Classification of Digital Systems

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Digital Systems

- **In many applications, we need to design a device that performs some operations on digital signals**

- **Such a device is called a digital *system***

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Digital Systems

- **In a simple digital system, the input $x(n)$ is transformed by the system into the output $y(n)$:**

$$y(n) = \mathrm{T}\left[x(n)\right]$$

where the symbol T **denotes the transformation (i.e. system)**

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Static vs. dynamic systems

- **A static system has an output at any time which depends on the input sample at the same time, but not on past or future samples of the input**

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- **In any other case, the system is dynamic**

- **The systems described by the following equations:**

$$y(n) = ax(n)$$

$$y(n) = nx(n) + bx^3(n)$$

are both static

Classification of Digital Systems

Static vs. dynamic systems

The system described by the following equation:

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$$y(n) = \sum_{k=0}^{n} x(n-k)$$

is a dynamic system

Classification of Digital Systems

Time-invariant vs. time-variant systems

- **A system is called time-invariant if its input-output characteristics do not change with time**

- **A system is time-invariant if and only if**

$$y(n) = \mathrm{T}\left[x(n)\right]$$

implies that

$$y(n-k) = \mathrm{T}\left[x(n-k)\right]$$

for every input signal and time shift

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Linear vs. nonlinear systems

- **A linear system is one that satisfies the superposition principle, i. e.,**

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$$T\left[a_1 x_1(n) + a_2 x_2(n)\right] = a_1 T\left[x_1(n)\right] + a_2 T\left[x_2(n)\right]$$

for any arbitrary inputs and constants.

- **If a system does not satisfy the superposition principle, it is called a nonlinear**

Classification of Digital Systems

Causal vs. non-causal systems

- **A system is said to be causal if the output of the system at any time depends only on present and past inputs, i. e.**

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$$y(n) = \mathrm{T}\left[x(n),\ x(n-1),\ \ x(n-2)\ldots\right]$$

- **If a system does not satisfy this definition, it is called non-causal**

Classification of Digital Systems

Stable vs. unstable system

- **An arbitrary system is said to be bounded input-bounded output stable if and only if every bounded input produces a bounded output**

- **The conditions that the input** $x(n)$ **and output** $y(n)$ **are bounded are that there exist some finite values, say** M_x **and** M_y **such that**

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$$|x(n)| \le M_x \le \infty \qquad |y(n)| \le M_y \le \infty$$

for all n

- **If for some bounded input, the output is unbounded (infinite), the system is classified as unstable**

Linear Time-Invariant Systems

Linear time-invariant (LTI) system satisfies both the linearity and time-invariance properties

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