MEEN 432 –Automotive Engineering

Fall 2026

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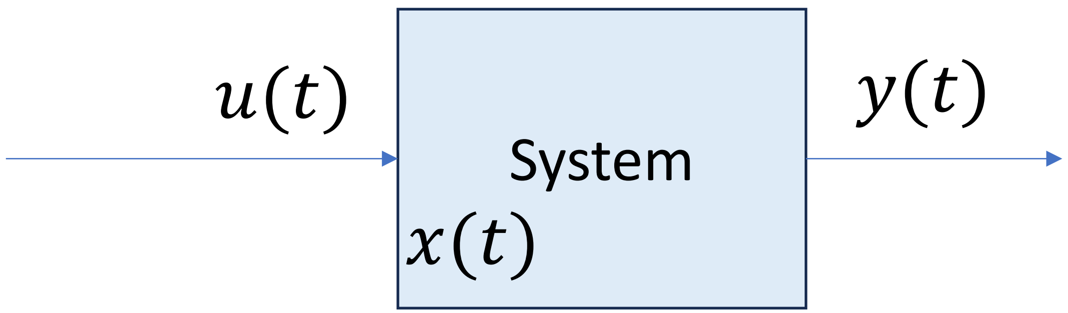
Lecture 3: Miscellaneous Topics

- PID
- Integration Step size and System Dynamics

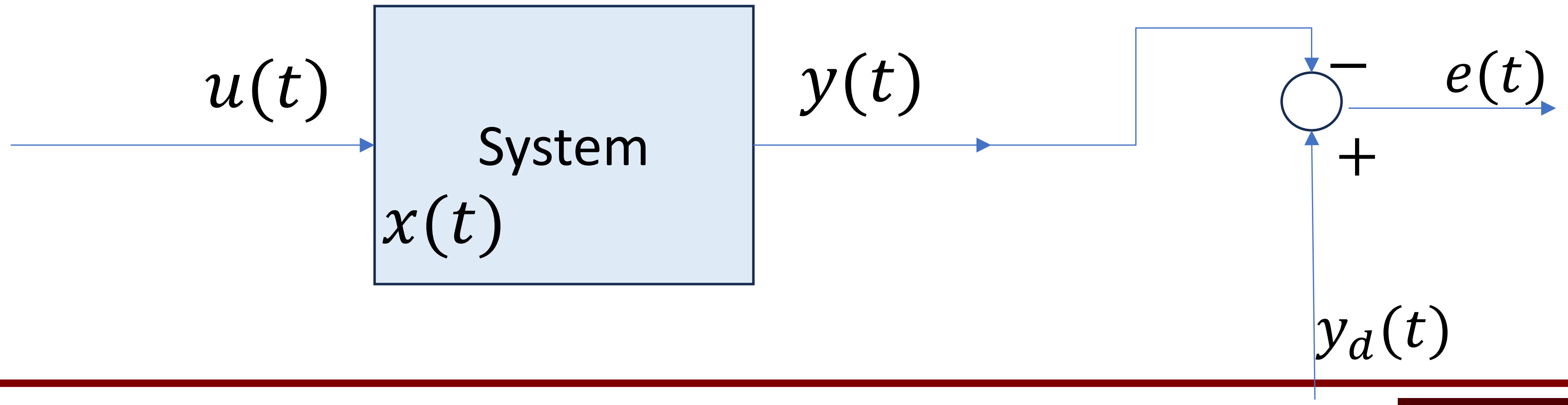
PID Control (quick recall) (1/3)

- Consider a dynamic system as shown:
  - Example: u is the axle torque τ_{axle}, output is the vehicle position x and velocity v, and the system dynamics is that of the vehicle's longitudinal dynamics



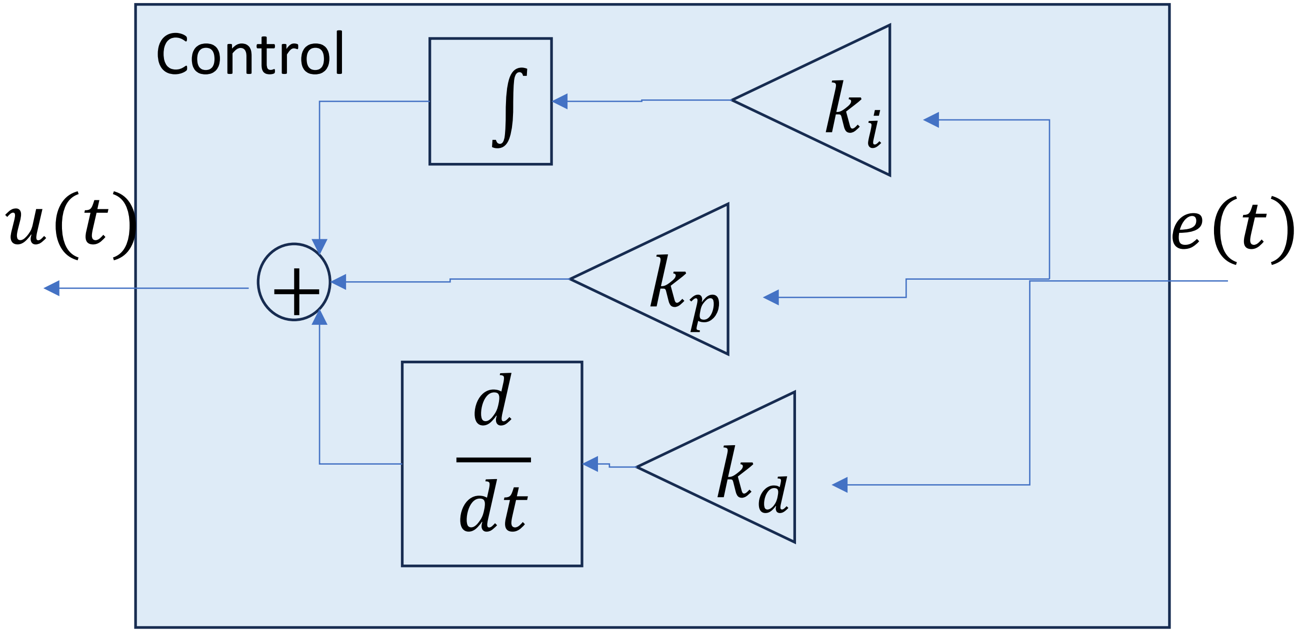
PID Control (quick recall) (2/3)

- Objective:
  - Choose the control $u(t)$ such that the output tracks a desired value: $y(t) \to y_d(t)$
  - Alternatively, defining $e \coloneqq y_d - y$, we require to choose $u(t)$ such that $\lim_{t\to\infty} e(t) = 0$



PID Control (quick recall) (3/3)

- Proportional-Integral-Derivative (PID) Control
  - Popular because of its simplicity and associated intuition
  - $u(t) = k_p e(t) + k_d \dot{e}(t) + k_i \int_0^t e(\tau) d\tau$



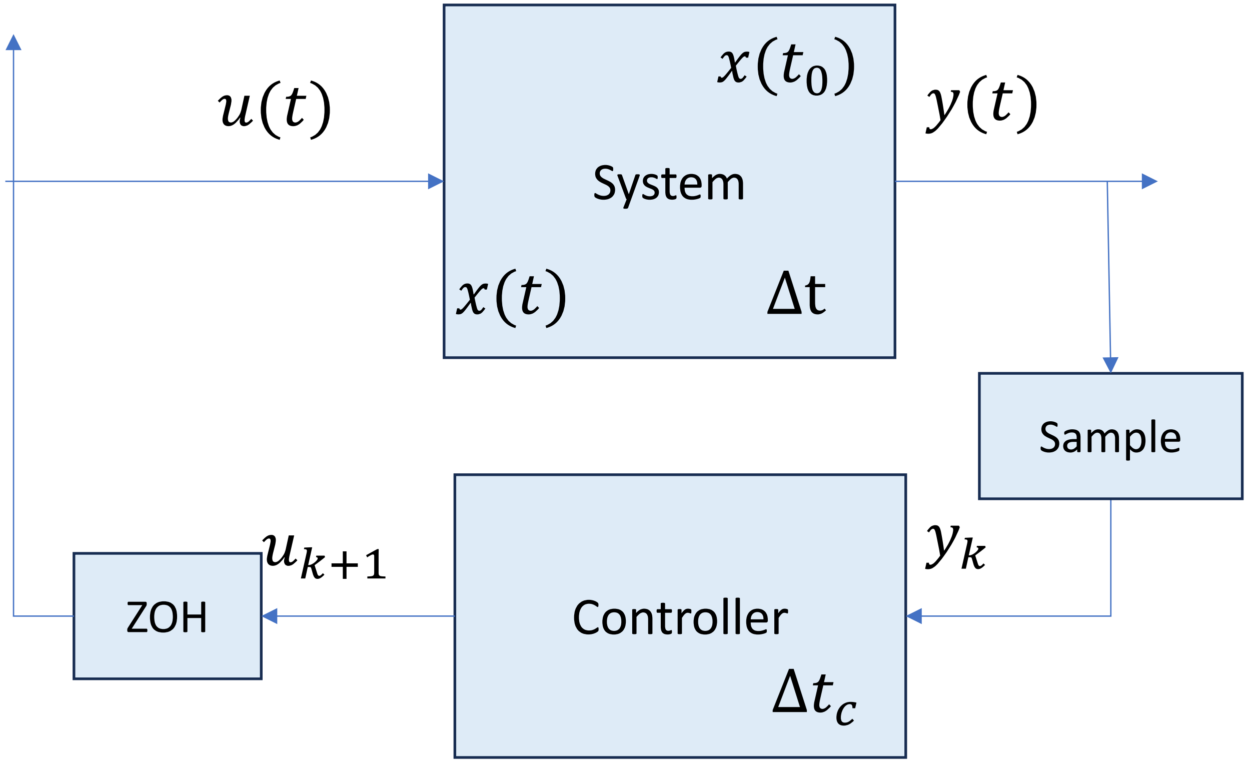
Proportional to error → need error to be non-zero for control to be non-zero

Proportional to derivative of error → challenge is calculation of $\dot{e}$. Sensitivity to Noise. This term provides "damping"

Proportional to accumulated error → remembers! non-zero control with zero error possible! Used to drive steady state error to zero

Integration Time Step vs Control Loop Time

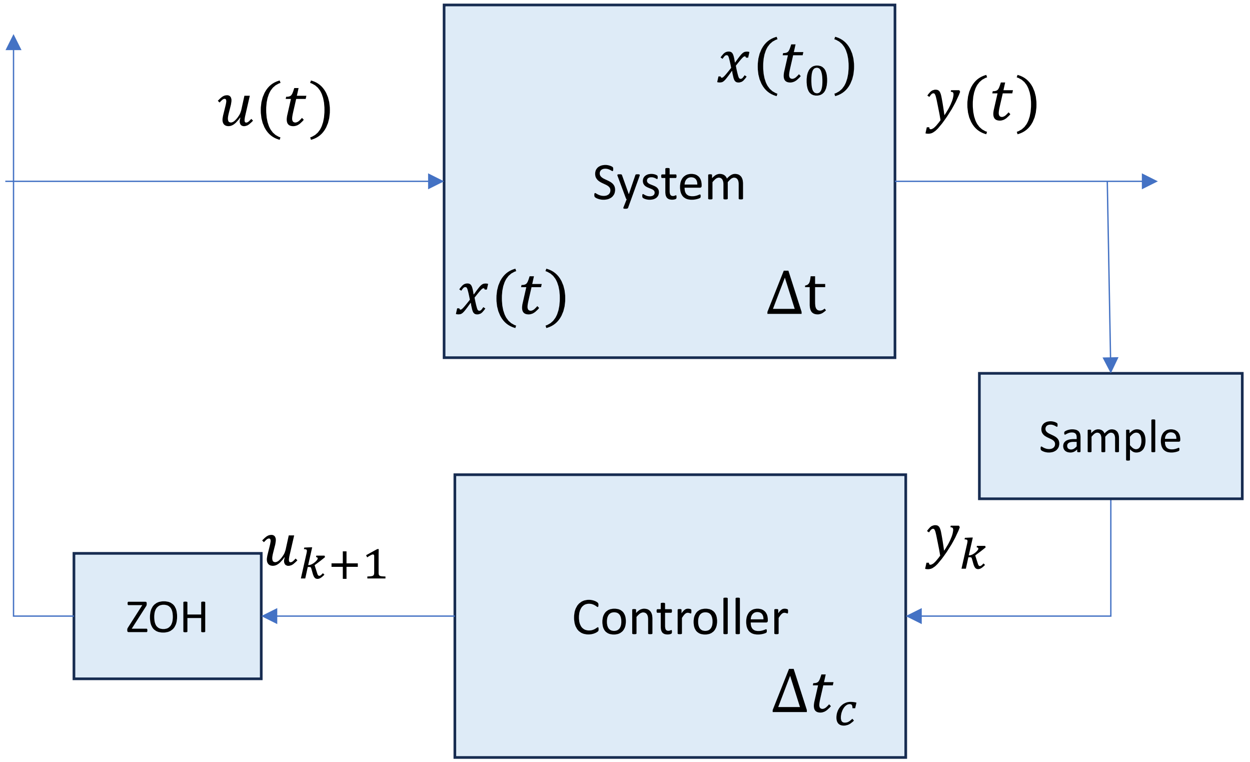
- Analog controllers can implement continuous controllers
  - E.g. Speed governors based on centrifugal forces
- Modern Systems are often implemented using digital (discrete) controls
  - $u(t)$ is not changed continuously, but changes at discrete instants of time (Control Loop Time)
  - The control is held constant within a Control Loop time



- $u(t) = u(t_k) \coloneqq u_k$ for $t_k \le t < t_{k+1}$ This is called the "Zero Order Hold" (ZOH) assumption

Integration Time Step vs Control Loop Time

- Usually, the control loop time is held constant: $t_{k+1} - t_k = \Delta t_C$ is a constant
- Sometimes, the control loop time is determined by external events, in which case it might not be a constant.
  - Example: t_k is the "event" when the piston reaches Top Dead Center. Then ΔT_C depends on the engine rpm!



Integration Time Step vs Control Loop Time

- In Simulation systems – the integration time step refers to the Δt used to integrate the system dynamics.
  - The control loop time refers to the Δt_C after which the control is updated
  - $\Delta t_c \geq \Delta t$
- For a discrete controller: Even with a variable time step integrator, No advantage for larger integration time steps, because you will be limited by the control loop time