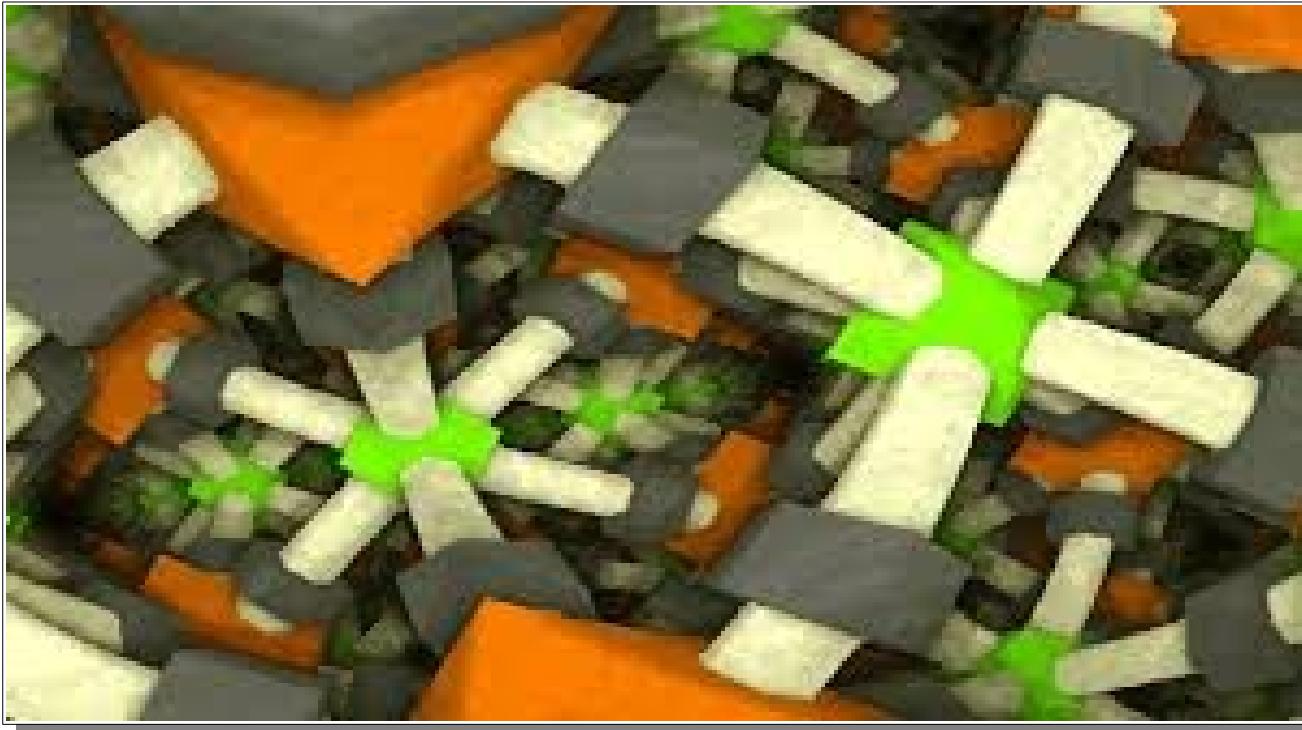


This page is intentionally left blank.

# 256-byte demoscene: extremly strong competition

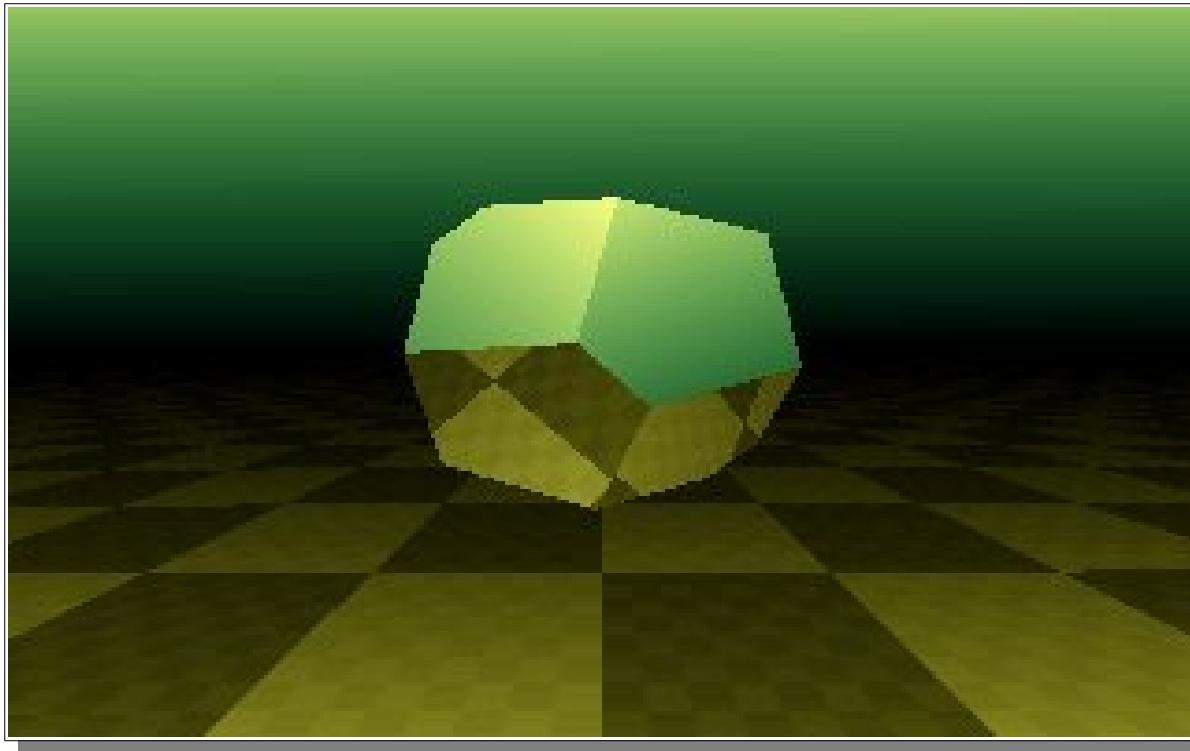


256-byte demoscene: extremly strong competition



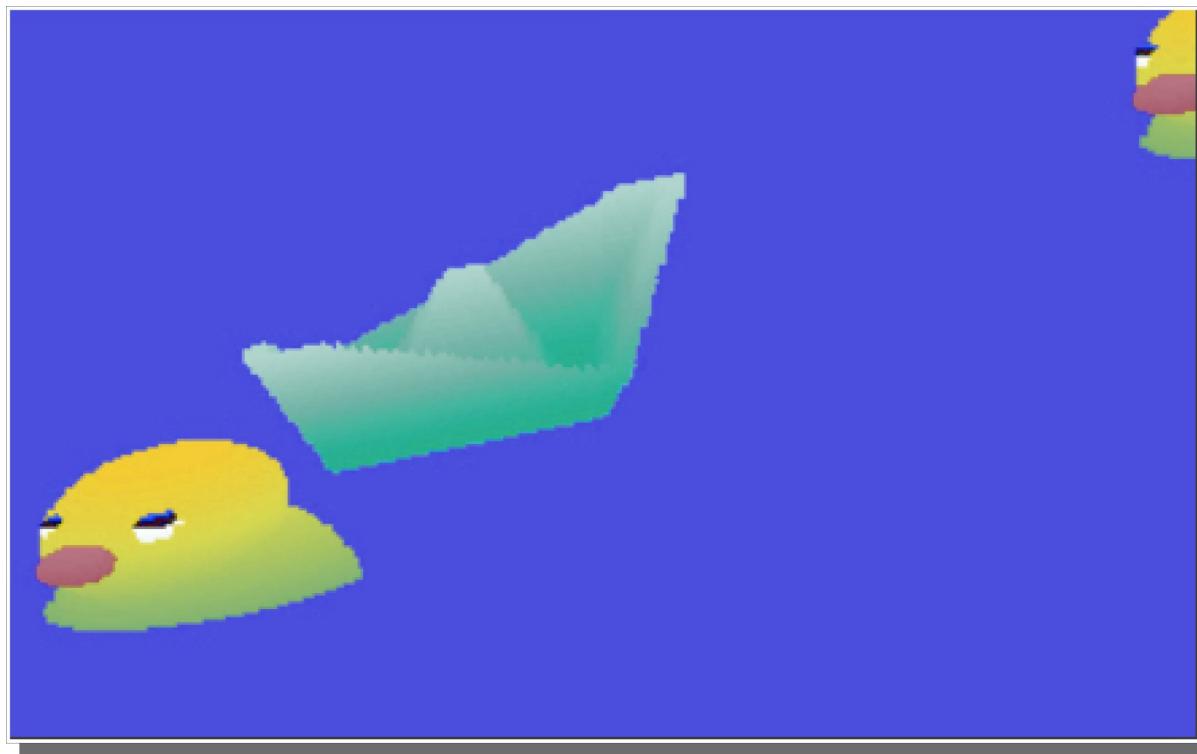
*Řrřola: Puls*

256-byte demoscene: extremly strong competition



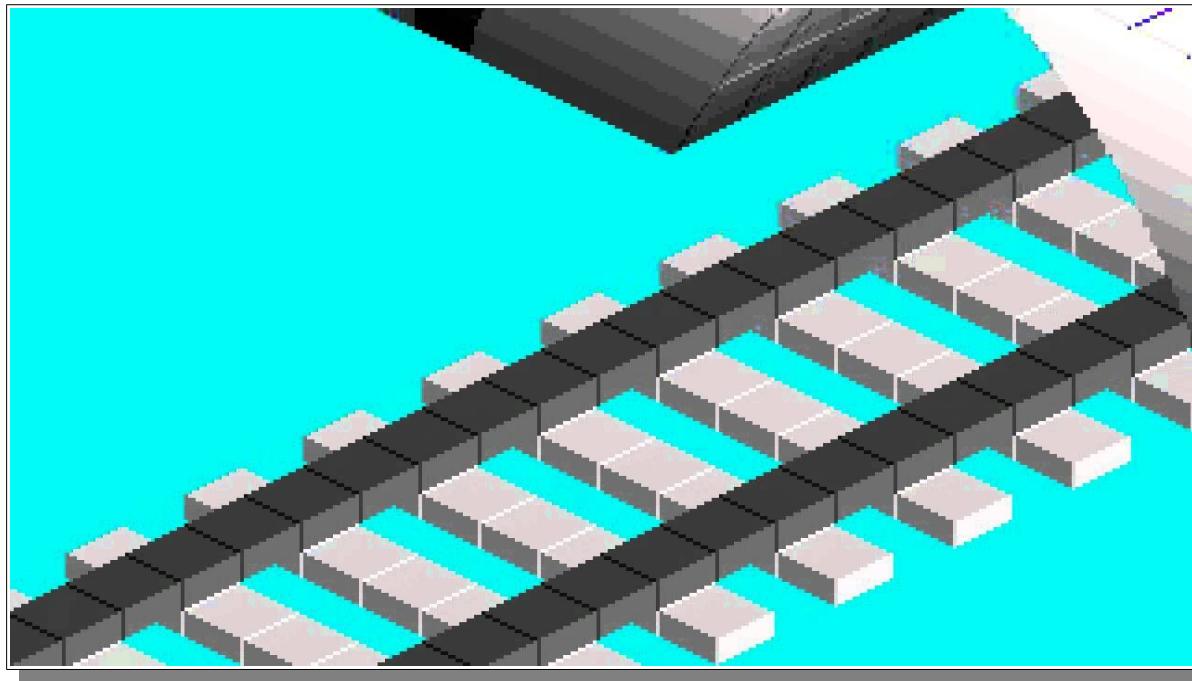
*Řrřola: Pyrit*

256-byte demoscene: extremly strong competition



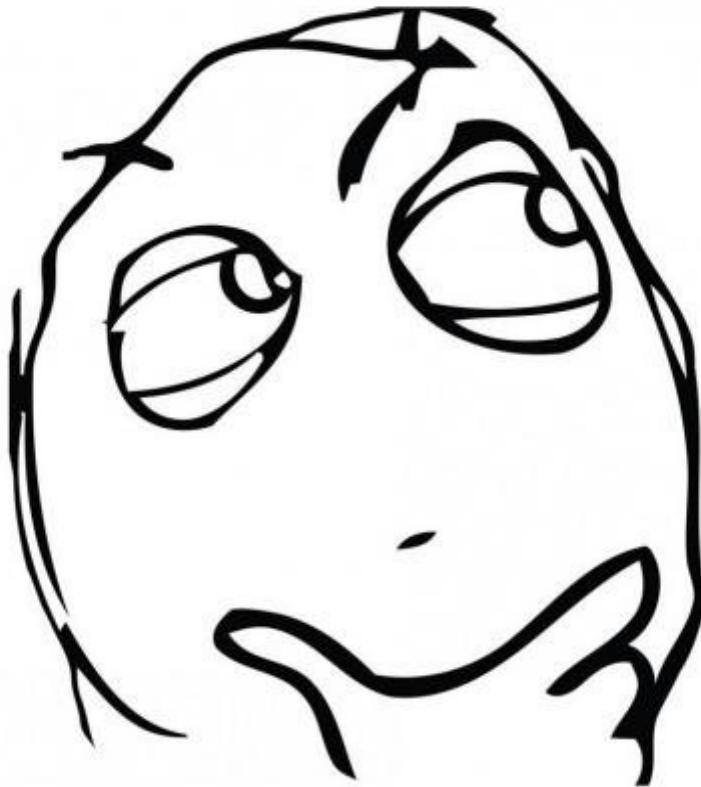
*Digimind: Pool Patrol*

256-byte demoscene: extremly strong competition



*Digimind: Immediate Railways*

256-byte demoscene: extremly strong competition

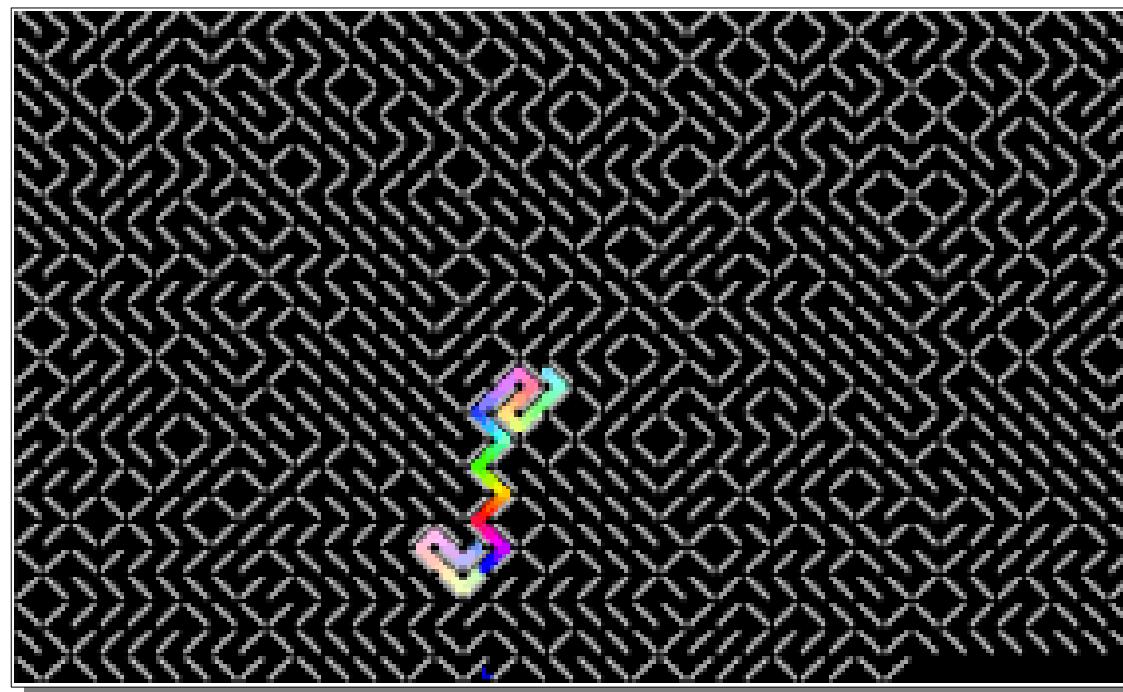


How to shine out of crowd?

# 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?

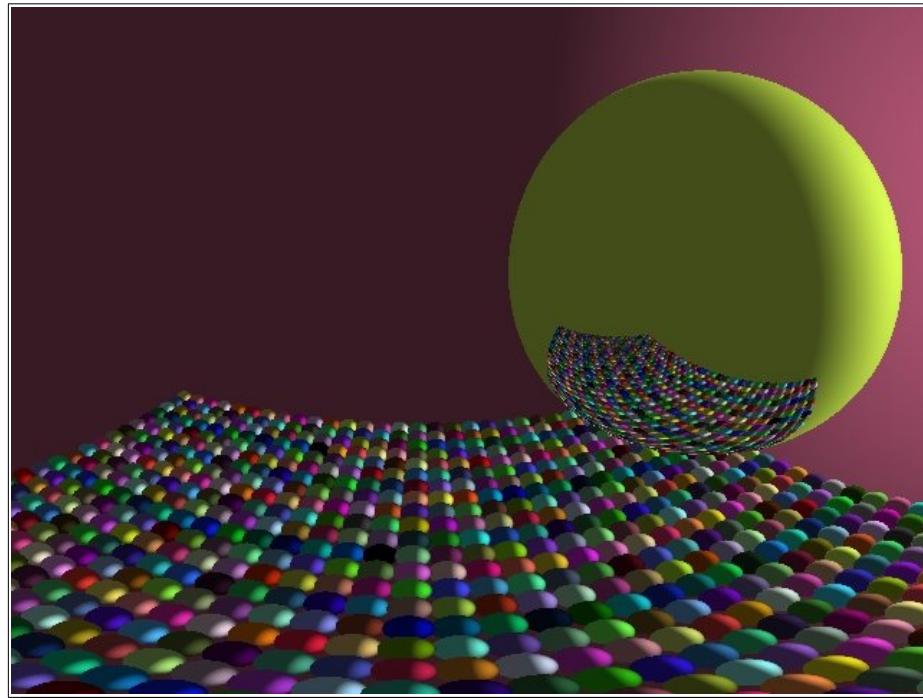
Image processing + fun



*TomCat: Be Happy!*

# 256-byte demoscene: how to beat competition?

## Raytracing



*TomCat: Colorful*

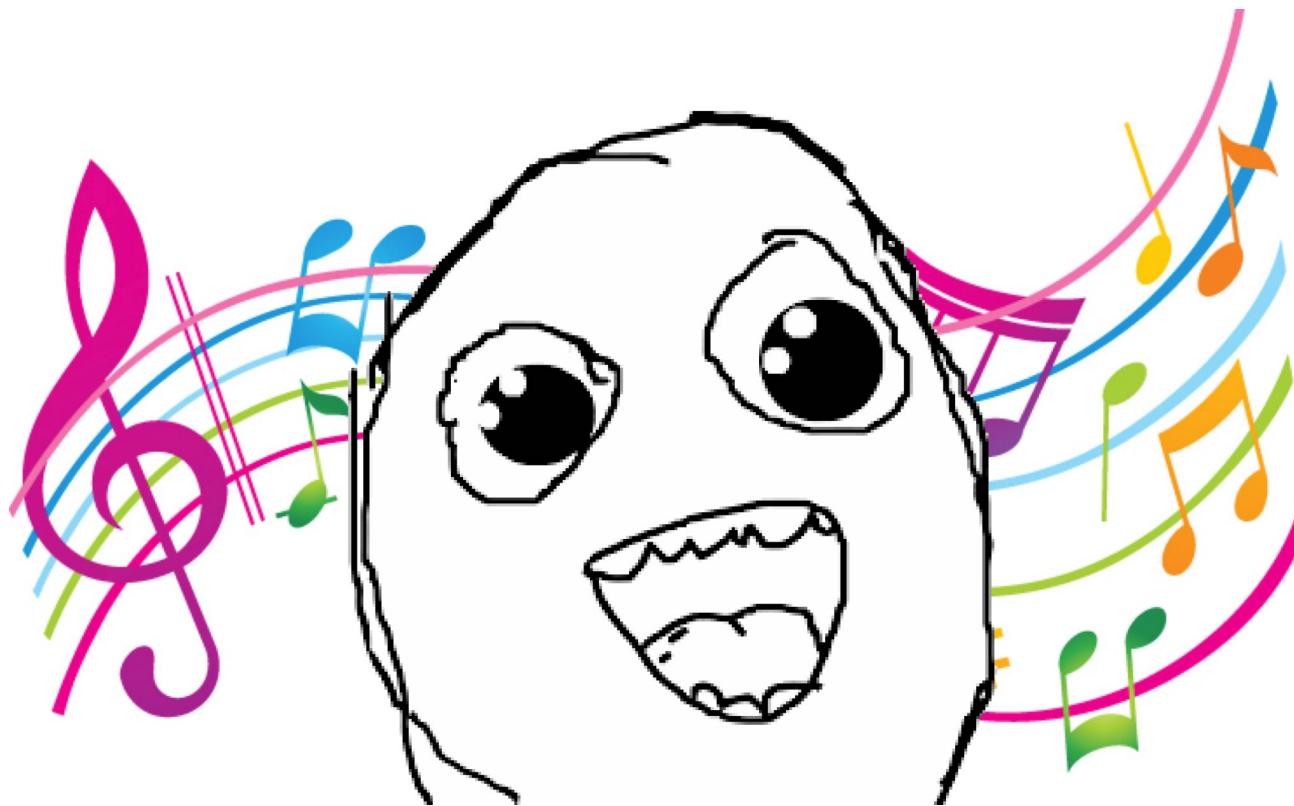
# 256-byte demoscene: how to beat competition?

Raytracing + fun



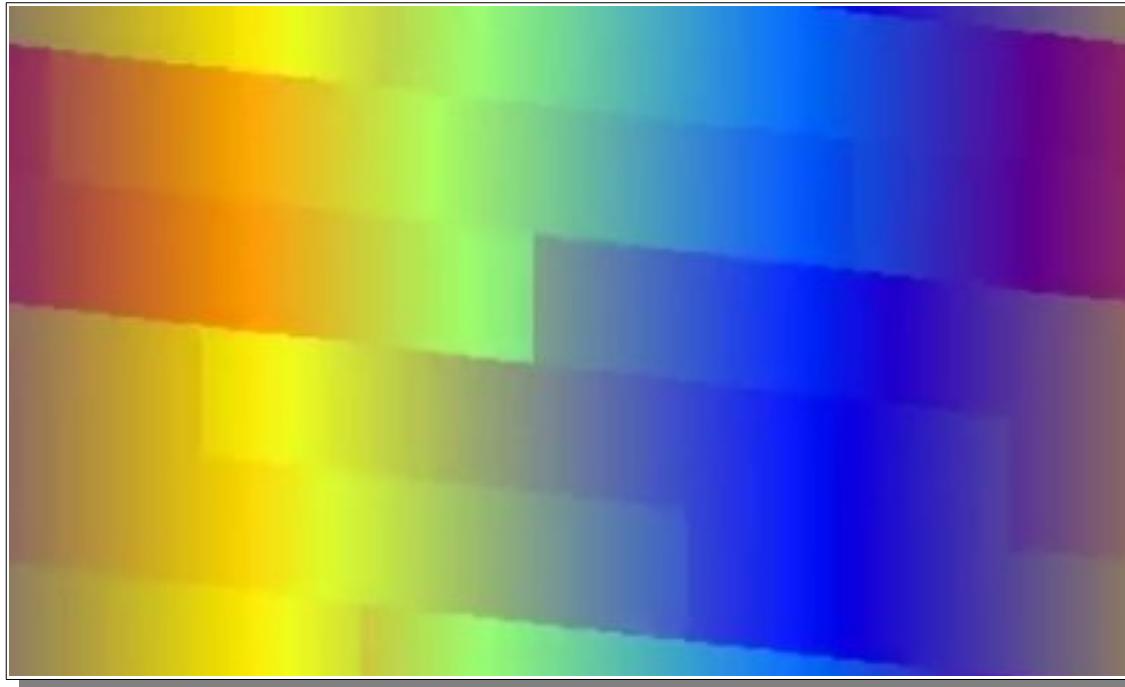
*TomCat: Pokeball*

# 256-byte demoscene: how to beat competition?



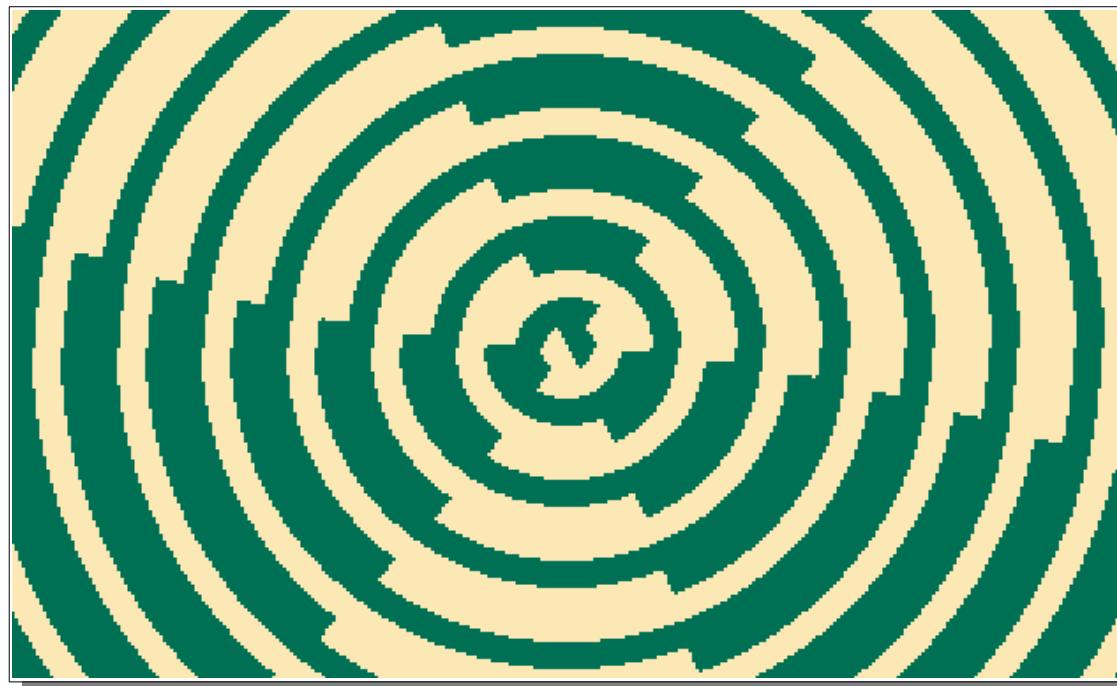
Music! Add music in 256-byte intros!

# 256 byte intro with music



*TomCat: 2(56)unlimited  
(bytebeat music by ern0)*

# 256 byte intro with music



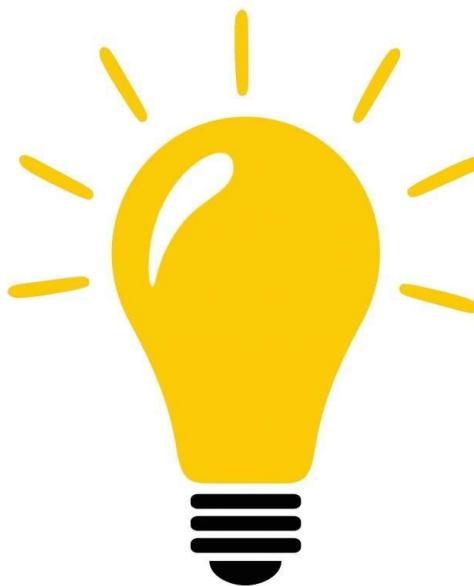
*TomCat: No Sleep!*  
*(buzzer music by ern0)*

256 byte intro with music

Everyone loves it!



# Create universal bytebeat tool



# Create universal bytebeat tool

- Bytebeat player & editor

*TomCat*



# Create universal bytebeat tool

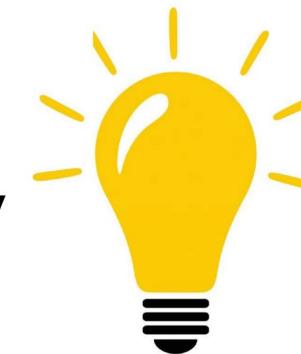
- Bytebeat player & editor

*TomCat*



- Formula compiler for assembly

*ern0*



# Create universal bytebeat tool

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



# Create universal bytebeat tool

- Bytebeat player & editor

*TomCat*



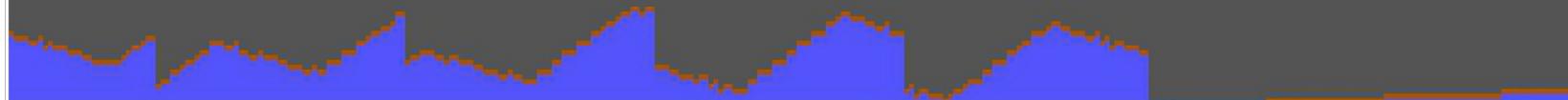
- Formula compiler for assembly

*ern0*



# Bytebeat Editor (TomCat)

```
BYTEBEAT by TomCat/Abaddon 7 24632
freq:18939 zoom:1 out:7 vol:11173
Kick drum no:CMP1Z skip:TSTONZ
rate:16383 len:24576 vol:64
Hihat no:CMP3B skip:TST96NZ
rate:63 ien: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
```



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

# Bytebeat Editor (TomCat)

## Features:

- realtime feedback

The screenshot shows the Bytebeat Editor interface. At the top, there is a text-based configuration section with various parameters for instruments and effects. Below this is a large waveform visualization showing a repeating pattern of blue and grey triangles. At the bottom, there is a hex dump of audio data.

```
BYTEBEAT by TomCat/Abaddon 2 12981
freq:18939 zoom:1 out:7 vol:35000
Kick drum no:CMP1Z skip:TSTONZ
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
```

```
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

The screenshot shows the Bytebeat Editor interface. At the top, there is a text-based configuration section with various parameters for instruments and effects. Below this is a graphical representation of a sound wave, consisting of blue vertical bars on a black background. At the bottom, there is a row of numerical data.

```
BYTEBEAT by TomCat/Abaddon 5 44539
freq:18939 zoom:1 out:7 vol:35000
Kick drum no:CMP1Z skip:TSTONZ
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
```

```
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
- save/restore modified code

BYTHEBEAT by TomCat/Abaddon 2 12981  
freq:18939 zoom:1 out:7 vol:35000  
Kick drum no:CMP1Z skip:TSTONZ  
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

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
- save/restore modified code

### Issues:

- more than 70 hotkeys

BYTHEBEAT by TomCat/Abaddon 5 44539  
freq:18939 zoom:1 out:7 vol:35000  
Kick drum no:CMP1Z skip:TSTONZ  
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

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

# Bytebeat Editor (TomCat)

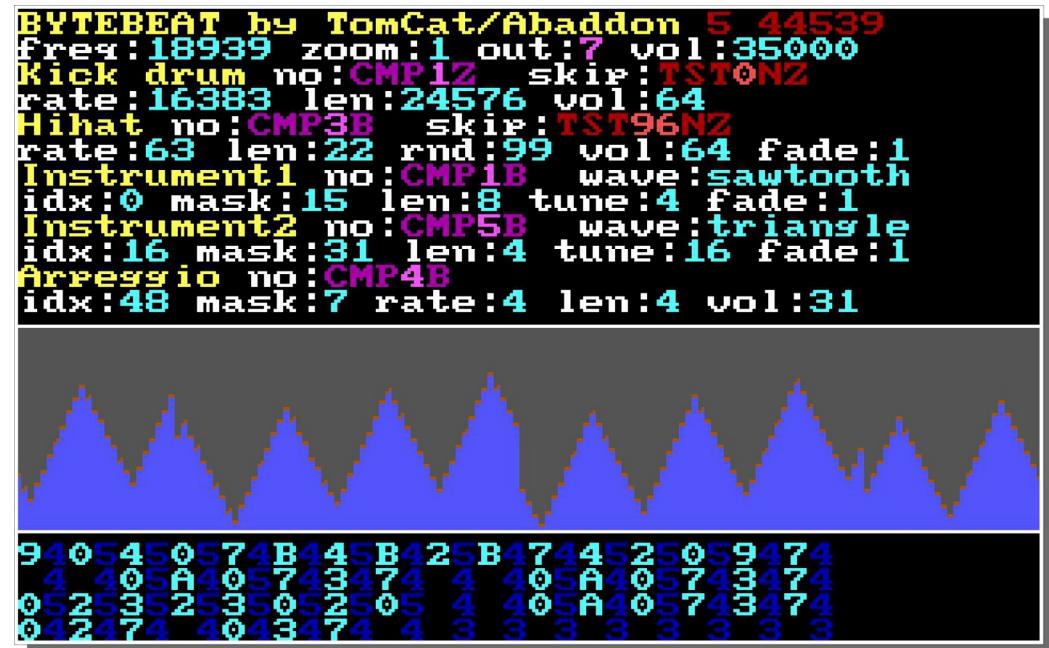
## Features:

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



## Issues:

- more than 70 hotkeys



# Bytebeat Editor (TomCat)

## Features:

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

## Issues:

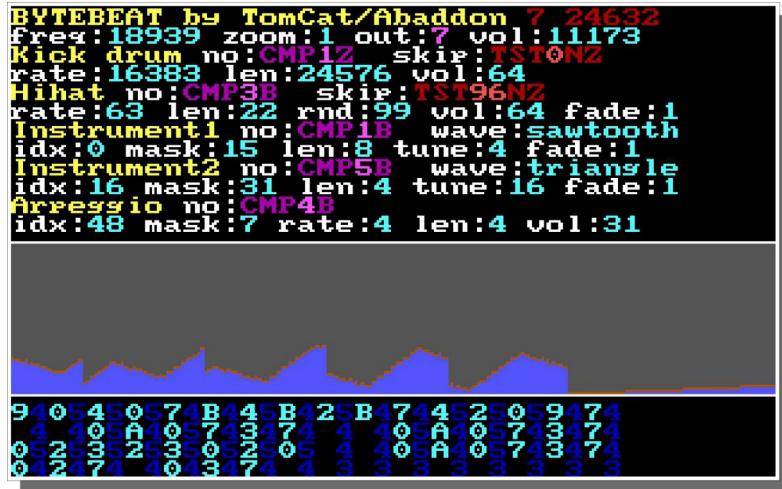
- more than 70 hotkeys
- needs some x86 coder knowledge  
e.g. you can set any flag for a conditional jump

The screenshot shows the Bytebeat Editor interface. At the top, there is assembly code for a song titled 'BYTEBEAT by TomCat/Abaddon 2 12981'. The code includes parameters for various instruments like Kick, Drum, Hihat, and Arpeggio. Below the code is a waveform visualization consisting of several blue triangles on a grey background. At the bottom, there is a memory dump showing a sequence of bytes.

```
BYTEBEAT by TomCat/Abaddon 2 12981
freq:18939 zoom:1 out:7 vol:35000
Kick drum no:CMP1Z skip:TSTONZ
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
```

```
9405450574B445B425B4744525059474
4405A4057434744405A405743474
05253525350525054405A405743474
0424744043474433333333333333333
```

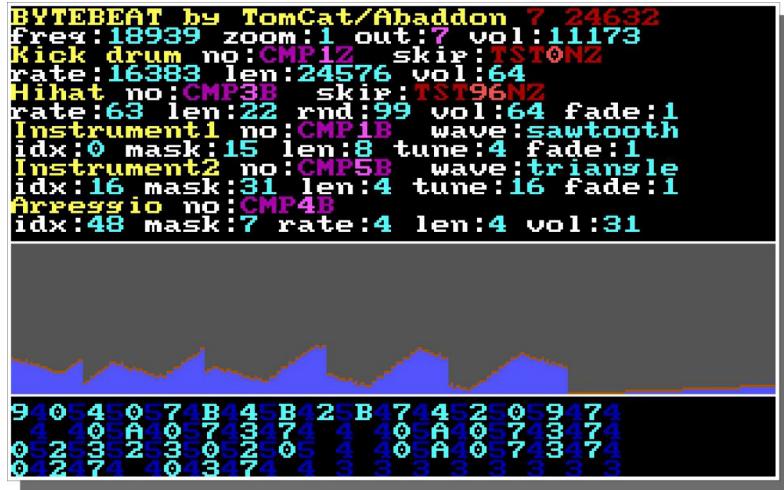
# *Bytebeat Editor (TomCat)*



Verdict:

- too complex, especially for musicians #UX

# Bytebeat Editor (TomCat)



## Verdict:

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

# *Bytebeat Editor (TomCat)*

BYTEBEAT by TomCat/Abaddon 7 24632  
freq:18939 zoom:1 out:7 vol:11173  
Kick drum no:CMP12Z skip:TSTONZ  
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  
Arrezzo no:CMP4B  
idx:48 mask:7 rate:4 len:4 vol:31

# Verdict

- Too complex, especially for users. UX does not provide enough feedback.

# *Assemblyzator (ern0)*

## *Assemblyzator (ern0)*

Transform bytebeat formula to assembly code...

## *Assemblyzator (ern0)*

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

# 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;
}
```

```
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;  
}
```

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

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

Very optimized!  
Such compiler!



# 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;  
}

b8 5c3 501 5c3 501  
 mov eax, 0x175e0e4  
 ret

~~Vc, optimized!  
such compiler!~~



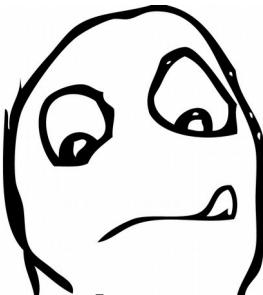
No modern compiler exists for **16-bit** target.

# *Assemblyzator (ern0)*

Let's write a compiler thing!

# *Assemblyzator (ern0)*

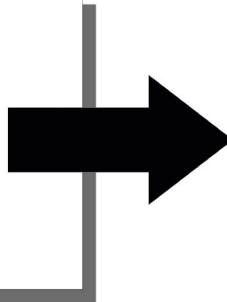
Let's write a compiler thing!



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
- handle num arrays
- handle string arrays

# *Assemblyzator (ern0)*

## *Features:*

- split formula
- handle num arrays
- handle string arrays
- remove duplications

# *Assemblyzator (ern0)*

## *Features:*

- split formula
- handle num arrays
- handle string arrays
- remove duplications

## *Design Flaws:*

- 3-op ( $A = B \text{ op } C$ )  
8086 assembly instructions are 2-operand

# *Assemblyzator (ern0)*

## *Features:*

- split formula
- handle num arrays
- handle string arrays
- remove duplications

## *Design Flaws:*

- 3-op ( $A = B \text{ op } C$ )  
8086 assembly instructions are 2-operand
- can't handle cond. op.  
 $A = ( B \text{ op } C ? D : E )$   
improperly designed Abstract Syntax Tree

# *Assemblyzator (ern0)*

## *Features:*

- split formula
- handle num arrays
- handle string arrays
- remove duplications

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- 3-op ( $A = B \text{ op } C$ )  
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 $A = ( B \text{ op } C ? D : E )$   
improperly designed Abstract Syntax Tree

## *Verdict:*

- nice try, but does not help much

# *Assemblyzator (ern0)*

## *Features:*

- split formula
- handle num arrays
- handle string arrays
- remove duplications

## *Design Flaws:*

- 3-op ( $A = B \text{ op } C$ )  
8086 assembly instructions are 2-operand
- can't handle cond. op.  
 $A = ( B \text{ op } C ? D : E )$   
improperly designed Abstract Syntax Tree

## *Verdict:*

- nice try, but does not help much
- writing a compiler is not as easy as it looks first

# Assemblyzator (ern0)

## Features:

- split formula
- handle num arrays
- handle string arrays
- remove duplications

## Verdict:

- nice try, but it does not help much
- writing a compiler is not as easy as it looks first

## Design Flaws:

- 3-op ( $A = B \text{ op } C$ )  
8086 assembly instructions are 2-operand  
can't handle cond. op.  
(A op, B ? C : D )  
improperly designed Abstract Syntax Tree



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

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

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

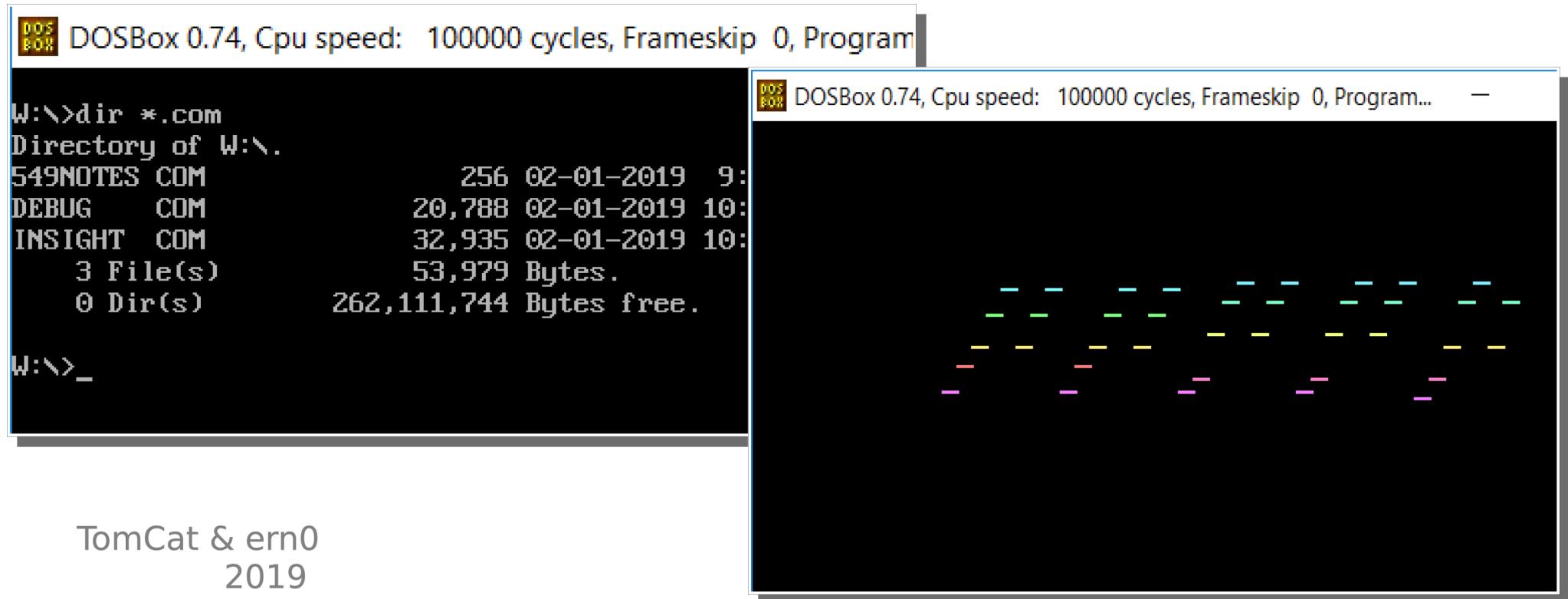


*Some hours later...*

[ern0] *I got the perfect one.*

# Making of **549NOTES.COM**

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



## *Table Of Contents*

I. Song ★★★★☆

II. Data ★★★★★☆

III. Code ★★★★★★

# I. Song

# Prelude I

In C major

BWV 846

Johann Sebastian Bach (1685 - 1750)

Piano

This system shows the beginning of the prelude. The treble staff consists of eighth-note pairs followed by a rest. The bass staff consists of quarter notes with fermatas. The key signature is C major.

This system continues the pattern established in the first system. The treble staff has eighth-note pairs followed by rests. The bass staff has quarter notes with fermatas. A sharp sign appears in the key signature, indicating a temporary change to G major.

# *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: “key up” message needed

*Switch sound card to MIDI mode:*

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



```
90H ; key down, ch=1  
al  
; pitch  
al  
al  
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:

Piano

The musical score displays two staves for a piano. The top staff uses a treble clef and a common time signature (indicated by a '4'). The bottom staff uses a bass clef and a common time signature. Both staves feature a key signature of one sharp (F#). The music consists of a repeating eighth-note pattern: a sixteenth note followed by a sixteenth note tied to a sixteenth note, with a short rest. This pattern is identical in both staves.

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

Repeating patterns 1/2:

Piano

The image shows two staves of a piano musical score. The top staff is in common time (indicated by '4') and the bottom staff is in common time (indicated by '4'). The key signature is C major. The music consists of eighth-note patterns. The first staff has four measures highlighted with green circles, followed by four measures highlighted with blue circles, and then four measures highlighted with pink circles. The second staff continues with four measures highlighted with green circles, followed by four measures highlighted with red circles, and then four measures highlighted with purple circles. The piano dynamic 'pp' (pianissimo) is indicated at the beginning of each measure.

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

Repeating patterns 1/2:

Piano

A musical score for the piano part of J.S. Bach's Prelude I. in C Major (BWV 846). The score consists of two staves: a treble staff and a bass staff. The treble staff starts with a green circle highlighting a sixteenth-note pattern, followed by a blue circle, a pink circle, and another pink circle. The bass staff follows a similar pattern with a green circle, a red circle, a purple circle, and a blue circle. The music is in common time (indicated by '4' at the beginning of each staff).

**16 → 8 notes**

A continuation of the musical score for the second half of the repeating pattern. The treble staff starts with a green circle, followed by a red circle, a purple circle, and a blue circle. The bass staff follows a similar pattern with a green circle, a red circle, a purple circle, and a blue circle.

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

Repeating patterns 2/2:

Piano

The musical score consists of two staves for piano. The top staff is in common time (4/4) and the bottom staff is also in common time (4/4). Both staves feature a repeating pattern of eighth-note pairs followed by a sixteenth-note pair, with a bass note on the first beat of each measure. The pattern repeats six times in the top staff and five times in the bottom staff.

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

Repeating patterns 2/2:

Piano

The image shows two staves of musical notation for a piano. The top staff is in common time (indicated by '4') and the bottom staff is in common time (indicated by '4'). The notation consists of eighth and sixteenth notes. In the first measure, the pattern is a eighth note followed by a sixteenth note. This pattern repeats three times in the first measure. In the second measure, the pattern changes to a sixteenth note followed by an eighth note. This pattern repeats three times in the second measure. The third measure starts with a sixteenth note followed by an eighth note, which then changes to a eighth note followed by a sixteenth note. The fourth measure starts with a eighth note followed by a sixteenth note. The notes are highlighted with colored overlays: purple, green, blue, and red. The purple highlights are on the first two measures, the green highlights are on the third measure, the blue highlights are on the first two measures, and the red highlights are on the third measure.

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

Repeating patterns 2/2:

Piano

4

4

**8 → 5 notes**

4

4

# Raw Data

<i>part</i>	<i>effective notes</i>	<i>raw data</i>
<i>repeating</i>	512	160
<i>non-repeating</i>	32	32
<i>final chord</i>	5	5
<b><i>total</i></b>	<b>549</b>	<b>197</b>

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

# Histogram of raw (31 values, 197 notes)

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

```

; 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-2:58  11 #####
; 7. f-2:53  10 #####
; 8. f-3:65  9 #####
; 9. h-2:59  8 #####
; 10. g-1:43  7 #####
; 11. d-2:50  6 #####
; 12. d-4:74  5 #####
; 13. c-4:72  4 #####
; 14. h-3:71  3 #####
; 15. c-2:48  3 #####
; 16. e-2:52  3 #####
; 17. c-1:36  2 #####
; 18. a-3:69  2 #####
; 19. f-4:77  1 #####
; 20. f#3:66  1 #####
; 21. e-4:76  1 #####
; 22. a#2:58  1 #####
; 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 #

```

**note range: 36 .. 81: 45 values**

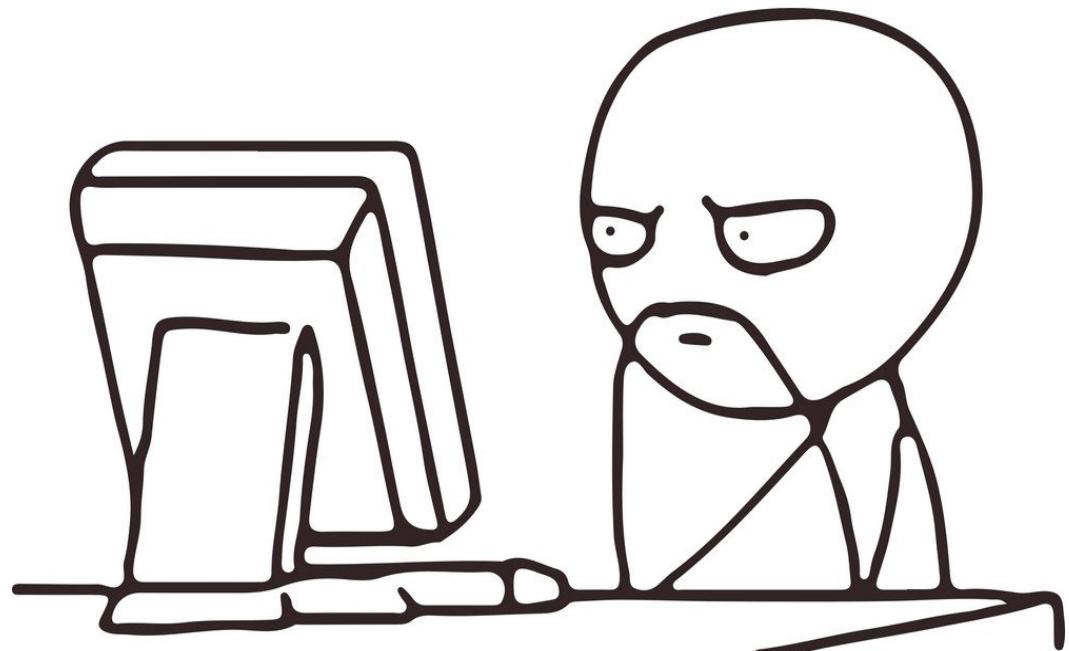
**values: 6 bit x 197 = 148 byte**

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

# Think Diff

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

## *Think Diff: why raw-diff-5?*

### Why raw?

- Two options:
  - raw MIDI notes or
  - mapped data
- Dispersion: 31 values in range of 45

## *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

## *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, only 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?

- Part 1 contains chord breaks
- Chords are evolving slowly to next one
- Slowness is emphasized by repeating all chord breaks twice (not stored)

*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**

*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?

- 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

## *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: <b>+29</b>	c-3:60: <b>+12</b>	a-2:57:+04				
c-3:60:+03	a-2:57:-03	f-2:53: <b>-12</b>	a-2:57:-03	f-2:53:-04	d-2:50:-10	f-2:53:-04	d-2:50:-03				
c-1:36: <b>-21</b>	h-1:47:-06	g-3:67: <b>+17</b>	h-3:71: <b>+18</b>	d-4:74: <b>+24</b>	f-4:77: <b>+41</b>	d-4:74: <b>+27</b>	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
c-2:48:-03 a-2:48:-05 c-2:57:=00 c-3:60:=00 d-3:62:-02
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:-01 e-2:52:-01 g-2:55:=00 c-3:60:+01 e-3:64:+02
g-1:43:-00 d-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:-01 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 (0.4%)

# 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**

The diagram illustrates a compressed storage structure. On the left, ten instances of the string "ccc" are shown in a row. To the right of this row is a yellow rectangular box containing the text "COMP". A horizontal grey bar spans the width of the "ccc" row and ends at the "COMP" box, indicating the total length of the compressed data.

# *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
- The diagram shows a sequence of nine short words, each consisting of three lowercase letters 'c', 'c', and 'c'. These are followed by a single long word 'COMP' enclosed in a yellow rectangular box. The entire sequence is centered on the slide.

cccccccccc COMP
- Store special marker 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 COMP

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

sss+uuuuu sss+uuuuu sss+uuuuu ccc ccc sss+uuuu

## 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 COMP

- Store special marker 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 COMP

- Store special marker 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



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



- 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



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



- 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



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



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

*Compression: raw-diff-5 @ 2*

<pre>; 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 #</pre>	<hr/> <p><b>55%: 2-bit</b></p> <hr/> <p><b>45%: 7-bit</b></p>
--	---

# *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 #
94%: 4-bit
; 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 #
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*

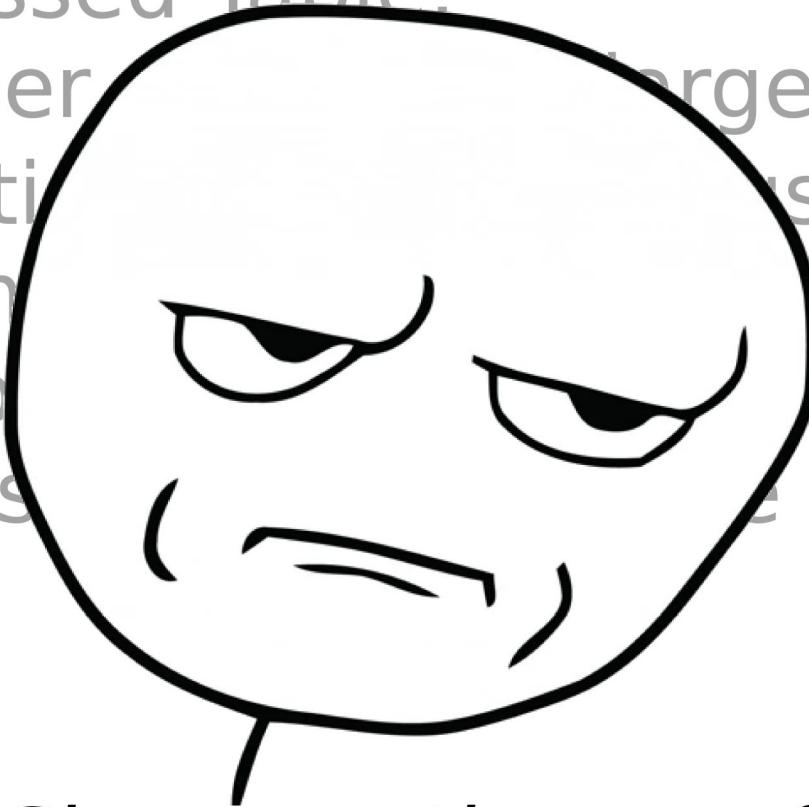
### No Uncompressed Table:

- 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 of entries (large table)
- Low utilization (usually 1 note)
- Range of memory addresses (high num entries) in table size
- Table needs to be compressed



*Show me the proof!  
I need evidence*

# *Compression: nutab*

<i>split</i>	<i>table</i>	<i>value range</i>	<i>bits per item</i>	<i>storage + table</i>	<i>ucomp total</i>
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

<i>split</i>	<i>table</i>	<i>value range</i>	<i>bits per item</i>	<i>storage + table</i>	<i>ucomp total</i>
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	

Okay.



## *Compression: nctab*

No Compressed Table

## *Compression: nctab*

No Compressed Table:

- Top values are almost continuous

## *Compression: nctab*

### No Compressed Table:

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

## *Compression: nctab*

### No Compressed Table:

- Top values are almost continuous
- Swap values for continuous 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*

<i>note</i>	<i>diff</i>	<i>compressed word size</i>	<i>compressed table</i>	<i>uncompressed table</i>
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

$$2 * 9 * 4 * 2 * 2 = \mathbf{288} \text{ variations}$$

## *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*

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

## *Compression: compare methods*

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

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	
<b>; storage:</b>	<b>59.c</b>	<b>47.u</b>	<b>107.t</b>
<b>; table:</b>	<b>7.c</b>	<b>0.u</b>	<b>7.t</b>

Storage needed for tables:

- 7 bytes for compressed

## *Compression: compare methods*

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

Storage needed for tables:

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

## Compression: compare methods

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

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:  $107 + 5 + 7 = \text{120 bytes}$

## *Compression: compare methods*

We have histogram,  
estimation and  
data generator  
for all the  
**288**  
variations

# *Compression: compare methods*

The winner is...



# Compression: compare methods

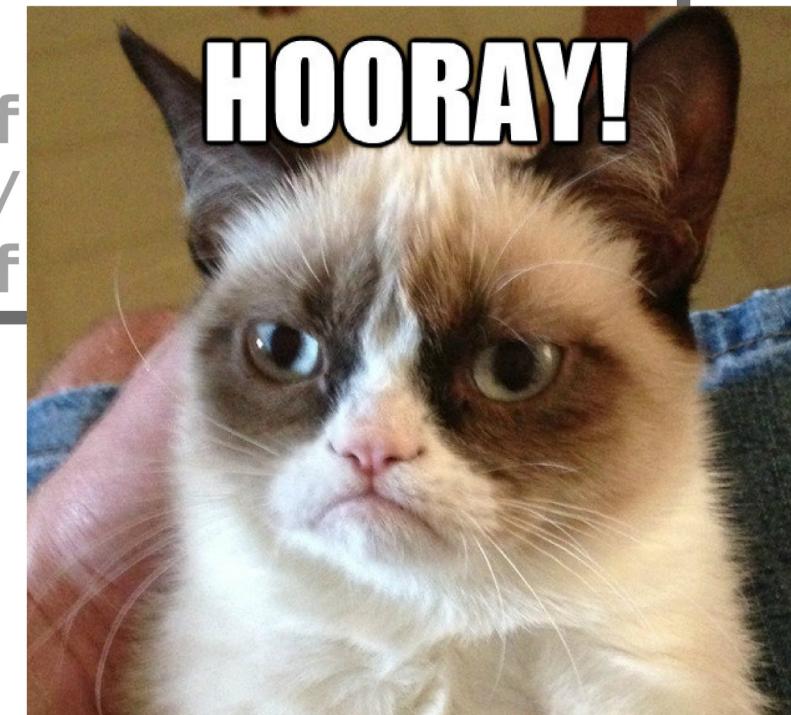
;	<b>raw-diff-mixed/1/5</b> @ 4 nctab nutab	=	114
;	<b>raw-diff-mixed/1/5</b> @ 3 nutab	=	117
;	<b>raw-diff-5</b> @ 3 nctab nutab	=	118
;	<b>raw-diff-5</b> @ 4 nctab nutab	=	118
;	<b>raw-diff-5</b> @ 3 nutab	=	120
;	<b>raw-diff-mixed/1/5</b> @ 4 nctab	=	122
;	<b>raw-diff-mixed/1/5</b> @ 4 nutab	=	124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



# 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          ; AI := 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_uncompre
```

```
    mov bl,DATA_CSUB
```

```
    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 #####
; 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

# 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 #####
; 6. -07 11 148 #####
; 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

# 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 #####
; 9. -04 5 170 #####
; 7. -03 11 159 #####
; 8. +05 6 165 #####
; 6. -07 11 148 #####
; 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      -04: 5 notes

---

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

```
load_play_note:
```

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

```
    mov ax,$2000          ; AI := 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_uncompre
```

```
    mov bl,DATA_CSUB
```

```
    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_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

```

**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 ; 4
    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 marker (%000),  
the word is almost ok (later)  
If it's a SPEC marker...

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

```

load_play_note:
    mov bl, DATA_CSUB ; DATA_CSUB = 4
@next_bit:
;word
    jnz @adjust_word
    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_bit
@read_bit:
    or cl,cl
    jnz @shift_latch
    ...it works as shift counter as well.
;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_bit
;word_read:
    or al,al
    jnz @adjust_word
;load_uncompressed:
    mov bl,DATA_USUB
    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_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

```

**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
    jz @shift_latchn
;load:
    in al,bl
    mov bl,al
    jz @shift_latchn
    Shift latch counter (CL) and value (CL)
    Latch value is shifted to CF, copied to AL
@shift_latchn:
    sal ax,1
    sal cx,1
    adc al,0
    jmp @next_bit
@adjust_word:
    sub al,bl

```

Shift latch counter (CL) and value (CL)  
 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 subtracted from it

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

*cont...*