# For the Love of Commodore 64 Music

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# Me Me Me

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# Agenda

None!

This will be a pretty random walk down memory lane, creating a player for Commodore 64 music, and “modernizing” the music a bit.

You won’t learn a single useful thing!

# I Love Commodore 64 Music!

# But Not Just the ”Sound” – the Music!

Others too – online collections of Commodore 64 music, various players, wikis, even live bands playing Commodore 64 music.

But I also want to experiment with the music

# Vision: Allow people to experiment with Commodore 64 Music

# But First…

What is a Commodore 64?


commodore 64
commodore 64
PERSONAL COMPUTER

# Solving Tech Issues Back Then…

# Commodore 64

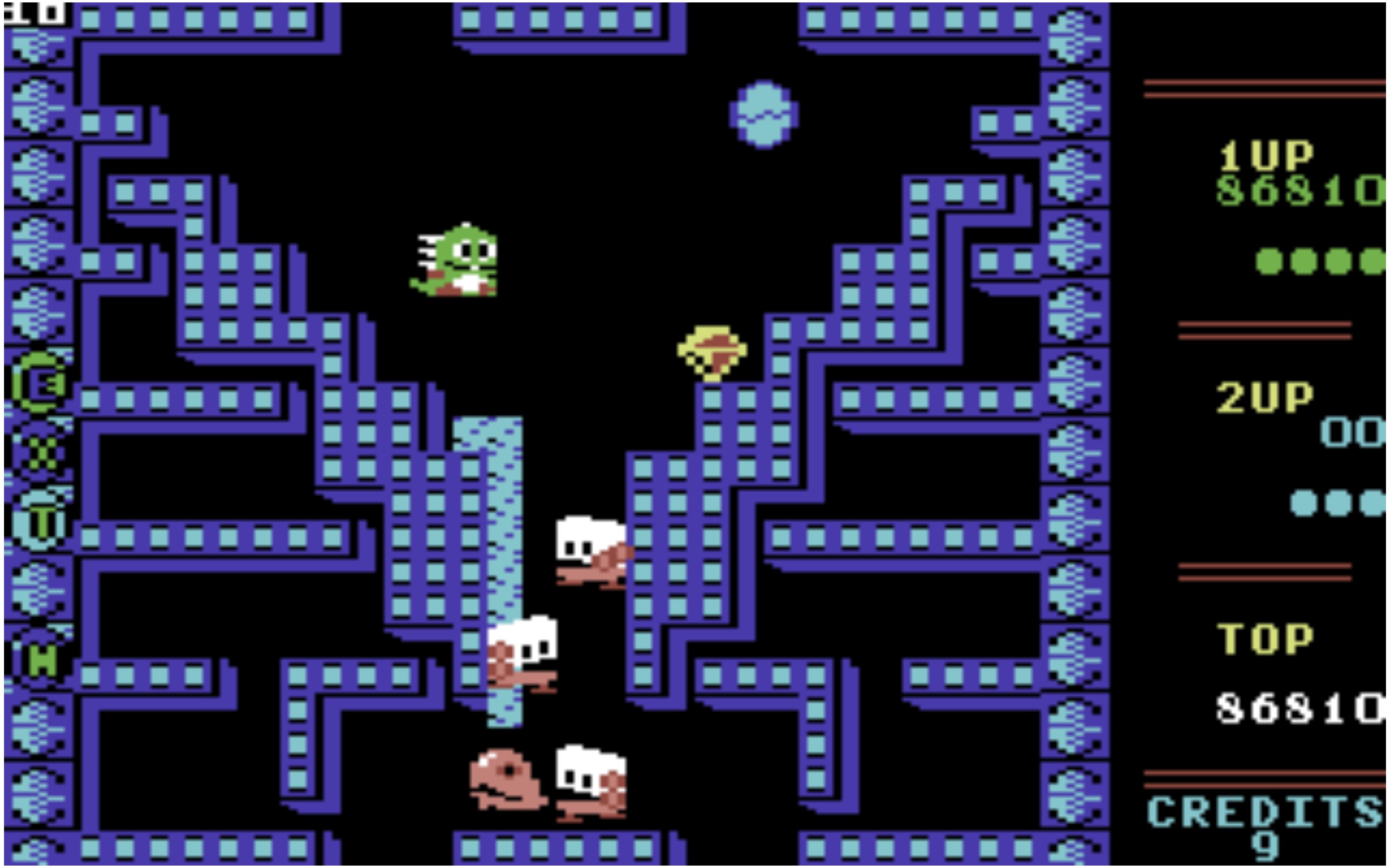
- 64 KB of RAM
- MOS 6510 processor (8 bit, 16 bit addressing)
- 1 MHz
- Tape drive, later also floppy disk drive
- 320x200, 16 color image output
- Sound: SID (Sound Interface Device)


**** COMMODORE 64 BASIC V2 ****
64K RAM SYSTEM  38911 BASIC BYTES FREE
READY.

# How Did it Sound?

# Paperboy – Mark Cooksey

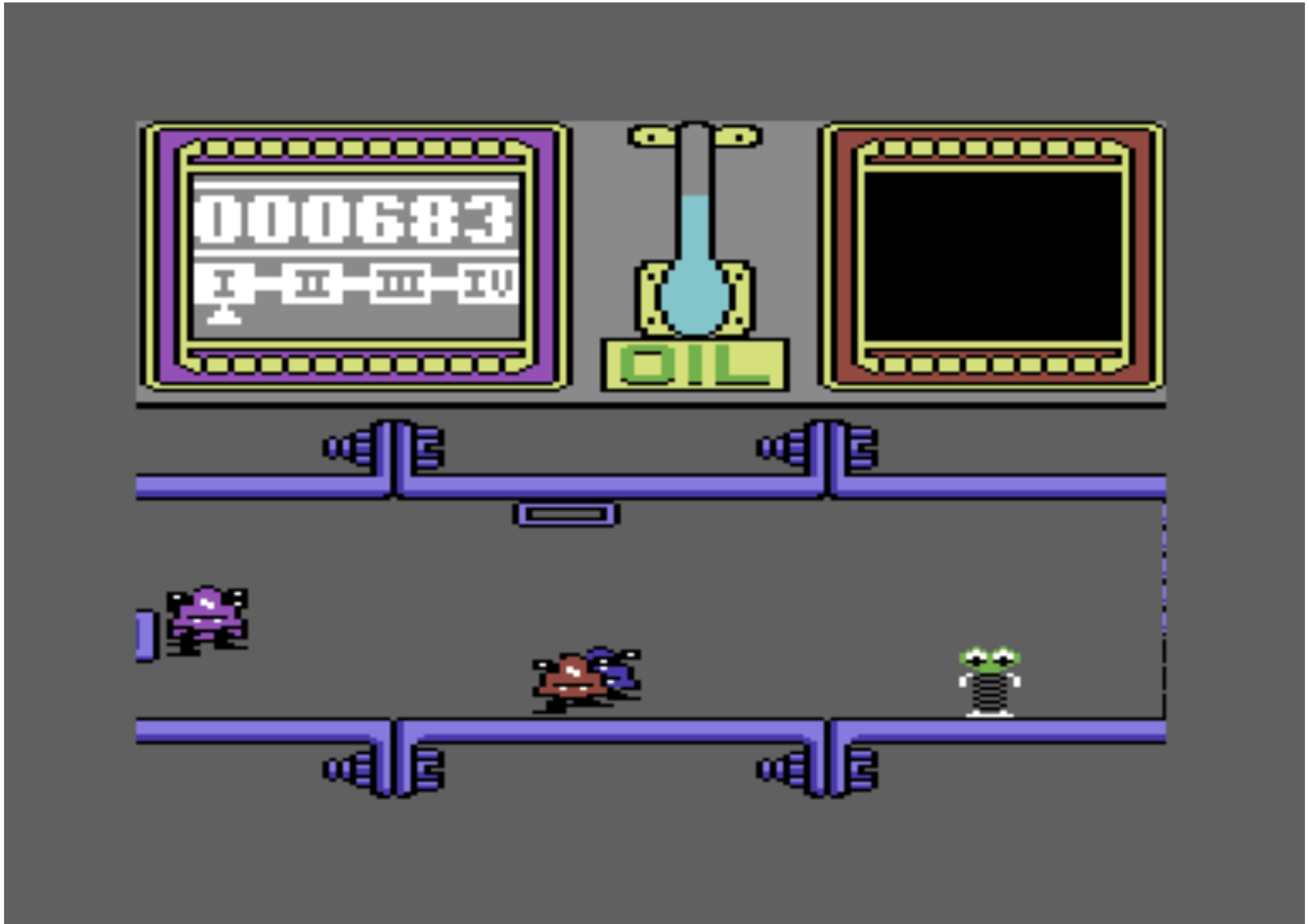
# Bubble Bobble – Peter Clarke



# Outrun – Ian Crabtree

# 1942 – Mark Cooksey

# Thing on a Spring – Rob Hubbard



# Commando – Rob Hubbard

# Last Ninja – Ben Daglish

# Anyhow… the Music!

High Voltage SID Collection (HVSC):
https://www.hvsc.c64.org

All the music from the Commodore 64 games, in ".sid" format!

# Mission: Understand the SID Format and Convert it to Other Formats

# (And do it in Ruby)

# Step 1: Learn the SID File Format

# SID File Format

## +00 magicID: 'PSID' or 'RSID’

This is a four byte long ASCII character string containing the value 0x50534944 or 0x52534944

## +04 WORD version

Available version number can be 0001, 0002, 0003 or 0004

## +06 WORD dataOffset

This is the offset from the start of the file to **😱the C64 binary data area!😱**

## +08 WORD loadAddress

The C64 memory location where to put the C64 data

## +0A WORD initAddress

The start address of the machine code subroutine that initializes a song

# Partial Commodore 64 Emulator Required!

# CPU: MOS 6510

Relatively simple processor

One 8-bit accumulator register, two 8-bit index registers, an 8-bit stack pointer, a 16-bit program counter, and a status register

14 addressing modes (absolute, use index registers, relative to accumulator, use indirect index registers, …)

57 instructions

In total, 256 combinations of instructions with addressing modes

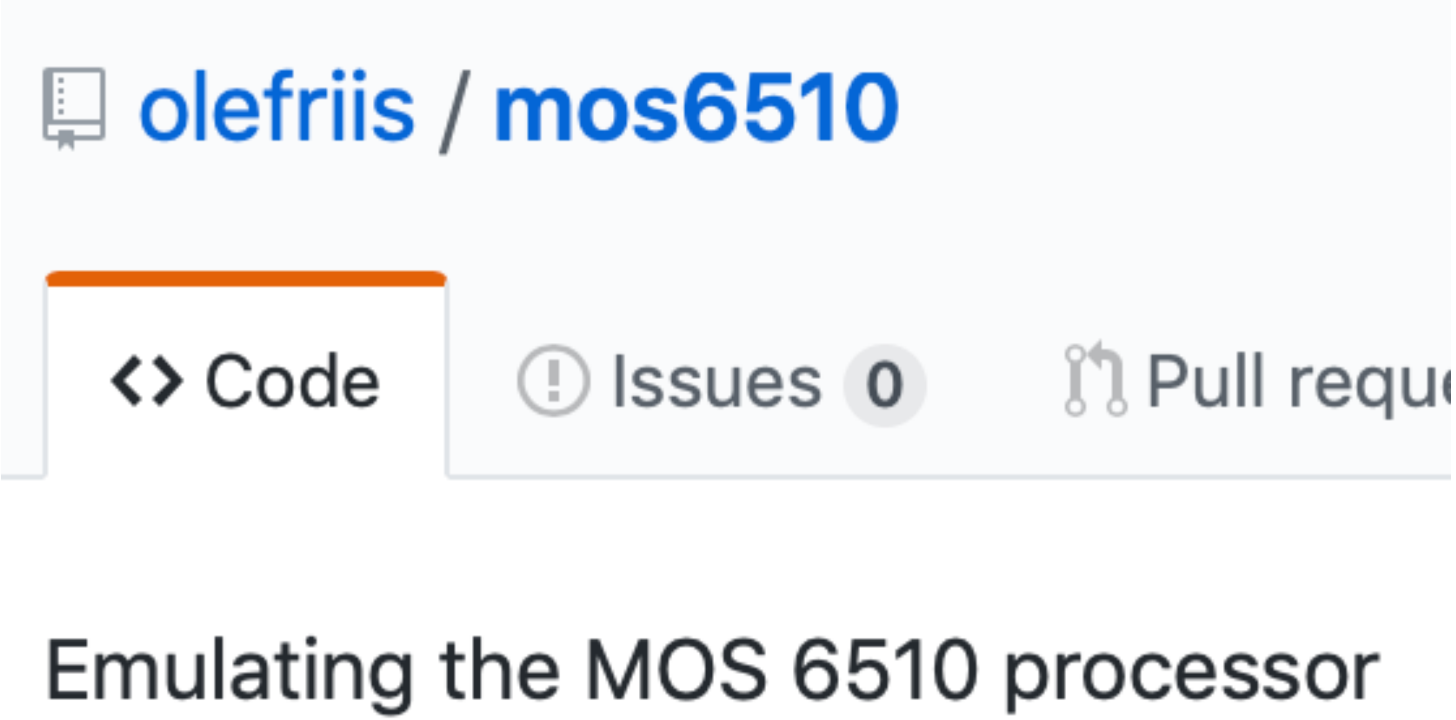
# SID Chip: MOS 6581 / 8580

- 12V (6581) / 9V (8580)
- 3 voices
- 4 wave forms (triangle, saw, pulse, noise)
- 16 volume levels (4 bit)
- Attack-Decay-Sustain-Release (ADSR)
- Filters
- Ring modulation

I don’t really want to spend time on a MOS 6510 emulator, but there was no such Ruby gem…

# 2 Hours and a Hack Later…

- (Don't look! ☺ )



However, no way around emulating the SID

# The Original SID Specification

**commodore**
**mos technology**
**NMOS**

950 Rittenhouse Rd., Norristown, PA 19403 • Tel.: 215/666-7950 • TWX: 510/660-4168

## 6581 SOUND INTERFACE DEVICE (SID)

6581 SOUND INTERFACE DEVICE (SID)

**CONCEPT**

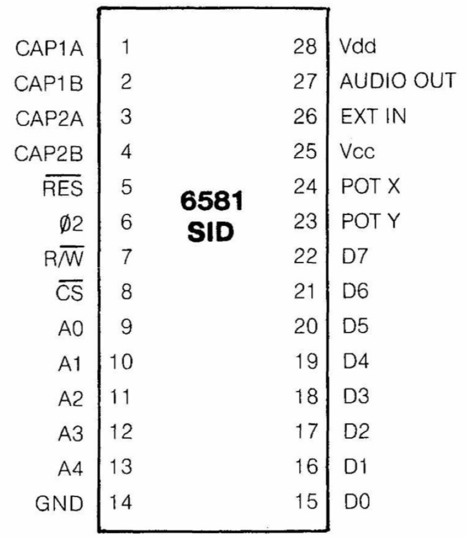
The 6581 Sound Interface Device (SID) is a single-chip, 3-voice electronic music synthesizer/sound effects generator compatible with the 65XX and similar microprocessor families. SID provides wide-range, high-resolution control of pitch (frequency), tone color (harmonic content) and dynamics (volume). Specialized control circuitry minimizes software overhead, facilitating use in arcade/home video games and low-cost musical instruments.

# The Original SID Specification

**FEATURES**

- 3 Tone Oscillators
  Range: 0-4 kHz
- 4 Waveforms per Oscillator
  Triangle, Sawtooth,
  Variable Pulse, Noise
- 3 Amplitude Modulators
  Range: 48 dB
- 3 Envelope Generators
  Exponential response
  Attack Rate: 2mS-8S
  Decay Rate: 6mS-24S
  Sustain Level: 0-peak volume
  Release Rate: 6mS-24S
- Oscillator Synchronization
- Ring Modulation
- Programmable Filter
  Cutoff range: 30 Hz-12 kHz
  12 dB/octave Rolloff
  Low pass, Band pass,
  High pass, Notch outputs
  Variable Resonance
- Master Volume Control
- 2 A/D POT Interfaces
- Random Number/Modulation Generator
- External Audio Input

**6581 PIN CONFIGURATION**



## SID CONTROL REGISTERS

There are 29 eight-bit registers in SID which control the generation of sound. These registers are either WRITE-only or READ-only and are listed below in Table 1.

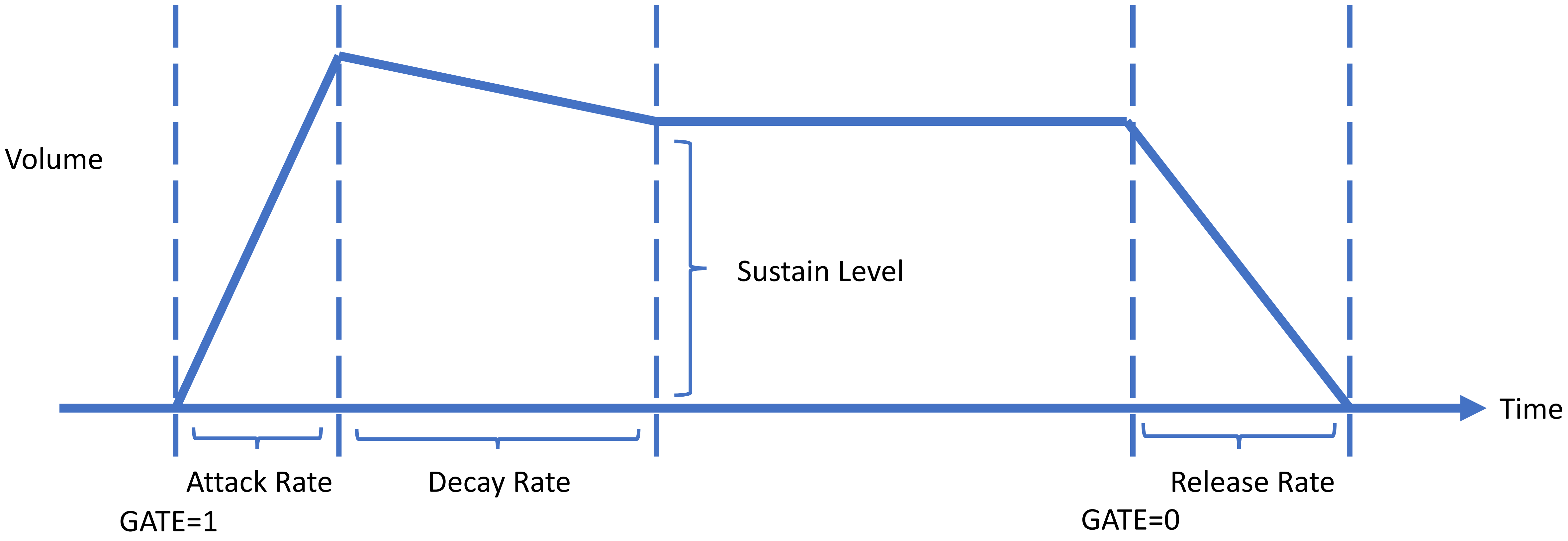
| | Address | | | | | Reg # | Data | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A4 | A3 | A2 | A1 | A0 | (Hex) | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | Reg Name | Reg Type |
| | | | | | | | | | | | | | | | **VOICE 1** | |
| 0 | 0 | 0 | 0 | 0 | 0 | 00 | F7 | F6 | F5 | F4 | F3 | F2 | F1 | F0 | Freq Lo | Write-only |
| 1 | 0 | 0 | 0 | 0 | 1 | 01 | F15 | F14 | F13 | F12 | F11 | F10 | F9 | F8 | Freq Hi | Write-only |
| 2 | 0 | 0 | 0 | 1 | 0 | 02 | PW7 | PW6 | PW5 | PW4 | PW3 | PW2 | PW1 | PW0 | PW LO | Write-only |
| 3 | 0 | 0 | 0 | 1 | 1 | 03 | — | — | — | — | PW11 | PW10 | PW9 | PW8 | PW HI | Write-only |
| 4 | 0 | 0 | 1 | 0 | 0 | 04 | NOISE | | | | TEST | RING MOD | SYNC | GATE | Control Reg | Write-only |
| 5 | 0 | 0 | 1 | 0 | 1 | 05 | ATK3 | ATK2 | ATK1 | ATK0 | DCY3 | DCY2 | DCY1 | DCY0 | Attack/Decay | Write-only |
| 6 | 0 | 0 | 1 | 1 | 0 | 06 | STN3 | STN2 | STN1 | STN0 | RIS3 | RIS2 | RIS1 | RIS0 | Sustain/Release | Write-only |
| | | | | | | | | | | | | | | | **VOICE 2** | |
| 7 | 0 | 0 | 1 | 1 | 1 | 07 | F7 | F6 | F5 | F4 | F3 | F2 | F1 | F0 | Freq LO | Write-only |
| 8 | 0 | 1 | 0 | 0 | 0 | 08 | F15 | F14 | F13 | F12 | F11 | F10 | F9 | F8 | Freq Hi | Write-only |
| 9 | 0 | 1 | 0 | 0 | 1 | 09 | PW7 | PW6 | PW5 | PW4 | PW3 | PW2 | PW1 | PW0 | PW LO | Write-only |
| 10 | 0 | 1 | 0 | 1 | 0 | 0A | — | — | — | — | PW11 | PW10 | PW9 | PW8 | PW HI | Write-only |
| 11 | 0 | 1 | 0 | 1 | 1 | 0B | NOISE | | | | TEST | RING MOD | SYNC | GATE | Control Reg | Write-only |
| 12 | 0 | 1 | 1 | 0 | 0 | 0C | ATK3 | ATK2 | ATK1 | ATK0 | DCY3 | DCY2 | DCY1 | DCY0 | Attack/Decay | Write-only |
| 13 | 0 | 1 | 1 | 0 | 1 | 0D | STN3 | STN2 | STN1 | STN0 | RIS3 | RIS2 | RIS1 | RIS0 | Sustain/Release | Write-only |
| | | | | | | | | | | | | | | | **VOICE 3** | |
| 14 | 0 | 1 | 1 | 1 | 0 | 0E | F7 | F6 | F5 | F4 | F3 | F2 | F1 | F0 | Freq Lo | Write-only |
| 15 | 0 | 1 | 1 | 1 | 1 | 0F | F15 | F14 | F13 | F12 | F11 | F10 | F9 | F8 | Freq Hi | Write-only |
| 16 | 1 | 0 | 0 | 0 | 0 | 10 | PW7 | PW6 | PW5 | PW4 | PW3 | PW2 | PW1 | PW0 | PW LO | Write-only |
| 17 | 1 | 0 | 0 | 0 | 1 | 11 | — | — | — | — | PW11 | PW10 | PW9 | PW8 | PW HI | Write-only |
| 18 | 1 | 0 | 0 | 1 | 0 | 12 | NOISE | | | | TEST | RING MOD | SYNC | GATE | Control Reg | Write-only |
| 19 | 1 | 0 | 0 | 1 | 1 | 13 | ATK3 | ATK2 | ATK1 | ATK0 | DCY3 | DCY2 | DCY1 | DCY0 | Attack/Decay | Write-only |
| 20 | 1 | 0 | 1 | 0 | 0 | 14 | STN3 | STN2 | STN1 | STN0 | RIS3 | RIS2 | RIS1 | RIS0 | Sustain/Release | Write-only |
| | | | | | | | | | | | | | | | **Filter** | |
| 21 | 1 | 0 | 1 | 0 | 1 | 15 | — | — | — | — | — | FC2 | FC1 | FC0 | FC LO | Write-only |
| 22 | 1 | 0 | 1 | 1 | 0 | 16 | FC10 | FC9 | FC8 | FC7 | FC6 | FC5 | FC4 | FC3 | FC HI | Write-only |
| 23 | 1 | 0 | 1 | 1 | 1 | 17 | RES3 | RES2 | RES1 | RES0 | Filt EX | Filt 3 | Filt 2 | Filt 1 | RES/Filt | Write-only |
| 24 | 1 | 1 | 0 | 0 | 0 | 18 | 3 OFF | HP | BP | LP | VOL3 | VOL2 | VOL1 | VOL0 | Mode/Vol | Write-only |
| | | | | | | | | | | | | | | | **Misc** | |
| 25 | 1 | 1 | 0 | 0 | 1 | 19 | PX7 | PX6 | PX5 | PX4 | PX3 | PX2 | PX1 | PX0 | POTX | Read-only |
| 26 | 1 | 1 | 0 | 1 | 0 | 1A | PY7 | PY6 | PY5 | PY4 | PY3 | PY2 | PY1 | PY0 | POTY | Read-only |
| 27 | 1 | 1 | 0 | 1 | 1 | 1B | 07 | 06 | 05 | 04 | 03 | 02 | 01 | 00 | OSC3/Random | Read-only |
| 28 | 1 | 1 | 1 | 0 | 0 | 1C | E7 | E6 | E5 | E4 | E3 | E2 | E1 | E0 | ENV3 | Read-only |

**TABLE 1 — SID REGISTER MAP**

# The Original SID Specification

| | Address | | | | | Reg # | Data | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A4 | A3 | A2 | A1 | A0 | (Hex) | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | Reg Name | Reg Type |
| | | | | | | | | | | | | | | | VOICE 1 | |
| 0 | 0 | 0 | 0 | 0 | 0 | 00 | F7 | F6 | F5 | F4 | F3 | F2 | F1 | F0 | Freq Lo | Write-only |
| 1 | 0 | 0 | 0 | 0 | 1 | 01 | F15 | F14 | F13 | F12 | F11 | F10 | F9 | F8 | Freq Hi | Write-only |
| 2 | 0 | 0 | 0 | 1 | 0 | 02 | PW7 | PW6 | PW5 | PW4 | PW3 | PW2 | PW1 | PW0 | PW LO | Write-only |
| 3 | 0 | 0 | 0 | 1 | 1 | 03 | — | — | — | — | PW11 | PW10 | PW9 | PW8 | PW HI | Write-only |
| 4 | 0 | 0 | 1 | 0 | 0 | 04 | NOISE | | | | TEST | RING MOD | SYNC | GATE | Control Reg | Write-only |
| 5 | 0 | 0 | 1 | 0 | 1 | 05 | ATK3 | ATK2 | ATK1 | ATK0 | DCY3 | DCY2 | DCY1 | DCY0 | Attack/Decay | Write-only |
| 6 | 0 | 0 | 1 | 1 | 0 | 06 | STN3 | STN2 | STN1 | STN0 | RIS3 | RIS2 | RIS1 | RIS0 | Sustain/Release | Write-only |

# Attack-Decay-Sustain-Release



# The Original SID Specification

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | **Filter** | |
| 21 | 1 | 0 | 1 | 0 | 1 | 15 | — | — | — | — | — | FC2 | FC1 | FC0 | FC LO | Write-only |
| 22 | 1 | 0 | 1 | 1 | 0 | 16 | FC10 | FC9 | FC8 | FC7 | FC6 | FC5 | FC4 | FC3 | FC HI | Write-only |
| 23 | 1 | 0 | 1 | 1 | 1 | 17 | RES3 | RES2 | RES1 | RES0 | Filt EX | Filt 3 | Filt 2 | Filt 1 | RES/Filt | Write-only |
| 24 | 1 | 1 | 0 | 0 | 0 | 18 | 3 OFF | HP | BP | LP | VOL3 | VOL2 | VOL1 | VOL0 | Mode/Vol | Write-only |
| | | | | | | | | | | | | | | | **Misc** | |
| 25 | 1 | 1 | 0 | 0 | 1 | 19 | PX7 | PX6 | PX5 | PX4 | PX3 | PX2 | PX1 | PX0 | POTX | Read-only |
| 26 | 1 | 1 | 0 | 1 | 0 | 1A | PY7 | PY6 | PY5 | PY4 | PY3 | PY2 | PY1 | PY0 | POTY | Read-only |
| 27 | 1 | 1 | 0 | 1 | 1 | 1B | 07 | 06 | 05 | 04 | 03 | 02 | 01 | 00 | OSC3/Random | Read-only |
| 28 | 1 | 1 | 1 | 0 | 0 | 1C | E7 | E6 | E5 | E4 | E3 | E2 | E1 | E0 | ENV3 | Read-only |

# The Original SID Specification

## APPENDIX A — EQUAL-TEMPERED MUSICAL SCALE VALUES

The following table lists the numerical values which must be stored in the SID Oscillator frequency control registers to produce the notes of the equal-tempered musical scale. The equal-tempered scale consists of an octave containing 12 semitones (notes): C, D, E, F, G, A, B and C#, D#, F#, G#,A#. The frequency of each semitone is exactly the 12th root of 2 ($\sqrt[12]{2}$) times the frequency of the previous semitone. The table is based on a Ø2 = clock of 1.0 Mhz. Refer to the equation given in the Register Description for use of other master clock frequencies. The scale selected is concert pitch, in which A4 = 440 Hz. Transpositions of this scale and scales other than the equal-tempered scale are also possible.

| Musical Note | Freq (Hz) | Osc Fn (Decimal) | Osc Fn (Hex) | Musical Note | Freq (Hz) | Osc Fn (Decimal) | Osc Fn (Hex) |
|---|---|---|---|---|---|---|---|
| 0 C0 | 16.35 | 274 | 0112 | 48 C4 | 261.63 | 4389 | 1125 |
| 1 C0$ | 17.32 | 291 | 0123 | 49 C4$ | 277.18 | 4650 | 122A |
| 2 D0 | 18.35 | 308 | 0134 | 50 D4 | 293.66 | 4927 | 133F |
| 3 D0$ | 19.44 | 326 | 0146 | 51 D4$ | 311.13 | 5220 | 1464 |
| 4 E0 | 20.60 | 346 | 015A | 52 E4 | 329.63 | 5530 | 159A |
| 5 F0 | 21.83 | 366 | 016E | 53 F4 | 349.23 | 5859 | 16E3 |
| 6 F0$ | 23.12 | 388 | 0184 | 54 F4$ | 370.00 | 6207 | 183F |
| 7 G0 | 24.50 | 411 | 018B | 55 G4 | 392.00 | 6577 | 1981 |
| 8 G0$ | 25.96 | 435 | 01B3 | 56 G4$ | 415.30 | 6968 | 1B38 |
| 9 A0 | 27.50 | 461 | 01CD | 57 A4 | 440.00 | 7382 | 1CD6 |
| 10 A0$ | 29.14 | 489 | 01E9 | 58 A4$ | 466.16 | 7821 | 1E80 |
| 11 B0 | 30.87 | 518 | 0206 | 59 B4 | 493.88 | 8286 | 205E |
| 12 C1 | 32.70 | 549 | 0225 | 60 C5 | 523.25 | 8779 | 224B |
| 13 C1$ | 34.65 | 581 | 0245 | 61 C5$ | 554.37 | 9301 | 2455 |
| 14 D1 | 36.71 | 616 | 0268 | 62 D5 | 587.33 | 9854 | 267E |
| 15 D1$ | 38.89 | 652 | 028C | 63 D5$ | 622.25 | 10440 | 28C8 |
| 16 E1 | 41.20 | 691 | 02B3 | 64 E5 | 659.25 | 11060 | 2B34 |
| 17 F1 | 43.65 | 732 | 02DC | 65 F5 | 698.46 | 11718 | 2DC6 |
| 18 F1$ | 46.25 | 776 | 0308 | 66 F5$ | 740.00 | 12415 | 307F |
| 19 G1 | 49.00 | 822 | 0336 | 67 G5 | 783.99 | 13153 | 3361 |
| 20 G1$ | 51.91 | 871 | 0367 | 68 G5$ | 830.61 | 13935 | 366F |
| 21 A1 | 55.00 | 923 | 039B | 69 A5 | 880.00 | 14764 | 39AC |
| 22 A1$ | 58.27 | 978 | 03D2 | 70 A5$ | 932.33 | 15642 | 3D1A |
| 23 B1 | 61.74 | 1036 | 040C | 71 B5 | 987.77 | 16572 | 40BC |
| 24 C2 | 65.41 | 1097 | 0449 | 72 C6 | 1046.50 | 17557 | 4495 |
| 25 C2$ | 69.30 | 1163 | 048B | 73 C6$ | 1108.73 | 18601 | 48A9 |
| 26 D2 | 73.42 | 1232 | 04D0 | 74 D6 | 1174.66 | 19709 | 4CFC |
| 27 D2$ | 77.78 | 1305 | 0519 | 75 D6$ | 1244.51 | 20897 | 518F |
| 28 E2 | 82.41 | 1383 | 0567 | 76 E6 | 1318.51 | 22121 | 5669 |
| 29 F2 | 87.31 | 1465 | 05B9 | 77 F6 | 1396.91 | 23436 | 5B8C |
| 30 F2$ | 92.50 | 1552 | 0610 | 78 F6$ | 1479.98 | 24830 | 60FE |
| 31 G2 | 98.00 | 1644 | 066C | 79 G6 | 1567.98 | 26306 | 6602 |
| 32 G2$ | 103.83 | 1742 | 06CE | 80 G6$ | 1661.22 | 27871 | 6CDF |
| 33 A2 | 110.00 | 1845 | 0735 | 81 A6 | 1760.00 | 29528 | 7358 |
| 34 A2$ | 116.54 | 1955 | 07A3 | 82 A6$ | 1864.65 | 31234 | 7A34 |
| 35 B2 | 123.47 | 2071 | 0817 | 83 B6 | 1975.53 | 33144 | 8178 |
| 36 C3 | 130.81 | 2195 | 0893 | 84 C7 | 2093.00 | 35115 | 892B |
| 37 C3$ | 138.59 | 2325 | 0915 | 85 C7$ | 2217.46 | 37203 | 9153 |
| 38 D3 | 146.83 | 2463 | 099F | 86 D7 | 2349.32 | 39415 | 99F7 |
| 39 D3$ | 155.56 | 2610 | 0A32 | 87 D7$ | 2489.01 | 41759 | A31F |
| 40 E3 | 164.81 | 2765 | 0ACD | 88 E7 | 2637.02 | 44242 | ACD2 |
| 41 F3 | 174.61 | 2930 | 0B72 | 89 F7 | 2793.83 | 46873 | B719 |
| 42 F3$ | 185.00 | 3104 | 0C20 | 90 F7$ | 2959.95 | 49660 | C1FC |
| 43 G3 | 196.00 | 3288 | 0C08 | 91 G7 | 3135.96 | 52613 | C085 |
| 44 G3$ | 207.65 | 3484 | 0D9C | 92 G7$ | 3322.44 | 55741 | 0980 |
| 45 A3 | 220.00 | 3691 | 0E6B | 93 A7 | 3520.00 | 59056 | E6B0 |
| 46 A3$ | 233.08 | 3910 | 0F46 | 94 A7$ | 3729.31 | 62567 | F467 |
| 47 B3 | 246.94 | 4143 | 102F | 95 B7 | 3951.06 | *66288 | *1F2F0 |

# The Original SID Specification

Although the table above provides a simple and quick method for generating the equal-tempered scale, it is very memory inefficient as it requires 192 bytes for the table alone. Memory efficiency can be improved by determining the note value algorithmically. Using the fact that each note in an octave is exactly half the frequency of that note in the next octave, the note look-up table can be reduced from 96 entries to 12 entries, as there are 12 notes per octave. If the 12 entries (24 bytes) consist of the 16-bit values for the eighth octave (C7 through B7), then notes in lower octaves can be derived by choosing the appropriate note in the eighth octave and dividing the 16-bit value by two for each octave of difference. As division by two is nothing more than a right-shift of the value, the calculation can easily be accomplished by a simple software routine. Although note B7 is beyond the range of the Oscillators, this value should still be included in the table for calculation purposes (the MSB

Remember, we are not trying to do an authentic SID emulation

# Playback: Sonic Pi

# Let’s try to implement (parts of) the SID specification!

We did it!

But…

Can’t we get the music in a format for further refinement?

# sidtool

## Usage

You can find lots of `.sid` files (and a super nice list of players for a wide range of platforms) at the High Voltage SID Collection homepage.

Show information, like the author and number of songs in a file:

```
$ sidtool --info <input file>
```

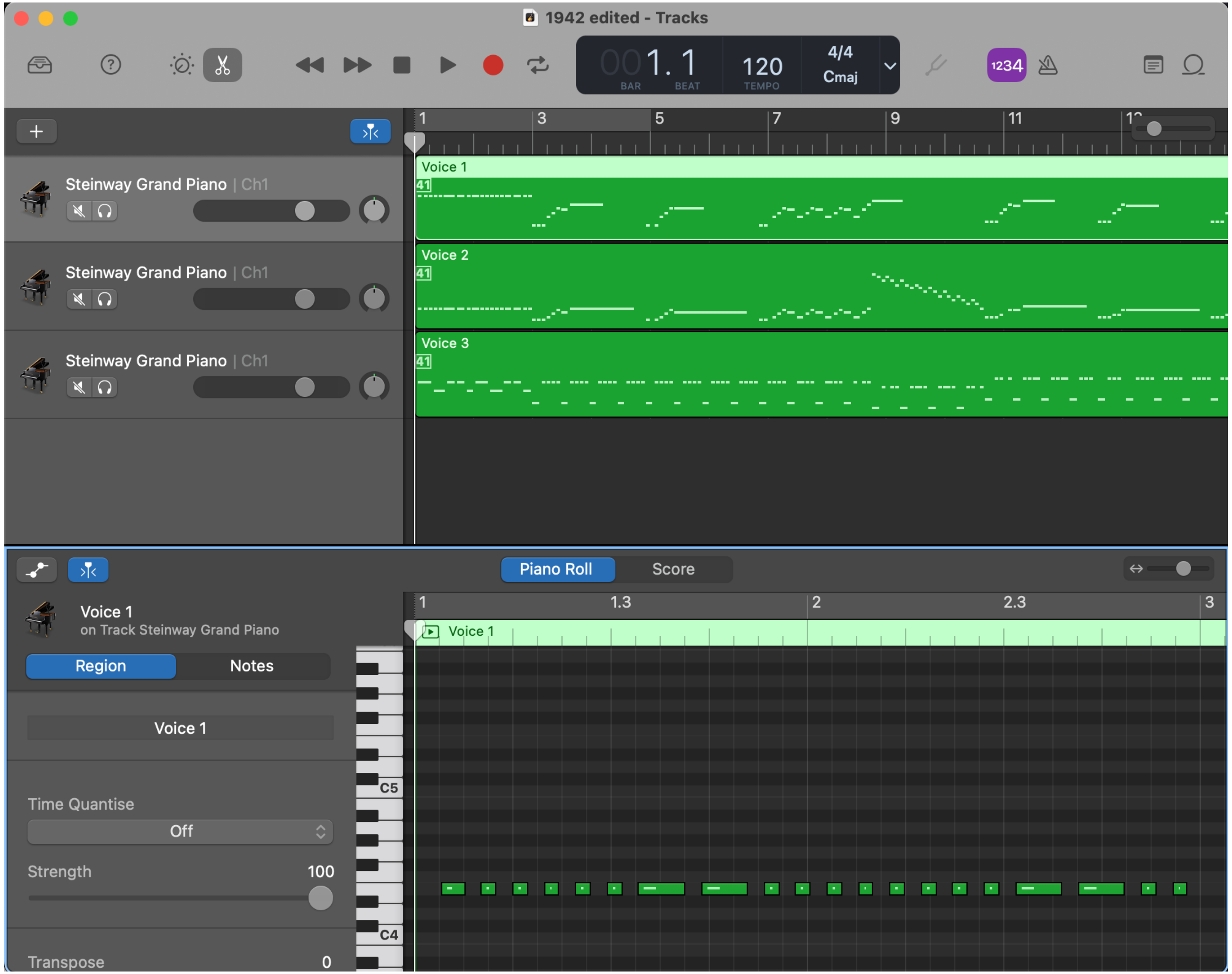
Convert the default song from a `.sid` file to a midi file:

```
$ sidtool --out <output file> --format midi <input file>
```

Convert the default song from a file to a Ruby list (`--format ruby` is the default):

```
$ sidtool --out <output file> <input file>
```

# Create midi files, experiment!



# Links

Sonic Pi: https://sonic-pi.net

MOS 6581 (SID) specification: http://archive.6502.org/datasheets/mos_6581_sid.pdf

High Voltage SID Collection: https://www.hvsc.c64.org

jsSID: https://github.com/jhohertz/jsSID

sidtool: https://github.com/olefriis/sidtool

Code for this presentation: https://github.com/olefriis/c64-music-presentation

# The Last Ninja

Into the Wastelands

# Ben Daglish

1966-2018

# Thank you!