Sampling Synthesis

- some history
- looping
- pitch shifting
- data reduction

A Little History

The **Mellotron** is an electromechanical polyphonic keyboard musical instrument originally developed and built in Birmingham, England in the early 1960s.

The heart of the instrument is a bank of parallel linear (not looped) strips of magnetic tape, each with approximately eight seconds of playing time; playback heads underneath (but not directly underneath) each key enable performers to play the pre-recorded sound assigned to that key when pressed.

Tape samplers had been explored in research studios the best example being Hugh LeCaine's 1955 keyboard-controlled "Special Purpose Tape Recorder", which he used when recording his classic "Dripsody".

Fairlight Instruments

Fairlight Instruments was started in Sydney Australia in 1975 by Peter Vogel and Kim Ryrie and was originally established as a manufacturer and retailer of video special effects

The Fairlight CMI or Computer Music Instrument, released in (1979), started life as the QASAR M8. The M8 was hand-wired and legend has it that it took 2 hours to boot up! The CMI was the first commercially available digital sampling instrument. The original Fairlight CMI sampled using a resolution of 8-bits at a rate of 10 kHz; it was equipped with two six octave keyboards, an alphanumeric keyboard, and an interactive video display unit (where soundwaves could be edited or even drawn from scratch using a light pen). Software allowed for editing, looping, and mixing of sounds which could then be played back via the keyboard or the software-based sequencer. It retailed for around $25,000 US.

E-mu Systems

E-MU Systems **Emulator** (1981) was E-mu Systems initial foray into sampling, and saved the company from financial disaster after the complete failure of the Audity due to a price tag of $70,000! The name 'Emulator' came as the result of leafing through a thesaurus and matched the name of the company perfectly.

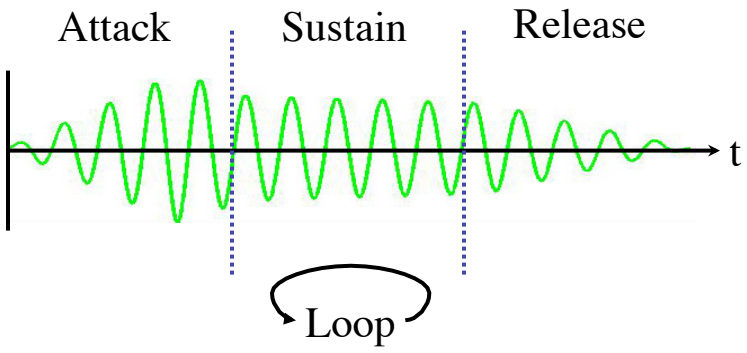
The Emulator came in 2-, 4-, and 8-note polyphonic versions, the 2-note being dropped due to limited interest, and featured a maximum sampling rate of 27.7 kHz, a four-octave keyboard and 128 kB of memory.
E-mu Systems Emulator II (1985) featured 8-bit sampling, up to 1 MB of sample memory, an 8-track sequencer, and analog filtering. With the addition of the hard disk option, the Emulator II was comparable to samplers released 5 years later.
E-mu Systems Emulator III (1987) was a 16-bit stereo digital sampler with 16-note polyphony, 44.1 kHz maximum sample rate and had up to 8 MB of memory. It featured a 16 channel sequencer, SMPTE and a 40 MB hard disk.
E-mu Systems SP-1200 was, and still is, one of the most highly regarded samplers for use in hip-hop related production. Its 12-bit sampling engine gave a desirable warmth to instruments and a gritty punch to drums. It featured 10 seconds of sample time spread across four 2.5-second sections.

Akai

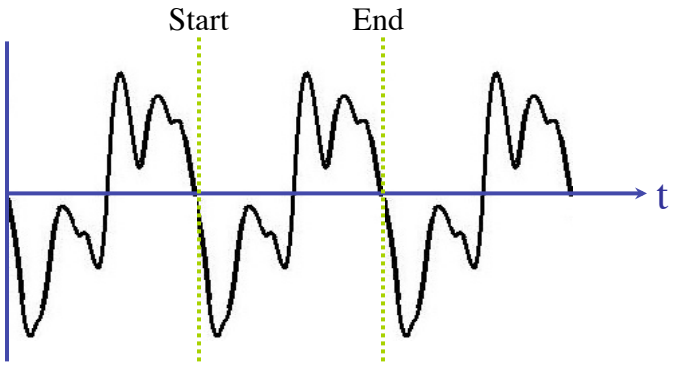
Akai entered the electronic musical instrument world in 1984 with the first in a series of affordable samplers the S612, an 8bit digital sampler module. The S612 was superseded in 1986 by the 16 bit S900.

The Akai S900 (1986) was the first truly affordable digital sampler. It was 8-note polyphonic and featured 12-bit sampling with a frequency range up to 40 kHz and up to 750 kB of memory that allowed for just under 12 seconds at the best sampling rate. It could store a maximum of 32 samples in memory. The operating system was software based and allowed for upgrades that had to be booted each time the sampler was switched on.

Sampling Synthesis



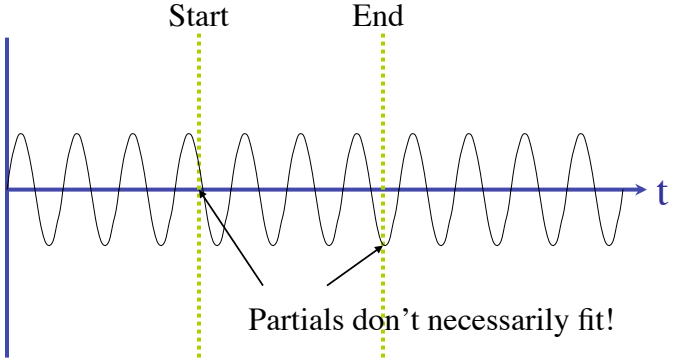
Looping - Splicing



Can you loop it?

Do zero crossings really matter?

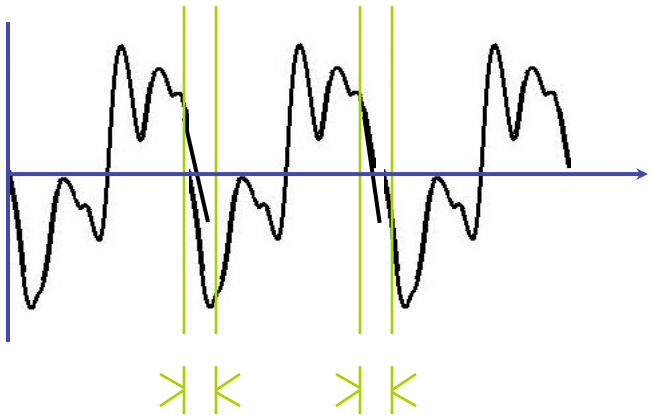
Looping



How do you overcome this?

Looping - Cross fade

Limit the audible artifacts



Pitch Shifting

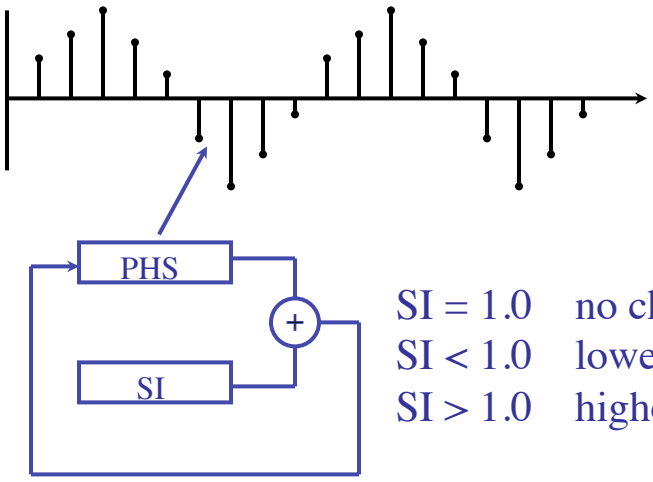
Variable DAC speed

Separate hardware output stage for each voice running at a different sample rate, then followed by analog mixing.

Sample-rate Conversion

Digital pitch shifting, mixing, and one DAC output.

Sample Rate Conversion



SI = 1.0 no change
SI < 1.0 lower
SI > 1.0 higher

SI = 1.0 no change

SI < 1.0 lower Decimation "downsampling"

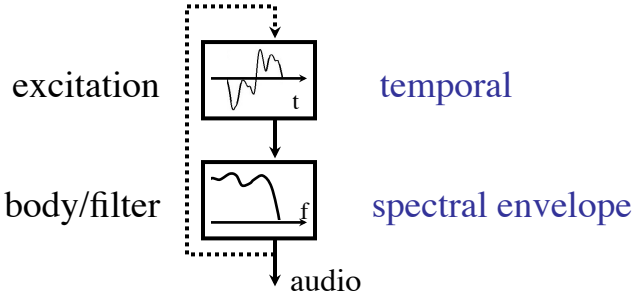
SI > 1.0 higher Interpolation "upsampling"

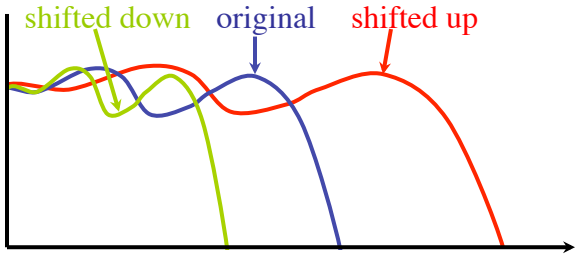
$$SI = \frac{\text{intended frequency}}{\text{original frequency}}$$

For intended pitches expressed in half steps (h):
intended frequency = 2 $^{(h/12)}$ original frequency

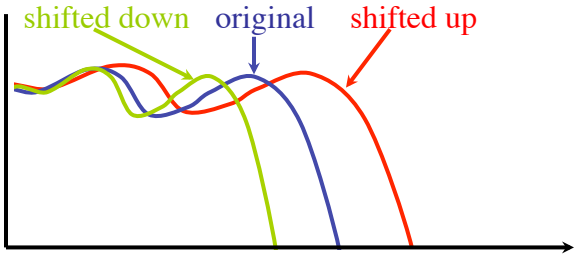
1 half step up is 1.059463 * original frequency

Problems with Extreme Pitch Shifting (Mickey Mouse effect)





How far can you pitch shift?



- For instruments with a single fixed body, the limit is about a major/minor third.
- For instruments with multiple body sections (marimba, panpipes, etc.), the limit is much wider.

Called "multisampling" in some commercial literature.

Data Compression

encode:decode

Data bases of tone samples data (attack, loop, release) make it possible to use MIDI-like scores for music.

- Eliminates redundancies in data
- Eliminates unessential information (later topic: perceptual encoding)

This is important for internet-based applications.

MIDI and Beyond: Evolution

- Hardware standard
- Software Standard
- "General" MIDI standard synthesizer
- Downloadable Sounds, especially General Midi - "samples"
- Soft Synth ("sampling synth")
- MPEG-4 Structured Audio enables programmable software synthesis

Standards

Sound and Score

mod files

mov Quicktime

Beatnik
ActiveX

MPEG-4