

K-Meter

Free implementation of a K-System meter
according to Bob Katz' specifications



Last edited on 4th November 2020



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1 The loudness race

When comparing two similar pieces of music, the louder one is perceived as sounding better. This is only true for very short periods of time and there is no evidence that louder music sells better. Still, the loudness of music productions has continuously grown during the last decades.

As maximum levels of records, tapes and digital media have a natural limit, however, mastering engineers use sophisticated dynamic compression techniques to achieve higher loudness without distorting the music. Unfortunately, they have even started distorting the music and reducing its stereo width to achieve even higher perceived loudness.

This decrease in dynamic range does not leave the music unharmed. Current compressed music blasts away your ears and makes you turn down the volume of your amplifier. Having lowered the volume, you'll find that the "better-sounding" compressed music suddenly sounds very dull and boring in comparison to music with less compression. In contrast, music with high dynamic range makes you turn up the volume – heck, it even sounds better when being broadcast on the radio!

2 The K-System

The K-System has been devised by mastering engineer Bob Katz in order to counteract the ongoing loudness race and to help adjusting the levels of different songs during mastering. K-System meters are level meters that do **not** place the 0 dB mark on top of the meter. Instead, 0 dB on K-System meters relates to a reference loudness. There are three K-System scales:

- K-20 (0 dB at –20 dB FS, recommended)
- K-14 (0 dB at –14 dB FS)
- K-12 (0 dB at –12 dB FS)

Using the K-System is easy. Just calibrate your monitor system so that pink noise (–20 dB FS RMS, 20 Hz to 20 kHz) yields 83 dB SPL¹ on each channel². Then mark the monitor’s gain position as “K-20”. Jump to [chapter 6](#) for information on how to find a suitable audio file.

¹This level has to be adapted to room size. You can find recommended sound pressure levels for different room **volumes** in table 10.2 of ATSC Recommended Practice [A/85:2013](#). To help you with conversion, 35 cubic feet are roughly equivalent to 1 m³.

²Measure with all other channels muted. Be careful to take different panning laws into consideration.

When your mixes or masters seem to have just the right loudness, they should now yield 0 dB on a K-20 meter.

In case you want to use the K-14 meter, attenuate the monitor gain by 6 dB or repeat the above process so that pink noise yields 77 dB SPL. For K-12, attenuate the monitor gain by another 2 dB (pink noise should yield 75 dB SPL). Please note, however, that this will lead to mixes and masters with a lot of compression.

For more information about the K-System, please see [Bob's website](#) or his great book “Mastering Audio – The Art and the Science (second edition)”.

3 Installation

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

K-Meter 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](#).

Loading K-Meter may take a few seconds: it checks your computer's capabilities on start-up so that FFT calculations will run at maximum speed. Be patient – this little wait in the beginning may well result in lower resource usage later.

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

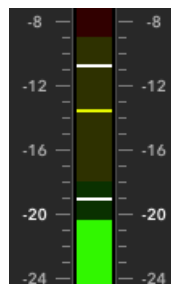
4 Controls

4.1 Meter selection

You can select the different K-System meter scales (**K-20**, **K-14** and **K-12**) by clicking on these radio buttons. In the rare case that you want to use the meter in a mixer's channel strip, click the **Normal** button which will place 0 dB FS on top of the meter's scale.

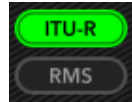


The **Normal** scale looks a little different. It has been designed for gain staging during recording: average levels should stay in the lower green area (and thus below **-18 dB FS**), while peak levels should not exceed the upper yellow bar (**-10 dB FS**). However, you may find my latency-free plug-in [traKmeter](#) better suited for gain staging.



4.2 Averaging method

The average level meters can either read unweighted levels (**RMS**) or loudness-weighted levels according to [ITU-R BS.1770-1](#) (**ITU-R**). Click on the corresponding radio button to make your selection.

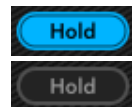


According to Bob Katz, the unweighted **RMS** method has been designed for stereophonic metering and calibration, while the loudness-weighted **ITU-R** method should be used for channel-summed loudness metering. To reference a meter, state both K-System meter scale and averaging method, separated by a slash, such as “K-20/ITU-R”.

Note: K-Meter fully implements Annex 1 of the now superseded ITU-R BS.1770-1 standard ('K' frequency weighting, mean square calculation and channel-weighted summation), whereas the gated loudness measurement specified in ITU-R BS.1770-4 is not supported.

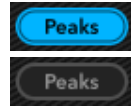
4.3 Infinite peak hold

Click on this button to toggle between infinite peak hold and “falling peaks”. This setting applies to both average and peak meters.



4.4 Show peak level meter

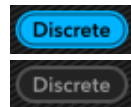
Click on this button to toggle display of the peak level meters. The original K-System meter specification demands peak level meters, but Bob Katz has asked me to hide them by default:



“Too many people will try to normalize the peak to full scale if they see a peak meter, and that’s what we want to avoid. You can still make a K-System meter like the original, but if we meet again in 15 years I hope that peak metering will be outlawed.”

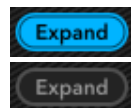
4.5 Discrete segments

This button switches between the discrete meters that are used on analogue gear and the continuous meters typically found in DAWs.



4.6 Magnify meters

This button magnifies both average and peak level meters to 0.1 dB steps. If switched on, the 0 dB mark (or -22 dB mark when using the **normal** scale) is placed near the meter’s bottom.



4.7 Monitoring section

4.7.1 Dim outputs

Clicking on this button attenuates K-Meter's output level by -20 dB. Click again to restore the original loudness.



4.7.2 Mute outputs

Clicking on this button mutes K-Meter's outputs. Click again to restore the output signal. Simple enough ...



4.7.3 Stereo flip

Clicking this button will flip the left and right channels. This is great to check if your ears or your room are playing any tricks on you.



Note: This button does not work in the surround version yet. I have an idea how to implement it, but I can't test it due to the lack of a surround system.

4.7.4 Mono

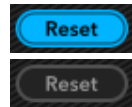
Click this button to check the mono compatibility of your stereo mix or master. The audio channels will be down-mixed to mono and the meters will be linked.



*Note: If you insert the stereo plug-in into a mono channel strip, the **mono** button will be selected and cannot be toggled. In the surround version, this button is disabled.*

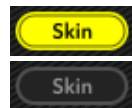
4.8 Reset button

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



4.9 Select a skin

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



4.10 Validation button

Click on this button to open the **validation window** (see [chapter 6](#)) which allows you to play an audio file through K-Meter 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 K-Meter 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.

4.11 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.



4.12 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 ...



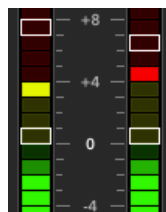
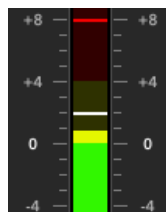
5 Meters

In accordance with [ITU-R BR.779-2](#) and [BS.1738](#), K-Meter assumes a 5.1 surround channel order of *L*, *R*, *C*, *LFE*, *Ls* and *Rs*. Please double-check whether this matches your host's channel order!

5.1 K-System meter

The K-System meter consists of an average level meter (coloured bar) and an optional peak level meter (single coloured segment). The recommended K-20 scale has 20 dB of headroom above 0 dB, while the K-14 and K-12 scales have 14 dB and 12 dB of headroom, respectively.

The discrete level meters are divided into steps of 1 dB, with the exception of the top 2 dB (steps of 0.5 dB) and the non-linear bottom end. Magnified discrete level meters are divided into steps of 0.1 dB.



Note: In ITU-R mode, the average level meter is graded in LK which stands for Loudness, K weighted and is by all means equivalent to dB.

Recent maximum levels are displayed by white bars or rectangles. Unless “Infinite peak hold” is switched on, maximum levels are held for 10 s and then start falling with a fall time of 8.67 dB/s.

Both stand-alone application and the plug-in only work at sampling rates between 44.1 kHz and 192 kHz and introduce a latency of 1024 samples. This latency is reported to your plug-in host so it may compensate for the introduced delay. Needless to say, the original unfiltered signal is passed to the outputs.

You can reset all meters by clicking on the “Reset” button.

5.2 Average level meter

The average level meter uses an averaging period of 1024 samples. In **RMS** mode, this meter exhibits a flat frequency response between 20 Hz and 20 kHz (± 0.01 dB), whereas **ITU-R** mode implements ‘K’ frequency weighting and also sums all channels as specified in [ITU-R BS.1770-1](#).

In all modes, the average level meter is band-limited using a windowed-sinc low-pass filter with a cutoff frequency of 21.0 kHz. On level changes, it takes 600 ms for the meter to reach 99 % of the final reading.

Note: Unfortunately, the specifications of ITU-R BS.1770-1 clash with those for K-System meters. I have discussed this in depth with Bob Katz and we decided that it makes more sense to adhere to ITU-R BS.1770-1 in these cases.

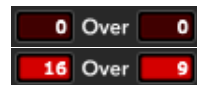
*Thus, in ITU-R mode sine waves do not read the same on average and peak level meters. Moreover, pink noise (-20 dB FS RMS, 20 Hz to 20 kHz) does not read 0 dB on the K-20 average level meter. **So for calibration, please switch K-Meter to RMS mode!***

5.3 Peak level meter

The peak level meter displays the unfiltered sample peak level and thus possesses a completely flat frequency response. It has a rise time of one sample and a fall time of 8.67 dB/s.

5.4 Overload counter

The overload counter displays the number of samples that have reached or exceeded digital full scale (to be exact, the counter registers levels above -0.001 dB FS to address the granularity of 16-bit floating-point numbers).



Please note that this counter does not register inter-sample peaks.

5.5 Maximum true peak display

This meter displays the maximum inter-sample peak level encountered so far in dB. True peak level is measured according to Annex 2 of [ITU-R BS.1770-4](#).



In case the true peak level exceeds -0.20 dB FS, the meter will turn blue. The meter has an expected under-read of 0.17 dB at half the original sampling rate. So you should be able to avoid clipping during digital-to-analogue-conversion by keeping the meter out of the blue.

5.6 Maximum peak display

This meter displays the maximum sample peak level encountered so far in dB. In case the level exceeds -0.2 dB FS, the meter will turn red.



5.7 Phase correlation meter

This meter only works for stereo channels and displays the cross correlation between left and right channel. Cross correlation is a measure of how much two signals are correlated. Thus, a value of $+1$ means



that both channels are *in phase*, whereas a value of -1 signals that the channels are completely *out of phase*. Please note that the meter's scale is not linear!

For the non-tech savvy musician: if you find that this meter hits the red area, you should check the mono-compatibility of your mix. But although phase correlation meters often prove helpful, you cannot always rely on their readout. The only way to make sure that your mixes are mono-compatible is to actually listen to them in mono.

That's a universal truth, by the way. Do not mix by your eyes, mix by your ears!

5.8 Stereo meter

The stereo meter obviously only works for stereo channels and displays the average stereo position of your mix. It may indicate a bias to one stereo channel that you might have overheard due to impaired hearing, wrong placement of your monitors or similar problems.



But please don't get the false notion that the needle should stay in the middle all the time in order to achieve a good mix. Quite the contrary! As I said before, you should not mix by your eyes ...

6 Validation

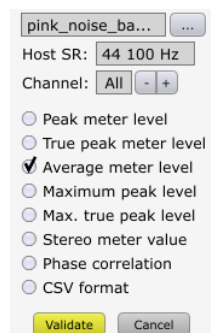
I have gone to great lengths to ensure that all meters read correctly. You want to validate for yourself? Just download and extract the source code. The directory `validation` contains instructions and FLAC-compressed wave files. To validate **ITU-R** mode, please download [ITU-R BS.2217-1](#) and follow the instructions (ignore the tests for loudness gating). A word of warning: these audio files may **damage your ears** and speakers, so please watch your monitor levels!

Begin by starting K-Meter. If in a Bash shell, try this:

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

After opening the **validation window** (see [section 4.10](#)), click on the ellipsis button (the one with the dots) to select an audio file for playback through K-Meter.

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

Should the sample rates of your host (**Host SR**) and the audio file not match, you will get a warning and validation will stop. This will keep you from getting incorrect results.

In case you want to calibrate your monitor system, locate the file `pink_noise_bandlimited.flac` in the directory `validation`, 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.

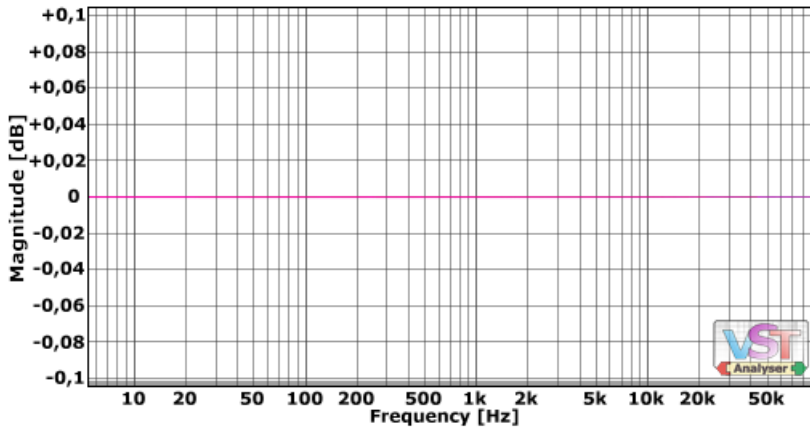
6.1 Validation status

	Readout	RMS	ITU-R
Avg level meter	meter ballistics	✓	—
	readings	✓	—
	frequency response	✓	✓
	pink noise	✓	—
	ITU-R BS.2217-1	—	✓
Peak level meter	meter ballistics	✓	✓
	readings	✓	✓
Maximum peak	readings	✓	✓
Max. true peak	EBU Tech 3341	✓	✓
Overload counter	readings	✓	✓
Phase correlation	readings	✓	✓
Stereo meter	readings	✓	✓

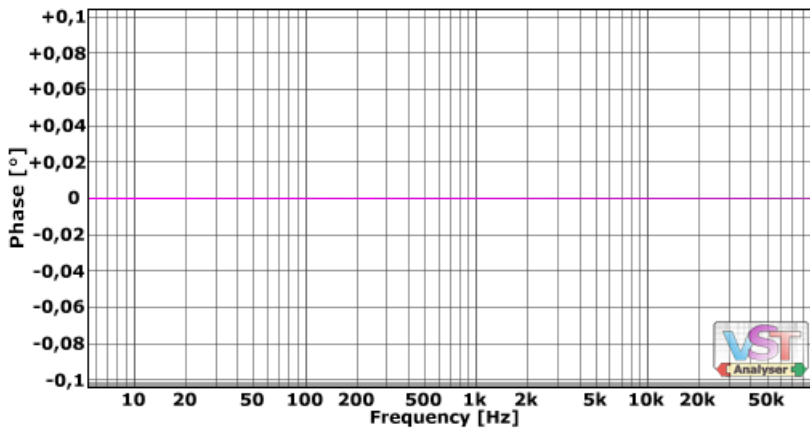
6.2 Frequency and phase response

Frequency and phase response have been determined using Christan Budde's great [Plugin Analyser](#) with a sample rate of 192 kHz and a log sine sweep as input signal (set using Ctrl-Shift-F).

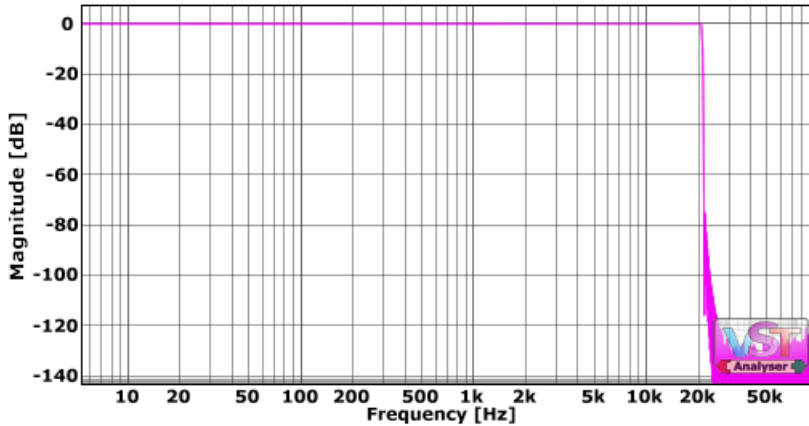
Frequency response of complete effect path (5 Hz to 96 kHz, 0 dB \pm 0.1 dB):



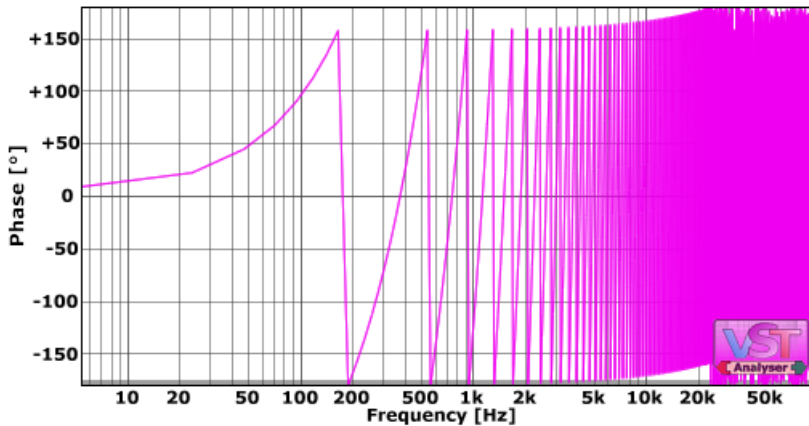
Phase response of complete effect path (5 Hz to 96 kHz, 0° \pm 0.1°):



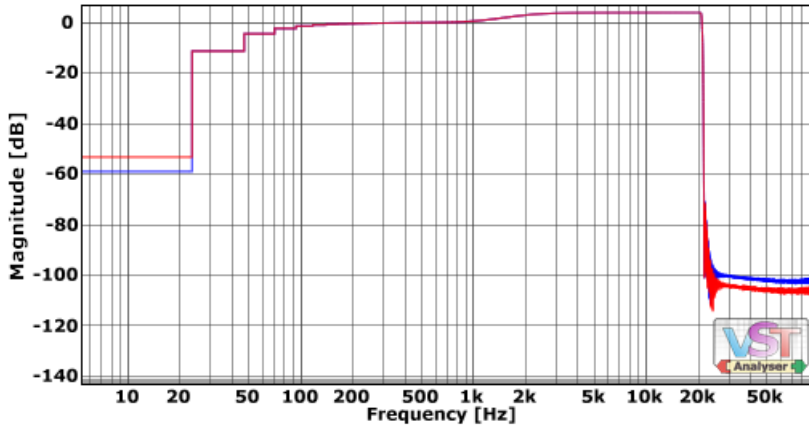
Frequency response of band-limited RMS detection stage (5 Hz to 96 kHz, -140 dB to 5 dB):



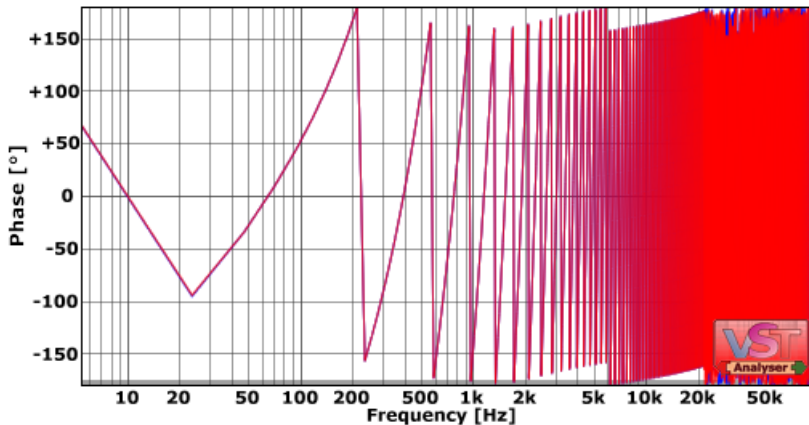
Phase response of band-limited RMS detection stage (5 Hz to 96 kHz, -180° to +180°):



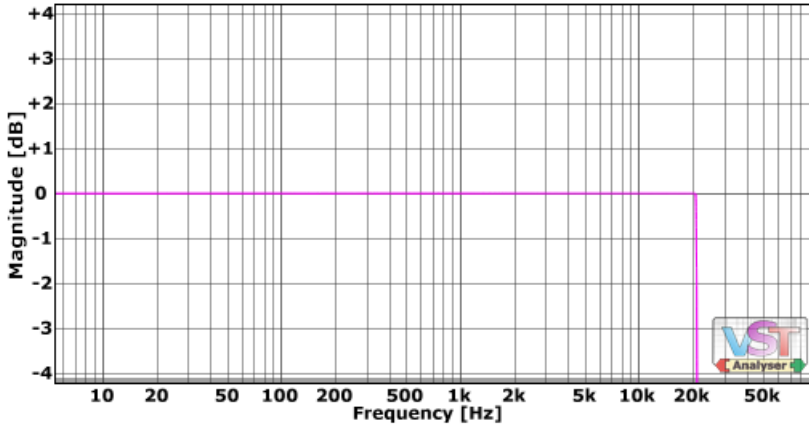
Frequency response of band-limited ITU-R BS.1770-1 detection stage (5 Hz to 96 kHz, -140 dB to 5 dB):



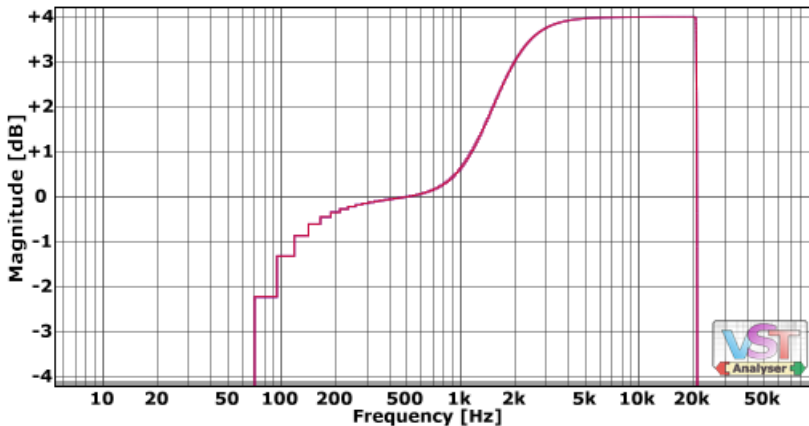
Phase response of band-limited ITU-R BS.1770-1 detection stage (5 Hz to 96 kHz, -180° to +180°):



**Frequency response of band-limited RMS detection stage
(5 Hz to 96 kHz, 0 dB \pm 4 dB):**



**Frequency response of band-limited ITU-R BS.1770-1 de-
tection stage (5 Hz to 96 kHz, 0 dB \pm 4 dB):**



7 Final words

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 **Tod Gentile** for creating the Mac binaries, **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. **David Tkaczuk** suggested some great improvements. I must also thank the **beta testers** and **users of K-Meter** 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 K-Meter has been a lot of fun, it has also been a lot of work. So if you like K-Meter, 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 6.0 (or gcc 7.5.0)

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: 5.4.7

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 Fastest Fourier Transform in the West

Importance: required
Version: 3.3.5
License: GPL v2
Homepage: www.fftw.org

Installation on GNU/Linux

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

64 bit

```
./configure --enable-float --with-pic \  
  --enable-sse2 --enable-avx  
make  
mkdir -p bin/linux/amd64/  
mv .libs/* bin/linux/amd64/  
make clean
```

Installation on Mac OS X

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

64 bit

```
./configure --enable-float --with-pic \  
  --enable-sse2 --enable-avx  
make  
mkdir -p bin/mac/x64/  
mv .libs/* bin/mac/x64/  
make clean
```

Installation on Microsoft Windows

Extract the source code archive into the directory `libraries/fftw` and the archive containing the pre-compiled binaries into the directory `libraries/fftw/bin`.

Please note that in order to run K-Meter on Windows, the directory `kmeter` containing the FFTW libraries (and skins) **must** be located in the same directory as the stand-alone or plug-in. To make things a little easier for you, I have already placed this directory in `bin`.

A.1.6 Python

Importance: optional

Version: 3.6 (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.1.7 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.1.8 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.1.9 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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