Modern Electronics Circuits
EC560
Lecture 1

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References

- **“The Design of CMOS Radio Frequency Integrated Circuits,” Thomas Lee, Cambridge University Press, 2nd Edition, 2004**
- **MIT Open Courseware (OCW), EE & CS, 6.776, “High Speed Communication Circuits”, H-S. Lee and M. Perrott, Spring 2005:**

http://ocw.mit.edu/courses/electrical-engineering-and-computer-scienc

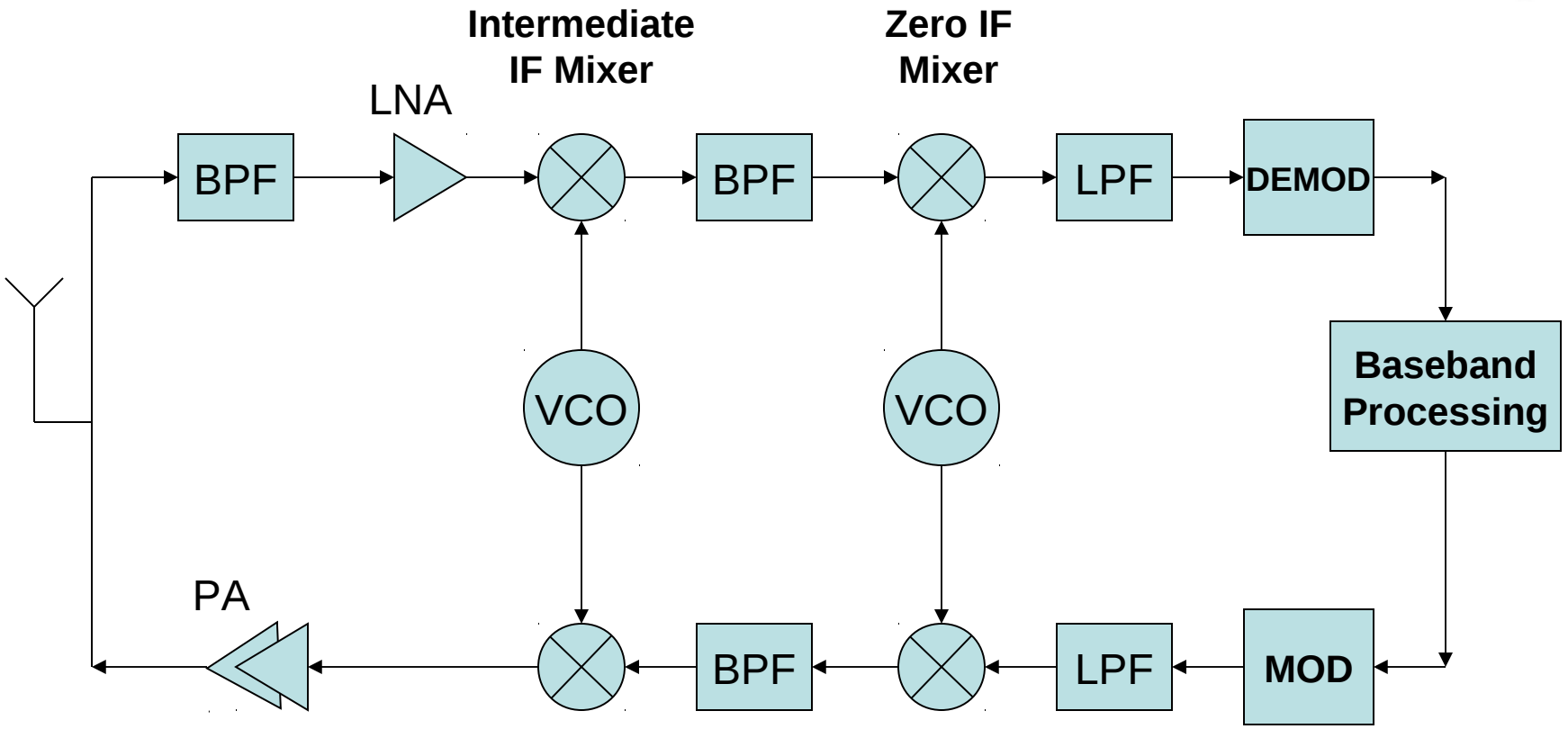
Introduction

- **Communications systems now include:**
  - **Personal: mobile phones CDMA, TDM**
  - **Data: Gigabit Ethernet, WiFi**
  - **Computing Systems: memory-CPU, hard disk serial bus (SATA), USB, graphics data bus**
  - **Consumer: High Definition TV, digital satellite receiver, TV over mobile phone**
- **All these systems share the same concepts, and differ only in method of implementation at some blocks (such as modulation technique, transmission medium, clocking techniques, …)**

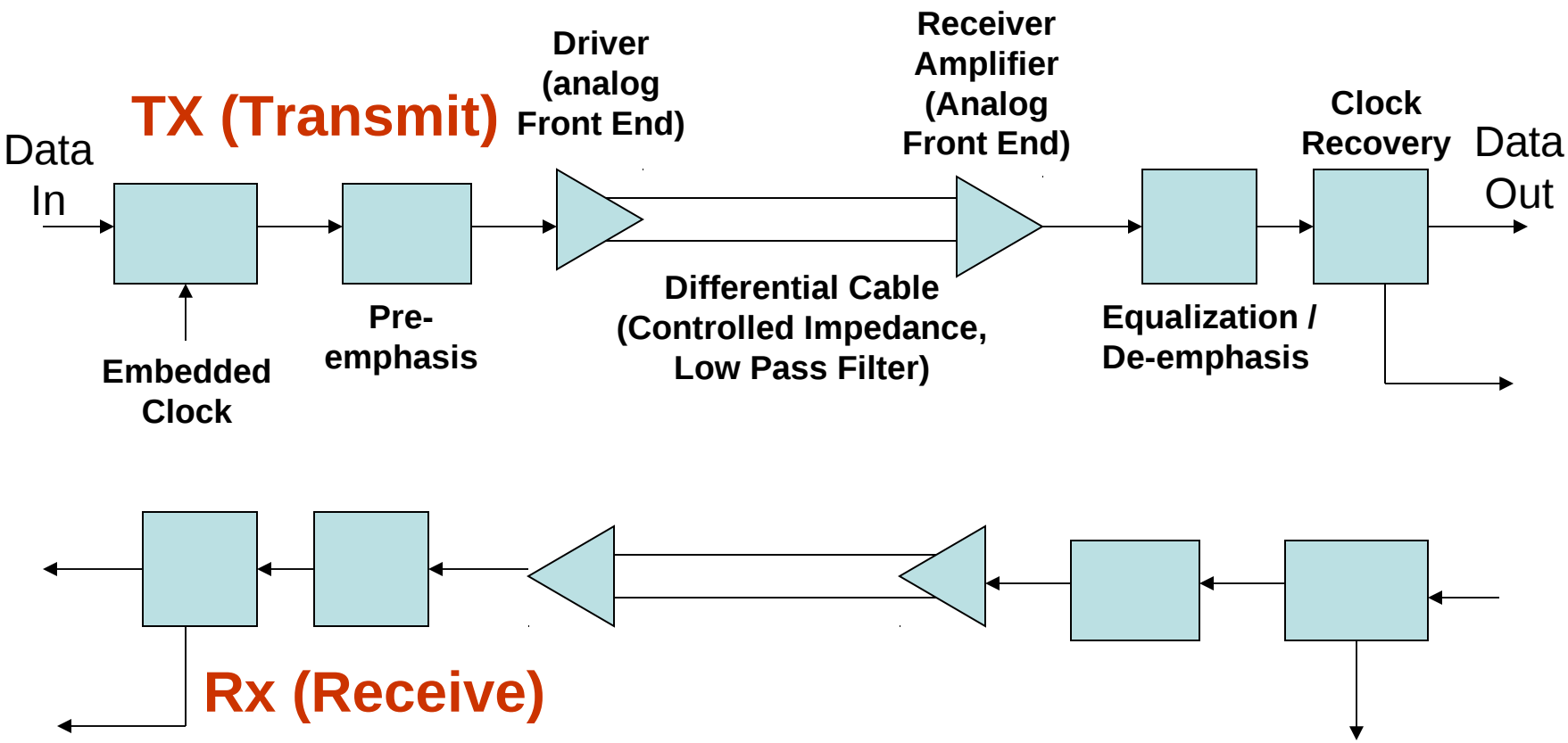
Building Blocks

- Mixers: Up-Converters and Down-Converters
- Voltage Controlled Oscillators (VCO)
- Phase Locked Loops (PLL)
- Low Noise Amplifiers (LNA)
- Power Amplifiers (PA)
- Serial Links - Physical Layer - (PHY):
  - Wired: Low Voltage Differential Signaling (LVDS)
  - Wireless: Antennas
- Serial Links (Data Layer):
- Modulators and Demodulators
- Power Supplies

Wireless Transceiver Architecture



“Wired” High Speed Serial Links: Low Voltage Differential Signaling (LVDS)



Sometimes Transmit & Receive use same cable

Building Blocks: Phase Locked Loop (PLL)

- **Local Oscillator (LO) needs to have:**
  - **Same Frequency as incoming signal**
  - **Predetermined phase (0, 90 deg, …) as incoming signal**
- **Multiplication Equation:**

$$A\cos(\omega_1 t) * B\cos(\omega_2 t) = (1/2)\,AB\,[\cos(\omega_1-\omega_2)t + \cos(\omega_1+\omega_2)t]$$

- **Any added phase $(\omega t + \phi)$ or frequency drift $(\omega+\Delta)t$ will alter this equation**
- **PLL acts on error with incoming signal to "lock" frequency & phase**
- **Used also for clock synchronization and extraction in serial links**

Building Blocks: Voltage Controller Oscillators (VCO)

- **Local Oscillator (LO) needs to track original signal:**
  - **Same Frequency as incoming signal**
  - **Predetermined phase as incoming signal**
- **Therefore, the frequency and phase of the oscillators need to be variable and circuit-controlled**
- **Using voltage as a control signal, the frequency of VCO follows the control voltage:**

$$\omega = f(V)$$

- **V represents error signal in phase between input & local signals => ω will become stable when V is zero**
- **Error will be zero only when $\omega_{in} = \omega_{LO}$ and $\Phi_{in} = \Phi_{LO}$**

Building Blocks: Mixer

- **Mixer is mainly a multiplier (usually analog):**

  $A\cos(\omega_1 t) * B\cos(\omega_2 t) = (1/2)\,AB\,[\cos(\omega_1-\omega_2)t + \cos(\omega_1+\omega_2)t]$

- **Down-conversion (Receiver): use** $(\omega_1-\omega_2)$
- **Up-conversion (Transmitter): use** $(\omega_1+\omega_2)$
- **Could be either:**
  - **Intermediate Frequency (IF) : Heterodyne, or**
  - **Direct Conversion (Zero IF): Homodyne**
- **Needs careful filter design to remove image, out-of-band, and unwanted product terms:**
  - **Both input and output need these filters (Bandpass or Low pass)**

Building Blocks: Low Noise Amplifier (LNA)

- First stage in receiver
- Focuses on very low internal noise generation, even if it sacrifices some amplification gain
- Usually preceded by a low (LPF) or band (BPF) pass filter, to remove signals out-of-band
- Usually operates in RF band:
  - Has matched impedance (usually 50 or 75 ohm),
  - Carefully designed S-parameters: tries to maximize transmission and minimize reflection
  - Preceded and followed by transmission lines (coaxial, microstrip, …)

Building Blocks: Power Amplifier (PA)

- **Needed in transmitter**
- **Operates in RF**
- **Coupled to antenna, using S-parameter matching**
- **Focus on power level**
- **Usually it has control to adjust power level, based on transmission conditions (e.g. feedback from base station)**

LVDS

- **Differential signaling:**
  - **Removes common external noise/crosstalk**
  - **Better Electromagnetic Interference (EMI)**
  - **Maximizes (doubles) voltage swing**
- **Transmission line design: Gigabit data/clock rates**
- **Pre-emphasis & equalization to overcome low pass characteristics**
- **Usually negotiates data rate**
- **Clock could be embedded or separate**
- **Receive and transmit channels could be separate or shared**
- **Uses special schemes to improve clock recovery**