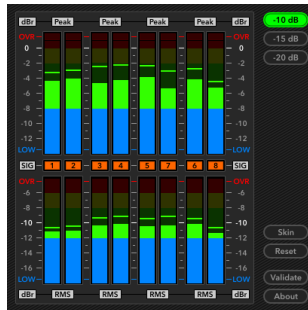


trakmeter

Loudness meter for correctly setting up
tracking and mixing levels



Last edited on 10th December 2020



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1 Digital recordings

The digital revolution brought many advantages to the field of audio processing: higher fidelity, less noise, non-degrading copies and the endless possibilities of digital signal processing. Unfortunately, however, digital audio also introduced some problems of its own.

Whereas the analogue domain is relatively inert against very high levels (overdriving some analogue equipment actually sounds pretty good), the digital domain punishes even small transgressions into forbidden territory with harsh clipping.

And while digital audio can be transferred without loss in quality, it is degraded by each and every calculation, be it a simple change in level, equalisation or a fancy effect. Crossing domains from analogue to digital and *vice versa* leads to additional degradation. Finally, changes in bit depth or sampling rate, jitter and inter-sample peaks are nothing for the weak of heart.

However, most of these obstacles can easily be overcome by proper gain staging, dithering, minimising the crossing of domains and choosing appropriate bit depths and sampling rates right from the beginning.

If you carefully choose, test and operate your equipment, you're well on your way to pure audio bliss ...

1.1 Definitions

RMS <i>root mean square</i>	statistical method used for calculating an average from fluctuating values
dBu <i>decibel unterminated</i>	level ratio with an analogue reference level of $0.7746 V_{\text{RMS}}$
dB FS <i>decibel relative to digital full-scale</i>	level ratio with a reference level equal to the maximum representable value of a digital signal
dBr <i>decibel relative to reference level</i>	level ratio with an arbitrary reference level that must be specified; for instance, 0 dBr may be equal to -20 dB FS

1.2 Gain staging

The process of setting audio devices to run at optimal input and output levels is called *gain staging*.

Professional analogue audio equipment is designed to be run at a nominal level of +4 dBu. This leaves a headroom for peaks of at least **20 dB** to the clipping point. Thus, driving all analogue audio equipment at +4 dBu ensures an optimal

signal-to-noise ratio while preventing clipping and keeping all transients intact.

Now let's transfer this to the digital domain. First, choose an analogue reference level for your converter.¹ Then, record with an average input level of **-20 dB FS RMS**. Again, this ensures a good signal-to-noise ratio while preventing clipping. In addition, this level drives your outboard equipment and most of your plug-ins at their "sweet spot".

I also recommend recording with a maximum level of **-10 dB FS peak**. This will leave enough space for sudden jumps in level and may also improve the sound of your recordings. Some analogue-to-digital converters already degrade audio when fed with levels close to digital full-scale (0 dB FS), resulting in the "harshness" that is often attributed to digital audio.

Try this: record a clearly defined signal (such as a sine wave) and increase its level while analysing the obtained signal with a spectrum meter. Overtones will probably appear at levels way below clipping point (see [section 1.5](#)). Their individual level may be low but will accumulate when you mix recordings – and our ears are sensitive for distortion.

Gain staging doesn't stop here. Set up your mixer so that channel levels are lower than subgroup levels, which in turn should be lower than the master output levels. No clipping should occur anywhere in the mixer, which is especially important if you want to insert external analogue

¹for more information, see [Level Practices \(Part 1\)](#) by Bob Katz; a reference level of +4 dBu = -15 dB FS works well for me

gear.² Do not overload effects or plug-ins and (if possible) try to match their input and output volume.³

Speaking of me, once I transitioned to proper gain staging, my recordings and mixes became much cleaner. And the effort involved was pretty small!

1.3 Digital audio myths

I can almost hear you: digital recordings should be made at peak levels close to but not exceeding 0 dB FS. Unfortunately, this misleading information has ended up in many manuals for professional audio equipment. But that doesn't make it any truer ...

Even if you record at *peak* levels of -18 dB FS, a bit depth of 16 bits will yield a signal-to-noise ratio of 78 dB. That is about what you can expect from the best professional analogue tape machines and recording desks!

But think of the approximate 19 bits modern converters can capture.⁴ In this case, recording at peak levels of -18 dB FS yields an incredible signal-to-noise ratio of 96 dB. This is

²for mixer inserts, I recommend maximum input and output levels of **-10 dB FS peak** for the same reasons mentioned above

³many digital signal processors use floating-point calculations and handle clipping gracefully; others, especially those modelling old analogue equipment, may clip badly

⁴all real-world analogue circuits are contaminated with thermal noise which limits the achievable signal-to-noise ratio of converters

fully equivalent to using a bit depth of 16 bits and recording at levels close to clipping point!

So there really is no point in recording at extreme levels.

If you are still sceptical, read these three GearsLutz posts written by a renowned engineer: [#1](#), [#2](#) and [#3](#). The highly regarded manufacturer *Harrison Audio* also recommends a maximum peak recording level of [-15 dB FS](#) for their *Mixbus 32C* digital audio workstation. Finally, I highly recommend reading [this article](#) in *Sound On Sound*.

1.4 Introducing traKmeter

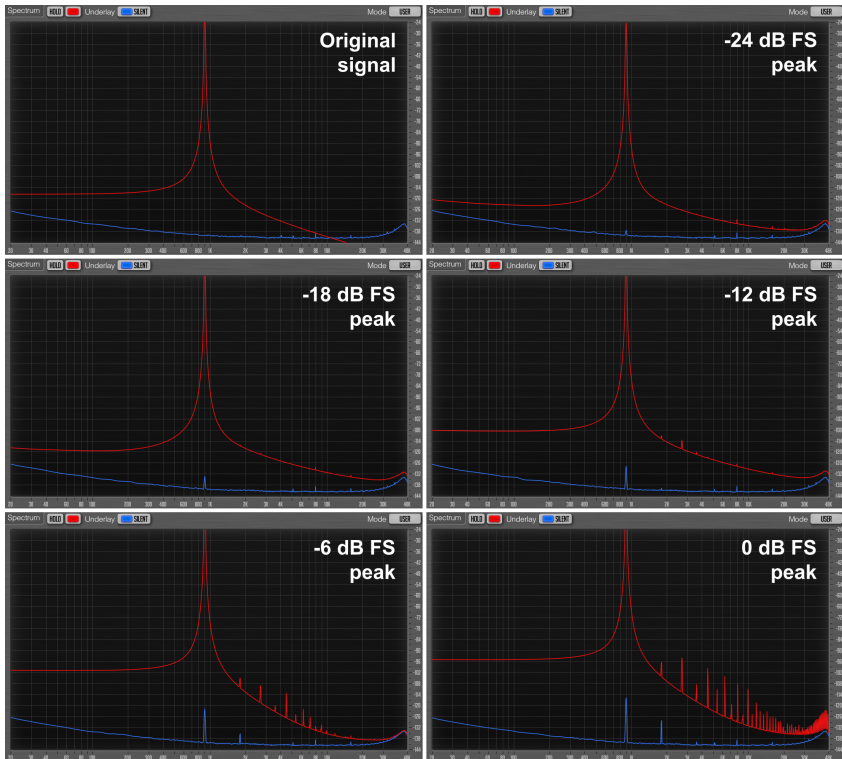
Sadly, most digital audio equipment only has peak meters. This is readily understandable as you want to avoid digital clippings by all means. However, badly chosen meter ranges and scales often render these meters useless. And the lack of average meters does not exactly facilitate gain staging.

When I had realised this, I started coding traKmeter. It has evolved with my growing knowledge and recording experience, but the underlying ideas haven't changed at all.

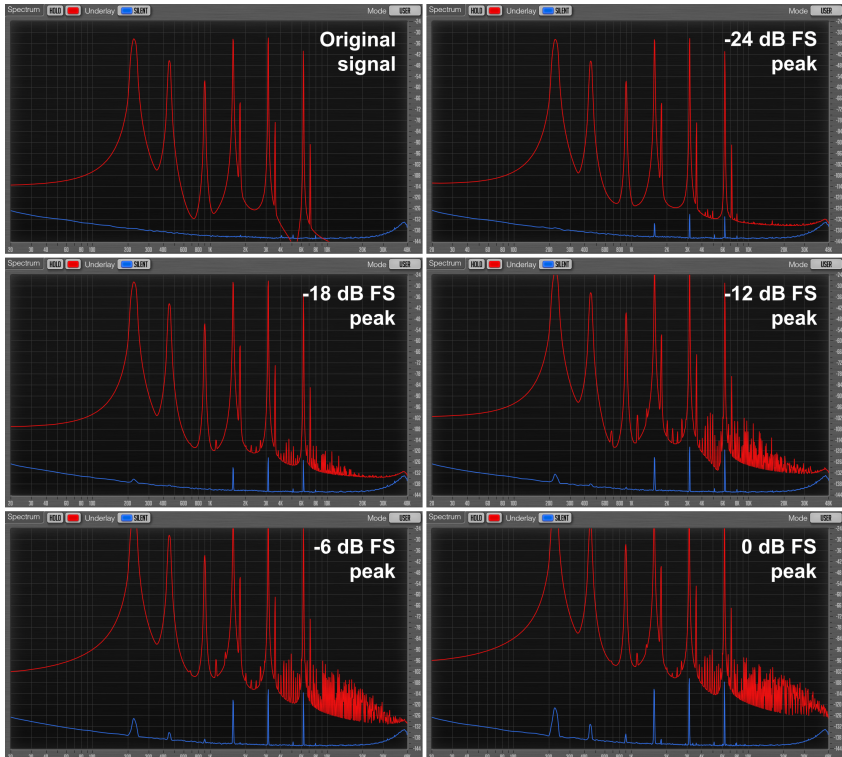
1.5 Converter clipping

This experiment was conducted with a *RME Fireface 800* interface (96 kHz, 24 bits, 0 dB FS set to +19 dBu). Signals were sent to an output connected directly to an input (**red lines**). A floating input served as reference (**blue lines**).

1.5.1 Single sine wave



1.5.2 Complex signal (several sine waves)



2 traKmeter

traKmeter consists of two meters, a peak meter on top and an average meter below. The meters are separated by an orange signal LED and consist of a green area that is enclosed by a blue one (lower levels) or a yellow and red one (higher levels).

The average meter's green area is centred around the **-10 dBr RMS** mark. With a reference level of -10 dB FS, this corresponds to the **-20 dB FS RMS** we have determined to be the optimal average recording level in the digital domain.

The peak meter's yellow area reaches up to **0 dBr peak**. Given the same reference level, this corresponds to **-10 dB FS peak** and peak levels shouldn't exceed this level.

Thus, by keeping the meter's readout **in the green** and yellow areas and **out of the red** areas, you will automatically track at optimal audio levels. It's as simple as that!



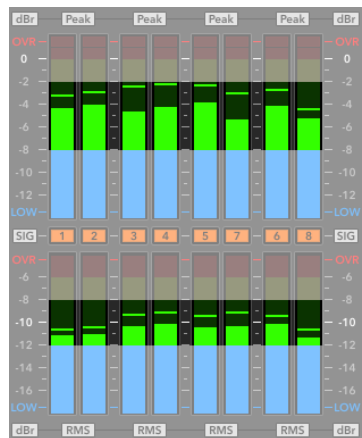
2.1 Tracking with traKmeter

Open up an instance of traKmeter and set it up so that it measures your audio input. That can be done either by starting the stand-alone version and connecting it to one or more input channels of your analogue-to-digital converter, or by inserting a plug-in instance into an input channel of your digital audio workstation (no latency is added).

In the second case, take care that your digital audio workstation doesn't add additional headroom and that no processing takes place before traKmeter. This can be ascertained by feeding calibration tones into your converter or by directly comparing the readouts of stand-alone and plug-in version.

Now, feed the signal you want to record into an audio input channel and adjust its level (in the analogue domain!). Try to set the input level so that it falls into the average meter's **-10 dBr** area.

Make sure that peak levels very rarely (if ever) exceed **0 dBr**. In case both conditions cannot be met simultaneously, adjust the peak level only.



2.2 Mixing with traKmeter

When you get someone else's tracks for mixing, chances are that they have been recorded far too hot. While you can't change that, you should adjust the tracks to optimal loudness in the gain staging phase. This is easily accomplished using traKmeter and either the mixer's trim knob or a (properly dithered!) gain plug-in. Just make sure that the gain change precedes all future processing.

Mixing levels will now be much lower than what you might be used to. This can easily be corrected by either adjusting the output gain of your subgroups or by inserting a gain plug-in in your master track.

To preserve all transients, the final loudness of your mix should stay within certain average level ranges. My plug-in **K-Meter** may help you with setting up correct mixing levels. Remember that smashed transients will be gone forever, whereas you can always bring up the volume during mastering!

3 Installation

In order to use the pre-compiled binaries, simply extract the traKmeter 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 `trakmeter` is mandatory and must be moved to the plug-in (or stand-alone) folder!

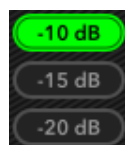
traKmeter requires a processor which supports the SSE2 instruction set. On Windows, you might also have to install the [Visual C++ Redistributable for Visual Studio 2017](#).

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

4 Controls

4.1 Reference level buttons

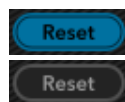
Set your reference level (corresponding to the preferred maximum peak recording level) with these buttons. To follow the advice in [section 1.2](#), leave this at the default setting of **−10 dB FS**.



If you record very dynamic material or have problems getting a clean signal, you can try the other settings. They shift both meter scales down by 5 dB to 10 dB and add additional headroom at the cost of a higher noise floor. Which you probably won't even notice, as the signal-to-noise ratio of modern converters is extremely high.

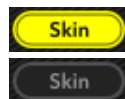
4.2 Reset button

Click on this button to reset all meters. This action will also reload the current skin and re-draw everything.



4.3 Select a skin

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



4.4 Validation button

Click on this button to open the **validation window** (see [chapter 7](#)) which allows you to play an audio file through traKmeter and dump internal data. During validation, the button will light up and clicking on it will stop validation early.



On Linux, dumped data will be written to `stderr`, so just start the traKmeter stand-alone or your plug-in host from the shell and watch the output coming. On Windows, you can use DebugView by Sysinternals (stand-alone) or have a look at Ableton Live's log files (plug-in). If none of that works, you might have to start either the stand-alone or your plug-in host from a debugger.

As a side note, **SMA(50)** designates the simple moving average of 50 values, a neat way to emphasise trends and eliminate short-term fluctuations.

4.5 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.



4.6 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 web browser ...



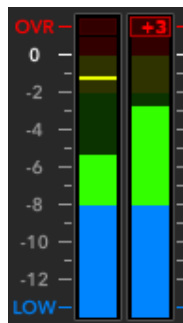
5 Meters

All meters possess a flat frequency response. Meter scales are in dBr and their reference level is adjustable (see [section 4.1](#)). This way, scales remain the same even when the reference level changes.

5.1 Peak level meter

This meter shows the current peak level in dBr. Rise time is one sample and fall time is 8.67 dB/s. Peak levels exceeding 0 dBr are displayed on the red LED marked “OVR”.

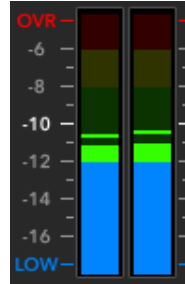
The highest encountered peak level will be held indefinitely until the meter is reset.



5.2 Average level meter

The average level meter uses an averaging period of 1024 samples. It has been calibrated so that sine wave signals read the same on both peak and average meters. Similar to a VU meter, it takes 300 ms for the meter to reach 99 % of the final reading. There is no overshoot, however.

Peaks will be held for 10 s and then fall with a speed of 8.67 dB/s.



5.3 Signal meter

The orange signal meter detects peak levels at a threshold of -60 dB FS. It has a rise time of one sample and fades out when the level falls below the threshold.



6 Recording advice

Over the years, I have learned how to and how not to record, and this seems like a good place to summarise my knowledge. For controversial advice, I will try to reference the opinion of professionals.

Use a good pre-amplifier. “Good” doesn’t mean your pre-amplifier has to have a lot of channels or features. To the contrary! Go for a simple design and invest your money in professional quality instead. Recordings made with a good pre-amplifier sound better and make mixing much easier – the tracks simply seem to fall into place.

Use the pre-amplifier’s gain control. If necessary, crank up the gain control to yield the correct output level. Do not fear the pre-amplifier’s internal noise – boosting a low-gain recording in later stages will result in even more noise!

Avoid unbalanced equipment. Run all signals on balanced lines with a nominal level of +4 dBu. If you can’t, use DI boxes and transformers to convert the signals as early in the audio chain as possible.

And do not even *think* of buying equipment that has analogue RCA connectors!¹

Use short audio chains. All equipment adds noise or may otherwise degrade audio, so keep your audio recording chains short and simple. This has the additional benefit that you can focus on recording.

Here is an example: instead of routing your mixer between pre-amplifier and converter, connect the mixer to your converter's outputs. This simple change can lead to much better recordings (especially with cheap mixers) and the artist will still be able to hear playback and herself during recording.

Work at a defined reference level. See the article [Level Practices \(Part 1\)](#) by Bob Katz.

Record at lower levels. During recording, do not let peak levels exceed **-10 dB FS**. For an in-depth explanation and references, see [section 1.2](#).

Record in mono. Most audio sources do not contain stereo information that is useful in a mixing context (notable exceptions are audience recordings, orchestras and occasionally pianos). The pseudo-stereo effects of synthesizers often cause phasing issues.

Recording such sources in stereo wastes space on your hard disk – and someone's time at a later stage.

¹“I have a real aversion to anything that calls itself ‘professional’ and has RCA jacks on it. That's just contradictory.”

Whitlock B. [Audio System Grounding & Interfacing – An Overview](#). 126th AES Convention; Munich; May 2009.

Use high bit depths. Do yourself a favour and record at a bit depth of 24 bits instead of 16 bits. The additional bits allow recording at lower levels and provide an incredible amount of extra detail. When disk space runs low, choose more bits over a higher sampling rate.²

The usable bit depth of converters is limited to approximately 20 bits by thermal noise. However, the mixer in your digital audio workstation should use floating point numbers with 32 bits *at the very least*. Calculation errors are inevitable in digital signal processing, so more bits mean smaller (and thus quieter) errors.

Use sensible sampling rates. The preferred sampling rate for recording audio is 96 kHz (88.1 kHz is just as good, but sees less support).³ Additionally, latency is lower at higher sample rates, and many plug-ins that internally use 96 kHz can bypass their oversampling.

Concentrate on recording. When tracking, try to not interfere with the flow of the session. Keep editing and mixing to the bare minimum!

Fix it now. Contrary to popular belief, you cannot “fix it in the mix” – a bad recording is nothing more than a bad recording. So editing and tools like Auto-Tune and extreme EQ should be seen as a last resort.

²see the [AES Pro Audio Reference](#) for more information

³“Although 60 kHz would [be ideal], 88.2 kHz and 96 kHz are closest to the optimal sample rate.” I highly recommend reading this paper!

Lavry D. [The Optimal Sample Rate For Quality Audio](#). *Lavry Engineering; White Paper; May 2012.*

Apart from the precious time lost in editing, it's easy to kill all of a track's vibe in the process.

Instead, keep recording until you capture a great take. Treat your room acoustically and in terms of positive vibe. Experiment with microphone placement. And try absolutely everything that may help the artist in achieving a stunning performance!

Make it exciting. A lot of today's music sounds like (and actually is) one short loop that was "arranged" by muting different tracks at different times. This takes away all the small inaccuracies of human players and often leads to boring and lifeless songs.

So think of a good arrangement before you even start recording. And instead of looping a track, record a couple of takes and comp the best ones. You'll be surprised at the difference it makes!

7 Validation

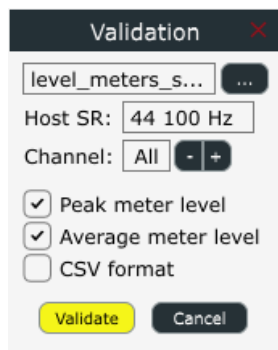
I have gone to great lengths to ensure that the meters read correctly. You want to validate for yourself? Just download and extract the source code. The directory `validation` contains instructions and FLAC-compressed wave files. A word of warning: these audio files may **damage your ears** and speakers, so please watch your monitor levels!

Begin by starting `traKmeter`. If in a Bash shell, try this:

```
_____ 32 and 64 bit _____  
./trakmeter_stereo 2>&1 | tee /tmp/validate.log
```

After opening the **validation window** (see [section 4.4](#)), click on the ellipsis button (the one with the dots) to select an audio file for playback through `traKmeter`. Please make sure that the sampling rates of your host (**Host SR**) and the audio file match, otherwise the results will not be correct.

Now, select which **variables** (if any) should be dumped. You may also re-



strict dumped data to a specific audio **channel**. Check **CSV** if you want to feed the output to a parser.

Finally, click on the **validate** button to reset all meters and start playback of the selected audio file. All audio input will be discarded during playback and for an additional twenty seconds. To stop playback early, simply click on the **validate** button again.

7.1 Validation status

	Test	Valid
Average level meter	visuals	✓
	readout	✓
Peak level meter	visuals	✓
	readout	✓
Signal meter	visuals	✓

8 Help needed

As traKmeter was coded using cross-platform code, it should be easy to compile on Mac OS X. Unfortunately, I happen to not have a Mac ...

In case you want to help, please see the next chapter for an email address. You'll need sufficient experience in coding, compiling and debugging, though, so no beginners please!

9 Final words

I want to thank **Rickard** of Interfearing Sounds for asking me how to use K-Meter for tracking. This question and the following thoughts really got traKmeter started. I'd like to thank **bram@smartelectronix** for his code to calculate logarithmic rise and fall times.

I must also thank the **beta testers** and **users of traKmeter** 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 traKmeter has been a lot of fun, it has also been a lot of work. So if you like traKmeter, 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!

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 / 3.6.14
License: proprietary / GPL v3
Homepage: www.steinberg.net

Installation

Extract the archives into the directories `libraries/vst2` and `libraries/vst3`. The proprietary VST2 SDK is not available anymore. **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=build \
  --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 pre-make 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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Version 3, 29 June 2007

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