EEE 321
Signals and Systems

Ankara University

Faculty of Engineering

Electrical and Electronics Engineering Department

Transformations of The Independent Variable

EEE321 Signals and Systems

Lecture 2

Agenda

- Independent variable
- Transformation of independent variable
- Time Shifting
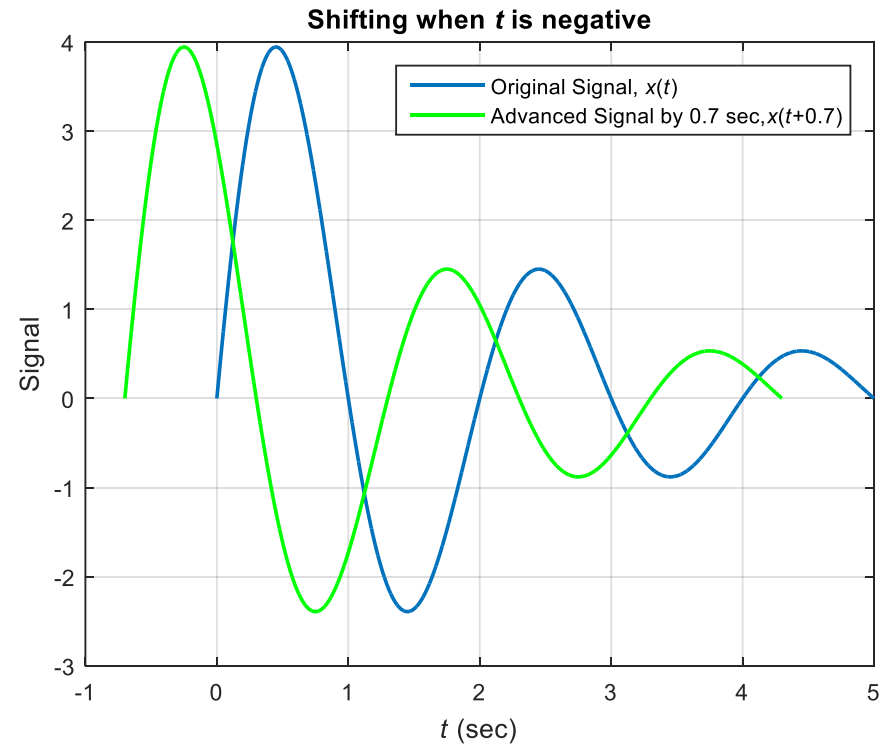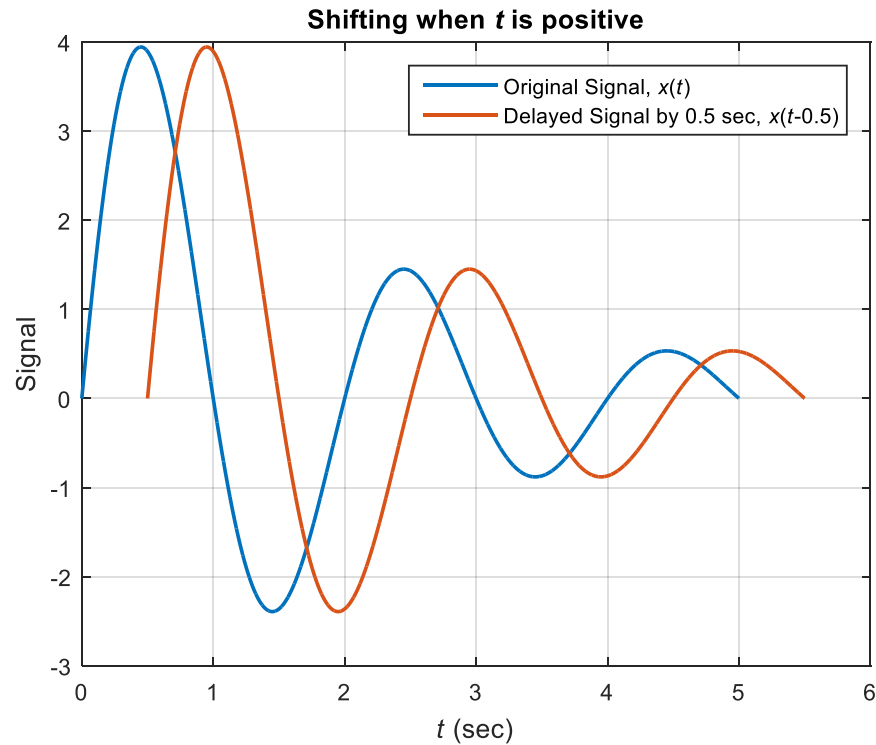- Time Reversal
- Time Scaling

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.

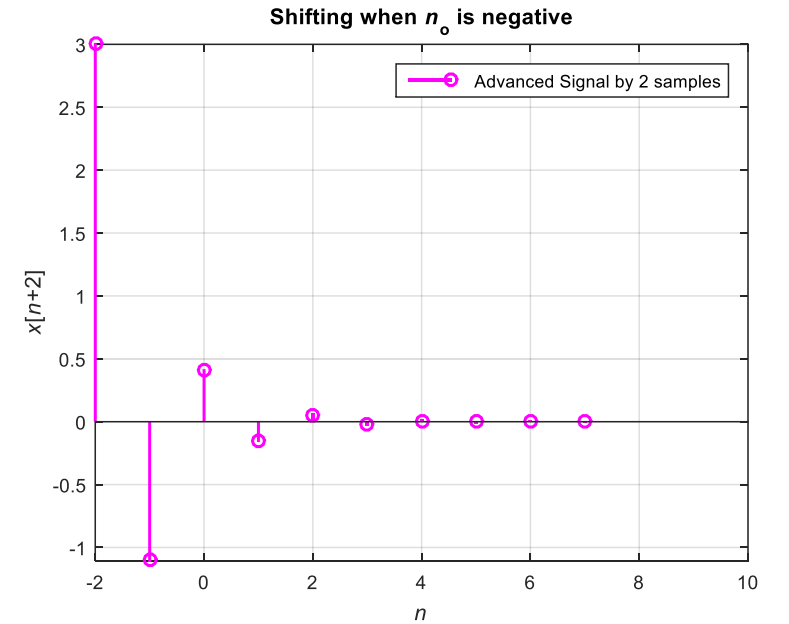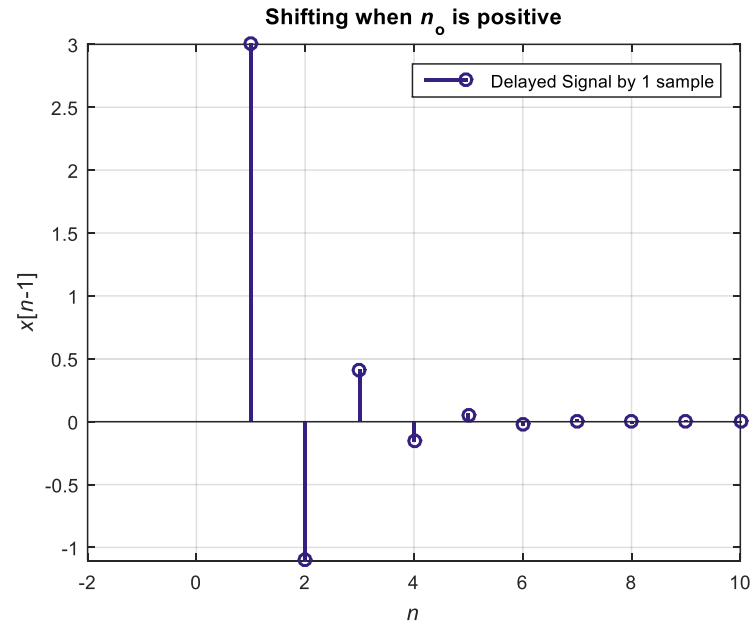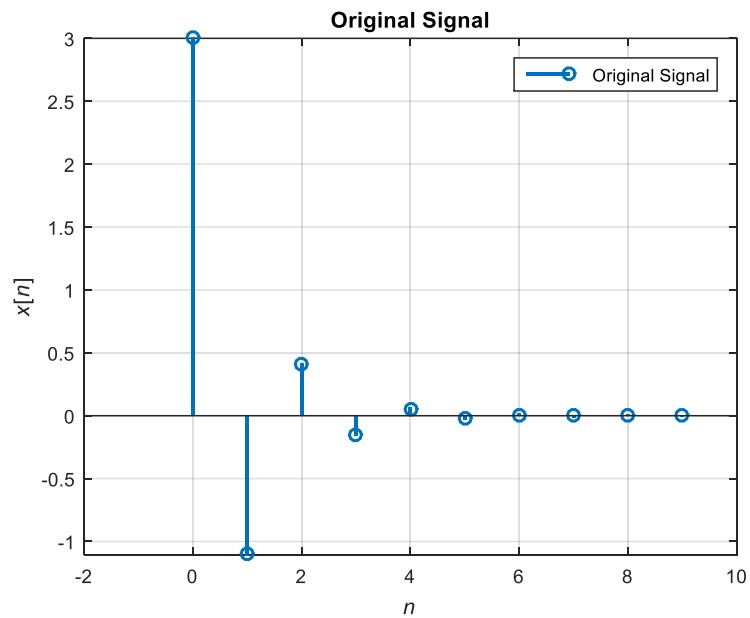# Time Shifting
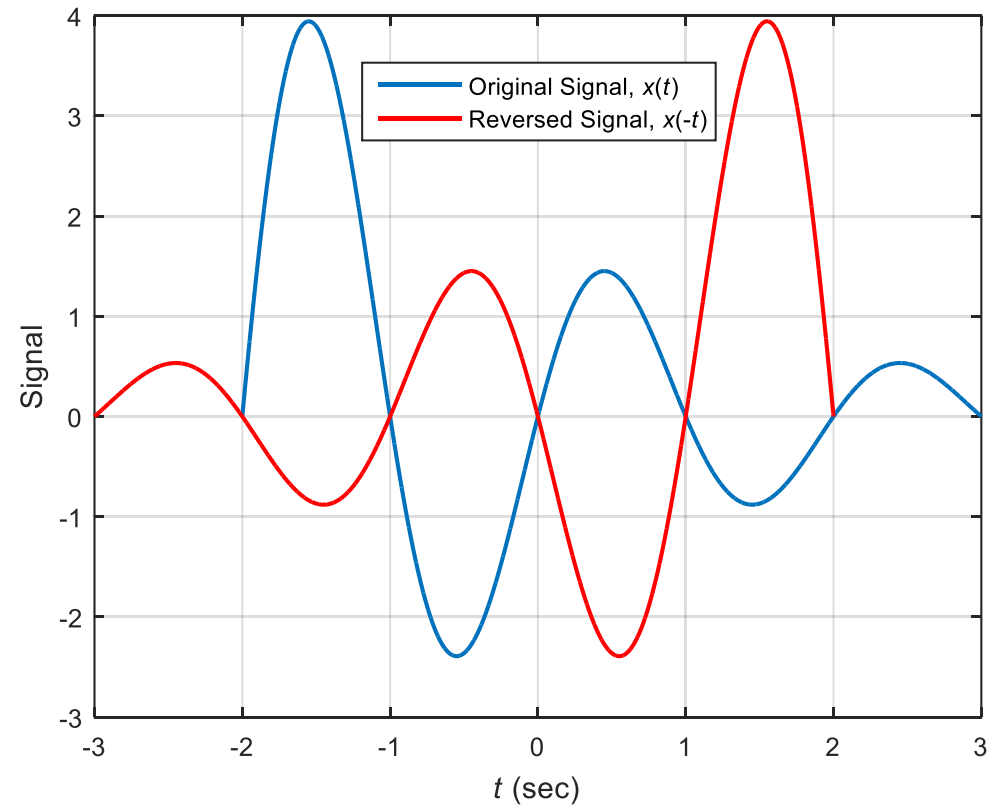
- ## Continuous time example

Time Shifting

- Discrete time example
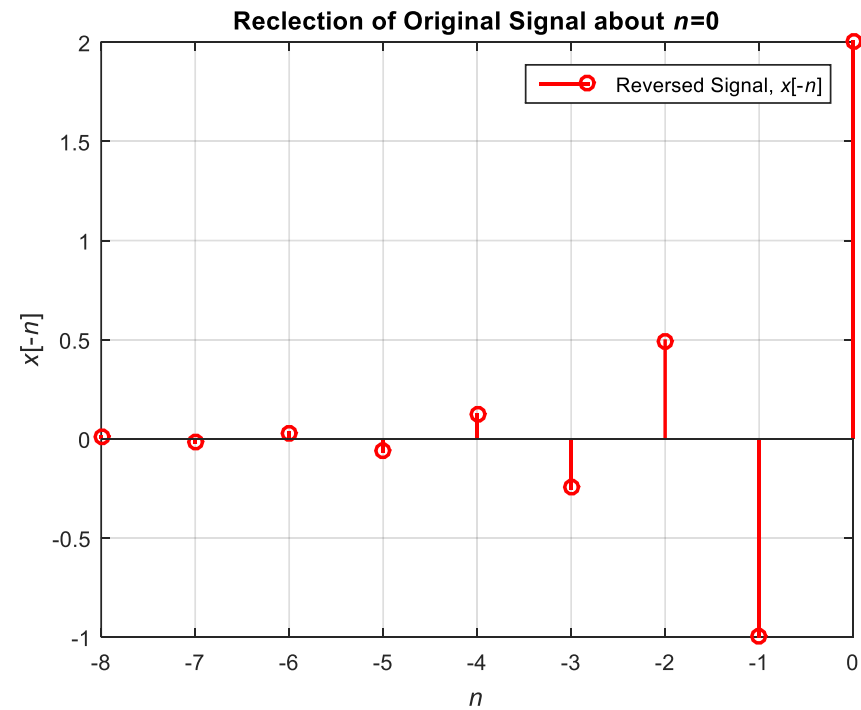
Time Reversal
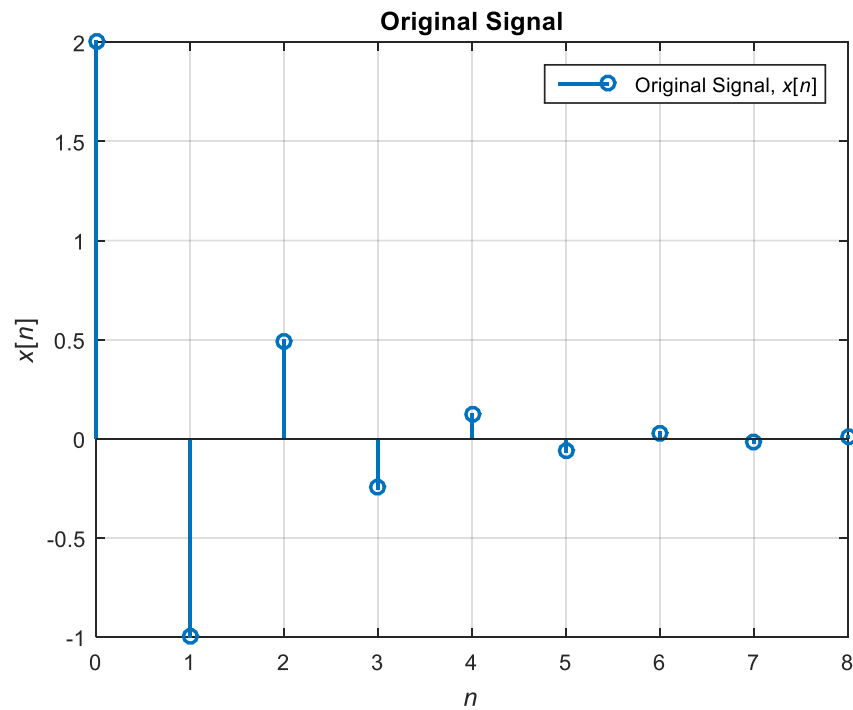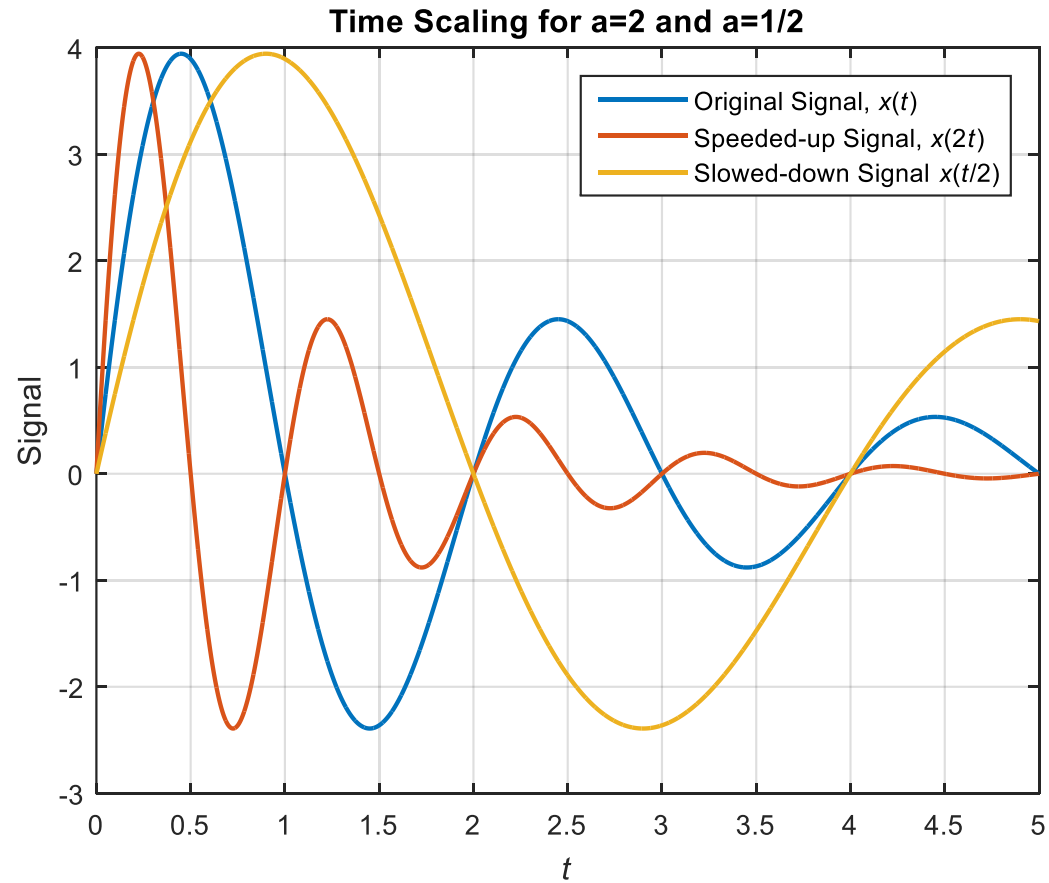
- Continuous time example

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

Time Reversal

- Discrete time example

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Time Scaling

Time Scaling for a=2 and a=1/2

Legend:
- Original Signal, $x(t)$
- Speeded-up Signal, $x(2t)$
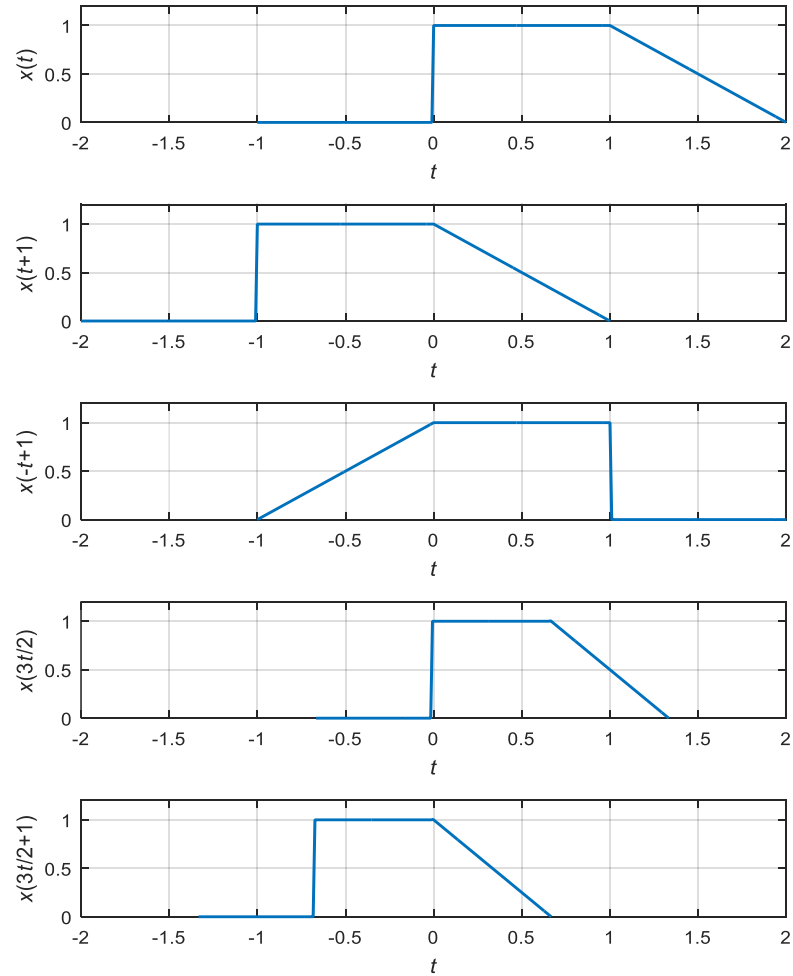- Slowed-down Signal $x(t/2)$

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