# ME 343 – Control Systems

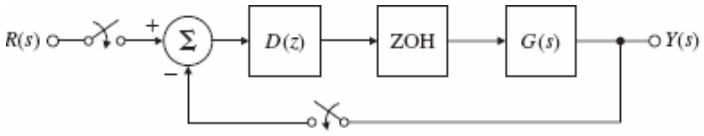
Lecture 42

December 4 , 2009

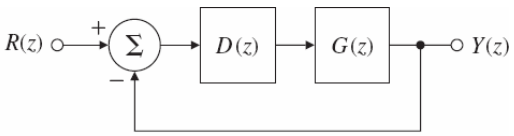


## Control Design

Emulation (Discrete Equivalent):

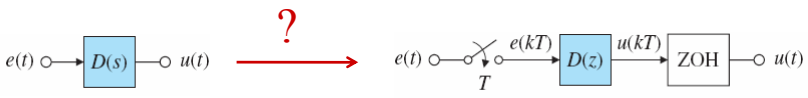


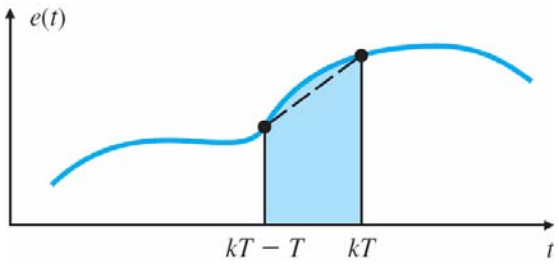

Discrete Design:



# Discrete Equivalent (Emulation) Design

## Tustin's (Bilinear) Method:




$$s = \frac{2}{T}\frac{1 - z^{-1}}{1 + z^{-1}}$$



# Discrete Equivalent (Emulation) Design

## Nyquist Theorem:

The Nyquist theorem states that a signal must be sampled at least twice as fast as the bandwidth of the signal to accurately reconstruct the waveform; otherwise, the high-frequency content will *alias* at a frequency inside the spectrum of interest (passband). An alias is a false lower frequency component that appears in sampled data acquired at too low a sampling rate.

An analog anti-alias filter is often placed between the sensor and the A/D converter. Its function is to reduce the higher-frequency noise components in the analog signal in order to prevent aliasing, that is, having noise or high-frequency components being modulated to a lower frequency by the sampling process.

If designing by discrete equivalents, a minimum sample rate of 20 times the bandwidth is recommended. Typically, even faster sampling is useful for best performance. Computational delay should be less than $T/10$.

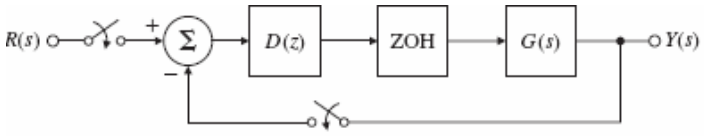
# Discrete Equivalent (Emulation) Design

Examples:

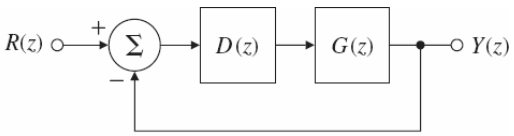


# Control Design

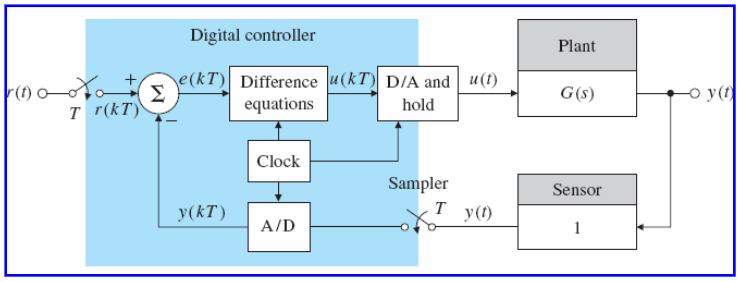
Emulation (Discrete Equivalent):

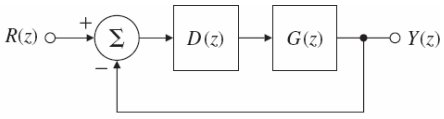



Discrete Design:



# Discrete Design




What is the TF between $u(kT)$ and $y(kT)$?

$$G(z) = \left(1 - z^{-1}\right) Z\left\{G(s)/s\right\}$$



# Discrete Design

Examples: