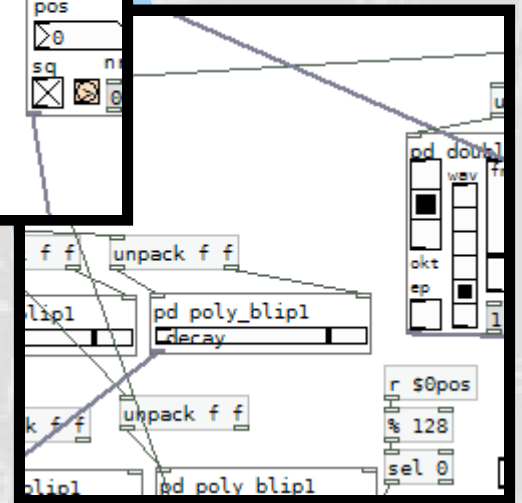
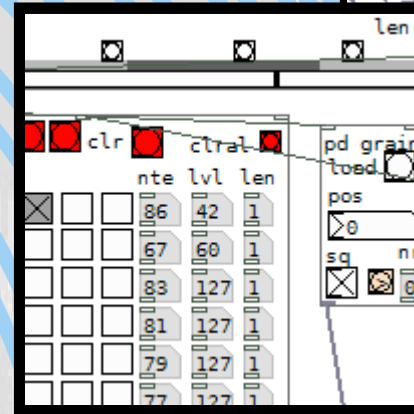
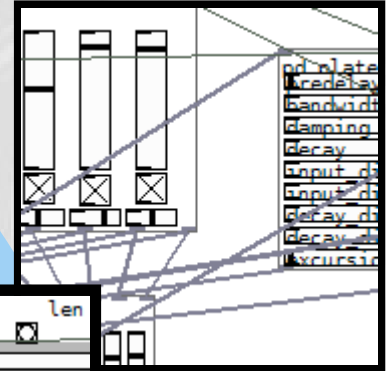


3D Audio

3D Audio

3D Audio

3D Audio



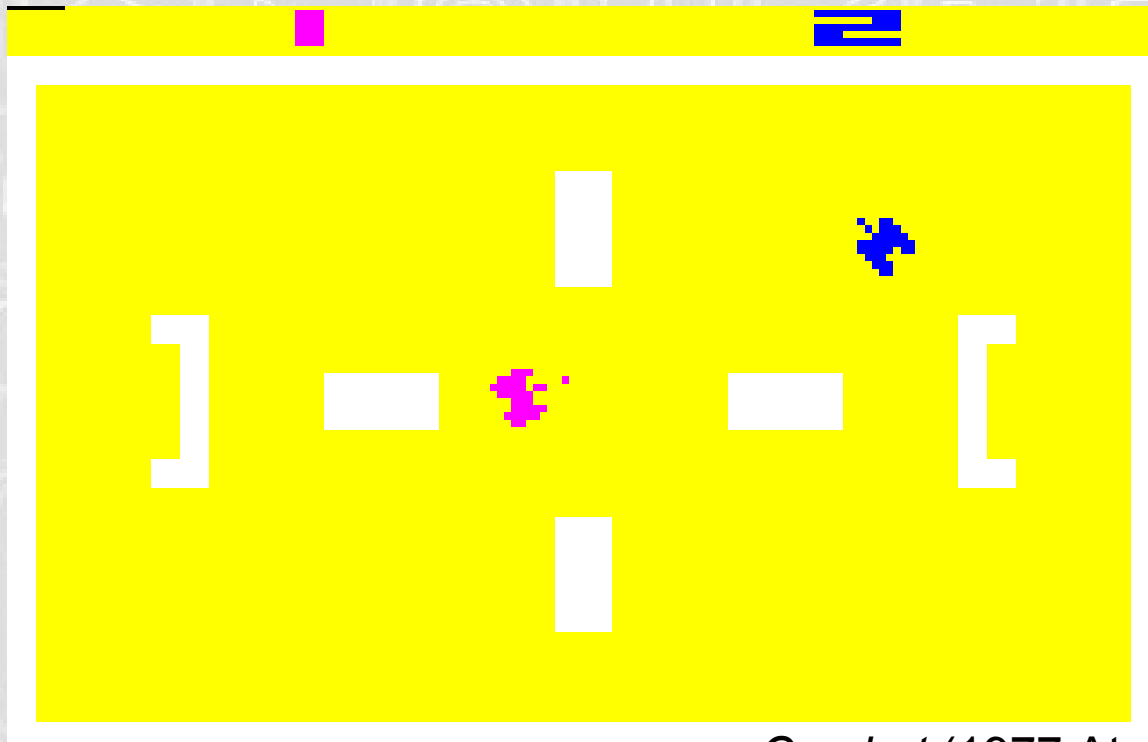
Leonard J. Paul
Vancouver, Canada

<http://VideoGameAudio.com>

@VideoGameAudio

Game Audio Beginnings

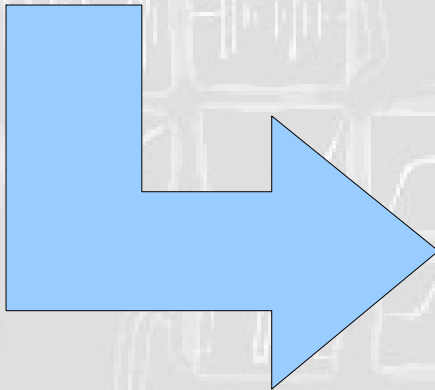
- 1977 – Atari VCS / 2600
- 1 mhz processor, 16 colours...



Combat (1977 Atari)

Combat ROM

- 2KB ROM!
- 2 Voices



```
78 d8 a2 ff 9a a2 5d 20 bd f5 a9 10 8d 83 02 85 a6 b5 95 95 97 a9 1f 95 9b a9 00 95 9d 4c cb f3
88 20 a3 f1 20 32 f0 20 57 f1 20 72 f5 20 da f2 b5 9f f0 0d a9 04 95 15 a9 07 95 19 b5 9b 95 17
20 44 f4 20 14 f2 20 a9 f2 20 f2 f1 20 54 f0 4c 60 a4 85 b9 33 f7 25 88 95 19 b9 36 f7 95 15 18
14 f0 e6 86 85 2b a9 02 85 02 85 01 85 02 85 02 a9 00 88 30 04 69 0c 10 f9 75 8b a8 8a 0a 79 39
85 02 85 00 85 02 85 02 a9 00 85 02 85 00 a9 2b f7 95 17 60 a2 01 b5 30 10 2c 24 84 50 06 b5 9b
8d 96 02 60 a9 20 85 b4 85 02 85 2a ad 84 02 d0 c9 1f f0 22 f6 95 f6 97 f8 b5 a1 18 69 01 95 a1
fb 85 02 85 2c 85 01 ba 86 d3 a9 02 85 0a a6 dc d8 8a 18 69 fd 85 8a a9 ff 85 28 85 29 a9 00 95
85 02 ca d0 fb a5 dc c9 0e f0 52 a2 05 a9 00 85 19 85 99 85 9a 60 24 a3 10 03 4c 01 f5 b5 9f f0
de 85 df 85 02 a5 de 85 0e a4 e2 b9 c5 f5 29 f0 0a c9 04 f6 9f 90 04 a9 00 95 9f b5 34 30 07 a9
85 de a4 e0 b9 c5 f5 29 0f 05 de 85 de a5 df 85 00 95 9d 4c d6 f4 24 82 50 36 b5 9d d0 19 f6 9f
0e a4 e3 b9 c5 f5 29 f0 85 df a4 e1 b9 c5 f5 25 d6 9b b5 97 95 b2 49 ff 95 97 f6 97 b5 97 29 03
87 85 02 05 df 85 df a5 de 85 0e ca 30 0f e6 0e d0 02 f6 97 4c d4 f4 c9 01 f0 0b c9 03 90 15 d0
e6 e2 e6 e1 e6 e3 a5 df 85 0e 4c 83 f0 a9 00 85 13 b5 b2 4c c8 f4 b5 97 18 69 08 95 97 4c d4 f4
0e 85 02 a9 05 85 0a a5 d6 85 06 a5 d7 85 07 a2 a9 01 95 99 f6 9d b5 32 30 04 a5 37 10 09 a5 8a
1e 9a 38 a5 a4 e5 b4 29 fe aa 29 f0 f0 04 a9 00 c9 02 90 09 20 08 f5 a9 03 95 e4 d0 14 d6 e4 30
f0 02 b5 bd 85 02 85 1b a5 a7 45 b4 29 fe 08 a5 06 b5 8b f0 0c d0 02 f6 95 b5 95 18 69 08 20 0f
46 45 b4 29 fe 08 a5 b4 10 02 49 f8 c9 20 90 04 f5 ca 30 03 4c 46 f4 60 8a 49 01 a8 b9 97 00 29
4a 4a 4a a8 a5 a5 38 e5 b4 e6 b4 ea 09 01 aa 29 0f a8 b9 27 f6 20 7c f2 a9 00 95 a8 aa 95 8d
f0 f0 04 a9 00 f0 02 b5 bd 24 82 85 1c 30 0c b1 b5 d8 95 d6 60 a6 85 bd c6 f7 85 bb bd c9 f7 85
b5 85 0d b1 b7 85 0e b1 b9 85 0f e6 b4 a5 b4 49 bc a5 a3 4a 4a 29 03 aa a5 a3 10 0a 29 08 f0 04
ec d0 9c a6 d3 9a 85 1d 85 1e 85 1b 85 1c 85 1b a2 03 10 04 a9 80 85 82 a5 a3 0a 0a 24 a3 30 06
85 0d 85 0e 85 0f 60 ad 82 02 4a b0 13 a9 0f 85 85 02 85 84 29 80 85 83 a9 f7 85 b6 85 b8 85 ba
87 a9 ff 85 88 a9 80 85 dd a2 e6 20 bd f5 f0 60 bd cc f7 85 10 85 b5 bd d0 f7 85 b7 bd d4 f7 85
a0 02 a5 dd 25 88 c9 f0 90 08 a5 86 29 30 d0 02 b9 60 a5 a3 29 87 30 02 a9 00 0a aa bd 5d f7 85
a0 0e 84 dc a5 86 29 3f d0 08 85 89 e6 dd d0 02 04 bd 5e f7 85 05 a5 a3 29 c0 4a 4a 4a a8 a5
85 88 ad 82 02 29 02 f0 04 85 89 d0 54 24 89 30 88 8d 82 02 49 ff 25 dd 85 d1 a2 ff ad 82 02 29
50 e6 80 a2 df 20 bd f5 a9 ff 85 89 a4 80 b9 d8 08 d0 04 a0 10 a2 0f 86 d2 a2 03 b9 65 f7 45 d1
f7 85 a3 49 ff d0 04 a2 dd d0 ea a5 81 f8 18 69 25 d2 95 06 95 d6 95 d8 c8 ca 10 ef 60 a9 00 e8
01 85 81 85 a1 d8 24 a3 10 06 e6 85 50 02 e6 85 95 a2 d0 fb 60 0e 0a 0a 0a 0e 22 22 22 22 ee
20 25 f5 a9 32 85 a5 a9 86 85 a4 24 a3 30 12 85 22 ee 88 ee ee 22 66 22 ee aa aa ee 22 22 ee 88
a5 85 11 a9 08 85 96 a9 20 85 20 85 21 85 02 85 ee 22 ee ee 88 ee aa ee ee 22 22 22 ee aa ee
2a 60 a2 01 b5 a1 29 0f 85 d2 0a 0a 18 65 d2 95 aa ee ee aa ee 22 ee f8 f7 f6 06 06 16 17 18
e0 b5 a1 29 f0 4a 4a 85 d2 4a 4a 18 65 d2 95 e2 19 1a 0a 0a 0a fa f9 f8 f7 f6 f6 06 16 17 18
ca 10 e1 60 24 83 50 04 a9 30 10 02 a9 20 85 b1 19 1a 1a 0a fa fa f9 e8 e6 e4 f4 04 14 24 26 28
a2 03 20 54 f2 ca 20 54 f2 ca b5 8d 29 08 4a 4a 2a 2c 1c 0c fc ec ea c8 c4 c0 e0 20 40 44 48
86 d1 18 65 d1 a8 b9 a8 00 38 30 01 18 2a 99 a8 4c 4f 2f 0f ef cf cc 00 00 80 84 20 88 88 92
00 90 0d b5 ac 29 01 0a 0a 0a 0a 85 b1 20 54 f2 48 a4 a4 a9 52 aa aa d5 aa da da db 6d ee ee 00
ca f0 d7 60 f6 ac b5 95 29 0f 18 65 b1 a8 b9 f7 fc fc 38 3f 38 fc fc 1c 78 fb 7c 1c 1f 3e 18 19
f5 85 b0 24 82 70 13 b5 95 38 e9 02 29 03 d0 0a 3a 7c ff df 0e 1c 18 24 64 79 ff ff 4e 0e 04 08
b5 ac 29 03 d0 04 a9 08 85 b0 a5 b0 95 20 29 0f 08 6b 7f 7f 7f 63 63 24 26 9e ff ff 72 70 20 98
38 e9 08 85 d4 18 75 a4 24 a3 30 04 e0 02 b0 10 5c 3e ff fb 70 38 18 38 1e df 3e 38 f8 7c 18 60
c9 db b0 04 c9 25 b0 08 a9 49 24 d4 30 02 a9 28 70 78 ff 78 70 60 00 00 c1 fe 7c 78 30 30 30 00
95 a4 e0 02 b0 02 95 25 60 a9 01 25 86 aa b5 95 03 06 fc fc 3c 0c 0c 02 04 0c 1c fc fc 1e 06 10
95 0b 29 0f a8 24 83 10 02 94 97 8a 49 0e aa 98 10 10 38 7c fe fe 10 40 20 30 38 3f 3f 78 60 40
0a 0a 0a c9 3f 18 30 03 38 49 47 a8 b1 bb 95 bd 60 3f 1f 1e 1e 18 18 00 83 7f 3e 1e 0c 0c 0c 00
90 02 88 88 c8 ca ca 10 f3 60 a5 8a 38 e9 02 90 8e 84 ff ff 04 0e 00 00 0e 04 8f 7f 72 07 00 10
2b 85 8a c9 02 90 24 29 01 aa f6 95 b5 d8 95 d6 36 2e 0c 1f b2 e0 40 24 2c 5d 1a 1a 30 60 60 18
a5 8a c9 f7 90 03 20 08 f5 a5 8a 10 0e 4a 4a 4a 5a 7e 5a 18 18 18 78 34 36 5a 78 2c 0c 06 0c 08
95 19 a9 08 95 15 bd fe f7 95 17 60 a2 01 ad 82 6c 70 b8 dc 4e 07 06 38 10 f0 7c 4f e3 02 00 00
02 85 d5 ad 80 02 24 88 30 02 a9 ff 49 ff 29 0f 0b 16 00 10 00 ff 01 11 01 ff 0f 1f 05 5f 51
85 d2 a4 85 b9 0f f7 18 65 d2 a8 b9 12 f7 29 0f ff 30 3f 31 ff 70 7f 71 90 b0 70 ff 91 b1 71 ff
85 d1 f0 04 d5 91 d0 04 d6 93 d0 d0 95 91 a9 0f 9f bf 7f 08 02 02 02 03 08 1d 05 00 00 00 00 00
95 93 a5 d1 18 75 95 95 95 f6 8d 30 1e b9 12 f7 00 00 00 00 00 00 00 1d 1d 16 16 0f 0f 00 00 00
4a 4a 4a 4a 24 d5 30 23 95 8b 0a a8 b9 37 f6 95 00 00 00 00 00 00 12 10 10 0c 07 07 00 00 01
a8 c8 b9 37 f6 95 aa a9 f0 95 8d 20 80 f3 ad 80 01 00 03 27 03 ea 3c 82 44 32 2c 8a da 80 9c da
02 4a 4a 4a 4a 06 d5 ca f0 9c 60 38 e5 85 10 d8 3a 64 a8 da 4a 08 04 00 0e f0 10 10 10 10 10 10
a5 a3 30 08 29 01 f0 04 a5 db 95 d6 b5 99 f0 27 10 10 10 10 10 ff 00 00 00 38 00 00 60 20 20
b5 d8 95 d6 b5 99 c9 07 90 14 24 d5 10 04 c9 1c 23 ff 80 80 00 00 00 1c 04 00 00 00 ff 00 00
90 0c c9 30 90 1f c9 37 b0 21 24 83 50 1d a9 00 00 00 00 00 00 00 00 00 00 00 07 1f 3f 7f ff 00
95 99 a9 ff 95 28 60 24 88 10 04 b5 3c 10 37 20 00 00 00 00 00 00 60 20 21 ff 00 00 00 80 80
10 f4 4c ae f3 20 10 f4 4c de f3 b5 9f 00 0a 20 80 80 00 00 00 07 4f cf 8f fe f6 f6 75 75 9a
10 f4 a9 30 95 99 4c de f3 b5 99 20 00 f3 a5 86 81 99 aa 9d 8d 99 b6 9d 24 28 06 20 48 40 54
29 03 f0 0c 24 84 70 0a 24 82 50 04 29 01 d0 02 58 25 29 49 55 59 a8 88 98 90 a1 83 e8 c8 e0 c0
d6 99 a9 00 f0 be a9 3f 95 99 38 b5 a4 e9 06 95 e9 e2 c1 ff 00 00 00 00 00 00 00 00 00 f0 0f 11
```

Retro City Rampage



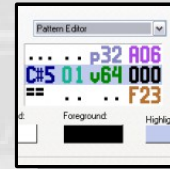
- Trailer video

Retro City Rampage

- In Retro City Rampage almost all sounds & music are synthesized from just pulse, triangle and noise waves
- Mod trackers allow composer control over parameters and mix of synthesis + samples but it is also tricky to learn
- **OpenModPlug Tracker** is free

#0	1: Pulse1	2: Pulse2	3: Tri	4: Noise	5: DPCM
00	C-3 01 .. E33	G-3 01 .. E33	E-2 05 v00RCE	C-2 06 ..	...
01
02
03
04
05
06
07
08
09
0A
0B
0C
0D
0E
0F
10	C-8 04 v41 DOF	...	...	...	...
11
12
13	...	F#9 04 v46 DOF	...	...	...
14
15	...	G-8 03 v38 DOF	...	...	...
16	F#8 02 v56 DOF	...	...	...	...
17
18
19	F#8 02 v56 DOF	...	...	...	...
1A	C-8 04 v00 ...	...	...	...	...
1B	F#7 01 v48 DOF	F#9 04 v46 DOF	...	...	...
1C
1D	C-8 04 v41 DOF	...	...	...	...
1E
1F
20
21	...	G-8 03 v38 DOF	...	...	...
22
23	C-8 01 v27 DOF	...	...	...	...
24
25
26	F#8 02 v56 DOF	...	...	...	...
27	C-8 04 v00 ...	F#9 04 v46 DOF	DF2	...	...
28	F#7 01 v48 DOF	...	...	...	...
29
2A
2B
2C
2D	...	G-8 03 v38 DOF	...	...	...
2E
2F
30
31
32
33
34
35
36
37

How to start ?



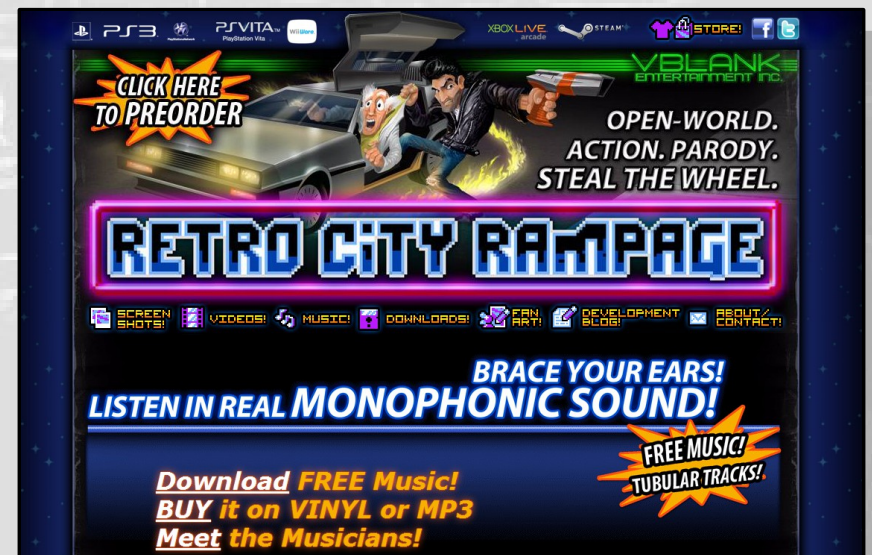
- Download OpenMPT, look through the example songs and read the very detailed online help files
- Read OpenMPT Offline Help [Manual](#) (200 pages!)
- Join the forum at [ChipMusic.org](#)
- Listen to [Kohina.com](#) and other online stations
- Buy a Gameboy, buy a flash ROM cart & do [LSDJ](#)
- Download [Famitracker](#) to do NES songs
- Try out [GoatTracker](#) for Commodore 64 songs
- + many, many more ways.. :)



Download the RCR Theme



- We've released the [source](#) to the theme music of Retro City Rampage
- It is in .it (Impulse Tracker) format which works best in OpenMPT
- Have a look through the tasty details by virt
- Stems are on [SoundCloud](#)
- [MIDI](#) file available too
- All good for remixing..!



Ahh the details...

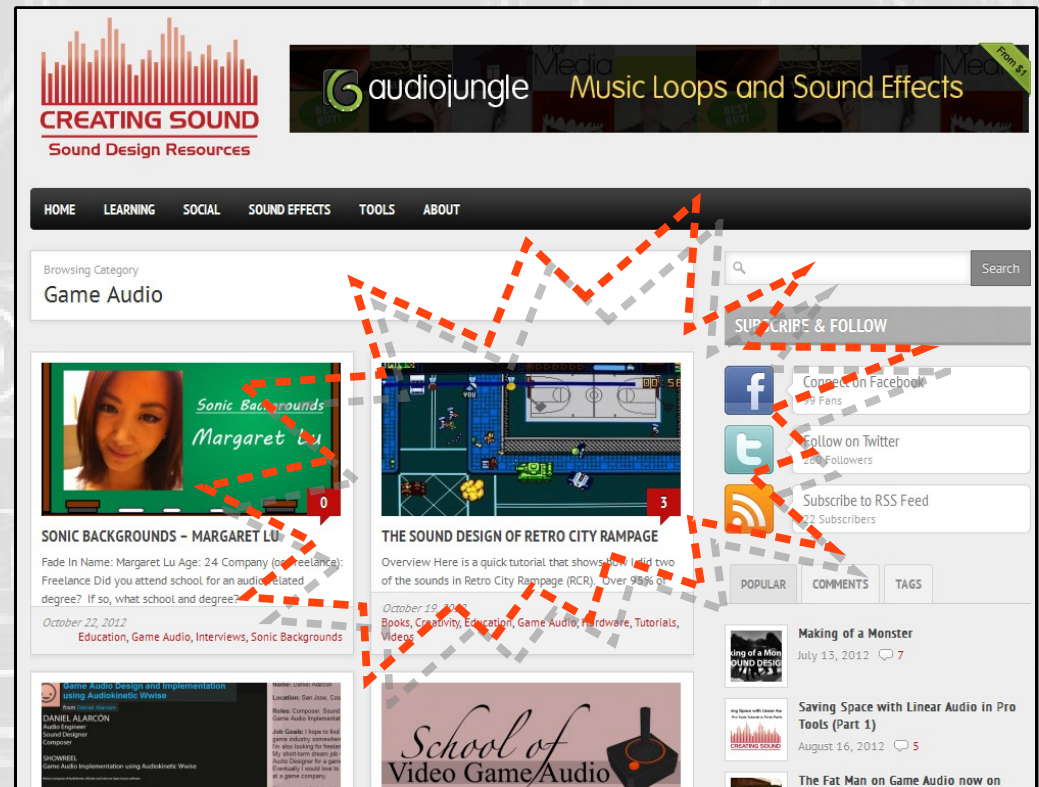
#15	1: Pulse1	2: Pulse2	3: Triangle	4: Noise	5: DPCM
66	F-5 01	C-3 01v44	F-4 15		C-5 22 SD2
67				S00	
68	F#5 01	C-5 01v44	F-5 15	A-5 24v40	D-5 22
69	G-5 01			S00	
70	F#5 01	A#4 01v44	D#5 15		C-5 22
71				S00	
72	C-6 01	F#4 01v44	B-4 15	G-5 24v20	C-5 22
73				S00	
74	F#5 01	C-4 01v44	F-4 15		C-5 22
75				S00	
76	C-6 01	C#4 01v44	F#4 15	A-5 24v40	D-5 22
77				S00	
78		F#3 01v44	B-3 15		C-5 22
79	H00			S00	
80	H00	C#4 01v44	F#4 15	G-5 24v20	C-5 22
81				S00	
82	H00	C-4 01v44	F-4 15		C-5 22
83	H00			S00	
84	F#5 01	A#3 01v44	D#4 15	A-5 24v40	D-5 22
85				S00	
86	C-6 01	C#4 01v44	F#4 15		C-5 22
87				S00	
88	F#5 01	C-4 01v44	F-4 15	G-5 24v20	C-5 22
89				S00	
90	F-5 01	A#3 01v44	D#4 15		C-5 22
91				S00	
92	D#5 01	G-3 01v44	C-4 15	A-5 24v47	D-5 22
93				S00	A-5 23 SD1
94	C-5 01	F-3 01v44	A#3 15		E-5 23 SD2
95				S00	
96	G-5 01	G-3 01v44	C-4 16	C-5 24v40	C-5 22
97		F-3 01v44 SD1	A#3 16		SD1
98	D#5 01	G-3 01v44 SD2	C-4 16		SD2
99				SC2	
100		A#3 01v44	D#4 15	A-5 24v40	D-5 22
101	C-5 01				SD1
102					C-5 22
103					SD1
104	F-5 01	C-4 01v44	C-4 16	C-5 24v40	C-5 22
105		A#3 01v44 SD1	A#3 16		SD1
106	C-5 01	C-4 01v44 SD2	C-4 16		SD2
107				SC2	
108	D#5 01	A#3 01v44	D#4 15	A-5 24v40	D-5 22
109					
110	F10				
111					
112	D#5 01	C-5 03v30 J00	C-4 15	G-5 24v40	D-5 22
113				S00	D-5 22 SD1
114		C-6 03v30 J00	C-5 15	G-5 24v30 SD2	C-5 22 SD2
115				S00	
116	H8F	C-5 03v30 J00	C-4 15		C-5 22
117	H00			S00	G-5 24v40 SD1
118	H00	A#5 03v30 J00	A#4 15		C-6 23 SD1
119	H00			S00	C-6 23 SD2
120	H00	C-5 03v30 J00	C-4 15	G-5 24v30	F-5 23
121	H00			S00	F-5 23 SD1
122	H00	A-5 03v30 J00	A-4 15	A-5 24v40 SD2	A-5 23 SD2
123	E10			S00	
124	E00	C-4 03v30 J00	C-4 15		A-5 23
125	E00			S00	D-5 23 SD1
126	E00	A#5 03v30 J00	A#4 15	G-5 24v40 SD1	D-5 23 SD2
127	E00			S00	

- Pattern 15: 0:53-0:57 seconds into the song
- Lead guitar on Pulse1
- Second guitar on Pulse2
- Bass on Triangle
- Hi-hat & snare on Noise
- Kick, snare & toms on DPCM
- Plenty of arpeggios (J00)
- Tripplets (SD1 & SD2)
- ... + plenty more details!

Chiptune Sound effects?



- We've released some RCR sound effect sources and have a whole article on how they were created on CreatingSound.com
- Sounds are made exactly the same as the music but less “music-ish-ly”

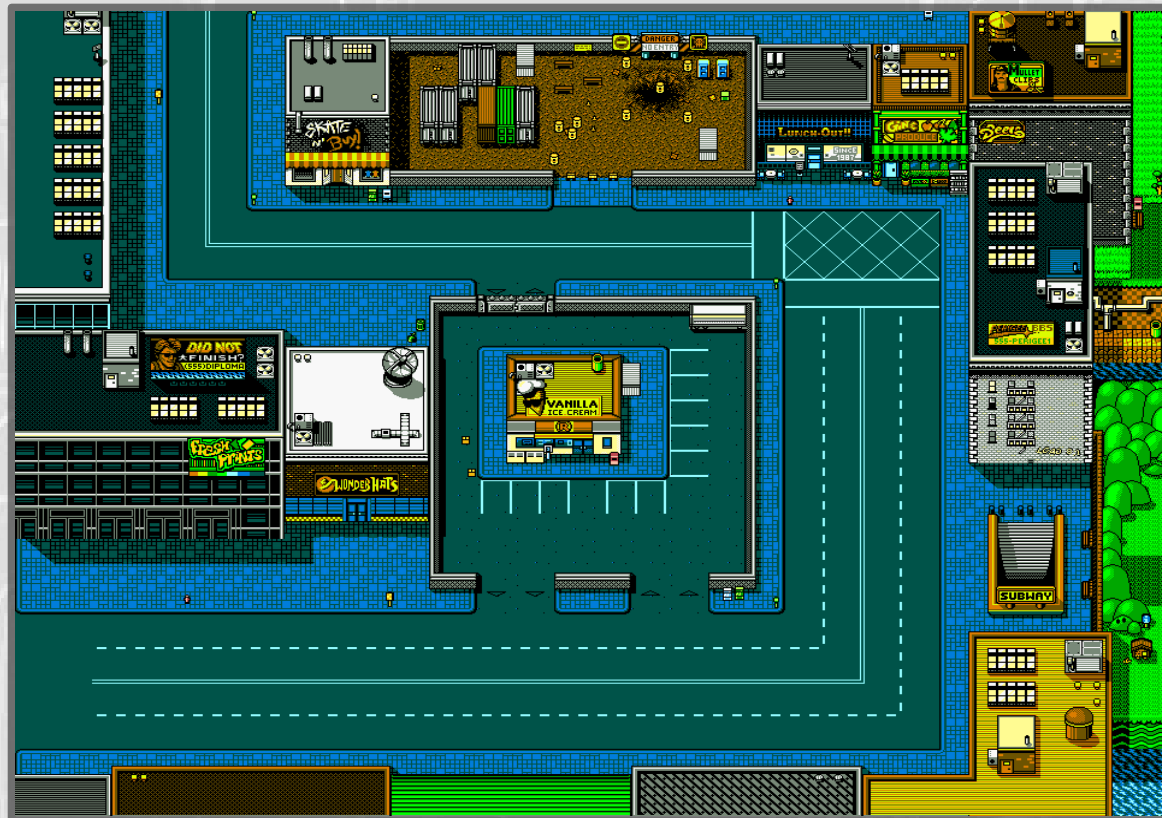


Advanced Uses

- You can use it for adaptive music by muting tracks, changing tempo/instruments/fx/etc..
- Synchronized meta data can easily be added to songs (or sfx) to allow game to sync with specific hits in the music or to do visualizations defined by composer
- The addition of extra commands can enable behaviour changes such as randomization between patterns (branching) or even the insertion of scripting into the patterns themselves
- Can use as an open multitrack format
- Custom software synths and effects can create a more convincing songs

Indie Games → Make your Own :)

- 2012/13 – *Retro City Rampage*



RetroCityRampage.com

NBA Jam 2010

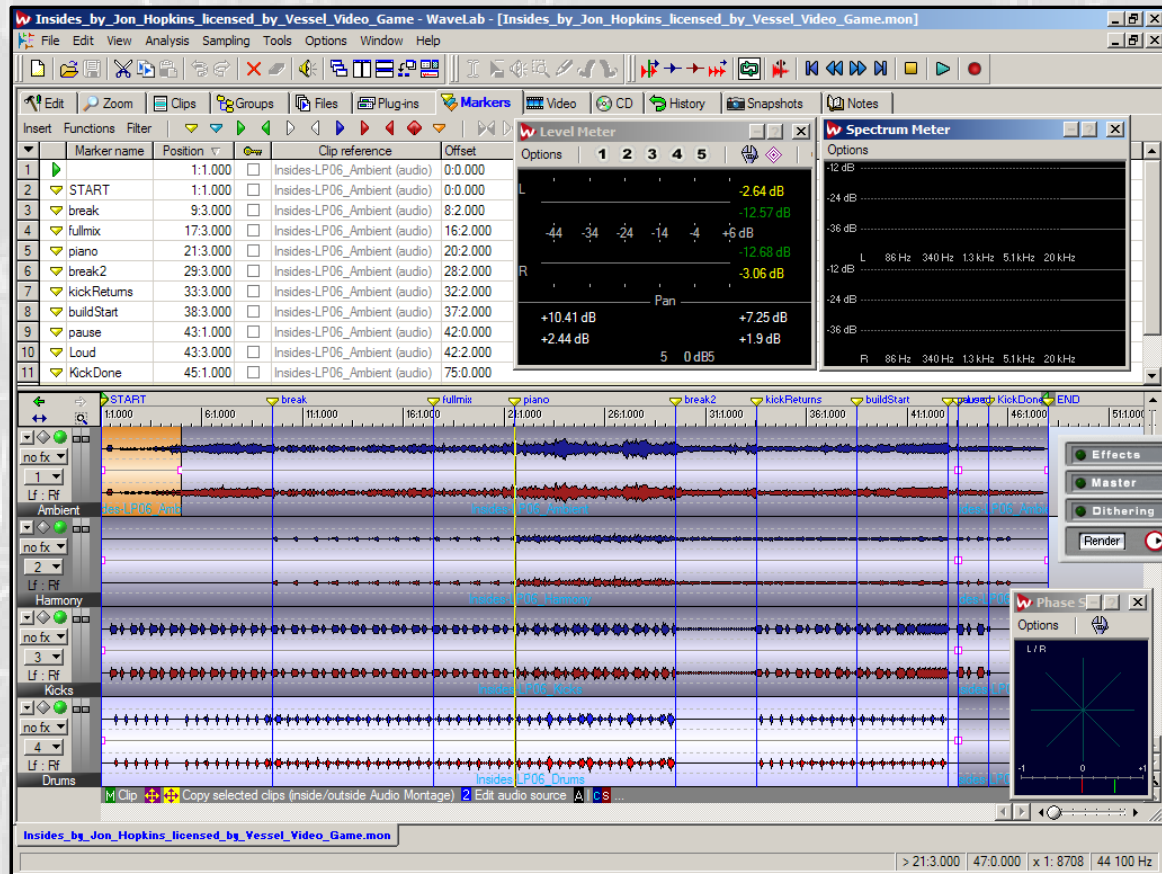


Vessel by Strange Loop Games



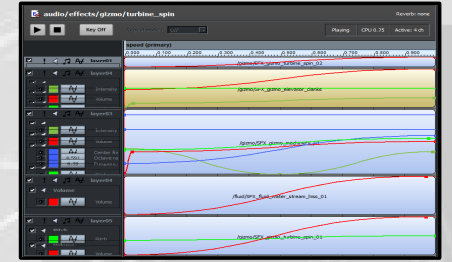
<http://www.strangeloopgames.com/>

Music of Vessel



- Video on music – Jon Hopkins soundtrack in Vessel - YouTube

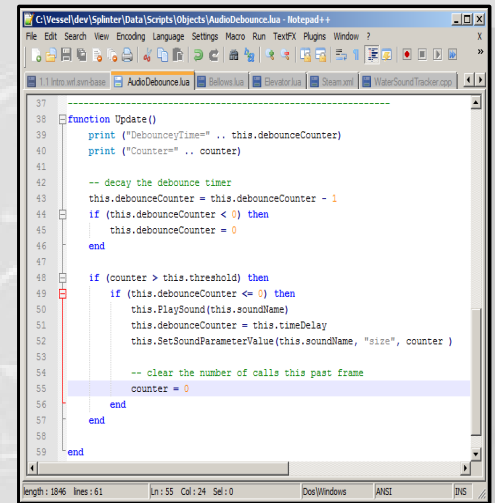
FMOD



- Robust audio library and designer tool
- Shipped in many games since 2002
- Cross-platform: PC, 360, PS3, Vita, Mac, iOS, Wii, 3DS + more
- Good: Parameter modulation, FX, cost & speed
- Cons: Mixing, interactive music & presentation
- Overall, it's a very strong toolset and library
- FMOD Studio is now available

Lua

- Free open source scripting
- Fast, easy and efficient
- Code layer between FMOD library & C++
- Allows sound artist to make complex state aware behaviours not possible in FMOD (such as debouncing) - perfect for interactive objects
- Used extensively throughout Vessel
- Doesn't require recompilation
- Great scripting language for video games



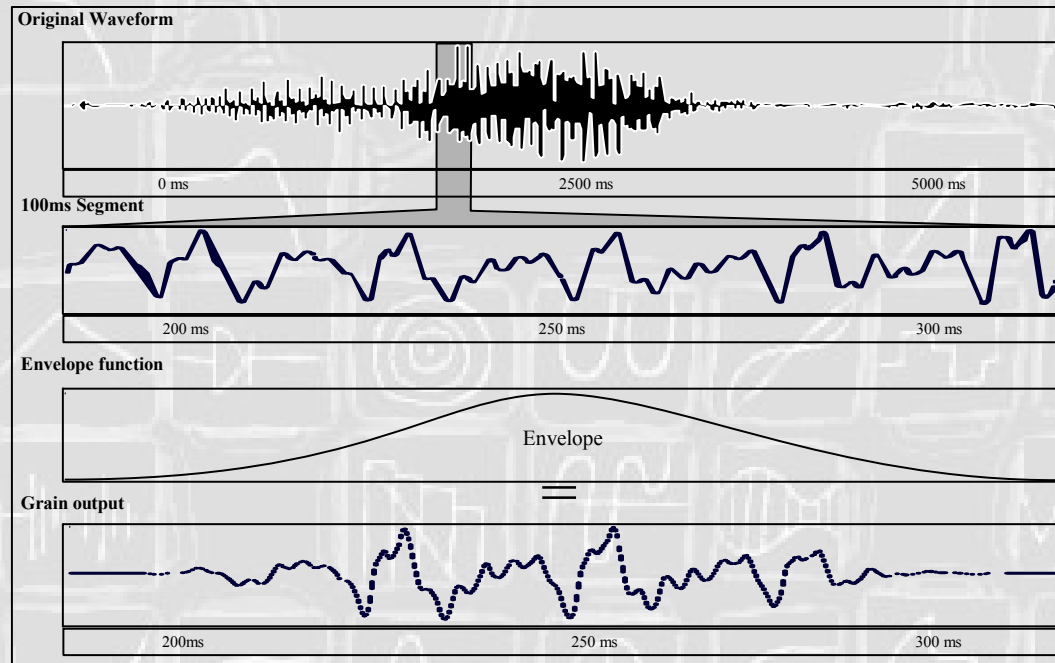
```
37
38
39 function Update()
40     print ("DebounceTime" .. this.debounceCounter)
41     print ("Counter" .. counter)
42
43     -- delay the debounce timer
44     this.debounceCounter = this.debounceCounter - 1
45     if (this.debounceCounter < 0) then
46         this.debounceCounter = 0
47     end
48
49     if (counter > this.threshold) then
50         if (this.debounceCounter <= 0) then
51             this.PlaySound(this.soundName)
52             this.debounceCounter = this.timeDelay
53             this.SetSoundParameterValue(this.soundName, "size", counter )
54
55             -- clear the number of calls this past frame
56             counter = 0
57         end
58     end
59 end
```


Procedural Audio



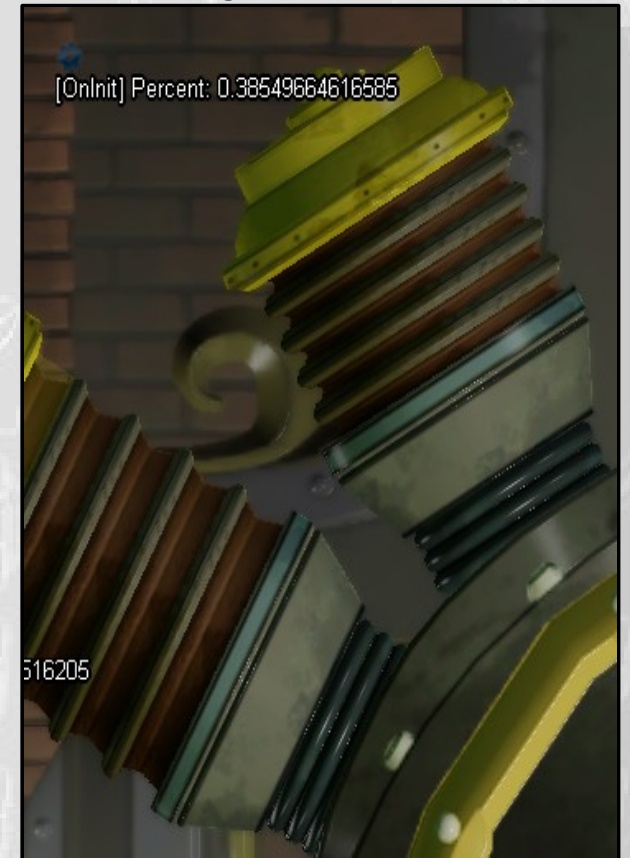
- Generate audio in real-time based on rules & behaviours (physical modeling, modal synthesis etc..)
- Main advantage is the possibility of realism
- Drawbacks include realism, scalability, dev time & CPU time
- Can combine samples, fx & procedural audio
- Granulation is commonly used in *Vessel*

Granulation



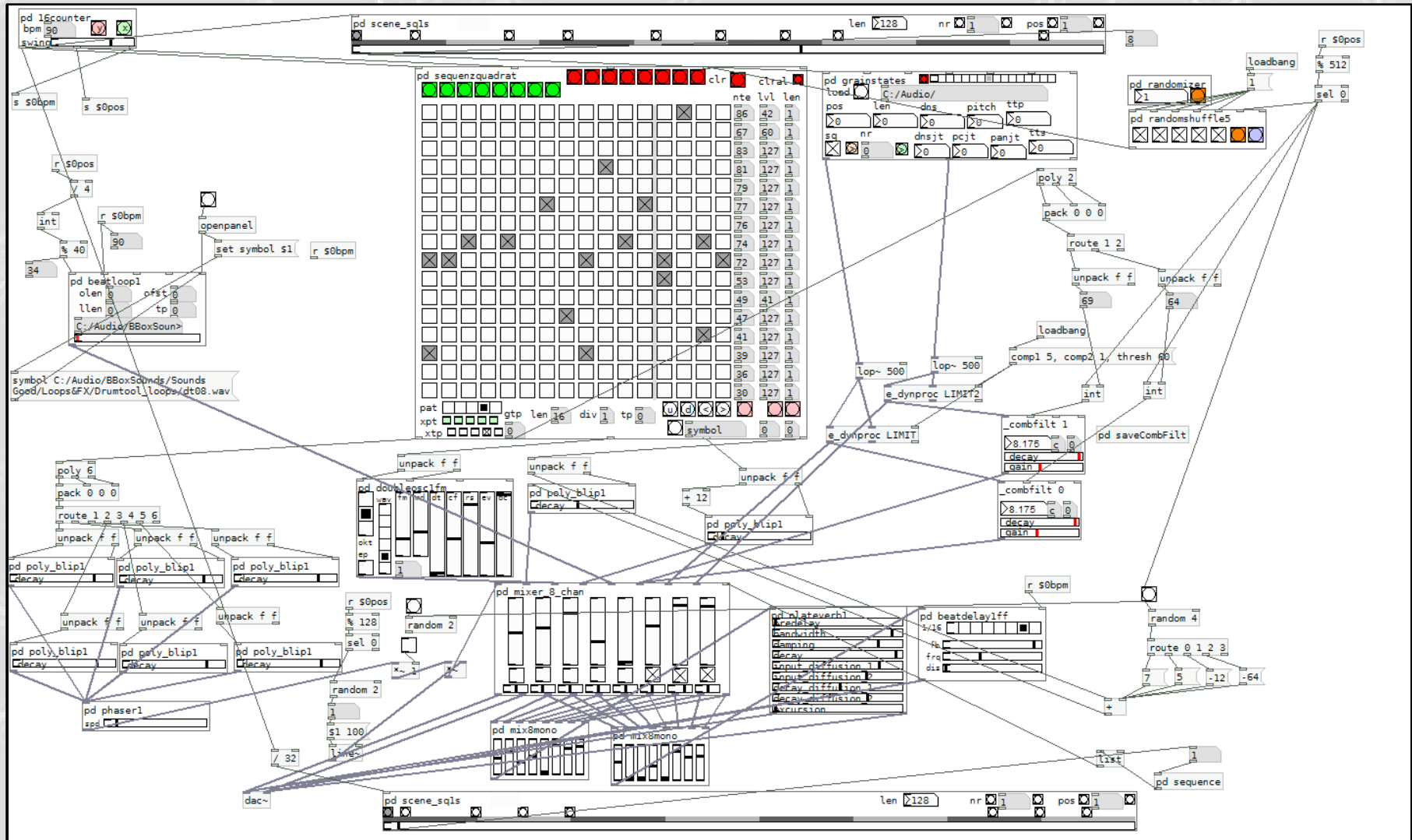
- Splits sample to granules & decrease repetition with independent frequency and tempo
- Manual segmentation done in *Vessel* to preserve transients

Granulation & Subtractive Synthesis



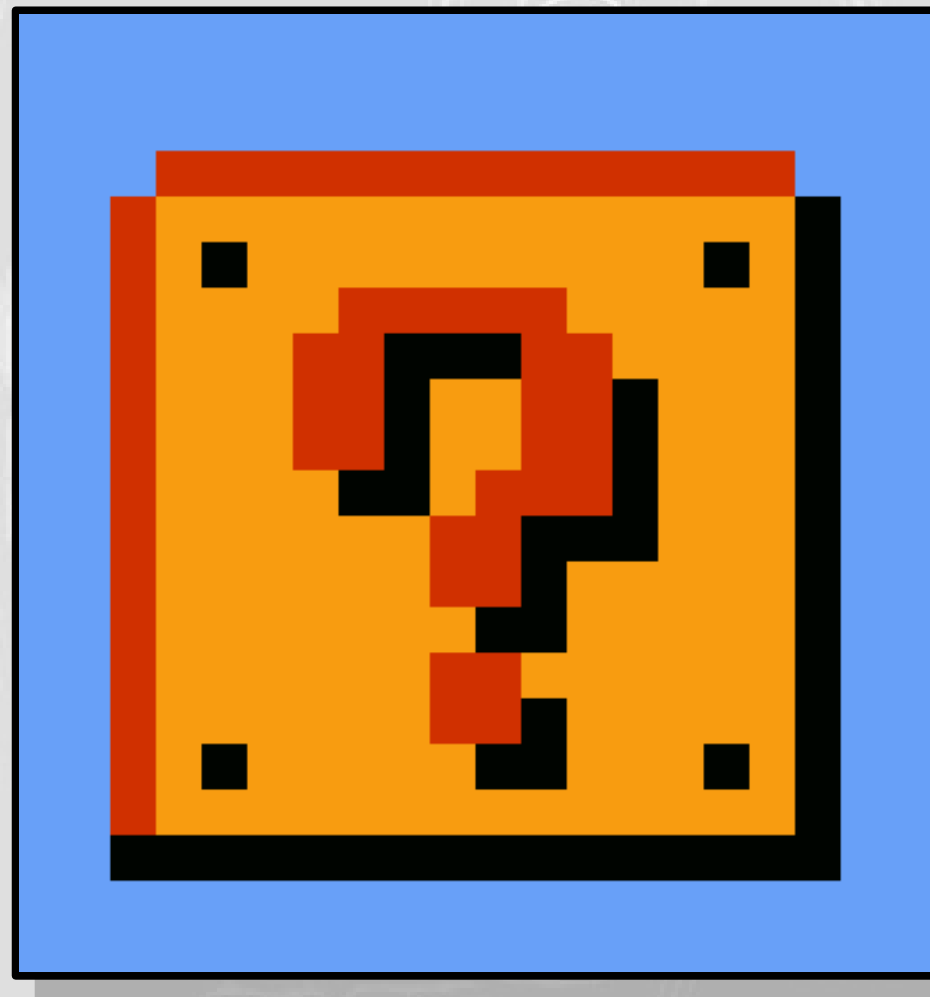
- Air is synthesized by subtractive synthesis
- Leather squeaks are granulated

Generative Music : Work in Progress



Questions?

- Trackers
- Chiptunes
- Adaptive music
- Dynamic sound design
- FMOD
- Lua
- Granulation
- Generative Music
- ... ?



Contact

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VideoGameAudio.com

[@VideoGameAudio](https://www.instagram.com/VideoGameAudio)