the manipulated variable changes quickly.
- As a result, the system deviation becomes smaller and the manipulated variable changes more slowly until equilibrium is reached.
- A pure I controller is unsuitable for most controlled systems, as it either causes oscillation of the closed loop or it responds too slowly to system deviation in systems with a long-time response.
- In practice there are hardly any pure I controllers.
- In a integral control mode, the rate of change of controller output is proportional to the error. So the output can be expressed as:

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

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.



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