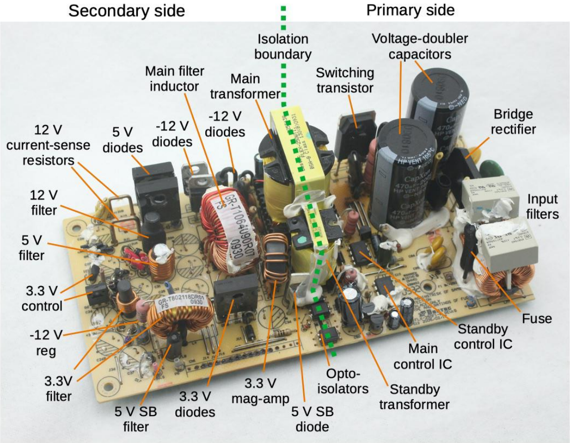


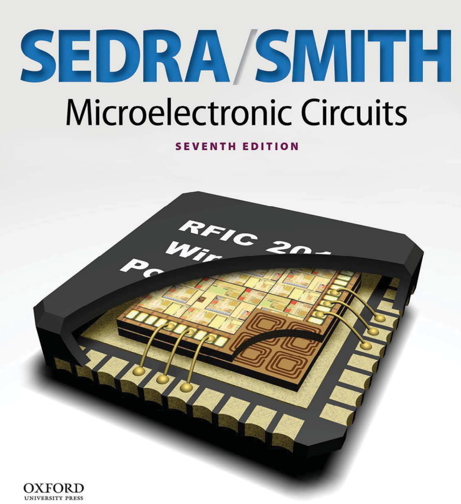
https://qiriro.com/epe2165/

Electrical signals

Kizito NKURIKIYEYEZU, Ph.D.

Readings

- **Read sections 1.1-1.3 (pages 6-16)**
- **Understand examples 1.1 on page 7**
- Do exercises 1.1, 1.5, 1.6, 1.14 on page 46



[1] Readings are based on Sedra & Smith (2014), Microelectronic Circuits 7th edition.
[2] Bold reading section are mandatory. Other sections are suggested but not required readings

Learning outcomes

- That electronic circuits alertprocess signals, and thus understanding electrical signals is essential to appreciating the material in this book.
- Review the Thevenin and Norton representations of signal sources.
- The representation of a signal as sum of sine waves.
- The analog and digital representations of a signal.

Signals and amplifiers

- Real-world signals are not electrical
- To extract required information from a set of signals, a signal must first be converted into an electrical signal by transducers
- The signals are also very weak and need to be amplified
- Example: A radio receiver (Fig. 1)'s antenna get very low power level, on the order of picowatts or femtowatts.
- To produce an audible signal, this signal to be amplified a trillion-fold.

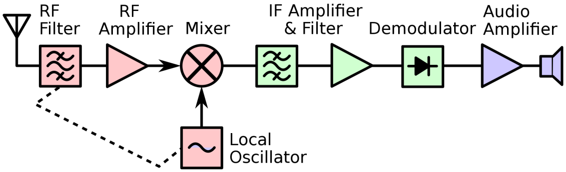


FIG 1. Diagram of a typical radio receiver[1]
Red parts are those that handle the incoming radio frequency (RF) signal; green are parts that operate at the intermediate frequency (IF), while blue parts operate at the modulation (audio) frequency. The dotted line indicates that the local oscillator and RF filter must be tuned in tandem.

[1] https://en.wikipedia.org/wiki/Superheterodyne_receiver

Electrical signals

- A signal contains information e.g. voice of a person (Fig. 2)
- Process —an operation which allows an observer to understand this information from a signal generally done electrically
- Transducer —device which converts signal from non-electrical to electrical form e.g. microphone (sound to electrical)

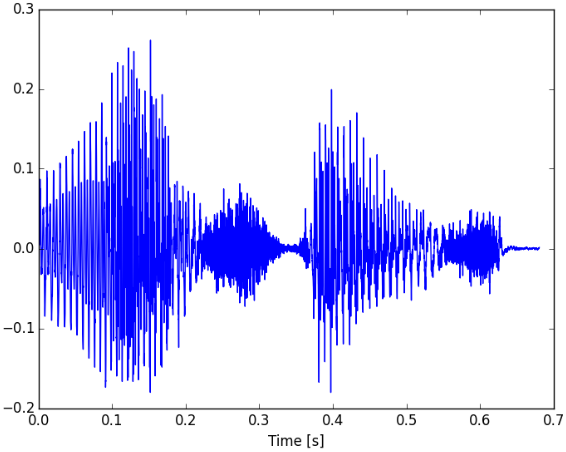
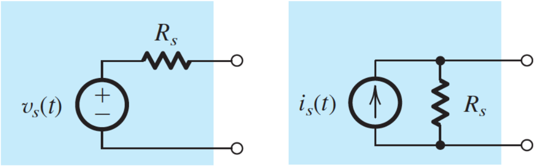


FIG 2. Signal representation of sound wave

Signal representation

- A an electrical signal can be represented by a voltage source or a current source.
- Thevenin form —voltage source $v_S(t)$ with series resistance R_S, preferable when R_S is low
- Norton form —current source $i_S(t)$ with parallel resistance R_S, preferable when R_S, is high
- In depth explanation in Example 1.1 on page 7 in the textbook

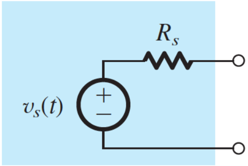


(a) Thevenin form (b) Norton form

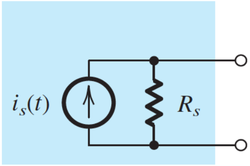
FIG 3. Two representations of a signal source

Example 1.1—Signal representation

- Consider the Thevenin and Norton form of the signal shown in Fig. 4
- Note that the output resistance of a source limits its ability to deliver a signal at full strength
  - What is the relationship between the source and output when maximum poweris delivered?
  - what are ideal values of R_S for norton and thevenin representations?
- In depth explanation in Example 1.1 on page 7 in the textbook



(a) Thevenin form



(b) Norton form

FIG 4. Two representations of a signal source

Frequency spectrum of signals

- A sine-wave signal is completely characterized by its peak value V_a, its frequency ω, and its phase.
- Frequency spectrum —defines the a time-domain signal in terms of the strength of harmonic components
- Harmonics components undesirable distortion of a sinusoidal waveform by waveforms of different frequencies which deviate it from sinusoidal waveforms

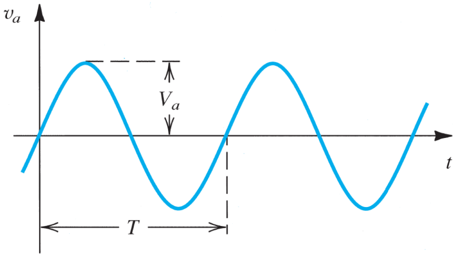


FIG 5. Sine-wave voltage signal of amplitude V_a and frequency $f = 1/T$ Hz. Angular frequency $\omega = 2\pi f$ rad/s

Fourier series

- Fourier series allow to express any signal as the sum of an infinite number of sinusoids whose frequencies are harmonically related
- For instance, the symmetrical square-wave signal in Fig. 6 can be expressed by Equation (1)

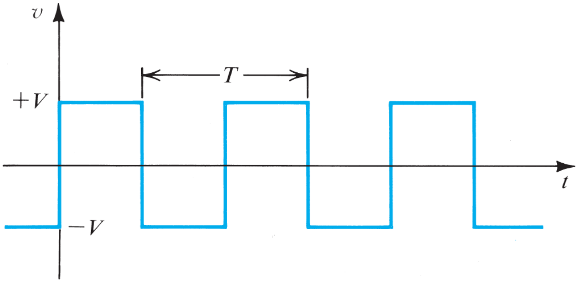


FIG 6. A square-wave signal of amplitude V

$$v(t) = \frac{4V}{\pi}\left(\sin(\omega_0 t) + \frac{1}{3}\sin(3\omega_0 t) + \frac{1}{5}\sin(5\omega_0 t)\right) \quad (1)$$

Analog and digital signals

- analog signal —is continuous with respect to both value and time
- discrete-time signal —is continuous with respect to value but sampled at discrete points in time
- digital signal —is quantized as well as sampled at discrete points in time

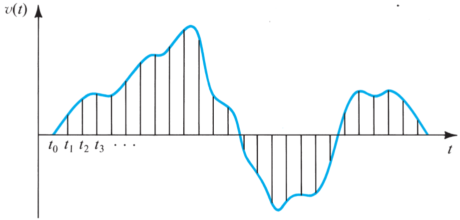


FIG 7. Sampling an analog signal

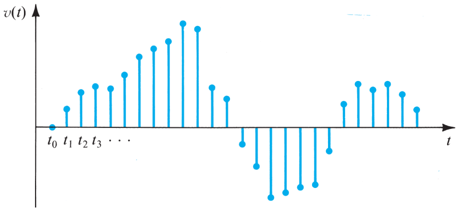


FIG 8. Resulting discrete-time signal

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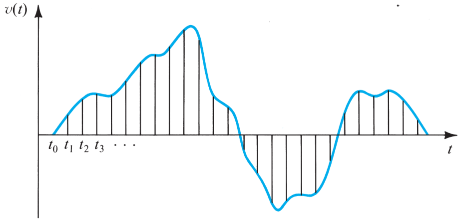

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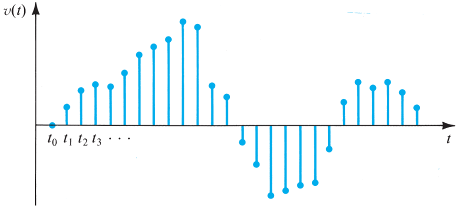

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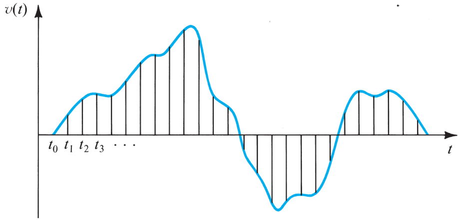

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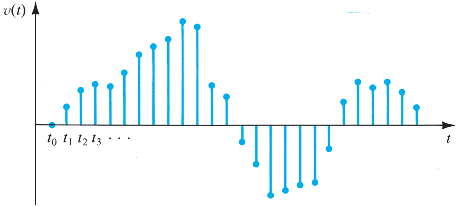


FIG 8. Resulting discrete-time signal

Digital data acquisition process

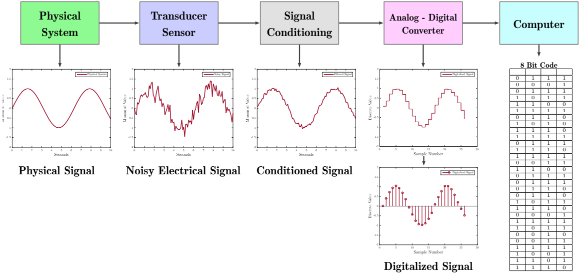
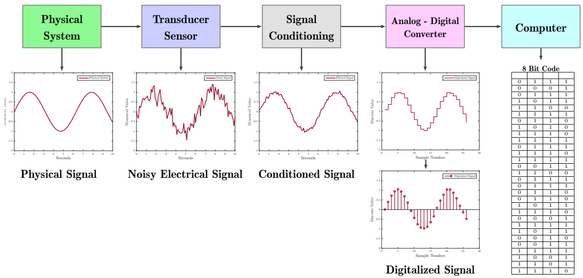


FIG 9. Digital data acquisition system[1]

[1] https://en.wikipedia.org/wiki/Data_acquisition

[2] https://www.allaboutcircuits.com/technical-articles/an-introduction-to-digital-signal-processing/

Digital data acquisition process



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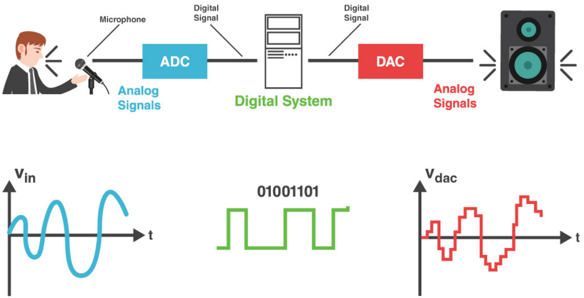

FIG 10. Analog to Digital Converters (ADC) and Digital to Analog Converters (DAC)[2]

[1] https://en.wikipedia.org/wiki/Data_acquisition

[2] https://www.allaboutcircuits.com/technical-articles/an-introduction-to-digital-signal-processing/

The end