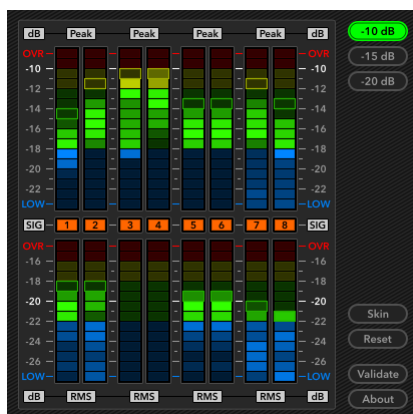


traKmeter

Loudness meter for correctly setting up
tracking and mixing levels



Last edited on 11th August 2018



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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. And 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 untermiated</i>	analogue level ratio with a reference level of $0.7746 V_{\text{RMS}}$
dB FS <i>decibel relative to digital full-scale</i>	digital level ratio with a reference level equal to the maximum representable value

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 experiment: record a sine wave and increase its level while checking the input with a spectrum meter. It is quite possible that overtones appear at levels way below the clipping point.

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 got much better. And apart from coding traKmeter, 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 misinformation 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 -20 dB FS and you discard the least significant bit (which mostly consists of errors and dithering noise), a bit depth of 16 bits would still leave you with a signal-to-noise ratio of 70 dB. That is about what you can expect from some of the best professional analogue tape machines and recording desks! And we're not even

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

³Today, most digital signal processors use floating-point calculations and handle clipping gracefully. But I wouldn't rely on that ...

talking of the 20 bits⁴ that you can capture with modern converters ...

You don't have to take my word – read these three Gearslutz posts written by a renowned engineer: [#1](#), [#2](#) and [#3](#). Also, the highly regarded manufacturer Harrison Audio recommends a maximum peak recording level of [-15 dB FS](#) for the Mixbus 32C digital audio workstation.

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.

⁴In the real world, all analogue circuits are contaminated with thermal noise which limits the usable bit depth of converters. Among other factors, the amount of thermal noise depends on temperature and sampling frequency – see [here](#) for more information.

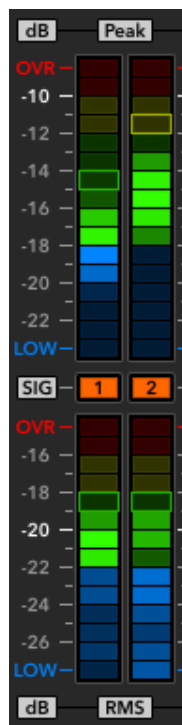
2 traKmeter

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 an area of green LEDs that is enclosed by either blue ones (lower levels) or yellow and then red ones (higher levels).

The average meter's green area is centred around the **-20 dB FS RMS** mark. This number should be vaguely familiar: this is the level we have determined to be the optimal average recording level in the digital domain.

The highest yellow LED on the peak meter's top end corresponds to a level of **-10 dB FS peak**. Again, this number should be familiar: 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!

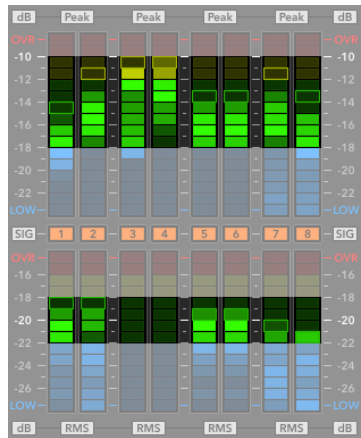


2.1 Tracking with traKmeter

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!) using traKmeter. Try to set the input level so that it falls into the average meter's **-20 dB FS** area. Make sure that peak levels very rarely (if ever) exceed **-10 dB FS**. 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.

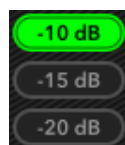
traKmeter requires a processor which supports the SSE2 instruction set. On Windows, you might also have to install the [Visual C++ Redistributable for Visual Studio 2017](#).

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

4 Controls

4.1 Recording level buttons

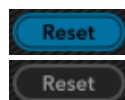
Select your preferred maximum peak recording level with these buttons. To follow the advice in [section 1.2](#), leave this at the default setting of **-10 dB FS**.



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.

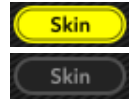
4.2 Reset button

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-ins are instantiated.



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 can be adjusted using the “Recording level” buttons (see [section 4.1](#)).

5.1 Peak level meter

This meter shows the peak level in dB FS and has been calibrated so that an input sample value of 1.0 reads 0 dB FS. Rise time is one sample and fall time is 8.67 dB/s. Should a meter overflow occur, the red LED marked “OVR” will display the corresponding peak level.

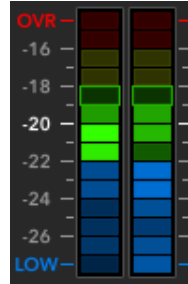
The highest encountered peak level will be held indefinitely until the meter is reset.



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 likely 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.

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 synthesisers may even cause phasing issues.

Recording such sources in stereo will only waste space on your hard disk. So don't!

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. See the [AES Pro Audio Reference](#) for more information.

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 at least 32 bits. Calculation errors are inevitable in digital signal processing, and more bits mean smaller (and thus quieter) errors.

Use sensible sampling rates. According to a [white paper](#) by Dan Lavry, manufacturer of high-quality converters, 88.1 kHz and 96 kHz are the preferred rates for recording audio. As support for 88.1 kHz is limited, I prefer to work at 96 kHz.

Concentrate on recording. When tracking, try to not interfere with the flow of the session. Just 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. 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. 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

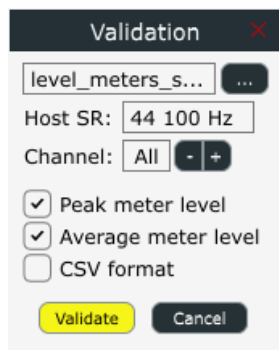
I have gone to great lengths to ensure that the meters read correctly. You want to validate for yourself? Just download and extract the source code. The directory `validation` contains instructions and FLAC-compressed wave files. A word of warning: these audio files may **damage your ears** and speakers,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

Here is my email address (please remove “-nospam”):

"Martin Zuther" <code-nospam@mzuther.de>

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

A How to build traKmeter

A.1 Dependencies

A.1.1 premake

Importance: required

Version: 5.0.0 (alpha12)

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/run_premake.sh` or `Builds/run_premake.bat`.

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

A.1.2 JUCE library

Importance: required

Version: 5.3.2

License: ISC and GPL v3 (among others)

Homepage: www.juce.com

Installation

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

If you want to build the LV2 plug-in, please extract the archive `distrho_lv2-xxxxxxxx.tar.gz` into the same directory.

A.1.3 Virtual Studio Technology SDK

Importance: optional

Version: 2.4 / 3.6.8

License: proprietary / GPL v3

Homepage: www.steinberg.net

Installation

Just extract the archive into the directory `libraries/vst`.

A.1.4 Python

Importance: optional

Version: 3.5 (or higher)

License: Python Software Foundation License

Homepage: www.python.org

You'll only need Python if you want to change the premake file (see [section A.1.1](#)) using Jinja templates.

Installation (Windows)

You can download an installer from the website.

A.1.5 Jinja

Importance: optional

Version: 2.8 (or higher)

License: BSD

Homepage: jinja.pocoo.org

You'll only need Jinja if you want to change the premake file using templates (see [section A.1.1](#)).

A.1.6 Artistic Style

Importance: optional

Version: 2.05.1

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 traKmeter.

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.2 GNU/Linux

A.2.1 Environment

To build traKmeter 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 18, but the procedure should be similar on your distribution of choice.

Start by installing the necessary packages:

32 and 64 bit

```
sudo apt-get install debootstrap schroot
```

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

32 bit

```
sudo debootstrap --variant=buildd \  
  --arch i386 stable \  
  /srv/chroot/stable_i386 \  
  http://httpredir.debian.org/debian
```

64 bit

```
sudo debootstrap --variant=buildd \  
  --arch amd64 stable \  
  /srv/chroot/stable_amd64 \  
  http://httpredir.debian.org/debian
```

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):

```
32 and 64 bit
[stable-i386]
description=Debian stable (i386)
directory=/srv/chroot/stable_i386
profile=default
personality=linux32
type=directory
users=username

[stable-amd64]
description=Debian stable (amd64)
directory=/srv/chroot/stable_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 `stable` to a release name such as `wheezy`.

When debootstrap is done, log in as superuser:

```
32 bit
schroot -c stable-i386 -u root
```


64 bit

```
schroot -c stable-amd64 -u root
```

You'll have to install a few packages – less and vim are optional, but might come in handy:

32 and 64 bit

```
apt-get update
apt-get -y install bash-completion clang \
    libasound2-dev libjack-jackd2-dev \
    mesa-common-dev xorg-dev less vim
apt-get 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:

32 bit

```
schroot -c stable-i386
```

64 bit

```
schroot -c stable-amd64
```

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

A.2.2 Build

After preparing the dependencies, start your chroot environment

32 bit
`schroot -c stable-i386`

64 bit
`schroot -c stable-amd64`

change into the directory `build` and execute

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

where `CFG` is one of `debug_x32`, `debug_x64`, `release_x32` and `release_x64`, and `TARGET` is the version you want to compile, such as `linux_standalone_stereo`.

You can 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.3 Microsoft Windows

A.3.1 Build

After preparing the dependencies, change into the directory build and execute

_____ 32 and 64 bit _____
./run_premake.bat

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

The compiled binaries will end up in the directory bin.

B Licenses

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Version 3, 29 June 2007

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