Feedback Delay and Echo

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Definition

From Wikipedia[1], “To simulate the effect of reverberation in a large hall or cavern, one or several delayed signals are added to the original signal. To be perceived as echo, the delay has to be of order 35 milliseconds or above. Short of actually playing a sound in the desired environment, the effect of echo can be implemented using either digital or analog methods. Analog echo effects are implemented using tape delays or bucket-brigade devices. When large numbers of delayed signals are mixed a reverberation effect is produced; the resulting sound has the effect of being presented in a large room.”

There are two different ways to perform the delay or echo: with a feedback of the delayed output, or by adding one or more delayed copies to the output. Theoretically the number of echoes in the feedback version is infinity, while the number of repetitions in the feedforward delay is limited. The disadvantage of the feedback delay is that the output signal can become unstable, resulting in clipping, distortion or saturation. This is particularly critical with high feedback gains and short delay times.

Feedback Delay & Echo

There are two different ways to perform the delay and echo effect: with signal feedback and without feedback. The disadvantage of the feedback effect is that the output signal can become unstable, but produces a more realistic reverberation sound. The Feedback Delay and Echo block diagram can be seen in the Figure 1. This model comprises an input gain b and a feedback gain a. High values of a increase the number of echoes or delays added to the dry signal, but can produce “metallic” sounds if the time delay is short, or even saturation for even shorter delay. A low pass filter in the feedback loop can improve stability by reducing the metallic sound of high frequency. Table 1 compares the main characteristics of some audio effects.

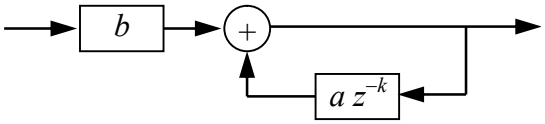

Fig. 1 – Block diagram in Z transform of the Feedback Delay and Echo.

Table 1 – Effect composition and applied modulation

Effect	Dry		Wet		
	Output	Amplitude modulation	Number of delayed signals	Pitch modulation	Amplitude modulation
Chorus	✓		≥1	✓	✓
Vibrato	×		1	✓	×
Delay & Echo	✓	×	≥1	×	×
Reverber	✓	×	>>1	×	×
Flanger	✓	×	1	×	×
Tremolo	✓	✓	0	×	×

The Feedback Delay and Echo are modeled by the linear difference equation:

$$y(i) = b\,x(i) + a\,y(i-k)\,,$$

in which b is the input gain, a is the feedback gain and k is the number of samples in the delay time, obtained from

$$k = f_{sr}\,\delta_{dt}\,,$$

where f_{sr} is the audio sampling rate and δ_{dt} is the delay time. For time delay below 0.0003 seconds (~15 samples for sampling rate of 44.1 kHz) saturations may occur. Time delay ranging from 0.0003 up to 0.05 seconds sounds like a Delay pedal, if the feedback gain is less than 0.7. For feedback gains above 0.7 a metallic sound is produced, similar to Phaser. For time delay ranging from 0.05 up to 0.2 seconds a large reverberation is achieved, and an echo is perceived above 0.2 seconds.

References

[1] Wikipedia. Sound Effect. Available at: <https://en.wikipedia.org/wiki/Sound_effect>, 2023.