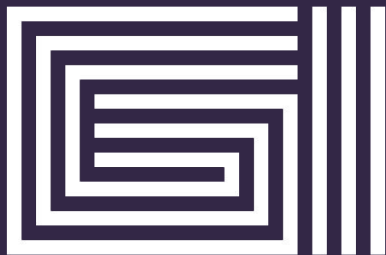


Ancient Game Audio

The Invention of Sound for Video Games

Jakob Schmid
Geometric Interactive



GEOMETRIC INTERACTIVE

2026-10-01



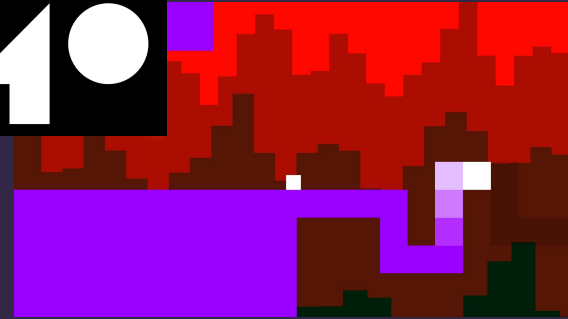
Who am I?

Computer scientist, Aalborg University, Denmark

19 years game development experience

Audio programmer on INSIDE

Geometric Interactive co-founder / audio director



Topics

One Way to Understand Video Game History

Audio Hardware 1970-1980s



One Way to Understand Video Game History

My frame of analysis for this talk:

Video games represent a dialogue between artistic ideas and external constraints

Let's look at an example

Ideas / Constraints Dialogue Example



Artistic idea:
An action game with fantasy art like Boris Vallejo

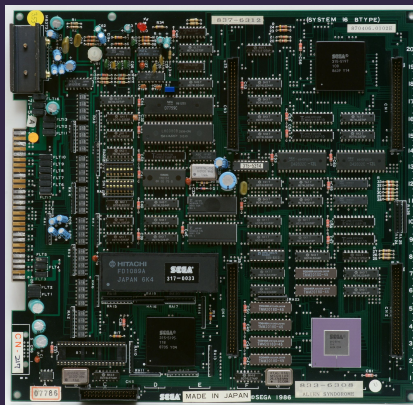


The Two-Headed Beast (Vallejo 1984)

Ideas / Constraints Dialogue Example



Artistic idea:
Fantasy art like Boris Vallejo

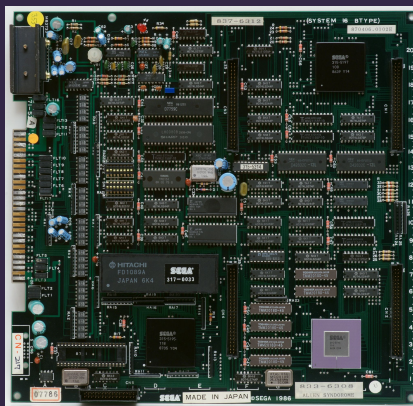


Hardware constraints:
Sega System 16 (1985)

Ideas / Constraints Dialogue Example



Artistic idea:
Fantasy art like Boris Vallejo



Hardware constraints:
Sega System 16 (1985)



End result

Title : Golden Axe
Platform : Arcade (System 16)
Year : 1989
Developer : Sega

How can we observe this dialogue?

Noticing Hardware Constraints



Title : Zombies Ate my Neighbors
Platform : Sega Mega Drive
Year : 1993
Developer : Lucasfilm Games

What graphical constraints can we see here?

Noticing Hardware Constraints

Background graphics are constrained to 8x8 grid!



Noticing Hardware Constraints



Title : Congo Bongo
Platform : ColecoVision
Year : 1984
Developer : Sega



Title : Girl's Garden
Platform : SG-1000
Year : 1985
Developer : Sega



Title : Penguin Adventure
Platform : MSX
Year : 1986
Developer : Konami



What do these games have in common?

Noticing Hardware Constraints

256x192 resolution with 15-color fixed palette
32 single-color sprites



Why do 3 games for 3 different platforms have exactly the same graphics constraints?

TMS9918

MSX, ColecoVision, Sega SG-1000
Same graphics chip: TMS9918



Platform : MSX
Year : 1983
Developer : Microsoft/ASCII Corp



Platform : ColecoVision
Year : 1982
Developer : Coleco Industries



Platform : SG-1000
Year : 1983
Developer : Sega

Ideas / Constraints Dialogue

- Hardware constraints affect the execution of ideas
- Same for development constraints
- Sometimes they inhibit, sometimes they inspire

Disclaimer

- I don't see constraints as a negative
- I impose artificial constraints on myself (and others) as inspiration
- Many of the developers, sound designers, composers we will talk about today agree



Video Games 1970-1980

- Arcade games was the cutting edge of the medium
- Sound was essential



Mechanical Arcade Games

Existed since early 1900s

Pinball machines and other electro-mechanical arcade games



Title : Ace High
Year : 1957
Platform : Pinball
Developer : Gottlieb



Title : Knock Out Fighters
Year : 1928
Platform : Arcade machine
Developer : National Novelty



Title : Sky Raider
Year : 1958
Platform : Arcade machine
Developer : United

Mechanical Sound: Pinball

Physical sounds

- Ball
- Flippers
- Bumpers

Electro-mechanical sounds

- Clicks
- Bells



Title : Old Chicago
Year : 1976
Company : Bally
Sound : Electro-mechanical

Electro-Mechanical Pinball Sounds

How do the electro-mechanical sounds work?

Let's ask a YouTube guy



Title : Aztec
Year : 1976
Company : Williams
Sound : Electro-mechanical

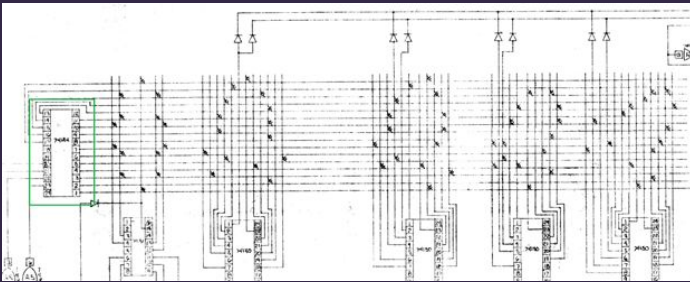
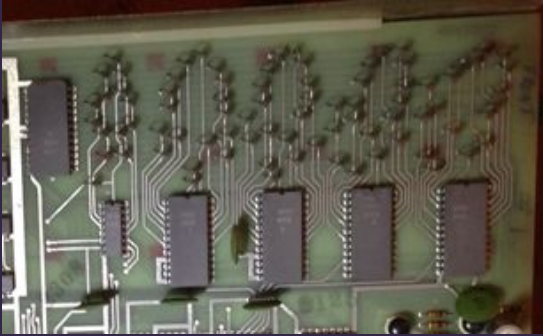
First Arcade Video Game



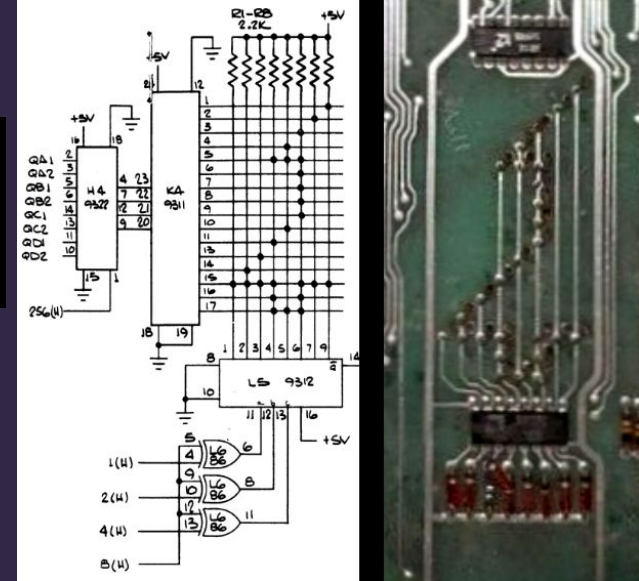
Title : Computer Space
Year : 1971
Company : Syzygy Engineerings

How were games designed in the early 1970s?

No CPU, No Software, No ROM Data



Title : Computer Space
Year : 1971
Company : Syzygy Engineerings



Title : Space Race
Year : 1973
Company : Atari

Let's look at a game in detail!

Pong

- Two-player tennis game
- Controlled with analog knobs
- Assigned as an exercise for new hire Allan Alcorn
- Designed in 2 months
- First commercially successful video game, sold 35,000 units
- Profit 17.5 m\$ (~ 135 m\$ in 2026) on arcade units alone



Title	: Pong
Year	: 1972
Platform	: Arcade machine
Developer	: Atari

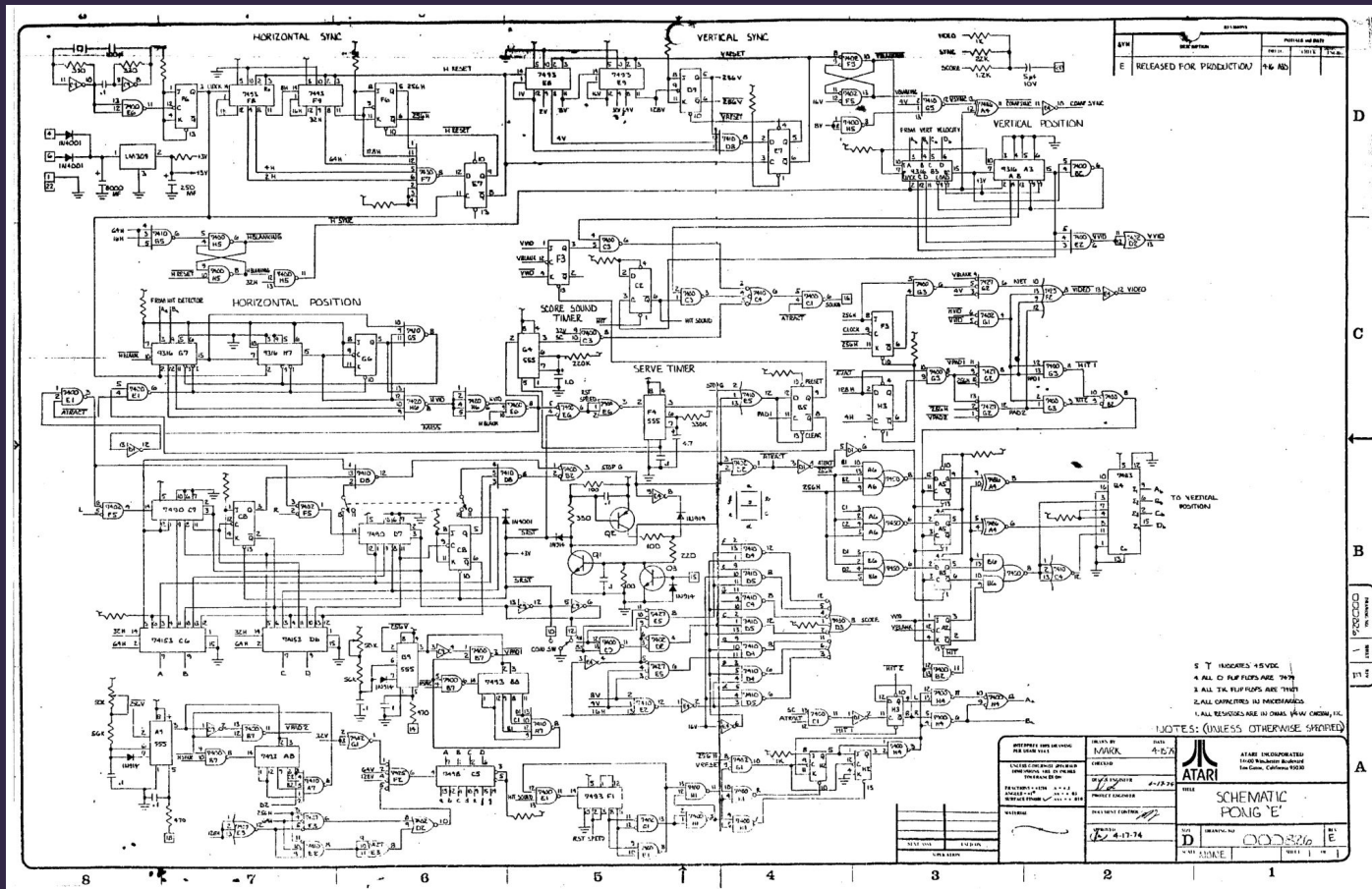
How was it designed?

Pong

This is Pong:

- Game logic
- Art
- Sound
- Video controller

Everything!



Does Pong have sound?

Pong Sound

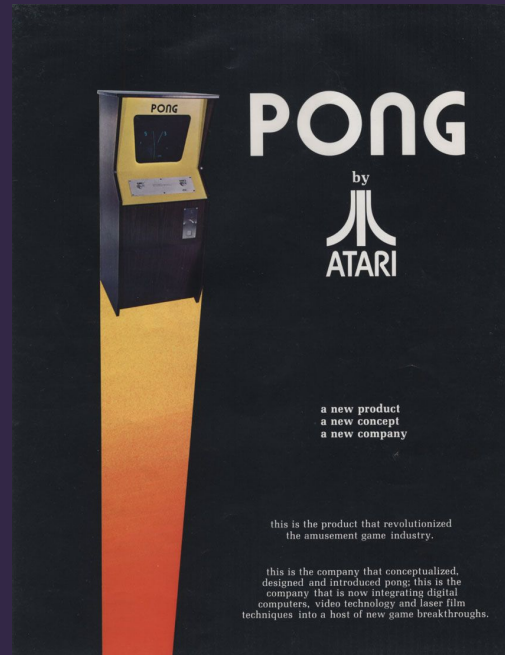
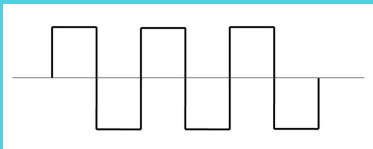
Pong has 3 sounds:

TOP BOTTOM HIT	(short 246 Hz square wave)
PADDLE HIT	(short 592 Hz square wave)
SCORE	(longer 246 Hz square-ish wave)

AUDIO TERMS

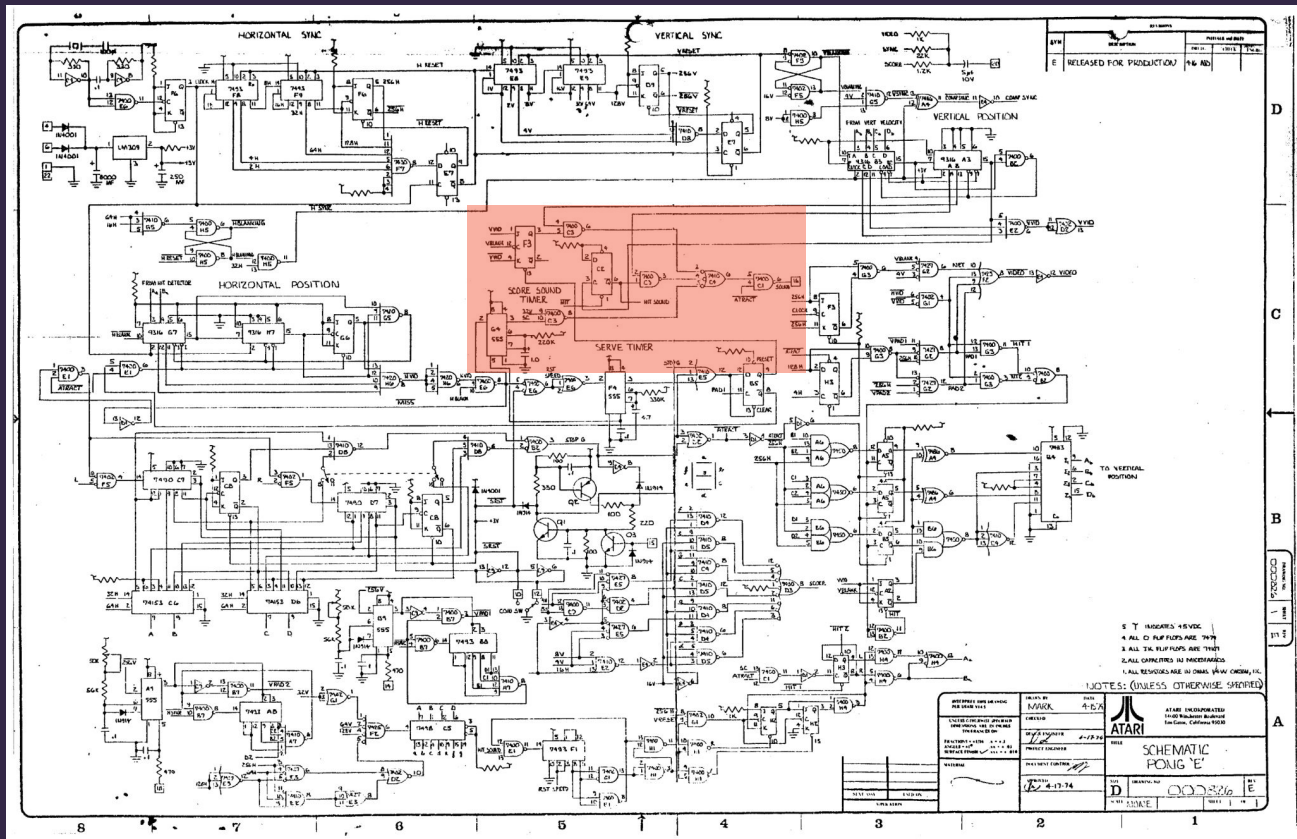
Hz measures frequency of signals. The higher the value, the more high pitch the sound.

*A **square wave** is an example of a signal with a well-defined pitch.*



Title	: Pong
Year	: 1972
Platform	: Arcade machine
Developer	: Atari

Pong Sound



How does it work?

Sound Circuits

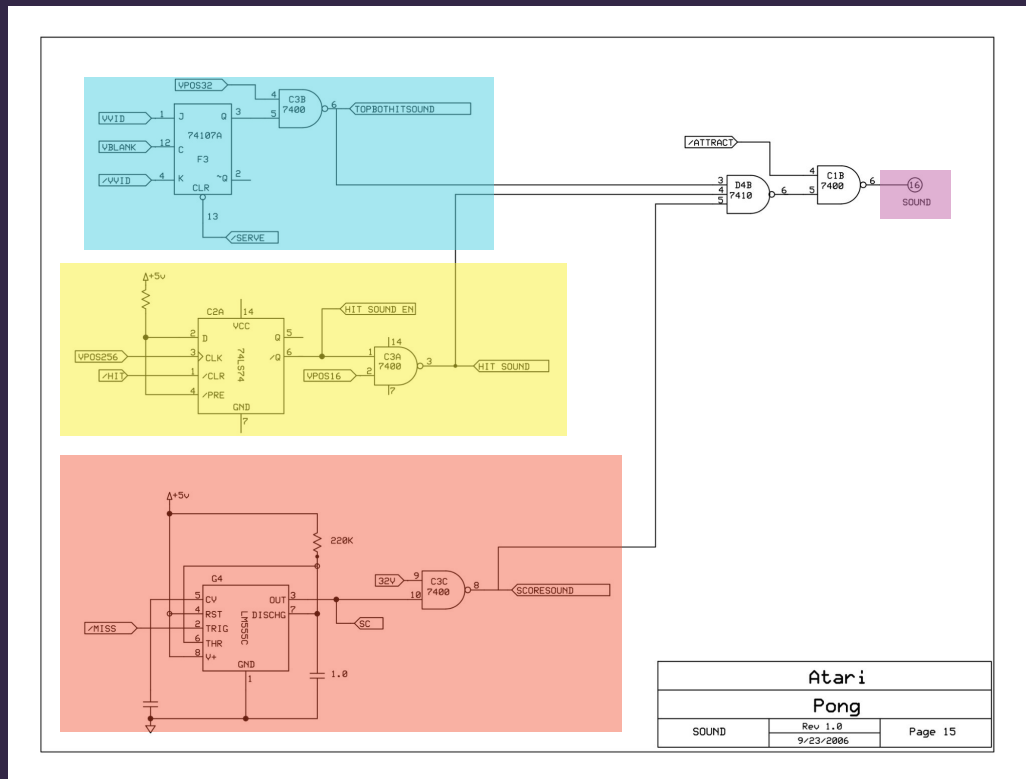
The three sounds each have their own circuit:

TOP BOTTOM HIT

PADDLE HIT

SCORE

They are digitally mixed and sent to
SOUND output



Let's look at the SCORE sound

SCORE Sound

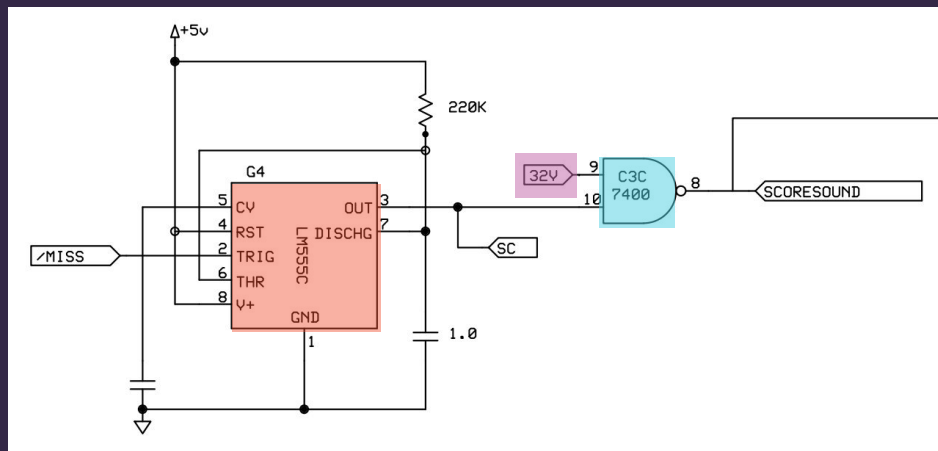
Components:

555 : timer

7400 : NAND (NOT AND operation - works here as a binary AND)

- 555 triggered by /MISS when ball goes out of bounds
- OUT goes high for 242 ms
- Gates 32V signal to output
- 32V is a 246 Hz digital square wave generated by the video controller for vsync

The output is a 1-bit digital signal



And that's it for this sound!

Digital Hardware Synthesis

- No CPU, no software, no ROM data
- Designed like a computer
- Implemented using discrete TTL logic
- 1-bit digital audio, 3 different sounds
- Generated from video sync clocks

How did the designer approach the audio?

Idea / Constraints

Al Alcorn, designer of Pong:

I was running out of parts on the board.

Nolan wanted [...] the approving roar of cheering people when you made a point.

Ted Dabney told me to make a boo and a hiss when you lost a point [...].

*I said, "Screw it, I don't know how to make any one of those sounds. I don't have enough parts anyhow."
Since I had the wire wrapped on the scope, I poked around the sync generator to find an appropriate frequency or a tone.*

So those sounds were done in half a day. They were the sounds that were already in the machine.



Analog Hardware Synthesis

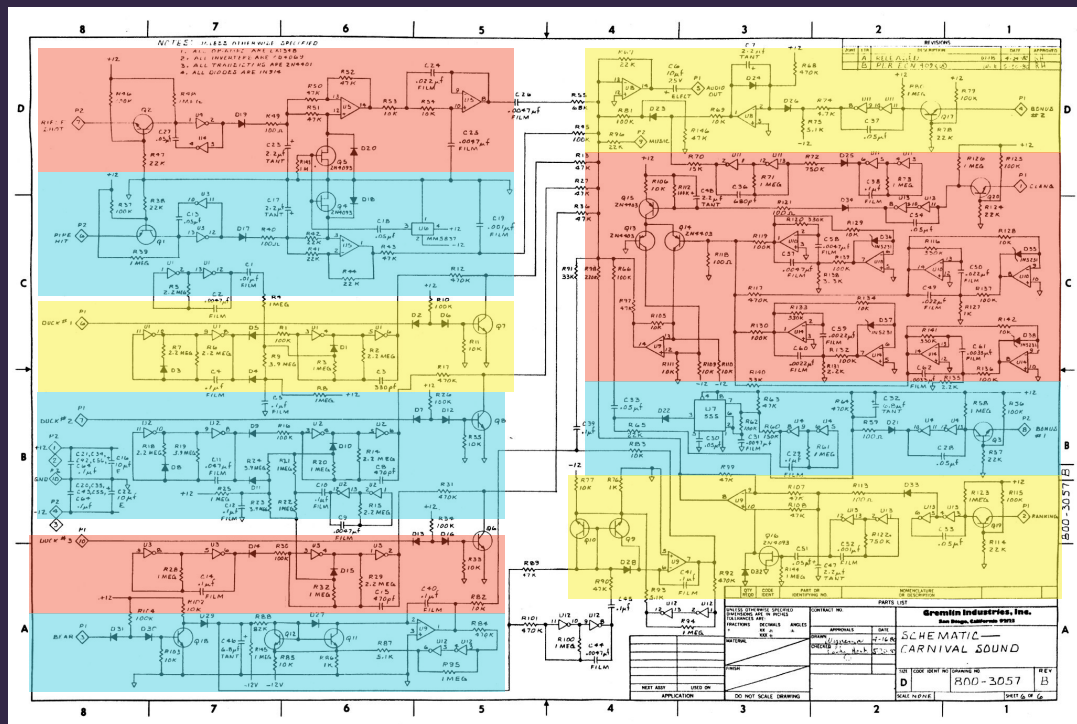
- Carnival by Sega (1980)
- Gallery shooting game
- Capture experience of going to a traveling carnival
- Runs on a Z80 CPU
- In-game music toggle!



Title	: Carnival
Year	: 1980
Platform	: Arcade machine
Developer	: Sega
Sound	: Analog H/W Synthesis

Carnival Sound Board

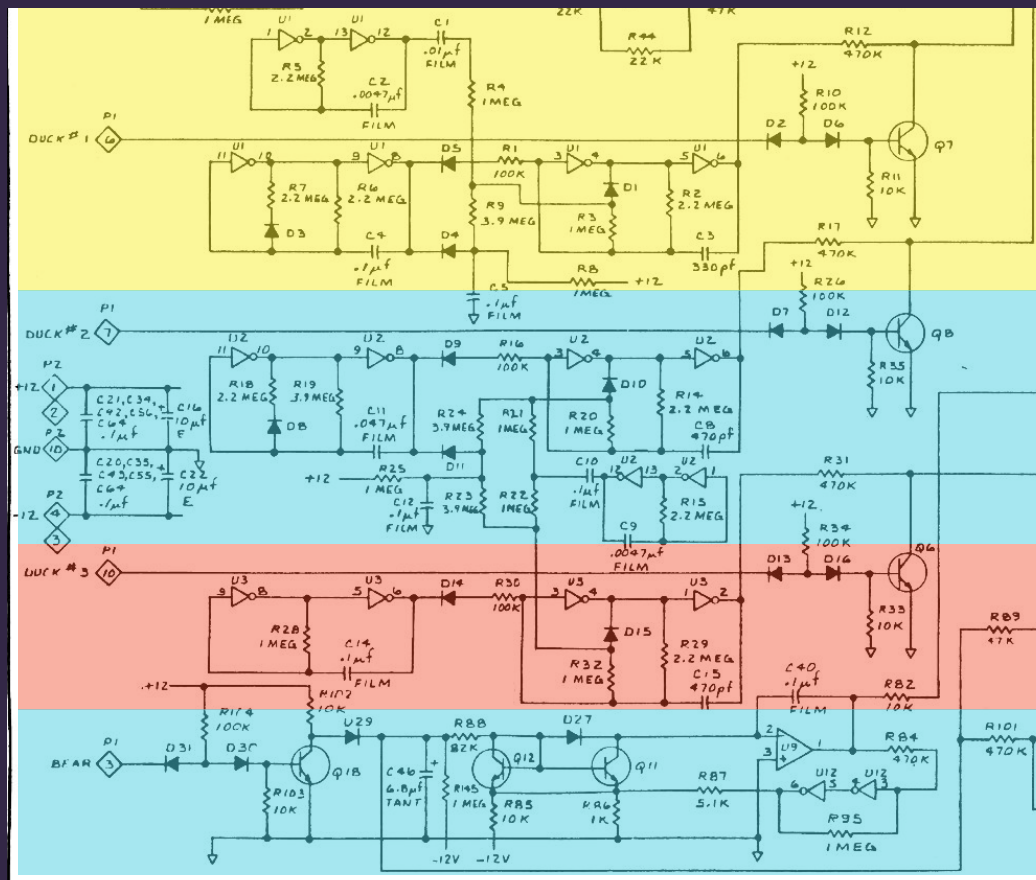
- Sound only, music is its own board
- Individual sounds triggered on left and right sides
- 10 sounds, 10 analog circuits



Let's look closer!

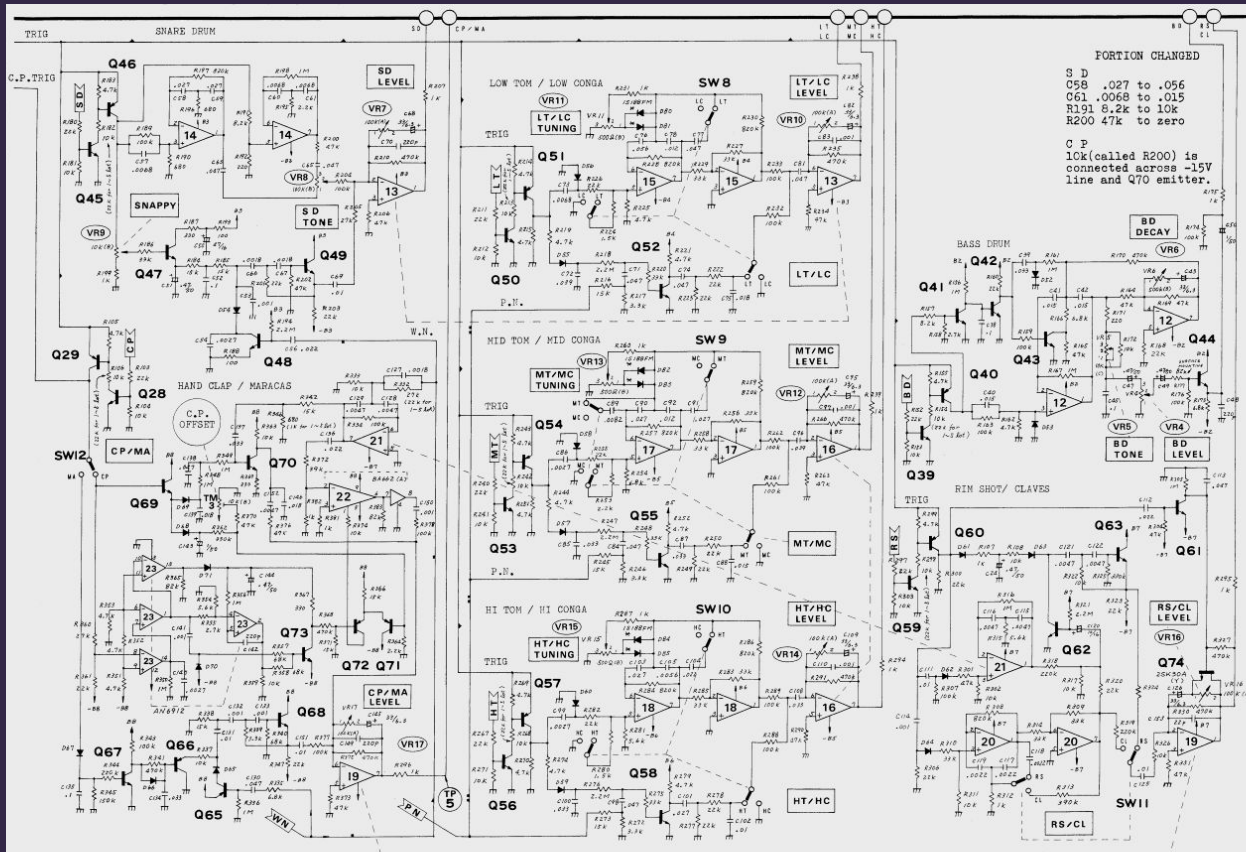
Carnival Sound Board

- Each sound has its own analog circuit
- Using amps, inverters, transistors, diodes
- Here we see sounds DUCK #1-3 and BEAR



This reminds me of something...

Analog Hardware Synthesis



What is this?

Roland TR-808



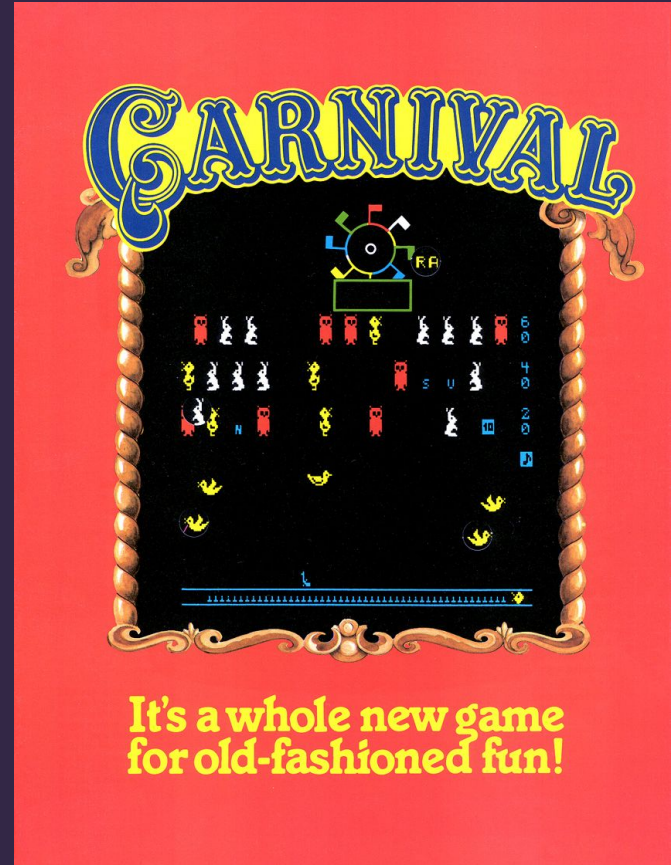
How was the Carnival audio developed?

Idea / Constraints

I couldn't find information about the development of Carnival.

But we can speculate:

- Unique hardware was designed for every sound effect.
The designer of Carnival seemingly wanted players to have a realistic shooting gallery experience
- Music was added to enhance carnival ambience



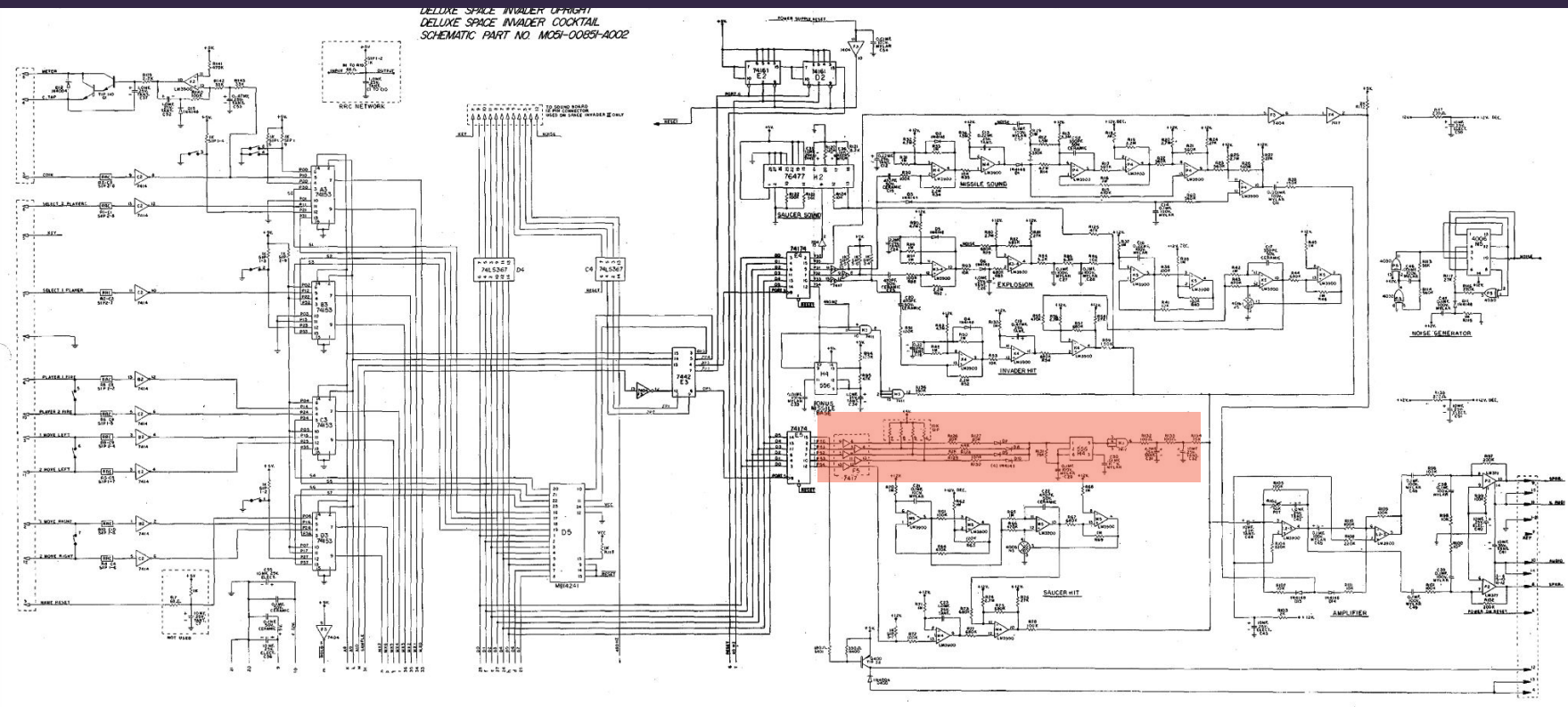
Music Synthesis

- Space Invaders!
- Immensely succesful worldwide
- Generated 4 b\$ in 1978-1982 (~ 14 b\$ in 2026)
- Analog sound board similar to Carnival



Title	: Space Invaders
Year	: 1978
Platform	: Arcade machine
Developer	: Taito
Sound	: Analog H/W Synthesis

Space Invaders Music



How's that music?

Space Invaders Music

- 556 is a timer (like 555 in Pong)
- Works as an oscillator in this configuration
- Generates pitch based on the input resistance
4 different resistor combinations are selected

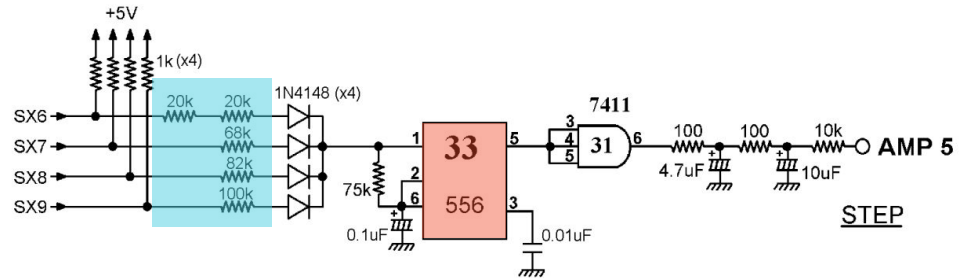
Generating frequencies:

34.9 Hz

30.0 Hz

28.1 Hz

25.8 Hz



What are these frequencies?

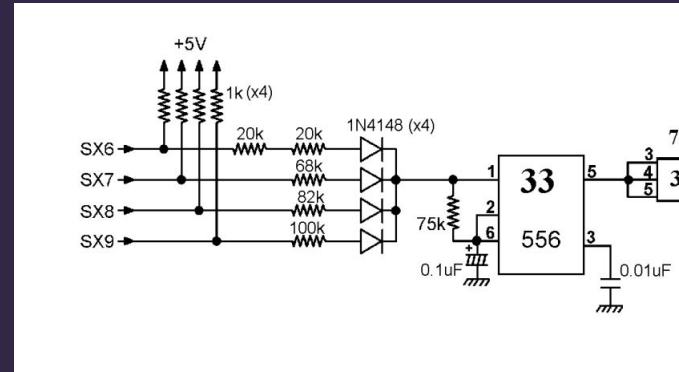
Space Invaders Music Notes

34.9 Hz ~ C#1

30.0 Hz ~ B-0

28.1 Hz ~ A-0

25.8 Hz ~ G#0



And the tempo of the notes?

Adaptive Tempo

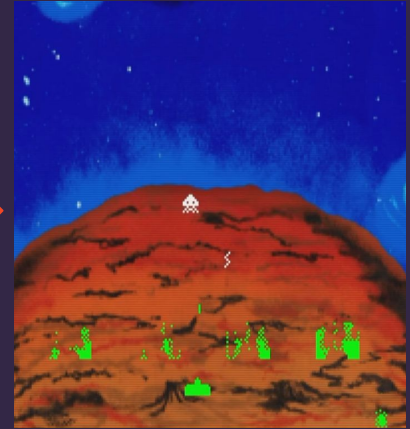
- Tempo increases as gameplay gets faster
- Starts at 69 BPM and accelerates to 690 BPM (when shooting the final alien)

AUDIO TERMS

BPM (*Beats Per Minute*) is used to measure frequency, most often rhythms. 60 BPM = 1 beat/second.



69 BPM



690 BPM

How were sounds and music designed?

Idea / Constraints

Taito audio engineer Michiyuki Kamei:

- Worked on 'Blue Shark' and 'Space Invaders' at the same time, around 4-5 months.
- Modified 'Blue Shark' sound board for 'Space Invaders' due to time pressure.
- Shot sound has most components, because of its importance
- Music originally played at higher pitch, but was lowered to fit scary cabinet art. Inspired by John Williams' 'Jaws' theme (1975).
- Cabinet speakers broke from too much bass. Taito employees had to go and replace speakers with stronger ones.



Inventing Ambience

- Ambience was rarely used in arcade games, possibly because arcades tend to have their own loud ambience already.
- More common in home computer games
- More common in European games than US/Japanese games

AUDIO TERMS

Ambience is the background sound in a particular location, such as wind or an electrical hum.

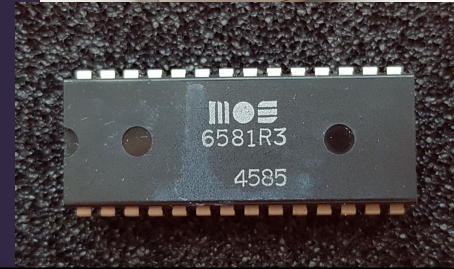
Which home computer?

Commodore 64

The Commodore 64 is the best selling home computer in history (>12 million units)

Its sound chip is called the SID

- SID is a Programmable Sound Generator (PSG)
- Fixed-function sound generation
- Digital hardware synthesis in a convenient chip



Title	: 6581
Year	: 1982
Developer	: MOS Technology
Type	: Digital oscillators Analog filter
Used in	: Commodore 64

Let's see the SID in more detail

Commodore 64 SID Chip

- 3 digitally controlled oscillators
- Selectable waveforms: pulse, triangle, saw, noise
- Can change waveform on the fly
- Ring modulation, oscillator sync
- Multimode filter: low-, high-, bandpass (6dB/12dB rolloff)
- 3 Envelope generators



AUDIO TERMS

Ring modulation and oscillator sync are ways of combining two oscillators to generate new sounds

Low-pass filters remove high frequencies. High-pass filters remove low frequencies. Band-pass filters remove high and low frequencies.

Pulse, triangle, and saw waves are different types of oscillators that sound different.



Inventing Ambience

The SID chip was very flexible, and was capable of synthetic ambience.

Enjoy these examples!



Title	: Arctic Shipwreck
Year	: 1983
Platform	: Commodore 64
Developer	: F451 Software
Sound	: SID

Idea / Constraints

We can speculate about developer ideas:

- Ambiences simulating real world phenomena
- Waves, wind, thunder, crowd noise, room tones

Harsh constraints:

- SID chip has 3 oscillators and a filter for all sound
- Games need sound effects, so either ambient or music!



Software Synthesis

- The availability of CPUs and ROM chips enabled software synthesis
- In the mid-1970s, arcade manufacturers started using CPUs

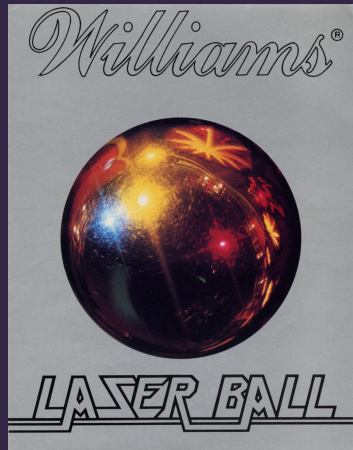
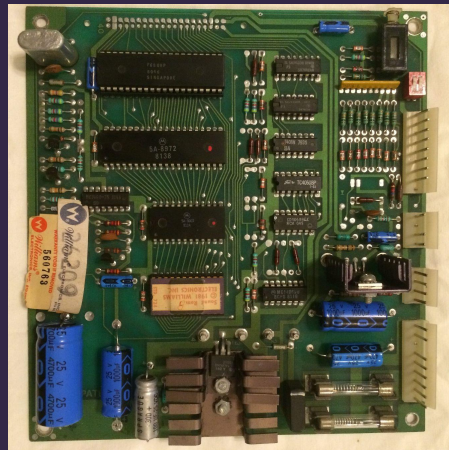
AUDIO TERMS

***Synthesis** is generating an audio signal.
Software synthesis is generating audio signals through code.*

Can the CPU be used to generate sound?

GWave

- Software synthesis sound board
- Eugene Jarvis created for 'Laser Ball' (1979)
- MC6800 CPU running code from ROM
- Renders 8-bit sound output



Title : Laser Ball
Year : 1979
Company : Williams
Platform: Pinball
Sound : Software synthesis

How is the hardware designed?

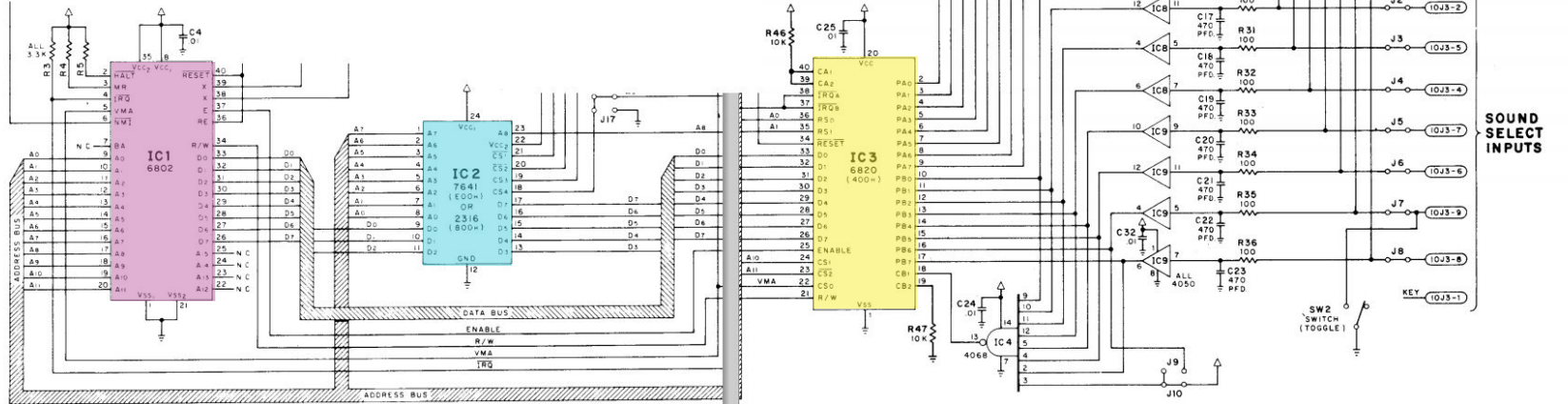
GWave Sound Board

MC6802 Processor

MC1408 8-bit D/A converter

MC6821 Peripheral Interface Adapter

Harris 7641 PROM: 2048 bytes



Defender

- Super-intense scrolling shooter from 1981
- Reused Laser Ball GWave sound board
- ROM was updated, new sounds



Defender Sound ROM

2048 bytes for all Defender audio



What's in that ROM?

Defender Sound ROM, 2048 bytes

[illegible]

what is this madness?

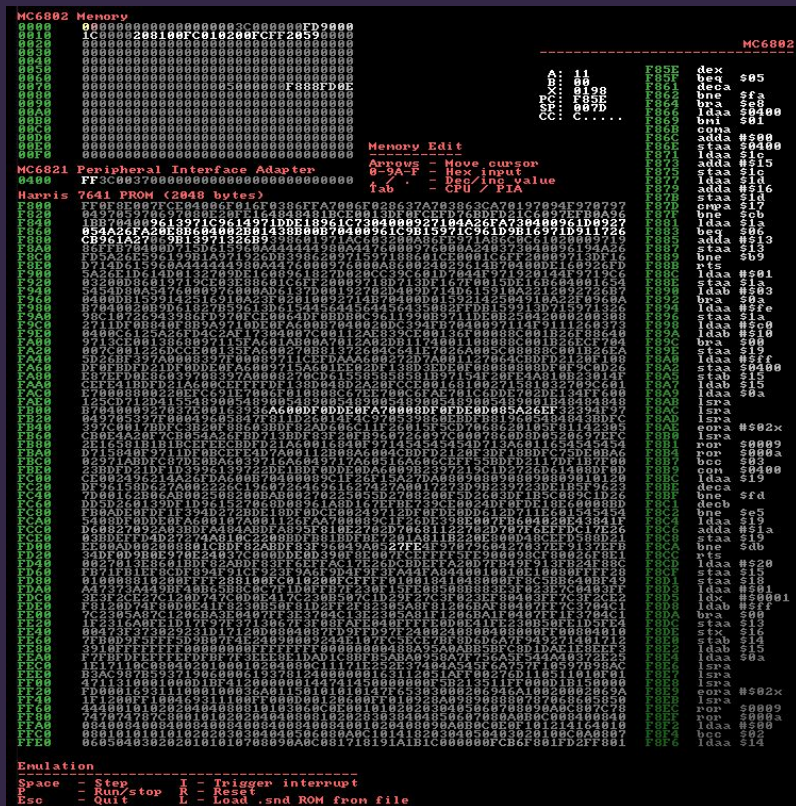
Defender Sound ROM Map

CLEAR VARS	SYNTH 1 (BOOT)
SYNTH 2 (PWM?)	SYNTH 3
SYNTH 4	SYNTH 5
SYNTH 6 (PWM?)	SYNTH 7
SUPPORT .. SUPPORT	SYNTH 8
SYNTH 9, USES SYNTH 10	SUPPORT .. RESET VARS .. SUPPORT
SYNTH 10	SUPPORT .. INTERRUPT HANDLER: SELECT SOUND .. SU
PPORT	INTERRUPT HANDLER: SELECT SOUND ..
BOOT CODE ?	
WAVE TABLES, FREQUENCY TABLES	

Can we see this while the game is running?

defendemu

- Wrote Defender sound board emulator in 2015
- Emulated just enough of the MC6800 instruction set for a few sounds to play
- Active memory is highlighted



Idea / Constraints

On this game the memory was only 512 bytes for all program and data. It was this extreme memory crunch that inspired the Gwave wave table synthesizer.

[..] a sound could be characterized by a few bytes. To get further mileage, echo, distortion, LFO, and white noise systems were also employed at a cost of only a few extra bytes.

[..] the most brilliant sounds were often created by typing in random numbers for the parameters. Often incredible sounds were generated by inputting mathematically undefined values, such as echoing a sound "0" times. The crudeness and lack of bounds checking of the program allowed for mathematical wraparound and error accumulation that sounded ethereal.



How did Defender inspire me personally?

COCOON

- Synthesized ambient music
- Was this even possible?
- Defender was the main inspiration



What were my thoughts at the time?

Reverse Idea/Constraints Dialogue

- My constraints were chosen willingly
- The ideas came out of the constraints
- Constraints led to artistic framework for music and sound design

COCOON Artistic Framework

Ambient music

Real-time synthesized ambient music for puzzle gameplay

Vignettes

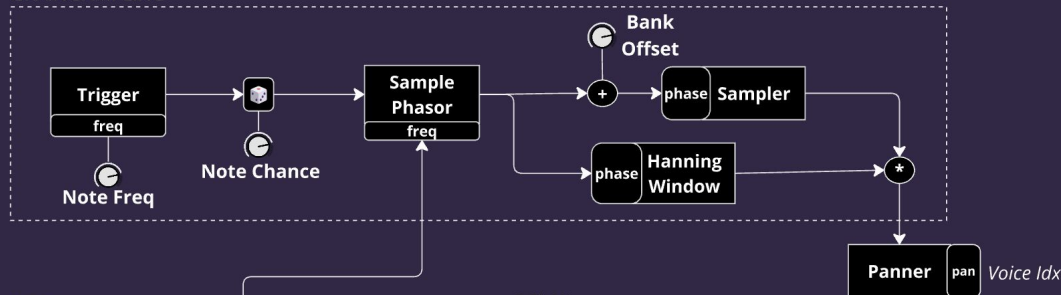
Pre-rendered synthetic music vignettes for big moments

Sound design

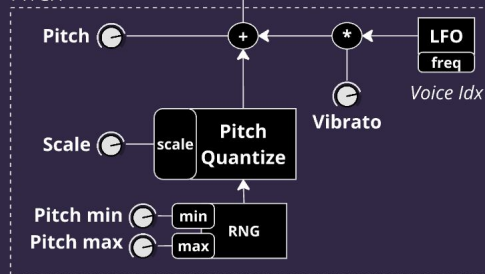
Pre-rendered synthetic sounds for all sound design

COCOON Synth Development

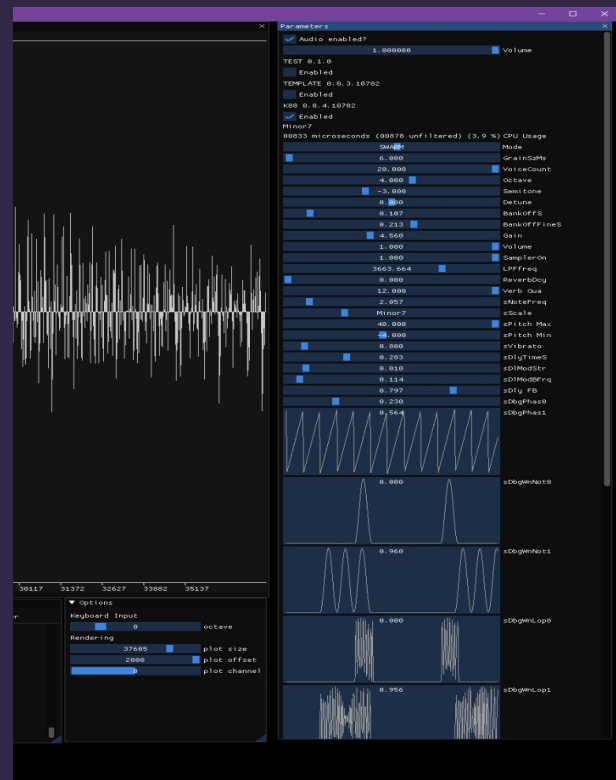
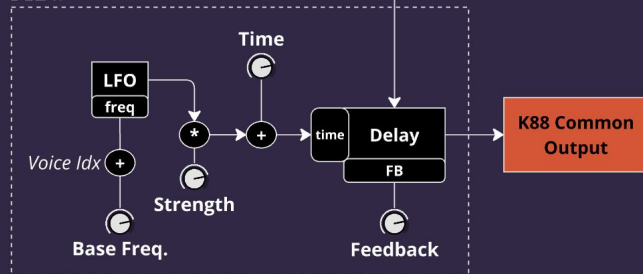
GRAIN SAMPLING



PITCH

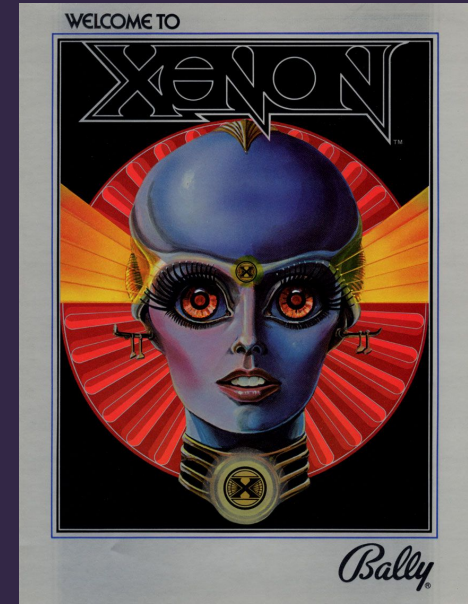


DELAY



Sampling

- Sample ROMs unrealistic during the 1970s due to cost
- From around 1980, expensive hardware was able to support sampling

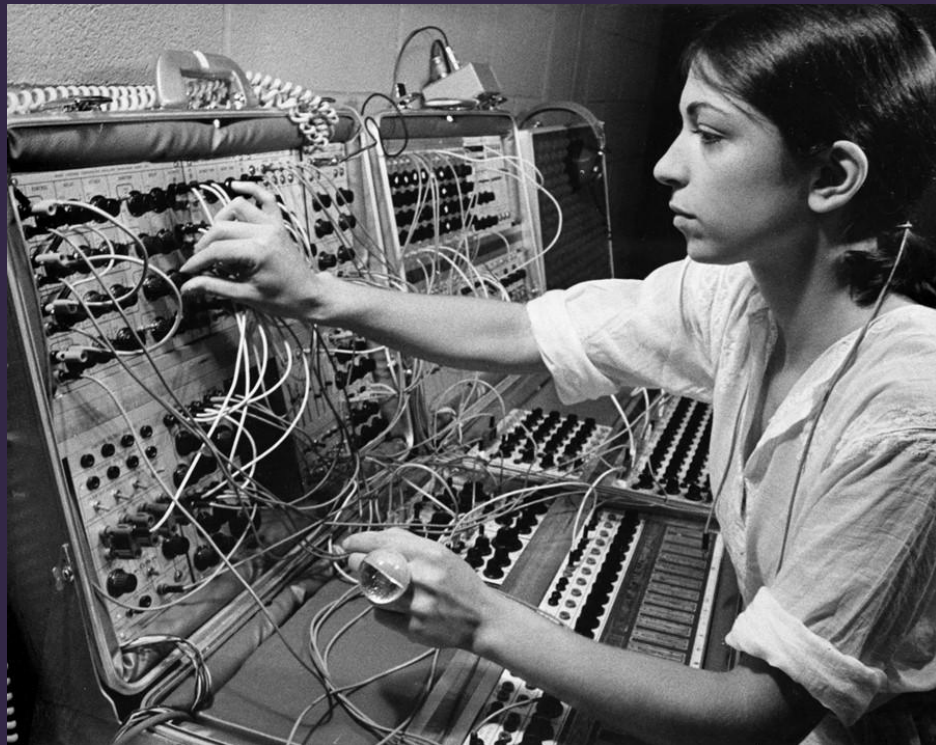


Title	: Xenon
Year	: 1980
Platform	: Pinball
Developer	: Bally
Sound	: Samples, AY-3-8910, mechanical

Xenon

Very ambitious pinball machine project
by Bally Manufacturing.

Sound design and music by
Suzanne Ciani



Three Different Audio Types

Xenon had 3 different types of audio tech:

- MC6802 and 7 ROM chips (40 KB in total including other data) for voice samples and adaptive sampled music
- Programmable Sound Generator (AY-3-8910) for sound effects
- Physical mechanical sounds: ball, flippers, bumpers

AUDIO TERMS

***Adaptive music** is music that reacts to changes in game state.*

Idea / Constraints

The idea of using short grunts and groans came to me when I watched people play the game. The way people expressed their frustrations or their involvement with the game, and I wanted the game to [...] talk back to the people playing.

The sound was designed to support the emotional levels and to be responsive to all the pinball gestures. [...] I saw that players were "performing" the game and thus the music!

The biggest challenge was how small the chip was, but limitations always inspire solutions. I was also the first female voice in a pinball game [...]



THE INDUSTRY'S MOST SOPHISTICATED VOICE PACKAGE ENERGIZES PLAYERS

From "Welcome to Xenon" the incredibly alluring Xenon girl instructs on shots, gives information on ball entries and entices players to "Try Xenon Again." The first female voice in the industry complements the intensity—building background sounds and the game's exciting stroboscopic infinity backbox. Xenon volume control is now conveniently located in the front door.



Inventing Voice Acting

What if you want voice acting but cheap
out on sampling hardware?

Inventing Voice Acting

What if you want voice acting but cheap
out on sampling hardware?

Title : Shark Attack
Year : 1980
Platform : Arcade
Developer : Pacific Novelty
Sound : 2 x AY-3-8910 + ?



SHARK ATTACK

TAKE A DIVER TO LUNCH

Sharks munch a bunch for lunch in exciting new shark/diver challenge!

- 19" Color Monitor with seawater background.
- It's Shark vs Divers.
- Divers appear in squadrons of four.
- Screams of pain are heard as shark munches on divers.
- Bonus after shark eliminates 7 squadrons.
- Personal involvement ... high scoring player initials high score to date.

KEEP YOUR EYE ON GPI

GPI Game Plan, Inc.
1515 Fullerton Ave. Addison, IL 60101
Phone: 312/628-6200 Telex: 26-6098

THRUST and MUNCH...
the bottom line is profit
you can trust!

SHARK ATTACK

Divers talk to each other.
Heartbeats race as danger mounts.
Shark control ... adjustable to 3, 4 or 5 sharks per game.
Challenge increases with player ability.
Service door exposes all electrical components.
The bottom line ... more profit for you!

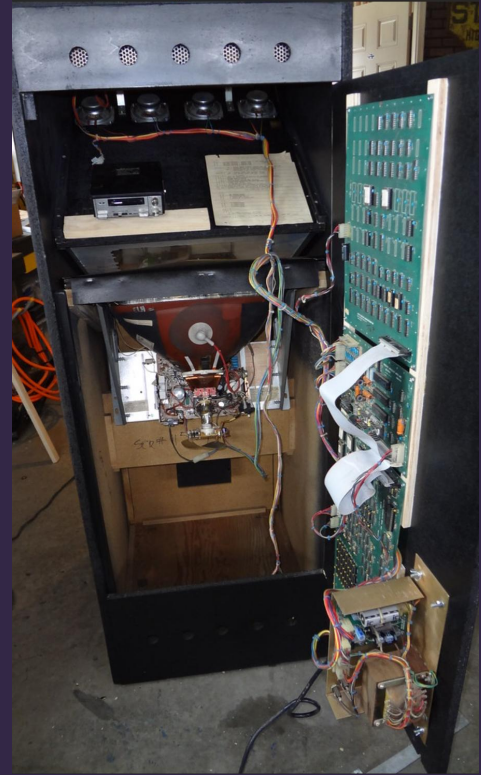
DIMENSIONS: 68" High x 30" Deep x 25 1/4"
WEIGHT: 275 Pounds Crated

GPI Game Plan, Inc.
1515 Fullerton Ave. Addison, IL 60101
Phone: 312/628-6200 Telex: 26-6098

Form No. 6-81-1211-25M Printed in U.S.A.

Tapes

You stick a car stereo cassette tape player
with auto reverse into your game
and enable/disable it from game logic



Idea / Constraints Dialogue

In the 1970-1980s game developers invented new types of audio for the medium:

- sound effects
- adaptive and interactive music
- ambience
- voice acting

Idea / Constraints Dialogue

The era imposed harsh time and hardware constraints on developers

But still, we saw developers:

- invent quick, effective solutions (Pong, Space Invaders)
- create new sound hardware from scratch (Carnival, Space Invaders)
- use/abuse limited hardware to create realistic sounds and great music (AY-3-8910, C64 SID)
- experiment with quirks, errors and limitations to create new sounds (Defender)
- create a sonic dialogue between human and machine (Xenon)
- stick a cassette player in an arcade cabinet (Shark Attack)

1980 vs. 2026

1980

Huge variety in sound reproduction technology

2026

Homogeneity in sound reproduction technology:

Digital software synthesis
(e.g. Wwise, FMOD, etc.)

However, huge variety in sound production techniques

Questions?

Thank you!

Web

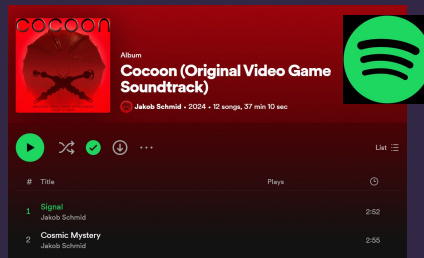
cocoongame.com

E-mail

jakob@schmid.dk

Slides will be here

schmid.dk/talks



AVAILABLE NOW ON



schmid-ddays-2026-10-01-1120.pdf

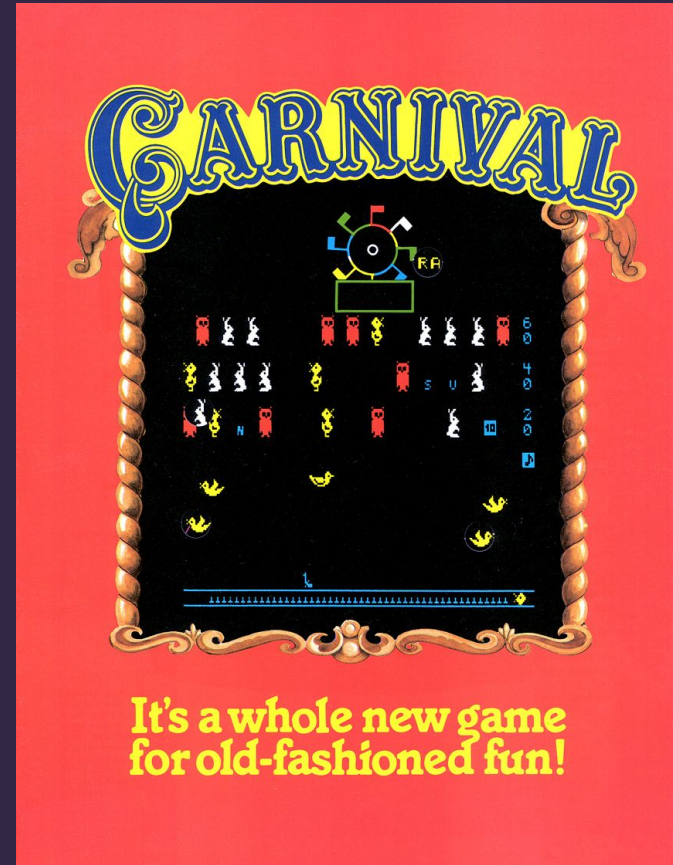
Carnival Music

Uses General Instruments AY-3-8910 (1978) - more on this chip later



Carnival Music

- General Instruments AY-3-8910 (1978)
- This is a Programmable Sound Generator (PSG)

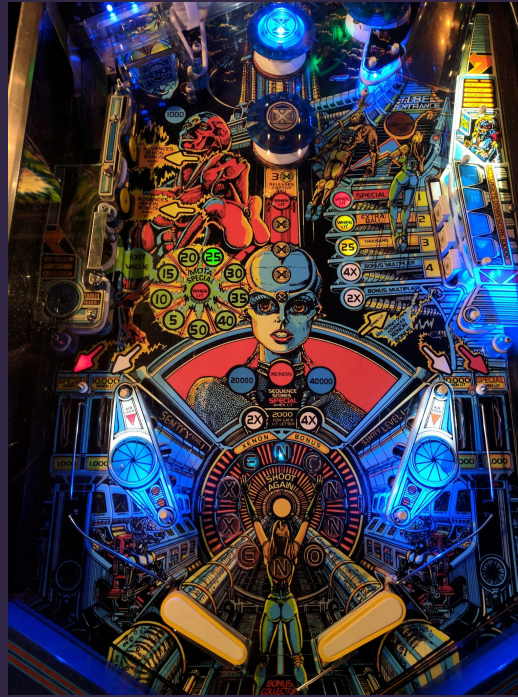


Are there more PSGs?

AY-3-8910



Platform : MSX
Year : 1983
Developer : Microsoft/ASCII Corp
Sound : AY-3-8910



Title : Xenon
Year : 1980
Platform : Pinball
Developer : Bally
Sound : Samples, AY-3-8910, mechanical



Title : Carnival
Year : 1980
Platform : Arcade machine
Developer : Sega
Sound : 2 x AY-3-8910

Any other uses?

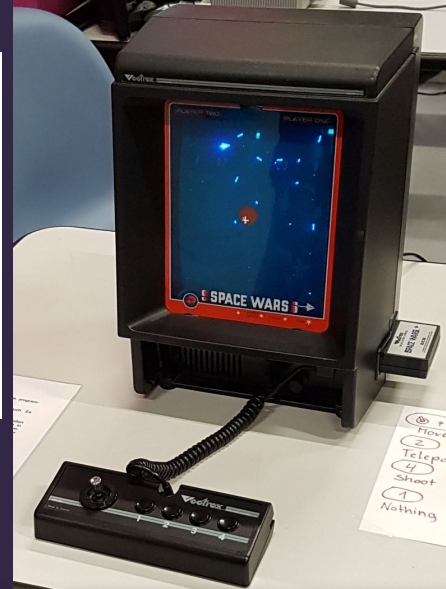
AY-3-8910



Platform : Atari ST
Year : 1985
Developer : Atari
Sound : AY-3-8910



Platform : Intellivision
Year : 1979
Developer : Mattel
Sound : AY-3-8910

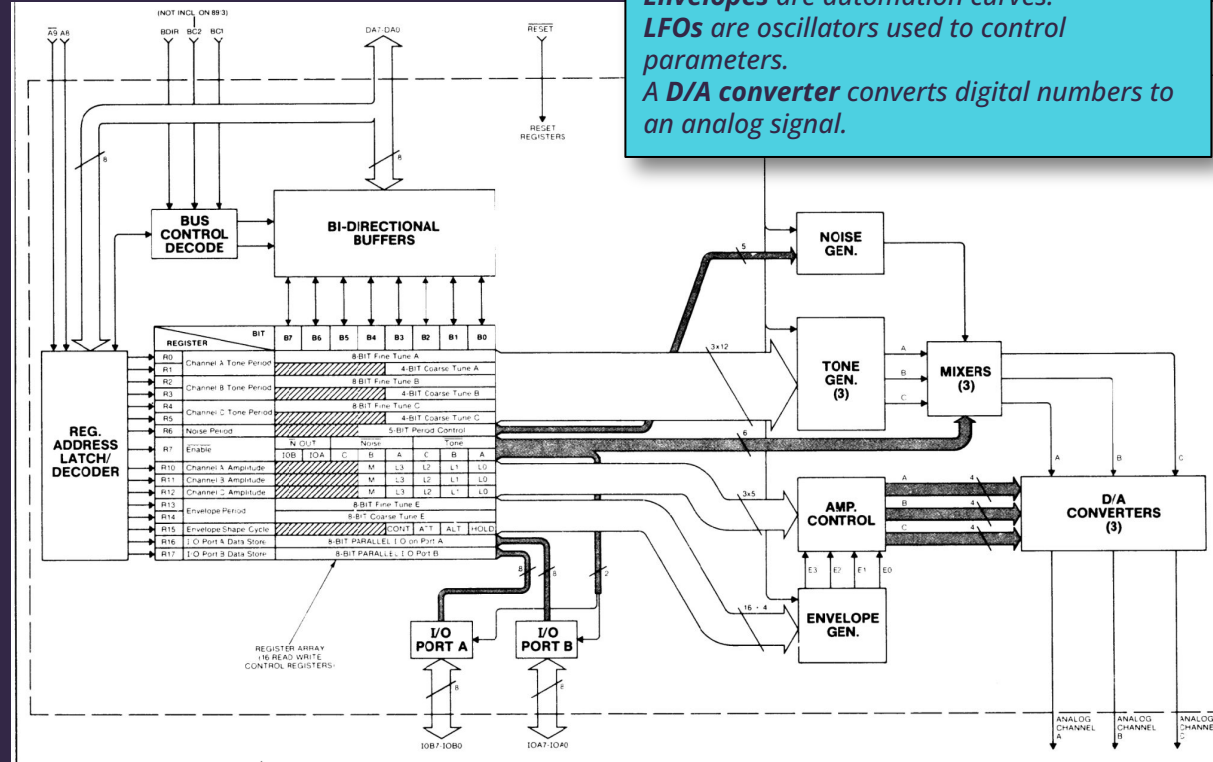


Platform : Vectrex
Year : 1979
Developer : General Consumer Electronics
Sound : AY-3-8910

How does it work?

AY-3-8910

- 3 square wave oscillators
- 12-bit frequency
- Amplitude control
- Fixed envelope shapes (can be envelopes or LFOs)
- Noise - 5-bit freq. control
- Fully digital, converts with built-in D/A converter



AUDIO TERMS

An **oscillator** is a component that generates a periodic signal.

Amplitude is a measure of 'loudness'.

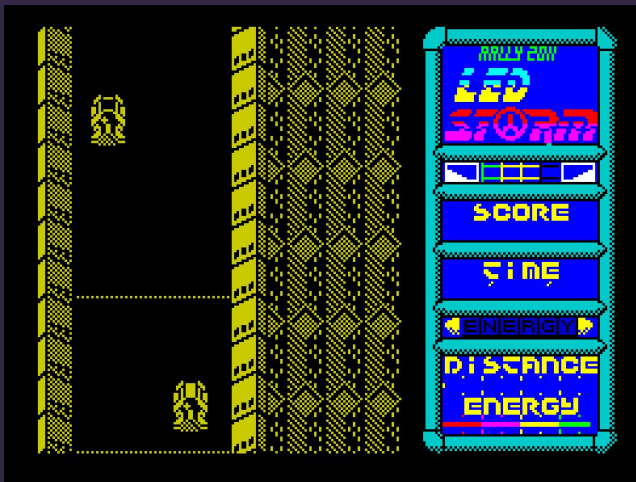
Envelopes are automation curves.

LFOs are oscillators used to control parameters.

A **D/A converter** converts digital numbers to an analog signal.

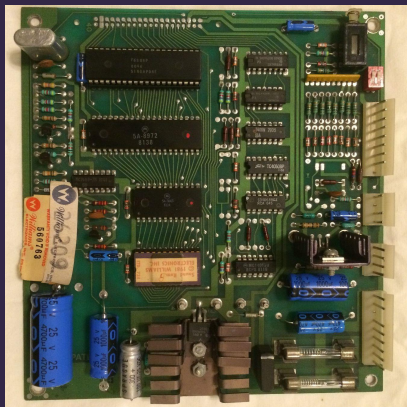
L.E.D. Storm

Music by Tim Follin



Title	: L.E.D. Storm
Year	: 1988
Platform	: ZX Spectrum 128
Developer	: Software Creations
Sound	: AY-3-8910

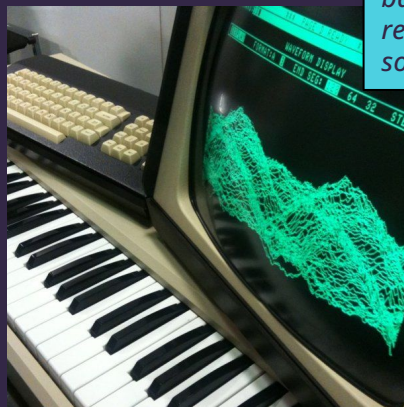
Laser Ball vs. Fairlight CMI



Laser Ball Sound Board (1979)

CPU: 1 x MC6800
2 KB ROM
128 B RAM

Output: Variable freq. 8-bit samples



Fairlight Computer Musical Instrument (1979)

CPU: 2 x MC6800
8 * 16 KB sample RAM
64 KB system RAM

Output: 24 KHz 8-bit samples

AUDIO TERMS

*The **Fairlight CMI** was a revolutionary and very expensive musical instrument, based on **sampling**, meaning digital recording and playback of analog sounds.*