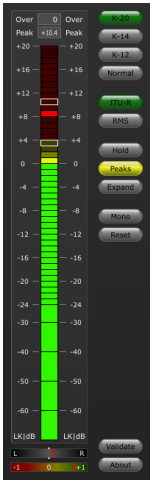
traKmeter

Loudness meter for correctly setting up
tracking and mixing levels



Last edited on 30th September 2012

Contents

1 Digital recordings

The digital revolution brought a lot of advantages to the field of audio processing such as higher fidelity, less noise and non-degrading copies. Unfortunately, however, digital audio also introduced some problems of its own.

Whereas the analog domain is relatively inert against levels exceeding 0 dB FS (overdriving some analog equipment actually sounds 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 analog to digital and *vice versa* leads to additional degradation. Finally, changes in bit depth and sample rate, jitter and inter-sample peaks are nothing for the weak of heart.

However, most of these obstacles can be overcome easily by proper gain staging, minimising the crossing of domains and choosing appropriate bit depth and sample rates. If you also learn how to properly test and operate your equipment, you're well on your way to pure audio bliss!

1.1 Gain staging

Professional analog audio equipment is designed to be run at nominal levels of +4 dBu (1.23 V_{RMS}), leaving a headroom for peaks of about 20 dB. This is consistent with the maximum crest factor of analog audio signals.

Thus, driving all equipment at +4 dBu ensures an optimal signal-to-noise ratio while preventing clipping and keeping transients intact. The process of setting optimal input and output levels is called gain staging. It starts at using a good preamp and cranking it up to the needed output level. Do not fear the preamp's internal noise – making up for low gain in later stages will only result in even more noise!

Now let's transfer gain staging to the digital domain. The maximum crest factor of analog audio signals is around 20 dB, so we'll have to adjust the headroom accordingly. To keep with international standards, we'll follow the EBU R68-2000 recommendation and set our average input and output levels to −18 dB FS RMS.

Again, this ensures an optimal signal-to-noise ratio while preventing clipping. It also drives (most of) your digital audio equipment and plug-ins at the "sweet spot".

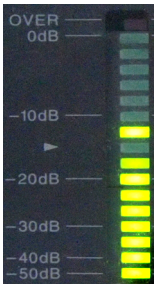
Another recommendation is that peak levels should not exceed −9 dB FS (EBU R68-2000) during recording, leaving enough space for inter-sample peaks. Inter-sample peaks are audio peaks that lie *in between* two successive samples and may lead to unpredictable clippings during digital-to-analog conversion.

1.2 Digital audio myths

I can almost hear you: you have heard that digital recordings should be performed at levels close to but not exceeding 0 dB FS ("digital full-scale"). Heck, this misinformation has ended up in the manuals of some professional audio equipment. But for the given reasons it is plain wrong.

Just do the math for a bit depth of 16 bit: even if your recordings peak at a (relatively low) level of −18 dB FS and you discard the least significant bit (some people claim that it mostly consists of errors), this still leaves you with a signal-to-noise ratio of 72 dB. That is about what you can expect from the best professional analog tape machines and recording desks!

As some sort of proof, the analog inputs and outputs of my 16-bit hard disk recorder (Otari PD-80) are aligned to "+4 dBu (−15 dB from digital full-scale)". The manufacturer has even marked this level on the meter bridge (small triangle on the photo). Although I admit that the mark is only useful for audio alignment, given that it sits on a peak meter…



If you do not believe me yet, simply record a couple of tracks at −2 dB FS peak and then repeat the experiment at −10 dB FS peak. Mix the tracks, adjust master levels and compare the mixes. The mix from the tracks recorded at higher level will almost certainly sound worse.

1.3 Introducing traKmeter

Most digital audio equipment sadly only has peak meters. This is readily understandable as you want to avoid digital clippings by all means. However, the lack of average meters makes correct gain staging harder. And this is were **traKmeter** comes in.

2 Recording tips

Over the years, I have accumulated a couple of recording tips. You may not know some of them, so read ahead!

Use a good preamp. Crank it up. "Good" doesn't mean your preamp has to have a lot of channels or features. In the contrary! Go for a simple design and invest your money in better quality instead.

Crank the preamp up to the needed output level. Do not fear the preamp's internal noise – making up for low gain in later stages will only result in even more noise! Also see section 1.1.

Avoid unballanced equipment. Run all signals on balanced lines with a nominal level of +4 dBu. If you can't, use DI boxes or transformers and read the previous sentence again.

Use short audio chains. All equipment adds noise or may otherwise degrade audio, so keep your audio chains as short as possible.

Record at lower levels. Record digital audio at −18 dB FS RMS with peak levels not exceeding −9 dB FS. For an in-depth explanation, see section 1.1.

Record in mono. Most audio sources do not contain stereo information that is useful in a mixing context (notable exceptions are audience recordings, string sections and sometimes pianos). The pseudo-stereo effects of some synthesisers may even cause phasing issues in the mixing stage.

Recording these sources in stereo will only waste space and make you miserable during mixing. So simply record them in mono.

Use high bit depths. Do yourself a favour and record at 24 bit instead of 16 bit. The additional bits provide an incredible amount of extra detail and you can record at lower levels without losing information. When properly dithered, changing to a lower bit depth even preserves some of that detail.

Also, if you edit audio files or apply effects, calculation errors are inevitable. At 24 bit, however, these artifacts are 48 dB lower in level (and thus inaudible) compared to 16 bit audio files.

Your digital audio workstation's bus should use at least 32 bits to avoid accumulation of the above-mentioned artifacts.

Avoid sample rate conversion. Sample rate conversion usually degrades audio (especially small changes of a few kHz), so try to record at the target sample rate. For instance, tracking for a CD release should be carried out at 44.1 kHz instead of 48 kHz.

There are of course exceptions to the rule, for instance you may prefer to track on a professional DAT machine (48 kHz) when your only other choice is using a consumer audio interface.

For tracking at higher sample rates, it pays to use exact multiples of your target sample rate (such as 88.2 kHz instead of 96 kHz) if your hardware and software permit. Please note that some professionals actually advise against using higher sample rates due to the possible build-up of noise beyond 20 kHz. It is also much more demanding on your computer, audio equipment and plug-ins – and may not be worth it. Try changing from recording at 16 bit to 24 bit first!

Finally, only use professional software for sample rate conversion. This is by no means a trivial task.

Dither often.

Treat your room.

Experiment with microphone placement.

3 Installation

In order to use the pre-compiled binaries, simply extract the traKMeter files from the downloaded archive. For the VST plug-in, you'll then have to move the extracted files to your plug-in folder (`~/.vst`, `C:\Program Files\Steinberg\VstPlugins\` or the like).

4 Controls

4.1 Reset button

Click on this button to reset all meters and peaks. You can also get rid of graphical artifacts, because the meters will be redrawn as well.

4.2 Validation button

Click on this button to open the **validation window** (see chapter 6) which allows you to play an audio file (WAV, AIFF or FLAC) through traKMeter and dump internal data. During validation, the button will light up and clicking it will stop the validation.

On Linux, dumped data will be written to `stderr`, so just start the traKMeter standalone or your VST host from the shell and watch the output coming. On other systems, have a look at your VST host's log files (I have successfully used Ableton Live for this). If that doesn't work, you might have

to start either the traKMeter standalone or your VST 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.

4.3 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.

4.4 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

5.1 Average level meter

The average level meter uses an averaging period of 1024 samples. This meter exhibits a completely flat frequency response.

On rising levels, it takes 10 ms for the meter to reach 99 % of the final reading (logarithmic). When the levels start falling, it generally has a fall time of 6 dB per second (linear), unless the level falls below -22 dB FS, when the ballistics change to 300 ms for the meter to reach 99 % of the final reading.

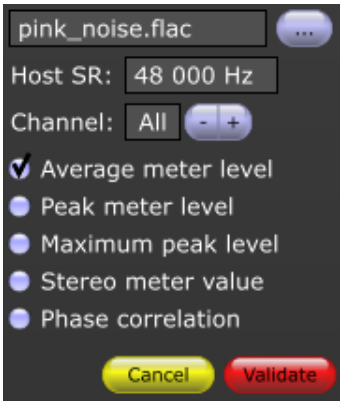
5.2 Peak level meter

The peak level meter displays also possesses a completely flat frequency response. It has a rise time of one sample and a fall time of 8.67 dB/s (linear).

6 Validation

TO DO!

I have gone to great lengths to ensure that all 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. To validate **ITU-R** mode, please download ITU-R BS.2217 and follow the instructions (at the time being, the tests for loudness gating should be ignored). A word of warning: these audio files may **damage your ears** and speakers, so please watch your monitor levels!



After opening the **validation window** (see section 4.2), click on the ellipsis button (the one with the dots) to select an audio file for playback through traKMeter. Please make sure that the sample 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 restrict dumped data to a specific audio **channel**.

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 ten seconds. To stop playback early, simply click on the **validate** button again.

In case you want to calibrate your monitor system, head over to Bob Katz's download section, get the file labelled **−20 dB FS RMS pink noise stereo 44.1**, set K-meter to **RMS** mode and click on the **validate** button. Please ensure that all intermediate software and hardware mixers are set to the correct levels.

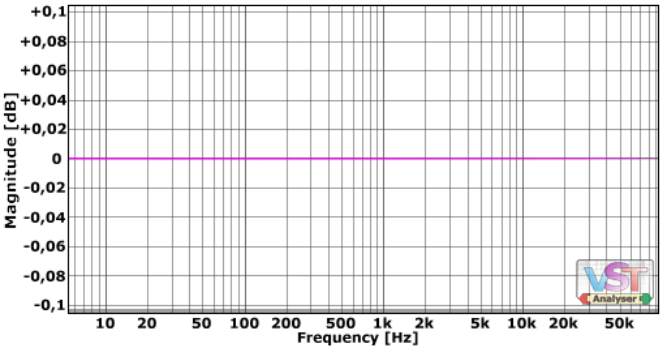
6.1 Validation status

	Readout	RMS	ITU-R
Avg level meter	meter ballistics	✓	✓
	readings	✓	—
	frequency response	✓	✓
	pink noise	✓	—
	ITU-R BS.2217	—	✓
Peak level meter	meter ballistics	✓	✓
	readings	✓	✓
Maximum peak	readings	✓	✓
Overload counter	readings	✓	✓
Phase correlation	readings	✓	✓
Stereo meter	readings	✓	✓

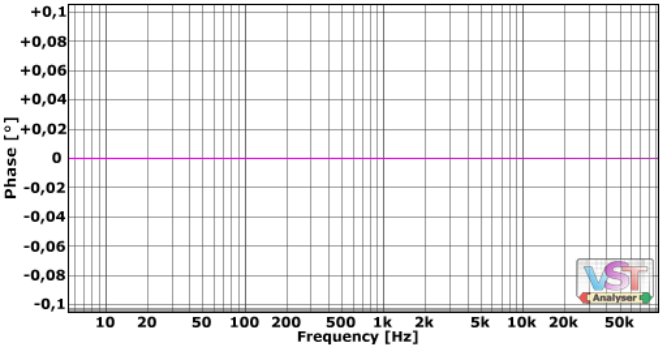
6.2 Frequency and phase response

Frequency and phase response have been determined at a sample rate of 192 kHz using VST Plugin Analyser.

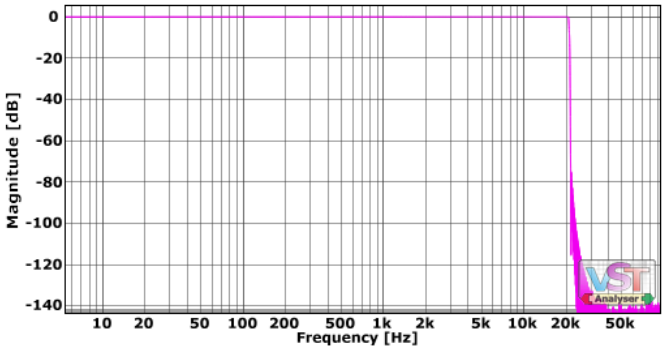
Frequency response of complete effect path (5 Hz to 96 kHz, 0 dB ±0.1 dB):



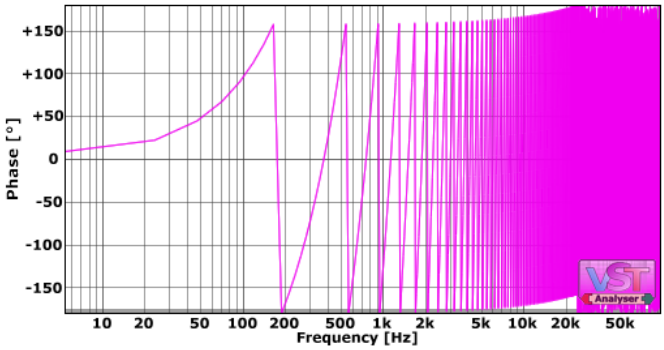
Phase response of complete effect path (5 Hz to 96 kHz, 0° ±0.1°):



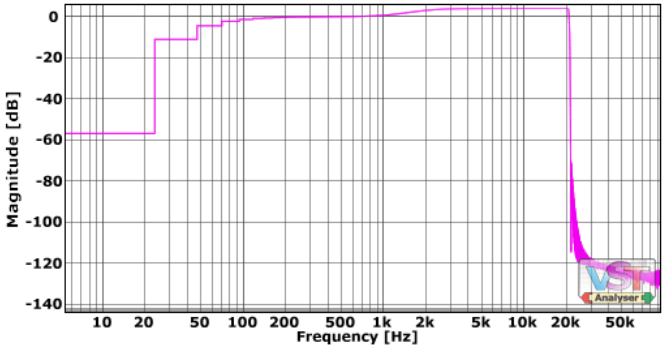
Frequency response of band-limited RMS detection stage (5 Hz to 96 kHz, −140 dB to 5 dB):



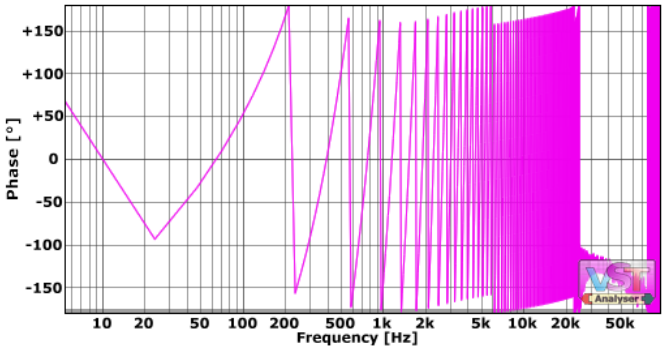
Phase response of band-limited RMS detection stage (5 Hz to 96 kHz, −180° to +180°):



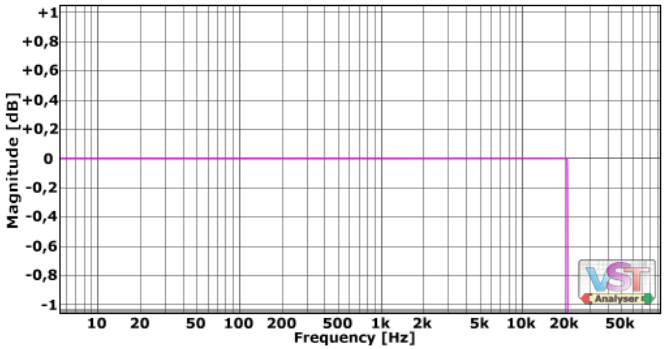
Frequency response of band-limited ITU-R BS.1770-1 detection stage (5 Hz to 96 kHz, −140 dB to 5 dB):



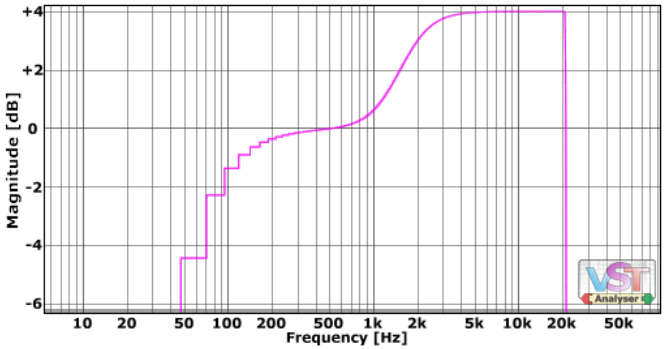
Phase response of band-limited ITU-R BS.1770-1 detection stage (5 Hz to 96 kHz, −180° to +180°):



Frequency response of band-limited RMS detection stage (5 Hz to 96 kHz, 0 dB ±1 dB):



Frequency response of band-limited ITU-R BS.1770-1 detection stage (5 Hz to 96 kHz, 0 dB −6 dB to 4 dB):



7 Help needed

As traKmeter was coded using cross-platform code, it should be easy to compile versions for Windows (64 bit) and Mac OS X. I just don't have the adequate systems and compilers.

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!

8 Final words

TO DO!

I want to express my gratitude to **Bob Katz** for kindly answering all of my questions regarding the K-System meter and checking this document for technical errors. I'd further like to thank **bram@smartelectronix** for his code to calculate logarithmic rise and fall times, and **Raiden** for working out the ITU-R BS.1770-1 filter specifications. 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 theme – do whatever you like!

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!

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A How to build traKmeter

TO DO!

A.1 Preparing GNU/Linux

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 13 (Maya), but the procedure should be similar on your distribution of choice. If you aim at generic 64-bit compilation, simply change `i386` to `amd64`.

To install the necessary packages and install the `chroot` base system, execute the following statements (please change `http://ftp.de.debian.org/debian/` to a mirror close to you):

```
sudo apt-get install debootstrap schroot

sudo mkdir -p /srv/chroot/squeeze_i386
sudo debootstrap --variant=buildd \
```

```
--arch i386 squeeze \
/srv/chroot/squeeze_i386 \
http://ftp.de.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):

```
[squeeze-i386]
description=Debian 6 (Squeeze, i386)
directory=/srv/chroot/squeeze_i386
personality=linux
root-users=username
type=directory
users=username,another_user
```

Please make the necessary changes to `username`. You may also add additional users, like `another_user`. In case you are setting up a 32-bit `chroot` environment on a 64-bit system, you'll also have to change `linux` to `linux32`.

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

```
schroot -c squeeze-i386 -u root
```

to install a few packages. The packages `less` and `vim` are optional, but might come in handy:

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

```
# enable bash completion in interactive shells
[two more lines...]
fi
```

Finally, log out and log in as normal user:

```
schroot -c squeeze-i386
```

Congratulations – after you have installed the dependencies (see below), you are ready to build traKMeter!

A.2 Dependencies

A.2.1 premake4

Importance: required
Version: 4.3
License: BSD
Homepage: industriousone.com/premake

Installation

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

A.2.2 JUCE library

Importance: required
Version: 1.53
License: GPL v2
Homepage: www.rawmaterialsoftware.com/juce.php

Installation

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

A.2.3 Virtual Studio Technology SDK

Importance: optional
Version: 2.4
License: proprietary
Homepage: ygrabit.steinberg.de

Installation

Just extract the archive into the directory `libraries/vstsdk2.4`.

A.2.4 Audio Streaming Input Output SDK

Importance: optional
Version: 2.2
License: proprietary
Homepage: ygrabit.steinberg.de

Installation

Simply extract the archive into the directory `libraries/asiosdk2.2`.

A.2.5 Artistic Style

Importance: optional
Version: 2.01
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 `src/format_code.sh` or `src/format_code.bat`.

A.3 Building on GNU/Linux

After preparing the dependencies, start your `chroot` environment, change into the directory `build` and execute

```
./run_premake.sh
make config=CFG TARGET
```

where `CFG` is one of `debug32`, `debug64`, `release32` and `release64`, and `TARGET` is one of `linux_standalone_stereo`, `linux_standalone_surround`, `linux_vst_stereo` and `linux_vst_surround`.

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

A.4 Building on Microsoft Windows

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

```
./run_premake.bat
```

Then change into the directory `build/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 GNU General Public License

Version 3, 29 June 2007

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