Slide 1

ESE

Work on preclass.
Lecture starts 4:35pm

Lecture #1 - Course Introduction / Intro to Digital Audio

ESE 150 –
DIGITAL AUDIO BASICS

Based on slides © 2009-2020 DeHon
Additional Material © 2014-2017 Farmer

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Slide 2

LECTURE TOPICS

- **History & Motivation**
  - Computing and Digital Audio
- **Overview of Class Schedule**
  - Big picture of our class goals
- **Course Introduction / Goals of Class**
  - Syllabus; Laboratory; Grading
- **Course Content Overview**
  - Week by week breakdown of class itself
- **Summary**

2

Slide 3

| History & Motivation |
| Short Story / Overview |
| Course Introduction |
| Learning Styles |
| Long Story / Intro to Sound |
| Summary |

HISTORY & MOTIVATION

3

Slide 4

POLL

- **How many of you:**
  - have cell phone ?
  - use GPS?
- **How do you obtain music?**
- **Communicate with friends outside of school?**
  - Voice phone, e-mail, text message, facebook, skype?
- **Where do you go to find answers?**
  - Google, wikipedia

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Slide 5

CHANING WORLD

Moore's Law – The number of transistors on integrated circuit chips (1971-2018)

Moore's law describes the empirical regularity that the number of transistors on integrated circuits doubles approximately every two years. This advancement is important as other aspects of technological progress – such as processing speed or the price of electronic products – are linked to Moore's law.

https://commons.wikimedia.org/wiki/File:Moore%27s_Law_Transistor_Count_1971-2018.png

- **Moore's Law:** Every 18 months, size of transistor halved
  - Who cares?
    - In same area, can fit twice as many transistors, twice the computing power!
    - Also, generally: if you make a transistor smaller, it gets a bit faster
      - …up to a point…

5

Slide 6
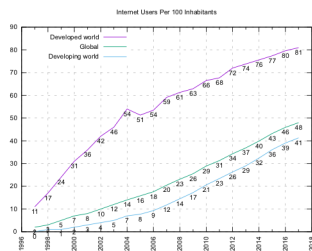
CHANING WORLD

- **Moore's Law**
- **Internet Grew**

Internet Hosts Count

By Kopiersperre , Ke4roh - Own work, CC BY-SA 3.0,
https://commons.wikimedia.org/w/index.php?curid=36391402

6

1

Connecting the World

Internet Users Per 100 Inhabitants

By Jeff Ogden (W163) and Jim Scarborough (Ke4roh) - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=18972898

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In Your Lifetime…

- 1998: Google, PayPal, First commercial MP3 player
- 2001: iPod, Wikipedia launched
- 2002: Go Pro launched
- 2003: iTunes launched, Skype released, Tesla launched
- 2004: Facebook launched
- 2005: YouTube launched
- 2006: Twitter launched, DJI launched
- 2007: iPhone introduced, Hulu launched, Netflix add video streaming
- 2008: Bitcoin, Spotify
- 2009: Venmo
- 2010: Instagram
- 2011: Siri, Snapchat, Google driverless cars, Uber
- 2012: Makerbot Replicator, Tinder launched
- 2013: Google Glass
- 2014: Amazon Alexa
- 2015: iWatch
- 2016: AirPods, Pokemon Go
- 2017: Tik Tok
- 2019: Disney+, Apple+

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Cool Stuff of Today…

- Today's "must have" technology is:
  - computerized, networked, and based on digital media
- Cell phones
- MP3 players (Digital Audio Players)
  - Internet enabled
- Digital cameras and video recorders (part of phones!)
- Realistic Video Games
- Integrated (e.g. iPhone, iPad)
- DVRs (e.g. TiVo)
- E-book readers (e.g. Kindle)
- 3D printers (e.g. Makerbot)
  - Circuit Scribe – draw actual circuits, electric ink!
  - Replicator…
- Augmented Reality (e.g. Jedi Challenge, Pokemon-Go)
  - Holodeck…

What else add to this list?

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What makes us safer, live longer?

- **Transportation**
  - Anti-lock brakes
  - Traction control
  - Blind-side assist
- **Watch over**
  - Security cameras
  - Baby monitors
- **Medical Devices**
  - Ultrasound
  - MRI
  - DNA sequencing
  - Pacemakers

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What do these things involve?

- **Computation**
- **Communications**
- **Hardware**
- **Substantial software**

- ➜ **Products of Computer Engineers**

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Changing World: Small World

- **Ubiquitous Internet**
  - This changed everything
  - Smartphone let us carry Internet with us
- **Facebook**
  - Allowed us instantly find anyone!
  - United the world in many ways

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2

CHANGING WORLD: EASY SHARING

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

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CHANGING WORLD: INSTANT GRATIFICATION

× **Search engines**
  + Instant access to knowledge
× **iTunes/Spotify**
  + Instant access to music/casts/apps/video too
× **Streaming video**
  + Instant access to video/news/visual information
  + Internet services/Netflix/Hulu/YouTube/On-Demand/etc.
× **Amazon.com**
  + Instant access to nearly any product, ~drone delivery!

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CHANGING WORLD: NEW WEALTH, NEW PLAYERS

× **Microsoft founded 1975**
  + World's richest man…for a while
× **Apple founded 1976**
  + Highest valued company
× **Oracle 1977**
× **CISCO 1984**
× **NVIDIA 1993**
× **Amazon.com 1994**
  + New world's richest man…
× **E-Bay 1995**
× **Google, Netflix, PayPal 1998**
× **Tesla 2003**
× **Facebook 2004**
× **Twitter 2006**
× **Bitcoin 2008**
× **Venmo 2009**

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CONVERGENCE

× **Big Ideas and Advanced Technology**
  + Digitize Everything
  + Cheap Digital Processing
  + Cheap Storage
  + Cheap Digital Bandwidth
× **Driven by Moore's Law**
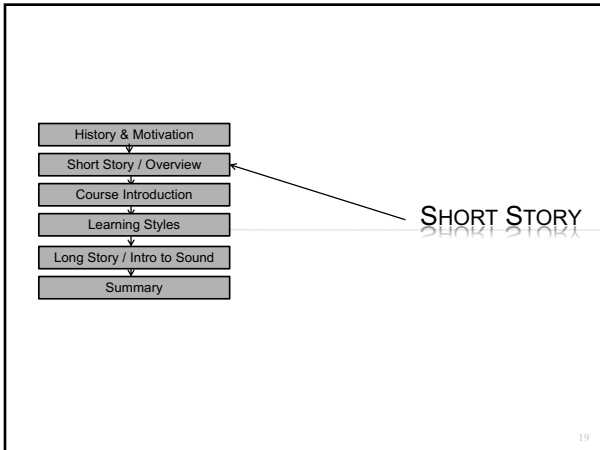 + Store and compute more bits per $$

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ENABLED BY VISIONARY ENGINEERS

× **Hard work, inspiration, and competition**
  + …would not have just happened
  + Certain applications/products tie many things together
    × No one realized facebook/music would be "killer app" for smartphone revolution
× **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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BEFORE GOING ON…MINI-QUIZ:

× **What is a bit (a Binary Digit)?**
  + Smallest piece of information we can store (on/off)
  + Indicates true or false
× **How many bits in a byte?**
  + 8
× **Bytes in a Kilobyte?**
  + 2^{10} x 1 byte = 1024 bytes
× **Bytes in a Megabyte?**
  + 2^{10} x 1KB = 1,048,576 bytes
× **Bytes in a Gigabyte?**
  + 2^{10} x 1MB = 1,073,741,824 bytes
× **How many bits to store a typical song?**

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Slide 19 — Short Story

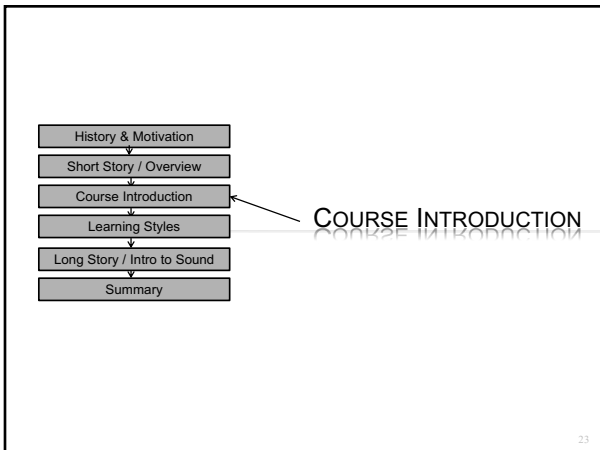| |
|---|
| History & Motivation |
| Short Story / Overview |
| Course Introduction |
| Learning Styles |
| Long Story / Intro to Sound |
| Summary |

SHORT STORY

Slide 20 — VIRTUALIZATION OF THE WORLD

- **Can represent things as bits**
  - sound, pictures, movies
  - location, situation, …
  - shapes, circuits, drugs, DNA
- **Cheap/powerful ways to automatically manipulate**
  - …and reproduce

Slide 21 — CLASS STORY: ONE SLIDE

sample ↔ domain conversion / freq ↔ pyscho-acoustics ↔ Compress

- **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

Slide 22 — COURSE MAP

7,8,9   10101001101

MIC   CPU   File-System

A/D   10101001101   10

Music   1   NIC

Numbers correspond to course weeks

sample   2   domain conversion   freq   4   5,6   pyscho-acoustics   3   compress

Cloud

13   11

EULA --------- click OK

D/A   NIC

speaker   12

MP3 Player / iPhone / Droid

Slide 23 — Course Introduction

History & Motivation
Short Story / Overview
Course Introduction
Learning Styles
Long Story / Intro to Sound
Summary

COURSE INTRODUCTION

Slide 24 — ABOUT THE COURSE

ESE150

Compression, MP3s, Psychoacoustics, and Everything

- **ESE 150: Digital Audio Basics**
  - But really: "Introduction to Computer Engineering"
- **Our Goals:**
  - Give you broad context for Computer Engineering
    - Each lecture full course on later; 13 different courses!
  - Expose you to the *big* topics in Computer Engineering
    - You won't like them all…but you will probably love 1 or 2!
    - Help you figure out which path in Comp. Eng. to take
  - Use digital audio as common theme between lectures
    - This information goes way beyond digital audio
  - Tie theory to practice ("feel-the-bits") through a weekly lab
    - To see concepts discussed in lecture in a lab environment
    - Labs are not perfect, connections sometimes not obvious at first
      - You might think lab is "stand-alone"…not really true!

MECHANICS OF THE CLASS

- **Wednesday: Lecture**
  - Introduce concepts (theory)
  - Help paint the big picture
- **Monday: Lab**
  - Put theory into practice
  - Apply 1 big concept in real world
    - Many concepts may appear in lecture…
    - One will be put to use in guise of digital audio in the lab
  - Work in teams of 2
  - Individual lab report write-ups
- **Friday: Lab Report due**
  - (except formal one – Sunday, and final one…)

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LECTURE TIMELINE

- **4:25pm – target to setup, have preclass available**
  - Start working on preclass as you arrive
- **4:35pm – start lecture**
- **5:55pm – end lecture**
  - Need to leave earlier, go ahead.

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GRADING

- **10% - Class Participation and Quizzes (if necessary)**
  - Based on assigned reading material
- **50% - Weekly Lab Report Writeup**
  - Work in groups of 2 (we assign and mix up week-to-week)
  - Some labs may have "prelab" work to do – counted as part of lab writeup
  - Drop lowest score on attempted labs
- **20% - Formal Lab Report**
- **5% - Midterm Exam**
  - Warmup for final
- **15% - Final Exam**
  - Based on reading material, lecture material, lab work
- **Read web page for policies**
  - Not hard, but must show up, engage, do the work

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COMPONENTS

- **Lecture slides online morning of lecture**
- **Big Idea – 1p'er for every lecture**
- **Reading**
- **Preclass – available beginning (ideally 4:25pm)**
  - Work through to get you thinking about the topic
  - …and gives you some of the questions will ask in lecture
  - Won't be available later, online → get them in lecture
- **"Warm" Calls**
  - Promote interaction/engagement
- **Feedback sheets**
  - Turn in at end of lecture
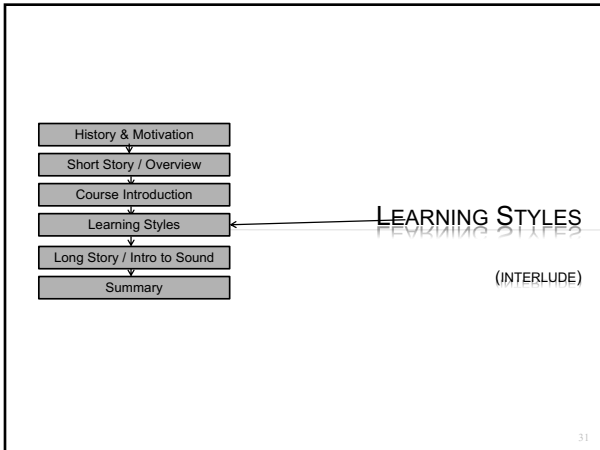 - Help me tune lecture for class

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CLASS GOALS

- **Context and motivation for CMPE major**
- **Appreciate how CMPE, EE, CSCI, SSE:**
  - Work together
  - How they impact today's world
- **Start thinking like an engineer!**

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OUTCOMES

- **Able to conduct experiments**
  - Psychoacoustic, network, hardware
- **Able to optimize information encoding**
- **Able to design file system for multiple views**
- **Able to quantify quality vs. size tradeoffs in audio**
- **Able to use oscilloscope, matlab, arduino**
- **Able to write formal lab report**
- **Understand role of Intellectual Property**
- **Appreciate User Interface design**
- **Understand technology enables new capabilities**

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History & Motivation
Short Story / Overview
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LEARNING STYLES

(INTERLUDE)

HOW DO PEOPLE COME OUT?

- **Create Histogram**
- **How I came out…**
- **Count numbers by students:**
  - Bin: 9+, 8-4, 3-1, 0, 1-3, 4-8, 9+
- **Histograms:**
  - Active/Reflective
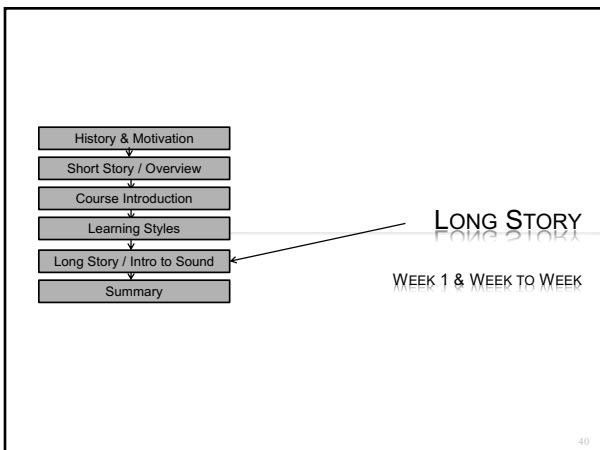 - Sensing/Intuitive
  - Visual/Verbal
  - Sequential/Global

DIMENSIONS

- **Active (ACT) vs. Reflective (REF)**
  - Doing vs. thinking
- **Sensing (SEN) vs. Intuitive (INT)**
  - Facts and methods vs. abstractions and innovation
- **Visual (VIS) vs. Verbal (VRB)**
  - Pictures, diagrams vs. descriptions
- **Sequential (SEQ) vs. Global (GLO)**
  - Linear steps vs. context and connections

See reading link on syllabus.

AWARE OF DIFFERENCES

- **Differences among people**
- **Differences between faculty and students?**
  - Claim college courses are biased toward:
    - Reflective, intuitive, verbal, sequential
- **This course:**
  - Active, sensing?, visual, global
- **Read explanation**
  - Being aware and how to cope useful for navigating all your courses at Penn

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History & Motivation
Short Story / Overview
Course Introduction
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Summary

LONG STORY

WEEK 1 & WEEK TO WEEK

WEEK 1: INTRODUCTION TO SOUND

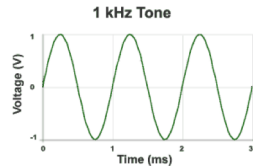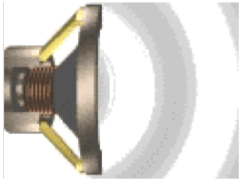- **Sound is a pressure wave**

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

WEEK 1: INTRODUCTION TO SOUND WAVES

Cycle = 1 iteration of sine wave
Hertz (Hz) = 1 cycle per second

1kHz = 1000 cycles/s

1 kHz Tone

Source: http://www.mediacollege.com/audio/01/sound-waves.html

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WEEK 1: PRESSURE TO VOLTAGE

× Microphones convert pressure to voltage
  + (speakers/headphones voltage to pressure)
  + Physical position to voltage
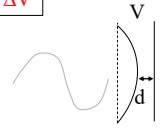
$\Delta d \rightarrow \Delta C \rightarrow \Delta V$

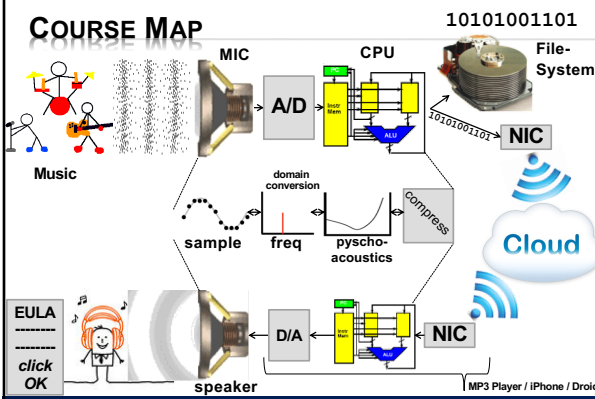× Reason as parallel plate capacitor
  + ESE 112 or PHYS 151

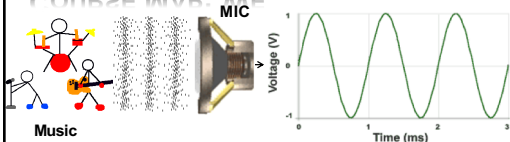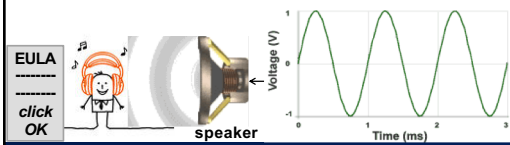$$C = \frac{\varepsilon A}{d}$$

$$Q = CV \qquad V = \frac{Q}{C}$$

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COURSE MAP

10101001101

MIC CPU File-System
A/D NIC
Music
domain conversion
sample freq pyscho-acoustics compress
Cloud
EULA

----
click OK
D/A NIC
speaker
MP3 Player / iPhone / Droid

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COURSE MAP: WEEK 1

MIC

you will do this in first lab!

Music
EULA

----
click OK
speaker

45

WEEK 2: DISCRETE SAMPLING

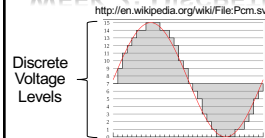http://en.wikipedia.org/wiki/File:Pcm.svg

Discrete Voltage Levels

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

× **Voltages can be sampled discretely**
  + Both in time and amplitude
× **How many bits to represent one of 16 discrete values?**
× **In general: 1 of N discrete values?**
× **Alternately: B bit number can represent how many things?**

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WEEK 2: DISCRETE SAMPLING

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

Discrete Voltage Levels
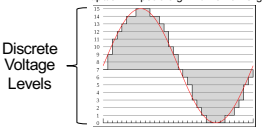
http://en.wikipedia.org/wiki/File:Compact_disc.svg

× **Voltages can be sampled discretely**
  + Both in time and amplitude
× **In general: 1 of N discrete values?**
× **Alternately: B bit number can represent how many things?**
× **N=2^B**   **B=$\lceil log_2(N) \rceil$**

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WEEK 2: DISCRETE SAMPLING

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

Discrete Voltage Levels

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

× **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 ….
× **What precision do we need?**
  + Compact Disks: 16bits at 44KHz
    × How many bits is a typical 3-minute song?

$$\left(44{,}000 \ \frac{samples}{1 \ sec}\right)\left(16 \ \frac{bits}{sample}\right)\left(60 \ \frac{sec}{1 \ min}\right)\left(3 \ \frac{min}{song}\right) = 126{,}720{,}000 \ \frac{bits}{song} = 15{,}840{,}000 \ \frac{bytes}{song} = 15.1 \ \frac{MB}{song}$$
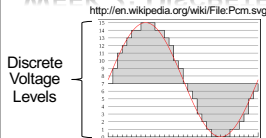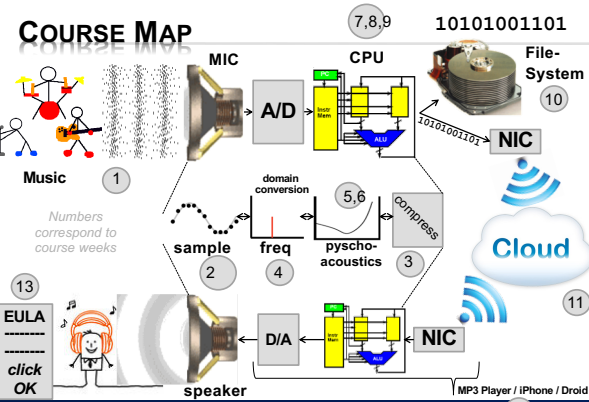
48

COURSE MAP

7,8,9   10101001101

MIC   CPU   File-System

A/D

Music   1

NIC

domain conversion

5,6

compress

sample   freq   pyscho-acoustics

Cloud

Numbers correspond to course weeks

2   4   3

13

11

EULA

----
click OK

D/A   NIC

speaker   MP3 Player / iPhone / Droid

12   49

COURSE MAP: WEEK 2

MIC

A/D

Music   1

Numbers correspond to course weeks

sample

2

EULA

----
click OK

D/A
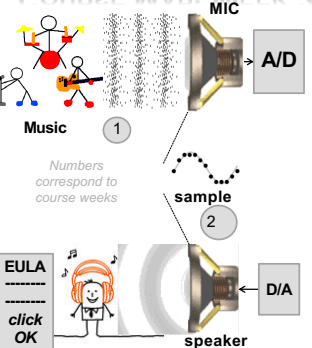
speaker

50

DIGITAL STORAGE (WEEK 10)

× **Record bits to non-volatile memory**
  + Store and reproduce sound
× **Media: CD, Hard Disk, Flash**

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
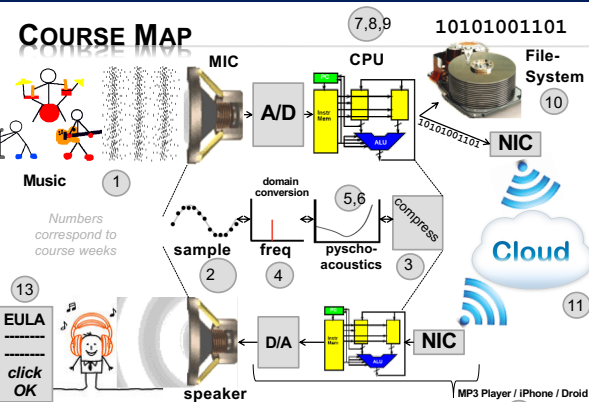
51

CALCULATING CAPACITY

× **How many songs can we fit on a CD?**
  + How many MB can a CD hold?
    × 650 MB (for Data)
    × About 780 MB (for Audio)
  + If 3 minute song = 15.1 MB…
    × 1 minute audio ~ 5.04MB
    × But, we record in stereo: (R/L)
      × 5.04 MB x 2 = 10.07 MB per minute
    × 780 MB / 10.0 MB per minute ~ 78 minutes
× **How much memory does your phone (MP3 player) have?**
  + Given unit of information to store, we can architecture storage!

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COURSE MAP

7,8,9   10101001101

MIC   CPU   File-System

A/D

Music   1

NIC

domain conversion

5,6

compress

sample   freq   pyscho-acoustics

Cloud

Numbers correspond to course weeks

2   4   3

13

11

EULA

----
click OK

D/A   NIC

speaker   MP3 Player / iPhone / Droid

12   53

8

COURSE MAP: WEEK 10

10101001101

File-System ⑩

MIC

→ A/D

Music ①

Numbers correspond to course weeks

sample ②

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WEEK 3: LOSSLESS COMPRESSION

Enables: Kindle to store 1500 books in 2GB, SMS text

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

Relative Frequency (in percent)

e t a o i n s h r d l c u m w f g y p b v k j x q z
Letter

- **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 to store or transmit!
- **Famous Example of statistical storage: Morse Code:**
- THE = — •••• • = 6 symbols (not 18 as you might expect)

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COURSE MAP

⑦,8,9   10101001101

MIC   **CPU**   **File-System** ⑩

→ A/D

10101001101

NIC

Music ①

Numbers correspond to course weeks

domain conversion

sample ②   **freq** ④   ⑤,6 **pyscho-acoustics** ③   **compress**

Cloud

⑪

⑬

EULA

----
click OK

← D/A ← **NIC**

speaker   MP3 Player / iPhone / Droid

② 56

COURSE MAP: WEEK 3

10101001101

MIC   **File-System** ⑩

→ A/D

Music ①

Numbers correspond to course weeks

sample ②

compress ③

speaker

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TIME-FREQUENCY CONVERSION

- **There are other ways to represent**

How does the musical staff representation of sound differ from time samples?

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WEEK 4: TIME-FREQUENCY CONVERSION

- **There are other ways to represent**
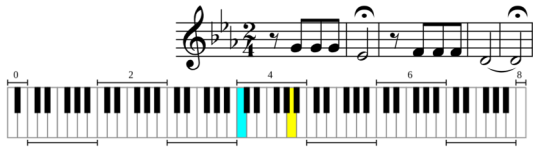 + Frequency representation particularly efficient
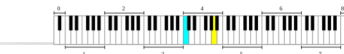
392   311   348   294

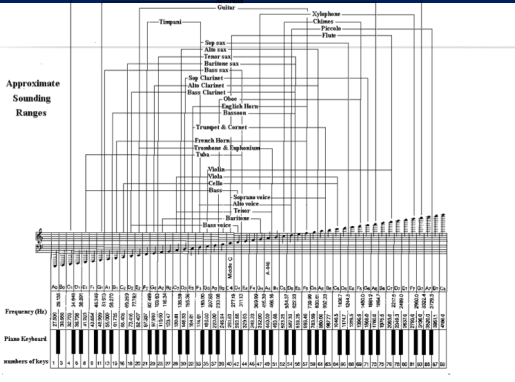Frequencies in Hertz

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TIME-FREQUENCY CONVERSION

- **1s / quarter note ➜ 10s of sound**
  + 44K Hz x 16b/sample x 10s = 7040K =7Mbits
- **How many keys on piano?**
  + (7b/note+8b/duration) x 7 note = 105 bits?

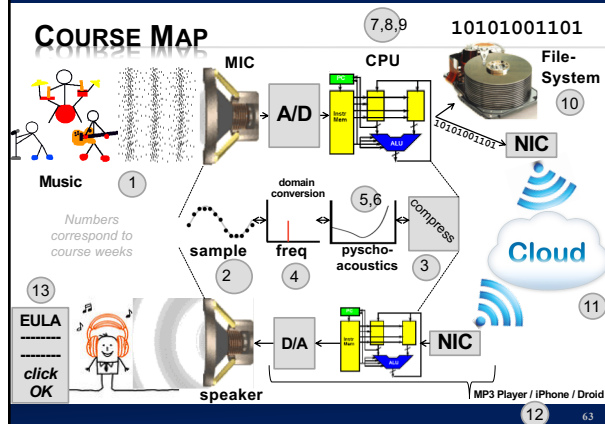AlwaysAngry: https://commons.wikimedia.org/wiki/File%3APiano_Frequencies.svg

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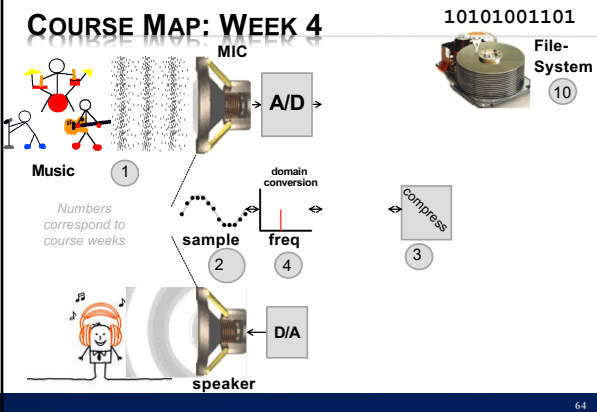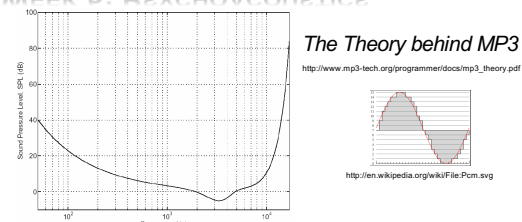Hamburg Steinway D-274 Piano photo by Karl Kunde

https://commons.wikimedia.org/wiki/File:D274.jpg

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Approximate Sounding Ranges

Larry Solomn: http://solomonsmusic.net/insrange.htm

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COURSE MAP

7,8,9 10101001101

MIC CPU File-System

Music 1

Numbers correspond to course weeks

sample 2 freq 4 domain conversion 5,6 pyscho-acoustics 3 compress

A/D NIC 10

Cloud

13 EULA

click OK

D/A NIC 11

speaker 12

MP3 Player / iPhone / Droid

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COURSE MAP: WEEK 4

10101001101

MIC File-System 10

A/D

Music 1

Numbers correspond to course weeks

sample 2 freq 4 domain conversion compress 3

D/A

speaker

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WEEK 5: PSYCHOACOUSTICS

The Theory behind MP3

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

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

- **Human input apparatus is limited**
- **If we only care about human perception**
  + …that reduces the information needed (reduces samples/sec)
- **Limited maximum frequency**

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COURSE MAP

7,8,9 · 10101001101

MIC · CPU · File-System

A/D · NIC · 10

Music · 1

Numbers correspond to course weeks

sample · 2 · domain conversion · freq · 4 · 5,6 · pyscho-acoustics · 3 · compress

Cloud · NIC · 10101001101 · 11

13 · EULA · --------- · --------- · *click OK* · D/A · NIC · speaker · 12 · MP3 Player / iPhone / Droid · 66

COURSE MAP: WEEK 6

10101001101

MIC · File-System · 10

A/D

Music · 1

Numbers correspond to course weeks

sample · domain conversion · freq · 4 · 6 · pyscho-acoustics · 3 · compress
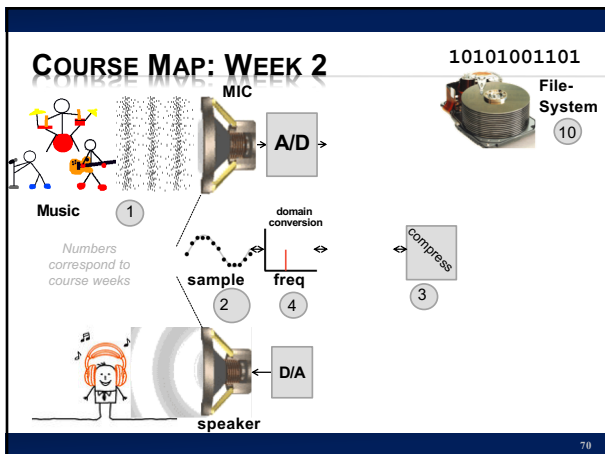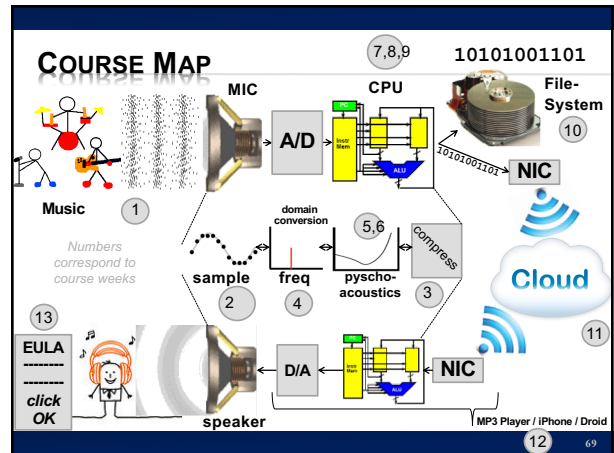
D/A · speaker · 67

WEEK 2: NYQUIST-SHANNON

- **Sampling Theorem:**
  - Only need to sample 2 x maximum frequency component of a signal
- **Range of human hearing?**
  - 20 Hz → 20 kHz
- **How many samples?**
  - 2 x 20 kHz = 40 kHz
- **CD samples /sec:**
  - 44,000 Samples / sec

The Theory behind MP3
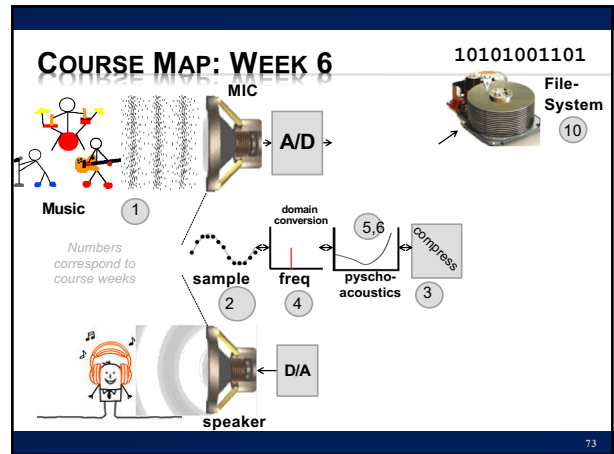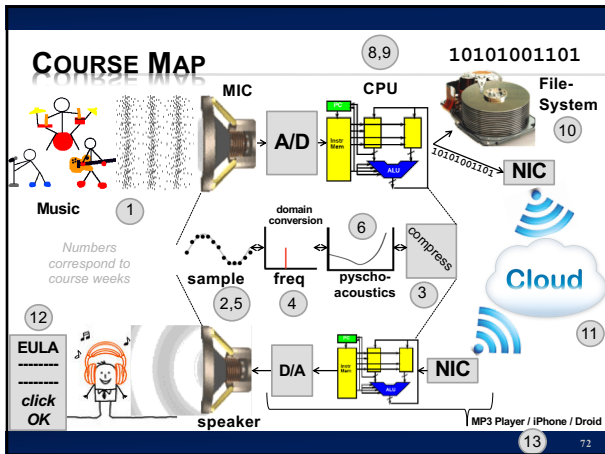
http://www.mp3-tech.org/programmer/docs/mp3_theory.pdf

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COURSE MAP

7,8,9 · 10101001101

MIC · CPU · File-System

A/D · 10

Music · 1

Numbers correspond to course weeks

sample · 2 · domain conversion · freq · 4 · 5,6 · pyscho-acoustics · 3 · compress

NIC · 10101001101 · Cloud · 11

13 · EULA · --------- · --------- · *click OK* · D/A · NIC · speaker · 12 · MP3 Player / iPhone / Droid · 69

COURSE MAP: WEEK 2

10101001101

MIC · File-System · 10

A/D

Music · 1

Numbers correspond to course weeks

sample · 2 · domain conversion · freq · 4 · compress · 3

D/A · speaker · 70

WEEK 6: PSYCHOACOUSTIC COMPRESSION

- **MP3 based on putting these together**
  - Convert to frequencies
  - **Determine frequencies that don't matter**
  - Quantize (fewer than 16b) for less important
- **Significantly smaller size than raw, sampled bits**

Bands

Q_1 Q_2 $Q_3 Q_4 Q_5$ ... $Q_k Q_k Q_{(k+1)}$ ... Q_{k4}

1 · 2 · ... k ... · 22

Lossy Coding

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COURSE MAP

8,9   10101001101

MIC CPU File-System 10

A/D Instr Mem ALU 10101001101 NIC

Music 1

Numbers correspond to course weeks

domain conversion 6 compress Cloud

sample freq pyscho-acoustics 3
2,5   4

12

EULA

----
click OK

D/A Instr Mem ALU NIC 11

speaker MP3 Player / iPhone / Droid 13 72

COURSE MAP: WEEK 6

10101001101

MIC File-System 10

A/D

Music 1

Numbers correspond to course weeks

domain conversion 5,6 compress

sample freq pyscho-acoustics 3
2   4

D/A

speaker 73

WEEK 7: HARDWARE

× **CPUs: We'll look at their operation and architecture**

× **How fast does your laptop or cell phone run?**

× **Modern chips run 100MHz to 4 GHz**
  + → only need one multiplier, adder
  + Reuse hardware it in time

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WEEK 8: HARDWARE

× **To perform decompression**
  + For audio playback
× **Need to perform**
  + a few million operations
    × Operations addition, multiplication
      × Calculate cosines
      × Scale values
      × Add waveforms
  + per second of audio
× **How fast does CPU need to be to work with audio?**
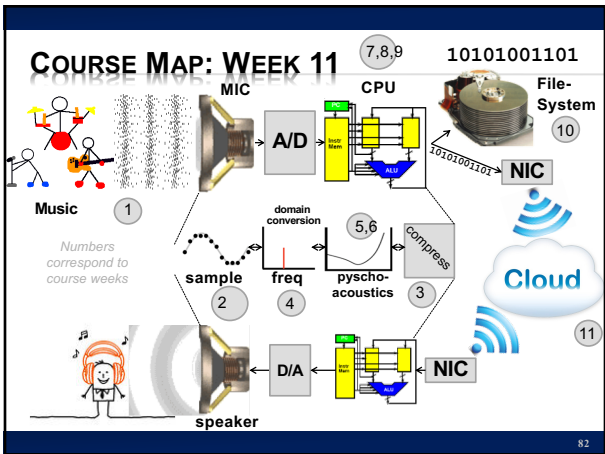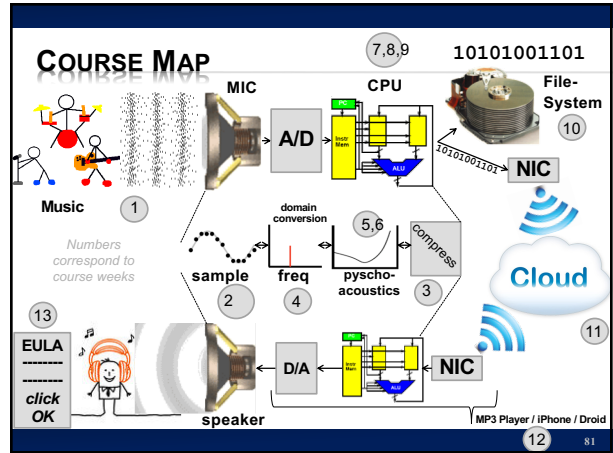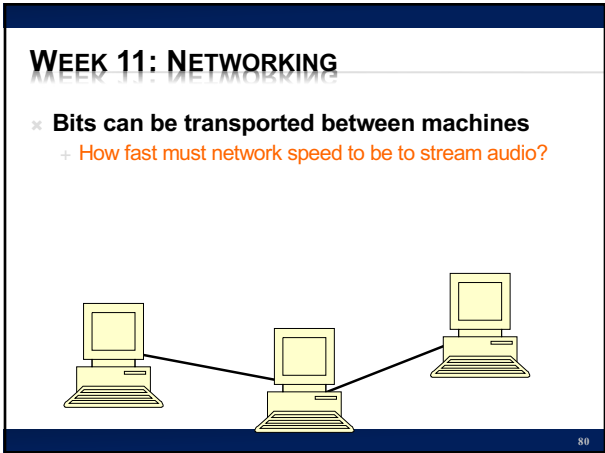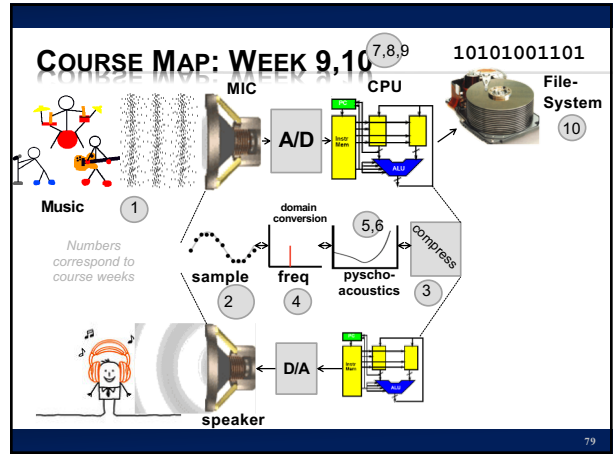
75

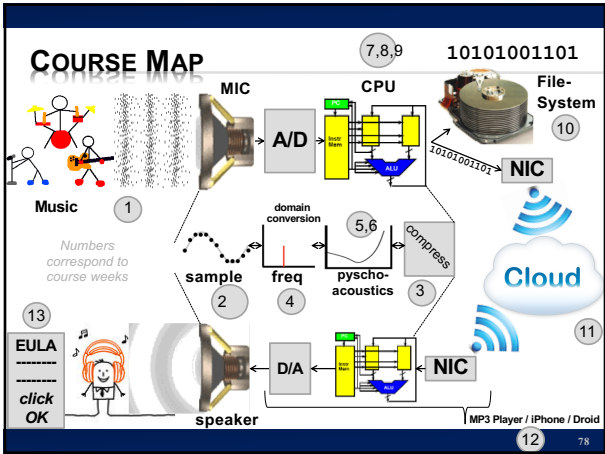
WEEK 8: IPOD PROCESSOR

× **Early based on PortalPlayer series**
  + Two ARM7TDMI cores
  + 80MHz each
× **Current use ARM7 or ARM8**

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WEEK 9: OPERATING SYSTEM

× **This hardware can be virtualized and shared among tasks**
  + How does OS control hardware?
  + Do we need giant OS or small portion for mp3?

Phone mp3 App Dejour

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WEEK 11: NETWORKING

- **Bits can be transported between machines**
  - How fast must network speed to be to stream audio?
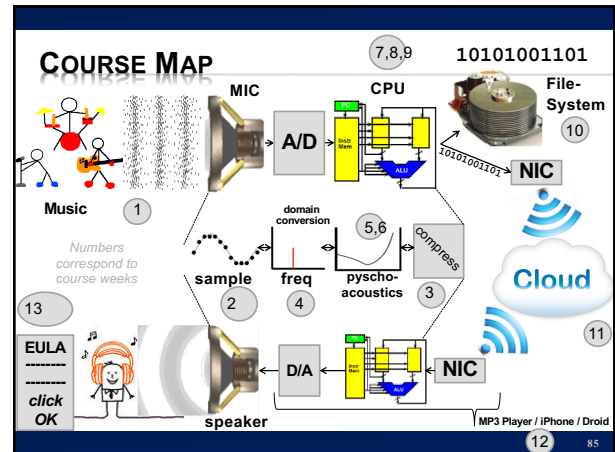

WEEK 12: USER INTERFACES

- **These capabilities can be harnessed by all people**
  - Not just engineers
- **…but we must designed for people**
  - For the non-engineers
- **iPhone is a classic example:**
  - product that didn't do anything new
  - BUT, it made everything simple
  - thanks to well designed UI

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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?

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COURSE MAP
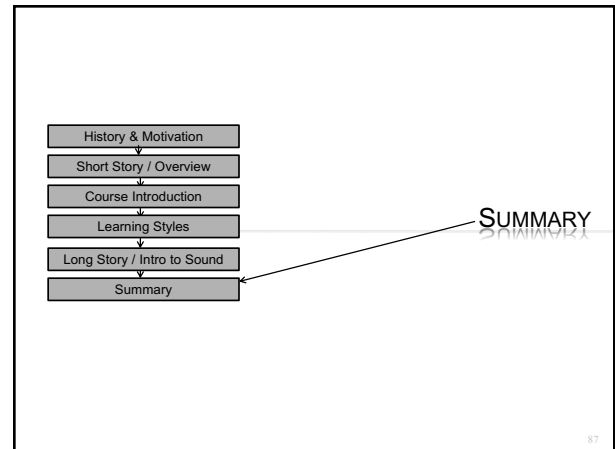

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ESE150

Compression, MP3s, Psychoacoustics, and Everything

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History & Motivation
Short Story / Overview
Course Introduction
Learning Styles
Long Story / Intro to Sound
Summary

SUMMARY

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THIS COURSE

- Always trying to improve:
  - Attempts to explain a great deal of Computer Engineering
    - Without going to far in depth
  - Lecture/Lab
    - Intent is to tie them together well
    - Inevitably, the tie won't always be obvious
  - Help us, help you (and future students):
    - The more feedback you provide, the better we can make this course
    - If a tie isn't obvious, let us help make the connection stronger
    - We want you to love Comp Engineering as much as we do ☺
  - One form: daily feedback sheets

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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**

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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?**

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