ECE 452/552 Chapter 1

R. TYMERSKI

SIGNALS

A continuous-time signal is a signal defined over a continuous range of time. The amplitude may assume a continuous range of values or may assume a finite number of distinct or quantized values. An *analog* signal is one where both the amplitude and time are continuous.

A discrete-time signal is a signal define only at discrete instants of time i.e. t is quantized. If the amplitude can assume a continuous range of values, then the signal is called a *sampled-data* signal, as it can be generated by sampling an analog signal. A *digital* signal is discrete-time signal with quantized amplitude. Such a signal can be represented by a sequence of numbers.



SYSTEMS

Discrete-time control systems are control systems in which one or more variables can change only at discrete instants of time. These instants will be denoted by kT or t_k (k = 0, 1, 2, ...)

We will be dealing mainly with linear, time-invariant discrete-time systems, which can be described by *linear difference equations*.

The general form of an nth-order linear difference equation is:

 $x(k) = \alpha_n \ e(k) + \alpha_{n-1} \ e(k-1) + \dots + \alpha_0 \ e(k-n) - \beta_{n-1} \ x(k-1) - \dots - \beta_0 \ x(k-n)$

The solution of difference equations may be approached by using the z-transform.

DIGITAL CONTROL SYSTEMS



Advantages over analog control:

- 1. Data processing is straightforward.
- 2. Control programs (controller characteristics) can be easily changed.
- 3. Less problems due to internal noise and drift effects.

Disadvantages:

- 1. The sampling and quantizing process tend to result in more errors, which degrade system performance.
- 2. Designing to compensate for such degradation is more complex.

A more detailed block diagram of a digital control system:



Types of Sampling

- 1. Periodic. $t_k = kT$ $(k = 0, 1, 2, \cdots)$, gives equally spaced samples.
- 2. Multi-order sampling. The pattern of the t_k 's is repeated periodically.
- 3. Multi-rate. Different sampling rates used throughout the system.
- 4. Random. t_k is a random variable.
- Generally, periodic sampling will be used.

Selection of sampling rate

Sampling theorem: if a continuous-time signal is bandlimited or contains no frequency components higher than w_c , then theoretically the original signal can be reconstructed without distortion if it is sampled at a rate of at least $2w_c$.

In practice, the sampling frequency is chosen to be much higher the $2w_c$, usually 8-10 times w_c .

Note: the sampling frequency affects the stability of a closed-loop digital control system.