

FluidSynth Plugin

*Simple Wrappers Around the **FluidSynth** Library as
DAW Plugin and Pedantic Command Line Processor*

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Chapter 1

Introduction

1.1 Overview

FluidSynth [FluidSynthDOC] is one of the most prominent open source MIDI players. It is reasonably flexible, delivers a good audio quality and is available for the typical platforms. A common scenario is to use it for either rendering live MIDI data on some audio device or converting MIDI files into audio files by command-line batch processing.

Basis of **FluidSynth** are the so-called *SoundFonts*. SoundFonts contain sampled instruments together with envelope and modulation definitions and other descriptive settings. It is easy to find really usable ones in the internet and also several of those cover all general MIDI instruments (for example, the FluidR3_GM.sf2).

So when using **FluidSynth** in a command-line driven context all is well. But when you want play around with settings for **FluidSynth** interactively in a DAW, you need some DAW plugin rendering audio from MIDI as close as possible to the original command-line fluidsynth.

So far there is no such thing to exactly emulate FluidSynth in a DAW context.

There were some previous efforts like Alexey Zhelezov's FluidSynthVST [FluidSynthVST] or Birch Labs' JuicySFPlugin [JuicySFPlugin], but those are a bit tricky to use and support for them is unclear. But the main point is that even though they rely on the **FluidSynth** library, they **do not exactly reproduce an external fluidsynth rendition of some MIDI data**. Reasons for that will be explained below.

The reason for being picky about the exact rendering is as follows: my scenario is a command-line based rendering of notation videos for a band (the LilypondToBandVideoConverter [LTBVC]). Part of that chain is fluidsynth, but I want to experiment interactively with settings in a DAW to optimize the audio and then have a faithful reproduction of the external rendering

pipeline within the DAW.

So the first component of this package is a DAW plugin called “**FluidSynth-Plugin**”. It has a simplistic interface where you specify a SoundFont, several fluidsynth settings and possibly a MIDI preset to be selected by putting text data in a text field. Then you are able to convert an incoming MIDI stream in a DAW to audio using the **FluidSynth** library.

But when playing around with that plugin some inexplicable differences to the command-line **FluidSynth** occurred. Even when using innocent SoundFonts (without chorus and other modulators), sample playback in the plugin and the command-line player were not absolutely identical. Analysis and contact with the **FluidSynth** team revealed that in that program MIDI events are quantized onto some processing raster in the millisecond range while the plugin quantizes them onto the smallest time unit: the sample raster itself.

So, for example, for a sample rate of 44.1kHz this 64 sample offset might lead to a time difference of more than 1ms between events in the DAW and in an external tool chain. You cannot hear this, but of course this leads to significant differences in the rendered audio (for example, when doing a spectrum analysis). In section 3.5 we will see that although the plugin feeds the events with sample raster precision to the **FluidSynth** library some inevitable internal rasterization happens there.

Another tool mitigates the rasterization by the player of **FluidSynth**. That second component of this package is a simplistic but pedantic command-line converter called “**PedanticFluidSynthConverter**”. It converts a MIDI file into a WAV file, is also based on the fluidsynth library and does the same sample-exact event feeding into that library as the plugin. Hence it should produce identical results when some circumstances are guaranteed (see section 3.5).

When using both components (command-line and DAW) on the same MIDI data they produce audio output with a difference of less than -200dBFS in a spectrum analysis.

Those components are available for the x86-64 architecture in Windows, MacOS and Linux with the plugin having either VST3 (Windows, Linux) or AU format (MacOS).

All the code is open-source; hence you can check and adapt it to your needs (see chapter 5).

1.2 Acknowledgements

This project is a derivative work based on the foundations laid by the **FluidSynth** community.

1.2. ACKNOWLEDGEMENTS

My thanks go to the FluidSynth team: Peter Hanappe, Conrad Berhörster, Antoine Schmitt, Pedro López-Cabanillas, Josh Green, David Henningsson and Tom Moebert. Without your effort this would not have been possible!

I would also like to thank S. Christian Collins for very helpful discussions and his suggestions to improve the plugin, especially the great input to enhance the user interface beyond the original academic approach.

Chapter 2

Installation of the FluidSynth-Plugins

The installation is as follows:

1. Copy the plugins from the appropriate subdirectory for your platform of `_DISTRIBUTION/targetPlatforms` directory in [FluidSynthPlugin] into the directory for VST or AU plugins of your DAW.
2. If helpful, you can put this documentation pdf file contained in subdirectory `doc` and test files in subdirectory `test` (see section 4) somewhere.
3. Depending on your target operating system, additional steps might be necessary:
 - When installing the plugins on Linux, you have to ensure that the `fluidsynth` package is already installed. Appendix A.1 gives details on how to do that.
 - When installing the plugins on MacOS, note that those are **not signed**; so you have to explicitly remove the quarantine flag from them (e.g. by applying the command `sudo xattr -rd com.apple.quarantine «vstPath»`).
 - When installing the plugin and program on Windows, they require the so-called Microsoft Visual C++ Redistributable library [VCCLib]. Very often this is already installed on your system; if not, you have to install it from the Microsoft site.
4. Restart your DAW and rescan the plugins. You should now be able to select the FluidSynthPlugin.
5. The command-line version `PedanticFluidSynthConverter` can be put in an arbitrary location for executables. Ensure that the dynamic libraries in its directory are also placed appropriately.

Note that the connection to the **FluidSynth** version can be changed *since that library is dynamically linked*. This has been a major design goal to be able to update the **FluidSynth** functionality without having to update the **FluidSynth-Plugins**.

For Linux this is just done by installing a new **fluidsynth** package, for Windows and MacOS both the plugin directory and the directory of the **Pedantic-FluidSynthConverter** contain a version of **FluidSynth** as well as related libraries. You can easily exchange those for more current versions or delete them and just use the **FluidSynth** library already installed on your system. For that you just have to delete the DLL (Windows) or DYLIB (MacOS) files in the plugin and converter directories.

The version of the underlying **FluidSynth** library can be found in the **About...** dialog in the context menu of the **FluidSynthPlugin** text widget.

Chapter 3

Description of the FluidSynth-Plugins

3.1 General Remarks

As mentioned in the introduction this package provides tools written in C++ for emulating FluidSynth bit-exactly: a plugin called “FluidSynthPlugin” and a very precise command-line clone of FluidSynth called “Pedantic-FluidSynthConverter”.

The term “bit-exactly” is a bit misleading: because the tools considered (including FluidSynth) have different execution environments (with some data conversions and roundings involved), absolute identical outputs are unreasonable. But what can be achieved is that they are identical to a degree that cannot be heard. If you analyze the spectrum of the difference signal and this difference lies below some assumed threshold, this will be good enough. The threshold here is -200dBFS which is about 100dB below the noise level of a CD.

So both tools render MIDI data similarly to FluidSynth and identical to each other. And when there is no difference in rasterization the difference between the audio from those tools is identical — up to that precision — to FluidSynth.

So why is there a difference between FluidSynthPlugin and FluidSynth in some cases? The differences come from the fact that FluidSynth shifts MIDI events onto some broader raster for audio samples while both programs presented here place an event onto a sample position. This means that there is a slight delay in audio in FluidSynth and original audio and emulated do not cancel out when subtracted.

Figure 1 shows the problem: when an event occurs the waveform is started in FluidSynthPlugin at the next sample position while it starts in FluidSynth

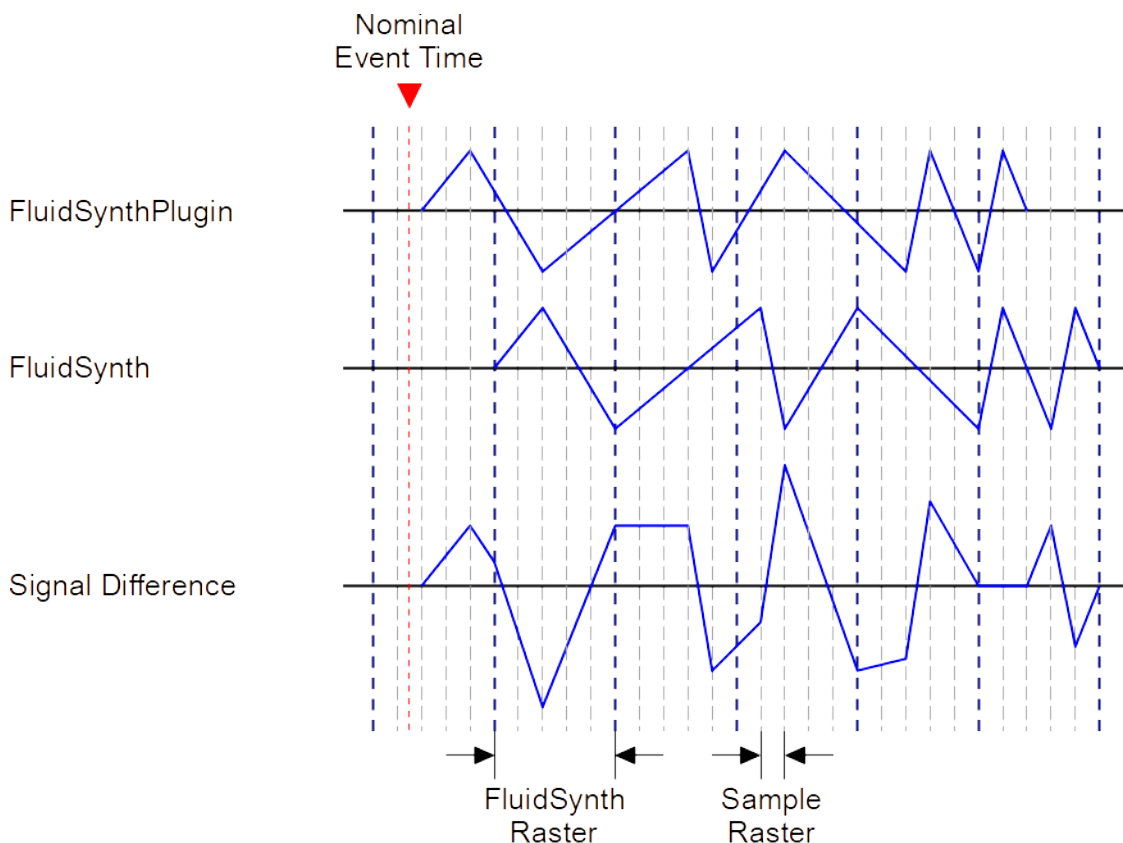


Figure 1: Rasterization Problem in FluidSynth

at the 64 sample raster. As can be easily seen, the difference is not zero, but some other complex waveform.

Note that this is not the complete truth as will be discussed in section 3.5: some shifting will still be done in the underlying FluidSynth library.

3.2 Supported FluidSynth Settings

Both programs support a subset of settings from FluidSynth. It is a subset, because, for example, all settings related to driver selection are omitted: those do not make any sense in the context of these programs.

The supported settings are shown in figures 2, 3 and 4 (with short explanations taken from from [FluidSynthSettings]).

Besides the standard settings from FluidSynth there are three special settings available: **preset** **soundfont** and **synth.interpolation-method**.

Note that the specified SoundFont path must be an *absolute path*, because it is impossible for the plugin to find out the path of the enclosing project in the

| Parameter | Description | Type |
|---|---|---------|
| <code>synth.chorus.active</code> | tells whether chorus will be added to the output signal | boolean |
| <code>synth.chorus.depth</code> | specifies the modulation depth of the chorus | float |
| <code>synth.chorus.level</code> | specifies the output amplitude of the chorus signal | float |
| <code>synth.chorus.nr</code> | sets the voice count of the chorus | integer |
| <code>synth.chorus.speed</code> | sets the modulation speed in Hz | float |
| <code>synth.default-soundfont</code> | default SoundFont file to use by the program | string |
| <code>synth.dynamic-sample-loading</code> | tells whether samples are loaded to and unloaded from memory whenever presets are being selected or unselected for a MIDI channel | boolean |

Figure 2: Common Synthesizer Settings for `FluidSynthPlugin` and `PedanticFluidSynthConverter` (Part 1)

DAW and then use a relative path specification. Normally this should not be a problem — because SoundFonts are often located in a specific directory in a system —, but it somewhat impedes portability of a DAW project containing this plugin.

But you can use environment variables in the path specification enclosed by `${` and `}`, for example `${soundFontDirectory}`.

3.2. SUPPORTED FLUIDSYNTH SETTINGS

| Parameter | Description | Type |
|--|--|---------|
| <code>synth.gain</code> | gain applied to the final or master output of the synthesizer | float |
| <code>synth.midi-bank-select</code> | defines how the synthesizer interprets bank select messages | string |
| <code>synth.min-note-length</code> | sets the minimum note duration in milliseconds | integer |
| <code>synth.overflow.age</code> | tells how event age is accounted for in a voice overflow situation | float |
| <code>synth.overflow.important</code> | another parameter for voice overflow handling | float |
| <code>synth.overflow.important-channels</code> | comma-separated list of MIDI channel numbers that should be treated as “important” by the overflow calculation | string |
| <code>synth.overflow.percussion</code> | overflow priority score to be added to voices on a percussion channel | float |
| <code>synth.overflow.released</code> | overflow priority score added to voices that have already received a note-off event | float |
| <code>synth.overflow.sustained</code> | overflow priority score added to currently sustained voices | float |
| <code>synth.overflow.volume</code> | overflow priority score added to voices based on their current volume | float |

Figure 3: Common Synthesizer Settings for `FluidSynthPlugin` and `PedanticFluidSynthConverter` (Part 2)

| Parameter | Description | Type |
|-------------------------------------|---|---------|
| <code>synth.polyphony</code> | defines how many voices can be played in parallel | integer |
| <code>synth.reverb.active</code> | tells whether reverb will be added to the output signal | boolean |
| <code>synth.reverb.damp</code> | sets the amount of reverb damping | float |
| <code>synth.reverb.level</code> | sets the reverb output amplitude | float |
| <code>synth.reverb.room-size</code> | sets the room size (i.e. amount of wet) reverb | float |
| <code>synth.reverb.width</code> | sets the stereo spread of the reverb signal | float |
| <code>synth.sample-rate</code> | sample rate of the audio generated by the synthesizer (only available for the <code>PedanticFluidSynthConverter</code> , because the sample rate for the plugin is defined by the VST host) | float |
| <code>synth.verbose</code> | tells whether synthesizer will print out information about the received MIDI events to stdout | boolean |

Figure 4: Common Synthesizer Settings for `FluidSynthPlugin` and `PedanticFluidSynthConverter` (Part 3)

| Parameter | Description | Type |
|--|--|----------------------|
| <code>preset</code> <i>or</i> <code>program</code> | gives the preset to use; format is bankNumber:programNumber where counting for both numbers starts at zero; the program number is mandatory, the bank number defaults to zero | string |
| <code>soundfont</code> | gives the path to the SoundFont and may contain environment variables enclosed by <code>\${</code> and <code>}</code> | string |
| <code>synth.interpolation-method</code> | sets synthesis interpolation method on all MIDI channels: the variants are 0 for no interpolation, 1 for straight-line interpolation, 4 for fourth-order interpolation and 7 for seventh-order interpolation | integer (0, 1, 4, 7) |

Figure 5: Additional Settings in FluidSynthPlugin and PedanticFluidSynthConverter



Figure 6: FluidSynthPlugin User Interface

3.3 Using the FluidSynthPlugin

3.3.1 Overview

The “FluidSynthPlugin” is a MIDI instrument in a DAW converting incoming MIDI input into an outgoing audio stream.

The configuration of the plugin is done via a very simplistic interface: a multiline edit field can be used for command entry.

In this multiline field the FluidSynth commands from figures 2 to 5 can be written. Figure 6 shows how the user interface of the plugin looks like.

Each line may contain a FluidSynth setting or a definition for **soundfont** or **preset**. A setting consists of a key string (like e.g. `synth.reverb.active`), an equal sign and a value appropriate for the setting. Leading and trailing blanks are ignored; strings are given without quotes and float values must have a decimal point.

When data is entered in the multiline edit field, it changes its background from grey to white. This signifies that the data has not yet been registered by the plugin. To achieve this the Confirm button has to be pressed: the data is checked and then used by the underlying FluidSynth synthesizer.

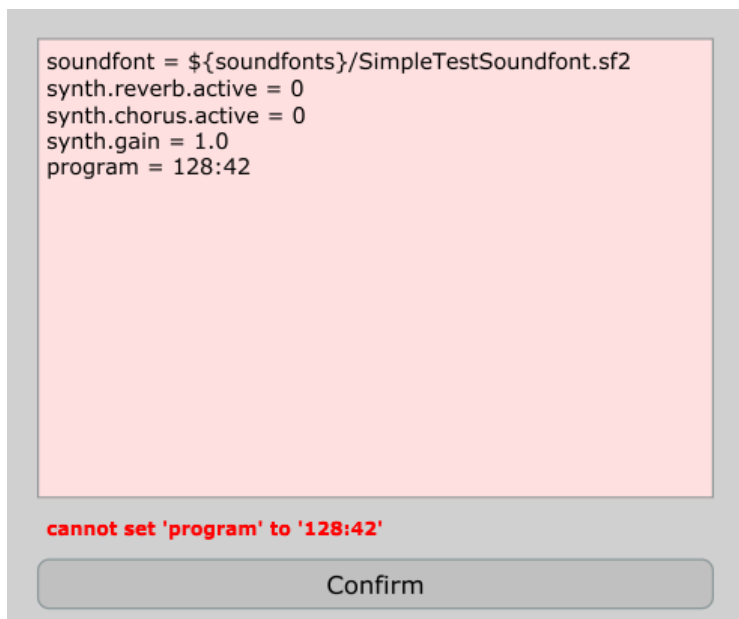


Figure 7: Error Message in FluidSynthPlugin

When the check fails, an error message is given and the edit field is still in edit mode. Note that only the first error encountered is reported, so you have to incrementally correct the settings. For example, in figure 7 the SoundFont path seems to be incorrect: this has to be corrected before any other error will be analyzed.

When there is an error for the SoundFont or the preset settings, **no sound will be produced**; errors for other settings do not affect the rendering, but, of course, either the default values or previous successful values are used for those parameters.

All settings are processed in the order given. So it is recommended to put the SoundFont first.

Note that also some error message is displayed, when the fluidsynth library cannot be found by the plugin. In that case please make sure that the installation has been correctly done (the plugin expects its dynamic libraries in the directory of the plugin vst3 file or — when not available — in the appropriate system paths).

For the VST3 plugin there is a problem caused by the VST3 API that has two consequences:

- Each program change in the MIDI event stream is converted into a plugin preset change. Unfortunately those changes might not be correctly sequenced with the notes in the stream and hence notes immediately following that change (within a few milliseconds) might still use the previous sound.

- Even though the `FluidSynthPlugin` and its underlying library would support it, it is not possible to use multiple MIDI channels with different sounds within a single plugin instance. **Each plugin instance can only play a single preset at a time.**¹

All bank and program changes in the MIDI stream are suppressed when there is a valid definition for a `preset` in the edit field.

3.3.2 User Interface Enhancements

It might be tedious to write all things manually into the edit field. Most of the settings have to be done like that, but at least the `SoundFont` and the `preset` can be edited more comfortably.

Setting the SoundFont

There are two ways to set the `SoundFont`:

1. The edit field has a context menu with menu item `Select SoundFont File....` When this item is clicked (with the right mouse button), a file selection dialog pops up where a `SoundFont` file may be selected. When the selection is successfully done, the `SoundFont` entry in the edit field is updated (see figures 8a and b).
2. Alternatively a `SoundFont` can be dragged onto the edit field. The field only accepts a single `.sf2` or `.sf3` file as the dragged file. When the file is successfully dropped, the `SoundFont` entry in the edit field is updated.
Unfortunately that mechanism does not yet work in Linux [JUCEDND] and will be hopefully available in a later version of the underlying JUCE framework.

Note that in both cases the edit field is selectively updated with the new file name and by that change set into the “unregistered” mode with the white background. When you want to make the `SoundFont` selection effective, you have to press the **Confirm** button in the main plugin window to register those changes.

As a simple optimization the plugin checks the `SoundFont` file path for a prefix given by some environment variable and replaces the longest match found by a reference to that environment variable.

¹Similar and much more prominent plugins like e.g. the `sfz-player sforzando` [Sforzando] follow the same single instrument approach. If you really need multiple channels, you can split the channels of the input within the DAW and then have a `FluidSynthPlugin` per channel. Furthermore then are even able to post-process each instrument differently.

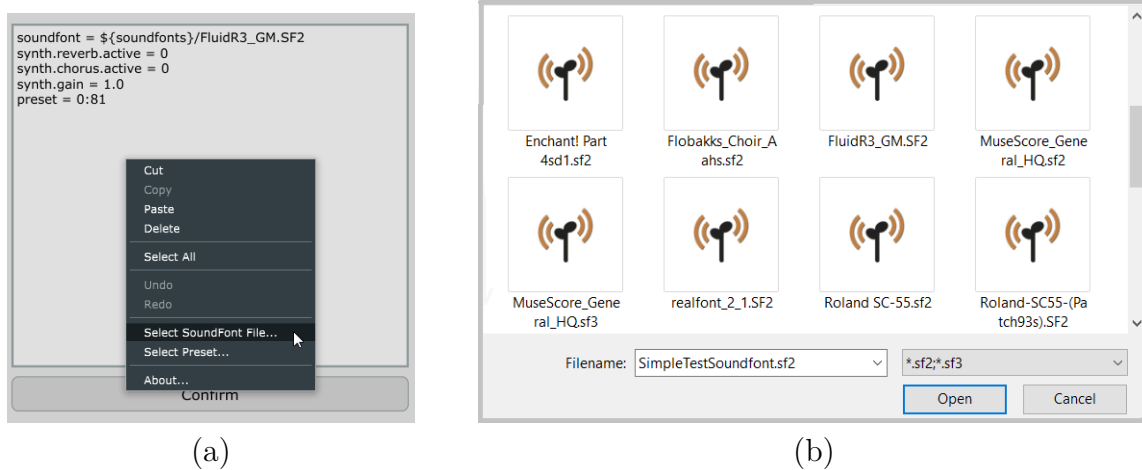


Figure 8: Edit Field Context Menu (a) and File Selection Dialog (b)

Setting the Preset

In the plugin edit field the SoundFont preset is given as a pair of bank number and program number separated by a colon. One might know most of the General MIDI preset numbers by heart, but very often it is tricky to find the correct one especially for SoundFonts that do not adhere to that convention. As a shortcut one can again right-click into the text field to show its context menu (see figure 8a) and select the menu item **Select Preset...**

A preset selection dialog with two columns comes up (see figure 9). In the left column a bank can be selected, in the right column on program within the bank. Note that a bank selection in the left column does **not at all** change the currently selected bank and program. This is indicated by a marker to the left of the bank with the selected program.

When changing the selected bank, the associated programs are scrolled such that a similar program number is visible as the currently selected program number. The idea behind that automatic scrolling is that normally programs in different banks with similar numbers represent similar sounds.

A new preset is **only** selected by clicking on a program in the right column. This is indicated by the marker to the left of that program which also is moved onto its containing bank. Note that also the selection bar is only visible on that specific entry.

The selected preset is immediately audible in the current effect.

When the preset selection is confirmed by **Ok** (or by double-clicking the item) the edit field is again selectively updated with the new preset number and by that change set into the “unregistered” mode with the white background. To make the preset selection effective, you have to press the **Confirm** button in

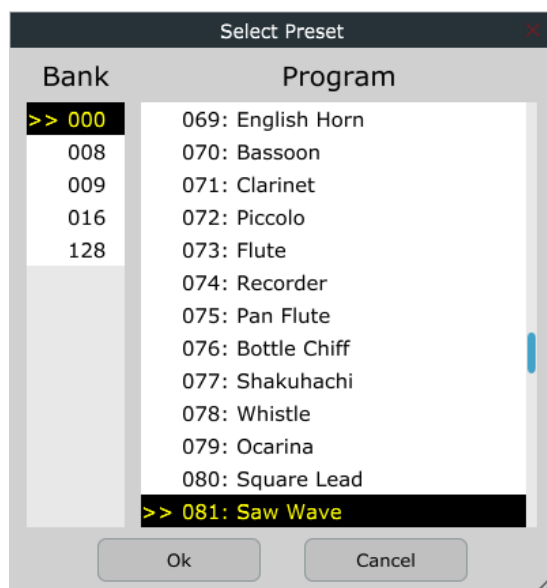


Figure 9: Preset Selection Dialog

the main plugin window to register those changes.

When the preset selection is confirmed by **Cancel** the previous preset is restored and the edit field is unchanged.

3.4 Using the PedanticFluidSynthConverter

The `PedanticFluidSynthConverter` is merely a functionally reduced clone of `FluidSynth`, but with a special property: it places MIDI events onto the raster given by the sample rate.

Hence similarly to `FluidSynth`, the `PedanticFluidSynthConverter` is a command-line program. But the converter does not have to do real-time processing, so the list of its options is reduced. On top of that it only supports a conversion from a MIDI file into an audio WAVE file.

The supported command line options are shown in figure 10 and 11. Any parameter not belonging to an option is interpreted as a file name. Files with their names ending in `.sf2` or `.sf3` are considered to be sound fonts, files with their names ending in `.mid` are considered to be MIDI files.

Hence the command line is

```
fluidSynthFileConverter [options] midifile soundfontfile
                        -F wavefile
```

So, for example, the command line

```
fluidSynthFileConverter -g 1.0 -R 0 test.mid FluidR3\_GM.sf2  
                        -F test.wav
```

produces a wave file “test.wav” from MIDI file “test.mid” using sound font “FluidR3_GM.sf2” with reverb turned off and gain set to unity.

| Option | Description |
|--------------------------------|--|
| -a --audio-driver=«name» | audio driver to use (IGNORED) |
| -C --chorus | turn the chorus on or off [0 1 yes no, default = on] |
| -c --audio-bufcount=«count» | number of audio buffers (IGNORED) |
| -d --dump | dump incoming and outgoing MIDI events to stdout (IGNORED) |
| -E --audio-file-endian | audio file endian (IGNORED: always little endian) |
| -f --load-config | load and execute a configuration file |
| -F --fast-render=«file» | name of target WAVE file (REQUIRED) |
| -G --audio-groups | define the number of LADSPA audio nodes (IGNORED) |
| -g --gain | set the master gain $0 < \text{gain} < 10$, default = 0.2 |
| -h --help | print out help summary |
| -i -no-shell | don't read commands from the shell (IGNORED) |
| -j -connect-jack-outputs | connect jack outputs to the physical ports (IGNORED) |
| -K -midi-channels=«num» | number of midi channels [default = 16] (IGNORED) |
| -L -audio-channels=«num» | number of stereo audio channels [default = 1] (IGNORED) |
| -l -disable-lash | don't connect to LASH server (IGNORED) |
| -m -midi-driver=«label» | name of the midi driver to use (IGNORED) |

Figure 10: Command Line Options for PedanticFluidSynthConverter (Part 1)

| Option | Description |
|---|---|
| <code>-n</code> <code>-no-midi-in</code> | don't create midi driver to read MIDI input events (IGNORED) |
| <code>-O</code> <code>-audio-file-format</code> | audio file format for fast rendering [double float s8 s16 s24 s32, default = s16] |
| <code>-o</code> | define a setting, -o name=value; see FluidSynth for details |
| <code>-p</code> <code>-portname=«label»</code> | set MIDI port name (IGNORED) |
| <code>-q</code> <code>-quiet</code> | do not print informational output |
| <code>-R</code> <code>-reverb</code> | turn reverb on or off [0 1 yes no, default = on] |
| <code>-r</code> <code>-sample-rate</code> | set the sample rate |
| <code>-s</code> <code>-server</code> | start FluidSynth as a server process (IGNORED) |
| <code>-T</code> <code>-audio-file-type</code> | audio file type for fast rendering (IGNORED: always WAV) |
| <code>-v</code> <code>-verbose</code> | print out verbose info about midi events (synth.verbose=1) |
| <code>-V</code> <code>-version</code> | show version of program |
| <code>-z</code> <code>-audio-bufsize=«size»</code> | size of each audio buffer (IGNORED) |

Figure 11: Command Line Options for PedanticFluidSynthConverter (Part 2)

3.5 Restrictions

No Timelocking Available

Often audio effects produce the same output for the same input, but sometimes effects behave differently in time, technically they are *time-variant*.

An example of the former is a filter: it does not care *when* a signal arrives, it always reacts in the same way. An example of the latter is a modulated effect like e.g. a tremolo: it produces a different sound for different event times because the modulation is normally in another phase.

Hence when looking at the behaviour at a specific point in time, those time-variant effects would behave differently when the effect start time is varied.

Of course, a sample player — like **FluidSynth** — very often is also time-variant. It is not, when only a sample playback is triggered, because the audio will be the same whenever you start its playback. But when there is some modulation happening (for example, caused by a chorus effect) the effect is time-variant: the audio output produced will not be the same for different playback start times unless the modulation is in some way synchronized.

So for some externally generated audio snippet with modulation at an arbitrary position in a DAW project, a modulation by a corresponding plugin would only be congruent by accident: typically it is out of phase. The reason for that is that plugins normally start their modulation when playback begins. This means technically the phase 0° of the modulation is on the time of playback start.

Figure 12 show that situation for an example. We assume that an amplitude modulation occurs in a SoundFont and we have inserted an externally rendered audio snippet (e.g. generated by **FluidSynth**) into the DAW starting at time t_{fragment} into an audio track. Now the playback in the DAW is assumed to start at time t_{play} . As one can easily see, the modulation for the externally processed fragment (that just puts a modulation on the raw sample data) has its phase 0° exactly at time t_{fragment} . However, the internal effect in the DAW has its phase 0° at time t_{play} (see also the red dots on the respective tracks marking the phase 0° positions). This would lead to massive differences between externally and internally generated audio.

But it could be rectified by defining for the internal effect *at which point in time the modulation phase should be 0°* (so-called “time-locking”). If you set this time offset parameter to t_{fragment} , the modulations will be synchronous (as you can see when comparing the second with the lowest track). Of course, the effect starts at t_{play} , but its modulation phase is shifted such that it reaches phase 0° exactly at t_{fragment} .

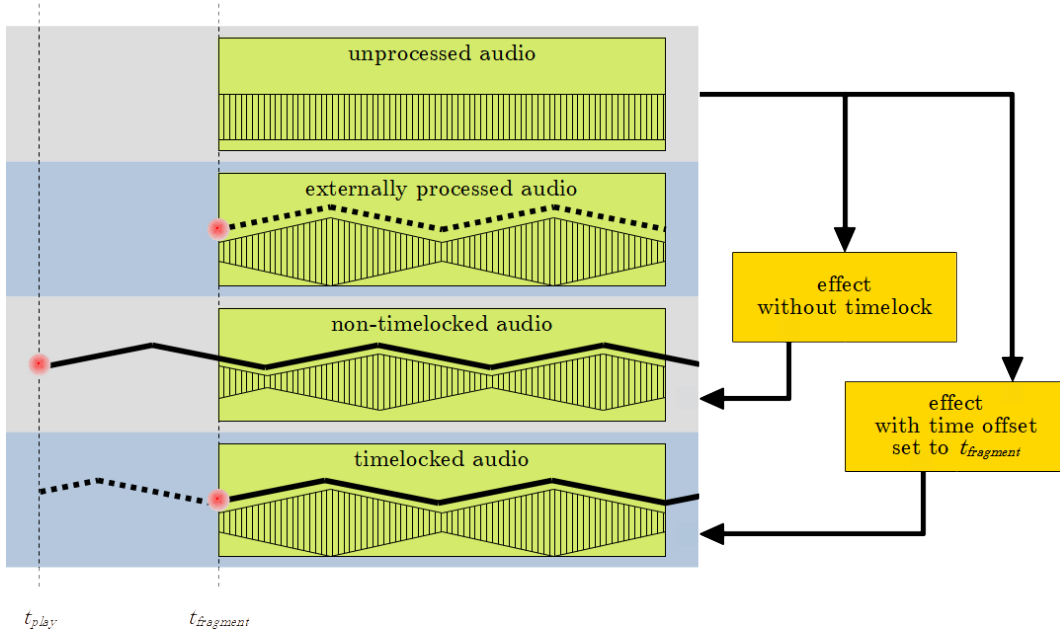


Figure 12: Deviation in Modulation between External and Internal Generation and Timelocking

While this method would lead to perfect reproduction of the external rendering, it is not feasible for the `FluidSynthPlugin`. There is no direct way to set the modulators in the underlying `FluidSynth` library to a specific phase. As a workaround when $t_{\text{fragment}} < t_{\text{play}}$ one could reset all modulators at playback start and first silently have the synthesizer process samples for a duration of $t_{\text{play}} - t_{\text{fragment}}$ to bring its modulators to the correct phases before finally putting out the “real” samples. But this is tedious, takes a lot of processing time and also does not help in a situation where the playback has to start **before** the start time of the corresponding fragment.

So there is no good solution for that.

When you need a bit-exact reproduction of externally rendered audio by the `FluidSynthPlugin`, some workaround has to be made as follows:

- The selected instrument(s) in the SoundFont must not contain any (free-running) modulators.
- Chorus must be deactivated (e.g. by setting `synth.chorus.active` to “0”).

Forced Rasterization by FluidSynth

As mentioned in the introduction the important difference between using the standard `FluidSynth` from the command-line versus from a DAW is that there is a forced rasterization to 64 samples’ intervals.

3.5. RESTRICTIONS

Unfortunately this rasterization is not just done by `FluidSynth` when communicating with audio drivers or its file renderer, but also done internally by the `fluidsynth` synthesizer in the library. The length of the smallest unit for which `FluidSynth` can make state changes and does buffering is a constant called `FLUID_BUFSIZE` and this is fixed to the value 64.

So what can we do?

- We could recompile the `FluidSynth` library and set this value to 1. This would on the one hand lead to a performance penalty, but would on the other hand provide sample-exact processing.

I did not choose that option, because I wanted to use the *stock* `FluidSynth` library on all platforms.

- As an alternative we could do some intelligent buffering to adapt in the DAW to the 64-sample raster of the external rendering regardless of the start time. I played around with that, but it also did not work out well: for example, when looping in the DAW there is no way to flush the buffer within the `FluidSynth` library and to reset the synthesizer: this is just not a use-case typical for applications of `FluidSynth` and hence it has not been provided in its API.

So we are out of luck.

But there is a workaround that helps in many situations: when your DAW allows to change the loop interval and also the play head position via its API one can *nudge all those positions onto the 64-sample raster*.

Since this heavily depends on the scripting facilities of a DAW, I have only provided a simple Lua script for the Reaper DAW in the `misc` subdirectory of the distribution called `ForceToFluidSynthRaster.lua`. When executed, it shifts the selection boundaries and the play head position onto the required raster.

It is even possible to provide some integral shift offset (e.g. when the externally rendered audio files do not start at time 0 in the DAW). This is done by setting the variable `sampleOffset` in the project notes to some integer value, e.g. by writing the following text:

```
sampleOffset = 20
```


Chapter 4

Regression Test

To test that the `FluidSynthPlugin` is really bit-identical to the `PedanticFluidSynthConverter` (and at least similar to the output of `FluidSynth`), a little test suite has been set up for checking DAW versus the command-line.

The suite assumes that command-line `FluidSynth` is installed in the search path of your operating system.

If so, a simple batch script generates — externally via the command line — audio files from three MIDI files and some simple sound font both with `PedanticFluidSynthConverter` and also `FluidSynth`. The batch script can be found in the `test` subdirectory and is called `makeTestFiles.bat` (for Windows) or `makeTestFiles.sh` (for MacOS and Linux).

Since there are so many DAWs available, it is hard to provide a test project for each of those. The distribution just contains a Reaper project referencing those rendered audio files in autonomous tracks (see figure 13). Adaption to other DAWs should be straightforward.

Besides the six externally rendered tracks there are three other tracks containing the MIDI file data and having a single `FluidSynthPlugin` effect converting MIDI to audio. Those instrument effects are configured with the exactly the same parameters as given in the batch file and hence correspondingly applied to the raw MIDI data.

When subtracting the rendered audio in Reaper and the externally rendered audio files from the `PedanticFluidSynthConverter`, they (almost) cancel out, because they use exactly the same scheduling of the MIDI events. This can be checked by a spectrum analyser in the master channel, which is shown in figure 14. It shows a noise floor of typically less than -100dB (also depending on the audio file bit depth).

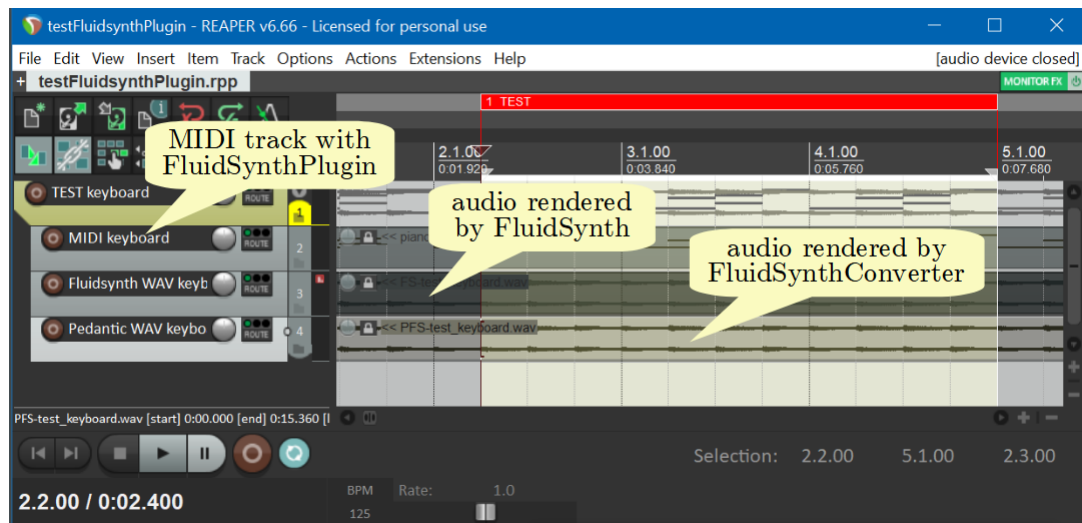


Figure 13: Regression Test Setup in Reaper

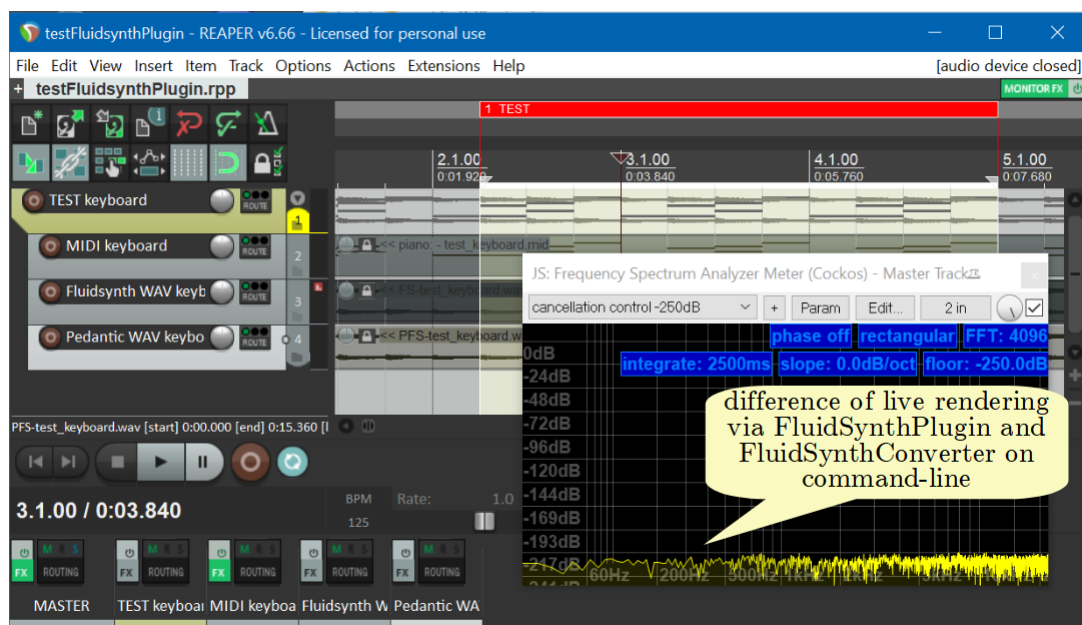


Figure 14: Example Noise Floor for Regression Test in Reaper

Chapter 5

Notes on the Implementation

5.1 Overview

The implementation of the `FluidSynthPlugin` and the `PedanticFluidSynthConverter` is done in C++. The former relies on the JUCE library [JUCE] and both — of course — use the `FluidSynth` library. The sequencer from that library is not used, because it also has some event rasterization (independent from the inevitable internal rasterization of the library).

The *bit-exact reproduction* of the `PedanticFluidSynthConverter` (as well as `FluidSynth` itself) by the `FluidSynthPlugin` in a DAW is almost achieved (see section 4), but some restrictions have to be adhered to.

The complete source code of the `FluidSynthPlugin` and the `PedanticFluidSynthConverter` is open-source for easy review and adaptation. Currently there is only a tool chain for VST3 plugins under Windows 10, VST3 and AU plugins under MacOS and VST3 under Linux, but in principle the code is easily portable to other plugin formats or platforms.

5.2 Building the Plugins

Preliminaries

In the GIT-project of `FluidSynthPlugin` (at [FluidSynthPlugin]) there is a build file for CMAKE to build the plugins for different platforms.

Minimum prerequisites for building are:

- a clone of the GIT-project at <https://github.com/prof-spock/FluidSynthPlugin>
- an installation of the audio framework JUCE [JUCE] with version 5 or

later plus any required packages (e.g. for Linux see appendix A.2),

- some C++ compiler suite for your platform (e.g. Visual Studio, XCode, clang or gcc), and
- an installation of the build automation platform CMAKE [CMAKE] with version 3.20 or later

For documentation generation you can *optionally* install:

- a L^AT_EX installation — like e.g. MikTeX — (for the manual), and
- doxygen [DOXYGEN] and graphviz [GRAPHVIZ] for the internal program documentation

Doing the Build

The full build process is started via CMAKE. It is recommended to do a so-called out-of-source-build for the FluidSynth-Plugins, that means, you define some build directory where all build activity is done.

The steps are as follows:

1. Define some build directory (lets say `_BUILD`) and change to it.
2. Find the path of the `CMakeList.txt` configuration file. Adapt the file `LocalConfiguration.cmake` accordingly to reflect the location of L^AT_EX as well as the JUCE and the doxygen/graphviz installation.
3. Configure the build process via

```
cmake -S <pathTo>/CMakeList.txt -B . \
      -DCMAKE_BUILD_TYPE=Release
```

4. Build all the plugins via

```
cmake --build . --config Release
```

5. Install the plugins into a architecture-specific subfolder in the `_DISTRIBUTION/targetPlatforms` directory and install also the documentation into the `_DISTRIBUTION` directory via

```
cmake --install . --config Release
```

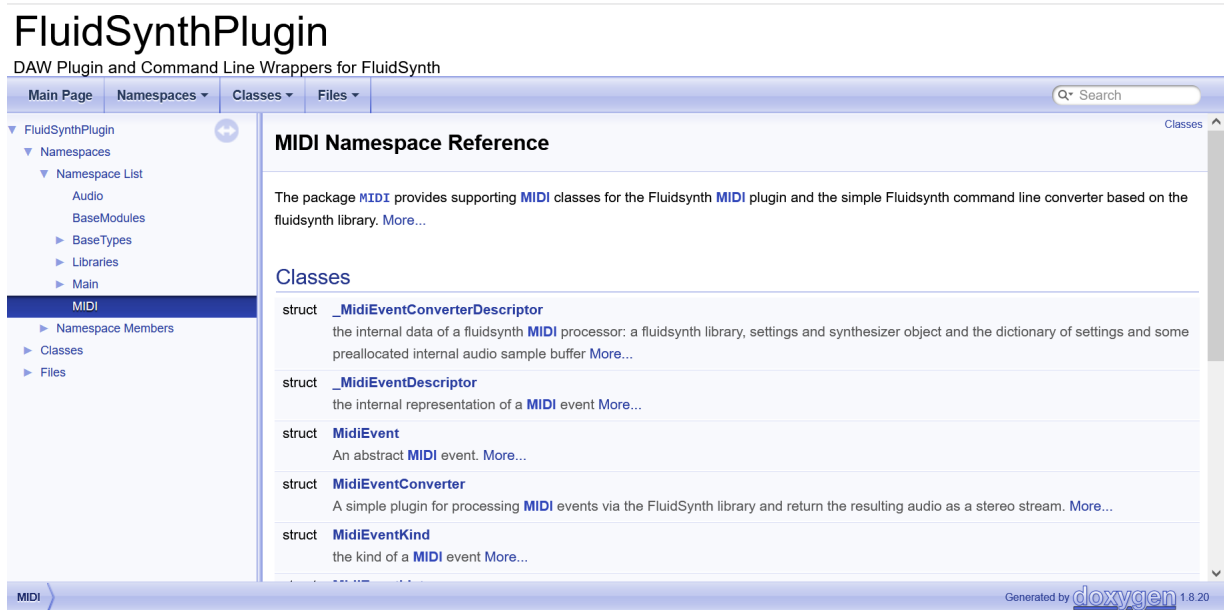


Figure 15: Example Namespace Page for Plugin from doxygen

5.3 Internal Documentation

In the github repository there is an extensive doxygen documentation available for the inner workings of the plugins at

<https://github.com/prof-spock/FluidSynthPlugin/tree/master/internalDocumentation/html>

with entry point

<https://github.com/prof-spock/FluidSynthPlugin/tree/master/internalDocumentation/html/index.html>.

Every public and private feature of all classes and data types is documented and can be analyzed in an HTML browser. Figure 15 gives an impression how such an HTML page looks like for the namespaces in FluidSynth-Plugins.

If you want to regenerate this documentation from the code, you need an installation of doxygen [DOXYGEN] and ideally also graphviz [GRAPHVIZ] on your computer. If you have that available, the generation can be done via the CMAKE chain as target `doxygenDocumentation` in the build directory:

```
cmake --build . --target internalDocumentation --config Release
```

If the command completes, the documentation in the `internalDocumentation` subdirectory of the project is updated.

5.4. AVAILABLE BUILD TARGETS

| Target Name | Description |
|--|---|
| documentation | the complete project documentation |
| <code><-- internalDocumentation</code> | the HTML doxygen documentation for the code |
| <code><-- pdfDocumentation</code> | the PDF manual for the plugins |
| SupportLibraries | the static libraries supporting the effects |
| <code><-- CommonProjectLibrary</code> | the static library with utility classes (like e.g. lists or logging) |
| <code><-- JuceFramework</code> | the static library with utility classes from the JUCE framework |
| FluidSynthFileConverter | the program for the command line <code>PedanticFluidSynthConverter</code> |
| FluidSynthPlugins | the static libraries for the FluidSynth-Plugin |
| <code><-- FluidSynthPlugins_Effect</code> | the static effect library for the FluidSynthPlugin |
| <code><-- FluidSynthPlugins_VST</code> | the VST3 library for the FluidSynth-Plugin |
| <code><-- FluidSynthPlugins_AU</code> | the AU libraries for the FluidSynth-Plugin (only on MacOS) |

Figure 16: Available Build Targets for CMAKE

To trigger regeneration, it suffices to delete the file `internalDocumentation/html/index.html`.

5.4 Available Build Targets

Figure 16 shows the available CMAKE targets. They can be used as

```
cmake --build . --config Release --target XXX
```

where XXX is the target name.

5.5 Debugging

For debugging purposes, for both the `FluidSynthPlugin` and the `PedanticFluidSynthConverter` the executable files build in debug mode do an extensive entry-exit-logging into some temporary directory. Note that this logging slows down processing extremely and produces large log files, but it helps to understand problems in case of errors. Figure 17 shows how a logging file looks like.

```

>>Main.FluidSynthPlugin.FluidSynthPlugin_EventProcessor.prepareToPlay (220338.07): sampleRate = 44100.000000, samplesPerBlock = 1024
--Main.FluidSynthPlugin.FluidSynthPlugin_EventProcessor.prepareToPlay (220338.07): currentTime = 0 [samples]
>>MIDI.MidiEventConverter.prepareToPlay (220338.07): sampleRate = 44100.000000, samplesPerBlock = 1024
>>MIDI.MidiEventConverterDescriptor.changeSettings (220338.07): key = synth.sample-rate, value = 44100.000000
>>Libraries.FluidSynth.FluidSynthSettings.set (220338.07): key = synth.sample-rate, value = 44100.000000
--Libraries.FluidSynth.FluidSynthSettings.set (220338.07): kind = F, value = 44100.000000
<<Libraries.FluidSynth.FluidSynthSettings.set (220338.07): true
<<MIDI.MidiEventConverterDescriptor.changeSettings (220338.07): true
<<MIDI.MidiEventConverter.prepareToPlay (220338.07)
<<Main.FluidSynthPlugin.FluidSynthPlugin_EventProcessor.prepareToPlay (220338.07)
>>Main.FluidSynthPlugin.FluidSynthPlugin_EventProcessor.getStateInformation (220338.10)
>>Main.FluidSynthPlugin.FluidSynthPlugin_EventProcessor.settings (220338.10)
<<Main.FluidSynthPlugin.FluidSynthPlugin_EventProcessor.settings (220338.10):
<<Main.FluidSynthPlugin.FluidSynthPlugin_EventProcessor.getStateInformation (220338.10): settings =
>>Main.FluidSynthPlugin.FluidSynthPlugin_EventProcessor.prepareToPlay (220338.11): sampleRate = 44100.000000, samplesPerBlock = 512
--Main.FluidSynthPlugin.FluidSynthPlugin_EventProcessor.prepareToPlay (220338.11): currentTime = 0 [samples]
>>MIDI.MidiEventConverter.prepareToPlay (220338.11): sampleRate = 44100.000000, samplesPerBlock = 512
>>MIDI.MidiEventConverterDescriptor.changeSettings (220338.11): key = synth.sample-rate, value = 44100.000000
>>Libraries.FluidSynth.FluidSynthSettings.set (220338.11): key = synth.sample-rate, value = 44100.000000
--Libraries.FluidSynth.FluidSynthSettings.set (220338.11): kind = F, value = 44100.000000
<<Libraries.FluidSynth.FluidSynthSettings.set (220338.11): true
<<MIDI.MidiEventConverterDescriptor.changeSettings (220338.11): true
<<MIDI.MidiEventConverter.prepareToPlay (220338.11)
<<Main.FluidSynthPlugin.FluidSynthPlugin_EventProcessor.prepareToPlay (220338.11)
>>Main.FluidSynthPlugin.FluidSynthPlugin_EventProcessor.prepareToPlay (220338.11): sampleRate = 44100.000000, samplesPerBlock = 512
--Main.FluidSynthPlugin.FluidSynthPlugin_EventProcessor.prepareToPlay (220338.11): currentTime = 0 [samples]
>>MIDI.MidiEventConverter.prepareToPlay (220338.11): sampleRate = 44100.000000, samplesPerBlock = 512
>>MIDI.MidiEventConverterDescriptor.changeSettings (220338.11): key = synth.sample-rate, value = 44100.000000
>>Libraries.FluidSynth.FluidSynthSettings.set (220338.11): key = synth.sample-rate, value = 44100.000000
--Libraries.FluidSynth.FluidSynthSettings.set (220338.11): kind = F, value = 44100.000000
<<Libraries.FluidSynth.FluidSynthSettings.set (220338.11): true
<<MIDI.MidiEventConverterDescriptor.changeSettings (220338.11): true
<<MIDI.MidiEventConverter.prepareToPlay (220338.11)
<<Main.FluidSynthPlugin.FluidSynthPlugin_EventProcessor.prepareToPlay (220338.11)
>>Main.FluidSynthPlugin.FluidSynthPlugin_EventProcessor.setStateInformation (220338.11)

```

Figure 17: Example for Logging File

Every non-trivial function is logged there at least twice with timestamps: “»” indicates the entry of that function (possibly with information on the argument values), “<” the exit of that function (possibly with the return value) and “--” indicates some intermediate information during the function processing. The logging data is hierarchical, hence you can see the function call structure in this file precisely.

All logging files go into the directory specified by the environment variables `tmp`, `temp` or into the directory `/tmp` (in that order).

Chapter 6

License

There are two license models for this project:

- The source code is provided with an **MIT license** [MIT].
- The VST and AU files given in the releases are provided with an **AGPL v3 license** [AGPL] since they contain parts of the JUCE framework.

This means that if you do *not* use the given binaries and compile the source code by yourself, the MIT license applies. If you *do* use the binaries directly, then the AGPL v3 license applies.

Bibliography

- [AGPL] Free Software Foundation.
GNU Affero General Public License.
<https://www.gnu.org/licenses/agpl-3.0.html>
- [CMAKE] Kitware, Inc.
CMAKE Build Automation System.
<http://cmake.org>
- [DOXYGEN] Dimitri van Heesch.
Doxygen - Generate Documentation from Source Code.
<https://www.doxygen.nl>
- [FluidSynthDOC] Tom Moebert et al.:
FluidSynth.
<http://www.fluidsynth.org>
- [FluidSynthSettings] Tom Moebert et al.:
FluidSynth - Synthesizer Settings Documentation.
https://www.fluidsynth.org/api/settings_synth.html
- [FluidSynthVST] Alexey Zhelezov.
FluidSynth VST Plugin.
<https://github.com/AZSlow3/FluidSynthVST>
- [FluidSynthPlugin] Thomas Tensi.
FluidSynth-Plugins
<https://github.com/prof-spock/FluidSynthPlugin>
- [GRAPHVIZ] Ellson, John; Gansner, Emden; Hu, Yifan; North, Stephen et al.:
Graphviz - Open Source Graph Visualization Software.
<https://graphviz.org/>
- [JUCE] Raw Material Software Limited.
JUCE Audio Framework.
<https://www.juce.com>

- [JUCEDND] Raw Material Software Limited.
JUCE Forum: Drag and Drop not working under VST in Linux.
<https://forum.juce.com/t/drag-and-drop-not-working-under-vst-in-linux/50410>
- [JuicySFPlugin] Alex and Jamie Birch.
Juicy SF Plugin.
<https://github.com/Birch-san/juicysfplugin>
- [LTBVC] Thomas Tensi.
LilypondToBandVideoConverter — Converter from Written Music to Notation Videos.
<https://github.com/prof-spock/LilypondToBandVideoConverter>
- [MIT] Massachusetts Institute of Technology.
MIT License.
<https://opensource.org/license/mit>
- [REAPER] Cockos Incorporated.
Reaper Digital Audio Workstation.
<https://www.reaper.fm>
- [Sforzando] Plogue Art et Technologie, Inc.
Sforzando.
<https://www.plogue.com/products/sforzando.html>
- [VCCLib] Microsoft.
Visual C++ Redistributable.
<https://learn.microsoft.com/cpp/windows/latest-supported-vc-redist>

Appendix A

Building and Installing in Linux

A.1 Installing the FluidSynth Package in Linux

On Linux the `FluidSynthPlugin` requires an existing installation of `FluidSynth` on the system. You would normally expect this to be part of the delivery, but because there are several Linux distributions available, it is difficult to do this.

Installation of `FluidSynth` on some Linux distribution is done on the command-line via a so-called *package manager* — that unfortunately depends on the distribution —. It requires super-user privileges and can be done as described in the following table:

| Distribution | Installation Command |
|--------------|---|
| Arch | <code>sudo pacman -S fluidsynth</code> |
| CentOS | <code>sudo dnf install fluidsynth</code> |
| Debian | <code>sudo apt install fluidsynth</code> |
| Fedora | <code>sudo dnf install fluidsynth</code> |
| Gentoo | <code>sudo emerge fluidsynth</code> |
| Kali Linux | <code>sudo apt install fluidsynth</code> |
| Mint | <code>sudo apt install fluidsynth</code> |
| openSuse | <code>sudo zypper install fluidsynth</code> |
| RHEL | <code>sudo dnf install fluidsynth</code> |
| Slackware | <code>sudo slackpkg install fluidsynth</code> |
| Ubuntu | <code>sudo apt install fluidsynth</code> |

From time to time you should upgrade the `FluidSynth` package via that package manager to make sure that the `FluidSynthPlugin` always works with the current `FluidSynth` library.

A.2 Required Packages for Linux Builds

When building the program yourself in Linux some packages must be available. Those are:

- build-essential, doxygen, fluidsynth, graphviz, pkg-config and texlive-latex-extra

and the libraries

- ladspa-sdk, libasound2-dev, libcurl4-openssl-dev, libfontconfig1-dev, libfreetype-dev, libglu1-mesa-dev, libjack-jackd2-dev, libwebkit2gtk-4.1-dev, libx11-dev, libxcomposite-dev, libxcursor-dev, libxext-dev, libxinerama-dev, libxrandr-dev, libxrender-dev and mesa-common-dev

Also have a look at <https://github.com/juce-framework/JUCE/blob/master/docs/Linux%20Dependencies.md> for a current list of package dependencies by the JUCE team.