Module # 1.4

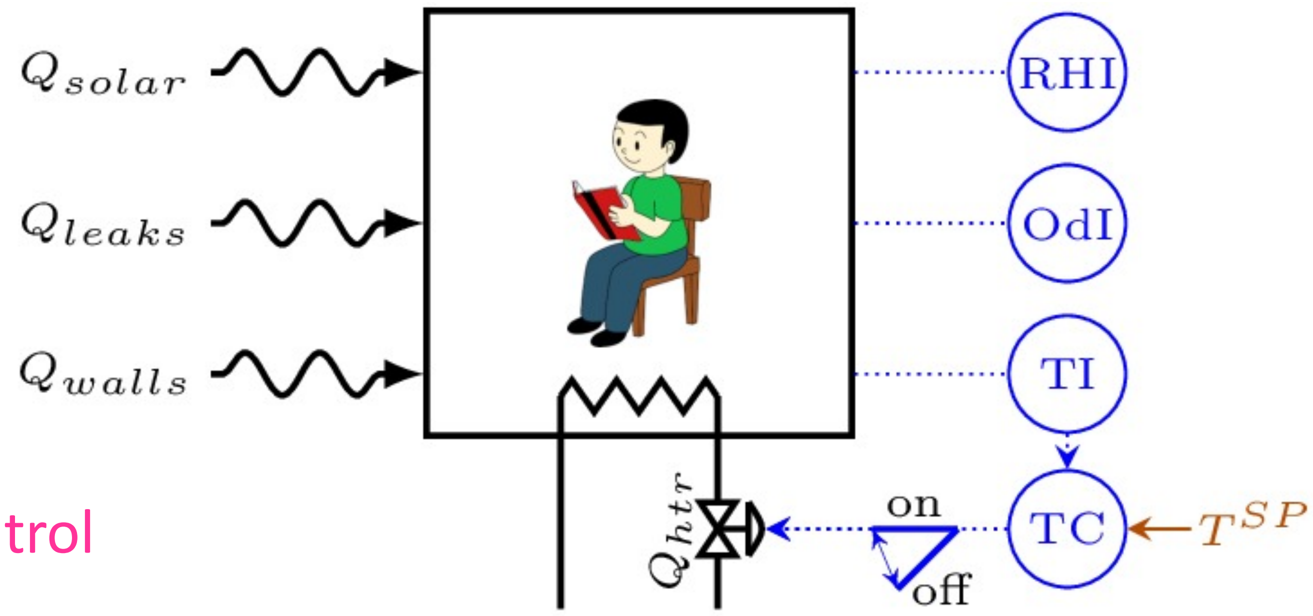
INTRODUCTION
SISO Control Algorithms

Lectures on

CHEMICAL PROCESS CONTROL
Theory and Practice

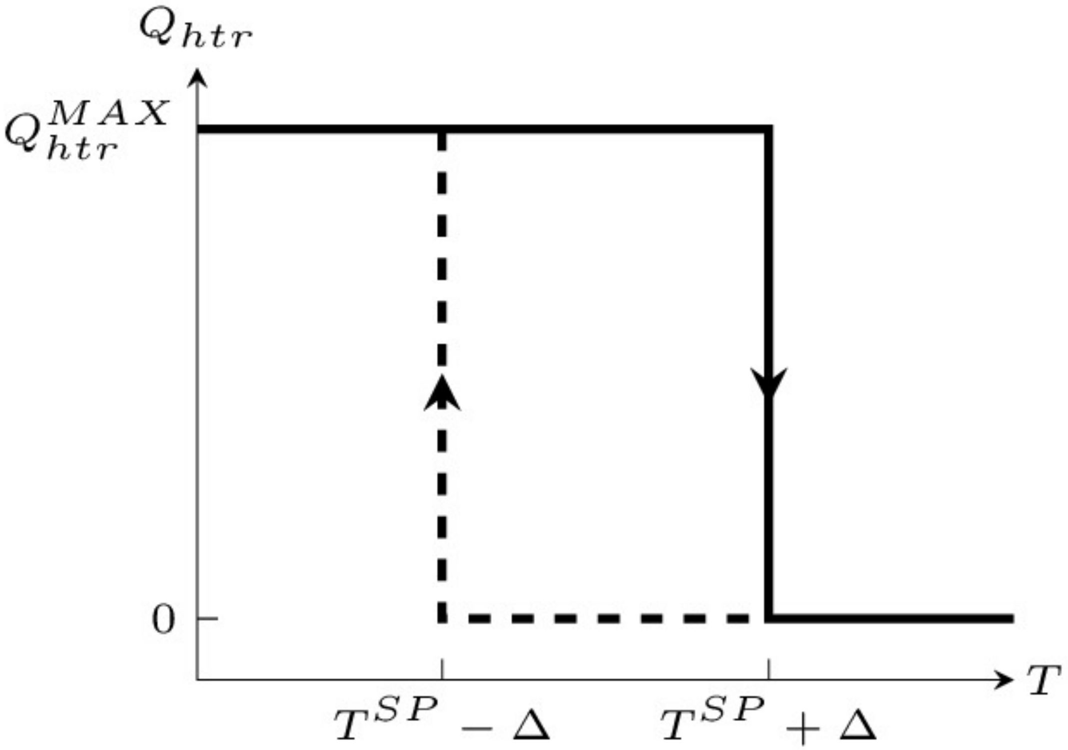
SISO Feedback Control Algorithms

- Feedback Control Algorithm
  - Quantitative relationship between MV and CV
  - $u_t = f(y_t)$
- Simple Control Algorithms
  - On Off Control
  - Proportional Control
  - Integral Control
  - Proportional Integral Control
  - Proportional Integral Derivative Control



On-Off Control

$$Q_{htr(t)} = \begin{cases} Q_{htr}^{MAX} & \text{if } T \leqslant T^{SP} - \Delta \\ Q_{htr(t^-)} & \text{if } T^{SP} - \Delta < T < T^{SP} + \Delta \\ 0 & \text{if } T \geqslant T^{SP} + \Delta \end{cases}$$



Proportional Control

$$Q_{htr\,(t)} = K_C\left(T^{SP} - T_{(t)}\right) + b$$

$$\frac{dQ_{htr}}{dt} = -K_C\frac{dT}{dt}$$

$$\left.\frac{dQ_{htr}}{dt}\right|_{t=\infty} = -K_C\left.\frac{dT}{dt}\right|_{t=\infty} = 0$$

$$\cancel{T_{(\infty)} = T^{SP}}$$

Expect Offset

How to Remove Offset?

At FSS

$$dQ_{htr}/dt|_{t=\infty} = 0$$

Want

$$T^{SP} - T_{(\infty)} = 0$$

$$\Rightarrow$$

$$\frac{dQ_{htr}}{dt} = \frac{K_C}{\tau_I}\left(T^{SP} - T_{(t)}\right)$$

$$Q_{htr\,(t)} = \frac{K_C}{\tau_I}\int_0^t \left(T^{SP} - T_{(t)}\right) dt + b$$

Integral Controller

Integral control gives ZERO OFFSET for constant setpoint

Proportional Integral Control

- Combine both proportional and integral modes

$$Q_{htr\,(t)} = K_C\left[\left(T^{SP} - T_{(t)}\right) + \frac{1}{\tau_I}\int_0^t \left(T^{SP} - T_{(t)}\right)dt\right] + b$$

Zero offset due to integral mode

The Derivative Mode

- To act when error is small but PV rate of change is large

$$Q_{htr(t)} = K_C\left(T^{SP} - T_{(t)}\right) + \frac{K_C}{\tau_I}\int_0^t \left(T^{SP} - T_{(t)}\right)dt \boxed{- K_C\tau_D\frac{dT_{(t)}}{dt}} + b$$

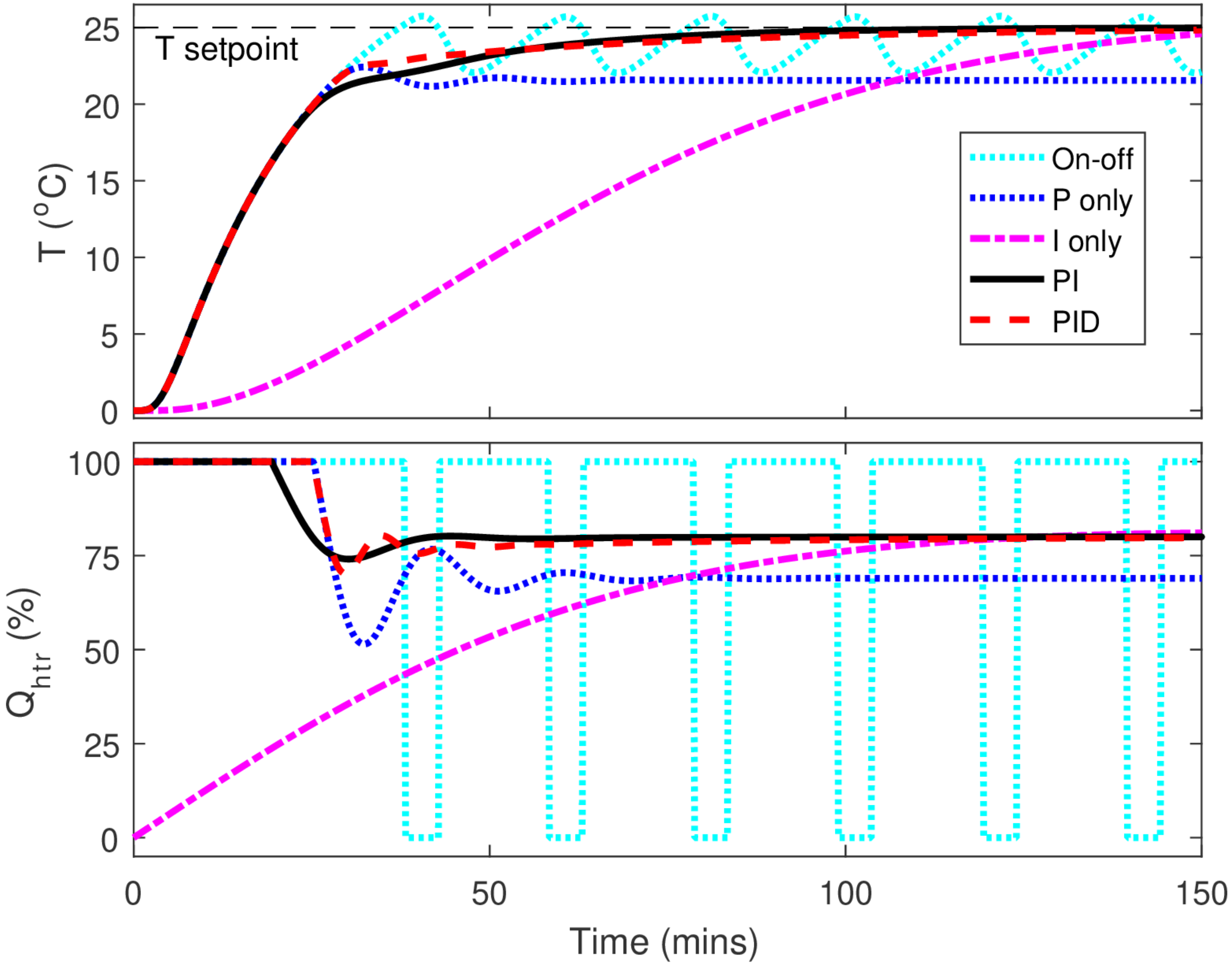
$$Q_{htr(t)} = K_C\left[\left(T^{SP} - T_{(t)}\right) + \frac{1}{\tau_I}\int_0^t \left(T^{SP} - T_{(t)}\right)dt + \tau_D\frac{d\left(T^{SP} - T_{(t)}\right)}{dt}\right] + b$$

PID

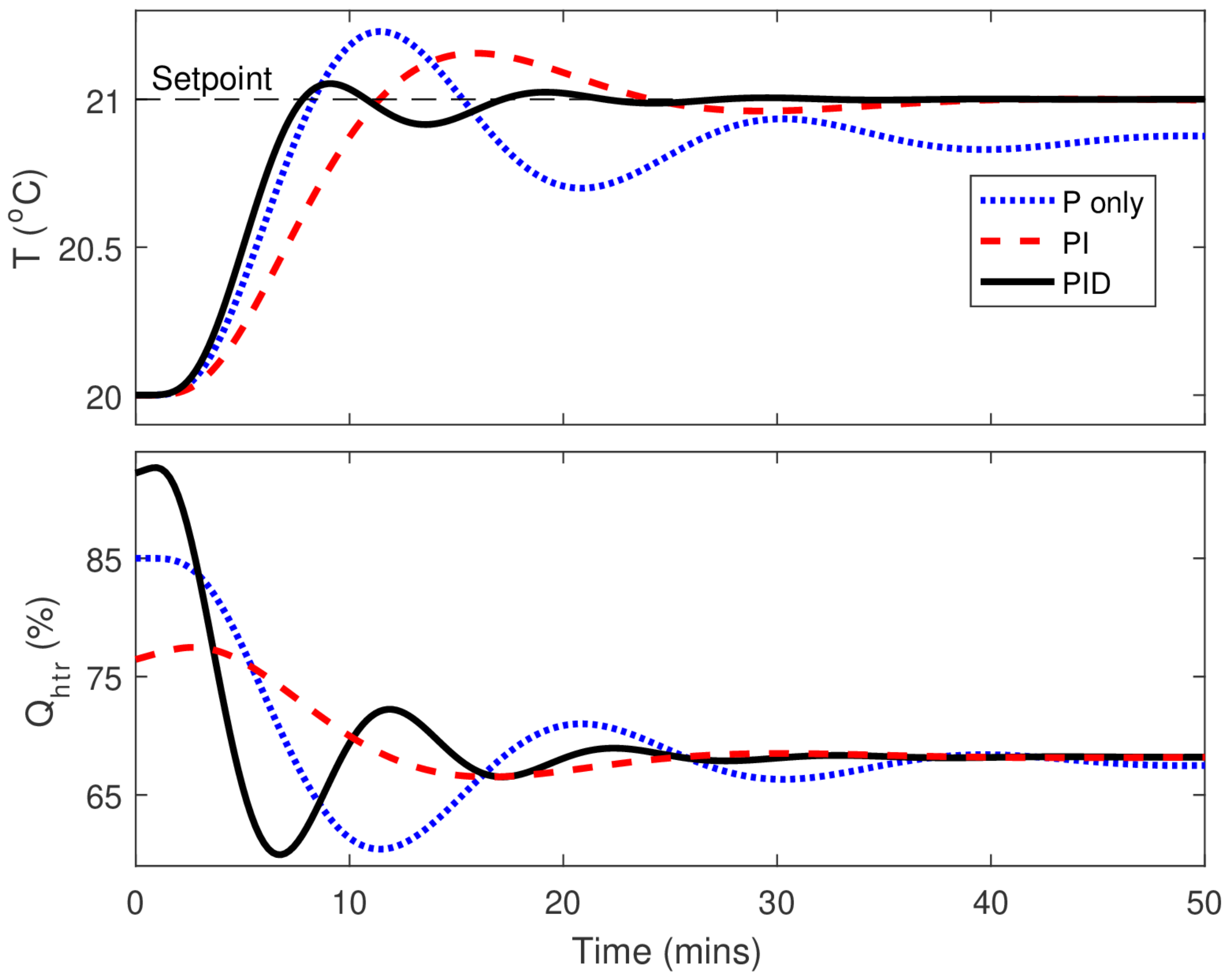
$$\boxed{u_{(t)} = K_C\left(e_{(t)} + \frac{1}{\tau_I}\int_0^t e_{(t)}dt + \tau_D\frac{de_{(t)}}{dt}\right) + b}$$

$$e_{(t)} = y^{SP}_{(t)} - y_{(t)}$$

Room SISO Temperature Control



T Setpoint Change Response



More Complex Control Algorithms

- Feedforward Ideas
  - Counter effect of a measured disturbance by adjusting MV
  - Requires MV-CV and disturbance-CV dynamic models
  - Major correction via feedforward. Minor correction via feedback
- Model based control
  - Major correction via model
  - Minor correction via feedback
  - Model based control + feedback
- Complexity vs Simplicity
  - Simple and robust but loose PV control
  - Complex and tight PV control but fragile

Feedback, Feedforward or Model-Based?

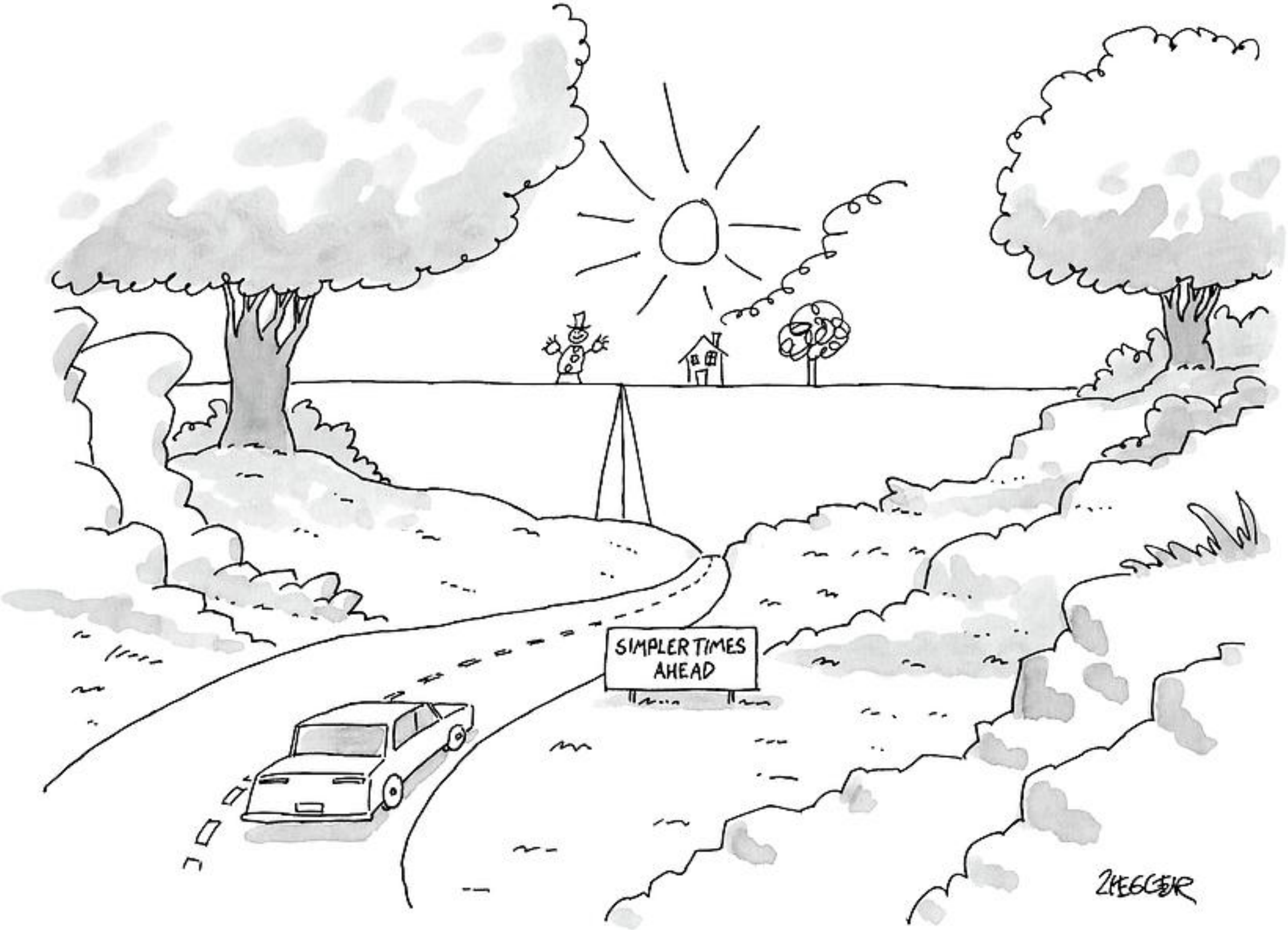
Balancing a Bike

Feedback, Feedforward or Model-Based?

Wading Through Traffic

Feedback, Feedforward or Model-Based?

Driving on a Highway



Feedback, Feedforward or Model-Based?

Near Exact Grocery Weighing

Feedback, Feedforward or Model-Based?

Fine Tuning Guitar Strings

Feedback, Feedforward or Model-Based?

Balancing a Stick

Summary

- PV feedback based adjustment of MV a powerful means for control
- Common SISO feedback control algorithms
  - On-off
  - PID
    - Most commonly employed industrial algorithm (>90%)
    - Integral mode gives off-set free control
    - Derivative mode allows accelerated MV adjustment
- More complex algorithms possible
  - Feedforward + feedback
  - Model + feedback
- Prefer simplicity over complexity