ESE250: Digital Audio Basics

Day 1: January 12, 2012

Overview

Please complete Student Questionnaire

Note lecture feedback form

Handouts:

- Administrative
- Idea/Lab1 (page 1)

Star Trek

Star Trek Technology

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

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

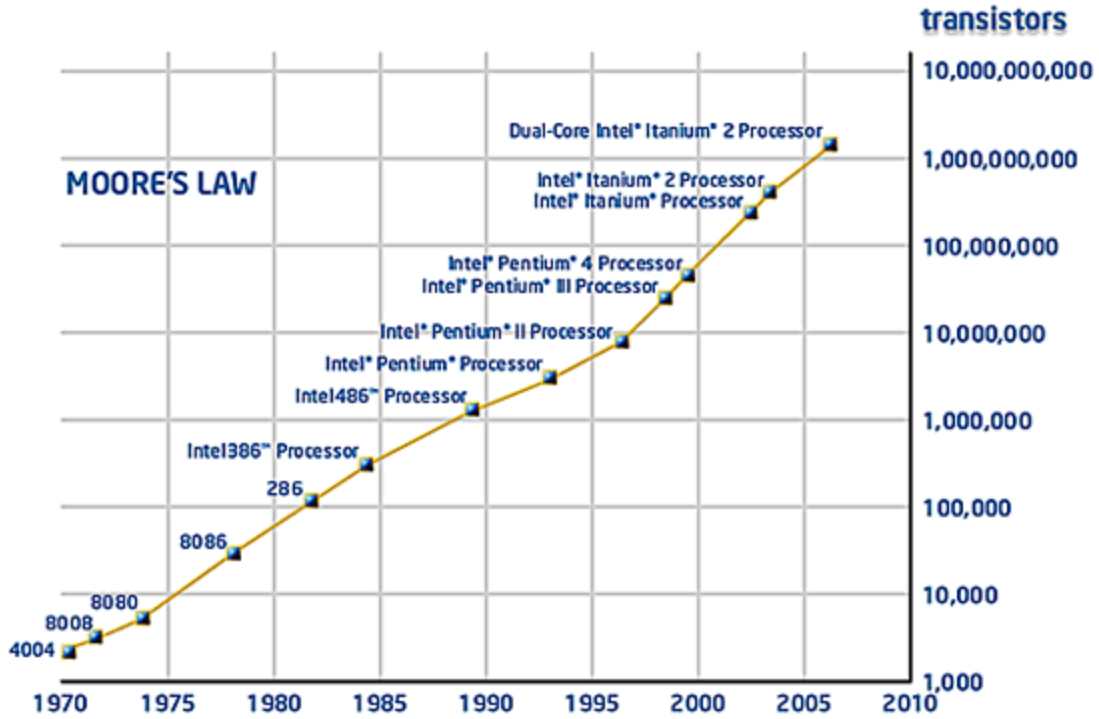
This was 1966

http://en.wikipedia.org/wiki/File:2007Computex_e21Forum-MartinCooper.jpg

- 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”

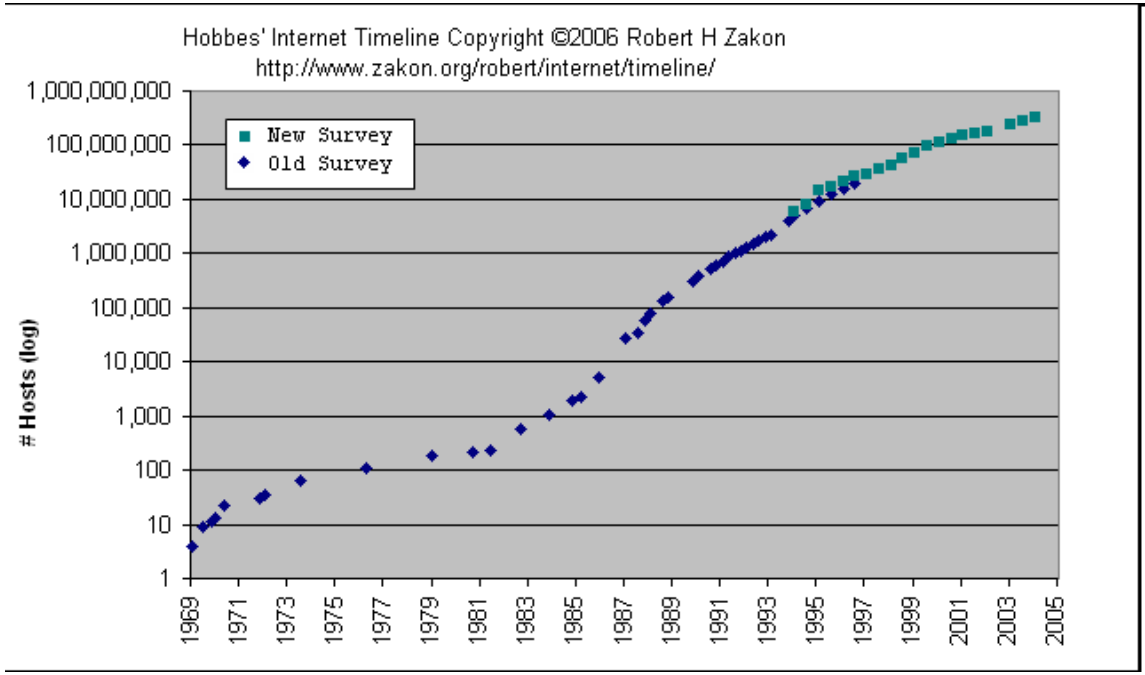
Things were brewing…

- Moore's Law
  - Q: "law" means it ***must*** grow this way?



Things were brewing…

- Moore's Law
- Internet Grew
  - Q: why do
    - two very different curves
    - grow with same pattern?



Things were brewing…

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

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

Things were brewing…

- Moore's Law
- Internet Grew
- Personal Stereo
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- Compact Discs 1982
  - 700MB, 80 minutes music

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

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

Cool Stuff 2009

- 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)

Changing World: Small World

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

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

Changing World: Instant Gratification

- Web Search
- iTunes
- Amazon.com

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

Convergence

Big Ideas and Advanced Technology

1. Digitize Everything
2. Cheap Digital Processing
3. Cheap Storage
4. Cheap Digital Bandwidth

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?

Outline

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

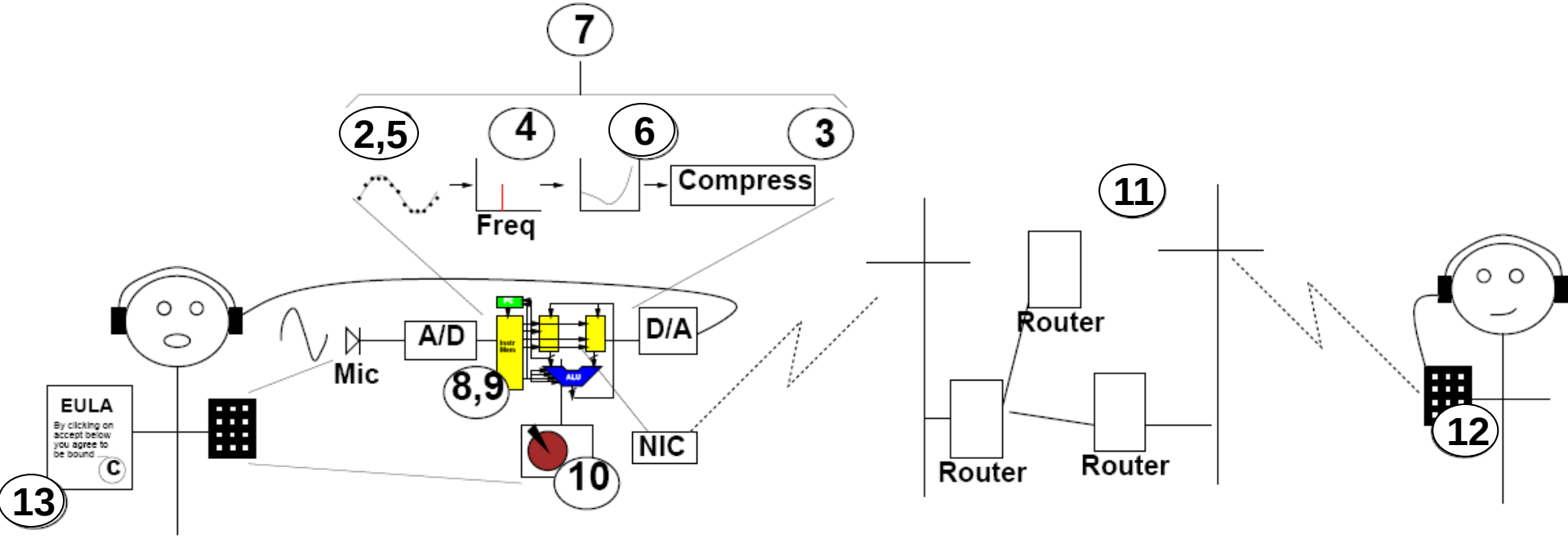
This Class

- Understand how your multi-function cell phone works
  - Cell phone + MP3 player
- Use as focal point to understand these
  - Ideas, trends, technologies
- Use as context for computer engineering

Class Story: One Slide

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

Course Map



Numbers correspond to course weeks

Longer Story

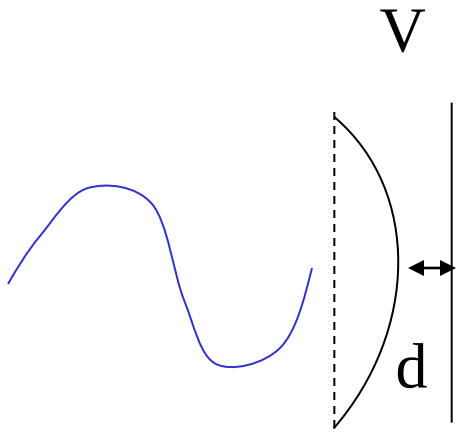
Sound

- 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
    - Δd → ΔC → ΔV



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

$$Q = CV$$

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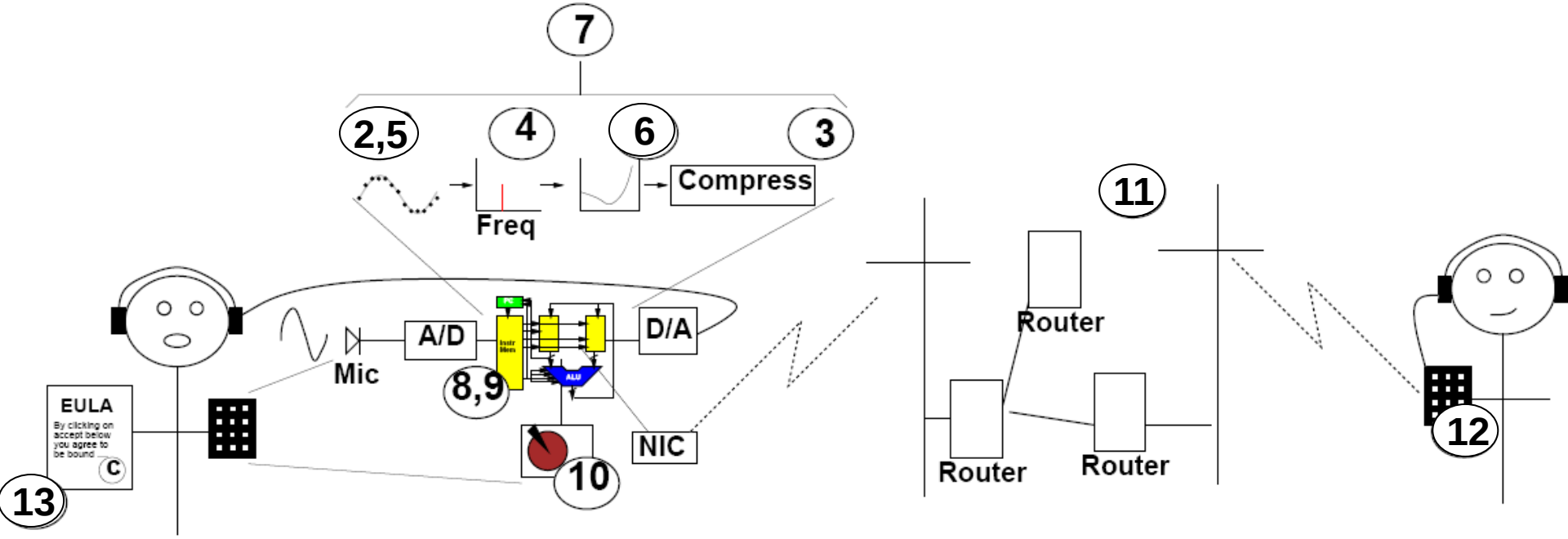
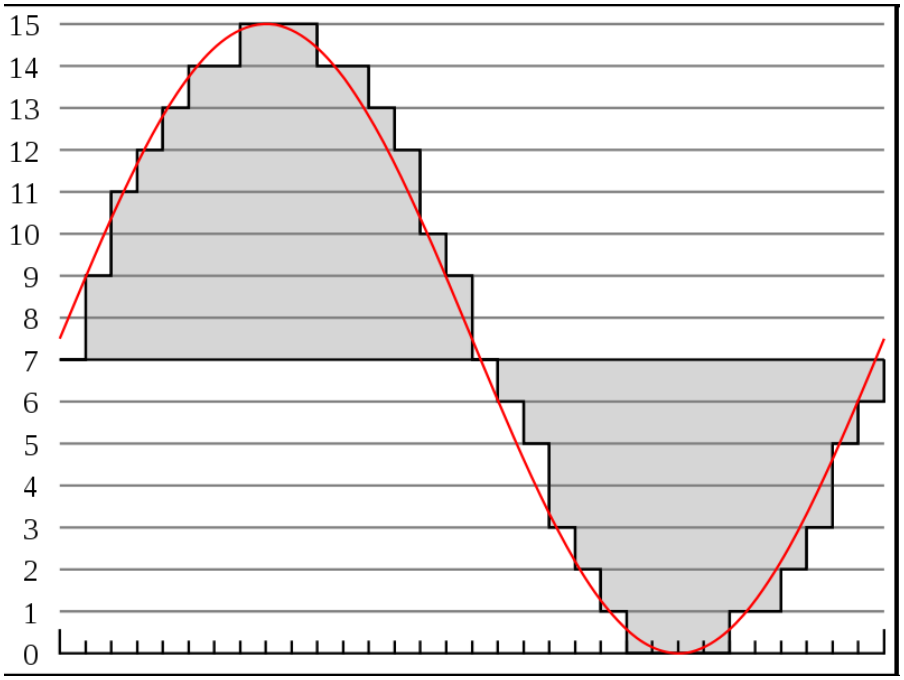


Numbers correspond to course weeks

Week 2: Discrete Sampling

- Voltages can be sampled discretely
  - 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 do we need?



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

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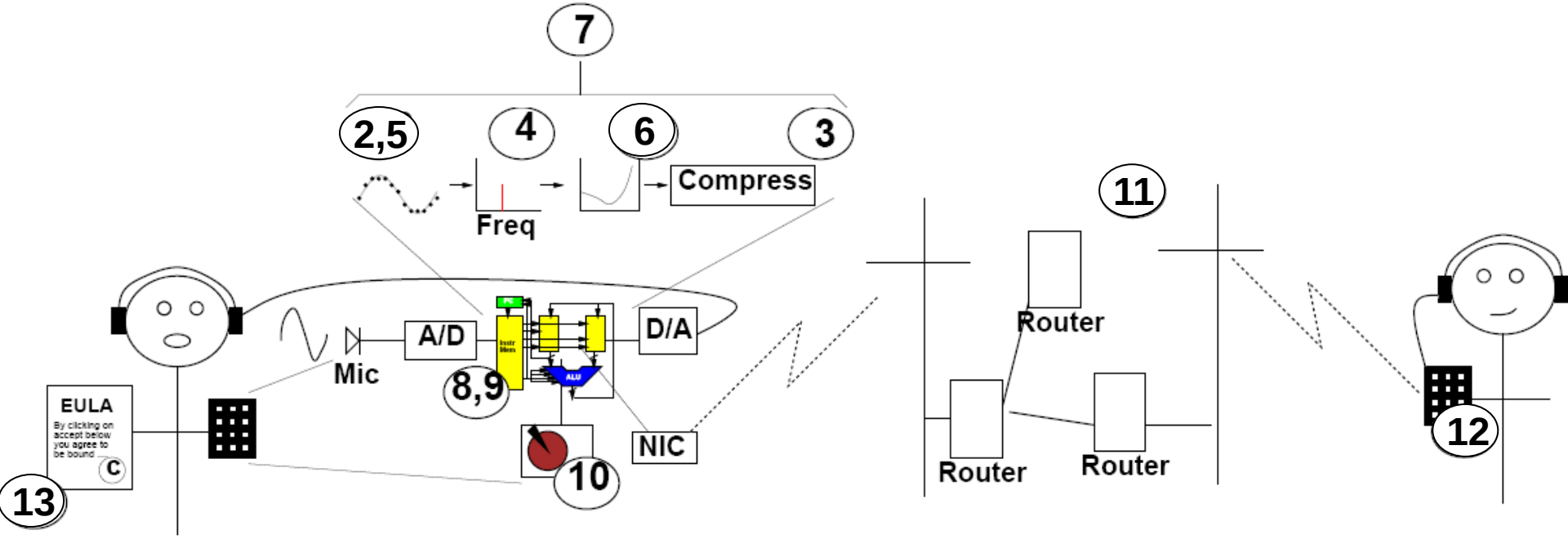
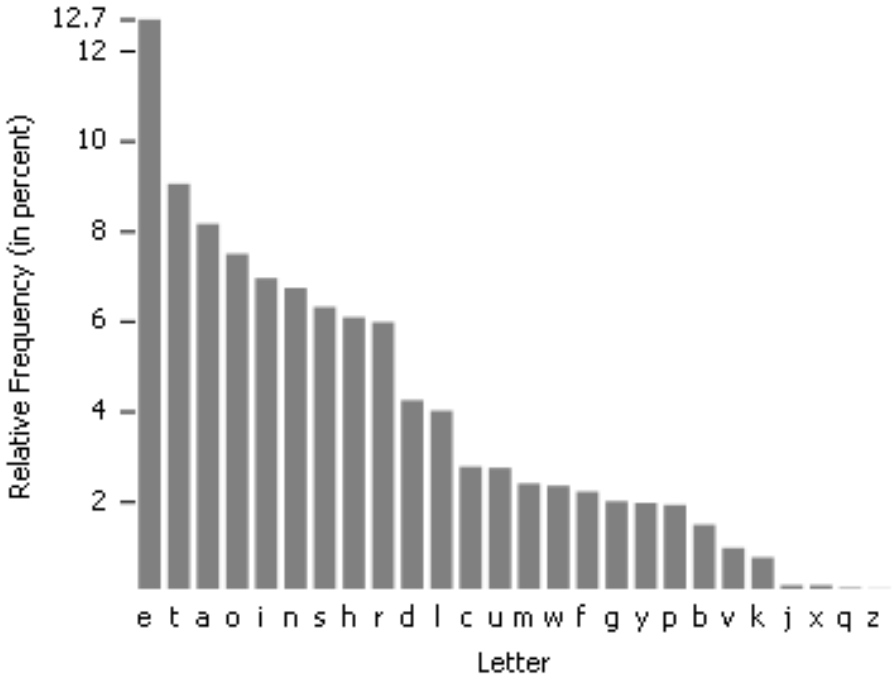


Numbers correspond to course weeks

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 ➔ 15



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

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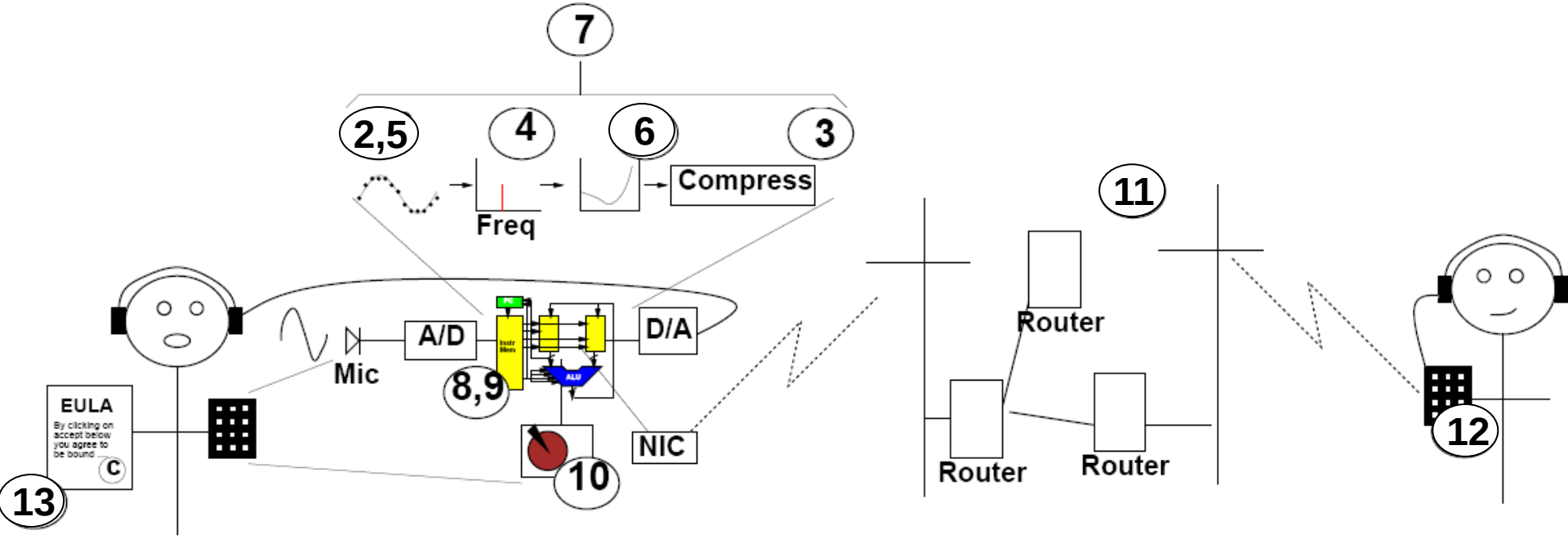
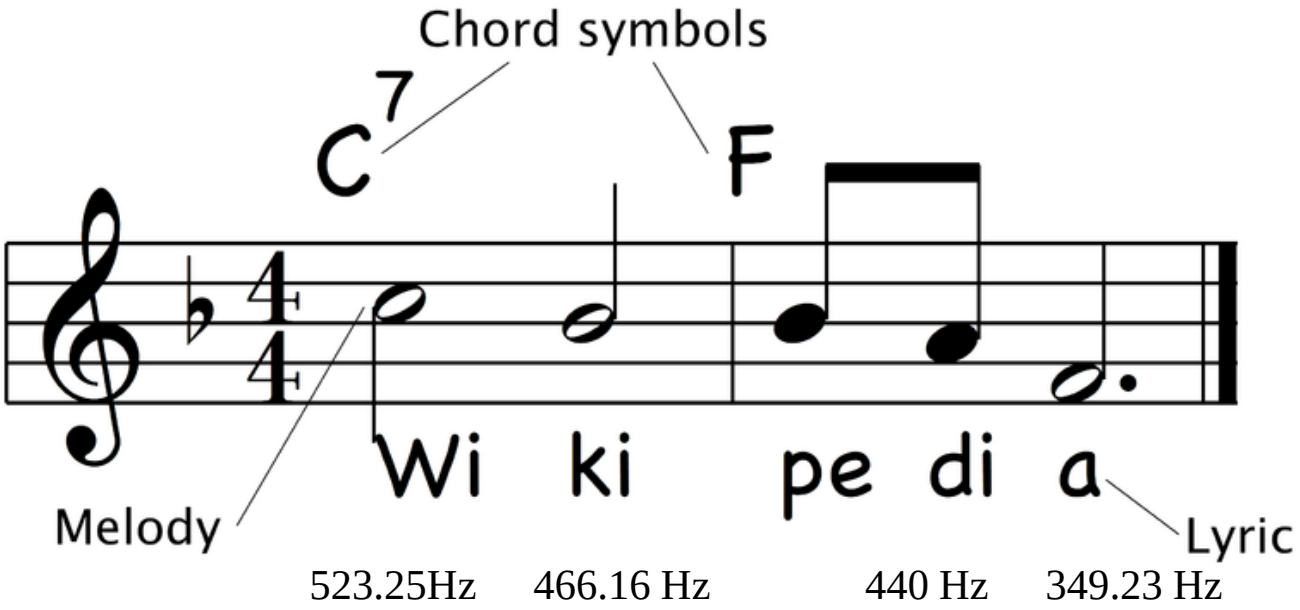


Numbers correspond to course weeks

Week 4: Time-Frequency

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

http://en.wikipedia.org/wiki/File:Lead_Sheet.png



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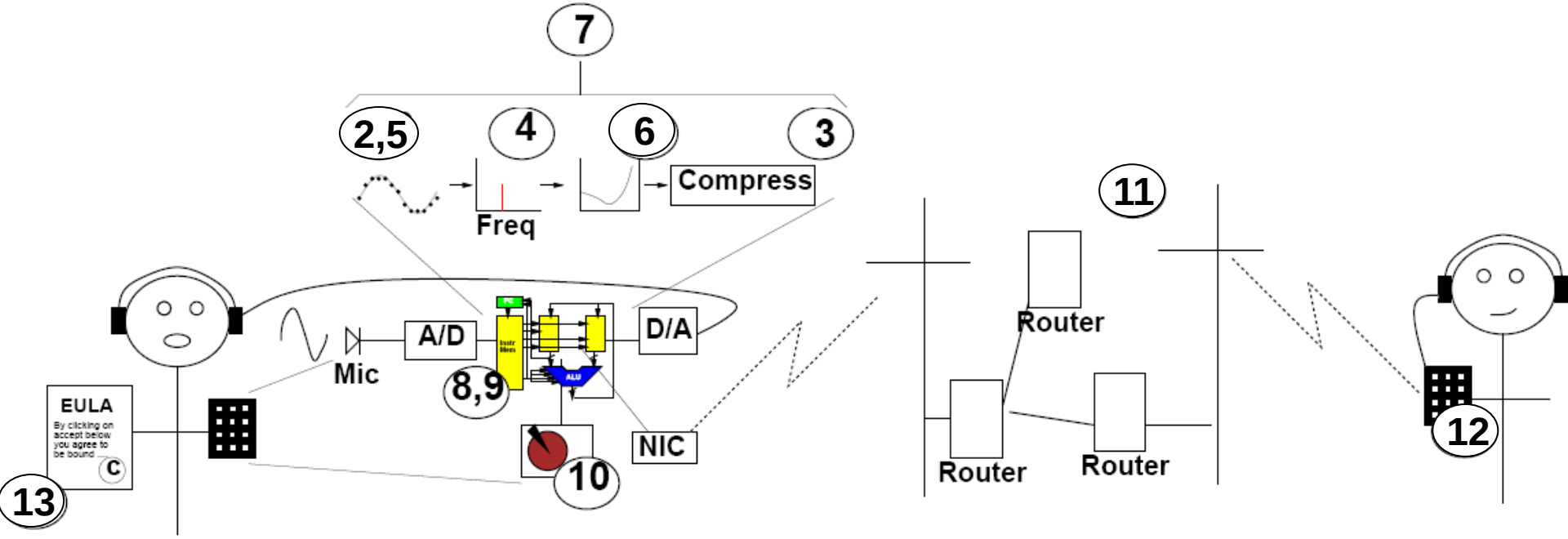
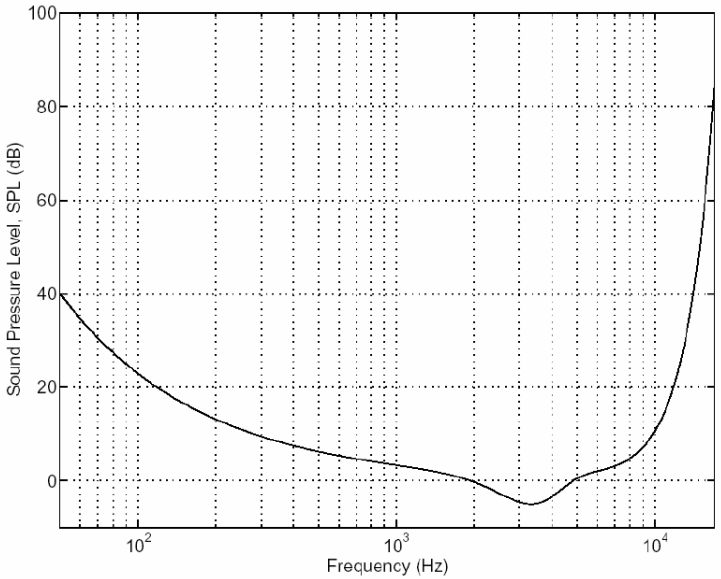


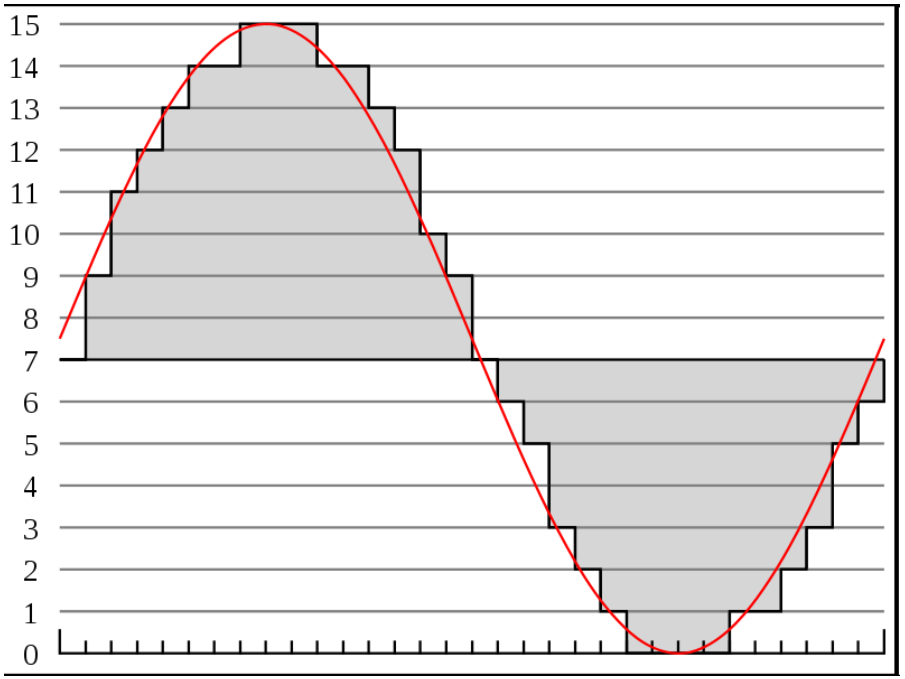
Numbers correspond to course weeks

Week 5: 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



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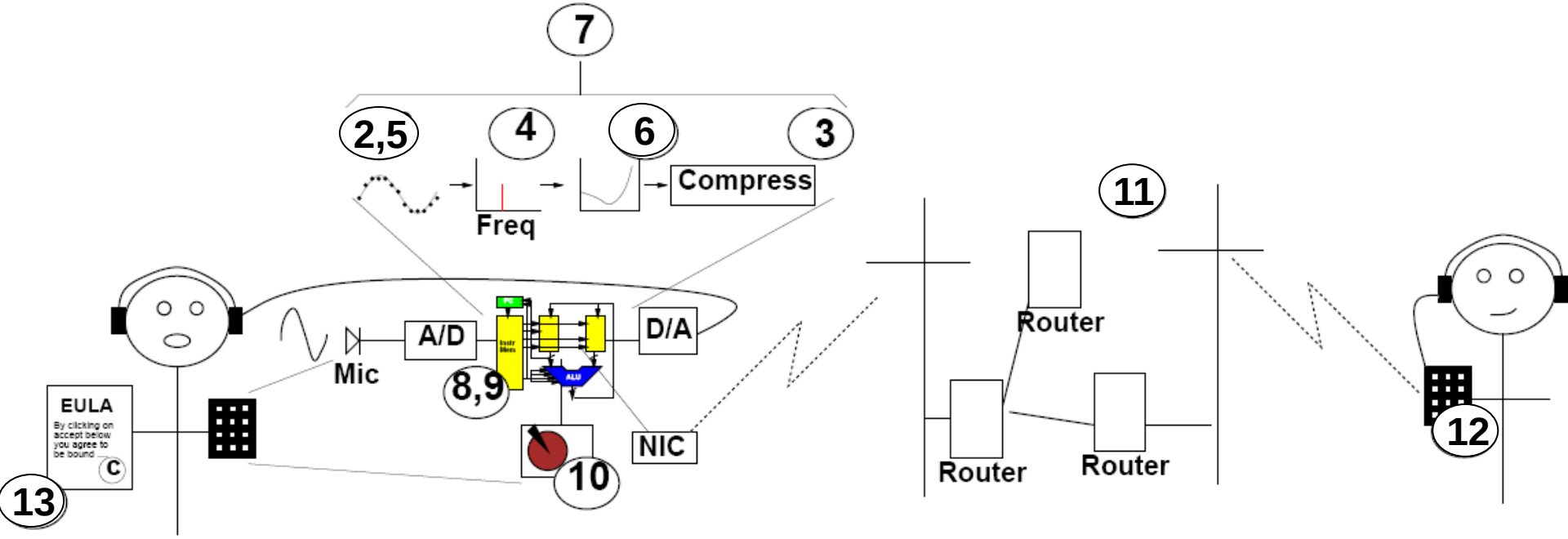
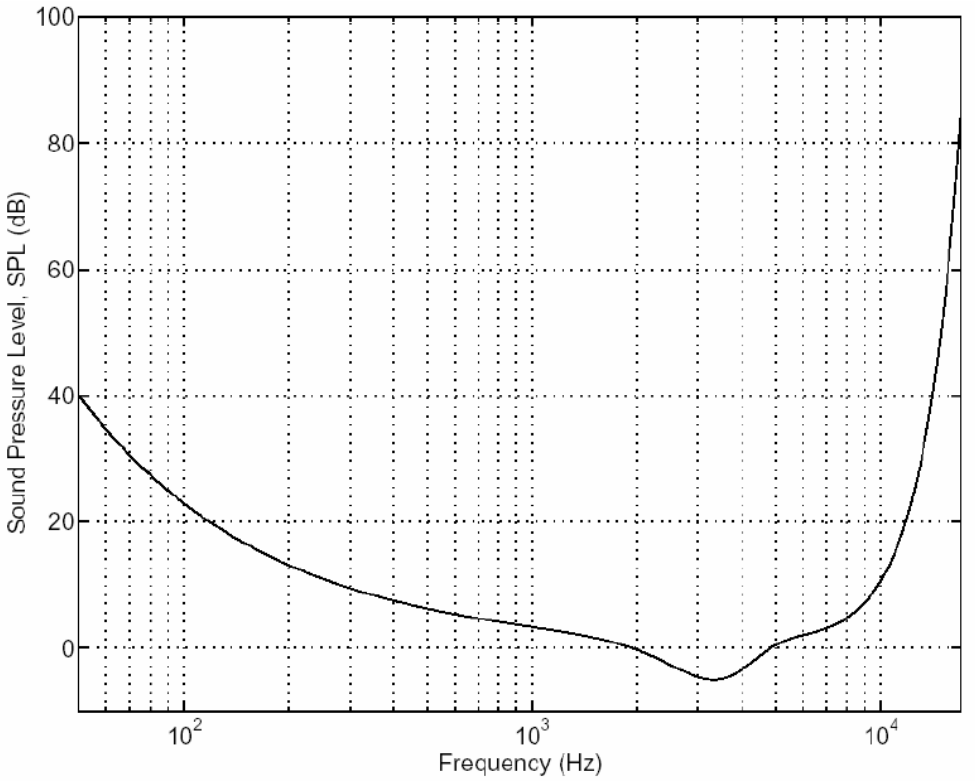


Numbers correspond to course weeks

Week 6: 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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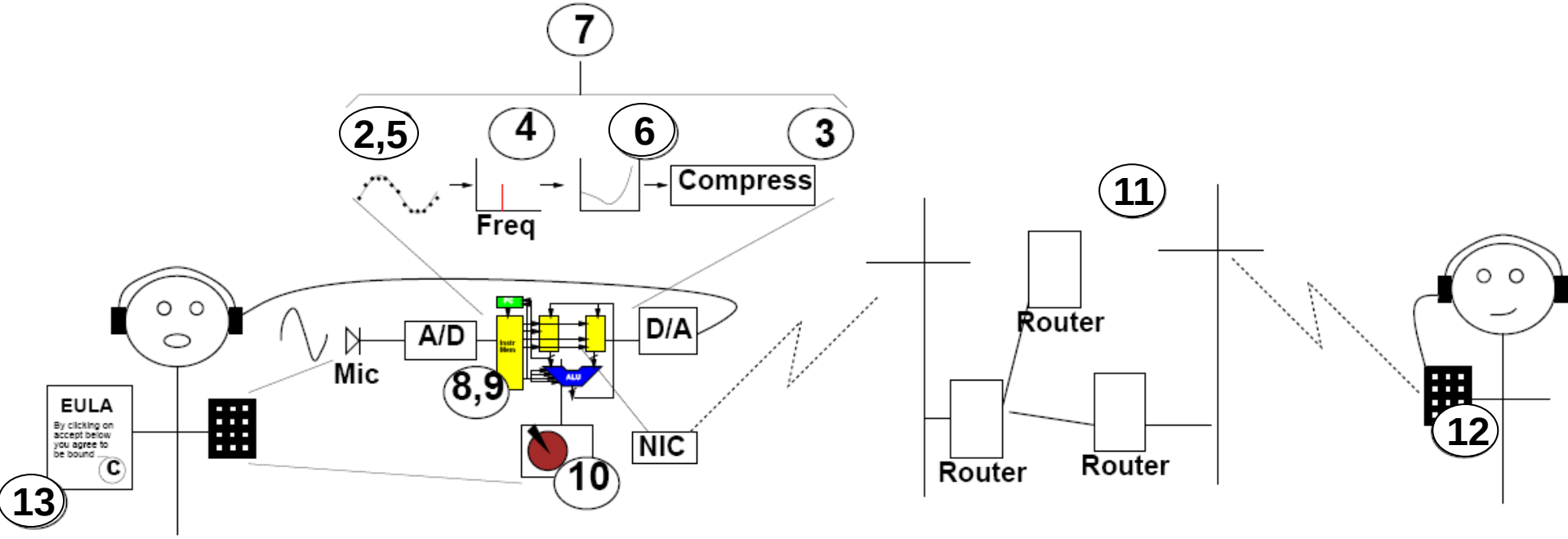
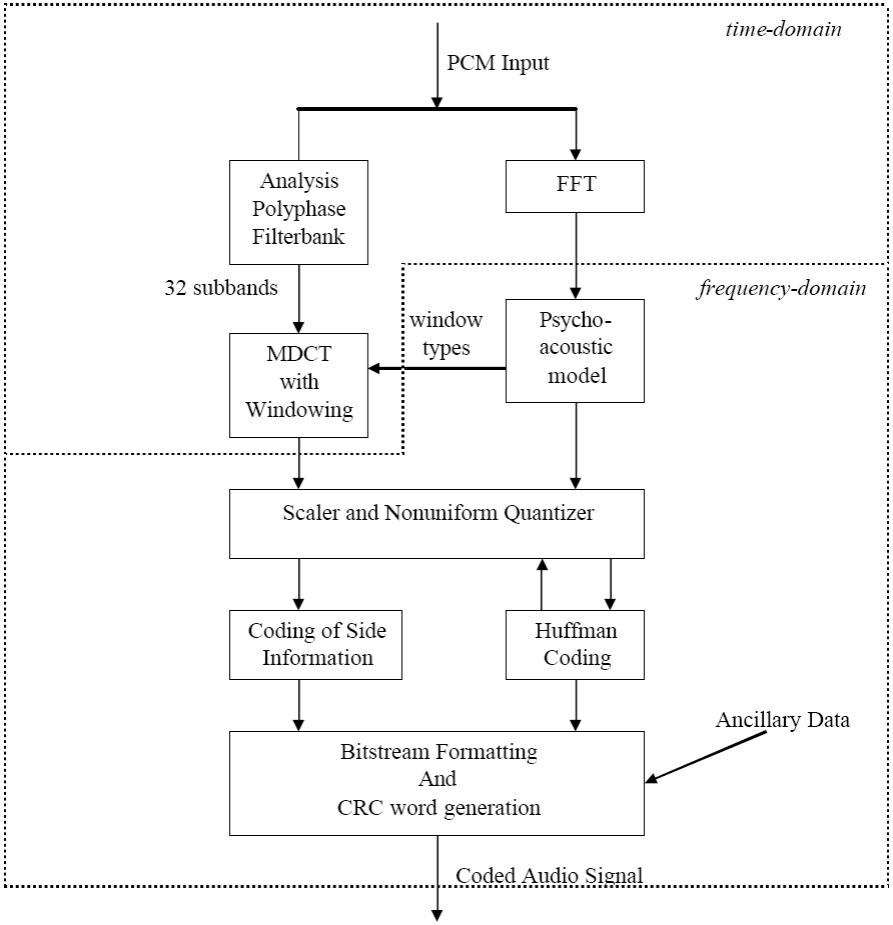


Numbers correspond to course weeks

Week 7: Psychoacoustic Compression

- MP3 based on putting these together
- Significantly smaller size than raw, sampled bits



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The Theory behind MP3

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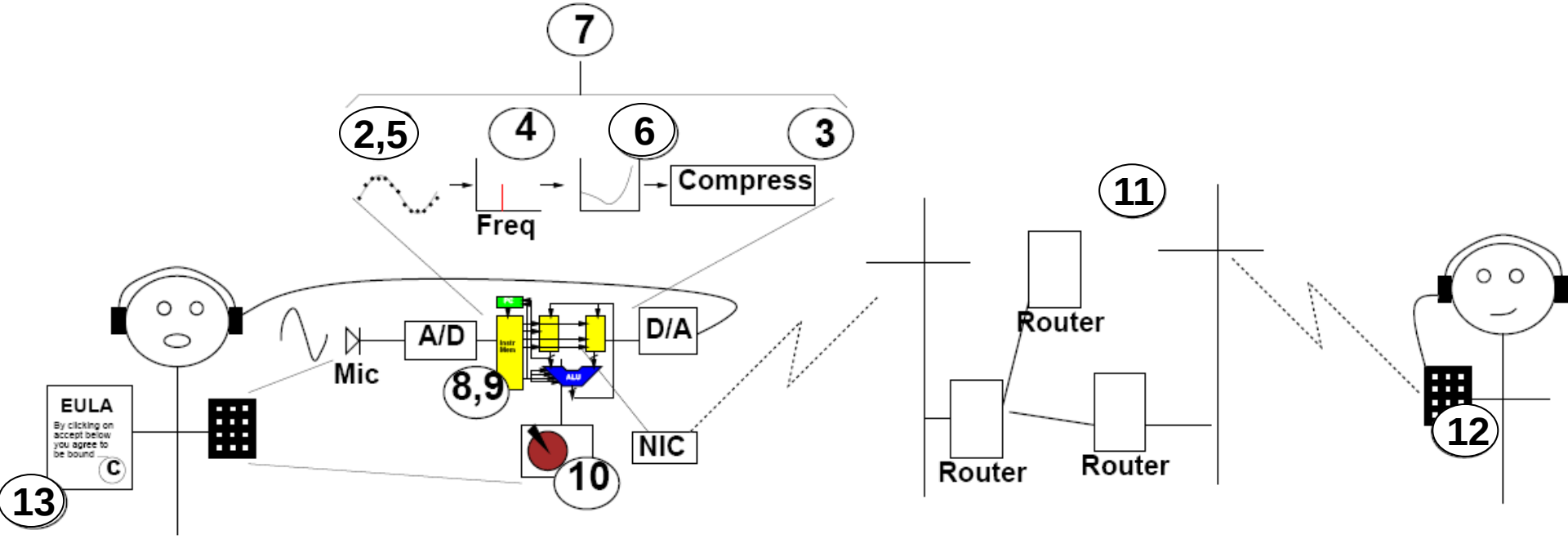
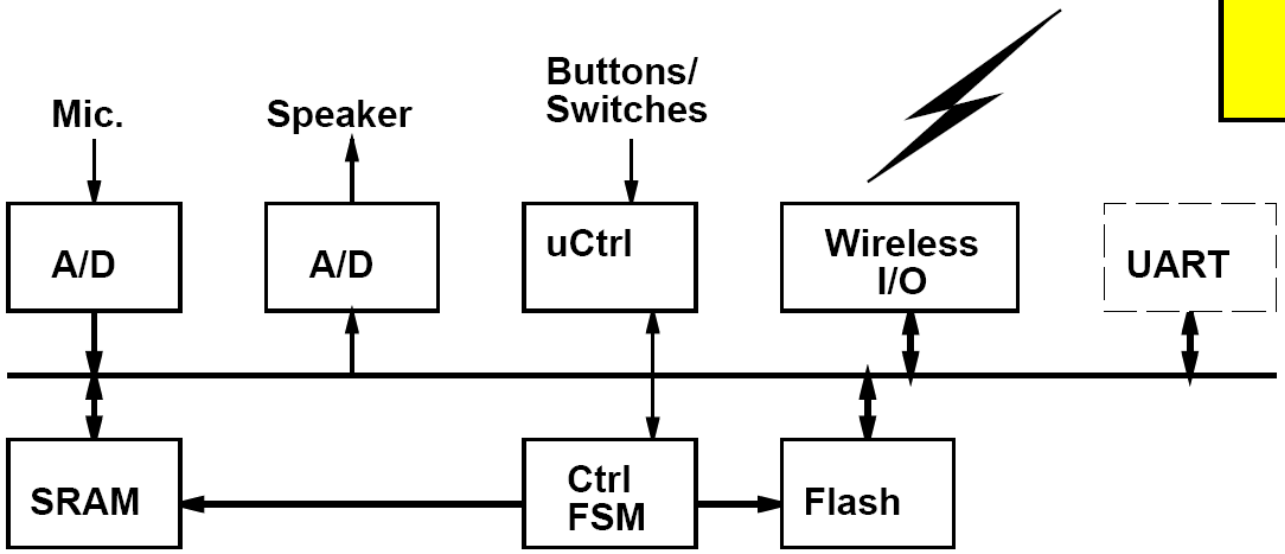
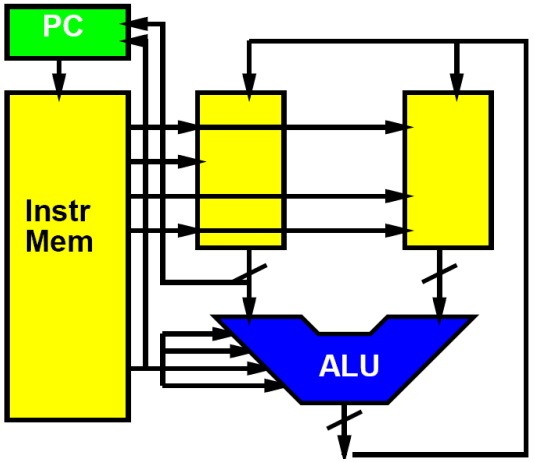


Numbers correspond to course weeks

Week 8: Hardware

- Simple, now cheap hardware can perform these tasks





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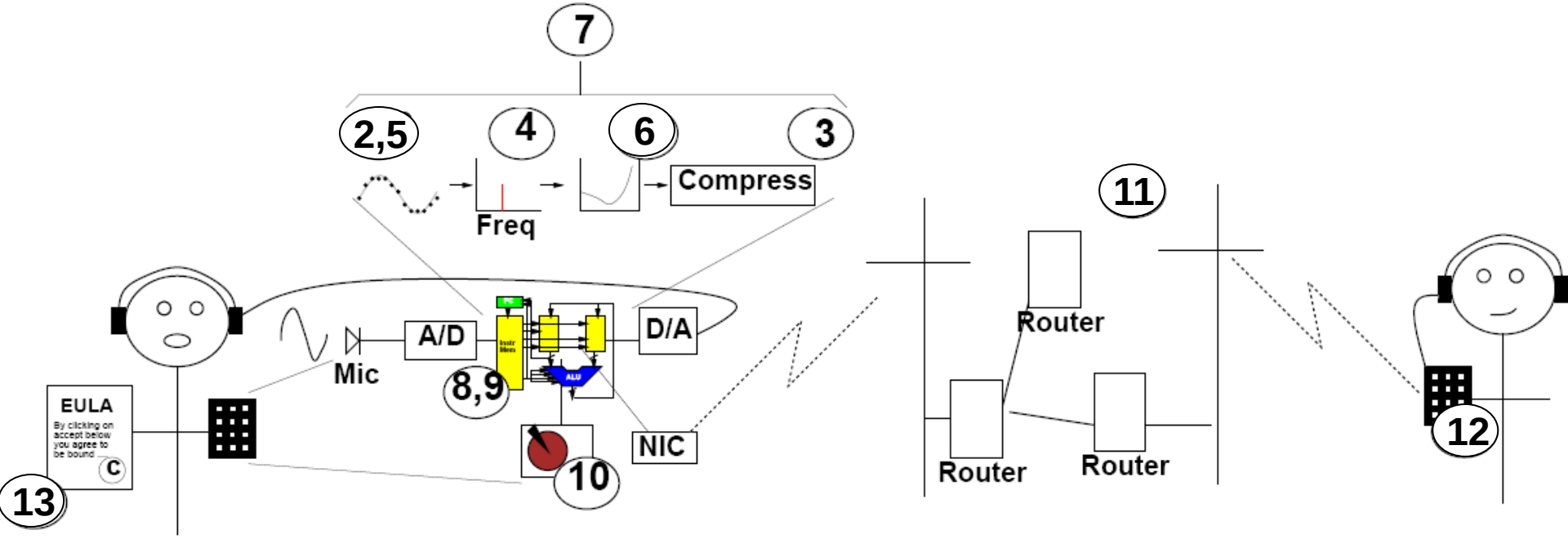
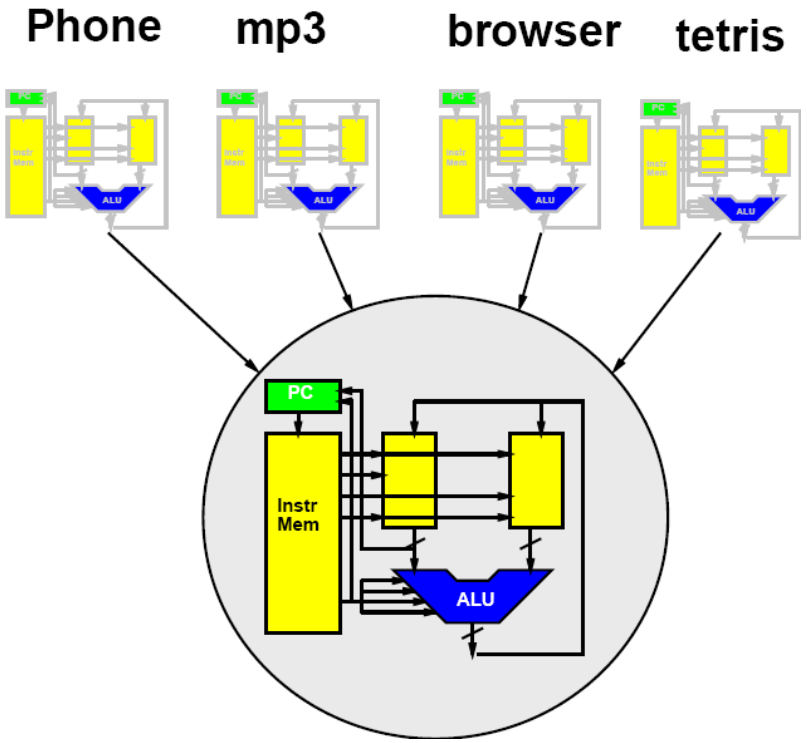


Numbers correspond to course weeks

Week 9: Operating System

- This hardware can be virtualized and shared among tasks



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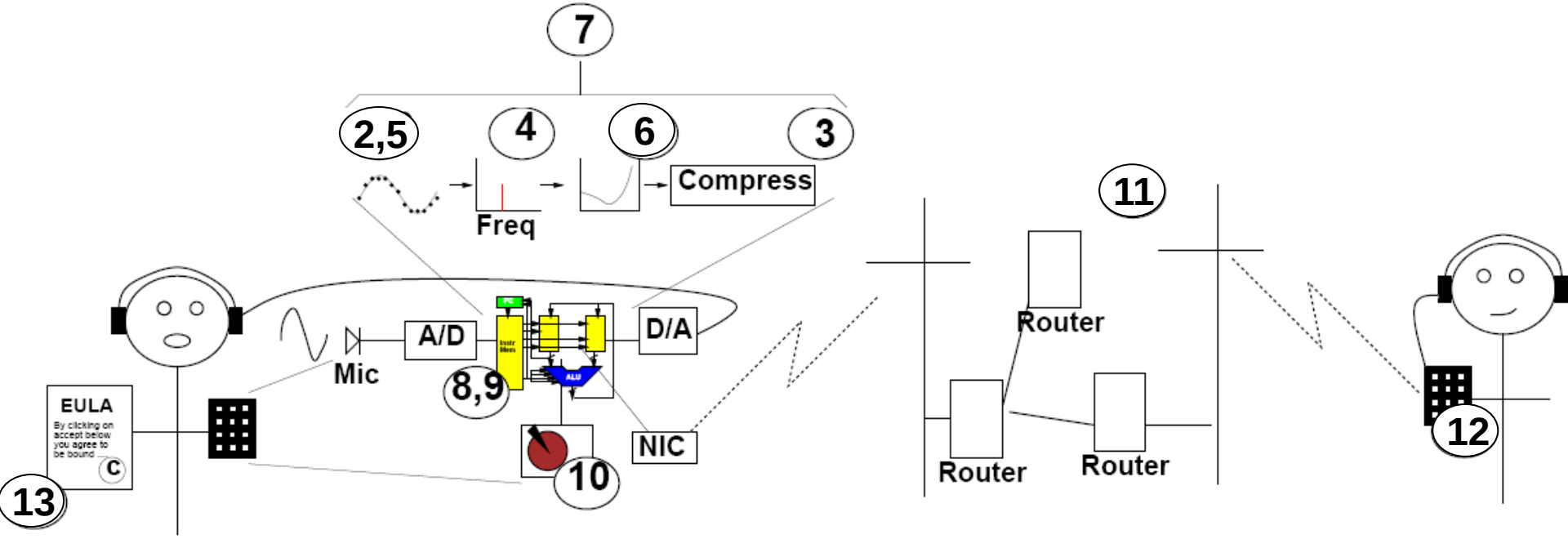
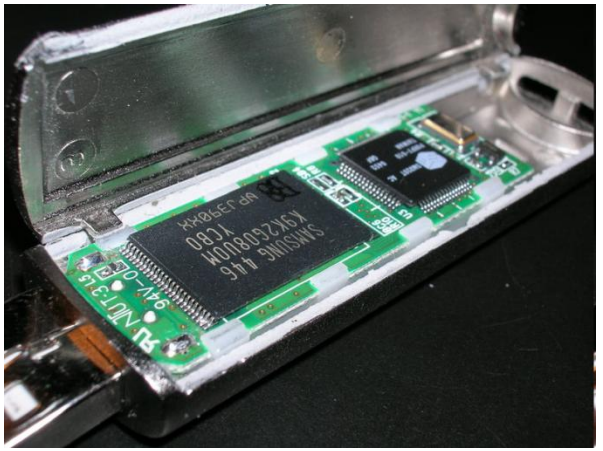


Numbers correspond to course weeks

Week 10: File Systems

- The data can be stored persistently, and organized so it can be found again.

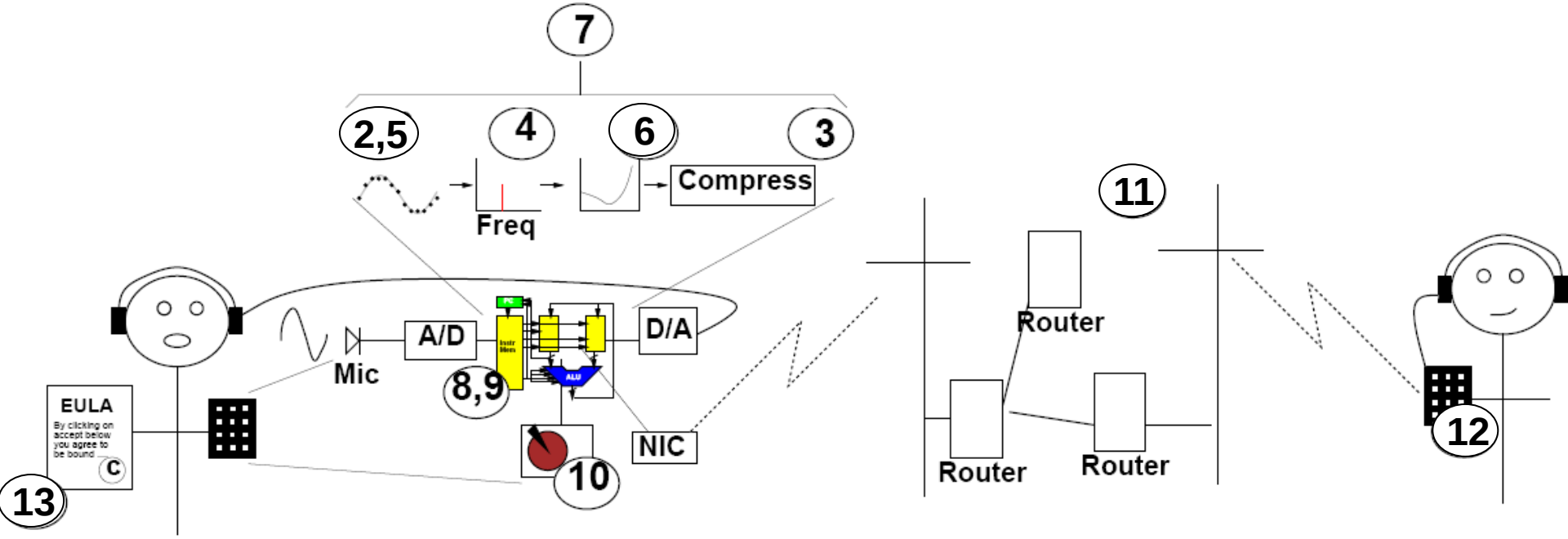


http://en.wikipedia.org/wiki/File:Compact_disc.svg

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

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

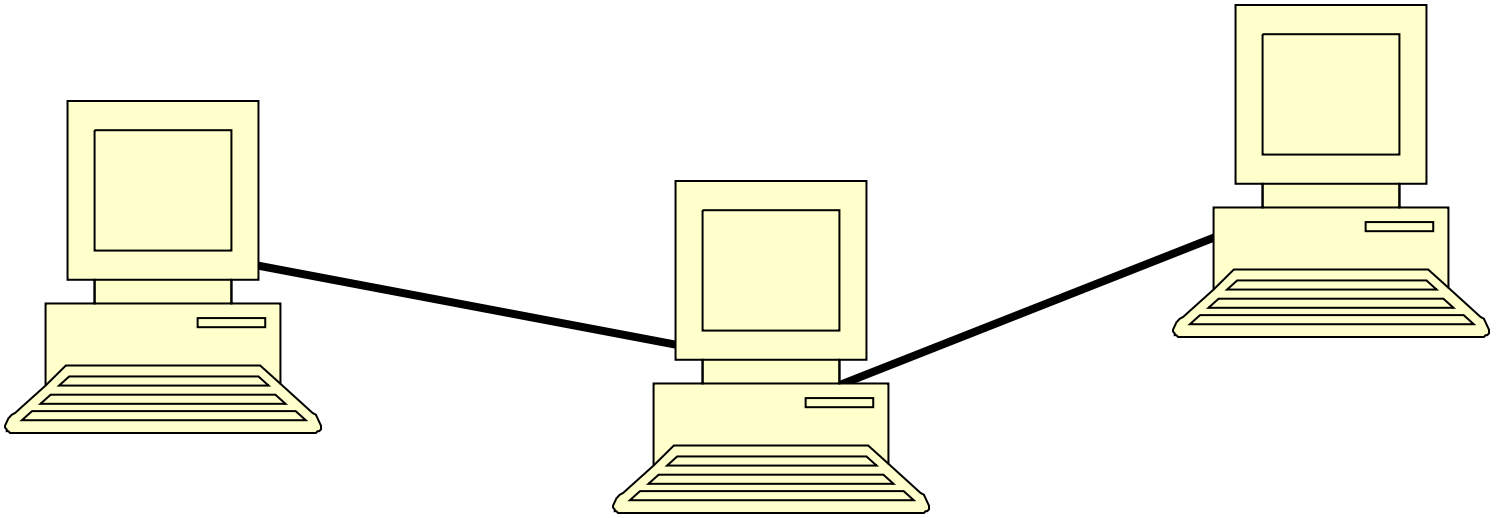
Course Map



Numbers correspond to course weeks

Week 11: Networking

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



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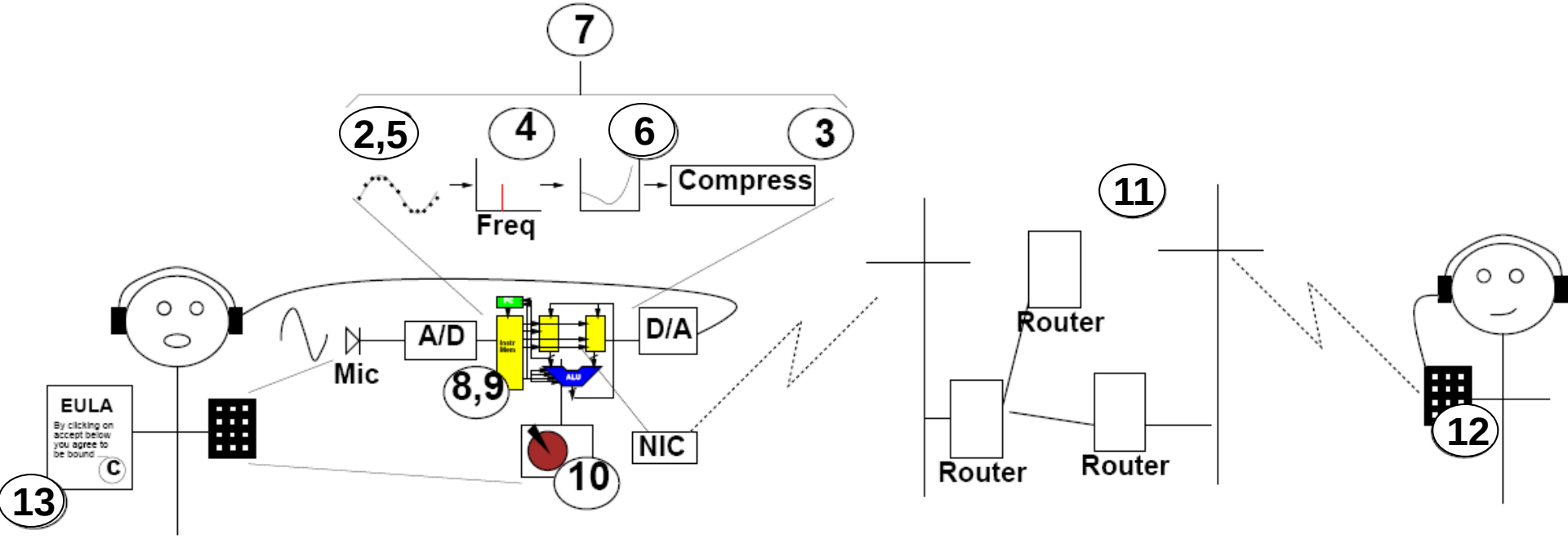

Numbers correspond to course weeks

Week 12: 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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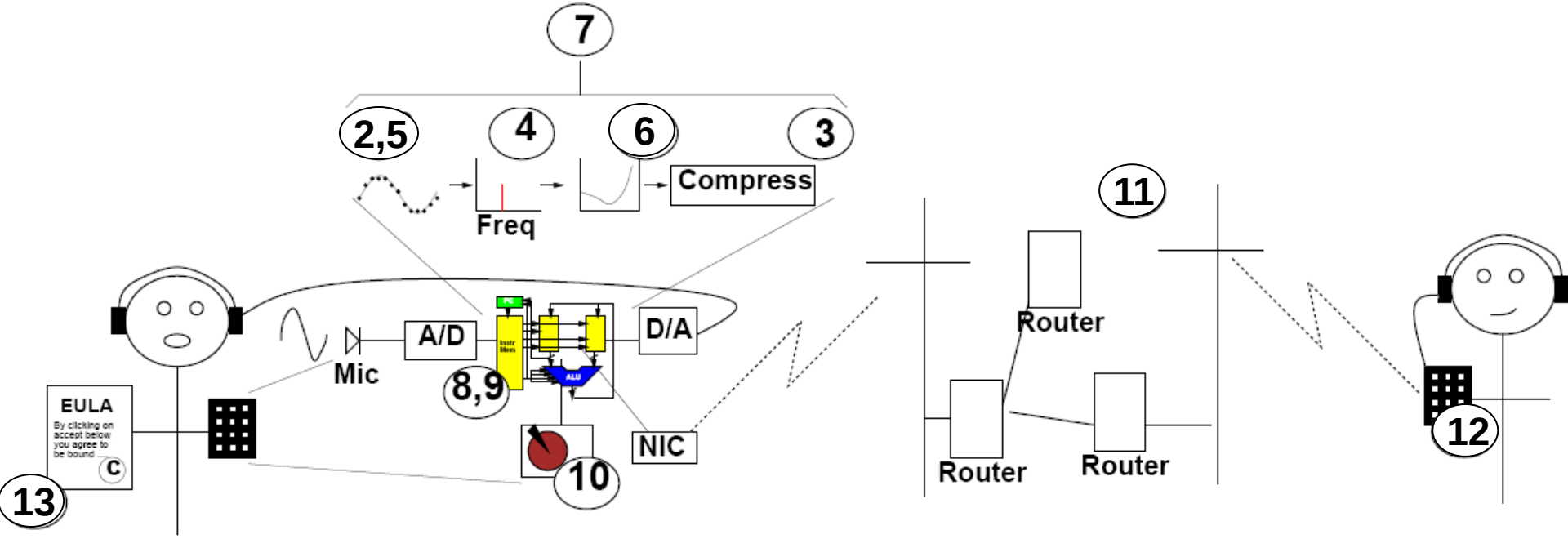

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Week 13: Intellectual Property

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

This Class: Operational

Online resources:

http://www.seas.upenn.edu/~ese250/

Blackboard Portal

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

Outcomes

- apply knowledge of math, science, and engineering (transforms, sound modeling)
- design and conduct experiments (psychoaccoustics 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)

Course Staff

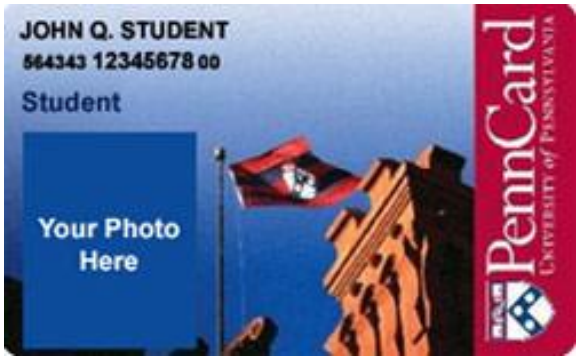
- TAs
  - Agatha Oliveira agathao@seas.upenn.edu
    - Cohort 2 + Lecture TA + Admin/Web
    - Office Hours: TBD
  - Eric Pinter pintej@seas.upenn.edu
    - Cohort 1 + Lab TA + Grades
    - Office Hours: TBD
  - Shilpa Sarode sarode@sas.upenn.edu
    - Cohort 2 + Lab TA + Grades
    - Office Hours: TBD
  - Emily Shaeffer he@seas.upenn.edu
    - Cohort 1 + Lecture TA + Admin/Web
    - Office Hours: TBD
- Instructor:
  - Dan Koditschek kod@seas.upenn.edu
  - Office Hours: Tu & Th 1:30 – 3:00 pm, 202 Moore
- Founders:
  - André DeHon
  - Benjamin Gojman

Course Organization

Labs that cannot accommodate the entire class population at once
- *perhaps: 1, 8, 9, 11*
- *will be administered in two cohorts*
- *possibly incurring repeated lecture days*
- *potentially requiring some weekend days*

- Lecture once a week
  - Nominally Thursdays
  - Large enrollment may perturb this
- Lab once a week
  - Nominally Tuesdays
  - Large enrollment may perturb this
- Materials:
  - Slides, big idea, further reading

Lab 1 Schedule



»Lab 1 in Detkin Lab Moore 101

- ID ends in ODD number: Lab1 Tuesday Jan 17

- ID ends in EVEN number: Lab1 Thursday Jan 19

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

Lab Assistant/TA

- Always looking for more students to help out & join ESE 250 cadre
  - future semesters' administrations
    - TA: lead labs; maintain course infrastructure
    - Grading
  - present semesters' administration
    - possibly need help with grading
    - 5-6 hours per week

Your Action

- Read: Big Idea
- Download Lab 1
- Prepare for lab
  - Further instructions on lab assignment
- Lab 1 in Detkin Lab (Moore 101)
  - Cohort 1 (ID ends in ODD number) Tuesday Jan 17
  - Cohort 2 (ID ends in Even number) Tuesday Jan 17

Changing World

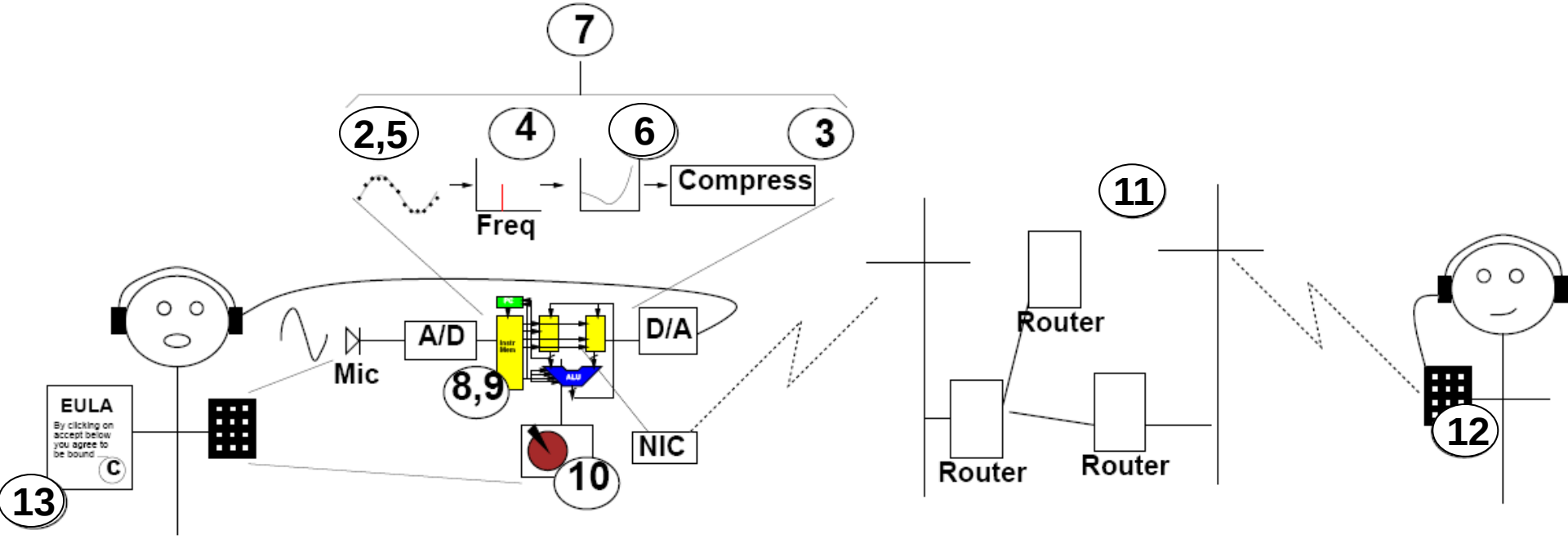
- Automated computation changed world
  - Faster than we imagined
- World being digitized and refitted for computerized control and mediation
  - People-to-people, people-to-machines
  - Infrastructure from bricks/concrete/steel to networking/computers/software
- Enabling new engineering
  - Computerization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



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