ELE 321
Linear System Analysis

Ankara University

Faculty of Engineering

Electrical and Electronics Engineering Department

Transformations of the Independent Variable

ELE321 Linear System Analysis

Lecture 2

Agenda

- Independent variable
- Transformation of independent variable
- Time shifting
- Time reversal
- Time scaling

Transformations of the Independent Variable

(Modifications of the independent variable, time)

- **Time shift:** $x(t) \rightarrow x(t-t_o)$, t_o can be (+) or (-).

  $x[n] \rightarrow x[n-n_o]$, n_o can be (+) or (-).
- If t_o is positive, $x(t-t_o)$ is delayed version of the original signal $x(t)$.
- If t_o is negative, $x(t-t_o)$ is advanced version of the original signal $x(t)$.

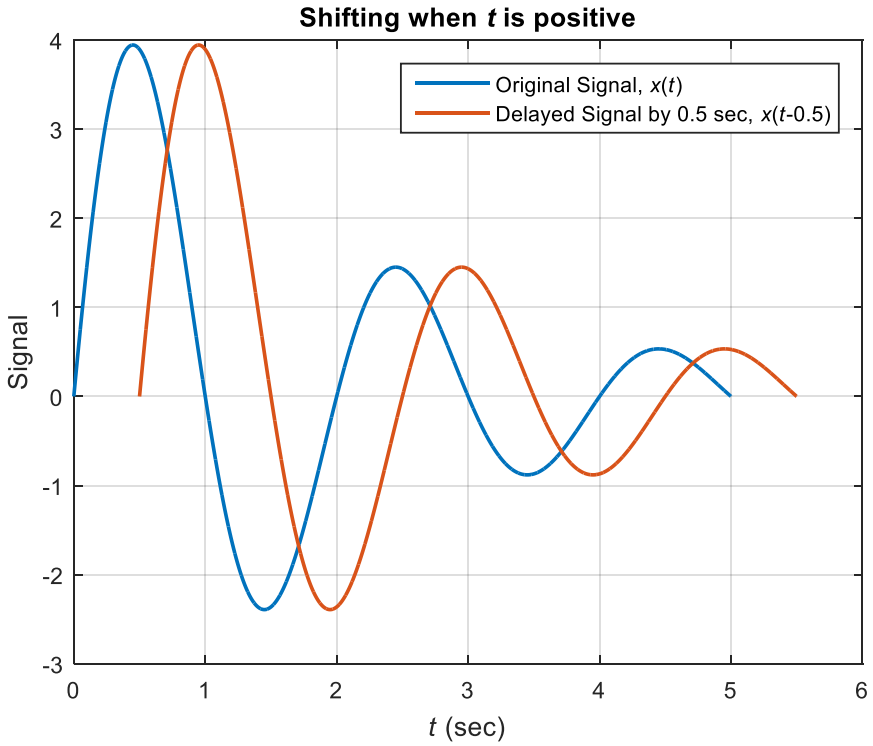
- **Time reversal:** $x(-t)$ (Reflection at t=0).

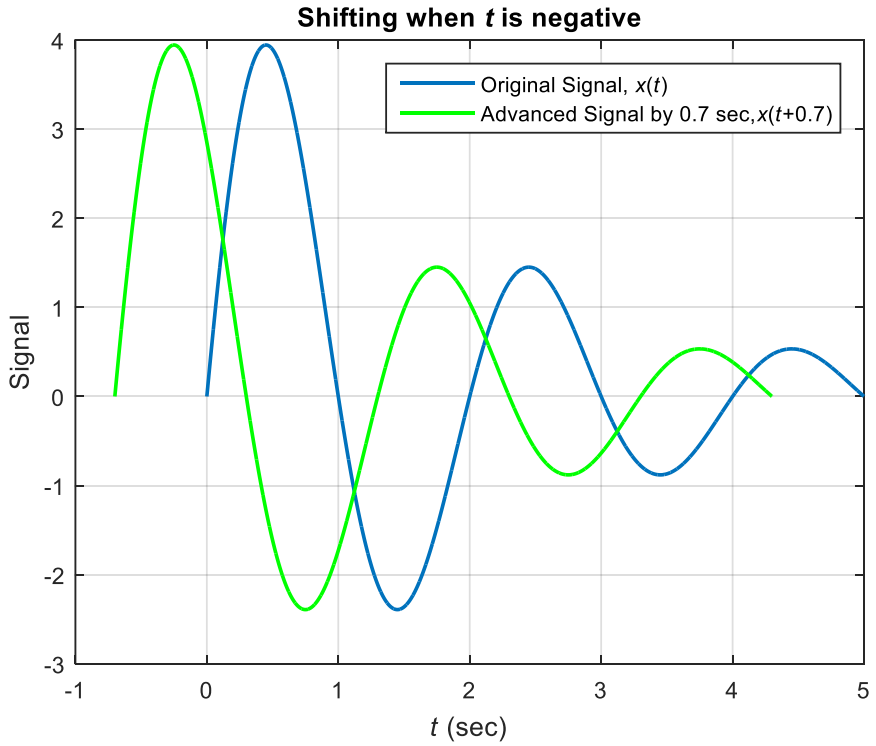
- **Time scaling:** $x(at)$, a: constant
- If a>1, $x(at)$ is speeded up signal.
- If a<1, $x(at)$ is slowed down signal.

* All operations are applicable to discrete-time signals as well.

Time Shifting

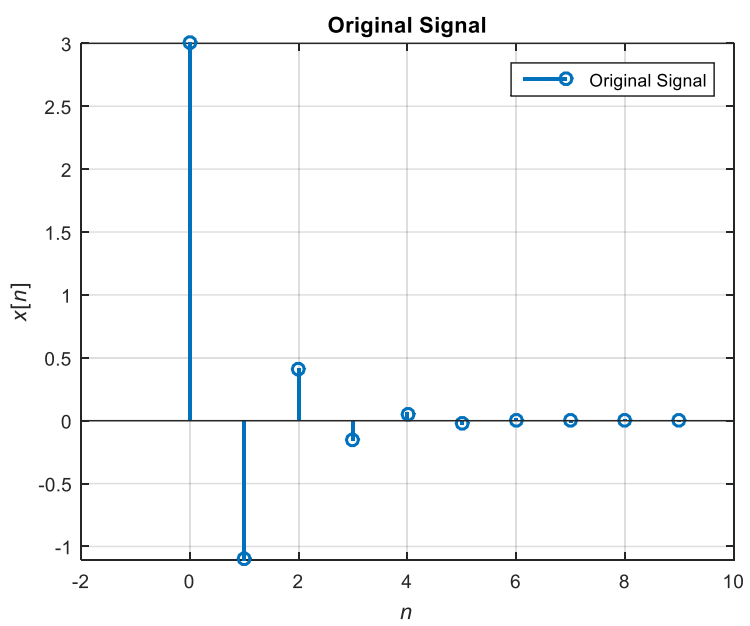
- Continuous time example

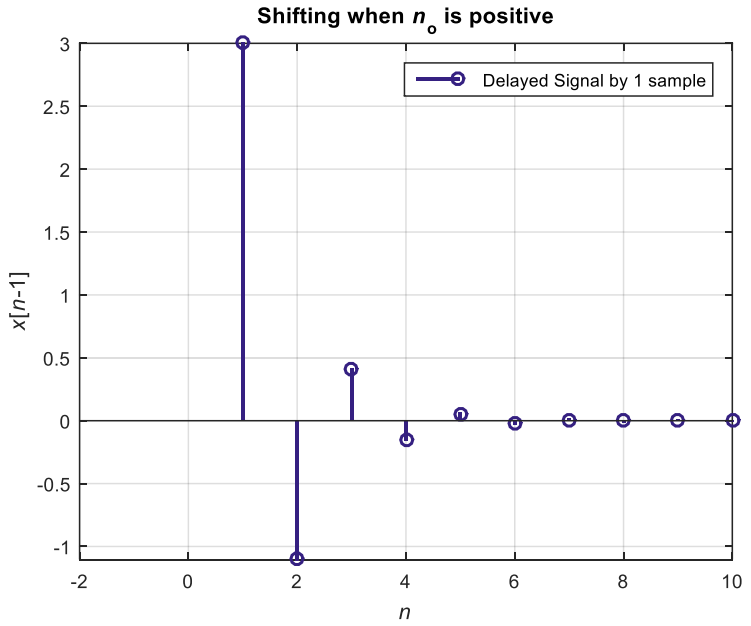


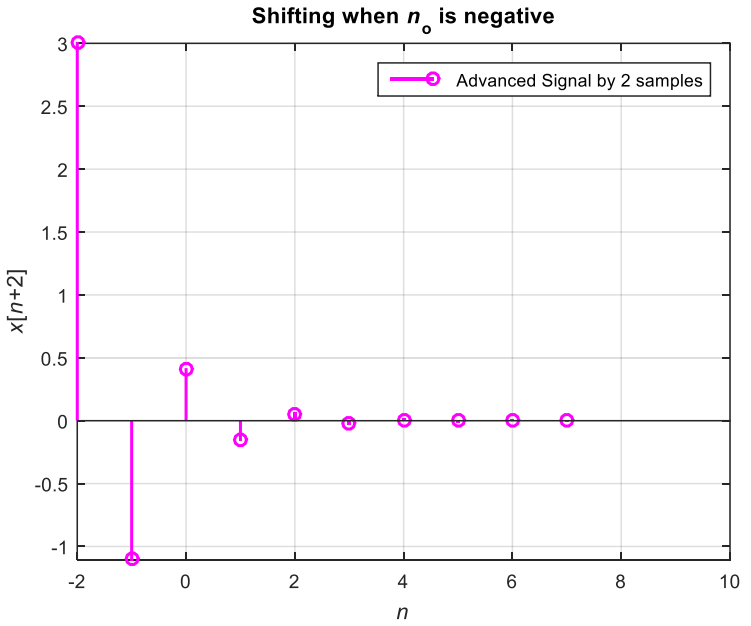


Time Shifting

- Discrete time example

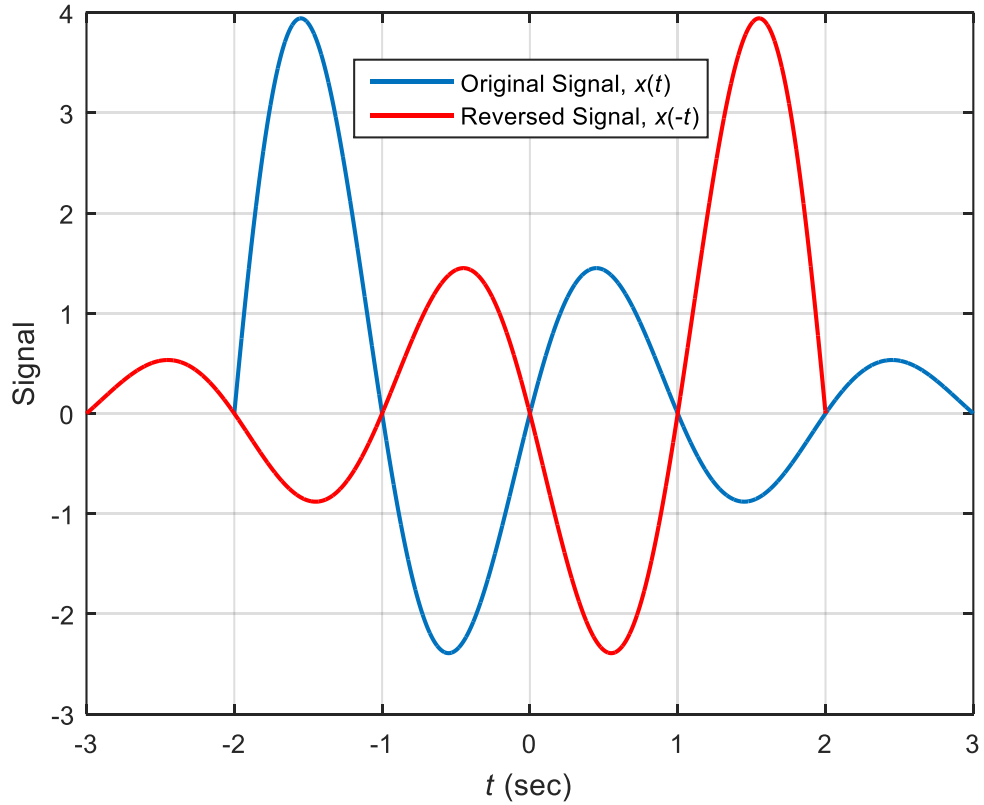






Time Reversal

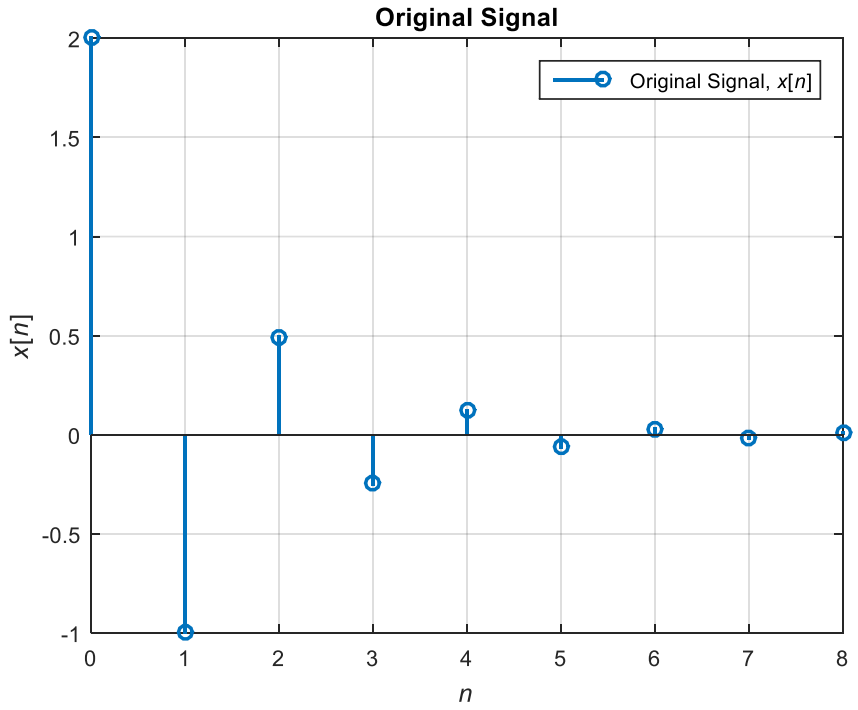
- Continuous time example

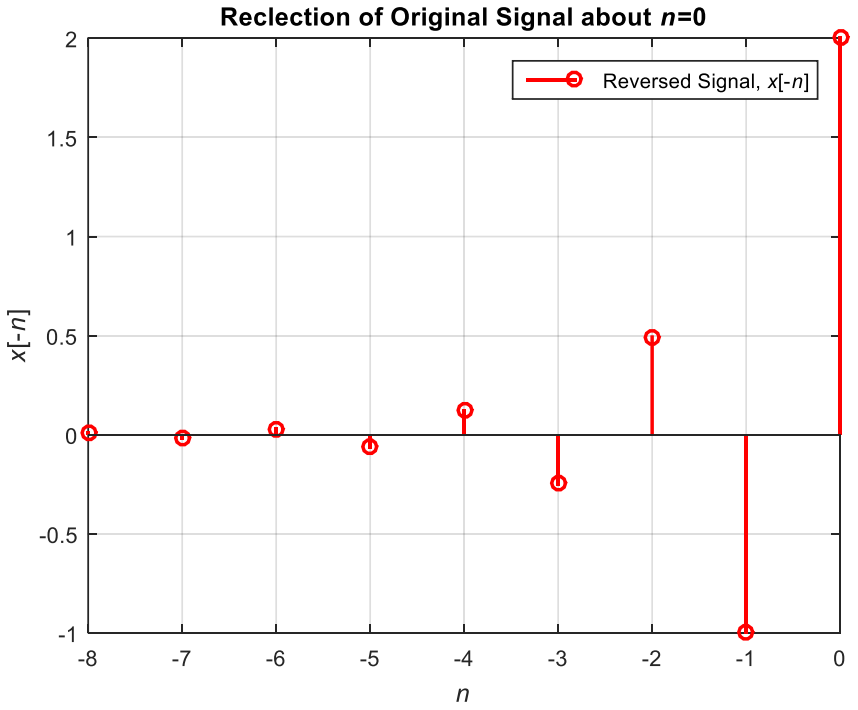


$x(-t)$ is obtained from the signal $x(t)$ by a reflection about t=0.

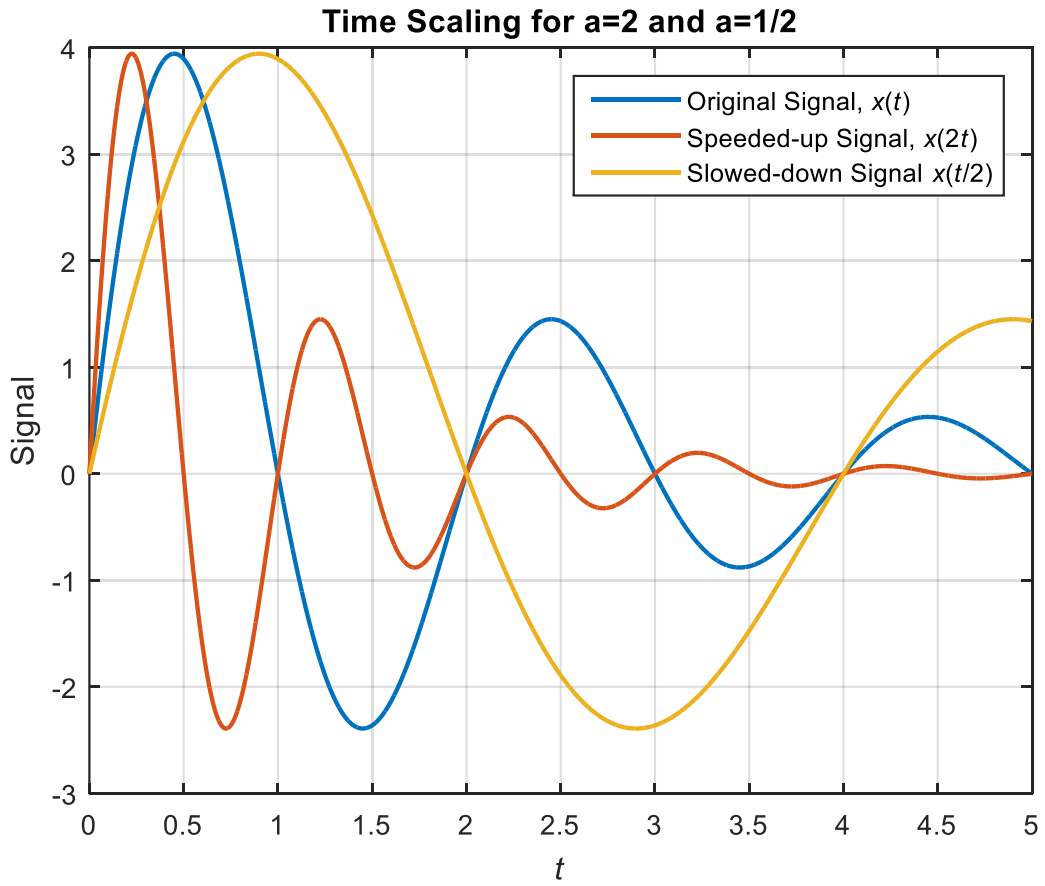
Time Reversal

- Discrete time example

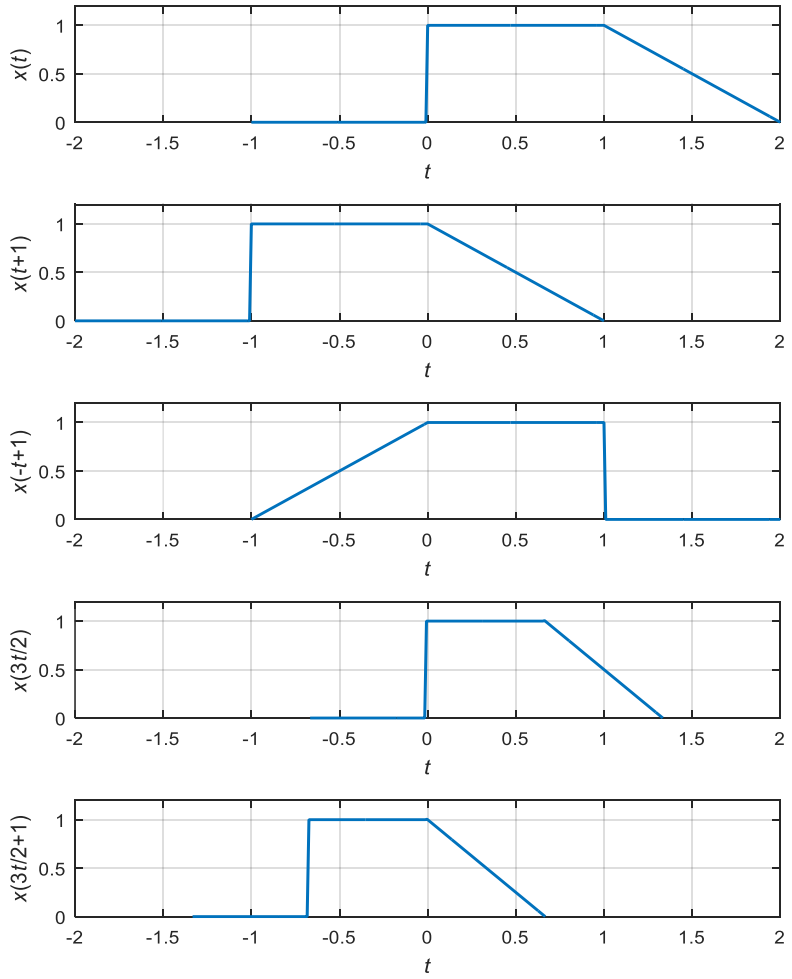




Time Scaling



Example *



* Example 1.1. Signals and Systems, A.V. Oppenheim, A. S. Willsky with S. H. Nawab

References

- Signals and Systems, 2nd Edition, Oppenheim, Willsky, Nawab