BENHA UNIVERSITY
FACULTY OF ENGINEERING (SHOUBRA)
ELECTRONICS AND COMMUNICATIONS ENGINEERING

ECE 444
Industrial Electronics

(2022 - 2023) 1st term

Lecture 2: Control System Evaluation and Analog and Digital Processing.

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Outlines:

Lec. 2 Part 1: Control System Evaluation

- Control System Evaluation.
- Best Controlling of the Error.
- Stability.
- Steady-State Regulation.
- Transient Regulation.
- Evaluation Criteria and tuning.

Control System Evaluation:

- A process-control system is used to regulate the value of some process variable.

- When such a system is in use, it is natural to ask, How well is it working?

- The variable used to measure the performance of the control system is the error e(t):

$$e(t) = r - c(t)$$

where
r : the constant setpoint or reference value
c(t) : the controlled variable

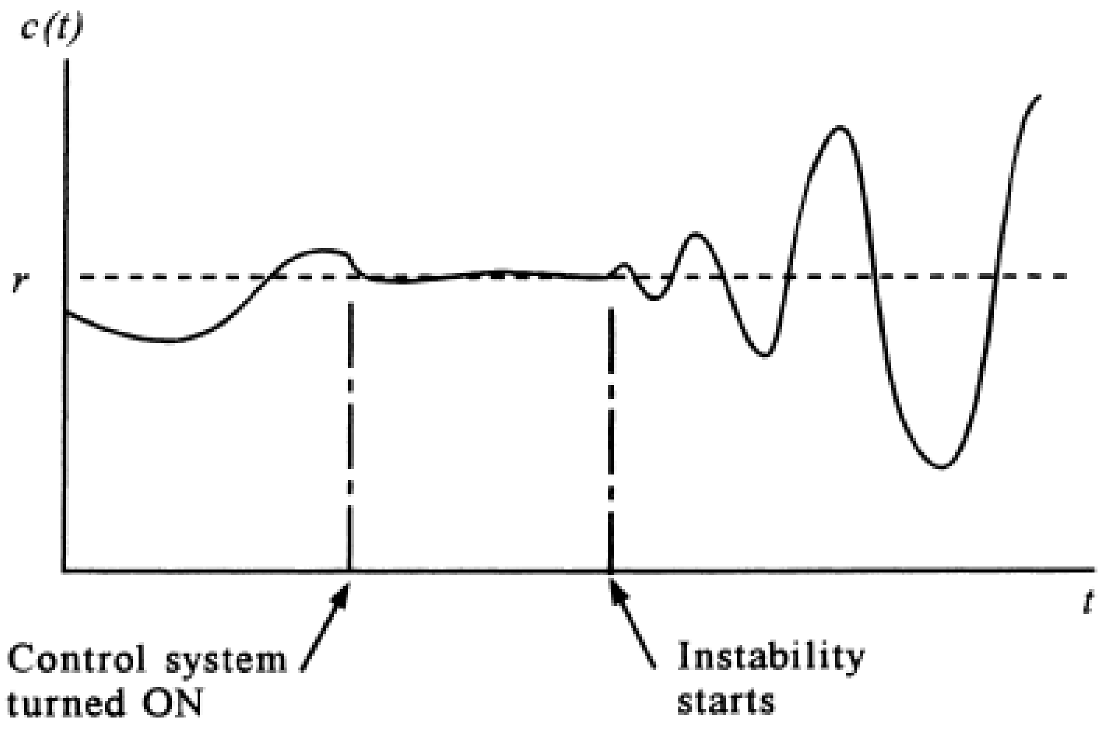
Best Controlling of the Error:

- The objective of a control system is to make the error exactly zero.
- When an error occurs, the control system takes action to drive it to zero.
- This objective can never be perfectly achieved.

- The question of evaluation becomes one of:
    1) how large the error is?
    2) how it varies in time?
- The requirements for higher performance control system:
    1) **Stability**
    2) **Steady state regulation**
    3) **Transient regulation**

Stability:

- The purpose of the control system is to regulate the value of some variable.
- This requires that action be taken on the process itself in response to a measurement of the variable.
- If this is not done correctly, the control system can cause the process to become unstable.



Steady-State Regulation:

- The objective of the best possible steady-state regulation simply means that the steady state error should be a minimum.

- Generally, when a control system is specified, there will be some allowable deviation $\pm\Delta c$ about the setpoint.

- This means that variations of the variable within this band are expected and acceptable.

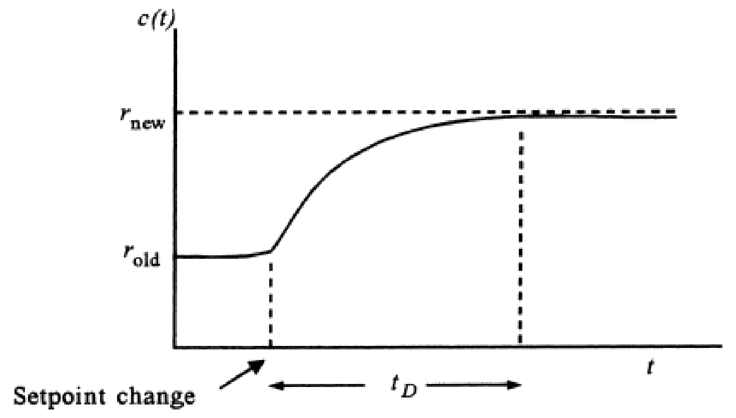
Example

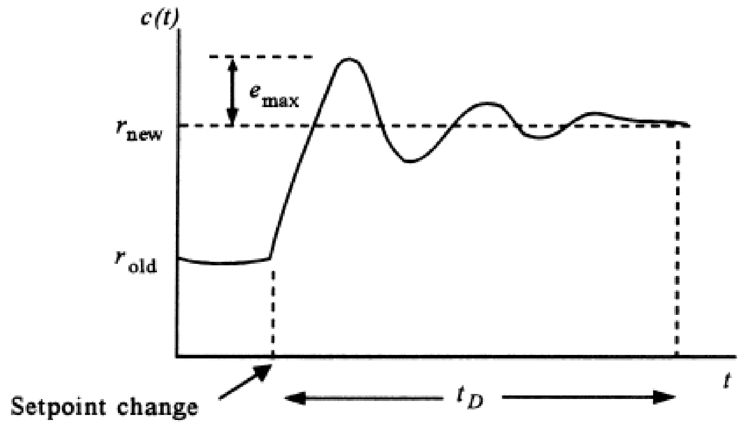
A process-control technologist might be asked to design and implement a control system to regulate temperature at 150 c within ±2 c. This means the setpoint is to be 150 c, but the temperature may be allowed to vary within the range of 148 to 152 c.

Transient Regulation:

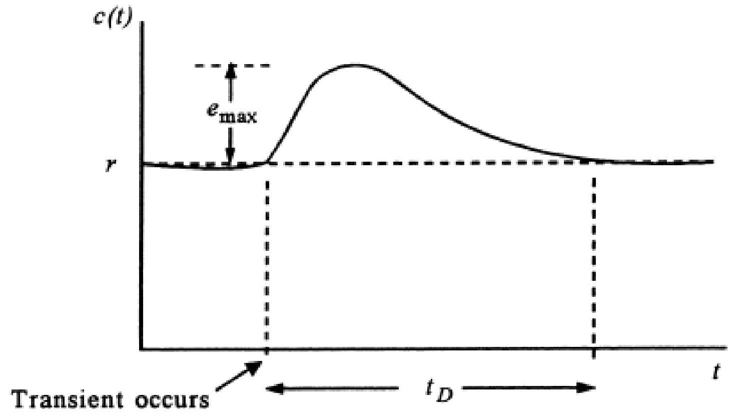
- The controlled variable may be driven to change either by:

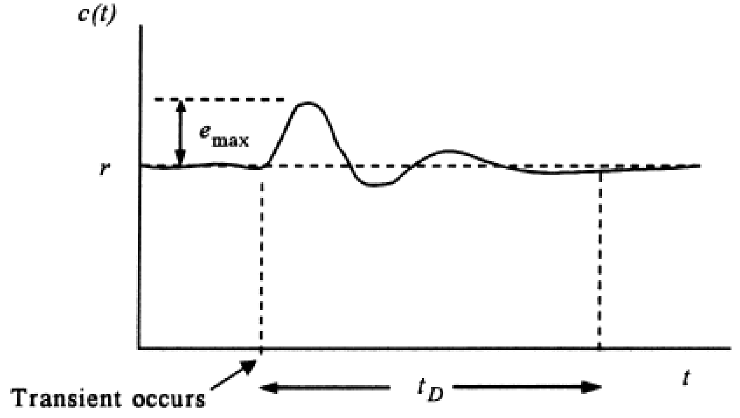
A change of setpoint





A sudden change of some other process variable





Evaluation Criteria:

- The question of how well the control system is working is thus answered by:

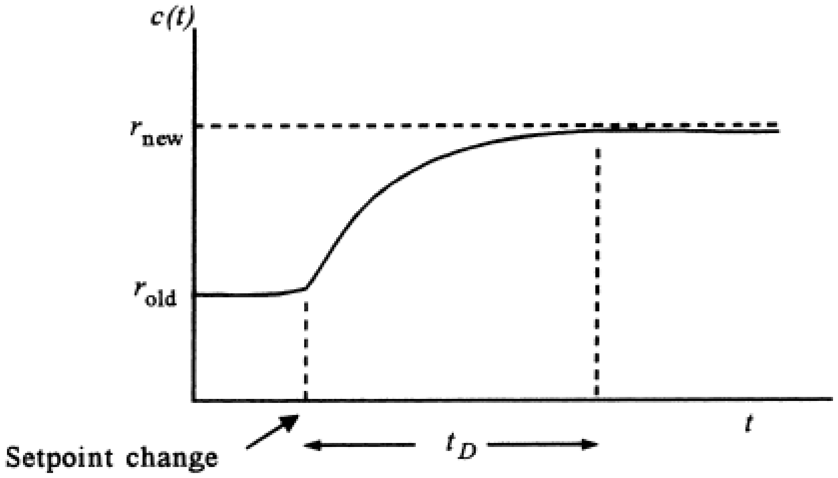
  1) ensuring stability

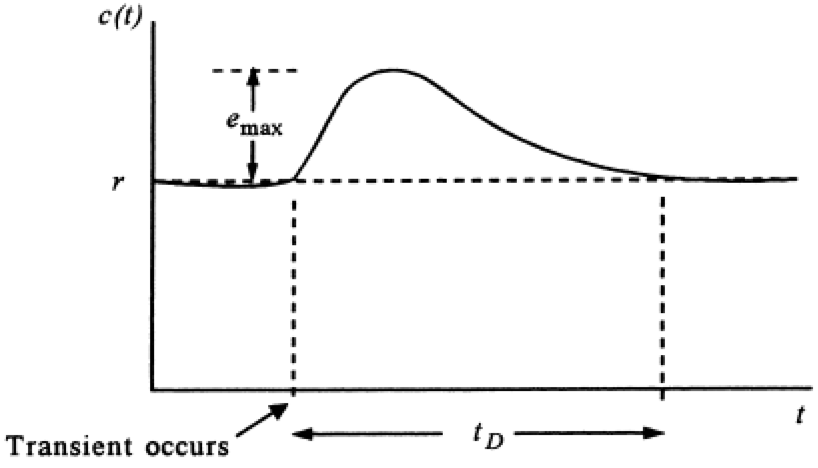
  2) evaluating steady-state response

  3) evaluating the response
     - Damped Response
     - Cyclic Response

Damped Response:

- When the error is of only one polarity.
- The response quality measurement depends on the response shape:
  - In the case of setpoint change, it is calculated by the duration time t_D which is the time taken for the controlled variable to go from 10% of the change to 90% of the change follow following a setpoint change
  - In the case of a transient, it is calculated by the duration time t_D which is the time from the start of the disturbance until the controlled variable is again within 4% of the reference, and the maximum error e_{max} for a given input.



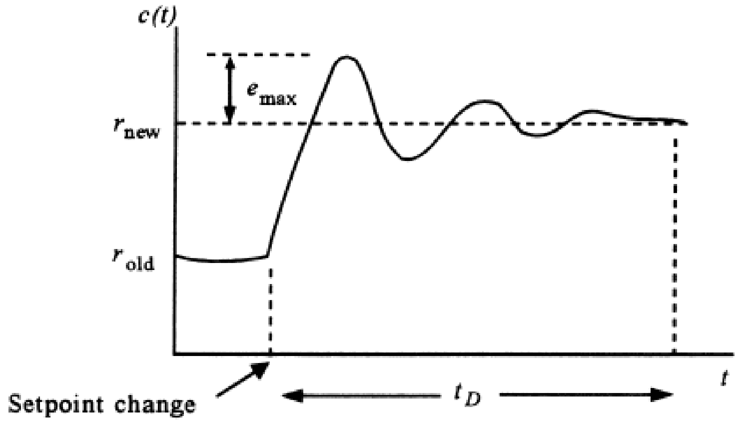


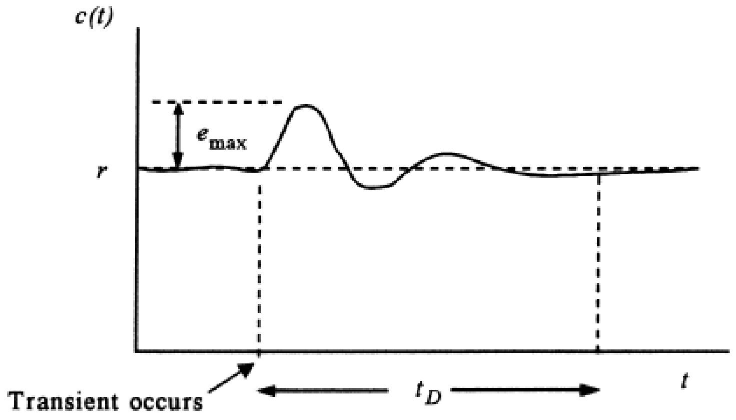
Cyclic Response:

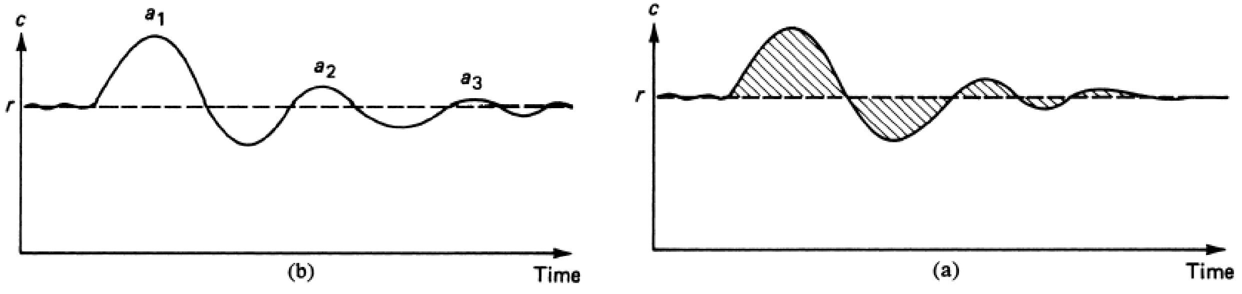
- When the controlled variable oscillates about the setpoint.
- The nature of the response is modified by tuning (adjusting the control loop parameters)
- Two common types tuning used:

  - Minimum area: the tuning is adjusted until the net area under the error-time curve is a minimum.

  - Quarter-amplitude: specifies that the amplitude of each peak of the cyclic response be a quarter of the preceding peak.







Outlines:

Lec. 2 Part 2: Analog and Digital Processing

- Data Representation.
- Analog Data and Digital Data.
- Data Conversions.
- ON/OFF Control.
- Analog Control.
- Digital Control.

Data Representation:

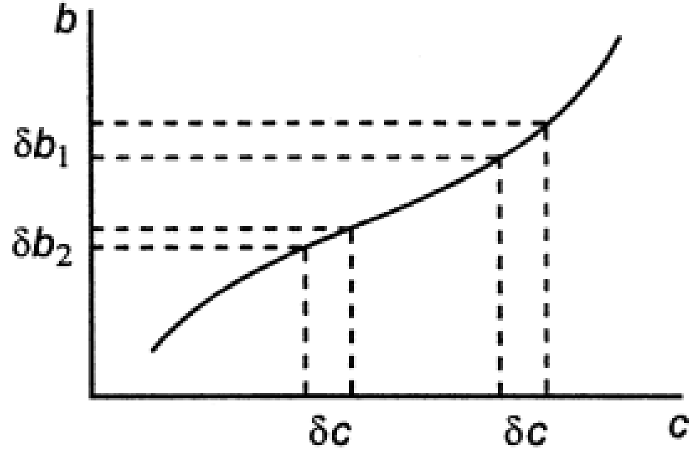
- The representation of data refers to how the magnitude of some physical variable is represented in the control loop.

- For example, if a sensor outputs a voltage whose magnitude varies with temperature, then the voltage represents the temperature.

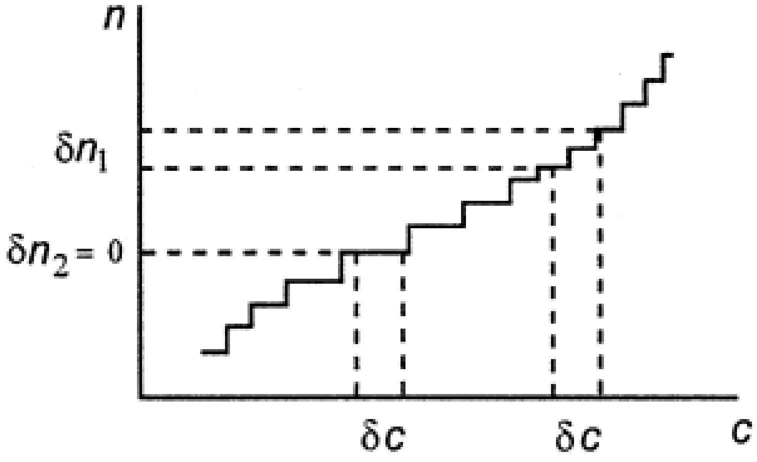
- Analog and digital systems represent data in very different fashions.

Analog Data and Digital Data:

- An analog representation of data means that there is a smooth and continuous variation between a representation of a variable value and the value itself.
- The relationship, in the figure, is called nonlinear because the same δc does not result in the same δb.

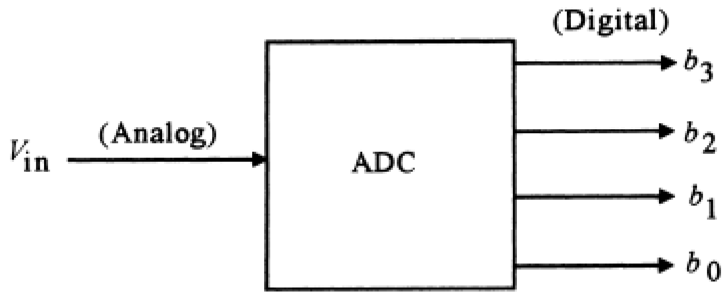


- Digital data means that numbers are represented in terms of binary digits, also called bits (1 and 0).
- When data are represented digitally, some range of analog numbers is encoded by a fixed number of binary digits (resolution). (a loss of information)



Data Conversions:

- Analog-to-Digital Converters (ADCs) are employed to convert analog voltages into a digital representation.



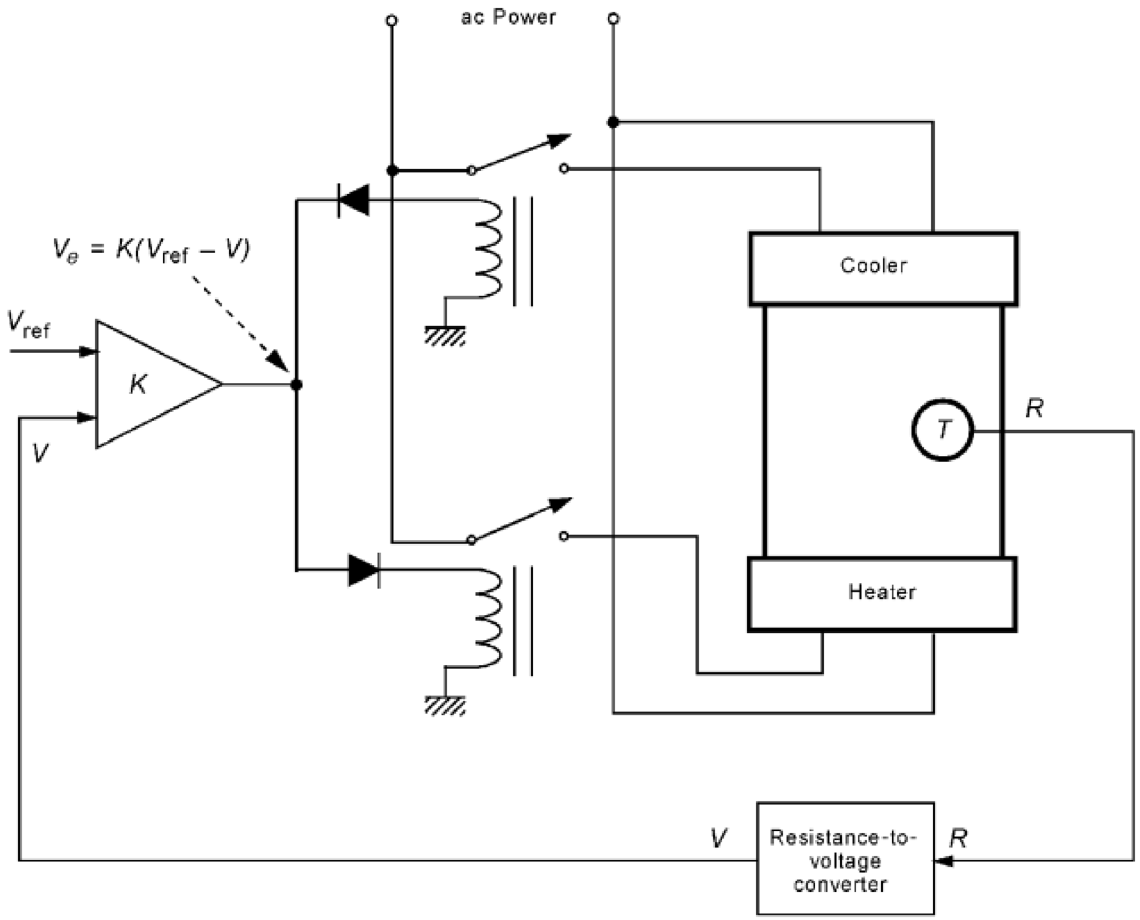
- In a control system, the sensor often produces an analog output such as a voltage. Then an ADC is used to convert that voltage into a digital representation for input to the computer.

- Digital-to-Analog Converters (DACs) convert a digital signal into an analog voltage. These devices are used to convert the control output of the computer into a form suitable for the final control element.

ON/OFF Control:

- It is called ON/OFF control because the final control element has only two states, on and off. Thus, the controller output need have only these two states as well.

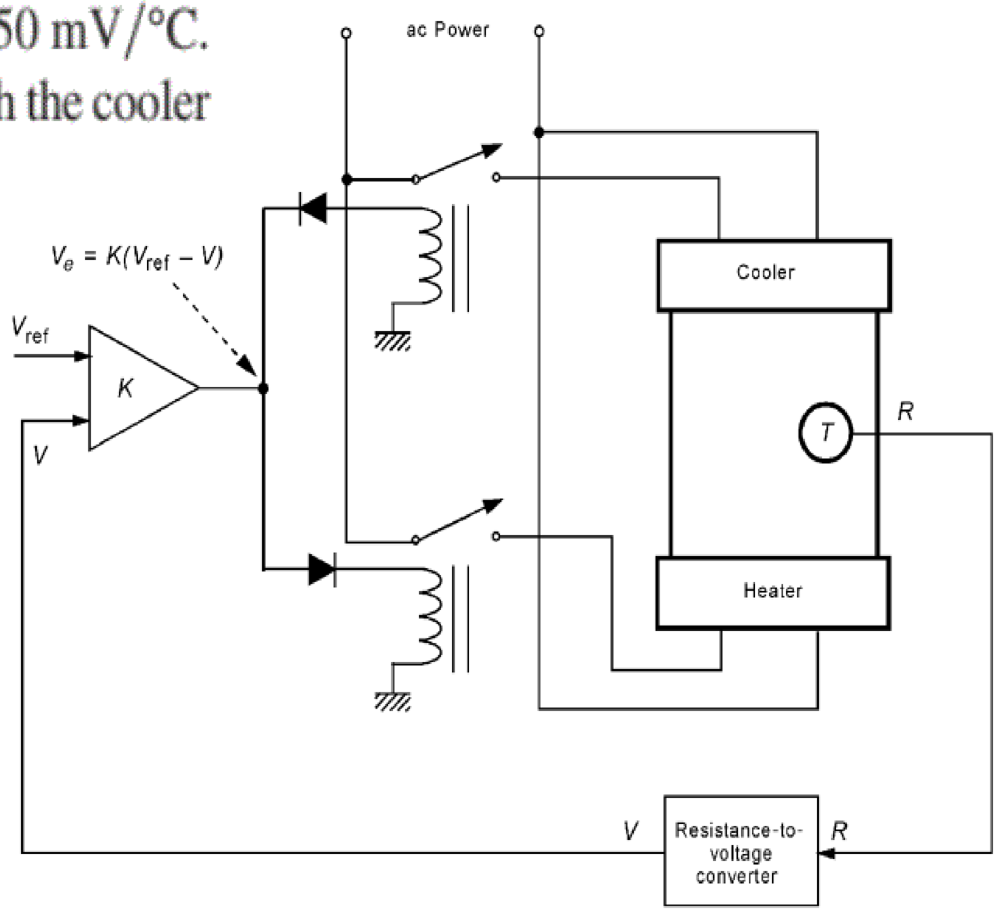
- It can be said that the controller output is a digital representation of a single binary digit, 0 or 1.



ON/OFF Control:

➢ Example

11 For the process-control system in Figure 13, suppose that the relays close at |1.5| V and open at |1.1| V. This means that as the voltage on the relay reaches ±1.5 V, it closes, and does not open again until the voltage drops to 1.1 V (i.e., there is a deadband). The amplifier has a gain of 10, the reference is 3 V, and the sensor outputs 150 mV/°C. Calculate the temperatures at which the heater turns on and off and at which the cooler turns on and off.



➢ Solu

relay close $V_{close} = |1.5|$ V

relay open $V_{open} = |1.1|$ V

amplifier gain = K = 10 , V_{ref} = 3V , sensor o/p = 150 mV/c°

Calculate Temp of heater on, off & Cooler on, off.

$$T_{ref} = \frac{V_{ref}}{\text{Sensor o/p}} = \frac{3V}{150\ mV/c^{\circ}} = 20^{\circ}C$$

$$\therefore V_e = K(V_{ref} - V)$$

ON/OFF Control:

- **Solu**

(I) heater ON:

$$V_e = +1.5 = 10\,(3 - V)$$
$$\Rightarrow V = 2.85\ V$$
$$\therefore T_{heater\ on} = \frac{2.85}{150 \times 10^{-3}} = 19^\circ C$$

(II) heater off:

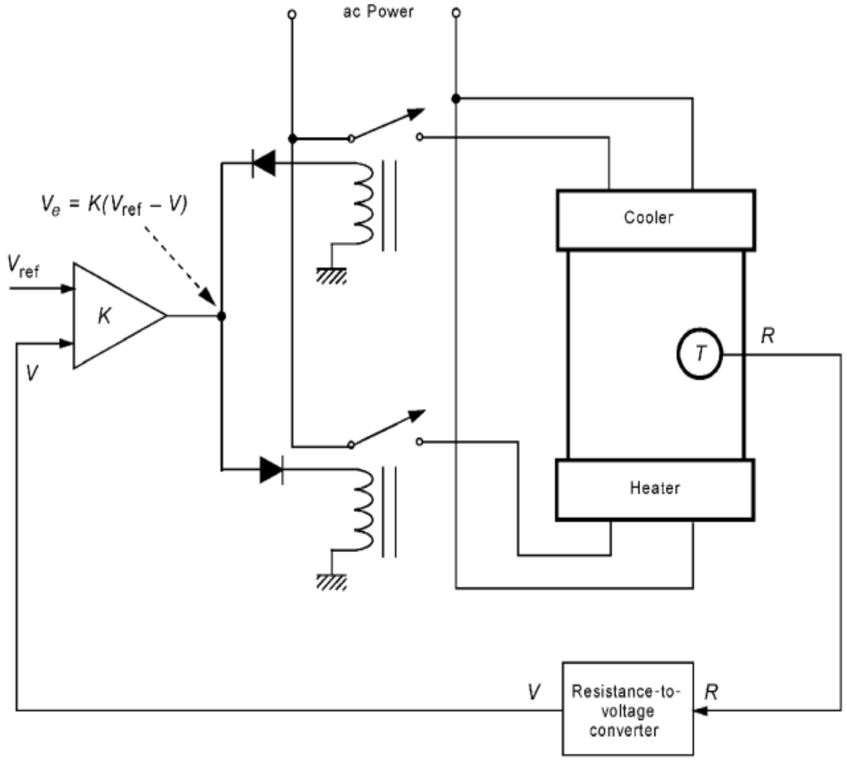
$$V_e = +1.1 = 10\,(3 - V)$$
$$\Rightarrow V = 2.89\ V$$
$$\therefore T_{heater\ off} = \frac{2.89}{150 \times 10^{-3}} = 19.3^\circ C$$

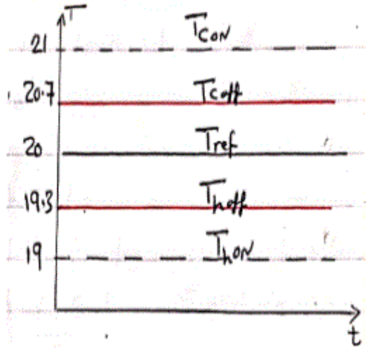
Cooler ON:

$$V_e = -1.5 = 10\,(3 - V)$$
$$V = 3.15\ V$$
$$T_{cooler\ on} = \frac{3.15}{150 \times 10^{-3}} = 21^\circ C$$

Cooler off:

$$V_e = -1.1 = 10\,(3 - V)$$
$$V = 3.11\ V$$
$$T_{cooler\ off} = \frac{3.11}{150 \times 10^{-3}} = 20.7^\circ C$$



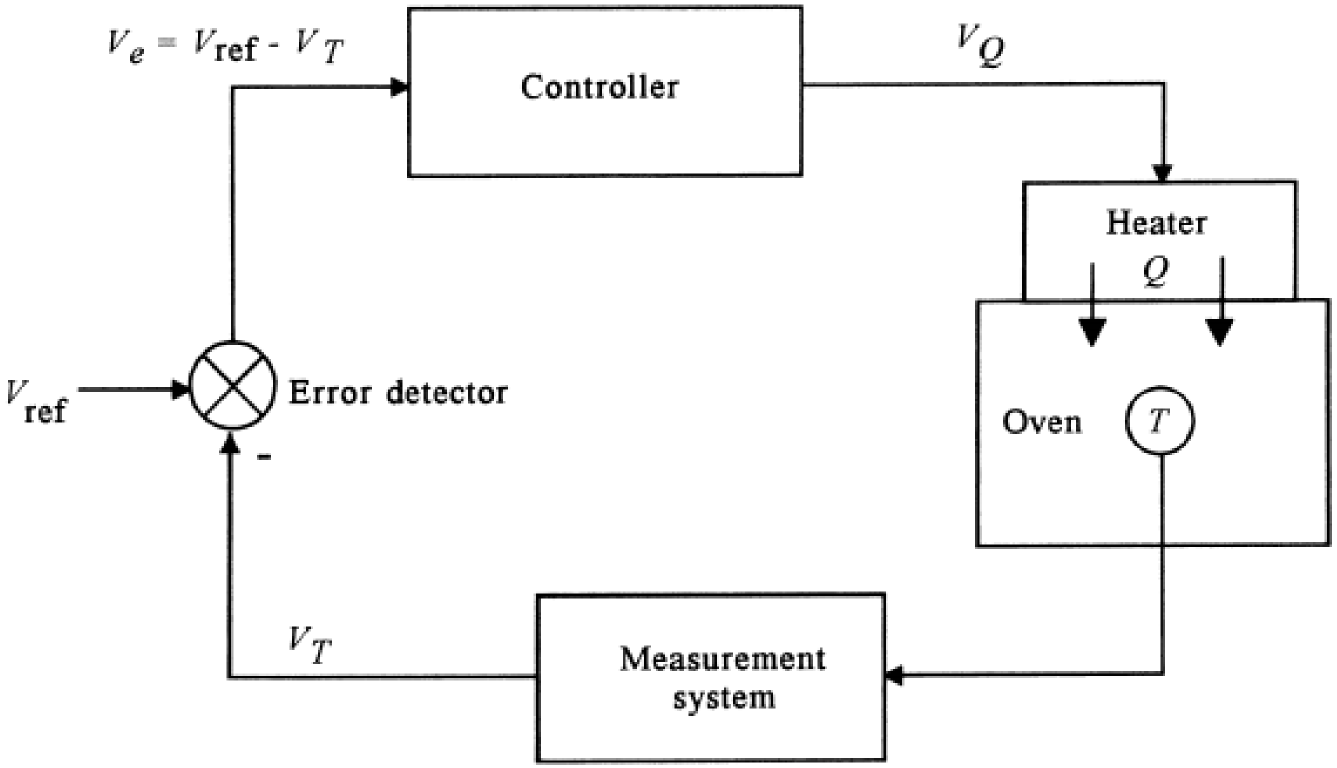


- *Deadband:* is a range, of temperature in this case, wherein no action will occur.

- *Hysteresis:* means that the behavior of the system is different at the same value of temperature, depending on whether the temperature is increasing or decreasing.

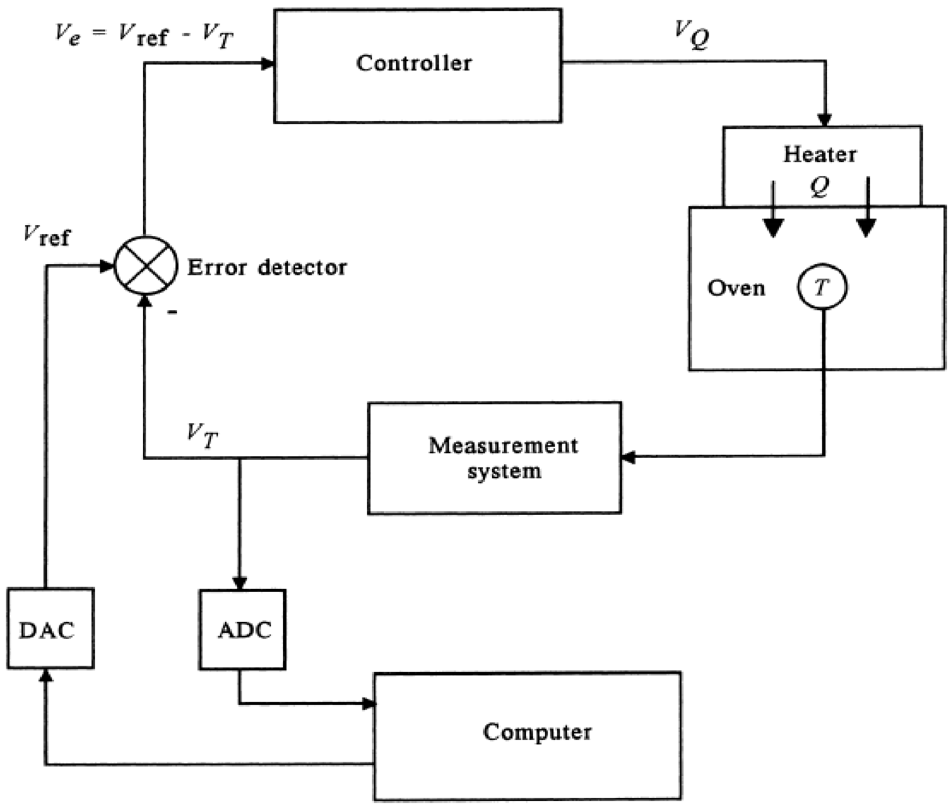
Analog Control:

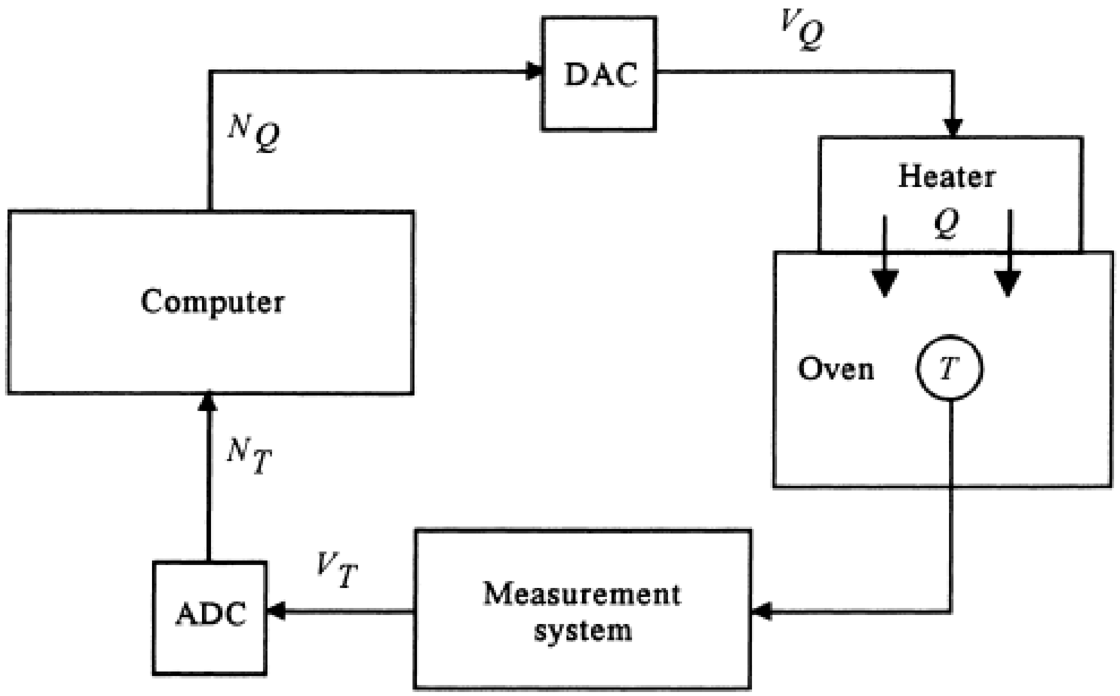
- True analog control exists when all variables in the system are analog representations of another variable.



Digital Control:

- There are two approaches to using computers for control.
  1) Supervisory Control
  2) Direct Digital Control (DDC)





END OF LECTURE

BEST WISHES