BEE2143 – Signals & Networks

Chapter 1 – Introduction to Signals and Systems

Raja M. Taufika R. Ismail

Universiti Malaysia Pahang

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Classification of signals and systems

Signal Characteristic

Time and Frequency domains

Classification of signals and systems

Classification of signals:

- Continuous-time
- Discrete-time
- Continuous-value
- Discrete-value
- Random
- Nonrandom

Continuous-time signals	Discrete-time signals
– Defined values at every instant of time over time interval	– Defined values only at discrete points in time (not between them)
– Real world (analog)	– Set of samples (usually transmitted as digital signal)
– E.g.: voltage, current, temperature, velocity	– E.g.: population, DNA based sequence

Classification of systems:

- Memoryless and memory
- Causal and non-causal
- Linear and nonlinear
- Time-invariant and time-variant
- Linear time-invariant (LTI)

Memoryless system	**Memory system**
– The output at time t_0 depends only on the input at the same time t_0	– The output at time t_0 depends on the input at the some range of time t

Causal system	**Non-causal system**
– The output at time t_0 depends only on the input for $t_i \leq t_0$ (the system cannot anticipate the input)	– A system that is not a causal system (depends on some future input values and possibly on some input values from the past or present)

Linear system	Nonlinear system
– The output is proportional to the input – Satisfies the additive, superposition and scaling properties	– Does not satisfy the additive, superposition and scaling properties

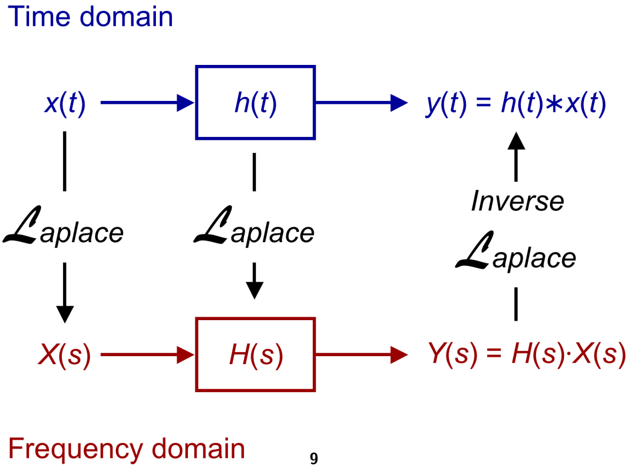
Time-invariant system	Time-variant system
– A system whose output does not depend explicitly on time – If the input signal $x(t)$ produces an output $y(t)$ then any time shifted input, $x(t+\delta)$, results in a time-shifted output $y(t+\delta)$	– A system whose output characteristics depend explicitly upon time

Linear time-invariant (LTI) system

- LTI system is a system that is both linear and time-invariant
- Any LTI system can be characterized entirely by a single function called the system's impulse response
- The output of the system is simply the convolution of the input to the system with the system's impulse response
- Equivalently, any LTI system can be characterized in the frequency domain by the system's transfer function, which is the Laplace transform of the system's impulse response (or Z transform in the case of discrete-time systems)
- The output of the system in the frequency domain is the product of the transfer function and the transform of the input

Linear time-invariant (LTI) system (cont.)

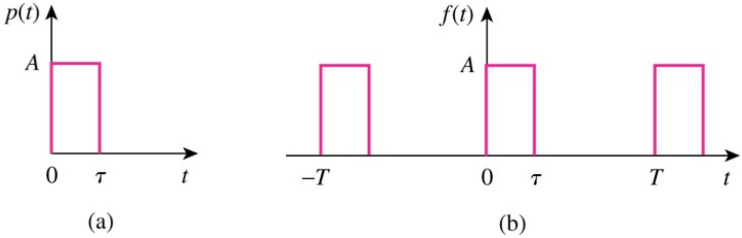
- In other words, convolution in the time domain is equivalent to multiplication in the frequency domain



Signal Characteristic

Periodic signals

- Periodic functions satisfy $f(t) = f(t + T)$



Symmetry signals

- A function $f(t)$ is even symmetry if its plot is symmetrical about the vertical axis, that is,

$$f(-t) = f(t)$$

- A function $f(t)$ is said to be odd symmetry if its plot is antisymmetrical about the vertical axis, that is,

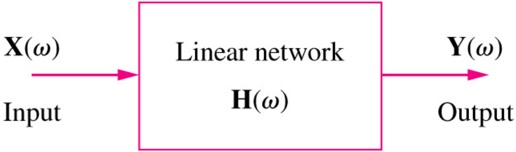
$$f(-t) = -f(t)$$

Time and Frequency domains

- In our sinusoidal circuit analysis, we have learned how to find voltages and currents in a circuit with a constant frequency source
- If we let the amplitude of the sinusoidal source remain constant and vary the frequency, we obtain the circuit's frequency response
- The frequency response of a circuit is the variation in its behavior with change in signal frequency

- The sinusoidal steady-state frequency responses of circuits are of significance in many applications, especially in communications and control systems
- A specific application is in electric filters that block out or eliminate signals with unwanted frequencies and pass signals of the desired frequencies
- Filters are used in radio, TV, and telephone systems to separate one broadcast frequency from another

- In general, a linear network can be represented by the block diagram shown in Fig. 14.1

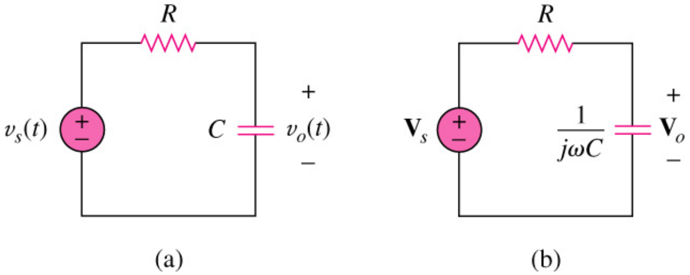


- The transfer function $\mathbf{H}(\omega)$ of a circuit is the frequency-dependent ratio of a phasor output $\mathbf{Y}(\omega)$ (an element voltage or current) to a phasor input $\mathbf{X}(\omega)$ (source voltage or current)

Example 14.1, pg. 615 (Alexander & Sadiku, 2009)

For the RC circuit in Fig. 14.2(a), obtain the transfer function V_o/V_s and its frequency response. Let $v_s = V_m \cos \omega t$.

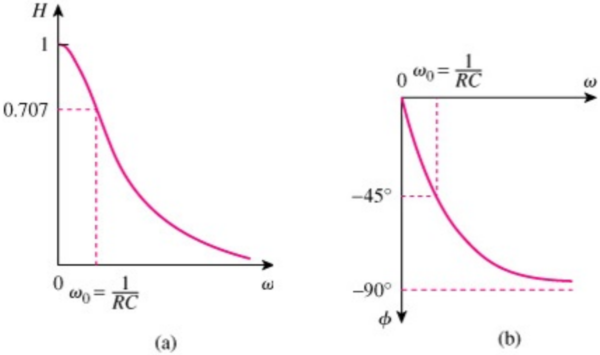
Answer:



$$\mathbf{H}(\omega) = \frac{1}{1 + j\omega RC}$$

Example 14.1, pg. 615 (Alexander & Sadiku, 2009) (cont.)

$$H = \frac{1}{\sqrt{1 + \left(\frac{\omega}{\omega_0}\right)^2}}, \quad \phi = -\tan^{-1}\frac{\omega}{\omega_0}, \quad \omega_0 = \frac{1}{RC}$$



List of References

1. C.K. Alexander and M.N.O. Sadiku (2009), Fundamentals of Electric Circuits 4th ed., New York: McGraw-Hill.