



STOMPBOX DESIGN WORKSHOP

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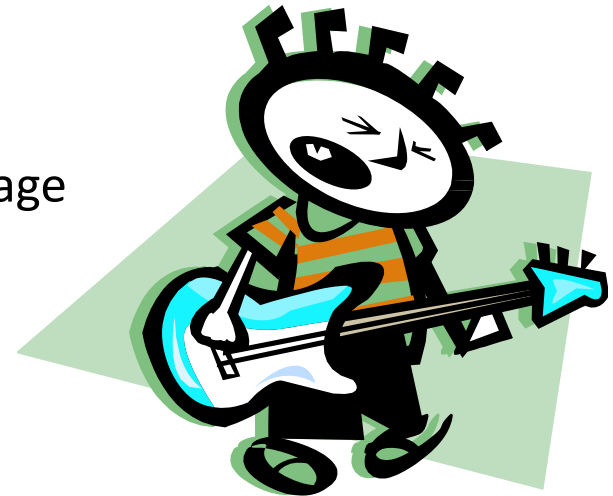
FX Basics: Distortion Effects

Distortion effects are some of the better known and **most popular** effects associated with electric guitar since the 1960s.

They emerged as a result of accidental damage to amplifier vacuum tubes. Recordings were carried out by using damaged units or units working under stress.

Damage or overstress in amplifier circuitry or speaker systems often results into a **severe degradation of the signal waveform**. Distortion stompboxes often simulate such degradation by dedicated circuitry.

Ex: overdrive, distortion, fuzz



Distortion Principles

FX Basics:
Distortion Effects

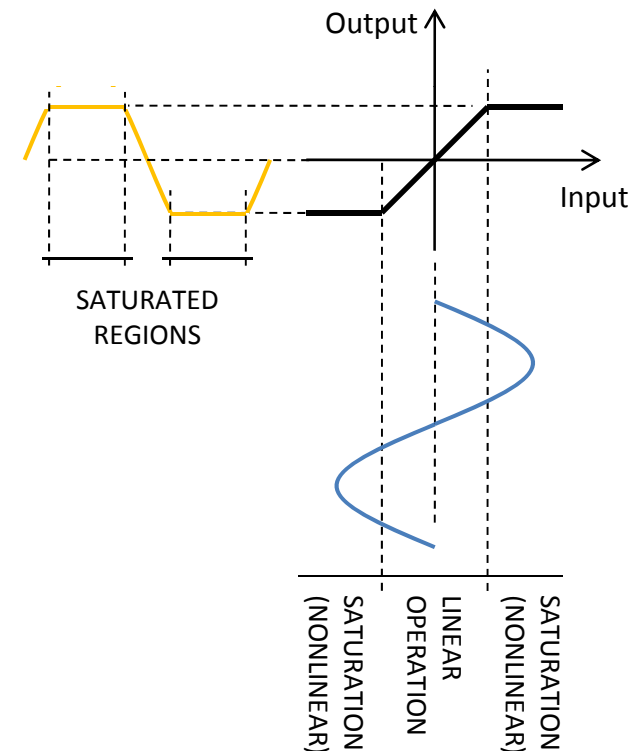


The principle of distortion resides on **drastically altering the wave shape** (morphology) of a signal in a way **not possible** to achieve **by** conventional **linear filtering**.

The basic phenomenon behind early days accidental distortion is called **saturation**.

Basically, **saturation may result** from **driving** an electrical (e.g. amplifier) or mechanical (e.g. speaker spider) device **beyond its nominal, linear operation**.

Much of **digital modeling of distortion effects** deals with a **computational representation** of the **nonlinearities** introduced saturation-like phenomena.

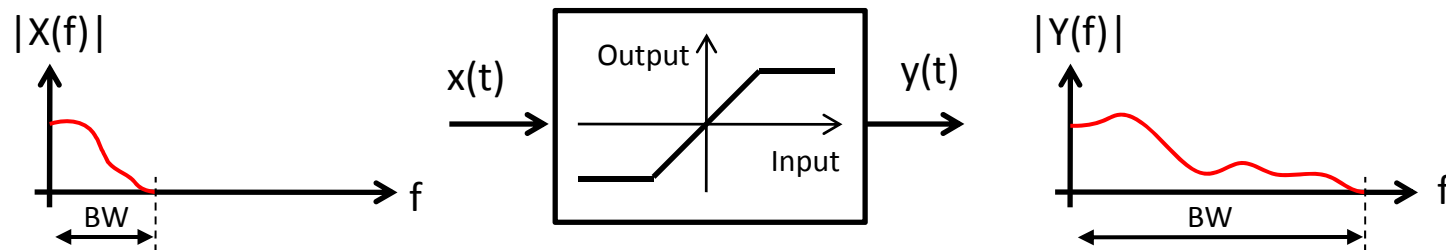


Distortion Principles (ii)

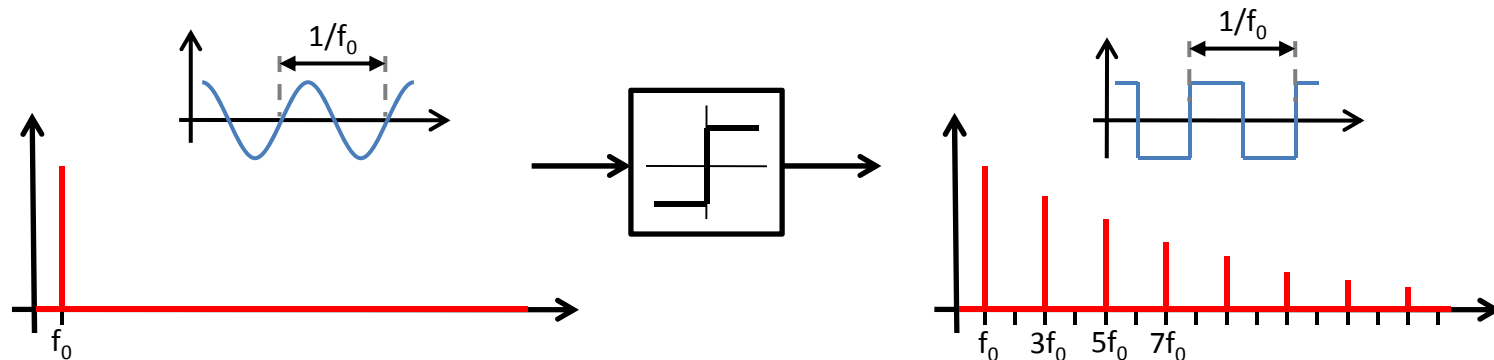
FX Basics:
Distortion Effects



In general, nonlinearities of the type used in distortion-dedicated circuits **cause the bandwidth of the original signal to expand** through an **enrichment of the spectral content** in the form of **additional overtones**.



EXTREME EXAMPLE | From sinusoidal to square wave:

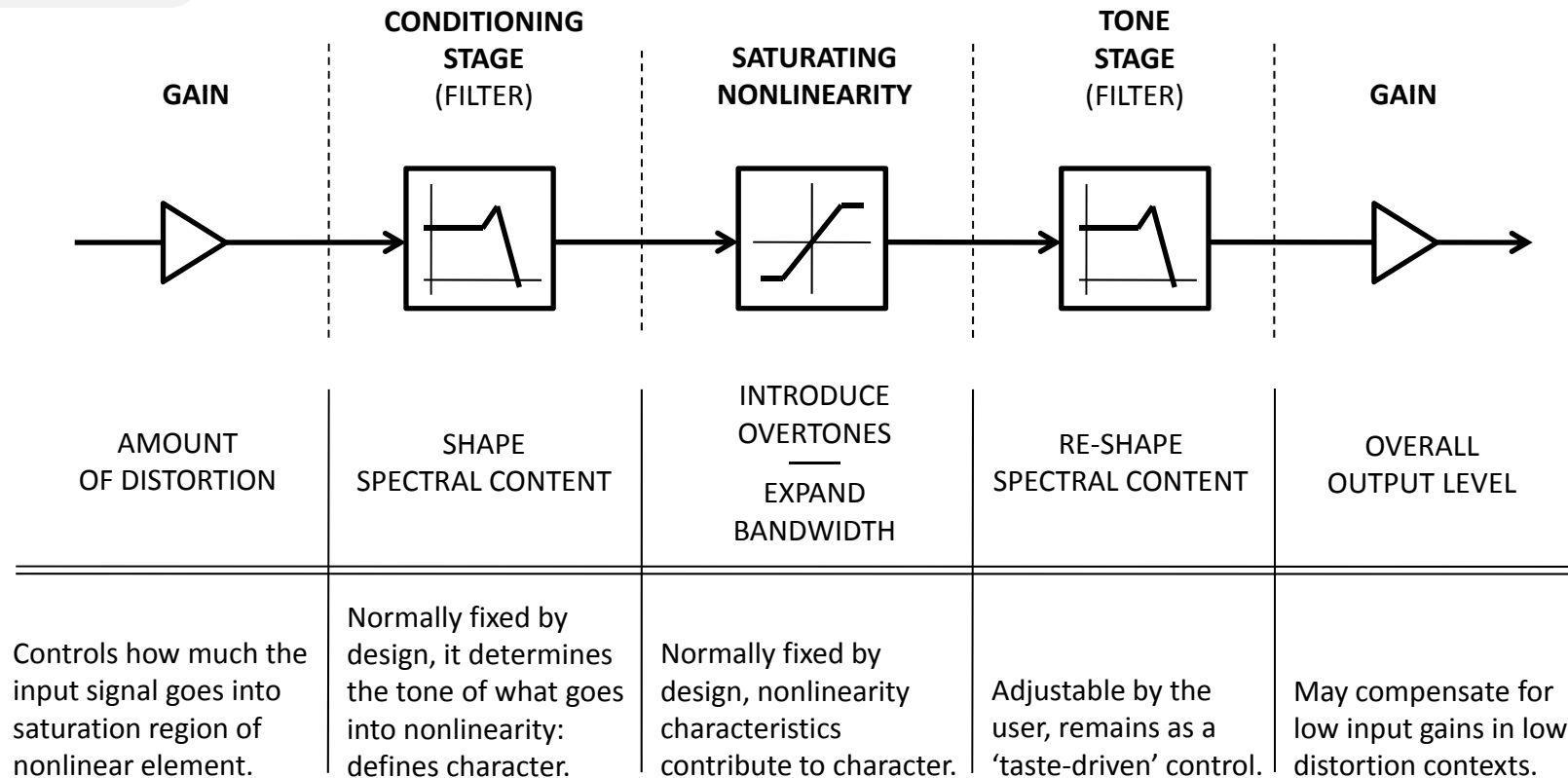


Distortion Schema

FX Basics:
Distortion Effects



Generally, distortion-dedicated schemas present a **saturation nonlinearity surrounded by tone stages** (filters).



Saturating Nonlinearities

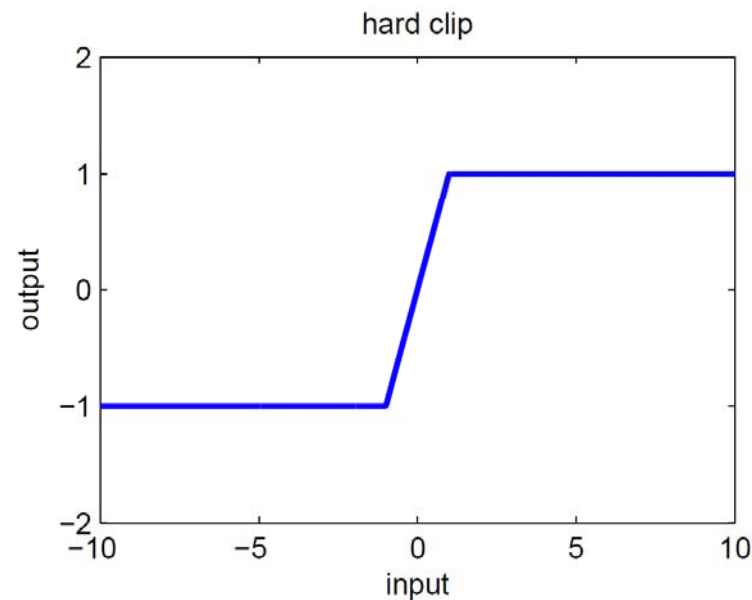
FX Basics:
Distortion Effects



In digital modeling of distortion, some of the most **common models** for saturating nonlinearities are:

HARD CLIP

$$f(x) = \begin{cases} x, & |x| \leq a \\ a, & \textit{otherwise} \end{cases}$$



Saturating Nonlinearities (ii)

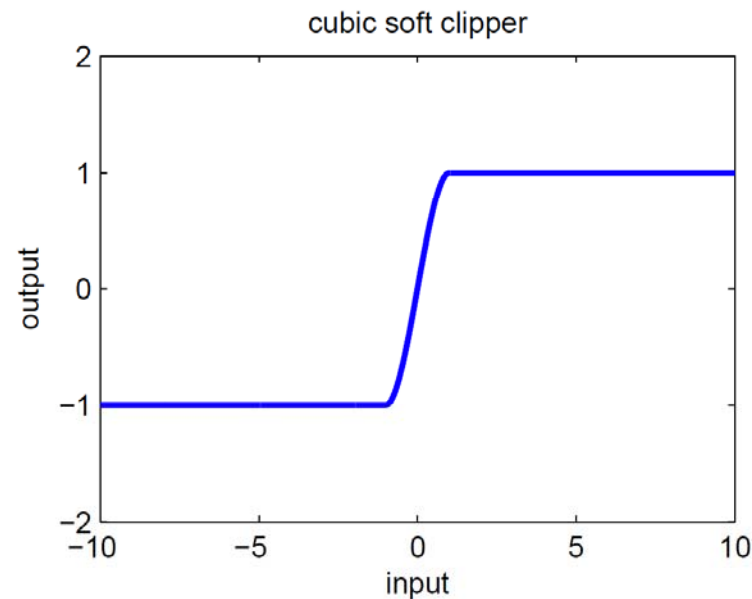
FX Basics:
Distortion Effects



In digital modeling of distortion, some of the most **common models** for saturating nonlinearities are:

CUBIC SOFT CLIPPER

$$f(x) = \begin{cases} -\frac{2}{3}, & x \leq -1 \\ x - \frac{x^3}{3}, & -1 \leq x \leq 1 \\ \frac{2}{3}, & x \geq 1 \end{cases}$$



Saturating Nonlinearities (iii)

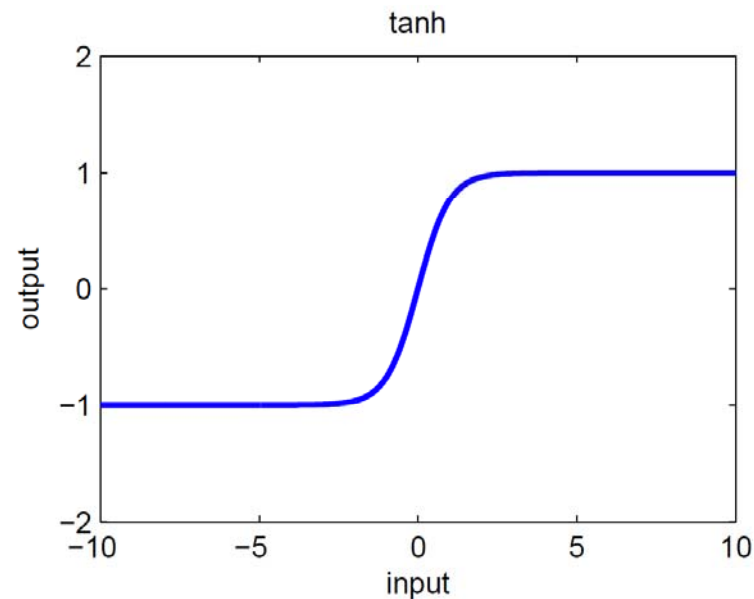
FX Basics:
Distortion Effects



In digital modeling of distortion, some of the most **common models** for saturating nonlinearities are:

SIGMOID

$$f(x) = \tanh(x)$$



Saturating Nonlinearities (iv)

FX Basics:
Distortion Effects

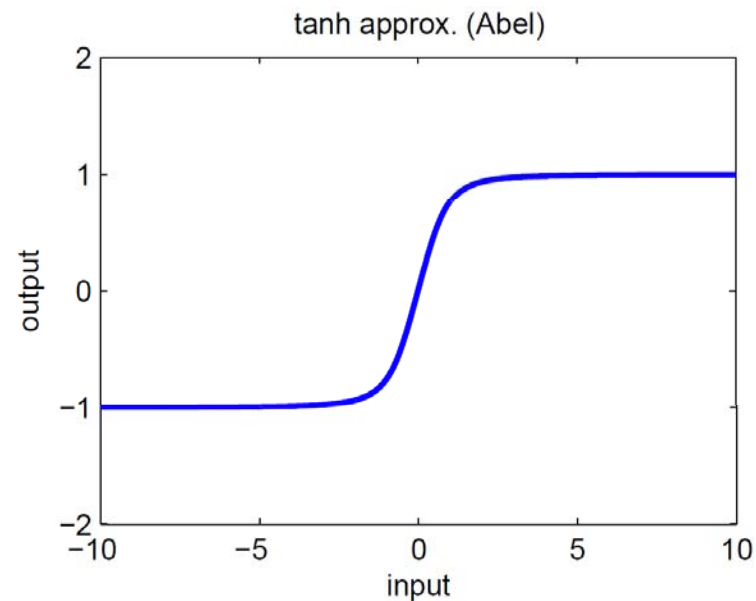


In digital modeling of distortion, some of the most **common models** for saturating nonlinearities are:

Abel SIGMOID

$$f(x) = \frac{x}{(1 + |x|^n)^{1/n}}$$

$$n = 2.5$$



Saturating Nonlinearities (v)

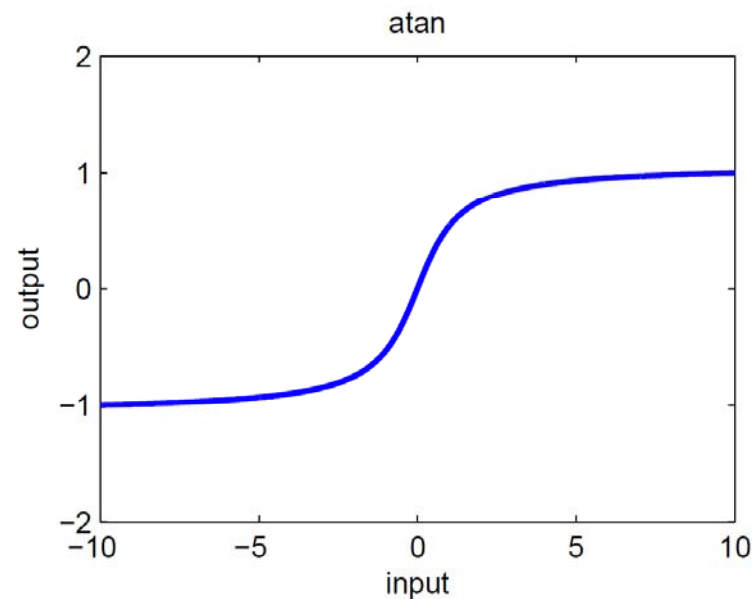
FX Basics:
Distortion Effects



In digital modeling of distortion, some of the most **common models** for saturating nonlinearities are:

ARCTANGENT

$$f(x) = \tan^{-1}(x)$$



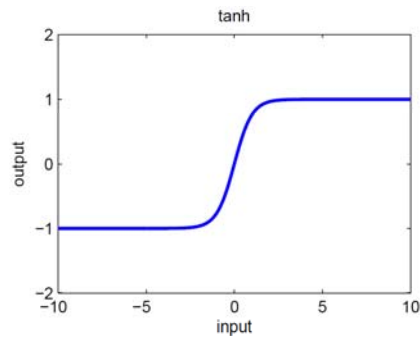
Saturating Nonlinearities (vi)

FX Basics:
Distortion Effects

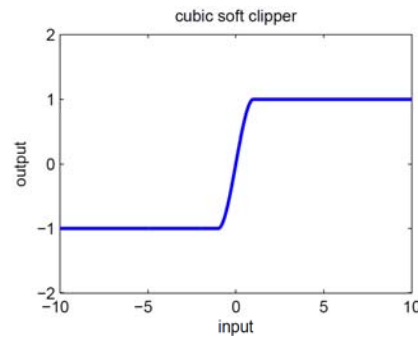


In general, the sharper the saturation corners, the more bandwidth expansion happens.

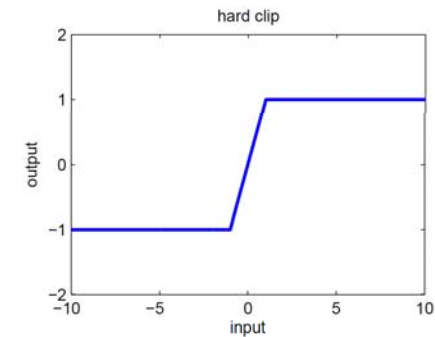
SIGMOID



SOFT CLIPPER



HARD CLIPPER



AMOUNT OF BANDWIDTH EXPANSION

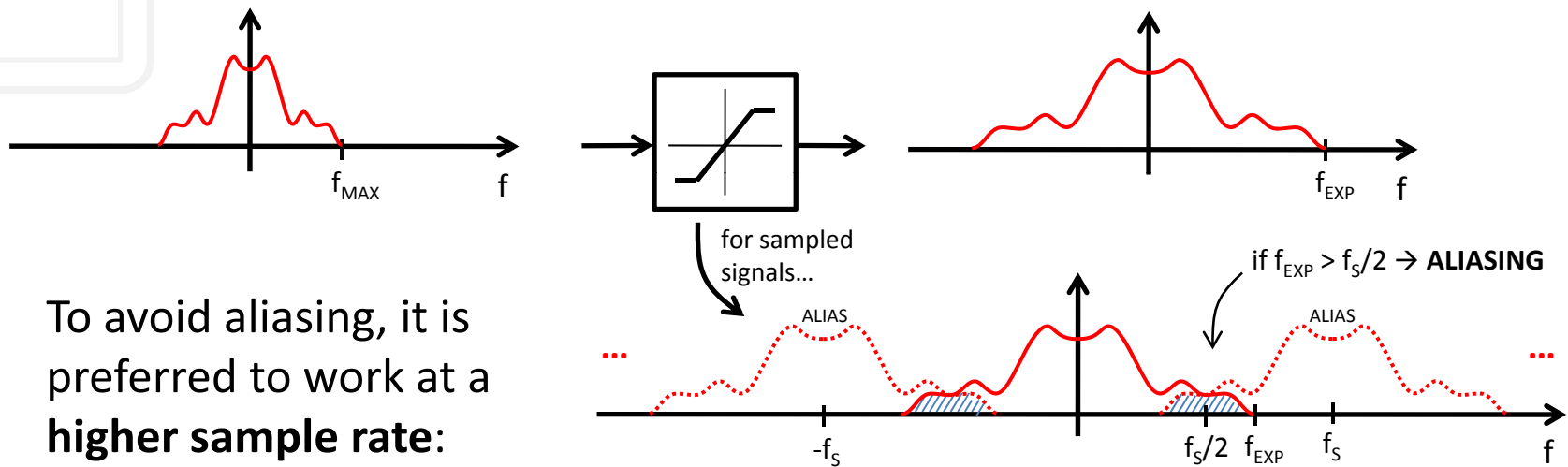


Aliasing: oversampling

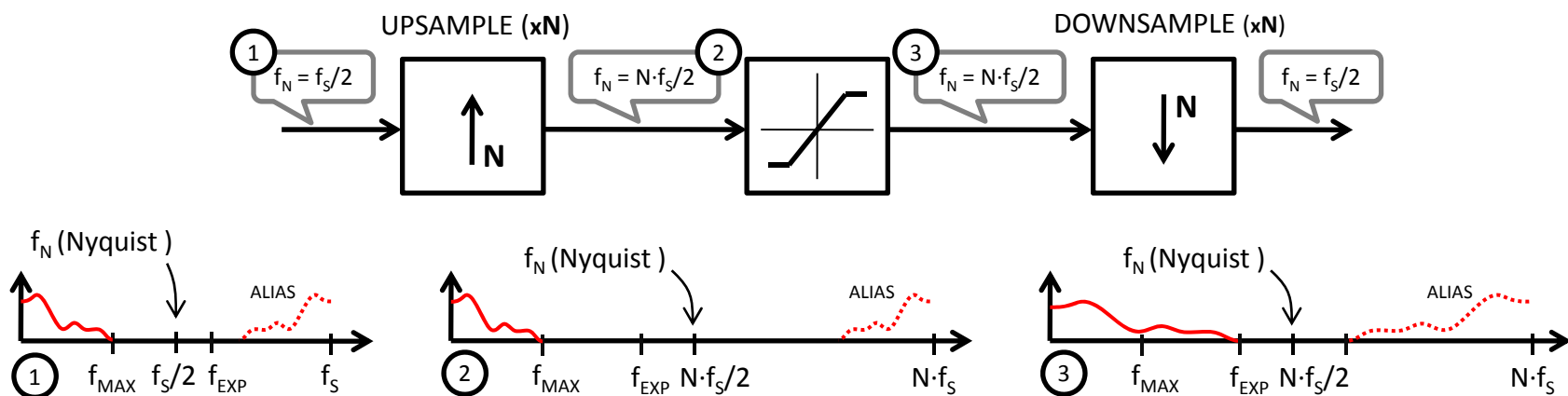
FX Basics:
Distortion Effects



Due to bandwidth expansion, **aliasing** may appear:



To avoid aliasing, it is preferred to work at a **higher sample rate**:



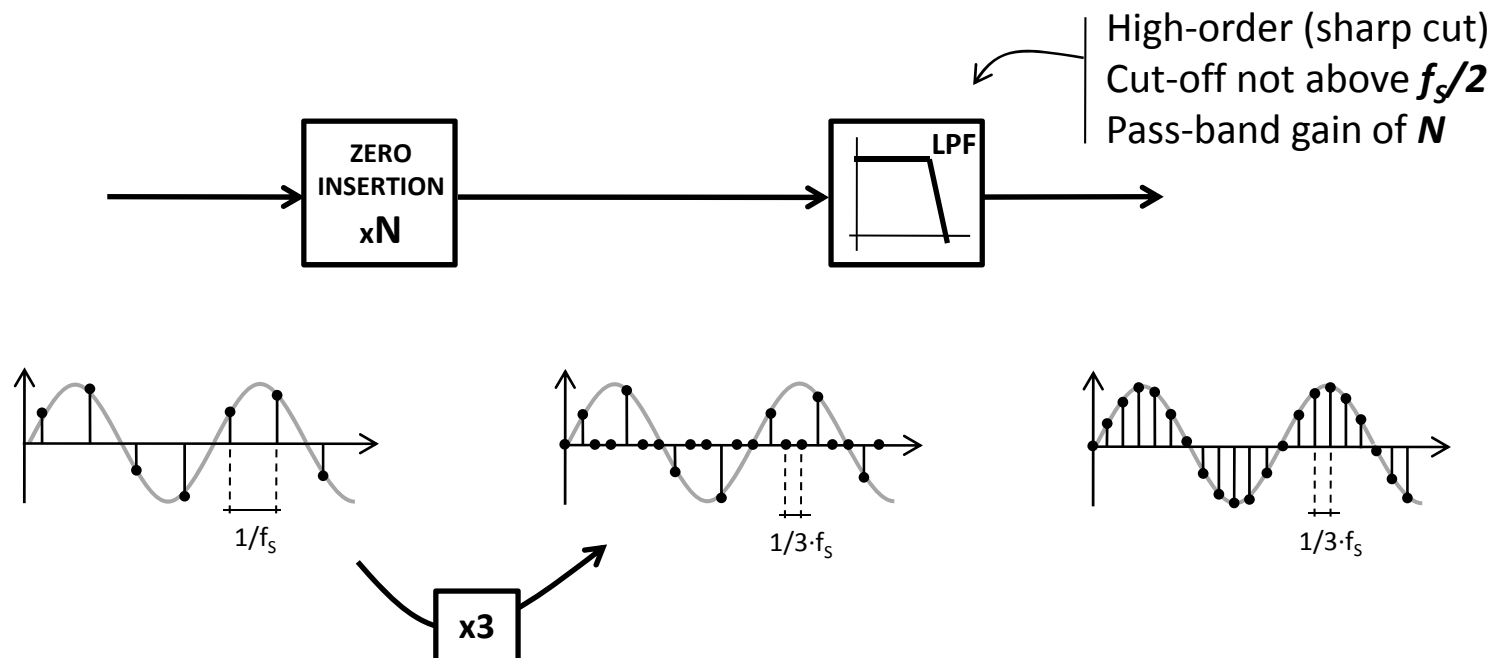
Aliasing: oversampling (ii)

FX Basics:
Distortion Effects



UPSAMPLING

A very effective method for *upsampling* (increasing the sample rate of) a signal is by **zero-stuffing** and **low-pass filtering**.



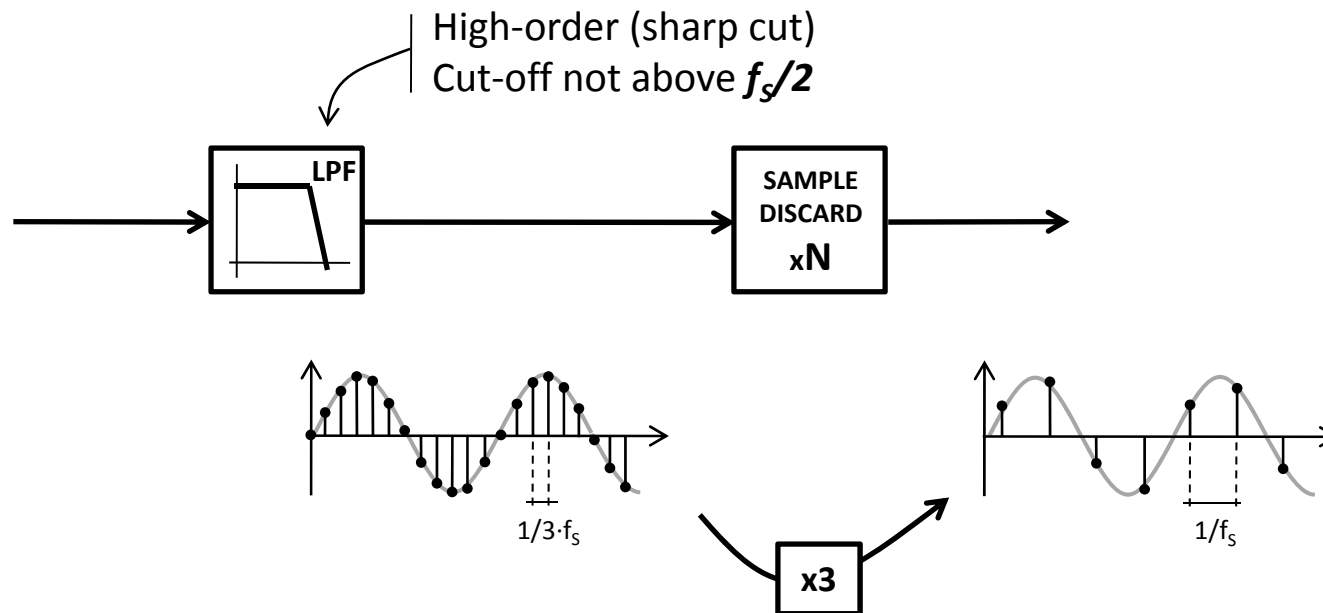
Aliasing: oversampling (iii)

FX Basics:
Distortion Effects



Downsampling

In order to carry out *downsampling* (decreasing the sample rate) and return to the original sample rate, one can **low-pass filter** and **discard samples**:



Overdrive/Distortion/Fuzz

FX Basics:
Distortion Effects



The basic 'operational' difference between different distortion effects is the **amount of distortion** they produce.
→ By increasing order: **overdrive**, **distortion**, and finally **fuzz**.

The line between overdrive and distortion is thinner:

- **OVERDRIVE**: can be seen as only introducing distortion above certain input amplitude (as a simulation of *overdrive*).
- **DISTORTION**: by design, distortion may be introduced equally at all input amplitude levels; also, a harder nonlinearity may be used.



https://ccrma.stanford.edu/~dtyeh/papers/yeh07_dafx_distortion.pdf

For the case of **FUZZ** effects, hard-clipping the input signal even at low amplitudes produces a **square-like wave** which, once tone-shaped, may then be further processed (ex: ring modulator) before being sent out.



06_stomp_distortion.pd