

ESE250: Digital Audio Basics

Week 1: Jan. 14, 2010
Overview

Please complete Student Questionnaire
Note lecture feedback form

Handouts:

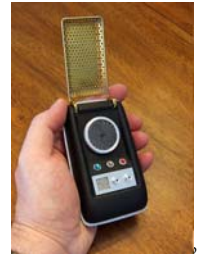
- Administrative
- Idea/Lab1 (page 1)



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Star Trek Technology

- Forward looking Science Fiction
- Envisioned many wonderful things
 - Warp Drive
 - Transporter
 - Phasor
 - ...and a hand-held communicator



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http://en.wikipedia.org/wiki/File:20090704-1971_StarTrekTOSCommunicatorReplica.jpg

This was 1966

- Star Trek debut
- 20lb. Cell phone 1965
 - Motorola 1973
- Long distance was expensive
- Computers owned by companies and universities
 - 20 years after ENIAC, 10 years before Apple
- Internet was conceived (but 3 yrs to first node)
- Cameras used film
- Beatles release “Yesterday and Today” on LP
 - And you had to go to a record store to buy it
- One year after Gordon Moore hypothesized his famous “Law”



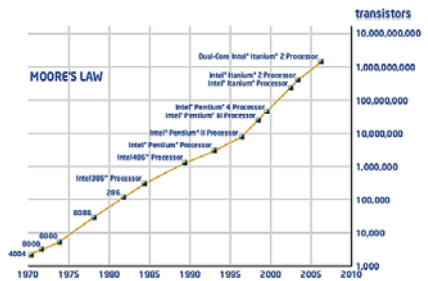
http://en.wikipedia.org/wiki/File:2007_Computer_c21_Forum_MartinCooper.jpg

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Things were brewing...

- Moore’s “Law”

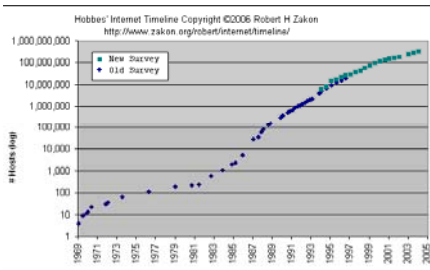


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Things were brewing...

- Moore’s Law
- Internet Grew



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Things were brewing...

- Moore’s Law
- Internet Grew
- Personal Stereo
 - Sony Walkman 1979



http://en.wikipedia.org/wiki/File:Sony_Walkman_WM-2.jpg

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Things were brewing...

- Moore's Law
- Internet Grew
- Personal Stereo
 - Sony Walkman 1979
- Compact Discs 1982
 - 700MB, 80 minutes music http://en.wikipedia.org/wiki/File:Compact_disc.svg



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Things were brewing...

- Moore's Law
- Internet Grew
- Personal Stereo
 - Sony Walkman 1979
- Compact Discs 1982
 - 700MB, 80 minutes music
- IBM PC/XT 1983
 - 10MB Hard Disk



http://en.wikipedia.org/wiki/File:IBM_px_xt_color.jpg

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Cool Stuff 2010

- Today's Cool Stuff is: **computerized**, **networked**, and based on **digital media**
- Cell phones (smaller than ST Communicator)
- MP3 players (make walkman bulky)
- Internet enabled
- Digital cameras and video recorders
- Games
- Integrated (e.g. iPhone)
- Laptops
- DVRs (e.g. TiVo)
- E-book readers (e.g. Kindle)

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Changing World: Small World

- Skype and cheap long distance
- Ubiquitous Internet
 - (even your grandparents)
- Ubiquitous SMS texting
- Facebook
- Instantly in touch
- ...compare old movies...



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Changing World: Easy Sharing

- Easy Instant sharing and storage
- Photos, videos, writing
- Web, Facebook, Youtube, Blogs
- Backed up
- Accessible anywhere in the world
- Indexed and searchable
- Can carry it with you

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Changing World: Instant Gratification

- Web Search
- iTunes
- Amazon.com

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Changing World: New Wealth, New Players

- Microsoft founded 1975
 - World's richest man
- Apple founded 1976
- Oracle 1977
- CISCO 1984
- NVIDIA 1993
- E-Bay 1995
- Google 1998
- Facebook 2004

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Convergence

Big Ideas and Advanced Technology

1. Digitize Everything (Information Ubiquity)
2. Cheap Digital Processing
3. Cheap Storage
4. Cheap Digital Bandwidth

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Enabled by Visionary Engineers

- Hard work, inspiration, and competition
 - ...would not have just happened
- Most inconceivable just prior
 - Compare how archaic the “future” looks in most movies just 20 years old
- What's next?
- How can we harness to make the world better?

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Outline

- Motivational Introduction (completed)
- Short version: what this class is about
- Class story: 1 slide / week
- This Class: operationally
- Wrapup

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This Class

- Understand (at broad, general level)
 - how your multi-function “smart” phone works
 - Cell phone + MP3 player + palm computer
- Use as focal point to understand these
 - Ideas, trends, technologies
- Use as context for
computer engineering

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Class Story: One Slide

- Sound can be converted to/from bits
 - And compressed
 - Without loss of information (= “lossless coding”)
- More information can be discarded (= “lossy coding”)
 - without humans noticing
 -) fewer bits
- Process this information with inexpensive machines
- Store it for retrieval
- Send it between machines
 - Even if not directly connected

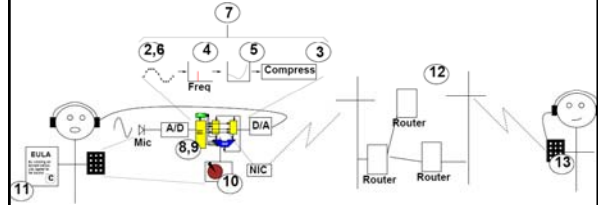
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Class Exercise

- You Design ESE 250:
 - What topics?
 - What order?
 - What depth?
 - What background?

Course Map

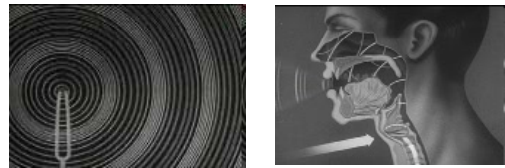


Numbers correspond to course weeks

Longer Story

Sound

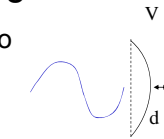
- Sound is a pressure wave



<http://www.archive.org/details/SoundWavesAn>

Pressure to Voltage

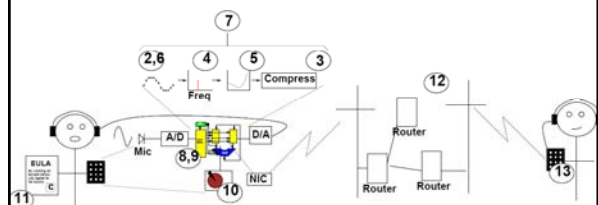
- Microphones convert pressure to voltage
 - (speakers/headphones voltage to pressure)
- Parallel plate capacitor with pressure activated plate
 - Over short time scale
 - Q conserved
 - $\Delta d \rightarrow \Delta C \rightarrow \Delta V$



$$C \propto \frac{A}{d}$$

$$Q = CV$$

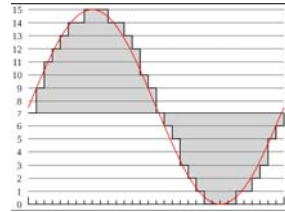
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Numbers correspond to course weeks

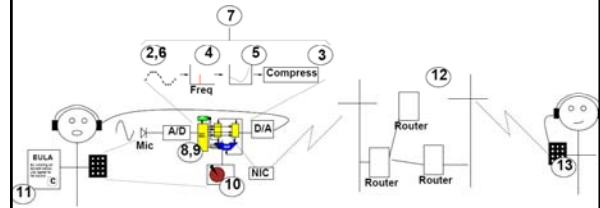
Week 2: Discrete Sampling

- Voltages can be sampled discretely (= "recorded as streamed bits")
 - Both in time and amplitude
- Can turn sound wave into sequence of bits
 - 0111 1001 1011 1100 1101 1110 1110 1111 1111
- Why can we do this?
- What precision
 - can we achieve?
 - do we need?



<http://en.wikipedia.org/wiki/File:Pcm.svg>

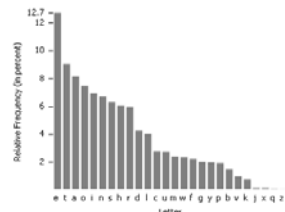
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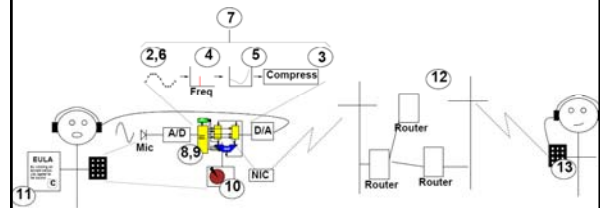
Week 3: Lossless Compression

- Statistics of data allow compression
- If all symbols (characters, voltages) aren't equally likely,
 - Can assign shorter bit sequences to most common cases
 - and reduce bits required
- Morse Code: **THE**
 - = 6 symbol
 - Not $\log_2(26) = 5$ / letter \rightarrow 15



<http://en.wikipedia.org/wiki/File:English-slf2.PNG>

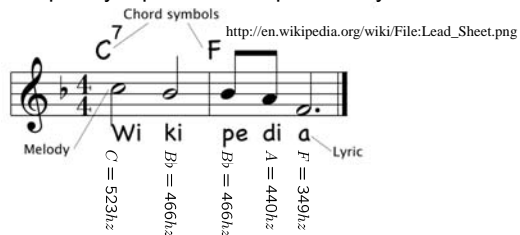
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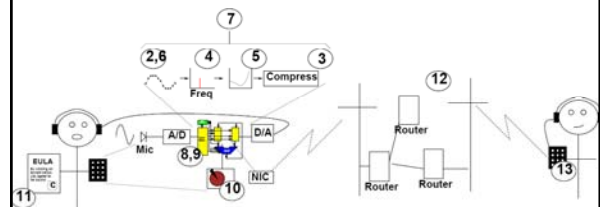
Numbers correspond to course weeks

Week 4: Time-Frequency

- There are other ways to represent
 - Frequency representation particularly efficient



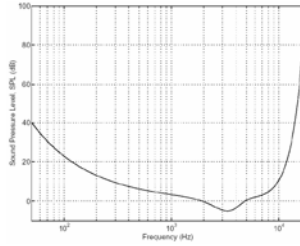
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Week 5: Psychoacoustics

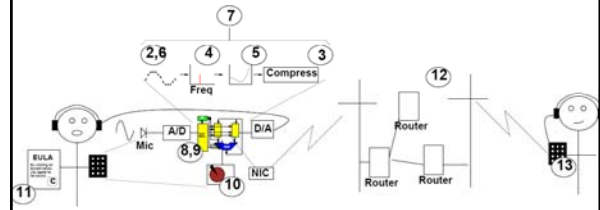
- Human input apparatus is limited
- If we only care about human perception
- ...that reduces the information needed



The Theory behind MP3

http://www.mp3-tech.org/programmer/docs/mp3_theory.pdf

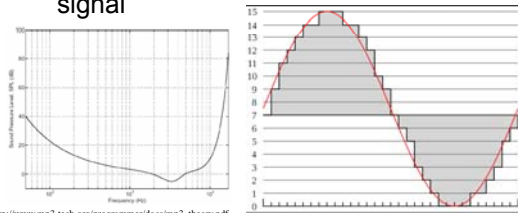
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Week 6: Nyquist-Shannon

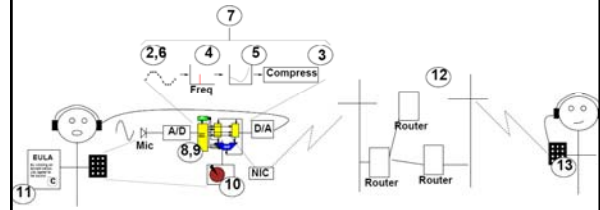
- We only need to sample **twice** the maximum frequency component of a signal



http://www.mp3-tech.org/programmer/docs/mp3_theory.pdf

<http://en.wikipedia.org/wiki/File:Pcm.svg>

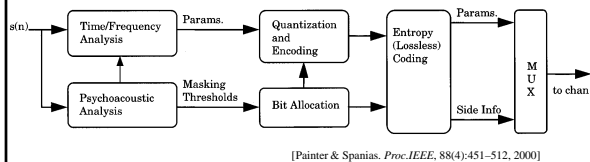
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Week 7: Psychoacoustic Compression

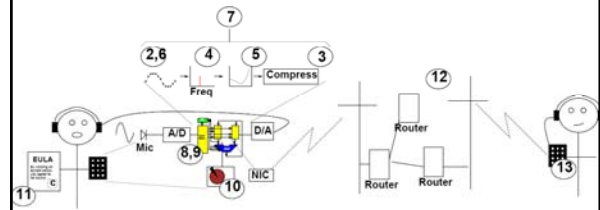
- MP3 based on putting these together



[Painter & Spanias. *Proc.IEEE*, 88(4):451-512, 2000]

- Significantly smaller size than raw, sampled bits

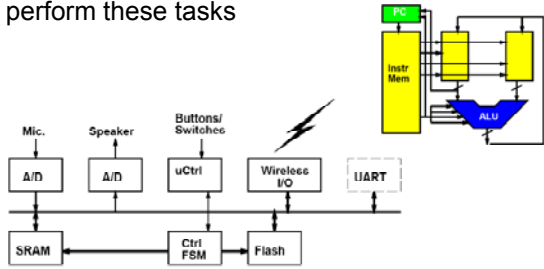
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Week 8: Hardware

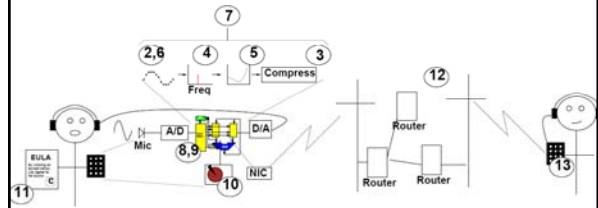
- Simple, now cheap hardware can perform these tasks



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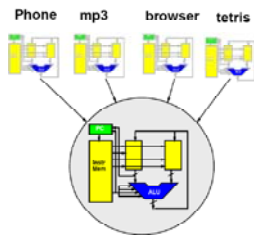
Numbers correspond to course weeks

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Week 9: Operating System

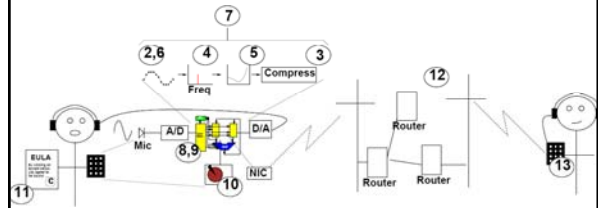
- This hardware can be virtualized and shared among tasks



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Digital Storage (week 10)

[<http://www.tdp.org/LDP/ik/6/filesystem.html>]

- Record bits to non-volatile memory
 - Store sound (persistently)
 - and reproduce sound (find again reliably)
- Media: CD, Hard Disk, Flash

http://en.wikipedia.org/wiki/File:Hard_disk_platters_and_head.jpg



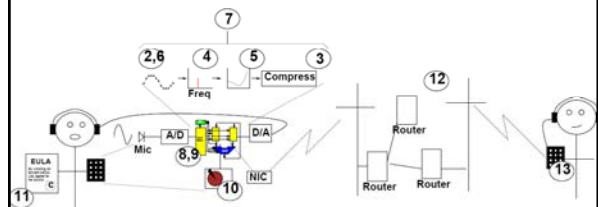
http://en.wikipedia.org/wiki/File:Compact_disc.svg

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<http://en.wikipedia.org/wiki/File:DSCN0411.JPG>

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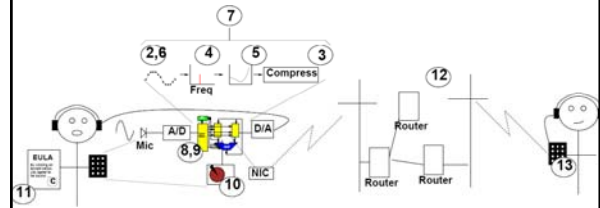
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Week 11: Intellectual Property

- Who owns the bits?
- What is the law?
- Why is the law?
- Why should you care (as engineers)?
- How is the world changing?

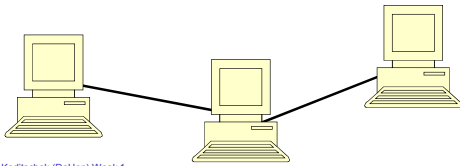
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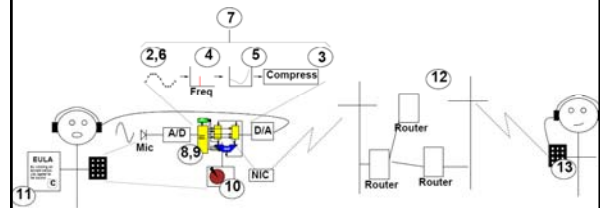
Numbers correspond to course weeks

Week 12: Networking

- Bits can be transported between machines
 - Giving rise to near speed-of-light “travel” and connectivity



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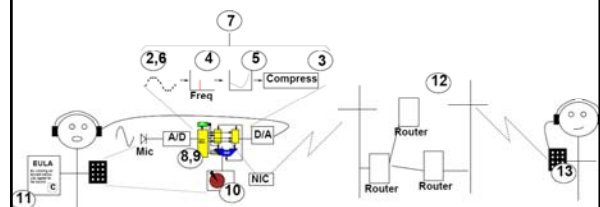


Numbers correspond to course weeks

Week 13: User Interfaces

- These capabilities can be harnessed by all people
 - Not just engineers
- ...but we must design for people
 - For the non-engineers

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Numbers correspond to course weeks

Operational Details

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Class Goals

- Provide digital audio background for ESE350
 - Where will build digital audio platform
- Context and motivation for CE major
- Appreciate how CE, EE, CIS impact today's world
- Help you start thinking like engineers

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Outcomes

- apply knowledge of math, science, and engineering (transforms, sound modeling)
- design and conduct experiments (psychoacoustics experiments, hardware bottlenecks, software behavior)
- design a system to meet needs (design file system)
- understand professional and ethical responsibility (intellectual property, user interfaces)
- understand the impact of engineering solutions in global, economic, environmental, and societal context (security and enabled capabilities)
- knowledge of contemporary issues (grounding in contemporary performance of components, security, user interfaces)
- use the modern engineering tools (oscilloscopes, graphical programming for signal processing, spreadsheets and programming, benchmarking, and profiling)

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Course Staff

- Course Concept and Development:
André DeHon
- Lab Development:
Benjamin Gojman
- Spring 2010 Course Instructor:
Dan Koditschek
- Spring 2010 Course TAs:
 - Philip Asare
 - Victor Janmey
 - Sriram Radhakrishnan

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Course Organization

- Lecture once a week (Thurs)
- Lab once a week (Tues)
- Weekly Materials
 - Input:
 - Slides
 - big idea, further reading
 - Output:
 - **requested:** lecture/lab feedback
 - **required:** lab reports
 - due by noon the Monday following the lab
 - only accepted via Penn Blackboard/ESE250/Assignment
 - **no late labs will be accepted**

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Grading

- Based on lab work
- Teams of 2-3 in lab
- Individual writeups
- Drop lowest score on attempted labs
- **Read admin handout** on policies
 - Collaboration, lateness, credit adjustment

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New-ish Course

- Second time running
- There will (still) be rough edges
- Need your help and feedback
- Always looking for (more senior) students to help out
 - With grading: 5-6 hours
 - with (future years) lab

Summary: Your Weekly Responsibilities

- By Tuesday:
 - Download Lab (from <http://www.seas.upenn.edu/~ese250/schedule.html>)
 - Prepare for lab
 - Detailed instructions on lab assignment sheet
 - Moore 101 ! Moore 207
- By Thursday:
 - Strongly Recommended: download and read “Big Idea”
 - Optional: download slides for the week’s lecture
- By the following Monday: [upload lab report](#)

Changing World

- Automated computation changed world
 - Faster than we imagined
- World being digitized and refitted for computerized control and mediation
 - People-to-people, people-to-machines
 - Infrastructure from bricks/concrete/steel to networking/computers/software
- Enabling new engineering
 - Computerization at center
- Exciting and dangerous
- Computer Engineering at center

Parting Thought

- From 1st computer to PCs in 30 years
 - Eniac 1946 → Apple 1976
- From first PCs to iPhone next 30 years
 - Apple 1976 → iPhone 2007
- What will next 30 years hold?
 - Beginning of your career
- What will **you** imagine, create, enable?

Please Return

- Student Questionnaires
- Lecture Feedback

