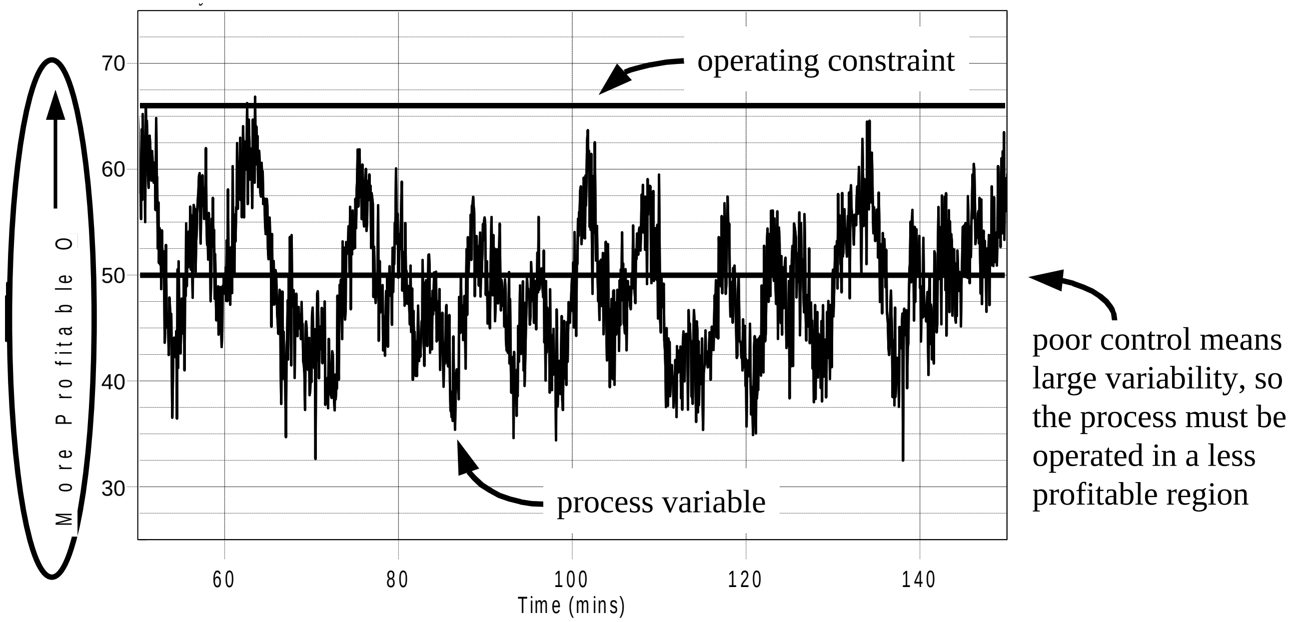
Fundamental Principles of Process Control

Motivation for Process Control

- Safety First:
  - people, environment, equipment

- The Profit Motive:
  - meeting final product specs
  - minimizing waste production
  - minimizing environmental impact
  - minimizing energy use
  - maximizing overall production rate

“Loose” Control Costs Money

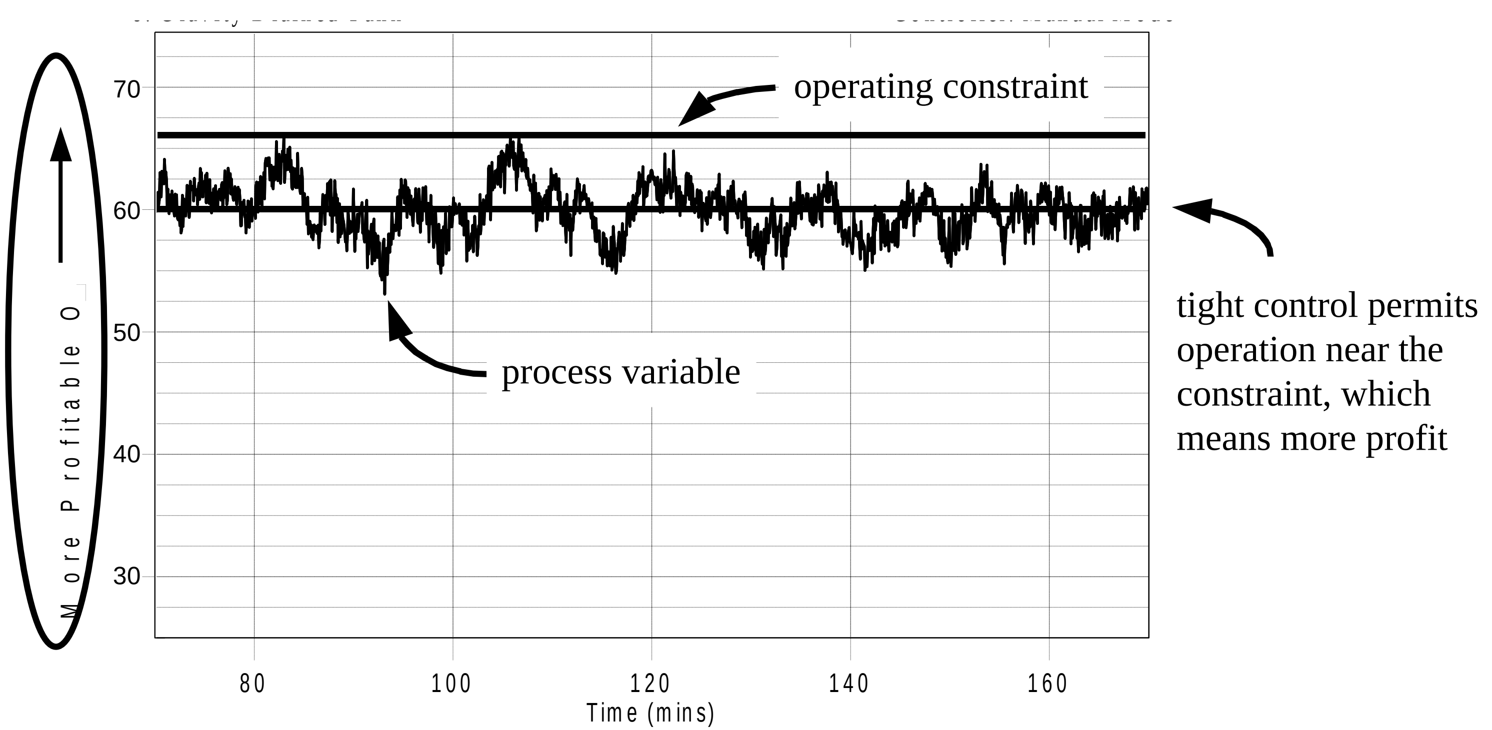


Examples

- It takes more material to make a product thicker, so greatest profit is to operate as close to the minimum thickness constraint as possible without going under

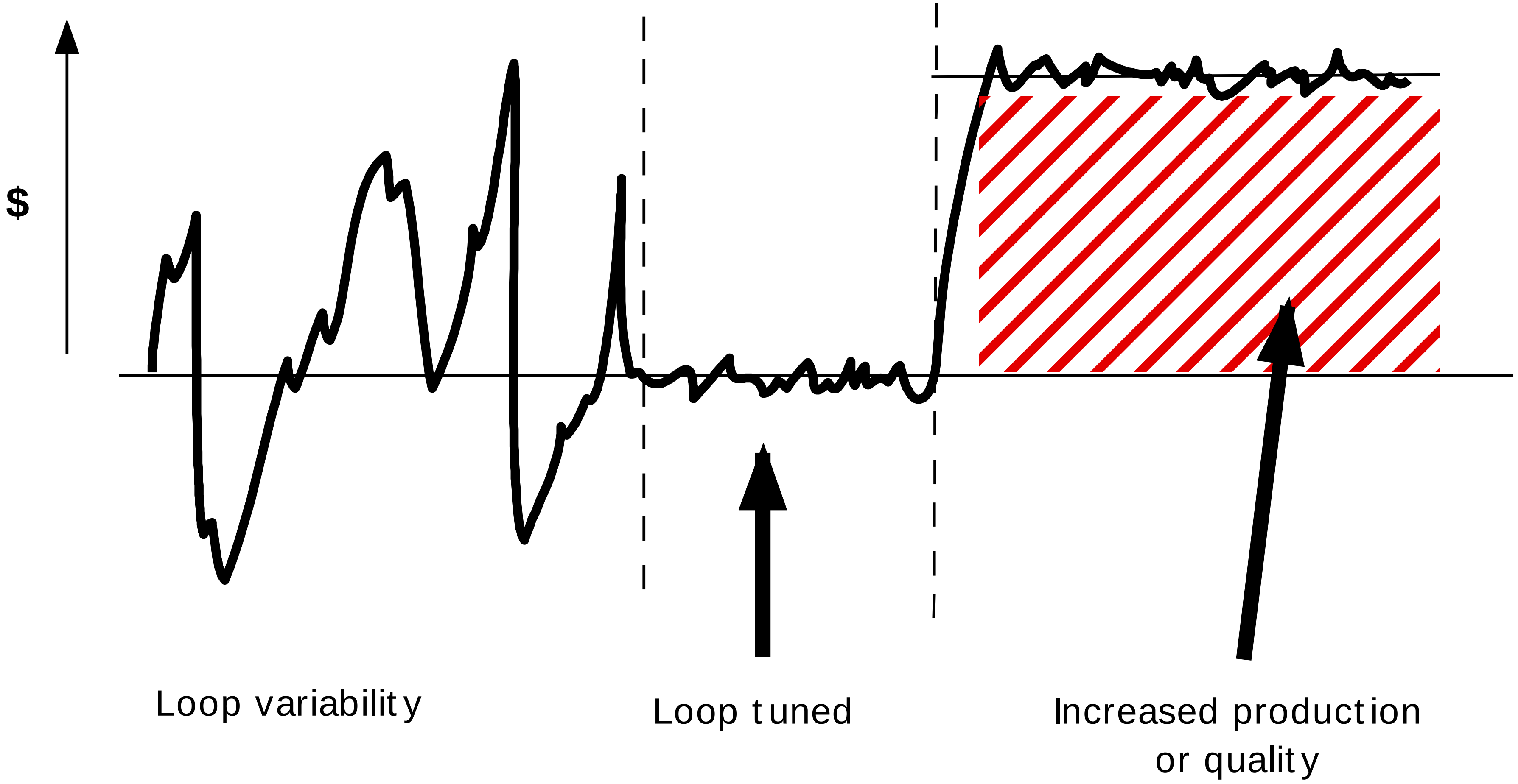
- It takes more processing to remove impurities, so greatest profit is to operate as close to the maximum impurities constraint as you can without going over

Tight Control = Most Profitable Operation

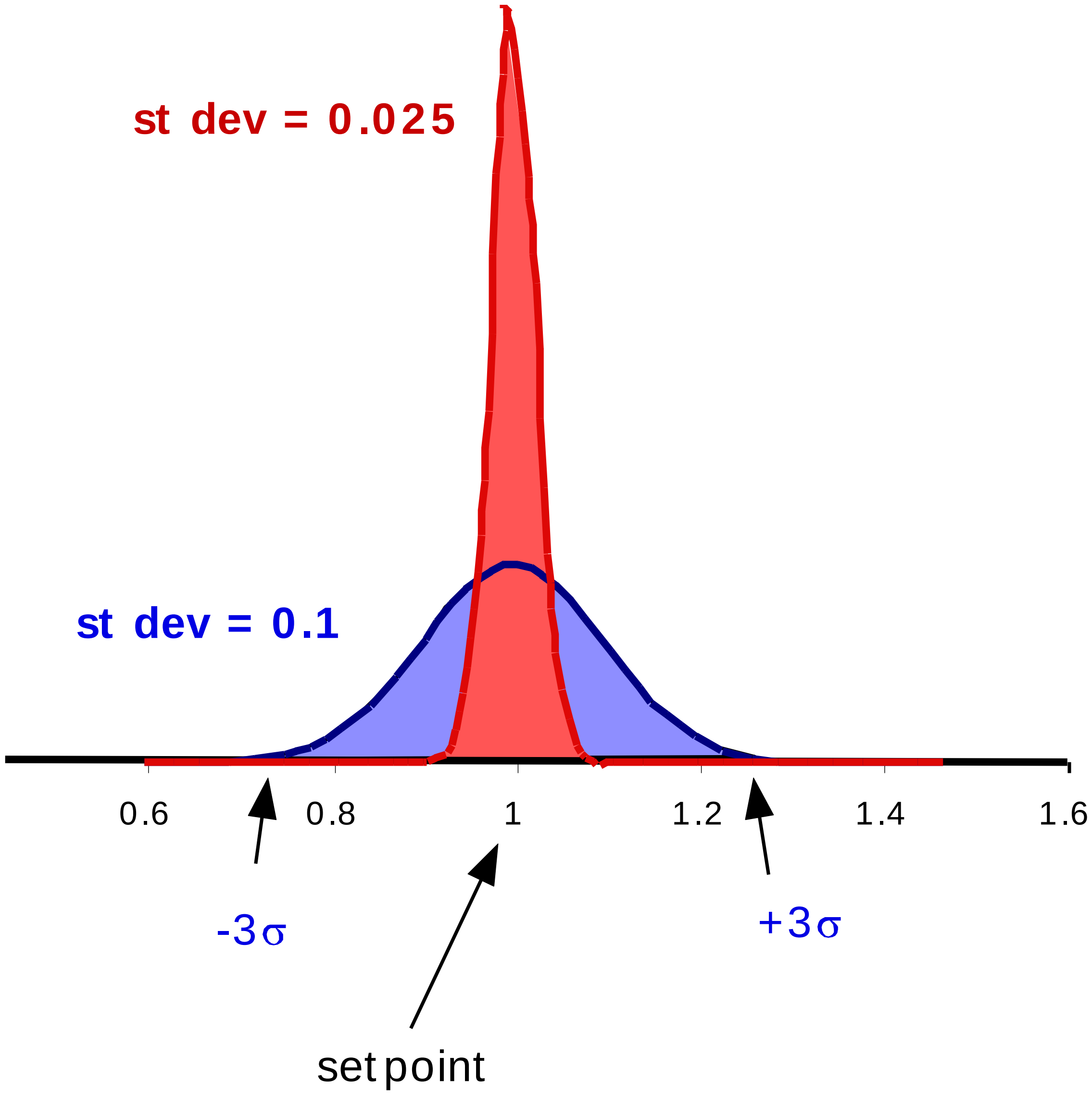


- A well controlled process has less variability in the measured process variable, so the process can be operated close to the profitable constraint

Profitability of the Process Can Be Improved by Reducing Variability in the Control Loop

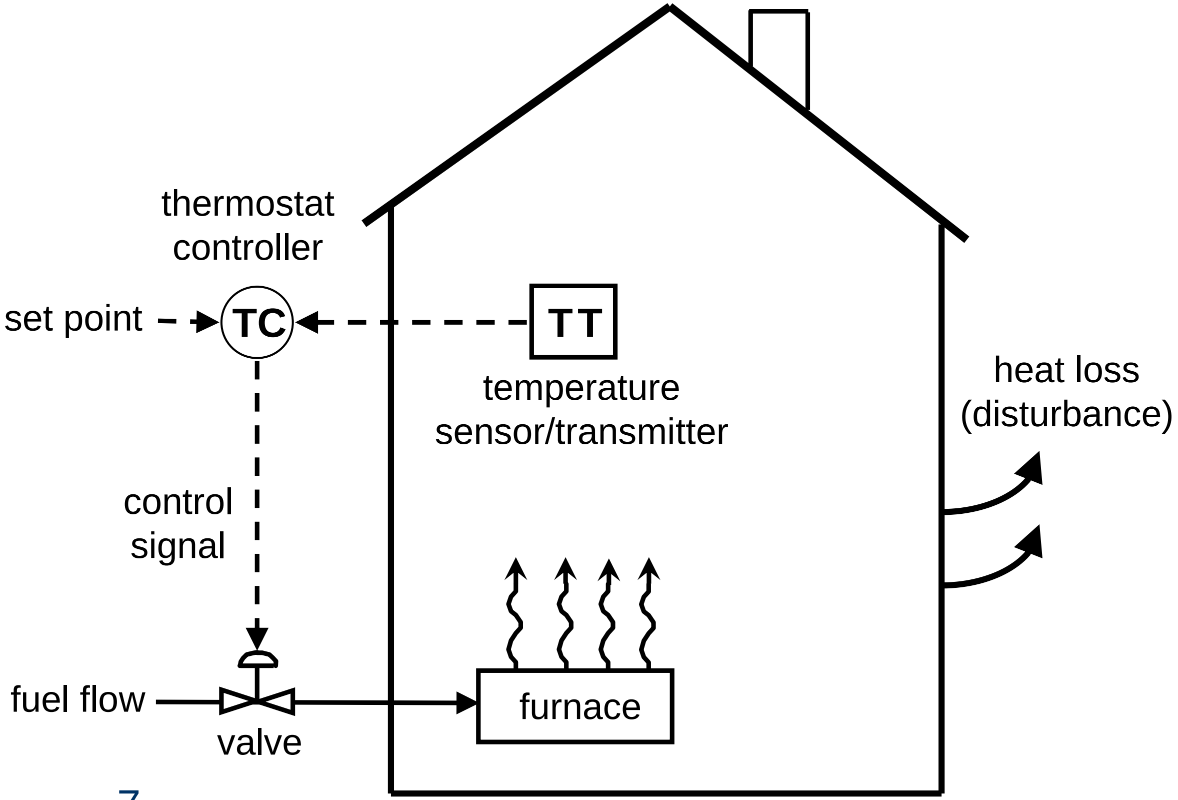


Standard Deviation: Controller Performance Benchmark



Terminology for Home Heating Control

- Control Objective = Set Point (SP)
- System Output (Y)
  - PID: Measured Process Variable (PV)
  - MPC: Controlled Variable (CV)
- System Input (U)
  - PID: Controller Output (CO or OP)
  - MPC: Manipulated Variable (MV)
- Disturbances (D)



Automatic Control is Measurement → Computation → Action

- Is house cooler than set point? $(T_{Setpoint} – T_{house} > 0)$

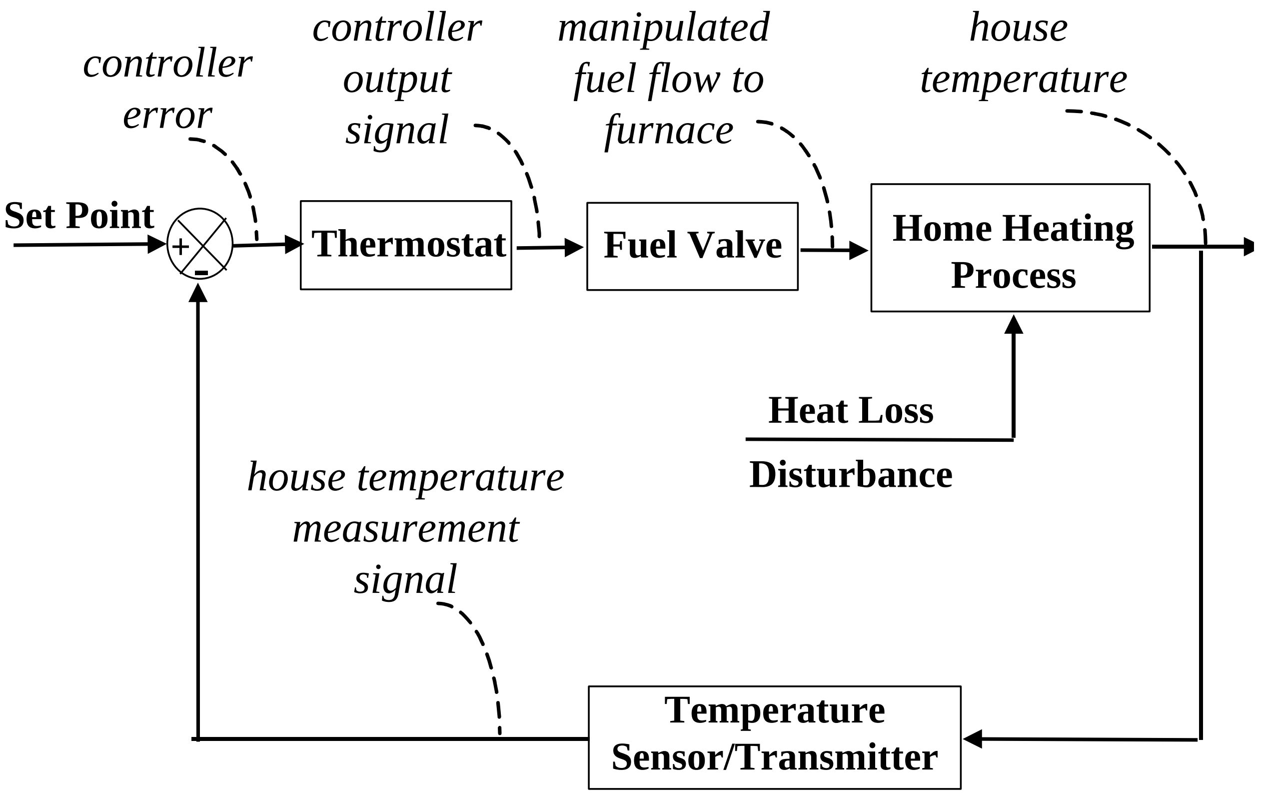
  Action → open fuel valve

- Is house warmer than set point? $(T_{Setpoint} – T_{House} < 0)$

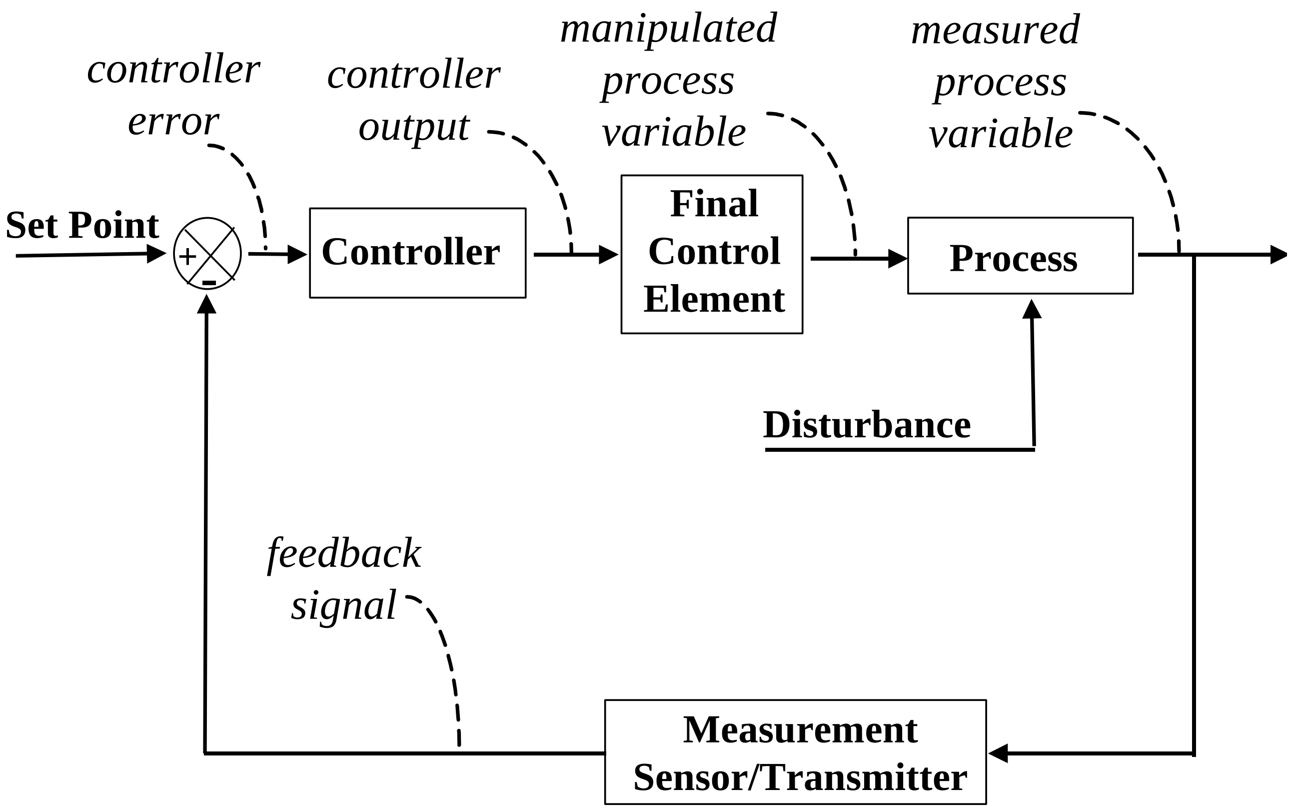
  Action → close fuel valve

Components of a Control Loop

Home heating control block diagram



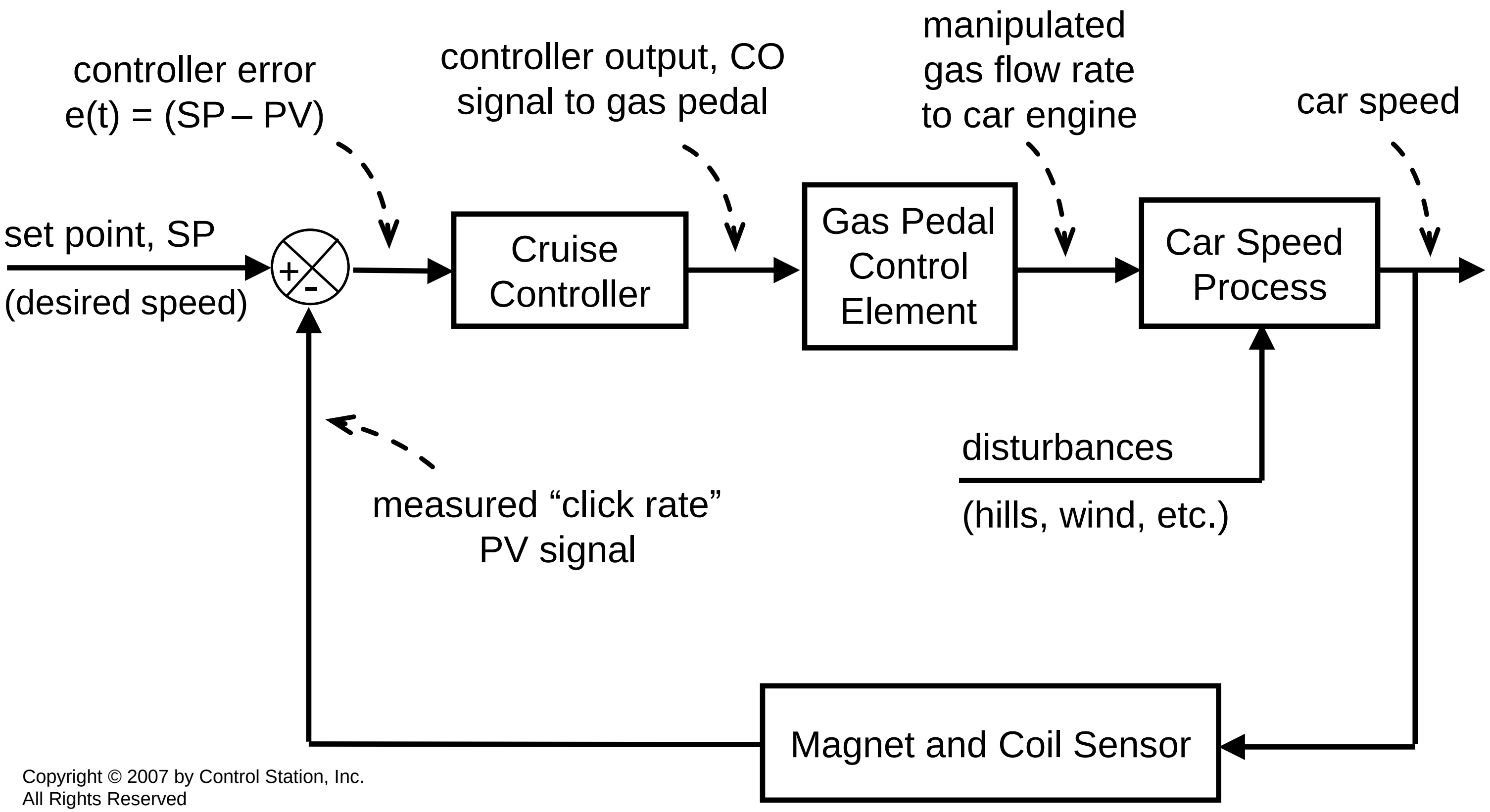
General Control Loop Block Diagram



Thought Experiment: Cruise Control in a Car

- Control Objective:
  - maintain car velocity
- Measured Process Variable (PV):
  - car velocity ("click rate" from transmission rotation)
- Manipulated Variable:
  - pedal angle, flow of gas to engine
- Controller Output (CO):
  - signal to actuator that adjusts gas flow
- Set point (SP):
  - desired car velocity
- Disturbances (D):
  - hills, wind, curves, passing trucks....

Cruise Control Block Diagram



The PID Controller

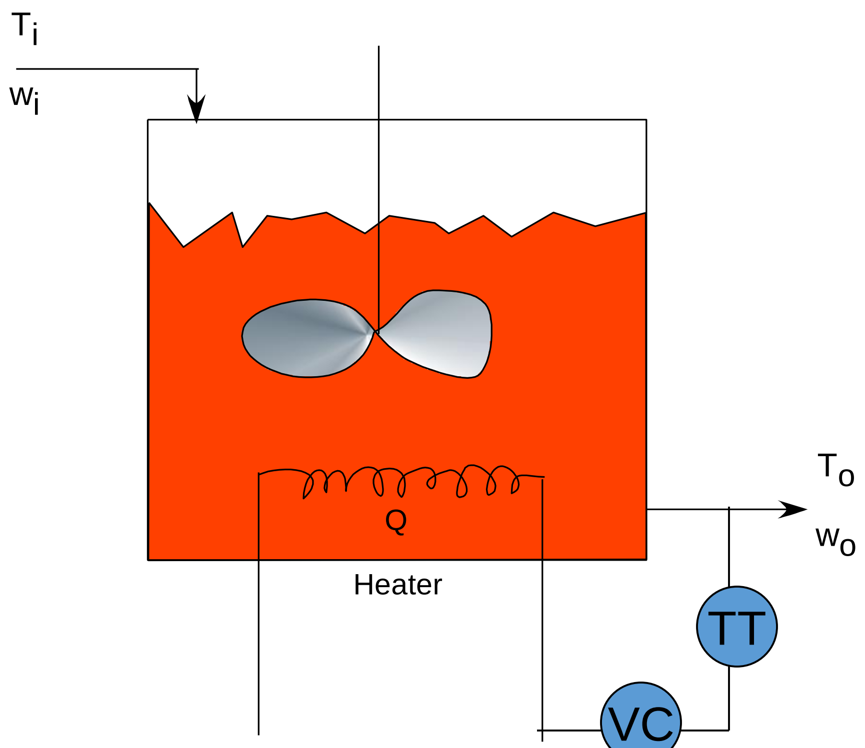
$$OP = OP_{bias} + K_c e(t) + \frac{K_c}{\tau_I}\int e(t)dt - K_c \tau_D \frac{\partial PV}{\partial t}$$

where:

- OP = controller output signal (also seen as CO in PPC)
- OP_{bias} = controller bias or null value
- PV = measured process variable
- SP = set point
- e(t) = controller error = SP – PV
- Kc = controller gain (a tuning parameter)
- τ_I = controller reset time (a tuning parameter)
- τ_D = controller derivative action (a tuning parameter)

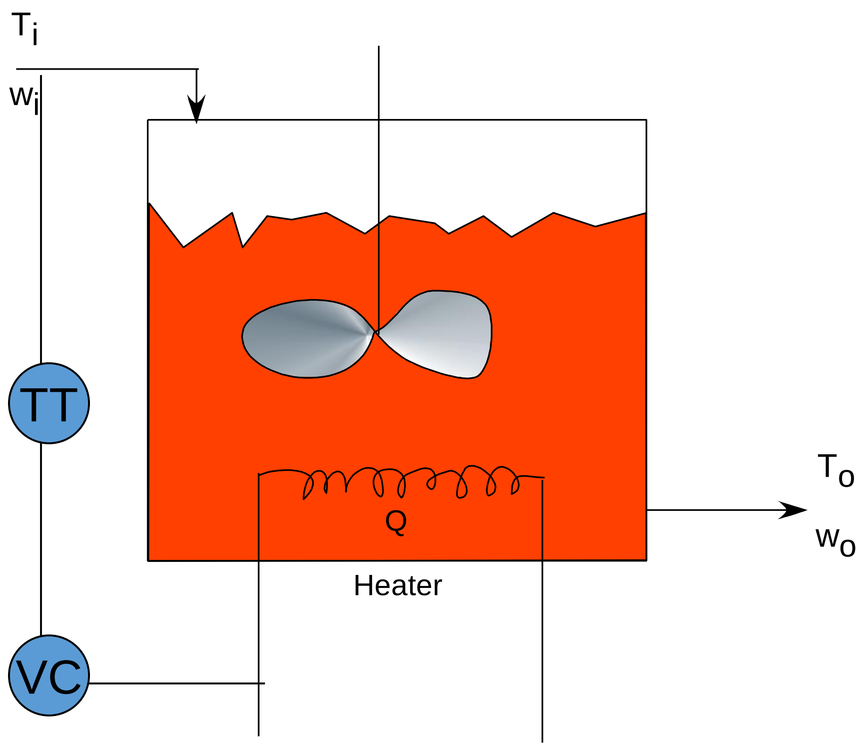
- τ_I is in denominator so smaller values provide a larger weighting to the integral term
- τ_I and τ_D have units of time and are always positive

Example: Heated Tank



- Controlled variable:
  - T_o
- Feedback
  - Measure T_0
  - Control voltage to heater

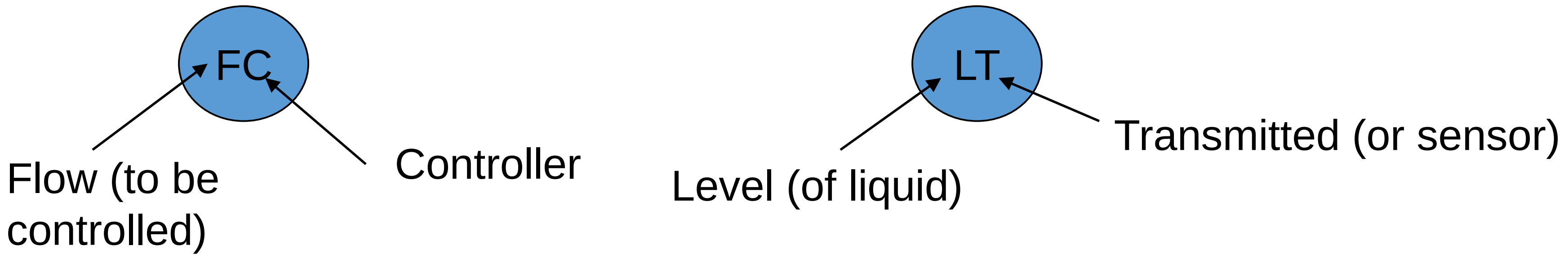
Example: Heated Tank



- Controlled variable:
  - T_o
- Feedback
  - Measure T_0
  - Control voltage to heater
- Feedforward
  - Measure T_i
  - Control voltage to heater

Other Definitions

- Final Control Element
  - Usually a valve or pump
  - Electricity (to heat or cool)
  - Solenoid valve (open or shut)
- SISO
  - Single input, single output
- Nomenclature



In-Class Activity