SOUND DESIGN

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4P

AUDIO SYNTHESIS TECHNIQUE IN PURE DATA

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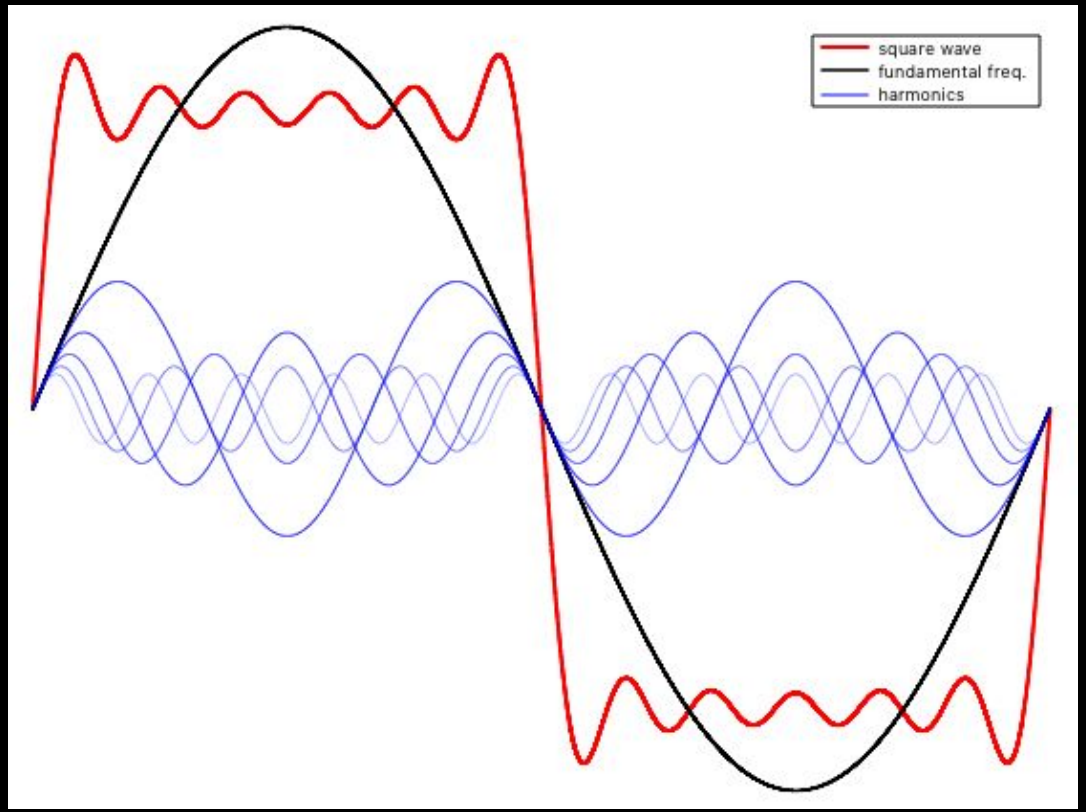
Complex periodic Sound - Square Wave



the **square wave** is a periodic complex sound widely used in electronic music.

It is composed of the fundamental frequency and only odd harmonics which amplitude is divided by the harmonic order.

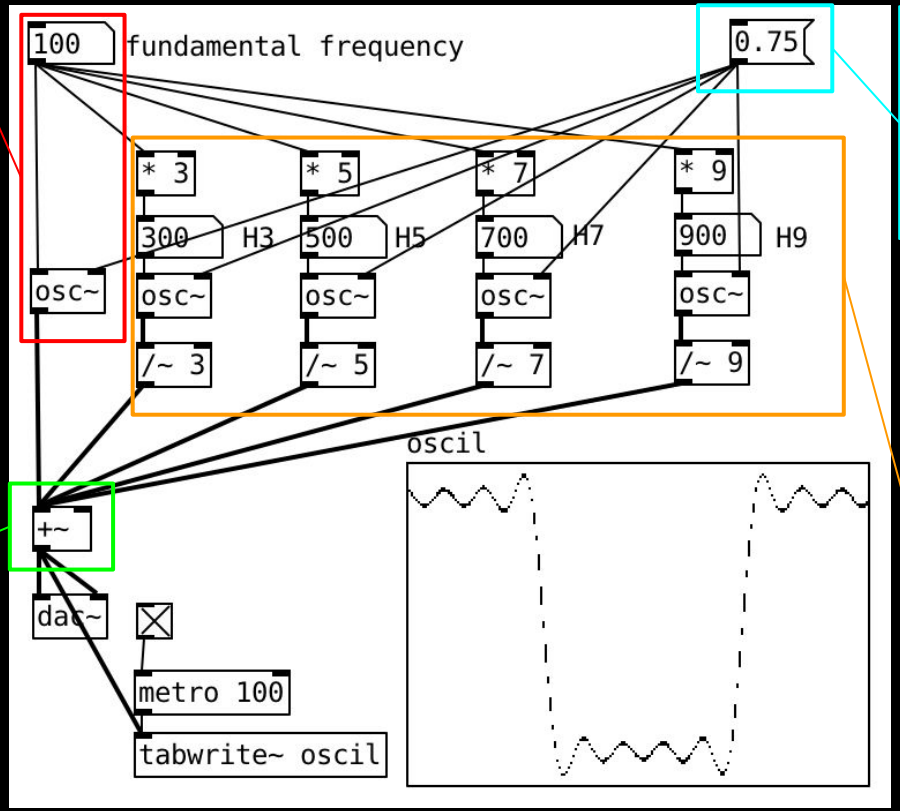
$$\sum_{n=1,3,5,7,\ldots}^{\infty} \frac{1}{n} \sin(2\pi\alpha n t)$$

n = harmonic order (only odd harmonic)
α = fundamental frequency (Hz)
$\sin(2\pi\alpha t)$ = sinusoid formula
2πα = angular velocity (ω)
t = discrete time

Additive Synthesis (Square Wave)

The **additive synthesis** is the sound synthesis technique that create sound timbre (like square waves) by adding sinusoidal wave together

fundamental frequency



the osc~ object generates cosinusoidal waves. To obtain a sinusoid from a cosinusoid we have to move the phase of 3pi/2 (270°) that is 0.75 in cycles

Only odd harmonics.

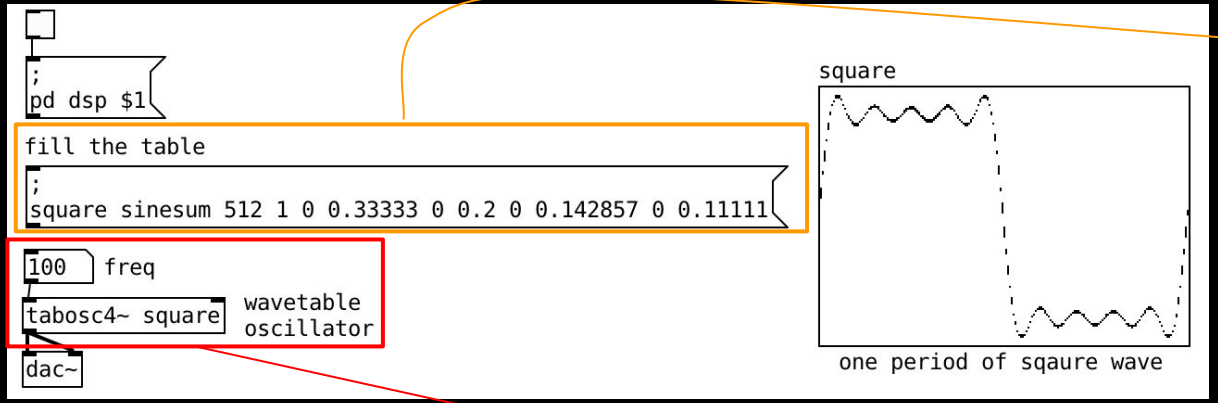
The **frequency** is obtained by the multiplication of the fundamental frequency with the harmonic order (3, 5, 7, 9).

The **amplitude** is obtained by calculate the division by the harmonic orders.

The sum of sinusoids

Wavetable synthesis (Square Wave)

In the oscilloscope, we convert a signal to a numeric array (in the table). The **wavetable synthesis** is the opposite, we convert a numeric array in a signal. The numeric array represents only one period of a periodic signal which is repeated as many times per seconds as the frequency of the signal.



tabosc4~ is a wavetable lookup oscillator. It is like the **osc~** but instead of play a cosinusoidal wave it play whatever wave is described inside the linked array.

- To link an array, type its name as argument of tabosc4~ (square in the figure);
- The inlets and outlets have the same functionalities as those ones of the osc~;

The array should have a power of two points plus three points (the three additional points are the “guard point” used in the wavetable synthesis - see help). For good results use 515 (512 + 3)

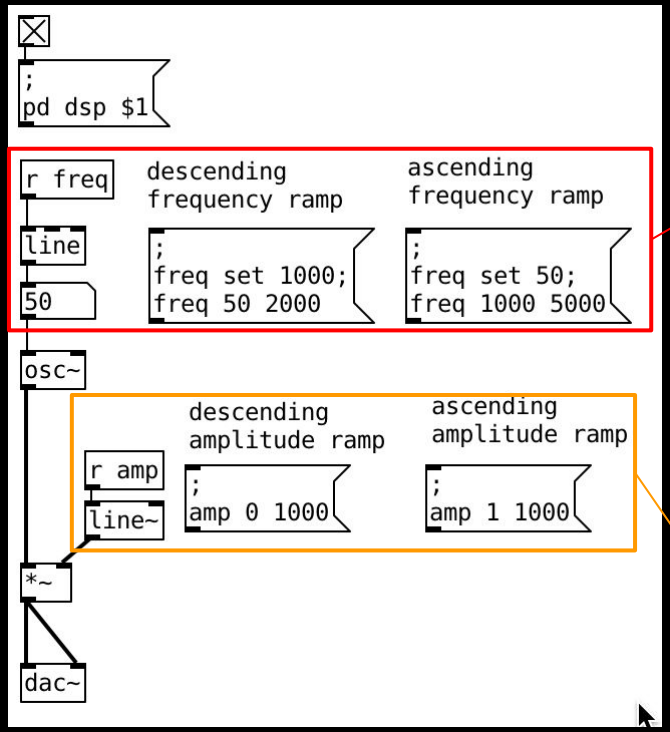
We can fill the table in a different way. We can write into it with the mouse, or use a signal (like in the oscilloscope) or other objects.
But we can also use a message.

As shown in the figure, we send a particular message to the array, the **sinesum** message. This message allows building a wave in the array through the sinusoidal sum (like the additive synthesis). After sinesum the first argument is the size of the array (minus three “guard points”) and the others are the amplitude of the signal’s harmonics (integer multiple of the fundamental) starting from the fundamental (the first number after size).

In the figure, we have built the same wave in the previous slide, a square wave with only 4 odd harmonics. The amplitude zeros is for the even harmonics.

Ramps

With ramps we can change values over time with only one click.
We can have numeric ramps (**line**) and audio ramps (**line~**)



Numeric Ramps
line is a numeric ramp generator. It reaches a specific number over the time given.

It takes a message composed by two number 1) the number to reach 2) the time (in milliseconds) taken to reach the first number.

With the message *set* we set the ramp starting point.

Audio Ramps
line~ is a audio ramp generator whose levels and timing are determined by the messages you send.

It takes a message composed by two number 1) the value to reach 2) the time (in milliseconds) taken to reach the first number.

Does not work the message *set*

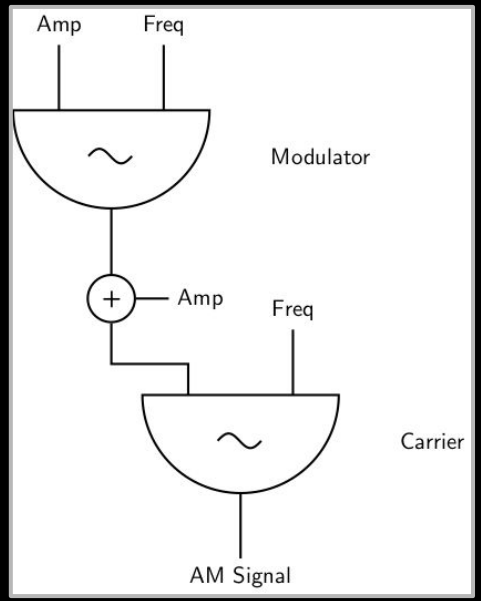
We use the message to send the line and line~ command without link. In this case we use the [r] object (receiver object) to catch the message with the specific "destination reference" (in this case *freq* or *amp*).

In the case of the *freq* we send two command with only one message (and therefore with only one click). The two messages are separated by the semicolon. The messages are sent one after another (from the highest to the lowest). In the first of these cases, we set the frequency to 1000 Hz and then we start the ramp of 2 seconds toward 50 Hz.

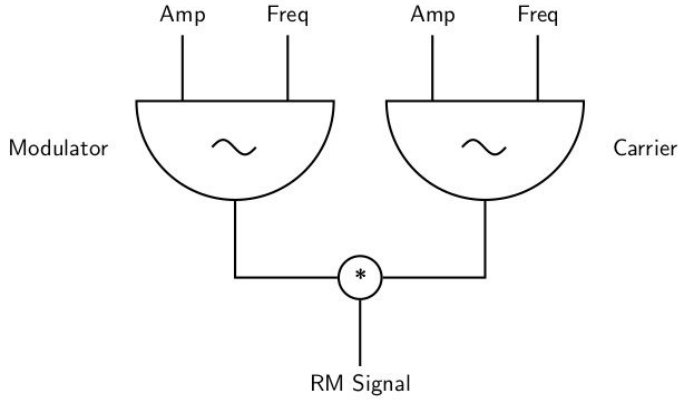
Modulation Synthesis

By changing the frequency or amplitude of a signal (carrier signal) with the output of a second signal (modulator signal) we obtain three different modulation synthesis:

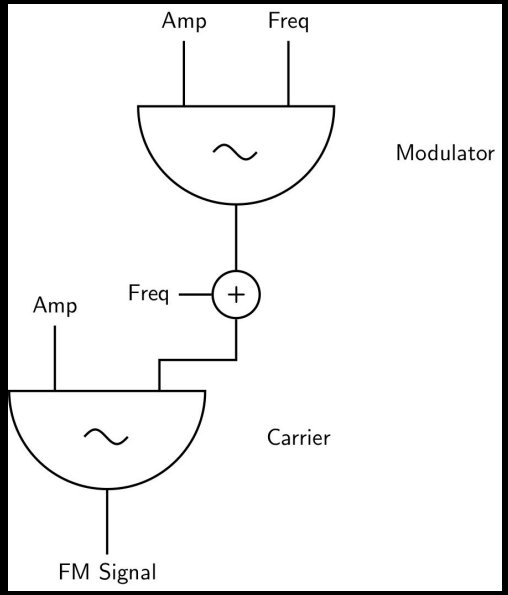
Amplitude Modulation (AM)



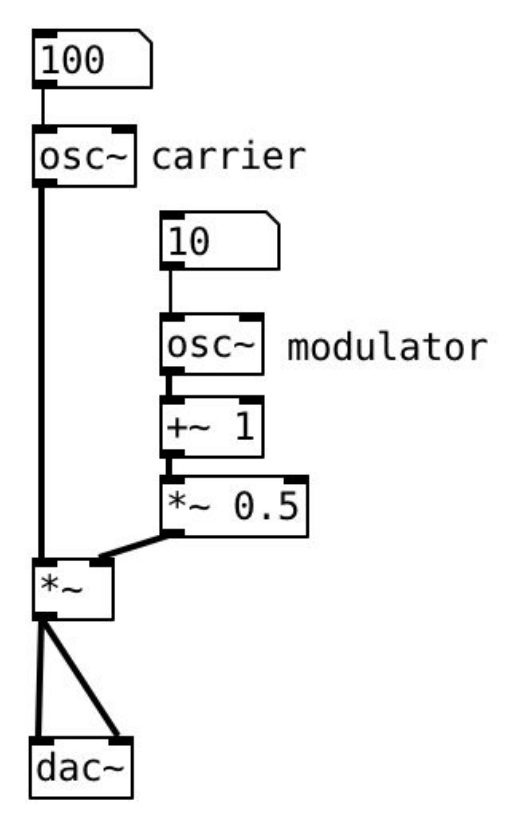
Ring Modulation (RM)



Frequency Modulation (FM)



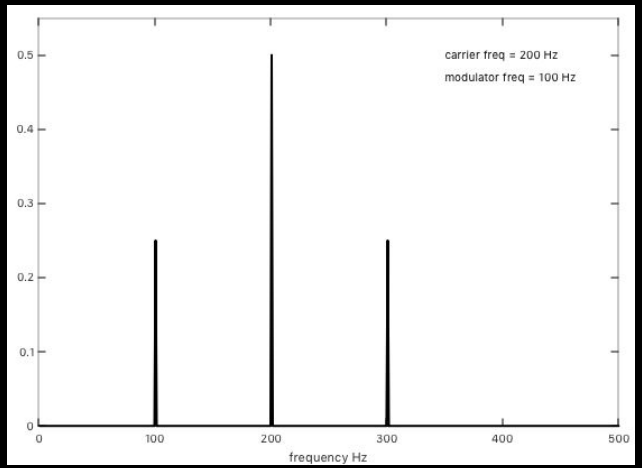
Amplitude Modulation (AM)



In the amplitude modulation (AM) we modulate the amplitude of a signal (carrier) with the output of another signal (modulator).

$$x(t) = \left[\frac{1 + \sin(\omega_m t)}{2}\right] \cdot \sin(\omega_c t)$$

When we use a sinusoids as modulator we have to apply some operation to the signal. In the sinusoids, the wave oscillate in the range [-1 1] but the amplitude of a signal range from 0 to 1. So we have to increase the offset of 1 (+1) and scale the signal (/2)



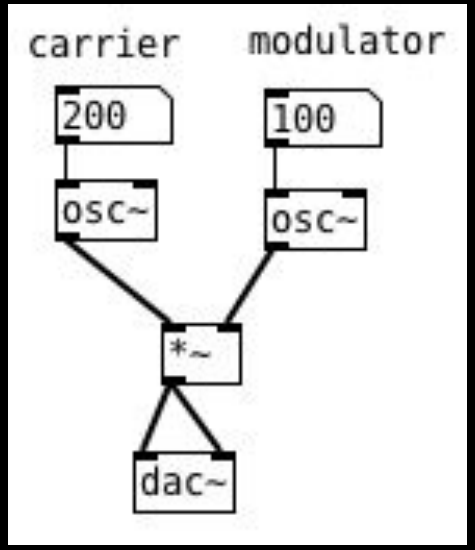
When we use sinusoids with such modulation we obtain this particular spectrum (figure)

We add to frequency 2 frequencies (100 and 300 Hz in the figure) to the original signal (the carrier signal - 200 Hz in the figure).

This frequencies are called sidebands and they are equal to:
lower sideband = fc - fm
upper sideband = fc + fm

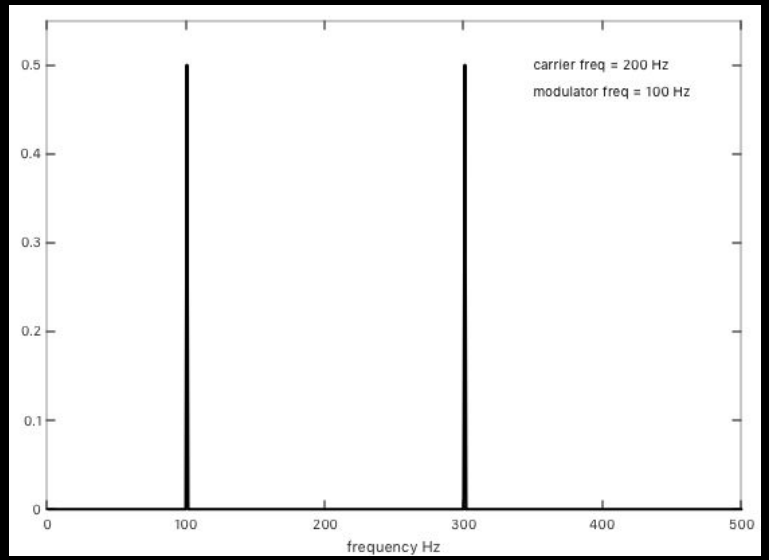
where fc is the frequency of the carrier sinusoid and fm is the frequency of the modulator

Ring Modulation (RM)



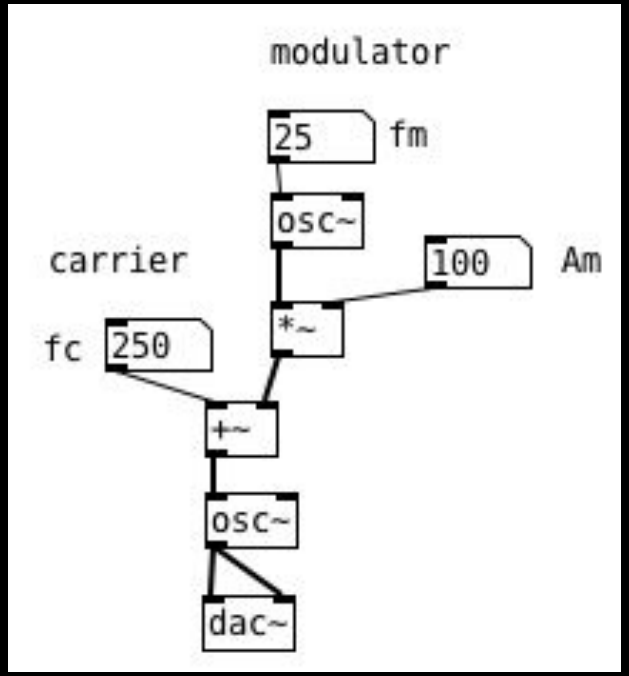
In the ring modulation (RM) we multiply the output of two signal (carrier and modulator)

$$x(t) = \sin(\omega_m t) \cdot \sin(\omega_c t)$$



The resulting spectrum is very similar to AM spectrum but with an important difference: we don't have the carrier frequency but only the sidebands.

Frequency Modulation (FM)

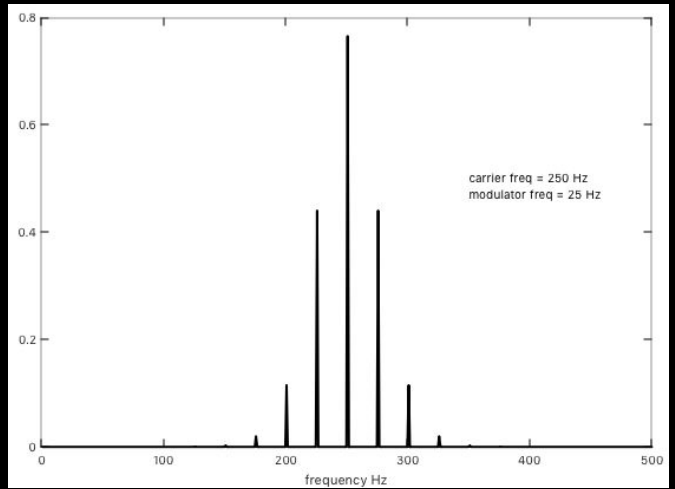


In the Frequency Modulation (FM) we modulate the frequency of a signal (carrier) with the output of another signal (modulator)

$$x(t) = \sin\left[\omega_c t + A_m \sin(\omega_m t)\right]$$

The modulator amplitude (Am) is very significant in the FM and it is called the *frequency deviation*. The frequency deviation tells how much the carrier frequency (fc) is deviate.

In the path (figure on left) the fc will be deviate 35 times per seconds from 150 to 350.



The FM resulting spectrum is far more complex than the other modulations.

The spectrum is composed of the carrier frequency (fc) and a number of sidebands on either side of it, spaced at a distance equal to the modulator frequency(fm).
The sideband pairs are calculated as follows:
lower sidebands = fc - k*fm
upper sidebands = fc + k*fm
where k is an integer, greater than zero, which corresponds to the order to the partial counting from fc
The amplitude of the sidebands are determined by the frequency deviation