FX Basics

Dynamics Effects

STOMPBOX DESIGN WORKSHOP

Esteban Maestre

CCRMA - Stanford University

July 2011
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.

\[ \text{Input signal} \rightarrow \text{Gain} \rightarrow \text{Output signal} \]

Amplitude vs. seconds graphs showing gain > 1 comparison.
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.

![Input signal](image1) \[X\] \[ON/OFF\] \[Gain\] \[Output signal\]

Stompbox Design Workshop  
July 2011 - CCRMA, Stanford University
Volume Boost (ii)

FX Basics: Dynamics Effects

Stompbox Design Workshop

July 2011 - CCRMA, Stanford University
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):

\[
\text{FREQUENCY (} f_0 \text{)} \quad \text{AMPLITUDE}
\]

- Oscillator
- LFO
- Output signal

- Diagram showing the interaction between frequency, amplitude, and output signal.
Tremolo (ii)

Typically, two controls are offered:
- RATE: Sets the frequency of the volume oscillation
- DEPTH: Sets the amplitude of the volume oscillation

[Diagram of Tremolo effect with input signal, LFO, addition, multiplication, and output signal.]
Tremolo (iii)

FX Basics:
Dynamics Effects

RATE  DEPTH  ON/OFF

Frequency  Amplitude  1

Input signal  +  Output signal

LFO

pd~ 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
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.png)
TIME AVERAGE
Acts as a smoothing function:

$x[n]$  \rightarrow \text{Smoothing Function} \rightarrow y[n]$

Input Signal  \rightarrow \text{Output Signal}

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

\[ y[n] = b_0 \cdot x[n] + b_1 \cdot x[n-1] + \ldots + b_N \cdot x[n-N] \]

\[ - a_1 \cdot y[n-1] - \ldots - a_N \cdot y[n-N] \]

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
/
Fourier
Transform

FREQUENCY
DOMAIN

Stompbox Design Workshop
July 2011 - CCRMA, Stanford University
$$x(t) = 1.0 \cdot \sin(2 \pi \cdot 500 \cdot t) + 0.4 \cdot \sin(2 \pi \cdot 5000 \cdot t)$$
FX Basics:
Dynamics Effects

Magnitude

- Slower Components
- Quicker Components

Low Frequencies  High Frequencies

$f_s/2$ (Nyquist)
One can design a Low-Pass filter so that components above a certain ‘characteristic’ frequency ($f_c$) get attenuated...
FX Basics: Dynamics Effects

\[ y[n] = 0.0344 \cdot x[n] + 0.0344 \cdot x[n-1] + 0.9312 \cdot y[n-1] \]

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

Basics of DIGITAL FILTERS (to come...)

Stompbox Design Workshop

July 2011 - CCRMA, Stanford University
Noise gate (iii)

RMS Envelope Follower

Rapid oscillation (quicker components) have been attenuated

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

RMS ENVELOPE FOLLOWER

Stompbox Design Workshop

July 2011 - CCRMA, Stanford University
Noise gate (iv)

Example of basic operation

Input

TH

Gain

1

RANGE

ON

Output

TH

Chattering

Abrupt ON-OFF / OFF-ON transitions
Noise gate (v)

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

Input

\[ \text{TH}_{\text{ON-OFF}} \]

\[ \text{TH}_{\text{OFF-ON}} \]

Gain

1

RANGE

Output

\[ \text{pd}^\sim \]

02_stomp_dynamics_3.pdf

Avoids chattering

Smotherer transitions
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)

FEED-FORWARD basic structure

FEED-BACK basic structure

Stompbox Design Workshop

July 2011 - CCRMA, Stanford University
Dynamic Range Compressor (iii)

Example of basic operation

Output Level

ON: Gain < 1

OFF: Gain = 1

LEVEL

Input Level

1:1

2:1

4:1

Inf:1

Stompbox Design Workshop

July 2011 - CCRMA, Stanford University
Dynamic Range Compressor (iv)

Further available controls, depending on application:

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

Stompbox Design Workshop

July 2011 - CCRMA, Stanford University