

# Electronic Signals

Maxx Seminario

University of Nebraska-Lincoln

January 2025

# Signals: Information Carriers

ECEN 463/863

Maxx Seminario

What are  
Signals?

Signal Source  
Representations

Time-Domain  
Signal  
Representation

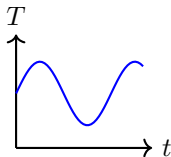
Frequency  
Spectrum

Summary

**Definition:** Signals contain information about physical phenomena

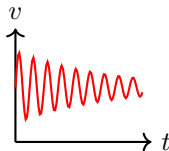
## Weather:

- Temperature
- Pressure
- Humidity



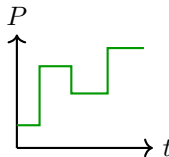
## Audio:

- Voice
- Music
- Environmental sounds



## Industrial:

- Machine status
- Process control
- Safety monitoring



## The Challenge

How do we extract useful information from these signals?

# From Physical to Electrical Signals

ECEN 463/863

Maxx Seminario

What are  
Signals?

Signal Source  
Representations

Time-Domain  
Signal  
Representation

Frequency  
Spectrum

Summary

## The Transducer:

- Converts physical signals to electrical
- Output: voltage or current
- Many types for different phenomena

## Examples:

- Microphone: sound  $\rightarrow$  voltage
- Thermistor: temperature  $\rightarrow$  resistance
- Photodiode: light  $\rightarrow$  current
- Accelerometer: motion  $\rightarrow$  voltage

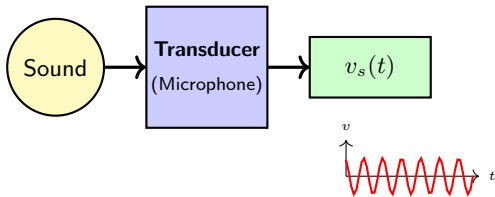


Figure 1: Transducer converts physical signal to electrical

## Assumption in This Course

Signals already exist in the electrical domain (voltage or current)

# Thevenin and Norton Representations

ECEN 463/863

Maxx Seminario

What are  
signals?

Signal Source  
Representations

Time-Domain  
Signal  
Representation

Frequency  
Spectrum

Summary

## Thevenin Form:

- Voltage source  $v_s(t)$
- Series resistance  $R_s$

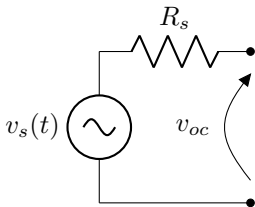


Figure 2: Thevenin equivalent circuit

## Norton Form:

- Current source  $i_s(t)$
- Parallel resistance  $R_s$

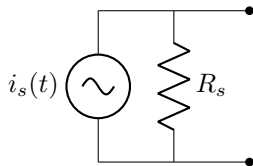


Figure 3: Norton equivalent circuit

## Equivalence Condition

$v_s(t) = R_s \cdot i_s(t)$  For the two representations to be equivalent

# Source Resistance: The Imperfection

ECEN 463/863

Maxx Seminario

What are  
signals?

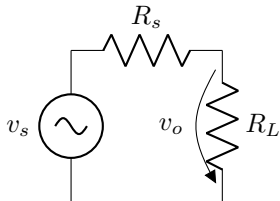
Signal Source  
Representations

Time-Domain  
Signal  
Representation

Frequency  
Spectrum

Summary

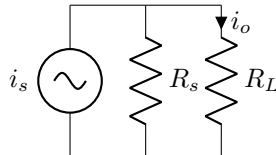
## Thevenin Source with Load:



**Voltage divider:**  $v_o = v_s \frac{R_L}{R_L + R_s}$

**Condition for  $v_o \approx v_s$ :**  $R_s \ll R_L$

## Norton Source with Load:



**Current divider:**  $i_o = i_s \frac{R_s}{R_s + R_L}$

**Condition for  $i_o \approx i_s$ :**  $R_s \gg R_L$

**Important**

Source resistance  $R_s$  limits signal delivery to the load!

# Signal Loss Due to Source Resistance

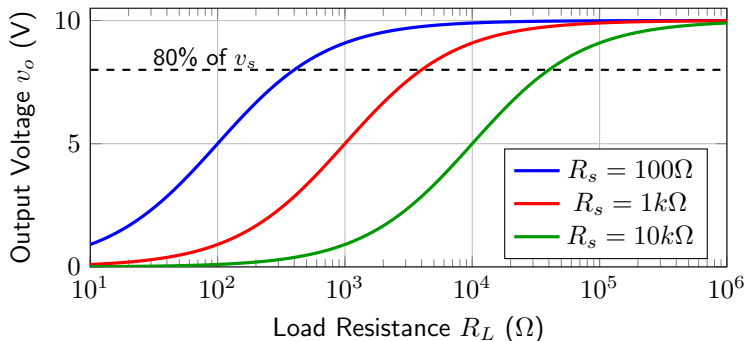


Figure 4: Thevenin source: output voltage vs. load resistance ( $v_s = 10V$ )

## Design Insight

Higher  $R_s$  requires higher  $R_L$  to minimize signal loss

# Arbitrary Time-Domain Signals

ECEN 463/863

Maxx Seminario

What are  
Signals?

Signal Source  
Representations

Time-Domain  
Signal  
Representation

Frequency  
Spectrum

Summary

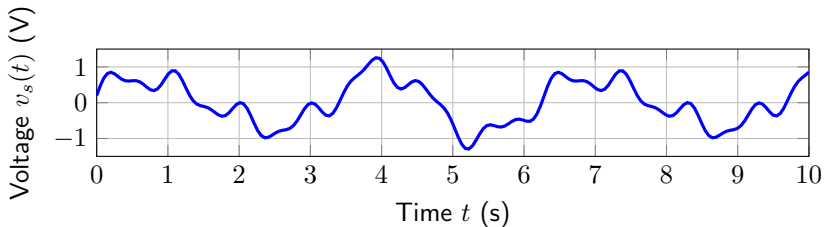


Figure 5: Example of an arbitrary voltage signal  $v_s(t)$

## Characteristics:

- Information in the “warbles”
- Difficult to describe mathematically

## The Challenge:

- How to process?
- How to design circuits?

## Solution

Frequency spectrum representation (Recall from Calculus: Fourier Series)

# The Sinusoid: Building Block of Signals

ECEN 463/863

Maxx Seminario

What are  
Signals?

Signal Source  
Representations

Time-Domain  
Signal  
Representation

Frequency  
Spectrum

Summary

## Sine Wave Equation:

$$v_a(t) = V_a \sin(\omega t)$$

### Parameters:

- $V_a$ : Peak amplitude (V)
- $\omega$ : Angular frequency (rad/s)
- $f = 1/T$ : Frequency (Hz)
- $T$ : Period (s)

### RMS Value:

$$V_{rms} = \frac{V_a}{\sqrt{2}}$$

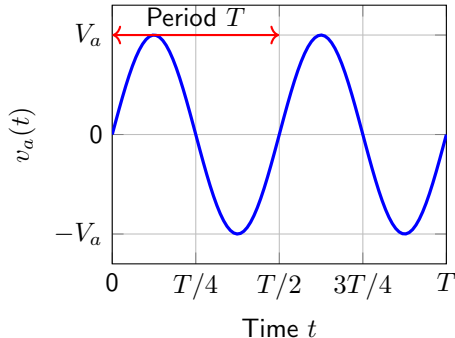


Figure 6: Sinusoidal voltage signal

### Key Concept

ANY signal can be represented as a sum of sinusoids



# Fourier Series: Periodic Signals

ECEN 463/863

Maxx Seminario

What are  
Signals?

Signal Source  
Representations

Time-Domain  
Signal  
Representation

Frequency  
Spectrum

Summary

**Concept:** Express periodic signals as sum of harmonically related sinusoids

**Square Wave Example:**

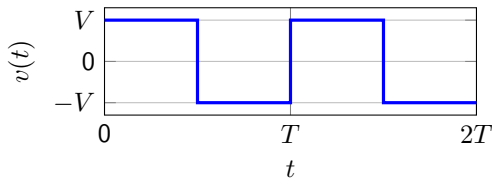


Figure 7: Symmetrical square wave

**Frequency Spectrum:**

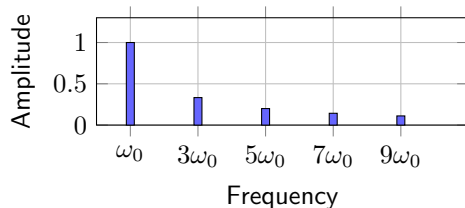


Figure 8: Line spectrum of square wave

**Fourier Series:**

$$v(t) = \frac{4V}{\pi} \left( \sin \omega_0 t + \frac{1}{3} \sin 3\omega_0 t + \frac{1}{5} \sin 5\omega_0 t + \cdots \right), \text{ where } \omega_0 = \frac{2\pi}{T} \text{ is the fund. freq.}$$

# Building a Square Wave from Sinusoids

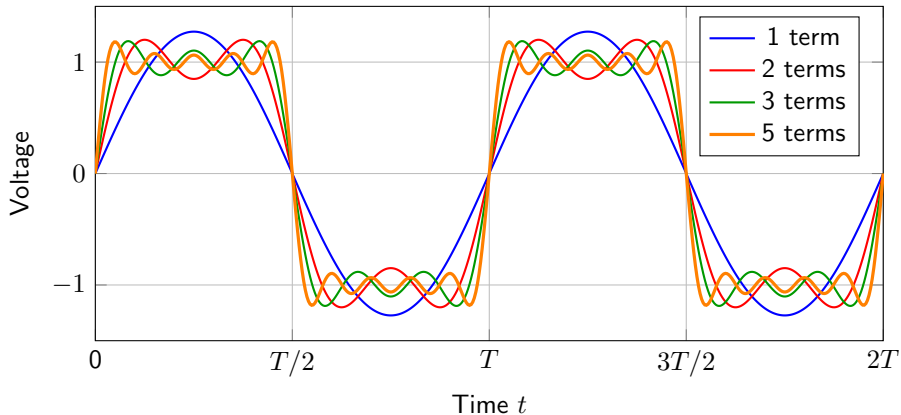


Figure 9: Fourier series approximation improves with more terms

# Fourier Transform: Nonperiodic Signals

ECEN 463/863

Maxx Seminario

What are  
Signals?

Signal Source  
Representations

Time-Domain  
Signal  
Representation

Frequency  
Spectrum

Summary

## For Nonperiodic Signals:

- Fourier Transform (not series)
- **Continuous** frequency spectrum
- Contains all frequencies
- Notation:  $v_a(t) \leftrightarrow V_a(\omega)$

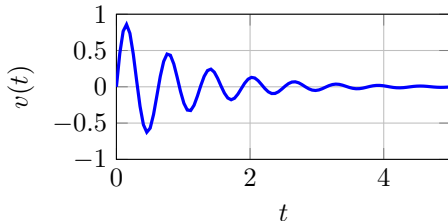


Figure 10: Nonperiodic signal

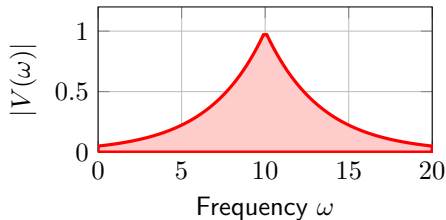


Figure 11: Continuous frequency spectrum

# Time vs. Frequency Domain

ECEN 463/863

Maxx Seminario

What are  
signals?

Signal Source  
Representations

Time-Domain  
Signal  
Representation

Frequency  
Spectrum

Summary

## Time Domain:

- Signal as  $v(t)$  vs. time
- Shows temporal behavior
- Direct measurement
- Oscilloscope view

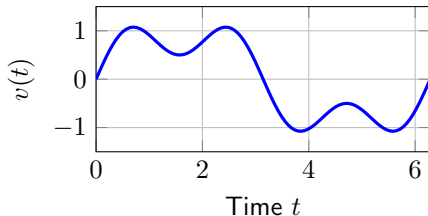


Figure 12: Time-domain representation

## Frequency Domain:

- Signal as  $V(\omega)$  vs. frequency
- Shows frequency content
- Reveals hidden components
- Spectrum analyzer view

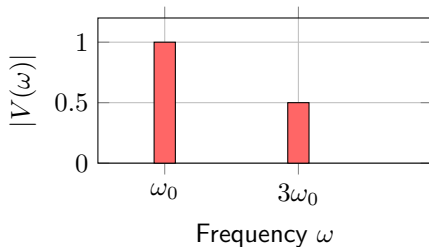


Figure 13: Frequency-domain representation

# Summary

ECEN 463/863

Maxx Seminario

What are  
Signals?

Signal Source  
Representations

Time-Domain  
Signal  
Representation

Frequency  
Spectrum

Summary

## Signals:

- Carry information
- Transducers convert to electrical
- Represented as voltage or current

## Signal Sources:

- Thevenin: voltage +  $R_s$
- Norton: current +  $R_s$
- Source resistance limits delivery

## Frequency Spectrum:

- Signals as sum of sinusoids
- Fourier series: periodic signals
- Fourier transform: nonperiodic
- Line vs. continuous spectra

## Two Representations:

- Time domain:  $v(t)$
- Frequency domain:  $V(\omega)$