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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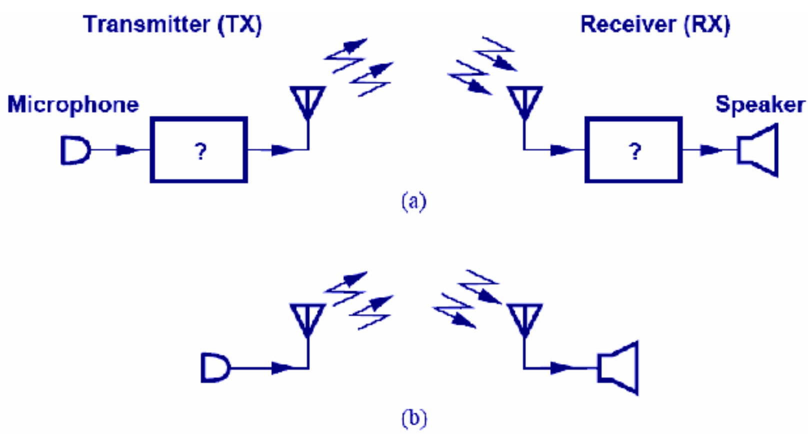
Chapter 1 Why Microelectronics?

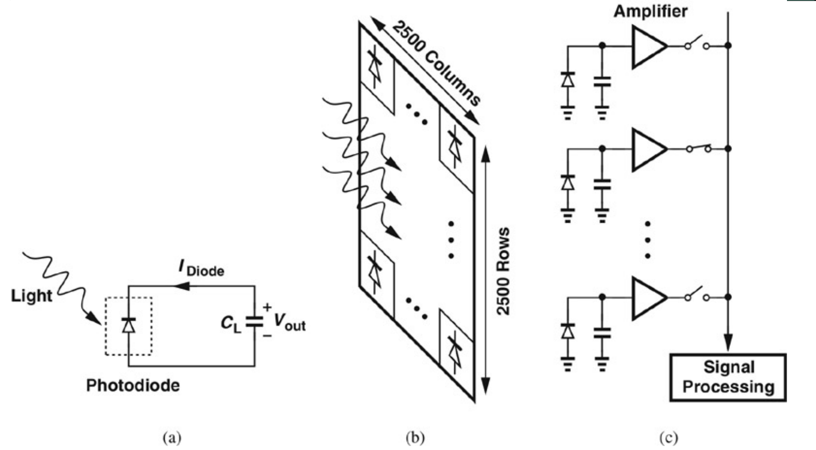
- 1.1 Electronics versus Microelectronics
- 1.2 Example of Electronic Systems
  - Cellular Telephone
  - Digital Camera
  - Analog versus Digital
- 1.3 Basic Concepts

Cellular Technology



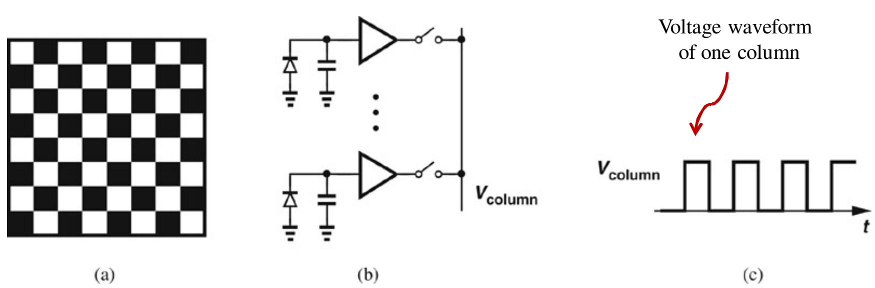
- An important example of microelectronics.
- Microelectronics exist in black boxes that process the received and transmitted voice signals.

Digital Camera



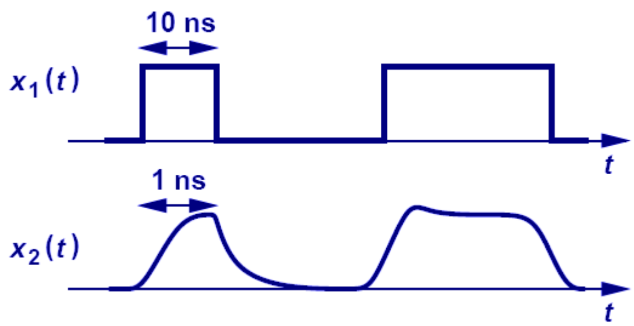
- The front-end of the camera must convert light to electricity by an array (matrix) of "pixels"
- Each pixel provides a voltage proportional to the "local" light intensity

Digital Camera - Example



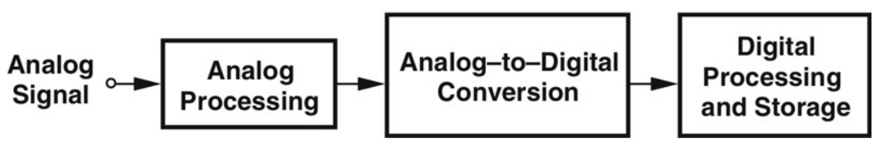
- *A digital camera is focused on a chess board.*
- *Sketch the voltage produced by one column as a function of time*
- *The pixels in each column receive light only from the white squares.*

Digital or Analog?

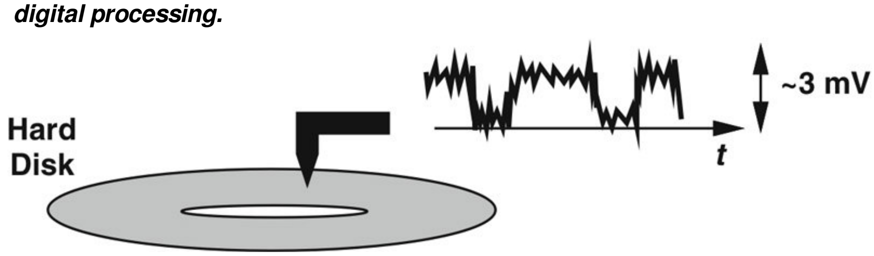


- *X1(t) is operating at 100Mb/s and X2(t) is operating at 1Gb/s.*
- *A digital signal operating at very high frequency is very "analog".*

Signal Processing in a Typical System



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



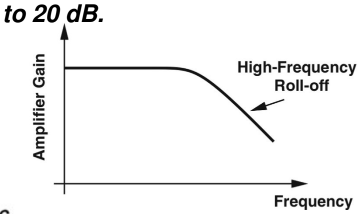
Analog Circuits

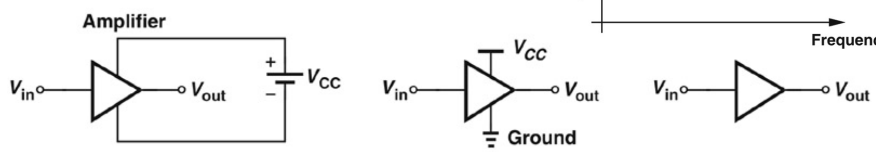
- ***The most commonly used analog function is amplification***
- ***A voltage amplifier produces an output swing greater than the input swing.***
- ***The voltage gain Av is defined as***

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

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

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

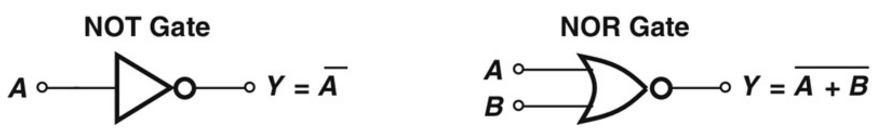


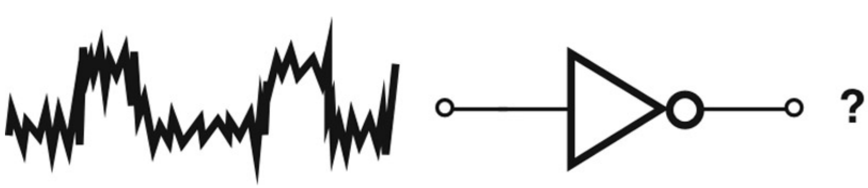


(a) (b) (c)

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.***

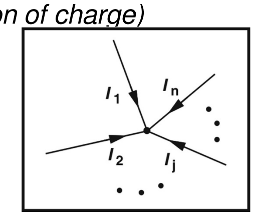




Basic Circuit Theorems

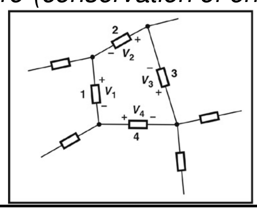
- ***How do we analyze circuits?***
- ***Kirchoff's Laws***
  - *The Kirchoff Current Law (KCL) states that the sum of all currents flowing into a node is zero (conservation of charge)*

$$\sum_j I_j = 0$$



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

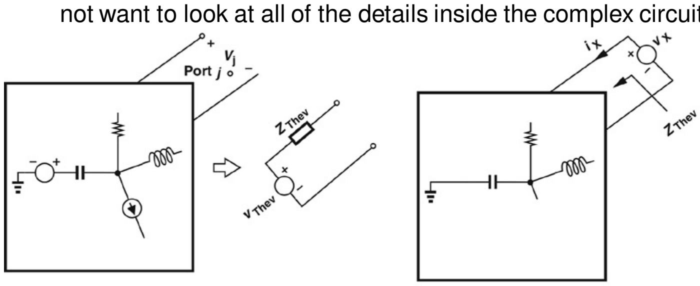
$$\sum_j V_j = 0$$



Polarities of voltages and current?

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



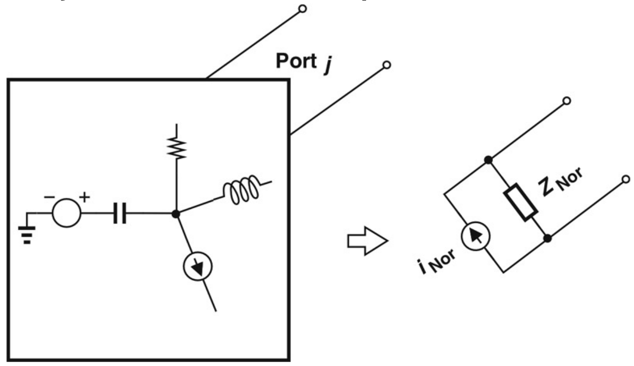
(a) (b)

(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.

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

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