FX Basics

Time Effects

STOMPBOX DESIGN WORKSHOP

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FX Basics: Time Effects

Time-based effects are built upon the artificial **introduction of delay** and creation of **echoes** to be added to the original signal.

Emerged in the late 1940s and were created by loops of tape or other recording media; variable delay was achieved by changing write/read heads.

The idea behind time-based digital effects is to **temporarily store** a portion of the input signal **into a buffer of variable length**, and **recover it later** for mixing it with the original.

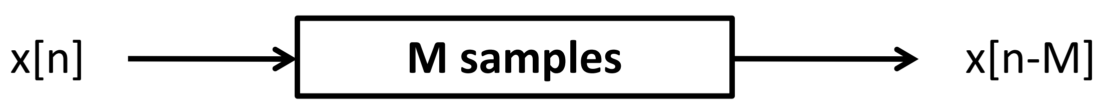
Ex: delay/echo, flanger, phaser, reverb

Delay / Echo

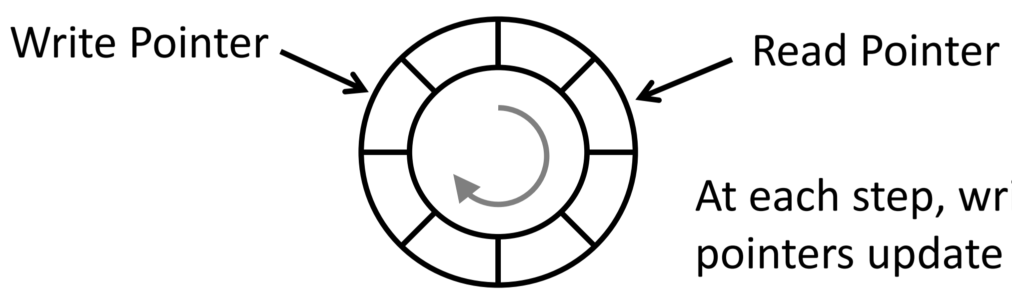
Produce the effect of an echo by creating a duplicate of the input signal and adding it with a slight time delay.

In order to present the simplest approach to digital delay, let’s first introduce the concept of **delay line**:

→ At each seq. order (or time) *n*,
it outputs the sample fed in at time *n-M*



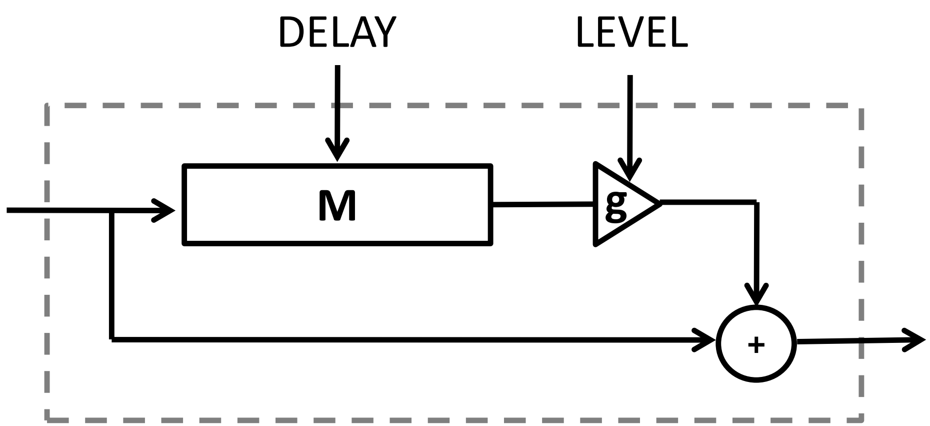
→ Usually implemented as fixed length buffer with write and read pointers ‘spaced’ M samples from each other:



At each step, write and read pointers update their position.

Delay / Echo (ii)

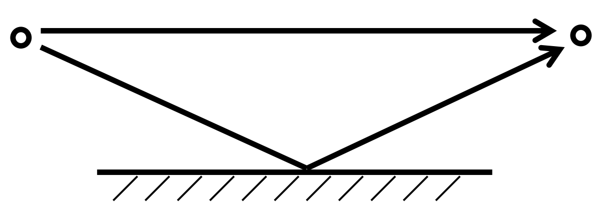
The simplest, single-echo delay digital effect can be constructed with a variable length delay line plus a gain control:



If the 'DELAY' control is set to be expressed in 'seconds', such value will have to be converted to 'number of samples'...

What if M needs to be non-integer?
FRACTIONAL DELAY!

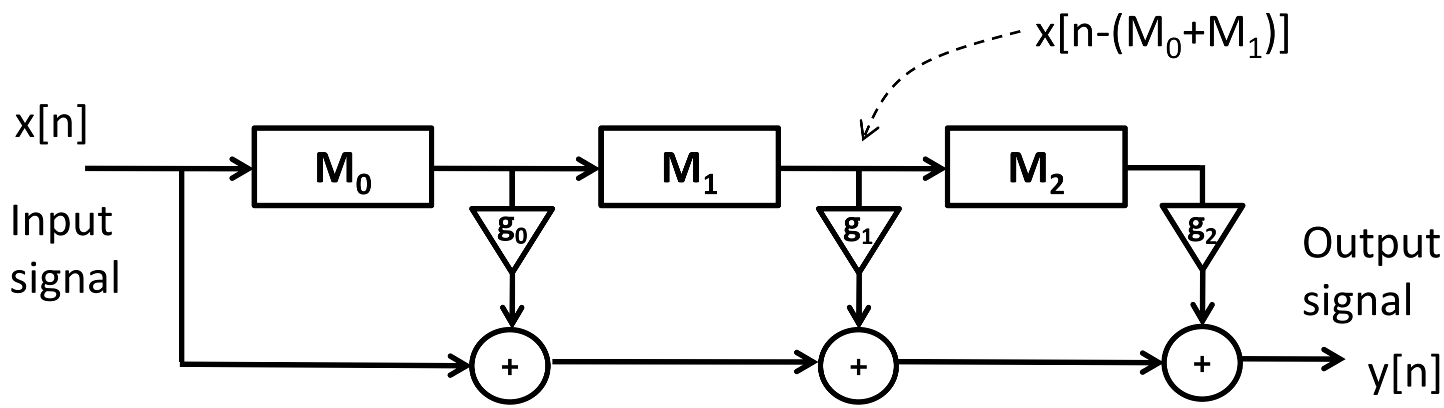
Can be used to simulate a simple acoustical echo:



pd~ 07_stomp_time_1.pd

Delay / Echo (iii)

By cascading several delay lines,
one can obtain a **tapped delay** effect, which leads to a multiple echo:



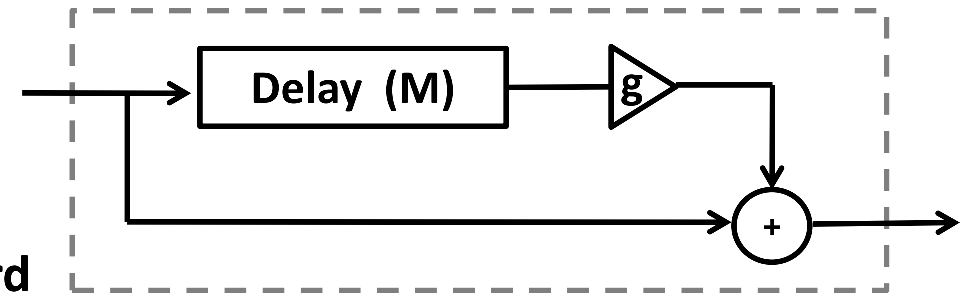
pd~ 08_stomp_time_2.pd

Before getting further with time-based effects: **COMB FILTERS**

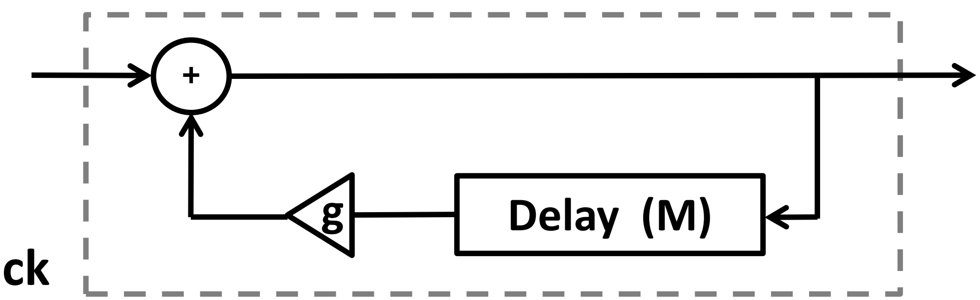
Comb Filters

A comb filter adds a delayed version of a signal to itself.

Ex: the single-echo effect presented before represents an instance of a comb filter.



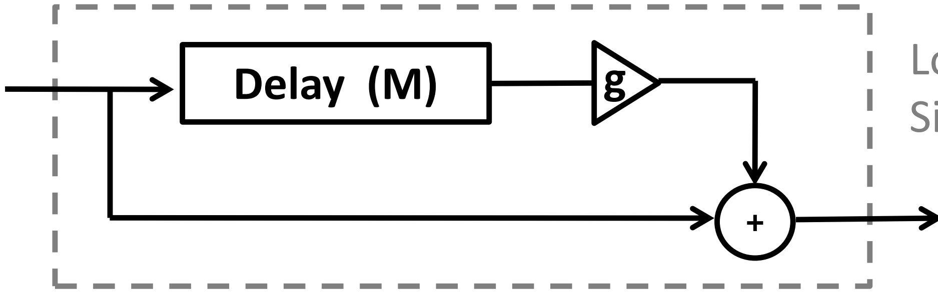
Feed-Forward



Feed-Back

Comb Filters (ii)

Feed-Forward Comb Filter

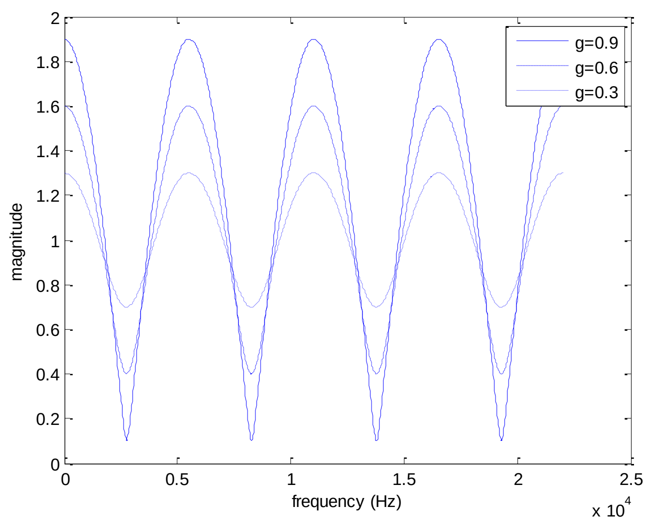


Long Delay:
Single ‘echo’

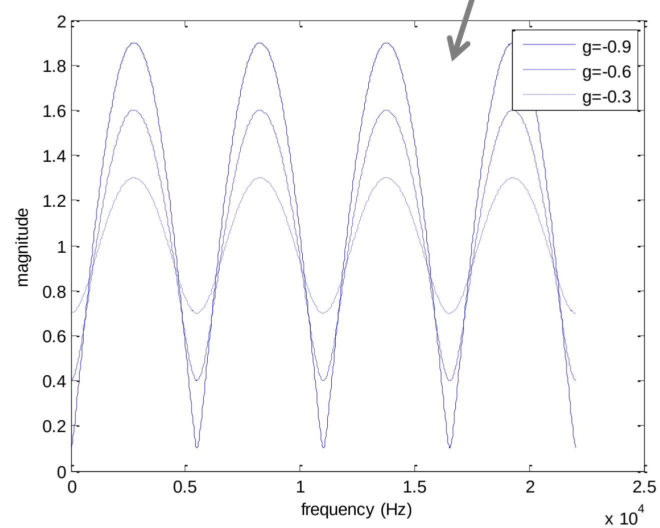
Presents a notch at every f_s/M

M=8

0 > g > 1



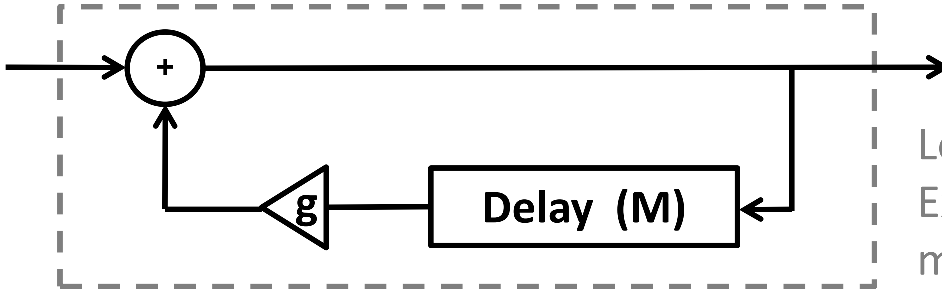
-1 < g < 0



Comb Filters (iii)

FX Basics:
Time Effects

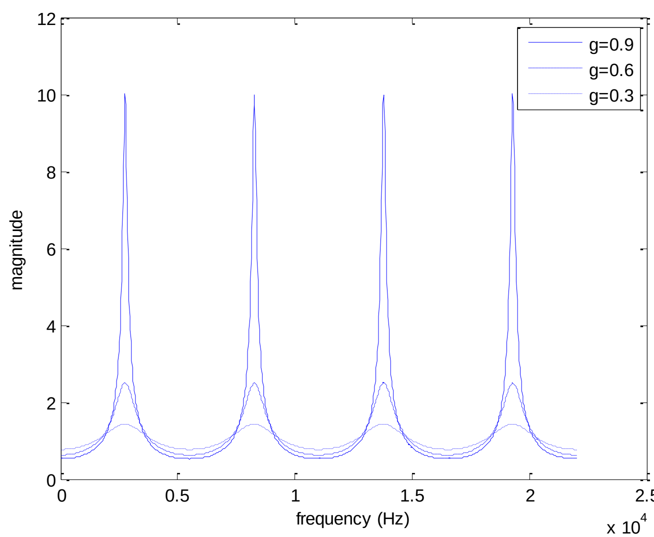
Feed-Back Comb Filter



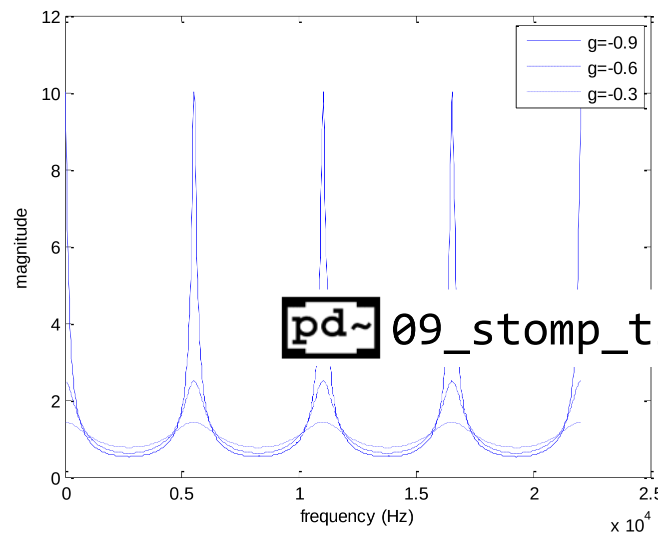
Long Delay:
Exponentially decaying, multiple 'echo'

M=8

0 > g > 1



-1 < g < 0

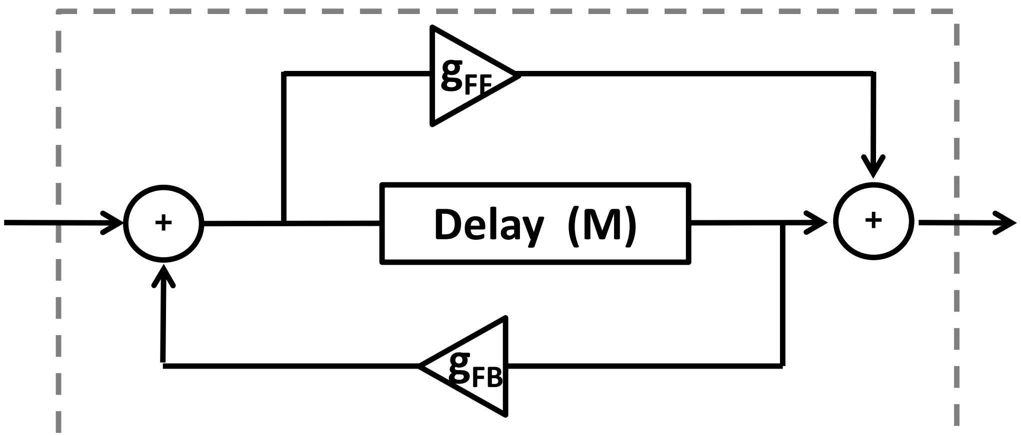


pd~ 09_stomp_time_3.pd

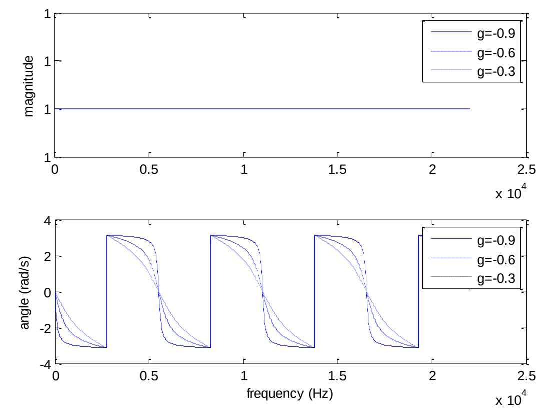
Comb Filters (iv)

All-Pass Filter from Two Comb Filters

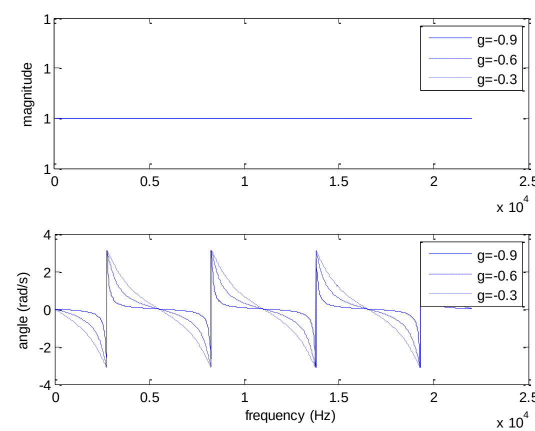
By cascading a Feed-Forward Comb Filter (FFCB) and a Feed-Back Comb Filter (FBCB), one obtains a particular All-Pass Filter whenever $\mathbf{g_{FF} = - g_{FB}}$.



$g_{FF} < 0$



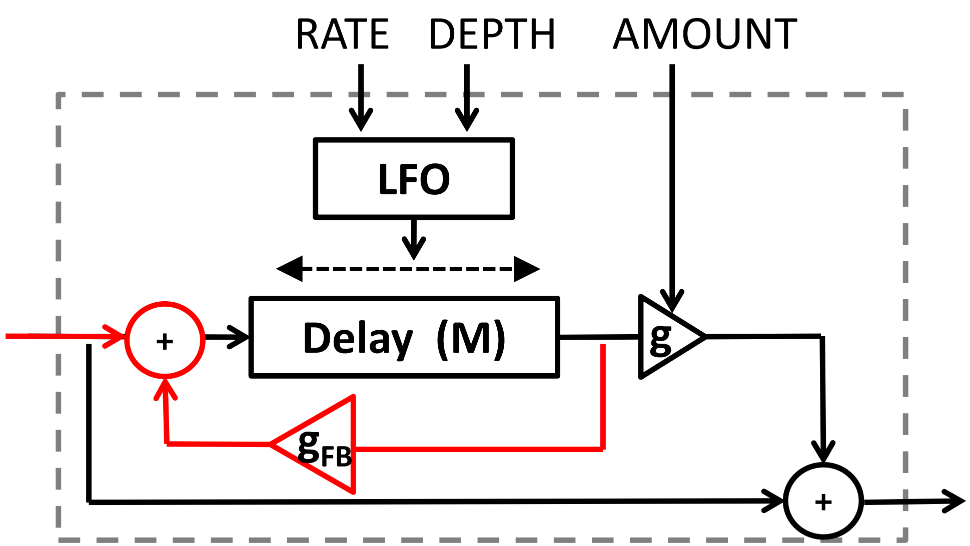
$g_{FF} > 0$



Flanger

Available since the 1960s in recording studios, it was originated by using **2 tape machines** (playing in unison) while **pressing and releasing the flange** of one of them, and thus introducing a **changing, short delay** between read signals before being mixed.

A simple flanger can be modeled as a **LFO-controlled**, **variable-delay FFCF**:



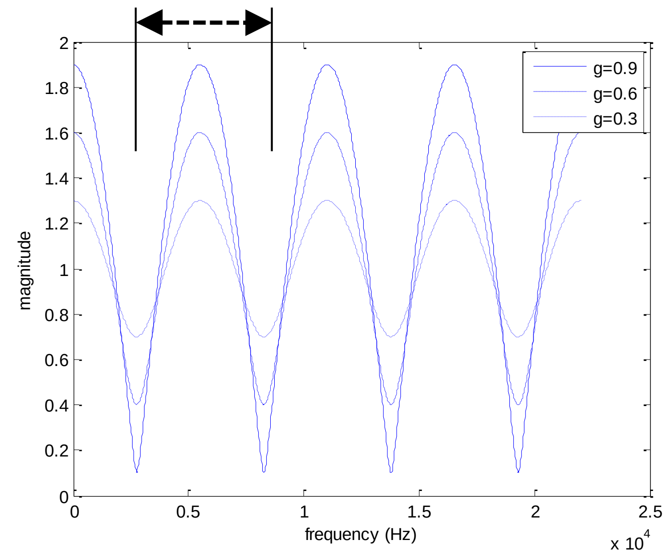
Harmonic series of notches in magnitude response; notches are **uniformly spaced** (at f_S/M).

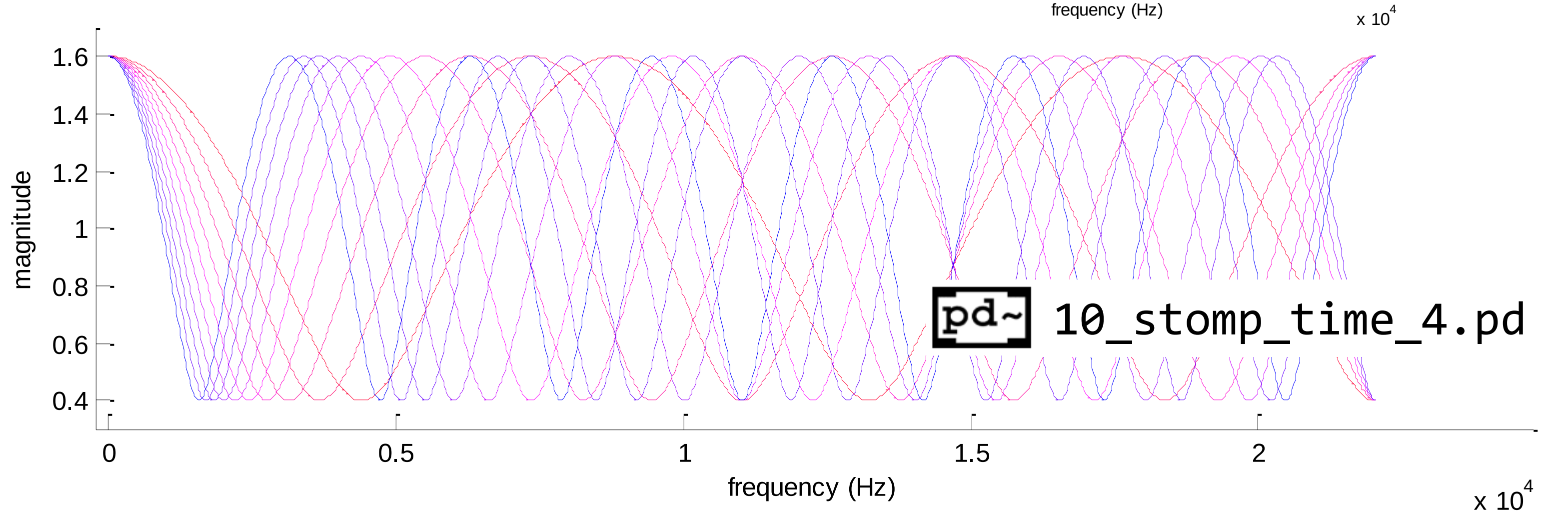
Sometimes, a Feedback control can be added.

FX Basics:
Time Effects

Flanger (ii)

Notch spacing is controlled by the length of the delay line, which is itself controlled by the LFO.



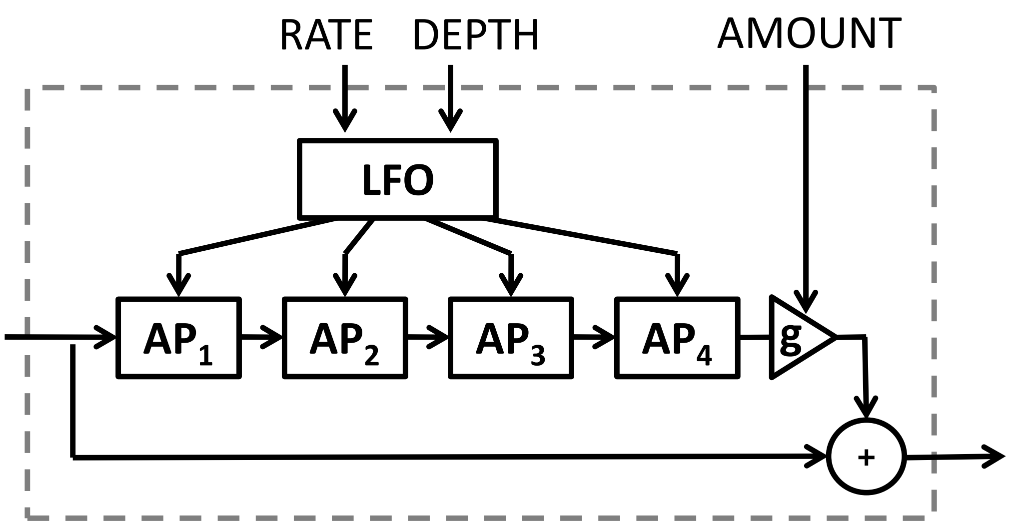


pd~ 10_stomp_time_4.pd

Phaser / Phase shifter

Closely related to the Flanger, it dates from the 1960s, too.

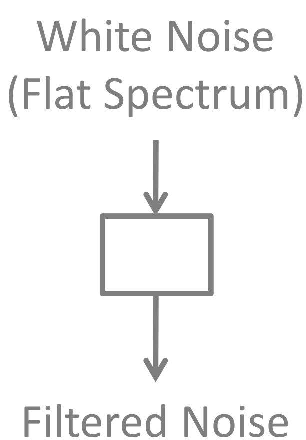
Also based on slightly delaying a signal and adding it to itself, substitutes the variable delay line of the Flanger by a **cascade of low-order All-Pass filters**.



Notches in magnitude response **are finite** (as a function of the number of stages.

pd~ Audio Examples: Section H

Flanger vs Phaser

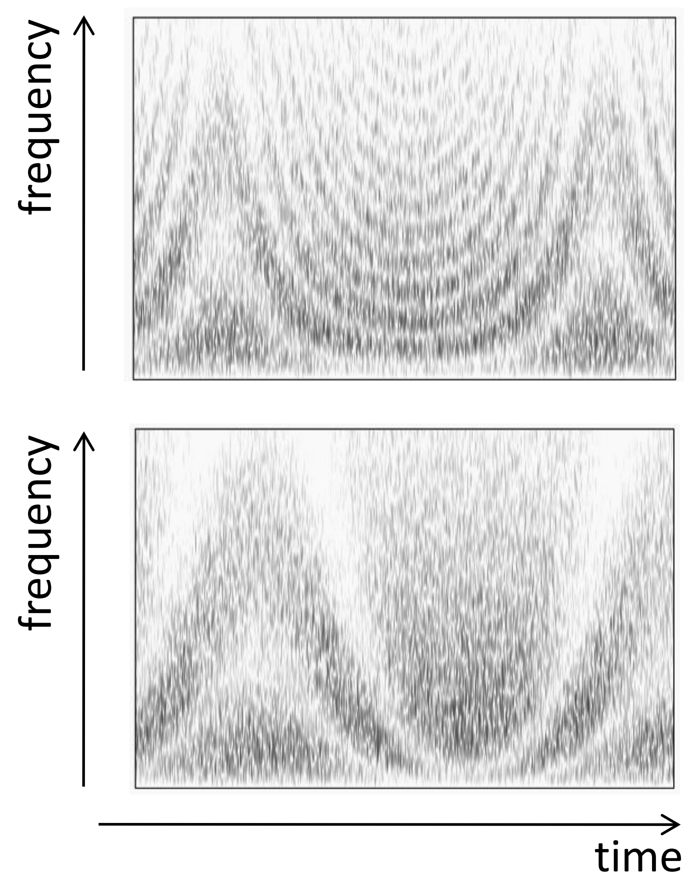


FLANGER

Infinite series of notches, uniformly spaced

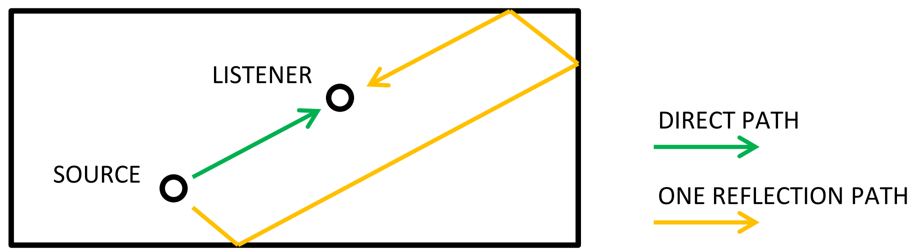
PHASER

Finite series of notches, arbitrarily located



Reverb

In real spaces, reverberation arises from a complicated **pattern of sound reflections** off the walls and other objects.

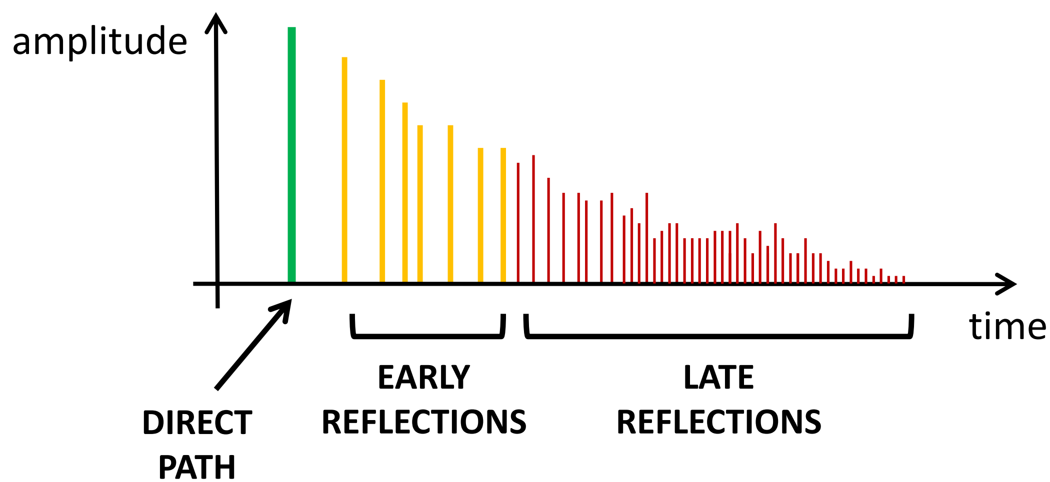


Artificial reverberation represents a very challenging problem, presenting a very **high computational cost** when modeled **from** a purely **physical perspective** (too many computations needed to simulate sound propagation in a 3D space).

However, it is possible to construct **efficient** artificial reverberation **models using delay lines** as basic building blocks.

Reverb (ii)

The profile of a reverberation can be **modeled** as sequence of delayed copies (echoes) of the source sound:



Echo density increases

Amplitude decreases

RELEVANT MEASURES

Arrival time of first reflection

Should be below 40-50ms,
or it may be perceived as echo.

Reverberation time (**T_{60}**):

Time needed to drop 60dB.
Larger, less absorbent spaces present a higher T_{60} value.

Echo density increase rate

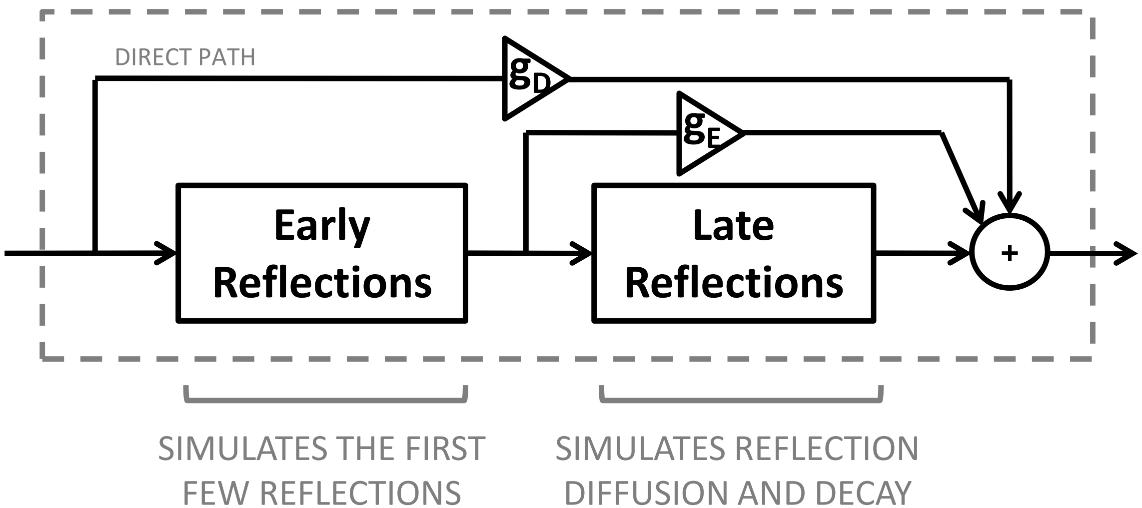
Linked to T_{60}, should show a behavior inversely related to space size.

Reverb (iii)

One can find many strategies for constructing, via delay lines, artificial reverberators that result perceptually satisfactory.

It is **not straightforward** to design delay line-based reverberators so that target measures can be met.

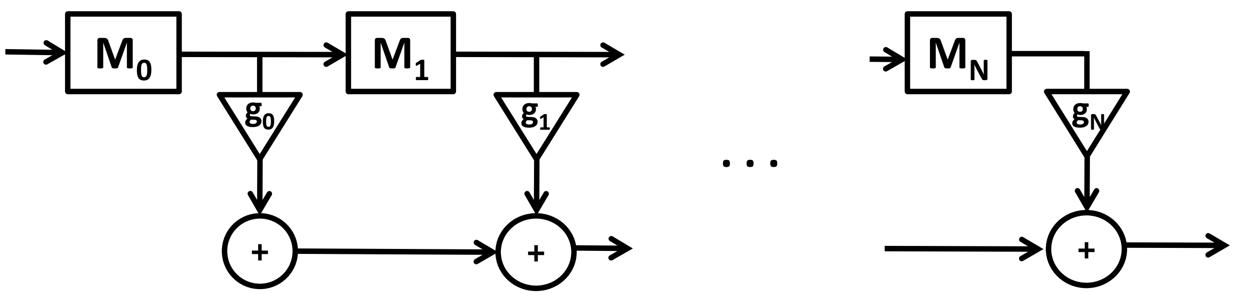
A common approach is to use **2 different stages**, each one in charge of representing the two differentiated observed behaviors:



Reverb (iv)

EARLY REFLECTIONS

One can use a tapped delay line line (one tap per reflection) with tuned delays $\mathbf{M_n}$ and gains $\mathbf{g_n}$.



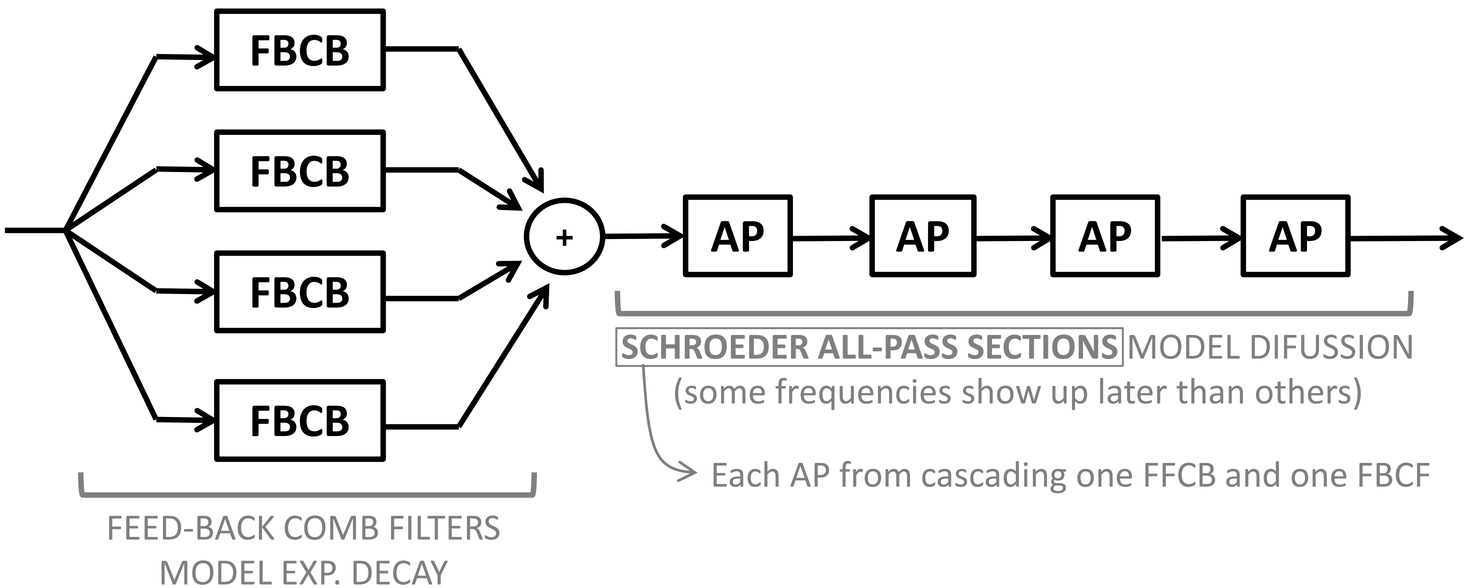
It is suggested that none of the taps' delay exceeds **40-50ms,** since it is acknowledged as the threshold for echo perception.

An idea is to control delays and gains with a 'shared' parameter.

Reverb (v)

LATE REFLECTIONS (including DIFFUSION)

Different variations over structures based on cascading AP sections with particular settings (*Schroeder All-Pass Sections*):



Delay line lengths must be set to be **mutually prime**, so smooth decay and echo density increase are ensured.

pd~ ‘Freeverb’

http://www.bagger288.com/temp/aboutThisReverberationBusiness.pdf