Instrument Pickups

Mikes have problems with feedback and crosstalk.

Active vs. Passive

Active has greater signal/noise, but requires battery or phantom power.

Contact pickups

Piezo, dynamic, or more recently condenser

Register the vibrations of the instrument.

Less feedback, but still some through resonance of instrument body.

Magnetic pick-ups for electric guitar and bass,

Register the vibrations of ferromagnetic nickel or steel strings

Permanent magnet magnetizes string, which generates sizable voltage in coil (can be ~1 V).

Humbucker – six coils wound in alternating directions with magnetic cores also alternating. Ambient EM noise cancels, while signal adds. Figure from Seth Lover's 1955 patent (2,896,491) shows string 2 over a pair of pickups

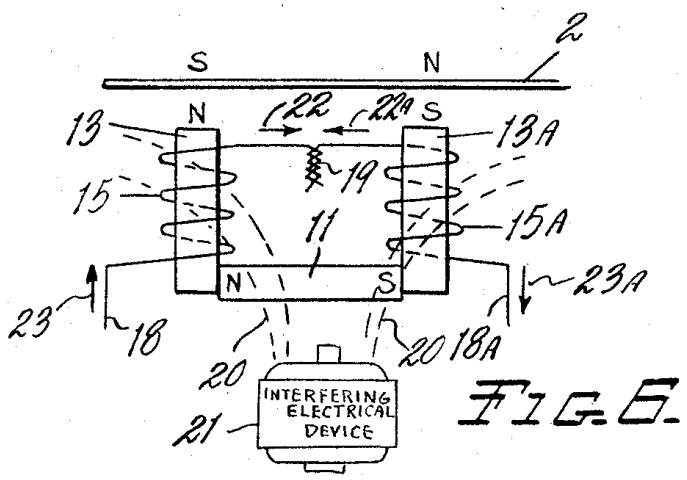


FIG. 6.

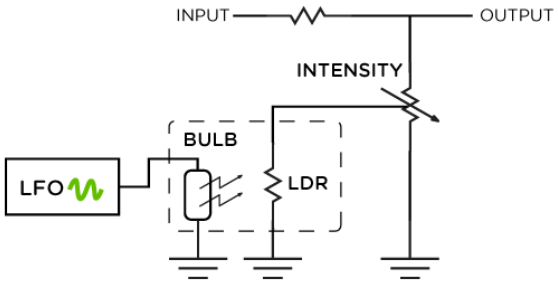
Effects

Stereo

Pan (from Left to Right)

L/R (left right) vs. M/S (mid/sides): M = L+R and S = L-R

Tremolo (varying the volume)



Easy to do with photo-resistor ("Light Dependent Resistor" LDR in figure) and neon (fast) light bulb powered by Low Frequency Oscillator (LFO).

Photo-resistor is linear, does not distort.

1960's "beach" guitar sound

SV1 CLAV Variation 1, use the editor to show it, and the "Spread" knob to pan it left and right.

Vibrato (varying the frequency)

Rotating (Leslie) speaker – Doppler shift.

Now done digitally by frequency shifting.

Chorus effect

The SV1 CLAV Variation 1, the editor lists it as "Organ Vib/Chorus"

The chorus effect in acoustic music is achieved by having more than once voice singing (nearly) the same note in a chorus, more than one string in a piano, 12-string guitar, or mandolin. Electronically, it can be produced by shifting the frequency slightly between multiple tone sources.

Wa-Wa

Sweeping a band-pass (or cut-off for a low-pass) filter. Imitates spectral content of vowels “ooo” and “ah”

Flanging

Flanging is produced by mixing two identical signals together, one signal delayed by a small and gradually changing period, usually smaller than 20 milliseconds. This produces a swept comb filter effect: peaks and notches are produced in the resultant frequency spectrum, related to each other in a linear harmonic series. Varying the time delay causes these to sweep up and down the frequency spectrum. The "flange" effect originated with a tape recording technique using two tape machines, when an engineer put a finger on the flange, or rim, of one of the tape reels so the machine was slowed, slipping out of sync by tiny degrees with the other machine. John Lennon came up with the name “flanging” during the recording of Abbey Road. More generally flanging is a type of phasing, namely, when the phase shift is proportional to frequency, yielding a constant time delay across all frequencies. (from Wikipedia) Other phase delay devices are also available.

Phaser

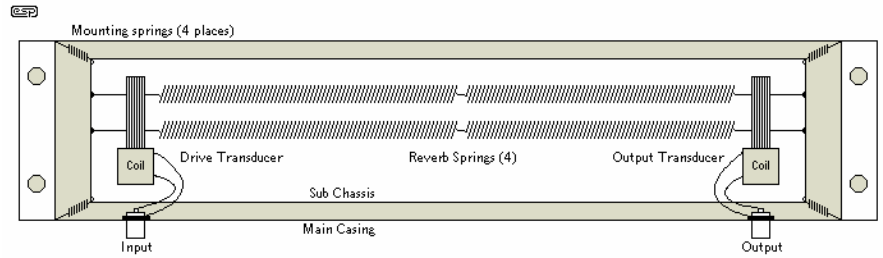
Made of a bank of “all pass filters,” which do not effect amplitude, but introduce a frequency dependent phase shift. When mixed with the original signal, this creates notches in the spectrum that can be swept, resulting in a sound similar to Phasing. Whereas Flanging sounds somewhat natural, but like under water, the Phaser is more other-worldly.

Reverb

Originally used a speaker and microphone in isolated room.

Analog circuit including actuator and pickup with springs hung between them. Do not bump!

Later, progressed to tapped analog and or digital delay lines, eventually in software: CONVOLUTION.



Echo

Originally used tape loops with separated playback and record heads.

Now easily done digitally.

Compression

Intentional *linear* adjustment of volume.

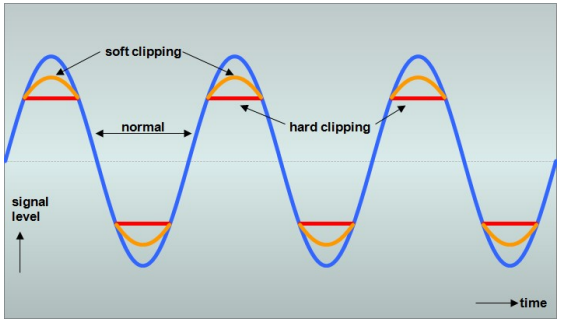
Automatic Gain Control (AGC), to keep perceived volume the same.

Dolby Noise Reduction: reduced noise in analog recording and transmission systems by boosting quiet parts.

Compressors common in mixing/mastering. Can be M/S for stereo, so that it reacts to the M (L+R) channel, to avoid moving the stereo image. Can be triggered by certain frequencies, such as a “de-esser” for removing sibilants (s, z, sh).

Limiter

Similar to a compressor, except that the limiter compresses only signals that exceed the specified level to lower unnecessary peak signals.



Distortion:

Intentional *non-linear* treatment of signal.

Clipping, hard (digital, solid state) vs. soft (vacuum tubes).

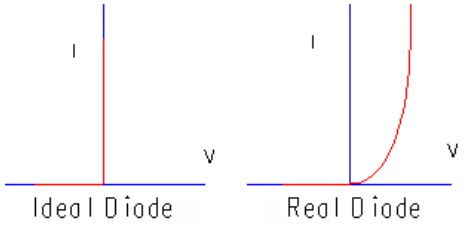
Introduces new harmonics to single pitch signals.

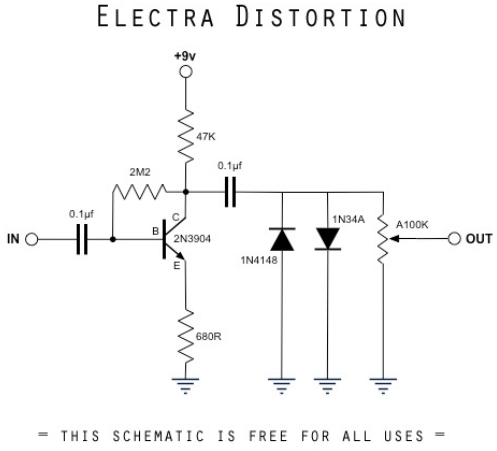
Introduces new pitches to multi-pitch signals, because pitches interact non-linearly

Overdriving speakers, combines nicely with intentional runaway feedback (Hendrix).

Causes *sustain*, as note takes longer to die out before get dropping below the clipping point.

"Fuzz box" in 1960's using non-linearity of diodes.





Analog Synthesis

Theremin

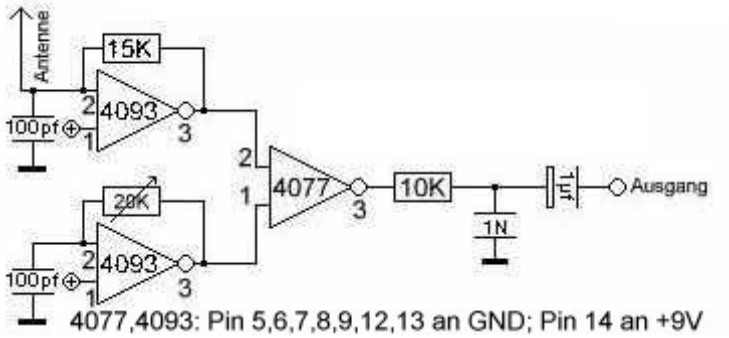
Léon Theremin 1920, Soviet research into proximity sensors, patented 1928 in US, sold to RCA.

Operates by generating beat frequency between two oscillators, with one of the oscillators having an antenna attached to one of the plates of the timing capacitor.

Oscillators lock to each other through the power supply when hand is not near antenna.

Beach Boys *Good Vibrations*.

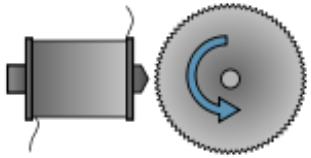
https://www.youtube.com/watch?v=K6KbEnGnymk



Hammond Organ

Laurens Hammond, first produced in 1935.

Three rotating a metal “tonewheels” near an electromagnetic pickup.



Not a tempered scale! Each of the 3 diminished 7th chords (4 notes separated by minor 3rds) is perfectly in tune.

Slide Bars to control harmonic structure of each note.

Leslie Rotating speaker introduces tremolo and vibrato (Doppler shift).

Jimmy Smith jazz organist,

https://www.youtube.com/watch?v=MAT3ljM-Vec (8:08)

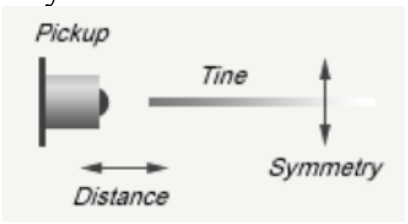
countless rock ‘n roll classics.

Fender Rhodes Electric Piano

Invented by Harold Rhodes during World War II to create a piano that injured soldiers could play while lying in a hospital bed.

Piano counterpart to the Electric Guitar.

Asymmetric Sound Bar or “tine” (tuning fork) with little weight on small shaft to tune.



Very expressive response to touch.

Chick Korea, *Spain*.

https://www.youtube.com/watch?v=sEhQTjgoTdU (4:50)

Wurlitzer

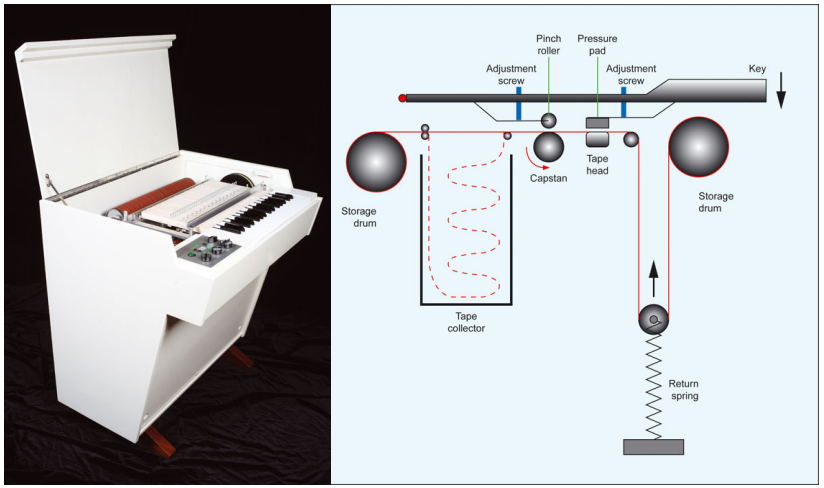
1954

Steel reeds.

from applied-acoustics.com

from Vintage Vibe

Melatron



Manufactured 1963-1970.

Bank of tape strips controlled by a keyboard, with tape physically pushed against tape.

Strips pulled back to beginning after key released, to allow recorded attack.

Analog predecessor to digital sampling.

Moody Blues, King Crimson.

https://www.youtube.com/watch?v=KdYea33BxN0

Electric Organs

First discrete transistorized organs in mid 1960's, used by the Doors, Beatles, etc.

Oscillators with divide-by-2 flip-flops to produce octaves.

Square waves, with passive filters, tremolo and vibrato.

https://www.youtube.com/watch?v=D0DTLAMXOsc

Vox

Farfisa

Moog Synthesizer

Evolved from Analog Computers.

Robert Moog, physicist, produced first commercial model in his basement in 1964.

Competitor was Buchla Synthesizer, invented simultaneously.

Voltage Controlled Amplifier (VCA), Oscillator (VCO), Filter (VCF). Attack, sustain, decay envelope.

Wendy Carlos, *Switched on Bach*.

https://www.youtube.com/watch?v=Yn0HAWX1TSA

Keith Emerson (Emerson Lake and Palmer) purchased the 2nd Moog after hearing Switched on Bach.

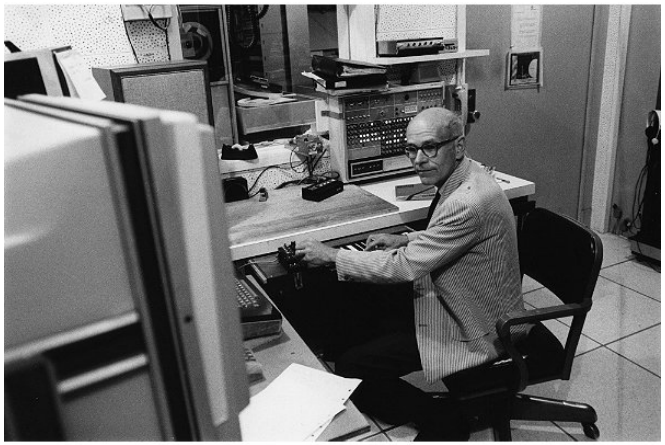
https://www.youtube.com/watch?v=epJ03N31MYk

Stevie Wonder.

https://www.youtube.com/watch?v=zOW2UfvWWAE

Digital Synthesis and Computer Music

Nice reference: The Oxford Handbook of Computer Music



Max Matthews at Bell Labs 1957, "father of computer music", wrote first computer music language "MUSIC-N" (MUSIC I, II, III etc). Also early speech synthesis,

Original synthetic voice singing

http://www.youtube.com/watch?v=41U78QP8nBk (1:00)

Adapted to movie. 2001: A Space Odyssey (1968).

http://www.youtube.com/watch?v=TakqPZu4dEw

Barry Verco at MIT (now Media Lab), carried it on with Music 360 (IBM 360), Music 11 (DEC 11 – Unix) now called CSound (open source).

founded MIT Experimental Music Studio (1973)

co-founded MIT Media Lab (1978)

"Synthesism" (1970) http://www.youtube.com/watch?v=veE38gmGg4U ("from another planet").

I was a staff member for Barry Verco at MIT in 1978. Worked on prototype graphical interfaces.

http://www.vialab.org/main/Publications/pdf/Silverman_RealPaper_1979.pdf

Capabilities at that time

Sampling

Modeling analog synthesizers with computers

Additive Synthesis, initial attack is important

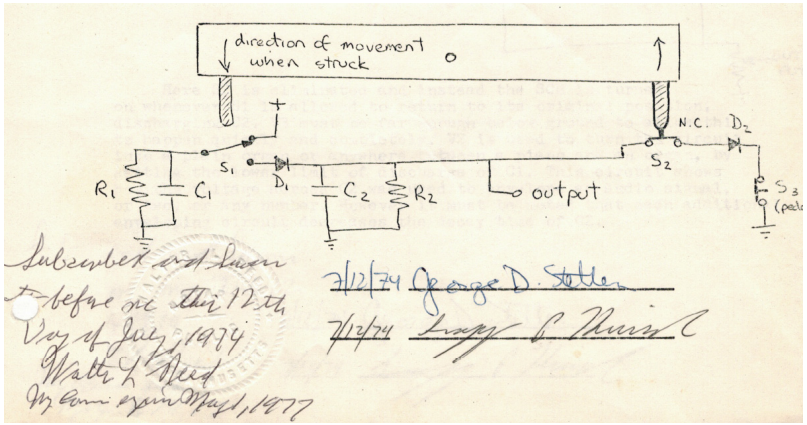
http://en.wikipedia.org/wiki/Additive_synthesis (nice sound files)

Frequency variation of harmonics. Can produce nausea.

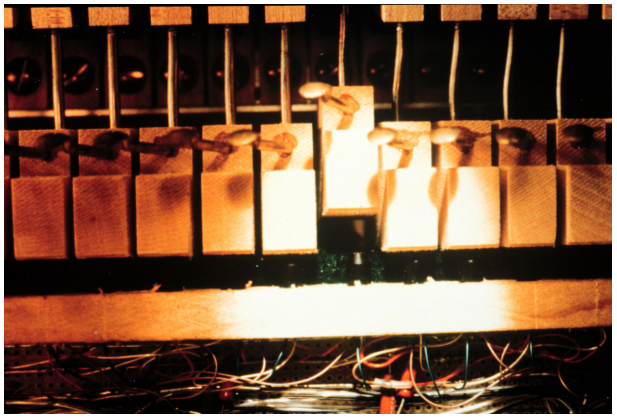
The ever-increasing pitch example.

Needed better input devices

Touch sensitivity (MIDI specifies which instrument, which note, and *how loud*).



Touch sensitive piano key, 1974



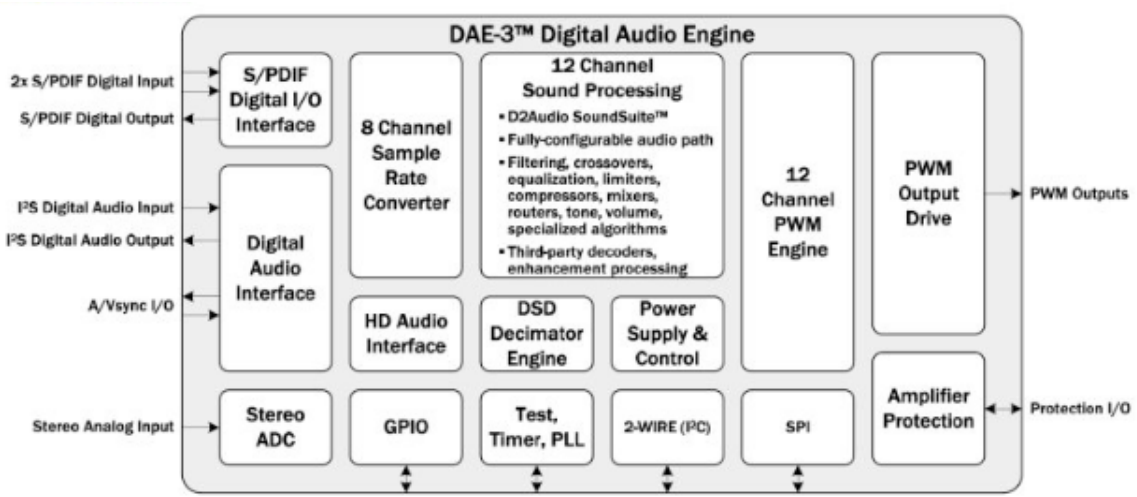
Infrared piano key sensor, 1979

Wanted to merge Composing and Performing.

Computer music was not real time

Had to compile sound files for hours for a few seconds of music.

Digital Signal Processors (DSP's) introduced in 1980's, permitted real time operation.



Now has come full circle with multi-core computers fast enough themselves for a good deal of software synthesis and processing.

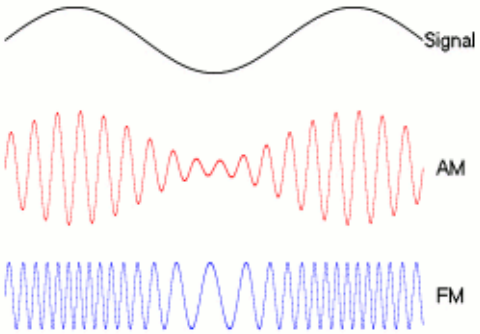
Computers still have too much lag in input/output for software synths to be free from lag. Hardware based instruments (like our Korg SV1) are still superior.

FM Synthesis

John Chowning founding director in 1975 of the Center for Computer Research in Music and Acoustics (CCRMA) at Stanford.

By frequency modulating at the audio frequency itself, or harmonics thereof, a wide variety of timbers could be simulated, including 'metal striking' or 'bell like' sounds, with very few parameters. The sidebands include negative frequencies, which fold back to become changing amplitudes.

Yamaha DX7, 1983, Stanford's most lucrative patent at the time.



http://www.youtube.com/watch?v=nmp9yqhsjqg&list=RD02qPPg12eriIo

Chet Gnegy

http://www.youtube.com/watch?v=AcFh89b3-0o

Ge Wang, Assistant Professor in CCRMA, orchestras of iPhones, https://www.ted.com/talks/ge_wang_the_diy_orchestra_of_the_future?language=en, (6:15)

https://ccrma.stanford.edu/~ge/cv.pdf

Modeling

Computers and DSP now fast enough to simulate mechanical instruments.

Models can be 3D (e.g. Finite Element Analysis) or simply span the entire space of possible outputs.

What is missing?

- Realistic biomechanical interfaces to the human performer.
- Realistic “infinite-array” surfaces to produce sound.
- Centuries of development.
- Magical constraints of physical systems?

How long does it take to accept a new instrument?

- Manufacturers must develop and produce.
- Performers must master.
- Composers/improvisers must create repertoire.
- Audiences must learn to appreciate.