MODULE 7: Analog Transmission

SUMMER CHALLENGE

Electrical Engineering: Smart Lighting

Prachi Shukla
PhD Candidate
Boston University
prachis@bu.edu

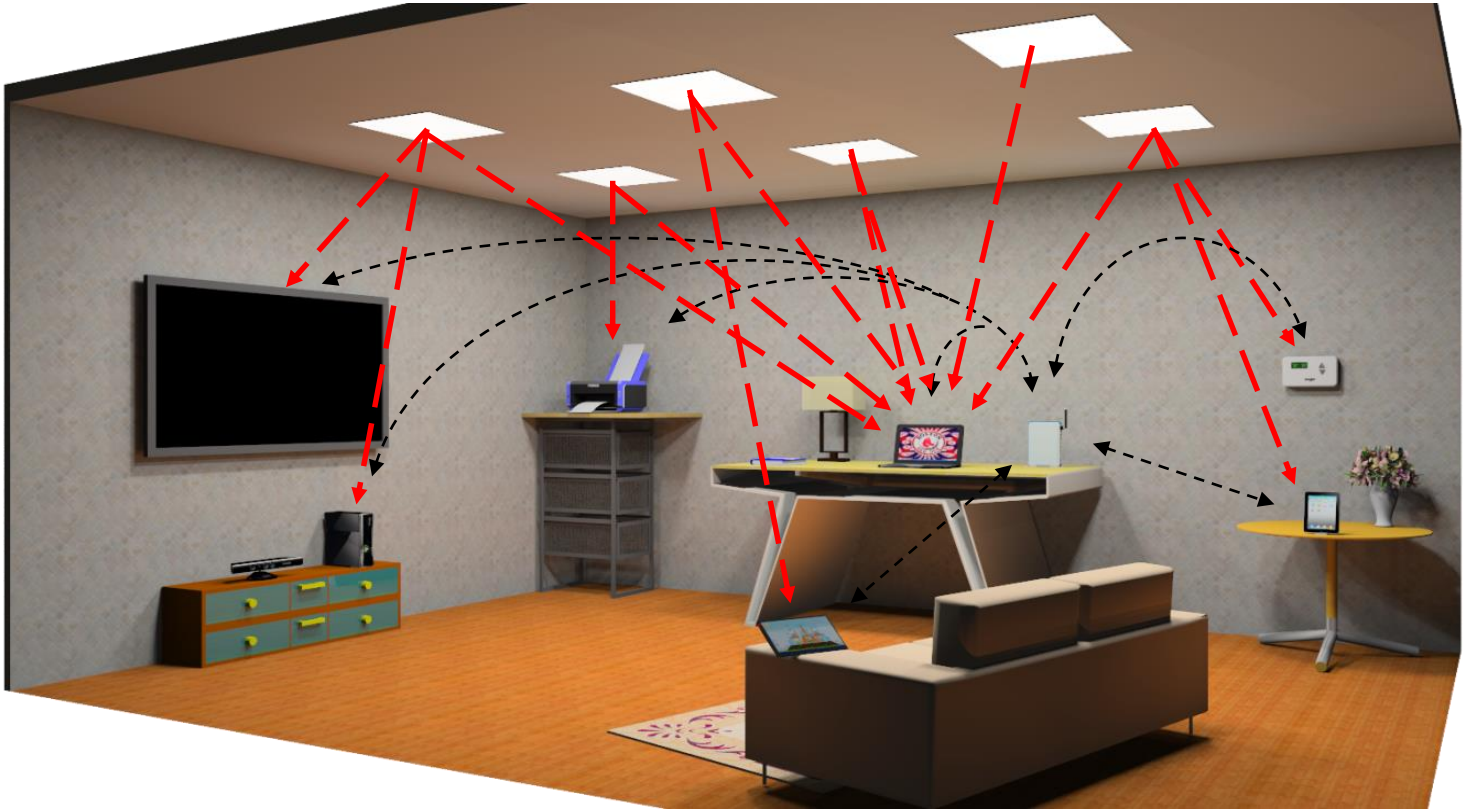
BOSTON UNIVERSITY

Overview

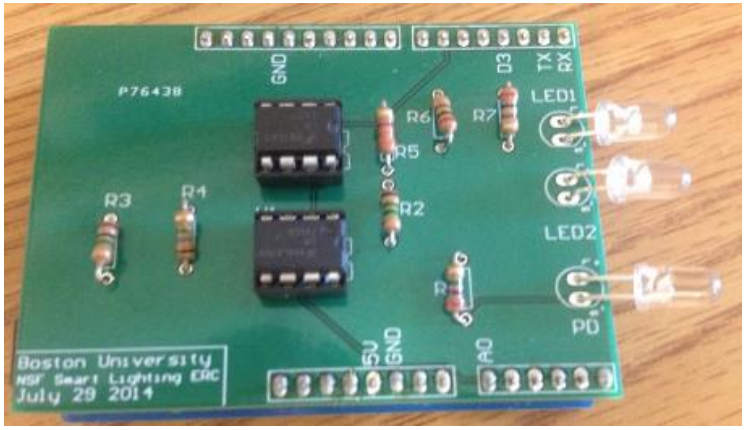
- Visible Light Communication
- Audio Signals
- Amplitude Modulation
- Digital Sampling and Binary Representation
- Experiment
  - Analog Modulation with VLC Transceivers

Visible Light Communication (VLC)

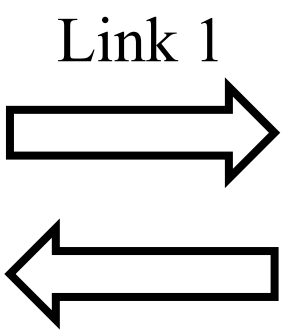
- Radio spectrum is congested, visible spectrum has potential!



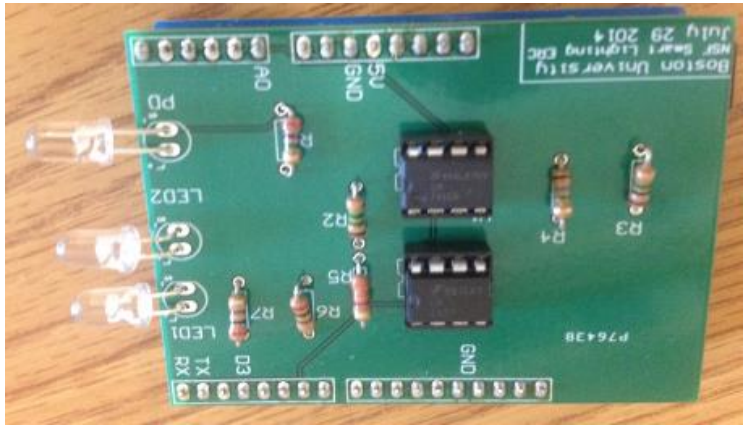
Visible Light Communication Transceiver

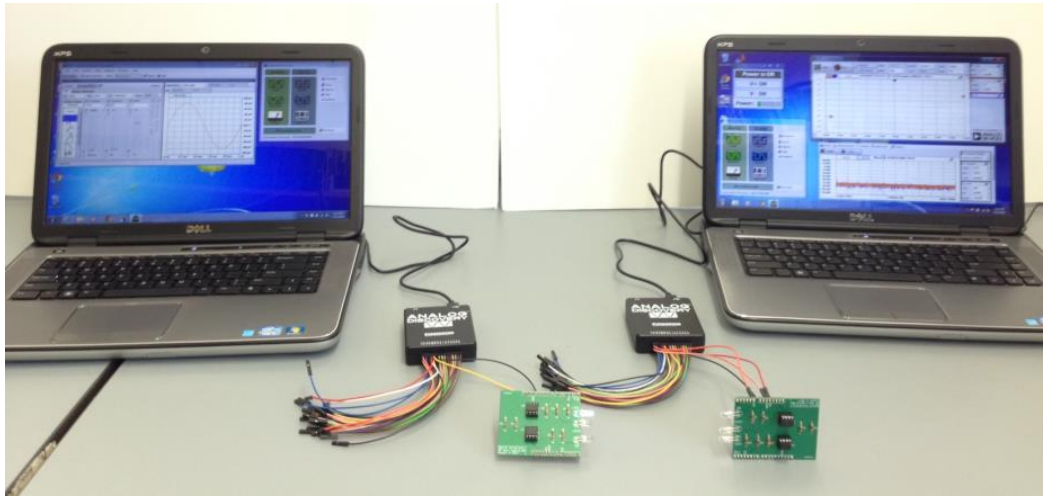


Link 1



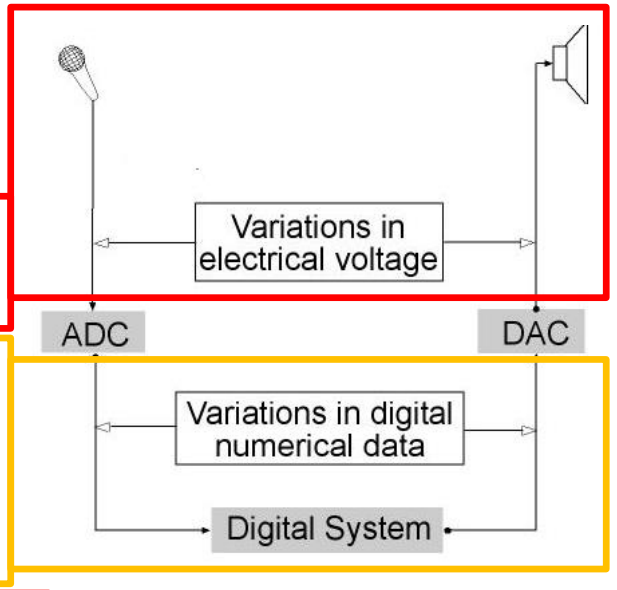
Link 2



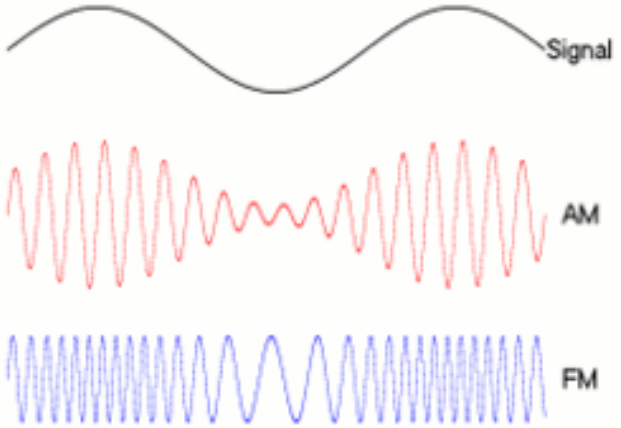


Audio Signals

- Audio Signals
  - Acoustic Input (e.g., microphone) converts air pressure variations into an electrical signal.
  - ADC converts to digital data representing the *sampled* electrical signal.
  - DAC converts digital samples back into a continuous time electrical signal
  - Acoustic output (e.g., speaker) converts voltage back to air pressure variations.



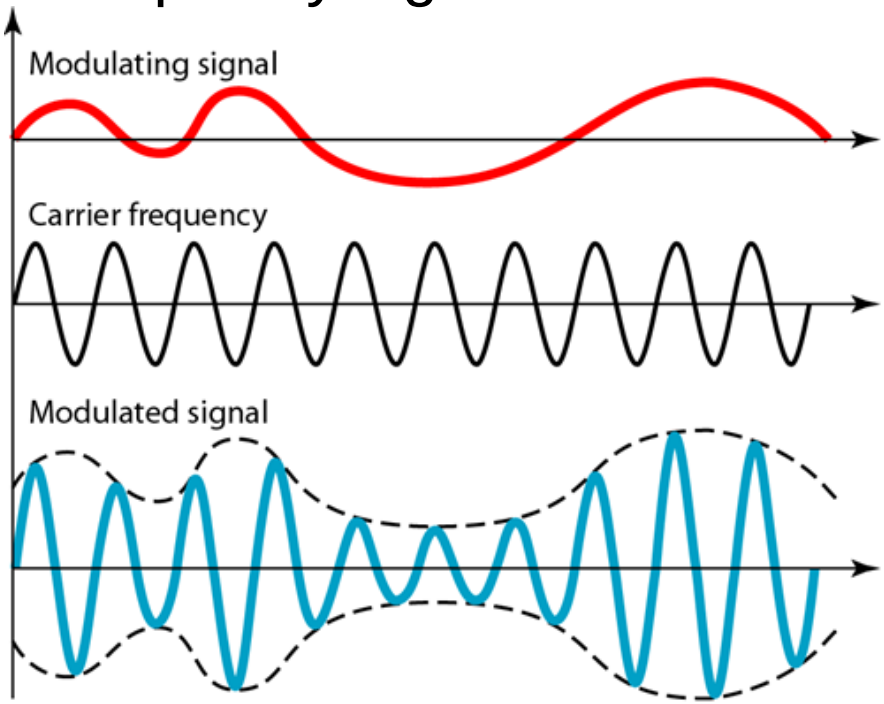
- AM Radio? FM Radio?
  - AM: Amplitude Modulation
  - FM: Frequency Modulation
  - Sirius Satellite *Digital* Radio



Electrical signal is transmitted via electromagnetic signals at a specified *carrier frequency.*

Amplitude Modulation

- Carrier Modulation: “Placement” of input signal onto a high frequency carrier for transmission
- Carrier Demodulation: Retrieving the baseband or low frequency signal from the carrier-modulated signal

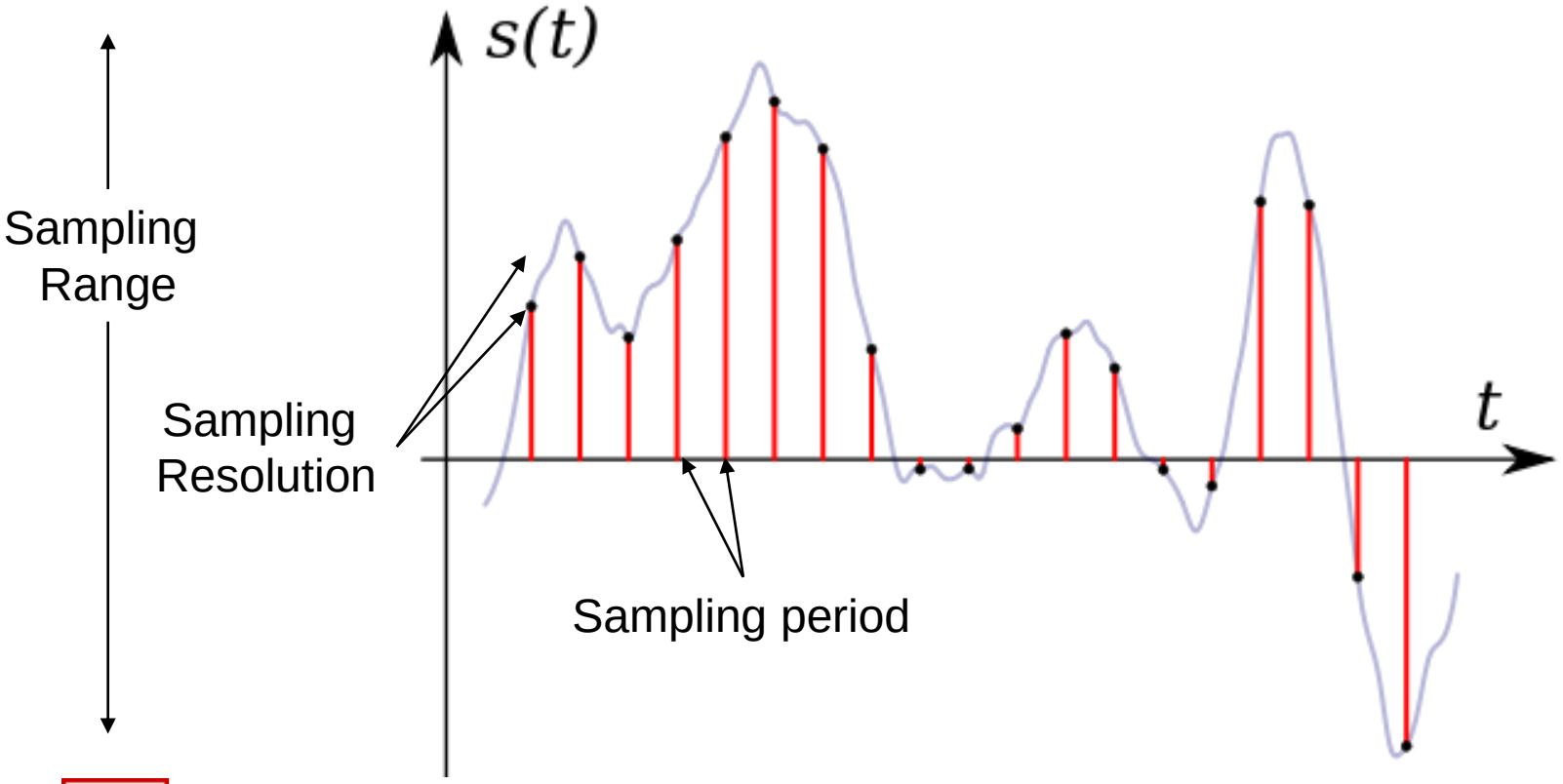


In VLC signals, optical intensity is modulated.

Carrier frequency is NOT required. Technically, the signal is modulated in THz

Digital Sampling

- To convert an analog signal into a digital representation:
  - Discrete time samples
  - Discrete value amplitude

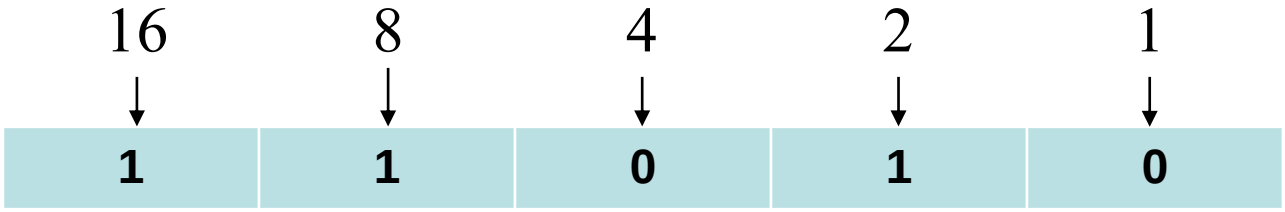


Binary Representation

- We typically consider numbers in decimal, *base-10*

$$39512 = 3(10000) + 9(1000) + 5(100) + 1(10) + 2(1)$$

- Binary is a numeric system with *base-2*
  - Value of any digit (or *bit*) can either be '0' or '1'
  - Each digit is a power of 2 rather than a power of 10



$$1(16) + 1(8) + 0(4) + 1(2) + 0(1) = 26$$

- A byte is a set of 8 bits

Digital Sampling

- Digital sample values are stored in binary

Binary Form					Decimal Form
16	*8*	*4*	*2*	*1*	
0	0	0	0	0	0
0	0	0	0	1	1
0	0	0	1	0	2
0	0	0	1	1	3
0	0	1	0	0	4
0	0	1	0	1	5
0	0	1	1	0	6
0	0	1	1	1	7
0	1	0	0	0	???
1	0	0	0	0	???
1	1	1	1	1	???

Nyquist Sampling Theorem

- *Reconstruction of a signal is possible when sampling frequency is greater than twice the maximum frequency of the signal being sampled*
- Human hearing can recognize frequencies up to 20kHz
- The typical sampling rate for audio is 44.1kHz. Why?
- Digital Storage Example:
  - How much space is needed for 70 minutes of music with 16 bit resolution?

$$(2\text{ channels})\left(16\frac{\text{bits}}{\text{sample}}\right)\left(44.1\text{k}\frac{\text{samples}}{\text{second}}\right)\left(60\frac{\text{seconds}}{\text{minute}}\right)(70\text{ minutes})$$

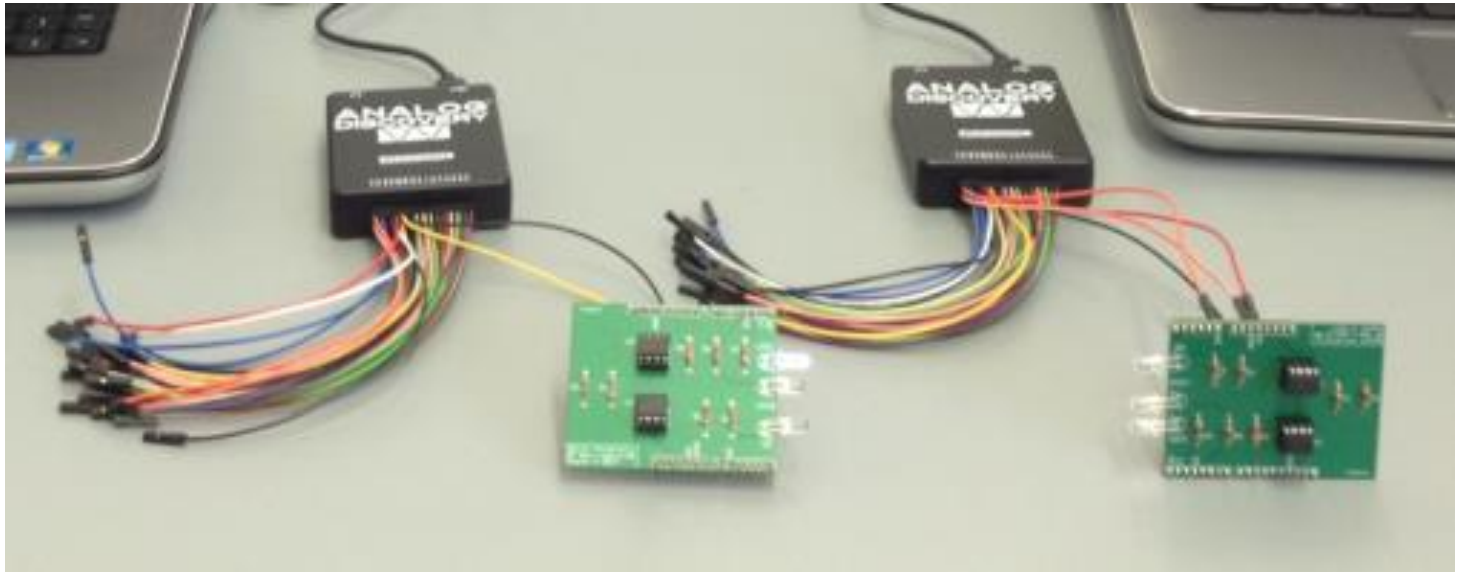
$$= 5{,}927{,}040{,}000\text{ bits}$$

Teams

Team 1: Ricky and Sean	Visual Light Communication
Team 2: Becca and Yutong	Resistors and Capacitors
Team 3: Charlotte and Genie	LEDs
Team 4: Eliza and Madeline	Resistors
Team 5: Tucker and William	Analog signals
Team 6: Krish and Mark	Soldering
Team 7: Ethan and Bing	Parallel and series circuits
Team 8: Ian and Youtai	Photo-diodes

Experiment

- Generate analog signals between VLC transceivers
  - Observe on oscilloscope and spectrum analyzer
  - Transmit audio file (bu.edu/peaclab/busc19)



Recap

- What did you 

today?