21M.380

Music and Technology: Contemporary History and Aesthetics

Christopher Ariza

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by Christopher Ariza

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Chapter 1. Meeting 1, Foundations: Music and Music Technology

1.1. Announcements

- 21M.380: Music Technology: Contemporary History and Aesthetics

1.2. An Intertwined History

- Since humans have made music with things other than the voice, technology and music have always been interrelated
  - Instruments and interfaces
  - Storing and communicating music
  - Conceptualizing and producing music
- Old problems repeatedly find new solutions
- New problems emerge, leading to new solutions
- New solutions cause new problems

1.3. Example: The Drum Machine

- Developed out of need to have auto-accompaniment for home organs
- Earliest solutions used transistors to produce poor imitations of drum sounds
- 1980: Roland TR-808 Rhythm Composer

Image courtesy of dAvid on Flickr.

- hobnox: Audiotool: Software recreation of hardware http://www.hobnox.com/index.1056.de.html
- New sounds were embraced by some, and influenced new musical styles
- The interface permitted a new way of thinking about rhythm and rhythmic cycles
- As others tried to solve this problem, new solutions emerged
- As new solutions emerged, musicians created new problems

1.4. Technology is Messy

- “Technology is messy and complex. It is difficult to define and to understand. In its variety, it is full of contradictions, laden with human folly, saved by occasional benign deeds, and rich with unintended consequences.”

  “Yet today most people in the industrialized world reduce technology’s complexity, ignore its contradictions, and see it as little more than gadgets and as a handmaiden of commercial capitalism and the military. Too often, technology is narrowly equated with computers and the Internet …” (Hughes 2004, p. 1)

- What is technology?

1.5. The Particular Problem of Technology in the Arts

- The arts have always exploited new technologies for new creative agenda
- Discrete measures of success or utility for individual artistic technologies do not exist
- Success or utility for individual technologies may not directly relate to the qualities or innovations of the technology
- Success may be more a result of the operator
- Success may be more a result of aesthetic criteria

1.6. Historical Considerations of Technology in the Arts: Benjamin

- Often a tension exists in the application of new technologies in the arts
- The mechanical reproduction of art works
  - Walter Benjamin (1936), "The Work of Art in the Age of Mechanical Reproduction"
  - Reproduction destroyed the "aura" of a work
  - Reproduction permitted a *democratization* of art
  - "Mechanical reproduction of art changes the reaction of the masses toward art. The reactionary attitude toward a Picasso painting changes into the progressive reaction toward a Chaplin movie. ... The conventional is uncritically enjoyed, and the truly new is criticized with aversion."
  - Reproduction reduces the acceptance of innovation, encourages homogeny

1.7. Historical Considerations of Technology in the Arts: Russolo

- Often new technologies suggest new artistic forms
- The hope of new artworks through new technologies that transform society
  - Italian futurists in first decades of twentieth century: F.T. Marinetti, Balilla Pratella, Luigi Russolo
  - Luigi Russolo (1913), "The Art of Noises"
  - "In the nineteenth century, with the invention of the machine, Noise was born. Today, Noise triumphs and reigns supreme over the sensibility of men. ... To excite and exalt our sensibilities, music developed towards the most complex polyphony and the maximum variety, seeking the

most complicated successions of dissonant chords and vaguely preparing the creation of musical noise. This evolution towards ‘noise sound’ was not possible before now.”

- Technology makes new types of sounds and materials musical

1.8. Historical Considerations of Technology in the Arts: Les Paul

- Guitarist, amateur engineer, tinkerer
- 1940s: experiments with adding and bouncing tracks in direct to disk recording
- 1948: produced “Lover (When You're Near Me)” album with this technique, combining up to 8 guitars
- Modifies an Ampex Model 300 mono tape recorder to record multiple individual tracks
- By 1953 develops first 8 track recorder
- Fundamentally changes approaches to recording and making music
- Experimentation and innovation by amateurs

1.9. The Inherent Sonic Ambiguity of Contemporary Music

- Is there a necessary connection between what is heard and how it is made?
- Does it matter how the sounds we hear are produced? Do technologies (combined with techniques) contribute to the value of the final musical product?

1.10. Aesthetics

- Can we make musical judgements independent taste?
- Can we make objective musical judgements?
- Cavell, after Kant: there is a difference between reasoned and supported arguments about aesthetic works and statements of personal taste, “a retreat to personal opinion” (Cavell 2002)
- Subjective observations (personal opinions) are valuable, but we can try to do more

1.11. Listening

- What are we hearing, how was it made? What musical features are dependent on or independent of technology?

- Audio: Kid Koala, "Like Irregular Chickens."

1.12. Listening

- What are we hearing, how was it made? What musical features are dependent on or independent of technology?
- Audio: Cage, "Sontata V"

1.13. 21M.380: Objectives

- Gain a critical understanding of the recent history of music technology
    - Focus on innovations from the 19th century to the present
    - Focus on music and performances, and what roles technology plays
    - Learn specific technologies, musicians, innovators, and composers
- Develop critical listening skills from a wide range of musical traditions
- Develop ability to evaluate claims about aesthetic and technological advancement
- Gain hands-on experience and creativity with select music technologies

1.14. 21M.380: Prerequisites

- Curiosity
- Experience in computer science, electronics, and music theory can be explored in individual projects

1.15. 21M.380: Four Divisions

- Fundamentals
- Recording and distribution

- Instruments and interfaces
- Languages and representations
- Excluding: Generative music systems

1.16. 21M.380: Themes

- A feedback system exists between technological development and musical innovation
- There is no necessary connection between a musical product and the means of musical production
- Technological and musical developments do not follow a linear path
- Musical devices are often coerced from other disciplines
- Musical technologies are often abstracted toward more general tools.
- Idiomatic uses of technological devices often result in innovative musical expressions

1.17. 21M.380: Course Meetings and Materials

- Two types of meetings
    - Topic meetings: focused on material in readings, listening, and themes, combining lecture, discussion, demonstration, and listening
    - Discussion and workshop: focus on discussion, hands-on experimentation, and improvisation
- Materials for demonstration and exploration
    - Software: PD, Supercollider, Martingale, Audacity, and Freesound
    - Circuits: breadboards and ICs, small amplifiers, speakers, toys
    - Acoustic and mechanical constructions
- Lecture Notes
    - [Posted in OCW]

1.18. 21M.380: Assignments: Reading

- 1. Braun, H. 2002. *Music and Technology in the Twentieth Century*. Baltimore: The Johns Hopkins University Press.

  2. Collins, N. 2009. *Handmade Electronic Music: The Art of Hardware Hacking*. 2nd ed. New York: Routledge.

  3. Holmes, T. 2008. *Electronic and Experimental Music*. Third ed. New York: Routledge.

- Numerous additional readings from many disciplines.

  1. Bimber, B. 1990. "Karl Marx and the Three Faces of Technological Determinism." *Social Studies of Science* 20(2): 333-351.

  2. Brown, B. 1981. "The Noise Instruments of Luigi Russolo." *Perspectives of New Music* 20(1-2): 31-48.

  3. Collins, K. 2007. "In the Loop: Creativity and Constraint in 8-bit Video Game Audio." *twentieth-century music* 4(2): 209-227.

  4. Fouché, R. 2006. "Say It Loud, I'm Black and I'm Proud: African Americans, American Artifactual Culture, and Black Vernacular Technological Creativity." *American Quarterly* 58(3): 639-661.

  5. Ghazala, Q. R. 2004. "The Folk Music of Chance Electronics: Circuit-Bending the Modern Coconut." *Leonardo Music Journal* 14(1): 97-104.

  6. Horning, S. S. 2004. "Engineering the Performance: Recording Engineers, Tacit Knowledge and the Art of Controlling Sound." *Social Studies of Science* 34(5): 703-731.

  7. Lessig, L. 2005. *Free Culture*. New York: Penguine Books. Internet: http://www.free-culture.cc/freeculture.pdf.

  8. Loy, D. G. 1985. "Musicians Make a Standard: The MIDI Phenomenon." *Computer Music Journal* 9(4): 8-26.

  9. Nielsen, S. H. and T. Lund. 2003. "Overload in Signal Conversion." *AES 23rd International Conference*.

  10. Oswald, J. 1985. "Plunderphonics, or Audio Piracy as a Compositional Prerogative." *Wired Society Electro-Acoustic Conference*. Internet: http://www.plunderphonics.com/xhtml/xplunder.html.

  11. Pinch, T. J. and W. E. Bijker. 1984. "The Social Construction of Facts and Artefacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other." *Social Studies of Science* 14(3): 399-441.

12. Roads, C. 1980. "Interview with Max Mathews." *Computer Music Journal* 4(4): 15-22.

13. Sousa, J. P. 1993. "Machine Songs IV: The Menace of Mechanical Music." *Computer Music Journal* 17(1): 14-18.

14. Sterne, J. 2006. "The mp3 as cultural artifact." *new media & society* 8(5): 825-842.

15. Walser, R. 1995. "Rhythm, Rhyme, and Rhetoric in the Music of Public Enemy." *Ethnomusicology* 39(2): 193-217.

1.19. 21M.380: Assignments: Listening

- Listening assignments are critical
- Reading notation and scores are not required
- Take notes when you listen
- What to listen for: duration, instrumentation, method of production, recording or performance context, notable sonic events, form, temporal design and proportions, aesthetic or historical contexts, and/or critical and subjective responses

1.20. 21M.380: Assignments: Discussion Leader

- Two students are assigned to cover reading and listening assignments for each class
- Must be available to lead discussion, answer questions, and provide a resource to class
- Must distribute minimal notes to the class.

1.21. 21M.380: Assignments: Music Technology Case Study

- A research paper into the development, use, exploitation, or deployment of any musical technology
- Must, at least in part, employ approaches to investigating the aesthetic and cultural context and construction of the music technology.
- Complete draft: 3 November
- Final draft: 24 November (before Thanksgiving)

1.22. 21M.380: Assignments: Sonic System Project and Presentation

- An original sonic system that functions as either an instrument with a performance interface or as a static or dynamic musical work
- May explore any software or hardware system or interface; can extend class examples or produce completely original works
- Includes a short written report describing approaches and design
- Preliminary demonstration: 12 November
- Final presentation: 3 December

1.23. 21M.380: Assignments: Submission

- All assignments are submitted digitally via email attachment (or Forum posts)
- All assignments are due at 11:59:59 PM on due date
- Late within 1 week: 20% reduction; no assignments accepted after 1 week

1.24. 21M.380: Attendance

- Mandatory and essential
- More than one unexcused absence incurs a 3% grade reduction

1.25. 21M.380: Exams and Quizzes

- All short written answers
- Quizzes will be announced, and frequent
- Quizzes will be based on reading, listening, and course content

1.26. 21M.380: Grading

- Reading and Listening Discussion Leader: 20%
- Music Technology Case Study: 25%
- Music Technology Case Study Draft: 5%
- Sonic System Project and Presentation: 20%

- Sonic System Project Draft: 5%
- Quizzes: 15%
- Participation: 10%

1.27. 21M.380: Additional Policies

- Read entire syllabus
- Common courtesies
- Computers in class
- Academic integrity

1.28. 21M.380: Contact

- Always feel free to contact me with any problem or concern with this class

1.29. Us

- Backgrounds, experiences, goals

1.30. PureData and Martingale

- There will be frequent demonstrations of sound and sound processes
- These will be done mostly in PureData (PD), also in Supercollider
- All PD and other code examples will be made available through an open source library called Martingale: http://code.google.com/p/martingale
- Those familiar with SVN can join and submit code

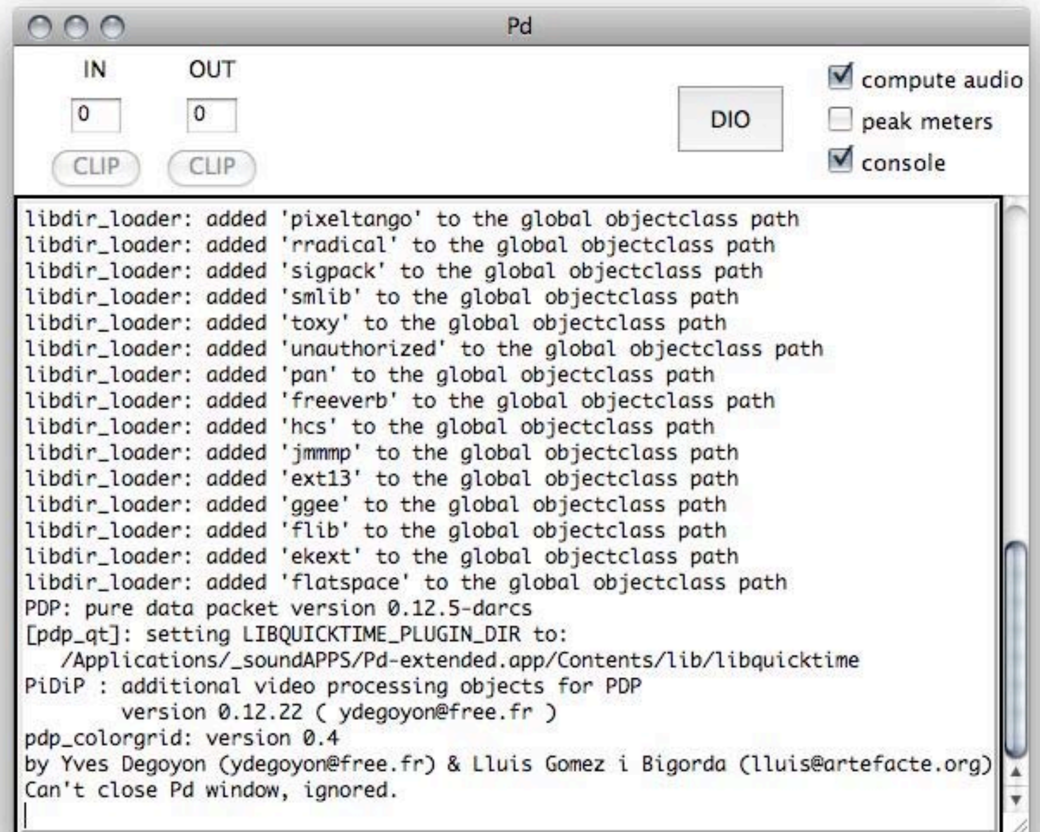
1.31. Downloading PD

- Best to install on your own computer
- Processor performance matters: you may need to tune system

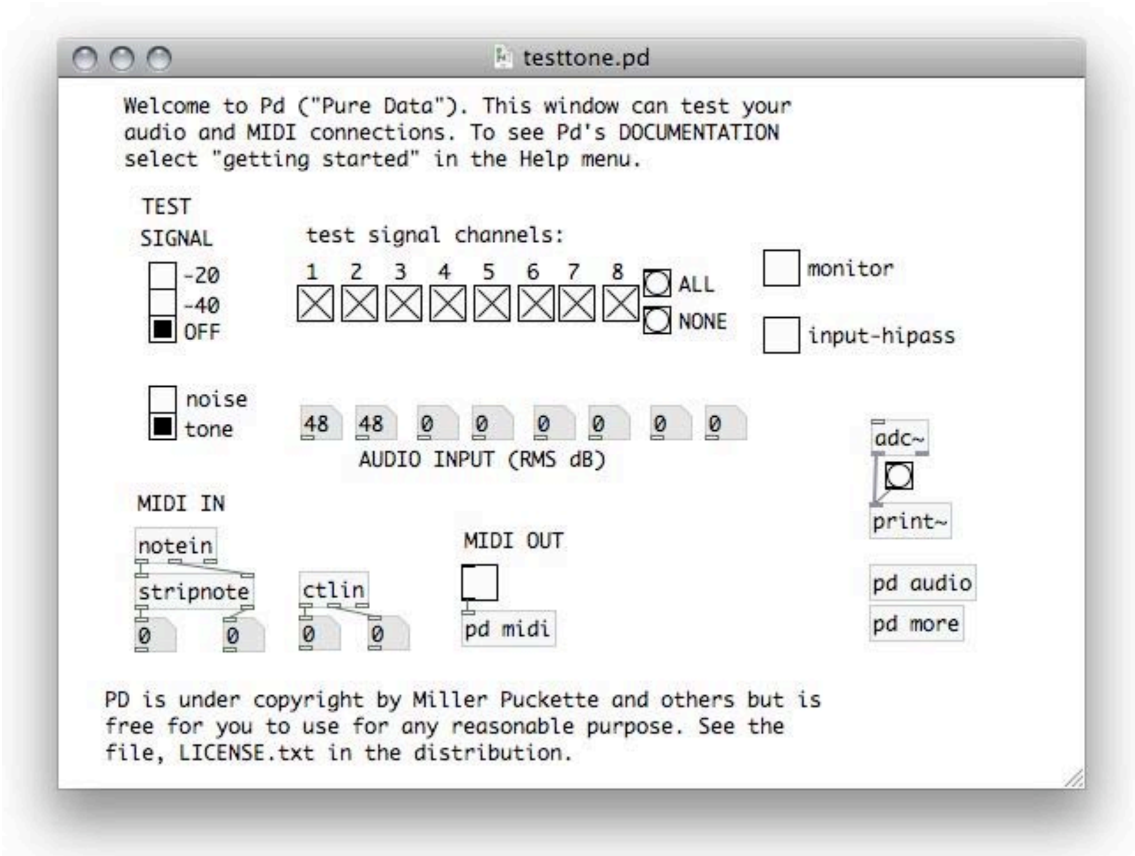
- Download PD-Extended for your platform: http://puredata.info/downloads

1.32. Installing and Testing PD

- Follow default install instructions (unless you know what you are doing)
- Open application; should see the "Pd window"



- Select: Menu: Media > Test Audio and MIDI



- Find “TEST SIGNAL”; click boxes next to -40, -20, listen (raise system volume, unplug headphones, etc.)
- If the tone is distorted, rough, or broken sounding, contact me
- If there is no sound, go to Menu: Preferences > Audio Settings
- Try to select a different “output device 1”
- If this fails, quit and repeat
- If this fails, contact me

1.33. Listening

- What are we hearing, how was it made? What musical features are dependent on or independent of technology?
- Audio: John Oswald, "Dab"

1.34. Listening

- What are we hearing, how was it made? What musical features are dependent on or independent of technology?
- Audio: Aphex Twin, "Cock/Verlo"

1.35. Discussion Leaders

- [Content removed for OCW publication]

1.36. For Next Meeting

- Read *entire* syllabus
- Listening: only La Monte Young
- Reading: Holmes, Sousa
- Discussion leader assignments will go out via email

Chapter 2. Meeting 2, Foundations: The Science and Visualization of Sound

2.1. Announcements

- Check course notes for reading and listening discussion leaders
- We will cover the basics of using PD and Martingale during Meeting 5, next week

2.2. Reading: Sousa

- Sousa, J. P. 1993. "Machine Songs IV: The Menace of Mechanical Music." *Computer Music Journal* 17(1): 14-18.
- What technologies is Sousa concerned about?
- What does Sousa claim are the detriments? What is being lost?
- What other causes, ignored by Sousa, might lead to the conditions he describes?
- Sousa suggest that the goal of music is the "expression of soul states"; is this true?
- What generalities does Sousa suggest about American music, and the history of music?
- For Sousa, can mechanically reproduced music have expression?
- Did copyright law, during this period, see recordings as a copy of a musical work? Why or why not?
- Dose Sousa attribute agency to machines? Why is this relevant?

2.3. Listening: Young

- La Monte Young: "Excerpt 31 | 69 c. 12:17:33-12:25:33 PM NYC" & "31 | 69 C. 12:17:33-12:24:33 PM NYC"
- What are we hearing, and how is it made?
- Is the timbre constant; when does it change?

- What sort of performance context might this work within?
- What affect does this music have on the audience? What is the role of the listener?

2.4. The Science of Sound

- The attributes and measurements of sounds
- How we visualize and display these attributes
- How these measurements relate to human hearing and the brain: psychoacoustics

2.5. Relevance to the Study of Music and Technology

- To describe and understand the abilities of various technologies
- To measure technological progress or decline
- To compare products and evaluate claims
- To measure the efficacy of various technologies for humans

2.6. What Is Sound?

- Variations in pressure through a medium

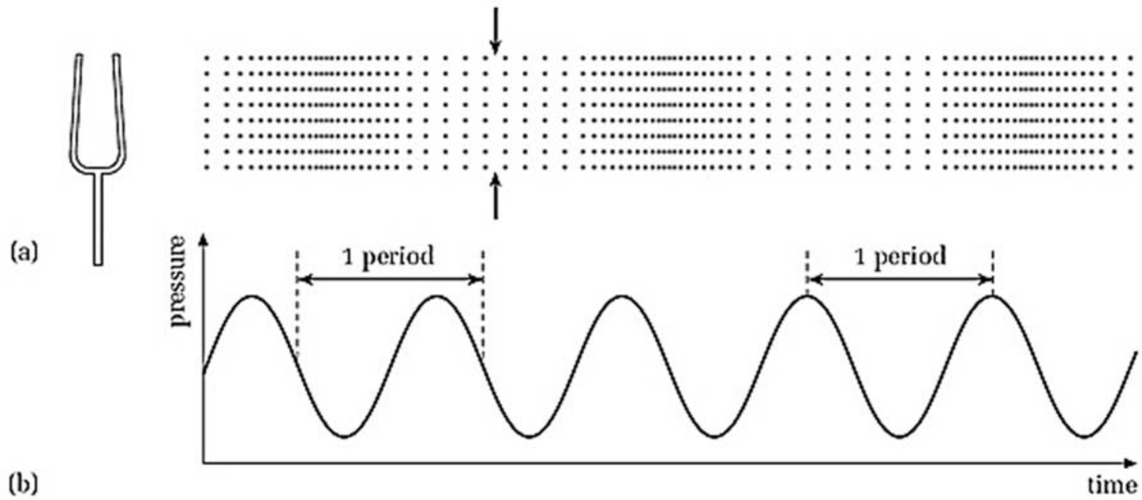
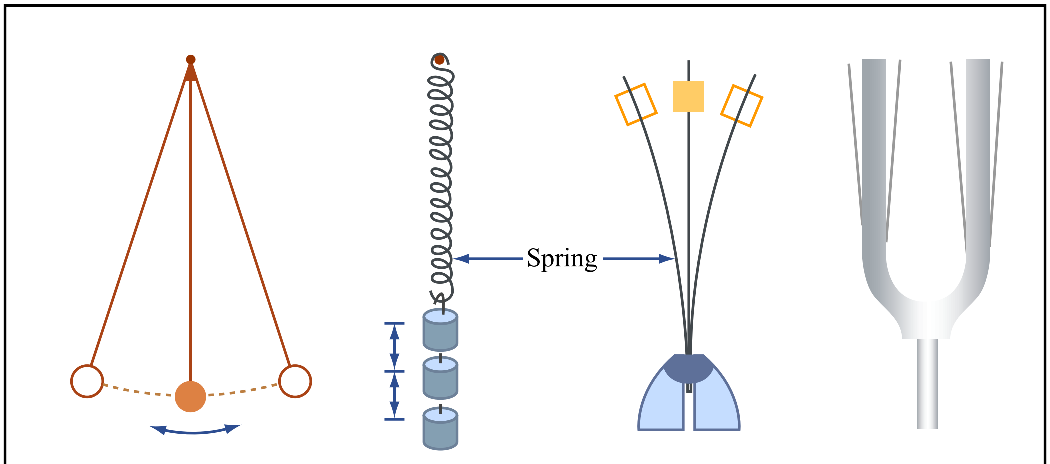


Image: "Sinusoidal pressure waves" from *Sound for music technology: an introduction*. http://openlearn.open.ac.uk/mod/resource/view.php?id=285732.
(c) The Open University.

- A disturbance in equilibrium
- Vibration: special kind of disturbance
- Vibration: an oscillating disturbance in an elastic medium

2.7. Oscillation: The Simplest Case

- Oscillation is the natural motion of many physical objects disturbed from equilibrium



Four types of vibrating objects: simple pendulum, spring pendulum, vibrating strip, and tuning fork.

Figure by MIT OpenCourseWare.

- Oscillation is a back and forth motion (up and down) over time
  - Pendulums (Swings)
  - Strings
- A natural point of oscillation in an object is a resonance
- Perfect oscillations are periodic
- Perfect oscillations are impossible in nature
- Noise breaks perfection: damping, friction, resistance

2.8. An Artificial Case: Perfect Oscillation

- A sine wave is a perfect oscillation
  - An unraveled circle; back and forth over time

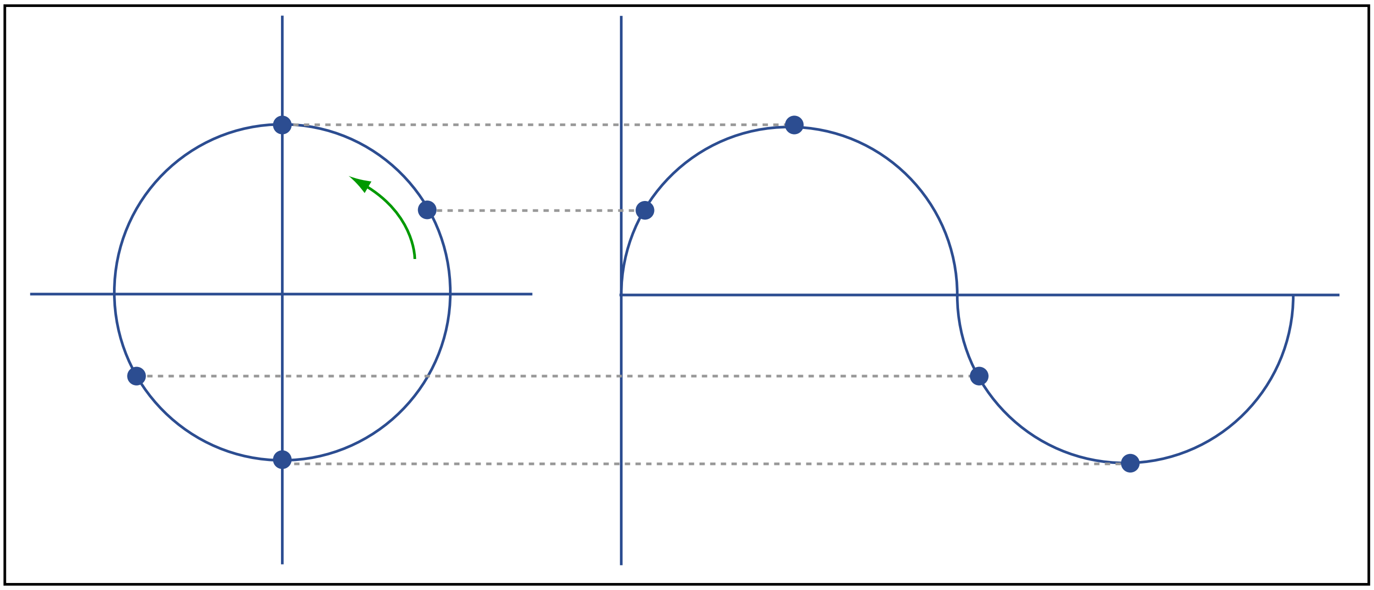
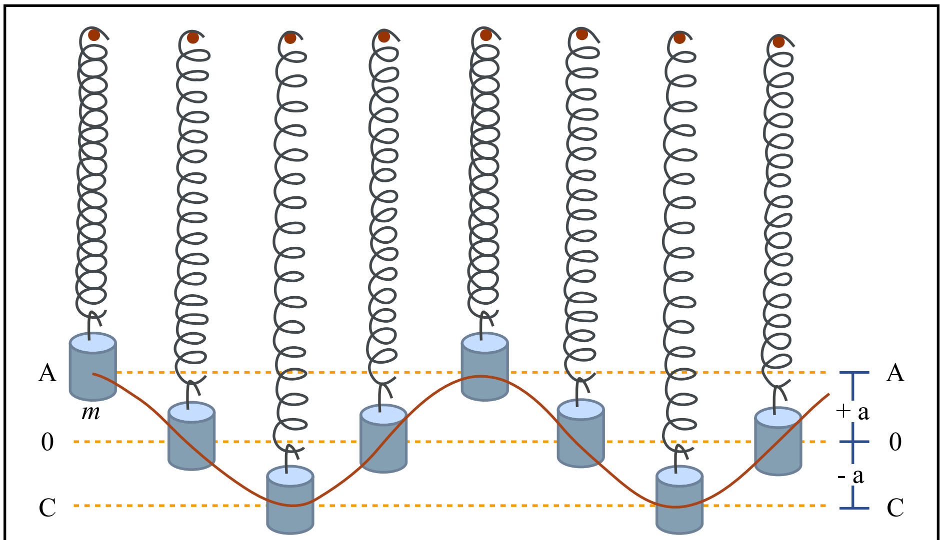


Figure by MIT OpenCourseWare.

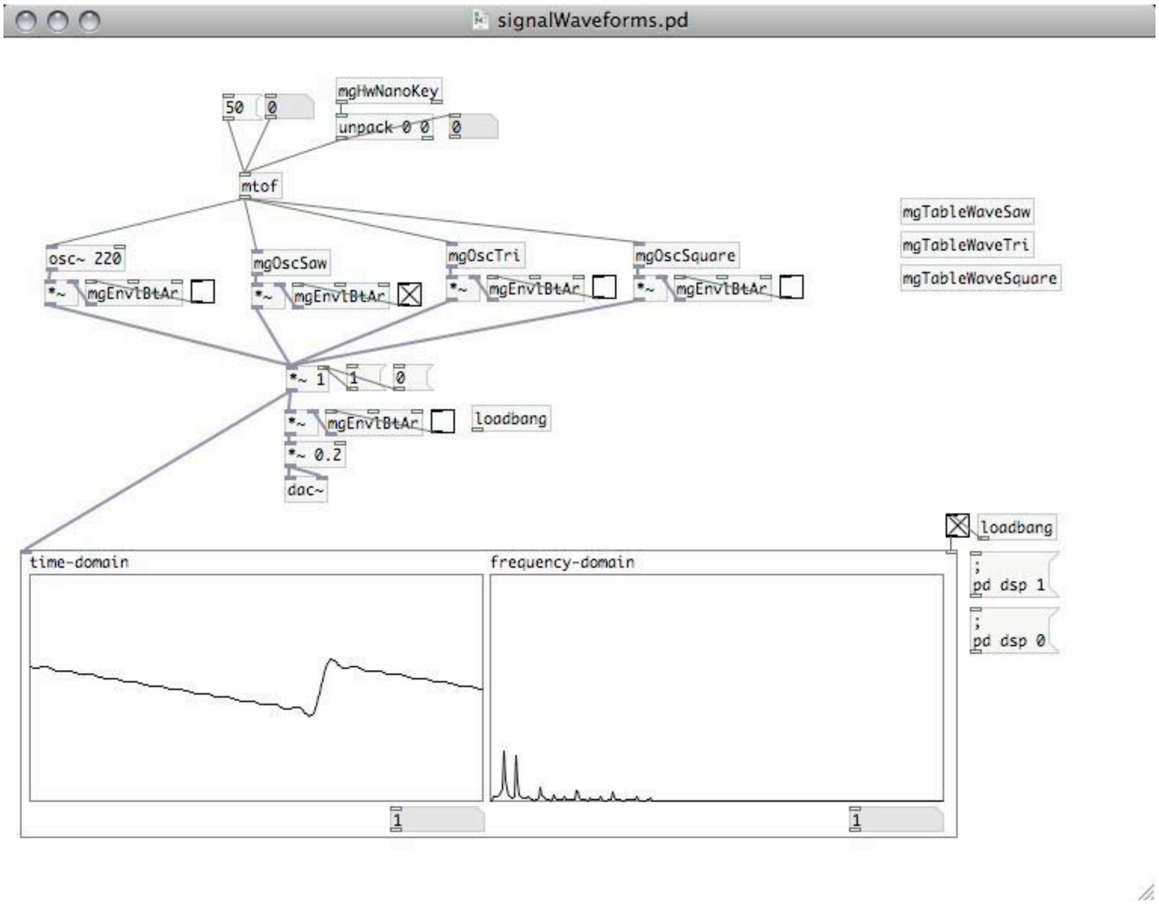


Positions of a vibrating mass at equal time intervals.

Figure by MIT OpenCourseWare.

- No damping or resistance
- No noise
- Machine-made

- With machines, other shapes can be perfectly oscillated [demo/signalWaveforms.pd]



- Sine wave: a circular oscillation
- Square (rectangle) wave
- Triangle wave
- Sawtooth wave

- When things oscillate, humans hear a tone
- The shape of the oscillation makes a difference in the quality of the tone
- The sine wave has advantages
  - It is easy to generate mechanically and mathematically
  - It resembles natural resonances in physical objects (simple harmonic motion)
  - It sounds as a simple, single isolated tone
  - An excellent point of oscillation (frequency) reference

2.9. Measuring: Time

- Sound requires time
- Measured in seconds
- 1 millisecond is equal to .001 second
- 1 second is equal to 1000 milliseconds
- The ear can hear discrete time intervals down to about 30 milliseconds [demo/earLimits.pd]

2.10. Measuring a Sine Wave: How Often?

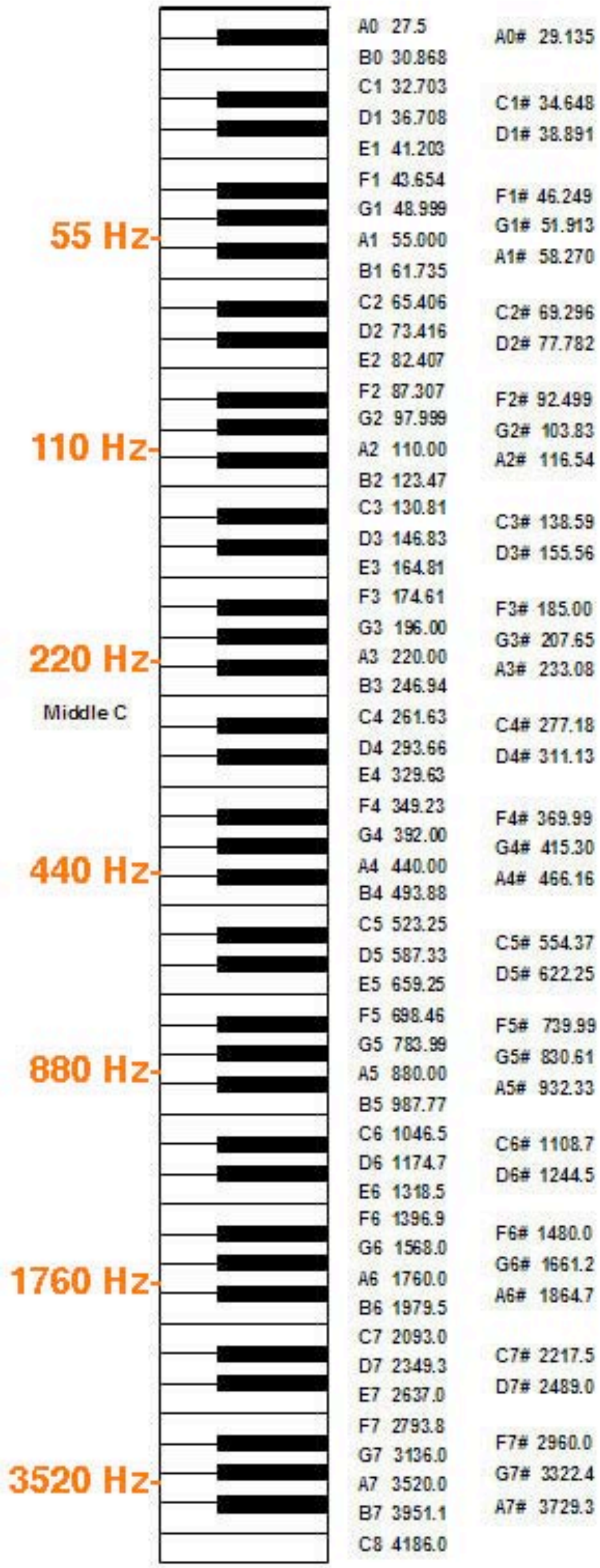
- How often it oscillates: its frequency
  - Measured in Cycles Per Second (CPS) or Hertz
  - Measure from crest to crest, or one period
- Low frequencies correlate to what we call "low" sounds; high frequencies correlate to what we call "high" sounds
- Frequency is similar to pitch, but not the same
- An octave, or a frequency ratio of 2:1, is a fundamental unit of pitch
- Ideal frequency range of the human ear: 20 to 20,000 Hertz
  - Piano keyboard: 8 octaves: A0 (27 Hz) to C8 (4186 Hz)
  - Audible range: 10 octaves: 20 to 20000 Hz [demo/earLimits.pd]

2.11. Frequency and Time

- Frequency is a another way of specifying a duration
- 1 Hz means is a cycle with duration of 1000 ms
- 0.5 Hz is a duration of 2000 ms
- 440 Hz is a duration of 2.27273 ms
- Milliseconds and frequency can be converted each way

2.12. Our Ear Hears Logarithmically: Pitch

- Octave: an equal unit of perceived pitch, a 2:1 ratio of frequencies
- Octaves are frequently divided into 12 half steps (or semitones)
- MIDI pitch values provide a numerical reference to pitch (where middle C is 60 and half-steps are integers)
- A change from 55 to 110 Hz (a difference of 55 Hz) sounds the same to our ear as a change from 1760 to 3520 Hz (a difference of 1760 Hz) [demo/earLogFrequency.pd]



Courtesy of Tom Irvine. Used with permission.

- 10 octaves of the audible frequency range:

  20-40 Hz

  40-80 Hz

  80-160 Hz

  160-320 Hz

  320-640 Hz

  640-1280 Hz

  1280-2560 Hz

  2560-5120 Hz

  5120-10240 Hz

  10240-20480 Hz

- Frequency domain graphs often use a logarithmic graph of frequency

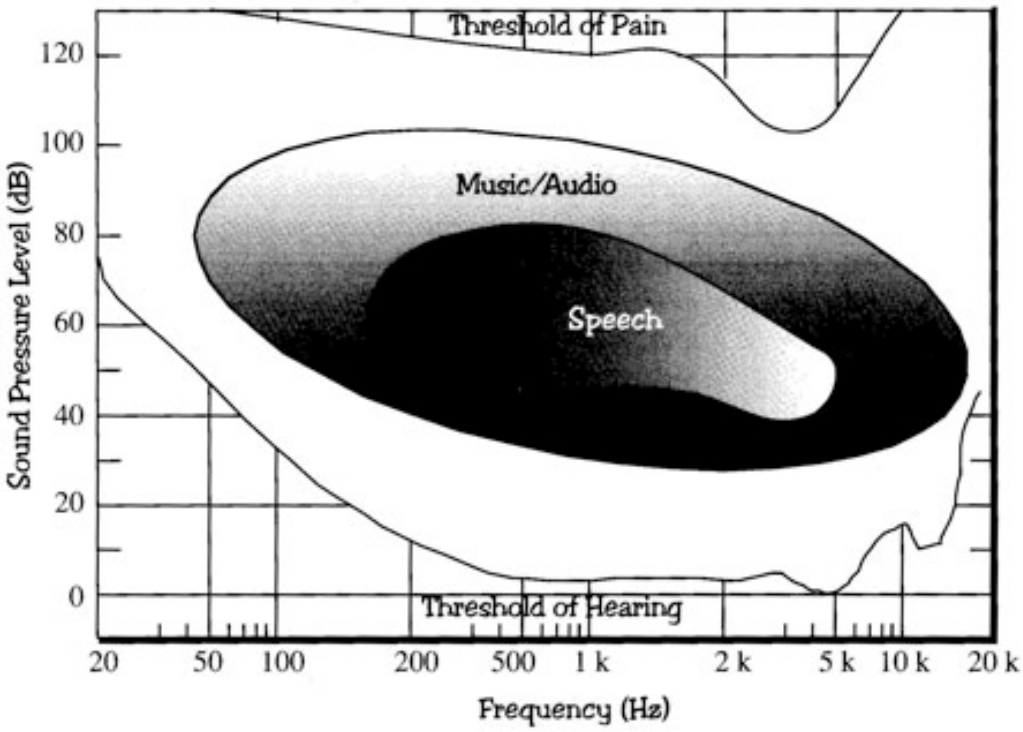


Fig. 11.1. A more detailed picture of our audio window. Most music does not exceed a range of level of about 75 dB from softest to loudest. Similarly, most recorded music does not contain much information above 18 kHz.

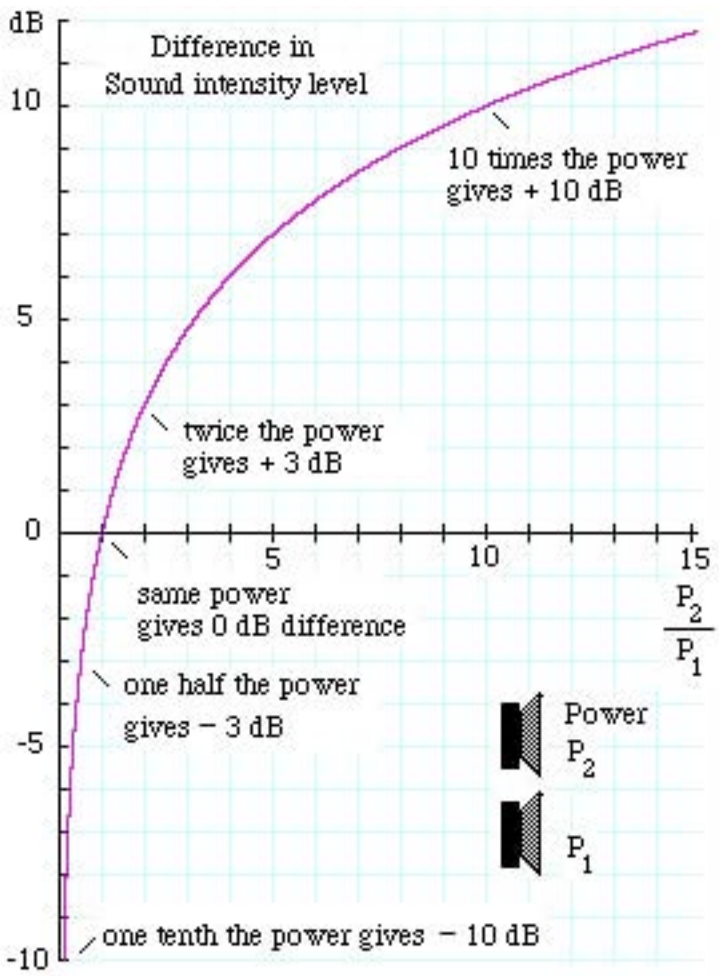
2.13. Measuring a Sine Wave: Where?

- Phase refers to position or offset within oscillation or wave shape
- Only meaningful in relation to a reference point or another wave
- Often measured between -1 and 1, 0 to 360 degrees, or 0 to 2 π radians
- 180 degrees is one half-cycle out of phase
- Flipping the phase is multiplying a signal times -1
- The combination of signals in and out of phase is frequently used as a creative way to shape timbre

2.14. Measuring a Sine Wave: How Much?

- How large are the oscillations: its amplitude

- Numerous measurement types
  - Acoustical power, a measure of pressure: watts, dynes/cm2, pascals (force over area)
  - In relation to a minimum and a maximum: 0% to 100%, or -1.0 to 1.0
  - In relation to some defined measure: Bels, decibels (dB)
- Decibels: condense a wide range of numbers into a smaller range
  - A non-linear measure in relation to power



Courtesy of Joe Wolfe. Used with permission. http://www.phys.unsw.edu.au/music

  - -3 dB change is a factor of .5 (half power/intensity)
  - -6 dB change is a factor of .25 (but half the voltage/linear amplitude)
- Numerous types of dB

- Sound Pressure Levels (SPL)
- Voltages: dBV, dBu
- Digital Bits: dBFS

- High dBs (SPLs) correlate to what we call loud; low dBs (SPLs) correlate to what we call quiet
- Amplitude is similar to loudness, but not the same
- Root mean square (RMS) averaging is frequently used to approach a measure of loudness
- A range of usable amplitudes is called a dynamic range
- Amplitude range of human ear: from 0 to 120 dB SPL, or 120 dB of dynamic range

2.15. Our Ear Hears Logarithmically: Amplitude

- The ear can handle a range of pressure from .00002 to 1000000 pascals
- dB is a logarithmic measure: adding 3 dB *doubles* the audio power

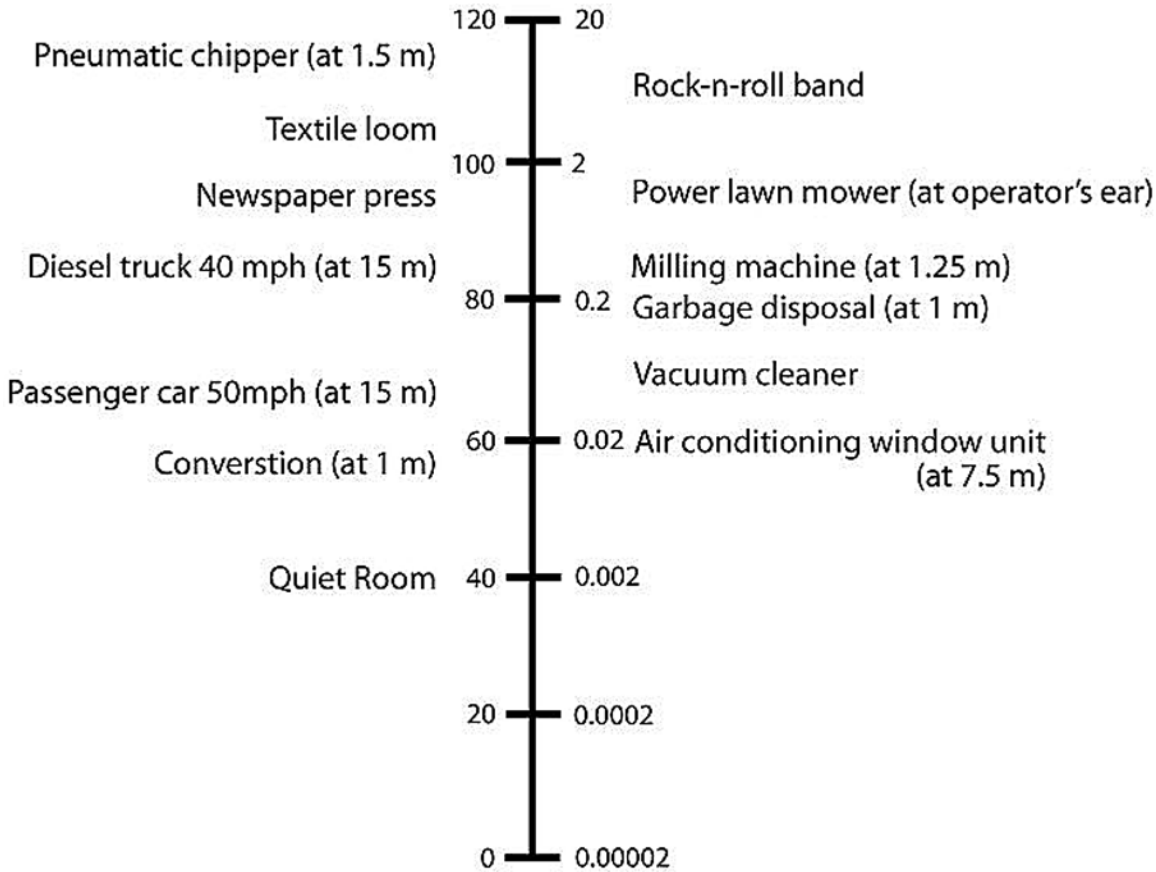


Image: "Sound Pressure Level (SPL) and Sound Pressure (Pa)"
from *Principles of Industrial Hygiene*. Available at: http://ocw.jhsph.edu.

- dB is not the same as perceived loudness [demo/earLogAmp.pd]

2.16. Aesthetic Considerations of a Sine Wave

- Unnaturally unending, simple, and perfect

- Musical applications still exist

2.17. The Power of Frequency Ratios

- The Dream House (Krueger 2008)

- 35 sine tones distributed over four speakers

- The Base 9:7:4 Symmetry in Prime Time When Centered above and below The Lowest Term Primes in The Range 288 to 224 with The Addition of 279 and 261 in Which The Half of The Symmetric Division Mapped above and Including 288 Consists of The Powers of 2 Multiplied by The Primes within The Ranges of 144 to 128, 72 to 64 and 36 to 32 Which Are Symmetrical to Those Primes in Lowest Terms in The Half of The Symmetric Division Mapped below and Including 224 within The Ranges 126 to 112, 63 to 56 and 31.5 to 28 with The Addition of 119 (Krueger 2008)

- A very poor simulation, yet still a complex timbre with extreme sensitivity to head position [demo/sinePrimeRatios.pd]

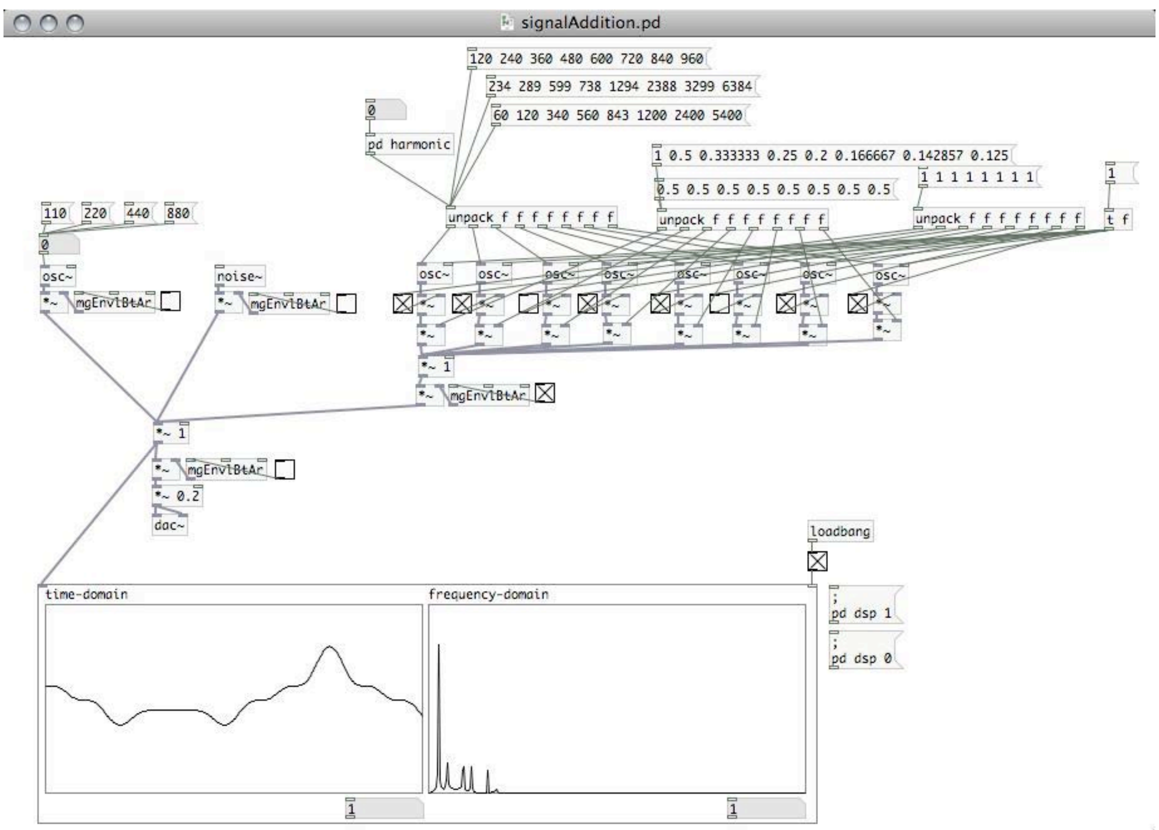
2.18. Listening

- Sine drone as thematic content

- Aphex Twin: “Ventolin,” *I Care Because You Do*, 1994

2.19. Visualizing Sounds, Waves, and Signals

- Waves can store multiple signals at multiple frequencies
- Waves can be added (mixed together) to result in more complex waves
- Sometimes these combined waves can be later decomposed into simple waves
- A single wave can store a tremendous amount of complexity (information)
- Noise can ride on sine waves [demo/signalAddition.pd]

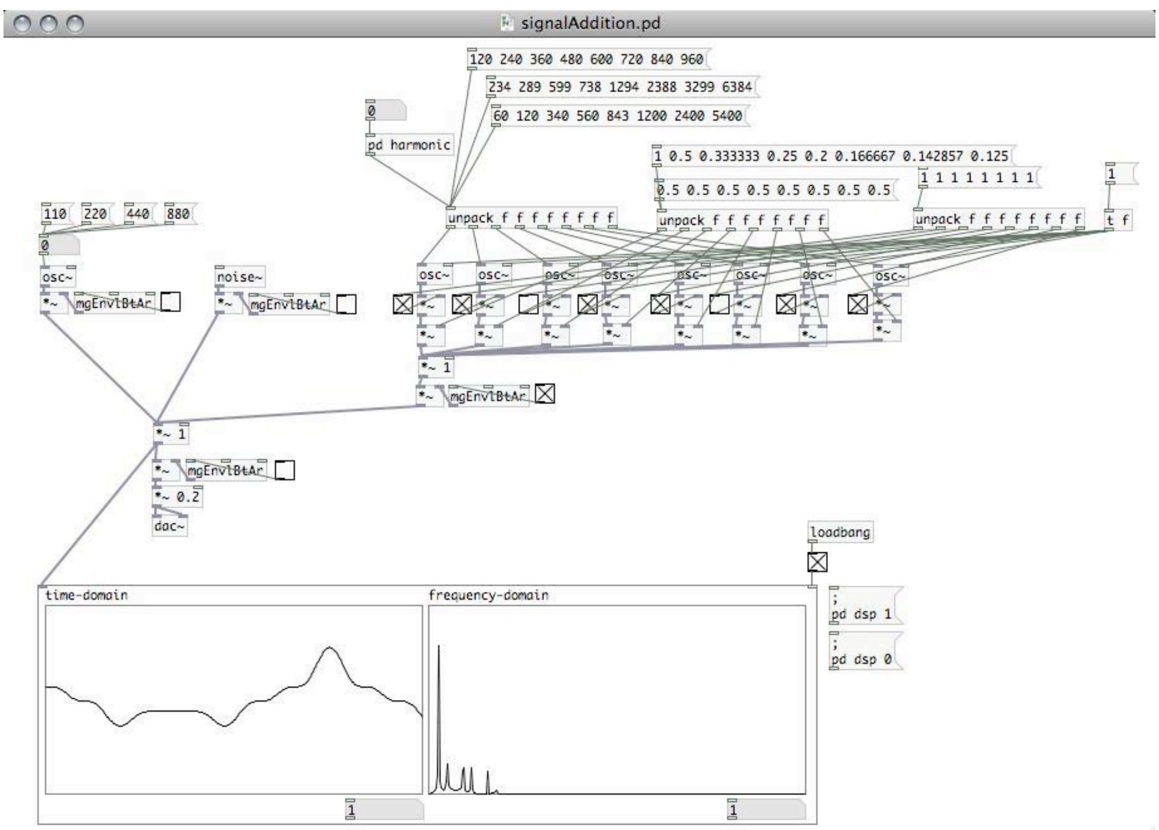


2.20. Visualizing Sounds: Time Domain

- Graph of displacement (amplitude, pressure, voltage) over time [demo/signalAddition.pd]
- Graph amplitude change (y-axis) over time (x-axis)
- Illustrates the movement of a speaker, microphone, or other transducer in two dimensions
- Acoustical pressure is similar but more complex
- Common representation of digital sound files
- Computationally easy to do

2.21. Visualizing Sounds: Frequency Domain

- Graph of frequency amplitudes within a single time window [demo/signalAddition.pd]

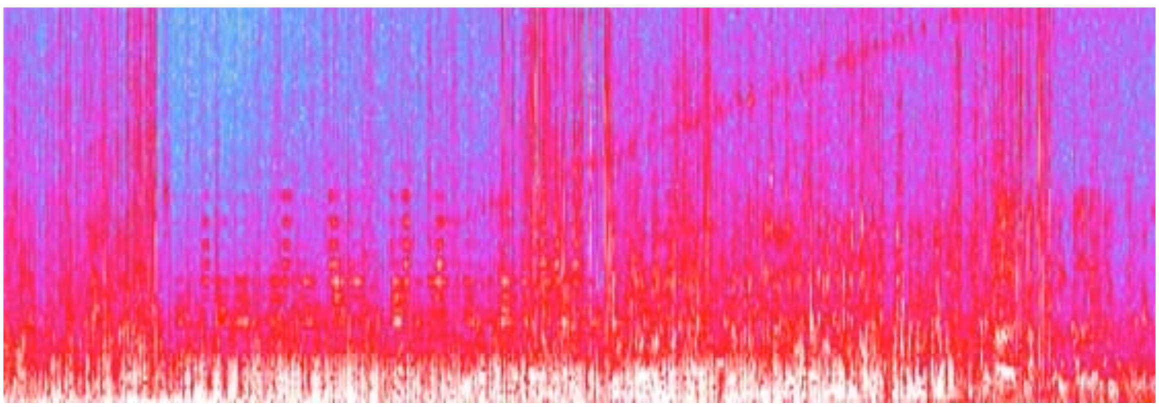


- Graph amplitude (y-axis) over frequency (x-axis)

- Illustrates what the ear hears at a given moment
- Requires mathematical decoding: Fourier Transform
- Reveals the spectrum of a sound
- Computationally taxing

2.22. Visualizing Sounds: Three Dimensions

- At least wo ways:
  - Graph of frequency (x-axis), amplitude (color), and time (y-axis)



  - Graph of frequency (x-axis), amplitude (y-axis), and time (z-axis)

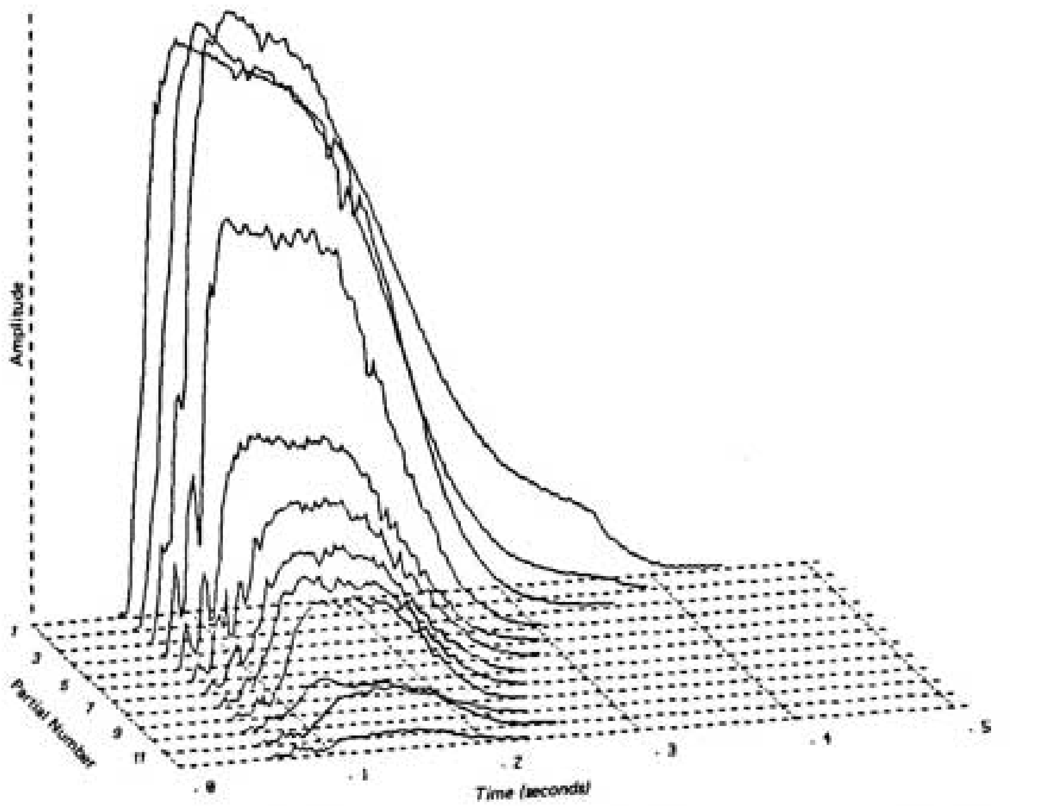


FIGURE 2.30 The amplitude progression of the partials of a trumpet tone as analyzed by Grey and Moorer.

Source: Moorer, J., J. Grey, and J. Strawn. "Lexicon of Analyzed Tones (Part 3: The Trumpet)." Computer Music Journal 2, no 2 (1978): 23-31.

- Closest representation to our experience of sound
- Not perfect for technical and psychoacoustic reasons

2.23. History of Sound Analysis

- Manometric flames for waveform analysis (Roads 1996)

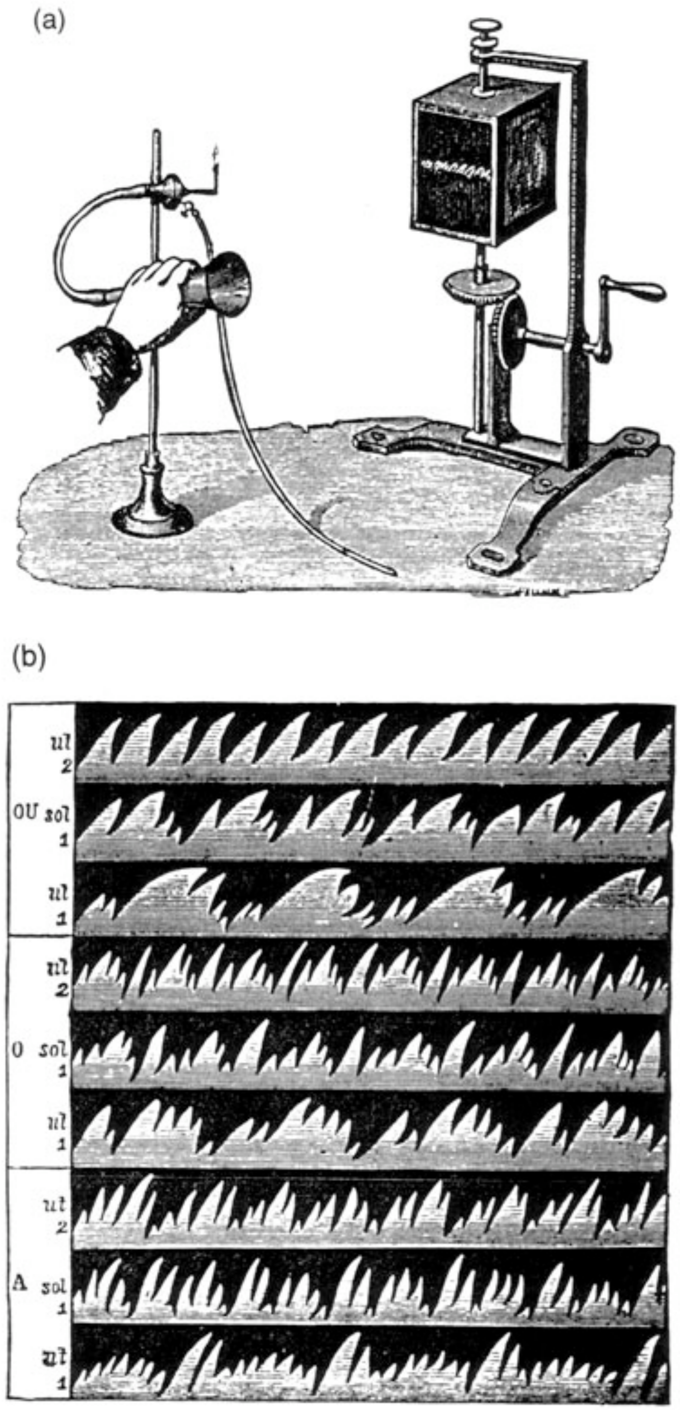


Figure 12.1 Manometric flames for waveform analysis. (*a*) Apparatus. Sounds picked up by the mouthpiece modulate the bunsen burner flame within the box. When the box is rotated, mirrors on the outside of the box project the flame as a continuous band with jagged edges or teeth corresponding to the pitch and spectrum of the input sound. (*b*) Flame pictures of the French vowel sounds [OU], [O], and [A] by R. Koenig, sung at the pitches C1 (bottom of each group), G1 (middle of each group), and C2 (top of each group). (After Tyndall 1875.)

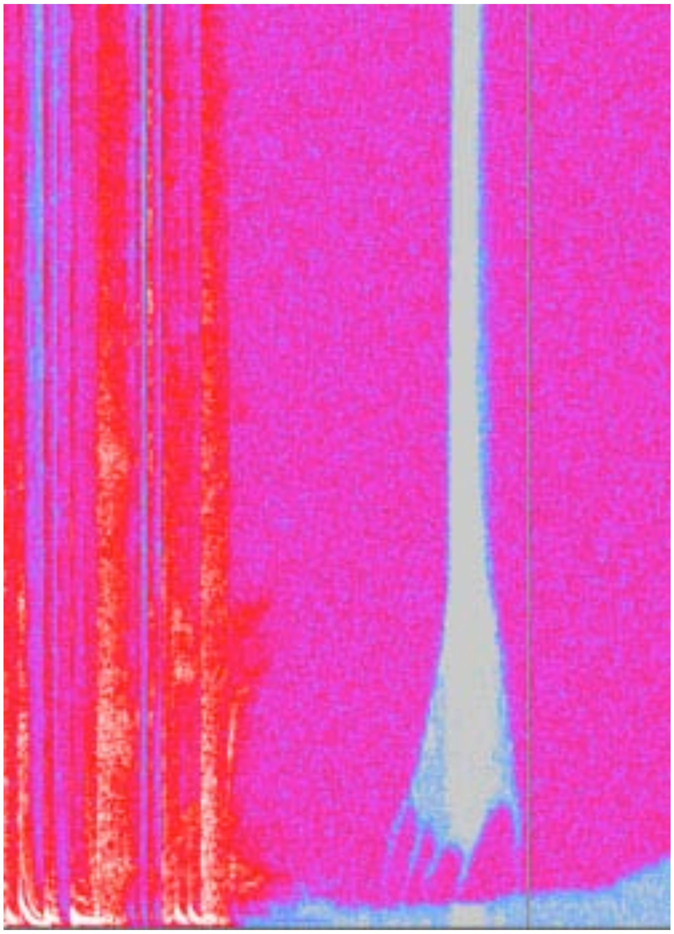
Source: Roads, C. *The Computer Music Tutorial.* Cambridge, MA: MIT Press, 1996.

- Recognized that different vowels had different wave forms

2.24. Spectrum as Thematic Content: NIN

- NIN: Year Zero, album cover

- Pre/post apocalyptic mass-hallucinations of hands descending from the sky
- Encoding a visual thematic element in the spectral analysis of a sound
- NIN: Year Zero, “The Warning,” spectral analysis



- Audio: Nine Inch Nails, “The Warning,” *Year Zero*, 2007

2.25. Making the Sine Wave More Natural: Shaping Amplitude

- Envelopes: dynamic changes in amplitude applied to a sound
- A simplification of acoustic instruments: ADSR [demo/envelopes.pd]

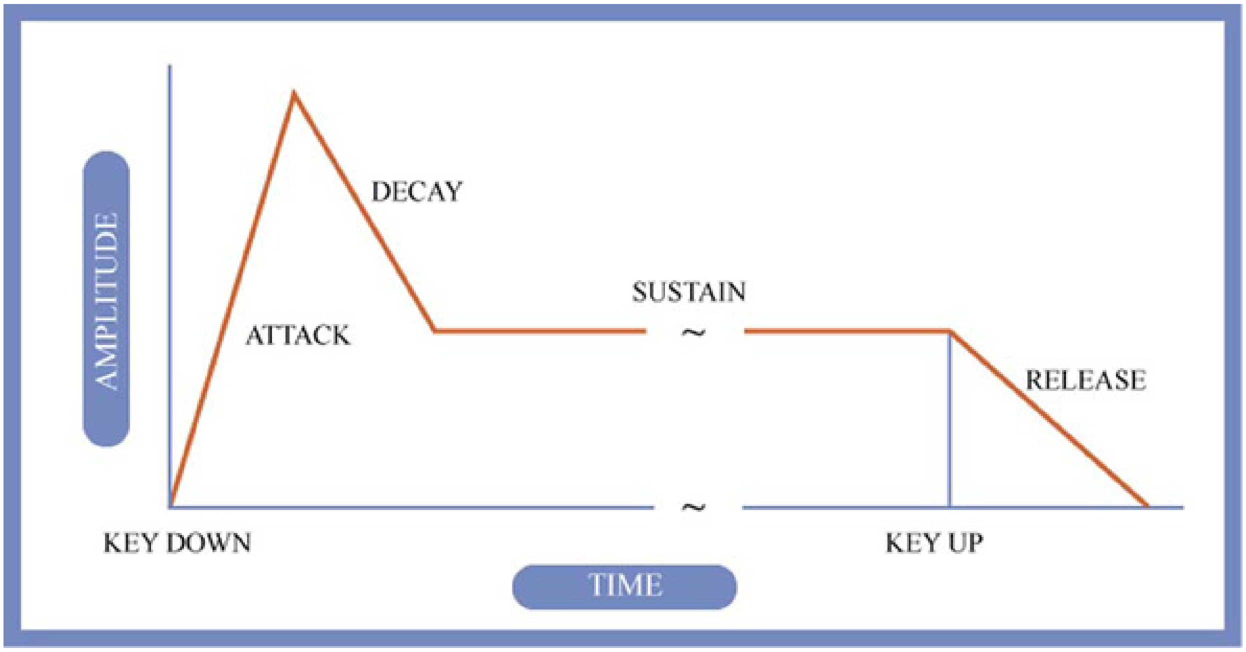
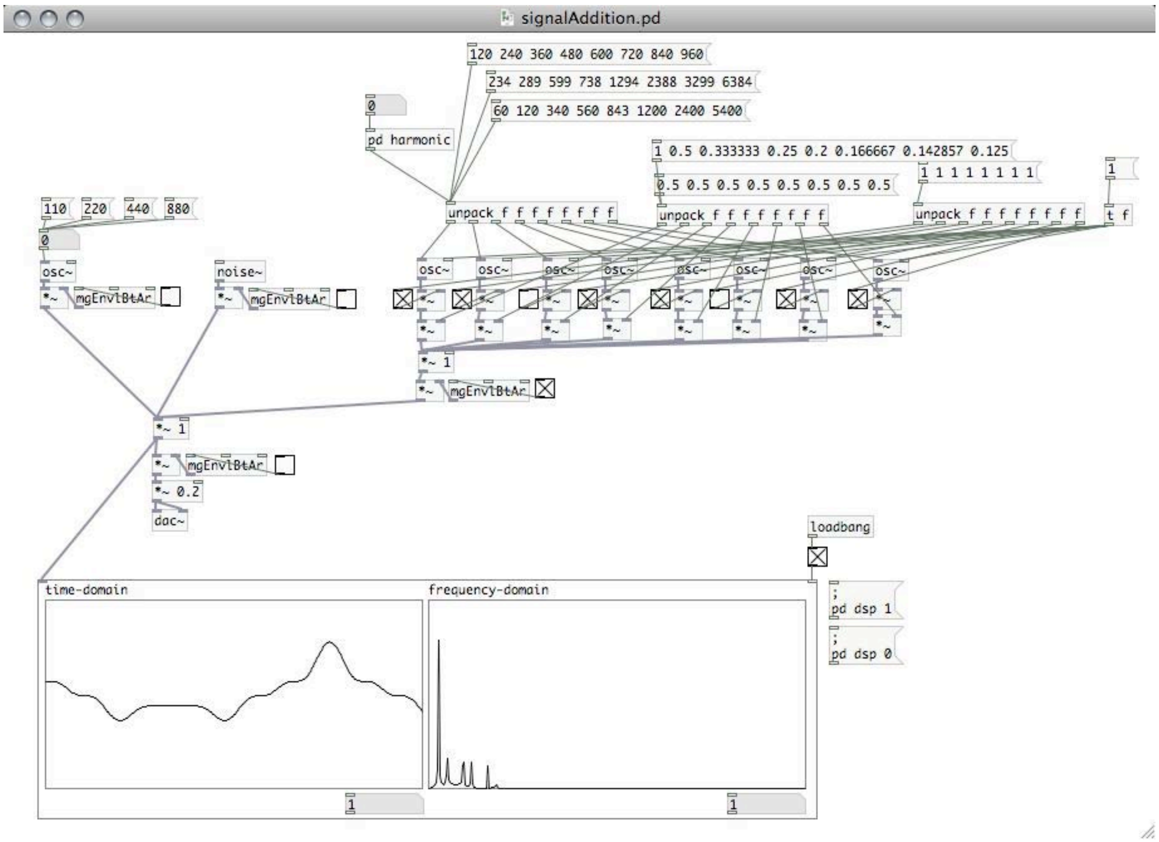


Figure by MIT OpenCourseWare.

- Attack: the initial and rapid increase in amplitude
- Decay: from the peak to a steady state
- Sustain: the amplitude (usually a percentage ratio) of the steady state
- Release: damping from steady state to silence

2.26. Making the Sine Wave More Natural: More Complexity

- Acoustic instruments do not make sine waves
- Acoustic instruments produce multiple resonances from a single tone combined with various types of noise
- These multiple resonances are called harmonics (sometimes overtones or partials), and create timbre
- Each harmonic can be modeled as an additional sine wave [demo/signalAddition.pd]

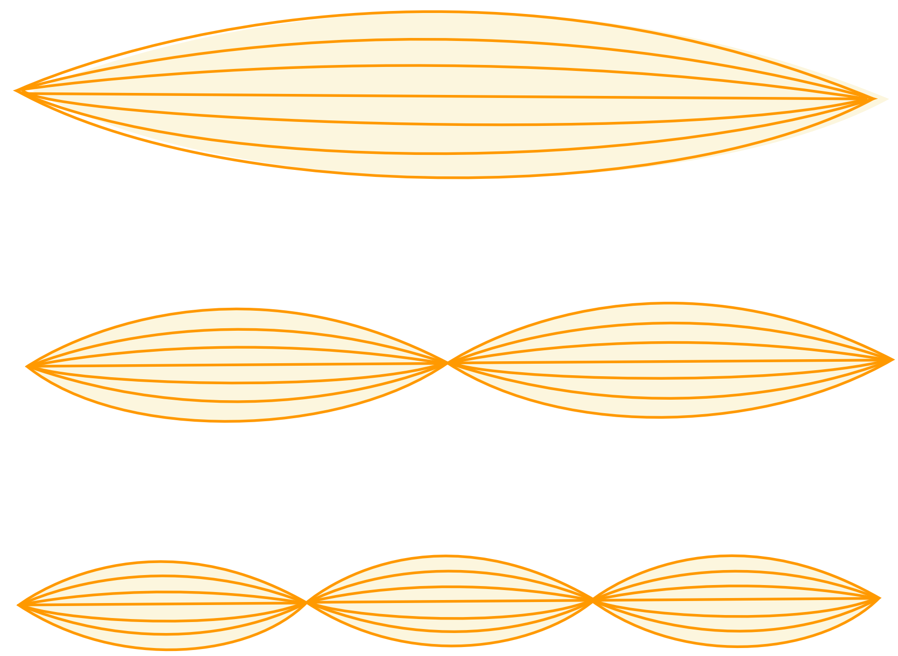


2.27. Timbre

- Timbre is the combination of frequencies (sometimes sine-like waves) that make up a rich tone
- Our ears are designed to distinguish sounds based on timbre
- We hear in the frequency domain

2.28. Harmonics, Overtones, and Partials

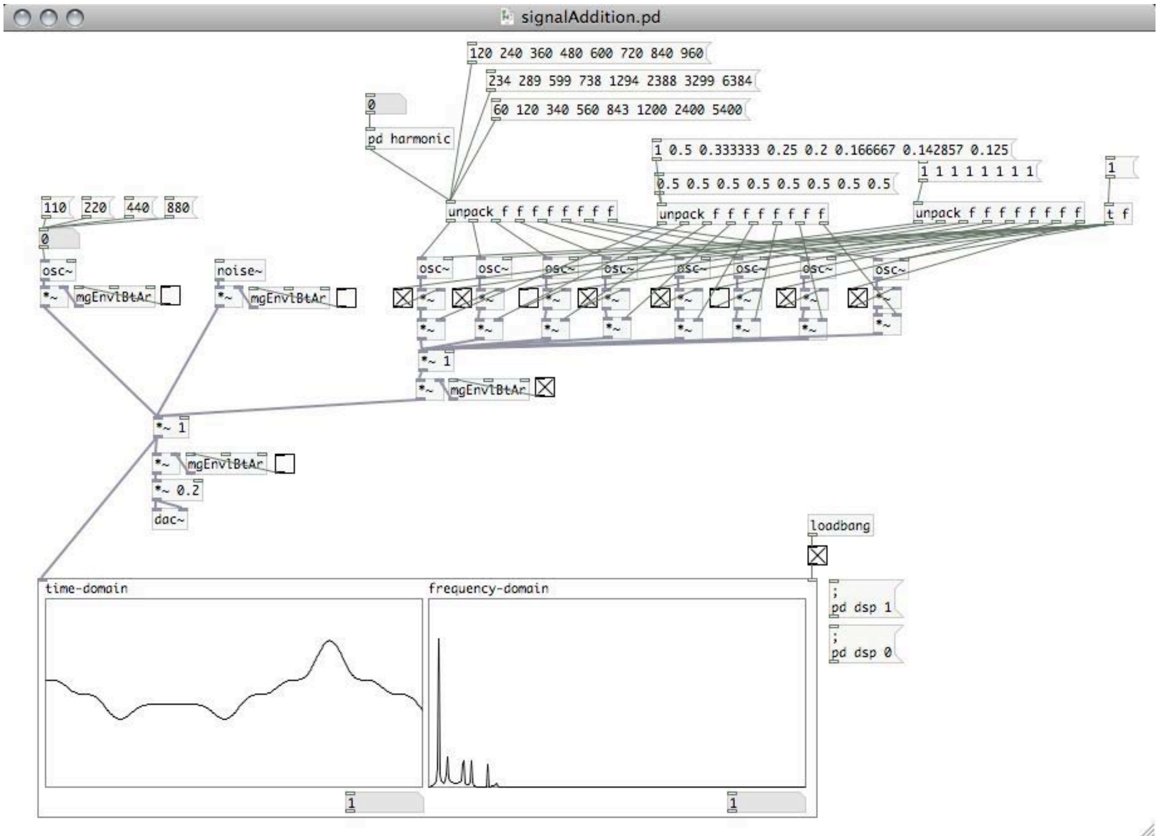
- All sounds in nature are more complex than a sine wave (pure frequency)
- Many physical objects (strings, air-columns) have multiple points of resonance



Characteristic vibrations of a stretched string. Vibrating in one, two or three equal parts emits the fundamental tone, octave and twelfth respectively.

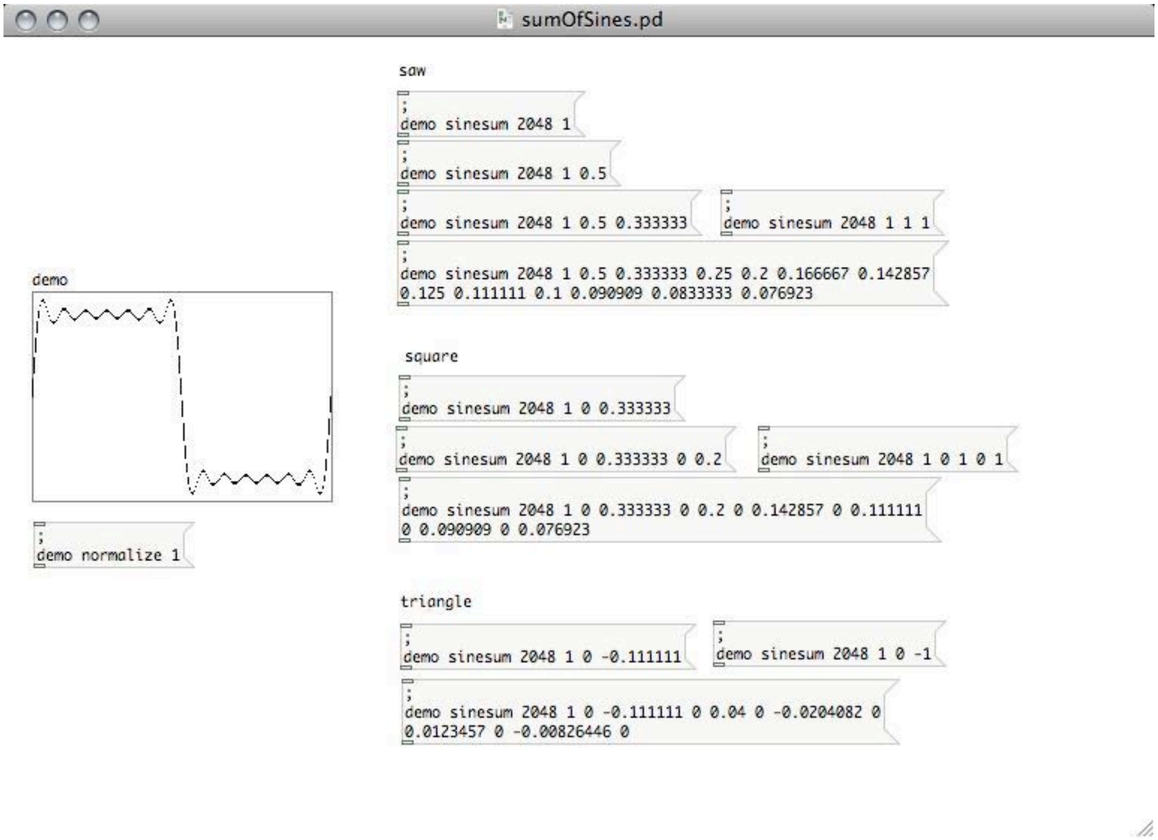
Figure by MIT OpenCourseWare.

- The difference in the sound between two instruments has to do with which resonances are prominent
- The lowest resonance is called the fundamental, or the first harmonic (f0)
- Higher resonances are called harmonics, partials, or overtones
- These components define the spectrum (or timbre or tone color) of a sound
- In some objects these modes are in predictable arrangements: harmonic
- In other objects these modes are in complex arrangements: inharmonic [demo/signalAddition.pd]

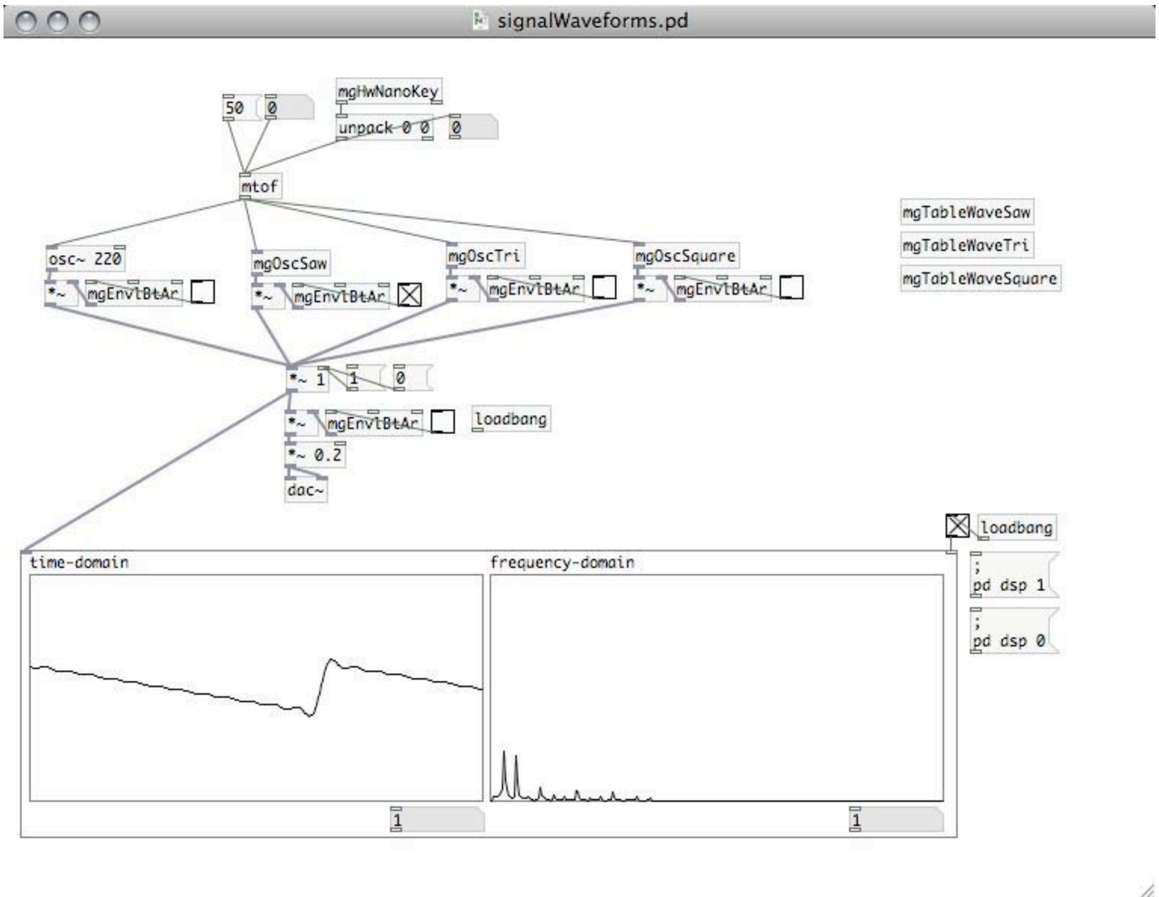


2.29. Common Waveforms and Timbre

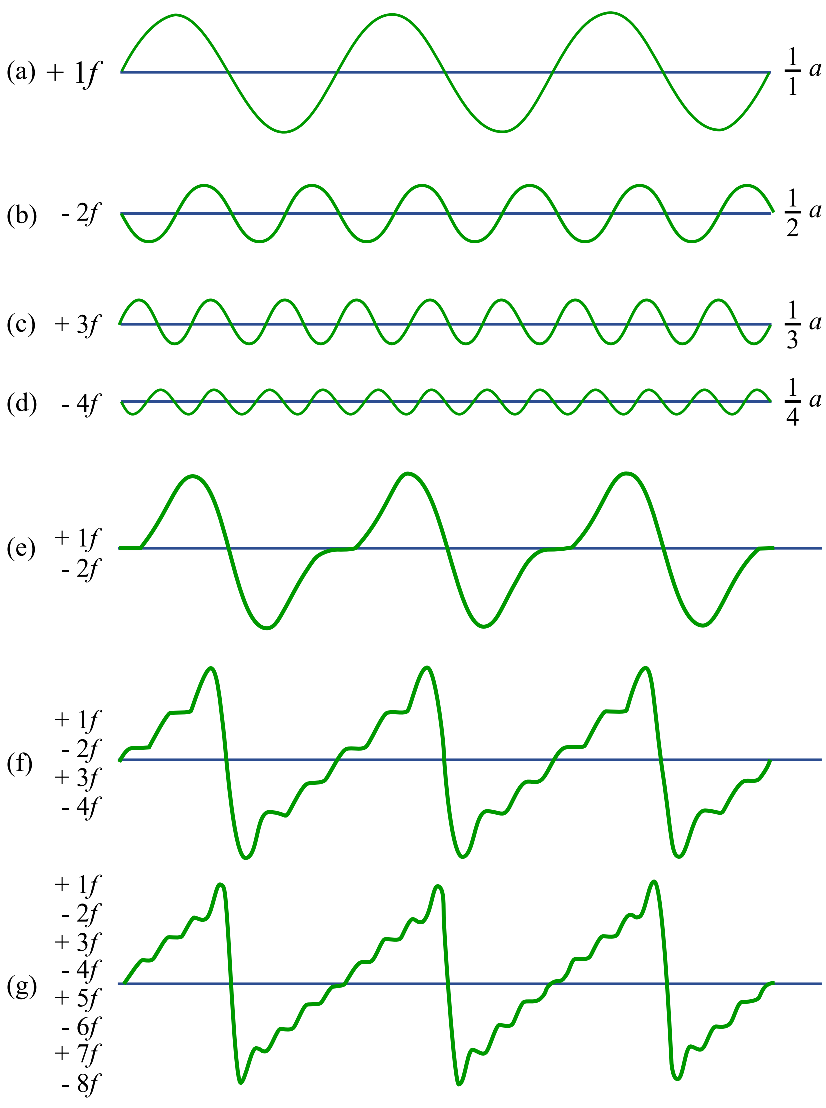
- Harmonically related sine tones, when summed, produce familiar shapes [demo/sumOfSines.pd]


sumOfSines.pd
saw
;
demo sinesum 2048 1
;
demo sinesum 2048 1 0.5
;
demo sinesum 2048 1 0.5 0.333333
;
demo sinesum 2048 1 1 1
;
demo sinesum 2048 1 0.5 0.333333 0.25 0.2 0.166667 0.142857 0.125 0.111111 0.1 0.090909 0.0833333 0.076923
demo
;
demo normalize 1
square
;
demo sinesum 2048 1 0 0.333333
;
demo sinesum 2048 1 0 0.333333 0 0.2
;
demo sinesum 2048 1 0 1 0 1
;
demo sinesum 2048 1 0 0.333333 0 0.2 0 0.142857 0 0.111111 0 0.090909 0 0.076923
triangle
;
demo sinesum 2048 1 0 -0.111111
;
demo sinesum 2048 1 0 -1
;
demo sinesum 2048 1 0 -0.111111 0 0.04 0 -0.0204082 0 0.0123457 0 -0.00826446 0

- Oscillating common waveforms is a shortcut to getting rich timbre [demo/signalWaveforms.pd]



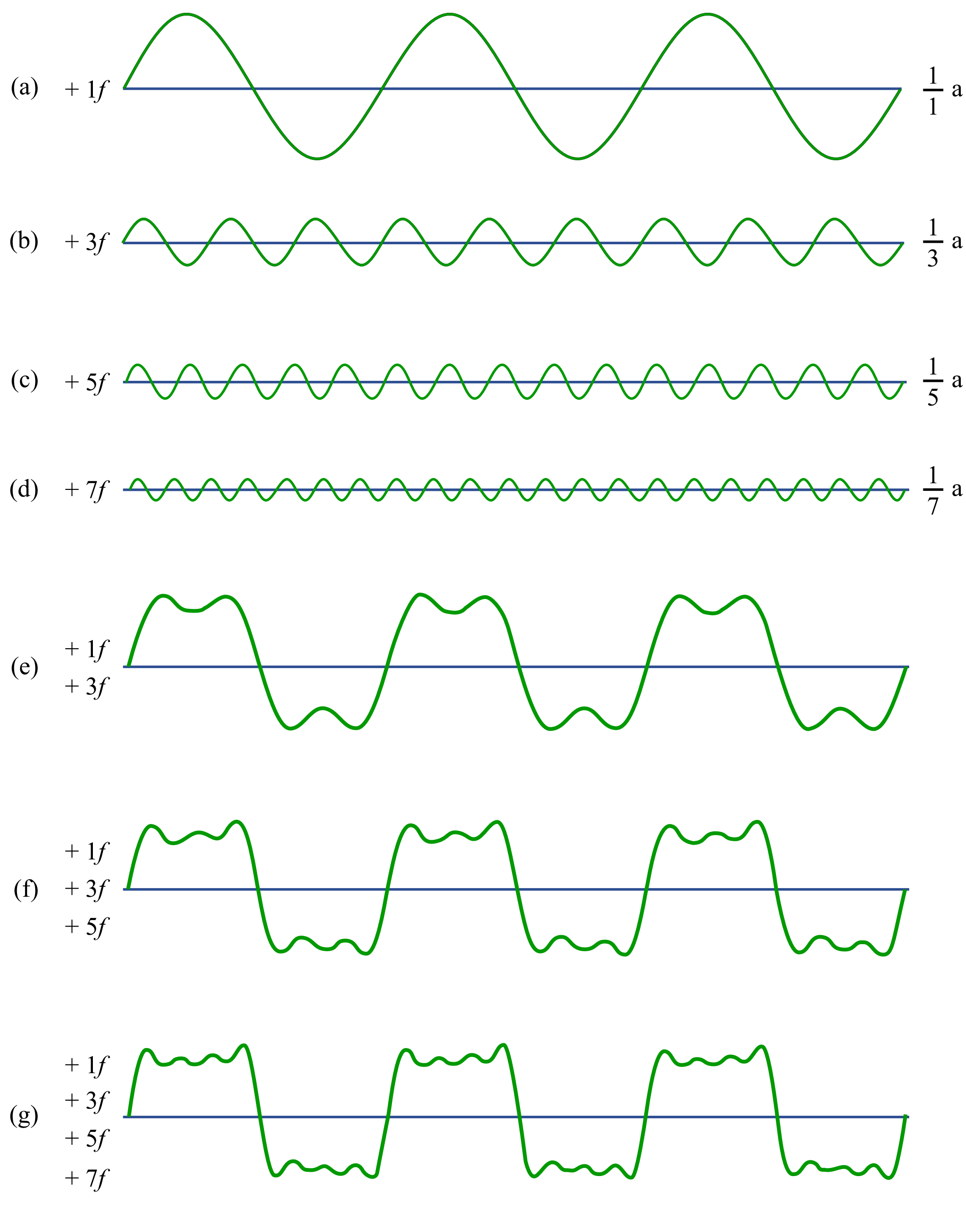
- Sawtooth wave: the sum of sines with decreasing amplitude (for each overtone n the amplitude is 1/n)



Sawtooth waves, analyzed as an additive series of harmonics.

Figure by MIT OpenCourseWare.

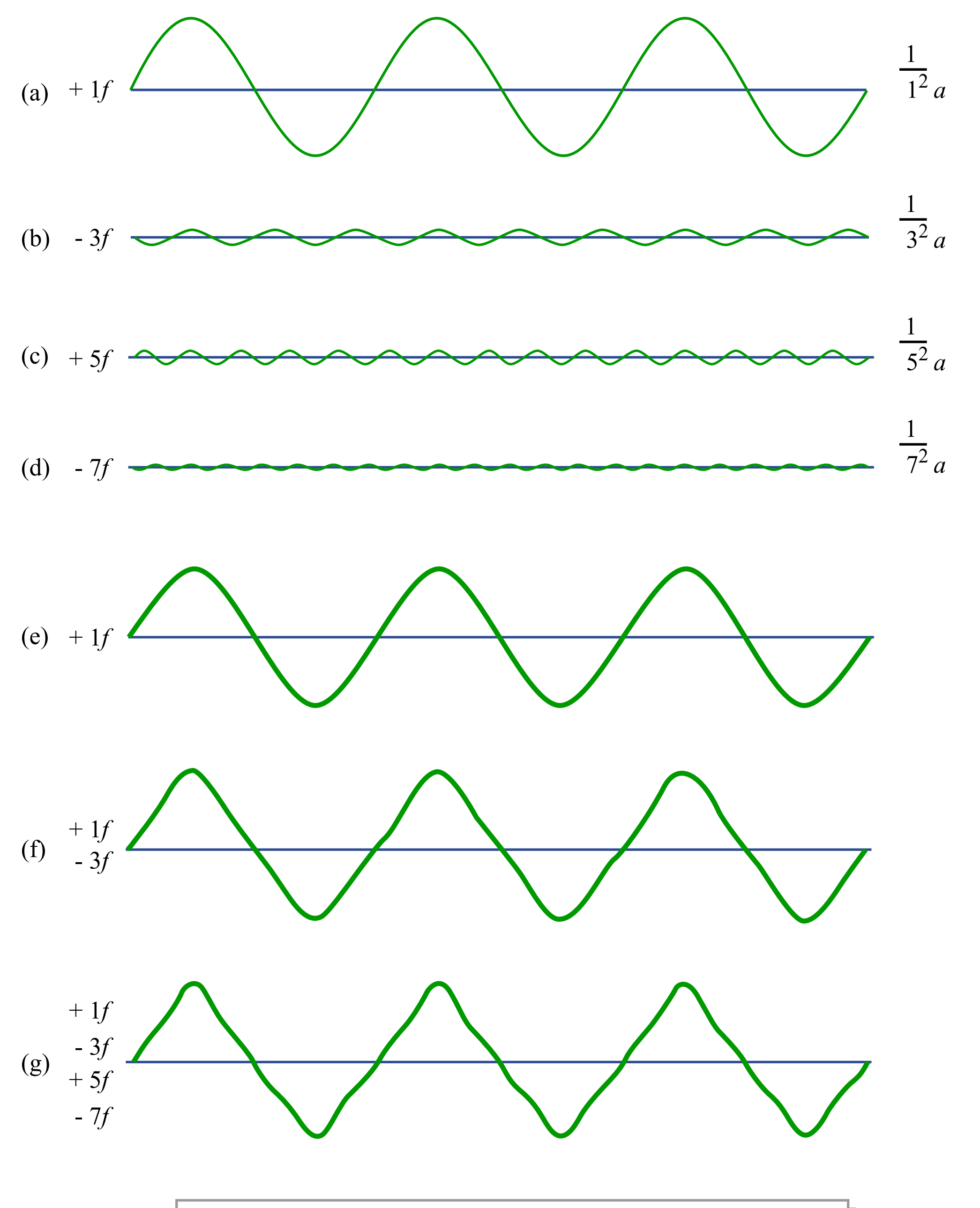
- Square wave: the sum of odd harmonics with decreasing amplitude



Square waves, analyzed as an additive series of harmonics.

Figure by MIT OpenCourseWare.

- Triangle wave: only add harmonics with decreasing amplitude and alternating inversion



Triangle waves, analyzed as an additive series of harmonics.

Figure by MIT OpenCourseWare.

2.30. Noise Spectra

- Noise can be represented as a random set of amplitude points
- White noise, averaged, produces equal amplitude for all frequencies
- A sine tone has all energy at one frequency; white noise has energy at all frequencies

2.31. How the Ear Works: Components

- The components of the ear

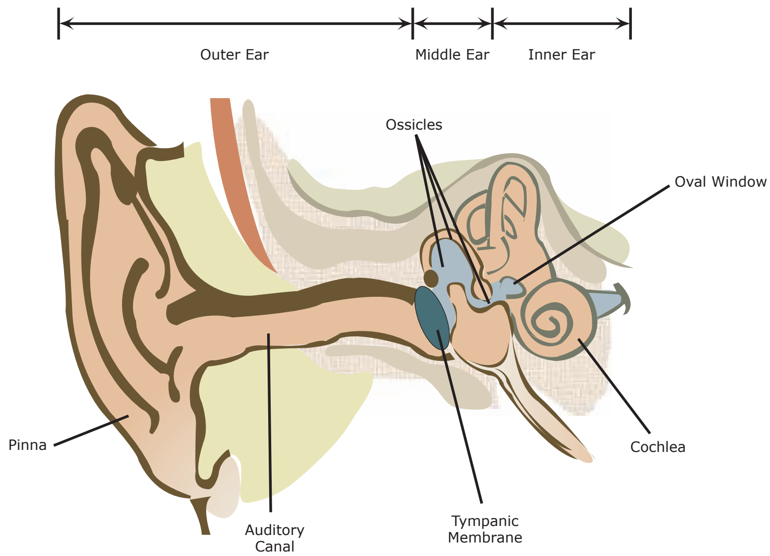


Figure by MIT OpenCourseWare. After figure 11.3 in: Bear, Mark F.,Barry W.Connors, and Michael A. Paradiso*. Neuroscience: Exploring the Brain*. 2nd ed. Baltimore, Md.:Lippincott Williams & Wilkins, 2001. ISBN: 0683305964.

2.32. How the Ear Works: The Pathway of Sound

- Transduction: the process of converting sound from on medium into another
- Sound is transduced from air to skin (tympanic membrane), from skin to bone (ossicles), from bone to skin (oval window), from skin to fluid (perilymph), from fluid to hair (basilar membrane)

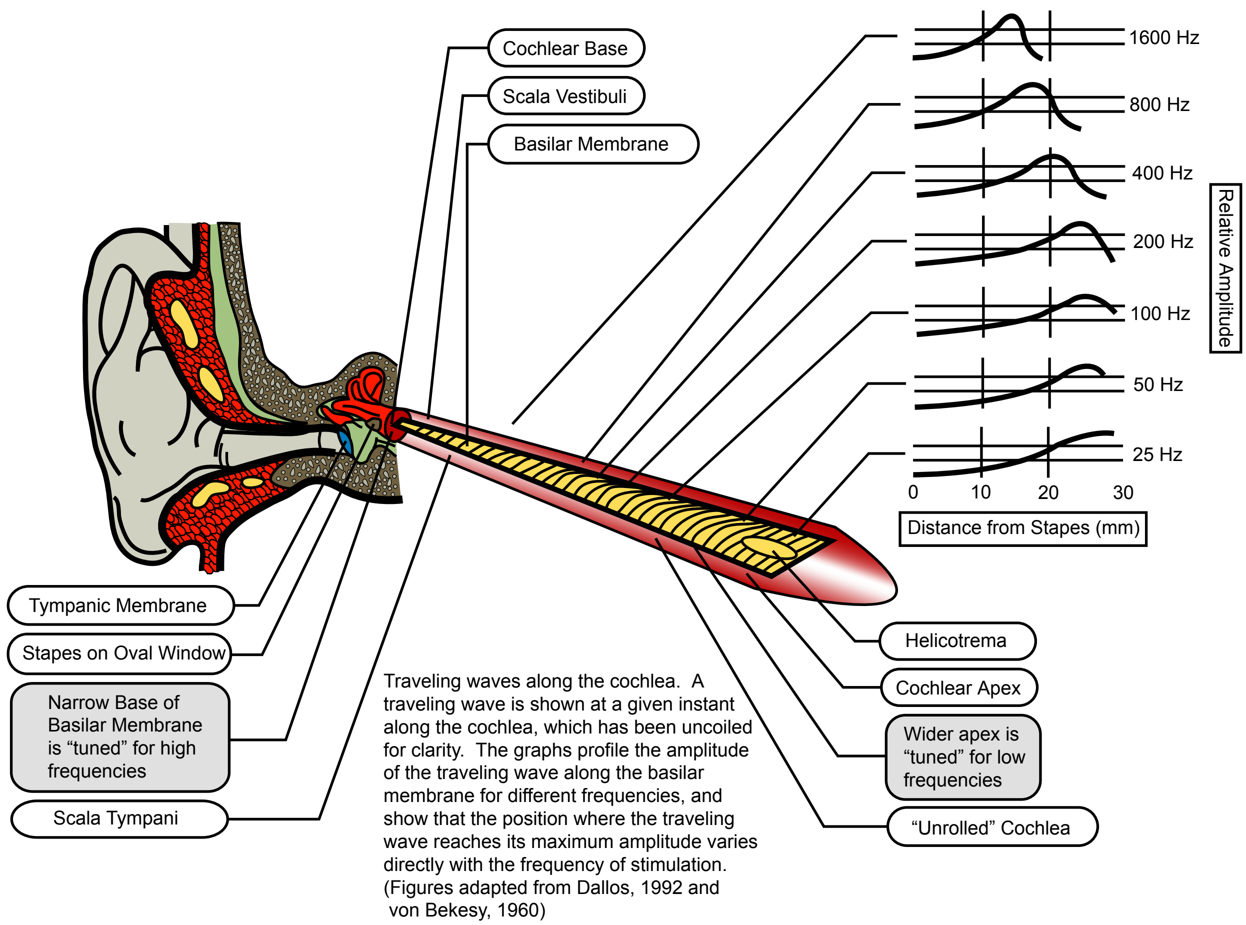


Figure by MIT OpenCourseWare.

2.33. How the Ear Works: The Cochlea

- The basilar membrane gets more narrow and more thin from base to tip
- Lower frequencies resonate near the tip (least stiff); higher frequencies resonate near the base (most stiff, near the oval window)
- Basilar membrane resonates at each component frequency in a sound

- 20,000 hair cells on basilar membrane send messages to the brain
- The cochlea performs spectral analysis with hair

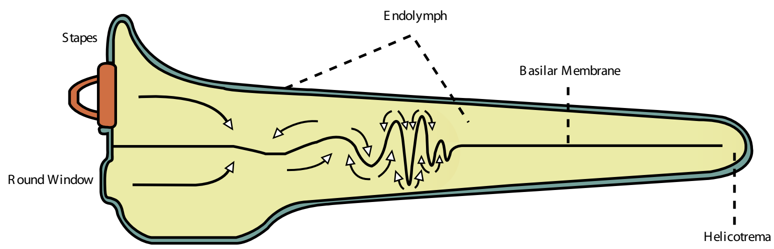


Figure by MIT OpenCourseWare. After figure 11.9 in: Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience: Exploring the Brain*. 2nd ed. Baltimore, Md.: Lippincott Williams & Wilkins, 2001. ISBN: 0683305964.

2.34. Our Ear is Tuned for Speech

- Amplitude is not the same as loudness
- Perceived loudness is measured in phons, not dB
- Fletcher Munson (Robinson and Dadson/ISO 226:2003) equal loudness curves define phones

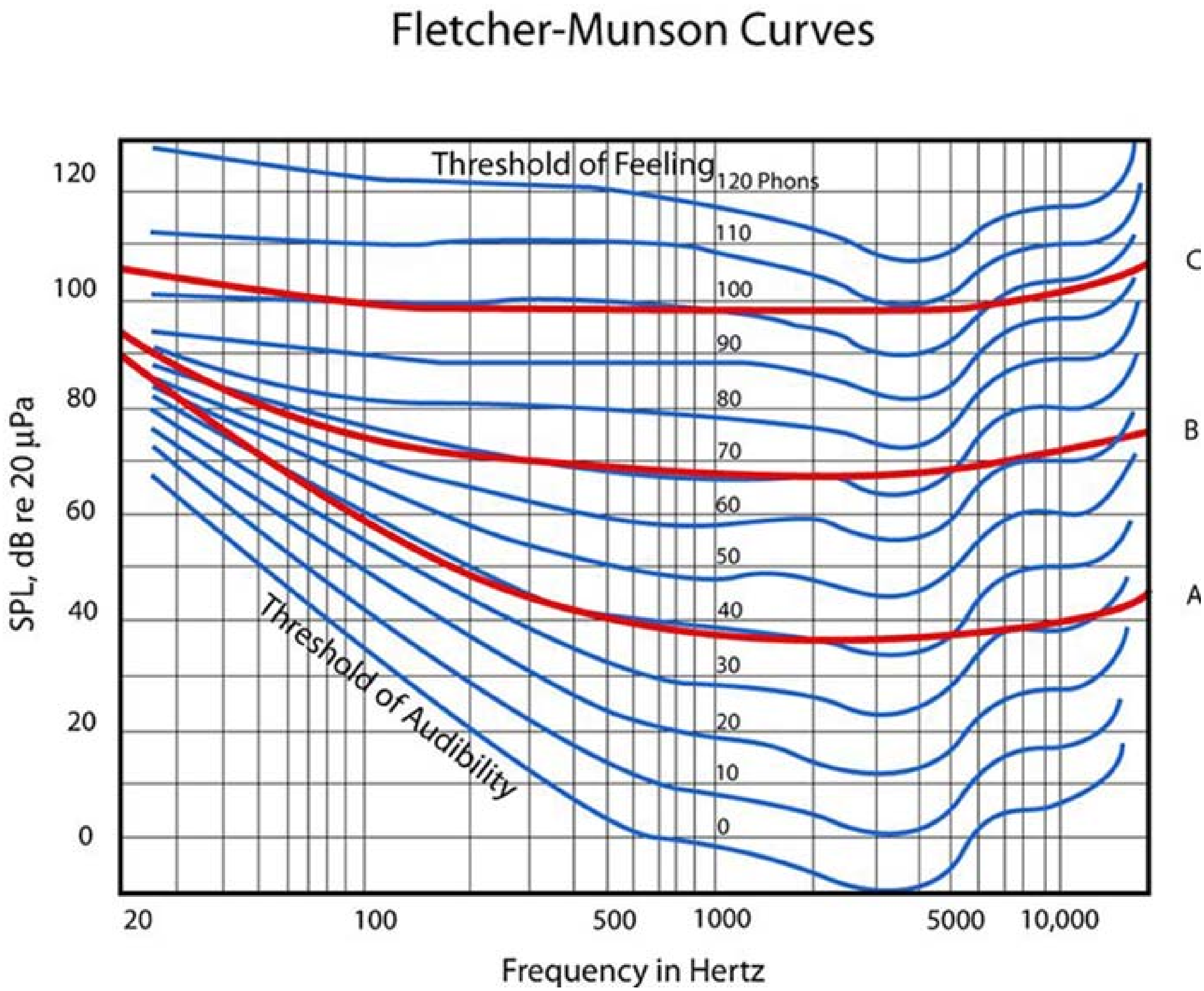


Image: "Fletcher-Munon Curves" from *Principles of Industrial Hygiene*.
Available at: http://ocw.jhsph.edu.
Copyright © Johns Hopkins Bloomberg School of Public Health.

- The ear is tuned for speech: low and high frequencies require more amplitude to sound equally loud

2.35. Listening

- Sine tones in context
- Audio: Alva Noto and Ryuichi Sakamoto, “Noon,” *Vrioon* 2002

Chapter 3. Meeting 3, Recording: The History of Analog Audio

3.1. Announcements

- Check course notes for reading and listening discussion leaders
- Quiz next Tuesday

3.2. A History of Analog Recorded Mediums

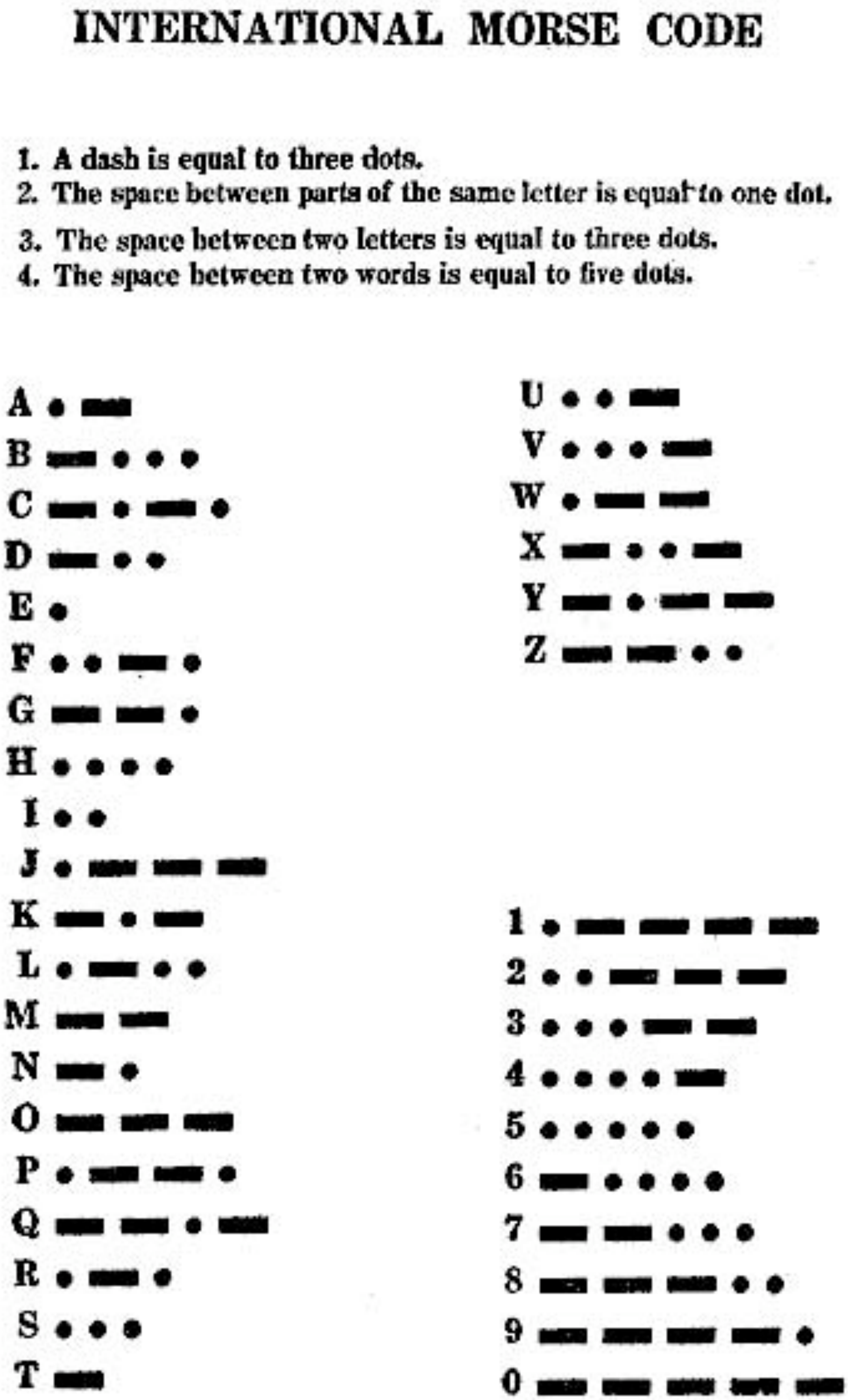
- From the helix, to the spiral, to the line
- A reduction in dimensionality
- A trend towards facilitating non-linearity

3.3. What is Analog

- Something that is analogous to something else
- A direct, continuous, sonic transduction
- The earliest methods of storing and transporting sound were all analog

3.4. Sending Messages: Telegraphy

- tele (far) + graph (write)
- Transmission of messages using optics, radio, or other mediums
- Electrical telegraph (telegraphs): foundation of modern communication systems
- 1837: Samuel Morse (1791-1872) patents electrical telegraph


INTERNATIONAL MORSE CODE

1. A dash is equal to three dots.
2. The space between parts of the same letter is equal to one dot.
3. The space between two letters is equal to three dots.
4. The space between two words is equal to five dots.

A · –
B – · · ·
C – · – ·
D – · ·
E ·
F · · – ·
G – – ·
H · · · ·
I · ·
J · – – –
K – · –
L · – · ·
M – –
N – ·
O – – –
P · – – ·
Q – – · –
R · – ·
S · · ·
T –
U · · –
V · · · –
W · – –
X – · · –
Y – · – –
Z – – · ·

1 · – – – –
2 · · – – –
3 · · · – –
4 · · · · –
5 · · · · ·
6 – · · · ·
7 – – · · ·
8 – – – · ·
9 – – – – ·
0 – – – – –

Source: Wikimedia.
From Snodgrass, R. T., and V. F. Camp. *Radio Receiving for Beginners.*
New York, NY: MacMillan, 1922.

- 1866: first trans-atlantic cable
- 1891 international telegraph lines, the Victorian internet (Standage 2007)

Source: Wikipedia

3.5. Sending Sonic Messages: Bell

- Alexander Graham Bell (1847-1922)
- Desire to transmit the sound of the human voice by telegraph
- Desire to reduce traffic on telegraph lines by accommodating multiple signals at different frequencies (acoustic telegraphy)
- Initially called the device the harmonic telegraph: transmit sound through analog wave-forms in electronic currents
- 10 March 1876: through prototype told his assistant: "Mr. Watson, come here"
- 1876: Bell files patent application for telephone: "the method of, and apparatus for, transmitting vocal or other sounds telegraphically … by causing electrical undulations, similar in form to the vibrations of the air accompanying the said vocal or other sound."
- Early designs used "microphones" filled with fluid that responded to changes in air pressure and created an analogous voltage
- 1877: Bell Telephone Company was created
- 1879: Began using an improved microphone

3.6. Sending Sonic Messages: Gray and Meucci

- Antonio Meucci (1909-1896)
- Created, tested, demonstrated, and filed for patents on telephone models prior to Bell's work, as early as 1857
- Had failed to file patent before Bell's patent (filed a patent caveat in 1871)
- Elisha Gray: presents a similar telephone at Philadelphia Exhibition
- Files patent on the same day as Bell: 14 February 1876

3.7. Sound Analysis to Sound Recording: Phonoautograph

- Édouard-Léon Scott: Parisian typesetter and inventor
- 1857: Leon Scott builds phonoautograph, tracing waveform on smoked paper

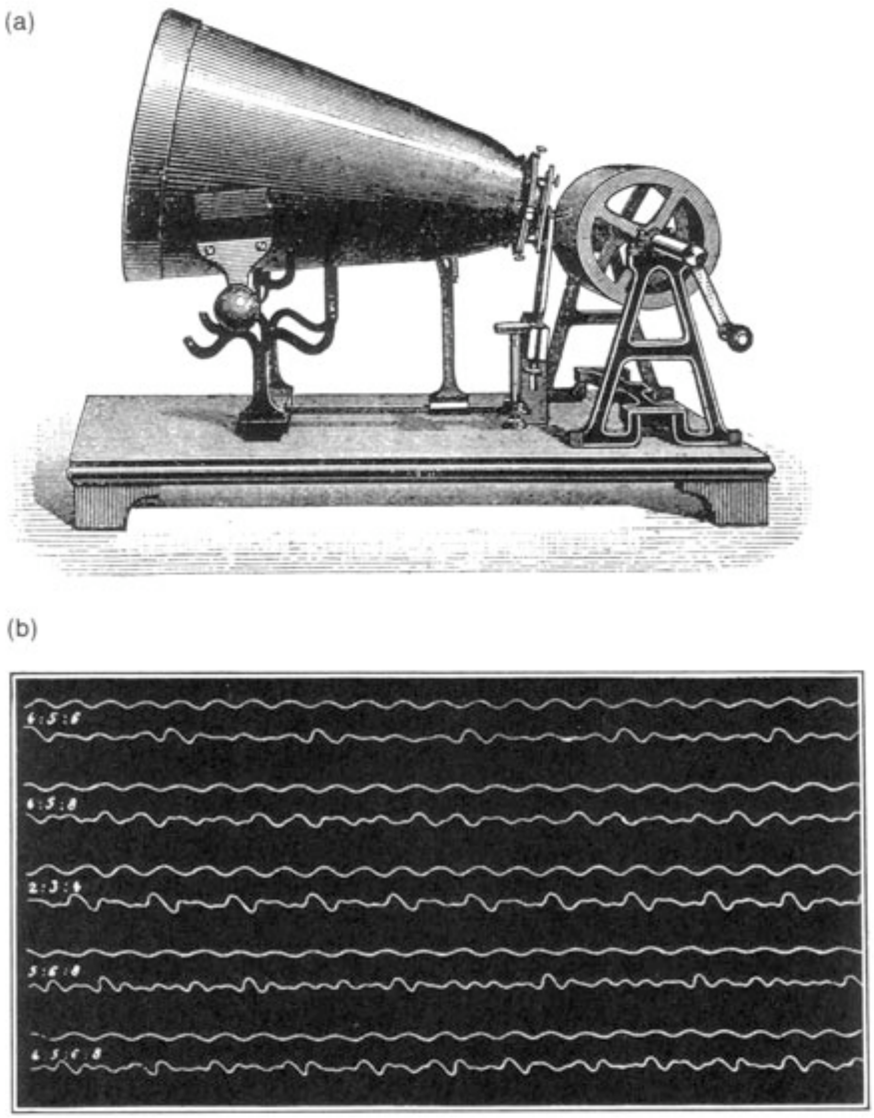
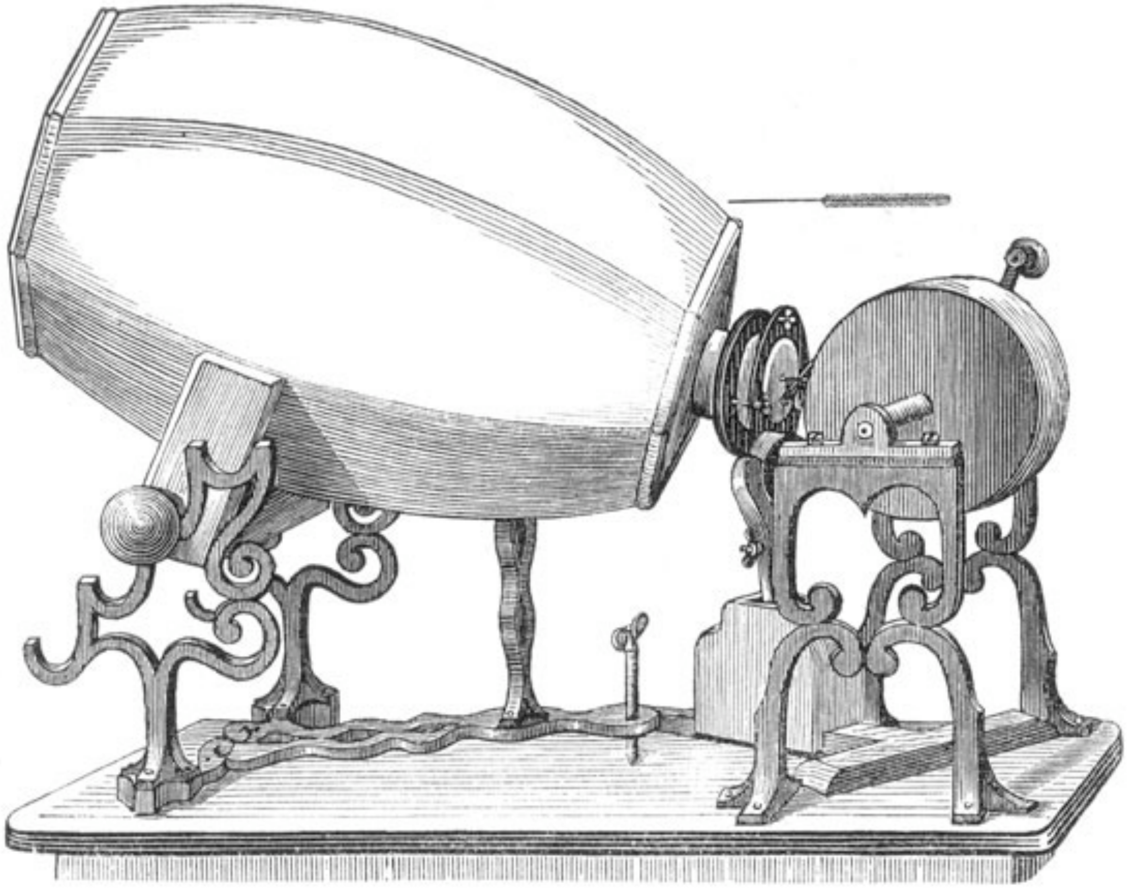


Figure 12.2 Rudolf Koenig's version of the Phonoautograph for recording images of sound waveforms. (*a*) Apparatus. (*b*) Recordings.

Source: Roads, C. *The Computer Music Tutorial.* Cambridge, MA: MIT Press, 1996.
Courtesy of MIT Press. Used with permission.

- Did not conceive of recording sound for playback, but for study and analysis
- Possibly the earliest recordings from 1860 (Rosen 2008)



Courtesy of FirstSounds.org. Source: Franz Josef Pisko, *Die neuere Apparate der Akustik* (Vienna, 1865).

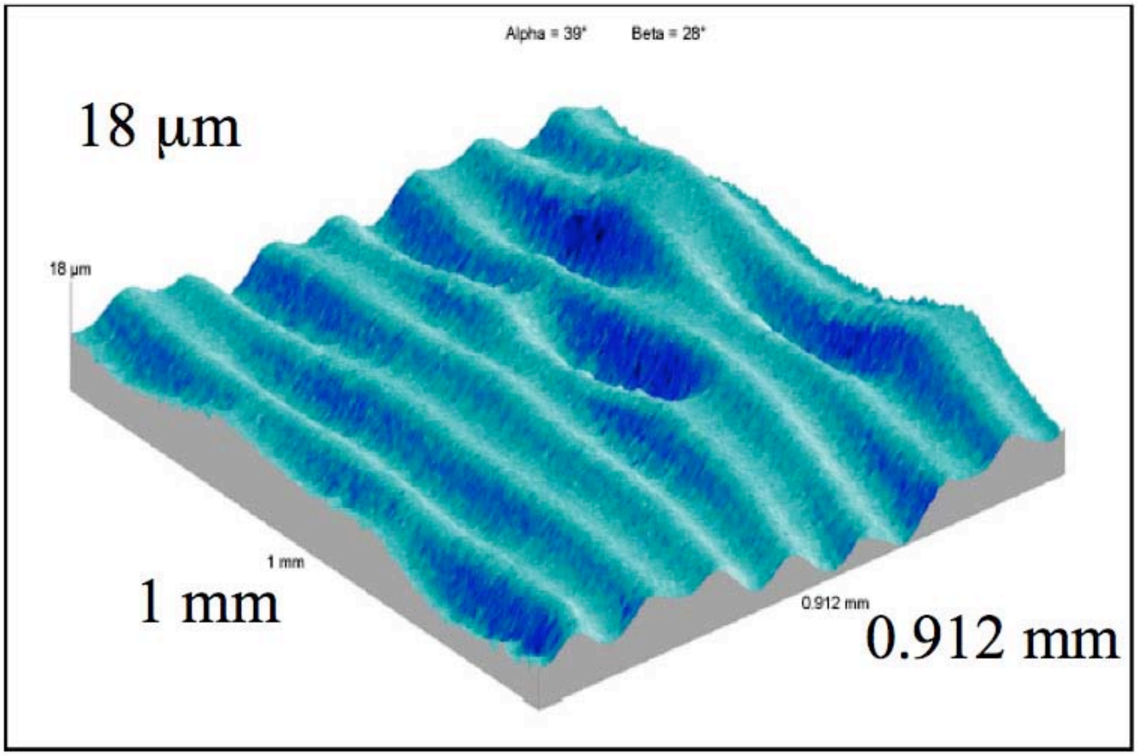
Recording reconstructed from scanned imprint:

1860 phonautograms by Édouard-Léon Scott de Martinville, restored by FirstSounds.org.
"Au Clair de la Lune."

Courtesy of FirstSounds.org. Source: Franz Josef Pisko, *Die neuere Apparate der Akustik* (Vienna, 1865).

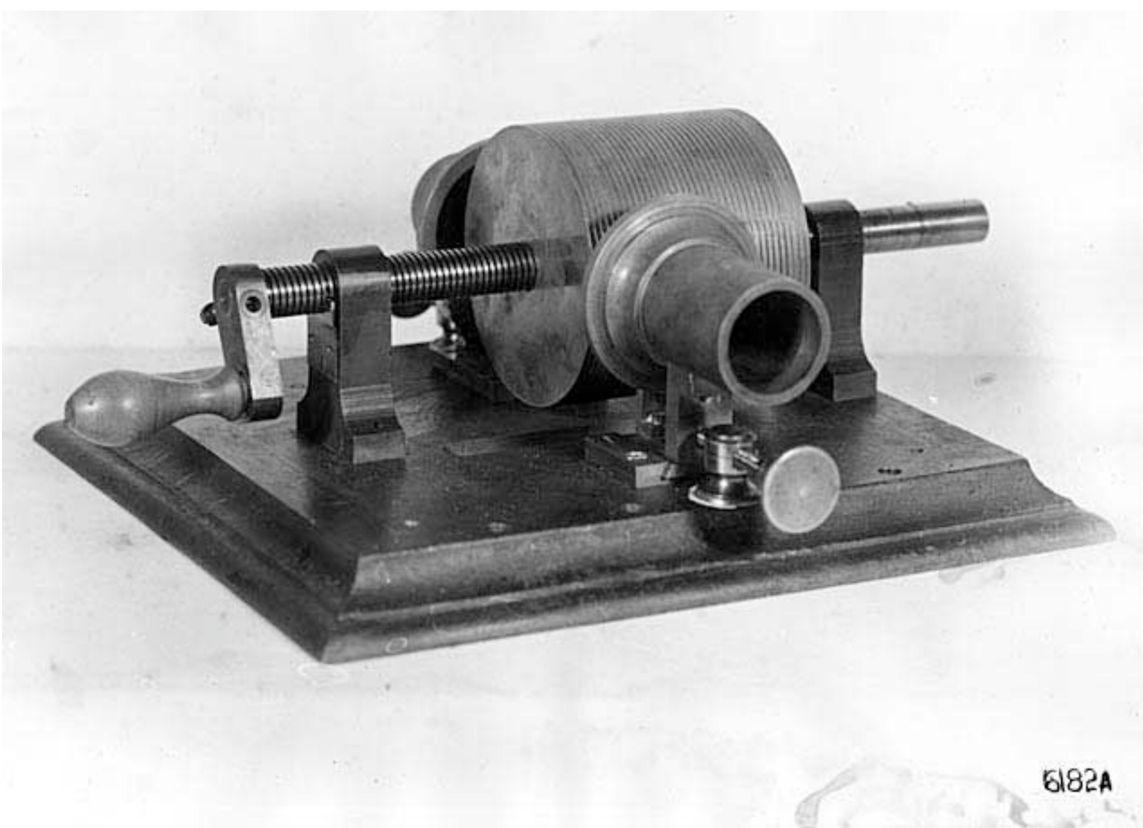
3.8. Recording Sonic Messages: Vertical Cuts in Tin

- Thomas Alva Edison (1847-1931)
- First prototype of the phonograph tested in 1877
  - Hand crank to turn a cylinder covered in tin
  - Hill and dale vertical cuts



  - Produced a helical trace around the cylinder

- Original 1877 Edison model



Source: U.S. National Park Service

- A refined production model

Source: U.S. Library of Congress

- Mechanical recording and mechanical playback

3.9. Tracks on Wax

- 1888 first commercial phonographs in production
- Replaced tin with a wax coating
- Four inch cylinder could record between 3 and 4 minutes
- Hand cranks soon replaced with spring-wound mechanisms

3.10. The Voice of Edison

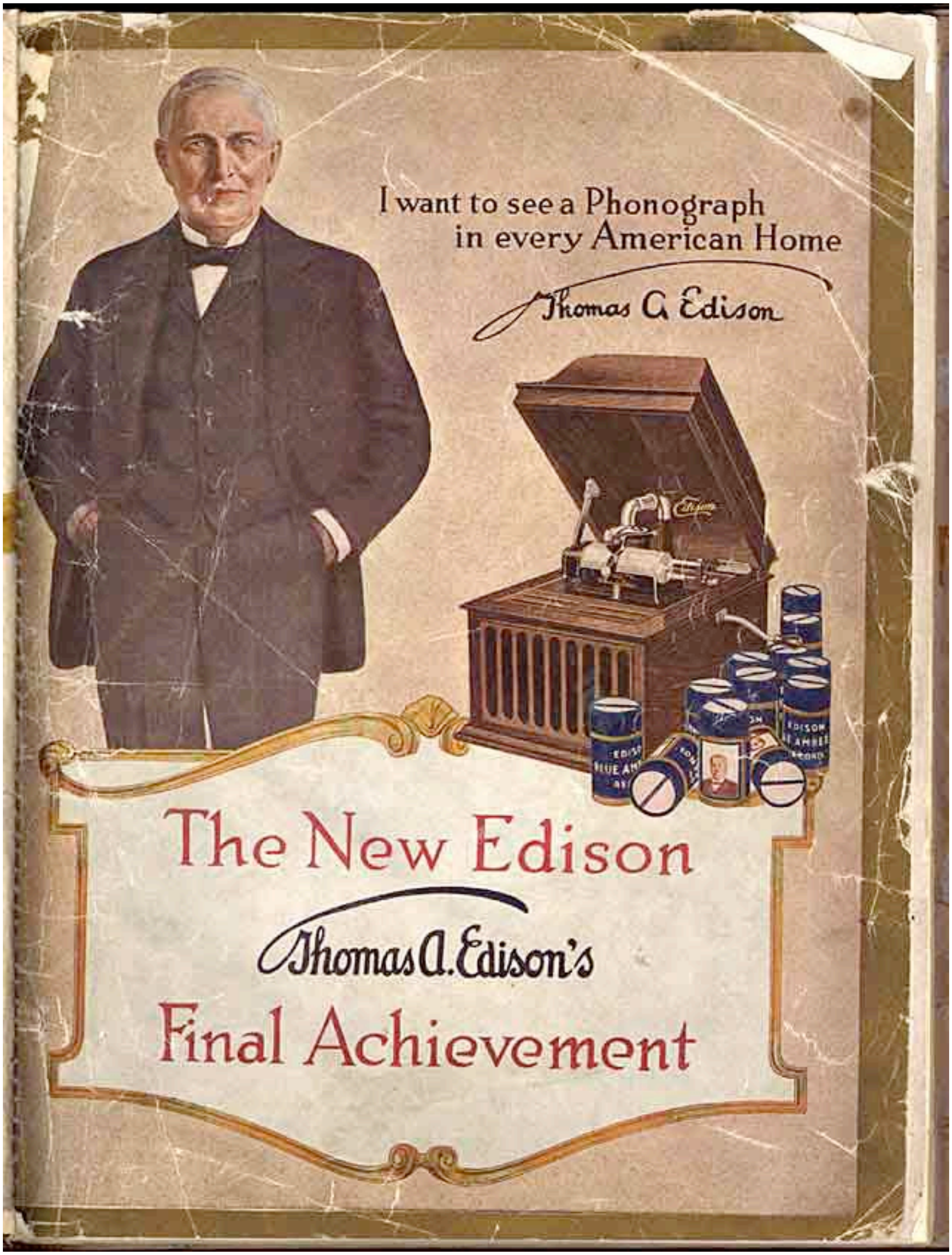
- Earliest known recording of Edison
- Recorded on an Edison yellow paraffin cylinder in 1888
- Audio: Thomas A. Edison: "Around the world on the phonograph," 1888
- Extensive archive of early recordings by Edison: http://www.nps.gov/edis/photosmultimedia/the-recording-archives.htm

3.11. Recorded Sound: A Commercial Endeavor

- Edison desired that the phonograph be used for business: "… I don't want the phonograph sold for amusement purposes, it is not a toy. I want it sold for business purposes only" (Brady 1999, p. 22).
- Wanted to lease machines to businesses
- Marketed applications included creating audio albums of voices of the dead
- Advertisement from Harpers, 1898

Source: U.S. Library of Congress

- Eventually accepts home use, but still not for music



Source: U.S. Library of Congress

3.12. A Spiral not a Helix: The Innovation of the Disc

- 1887: Emile Berliner (1851-1929) introduces the disc-based Gramophone

Source: U.S. Library of Congress

- 1888: Emile Berliner publishes “Etching The Human Voice”

Copy from which I read the paper May 16/88.

The text was changed here and there for publication in Journal of the F.I.

THE GRAMOPHONE.

ETCHING THE HUMAN VOICE.

By Emile Berliner.

[*To be read at the Stated Meeting, Wednesday, May 16, 1888.*]

Members of the Franklin Institute, Ladies and Gentlemen:—The last year in the first century of the history of the United States was a remarkable one in the history of science.

There appeared about that period something in the drift of scientific discussions, which, even to the mind of an observant amateur, foretold the coming of important events.

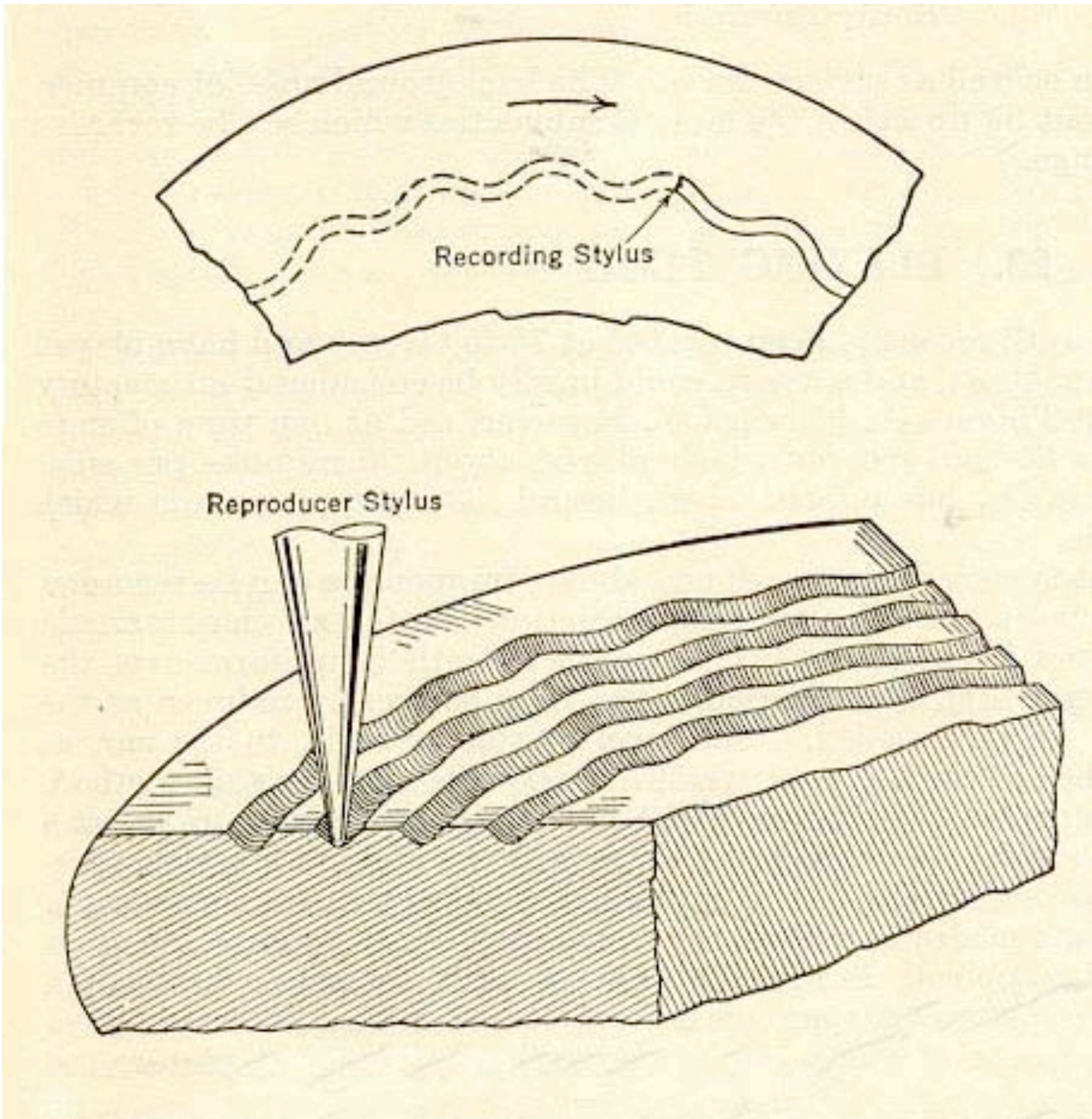
The dispute of Religion *versus* Science was once more at its height; prominent daily papers commenced to issue weekly discussions on scientific topics; series of scientific books in attractive popular form were eagerly bought by the cultured classes; popular lectures on scientific subjects were sure of commanding enthusiastic audiences; the great works on evolution had just commenced to take root outside of the small circle of logical minds from which they had emanated, and which had fostered hem. Scientific periodicals were expectantly scanned for new nformation, and the minds of both professionals and amateurs were on the *qui vive*.

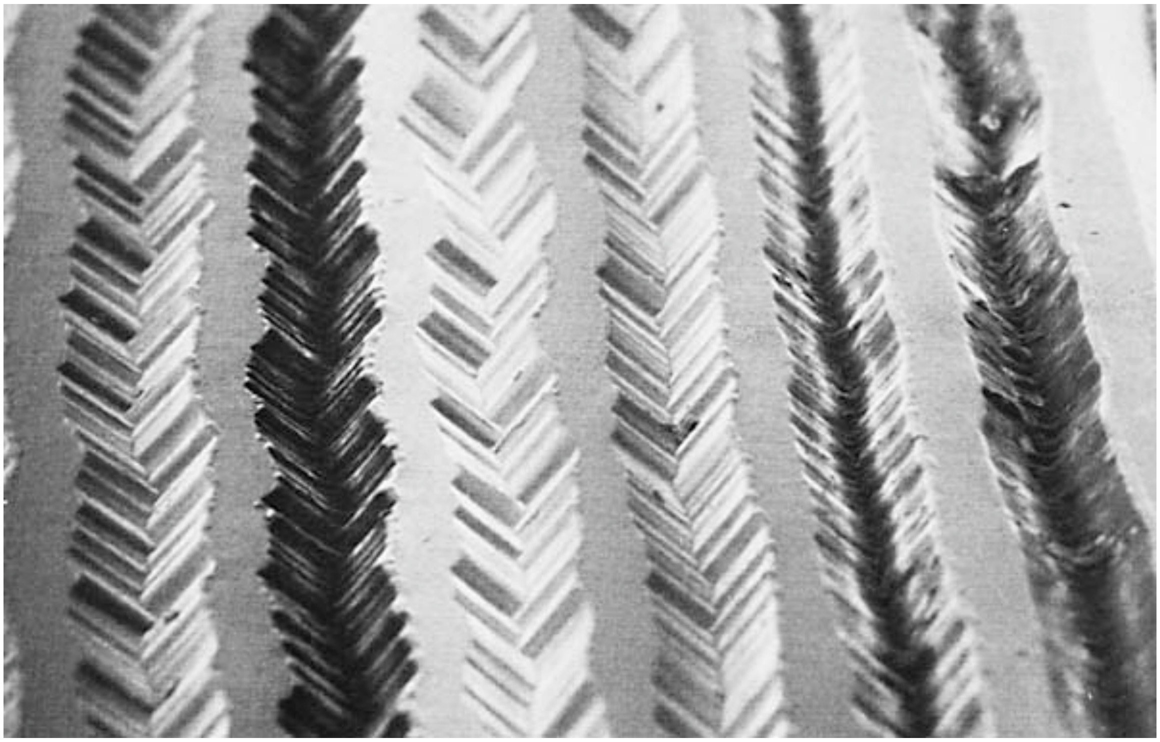
Add to this the general excitement prevailing on account of the forthcoming centennial celebration with its crowning event, so dear to this nation of inventors, the world's exhibition, and even those who did not at the time experience the effects of an atmosphere pregnant with scientific ozone, can, in their minds, conjure up the pulsating, swaying, and turbulent sea of scientific research of that period. Science evidently was in labor.

The year 1876 came, and when the jubilee was at its very height, and when this great City of Philadelphia was one surging mass of patriots filling the air with the sounds of millions of shouts, a still small voice, hardly audible, and coming from a

Source: U.S. Library of Congress

- First discs were made of acid-etched zinc
- Later discs made of glass, plastics, other materials.
- Transduced waveform into lateral, rather than vertical, cuts





- 1895: Commercial pre-recorded discs were available for sale
- Still using mechanical recording and mechanical playback
- 1901: Eldridge Johnson, along with Berliner, incorporate Victor Talking Machine Company, merging Berliner's Berliner Gramophone and Johnson's Consolidated Talking Machine Company

3.13. The Cylinder and the Disc

- The cylinder permitted recording, at home or in the office
- The disc was cheap to reproduce, and was primarily for distribution of pre-recorded material
- Between 1890 and 1910 pre-recorded programs on discs out-sell recordable blank cylinders
- By 1913: Edison is the last manufacturer to stop selling cylinders

3.14. Recorded Sound: A Commercial Mascot

- Nipper: 1884-1895
- Painting by his owner, Mark Barraud, renamed "His Master's Voice"

- Painting bought by The Gramophone Company (became EMI) in 1899, and replaced the phonograph with a gramophone

- Used in advertising in 1900
- Berliner buys rights in 1902 for Victor Talking Machine Company (later RCA Victor)

3.15. The Age of the Disc

- 1910s onward the disc is the medium of recorded sound
- Edison reluctantly creates and sells disc-based players

3.16. Analog Recording from 1890 to 1920s

- Social issues
  - Edison Realism Test: a formalized, marketing procedure to encourage listeners to imagine performance while listening
  - Illustrated song machine and the projecting phonograph: attempts to restore visual element with graphical mechanizations
  - 1903 Rosenfield Illustrated song machine

- Personification and anthropomorphism: Talking Machines
- Technical issues
    - Record entire ensemble with one horn, mechanically
    - Some instruments and singers recorded better than others

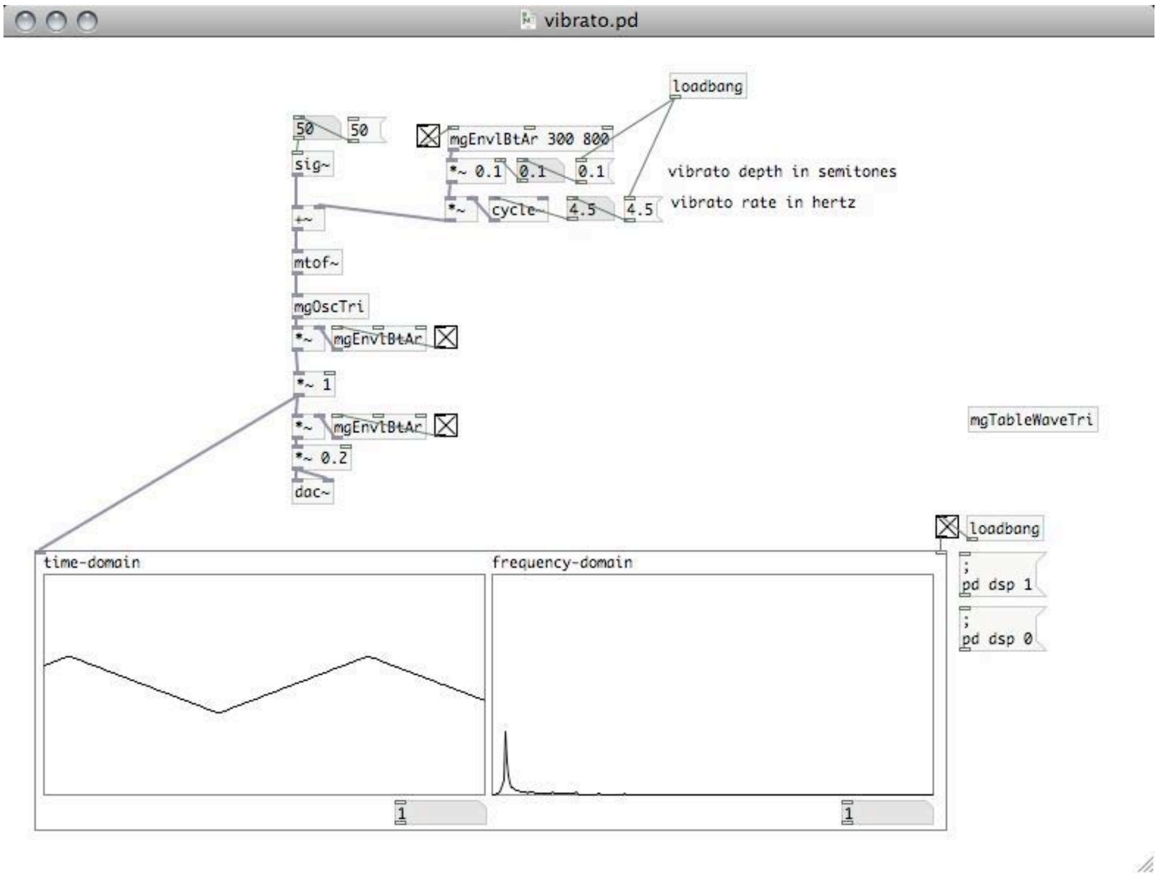
By the courtesy of the Gramophone Co., Ltd.

CARICATURE OF CARUSO MAKING A RECORD
Drawn by himself

3.17. Reading: Katz

- Katz, M. 2002. "Aesthetics out of Exigency: Violin Vibrato and the Phonograph." In *Music and Technology in the Twentieth Century*. H. Braun, ed. Baltimore: The Johns Hopkins University Press. 174-185.

- Vibrato [vibrato.pd]



- What stages of a change in vibrato performance does Katz document?
- What reasons, other than recording, does Katz state others have offered?
- What are the three reasons Katz sees the increase in vibrato as “a response to the exigencies of sound recording”
- How else might recording be seen as a catalyst rather than a tool of preservation?
- The idiomatic of new mediums: “necessity ... may sometimes be the mother of aesthetics”

3.18. Electrification of Sound

- Phonographs and gramophones: mechanical recording, mechanical playback
- late 1920s: innovations in microphones led to electrical recording
- 1930s: electrical playback and amplification

3.19. The Fidelity of Recorded Audio

- 1890s to 1920s (1925)
  - Narrow frequency response: best 200 and 2k Hertz
  - Very low dynamic range
  - Poor signal to noise ratio
- 1930s
  - Frequency response from 100 to 4.5k
  - Dynamic range of 30 dB
- Wagner: Ride of the Valkyries, from Die Valkyrie, 1921, American symphony Orchestra, Edison Diamond Disc [samplePlayer.pd]
- Audio: local
- Wagner: Ride of the Valkyries, from Die Valkyrie, 1988, Cincinnati Pops Orchestra
- Audio: local

3.20. Disc Formats

- 78 RPM discs
  - 1900 to 1925 discs recorded between 74 and 82 rpm
  - 78 rpm based on a 3600 rpm motor with 46:1 gear ratio: 78.26 rpm
  - Covered in shellac: Asian beetle juice
  - Available in 10 inch (3 minutes) and 12 inch (4-6 minutes) formats
- 33.333333 RPM discs
  - Columbia Records (owned by CBS): June 1948 releases Long Playing Record
  - Use of more-narrow grooves (microgroove)
  - Use of vinyl offered better sound quality

- 12 inch diameter, 30 minutes or more per side

- 45 RPM discs
  - RCA Victor introduces in 1949, 7 months after LP
  - 7 inch diameter, 4 minutes per side
  - Designed to have uniform size, easy distribution, automatic changers (jukebox)
  - Became known as "singles": one tune per side
  - The B or flip side offered a bonus track
  - Extended Play (EP) 45s achieved 7 minutes per side
  - Early model manufactured by RCA

  - RCA advertisement

GREATEST MUSICAL ADVANCE IN 50 YEARS

New RCA VICTOR System

OF RECORDED MUSIC

The modern, inexpensive way to enjoy music in the home

The new RCA Victor system has more advantages, offers more enjoyment than any other system ever devised. From the new compact player to the distortion-free 7-inch record, it marks an impressive milestone in RCA Victor's lifetime goal—to make the pleasures of recorded music a reality in every home.

WORLD'S FASTEST CHANGER

Lightning fast! This changer plays up to ten of the 7-inch, 45 rpm records like the new RCA Victor record . . . the first record distortion-free over its entire playing surface. These non-breakable records can play just as long as ordinary 12-inch discs . . . cost far less.

The new changer is the *easiest* to operate. Slip up to ten records on the spindle . . . push one button and enjoy over 50 minutes of just the music you want. It is the *surest* operating player ever. No chipping of center hole. No more "spindle-seeking" while loading.

COLLECT RECORDS AT LESS COST

Yet, with all its advantages, the new RCA Victor system costs far less. Smaller size and fewer parts naturally mean greater savings. No wonder this amazing new system has been acclaimed the modern, inexpensive way to enjoy music in the home.

Model 9-JY • Now you can enjoy the advantages and savings of the new RCA Victor system at an unbelievably low cost. Model 9-JY can be easily attached to your present instrument, regardless of make or model. Even in this small attachment, surface noise is virtually eliminated. Plays up to 10 of the new records.

Model 9-W-103 • A modern console featuring the new RCA Victor system. AM-FM radio. "Golden Throat" tone system. Storage for 24 albums or 189 singles. And new records fit ordinary bookshelves. Lovely walnut, mahogany or limed oak finish. A great achievement in styling, performance and price.

Theoretically, every record can have a "quality zone" . . . a portion of the record in which no distortion occurs. The new RCA Victor 7-inch record is the *first* to be recorded *entirely* in the "quality zone."

Model 9-W-105 • A must for music lovers who already have collections of 10- and 12-inch records. Two changers, AM-FM radio. "Golden Throat" tone system. Plays standard 10- and 12-inch records as well as the low-cost, distortion-free 7-inch records. Ample record storage space in the lovely, Period cabinet.

3.21. The Expansion of the Music Business

- 1927: 104 million discs sold
- From 1934 to 1939: 6,000 to 152,000 record players produced (Magoun 2002, p. 149)
- Marketed to middle class for consumer usage
- 1930s: gramophones packaged with radios

3.22. Reading: Magoun

- Magoun, A. B. 2002. "The Origins of the 45-RPM Record at RCA Victor, 1939-1948." In *Music and Technology in the Twentieth Century*. H. Braun, ed. Baltimore: The Johns Hopkins University Press. 148-157.
- What were some of the motivations for the 45-RPM disc?
- What audience, and what music, was associated witht the 45-RPM disc?
- Was fidelity and sound quality a driving force in product design? Is it today?
- What other entertainment was competing with record sales?

3.23. Stereo

- By recording two channels (sometimes called tracks), sound could be panned left and right
- Increase sense of space in recorded sound
- 1958: first stereo records issues

3.24. Aural Transduction to Magnetic Flux

- Magnetic wire recording in 1898: Valdemar Poulsen
- Magnetic tape in 1928: Firtz Pfleumer (Germany)
    - Wire was difficult to record, cut, and splice
    - Cellulose acetate coated in iron oxide
    - Permitted splicing with adhesive tape
- How it works

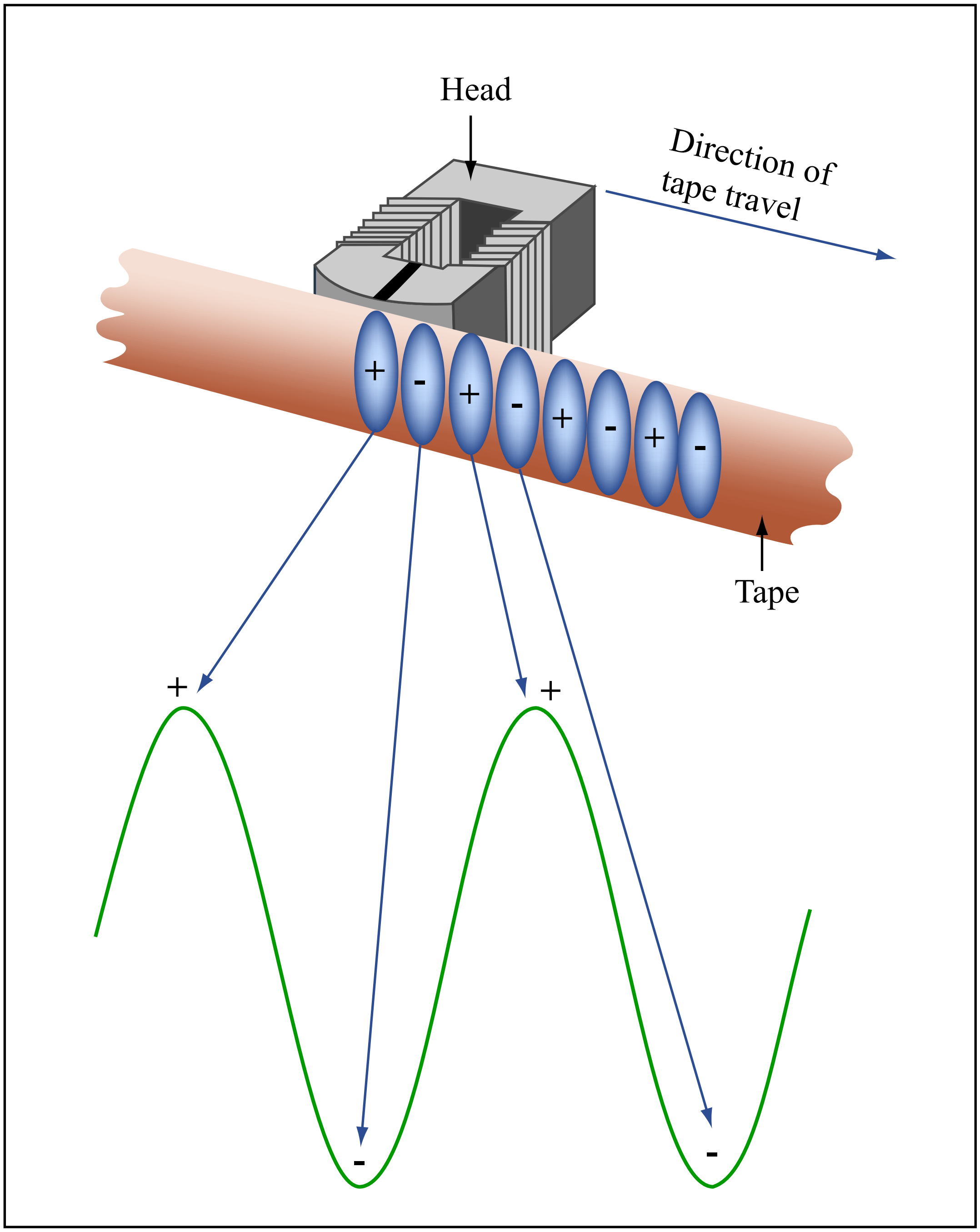


Figure by MIT OpenCourseWare.

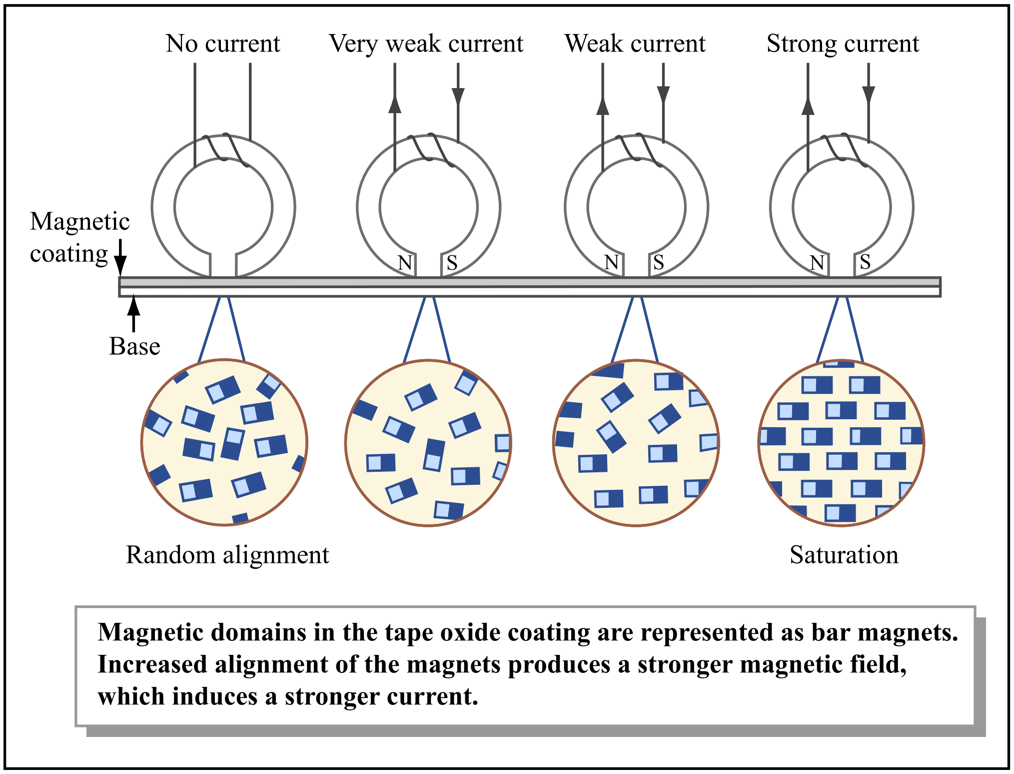
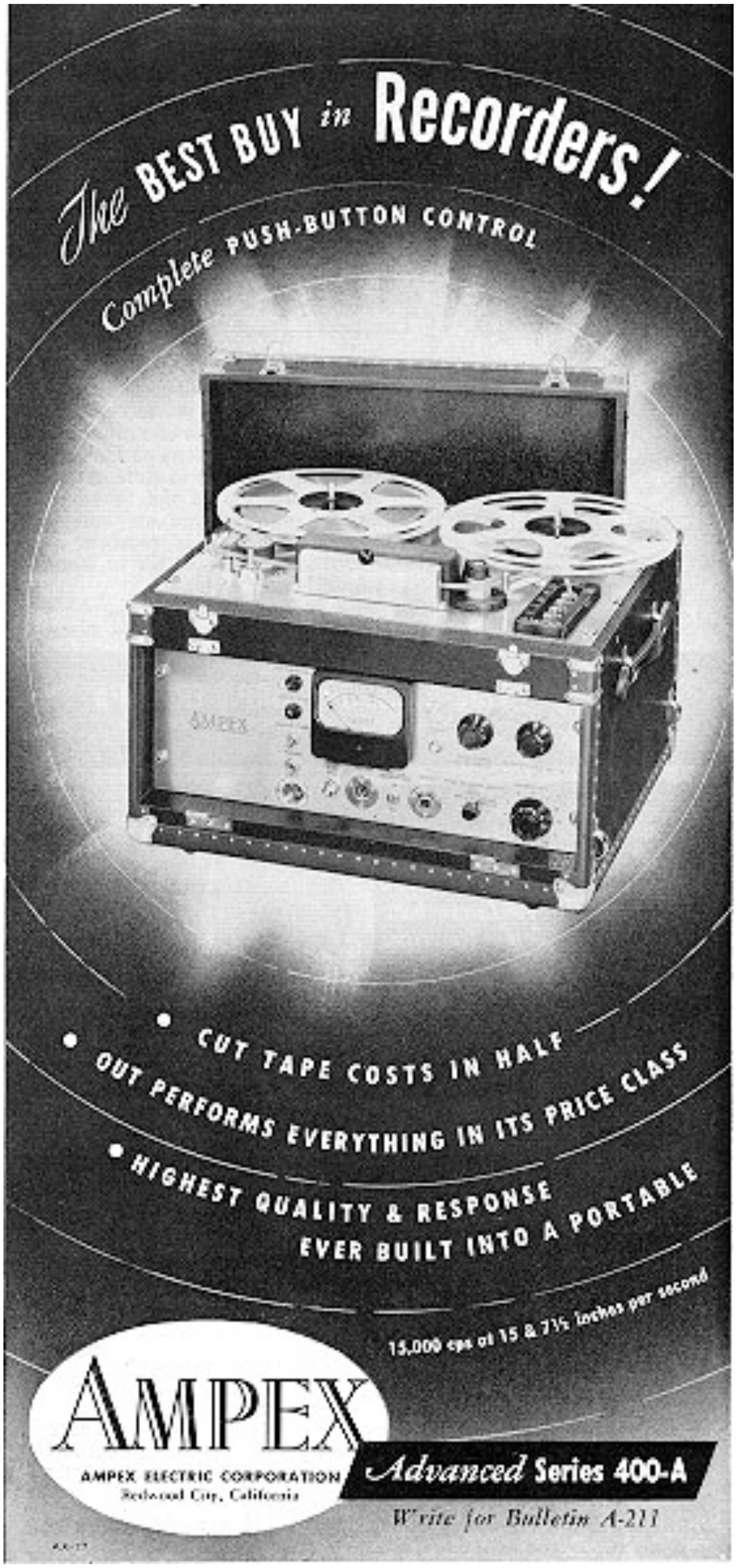


Figure by MIT OpenCourseWare.

3.25. Early Magnetic Recording Devices

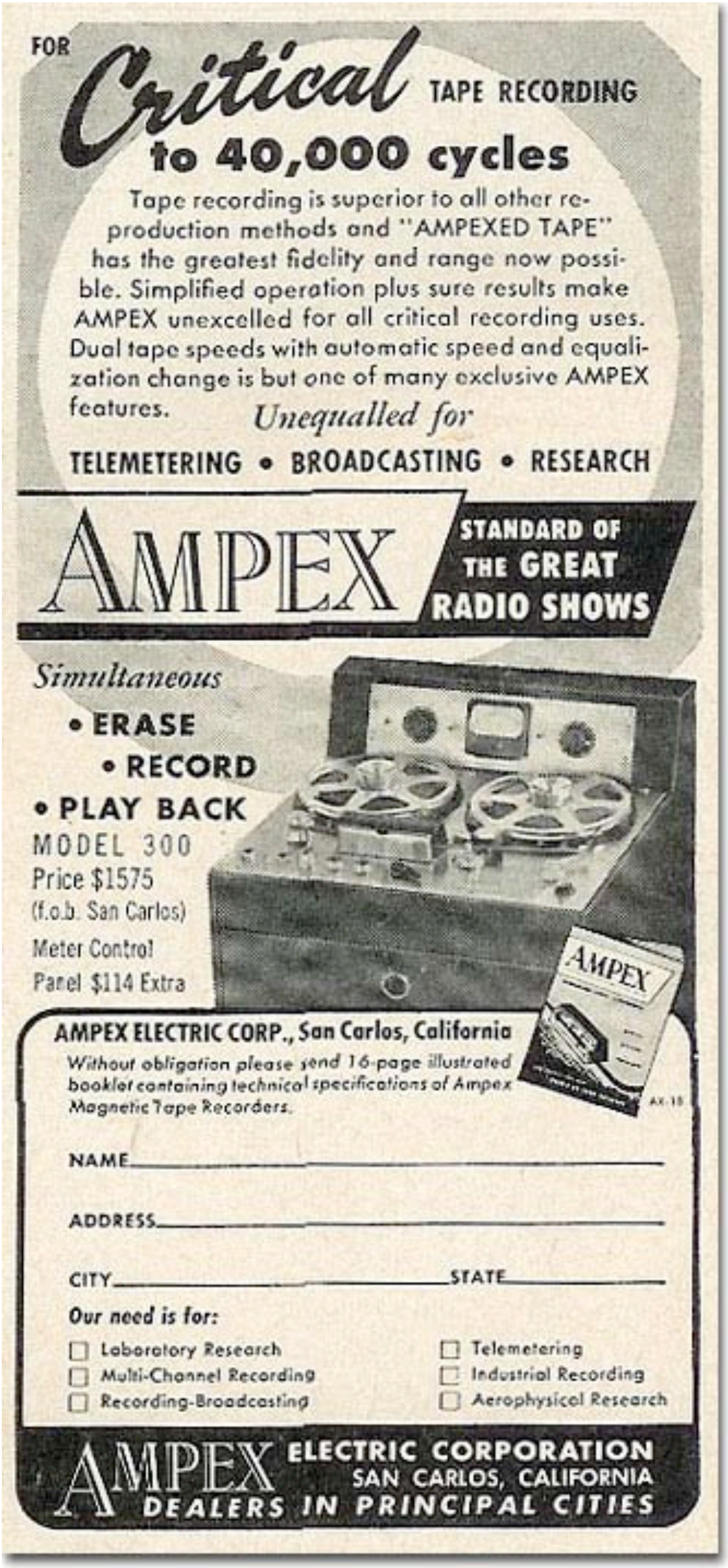
- 1930s: Magnetophone (AEG, Germany)
- 1940s: Commercially developed in the late 1940s by American Jack Mullin with Bing Crosby
- Reel to reel audio tape recording machines spread in 1950s with companies like Ampex


The BEST BUY in Recorders!
Complete PUSH-BUTTON CONTROL
• CUT TAPE COSTS IN HALF
• OUT PERFORMS EVERYTHING IN ITS PRICE CLASS
• HIGHEST QUALITY & RESPONSE EVER BUILT INTO A PORTABLE
15,000 cps at 15 & 7½ inches per second
AMPEX
AMPEX ELECTRIC CORPORATION
Redwood City, California
Advanced Series 400-A
Write for Bulletin A-211

- Tape permitted multitrack recording
- Pioneered by Les Paul, developed as early as 1954

3.26. Analog Audio Multitracks: Les Paul

- 1940s: Guitarist Les Paul (1915-) experiments with adding and bouncing tracks in direct to wax disk recording
- 1948: produced “Lover (When You're Near Me)” album with this technique, combining up to 8 guitars
- Modifies an Ampex Model 300 mono tape recorder to record multiple individual tracks


FOR Critical TAPE RECORDING
to 40,000 cycles
Tape recording is superior to all other reproduction methods and "AMPEXED TAPE" has the greatest fidelity and range now possible. Simplified operation plus sure results make AMPEX unexcelled for all critical recording uses. Dual tape speeds with automatic speed and equalization change is but one of many exclusive AMPEX features.
Unequalled for
TELEMETERING • BROADCASTING • RESEARCH
AMPEX
STANDARD OF THE GREAT RADIO SHOWS
Simultaneous
• ERASE
• RECORD
• PLAY BACK
MODEL 300
Price $1575
(f.o.b. San Carlos)
Meter Control Panel $114 Extra
AMPEX
AMPEX ELECTRIC CORP., San Carlos, California
Without obligation please send 16-page illustrated booklet containing technical specifications of Ampex Magnetic Tape Recorders.
NAME
ADDRESS
CITY
STATE
Our need is for:
Laboratory Research
Multi-Channel Recording
Recording-Broadcasting
Telemetering
Industrial Recording
Aerophysical Research
AMPEX ELECTRIC CORPORATION
SAN CARLOS, CALIFORNIA
DEALERS IN PRINCIPAL CITIES

- By 1953 develops first 8 track recorder
- Employed recording at different speed to transpose guitar part on playback
- Les Paul and his wife Mary

3.27. Listening

- Les Paul, "Lover," 1948

3.28. Music in Your Pocket: The Cassette

- 1962: Philips releases compact cassette

- 45 minutes per side
- Initially had less quality than larger formats

- Improved frequency response from 30-18000 Hertz

- 1963 to 1968: 9000 to 2.4 million players sold
- Affordable home recording
- Double cassette decks: easy copying
- Home Taping is Killing Music: 1980s anti-copyright infringement campaign by British Phonographic Industry (similar to RIAA)

3.29. Reading: Millard: Tape Recording and Music Making

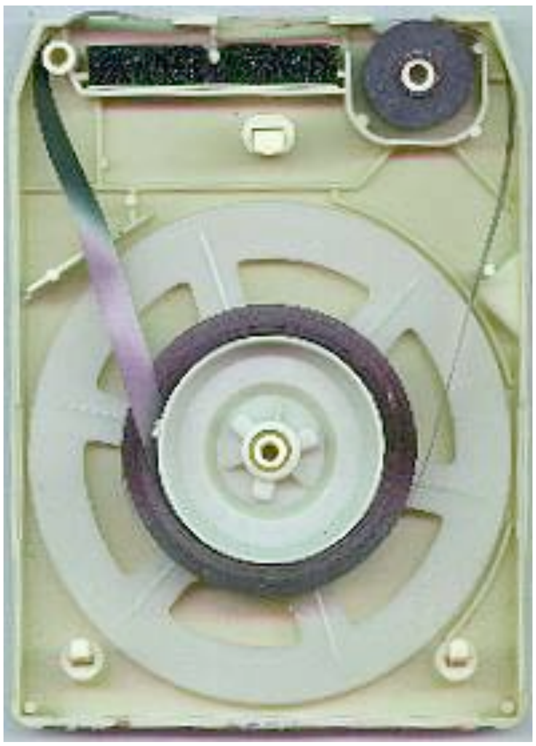
- How did tape recording relate to the Edison cylinder?
- Who were the early adopters of tape recording devices, and what did they do with them?
- What new techniques were possible with tape recording?
- What musical genres were particularly influenced by the cassette, and why?

3.30. Reading: Collins

- Collins, N. 2009. *Handmade Electronic Music: The Art of Hardware Hacking*. 2nd ed. New York: Routledge.
- Creative applications of tape heads and tape

3.31. Tape Cartridges and Stereo 8

- The 8-track cartridge
- 1964 to 1982-1988
- An endless tape loop: one continuous piece of tape
- Self winding, and could not rewind



Source: Wikipedia

- Four tracks: two pairs of stereo tracks side by side
- 1965: Ford puts 8-tracks in cars
- Tape head alignment was a regular problem

Chapter 4. Meeting 4, Recording: Microphones and Radio

4.1. Announcements

- Next meeting: discussion workshop meeting
- Next meeting: cover basics of using PD: bring your laptop
- Next meeting: experiment with speakers, tape heads, microphones, and contact microphones
- Things to bring (if you have): an open speaker, small conductive speakers, tape heads, old tapes you want to destroy, a resonant acoustic instrument
- Next meeting: discuss readings by Pinch and Bijker, and Fouché

4.2. Reading: Horning

- Horning, S. S. 2004. "Engineering the Performance: Recording Engineers, Tacit Knowledge and the Art of Controlling Sound." *Social Studies of Science* 34(5): 703-731.
- What is tacit knowledge, and why might audio recording require it?
- What are some of the non-technical skills required of recording engineer, both in the past and present?
- Horning describes the changing technical skills of audio engineers: summarize this trajectory.
- Horning suggest that a focus on microphone technique, starting in the 1950s, was the result of "inadequacies of related technology": explain and argue for or against this view.
- Horning suggests, through quotes of Brian Eno, that presently technology is now a greater impediment to recording and creativity. Explain and argue for or against this view.

4.3. Quiz

- 10 minutes

4.4. The Technology of Radio

- Radio is a broadcast signal, using modulated electromagnetic waves
- Other electromagnetic radiation: microwaves, visible light

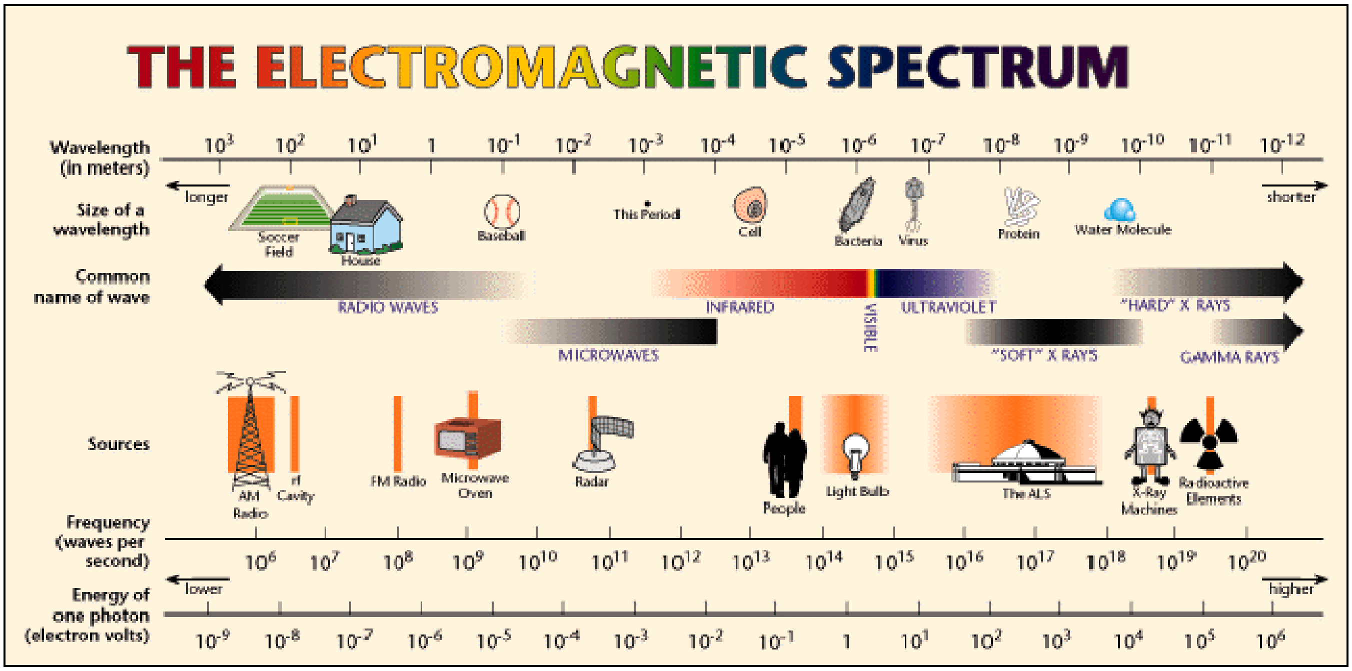


Image: NASA.

- Oscillating electromagnetic fields pass through the air and space
- We can imagine electromagnetic waves as similar to sound waves

4.5. Encoding Messages with Modulation

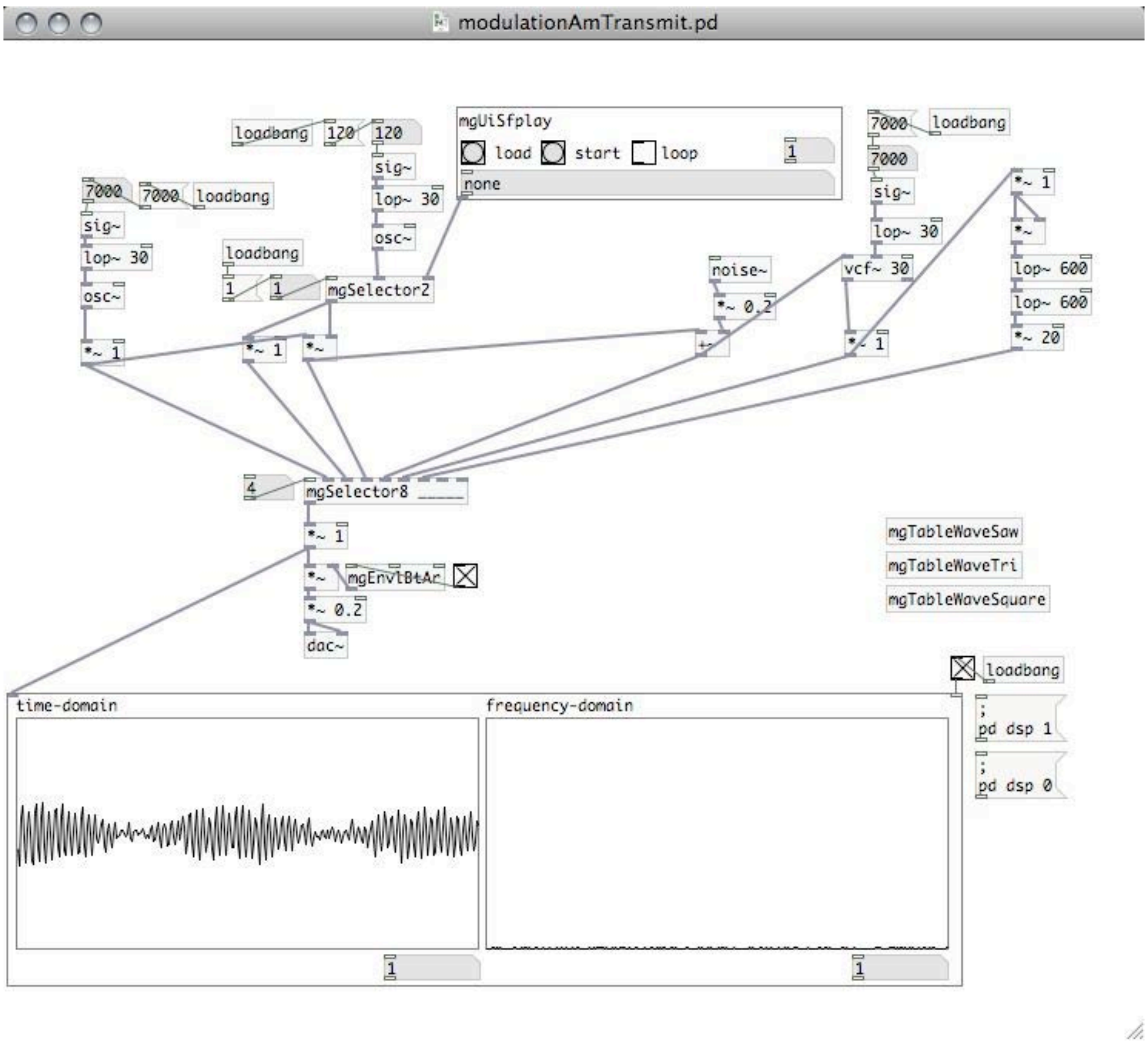
- Take a sine wave as a carrier
- When transmitting, vary (modulate) the sine wave's amplitude or frequency in some pattern
- Derive (encode) the modulator from a different signal (the message you want to send)
- When the carrier is received, the modulation (the message) is decoded from the carrier

4.6. Amplitude Modulation

- Encode by modifying the amplitude of the carrier in proportion to another signal; decode (demodulate) by finding the carrier frequency and measuring the change in amplitude
- Carrier Frequencies between 300 kHz and 3 MHz
- Common usage frequencies in US between 535 kHz and 1.7 MHz
- Short wave radio: 2.3 MHz to 26 MHz: long distance
- Frequency response from 40 to 7000 Hertz
- AM modulation has applications in sound synthesis [modulationAmBasic.pd]

4.7. Amplitude Modulation with Sound Waves

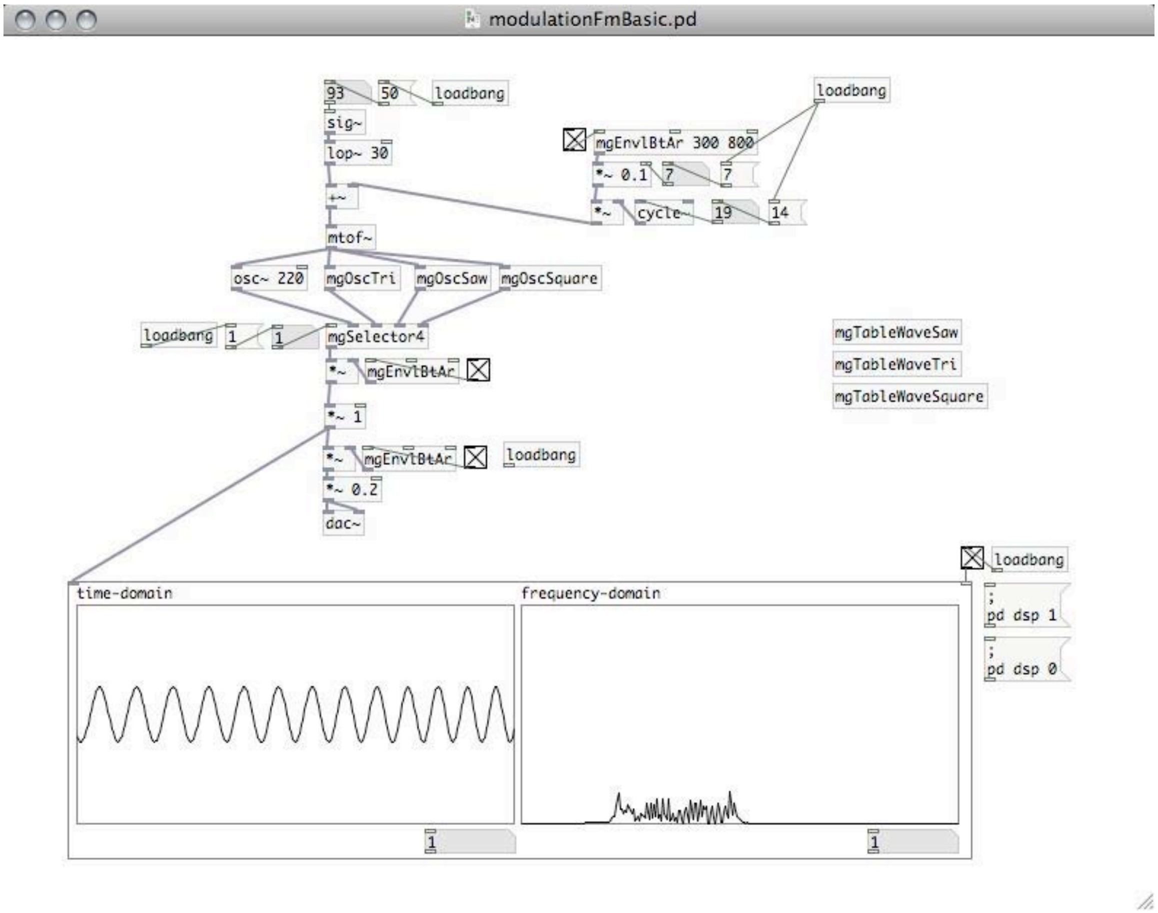
- Carrier is within range of hearing (20-20000 Hertz) [modulationAmTransmit.pd]



4.8. Frequency Modulation

- Carrier Frequencies between 30 MHz and 300 MHz
- Common usage frequencies in US between 88 and 108 MHz
- Frequency response from 30 (50) to 15000 Hertz
- Encode by modifying the frequency of the carrier at a rate in proportion to another signal; decode (demodulate) by finding the carrier frequency and measuring the change rate of change in the frequency

- FM modulation has applications in sound synthesis [modulationFmBasic.pd]



4.9. The History of Radio

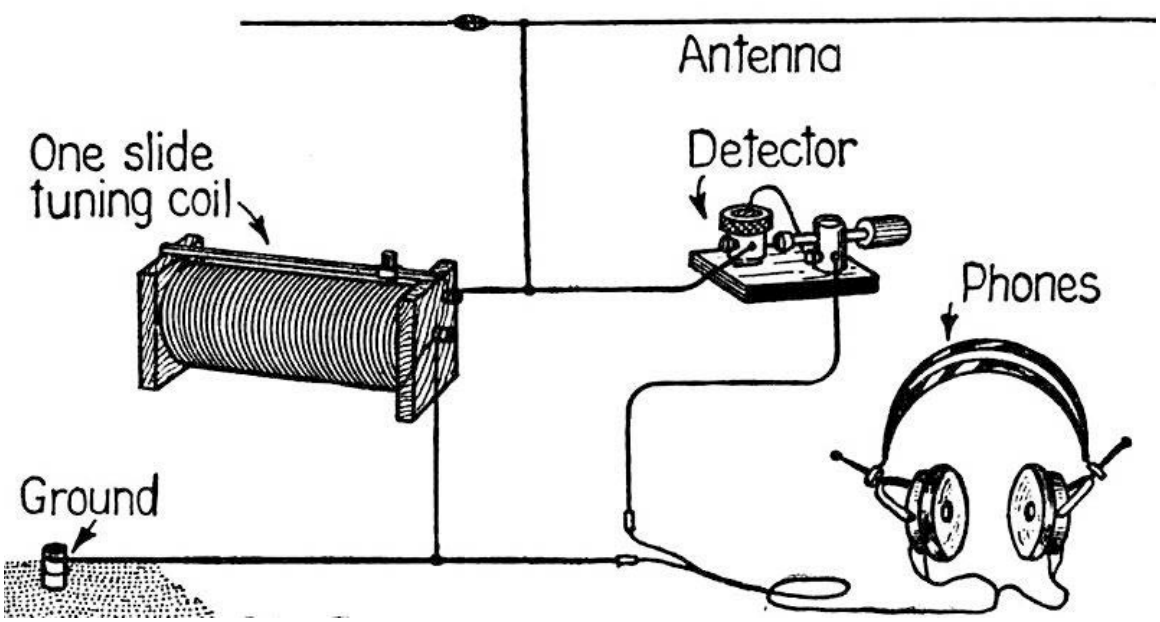
- First called wireless telegraphy (Marconi) and used for transmitting telegraph messages with spark-gap radio transmitters

- Numerous inventors and contributors: Guglielmo Marconi (1894-1897), Nikola Tesla (1893), Alexander Stepanovich Popov

- 1897: First radio station established by Marconi

- 1906: Reginald Fessenden employs Amplitude Modulation for radio broadcast

- 1910: M. H. Dodd Wireless Receiver (Rogers 2009)



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- 1915: speech first transmitted from New York City to San Francisco
- 1920s: first entertainment broadcasts
- 1921: Westinghouse Radiola Senior and Radiola A.C. (Rogers 2009)

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- Edwin H. Armstrong invents Frequency Modulation, with help from Radio Corporation of Americas (RCA) in mid 1930s
- 1934: RCA Victor Model 143 (Rogers 2009)

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- 1940s: regular use of radio to transmit television
- By 1941 over 50 FM stations on the air
- 1940: Scott Radio Laboratories: AM-FM Philharmonic

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- 1954: first pocket transistor radio, Regency TR-1

Courtesy of Michael Jack on Flickr. Used with permission.

4.10. Radio, Music, and Speech

- Used for entertainment
- Used to market and distribute music
- Competition with gramophones as medium of music consumption (from the 1920s onward)
- Used as a unique aural medium

4.11. Radio as a Medium: Glenn Gould

- Glenn Gould: Pianists and radio artists
- Well known for piano playing: Bach: The Goldberg Variations, The Well-Tempered Clavier
- In the early 1960s, grew disinterested in concert performance: "that way of presenting music is passe. If there is a more viable way to reach audiences, it has to be through recordings. Concerts as they are now known will not outlive the 20th century" (1965)
- Series broadcast on CBC Canadian radio in 1960
- The Idea of North (1967), from The Solitude Trilogy

4.12. Listening: Glenn Gould

- Audio: Glen Gould: “The Idea of North,” 1967

- What sort of musical features are shown in the use of speakers, voices, and stories?
- What sounds, other than spoken words, are used? How do they contribute to the stories?
- How is music used in this work?
- What are some of the issues faced by people in The North
- What are some of the features of the relationship between The North and the rest of Canada?
- Is the ending of this piece climatic, and/or concluding?

4.13. Radio as a Medium: Joe Frank

- Worked at WBAI in New York, National Public Radio
- 1986: moved to Santa Monica and started “Joe Frank: Work in Progress”
- 1986-2002: “In the Dark,” “Somewhere Out There,” “The Other Side” (over 230 hours)
- Can still be heard weekly on WNYC AM, Sunday from 11 PM to 12 AM

4.14. Listening: Joe Frank

- Audio: Joe Frank: “Eye in the Sky,” 1996

- What sort of musical features are shown in the use of speakers, voices, and stories?
- What sounds, other than spoken words, are used? How do they contribute to the stories?
- How is music used in this work?
- How are conventions of radio used?

- Frank uses long lists of specific details: how does this contribute or detract from the narrative and work?
- Frank uses irony in a number of ways: what are a few?
- We hear different sonic and acoustic environments; how do these build the narrative?
- We hear other speakers, both in the voice of Joe Frank and in other speakers; how do these build the narrative?
- What is this radio show about?
- Is the form balanced?

4.15. Electric Transduction: the Microphone

- Early mechanical quasi-microphones

Sir Edward Elgar conducting "The Symphony Orchestra," 1914.

- Modern transduction from air pressure to electricity
- Many ways of converting mechanical movement into analogue voltages
- Most microphones translate movement of air into movement of a diaphragm that in-turn creates an analog voltage

4.16. Early History of the Microphone

- The microphone was the critical component of the telephone

- Alexander Grahm Bell gets patent 174,465 in 1876 for (March): "… the method of, and apparatus for, transmitting vocal or other sounds telegraphically … by causing electrical undulations, similar in form to the vibrations of the air accompanying the said vocal or other sound"

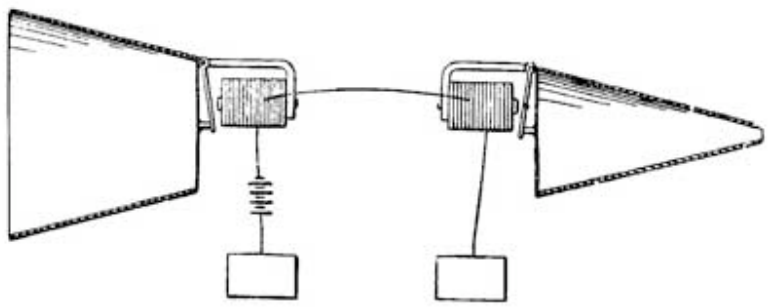
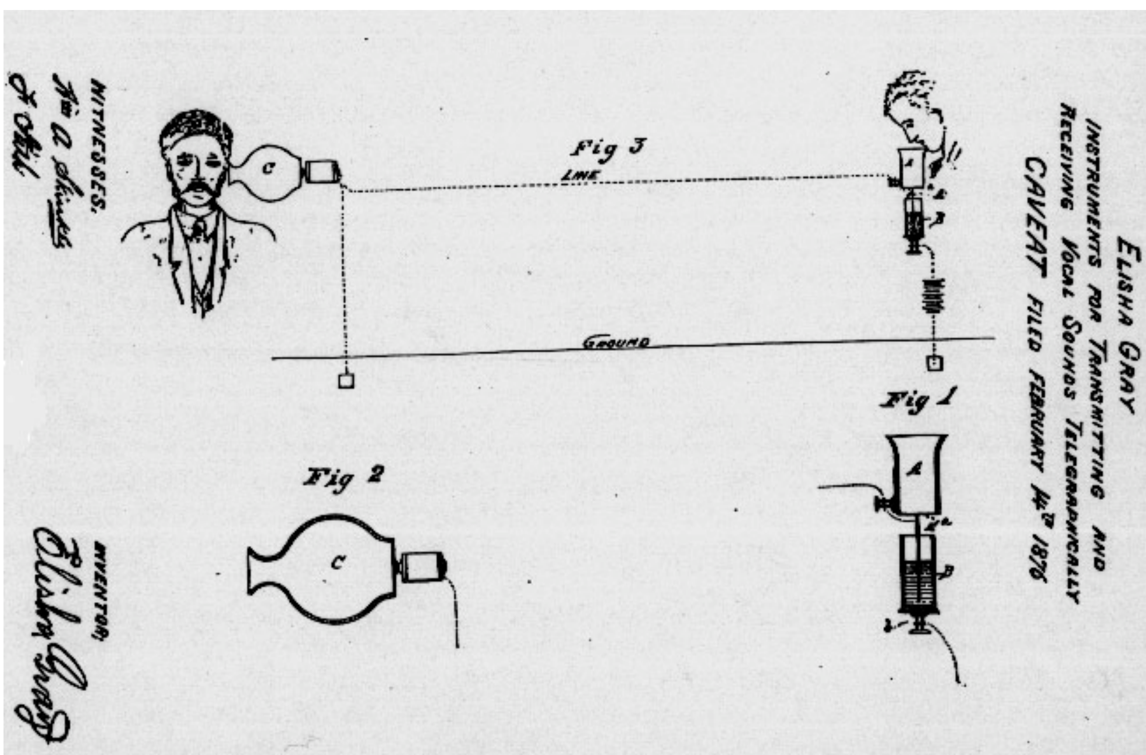


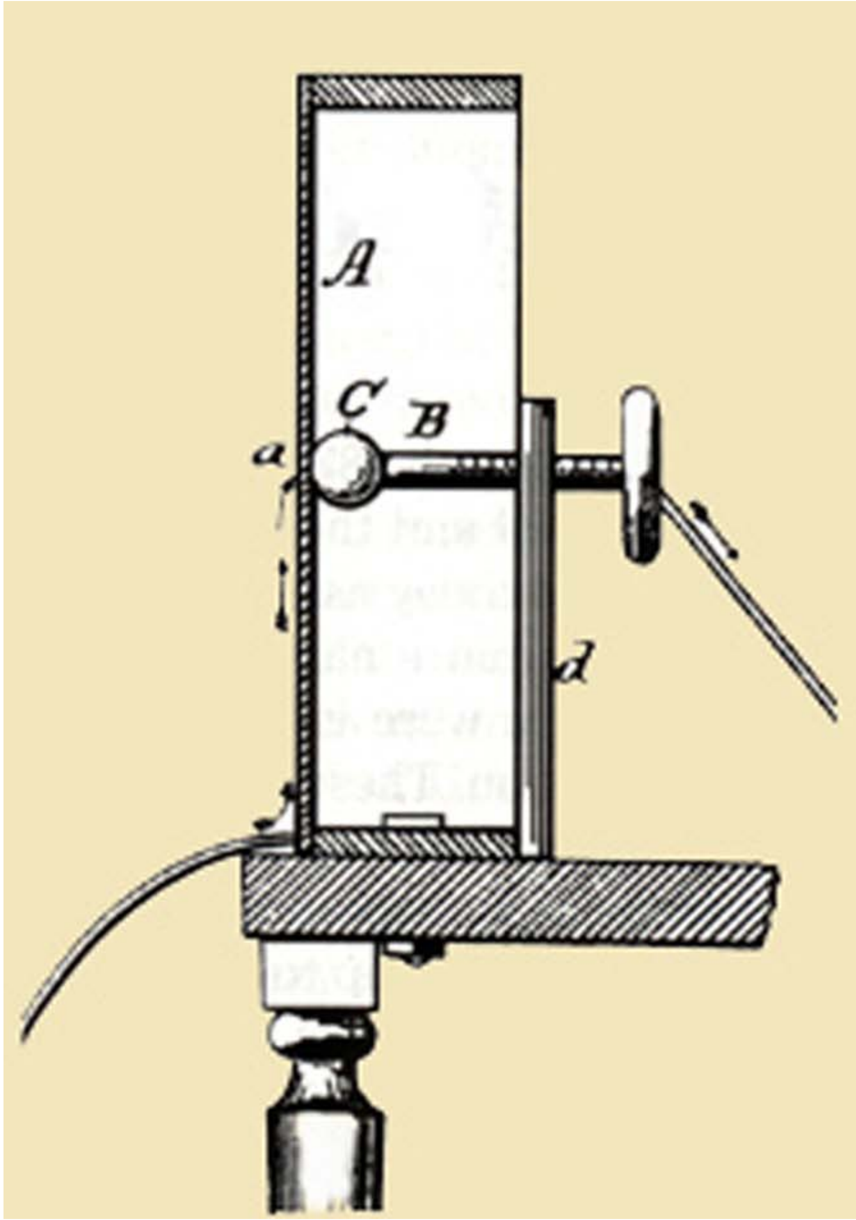
FIGURE 1-1

The beginnings of telephony; Bell's original patent.

- Elisha Gray: patents similar device



- Berliner, 1877 (March): a steel ball against a stretched diaphragm



Berliner's variable contact microphone (1877)

- Francis Blake, 1881: platinum bead against a carbon disc: 50 dB dynamic range, 380 to 2,000 Hertz frequency response
- Carbon microphone from the 1920s; varying pressure on carbon granules results in variable resistance (Rogers 2009)

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4.17. Broadcasting and the Need for Better Microphones

- 19th century technology was fine for telephones
- With the rise of radio in the 1920s there created a need for better microphones
- Two basic methods were perfected: electrostatic (capacitor or condenser) and electromagnetic (dynamic or moving conductor and ribbon)
- 1930s: Western Electric Condenser Microphone - 660 (Rogers 2009)

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- Turner Variable Impedance Dynamic Microphone - U9S (Rogers 2009)

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- Shure Brothers, Inc. "Voice Unidyne" Dynamic Microphone Model 55CV (Rogers 2009)

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- 1931: RCA 44-BX - Velocity Ribbon Microphone (Rogers 2009)

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4.18. Modern Microphones

- Two common types: condenser (electrostatic) and dynamic (electromagnetic)
- Ribbon microphones are a type of electromagnetic
- Piezo-electric microphones: piezo crystals
- Anything that can transduce a vibration: lasers, etc.

4.19. Modern Microphones: Condenser

- Two metal plates with electrostatic capacitance between them; air pressure causes changes in capacitance; produces a change in voltage
- Early capacitor microphones in 1917 (Wente)

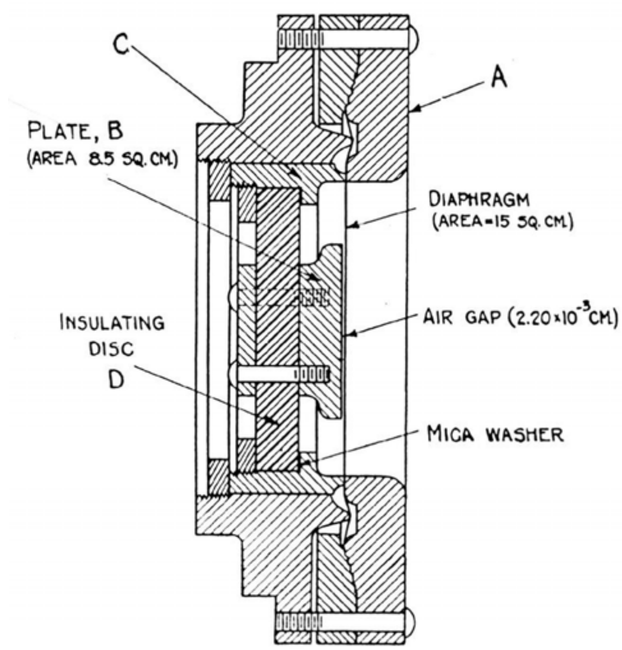


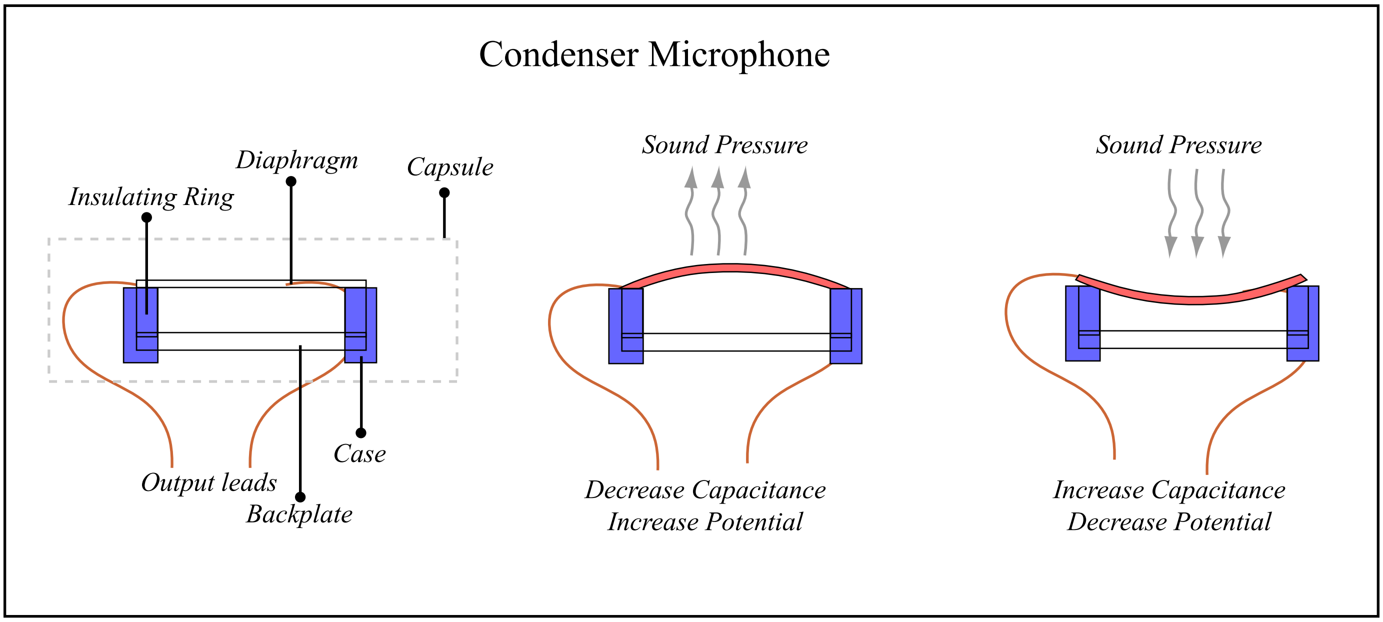
Fig. 2.

Sectional drawing of transmitter.

Wente condenser microphone, from *Physical Review* (1917)

- Used in broadcasting since 1940s
- Requires power for amplification inside of the microphone
- Very small movement of diaphragm displacement: very accurate response


AT4050



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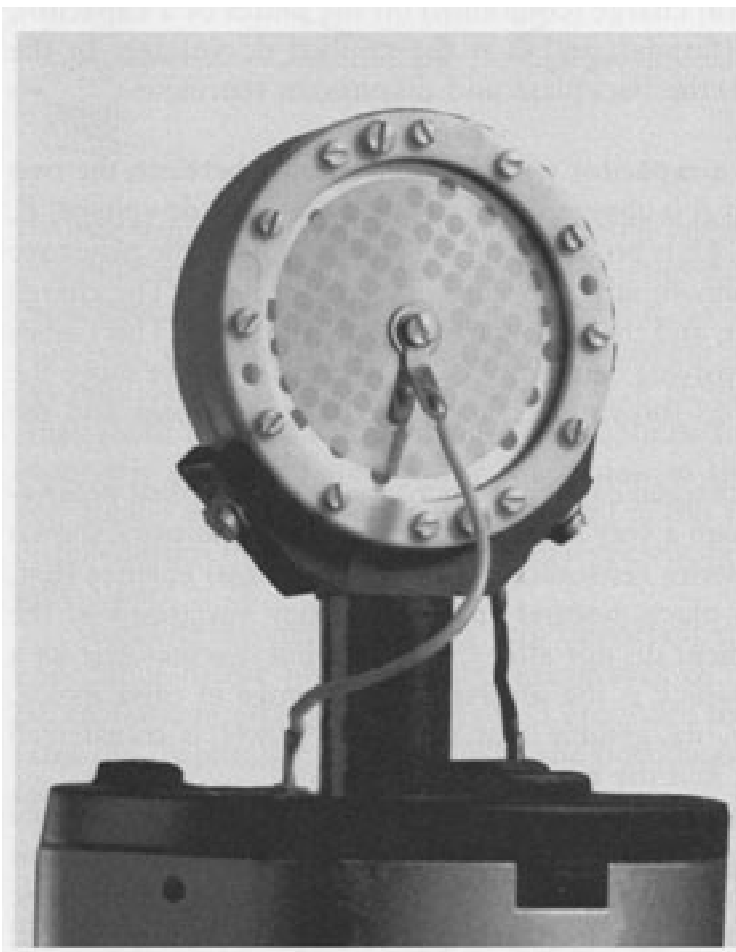
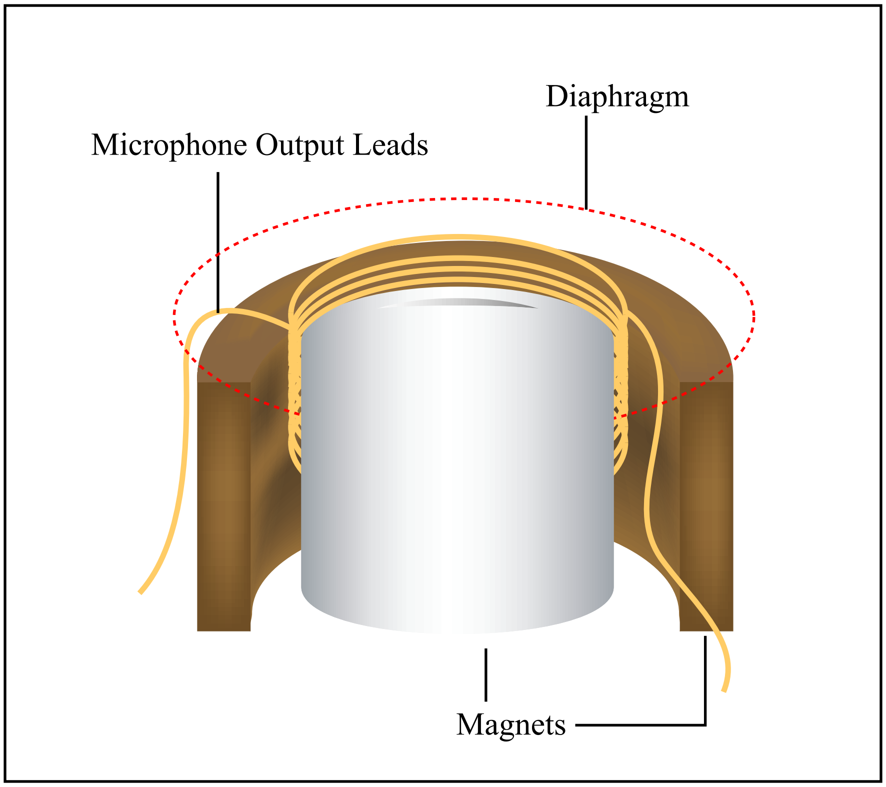


Neumann center-clamped condenser microphone capsule.

4.20. Modern Microphones: Dynamic

- Air pressure moves a diaphragm that is connected to a coil wire within a magnetic field; produces a change in voltage
- Early dynamic microphones in 1920s: RCA, Shure Brothers, and Electro-Voice

- No power required in the microphone; heavy magnets
- Larger movement of diaphragm displacement: less accurate response



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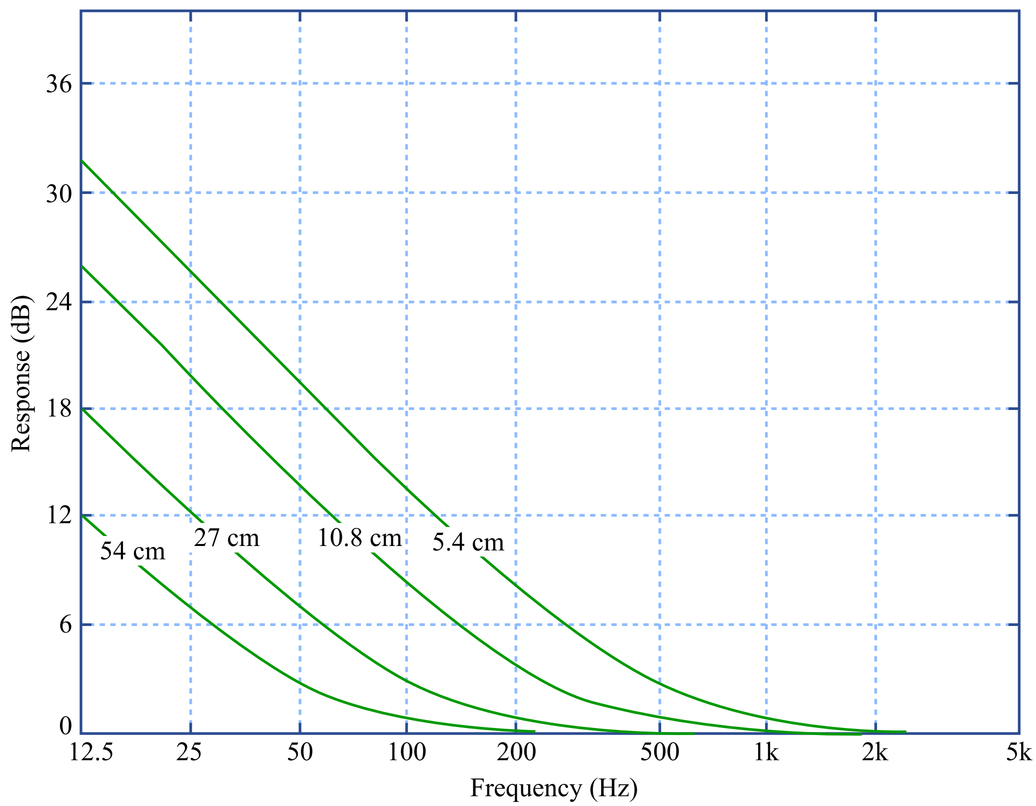
SHURE

4.21. The Proximity Effect and Crooning

- Within six inches of a directional microphone, a low frequency emphasis results



Graph of the proximity effect vs. distance for a cardioid microphone, on axis.

Figure by MIT OpenCourseWare.

4.22. The Proximity Effect and Crooning

- Crooning: a style from 1920s to 1950s
- Sliding up to and around notes; singing very softly with a low frequency emphasis
- An artificial sound of intimacy
- Associated with Rudy Vallee, Bing Crosby, Perry Como, Frank Sinatra
- Sinatra says he and Bing were singers, not crooners; Russ Colombo and Rudy Vallee were crooners

  Sinatra as "the first to master microphone technique" (Horning 2004)

  Audio: Frank Sinatra: from a documentary with Walter Cronkite

- Audio: Rudy Vallee, "Brother can you spare a dime?" (The Great Depression - American Music in the 30s)

4.23. Piezoelectric (Contact) Microphones

- Piezoelectricity: ability of materials to generate electricity when stressed
- Crystalline structures that develop voltages on opposite faces when bent

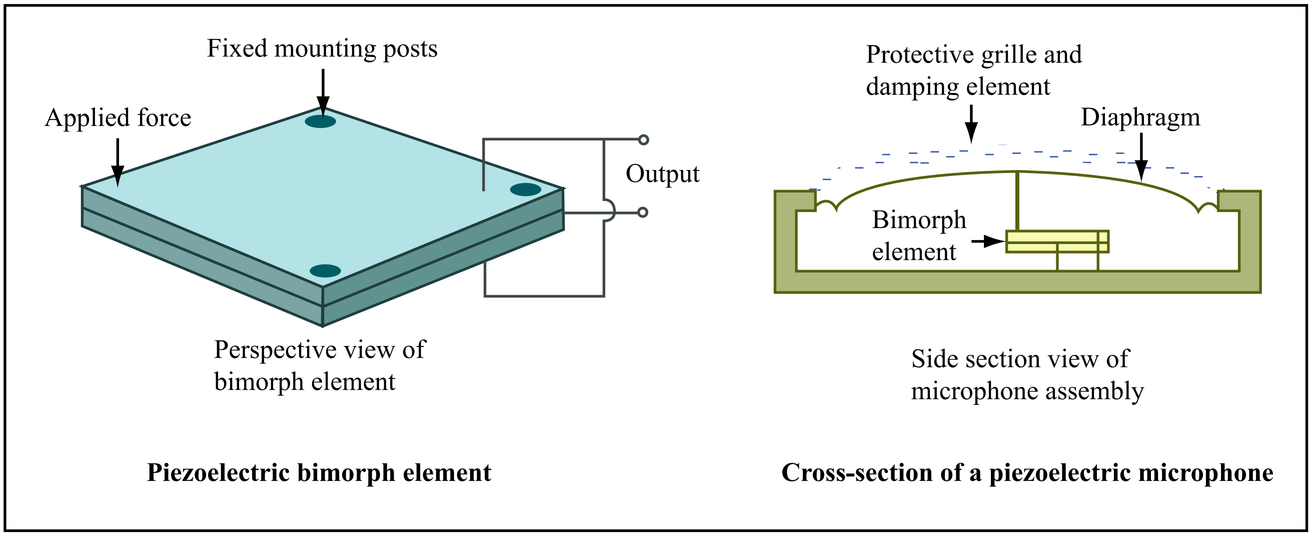


Figure by MIT OpenCourseWare.

- Does not require power to operate
- Can be used for direct sound transduction
- A piezo element that acts as a direct transducer of vibrations

Courtesy of Erinys. Used with permission.

- 1933: D-104 Astatic Microphone Laborartory (Rogers 2009)

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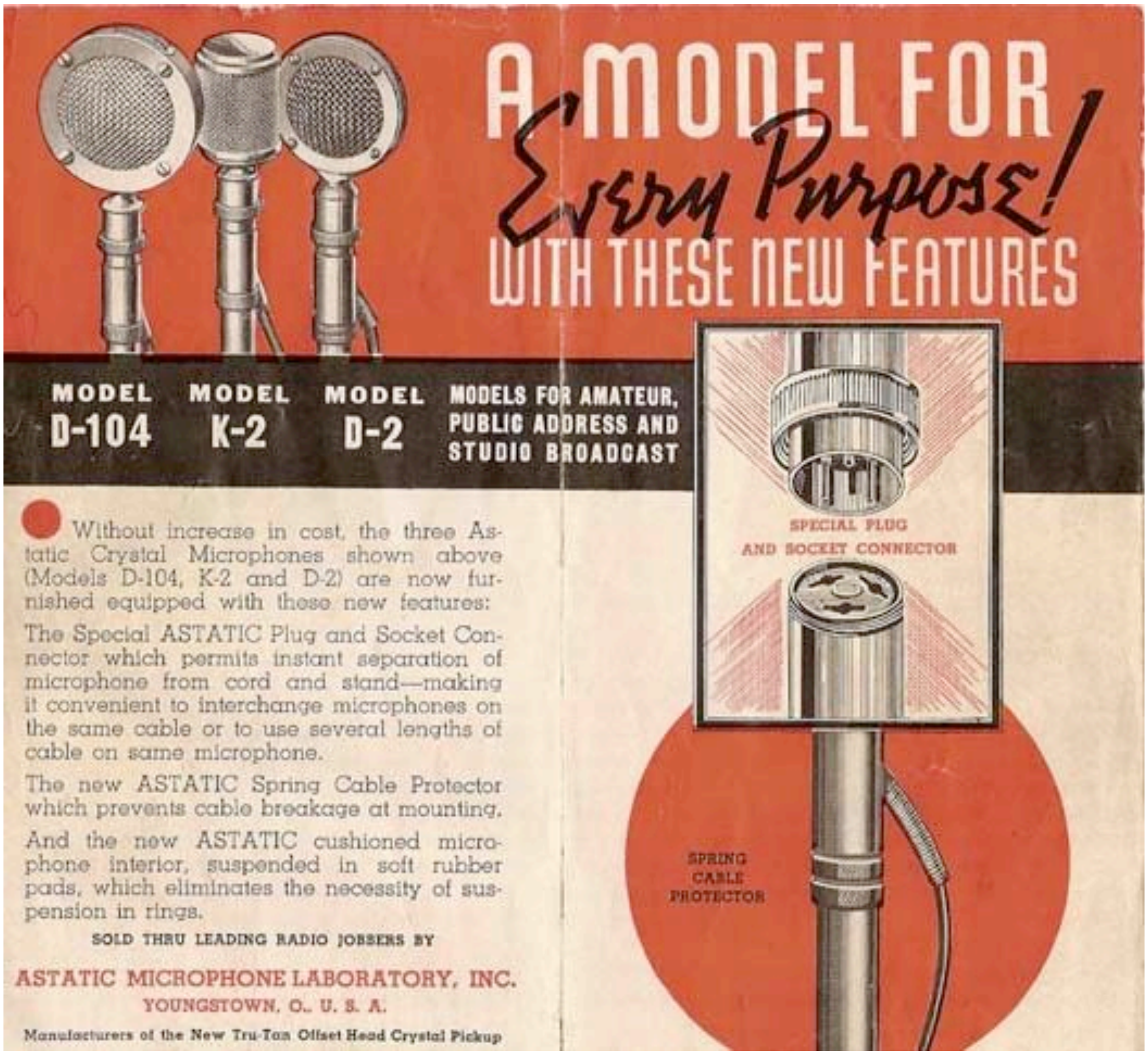

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4.24. Piezoelectric (Contact) Microphones

- Can be attached to any vibrating surface

- Audio: the Sound of the Ants, Adriano Zanni
- Recording wind resonance through a post

  YouTube (http://youtube.com/watch?v=gbxSrvhdDFc)
- Audio: Contact microphone on a grand piano (by Christopher Ariza)

4.25. Reading: Collins

- Collins, N. 2009. *Handmade Electronic Music: The Art of Hardware Hacking*. 2nd ed. New York: Routledge.
- Coils and electromagnetism, and motor as oscillator: we will explore this later
- The Victorian oscillator: next class

Chapter 5. Meeting 5, Discussion and Workshop

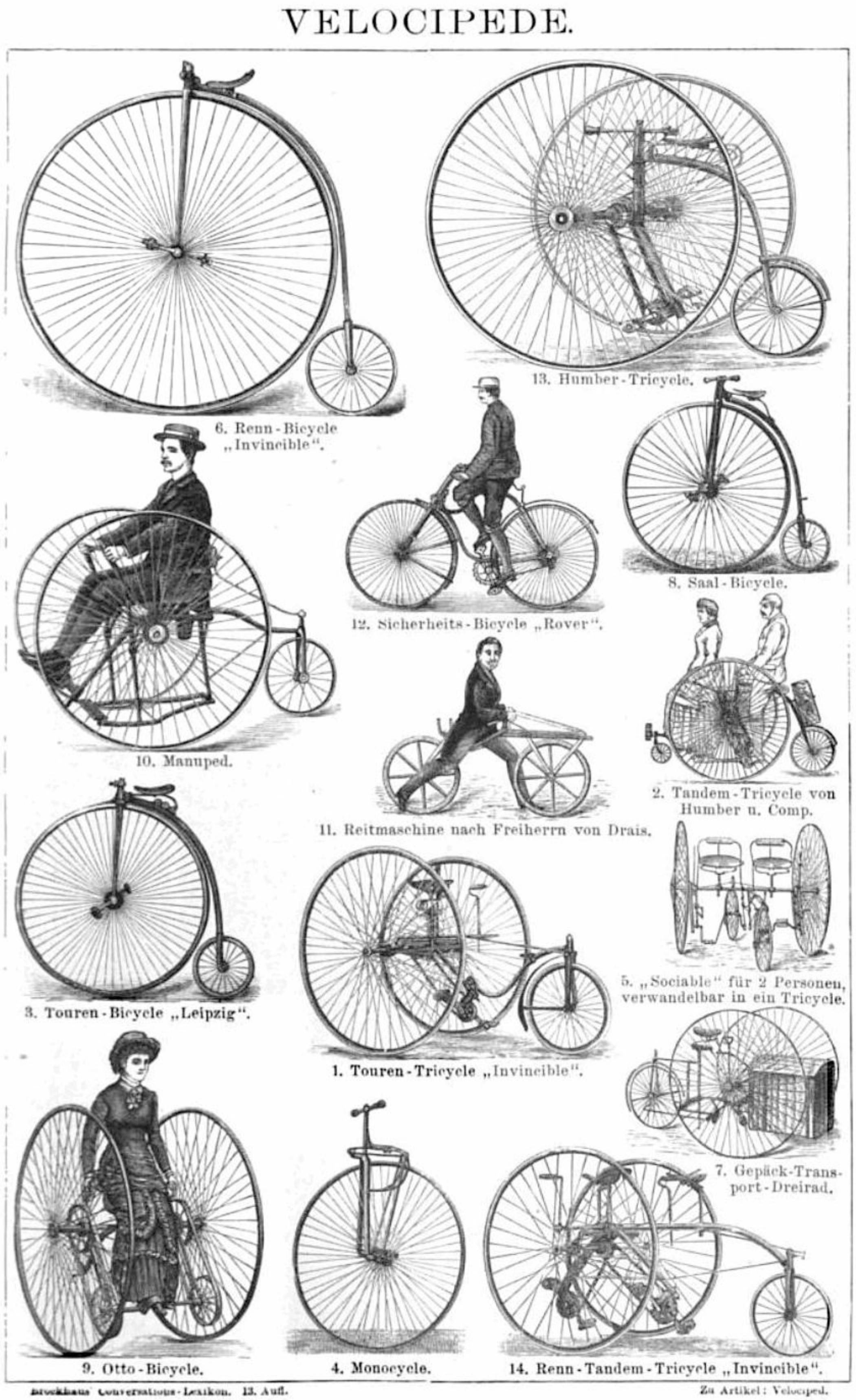
5.1. Announcements

- We will review quizzes on Tuesday

5.2. Reading: Pinch and Bijker

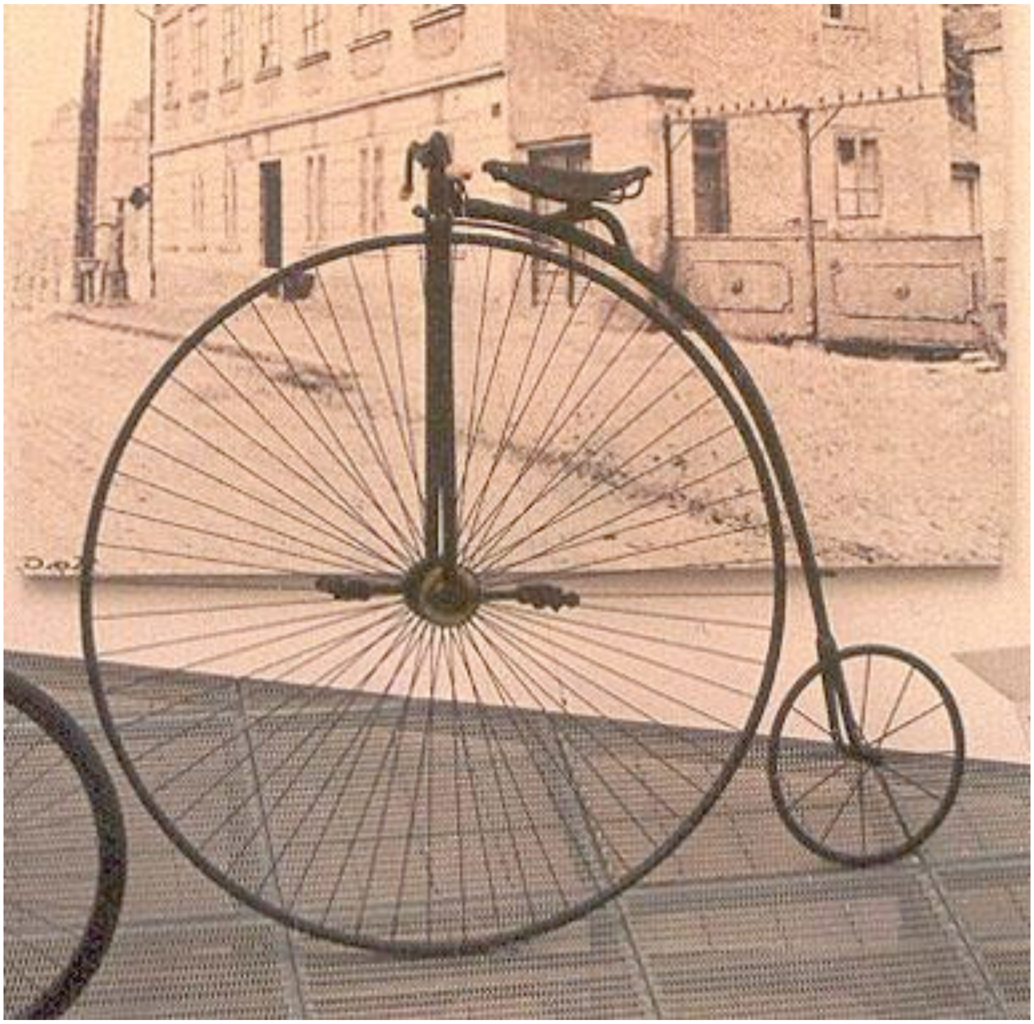
- Pinch, T. J. and W. E. Bijker. 1984. "The Social Construction of Facts and Artefacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other." *Social Studies of Science* 14(3): 399-441.

- Velocipedes, Boneshaker



Source: Wikimedia Commons. From Brockhaus, F. A., ed. *Brockhaus' Conversations-Lexikon*. Vol. 16, 13th ed. Leipzig, Germany, 1887. pp. 142. Public domain.

- Penny-Farthing, or Ordinary

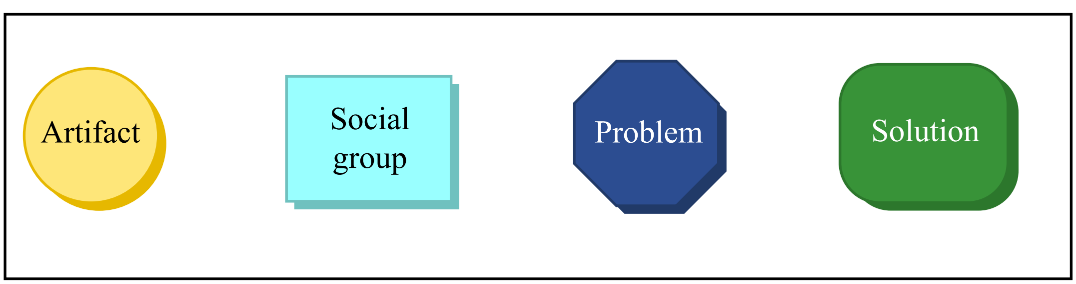


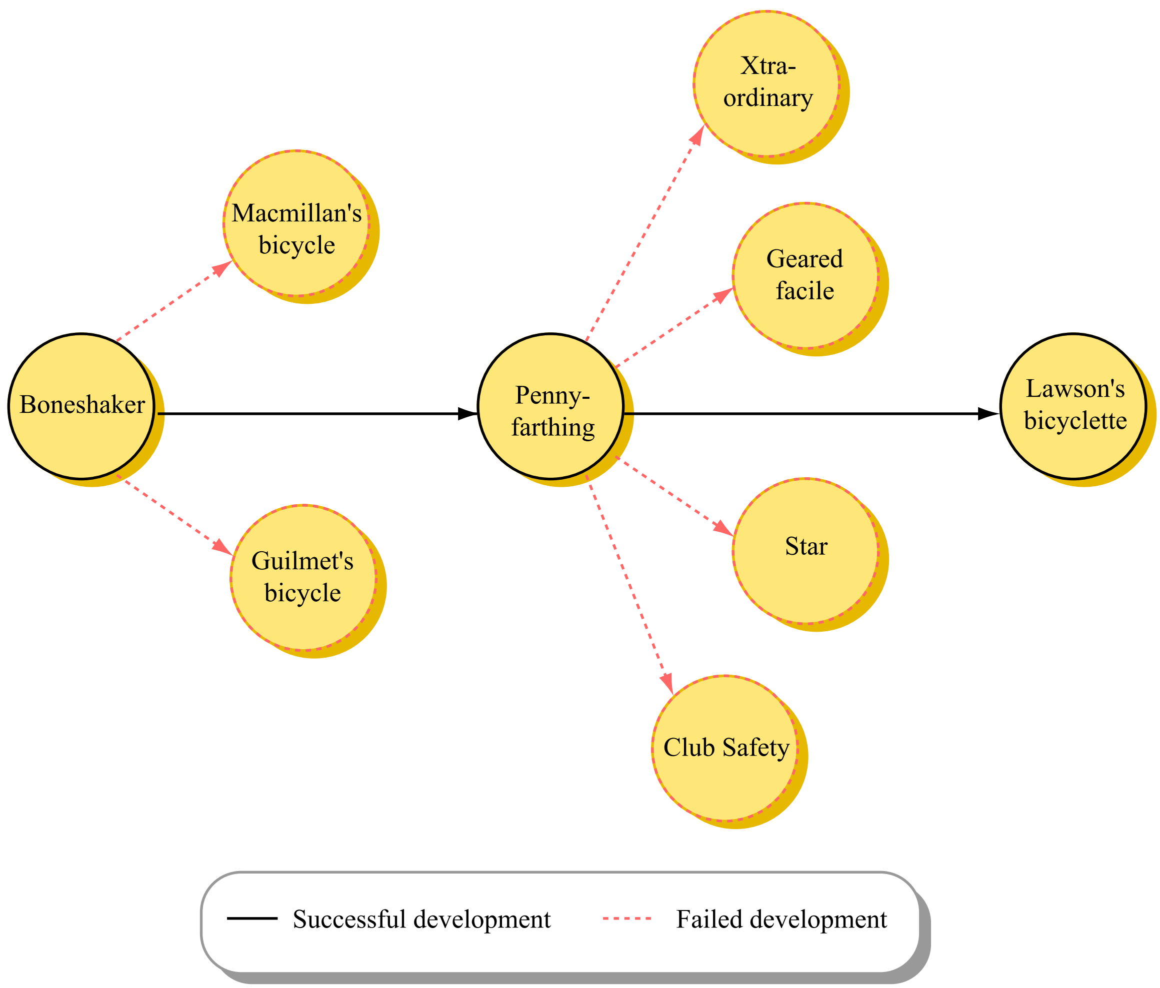
Source: Wikipedia

- Bicyclette, or Safety

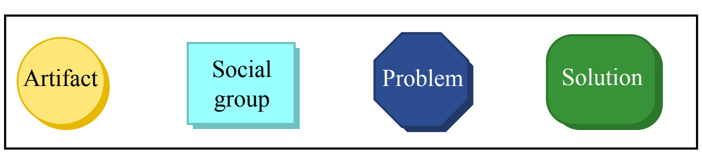
Source: Wikimedia Commons.
Wolverhampton, UK, 1887. Public domain.

- Diagrams:





The traditional Quasi-linear view of the developmental process of the Penny-Farthing Bicycle



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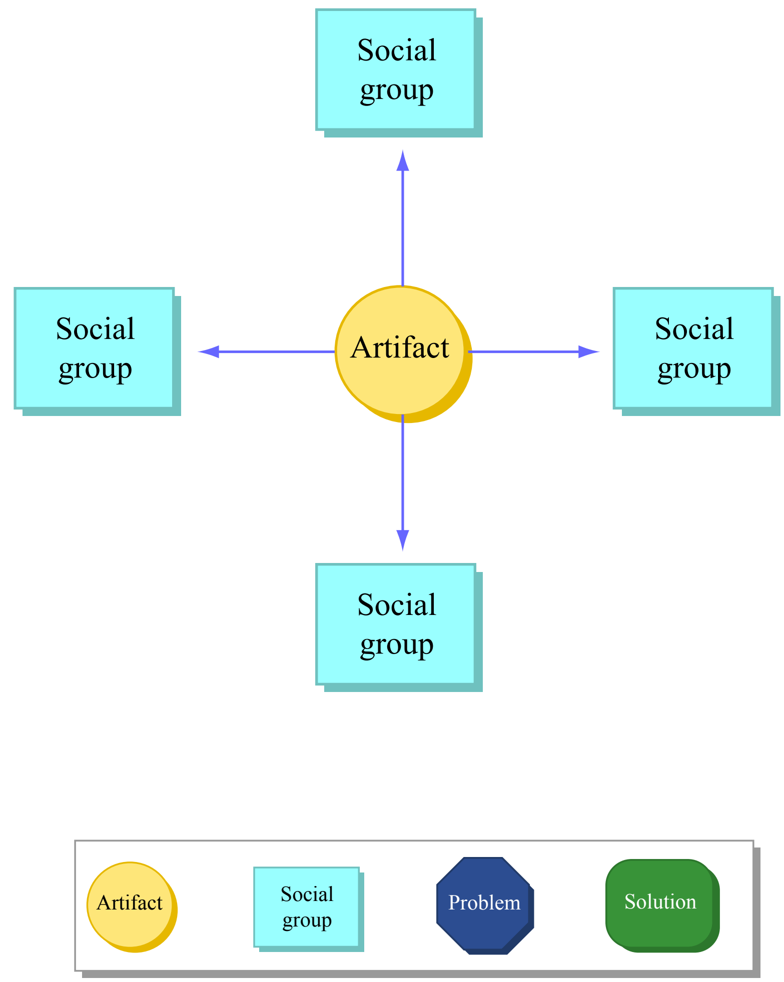
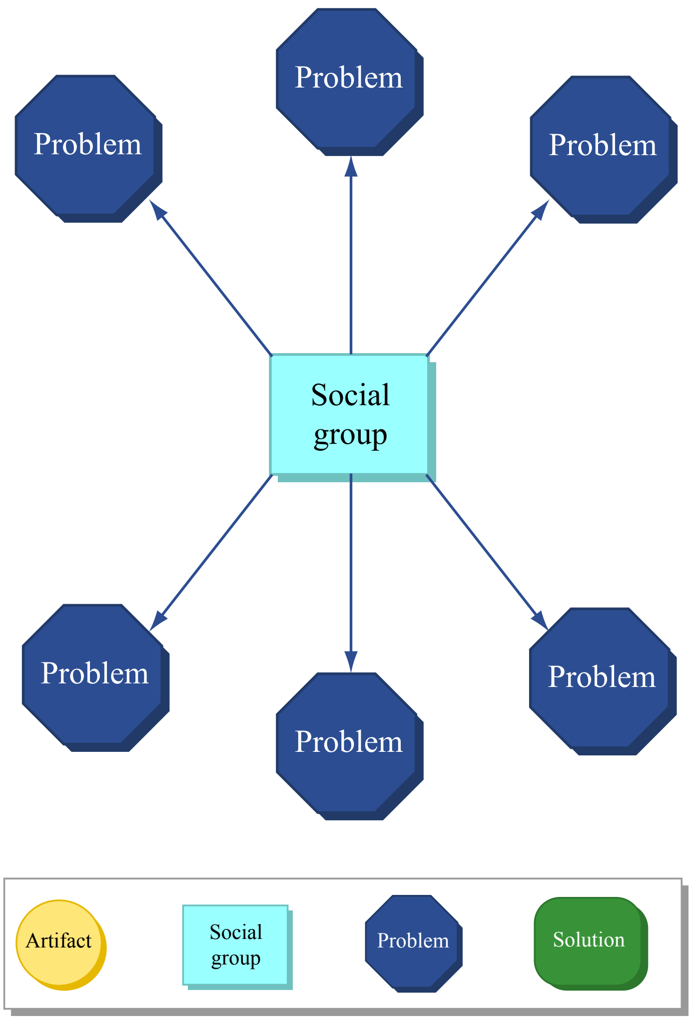
- Diagrams:



The relationship between an artifact and the relevant social groups

Image by MIT OpenCourseWare. After Pinch and Bijker, 1984.



Relationship between a social group and its perceived problems.

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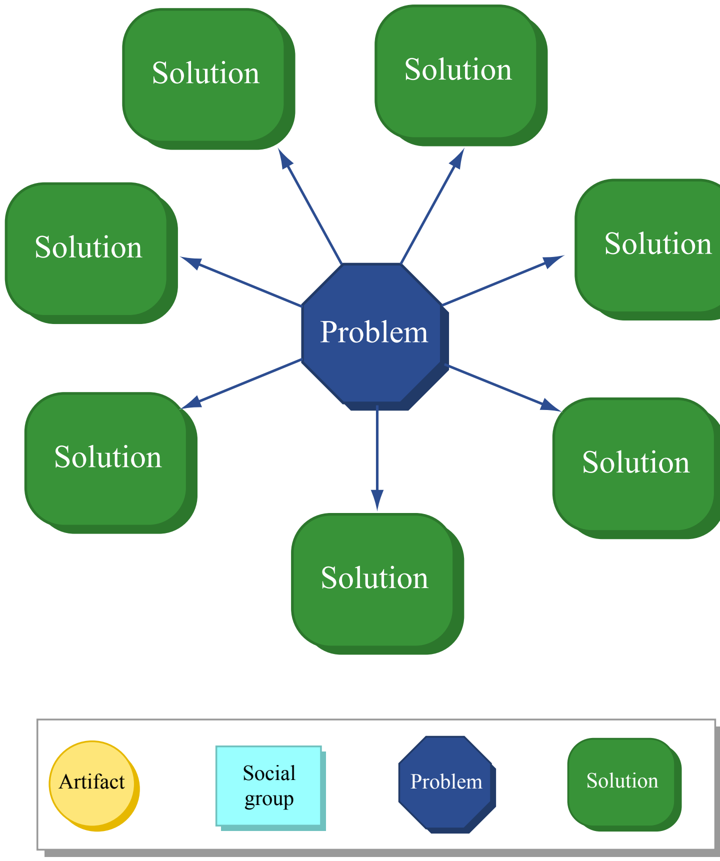
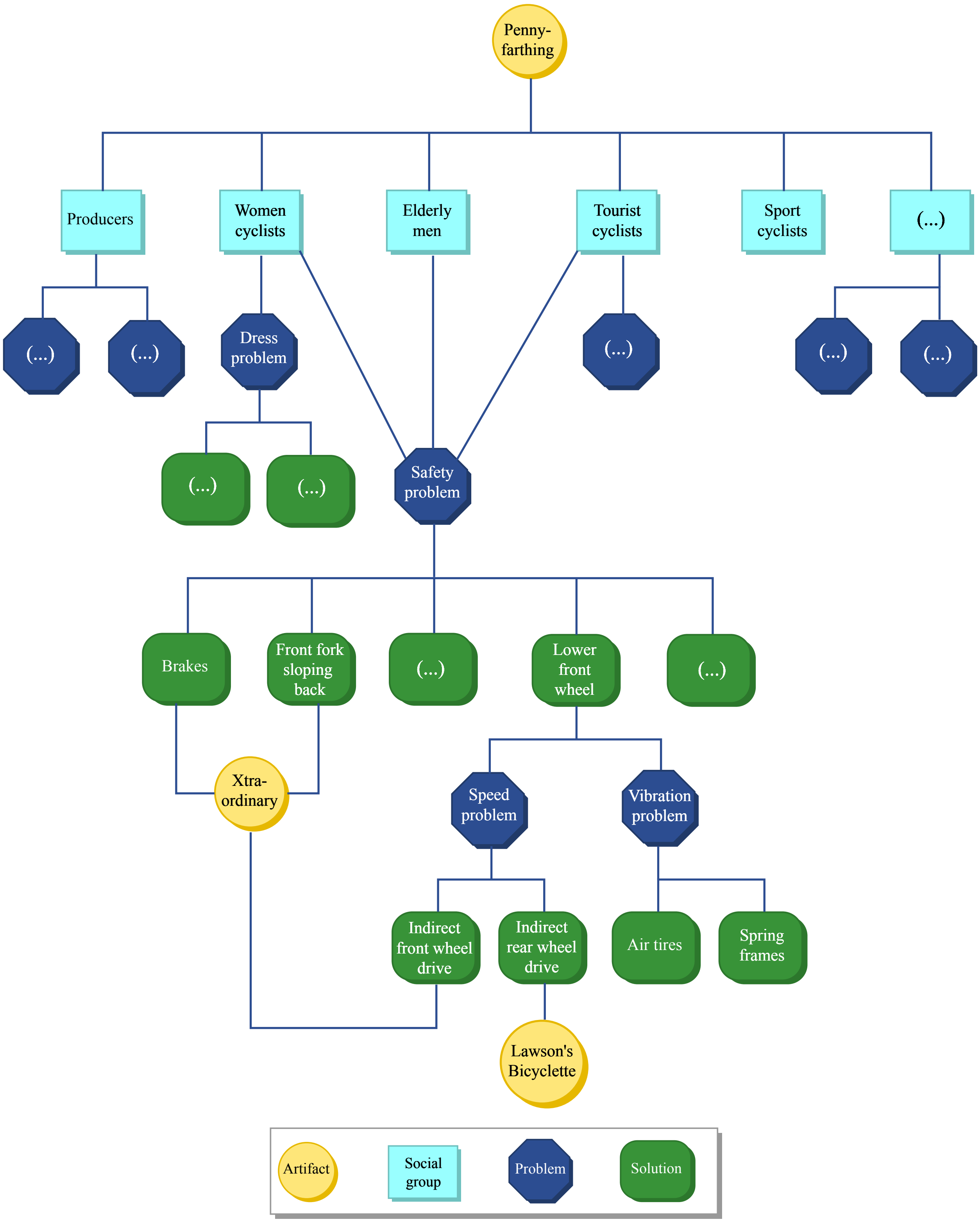


Relationship between a problem and its possible solutions

Image by MIT OpenCourseWare. After Pinch and Bijker, 1984.



Some social groups, problems and solutions in the developmental process of the penny-farthing bicycle.

Image by MIT OpenCourseWare. After Pinch and Bijker, 1984.

5.3. Reading: Pinch and Bijker

- Pinch, T. J. and W. E. Bijker. 1984. "The Social Construction of Facts and Artefacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other." *Social Studies of Science* 14(3): 399-441.

- On the necessity of sociological explanation:

Text quotes from the paper removed due to copyright restrictions.

- On symmetrical explanation:

Text quotes from the paper removed due to copyright restrictions.

- On the multi-directional model

Text quotes from the paper removed due to copyright restrictions.

- On relevant social groups:

Text quotes from the paper removed due to copyright restrictions.

- On closure:

Text quotes from the paper removed due to copyright restrictions.

5.4. Reading: Fouché

- Fouché, R. 2006. "Say It Loud, I'm Black and I'm Proud: African Americans, American Artifactual Culture, and Black Vernacular Technological Creativity." *American Quarterly* 58(3): 639-661.

- Fouché criticizes SCOT in its reliance on “relevant social groups” and the idea of “closure”: how are these concepts relevant to the African Americans he writes about?
- Fouché states that, even with a more fluid definition of social groups, “SCOT still is limited by overlooking structural factors such as institutional racism, regional discrimination, economic disparity, and a host of other factors that have led many forms of African American technological creativity to be categorized as inferior” (646); do you agree?
- How can technologies be redeployed, reconceived, and recreated?
- Fouché states that, “by acknowledging the tensions between discordant discourses and accepting nondominant communities as legitimate locations from which to explore the nature of technology within American culture, we can embrace the complexity and contradiction in technology and societies” (650): in addition to African American, what other non-dominant communities might be addressed with this approach?

5.5. The PD Window

- Reports system status
- Console can be used to see printed output with [print]
- Used to turn audio process on and or off: “compute audio”
- No sound or signals will happen without “compute audio”

5.6. The Patcher Window

- A window represents a patch
- Windows can communicate between each other
- A patch can be embedded in another patch
- A patch can be stored as a file and loaded into another patch (abstraction)

5.7. The Patcher Window: Edit and Run Modes

- Patch windows have two modes: edit and run
- Changing modes: Menu: Edit > Edit mode (command E)
- Edit mode: configure objects, create patches, move things around, selected objects are blue
- Run mode: objects do not move, user interface components (knobs, sliders) function

- Example: Put a Vslider; when blue, in edit mode, cannot use slider; in run mode, black, can use slider

5.8. Objects

- An object has a class: a paradigm, an archetype
- We can make many instances of the same object, each with its own behavior and settings
- Example: [random 20], [random 4]

5.9. Objects: Creation

- Use the Put menu: Menu: Put > Object (command 1)
- An empty dotted-line box emerges: this is not an object
- An object has to have at least one creation argument to specify its type
- Example: [+], [random], [line], [select], [print], [osc~]

5.10. Objects: Types

- There are event objects and signal objects
- Event objects process data: [line], [select]
- Signal (tilde) objects process signals: [line~], [osc~]
- There may be two versions of a type of object, one for events, one for signals: [+], [+~]

5.11. Object Inlets

- Inlets provide data or signals into objects
- White inlets are for data, dark inlets are for signals
- Example: [+], [+~]
- For some event objets, leftmost inlet is hot: output is provided only when values are provided in this inlet
- Example: [+], [pack]

5.12. Object Outlets

- White outlets are for data, dark inlets are for signals
- Example: [+], [+~]
- Outlets usually provide output from right to left
- Example: [unpack f f f]

5.13. Object Interconnections

- Connections between objects can transmit signals or data
- Signal and data connections are different, and cannot be interconnected
- To create a connection: in Edit mode, mouse over outlet until cursor is a circle; click and hold; mouse over desired inlet until cursor is a circle; release click.
- Example: [* 4] to [+ 3], [*~ 4] to [+~ 3]

5.14. Data

- Data can be bangs, numbers, symbols, lists, or signals
- Bangs (b): a trigger, an event, a "do something now"
- Numbers (f): numbers can be integers or floating point values
- Symbols (s): character strings
- Lists (l): a space separated collection of numbers or symbols
- Signals (v): floating-point number stream at the sampling rate (when "computer audio" is on)

5.15. Data Storage

- Data can be seen (in objects, interfaces, etc) and unseen (in objects, through patch connections)
- Only data that is "seen" is saved with patch

5.16. Data Storage: Message Boxes

- Use the Put menu: Menu: Put > Message (command 2)

- One inlet, one outlet; note curved left side
- Store bangs, numbers, symbols, or lists
- Saved with patches
- Provide a user interface: can be clicked in Run mode to provide output
- Example: (bang) to [random 10] to [print]
- Example: (3) and (10) to [+] to [print]

5.17. Data Storage: Objects

- Objects can have additional construction arguments
- These arguments configure how the object performs
- These arguments can sometimes be overridden by inlet values
- Example: [* 3]

5.18. Interface Objects: Number Boxes

- Can be used to provide number inputs to other objects
- Can be used to receive the numbers outputted from objects
- Can be varied only in Run mode
- Holding down shift permits enter floating point values

5.19. Interface Objects: Bang

- Can click to send a bang
- When receiving a bang, darkens
- Sending a bang can be replaced by a message box with “bang” specified

5.20. Selecting, Moving, and Copying Objects

- Objects can only be moved in edit mode
- Can click and drag to create a selection area

- Objects (and interconnections) can be duplicated and copied
- Always duplicate

5.21. Object Help, Documentation, and Tutorials

- Control click on an object and select "help" to view a help patch
- Demo patches provide examples and explanation
- The PD Glossary http://www.flexatone.net/docs/pdg/
- Kreidler, J. 2009. "Programming Electronic Music in Pd." Wolke Publishing House. Internet: http://www.pd-tutorial.com.

5.22. Object Properties

- Control click on a bang interface object and select "properties" to specify visual appearance
- Colors and other attributes can be configured

5.23. Comments

- Comments are notes left to readers of the program
- Comments cannot be used as data in a patch
- Use the Put menu: Menu: Put > Comment (command 5)

5.24. Saving Patches and PD files

- Always save files with a .pd extension at the end
- PD files are text files that specify the interconnections between objects

5.25. Abstractions and Martingale

- Abstractions are PD patches that can be used in other PD patches
- Abstractions may have any number of inlets or outlets
- To load an abstraction, it must be placed in a directory that PD knows about
- Download Martingale manually: http://code.google.com/p/martingale/

- Get Martingale via SVN command-line argument: svn checkout http://martingale.googlecode.com/svn/trunk/ martingale-read-only
- Add the "martingale/pd/lib" directory to Preferences > Path; this permits loading abstractions from the martingale library

5.26. Managing Files

- PD patch files can be stored anywhere
- Any number of additional paths can be added to the Path list to load user-created abstractions

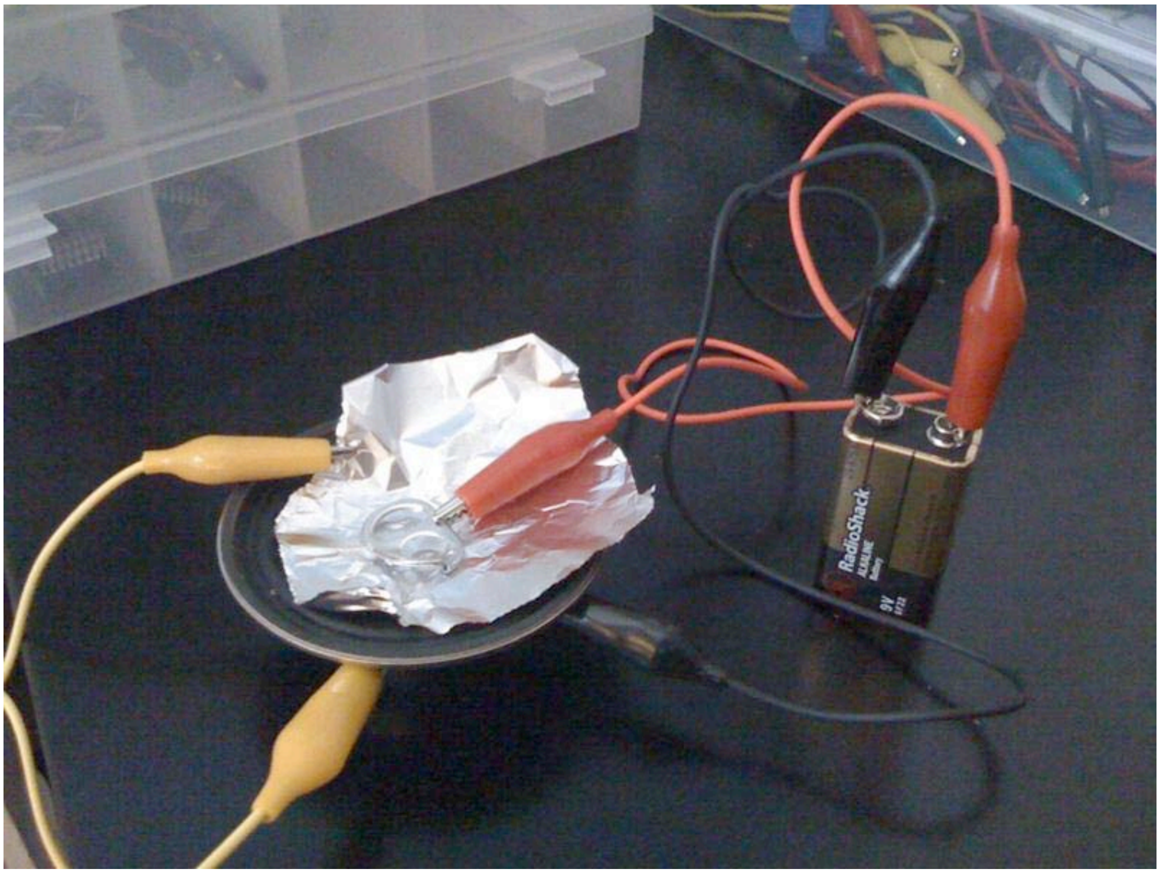
5.27. Hardware Hacking: Speaker as Dynamic Microphone and Feedback Generator

- Simply connect speaker to amp


HONEYTONE

5.28. Hardware Hacking: The Jumping Speaker and Victorian Oscillator

- Mechanical/electrical feedback loop (Collins 2009, pp. 23-25)



5.29. Hardware Hacking: Tape Heads

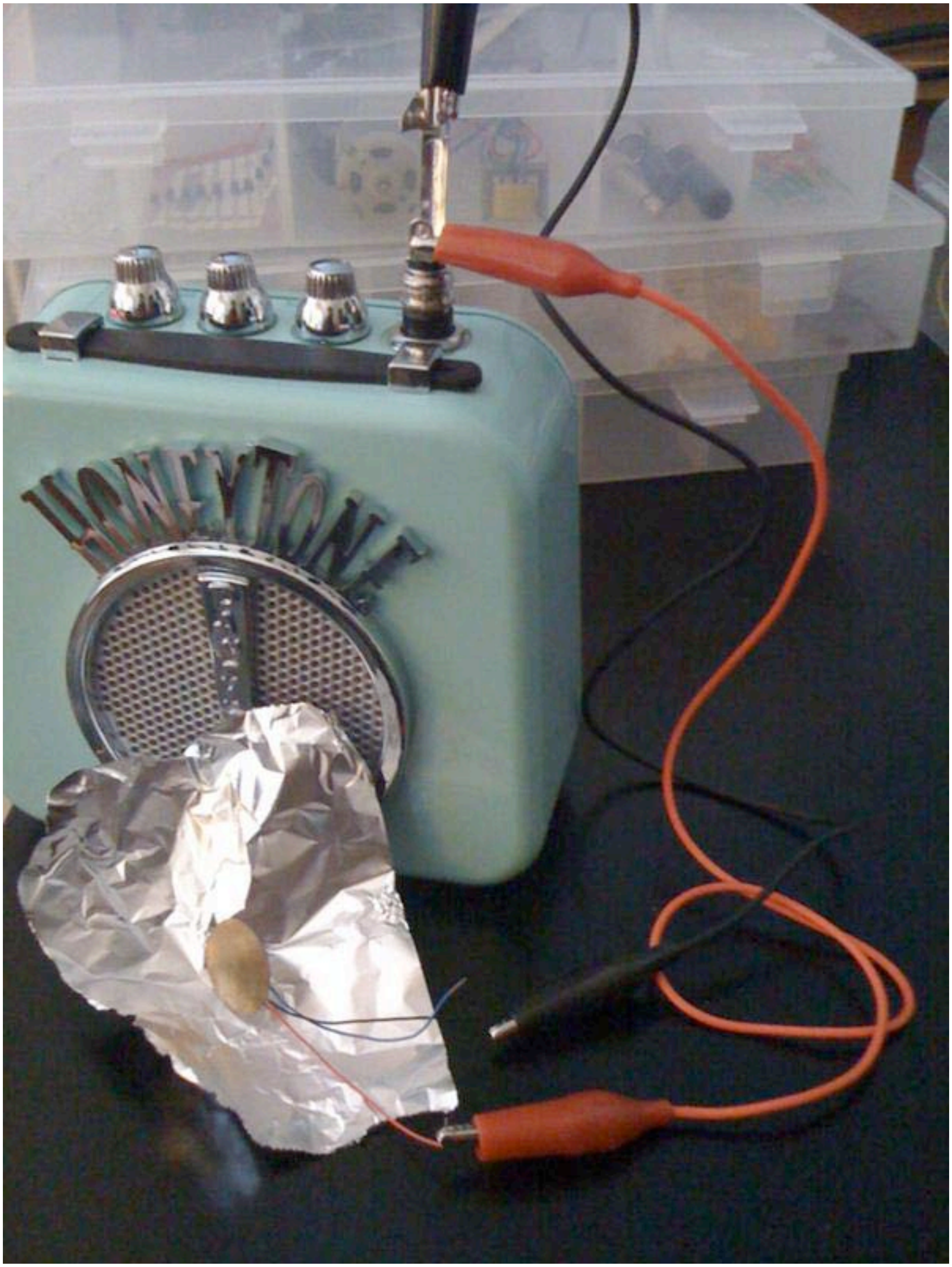
- Reading data from cards, tapes (Collins 2009, pp. 59-60)


COBY
AUTO STOP
MECHANISM
CX-49 AM/FM RADIO CASSETTE PLAYER


HONEYTONE
PROFESSIONAL
SM-X90

5.30. Hardware Hacking: Piezo Microphones

- Feedback through aluminum foil (Collins 2009, pp. 32-34)



5.31. Hardware Hacking: Condenser Microphone

- The breadboard

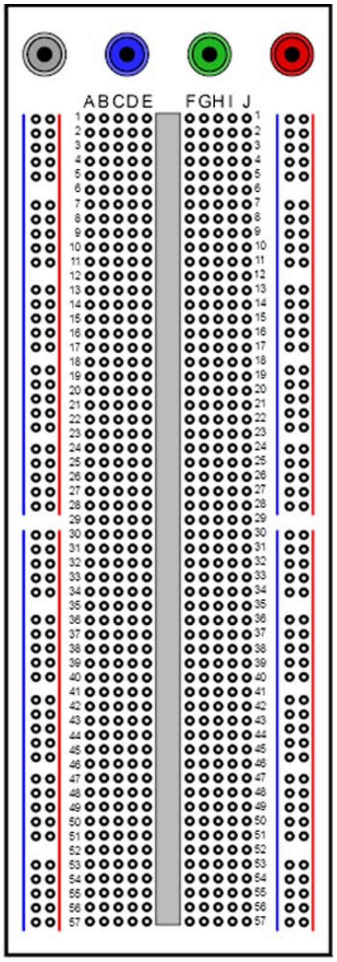
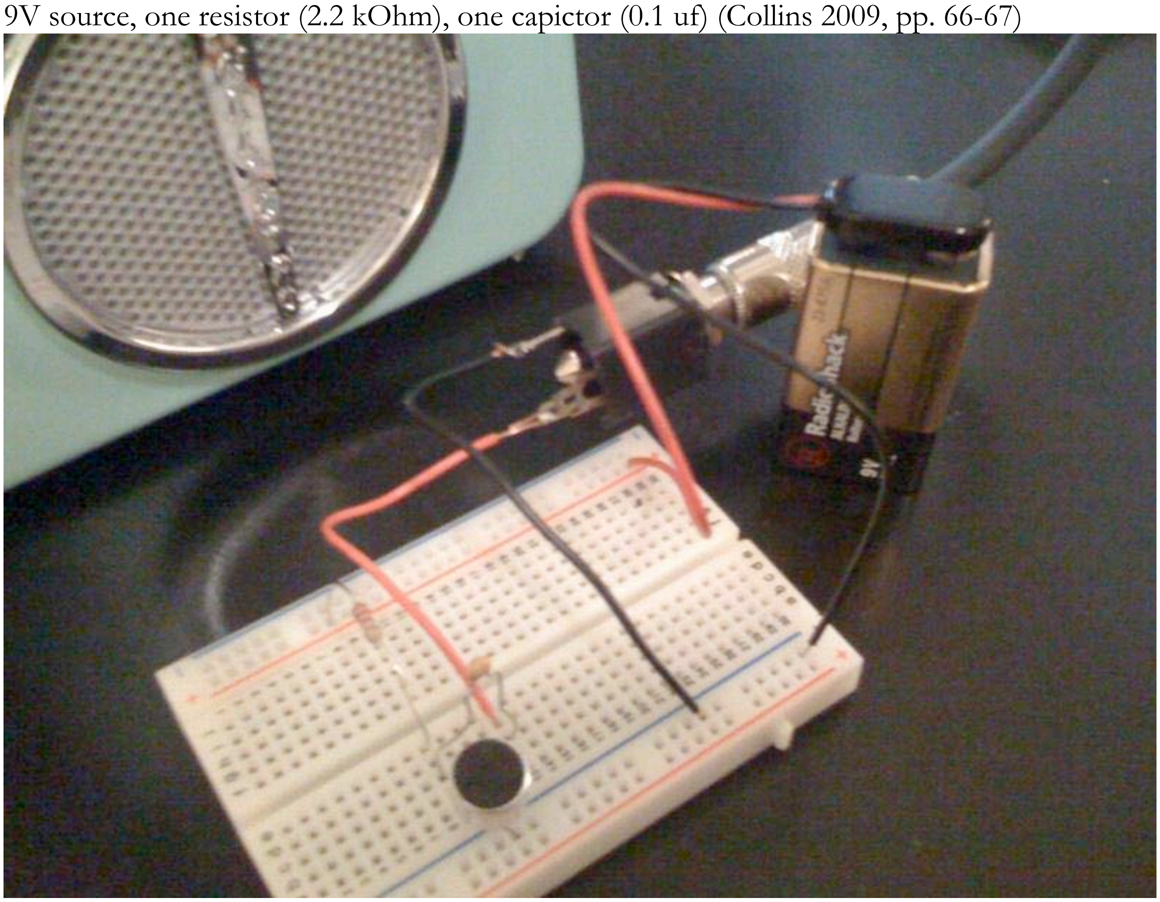


Image: Wikpedia (public domain)

- 9V source, one resistor (2.2 kOhm), one capictor (0.1 uf) (Collins 2009, pp. 66-67)



Chapter 6. Meeting 6, Recording: Digital Audio

6.1. Announcements

- Next quiz will be next week

6.2. Quiz Review

- ?

6.3. Listening: League of Automatic Composers

- Listening: League of Automatic Music Composers, "Oakland One," *League of Automatic Music Composers 1978-1983*

- The League of Automatic Music Composers: founded in the 1970s by Jim Horton and including John Bischoff, Tim Perkins, and Rich Gold (Holmes 2008, p. 276)

- Made use of the KIM-1, created by MOS Technologies in 1975 (Holmes 2008, p. 275)

Source: Wikipedia, by user en:Wtshymanski. Public domain image.

Source: Wikipedia, by user Swtpc6800. Public domain image.

6.4. Basics of Digital Encoding

- Digital is discrete, analog is continuous
- Take discrete time samples of a smooth analog signal
- Each sample measures amplitude at a point in time
  - Time interval (spacing) is constant; often given as a rate in samples per second
  - Amplitude steps are positive or negative values within a fixed range of values
- Encoding (analog to digital conversion) is always lossy
- Decoding (digital to analog conversion) my repair some of the loss
- PCM: Pulse Code Modulation

6.5. Two Parameters of Digital Encoding: Sampling Rate

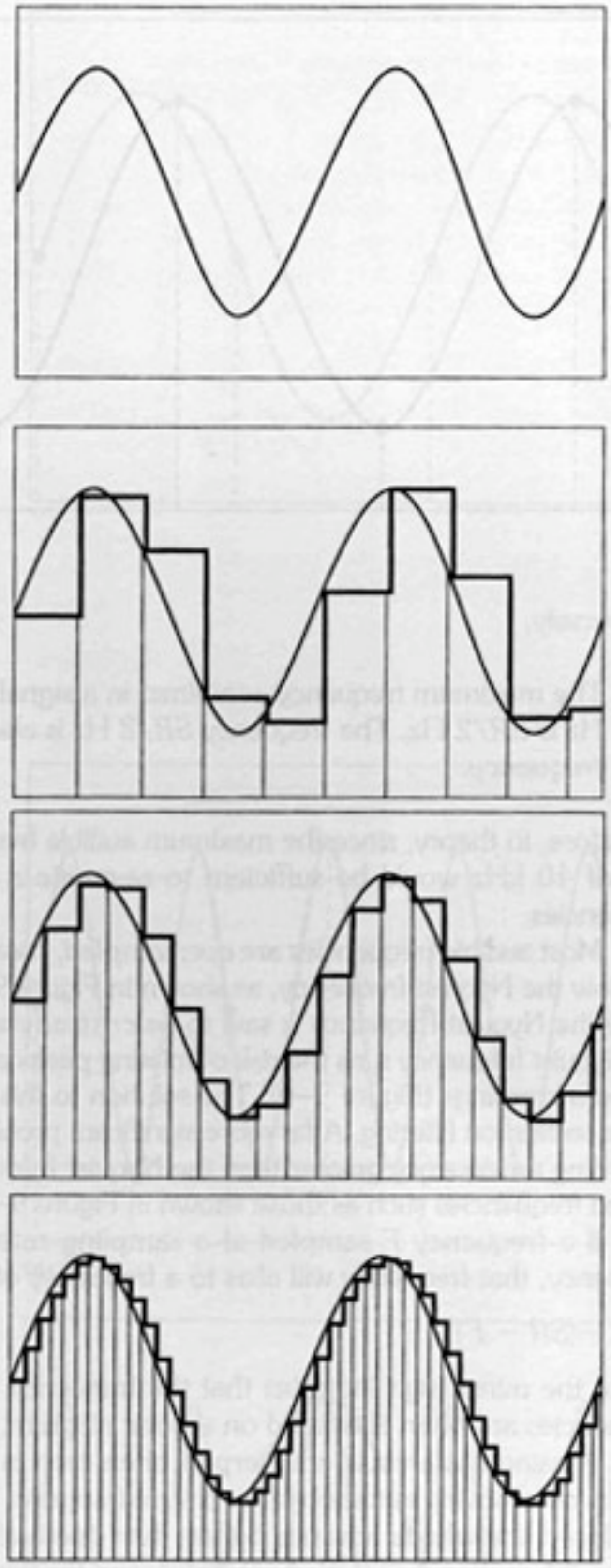
- Sampling rate
- Bit depth

6.6. Two Parameters of Digital Encoding: Sampling Rate

- Sampling rate
  - How quickly amplitudes are measured, or the time resolution

Figure 9–4

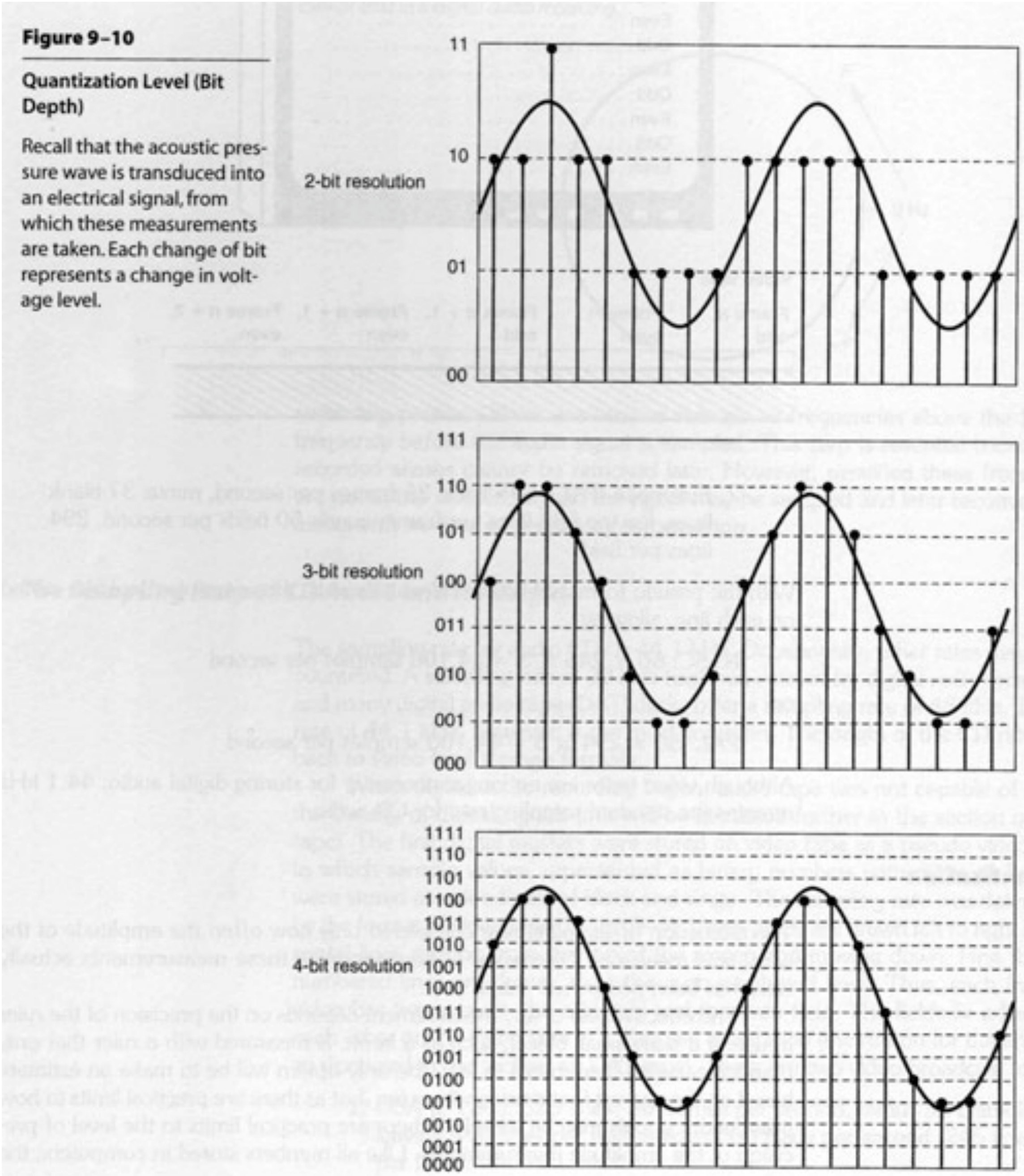
Sampling Rates of a Continuous Wave



- Determines what frequencies can be recorded: higher sampling rates can record higher frequencies
- Doubling the sampling rate doubles the amount of data stored
- Measured in Hertz (samples per second)
- Examples: 44100 Hertz (CD Audio), 48000 Hertz, 88.2k, 96k

6.7. Two Parameters of Digital Encoding: Bit Depth

- Bit depth
  - How accurate are amplitude measurements when sampled

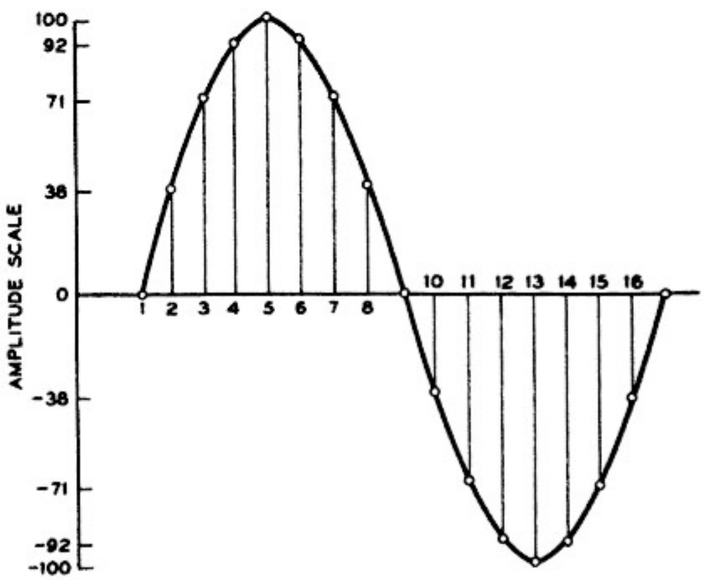


Source: Ballora, Mark. *Essentials of Music Technology*.

- Determines what range of amplitudes can be recorded, or dynamic range: higher bit depths can record more dynamic range
- Doubling the bit depth doubles the amount of data stored
- Measured in bits
- Examples: 16 bit (CD Audio), 24 bit, 32 bit

6.8. Encoding and Decoding

- Encoding: smooth analog wave forms are measured in discrete samples



SAMPLE NUMBER	AMPLITUDE
1	0
2	38
3	71
4	92
5	100
6	92
7	71
8	38
9	0
10	-38
11	-71
12	-92
13	-100
14	-92
15	-71
16	-38
ETC.	

FIGURE 2
SAMPLING A SINE-WAVE

Figure 2 in Tenney, James C. "Sound-Generation by Means of a Digital Computer." *Journal of Music Theory* 7, no. 1, 24-70.

- Decoding: digital information converted to pulses that are filtered into smooth analog wave forms

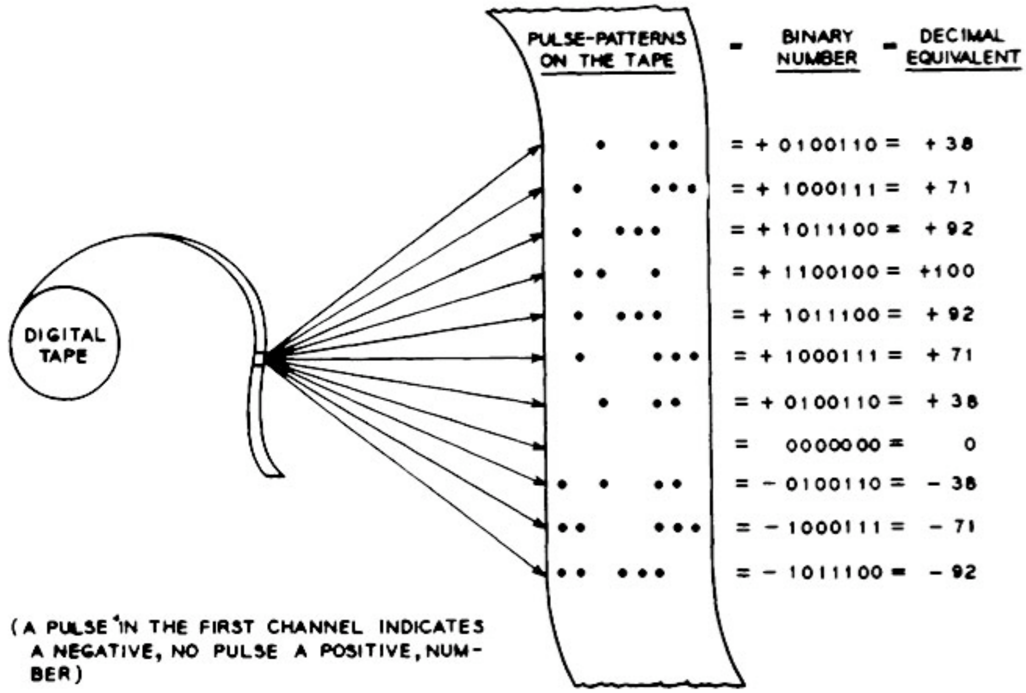


FIGURE 3
REPRESENTATION OF SAMPLE NUMBERS ON DIGITAL TAPE

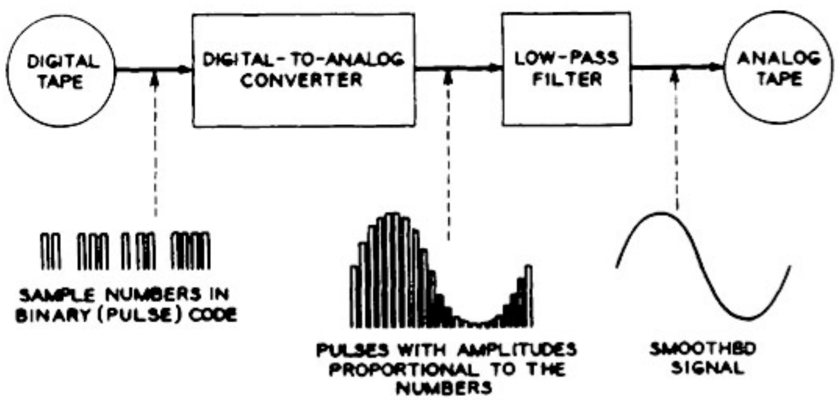


FIGURE 4
CONVERSION FROM DIGITAL TO ANALOG FORM

Figures 3 and 4 in Tenney, James C. "Sound-Generation by Means of a Digital Computer." *Journal of Music Theory* 7, no. 1, 24-70. Copyright 1963, Yale University. Reprinted by permission of the present publisher, Duke University Press.

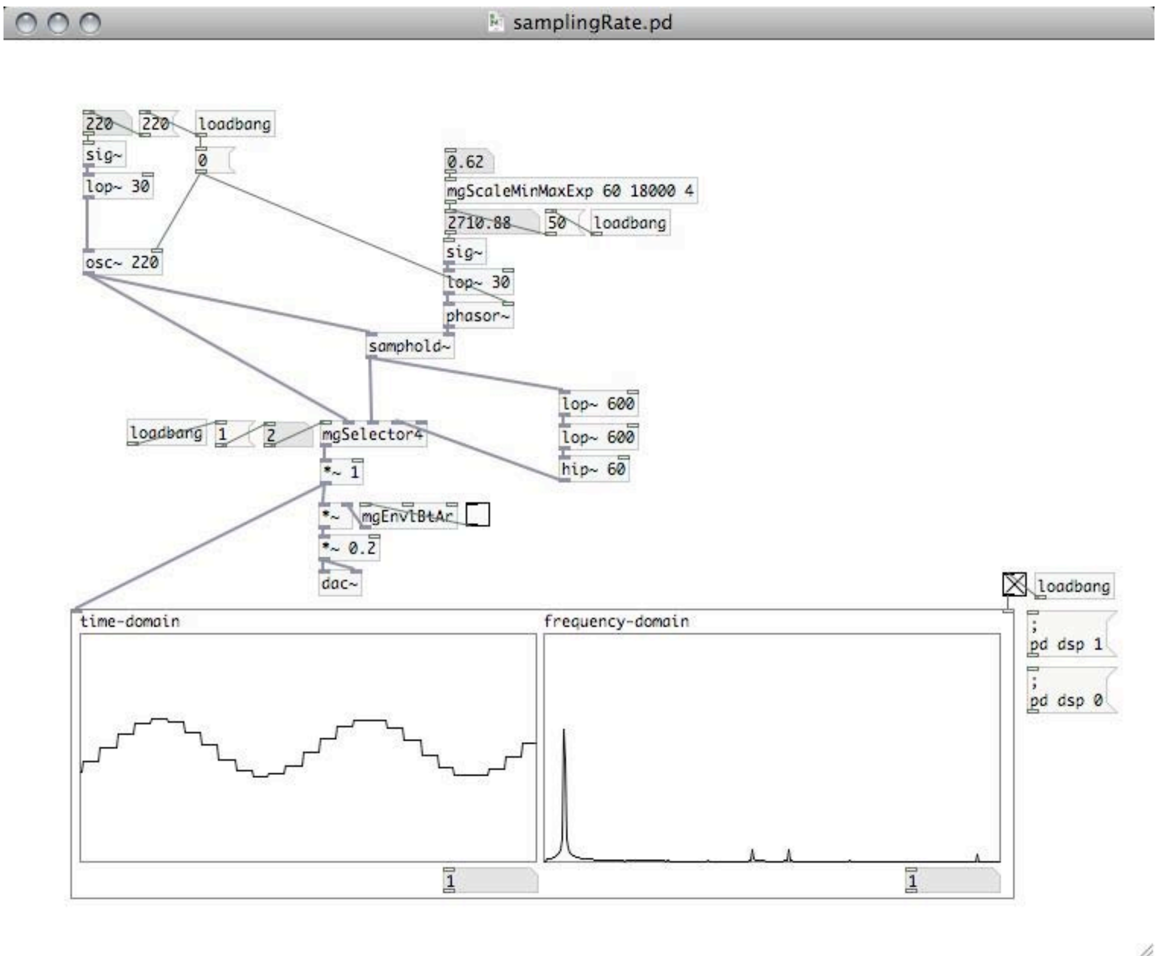
6.9. Sampling Rates: The Nyquist Theorem

- The highest frequency we can record is about half the sampling rate
- To sample a sine wave, at least two points per cycle must be sampled

- Trying to sample a frequency higher than the sampling rate leads to confusion: new frequencies are generated below the sampling rate
- Example: 44100 Hertz can record up to 22055 Hertz

6.10. The Limits of Sampling

- Resampling an audio signal at the audio rate [samplingRate.pd]



6.11. Bit Depth: Dynamic Range

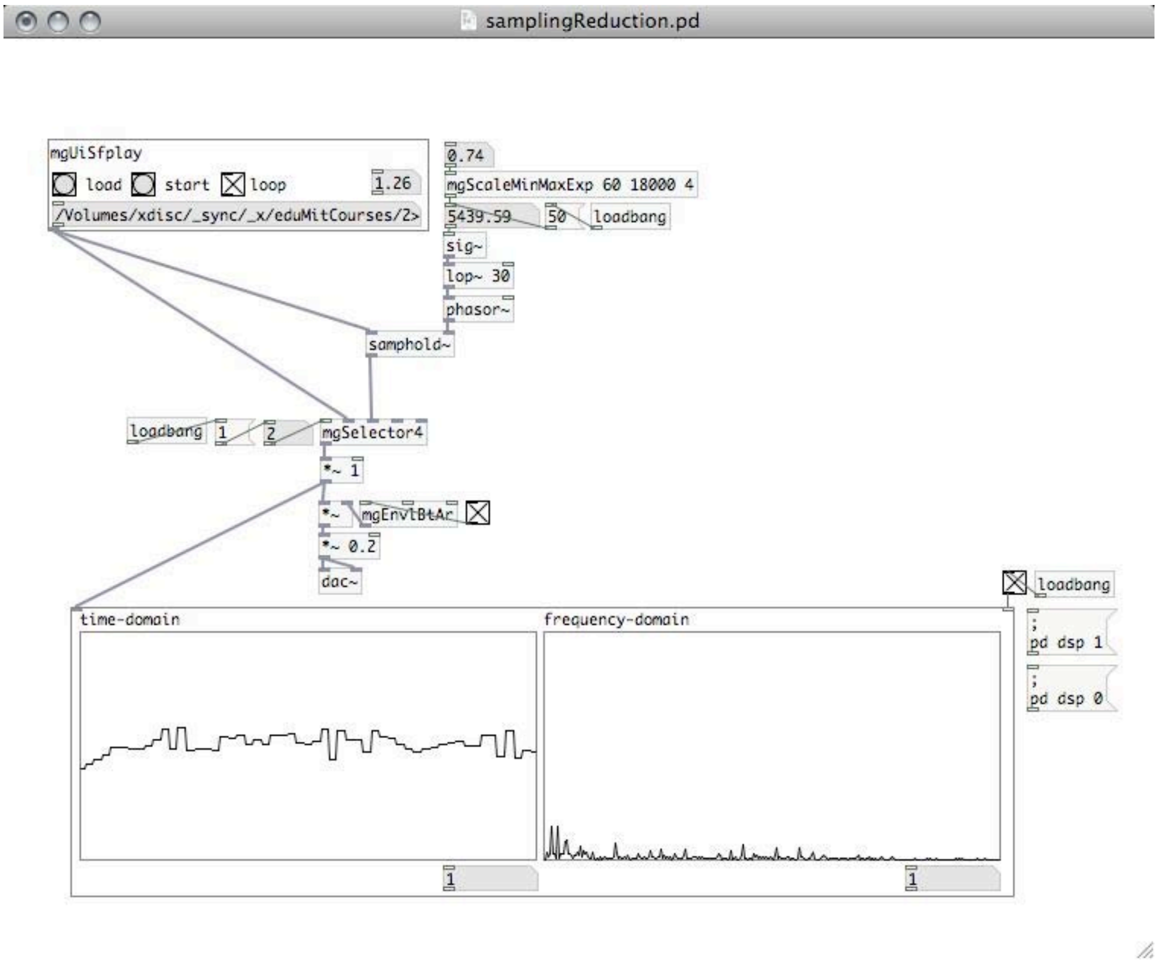
- The bit depth determines dynamic range
- 16 bit audio has 96 dB dynamic range (65536 discrete volume levels)
- 24 bit audio has over 110 dB dynamic range
- Each additional bit adds about 6 dB

6.12. A Bit on Bits

- Bits are a way of storing binary numbers
- The number of bits tells us how many numbers (things, positions, values) available
- One bit encodes two possible values: 0/1
- Two bits encode four possible values: 00/01/10/11
- Three bits encode eight possible values: 000/001/010/011/100/101/110/111
- 4 bits encode 16 possible values
- 8 bits (or one byte) encode 256 possible values
- 16 bits encode 65,536 possible values
- 24 bits encode 16,777,216 possible values
- In general: 2^{bits} = possible values

6.13. The Sound of Degradation

- Sample rate reduction and bit smashing
- Both make curves more square
- Making curves more square adds high frequencies [samplingReduction.pd]



6.14. Listening: Alva Noto

- Listening: Alva Noto, "Xerrox Meta Phaser," *Xerrox Vol. 2*, 2008

6.15. Digital Storage

- Audio files store digital sound information
- Can store multiple channels of digital audio in a single file
- Two components necessary

    - Header information: sampling rate, bit depth, number of channels
    - Data: a list of amplitude measurements
- Playback system must properly interpret header and read sample data
- Digital information can be stored on magnetic, optical, or other mediums

6.16. Digital Storage Size

- MB / min == Sampling rate * bytes per sample * channels * 60 (s/min)
- 44100 * 2 (16 bit) * 2 * 60 == 10 MB / min

6.17. Common PCM Digital Storage Formats

- A long list of sample values, with header information describing channels, sampling rate, and bit depth
- PCM Formats: AIFF, WAVE, others
- May have bit depth from 8 to 32, may have sampling rates from 22050 to 96000
- Compressed, non-PCM formats: MP3, M4A, MWA, OGG

6.18. History of Digital Audio

- 1928: Harold Nyquist at Bell Labs develops Nyquist Theorem
- 1938: A. Reeves develops first patented pulse code modulation technique for message transmission
- 1950s: Max Mathews at Bell Telephone Labs generates first synthetic sounds from a digital computer
- First digital one-channel audio recorder demonstrated by NHK in Japan
- 1973: Nippon Columbia (Denon) has digital audio recorder based on 1 inch video tape

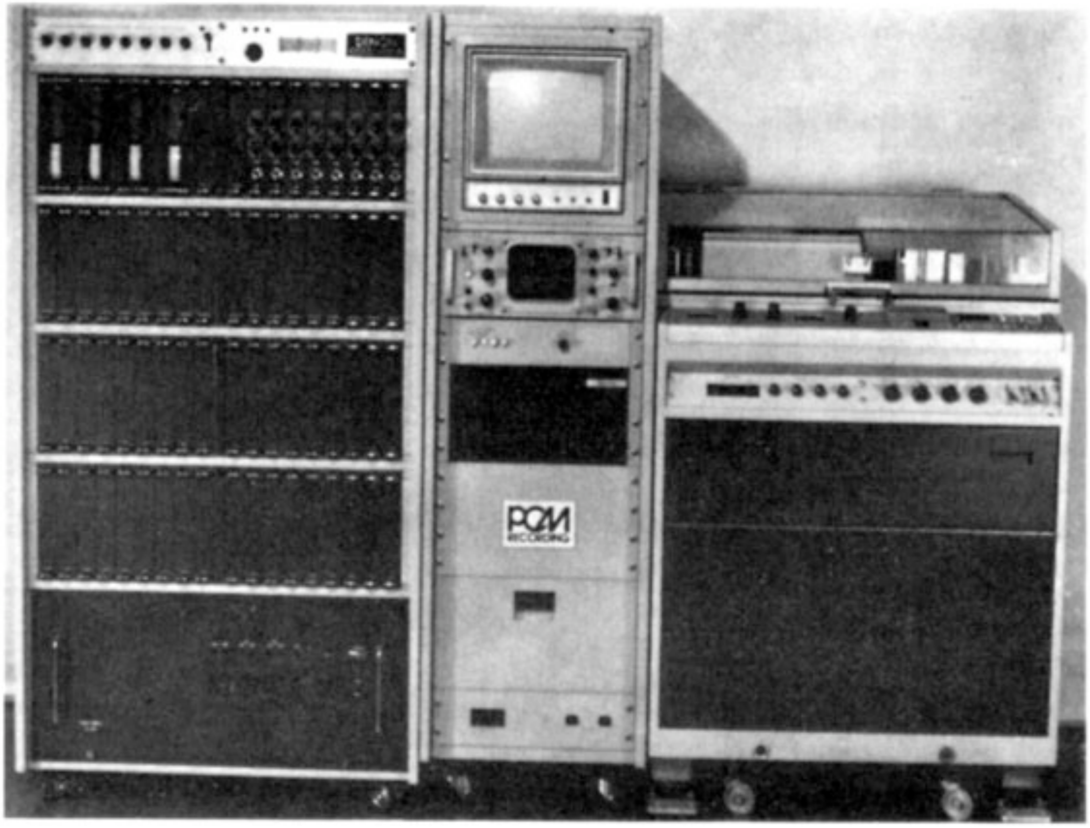


Figure 1.4 Nippon Columbia (Denon) digital audio recorder made in 1973 based on a 1-inch videotape recorder (on the right).

- 1977: first commercial digital recording system: Sony PCM-1: encode 13 bit digital audio onto Sony Beta videocassette recorders

- 1978: Sony PCM 1600: uses 16 bit encoders
- 1984: AMS NEVE Ltd release AudioFile system: first hard disk audio recording system (Holmes 2008)
- 1985: Audio Engineering Society establishes two standard sampling rates: 44.1 and 48 KHz

6.19. Consumer Digital Audio: CD

- 1982: Compact Disc becomes available (Philips and Sony)
- Within two years sells 1.35 million players and 10s of millions of discs

6.20. Consumer Digital Audio: DAT

- mid 1980s: Digital Audio Tape (DAT) released

- Popular for professional use in studios and field recording; commonly used for higher 48 kHz sampling rate
- 1992: Audio Home Recording Act: adds Serial Copy Management system to commercial DATs, adds royalty fees to digital records and blank digital media
- 2005: Sony announces that DAT machines will be discontinued

6.21. Consumer Digital Audio: New Formats

- DVD-Audio
    - Support for 96 kHz, 24 bit, 5.1 surround
    - Support for 5.1 and alternative formats
    - Partial compatibility with DVD Video players
    - Supports 8.5 GB of data
    - Maximum bit-rate of 9.6 mbps
- Super Audio CD (SACD)
    - As of May 2009, 5500 SACD releases, 20 times more titles are available on SACD than other high resolution formats, mostly "Classical" music
    - Supports 7.95 GB of data
    - Support for 5.1 surround and alternative surround formats
    - Hybrid discs are compatible with old CD players
    - Digital Stream Digital Encoding: not PCM
    - Pulse-density modulation encoding: significant debate on quality
    - Direct-Stream Digital (DSD) Encoding: not PCM

      Uses 1 bit encoding at a sampling rate of 2.8224 Mhz (1 bit times 64 times 44.1 kHz)

      Over 120 dB of dynamic range and frequency response over 90 kHz

      Significant debate over quality

      A type of pulse-density modulation

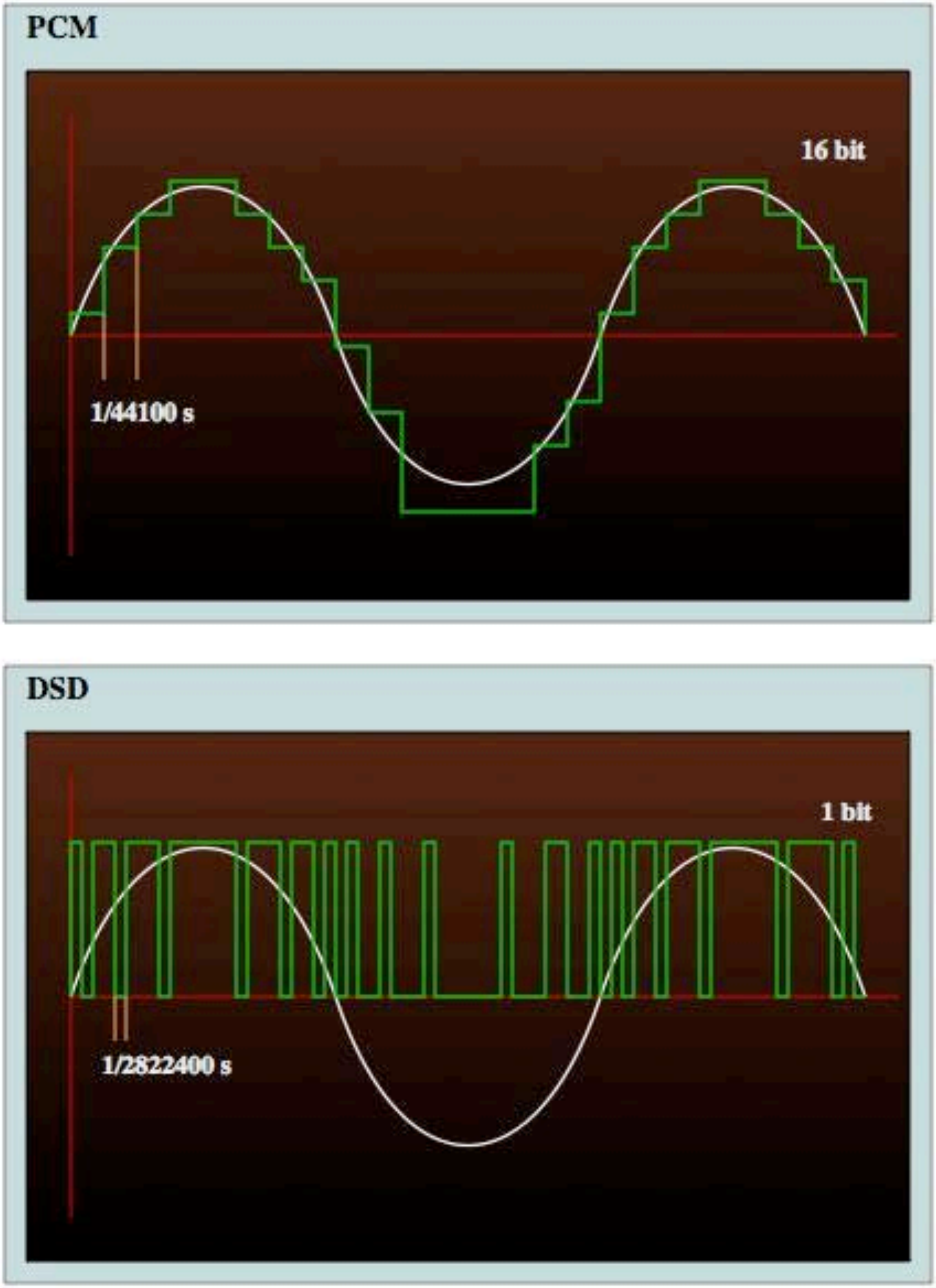
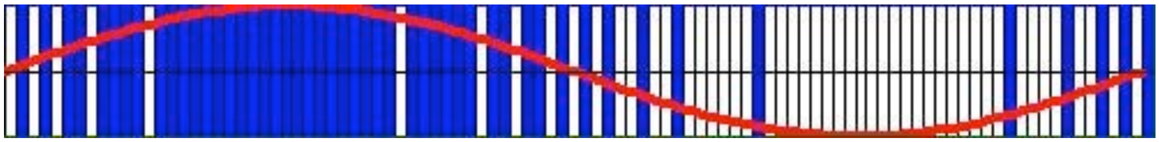


Image: Wikipedia, by Pawel Zdziarski, license CC BY.



6.22. Professional Digital Audio Multitracks

- 1978: 3M with BBC introduces first 32 track digital recorder
- 1970s: Soundstream releases first computer-based sound editor and mixer

Figure 16.38 The Soundstream editing system, ca. 1982. The console in the center was used to enter editing commands. The monitor at the left displayed time-domain waveform images.

- 1990s: low cost digital multitracks by Alesis (ADAT) and Tascam

- 1991: Digidesign releases first version of ProTools, supporting four 16-bit tracks (Holmes 2008)
- late 1990s: digital audio workstations (DAW) on personal computers

6.23. Digital Audio Workstations and Non-Destructive Editing

- DAWs separate the digital audio and the presentation of that digital audio
- Numerous different presentations of the same audio segment are possible, each with different boundaries and at different times in different tracks
- Removes risk of over-writing material (overdubs) and necessity of cutting and splicing tape

6.24. Reading: Sterne

- Sterne, J. 2006. "The mp3 as cultural artifact." *new media & society* 8(5): 825-842.
- Why might Sterne describe the mp3, after Mumford and Sofia, as a container for containers?
- "... the mp3 has been ascribed the status of a thing in everyday practice" (2006, p. 830); is the mp3 a thing?
- In numerous places Sterne assigns agency to the mp3: "the file is designed to figure out what you will not hear anyway and to get rid of the data for that portion of the sound" (2006, p. 832); "The encoder then decides how much data to retain and how much to discard ... The encoder calculates a new timbral measurement for each frame based on what it learned about the shape of the incoming signal" (2006, p. 833); "the mp3 encoding process puts the body on a sonic austerity program. It decides for its listeners what they need to hear and gives them only that" (2006, p. 838). Is this necessary, and does this support or hinder his overall argument?
- Sterne states that "Mp3s are designed to be heard via headphones while outdoors, in a noisy dorm room, in an office with a loud computer fan, in the background as other activities are taking place and through low-fi or mid-fi computer speakers" (2006, p. 835): what evidence supports this claim?
- What agency do humans have in producing and making mp3s? Does Sterne account for this source of agency?
- What other music technologies were "designed for massive exchange, casual listening and massive accumulation" (2006, p. 838)?
- Do you agree that the mp3 is a "celebration of the limits of auditory perception" (2006, p. 828)?

6.25. Compression: Non-Lossy (Lossless)

- All data is stored and can be retrieved
- Various approaches
  - Compact redundancies
  - Translation tables
  - Analyze and produce algorithmic replacements
- Examples: zip (LZW), Huffman coding, FLAC, Apple Lossless

6.26. Compression: Non-Lossy (Lossless): Example

- Run-length encoding

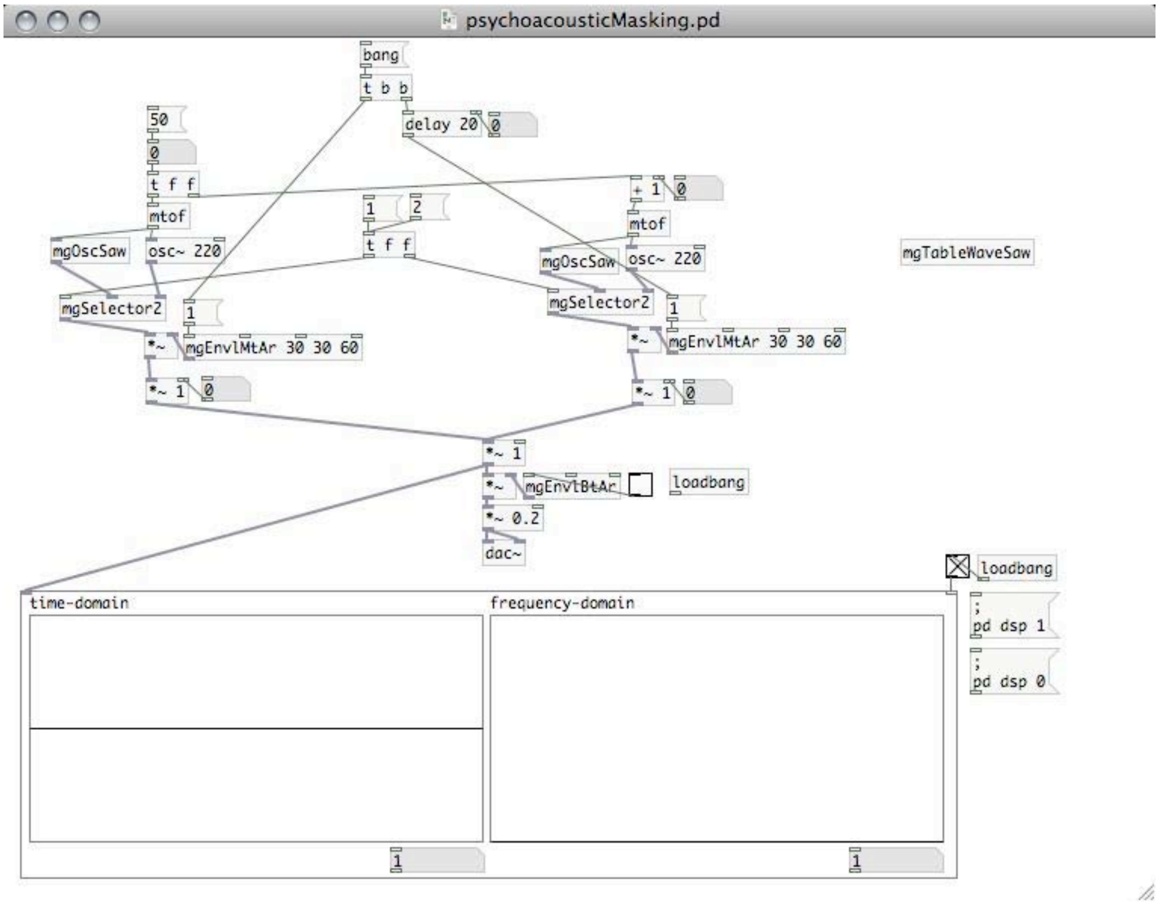
- Compact redundancies by replacing identical data with a code that gives the length of data
- C C E E E G G G D A G F G G G G C
- 2C3E3GDAGF4GC
- In terms of a PCM audio file, silence can be compressed more than noise

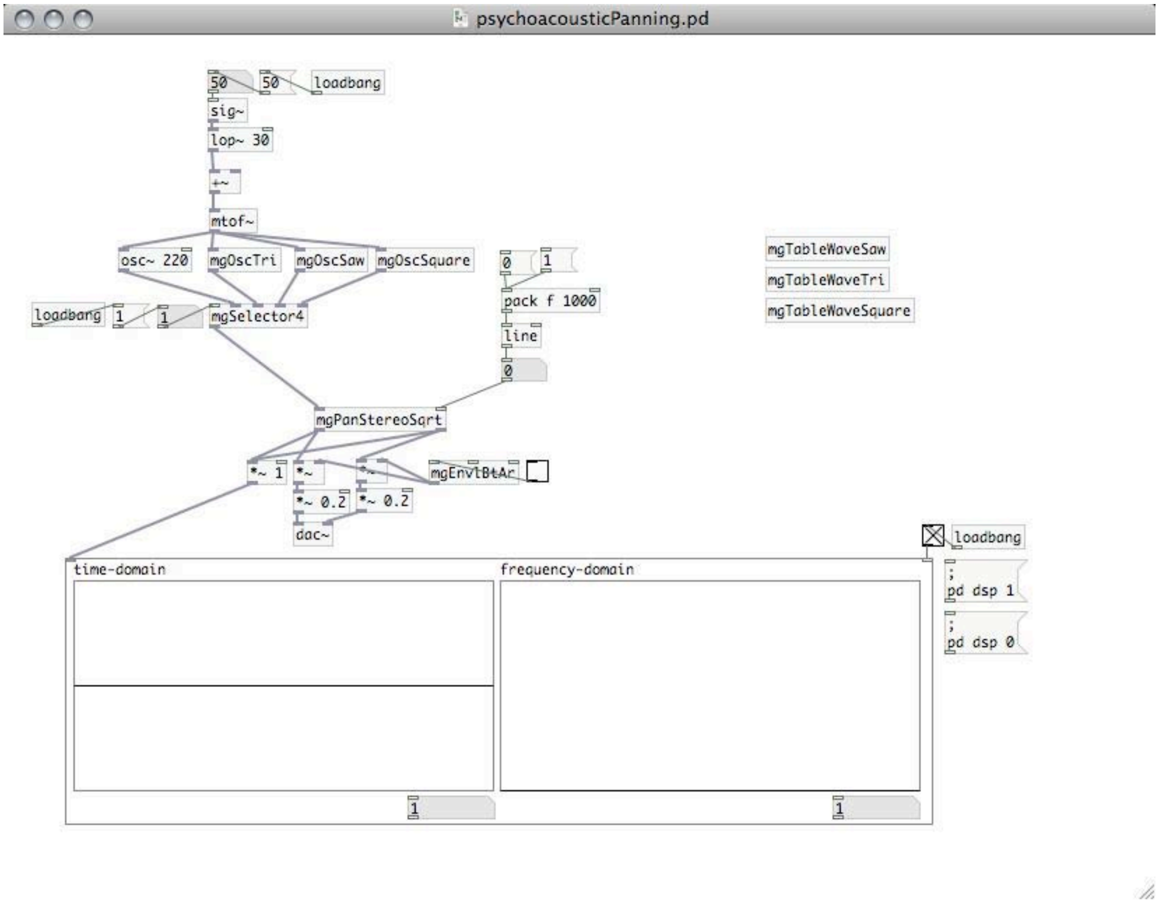
6.27. Compression: Lossy

- Data is lost
- Various approaches
  - Data is removed that is less relevant
  - Data is removed that is statistically predictable and common
- Examples: jpeg, mp3, aac, ogg

6.28. Compression: MP3

- Psychoacoustic measures are used to remove (supposedly) non-audible signal components [demo/psychoacousticMasking.pd, demo/psychoacousticPanning.pd]


psychoacousticMasking.pd
bang
t b b
delay 20
50
t f f
mtof
+ 1
mtof
1
2
t f f
mgOscSaw
osc~ 220
mgOscSaw
osc~ 220
mgTableWaveSaw
mgSelector2
mgSelector2
mgEnvlMtAr 30 30 60
mgEnvlMtAr 30 30 60
*~ 1
*~ 1
*~ 1
*~
mgEnvlBtAr
loadbang
*~ 0.2
dac~
loadbang
time-domain
frequency-domain
; pd dsp 1
; pd dsp 0



- Frequency-domain analysis: sound is broken up into many (32 or more) frequency bands
- Encoder analyzes data and removes data that is not expected to be heard based on frequency domain analysis
- Encoder performs lossless compression on data
- Bitrate (kbps) determines quality: 96 to 320 are common
- kbps: refers to kilo-bits per second: transmission rate necessary for real-time audio playback
- CD-audio (2 channels of 16 bit 44.1 kHz sampling rate audio) takes 14,000 kbps

6.29. Aural Comparison of MP3 Quality

- MP3 distortion is most often audible with complex signals in the mid-range (cymbals and high-hats in particular)
- Low bit rate encoders often remove high frequencies
- Comparison of AIFF, 320, 256, 128, 96, 48, 24

Chapter 7. Meeting 7, Recording: Processing Audio and the Modern Recording Studio

7.1. Announcements

- Quiz next Thursday
- Numerous listenings assignments for next week

7.2. Processing Audio

- Contemporary processors take many physical forms: effects units, stomp-boxes

Photo courtesy of kernelslacker on Flickr.

Photo courtesy of michael morel on Flickr.

Courtesy of George Massenburg Labs. Used with permission.

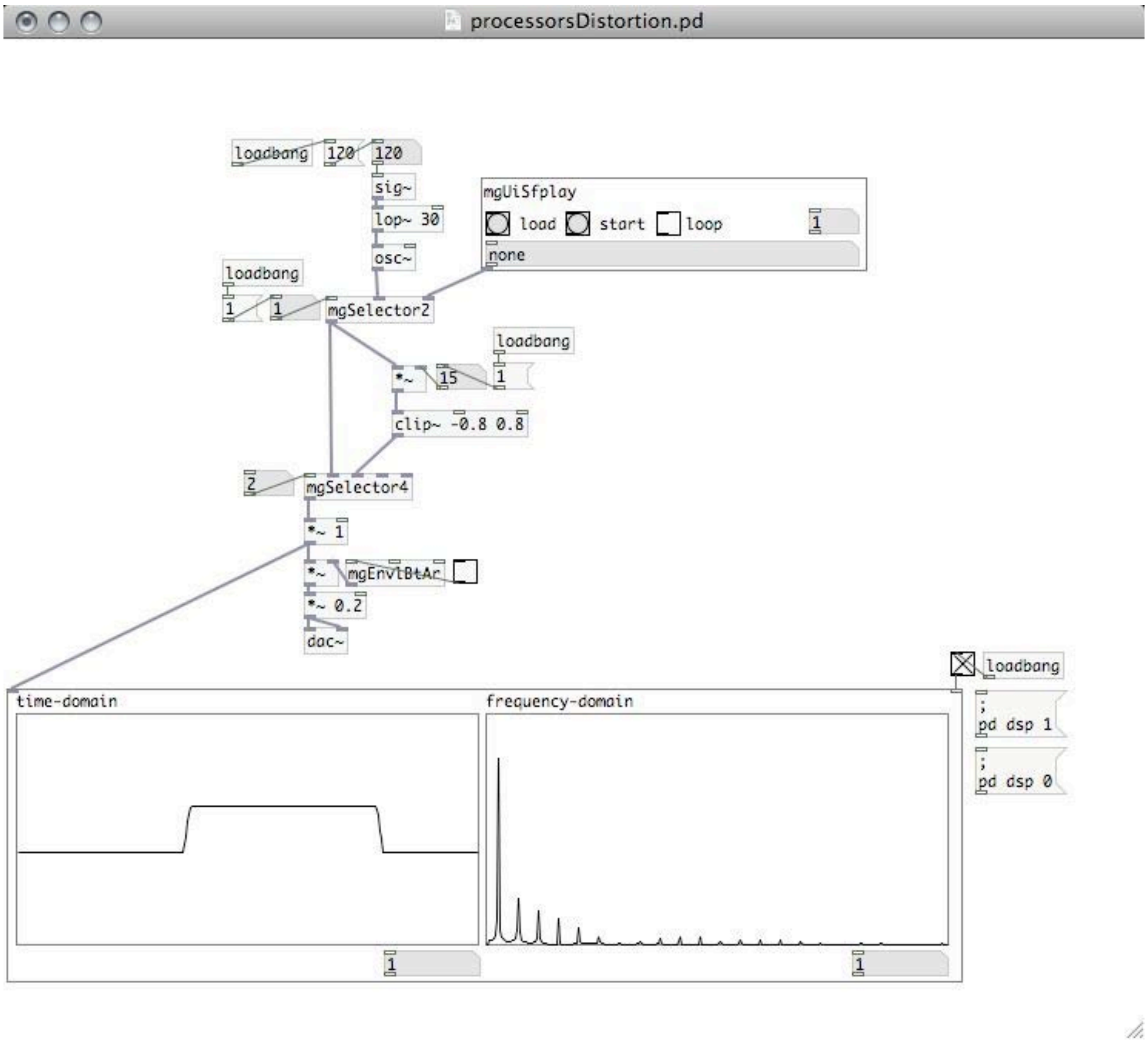
Original photo courtesy of eyeliam on Flickr; edited by Wikipedia User:Shoulder-synth.

- As software, most are implemented as plug-ins


Audio 1
a
Ring Modulator
bypass
TDM
<factory default>
compare
auto
safe
moogerfooger™
RING MODULATOR
LFO
AMOUNT
DRIVE
MIX
RATE
Audio 1
a
Lowpass Filter
bypass
TDM
<factory default>
compare
auto
safe
moogerfooger™
LOWPASS FILTER
ENVELOPE
AMOUNT
DRIVE
CUTOFF
SMOOTH
FAST
LEVEL
ENV
BYPASS
RESONANCE
Bob Moog
Audio 1
a
12-Stage Phaser
bypass
TDM
<factory default>
compare
auto
safe
moogerfooger™
12-STAGE PHASER
SWEEP
LFO
AMOUNT
DRIVE
LO
HI
RATE
Audio 1
a
Analog Delay
bypass
TDM
<factory default>
compare
auto
safe
moogerfooger™
ANALOG DELAY
DELAY TIME
DRIVE
FEEDBACK
LOOP GAIN
SHORT
LONG
MIX
INT. LOOP
EXT. LOOP
INPUT LEVEL
LOOP LEVEL
BYPASS
OUTPUT LEVEL
Bob Moog

7.3. Distortion

- Pushing a signal beyond its dynamic range squares the waveform
- Making round signals more square adds extra harmonics [demo/processorsDistortion.pd]



- Examples
  - Overdrive
  - Fuzz
  - Crunch

7.4. Dynamics Processors

- Transform the amplitude of a signal in real-time
- Amplitudes can be pushed down above or below a threshold to decrease or increase dynamic range
- Examples

- Compressors and Limiters
- Expanders and Gates

7.5. Dynamics Processors: Compression

- Reduces a signal's dynamic range
- Makes the quiet sounds louder
- Helps a track maintain its position in the mix
- Two steps
    - Reduce dynamic range: turn amplitudes down if a above a specific level (the threshold)
    - Increase amplitude of entire signal so that new peaks are where the old were

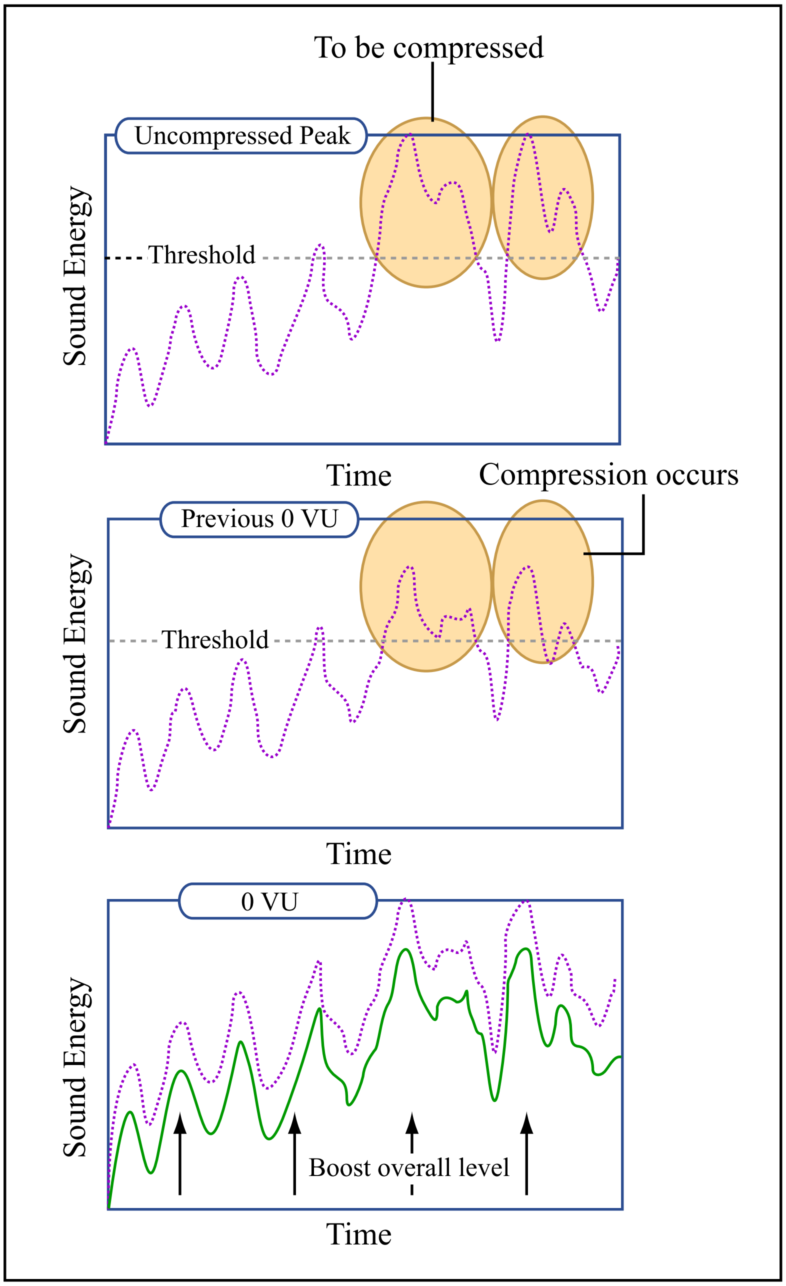
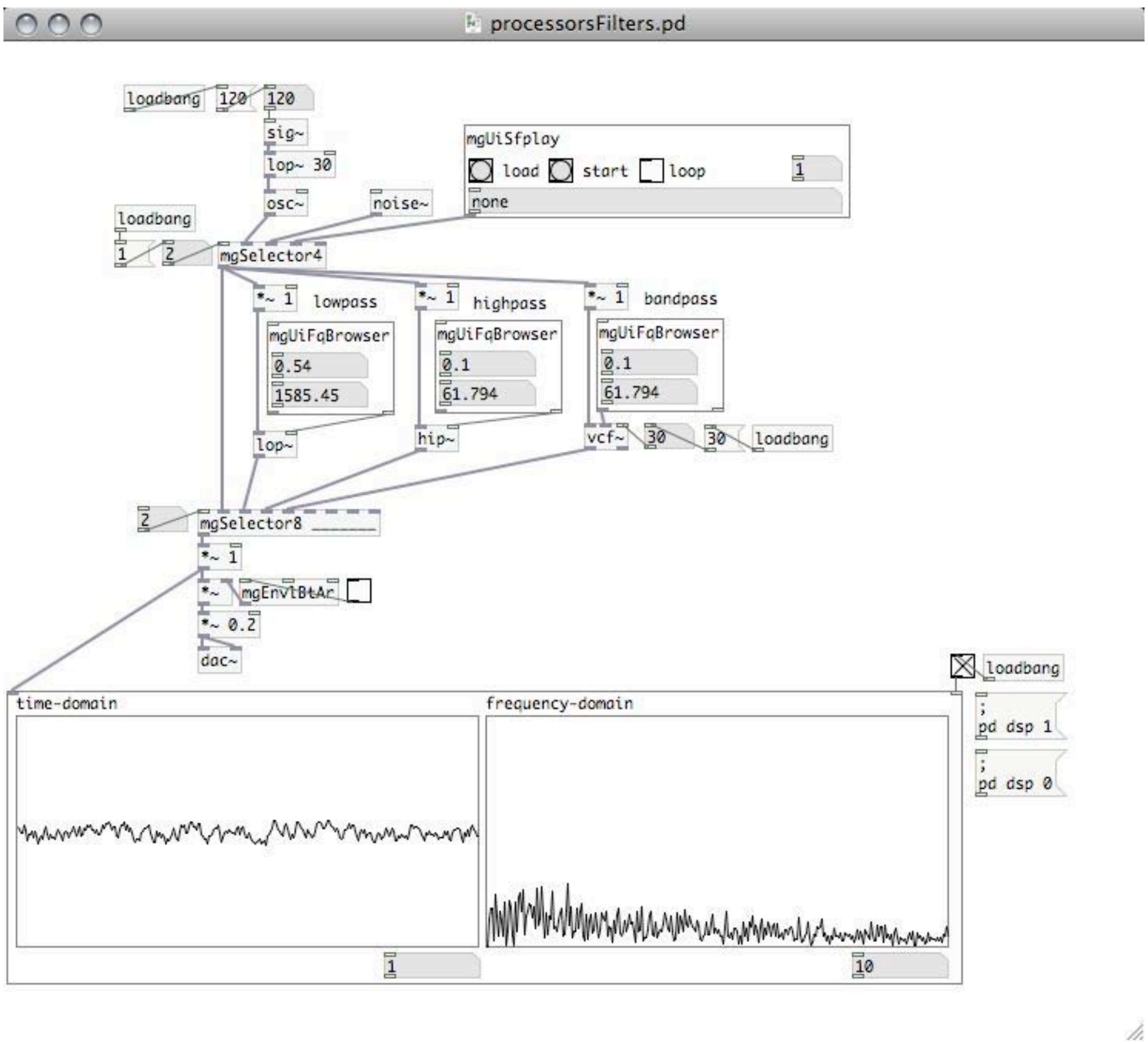


Figure by MIT OpenCourseWare.

- Negative effects: can increase noise, and create dynamic noise floors
- Negative effects: can make a musical part dynamic static

7.6. Filters

- A filter alters the timbre of a sound
- Some frequency components are boosted, others are cut [demo/processorsFilters.pd]



- The low pass and high pass filter
  - Cutoff frequency determines where the filter is active
  - May have a resonance control at the cutoff frequency

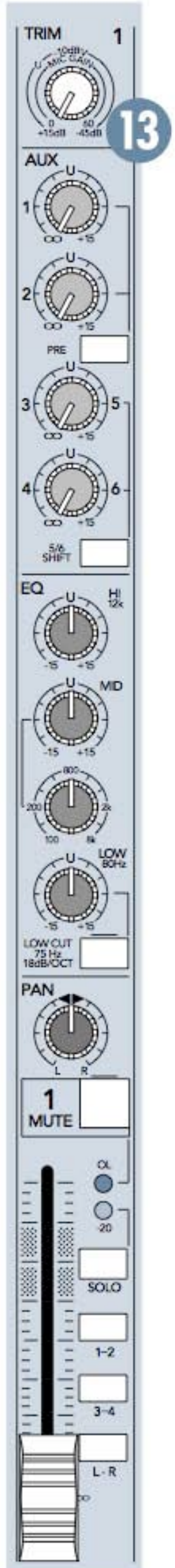
    - Can be thought of as smoothing the waveform
    - An easy filter to implement in analog and digital electronics
- The parametric filter
    - Center frequency, bandwidth (Q), and gain
    - The most precise filter

7.7. The Channel Strip

- A channel strip bundles together common musical processors
- A mixer (as hardware or software) consists of many parallel channel strips (and flexible ways to combine them)

- Filters are always included
- Dynamic effects may also be found: compressors and gates

- Mackie 1604 channel strip



- Mackie 2480 channel strip

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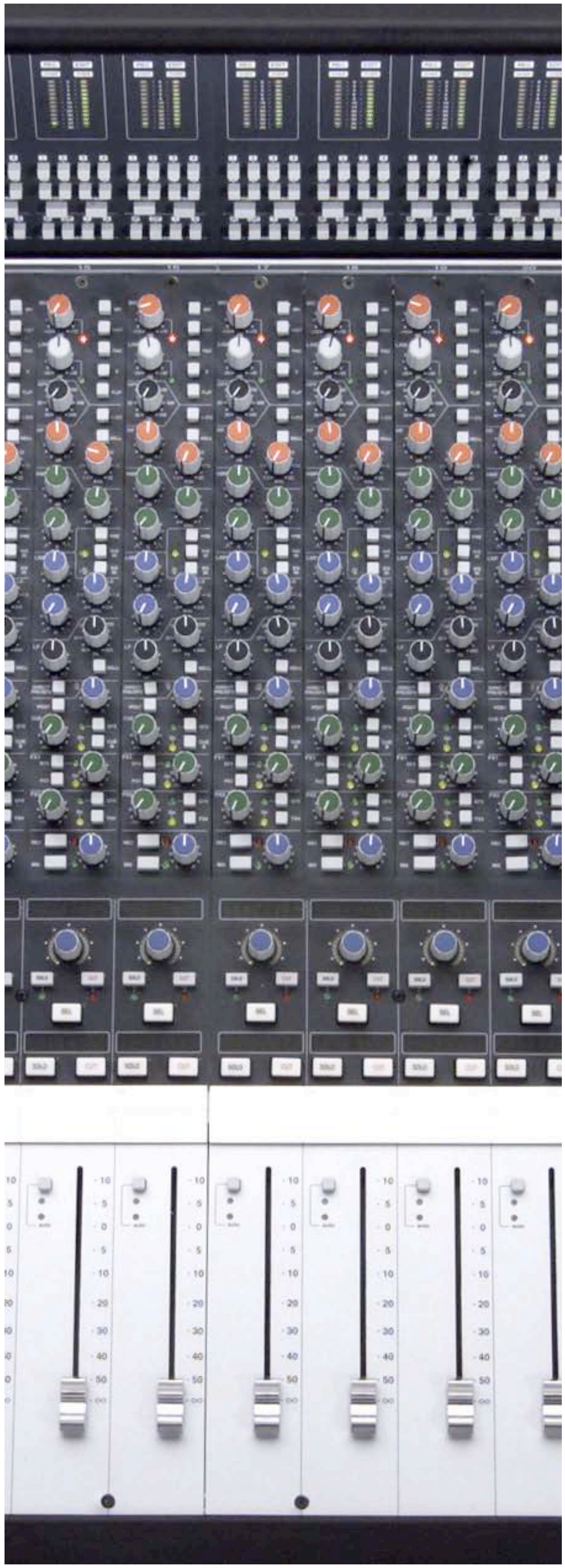
• SSL 900 channel strip



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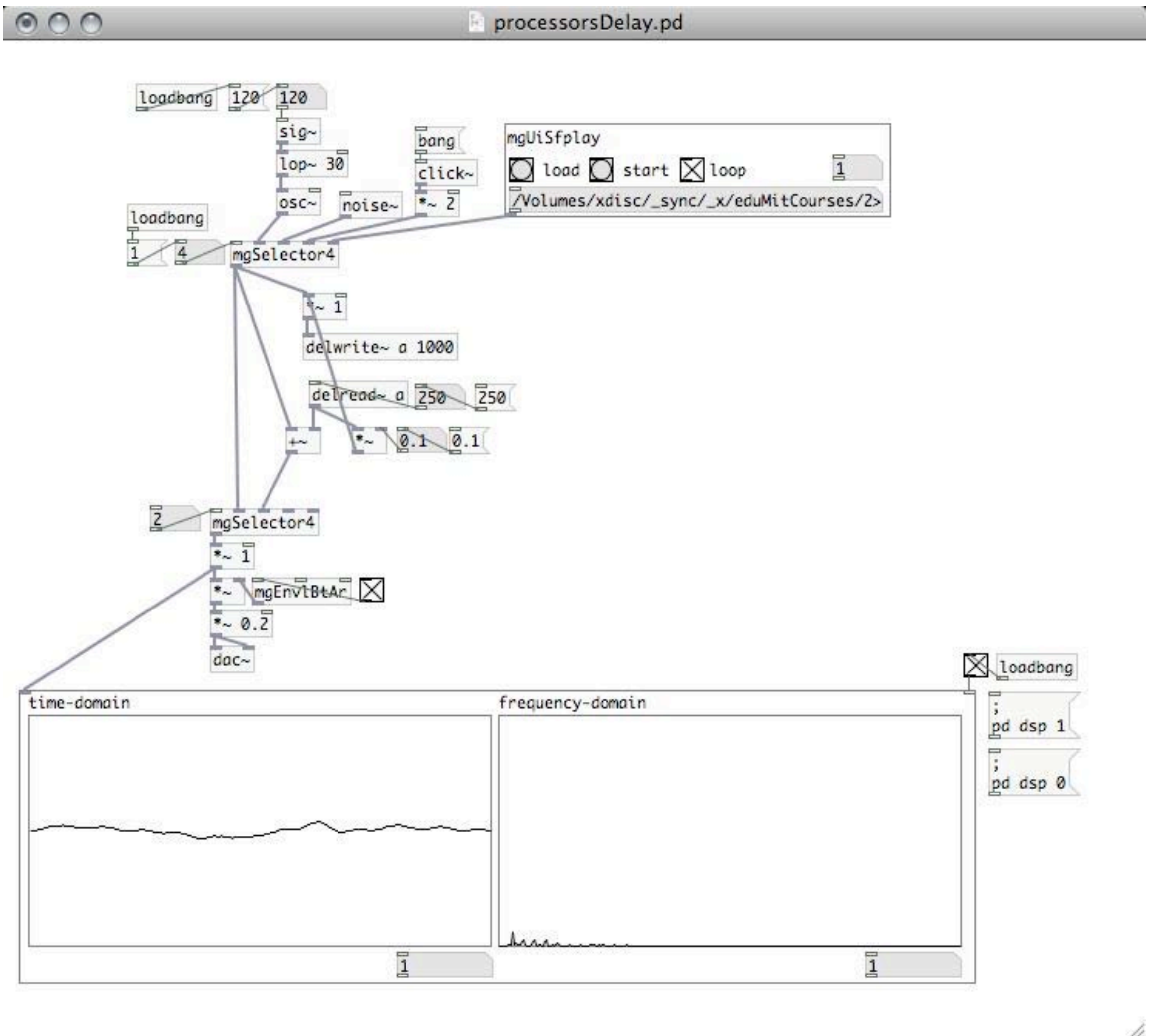
7.8. Delay

- Place signal in a buffer, wait, then send out [demo/processorsDelay.pd]

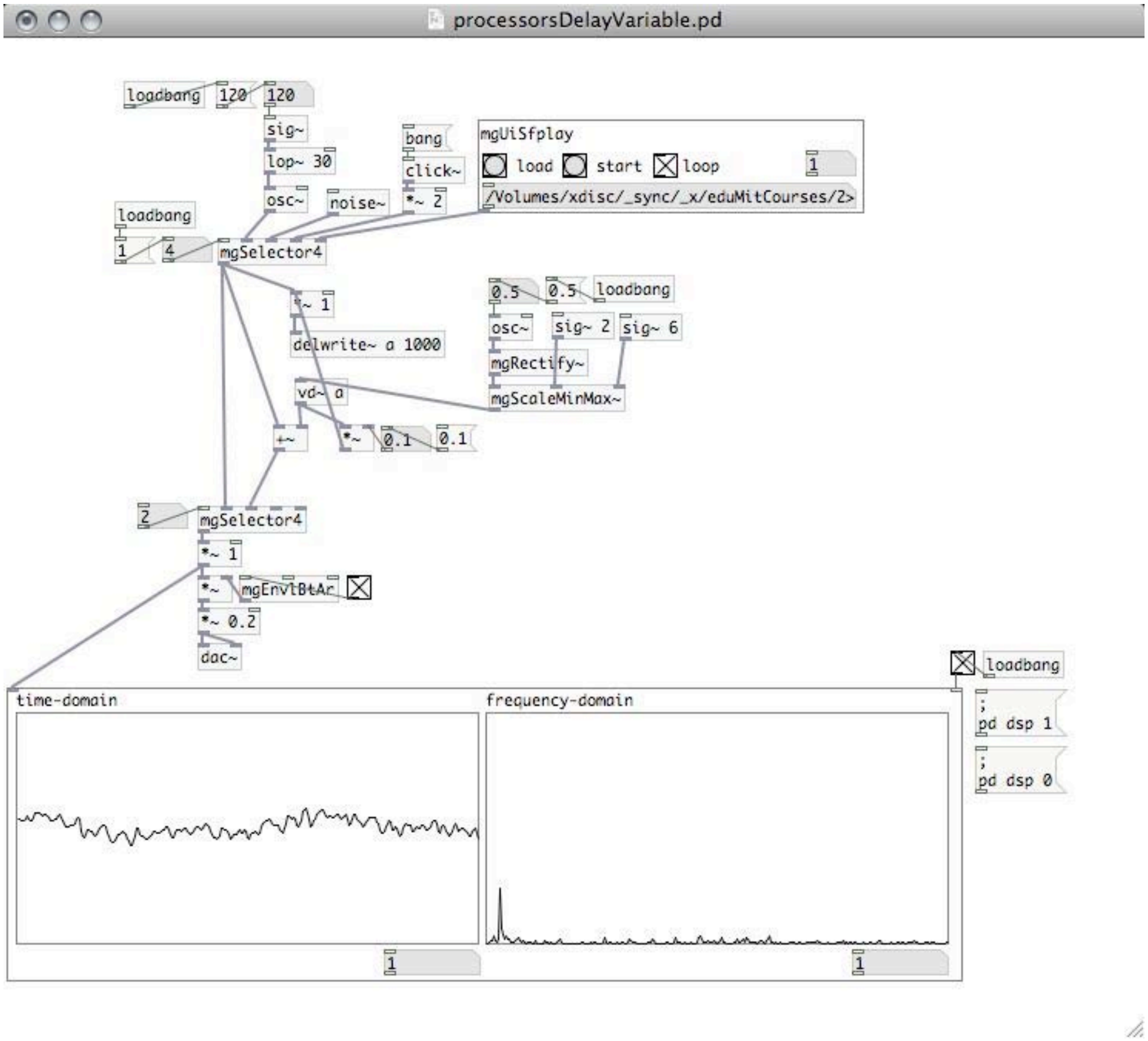


- Feedback: scale the amplitude of the delayed signal and then delay it again: creates a series of echos

7.9. Time-Variant Delays

- Vary the delay time with a time-varying signal (like a control-rate sine)

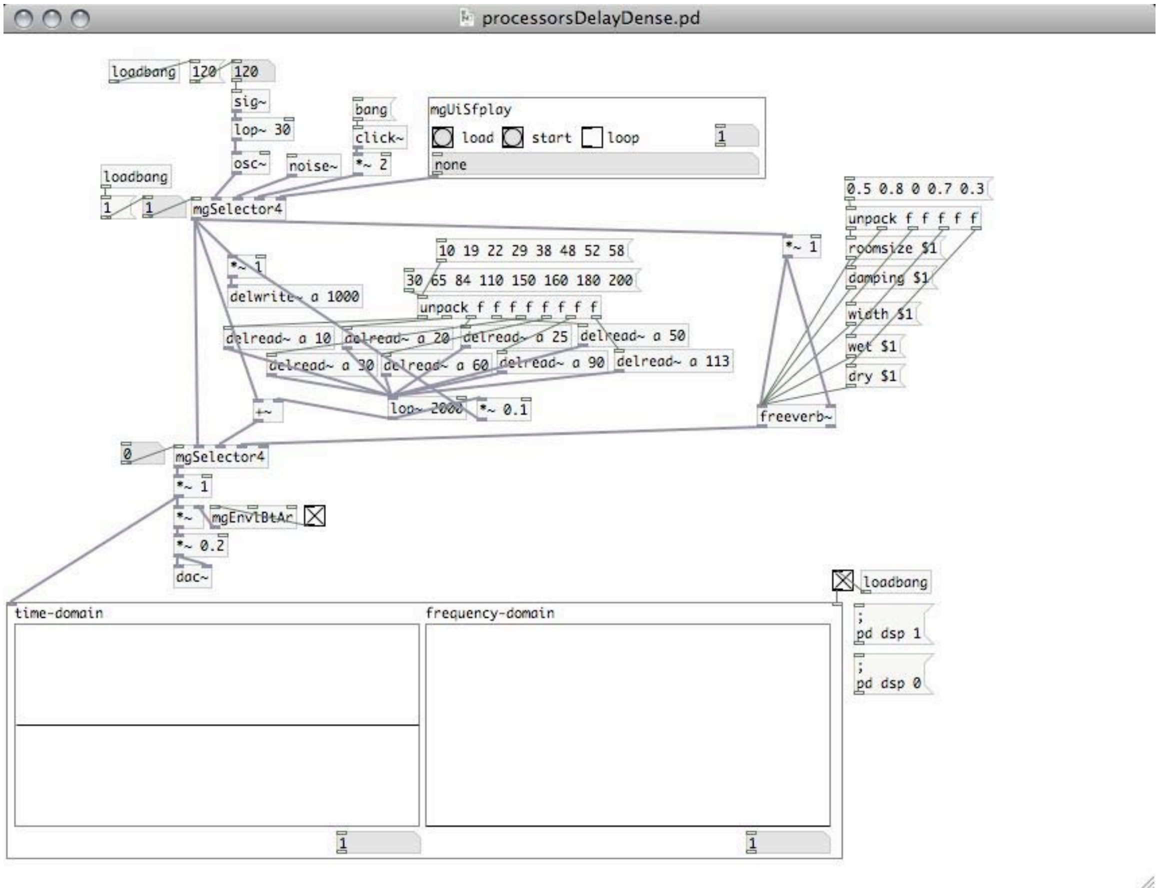
- Creates change in timbre through phase interference [demo/processorsDelayVariable.pd]



- Examples
    - Chorus
    - Flanging
    - Phasing

7.10. Dense Delay Structures

- Organized groups of very close spaced delays [demo/processorsDelayDense.pd]



- Less than 30 ms separation between echos will produce a continuous sound
- Examples
    - Chambers and Ambiences
    - Reverb
    - Plates, springs

7.11. Listening: The Southern Four and Parliament

- The Southern Four: “Swing Low, Sweet Chariot,” 1924, Edison Diamond Disc

7.12. The Mothership Connection

- "Starchild, Citizens of the Universe, Recording Angels...," "Swing down, sweet chariot. Stop, and let me ride"
- Afro-Futurism: African American strategies to overcome racial and social classification by means of technology and futuristic mythology
  - 1956: Sun Ra
  - 1970s: Parliament and George Clinton
  - 1982: Afrika Bambaataa
  - Paul Miller a.k.a. DJ Spooky that Subliminal Kid
- The Mothership Connection: the chariot of "Swing Low, Sweet Chariot" transformed into an interplanetary vessel
- Parliament: "Mothership Connection (Star Child)," 1976

7.13. Multitrack Recorders and DAWs

- Multitrack recording permits recording parts in layers
- Permits recording one track while monitoring (playing back) others
- Punching-in: permits replacing segments of each track
- Overdubs: permit adding additional tracks
- Digital Audio Workstations (DAWs) are software multitrack recorders that permit greater editing flexibility and integrate audio mixing and processing
- Common DAWs: Pro-Tools, Cubase/Nuendo, Logic, Digital Performer, Sonar, Fruty Loops, Live

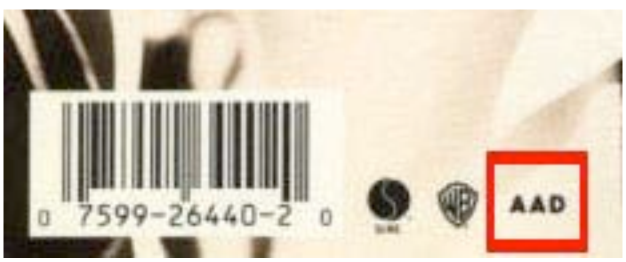
7.14. Non-Destructive Recording and Non-Linear Editing

- Audio data is recorded and stored on hard disk

- DAW tracks present a representation of a segment of the audio data (an audio region)
- The original audio is never cut or transformed
- Multiple regions can be deployed in multiple tracks without copying or duplicating audio data
- Offers efficiency, flexibility, and security

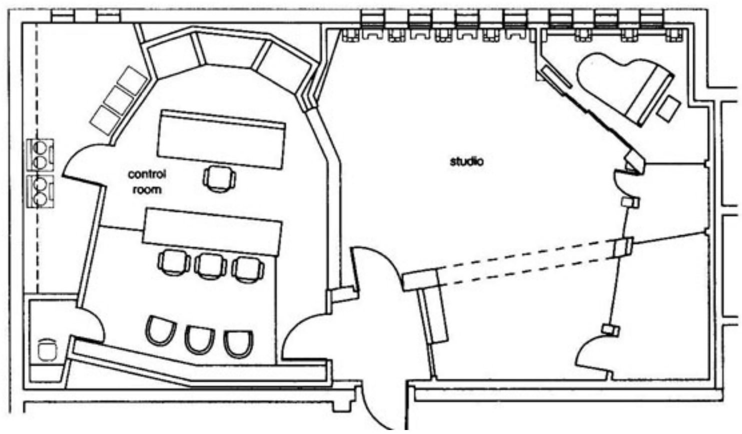
7.15. Modern Recording, A Three Step Process

- 1. Tracking (recording, overdubs)
- 2. Mixing (editing, cutting, processing, producing)
- 3. Mastering
- Each step may be done at different locations or studios
- Each step may be done in analog or digital
- CDs used to encode which step was analog or digital with a Society of Professional Audio Recording Studios (SPARS) Code



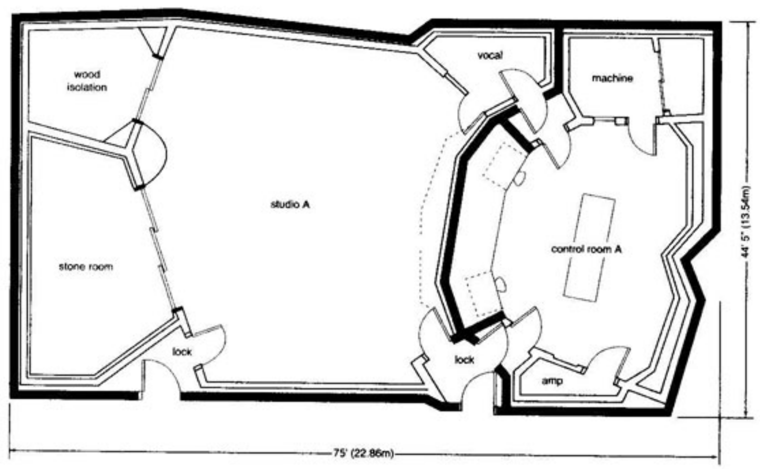
7.16. Division Between Control Room and Recording Rooms

- Recording to tape permitted monitoring what was actually being recorded as it was being recorded
- Main rooms and isolation booths: spaces to position and isolate performers
- Control room: acoustically treated space for critical monitoring of what the microphones are picking up
- Control room monitors are designed to be very accurate speakers
- Sony/Tree’s Music Studio, Nashville

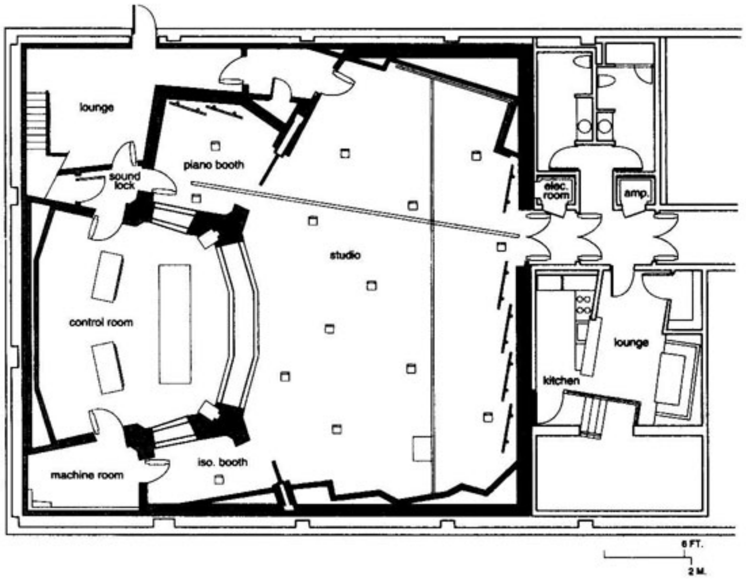


- Paisley Park's Studio A

Courtesy of Russ Berger Design Group, Inc. Used with permission.



- Studio X, Seattle



7.17. Close Microphone Captures and Track Isolation

- Goal of isolating each musical part in a separate track
- Use of specialized microphones placed very close to performers
- May record each instrument in isolated rooms or at different times
- May record multiple instruments in the same room, with dividers and microphones placed for greatest isolation

7.18. Problems and Benefits of Track Isolation

- Poses challenges to conventional musical communication: musicians need to hear and see each other
- Musicians may need to use ear-phones to monitor other musicians, processed sounds, or pre-recorded tracks
- Permits optimizing sound of each instrument
- Permits correcting errors in single parts
- Permits non-linear recording and audio production
- Permits musical re-arrangement and re-composition

7.19. Mixing and Automation

- Mixing can include fading and switching tracks on and off; adjusting levels, effects processing, filtering, and panning
- Before multi-track tape recording, mixing was done in real-time, direct to disc
- With multi-track tape recording, tracking and mixing became separate steps

7.20. Mixing and Automation: Control Surface

- Mixing consoles used to store processing power and provide an interface
- Soundcraft MH3 ($16k+)

- Control surfaces provide a dynamic interface to computer-based processing
- Digidesign ProTools D Command ($14k+)

7.21. Mixing and Automation: Traditional and Contemporary

- Traditional mixing is more like performing
  - After all tracks were recorded, engineers would create a script of changes to make during playback
  - Playing back all tracks, the mixing engineer would perform all changes in real time
  - Would likely do multiple takes of the mixing procedure, possible with multiple people performing the mix
- Contemporary mixing is more like composing
  - Track automation permits recording or directly specifying all dynamic changes to channel strip controls and effects
  - The mixing engineer might perform the mix, and then edit the performance data
  - The mixing engineer might directly specify (draw) the dynamic changes
  - Can compose and refine mix automation data

7.22. Tom Dowd: Engineering Innovator

- Video: Tom Dowd: The Language of Music, Chapter 2 (00:02-01:16, 2:42-3:47, 4:10-5:08)

- Video: Tom Dowd: The Language of Music, Chapter 7 (3:40-7:05)

7.23. Mastering for Distribution and Broadcast

- Process two channel mix to optimize audio performance on various mediums
- Processing tools may include special filters and compressors
- A necessary step to make tracks "gel" together
- Increases loudness of mix

7.24. The Loudness War

- Compete for attention by making music (or other audio programs) louder than adjacent audio programs
- Radio broadcasts: for transmission efficiency and to be louder than competition
- TV commercials: to be louder than the program and other commercials
- Popular Music: to sound bigger than other recordings
- Potential Negative Effects
  - Can distort musical dynamics and reduce musicality
  - Can lead to increasingly extreme dynamics
  - Can train listeners not to hear dynamic range
  - Can cause ear strain
  - Makes diverse playlists difficult to listen to.

7.25. Loudness War: Statistics

- Nielsen, S. H. and T. Lund. 2003. "Overload in Signal Conversion." *AES 23rd International Conference.*
- Statistical Evidence:

	Track	Notes	Artist	Year	Slow avg. [dB]	Max. dig. [dB FS]	Hot spots 1	Hot spots 2	Sum
1	Lose Yourself		Eminem	2002	-7.5	0.0	>25 s.	>25	4
2	Time of My Life		Macy Gray	2002	-8	0.0	16	8	3
3	Happy		Ashanti	2002	-9	0.0	18	10	3
4	La Fiesta De Amadito		Amadito Valdez	2002	-10	0.0	2	0	1
5	Don't Stop	PP	Anastacia	2001	-6	0.0	>25 s.	15	4
6	Played Alive		Safri Duo	2001	-7	0.0	>25	16	3
7	The Call	PP	Backstreet Boys	2000	-5	0.0	>25 s.	18	4
8	Livin' la Vida Loca		Ricky Martin	1999	-6.5	0.0	12	5	3
9	Need to Know		Marc Anthony	1999	-7	0.0	19	10	3
10	Razor Tongue		DJ Mendez	1999	-6	0.0	17 s.	9	4
11	I Got a Girl		Lou Bega	1999	-6.5	0.0	>25 s.	3	4
12	Let's Get Loud	PP	Jennifer Lopez	1999	-6	0.0	>25 s.	10	4
13	Smooth		Santana	1999	-7	0.0	20 s.	15	4
14	Oye Como Va	RM	Santana	1970 1999	-12	0.0	0	0	1
15	Avalon	RM	Roxy Music	1982 1999	-9	0.0	5	0	2
16	Believe		Cher	1998	-5.5	0.0	10	4	2
17	Miami		Will Smith	1997	-11	0.0	17	9	3
18	That Don't Impress...		Shania Twain	1998	-9	0.0	3	0	2
19	Vissa Har Det		Bo Kaspers Ork.	1998	-11	0.0	1	0	1
20	True Colors		Phil Collins	1998	-12	0.0	1	0	1
21	Block Rockin' Beats		Chemical Bros.	1997	-6	0.0	8	5	2
22	El Cuarte de Tula		Buena Vista SC	1997	-12	-0.2	0	0	1
23	Dimples		John Lee Hooker	1997	-11	0.0	0	0	1
24	Bla Bla Bla		Oestkyst Hustlers	1996	-9	0.0	3	0	2
25	Bob Yu Did Yu Job		Jimmy Cliff	1996	-12	0.0	6	1	2
26	Where It's At		Beck	1996	-10	0.0	1	0	1
27	Wannabe	PP	Spice Girls	1996	-8	0.0	5	0	2
28	The Only Thing		Bryan Adams	1996	-9	0.0	2	0	2
29	We'll be Together		Sting	1994	-12	-0.2	1	0	1
30	Off the Ground		Paul McCartney	1993	-12	0.0	1	0	1
31	I've Been to Memphis		Lyle Lovett	1992	-16	-0.9	0	0	1
32	Good Stuff	PP	B52's	1992	-12	0.0	5	0	2
33	Gloria's Eyes		B. Springsteen	1992	-11	0.0	0	0	1
34	Mysterious Ways		U2	1991	-11	-0.1	0	0	1
35	Something to Talk...		Bonnie Raitt	1991	-14	-0.9	0	0	1
36	Black or White	PP	Michael Jackson	1991	-11	-0.2	0	0	1
37	The End of the...		Don Henley	1989	-13	-2.2	0	0	1
38	Dirty Blvd		Lou Reed	1988	-14	-0.2	0	0	1
39	Nick of Time		Bonnie Raitt	1989	-17	-2.1	0	0	1
40	Living in America		James Brown	1986	-16	-2.6	0	0	1
41	Graceland		Paul Simon	1986	-16	-3.4	0	0	0
42	Two Tribes	PP	Frankie Goes...	1984	-6.5	-0.7	1	0	1
43	She Took Off My...		David Lindley	1981	-13	-1.9	0	0	1
44	Little Sister		Ry Cooder	1979	-22	-8.7	0	0	0

- James Brown (1986): average at -16 dB, peak at -3.4 dBFS
- Back Street Boys (2000): average at -5 dB, peak at 0 dBFS

7.26. Loudness War: Listening

- The Roots: Ital (The Univesal Side) (Illadelph Halflife, 1996)
- The Roots: Guns are Drawn (The Tipping Point, 2004)

7.27. Reading: Horning

- Horning, S. S. 2002. “From Polka to Punk: Growth of an Independent Recording Studio, 1934-1977.” In *Music and Technology in the Twentieth Century*. H. Braun, ed. Baltimore: The Johns Hopkins University Press. 136-147.
- What are some of the large-scale trajectories Horning illustrates over the life of the Cleveland Recording Company?
- What tools and approaches were borrowed from German audio engineers?
- What sort of technologies did Hamann develop?
- Horning describes recording studio innovation as contingent, multi-causal, and decentralized: explain her use of these terms.

Chapter 8. Meeting 8, Recording: Musique Concrète and Electronic Music

8.1. Announcements

- Quiz next meeting, on Thursday
- Discussion workshop meeting on Thursday; bring laptops, have PD working, install Martingale, install Audacity
- No class next Tuesday (Monday schedule)

8.2. Listening: Ruttman

- Walter Ruttman, Wochende (1930)
- A sound-portrait of a weekend
- Sampling, montage, and the inspiration of film (La Motte-Haber 2002, p. 201)
- Employed sound on film audio recording; permitted editing and splicing like tape
- How are narrative and musical elements developed?

8.3. Predecessors of Concrete Music

- Respighi: includes pre-recorded sounds of birds in performance of *The Pines of Rome* (1924) (Holmes 2008, p. 43)
- 1930: Grammophonmusik and Trickaufnahmen Experiments of Hindemith and Toch (Holmes 2008, p. 43)
- 1939: Cage *Imaginary Landscape No. 1*: variable speed-turntables playing test records as a sound source (Holmes 2008, p. 45)

8.4. Listening: Schaeffer

- Pierre Schaeffer, *Quatre études de bruits, 3. Etude aux chemins de fer*, 1948
- One of five studies of noise

8.5. Musique Concrète: Schaeffer

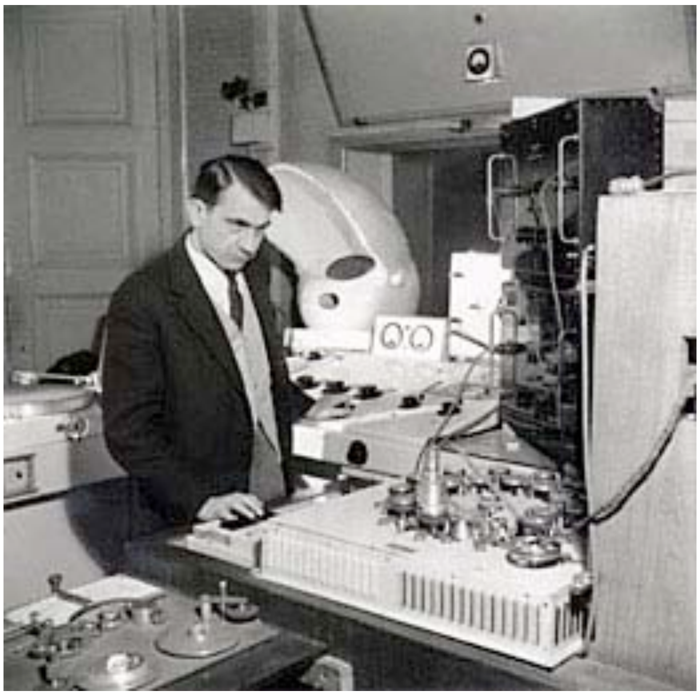
- Trained as a radio engineer for Radiodiffusion-Television Française (RTF)
- Early work in a radio opera, combining non-musical sounds in a radio montage: 1944: La Coquille à planètes
- Employed ideas of "sound object" from Abraham Moles (Holmes 2008, p. 45)
- Goal of music made concretely, working directly with sounds, not music made abstractly, with symbols (scores)
- Any sound source could become musical

8.6. Musique Concrète: Original Techniques

- In the late 1940s Schaeffer employed radio equipment at RTF
- Recording directly to disc: no tape
- Playback and mixing from four turntables (Holmes 2008, p. 49)
- Microphones, audio filters, reverberation units
- Sound effects libraries for radio
- Lockgrooves as loops (Holmes 2008, p. 49)
- 1951: Schaeffer organizes studio with tape-based recorders, forms Groupe de Recherche de Musique Concrète, by 1958 becomes Groupe de Recherches Musicales (GRM)

8.7. Early Tape Music: Tools and Techniques

- Cutting, splicing, and mixing
- Creative cutting to mask, fade, and alter amplitudes (Holmes 2008, p. 126)
- Altering and reversing playback speed of tape [samplePlayer.pd]
    - With recording device
    - With a keyboard: the Phonogène à clavier (1952)



- Filtering
- Amplitude envelopes, amplitude modulation, ring modulation
- Delays, loops, echos, feedback, and reverbs
    - With tape-based devices
    - With physical re-recording devices

8.8. The Click

- When a signal is forced to jump to zero, a high frequency click occurs

- Can happen when cutting between tape or digital audio
- A technical error more often than an aesthetic choice [signalWaveforms.pd]

8.9. Listening: Schaeffer

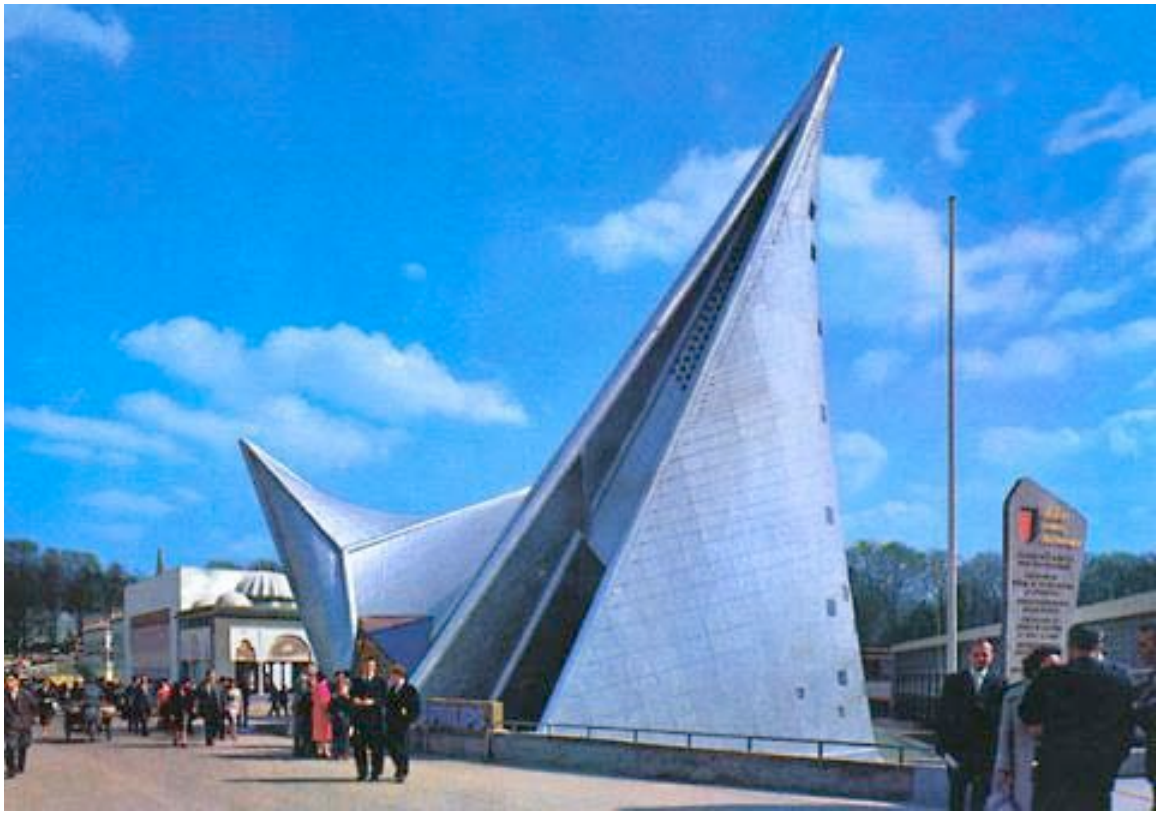
- Pierre Schaeffer, *Etude aux objets, 2. Objets étendus* , 1959
- Extended, or wide, objects

8.10. Listening: Le Caine

- Hugh Le Caine, Dripsody (1955)
- Transformations of a single sound source as an organizing principle

8.11. The 1958 Brussels World's Fair

- Brussels Worlds Fair, Philips Pavilion, 1958
- Building "designed" by Le Corbusier (1887-1965) with Xenakis as assistant



- Xenakis based his design on structures used in the composition of a musical work

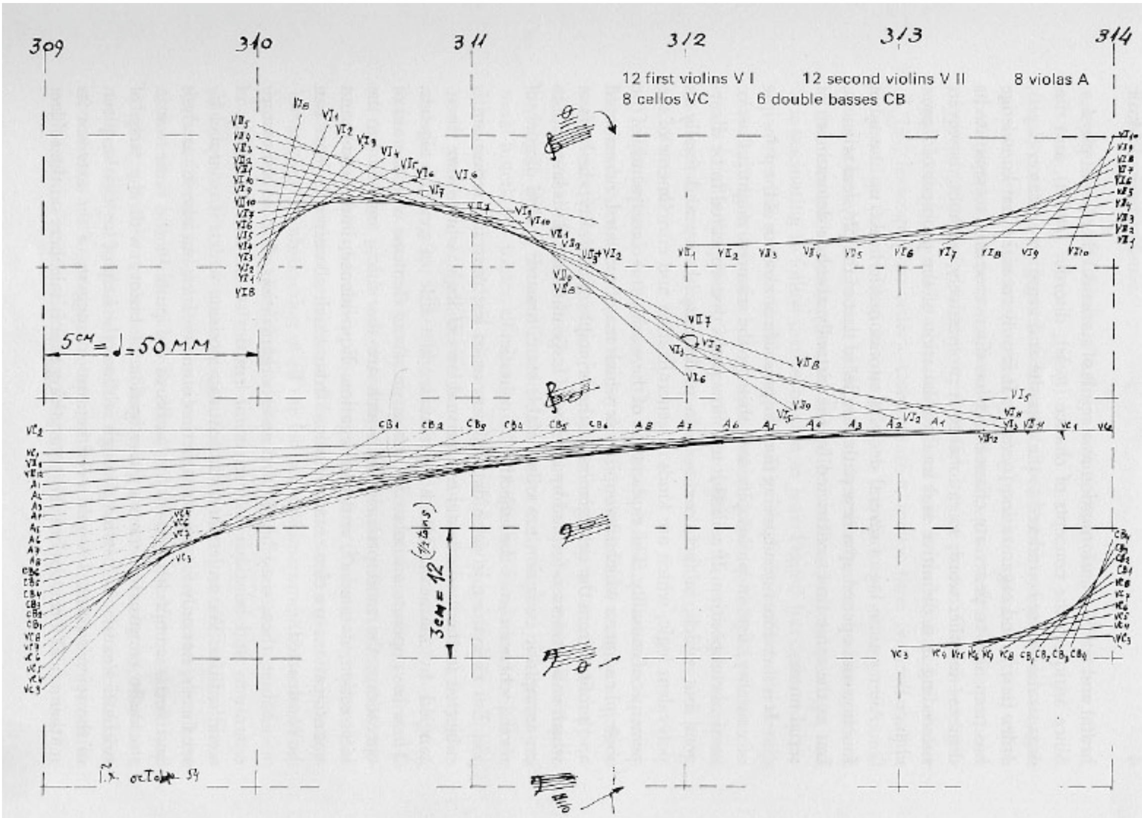
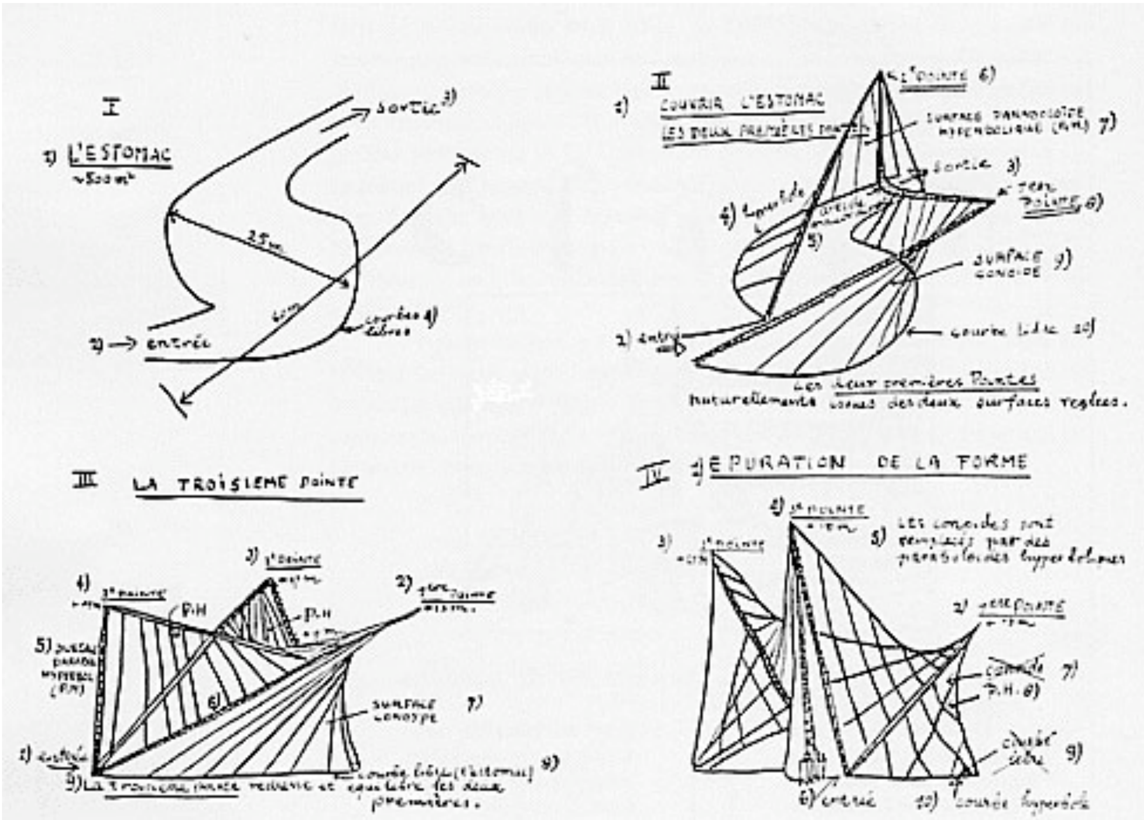


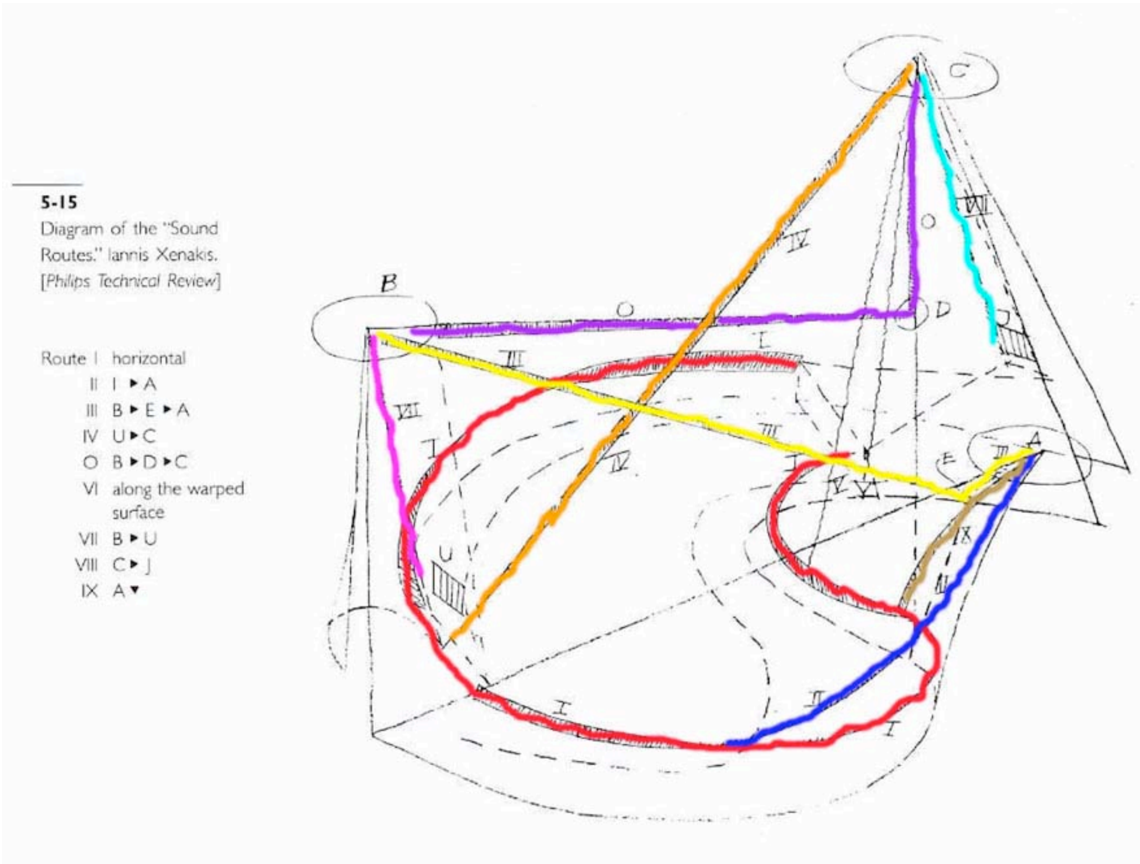
Fig. I–2. String Glissandi, Bars 309–14 of *Metastasis*

Source: Xenakis, I. *Formalized Music: Thought and Mathematics in Music.* Hillsdale, NY: Pendragon Press, 1992.



- Projected image montages by Philino Agostini
- Entry music by Xenakis

  Xenakis: "Concret PH" (1958)
- Main music by Varèse
- Developed using tools at the Philips laboratory in Eindhoven
- 350 speakers, mounted on walls, with 10 on the floor



- 500 people saw the 10 minute performance at a time; 2 million had seen it by the end of the Worlds Fair
- Varèse: Poem Electronique, 1958
- First electroacoustic work integrated with an audiovisual context (Lombardo et al. 2009, p. 24)
- Thematic organization (Lombardo et al. 2009, p. 24)

Table 1. Thematic Sections of *Poème Électronique*: Selection of Images from the Film and Sounds from the Music Soundtrack

Section	*Film images*	*Sounds*
Genesis 0″–60″	Le taureau [the bull], Le toréador [the bullfighter], Tête du jour de Michel-Ange [Head of the day of Michelangelo], Un film animé: un visage de femme s'éveillant, souriante puis ahurie [An animated film: a face of woman awakening, smiling, then dazed]	Bell, Wblock, Oscsweep, Ebtuplets, HisynSwell, GrainAb, Osc's, LoblipE-B, Metalshake
Spirit and Matter 61″–120″	Crane [Skull], Objets L.C. [Objects from Le Corbusier's collection], Les quatre savants [the four wise men], Tête de nègre Congo [Congolese head], Tête de fille Monebutu [Head of Monebutu girl], Courbet femme couchée [Courbet's woman lying down], Art Sumérien [Sumerian art], Squelette d'homme et dinosaurien [Skeleton of man and dinosaur], Les masques esquimaux [Eskimo masks]	Oscshake, 4hits, Shakes, Machinesweep, 3squeeks, 4bassoonnotes, Sigh, Bassoonsolo, Gulls
From Darkness to Dawn 121″–204″	Yeux de hibou [Eyes of owl],Tête de pintade [Head of guinea fowl], Les écrans sont blancs [White screens], Statue Dieu de la guerre [God of war statue], La main du squelette de Cro-magnon [Hand of Cro-magnon skeleton], Camp Ohreruf [Ohreruf Camp], Jouets d'enfants [Children's toys], Descente de croix de Giotto [Giotto's descent from the cross], Christ, Vierge et enfant [Virgin and child], La vierge de douleur [Virgin of pain]	Timpani, Tju-tja, Tjukketjuk, WhistleFinger, Oempang, pss-pss, Parabool, Tok-Tok, Reeds
Man-Made Gods 205″–240″	Île de Pâques [Easter Island], Tôto Angkor, Coquillages L.C. [Le Corbusier's shells], Bouddha [Buddha], Art Baga nègre [Black Baga art], Le signe de Mahomet [Muhammad's sign], Les mains de Bouddha [Buddha's hands]	Shakers, Slowblocks, 4notes, Vox_lowtrill, Uhh-gah, Wehweh, 4-blocks, Ooo
How Time Molds Civilization 241″–300″	Variations sur la tête et les outils de l'ingénieur atomique [Variations on the head and the tools of the atomic engineer], Variations sur la foule [Variations on crowd], Stratosphère	Longooo, Voxperc-hit, Percmusic, Vocal, Lowtamhit, Footsteps, Lf-beasts
Harmony 301″–360″	Télescope, Radar, Fusée et lune [Rocket and moon], Les L43 regardent [The L43s look], Les explosions nucléaires [The nuclear explosions], L'écheveau embrouillé [The tangled hank], Les treillis ordonnées de la tour Eiffel [The ordered wire grills of the Eiffel tower], Ballet des éléments mécaniques [Dance of mechanic elements], Visages [Faces]	Osc-cluster
To All Mankind 361″–480″	Laurel et Hardy, Galaxie [Galaxy], Eclipse solaire [Solar eclipse], Flammes solaires [Solar flames], Charlot, 2 amoureux sur un banc [2 in love on a bench], Noir [Black], Les bébés [Babies], Les 4 gratte-ciel Paris [The four Paris skyscrapers], New-York hirsute [Shaggy New York], Chandigarh, Nantilus Modulor, Le plan de Paris [The plan of Paris], Le plan dessiné au fusain extrait du film Kast [The plan drawn in charcoal, extracted from the film *Kast*], Jeu des 2 enfants [Game of 2 children], La main ouverte [The open hand], Femme seule [Solitary woman], Clochard [Tramp], Gosses [Kids], Le chemin dans la boue [The path into the mud], Le ballet des bébés [Dance of babies]	Lowperc, Loworgan, Drums, Highblocks, stereojet, Metalclang, Electricbell, Scrapes, Timbales, Organbursts, Highticks, Tonebend, Tone2jet

The descriptive names of the images and sounds are either original names from the scenario and the 30-second control score ("Tju-tja," "Tjukketjuk," etc.; see Figure 4) or guesses using a similar style ("Footsteps," "Uhh-gah," etc.). The sounds can be easily recognized in listening to the *Poème.*

Source: Lombardo, V., et al. "A Virtual-Reality Reconstruction of *Poème Électronique* Based on Philological Research" *Computer Music Journal* 33, no. 2 (Summer 2009): 24-47. Courtesy of MIT Press. Used with permission.

8.12. Cologne and Paris

- 1951: NWDR (Northwest German Broadcasting) organizes electronic music demonstration and lectures with Werner Meyer-Eppler, Herbert Eimert, and others
- Leads to formation of a studio (later WDR) under the direction of Eimert
- Post WWII tensions
- Musique Concrète as "fashionable and surrealistic" (Holmes 2008, p. 58)
- Serialism as an organizing principle for electronic music

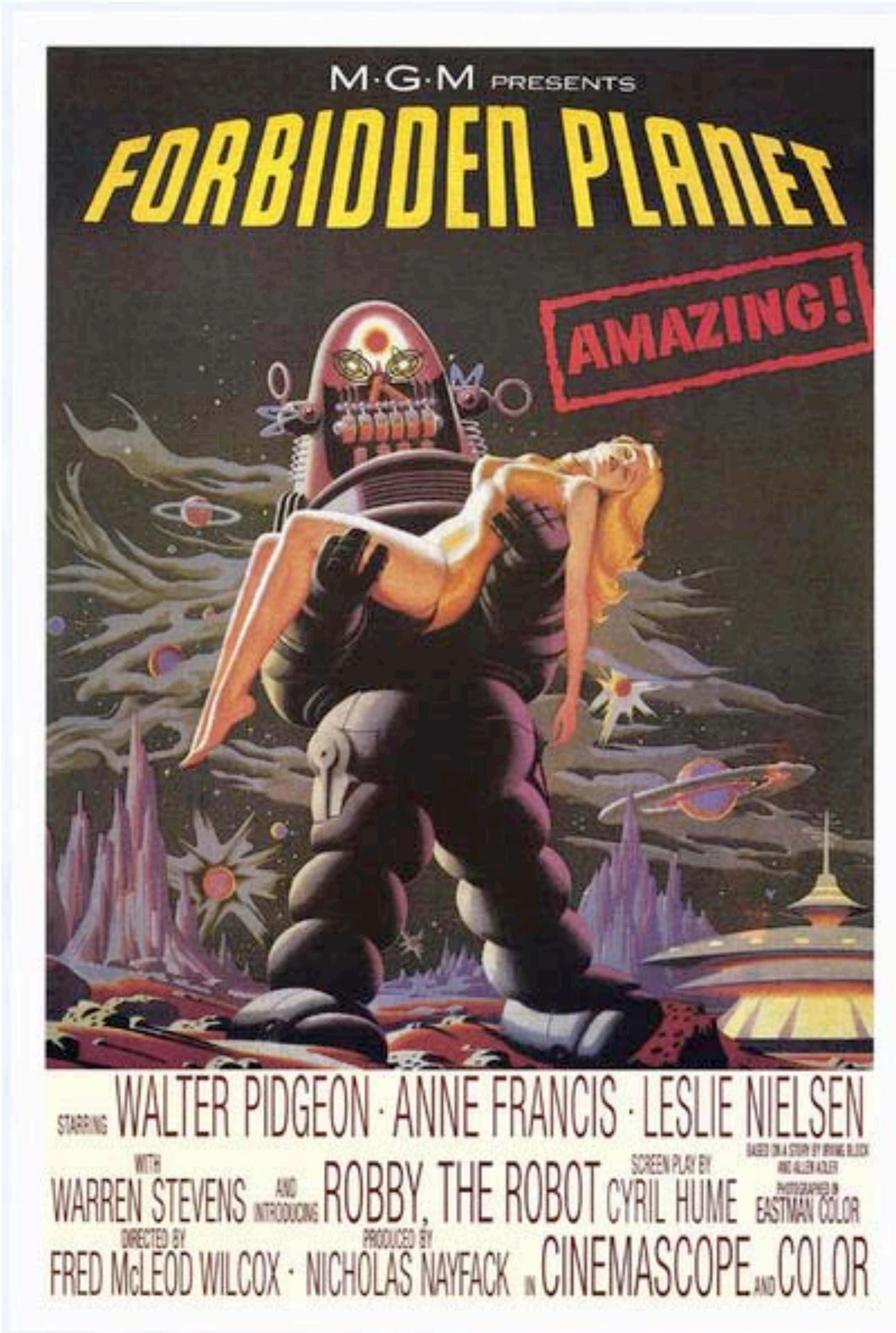
- Aesthetic position of order and control (sound sources, compositional methodology)
- Eimert, *Klangstudie II*

8.13. Listening: Stockhausen

- Stockhausen, *Studie I*
- Application of serial procedure to tape composition (Holmes 2008, p. 63)
- Stockhausen, *Gesang der Jünglinge*, (1955-56)
- Composed for 5-channels
- Integration of voice and electronics, with singer actually imitating pitches of electronic sound (Holmes 2008, p. 66)

8.14. Electronic Music in Cinema: Forbidden Planet

- Louis and Bebe Barron


M·G·M PRESENTS
FORBIDDEN PLANET
AMAZING!
STARRING WALTER PIDGEON · ANNE FRANCIS · LESLIE NIELSEN
WITH WARREN STEVENS AND INTRODUCING ROBBY, THE ROBOT
SCREEN PLAY BY CYRIL HUME
PHOTOGRAPHED IN EASTMAN COLOR
DIRECTED BY FRED McLEOD WILCOX · PRODUCED BY NICHOLAS NAYFACK
IN CINEMASCOPE AND COLOR

1956: "In the year 2257, a spaceship ventures to the planet Altair-IV, where an Earth colony had mysteriously vanished years earlier. There, Commander Adams and his crew meet colony survivors Dr. Morbius, his daughter Altaira, and their mechanized servant, Robby the Robot. But to their dismay they also come into contact with an invisible monster which attacks their spaceship! In order to survive the attack, the crew embarks on a mission more fascinating and complex than they could ever have imagined."

- Clip viewed in class: Opening credits

- Clip viewed in class: Ship landing

- Clip viewed in class: Climatic scene

- Clip viewed in class: Interview with Bebe Barron

Chapter 9. Meeting 9, Discussion and Workshop

9.1. Announcements

- No class next Tuesday (Monday schedule)
- Make appointments to meet with me to talk about projects

9.2. Tape Processes

- Working with tape promoted procedural approaches to creating music
- Acoustical compositional practices of serialism, indeterminism, and minimalism suggested organizing principles

9.3. Quiz

- 10 Minutes

9.4. Workshop: Sound Sequencing and Layering

- Open Audacity or another DAW; create three tracks
- Mute the first audio track; place a few sound files in this track
- Select and copy regions of audio from this track to the second and third tracks
- Use changes in amplitude to fade and cross fade between these two tracks
- Repeat, edit, listen, compose

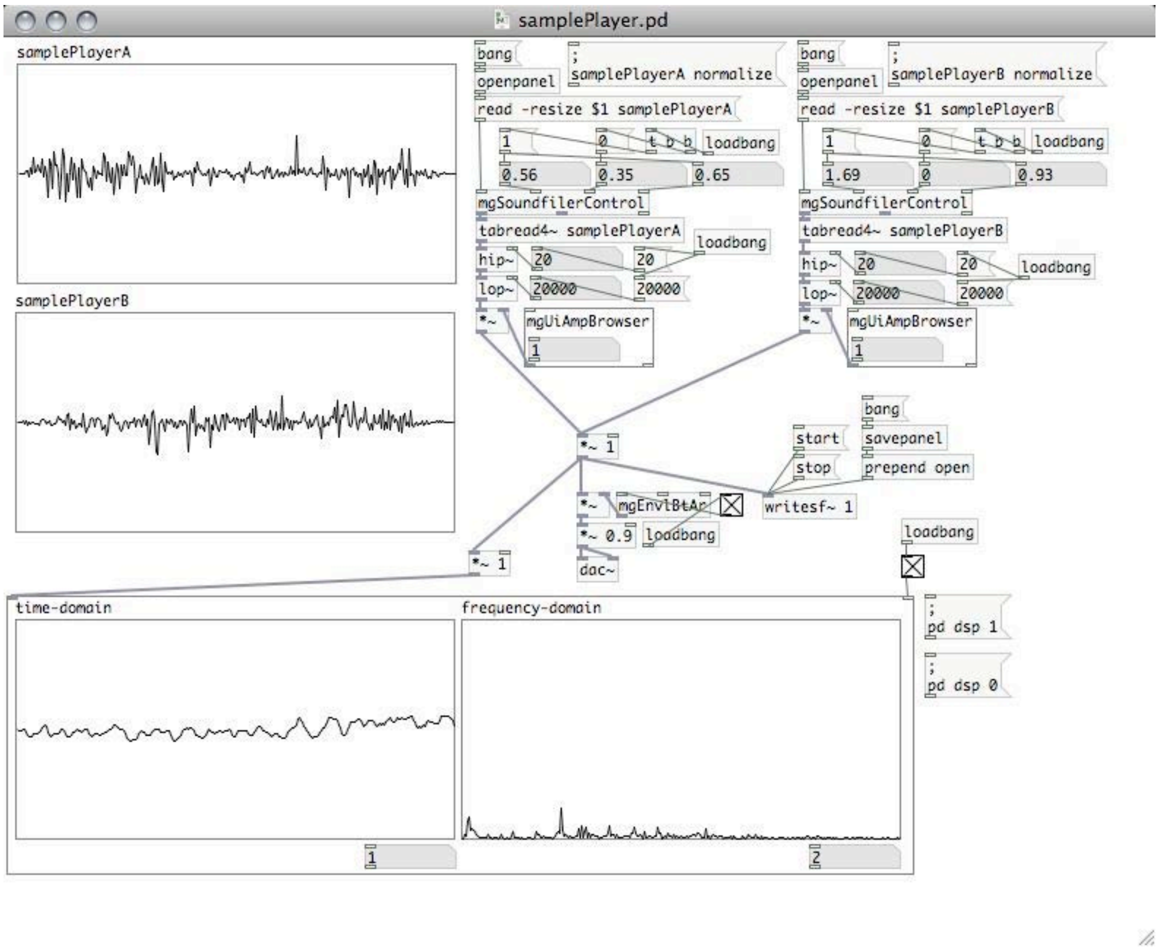
9.5. Listening: Cage

- John Cage (1912-1992)
- 1951: Cage, with grant form Paul Williams, *Project of Music for Magnetic Tape* in New York
- Works with studio and equipment of Luis and Bebe Barron
- Composes *Imaginary Landscape No. 5*, employing audio from 42 records organized into multiple tape parts cut according to chance operations

- Cage commissions Barrons to create collection of field recordings
- Cage develops a system for selecting and organizing material using the I Ching
  - 8 Tapes assembled and played simultaneously
  - Toss three coins six times to generate a random number between 1 and 64
  - Random values used to select type of sound, track assignment, duration, and envelope and tape cut
  - 192 page score provides creative patterns for cutting and splicing tape (Homes 2008, p. 83)
  - Took over 9 months to compose
- Cage: "Williams Mix" (1952)

9.6. Workshop: Looping in PD

- Install Martingale, open PD
- Open demo/samplePlayer.pd



- Press "bang" above two top most [openpanel] boxes; open "sampleFrench.aif" for both samplePlayerA and samplePlayerB

- Set start and end times for both samples at .25 and .27

- Set playback speeds for each player at 1 and .98

- Repeat, edit, listen, compose

9.7. Listening: Reich

- Steve Reich (1936-)

- Influenced by techniques of minimalism based in part on music of Terry Riley, La Monte Young, and others

- Explored phasing, or phase-shifting, with tape loops: gradual changes in time alignment of loops

- Employed a recording of a Pentecostal preacher (Brother Walter) recorded in Union Square, San Francisco

- Up to eight tape loops of the same fragment of speech are layered

- Reich: “Its Gonna Rain” (1965)

- “Scorification” of a technological process for acoustic instruments

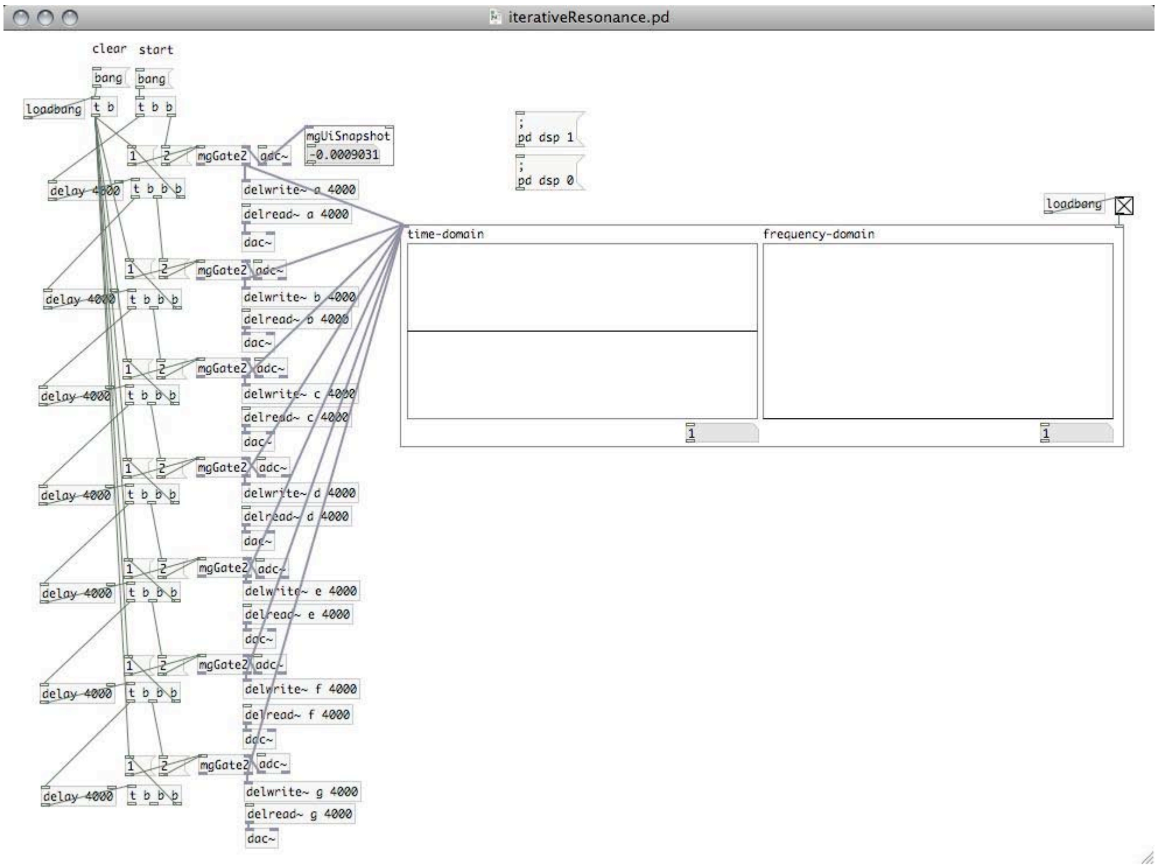
- Reich: “Piano Phase” (1967)

9.8. Listening: Lucier

- Alvin Lucier (1931-)

- “godfather of process music” (Holmes 2008, p. 395)

- Iterative re-resonance, employing filtering and noise from room, microphone, and speaker [demo/iterativeResonance.pd]



- Generations re-recorded (at least) 16 times
- Lucier: "I Am Sitting in a Room" (1969)

9.9. Workshop: The Techniques of Early Tape Music

- Install Martingale, open PD
- Open demo/samplePlayer.pd
- Load one or more samples
- Manipulate playback speed and start and end loop points
- Adjust low and high pass filters to select regions of sound

- Record sounds by first pressing the "bang" above the [savepanel] object, then pressing [start] and [stop]
- Import these sounds into Audacity or another DAW, position and layer
- Repeat, edit, listen, compose

Chapter 10. Meeting 10, Interfaces: Mechanical Automations and Innovations

10.1. Announcements

- Music Technology Case Study Draft due 3 November

10.2. Interfaces and Instruments

- A musical interfaces is a place of interaction between sound production and/or compositional ideas
- An interface, more than sound production method, quantity, or source, defines an instrument

10.3. The Organ

- A wind instrument controlled by a keyboard and pedals
- Sometimes with multiple manuals (keyboards) and stops (timbral controls)
- With the clock, one of the most complex mechanical devices developed up until the 19th century
- A locus of technological innovation: new technologies quickly adapted and incorporated
- A very old “unnatural” and “modern” instrument
  - Bellows permit continuous sound
  - Tuned pipes provide fixed pitch
  - Multiple interface types: multiple manuals, pedals, and stops
  - Custom instrument installation motivates diverse designs

10.4. The Organ: Valves as Triggers and Selectors

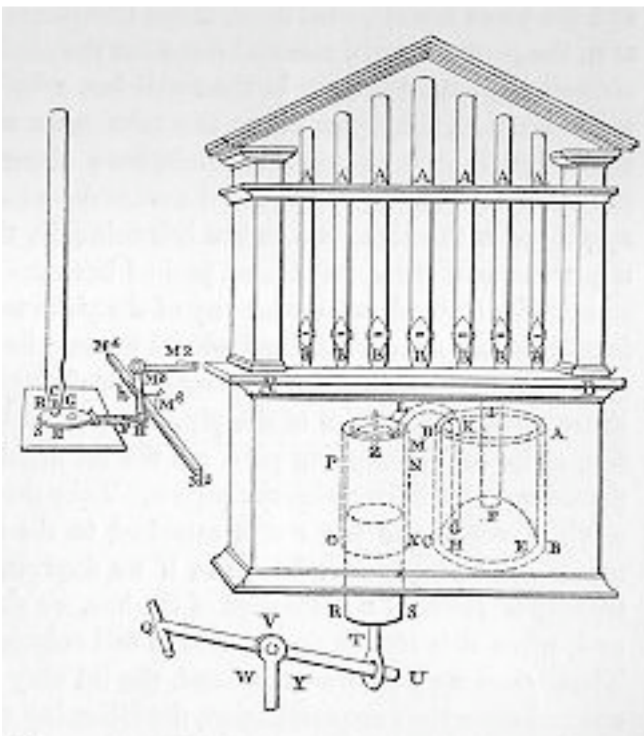
- Modern single-manual organ with suspended action

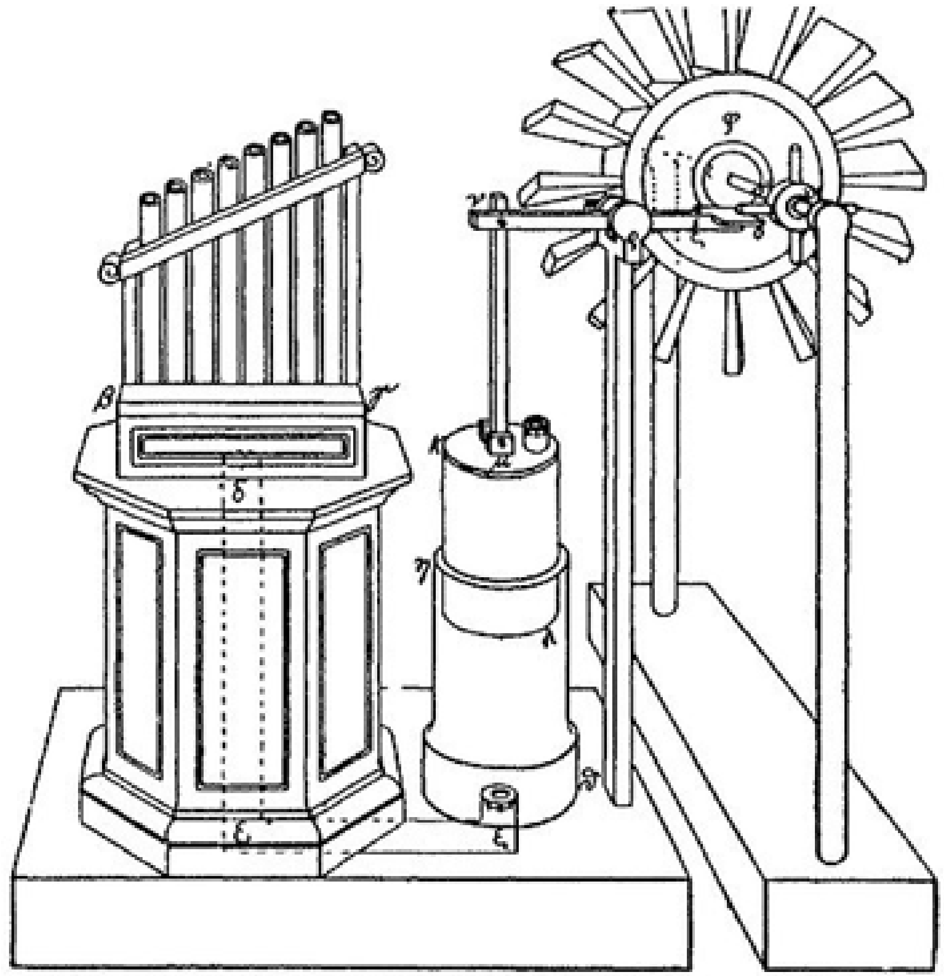
Image removed due to copyright restrictions.
"Key- and stop-mechanism of a single-manual organ with suspended action"
from Grove Dictionary of Music (Online).

- By pulling different stops, the operator could change the timbre of the instrument while playing
- Switches and slides (in addition to keys) become a musical interface

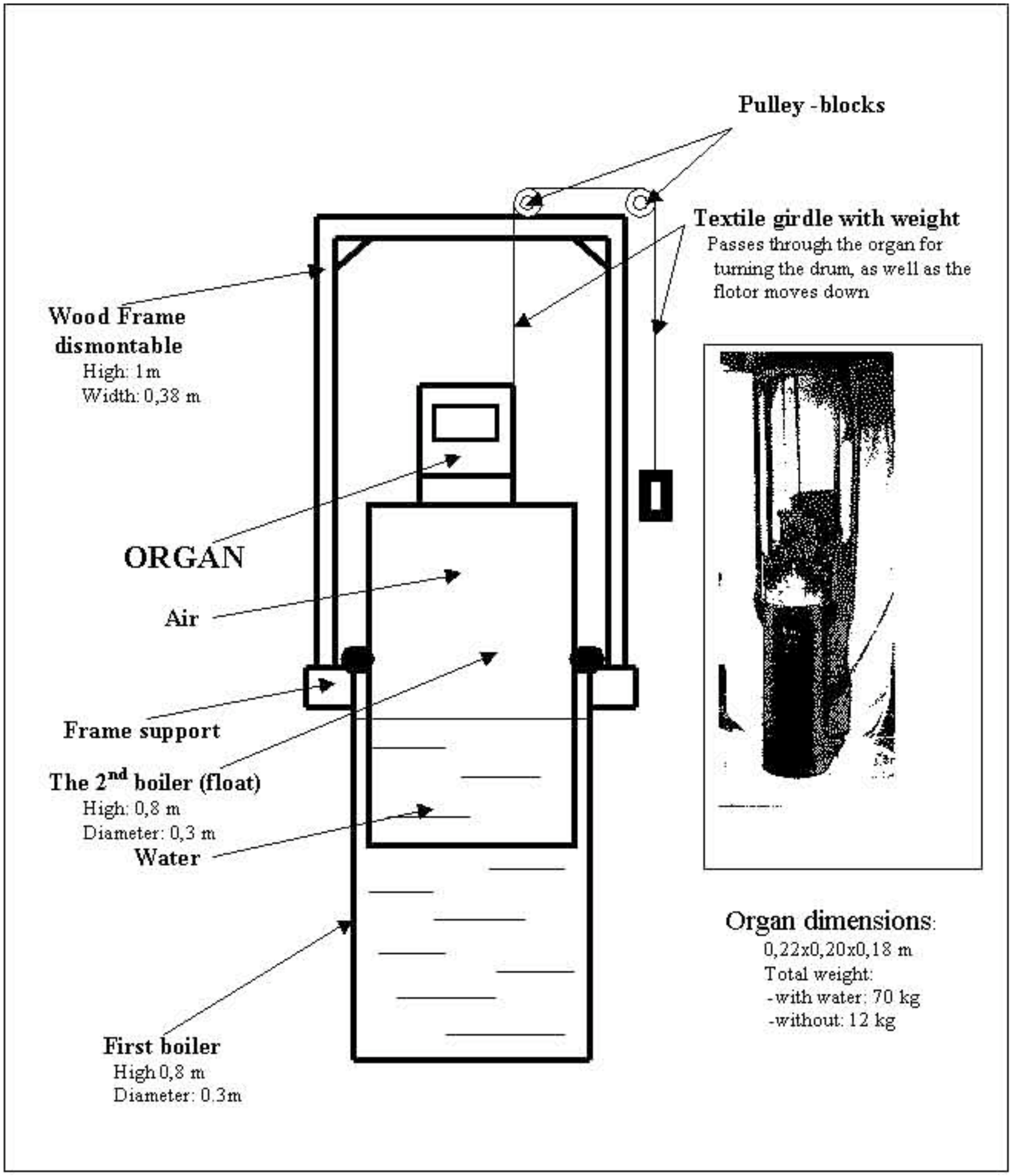
10.5. The Organ: The Hydraulic Organ (Hydraulis)

- Greeks explored pneumatics and hydraulic devices: Hero of Alexandria
- The hydraulis, hydraulos, hydraulus or hydraula: a Greek invention of 3rd century BCE
- Possibly invented by Ctesibius of Alexandria in 246 BCE
- Wind supply to the pipes regulated by water pressure





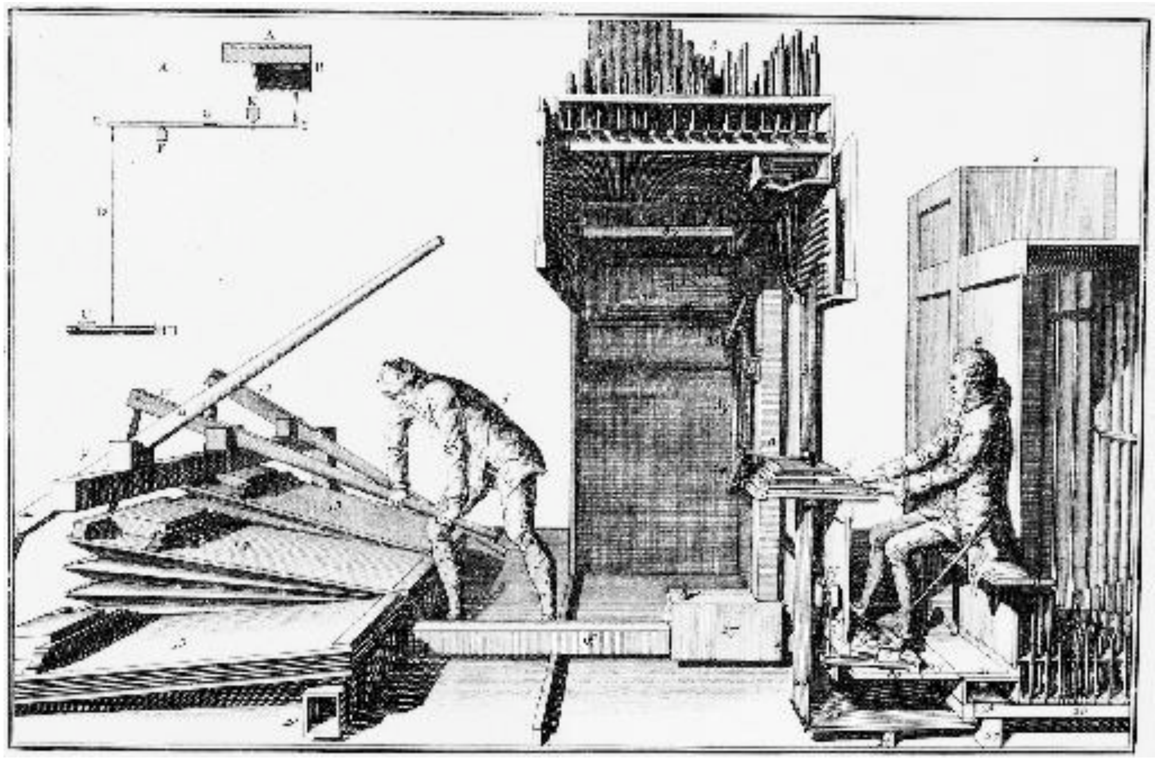
Heron's Windwheel. (1899, public domain, via Wikipedia.)



10.6. The Organ: Bellows and the Need for Air Pressure

- Need for regular air pressure leads to numerous technological solutions
- Late 15th century

- 18th century multifold bellows



YouTube (http://www.youtube.com/watch?v=qccBF1beTmY)

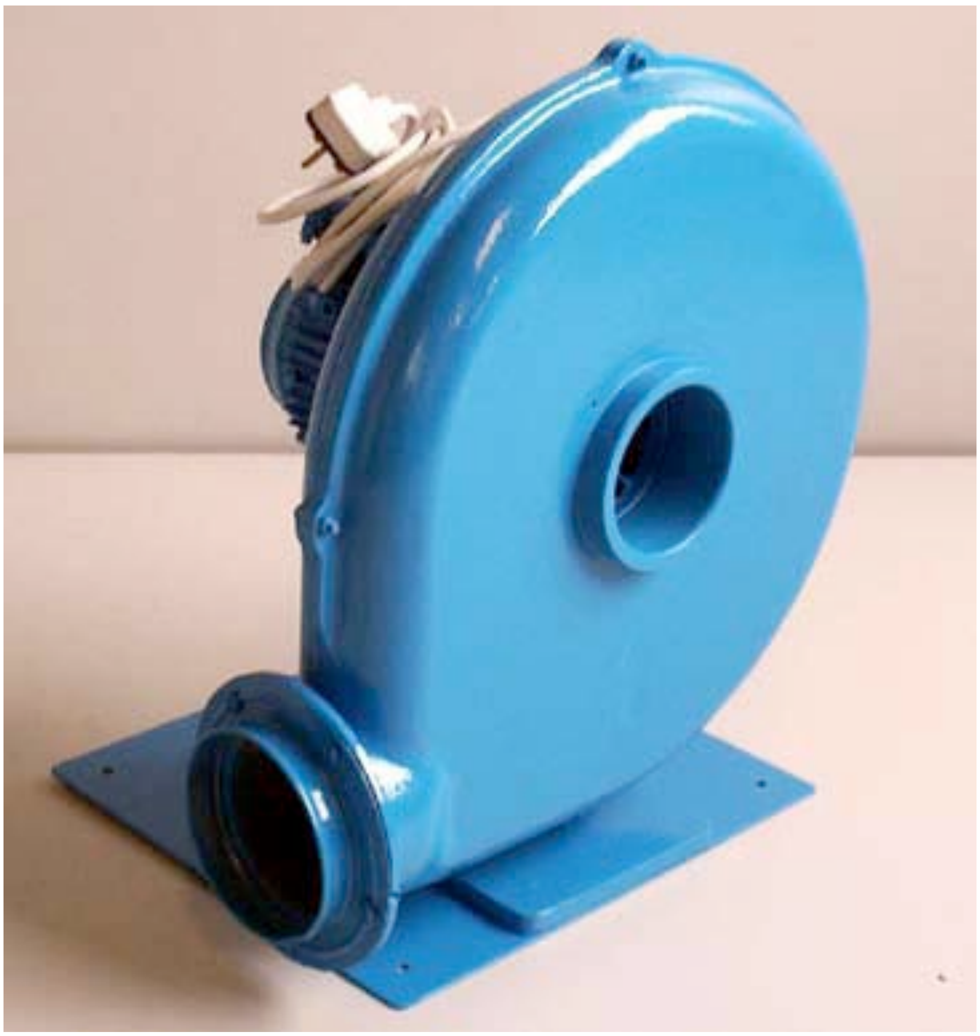
- Mid 19th century: steam power

Calliope

YouTube (http://www.youtube.com/watch?v=odMCKR54VRc)

- Early 20th century: electrical fan blowers

Courtesy of James H. Cook. Used with permission.



Courtesy of B.O.B. Stevenson Ltd. Used with permission.

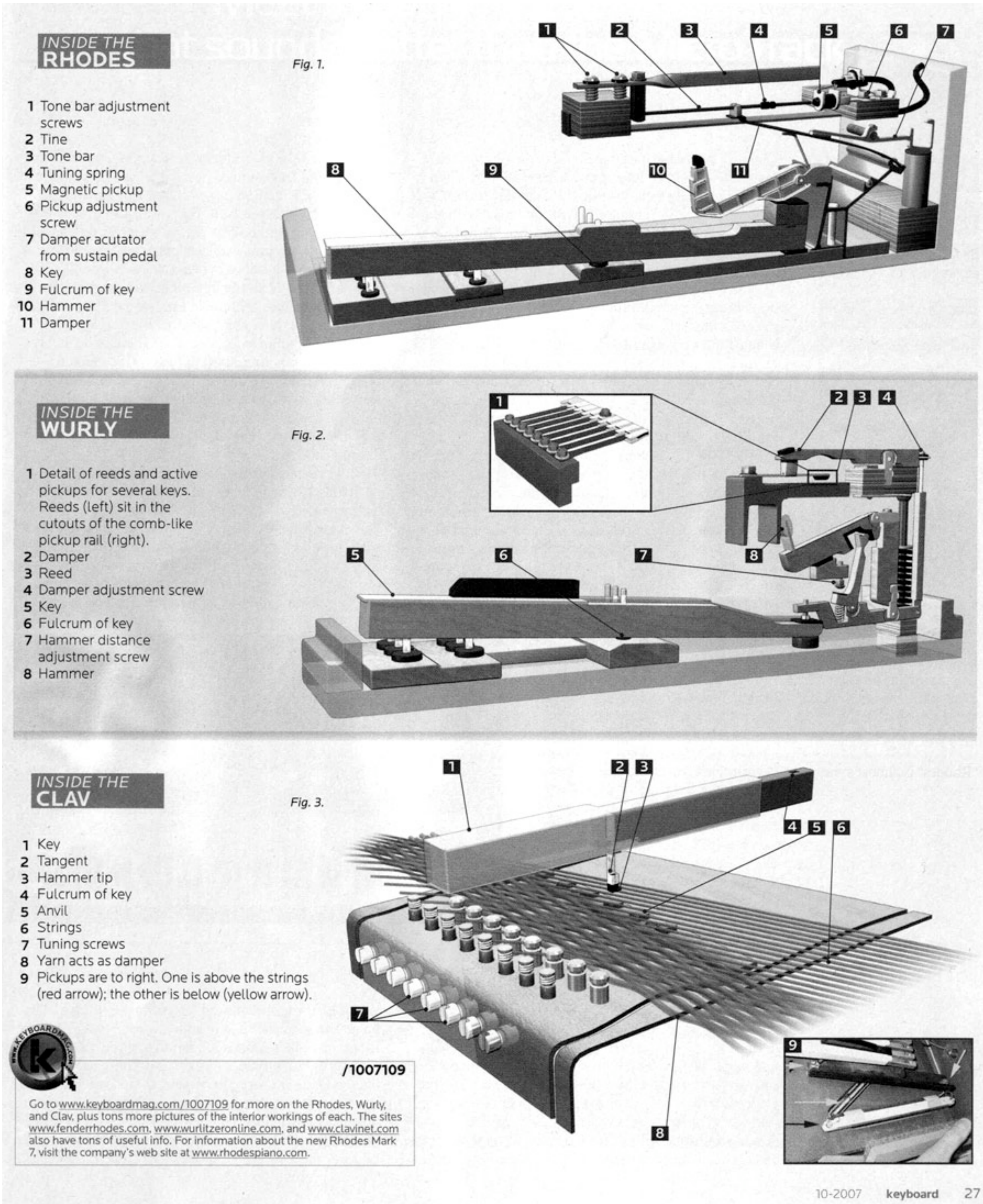
10.7. Electroacoustic Keyboard Instruments

- Electroacoustic instrument: acoustic sounds are electronically amplified

- Common approach to use brass reeds that vibrate and are then amplified with pickups
- 1934: Everett Orgatron
- 1947: Wurlitzer electric piano, based on Orgatron, produced in New York

  YouTube (http://www.youtube.com/watch?v=3bGqHuJoB9M)

  YouTube (http://www.youtube.com/watch?v=2aEL5AQG2fQ)
- Rhodes, Wurlitzer, Clavichord



- Internals of the Rhodes

  YouTube (http://www.youtube.com/watch?v=cZW00m81WW8)

10.8. Hammond B3: History

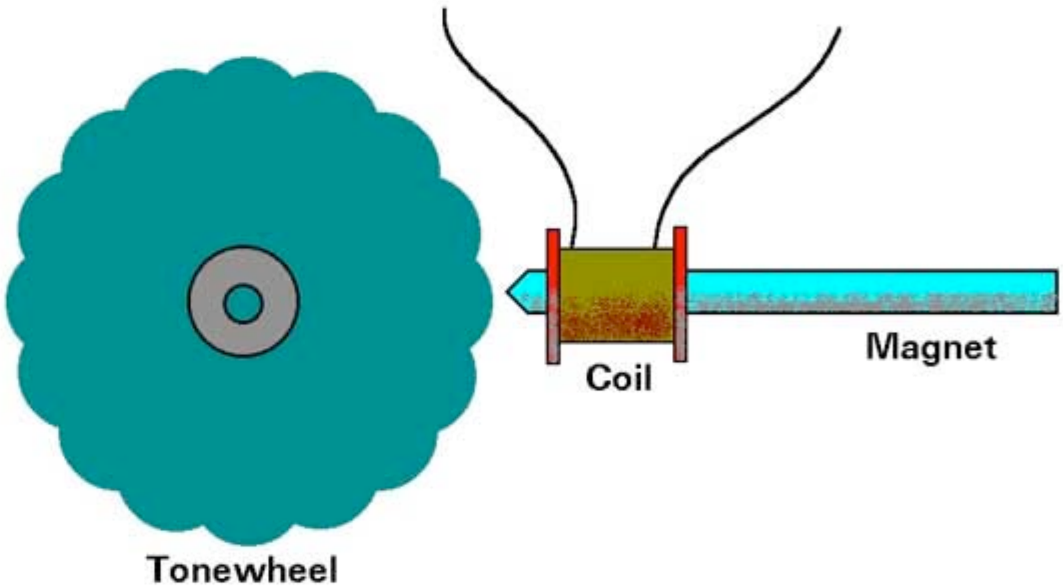
- 1935: Laurens Hammond with his instrument

- 1939: Hammond demonstrates B3 at AES in New York
- Two 61 note keyboards

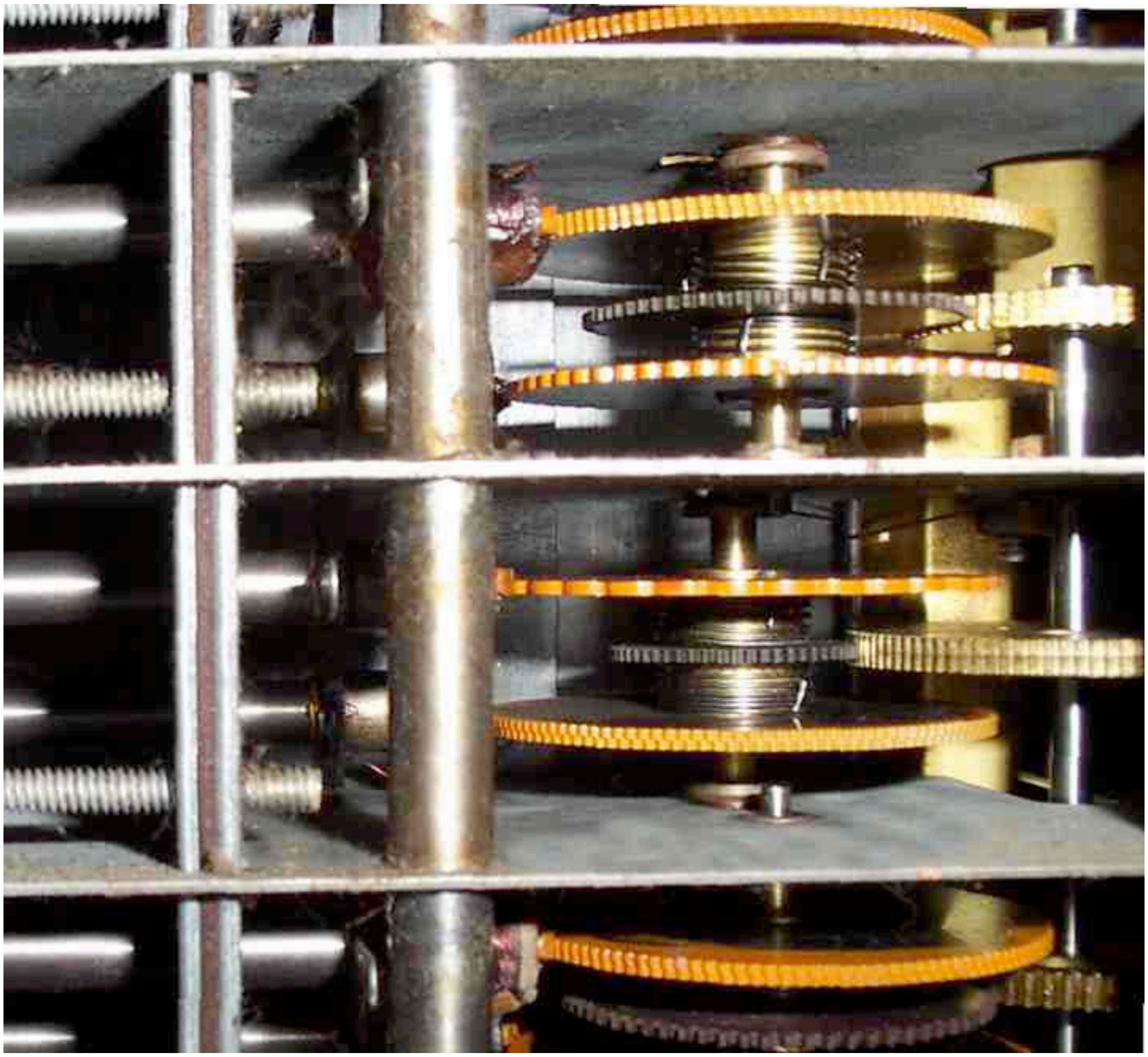
- 400 pounds

10.9. Hammond B3: Technologies

- 91 tone wheels: rotating discs that electro-magnetically generate a tone
  - Similar to a dynamic microphone, tone wheels generate a tone through electromagnetic induction

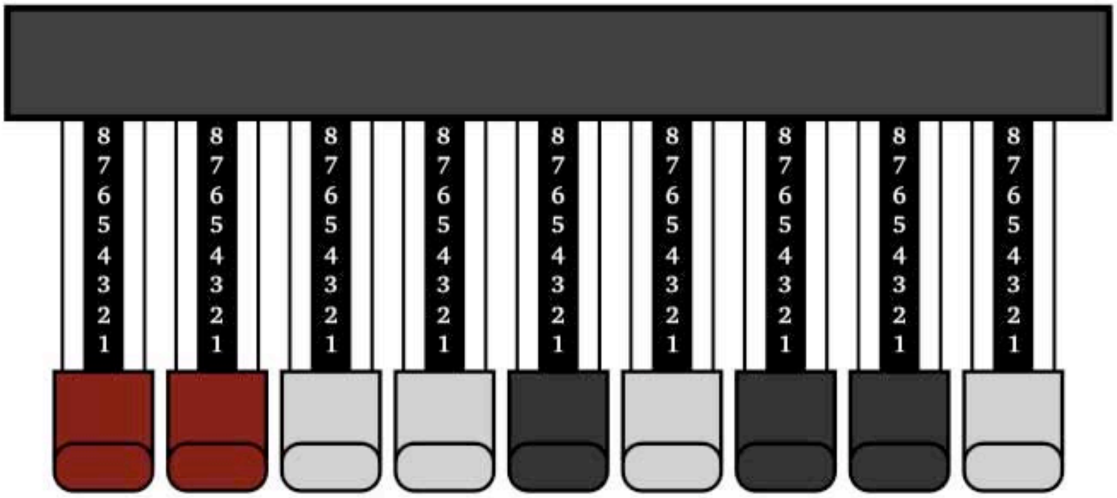


Courtesy of Eric C. Larson. Used with permission.



Courtesy of Eric C. Larson. Used with permission.

- Two sets of 9 drawbars
  - Drawbars control amplitude of harmonics: sub-octave, unison, 8th, 12th, 15th, 17th, 19th, 22nd



  - Drawbars provide an interface to additive synthesis
- Required external amplification
- Examples

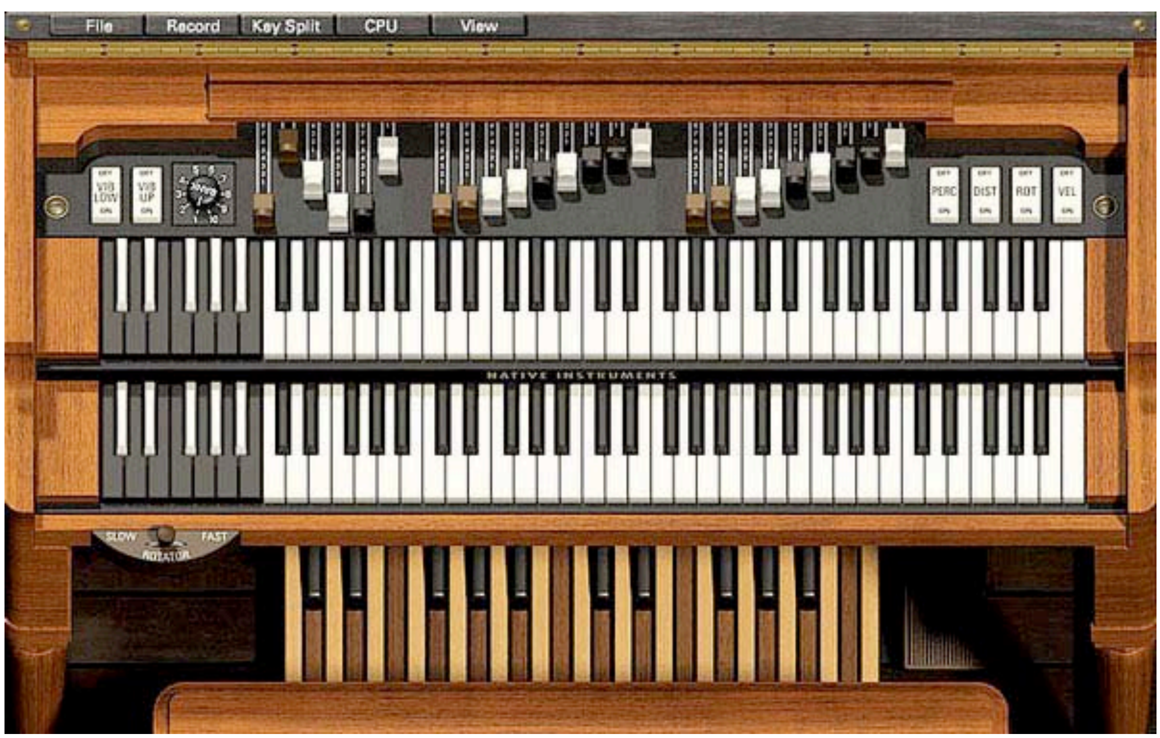
  YouTube (http://www.youtube.com/watch?v=vQUr-TKC76g)

  YouTube (http://www.youtube.com/watch?v=0nsPgSl52qY)

10.10. Hammond B3: Dynamic Timbre Control

- Drawbars permit dynamic timbre: sliders instead of stops
- Drawbars become an interface
- Hammond XK-3 ($2195): 96 Digital Tone Wheels/Vacuum Tube

- Native Instruments B4 ($199): Virtual Instrument



- Native Instrument B4D

10.11. Listening: Jimmy Smith and Wes Montgomery

- Jimmy Smith and Wes Montgomery: "O.G.D. (Road Song)" (Jimmy & Wes: The Dynamic Duo, 1966

- What gives Jimmy Smith's solo (from 2:26) a compelling forward momentum?

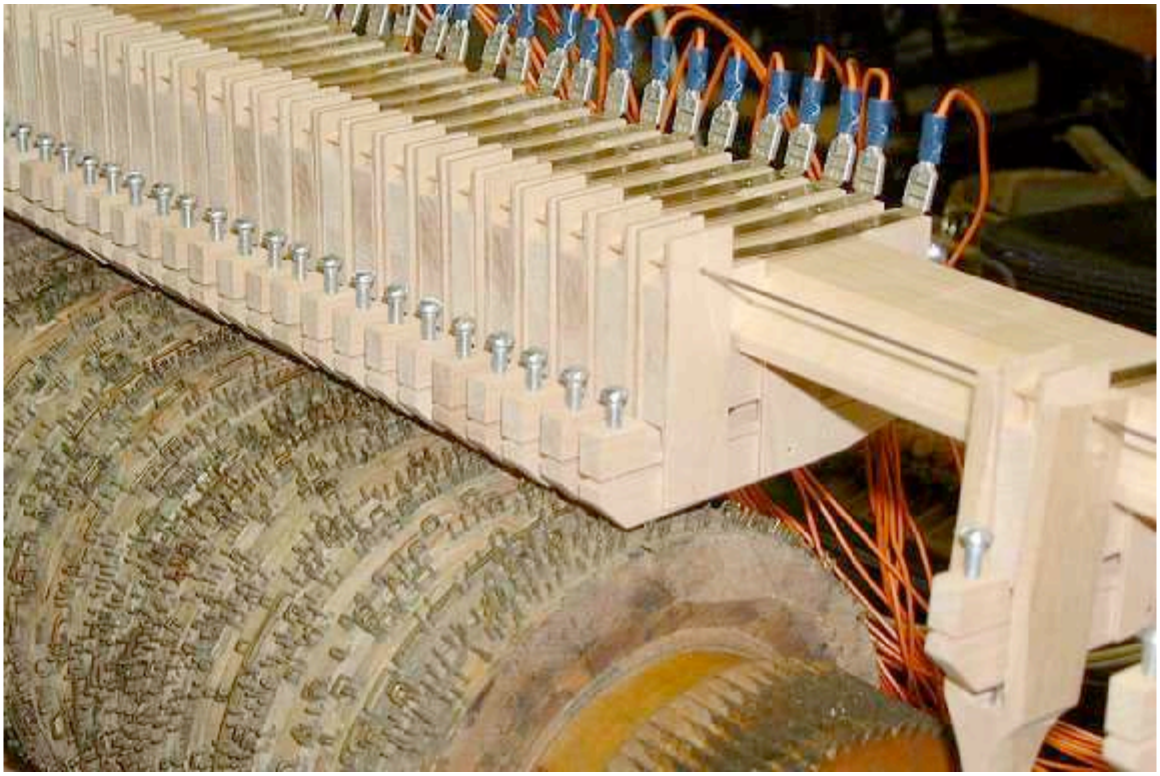
10.12. Listening: Medeski, Martin, and Wood

- Medeski, Martin, and Wood: "Hypnotized," 1998

- How is the sound of the Hammond transformed, and to what creative ends?

10.13. The Player Piano: History

- late 1800s: Barrel piano: stubs on cylinder encode music
- 1804: John Longman introduces drawing-room barrel piano with no keyboard
- 1800s: Portable barrel pianos popular street entertainment



- 1863: Henri Fourneaux develops Pianista: first pneumatic piano playing machine
- 1895: Edwin Scott Votey creates the Pianola
- 1904: Edwin Welte completes first “reproducing piano”
- 1904: Welte in Germany records a performer for use in creating player piano rolls (2002, p. 84)
- 1900-1930: 2.5 million instruments sold in U.S.
- Gramophones and radio reduced demand by 1930s
- Depression up until WWII led to demise of industry

10.14. The Player Piano: Mechanics

- Pneumatic power: paper-as-a-valve system

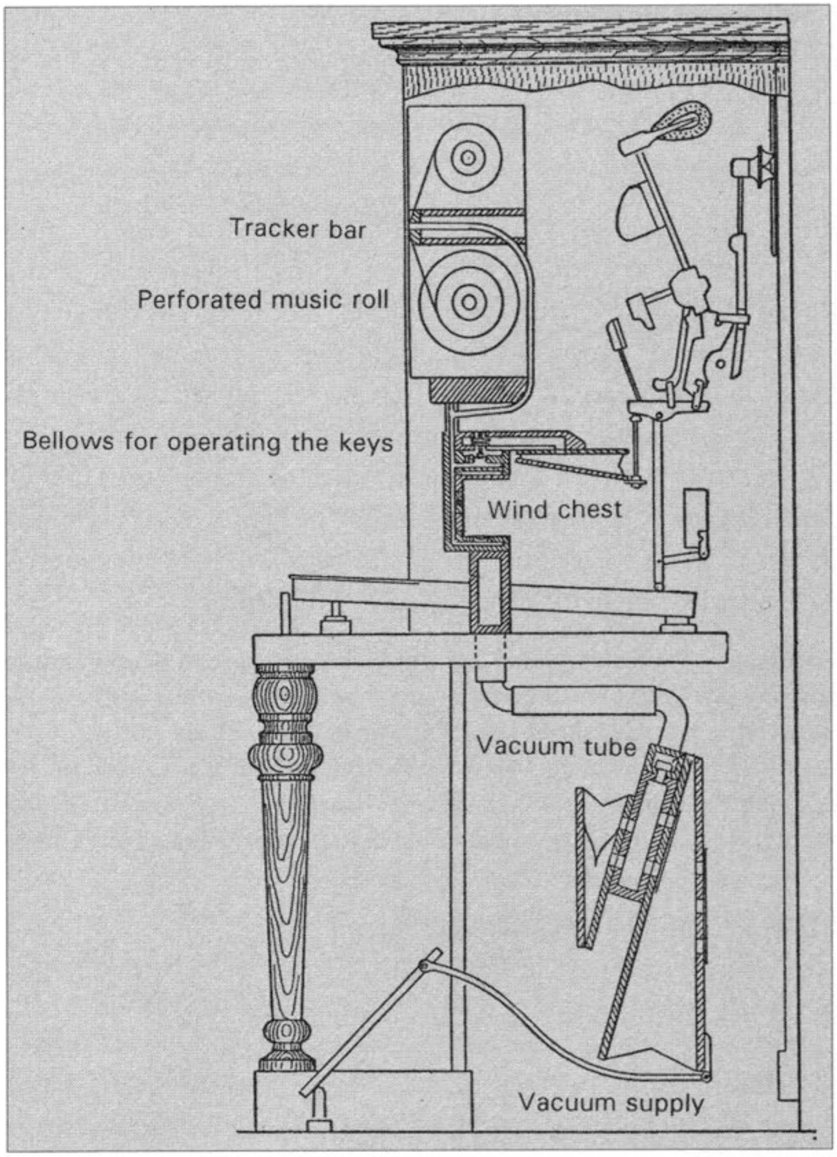


Fig. 3: Principle of a player piano

Courtesy of Jürgen Hocker. Used with permission.

Image removed due to copyright restrictions.
Player piano "Reproducing mechanism diagram" from Grove Dictionary of Music (Online).

- Ampico system: 98 tracks per line, 83 for controlling piano notes, 1 track for left pedal, 1 track for right pedal, 6 tracks for controlling bass dynamics, 6 tracks for controlling treble dynamics (Hocker 2002, p. 88)

- Player piano in motion

  YouTube (http://www.youtube.com/watch?v=MhSnUprw7XY)

YouTube (http://www.youtube.com/watch?v=0GfKEv12-sg)

- Alternative approaches

10.15. Conlon Nancarrow

- Conlon Nancarrow (1912-1997)
- Born in Arkansas, fought in Spain against Franco, emigrates to Mexico
- Influenced by Henry Cowell's recommendation perform complex rhythms on player piano (Hocker 2002, p. 87)
- Frustrated with limitations of human players
- 1947: Bought a player piano roll cutting machine
- 1949: First original composition for player piano
- Composes 49 studies for player piano
- First 20 studies written out in standard notation (Hocker 2002, p. 90)

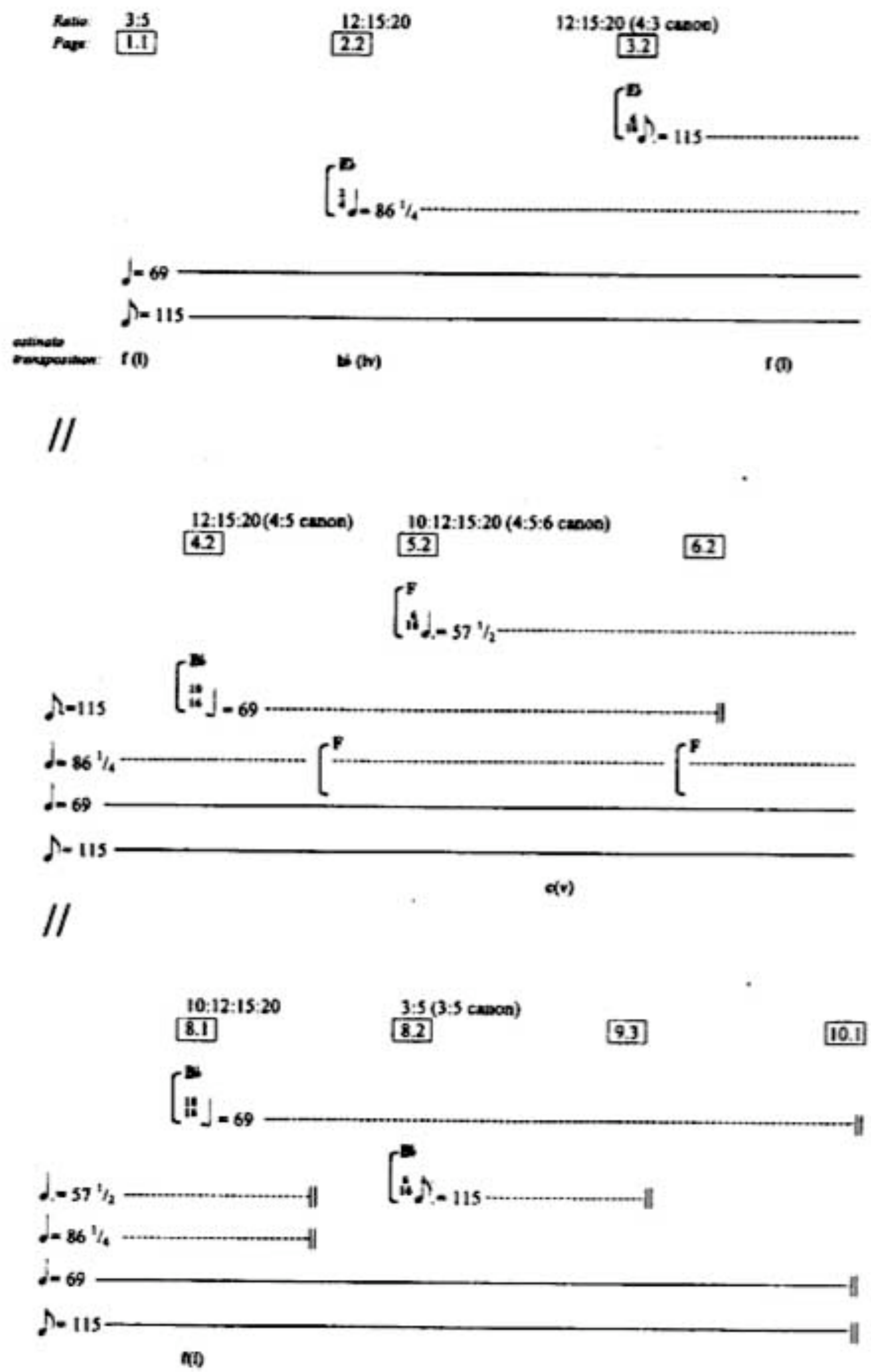
- Explored speeds and densities idiomatic to the player piano
    - Player piano: 200 notes / second (Human: 15 notes per second)
    - Player piano: 40 notes at once (Human: 12-15 notes at once)

10.16. Conlon Nancarrow: Music

- Idea of temporal dissonance (Hocker 2002, p. 93)

  Examples via Frere Jacques (http://willshare.com/willeyrk/creative/papers/study37/tempdiss.htm)
- Often used poly-tempi and poly-meter
- Complex temporal canons
- Precise ratio-based acceleration and deceleration
- Study 2

Example 5. Nancarrow, Study No. 2.
Summary of tempos and material.



Courtesy of Margaret Thomas. Used with permission.

- Study 25

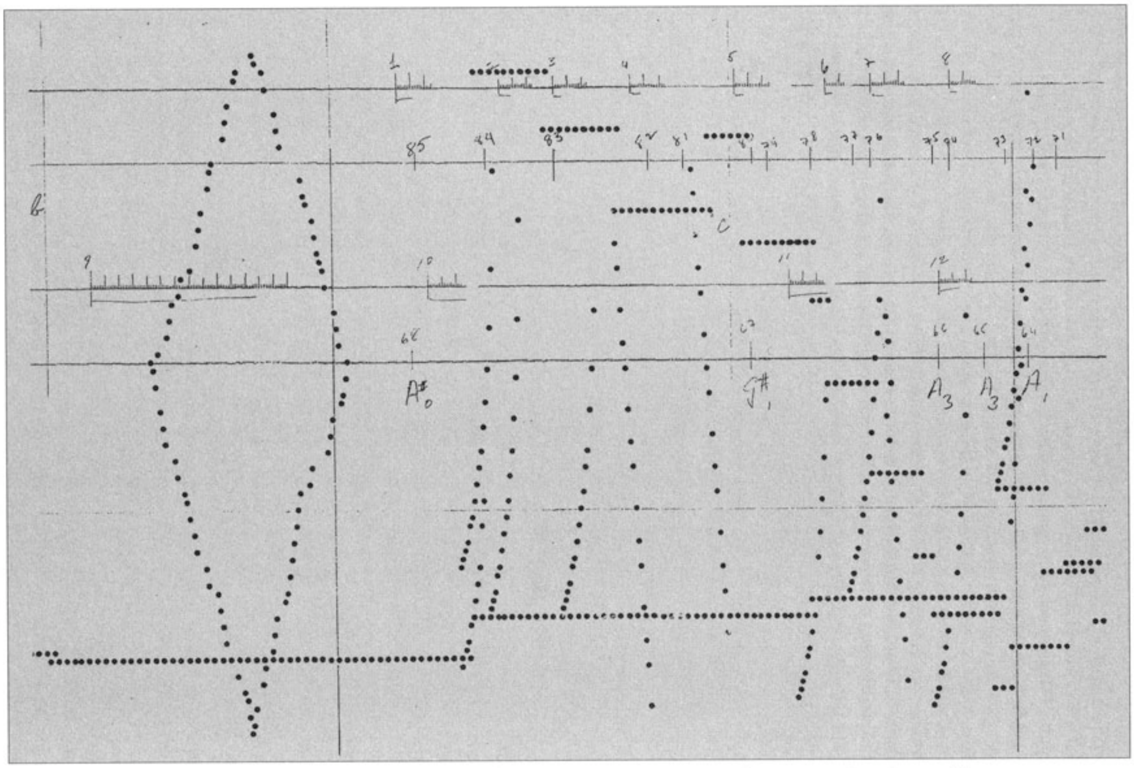


Fig 4: Conlon Nancarrow, Study No. 25. Section of the piano roll. Single points (perforations in the piano roll) are staccato notes. Horizontal rows of perforations show sustained notes. Nancarrow used different scales for the different speeds of voices.

10.17. Listening: Conlon Nancarrow

- Conlon Nancarrow: "Study #1"

- Conlon Nancarrow: "Study #36"

10.18. Reading: Hocker

- Hocker, J. 2002. "My Soul is in the Machine — Conlon Nancarrow — Composer for Player Piano — Precursor of Computer Music." In *Music and Technology in the Twentieth Century*. H. Braun, ed. Baltimore: The Johns Hopkins University Press. 84-96.

- How is the composer's interface altered if permitted to draw compositions on paper rolls?

- Is unplayability an important feature for Nancarrow?

10.19. Ideas of a new Music

- 1907: Ferruccio Busoni: *Outline of a New Aesthetic of Music*

- 1910-1912: Manifesti of Ballila Pratella

- 1913: Russolo: *Art of Noises*

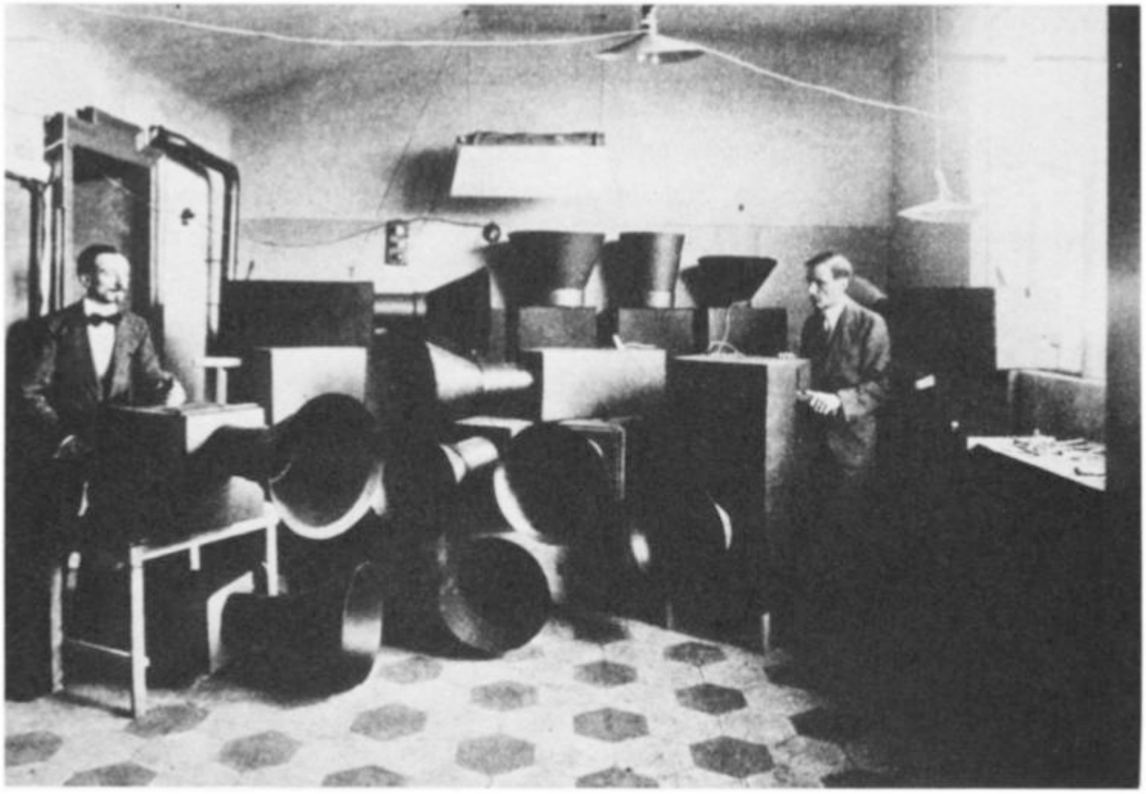
- 1919-1930: Henry Cowell: *New Musical Resources*

10.20. Reading: Brown

- Brown, B. 1981. "The Noise Instruments of Luigi Russolo." *Perspectives of New Music* 20(1-2): 31-48.

- From where did Russolo get his inspiration?

- What was the basic sound producing mechanism of the intonarumori



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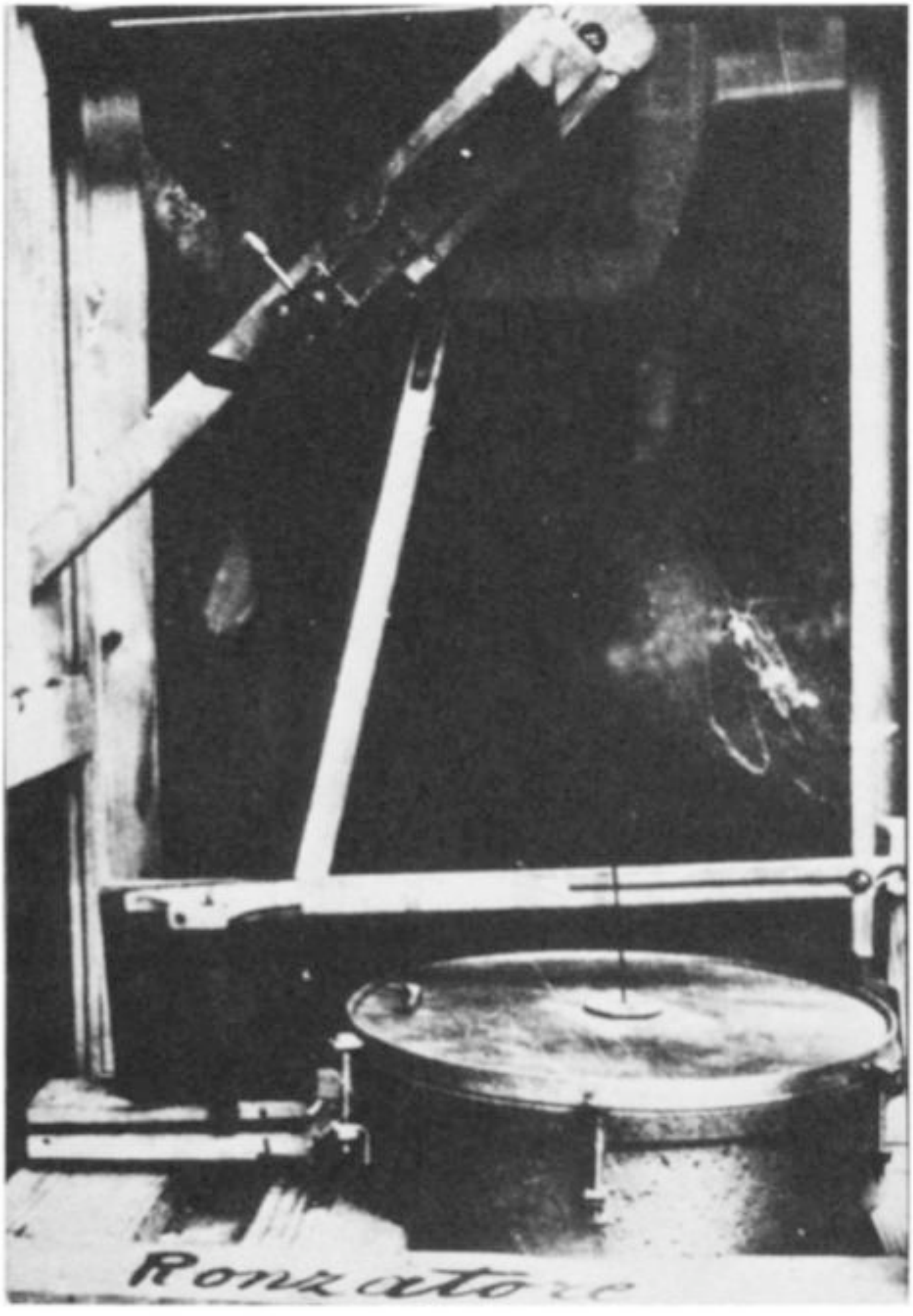


Public domain photo.

- What was the interface of the Intonarumori?

- What were Russolo's goals of developing and extending the Intonarumori?

10.21. Reading: Bijsterveld

- Bijsterveld, K. 2002. "A Servile Imitation. Disputes about Machines in Music, 1910-1930." In *Music and Technology in the Twentieth Century*. H. Braun, ed. Baltimore: The Johns Hopkins University Press. 121-135.

- Was Russolo a (sonic/musical) revolutionary?

- What motivated Russolo to say the following: "... the ear must hear these noises mastered, servile, completely controlled, conquered and constrained to become elements of art" (2002, p. 124)

- What were some of the criticisms of Russolo's instruments and compositions?

10.22. Listening: Russolo

- Listening: Luigi Russolo, "Intonarumori: crepitatore (crackler)," 1977

- Luigi Russolo, "Intonarumori: gorgogliatore (gurgler)" 1977

- Luigi Russolo, "Risveglio di una Citta (Extract)," 1977

Chapter 11. Meeting 11, Interfaces: Electronic and Electromagnetic Instruments

11.1. Announcements

- Next class is a Discussion and Workshop meeting
- Focus on Bimber reading
- Experiment with electro-magnetic pickups (bring anything with vibrating metal)
- Building oscillators with Collins CMOS Hex Schmitt Trigger IC design

11.2. Quiz Review

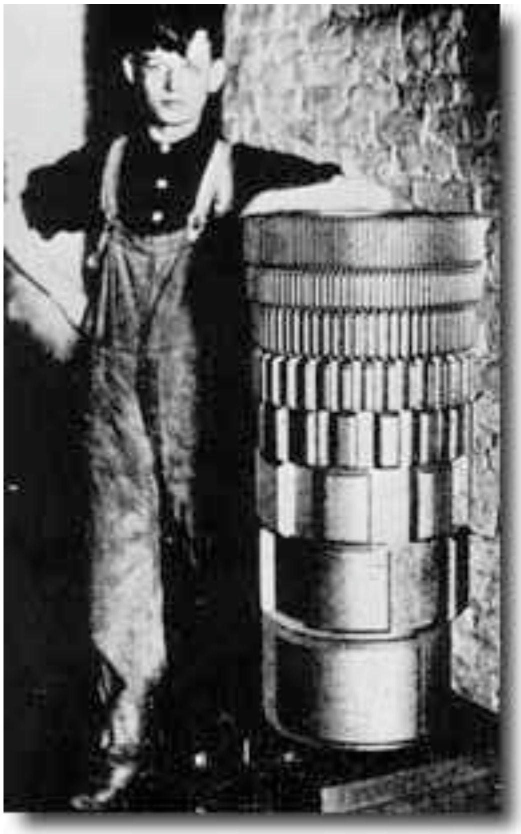
- ?

11.3. Reading: McSwain

- McSwain, R. 2002. "The Social Construction of a Reverse Salient in Electric Guitar Technology: Noise, the Solid Body, and Jimi Hendrix." In *Music and Technology in the Twentieth Century*. H. Braun, ed. Baltimore: The Johns Hopkins University Press. 186-198.
- What are the three stages of suggested for electric guitar development?
- What is a technological reverse salient
- What does it mean to re-conceptualize a reverse saliet? What are the possible outcomes?

11.4. The Telharmonium (Dynamophone): Idea

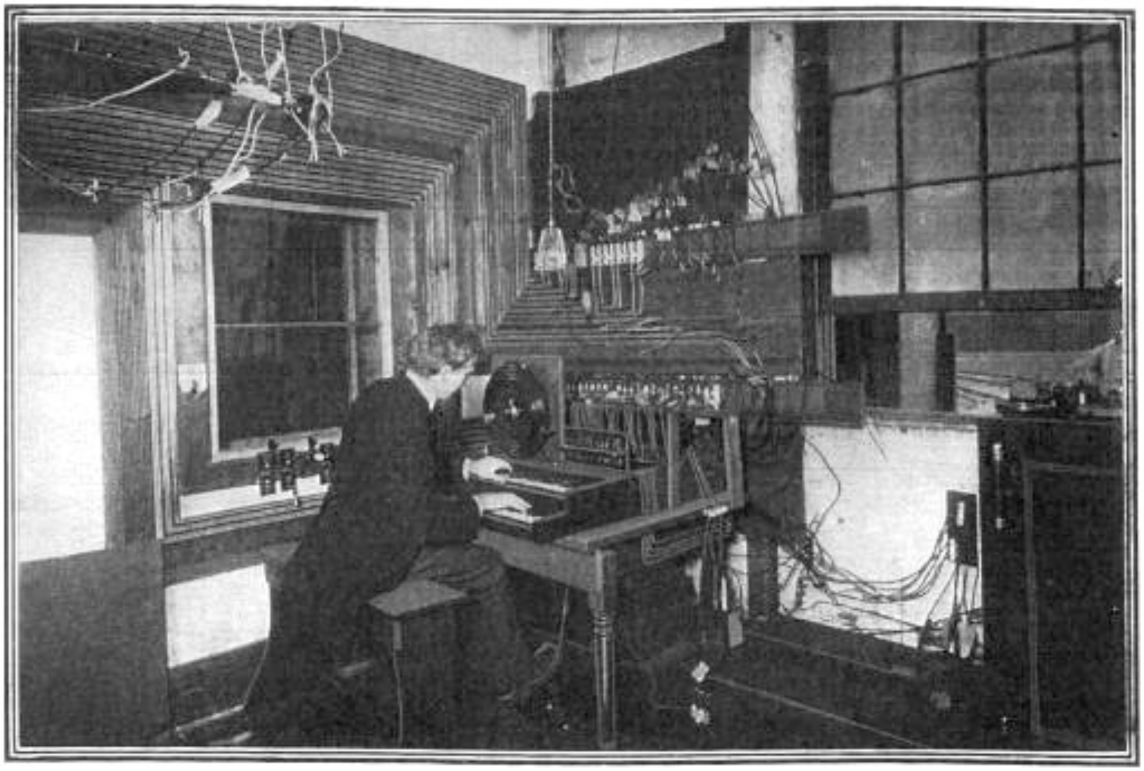
- Thaddeus Cahill (1872-1917)
- Considered the first electronic polyphonic instrument
- One or two performers sit at a keyboard with multiple manuals
- Keyboards trigger dynamo oscillators
- Dynamos contain large cylinders on pitch shafts (Holmes 2008, p. 8) with raised bumps called rheotome

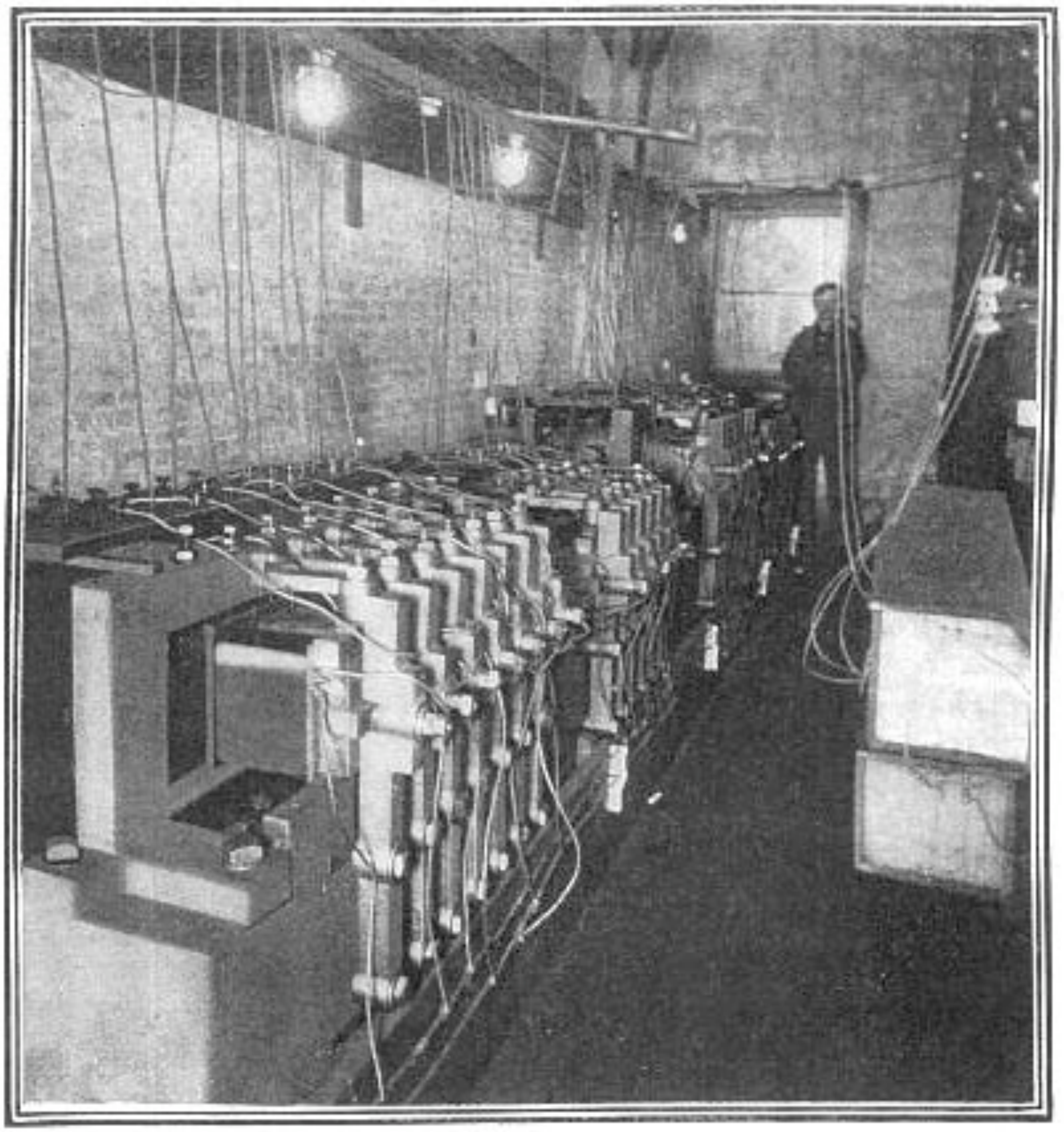


- Size and number of teeth in each rotor determines frequency (similar to a tone wheel)
- Up to five (Holmes 2008, p. 9) Sine-like tones mixed and processed to produce more complex tones
- Output distributed over conventional telephone lines
- Goal of distributing music (Telharmony) everywhere via phone lines as a commercial service to restaurants, hotels, and individuals

11.5. The Telharmonium (Dynamophone): Images

- Photos





- Patent drawings

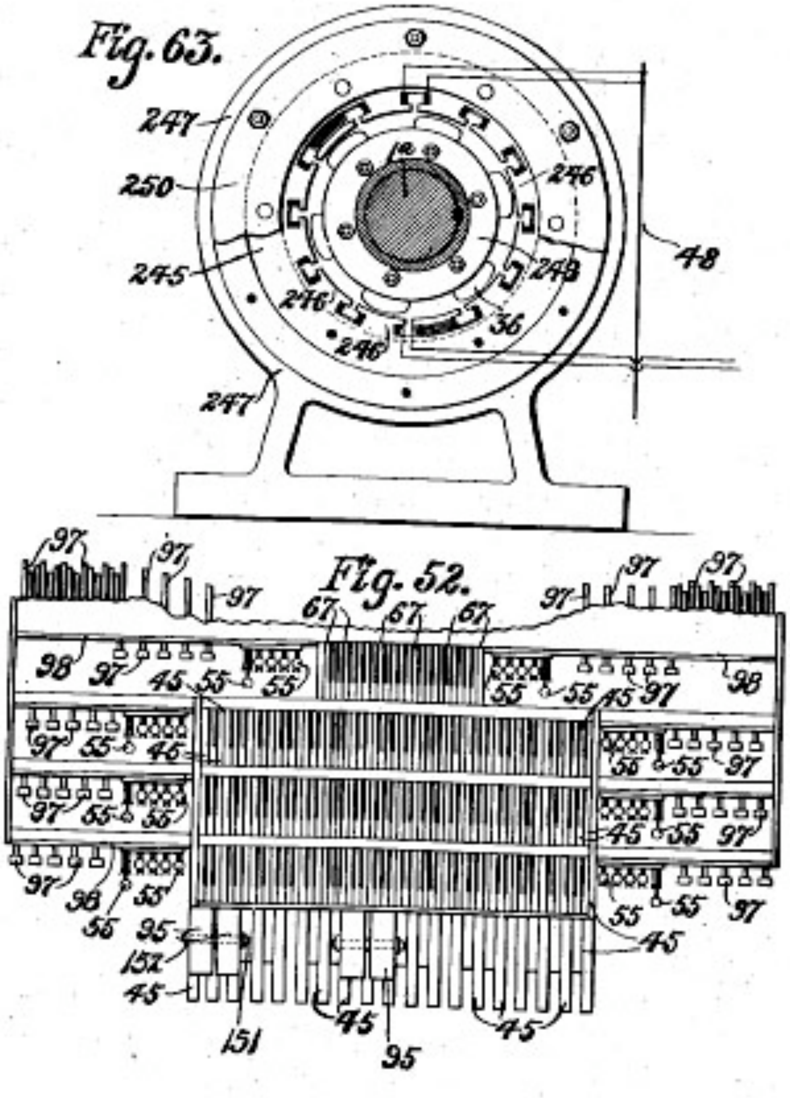
T. CAHILL.

ART OF AND APPARATUS FOR GENERATING AND DISTRIBUTING MUSIC ELECTRICALLY.

APPLICATION FILED APR. 27, 1915.

1,213,804. Patented Jan. 23, 1917.

54 SHEETS—SHEET 34.



WITNESSES:

Arthur T. Cahill.

Geo. T. Barber

INVENTOR

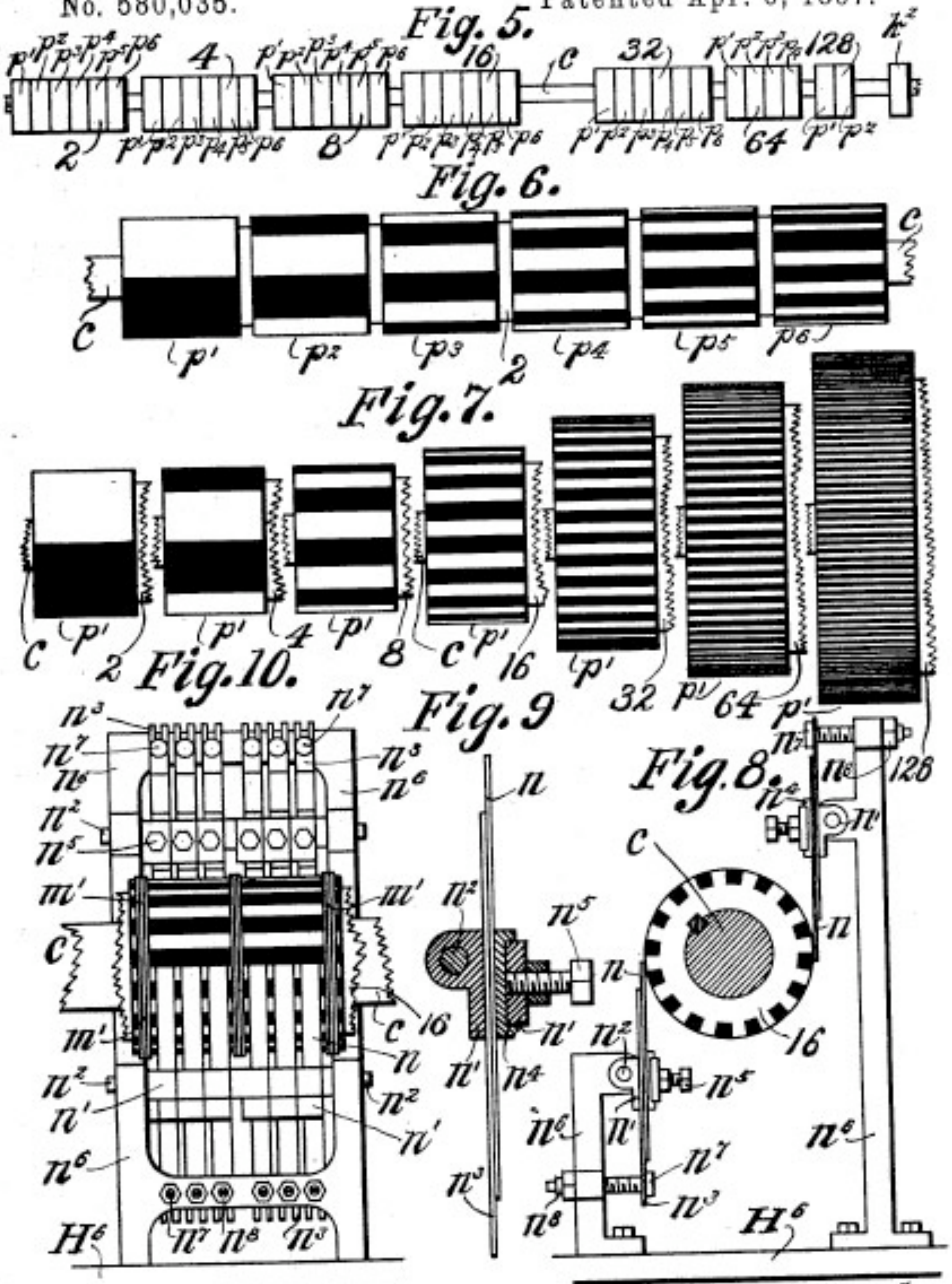
Thaddeus Cahill

(No Model.) 10 Sheets—Sheet 4.

T. CAHILL.

ART OF AND APPARATUS FOR GENERATING AND DISTRIBUTING MUSIC ELECTRICALLY.

No. 580,035. Patented Apr. 6, 1897.

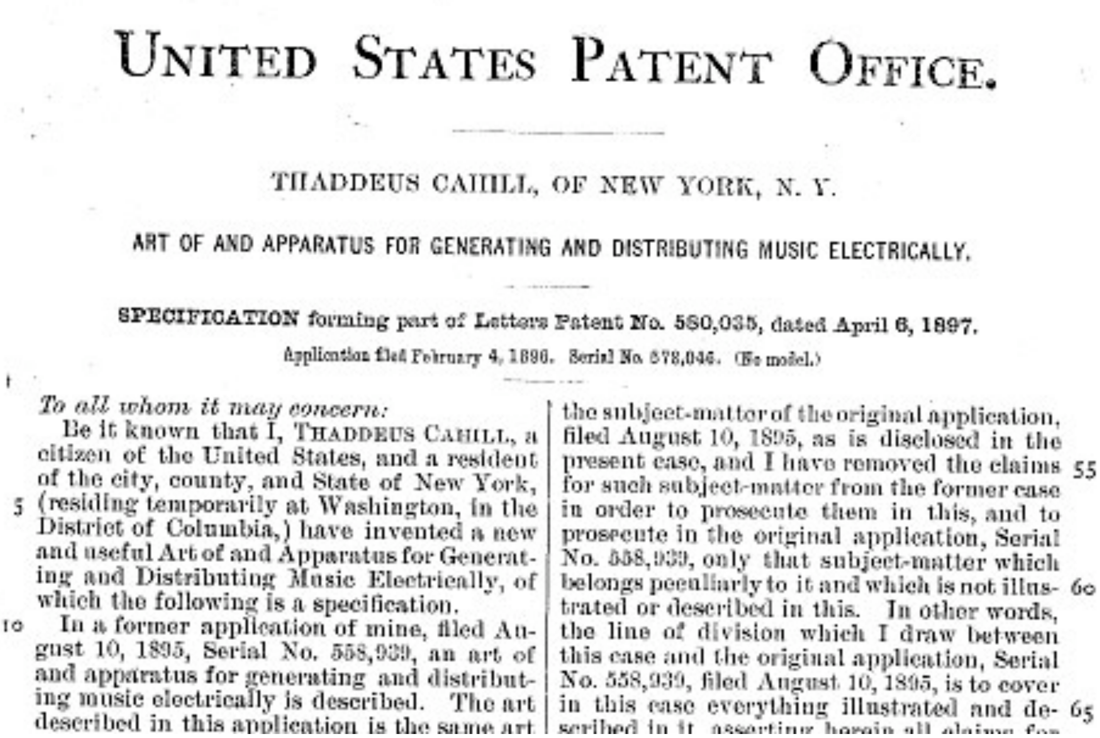


Attest:
Arthur T. Cahill.
M. H. Cahill.

Inventor:
Thaddeus Cahill

11.6. The Telharmonium (Dynamophone): History

- 1884: Cahill was a student at Oberlin Conservatory in Ohio (Holmes 2008, p. 8), learned of Helmoholtz
- Began experiments with telephones in 1893
- First patents in 1895, 1896, and 1897



UNITED STATES PATENT OFFICE.

THADDEUS CAHILL, OF NEW YORK, N. Y.

ART OF AND APPARATUS FOR GENERATING AND DISTRIBUTING MUSIC ELECTRICALLY.

SPECIFICATION forming part of Letters Patent No. 580,035, dated April 6, 1897.

Application filed February 4, 1896. Serial No. 578,046. (No model.)

To all whom it may concern:

Be it known that I, THADDEUS CAHILL, a citizen of the United States, and a resident of the city, county, and State of New York, (residing temporarily at Washington, in the District of Columbia,) have invented a new and useful Art of and Apparatus for Generating and Distributing Music Electrically, of which the following is a specification.

In a former application of mine, filed August 10, 1895, Serial No. 558,939, an art of and apparatus for generating and distributing music electrically is described. The art described in this application is the same art the subject-matter of the original application, filed August 10, 1895, as is disclosed in the present case, and I have removed the claims for such subject-matter from the former case in order to prosecute them in this, and to prosecute in the original application, Serial No. 558,939, only that subject-matter which belongs peculiarly to it and which is not illustrated or described in this. In other words, the line of division which I draw between this case and the original application, Serial No. 558,939, filed August 10, 1895, is to cover in this case everything illustrated and described in it, asserting herein all claims for

- First prototype built from 1898-1901
- 1901: Demonstrated in Baltimore at the Maryland Club, with sounds generated in Washington D.C. on one-octave instrument (Holmes 2008, p. 9)
- Moved to Holyoke Massachusetts to build improved model, started Cahill Telharmonium Company
- Moved Telharmonium to New York City on 30 railroad flat cars
    - 1905: New York Electric Music Company established
    - Telharmonic Hall: 39th St and Broadway, NYC
    - Weighed over 200 tons, measured over 60 feet long, required 2000 switches (Holmes 2008, p. 10), and included 145 dynamos

    - NYC premier: 26 September 1906, later up to four public performances a day
    - 1908: New York Electric Music Company collapsed
    - Problems with maintaining volume, power consumption, and crosstalk
- 1909: Third Telharmonium completed
    - 1910: The New York Cahill Telharmonic Company
    - 1911: installed new Telharmonium at 535 West 56th Street, NYC
    - 1912: demonstrated at Carnegie hall
    - 1914: Company bankrupt
- Operation ceased in 1916

11.7. The Theremin: Idea

- Lev Sergeyevich Termen (1896-1993)
- The first successful monophonic electronic instrument, first gesture controlled instrument
- Performer's hands act as the grounded plate of a variable capacitor
- Vertical antenna: distance from performer's hand determines frequency via capacitance
- Horizontal loop: distance from performer's hand determines amplitude via capacitance
- Beat frequency oscillator: employs two supersonic radio frequency oscillators that are heterodyned to produce the audible frequencies
- Early models included an integrated Loudspeaker
- Some models offer different timbres available with switches

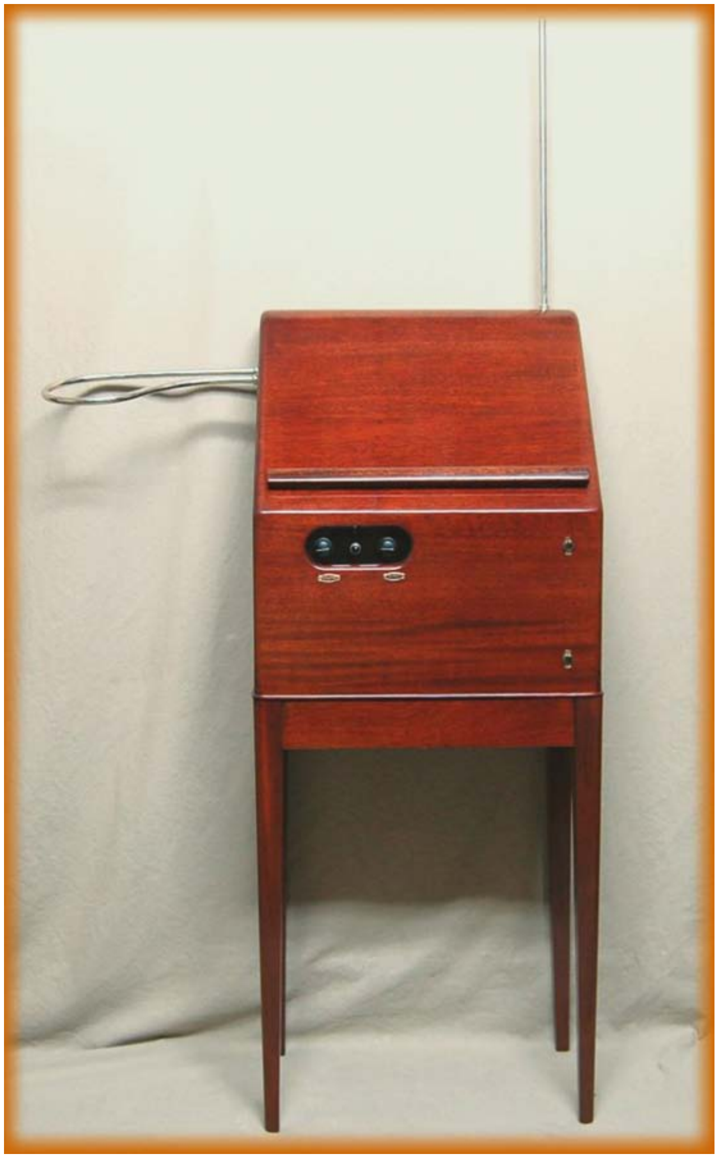
11.8. The Theremin: History

- 1920: first demonstrated in Russia
- 1922: demonstrated to Lenin
- 1927 to 1938: Theremin, in U.S., spies for the Soviet Union (Holmes 2008, p. 22)
- late 1920s (1925 or 1929): RCA manufactures 500 theremins
- 1920s: composers such as Pashchenko, Shillinger, and Varèse compose works with the Theremin

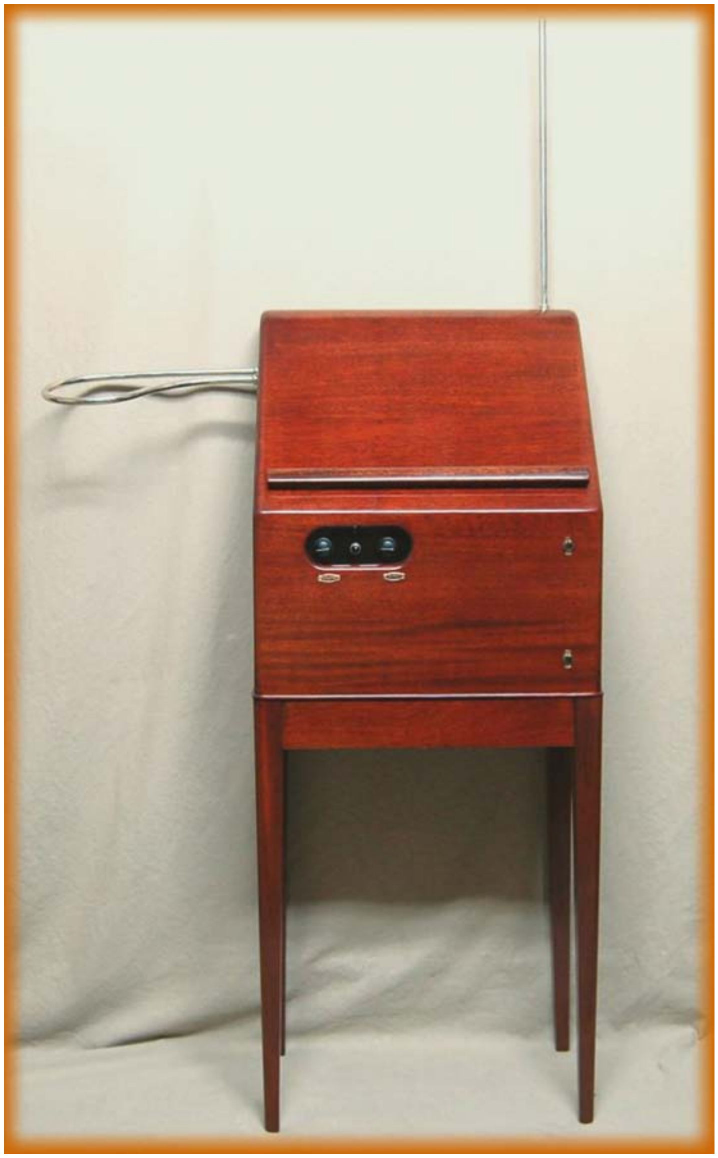
- 1954: Bob Moog begins to build theremins

11.9. The Theremin: Images

- Historic Models (RCA)



Courtesy of Sonny the Radiolaguy (http://www.radiolaguy.com). Used with permission.



Courtesy of Sonny the Radiolaguy (http://www.radiolaguy.com). Used with permission.

- Contemporary Models: Moog Theremin ($419)

- Contemporary Models: Moog Etherwave Pro ($1395)

11.10. The Theremin: Video

- Theremin virtuoso Clara Rockmore

11.11. The Ondes Martenot: Idea

- Maurice Martenot (1898-1980), influenced by Leon Termin
- Monophonic instrument with a vacuum tube oscillator, designed to be a symphonic instrument
- First models used a “pull wire” to control pitch; a conventional keyboard was added in fourth version (1930)
- Originally used a touch sensor; the fifth version added a ribbon controller (1933)
- Keys can be moved laterally to create small pitch changes
- Amplitude was controlled by a pressure sensitive key for the left hand, switches could be used to alter timbre
- Same synthesis technique as the Theremin: (beat-frequency oscillator)
- Used in works by Boulez, Varèse, Milhaud, Honegger, and others

11.12. The Ondes Martenot: History

- 1923: Martenot meets Termin
- 1928: Patents instrument as “Perfectionnements aux instruments de musique électriques”
- 1929, 1930, 1933: improved versions
- 1930-1931: tours with instrument
- 1947: Martenot establishes classes at Paris Conservatory

11.13. The Ondes Martenot: Images

- Photos

- Jean Laurendeau and the Ondes Martenot

  YouTube (http://youtube.com/watch?v=Yy9UBjrUjwo)

11.14. Listening: Oraison

- Oliver Messiaen (1908-1992), French composer, interested in new harmonic and rhythmic structures
- 1937: Oliver Messiaen: Oraison for Ondes Martenot Quartet

11.15. The Ondes Martenot: Abstraction of a Musical Interface

- Modern Controller: Analogue Systems French Connection with Wire Traveller

- Examples

  YouTube (http://youtube.com/watch?v=5XsLwkc67lw)

  YouTube (http://youtube.com/watch?v=MnxE7Mu115o)

11.16. The Electric Guitar: History

- Oud: possibly the earliest lute, from Mesopotamia 3 BCE

YouTube (http://youtube.com/watch?v=c5Ra5NHacxE)

- 1920s: Los Angeles, George Beauchamp tries to build louder guitars with horns
- 1920s: with John Dopyera, builds guitar with metal resonators (the Tri-Cone)

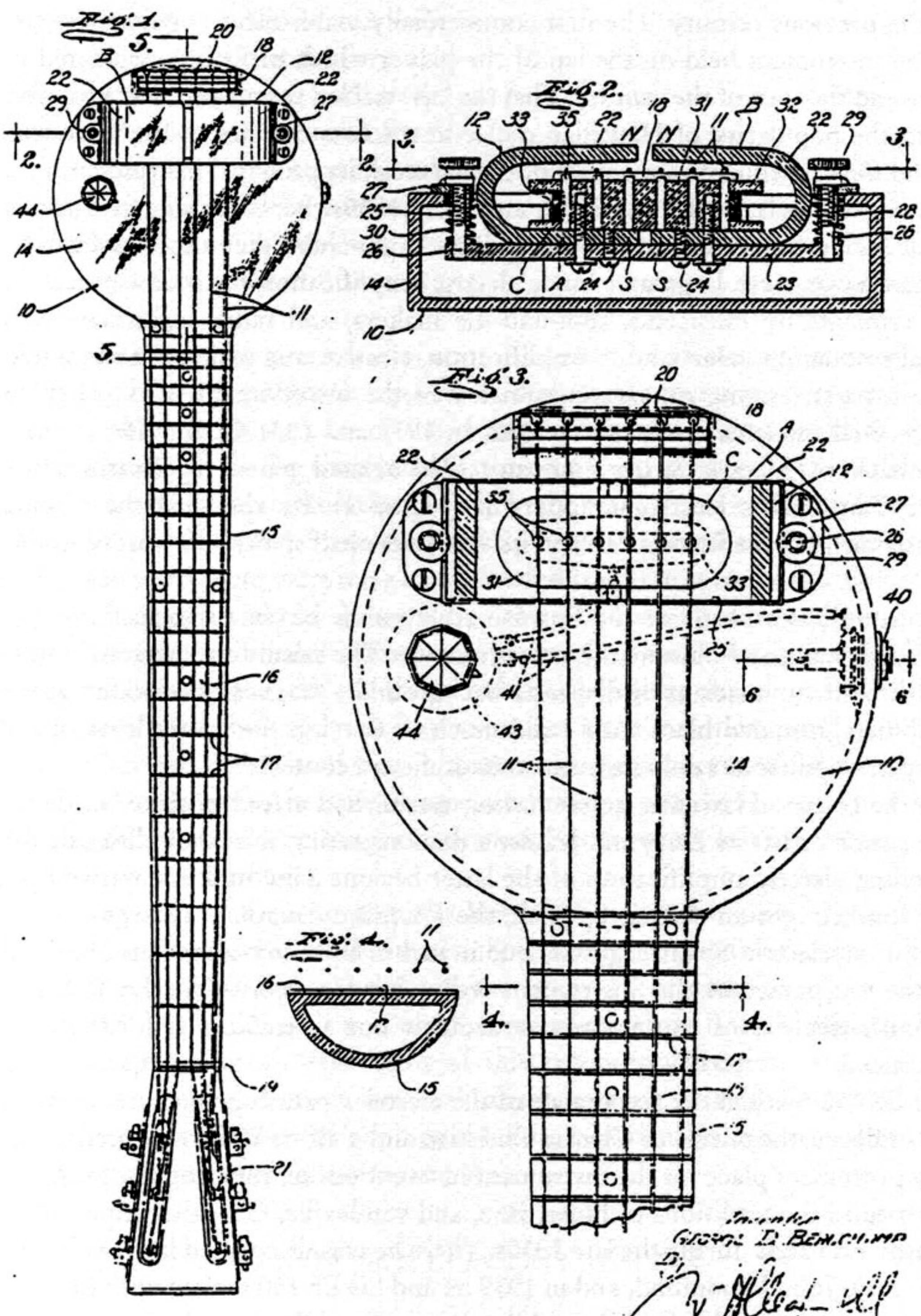
YouTube (http://youtube.com/watch?v=HAf6HPPv-sE)

- 1920s: with John Dopyera, Beauchamp leaves and forms Dobro Corporation
- 1930s: George Beauchamp develops a pickup with magnets

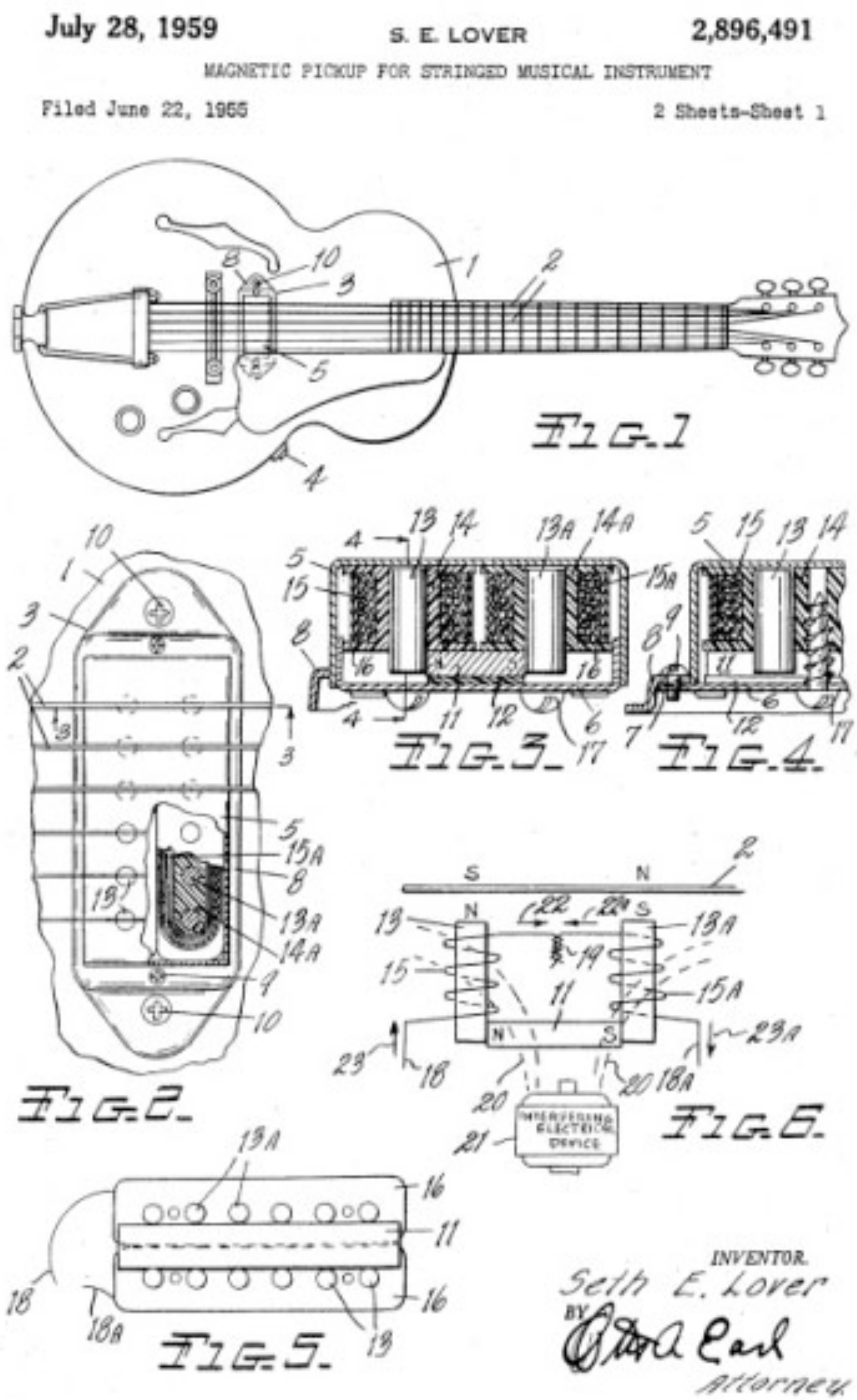
Aug. 10, 1937. G. D. BEAUCHAMP 2,089,171

ELECTRICAL STRINGED MUSICAL INSTRUMENT

Filed June 2, 1934 3 Sheets-Sheet 1



- 1935: Rickenbacker (then Electro String) releases The Frying Pan, or the Electro Spanish guitar (Bakelite A22)
- 1935: Rickenbacker Bakelite Model B Spanish guitar (thick plastic semi-solid)
- 1940s: Les Paul begins developing guitars
- 1950: Leo Fender begins work
- 1950s: Seth Lover at Gibson develops humbucker (PAF)



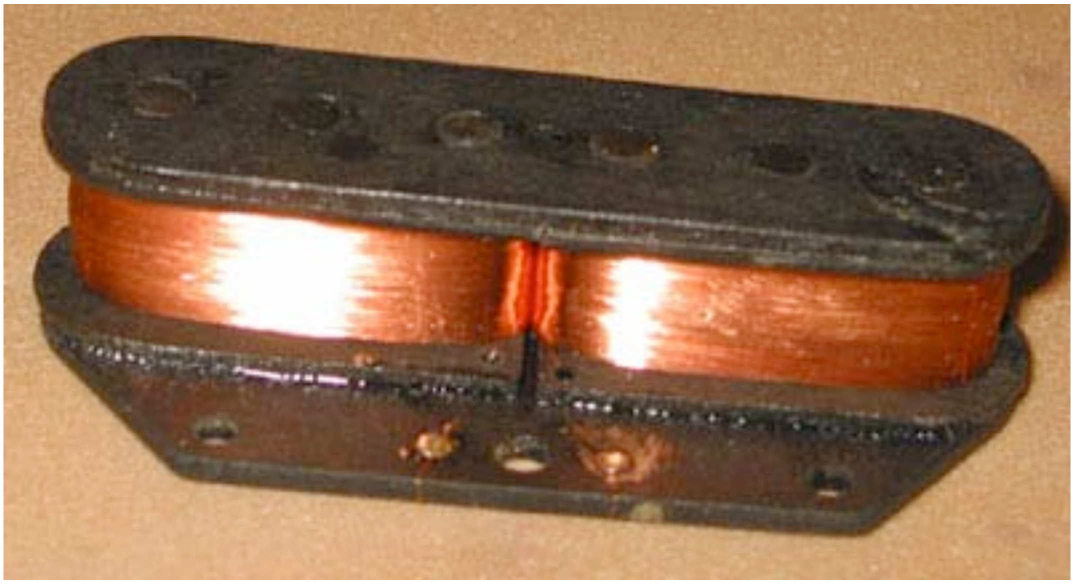
- 1952: Gibson Les Paul released
- 1954: Fender Stratocaster

11.17. The Electric Guitar: Concepts

- The problem of loudness
- Moving metal in a magnetic field
  - Telharmonium dynamos
  - Hammond tone wheels
  - Pickups: a metal string in magnetic field
- Instrument does not have to be a full resonator: solid body
- Excessive resonation can lead to feedback
- Electrical output signal can be further processed and modified

11.18. The Electric Guitar: Single Coil Pickups

- Copper wire coiled around a bar or 6 rods
- Earliest models from 1930s
- Rods focus magnetic field around each string



- Bright and clear sound
- May induce electrical noise (hum) due to polarity of magnetic field

11.19. The Electric Guitar: Dual-Coil Pickups

- Humbucker: buck the hum
- Two coils in reversed polarity: cancels noise when summed

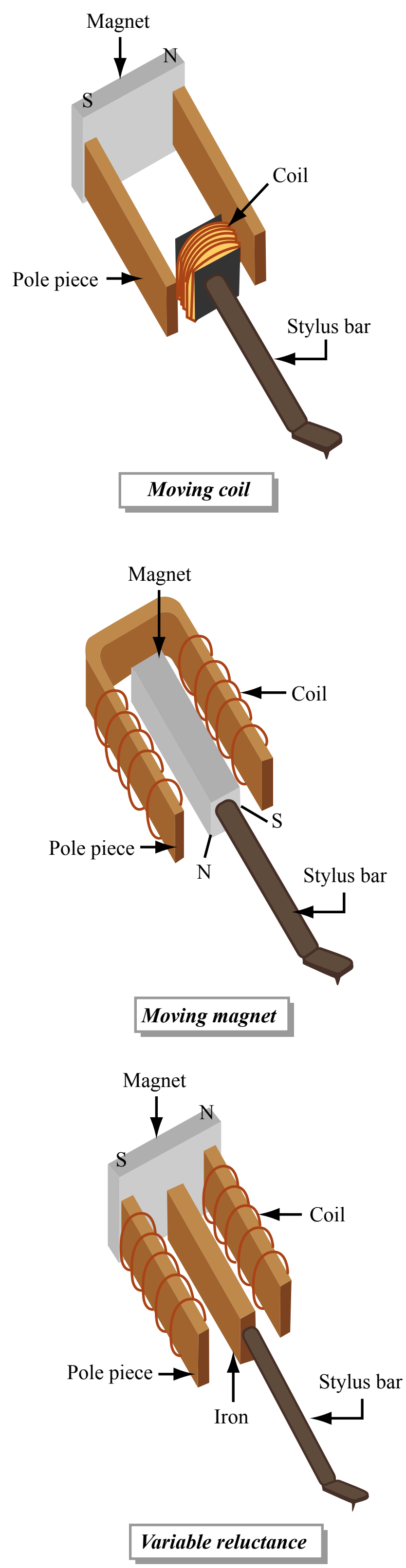
- Higher output, better signal to noise ratio
- Warm and fat
- Can be packed into a single coil form

11.20. Listening: Hendrix

- Jimi Hendrix (1942-1970)
- Clear overdrive tone, extreme sustain
- Jimi Hendrix: "Machine Gun," Band of Gypsys, 1970

11.21. Analog Turntable Pickups

- Phonograph pickups (styli): piezoelectric crystal (contact microphone) or electromagnetic induction (dynamic microphone)



Basic structures of three types of magnetic phonograph pickups.

Figure by MIT OpenCourseWare.

11.22. Listening: Cage

- Cage uses turntables playing test-tones in a composition
- Imaginary Landscape No. 1: four performers playing piano, cymbal, and two variable speed phonographs
- John Cage, Imaginary Landscape No. 1, 1939

11.23. Listening: Cage

- Creative applications of phonograph cartridges
- "In “Cartridge Music” one inserts all kinds of small objects into the cartridges, such as pipe-cleaners, matches, feathers, wires etc. Furniture is used as well, with contact microphones connected to them. All sounds are to be amplified and controlled by the performer(s). The number of performers should be at least that of the cartridges and not greater than twice the number of cartridges. Each performer makes his part from the materials provided: 20 numbered sheets with irregular shapes (the number of shapes corresponding to the number of the sheet) and 4 transparencies, one with points, one with circles, another with a circle marked like a stopwatch and the last with a dotted curving line, with a circle at one end. These transparencies should be superimposed on one of the 20 sheets, in order to create a constellation from where one can create one’s part." (www.johncage.info)

- John Cage, Cartridge Music, 1960

Chapter 12. Meeting 12, Discussion and Workshop

12.1. Announcements

- Quiz next Thursday

12.2. Reading: Bimber

- Bimber, B. 1990. “Karl Marx and the Three Faces of Technological Determinism.” *Social Studies of Science* 20(2): 333-351.

- What is technological determinism?

- Bimber describes three accounts of technological determinism: Norm-Based Accounts, Logical Sequence Accounts, Unintended Consequences. How do these accounts differ?

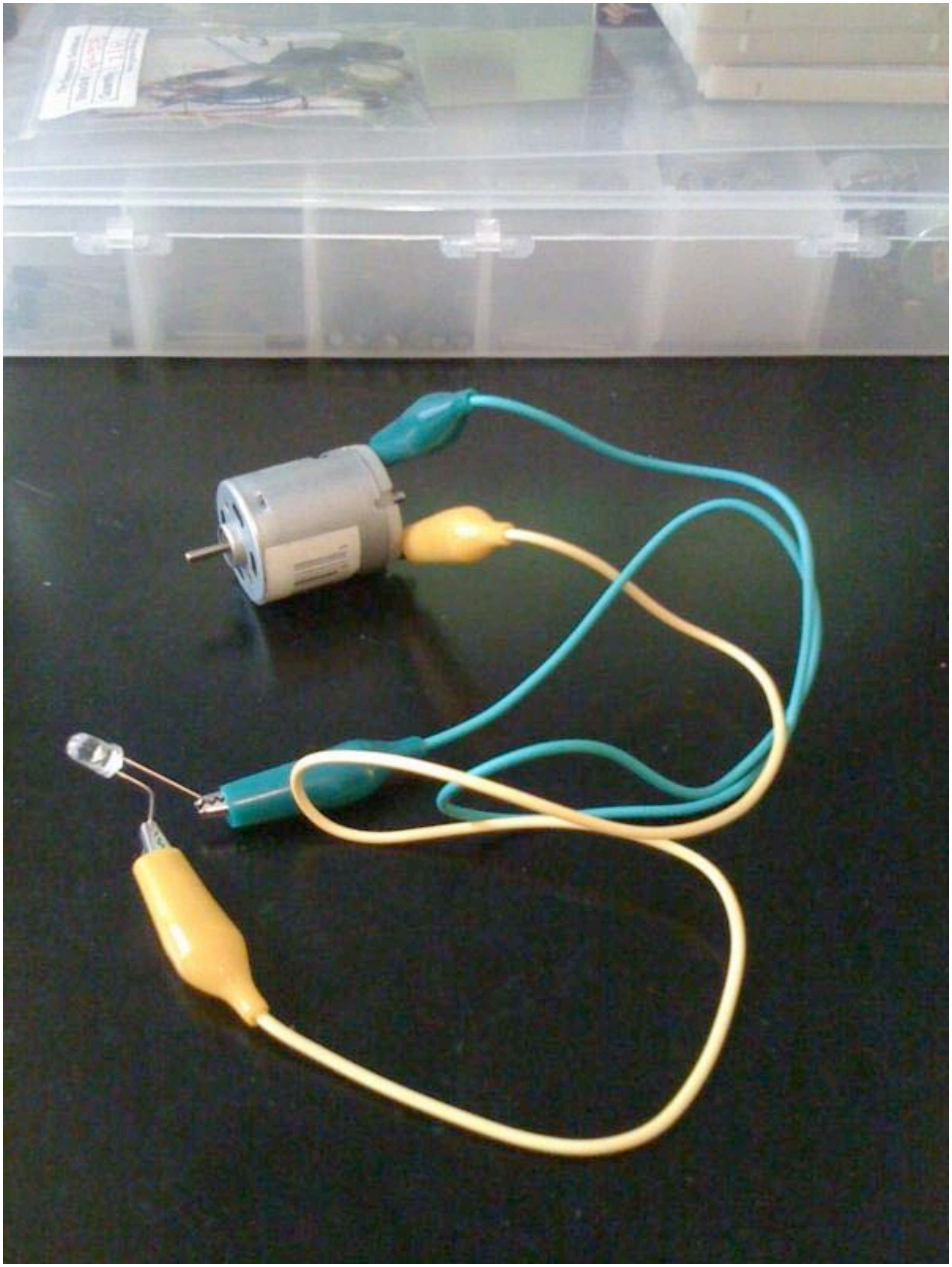
- For Bimber, which of the three acounts meets the requirements technological determinism, and why?

- What are some of examples of deterministic ideas about technology in common discourse?

- Does the history of music technology support notions of technological determinism?

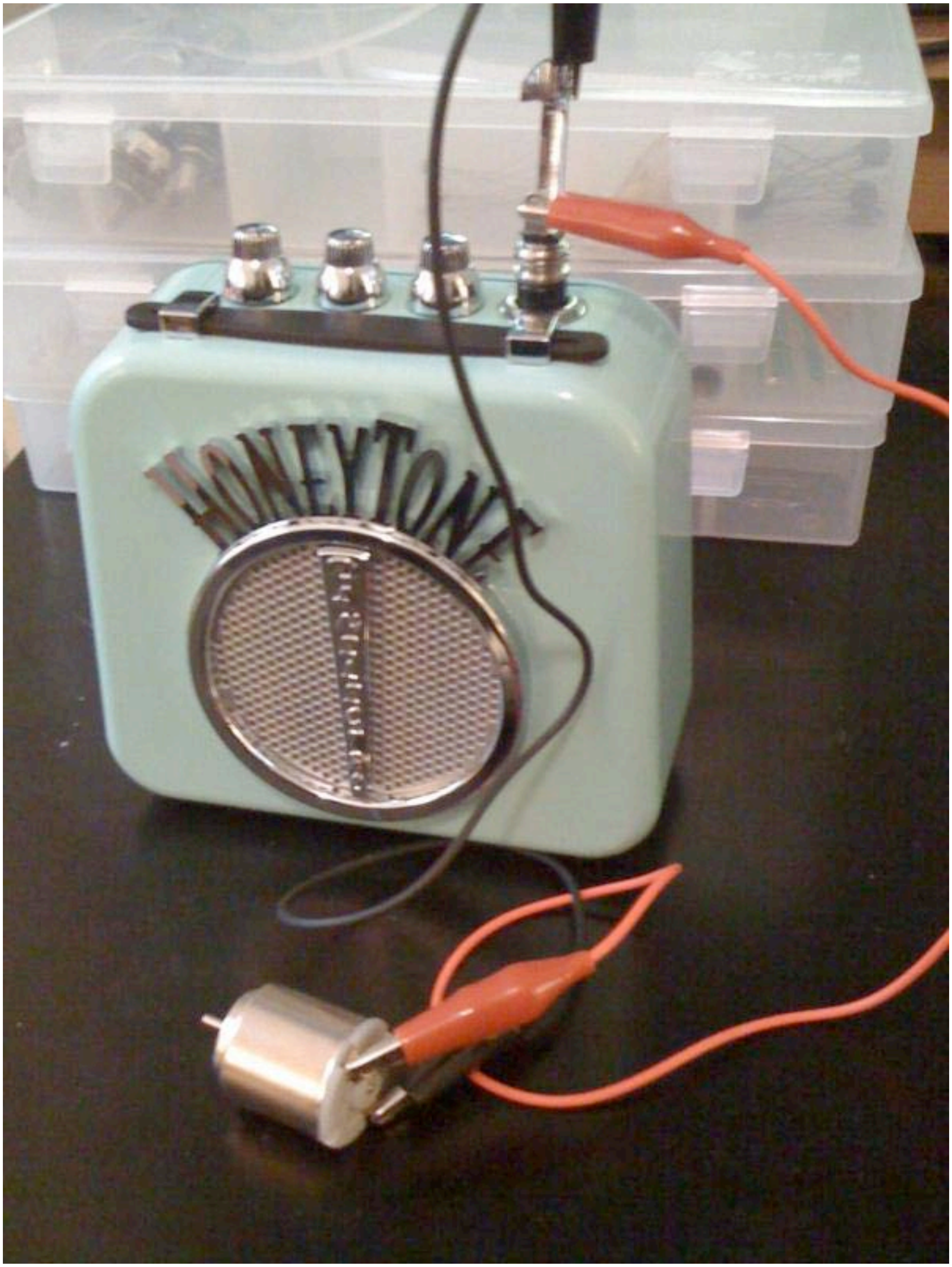
12.3. Hardware Hacking: Motor as Dynamo

- Using a motor as a dynamo to drive an LED



12.4. Hardware Hacking: Dynamo as Oscillator

- A Telharmonium Lite (Collins 2009, p. 20)



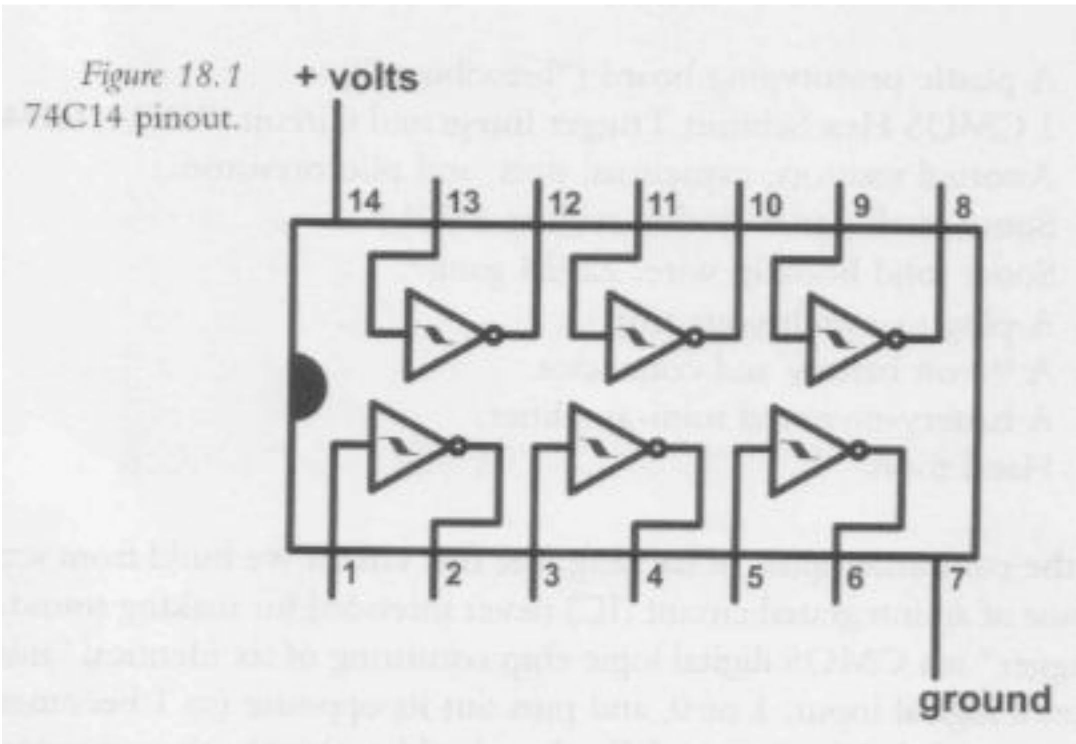
12.5. Hardware Hacking: Humbuckers

- Exploring the sound of motors, piano strings, and portable electronics

12.6. Hardware Hacking: Simple Oscillator

- The Hex Schmitt Trigger digital logic chip: six inverters on a chip

- Given an input of 1 (9 volts) output 0 (0 volts) and vica versa
- The resistor permits feedback, causing alternation between 9 and 0 volts and producing a squarish sound wave
- 74C14 Pins



- Using a resistor to create feedback oscillation

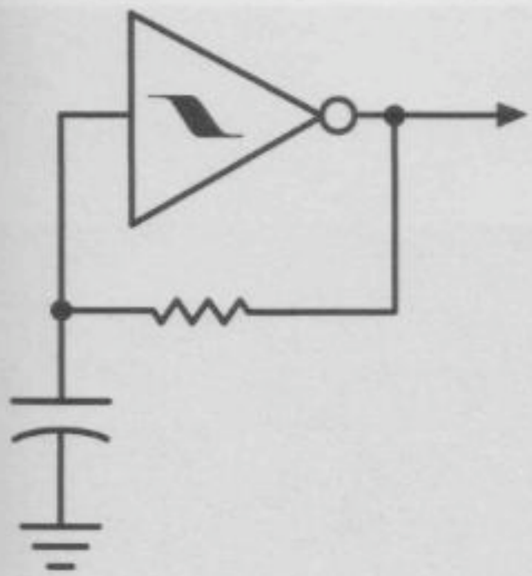
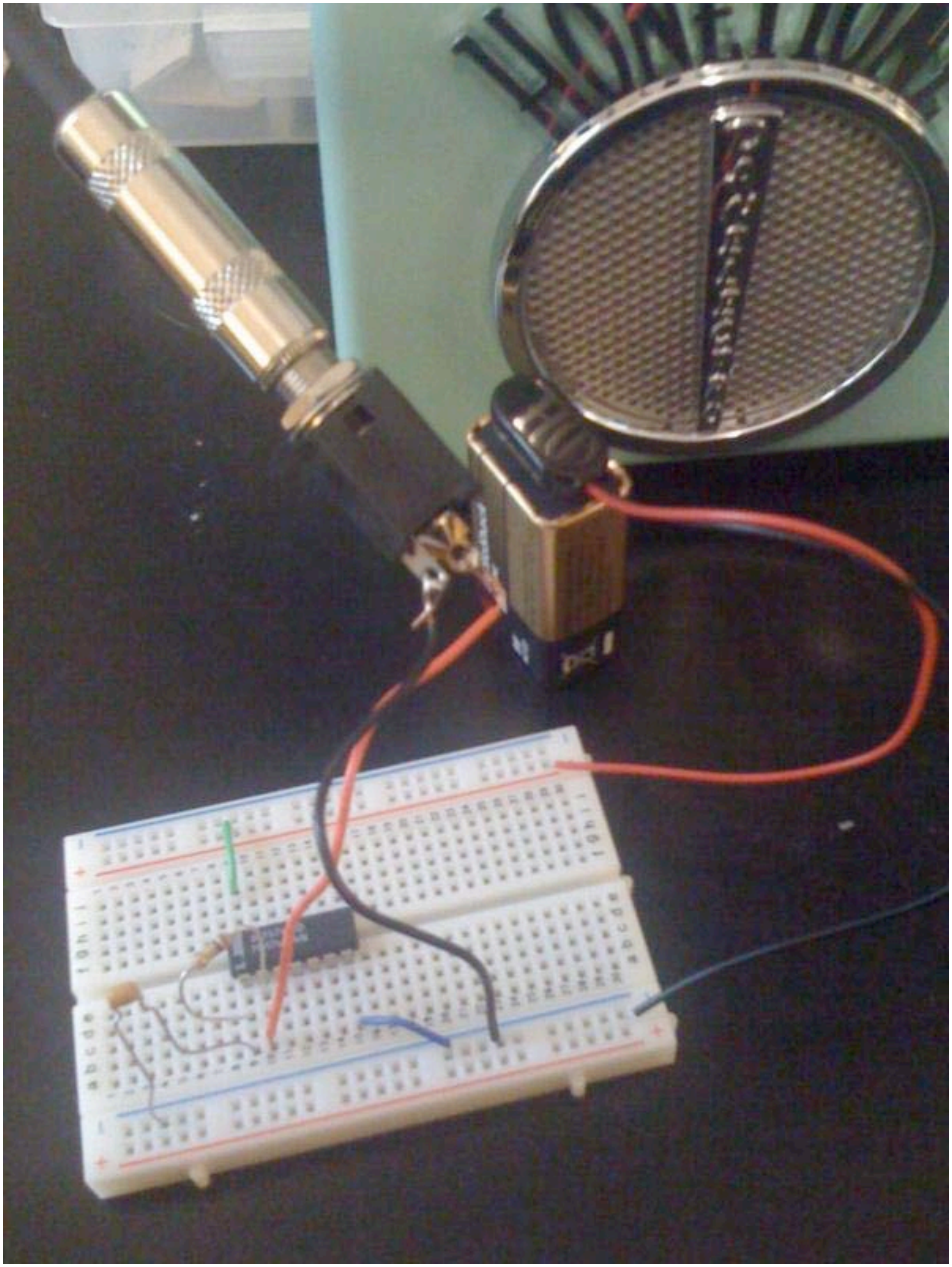


Figure 18.8
Schematic representation of our oscillator.

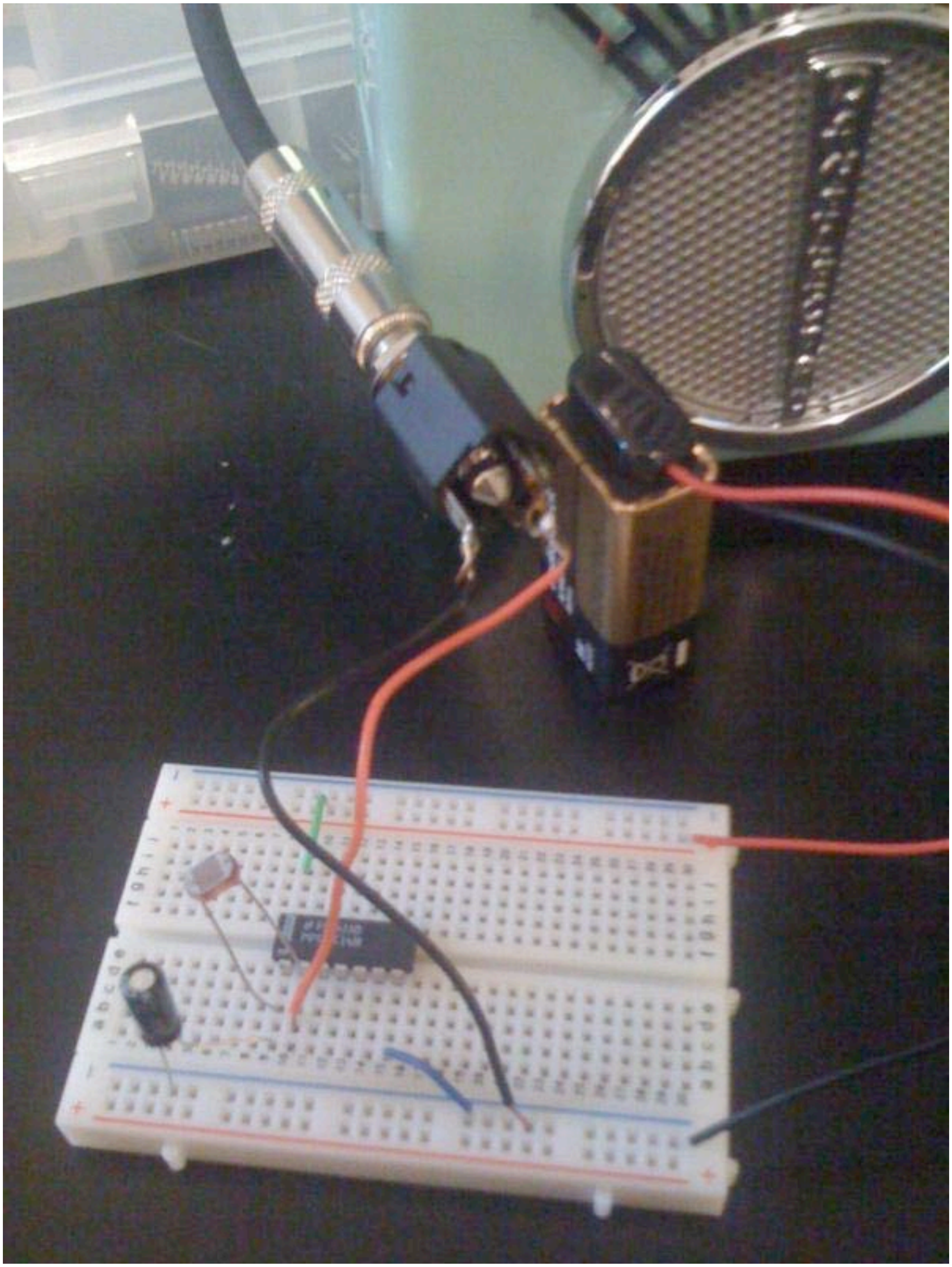
- Breadboard



12.7. Hardware Hacking: Photocell Controlled Oscillator

- Varying resistance changes the frequency of oscillation

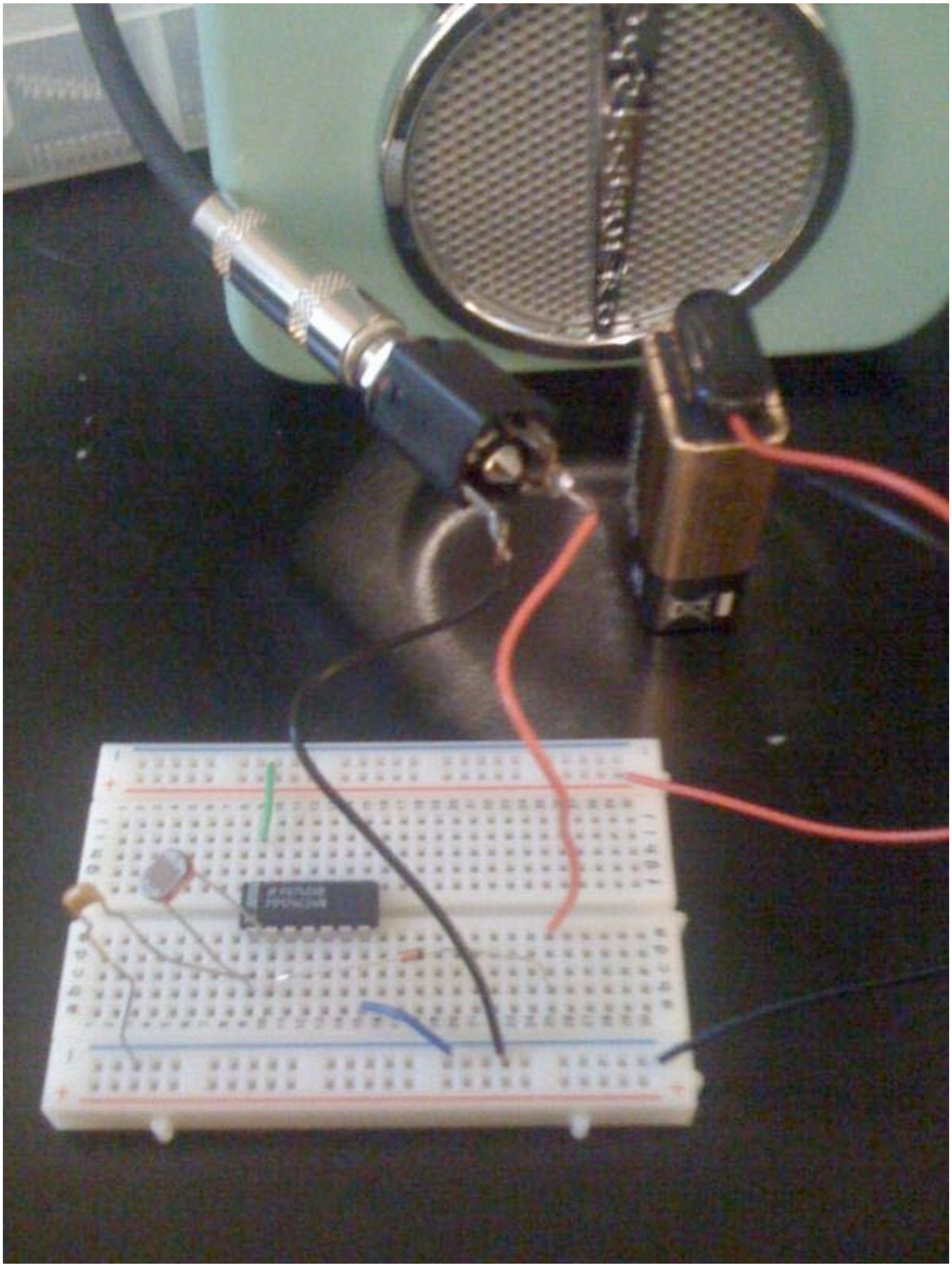
- A photoresistor decreases resistance with more light, increases resistance with less light
- Varying the capacitor sets the range of oscillation
- Breadboard



12.8. Hardware Hacking: Oscillator through Diode

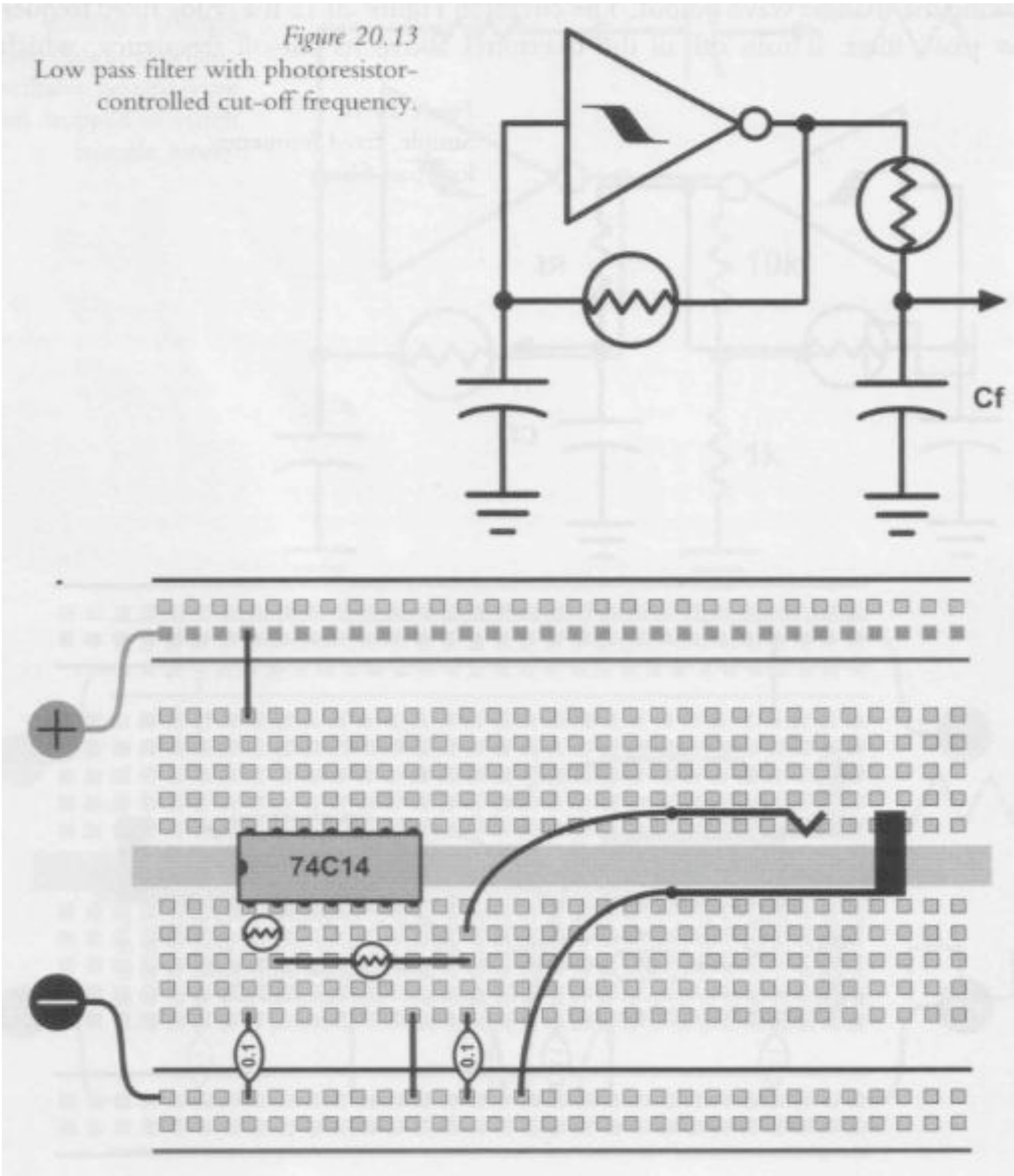
- Pasing the signal through a diode alters the timbre

- Breadboard

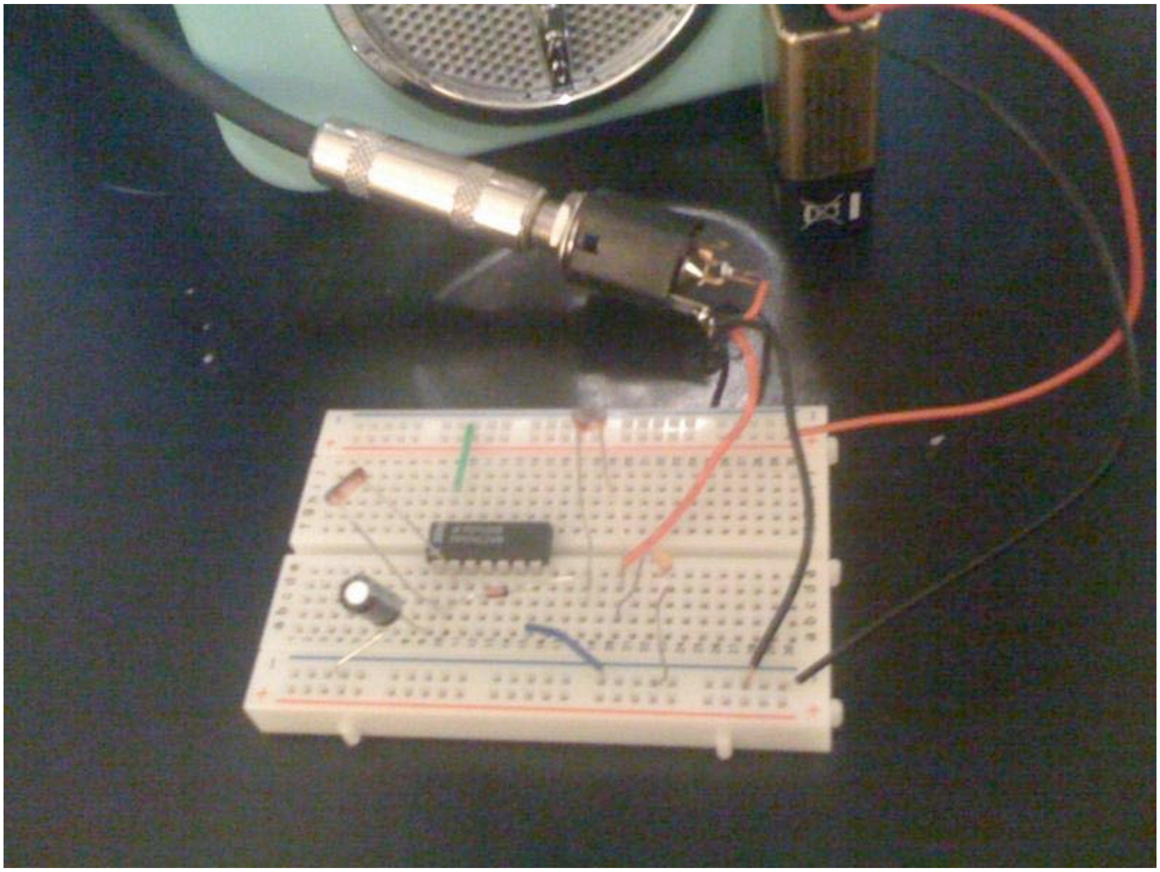


12.9. Hardware Hacking: Oscillator with Low Pass Filter

- A basic low pass filter using a photoresistor and a capacitor



- Breadboard



Chapter 13. Meeting 13, Interfaces: Modular Synthesizers

13.1. Announcements

- Quiz on Thursday
- Music Technology Case Study Drafts due next Tuesday

  Draft should meet minimum requirements of final paper

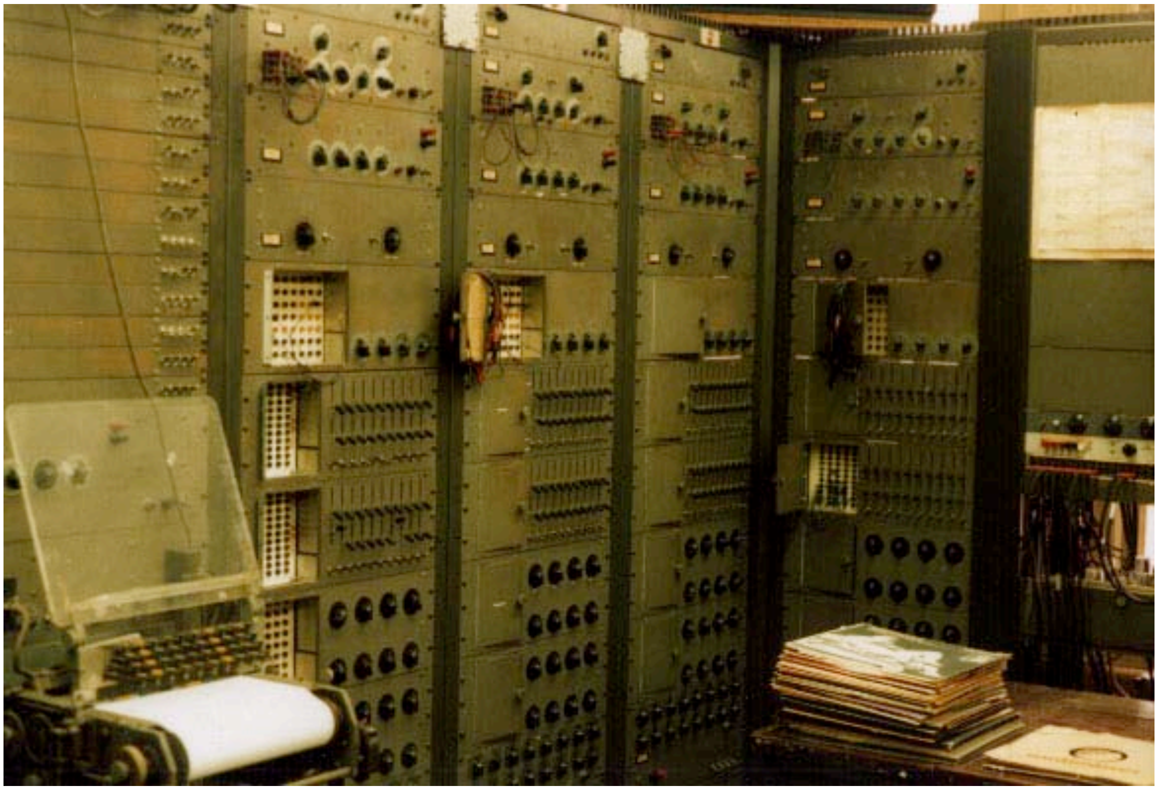
  Contact me with questions or problems
- Today: we will look at modular synthesizers in part through Arturia's virtual instrument emulations. Next Tuesday we will build similar models in PD.

13.2. The Modular Synthesizer: Overview

- The Modular Synthesizer: a collection of voltage-producing components with inputs and outputs freely inter-connected with patch cables
- Semi-modular synthesizers: voltage producing components with a mixture of fixed, switchable, and/or selectable interconnections
- While composers such as Varèse and Stockhausen were synthesizing tones in the 1950s, the synthesizer was not a conceived of as a single hardware entity
- The modular synthesizer was, in part, a consolidation and repackaging of existing technologies
- Voltage control, the flexible automation of parameters, was a (the?) key innovation

13.3. Foundations: RCA Synthesizer

- RCA Synthesizer



Courtesy of Kevin Lightner. Used with permission.

- 1940s-1950s: Harry Olsen and Herbert Belar, working for RCA, explore music machines with vacuum tube and tuning fork oscillators

- 1955: complete Mark I, features 2 voices

  Sine tooth signal from tuning forks converted to square and then sawtooth waveforms (1955, p. 599)

  A variety of AR envelopes possible with "growth and decay" generators (1955, p. 602)

  Timbre control with high and low pass filters with variable cutoff frequencies and a "resonator chain" (1955, p. 605)

- Olson, H. F. and H. Belar. 1955. "Electronic Music Synthesizer." *Journal of the Acoustical Society of America* 27(3): 595-612.

  Perhaps the first description of an instrument as a "synthesizer"

  Two channel, fixed signal flow, controlled by punched paper

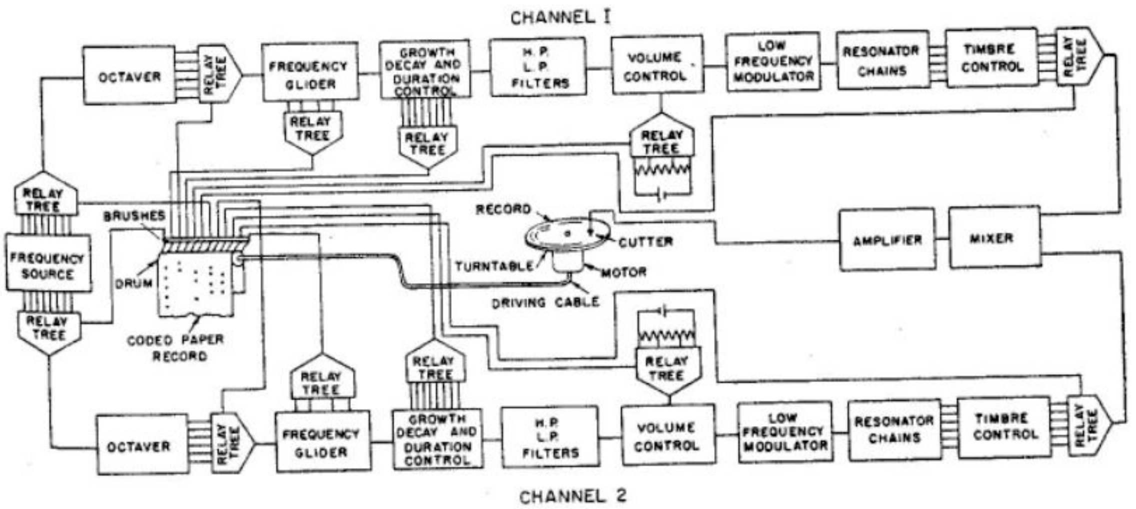
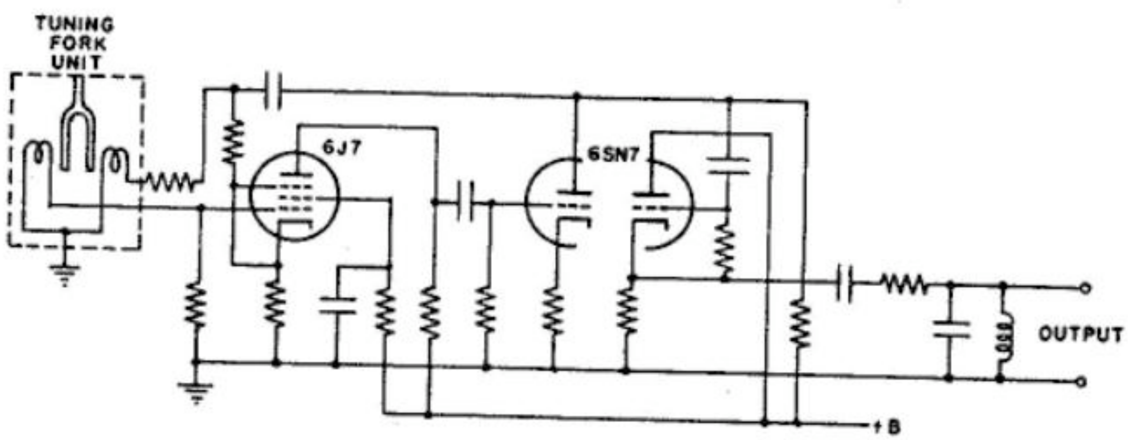


FIG. 2. Schematic diagram of the electronic music synthesizer.

Electromagnetically driven tuning fork oscillators



3 and 4 bit binary parameter specifications

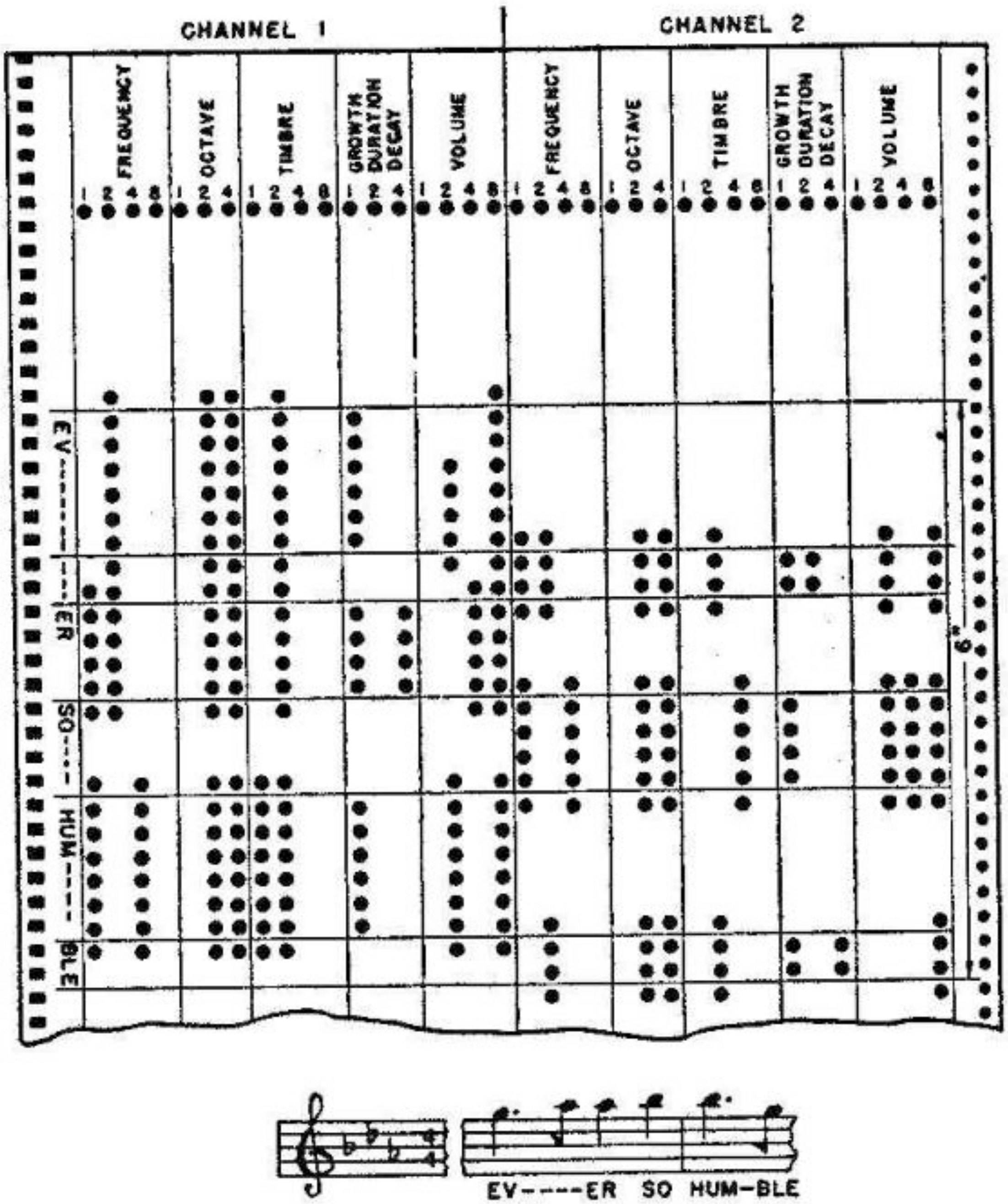


FIG. 27. The punched paper record.

Direct to disk output recording

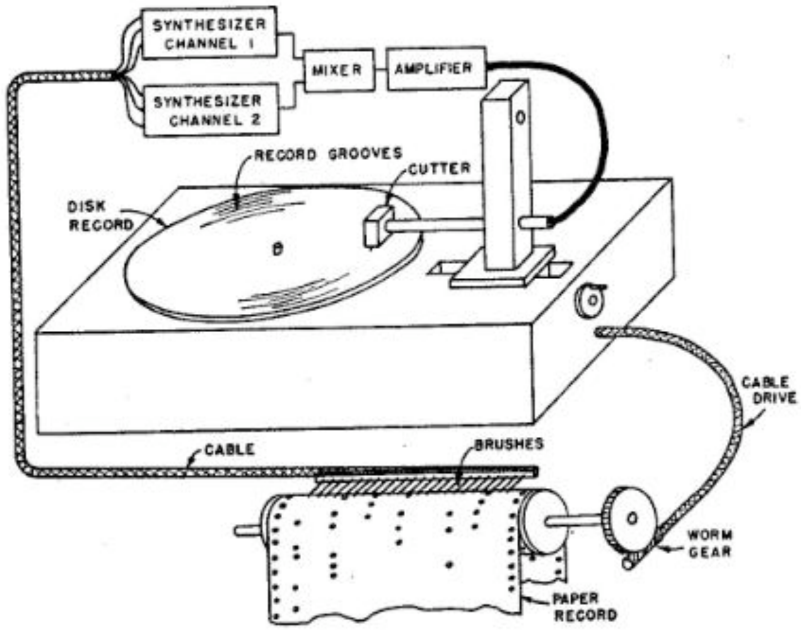
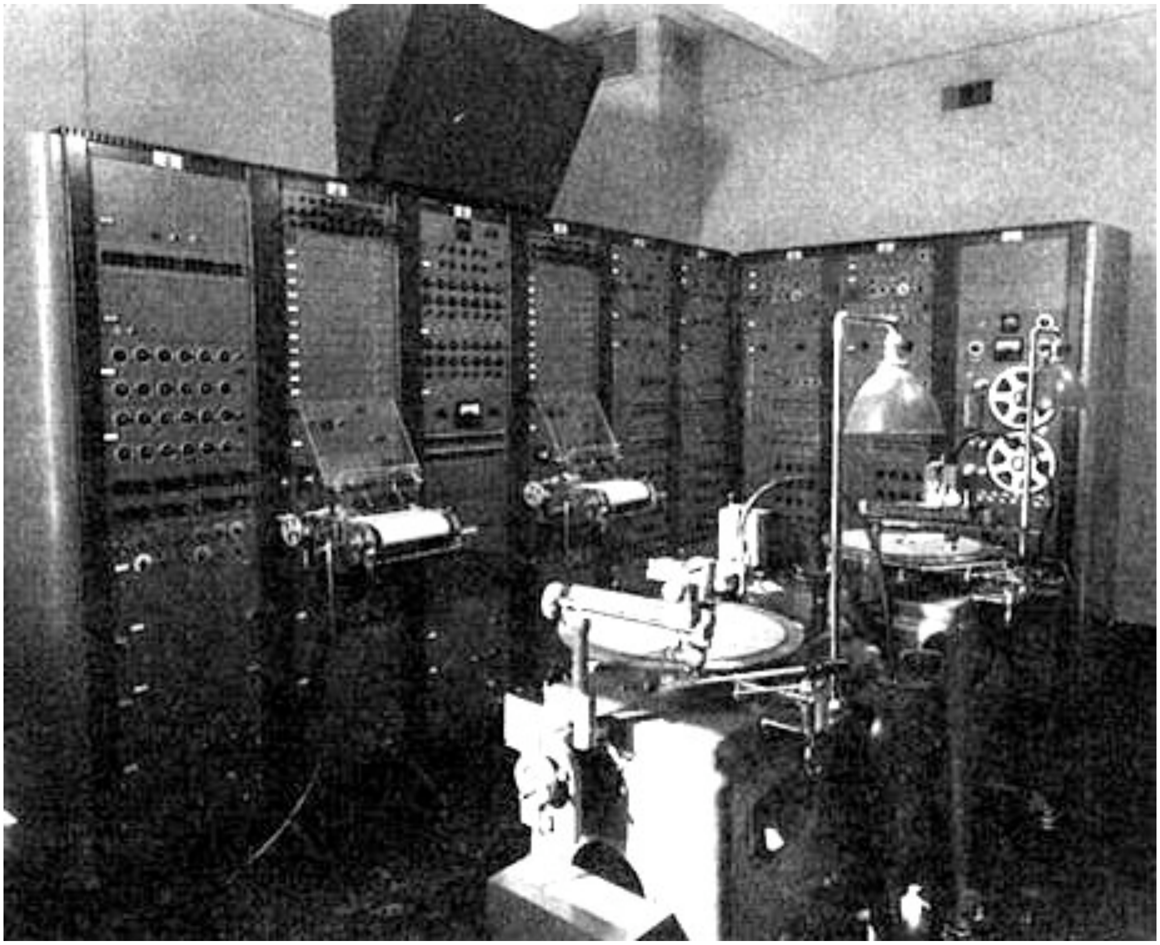


Fig. 28. Perspective view and schematic diagram of the paper record and the disk recording system of the music synthesizer.

- A first attempt at a rigorous, fixed, and complete parameterization of musical events
- Not a performance instrument

13.4. Foundations: RCA Synthesizer Mark II

- 1957-1959: Columbia University, with Rockefeller Foundation grants, purchases the RCA Synthesizer Mark II and establishes the Columbia-Princeton Electronic Music Centre.
- Mark II features four voices similar to the Mark I, adds a white-noise generator, microphone input, and variable frequency oscillators
- Olson, H. F. and H. Belar, J. Timmens. 1960. "Electronic music synthesis: the Mark II R.C.A. Synthesizer." *Journal of the Acoustical Society of America* 32(3): 311-319.
- RCA Synthesizer disk cutting lathe



- Eventually installed three-track Ampex tape recorders
- Audio: 1955 Demo recording demonstrates dance band synthesis

13.5. Listening: Babbit

- Audio: Milton Babbitt, *Philomel*, 1964

- 12-tone technique applied to pitch and other synthesis parameters
- What is the role of the electronics in the context of the piece?

13.6. Foundations: Buchla

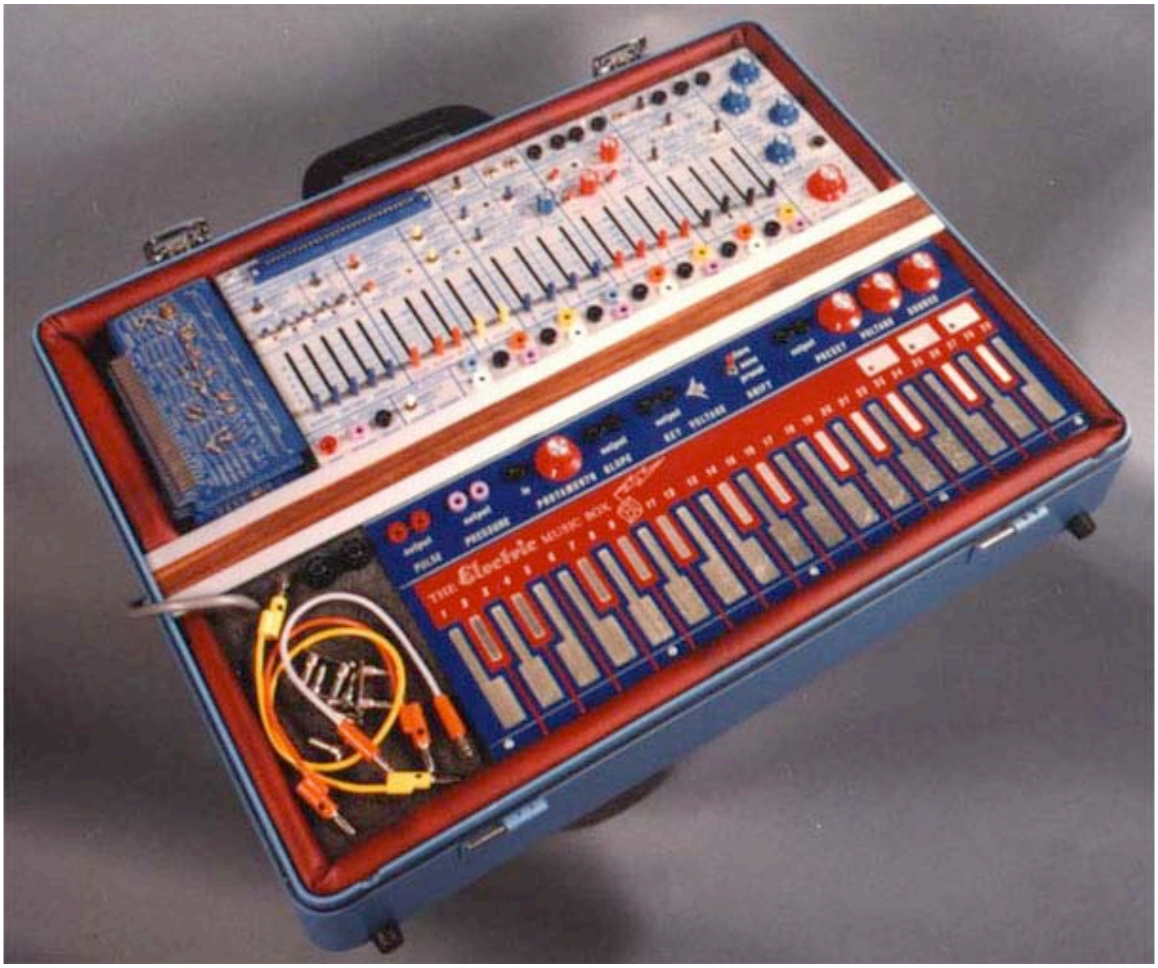
- 1963: 100 Series Modular Electronic Music System

Courtesy of Buchla and Associates. Used with permission.

- 1965: Buchla releases Buchla Box, without a keyboard
- 1970: 200 Series Electric Music Box

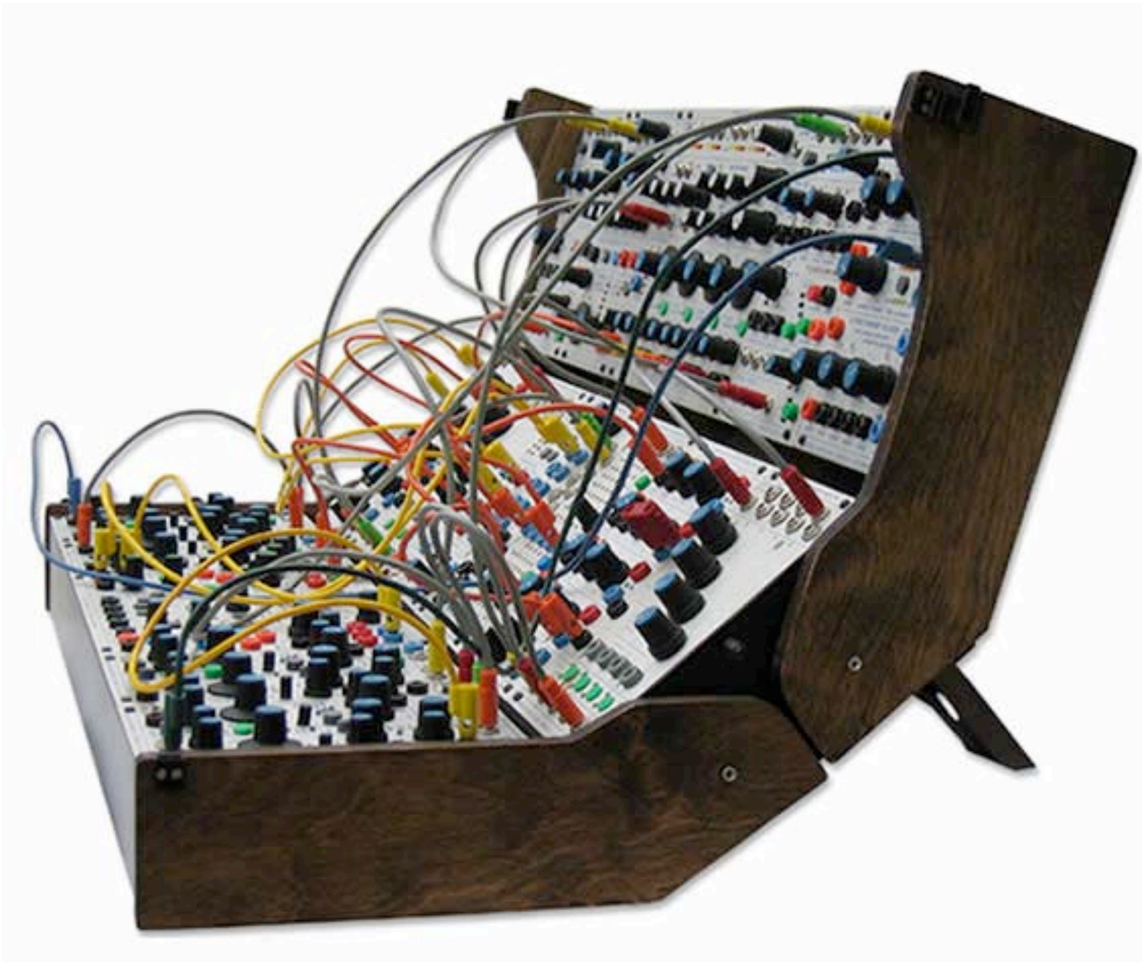
Courtesy of Buchla and Associates. Used with permission.

- 1971: 500 Series: First digitally controlled analog synthesizer
- 1972: Music Easel



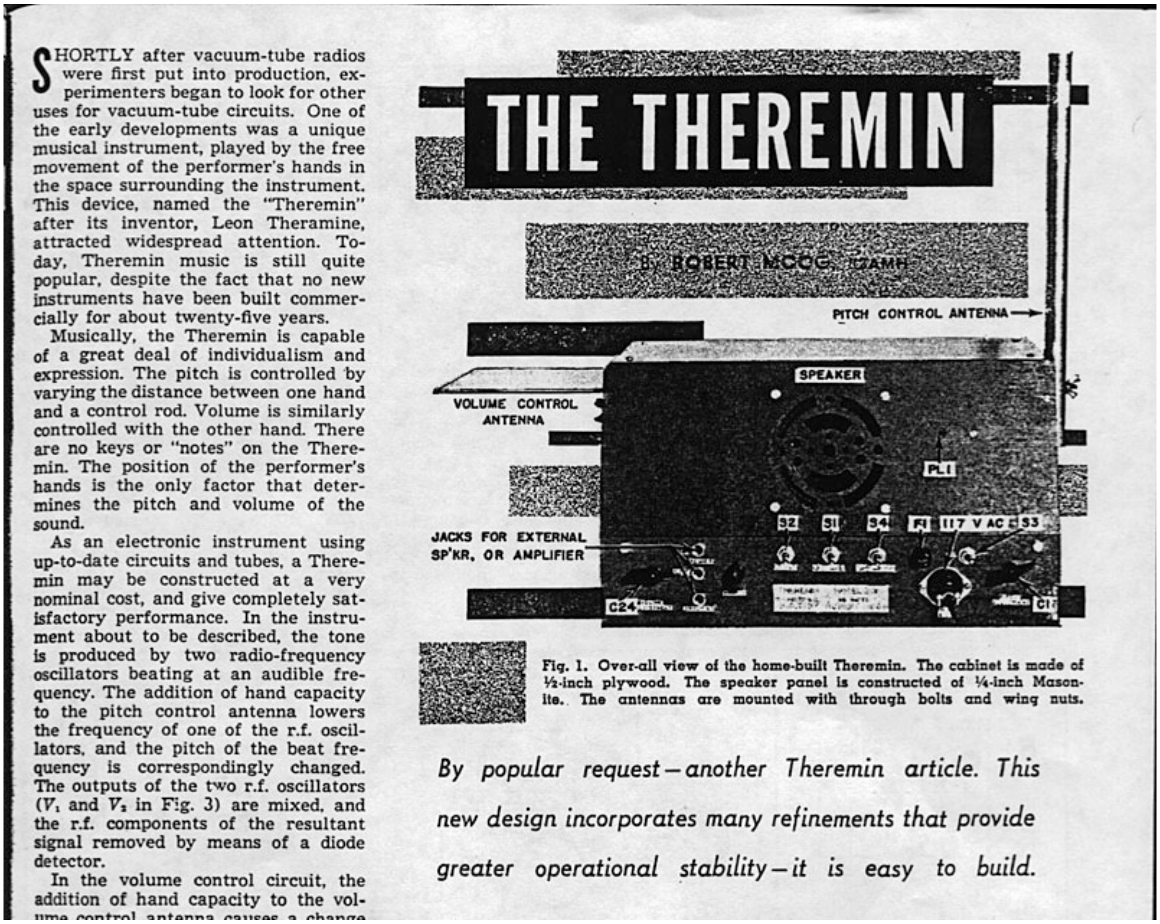
Courtesy of Buchla and Associates. Used with permission.

- 2002: Buchla 200e (19k+)


Courtesy of Buchla and Associates. Used with permission.

13.7. Foundations: Moog

- 1954: Moog publishes article in *Radio and Television News* on how to build a Theremin



THE THEREMIN

By ROBERT MOOG, W2AMH

SHORTLY after vacuum-tube radios were first put into production, experimenters began to look for other uses for vacuum-tube circuits. One of the early developments was a unique musical instrument, played by the free movement of the performer's hands in the space surrounding the instrument. This device, named the "Theremin" after its inventor, Leon Theramine, attracted widespread attention. Today, Theremin music is still quite popular, despite the fact that no new instruments have been built commercially for about twenty-five years.

Musically, the Theremin is capable of a great deal of individualism and expression. The pitch is controlled by varying the distance between one hand and a control rod. Volume is similarly controlled with the other hand. There are no keys or "notes" on the Theremin. The position of the performer's hands is the only factor that determines the pitch and volume of the sound.

As an electronic instrument using up-to-date circuits and tubes, a Theremin may be constructed at a very nominal cost, and give completely satisfactory performance. In the instrument about to be described, the tone is produced by two radio-frequency oscillators beating at an audible frequency. The addition of hand capacity to the pitch control antenna lowers the frequency of one of the r.f. oscillators, and the pitch of the beat frequency is correspondingly changed. The outputs of the two r.f. oscillators (V_1 and V_2 in Fig. 3) are mixed, and the r.f. components of the resultant signal removed by means of a diode detector.

In the volume control circuit, the addition of hand capacity to the vol-

Fig. 1. Over-all view of the home-built Theremin. The cabinet is made of ½-inch plywood. The speaker panel is constructed of ¼-inch Masonite. The antennas are mounted with through bolts and wing nuts.

By popular request—another Theremin article. This new design incorporates many refinements that provide greater operational stability—it is easy to build.

- 1961: Moog publishes article in *Electronics World* describing his transistor-based Theremin
- 1964: Moog, with composer Deutsch, builds first synthesizer prototype
- 1965: Moog releases 900 series for commercial sales

  Synthesizers used by composers, for advertising, jingles, and in recording studios
- 1966: Moog patents the 904A low/high-pass voltage-controlled filter with 24 dB / octave rolloff and resonance up to self-oscillation

ELECTRONIC HIGH-PASS AND LOW-PASS FILTERS EMPLOYING THE BASE TO EMITTER DIODE RESISTANCE OF BIPOLAR TRANSISTORS

Filed Oct. 10, 1966

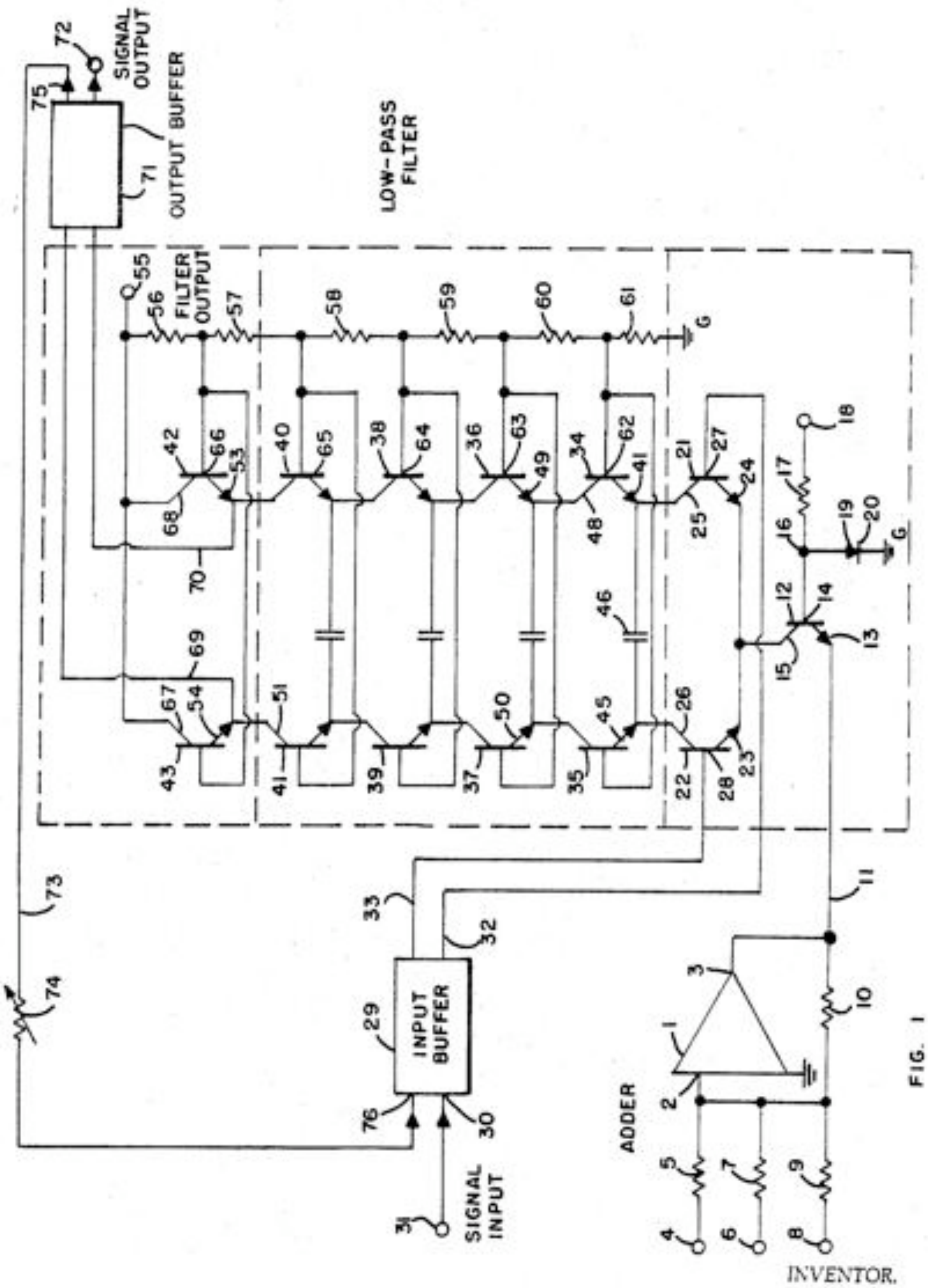


FIG. 1

INVENTOR.

ROBERT A. MOOG

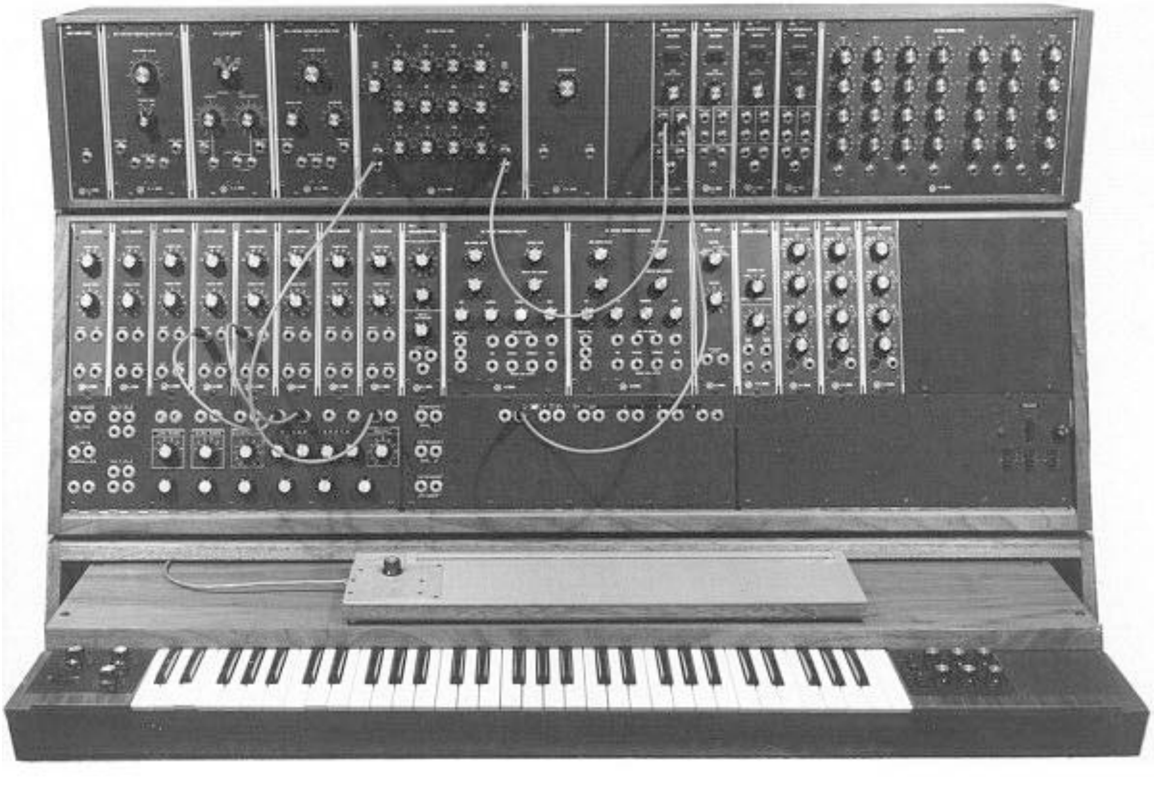
BY

Alfred W. Barber

ATTORNEY

- 1967: Moog releases modular systems I, II, and III

Courtesy of Roger Luther (http://www.moogarchives.com). Used with permission.



Courtesy of Roger Luther (http://www.moogarchives.com). Used with permission.

901-C OUTPUT STAGE: In conjunction with a 901-B oscillator, this instrument produces two outputs of equal magnitude but opposite sign, of any of the 901-B waveforms. The output is variable, and is used as a control voltage.

$ 45.00

901-D VARIABLE WAVEFORM OUTPUT STAGES; In conjunction with a 901-B oscillator, this instrument produces two outputs of equal magnitude but opposite sign. All of the 901-B waveforms are available and may be mixed in any proportion. In addition, variable clipping is provided to shape the triangular wave. Outputs are used as control voltages.

$ 75.00

902 VOLTAGE-CONTROLLED AMPLIFIER: A universal "variable-gain black box" with balanced, direct-coupled inputs and outputs. In conjunction with control voltage generators such as the 901, 911, 912, or 955, this instrument will perform virtually any amplitude-varying function.

$150.00

902-A BAND PASS FILTER ADAPTOR: Converts a 902 VCA into a voltage-controlled bandpass filter with a three octave range.

$100.00

903-WHITE SOUND SOURCE: Generates white noise over a 1-20,000 cps bandwidth.

$ 60.00

904-VOLTAGE CONTROLLED LOW-PASS HIGH-PASS FILTER: Provides voltage controlled filtering over a seven-octave frequency range. High pass, low pass, and resonant modes are available. The high pass and low pass modes may be combined for broad band-pass or band-reject functions.

$475.00

904-A LOW PASS FILTER: The low pass section of the 904.

$250.00

904-B HIGH PASS FILTER: The high pass section of the 904.

$230.00

October, 1965 Catalog -2-

Courtesy of Roger Luther (http://www.moogarchives.com). Used with permission.

- 1968: Wendy Carlos records *Switched on Bach*

13.8. Concepts: Generators and Modifiers

- Modules are individual signal generating/processing components
- Two basic types of components: generators and modifiers
- Input is from front-panel knobs or voltages
- Output is a voltage

13.9. Concepts: Control and Audio Signals

- Two types of signals (voltages): audio and control signals
- Audio signals:
  - Sounds, alternating (bipolar) voltages in the audio range (faster than 20 to 30 Hz)
  - Voltage range from -3 to 3 volts (or wider)
- Control signals
  - Parameter values, (unipolar) voltages
  - Voltage range from 0 to 5 volts (or up to 15 volts)
  - Used to send control information to other modules
  - Used to provide envelope shapes

13.10. Concepts: Reuse and Interoperability

- Can use output of one module as a signal (audio or control) input to another
- Can use an audio signal (shifted or scaled) as a control signal

13.11. Concepts: Creative Patching

- Developing new signal flows becomes a compositional task
- New signal flows may be timbral adjustments, instrument designs, or compositional procedures
- Patching modules and organizing control voltages becomes an interface

13.12. Synthesizer Components: Generators

- Generators: produce raw signals for further processing
- Oscillators (VCO): sine, square, triangle, sawtooth

Courtesy of Arturia. Used with permissiom.

- Low frequency oscillator (LFO): specialized for slow speeds
- Noise: white and pink

Courtesy of Arturia. Used with permissiom.

- Sample and hold (SAH): sample a generator and transform it into a stepped signal

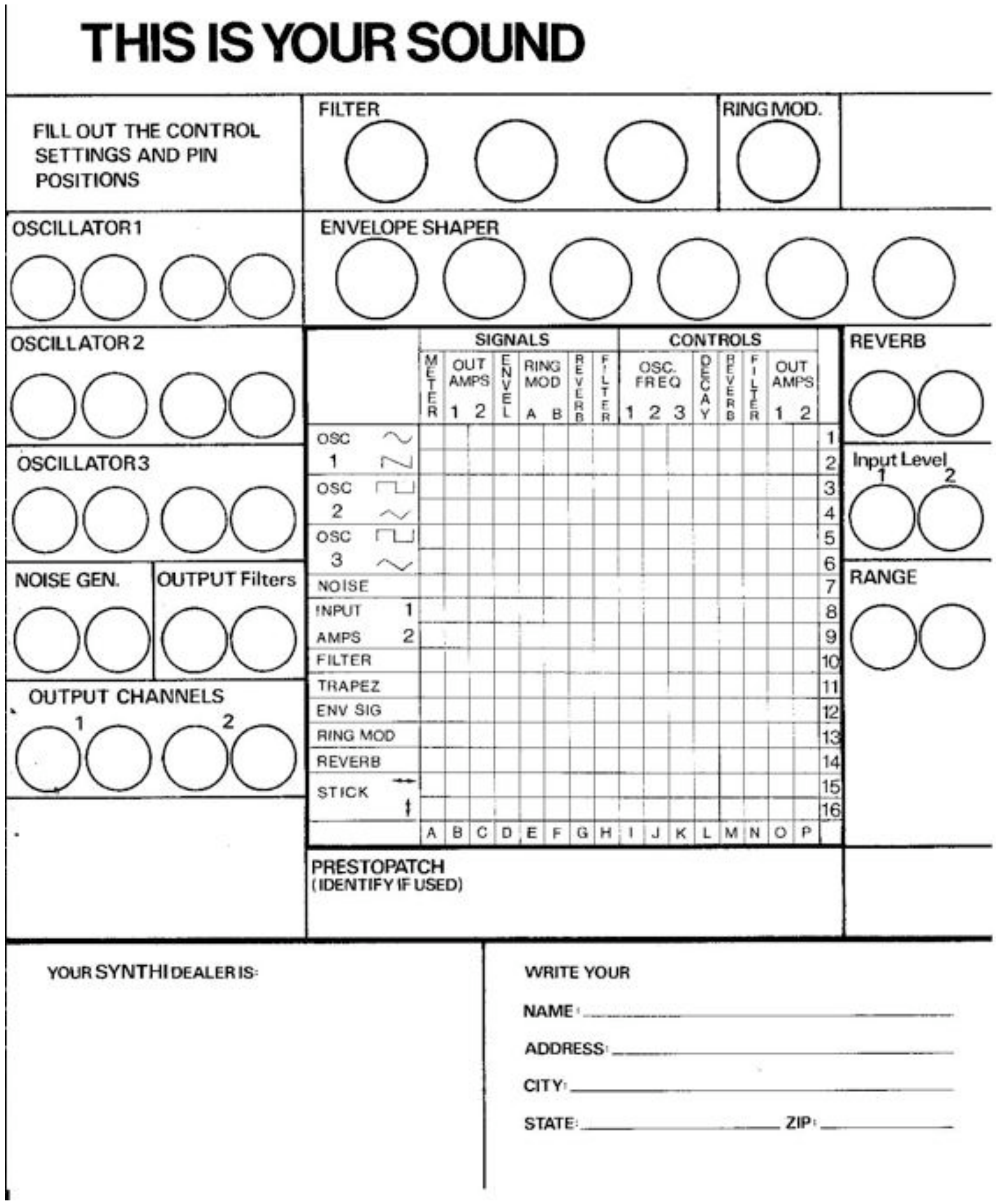
Courtesy of Arturia. Used with permissiom.

13.13. Synthesizer Components: Signal Mixing, Amplifying, and Routing

- Mixers (adding, summing) and amplifiers (scaling, multiplying)
- Voltage controlled amplifier (VCA)
- Mixer with toggles

- Matrix patching and mixing

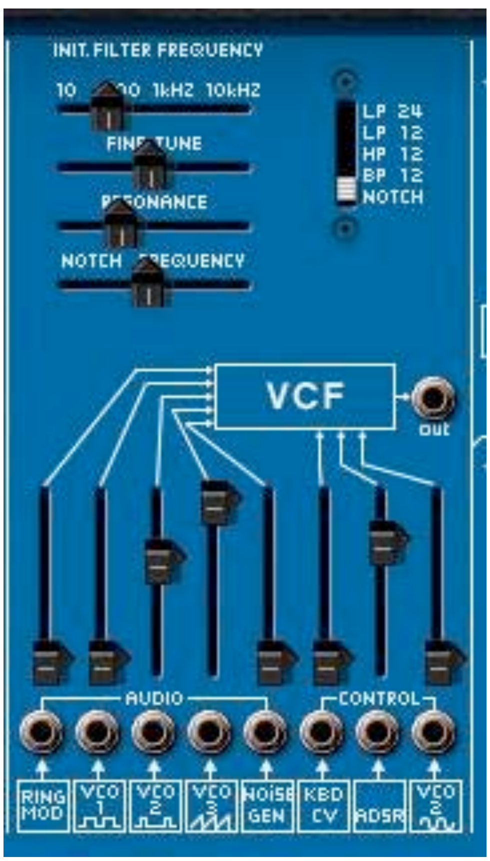
Courtesy of Electronic Music Studios. Used with permission.



Courtesy of Electronic Music Studios. Used with permission.

13.14. Synthesizer Components: Filters

- Boost or cut the amplitude of spectral components, changing the timbre of the sound
- Common varieties: low pass (LPF), high pass (HPF), band pass (BP), notch
- Voltage controlled filter (VCF)



Courtesy of Arturia. Used with permissiom.

13.15. Synthesizer Components: Envelopes

- Unipolar control rate signals used for controlling amplitudes and parameters of other modules (e.g. filter cutoff frequencies)

- Attack, decay, sustain, release (AR, ADS, ADSR)

  ADSR design built by Moog at request of Ussachavesky (Pinch and Trocco 2002, p. 71)

Courtesy of Arturia. Used with permissiom.

Courtesy of Arturia. Used with permissiom.

13.16. Subtractive Synthesis

- Start with a rich, complex tone produced with oscillators and/or noise
- Apply filters to create timbral variation
- Apply amplitude envelopes to shape dynamic amplitude (and filter) contours
- Use modulation of any of these parameters to create dynamic changes, triggered either at the start of each event (by an envelope) or continuously (by an LFO)
- Modulate the modulators!

13.17. Combining and Detuning Oscillators

- Oscillators are commonly grouped in bundles: three 921b oscillators managed by a 921a controller
- Multiple waveform shapes can be used from one oscillator simultaneously
- Driver provides frequency for all oscillators; each oscillator then has tuning to adjust each tone

- Pulse-width and frequency modulation input on driver affect all frequencies
- Three oscillators mixed together, and sent to ADSR. Leftmost ADSR envelope is triggered by keyboard and sent to main outs by default

Courtesy of Arturia. Used with permissiom.

13.18. Applying Filters

- Low pass filtering with cutoff frequency modulation by LFO

- Low pass filtering with cutoff frequency modulation by envelope

Courtesy of Arturia. Used with permissiom.

13.19. Amplitude Modulation and Ring Modulation

- Modulate the amplitude with a waveform moving between -1 and 1 (ring modulation) or 0 and 1 (amplitude modulation)
- Creating tremolo effects: modulator is an LFO at a sub-audio rate (slower than 20 Hz)
- Creating new harmonics: modulation at the audio rate (faster than 20 Hz)
- Using unconventional waveforms may produce interesting effects
- Three oscillators mixed and sent to an amplifier; the amplifier is modulated by sine wave; the output is sent to the ADSR.

Courtesy of Arturia. Used with permissiom.

- Modulate the frequency of the modulator: three oscillators mixed and sent to an amplifier; the amplifier is modulated by sine wave; the rate of this modulation is modulated by another sine wave; the output is sent to the ADSR.

Courtesy of Arturia. Used with permissiom.

13.20. Ring Modulation

- Dedicated ring modulators offer controls for frequency and depth; built in oscillator offers sine wave modulator
- Three oscillators are mixed; the signal is sent to the ring modulator; the signal is sent to the ADSR

Courtesy of Arturia. Used with permissiom.

- Can modulate frequency and/or depth of ring modulation with LFO or envelope

13.21. Vibrato

- Modulate the frequency of an oscillator with a sine wave

- Scale the modulator by an envelope triggered at the start of the event, fading the vibrato in and out

Courtesy of Arturia. Used with permissiom.

13.22. Frequency Modulation

- Modulate the frequency with a sine wave so fast and wide as to create new harmonics

Courtesy of Arturia. Used with permissiom.

- Modulate the modulator

Courtesy of Arturia. Used with permissiom.

13.23. Filtered Noise

- Use a narrow band filter controlled by the keyboard to filter noise

Courtesy of Arturia. Used with permissiom.

13.24. Sample and Hold

- Sample and hold applying noise to frequency modulation

Courtesy of Arturia. Used with permissiom.

13.25. Listening: Carlos

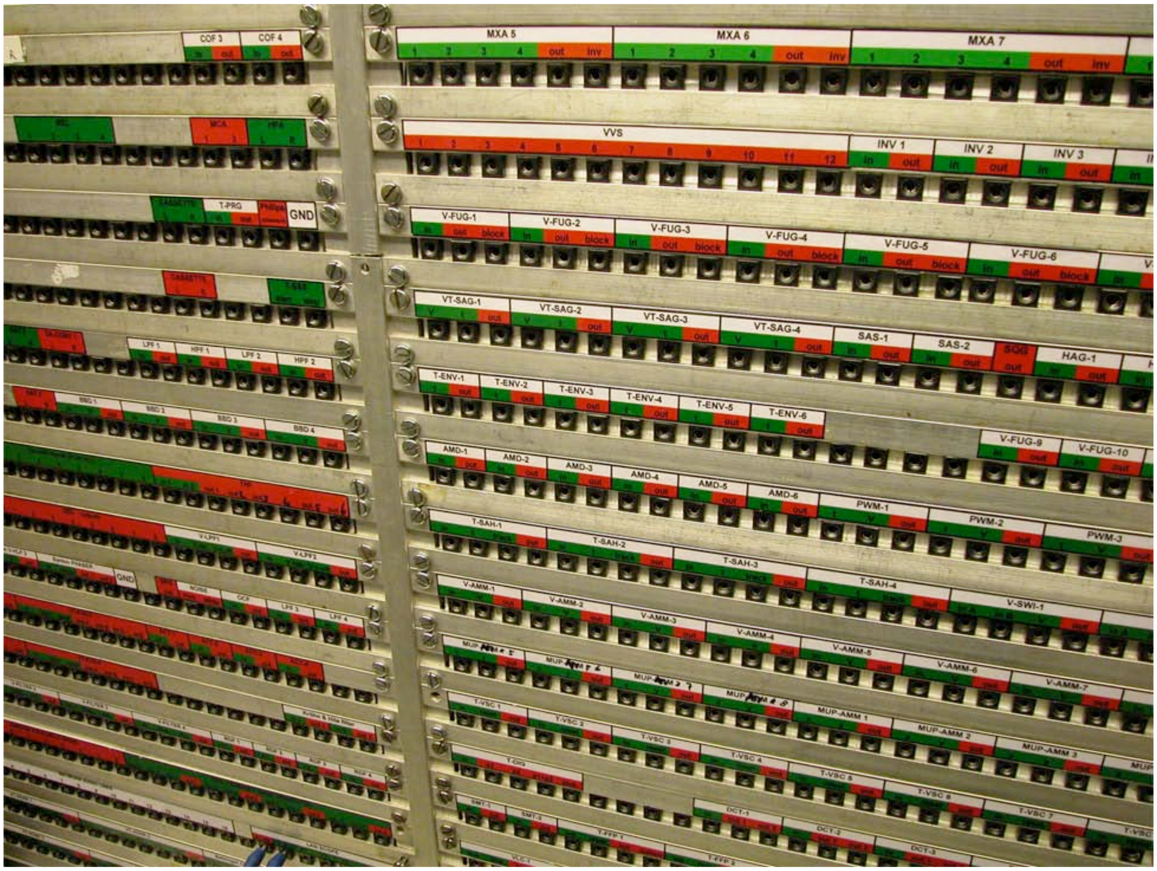
- Graduate student at Columbia during the time of the RCA Mark II Synthesizer
- 1966: Works with Moog to design custom system and produce a Moog demo LP (2008, p. 218)
- 1968: *Switched-on Bach* is the first Platinum-selling classical album

- Performed Bach on a Moog synth, with multi-track recording and layering of parts
- Audio: Wendy Carlos on the production
- Audio: Wendy Carlos, Cantata #147, BWV 147, *Switched on Bach*, 1969

- Audio: Wendy Carlos, The Well-Tempered Clavier, Book 1 - Prelude & Fugue #2 In C Minor, BWV 847, *Switched on Bach*, 1969

13.26. Listening: Koenig

- The Institute of Sonology modular synthesizer (BEA-V)



- Explored approaches to automating synthesis parameters based on a single voltage-control pattern, applied and mapped in a variety of ways
- Audio: Gottfried Michele Koenig, *Funktion Grau*, 1969

13.27. Listening: Subotnick

- Audio: Morton Subotnick, *Silver Apples of the Moon*, Parts A and B, 1967

- Composed on a Buchla synthesizer, with the use of a sequencer to organize musical structures (Holmes 2008, p. 224)
- First electronic composition conceived and recorded for release on a commercial recording (Holmes 2008, p. 431)
- How is noise and randomness used in this composition?
- Do we hear sounds performing roles similar to acoustic instruments?

13.28. Listening: Oliveros

- Audio: Pauline Oliveros, “Alien Bog,” 1967

- Created on a Buchla Box 100 series synthesizer
- Do we hear sounds performing roles similar to acoustic instruments?

13.29. The ARP 2600

- ARP founded by Alan R. Pearlman and others in 1969
- Released the ARP 2500 modular synthesizer in 1970

- Released the ARP 2600 in 1971

Courtesy of ToneTweakers. Used with permission.

- Semi-modular: fixed collection of modules in each package, and default connections that could be altered with patch cables
- Featured built-in speakers and spring reverb
- ARP was market leader in synthesizers in the 1970s, with 40% of market share
- 1976: ARP releases 16 step sequencer

13.30. The Minimoog

- 1969: Moog receives requests for more compact and portable instrument
- Contained around 300 transistors and took Moog six months to design (Theberge 1997, p. 70)
- Early prototypes

- Introduced in 1970: "a compact, moderately priced electronic music synthesizer designed and built especially for live performance"

introducing...

the mini moog model d

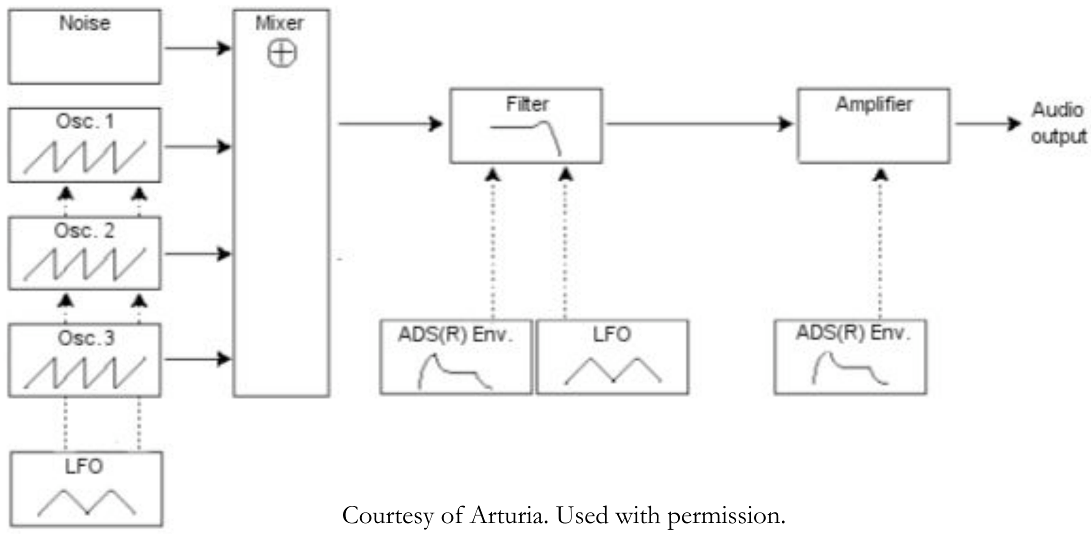
Here it is! A compact, moderately priced electronic music synthesizer designed and built especially for live performance by R. A. Moog, Inc., leading manufacturer of new electronic musical instruments for nearly two decades. The Mini Moog is not merely another sound modifier built to enhance the sound of other instruments, although it can perform this function and many more. It is not another electronic organ with added gimmicks for creating special effects. It is a completely new musical instrument, designed from the bottom up with today's performing musician in mind, and making accessible for the first time a vast range of sound possibilities which had hitherto been available only to experimental composers with an involved knowledge of studio techniques. The Mini Moog incorporates the basic synthesizer functions, so widely in demand by avant-garde, jazz, rock, and pop musicians familiar with the new sounds of electronic music, in an inexpensive, lightweight, portable package designed to be easily set up and played.

The most popular and useful types of sound generators, sound modifiers, and control devices to be found on our large studio model Moog synthesizers are all incorporated in the Mini Moog. Sound generators include three oscillators, producing pitched tones over the entire range of human hearing with several different waveforms, a noise source for producing pitchless sound, and a microphone/accessory amplifier through which sounds from other sources may be introduced into the Mini. Sound modifiers include a wide-range voltage-controlled lowpass filter and a voltage-controlled amplifier, each with its own contour generator. Control devices include a full-size 44-note keyboard and two special slide controllers for touch-sensitive modulation of the tone.

These basic functions make immediately accessible a vast realm of new musical material. Because all component circuits in the Mini Moog are independent of one another, the musician is able to combine them in a variety of ways. Thus rather than being tied down to a limited set of sounds or effects, he is really free to explore all the basic aspects of musical sonority, setting, shaping, and modulating each aspect of the tone color to suit his own tastes. The Mini Moog for the first time places the control of many parameters of sound literally at the fingertips of the creative and imaginative musician.

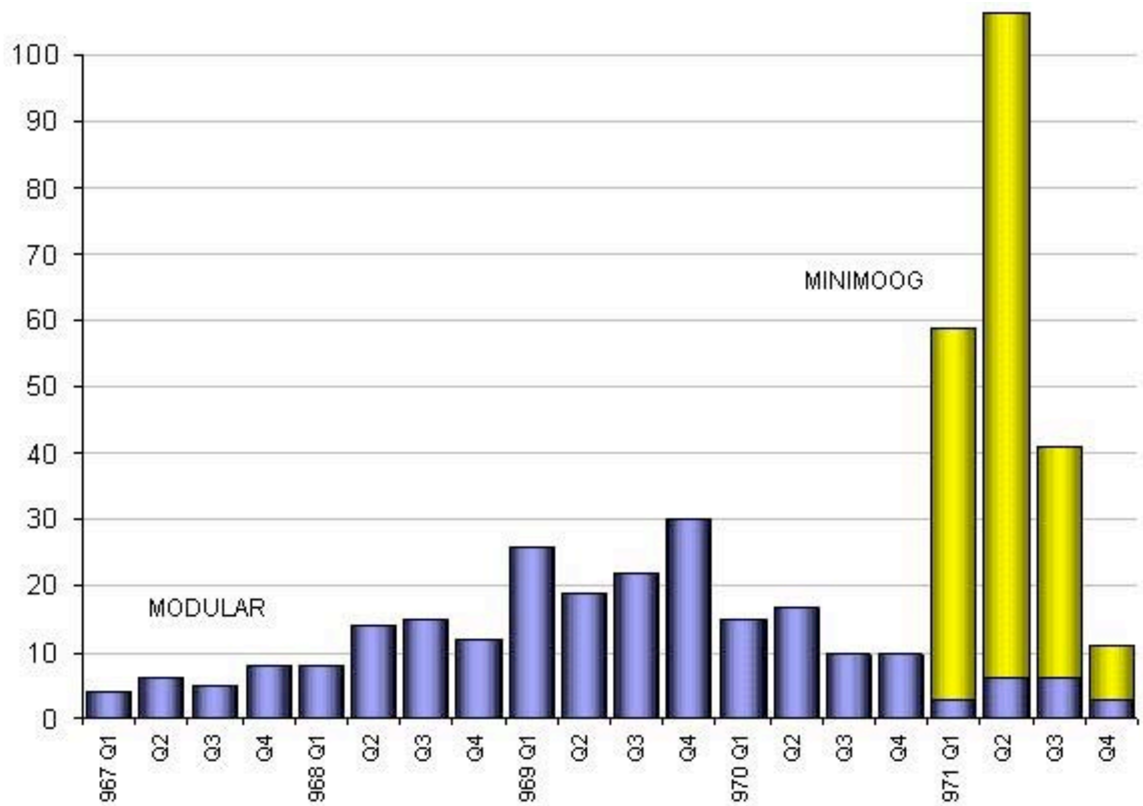
R. A. MOOG, INC., TRUMANSBURG, NEW YORK 14886 PHONE (607) 387-6101

- Simplified abstraction of subtractive synthesis



Courtesy of Arturia. Used with permission.

- Sales were much greater than modular systems



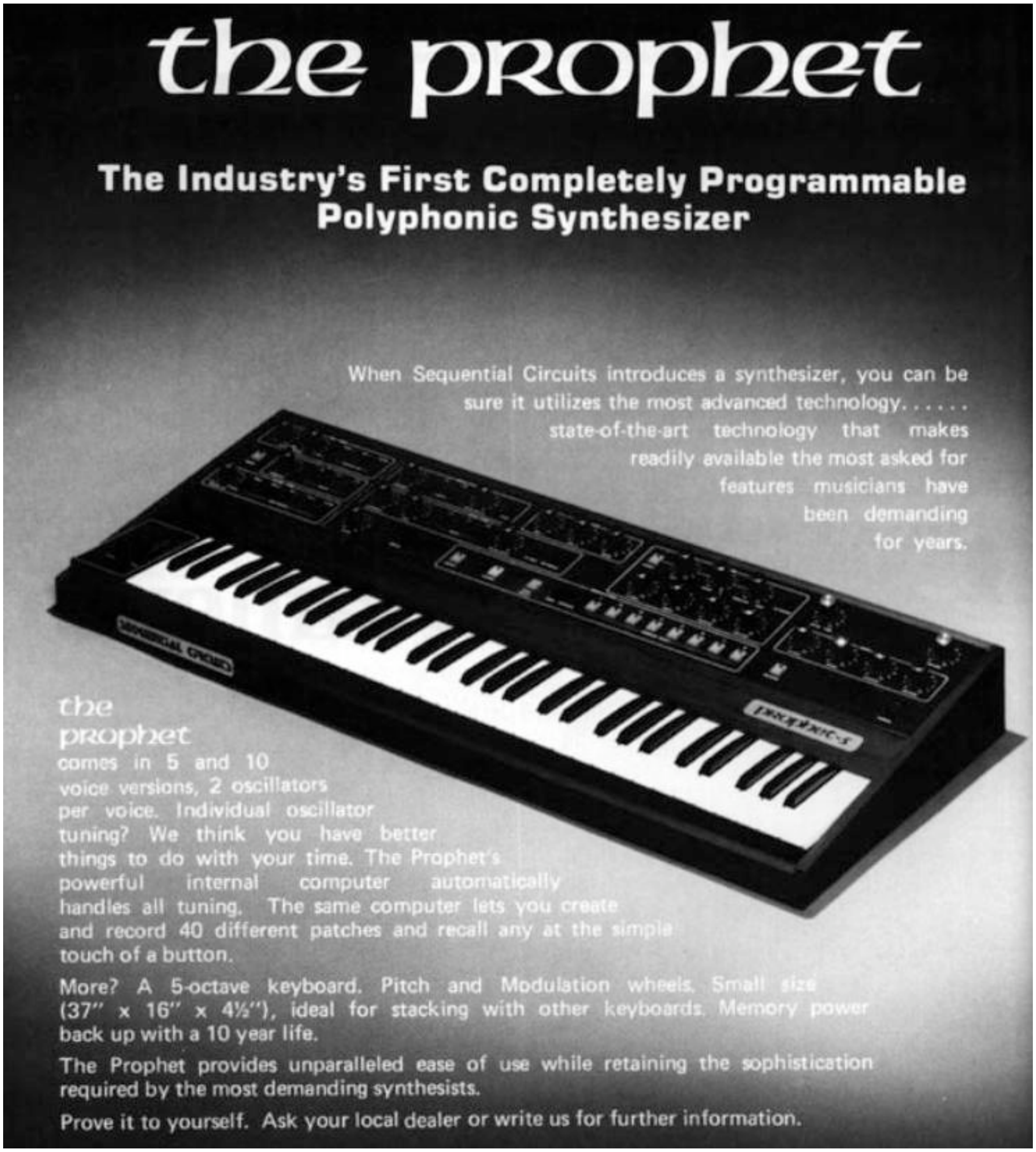
Courtesy of Roger Luther (http://www.moogarchives.com). Used with permission.

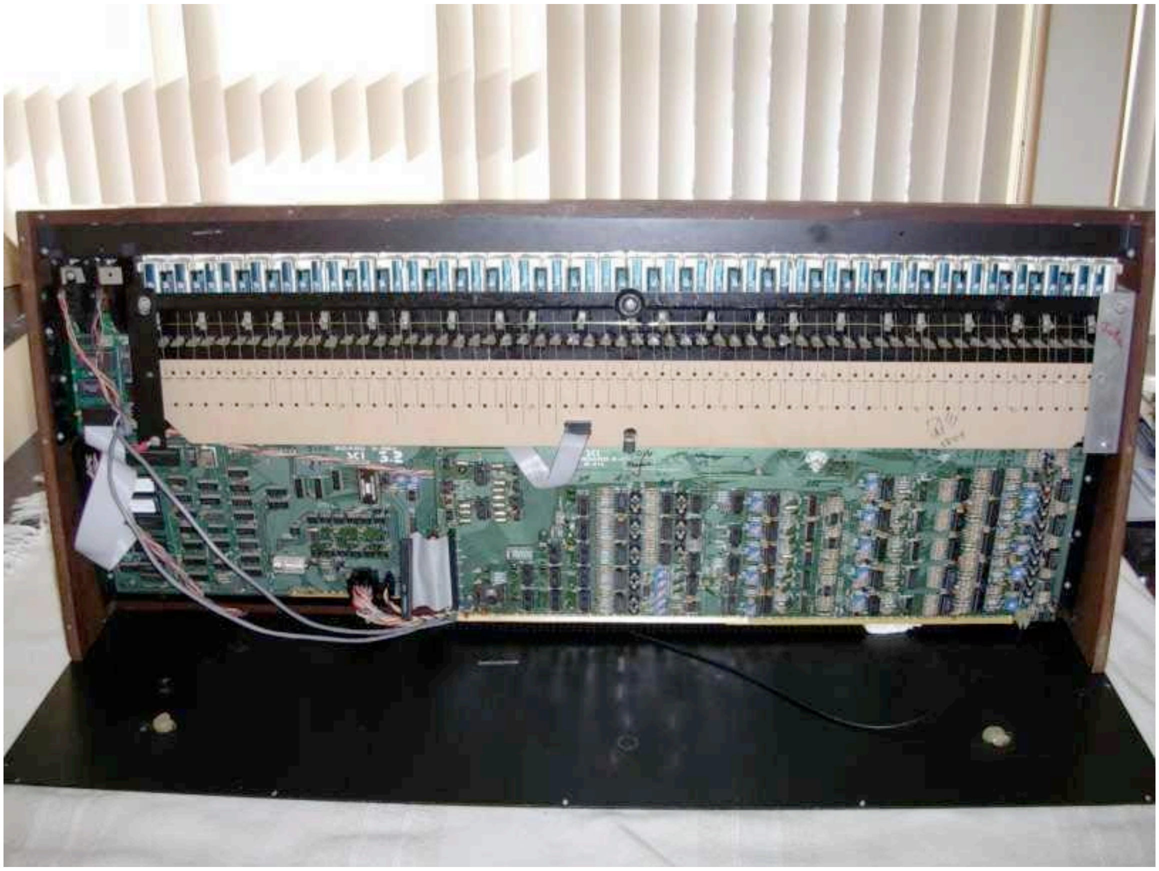
- 1972 to 1981: main production models distributed

13.31. The Sequential Circuits Prophet 5

- 1978: Dave Smith and others start company out of Smith's garage
- 1978: Sequential Circuits releases Prophet-5

Courtesy of Arturia. Used with permission.


the prophet
The Industry's First Completely Programmable Polyphonic Synthesizer
When Sequential Circuits introduces a synthesizer, you can be sure it utilizes the most advanced technology...... state-of-the-art technology that makes readily available the most asked for features musicians have been demanding for years.
the prophet comes in 5 and 10 voice versions, 2 oscillators per voice. Individual oscillator tuning? We think you have better things to do with your time. The Prophet's powerful internal computer automatically handles all tuning. The same computer lets you create and record 40 different patches and recall any at the simple touch of a button.
More? A 5-octave keyboard. Pitch and Modulation wheels. Small size (37" x 16" x 4½"), ideal for stacking with other keyboards. Memory power back up with a 10 year life.
The Prophet provides unparalleled ease of use while retaining the sophistication required by the most demanding synthesists.
Prove it to yourself. Ask your local dealer or write us for further information.



- Described as "5 Minimoogs in one box"
- Original prices between $4000 and $5000
- A digital-analog hybrid: interface provides data to a "microcomputer system which in tern 'programs' the voices." (1982 Operation Manual)
- First synthesizer to permit storing and recalling presets
- "... several months after the introduction of the Prophet-5 in 1978, the service department at Sequential Circuits began to notice that most of the instruments returned to the factory for repairs still had the factory preset programs in their memory banks. They thus assumed that the majority of users, 80 percent or more, were not actually programming at all but were relying almost exclusively on the presets." (Theberge 1997, p. 75)
- Led to the development of a preset- or patch-making industry
- Prophet VS released in 1986 and 1987: permitted cross-fading between waveforms and free assignment within modulation matrix

13.32. Reading: Pinch and Trocco

- Pinch, T. and F. Trocco. 2002. "The Social Construction of the Early Electronic Music Synthesizer." In *Music and Technology in the Twentieth Century*. H. Braun, ed. Baltimore: The Johns Hopkins University Press. 67-83.
- How did the availability of cheap transistors in the 1960s influence the development of the synthesizer?
- Pinch and Trocco quote Moog describing a particular pose favored in product photographs: what was this pose, and why was it desirable?
- What ideas about the early synthesizer reached closure by the early 1970s?
- What relevant social groups participated in the development of the early synthesizer?

Chapter 14. Meeting 14, Interfaces: Sequencers, Rhythm Machines, and Samplers

14.1. Announcements

- Music Technology Case Study Drafts due next Tuesday

  Draft should meet minimum requirements of final paper

  Contact me with questions or problems

  Submit draft digitally by midnight on Tuesday

- Next Tuesday: bring your laptops with PD-Extended and Martingale

14.2. Quiz

- 10 Minutes

14.3. Listening: Oswald

- Audio: John Oswald, "Black"

14.4. Reading: Oswald

- Oswald, J. 1985. "Plunderphonics, or Audio Piracy as a Compositional Prerogative." *Wired Society Electro-Acoustic Conference*. Internet: http://www.plunderphonics.com/xhtml/xplunder.html.

- 1960s: Mellotron, tape-based sample playback machine where each key pressed a tape-head onto a tape

- 1979: Fairlight Computer Musical Instrument (CMI): first polyphonic digital sampler

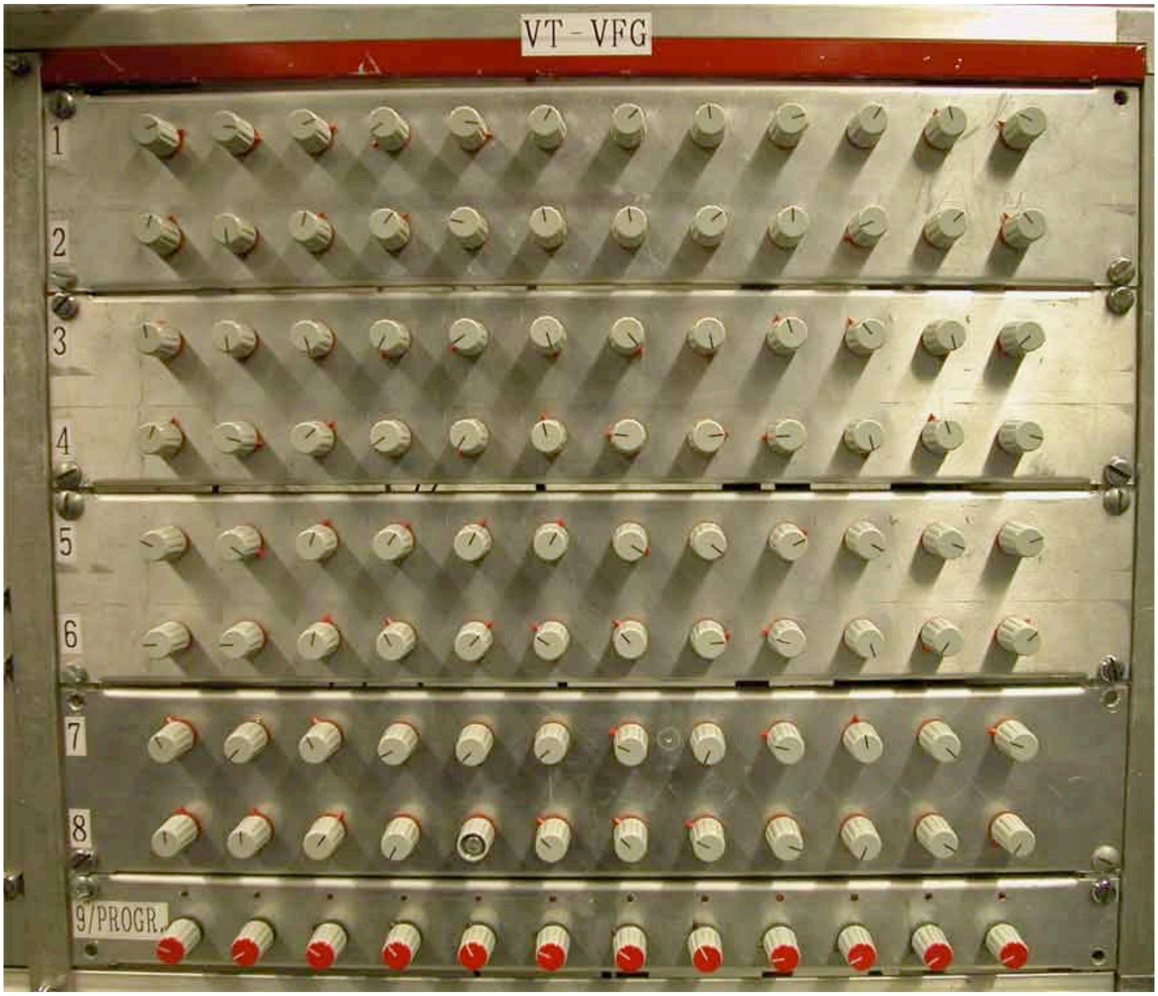
  YouTube (http://www.youtube.com/watch?v=n6QsusDS_8A)

- 1984: Ensoniq Mirage sampler: first affordable sampler

- Can an instrument or a timbre be considered a composition, like a sample?
- Is it a problem that musical notation does not have a quotation mark?
- How can a casual home listener become a more active listener?
- Why, in Oswald's view, might all popular or folk music be public domain?

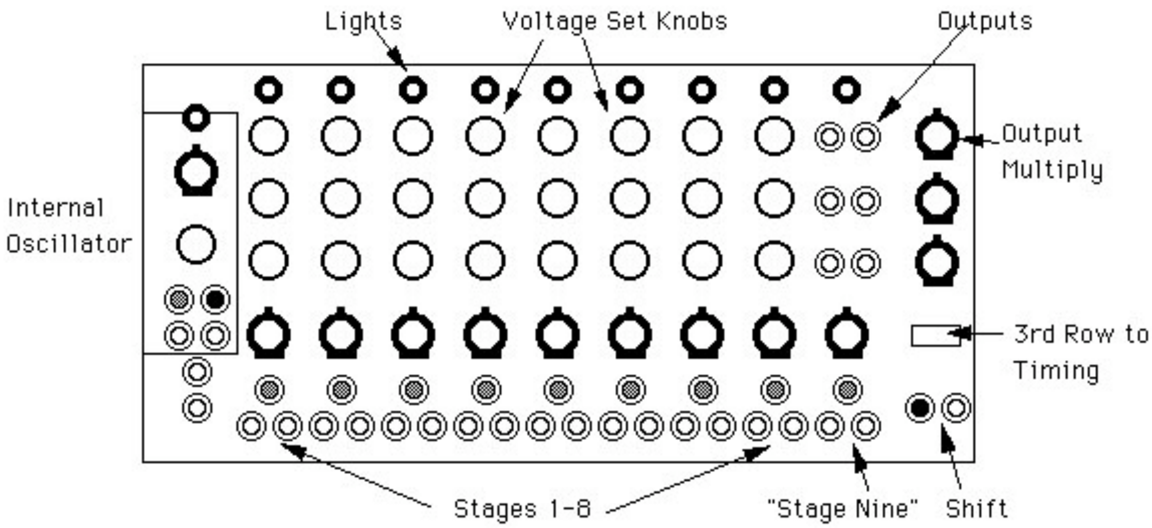
14.5. The Sequencer

- Numerous early synthesizers by Moog, Buchla, and ARP offered various forms of step sequencers
- At a minimum, provided a series of voltages that could be stepped through
- A custom-shaped LFO
- The Sonology Variable Function Generator: a custom sequencer capable at running at the audio rate

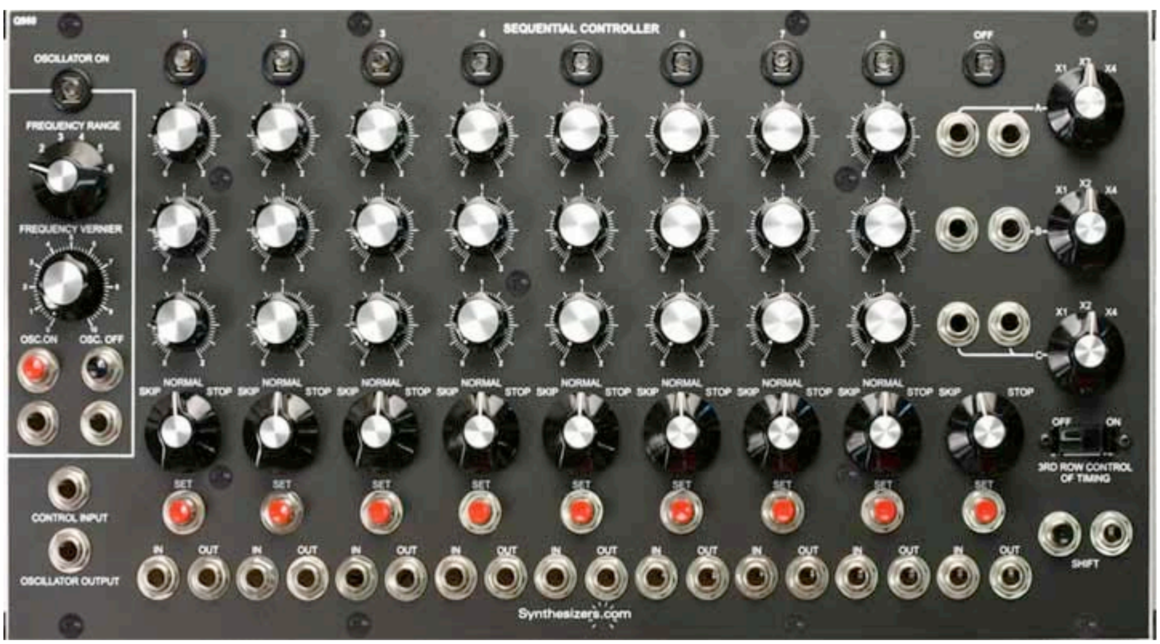


14.6. Moog 960 Sequential Controller

- Sequential controller provided a sequence of voltages that could be used to control any musical parameter
- Moog 960 Sequential Controller (1968)



Courtesy of the Electronic Music Studios at the University of California, Santa Cruz. Used with permission.



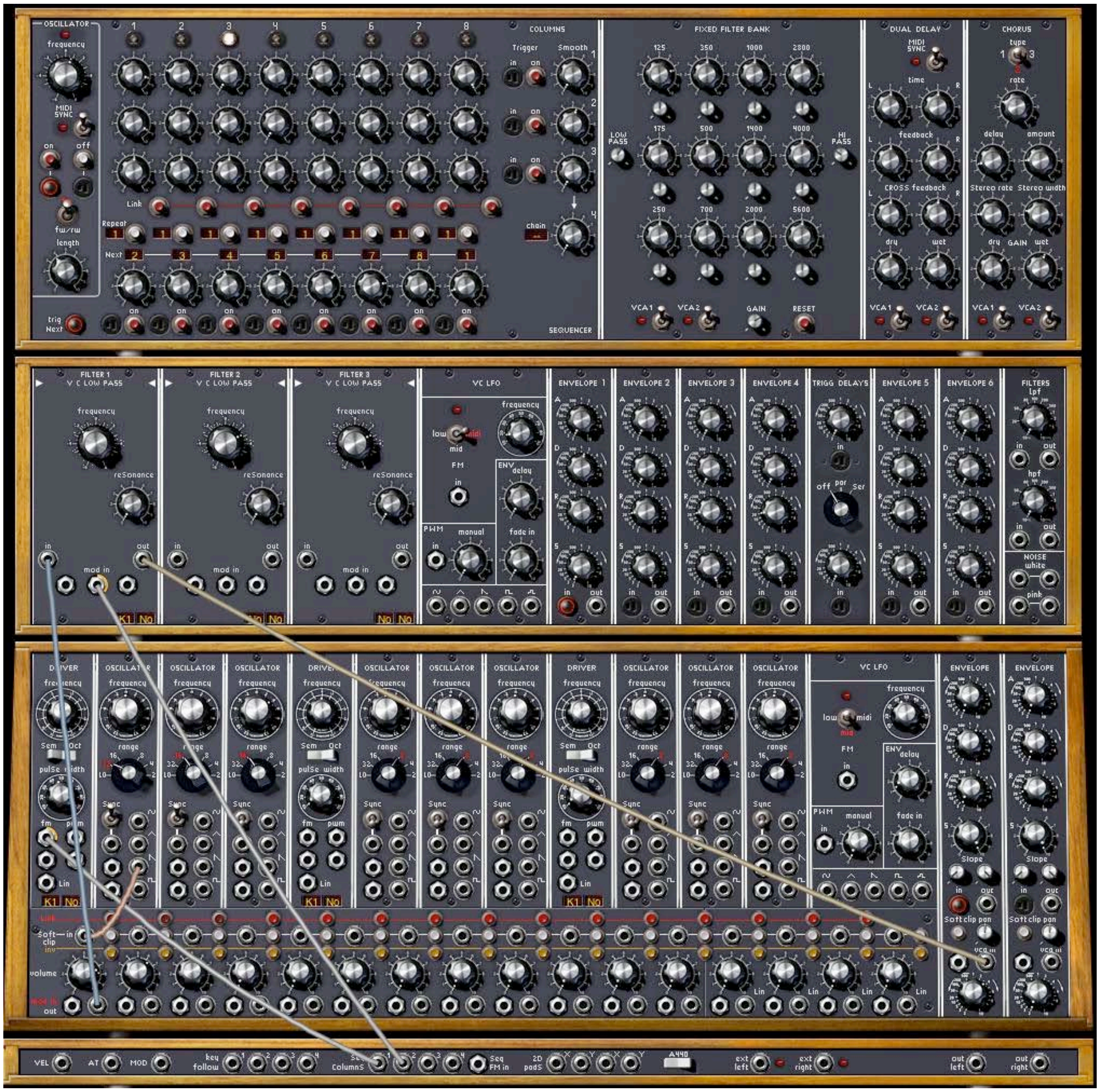
Courtesy of Synthesizers.com. Used with permission.

- Permitted 8 steps, each step with three voltages
- Each step could be played, skipped, or used as a point of loop-back
- With a Moog 962, three rows could be treated as one 24 step sequence
- Output could be shifted by another, independent voltage to create arpeggios
- Examples

  YouTube (http://www.youtube.com/watch?v=H2zpMKKamWI)

  YouTube (http://www.youtube.com/watch?v=gNmzyZaqVwI)

- Arturia virtual Moog modular, with row 1 modulating oscillator frequency and row 2 modulating filter cutoff frequency



Courtesy of Arturia. Used with permission.

14.7. Drum Machines: Early Experiments: Rhythmicon

- 1931: Henry Cowell commissioned Termin to build a machine that could play complex rhythms
- Could produce sixteen parts
- Schillinger with the Rhythmicon

- American Mavericks: The Online Rhythmicon: site (http://musicmavericks.publicradio.org/rhythmicon/index.html)

14.8. Drum Machines: Organ Accompanists

- 1959-1964: Wurlitzer Sideman

  Analog sound sources employing tubes

YouTube (http://www.youtube.com/watch?v=QLgyQG8Pu8s)

14.9. Drum Machines: Analog Drums

- 1970s: Rhythm Ace, by Ace Tone (later Roland)

- 1978: Roland CR-78: programmable drum machine, analog drum voices

preset rhythms for Waltz, Bossa Nova and Rhumba; preset fills and variations

YouTube (http://youtube.com/watch?v=b0tdkP4GaGg)

- 1980: Roland TR-808 Rhythm Composer

  transistor rhythm (TR); sixteen sounds; 32 programmable steps

Image courtesy of dAvid on Flickr.

YouTube (http://youtube.com/watch?v=jUx7ax62OBo)

- Numerous software emulations available: http://www.hobnox.com/index.1056.de.html

14.10. Afrika Bambaataa

- Associated with Afro-futurism
- From the South Bronx and development of hip-hop in the late 1970s
- Embrace of analog drum sounds and drum machines when not broadly accepted

14.11. Listening: Bambaataa

- Audio: Afrika Bambaataa, "Planet Rock" 1982

14.12. Drum Machines: Digital Sampling

- 1979: Linn Electronics LM-1

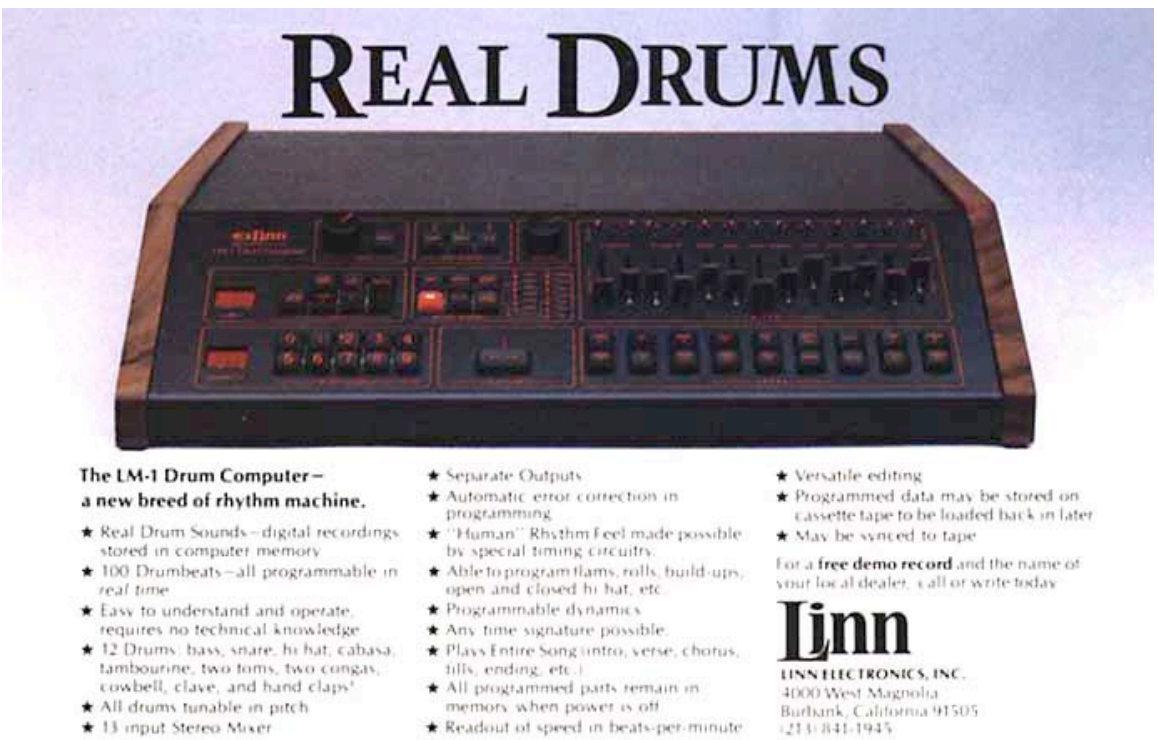
  First programmable sampling drum machine; 18 sounds, $5000

Courtesy of Roger Linn Design. Used with permission.

- 1982: LinnDrum

  $3000

Courtesy of Roger Linn Design. Used with permission.



Courtesy of Roger Linn Design. Used with permission.

- 1984: Linn 9000

Sampling drum machine with MIDI sequencer

Courtesy of Roger Linn Design. Used with permission.

- 1988: Akai MPC60

  Linn worked with Akai to create MPC series

Courtesy of Roger Linn Design. Used with permission.

- recent: Akai MPC1000

  64 track MIDI sequencer, 32 voice stereo sampler, compact flash data storage

- Pete Rock on the MPC (1:43, 2:43)

  YouTube (http://youtube.com/watch?v=Faad8AmCl8c)

- Examples

  YouTube (http://www.youtube.com/watch?v=gFWazOuwwgw)

14.13. Listening: Public Enemy

- Audio: Public Enemy: "Fight the Power"

14.14. Reading: Walser

- Walser, R. 1995. “Rhythm, Rhyme, and Rhetoric in the Music of Public Enemy.” *Ethnomusicology* 39(2): 193-217.

Figure 1: "Fight the Power," opening groove

Courtesy of University of Illinois Press. Used with permission.

- Why does Walser see the use of transcriptions as important?

- What are common arguments why rap is not music?
- What techniques of sampler misuse and audio production are used to create the Bomb Squad sound?

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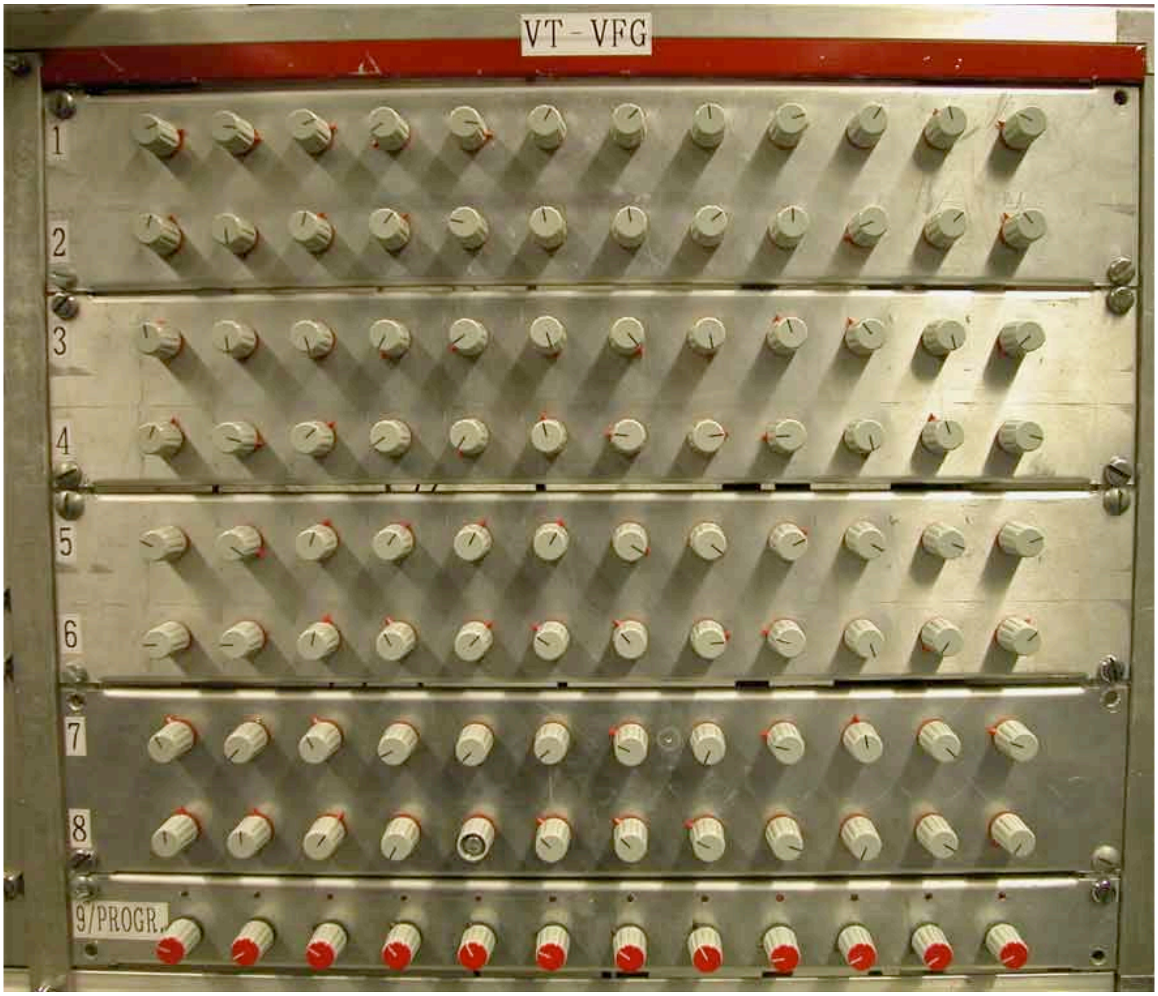

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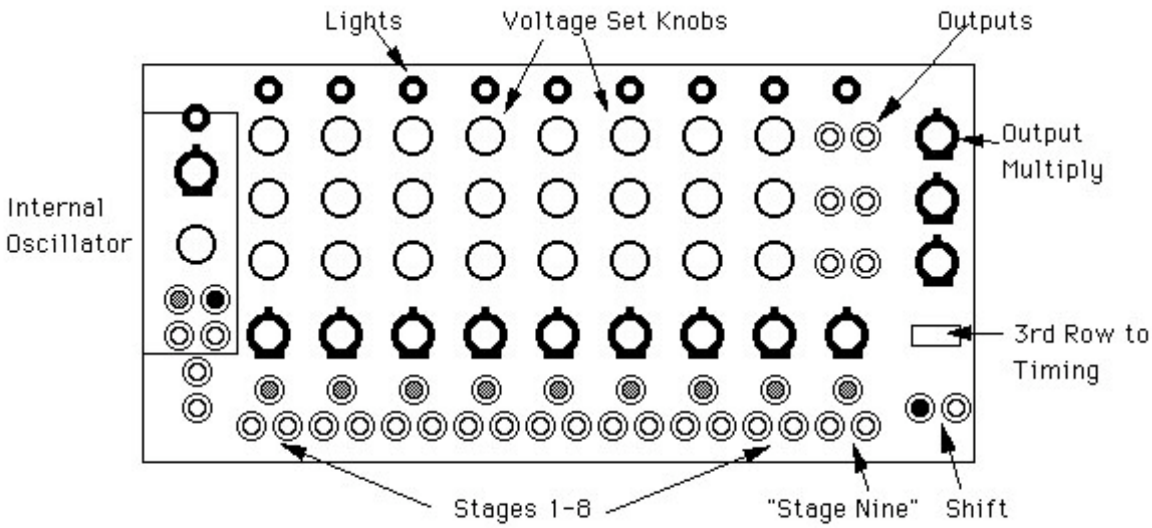

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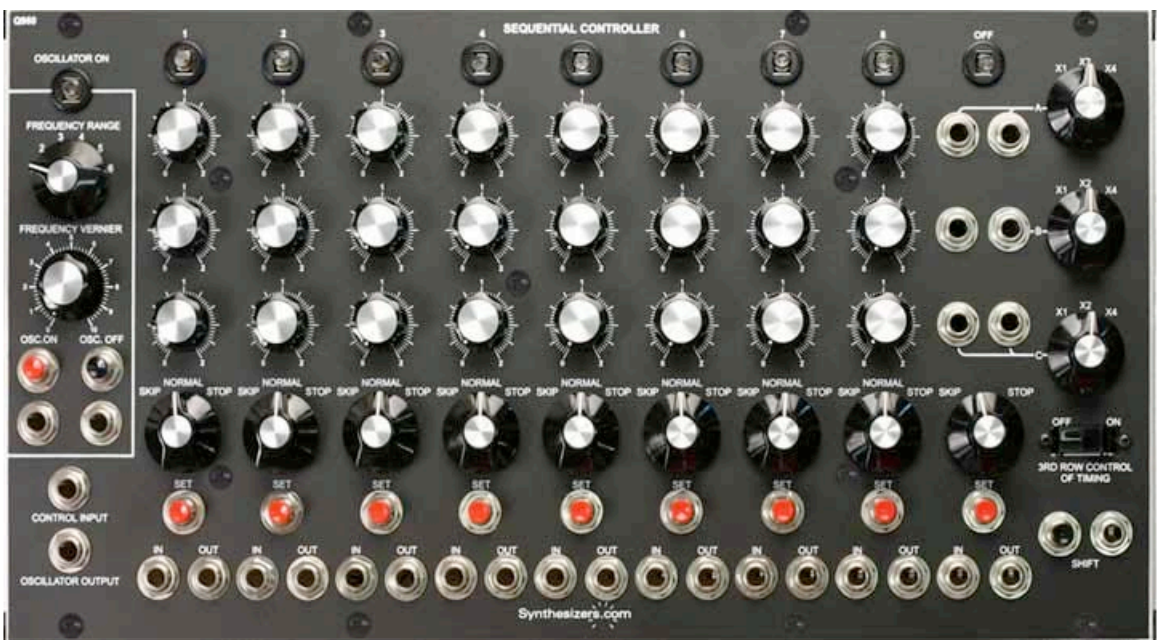

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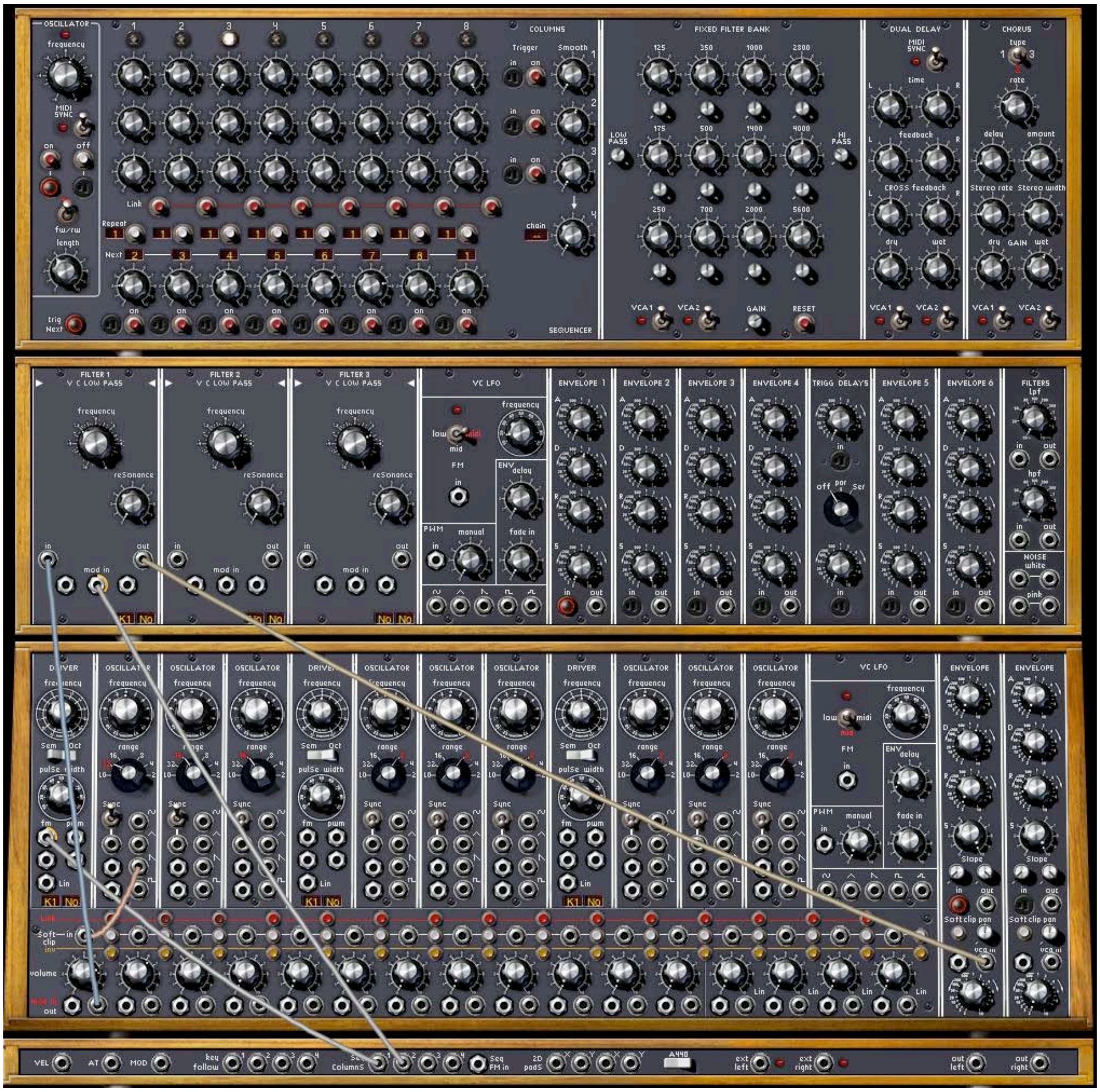

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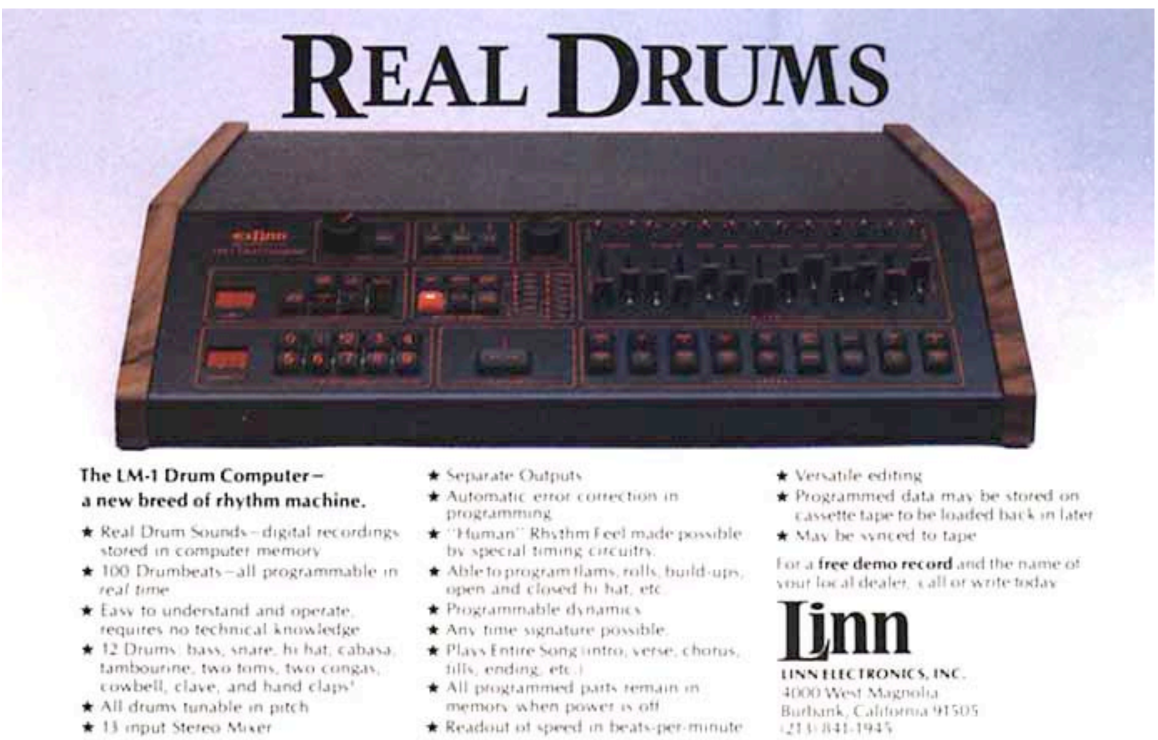

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Chapter 15. Meeting 15, Discussion and Workshop

15.1. Announcements

- Due Today: Music Technology Case Study Draft
- Due Thursday, 12 November: Sonic System project Draft

  Bring prototypes, sketches, ideas to class for discussion

15.2. Quiz Review

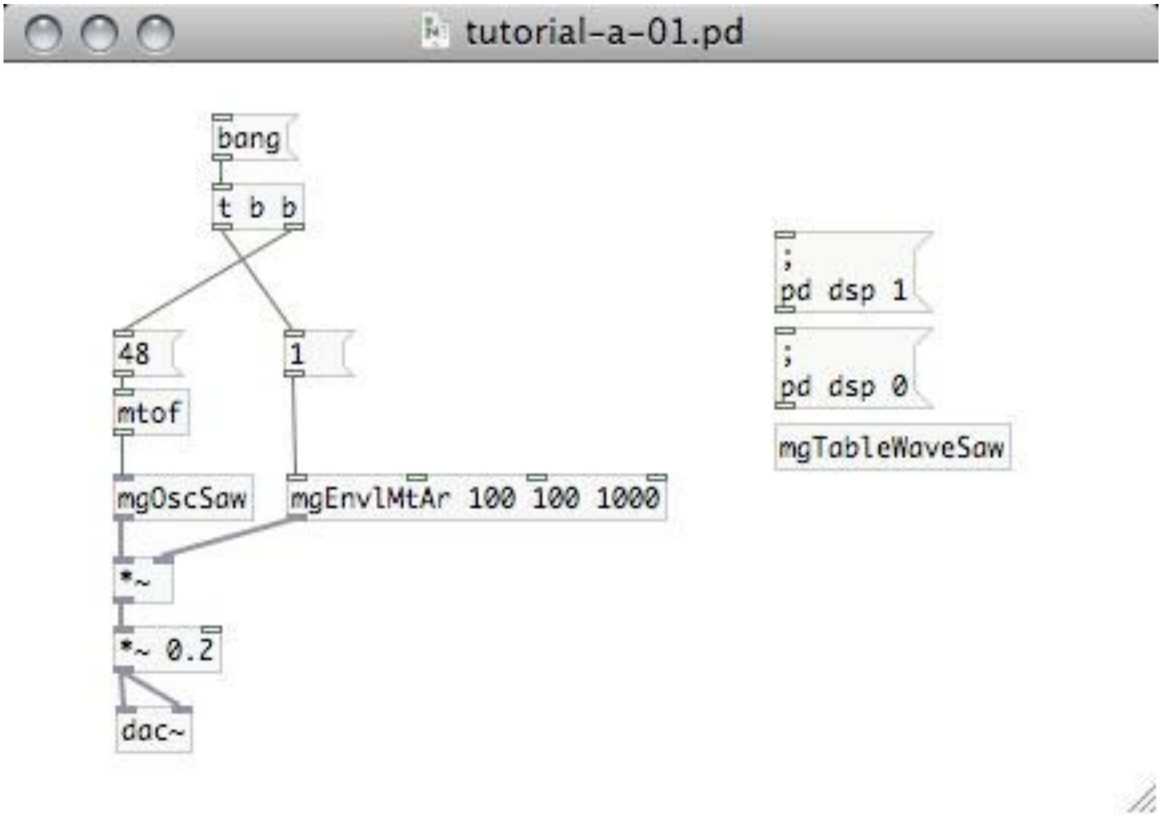
- ?

15.3. Reading: Collins

- Collins, K. 2007. "In the Loop: Creativity and Constraint in 8-bit Video Game Audio." *twentieth-century music* 4(2): 209-227.
- What is technological constraint, and is it like determinism?
- What does it mean to "aestheticize" technical limitations?
- Collins divides dynamic music into interactive and adaptive: what is the difference?
- What were some of the features and constraints of the NES sound chip?
- Collins writes about the influence of social constraints on the development of 8 bit game music: what were these social constraints?
- Collins writes that, in the context of musical features such as loops and repetitions, "the game's audio aesthetic was chosen as much as determined..."; why does she make this distinction?
- What are some of the approaches to looping Collin's describes?

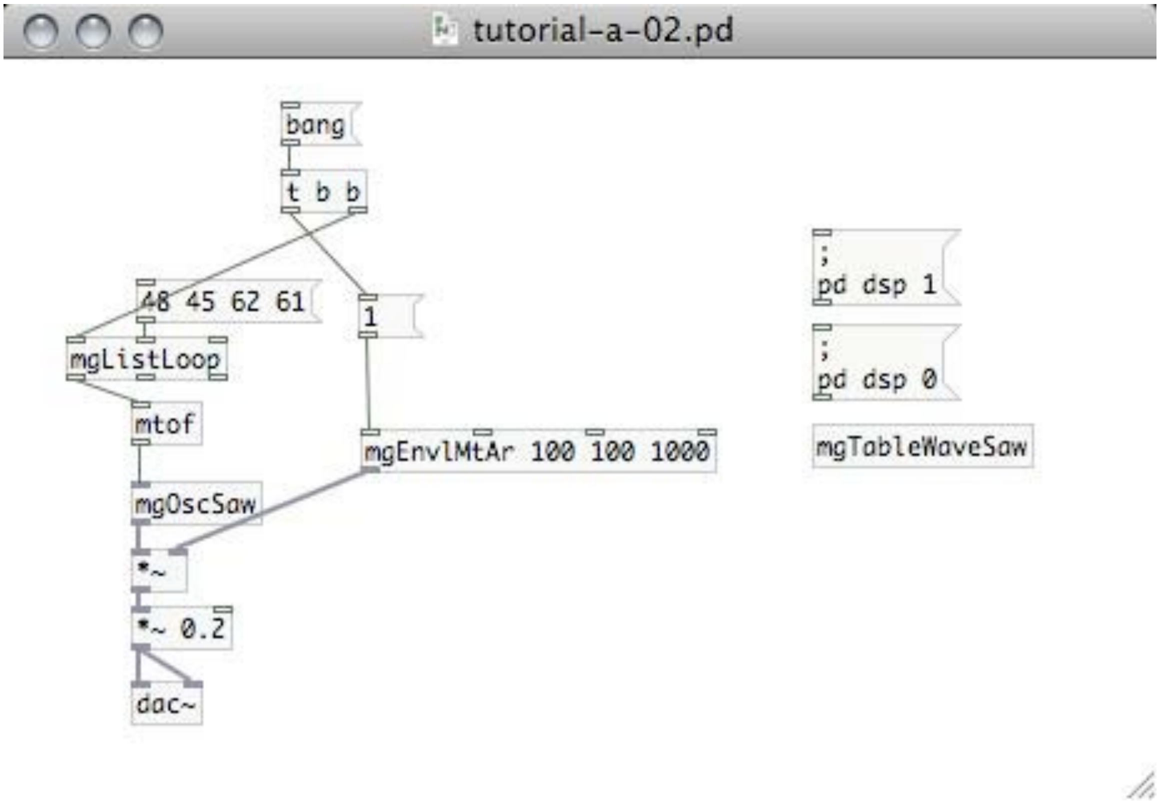
15.4. Workshop: A Basic Synthesizer: Envelope

- Apply an AR envelope to a Saw wave with fixed pitch



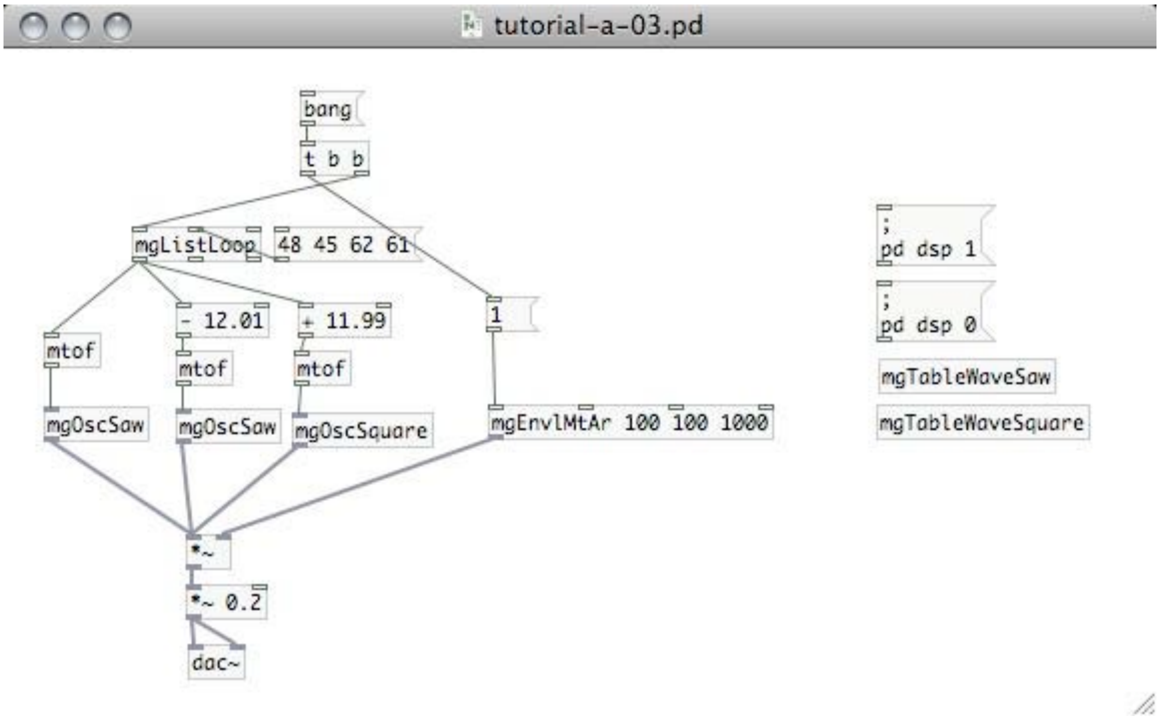
15.5. Workshop: A Basic Synthesizer: Looping Pitches

- Loop through a list of MIDI pitches with [mgListLoop]



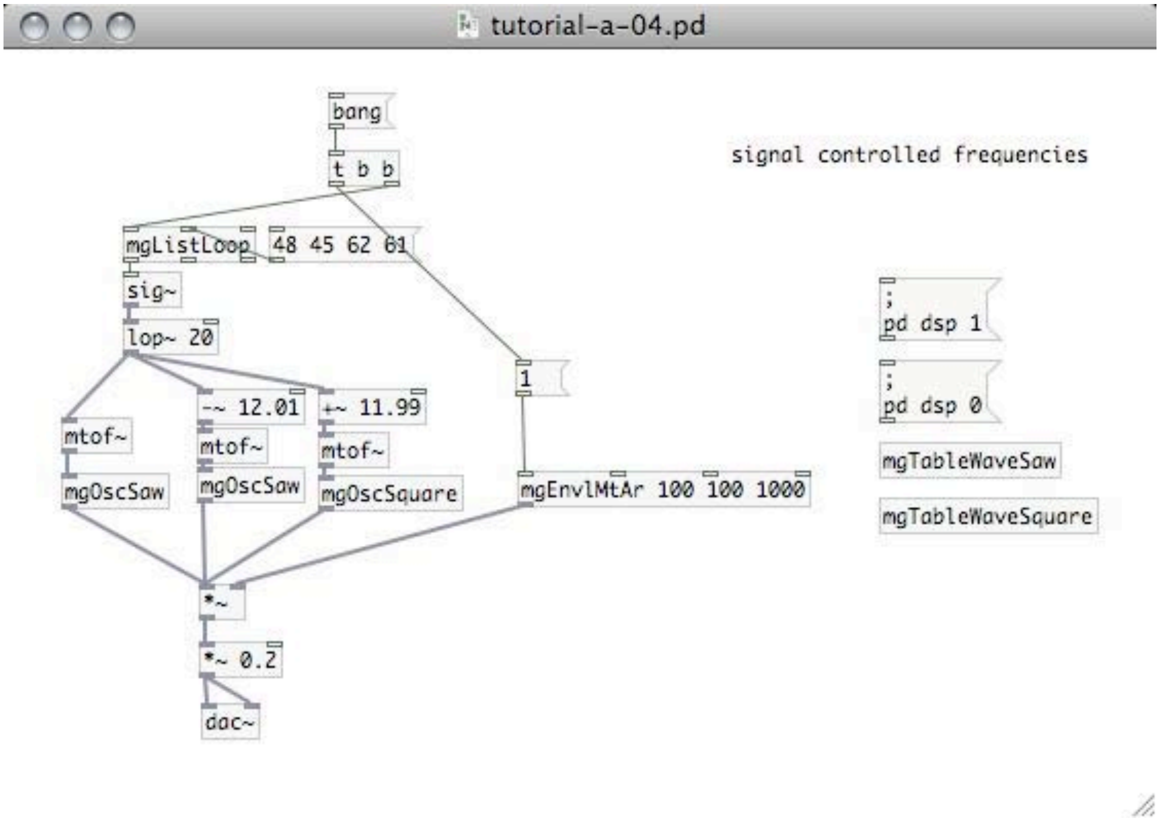
15.6. Workshop: A Basic Synthesizer: Mixing Oscillators

- Combine oscillators with different waveshapes in different octaves and tunings



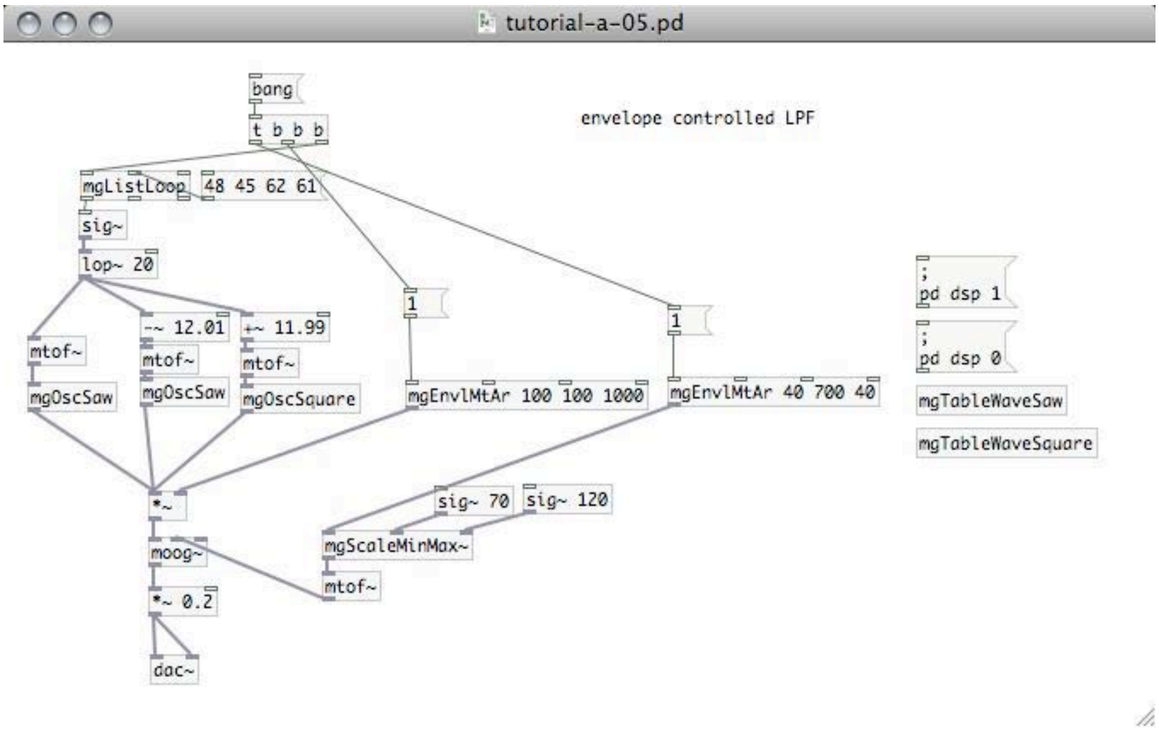
15.7. Workshop: A Basic Synthesizer: Signal Pitch Control

- Convert the MIDI pitch value to a signal and low-pass filter [lop~ 20] to smooth transitions



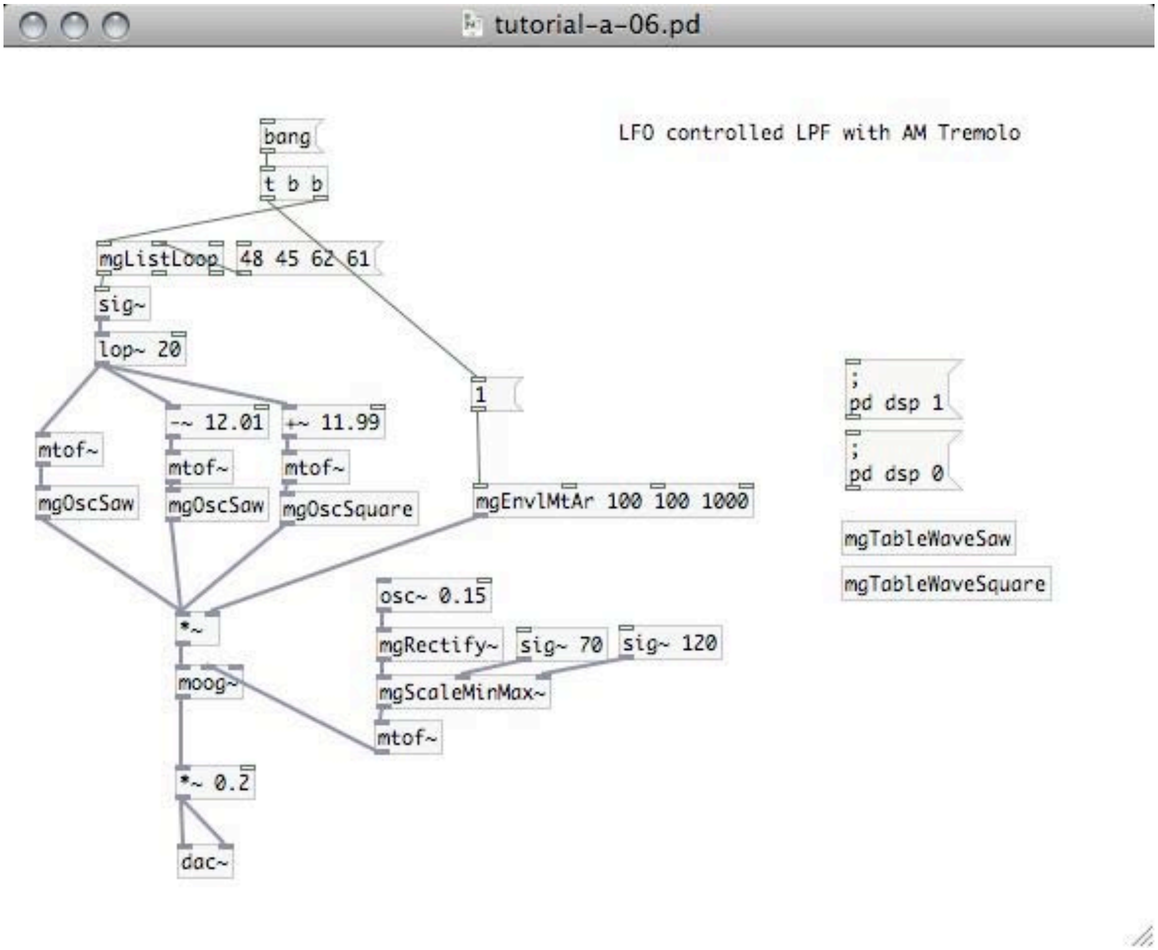
15.8. Workshop: A Basic Synthesizer: LPF Envelope Modulation

- Modulate the cutoff frequency of the low pass filter [moog] with an AR envelope



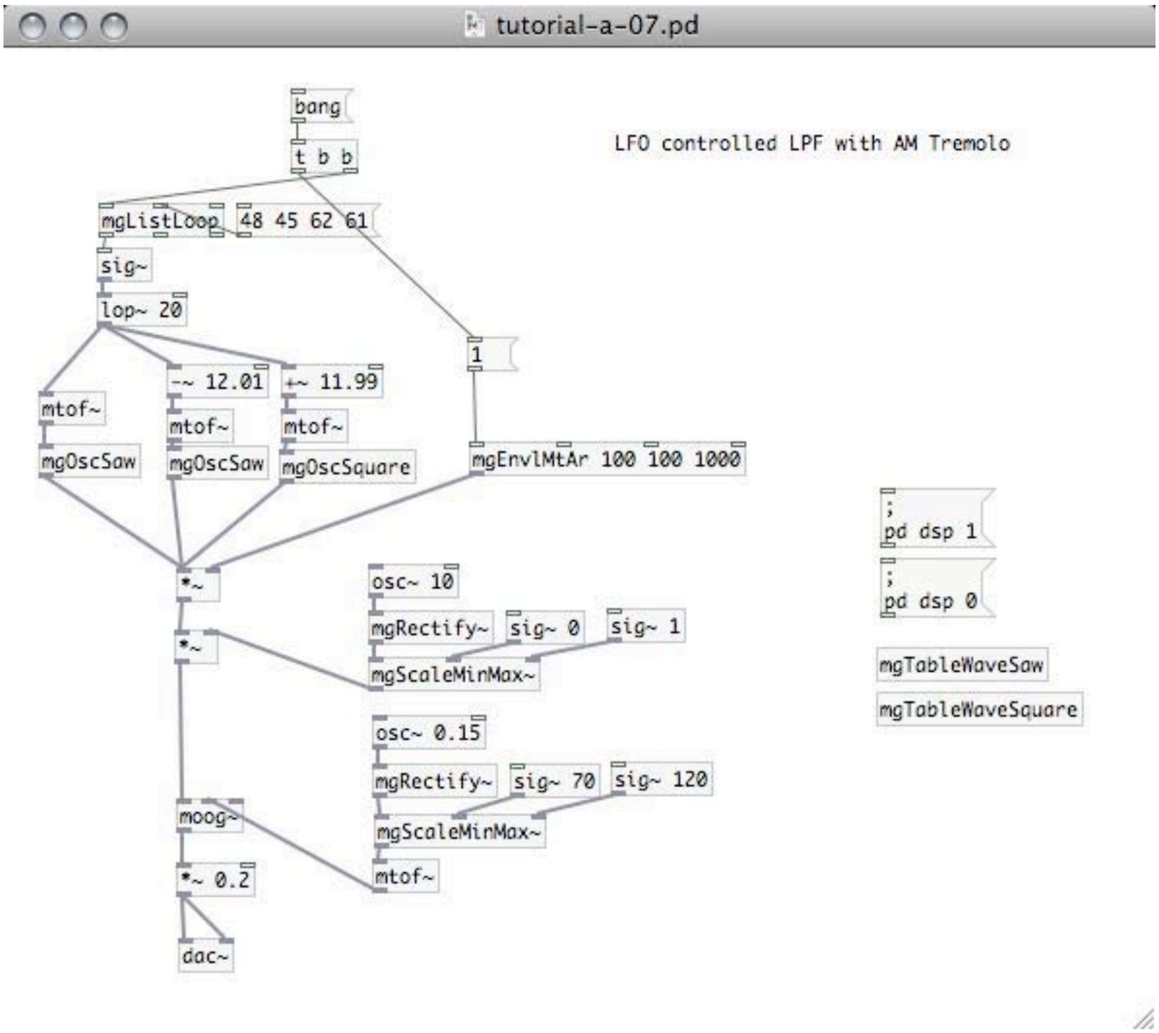
15.9. Workshop: A Basic Synthesizer: LPF Modulation with LFO

- Modulate the cutoff frequency of the low pass filter with a sine wave [osc~ 0.15]



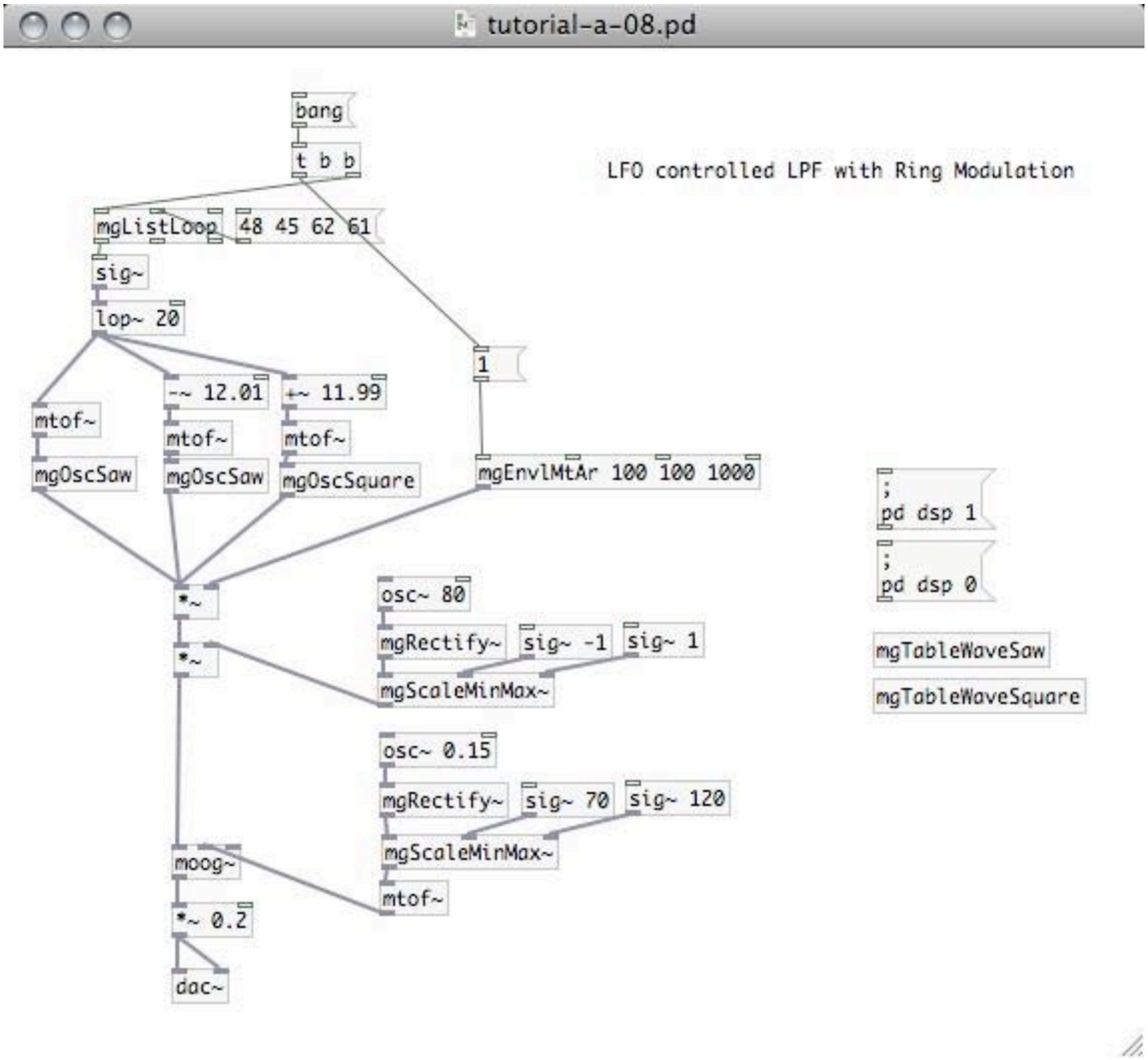
15.10. Workshop: A Basic Synthesizer: AM Tremolo

- Modulate the amplitude between 0 and 1 below the audio rate



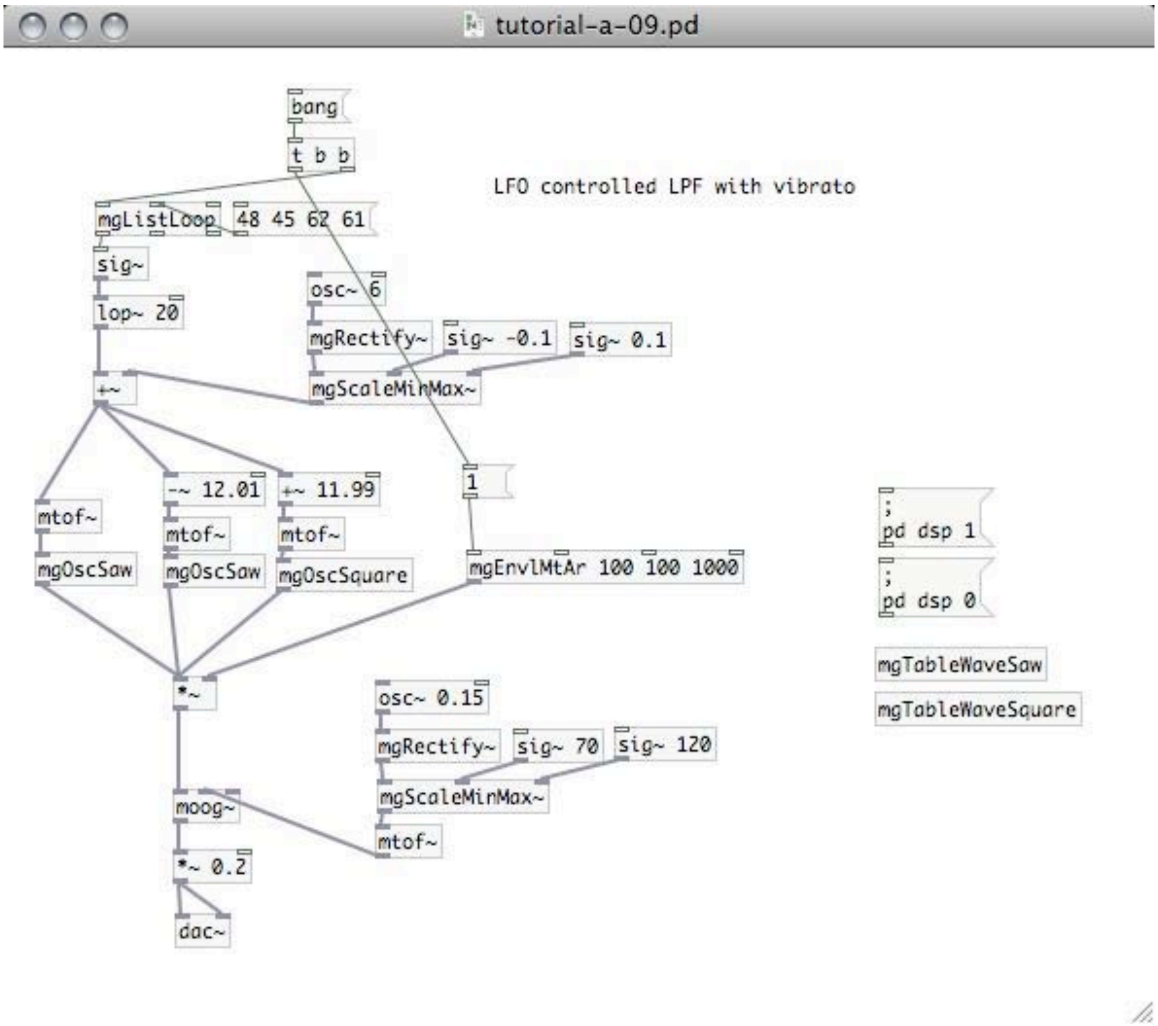
15.11. Workshop: A Basic Synthesizer: Ring Modulation

- Modulate the amplitude between -1 and 1 above the audio rate



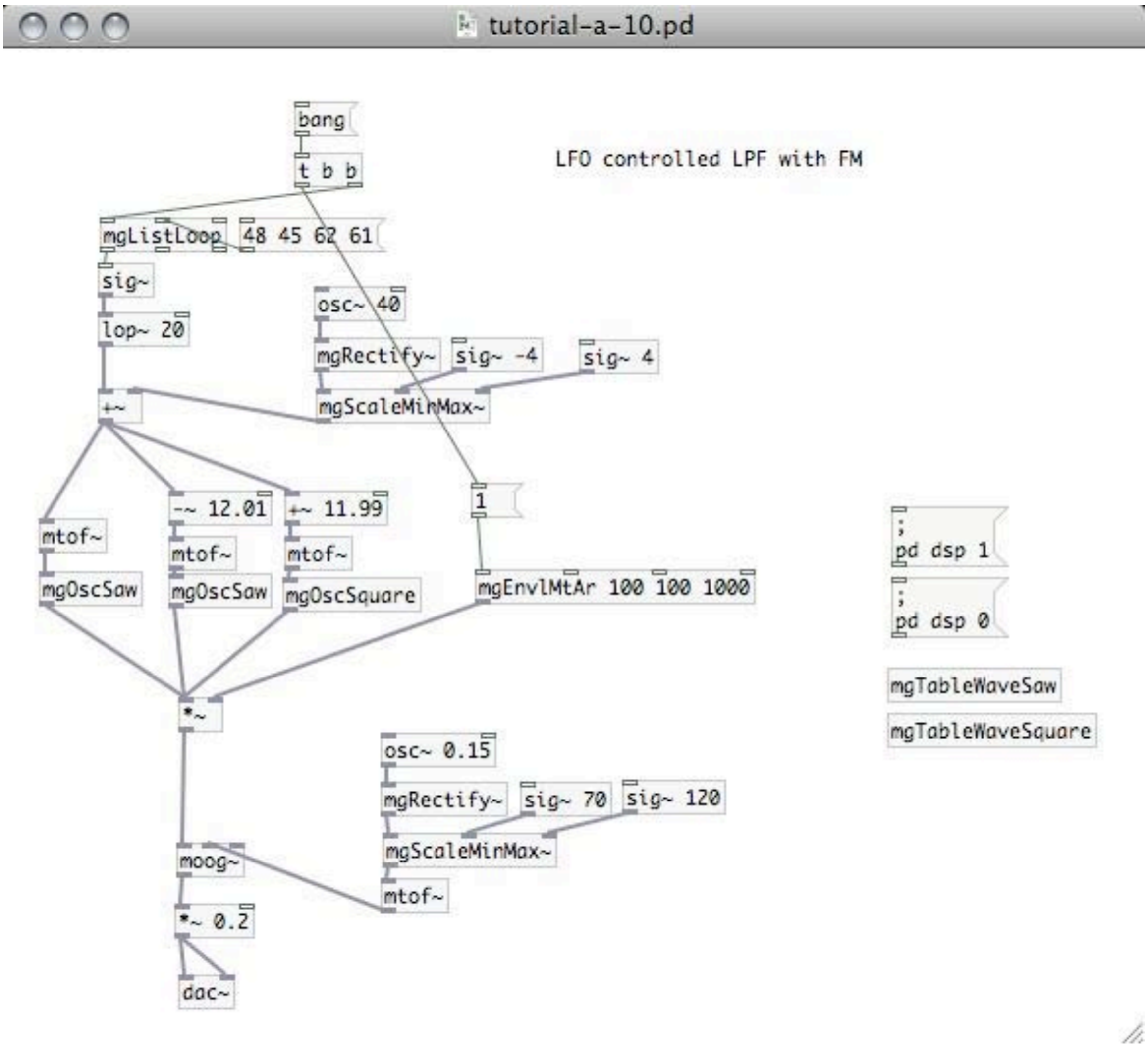
15.12. Workshop: A Basic Synthesizer: Vibrato

- Modulate the oscillator frequency between -0.1 and 0.1 MIDI steps at a slow rate (6 Hz)



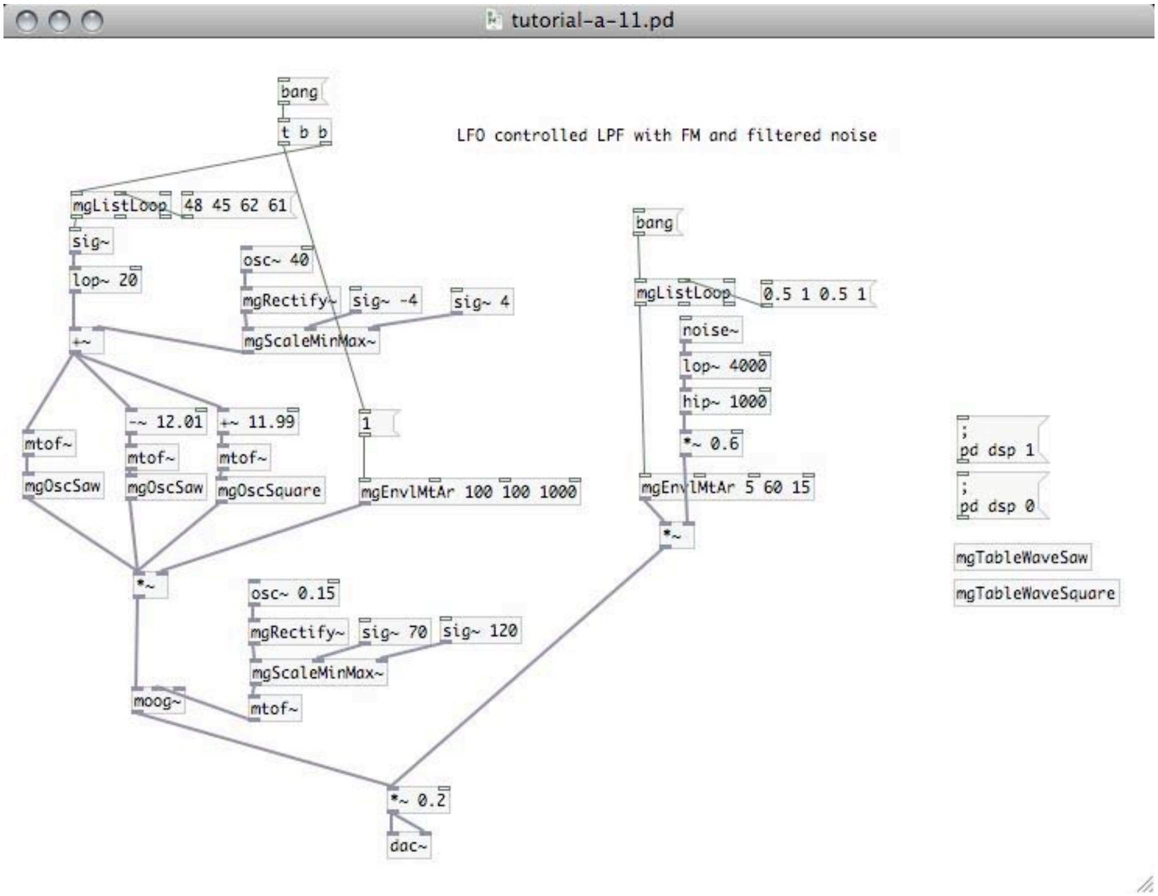
15.13. Workshop: A Basic Synthesizer: Frequency Modulation

- Modulate the oscillator frequency between -4 and 4 MIDI steps at a fast rate (40 Hz)



15.14. Workshop: A Basic Synthesizer: Filtered Noise

- Use a low-pass filtered noise for a percussion sound



15.15. Hardware Hacking: Oscillator Clock Controlled Sequencer

- 74C14 Oscillator (Collins 2009, p. 135)

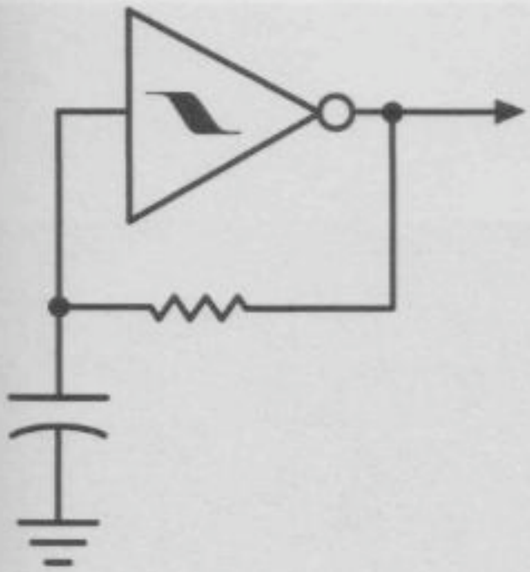
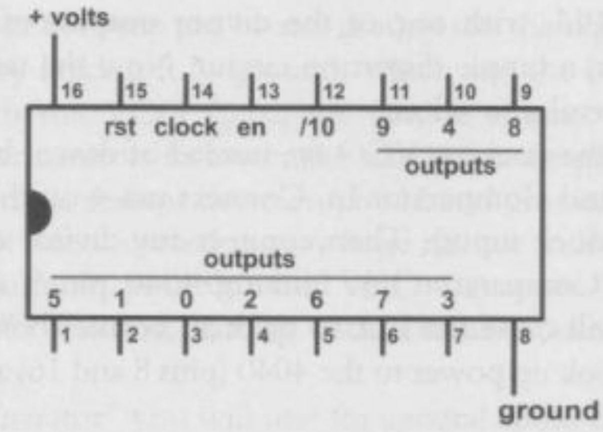


Figure 18.8
Schematic representation of our oscillator.

- CD4017: decade counter, providing 10 output voltages at rate determined by a clock (Collins 2009, p. 208)

  Cycle lengths can be altered by connecting an output to the reset input

Figure 23.9
CD4017 pinout.



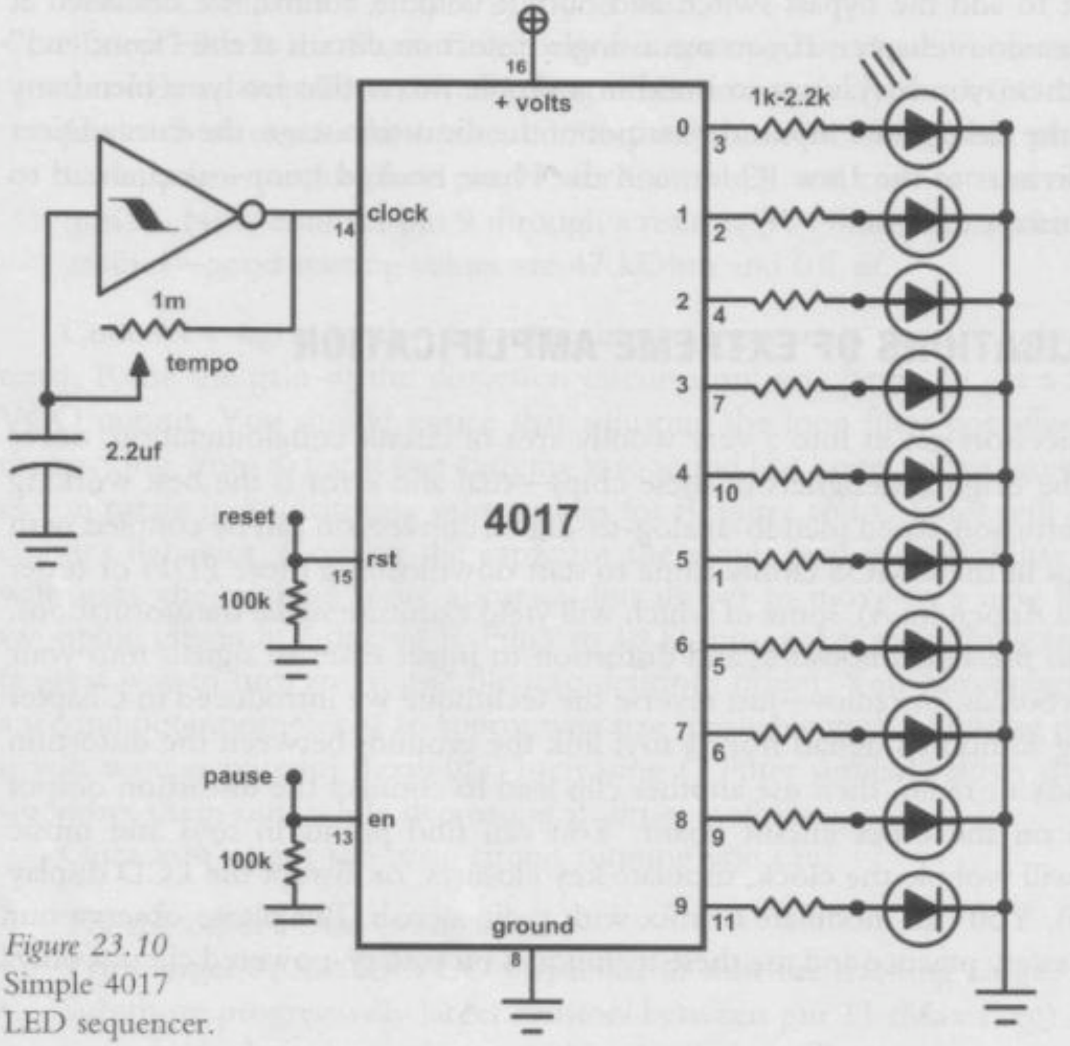
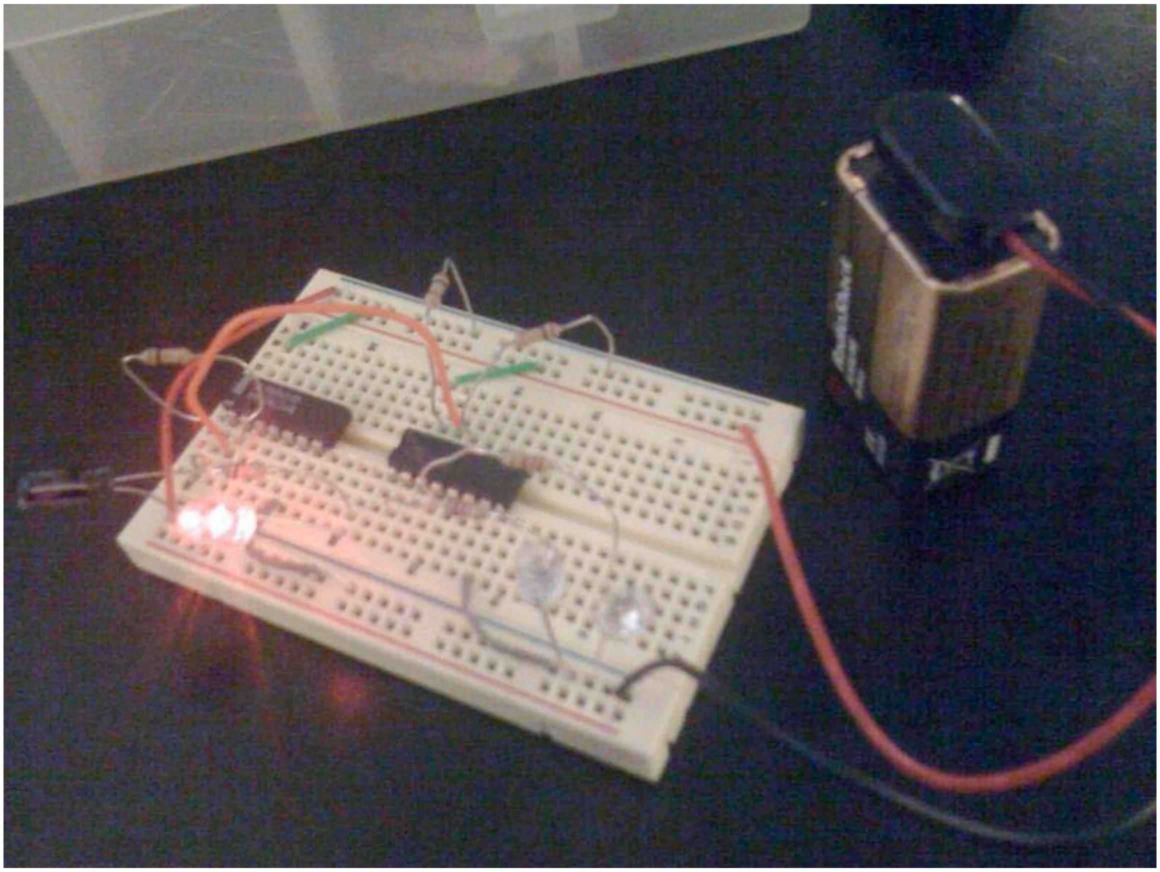


Figure 23.10
Simple 4017
LED sequencer.



- CD4046: Voltage controlled oscillator (capable of pitch tracking) (Collins 2009, p. 204)

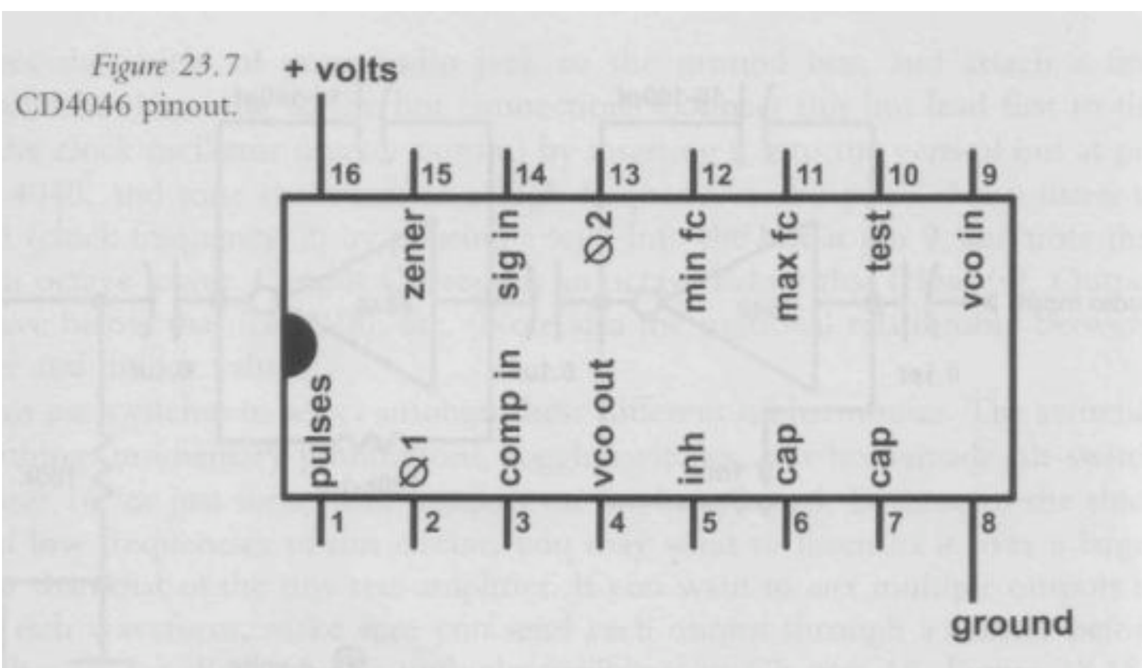


Figure 23.7 CD4046 pinout.

- VCO driven by voltages of the CD4017 (Collins 2009, p. 209)

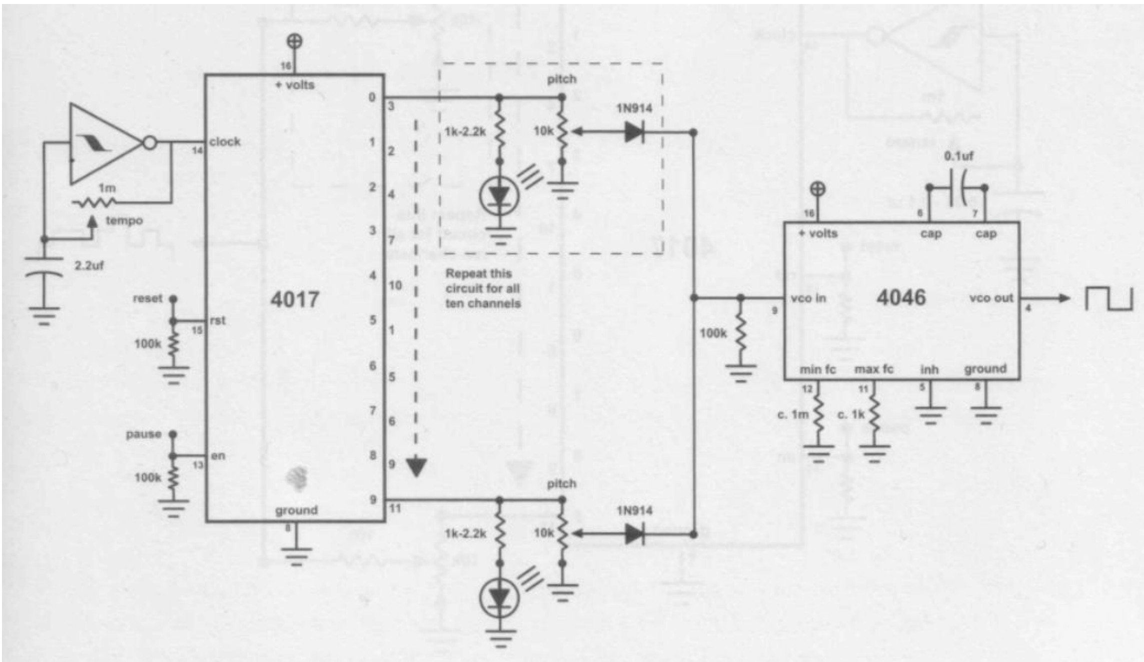
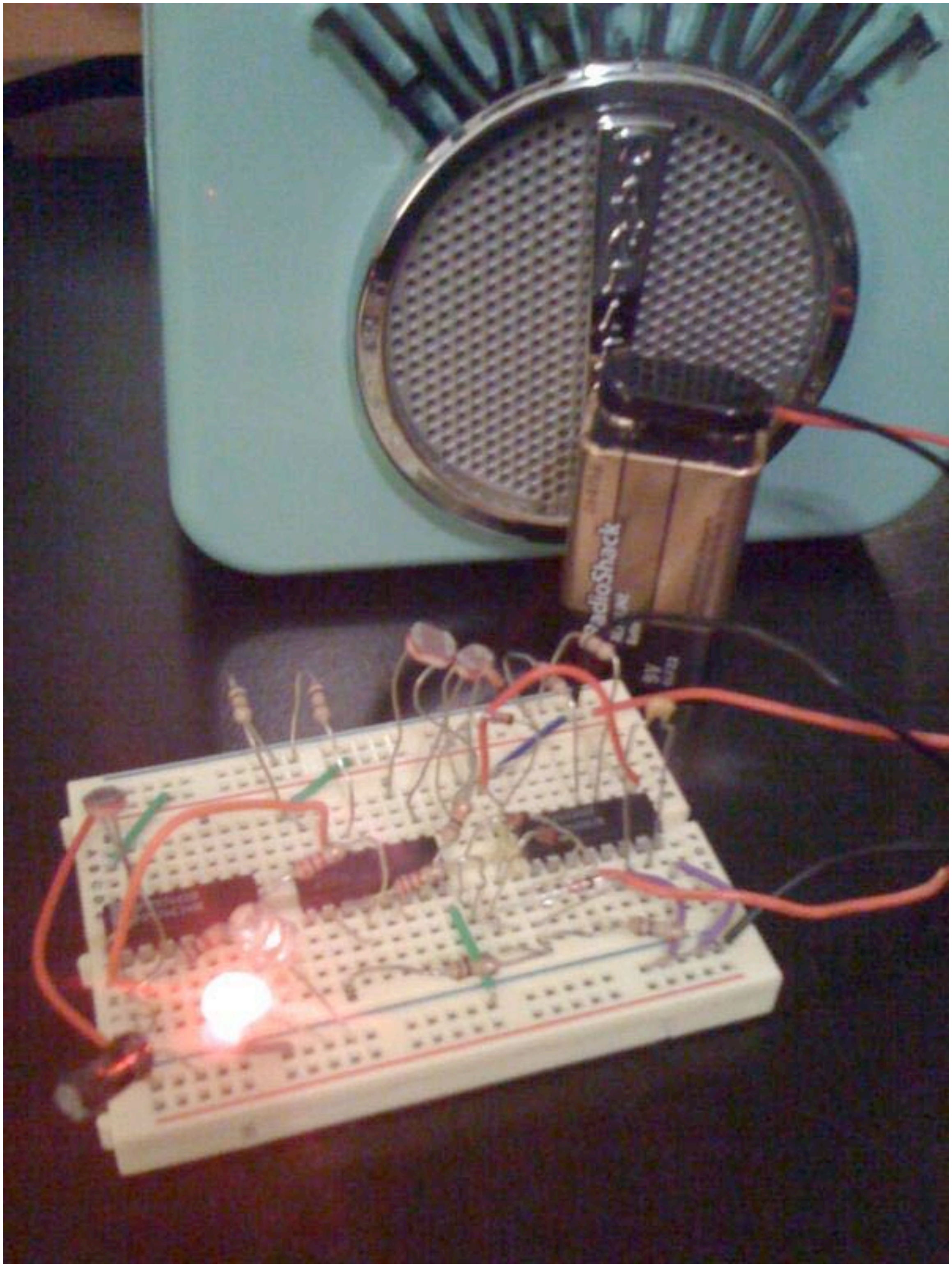


Figure 23.11 Ten-step analog sequencer driving a voltage-controlled oscillator.

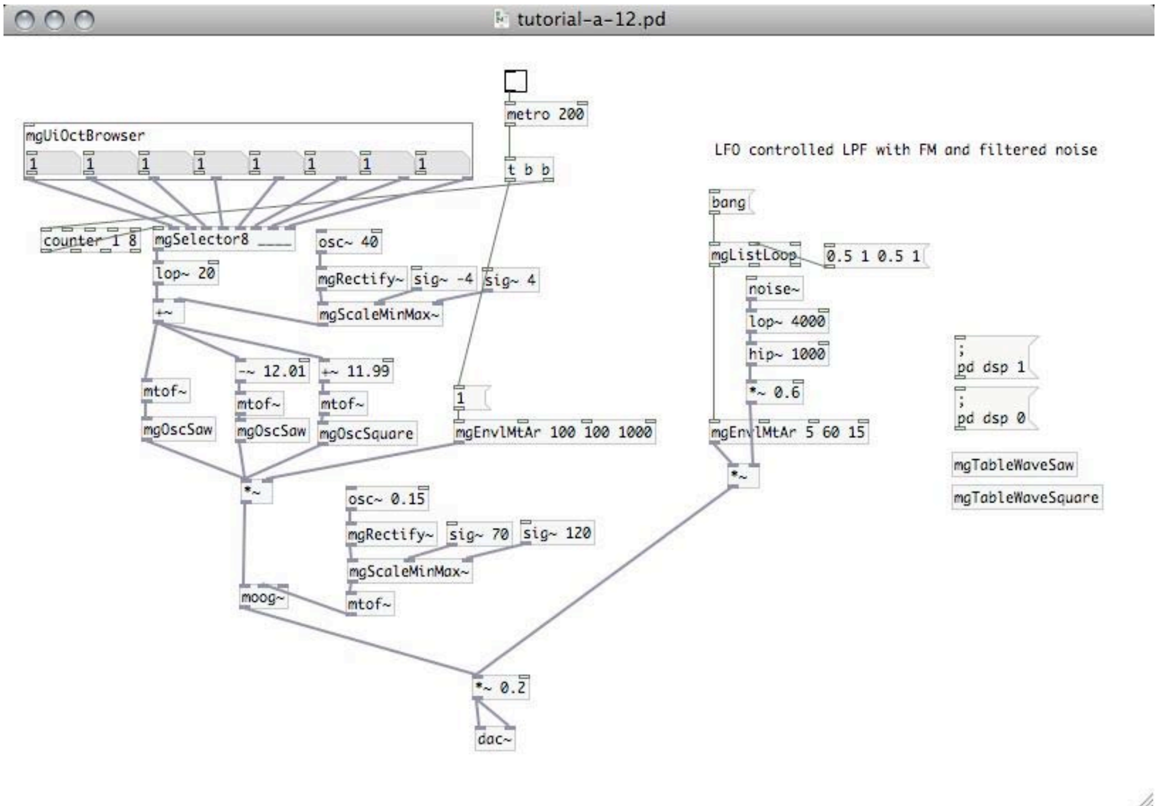


- Alternative examples

YouTube (http://www.youtube.com/watch?v=FqWzJt3Nm-U)

15.16. Workshop: A Basic Synthesizer: Sequencer Pitch Control

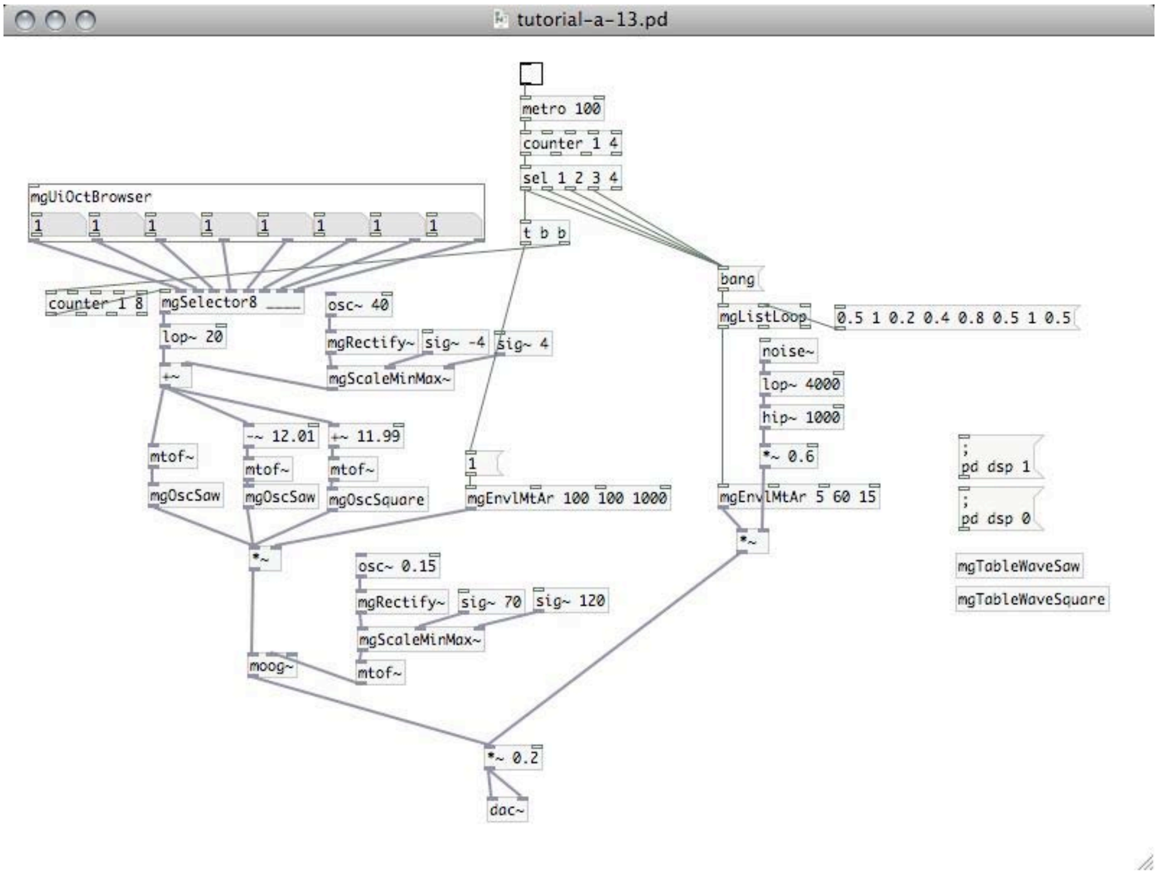
- Counter controlled selection between 8 different MIDI pitch values



15.17. Workshop: A Basic Synthesizer: Sequencer Pitch and Rhythm Control

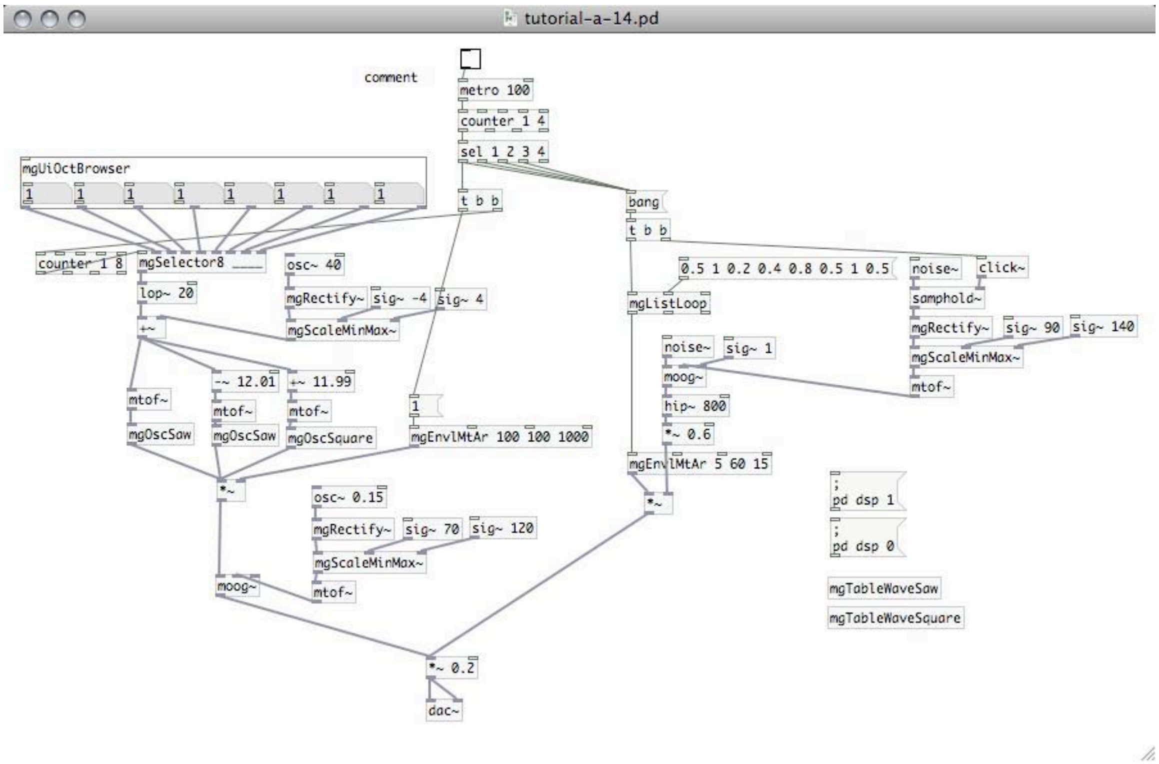
- Apply event triggers to pitched sequencer value selection and rhythm amplitude list loop

  Selecting triggers from a counter provides rhythmic subdivisions



15.18. Workshop: A Basic Synthesizer: Sequencer Control with SAH Random LPF Modulation

- Use noise through a SAH to produce random LPF cutoff frequencies applied ot noise



15.19. Listening: Vaggione

- Audio: Horacio Vaggione, "24 Variations," 2002
- Contemporary electro-acoustic music employing approaches to sample layering, transformation, and micro-organization (micromontage and granular synthesis)

Chapter 16. Meeting 16, Interfaces: Turntables

16.1. Announcements

- Due Thursday, 12 November: Sonic System project Draft

  Bring prototypes, sketches, ideas to class for discussion

16.2. The Turntable as an Interface

- Foundations of hip-hop
- Modern turntables and DJ mixers
- Early and modern turntable innovators
- The abstraction of the turntable

16.3. People Who Still Live in the Folklore

- People Under the Stairs: hip hop group from Los Angeles consisting of Thes One and Double K
- Folklore as this historical in the foundations of hip-hop
- "... forty days in the studio, struck water from ADATs, on top of a mountain made of milk crates, throwing the tablet down, on top of breaks and dub it to black plates for for the chosen, people who still live in the folklore, of DJ Cool Herc, Bam and Grand Wizard Theodore, before any punk with a keyboard could do it, yo Apache was the @#$%, and every b-boy new it..."

  "... and so we do it, cause we follow original rules, when only microphones and old records were tools, flash forward twenty years later, they calling us haters, yo popular rappers call it progress they ain't no greater than late seventies disco..."
- ."'.. yo its number one rap; I'd rather hear an 808 hand clap than that ... ... paying homage to crates ... paying dues "

- Audio: People Under the Stairs: "Stay Home," Question in the Form of an Answer 2000

16.4. The Turntable: A Disc- and Momentum-Based Playback Controller

- 1877: Phonograph
- 1887: Gramophone
- 1948: Columbia releases 33.1/3 RPM LP
- 1969: Technics releases SP-10, first direct drive turntable

  Attaches platter directly to the drive without belts
- 1969: Technics releases SP-1100 for larger audience
- 1972: Technics SL-1200

  Features variable plaback speed slider

- Using a turntable with a slipmat, easily adjusting playback speed with the hand is possible

The Baby Scratch: YouTube (http://www.youtube.com/watch?v=m2SzUmGdCOc)

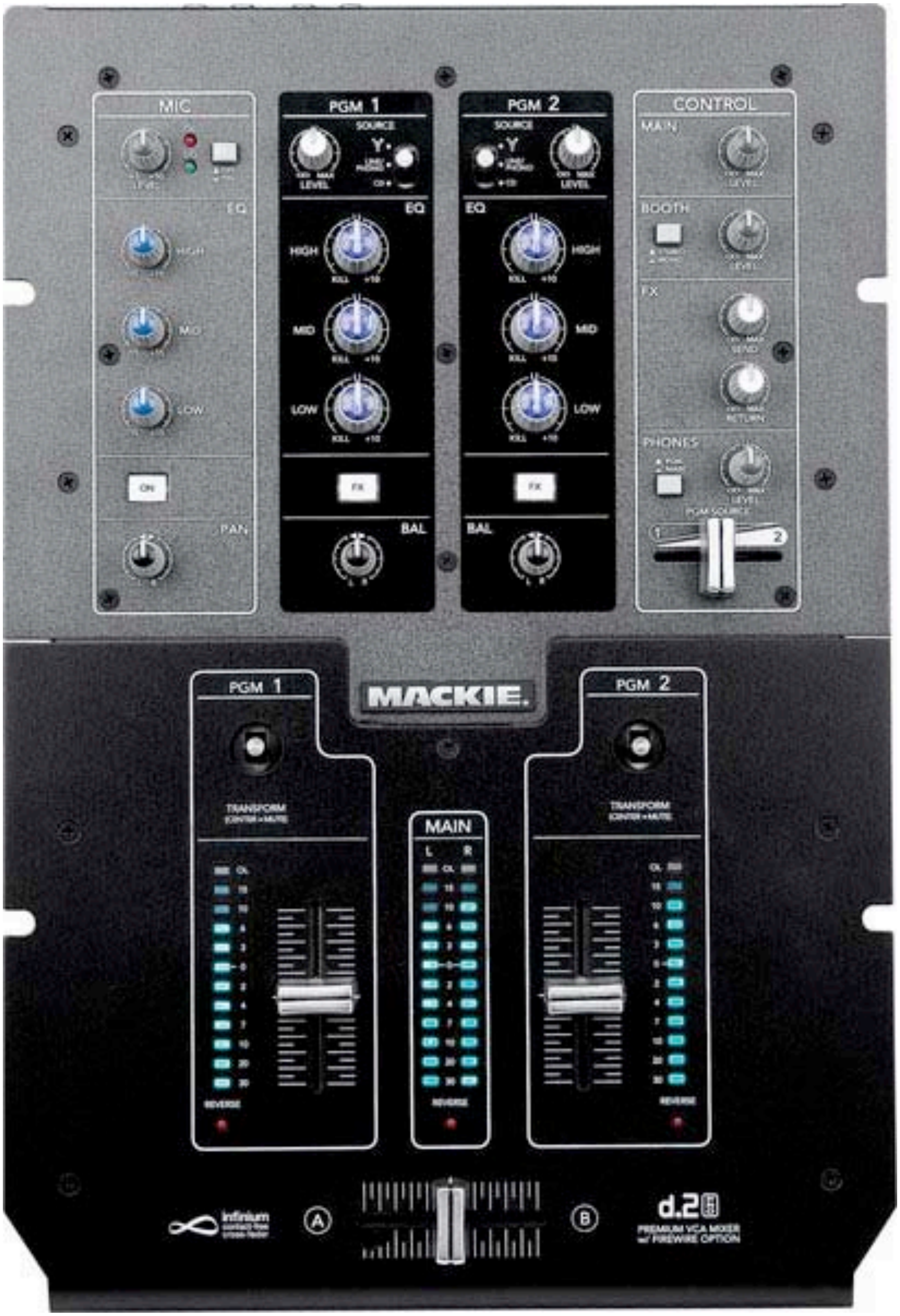
The Phazers: YouTube (http://www.youtube.com/watch?v=2CGnM4OEBdo)

The Waves: YouTube (http://www.youtube.com/watch?v=S9bKaqbWtJ4)

16.5. The DJ Mixer

- Quickly switch between two sources (two turntables) with a crossfader
- Include toggle switches to mute sources in and out
- Ability to listen to a record before playing it to the audience: cue or phones output
- May include filters, effects, and samplers
- Mackie D2

  Features optical cross fader



YouTube (http://www.youtube.com/watch?v=-XpIvCa_Ul0)

- Numark DXM 09

  Features beat-synchronized effects

- Numark 5000FX

  Features integrated sampler

- Vestax QFO integrates mixer cross fader into turntable

- Using a turntable with a crossfader (DJ mixer), a wide range of musical gestures are possible

  The Transformer: YouTube (http://www.youtube.com/watch?v=m2SzUmGdCOc)

  The Chirp (1:05) YouTube (http://www.youtube.com/watch?v=r928CTdI22A)

  The Crab (:48) YouTube (http://www.youtube.com/watch?v=w5OeaC3rI-A)

16.6. Jamaican Sound Systems

- 1950s: Turntables were very expensive
- People would gather at "community record players" to dance and listen to music
- Clement Dodd (Coxsone) (1932-2004): credited with invention sound-system concept

  1950s: established the Downbeat Sound System

  1963: opened Studio One in Kingston, where he later met Bob Marley

- 1960s: Instrumental B-side versions on 45 RPM EPs released by Jamaican record labels
- DJs such as King Tubby (Osborne Ruddock) (1941-1989) began re-recording (dubing) and remixing B-sides with creative use of filters, reverb, and other effects

  Musicians and producers such as Augustus Pablo produced albums based on this sound

- Audio: Augustus Pablo: "555 Dub Street," King Tubby Meets Rockers Uptown, 1976

- DJs such as Ewart Beckford (U-Roy) began to toast over dub instrumentals
- Jamaican DJs may have been influenced by black American radio DJs who would introduce songs with rhymes

16.7. DJ Kool Herc (Clive Campbell)

- ... people who still live in the folklore, of DJ Cool Herc, Bam and Grand Wizard Theodore...
- 1967: Moves from Jamaica to the Bronx
- Transplanted Jamaican sound-system concepts to Bronx parties
- With MC Coke La Rock, toasted over American funk and disco
- Began experimenting with two turntables, each with the same record

16.8. DJ Kool Herc (Clive Campbell): Two Turntables

- the Merry-Go-Round: cutting back and forth to extend popular beats
- later called break beats
- Audio: Gross, T. 2005b. "Interview on 30 March 2005: Kool Herc: A Founding Father of Hip Hop." National Public Radio. Internet: http://www.npr.org/templates/story/story.php?storyId=4567450.

16.9. Breakbeats: Apache

- ... yo Apache was the @#$%, and every b-boy new it...
- Matos, M. 2005. "All Roads Lead to Apache."
  Internet: http://soul-sides.com/2005/04/all-roads-lead-to-apache.html.
- 1960: Bert Weedon, song composed by Burt Lancaster
- 1960: Cliff Richard and the Shadows
- 1973: Michael Viner's Incredible Bongo Band, *Bongo Rock*
- 1973: Sugar Hill Gang
- 1996: Future Sound of London, *We Have Explosives*
- 2002: Roots, Thought @ Work

16.10. Breakbeats: The Amen Break

- 4-bar drum solo from "Amen Brother," The Winstons, B-side, released in 1969
- Harrison, N. 2004. "Can I Get An Amen." Internet:
  http://nkhstudio.com/pages/popup_amen.html.

- Original context: The Winstons, “Amen Brother,” B-side, released in 1969

- Used in rap, hip-hop, (ragga) jungle, drum and bass
  - N.W.A: Straight Outta Compton (1989) (3:55-)
  - Mantronix, “King of the Beats” (1990)
  - Shy FX, “Original Nattah” (1994)
  - L Double & Younghead, “New Style” (1996)

  - Jeep Commercial from California (2004)

16.11. Grand Wizard Theodore

- ... people who still live in the folklore, of DJ Cool Herc, Bam and Grand Wizard Theodore...
- 1970s: pulled a record back to keep its position as his Mom complained about his music (Katz 2004); often credited with inventing the scratch
- Rapid alterations of playback speed: called rubbing, cutting, or scratching
- Added rhythmic emphasis to the rub

16.12. Grandmaster Flash (Joseph Saddler)

- Known for rapid mixing and cutting, use of drum machines, and innovating components of the DJ mixer
- Credited for inventing the cross-fader
- the Quick Mix Theory (backspin technique): extending beats as with the Merry-Go-Round
- Developed and extended techniques: punch-phase (clock theory), rub, cut, and scratch
- Grandmaster Flash: The Adventures Of Grandmaster Flash On The Wheels Of Steel (1981)

- Gross, T. 2005a. "Interview on 26 December 2002: DJ and hip-hop forefather Grandmaster Flash." National Public Radio. Internet: http://www.npr.org/templates/story/story.php?storyId=889654.

  Specifically:
  Narration of techniques used in "The Adventures Of Grandmaster Flash On The Wheels Of Steel"

16.13. The the DJ as Soloist

- Grandmixer DST
- Audio: Herbie Hancock, "Rock It," 1983

- The song, along with the MTV video, did much to popularize turntablism

  YouTube (http://www.youtube.com/watch?v=nK0Pi4wC8Hk)

16.14. The Turntablist Transcription Method

- Turntablist LLC. 2005. "TTM: Turntablist Transcription Method." Internet: http://ttmethod.com/.
- Audio samples are shown on the left, as instrument names, or attached to scratch lines
- Time on the x axis with grids for beat divisions
- Blue lines are used to show speed of scratch, where slower scratches are more horizontal
- Transcriptions: Grand Master Flash on the Wheels of Steel

  Transcriptions: Rock It

16.15. The Scratch as Rhythm Section

- Audio: Erik B and Rakim: "I Ain't No Joke", Paid in Full 1987
- Scratching used to alternate with lyrics and percussion

16.16. Modern Techniques and the Economy of Resources

- Audio: D-Styles and featuring DJs Melo-D, Babu, and DJ Qbert: "Felonius Funk" 2002
- Use of short spoken passages as motives for extended solos

16.17. The Abstraction of the Turntable

- Records are expensive and fragile
- New interfaces attempt to isolate essential features
- New interfaces control digital audio buffers on CDs or computers

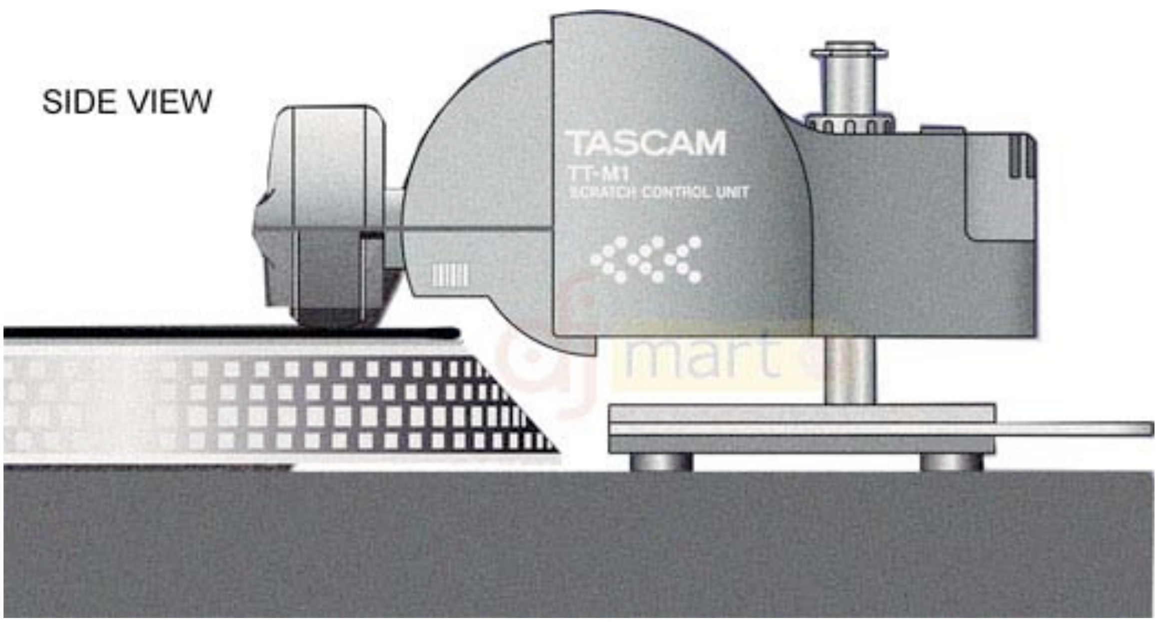
16.18. The Abstraction of the Turntable: Example

- Technics SL-DZ1200

16.19. The Abstraction of the Turntable: Example

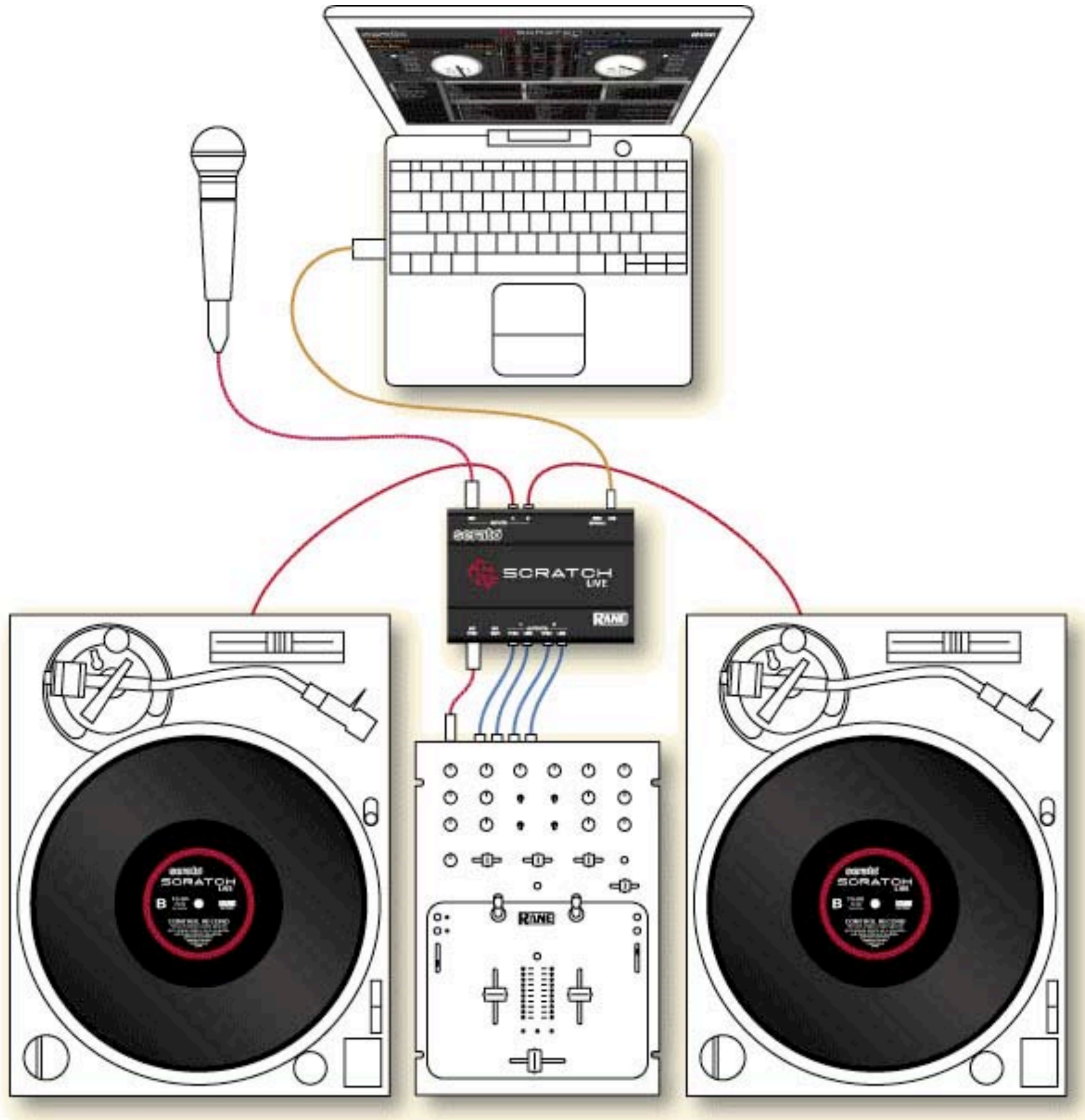
- Tascam TT-M1


TASCAM
TT-M1
SCRATCH CONTOROL UNIT


SIDE VIEW
TASCAM
TT-M1
SCRATCH CONTROL UNIT

16.20. The Abstraction of the Turntable: Example

- Rane Serato Scratch LIVE system with Control Vinyl


serato
SCRATCH
LIVE
RANE


serato
MIC
INPUTS
1
2
SCRATCH
LIVE
9VDC
(OPTIONAL)
USB
MIC
THRU
MIC
GAIN
THRU
1
LINE
OUTPUTS
2
THRU
LINE
RANE

16.21. The Abstraction of the Turntable: Example

- Numark NS7 Turntable Controller ($1,299)

16.22. From Coercion to Abstraction

- A trajectory of technological change

Chapter 17. Meeting 17, Interfaces: Live Electronics and Circuit Bending

17.1. Announcements

- Due Thursday, 12 November: Sonic System project Draft

  Bring prototypes, sketches, ideas to class for discussion

- Bring laptops for more work with PD and Martingale
- Quiz next Thursday

17.2. Motivations for Live Electronics

- Music as performance and theater
- Cage's observation on the problem of speaker music (Holmes 2008)
- Engaging and extending improvisation

17.3. Listening: David Tudor

- Tudor began working with Cage and Cunninghnam in the 1950s developing live electronics for dance
- David Tudor, *Rainforest*, 1973
- A series of pieces beginning in 1978
- Sounds are played through transducers affixed to solid objects; objets filters and project sounds, as speakers; contact mics on objects are used to amplify sounds sent to conventional speakers (Collins 2009, p. 48)

Image removed due to copyright restrictions. "Circuit diagram for "Rainforest IV."

See: http://www.getty.edu/research/conducting_research/digitized_collections/davidtudor/zoom/grl_tudor39l.html.

- David Tudor, *Pulsers*, 1976
- Manipulation of feedback (Holmes 2008, p. 187)

- David Tudor, *Toneburst*, 1975

17.4. Listening: Gordon Mumma

- 1950s: Gordon Mumma, with Robert Ashley, begin staging weekly performances of live electronic music at the Space Theater (Holmes 2008)
- 1961: begin ONCE festival of contemporary music, continues until 1965 (Holmes 2008)
- 1966-76: Robert Ashley, Gordon Mumma, David Behrman, and Alvin Lucier form Sonic Arts Union (Holmes 2008)
- Gordon Mumma, *Hornpipe*, 1967

- "The cybersonic console monitors the resonances of the horn in the performance space and adjusts its electronic circuits to complement theses resonances": a form of feedback (Holmes 2008, p. 390)
- A long tradition of works for solo instrument and live electronics
- Do we hear interaction, or cause and effect?
- Do we hear a duet, a solo, or something else?

17.5. Listening: Robert Ashley

- Narrative and storytelling music in multimedia
- Robert Ashley, *Automatic Writing*, 1974-79
- Released in 1979
- Compared to minimalism, called text-sound composition
- Closely miked spoken voice performing involuntary speech
- Idea of four characters: two vocal, two instrument (2008, p. 392)

- Robert Ashley, *The Wolfman*, 1964
- Employs slow, modulating feedback controlled by a vocalist's mouth (2008, p. 186)

17.6. Ensemble-based Live Electronics

- Ensembles of live electronics performers, sometimes mixed with acoustic or conventional electronic instruments
- 1960s: Musica Eletronica Viva (Holmes 2008, p. 963)
- AMM: touring group of jazz and electronic musicians (Holmes 2008, p. 963)
- SuperSilent

17.7. The Isolation of the Input Interfaces

- The modular synthesizer integrated sound production, sound design, and input interfaces
- Modular synthesizers explored modular input devices: keyboards, modulation wheels, buttons, sliders, and knobs
- With the establishment of a common control language (voltages, MIDI, OSC, etc.) input interface devices are decoupled from sound production devices

17.8. The Controller

- Input interfaces as a modular component separate from sound producing components
- Input interfaces make no sound: they only provide data output
- Input interfaces may use voltages, MIDI, OSC, or other languages to communicate to sound producing entity
- With a common input language many input interfaces become interchangeable

17.9. The Parameterization of Musical Events

- Western notation began parameterization of sound-events into discrete symbols
- The modular synthesizer suggested the description of musical values in isolated units
- Synthesis and processing parameters: envelope shapes, filter frequencies and shapes, processing parameters
- The use of controllers forces explicit parameterization

17.10. Mapping

- Translation of one sequence of values to another
- May involve scaling and shifting values
- One-to-one map from one range to another; map from one type of scale to another scale
- Example: 0, 1, 2, 3 (integers) to C, C#, D, D# (pitches)
- Example: .25, .5, .75, 1 (unit interval floating-point values) to *pp*, *mp*, *mf*, *ff* (dynamic symbols of Western notation)

17.11. Mapping Input Data to Musical Parameters

- Each input type is (often) applied to a single parameter
- If the input has multiple two or more dimensions of control, each dimension can be applied to a different parameter
- Musical mappings are aesthetic, creative choices

17.12. Models of Traditional Instruments: Piano

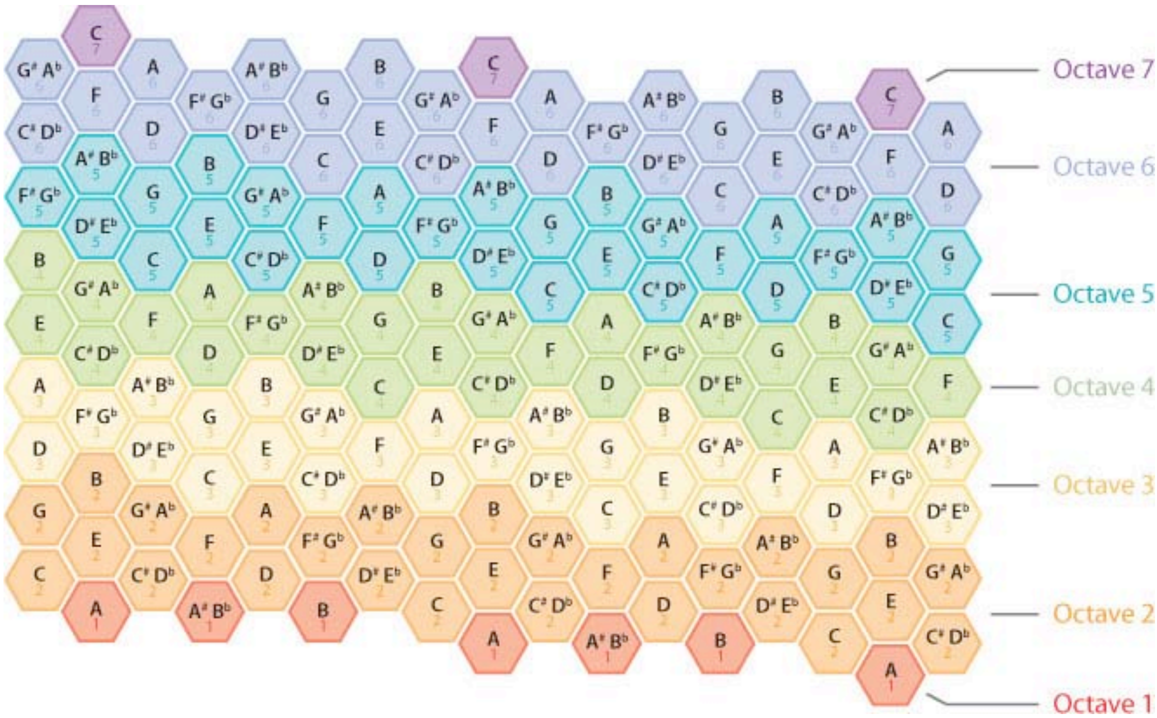
- Keyboard controllers without sound sources and the keytar
- 1980: Moog Liberation (14 Lbs)

Courtesy of Roger Luther (http://www.moogarchives.com). Used with permission.

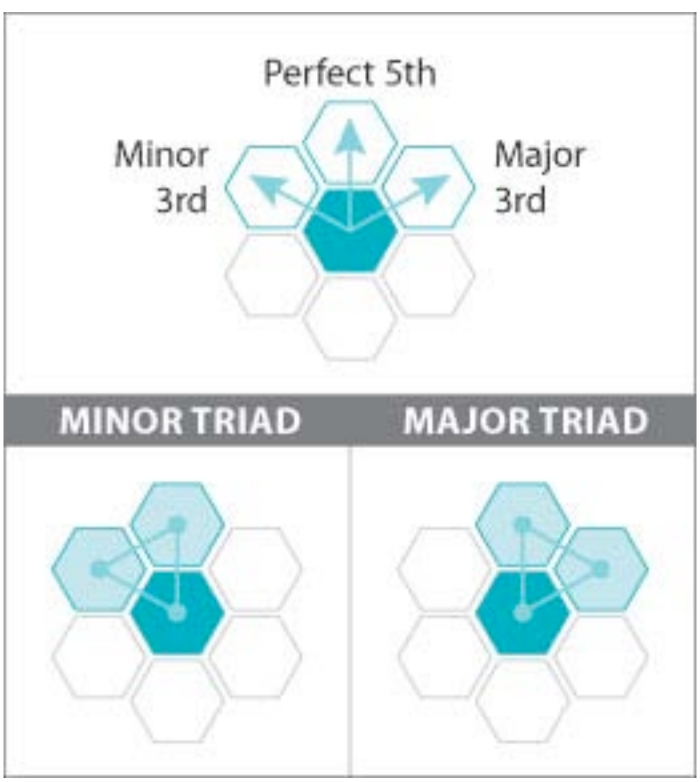
- Roland AX-7 (6 Lbs)

- C-Thru Music Axis 64

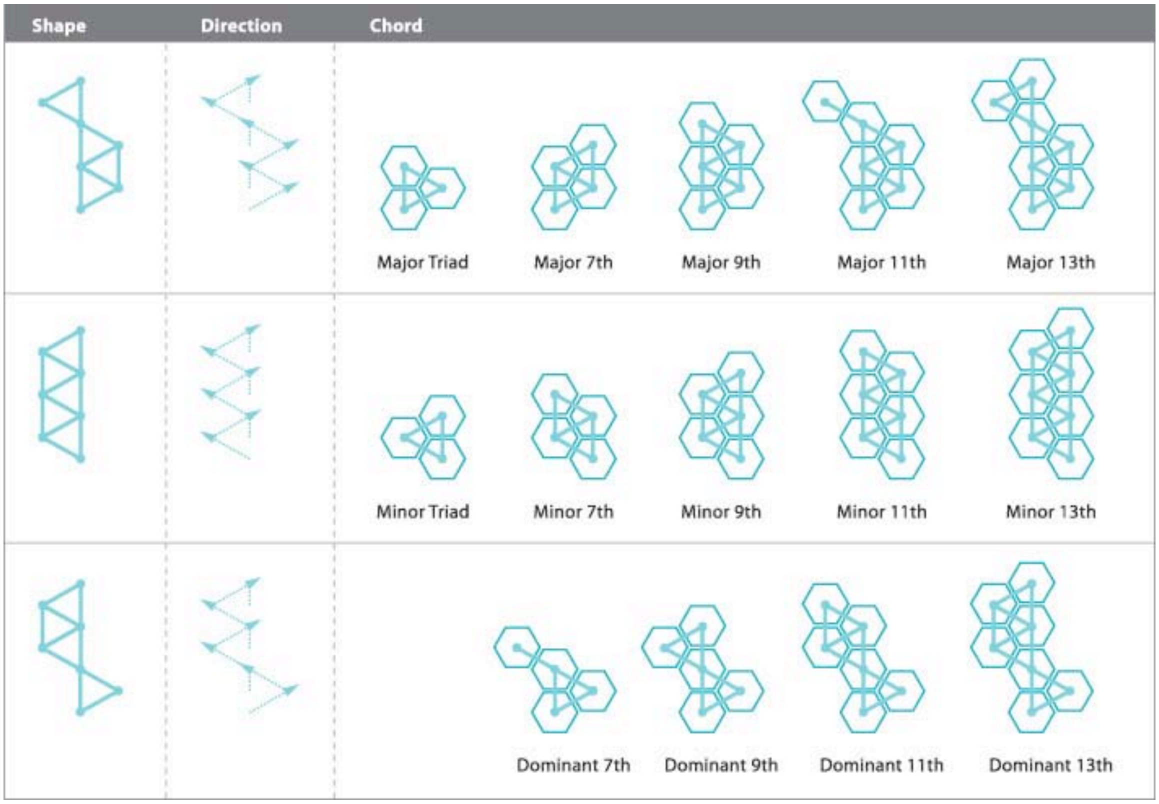
Courtesy of C-Thru Music Ltd. Used with permission.



Courtesy of C-Thru Music Ltd. Used with permission.



Courtesy of C-Thru Music Ltd. Used with permission.



Courtesy of C-Thru Music Ltd. Used with permission.

YouTube (http://www.youtube.com/watch?v=D7OeRkXWTtQ)

17.13. Models of Traditional Instruments: Guitar

- Conventional guitar used as a MIDI controller

  YouTube Video (http://www.youtube.com/watch?v=JTjoy_CQn1g)

- Casio DG 20

Courtesy of Uncyclopedia User:Kaiser Sma

YouTube Video (http://www.youtube.com/watch?v=cpdq-Anid-U)

17.14. Models of Traditional Instruments: Aerophones

- Example: Yamaha WX5

- Example: Akai EWI 4000s

YouTube (http://youtube.com/watch?v=N4Ex1sC4xMc)

- Example: YamahaBc3a

Single parameter breath controller

- Example: Morrison Digital Trumpet

YouTube (http://www.youtube.com/watch?v=BxLlym502bI)

17.15. Models of Traditional Instruments: Percussion

- 1988: Akai MPC60

- Example: Akai MPD-16

- Example: Roland Handsonic HPD 15

YouTube Video (http://youtube.com/watch?v=UYoCBWDHVt0)

17.16. Data Input: Sliders and Knobs

- Example: Evolution UC-33

- Example: Novation Remote Zero

- Example: Evoluion X-Session

- Example: Bitstream 3x

17.17. Data Input: Touch Pads

- Example: Buchla Thunder (1990)

Courtesy of Buchla and Associates. Used with permission.

YouTube (http://www.youtube.com/watch?v=GYBEoZXxym4)

- Example: Novation Remote 81

- Example: Korg KAOSS

YouTube (http://youtube.com/watch?v=9LxWnHZESeg)

YouTube (http://youtube.com/watch?v=1hdhCSSWn-s)

- Haken Continuum

Three parameters on touch surface (x, y, and pressure)

Courtesy of Lippold Haken. Used with permission.

YouTube (http://www.youtube.com/watch?v=Mrmp2EaVChI)

- Example: Monome

  YouTube (http://www.youtube.com/watch?v=LuV9Eg6HC34)

  YouTube (http://www.youtube.com/watch?v=14HG0QOp-0g)

  YouTube (http://www.youtube.com/watch?v=F0A8xR8ieek)

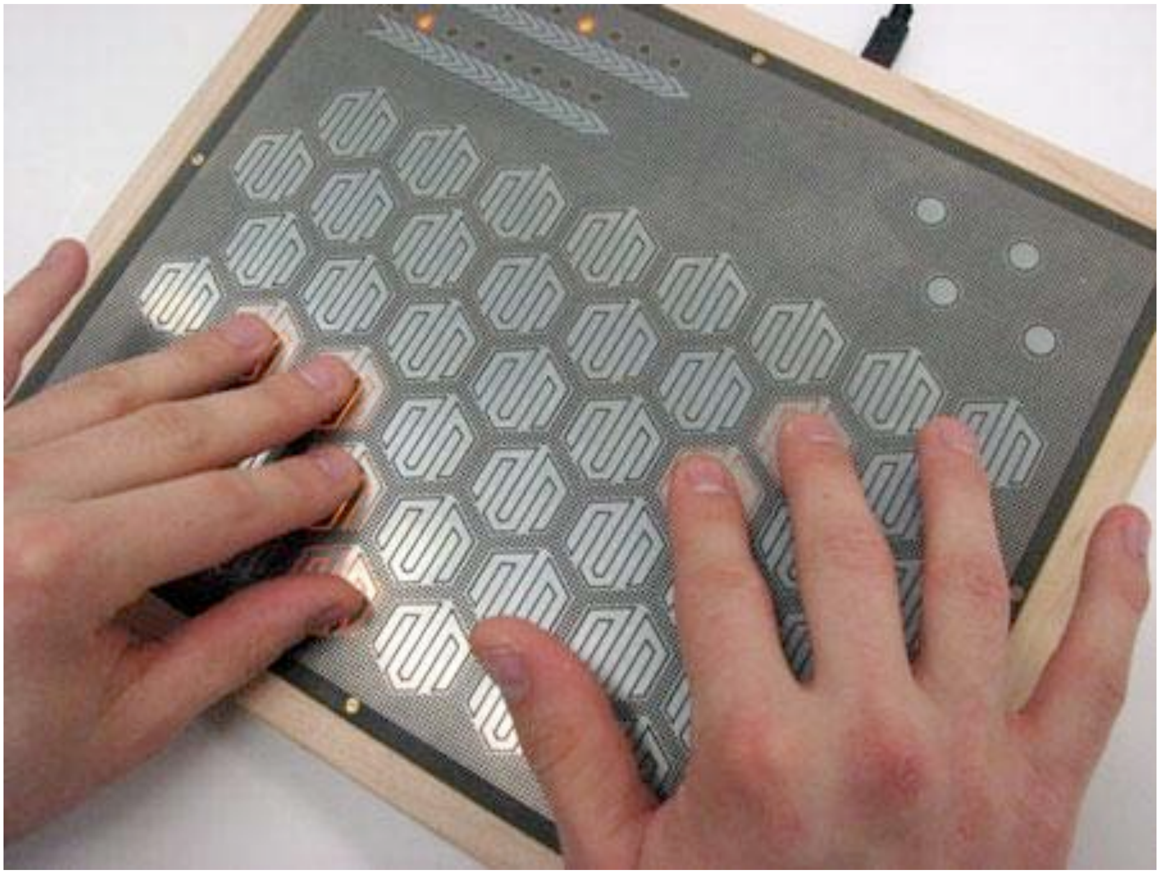
- Example: Yamaha Tenori On ($999.99)

YouTube (http://www.youtube.com/watch?v=_SGwDhKTrwU)

YouTube (http://www.youtube.com/watch?v=R1ulyBiKf9M)

- Example: Snyderphonics Manta ($700)

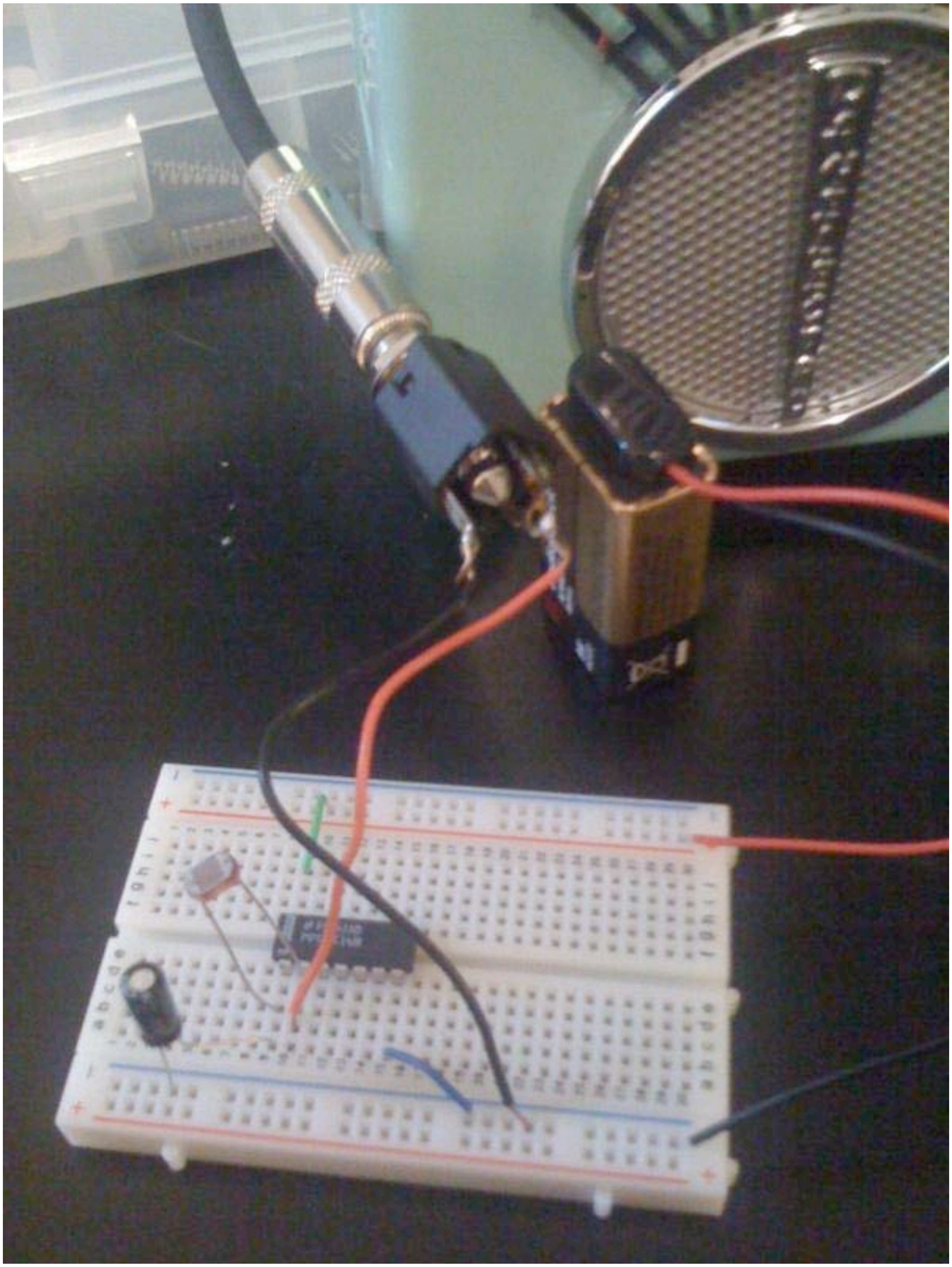
  Triggers that report amount of finger surface area as a parameter



Courtesy of Snyderphonics. Used with permission.

17.18. Data Input: Light and Infrared Sensors

- Photoresistors have been used in custom electronics since the 1960s



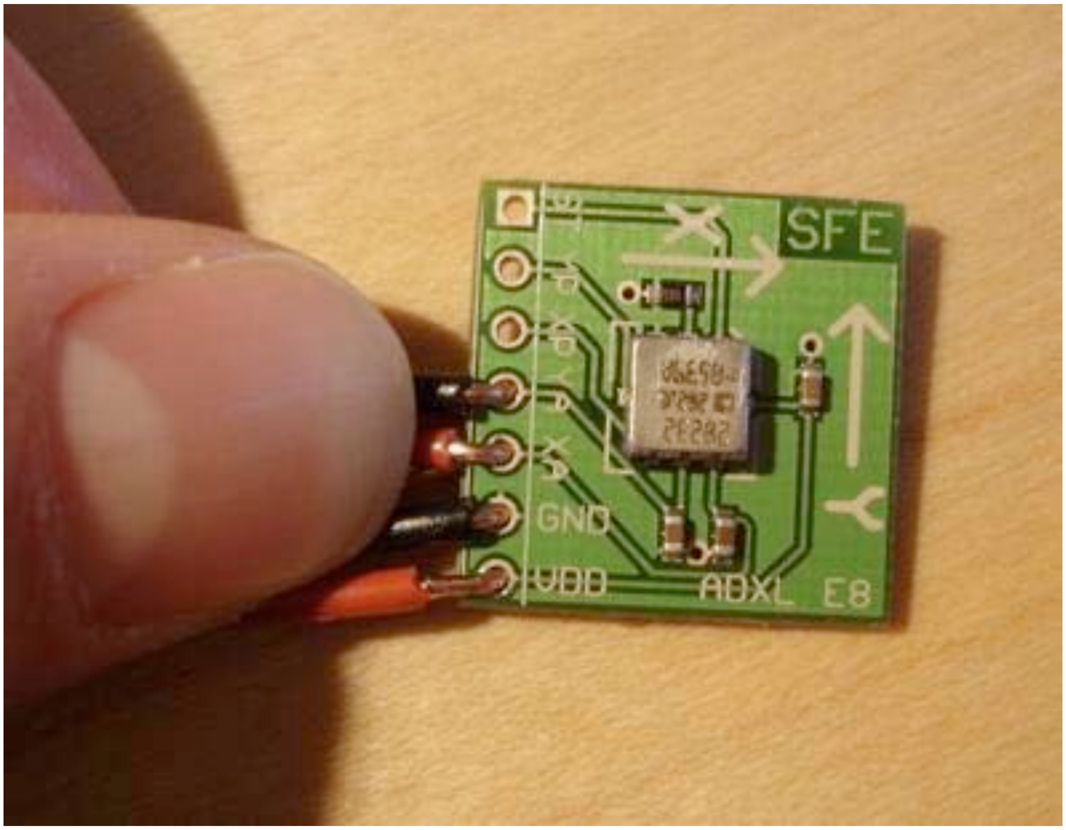
- Example: Roland D-Beam

YouTube Video (http://youtube.com/watch?v=8Ir22l-TTZQ)

17.19. Data Input: Spatial and Movement Detection

- Radio signals and theremin style antennae have been used since 1960s

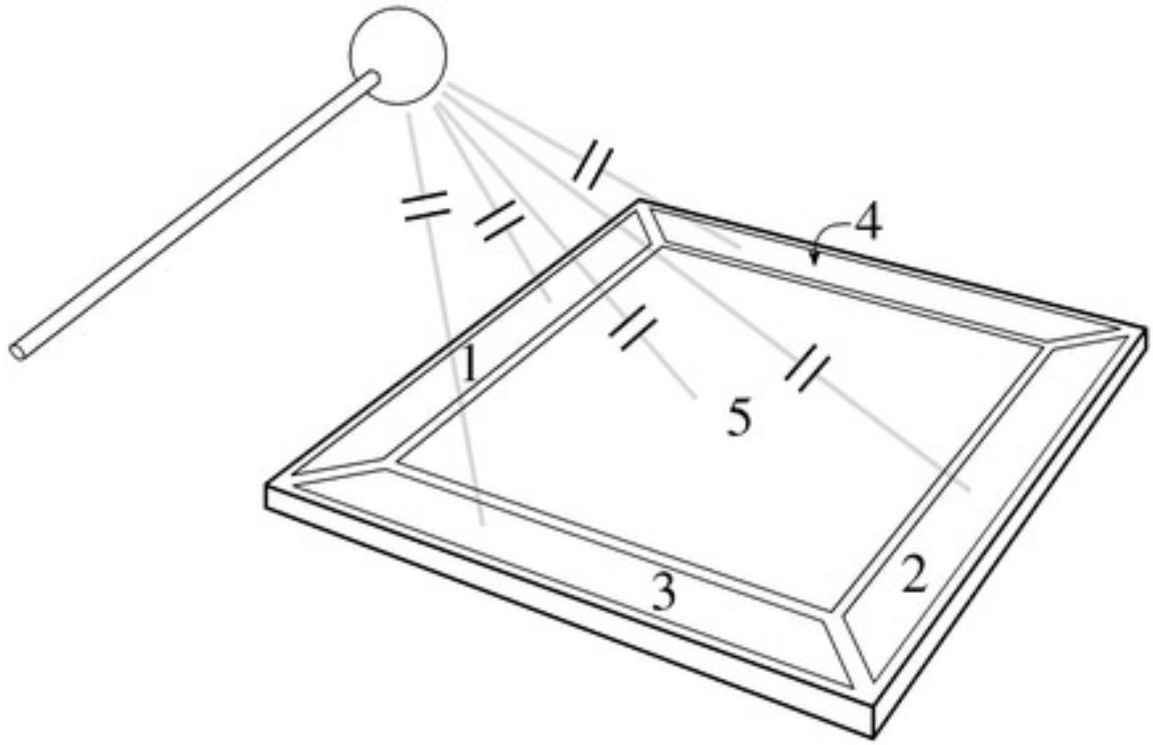
  Contemporary accelerometers offer an expensive and widely-used option



Courtesy of Anita Lillie. Used with permission.

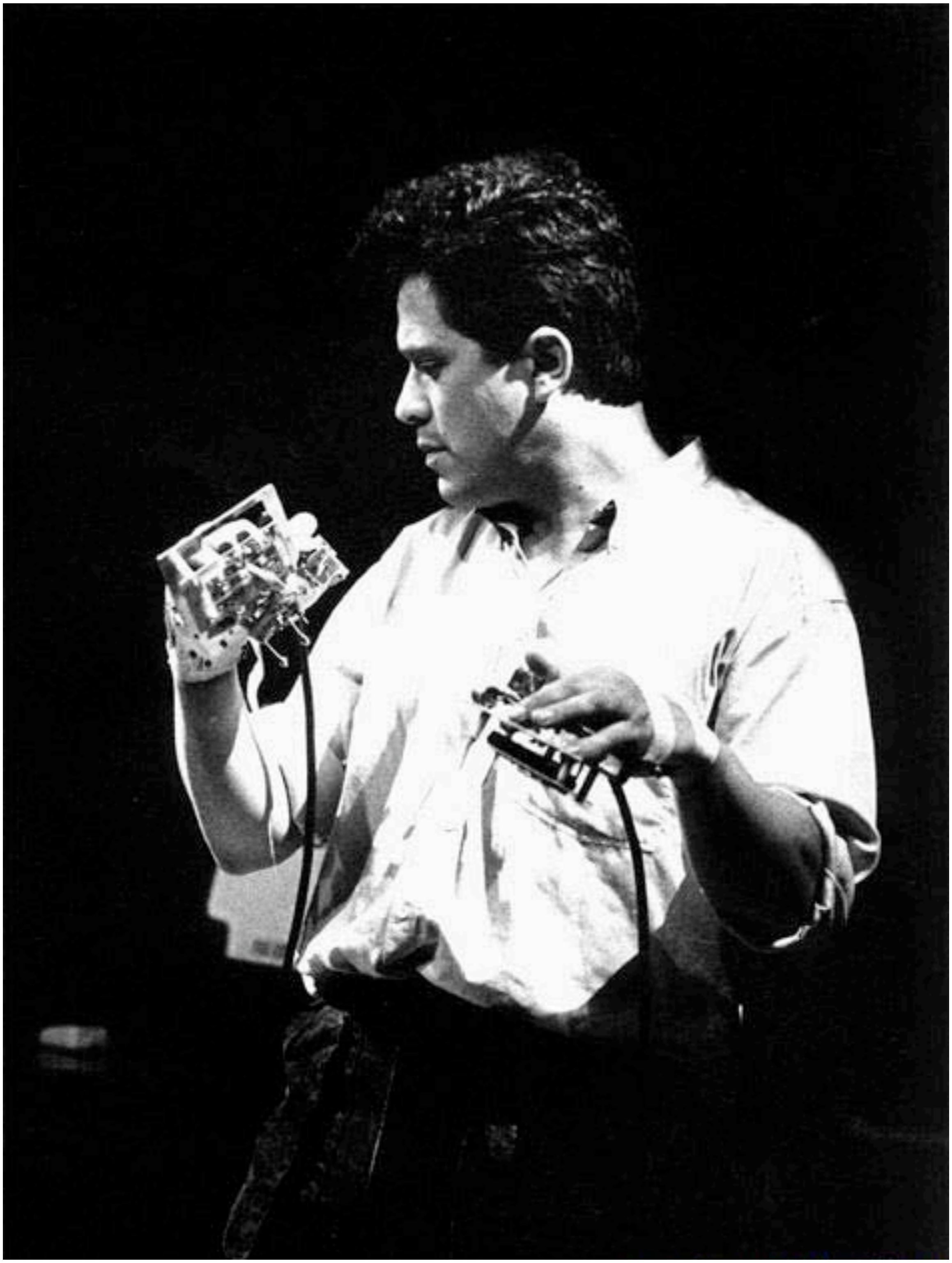
- Example: Radio Baton, Max Mathews (1980), developed with Oberheim

  Each baton has provides three parameters: x, y, and z position


4
1
5
2
3

Courtesy of Max Mathews. Used with permission.

- Example: The Hands, Michel Waisvisz (1984)



Courtesy of Crackle.org. Used with permission.

Courtesy of Crackle.org. Used with permission.

17.20. Data Input: Joysticks

- Example: Novations Remote 81

- Example: JL Cooper Panner

Courtesy of JLCooper Electronics. Used with permission.

- Example: Logitech Dual Action Gamepad

- Example: Logitech Force

17.21. Data Input: Modular and Programmable Input Devices

- Mawzer Modular Interface


SWITCH OFF BEFORE PLUGGING MODULES
MAWZER

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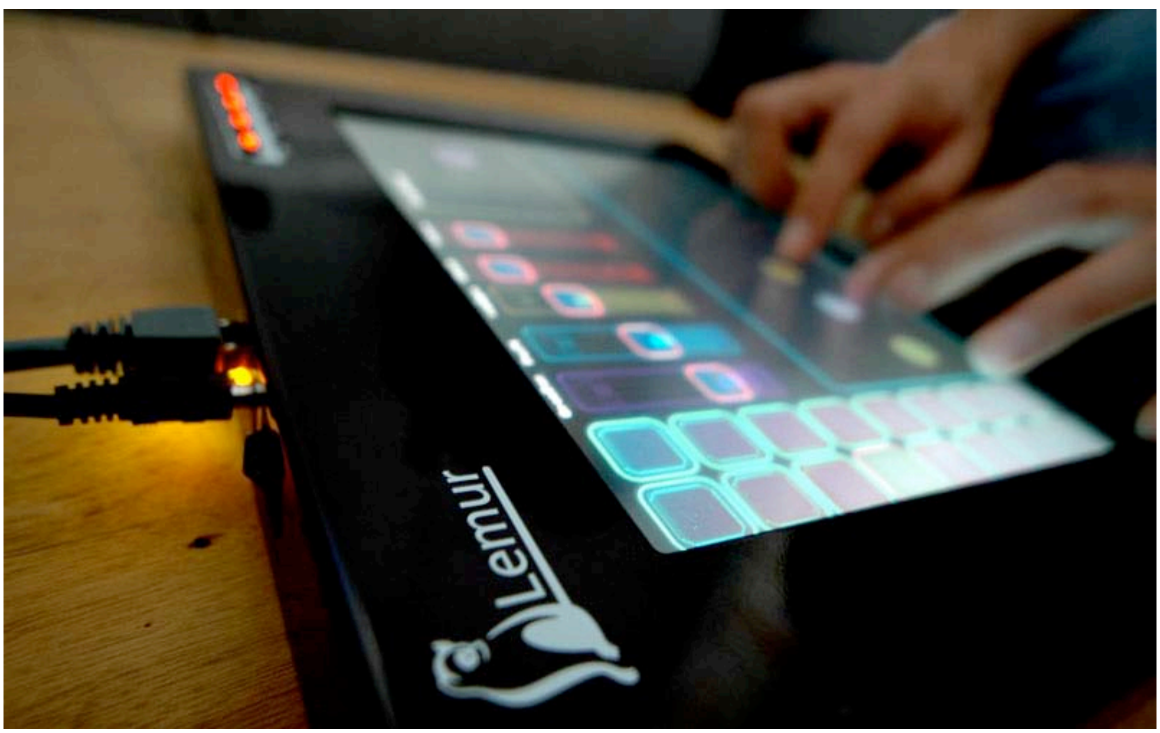
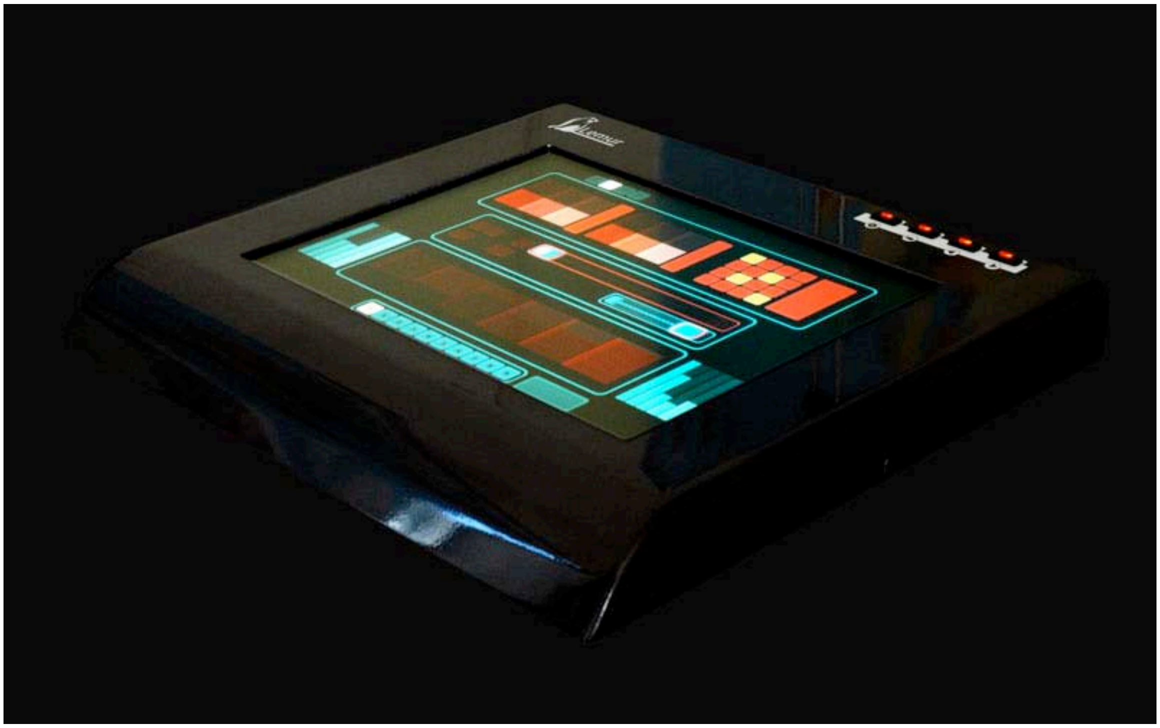
- JazzMutant: Lemur





YouTube (http://www.youtube.com/watch?v=59JFTisR-oc)

17.22. Controller Case Study: Logitech Dual Action

- Standard USB input device: preferred for low coast, high ergonomics
- 10 buttons, 1 pad controller, 2 x/y analog joysticks
- Developed as an interface in conjunction with other controllers for performances with KIOKU

  KIOKU site (http://www.kiokugroup.com/)


AKAI

17.23. Controller Case Study: Filtered Noise with Joysticks

- Various types of noise filtered with a low-pass and high-filter
- Joystick A: y axis controls amp; x axis high pass filter
- Joystick B: y axis controls filter resonance; x axis controls low pass filter
- Buttons trigger diverse noise sources

17.24. Controller Case Study: A Synth Bass with Joysticks

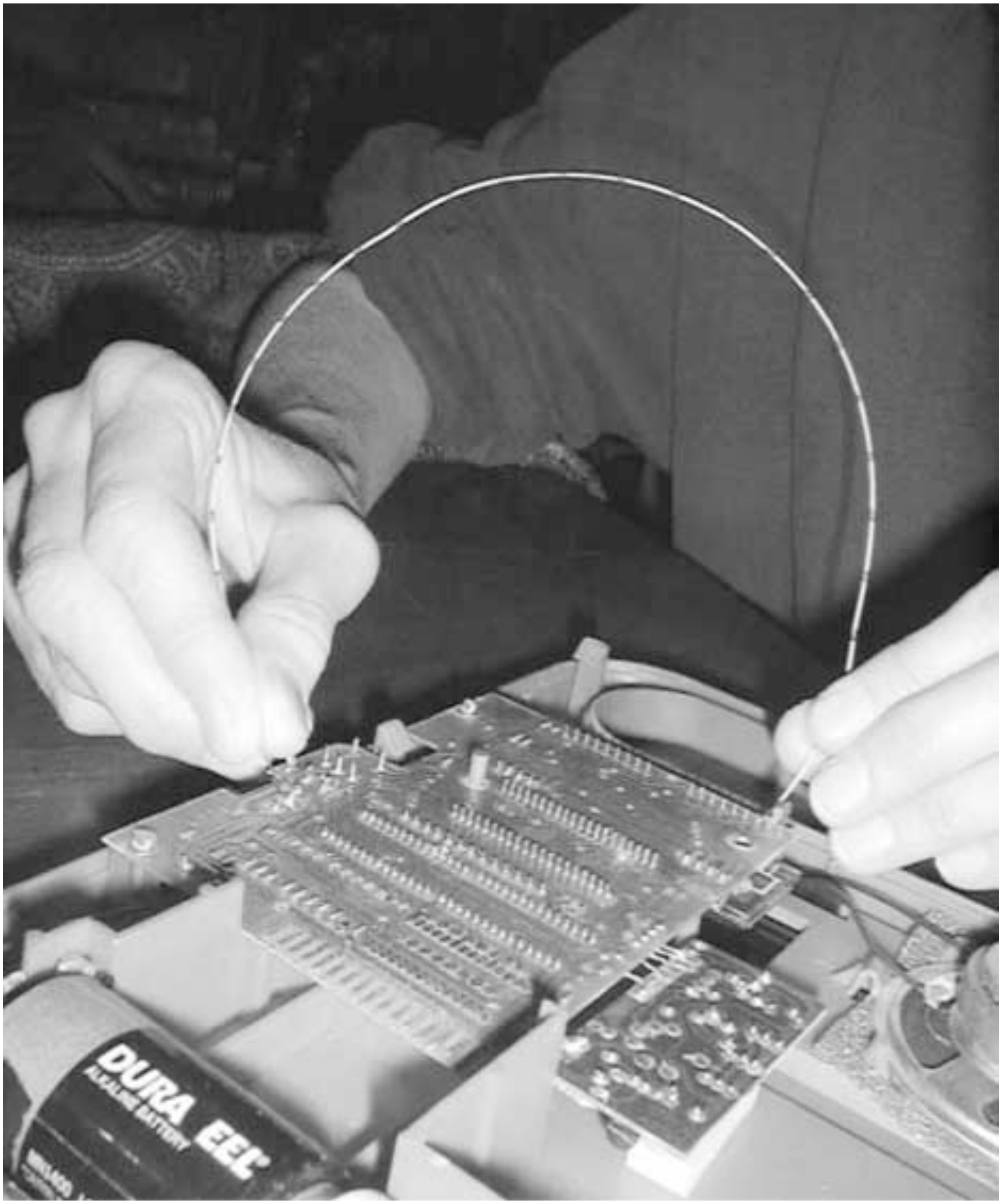
- Synthesized bass tone made of square and sine waves
- Joystick A: y axis controls amplitude; x axis controls pitch bend
- Joystick B: y axis controls low pass filter; x axis controls square wave width
- Buttons trigger pitches
- Pad switches octave

17.25. Controller Case Study, Variable-Speed Buffer with Joysticks

- Looped samples
- Joystick A: y axis controls amplitude; x axis controls playback speed
- Joystick B: x axis scales end position of loop
- Button opens envelope
- Pad switches samples within a two-dimensional grid

17.26. Circuit Bending

- Modification of conventional electronics for creative musical (aesthetic) output
- Applied to battery-powered toys, effects, old synthesizer, or any electronic device that makes noise
- The interface is extended to include modifying circuit boards
- Often results are obtained from blind experimentation



Courtesy of Qubais Reed Ghazala, http://www.anti-theory.com/. Used with permission.

17.27. Reading: Ghazala

- Ghazala, Q. R. 2004. "The Folk Music of Chance Electronics: Circuit-Bending the Modern Coconut." *Leonardo Music Journal* 14(1): 97-104.

- Examples: incantor, bent Speak and Spell www.anti-theory.com (http://www.anti-theory.com/bentsound/incantors/incantor_straight_03.mp3)

www.anti-theory.com (http://www.anti-theory.com/bentsound/incantors/sg6.mp3)

- How does chance electronics relate to chance music?
- What does Ghazala mean when he refers to the immediate canvas?
- Why is the metaphor of a coconut useful in understanding circuit bending?
- For Ghazala, is anti-theory against theoretical understanding of music and circuits?

17.28. Circuit Bending: Documentary

- What is Circuit Bending (2004) by Derek Sajbel

  YouTube (http://www.youtube.com/watch?v=w6Pbyg_kcEk)

Chapter 18. Meeting 18, Discussion and Workshop

18.1. Announcements

- Quiz next Thursday
- Download fresh martingale now:

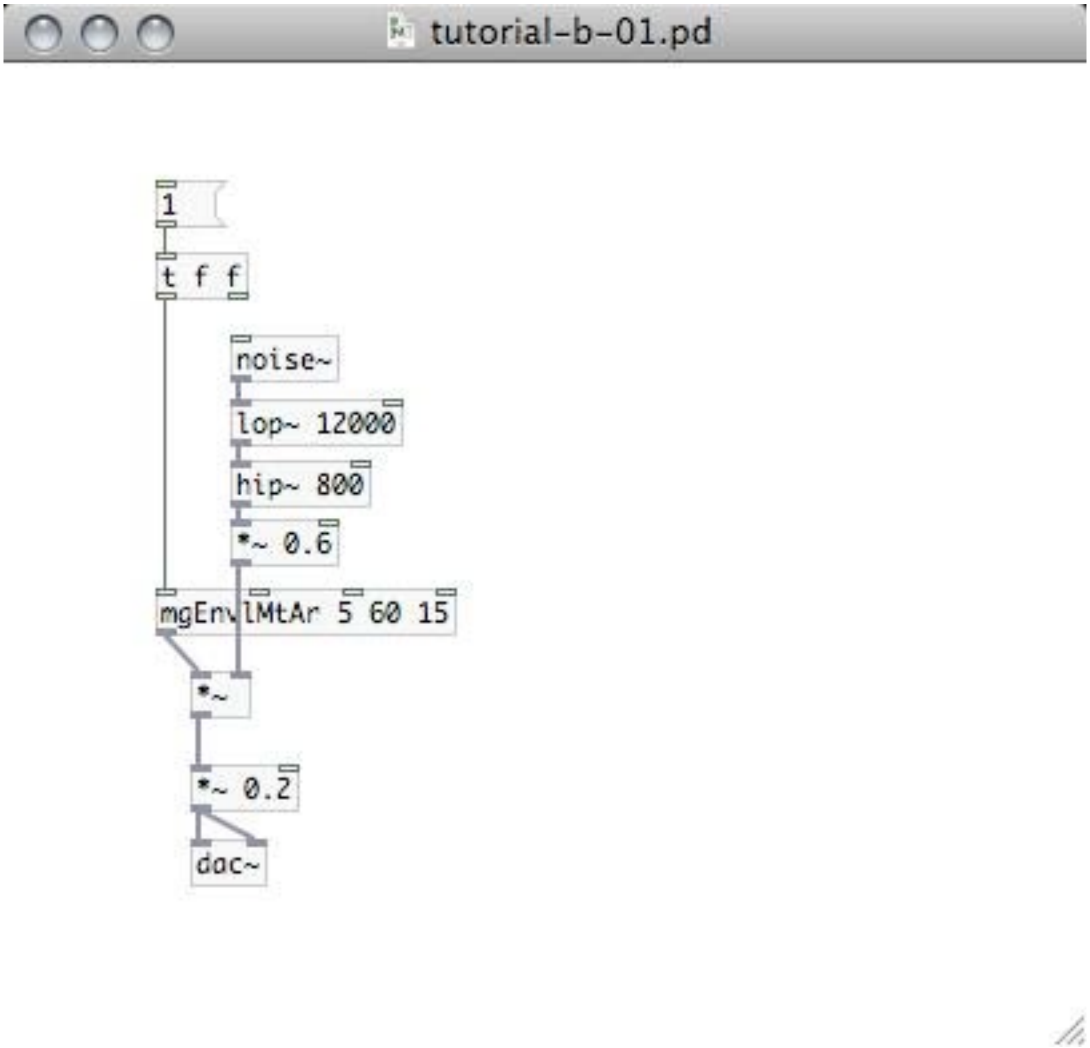
  http://code.google.com/p/martingale

18.2. Sonic System Project Draft

- Presentations

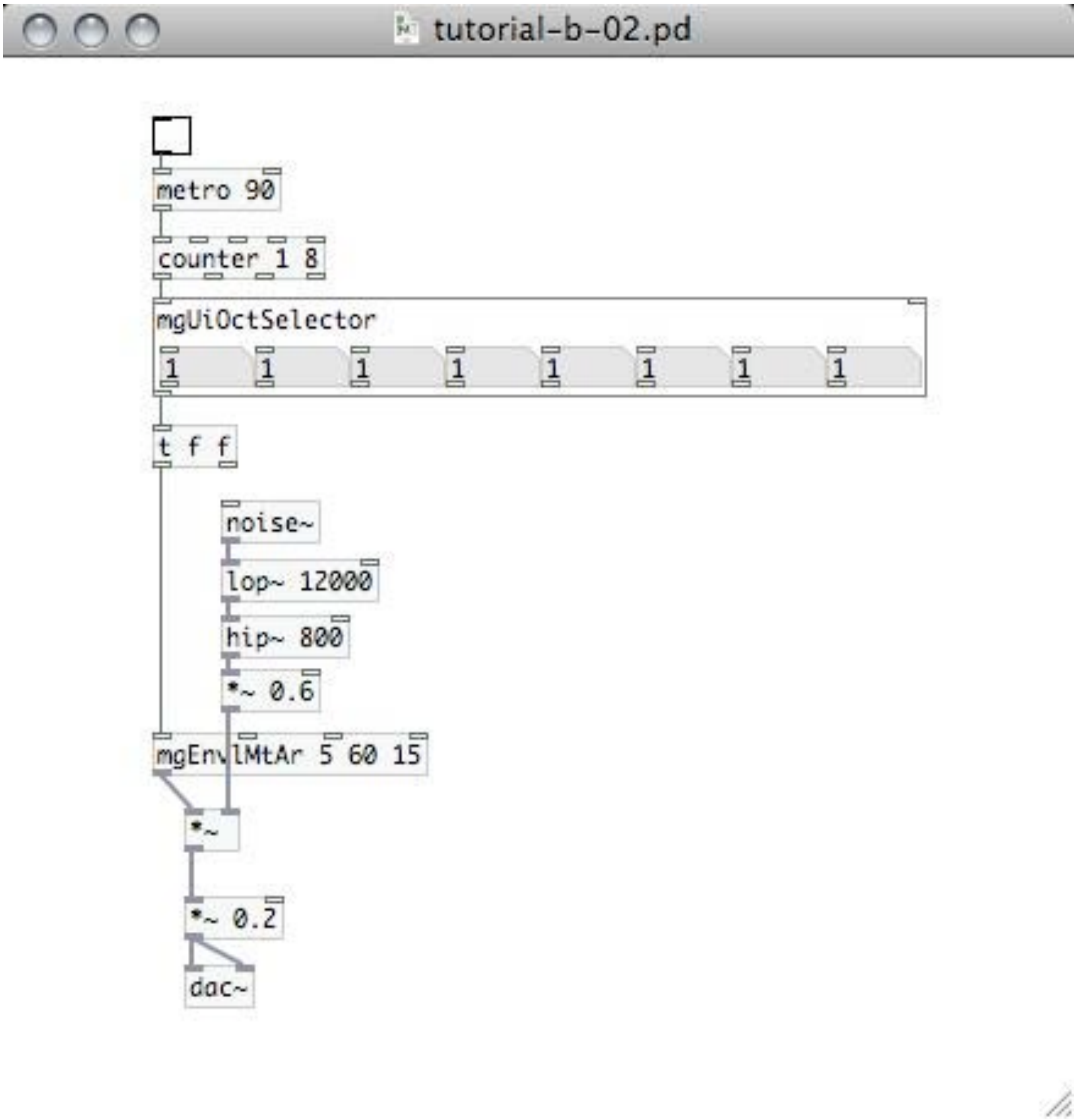
18.3. Workshop: A Subtractive Snare Drum: Envelope

- Noise filtered through a low and high pass filter with an AR envelope



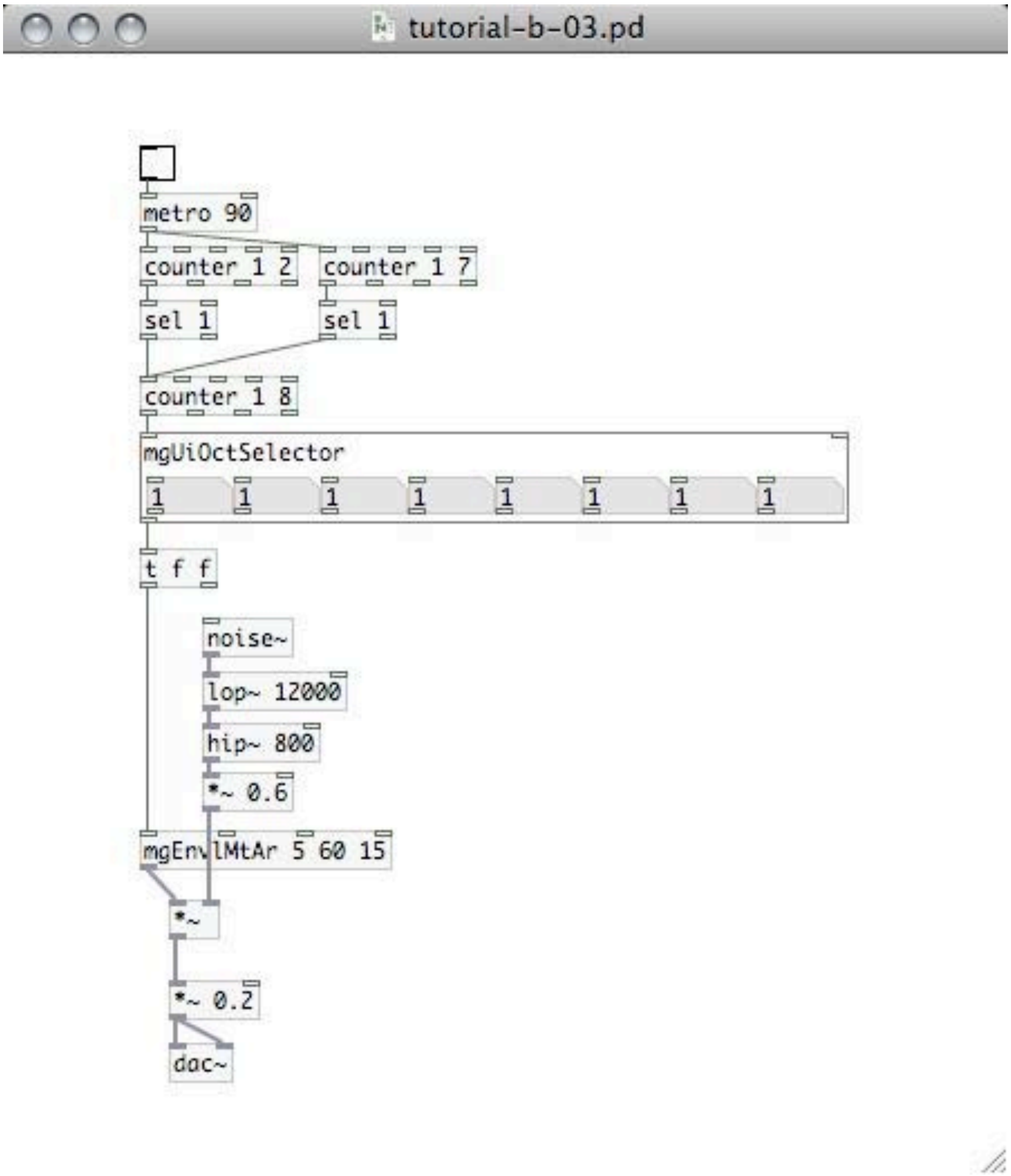
18.4. Workshop: A Subtractive Snare Drum: Sequencer

- A metro sends out bangs at 90 ms intervals; a [counter] provides values to [mgUiOctSelector]; these values are treated as peak amplitudes for the noise instrument



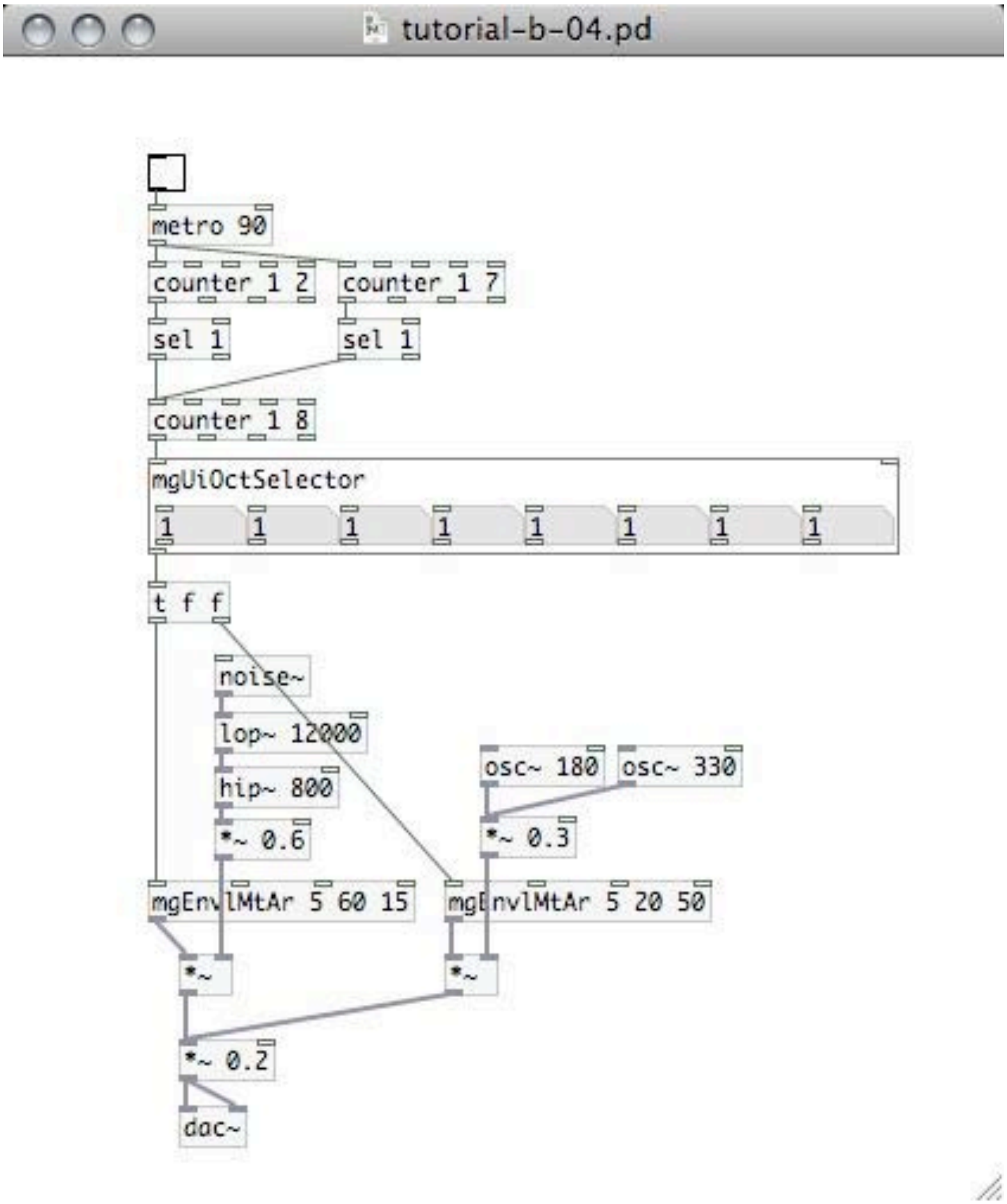
18.5. Workshop: A Subtractive Snare Drum: Polyrhythmic Cycles

- Individual counters provide alternative time unit multiples; selecting one provides a bang at the start of each cycle



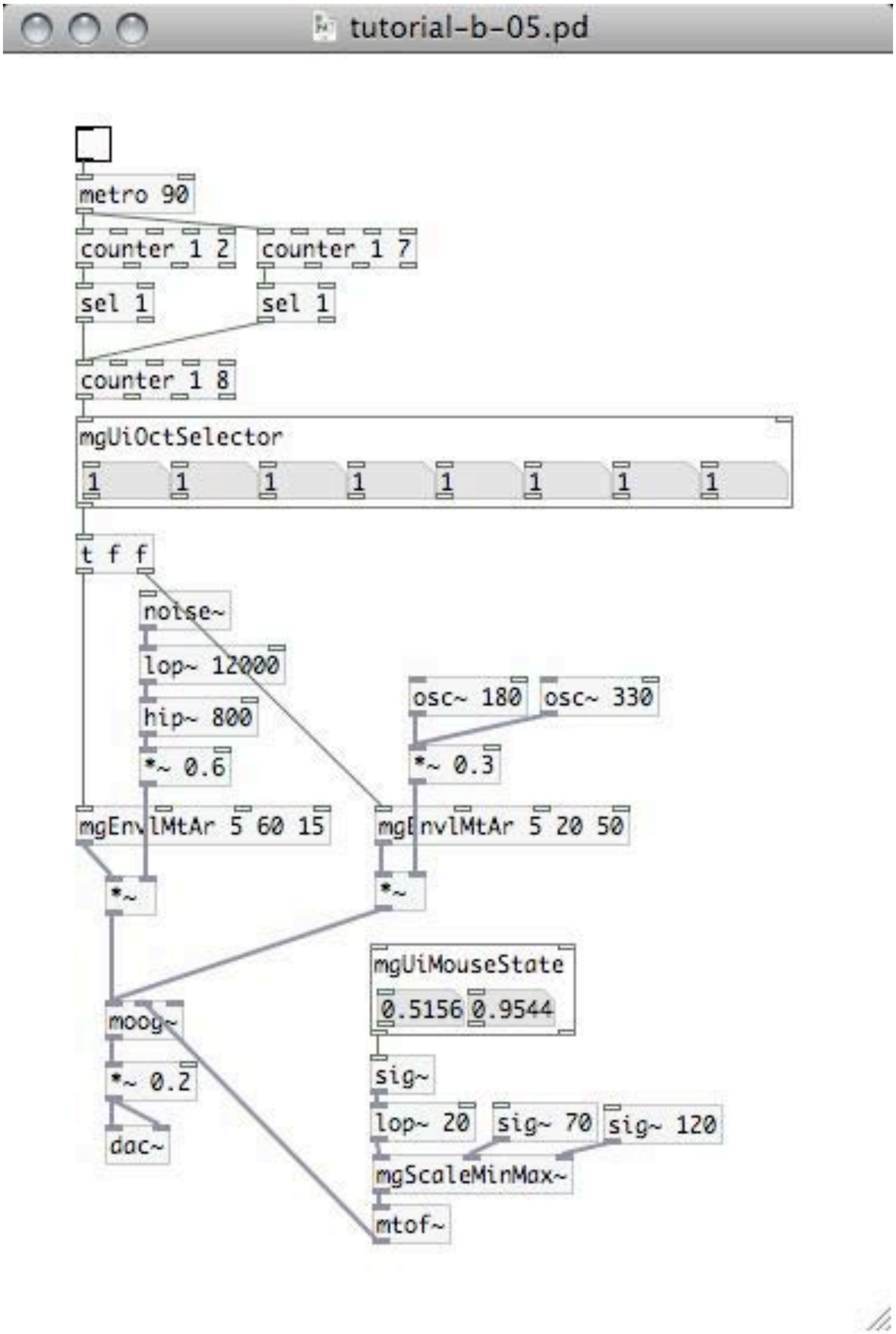
18.6. Workshop: A Subtractive Snare Drum: Adding Tone

- Sine waves can be added to create a resonant pitched tone



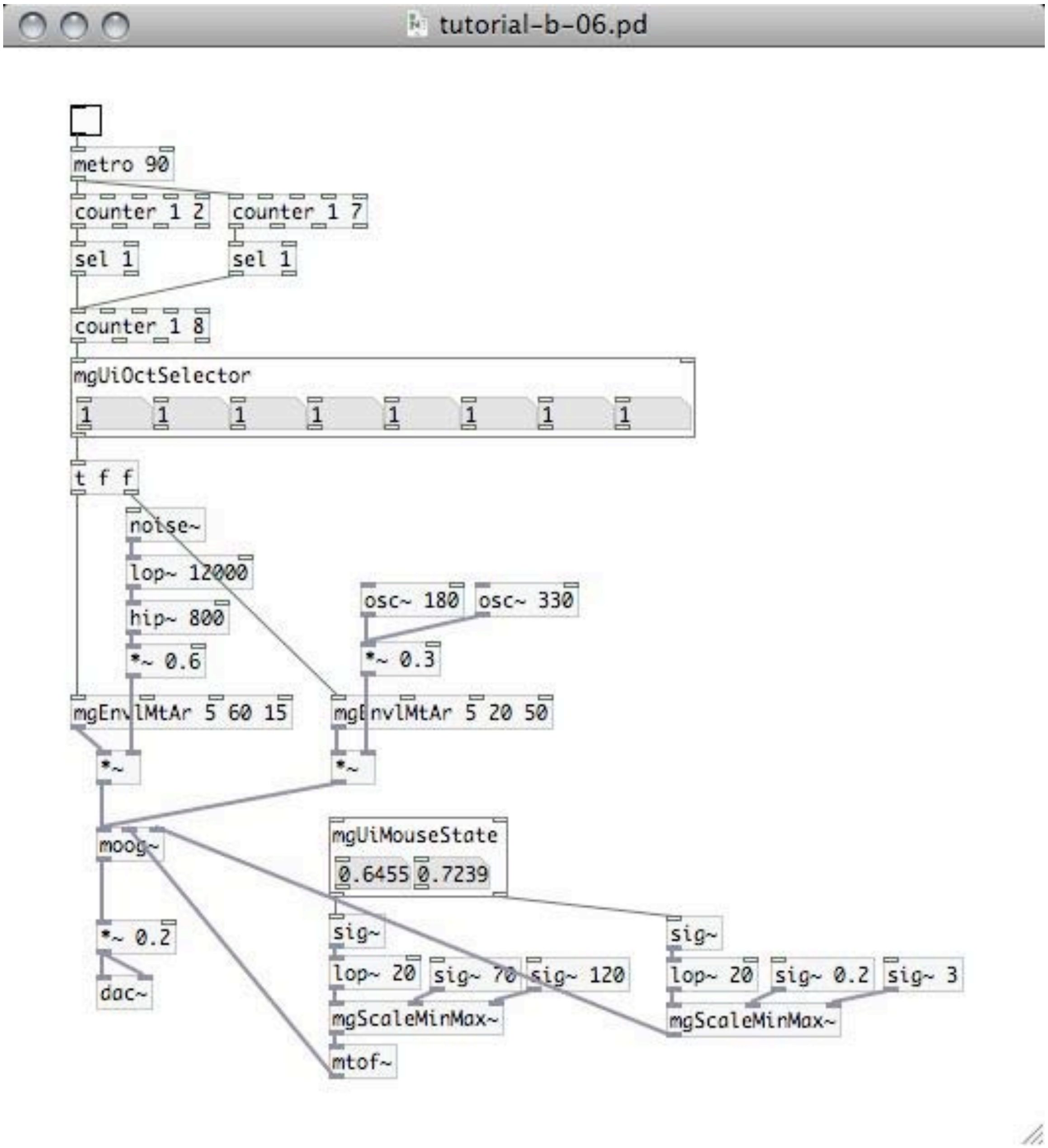
18.7. Workshop: A Subtractive Snare Drum: Modulating LPF Cutoff Frequency

- Using mouse x-position to control [moog~] cutoff frequency


tutorial-b-05.pd
metro 90
counter 1 2
counter 1 7
sel 1
sel 1
counter 1 8
mgUiOctSelector
1
1
1
1
1
1
1
1
t f f
noise~
lop~ 12000
hip~ 800
*~ 0.6
osc~ 180
osc~ 330
*~ 0.3
mgEnvlMtAr 5 60 15
mgEnvlMtAr 5 20 50
*~
*~
mgUiMouseState
0.5156
0.9544
moog~
*~ 0.2
dac~
sig~
lop~ 20
sig~ 70
sig~ 120
mgScaleMinMax~
mtof~

18.8. Workshop: A Subtractive Snare Drum: Modulating Cutoff and Resonance

- Using mouse x-position and y-position to control [moog~] cutoff frequency and resonance



18.9. Listening: MEV

- Musica Elettronica Viva: formed in 1966 by Alan Bryant, Alvin Curran, Jon Phetteplace, Frederic Rzewski, along with others

- 1960s: more than 100 concerts in 30 cities in Europe (Holmes 2008, p. 396)
- Musica Elettronica Viva (MEV), *Spacecraft*, 1967

18.10. Listening: AMM

- AMM: formed in 1966 with Cornelius Cardew, Christopher Hobbs, Lou Gare, Edwin Prevost, Keith Rowe
- Touring group of jazz and electronic musicians
- AMM, "The Great Hall 1," *Laminal*, 1982

18.11. Listening: Supersilent

- Norwegian ensemble of acoustic and electronic instruments
- Strong emphasis on free improvisation and spontaneous composition
- SuperSilent, "5.1," *5*, 2001

- SuperSilent, "6.2," *6*, 2001

Chapter 19. Meeting 19, Languages: The History of Notation and MIDI

19.1. Announcements

- Quiz on Thursday
- Music Technology Case Study Final Draft due Tuesday, 24 November

19.2. Listening: Lockwood

- Exclusive use of natural, environmental sounds
- Tape composition, "a musical travelogue of nature sounds that was pieced together as carefully as a dovetail joint to mesh the rhythms of one segment with those of the next" (Holmes 2008, p. 399)
- Interested in using found sounds, did not employ explicit loops or manipulations
- Interested in "acoustic commonalities amongst various disparate sounds" (Holmes 2008, p. 399)
- Originally for 10 channel audio and live mixing and gong
- Listening: Annea Lockwood, *World Rhythms*, 1975

19.3. Listening: Eno

- Trained as a painter and visual artist, influenced by minimalist composers, began musical work on tape recorders
- 1969: Joined Cornelius Cardew's Scratch Orchestra
- 1971: member of glam band Roxy Music
- First solo album: *Here Come the Warm Jets*
- *Ambient 1: Music for Airports*: divided into four tracks: 1/1, 1/2, 2/1, 2/2

- “Not music from the environment but music for the environment” (Holmes 2008, p. 400)
- Goal of creating environmental music suited for moods and atmospheres; “ambient music must be able to accommodate many levels of listening attention without enforcing one in particular...” (Holmes 2008, p. 401)
- Piano and various synthesized sound are combined in all
- Listening: Brian Eno, “1/2,” *Ambient 1: Music for Airports*, 1978

19.4. Languages Used for Music

- Descriptive
  - Western notation
  - Music storage and data languages: MIDI, OSC, MusicXML
- Generative
  - Programming languages for synthesis and sound generation
  - Programming languages for interaction and interface

19.5. Western Notation

- Split sound production from sound instruction
- Motivated by pedagogical needs
- Developed in the European church for vocal music
- Led to a process of increased parameterization
- Led to techniques of creating music
- “... musical notation ... originated first as a mnemonic device for already well-established musical practice, but, like writing, it quickly grew to dominate that musical practice” (Wishart 1996, p. 18)

19.6. Western Notation: Basic features

- Time moves from left to right; spacing is not proportional
- A score consists of one or more parallel staffs; where each staff represents an instrument or part
- Pitch space is represented by notes placed on a vertical grid (the staff); spacing is not proportional
- Rhythm is represented by note shape (solid or empty) and/or flags or beams (with more flags/ beams indicating shorter durations)
- Dynamics (amplitudes) are represented with word abbreviations (e.g. *f* for forte, *p* for piano)
- Listening: Stravinsky: "Le violon du Soldat," Mvmt II from *L'histoire du soldat,* 1918

19.7. The History of Notation: Neumes

- 800s: Earliest neumatic notation

- 900s to 1100s: widespread, diverse practices
- Few musical parameters provided
- Data for parameters provided in general, qualitative values

19.8. The History of Notation: Example Neumes

- 900s to 1000s

Table removed due to copyright restrictions. Neumes of the 10th - 11th centuries, from Grove Music Online.
See Wikipedia: Neume as replacement.

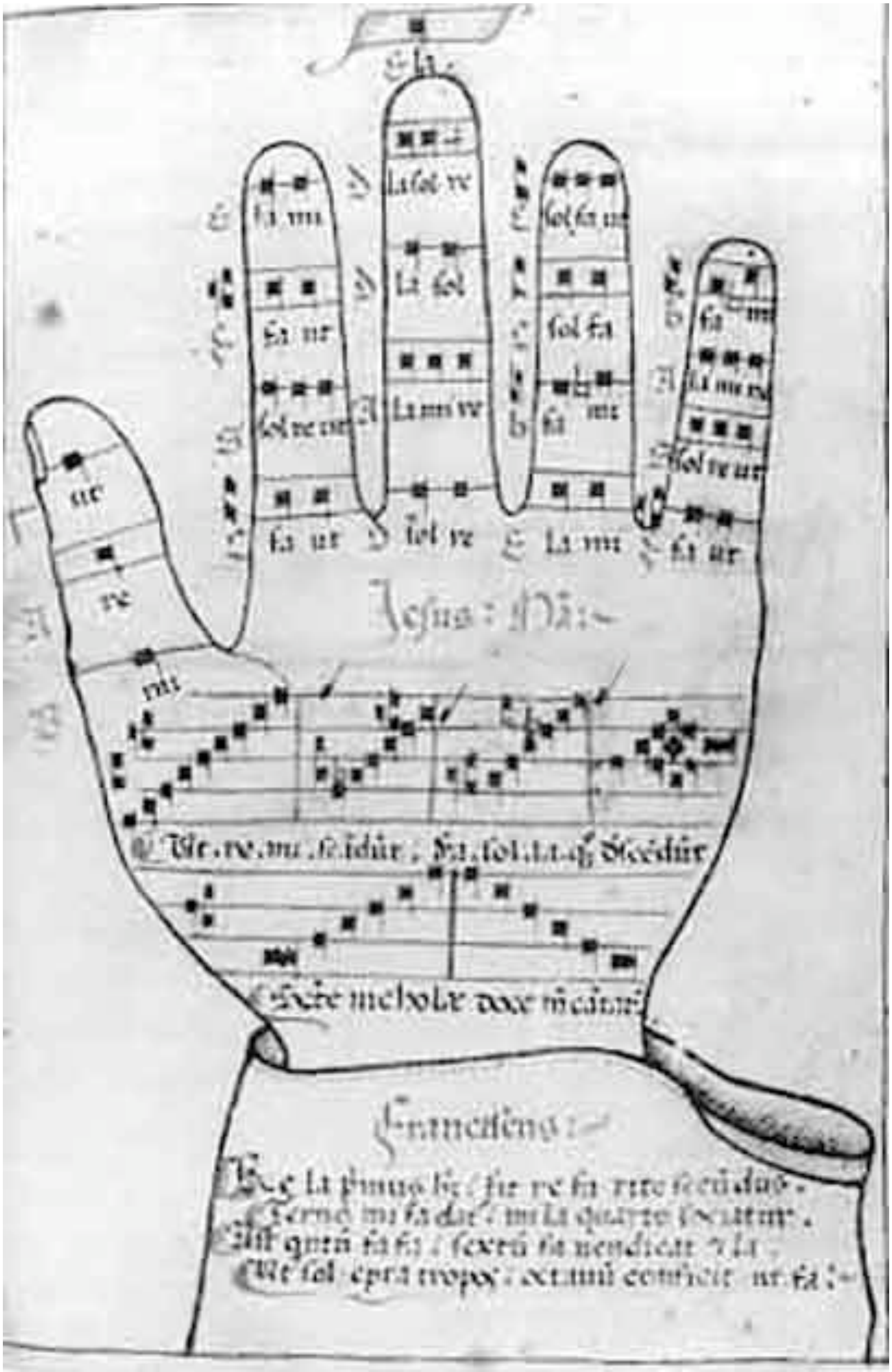
- 1000s to 1100s

Table removed due to copyright restrictions. Neumes of the 11th-12th centuries, from Grove Music Online. See Wikipedia: Neume as replacement.

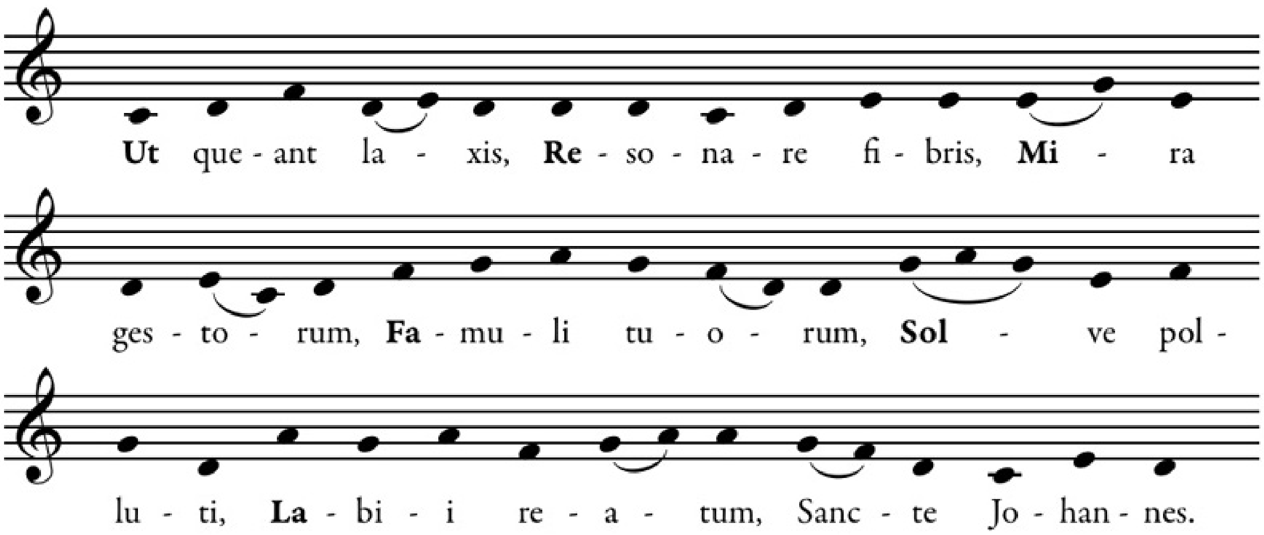
19.9. The History of Notation: Discrete Pitch

- Guido of Arezzo: monk, teacher of music to singers
- after 1026: *Micrologus*
- Proposed system of pitch notation with lines and spaces
- Introduced method of sight-singing with ut, re, mi, fa, sol, la

  Introduced mnemonic device to help singers through three octaves of pitches



la sol re
la sol
la mi re
sol re
la mi
fa ut
ut
re
mi
Jesus : Ma



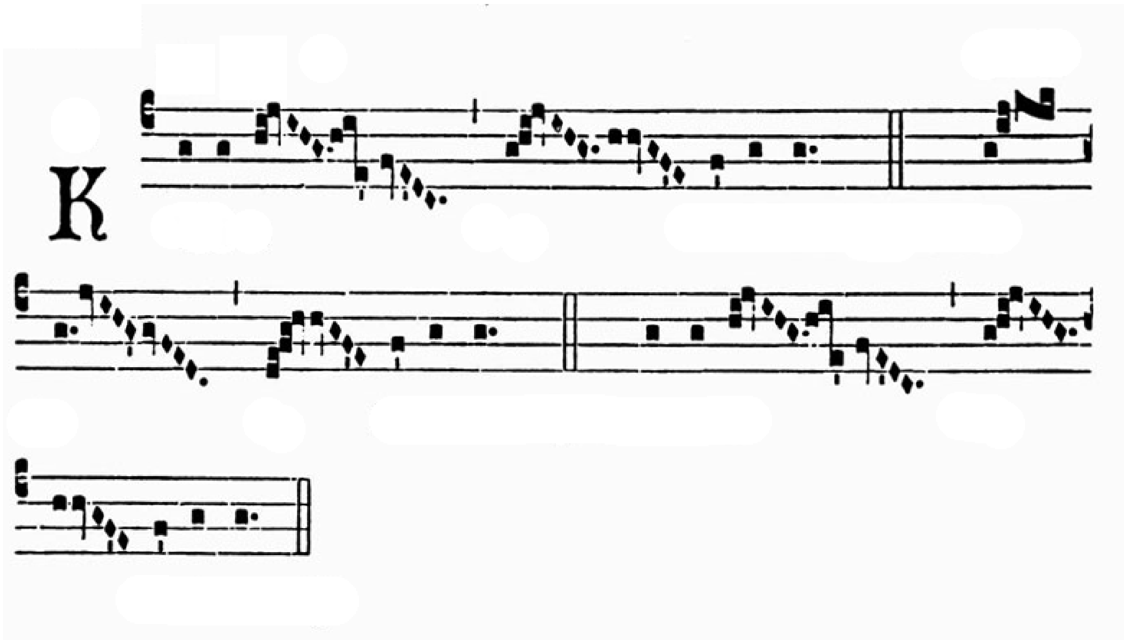
Public domain image.

19.10. The History of Notation: Gregorian Chant

- Chant practices of the Catholic church solidified between 1000s to 1200s
- Graduale Aboense, 14th to 15th c hymn book

- *Liber Usualis* (Common Book): issued by monks of Solesmes in 1896

- Kyrie



Listening: Kyrie excerpt

19.11. The History of Notation: Modal Rhythm

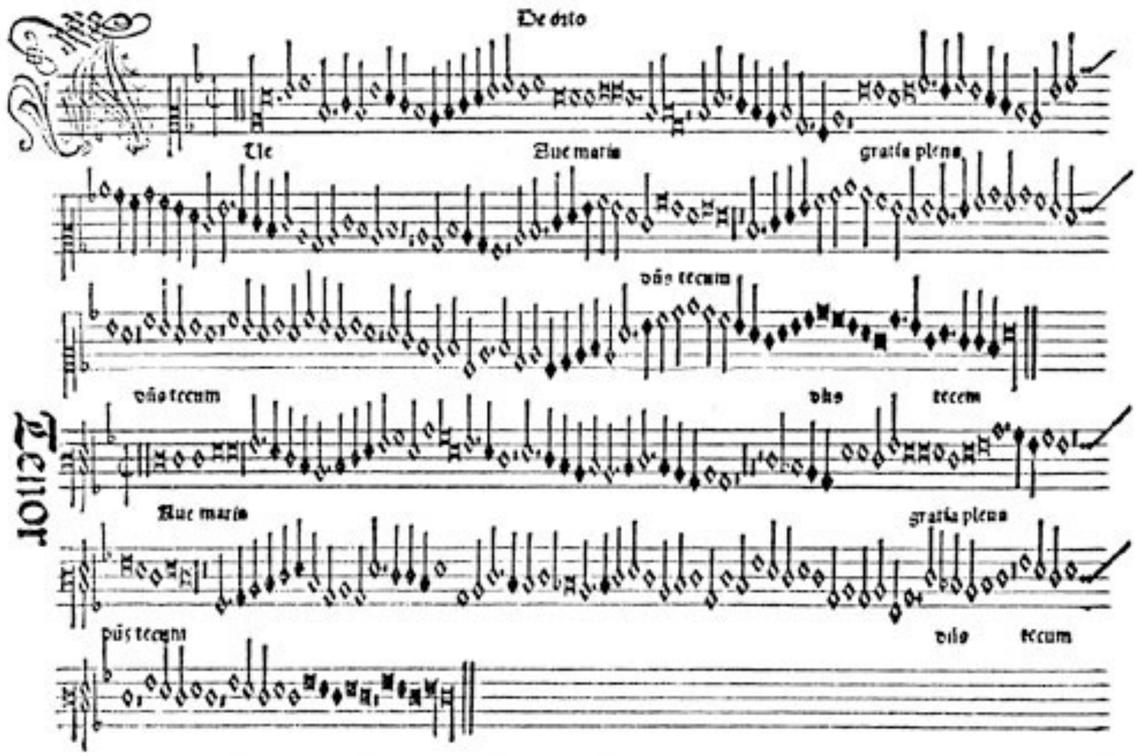
- Notated conventional patterns, not discrete rhythms
- Rhythms based on context, closely related to poetic feet (troche, iamb, dactlye, anapest, spondee, pyrrhic)
- 1100s to 1200s

19.12. The History of Notation: Rhythm

- Franco of Cologne: uses shapes to express durations
- Around 1250: *Ars cantus mensurabilis*
- Rhythms based on note appearance

19.13. The History of Notation: Printing

- 1436: Johannes Gutenberg does first printing with movable type, replace block printing
- Ottavio Petrucci
- 1498: Granted privilege to print music
- 1501: *Harmonice musices odhecaton A*



- First printer to use movable type
- First used three passes: staves, music, and words
- Later used two passes: staves and words, music

19.14. The History of Notation: Dynamics

- Rare before 1600
- 1700s: range of *pp*, *p*, *f*
- Hairpins for crescendi and decrescendi: late 1700s
- 1800s: range of *ppp* to *fff*
- late 1800s: range of *pppppp* to *ffff*

19.15. The History of Notation: Example: Corelli and Bach

- Listening: Corelli (1653-1713): Trio Sonata, Opus 3, Number 2

SONATA II.

Augener's Edition

8442

Arcangelo Corelli, Trio Sonata, Op. 3, No. 2. Source: IMSLP (public domain). From Joachim and Chrysander edition, London, UK: Augener & Co, 1888-1891.

- Listening: J. S. Bach (1685-1750): Goldberg Variation 24

Source: IMSLP (public domain). From C. F. Becker edition, Leipzig: Breitkopf & Härtel (1853).

19.16. The History of Notation: Twentieth Century

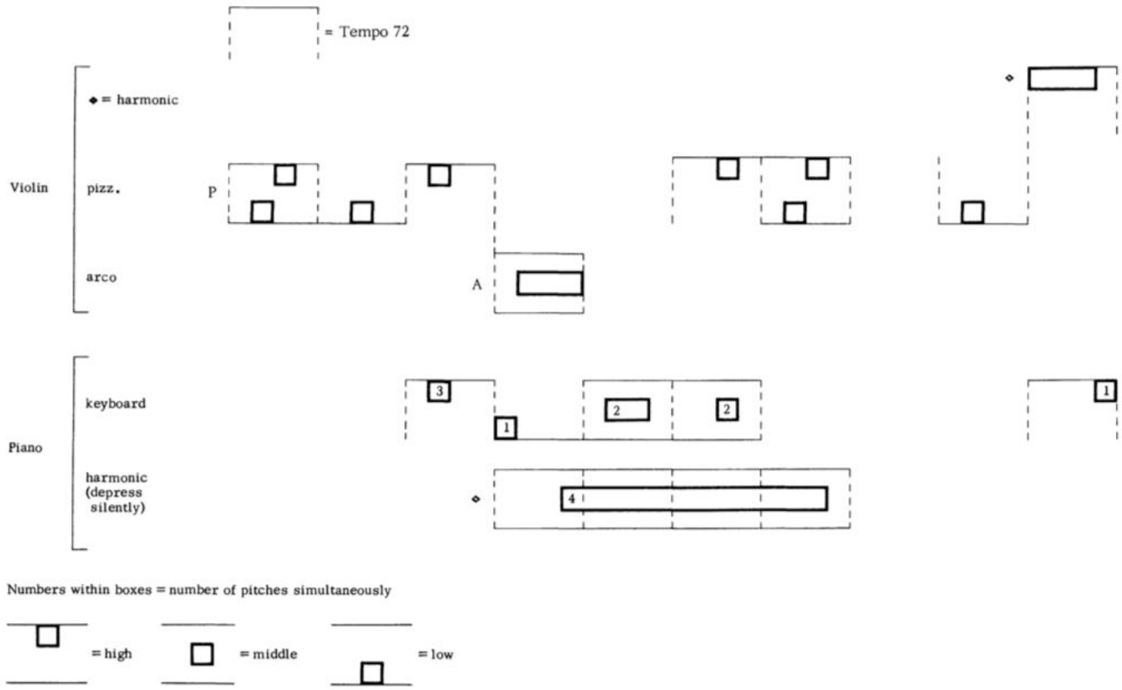
- Complex pitches, microtones, bent and altered pitches
- Great detail to articulation and performance techniques
- New symbols required for new instruments and electronics
- New symbolic systems for improvisation, indeterminacy, and new musical contexts

19.17. The History of Notation: Example: Twentieth Century Music

- Listening: Donald Martino (1931-2005): *Notturno*, for flute, clarinet, violin, violoncello, percussion, and piano

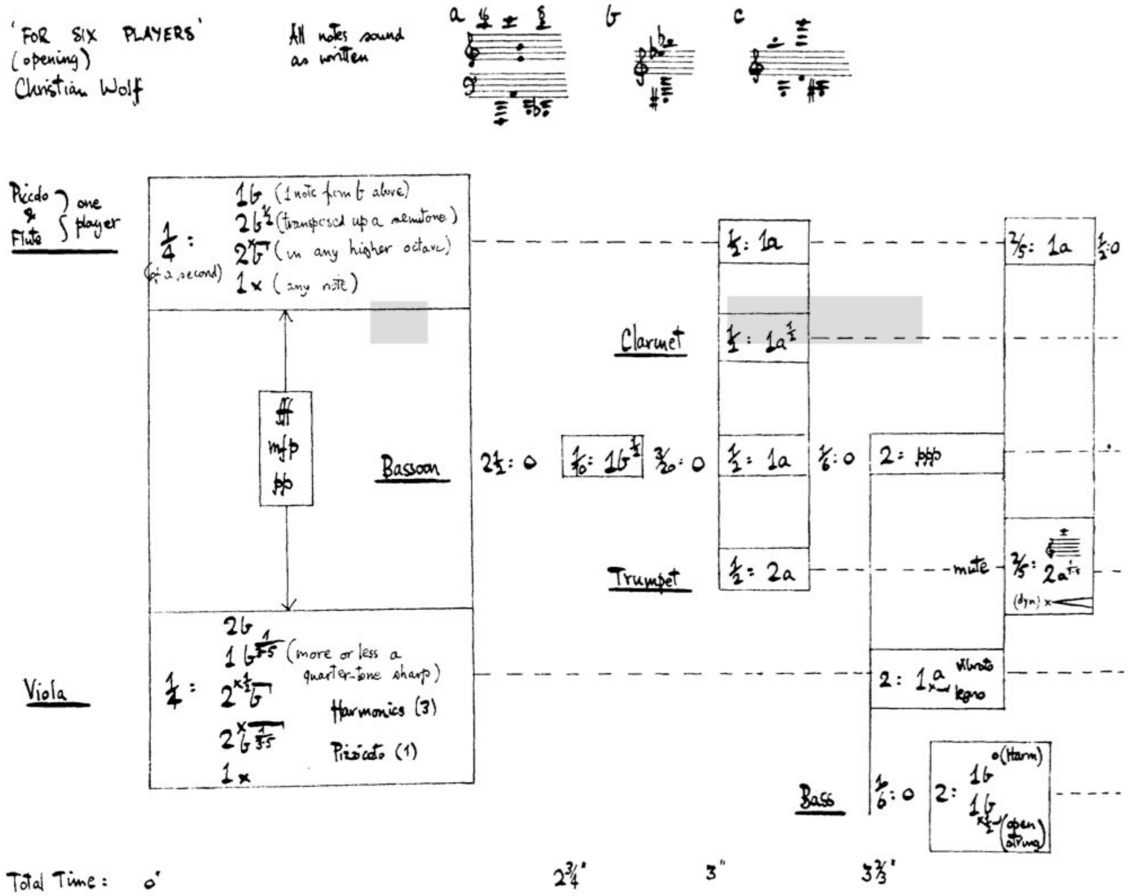
19.18. The History of Notation: Examples: Twentieth Century Music

- While some composers sought more parameters, others looked for alternative parametric representations
- Morton Feldman: *Projection IV* (Behrman 1965, p. 64)

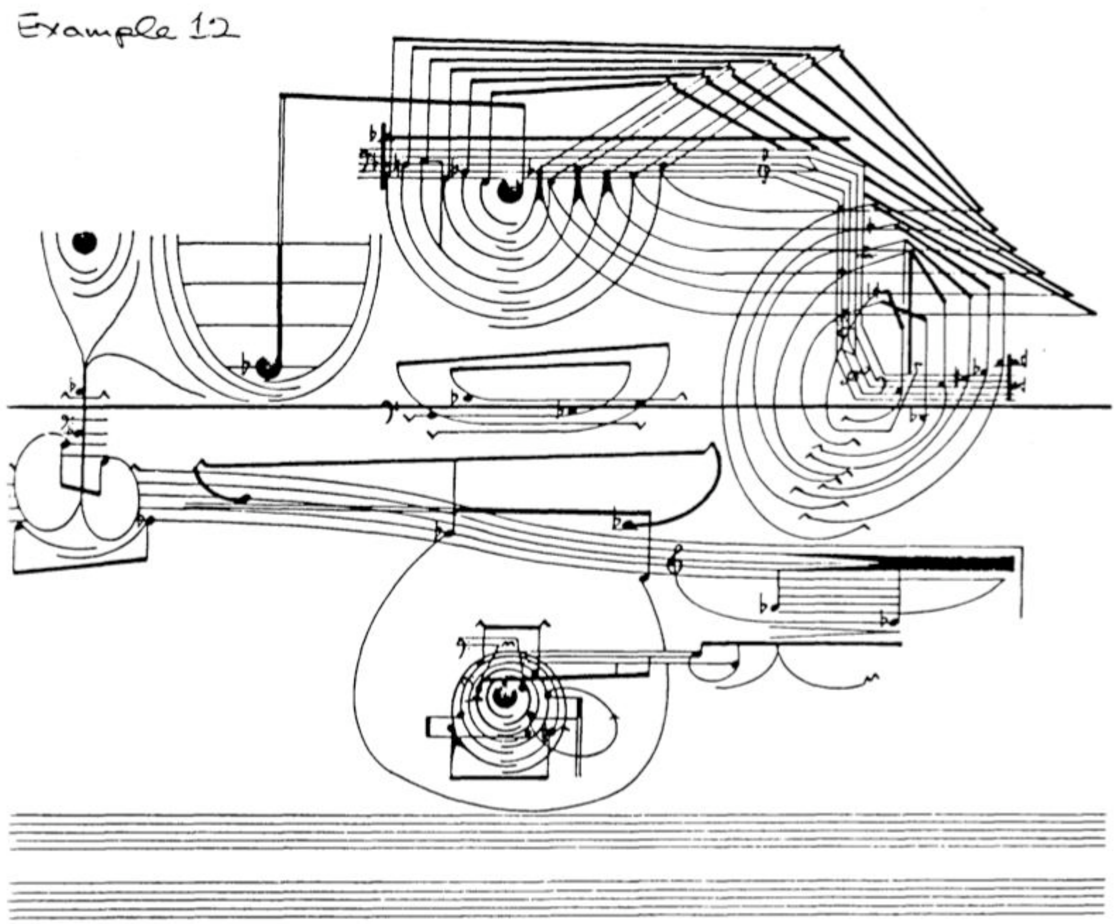


Ex. 4, Feldman, *Projection IV,* first page

- Christian Wolf: *For Six Players* (Cardew 1961, p. 24)



- Cornelius Cardew: *Treatise* 1963-1967 (Dennis 1991, p. 24)



19.19. Voltage as a Control Language

- Modular synthesizers used voltages to transmit control information
- Control information could be continuous parameter changes (a varying voltage)
- Control information could include event durations, pitches, and amplitudes
- Control information could include envelope, filter, and oscillator parameters
- No standards for voltage control between manufacturers
    - Ranges and mapping of volts were often different between devices
    - Example: 1 volt per octave, 1/3 volt per octave, or volt to Hz mapping

19.20. MIDI: Motivation

- Inconvenience and unreliability of voltage signals

- Desire to save and store control information (not audio)
- Desire to control multiple synthesizers from one input interface
- Many manufacturers developed proprietary communication systems: Roland, Oberheim, Sequential Circuits, and Fender Rhodes

19.21. MIDI: History

- 1981: Sequential Circuits (Smith and Wood) propose a Universal Synthesizer Interface
- 1982 (December): First MIDI synthesizer, Sequential Circuits Prophet 600, ships
- 1983: first demonstration of communication between two synthesizers by different manufacturers (Prophet 600 and Roland Jupiter 6)
- 1983 (October): official MIDI 1.0 Detailed Specification published

19.22. MIDI: 1.0 Detailed Specification

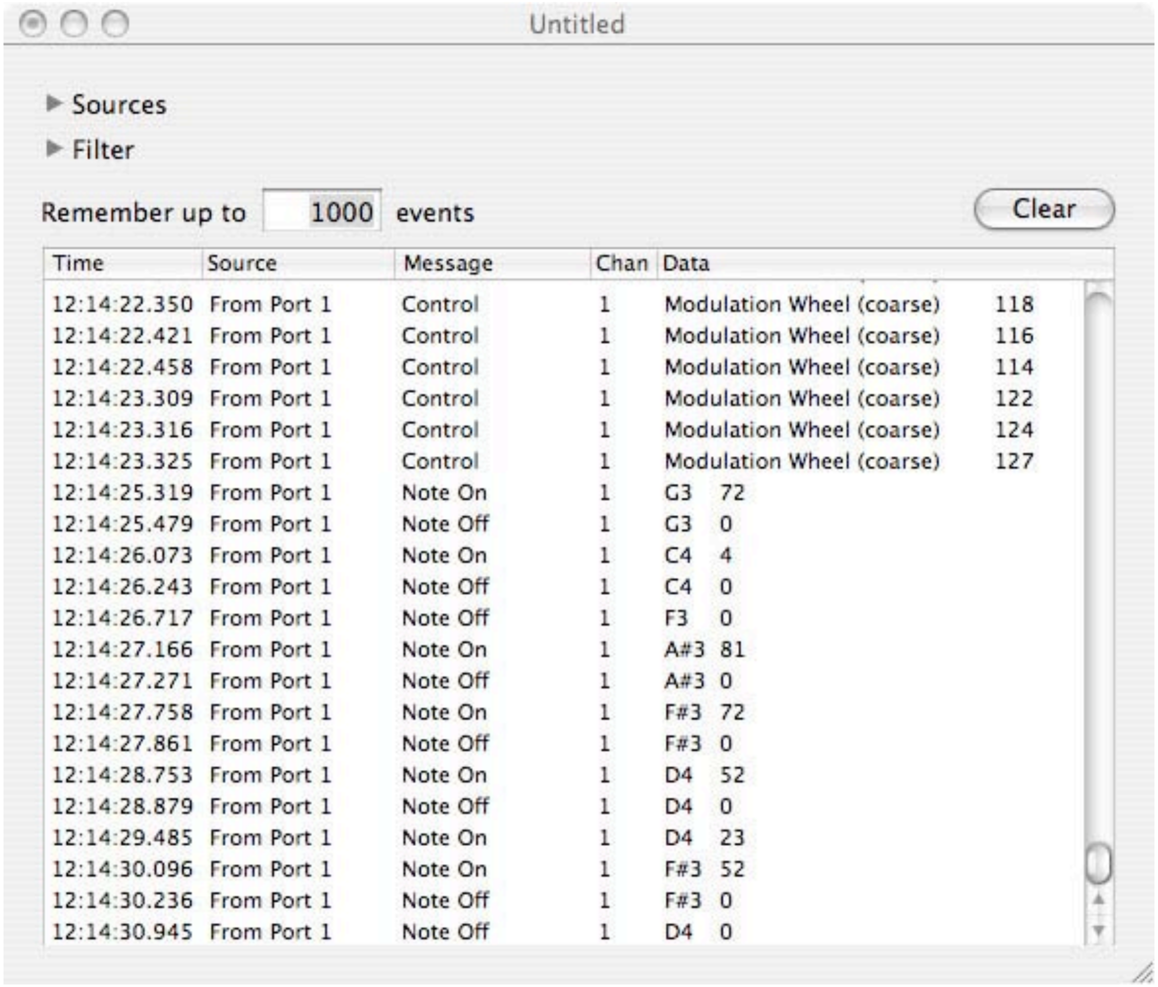
- Compliance with the specification was voluntary
- Designed for universality and expandability
- Designed with un-implemented and un-designed “holes”
- Designed to be cheap: originally assessed to add $5 to $10 to manufacturing prices

19.23. MIDI: A Language for Control Data

- MIDI sends and receives digital control data
- MIDI does not send digital or analog audio
- MIDI provides instructions for producing sounds, not the sounds themselves
- Where digital audio requires lots of data and provides a complete specification, MIDI requires little data and is an incomplete specification
- The quality of MIDI playback is based entirely on the playback device (keyboard, synthesizer, computer, etc.)

19.24. Viewing MIDI Input

- MIDI Monitor



Time	Source	Message	Chan	Data	
12:14:22.350	From Port 1	Control	1	Modulation Wheel (coarse)	118
12:14:22.421	From Port 1	Control	1	Modulation Wheel (coarse)	116
12:14:22.458	From Port 1	Control	1	Modulation Wheel (coarse)	114
12:14:23.309	From Port 1	Control	1	Modulation Wheel (coarse)	122
12:14:23.316	From Port 1	Control	1	Modulation Wheel (coarse)	124
12:14:23.325	From Port 1	Control	1	Modulation Wheel (coarse)	127
12:14:25.319	From Port 1	Note On	1	G3 72	
12:14:25.479	From Port 1	Note Off	1	G3 0	
12:14:26.073	From Port 1	Note On	1	C4 4	
12:14:26.243	From Port 1	Note Off	1	C4 0	
12:14:26.717	From Port 1	Note Off	1	F3 0	
12:14:27.166	From Port 1	Note On	1	A#3 81	
12:14:27.271	From Port 1	Note Off	1	A#3 0	
12:14:27.758	From Port 1	Note On	1	F#3 72	
12:14:27.861	From Port 1	Note Off	1	F#3 0	
12:14:28.753	From Port 1	Note On	1	D4 52	
12:14:28.879	From Port 1	Note Off	1	D4 0	
12:14:29.485	From Port 1	Note On	1	D4 23	
12:14:30.096	From Port 1	Note On	1	F#3 52	
12:14:30.236	From Port 1	Note Off	1	F#3 0	
12:14:30.945	From Port 1	Note Off	1	D4 0	

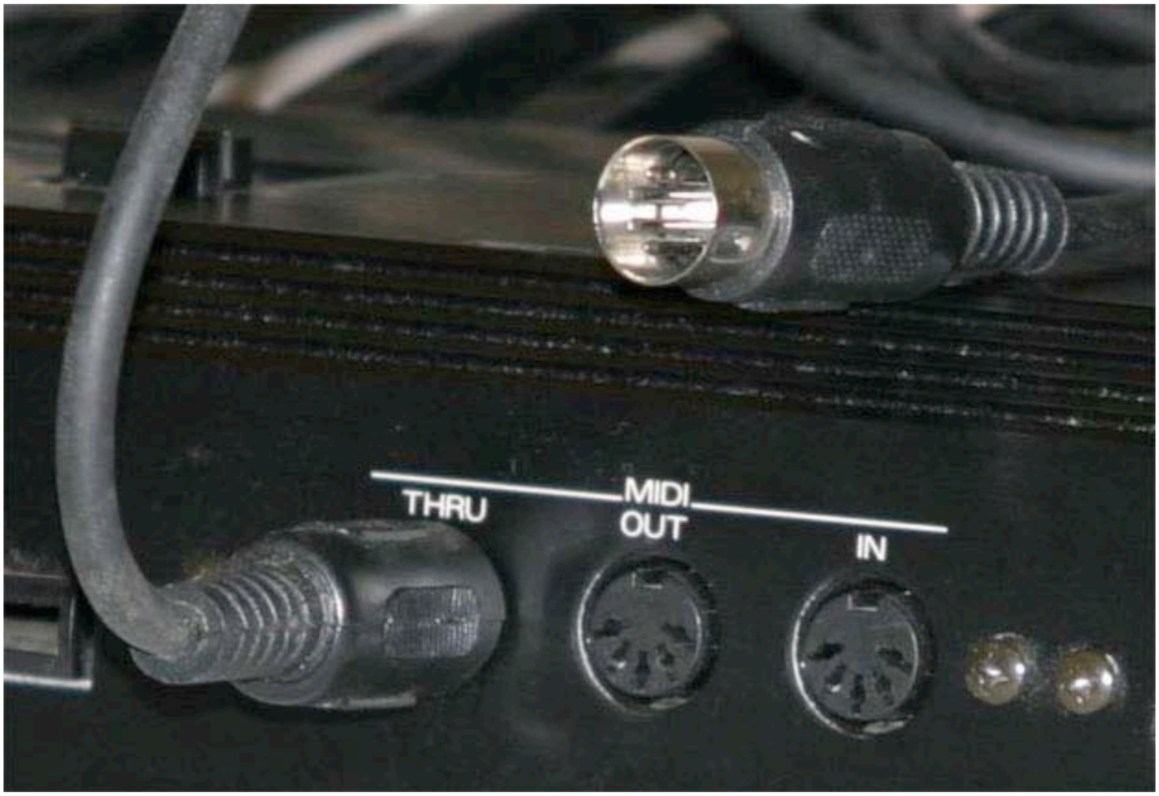
- Observe: when information changes and the range of values
- Note-on, note-off and control change messages

19.25. MIDI: Features: Bits, Bytes, and the Serial Interface

- Serial: sends one message at a time in one direction
- A message is usually two or three bytes
- Each byte is eight bits (a series of 8 ones or zeros)
- Each byte can encode 256 possible values (2^8)
- MIDI specifies the meaning and ordering of messages
- MIDI can pass messages as a stream, or store messages in a file

19.26. MIDI: Cables and Jacks

- 5-pin DIN connectors

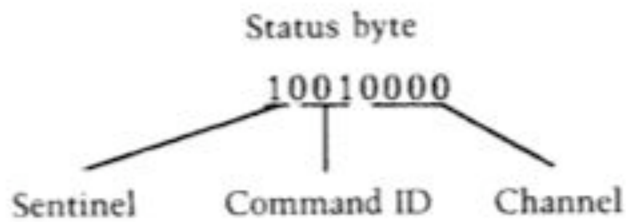


- DIN Cable: Deutsche Industrie Norm, originally used in European audio equipment
- Only three pins are used, only one with data: (5) MIDI signal, (4) bias voltage, (2) shield
- In, out, and thru jacks demonstrate that this is a mono-directional, serial interface
- Often USB (Universal Serial Bus) is used to transmit MIDI

19.27. MIDI: Messages

- A message is (generally) two or three bytes
- A message consists of a command byte and one or two data bytes
- The 256 values of each byte is split in half to distinguish command from data bytes (the MSB as a sentinal bit)

Fig. 9. Channel command layout.



Source: Loy, G. "Musicians Make a Standard: The MIDI Phenomenon."
Computer Music Journal 9, no. 4 (Winter 1985): 8-26.

- Command byte values are in the range of 128 to 255
- 8 types of command bytes are repeated 16 times, once for each channel
- Single data byte values are in the range of 0 to 127
- Double data byte values are in the range of 0 to 16384

19.28. MIDI: Messages: Example

- Pressing a key on a keyboard is a note-on message
- Message byte 1: Command Byte: type of action (note on) and specific channel
- Message byte 2: Data Byte: the key number pressed
- Message byte 3: Data Byte: the velocity of the key pressed
- Binary: 10010000 01000101 01100101
- English: Note on, pitch F above middle C, with a velocity of 101

19.29. MIDI: Channels

- Channels permit different devices to tune in to different information
- All information is passed through the same cable, in the same stream

- Multiple MIDI cables can be used for more as many as 128 channels

19.30. MIDI: Command and Data Bytes

- Note Off for channels 1 to 16: 128-143; requires two data bytes (note number, velocity)
- Note On for channels 1 to 16: 144-159; requires two data bytes (note number, velocity)
- Other command bytes: Key Pressure, Control Change, Program Change, Channel Pressure, Pitch Bend, System Exclusive
- System Exclusive messages permit sending arbitrary-length data to any device
- Summary of commands (Loy 1985, p. 15)

Table 1: Summary of MIDI codes

Status	Arg 1	Arg 2	Mnemonic
		CHANNEL COMMANDS	
80	Key	Velocity	Key off
90	Key	Velocity	Key on
A0	Key	Pressure	Polyphonic key pressure (*after-touch*)
B0	Index	Value	Control change
C0	Index	(None)	Program change
D0	Pressure	(None)	Pressure (*after-touch*)
E0	LSB	MSB	Pitch wheel change
		SYSTEM EXCLUSIVE COMMAND	
F0	Mfg. ID	. . .	System exclusive command
		SYSTEM COMMON COMMANDS	
F2	LSB	MSB	Program position select
F3	Index	(None)	Program select
F6	(None)	(None)	Tune request
F7	(None)	(None)	End of system exclusive
		REALTIME COMMANDS	
F8	(None)	(None)	Timing clock
F9	(None)	(None)	Undefined
FA	(None)	(None)	Start
FB	(None)	(None)	Continue
FC	(None)	(None)	Stop
FD	(None)	(None)	Undefined
FE	(None)	(None)	Active sensing
FF	(None)	(None)	System reset

Note: All values are in hexadecimal notation. See the text for a further description.

Source: Loy, G. "Musicians Make a Standard: The MIDI Phenomenon."
Computer Music Journal 9, no. 4 (Winter 1985): 8-26.

19.31. MIDI: Control Change Commands

- Incorrectly called continuous controllers (not continuous)
- Commonly used for a wide range of dynamic parameter values: panning, volume, modulation, expression
- Two data bytes: type of controller (128 values), controller value (128 values)
- First 64 controllers designed to permit sending two data bytes to provide double resolution (16384 values)

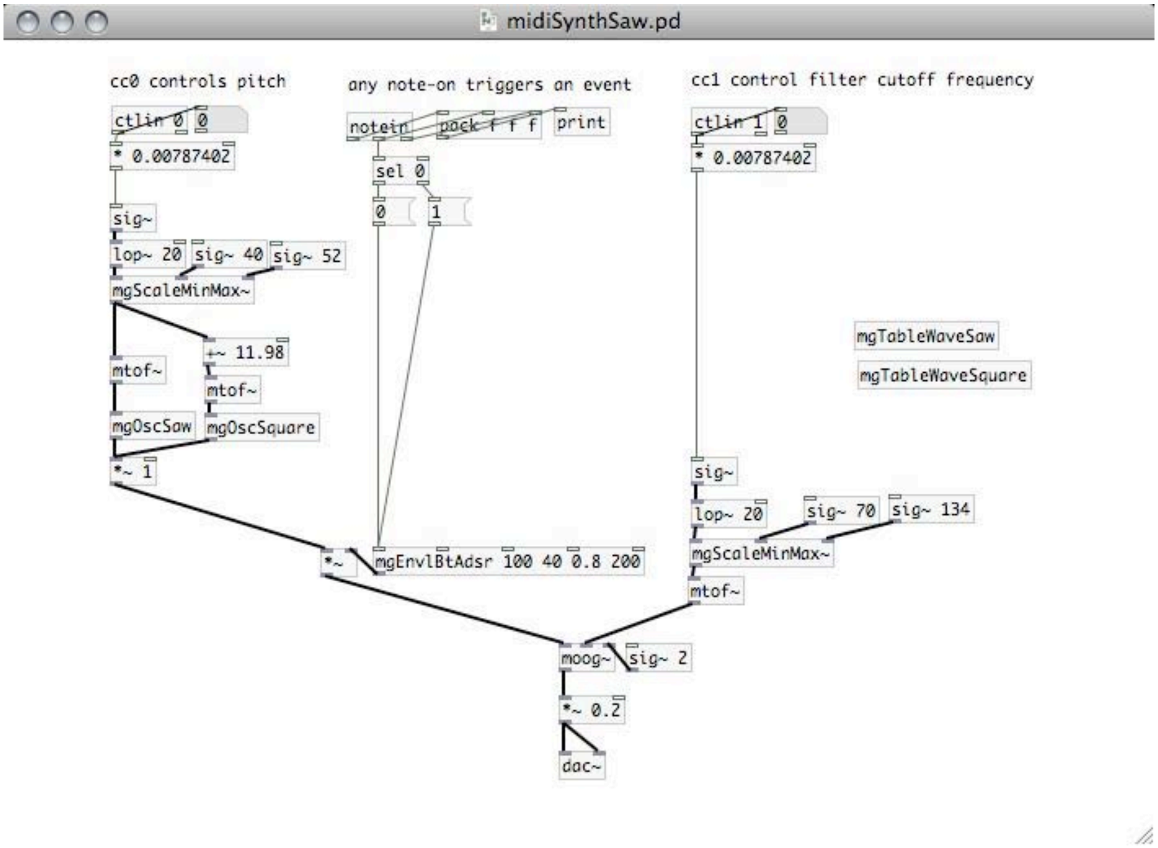
19.32. Reading: Loy

- Loy, D. G. 1985. "Musicians Make a Standard: The MIDI Phenomenon." *Computer Music Journal* 9(4): 8-26.
- Does Loy suggest that MIDI comes from a particular standpoint or bias?
- Does Loy approach MIDI from a particular standpoint or bias?
- What are the misconceptions Loy wants to address?

19.33. Configuring a MIDI Controller

- Most controllers can be configured to send various MIDI messages
- Korg Kontrol Editor for Korg nano series

- Basic synthesizer employing continuous controllers for pitch and LPF cutoff frequency; note-on/off message start envelope [instruments/midiSynthSaw.pd]



19.34. Open Sound Control: OSC

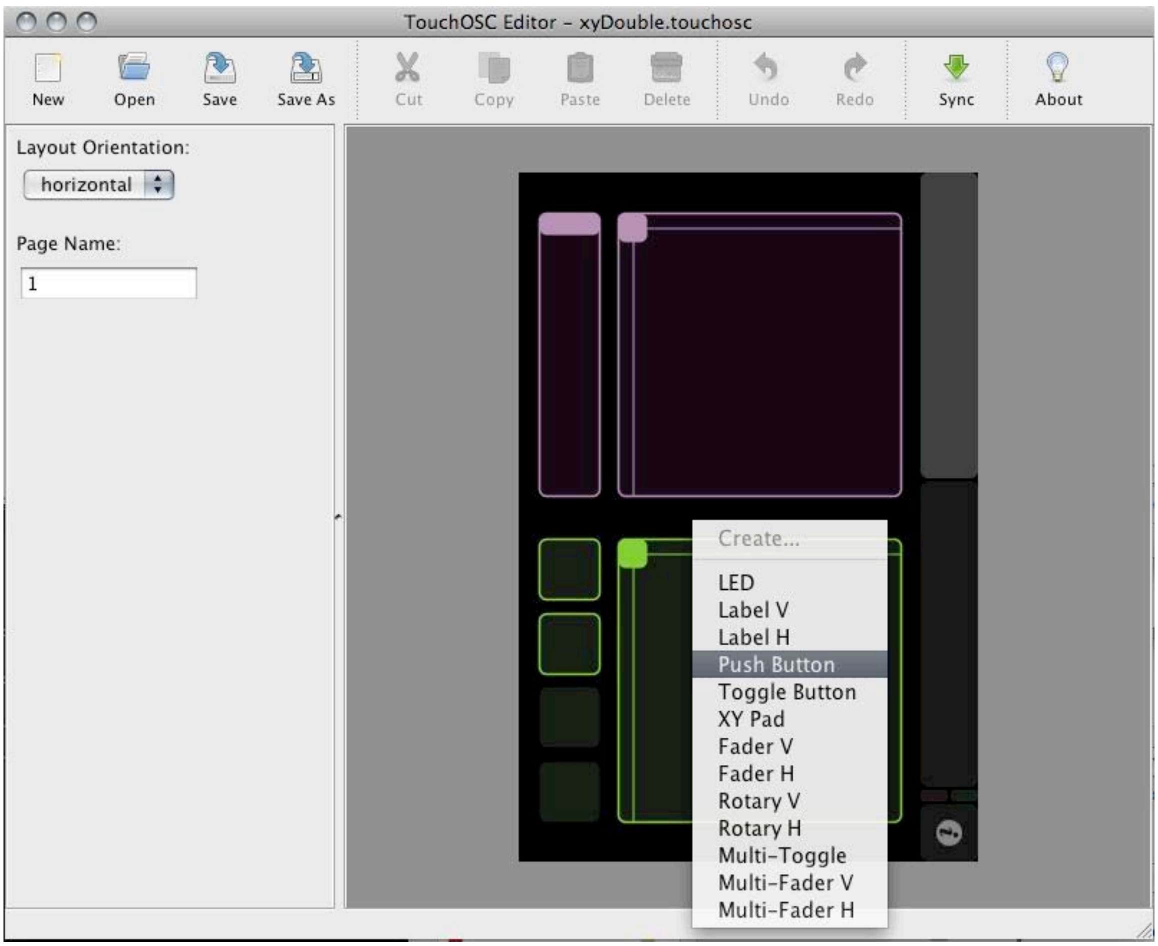
- OSC: Open Sound Control, first released in 1997 (Wright and Freed 1997)
- Open, extensible networking protocol using User Datagram Protocol (UDP) or TCP/IP
- Entities (parameter fields) named with open-ended, URL-style, symbolic, hierarchical address space (Wessel and Wright 2002, p. 17)
- User- and system-definable name spaces
- Messages can be time tagged to permit sending message for later scheduling and performance
- Significant advantage over MIDI is in freedom of parameter organization and labeling

  "... we wanted to name our control parameters as we designed them rather than pick from control parameter names pre-seelcted by the author of a networking protocol" (Wessel and Wright 2002, p. 18)

"... we wanted to organize the control interface according to project-specific structures without being bound by fixed architectures such as 'notes' within 'channels'" (Wessel and Wright 2002, p. 18)

19.35. Configuring an OSC Controller

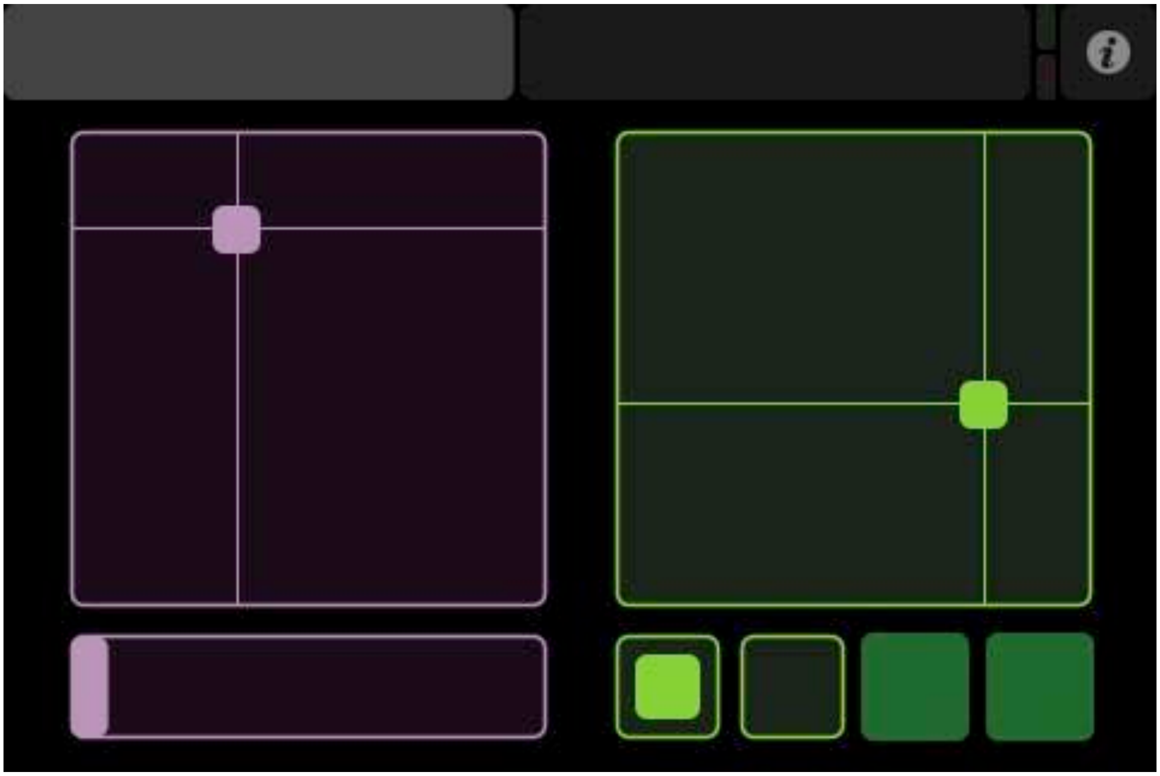
- TouchOSC Editor: design custom interfaces for sending OSC messages via iPod Touch / iPhone



Courtesy of Hexler. Used with permission.

- Double XY pad control for filtered noise

  Note clear organization and labeling of OSC parameter values



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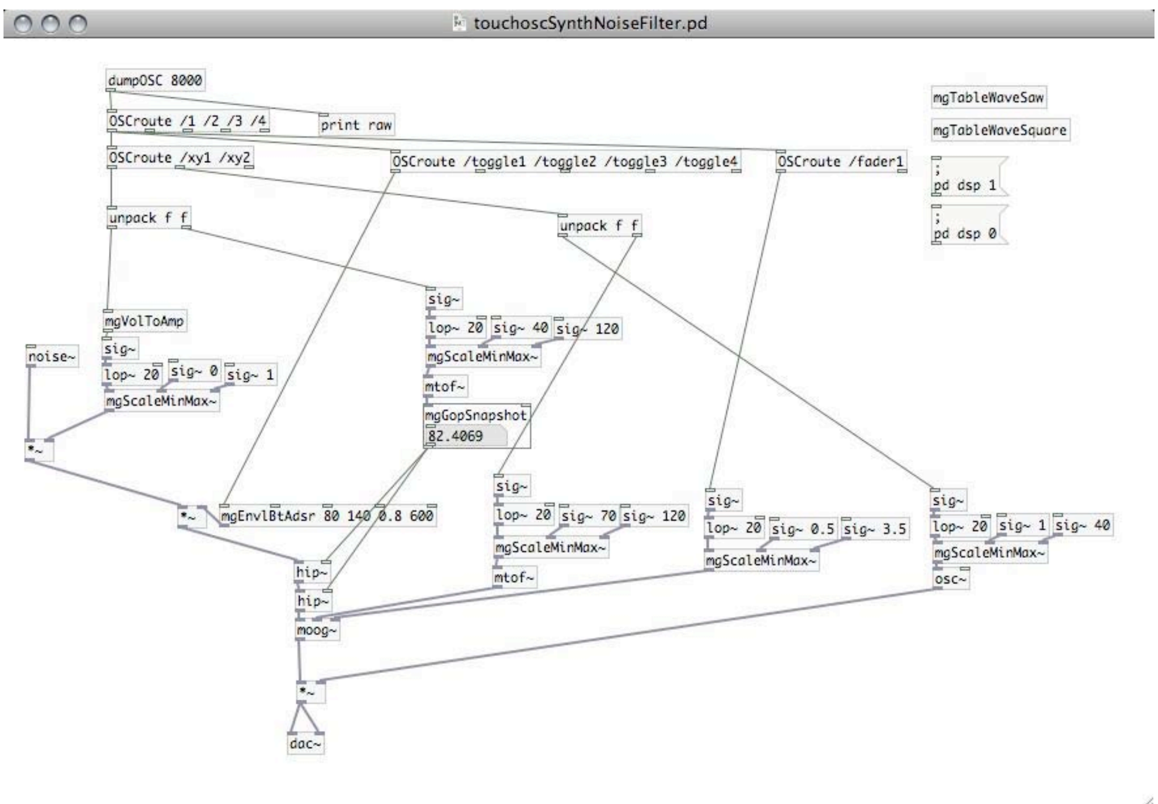
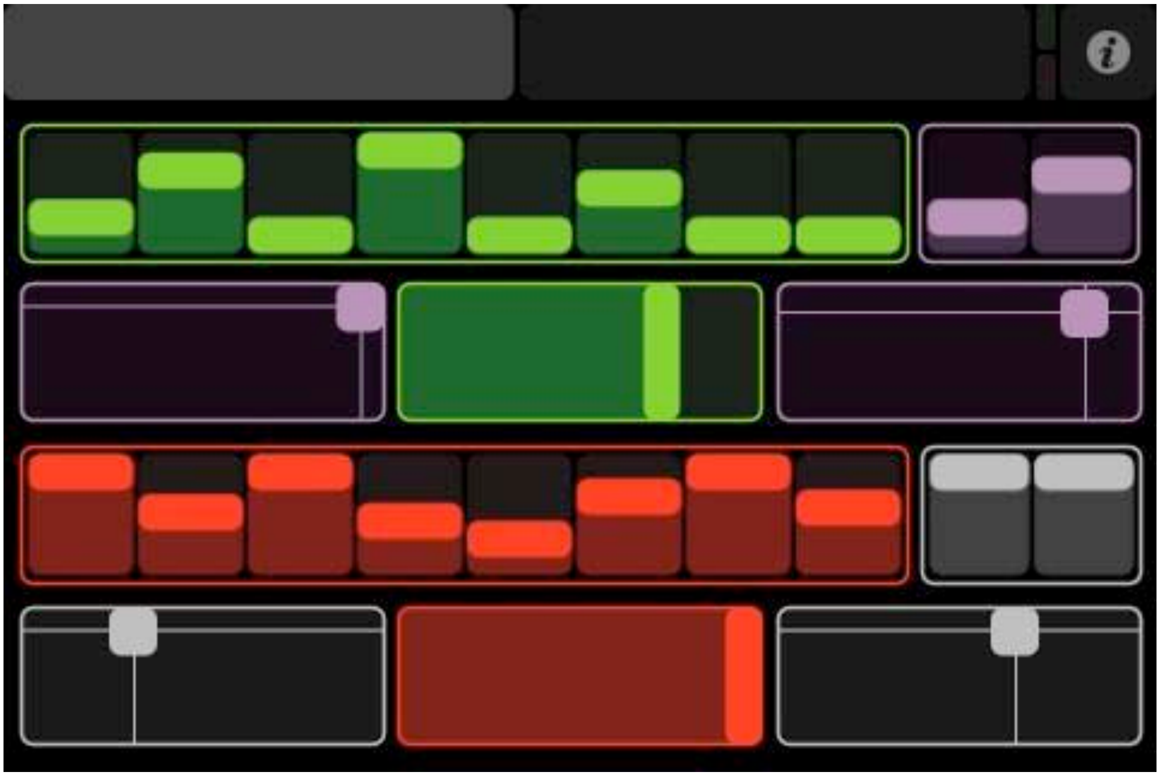


- Double 8-step sequences with cycle length (1-8), beat multiplier (1-8), double XY pad control, and level control.



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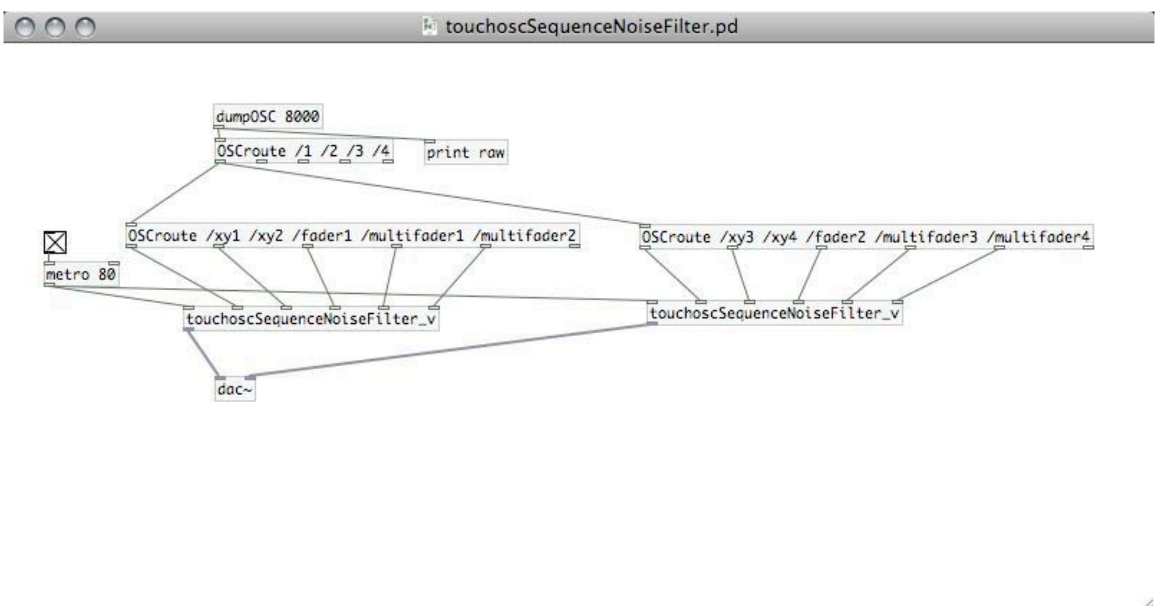


Chapter 20. Meeting 20, Languages: The Early History of Music Programming and Digital Synthesis

20.1. Announcements

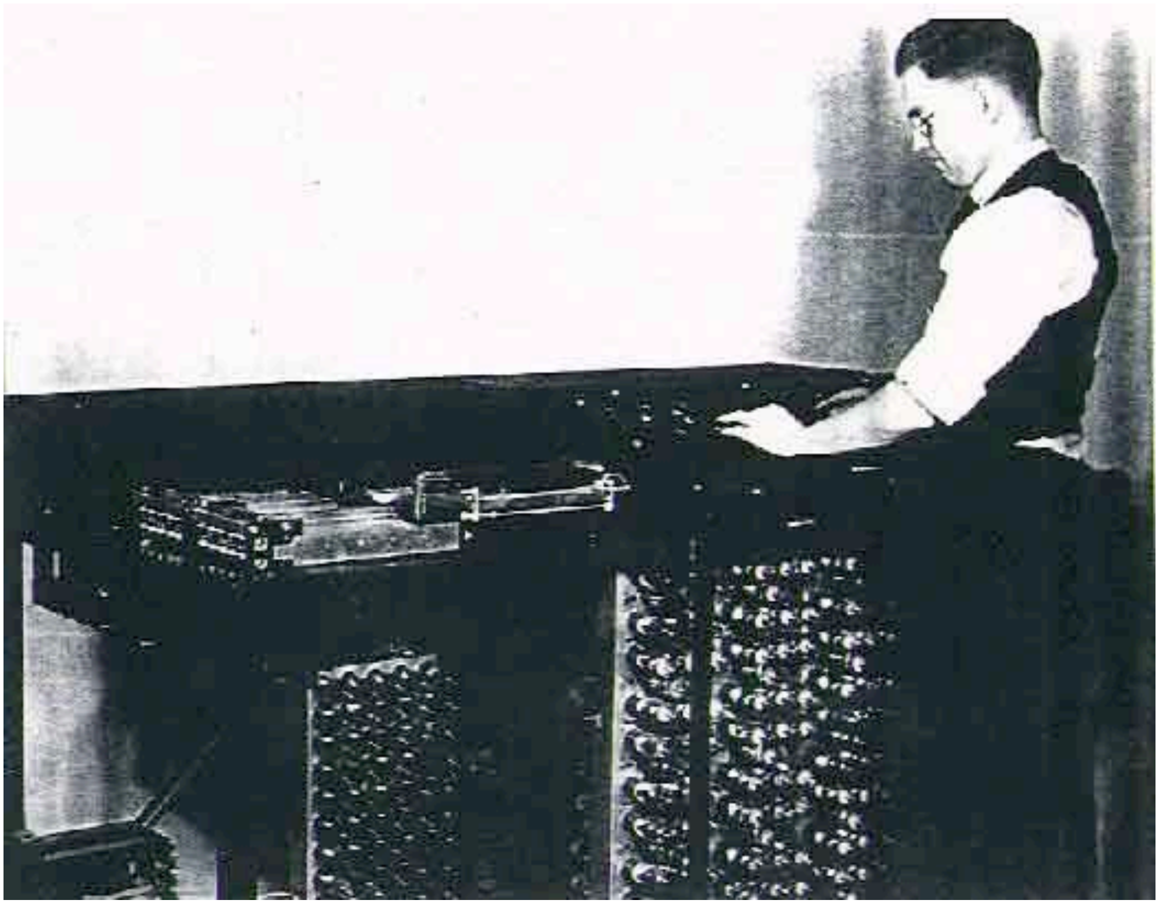
- Music Technology Case Study Final Draft due Tuesday, 24 November

20.2. Quiz

- 10 Minutes

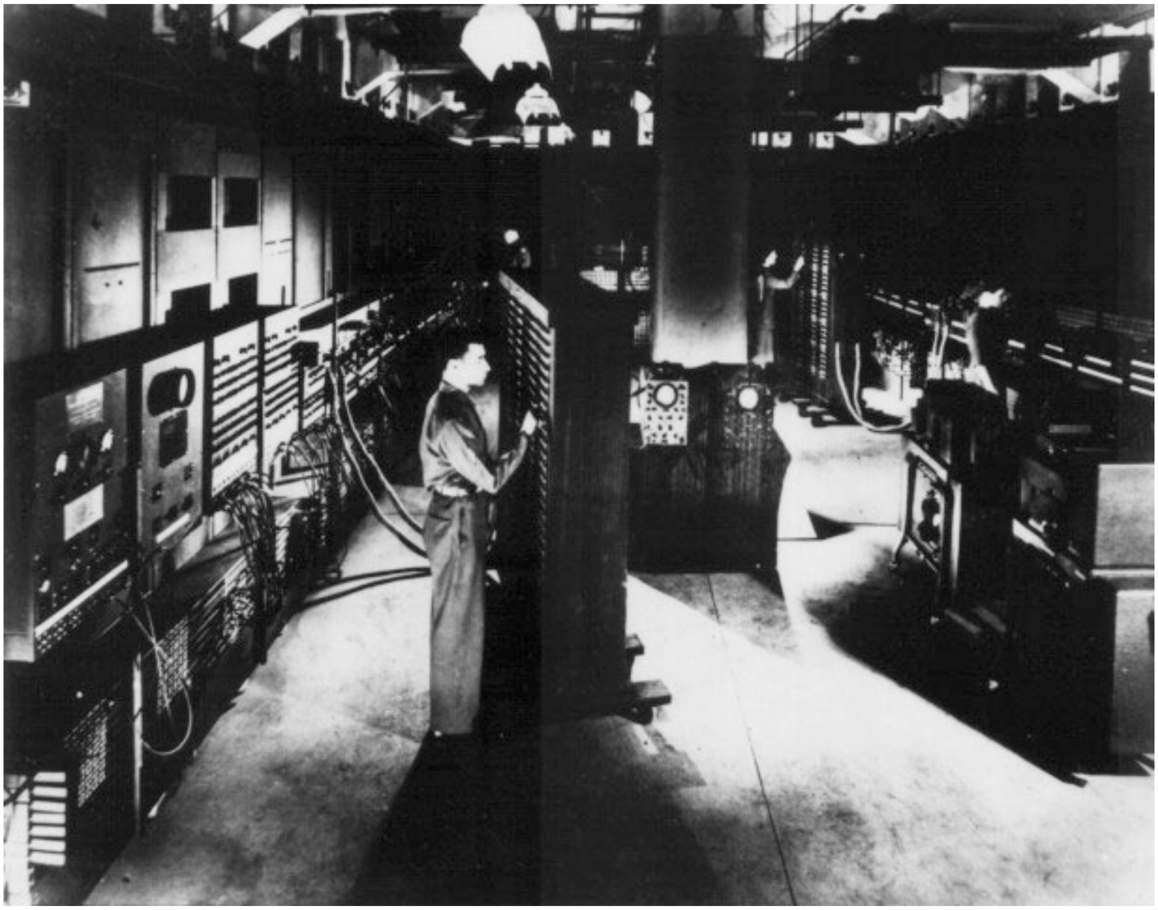
20.3. The Early Computer: History

- 1942 to 1946: Atanasoff-Berry Computer, the Colossus, the Harvard Mark I, and the Electrical Numerical Integrator And Calculator (ENIAC)
- 1942: Atanasoff-Berry Computer



Courtesy of University Archives, Library, Iowa State University of Science and Technology. Used with permission.

- 1946: ENIAC unveiled at University of Pennsylvania



Source: US Army

- Diverse and incomplete computers

Defining characteristics of five first operative digital computers

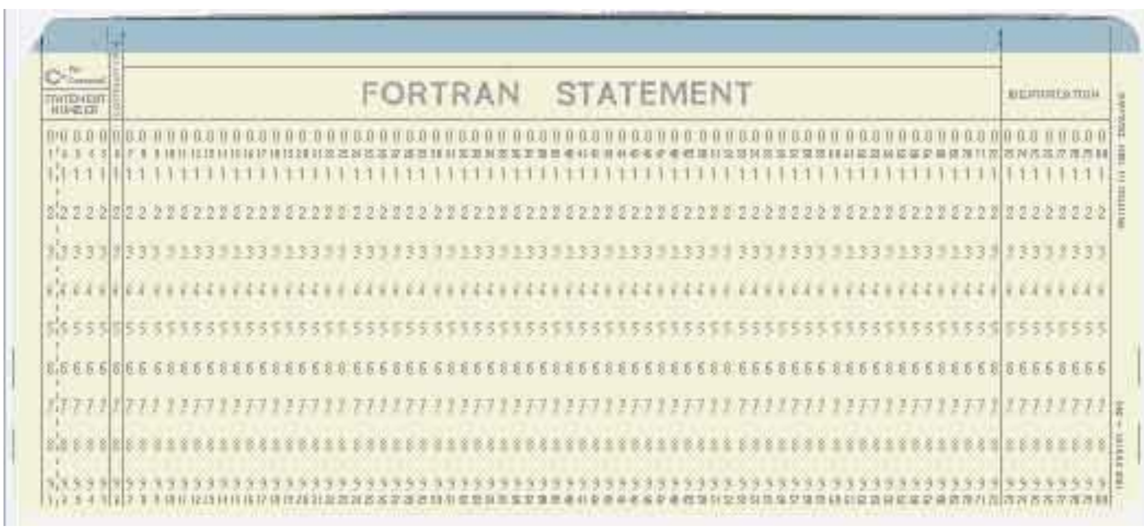
Computer	Nation	Shown working	Digital	Binary	Electronic	Programmable	Turing complete
Zuse Z3	Germany	May 1941	Yes	Yes	No	By punched film stock	Yes (1998)
Atanasoff-Berry Computer	USA	Summer 1941	Yes	Yes	Yes	No	No
Colossus computer	UK	1943	Yes	Yes	Yes	Partially, by rewiring	No
Harvard Mark I/IBM ASCC	USA	1944	Yes	No	No	By punched paper tape	No
ENIAC	USA	1944	Yes	No	Yes	Partially, by rewiring	Yes
		1948	Yes	No	Yes	By Function Table ROM	Yes

20.4. The Early Computer: Interface

- Punchcards
- 1960s: card printed for Bell Labs, for the GE 600

Courtesy of Douglas W. Jones. Used with permission.

- Fortran cards



Courtesy of Douglas W. Jones. Used with permission.

20.5. The Jacquard Loom

- 1801: Joseph Jacquard invents a way of storing and recalling loom operations

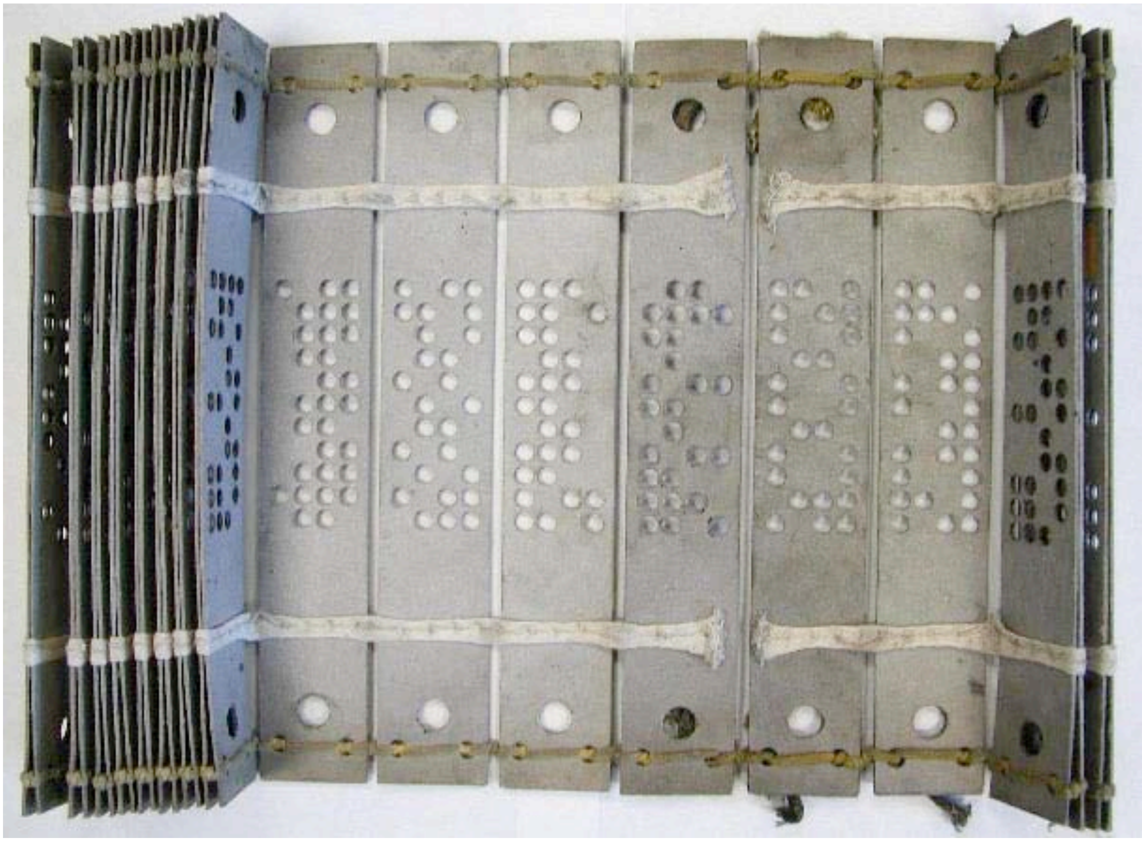


Photo courtesy of Douglas W. Jones at the University of Iowa.

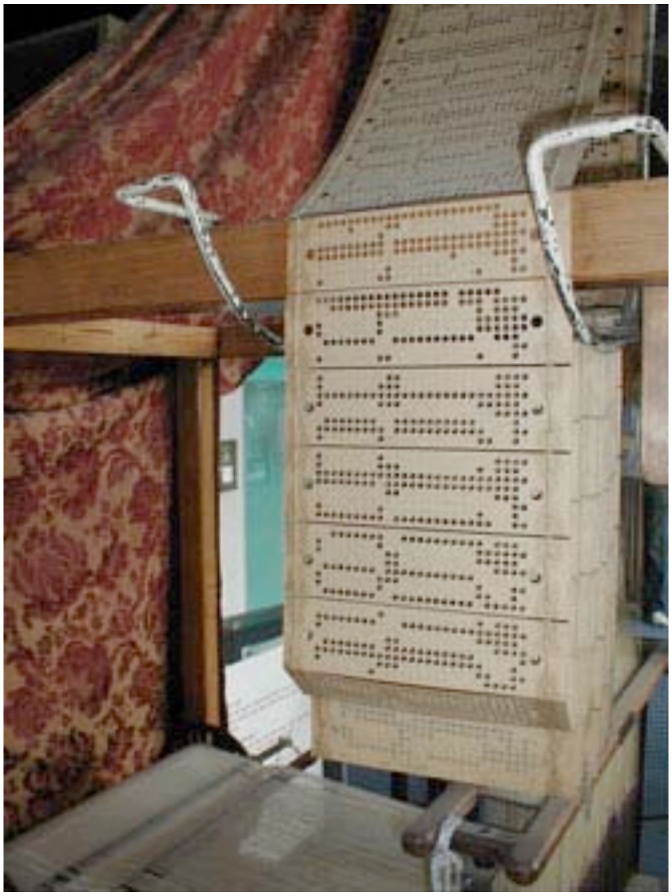


Photo by George H. Williams, from Wikipedia (public domain).

- Multiple cards could be strung together
- Based on technologies of numerous inventors from the 1700s, including the automata of Jacques Vaucanson (Riskin 2003)

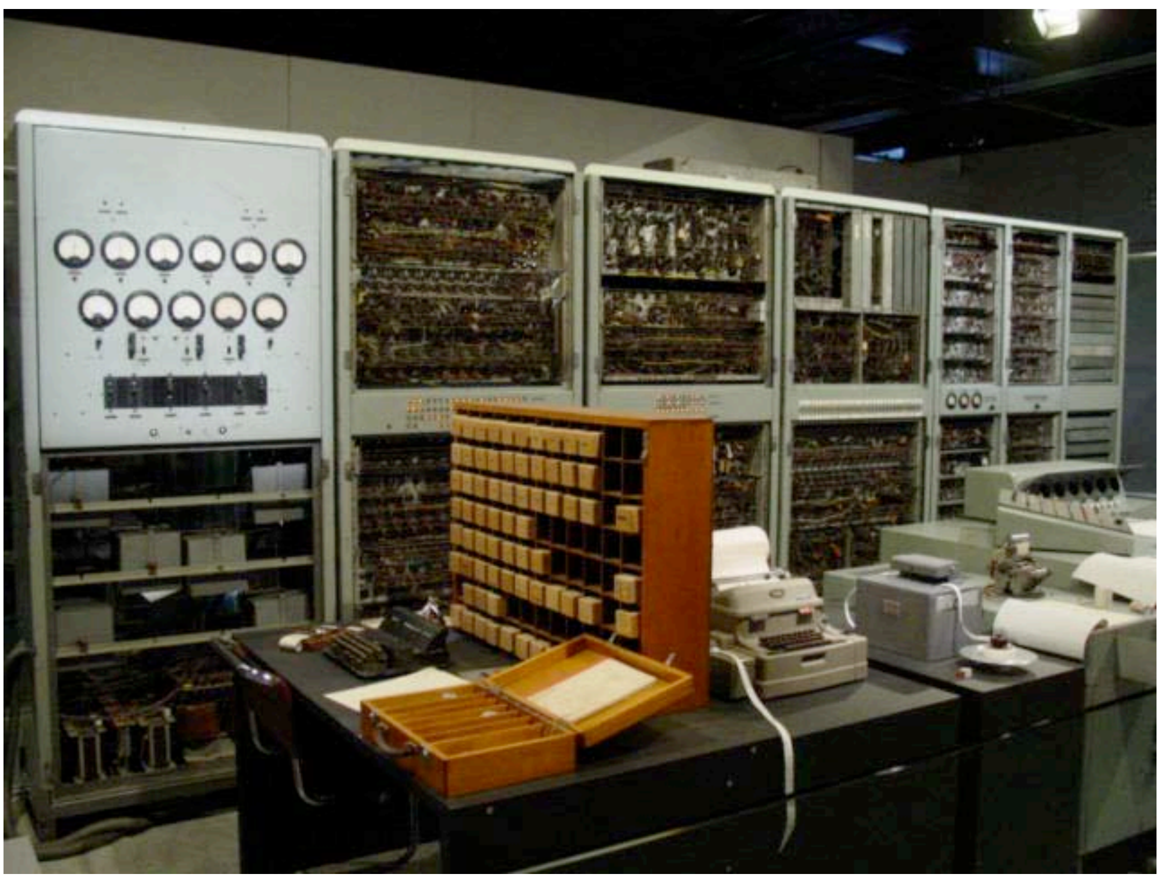
20.6. Computer Languages: Then and Now

- Low-level languages are closer to machine representation; high-level languages are closer to human abstractions
- Low Level
    - Machine code: direct binary instruction
    - Assembly: mnemonics to machine codes
- High-Level: FORTRAN
    - 1954: John Backus at IBM design FORmula TRANslator System
    - 1958: Fortran II

- 1977: ANSI Fortran
- High-Level: C
  - 1972: Dennis Ritchie at Bell Laboratories
  - Based on B
- Very High-Level: Lisp, Perl, Python, Ruby
  - 1958: Lisp by John McCarthy
  - 1987: Perl by Larry Wall
  - 1990: Python by Guido van Rossum
  - 1995: Ruby by Yukihiro "Matz" Matsumoto

20.7. The Earliest Computer Sounds: CSIRAC

- late 1940s: The Australian Council for Scientific Industrial Research develop the (CSIR) Mk 1 computer, later CSIRAC (Council for Scientific and Industrial Research Automatic Computer)



- 1951: CSIR programmed by Geoff Hill to play simple melodies with a pulse-wave through its integrated loudspeaker
- CSIRAC Performance: .001 Mhz speed, less than 768 bytes of RAM, consumed 30,000 watts of power, and weighed 7,000 Kg
- Listen: Reconstruction of CSIRAC music, *Colonel Bogey*

- Listen: Reconstruction of CSIRAC music, *In Cellar Cool*, with simulated machine noise

20.8. The Earliest Computer Sounds: The Ferranti Mark 1 and MIRACLE

- Recently original recordings of early computers have been released
- 1951: Christopher Strachey, under guidance from Alan Turing, writes a program for Ferranti Mark 1 at the University of Manchester (Fildes 2008)

  Listen: Christopher Strachey. "God Save the King" and more (BBC News website)

- 1955: David Caplin and Dietrich Prinz write a program to generate and synthesize the Mozart Dice Game on a Ferranti Mark 1* (MIRACLE) at Shell laboratories in Amsterdam (Ariza 2009b)

Listening: Mozart "Dice Game" on the Ferranti Mark 1.

20.9. 1950s: The First Synthesis Language

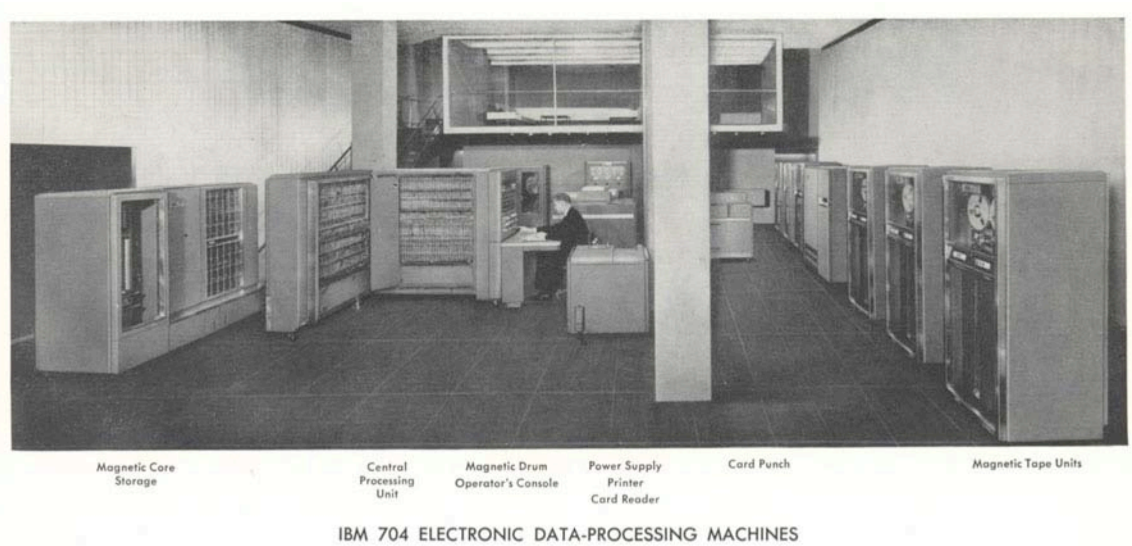
- Max Mathews, working at the acoustics research department Bell Laboratories in New Jersey, conducted experiments in analog to digital conversion (ADC) and digital to analog conversion (DAC)

- 1957: Music I is used on an IBM 704 to render compositions by Newman Guttman

  Listening: *The Silver Scale* (1957): frequently cited as the first piece of computer music

- IBM 704, released in 1954, was the first mass-produced computer with core memory and floating-point arithmetic

Photo: Lawrence Livermore National Laboratory



- Music 1: one voice, one waveform (triangle), square envelope, and control only of pitch, loudness, and decay

- The IBM 704 was in NYC; output has to be taken to a 12 bit DAC at Bell Labs in New Jersey (1980, p. 15)
- Mathews: "... as far as I know there were no attempts to perform music with a computer" (1980, p. 16)

  "Music I sounded terrible and was very limited" (1980, p. 16)
- 1958: Music II: adds four voices and 16 stored waveforms
- Moves to IBM 7094

20.10. 1950s: Early Concepts of Music N

- 1960: Music III: solidified fundamental concepts
- Unit generator: modular building blocks of sound processing similar to the components of a modular synthesizer

  Mathews: "I wanted to give the musician a great deal of power and generality in making the musical sounds, but at the same time I wanted as simple a program as possible" (1980, p. 16)

  Mathews: "I wouldn't say that I copied the analog synthesizer building blocks; I think we actually developed them fairly simultaneously" (1980, p. 16)
- Wavetables: stored tables of frequently used data (often waveforms) retained and reused for efficiency
- Two code files (then punch cards) required to produce sounds
  - Orchestra: synthesis definitions of instruments with specified parametric inputs
  - Score: a collection of event instructions providing all parameters to instruments defined in the Orchestra

20.11. Listening: Tenney

- James Tenney: student of Lejaren Hiller at the University of Illinois
- Mathews: "to my mind, the most interesting music he did at the Laboratories involved the use of random noises of various sorts." (1980, p. 17)
- Employed randomness as a sound source and as a compositional strategy (Mathews and Pierce 1987, p. 534)
- Listen: James Tenney, *Analog #1: Noise Study*, 1961

20.12. 1960s: Distribution

- Lack of portable, hardware independent languages led to new versions of Music-N for each machine
- 1962: Music IV: Mathews and Joan Miller complete on IBM 7094 computer

- Early 1960s Max Mathews distributes Music IV to universities with computers
- Leads to MUSIC 4B (Hubert Howe and Godfrey Winham), MUSIC 4BF, in Fortran, and MUSIC 360, developed for the IBM 360, written by Barry Vercoe

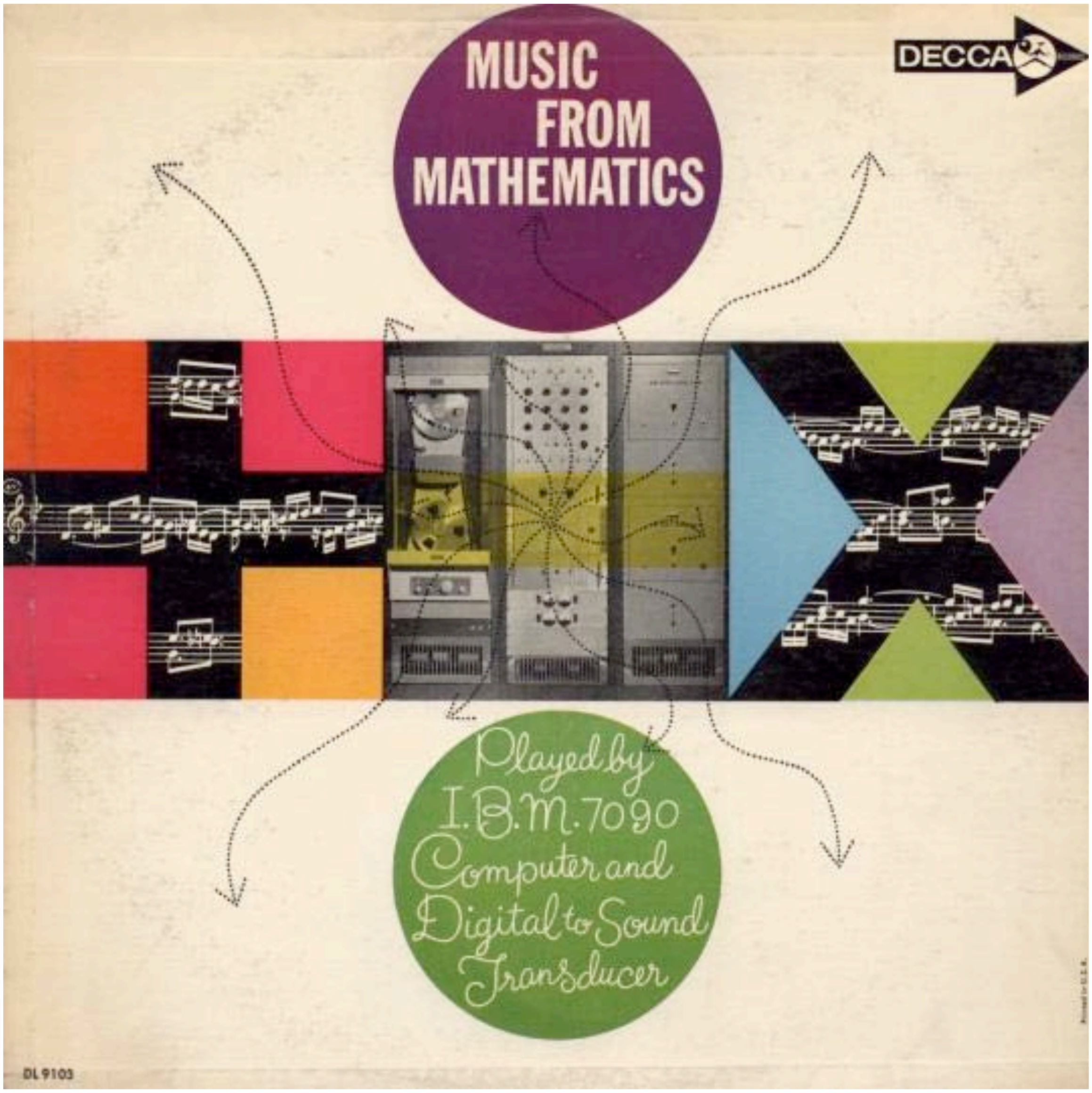
- 1967-1968: Mathews completes Music V, written in FORTRAN with inner loops of unit generators coded in machine language (1980, p. 17)
- Music V: source code distributed as boxes of 3500 punch cards (Chadabe 1997, p. 114)

20.13. 1960s: Working Methods

- Music V was a multi-pass batch program
- IBM 7094 was used to generate digital audio samples that were stored on magnetic tape
- IBM 1620 was used to convert samples into analog audio signals
- Rendering audio and DA conversion would take up to two weeks

20.14. Music from Mathematics

- Album released on Decca Records in 1962 with early computer music by Mathews, J.R. Pierece, David Lewin, James Tenney, and others.



20.15. Listening: Jean-Claude Risset

- Risset visits Bell Labs in 1964, works with Mathews
- Had researched timbre analysis methods and held a Ph.D. in physics
- 1969: Works with sounds entirely synthesized with a computer at Bell Labs using Music V
- Used of additive and FM synthesis techniques
- Listen: Jean-Claude Risset: "Mutations," 1969

20.16. 1970s: Music 11 and Control Rate Signals

- 1973: Vercoe, at MIT, releases Music 11 for the Digital Equipment PDP-11
- Optimized performance by introducing control rate signals (k-rate) separate from audio rate signals (a-rate)

20.17. Listening: Barry Vercoe

- Composition for Viola and Computer
- All digital parts produced with Music 11
- Listen: Vercoe: “Synapse” 1976

20.18. Listening: James Dashow

- Completed at MIT with Music 11
- Listen: Dashow: “In Winter Shine” 1983

20.19. 1980s: Portability

- Machine specific low-level code quickly became obsolete

- Machine independent languages, such as C, offered greatest portability
- 1985: Vercoe translates Music 11 into C, called Csound
- 1990: Vercoe demonstrates real-time Csound
- Csound is ported to all platforms and is modern Music-N

20.20. Reading: Roads: Interview with Max Mathews

- Roads, C. 1980. "Interview with Max Mathews." *Computer Music Journal* 4(4): 15-22.
- Mathews states that "the only answer I could see was not to make the instruments myself -- not to impose my taste and ideas about instruments or the musicians -- but rather to make a set of fairly universal building blocks and give the musician both the task and the freedom to put these together into his or her instruments" (1980, p. 16); is this goal possible?
- Mathews states that "The reaction amongst all but a handful of people was a combination of skepticism, fear, and complete lack of comprehension" (1980); what motivated these responses, and how were these responses different based on established musical roles?
- What does Mathews later work with GROOVE, the Sequential Drum, and electric violins suggest about his interests after Music V?

20.21. Listening: Spiegel

- Laurie Spiegel: worked at Bell Labs from 1973 to 1979
- Worked with Mathews on the GROOVE system
- Appalachian Grove composed with the GROOVE system
- Listen: Laurie Spiegel, *Appalachian Grove I*, 1974

- *Improvisation on a "Concerto Generator"*, realized on the Alles synthesizer with interactive control software written in C for the DEC PDP-11

YouTube (http://www.youtube.com/watch?v=fWKDsfARXMc)

Chapter 21. Meeting 21, Languages: Synthesis with Code

21.1. Announcements

- Music Technology Case Study Final due Today, 24 November
- Sonic System Project Report due Thursday, 3 December
- Last quiz: Thursday, 3 December

21.2. Quiz Review

- ?

21.3. Modern Music-N

- 1985: Csound
- Command-line program
- Currently available for many platforms, with many interfaces
- http://www.csounds.com

21.4. Csound: Score, Orchestra, and CSD Files

- Orchestra (a .orc file) defines synthesis processing and interconnections (instruments)
- Score (a .sco file) defines control information (events and parameters)
- A CSD file combines the score and orchestra into a single file delimited by XML-style markup
    - Outermost: <CsoundSynthesizer> </CsoundSynthesizer>
    - Orchestra: <CsInstruments> </CsInstruments>
    - Score: <CsScore> </CsScore>

21.5. Csound: Orchestra Syntax: Instrument Blocks

- A quasi programming language, closer in way to an assembly language

Orchestra procedures can be extended with Python (Ariza 2008)

- Consists of statements, functions, and opcodes
- Opcodes are unit generators
- Comments: start with a semicolon
- Instruments in blocks, named with a number:
    - Start marker: “instr” and a number
    - End marker: “endin”
    - Trivial example instrument definition

```
instr 100
   ; comments here!
endin
```

21.6. Csound: Orchestra Syntax: Signals

- Signals are created and interconnected (patched) within instrument blocks
- Signals: cary streams of amplitude values as numbers within the dynamic range (16 bit audio uses integers from -32768 to 32768)
- Signal paths (like patch cords) are named variables
- Signal variables can be at different rate resolutions depending on the first letter of the variable name
    - a-rate: Audio, name starts with an “a” (e.g. aNoise)
    - k-rate: Control signals, name starts with an “k” (e.g. kEnvl)
    - i-rate: Initialization values, name starts with an “i” (e.g. iFq)
    - Example

```
aNoise   random   -12000, 12000
```

- Opcodes: unit generators
    - Syntax uses spaces and commas to delineate:

      Provide variable, opcode, and space-separated parameter arguments

```
destinationSignal  opcodeName   arg1, arg2, ...
```

- Example: “random”; takes two arguments: min and max
- Example: “outs”: takes two arguments: two signals

- Example

```
instr 100
    aNoise   random   -12000, 12000
             outs     aNoise, aNoise
endin
```

21.7. Csound: Score Syntax

- A list of events and parameters given to instruments in the orchestra

- Provide a space-separated list of at least three values on each line:

```
i  instrumentNumber  startTime  duration  p4  p5  ...
i  instrumentNumber  startTime  duration  p4  p5  ...
i  instrumentNumber  startTime  duration  p4  p5  ...
```

- Additional parameters (called p-fields) can be added after duration and provided to the instrument in the score

- Example: Two events for instrument 23 lasting two seconds, starting at 0 and 5 seconds

```
i  23  0.0  2.0
i  23  5.0  2.0
```

21.8. Csound: Rendering an Audio File

- Call the CSD file with the csound command-line application on the CSD file to render audio

```
csound -d -A noise.csd -o out.aif
```

- Provide a “flag” to indicate type of audio output
  - -A (aiff output)
  - -W (wave output)

- Give sampling rate, control rate, and number of channels in a header

```
sr     = 44100
kr     = 4410
ksmps  = 10
nchnls = 2
```

- Example: a noise instrument

- Example: tutorial-a-01.csd

```
<CsoundSynthesizer>
<CsInstruments>
sr     = 44100
ksmps  = 10
nchnls = 2

instr 100
   aNoise   random  -12000, 12000
            outs    aNoise, aNoise
endin

</CsInstruments>
<CsScore>
i  100  0    2
i  100  3    2
i  100  6    2
</CsScore>
</CsoundSynthesizer>
```

21.9. Csound: GEN Routines and Wave Tables

- Some opcodes require a wave table identification number as an argument
- Wave tables are created with GEN routines in the score file, before events are listed
- Example: a GEN routine used to create a 16384 point sine wave as a wave table

```
f  99  0  16384  10  1
```

- Oscillators require a wave table to provide a shape to oscillate

  The oscili opcode oscillates (and interpolates) any shape given in the f-table argument

```
aSrc    oscili      amplitude, frequency, functionTable
```

- Example: two instruments, a noise and a sine instrument
- Example: tutorial-a-02.csd

```
<CsoundSynthesizer>
<CsInstruments>
sr     = 44100
ksmps  = 10
nchnls = 2

instr 100
   aNoise   random      -12000, 12000
            outs        aNoise, aNoise
endin

instr 101
   aSine    oscili      12000, 800, 99
            outs        aSine, aSine
endin

</CsInstruments>
<CsScore>
f  99   0    16384  10  1
```

```
i  100  0    2
i  100  3    2
i  100  6    2

i  101  2    6
</CsScore>
</CsoundSynthesizer>
```

21.10. Csound: Scaling and Shifting Signals

- Example: using a scaled sine wave as an envelope of noise
- Assignment (=) and operators (+, *) permit mixing and scaling signals
- Example: tutorial-a-03.csd

```
<CsoundSynthesizer>
<CsInstruments>
sr     = 44100
ksmps  = 10
nchnls = 2

instr 102

   aEnvl    oscili      .5, 6.85, 99
   aEnvl    = aEnvl + .5


   aNoise   random      -12000, 12000
   aNoise   = aNoise * aEnvl
            outs        aNoise, aNoise
endin
</CsInstruments>
<CsScore>
f  99   0    16384  10  1
i  102  0    2
i  102  3    2
</CsScore>
</CsoundSynthesizer>
```

21.11. Csound: Adding Parameters to Score and Orchestra

- pN (p1, p2, p3, p4, ...) variables in orchestra permit additional parameter values to be provided from the score to the instrument
- Design of instruments in the orchestra requires choosing what parameters are exposed in the score
- Example: tutorial-a-04.csd

```
<CsoundSynthesizer>
<CsInstruments>
sr     = 44100
ksmps  = 10
nchnls = 2
```

```
instr 102

   iDur = p3
   iTrem = p4

   aEnvl    oscili      .5, iTrem, 99
   aEnvl    = aEnvl + .5

   aNoise   random      -12000, 12000
   aNoise   = aNoise * aEnvl
            outs        aNoise, aNoise
endin
</CsInstruments>
<CsScore>
f  99   0    16384  10  1
i  102  0    2   6.2  ; fourth parameter is frequency of sine envelope
i  102  3    2   23
i  102  6    2   45.6
</CsScore>
</CsoundSynthesizer>
```

21.12. Csound: Adding Filters

- Numerous opcodes exist to explore a wide range of common synthesis tools
- Low pass filter

```
aDst    lowpass2     aSrc, cutoffFrequency, resonance
```

- Can create a control signal to adjust a lowpass filter cutoff frequency, and applying that lowpass filter to noise
- Example: tutorial-a-05.csd

```
<CsoundSynthesizer>
<CsInstruments>
sr     = 44100
ksmps  = 10
nchnls = 2

instr 102
   iDur = p3
   iTrem = p4
   iFilterRate = p5

   aEnvl    oscili      .5, iTrem, 99
   aEnvl    = aEnvl + .5

   aNoise   random      -12000, 12000
   aNoise   = aNoise * aEnvl

   kCutoff  oscili      .5, iFilterRate, 99
   kCutoff  = kCutoff + .5
   kCutoff  = kCutoff * 8000 + 900

   aPost    lowpass2    aNoise, kCutoff, .85
            outs        aPost, aPost
endin
</CsInstruments>
<CsScore>
```

```
f  99   0    16384  10  1
i  102  0    2   6.2   .85
i  102  3    2   23    .65
i  102  6    2   45.6  .50
</CsScore>
</CsoundSynthesizer>
```

21.13. Csound: A Classic Synthesizer

- A class subtractive synth sound with detuned oscillators, an LPF with modulated cutoff, and an ADSR envelope

- Voltage controlled oscillator (vco): anlogue modelled digital oscillator

```
aOsc    vco     amp, cps, waveShape, pulseWidth, functionTable
```

- ADSR envelope

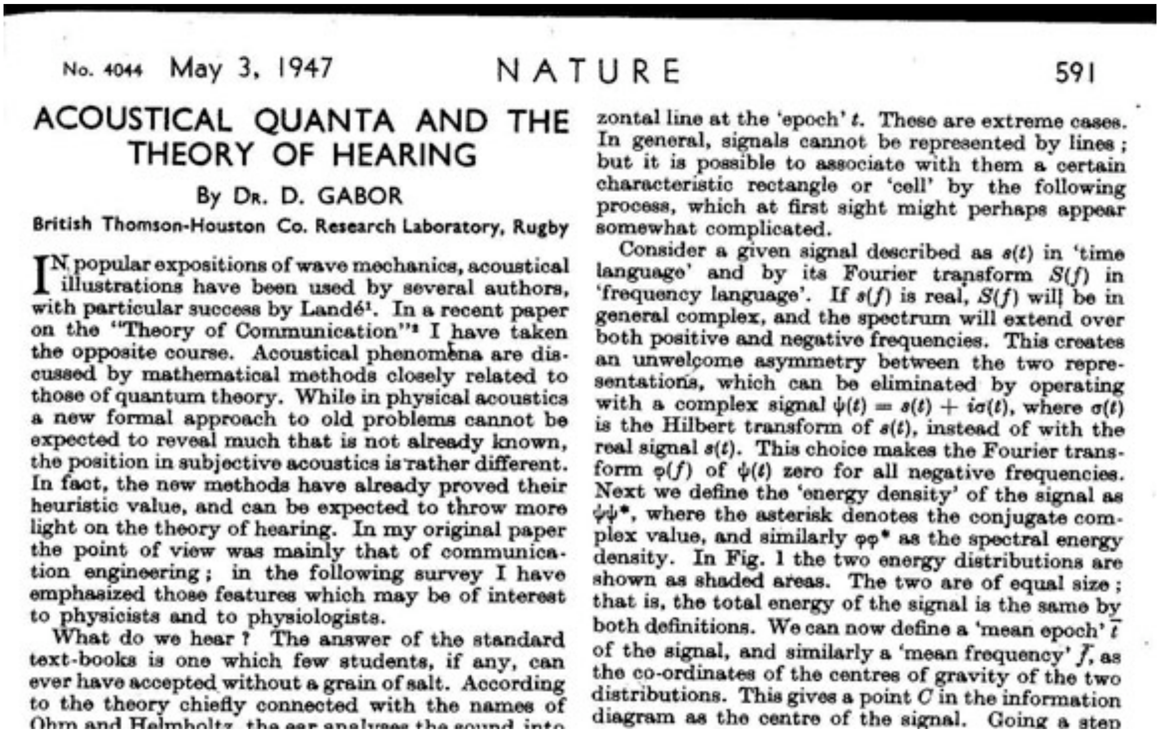
```
kEnvel    adsr     attack, decay, sustainLevel, release
```

- Example: tutorial-a-06.csd

```
<CsoundSynthesizer>
<CsInstruments>
sr     = 44100
ksmps  = 10
nchnls = 2

instr 103

   iDur = p3
   iAmp  = ampdbfs(p4)
   iPitch = cpsmidinn(p5)
   iFilterRate = p6

   kCutoff  oscili      .5, iFilterRate, 99
   kCutoff  = kCutoff + .5
   kCutoff  = kCutoff * 4000 + 400

   aOscA    vco        iAmp, iPitch, 2, .5, 99
   aOscB    vco        iAmp, iPitch*.499, 1, .5, 99

   aPost    lowpass2   aOscA+aOscB, kCutoff, 1.2
   kEnvl    adsr      .1*iDur, .2*iDur, .8, .2*iDur
            outs        aPost*kEnvl, aPost*kEnvl
endin
</CsInstruments>
<CsScore>
f  99   0    16384  10  1
i  103  0    2   -12    52  .5
i  103  3    2   -18    51  1.2
i  103  6    4   -24    48  3
</CsScore>
</CsoundSynthesizer>
```

21.14. Granular Synthesis: History

- Isaac Beekman (1588-1637): 1616: corpuscular theory of sound: sound cuts air
- 1947: Gabor proposes acoustical quanta: like photons for sound (1947)



No. 4044 May 3, 1947 NATURE 591

ACOUSTICAL QUANTA AND THE THEORY OF HEARING

By DR. D. GABOR

British Thomson-Houston Co. Research Laboratory, Rugby

IN popular expositions of wave mechanics, acoustical illustrations have been used by several authors, with particular success by Landé[1]. In a recent paper on the "Theory of Communication"[2] I have taken the opposite course. Acoustical phenomena are discussed by mathematical methods closely related to those of quantum theory. While in physical acoustics a new formal approach to old problems cannot be expected to reveal much that is not already known, the position in subjective acoustics is rather different. In fact, the new methods have already proved their heuristic value, and can be expected to throw more light on the theory of hearing. In my original paper the point of view was mainly that of communication engineering; in the following survey I have emphasized those features which may be of interest to physicists and to physiologists.

What do we hear? The answer of the standard text-books is one which few students, if any, can ever have accepted without a grain of salt. According to the theory chiefly connected with the names of Ohm and Helmholtz, the ear analyses the sound into

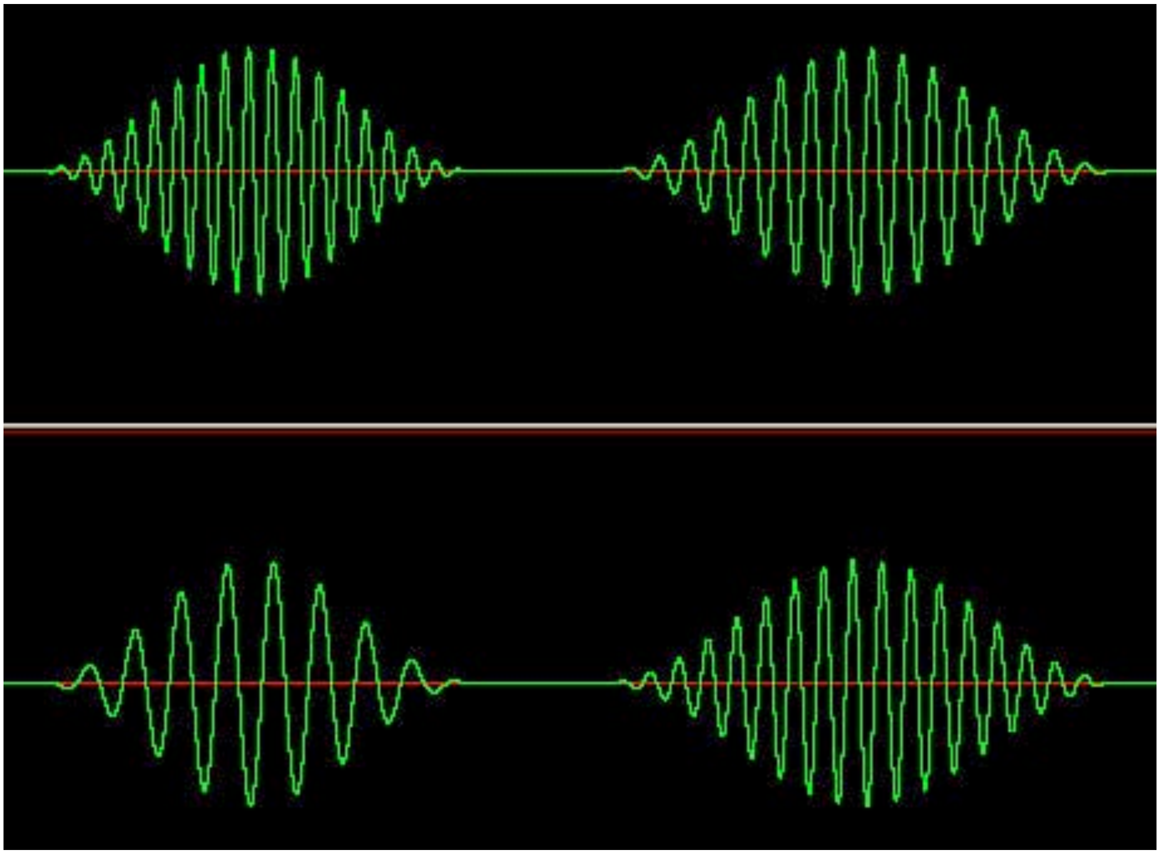
zontal line at the 'epoch' t. These are extreme cases. In general, signals cannot be represented by lines; but it is possible to associate with them a certain characteristic rectangle or 'cell' by the following process, which at first sight might perhaps appear somewhat complicated.

Consider a given signal described as $s(t)$ in 'time language' and by its Fourier transform $S(f)$ in 'frequency language'. If $s(f)$ is real, $S(f)$ will be in general complex, and the spectrum will extend over both positive and negative frequencies. This creates an unwelcome asymmetry between the two representations, which can be eliminated by operating with a complex signal $\psi(t) = s(t) + i\sigma(t)$, where $\sigma(t)$ is the Hilbert transform of $s(t)$, instead of with the real signal $s(t)$. This choice makes the Fourier transform $\varphi(f)$ of $\psi(t)$ zero for all negative frequencies. Next we define the 'energy density' of the signal as $\psi\psi^*$, where the asterisk denotes the conjugate complex value, and similarly $\varphi\varphi^*$ as the spectral energy density. In Fig. 1 the two energy distributions are shown as shaded areas. The two are of equal size; that is, the total energy of the signal is the same by both definitions. We can now define a 'mean epoch' $\bar{t}$ of the signal, and similarly a 'mean frequency' $\bar{f}$, as the co-ordinates of the centres of gravity of the two distributions. This gives a point C in the information diagram as the centre of the signal. Going a step

- 1960: Xenakis expands theory of screens and grains for creative sound production (Xenakis 1992)
- 1978: Curtis Roads introduces software for Granular Synthesis (Roads 1978, 1996, p. 168, 2002)

21.15. Granular Synthesis: Concepts

- Produce a stream of sounds with very short envelopes (10 to 200 ms)
- Envelopes function like windows; multiple windows are often overlapped
- Sounds may be derived from synthesized or sampled sources
- Parameters are frequently randomly adjusted (spacing, amplitude, duration)

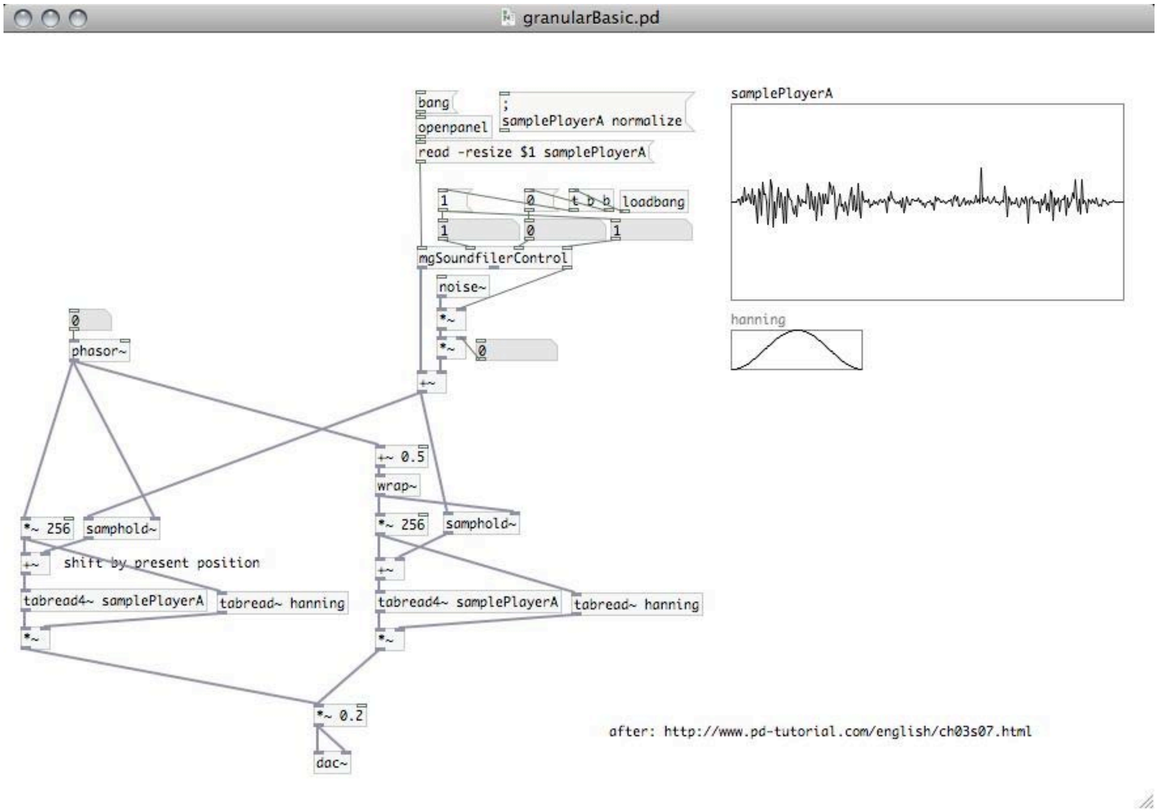


- Multiple streams are often combined combined
- Extreme control and speed suggests a procedure idiomatic to computer-based synthesis

21.16. Granular Synthesis: Pitch Shifting and Time Stretching

- The Eltro Information Rate Changer (1967)

- Four playback heads 90 degrees apart on a cylinder; when spun can make continuous contact with the tape
- By changing the direction and speed of the tape head rotation, could re-sample small bits of audio at a different speed without changing playback speed
- By changing the tape speed and the tape head rotation speed, could alter tempo without altering pitch
- Granular pitch/time shifting reads overlapping segments of an audio buffer, where each segment start position is consistent with the source playback speed, yet the reading of that segment can happen at a variable rate [demo/granularBasic.pd]



21.17. Grains in Csound

- Numerous highly-specialized, advanced opcodes are available in Csound and other synthesis languages
- "grain," "granule," (and more) for granular synthesis
- An instrument that smoothly moves from min to maximum density, granulating an audio file loaded into a wave-table
- Example: tutorial-a-07.csd

```
<CsoundSynthesizer>
<CsInstruments>
sr     = 44100
ksmps  = 10
nchnls = 2

instr 104
   iDur = p3
   iDensityMin = p4
   iDensityMax = p5

   iSnd = 98
   iBaseFq = 44100 / ftlen(iSnd)

   kDensity    line     iDensityMin, iDur, iDensityMax
   kGrainDur   line     .010, iDur, .030
```

```
   kAmpDev     line     0, iDur, 1000

   aSrc   grain  16000, iBaseFq, kDensity, kAmpDev, 0, kGrainDur, iSnd, 99, .100
          outs     aSrc, aSrc
endin
</CsInstruments>
<CsScore>
f  99   0    16384   20  1
f  98   0    1048576  1  "sax.aif" 0 0 0

i  104   0.0  10  .05 20
i  104  11.0  10   35 200
</CsScore>
</CsoundSynthesizer>
```

21.18. Listening: Curtis Roads

- Composer, computer musician, writer
- Significant early work with granular techniques
- Curtis Roads: "Now": *Line Point Cloud*

21.19. Listening: Trevor Wishart

- Sound mutations and transformations
- Interest in vocal sounds and new notations (Wishart 1996)
- Trevor Wishart, *Red Bird*, 1977

21.20. More Synthesis with Code

- A variety of low-level frameworks for DSP in C and C++: STK, openAL
- Numerous high-level languages related to Csound, often built in C/C++

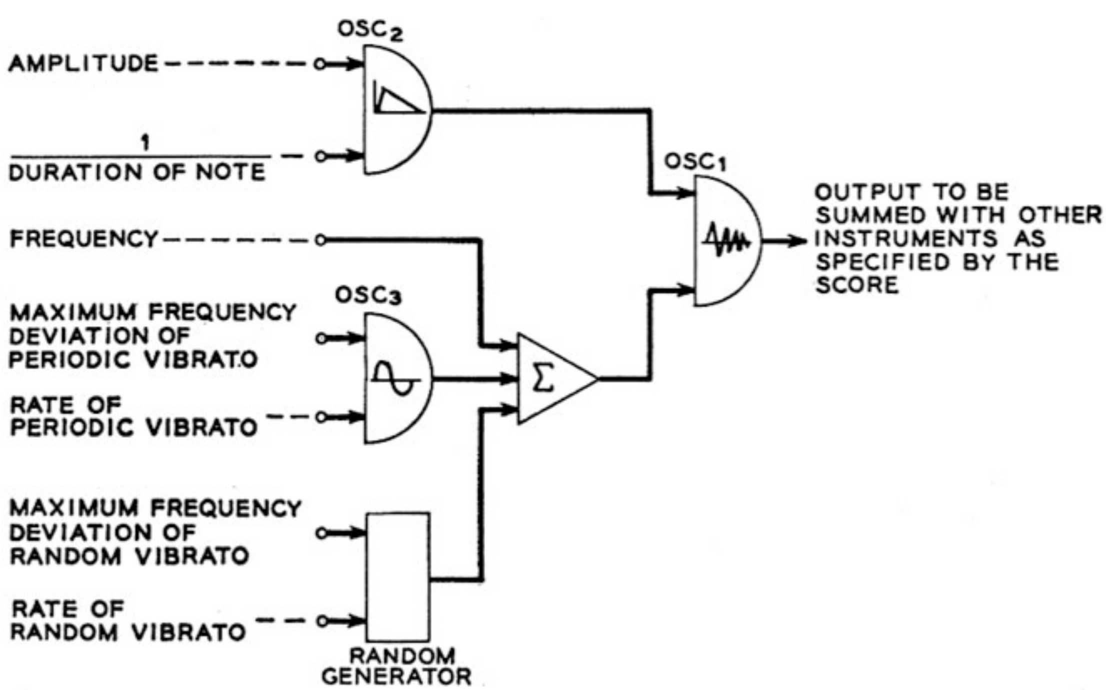
- Text-based: SuperCollider, ChucK, Nyquist, Cmix, Cmusic
- Graphic-based: PD/MaxMsp, Open Sound World, Reaktor

21.21. The Problem of Text

- Systems like Csound are powerful, but may make exploration and experimentation difficult
- Batch processing did not permit real-time, interactive systems
- Signal graph (or signal network or patching) can be spread across multiple lines of text

21.22. Signal Processing Block Diagrams

- Used in audio engineering
- Used to plan voltage-controlled synthesis systems before execution
- Used to illustrate unit generators and types of inputs and output in Music N languages
- Examples:



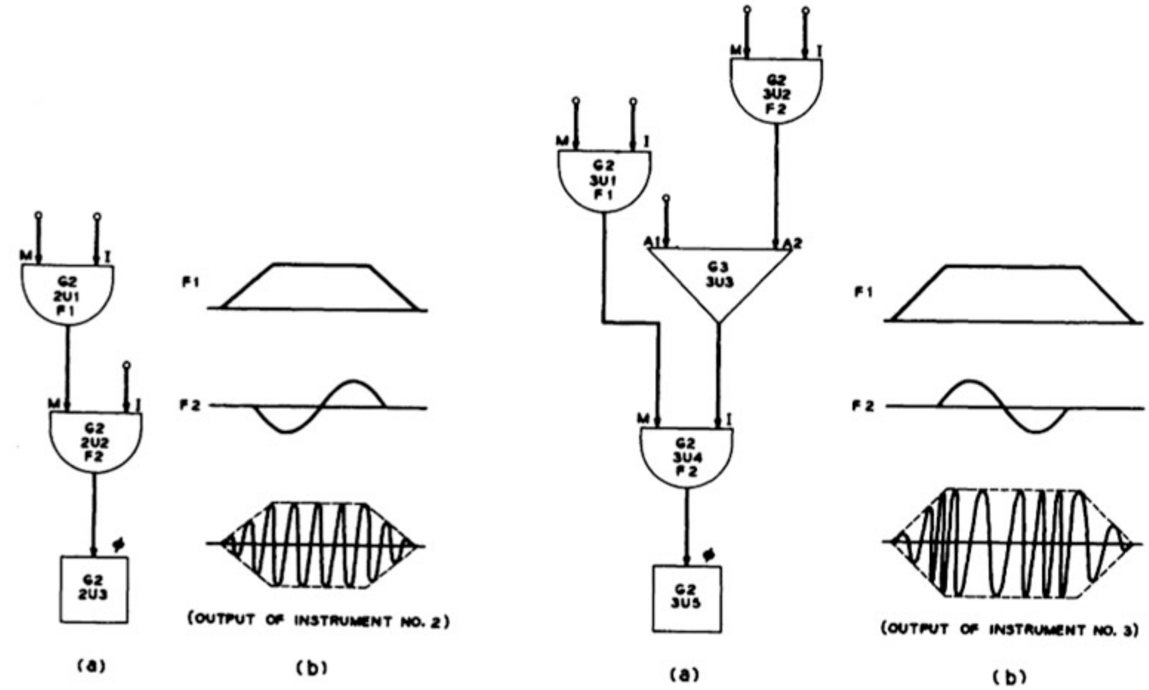


FIGURE 8
AN INSTRUMENT WITH ENVELOPE CONTROL

FIGURE 9
AN INSTRUMENT WITH ENVELOPE CONTROL AND VIBRATO

21.23. MaxMSP/PD

- Max is a visual programming paradigm
- Many diverse implementations: MaxMSP, jMax, Pd
- Emphasizes real-time control and signal flow design
- Emphasizes processes more than data

21.24. MaxMSP/PD: History

- 1979-1987: Miller Puckette studied with Barry Vercoe
- 1982: Puckette releases Music 500
- 1985: Working on a dedicated digital audio processor, Puckette designs a new system, keeping the Music 500 control structure; names it Max after Max Mathews's RTSKED (Puckette 1985)
- 1987: Re-rewrites Max in C for Macintosh (Puckette 1988)
- Max commercialized by David Zicarelli, fell through two companies, than reconsolidated at Cycling 74

- Puckette reprograms Max for IRCAM ISPW and NeXT Cube, and adds signal processing to Max (called Faster Than Sound (FTS))
- 1991: Max/FTS ported to other architectures
- IRCAM version becomes jMax
- Puckette reprograms system as Pure Data (PD), releases in 1997 as an open-source tool (Puckette 1997)
- Zicarelli, after PD's signal processing, creates Max Signal Processing (MSP) (Puckette 2002)
- PD-Extended offers a complete package of PD tools for all platforms

  http://puredata.info/downloads

21.25. SuperCollider: History

- Programming language and development environment for real-time signal processing
- First released in 1996 by James McCartney (McCartney 1996; McCartney 1998)
- 1999: version 2 released (Wells 1999)
- In 2002 version 3 released as an open source project

21.26. SuperCollider: Concepts

- Unit Generators are combined to produce SynthDefs
- A server-based architecture: SynthDefs live on a server and send and receive messages and signals
- A complete object-oriented language: create objects, manipulate, and reuse code
- Designed for real-time performance and experimentation
- Code can be executed piece by piece in the development environment
- Under active development and supported by a robust community

  http://supercollider.sf.net

21.27. SuperCollider: Basic Patching

- Can evaluate code interactively by selecting expressions and pressing Enter (not Return!)

- Creating noise

```
{WhiteNoise.ar(0.2)}.play
```

- Enveloping noise with a sine envelope scaled

```
{WhiteNoise.ar(0.2) * SinOsc.kr(4, mul:0.5, add:0.5)}.play
```

- Oscillating rate of envelope applied to noise

```
{
var envRate;
envRate = SinOsc.kr(0.3, mul:20, add:1.5);
WhiteNoise.ar(0.2) * SinOsc.kr(envRate, mul:0.5, add:0.5);
}.play
```

- Applying a low-pass filter

```
{
var envRate, preFilter;
envRate = SinOsc.kr(0.3, mul:20, add:1.5);
preFilter = WhiteNoise.ar(0.2) * SinOsc.kr(envRate, mul:0.5, add:0.5);
LPF.ar(preFilter, 900);
}.play
```

- Applying a low-pass filter with a cutoff frequency controlled by an oscillator; translating MIDI values to Hertz

```
{
var envRate, preFilter, cfControl;
envRate = SinOsc.kr(0.3, mul:20, add:1.5);
cfControl = SinOsc.kr(0.25, mul:0.5, add:0.5);
cfControl = (cfControl * 70) + 50;
preFilter = WhiteNoise.ar(0.2) * SinOsc.kr(envRate, mul:0.5, add:0.5);
LPF.ar(preFilter, cfControl.midicps);
}.play
```

21.28. SuperCollider: Creating SynthDefs and Sending Parameters

- Most often, SynthDefs are created and sent signals or parameters from other processes

- Create a SynthDef; create an envelope opened and closed by a gate; create LPF filtered noise; control the amplitude of the noise by the envelope; create a Task to loop through parameters for duration, sustain, and cutoff frequency scalar

- Example: tutorial-b.rtf

```
(
SynthDef(\noise, {|sus=2, ampMax=0.9, lpfCfScalar=20|
   var env, amp, gate, sigPrePan, cfControl;

   gate = Line.ar(1, 0, sus, doneAction: 2);
   env = Env.adsr(0.1*sus, 0.2*sus, 0.8, 0.1*sus, ampMax);
   amp = EnvGen.kr(env, gate);

   cfControl = SinOsc.kr(12, mul:0.5, add:0.5);
```

```
   cfControl = (cfControl * lpfCfScalar) + 40;

   sigPrePan = LPF.ar(WhiteNoise.ar(amp), cfControl.midicps);
   Out.ar(0, Pan2.ar(sigPrePan, 0.5));
}).send(s);

r = Task({
        var dur, sus, fq, delta;
        dur = Pseq([0.5, 0.5, 0.25], 6).asStream;
        sus = Pseq([0.2, 0.2, 0.2], 6).asStream;
        fq = Pseq([60, 30, 20, 40], 6).asStream; // midi pitch values

        while {delta = dur.next;
                 delta.notNil
        } {
                Synth(\noise, [sus: sus.next, lpfCfScalar: fq.next]);
                delta.yield;
        }
});
r.play()
)
```

- Adding randomized panning control and cutoff frequency scalar
- Example: tutorial-c.rtf

```
(
SynthDef(\noise, {|sus=2, ampMax=0.9, lpfCfScalar=20, pan=0.5|
   var env, amp, gate, sigPrePan, cfControl;

   gate = Line.ar(1, 0, sus, doneAction: 2);
   env = Env.adsr(0.1*sus, 0.2*sus, 0.8, 0.1*sus, ampMax);
   amp = EnvGen.kr(env, gate);

   cfControl = SinOsc.kr(12, mul:0.5, add:0.5);
   cfControl = (cfControl * lpfCfScalar) + 40;

   sigPrePan = LPF.ar(WhiteNoise.ar(amp), cfControl.midicps);
   Out.ar(0, Pan2.ar(sigPrePan, pan));
}).send(s);

r = Task({
        var dur, sus, fq, delta, pan;
        dur = Pseq([0.5, 0.5, 0.25], 6).asStream;
        sus = Pseq([0.2, 0.2, 0.2], 6).asStream;
        fq = Pshuf([60, 30, 20, 40], 6).asStream; // midi pitch values
        pan = Pshuf([0, 0.2, 0.4, 0.6, 0.8, 1], 6).asStream;

        while {delta = dur.next;
                 delta.notNil
        } {
                Synth(\noise, [sus: sus.next, lpfCfScalar: fq.next, pan: pan.next]);
                delta.yield;
        }
});
r.play()
)
```

21.29. Live Coding

- A performance practice of computer music that emphasizes the creation of code

- Computer screens are projected while code is used to build-up musical parts
- Software such as SuperCollider, Impromptu, and ChucK are used
- Live Coding with aa-cell

  YouTube (http://www.youtube.com/watch?v=OBt4PLUv2q0)

Chapter 22. Meeting 22, Discussion and Workshop

22.1. Announcements

- Sonic System Project Report due Thursday, 3 December
- Quiz this Thursday
- Download fresh martingale now:

  http://code.google.com/p/martingale

- Download this audio file:

  http://bit.ly/7ZkobO

22.2. Listening: Ariza

- An exploration in rhythm, time, and texture
- Christopher Ariza: *onomatopoeticized*

22.3. The Vocoder: Concept

- Extending the concept of envelope following
- Analyze a signal with a narrow-band filter
- Smooth the energy in that filter to get a control signal proportional to the amplitude (envelope following)
- Use that control signal as an envelope
- Use the envelope to shape a simple sound source (sine or noise) at the analysis frequency
- Can remap energy from one frequency range to another

22.4. The Vocoder: History

- 1928: invented at Bell Labs by Homer Dudley
- 1935: Vocoder patented
- 1940s: SIGSALY (secure speech communication) system used Dudley's vocoder

  Voice signal first vocoded into 10 bands to reduce information, then encrypted

Image: Public domain, U.S. NSA.

- 1977: EMS Vocoder 3000

  16 bands each with independent level control

Vocoder 3000

- 1979: Moog 16 channel Vocoder released

  16 bands from 50 to 5080 Hz

- 1978-1982: Korg VC-10 Vocoder

  20 bands

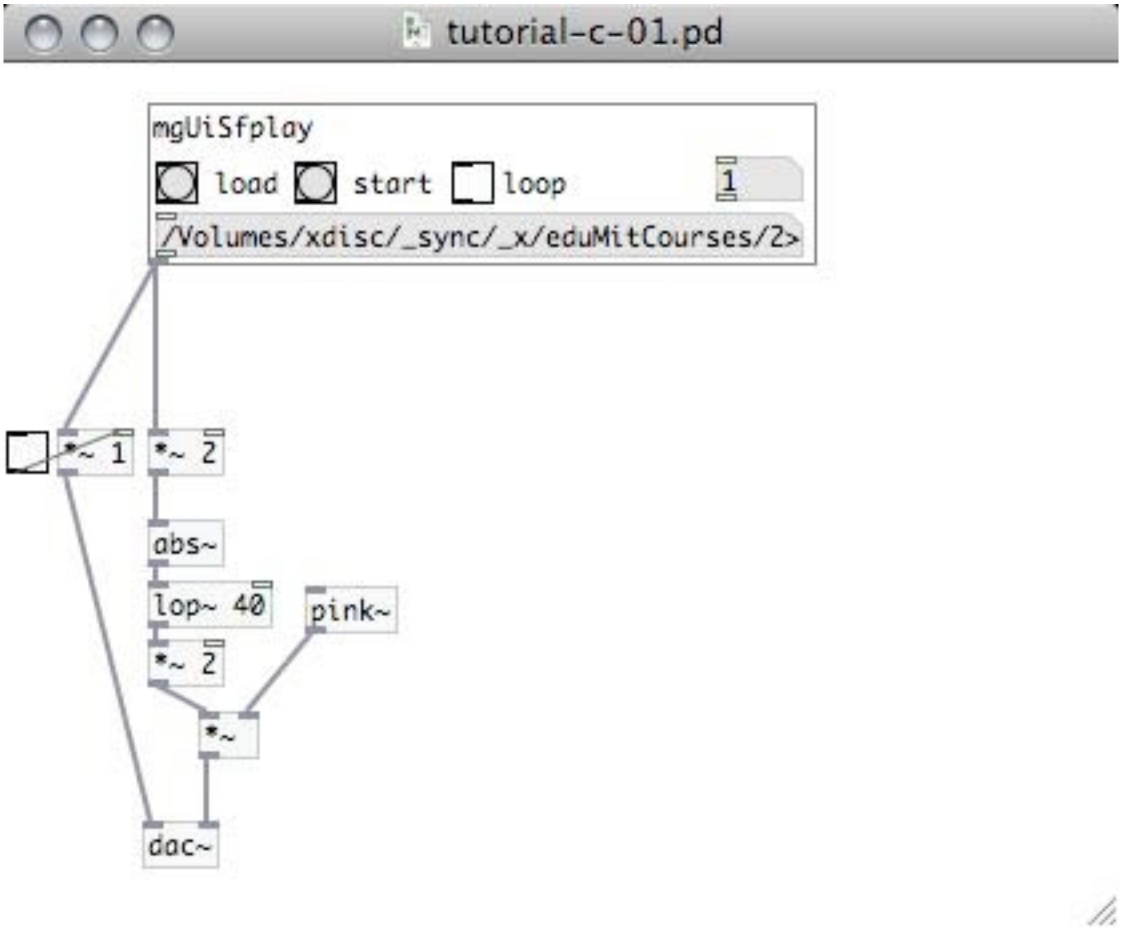
- 1980s: robot voices, Transformers (Soundwave), Cylons (Battlestar Galactica), et cetera
- Soundwave (the original)

Image removed due to copyright restrictions.
"Soundwave" Transformers toy.

YouTube (http://youtube.com/watch?v=OWb43IB3W-c)

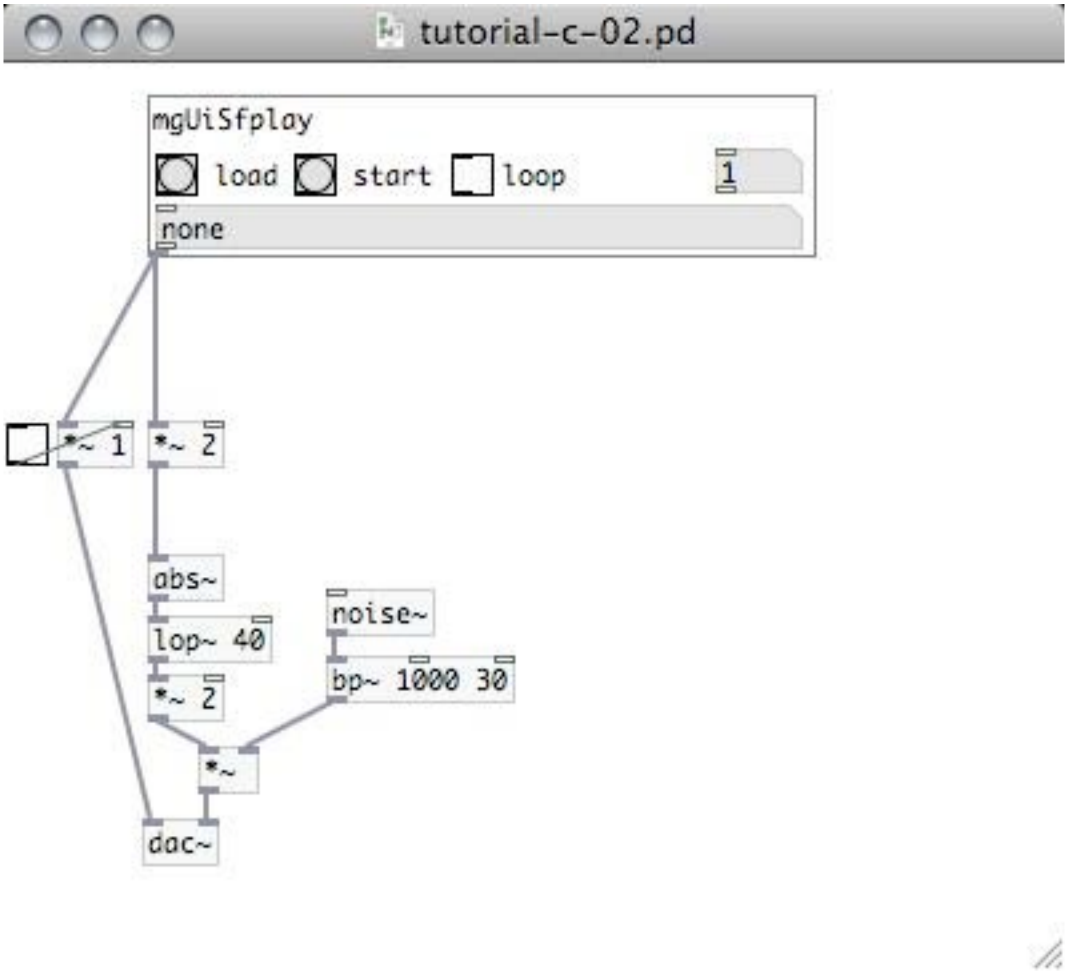
22.5. Workshop: A Vocoder: Envelope Following

- Smoothing a bipolar signal by taking the absolute value and low-pass filtering into a control signal; apply this control signal to the amplitude of pink noise



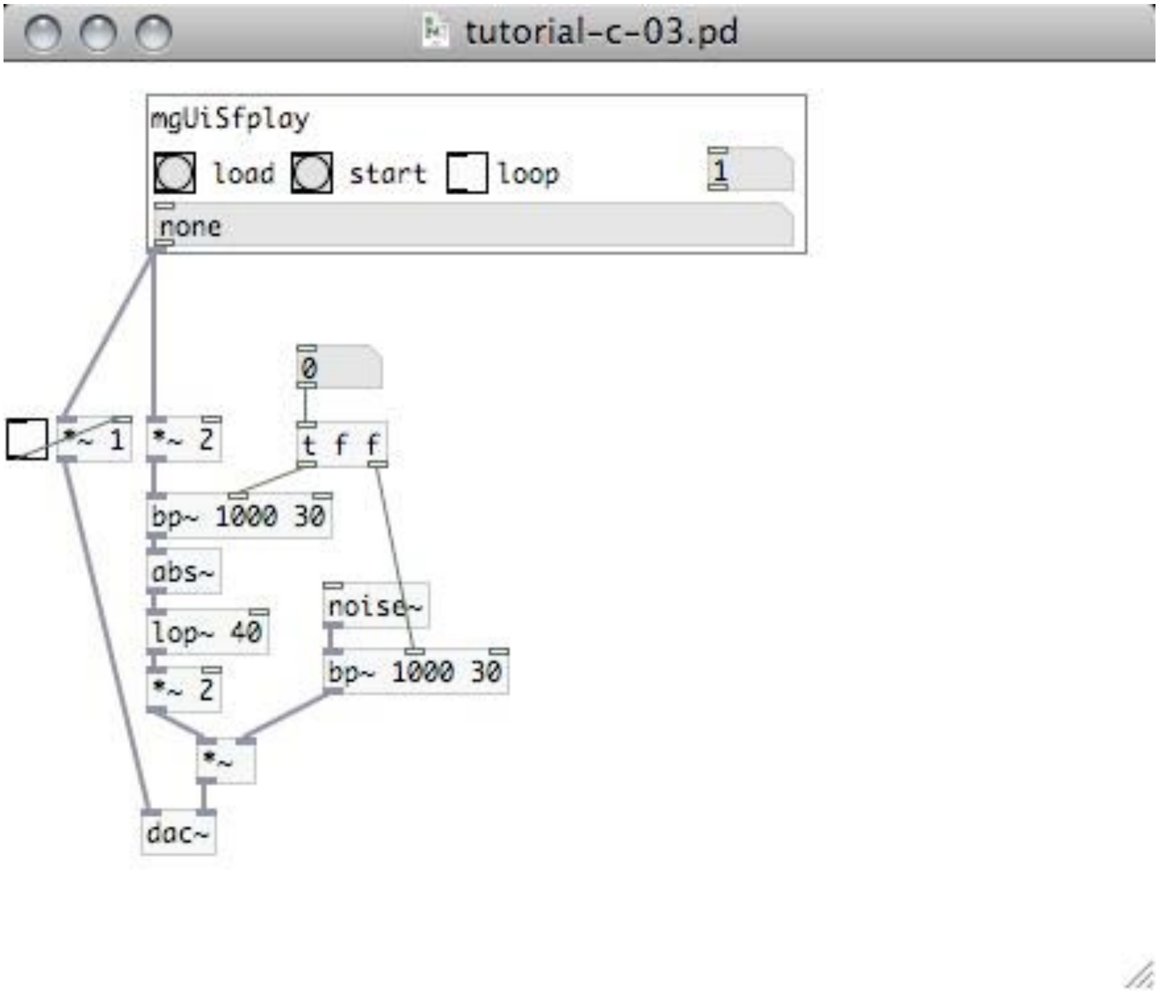
22.6. Workshop: A Vocoder: Controlling Band-Filtered Noise

- Applying the control signal to band-pass filtered white noise



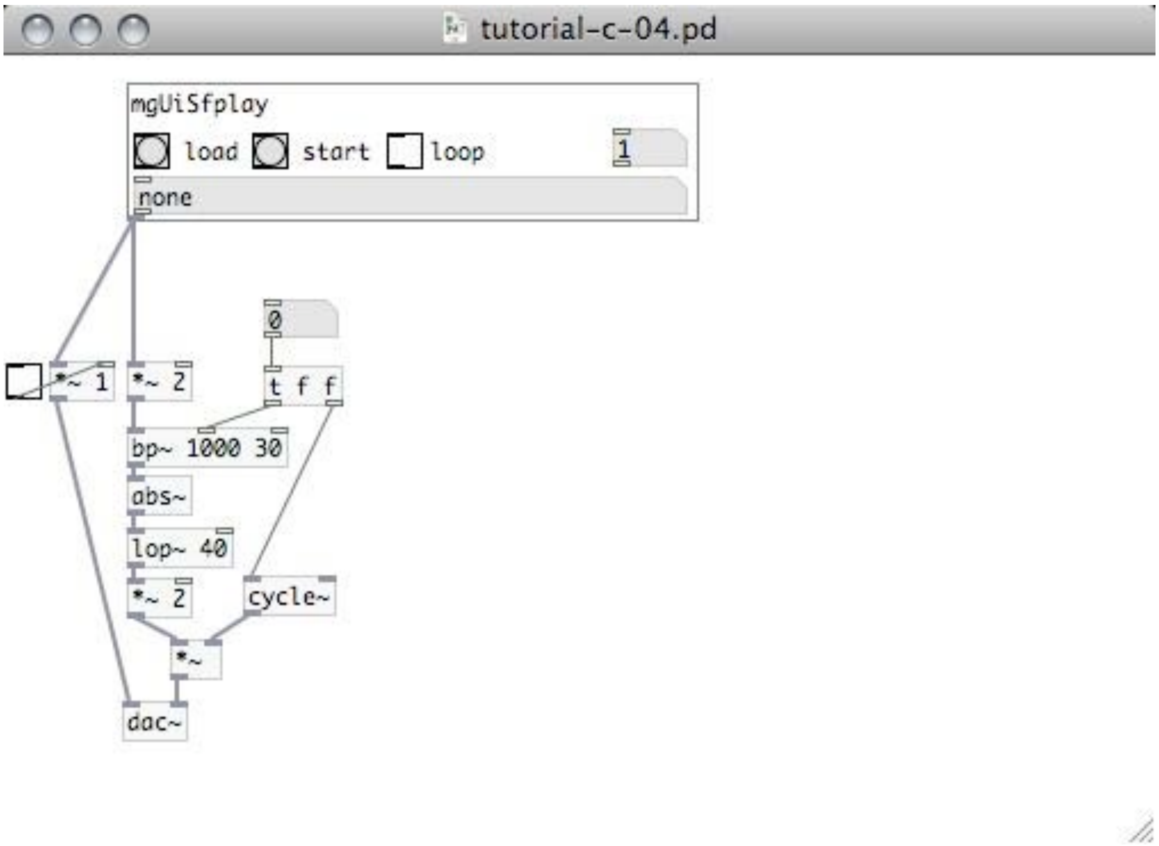
22.7. Workshop: A Vocoder: Analyzing and Generating a Signal

- A narrow frequency region is analyzed with a band-pass filter; filtered noise, tuned to the same frequency, is used for generation



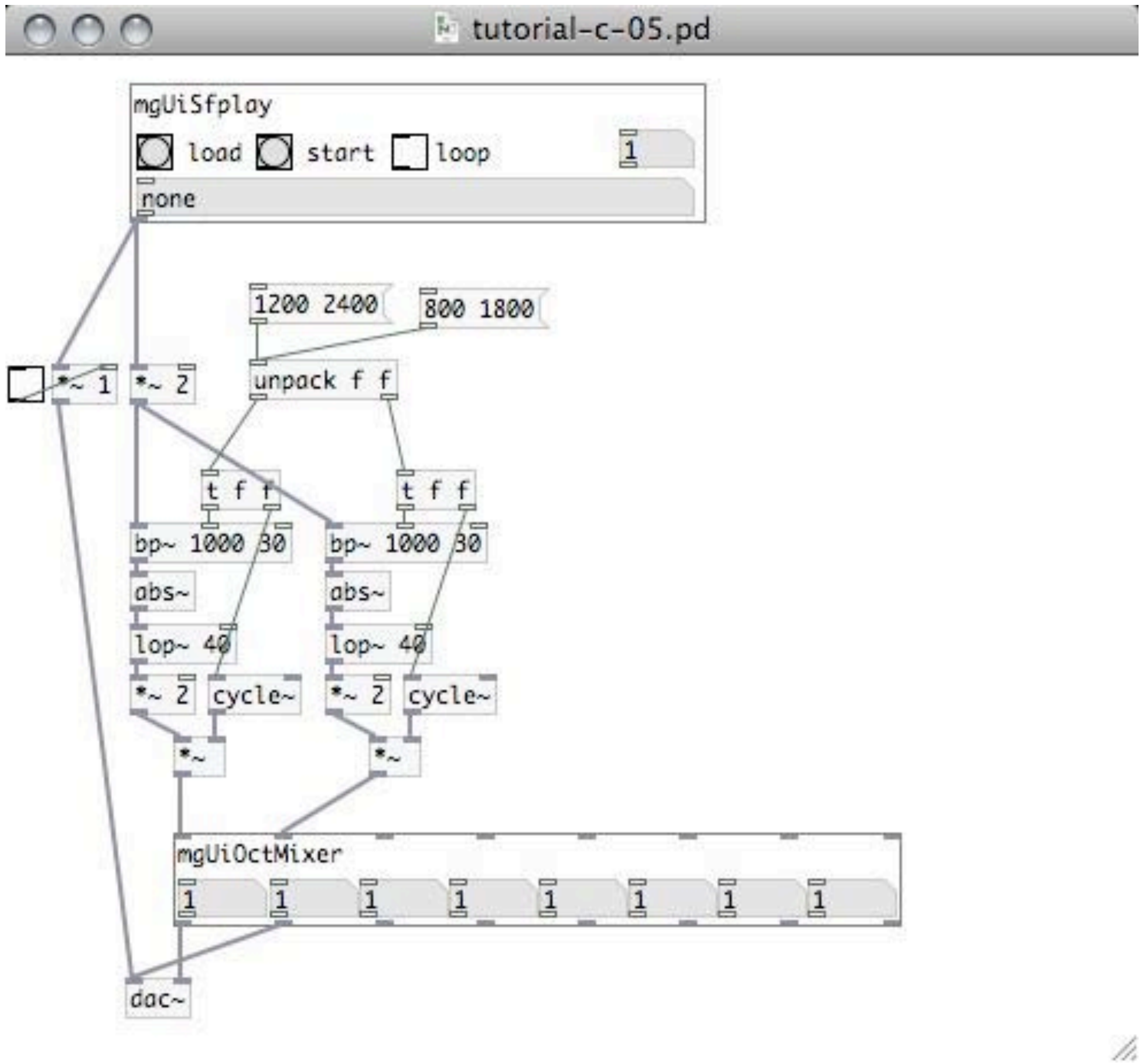
22.8. Workshop: A Vocoder: Sine Wave Generation

- Instead of filtered noise, the generated sound can be a sine tone tuned to the same frequency



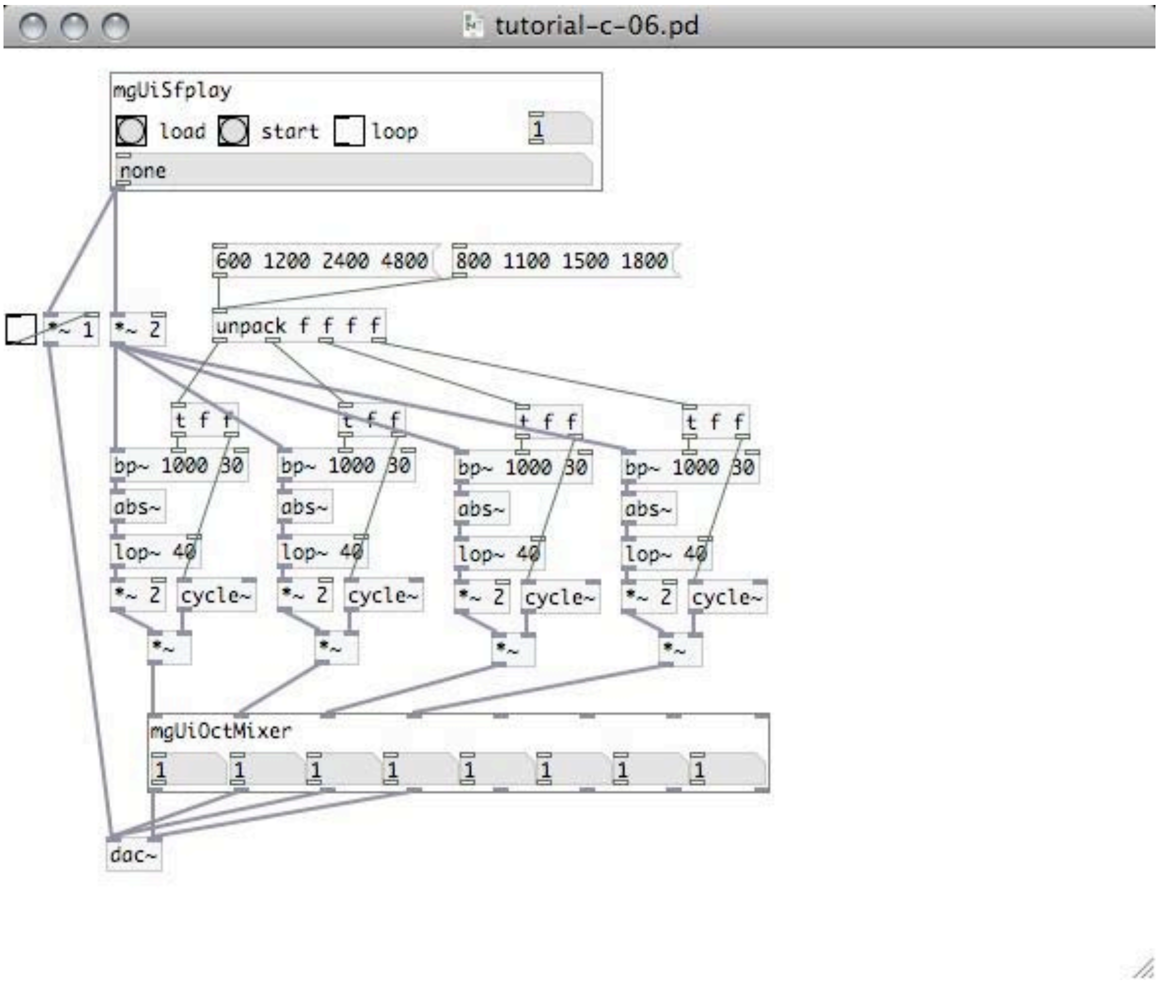
22.9. Workshop: A Vocoder: Two Bands with Sine Wave Generation

- Tune simultaneous bands to different frequencies; mix on output



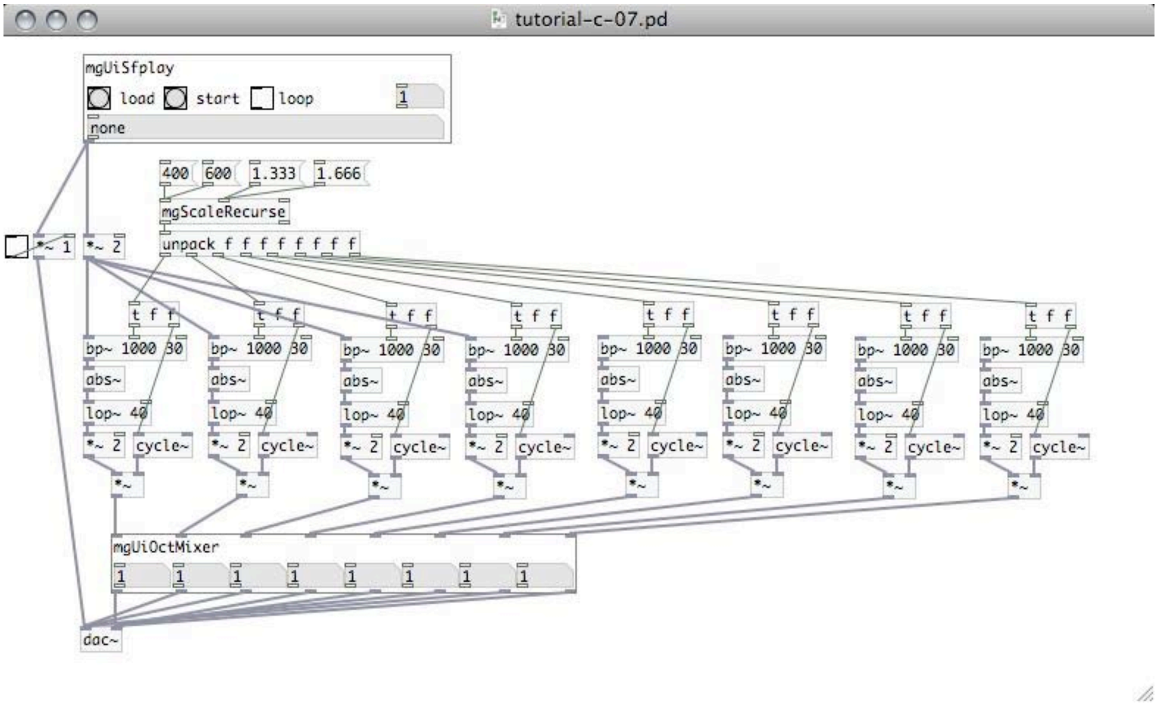
22.10. Workshop: A Vocoder: Four Bands

- Tuning for four simultaneous bands



22.11. Workshop: A Vocoder: Eight Bands

- Eight simultaneous bands with automatic frequency value generation



- Connecting different analysis envelopes to different generation signals permits creative remapping of spectral energy

Chapter 23. Meeting 23, Languages: Intellectual Property and Copyright

23.1. Announcements

- Sonic System Project Report due Today, 3 December

23.2. Quiz

- 10 Minutes

23.3. Copyright

- Copyright: the right to copy
- An intangible property right: right of copyright is based on authorship and exists separate and apart from any particular physical expression
- Protects the *expression* of ideas, not the ideas themselves
- Original copyright holders have exclusive right of first publishing

23.4. Public Domain

- Works created prior to copyright law, or that have fallen out of copyright, are in the public domain
- No person or entity can claim the work as private property, and the work cannot be re-copyrighted
- Works may be used for commercial or non-commercial applications

23.5. The Value of the Public Domain

- Provide a pool of shared resources for reworking and remixing

- Reworking and remixing is a type of creativity

23.6. What can be Copyrighted

- Facts, ideas, procedures, processes, systems, methods of operation, concepts, principles, and discoveries are not copyrightable (Moser 2006, p. 38)
- Copyright protects original expressions in a fixed medium
- Sound recordings are a separate copyright (a separate expression in a fixed medium) from the underlying musical composition
- Improvisation (as not fixed in a medium) is not copyrighted unless it is recorded; a copyright then exists for the composition and the recording (Moser 2006, p. 39)

23.7. Copyright Origins

- Technology and copyright have always been intertwined
- Copyright's origins as "... a delayed response to technological advances" (Moser 2006, p. 12)
- 1710: The Statute of Anne in England: Granted authors a copyright of 14 years, with a 14 year extension

Anno Octavo

Annæ Reginæ.

An Act for the Encouragement of Learning, by Veſting the Copies of Printed Books in the Authors or Purchaſers of ſuch Copies, during the Times therein mentioned.

Whereas Printers, Bookſellers, and other Perſons have of late frequently taken the Liberty of Printing, Reprinting, and Publiſhing, or cauſing to be Printed, Reprinted, and Publiſhed Books, and other Writings, without the Conſent of the Authors or Proprietors of ſuch Books and Writings, to their very great Detriment, and too often to the Ruin of them and their Families: For Preventing therefore ſuch Practices for the future, and for the Encouragement of Learned Men to Compoſe and Write uſeful Books; May it pleaſe Your Majeſty, that it may be Enacted, and be it Enacted by the Queens moſt Excellent Majeſty, by and with the Advice and Conſent of the Lords Spiritual and Temporal, and Commons in this preſent Parliament Aſſembled, and by the Authority of the ſame, That from and after the Tenth Day of April, One thouſand ſeven hundred and ten, the Author of any Book or Books already Printed, who hath not Transferred to any other the Copy or Copies of ſuch Book or Books, Share or Shares thereof, or the Bookſeller or Bookſellers, Printer or Printers, or other Perſon or Perſons, who hath or have Purchaſed or Acquired the Copy or Copies of any Book or Books, in order to Print or Reprint the ſame, ſhall have the ſole Right and Liberty of Printing ſuch Book and Books for the Term of One and twenty Years, to Commence from the ſaid Tenth Day of April, and no longer; and that the Author of any Book or Books already Compoſed and not Printed and Publiſhed, or that ſhall hereafter be Compoſed, and his Aſſignee, or Aſſigns, ſhall have the ſole Liberty of Printing and Reprinting ſuch Book and Books for the Term of Four-

6 Ttt 2 teen

Whereas Printers, Booksellers, and other Persons, have of late frequently taken the Liberty of Printing, Reprinting, and Publishing, or causing to be Printed, Reprinted, and Published Books, and other Writings, without the Consent of the Authors or Proprietors of such Books and Writings, to their very great Detriment, and too often to the Ruin of them and their Families: For Preventing therefore such Practices for the future, and for the Encouragement of Learned Men to Compose and Write useful Books; May it please Your Majesty, that it may be Enacted ... That from and after the Tenth Day of April, One thousand seven hundred and ten, the Author of any Book or Books already Printed, who hath not Transferred to any other the Copy or Copies of such Book or Books, ... shall have the sole Right and Liberty of Printing such Book and Books for the Term of One and twenty Years, to Commence from the said Tenth Day of April, and no longer; and that the Author of any Book or Books already Composed and not Printed and Published, or that shall hereafter be Composed, and his Assignee, or Assigns, shall have the sole Liberty of Printing and Reprinting such Book and Books for the Term of fourteen

- Applied only to books

23.8. The U.S. Constitution

- 1783: Article I, Section 8, Clause 8: the Progress Clause
- Congress is empowered "to Promote the Progress of Science and useful Arts, by securing for limited Times to Authors and Inventors the exclusive Right to their respective Writings and Discoveries."

23.9. Copyright Act of 1790

- First implementation of constitutional mandate
- Modeled on Statute of Anne
- Gave authors 14 years of copyright, with the option to renew
- Later extended to 28 years, renewable for 14 years (Krasilovsky 2003, p. 103)
- Protected books, charts, maps; music was not protected

23.10. Copyright Act of 1909

- Offered protection to "all the writings of an author" independent of medium

  Supreme Court interprets this as applying to the results of all creative and intellectual labor

- Total copyright term extended to 56 years: original term of 28 years, renewable for 28 years (Krasilovsky 2003, p. 103)
- Copyright granted to composers and music publishers; not to musicians and record companies

- Copyright protections only granted to registered works
- Created a compulsory mechanical license to reproduce and distribute sound recordings of musical compositions

23.11. Copyright Act of 1909: Compulsory Mechanical Licenses

- An exception to copyright, where the copyright holder's permission is not required
- Motivated in part by popularity of player pianos and the market for selling piano rolls
- After initial authorization of recording distribution, any other person may also record and distribute recordings of the work after giving written notice and paying statutory royalty (starting at 2 cents) on each record made and distributed
- Audio recordings and piano rolls themselves could not yet be copyrighted; only the underlying composition was protected
- 1909: statutory rate of 2 cents per unit for each mechanical license (Krasilovsky 2003, p. 98)
- 2006: 9.1 cents or 1.75 cents per minute of playing time or fraction thereof, whichever is great

23.12. Copyright Act of 1976

- Went in to effect on 1 January 1978
- Copyright becomes automatic: no registration is required
- Any work of original authorship can be protected
- Duration extended to life of author plus 50 years
- Fair use doctrine is introduced

23.13. Copyright Act of 1976: Music

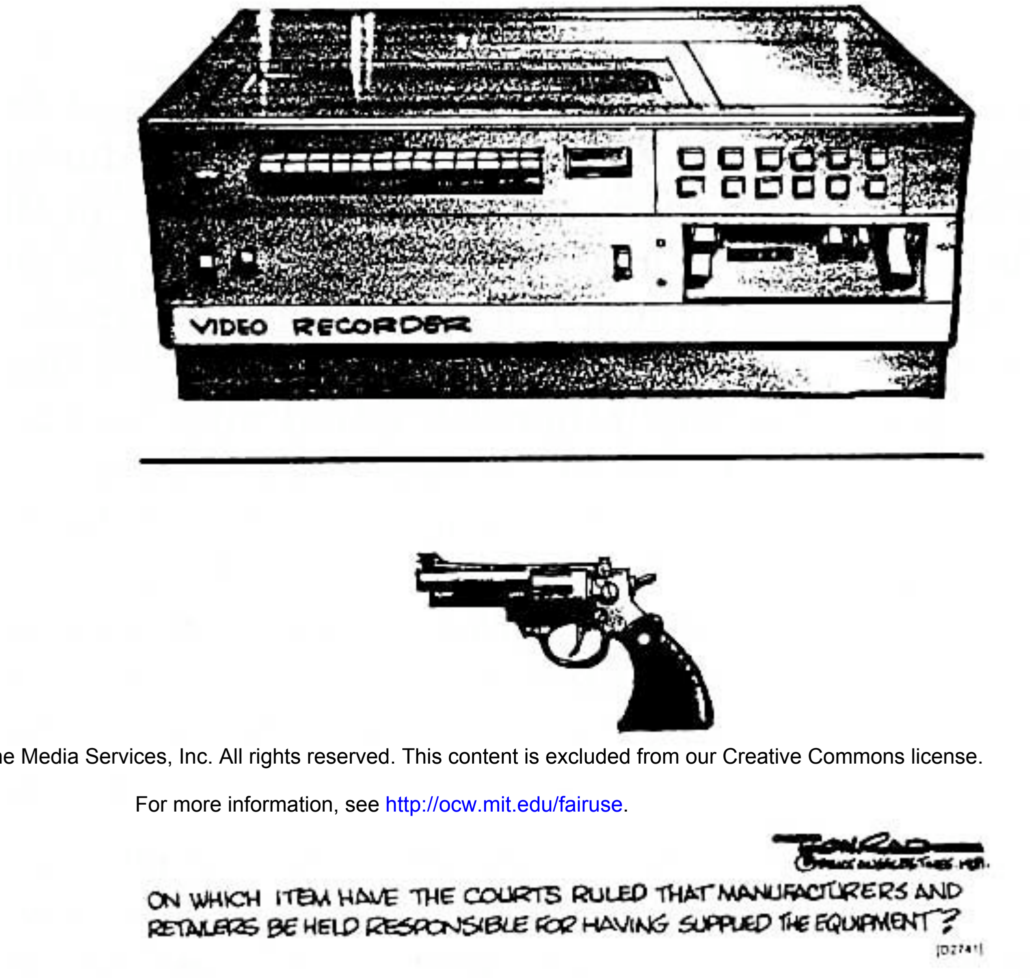
- Recordings themselves (not only the composition) are protected for the first time
- Copyright protection given for all sound recordings first fixed and published on or after 15 February 1972
- Recordings pre 1972 were protected by state laws
- Recordings before 1972 would have fallen into the public domain on 2047, but this was extended by the CTEA to 2067.

23.14. Copyright Act of 1976: Fair Use

- Permits some copying and distribution without permission
- Four determining factors, but no certainty prior to litigation
  - 1. Purpose and character of use: commercial v. nonprofit educational purposes
  - 2. Nature of the copyrighted work
  - 3. Amount and substantiality of the portion used in relation to the copyrighted work as a whole
  - 4. The effect of the use upon the potential market for or value of the copyrighted work
- There are no rules as to proportions of a work (percentage, notes, seconds) that can be used for fair use

23.15. Sony Corp. of America v. Universal City Studios, Inc. 1984

- 1981: Ninth Circuit Court of Appeals found that "… the home use of video recorders was not a fair use, and that Sony could be held liable for supplying a product whose primary and intended purpose was to tape commercial television programs, virtually all of which were copyrighted"



- Film studios sued Sony over a video copying technology (Betamax)

  Known as the Betamax case

- Supreme Court rules that making copies of complete television shows does not constitute copyright infringement

- "… ensures that new forms of technology that can be used to infringe copyrights cannot be banned as long as they also have substantial non-infringing uses" (Moser 2006, p. 19)

23.16. Berne Implementation Act of 1989

- Copyright notices become optional

- Prior to this, works without copyright notices (within up to 5 years) fell into the public domain

- The lack of required notices and registration makes it difficult to gain permission from a copyright holder

23.17. Audio Home Recording Act of 1992

- Motivated by the DAT
- Required "serial copyright management systems" in digital audio recorders
- Imposes royalties on the sale of digital audio recording devices and media
- "… exempted individuals from liability for copyright infringement for private, non-commercial copying" (Moser 2006, p. 19)

23.18. 1997: No Electronic Theft (NET) Act

- Government can prosecute both those who sell, and those who give away for free, copyrighted works
- Such electronic theft is a felony
- Prior to this, if a copyrighted work had been given away for free it was (possibly) not a copyright violation
- Motivated in part by the dismissal of United States v. LaMacchia (1994)

  Macchia, an MIT student, provided a server (Cynosure) to which users could post and (through a different server) download commercial software

  Congress closed the "LaMacchia loophole" with the NET Act

23.19. 1998: Sonny Bono Copyright Term Extension Act (CTEA)

- Automatically extended copyright term for works copyrighted between 1964 and 1977 to 67 years
- Increased term of new copyrights to life plus 70 years
- Promoted by Mary Bono, widow, claiming that Sonny believed "… that copyrights should be forever" (Lessig 2005, p. 215).
- In House, 10 of 13 sponsors received maximum contribution from Disney's PAC. In Senate, 8 of 12 sponsors received money form Disney's PAC. RIAA and MPAA paid more then 200,000 in campaign contributions (Lessig 2005, p. 218).

23.20. Reading: Lessig

- Lessig, L. 2005. *Free Culture*. New York: Penguine Books. Internet: http://www.free-culture.cc/freeculture.pdf.
- What was problematic about the Sony Bony Copyright Term Extension Act (CTEA)?
- What motivated Eldred to challenge the CTEA?
- Does Lessig suggest that congress acts in the public's best interests in establishing copyright laws? Whose interests are being met?
- What was the significance of United States v. Lopez as it related to copyright law?
- Is piracy of the public domain possible?
- How does the public domain promote progress?
- Why does Lessig argue that real harm of copyright extensions falls upon works that are not commercially exploited?
- What was Lessig's argument in the Eldred case? What was the government's argument?
- What did Lessig think he did wrong in arguing this case?

23.21. 1998: Eldred v. Ashcroft

- Challenge to the CTEA by Eric Eldred
- Eldred designed and hosted a non-commercial web-based library of public domain writings
- Argument: it is a violation of the constitution for congress to be allowed to extend an existing copyright
- The case lost 7 to 2

Courtesy of Ruben Bolling.

23.22. A & M Records v. Napster 2000

- File sharing service created by Shawn Fannin in 1999

- Not a true peer-to-peer system, as central servers maintained master lists of files and users
- A & M Records and 17 record companies file a complaint on 6 December 1999 for contributory and vicarious copyright infringement against Napster, Inc.
- Napster designed a system that permitted "transmission and retention of sound recordings employing digital technology"
- Court rules that Napster had knowledge of direct infringement, and materially contributed to infringement
- July 2001 Napster was shut down

23.23. MGM Studios, Inc. v. Grokster, Ltd 2005

- Between software manufacturers and consortium of 28 entertainment companies
- Supreme Court unanimously states that file sharing companies can be sued for inducing copyright infringement
- "We hold that one who distributes a device with the object of promoting its use to infringe copyright, as shown by clear expression or other affirmative steps taken to foster infringement, is liable for the resulting acts of infringement by third parties."
- Question remains as to what evidence is necessary to prove that copyright infringement is being fostered

Chapter 24. Meeting 24

24.1. Announcements

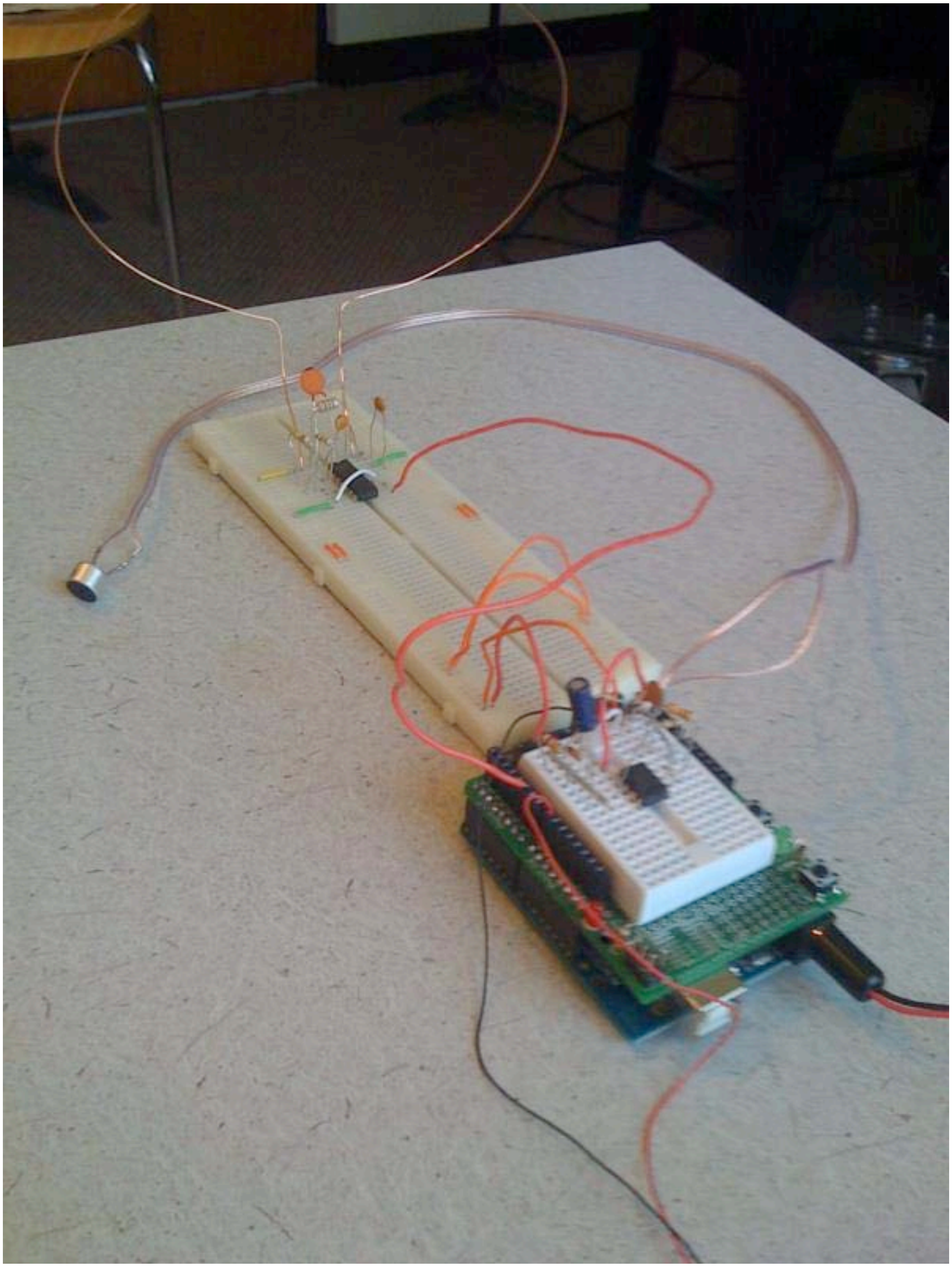
24.2. Sonic System Projects: The Turbo Sonic Whopper

- Created by Jillian Reddy, this instrument combines features of a turntable with a tape head and a magnetic disc


INPUT
VOLUME
GAIN
VOLUME
TREBLE
MIDDLE
BASS
POWER
Fender

24.3. Sonic System Projects: The Airemino

- Created by an anonymous MIT student, this instument provides Theremin-style pitch control with breath-control event trigger



24.4. Sonic System Projects: The XY Drum

- Created by an anonymous MIT student, a piezo-based drum trigger using a custom on-board microcontroller for signal analysis and synthesis

24.5. Sonic System Projects: The ChordMaster

- Created by Andrew Sugaya, this iPhone app permits storing up to six chords for playback by strumming gestures


Major
Octave: 1

Chapter 25. Meeting 25

25.1. Announcements

25.2. Evaluations

- Please complete an on-line evaluation for this subject

25.3. Quiz Review

- ?

25.4. Music Technology: Divisions

- Four Divisions
  - Sound recording and its influences
  - Instruments and interfaces
  - Languages and representations
  - Algorithmic and generative music systems (Spring 2010)
- Alternative organizations?
- What is left out?

25.5. Music Technology: Trends

- Musical and technological influence of persons from diverse backgrounds
- Faster, cheaper, easier
- Coercion and abstraction, bending and hacking

- Modularity and reuse
- New types of collaboration, interaction, and authorship
- Others?

25.6. The Future: Tools, Control, and Creativity

- Will new tools offer greater musical diversity or greater homogenization?
- Which is more important: hardware capabilities or software designs and interfaces? Will faster machines give us better musical tools? An engineering problem or an aesthetic and cultural problem?
- Dynamic systems over fixed works? Consumers as co-producers?

25.7. Sonic System Projects: Convolver

- Created by an anonymous MIT student, this Java-based implementation of a convolution reverb permits re-iterative processing in the sprit of Alvin Lucier.

25.8. Sonic System Projects: SlowCoder

- Created by Gerg Perkins, this PD-based implementation of a 60-band vocoder uses amplitude envelope feedback to provide creative manipulation of time-domain re-synthesis.

25.9. Sonic System Projects: Melow

- Created by Joseph Diaz, this PD-based implementation of a Melotrone re-creation employs noise and random-probabilities to emulate the unpredictable performance of the Melotron.

References

Anonymous. 1965. "Age of the Patchwork." *Time* September 24.

Ariza, C. 2008. "Python at the Control Rate: athenaCL Generators as Csound Signals." *Csound Journal* 9.

Ariza, C. 2009a. "Pure Data Object Glossary." Internet: http://flexatone.net/docs/pdg.

Ariza, C. 2009b. "Two Experiments in the Early History of Computer-Aided Algorithmic Composition."

Ballora, M. 2003. *Essentials of Music Technology*. Upper Saddle River: Prentice Hall.

Behrman, D. 1965. "What Indeterminate Notation Determines." *Perspectives of New Music* 3(2): 58-73.

Benjamin, W. 1936. "The Work of Art in the Age of Mechanical Reproduction." *Zeitschrift für Sozialforschung* 5(1).

Bijker, W. E. 1989. "The Social Construction of Bakelite: Toward a Theory of Invention." In *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*. W. E. Bijker, T. P. Hughes and T. J. Pinch, eds. Cambridge: MIT Press. 159-190.

Bijsterveld, K. 2002. "A Servile Imitation. Disputes about Machines in Music, 1910-1930." In *Music and Technology in the Twentieth Century*. H. Braun, ed. Baltimore: The Johns Hopkins University Press. 121-135.

Bijsterveld, K. and M. Schulp. 2004. "Innovation in Today's Classical Musical Instruments." *Social Studies of Science* 34(5): 649-674.

Bimber, B. 1990. "Karl Marx and the Three Faces of Technological Determinism." *Social Studies of Science* 20(2): 333-351.

Boulanger, R. C. 2000. *The Csound Book: Perspectives in Software Synthesis, Sound Design, Signal Processing, and Programming*. Cambridge: MIT Press.

Brady, E. 1999. *A Spiral Way*. Jackson: University Press of Mississippi.

Braun, H. 2002. *Music and Technology in the Twentieth Century*. Baltimore: The Johns Hopkins University Press.

Brown, B. 1981. "The Noise Instruments of Luigi Russolo." *Perspectives of New Music* 20(1-2): 31-48.

Burr, S. L. 2004. *Entertainment Law*. St. Paul: Thomson West.

Burroughs, W. S. 1964. "The Cut-Up Method of Brion Gysin." Internet: http://www.ubu.com/papers/burroughs_gysin.html.

Cardew, C. 1961. "Notation: Interpretation, etc." *Tempo* 58: 21-33.

Cavell, S. 2002. *Must We Mean What We Say?: A Book of Essays*. Cambridge: Cambridge University Press.

Chadabe, J. 1997. *Electric Sound: The Past and Promise of Electronic Music*. New Jersey: Prentice-Hall.

Chanan, M. 1995. *Repeated Takes: A Short History of Recording and its Effects on Music*. London: Verso.

Chang, J. 2005. *Can't Stop Wont't Stop: A History of the Hip-Hop Generation*. New York: St. Martin's Press.

Chang, K. O. and W. Chen. 1998. *Reggae Routes: The Story of Jamaican Music*. Temple University Press.

Collins, K. 2007. "In the Loop: Creativity and Constraint in 8-bit Video Game Audio." *twentieth-century music* 4(2): 209-227.

Collins, N. and J. d'Escriván. 2007. *The Cambridge Companion to Electronic Music*. Cambridge: Cambridge University Press.

Collins, N. 2009. *Handmade Electronic Music: The Art of Hardware Hacking*. 2nd ed. New York: Routledge.

Crab, S. 2004. "120 Years Of Electronic Music." Internet: http://www.obsolete.com/120_years/.

Dennis, B. 1991. "Cardew's 'Treatise' (Mainly the Visual Aspects)." *Tempo* 177: 10-16.

Doornbusch, P. 2004. "Computer Sound Synthesis in 1951: The Music of CSIRAC." *Computer Music Journal* 28(1): 10-25.

Eargle, J. 2004. *The Microphone Book*. 2nd ed. Boston: Focal Press.

Fildes, J. 2008. "'Oldest' computer music unveiled." *BBC News*.

Fouché, R. 2006. "Say It Loud, I'm Black and I'm Proud: African Americans, American Artifactual Culture, and Black Vernacular Technological Creativity." *American Quarterly* 58(3): 639-661.

Gabor, D. 1947. "Acoustical quanta and the theory of hearing." *Nature* 159(1044): 591-594.

Gennet, R. and S. Fortner. 2007. "Rhodes! Wurly! Clav!." *Keyboard* 33(10): 26-27.

Ghazala, Q. R. 2004. "The Folk Music of Chance Electronics: Circuit-Bending the Modern Coconut." *Leonardo Music Journal* 14(1): 97-104.

Gladwell, M. 2008. "In the Air: Who says big ideas are rare?." *The New Yorker* May 12.

Gross, T. 2005a. "Interview on 26 December 2002: DJ and hip-hop forefather Grandmaster Flash." National Public Radio. Internet: http://www.npr.org/templates/story/story.php?storyId=889654.

Gross, T. 2005b. "Interview on 30 March 2005: Kool Herc: A Founding Father of Hip Hop." National Public Radio. Internet: http://www.npr.org/templates/story/story.php?storyId=4567450.

Hocker, J. 2002. "My Soul is in the Machine — Conlon Nancarrow — Composer for Player Piano — Precursor of Computer Music." In *Music and Technology in the Twentieth Century*. H. Braun, ed. Baltimore: The Johns Hopkins University Press. 84-96.

Holmes, T. 2008. *Electronic and Experimental Music*. Third ed. New York: Routledge.

Horning, S. S. 2004. "Engineering the Performance: Recording Engineers, Tacit Knowledge and the Art of Controlling Sound." *Social Studies of Science* 34(5): 703-731.

Huber, D. M. and R. E. Runstein. 2001. *Modern Recording Techniques*. Boston: Focal Press.

Hughes, T. P. 1979. "The Electrification of America: The System Builders." *Technology and Culture* 20(1): 124-161.

Hughes, T. P. 2004. *Human-Built World: How to Think About Technology and Culture*. Chicago: University of Chicago Press.

Katz, M. 2002. "Aesthetics out of Exigency: Violin Vibrato and the Phonograph." In *Music and Technology in the Twentieth Century*. H. Braun, ed. Baltimore: The Johns Hopkins University Press. 174-185.

Katz, M. 2004. *Capturing Sound: How Technology Has Changed Music*. Berkeley: University of California Press.

Kenney, W. H. 1999. *Recorded Music in American Life*. Oxford: Oxford University Press.

Klein, H. K. and D. L. Kleinman. 2002. "The Social Construction of Technology: Structural Considerations." *Science, Technology, & Human Values* 27(1): 28-52.

Kline, R. and T. Pinch. 1996. "Users as Agents of Technological Change: The Social Construction of the Automobile in the Rural United States." *Technology and Culture* 37(4): 763-795.

Krasilovsky, M. W. and S. Shemel. 2003. *This Business of Music*. Billboard Books.

Kreidler, J. 2009. "Programming Electronic Music in Pd." Wolke Publishing House. Internet: http://www.pd-tutorial.com.

Krueger, T. 2008. "This is Not Entertainment: Experiencing the Dream House." *Architectural Design* 78(3): 12-15.

La Motte-Haber, H. de. 2002. "Soundsampling: An Aesthetic Challenge." In *Music and Technology in the Twentieth Century*. H. Braun, ed. Baltimore: The Johns Hopkins University Press. 199-206.

Lehrman, P. D. and T. Tully. 1993. *MIDI for the Professional*. New York: Amsco Publications.

Lessig, L. 2005. *Free Culture*. New York: Penguine Books.

Lombardo, V. and A. Valle, J. Fitch, K. Tazelaar, S. Weinzierl, W. Borczyk. 2009. "A Virtual-Reality Reconstruction of Poème Électronique Based on Philological Research." *Computer Music Journal* 33(2): 24-47.

Loy, D. G. 1985. "Musicians Make a Standard: The MIDI Phenomenon." *Computer Music Journal* 9(4): 8-26.

Magoun, A. B. 2002. "The Origins of the 45-RPM Record at RCA Victor, 1939-1948." In *Music and Technology in the Twentieth Century*. H. Braun, ed. Baltimore: The Johns Hopkins University Press. 148-157.

Marx, L. 1978. "Reflections on the Neo-Romantic Critique of Science." *Daedalus* 107(2): 61-74.

Mathews, M. V. 1969. *The Technology of Computer Music*. Cambridge: MIT Press.

Mathews, M. V. and J. R. Pierce. 1987. "Some Recollections of James Tenney." *Perspectives of New Music* 25(1-2): 534-535.

McCartney, J. 1996. "SuperCollider: a New Real Time Synthesis Language." In *Proceedings of the International Computer Music Conference*. San Francisco: International Computer Music Association.

McCartney, J. 1998. "Continued Evolution of the SuperCollider Real Time Synthesis Environment." In *Proceedings of the International Computer Music Conference*. San Francisco: International Computer Music Association.

Millard, A. 2002. "Tape Recording and Music Making." In *Music and Technology in the Twentieth Century*. H. Braun, ed. Baltimore: The Johns Hopkins University Press. 158-167.

Moog, R. 1954. "The Theremin." In *Radio and Television News*. January: 37-39.

Moore, F. R. 1988. "The Dysfunctions of MIDI." *Computer Music Journal* 12(1): 19-28.

Moser, D. J. 2006. *Moser on Music Copyright*. Boston: Thompson Course Technology.

Nielsen, S. H. and T. Lund. 2003. "Overload in Signal Conversion." *AES 23rd International Conference*.

Olson, H. F. and H. Belar. 1955. "Electronic Music Synthesizer." *Journal of the Acoustical Society of America* 27(3): 595-612.

Oswald, J. 1985. "Plunderphonics, or Audio Piracy as a Compositional Prerogative." *Wired Society Electro-Acoustic Conference*.

Pareles, J. 2009. "Les Paul, Guitar Innovator, Dies at 94." *New York Times* August 14.

Petzold, C. 1999. *Code*. Redmond: Microsoft Press.

Pinch, T. J. and W. E. Bijker. 1984. "The Social Construction of Facts and Artefacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other." *Social Studies of Science* 14(3): 399-441.

Pinch, T. J. and K. Bijsterveld. 2003. "'Should One Applaud?': Breaches and Boundaries in the Reception of New Technology in Music." *Technology and Culture* 44(3): 536-559.

Pinch, T. and K. Bijsterveld. 2004. "Sound Studies: New Technologies and Music." *Social Studies of Science* 34(5): 635-648.

Pinch, T. and F. Trocco. 2002. "The Social Construction of the Early Electronic Music Synthesizer." In *Music and Technology in the Twentieth Century*. H. Braun, ed. Baltimore: The Johns Hopkins University Press. 67-83.

Pinch, T. and F. Trocco. 2004. *Analog Days: The Invention and Impact of the Moog Synthesizer*. Cambridge: Harvard University Press.

Porcello, T. 2004. "Speaking of Sound: Language and the Professionalization of Sound-Recording Engineers." *Social Studies of Science* 34(5): 733-758.

Puckette, M. 1985. "A real-time music performance system." *MIT Experimental Music Studio*.

Puckette, M. 1988. "The Patcher." In *Proceedings of the International Computer Music Conference*. San Francisco: International Computer Music Association. 420-429.

Puckette, M. 1997. "Pure Data." In *Proceedings of the International Computer Music Conference*. San Francisco: International Computer Music Association. 224-227.

Puckette, M. 2002. "Max at 17." *Computer Music Journal* 26(4): 31-43.

Riskin, J. 2003. "The Defecating Duck, or, the Ambiguous Origins of Artificial Life." *Critical Inquiry* 29(4): 599-633.

Roads, C. 1978. "Automated Granular Synthesis of Sound." *Computer Music Journal* 2(2): 61-62.

Roads, C. 1980. "Interview with Max Mathews." *Computer Music Journal* 4(4): 15-22.

Roads, C. 1996. *The Computer Music Tutorial*. Cambridge: MIT Press.

Roads, C. 2002. *Microsound*. Cambridge: MIT Press.

Robertson, A. and M. D. Plumbley, N. Bryan-Kinns. 2008. "A Turing Test for B-Keeper: Evaluating an Interactive Real-Time Beat-Tracker." *Proceedings of the New Interfaces for Musical Expression Conference (NIME08)* 319-324.

Rogers, H. 2009. "Western Historic Radio Museum." Internet: http://www.radioblvd.com/BCMICS.htm.

Rosen, J. 2008. "Researchers Play Tune Recorded Before Edison." *New York Times*.

Rossing, T. D. and F. R. Moore, P. A. Wheeler. 2001. *The Science of Sound*. Boston: Addison Wesley.

Russolo, L. 1913. "The Art of Noises."

Schaeffer, P. 2004. "Acousmatics." In *Audio Culture: Readings in Modern Music*. C. Cox and D. Warner, eds. New York: Continuum. 76-81.

Schedel, M. 2002. "Anticipating interactivity: Henry Cowell and the Rhythmicon." *Organised Sound* 7(3): 247-254.

Schwarz, R. 1996. *Minimalists*. London: Phaidon Press.

Scranton, P. 1995. "Determinism and Indeterminacy in the History of Technology." *Technology and Culture* 36(2): 21-53.

Smith, M. R. and L. Marx. 1994. *Does Technology Drive History? The Dilemma of Technological Determinism*. Cambridge: MIT Press.

Sorensen, A. and A. R. Brown. 2007. "aa-cell in Practice: An Approach to Musical Live Coding." In *Proceedings of the International Computer Music Conference*. San Francisco: International Computer Music Association. 2: 292-299.

Sousa, J. P. 1993. "Machine Songs IV: The Menace of Mechanical Music." *Computer Music Journal* 17(1): 14-18.

Standage, T. 2007. *The Victorian Internet*. New York: Walker & Company.

Sterne, J. 2006. "The mp3 as cultural artifact." *new media & society* 8(5): 825-842.

Taylor, T. 2002. *Strange Sounds: Music, Technology and Culture*. London: Routledge.

Thomas, M. 2000. "Nancarrow's temporal dissonance: Issues of tempo proportions, metric synchrony, and rhythmic strategies." *Integral* 14: 137-180.

Théberge, P. 1997. *Any Sound You Can Imagine: Making Music / Consuming Technology*. Hanover: Wesleyan University Press.

Théberge, P. 2004. "The Network Studio: Historical and Technological Paths to a New Ideal in Music Making." *Social Studies of Science* 34(5): 759-781.

Turntablist LLC. 2005. "TTM: Turntablist Transcription Method." Internet: http://ttmethod.com/.

Waksman, S. 2004. "California Noise: Tinkering with Hardcore and Heavy Metal in Southern California." *Social Studies of Science* 34(5): 675-702.

Walser, R. 1995. "Rhythm, Rhyme, and Rhetoric in the Music of Public Enemy." *Ethnomusicology* 39(2): 193-217.

Wells, T. 1999. "JAMES MCCARTNEY SUPERCOLLIDER 2.0 (MAC)." *Electronic Musician*.

Wessel, D. and M. Wright. 2002. "Problems and Prospects for Intimate Musical Control of Computers." *Computer Music Journal* 26(3): 11-22.

Whiteley, S. 1990. "Progressive Rock and Psychedelic Coding in the Work of Jimi Hendrix." *Popular Music* 9(1): 37-60.

Wishart, T. 1996. *On Sonic Art*. New York: Routledge.

Wright, M. and A. Freed. 1997. "Open Sound Control: A New Protocol for Communicating with Sound Synthesizers." In *Proceedings of the International Computer Music Conference*. San Francisco: International Computer Music Association. 101-104.

Xenakis, I. 1992. *Formalized Music: Thought and Mathematics in Music*. Indiana: Indiana University Press.

Xenakis, I. 1996. "Determinacy and Indeterminacy." *Organised Sound* 1(3): 143-155.

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