FX Basics

Dynamics Effects

STOMPBOX DESIGN WORKSHOP

Esteban Maestre

CCRMA - Stanford University
July 2012
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.

Gain > 1

Stompbox Design Workshop

July 2012 - CCRMA, Stanford University
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]

Stompbox Design Workshop

July 2012 - 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)**:

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

\[ \xrightarrow{\sim} \quad \xrightarrow{X} \]

Oscillator

LFO

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 (ii)]
**Tremolo (iii)**

FX Basics: Dynamics Effects

```
\[pd~ \ 01\_stomp\_dynamics\_2.pd\]
```
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.

\[
\begin{align*}
\text{Input Signal} & \xrightarrow{^2} & \text{AVG. TIME} & \xrightarrow{\text{AVG}} & \text{SQRT} & \xrightarrow{} & \text{Output Signal}
\end{align*}
\]

RMS ENVELOPE FOLLOWER
TIME AVERAGE
Acts as a smoothing function:

\[ y[n] = \text{Average of current and previous input samples} \]

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

amplitude

0.564 0.566 0.568 0.57 0.572 0.574 0.576 0.578 0.58

-1
-0.5
0
0.5
1
seconds

TIME
DOMAIN

1/1200
1/500

FREQUENCY
DOMAIN

Fourier
Transform

500 1200

f_s/2 (Nyquist)

0 0.2 0.4 0.6 0.8 1
magnitude

0 0.5 1 1.5 2 2.5
frequency (Hz)

x 10^4
\[ x(t) = 1.0 \cdot \sin(2\pi \cdot 500 \cdot t) + 0.4 \cdot \sin(2\pi \cdot 5000 \cdot t) \]
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...

![Graph](image-url)
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 2012 - CCRMA, Stanford University
Noise gate (iii)

RMS Envelope Follower

Rapid oscillation (quicker components) have been attenuated

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

RMS ENVELOPE FOLLOWER
Noise gate (iv)

Example of basic operation

Input

TH

Gain

1
RANGE

Output

TH

Chattering

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

Noise gates often include **HYSTERESIS** and **ATTACK/RELEASE** times.
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. COMPRESION/RATIO and LEVEL).

Ex: reduce intensity differences, soften the amplitude of very loud attacks.

![Diagram of Dynamic Range Compressor]

- Level Detector
- COMPRESSION
- LEVEL
- Output Level
- Input Level
- Bypass
- Hard Limiter

Stompbox Design Workshop

July 2012 - CCRMA, Stanford University
Dynamic Range
Compressor (ii)

FEED-FORWARD
basic structure

LEVEL
Detector
COMPRESSION
Gain
Computer
FEED
FORWARD
基本结构

FEED-BACK
basic structure

LEVEL
Gain
Computer
Detector
FEED
BACK
基本结构
Dynamic Range Compressor (iii)

Example of basic operation

Input Level

Output Level

Gain

OFF: Gain = 1
ON: Gain < 1
Gain = 1
Gain < 1

Output

LEVEL

OFF: Gain = 1
ON: Gain < 1

1:1
2:1
4:1
Inf:1

FX Basics: Dynamics Effects
Dynamic Range
Compressor (iv)

Further available controls, depending on application:

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