Squeezer

Flexible general-purpose audio compressor
with a touch of citrus

Last edited on 19th September 2021

Contents

1 About Squeezer

I wrote this compressor[1] to finally understand and master audio compression. It took me several months to gather specs, papers and find intuitive knob settings.

But it was worth it. Squeezer is highly flexible and can be set up quickly. Moreover, it still allows fine-tuning of its settings should the need arise. It has become my go-to software compressor and I rarely use other compressors.

Squeezer is different from all the compressors I know: its knobs are stepped to fine-tuned *preset* values, but can be changed to *continuous* values by clicking a small orange light located next to them. This allows you to find nice settings fast while not preventing optimisation of settings.

Squeezer adapts easily to many tastes and use cases:

- feed-forward & feed-back design
- linear, logarithmic & smooth release stage
- optical & FET detectors

[1] In this manual, I will use *compression* synonymous with *downward compression*. There are other ways to reduce dynamic range, but in audio, downward compression is used almost exclusively.

- peak & RMS sensing
- hard, medium & soft knee
- flexible side-chain & parallel compression

Squeezer has given me a deep insight into compression. But above that, it has quickly become my go-to generic compressor.

I hope that you have as much fun with Squeezer as I had when I coded it!

2 What is compression?

2.1 The Tale of the Barkeeper

Once upon a time there was a bar. Customers enjoyed their drinks and music played in the background. After a while, the barkeeper noticed that his drinks sold best when the music had a certain loudness. Unfortunately, almost every record they played had a different loudness.

So he bought a loudness meter and wrote a set of instructions for the DJ:

80 dB SPL	set mixer's output gain to 0 dB
85 dB SPL	set mixer's output gain to –5 dB
90 dB SPL	set mixer's output gain to –10 dB
95 dB SPL	set mixer's output gain to –15 dB

This worked quite well and he could finally afford to buy a shiny new bar counter. Upon which the DJ gave notice (he had always dreamt of getting a *stereo* mixer, so the new counter didn't go down too well with him).

After an initial shock, the barkeeper was quite content. The DJ really *had* been lousy. But how to keep the impressive sales figures for his drinks?

Being an entrepreneur, the barkeeper loved challenges and connected the mixer's output to a simple amplifier. The amplifier's gain was regulated by a level sensor which in turn was connected to the amplifier's output.[1]

Although the new device exactly followed the DJ's instructions (and didn't smell as bad), customers complained about a decline in sound quality. The barkeeper had invented a *wave shaping* device – gain changes were applied instantly which *distorted* its output signal.

Fortunately, the barkeeper remembered a very important thing: the DJ had often been drunk and taken his time to apply gain changes. So the barkeeper improved his device by smoothing the level sensor's output.

He could have become very rich. But he didn't realise the magnitude of his invention and continued being a happy barkeeper. Which is not the worst thing, when you come to think of it.

To this day, however, sound engineers fall silent in awe when they hear his name – the name of the barkeeper who **invented the compressor**.

[1] engineers call this a negative feed-back loop

2.2 How does a compressor work?

Compressors are inherently complex sound processors. Their technology is quite simple – complexity arises from the dynamic interaction of their controls. While this is definitely a downside when you try to understand compression, it is also what allows you to use compression creatively!

A compressor is a device for reducing the dynamic range[2] of audio material. In its most basic form, it consists of four modules:

Level detector	measures level of audio at its input and sends it to gain computer
Gain computer	calculates difference between input level and desired output level and sends resulting *target* gain reduction to smoothing filter
Smoothing filter	smoothly adjusts *current* gain reduction in direction of *target* reduction and sends result to gain stage; the "speed" of smoothing can often be adjusted (*attack and release times*)
Gain stage	attenuates audio input by *current* gain reduction

The first three modules are also called *side-chain*. That's because they form a sideline of processing that will only be *utilised for*, but not *heard in* the compressor's output.

[2] difference between loudest and quietest signal

2.3 Level detector

As its name implies, a level detector senses the level of an audio signal. It can either detect the input wave form directly (peak sensing) or an estimate of its loudness (average sensing, usually with a RMS[3] filter).

Peak sensing allows a compressor to quickly react to sudden changes in level, whereas *average sensing* detects changes over longer periods of time.

There are also two ways of connecting level detectors: vintage compressors sense the gain stage's *output* level (feedback design), leading to a very distinct "bouncing" sound. Modern compressors sense the compressor's *input* signal (feed-forward design) which often results in a more natural sound.

2.4 Gain computer

The level detector's signal is sent to a gain computer[4] which determines the output level the signal should have. It then calculates a corresponding gain reduction ("attenuate the current input signal by 3.14 dB"). This **gain reduction constantly changes** over time.

[3] root mean square

[4] in the sense of *calculator* – some gain computers are entirely built from analogue circuitry!

The most common gain computer design is a *threshold* control. It sets a level below which all input passes unchanged. Levels exceeding the threshold are attenuated by a *compression ratio*, set through a second control. Higher ratios effect more compression than lower ratios.[5]

Need an example? A threshold of –20 dB FS yields a gain reduction of 0 dB (no compression) for all levels below –20 dB FS. A signal of –18 dB FS however will produce a gain reduction of 1 dB for a compression ratio of 2:1[6] and 0.5 dB for a ratio of 4:1.

There may be a third control called *knee width*. It defines a transition zone around the threshold. In this zone, the compression ratio gradually changes from 1:1 (no compression) to the selected ratio (full compression) – quieter signals receive less compression than louder ones. This reduces distortion caused by abrupt transitions between compressed and uncompressed signal.

2.5 Smoothing filter

This was the easy part, but from now on most explanations start to fail. I'll try my best and continue anyway . . .

If you stopped here and let the gain computer control the gain stage directly, you'd have a wave shaping device.[7] By

[5] a compression ratio of 1:1 effectively bypasses the compressor
[6] a ratio of 2:1 means that 2 dB on the input yields 1 dB at the output
[7] *wave shaping* is a fancy way of saying *distortion*

reacting immediately, the compressor would relentlessly change the shape of *single wave forms*. Don't get me wrong: this already *is* compression and I occasionally *do* like its sound – but it's not something you want to have on every track, let alone a full mix.

Listen for yourself! Load a drum track into your DAW, add the Squeezer plug-in, unlock attack and release time[8] *and set them to the lowest possible value. Make sure the compressor uses peak sensing*[9] *and a high compression ratio. Now lower the threshold until you can clearly hear the wave shaping. Keep the DAW open for now.*

To change *sounds* instead of *single wave forms*, the *current* gain reduction has to be slowed down and smoothly adjusted in the direction of the *target* gain reduction.

One possibility is using averaging level detectors,[10] employing photo ("optical" or "opto") cells is another.[11] Both solutions effectively slow down the compressor's response time, but somewhat crudely.

Play the drum track and engage the "RMS" button – the distortion vanishes. Disengage the "RMS" button and enable the "Opto" button instead – again, the distortion vanishes, but the track sounds different. You can now close the DAW.

[8] click on the orange light next to a knob so it lights up

[9] "RMS" button is not engaged

[10] this is *not* the reason why compressors have averaging level detectors; they let compressors react to changes in *loudness*

[11] photo cells react to level changes in complex time-dependant ways

2.5.1 Attack and release time

With a little experimentation, it becomes clear that compressors sound best when gain reduction is increased quickly, but released much more slowly.[12] Moreover, a single smoothing "speed" could not accommodate the many different types of sound we encounter. So it makes sense to split response time into (at least) two controls:

Attack is the length of time it takes to apply roughly[13] two-thirds of an *upward* change in gain reduction.

Release is the length of time it takes to apply roughly two-thirds of a *downward* change in gain reduction.[14]

With this in mind, here are the important facts that almost every explanation gets wrong:[15]

- compression starts **the very moment the detected level passes threshold**, it is not delayed by attack time
- compression continues **even after the detected level falls below threshold**, at least for a short while
- compression occurs **whenever *current* and *target* gain reduction differ**; this means **all of the time the detected level is above threshold** and slightly after

[12] incidentally, that is *exactly* how vintage photo cells react to changes
[13] every manufacturer defines attack and release times differently
[14] these definitions were shamelessly paraphrased from Demolishing the Myths of Compression by Gregory Scott, one of the few articles on compression actually worth reading; I also highly recommend working through Bob Katz's book Mastering Audio
[15] for simplicity, I will elide the effects of knee width

The last list item may need some explanation. Imagine a signal above threshold.[16]

Whenever the signal's slope is rising, *current* gain reduction will fall below *target* gain reduction and will be smoothed using the *attack* time. Even when the slope starts to drop, *current* gain reduction may still be below *target* gain reduction and will be affected by the attack time.

If the slope keeps falling, *current* gain reduction will eventually rise above *target* gain reduction and will be smoothed according to the *release* time. This continues until the slope starts to rise again and *current* gain reduction falls below *target* gain reduction. Now, the *attack* time will once again take over.

In other words: with any real-world audio signal, compressors enter an ever-changing dynamic state as soon as the input signal passes threshold. This is what makes them so hard to explain – and I'm quite confident that it is also what makes them sound so damn good.

The good news is that you can use compressors without fully understanding this dynamic state. However, the information contained in this chapter will help you in ignoring the countless erroneous explanations out there.[17]

[16] with a compression ratio above 1:1 and below $1{:}\infty$

[17] they were the reason for developing Squeezer in the first place

2.5.2 Curve shape

Attack and release times can be implemented in a number of ways. Vintage compressors use simple analogue filters with *logarithmic* curves. Speed depends on the difference between *current* and *target* gain reduction – initial change is fast and slows down as the difference gets smaller.

Newer compressors often have *linear* curves – the *target* gain reduction is approached with constant speed.

In Squeezer, attack phase always has a *logarithmic* curve. The curve of its release phase can be set to *linear*, *logarithmic* or *smooth*. *Smooth* behaves like a logarithmic curve, but when an attack phase changes to release, a smooth transition between the curves prevents a sharp drop in gain reduction. This reduces yet another type of distortion exhibited by compressors.

It is hard to say which curve sounds best, as it really depends on source material and personal taste.

2.6 Gain stage

The gain stage is an amplifier that attenuates the input signal using the *current* gain reduction. There may be an additional gain control to make up for any level lost during compression (also called *make-up gain*).

That's it.

2.7 Advanced topics

2.7.1 Stereo linking

When each channel of a stereo signal is compressed separately, the stereo image may shift uncontrollably. This can be prevented by mixing the outputs of all level detectors and sending the *mixed* signal to each gain computer.

Squeezer automatically links its channels when placed on a stereo channel. Occasionally, you may want to override this behaviour, so Squeezer lets you control the amount of stereo linking.

2.7.2 Parallel compression

So far, I have described *downward* compression. As you know, it works by bringing high-level signals down and leaving low-level signals untouched. In other words, downward compression changes – and possibly damages – the *transients.*

This may not be what you want, so *upward* compression works the other way round. Low-level signals are brought up and high-level signals are left alone. This approach has a huge problem, though – it also amplifies the noise floor! This is probably the reason why I have never seen an upward compressor in the wild …

Parallel compression[18] is similar to *upward* compression, but it preserves transients *and* leaves the noise floor alone. Here is how it works: you compress a signal (often heavily) and add some of the compressed signal to the original.

Squeezer provides a latency-compensated *wet/dry* control that allows you to apply parallel compression easily.

2.7.3 Side-chain filtering

Bass frequencies contain most of a signal's energy, so bus compression will often "pump" in the rhythm of the bass instruments.[19] A filter that removes bass frequencies (*high-pass* filter) from the side-chain helps in achieving better compression results.

Squeezer also provides a *low-pass* filter to remove treble frequencies, although this is used less often. For frequency-specific compression, you can leave only desired frequencies by employing both filters simultaneously.

2.7.4 External side-chain input

Squeezer also lets you feed an external input into the side-chain. You can use this either for advanced filtering or as an

[18] also known as *New York compression*, but in this case, the signal is also equalised prior to compression

[19] in addition, music tends to contain more bass frequencies than treble as the human ear is least sensitive to bass frequencies

effect. In electronic dance music, compressor “pumping” triggered by the bass drum has become rather cliché …

Depending on your DAW, setting up an external side-chain can be simple or highly complicated. I cannot (and will not) help you with it, so please refer to your DAW’s manual or manufacturer. I will however provide some information to get you started.

The input channels of Squeezer’s stand-alone application and VST2 plug-in are *doubled* and divided into main inputs (first half of the channels) and side-chain inputs (second half).

The other plug-in formats are properly tagged. They notify your DAW about each channel’s role and should work without problem.

3 Installation

In order to use the pre-compiled binaries, simply extract Squeezer's files from the downloaded archive. For the plug-ins, you'll then have to move the extracted files to your respective plug-in folder.

The folder `squeezer` is mandatory and must be moved to the plug-in (or stand-alone) folder!

VST2 plug-ins with "`no side-chain`" *in their name lack the external side-chain input. Use them if your DAW behaves erratically with the "regular" VST2 plug-ins.*

Squeezer requires a processor which supports the SSE2 instruction set. On Windows, you might also have to install the Visual C++ Redistributable for Visual Studio 2017.

Should the stand-alone version ever fail to start, you can reset its settings by deleting the file `Squeezer (Stereo).settings` or `Squeezer (Mono).settings`. These files are located in `~/.config` (GNU/Linux) or `%appdata%\.config\` (Windows).

4 Troubleshooting

My DAW acts weirdly if I insert Squeezer (VST2).

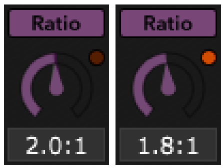
VST2 doesn't support side-chains, so I had to use a hack. It works with a few DAWs, but **FL Studio** for example outputs a mono signal if you insert a stereo instance of Squeezer.

Please use the VST2 plug-ins with "`no side-chain`" in their name – they disable external side-chain input. In case you need an external side-chain, please use VST3 plug-ins (VST3 officially supports side-chains).

5 Knobs

Double-click a knob to reset it to its default position. For finer control, hold the *Ctrl* key when turning a knob.

5.1 Unlock knobs



By default, Squeezer's knobs are stepped to *preset* values. I have invested a lot of time to fine-tune these values and ensure that they are useful in practice.

If you need finer control, however, every knob can be changed to *continuous* values. Just click the small orange light located in its upper right corner.

Depending on your action, Squeezer either preserves your current setting or snaps to the value closest to it.

5.2 Threshold and compression ratio

These knobs control **threshold** and compression ratio.

A **compression ratio** of 2:1 means that 1 dB on the input yields 0.5 dB at the output. Thus, a setting of 1:1 effectively disables Squeezer.

You can set this knob to values below 1:1. This transforms Squeezer into an *upward expander* – an **expansion ratio** of 0.5:1 means that 1 dB on the input yields 2 dB at the output. This allows you to *add transients* to boring and over-compressed recordings.

Note: upward expansion can massively *increase* the output level, so take care of you ears – especially when you switch from compression to expansion!

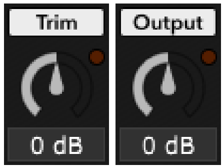
5.3 Attack and release time

Change attack and release time using these two knobs.

Attack is the length of time it takes to apply 90 % of an upward change in gain reduction.

Release is the length of time it takes to apply 90 % of a downward change in gain reduction (*logarithmic* and *smooth* curves). Alternatively, this is the length of time it takes gain reduction to fall by 10 dB (*linear* curve).[1]

5.4 Input trim and output gain



Trim changes Squeezer's input gain without affecting its output level. *You can also think of this as attenuating threshold by the value of trim.*

Output controls output gain (also called make-up gain). There are several use cases:

- use *output gain* to match the loudness of compressed and direct signal before comparing them[2]
- set the threshold to a fixed value and control Squeezer *vintage style* by changing *trim* and *output gain* only
- improve automatic make-up gain (section 6.8) by adjusting *trim* so that changing the threshold control doesn't change the apparent output volume
- if Squeezer sounds well and the level of the incoming signal changes for some reason, it may be more obvious to adjust *trim* instead of *threshold*

[1] often called release *rate* because the actual release *time* depends on the amount of applied gain reduction; linear release curves can sound very different from logarithmic ones

[2] the brain perceives a louder signal to sound better than a quieter one

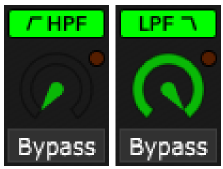
5.5 Stereo linking and wet/dry ratio

Link controls the amount of stereo linking.[3] 100 % enforces full linking, whereas 0 % disables linking and processes every channel independently.

Wet controls the ratio between wet (compressed) and dry (uncompressed) signal. When set to 100 %, you hear only compressed signal. A value of 50 % yields an equal mix of compressed and direct signal, and 0 % effectively bypasses Squeezer.

Mixing is latency-compensated, so you can use the wet control to employ *parallel compression*.

5.6 Side-chain filters



The side-chain is equipped with a high-pass filter and a low-pass filter. These knobs control their **cutoff frequencies**.

Both filters are connected in series so you can use them simultaneously to remove everything but a specific band of frequencies.

[3] Squeezer does not support mid/side processing

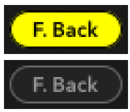
6 Buttons

6.1 Release curve type

Attack phase always has a *logarithmic* curve. Use these buttons to change the *release phase*. All options (**linear**, **logarithmic** and **smooth** curve) are detailed in section 2.5.2.

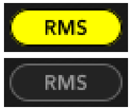
6.2 Detector placement

Engaging the **feed-back** button places the level detector at the gain stage's output. Otherwise, the detector is fed with the uncompressed input signal (**feed-forward**).



6.3 RMS filter

This button switches the detector between peak-sensing and average-sensing using an **RMS** filter (window size of 30 ms). RMS filter and the “Opto” detector type are independent – both buttons can be engaged at the same time.



6.4 Detector type

Engage this button to switch between the linear response of a field-effect transistor (**FET**) and a photo cell emulation (**Opto**). Detector type and “RMS” filter are independent – both buttons can be engaged at the same time.

6.5 Knee width

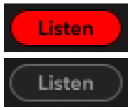
These buttons let you select the compressor’s knee width. **Hard** abruptly transitions between compressed and uncompressed signal at the threshold. **Medium** sets a knee width of 24 dB[1] and **soft** a knee width of 48 dB.

[1] transition zone starts 12 dB below threshold and ends 12 dB above

6.6 External side-chain

Use this button to feed Squeezer's side-chain with an **external** signal. For more information, please see section 2.7.4.

6.7 Listen to side-chain



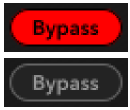
Listen to the internal or external side-chain by clicking this button. If you have engaged the side-chain filters, you will hear the *filtered* signal.

6.8 Automatic make-up gain

When this button is engaged, Squeezer tries to counter the jumps in level caused by changing threshold and compression ratio.

Implementing **automatic make-up gain** is an exercise in compromise, so its quality depends on the incoming signal's level (among a lot of other factors). Changing input trim (section 5.4) can sometimes improve results.

6.9 Bypass compression



Click on this button to **bypass** Squeezer. I regard this as the most important control of any compressor, as its easy to *deteriorate* a signal by compression without noticing it.

Thus, I recommend matching the levels of compressed and uncompressed signal (see section 5.4) and comparing them by toggling the bypass button.

6.10 Reset button

A click on this button **resets** all meters. This action will also reload the current skin and re-draw everything.

6.11 Select a skin

Click on this button to select a new Squeezer **skin**. You can also set a default skin that will be loaded when new plug-in instances are started.

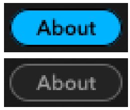
6.12 View and copy settings

Display all of Squeezer's **settings** with a click on this button. This information is also copied to the clipboard for pasting into a text editor.

I wrote Squeezer while attending a course on compression and this feature made my life much easier.

6.13 About button

Clicking on this button will open the **about window** where you will be informed about version number, contributors, copyright and the GNU General Public License.

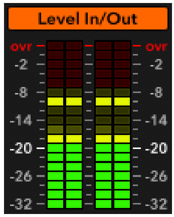


6.14 Display license

This button is located in the **about window** and does not only advertise that you are using free software licensed under the **GNU General Public License** – when clicked, it will also open the license's website in your browser . . .

7 Meters

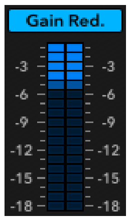
7.1 Input and output level



Squeezer's **level meters** consist of an average level meter (coloured bar) and a peak level meter (single coloured segment riding on top). The meters are divided into steps of 2 dB and exhibit a flat frequency response.

The *average* level meter reaches 99 % of the final reading in 300 ms, whereas the *peak* level meter has a rise time of one sample and a fall time of 8.67 dB/s.

7.2 Gain reduction



The **gain reduction meter** is divided into steps of 1 dB and displays *current* gain reduction. It also indirectly reflects ratio, attack and release time.

The gain reduction meter should always be in motion. If a part of the meter is always lit, consider reducing the threshold.

8 Final words

I want to express my gratitude to the **Audio Engineering Society** and to the **Rane Corporation** for their wonderful E-Libraries. This includes everybody who wrote the fine papers and notes, especially Dimitrios Giannoulis *et al.*[1] and Rick Jeffs *et al.*[2]

I must also thank the **beta testers** and **users of Squeezer** for sending kind words, suggestions and bug reports. Finally, I want to thank the **open source community** for making all of this possible.

Although coding Squeezer has been a lot of fun, it has also been a lot of work. So if you like Squeezer, why not send me an email and tell me so? Write a few words about yourself, send suggestions for future updates or volunteer to create a nice skin. I also really enjoy listening to music that you have produced using my software . . .

Thanks for using free software. I hope you'll enjoy it!

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[1] **Giannoulis, Dimitrios; Massberg, Michael; Reiss, Joshua D.** Digital Dynamic Range Compressor Design – A Tutorial and Analysis. *JAES Volume 60 Issue 6 pp. 399-408; June 2012.*

[2] **Rick Jeffs; Scott Holden; Dennis Bohn.** Dynamics Processors – Technology & Application Tips. *Rane Corporation; Rane Note 155; 2005.*

A Build process

A.1 Dependencies

A.1.1 premake

Importance:	required
Version:	5.0.0 (alpha15)
License:	BSD
Homepage:	premake.github.io

Installation

Place the binary somewhere in your `PATH`. Depending on your platform, you should run `premake` using the scripts `Builds/render_templates.sh` or `Builds/render_templates.bat`.

To change the premake file using Jinja templates, you'll also have to install the necessary dependencies.

A.1.2 Compilers

Importance:	required
Linux:	Clang 10.0 (or gcc 9.3.0)
Windows:	Visual Studio 2019 (and above)
License:	proprietary (Visual Studio) / Open Source

Use premake (section A.1.1) to generate the Make files (or project) files needed by different compilers.

Different compiler versions may work, and premake supports other compiler tool sets as well. But in this case, you're on your own!

A.1.3 JUCE library

Importance:	required
Version:	6.0.5
License:	ISC and GPL v3 (among others)
Homepage:	www.juce.com

Installation

Extract the archive into the directory `libraries/juce`.

A.1.4 Virtual Studio Technology SDK

Importance:	optional
Version:	2.4
License:	proprietary
Homepage:	www.steinberg.net

Installation

The VST3 SDK is now open source and included in JUCE.

For VST2 SDK, extract the archive into the directories `libraries/vst2`. The proprietary VST2 SDK is not available anymore and you may only distribute VST2 plug-ins if you have signed the old license agreement!

A.1.5 Python

Importance:	optional
Version:	3.8 (or higher)
License:	Python Software Foundation License
Homepage:	www.python.org

You'll only need Python if you want to auto-generate files from Jinja templates.

Installation (Windows)

You can download an installer from the website.

A.1.6 Jinja

Importance:	optional
Version:	2.10 (or higher)
License:	BSD
Homepage:	jinja.pocoo.org

You'll only need Jinja if you want to auto-generate files such as the premake file from templates (see section A.1.1).

A.1.7 Artistic Style

Importance:	optional
Version:	3.1
License:	LGPL v3
Homepage:	astyle.sourceforge.net

This application formats the code so it looks more beautiful and consistent. Thus, you only have to install it if you plan to help me with coding.

Installation

Place the binary somewhere in your `PATH`. Depending on your platform, you should run `astyle` using the scripts `Source/format_code.sh` or `Source/format_code.bat`.

A.1.8 googletest

Importance:	optional
Version:	1.10.0
License:	BSD 3-clauses
Homepage:	github.com/google/googletest

This is a framework for testing and mocking. You only need to install it if you plan to help me with coding.

Installation on GNU/Linux

Extract the archive into the directory `libraries/googletest`, change into this directory and run:

32 and 64 bit

```
mkdir googletest/build
cd googletest/build
```

64 bit

```
rm -f ./CMakeCache.txt
cmake ..
make
mkdir -p lib/linux/amd64/
mv lib/*.a lib/linux/amd64/
make clean
```

A.2 General preparation

Copy `Source/build_id-COPY.h` to `Source/build_id.h`.

Edit the copied file to add a custom build ID to the ”About” dialog. Or set up Git hooks that update the file for you.

A.3 GNU/Linux

A.3.1 Environment

Supporting 32-bit Linux has become very tedious in the last years, so I have officially dropped it. But it should be easy to adapt these instructions to 32-bit systems.

To build this application yourself, I recommend setting up a `chroot` environment. This is fast and easy to do on Debian-based systems and might save you a **lot** of trouble. At the time of writing, I'm using Linux Mint 20, but the procedure should be similar on your distribution of choice.

Start by installing the necessary packages:

32 and 64 bit

```
sudo apt install debootstrap schroot
```

Then install the `chroot` base system by executing the following statements:

64 bit

```
sudo debootstrap --variant=buildd \
  --arch amd64 focal \
  /srv/chroot/focal_amd64 \
  http://archive.ubuntu.com/ubuntu
```

Running `debootstrap` will take some time. Meanwhile, add the following lines to `/etc/schroot/schroot.conf` (make sure you remove all preceding white space so that each line begins in the first column):

64 bit

```
[focal-amd64]
description=Ubuntu focal (amd64)
directory=/srv/chroot/focal_amd64
profile=default
personality=linux
type=directory
users=username
```

Please make the necessary changes to `username`. If you experience problems, you can try to change `focal` to a release name such as `buster`.

When `debootstrap` is done, log in as superuser:

64 bit

```
sudo schroot -c focal-amd64
```

First, install a few packages (`less`, `mc` and `vim` are optional, but might come in handy):

32 and 64 bit

```
apt update
apt -y install bash-completion less vim
```

Then, use `vim` to change a line in `/etc/apt/sources.list` (please ignore the line break, it should be a single line):

32 and 64 bit

```
deb http://archive.ubuntu.com/ubuntu focal
main restricted universe
```

Now install the remaining packages:

32 and 64 bit

```
apt update
apt -y install clang cmake mc libasound2-dev \
  libjack-jackd2-dev libpthread-workqueue-dev \
  mesa-common-dev xorg-dev
apt clean
```

If you like `bash` completion, you might also want to open the file `/etc/bash.bashrc` and unquote these lines:

32 and 64 bit

```
# enable bash completion in interactive shells
if [...]
  [a couple of lines...]
fi
```

Finally, log out and log in as normal user:

64 bit

```
schroot -c focal-amd64
```

In this `chroot` shell, install the dependencies (section A.1). Congratulations – you are now ready to build!

A.3.2 Build

After preparing the dependencies, start your chroot environment

64 bit
```
schroot -c focal-amd64
```

change into the directory Builds and execute

32 and 64 bit
```
./render_templates.sh
make config=CFG TARGET
```

where CFG is debug_x64, or release_x64, and TARGET is the version you want to compile, such as linux_standalone_stereo.

In case you run into problems, you can try to switch compilers by opening the file run_premake.sh and using the premake options --cc=clang or --cc=gcc.

The compiled binaries will end up in the directory bin.

A.4 Microsoft Windows

A.4.1 Build

After setting up the dependencies, open the directory `Builds` and execute

32 and 64 bit

```
./render_templates.bat
```

Then change into the directory `Builds/windows/vs20xx`, open the project file with the corresponding version of Visual Studio and build the project.

The compiled binaries will end up in the directory `bin`.

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```
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