FX Basics
Distortion

STOMPBOX DESIGN WORKSHOP

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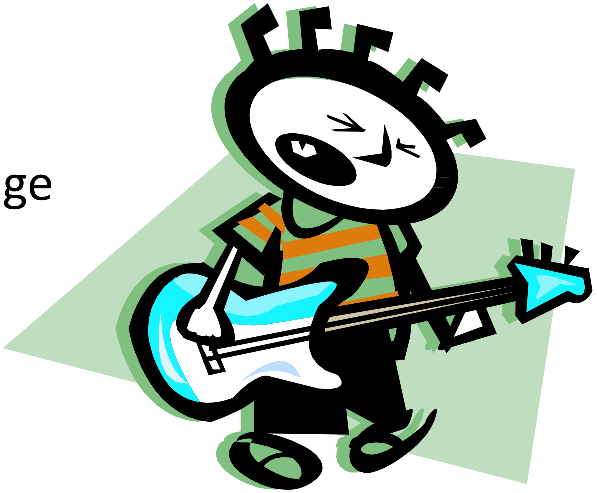
FX Basics: Distortion Effects

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 vaccum 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

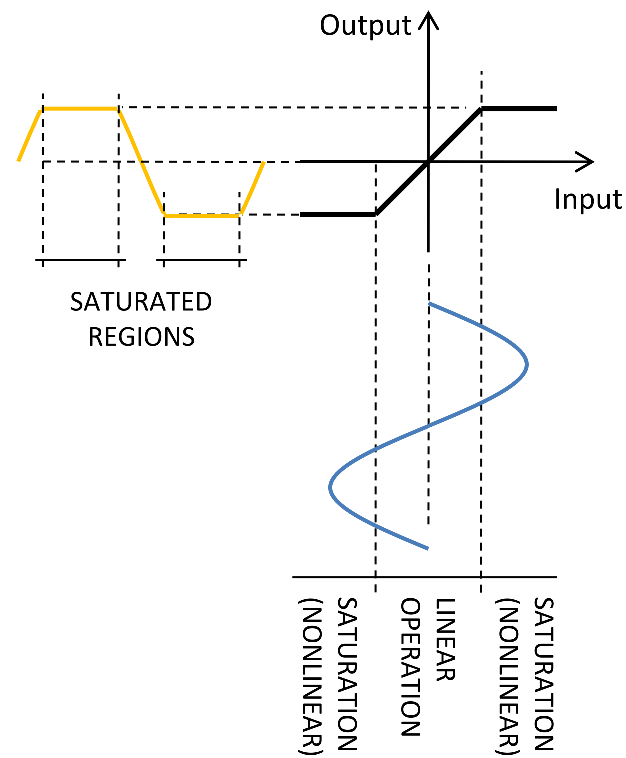
Distortion Principles

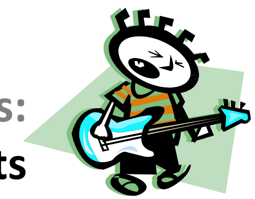
The principle of distortion resides on **drastically altering the wave shape** (morphology) of a signal in a way **not possible** to achieve **by** conventional **linear filtering**.

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

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

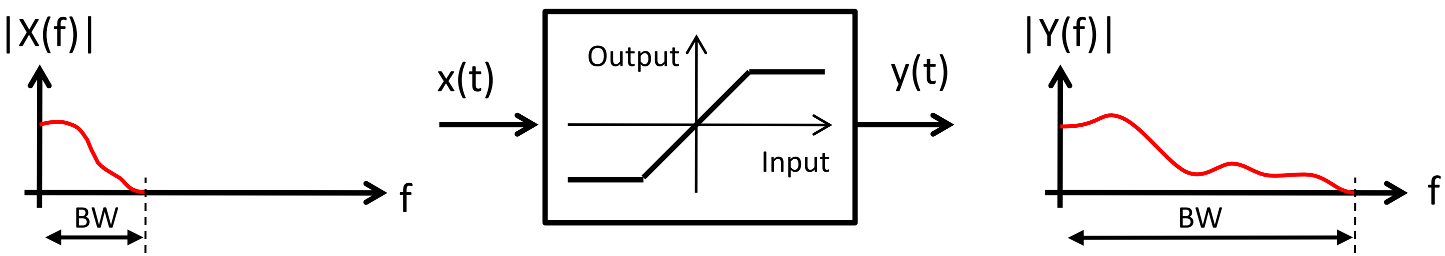
Much of **digital modeling of distortion effects** deals with a **computational representation** of the **nonlinearities** introduced saturation-like phenomena.



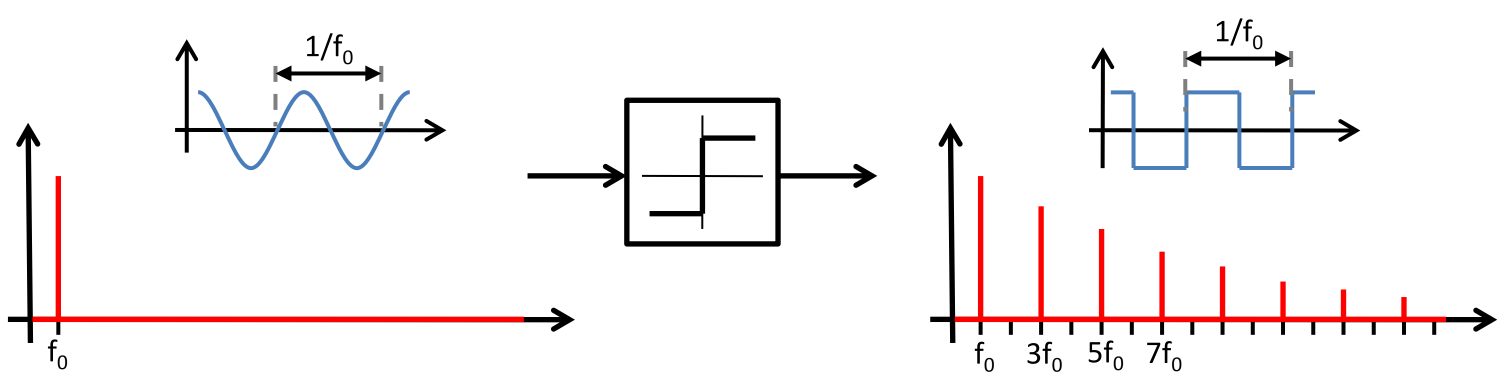


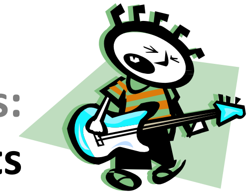
Distortion Principles (ii)

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**.



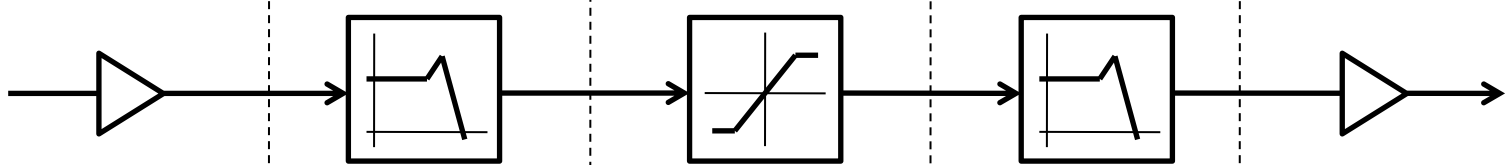
EXTREME EXAMPLE | From sinusoidal to square wave:





Distortion Scheme

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



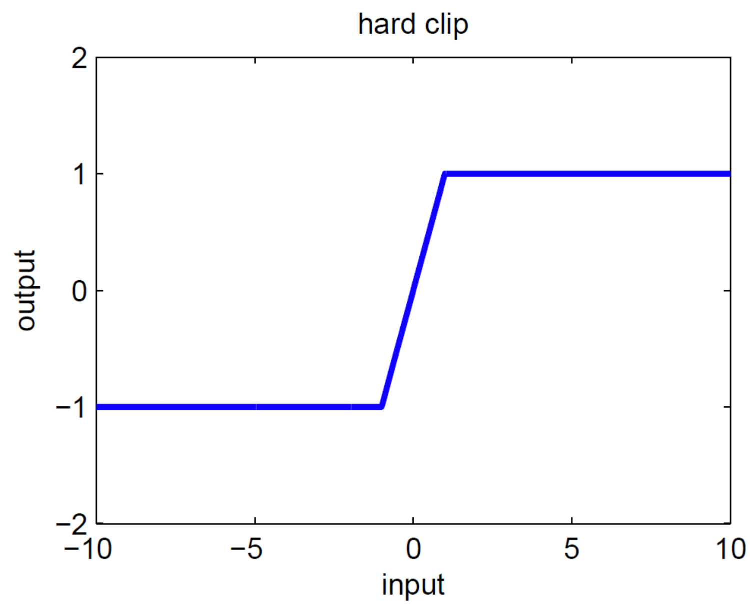
GAIN	**CONDITIONING STAGE** (FILTER)	**SATURATING NONLINEARITY**	**TONE STAGE** (FILTER)	**GAIN**
AMOUNT OF DISTORTION	SHAPE SPECTRAL CONTENT	INTRODUCE OVERTONES — EXPAND BANDWIDTH	RE-SHAPE SPECTRAL CONTENT	OVERALL OUTPUT LEVEL
Controls how much the input signal goes into saturation region of nonlinear element.	Normally fixed by design, it determines the tone of what goes into nonlinearity: defines character.	Normally fixed by design, nonlinearity characteristics contribute to character.	Adjustable by the user, remains as a ‘taste-driven’ control.	May compensate for low input gains in low-distortion contexts.

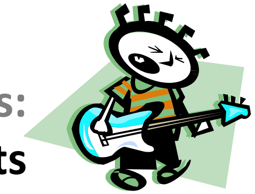
Saturating Nonlinearities

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

HARD CLIP

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



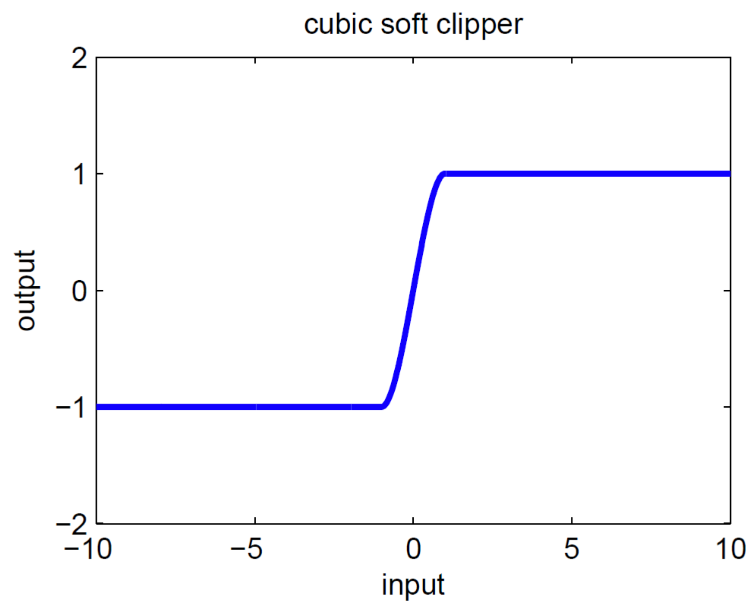


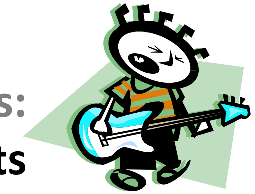
Saturating Nonlinearities (ii)

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

CUBIC SOFT CLIPPER

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



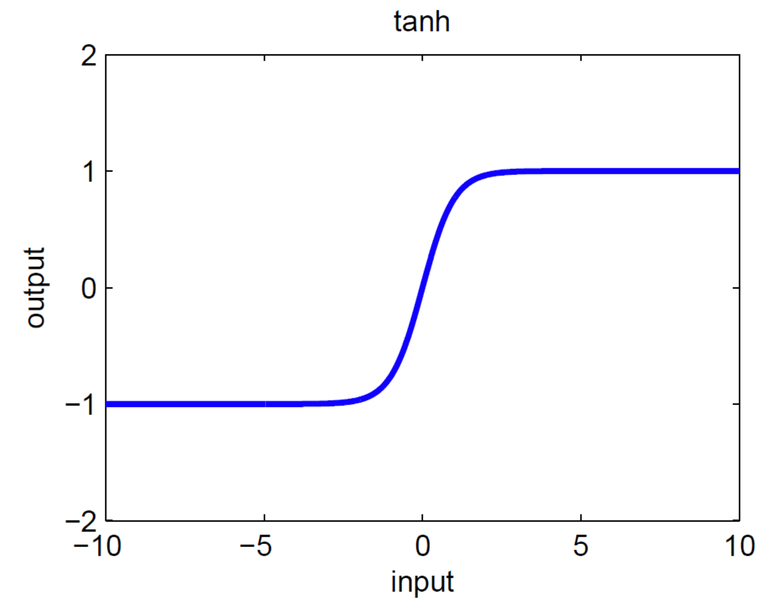


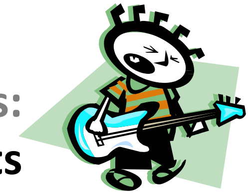
Saturating Nonlinearities (iii)

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

SIGMOID

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





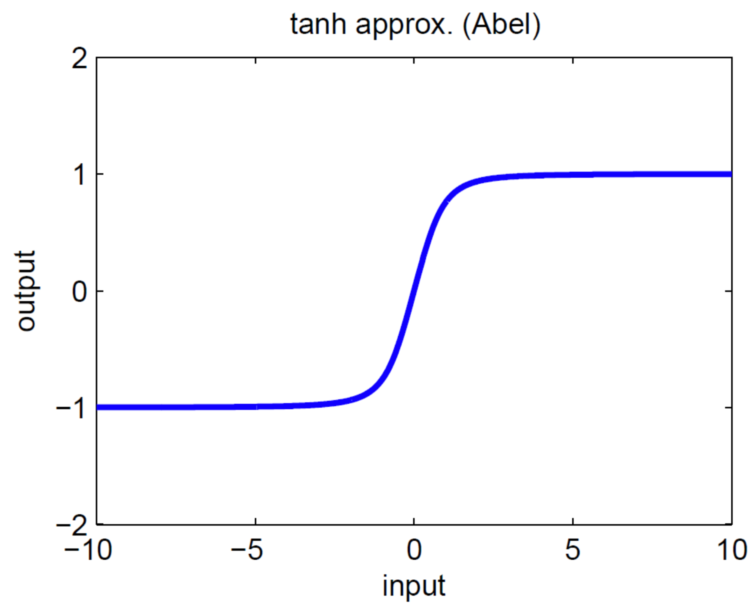
Saturating Nonlinearities (iv)

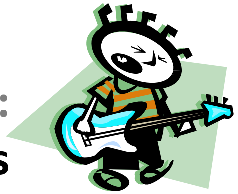
In digital modeling of distortion, some of the most **common models** for saturating nonlinearities are:

Abel **SIGMOID**

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

$$n = 2.5$$

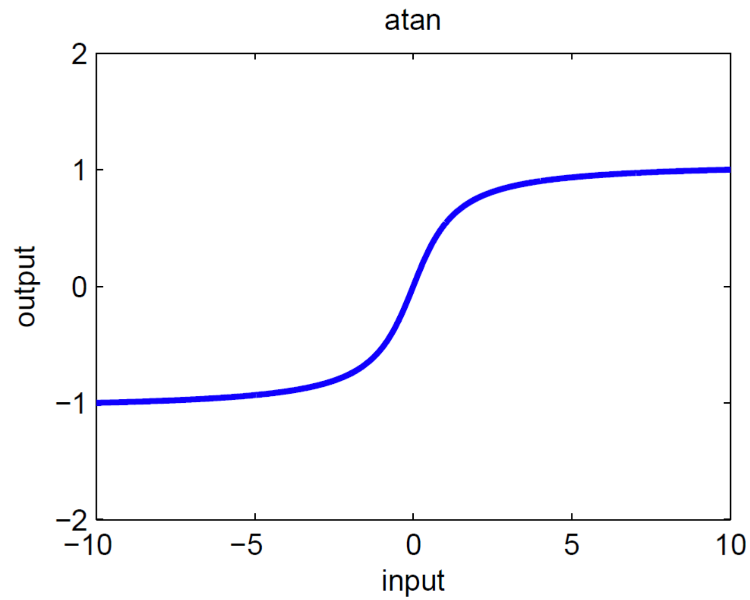




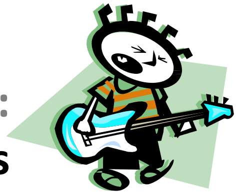
Saturating Nonlinearities (v)

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

ARCTANGENT



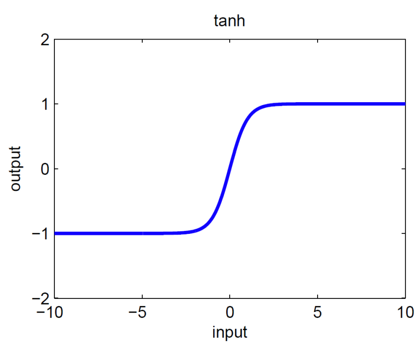
$$f(x) = \tan^{-1}(x)$$



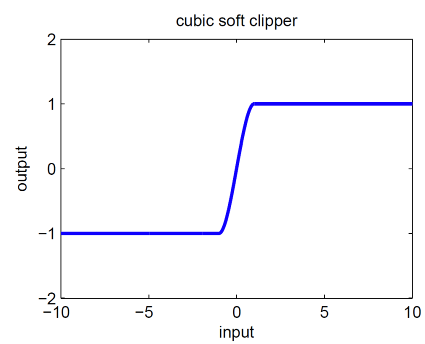
Saturating Nonlinearities (vi)

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

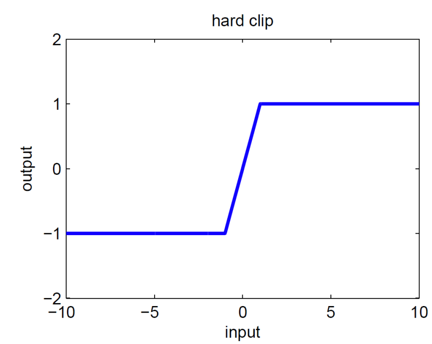
SIGMOID



SOFT CLIPPER



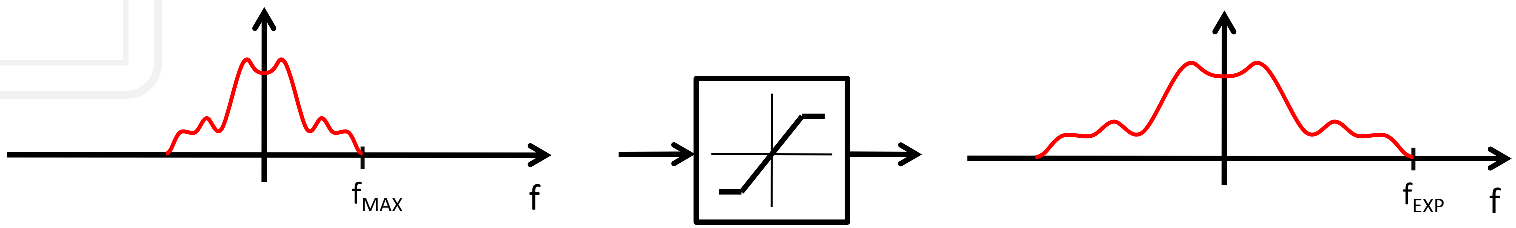
HARD CLIPPER

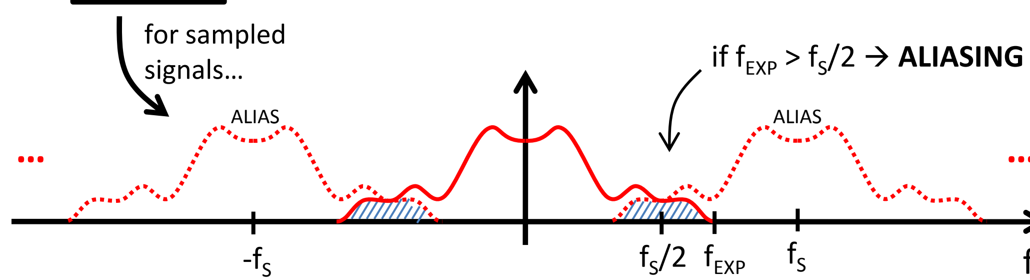


AMOUNT OF BANDWIDTH EXPANSION →

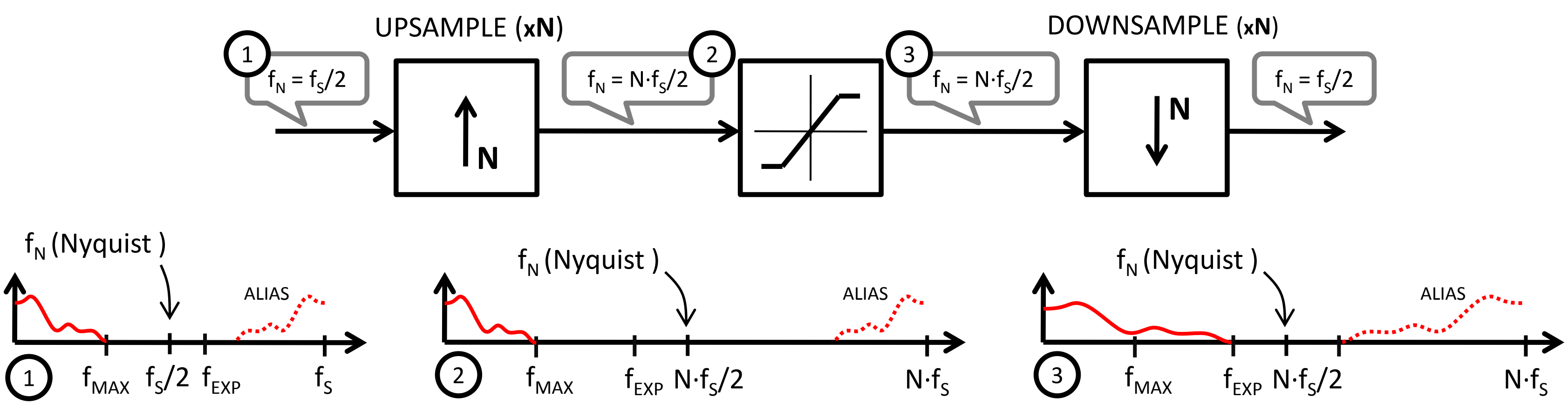
Aliasing: oversampling

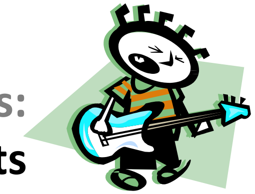
Due to bandwidth expansion, **aliasing** may appear:





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

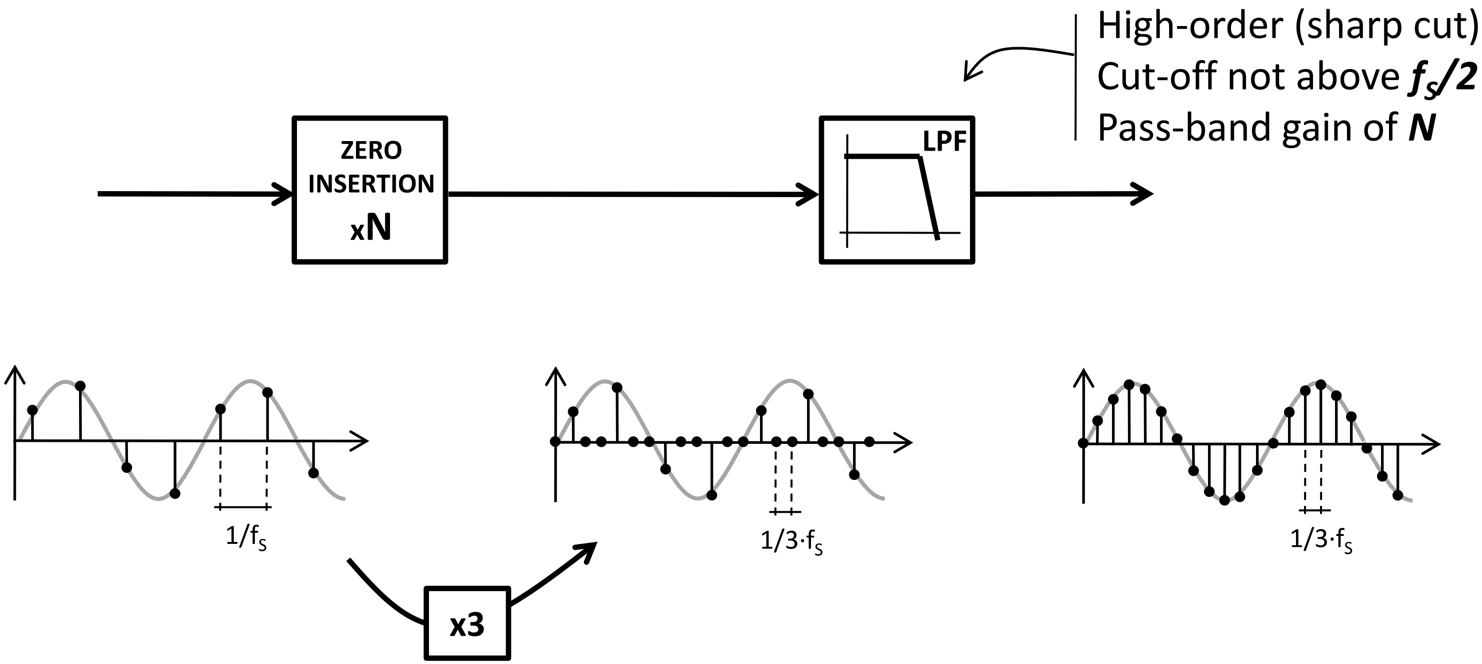


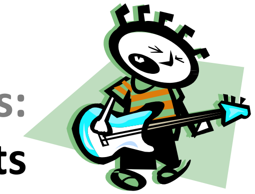


Aliasing: oversampling (ii)

UPSAMPLING

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

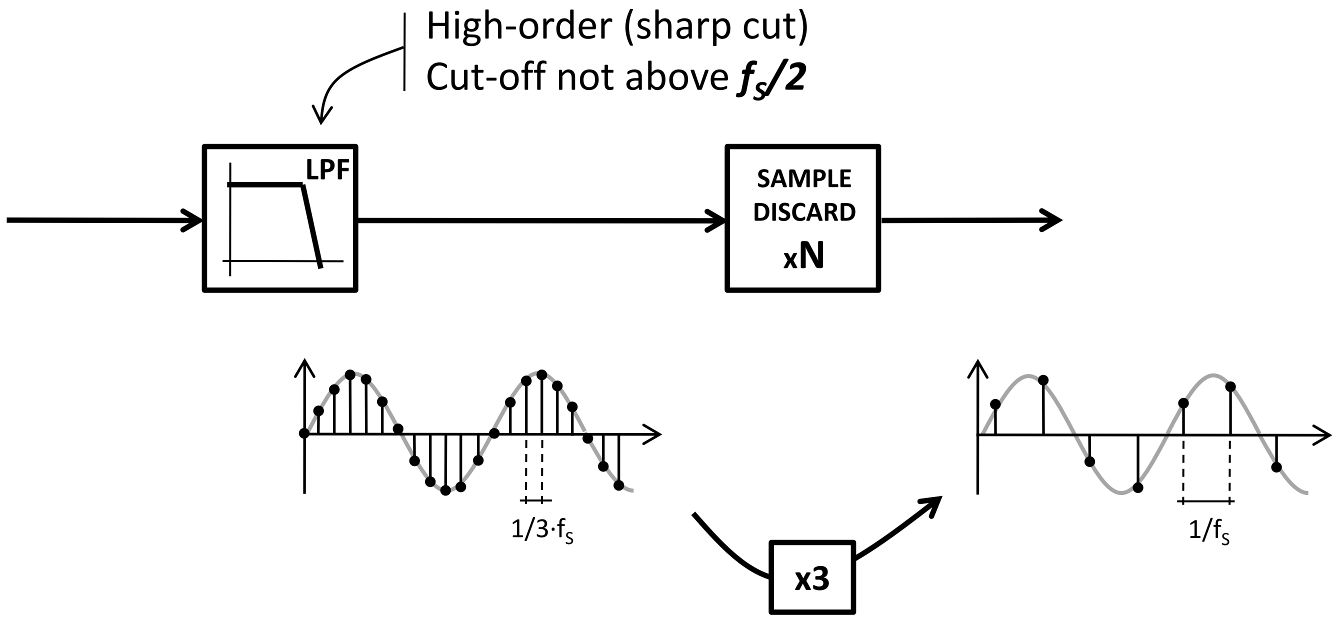


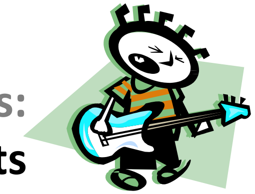


Aliasing: oversampling (iii)

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

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.

pd~ 06_stomp_distortion.pd