Electronic Signals

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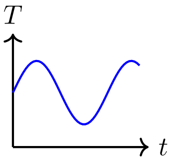
Signals: Information Carriers

Definition: Signals contain information about physical phenomena

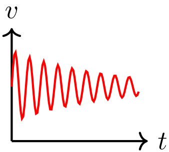
Weather:

- Temperature
- Pressure
- Humidity



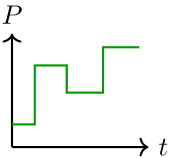
Audio:

- 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

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

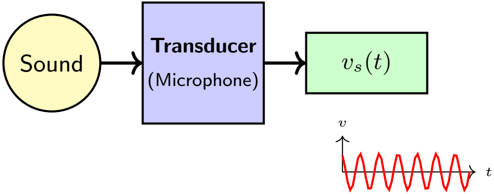


Figure 1: Transducer converts physical signal to electrical

Assumption in This Course

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

Thevenin and Norton Representations

Thevenin Form:

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

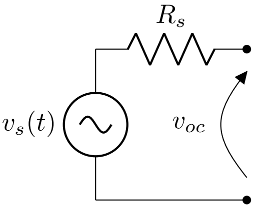


Figure 2: Thevenin equivalent circuit

Norton Form:

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

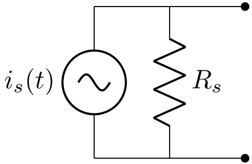


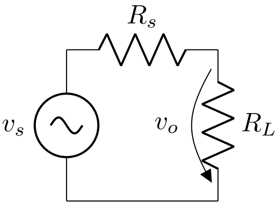
Figure 3: Norton equivalent circuit

Equivalence Condition

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

Source Resistance: The Imperfection

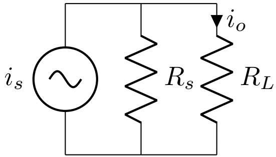
Thevenin Source with Load:



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

Condition for $v_o \approx v_s$: $\boxed{R_s \ll R_L}$

Norton Source with Load:



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

Condition for $i_o \approx i_s$: $\boxed{R_s \gg R_L}$

Important

Source resistance R_s limits signal delivery to the load!

Signal Loss Due to Source Resistance

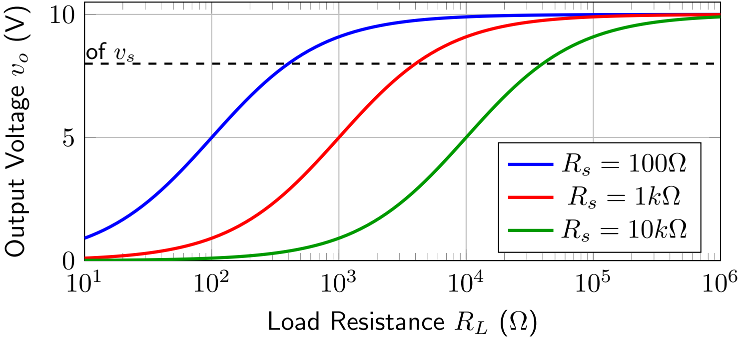


Figure 4: Thevenin source: output voltage vs. load resistance ($v_s = 10V$)

Design Insight

Higher R_s requires higher R_L to minimize signal loss

Arbitrary Time-Domain Signals

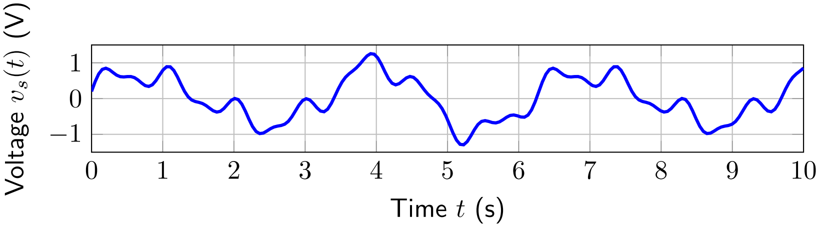


Figure 5: Example of an arbitrary voltage signal $v_s(t)$

Characteristics:

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

The Challenge:

- How to process?
- How to design circuits?

Solution

Frequency spectrum representation!

The Sinusoid: Building Block of Signals

Sine Wave Equation:

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

Parameters:

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

RMS Value:

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

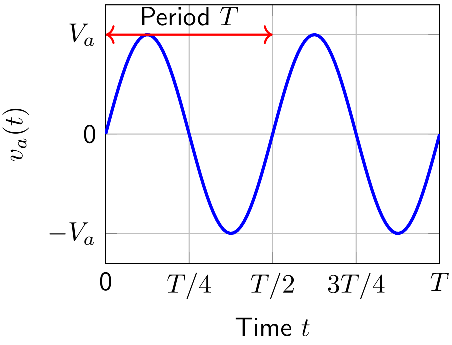


Figure 6: Sinusoidal voltage signal

Key Concept

ANY signal can be represented as a sum of sinusoids!

Fourier Series: Periodic Signals

Concept: Express periodic signals as sum of harmonically related sinusoids

Square Wave Example:

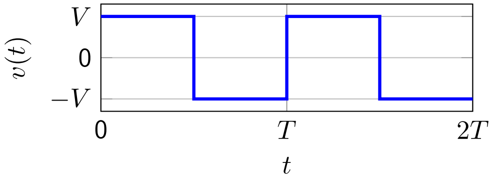


Figure 7: Symmetrical square wave

Frequency Spectrum:

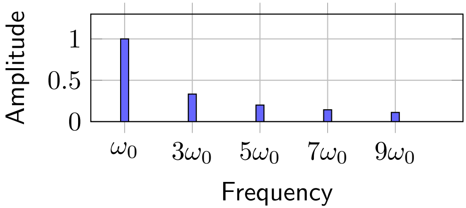


Figure 8: Line spectrum of square wave

Fourier Series:

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

Building a Square Wave from Sinusoids

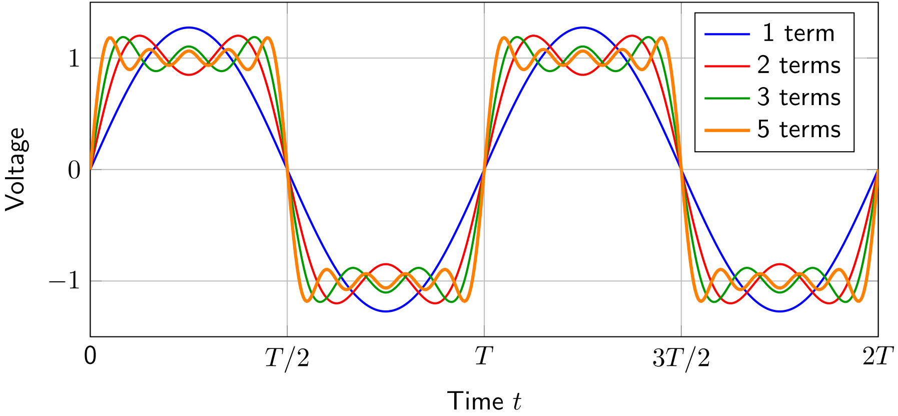


Figure 9: Fourier series approximation improves with more terms

Fourier Transform: Nonperiodic Signals

For Nonperiodic Signals:

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

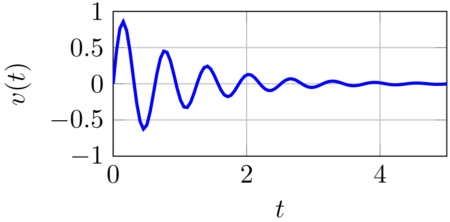


Figure 10: Nonperiodic signal

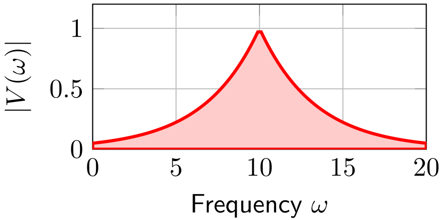


Figure 11: Continuous frequency spectrum

Time vs. Frequency Domain

Time Domain:

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

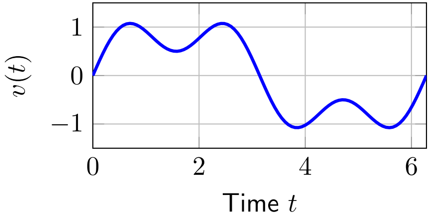


Figure 12: Time-domain representation

Frequency Domain:

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

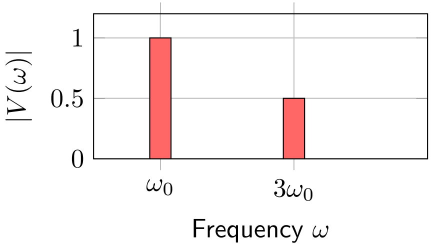


Figure 13: Frequency-domain representation

Summary: Key Concepts

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: $V(\omega)$