6.02 Fall 2009
Lecture #2

• Samples and Bits
• Real Wires
• Models
• Linearity and Superposition
6.02 Lecture 2 - Wires and Models

- Wires, Samples, and Bits
- Non-Ideal Transmission
  - Example wires and signal impact
  - Intersymbol Interference and Eye Diagrams
- Modeling Wires
  - Causality
  - Time-invariance
  - Linearity
- SUPERPOSITION
  - Demonstrating why it is so super
Types of Real “Wires”

IC Interconnect

Printed Circuit Board

Transatlantic Cable

Slow Response

Ringing

May also have long delays (Receiver does NOT know)
Transmission Setup and Notation

\[ X \equiv \text{entire sequence} \]
\[ x[n] \equiv n^{th} \text{ sample value} \]

\[ Y \equiv \text{entire sequence} \]
\[ y[n] \equiv n^{th} \text{ sample value} \]

Sample Rates:
- 1 million Samples/Second (IR Transceiver)
- Up to gigaSamples/Second (Fastest)
Samples, Bit Period, Bit Rate

• Our Hardware
  – Updates transmitter output voltage every microsecond (1 million times a second).
  – Remeasures receiver voltage every microsecond (1 million times a second).

• Bit Period and Bit Rate
  – BP = Samples/bit * 1 microsecond
  – BR = Bits transmitted per second
  – BR = (1 million) / (Samples/bit)

• Slower Bit Rate = Longer Bit Period
  – More time to propagate through channel
Sending 0101110, 10 microseconds/bit

Samples per bit = 10, Bit rate = 100000 bits/second

Received Voltage has not “settled”
Sending 0101110, 20 microseconds/bit

Samples per bit = 20, Bit rate = 50000 bits/second

Received Voltage is more “settled”.
Sending 0101110, 30 microseconds/bit

Samples per bit = 30, Bit rate = 33333.3 bits/second

Received Voltage much more "settled"
The 6.02 Infrared Transceiver

100 Samples/bit
The 6.02 IR Tranceiver - Faster and Noisier

20 Samples/bit

5 Samples/bit
Intersymbol Interference

Long Bit Period (slow rate)

Short Bit Period (Fast Rate)
Generate Eye Diagram

Eye Diagram Generated with 160 samples per bit
Eye diagram generated from 40 samples per bit and using a 200 bit long random sequence.
Eyes for Ringing versus Slow System

Medium Bit Period

Short Bit Period
Eye Diagram for IR Detector

Eye Diagram 20
Samples per bit, dark room

Eye Diagram 20
Samples per bit, lights on!
Superposition
Step Response and results from superposition
Rising Edge add step response
Falling Edge, subtract step response
Rising Edge add step response
Falling Edge, subtract step response

Time shifted and sign adjusted channel step responses

Summed responses = Rcv’d data
Step Response For Another Example Channel
Sending 0101110, 5 microseconds/bit
Eye Diagram for 5 microsecond bit period
Sending 0101110, 9 microseconds/bit
Eye Diagram for 9 microsecond bit period
Sending 0101110, 13 microseconds/bit
Eye Diagram for 13 microsecond bit period