noise.rb

How to annoy your cat with sound generators

Arlington Ruby, May 2012

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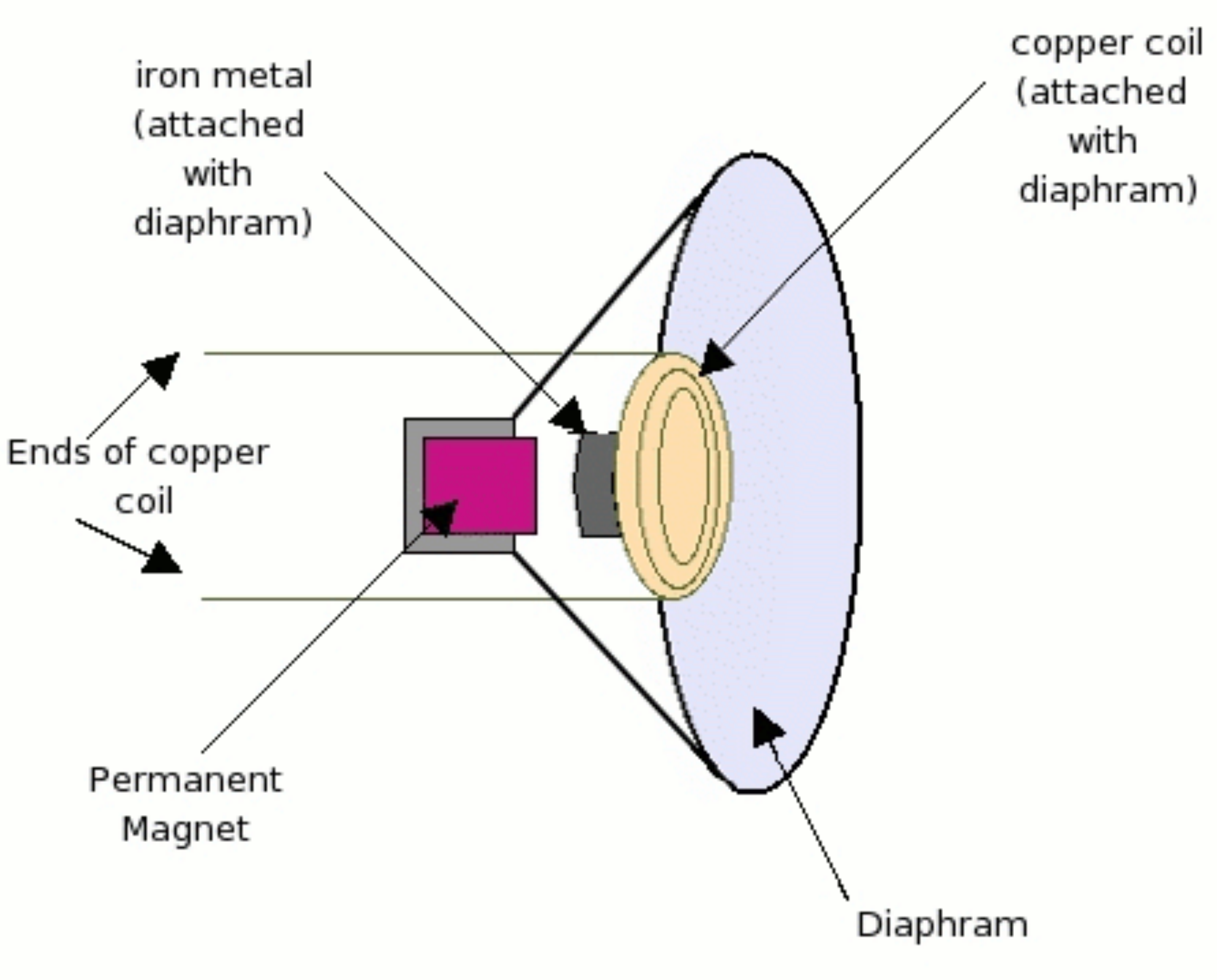
Let's build a software synthesizer in about ~~20~~ 40 minutes.

Digital Sound

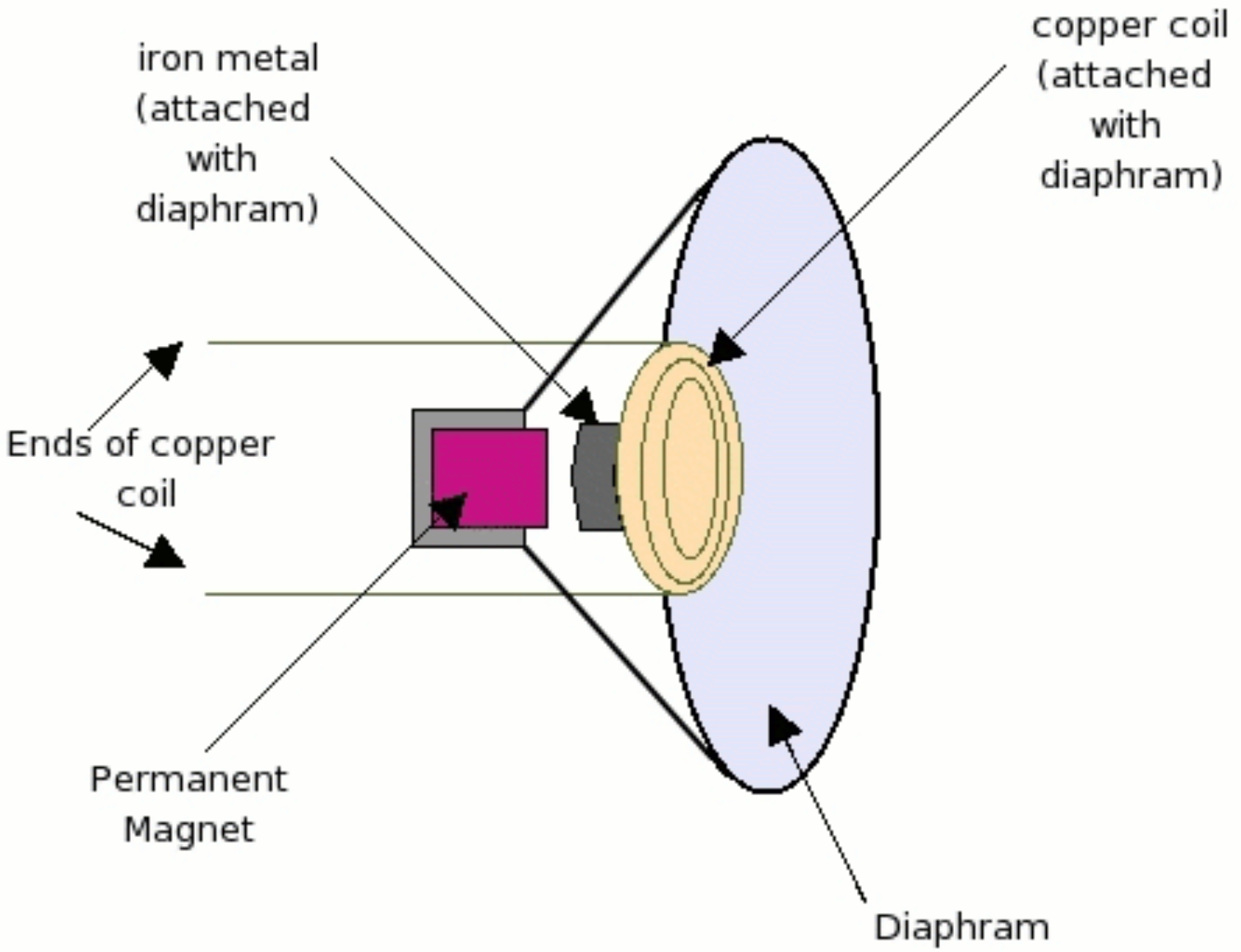
Exercises for reader:

Speakers → Ears → Consciousness

Let's start with speakers


iron metal (attached with diaphram)
copper coil (attached with diaphram)
Ends of copper coil
Permanent Magnet
Diaphram

Sideways is even better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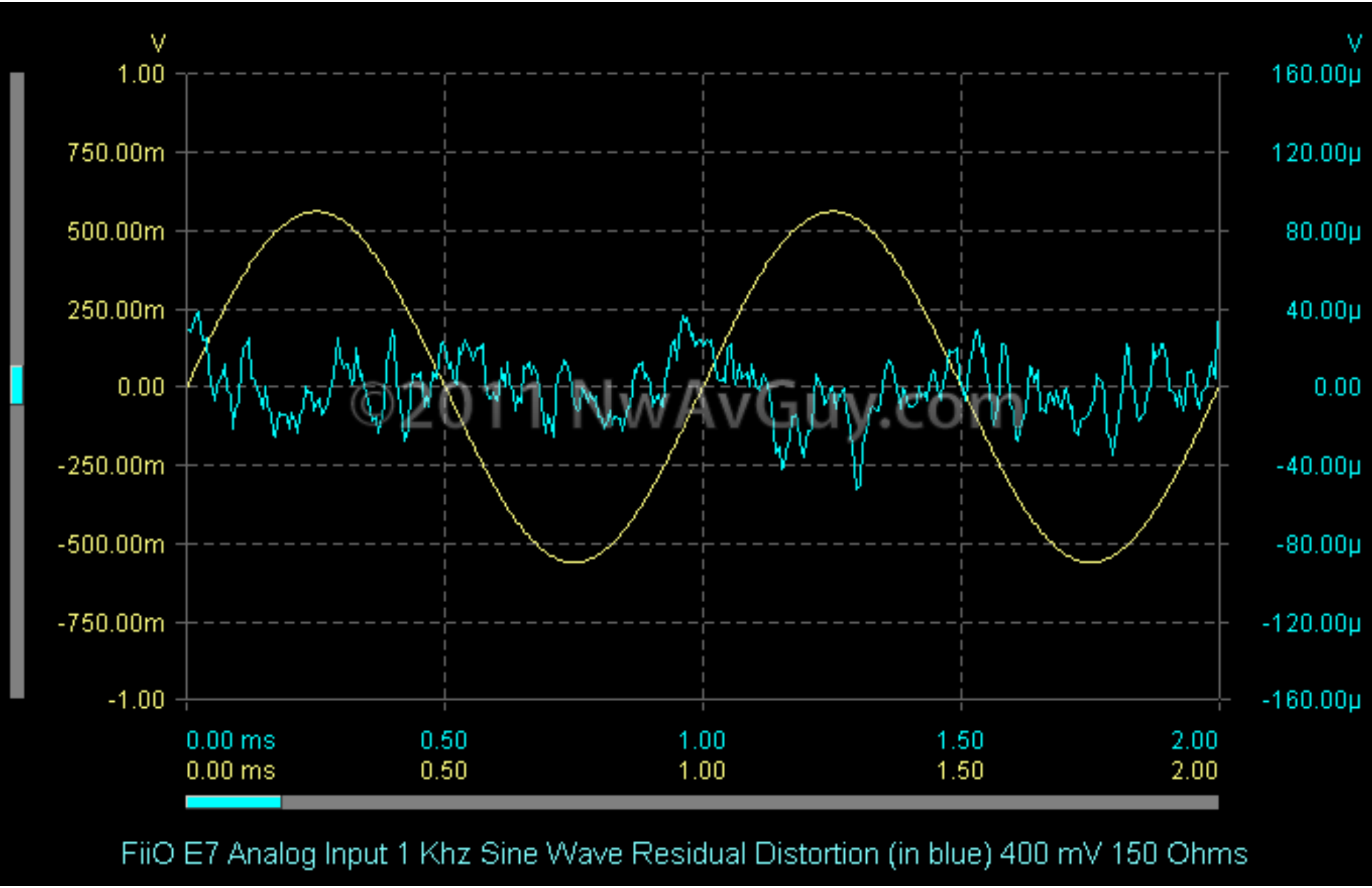
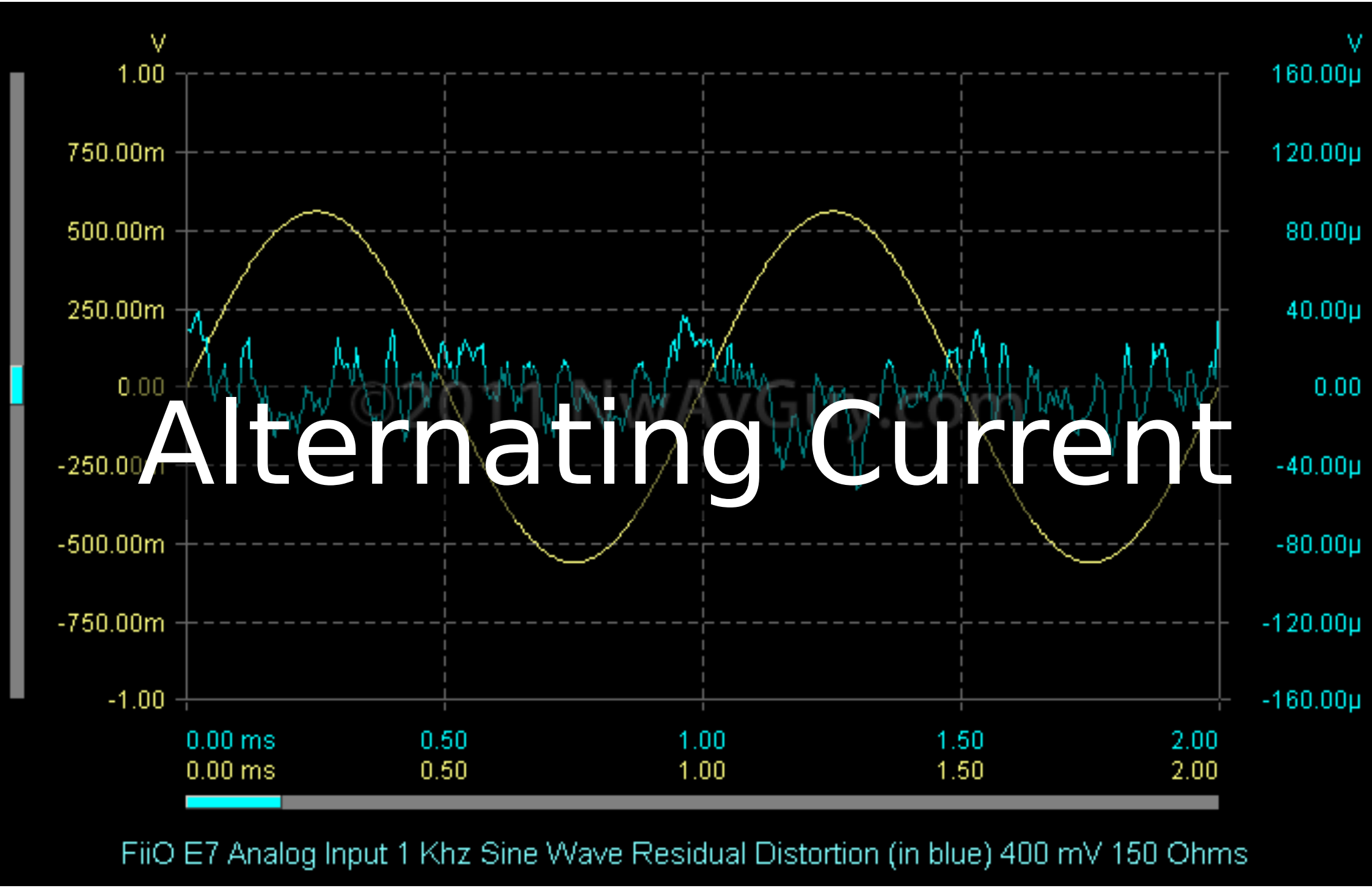
Ends of copper coil
Permanent Magnet
Diaphram



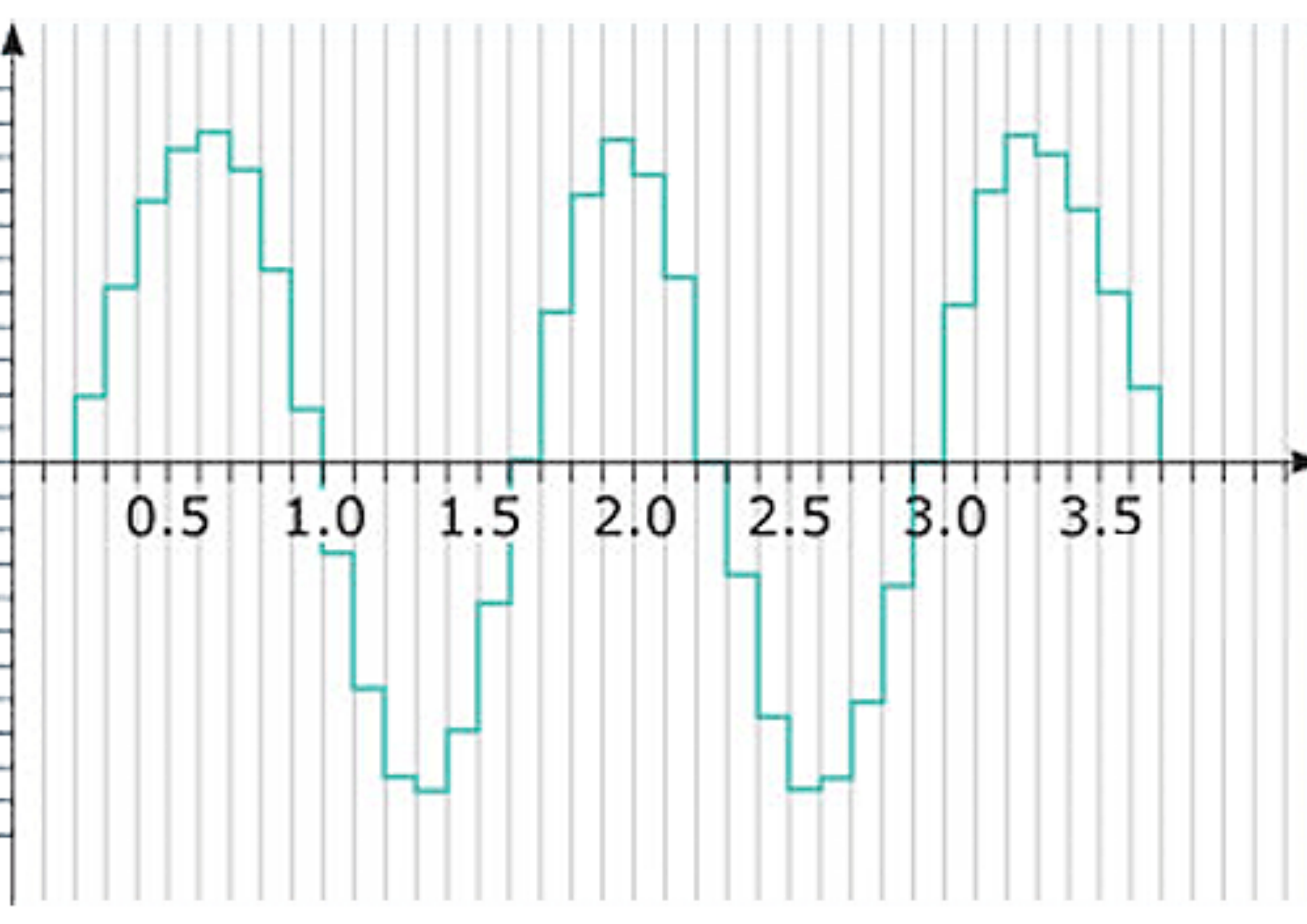
FiiO E7 Analog Input 1 Khz Sine Wave Residual Distortion (in blue) 400 mV 150 Ohms

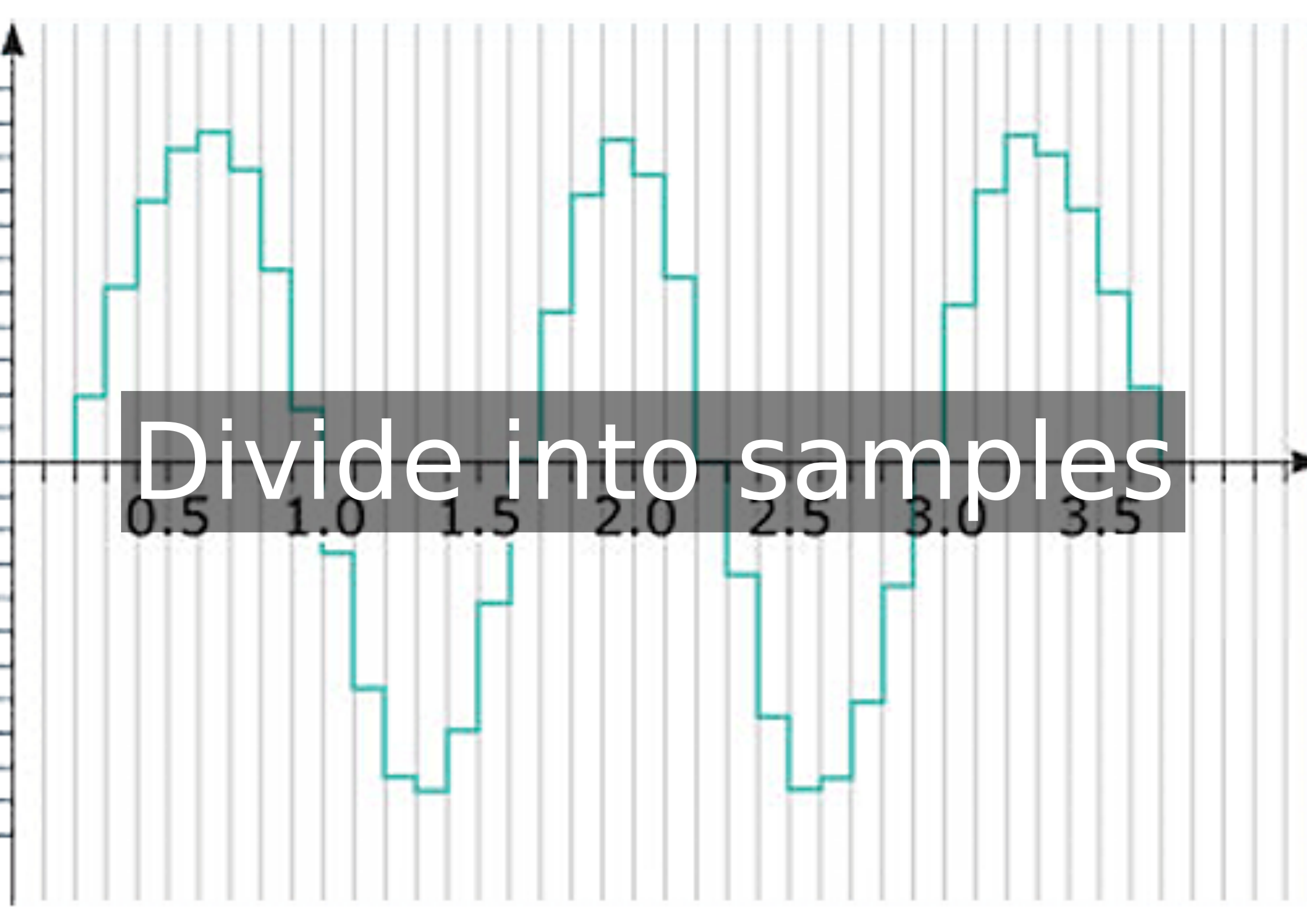

V
1.00
750.00m
500.00m
250.00m
0.00
-250.00m
-500.00m
-750.00m
-1.00
V
160.00µ
120.00µ
80.00µ
40.00µ
0.00
-40.00µ
-80.00µ
-120.00µ
-160.00µ
0.00 ms
0.50
1.00
1.50
2.00
0.00 ms
0.50
1.00
1.50
2.00
Alternating Current
FiiO E7 Analog Input 1 Khz Sine Wave Residual Distortion (in blue) 400 mV 150 Ohms

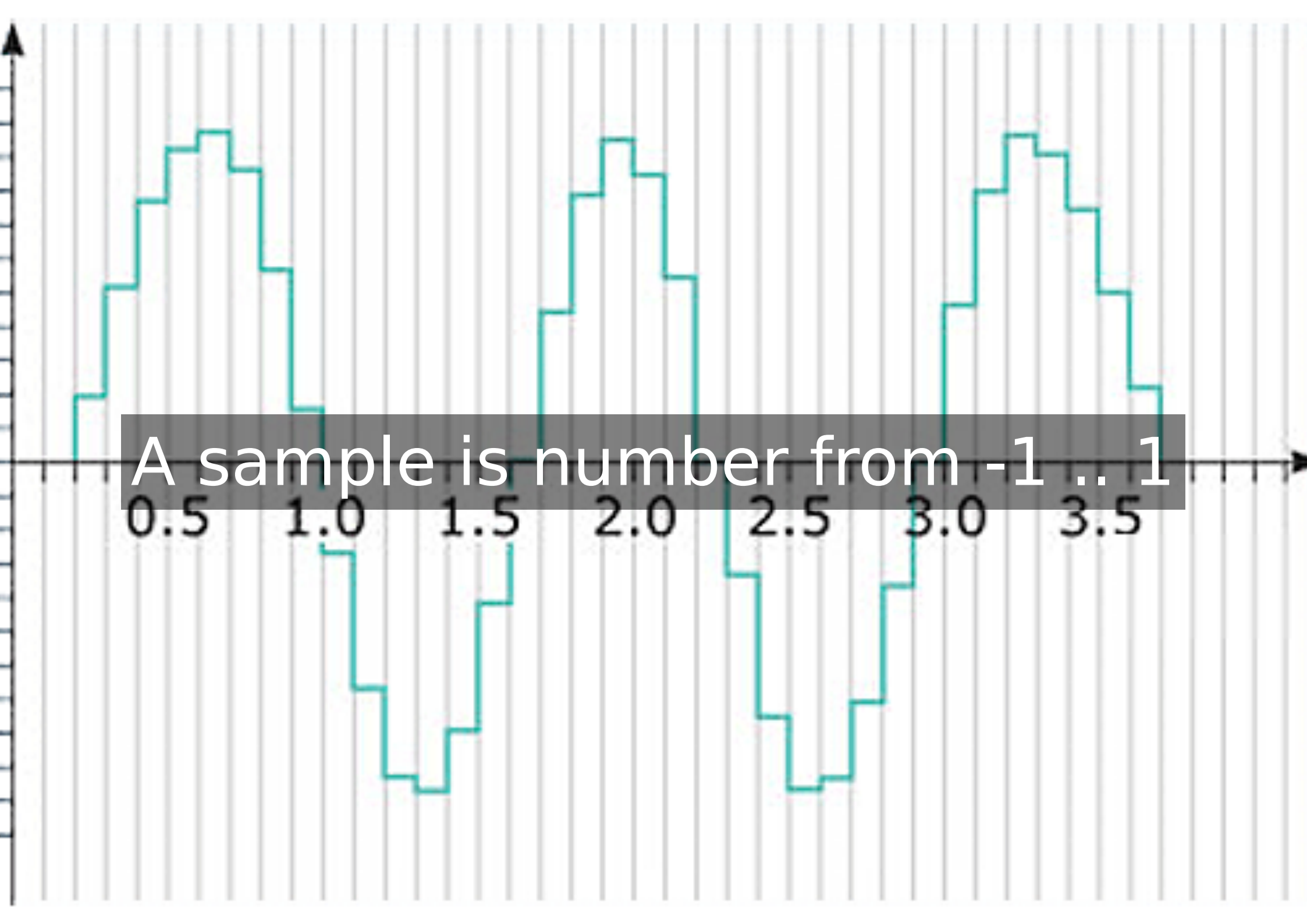
Sound = Speaker movement = Electrical input

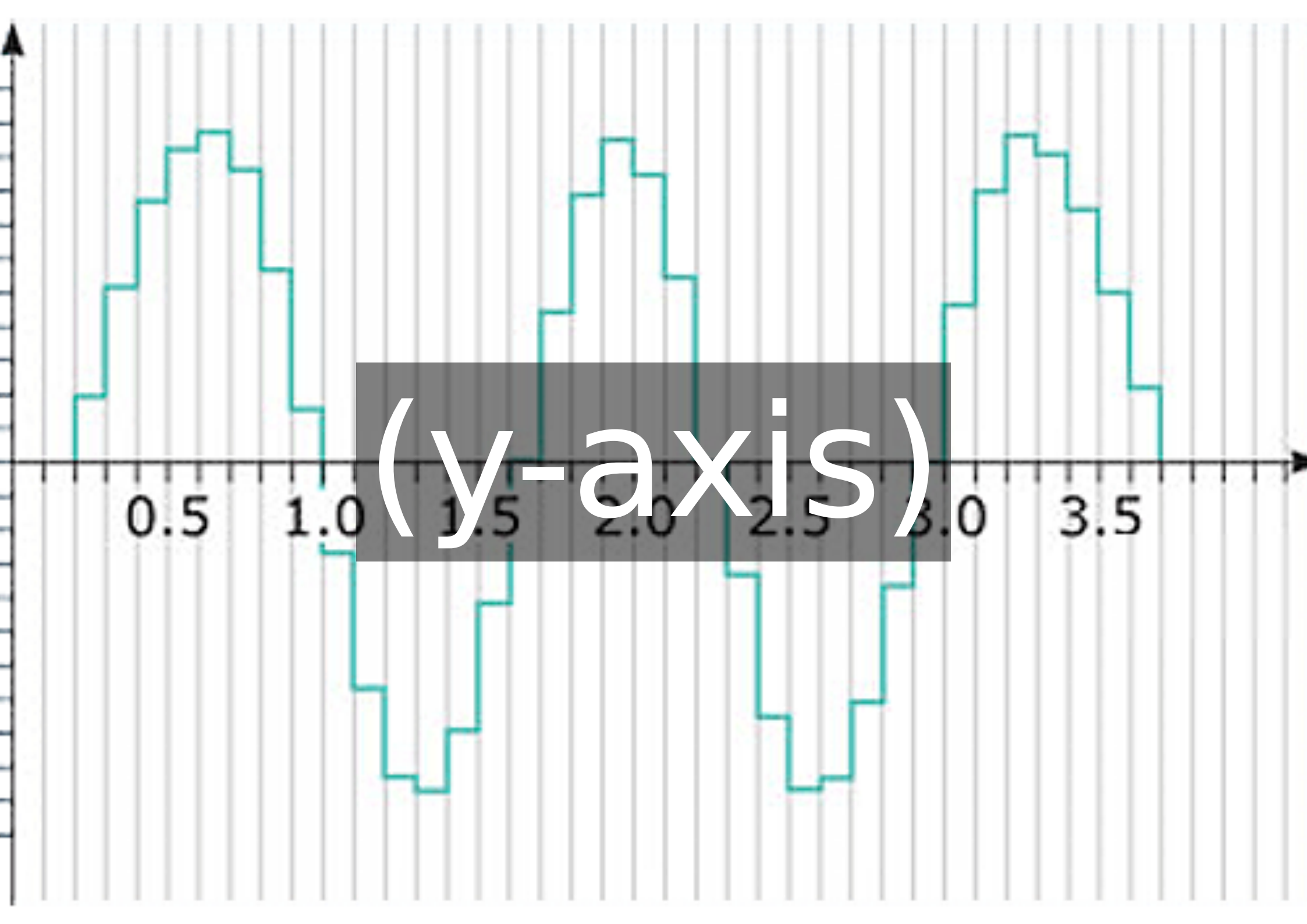

Waves

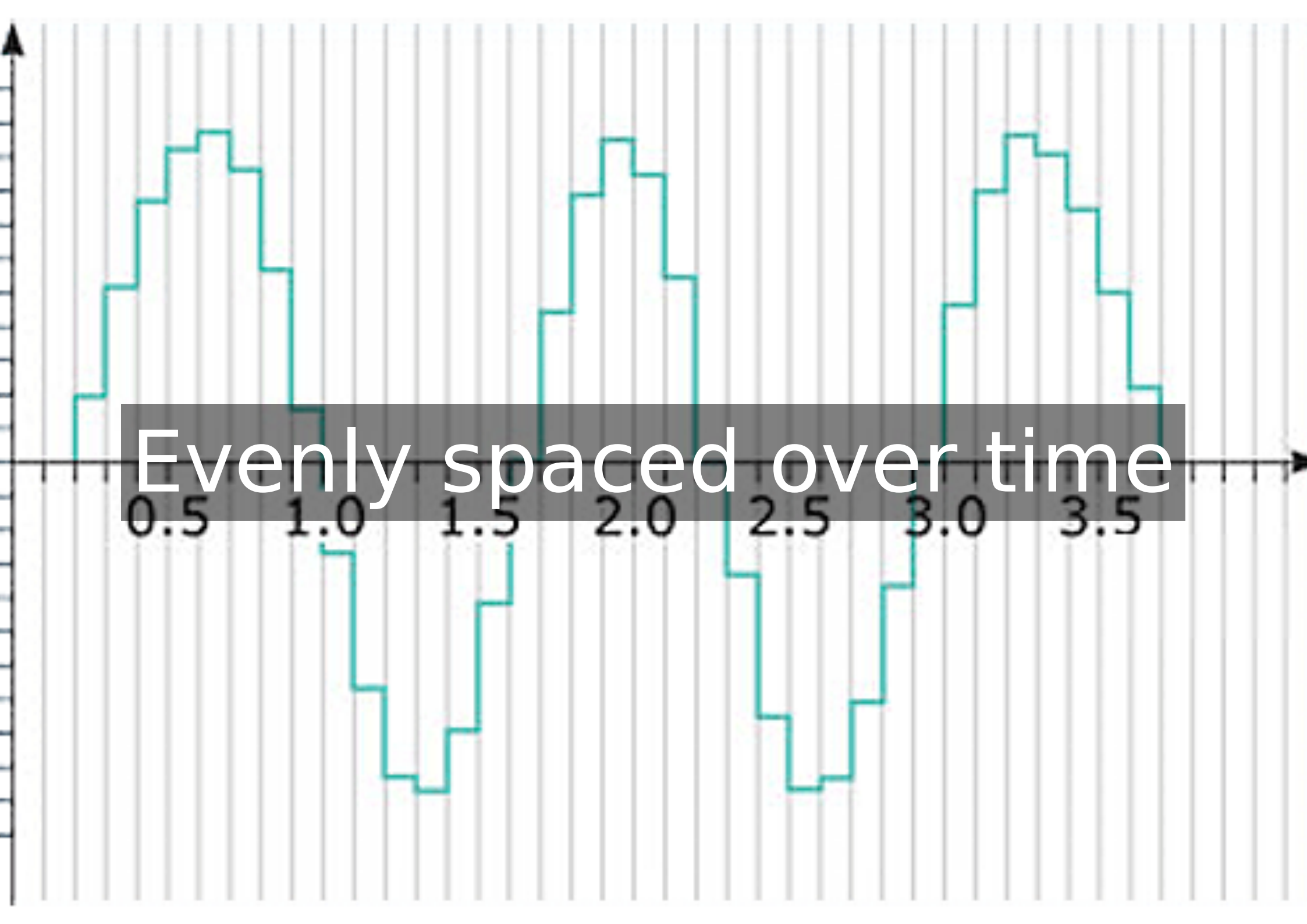
digital?

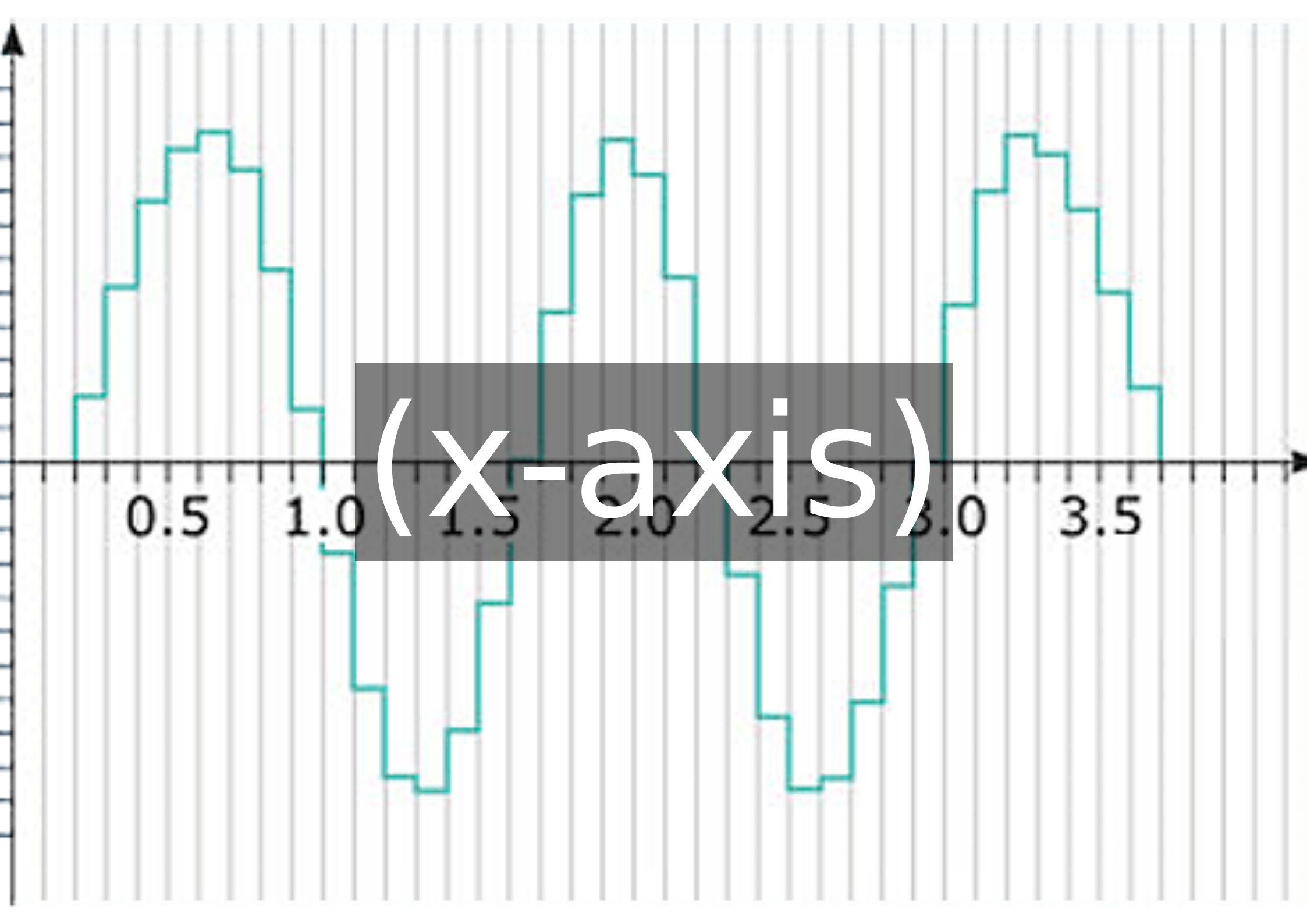

0.5
1.0
1.5
2.0
2.5
3.0
3.5


Divide into samples
0.5
1.0
1.5
2.0
2.5
3.0
3.5


A sample is number from -1 .. 1
0.5
1.0
1.5
2.0
2.5
3.0
3.5


(y-axis)
0.5
1.0
1.5
2.0
2.5
3.0
3.5


Evenly spaced over time
0.5
1.0
1.5
2.0
2.5
3.0
3.5


(x-axis)
0.5
1.0
1.5
2.0
2.5
3.0
3.5

Samples per second

↳ "Sample Rate"

Common sample rates:

DVD: 48,000
CD: 44,100
VOIP: 16,000
Telephone: 8,000

Representation of each sample

↳ "Bit Depth"

8 bit: 0..255 (old video games)

16 bit: 0..65535 (CD)

24 bit: 0..16777215 (DVD-Audio)

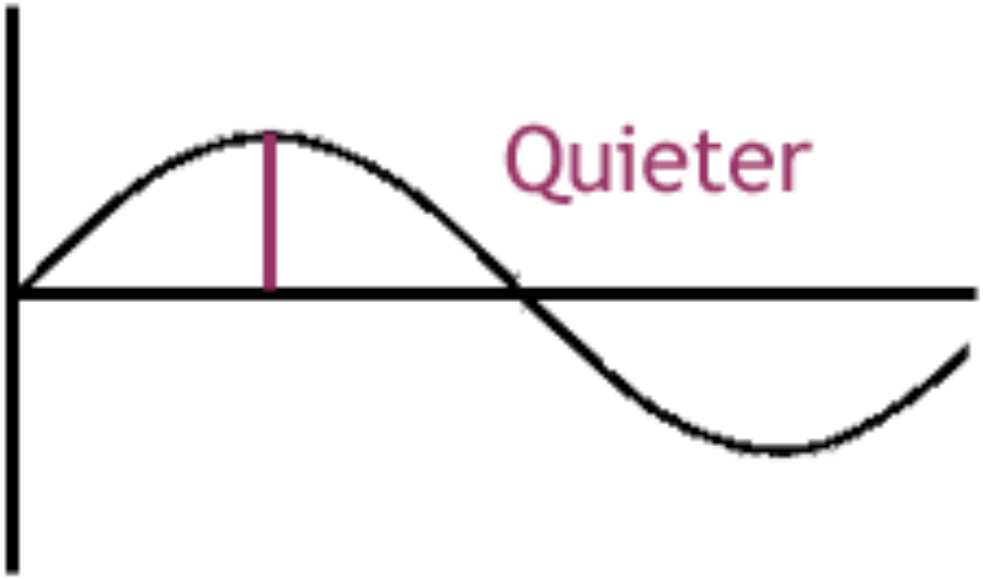
Human Ear: 21 bit @ 40k

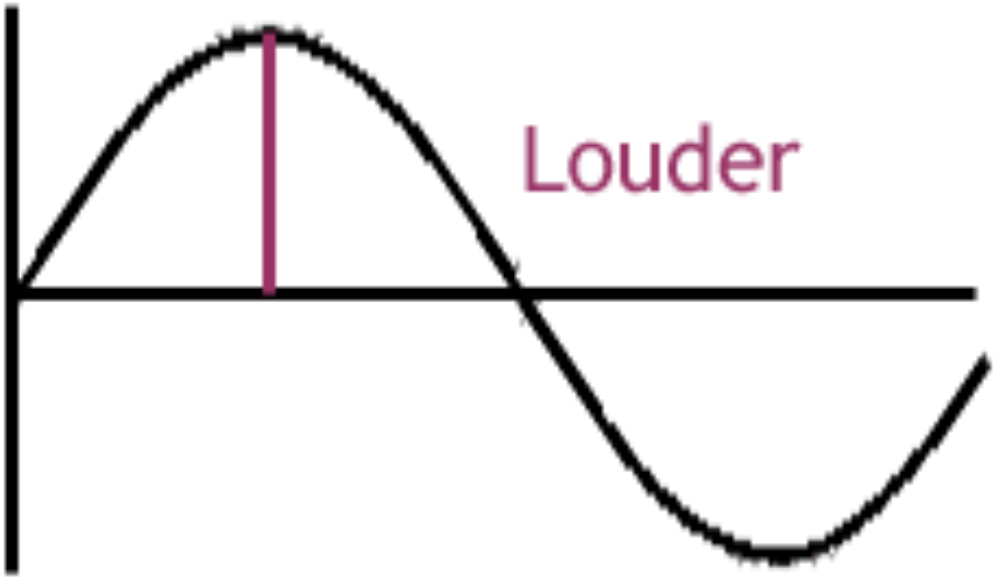
Volume (amplitude) and Frequency

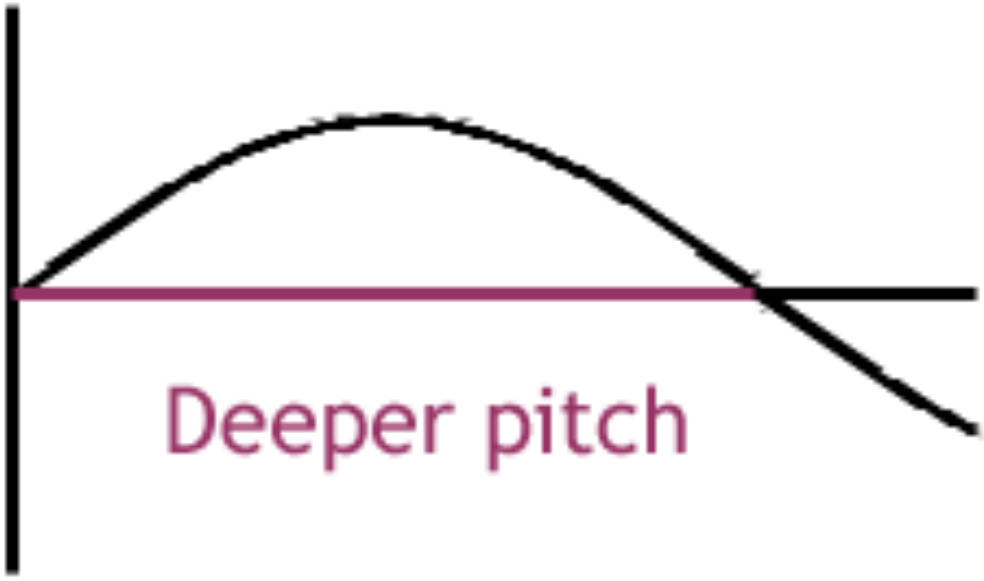
Volume is easy!

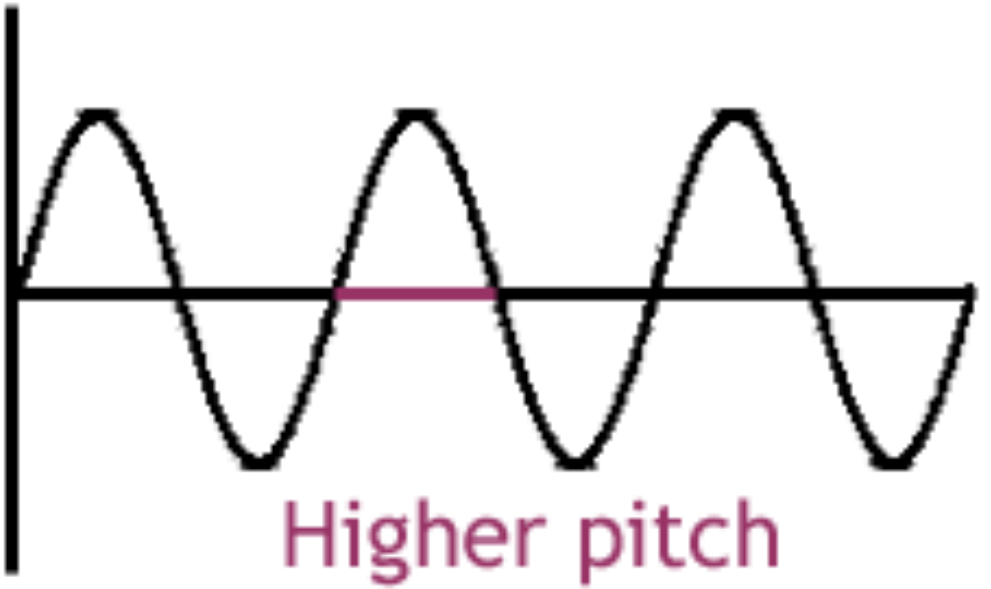
Frequency not so easy

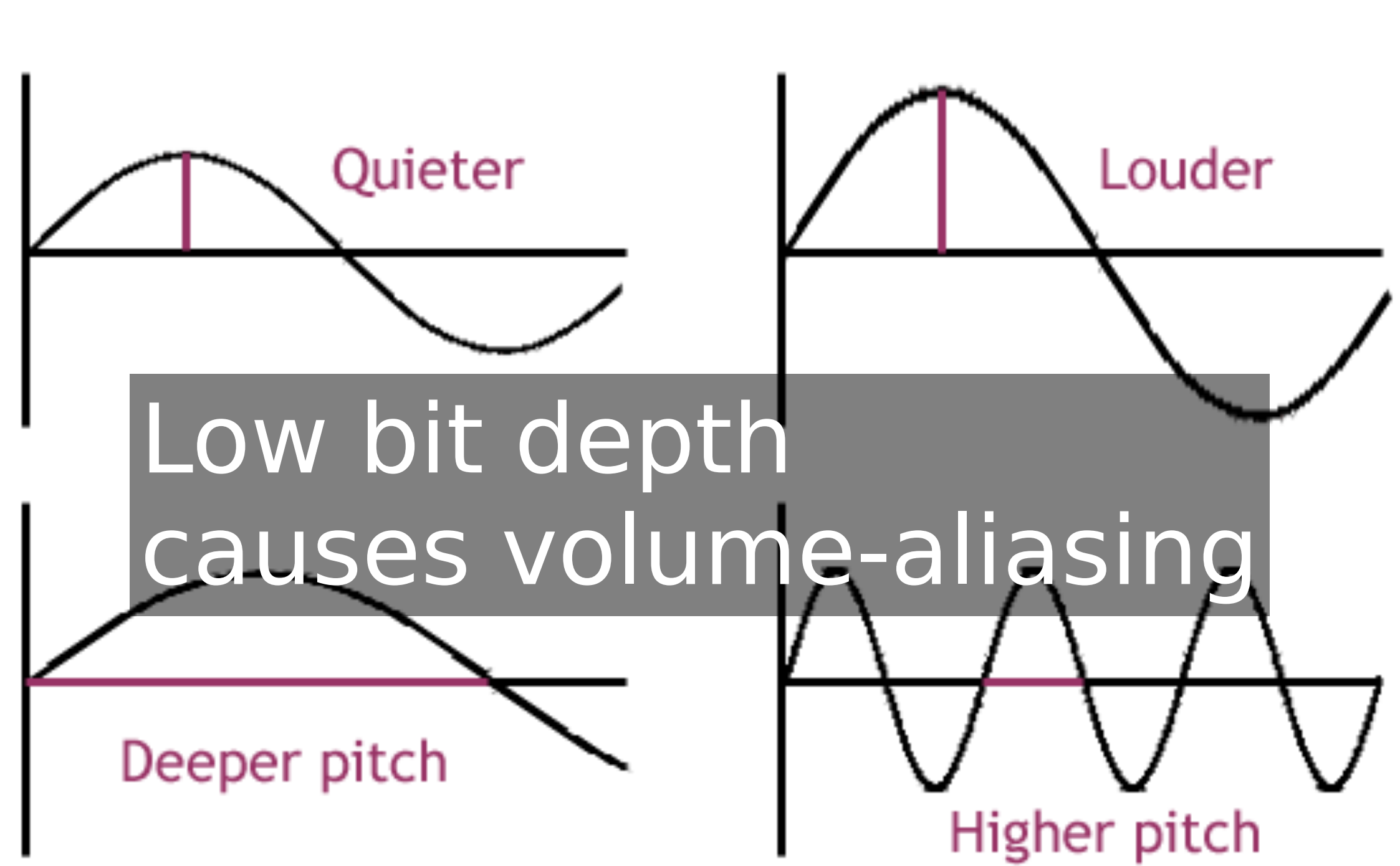
frequency = wiggle speed = pitch

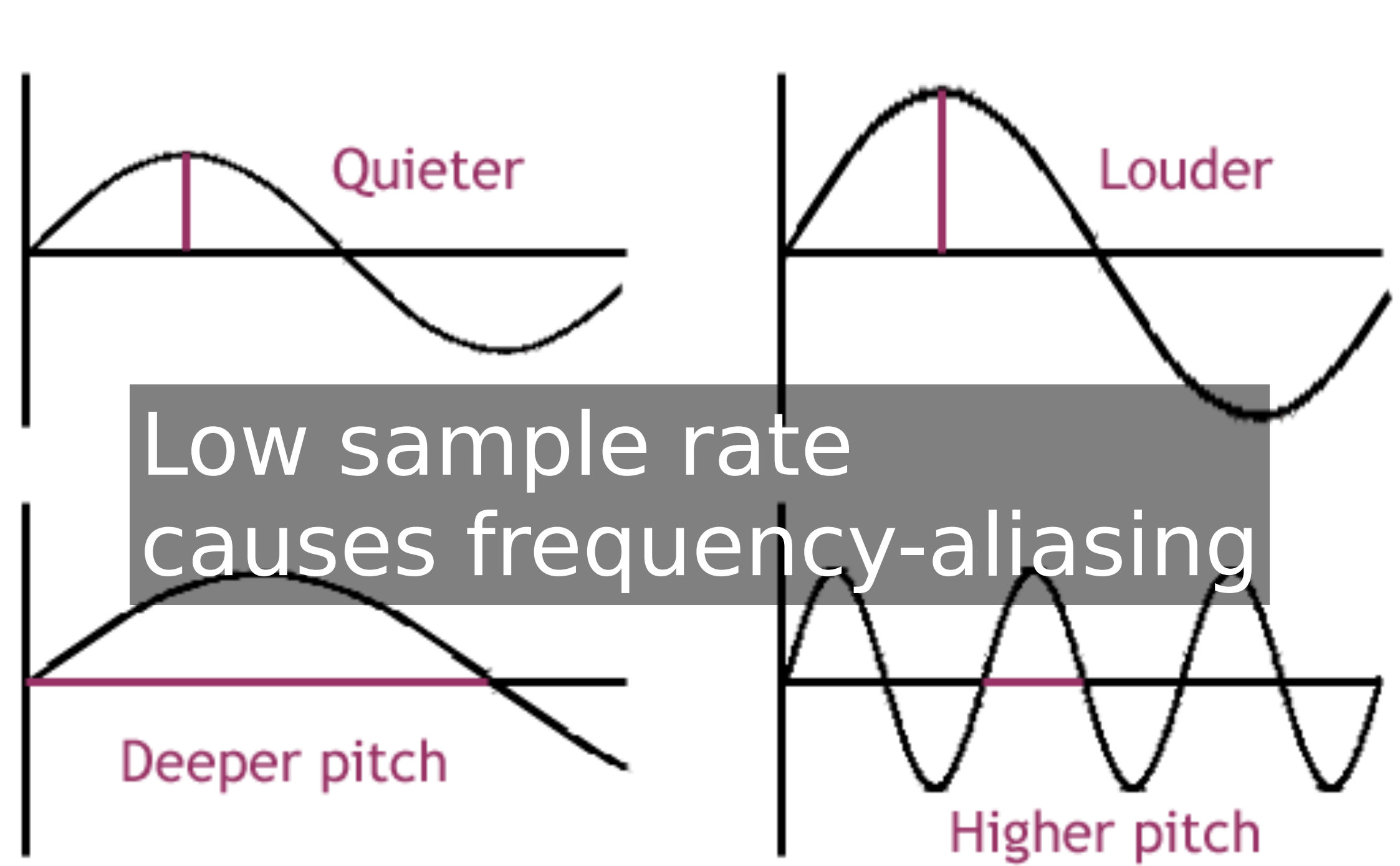









Quieter
Louder
Low bit depth
causes volume-aliasing
Deeper pitch
Higher pitch
© www.science aid.net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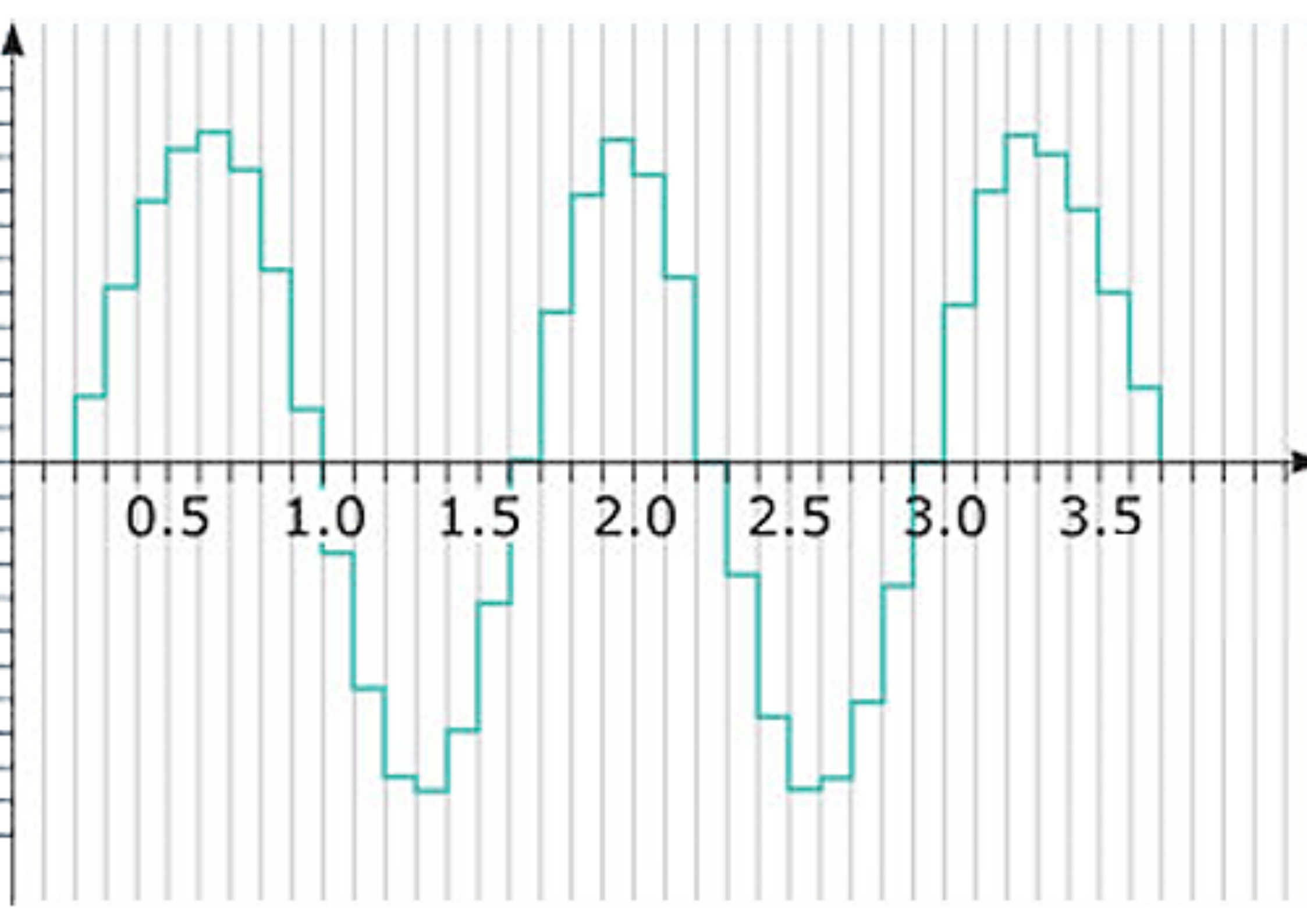

0.5
1.0
1.5
2.0
2.5
3.0
3.5

So!

We just gotta generate and play samples!

44100 of them per second!

No problem.

PortAudio

Alternatives: /dev/dsp, aplay, ...

```
PortAudio.init

stream = PortAudio::Stream.open(
  :sample_rate => 44100,
  :frames      => 512,
  :output      => {
    :device        => PortAudio::Device.default_output,
    :channels      => 1,
    :sample_format => :float32
  }
)

stream.start
```

```
buffer = PortAudio::SampleBuffer.new(
  :format   => :float32,
  :channels => 1,
  :frames   => 512
)
```

```
# smallnoise.rb

loop do
  buffer.fill {
    rand()*2 - 1 # From -1 .. 1
  }
  stream << buffer
end
```

Woo... static!

```
sample = rand()*2 - 1
```

```
# smallbeep.rb

time_step = 1 / 48000.0
time = 0.0
loop do
  buffer.fill {
    time += time_step;
    Math.sin( 2 * 3.1415 * time * 440 );
  }
  stream << buffer
end
```

Woo... beeping!

Two beeps at once?

Turns out you just add waves together

```
# smallbeep2.rb

sample  = Math.sin( 2 * 3.1415 * time * 440 );
sample += Math.sin( 2 * 3.1415 * time * 349.23 );
sample /= 2; # Avoid clipping!
```

Let's generalize

```
sample = get_next_sample();
```

Call get_next_sample() over and over

Get a new sample each time

```
def sine {
  Math.sin( 2 * 3.1415 * $time * 440 )
}
```

That was easy.

Not very configurable or dynamic though.

```
# What I want:

sample_gen = sine(440);

# ...

sample = sample_gen.call;
```

This is called a 'generator'

We can make this using a closure!

(aka lambda with bound variables)

```
def sine(freq)
  lambda {
    Math.sin( 2 * 3.1415 * $time * freq );
  }
}
```

```
# So now we have it:

sample_gen = sine(440);

# ... in 'play'

sample = sample_gen.call;
```

```
# Create a 440 Hz sine generator
gen = sine(440);

# Play it!
play( gen );
```

```
play( sine( 440 ) );
```

One more generator tweak

Parameterize generators with generators, and use named params

```
sub sine(freq) {
  freq = genize freq
  lambda {
    Math.sin( 2 * 3.1415 * $time * freq.call );
  }
}
```

```
# Take a parameter and ensure it is a generator.
# If it is already a generator leave it alone,
# otherwise wrap it up so that it *is* a generator.

def genize x
  if x.is_a?(Proc)
    return x
  end
  lambda { x }
end
```

Why would we use generators as parameters?

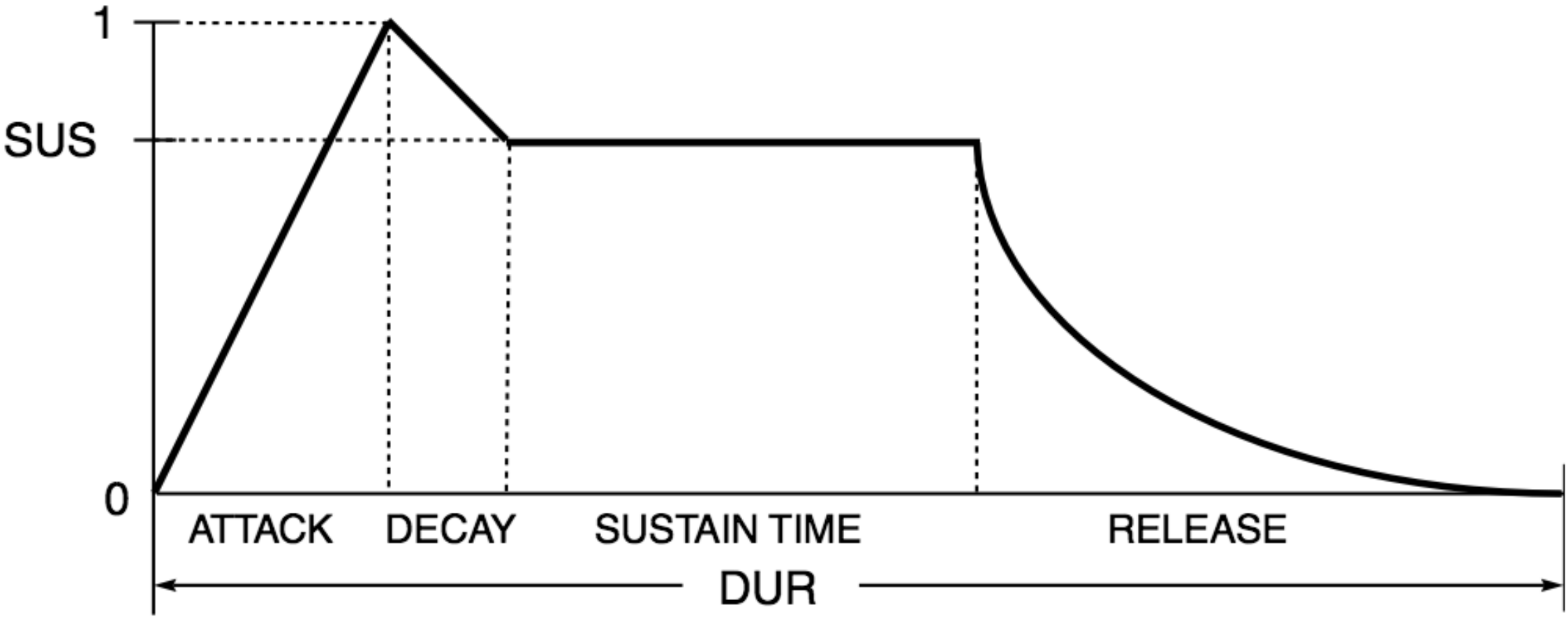
```
lfo = sine(5)
wobble_freq = lambda { lfo.call * 100 + 440 }

play( sine( wobble_freq ) );
```

Now we're cooking with FIRE!

Plays forever...

Envelope Generator

Attack, [Decay], Sustain, Release


1
SUS
0
ATTACK
DECAY
SUSTAIN TIME
RELEASE
DUR

```
envelope( gen, attack, sustain, release )

# For example

envelope( sine(440), 2, 0, 2 )
```

returns nil when done

Sequence Generator

```
seq( gens )

# For example

play(
  seq([
    envelope(square(440), 2, 0, 2),
    envelope(square(220), 2, 0, 2),
  ])
)
```

Simultaneous Generators Generator

```
play(
  sum([
    envelope(square(440), 2, 0, 2),
    envelope(square(220), 2, 0, 2),
    envelope(square(880), 2, 0, 2),
    envelope(square(660), 2, 0, 2),
  ])
)
```

Let's build something we can PLAY

Input Control Generator

Using my touch-screen

```
$ xmousepos
838 574 221 170
```

```
x = `xmousepos`.split[0];
```

```
def mousefreq()
  count = 0
  x = 0.0
  lambda {
    count += 1
    if count  % 1000 == 0
      x = `xmousepos`.split[0].to_f
    end
    x
  }
end
```

```
play(
   amp(
      sine( mousefreq() ),
      mousevol()
   )
);
```

And now we have a synth :)

THE END

References

Source Code:
http://thelackthereof.org/NoiseGen
http://github.com/awwaiid/ruby-noise

Digital fidelity discussion:
http://people.xiph.org/~xiphmont/demo/neil-young.html

BONUS SLIDES

Note / Song Generators

```
note( 'A4' )
```

```
segment( 'A4 F3' ),
```

```
combine([
    segment( 'A4' ),
    segment( 'F3' ),
])
```

Formula-Based Noise
http://countercomplex.blogspot.com/2011/10/algorithmic-symphonies-from-one-line-of.html