CS122A: Intermediate Embedded and Real Time Operating Systems

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Introduction to Control Systems

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- Cruise control and water heaters are common examples
- The **plant** is the device being controlled
- The **controller** takes feedback and controls the plant

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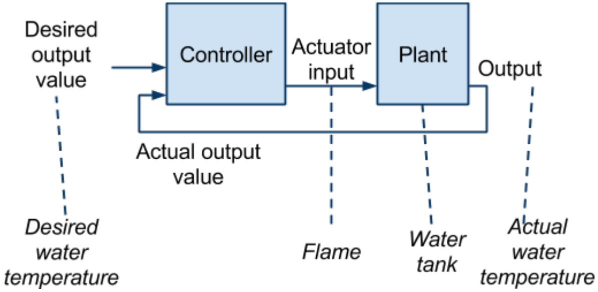

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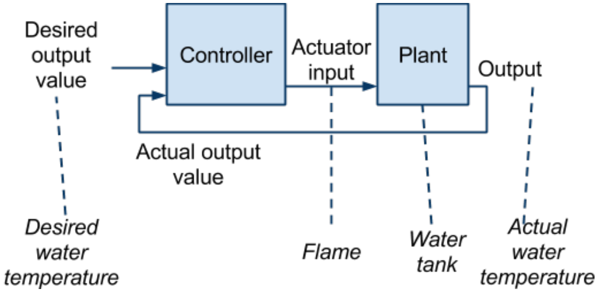

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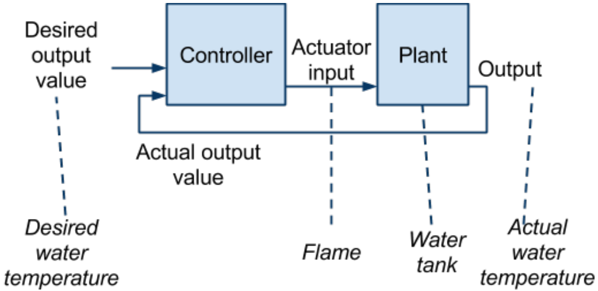

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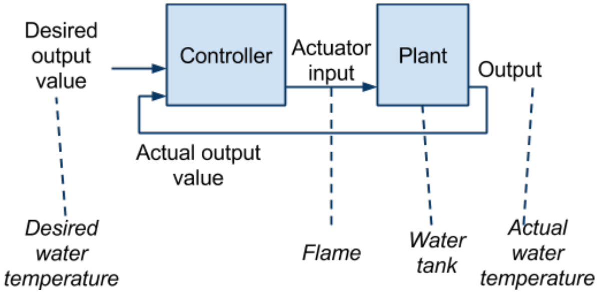

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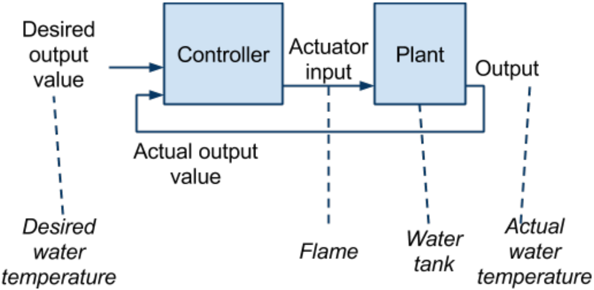

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- This actual value is used as **feedback** to the controller
- The controller uses the actuator input (flame) to alter the output
- The controller also has a desired output value (*desired water temperature*) as input

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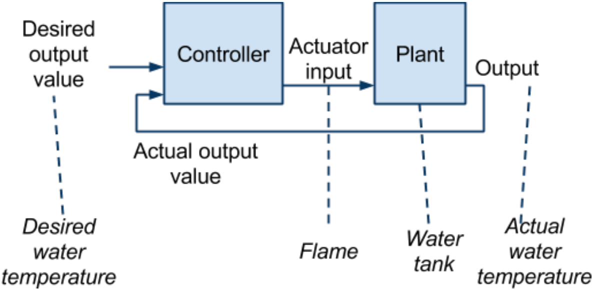

- The **error** is the difference between the desired and actual value (*desired* - *actual*)

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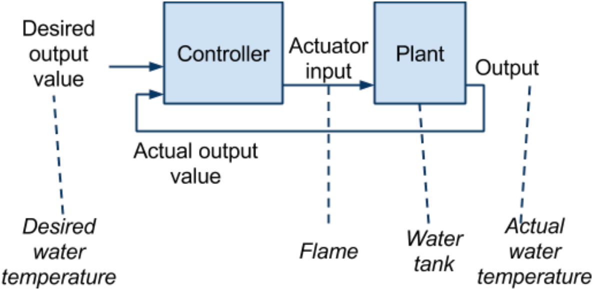

- The **error** is the difference between the desired and actual value (*desired - actual*)
- The job of the controller is to reduce this error to zero by altering the actuator input based on the feedback

Water Heater Example

Water Heater Controller

- Actuator (gas valve): 8 bit value (0-200) (B)
- Desired temperature: 4 bit value (0-100°C/ 10) (A3:0)
- Actual temperature: 4 bit value (0-100°C/ 10) (A7:4)

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#define Actuator B
unsigned char Desired(){
    return (A & 0x0F);
}
unsigned char Actual(){
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}
signed char Error;
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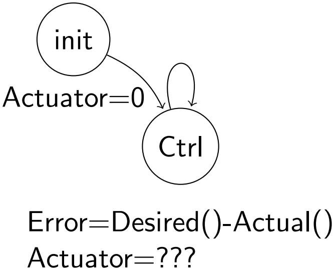

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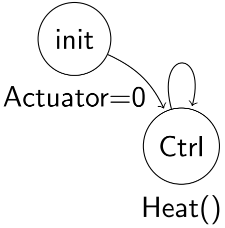

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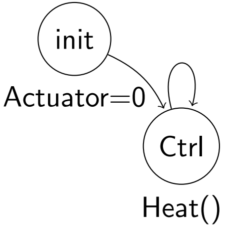
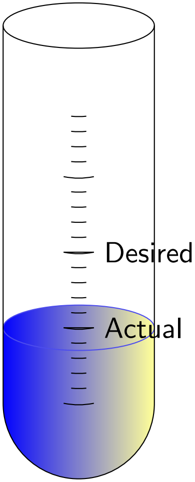



```
unsigned char Heat(){
  if (Desired() < Actual()) {
    Actuator = 200;
  }
}
```

Control Systems

- **On-off control** is the simplest method



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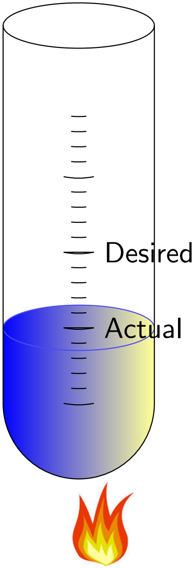

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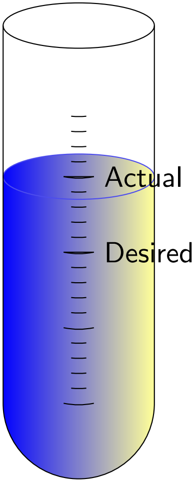

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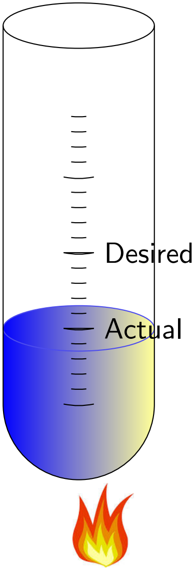

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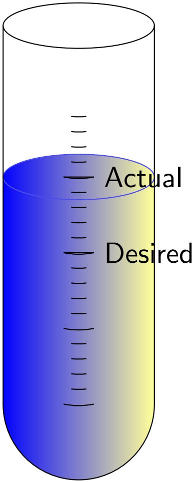
- Actual may **overshoot** desired
- Turning off actuator lowers the actual temperature
- Actual temperature will **oscillate** around desired temperature



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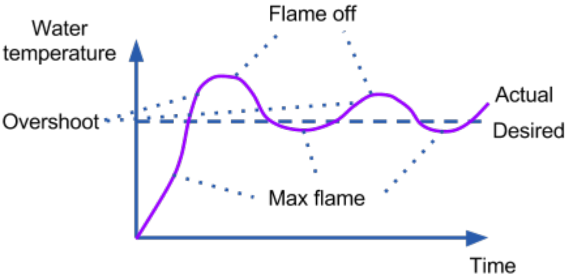
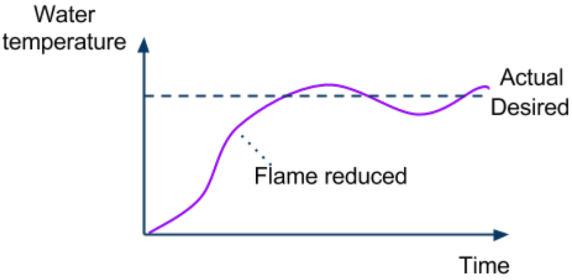
- Oscillation is also not desirable, although it is inevitable
- A system with oscillation amplitude *increasing* over time is said to be **unstable**

Proportional Control



- Overshoot needs to be avoided, rise time needs to be quick, and oscillation needs to be minimized

Proportional Control



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  $Actuator = Kp * Error$

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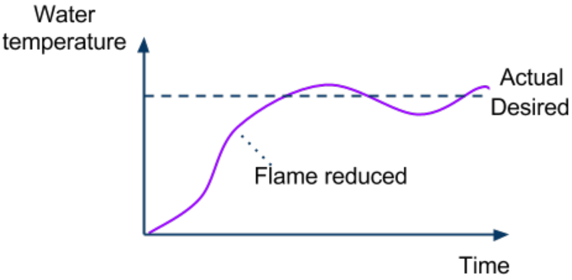

- Overshoot needs to be avoided, rise time needs to be quick, and oscillation needs to be minimized
- In a **proportional controller** the actuator (flame) is set *proportionally* to the error.
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- Actuator is reduced as actual approaches desired value

Proportional-Derivative (PD) Control

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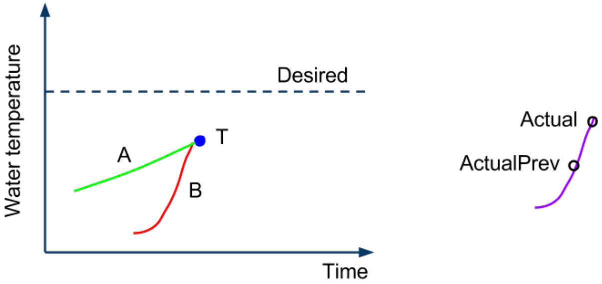
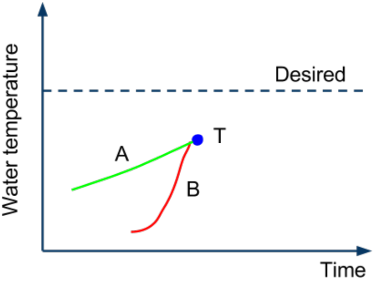
- Proportional control does not take into account the *rate of change* of the output value.
- Problems of overshoot, oscillation, and slow rise time can be overcome even further using a **Proportional-Derivative (PD) controller**

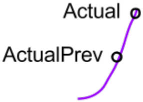
Proportional-Derivative (PD) Control



- The rate of change is used to calculate the actuator value

Proportional-Derivative (PD) Control





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$$Actuator = K_p * Error - K_d * Deriv$$

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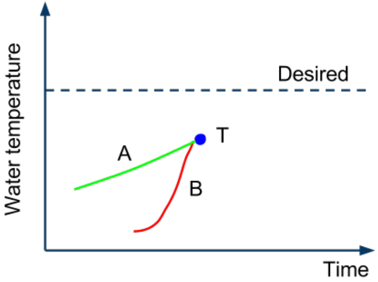

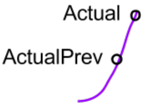

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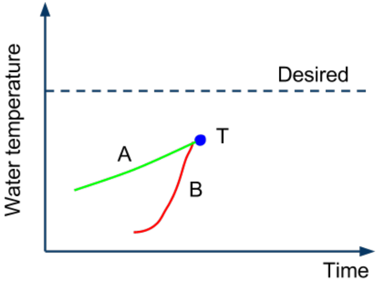

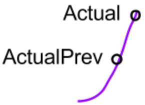

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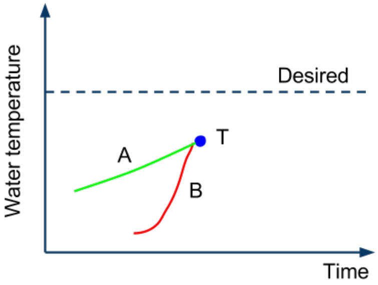

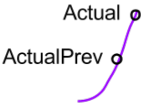

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$$Deriv = Actual - ActualPrev$$

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- These values are typically calculated using floating point numbers, which are computationally intensive, integer approximations can sometimes be acceptable