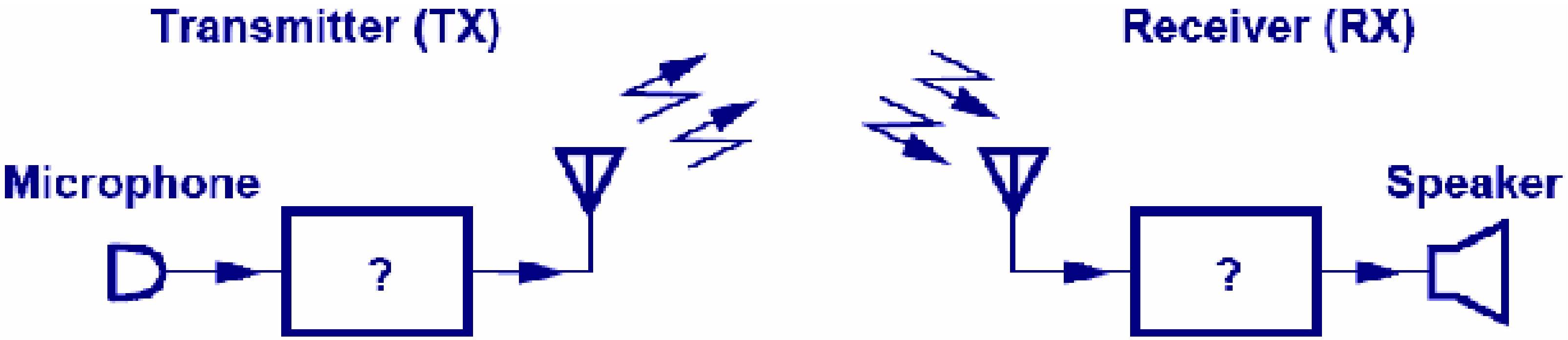
Fundamentals of Microelectronics

- 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
- CH16 Digital CMOS Circuits

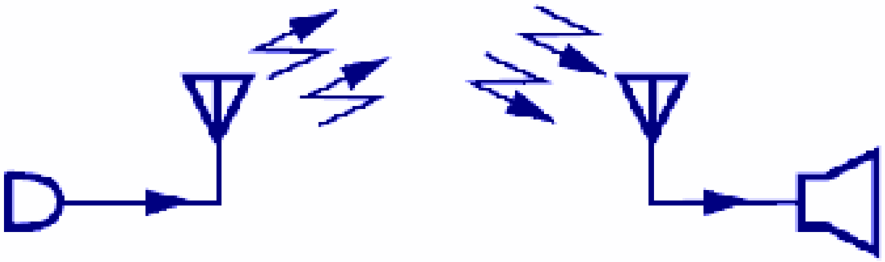
Chapter 1 Why Microelectronics?

- 1.1 Electronics versus Microelectronics
- 1.2 Example of Electronic System: Cellular Telephone
- 1.3 Analog versus Digital

Cellular Technology

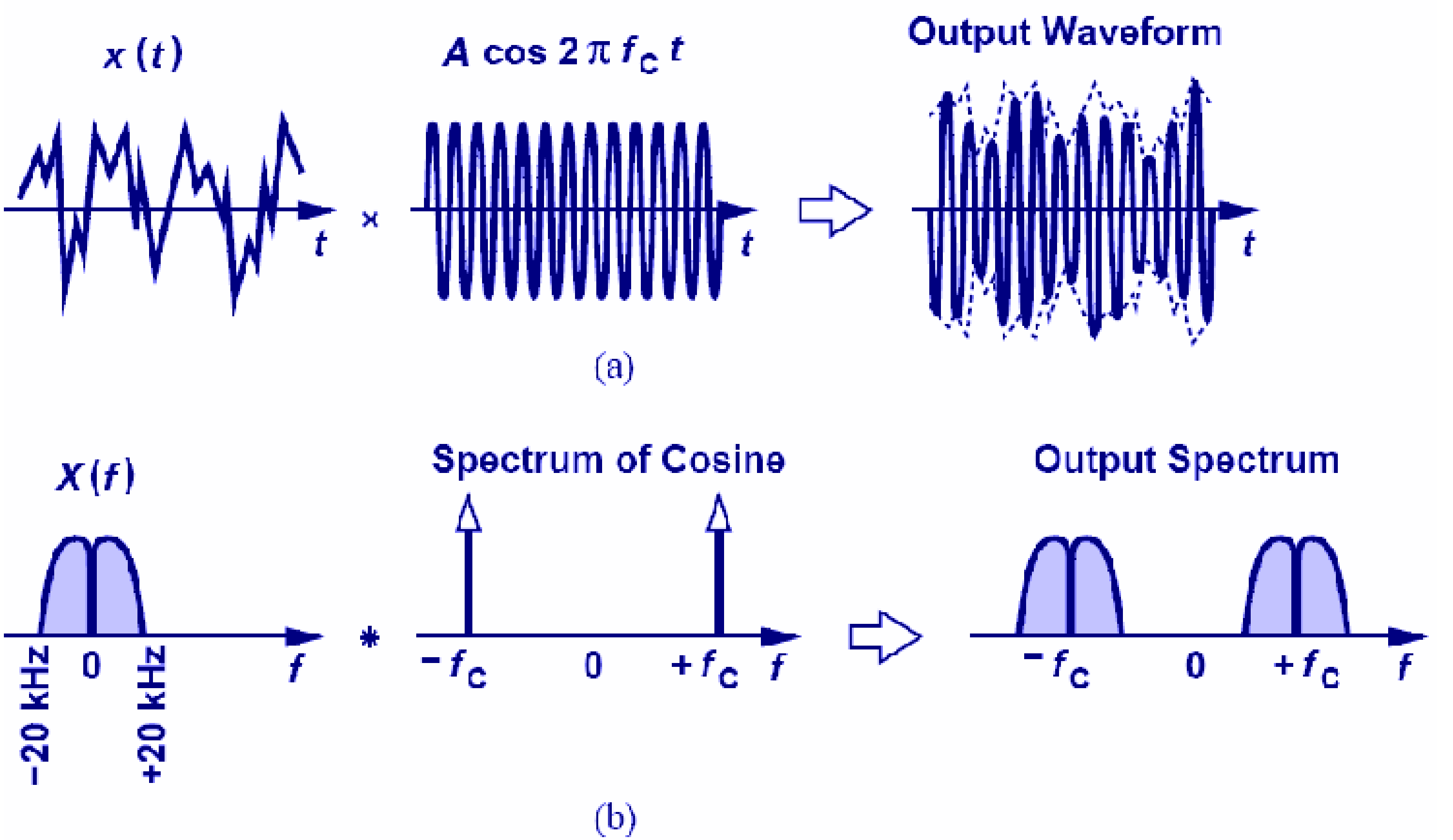


(a)


(b)

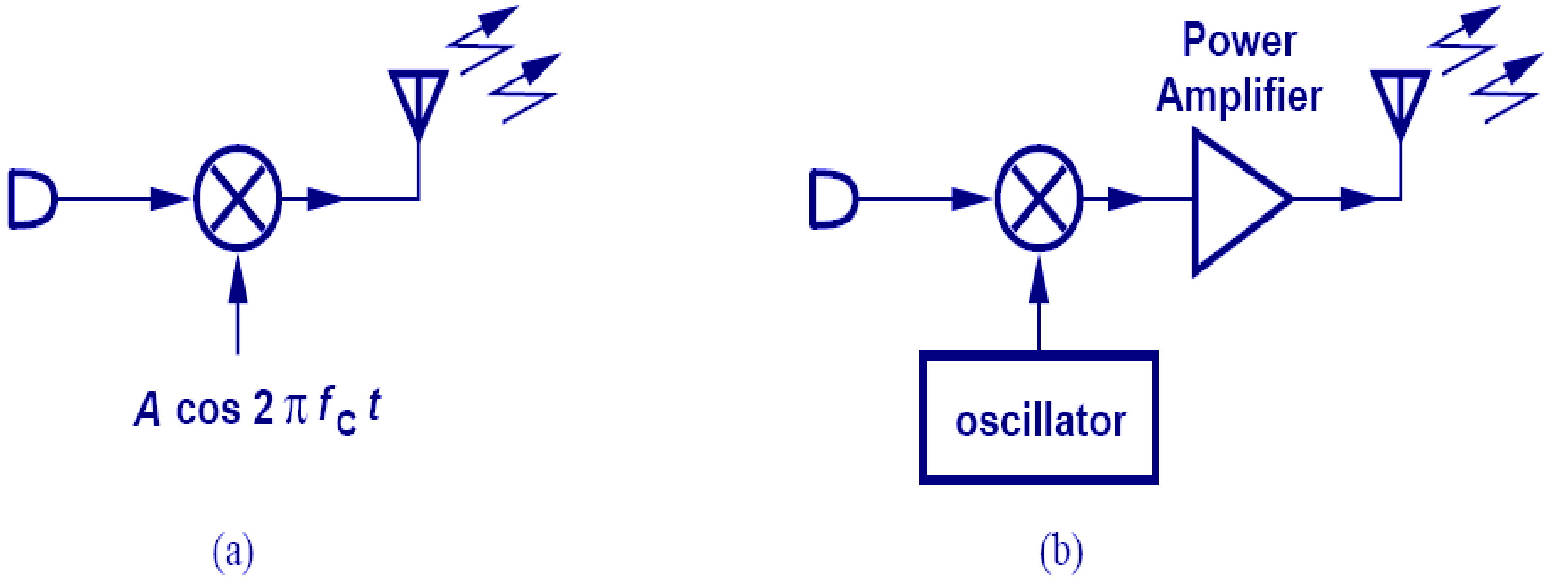
- An important example of microelectronics.
- Microelectronics exist in black boxes that process the received and transmitted voice signals.

Frequency Up-conversion



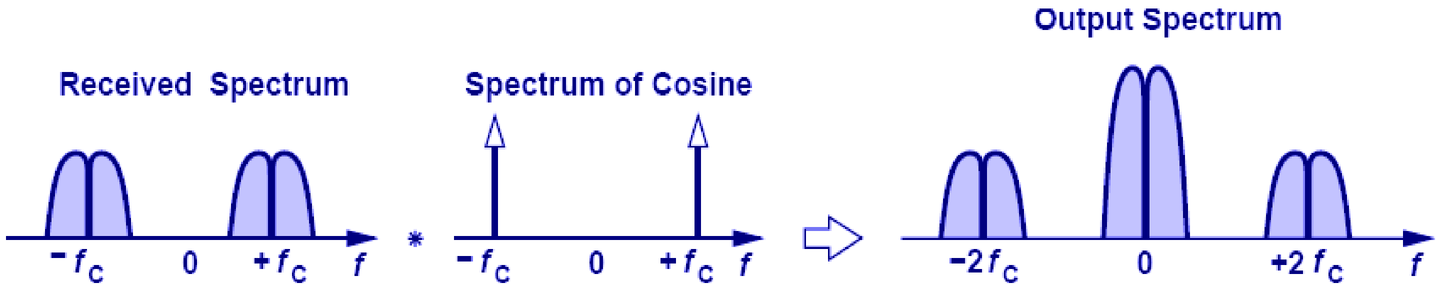
- Voice is "up-converted" by multiplying by sinusoidal carrier.
- When multiplied in time domain, their spectra are convolved in frequency domain.

Transmitter

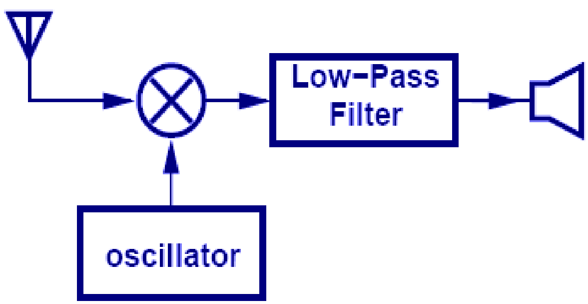


- Two signals are multiplied and radiated by an antenna in (a).
- A power amplifier is added in (b) to boost the signal.

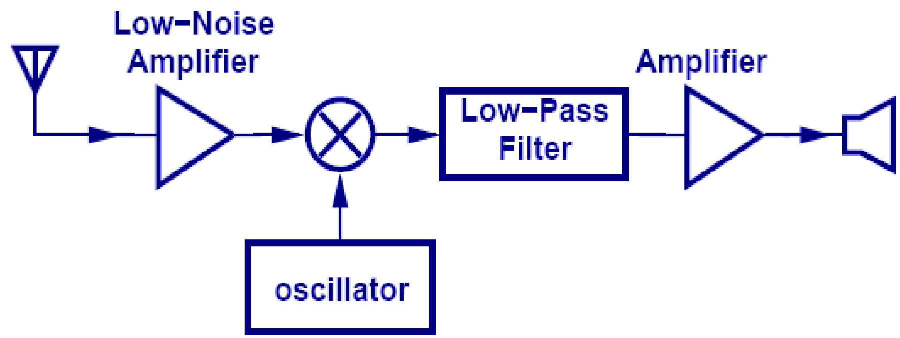
Receiver



(a)



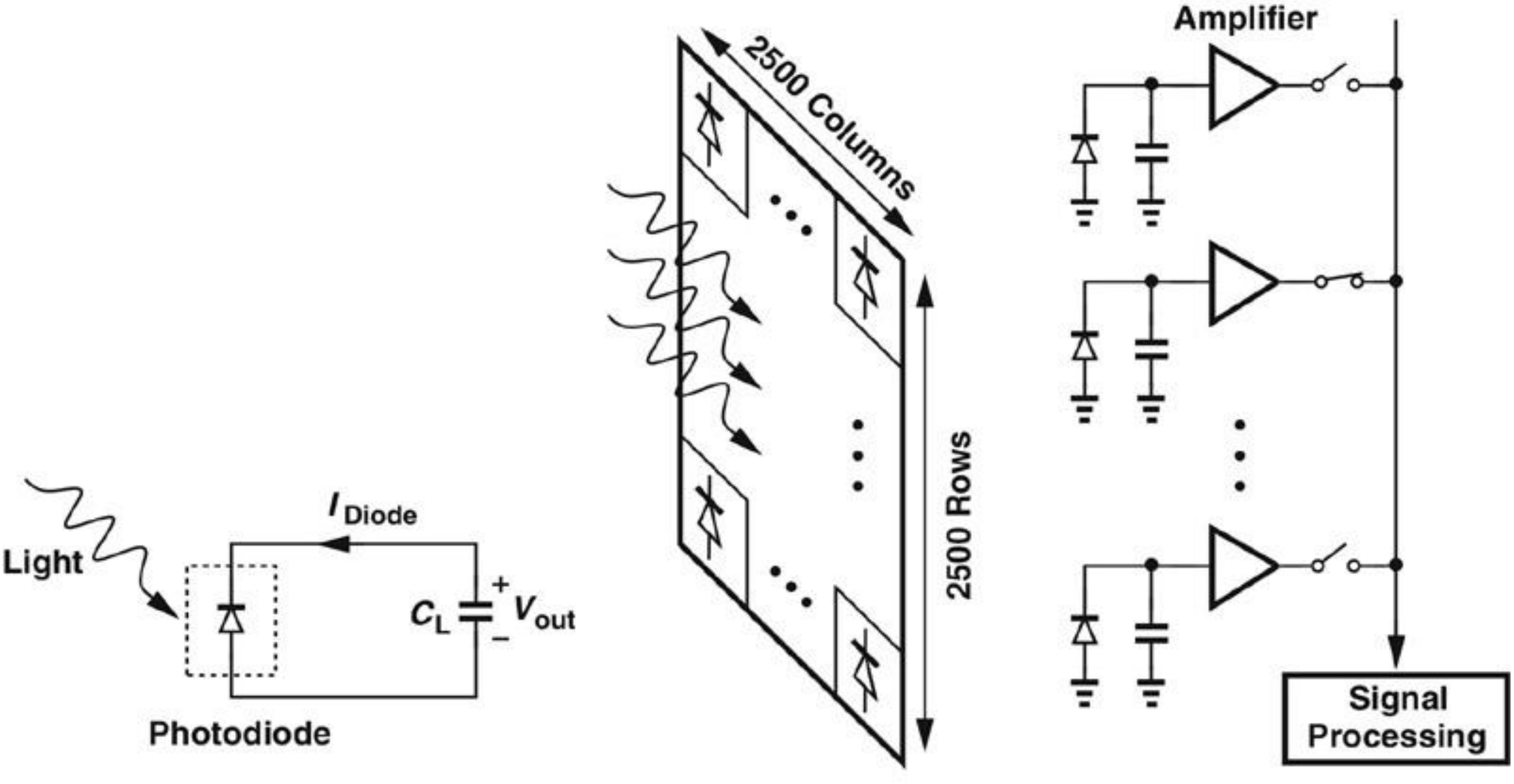
(b)



(c)

- **High frequency is translated to voice band by multiplying by f_C.**
- **A low-noise amplifier is needed for signal boosting without excessive noise.**

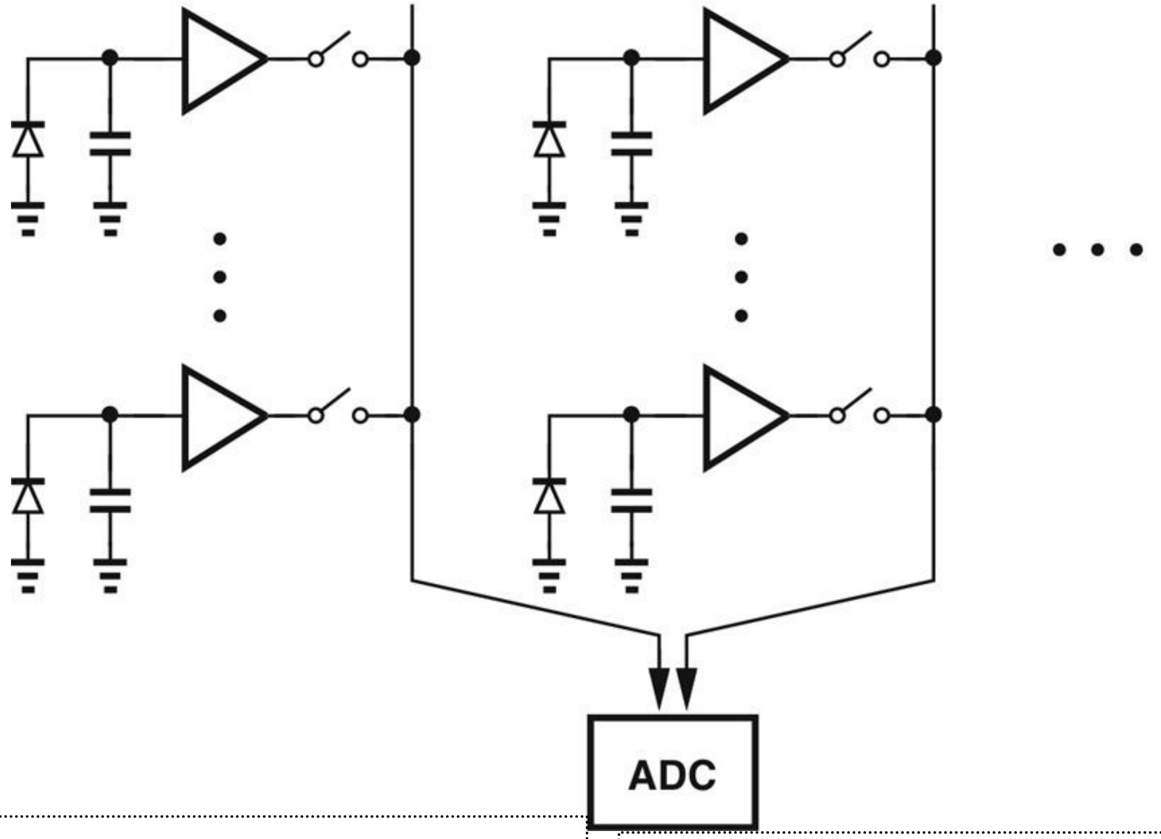
Digital Camera



(a) (b) (c)

- Operation of a photodiode
- Array of pixels in a digital camera
- One column of the array

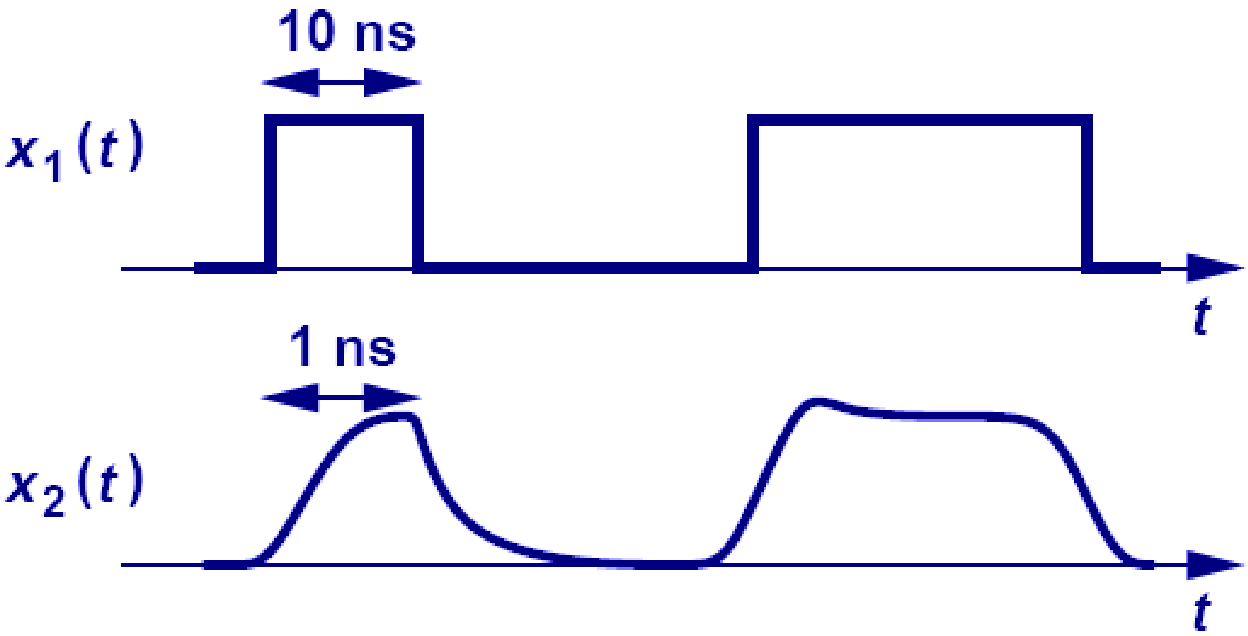
ADC in Digital Camera



- Sharing one ADC between two columns of a pixel array

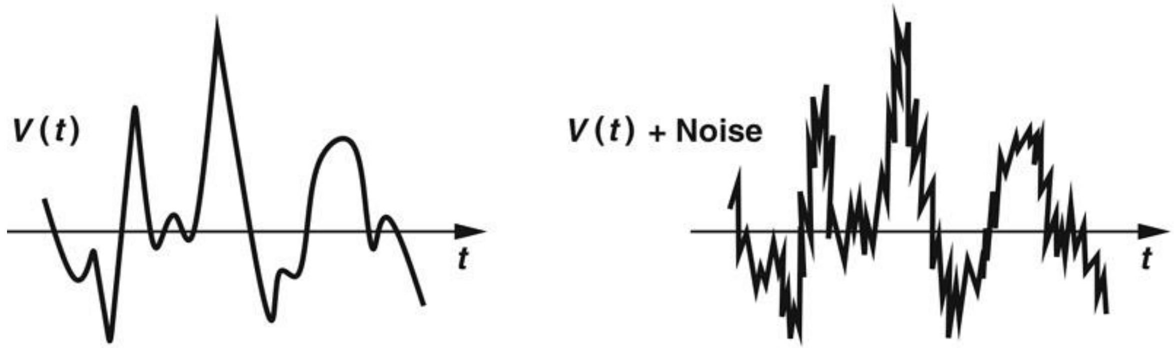
- Requiring the ADC to operate twice as fast

Digital or Analog?



- $X_1(t)$ 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".

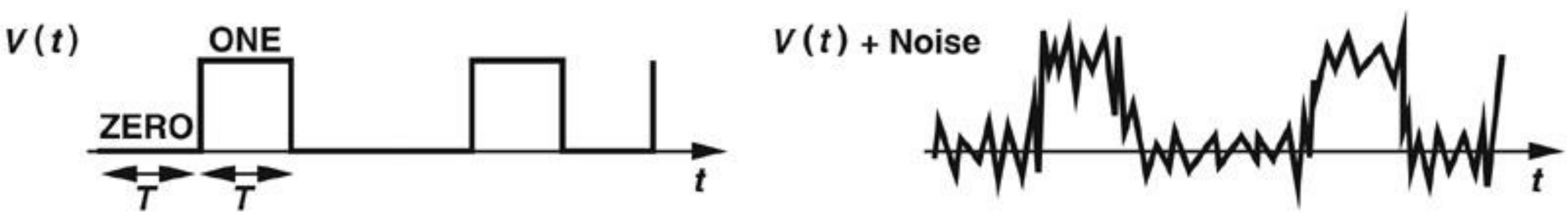
Analog and Digital Signals



(a) (b)

- Noisy analog signal
- Difficult to store

- An analog voltage waveform swings through a “continuum” of values and provides information at each instant of time

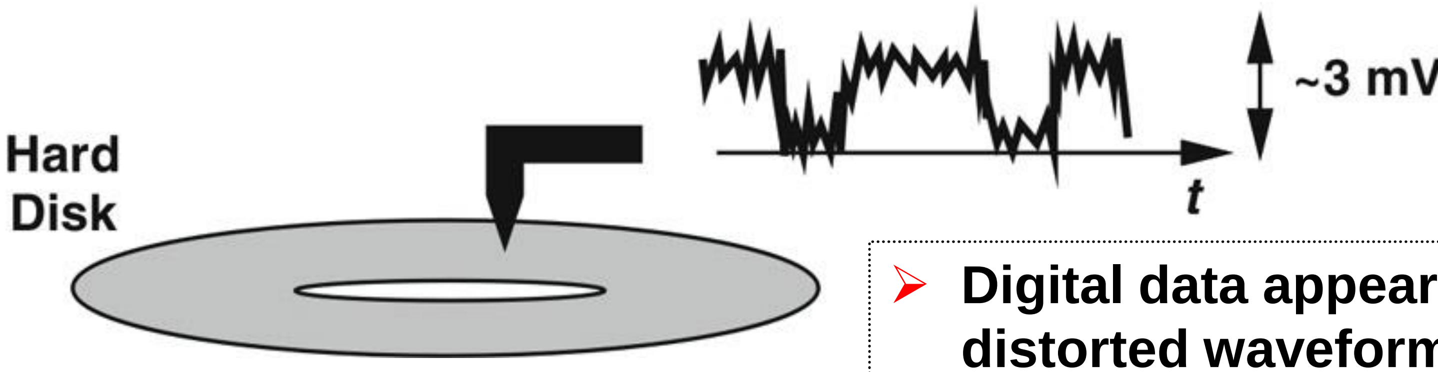


(a) (b)

- “binary” waveform → easy to store

- More robust than their analog counterparts

Digital Binary Signal Viewed as Analog Signal



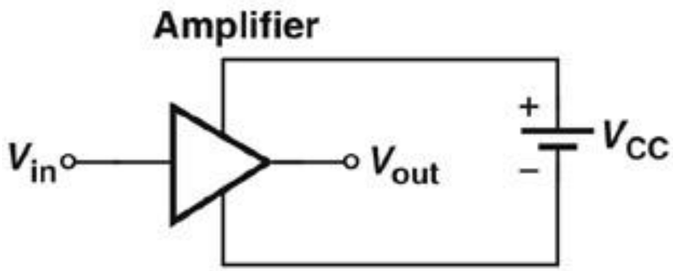
Signal picked up from a hard disk in a computer

- **Digital data appears as a distorted waveform with only a few millivolts of amplitude**

- **A great deal of amplification and other analog processing before the data reaches a robust digital form**

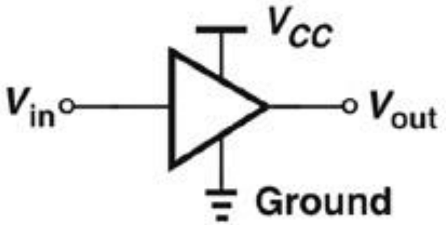
Analog Circuits: Amplification and Filtering

Amplification: voltage gain $A_v = \frac{v_{out}}{v_{in}}$, $\quad A_v\big|_{dB} = 20\log\frac{v_{out}}{v_{in}}$ in decibels (dB)



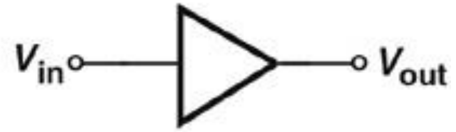
(a)

General amplifier symbol with its power supply



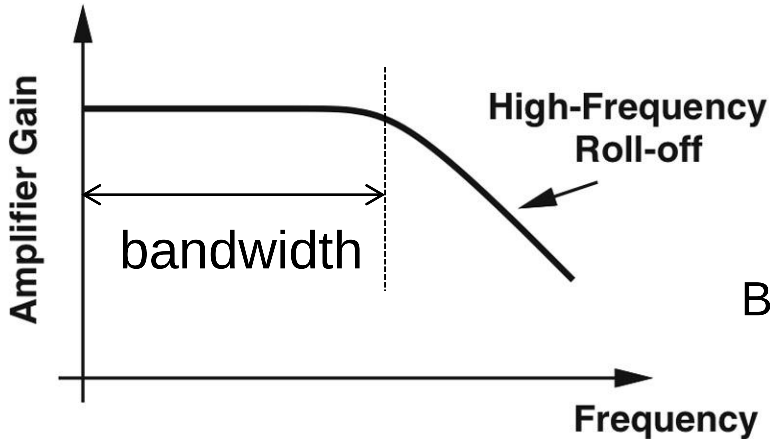
(b)

Simplified diagram of amplifier



(c)

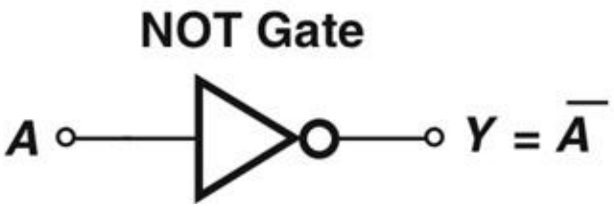
Amplifier with supply rails omitted

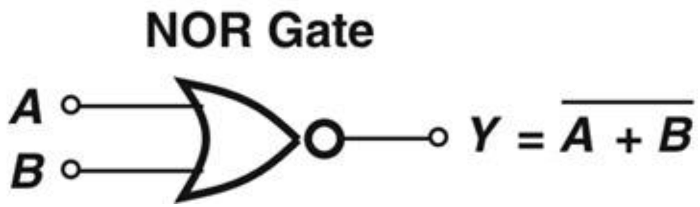


Bandwidth ~ 1/speed

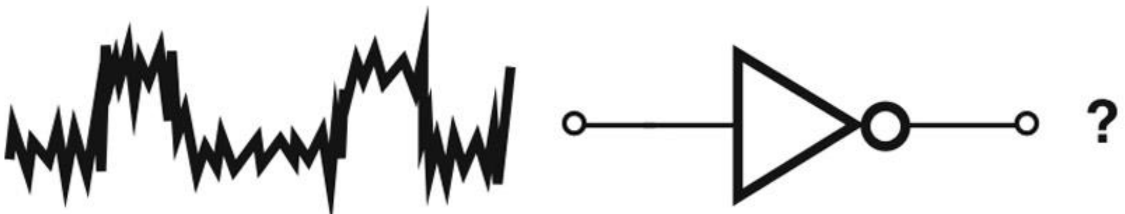
Digital Circuits

- Microprocessors, static and dynamic memories, and digital signal processors
- Complexity, speed, and power dissipation





- What speed? How much power? How robust?

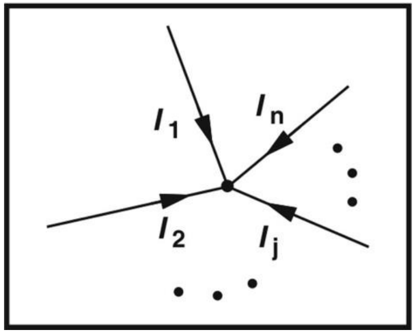


Noisy digital signal

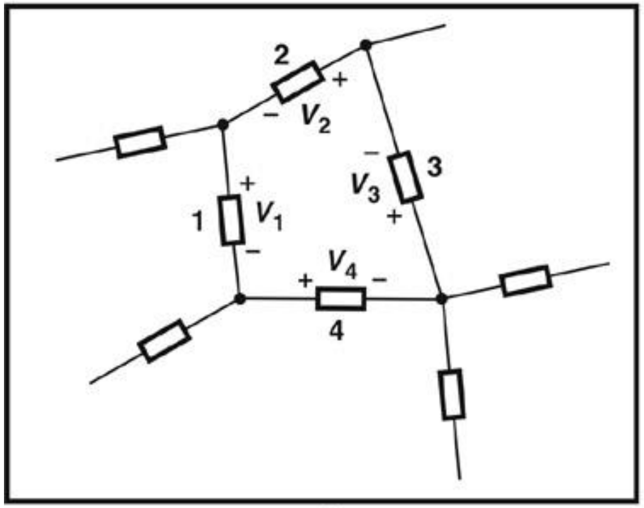
Basic Circuit Theorems

- **Kirchhoff's Laws**

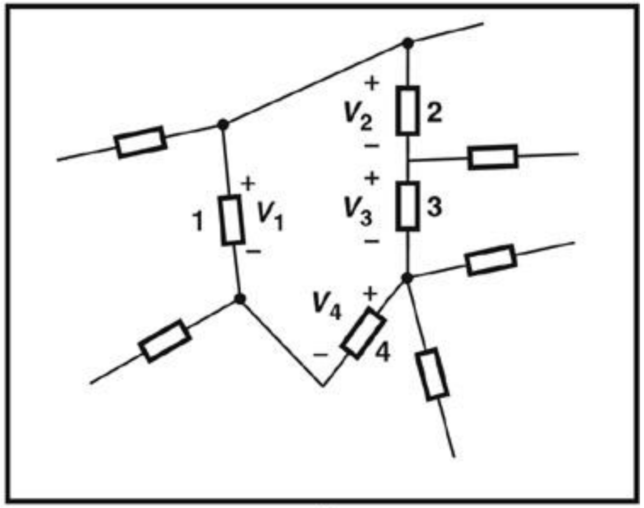
Kirchhoff Current Law (KCL): $\sum_j I_j = 0$



Kirchhoff Voltage Law (KVL): $\sum_j V_j = 0$



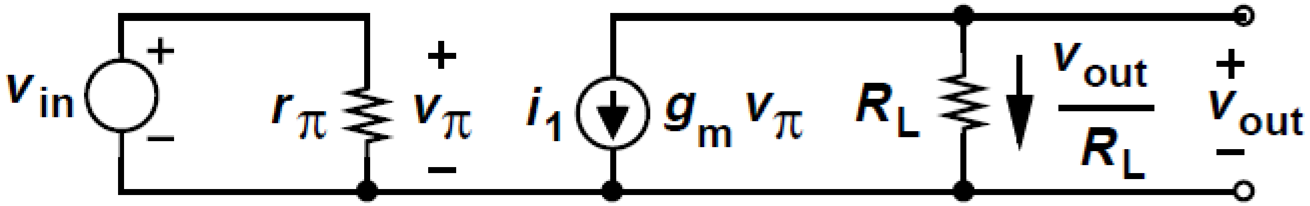
(a)



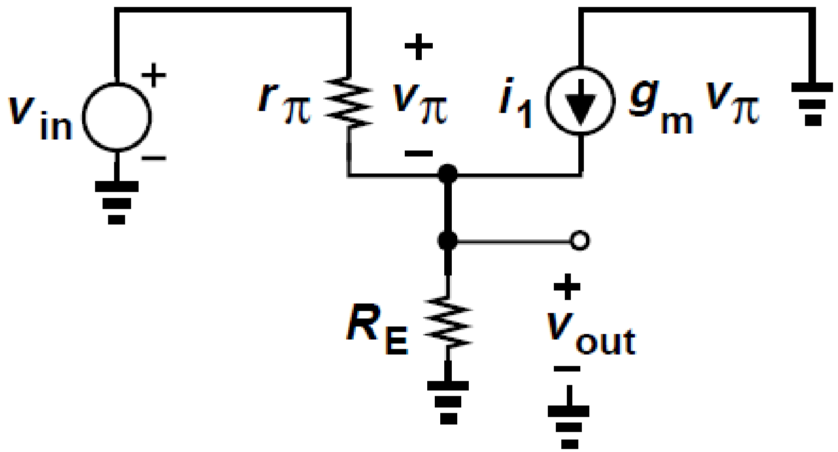
(b)

Determination of Voltage Gain

- **Derive the Voltage Gain: example 1.5**



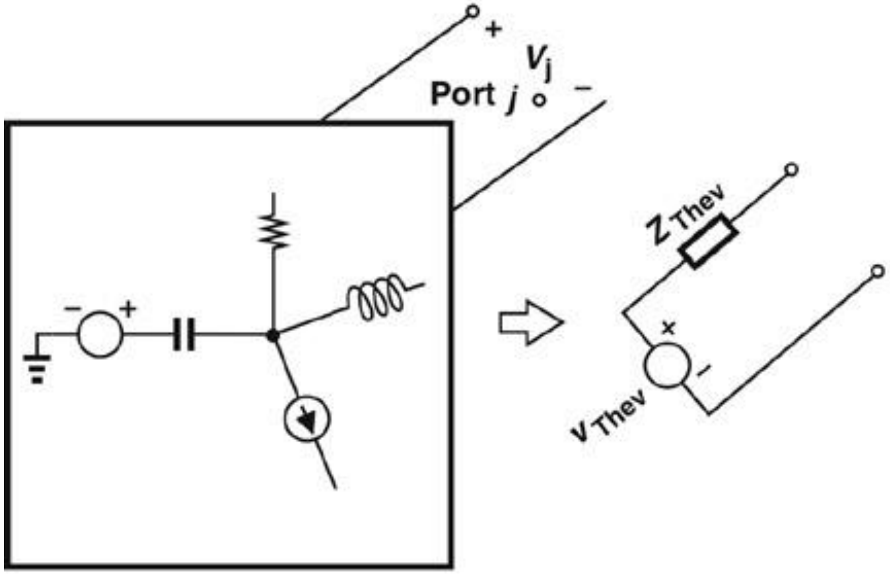
- **Derive the Voltage Gain: example 1.6**



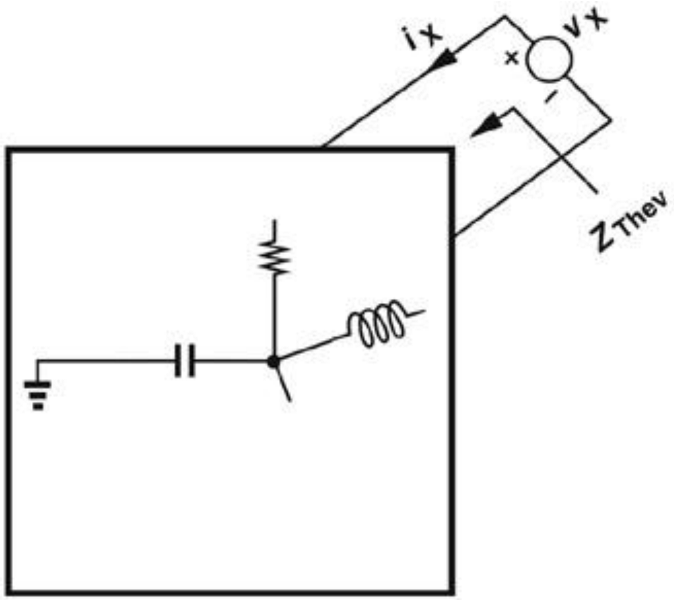
Basic Circuit Theorems

- **Thevenin Equivalents**

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



(a)



(b)

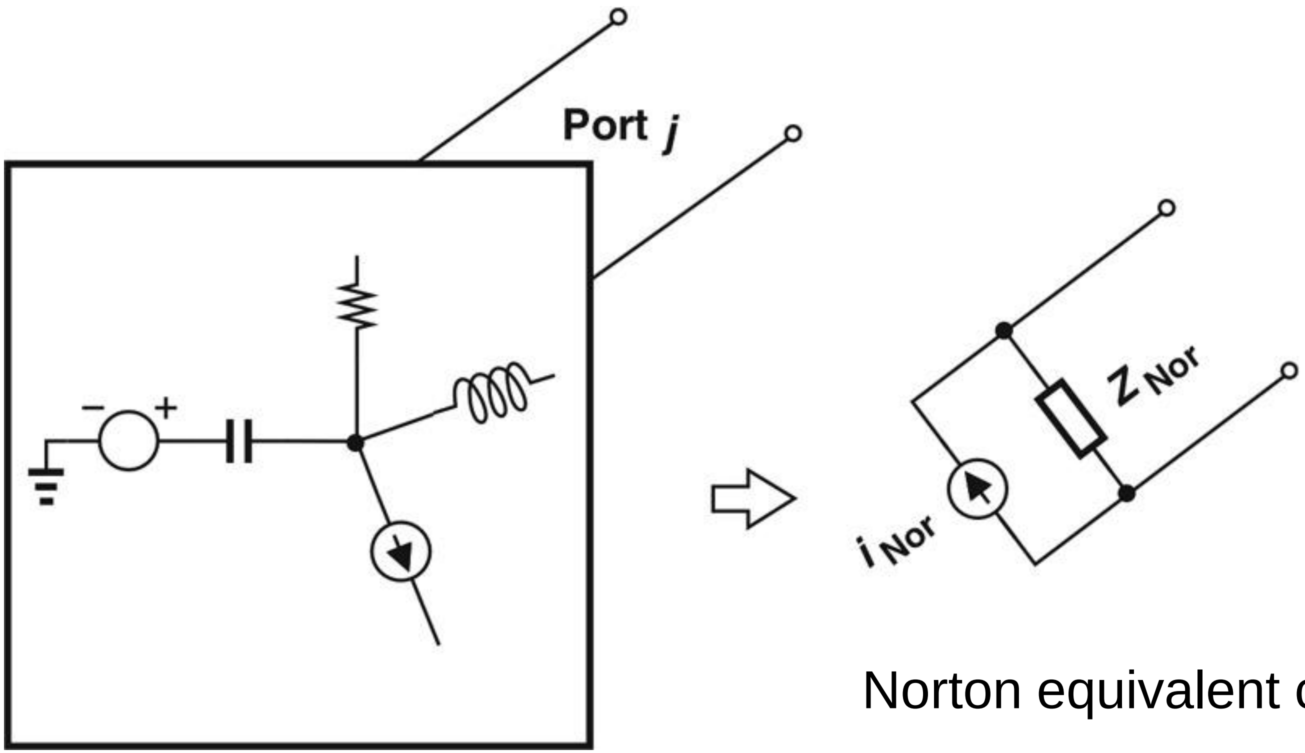
Thevenin equivalent circuit

Computation of equivalent impedance

Basic Circuit Theorems

- **Norton Equivalents**

➢ **Norton's theorem states that a one-port network can be replaced with an equivalent circuit consisting of one current source in parallel with one impedance**



Norton equivalent circuit

Cascade of Amplifiers

➢ **What is the overall gain of the two-stage amplifier?**