

## Fundamentals of Microelectronics

- CH1 Why Microelectronics?
- CH2 Basic Physics of Semiconductors
- CH3 Diode Circuits
- CH4 Physics of Bipolar Transistors
- CH5 Bipolar Amplifiers
- CH6 Physics of MOS Transistors
- CH7 CMOS Amplifiers
- CH8 Operational Amplifier As A Black Box
- CH9 Cascodes and Current Mirrors
- CH10 Differential Amplifiers
- CH11 Frequency Response
- CH12 Feedback

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## Suggestions for You

- **Rigor and Intuition** → “Machinery” and “feel”
- **Analysis by Inspection**
  - Looking at a complex circuit, we wish to map it to a simpler topologies (a few lines of algebra)
- **Forty Pages per Week**
  - The lectures give you the “skeleton” of each chapter, you fill up the rest by reading and understanding each chapter
- **Forty Problems per Week**
  - The more you struggle with a problem, the more appealing the answer will be
- **Homeworks and Exams**
  - Do homeworks on your own first and then discuss them with others
- **Time Management**
  - At least 10 hours per week
- **Prerequisites**
  - Circuit theory

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## Chapter 1 Why Microelectronics?

- **1.1 Electronics versus Microelectronics**
- **1.2 Example of Electronic Systems**
  - Cellular Telephone
  - Digital Camera
  - Analog versus Digital
- **1.3 Basic Concepts**

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## Cellular Technology

Transmitter (TX)                      Receiver (RX)

(a)

(b)

- **An important example of microelectronics.**
- **Microelectronics exist in black boxes that process the received and transmitted voice signals.**

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### Digital Camera

(a) (b) (c)

- The front-end of the camera must convert light to electricity by an array (matrix) of “pixels”
- Each pixel provides a voltage proportional to the “local” light intensity

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### Digital Camera - Example

(a) (b) (c)

- A digital camera is focused on a chess board.
- Sketch the voltage produced by one column as a function of time
- The pixels in each column receive light only from the white squares.

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### Digital or Analog?

The figure shows two graphs of signals over time  $t$ . The top graph, labeled  $x_1(t)$ , shows a digital signal with a sharp rectangular pulse. A double-headed arrow above the pulse indicates a width of 10 ns. The bottom graph, labeled  $x_2(t)$ , shows an analog signal with a smooth, rounded pulse. A double-headed arrow above the pulse indicates a width of 1 ns.

- $X_1(t)$  is operating at 100Mb/s and  $X_2(t)$  is operating at 1Gb/s.
- A digital signal operating at very high frequency is very “analog”.

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### Signal Processing in a Typical System

The diagram shows a flow from left to right: 'Analog Signal' enters a box labeled 'Analog Processing', which then connects to a box labeled 'Analog-to-Digital Conversion', which finally connects to a box labeled 'Digital Processing and Storage'.

- The foregoing observations favor processing of signals in the digital domain.
- Digital cameras and CD recorders perform some analog processing and digital processing.

The diagram shows a hard disk with a read/write head positioned over a track. To the right, a signal waveform is shown over time  $t$ . The waveform is highly irregular and noisy. A vertical double-headed arrow next to the waveform indicates a signal amplitude of approximately 3 mV.

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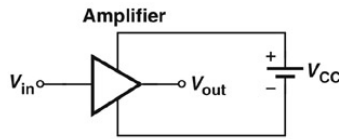
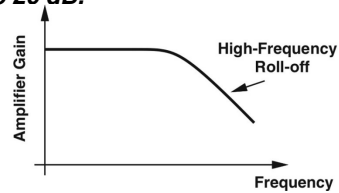
## Analog Circuits

- *The most commonly used analog function is amplification*
- *A voltage amplifier produces an output swing greater than the input swing.*
- *The voltage gain  $A_v$  is defined as*

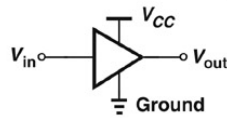
(linear scale)  $\rightarrow A_v = \frac{v_{out}}{v_{in}}$

(dB scale)  $\rightarrow A_{v,dB} = 20 \log_{10} \frac{v_{out}}{v_{in}}$

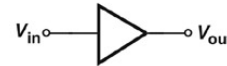
- *For example, a voltage gain of 10 translates to 20 dB.*
- *General amplifier symbols are shown below*



(a) CH1 Why Microelectronics?



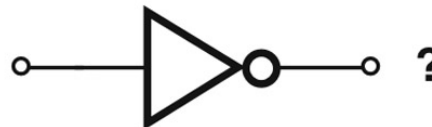
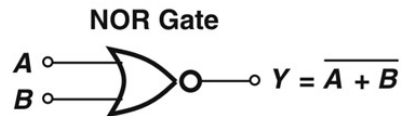
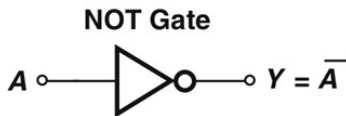
(b)



(c)

## Digital Circuits

- *In digital microelectronics, we study the design of the internal circuits of gates, flipflops, and other components.*
- *For example, we construct a circuit using devices such as transistors to realize the NOT and NOR functions shown below.*



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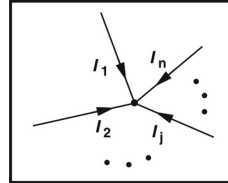
## Basic Circuit Theorems

➤ **How do we analyze circuits?**

➤ **Kirchoff's Laws**

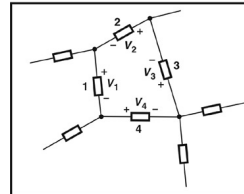
- **The Kirchoff Current Law (KCL)** states that the sum of all currents flowing into a node is zero (conservation of charge)

$$\sum_j I_j = 0$$



- **The Kirchoff Voltage Law (KVL)** states that the sum of voltage drops around any closed in a circuit is zero (conservation of energy)

$$\sum_j V_j = 0$$



Polarities of voltages and current?

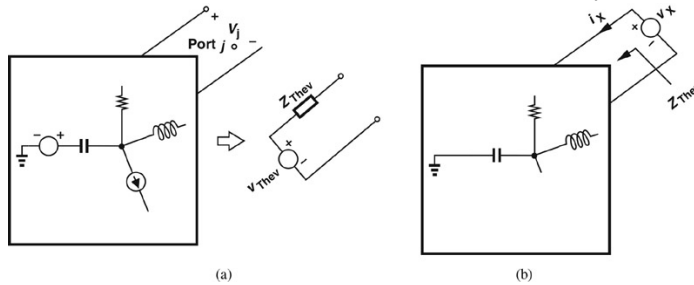
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## Thevenin and Norton Equivalents

➤ **The Thevenin Equivalent Circuit (TEC)** is a useful way of reducing complexity.

- If we have a complex circuit interacting with other circuits we may not want to look at all of the details inside the complex circuit



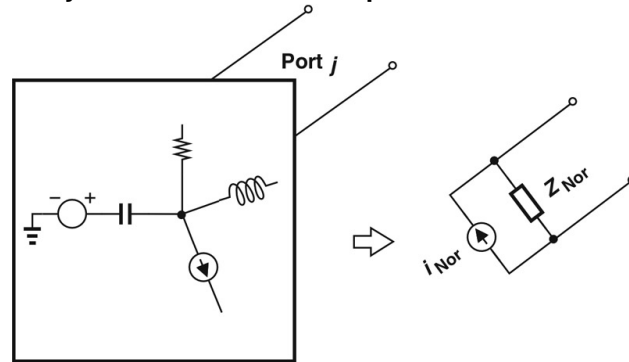
(a) Thevenin equivalent circuit (b) computation of equivalent impedance

- Thevenin's theorem states that a (linear) one-port network can be replaced with an equivalent circuit consisting of one voltage source in series with one impedance.

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## Norton's Theorem

- Norton's theorem states that a (linear) one-port network can be represented by one current source in parallel with one impedance.



- $i_{Nor}$  is determined by shorting the port of interest and computing the current that flows through it