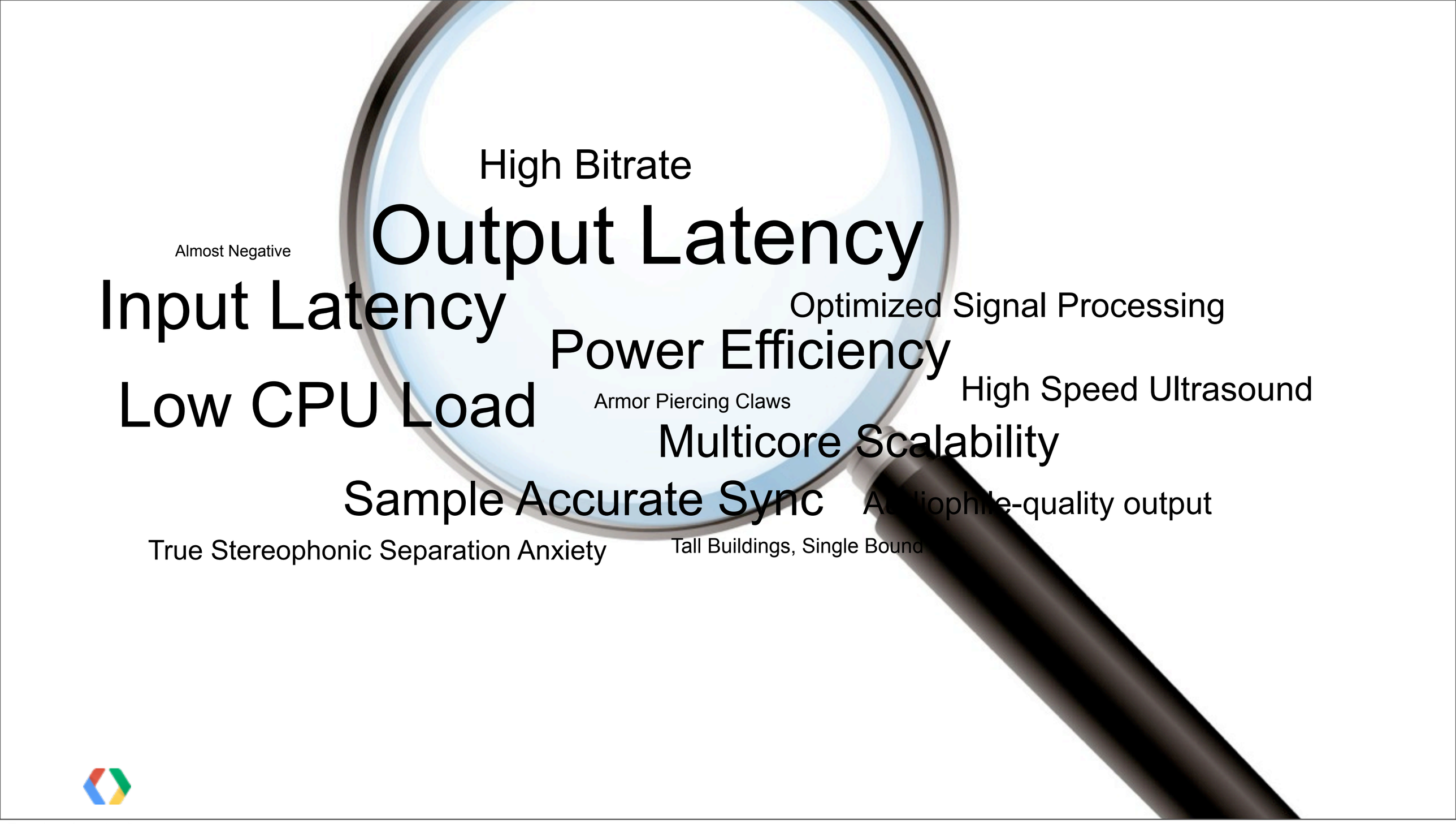
Google Developers

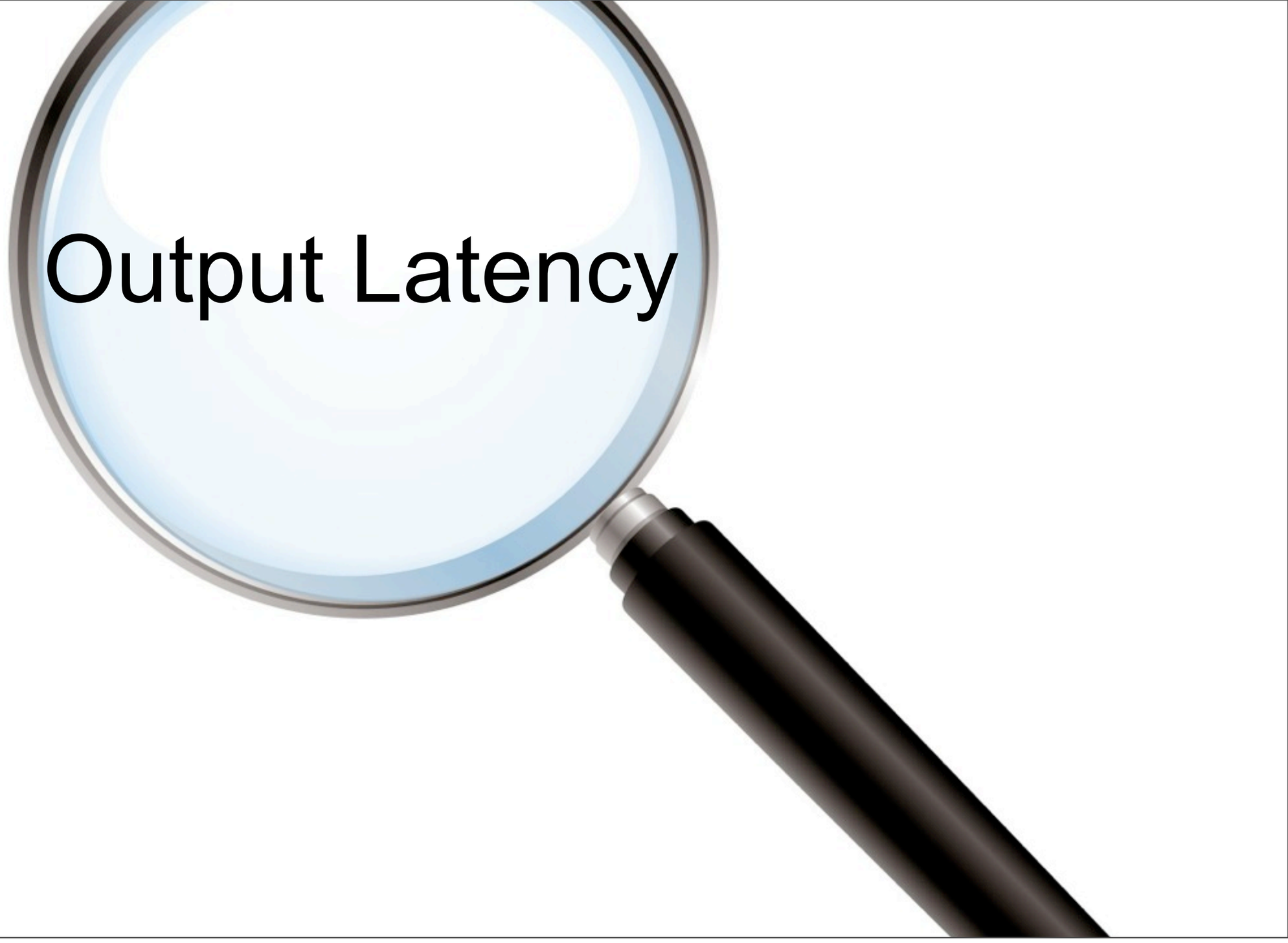
Google I/O 13

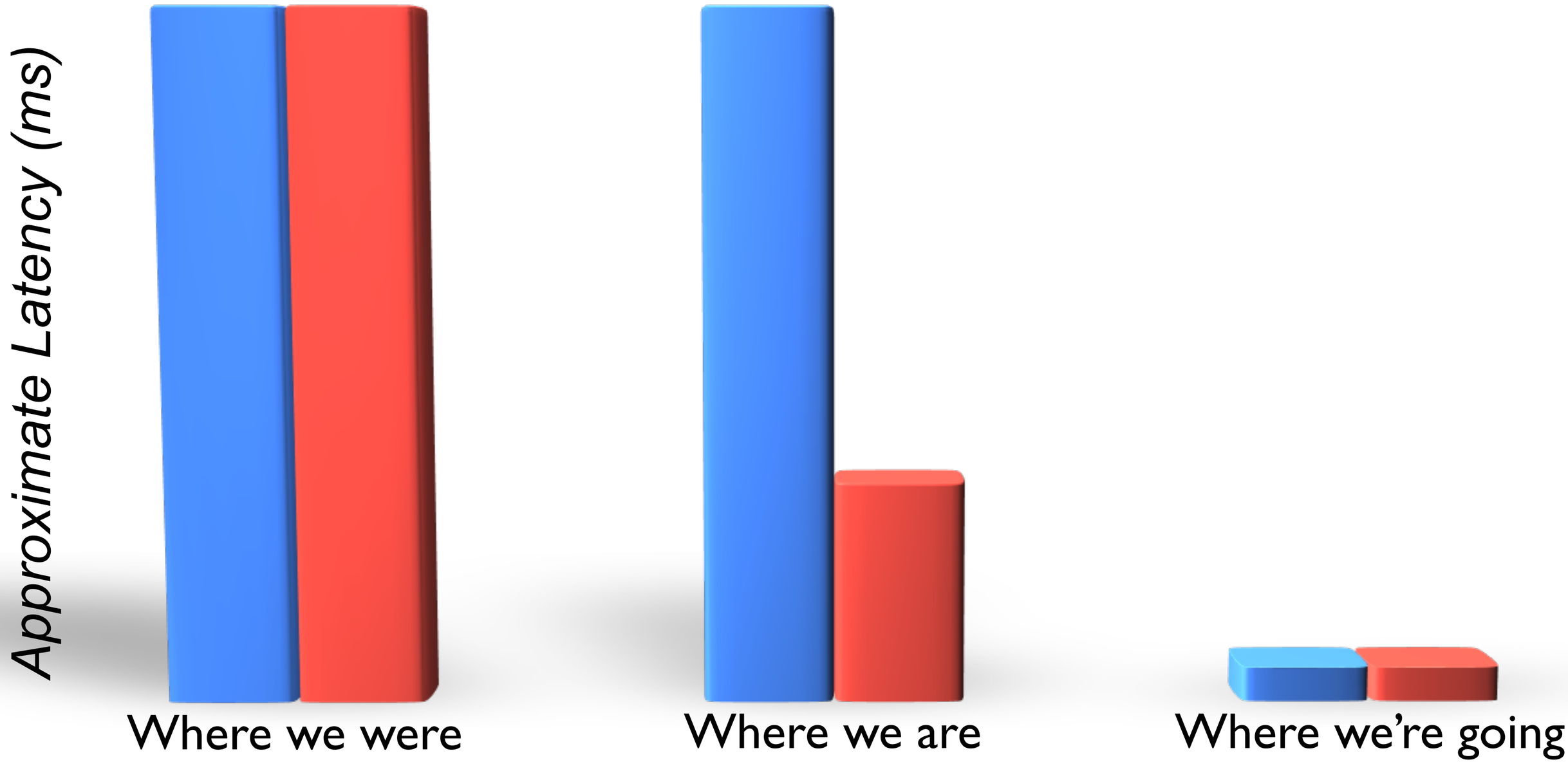
High Performance Audio on Android

Glenn Kasten, Raph Levien, Ian Ni-Lewis


High Bitrate
Output Latency
Almost Negative
Input Latency
Optimized Signal Processing
Power Efficiency
High Speed Ultrasound
Low CPU Load
Armor Piercing Claws
Multicore Scalability
Sample Accurate Sync
Audiophile-quality output
True Stereophonic Separation Anxiety
Tall Buildings, Single Bound

Output Latency




Approximate Latency (ms)
Where we were
Where we are
Where we're going

The Story

The Story

National Cancer Institute/Wikimedia Commons

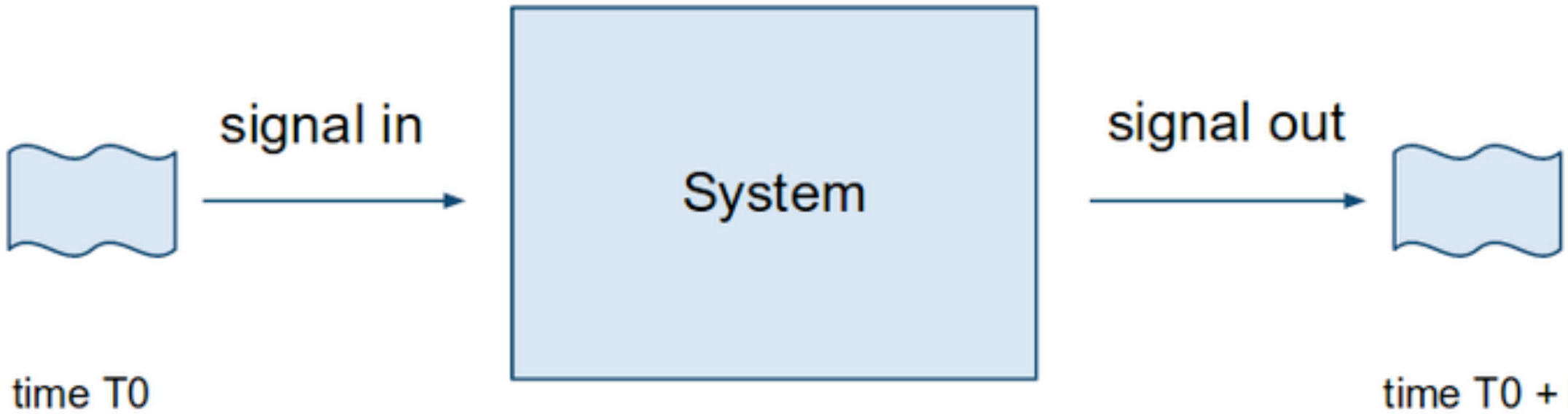
The latency

is too darn high

The latency

is too darn high

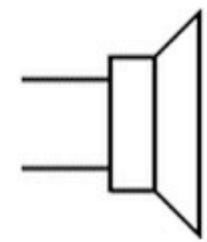
(ISSUE 3434)


signal in
System
signal out
time T0
time T0 + L

App

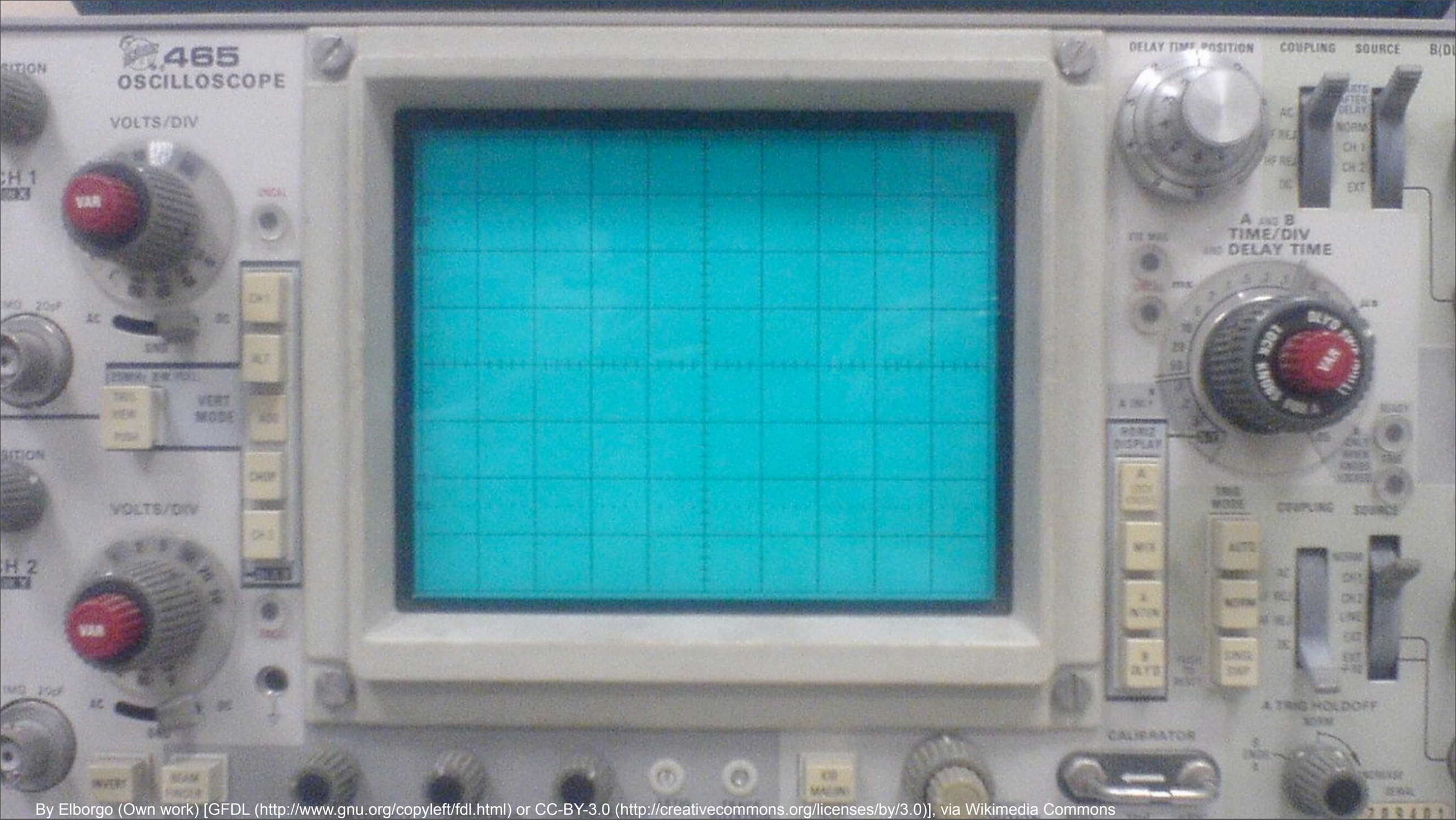
```
AudioTrack at = ...;
short[] data = ...;
for (int i = 0; i < data.length; ++i)
  short[i] = (i * 1000) % 10000 - 5000;
at.write(data, 0, data.length);
```

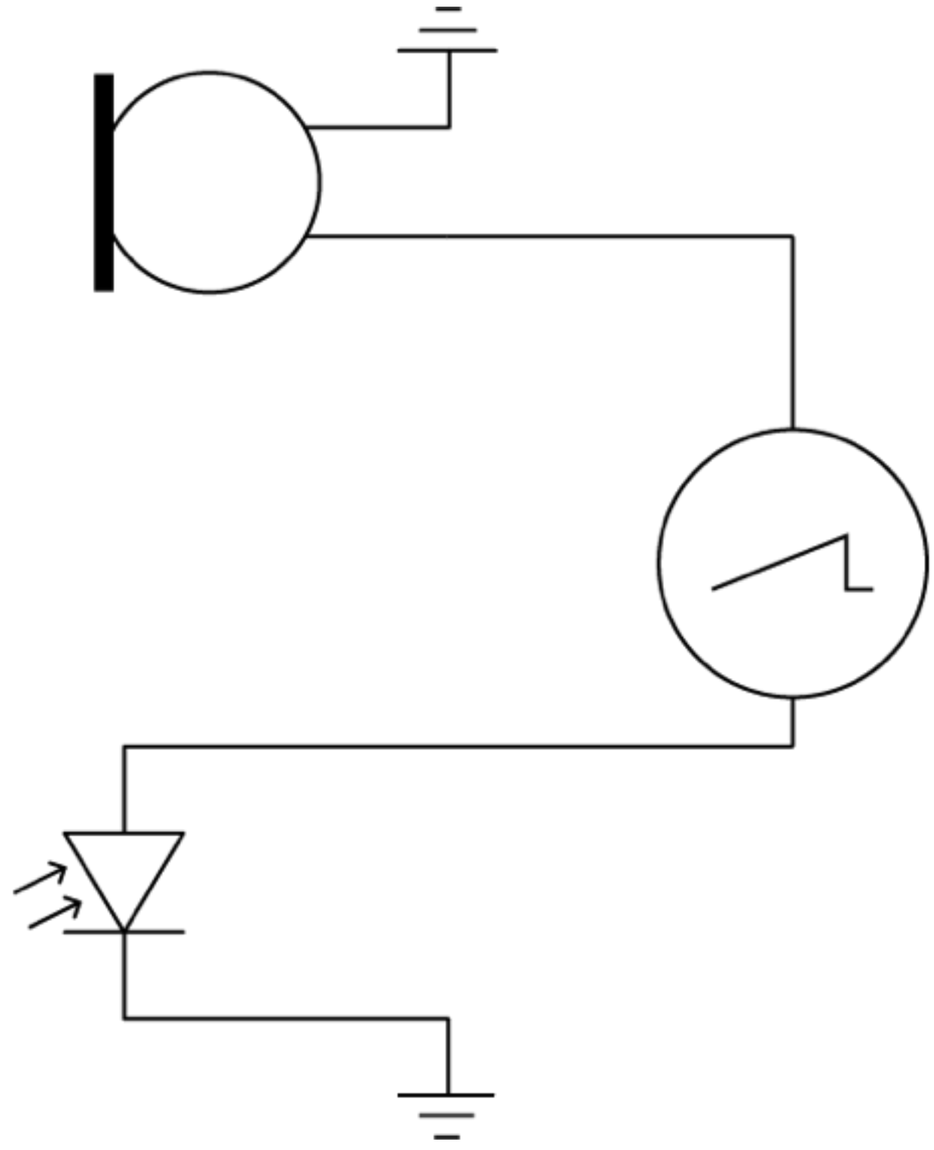
Android device



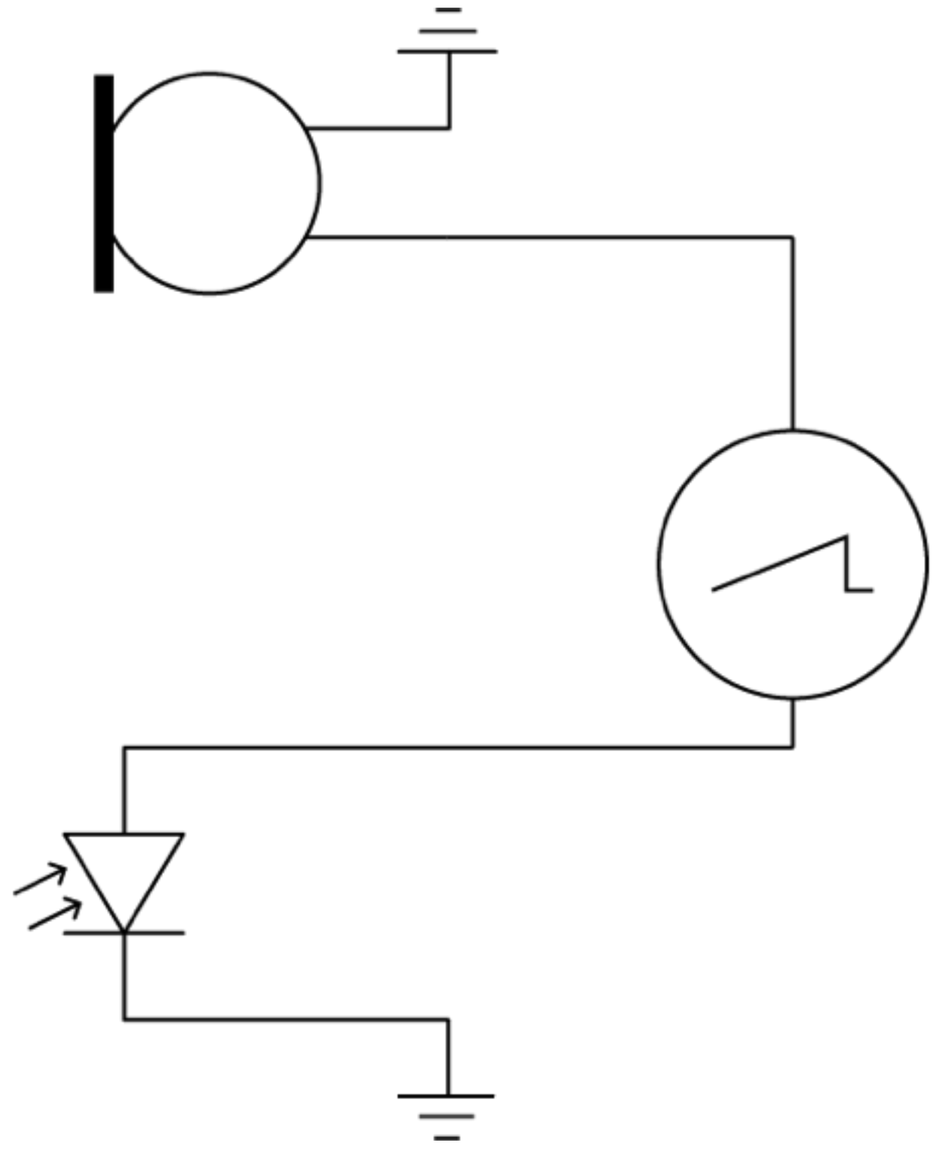
sound

speaker





photodiode: Omegatron/Wikimedia Commons
Microphone: J.P. Lon / Wikimedia Commons
Oscilloscope: MovGPO / Wikimedia Commons (de)
Galaxy Nexus: R. Nurik, I. Ni-Lewis / Google



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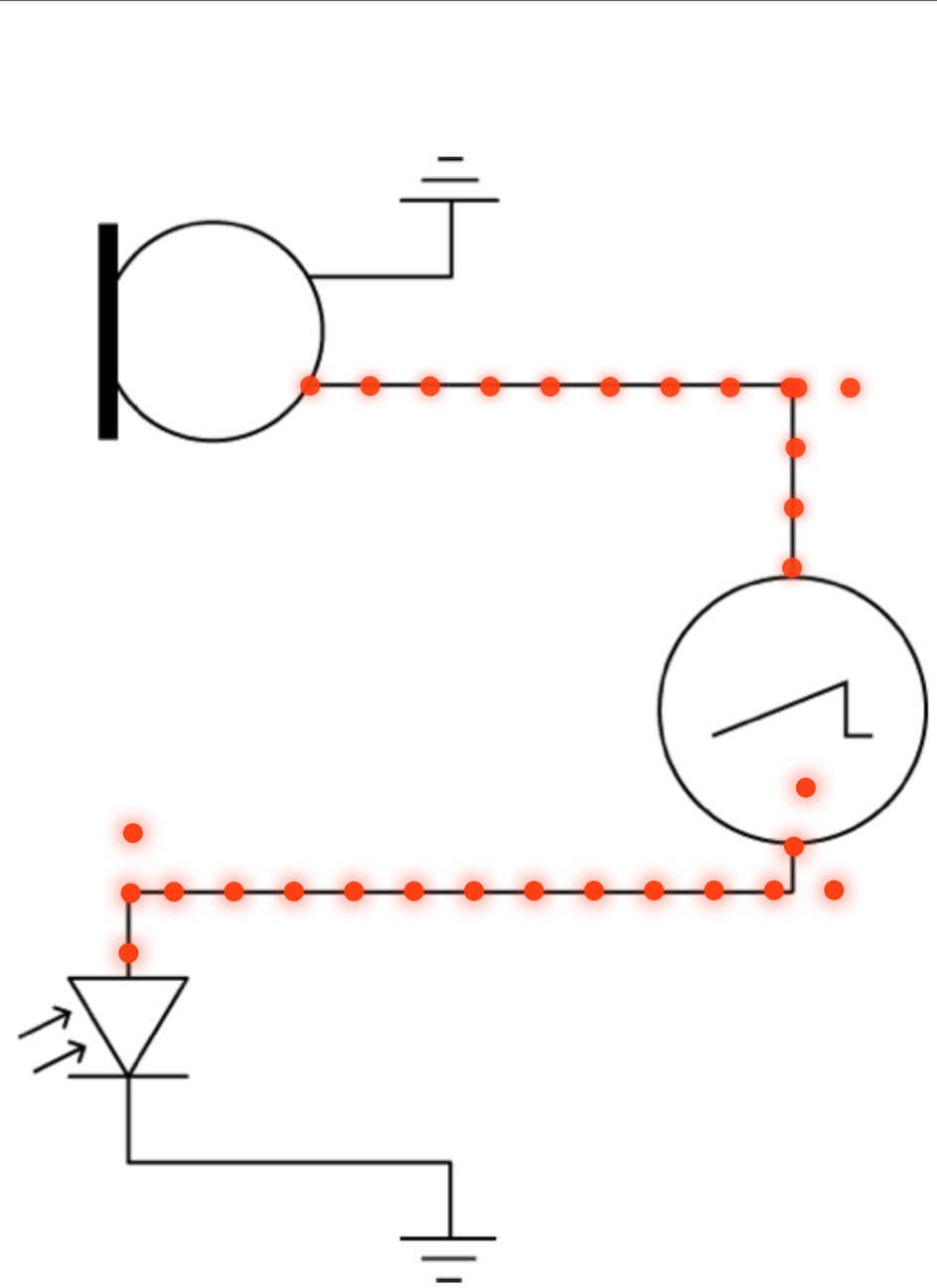
Galaxy Nexus: R. Nurik, I. Ni-Lewis / Google



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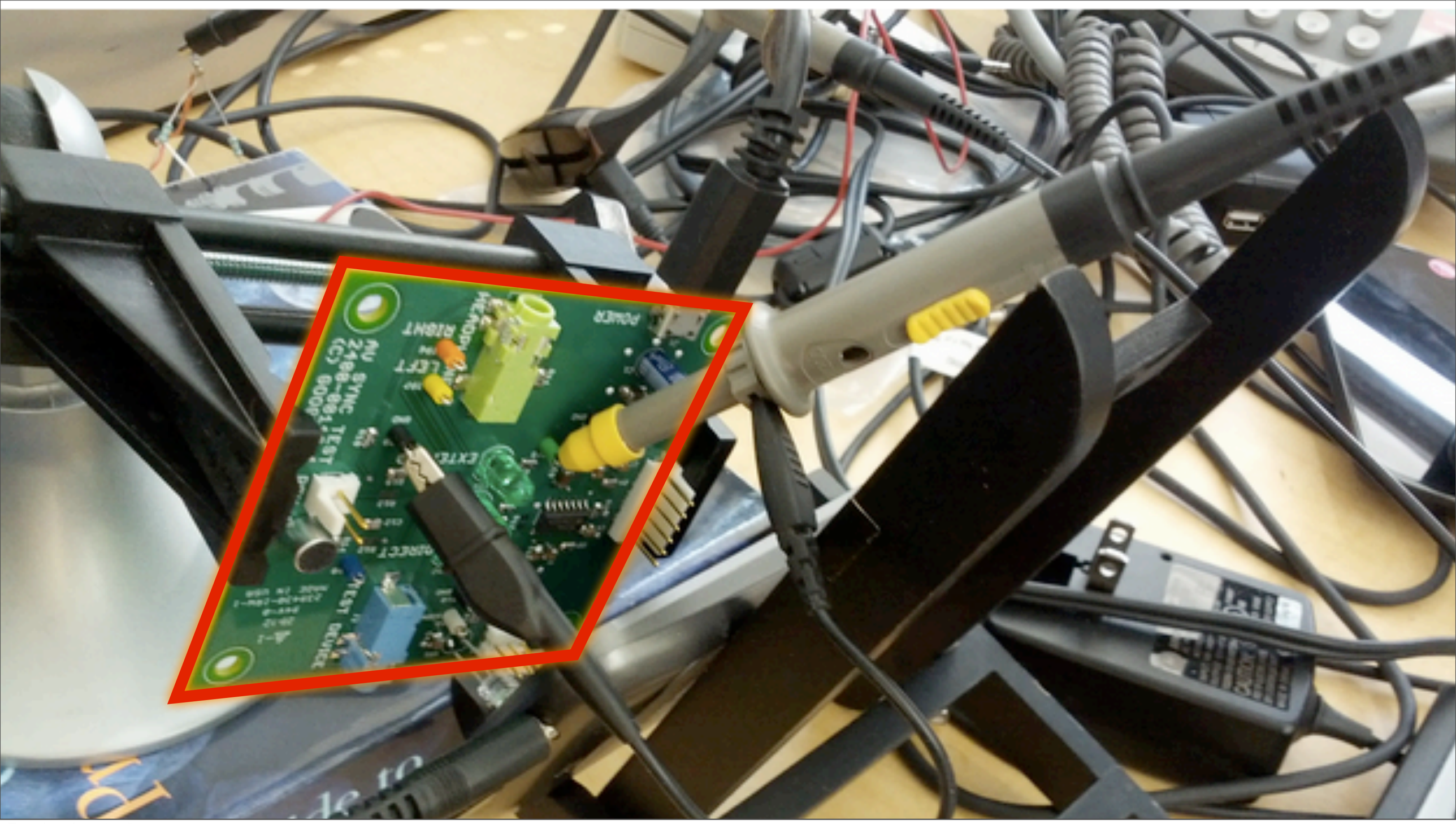
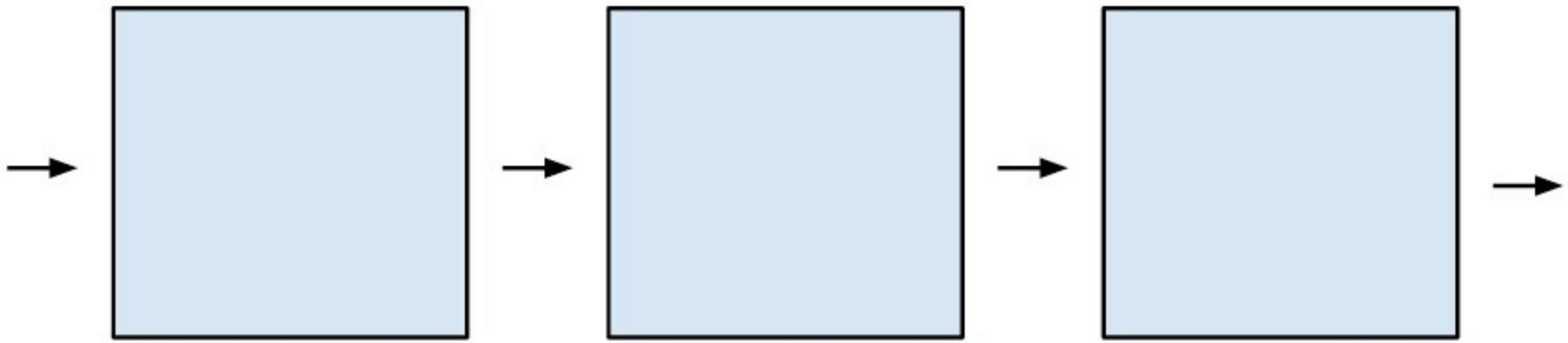
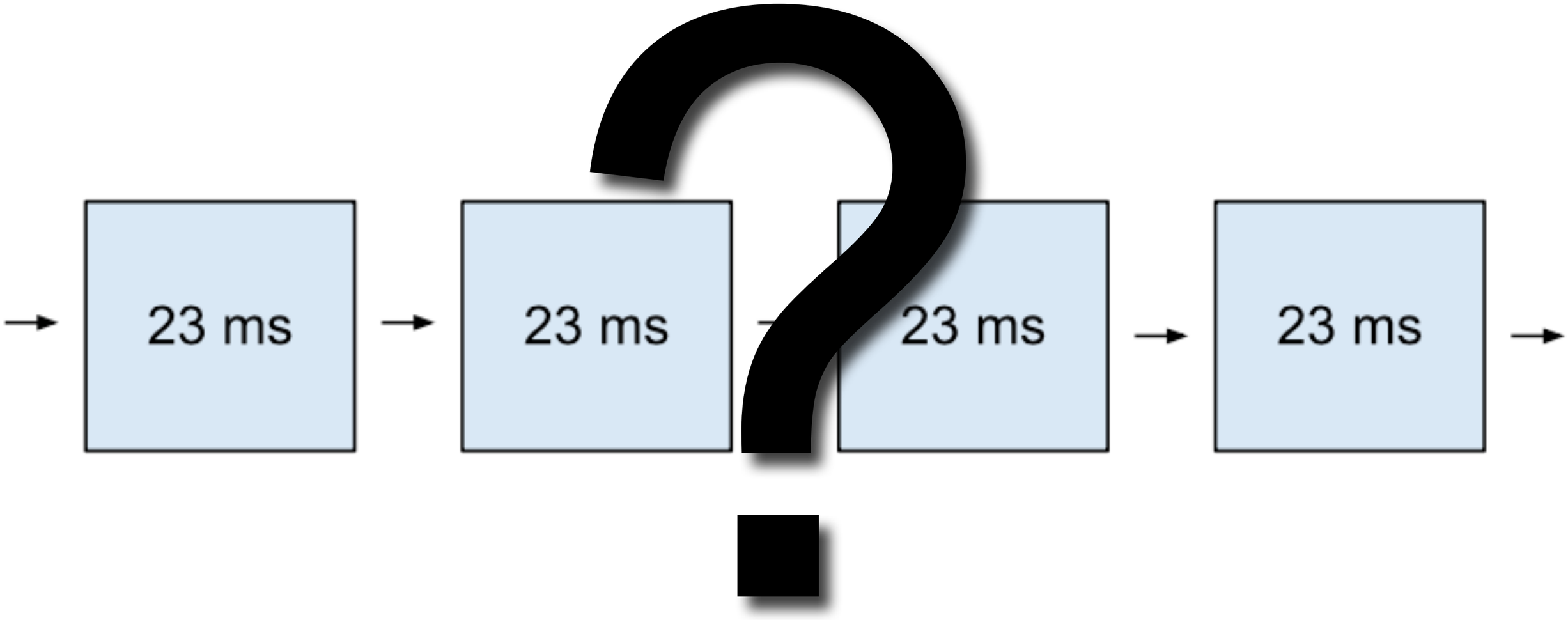
Galaxy Nexus: R. Nurik, I. Ni-Lewis / Google



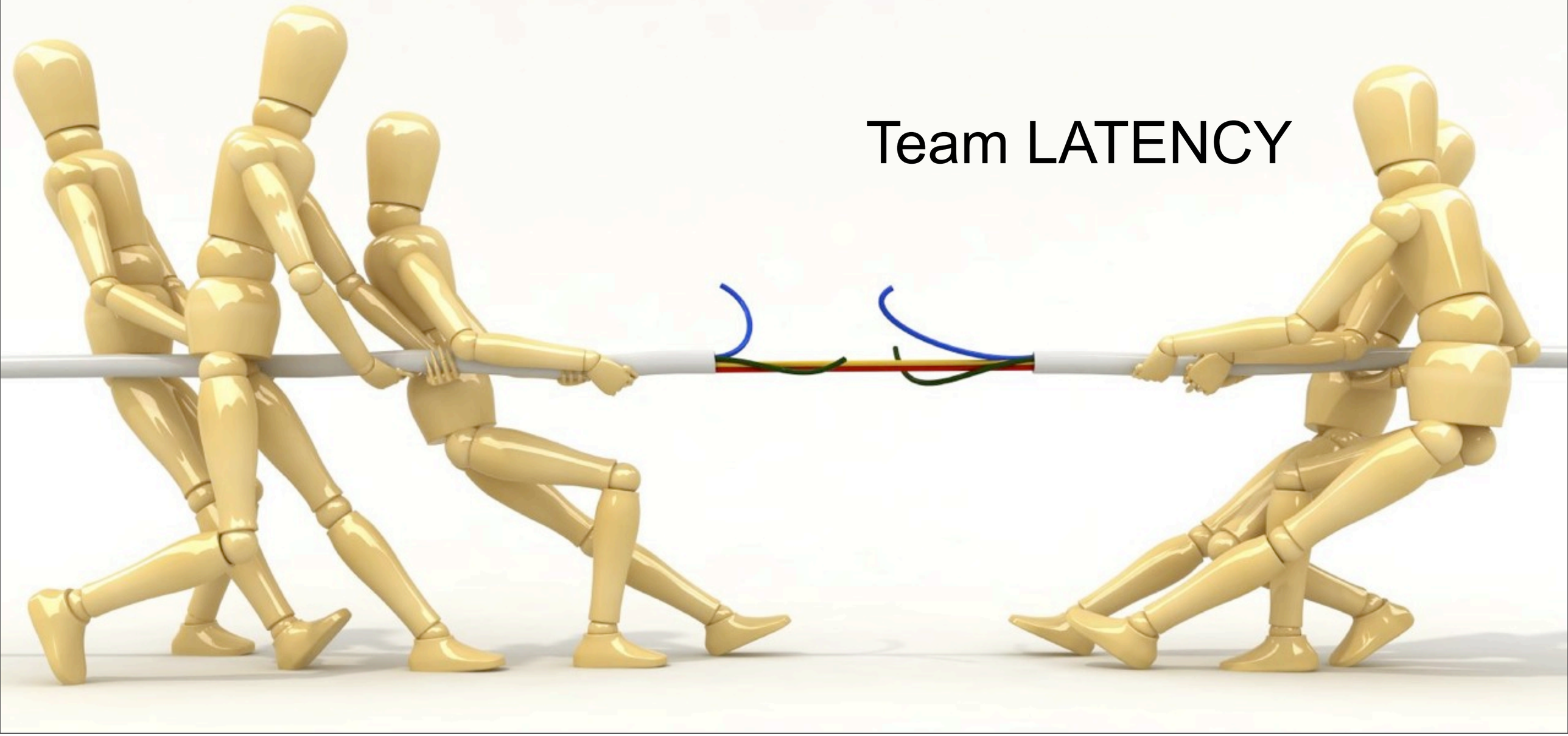
DS1102E
DIGITAL OSCILLOSCOPE
2 Channel
100MHz 1GSa/s
RIGOL
STOP
164mV
MENU
ON/OFF
MAT
REF

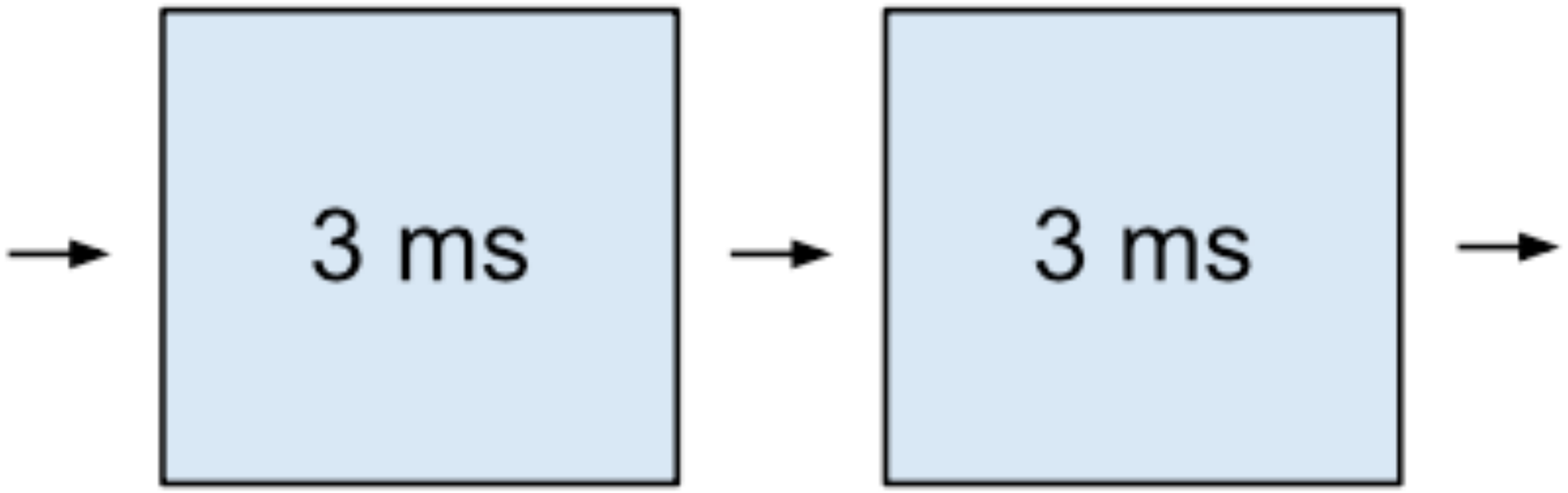



23 ms
23 ms
23 ms
23 ms

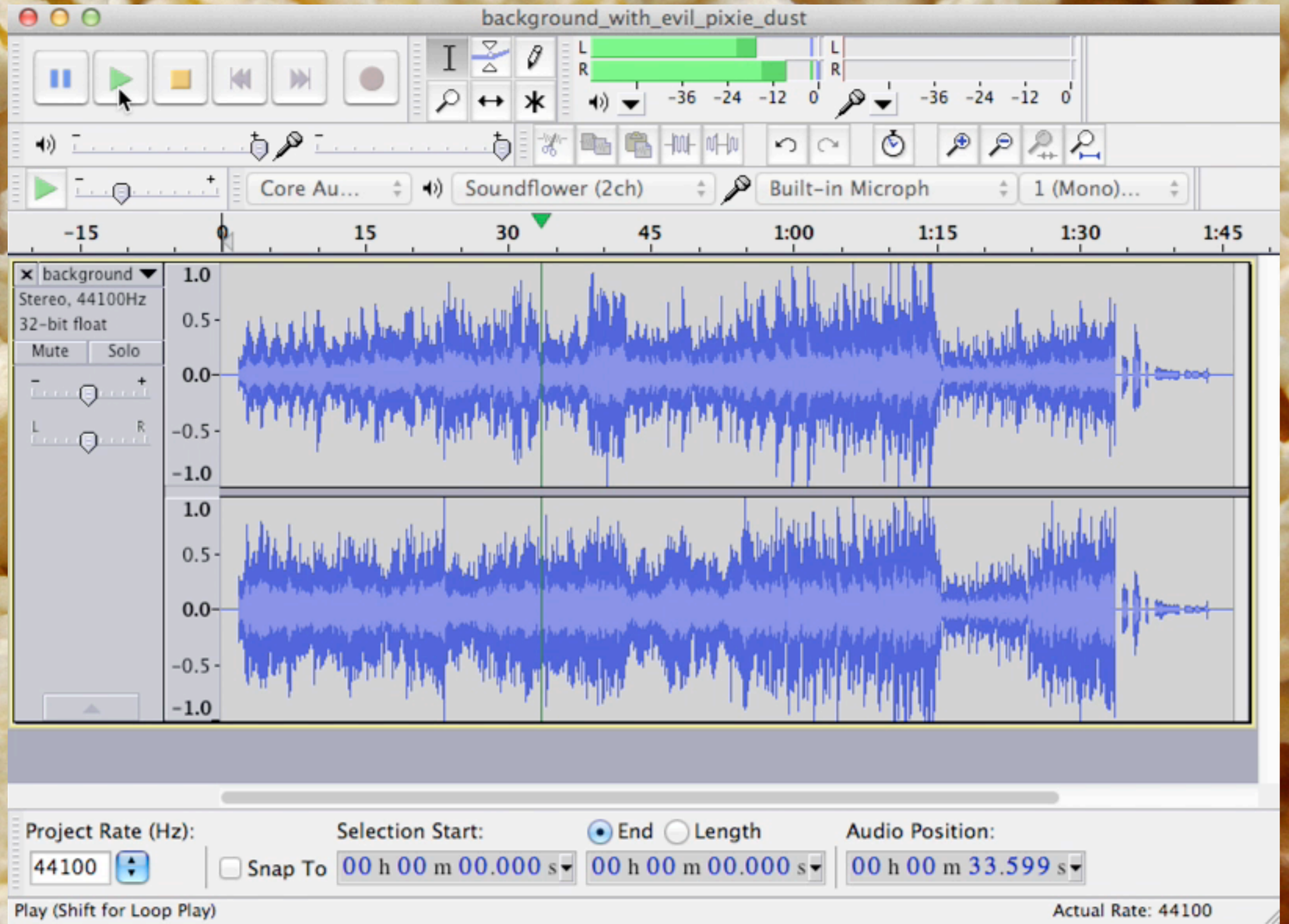
Team POWER

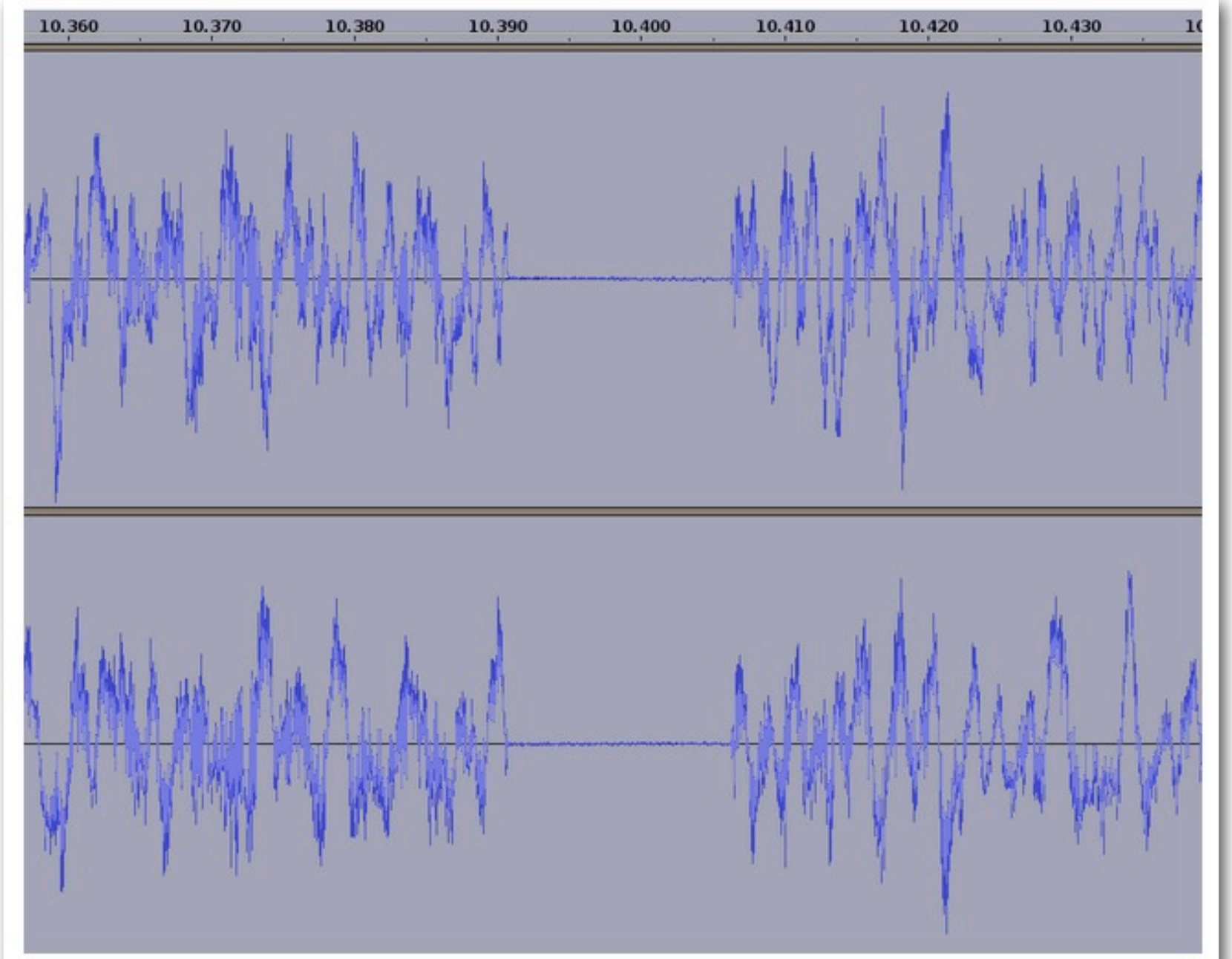
Team LATENCY

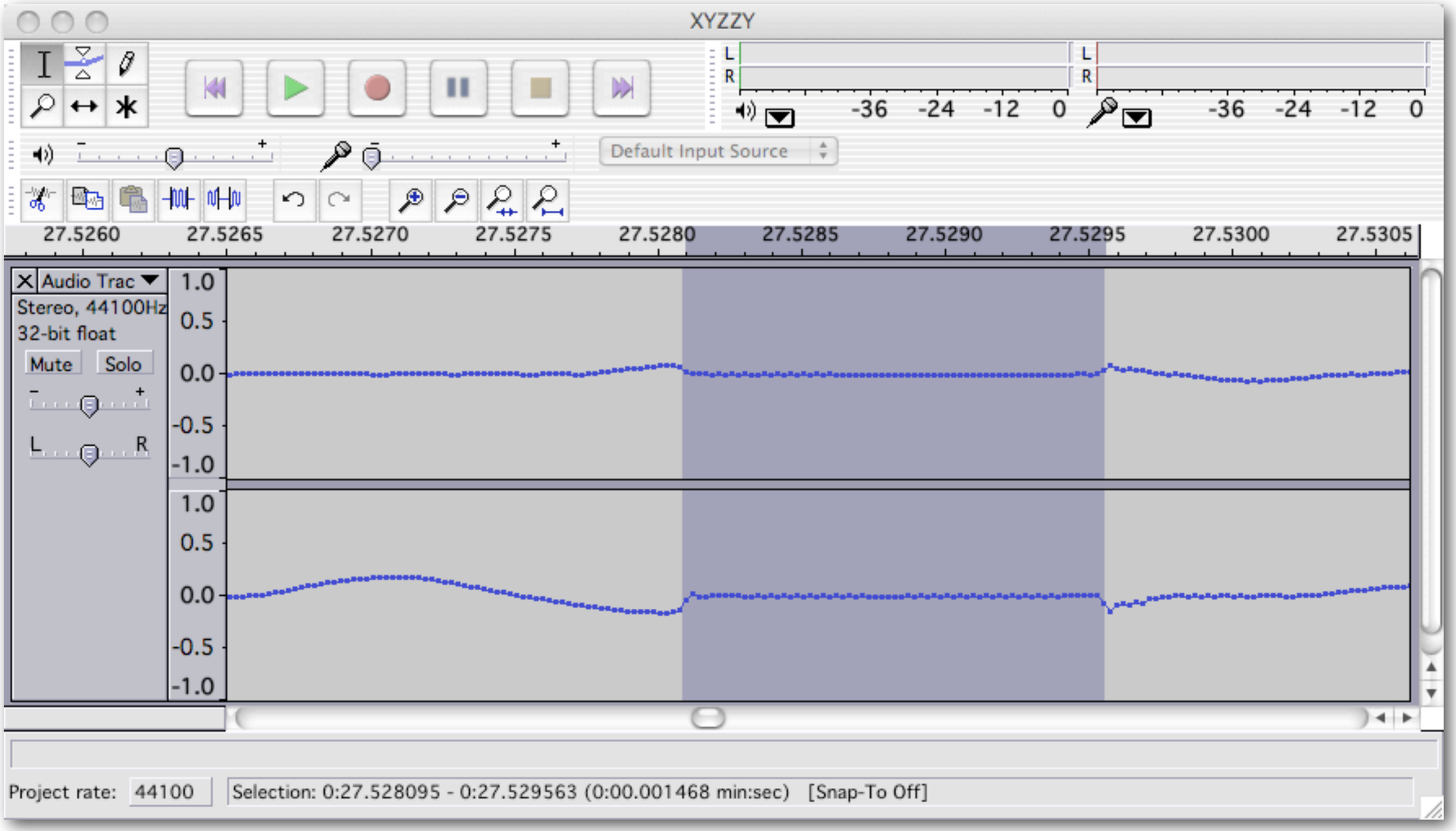


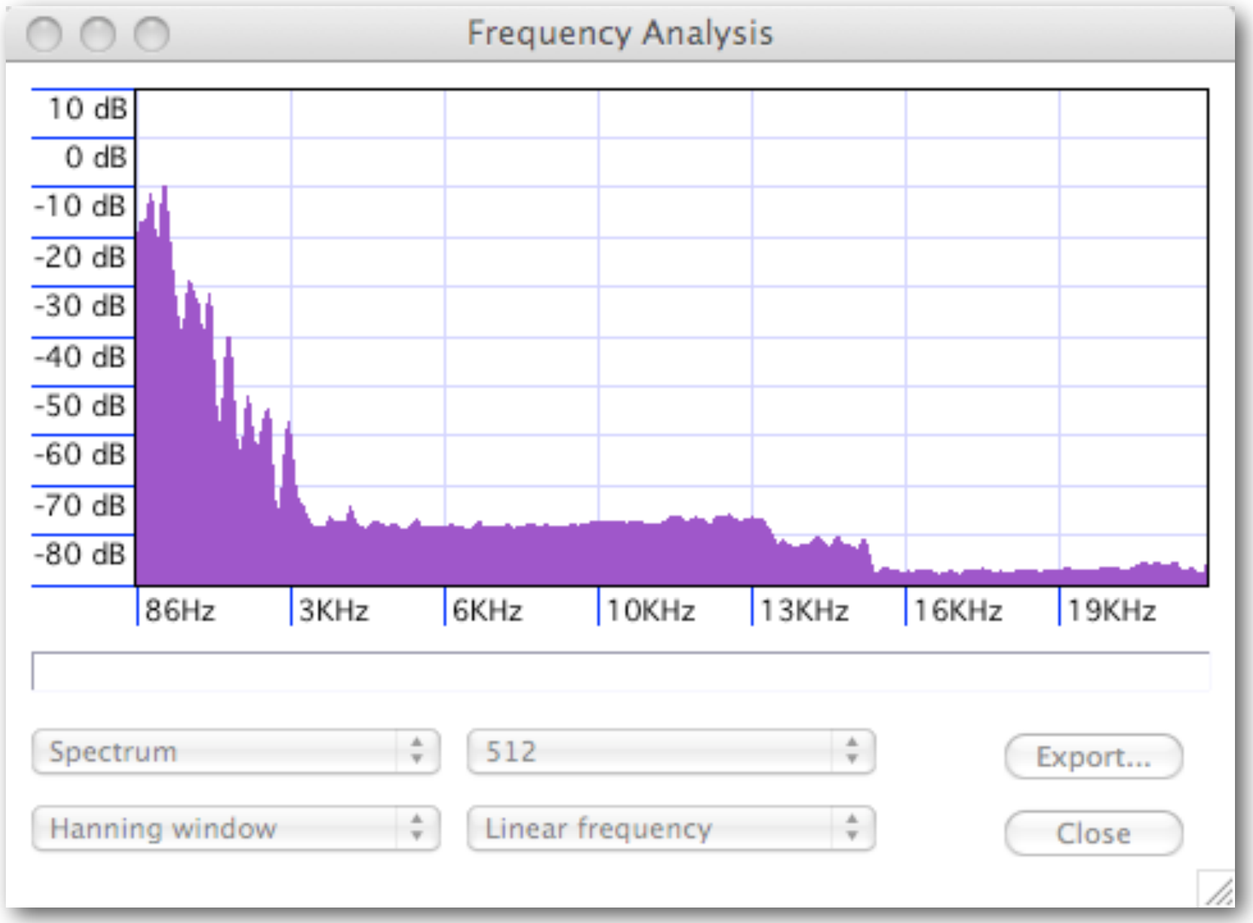

3 ms
3 ms


fir0002 | flagstaffotos.com.au

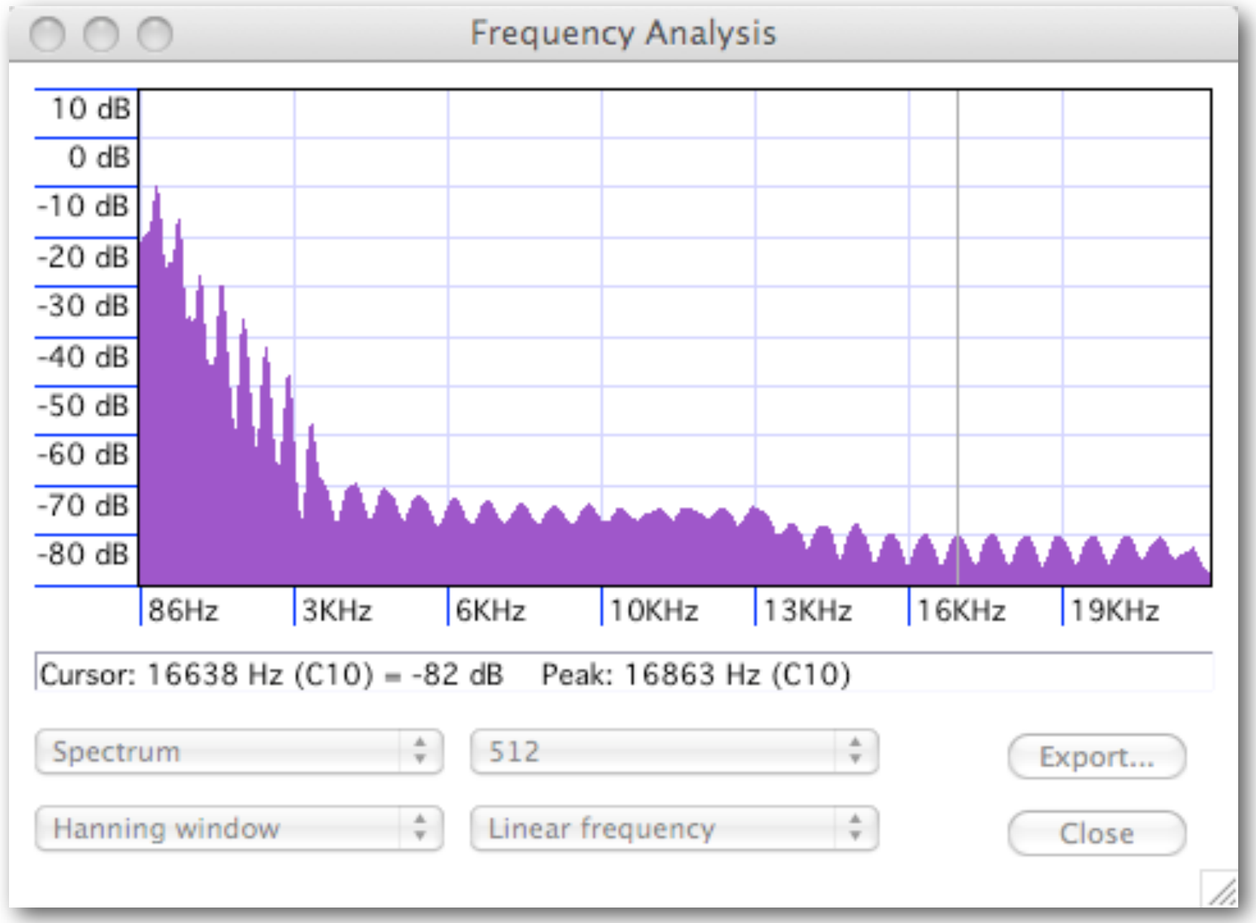



10.360
10.370
10.380
10.390
10.400
10.410
10.420
10.430


XYZZY
L
R
-36
-24
-12
0
Default Input Source
27.5260
27.5265
27.5270
27.5275
27.5280
27.5285
27.5290
27.5295
27.5300
27.5305
Audio Trac
Stereo, 44100Hz
32-bit float
Mute
Solo
L
R
1.0
0.5
0.0
-0.5
-1.0
Project rate:
44100
Selection: 0:27.528095 - 0:27.529563 (0:00.001468 min:sec) [Snap-To Off]


Frequency Analysis
10 dB
0 dB
-10 dB
-20 dB
-30 dB
-40 dB
-50 dB
-60 dB
-70 dB
-80 dB
86Hz
3KHz
6KHz
10KHz
13KHz
16KHz
19KHz
Spectrum
512
Export...
Hanning window
Linear frequency
Close

Good


Frequency Analysis
10 dB
0 dB
-10 dB
-20 dB
-30 dB
-40 dB
-50 dB
-60 dB
-70 dB
-80 dB
86Hz
3KHz
6KHz
10KHz
13KHz
16KHz
19KHz
Cursor: 16638 Hz (C10) = -82 dB Peak: 16863 Hz (C10)
Spectrum
512
Export...
Hanning window
Linear frequency
Close

Bad

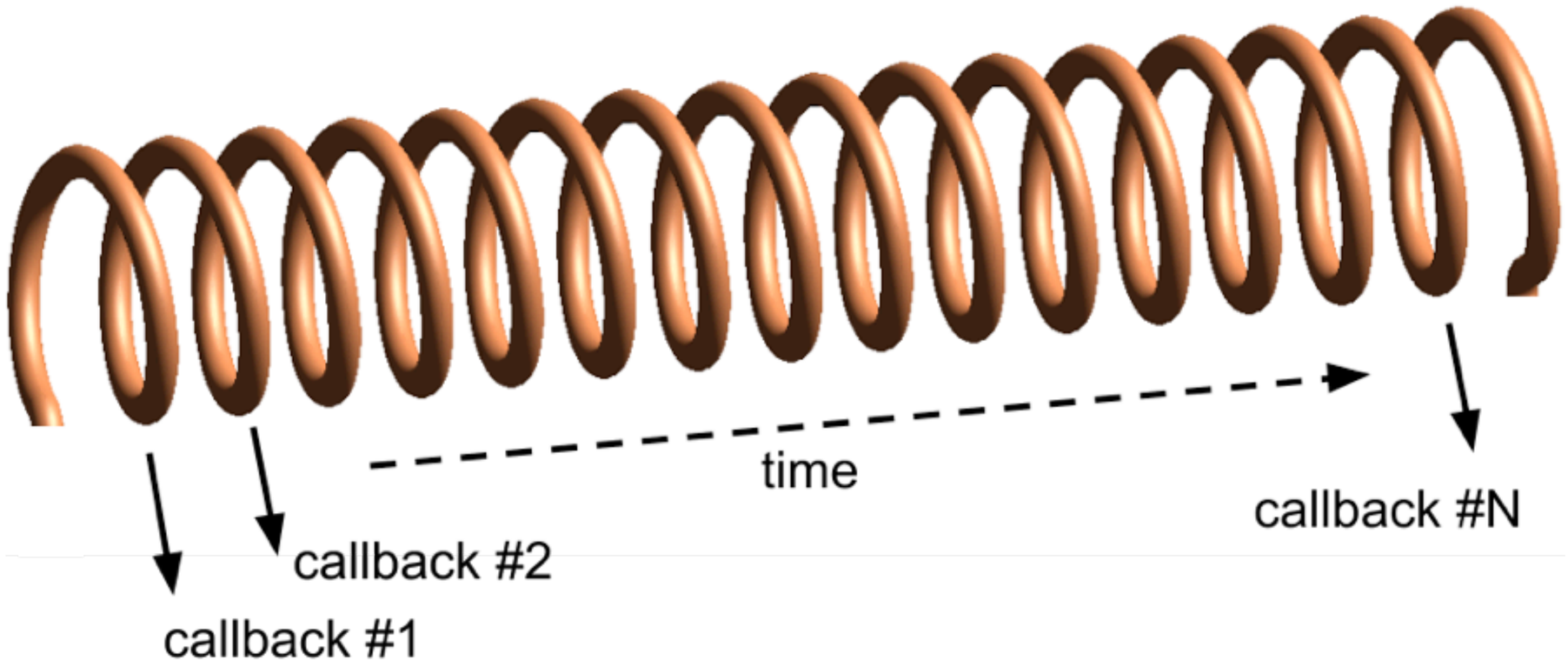

Extra Long
BUFFERING
BATTERY EXTENDER

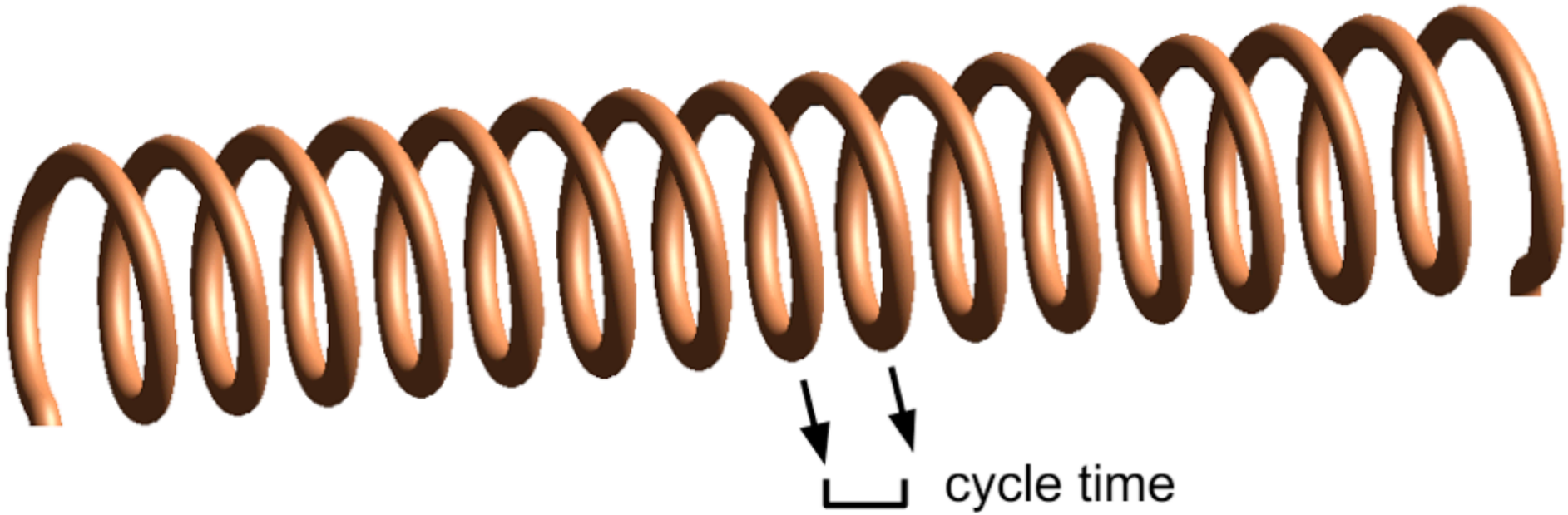
Extra Long

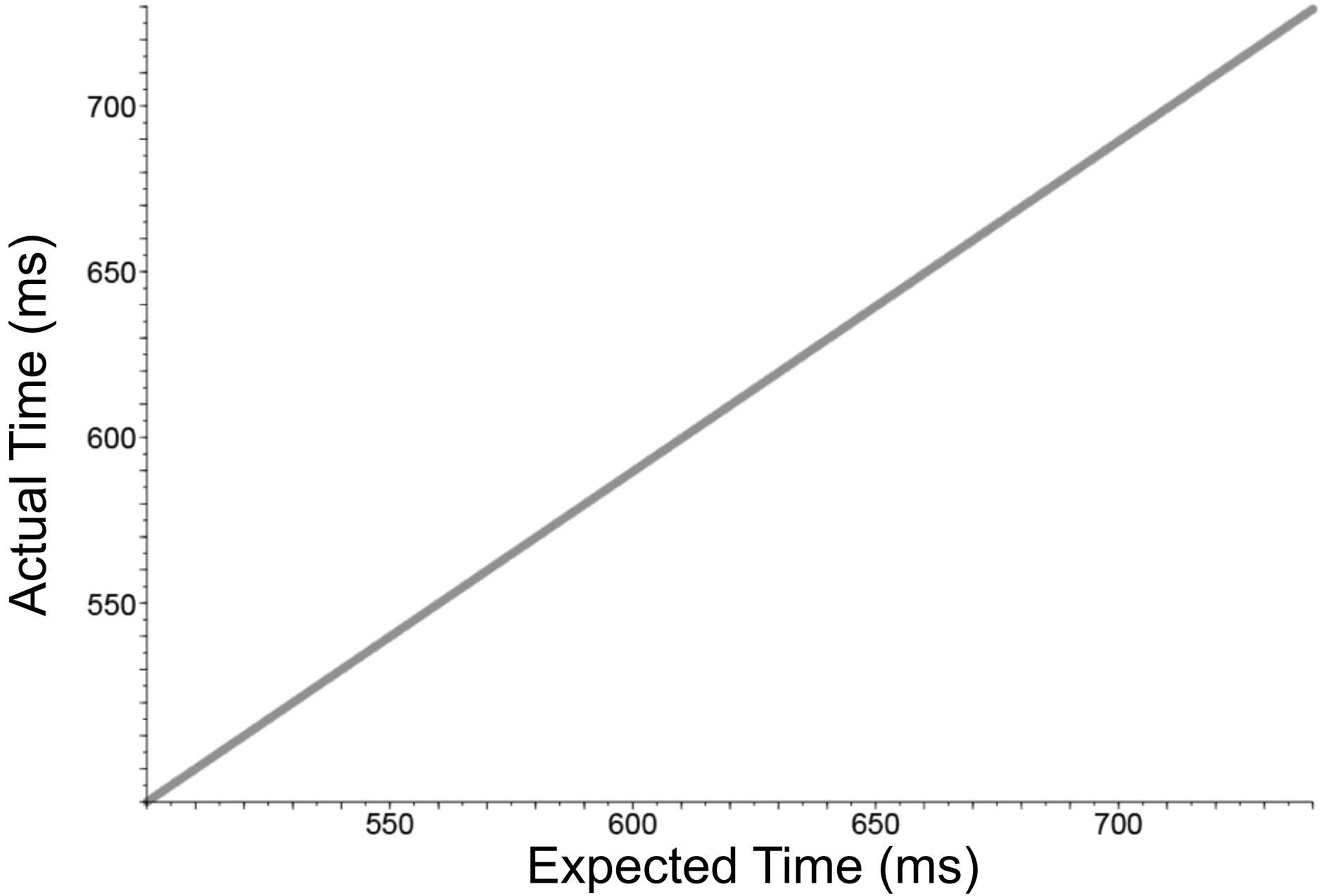
BUFFERING

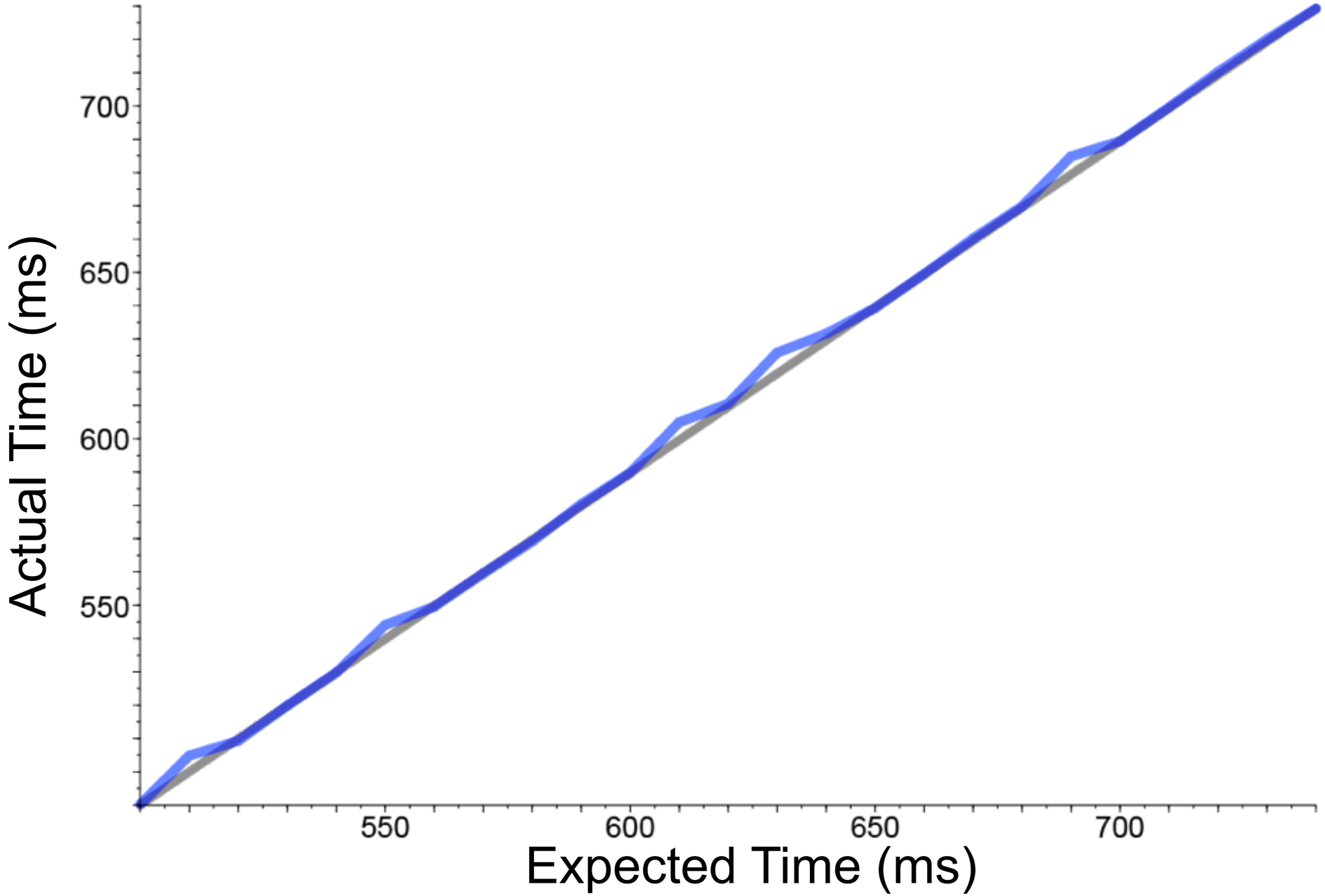
BATTERY EXTENDER * GLITCH REDUCER

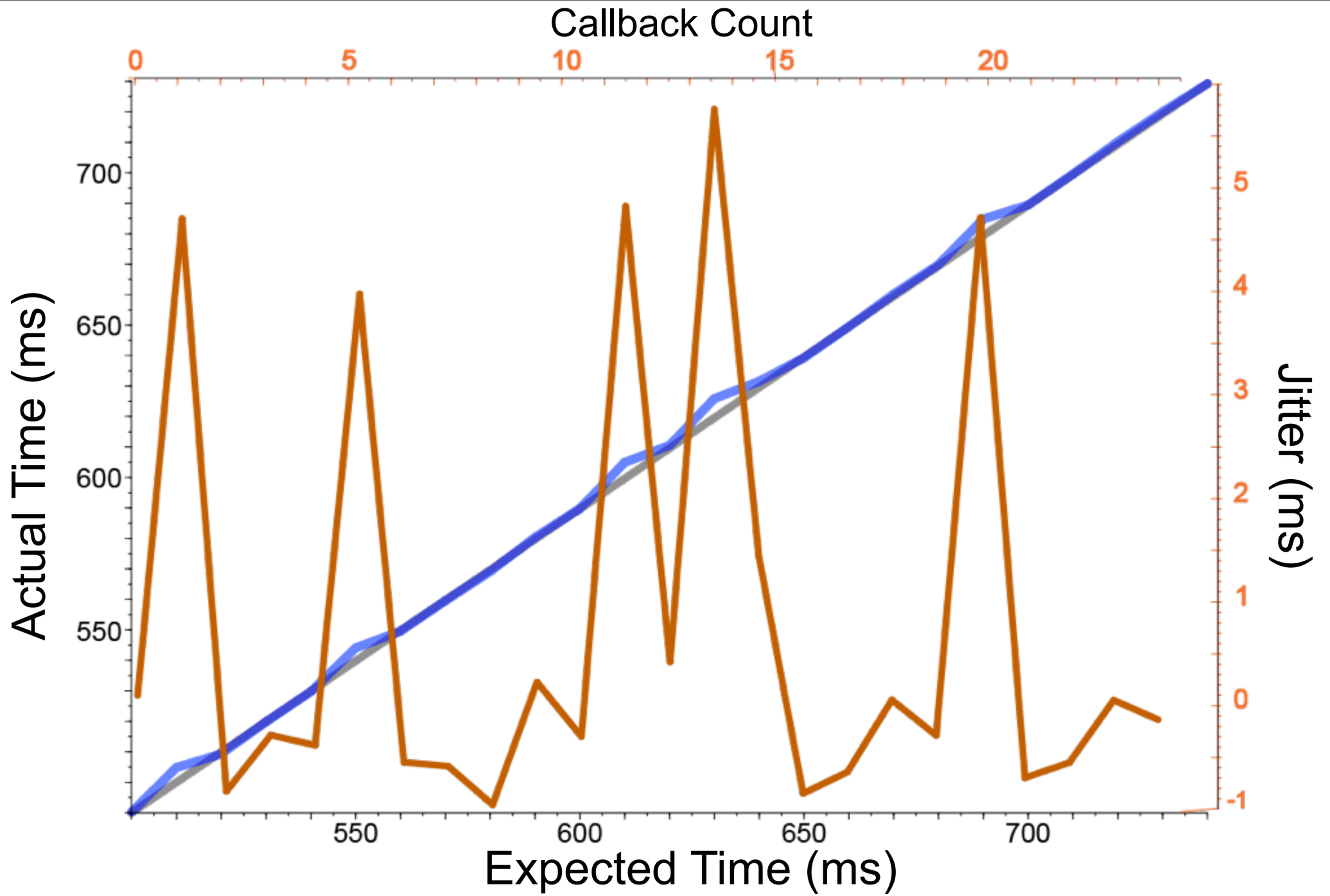
```
OpenSL_callback() {
  start_time = clock_gettime(CLOCK_MONOTONIC);
  calculate one buffer full of audio
  end_time = clock_gettime(CLOCK_MONOTONIC);
  buffer_queue->Enqueue();
  log start_time and end_time
}
```

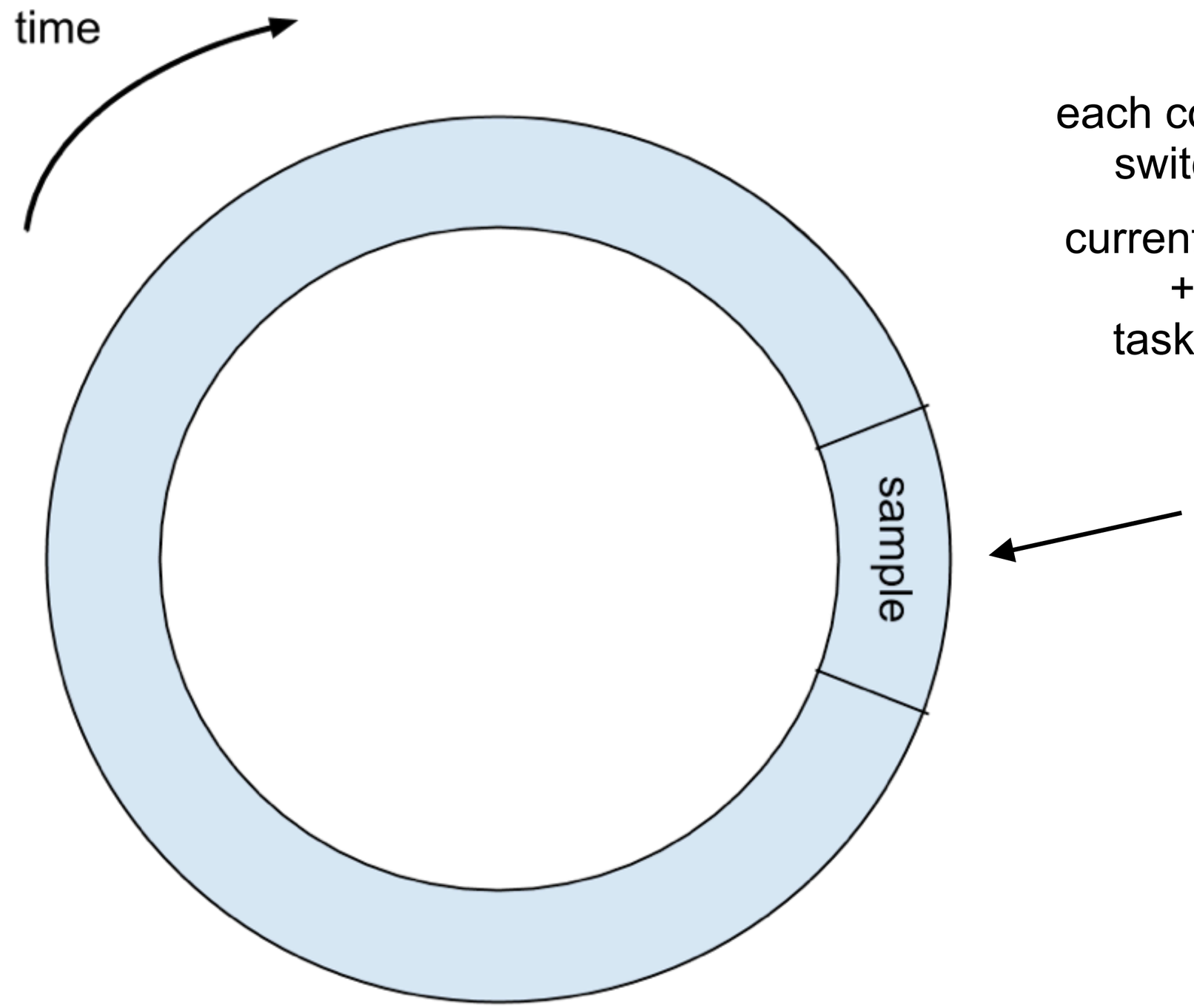

time
callback #N
callback #2
callback #1


cycle time


Actual Time (ms)
700
650
600
550
550
600
650
700
Expected Time (ms)


Actual Time (ms)
700
650
600
550
550
600
650
700
Expected Time (ms)

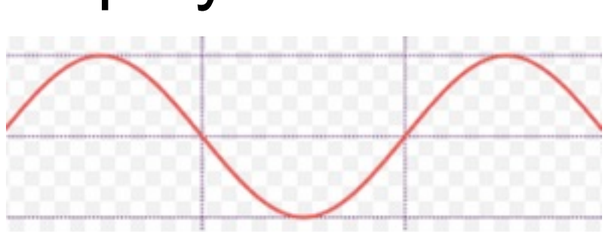

Callback Count
0
5
10
15
20
Actual Time (ms)
700
650
600
550
Jitter (ms)
5
4
3
2
1
0
-1
550
600
650
700
Expected Time (ms)



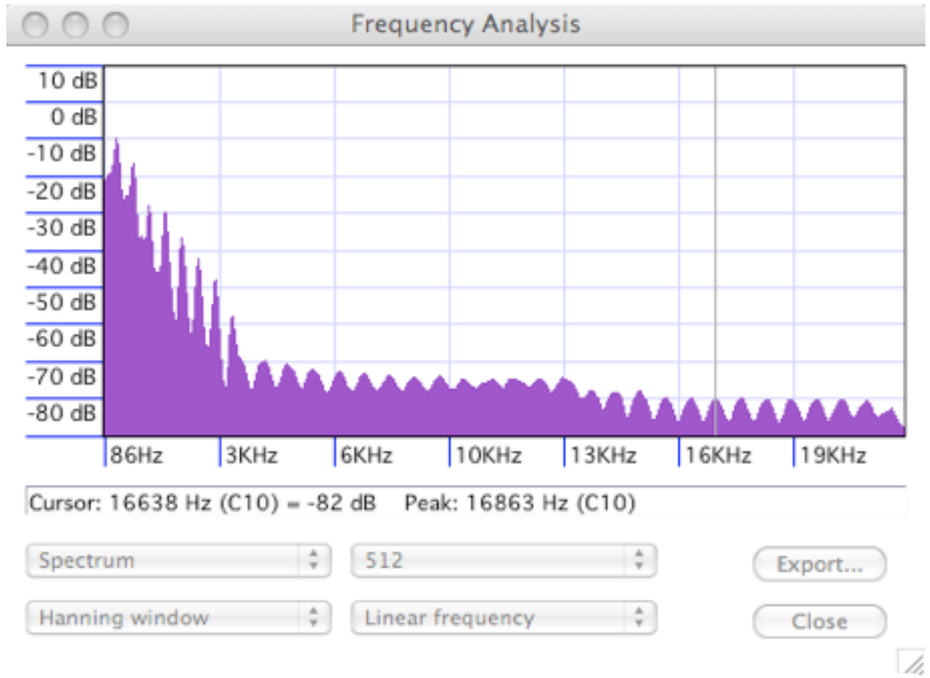
each context switch:

current time
+
task ID

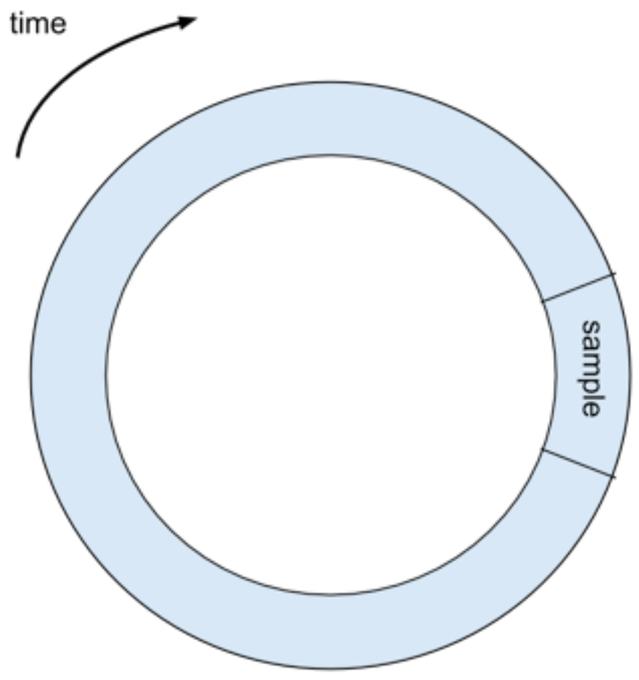
play audio



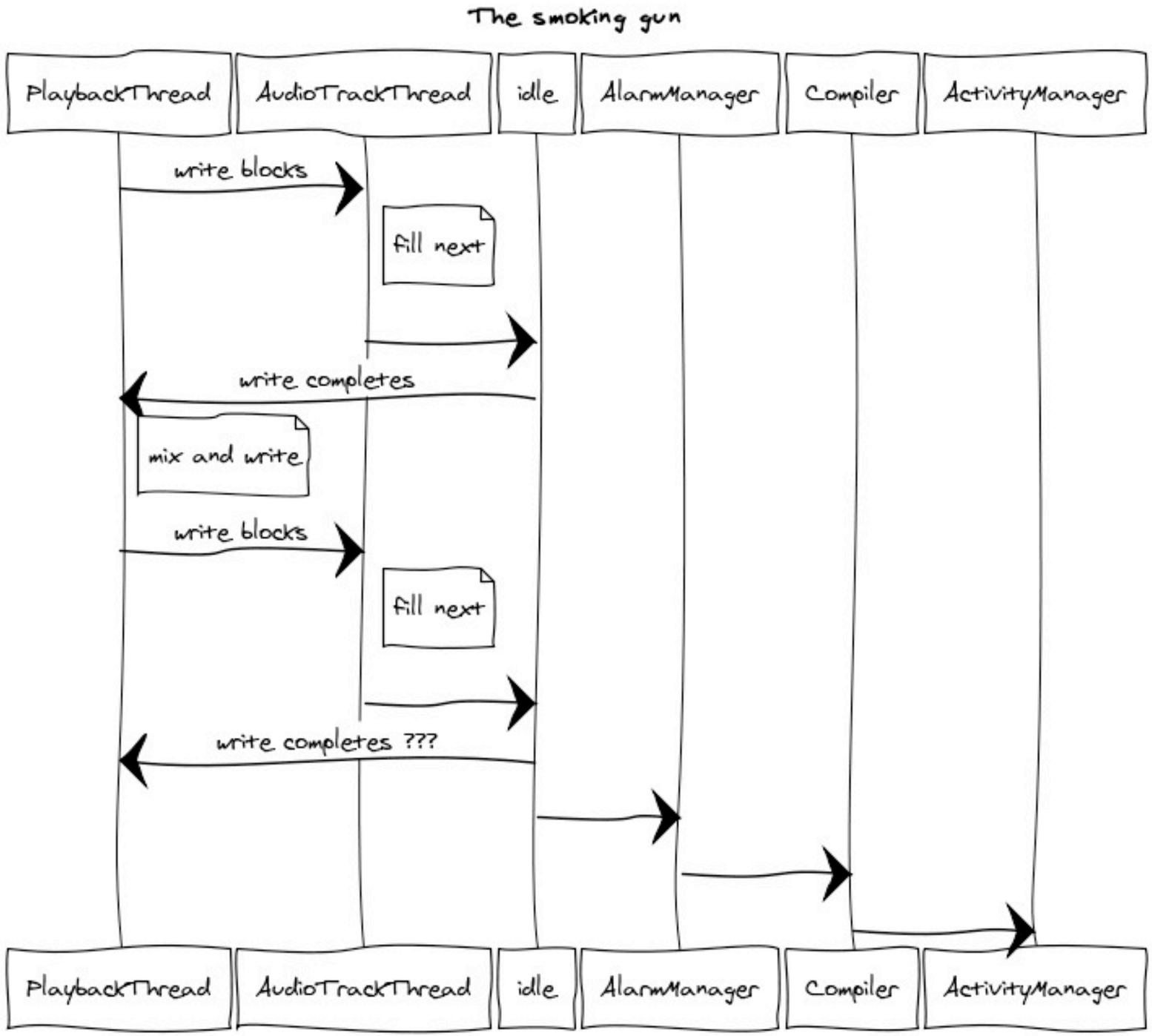
listen for
underruns

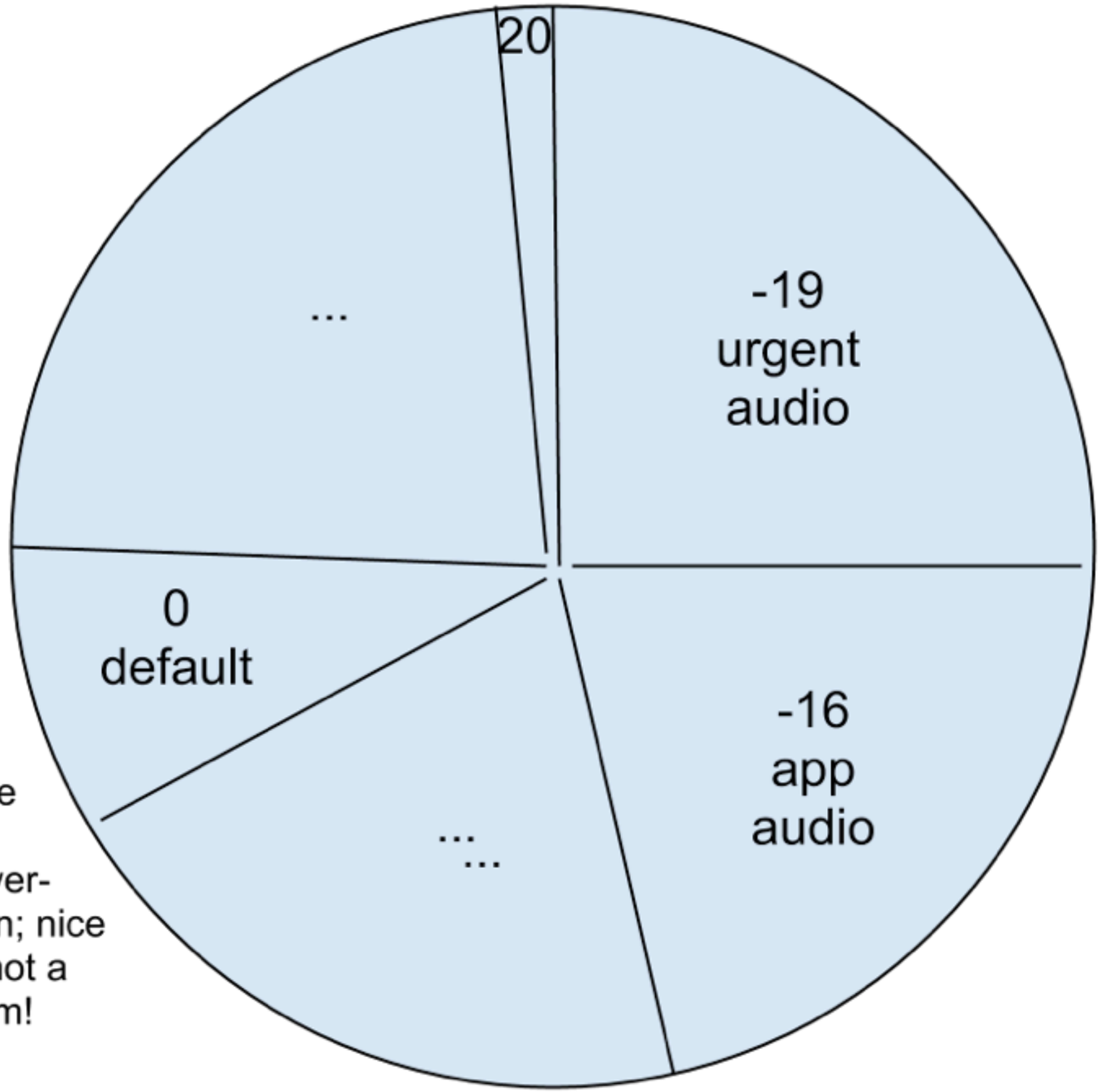


record
context
switches



Timestamp	Tid	Name	Delta time
2024372840	146	Playback Thread	
2024416840	900	AudioTrackThrea	44000
2024439840	0	idle	23000
2027275840	146	Playback Thread	2836000
2027319840	900	AudioTrackThrea	44000
2027339840	0	idle	20000
2030177840	146	Playback Thread	2838000
2030221840	900	AudioTrackThrea	44000
2030243840	0	idle	22000
2033081840	146	Playback Thread	2838000
2033126840	900	AudioTrackThrea	45000
2033145840	0	idle	19000
2035997840	192	AlarmManager	2852000
2036728840	160	Compiler	731000
2037092840	168	ActivityManager	364000
2037770840	167	er.ServerThread	678000


The smoking gun
PlaybackThread
AudioTrackThread
idle
AlarmManager
Compiler
ActivityManager
write blocks
fill next
write completes
mix and write
write blocks
fill next
write completes ???
PlaybackThread
AudioTrackThread
idle
AlarmManager
Compiler
ActivityManager



* not to scale

** a *huge* over-simplification; nice values are not a quota system!

CAT VIDEOS

AUDIO

CAT VIDEOS

AUDIO

EVIL PLOTS

AUDIO

SLACKING OFF

AUDIO

CAT VIDEOS

AUDIO

CAT VIDEOS

AUDIO

THUMB TWIDDLING

AUDIO

NEWS UPDATES

AUDIO

CAT VIDEOS

AUDIO

THUMB TWIDDLING

AUDIO

THUMB TWIDDLING

AUDIO

CAT VIDEOS

AUDIO

CAT VIDEOS

AUDIO

SLACKING OFF

AUDIO

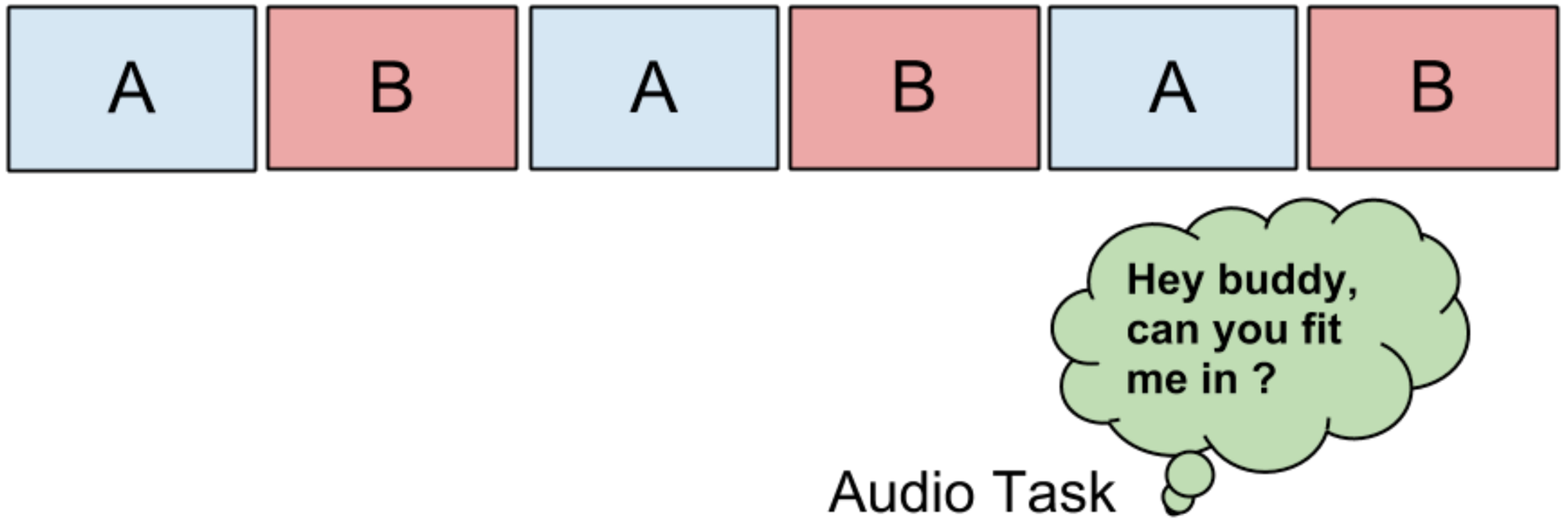
CAT VIDEOS

AUDIO

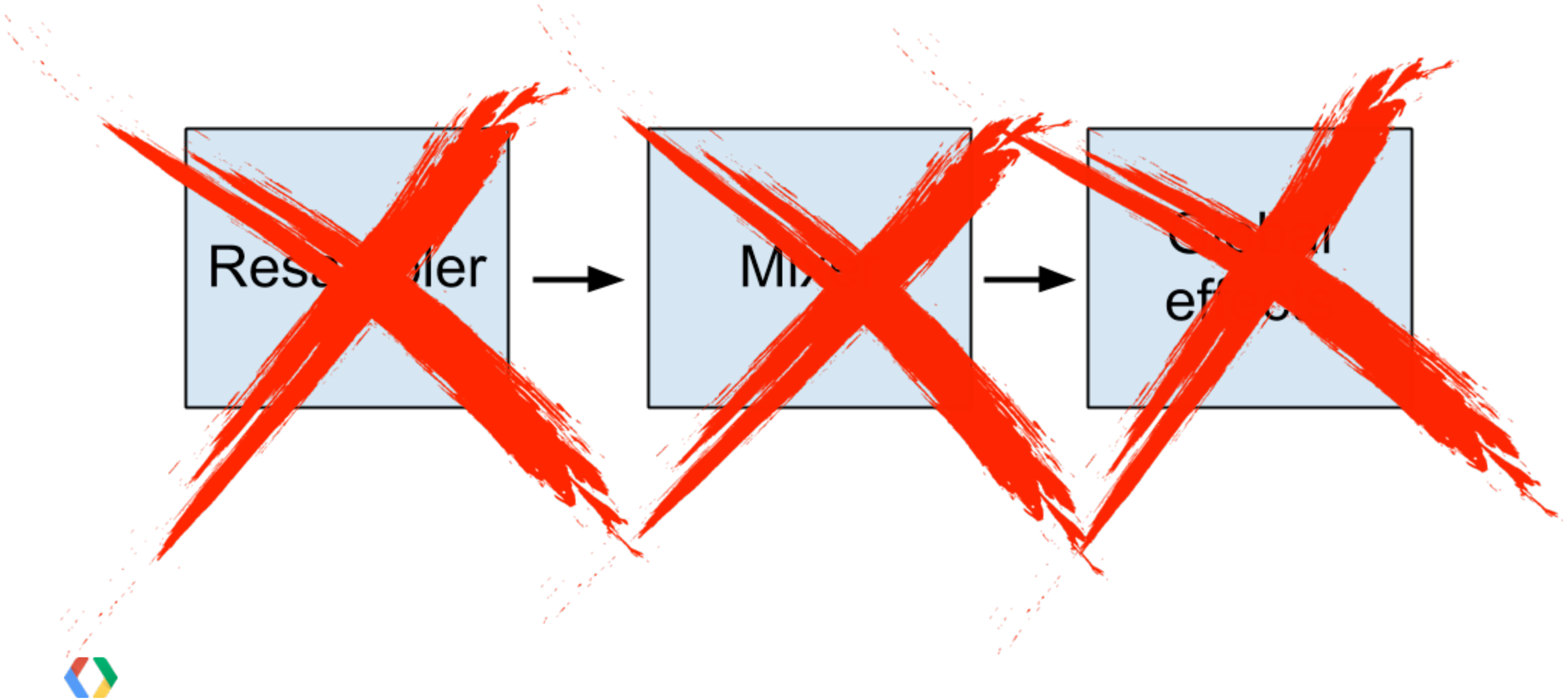
NEWS UPDATES

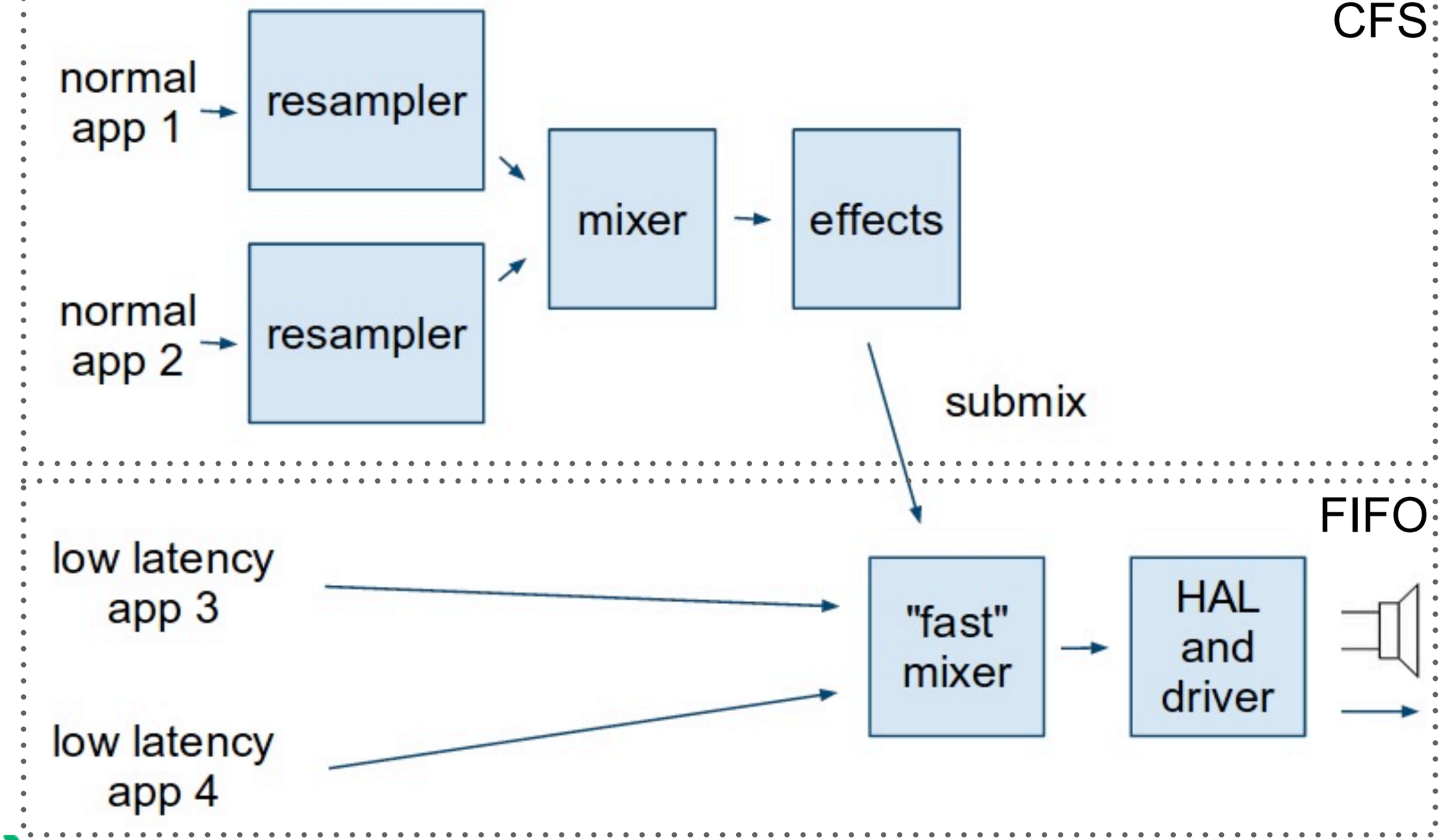
AUDIO

EVIL PLOTS


A
B
A
B
A
B
Hey buddy, can you fit me in ?
Audio Task
A
B
A
B
A
B
A
B
A
B
A
B
Thanks, CFS !
A
B

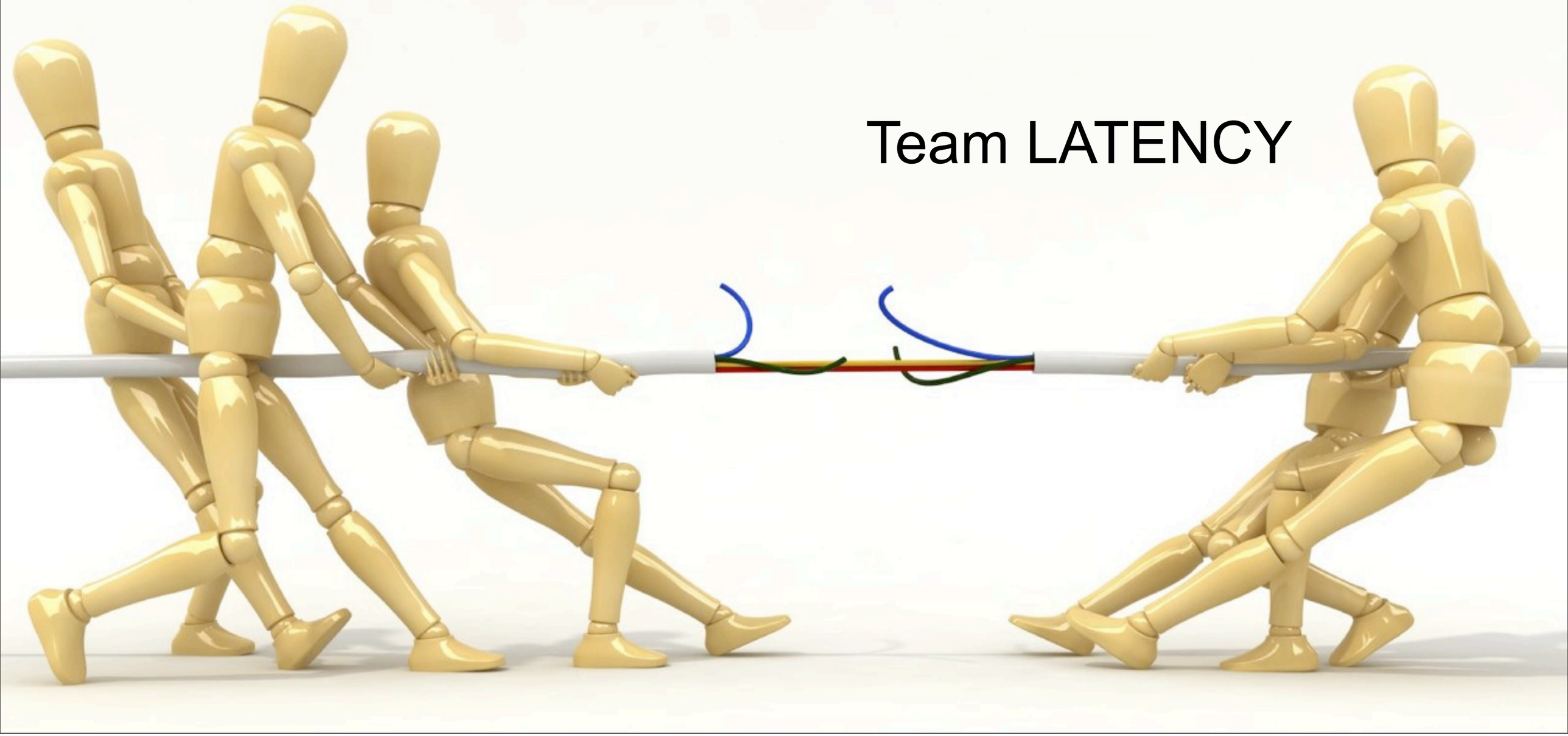

Resampler
Mixer
Global effects




CFS
normal app 1
resampler
normal app 2
resampler
mixer
effects
submix
FIFO
low latency app 3
low latency app 4
"fast" mixer
HAL and driver

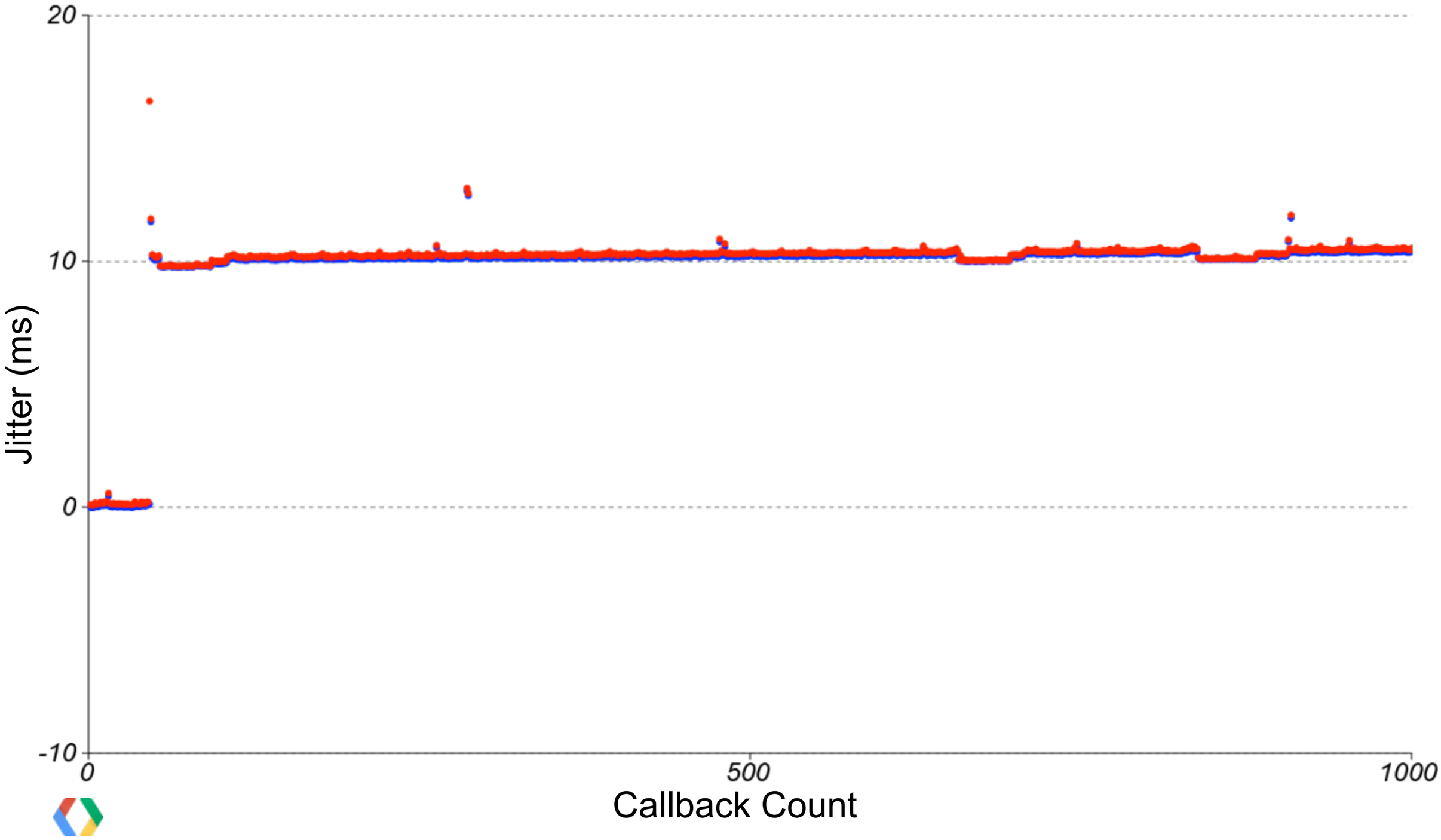
Team POWER

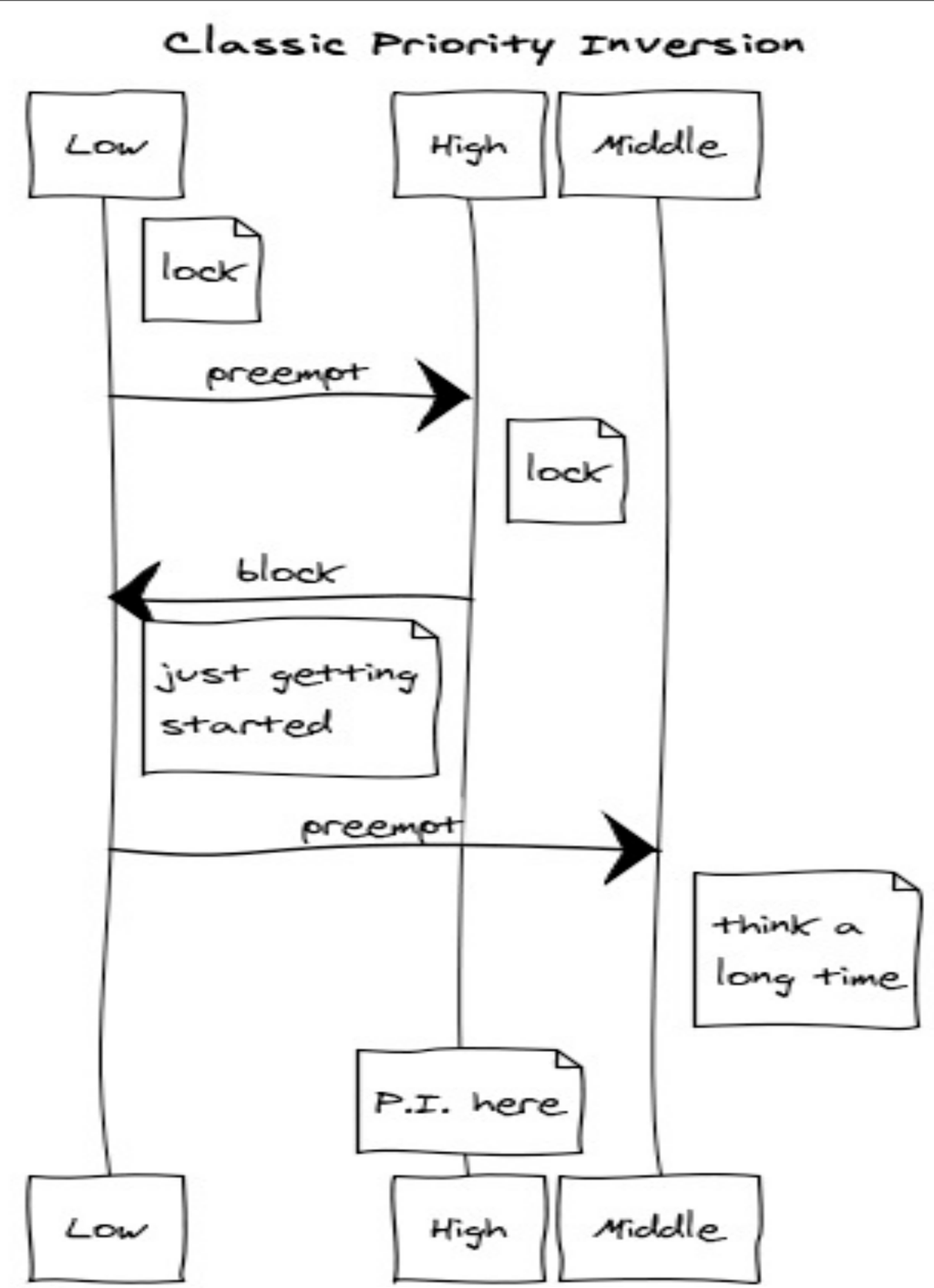
Team LATENCY

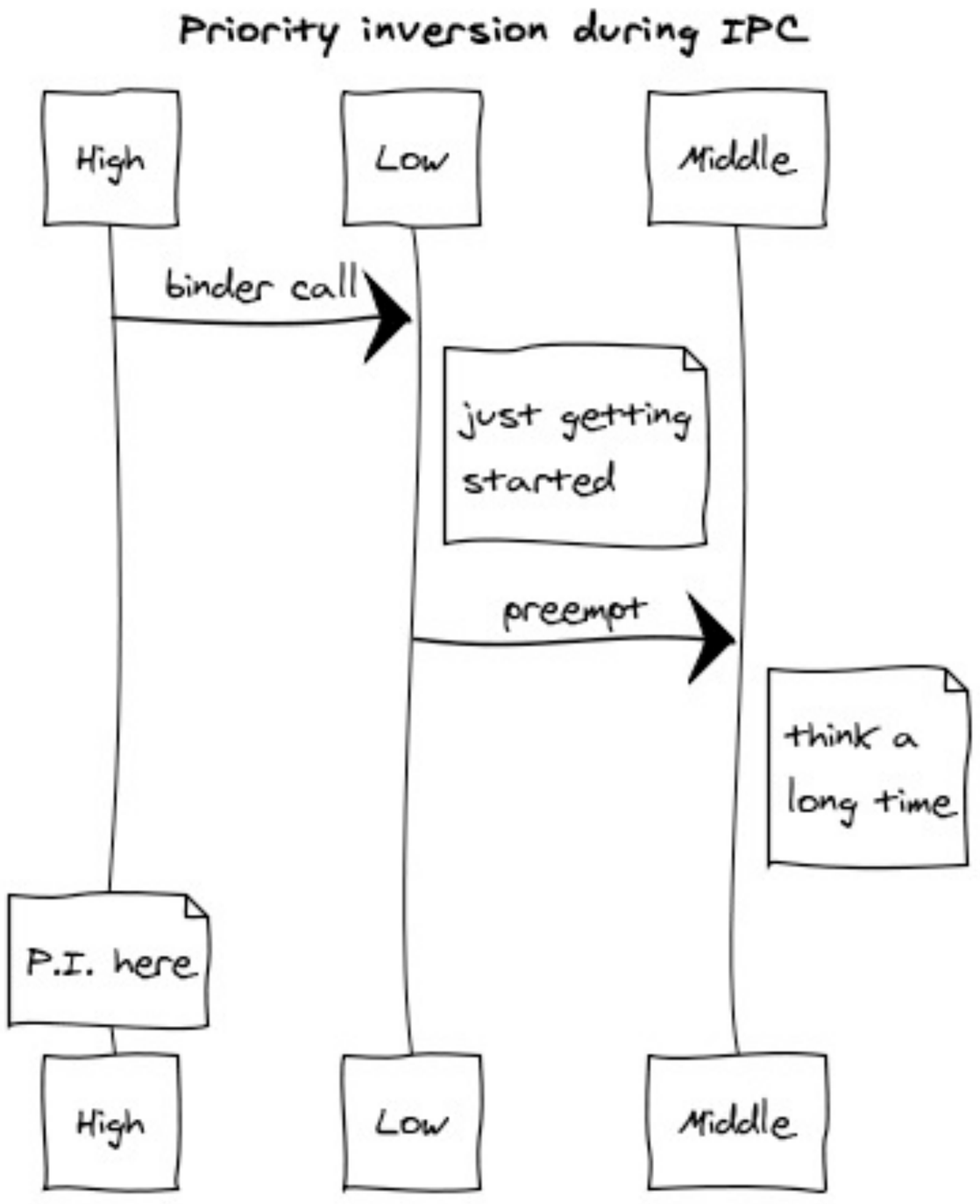


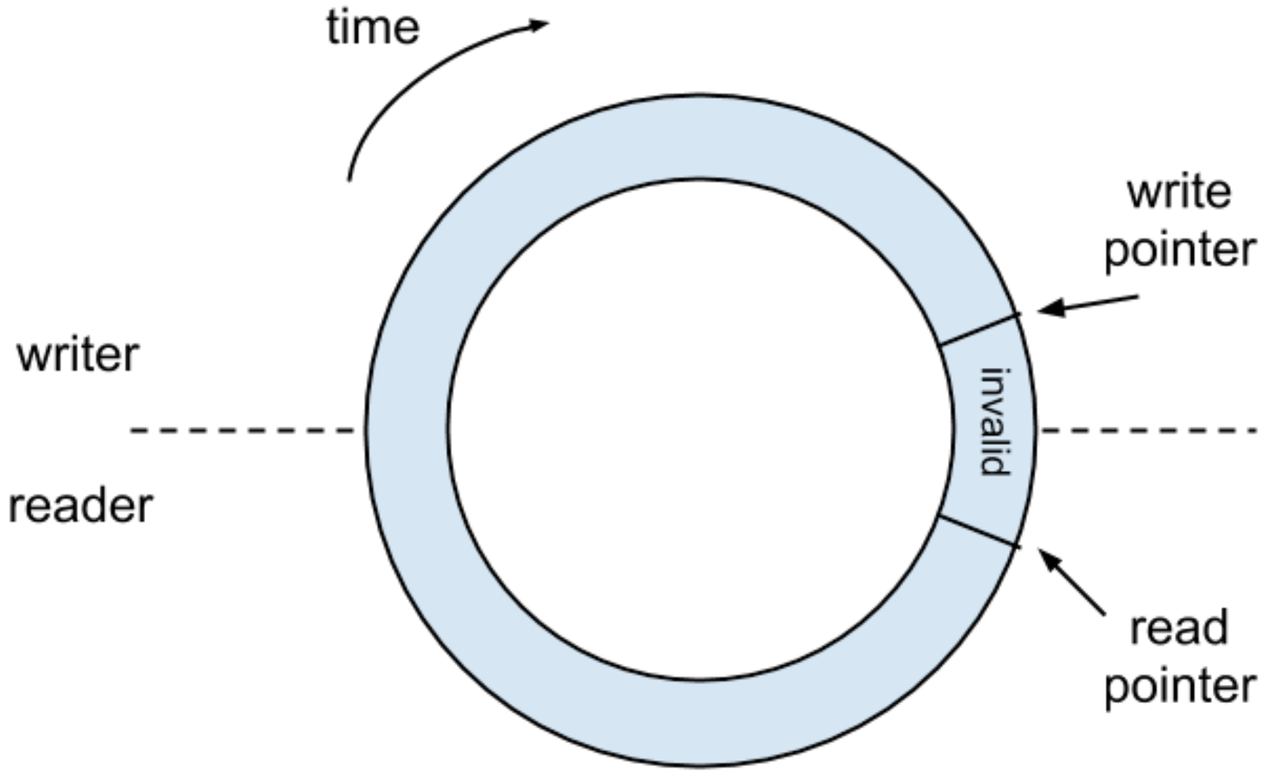
	Sample Rate	Buffer Size (frames)	Buffer Size (ms)
Nexus S	44100	880	19.95
Galaxy Nexus	44100	144 (JB) 968 (ICS)	3.26 (JB) 21.95 (ICS)
Nexus 4	48000	240	5
Nexus 7	44100	512	11.6
Nexus 10	44100	256	5.8

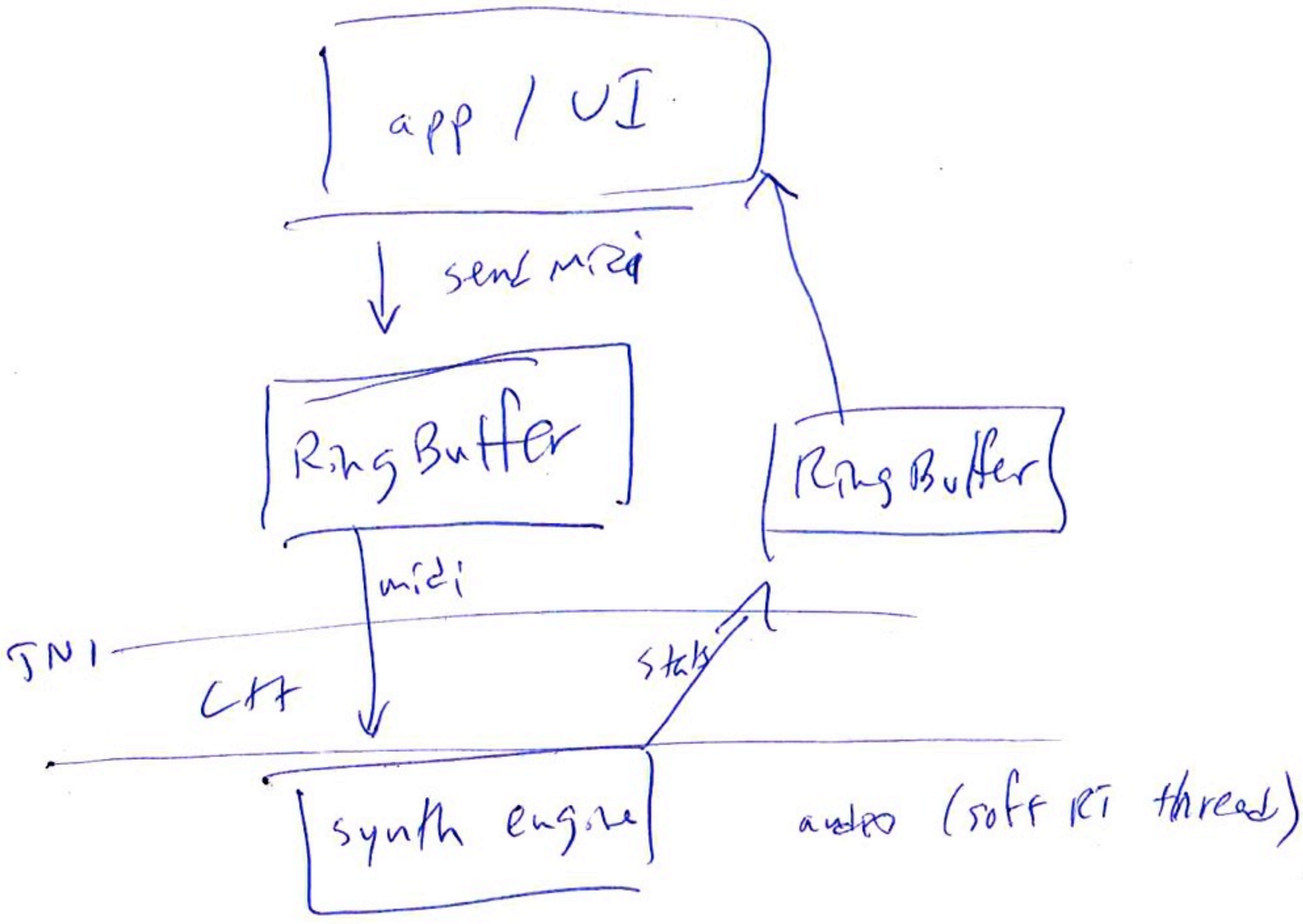
```
@TargetApi(Build.VERSION_CODES.JELLY_BEAN_MR1)
void getJbMr1Params(MyAudioParams params) {
  AudioManager audioManager =
    (AudioManager)this.getSystemService(Context.AUDIO_SERVICE);

  String rate = AudioManager.getProperty(
                  AudioManager.PROPERTY_OUTPUT_SAMPLE_RATE);

  String size = AudioManager.getProperty(
                  AudioManager.PROPERTY_OUTPUT_FRAMES_PER_BUFFER);

  params.sampleRate = Integer.parseInt(rate);
  params.bufferSize = Integer.parseInt(size);
}
```

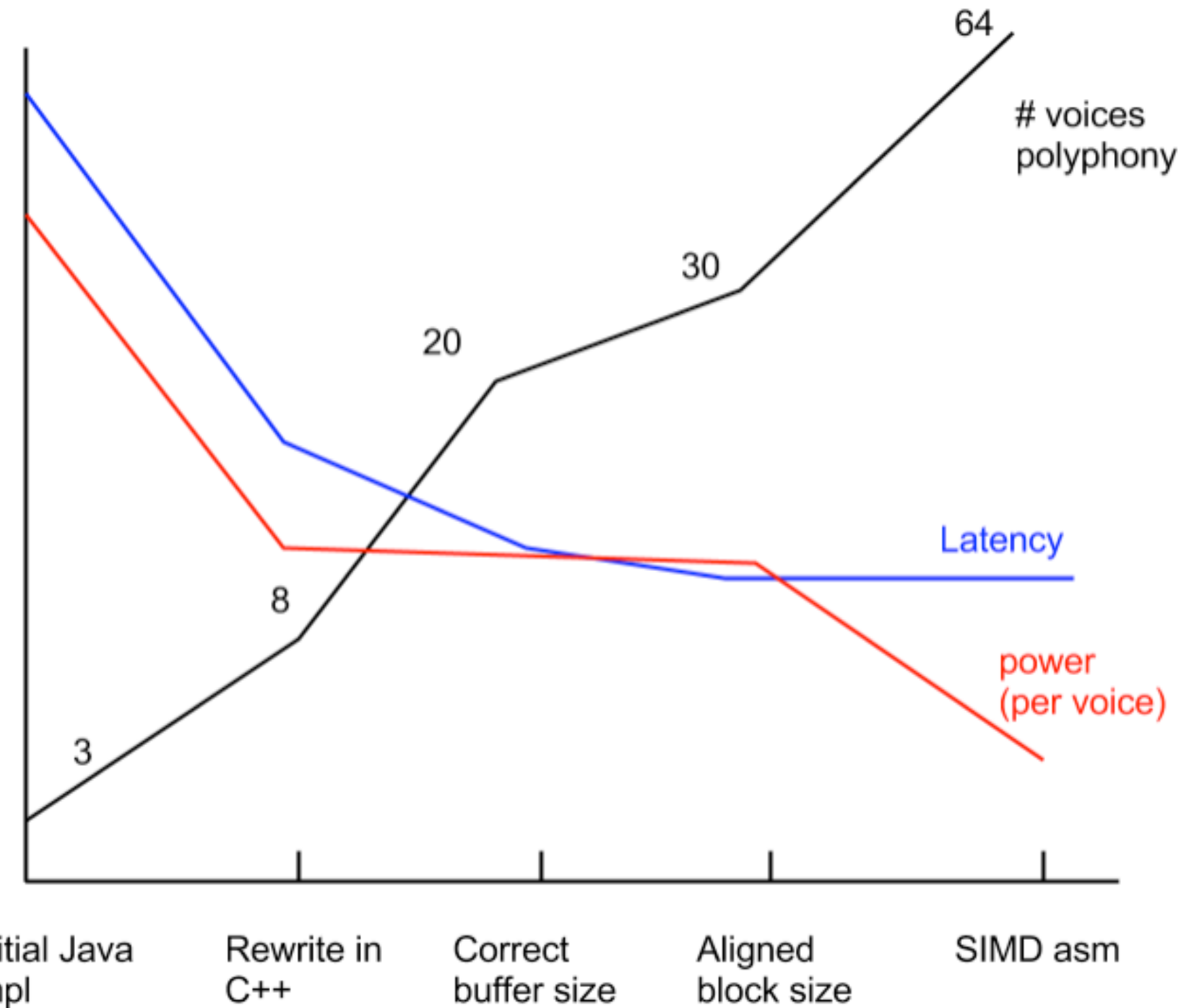

20
10
0
-10
Jitter (ms)
0
500
1000
Callback Count


Classic Priority Inversion
Low
High
Middle
lock
preempt
lock
block
just getting started
preempt
think a long time
P.I. here
Low
High
Middle


Priority inversion during IPC
High
Low
Middle
binder call
just getting started
preempt
think a long time
P.I. here
High
Low
Middle
www.websequencediagrams.com


time
write
pointer
writer
invalid
reader
read
pointer


app / UI
send MIDI
Ring Buffer
Ring Buffer
midi
JNI
CPP
Stats
synth engine
audio (soft RT thread)


64
voices
polyphony
30
20
8
3
Latency
power
(per voice)
Initial Java impl
Rewrite in C++
Correct buffer size
Aligned block size
SIMD asm

To Do: Android

1. Measure everything!
2. Use SCHED_FIFO
3. Implement fast path to system mixer
4. Add API to discover sample rate & buffer size
5. Keep improving!

To Do: You

1. Measure everything!
2. Process audio in OpenSL callback
3. Match device sample rate & buffer size
4. Eliminate blocking

Google Developers

code.google.com/p/high-performance-audio/