Bits over the Air: Pre-Lab 3

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VLSI Information Processing Group

- You can always ask questions (during pre-labs and labs, or via email* after the labs)
- During the labs, you can also ask us if you want to know more about a specific aspect!

- Please limit the use of social media…!

*studer@cornell.edu

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Wednesday overview

Bits over the air

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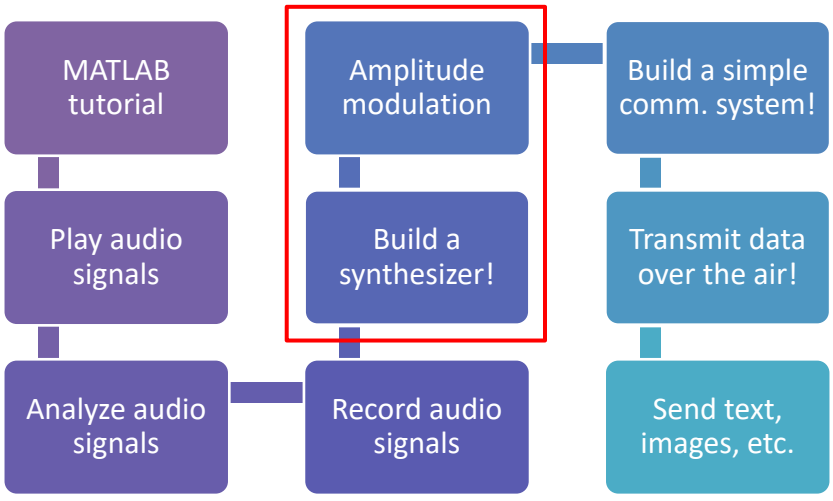
Today's goals:



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Project schedule

	Monday	Tuesday	Wednesday	Thursday	Friday
1pm-2pm	Pre-Lab 1: Introduction to MATLAB and digital communication	Pre-Lab 2: Signal processing, time-domain, spectrum, and spectrogram	Pre-Lab 3: Generating music with MATLAB and communication system basics	Pre-Lab 4: Communication via amplitude modulation and synchronization	Pre-Lab 5: Bits over the air: transmitting text and images over the air (reliably!)
2pm-3pm	Module 1: MATLAB basics 1	Complete previous modules	Complete previous modules	Complete previous modules	Complete previous modules
	15min break	15min break	15min break	15min break	15min break
3pm-4pm	Module 2: MATLAB basics 2	Module 4: Spectrum and spectrogram	Module 6: Generating music in MATLAB	Module 8: Simple communication system 2	Module 10: Transmitting bits over the air
4pm-5pm	Module 3: Play audio in MATLAB	Module 5: Record audio in MATLAB	Module 7: Simple communication system 1	Module 9: Synchronization	Work on presentations

- Scheduled break from 3:15pm to 3:30pm

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Remember: this is group work!

- Last chance to switch group! Send me an email: studer@cornell.edu
- Try to help each other (within group)
- This time no inter-group activities ☹
  - Reduces "interference" …

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Module 6

Generating music

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Digital sound synthesis

pulse-code modulation (PCM)

virtual-analog synthesis

frequency-modulation (FM) synthesis

additive synthesis (and others…)

- Music production is almost exclusively digital (sound synthesis, effects, mixing, recording,…)

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Sound synthesis → transmitter

- Digital sound synthesis is signal processing
- Digital synthesizer can be seen as a transmitter of a wireless system
- "Information" is contained in?
  - Notes (pitch)
  - Chords (relative pitch of multiple notes)
  - Amplitude (loudness)
  - Time when played
  - Timbre (tone "color")
- Ears are the receive antennas

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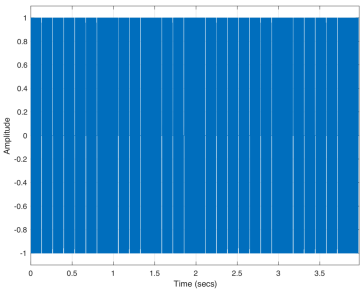
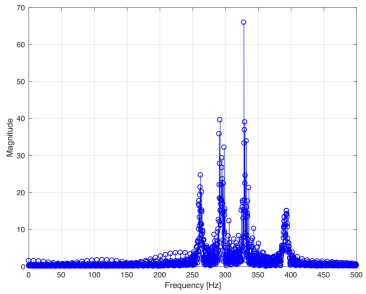
You will create a "synthesizer"

- MATLAB script: generates sequence of sine waves of varying pitch, length, & amplitude

time-domain signal



spectrum



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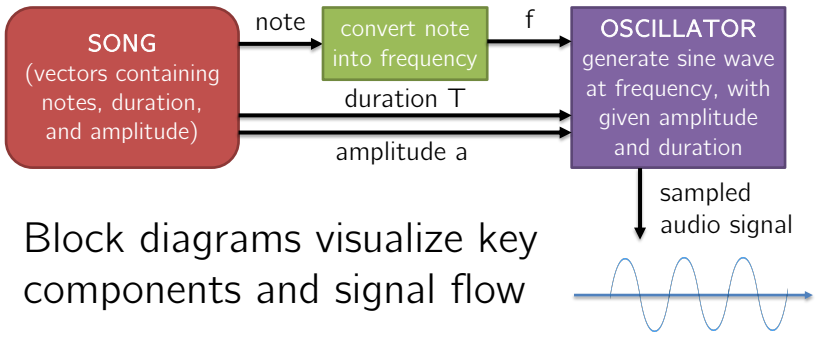
Block diagram of the synthesizer



- Block diagrams visualize key components and signal flow

- Engineers extensively use abstraction to design complex systems → block diagrams!

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You need some new MATLAB concepts

- Concatenating vectors
- If-statement (conditional execution)
- For-loops (repeat similar tasks)

very common in most programming languages

- Saving wav-files to hard-drive

- All of these will be used for your final acoustic wireless communication system

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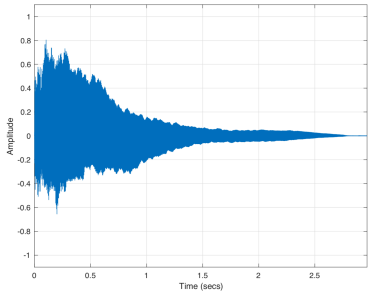
You will add more functionality

- Different waveforms than just sine waves
- Polyphonic sounds (multiple notes at once)
- If your group makes progress: sampling



- Piano C4 note recorded at FS=44,100Hz
- If you play only every other sample → C5!
- You can play any note!

You have designed a transmitter

- Your synthesizer already contains all components required for our transmitter!
- The field of signal processing includes:
  - Wireless communication
  - Music production
  - Digital photography
  - Video editing
  - Robot control
  - Self-driving cars
  - and….

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...digital mixing consoles!!!

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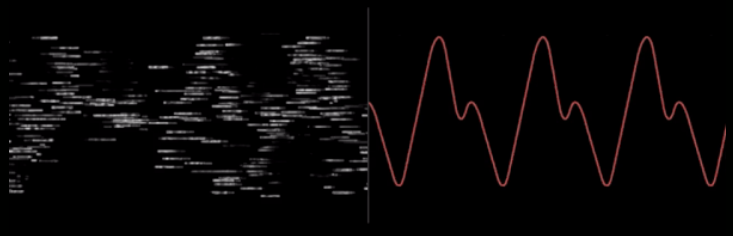
Do not forget:
Signal processing is part of
Electrical and Computer Engineering!



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Module 7

Design of a digital amplitude modulation (AM) transmitter

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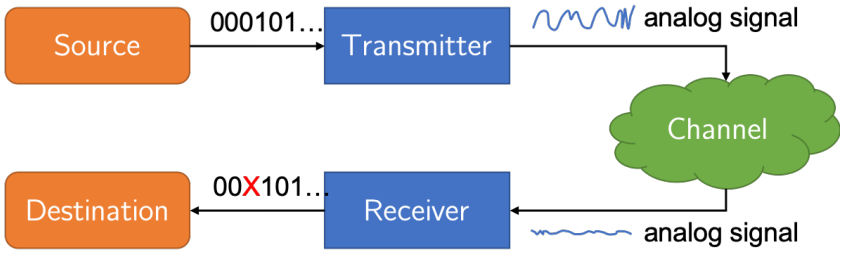
Digital communication system



- Transmitter takes information bits and creates analog (continuous) waveforms
- Receiver takes output of channel and tries to estimate transmitted information bits

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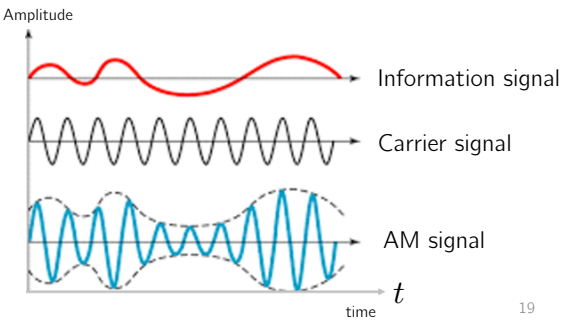
Amplitude modulation (AM)

- We want to transmit information (a signal) at a given carrier frequency f_c
- AM: information signal controls amplitude of carrier signal



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Mathematical operation

- Assume that information signal $s(t)$ has values only in the range [-1,+1]
- Let $\sin(2\pi f_c t)$ be our carrier signal
- Amplitude modulation:

$$y(t) = \underbrace{\frac{1}{2}(s(t)+1)}_{\text{converts information signal that is in range [-1,+1] to range [0,1]}} * \sin(2\pi f_c t)$$

modulation

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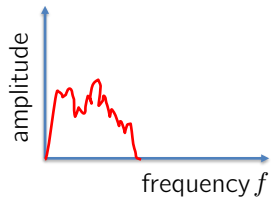
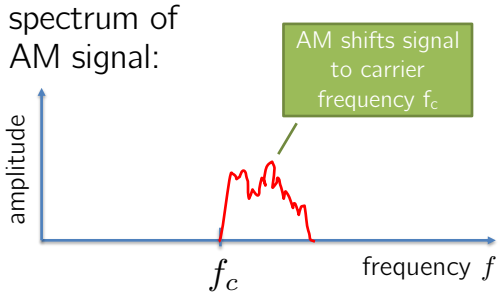
What happens in the spectrum?

spectrum of information signal:



spectrum of AM signal:



AM "magically" moves information signal in frequency-domain to the carrier frequency!

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(Why does AM shift signal in spectrum?)

- Trigonometric identities:

$$\sin(\alpha)\cos(\beta) = \frac{1}{2}(\sin(\alpha+\beta)+\sin(\alpha-\beta))$$

$$\sin(\alpha)\sin(\beta) = \frac{1}{2}(\cos(\alpha-\beta)-\cos(\alpha+\beta))$$

- Fourier series: We can decompose any signal into superposition of sine and cosine waves
- Multiplying sine/cosine with frequency f with sine wave f_c creates new sine/cosine at $f+f_c$

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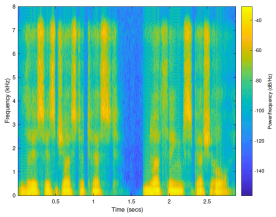
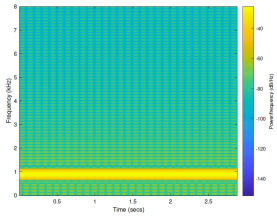
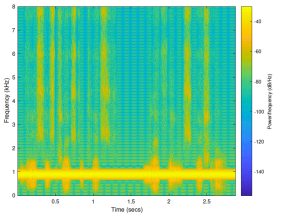
Example spectrogram



(a) Information signal (speech).



(b) 880 Hz carrier signal.



(c) AM transmit signal.

- Amplitude of carrier signal is modulated by information signal (speech in this case)
- AM transmit signal contains speech signal centered around the carrier signal

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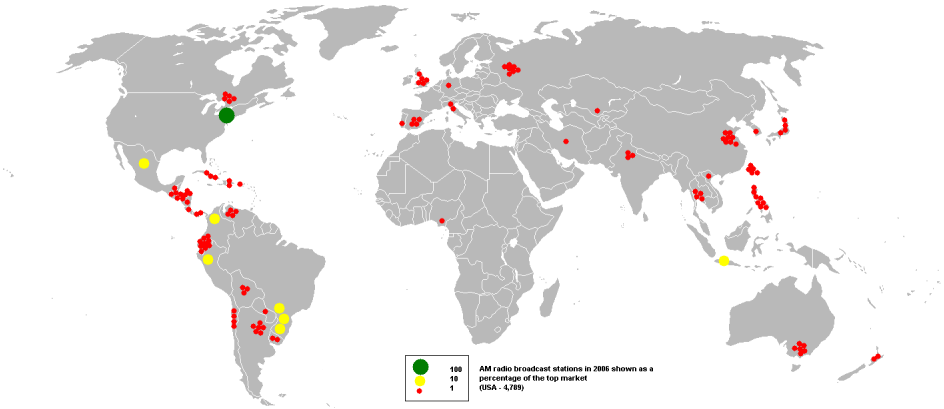
AM radio still exists!



- AM radio stations in 2006
- Carrier frequencies of 525kHz to 1705kHz
- Bandwidth of information (audio) signals: 10.5kHz

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Today: communication is digital

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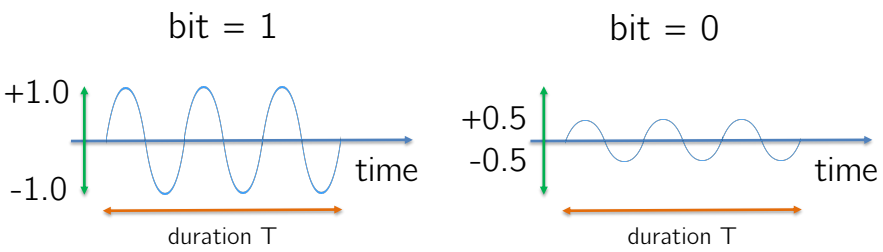
We want to transmit bits

- In this project, we will stick to AM
- Modern systems use better methods…
- We map bits to amplitude with the rule:



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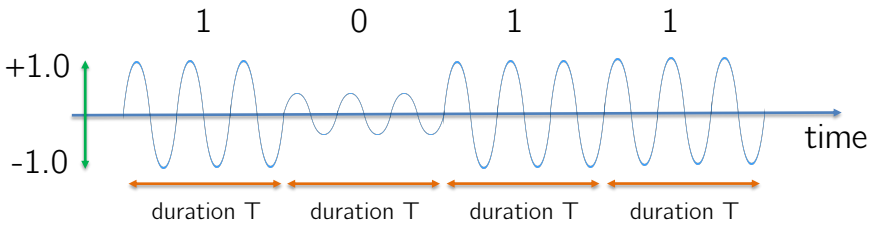
AM transmission = synthesizer

- bits = [1,0,1,1]



- The duration T per bit must stay constant
- The receiver must distinguish amplitudes!

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Some updates

Organization

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Project website: catalyst2019.github.io

- Updated modules
- Updated presentations
- Updated MATLAB files (in a zip-folder)

MATLAB function is on Cornell box

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To do

- Again, we slightly shuffled the groups ☹ but some students leave early on Saturday…
- Remember your (new) group number
- Then, we walk to the ACCEL labs
- Important: You are only allowed to start working on Module 7 after you talked to us

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