FX Basics

Dynamics Effects

STOMPBOX DESIGN WORKSHOP

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FX Basics: Dynamics Effects

Dynamics effects were the earliest effects to be introduced by guitarists.

The simple idea behind dynamics effects is to amplify or attenuate the amplitude of the electrical signal coming out from the pickup or microphone.

They first appeared in the 1940s as simple on/off switch boards, evolving to volume pedals in the 1950s.

Ex: volume pedal, boost, tremolo, noise gate, dynamic range compressor
Gain control

Achieved by means of a simple multiplication:

\[ \text{Gain} \times \text{Input signal} = \text{Output signal} \]

\[ \text{Gain} > 1 \] achieved by simple multiplication.

Graphs showing the effect of gain on signal amplitude over time.
Volume Boost

Generally used for *boosting* volume during solos and/or preventing signal loss in long *effect chains*.

Ex: when switching from rhythm guitar to lead guitar, a guitarist may use a clean boost to increase the volume of his or her solo.
Volume Boost (ii)

FX Basics: Dynamics Effects

[Graphs and diagrams showing volume control, gain, and OFF/ON switches]
**Tremolo**

Produces a slight, rapid oscillation of the signal amplitude; not to be confused with *tremolo bar* (pitch oscillation).

Based on the use of a Low Frequency Oscillator (**LFO**):

\[ \text{OUTPUT SIGNAL} = \text{OSCILLATOR} \times \text{LFO} \]

**FREQUENCY** \( (f_0) \)  **AMPLITUDE**

![Diagram of tremolo signal flow](image)

**FX Basics:**

Dynamics Effects
Tremolo (ii)

Typically, two controls are offered:
RATE: Sets the frequency of the volume oscillation
DEPTH: Sets the amplitude of the volume oscillation
Tremolo (iii)

FX Basics: Dynamics Effects

Input signal | LFO | Output signal
---|---|---
RATE | DEPTH | ON/OFF
Frequency | Amplitude | 

Input signal: 0.62, 0.625, 0.63, 0.635, 0.64, 0.645, 0.65, 0.655
Output signal: -1, -0.5, 0, 0.5

01_stomp_dynamics_2.pd
Noise gate

Attenuates signal when its level falls below a given threshold. Both the attenuation and threshold are usually available as user controls (resp. RANGE and LEVEL).

Ex: avoid unwanted noise floor when there is no signal coming from the instrument

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**Diagram:**

- **Input Signal**
- **Detector**
- **Level**
- **Range**
- **Output Signal**
- **< ?**
- **X**
Noise gate (ii)

**LEVEL DETECTOR** (Envelope Follower):

Often implemented as **Root Mean Square** (RMS) meter. RMS amplitude provides a measure of effective (short-time averaged) signal intensity.

‘Averaging time’ sets the responsiveness of the meter.

![Diagram of RMS Envelope Follower]

**Diagram:**
- **Input Signal**
- **^2**
- **AVG**
- **SQRT**
- **Output Signal**

**RMS ENVELOPE FOLLOWER**
TIME AVERAGE
Acts as a smoothing function:

**Input Signal** $x[n]$

**Smoothing Function**

**Output Signal** $y[n]$

Average of current and previous input samples
TIME AVERAGE:
\[ y[n] = \frac{1}{M} \cdot (x[n] + x[n-1] + \ldots + x[n-M+1] + x[n-M]) \]
Obtain M from ‘averaging time’: \( M = \text{avgTime} \cdot f_s \)

SMOOTHING WITH RECURSIVE EQUATION:
Find coefficients \( a \) and \( b \) so that equation
\[ y[n] = b_0 \cdot x[n] + b_1 \cdot x[n-1] + \ldots + b_N \cdot x[n-N] \]
\[ \quad - a_1 \cdot y[n-1] - \ldots - a_N \cdot y[n-N] \]
results into a smoothing function.
...digital implementation of a Low Pass (LP) filter.
RMS Envelope...

**With TIME AVERAGE:**

Averaging using 441 and 882 previous samples respectively (M=441; M=882)

**With Smoothing Low-Pass Filter (RECURSIVE):**

Both filters only using 1 previous sample (N=1) !!
FX Basics:
Dynamics Effects

TIME DOMAIN

\[
\text{Fourier Transform} \quad \rightarrow \quad \text{FREQUENCY DOMAIN}
\]

\[
\text{amplitude vs. seconds}
\]

\[
\text{magnitude vs. frequency (Hz)}
\]

\[
f_s/2 \quad (\text{Nyquist})
\]
\[ x(t) = 1.0 \cdot \sin(2 \pi \cdot 500 \cdot t) + 0.4 \cdot \sin(2 \pi \cdot 5000 \cdot t) \]
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Magnitude

Low Frequencies → High Frequencies

Slower Components → Quicker Components

\( f_s/2 \) (Nyquist)
One can design a Low-Pass filter so that components above a certain ‘characteristic’ frequency ($f_c$) get attenuated…
\[ y[n] = 0.0344 \cdot x[n] + 0.0344 \cdot x[n-1] + 0.9312 \cdot y[n-1] \]

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Dynamics Effects

How to ‘design’ the coefficients? (e.g. how many coefficients? which values?)

Basics of DIGITAL FILTERS (to come...)

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**Graph:**
- X-axis: seconds
- Y-axis: amplitude
- Magnitude vs. frequency (Hz)
  - Frequency peaks at 500 and 5000 Hz
  - X-axis: frequency (Hz) x 10^4

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0 0.5 1 1.5 2 2.5
x 10^4
0 0.2 0.4 0.6 0.8 1
magnitude
frequency (Hz)
Noise gate (iii)

RMS Envelope Follower

Rapid oscillation (quicker components) have been attenuated

\[ x[n] \xrightarrow{\wedge^2} \text{LP filter} \xrightarrow{\text{SQRT}} y[n] \]

RMS ENVELOPE FOLLOWER
Noise gate (iv)

Example of basic operation

Input

Gain

Output

TH

ON

ON

RANGE

1

Abrupt ON-OFF / OFF-ON transitions

Chattering
Noise gate ($v$)

Noise gates often include **HYSTERESIS** and **ATTACK/RELEASE** times.

- Avoids chattering
- Smoother transitions

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FX Basics: Dynamics Effects

Gain

Output

Input

$TH_{ON-OFF}$ $TH_{OFF-ON}$

RANGE

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Dynamic Range Compressor

Attenuates the signal when its level is higher than a certain threshold. Both the amount of attenuation and the threshold are the most typical user controls (resp. COMPRESSION/RATIO and LEVEL).

Ex: reduce intensity differences, soften the amplitude of very loud attacks.
Dynamic Range
Compressor (ii)

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Dynamics Effects

FEED-FORWARD
basic structure

FEED-BACK
basic structure

Level Detector → Gain Computer

Gain Computer → Level Detector

Level Detector → X

Gain Computer → X
Dynamic Range
Compressor (iii)

Example of basic operation
Dynamic Range Compressor (iv)

Further available controls, depending on application:

- **ATTACK / RELEASE TIMES**
- **HARD vs SOFT KNEE**
- **MAKE-UP GAIN**

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** Diagram: **

- **HARD KNEE**
- **MAKE-UP GAIN**
- **SOFT KNEE**

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** Graphs:**

- **Input vs Gain**
- **Output vs Level**

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