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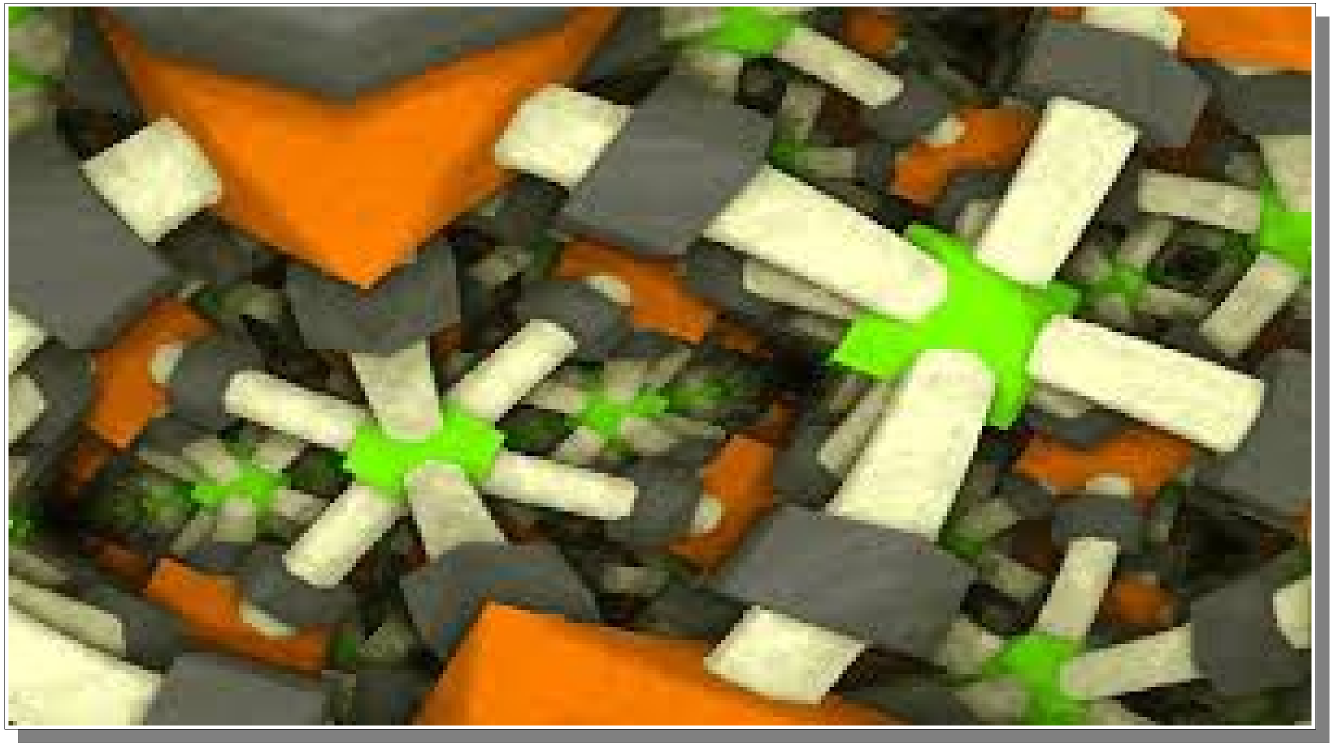
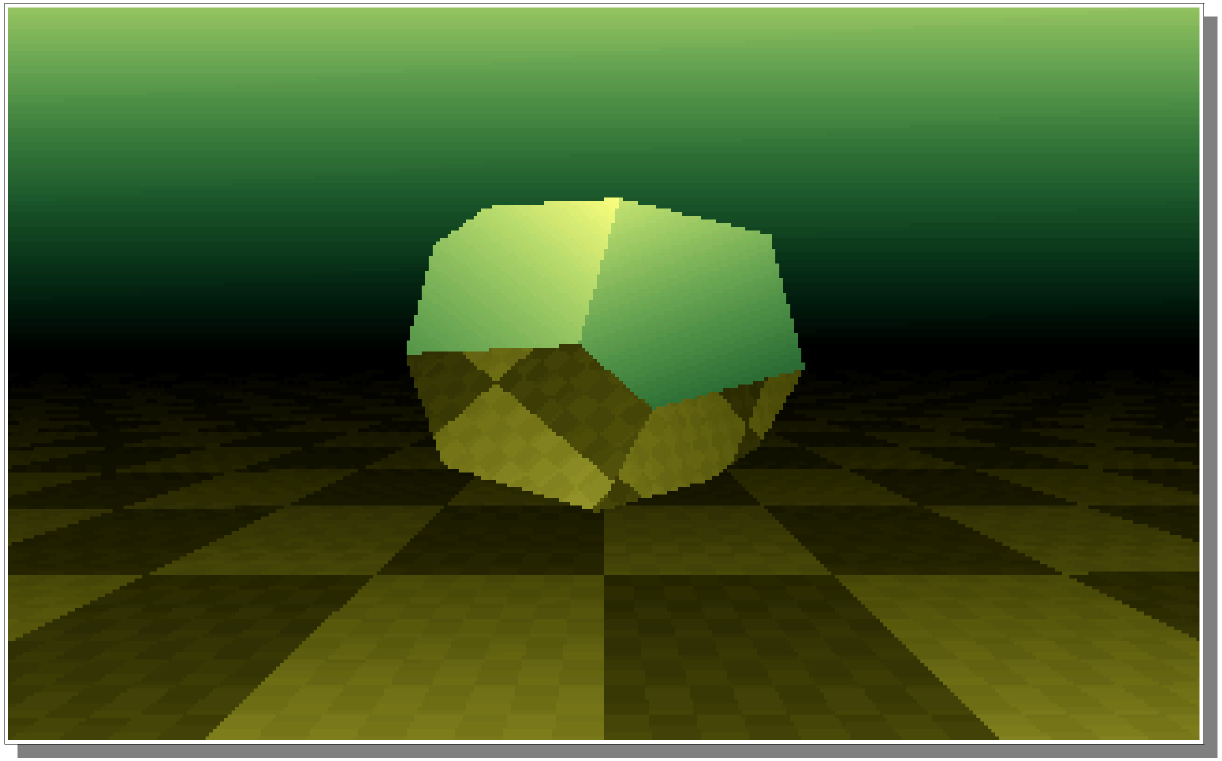
256-byte demoscene: extremly strong competition

256-byte demoscene: extremly strong competition



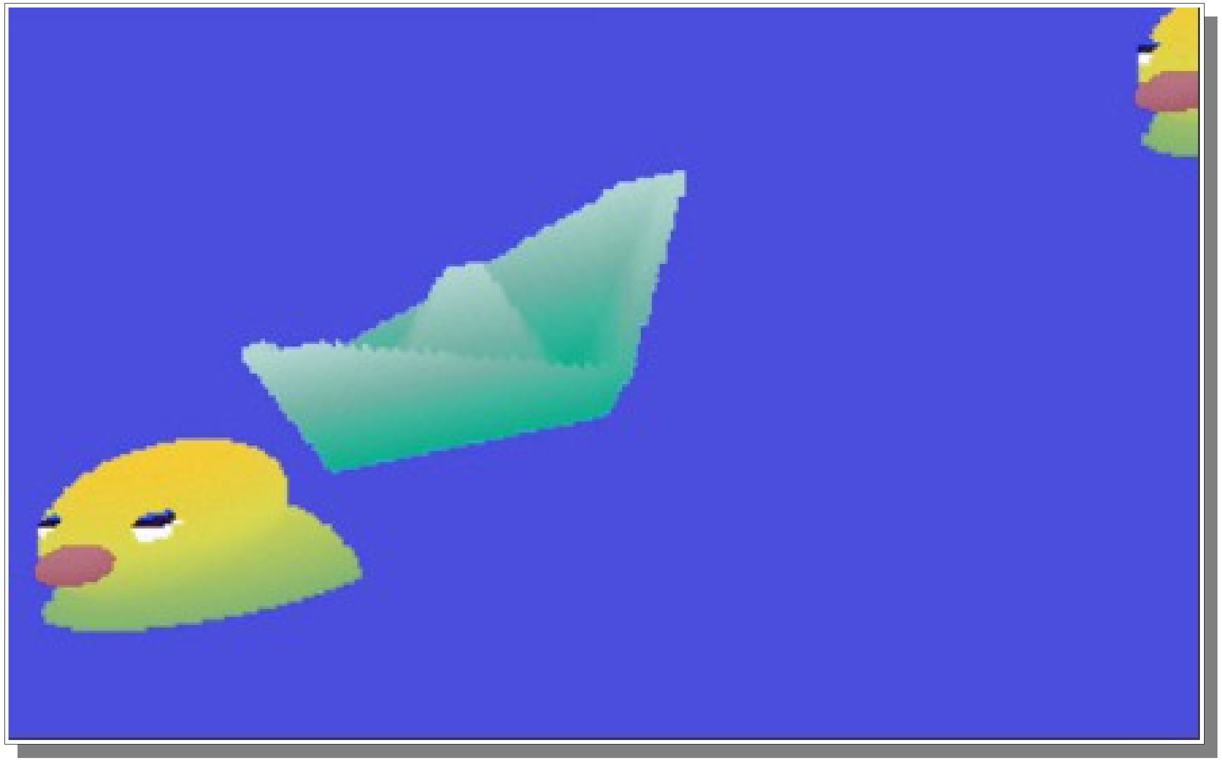
Řrřola: Puls

256-byte demoscene: extremly strong competition



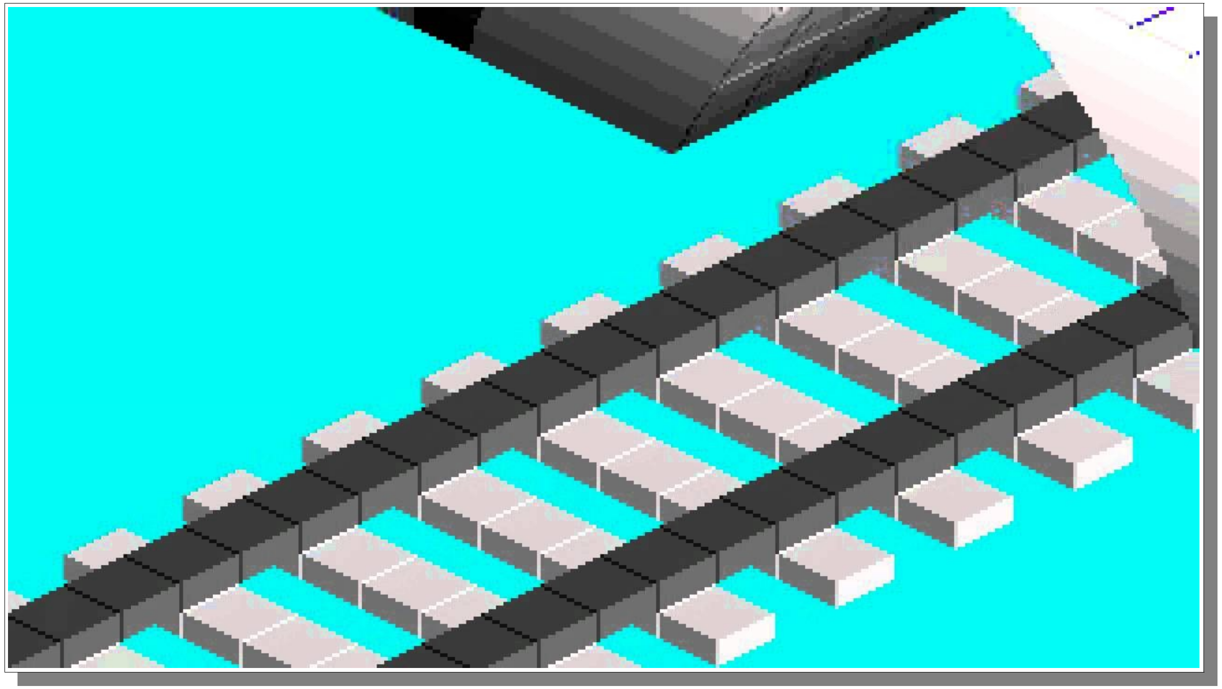
Řrřola: Pyrit

256-byte demoscene: extremly strong competition



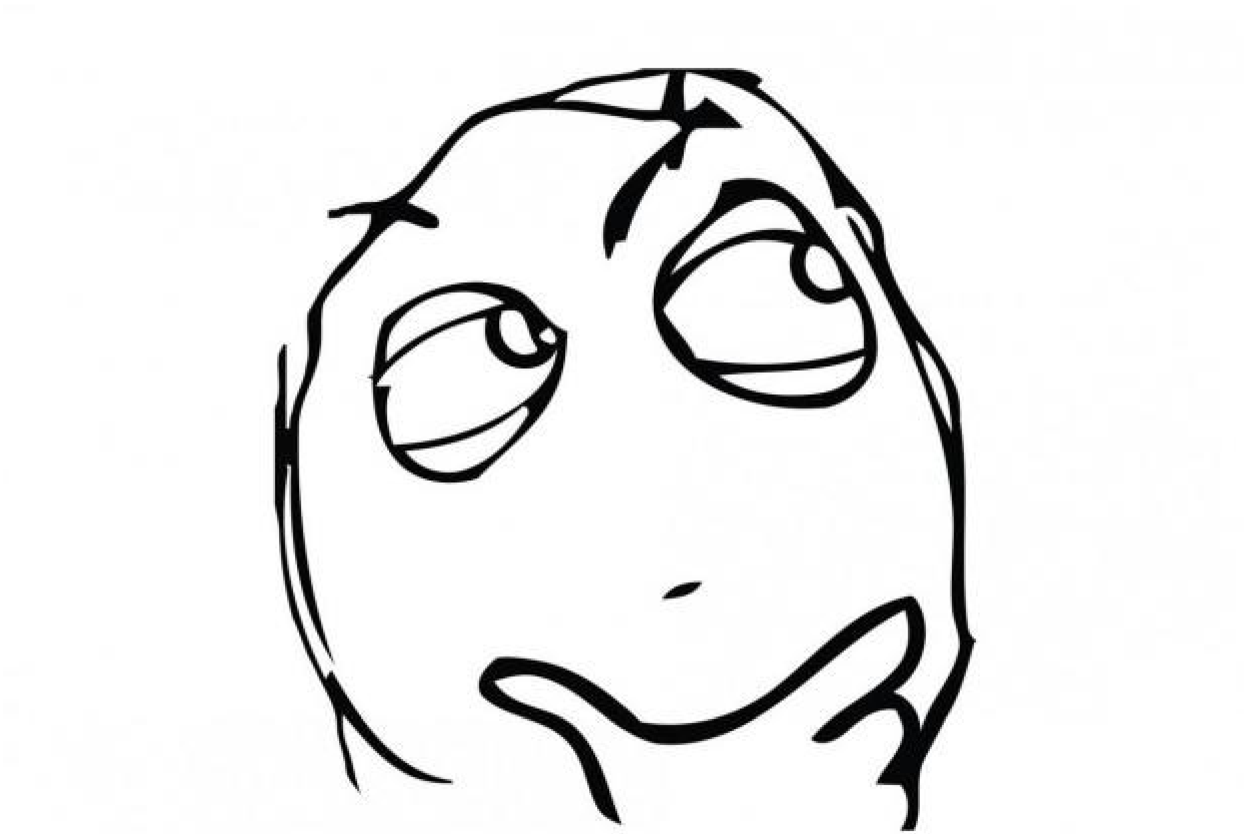
Digimind: Pool Patrol

256-byte demoscene: extremly strong competition



Digimind: Immediate Railways

256-byte demoscene: extremly strong competition

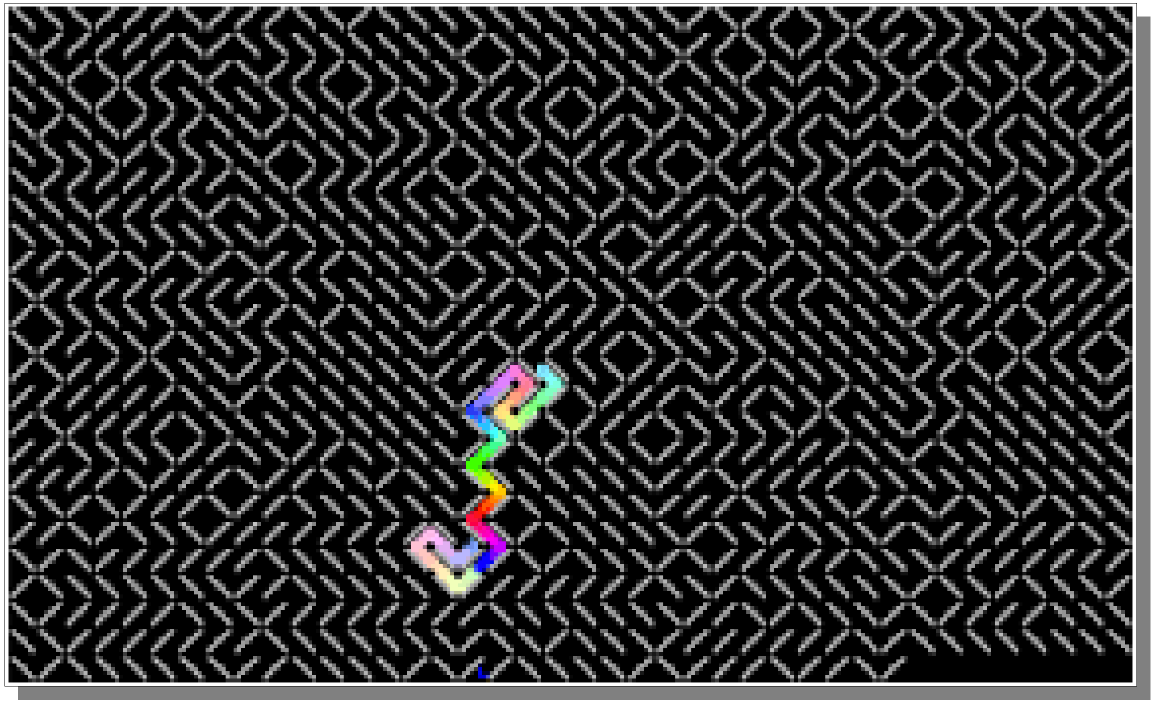


How to shine out of crowd?

256-byte demoscene: how to beat competition?

Fun

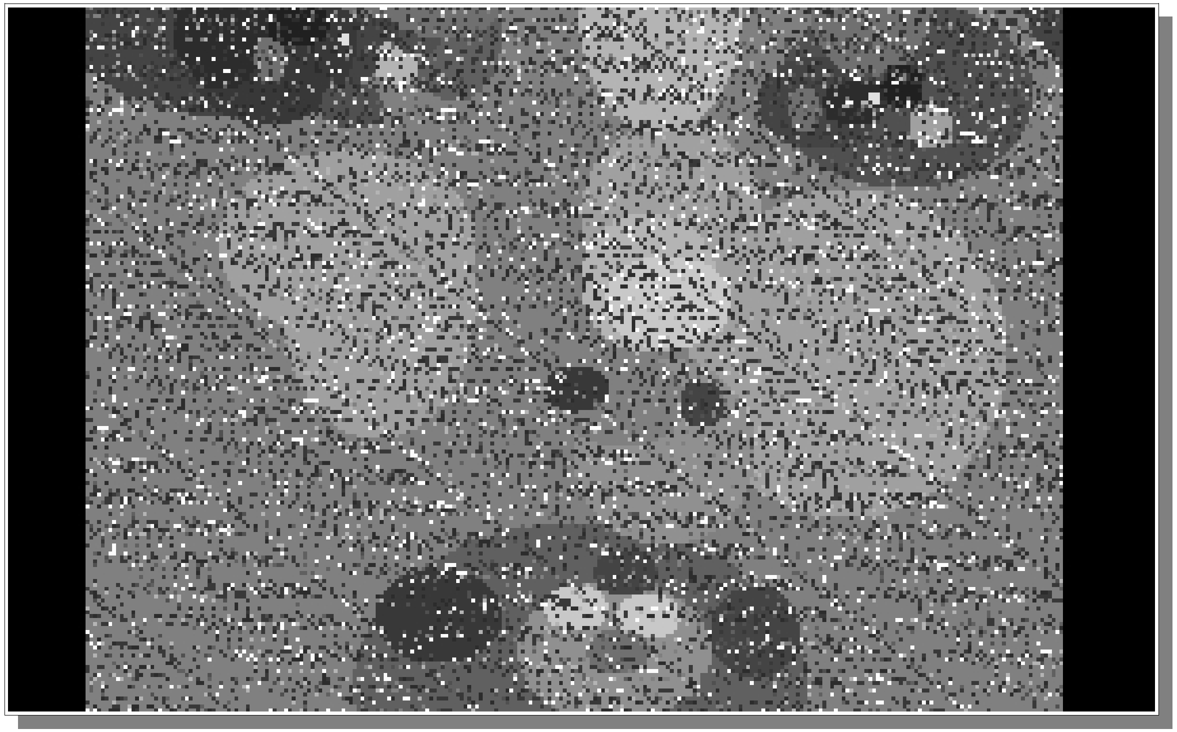
(if you are not a hardcore sizecoder)



ern0: Maze Solver

256-byte demoscene: how to beat competition?

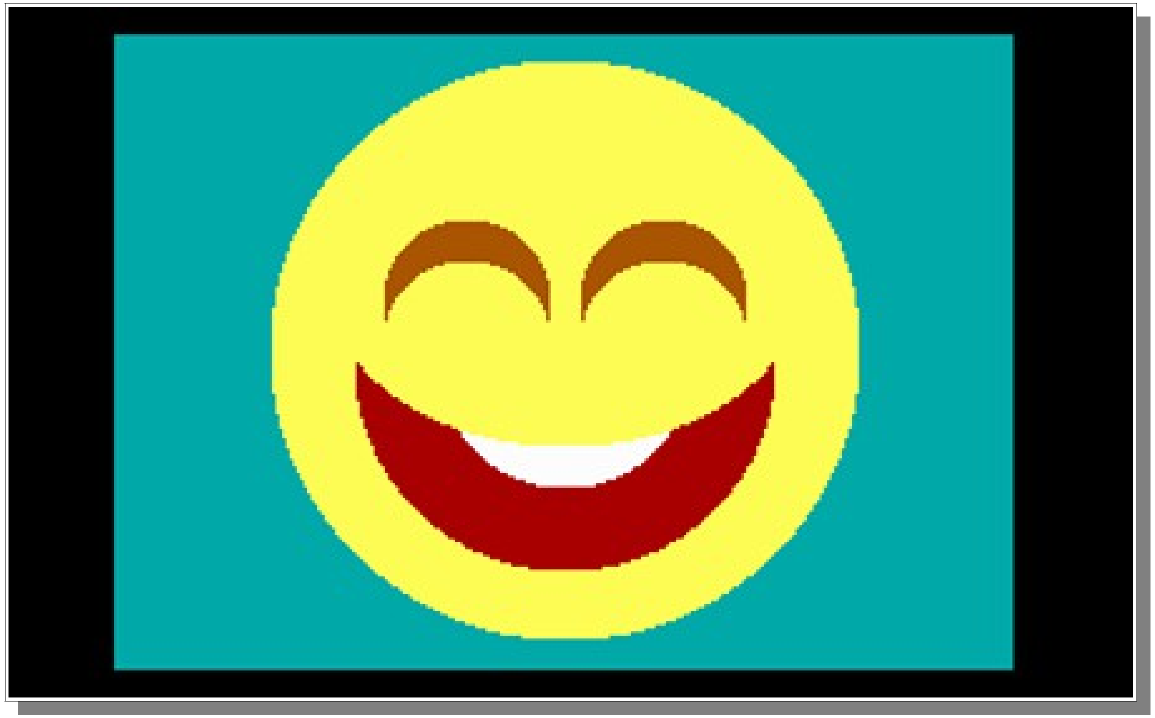
Image processing



TomCat: She – Weak Signal

256-byte demoscene: how to beat competition?

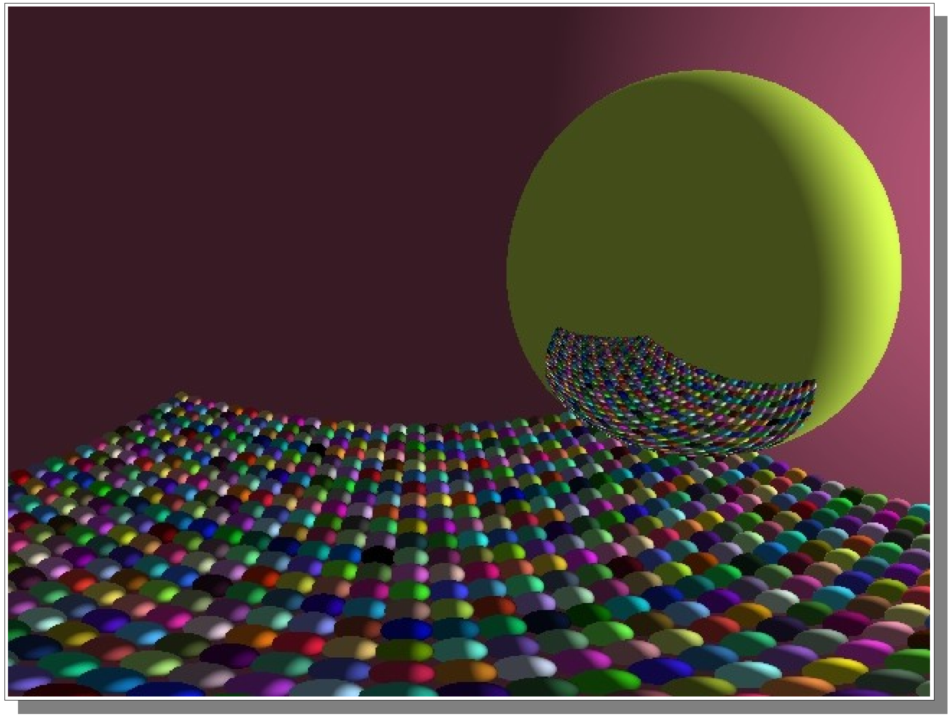
Image processing + fun



TomCat: Be Happy!

256-byte demoscene: how to beat competition?

Raytracing



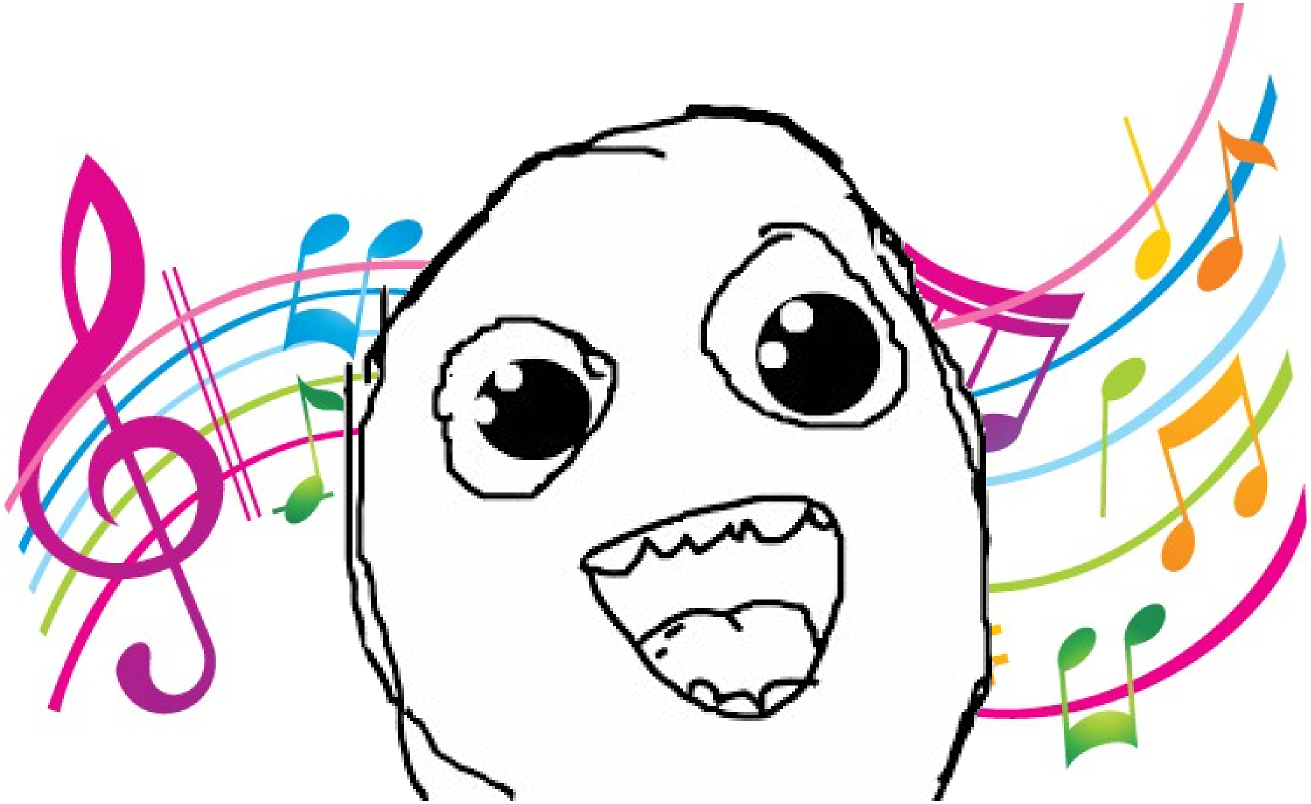
TomCat: Colorful

256-byte demoscene: how to beat competition?

Raytracing + fun

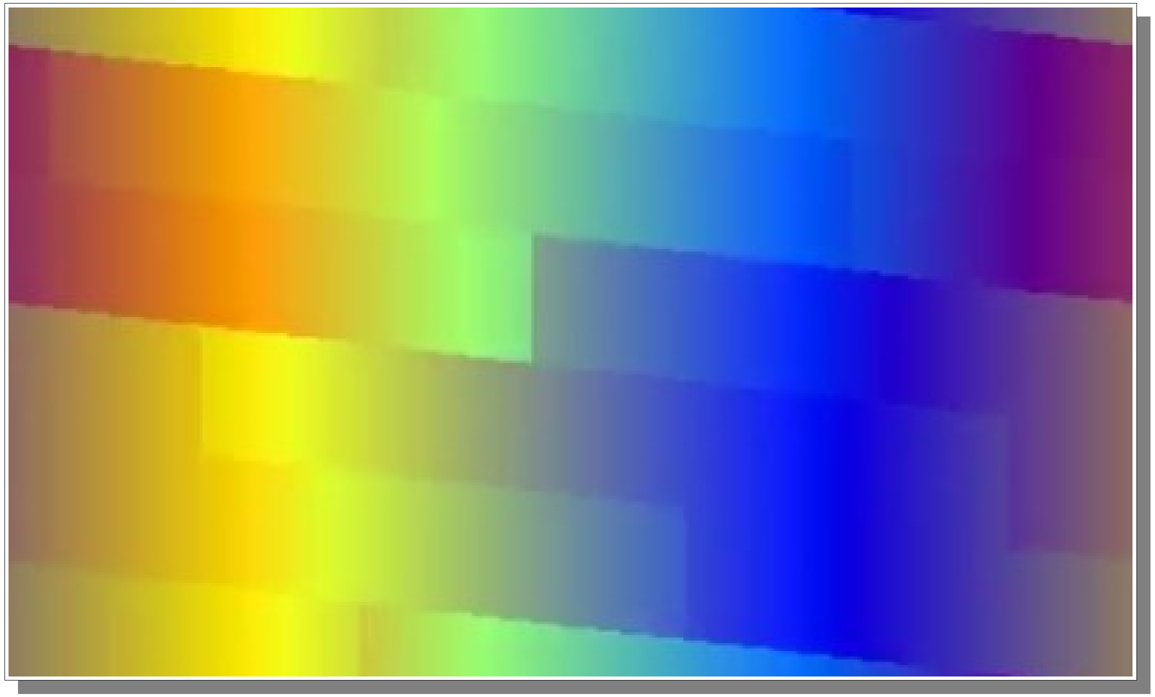
TomCat: Pokeball

256-byte demoscene: how to beat competition?



Music! Add music in 256-byte intros!

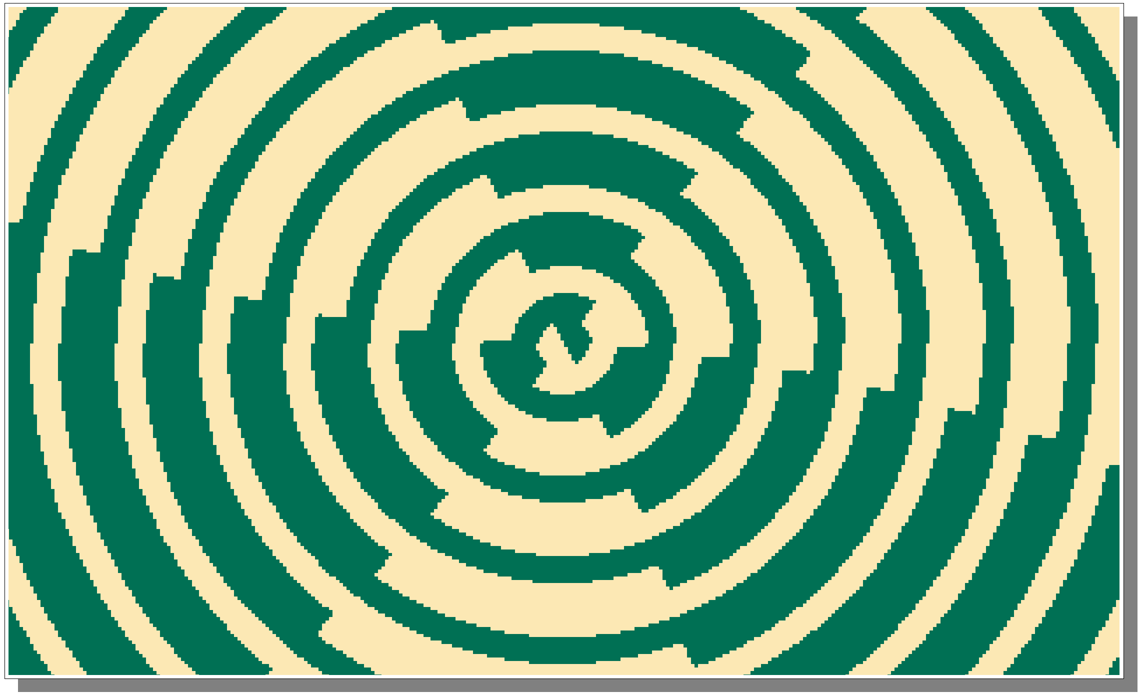
256 byte intro with music



TomCat: 2(56)unlimited

(bytebeat music by ern0)

256 byte intro with music



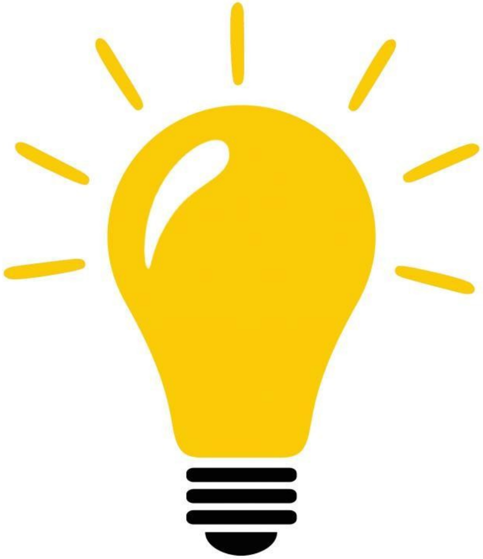
TomCat: No Sleep!

(buzzer music by ern0)

256 byte intro with music

Everyone loves it!

Create universal bytebeat tool



Create universal bytebeat tool

- Bytebeat player & editor

  TomCat

Create universal bytebeat tool

- Bytebeat player & editor
  TomCat
- Formula compiler for assembly
  ern0

Create universal bytebeat tool

- Bytebeat player & editor

  TomCat

FAIL

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  ern0

Create universal bytebeat tool

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FAIL

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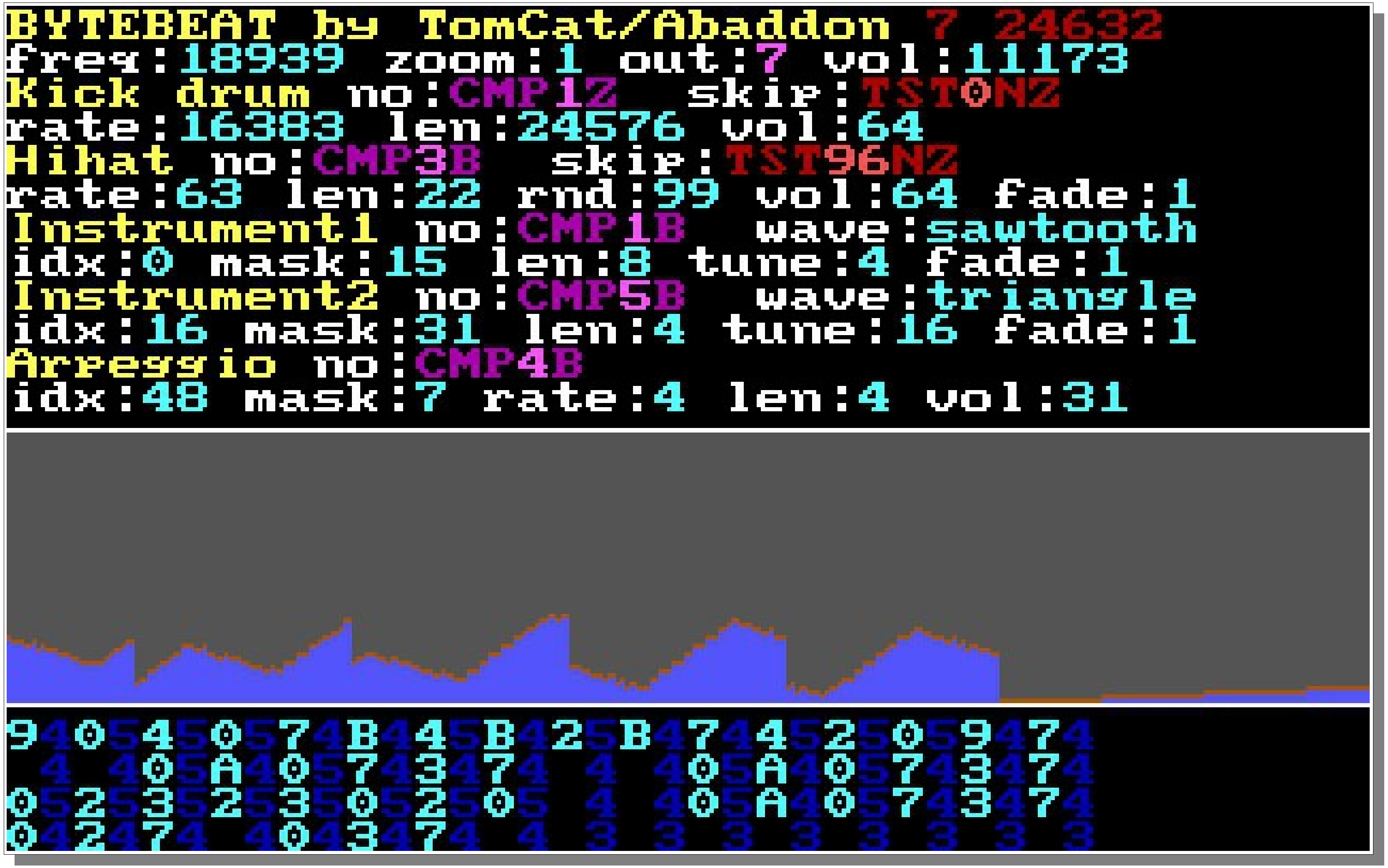
  ern0

FAIL

Bytebeat Editor (TomCat)



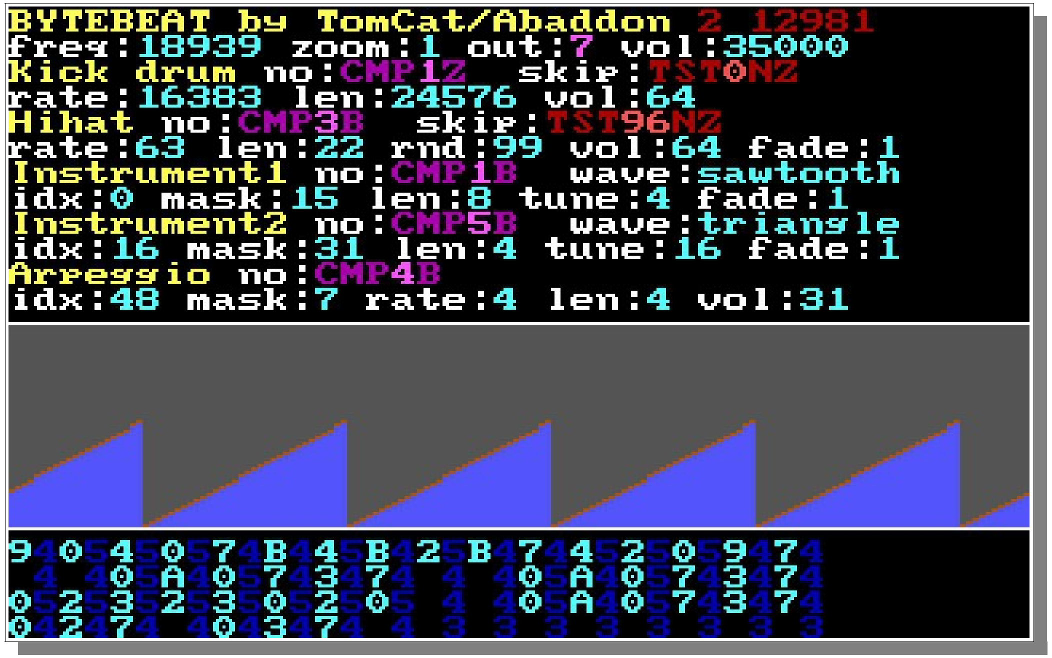
```
BYTEBEAT by TomCat/Abaddon 7 24632
freq:18939 zoom:1 out:7 vol:11173
Kick drum no:CMP1Z  skip:TST0NZ
rate:16383 len:24576 vol:64
Hihat no:CMP3B  skip:TST96NZ
rate:63 len:22 rnd:99 vol:64 fade:1
Instrument1 no:CMP1B  wave:sawtooth
idx:0 mask:15 len:8 tune:4 fade:1
Instrument2 no:CMP5B  wave:triangle
idx:16 mask:31 len:4 tune:16 fade:1
Arpeggio no:CMP4B
idx:48 mask:7 rate:4 len:4 vol:31
```

```
94054505574B445B425B4744525059474
 4 405A405743474 4 405A405743474
0525352535052505 4 405A405743474
042474 4043474 4 3 3 3 3 3 3 3 3
```

Bytebeat Editor (TomCat)

Features:

- realtime feedback



```
BYTEBEAT by TomCat/Abaddon 2 12981
freq:18939 zoom:1 out:7 vol:35000
Kick drum no:CMP1Z  skip:TST0NZ
rate:16383 len:24576 vol:64
Hihat no:CMP3B  skip:TST96NZ
rate:63 len:22 rnd:99 vol:64 fade:1
Instrument1 no:CMP1B  wave:sawtooth
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idx:16 mask:31 len:4 tune:16 fade:1
Arreggio no:CMP4B
idx:48 mask:7 rate:4 len:4 vol:31
```
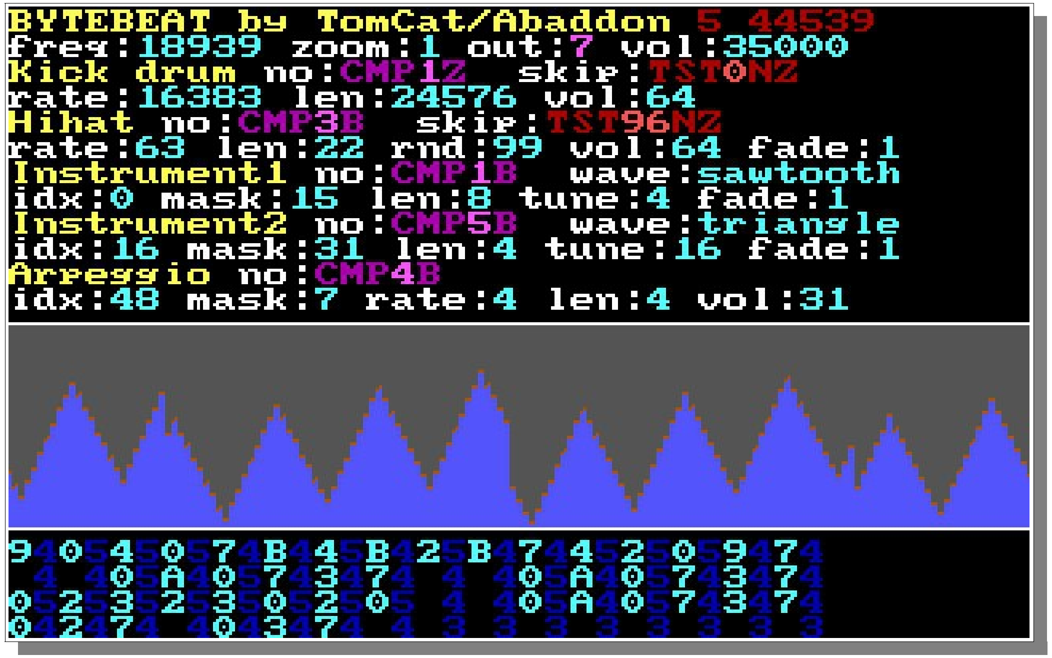

```
9405450574B445B425B4744525059474
 4 405A405743474 4 405A405743474
0525352535052505 4 405A405743474
042474 4043474 4 3 3 3 3 3 3 3 3
```

Bytebeat Editor (TomCat)

Features:

- realtime feedback
- graphical sound wave



```
BYTEBEAT by TomCat/Abaddon 5 44539
freq:18939 zoom:1 out:7 vol:35000
Kick drum no:CMP1Z  skip:TST0NZ
rate:16383 len:24576 vol:64
Hihat no:CMP3B  skip:TST96NZ
rate:63 len:22 rnd:99 vol:64 fade:1
Instrument1 no:CMP1B  wave:sawtooth
idx:0 mask:15 len:8 tune:4 fade:1
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Arpeggio no:CMP4B
idx:48 mask:7 rate:4 len:4 vol:31
```

```
9405450574B445B425B4744525059474
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042474 4043474 4 3 3 3 3 3 3 3 3
```

Bytebeat Editor (TomCat)

Features:

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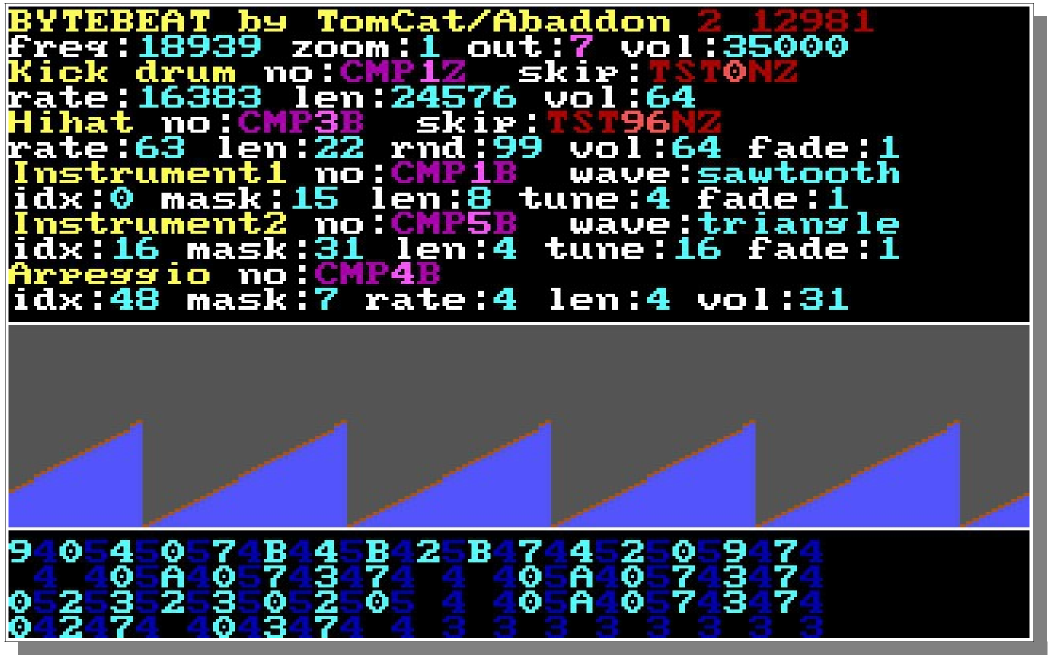
- save/restore modified code



```
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freq:18939 zoom:1 out:7 vol:35000
Kick drum no:CMP1Z  skip:TST0NZ
rate:16383 len:24576 vol:64
Hihat no:CMP3B  skip:TST96NZ
rate:63 len:22 rnd:99 vol:64 fade:1
Instrument1 no:CMP1B  wave:sawtooth
idx:0 mask:15 len:8 tune:4 fade:1
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idx:16 mask:31 len:4 tune:16 fade:1
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0525352535052505 4 405A405743474
042474 4043474 4 3 3 3 3 3 3 3 3
```

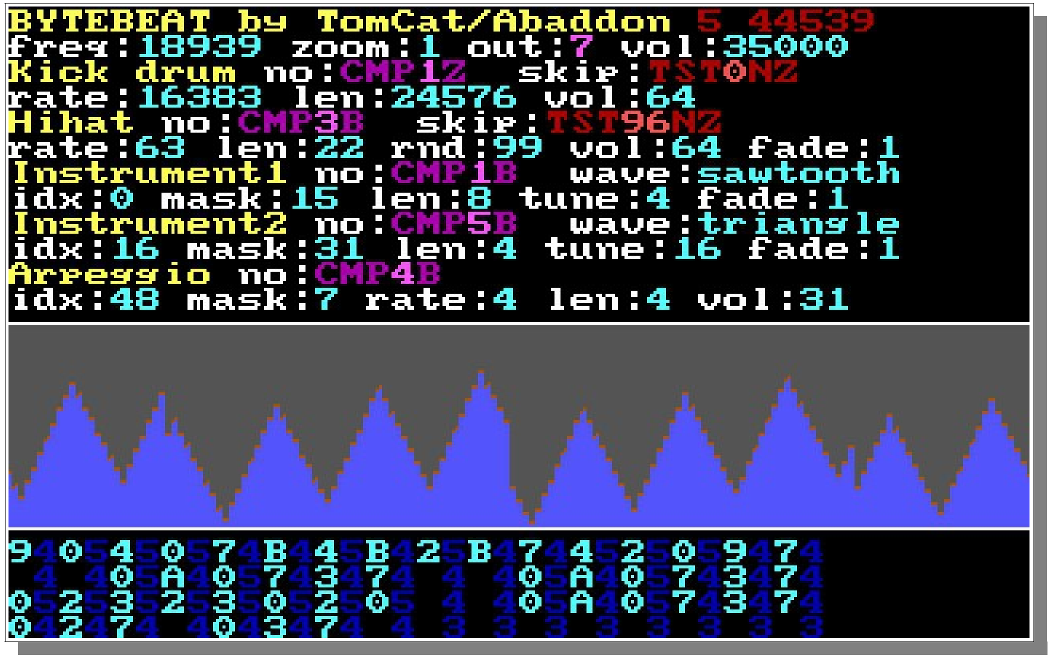
Bytebeat Editor (TomCat)

Features:

- realtime feedback
- graphical sound wave
- save/restore modified code

Issues:

- more than 70 hotkeys



```
BYTEBEAT by TomCat/Abaddon 5 44539
freq:18939 zoom:1 out:7 vol:35000
Kick drum no:CMP1Z  skip:TST0NZ
rate:16383 len:24576 vol:64
Hihat no:CMP3B  skip:TST96NZ
rate:63 len:22 rnd:99 vol:64 fade:1
Instrument1 no:CMP1B  wave:sawtooth
idx:0 mask:15 len:8 tune:4 fade:1
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idx:16 mask:31 len:4 tune:16 fade:1
Arpeggio no:CMP4B
idx:48 mask:7 rate:4 len:4 vol:31
```

```
9405450574B445B425B4744525059474
 4 405A405743474 4 405A405743474
0525352535052505 4 405A405743474
042474 4043474 4 3 3 3 3 3 3 3 3
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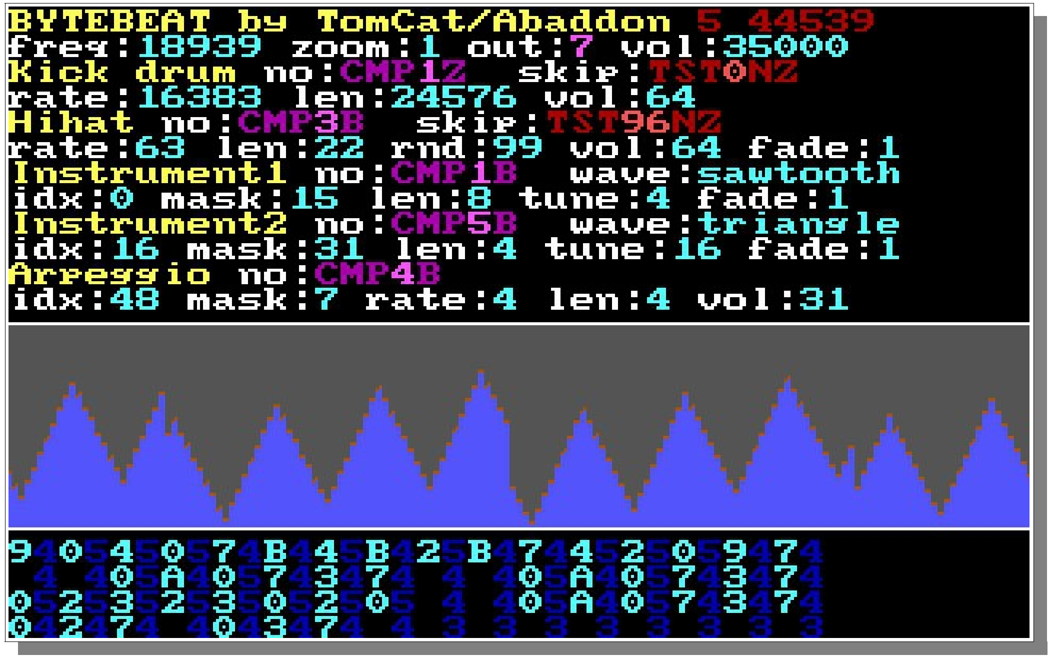

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Kick drum no:CMP1Z  skip:TST0NZ
rate:16383 len:24576 vol:64
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rate:63 len:22 rnd:99 vol:64 fade:1
Instrument1 no:CMP1B  wave:sawtooth
idx:0 mask:15 len:8 tune:4 fade:1
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idx:16 mask:31 len:4 tune:16 fade:1
Arpeggio no:CMP4B
idx:48 mask:7 rate:4 len:4 vol:31
```

```
9405450574B445B425B4744525059474
 4 405A405743474 4 405A405743474
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042474 4043474 4 3 3 3 3 3 3 3 3
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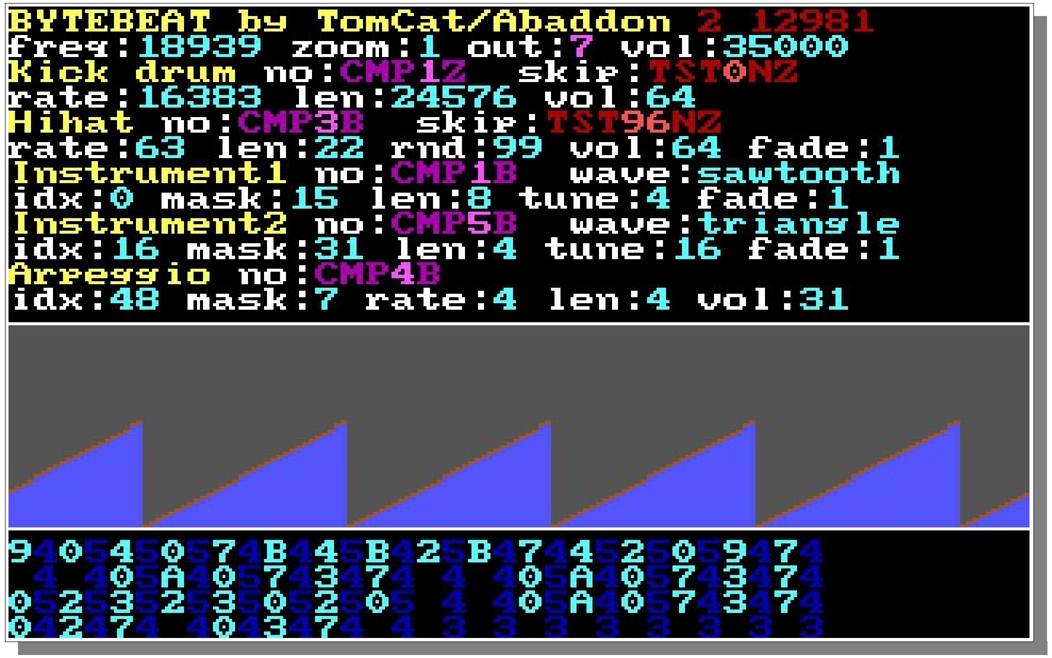

```
BYTEBEAT by TomCat/Abaddon 2 12981
freq:18939 zoom:1 out:7 vol:35000
Kick drum no:CMP1Z  skip:TST0NZ
rate:16383 len:24576 vol:64
Hihat no:CMP3B  skip:TST96NZ
rate:63 len:22 rnd:99 vol:64 fade:1
Instrument1 no:CMP1B  wave:sawtooth
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 4 405A405743474 4 405A405743474
0525352535052505 4 405A405743474
042474 4043474 4 3 3 3 3 3 3 3 3
```

Features:

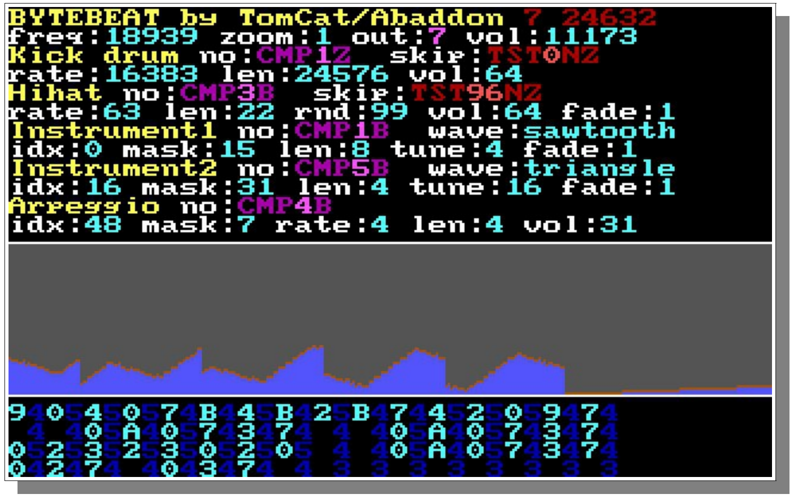
- realtime feedback
- graphical sound wave
- save/restore modified code

Issues:

- more than 70 hotkeys
- needs some x86 coder knowledge

  e.g. you can set any flag for a conditional jump

Bytebeat Editor (TomCat)



```
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freq:18939 zoom:1 out:7 vol:11173
Kick drum no:CMP1Z  skip:TST0NZ
rate:16383 len:24576 vol:64
Hihat no:CMP3B  skip:TST96NZ
rate:63 len:22 rnd:99 vol:64 fade:1
 Instrument1 no:CMP1B  wave:sawtooth
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idx:16 mask:31 len:4 tune:16 fade:1
Arpeggio no:CMP4B
idx:48 mask:7 rate:4 len:4 vol:31
```

```
9405450574B445B425B4744525059474
 4 405A405743474 4 405A405743474
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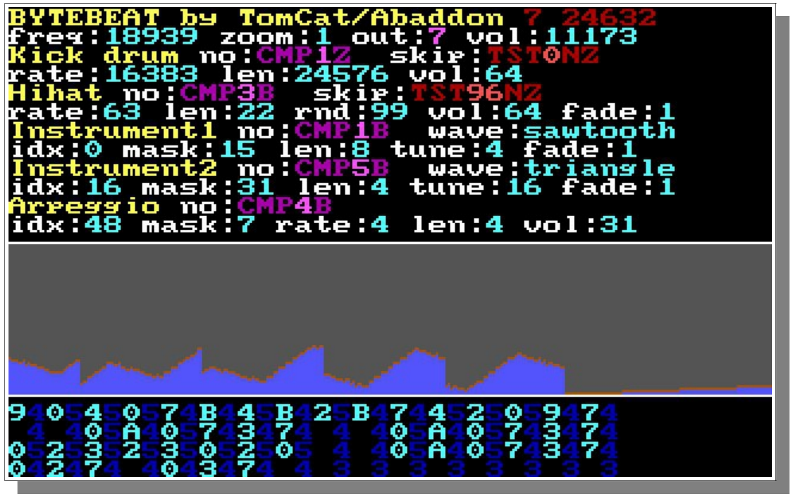
042474 4043474 4 3 3 3 3 3 3 3 3
```

Verdict:

- too complex, especially for musicians #UX

Bytebeat Editor (TomCat)



```
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freq:18939 zoom:1 out:7 vol:11173
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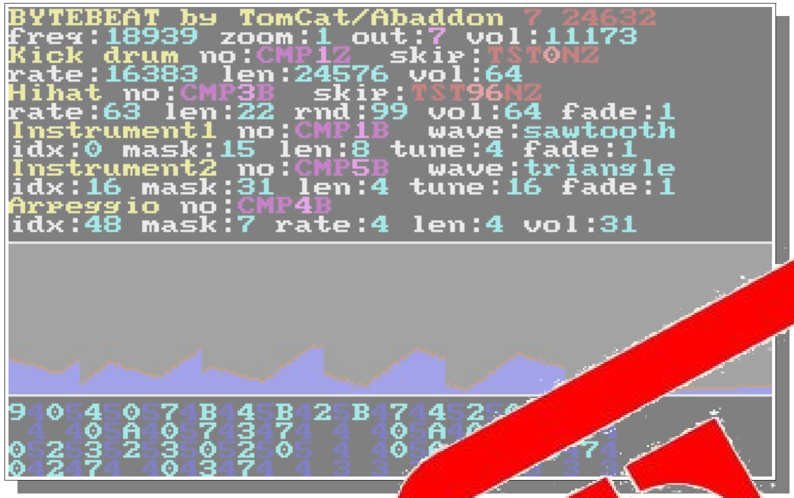
 Instrument2 no:CMP5B  wave:triangle
 idx:16 mask:31 len:4 tune:16 fade:1
Arpeggio no:CMP4B
 idx:48 mask:7 rate:4 len:4 vol:31
```

```
94054505 74B445B425B474452505947 4
 4 405A405743474 4 405A405743474
0525352535052505 4 405A405743474
042474 4043474 4 3 3 3 3 3 3 3 3
```

Verdict:

- too complex, especially for musicians #UX
- does not provide enough freedom

Bytebeat Editor (TomCat)



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Instrument2 no:CMP5B  wave:triangle
idx:16 mask:31 len:4 tune:16 fade:1
Arpeggio no:CMP4B
idx:48 mask:7 rate:4 len:4 vol:31
9405450574B445B425B4744525
 4 405A405743474 4 405A4
0525352535052505 4 405
042474 4043474 4 3 3
```

Verdict:

- too complex, especially for musicians / UX
- does not provide enough freedom

FAIL

Assemblyzator (ern0)

Assemblyzator (ern0)

Transform bytebeat formula to assembly code...

Assemblyzator (ern0)

Transform bytebeat formula to assembly code using a modern C compiler!

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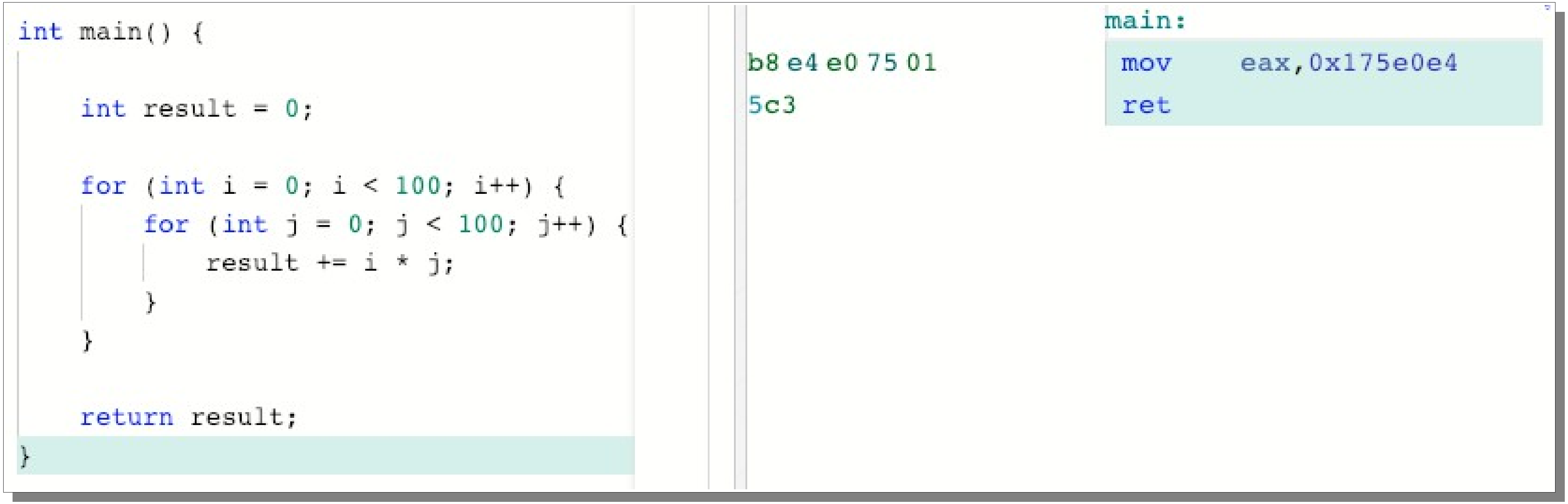
Transform bytebeat formula to assembly code using a modern C compiler!



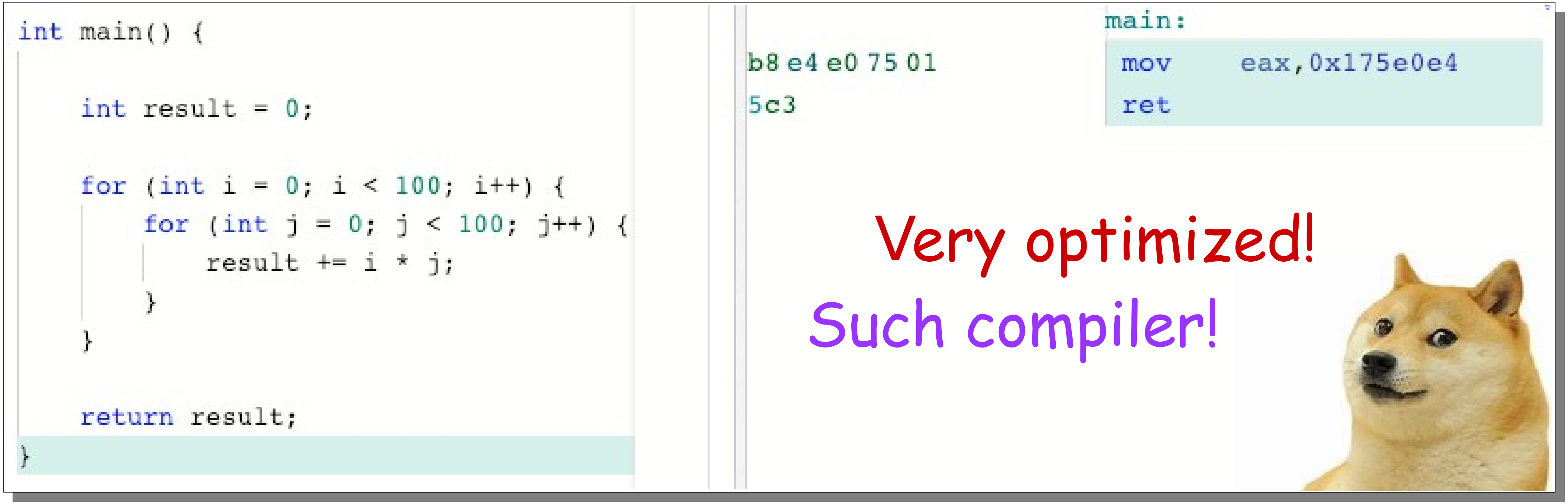
```
int main() {

    int result = 0;

    for (int i = 0; i < 100; i++) {
        for (int j = 0; j < 100; j++) {
            result += i * j;
        }
    }

    return result;
}
```

```
b8 e4 e0 75 01
5c3
```

```
main:
 mov     eax,0x175e0e4
 ret
```

Assemblyzator (ern0)

Transform bytebeat formula to assembly code using a modern C compiler!

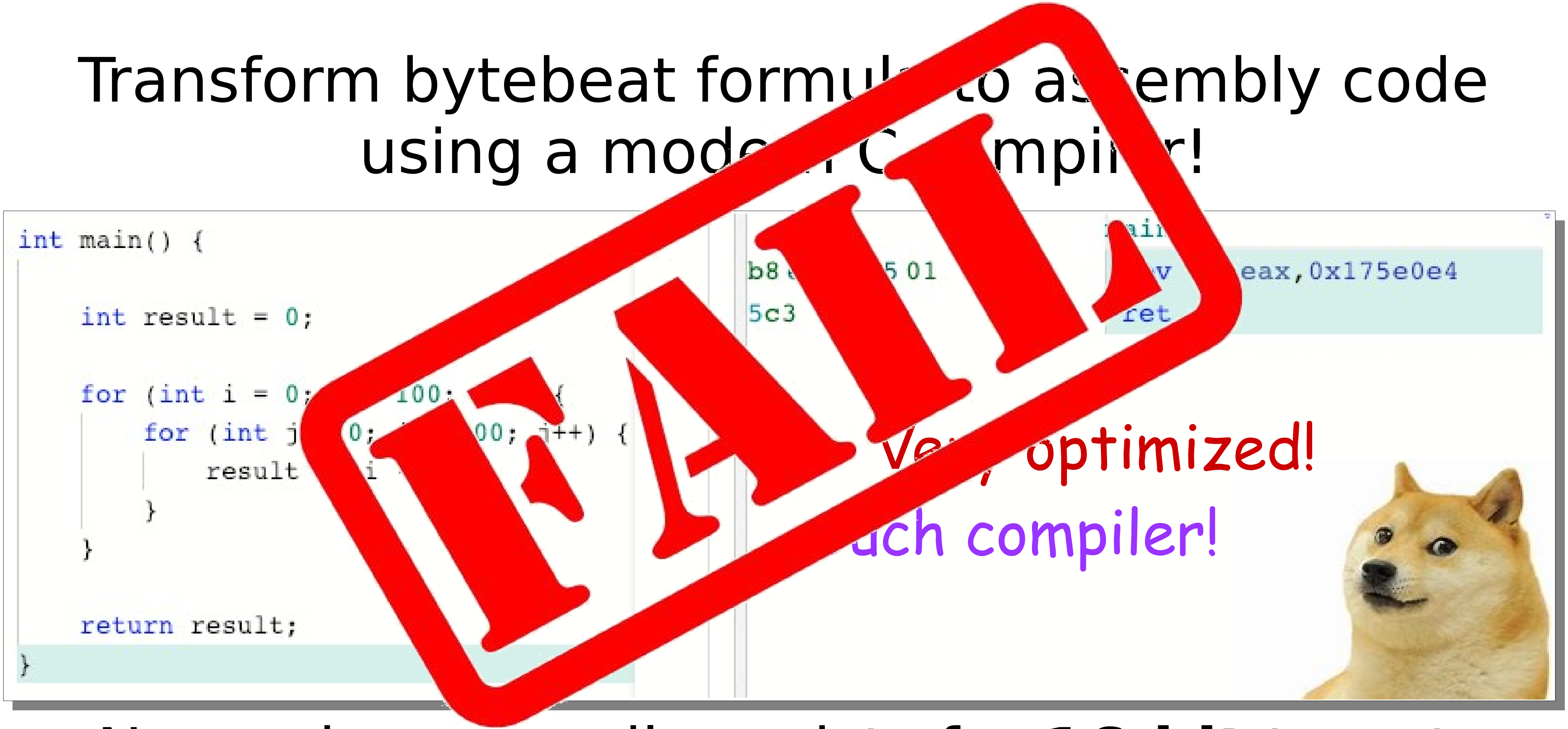


```
int main() {

    int result = 0;

    for (int i = 0; i < 100; i++) {
        for (int j = 0; j < 100; j++) {
            result += i * j;
        }
    }

    return result;
}
```

```
                          main:
b8 e4 e0 75 01             mov     eax,0x175e0e4
5c3                        ret
```

Assemblyzator (ern0)

Transform bytebeat formula to assembly code using a modern C compiler!



```
int main() {

    int result = 0;

    for (int i = 0; i < 100; i++) {
        for (int j = 0; j < 100; j++) {
            result += i * j;
        }
    }

    return result;
}
```

```
main:
b8 e4 e0 75 01    mov eax,0x175e0e4
5c3               ret
```

No modern compiler exists for **16-bit** target.

Assemblyzator (ern0)

Let's write a compiler thing!

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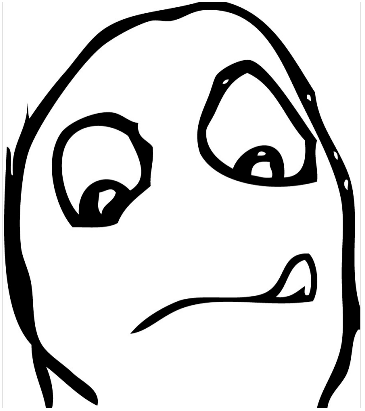
Let's write a compiler thing!



Split complex bytebeat formula
to series of simple formulas,
which is close to assembly

Assemblyzator (ern0)

```
((t<<1)^((t<<1)+
(t>>7)&t>>12))|
t>>(4-(1^7&(t>>19)))
|t>>7
```

```
var3 = t << 1
var7 = t >> 7
var5 = var3 + var7
var6 = t >> 12
var4 = var5 & var6
var1 = var3 ^ var4
var12 = t >> 19
var11 = 7 & var12
var10 = 1 ^ var11
var9 = -var10
var9 = var9 + 4
var8 = t >> var9
var2 = var8 | var7
result = var1 | var2
```

Assemblyzator (ern0)

Features:

- split formula

Assemblyzator (ern0)

Features:

- split formula
- handle num arrays

Assemblyzator (ern0)

Features:

- split formula
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Features:

- split formula
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- handle string arrays
- remove duplications

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Design Flaws:

- 3-op (A = B op C)
  8086 assembly instructions are 2-operand

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- split formula
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Design Flaws:

- 3-op (A = B op C)

  8086 assembly instructions are 2-operand

- can't handle cond. op.

  A = (B op C ? D : E)

  improperly designed Abstract Syntax Tree

Assemblyzator (ern0)

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Design Flaws:

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  8086 assembly instructions are 2-operand
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Verdict:

- nice try, but does not help much

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Verdict:

- nice try, but does not help much
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FAIL

[TomCat] *Instead of creating universal tools, we should choose one song and optimize for it*

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[ern0] *Right, I'll pick a song*

[TomCat] *Instead of creating universal tools, we should choose one song and optimize for it*

[ern0] *Right, I'll pick a song*

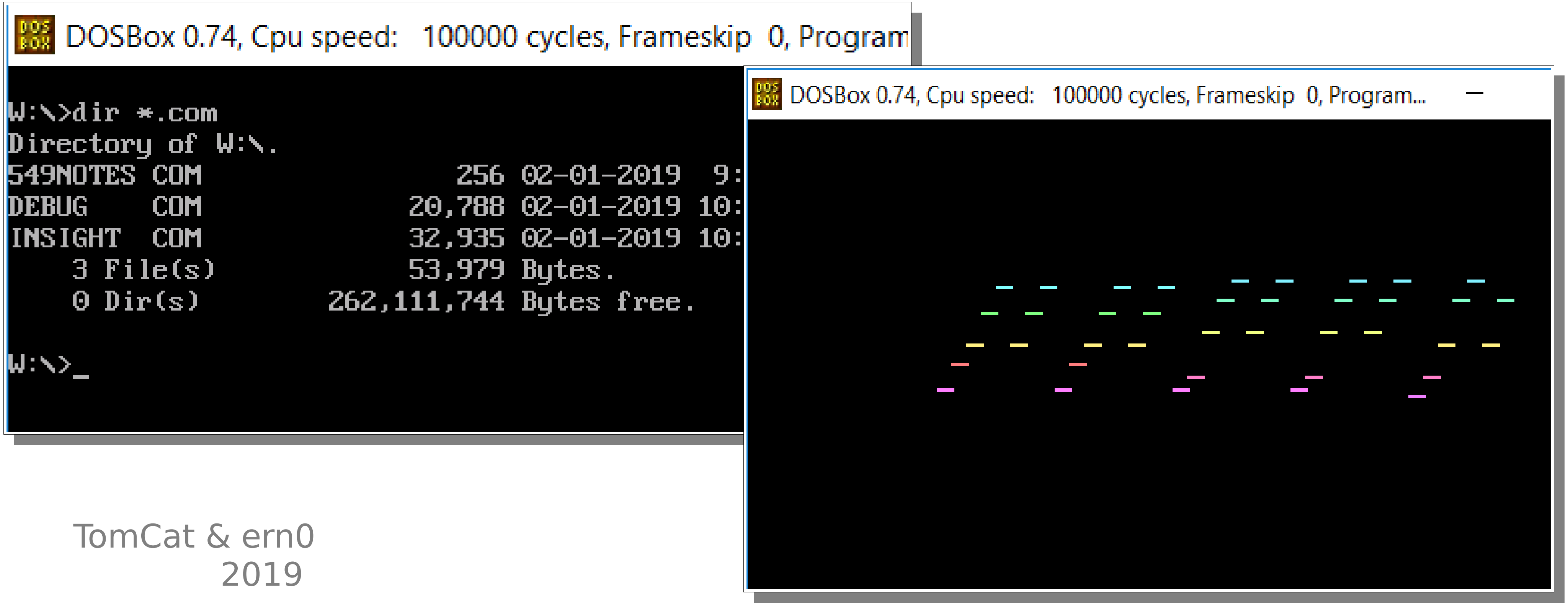
Some hours later...

[ern0] *I got the perfect one.*

Making of

549NOTES.COM

the 256-byte intro for PC-DOS
which plays 549 notes


DOSBox 0.74, Cpu speed: 100000 cycles, Frameskip 0, Program
DOSBox 0.74, Cpu speed: 100000 cycles, Frameskip 0, Program...

```
W:\>dir *.com
Directory of W:\.
549NOTES COM               256 02-01-2019  9:
DEBUG    COM            20,788 02-01-2019 10:
INSIGHT  COM            32,935 02-01-2019 10:
    3 File(s)           53,979 Bytes.
    0 Dir(s)       262,111,744 Bytes free.

W:\>_
```

TomCat & ern0
2019

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II. Data ★★★★☆

III. Code ★★★★★

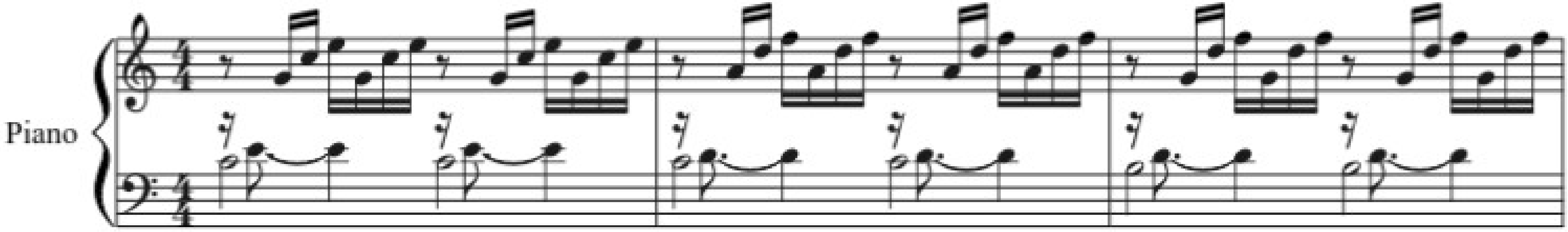
I. Song

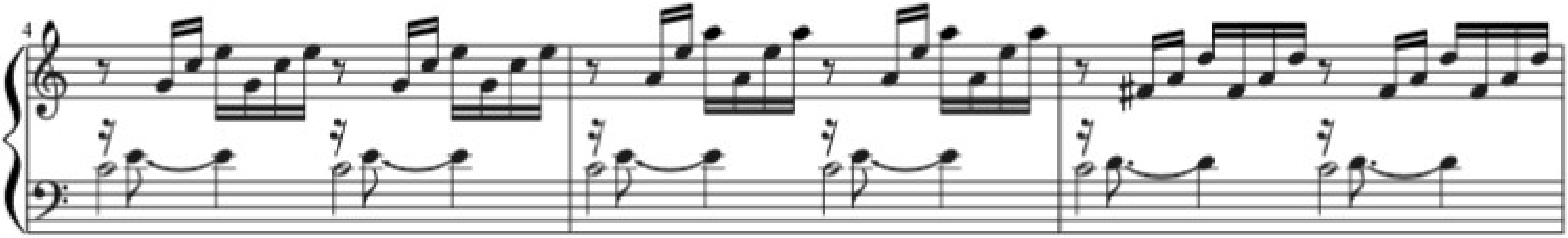
Prelude I

In C major

BWV 846

Johann Sebastian Bach (1685 - 1750)





J. S. Bach: Prelude I. in C Major (BWV 846)

1. Popular, well-known piece

J. S. Bach: Prelude I. in C Major (BWV 846)

1. Popular, well-known piece
2. Written for piano: optimal for MIDI...

J. S. Bach: Prelude I. in C Major (BWV 846)

- Piano (patch 1) is the default instrument on all channels for all General MIDI instruments

J. S. Bach: Prelude I. in C Major (BWV 846)

- Piano (patch 1) is the default instrument on all channels for all General MIDI instruments

Switch sound card to MIDI mode:

```
mov   al,3fH
mov   dx,331H
out   dx,al
```

J. S. Bach: Prelude I. in C Major (BWV 846)

- Piano (patch 1) is the default instrument on all channels for all General MIDI instruments
- Chord breaks: no „key up” message needed

Switch sound card to MIDI mode:

```
mov   al,3fH
mov   dx,331H
out   dx,al
```

J. S. Bach: Prelude I. in C Major (BWV 846)

- Piano (patch 1) is the default instrument on all channels for all General MIDI instruments
- Chord breaks: no „key up” message needed

Switch sound card to MIDI mode:

```
mov    al,3fH
mov    dx,331H
out    dx,al
```

Play a note:

```
dec    dx
mov    al,90H   ; key down, ch=1
out    dx,al
lodsb           ; pitch
out    dx,al
mov    al,7fH   ; velocity=127
out    dx,al
```

J. S. Bach: Prelude I. in C Major (BWV 846)

- Piano (patch 1) is the default instrument on all channels for all General MIDI instruments
- Chord breaks: no “key up” message needed

Switch sound card to MIDI mode:

```
mov   al,3fH
mov   dx,331H
out   dx,al
```

```
          H  ; key down, ch=1

             ; pitch
       ,al
mov   al,7fH  ; velocity=127
out   dx,al
```

J. S. Bach: Prelude I. in C Major (BWV 846)

1. Popular, well-known piece
2. Written for piano: optimal for MIDI
3. Simple rhythm, only a few tempo changes...

J. S. Bach: Prelude I. in C Major (BWV 846)

Tempo changes:

- slow down around the end

J. S. Bach: Prelude I. in C Major (BWV 846)

Tempo changes:

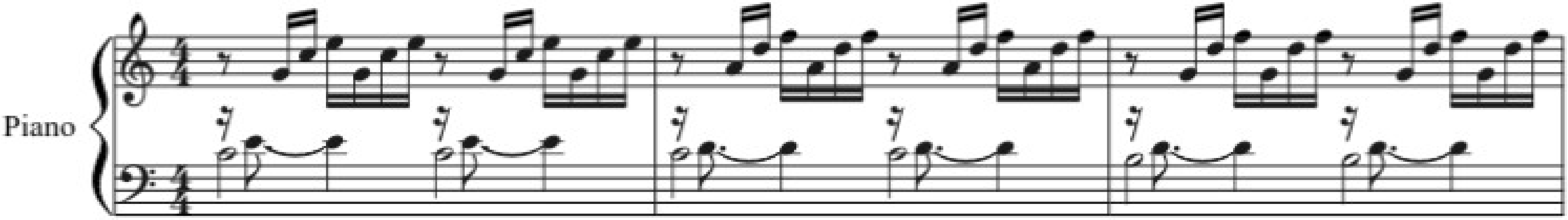
- slow down around the end
- set minimal pause for the last 5-note chord

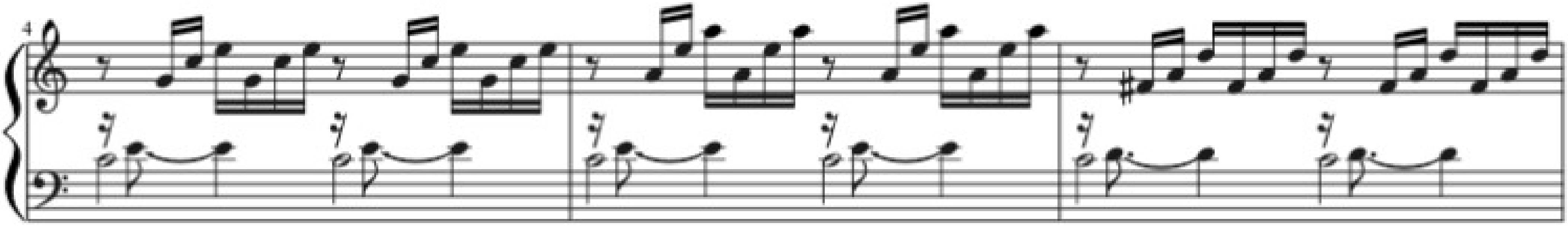
J. S. Bach: Prelude I. in C Major (BWV 846)

1. Popular, well-known piece
2. Written for piano: optimal for MIDI
3. Simple rhythm, only a few tempo changes
4. Contains repeating patterns...

J. S. Bach: Prelude I. in C Major (BWV 846)

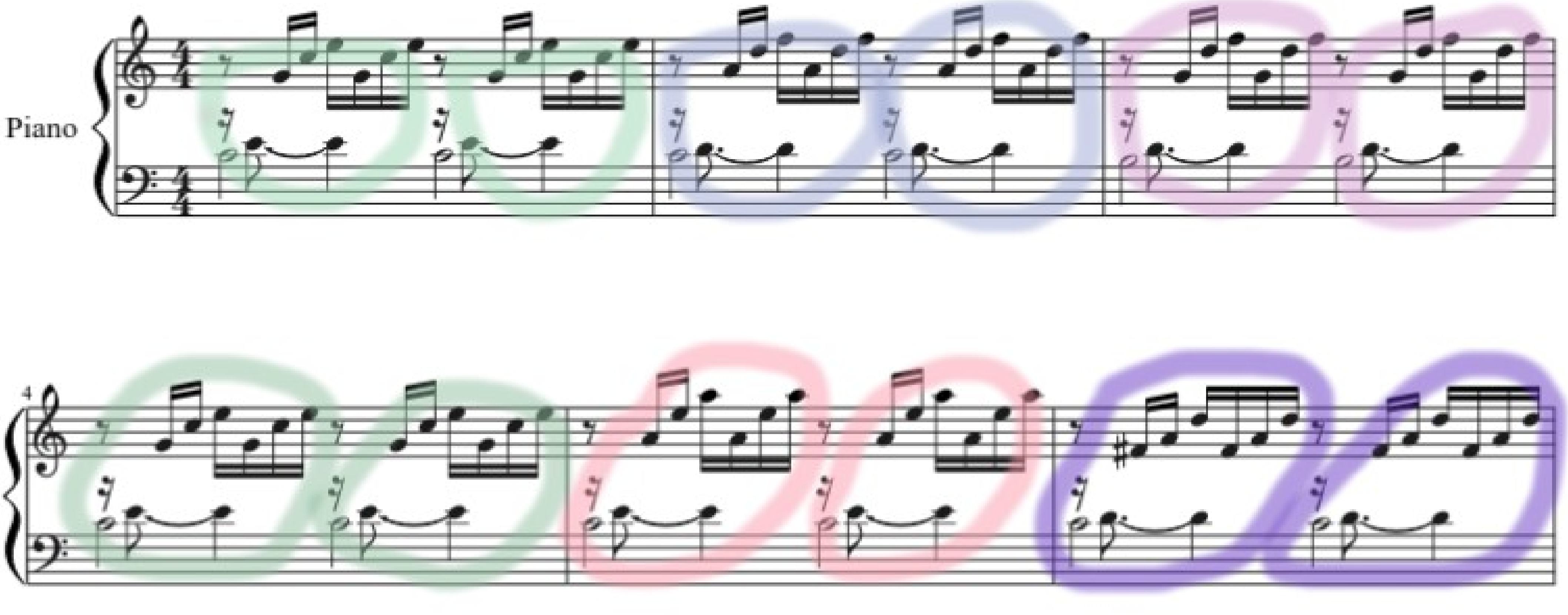
Repeating patterns 1/2:





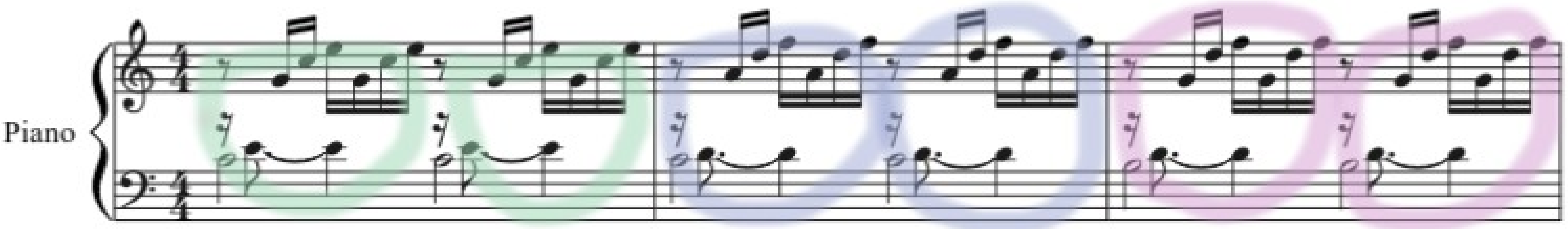
J. S. Bach: Prelude I. in C Major (BWV 846)

Repeating patterns 1/2:

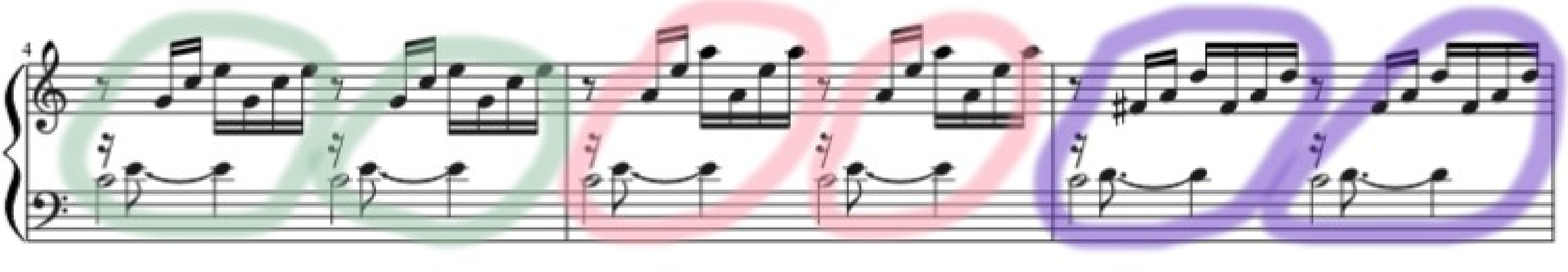


J. S. Bach: Prelude I. in C Major (BWV 846)

Repeating patterns 1/2:

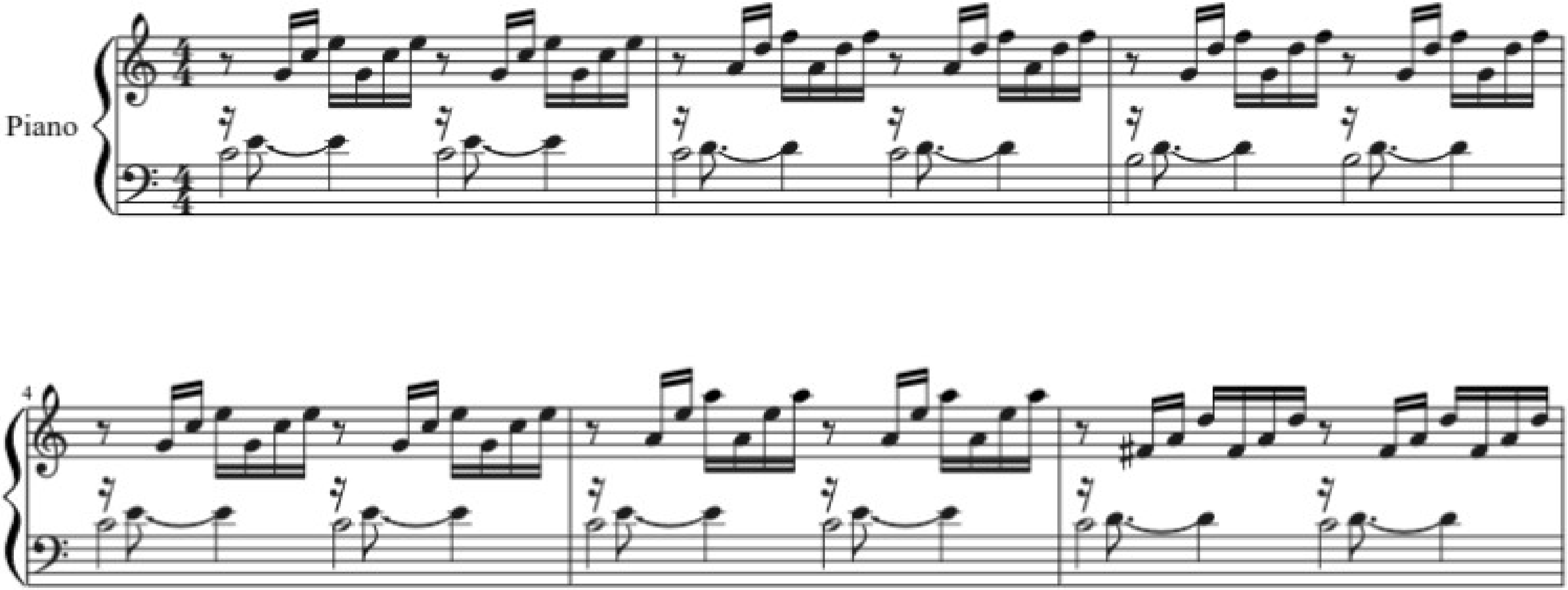


16 ➡ 8 notes



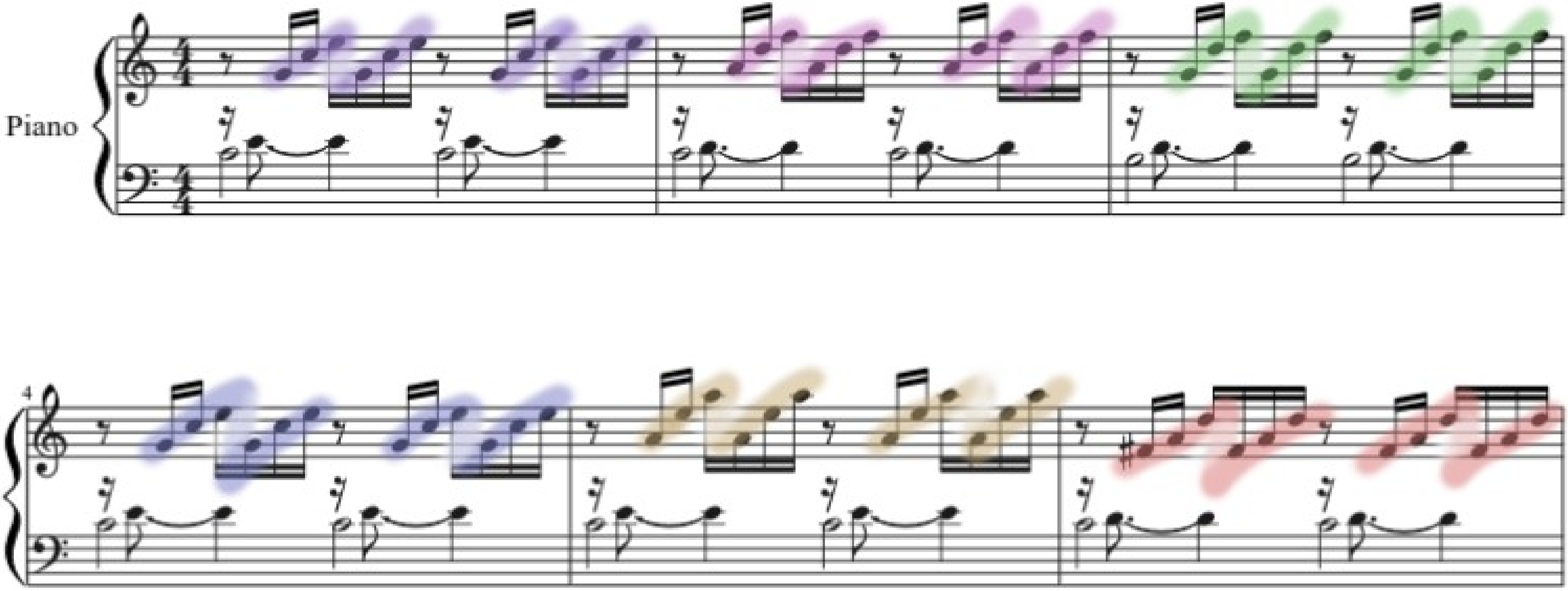
J. S. Bach: Prelude I. in C Major (BWV 846)

Repeating patterns 2/2:



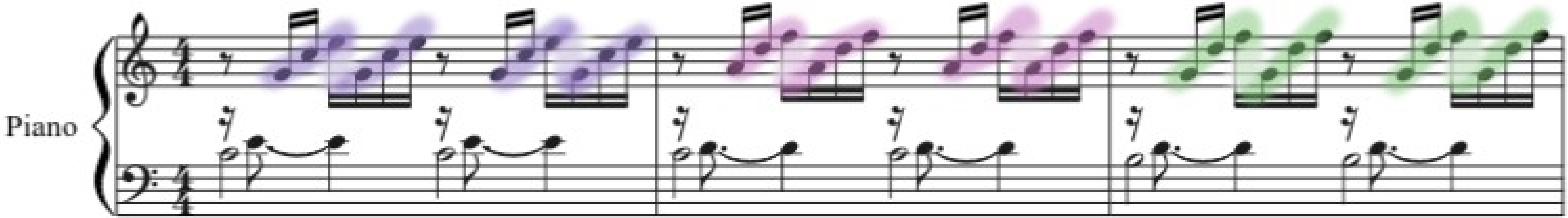
J. S. Bach: Prelude I. in C Major (BWV 846)

Repeating patterns 2/2:

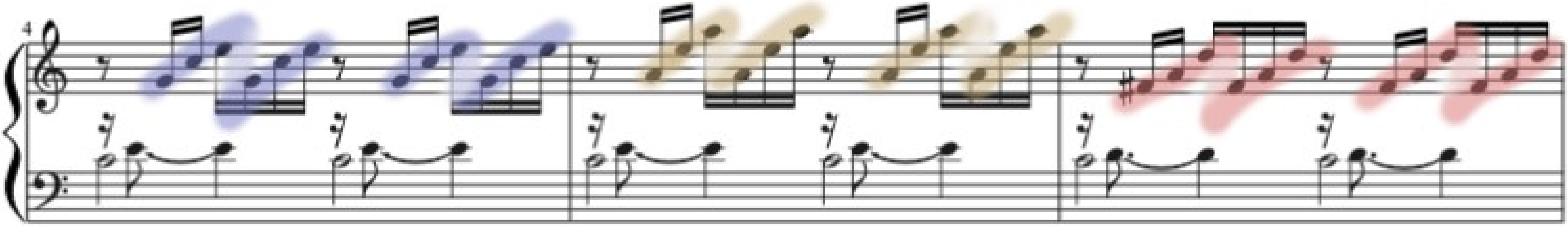


J. S. Bach: Prelude I. in C Major (BWV 846)

Repeating patterns 2/2:



8 ➡ 5 notes



Raw Data

part	*effective notes*	*raw data*
repeating	512	160
non-repeating	32	32
final chord	5	5
total	**549**	**197**

II. Data

Data overview

Data overview

```
"c-3","e-3","g-3","c-4","e-4",
"c-3","d-3","a-3","d-4","f-4",
"h-2","d-3","g-3","d-4","f-4",
"c-3","e-3","g-3","c-4","e-4",

"c-3","e-3","a-3","e-4","a-4",
"c-3","d-3","f#3","a-3","d-4",
"h-2","d-3","g-3","d-4","g-4",
"h-2","c-3","e-3","g-3","c-4",

"a-2","c-3","e-3","g-3","c-4",
"d-2","a-2","d-3","f#3","c-4",
"g-2","h-2","d-3","g-3","h-3",
"g-2","a#2","e-3","g-3","c#4",

"f-2","a-2","d-3","a-3","d-4",
"f-2","g#2","d-3","f-3","h-3",
"e-2","g-2","c-3","g-3","c-4",
"e-2","f-2","a-2","c-3","f-3",

"d-2","f-2","a-2","c-3","f-3",
"g-1","d-2","g-2","h-2","f-3",
"c-2","e-2","g-2","c-3","e-3",
"c-2","g-2","a#2","c-3","e-3",

"f-1","f-2","a-2","c-3","e-3",
"f#1","c-2","a-2","c-3","e-3",
"g#1","f-2","h-2","c-3","d-3",
"g-1","f-2","g-2","h-2","d-3",

"g-1","e-2","g-2","c-3","e-3",
"g-1","d-2","g-2","c-3","f-3",
"g-1","d-2","g-2","h-2","f-3",
"g-1","d#2","a-2","c-3","f#3",

"g-1","e-2","g-2","c-3","g-3",
"g-1","d-2","g-2","c-3","f-3",
"g-1","d-2","g-2","h-2","f-3",
"c-1","c-2","g-2","a#2","e-3"
```

Part 1:

Data overview

```
"c-3","e-3","g-3","c-4","e-4",
"c-3","d-3","a-3","d-4","f-4",
"h-2","d-3","g-3","d-4","f-4",
"c-3","e-3","g-3","c-4","e-4",

"c-3","e-3","a-3","e-4","a-4",
"c-3","d-3","f#3","a-3","d-4",
"h-2","d-3","g-3","d-4","g-4",
"h-2","c-3","e-3","g-3","c-4",

"a-2","c-3","e-3","g-3","c-4",
"d-2","a-2","d-3","f#3","c-4",
"g-2","h-2","d-3","g-3","h-3",
"g-2","a#2","e-3","g-3","c#4",

"f-2","a-2","d-3","a-3","d-4",
"f-2","g#2","d-3","f-3","h-3",
"e-2","g-2","c-3","g-3","c-4",
"e-2","f-2","a-2","c-3","f-3",

"d-2","f-2","a-2","c-3","f-3",
"g-1","d-2","g-2","h-2","f-3",
"c-2","e-2","g-2","c-3","e-3",
"c-2","g-2","a#2","c-3","e-3",

"f-1","f-2","a-2","c-3","e-3",
"f#1","c-2","a-2","c-3","e-3",
"g#1","f-2","h-2","c-3","d-3",
"g-1","f-2","g-2","h-2","d-3",

"g-1","e-2","g-2","c-3","e-3",
"g-1","d-2","g-2","c-3","f-3",
"g-1","d-2","g-2","h-2","f-3",
"g-1","d#2","a-2","c-3","f#3",

"g-1","e-2","g-2","c-3","g-3",
"g-1","d-2","g-2","c-3","f-3",
"g-1","d-2","g-2","h-2","f-3",
"c-1","c-2","g-2","a#2","e-3"
```

Part 1:

- 32 lines x 5 notes

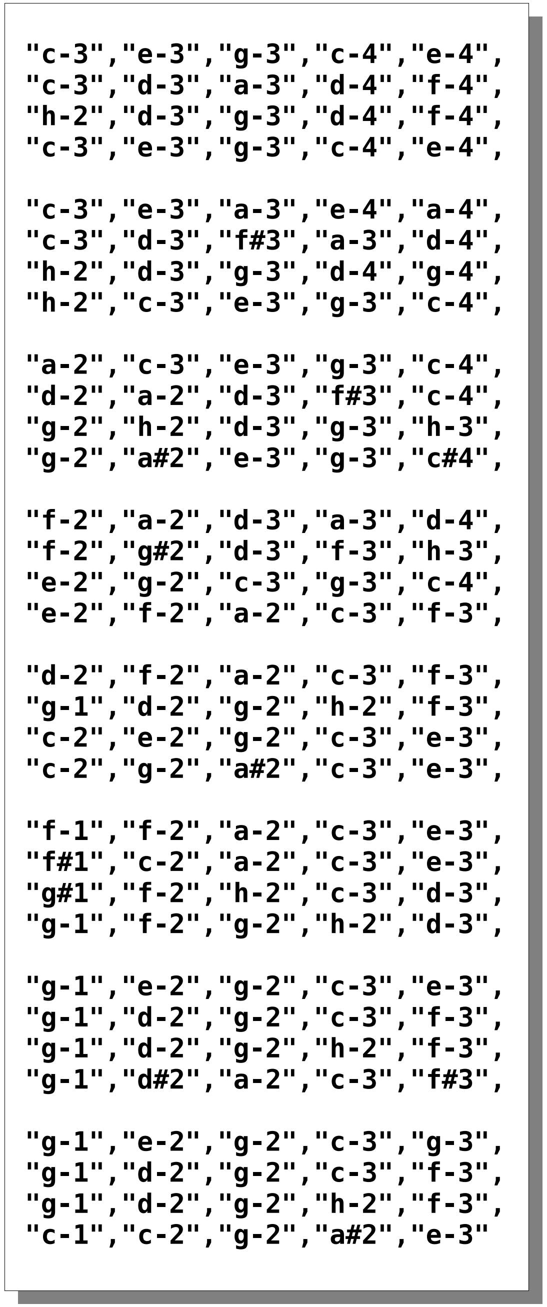
Data overview

```
"c-3","e-3","g-3","c-4","e-4",
"c-3","d-3","a-3","d-4","f-4",
"h-2","d-3","g-3","d-4","f-4",
"c-3","e-3","g-3","c-4","e-4",

"c-3","e-3","a-3","e-4","a-4",
"c-3","d-3","f#3","a-3","d-4",
"h-2","d-3","g-3","d-4","g-4",
"h-2","c-3","e-3","g-3","c-4",

"a-2","c-3","e-3","g-3","c-4",
"d-2","a-2","d-3","f#3","c-4",
"g-2","h-2","d-3","g-3","h-3",
"g-2","a#2","e-3","g-3","c#4",

"f-2","a-2","d-3","a-3","d-4",
"f-2","g#2","d-3","f-3","h-3",
"e-2","g-2","c-3","g-3","c-4",
"e-2","f-2","a-2","c-3","f-3",

"d-2","f-2","a-2","c-3","f-3",
"g-1","d-2","g-2","h-2","f-3",
"c-2","e-2","g-2","c-3","e-3",
"c-2","g-2","a#2","c-3","e-3",

"f-1","f-2","a-2","c-3","e-3",
"f#1","c-2","a-2","c-3","e-3",
"g#1","f-2","h-2","c-3","d-3",
"g-1","f-2","g-2","h-2","d-3",

"g-1","e-2","g-2","c-3","e-3",
"g-1","d-2","g-2","c-3","f-3",
"g-1","d-2","g-2","h-2","f-3",
"g-1","d#2","a-2","c-3","f#3",

"g-1","e-2","g-2","c-3","g-3",
"g-1","d-2","g-2","c-3","f-3",
"g-1","d-2","g-2","h-2","f-3",
"c-1","c-2","g-2","a#2","e-3"
```

Part 1:

- 32 lines x 5 notes
- last 3 notes are repeated

Data overview



```
"c-3","e-3","g-3","c-4","e-4",
"c-3","d-3","a-3","d-4","f-4",
"h-2","d-3","g-3","d-4","f-4",
"c-3","e-3","g-3","c-4","e-4",

"c-3","e-3","a-3","e-4","a-4",
"c-3","d-3","f#3","a-3","d-4",
"h-2","d-3","g-3","d-4","g-4",
"h-2","c-3","e-3","g-3","c-4",

"a-2","c-3","e-3","g-3","c-4",
"d-2","a-2","d-3","f#3","c-4",
"g-2","h-2","d-3","g-3","h-3",
"g-2","a#2","e-3","g-3","c#4",

"f-2","a-2","d-3","a-3","d-4",
"f-2","g#2","d-3","f-3","h-3",
"e-2","g-2","c-3","g-3","c-4",
"e-2","f-2","a-2","c-3","f-3",

"d-2","f-2","a-2","c-3","f-3",
"g-1","d-2","g-2","h-2","f-3",
"c-2","e-2","g-2","c-3","e-3",
"c-2","g-2","a#2","c-3","e-3",

"f-1","f-2","a-2","c-3","e-3",
"f#1","c-2","a-2","c-3","e-3",
"g#1","f-2","h-2","c-3","d-3",
"g-1","f-2","g-2","h-2","d-3",

"g-1","e-2","g-2","c-3","e-3",
"g-1","d-2","g-2","c-3","f-3",
"g-1","d-2","g-2","h-2","f-3",
"g-1","d#2","a-2","c-3","f#3",

"g-1","e-2","g-2","c-3","g-3",
"g-1","d-2","g-2","c-3","f-3",
"g-1","d-2","g-2","h-2","f-3",
"c-1","c-2","g-2","a#2","e-3"
```

Part 1:

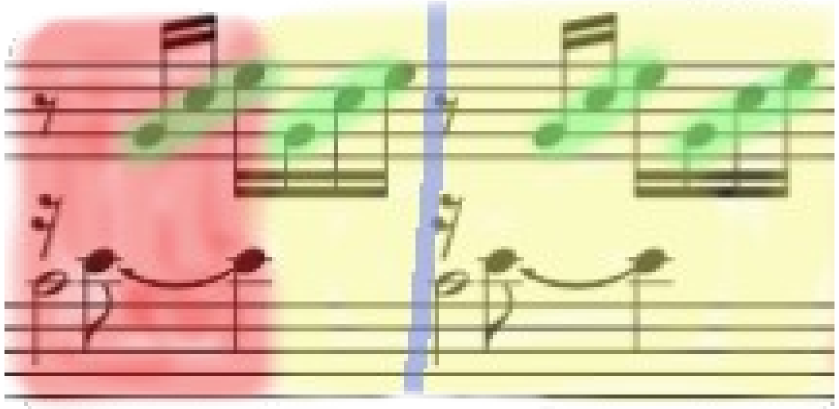
- 32 lines x 5 notes
- last 3 notes are repeated
- (8-note) lines are repeated

Data overview

```
"c-3","e-3","g-3","c-4","e-4",
"c-3","d-3","a-3","d-4","f-4",
"h-2","d-3","g-3","d-4","f-4",
"c-3","e-3","g-3","c-4","e-4",

"c-3","e-3","a-3","e-4","a-4",
"c-3","d-3","f#3","a-3","d-4",
"h-2","d-3","g-3","d-4","g-4",
"h-2","c-3","e-3","g-3","c-4",

"a-2","c-3","e-3","g-3","c-4",
"d-2","a-2","d-3","f#3","c-4",
"g-2","h-2","d-3","g-3","h-3",
"g-2","a#2","e-3","g-3","c#4",

"f-2","a-2","d-3","a-3","d-4",
"f-2","g#2","d-3","f-3","h-3",
"e-2","g-2","c-3","g-3","c-4",
"e-2","f-2","a-2","c-3","f-3",

"d-2","f-2","a-2","c-3","f-3",
"g-1","d-2","g-2","h-2","f-3",
"c-2","e-2","g-2","c-3","e-3",
"c-2","g-2","a#2","c-3","e-3",

"f-1","f-2","a-2","c-3","e-3",
"f#1","c-2","a-2","c-3","e-3",
"g#1","f-2","h-2","c-3","d-3",
"g-1","f-2","g-2","h-2","d-3",

"g-1","e-2","g-2","c-3","e-3",
"g-1","d-2","g-2","c-3","f-3",
"g-1","d-2","g-2","h-2","f-3",
"g-1","d#2","a-2","c-3","f#3",

"g-1","e-2","g-2","c-3","g-3",
"g-1","d-2","g-2","c-3","f-3",
"g-1","d-2","g-2","h-2","f-3",
"c-1","c-2","g-2","a#2","e-3"
```

Part 1:

- 32 lines x 5 notes
- last 3 notes are repeated
- (8-note) lines are repeated



Data overview

```
"c-3","e-3","g-3","c-4","e-4",
"c-3","d-3","a-3","d-4","f-4",
"h-2","d-3","g-3","d-4","f-4",
"c-3","e-3","g-3","c-4","e-4",

"c-3","e-3","a-3","e-4","a-4",
"c-3","d-3","f#3","a-3","d-4",
"h-2","d-3","g-3","d-4","g-4",
"h-2","c-3","e-3","g-3","c-4",

"a-2","c-3","e-3","g-3","c-4",
"d-2","a-2","d-3","f#3","c-4",
"g-2","h-2","d-3","g-3","h-3",
"g-2","a#2","e-3","g-3","c#4",

"f-2","a-2","d-3","a-3","d-4",
"f-2","g#2","d-3","f-3","h-3",
"e-2","g-2","c-3","g-3","c-4",
"e-2","f-2","a-2","c-3","f-3",

"d-2","f-2","a-2","c-3","f-3",
"g-1","d-2","g-2","h-2","f-3",
"c-2","e-2","g-2","c-3","e-3",
"c-2","g-2","a#2","c-3","e-3",

"f-1","f-2","a-2","c-3","e-3",
"f#1","c-2","a-2","c-3","e-3",
"g#1","f-2","h-2","c-3","d-3",
"g-1","f-2","g-2","h-2","d-3",

"g-1","e-2","g-2","c-3","e-3",
"g-1","d-2","g-2","c-3","f-3",
"g-1","d-2","g-2","h-2","f-3",
"g-1","d#2","a-2","c-3","f#3",

"g-1","e-2","g-2","c-3","g-3",
"g-1","d-2","g-2","c-3","f-3",
"g-1","d-2","g-2","h-2","f-3",
"c-1","c-2","g-2","a#2","e-3"
```

Part 1:

- 32 lines x 5 notes
- last 3 notes are repeated
- (8-note) lines are repeated

```
"c-1","c-2","f-2","a-2","c-3","f-3","c-3","a-2",
"c-3","a-2","f-2","a-2","f-2","d-2","f-2","d-2",
"c-1","h-1","g-3","h-3","d-4","f-4","d-4","h-3",
"d-4","h-3","g-3","h-3","d-3","f-3","e-3","d-3"
```

Part 2:

- 32 notes
- no tricks

Data overview

```
"c-3","e-3","g-3","c-4","e-4",
"c-3","d-3","a-3","d-4","f-4",
"h-2","d-3","g-3","d-4","f-4",
"c-3","e-3","g-3","c-4","e-4",

"c-3","e-3","a-3","e-4","a-4",
"c-3","d-3","f#3","a-3","d-4",
"h-2","d-3","g-3","d-4","g-4",
"h-2","c-3","e-3","g-3","c-4",

"a-2","c-3","e-3","g-3","c-4",
"d-2","a-2","d-3","f#3","c-4",
"g-2","h-2","d-3","g-3","h-3",
"g-2","a#2","e-3","g-3","c#4",

"f-2","a-2","d-3","a-3","d-4",
"f-2","g#2","d-3","f-3","h-3",
"e-2","g-2","c-3","g-3","c-4",
"e-2","f-2","a-2","c-3","f-3",

"d-2","f-2","a-2","c-3","f-3",
"g-1","d-2","g-2","h-2","f-3",
"c-2","e-2","g-2","c-3","e-3",
"c-2","g-2","a#2","c-3","e-3",

"f-1","f-2","a-2","c-3","e-3",
"f#1","c-2","a-2","c-3","e-3",
"g#1","f-2","h-2","c-3","d-3",
"g-1","f-2","g-2","h-2","d-3",

"g-1","e-2","g-2","c-3","e-3",
"g-1","d-2","g-2","c-3","f-3",
"g-1","d-2","g-2","h-2","f-3",
"g-1","d#2","a-2","c-3","f#3",

"g-1","e-2","g-2","c-3","g-3",
"g-1","d-2","g-2","c-3","f-3",
"g-1","d-2","g-2","h-2","f-3",
"c-1","c-2","g-2","a#2","e-3"
```

Part 1:

- 32 lines x 5 notes
- last 3 notes are repeated
- (8-note) lines are repeated

```
"c-1","c-2","f-2","a-2","c-3","f-3","c-3","a-2",
"c-3","a-2","f-2","a-2","f-2","d-2","f-2","d-2",
"c-1","h-1","g-3","h-3","d-4","f-4","d-4","h-3",
"d-4","h-3","g-3","h-3","d-3","f-3","e-3","d-3"
```

Part 2:

- 32 notes
- no tricks

```
"c-1","c-2","e-3","g-3","c-4"
```

Part3:

- 5 notes
- no tricks

Histogram of raw (31 values, 197 notes)

```
; c-1:36   4  ####
; f-1:41   1  #
; f#1:42   1  #
; g-1:43   9  #########
; g#1:44   1  #
; h-1:47   1  #
; c-2:48   6  ######
; d-2:50   9  #########
; d#2:51   1  #
; e-2:52   5  #####
; f-2:53  11  ###########
; g-2:55  14  ##############
; g#2:56   1  #
; a-2:57  12  ############
; a#2:58   3  ###
; h-2:59   9  #########
; c-3:60  23  #######################
; d-3:62  12  ############
; e-3:64  14  ##############
; f-3:65  10  ##########
; f#3:66   3  ###
; g-3:67  13  #############
; a-3:69   4  ####
; h-3:71   6  ######
; c-4:72   7  #######
; c#4:73   1  #
; d-4:74   8  ########
; e-4:76   3  ###
; f-4:77   3  ###
; g-4:79   1  #
; a-4:81   1  #
```

```
;  1. c-3:60  23  #######################
;  2. g-2:55  14  ##############
;  3. e-3:64  14  ##############
;  4. g-3:67  13  #############
;  5. d-3:62  12  ############
;  6. a-2:57  12  ############
;  7. f-2:53  11  ###########
;  8. f-3:65  10  ##########
;  9. h-2:59   9  #########
; 10. g-1:43   9  #########
; 11. d-2:50   9  #########
; 12. d-4:74   8  ########
; 13. c-4:72   7  #######
; 14. h-3:71   6  ######
; 15. c-2:48   6  ######
; 16. e-2:52   5  #####
; 17. c-1:36   4  ####
; 18. a-3:69   4  ####
; 19. f-4:77   3  ###
; 20. f#3:66   3  ###
; 21. e-4:76   3  ###
; 22. a#2:58   3  ###
; 23. h-1:47   1  #
; 24. g-4:79   1  #
; 25. g#2:56   1  #
; 26. g#1:44   1  #
; 27. f-1:41   1  #
; 28. f#1:42   1  #
; 29. d#2:51   1  #
; 30. c#4:73   1  #
; 31. a-4:81   1  #
```

Histogram of raw (31 values, 197 notes)

```
; c-1:36   4  ####
; f-1:41   1  #
; f#1:42   1  #
; g-1:43   9  #########
; g#1:44   1  #
; h-1:47   1  #
; c-2:48   6  ######
; d-2:50   9  #########
; d#2:51   1  #
; e-2:52   5  #####
; f-2:53  11  ###########
; g-2:55  14  ##############
; g#2:56   1  #
; a-2:57  12  ############
; a#2:58   3  ###
; h-2:59   9  #########
; c-3:60  23  #######################
; d-3:62  12  ############
; e-3:64  14  ##############
; f-3:65  10  ##########
; f#3:66   3  ###
; g-3:67  13  #############
; a-3:69   4  ####
; h-3:71   6  ######
; c-4:72   7  #######
; c#4:73   1  #
; d-4:74   8  ########
; e-4:76   3  ###
; f-4:77   3  ###
; g-4:79   1  #
; a-4:81   1  #
```

```
;  1. c-3:60  23  #######################
;  2. g-2:55  14  ##############
;  3. e-3:64  14  ##############
;  4. g-3:67  13  #############
;  5. d-3:62  12  ############
;  6. a-2:57  12  ############
;  7. f-2:53  11  ###########
;  8. f-3:65  10  ##########
;  9. h-2:59   9  #########
; 10. g-1:43   9  #########
; 11. d-2:50   9  #########
; 12. d-4:74   8  ########
; 13. c-4:72   7  #######
; 14. h-3:71   6  ######
; 15. c-2:48   6  ######
; 16. e-2:52   5  #####
; 17. c-1:36   4  ####
; 18. a-3:69   4  ####
; 19. f-4:77   3  ###
; 20. f#3:66   3  ###
; 21. e-4:76   3  ###
; 22. a#2:58   3  ###
; 23. h-1:47   1  #
; 24. g-4:79   1  #
; 25. g#2:56   1  #
; 26. g#1:44   1  #
; 27. f-1:41   1  #
; 28. f#1:42   1  #
; 29. d#2:51   1  #
; 30. c#4:73   1  #
; 31. a-4:81   1  #
```

```
notes: 5 bit x 197 = 124 byte
table:                31 byte
total:               155 byte
```

Histogram of raw (31 values, 197 notes)

note range: 36..81: 45 values

values: 6 bit x 197 = **148 byte**

```
; c-1:36   4  ####
; f-1:41   1  #
; f#1:42   1  #
; g-1:43   9  #########
; g#1:44   1  #
; h-1:47   1  #
; c-2:48   6  ######
; d-2:50   9  #########
; d#2:51   1  #
; e-2:52   5  #####
; f-2:53  11  ###########
; g-2:55  14  ##############
; g#2:56   1  #
; a-2:57  12  ############
; a#2:58   3  ###
; h-2:59   9  #########
; c-3:60  23  #######################
; d-3:62  12  ############
; e-3:64  14  ##############
; f-3:65  10  ##########
; f#3:66   3  ###
; g-3:67  13  #############
; a-3:69   4  ####
; h-3:71   6  ######
; c-4:72   7  #######
; c#4:73   1  #
; d-4:74   8  ########
; e-4:76   3  ###
; f-4:77   3  ###
; g-4:79   1  #
; a-4:81   1  #
```

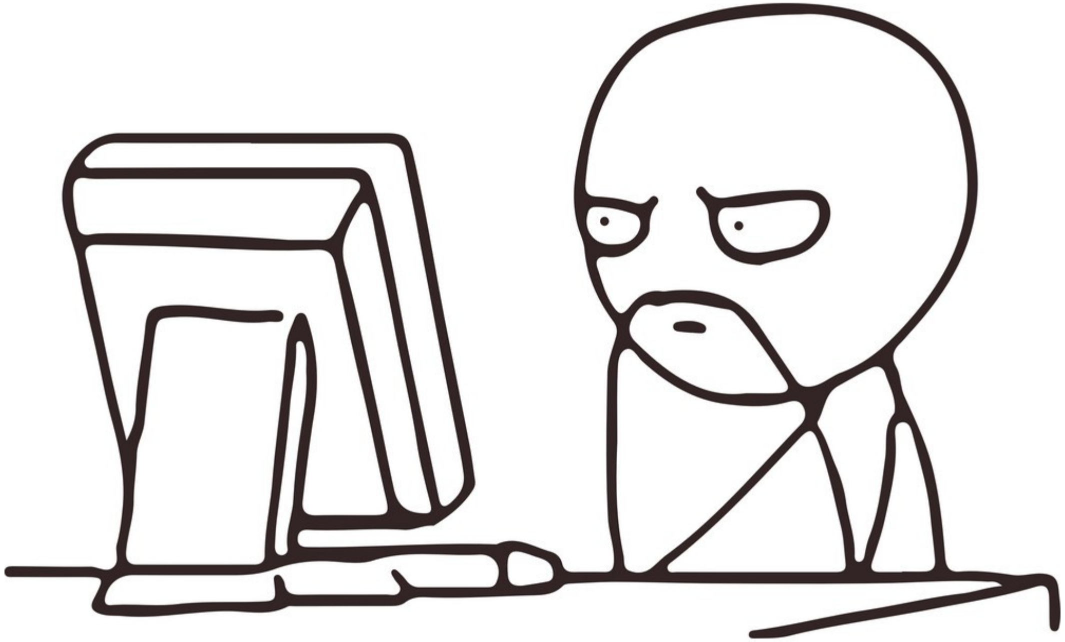
```
;  1. c-3:60  23  #######################
;  2. g-2:55  14  ##############
;  3. e-3:64  14  ##############
;  4. g-3:67  13  #############
;  5. d-3:62  12  ############
;  6. a-2:57  12  ############
;  7. f-2:53  11  ###########
;  8. f-3:65  10  ##########
;  9. h-2:59   9  #########
; 10. g-1:43   9  #########
; 11. d-2:50   9  #########
; 12. d-4:74   8  ########
; 13. c-4:72   7  #######
; 14. h-3:71   6  ######
; 15. c-2:48   6  ######
; 16. e-2:52   5  #####
; 17. c-1:36   4  ####
; 18. a-3:69   4  ####
; 19. f-4:77   3  ###
; 20. f#3:66   3  ###
; 21. e-4:76   3  ###
; 22. a#2:58   3  ###
; 23. h-1:47   1  #
; 24. g-4:79   1  #
; 25. g#2:56   1  #
; 26. g#1:44   1  #
; 27. f-1:41   1  #
; 28. f#1:42   1  #
; 29. d#2:51   1  #
; 30. c#4:73   1  #
; 31. a-4:81   1  #
```

Think Diff

Think Diff

```
; c-3:60  e-3:64  g-3:67  c-4:72  e-4:76  (...)
; c-3:60  d-3:62  a-3:69  d-4:74  f-4:77  (...)
; h-2:59  d-3:62  g-3:67  d-4:74  f-4:77  (...)
; c-3:60  e-3:64  g-3:67  c-4:72  e-4:76  (...)
; c-3:60  e-3:64  a-3:69  e-4:76  a-4:81  (...)
; c-3:60  d-3:62  f#3:66  a-3:69  d-4:74  (...)
; h-2:59  d-3:62  g-3:67  d-4:74  g-4:79  (...)
; h-2:59  c-3:60  e-3:64  g-3:67  c-4:72  (...)
; a-2:57  c-3:60  e-3:64  g-3:67  c-4:72  (...)
; d-2:50  a-2:57  d-3:62  f#3:66  c-4:72  (...)
; g-2:55  h-2:59  d-3:62  g-3:67  h-3:71  (...)
; g-2:55  a#2:58  e-3:64  g-3:67  c#4:73  (...)
; f-2:53  a-2:57  d-3:62  a-3:69  d-4:74  (...)
; f-2:53  g#2:56  d-3:62  f-3:65  h-3:71  (...)
; e-2:52  g-2:55  c-3:60  g-3:67  c-4:72  (...)
; e-2:52  f-2:53  a-2:57  c-3:60  f-3:65  (...)
; d-2:50  f-2:53  a-2:57  c-3:60  f-3:65  (...)
; g-1:43  d-2:50  g-2:55  h-2:59  f-3:65  (...)
; c-2:48  e-2:52  g-2:55  c-3:60  e-3:64  (...)
; c-2:48  g-2:55  a#2:58  c-3:60  e-3:64  (...)
; f-1:41  f-2:53  a-2:57  c-3:60  e-3:64  (...)
; f#1:42  c-2:48  a-2:57  c-3:60  e-3:64  (...)
; g#1:44  f-2:53  h-2:59  c-3:60  d-3:62  (...)
; g-1:43  f-2:53  g-2:55  h-2:59  d-3:62  (...)
; g-1:43  e-2:52  g-2:55  c-3:60  e-3:64  (...)
; g-1:43  d-2:50  g-2:55  c-3:60  f-3:65  (...)
; g-1:43  d-2:50  g-2:55  h-2:59  f-3:65  (...)
; g-1:43  d#2:51  a-2:57  c-3:60  f#3:66  (...)
; g-1:43  e-2:52  g-2:55  c-3:60  g-3:67  (...)
; g-1:43  d-2:50  g-2:55  c-3:60  f-3:65  (...)
; g-1:43  d-2:50  g-2:55  h-2:59  f-3:65  (...)
; c-1:36  c-2:48  g-2:55  a#2:58  e-3:64  (...)
```

```
; c-1:36  c-2:48  f-2:53  a-2:57  c-3:60  f-3:65  c-3:60  a-2:57
; c-3:60  a-2:57  f-2:53  a-2:57  f-2:53  d-2:50  f-2:53  d-2:50
; c-1:36  h-1:47  g-3:67  h-3:71  d-4:74  f-4:77  d-4:74  h-3:71
; d-4:74  h-3:71  g-3:67  h-3:71  d-3:62  f-3:65  e-3:64  d-3:62

; c-1:36  c-2:48  e-3:64  g-3:67  c-4:72
```



Think Diff

```
; c-3:60  e-3:64  g-3:67  c-4:72  e-4:76  (...)
; c-3:60  d-3:62  a-3:69  d-4:74  f-4:77  (...)
; h-2:59  d-3:62  g-3:67  d-4:74  f-4:77  (...)
; c-3:60  e-3:64  g-3:67  c-4:72  e-4:76  (...)
; c-3:60  e-3:64  a-3:69  e-4:76  a-4:81  (...)
; c-3:60  d-3:62  f#3:66  a-3:69  d-4:74  (...)
; h-2:59  d-3:62  g-3:67  d-4:74  g-4:79  (...)
; h-2:59  c-3:60  e-3:64  g-3:67  c-4:72  (...)
; a-2:57  c-3:60  e-3:64  g-3:67  c-4:72  (...)
; d-2:50  a-2:57  d-3:62  f#3:66  c-4:72  (...)
; g-2:55  h-2:59  d-3:62  g-3:67  h-3:71  (...)
; g-2:55  a#2:58  e-3:64  g-3:67  c#4:73  (...)
; f-2:53  a-2:57  d-3:62  a-3:69  d-4:74  (...)
; f-2:53  g#2:56  d-3:62  f-3:65  h-3:71  (...)
; e-2:52  g-2:55  c-3:60  g-3:67  c-4:72  (...)
; e-2:52  f-2:53  a-2:57  c-3:60  f-3:65  (...)
; d-2:50  f-2:53  a-2:57  c-3:60  f-3:65  (...)
; g-1:43  d-2:50  g-2:55  h-2:59  f-3:65  (...)
; c-2:48  e-2:52  g-2:55  c-3:60  e-3:64  (...)
; c-2:48  g-2:55  a#2:58  c-3:60  e-3:64  (...)
; f-1:41  f-2:53  a-2:57  c-3:60  e-3:64  (...)
; f#1:42  c-2:48  a-2:57  c-3:60  e-3:64  (...)
; g#1:44  f-2:53  h-2:59  c-3:60  d-3:62  (...)
; g-1:43  f-2:53  g-2:55  h-2:59  d-3:62  (...)
; g-1:43  e-2:52  g-2:55  c-3:60  e-3:64  (...)
; g-1:43  d-2:50  g-2:55  c-3:60  f-3:65  (...)
; g-1:43  d-2:50  g-2:55  h-2:59  f-3:65  (...)
; g-1:43  d#2:51  a-2:57  c-3:60  f#3:66  (...)
; g-1:43  e-2:52  g-2:55  c-3:60  g-3:67  (...)
; g-1:43  d-2:50  g-2:55  c-3:60  f-3:65  (...)
; g-1:43  d-2:50  g-2:55  h-2:59  f-3:65  (...)
; c-1:36  c-2:48  g-2:55  a#2:58  e-3:64  (...)
```

```
; c-1:36  c-2:48  f-2:53  a-2:57  c-3:60  f-3:65  c-3:60  a-2:57
; c-3:60  a-2:57  f-2:53  a-2:57  f-2:53  d-2:50  f-2:53  d-2:50
; c-1:36  h-1:47  g-3:67  h-3:71  d-4:74  f-4:77  d-4:74  h-3:71
; d-4:74  h-3:71  g-3:67  h-3:71  d-3:62  f-3:65  e-3:64  d-3:62

; c-1:36  c-2:48  e-3:64  g-3:67  c-4:72
```

Focus on values of Part 1

Think Diff

c-3:60
c-3:60
h-2:59
c-3:60
c-3:60
c-3:60
h-2:59
h-2:59
a-2:57
d-2:50
g-2:55
g-2:55
f-2:53
f-2:53
e-2:52
e-2:52

e-3:64
d-3:62
d-3:62
e-3:64
e-3:64
d-3:62
d-3:62
c-3:60
c-3:60
a-2:57
h-2:59
a#2:58
a-2:57
g#2:56
g-2:55
f-2:53

g-3:67
a-3:69
g-3:67
g-3:67
a-3:69
f#3:66
g-3:67
e-3:64
e-3:64
d-3:62
d-3:62
e-3:64
d-3:62
d-3:62
c-3:60
a-2:57

c-4:72
d-4:74
d-4:74
c-4:72
e-4:76
a-3:69
d-4:74
g-3:67
g-3:67
f#3:66
g-3:67
g-3:67
a-3:69
f-3:65
g-3:67
c-3:60

e-4:76
f-4:77
f-4:77
e-4:76
a-4:81
d-4:74
g-4:79
c-4:72
c-4:72
c-4:72
h-3:71
c#4:73
d-4:74
h-3:71
c-4:72
f-3:65

d-2:50
g-1:43
c-2:48
c-2:48
f-1:41
f#1:42
g#1:44
g-1:43
g-1:43
g-1:43
g-1:43
g-1:43
g-1:43
g-1:43
g-1:43
c-1:36

f-2:53
d-2:50
e-2:52
g-2:55
f-2:53
c-2:48
f-2:53
f-2:53
e-2:52
d-2:50
d-2:50
d#2:51
e-2:52
d-2:50
d-2:50
c-2:48

a-2:57
g-2:55
g-2:55
a#2:58
a-2:57
a-2:57
h-2:59
g-2:55
g-2:55
g-2:55
g-2:55
a-2:57
g-2:55
g-2:55
g-2:55
g-2:55

c-3:60
h-2:59
c-3:60
c-3:60
c-3:60
c-3:60
c-3:60
h-2:59
c-3:60
c-3:60
h-2:59
c-3:60
c-3:60
c-3:60
h-2:59
a#2:58

f-3:65
f-3:65
e-3:64
e-3:64
e-3:64
e-3:64
d-3:62
d-3:62
e-3:64
f-3:65
f-3:65
f#3:66
g-3:67
f-3:65
f-3:65
e-3:64

Think Diff

c-3:60
c-3:60
h-2:59
c-3:60
c-3:60
c-3:60
h-2:59
h-2:59
a-2:57
d-2:50
g-2:55
g-2:55
f-2:53
f-2:53
e-2:52
e-2:52

e-3:64
d-3:62
d-3:62
e-3:64
e-3:64
d-3:62
d-3:62
c-3:60
c-3:60
a-2:57
h-2:59
a#2:58
a-2:57
g#2:56
g-2:55
f-2:53

g-3:67
a-3:69
g-3:67
g-3:67
a-3:69
f#3:66
g-3:67
e-3:64
e-3:64
d-3:62
d-3:62
e-3:64
d-3:62
d-3:62
c-3:60
a-2:57

c-4:72
d-4:74
d-4:74
c-4:72
e-4:76
a-3:69
d-4:74
g-3:67
g-3:67
f#3:66
g-3:67
g-3:67
a-3:69
f-3:65
g-3:67
c-3:60

e-4:76
f-4:77
f-4:77
e-4:76
a-4:81
d-4:74
g-4:79
c-4:72
c-4:72
c-4:72
h-3:71
c#4:73
d-4:74
h-3:71
c-4:72
f-3:65

d-2:50
g-1:43
c-2:48
c-2:48
f-1:41
f#1:42
g#1:44
g-1:43
g-1:43
g-1:43
g-1:43
g-1:43
g-1:43
g-1:43
g-1:43
c-1:36

f-2:53
d-2:50
e-2:52
g-2:55
f-2:53
c-2:48
f-2:53
f-2:53
e-2:52
d-2:50
d-2:50
d#2:51
e-2:52
d-2:50
d-2:50
c-2:48

a-2:57
g-2:55
g-2:55
a#2:58
a-2:57
a-2:57
h-2:59
g-2:55
g-2:55
g-2:55
g-2:55
a-2:57
g-2:55
g-2:55
g-2:55
g-2:55

c-3:60
h-2:59
c-3:60
c-3:60
c-3:60
c-3:60
c-3:60
h-2:59
c-3:60
c-3:60
h-2:59
c-3:60
c-3:60
c-3:60
h-2:59
a#2:58

f-3:65
f-3:65
e-3:64
e-3:64
e-3:64
e-3:64
d-3:62
d-3:62
e-3:64
f-3:65
f-3:65
f#3:66
g-3:67
f-3:65
f-3:65
e-3:64

Think Diff

c-3:60	e-3:64	g-3:67	c-4:72	e-4:76
c-3:60	d-3:62	a-3:69	d-4:74	f-4:77
h-2:59	d-3:62	g-3:67	d-4:74	f-4:77
c-3:60	e-3:64	g-3:67	c-4:72	e-4:76
c-3:60	e-3:64	a-3:69	e-4:76	a-4:81
c-3:60	d-3:62	f#3:66	a-3:69	d-4:74
h-2:59	d-3:62	g-3:67	d-4:74	g-4:79
h-2:59	c-3:60	e-3:64	g-3:67	c-4:72
a-2:57	c-3:60	e-3:64	g-3:67	c-4:72
d-2:50	a-2:57	d-3:62	f#3:66	c-4:72
g-2:55	h-2:59	d-3:62	g-3:67	h-3:71
g-2:55	a#2:58	e-3:64	g-3:67	c#4:73
f-2:53	a-2:57	d-3:62	a-3:69	d-4:74
f-2:53	g#2:56	d-3:62	f-3:65	h-3:71
e-2:52	g-2:55	c-3:60	g-3:67	c-4:72
e-2:52	f-2:53	a-2:57	c-3:60	f-3:65

d-2:50	f-2:53	a-2:57	c-3:60	f-3:65
g-1:43	d-2:50	g-2:55	h-2:59	f-3:65
c-2:48	e-2:52	g-2:55	c-3:60	e-3:64
c-2:48	g-2:55	a#2:58	c-3:60	e-3:64
f-1:41	f-2:53	a-2:57	c-3:60	e-3:64
f#1:42	c-2:48	a-2:57	c-3:60	e-3:64
g#1:44	f-2:53	h-2:59	c-3:60	d-3:62
g-1:43	f-2:53	g-2:55	h-2:59	d-3:62
g-1:43	e-2:52	g-2:55	c-3:60	e-3:64
g-1:43	d-2:50	g-2:55	c-3:60	f-3:65
g-1:43	d-2:50	g-2:55	h-2:59	f-3:65
g-1:43	d#2:51	a-2:57	c-3:60	f#3:66
g-1:43	e-2:52	g-2:55	c-3:60	g-3:67
g-1:43	d-2:50	g-2:55	c-3:60	f-3:65
g-1:43	d-2:50	g-2:55	h-2:59	f-3:65
c-1:36	c-2:48	g-2:55	a#2:58	e-3:64

The raw-diff-5 theory

Think Diff: why raw-diff-5?

Why raw?

Think Diff: why raw-diff-5?

Why raw?

- Two options:
    - raw MIDI notes or
    - mapped data

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Why raw?

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  - raw MIDI notes or
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- Dispersion: 31 values in range of 45

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  - raw MIDI notes or
  - mapped data
- Dispersion: 31 values in range of 45
- Indexed requires extra 31-byte table

Think Diff: why raw-diff-5?

Why raw?

- Two options:
    - raw MIDI notes or
    - mapped data
- Dispersion: 31 values in range of 45
- Indexed requires extra 31-byte table
- Can't compress table, ony data

Think Diff: why raw-diff-5?

Why diff-5?

Think Diff: why raw-diff-5?

Why diff-5?

- Part 1 contains chord breaks

Think Diff: why raw-diff-5?

Why diff-5?

- Part 1 contains chord breaks
- Chords are evolving slowly to next one

Think Diff: why raw-diff-5?

Why diff-5?

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- Chords are evolving slowly to next one
- Slowness is emphasized by repeating all chord breaks twice (not stored)

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- Chords are evolving slowly to next one
- Slowness is emphasized by repeating all chord breaks twice (not stored)
- Slow change means small diffs

Think Diff: why raw-diff-5?

Why diff-5?

- Part 1 contains chord breaks
- Chords are evolving slowly to next one
- Slowness is emphasized by repeating all chord breaks twice (not stored)
- Slow change means small diffs
- Chord breaks are 8 notes long

Think Diff: why raw-diff-5?

Why diff-5?

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- Chords are evolving slowly to next one
- Slowness is emphasized by repeating all chord breaks twice (not stored)
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- Chord breaks are 8 notes long
- Which are stored in 5 bytes

Think Diff: why raw-diff-5?

Why diff-5?

- Part 1 contains chord breaks
- Chords are evolving slowly to next one
- Slowness is emphasized by repeating all chord breaks twice (not stored)
- Slow change means small diffs
- Chord breaks are 8 notes long
- Which are stored in 5 bytes
- Diff-5 is diff to previous line

Intermission: raw-diff-mixed/1/5

What is diff-mixed/1/5?

Intermission: raw-diff-mixed/1/5

What is diff-mixed/1/5?

- First note of the line: diff-5 (prev line)

Intermission: raw-diff-mixed/1/5

What is diff-mixed/1/5?

- First note of the line: diff-5 (prev line)
- Other notes: diff-1 (prev note)

Intermission: raw-diff-mixed/1/5

What is diff-mixed/1/5?

- First note of the line: diff-5 (prev line)
- Other notes: diff-1 (prev note)
- No negative diff-1 values

Intermission: raw-diff-mixed/1/5

What is diff-mixed/1/5?

- First note of the line: diff-5 (prev line)
- Other notes: diff-1 (prev note)
- No negative diff-1 values
- Requires extra code

Think Diff: raw-diff-5 data overview

Added diff values in dump:

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
c-3:60:=00  e-3:64:=00  a-3:69:+02  e-4:76:+04  a-4:81:+05
c-3:60:=00  d-3:62:-02  f#3:66:-03  a-3:69:-07  d-4:74:-07
h-2:59:-01  d-3:62:=00  g-3:67:+01  d-4:74:+05  g-4:79:+05
                          (...)
```

Think Diff: raw-diff-5 data overview

```
c-3:60:/00 e-3:64:/00 g-3:67:/00 c-4:72:/00 e-4:76:/00
c-3:60:=00 d-3:62:-02 a-3:69:+02 d-4:74:+02 f-4:77:+01
h-2:59:-01 d-3:62:=00 g-3:67:-02 d-4:74:=00 f-4:77:=00  d-2:50:-02 f-2:53:=00 a-2:57:=00 c-3:60:=00 f-3:65:=00
c-3:60:+01 e-3:64:+02 g-3:67:=00 c-4:72:-02 e-4:76:-01  g-1:43:-07 d-2:50:-03 g-2:55:-02 h-2:59:-01 f-3:65:=00
c-3:60:=00 e-3:64:=00 a-3:69:+02 e-4:76:+04 a-4:81:+05  c-2:48:+05 e-2:52:+02 g-2:55:=00 c-3:60:+01 e-3:64:-01
c-3:60:=00 d-3:62:-02 f#3:66:-03 a-3:69:-07 d-4:74:-07  c-2:48:=00 g-2:55:+03 a#2:58:+03 c-3:60:=00 e-3:64:=00
h-2:59:-01 d-3:62:=00 g-3:67:+01 d-4:74:+05 g-4:79:+05  f-1:41:-07 f-2:53:-02 a-2:57:-01 c-3:60:=00 e-3:64:=00
h-2:59:=00 c-3:60:-02 e-3:64:-03 g-3:67:-07 c-4:72:-07  f#1:42:+01 c-2:48:-05 a-2:57:=00 c-3:60:=00 e-3:64:=00
a-2:57:-02 c-3:60:=00 e-3:64:=00 g-3:67:=00 c-4:72:=00  g#1:44:+02 f-2:53:+05 h-2:59:+02 c-3:60:=00 d-3:62:-02
d-2:50:-07 a-2:57:-03 d-3:62:-02 f#3:66:-01 c-4:72:=00  g-1:43:-01 f-2:53:=00 g-2:55:-04 h-2:59:-01 d-3:62:=00
g-2:55:+05 h-2:59:+02 d-3:62:=00 g-3:67:+01 h-3:71:-01  g-1:43:=00 e-2:52:-01 g-2:55:=00 c-3:60:+01 e-3:64:+02
g-2:55:=00 a#2:58:-01 e-3:64:+02 g-3:67:=00 c#4:73:+02  g-1:43:=00 d-2:50:-02 g-2:55:=00 c-3:60:=00 f-3:65:+01
f-2:53:-02 a-2:57:-01 d-3:62:-02 a-3:69:+02 d-4:74:+01  g-1:43:=00 d-2:50:=00 g-2:55:=00 h-2:59:-01 f-3:65:=00
f-2:53:=00 g#2:56:-01 d-3:62:=00 f-3:65:-04 h-3:71:-03  g-1:43:=00 d#2:51:+01 a-2:57:+02 c-3:60:+01 f#3:66:+01
e-2:52:-01 g-2:55:-01 c-3:60:-02 g-3:67:+02 c-4:72:+01  g-1:43:=00 e-2:52:+01 g-2:55:-02 c-3:60:=00 g-3:67:+01
e-2:52:=00 f-2:53:-02 a-2:57:-03 c-3:60:-07 f-3:65:-07  g-1:43:=00 d-2:50:-02 g-2:55:=00 c-3:60:=00 f-3:65:-02
                                                        g-1:43:=00 d-2:50:=00 g-2:55:=00 h-2:59:-01 f-3:65:=00
                                                        c-1:36:-07 c-2:48:-02 g-2:55:=00 a#2:58:-01 e-3:64:-01

                    c-1:36:=00 c-2:48:=00 f-2:53:-02 a-2:57:-01 c-3:60:-04 f-3:65:+29 c-3:60:+12 a-2:57:+04
                    c-3:60:+03 a-2:57:-03 f-2:53:-12 a-2:57:-03 f-2:53:-04 d-2:50:-10 f-2:53:-04 d-2:50:-03
                    c-1:36:-21 h-1:47:-06 g-3:67:+17 h-3:71:+18 d-4:74:+24 f-4:77:+41 d-4:74:+27 h-3:71:+04
                    d-4:74:+03 h-3:71:-03 g-3:67:-10 h-3:71:-03 d-3:62:-09 f-3:65:-09 e-3:64:-07 d-3:62:-05

                                     c-1:36:-35 c-2:48:-14 e-3:64:-01 g-3:67:+03 c-4:72:+10
```

Think Diff: raw-diff-5 data overview

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
c-3:60:=00  e-3:64:=00  a-3:69:+02  e-4:76:+04  a-4:81:+05
c-3:60:=00  d-3:62:-02  f#3:66:-03  a-3:69:-07  d-4:74:-07
h-2:59:-01  d-3:62:=00  g-3:67:+01  d-4:74:+05  g-4:79:+05
h-2:59:=00  c-3:60:-02  e-3:64:-03  g-3:67:-07  c-4:72:-07
a-2:57:-02  c-3:60:=00  e-3:64:=00  g-3:67:=00  c-4:72:=00
d-2:50:-07  a-2:57:-03  d-3:62:-02  f#3:66:-01  c-4:72:=00
g-2:55:+05  h-2:59:+02  d-3:62:=00  g-3:67:+01  h-3:71:-01
g-2:55:=00  a#2:58:-01  e-3:64:+02  g-3:67:=00  c#4:73:+02
f-2:53:-02  a-2:57:-01  d-3:62:-02  a-3:69:+02  d-4:74:+01
f-2:53:=00  g#2:56:-01  d-3:62:=00  f-3:65:-04  h-3:71:-03
e-2:52:-01  g-2:55:-01  c-3:60:-02  g-3:67:+02  c-4:72:+01
e-2:52:=00  f-2:53:-02  a-2:57:-03  c-3:60:-07  f-3:65:-07
```

```
d-2:50:-02  f-2:53:=00  a-2:57:=00  c-3:60:=00  f-3:65:=00
g-1:43:-07  d-2:50:-03  g-2:55:-02  h-2:59:-01  f-3:65:=00
c-2:48:+05  e-2:52:+02  g-2:55:=00  c-3:60:+01  e-3:64:-01
c-2:48:=00  g-2:55:+03  a#2:58:+03  c-3:60:=00  e-3:64:=00
f-1:41:-07  f-2:53:-02  a-2:57:-01  c-3:60:=00  e-3:64:=00
f#1:42:+01  c-2:48:-05  a-2:57:=00  c-3:60:=00  e-3:64:=00
g#1:44:+02  f-2:53:+05  h-2:59:+02  c-3:60:=00  d-3:62:-02
g-1:43:-01  f-2:53:=00  g-2:55:-04  h-2:59:-01  d-3:62:=00
g-1:43:=00  e-2:52:-01  g-2:55:=00  c-3:60:+01  e-3:64:+02
g-1:43:=00  d-2:50:-02  g-2:55:=00  c-3:60:=00  f-3:65:+01
g-1:43:=00  d-2:50:=00  g-2:55:=00  h-2:59:-01  f-3:65:=00
g-1:43:=00  d#2:51:+01  a-2:57:+02  c-3:60:+01  f#3:66:+01
g-1:43:=00  e-2:52:+01  g-2:55:-02  c-3:60:=00  g-3:67:+01
g-1:43:=00  d-2:50:-02  g-2:55:=00  c-3:60:=00  f-3:65:-02
g-1:43:=00  d-2:50:=00  g-2:55:=00  h-2:59:-01  f-3:65:=00
c-1:36:-07  c-2:48:-02  g-2:55:=00  a#2:58:-01  e-3:64:-01
```

```
c-1:36:=00  c-2:48:=00  f-2:53:-02  a-2:57:-01  c-3:60:-04  f-3:65:+29  c-3:60:+12  a-2:57:+04
c-3:60:+03  a-2:57:-03  f-2:53:-12  a-2:57:-03  f-2:53:-04  d-2:50:-10  f-2:53:-04  d-2:50:-03
c-1:36:-21  h-1:47:-06  g-3:67:+17  h-3:71:+18  d-4:74:+24  f-4:77:+41  d-4:74:+27  h-3:71:+04
d-4:74:+03  h-3:71:-03  g-3:67:-10  h-3:71:-03  d-3:62:-09  f-3:65:-09  e-3:64:-07  d-3:62:-05
```

```
c-1:36:-35  c-2:48:-14  e-3:64:-01  g-3:67:+03  c-4:72:+10
```

Think Diff: raw-diff-5 data overview

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
c-3:60:=00  e-3:64:=00  a-3:69:+02  e-4:76:+04  a-4:81:+05
c-3:60:=00  d-3:62:-02  f#3:66:-03  a-3:69:-07  d-4:74:-07
h-2:59:-01  d-3:62:=00  g-3:67:+01  d-4:74:+05  g-4:79:+05
h-2:59:=00  c-3:60:-02  e-3:64:-03  g-3:67:-07  c-4:72:-07
a-2:57:-02  c-3:60:=00  e-3:64:=00  g-3:67:=00  c-4:72:=00
d-2:50:-07  a-2:57:-03  d-3:62:-02  f#3:66:-01  c-4:72:=00
g-2:55:+05  h-2:59:+02  d-3:62:=00  g-3:67:+01  h-3:71:-01
g-2:55:=00  a#2:58:-01  e-3:64:+02  g-3:67:=00  c#4:73:+02
f-2:53:-02  a-2:57:-01  d-3:62:-02  a-3:69:+02  d-4:74:+01
f-2:53:=00  g#2:56:-01  d-3:62:=00  f-3:65:-04  h-3:71:-03
e-2:52:-01  g-2:55:-01  c-3:60:-02  g-3:67:+02  c-4:72:+01
e-2:52:=00  f-2:53:-02  a-2:57:-03  c-3:60:-07  f-3:65:-07
```

```
d-2:50:-02  f-2:53:=00  a-2:57:=00  c-3:60:=00  f-3:65:=00
g-1:43:-07  d-2:50:-03  g-2:55:-02  h-2:59:-01  f-3:65:=00
c-2:48:+05  e-2:52:+02  g-2:55:=00  c-3:60:+01  e-3:64:-01
c-2:48:=00  g-2:55:+03  a#2:58:+03  c-3:60:=00  e-3:64:=00
f-1:41:-07  f-2:53:-02  a-2:57:-01  c-3:60:=00  e-3:64:=00
f#1:42:+01  c-2:48:-05  a-2:57:=00  c-3:60:=00  e-3:64:=00
g#1:44:+02  f-2:53:+05  h-2:59:+02  c-3:60:=00  d-3:62:-02
g-1:43:-01  f-2:53:=00  g-2:55:-04  h-2:59:-01  d-3:62:=00
g-1:43:=00  e-2:52:-01  g-2:55:=00  c-3:60:+01  e-3:64:+02
g-1:43:=00  d-2:50:-02  g-2:55:=00  c-3:60:=00  f-3:65:+01
g-1:43:=00  d-2:50:=00  g-2:55:=00  h-2:59:-01  f-3:65:=00
g-1:43:=00  d#2:51:+01  a-2:57:+02  c-3:60:+01  f#3:66:+01
g-1:43:=00  e-2:52:+01  g-2:55:-02  c-3:60:=00  g-3:67:+01
g-1:43:=00  d-2:50:-02  g-2:55:=00  c-3:60:=00  f-3:65:-02
g-1:43:=00  d-2:50:=00  g-2:55:=00  h-2:59:-01  f-3:65:=00
c-1:36:-07  c-2:48:-02  g-2:55:=00  a#2:58:-01  e-3:64:-01
```

```
c-1:36:=00  c-2:48:=00  f-2:53:-02  a-2:57:-01  c-3:60:-04  f-3:65:+29  c-3:60:+12  a-2:57:+04
c-3:60:+03  a-2:57:-03  f-2:53:-12  a-2:57:-03  f-2:53:-04  d-2:50:-10  f-2:53:-04  d-2:50:-03
c-1:36:-21  h-1:47:-06  g-3:67:+17  h-3:71:+18  d-4:74:+24  f-4:77:+41  d-4:74:+27  h-3:71:+04
d-4:74:+03  h-3:71:-03  g-3:67:-10  h-3:71:-03  d-3:62:-09  f-3:65:-09  e-3:64:-07  d-3:62:-05
```

```
c-1:36:-35  c-2:48:-14  e-3:64:-01  g-3:67:+03  c-4:72:+10
```

Think Diff: raw-diff-5 data overview

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
c-3:60:=00  e-3:64:=00  a-3:69:+02  e-4:76:+04  a-4:81:+05
c-3:60:=00  d-3:62:-02  f#3:66:-03  a-3:69:-07  d-4:74:-07
h-2:59:-01  d-3:62:=00  g-3:67:+01  d-4:74:+05  g-4:79:+05
h-2:59:=00  c-3:60:-02  e-3:64:-03  g-3:67:-07  c-4:72:-07
a-2:57:-02  c-3:60:=00  e-3:64:=00  g-3:67:=00  c-4:72:=00
d-2:50:-07  a-2:57:-03  d-3:62:-02  f#3:66:-01  c-4:72:=00
g-2:55:+05  h-2:59:+02  d-3:62:=00  g-3:67:+01  h-3:71:-01
g-2:55:=00  a#2:58:-01  e-3:64:+02  g-3:67:=00  c#4:73:+02
f-2:53:-02  a-2:57:-01  d-3:62:-02  a-3:69:+02  d-4:74:+01
f-2:53:=00  g#2:56:-01  d-3:62:=00  f-3:65:-04  h-3:71:-03
e-2:52:-01  g-2:55:-01  c-3:60:-02  g-3:67:+02  c-4:72:+01
e-2:52:=00  f-2:53:-02  a-2:57:-03  c-3:60:-07  f-3:65:-07
```

```
d-2:50:-02  f-2:53:=00  a-2:57:=00  c-3:60:=00  f-3:65:=00
g-1:43:-07  d-2:50:-03  g-2:55:-02  h-2:59:-01  f-3:65:=00
c-2:48:+05  e-2:52:+02  g-2:55:=00  c-3:60:+01  e-3:64:-01
c-2:48:=00  g-2:55:+03  a#2:58:+03  c-3:60:=00  e-3:64:=00
f-1:41:-07  f-2:53:-02  a-2:57:-01  c-3:60:=00  e-3:64:=00
f#1:42:+01  c-2:48:-05  a-2:57:=00  c-3:60:=00  e-3:64:=00
g#1:44:+02  f-2:53:+05  h-2:59:+02  c-3:60:=00  d-3:62:-02
g-1:43:-01  f-2:53:=00  g-2:55:-04  h-2:59:-01  d-3:62:=00
g-1:43:=00  e-2:52:-01  g-2:55:=00  c-3:60:+01  e-3:64:+02
g-1:43:=00  d-2:50:-02  g-2:55:=00  c-3:60:=00  f-3:65:+01
g-1:43:=00  d-2:50:=00  g-2:55:=00  h-2:59:-01  f-3:65:=00
g-1:43:=00  d#2:51:+01  a-2:57:+02  c-3:60:+01  f#3:66:+01
g-1:43:=00  e-2:52:+01  g-2:55:-02  c-3:60:=00  g-3:67:+01
g-1:43:=00  d-2:50:-02  g-2:55:=00  c-3:60:=00  f-3:65:-02
g-1:43:=00  d-2:50:=00  g-2:55:=00  h-2:59:-01  f-3:65:=00
c-1:36:-07  c-2:48:-02  g-2:55:=00  a#2:58:-01  e-3:64:-01
```

```
c-1:36:=00  c-2:48:=00  f-2:53:-02  a-2:57:-01  c-3:60:-04  f-3:65:+29  c-3:60:+12  a-2:57:+04
c-3:60:+03  a-2:57:-03  f-2:53:-12  a-2:57:-03  f-2:53:-04  d-2:50:-10  f-2:53:-04  d-2:50:-03
c-1:36:-21  h-1:47:-06  g-3:67:+17  h-3:71:+18  d-4:74:+24  f-4:77:+41  d-4:74:+27  h-3:71:+04
d-4:74:+03  h-3:71:-03  g-3:67:-10  h-3:71:-03  d-3:62:-09  f-3:65:-09  e-3:64:-07  d-3:62:-05
```

```
c-1:36:-35  c-2:48:-14  e-3:64:-01  g-3:67:+03  c-4:72:+10
```

Histogram of raw-diff-5 (27 values, 197 notes)

```
; -35  1   1 #
; -21  1   2 #
; -14  1   3 #
; -12  1   4 #
; -10  2   6 ##
; -09  2   8 ##
; -07 11  19 ###########
; -06  1  20 #
; -05  2  22 ##
; -04  5  27 #####
; -03 11  38 ###########
; -02 21  59 #####################
; -01 22  81 ######################
; =00 65 146 #################################################################
; +01 15 161 ###############
; +02 14 175 ##############
; +03  5 180 #####
; +04  3 183 ###
; +05  6 189 ######
; +10  1 190 #
; +12  1 191 #
; +17  1 192 #
; +18  1 193 #
; +24  1 194 #
; +27  1 195 #
; +29  1 196 #
; +41  1 197 #
```

Histogram of raw-diff-5 (27 values, 197 notes)

```
;  1. =00 65  65 #################################################################
;  2. -01 22  87 ######################
;  3. -02 21 108 #####################
;  4. +01 15 123 ###############
;  5. +02 14 137 ##############
;  6. -07 11 148 ###########
;  7. -03 11 159 ###########
;  8. +05  6 165 ######
;  9. -04  5 170 #####
; 10. +03  5 175 #####
; 11. +04  3 178 ###
; 12. -10  2 180 ##
; 13. -09  2 182 ##
; 14. -05  2 184 ##
; 15. -35  1 185 #
; 16. -21  1 186 #
; 17. -14  1 187 #
; 18. -12  1 188 #
; 19. -06  1 189 #
; 20. +41  1 190 #
; 21. +29  1 191 #
; 22. +27  1 192 #
; 23. +24  1 193 #
; 24. +18  1 194 #
; 25. +17  1 195 #
; 26. +12  1 196 #
; 27. +10  1 197 #
```

Histogram of raw-diff-5 (27 values, 197 notes)

```
;  1. =00 65  65 #################################################################
;  2. -01 22  87 ######################
;  3. -02 21 108 #####################
;  4. +01 15 123 ###############
;  5. +02 14 137 ##############
;  6. -07 11 148 ###########
;  7. -03 11 159 ###########
;  8. +05  6 165 ######
;  9. -04  5 170 #####
; 10. +03  5 175 #####
; 11. +04  3 178 ###
; 12. -10  2 180 ##
; 13. -09  2 182 ##
; 14. -05  2 184 ##
; 15. -35  1 185 #
; 16. -21  1 186 #
; 17. -14  1 187 #
; 18. -12  1 188 #
; 19. -06  1 189 #
; 20. +41  1 190 #
; 21. +29  1 191 #
; 22. +27  1 192 #
; 23. +24  1 193 #
; 24. +18  1 194 #
; 25. +17  1 195 #
; 26. +12  1 196 #
; 27. +10  1 197 #
```

Top-heavy:
33% weight for
top value (4%)

Histogram of raw-diff-5 (27 values, 197 notes)

```
;  1. =00 65  65 #################################################################
;  2. -01 22  87 ######################
;  3. -02 21 108 #####################
;  4. +01 15 123 ###############
;  5. +02 14 137 ##############
;  6. -07 11 148 ###########
;  7. -03 11 159 ###########
;  8. +05  6 165 ######
;  9. -04  5 170 #####
; 10. +03  5 175 #####
; 11. +04  3 178 ###
; 12. -10  2 180 ##
; 13. -09  2 182 ##
; 14. -05  2 184 ##
; 15. -35  1 185 #
; 16. -21  1 186 #
; 17. -14  1 187 #
; 18. -12  1 188 #
; 19. -06  1 189 #
; 20. +41  1 190 #
; 21. +29  1 191 #
; 22. +27  1 192 #
; 23. +24  1 193 #
; 24. +18  1 194 #
; 25. +17  1 195 #
; 26. +12  1 196 #
; 27. +10  1 197 #
```

Long tail:

11% weight for

63% of values

Compression

Compression

- Split data to top frequent and less frequent set of values around 80%..20% weight

Compression

- Split data to top frequent and less frequent set of values around 80%..20% weight
- Store most frequent values in short-words

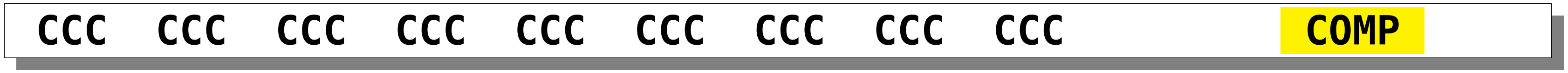
Compression

- Split data to top frequent and less frequent set of values around 80%..20% weight
- Store most frequent values in short-words

```
ccc  ccc  ccc  ccc  ccc  ccc  ccc  ccc  ccc
```

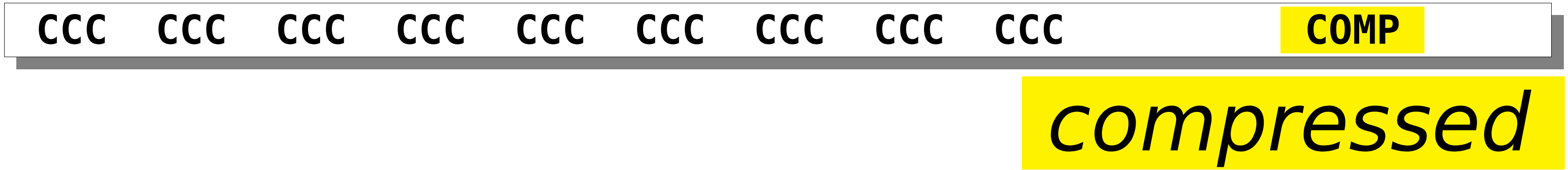
Compression

- Split data to top frequent and less frequent set of values around 80%..20% weight
- Store most frequent values in short-words



Compression

- Split data to top frequent and less frequent set of values around 80%..20% weight
- Store most frequent values in short-words

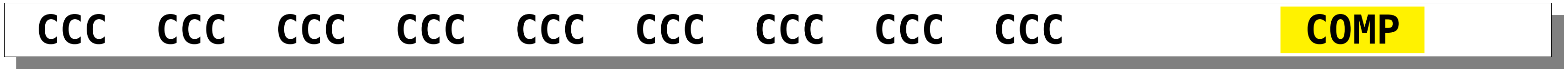


ccc ccc ccc ccc ccc ccc ccc ccc ccc COMP

compressed

Compression

- Split data to top frequent and less frequent set of values around 80%..20% weight
- Store most frequent values in short-words

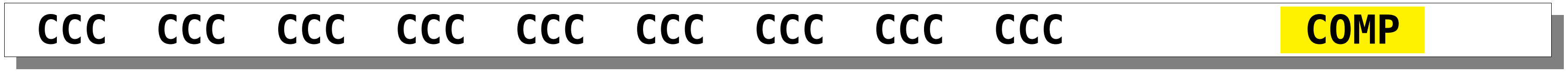


ccc ccc ccc ccc ccc ccc ccc ccc ccc COMP

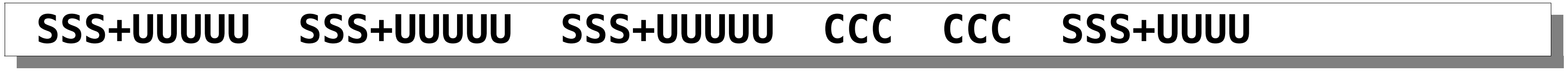
- Store special escape short-word followed by a long-word for less frequent values

Compression

- Split data to top frequent and less frequent set of values around 80%..20% weight
- Store most frequent values in short-words



- Store special escape short-word followed by a long-word for less frequent values



Compression

- Split data to top frequent and less frequent set of values around 80%..20% weight
- Store most frequent values in short-words

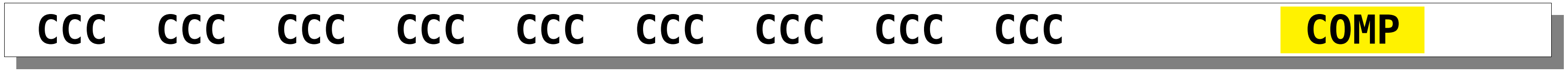
```
CCC  CCC  CCC  CCC  CCC  CCC  CCC  CCC  CCC          COMP
```

- Store special escape short-word followed by a long-word for less frequent values

```
SSS+UUUUU  SSS+UUUUU  SSS+UUUUU  CCC  CCC  SSS+UUUU   UCOMP
```

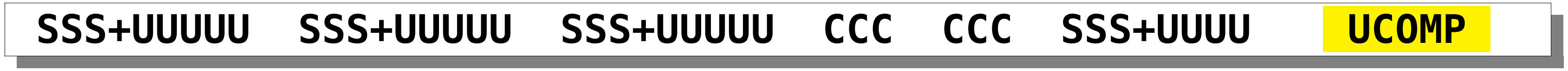
Compression

- Split data to top frequent and less frequent set of values around 80%..20% weight
- Store most frequent values in short-words



CCC CCC CCC CCC CCC CCC CCC CCC CCC COMP

- Store special escape short-word followed by a long-word for less frequent values

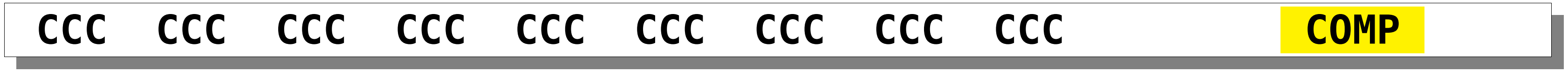


SSS+UUUUU SSS+UUUUU SSS+UUUUU CCC CCC SSS+UUUU UCOMP

uncompressed

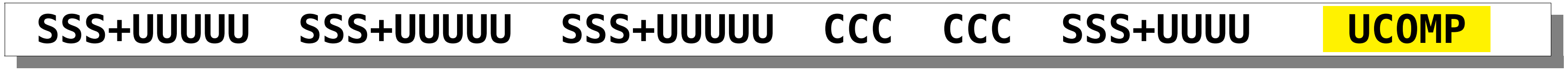
Compression

- Split data to top frequent and less frequent set of values around 80%..20% weight
- Store most frequent values in short-words



CCC CCC CCC CCC CCC CCC CCC CCC CCC COMP

- Store special escape short-word followed by a long-word for less frequent values

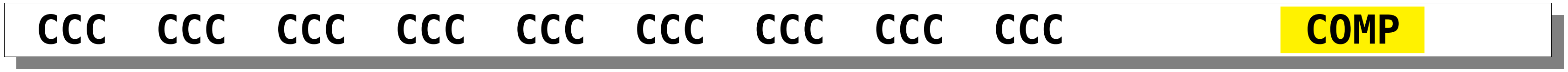


SSS+UUUUU SSS+UUUUU SSS+UUUUU CCC CCC SSS+UUUU UCOMP

- Needs index tables

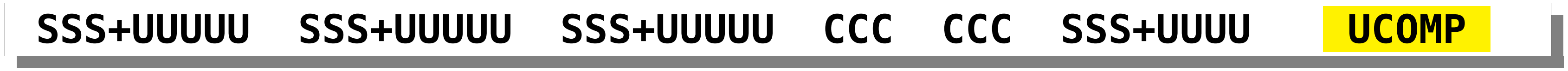
Compression

- Split data to top frequent and less frequent set of values around 80%..20% weight
- Store most frequent values in short-words



CCC CCC CCC CCC CCC CCC CCC CCC CCC COMP

- Store special escape short-word followed by a long-word for less frequent values



SSS+UUUUU SSS+UUUUU SSS+UUUUU CCC CCC SSS+UUUU UCOMP

- Needs index tables
- First notes must be stored (have no diff)

Compression

- Split data to top frequent and less frequent set of values around 80%..20% weight
- Store most frequent values in short-words

```
CCC  CCC  CCC  CCC  CCC  CCC  CCC  CCC  CCC          COMP
```

- Store special escape short-word followed by a long-word for less frequent values

```
SSS+UUUUU  SSS+UUUUU  SSS+UUUUU  CCC  CCC  SSS+UUUU  UCOMP
```

- Needs index tables
- First notes must be stored (have no diff)

Compression: raw-diff-5 @ 2

```
;  1. =00 65  65 #################################################################
;  2. -01 22  87 ######################
;  3. -02 21 108 #####################
;  4. +01 15 123 ###############
;  5. +02 14 137 ##############
;  6. -07 11 148 ###########
;  7. -03 11 159 ###########
;  8. +05  6 165 ######
;  9. -04  5 170 #####
; 10. +03  5 175 #####
; 11. +04  3 178 ###
; 12. -10  2 180 ##
; 13. -09  2 182 ##
; 14. -05  2 184 ##
; 15. -35  1 185 #
; 16. -21  1 186 #
; 17. -14  1 187 #
; 18. -12  1 188 #
; 19. -06  1 189 #
; 20. +41  1 190 #
; 21. +29  1 191 #
; 22. +27  1 192 #
; 23. +24  1 193 #
; 24. +18  1 194 #
; 25. +17  1 195 #
; 26. +12  1 196 #
; 27. +10  1 197 #
```

55%: 2-bit

45%: 7-bit

Compression: raw-diff-5 @ 3

```
;  1. =00 65  65 #################################################################
;  2. -01 22  87 ######################
;  3. -02 21 108 #####################
;  4. +01 15 123 ###############
;  5. +02 14 137 ##############
;  6. -07 11 148 ###########
;  7. -03 11 159 ###########
;  8. +05  6 165 ######
;  9. -04  5 170 #####
; 10. +03  5 175 #####
; 11. +04  3 178 ###
; 12. -10  2 180 ##
; 13. -09  2 182 ##
; 14. -05  2 184 ##
; 15. -35  1 185 #
; 16. -21  1 186 #
; 17. -14  1 187 #
; 18. -12  1 188 #
; 19. -06  1 189 #
; 20. +41  1 190 #
; 21. +29  1 191 #
; 22. +27  1 192 #
; 23. +24  1 193 #
; 24. +18  1 194 #
; 25. +17  1 195 #
; 26. +12  1 196 #
; 27. +10  1 197 #
```

81%: 3-bit

19%: 7-bit

Compression: raw-diff-5 @ 4

```
;  1. =00 65  65 #################################################################
;  2. -01 22  87 ######################
;  3. -02 21 108 #####################
;  4. +01 15 123 ###############
;  5. +02 14 137 ##############
;  6. -07 11 148 ###########
;  7. -03 11 159 ###########
;  8. +05  6 165 ######
;  9. -04  5 170 #####
; 10. +03  5 175 #####
; 11. +04  3 178 ###
; 12. -10  2 180 ##
; 13. -09  2 182 ##
; 14. -05  2 184 ##
; 15. -35  1 185 #
; 16. -21  1 186 #
; 17. -14  1 187 #
; 18. -12  1 188 #
; 19. -06  1 189 #
; 20. +41  1 190 #
; 21. +29  1 191 #
; 22. +27  1 192 #
; 23. +24  1 193 #
; 24. +18  1 194 #
; 25. +17  1 195 #
; 26. +12  1 196 #
; 27. +10  1 197 #
```

94%: 4-bit

6%: 8-bit

Compression: nutab

No Uncompressed Table

Compression: nutab

No Uncompressed Table:

- High number of values – large table

Compression: nutab

No Uncompressed Table:

- High number of values – large table
- Low utilization of the table (usually 1 note)

Compression: nutab

No Uncompressed Table:

- High number of values – large table
- Low utilization of the table (usually 1 note)
- Range of minimum and maximum value is not much bigger than table size

Compression: nutab

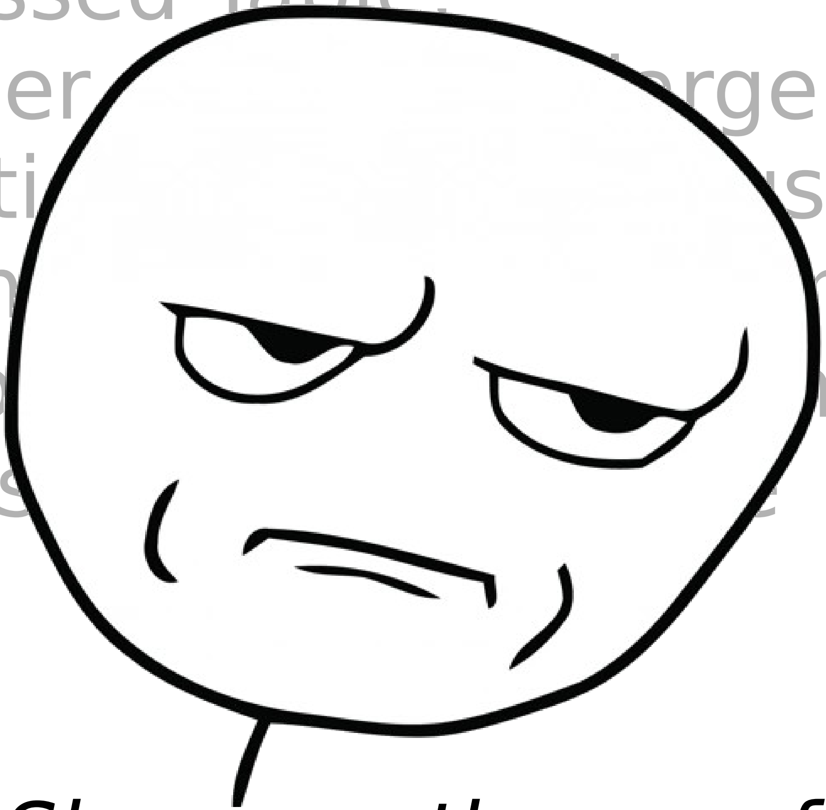
No Uncompressed Table:

- High number of values – large table
- Low utilization of the table (usually 1 note)
- Range of minimum and maximum value is not much bigger than table size
- Table needs some extra code

Compression: nutab

No Uncompressed Table:

- High number arge table
- Low utilizati usually 1 note)
- Range of m num
  value is no table size
- Table needs e



Show me the proof!
I need evidence

Compression: nutab

split	*table*	*value range*	*bits per item*	*storage + table*	*ucomp total*
raw-diff-5 @ 2	yes	24	5	77 + 24	101
	nutab	76	7	100	100
raw-diff-5 @ 3	yes	20	5	38 + 20	58
	nutab	76	7	47	47
raw-diff-5 @ 4	yes	12	4	12 + 12	24
	nutab	62	6	15	15

Compression: nutab

split	table	value range	bits per item	storage + table	ucomp total
raw-diff-5 @ 2	yes	24	5	77 + 24	101
	nutab	76	7	100	100
raw-diff-5 @ 3	yes	20	5	38 + 20	58
	nutab	76	7	47	47
raw-diff-5 @ 4	yes	12	4	12 + 12	24
	nutab	62	6	15	[illegible]

Okay.

Compression: nctab

No Compressed Table

Compression: nctab

No Compressed Table:

- Top values are almost continous

Compression: nctab

No Compressed Table:

- Top values are almost continous
- Swap values for continous range

Compression: nctab

No Compressed Table:

- Top values are almost continous
- Swap values for continous range
- Small compromise for eliminating Compressed Table

Compression: nctab

```
;  1. =00 65  65 #################################################################
;  2. -01 22  87 ######################
;  3. -02 21 108 #####################
;  4. +01 15 123 ###############
;  5. +02 14 137 ##############
;  6. -07 11 148 ###########
;  7. -03 11 159 ###########
;  8. +05  6 165 ######
;  9. -04  5 170 #####
; 10. +03  5 175 #####
; 11. +04  3 178 ###
; 12. -10  2 180 ##
; 13. -09  2 182 ##
; 14. -05  2 184 ##
; 15. -35  1 185 #
```

```
Swap  -07: 11 notes
With  +03:  5 notes
```

Compression: nctab

```
;  1. =00 65  65 #################################################################
;  2. -01 22  87 ######################
;  3. -02 21 108 #####################
;  4. +01 15 123 ###############
;  5. +02 14 137 ##############
; 10. +03  5 175 #####
;  7. -03 11 159 ###########
;  8. +05  6 165 ######
;  9. -04  5 170 #####
;  6. -07 11 148 ###########
; 11. +04  3 178 ###
; 12. -10  2 180 ##
; 13. -09  2 182 ##
; 14. -05  2 184 ##
; 15. -35  1 185 #
```

```
Swap  -07: 11 notes
With  +03:  5 notes
```

Compression: nctab

```
;  1. =00 65  65 #################################################################
;  2. -01 22  87 ######################
;  3. -02 21 108 #####################
;  4. +01 15 123 ###############
;  5. +02 14 137 ##############
; 10. +03  5 175 #####
;  7. -03 11 159 ###########
;  8. +05  6 165 ######
;  9. -04  5 170 #####
;  6. -07 11 148 ###########
; 11. +04  3 178 ###
; 12. -10  2 180 ##
; 13. -09  2 182 ##
; 14. -05  2 184 ##
; 15. -35  1 185 #
```

Top notes: -03..+03

Compression: select method

Compression: select method

note	*diff*	*compressed word size*	*compressed table*	*uncompressed table*
raw- mapped-	diff-1 diff-2 diff-3 diff-4 diff-5 diff-6 diff-7 diff-8 diff-mixed/1/5	@ 2 @ 3 @ 4 @ 6	yes nctab	yes nutab

2 * 9 * 4 * 2 * 2 = **288** variations

Compression: select method

Select compression method:

- Create estimation for all the 288 variations

Compression: select method

Select compression method:

- Create estimation for all the 288 variations
- Accurate estimation of data and table sizes

Compression: select method

Select compression method:

- Create estimation for all the 288 variations
- Accurate estimation of data and table sizes
- Can't calculate required code size

Compression: select method

Select compression method:

- Create estimation for all the 288 variations
- Accurate estimation of data and table sizes
- Can't calculate required code size

Challenge accepted.

Compression: compare methods

Compression: compare methods

```
; ---- estimation for raw-diff-5 @ 3 nutab ------
```

Compression: compare methods

```
; ---- estimation for raw-diff-5 @ 3 nutab ------
```

This is the estimation for:

- diff from 5 notes behind

Compression: compare methods

```
; ---- estimation for raw-diff-5 @ 3 nutab ------
```

This is the estimation for:

- diff from 5 notes behind
- compressed word size is 3-bit

Compression: compare methods

```
; ---- estimation for raw-diff-5 @ 3 nutab ------
```

This is the estimation for:

- diff from 5 notes behind
- compressed word size is 3-bit
- use table for compressed values

  (not mentioned)

Compression: compare methods

```
; ---- estimation for raw-diff-5 @ 3 nutab ------
```

This is the estimation for:

- diff from 5 notes behind
- compressed word size is 3-bit
- use table for compressed values
- no table for uncompressed values

Compression: compare methods

```
; ---- estimation for raw-diff-5 @ 3 nutab ------
;
```

Compression: compare methods

```
; ---- estimation for raw-diff-5 @ 3 nutab ------
;
; note num:      7.c   20.u   27.t
```

Compression: compare methods

```
; ---- estimation for raw-diff-5 @ 3 nutab ------
;
; note num:      7.c   20.u   27.t
```

Number of different note values:

Compression: compare methods

```
; ---- estimation for raw-diff-5 @ 3 nutab ------
;
; note num:      7.c   20.u   27.t
```

Number of different note values:

- 7 compressed (table index)

Compression: compare methods

```
; ---- estimation for raw-diff-5 @ 3 nutab ------
;
; note num:        7.c    20.u    27.t
```

Number of different note values:

- 7 compressed (table index)
- 20 uncompressed (nutab: raw pitch range)

Compression: compare methods

```
; ---- estimation for raw-diff-5 @ 3 nutab ------
;
; note num:      7.c   20.u   27.t
```

Number of different note values:

- 7 compressed (table index)
- 20 uncompressed (nutab: raw pitch range)
- 27 total

Compression: compare methods

```
; ---- estimation for raw-diff-5 @ 3 nutab ------
;
; note num:      7.c   20.u   27.t
; note count:  159.c   38.u  197.t
```

Compression: compare methods

```
; ---- estimation for raw-diff-5 @ 3 nutab ------
;
; note num:      7.c   20.u   27.t
; note count:  159.c   38.u  197.t
```

Note count (no. of occurrences):

Compression: compare methods

```
; ---- estimation for raw-diff-5 @ 3 nutab ------
;
; note num:      7.c   20.u   27.t
; note count:  159.c   38.u  197.t
```

Note count (no. of occurrences):

- 159 compressed

Compression: compare methods

```
; ---- estimation for raw-diff-5 @ 3 nutab ------
;
; note num:      7.c   20.u   27.t
; note count:  159.c   38.u  197.t
```

Note count (no. of occurrences):

- 159 compressed
- 38 uncompressed

Compression: compare methods

```
; ---- estimation for raw-diff-5 @ 3 nutab ------
;
; note num:      7.c   20.u   27.t
; note count:  159.c   38.u  197.t
```

Note count (no. of occurrences):

- 159 compressed
- 38 uncompressed
- 197 total

Compression: compare methods

```
; ---- estimation for raw-diff-5 @ 3 nutab ------
;
; note num:       7.c   20.u   27.t
; note count:   159.c   38.u  197.t
; note bits:      3.c   10.u
```

Compression: compare methods

```
; ---- estimation for raw-diff-5 @ 3 nutab ------
;
; note num:        7.c   20.u   27.t
; note count:    159.c   38.u  197.t
; note bits:       3.c   10.u
```

Storage needed by one note:

Compression: compare methods

```
; ---- estimation for raw-diff-5 @ 3 nutab ------
;
; note num:        7.c   20.u   27.t
; note count:  159.c   38.u  197.t
; note bits:       3.c   10.u
```

Storage needed by one note:

- 3 bits for compressed

Compression: compare methods

```
; ---- estimation for raw-diff-5 @ 3 nutab ------
;
; note num:       7.c   20.u   27.t
; note count:   159.c   38.u  197.t
; note bits:      3.c   10.u
```

Storage needed by one note:

- 3 bits for compressed
- 10 bits for uncompressed (spec: 3 + data: 7)

Compression: compare methods

```
; ---- estimation for raw-diff-5 @ 3 nutab ------
;
; note num:      7.c   20.u   27.t
; note count:  159.c   38.u  197.t
; note bits:     3.c   10.u
; storage:      59.c   47.u  107.t
```

Compression: compare methods

```
; ---- estimation for raw-diff-5 @ 3 nutab ------
;
; note num:      7.c   20.u   27.t
; note count:  159.c   38.u  197.t
; note bits:     3.c   10.u
; storage:      59.c   47.u  107.t
```

Storage needed for song data:

Compression: compare methods

```
; ---- estimation for raw-diff-5 @ 3 nutab ------
;
; note num:      7.c   20.u   27.t
; note count:  159.c   38.u  197.t
; note bits:     3.c   10.u
; storage:      59.c   47.u  107.t
```

Storage needed for song data:

- 59 bytes for compressed

Compression: compare methods

```
; ---- estimation for raw-diff-5 @ 3 nutab ------
;
; note num:      7.c   20.u   27.t
; note count:  159.c   38.u  197.t
; note bits:     3.c   10.u
; storage:      59.c   47.u  107.t
```

Storage needed for song data:

- 59 bytes for compressed
- 47 bytes for uncompressed

Compression: compare methods

```
; ---- estimation for raw-diff-5 @ 3 nutab ------
;
; note num:      7.c   20.u   27.t
; note count:  159.c   38.u  197.t
; note bits:     3.c   10.u
; storage:      59.c   47.u  107.t
```

Storage needed for song data:

- 59 bytes for compressed
- 47 bytes for uncompressed
- 107 bytes total

Compression: compare methods

```
; note num:      7.c   20.u   27.t
; note count:  159.c   38.u  197.t
; note bits:     3.c   10.u
; storage:      59.c   47.u  107.t
; table:         7.c    0.u    7.t
```

Compression: compare methods

```
; note num:        7.c   20.u   27.t
; note count:  159.c   38.u  197.t
; note bits:       3.c   10.u
; storage:        59.c   47.u  107.t
; table:           7.c    0.u    7.t
```

Storage needed for tables:

Compression: compare methods

```
; note num:      7.c   20.u   27.t
; note count:  159.c   38.u  197.t
; note bits:     3.c   10.u
; storage:      59.c   47.u  107.t
; table:         7.c    0.u    7.t
```

Storage needed for tables:

- 7 bytes for compressed

Compression: compare methods

```
; note num:         7.c   20.u   27.t
; note count:     159.c   38.u  197.t
; note bits:        3.c   10.u
; storage:         59.c   47.u  107.t
; table:            7.c    0.u    7.t
```

Storage needed for tables:

- 7 bytes for compressed
- none for uncompressed (nutab)

Compression: compare methods

```
; note num:        7.c   20.u   27.t
; note count:    159.c   38.u  197.t
; note bits:       3.c   10.u
; storage:        59.c   47.u  107.t
; table:           7.c    0.u    7.t
```

Storage needed for tables:

- 7 bytes for compressed
- none for uncompressed (nutab)
- 7 bytes total

Compression: compare methods

```
; ---- estimation for raw-diff-5 @ 3 nutab ------
;
; note num:        7.c   20.u   27.t
; note count:    159.c   38.u  197.t
; note bits:       3.c   10.u
; storage:        59.c   47.u  107.t
; table:           7.c    0.u    7.t
; total bytes (storage + leading + table): 120
```

Total storage required:

Compression: compare methods

```
; ---- estimation for raw-diff-5 @ 3 nutab ------
;
; note num:      7.c   20.u   27.t
; note count:  159.c   38.u  197.t
; note bits:     3.c   10.u
; storage:      59.c   47.u  107.t
; table:         7.c    0.u    7.t
; total bytes (storage + leading + table): 120
```

Total storage required: 107

Compression: compare methods

```
; ---- estimation for raw-diff-5 @ 3 nutab ------
;
; note num:      7.c   20.u   27.t
; note count:  159.c   38.u  197.t
; note bits:     3.c   10.u
; storage:      59.c   47.u  107.t
; table:         7.c    0.u    7.t
; total bytes (storage + leading + table): 120
```

Total storage required: 107 + 5

Compression: compare methods

```
; ---- estimation for raw-diff-5 @ 3 nutab ------
;
; note num:      7.c   20.u   27.t
; note count:  159.c   38.u  197.t
; note bits:     3.c   10.u
; storage:      59.c   47.u  107.t
; table:         7.c    0.u    7.t
; total bytes (storage + leading + table): 120
```

Total storage required: 107 + 5 + 7

Compression: compare methods

```
; ---- estimation for raw-diff-5 @ 3 nutab ------
;
; note num:      7.c   20.u   27.t
; note count:  159.c   38.u  197.t
; note bits:     3.c   10.u
; storage:      59.c   47.u  107.t
; table:         7.c    0.u    7.t
; total bytes (storage + leading + table): 120
```

Total storage required: 107 + 5 + 7 = **120** bytes

Compression: compare methods

We have histogram,
estimation and
data generator
for all the

288

variations

Compression: compare methods

The winner is...

Compression: compare methods

```
;       raw-diff-mixed/1/5 @ 4 nctab nutab  =  114
;             raw-diff-mixed/1/5 @ 3 nutab  =  117
;               raw-diff-5 @ 3 nctab nutab  =  118
;               raw-diff-5 @ 4 nctab nutab  =  118
;                     raw-diff-5 @ 3 nutab  =  120
;             raw-diff-mixed/1/5 @ 4 nctab  =  122
;             raw-diff-mixed/1/5 @ 4 nutab  =  124
;                     raw-diff-1 @ 3 nutab  =  125
;                     raw-diff-5 @ 4 nctab  =  126
;                     raw-diff-1 @ 2 nutab  =  127
;                     raw-diff-5 @ 3 nctab  =  127
;             raw-diff-mixed/1/5 @ 2 nutab  =  127
;                     raw-diff-5 @ 4 nutab  =  128
```

Compression: compare methods

```
;       raw-diff-mixed/1/5 @ 4 nctab nutab  =  114
;             raw-diff-mixed/1/5 @ 3 nutab  =  117
;               raw-diff-5 @ 3 nctab nutab  =  118
;               raw-diff-5 @ 4 nctab nutab  =  118
;                     raw-diff-5 @ 3 nutab  =  120
;             raw-diff-mixed/1/5 @ 4 nctab  =  122
;             raw-diff-mixed/1/5 @ 4 nutab  =  124
                        (...)
;                        mapped-diff-5 @ 3  =  160
;                mapped-diff-mixed/1/5 @ 4  =  160
;                           raw-diff-1 @ 5  =  161
```

Compression: compare methods

```
;       raw-diff-mixed/1/5 @ 4 nctab nutab   =  114
;             raw-diff-mixed/1/5 @ 3 nutab   =  117
;               raw-diff-5 @ 3 nctab nutab   =  118
;               raw-diff-5 @ 4 nctab nutab   =  118
;                     raw-diff-5 @ 3 nutab   =  120
;             raw-diff-mixed/1/5 @ 4 nctab   =  122
;             raw-diff-mixed/1/5 @ 4 nutab   =  124
                        (...)
;                        mapped-dif
;                mapped-diff-mixed/
;                           raw-dif
```

Creating data (raw-diff-5 @ 3 nctab nutab)

Creating data (raw-diff-5 @ 3 nctab nutab)

```
;  1. =00 65  65 #################################################################
;  2. -01 22  87 ######################
;  3. -02 21 108 #####################
;  4. +01 15 123 ###############
;  5. +02 14 137 ##############
; 10. +03  5 175 #####
;  7. -03 11 159 ###########
;  8. +05  6 165 ######
;  9. -04  5 170 #####
;  6. -07 11 148 ###########
; 11. +04  3 178 ###
; 12. -10  2 180 ##
; 13. -09  2 182 ##
; 14. -05  2 184 ##
; 15. -35  1 185 #
```

Top notes: -03..+03

remember...

Creating data (raw-diff-5 @ 3 nctab nutab)

```
cSub = 4
uSub = 42
spec = 0   # -4 + cSub

for i in range(0,len(self.notes)):
   note = self.notes[i]
   diff = note.get(”raw-diff-5”)

   if diff in (-3,-2,-1,0,1,2,3):
      self.renderDataBits(3,diff + cSub)
   else:
      self.renderDataBits(3,spec)
      self.renderDataBits(7,diff + uSub)
```

Creating data (raw-diff-5 @ 3 nctab nutab)

```
cSub = 4
uSub = 42
spec = 0   # -4 + cSub

for i in range(0,len(self.notes)):
   note = self.notes[i]
   diff = note.get(”raw-diff-5”)

   if diff in (-3,-2,-1,0,1,2,3):
      self.renderDataBits(3,diff + cSub)
   else:
      self.renderDataBits(3,spec)
      self.renderDataBits(7,diff + uSub)
```

Creating data (raw-diff-5 @ 3 nctab nutab)

compressed

```
cSub = 4
uSub = 42
spec = 0   # -4 + cSub

for i in range(0,len(self.notes)):
   note = self.notes[i]
   diff = note.get(”raw-diff-5”)

   if diff in (-3,-2,-1,0,1,2,3):
      self.renderDataBits(3,diff + cSub)
   else:
      self.renderDataBits(3,spec)
      self.renderDataBits(7,diff + uSub)
```

Creating data (raw-diff-5 @ 3 nctab nutab)

uncompressed

```
cSub = 4
uSub = 42
spec = 0   # -4 + cSub

for i in range(0,len(self.notes)):
   note = self.notes[i]
   diff = note.get(”raw-diff-5”)

   if diff in (-3,-2,-1,0,1,2,3):
      self.renderDataBits(3,diff + cSub)
   else:
      self.renderDataBits(3,spec)
      self.renderDataBits(7,diff + uSub)
```

Creating data (raw-diff-5 @ 3 nctab nutab)

The final data

```
; value to substract from compressed data
       DATA_CSUB = 4

; value to substract from uncompressed data
       DATA_USUB = 42

data_notes: ; bit packed note data

       db $92,$49,$16,$d5,$c5,$25,$d1,$39
       db $30,$5c,$17,$c4,$42,$30,$8d,$ca
       db $17,$85,$f1,$10,$8c,$23,$52,$48
       db $11,$94,$e0,$5f,$a5,$71,$e9,$93
       db $5a,$c7,$02,$62,$da,$d6,$22,$11
       db $84,$6a,$49,$02,$32,$9c,$0b,$f4
       db $ae,$7f,$20,$46,$9c,$94,$25,$92
       db $60,$bf,$44,$e0,$4c,$e4,$72,$e8
       db $a4,$b2,$47,$25,$d6,$ca,$a5,$8a
       db $45,$24,$70,$23,$51,$b9,$13,$09
       db $84,$70,$d8,$2e,$e4,$1e,$21,$30
       db $40,$13,$10,$54,$24,$0e,$c3,$c1
       db $08,$53,$11,$42,$ee,$42,$02,$10
       db $84,$21,$18,$4a,$03,$83,$8f,$86
       db $95
```

Creating data (raw-diff-5 @ 3 nctab nutab)

The final* data

```
; value to substract from compressed data
       DATA_CSUB = 4

; value to substract from uncompressed data
       DATA_USUB = 42

data_notes: ; bit packed note data

       db $92,$49,$16,$d5,$c5,$25,$d1,$39
       db $30,$5c,$17,$c4,$42,$30,$8d,$ca
       db $17,$85,$f1,$10,$8c,$23,$52,$48
       db $11,$94,$e0,$5f,$a5,$71,$e9,$93
       db $5a,$c7,$02,$62,$da,$d6,$22,$11
       db $84,$6a,$49,$02,$32,$9c,$0b,$f4
       db $ae,$7f,$20,$46,$9c,$94,$25,$92
       db $60,$bf,$44,$e0,$4c,$e4,$72,$e8
       db $a4,$b2,$47,$25,$d6,$ca,$a5,$8a
       db $45,$24,$70,$23,$51,$b9,$13,$09
       db $84,$70,$d8,$2e,$e4,$1e,$21,$30
       db $40,$13,$10,$54,$24,$0e,$c3,$c1
       db $08,$53,$11,$42,$ee,$42,$02,$10
       db $84,$21,$18,$4a,$03,$83,$8f,$86
       db $95
```

* not

Decoding data (raw-diff-5 @ 3 nctab nutab)

Decoding data (raw-diff-5 @ 3 nctab nutab)

```
db $92,$49,$16,$d5,$c5,$25,$d1,$39
db $30,$5c,$17,$c4,$42,$30,$8d,$ca
```

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
```

Decoding data (raw-diff-5 @ 3 nctab nutab)

$92 $49 $16 $d5

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
```

Decoding data (raw-diff-5 @ 3 nctab nutab)

$92 $49 $16 $d5

84218421 84218421 84218421 84218421

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
```

Decoding data (raw-diff-5 @ 3 nctab nutab)

```
    $92       $49       $16       $d5
 84218421  84218421  84218421  84218421
%10010010
```

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
```

Decoding data (raw-diff-5 @ 3 nctab nutab)

```
   $92        $49        $16        $d5
 84218421   84218421   84218421   84218421
%10010010 %01001001
```

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
```

Decoding data (raw-diff-5 @ 3 nctab nutab)

$92	$49	$16	$d5
84218421	84218421	84218421	84218421
%10010010	%01001001	%00010110	

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
```

Decoding data (raw-diff-5 @ 3 nctab nutab)

$92	$49	$16	$d5
84218421	84218421	84218421	84218421
%10010010	%01001001	%00010110	%11010101

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
```

Decoding data (raw-diff-5 @ 3 nctab nutab)

```
    $92        $49        $16        $d5
 84218421   84218421   84218421   84218421
%10010010  %01001001  %00010110  %11010101
 ###########
   4
```

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
```

Decoding data (raw-diff-5 @ 3 nctab nutab)

```
    $92          $49          $16          $d5
 84218421     84218421     84218421     84218421
%10010010    %01001001    %00010110    %11010101
 ########### ##########
   4     4
```

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
```

Decoding data (raw-diff-5 @ 3 nctab nutab)

```
   $92        $49        $16        $d5
 84218421   84218421   84218421   84218421
%10010010  %01001001  %00010110  %11010101
 ########### ########## ###################
     4         4           4
```

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
```

Decoding data (raw-diff-5 @ 3 nctab nutab)

```
     $92        $49        $16        $d5
  84218421   84218421   84218421   84218421
 %10010010  %01001001  %00010110  %11010101
  ########### ########## ################### ##########
     4    4       4       4
```

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
```

Decoding data (raw-diff-5 @ 3 nctab nutab)

```
     $92         $49         $16         $d5

  84218421    84218421    84218421    84218421
%10010010   %01001001   %00010110   %11010101
 ########### ########## ################### ########## ###########
     4          4            4              4          4
```

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
```

Decoding data (raw-diff-5 @ 3 nctab nutab)

```
   $92        $49        $16        $d5
 84218421   84218421   84218421   84218421
%10010010  %01001001  %00010110  %11010101
 ########### ##########  ################### ########## ###########
     4          4            4            4        4
```

CSUB=4

USUB=42

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
```

Decoding data (raw-diff-5 @ 3 nctab nutab)

```
   $92        $49        $16        $d5
 84218421   84218421   84218421   84218421
%10010010  %01001001  %00010110  %11010101
 ########### ##########  ################### ########## ###########
     4          4           4           4          4
     0          0           0           0          0
```

CSUB=4

USUB=42

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
```

Decoding data (raw-diff-5 @ 3 nctab nutab)

```
   $92        $49        $16        $d5
 84218421   84218421   84218421   84218421
%10010010 %01001001 %00010110 %11010101
 ########### ##########  ################### ########## ###########
     4          4             4             4          4
     0          0             0             0          0
```

CSUB=4
USUB=42

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
```

Decoding data (raw-diff-5 @ 3 nctab nutab)

```
     $92            $49             $16             $d5

  84218421       84218421        84218421        84218421
%10010010      %01001001       %00010110       %11010101
########### ##########  ################### ########## ########### ###################
   4     4        4        4     4
   0     0        0        0     0
```

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
```

Decoding data (raw-diff-5 @ 3 nctab nutab)

```
    $92      $49       $16       $d5
 84218421  84218421  84218421  84218421
%10010010 %01001001 %00010110 %11010101
########### ########## ################### ########## ########### ###################
  4  4   4   4  4   4
  0  0   0   0  0
```

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
```

Decoding data (raw-diff-5 @ 3 nctab nutab)

```
    $92         $49         $16         $d5
  84218421    84218421    84218421    84218421
%10010010 %01001001 %00010110 %11010101
 ########### ##########  ################### ########## ########### ###################
   4    4       4      4    4      4
   0    0       0      0    0      0
```

CSUB=4
USUB=42

c-3:60:/00	e-3:64:/00	g-3:67:/00	c-4:72:/00	e-4:76:/00
c-3:60:=00	d-3:62:-02	a-3:69:+02	d-4:74:+02	f-4:77:+01
h-2:59:-01	d-3:62:=00	g-3:67:-02	d-4:74:=00	f-4:77:=00
c-3:60:+01	e-3:64:+02	g-3:67:=00	c-4:72:-02	e-4:76:-01

Decoding data (raw-diff-5 @ 3 nctab nutab)

```
      $92             $49             $16             $d5
   84218421        84218421        84218421        84218421
 %10010010       %01001001       %00010110       %11010101
  ########### ##########  ################### ########## ########### ###################
     4           4           4           4           4           4
     0           0           0           0           0           0
```

c-3:60:/00	e-3:64:/00	g-3:67:/00	c-4:72:/00	e-4:76:/00
c-3:60:=00	d-3:62:-02	a-3:69:+02	d-4:74:+02	f-4:77:+01
h-2:59:-01	d-3:62:=00	g-3:67:-02	d-4:74:=00	f-4:77:=00
c-3:60:+01	e-3:64:+02	g-3:67:=00	c-4:72:-02	e-4:76:-01

Decoding data (raw-diff-5 @ 3 nctab nutab)

```
      $92        $49        $16        $d5
  84218421   84218421   84218421   84218421
%10010010  %01001001  %00010110  %11010101
 ########### ##########  ################### ########## ########### ################### ############
   4   4    4    4   4    4
   0   0    0    0   0    0
```

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
```

Decoding data (raw-diff-5 @ 3 nctab nutab)

```
      $92             $49             $16             $d5
   84218421        84218421        84218421        84218421
 %10010010       %01001001       %00010110       %11010101
  ########### ##########  ################### ########## ########### ################### ############
     4     4       4       4     4       4      2
     0     0       0       0     0       0
```

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
```

Decoding data (raw-diff-5 @ 3 nctab nutab)

```
    $92         $49         $16         $d5
  84218421    84218421    84218421    84218421
%10010010 %01001001 %00010110 %11010101
 ########### ########## ################### ########## ########### ################### ############
   4     4       4       4     4       4     2
   0     0       0       0     0       0    -2
```

CSUB=4
USUB=42

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
```

Decoding data (raw-diff-5 @ 3 nctab nutab)

```
    $92          $49          $16          $d5
  84218421     84218421     84218421     84218421
%10010010    %01001001    %00010110    %11010101
 ########### ##########  ################### ########## ########### ################### ###########
     4         4             4              4     4          4          2
     0         0             0              0     0          0         -2
```

CSUB=4
USUB=42

c-3:60:/00	e-3:64:/00	g-3:67:/00	c-4:72:/00	e-4:76:/00
c-3:60:=00	d-3:62:-02	a-3:69:+02	d-4:74:+02	f-4:77:+01
h-2:59:-01	d-3:62:=00	g-3:67:-02	d-4:74:=00	f-4:77:=00
c-3:60:+01	e-3:64:+02	g-3:67:=00	c-4:72:-02	e-4:76:-01

Decoding data (raw-diff-5 @ 3 nctab nutab)

```
      $92          $49          $16          $d5

   84218421     84218421     84218421     84218421
 %10010010    %01001001    %00010110    %11010101
  ########### ##########  ################### ########## ########### ################### ############
   4   4    4    4   4    4    2
   0   0    0    0   0    0   -2
```

c-3:60:/00	e-3:64:/00	g-3:67:/00	c-4:72:/00	e-4:76:/00
c-3:60:=00	d-3:62:-02	a-3:69:+02	d-4:74:+02	f-4:77:+01
h-2:59:-01	d-3:62:=00	g-3:67:-02	d-4:74:=00	f-4:77:=00
c-3:60:+01	e-3:64:+02	g-3:67:=00	c-4:72:-02	e-4:76:-01

Decoding data (raw-diff-5 @ 3 nctab nutab)

```
     $92         $49         $16         $d5

  84218421    84218421    84218421    84218421
%10010010 %01001001 %00010110 %11010101
########### ##########  ################### ########## ########### ################### ############ ##########
    4     4       4       4     4       4       2
    0     0       0       0     0       0      -2
```

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
```

Decoding data (raw-diff-5 @ 3 nctab nutab)

```
    $92       $49       $16       $d5
 84218421  84218421  84218421  84218421
%10010010 %01001001 %00010110 %11010101
 ########### ########## ################### ########## ########### ################### ############ ##########
  4  4   4   4  4   4   2  6
  0  0   0   0  0   0  -2
```

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
```

Decoding data (raw-diff-5 @ 3 nctab nutab)

```
       $92                $49                $16                $d5

   84218421           84218421           84218421           84218421
 %10010010          %01001001          %00010110          %11010101
   ########### ##########  ################### ########## ########### ################### ############ ##########
      4     4         4        4     4        4     2    6
      0     0         0        0     0        0    -2    2
```

CSUB=4
USUB=42

c-3:60:/00	e-3:64:/00	g-3:67:/00	c-4:72:/00	e-4:76:/00
c-3:60:=00	d-3:62:-02	a-3:69:+02	d-4:74:+02	f-4:77:+01
h-2:59:-01	d-3:62:=00	g-3:67:-02	d-4:74:=00	f-4:77:=00
c-3:60:+01	e-3:64:+02	g-3:67:=00	c-4:72:-02	e-4:76:-01

Decoding data (raw-diff-5 @ 3 nctab nutab)

```
     $92        $49        $16        $d5
   84218421   84218421   84218421   84218421
 %10010010  %01001001  %00010110  %11010101
  ########### ##########  ################### ########## ########### ################### ############ ##########
  4     4       4       4     4       4       2    6
  0     0       0       0     0       0      -2    2
```

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
```

Decoding data (raw-diff-5 @ 3 nctab nutab)

```
     $92       $49       $16       $d5

  84218421  84218421  84218421  84218421
%10010010 %01001001 %00010110 %11010101
 ########### ########## ################### ########## ########### ################### ############ ##########   ###########
   4   4       4       4   4       4       2   6         6
   0   0       0       0   0       0      -2   2         2
```

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
```

Decoding data (raw-diff-5 @ 3 nctab nutab)

```
     $92           $49           $16           $d5

  84218421      84218421      84218421      84218421
 %10010010     %01001001     %00010110     %11010101
  ########### ##########  #################### ########## ########### #################### ############ ##########   ###########
   4     4       4      4     4     4     2    6     6
   0     0       0      0     0     0    -2    2     2
```

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
```

Decoding data (raw-diff-5 @ 3 nctab nutab)

```
      $92              $49              $16              $d5

   84218421         84218421         84218421         84218421
 %10010010        %01001001        %00010110        %11010101
   ########### ########## ################### ########## ########### ################### ############ ##########      ########### ##########
   4    4     4     4    4     4     2    6          6    5
   0    0     0     0    0     0    -2    2          2    1
```

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
```

Decoding data (raw-diff-5 @ 3 nctab nutab)

```
      $92             $49             $16             $d5

  84218421        84218421        84218421        84218421
 %10010010       %01001001       %00010110       %11010101
  ########### ##########  ################### ########## ########### ################### ############ ##########     ########### ##########
    4     4       4       4     4       4       2     6         6     5
    0     0       0       0     0       0      -2     2         2     1
```

```
c-3:60:/00  e-3:64:/00  g-3:67:/00  c-4:72:/00  e-4:76:/00
c-3:60:=00  d-3:62:-02  a-3:69:+02  d-4:74:+02  f-4:77:+01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
```

Decoding data (raw-diff-5 @ 3 nctab nutab)

$92 $49 $16 $d5

```
 842                                                  421
%1001                                                 101
 ########### #                                    ####
  4
  0
```

Sorry, no uncompressed example...

```
  c-3:6                                                                 /00
  c-3:6                                                                 +01
  h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
  c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
```

Decoding data (raw-diff-5 @ 3 nctab nutab)

```
    $92        $49        $16        $d5

 842                                    421
%1001                                   101
 ########### #                      ####
  4
  0
```

Sorry, no uncompressed example...
Because it's so effective!

```
c-3:6                                                /00
c-3:6                                                +01
h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74:=00  f-4:77:=00
c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:72:-02  e-4:76:-01
```

Decoding data (raw-diff-5 @ 3 nctab nutab)

$92 $49 $16 $d5

```
 842                                                421
%1001                                               101
 ###########                                    ####
  4
  0
```

Sorry, no uncompressed example...
Because it's so effective!

```
  c-3:6
  c-3:6
  h-2:59:-01  d-3:62:=00  g-3:67:-02  d-4:74
  c-3:60:+01  e-3:64:+02  g-3:67:=00  c-4:7
```

III. Code

III. Code

Assembly code ahead!

Clean Code Decoder (raw-diff-5 @ 3 nctab nutab)

Clean Code Decoder (raw-diff-5 @ 3 nctab nutab)

How to decompress *diff* value:

Clean Code Decoder (raw-diff-5 @ 3 nctab nutab)

How to decompress *diff* value:

- not optimized yet, no sizecoding tricks

Clean Code Decoder (raw-diff-5 @ 3 nctab nutab)

How to decompress *diff* value:

- not optimized yet, no sizecoding tricks
- special code for *raw-diff-5 @ 3 nctab nutab*

Clean Code Decoder (raw-diff-5 @ 3 nctab nutab)

```
load_play_note:
    mov  bl,DATA_CSUB  ; DATA_CSUB = 4
    mov  ax,$2000      ; AL:=0, AH:=%xx10'0000: 3 SHL from zero
@next_bit:
    or   ah,ah
    jnz  @read_bit
;word_read:
    or   al,al         ; check for %000 special value
    jnz  @adjust_word
;load_uncompressed:
    mov  bl,DATA_USUB  ; 42, also a good value for bit counter
    mov  ah,bl         ; %xxxx'xx10: 7 SHL from zero
    jmp  @next_bit
@read_bit:
    or   cl,cl
    jnz  @shift_latch
;load_latch:
    inc  cx            ; INC CX for CL:=1, %xxxx'xxx1: 8 SHL from zero
    mov  ch,[bp]
    inc  bp
@shift_latch:
    sal  ax,1
    sal  cx,1
    adc  al,0
    jmp  @next_bit
@adjust_word:
    sub  al,bl
```

Clean Code Decoder (raw-diff-5 @ 3 nctab nutab)

```
load_play_note:
   mov  bl,DATA_CSUB   ; DATA_CSUB = 4
   mov   ax,$2000     ; AL:=0, AH:=%xx10'0000: 3 SHL from zero
@next_bit:
   or    ah,ah
   jnz   @read
;word_read:
   or    al,al
   jnz   @adju
;load_uncompre
   mov   bl,DA
   mov   ah,bl
   jmp   @next_bit
@read_bit:
   or    cl,cl
   jnz   @shift_latch
;load_latch:
   inc   cx            ; INC CX for CL:=1, %xxxx'xxx1: 8 SHL from zero
   mov   ch,[bp]
   inc   bp
@shift_latch:
   sal   ax,1
   sal   cx,1
   adc   al,0
   jmp   @next_bit
@adjust_word:
   sub   al,bl
```

```
word:   0    1   2   3   4   5   6   7
diff: SPEC -03 -02 -01 =00 +01 +02 +03

word - DATA_CSUB = diff
          BL
```

Clean Code Decoder (raw-diff-5 @ 3 nctab nutab)

```
;  1. =00 65  65 #################################################################
;  2. -01 22  87 ######################
;  3. -02 21 108 #####################
;  4. +01 15 123 ###############
;  5. +02 14 137 ##############
; 10. +03  5 175 #####
;  7. -03 11 159 ###########
;  8. +05  6 165 ######
;  9. -04  5 170 #####
;  6. -07 11 148 ###########
; 11. +04  3 178 ###
; 12. -10  2 180 ##
; 13. -09  2 182 ##
; 14. -05  2 184 ##
; 15. -35  1 185 #
```

Top notes: -03..+03

still remember...

Clean Code Decoder (raw-diff-5 @ 3 nctab nutab)

```
load_play_note:
   mov  bl,DATA_CSUB ; DATA_CSUB = 4
   mov   ax,$2000       ; AL:=0, AH:=%xx10'0000: 3 SHL from zero
@next_bit:
   or   ah,ah
   jnz  @read
;word_read:
   or   al,al
   jnz  @adju
;load_uncompre
   mov  bl,DA
   mov  ah,bl
   jmp  @next_bit
@read_bit:
   or   cl,cl
   jnz  @shift_latch
;load_latch:
   inc  cx            ; INC CX for CL:=1, %xxxx'xxx1: 8 SHL from zero
   mov  ch,[bp]
   inc  bp
@shift_latch:
   sal  ax,1
   sal  cx,1
   adc  al,0
   jmp  @next_bit
@adjust_word:
   sub  al,bl
```

```
word:   0    1   2   3   4   5   6   7
diff: SPEC -03 -02 -01 =00 +01 +02 +03

word - DATA_CSUB = diff
          BL
```

Clean Code Decoder (raw-diff-5 @ 3 nctab nutab)

```
load_play_note:
   mov  bl,DATA_CSUB  ; DATA_CSUB = 4
   mov  ax,$2000 ; AL:=0, AH:=%xx10'0000: 3 SHL from zero
@next_bit:
   or   ah,ah
   jnz  @read_bit
;word_read:
   or   al,al
   jnz  @adjust_wo
;load_uncompressed:
   mov  bl,DATA_USUB  ; 42, also a good value for bit counter
   mov  ah,bl         ; %xxxx'xx10: 7 SHL from zero
   jmp  @next_bit
@read_bit:
   or   cl,cl
   jnz  @shift_latch
;load_latch:
   inc  cx             ; INC CX for CL:=1, %xxxx'xxx1: 8 SHL from zero
   mov  ch,[bp]
   inc  bp
@shift_latch:
   sal  ax,1
   sal  cx,1
   adc  al,0
   jmp  @next_bit
@adjust_word:
   sub  al,bl
```

AL: result diff value, initialize
AH: shift counter, shift until zero
SHL AX: shift value and counter

Clean Code Decoder (raw-diff-5 @ 3 nctab nutab)

```
load_play_note:
    mov  bl,DATA_CSUB  ; DATA_CSUB = 4
    mov  ax,$2000      ; AL:=0, AH:=%xx10'0000: 3 SHL from zero
@next_bit:
    or   ah,ah
    jnz  @read_bit
;word_read:
    or   al,al         ;
    jnz  @adjust_word
;load_uncompressed:
    mov  bl,DATA_USUB  ; 42, also a good value for bit counter
    mov  ah,bl         ; %xxxx'xx10: 7 SHL from zero
    jmp  @next_bit
@read_bit:
    or   cl,cl
    jnz  @shift_latch
;load_latch:
    inc  cx            ; INC CX for CL:=1, %xxxx'xxx1: 8 SHL from zero
    mov  ch,[bp]
    inc  bp
@shift_latch:
    sal  ax,1
    sal  cx,1
    adc  al,0
    jmp  @next_bit
@adjust_word:
    sub  al,bl
```

AH: shift counter
If it's not zero, read next bit
If it's zero, word is read in AL

Clean Code Decoder (raw-diff-5 @ 3 nctab nutab)

```
load_play_note:
    mov   bl,DATA_CSUB   ; DATA_CSUB = 4
    mov   ax,$2000       ; AL:=0, AH:=%xx10'0000: 3 SHL from zero
@next_bit:
    or    ah,ah
    jnz  @read_bit
;word_read:
    or    al,al    ; check for %000 special value
    jnz  @adjust_word
;load_uncompressed:
    mov   bl,DATA_USUB
    mov   ah,bl          ;
    jmp   @next_bit
@read_bit:
    or    cl,cl
    jnz   @shift_latch
;load_latch:
    inc   cx            ; INC CX for CL:=1, %xxxx'xxx1: 8 SHL from zero
    mov   ch,[bp]
    inc   bp
@shift_latch:
    sal   ax,1
    sal   cx,1
    adc   al,0
    jmp   @next_bit
@adjust_word:
    sub   al,bl
```

If it's not SPEC escape (%000), the word is almost ok (later)

If it's a SPEC escape...

Clean Code Decoder (raw-diff-5 @ 3 nctab nutab)

```
load_play_note:
   mov  bl,DATA_CSUB  ; DATA_CSUB = 4

@nex

;wor
```

After SPEC: load uncompressed word

DATA_USUB transforms 1..127 data to -35..+41 diff, there's space for some optimization...

```
   jnz  @adjust_word
;load_uncompressed:
   mov  bl,DATA_USUB ; 42, also a good value for bit counter
   mov  ah,bl        ; %xxxx'xx10: 7 SHL from zero
   jmp  @next_b
@read_bit:
   or   cl,cl
   jnz  @shift_latch
;load_latch:
   inc  cx           ; INC CX for CL:=1, %xxxx'xxx1: 8 SHL from zero
   mov  ch,[bp]
   inc  bp
@shift_latch:
   sal  ax,1
   sal  cx,1
   adc  al,0
   jmp  @next_bit
@adjust_word:
   sub  al,bl
```

...it works as shift counter as well.

Clean Code Decoder (raw-diff-5 @ 3 nctab nutab)

```
load_play_note:
    mov   bl,DATA_CSUB   ; DATA_CSUB = 4
    mov   ax,$2000       ; AL:=0, AH:=%xx10'0000: 3 SHL from zero
@next_bit:
    or    ah,ah
    jnz  @read_bit
;word_read:
    or    al,al         ;
    jnz   @adjust_word
;load_uncompressed:
    mov   bl,DATA_USUB   ; 42, also a good value for bit counter
    mov   ah,bl          ; %xxxx'xx10: 7 SHL from zero
    jmp   @next_bit
@read_bit:
    or    cl,cl
    jnz   @shift_latch
;load_latch:
    inc   cx             ; INC CX for CL:=1, %xxxx'xxx1: 8 SHL from zero
    mov   ch,[bp]
    inc   bp
@shift_latch:
    sal   ax,1
    sal   cx,1
    adc   al,0
    jmp   @next_bit
@adjust_word:
    sub   al,bl
```

Read bits again with uncompressed counter (AH) and USUB (BL) value

Clean Code Decoder (raw-diff-5 @ 3 nctab nutab)

```
load_play_note:
    mov   bl,DATA_CSUB  ; DATA_CSUB = 4
    mov   ax,$2000      ; AL:=0, AH:=%xx10'0000: 3 SHL from zero
@next_bit:
    or    ah,ah
    jnz  @read_bit
;word_read:
    or    al,al         ; check for %000 special value
    jnz   @adjust_word
;load_uncompressed:
    mov   bl,DATA_USUB  ; 42, also a good value for bit counter
    mov   ah,bl
    jmp   @next_bit
@read_bit:
    or    cl,cl
    jnz   @shift_latch
;load_latch:
    inc   cx            ; INC CX for CL:=1, %xxxx'xxx1: 8 SHL from zero
    mov   ch,[bp]
    inc   bp
@shift_latch:
    sal   ax,1
    sal   cx,1
    adc   al,0
    jmp   @next_bit
@adjust_word:
    sub   al,bl
```

CL is the latch counter. If zero, new data byte must be read.

Clean Code Decoder (raw-diff-5 @ 3 nctab nutab)

```
load_play_note:
   mov  bl,DATA_CSUB  ; DATA_CSUB = 4
   mov  ax,$2000      ; AL:=0, AH:=%xx10'0000: 3 SHL from zero
@next_bit:
   or   ah,ah
   jnz  @read_bit
;word_read:
   or   al,al         ; check for %000 special value
   jnz  @adjust_word
;load_uncompressed:
   mov  bl,DATA_USUB  ; 42, also a good value for bit counter
   mov  ah,bl         ; %xxxx'xx10: 7 SHL from zero
   jmp  @next_bit
@read_bit:
   or   cl,cl
   jnz  @shift_lat
;load_latch:
   inc  cx  ; INC CX for CL:=1, %xxxx'xxx1: 8 SHL from zero
   mov  ch,[bp]
   inc  bp
@shift_latch:
   sal  ax,1
   sal  cx,1
   adc  al,0
   jmp  @next_bit
@adjust_word:
   sub  al,bl
```

Initialize latch counter (CL)

Read next data byte to latch (CH)

Clean Code Decoder (raw-diff-5 @ 3 nctab nutab)

```
load_play_note:
    mov   bl,DATA_CSUB  ; DATA_CSUB = 4
    mov   ax,$2000      ; AL:=0, AH:=%xx10'0000: 3 SHL from zero
@next_bit:
    or    ah,ah
    jnz   @read_bit
;word_read:
    or    al,al         ; check for %000 special value
    jnz   @adjust_word
;load_uncompressed:
    mov   bl,DATA_USUB  ; 42, also a good value for bit counter
    mov   ah,bl         ; %xxxx'xx10: 7 SHL from zero
    jmp   @next_bit
@read_bit:
    or    cl,cl
    jnz   @shift_latch
;load_latch:
    inc   cx            ; INC CX for CL:=1, %xxxx'xxx1: 8 SHL from zero
    mov   ch,[bp]
    inc   bp
@shift_latch:
    sal   ax,1
    sal   cx,1
    adc   al,0
    jmp   @next_bit
@adjust_word:
    sub   al,bl
```

Shift result, low bit is to be read from latch...

Clean Code Decoder (raw-diff-5 @ 3 nctab nutab)

```
load_play_note:
    mov   bl,DATA_CSUB   ; DATA_CSUB = 4
    mov   ax,$2000       ; AL:=0, AH:=%xx10'0000: 3 SHL from zero
@next_bit:
    or    ah,ah
    jnz  @read_bit
;word_read:
    or    al,al          ; check for %000 special value
    jnz   @adjust_word
;load_uncompressed:
    mov   bl,DATA_USUB   ; 42, also a good value for bit counter
    mov   ah,bl          ; %xxxx'xx10: 7 SHL from zero
    jmp   @next_bit
@read_bit:
    or    cl,cl
    j
;load
    i
    m
    i
@shift_latch:
    sal   ax,1
    sal   cx,1
    adc   al,0
    jmp   @next_bit
@adjust_word:
    sub   al,bl
```

Shift latch counter (CL) and value (CH)

Latch value is shifted to CF, copied to AL

Clean Code Decoder (raw-diff-5 @ 3 nctab nutab)

```
load_play_note:
    mov  bl,DATA_CSUB   ; DATA_CSUB = 4
    mov  ax,$2000       ; AL:=0, AH:=%xx10'0000: 3 SHL from zero
@next_bit:
    or   ah,ah
    jnz  @read_bit
;word_read:
    or   al,al          ; check for %000 special value
    jnz  @adjust_word
;load_uncompressed:
    mov  bl,DATA_USUB   ; 42, also a good value for bit counter
    mov  ah,bl          ; %xxxx'xx10: 7 SHL from zero
    jmp  @next_bit
@read_bit:
    or   cl,cl
    jnz  @shift_latch
;load_latch:
    inc  cx             ; INC CX for CL:=1, %xxxx'xxx1: 8 SHL from zero
    mov  ch,[bp]
    inc  bp
@shift_latch:
    sal  ax,1
    sal  cx,1
    adc  al,0
    jmp  @next_bit
@adjust_word:
    sub  al,bl
```

When a word is read to AL, then CSUB or USUB (BL) must be substracted from it

Clean Code Decoder (raw-diff-5 @ 3 nctab nutab)

Player prototype with data: **228 bytes** (no repeat)

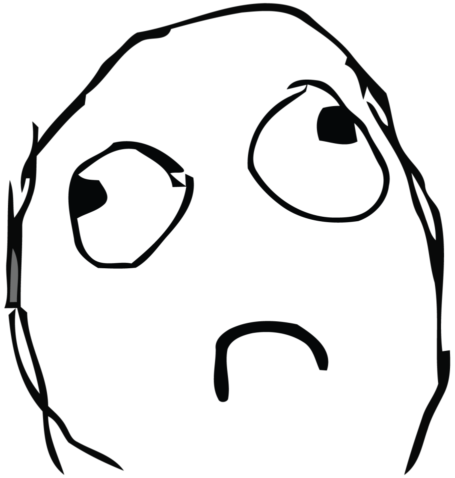
- data: 118 bytes
- playing all notes only once, not repeating
- no visual yet
- after draft implementation of repeating: 377 bytes

```
load_play_note:
@nex
;wor
;loa
    mov   ah,bl          ; %xxxx'xx10: 7 SHL from zero
    jmp   @next_bit
@read_bit:
    or    cl,cl
    jnz   @shift_latch
;load_latch:
    inc   cx             ; INC CX for CL:=1, %xxxx'xxx1: 8 SHL from zero
    mov   ch,[bp]
    inc   bp
@shift_latch:
    sal   ax,1
    sal   cx,1
    adc   al,0
    jmp   @next_bit
@adjust_word:
    sub   al,bl
```

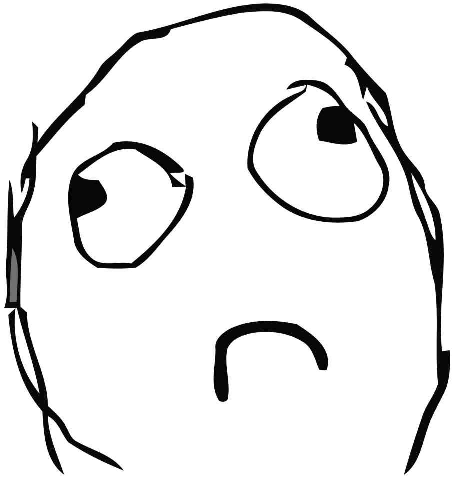
[ern0] *We are at 228 byte with repeats not implemented, no visual yet...*

[ern0] *We are at 228 byte with repeats
not implemented, no visual yet...
My concept does not work,
it's a slap in the dead end.*

[ern0] *We are at 228 byte with repeats not implemented, no visual yet...*
My concept does not work,
it's a slap in the dead end.

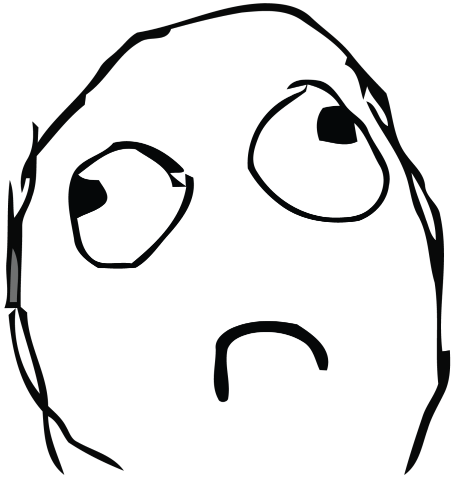


[ern0] *We are at 228 byte with repeats not implemented, no visual yet... My concept does not work, it's a slap in the dead end.*



[TomCat] *Well, let's see...*

[ern0] *We are at 228 byte with repeats not implemented, no visual yet...*
My concept does not work,
it's a slap in the dead end.



[TomCat] *Well, let's see...*

Fit into 256 bytes

Fit into 256 bytes

Fit into 256 bytes

	before	*after*
da	[illegible]	114
pla	[illegible]	[illegible]
vis	[illegible]	[illegible]
total	[illegible]	256

Fit into 256 bytes

	before	*after*
data	118	114
player	259	121
visual	0	21
total	377	256

Fit into 256 bytes

	before	*after*
data	118	114
player	259	121
visual	0	21
total	377	256

-53%

Fit into 256 bytes

Major steps of optimization:

Fit into 256 bytes

Major steps of optimization:

1. Shorter instructions

Fit into 256 bytes

1. Shorter instructions (example 1)

before (15 bytes)	*after (9 bytes)*

`push cx`
`lea  si,[data_start]`
`lea  di,[snapshot_start]`
`mov  cx,5`
`rep  movsb`
`pop  cx`
	`mov  si,data_start`
	`mov  di,snapsjot_start`
	`movsw`
	`movsw`
	`movsb`

Fit into 256 bytes

1. Shorter instructions – result:

cca. -60 bytes

Fit into 256 bytes

Major steps of optimization:

1. Shorter instructions
2. Reorganizing the code

Fit into 256 bytes

2. Reorganizing the code

Fit into 256 bytes

2. Reorganizing the code

- eliminating subroutines: remove "play_byte" and others

Fit into 256 bytes

2. Reorganizing the code

- eliminating subroutines: remove "play_byte" and others
- less CALL and RET insructions

Fit into 256 bytes

2. Reorganizing the code

- eliminating subroutines: remove "play_byte" and others
- less CALL and RET insructions
- usually only one subroutine is enough and optimal, we can reuse it's RET instruction to exit

Fit into 256 bytes

2. Reorganizing the code

- eliminating subroutines: remove "play_byte" and others
- less CALL and RET insructions
- usually only one subroutine is enough and optimal, we can reuse it's RET instruction to exit
- less jumps and conditional jumps

Fit into 256 bytes

2. Reorganizing the code – result:

cca. -40 bytes

Fit into 256 bytes

Major steps of optimization:

1. Shorter instructions
2. Reorganizing the code
3. Bitfields

Fit into 256 bytes

3. Bitfields

before	*after*

`@read_bit:`
`   (...)`
`  inc  cx`
`  mov  ch,[bp]`
`  inc  bp`
 	
`@shift_latch:`
`  sal  ax,1`
`  sal  cx,1`
`  adc  al,0`
	`@read_bit:`
	`  bt   [si-start+notes],bp`
	`  inc  bp`
	`  rcl  al,1`
	`  jnc  @read_bit`

Fit into 256 bytes

3. Bitfields – result:

cca. -20 bytes

Fit into 256 bytes

3. Bitfields – result:

cca. -20 bytes

Requires flipping the bit order of entire data

Fit into 256 bytes

Major steps of optimization:

1. Shorter instructions
2. Reorganizing the code
3. Bitfields
4. Combine play and copy

Fit into 256 bytes

4. Combine play and copy

before	*after*
pusha call eight_of_eight popa xchg si,di call eight_of_eight	sub si,3 mov cl,3+8 @three_of_eight: call play_note loop @three_of_eight
eight_of_eight: movsw movsw movsb	movsb
mov cl,3 sub si,cx @three_of_eight: lodsb call play_note loop @three_of_eight	

Fit into 256 bytes

4. Combine play and copy – result:

cca. -20 bytes

Fit into 256 bytes

Every byte has its own story:

Fit into 256 bytes

Every byte has its own story:

- Learn tricks from others - sizecoding.org

Fit into 256 bytes

The MIDI setup

before (6 byte)	*after (5 byte)*

`org  100H`
`mov  al,3fH`
`mov  dx,331H`
`out  dx,al`
	`org  100H`
	`db   3fH`
	`mov  dx,331H`
	`outsb`
	`; assume SI=100H`

3F: AAS instruction, doesn't hurt

Fit into 256 bytes

Every byte has its own story:

- Learn tricks from others - sizecoding.org
- Utilize initial register values

Fit into 256 bytes

When things go crazy – use initial register values

before (5 byte)	*after (4 byte)*

`; at startup AH=0`
`add  ah,4`
`jns  @next_line`
	`; at startup AH=0`
	`adc  ah,dh`
	`jns  @next_line`

Fit into 256 bytes

When things go crazy – use initial register values

before (5 byte)	*after (4 byte)*
; at startup AH=0 **add ah,4** **jns @next_line**	**; at startup AH=0** **adc ah,dh** **jns @next_line**

DX=0331H
(MIDI port)
DH=3

Fit into 256 bytes

When things go crazy – use initial register values

before (5 byte)	*after (4 byte)*

`; at startup AH=0`
`add  ah,4`
`jns  @next_line`
	`; at startup AH=0`
	`adc  ah,dh`
	`jns  @next_line`

with a compare instruction we can sure the carry flag is always set

Fit into 256 bytes

Every byte has its own story:

- Learn tricks from others - sizecoding.org
- Utilize initial register values
- Optimize data for decoder

Fit into 256 bytes

Optimal data for decoder (CSUB, USUB, SPEC)

before (15 byte)	*after (14 byte)*
`@load_uncompressed:`	`@load_uncompressed:`
`  mov  ax,256*DATA_USUB+2`	`  mov  ah,DATA_USUB`
`@read_bit:`	`@read_bit:`
`  bt   [si-start+notes],bp`	`  bt   [si-start+notes],bp`
`  inc  bp`	`  inc  bp`
`  rcl  al,1`	`  rcl  al,1`
`  jnc  @read_bit`	`  jnc  @read_bit`
`;word_read:`	`;word_read:`
`  test al,al; check for SPEC (0)`	`  cmp  al,2  ; check for SPEC (2)`
`  jz   @load_uncompressed`	`  je   @load_uncompressed`

Fit into 256 bytes

Optimal data for decoder (CSUB, USUB, SPEC)

before (15 byte)

```
@load_uncompressed:
  mov  ax,256*DATA_USUB+2
@read_bit:
  bt   [si-start+notes],bp
  inc  bp
  rcl  al,1
  jnc  @read_bit
;word_read:
  test al,al; check for SPEC (0)
  jz   @load_uncompressed
```

after (14 byte)

```
@load_uncompressed:
  mov  ah,DATA_USUB
@read_bit:
  bt   [si-start+notes],bp
  inc  bp
  rcl  al,1
  jnc  @read_bit
;word_read:
  cmp  al,2   ; check for SPEC (2)
  je   @load_uncompressed
```

AL=%xxxx'xx10:
7 SHL to carry

Fit into 256 bytes

Optimal data for decoder (CSUB, USUB, SPEC)

before (15 byte)

```
@load_uncompressed:
  mov  ax,256*DATA_USUB+2
@read_bit:
  bt   [si-start+notes],bp
  inc  bp
  rcl  al,1
  jnc  @read_bit
;word_read:
  test al,al; check for SPEC (0)
  jz   @load_uncompressed
```

SPEC=0 CSUB=8 USUB=42

after (14 byte)

```
@load_uncompressed:
  mov  ah,DATA_USUB
@read_bit:
  bt   [si-start+notes],bp
  inc  bp
  rcl  al,1
  jnc  @read_bit
;word_read:
  cmp  al,2   ; check for SPEC (2)
  je   @load_uncompressed
```

AL=%xxxx'xx10:
7 SHL to carry

SPEC=2 CSUB=10 USUB=58

Fit into 256 bytes

Optimal data for decoder (CSUB, USUB, SPEC)

before (15 byte)

```
@load_uncompressed:
  mov  ax,256*DATA_USUB+2
@read_bit:
  bt   [si-start+notes],bp
  inc  bp
  rcl  al,1
  jnc  @read_bit
;word_read:
  test al,al; check for SPEC (0)
  jz   @load_uncompressed
```

SPEC=0 CSUB=8 USUB=42

after (14 byte)

```
@load_uncompressed:
  mov  ah,DATA_USUB
@read_bit:
  bt   [si-start+notes],bp
  inc  bp
  rcl  al,1
  jnc  @read_bit
;word_read:
  cmp  al,2  ; check for SPEC (2)
  je   @load_uncompressed
```

SPEC=2 CSUB=10 USUB=58

AL=%xxxx'xx10:
7 SHL to carry

Fit into 256 bytes

”No such an optimized code, which couldn't be one byte shorter” *(TomCat, sizecoder)*

Fit into 256 bytes

Polling the interrupt

before	*after*

@loop_tick:
  mov si,1
  sub di,di
  es:
  rep movsw
@wait_tick:
  int 21H
  cmp bp,dx
  je   @wait_tick
  mov bp,dx
  mov ch,54H
  dec bx
  jne @loop_tick
	@loop_tick:
	  hlt
	  mov si,1
	  sub di,di
	  mov ch,54H
	  es:
	  rep movsw
	  dec bx
	  jne @loop_tick

Fit into 256 bytes

Polling the interrupt

before

```
@loop_tick:
  mov   si,1
  sub   di,di
  es:
  rep   movsw
@wait_tick:
  int   21H
  cmp   bp,dx
  je    @wait_tick
  mov   bp,dx
  mov   ch,54H
  dec   bx
  jne   @loop_tick
```

after

```
@loop_tick:
  hlt
  mov   si,1
  sub   di,di
  mov   ch,54H
  es:
  rep   movsw
  dec   bx
  jne   @loop_tick
```

Fit into 256 bytes

Polling the interrupt – result:

-8 bytes

Fit into 256 bytes

Polling the interrupt – result:

-8 bytes

3 weeks after release

248 bytes

Bugs

Bugs

Bugs

Bugs:

Bugs

Bugs:

- Dummy instruction trick to skip a branch

Bugs

Dummy instruction to skip a branch

wrong	*correct*
`  mov  ax,256*DATA_CSUB+16`	`  db   66H ; MOV EAX prefix`
`  db   38H ; CMP ?,BH`	`  mov  ax,256*DATA_CSUB+16`
`@load_uncompressed:`	`@load_uncompressed:`
`  mov  ah,DATA_USUB`	`  mov  ah,DATA_USUB`
`@read_bit:`	`@read_bit:`

Bugs

Dummy instruction to skip a branch

wrong

```
  mov   ax,256*DATA_CSUB+16
  db    38H ; CMP ?,BH
@load_uncompressed:
  mov   ah,DATA_USUB
@read_bit:
```

skip the next instruction

correct

```
  db    66H ; MOV EAX prefix
  mov   ax,256*DATA_CSUB+16
@load_uncompressed:
  mov   ah,DATA_USUB
@read_bit:
```

Bugs

Dummy instruction to skip a branch

wrong	correct
mov ax,256*DATA_CSUB+16 db 38H ; CMP ?,BH @load_uncompressed: mov ah,DATA_USUB @read_bit:	db 66H ; MOV EAX prefix mov ax,256*DATA_CSUB+16 @load_uncompressed: mov ah,DATA_USUB @read_bit:

skip the next instruction

skip the MOV AH instruction

Bugs

Bugs:

- Dummy instruction trick to skip a branch
- DOSBox timer – Windows vs MacOS

Half speed on MacOS using BIOS timer

DOS	*BIOS*

`  ; AH=2cH`
`@wait_tick:`
`  int  21H`
`  cmp  bl,dl`
`  je   @wait_tick`
	`@wait_tick:`
	`  int  1aH`
	`  cmp  bp,dx`
	`  je   @wait_tick`
	`  mov  bp,dx`

Half speed on MacOS using BIOS timer

DOS	*BIOS*
; AH=2cH @wait_tick: int 21H cmp bl,dl je @wait_tick	@wait_tick: int 1aH cmp bp,dx je @wait_tick mov bp,dx

Windows

MacOS

Bugs

Half speed on MacOS using BIOS timer

DOS	*BIOS*

`  ; AH=2cH`
`@wait_tick:`
`  int  21H`
`  cmp  bl,dl`
`  je   @wait_tick`
	`@wait_tick:`
	`  int  1aH`
	`  cmp  bp,dx`
	`  je   @wait_tick`
	`  mov  bp,dx`

✅ Windows

MacOS

Bugs

Half speed on MacOS using BIOS timer

DOS	*BIOS*

; AH=2cH
@wait_tick:
  int 21H
  cmp bl,dl
  je   @wait_tick
	@wait_tick:
	  int 1aH
	  cmp bp,dx
	  je @wait_tick
	  mov bp,dx

✅ Windows ✅

MacOS

Bugs

Half speed on MacOS using BIOS timer

DOS	*BIOS*

`  ; AH=2cH`
`@wait_tick:`
`  int  21H`
`  cmp  bl,dl`
`  je   @wait_tick`
	`@wait_tick:`
	`  int  1aH`
	`  cmp  bp,dx`
	`  je   @wait_tick`
	`  mov  bp,dx`

✅ Windows ✅

✅ MacOS

Bugs

Half speed on MacOS using BIOS timer

DOS	*BIOS*

`  ; AH=2cH`
`@wait_tick:`
`  int  21H`
`  cmp  bl,dl`
`  je   @wait_tick`
	`@wait_tick:`
	`  int  1aH`
	`  cmp  bp,dx`
	`  je   @wait_tick`
	`  mov  bp,dx`

✓	Windows	✓
✓	MacOS	✗

Bugs

Half speed on MacOS using BIOS timer

DOS

```
  ; AH=2cH
@wait_tick:
  int  21H
  cmp  bl,dl
  je   @wait_tick
```

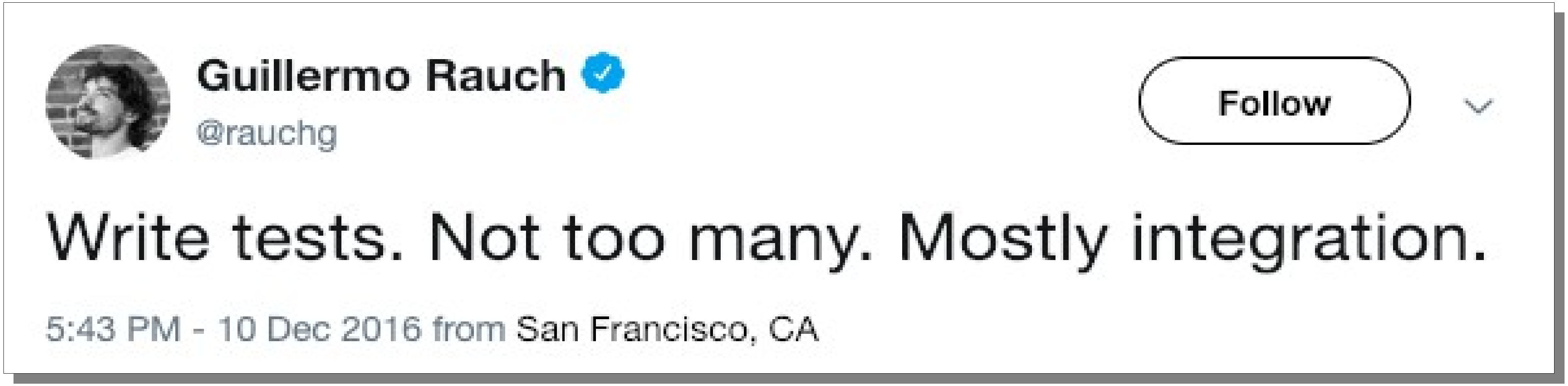
BIOS

```
   .t_tick:
    nt  1aH
    np  bp,dx
  je    @wait_tick
  mov   bp,dx
```

✓	Windows	✓
✓	MacOS	✗

Integration test

Integration test



Guillermo Rauch

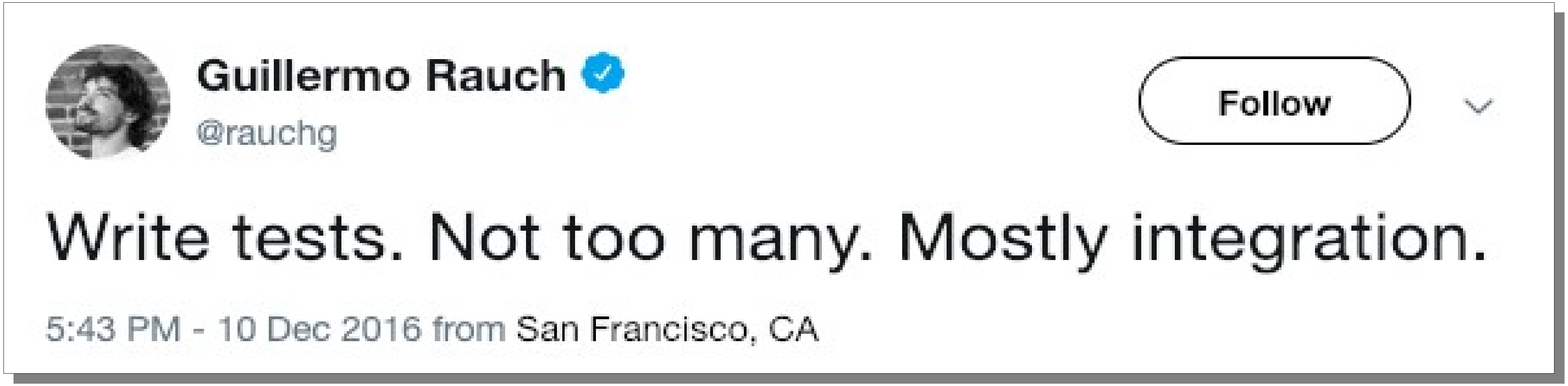
@rauchg

Follow

Write tests. Not too many. Mostly integration.

5:43 PM - 10 Dec 2016 from San Francisco, CA

Integration test



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Write tests. Not too many. Mostly integration.

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Integration test

How it works:

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- test data: 197 diff and 549 note values

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```
test_note_data:
   db 60,64,67,72,76,67,72,76
   db 60,64,67,72,76,67,72,76
   db 60,62,69,74,77,69,74,77
   db 60,62,69,74,77,69,74,77
   db 59,62,67,74,77,67,74,77
   db 59,62,67,74,77,67,74,77
   (...)

test_diff_data:
   db 0,0,0,0,0
   db 0,0,0,0,0
   db 0,-2,2,2,1
   db 0,-2,2,2,1
   db -1,0,-2,0,0
   db -1,0,-2,0,0
   (...)
```

Integration test

How it works:

- test data: 197 diff and 549 note values
- conditional compilation, on-board execution

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How it works:

- test data: 197 diff and 549 note values
- conditional compilation, on-board execution
- calls framework with diff and note values

Integration test

How it works:

- test data: 197 diff and 549 note values
- conditional compilation, on-board execution
- calls framework with diff and note values

```
@adjust_word:
   sub  al,bl

;rotate_notes:
   if TEST_MODE > 0
   call test_diff
   end if
```

```
play_note:
   if TEST_MODE > 0
   jmp  test_note
   end if
```

skip note playing and delay

Integration test

How it works:

- test data: 197 diff and 549 note values
- conditional compilation, on-board execution
- calls framework with diff and note values
- log reference and calculated values to file

Integration test

How it works:

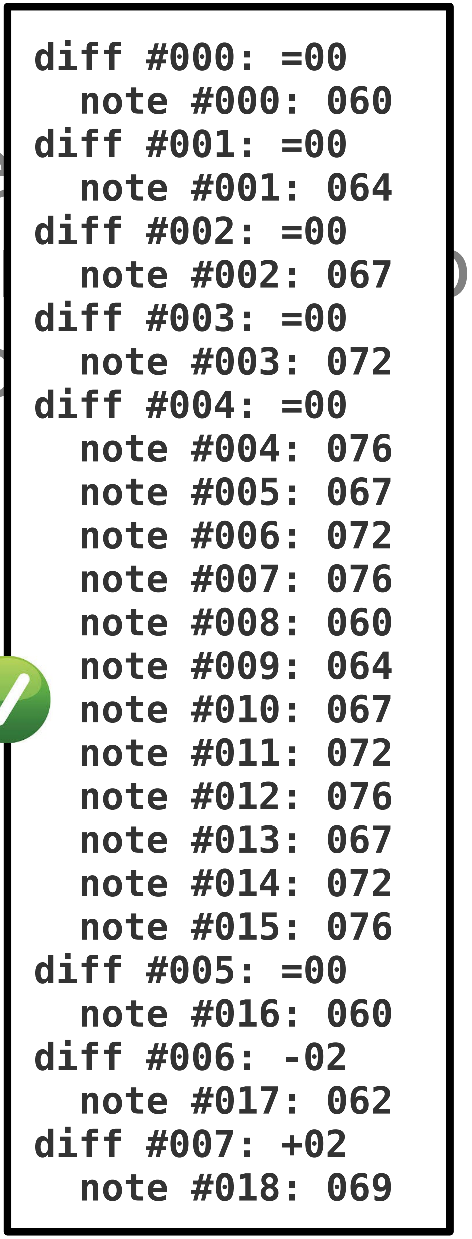
- test data: 197 diff and 549 note
- conditional compilation, on-boa on
- calls framework with diff and no
- log reference and calculated va

```
diff #000: =00
  note #000: 060
diff #001: =00
  note #001: 064
diff #002: =00
  note #002: 067
diff #003: =00
  note #003: 072
diff #004: =00
  note #004: 076
  note #005: 067
  note #006: 072
  note #007: 076
  note #008: 060
  note #009: 064
  note #010: 067
  note #011: 072
  note #012: 076
  note #013: 067
  note #014: 072
  note #015: 076
diff #005: =00
  note #016: 060
diff #006: -02
  note #017: 062
diff #007: +02
  note #018: 069
```

Integration test

How it works:

- test data: 197 diff and 549 note
- conditional compilation, on-boa on
- calls framework with diff and no
- log reference and calculated va



```
diff #000: =00
  note #000: 060
diff #001: =00
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diff #002: =00
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diff #004: =00
  note #004: 076
  note #005: 067
  note #006: 072
  note #007: 076
  note #008: 060
  note #009: 064
  note #010: 067
  note #011: 072
  note #012: 076
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  note #018: 069
```

✓

Integration test

How it works:

- test data: 197 diff and 549 note
- conditional compila on
- calls framework wit
- log reference and ca

```
diff #000: -05 <---- =00
  note #000: 055 <-- 060
diff #001: -08 <---- =00
  note #001: 056 <-- 064
diff #002: -05 <---- =00
  note #002: 062 <-- 067
diff #003: -08 <---- =00
  note #003: 064 <-- 072
diff #004: -05 <---- =00
  note #004: 071 <-- 076
  note #005: 064 <-- 067
```

```
diff #000: =00
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diff #001: =00
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   ote #004: 076
   ote #005: 067
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   ote #007: 076
   ote #008: 060
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   ote #011: 072
  note #012: 076
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  note #016: 060
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diff #007: +02
  note #018: 069
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diff #000: =00
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Integration test – save bug

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Symptoms:

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Symptoms:

- Test result shows errors, but the song plays OK

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Symptoms:

- Test result shows errors, but the song plays OK
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diff #000: -05 <---- =00
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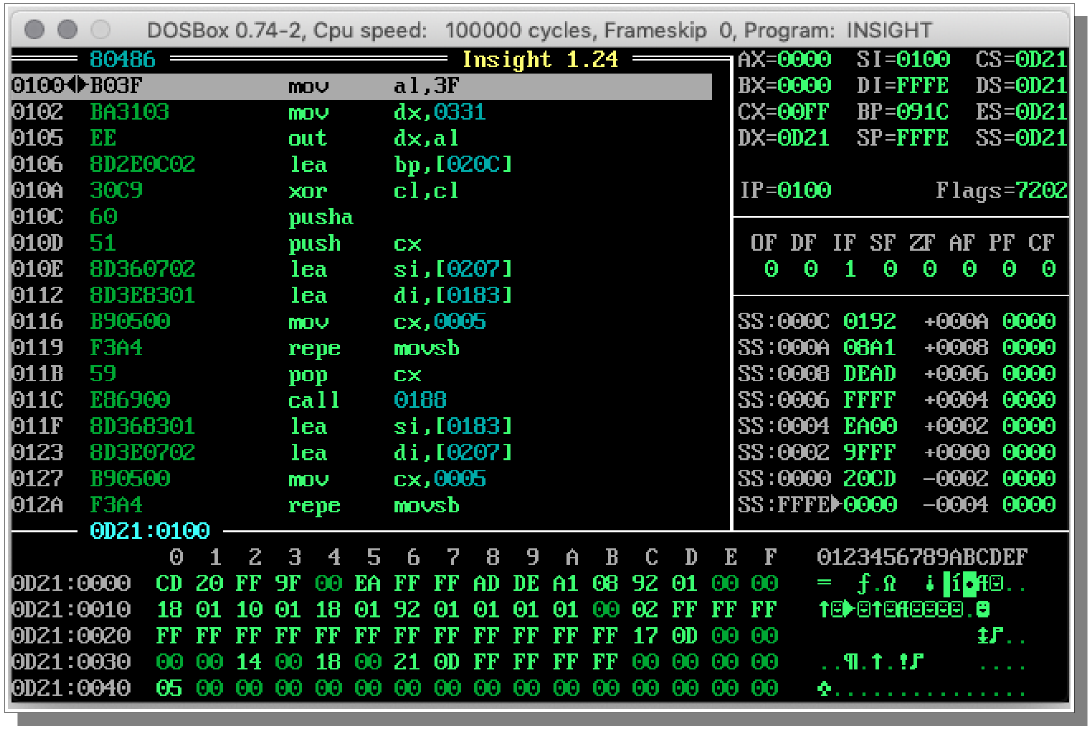
Integration test – save bug

Symptoms:

- Test result shows errors, but the song plays OK
- Closer look: it contains bad reference values
- Debugging: program works OK, good values



DOSBox 0.74-2, Cpu speed: 100000 cycles, Frameskip 0, Program: INSIGHT

```
══ 80486 ════════════════════ Insight 1.24 ═══ AX=0000  SI=0100  CS=0D21
0100◄►B03F           mov     al,3F              BX=0000  DI=FFFE  DS=0D21
0102  BA3103         mov     dx,0331            CX=00FF  BP=091C  ES=0D21
0105  EE             out     dx,al              DX=0D21  SP=FFFE  SS=0D21
0106  8D2E0C02       lea     bp,[020C]
010A  30C9           xor     cl,cl              IP=0100        Flags=7202
010C  60             pusha
010D  51             push    cx                  OF DF IF SF ZF AF PF CF
010E  8D360702       lea     si,[0207]            0  0  1  0  0  0  0  0
0112  8D3E8301       lea     di,[0183]
0116  B90500         mov     cx,0005            SS:000C 0192  +000A 0000
0119  F3A4           repe    movsb              SS:000A 08A1  +0008 0000
011B  59             pop     cx                 SS:0008 DEAD  +0006 0000
011C  E86900         call    0188               SS:0006 FFFF  +0004 0000
011F  8D368301       lea     si,[0183]          SS:0004 EA00  +0002 0000
0123  8D3E0702       lea     di,[0207]          SS:0002 9FFF  +0000 0000
0127  B90500         mov     cx,0005            SS:0000 20CD  -0002 0000
012A  F3A4           repe    movsb              SS:FFFE►0000  -0004 0000
───── 0D21:0100 ─────────────────────────────────────────────────────────
             0  1  2  3  4  5  6  7  8  9  A  B  C  D  E  F   0123456789ABCDEF
0D21:0000   CD 20 FF 9F 00 EA FF FF AD DE A1 08 92 01 00 00   ═  ƒ.Ω  ¡▐í◘Æ☺..
0D21:0010   18 01 10 01 18 01 92 01 01 01 01 00 02 FF FF FF   ↑☺►☺↑☺Æ☺☺☺☺.☻
0D21:0020   FF FF FF FF FF FF FF FF FF FF FF FF 17 0D 00 00               ↨♪..
0D21:0030   00 00 14 00 18 00 21 0D FF FF FF FF 00 00 00 00   ..¶.↑.!♪    ....
0D21:0040   05 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00   ♣...............
```

Integration test – save bug

Symptoms:

- Test result shows errors, but the song plays OK
- Closer look: it contains bad reference values
- Debugging: program works OK, good values
- When exiting after few notes: everything is OK

Integration test – save bug

Symptoms:

- Test result shows errors, but the song plays OK
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- Debugging: program works OK, good values
- When exiting after few notes: everything is OK
- If the song is shorter than 128 notes: OK

Integration test – save bug

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- Debugging: program works OK, good values
- When exiting after few notes: everything is OK
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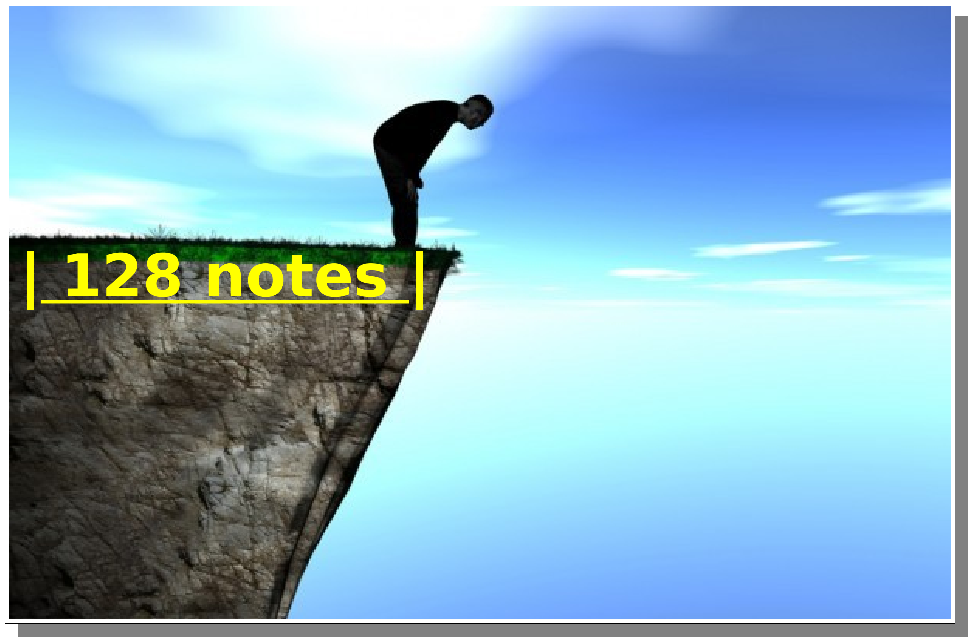

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- Test result shows errors, but the song plays OK
- Closer look: it contains bad reference values
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- When exiting after few notes: everything is OK
- If the song is shorter than 128 notes: OK
- Check test framework: no 8-bit counters used

Integration test – save bug

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- Test result shows errors, but the song plays OK
- Closer look: it contains bad reference values
- Debugging: program works OK, good values
- When exiting after few notes: everything is OK
- If the song is shorter than 128 notes: OK
- Check test framework: no 8-bit counters used
- WAT?

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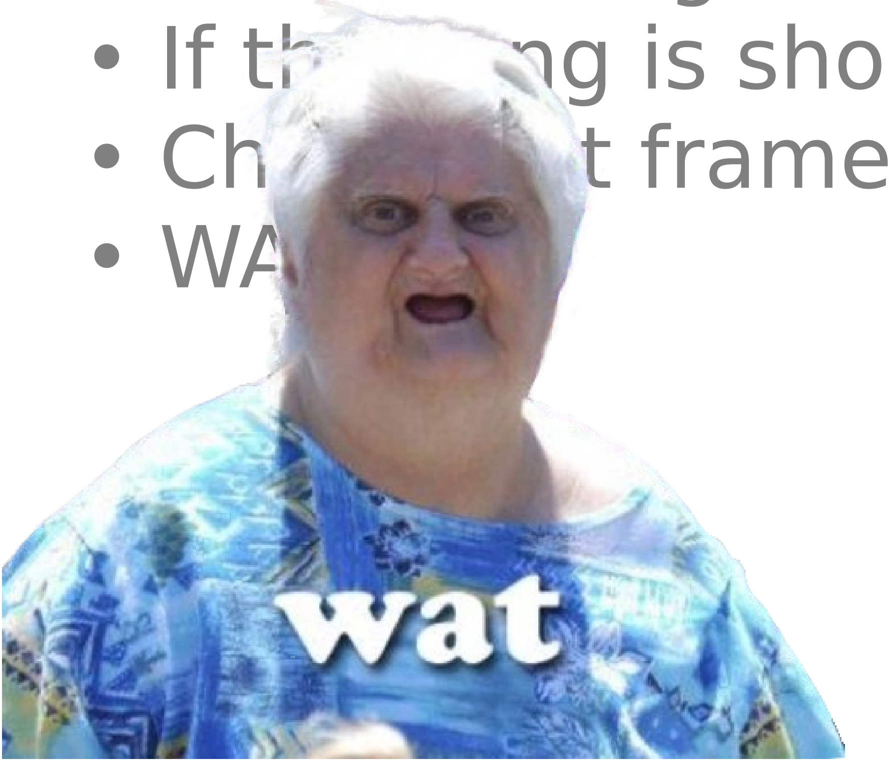

Integration test – save bug

Root cause:

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Root cause:

- DOS write() ruins the file, if the data is long

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Solution / workaround:

Integration test – save bug

Root cause:

- DOS write() ruins the file, if the data is long

Solution / workaround:

- Close and re-open file frequently

Integration test – save bug

Root cause:

- DOS write() ruins the f

Solution / workaround:

- Close and re-open file

```
test_reopen:

    mov  bx,[test_file_handle]
    mov  ah,3eH       ; close
    int  21H
    lea  dx,[test_close_failed_text]
    jc   .fail

    lea  dx,[test_file_name]
    mov  ax,3d02H     ; open for write
    int  21H
    lea  dx,[test_reopen_failed_text]
    jc   .fail

    mov  [test_file_handle],ax

    xor  cx,cx
    xor  dx,dx
    mov  bx,ax
    mov  ax,4202H     ; seek from end
    int  21H
    lea  dx,[test_lseek_failed_text]
    jc   .fail

    ret
```

Integration test – save bug

Root cause:

- DOS write() ruins the f

Solution / workaround:

- Close and re-open file
- A bit slower

```
test_reopen:

    mov  bx,[test_file_handle]
    mov  ah,3eH       ; close
    int  21H
    lea  dx,[test_close_failed_text]
    jc   .fail

    lea  dx,[test_file_name]
    mov  ax,3d02H     ; open for write
    int  21H
    lea  dx,[test_reopen_failed_text]
    jc   .fail

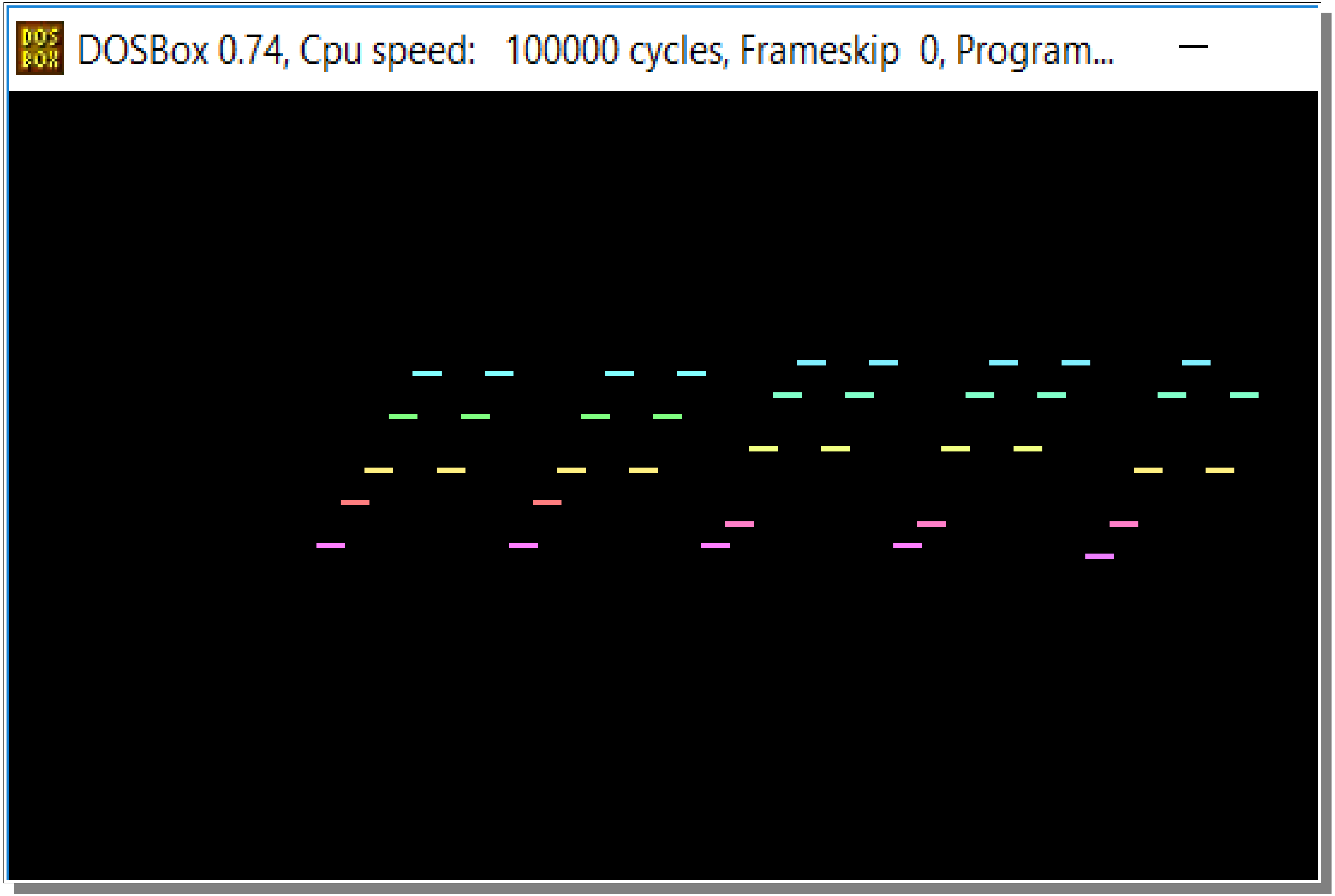
    mov  [test_file_handle],ax

    xor  cx,cx
    xor  dx,dx
    mov  bx,ax
    mov  ax,4202H     ; seek from end
    int  21H
    lea  dx,[test_lseek_failed_text]
    jc   .fail

    ret
```

Visual

Visual



DOSBox 0.74, Cpu speed: 100000 cycles, Frameskip 0, Program...

Visual

Plot routine:

```
push 0a000H
pop  es
pusha
mov  ax,90H
out  dx,al
lodsb
out  dx,al
imul di,ax,-320*2
mov  cl,bl
rep  stosb
inc  cx
mov  ax,2c7fH
out  dx,al
```

Visual

Plot routine:

- Interleaved with MIDI player

```
push 0a000H
pop  es
pusha
mov  ax,90H
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```

Visual

Plot routine:

- Interleaved with MIDI player
- AL: MIDI note + visual input

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Visual

Plot routine:

- Interleaved with MIDI player
- AL: MIDI note + visual input
- complex instruction, but we don't need other regs for calc

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out  dx,al
```

Visual

Plot routine:

- Interleaved with MIDI player
- AL: MIDI note + visual input
- complex instruction, but we don't need other regs for calc
- AX * -1: mirror, AX * 2: scale

  (draw lower notes on lower part of the screen, higher address)

```
push 0a000H
pop  es
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mov  ax,90H
out  dx,al
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imul di,ax,-320*2
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- Interleaved with MIDI player
- AL: MIDI note + visual input
- complex instruction, but we don't need other regs for calc
- AX * -1: mirror, AX * 2: scale

  (draw lower notes on lower part of the screen, higher address)
- bar width = delay length

```
push 0a000H
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mov  ax,90H
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Plot routine:

- Interleaved with MIDI player
- AL: MIDI note + visual input
- complex instruction, but we don't need other regs for calc
- AX * -1: mirror, AX * 2: scale
  (draw lower notes on lower part of the screen, higher address)
- bar width = delay length
- bar color = note pitch

```
push 0a000H
pop  es
pusha
mov  ax,90H
out  dx,al
lodsb
out  dx,al
imul di,ax,-320*2
mov  cl,bl
rep  stosb
inc  cx
mov  ax,2c7fH
out  dx,al
```

Visual

Scroll routine:

```
push 0a000H
pop  es
 (...)
sub  di,di
mov  si,1
mov  ch,54H
es:
rep  movsw
```

Visual

Scroll routine:

- ES=A000: video segment

```
push 0a000H
pop  es
 (...)
sub  di,di
mov  si,1
mov  ch,54H
es:
rep  movsw
```

Visual

Scroll routine:

- ES=A000: video segment
- Cheap destination address: 0

```
push 0a000H
pop  es
 (...)
sub  di,di
mov  si,1
mov  ch,54H
es:
rep  movsw
```

Visual

Scroll routine:

- ES=A000: video segment
- Cheap destination address: 0
- Source, scrolling left by 1 pixel

```
push 0a000H
pop  es
 (...)
sub  di,di
mov  si,1
mov  ch,54H
es:
rep  movsw
```

Visual

Scroll routine:

- ES=A000: video segment
- Cheap destination address: 0
- Source, scrolling left by 1 pixel
- Only 54H * 256 * 2 pixels

```
push 0a000H
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 (...)
sub  di,di
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```

Visual

Scroll routine:

- ES=A000: video segment
- Cheap destination address: 0
- Source, scrolling left by 1 pixel
- Only 54H * 256 * 2 pixels
- ES prefix: cheaper than set DS

```
push 0a000H
pop  es
 (...)
sub  di,di
mov  si,1
mov  ch,54H
es:
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```

Visual

Scroll routine:

- ES=A000: video segment
- Cheap destination address: 0
- Source, scrolling left by 1 pixel
- Only 54H * 256 * 2 pixels
- ES prefix: cheaper than set DS
- Copying by words

```
push 0a000H
pop  es
 (...)
sub  di,di
mov  si,1
mov  ch,54H
es:
rep  movsw
```

THE END

YouTube: https://www.youtube.com/watch?v=ns7islpMe1U

GitHub: https://github.com/ern0/549notes

THE END

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