The Tempo-Synchronised Stereo Time Delay Effect in Tandem Configuration

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Abstract

This document will demonstrate the creative use of two or more stereo time delay units in a tandem (series) configuration. In case of tempo-synchronised stereo delay plugins with cross-channel feedback, rhythmically panned echo patterns will be achieved, when exciting the effect set-up with percussive (pulse-like) sounds. Diagrams and score examples will illustrate the basic mono and stereo time delay effect, the difference between in-channel and cross-channel feedback, and the more complicated double delay effect chain with tempo-synchronised delay times.

Keywords: audio signal processing, music production, sound effects, mixing engineering, tempo-synchronised time delay effect, cross-channel feedback, syncopated rhythms.

1 Introduction

Audio mixing engineers use a variety of sound effect processors, either as hardware rack components or as software plugins on a Digital Audio Workstation (DAW computer) [1, 2, 3, 4]. *Time delay effects* are widely used processors in such a suite. They generate a series of time-delayed copies of the input signal, that are mixed with the original input signal. In case of a *stereo time delay* the effect operates on two separate audio channels in parallel (the right and left channel). Time delay settings may be absolute (in milliseconds) or tempo-synchronised (i.e., a fraction of the musical tempo unit, such as the duration of a quarter note or an 8th triplet note). The *feedback level* determines the number of echoes (from a single delayed version to an infinite echo series); the delayed versions will be of diminishing amplitude (audio signal strength). The stereo time delay has two in-channel feedback circuits, enabling different feedback levels for right and left channel. In case of a stereo time delay there may also be cross-channel feedback, where the left channel effect output is fed back into the right delay channel and vice versa for the right channel. A combination of both in-channel and cross-channel feedback may be achieved by balancing the four feedback level settings; in case of a tempo-synchronised delay this set-up yields right-left panned rhythmical echoes.

Mixing engineers use multiple time delays in parallel. Time delay settings may be set for specific audio effects; either in the *Haas* region (typically 5-20 milliseconds), the *slapback* region (typically 30-50 milliseconds) or audible *echoes* (typically more than 100-200 ms). Audio signals are then routed into one or more of these time delay effects.

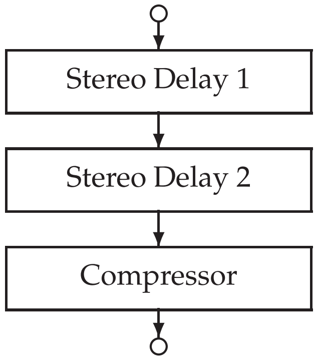

Figure 1: The series of two stereo time delays in tandem configuration and compressor may be used as either an insert on an audio or MIDI instrument channel or placed on an Aux bus.

Tandem configurations of audio effects are also used frequently; examples are the series configuration of an equalizer with a compressor, a time delay unit in series with a reverb unit, or two different reverb processors.[1]

However, the tandem configuration of two (or more) time delay units is rare. Undoubtedly this effect has been used in music production, but its potential for creating complex *percussive rhythms* is not described in the literature. The alternative for achieving this result is using dedicated *multi-tap time delay effects* (such as the Delay Designer plugin in Logic Pro [5]). However, in such a plugin many individual delay taps will have to be programmed and their parameter settings finetuned (level, panning, filtering) to achieve a syncopated panning rhythm. The same effect (and many more) can be easily achieved with setting only a very limited number of plugin parameters in the stereo time delay tandem configuration.

This document will illustrate the principle of applying multiple stereo time delay effects with cross-channel feedback in tandem configurations. Complex percussive patterns can be exciting this set-up with a pulse in one (or both) of the audio channels.[2]

The final, complete set-up that we will discuss here, is shown in diagram in Fig. 1: it consists of two stereo delays in series with a compressor at the end of the chain. This set could be used as in insert on an audio or MIDI instrument channel; alternatively, it is the set-up of an auxiliary bus, that receives sends from other audio signal channels.

This document is structured as follows: first, the basic single stereo delay unit is described. Diagrams and score examples will illustrate the working of the cross-channel feedback. Then the tandem configuration will be demonstrated. Finally, suggestions for further experimentation will be given. Have fun reading this document and then, please start experimenting with your audio equipment!

[1] A number of these tandem effect processor configurations have been demonstrated by mixing engineer Dave Pensado in his weekly episodes of *'Into the Lair'* on the online video podcast channel http://www.pensadosplace.tv. This is what triggered my own thinking and experimentation with two stereo time delays in series.

[2] In case of limited parameter sets for the time delay units (e.g., no stereo version available, no cross-channel feedback), the set-up herein can also be created with multiple mono time delay units on separate Aux channels with specific level and pan settings. However, that makes the design of panned rhythmic patterns far more complicated.

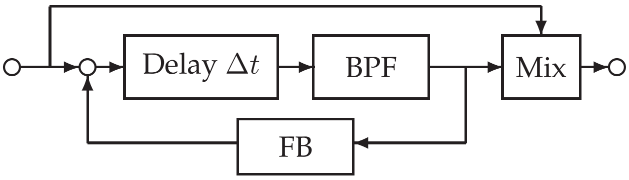

Figure 2: The single (mono) time delay effect. The delay time Δt may be synchronised to the tempo. The bandpass filter (BPF) has input parameters for low and high frequency cut-off $[f_{co,L}, f_{co,U}]$, the feedback (FB) level (in %) determines the number of signal repeats (echoes). The mix (Mix) setting determines the wet/dry output balance.

2 The basic time delay configuration

Let's start by explaining the fundamentals and working of the time delay effect. This will familiarize you with the terminology and the diagrams that will illustrate the effect on the audio signal. Some of you may want to skip this part and move on to the tandem configuration section.

2.1 The mono time delay effect

The basic single time delay effect is shown in diagram in Fig. 2. The mono audio signal enters the processor on the left. A copy of this signal is output after a time delay Δt and mixed with the direct signal (the Mix block will determine the wet/dry balance). A bandpass filter (BPF) will have both a highpass (low frequency cut-off) and a lowpass (high frequency cut-off) filter in order to colour and equalize the delayed signal. The feedback (FB) returns a fraction of the delay output back into the unit.

The time response of this time delay effect to a single pulse, entering the effect at time $t = 0$ s, is shown in Fig. 3. Without feedback (FB $= 0$) there is a single delayed pulse echo at time $t = \Delta t$. As the feedback value increases (going from FB_1 to FB_4 in the diagram) the number of echoes increases, while their strength is continuously decreasing (echo attenuation). The example shows a tempo-synchronised time delay with delay setting $\Delta t = 3$ time units (e.g., 3 beats in 4/4 meter). The tickmarks along the timeline represent time units (beat markers); for a 4/4 meter 18 beats are shown ($4\frac{1}{2}$ measures).

2.2 The stereo time delay effect

The stereo time delay with in-channel feedback is shown in Fig. 4. This may be considered as two mono time delay effect units in parallel, each of them processing an audio signal channel (left and right). The delay time Δt, feedback level (BF) and wet/dry mix level (Mix) may be different for the right and left channel. The bandpass filter (BPF) settings are equal for both channels (two blocks are shown in the diagram but they have identical parameter settings).

The response of the stereo time delay effect with in-channel feedback to a pulse signal on both channels at time $t = 0$ s (1st beat) is shown in Fig. 5. The echo signal strength is no longer shown in the figure (there are no arrows; the closed circles represent the time instances of the echo signal). The right audio channel has delay time $\Delta t_R = 2$ time units (or beats), the left channel has delay time $\Delta t_L = 3$ time units. For the given feedback levels this leads to a finite

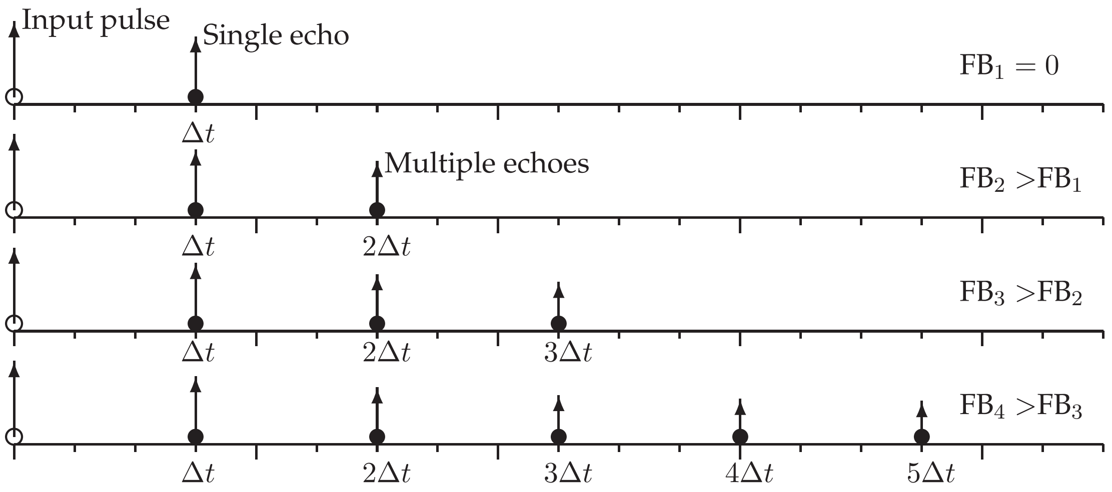

Figure 3: The pulse response of the mono time delay effect with in-channel feedback. The audio signal pulse enters the effect unit at time $t = 0$ s (1st beat in 4/4 meter, open circle). The delay time is $\Delta t = 3$ time units (beats). With increasing feedback value (FB) the number of echoes increases (from top to bottom, closed circles). The arrow length represents the strength (amplitude) of the echo signal. The tickmarks indicate the beats, with a longer tickmark at the beginning of a new measure in 4/4 meter.

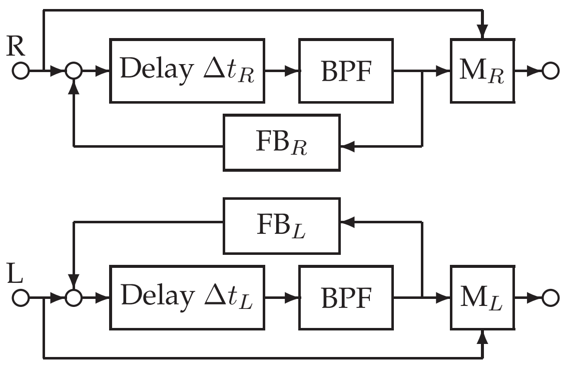

Figure 4: The stereo time delay effect with separate delay times ($\Delta t_R, \Delta t_L$), in-channel feedback levels (FB_R, FB_L) and wet/dry mix level (M_R, M_L) for the right and left audio channel. The bandpass filter settings (BPF) apply to both channels.

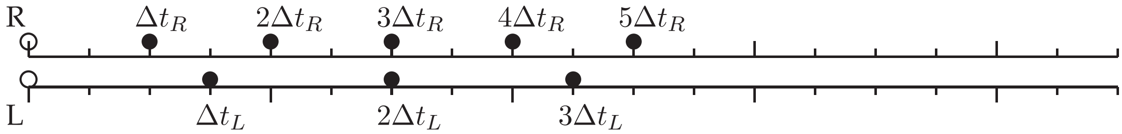

Figure 5: The pulse response of the stereo time delay effect with in-channel feedback. The audio pulse enters the effect unit on both channels at $t = 0$ s (1st beat). The delay times are $\Delta t_R = 2$ and $\Delta t_L = 3$ time units (beats). The feedback value in the right channel FB_R is higher than FB_L (the left channel has 3 echoes, the right channel 5 echoes).

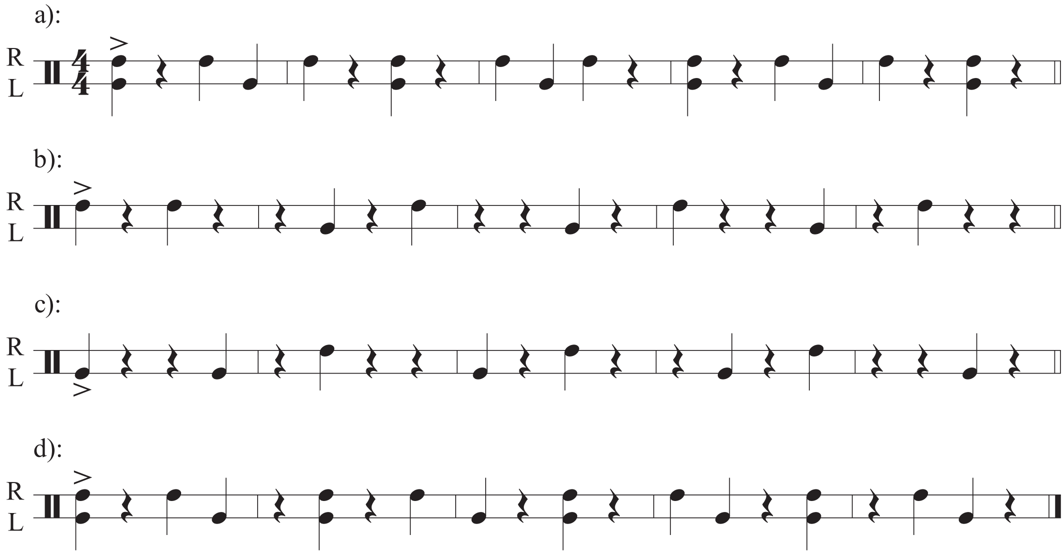

Figure 6: The pulse response of the stereo time delay effect. a): simultaneous input pulse on both channels (accented note on beat 1 in 4/4 meter), in-channel feedback. b): right channel pulse input, cross-channel feedback, c): left channel pulse input, cross-channel feedback, b): simultaneous pulse input on both channels, cross-channel feedback.

series of echoes, with *cross-rhythms*; each channel has its own rhythm (fixed time intervals), and occasionally the two echo pulses coincide.

The pulse response for the stereo time delay with in-channel feedback is shown in musical staff notation in Fig. 6.a.

2.3 The stereo time delay effect with cross-channel feedback

The stereo time delay effect with cross-channel feedback is shown in Fig. 7. Now, the right channel delay output signal is returned to (fedback into) the left audio channel and vice versa.

The response of the stereo time delay effect with cross-channel feedback to a pulse signal on the right audio channel at time $t = 0$ s (1st beat) is shown in Fig. 8.a . For the same effect settings the response to a pulse entering the left channel is shown in Fig. 8.b. When the pulse enters both channels simultaneously, the resulting echo series will be as shown in Fig. 8.c. Note that in all these cases the patterns repeat after five time units or beats; i.e., the periodicity of the rhythmic pulse pattern is $\Delta t_R + \Delta t_L = 2 + 3 = 5$ time units. For those who prefer reading

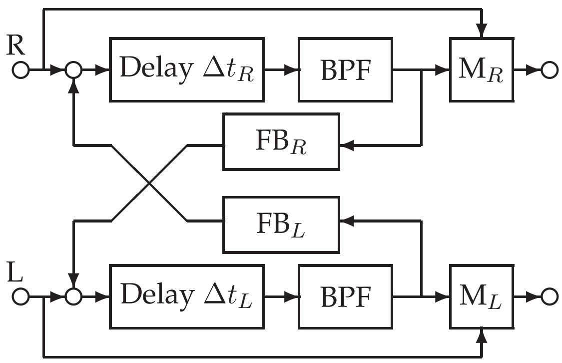

Figure 7: The stereo time delay effect with cross-channel feedback. Note how the feedback signal lines from FB_R and FB_L are connected to the opposite channel input (the right feedback signal enters the left audio channel and vice versa).

musical staff notation, see Fig. 6.b to 6.d.

As can already be seen from this single stereo time delay example, with high in-channel and cross-channel feedback levels the output echo series easily becomes cluttered. Note the long series of (regularly coinciding) echo pulses in Fig. 8.c; these are all the consequence of a single pulse at the effect input port. It takes consideration and careful parameter tuning in order to create musically interesting percussive patterns, rhythmically panned across the sound stage.

This concludes the basic stuf, i.e., the working of the single time delay unit. Now, let's get serious and creative!

3 The stereo time delay effect in tandem configuration

We're in for some great potential in sound effect creation with multiple time delay effect processors. We will discuss in great detail the chaining of two tempo-synchronised effect units in series, i.e., the *tandem configuration*, and present some examples.[3]

3.1 The tandem stereo time delays with channel swapping

The stereo time delay effect in tandem configuration with cross-channel feedback and channel swapping is shown in Fig. 9. Note how the right and left audio channel are swapped between the two stereo time delay units (crossing arrows at the centre of the figure). Each stereo time delay unit has its own parameter settings.

3.1.1 Example 1: Creating a syncopated 16th note rock groove

The response of this set-up to an input pulse signal on the right channel is shown in Fig. 10. There is a number of considerations when setting the effect parameters:

- The tandem configuration requires *significantly different time scales* in each stereo time delay unit, in order to achieve musically sensible rhythm patterns (although this is somewhat a matter of taste). What this means is that in the example Stereo Delay 1 has multiple

[3] All the examples have been designed and tested with the Stereo Delay effect plugin on an Aux mixer channel in Logic Pro [5], with a 16th note synthesizer FM pulse signal as input at tempo 60 and 120 BPM.

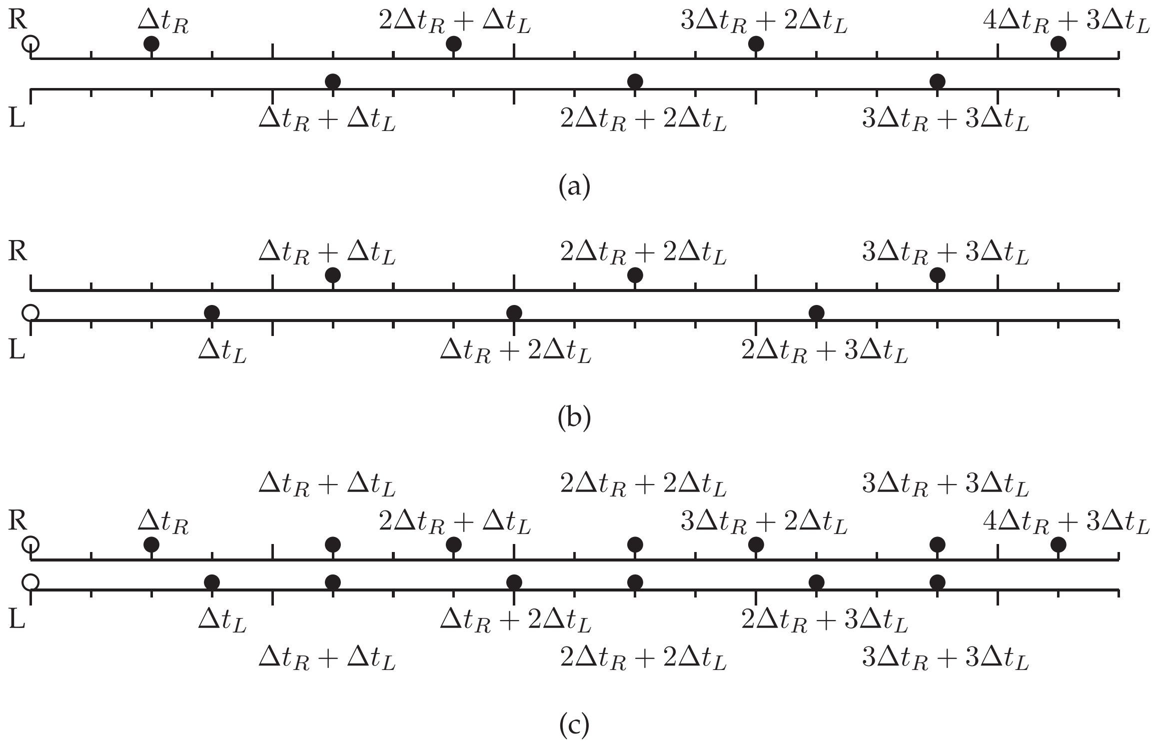

Figure 8: The pulse response of the stereo time delay effect with cross-channel feedback. (a): The input pulse enters the effect unit on the right channel at $t = 0$ s (1st beat). The delay times are $\Delta t_R = 2$ and $\Delta t_L = 3$ time units (beats). The feedback value in the right channel FB_R is higher than FB_L; the latter leads to three echo returns. (b): The pulse enters the left audio channel (for the same effect settings). (c): The pulse enters both channels simultaneously (panned center).

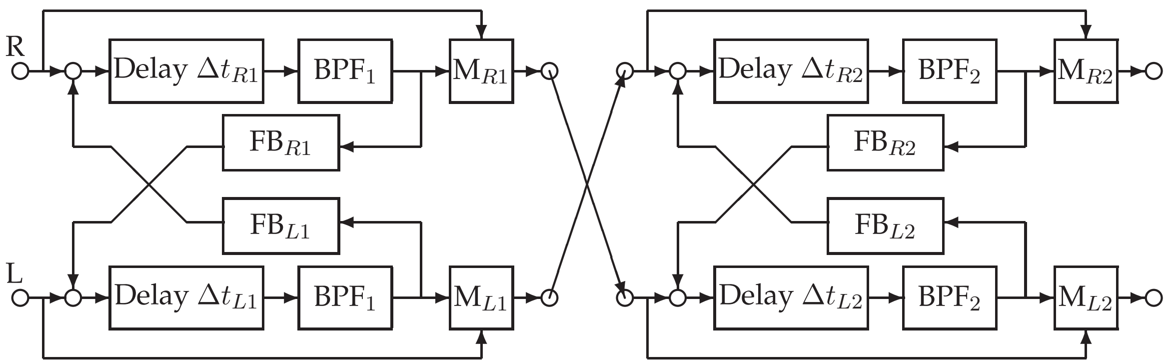

Figure 9: The stereo time delay effects in tandem configuration with cross-channel feedback and swapping the right and left channels when going from Stereo Delay 1 (left) to Stereo Delay 2 (right).

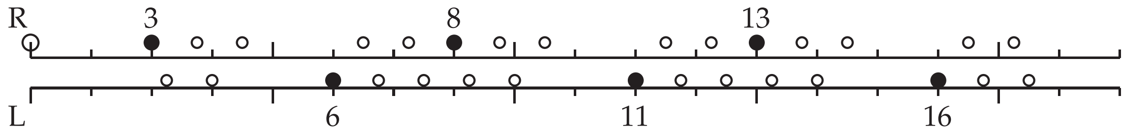

Figure 10: The pulse response of the tandem stereo time delay effect with cross-channel feedback and channel swapping between the delay units. Example 1: the audio signal pulse enters the effect unit on the right channel at the first beat, corresponding to $t = 0$ s (beat numbers shown). The delay times are $\Delta t_{R1} = 2$, $\Delta t_{L1} = 3$, $\Delta t_{R2} = \frac{1}{2}$ and $\Delta t_{L2} = \frac{1}{4}$ time units (beats). The result is a syncopated 16th note rock rhythm with alternate right-left panning. (The echoes generated by the 2nd time delay unit are shown as smaller open circles.)

integer time units in the delay settings ($\Delta t_{R1} = 2$ and $\Delta t_{L1} = 3$ time units or beats), while Stereo Delay 2 has fractions of time units as delay settings ($\Delta t_{R2} = \frac{1}{2}$ and $\Delta t_{L2} = \frac{1}{4}$ time units or beats).

- The echo pattern shows the effect of the 2nd unit, modulated by the 1st unit. The rapid 8th and 16th note patterns are repeated at longer time intervals, determined by the 1st unit. Note that there are 2 different patterns, depending on whether the echo series starts left or right (note the different rhythms between the echo series starting at beat 3 and 6).[4]
- The total duration of the effect is determined mainly by the feedback level in the 1st unit. In the example, Stereo Delay 1 feedback yields 3 repeats, while Stereo Delay 2 (with a lower feedback value) is repeated twice. The total duration is more than 16 beats, i.e., 4 measures in 4/4 meter. A second pulse signal entering at the input too early (i..e., before the resulting echo pattern of the first pulse has died out) will lead to echo overlap.
- When the feedback level in Stereo Delay 2 is high, the fast rhythm will overlap with the slower rhythm, created by Stereo Delay 1. The example has been carefully designed to prevent this phenomenon: see the result at beats 8 and 13. Of course there is nothing stopping you from doing just that, but you should be aware of the consequences of certain feedback settings.
- The reverse situation, with shorter, beat-fraction time delays in the first unit and longer, multiple integer delay times in the second unit, will also work, but is harder to understand.
- For this specific set-up, with each unit in cross-channel feedback and channel swapping between units, the echoes will alternate in panning position (right-left-right-left-right, etc).
- Obviously, these complex echo series can also be generated for fixed, tempo-independent time delays (with delay times set in milliseconds, not in beat units). However, the result will not be a *syncopated groove*, but more likely a *sound effect*.

[4]Count the total number of echo pulses in this example (the answer is 30) and you will realize that in order to reproduce this pattern with a plugin like Delay Designer in Logic Pro you would have to program the settings of 30 individual delay taps. Generating the example with two delay units in series involves setting the equivalent of only 4 delay taps.

Figure 11: The pulse response of the tandem stereo time delay effect configuration in music staff notation.The pulse signal input on the right audio channel is shown as an accented note on beat 1 in 4/4 meter. Echoes from Stereo Delay 2 are shown with crossed noteheads. a): Example 1: channel swapping between delay units, syncopated 16th note rock rhythm, b): Example 2: channel swapping between delay units, 8th note shuffle (triplet feel) rhythm, c): Example 3: without channel swapping between delay units, syncopated 16th note rock rhythm, b): Example 4: without channel swapping between delay units, 8th note shuffle rhythm.

The pulse response for the tandem stereo time delay configuration with cross-channel feedback and channel swapping between the delay units is shown in musical staff notation in Fig. 11.a.

3.1.2 Example 2: Creating a triplet 8th note shuffle rhythm

With the same time delay settings for Stereo Delay 1 as in the previous example, i.e., $\Delta t_{R1} = 2$ and $\Delta t_{L1} = 3$ units (beats), while changing the fractions in the second unit to $\Delta t_{R2} = \frac{2}{3}$ and $\Delta t_{L2} = \frac{1}{3}$ units (beats), yields an 8th note shuffle rhythm with triplet feel.[5] The response to a pulse entering the first unit on the right channel at time $t = 0$ (beat 1) is shown in Fig. 12. For music staff notation of Example 2, see Fig. 11.b.

Comparing with the 16th note rock rhythm from the first example, the feedback values have been somewhat reduced. Also in this example, the triplet note echoes are panned alternatingly left-right, the delay echoes from Stereo Unit 2 (smaller, open circles) do not overlap with the longer intervals generated by Stereo Delay 1 (closed circles). There are channel echo pulse repeats around beats 8 and 13 (right-right-left pulse sequence).

[5]When selecting the triplet 8th note value setting in a time delay unit, look for menu fields or buttons that display $8t$, or sliders that allow you to set 66% of an 8th note or 33% of a quarter note value.

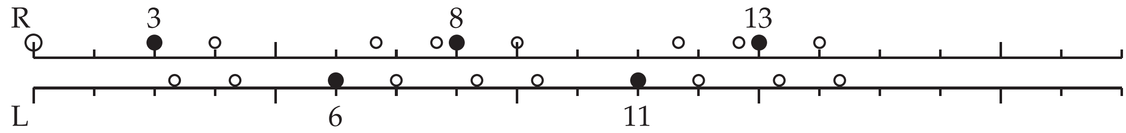

Figure 12: The pulse response of the tandem stereo time delay effect with cross-channel feedback and channel swapping between the delay units. Example 2: the audio signal pulse enters the effect unit on the right channel at the first beat $t = 0$. The delay times are $\Delta t_{R1} = 2$, $\Delta t_{L1} = 3$, $\Delta t_{R2} = \frac{2}{3}$ and $\Delta t_{L2} = \frac{1}{3}$ time units (beats). The result is an 8th note shuffle rhythm with alternate right-left panning.

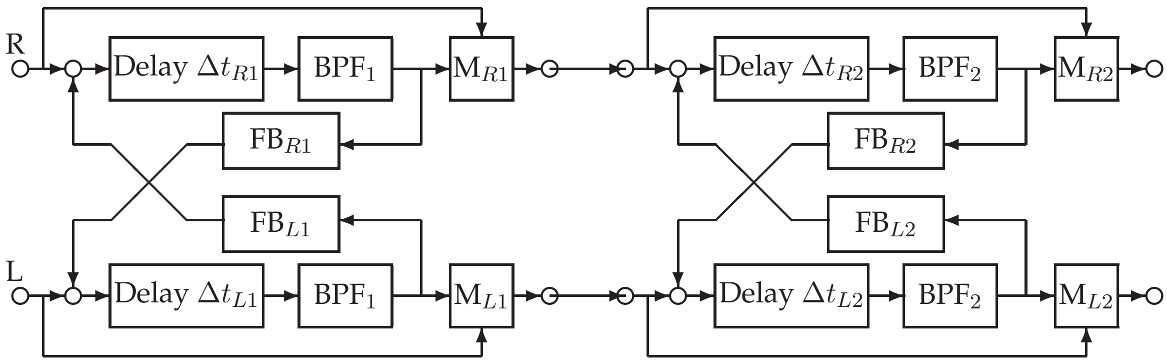

Figure 13: The stereo delay line in tandem configuration with cross-channel feedback and straightforward connection of Stereo Delay 1 and Stereo Delay 2 (no left-right audio channel swapping between the units; see the connections at the centre of the figure).

3.2 The tandem stereo time delays without channel swapping

The set-up is shown in Fig. 13. Note the straightforward connections between Stereo Delay 1 and 2; the left and right audio channels are connected without left-right swapping. When comparing this set-up with the case with audio channel swapping between time delay units, there is a change in the panning position sequence. The echo pulse time series, i.e., the time instances of echo pulses, will remain unchanged, but there will now be more repeated notes in either left or right audio channel. See the examples below for an illustration of this effect.

3.2.1 Example 3: creating a syncopated 16th note rock rhythm with repeated notes in one channel

The reponse to an audio signal pulse, entering the first unit at the first beat, is shown in Fig. 14. Similar to Example 1, the fractional setting of the second time delay unit ($\Delta t_{R2} = \frac{1}{2}$ and $\Delta t_{L2} = \frac{1}{4}$ time units) leads to a syncopated 16th note pattern. For music staff notation of Example 3, see Fig. 11.c.

Note that the first echo of Stereo Delay 2 sounds in the same channel as the output from Stereo Delay 1: e.g., right-right at beat 3, left-left at beat 6, etc. At beats 8 and 13 this yields three repeated notes in the right channel. This might be considered a more interesting audio signal result, compared to the set-up with channel swapping between the two stereo delay

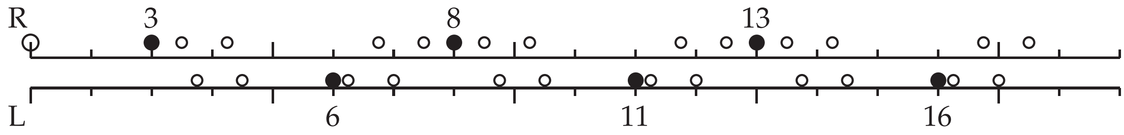

Figure 14: The pulse response of the tandem stereo time delay effect with cross-channel feedback, without channel swapping between the delay units. Example 3: the audio signal pulse enters the effect unit on the right channel at the first beat, i.e., $t = 0$ s (beat numbers shown). The delay times are $\Delta t_{R1} = 2$, $\Delta t_{L1} = 3$, $\Delta t_{R2} = \frac{1}{2}$ and $\Delta t_{L2} = \frac{1}{4}$ time units (beats). The result is a syncopated 16th note rock rhythm with repeated notes in either channel. (The echoes generated by the 2nd time delay unit are shown as smaller open circles.)

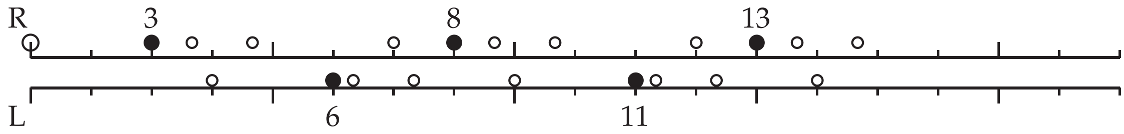

Figure 15: The pulse response of the tandem stereo time delay effect with cross-channel feedback, without channel swapping between the delay units. Example 4: the exciter pulse enters the effect unit on the right channel at the first beat $t = 0$. The delay times are $\Delta t_{R1} = 2$, $\Delta t_{L1} = 3$, $\Delta t_{R2} = \frac{2}{3}$ and $\Delta t_{L2} = \frac{1}{3}$ time units (beats). The result is an 8th note shuffle rhythm with repeated notes in either channel.

units.

3.2.2 Example 4: creating an 8th note shuffle rhythm with repeated notes in one channel

The reponse to an initial exciter pulse, entering the first unit at the first beat, is shown in Fig. 15. As was the case in Example 2, the fractional setting of the second time delay unit ($\Delta t_{R2} = \frac{2}{3}$ and $\Delta t_{L2} = \frac{1}{3}$ time units) leads to a syncopated 8th note shuffle pattern with triplet feel. Note once again that the first echo of Stereo Delay 2 sounds in the same channel as the output from Stereo Delay 1: e.g., right-right at beat 3, left-left at beat 6, etc. Because of the odd number of echo outputs from the second time delay unit (note the sets of three open circles), there will not be three repeated echoes in the right audio channel at beat 8 and 13 (as was the case in Example 3). Increasing the feedback level in right channel of Stereo Delay 2 slightly will change that phenomenon. For music staff notation of Example 4, see Fig. 11.d.

3.2.3 Exercise: pulse input on the left audio channel

As an exercise, try to predict (sketch or calculate) the effect of an audio signal pulse entering the left channel for the configurations in Example 1 to 4 (syncopated 16th note rock and 8th note shuffle rhythm, with and without channel swapping between the two stereo delay units).

Then build this set-up with your music production equipment and check the audio effect.

3.3 The compressor effect

In the introduction, the complete set-up was shown in Fig. 1. The diagram has a *compressor* after the two time delay units. The reason to put a compressor at the end of the effect chain is that it gives us a volume control for the later echoes, originating from the second time delay unit.

In order to prevent (too much) overlap between the two echo generators, we had to limit the feedback level of the second unit. However, lower feedback level will also lead to weaker, softer-sounding echoes. The compressor provides a tool to compensate for this attenuation side-effect, when desired. Light compression ratios, typically between 2 and 3, will usually suffice to bring back these softer echoes. This obviously also requires careful compressor input threshold level setting.

A signal *gate* effect unit might be used additionally to block (i.e., downward amplification) the last echoes from the second time delay unit, in case the total echo series duration is excessively long.

4 Where to go next

In the previous section we have demonstrated the potential of the tempo-synchronised dual stereo time delay units in series, by showing a a number of musically relevant examples. There are various options to proceed from the basic stereo delay cross-channel tandem. Here are a few suggestions:

- Use a combination of in-channel and cross-channel feedback in either one or two stereo time delays. This could mean combining in-channel and cross-channel feedback in Stereo Delay 1, or combining in-channel feedback in Stereo Delay 1 with cross-channel feedback in Stereo Delay 2, or any other mix of feedback levels (FB_{R1}, FB_{L1}, FB_{R2}, and FB_{R2}).

- Combine various forms of in-channel and cross-channel feedback configurations with straightforward delay unit connections and left-right channel swapping between units. Listen to the effects on both the echo time series and the right-left panning patterns.

- The time delay units usually also have the option to use the total signal (summed right and left audio signal: R+L) as either the left or right channel input.[6] Use this approach with one of the two stereo time delay units and there you have another set of options for creating interesting panned rhythmic patterns.

- Play with the feedback level on either stereo delay. Change the value of one or both left and right channels. However, realize, that increasing the feedback will yield additional (tempo-synchronised) echoes; doing this for Stereo Delay 2 will cause the later echoes to interfere with the later neighbouring echoes caused by Stereo Delay 1.

- Add a third stereo delay in series to this set-up, and the number of possible rhythmical patterns becomes almost limitless.

- Experiment and think of even more interesting extensions to this technique! Or, paraphrasing the well-known Gershwin song lyrics: *"Syncopating rhythms, you've got me on the go."*

[6]The Stereo Delay plugin in Logic Pro does have this input signal selection option [5].

5 Conclusion

This document presents a sound effect processor set-up with two tempo-synchronised stereo time delay units in tandem configuration, that create interesting syncopated echo patterns with a very limited number of effect parameter settings. The working principle has been explained and a number of examples have demonstrated the creative potential of this approach.

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