

CS4347

# Sound and Music Computing

## Music Production Audio Effects



By Shawn Ng Yong Kwang

# Hello there!

Been producing  
music for 12 years

- Sound design
- Synthesis
- Mixing
- Mastering
- ...



Worked with the following Digital Audio Workstations:



# How is Music Produced?



Digital Audio Workstation  
(DAW)

# Today's Topic: Audio Effects



# Today's Topic: Audio Effects

Dry Audio Signal



Wet Audio Signal

Audio Effect

# Audio Effects to Cover

- Time-based effects — Delay, Reverb
- Modulation effects — Tremolo, Flanger
- Distortion — Clipping, Bitcrushing, Downsampling

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- Time-based effects — Delay, Reverb
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# Echo

Sound reflected in a space



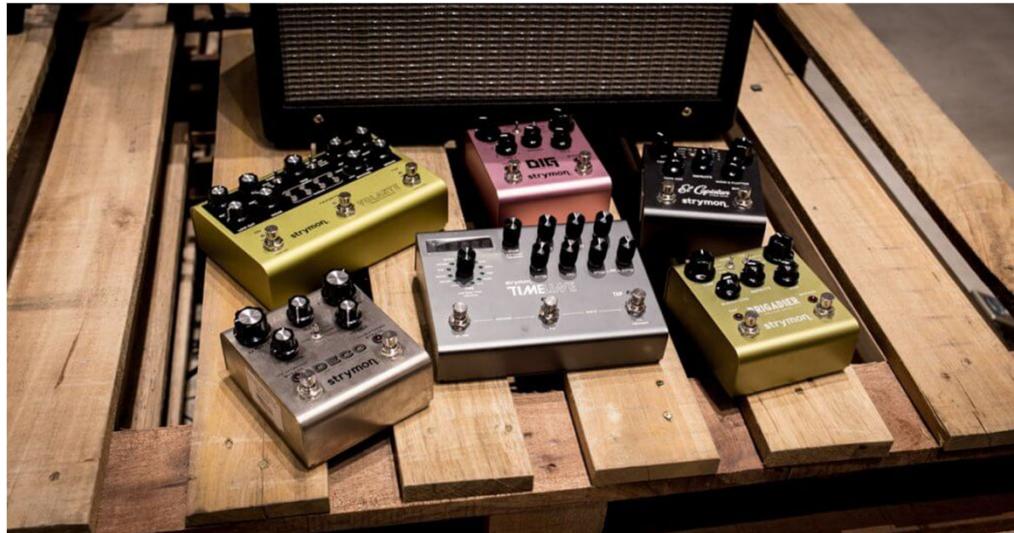
# Delay



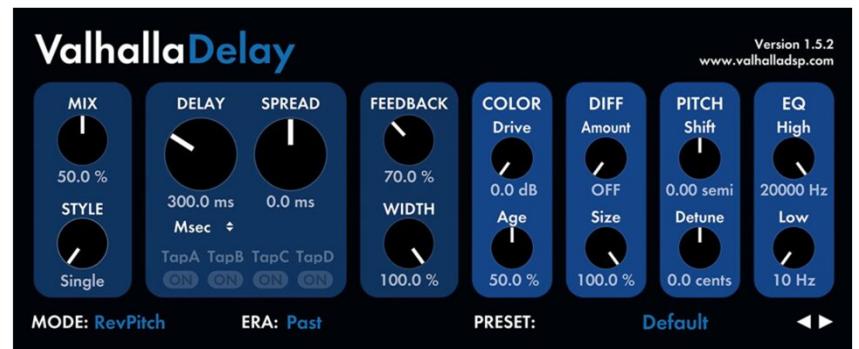
Analog Tape Delay



Digital Delay

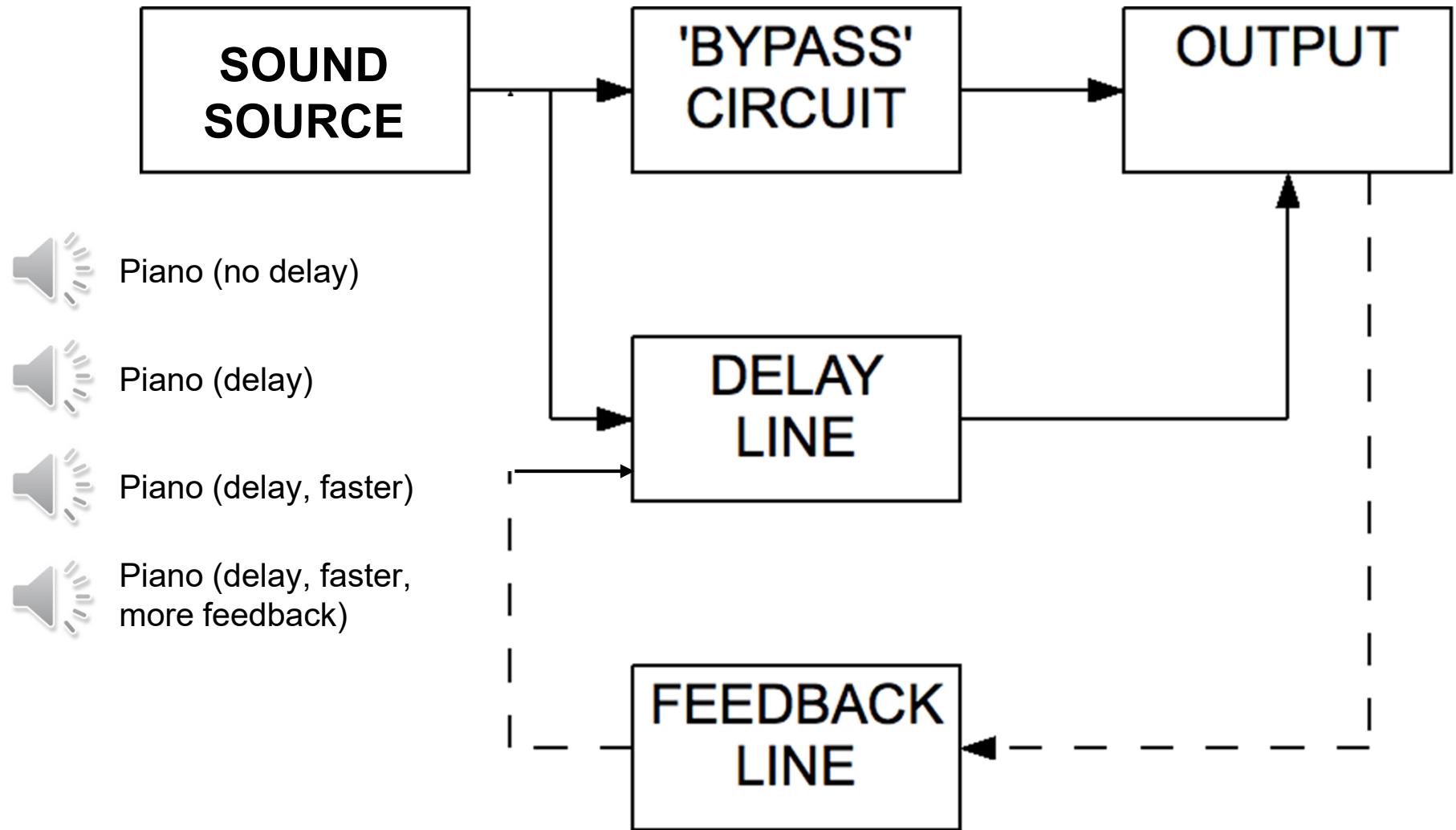


Delay Pedals

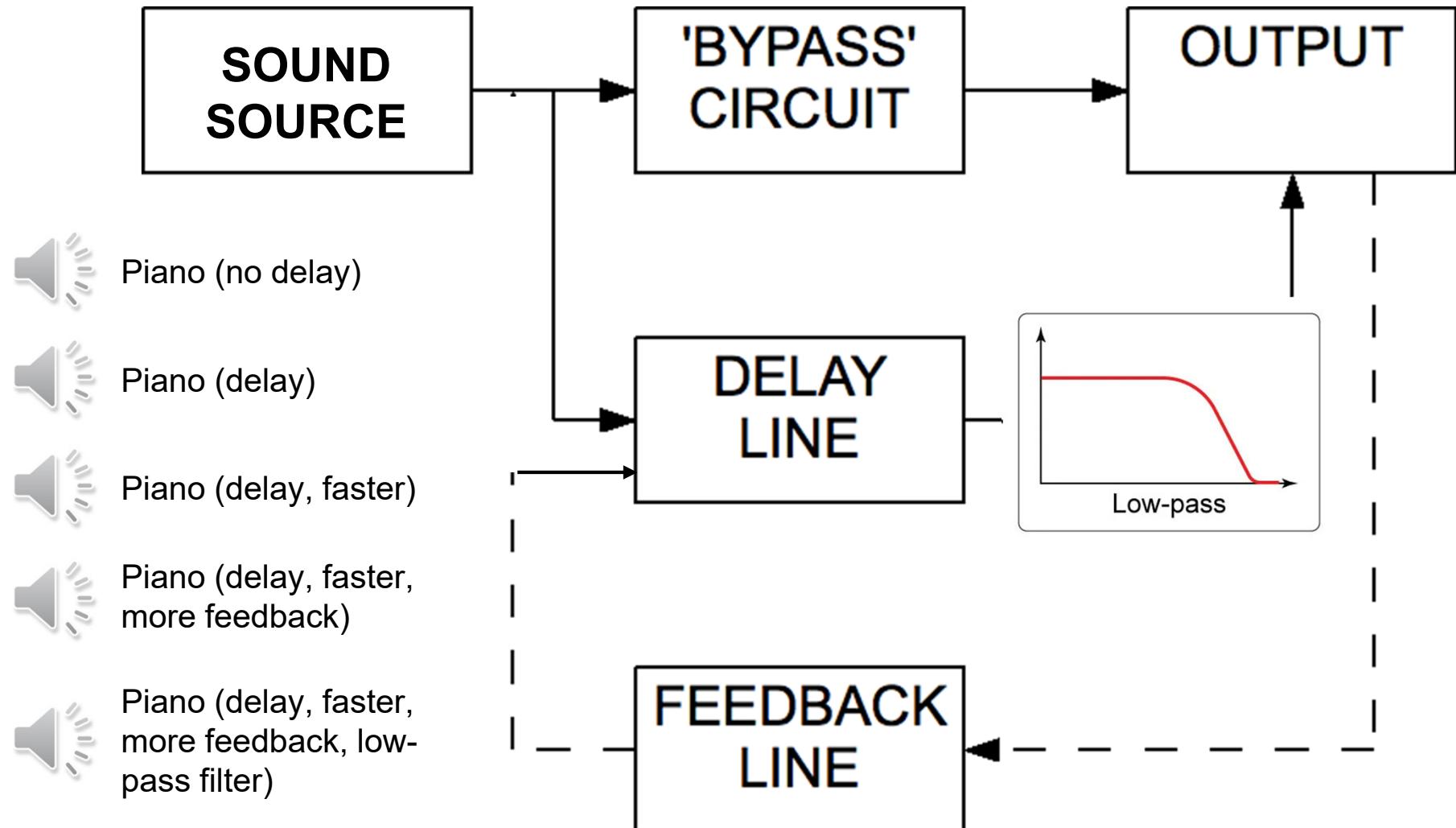


Delay Plugin

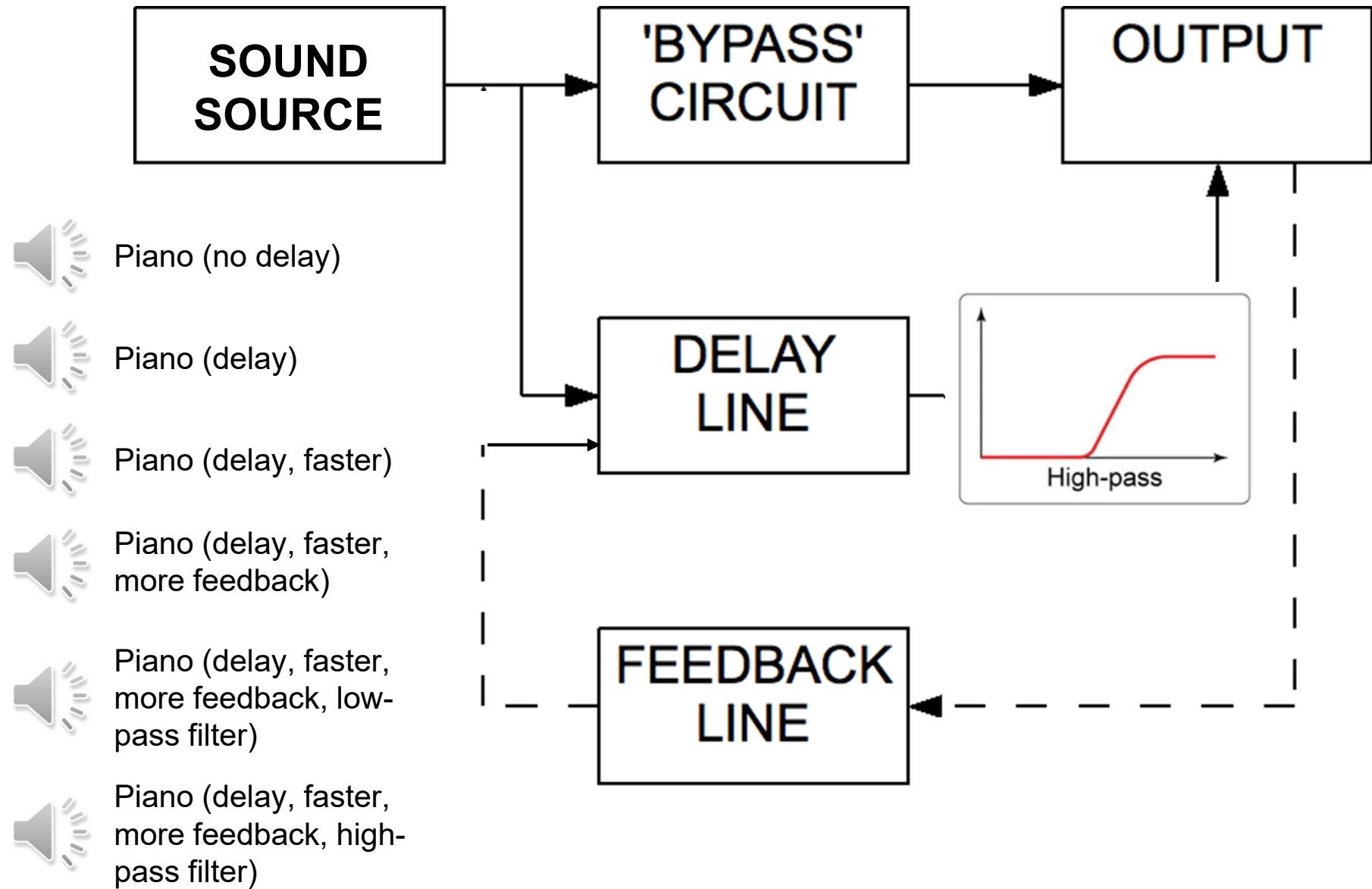
# Delay



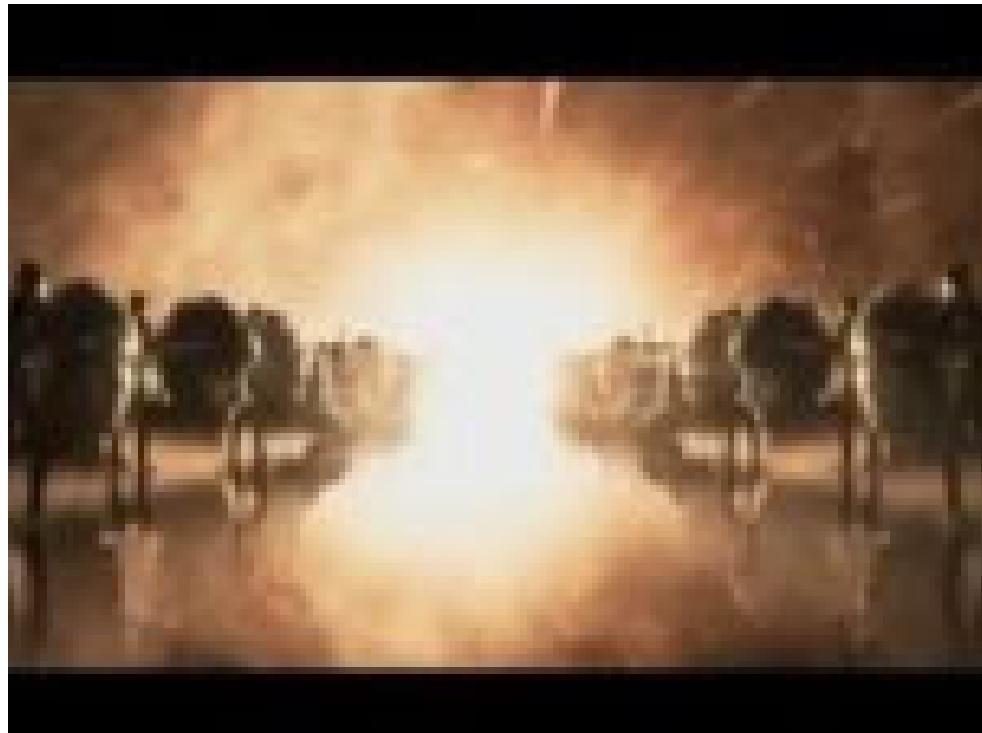
# Delay



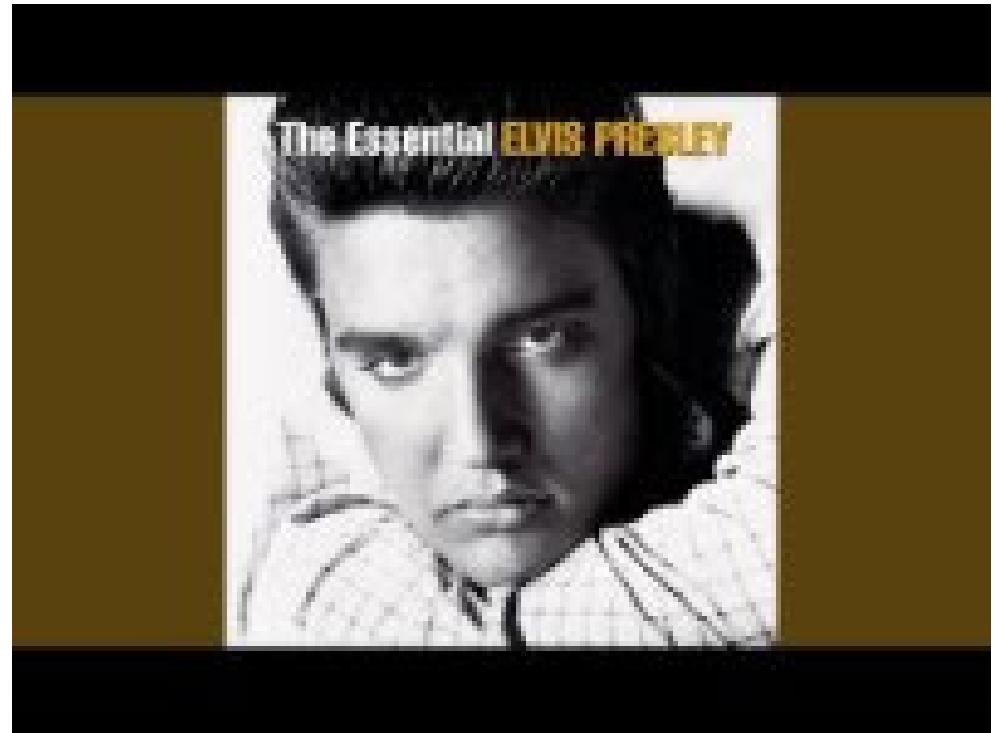
# Delay



# Delay - Song Examples



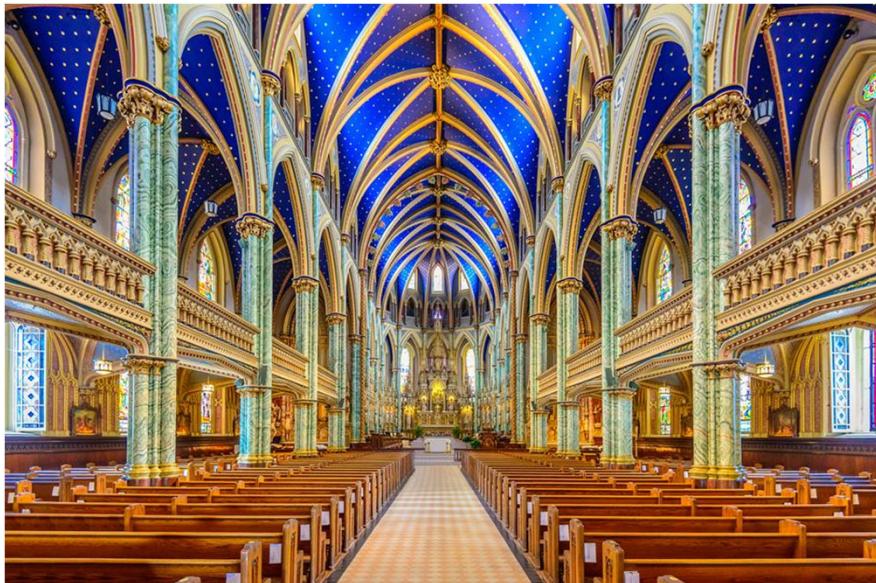
The Temper Trap - Sweet Disposition



Elvis Presley - Mystery Train

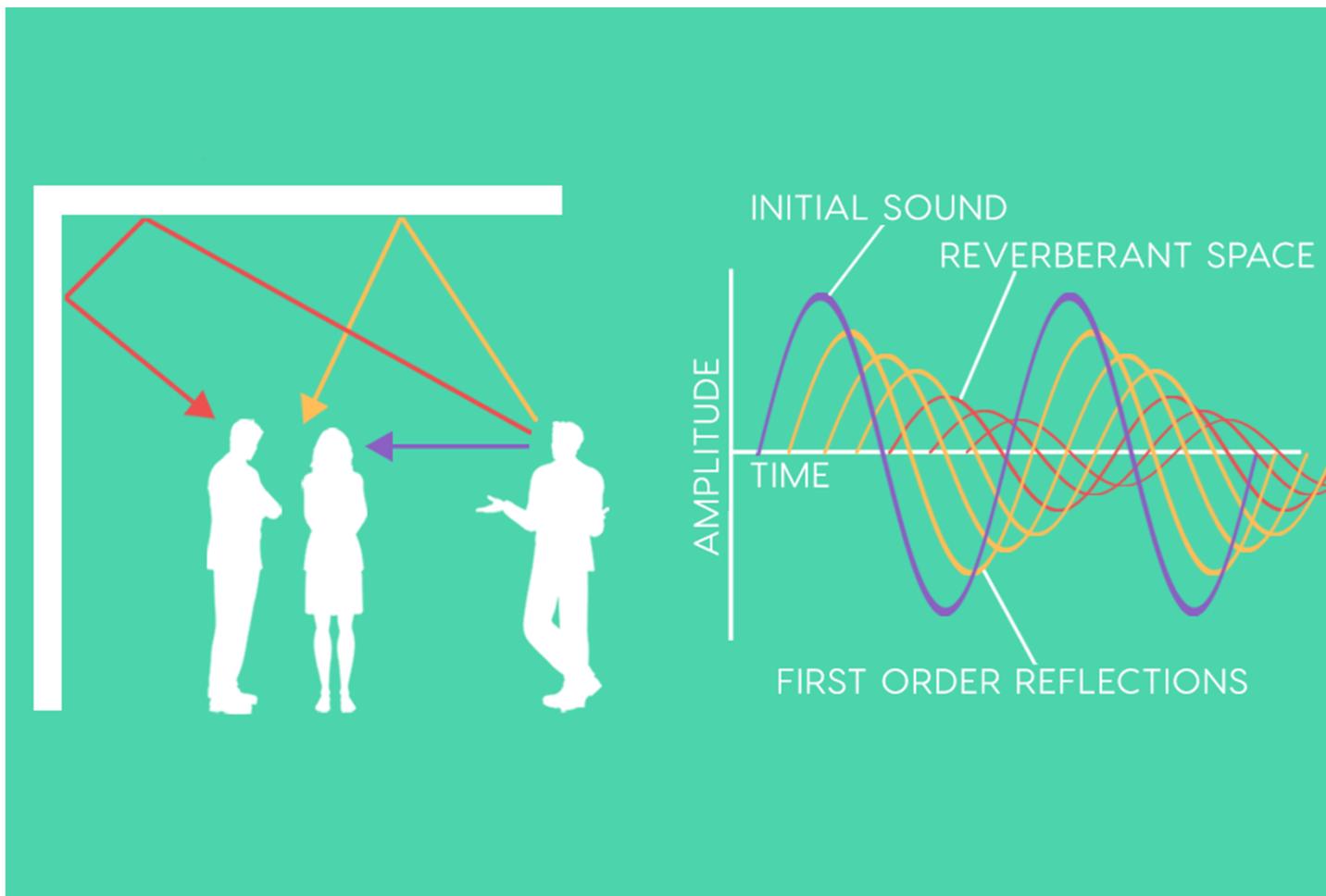
# Reverberation

Also sound reflected in a space



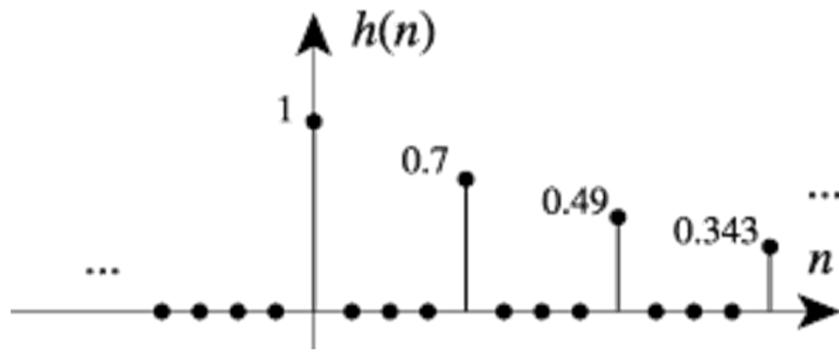
# Reverb vs. Echo

- Echoes: > 50ms - 100ms after the previous sound
- Reverb: < 50ms after the previous sound

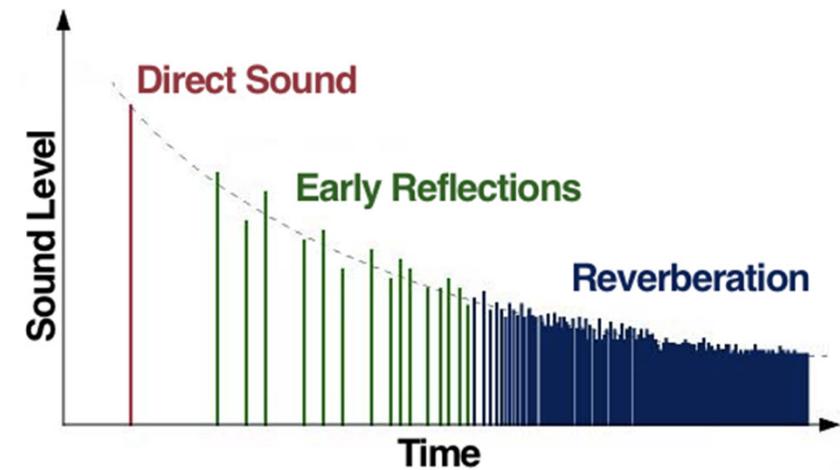


# Reverb vs. Echo

- Echoes: Evenly-spaced time intervals
- Reverb: Complex time intervals



Echoes

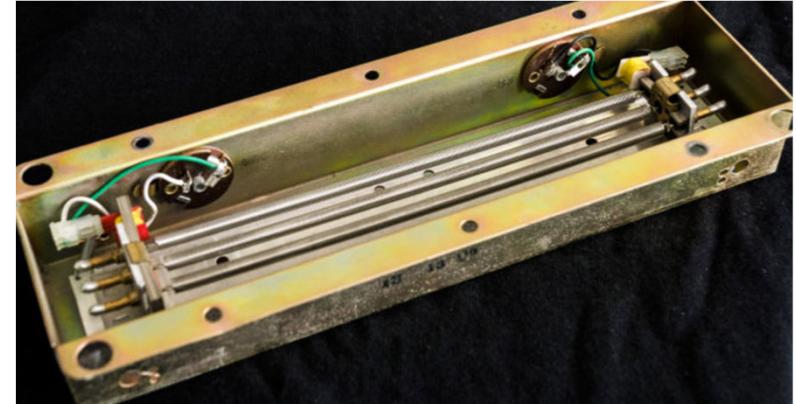


Reverb

# Types of Reverb



Plate Reverb



Spring Reverb



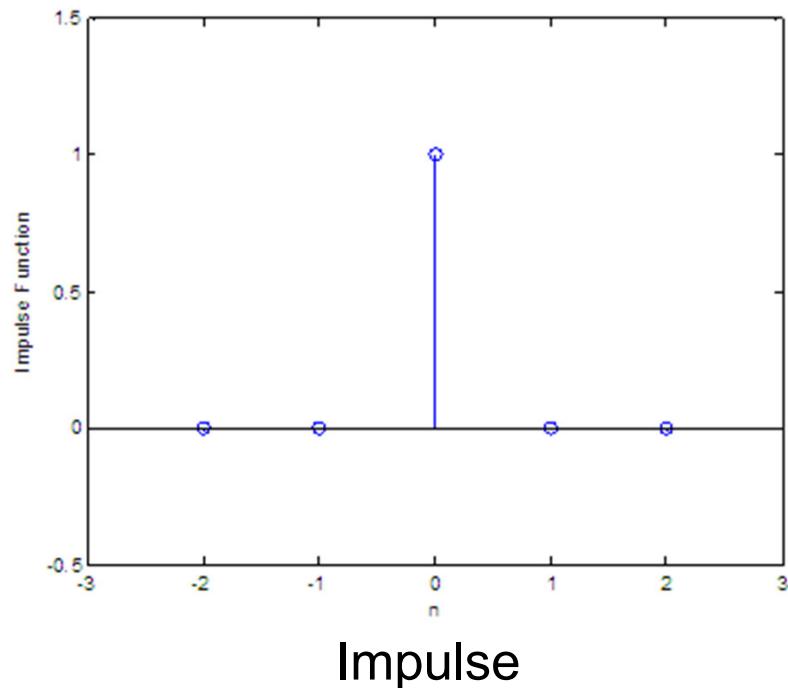
Digital/Algorithmic Reverb



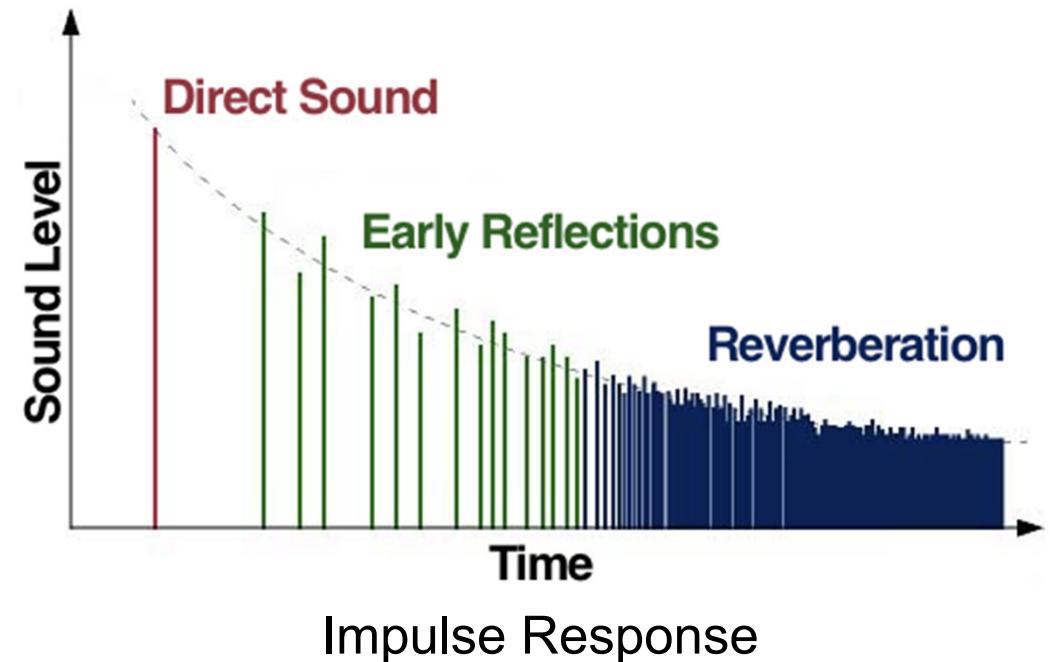
Convolution Reverb

And more!

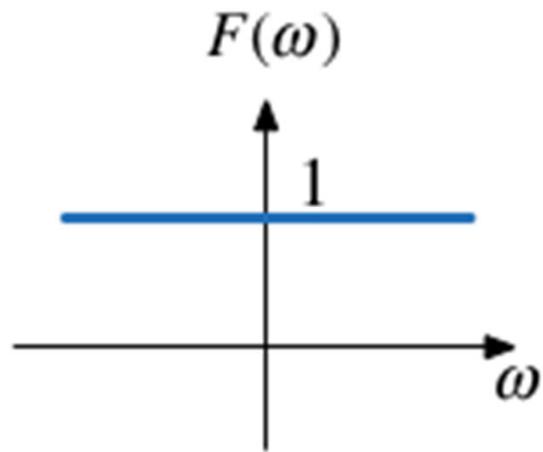
# Impulse Response



Impulse

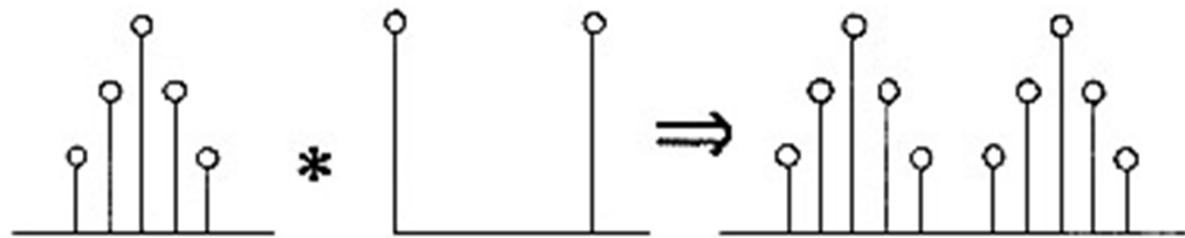


Impulse Response

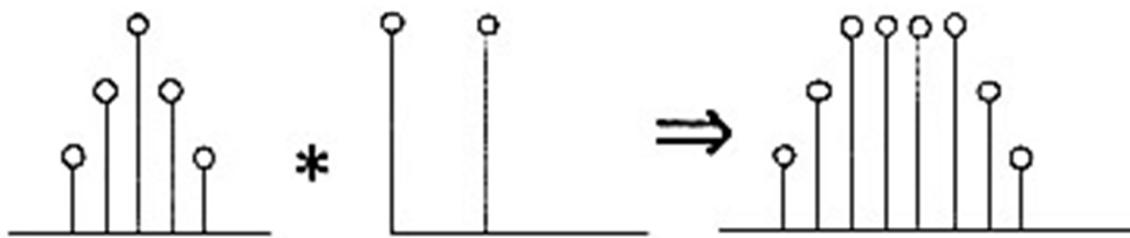


# Convolution Recap

(a)

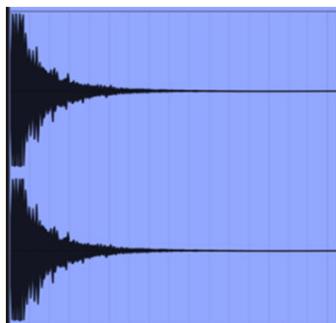


(b)

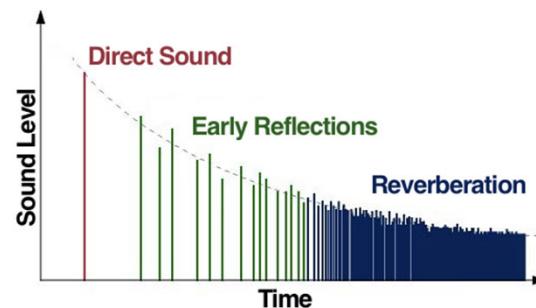


# Convolution Reverb

Snare



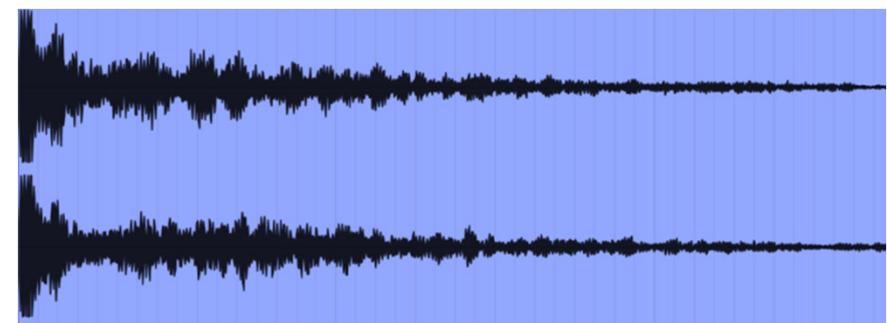
Impulse Response  
of Cathedral



\*



Snare in a cathedral

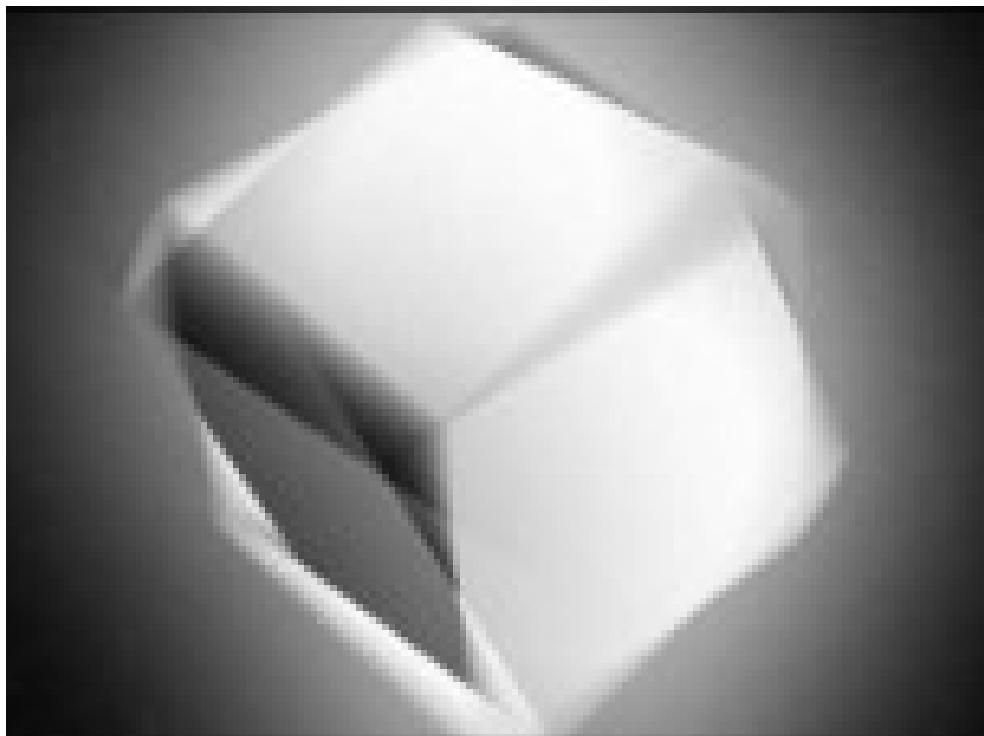


# Convolution Reverb



Demo of Altiverb, the leading convolution reverb plugin

# Reverb - Song Examples



Slowdive - Star Roving  
(@ 0:50)



Phil Collins - In The Air Tonight  
(@ 3:35)

# Audio Effects to Cover

- Time-based effects — Delay, Reverb
- Modulation effects — Tremolo, Flanger
- Distortion — Clipping, Bitcrushing, Downsampling

# Tremolo

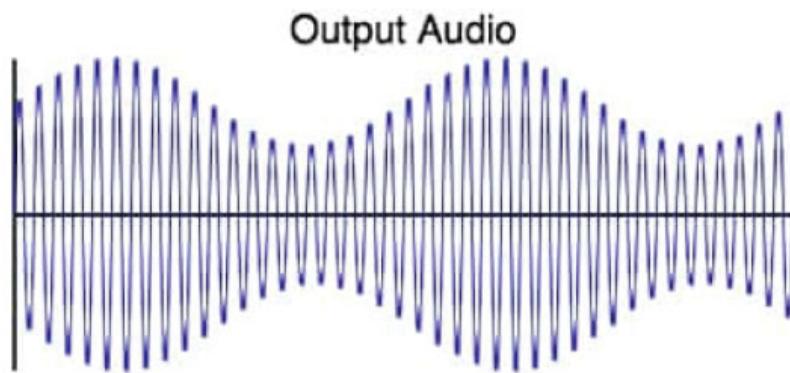
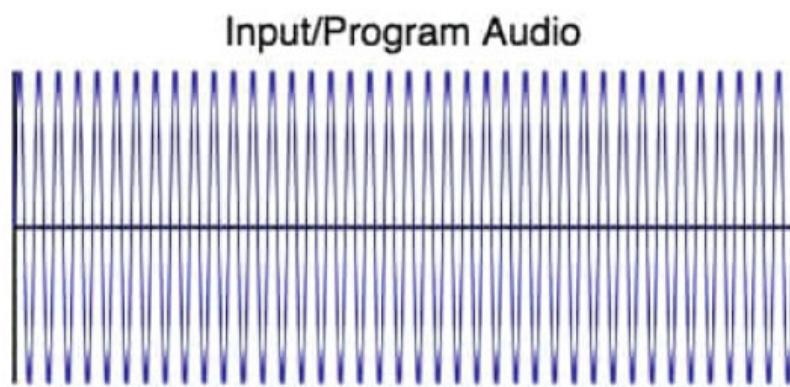
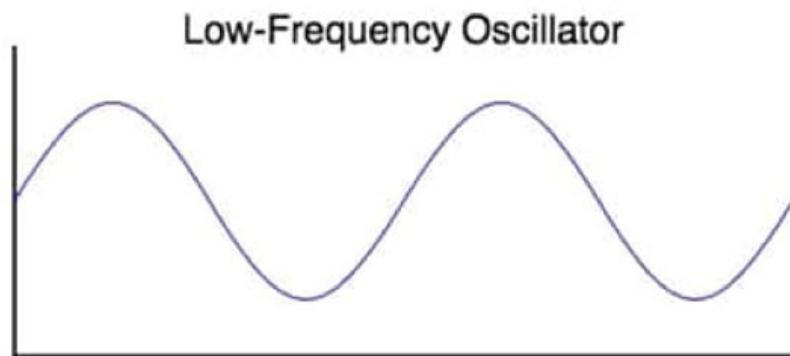


Tremolo Plugin



Tremolo Pedals

# Tremolo



Wurlitzer Electric Piano

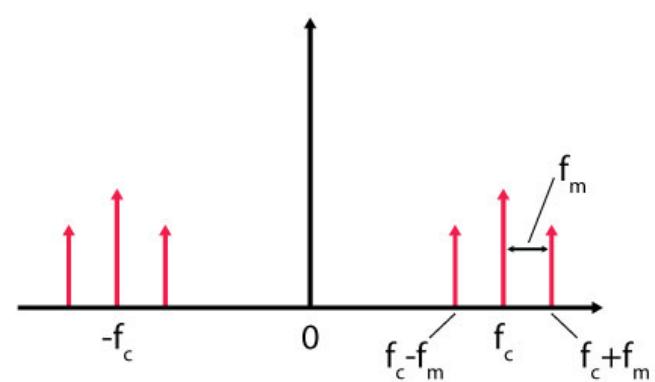
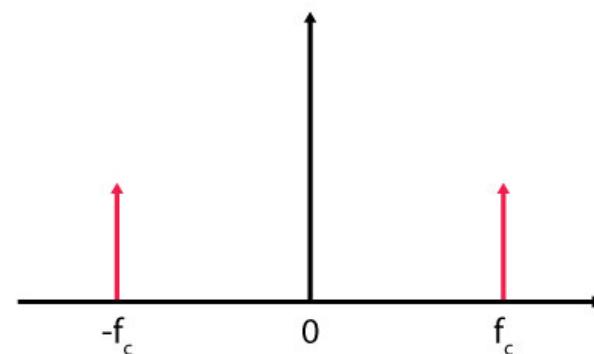
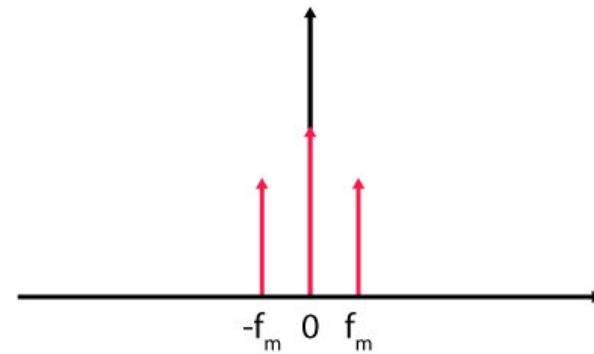
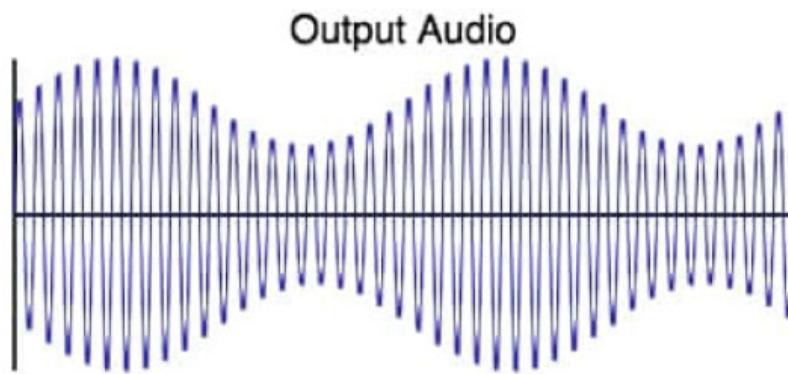
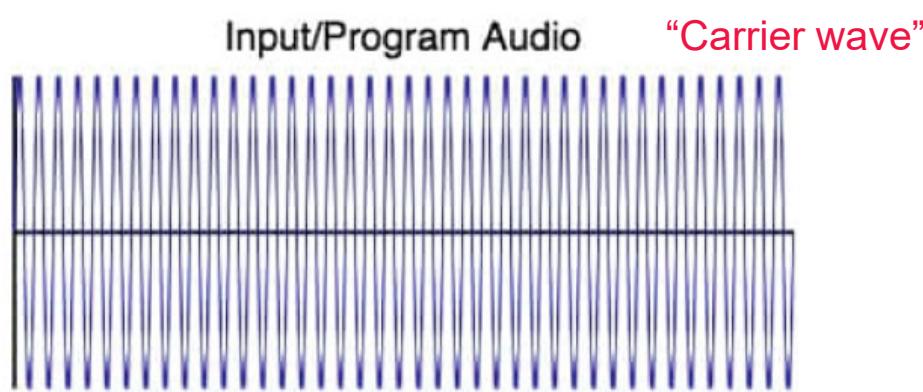
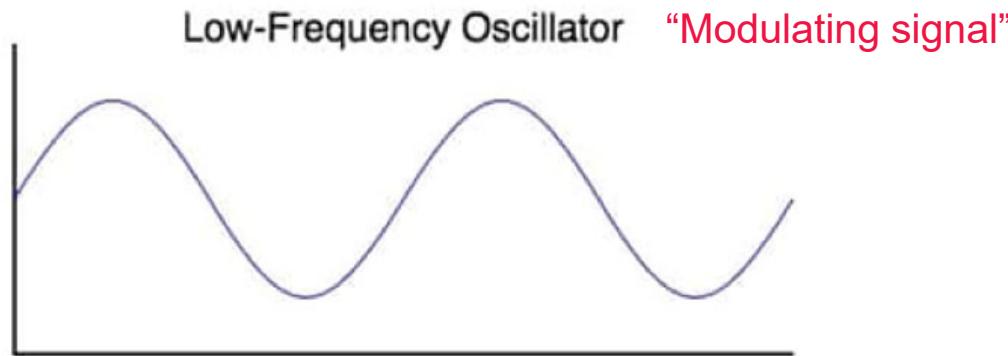


Electric Piano



Electric piano with tremolo

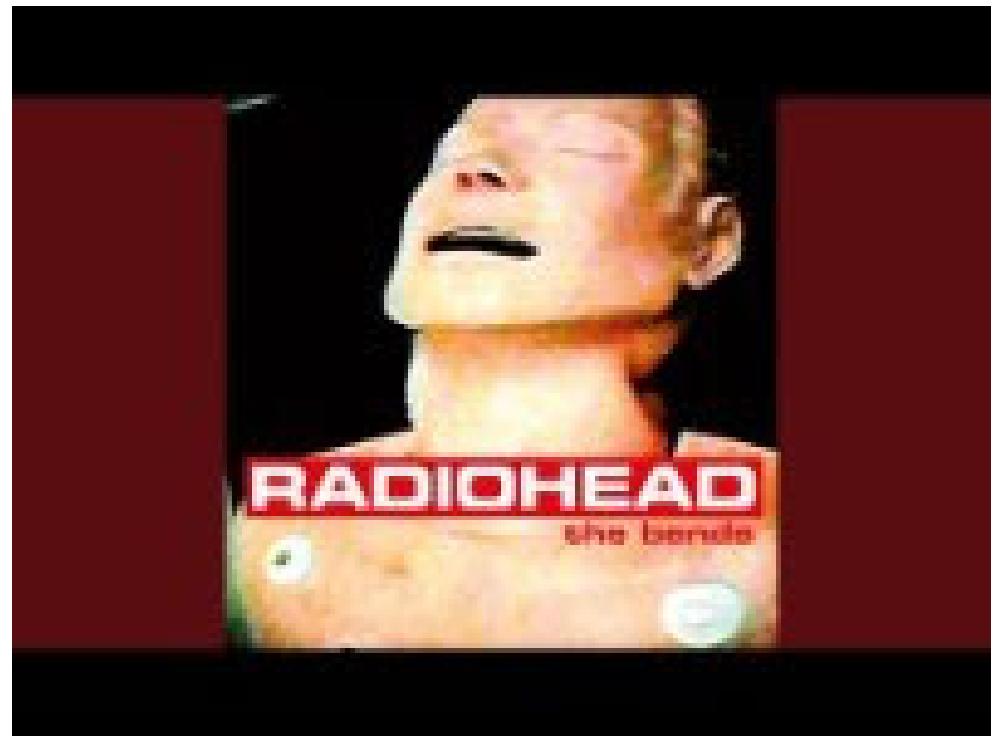
# Sidebands



# Tremolo - Song Examples



Beck - Where It's At



Radiohead - Bones

# Flanger



Electric Piano

Electric Piano  
(Flanged)

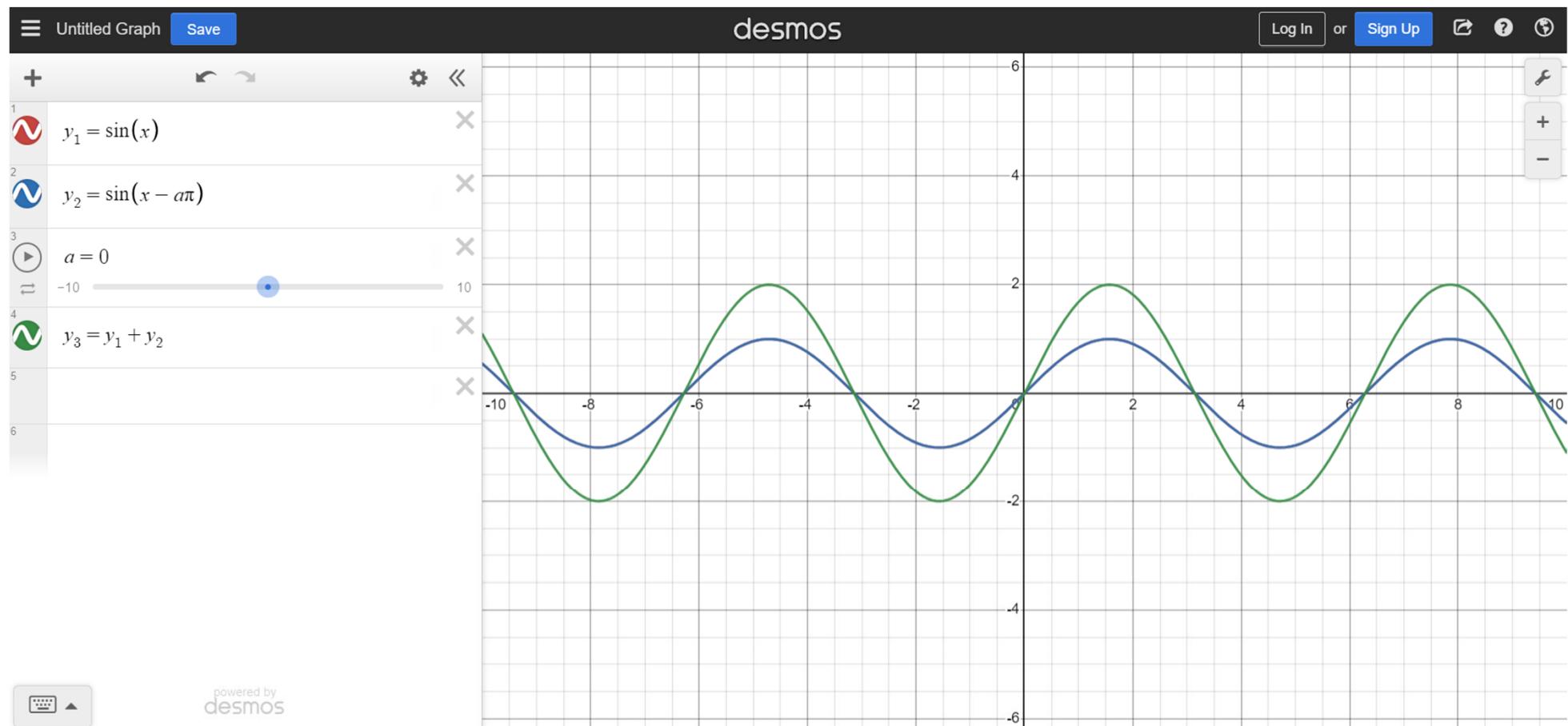


Flanger Pedal



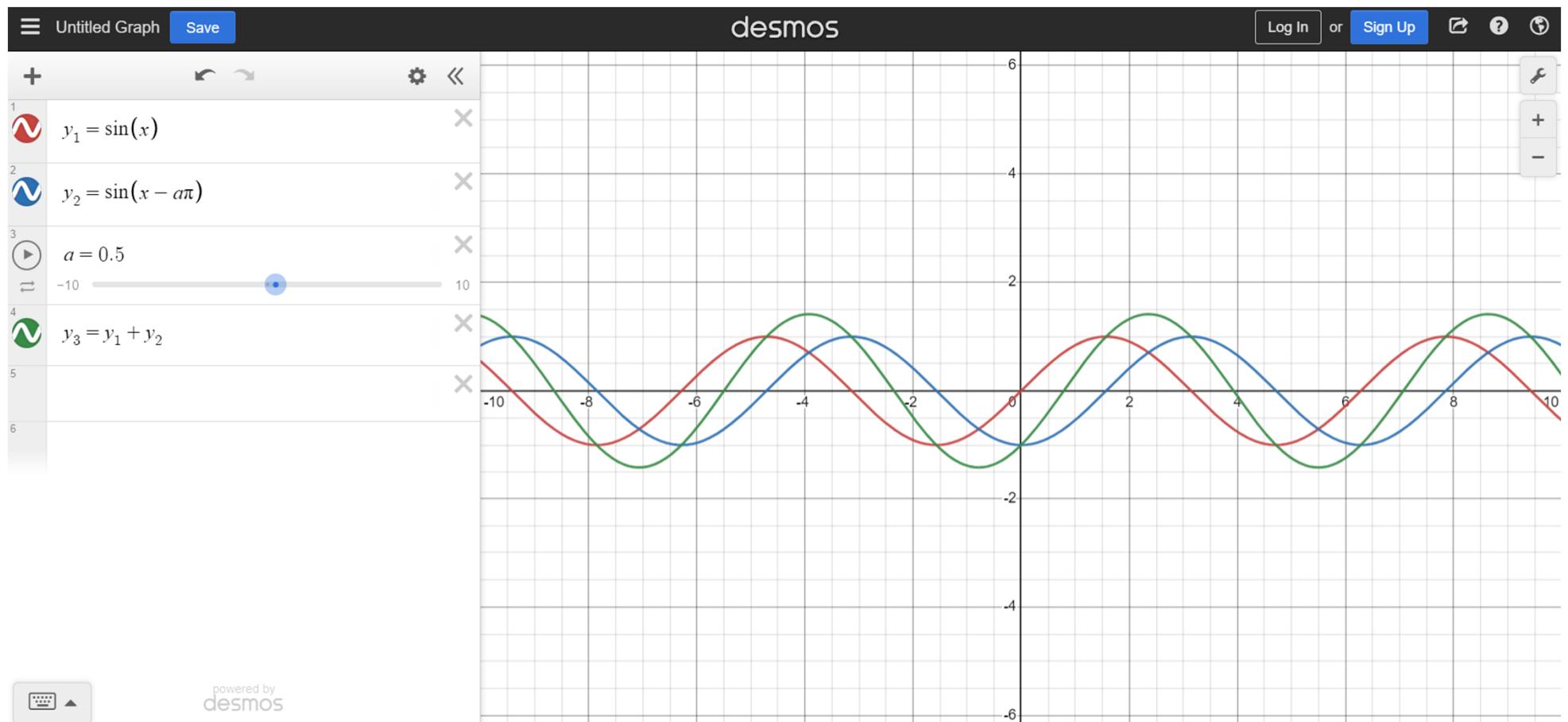
Flanger Plugin

# Phasing and Interference



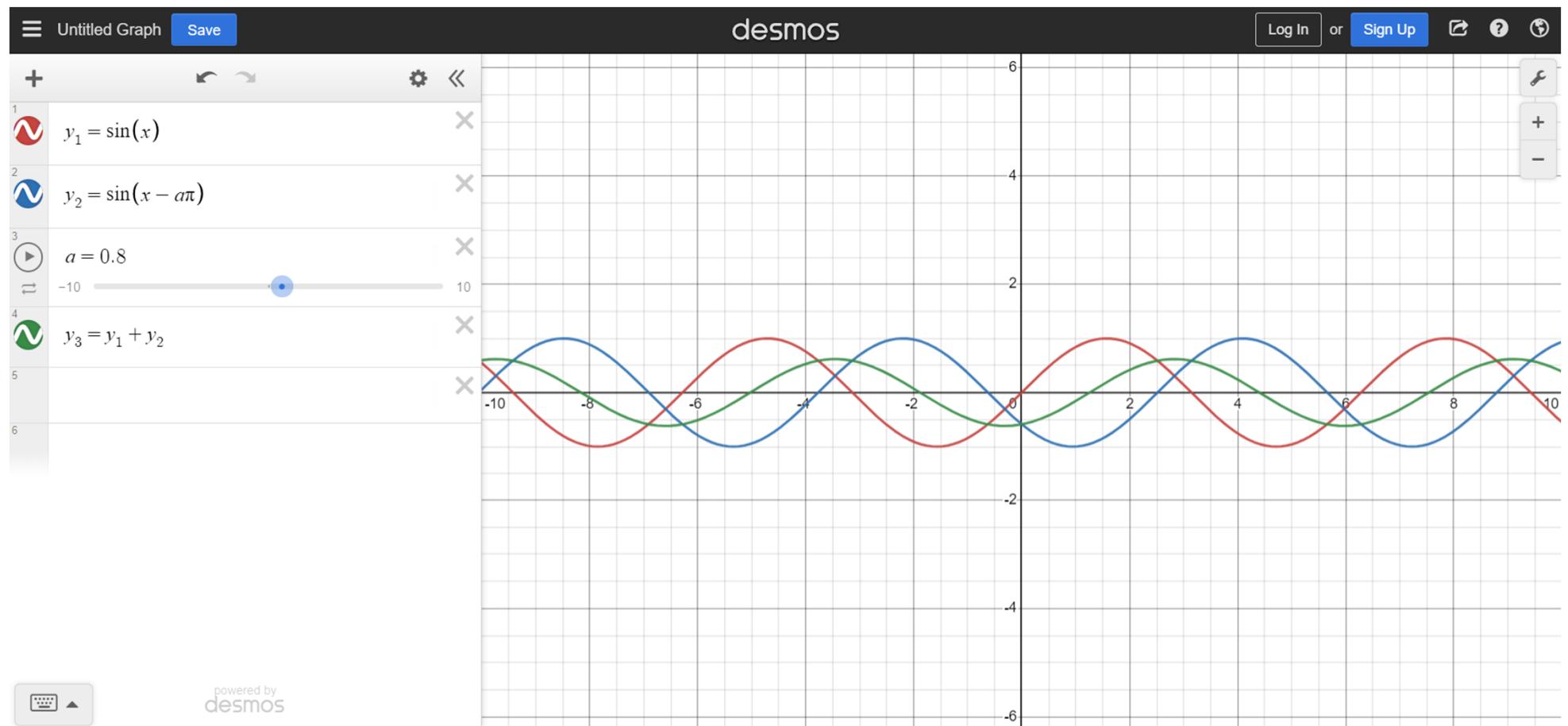
Complete constructive interference

# Phasing and Interference



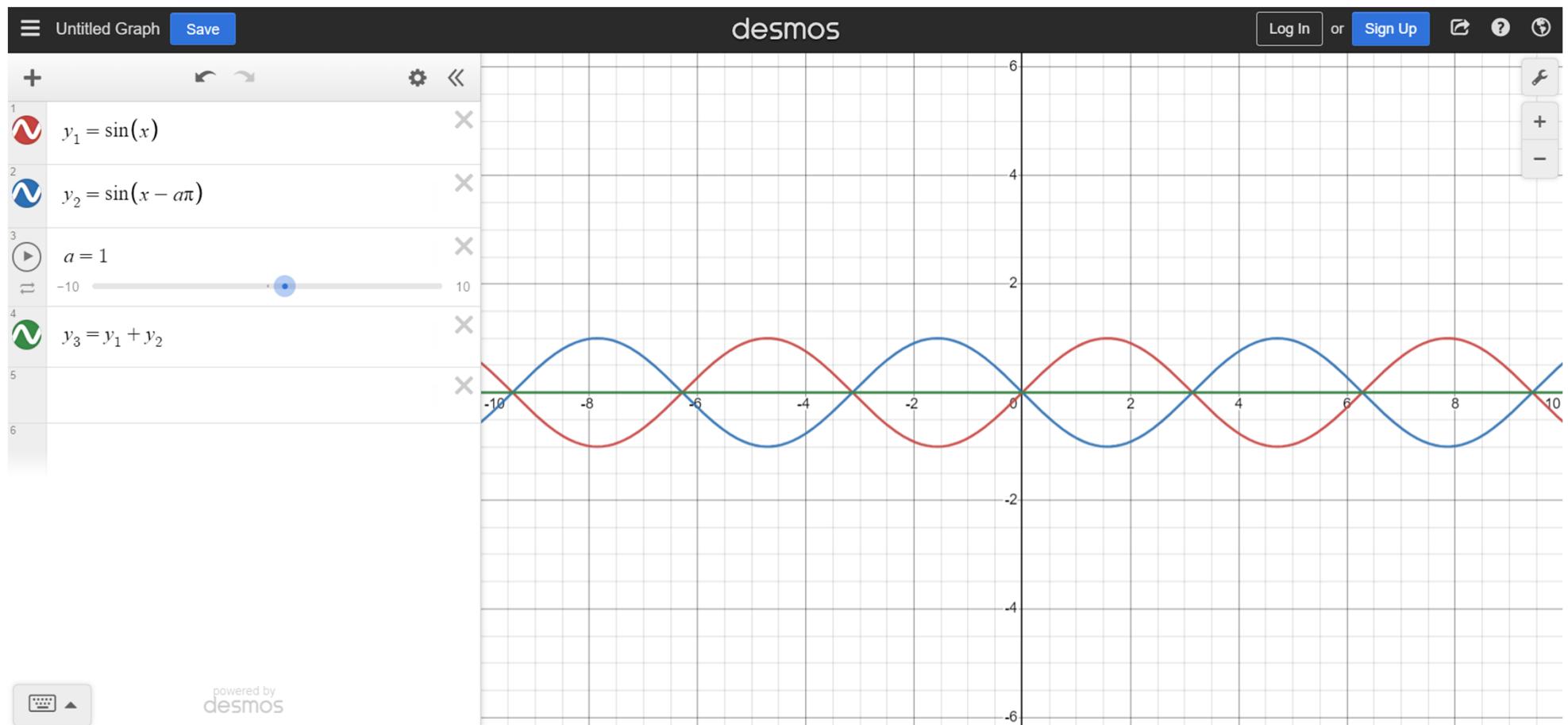
Partial constructive interference

# Phasing and Interference



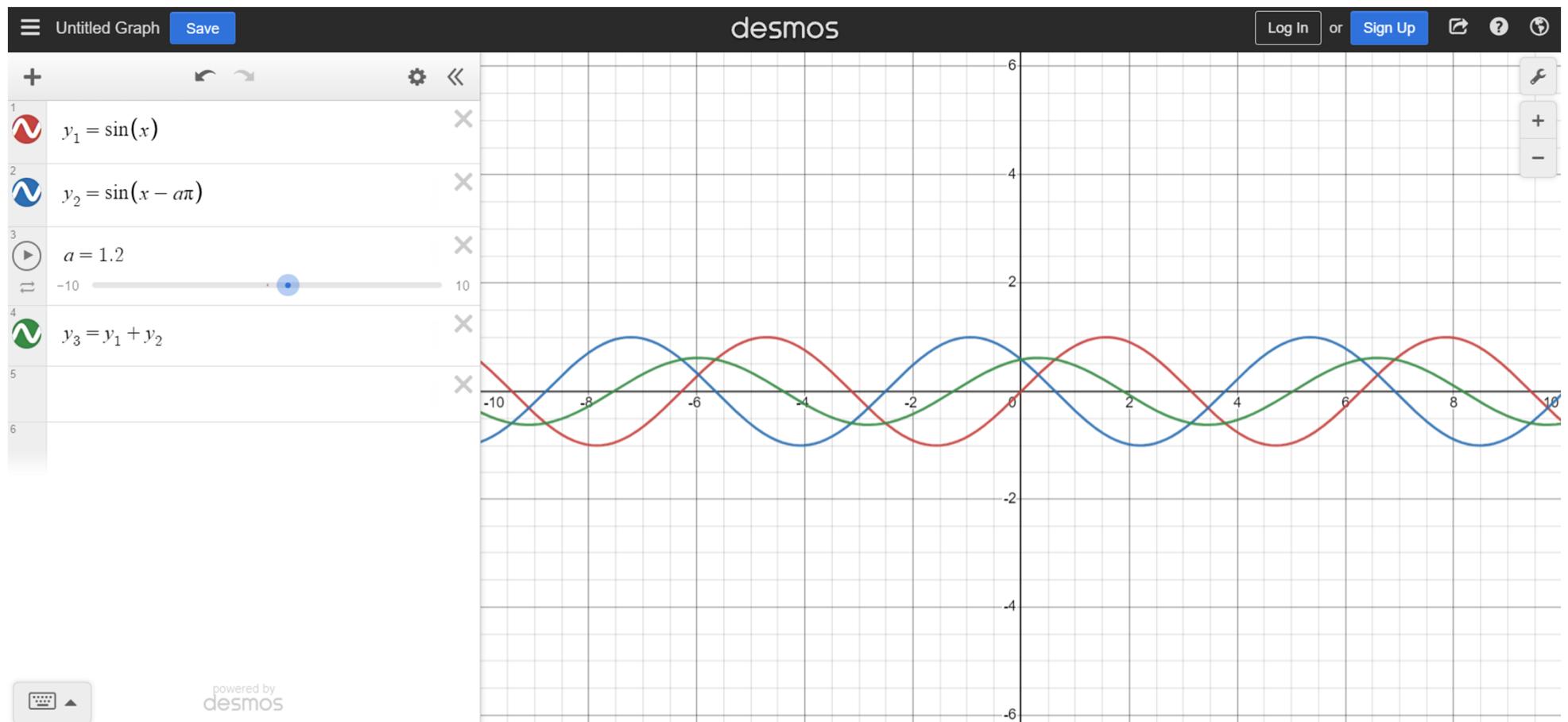
Partial destructive interference

# Phasing and Interference



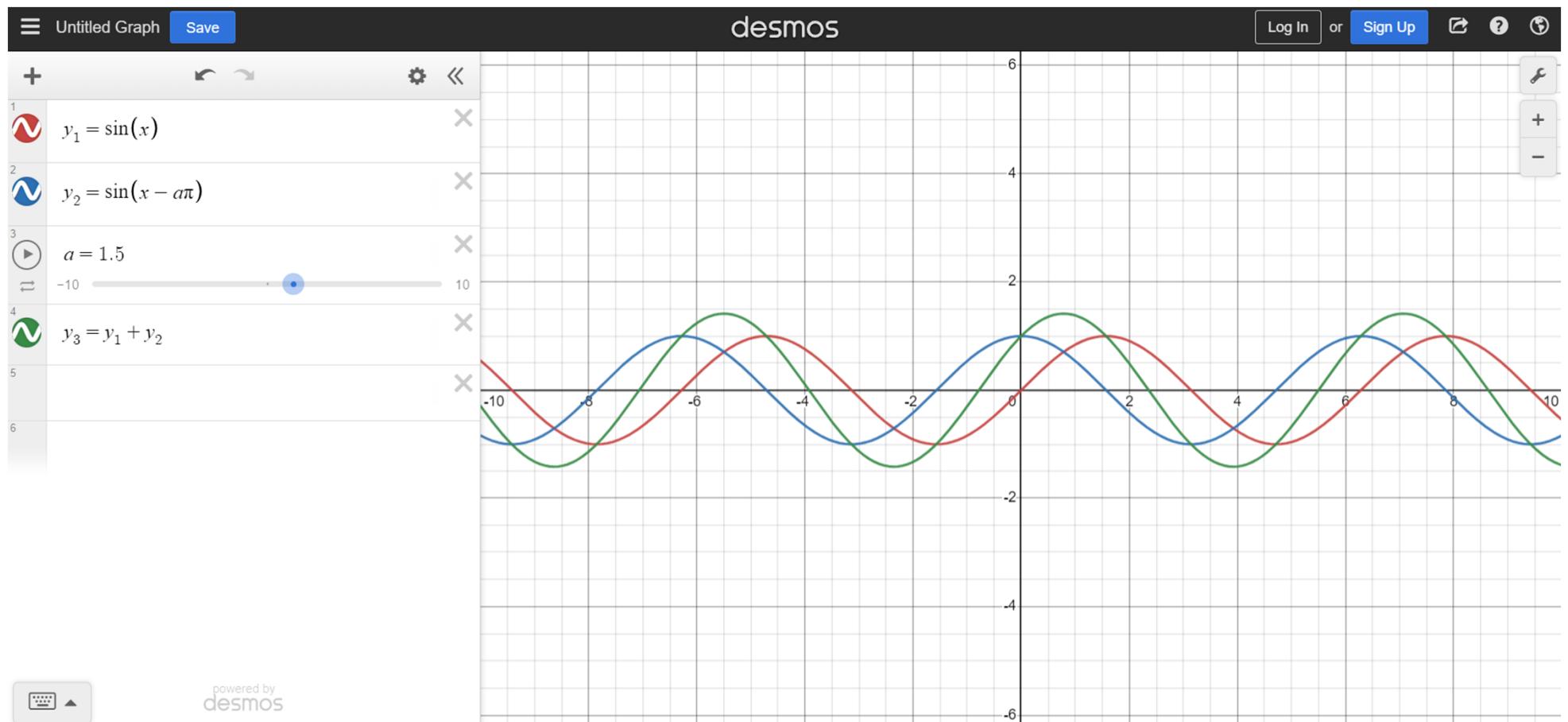
Complete destructive interference

# Phasing and Interference



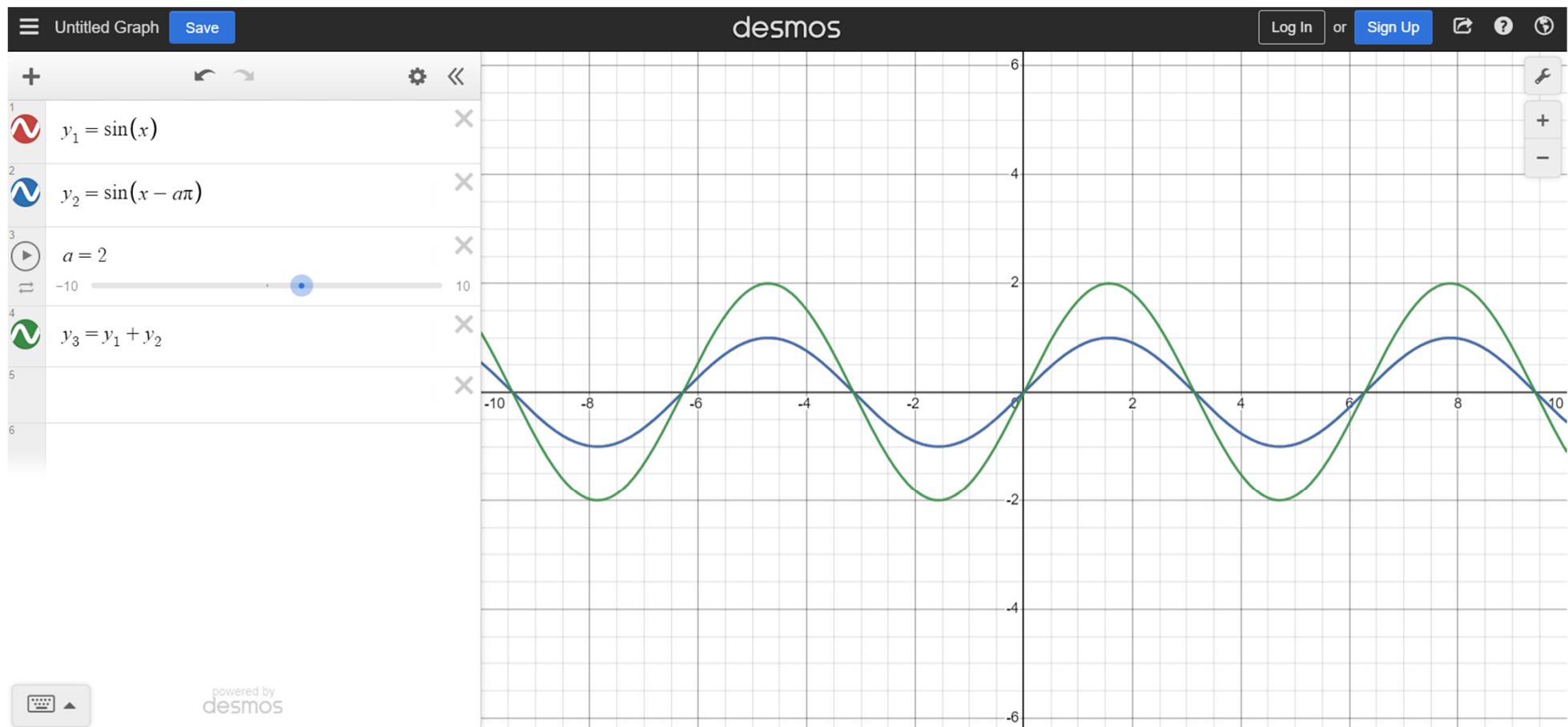
Partial destructive interference

# Phasing and Interference



Partial constructive interference

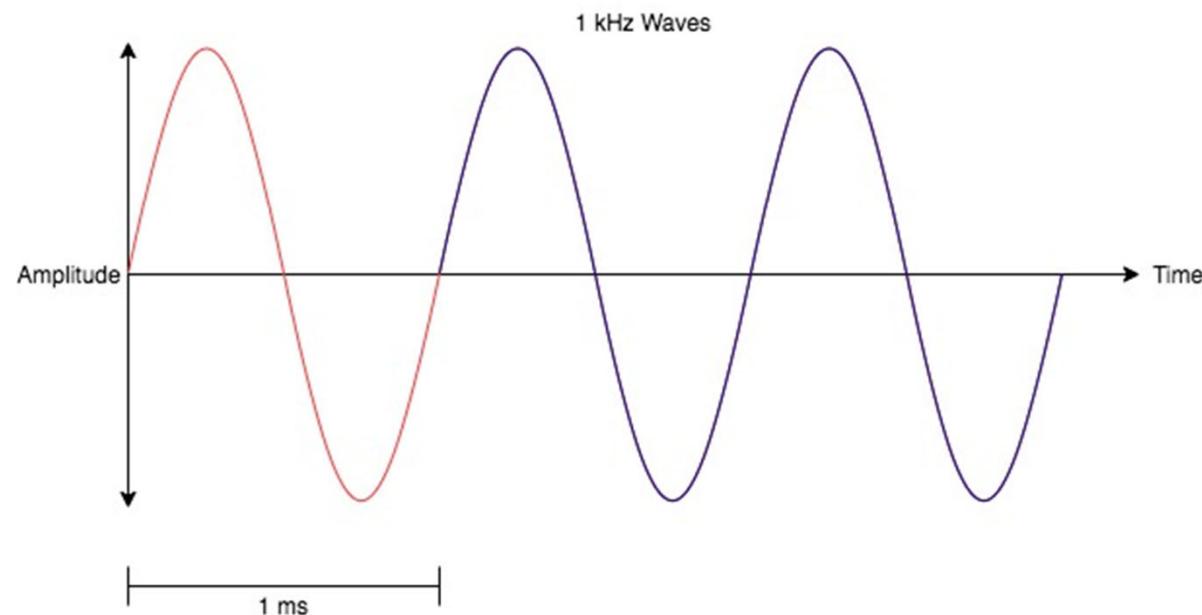
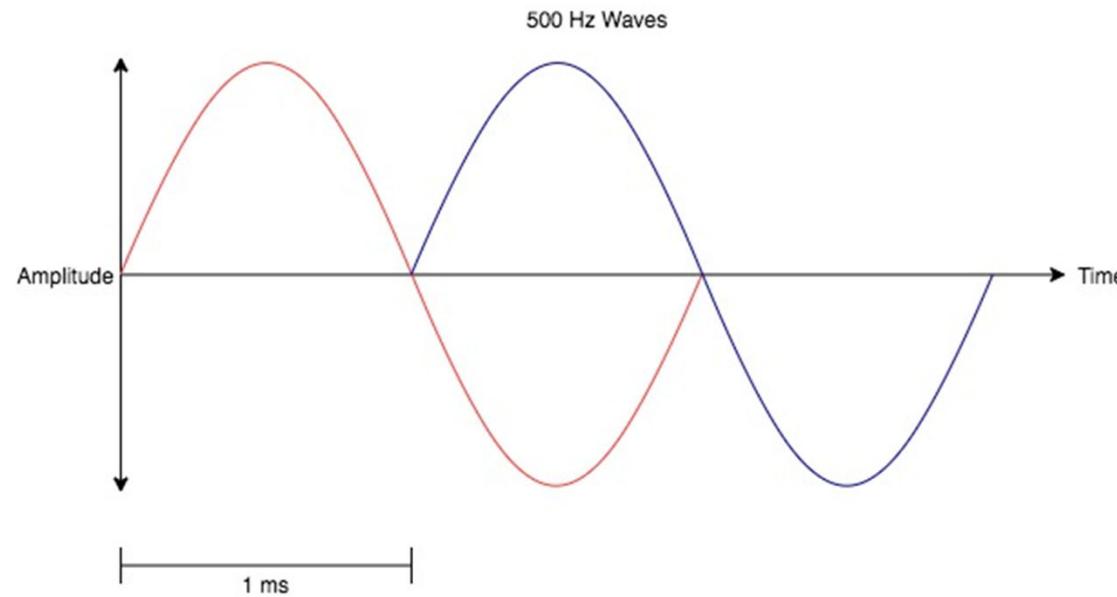
# Phasing and Interference



Complete constructive interference

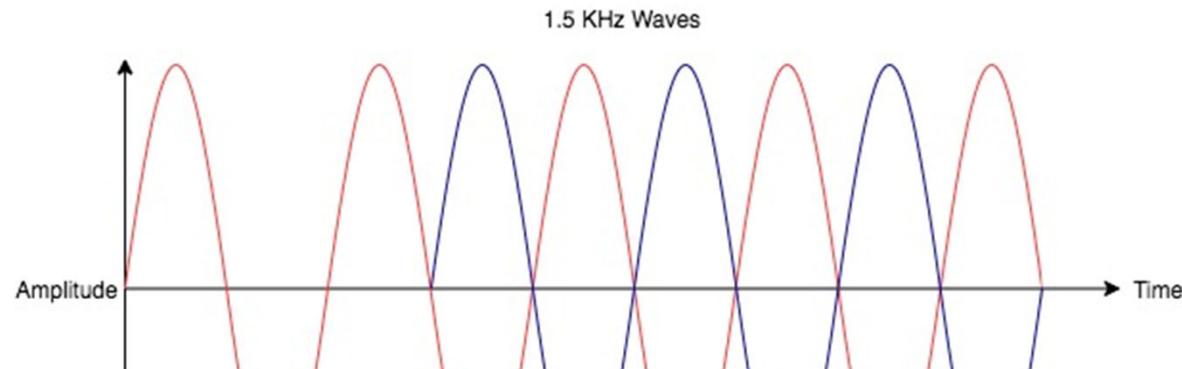
# Flanger

Duplicate an audio signal and offset it by 1ms

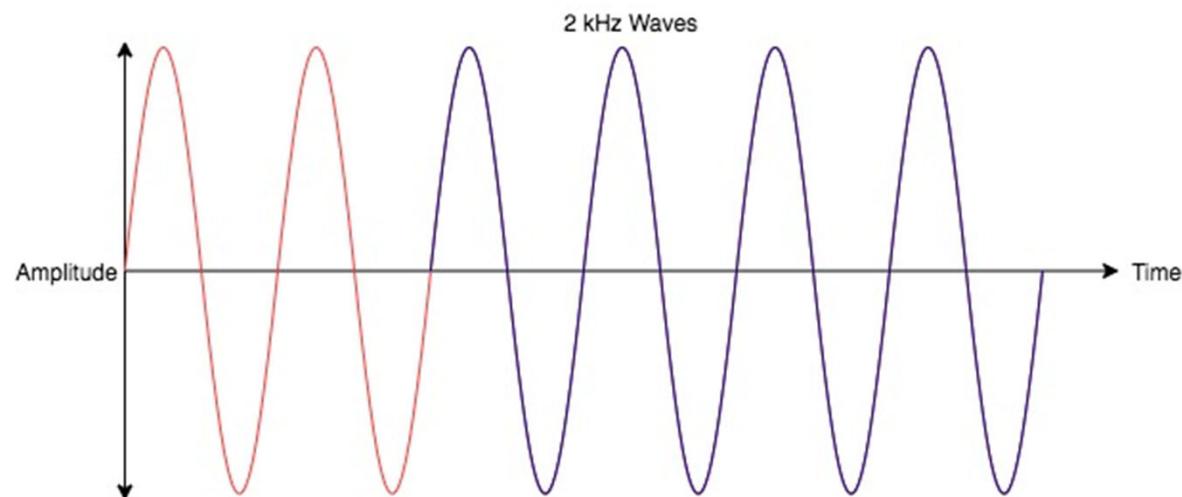


# Flanger

Duplicate an audio signal and offset it by 1ms



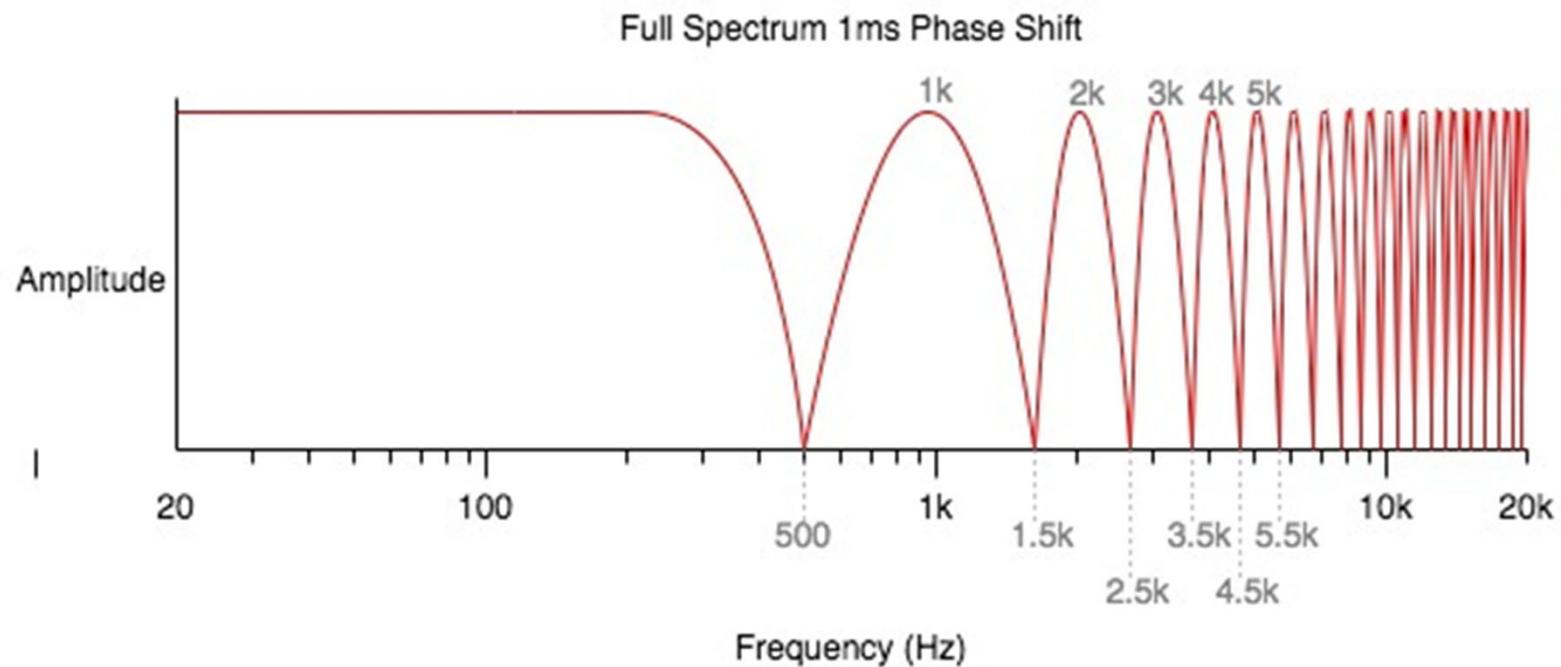
1 ms



1 ms

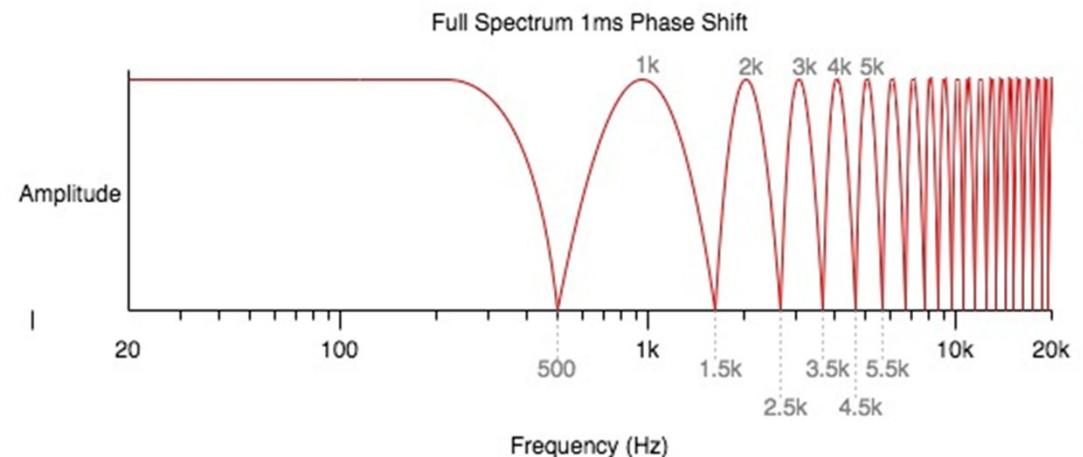
# Flanger

The resultant effect is equivalent to filtering the audio signal with this comb filter:



# Flanger

A flanger modulates the phase shift amount over time  
(e.g. swinging back and forth between 1ms to 3ms)



Electric Piano



Electric Piano (Flanged)



# Flanger and Co.



Flanger, Phaser, Chorus

# Flanger - Song Examples



Tame Impala - Endors Toi



Tears For Fears - Head Over Heels  
(@ 2:35)

# Audio Effects to Cover

- Time-based effects — Delay, Reverb
- Modulation effects — Tremolo, Flanger
- Distortion — Clipping, Bitcrushing, Downsampling

# Distortion



Harmonic Distortion / Saturation /  
Overdrive / Fuzz

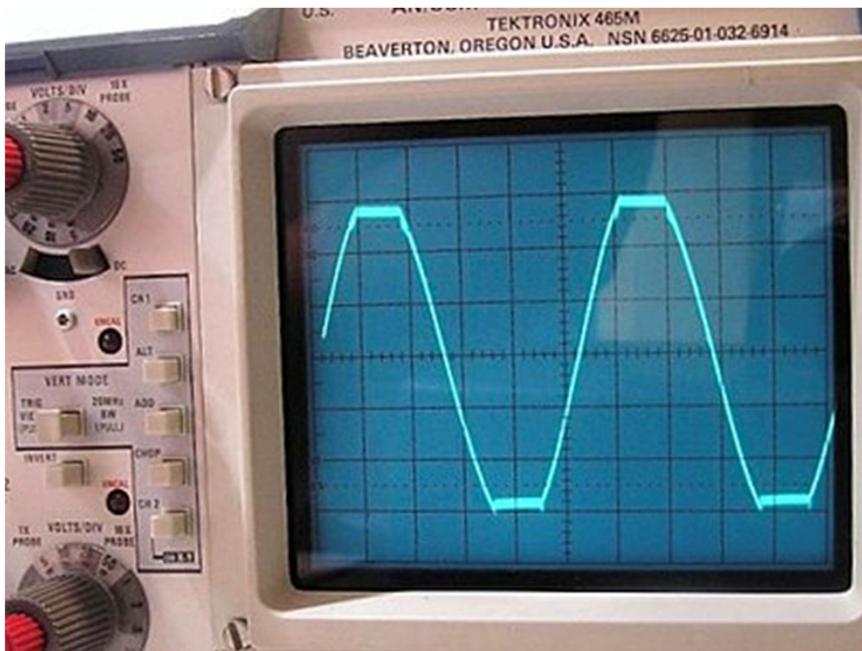


Bitcrush

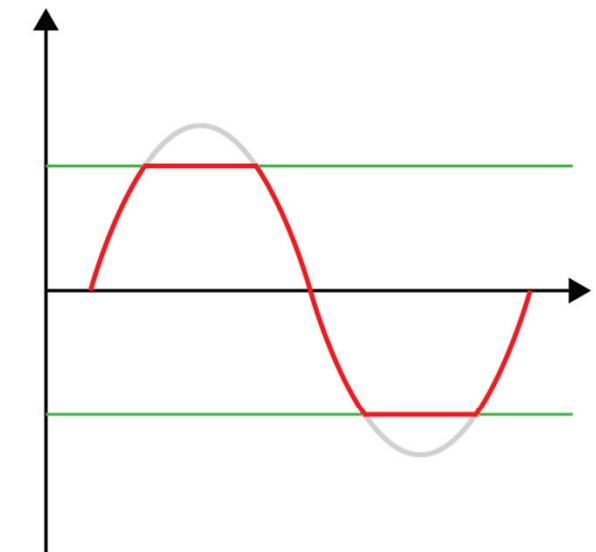
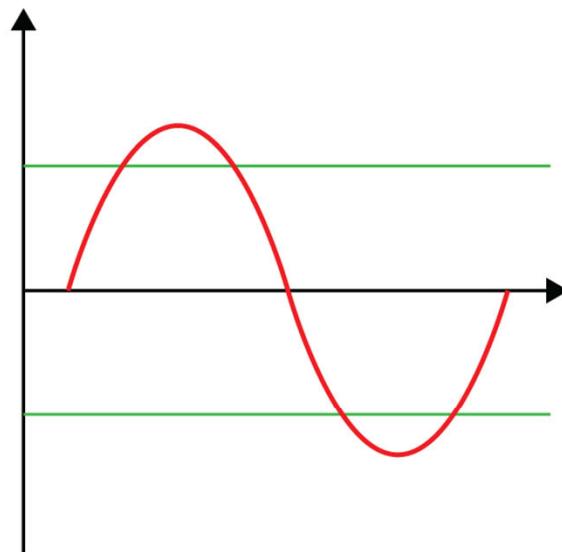
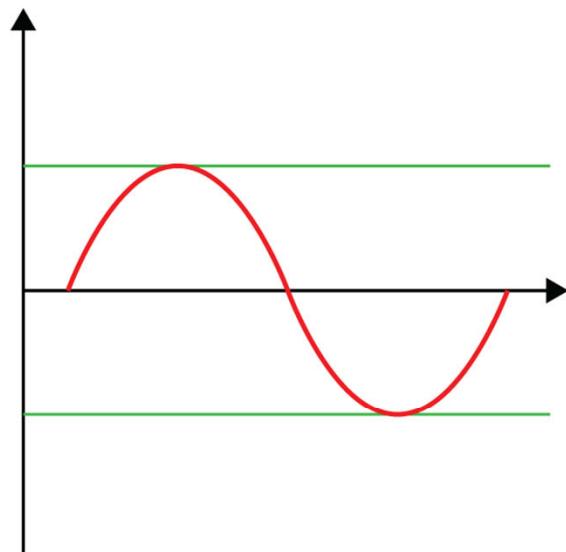


Clipping

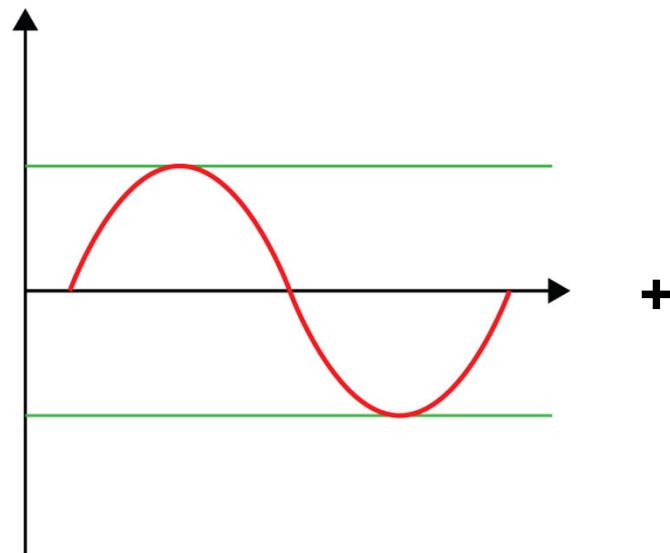
# Clipping



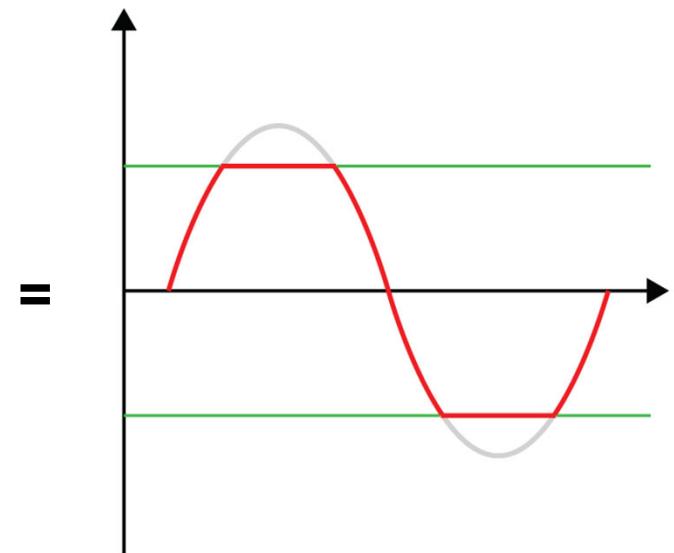
# Clipping



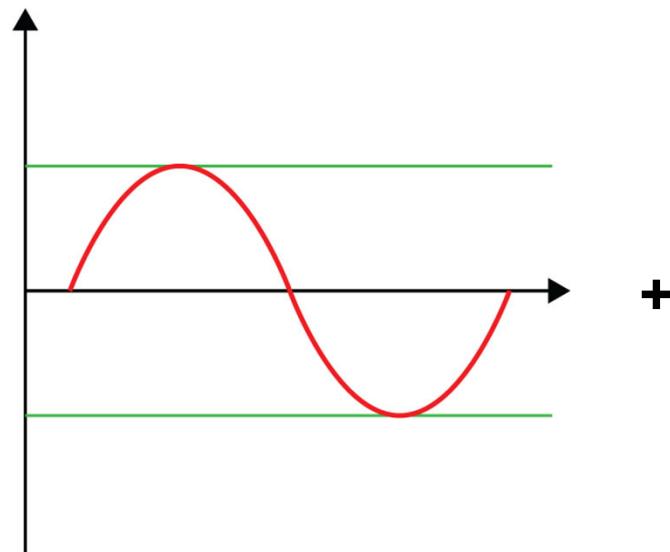
# Clipping



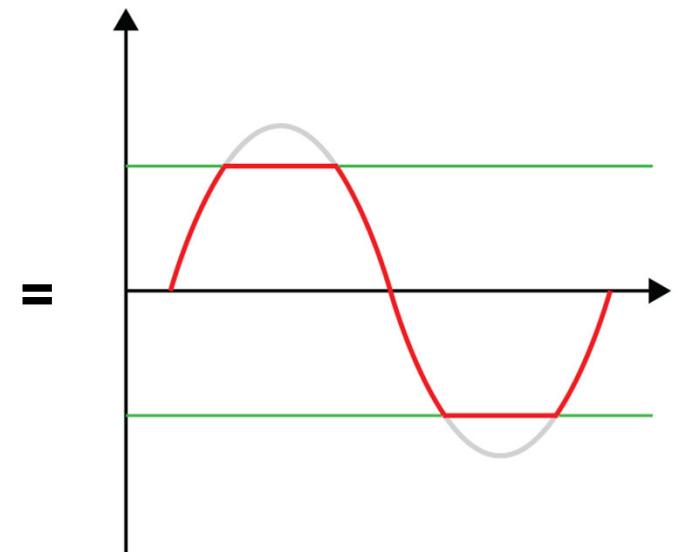
?



# Clipping

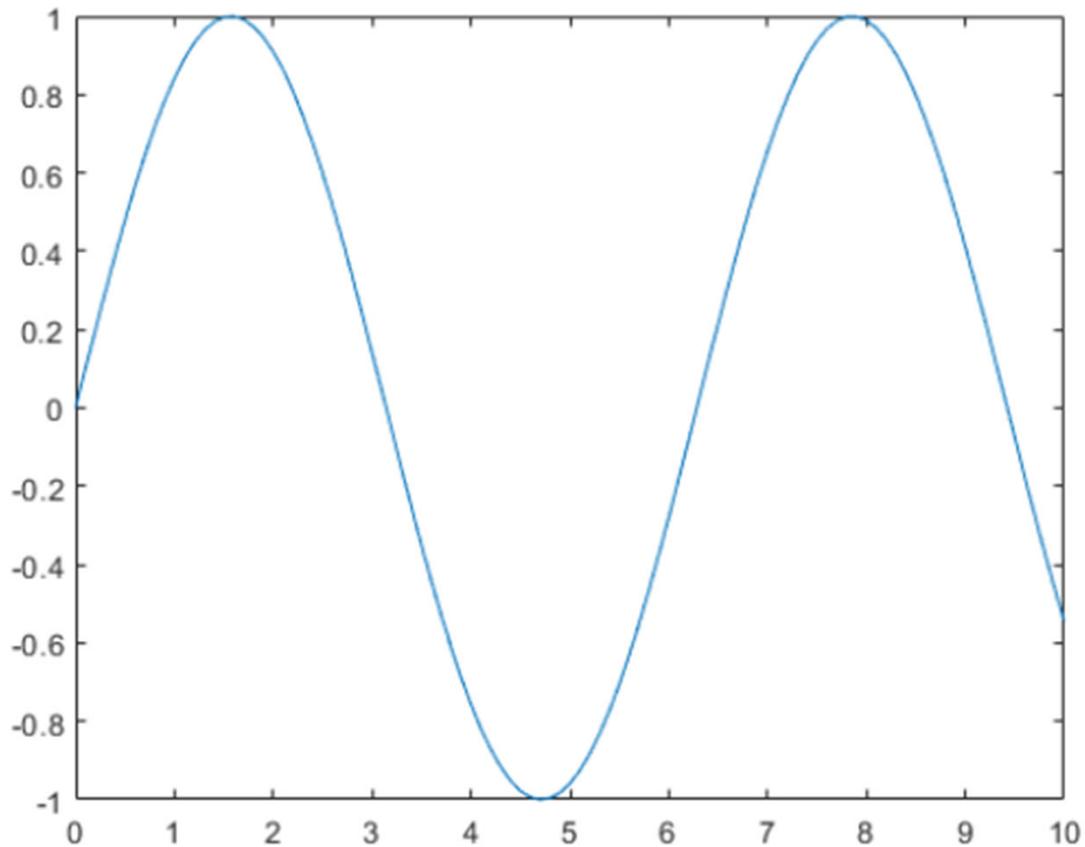


**Odd  
Harmonics**



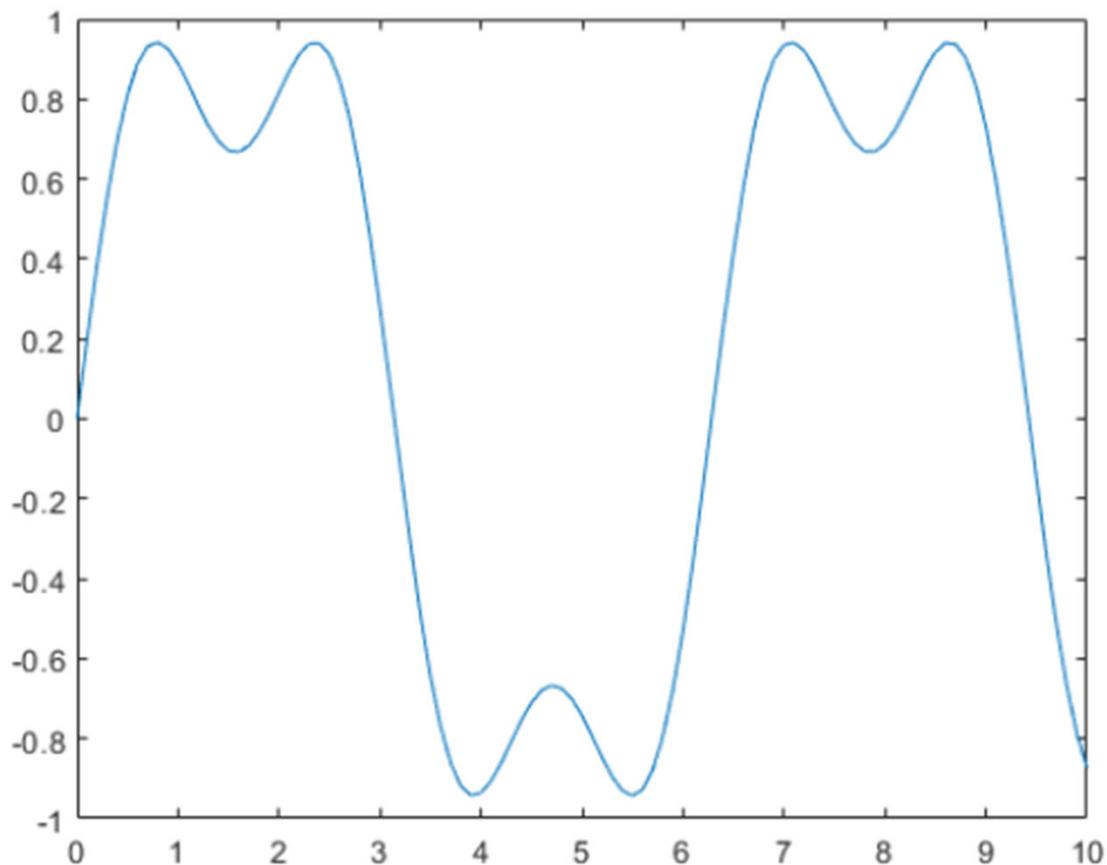
# Square Wave Harmonics

```
t = 0:.1:10;  
y = sin(t);  
plot(t,y);
```



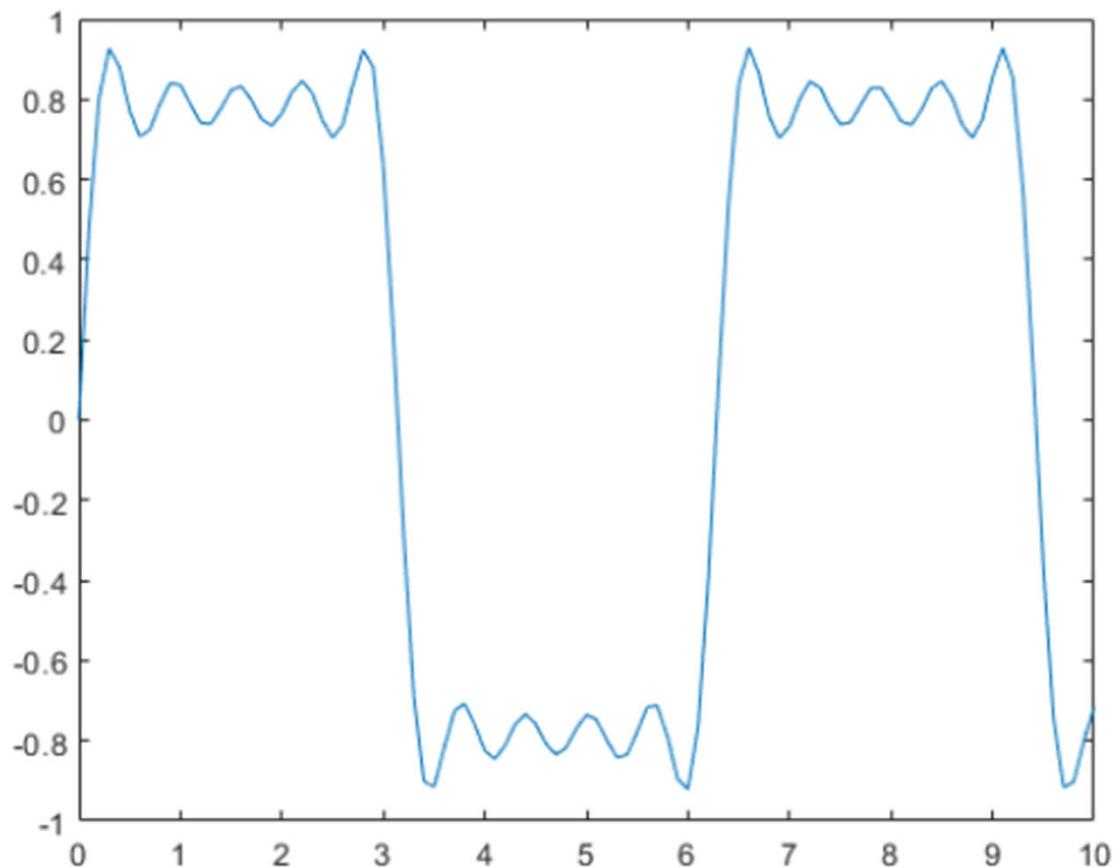
# Square Wave Harmonics

```
y = sin(t) + sin(3*t)/3;  
plot(t,y);
```



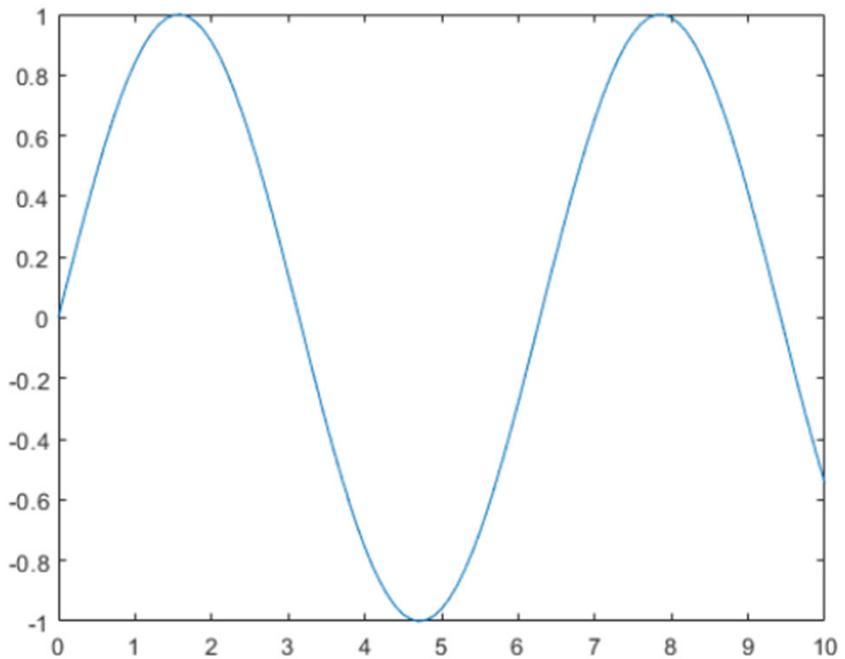
# Square Wave Harmonics

```
y = sin(t) + sin(3*t)/3 + sin(5*t)/5 + sin(7*t)/7 + sin(9*t)/9;  
plot(t,y);
```

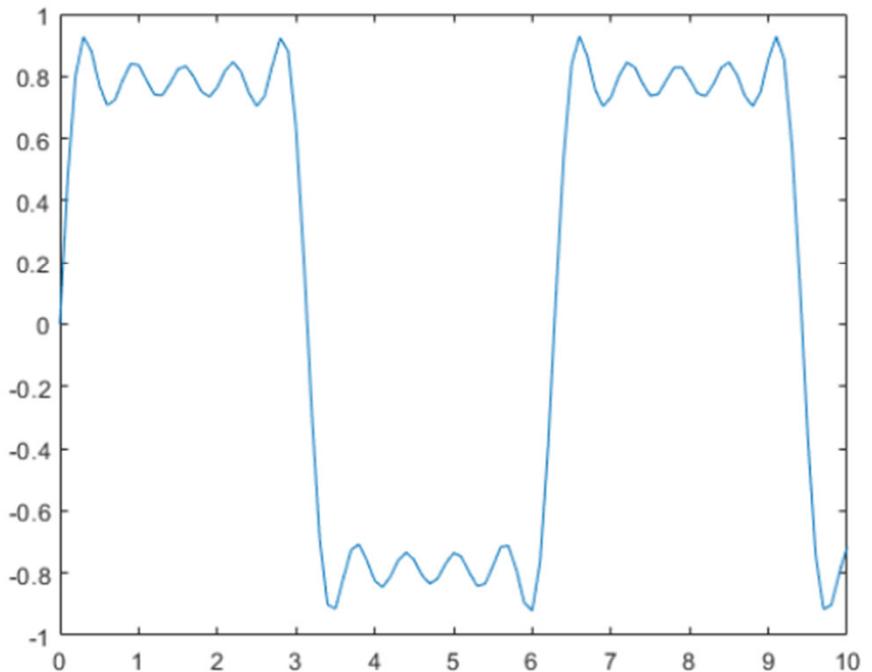


# Square Wave Harmonics

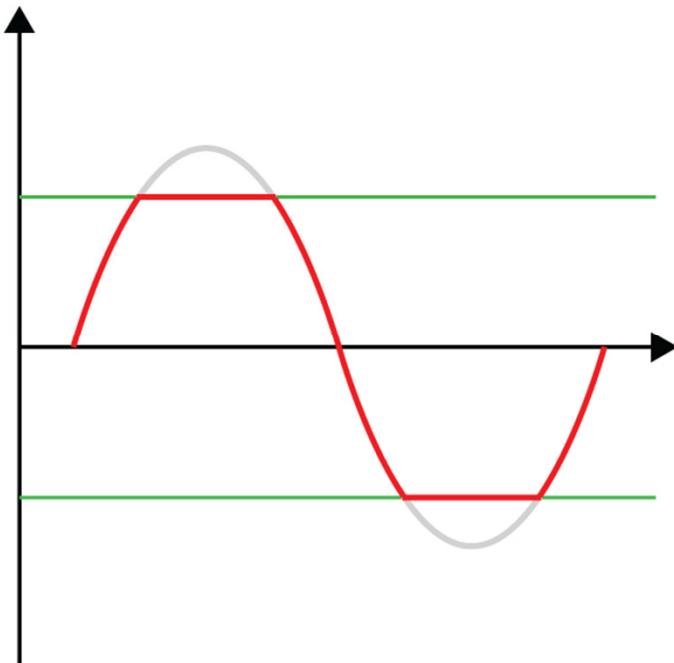
```
t = 0:.1:10;
y = sin(t);
plot(t,y);
```



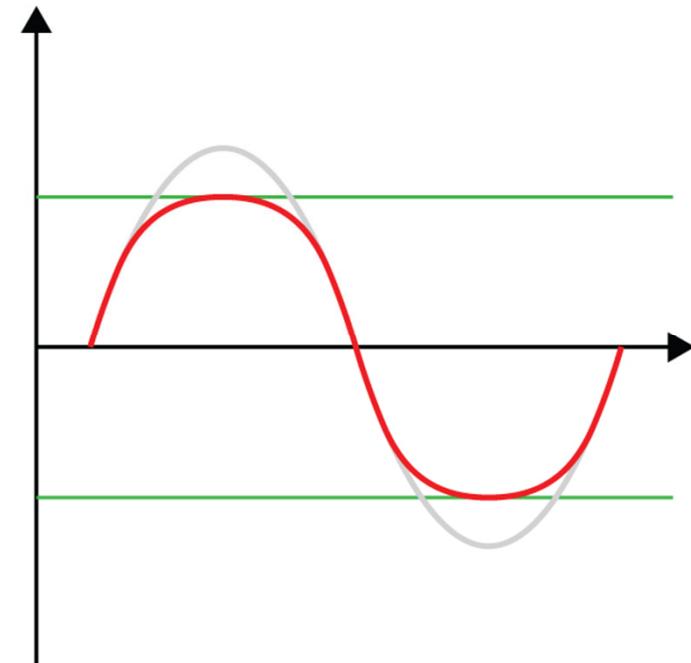
```
y = sin(t) + sin(3*t)/3 + sin(5*t)/5 + sin(7*t)/7 + sin(9*t)/9;
plot(t,y);
```



# Clipping



Hard clipping  
(Louder higher order harmonics)



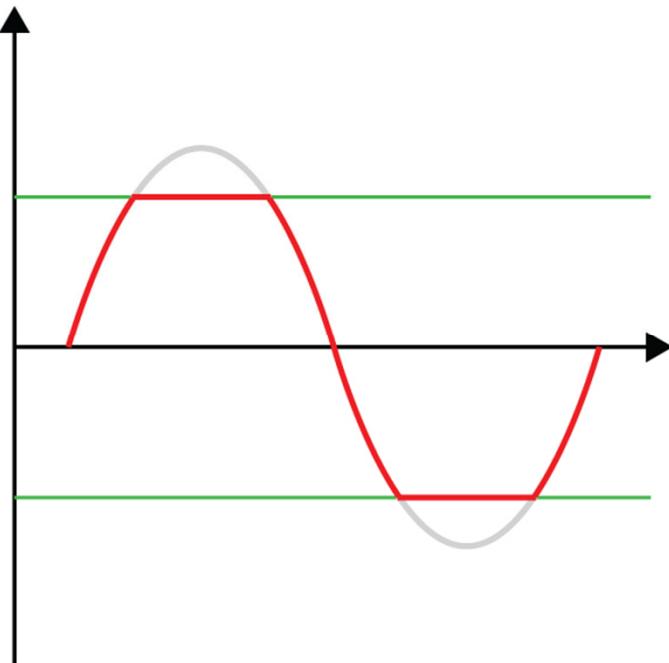
Soft clipping  
(Softer higher order harmonics)

# Clipping

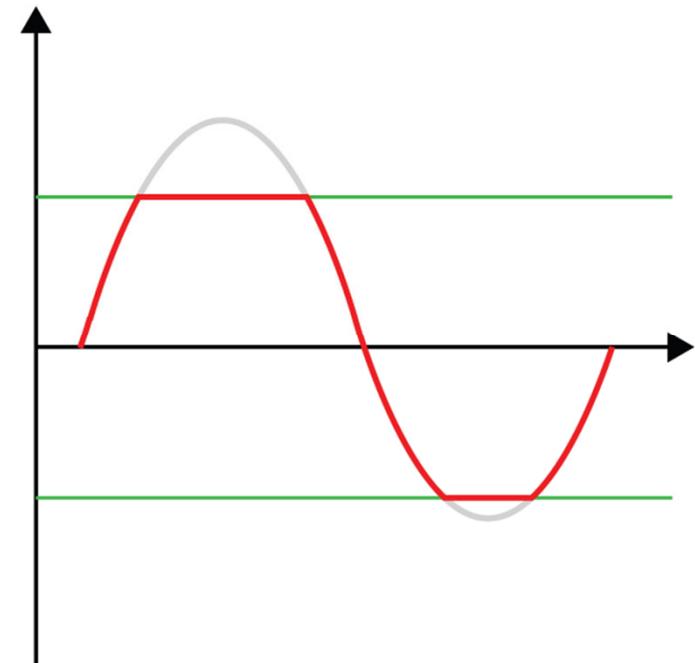


Hard vs. soft clipping  
(@ 4:26)

# Clipping



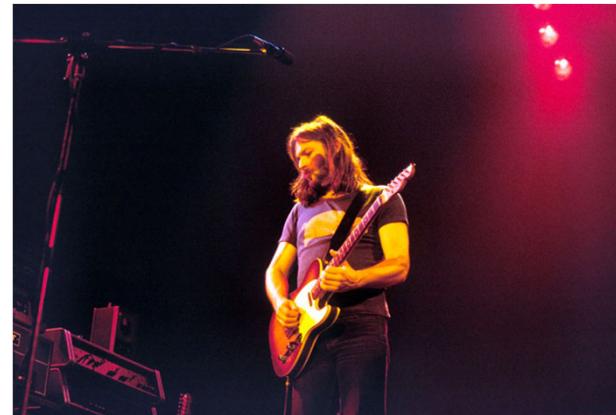
Symmetrical Clipping  
(Introduces odd harmonics)



Asymmetrical Clipping  
(Introduces odd and even harmonics)

# Clipping

Clipping is the basis for many different flavours of distortion!



# Clipping - Song Examples

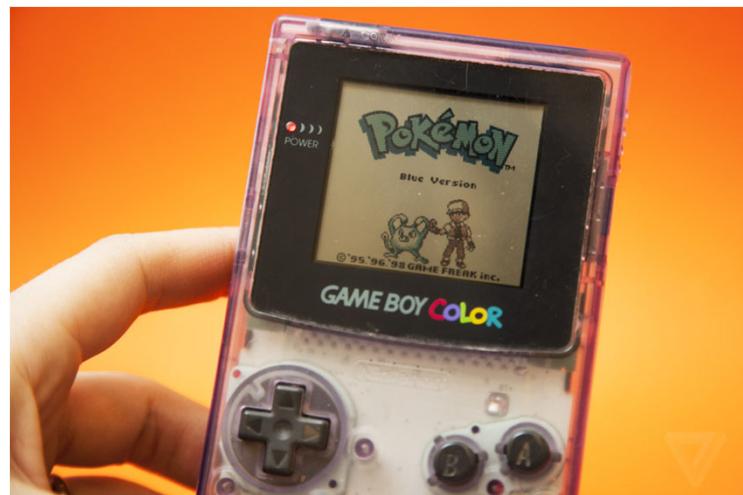
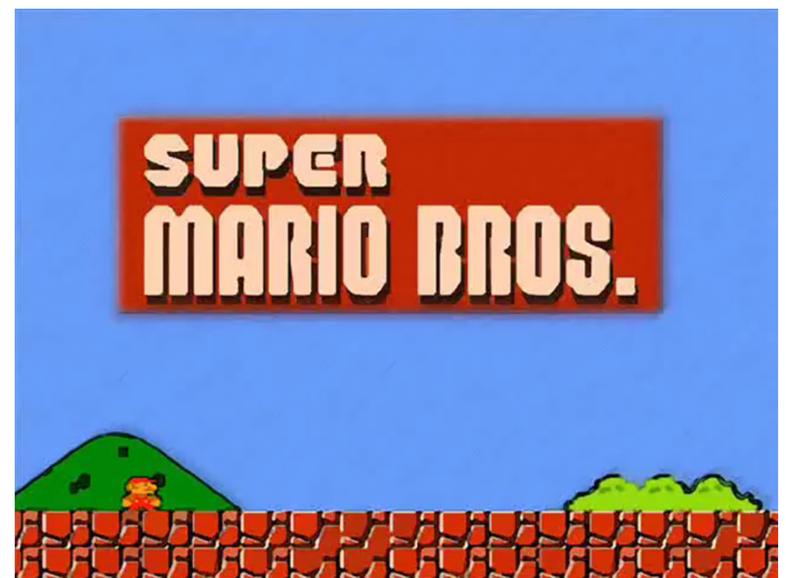


Guns N' Roses - Sweet Child O' Mine



Against All Logic - This Old House  
Is All I Have  
(@ 0:35)

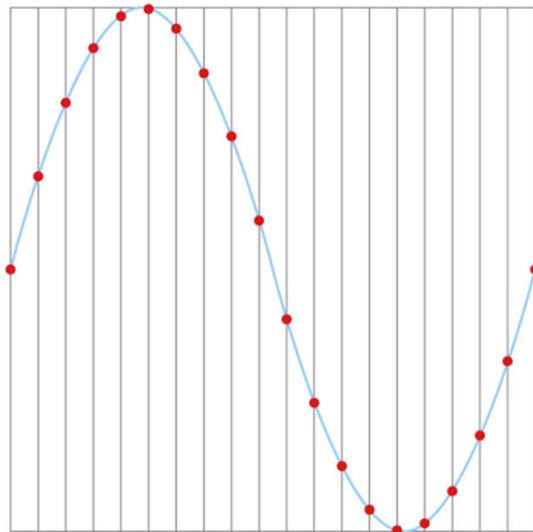
# Bitcrush



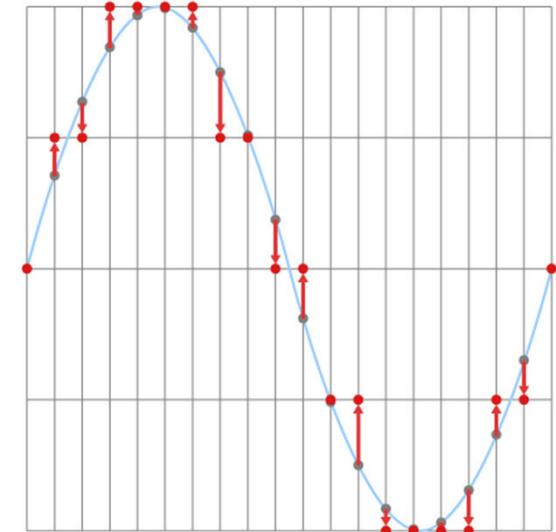
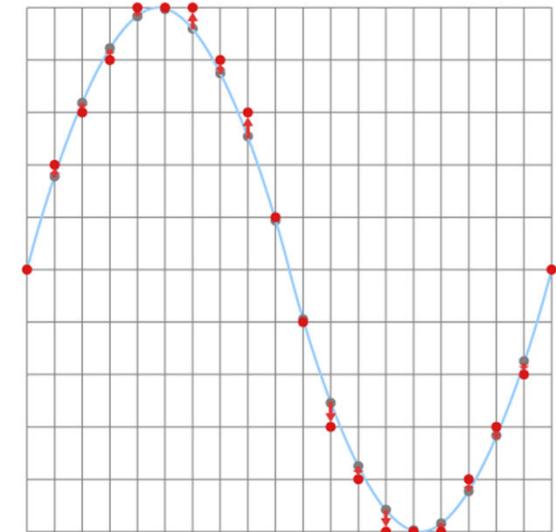
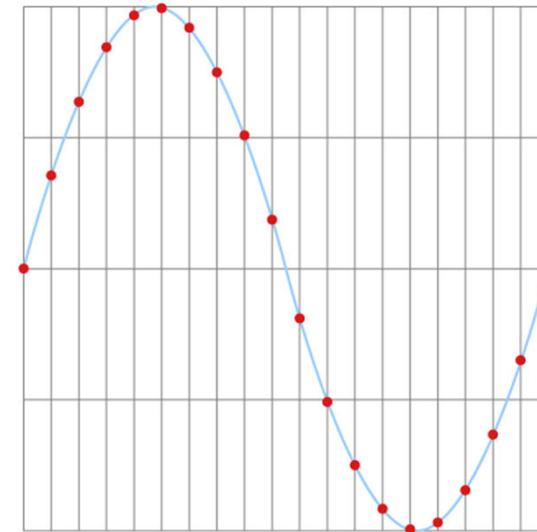
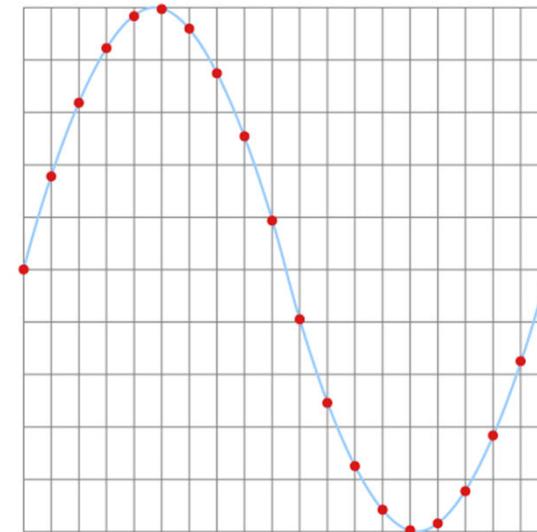
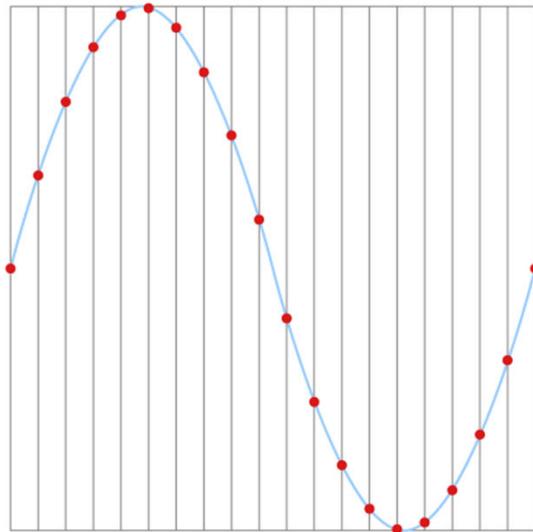
# Bitcrush

# Vals/Sample

11



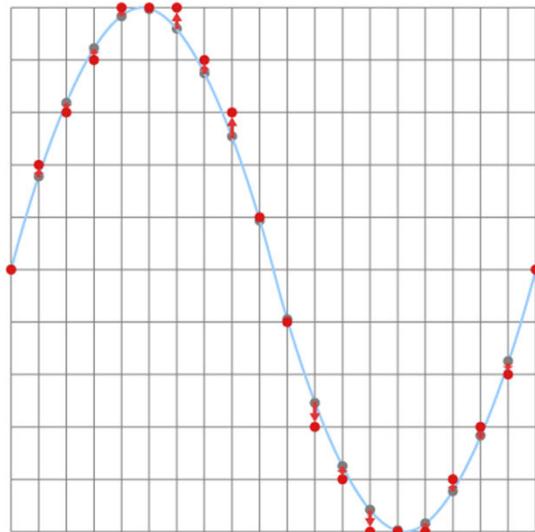
5



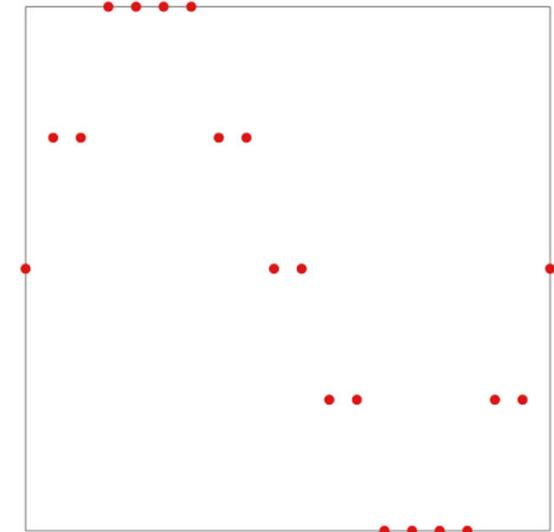
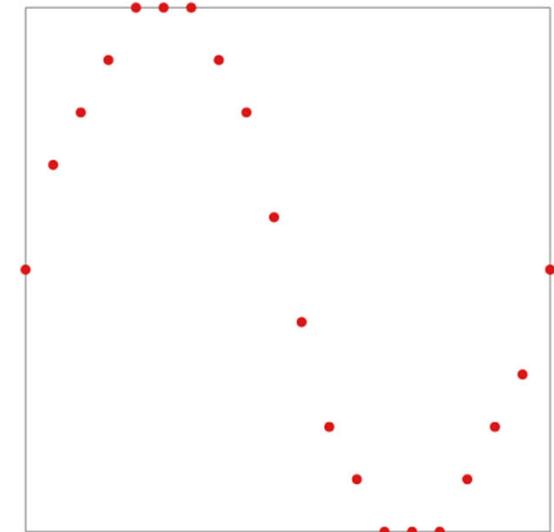
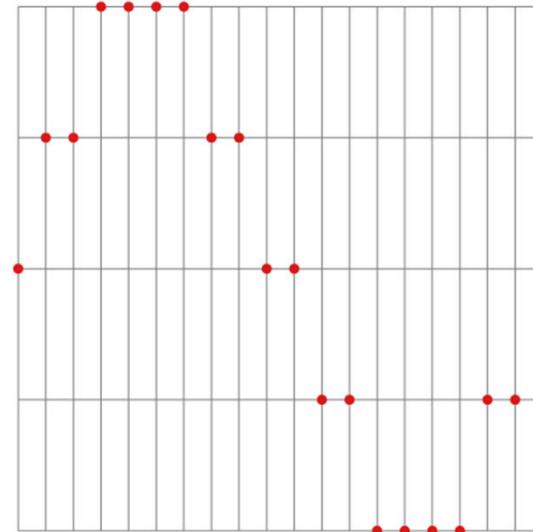
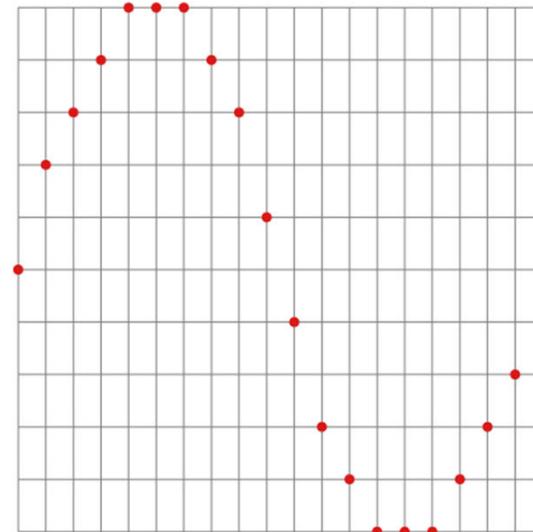
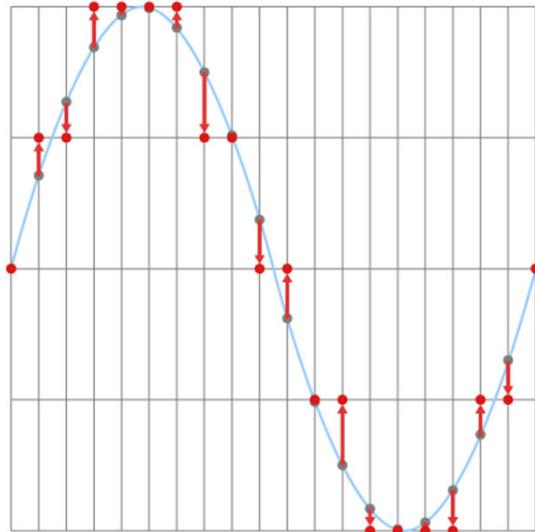
# Bitcrush

# Vals/Sample

11



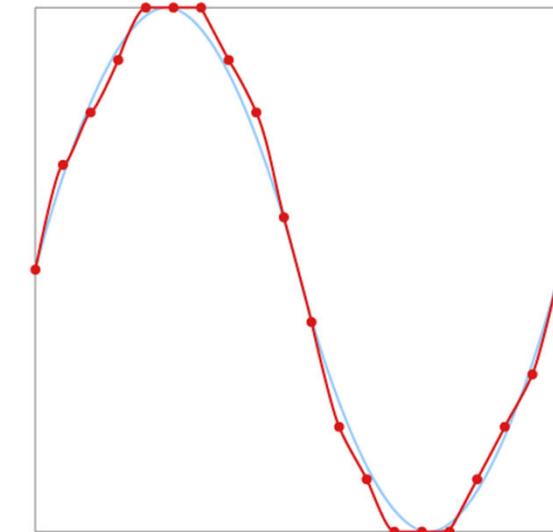
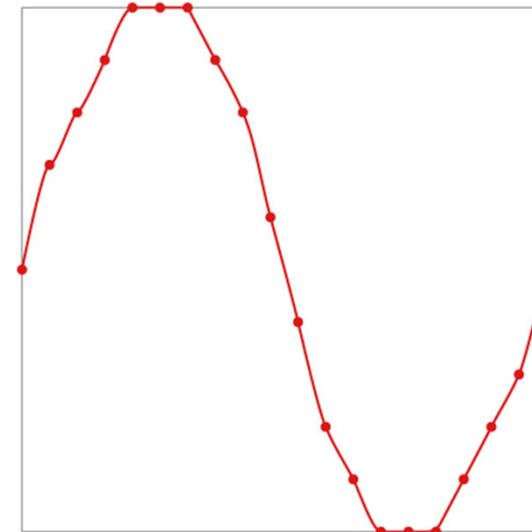
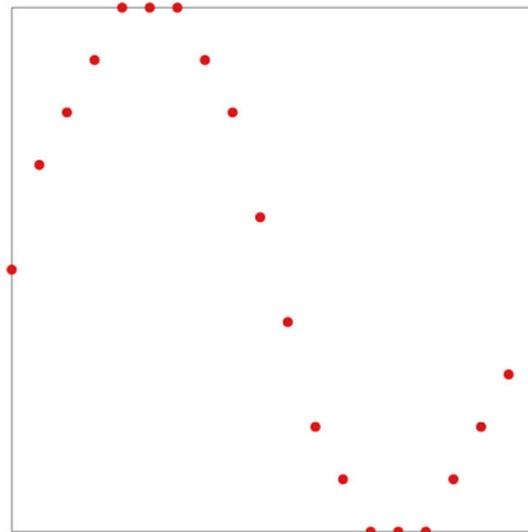
5



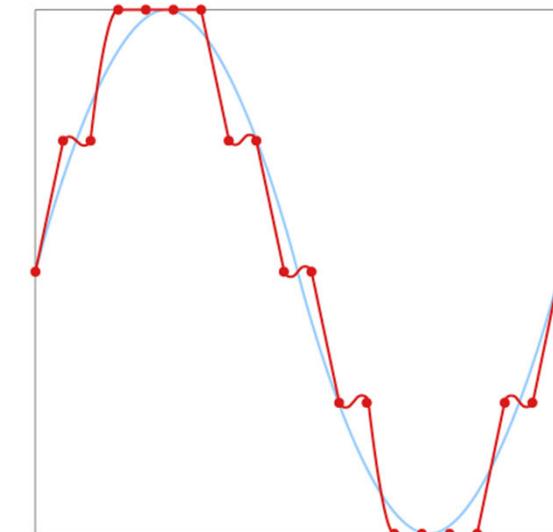
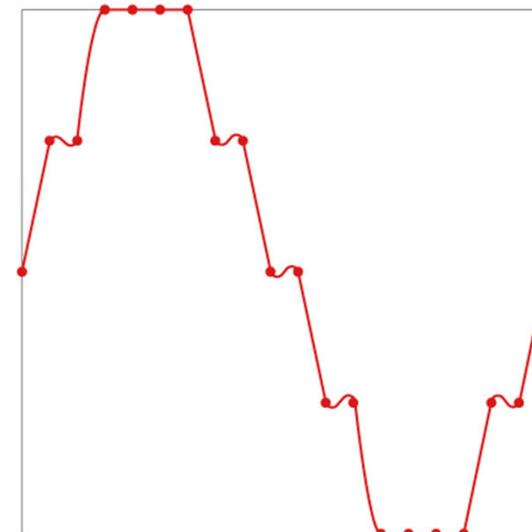
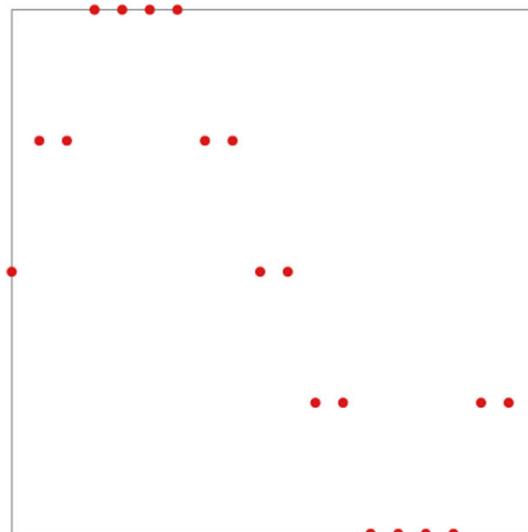
# Bitcrush

# Vals/Sample

11



5



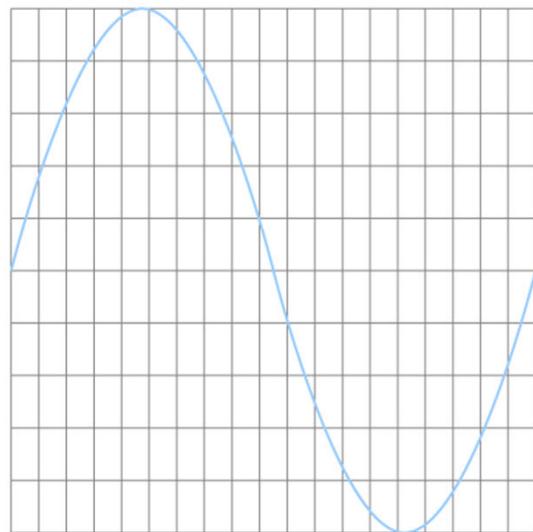
60

# Bitcrush

# Vals/Sample

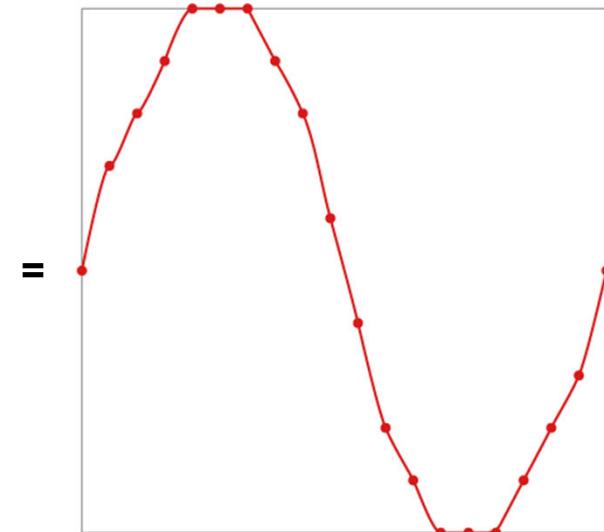
Original Signal

11

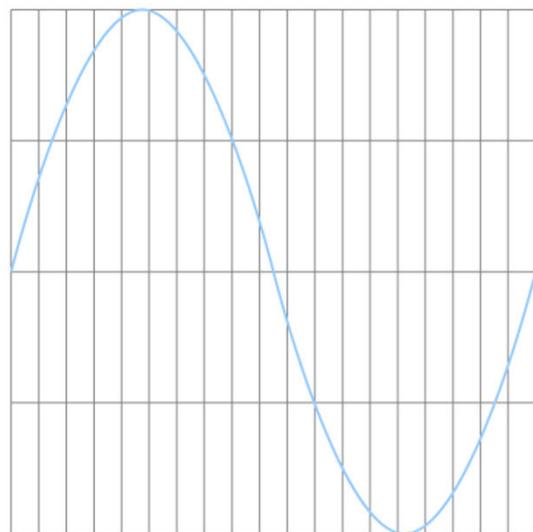


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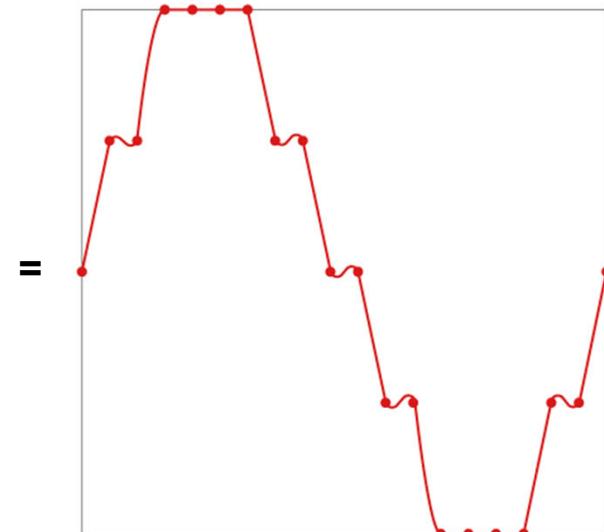


5



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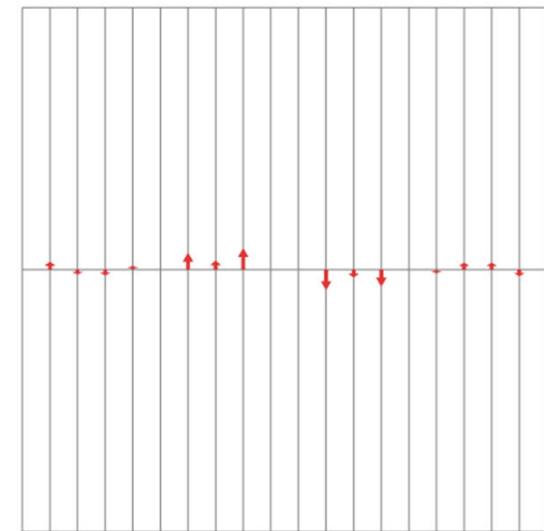
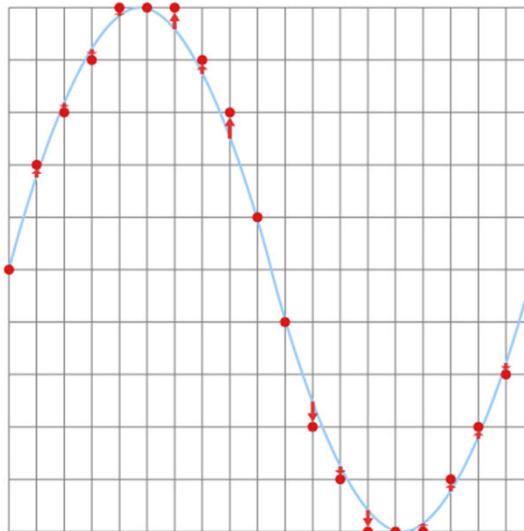
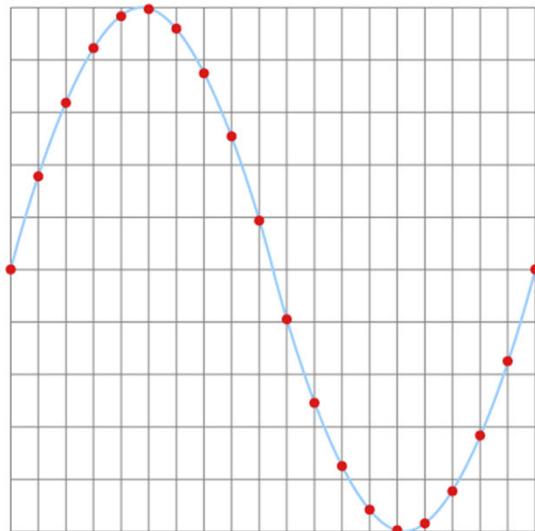
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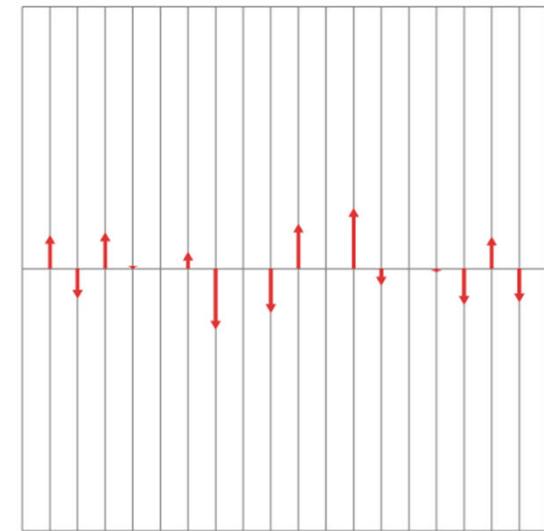
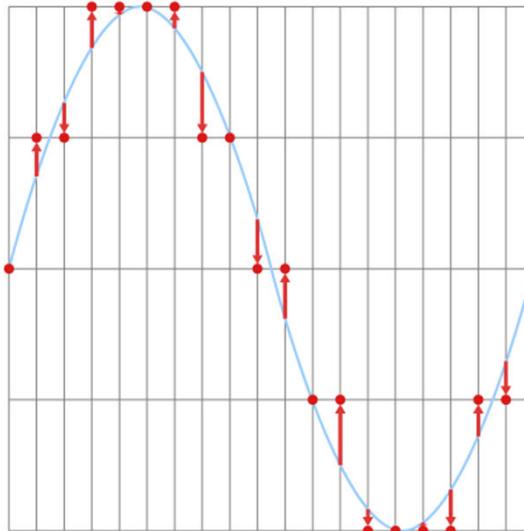
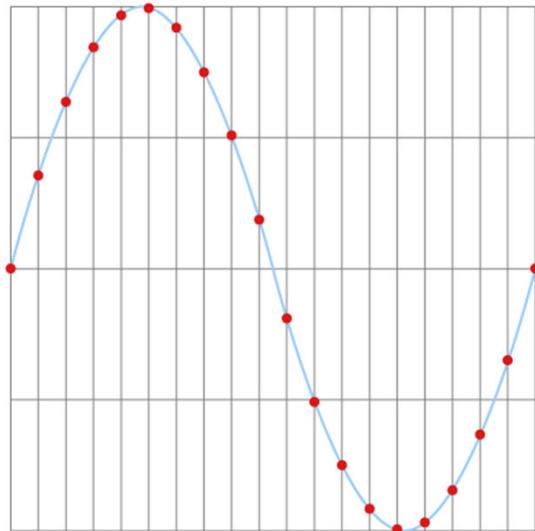
# Bitcrush

# Vals/Sample

11



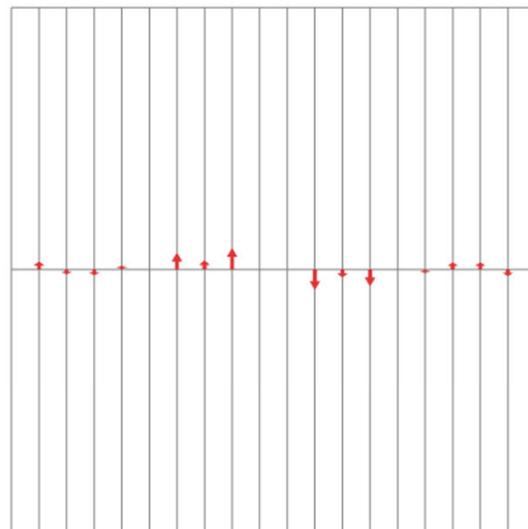
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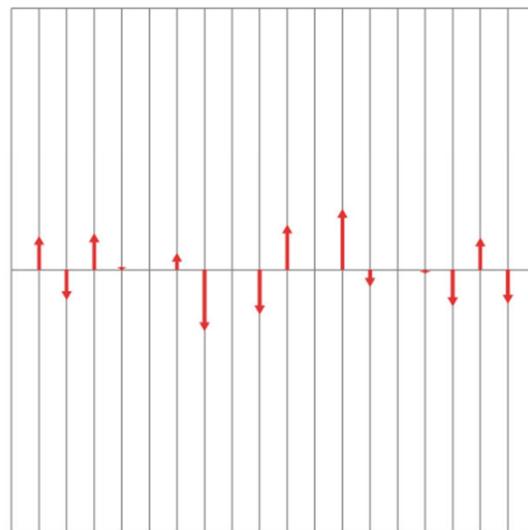
# Bitcrush

# Vals/Sample

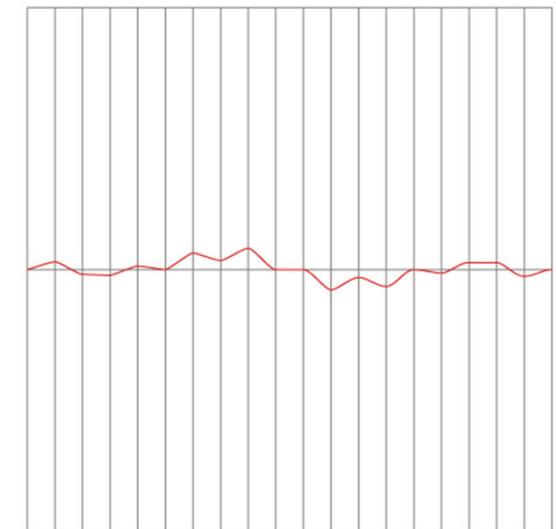
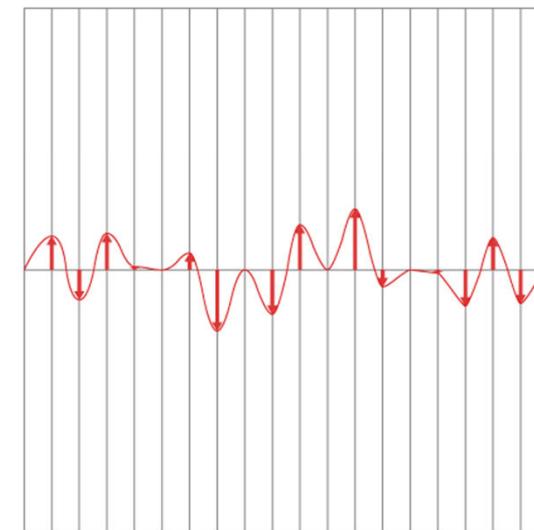
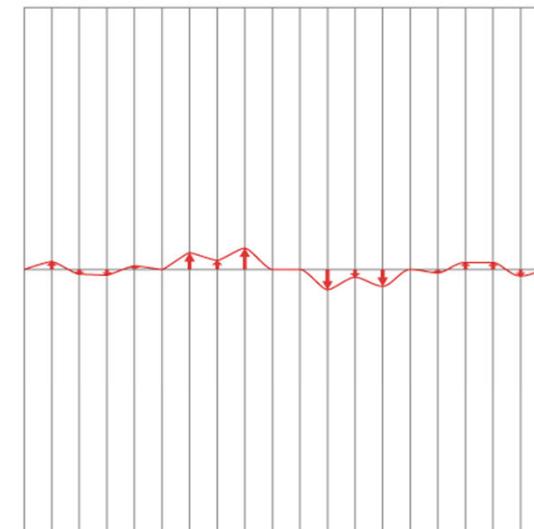
11



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Quantization Noise

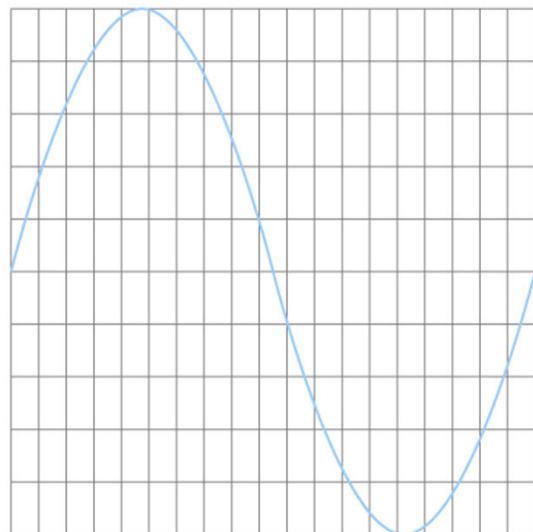


# Bitcrush

# Vals/Sample

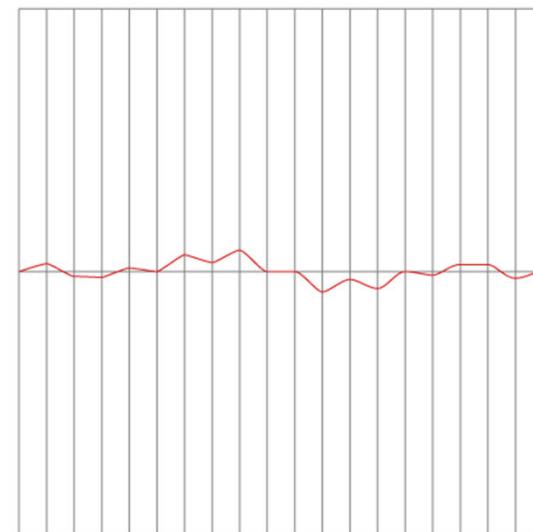
Original Signal

11

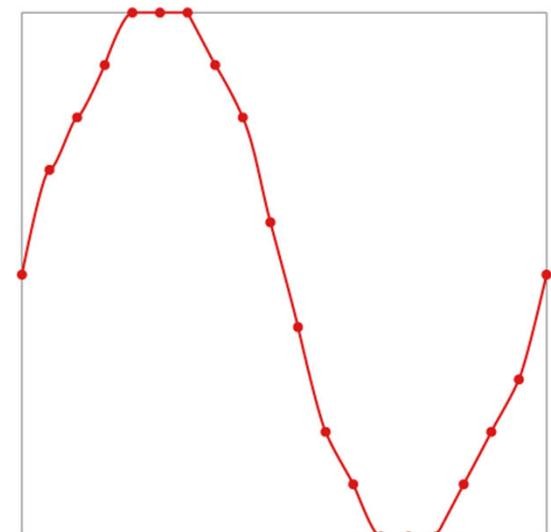


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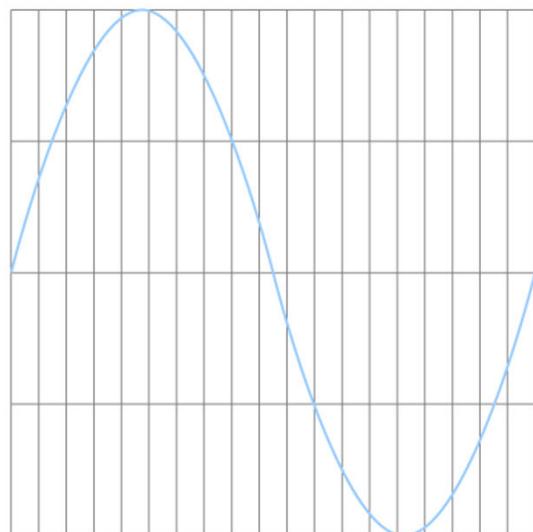
Quantization Noise



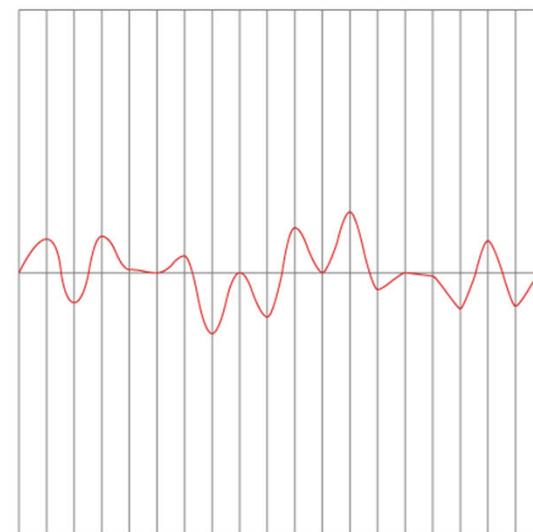
=



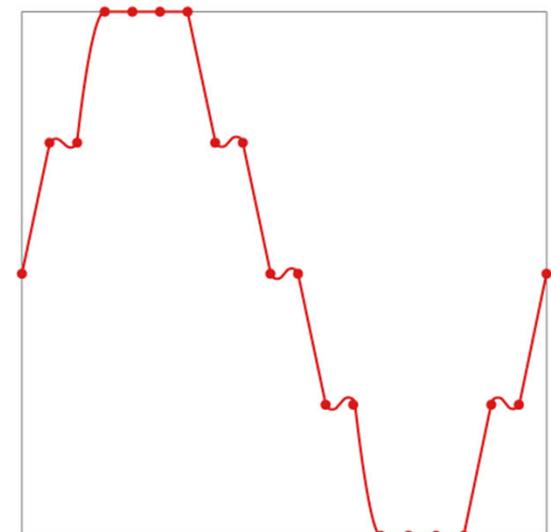
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64

# Bitcrush

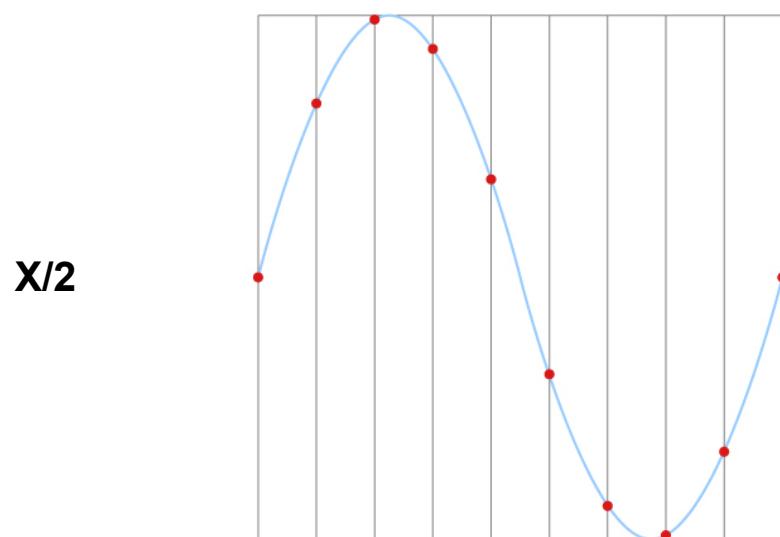
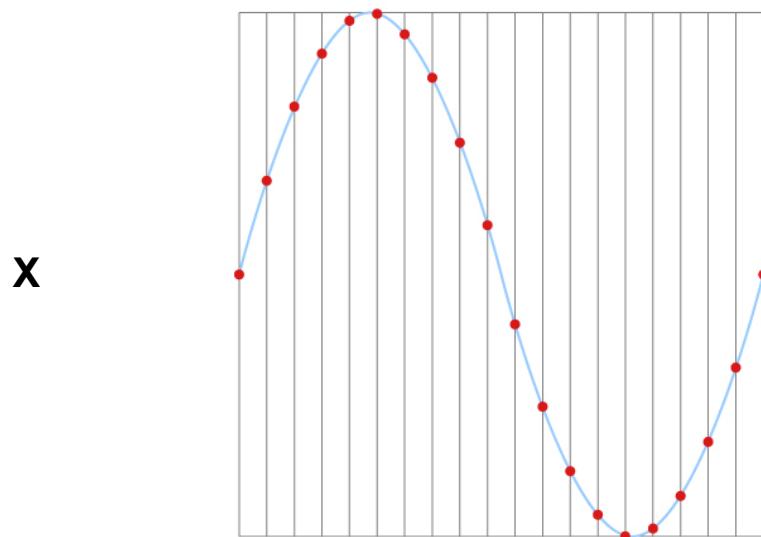
Bit Depth	Number of Values per Sample
2	$2^2 = 4$
4	$2^4 = 16$
8	$2^8 = 256$
16	$2^{16} = 65,536$
24	$2^{24} = 16,777,216$
32	$2^{32} = 4,294,967,296$

# Bitcrush

Bit Depth	Audio	Quantization Noise
Original		
8		
4		
3		
2		

# Downsampling

## Sample Rate

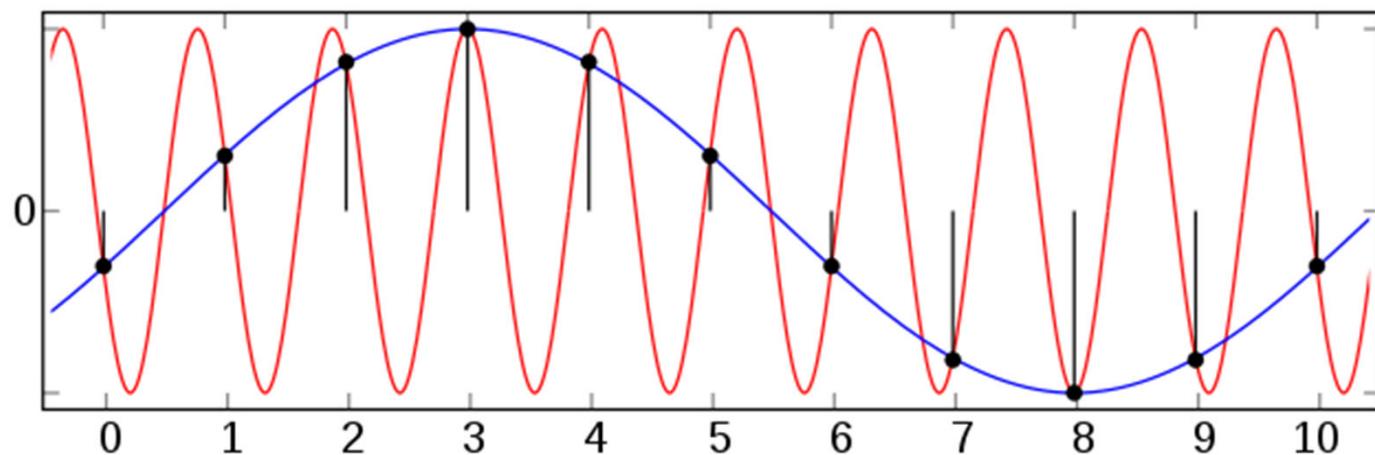


## The Nyquist-Shannon Theorem

If a system uniformly *samples* an analog signal *at a rate that exceeds the signal's highest frequency by at least a factor of two*, the original analog signal can be perfectly recovered from the discrete values produced by sampling.

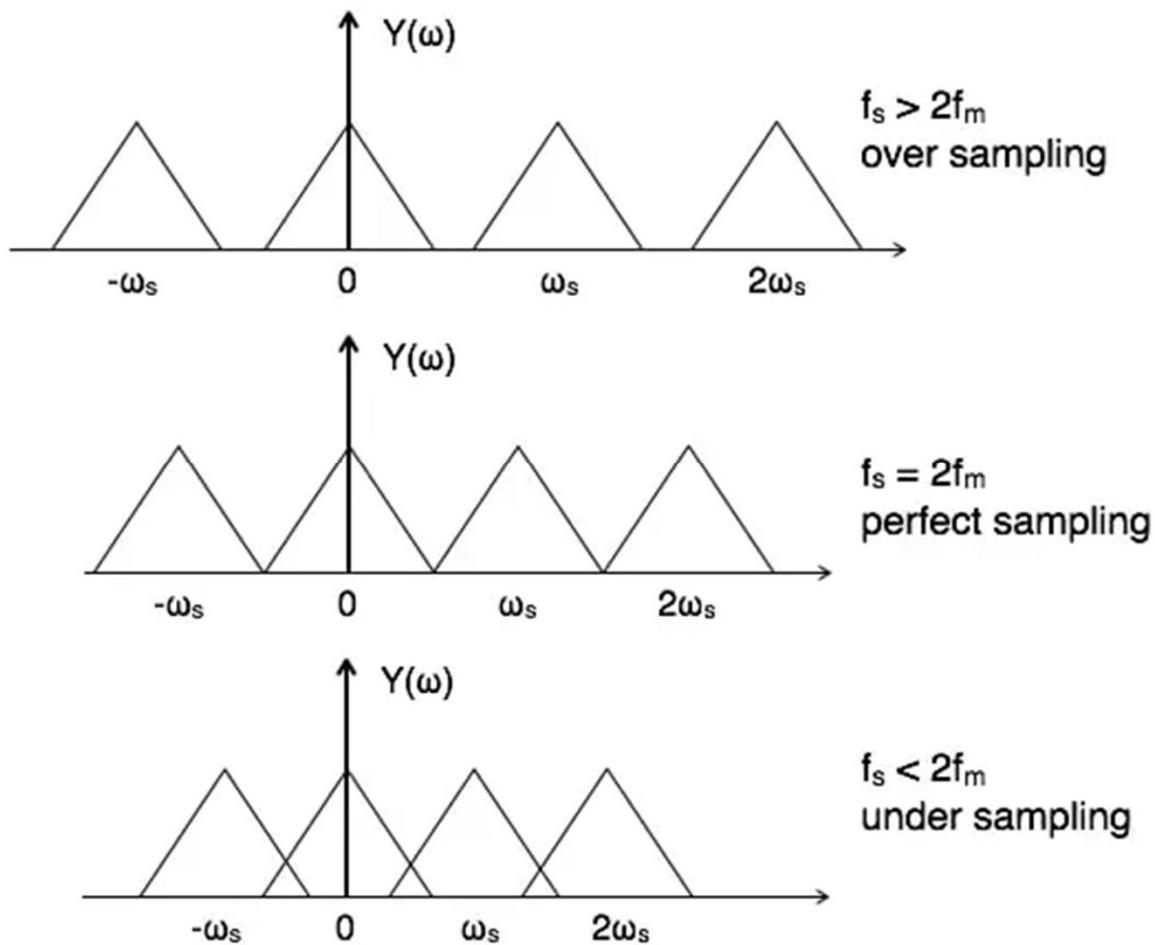
# Aliasing

Time Domain

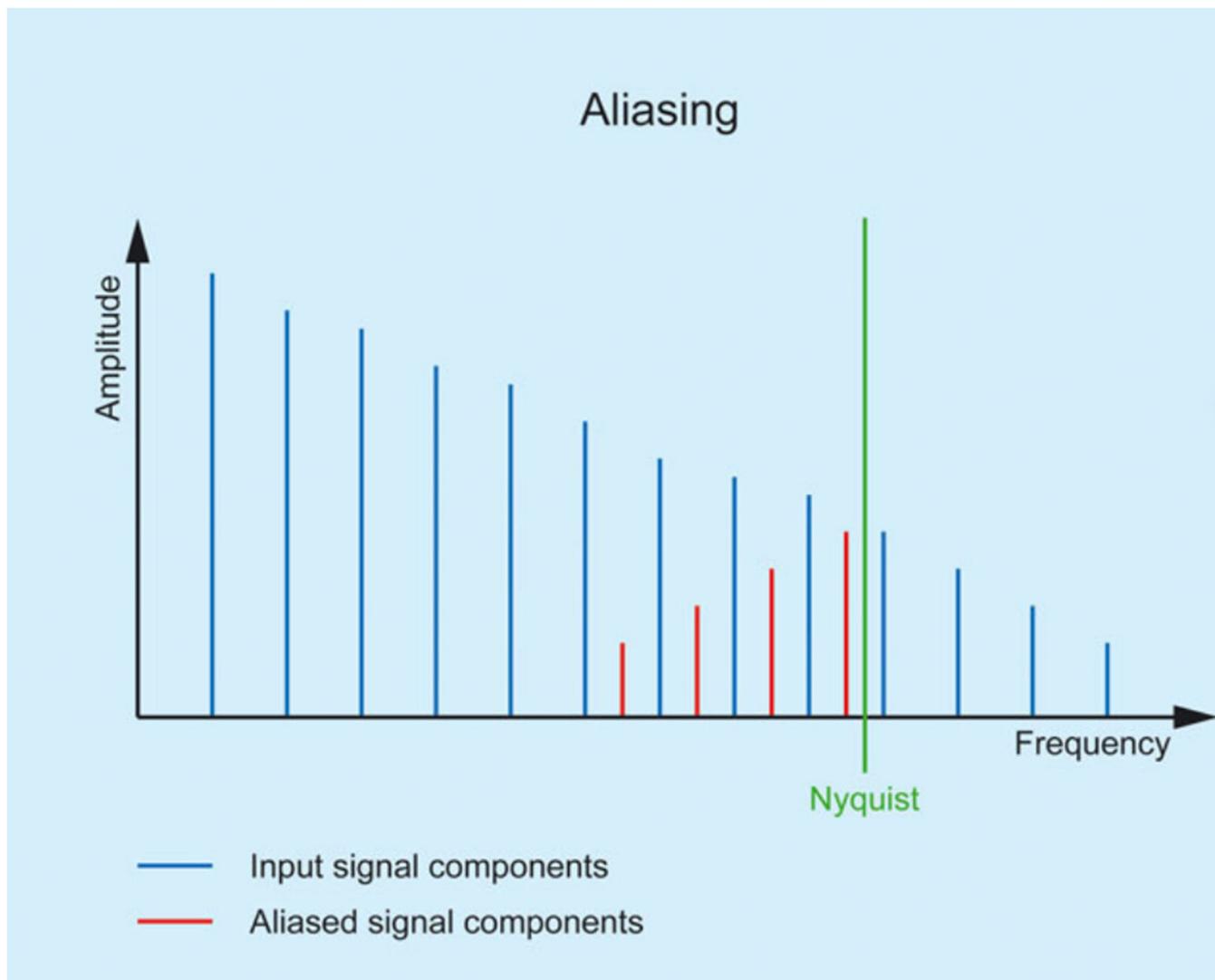


# Aliasing

Frequency Domain



# Aliasing



Alias frequencies are **not harmonically related**  
to the input signal!

# Downsampling

Sample Rate (Hz)	Nyquist Limit (Hz)	Downsampling	Audio (Strings)
44100	22050	None (original sample rate)	
22050	11025	2x	
11025	5512.5	4x	
7350	3675	6x	
5512	2756	8x	
4410	2205	10x	

# Bitcrush / Downsampling - Song Examples

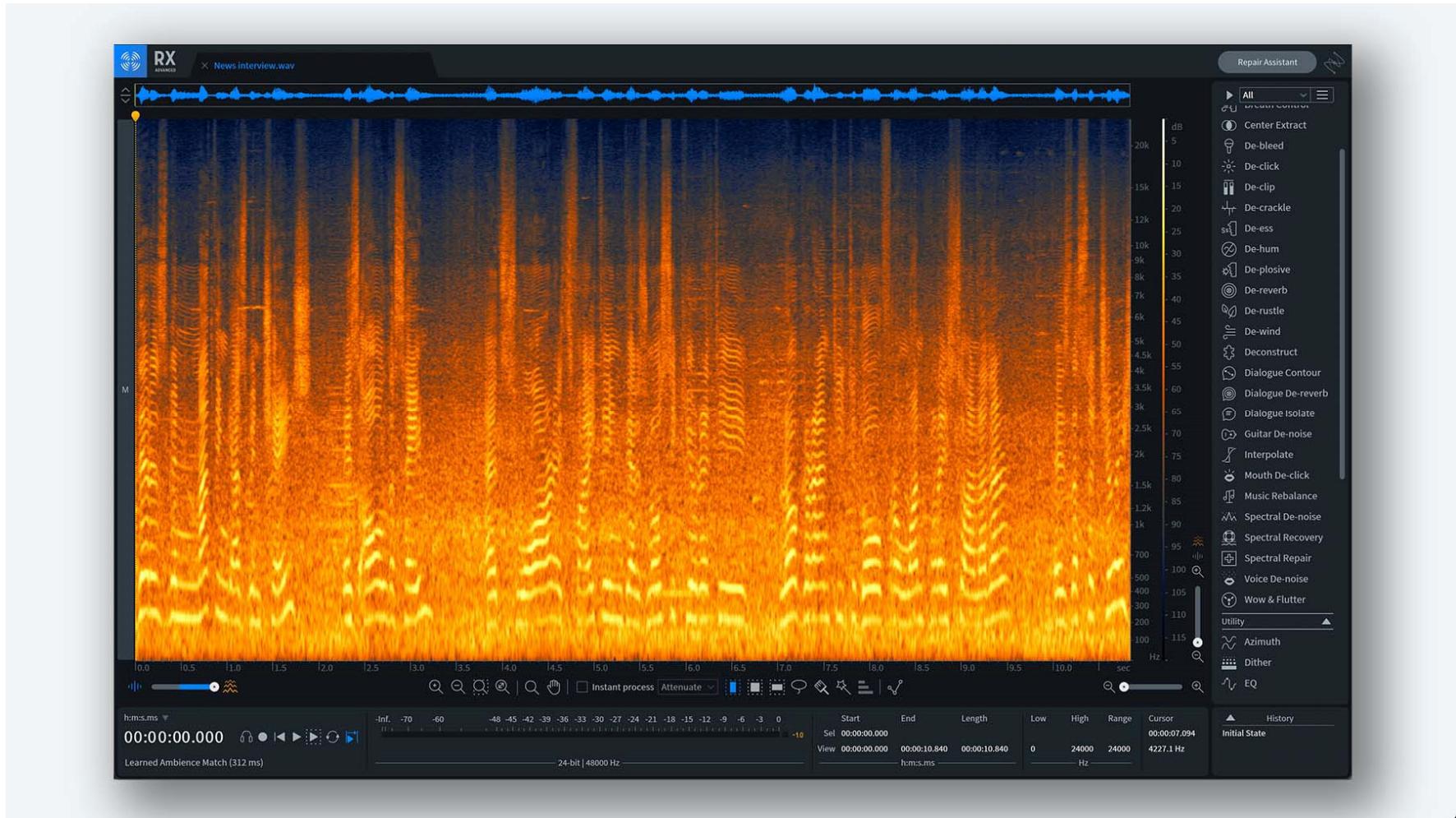


Magdalena Bay - You Lose!



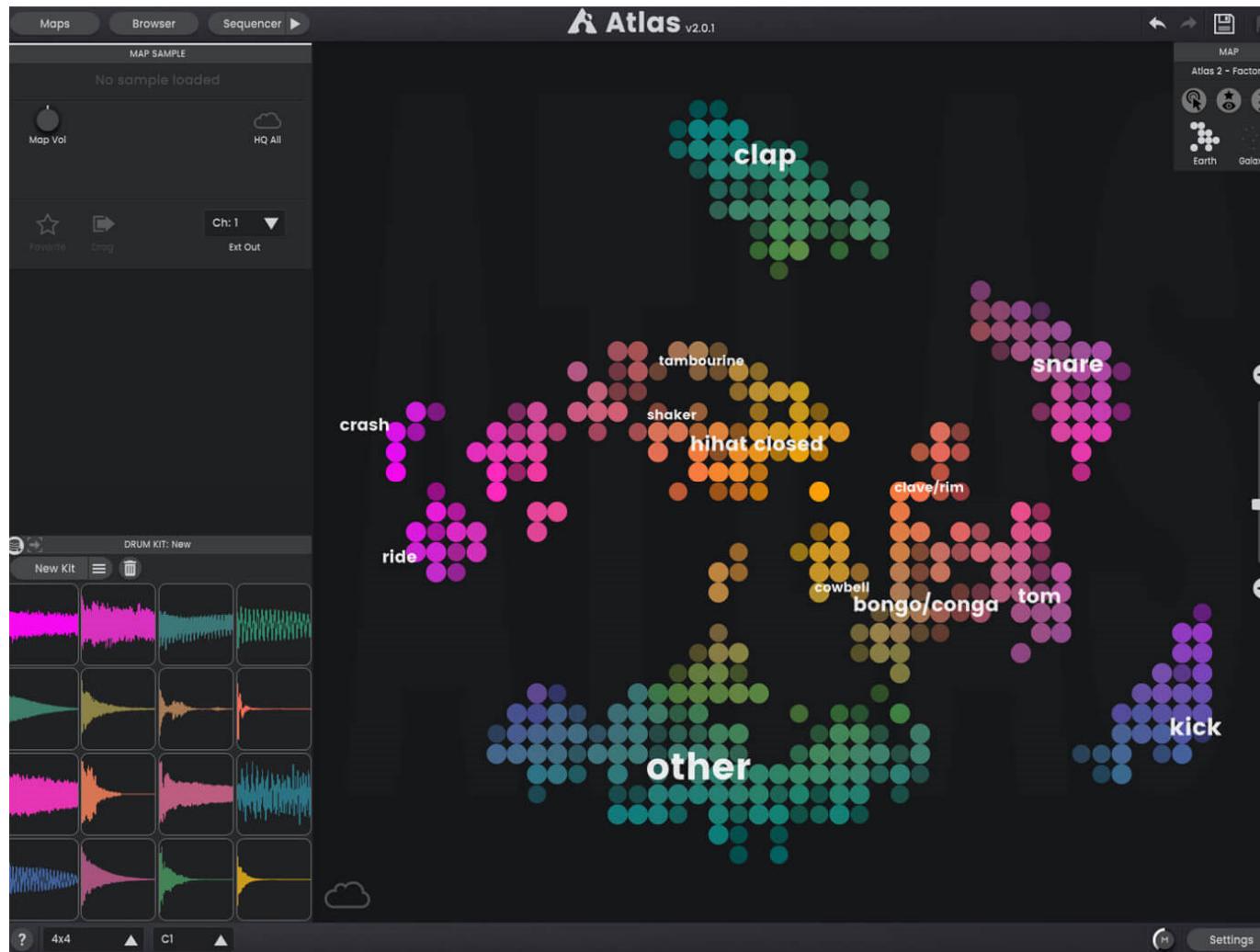
Daft Punk - Short Circuit

# Afterthought – AI in Music Production



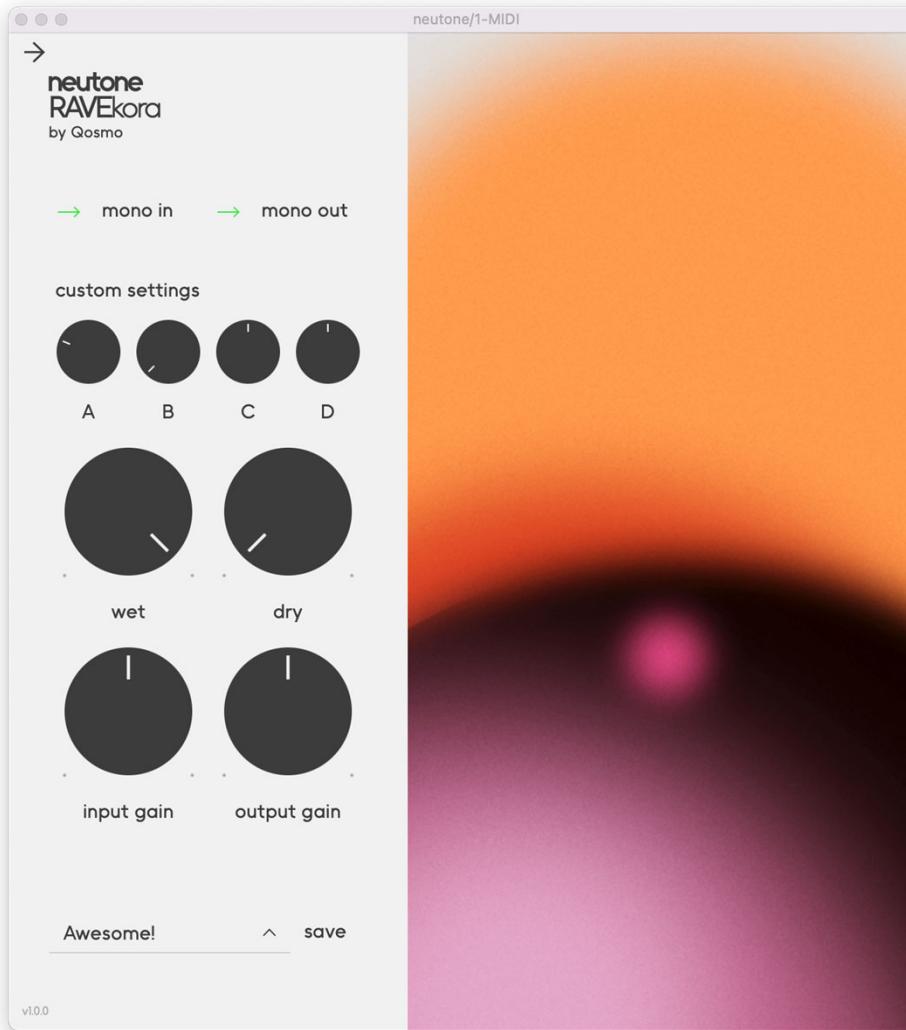
iZotope – RX  
Audio repair plugin

# Afterthought – AI in Music Production



Algonaut – Atlas  
Drum machine + sample manager plugin

# Afterthought – AI in Music Production



Neutone Inc. – Neutone  
Real-time neural audio effects plugin  
(Effects emulation / timbre transfer)

# Now You Know About

- Delay
- Reverb
- Tremolo
- Flanger
- Clipping
- Bitcrushing
- Downsampling



# Other Audio Effects to Explore

- Compressors
- Expanders
- Gates
- Chorus
- Phaser
- Ring modulation
- Time stretching/compressing
- Equalization (EQ)
- Filters
- Pitch correction
- Pitch shifting
- Formant shifting
- ...and many more!



