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Controller principles

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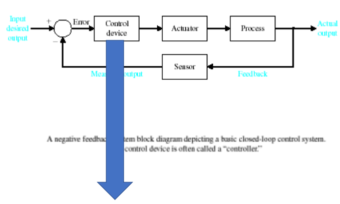
Examples of Control Systems



A negative feedba… …tem block diagram depicting a basic closed-loop control system. …control device is often called a "controller."

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PROCESS CHARACTERISTICS

1.Process Equation

A process-control loop regulates some *dynamic variable* in a process.

This controlled variable, a process parameter, may depend on many other parameters

We have selected one of these other parameters to be our controlling parameter.

If a measurement of the **controlled variable** shows a deviation from the setpoint, then the **controlling parameter** is changed, which in turn changes the controlled variable.

Eg:

$$T_L = F(Q_A, Q_B, Q_S, T_A, T_S, T_0)$$

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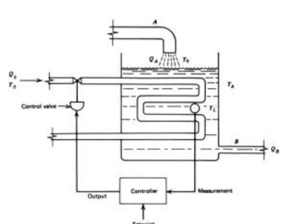

FIGURE 1
Control of temperature by process control.

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- **Process Load**
- From the process equation, or knowledge of and experience with the process, it is possible to identify a set of values for the process parameters that results in the controlled variable having the setpoint value.
- This set of parameters is called the *nominal set*. The term ***process load*** refers to this set of all parameters, **excluding the controlled variable.**

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Process Lag

- At some point in time, a process-load change or transient causes a change in the controlled variable.
- The process-control loop responds to ensure that, some finite time later, the variable returns to the setpoint value. Part of this time is consumed by the process itself and is called the *process lag.*

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Self regulation

- Some processes adopt a specific value of the controlled variable for nominal load with no control operations.
- The control operations may be significantly affected by such ***self regulation.***

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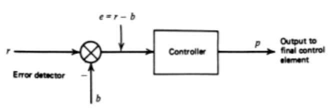
e = r – b



- To describe controller operation in a general way, it is better to express the error as percent of the measured variable range (i.e., the span).

$$e_p = \frac{r - b}{b_{\max} - b_{\min}} \times 100$$

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Measured variable range

- The measured value of a variable can be expressed as percent of span over a range of measurement by the equation

$$c_p = \frac{c - c_{\min}}{c_{\max} - c_{\min}} \times 100$$

c_p = measured value as percent of measurement range
c = actual measured value
$c_{\max}$ = maximum of measured value
$c_{\min}$ = minimum of measured value

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Control Parameter Range

- Often, the output is expressed as a percentage where 0% is the minimum controller output and 100% the maximum.
- The controller output as a percent of full scale when the output varies between specified limits is given by

$$p = \frac{u - u_{\min}}{u_{\max} - u_{\min}} \times 100$$

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Controller Modes

- A controller generates a control signal to the final element, based on a measured deviation of the controlled variable from the set point.
- The choice is a complicated decision.
- Involves process characteristics, cost analysis, product rate, etc.
- P is the *percent of controller output* relative to its total range.

$$p = F(e_p)$$

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Reverse and Direct Action

- *Direct action.*
  - when an increasing value of the controlled variable causes an increasing value of the controller output.
  - Eg: level-control.
- *Reverse action*
  - where an increase in a controlled variable causes a decrease in controller output.
  - Eg:a simple temperature control from a heater.

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- **Two-Position Mode (ON/OFF Mode)**

$$p = \begin{cases} 0\% & e_p < 0 \\ 100\% & e_p > 0 \end{cases}$$

- The measured value is less than the setpoint, full controller output results. When it is more than the setpoint, the controller output is zero.
  - Eg:A space heater

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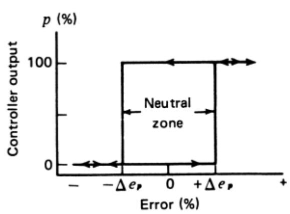

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A liquid-level control system linearly converts a displacement of 2 to 3 m into a 4- to 20-mA control signal. A relay serves as the two-position controller to open or close an inlet valve. The relay closes at 12 mA and opens at 10 mA. Find **(a)** the relation between displacement level and current, and **(b)** the neutral zone or displacement gap in meters.

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Multiposition Mode

- provide several intermediate, rather than only two, settings of the controller output

  reduce the cycling behavior and overshoot and undershoot inherent in the two-position mode

$$p = p_i \qquad e_p > |e_i| \; i = 1, 2, \ldots, n$$

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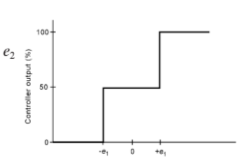
Three position controller

- As the error exceeds certain set limits , the controller output is adjusted to preset values

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



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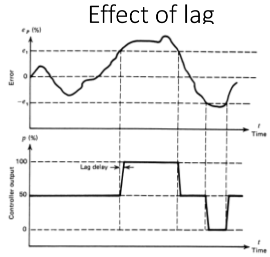
Effect of lag



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Floating-Control Mode

- Previously If the error exceeded some preset limit, the output was changed to a new setting **as quickly as possible**
- If the error is zero, the output does not change but remains (floats) at whatever setting it was when the error went to zero.

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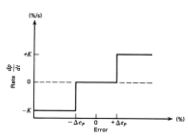

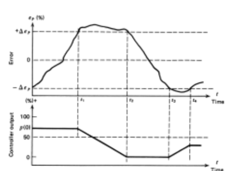

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Single Speed

- In the single-speed floating-control mode, the output of the control element changes at a fixed rate when the error exceeds the neutral zone. An equation for this action is

$$\frac{dp}{dt} = \pm K_F \qquad |e_p| > \Delta e_p$$

$\frac{dp}{dt}$ = rate of change of controller output with time
K_F = rate constant (%/s)
Δe_p = half the neutral zone

$$p = \pm K_F t + p(0) \qquad |e_p| > \Delta e_p$$

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- In the floating multiple-speed control mode, not one but several possible speeds (rates) are changed by controller output.
- If the error exceeds $\frac{dp}{dt} = \pm K_{Fi} \qquad |e_p| > e_{pi}$ or rises to exceed e_{p2}, the speed is increase

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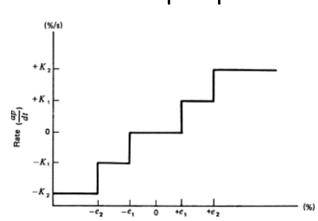
Multiple Speed



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