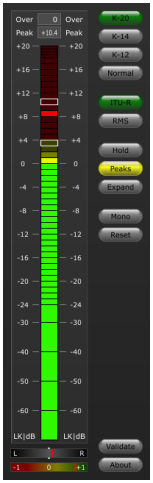
traKmeter

Loudness meter for correctly setting up
tracking and mixing levels



Last edited on 20th November 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 a nominal level of **+4 dBu** ($1.23\,V_{RMS}$) and leaves a headroom for peaks of about 20 dB. This in turn is consistent with the maximum crest factor of analog audio signals.

Thus, driving all analog audio equipment at +4 dBu ensures an optimal signal-to-noise ratio while preventing clipping and keeping transients intact. The process of setting audio devices to run at optimal input and output levels is called gain staging.

Now let's transfer this to the digital domain. As the maximum crest factor of analog audio signals amounts to 20 dB, we 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 a good signal-to-noise ratio while preventing clipping. Maybe even more important, this level also drives (most of) your digital audio equipment and plug-ins at their respective "sweet spot".

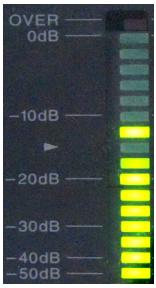
Another recommendation is that peak levels should not exceed **−9 dB FS** (EBU R68-2000) during tracking, leaving enough space for inter-sample peaks. Inter-sample peaks are audio peaks that lie *in between* two successive samples and may lead to unpredictable clippings during digital-to-analog conversion.

1.2 Digital audio myths

I can almost hear you: you have heard that digital recordings should be performed at peak 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 reasons given above it is plain wrong.

Let's look at the math for bit depths of 16 bit: even if your recordings peak at −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!

Or take my professional 16-bit hard disk recorder (Otari PD-80): its analog inputs and outputs 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). Even if the mark is only useful for audio alignment, given that it sits on a peak meter...



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 almost impossible.

For gain staging, you need average meters or – even better – a combination of peak and average meters. And this is were **traKmeter** comes in.

2 traKmeter

traKmeter consists of two meters, a peak meter on top and an average meter below. Both meters have an area of green LEDs that is enclosed by first yellow and then red LEDs.

You may have noticed that the average meter's green area is centred around the **−18 dB FS RMS** mark. This number should be vaguely familiar. Remember, it corresponds to the optimal average audio level in the digital domain.

A fully lit yellow LED on the top end of the peak meter corresponds to a level of **−9 dB FS**. Again, this number should be familiar: peak levels in the digital domain shouldn't exceed this level.

Thus, by keeping meter readout in the green areas and from entering the yellow and red areas on top of each meter, you will automatically track at optimal audio levels.

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 standalone version and connecting it to one or more input channels of your sound card, or by inserting a plug-in instance into an input channel of your digital audio workstation.

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 sound card or by directly comparing the readouts of standalone and plug-in version.

Now, feed the signal you want to record into an audio input channel and adjust its level using **traKmeter**. Try to set the input level so that transients reach **−18 dB FS RMS** on the average meter. Make sure that the peak level never exceeds **−9 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 might want to adjust them to optimal loudness so that your upcoming mix is not ruined.

If the original recordings were made with poor equipment and you have the time, it may be worth to **re-record** all tracks through a really good preamp and adjust their loudness at the same time. The result can be stunning!

Another option is to insert **traKmeter** on each channel as first plug-in, enable the "Mixing" button and adjust volume using the gain knob. When traKmeter is closed, the meters aren't updated, so the plug-in uses less system resources. On slow computers, however, use traKmeter to find the correct gain and then exchange it against a gain plug-in.

In any case, mixing levels will now be much lower than what you are 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 **−20 dB FS RMS** and **−16 dB FS RMS**. Remember that smashed transients will be gone forever, whereas you can always bring up the volume during mastering! My plug-in **K-Meter** and its K-20 scale may help you with setting correct mixing levels.

3 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. "Good" doesn't mean your preamp 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 preamp make mixing much easier – the tracks simply seem to fall into place.

Use the preamp's gain control. If necessary, crank up the preamp to yield the needed output level. Do not fear the preamp's internal noise – making up for low gain in later stages will 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.

For example, instead of routing your mixer between preamp and hard disk recorder, connect it to the hard disk recorder's *outputs*. This simple change can lead to much better recordings (especially with cheap mixers) and you'll still be able to hear yourself and other tracks during recording.

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. The solution is to 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 the hassle. 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.

Concentrate on recording. When tracking, try to not interfere with the flow of the session. This is easily done by keeping editing and mixing to the bare minimum.

For example, I currently track using an old hard disk recorder, as digital audio workstations tend to distract me too much.

Avoid copy'n'paste. TO DO!

Do not fix things later. A bad recording is a bad recording is a bad recording. You can't really "fix it in the mix". So tools like Auto-Tune, extreme EQ or the edit button should be seen as a last resort. It's easy to kill all of a track's vibe in the process.

Instead, record a few more takes. Treat your room (acoustically and in terms of positive vibe). Experiment with microphone placement. Try everything you can to help the musicians perform better. Maybe you even have to look for better musicians...

4 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).

5 Controls

TO DO!

6 Meters

6.1 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. The meter then switches to a linear fall time of 6 dB/s.

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

6.2 Peak level meter

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

Peak levels will be held until the meter is reset.

6.3 Signal meter

The blue signal meter detects peak levels of −60 dB FS and above. The meter has a rise time of one sample and falls to 99 % of the final reading in 2 s.

7 Validation

TO DO!

8 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 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!

A How to build traKmeter

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: 2.0
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_multi`, `linux_vst_stereo` and `linux_vst_multi`.

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

Preamble

The GNU General Public License is a free, copyleft license for software and other kinds of works.

The licenses for most software and other practical works are designed to take away your freedom to share and change the works. By contrast, the GNU General Public License is intended to guarantee your freedom to share and change all versions of a program–to make sure it remains free software for all its users. We, the Free Software Foundation, use the

GNU General Public License for most of our software; it applies also to any other work released this way by its authors. You can apply it to your programs, too.

When we speak of free software, we are referring to freedom, not price. Our General Public Licenses are designed to make sure that you have the freedom to distribute copies of free software (and charge for them if you wish), that you receive source code or can get it if you want it, that you can change the software or use pieces of it in new free programs, and that you know you can do these things.

To protect your rights, we need to prevent others from denying you these rights or asking you to surrender the rights. Therefore, you have certain responsibilities if you distribute copies of the software, or if you modify it: responsibilities to respect the freedom of others.

For example, if you distribute copies of such a program, whether gratis or for a fee, you must pass on to the recipients the same freedoms that you received. You must make sure that they, too, receive or can get the source code. And you must show them these terms so they know their rights.

Developers that use the GNU GPL protect your rights with two steps: (1) assert copyright on the software, and (2) offer you this License giving you legal permission to copy, distribute and/or modify it.

For the developers' and authors' protection, the GPL clearly explains that there is no warranty for this free software. For

both users' and authors' sake, the GPL requires that modified versions be marked as changed, so that their problems will not be attributed erroneously to authors of previous versions.

Some devices are designed to deny users access to install or run modified versions of the software inside them, although the manufacturer can do so. This is fundamentally incompatible with the aim of protecting users' freedom to change the software. The systematic pattern of such abuse occurs in the area of products for individuals to use, which is precisely where it is most unacceptable. Therefore, we have designed this version of the GPL to prohibit the practice for those products. If such problems arise substantially in other domains, we stand ready to extend this provision to those domains in future versions of the GPL, as needed to protect the freedom of users.

Finally, every program is threatened constantly by software patents. States should not allow patents to restrict development and use of software on general-purpose computers, but in those that do, we wish to avoid the special danger that patents applied to a free program could make it effectively proprietary. To prevent this, the GPL assures that patents cannot be used to render the program non-free.

The precise terms and conditions for copying, distribution and modification follow.

TERMS AND CONDITIONS

0. Definitions.

   "This License" refers to version 3 of the GNU General Public License.

   "Copyright" also means copyright-like laws that apply to other kinds of works, such as semiconductor masks.

   "The Program" refers to any copyrightable work licensed under this License. Each licensee is addressed as "you". "Licensees" and "recipients" may be individuals or organizations.

   To "modify" a work means to copy from or adapt all or part of the work in a fashion requiring copyright permission, other than the making of an exact copy. The resulting work is called a "modified version" of the earlier work or a work "based on" the earlier work.

   A "covered work" means either the unmodified Program or a work based on the Program.

   To "propagate" a work means to do anything with it that, without permission, would make you directly or secondarily liable for infringement under applicable copyright law, except executing it on a computer or modifying a private copy. Propagation includes copying, distribution (with or without modification), making available to the public, and in some countries other activities as well.

To "convey" a work means any kind of propagation that enables other parties to make or receive copies. Mere interaction with a user through a computer network, with no transfer of a copy, is not conveying.

An interactive user interface displays "Appropriate Legal Notices" to the extent that it includes a convenient and prominently visible feature that (1) displays an appropriate copyright notice, and (2) tells the user that there is no warranty for the work (except to the extent that warranties are provided), that licensees may convey the work under this License, and how to view a copy of this License. If the interface presents a list of user commands or options, such as a menu, a prominent item in the list meets this criterion.

1. Source Code.

   The "source code" for a work means the preferred form of the work for making modifications to it. "Object code" means any non-source form of a work.

   A "Standard Interface" means an interface that either is an official standard defined by a recognized standards body, or, in the case of interfaces specified for a particular programming language, one that is widely used among developers working in that language.

   The "System Libraries" of an executable work include anything, other than the work as a whole, that (a) is included in the normal form of packaging a Major Component, but which is not part of that Major Component, and (b) serves only to enable use of the work with

that Major Component, or to implement a Standard Interface for which an implementation is available to the public in source code form. A "Major Component", in this context, means a major essential component (kernel, window system, and so on) of the specific operating system (if any) on which the executable work runs, or a compiler used to produce the work, or an object code interpreter used to run it.

The "Corresponding Source" for a work in object code form means all the source code needed to generate, install, and (for an executable work) run the object code and to modify the work, including scripts to control those activities. However, it does not include the work's System Libraries, or general-purpose tools or generally available free programs which are used unmodified in performing those activities but which are not part of the work. For example, Corresponding Source includes interface definition files associated with source files for the work, and the source code for shared libraries and dynamically linked subprograms that the work is specifically designed to require, such as by intimate data communication or control flow between those subprograms and other parts of the work.

The Corresponding Source need not include anything that users can regenerate automatically from other parts of the Corresponding Source.

The Corresponding Source for a work in source code form is that same work.

2. Basic Permissions.

   All rights granted under this License are granted for the term of copyright on the Program, and are irrevocable provided the stated conditions are met. This License explicitly affirms your unlimited permission to run the unmodified Program. The output from running a covered work is covered by this License only if the output, given its content, constitutes a covered work. This License acknowledges your rights of fair use or other equivalent, as provided by copyright law.

   You may make, run and propagate covered works that you do not convey, without conditions so long as your license otherwise remains in force. You may convey covered works to others for the sole purpose of having them make modifications exclusively for you, or provide you with facilities for running those works, provided that you comply with the terms of this License in conveying all material for which you do not control copyright. Those thus making or running the covered works for you must do so exclusively on your behalf, under your direction and control, on terms that prohibit them from making any copies of your copyrighted material outside their relationship with you.

   Conveying under any other circumstances is permitted solely under the conditions stated below. Sublicensing is not allowed; section 10 makes it unnecessary.

3. Protecting Users' Legal Rights From Anti-Circumvention Law.

   No covered work shall be deemed part of an effective technological measure under any applicable law fulfilling obligations under article 11 of the WIPO copyright treaty adopted on 20 December 1996, or similar laws prohibiting or restricting circumvention of such measures.

   When you convey a covered work, you waive any legal power to forbid circumvention of technological measures to the extent such circumvention is effected by exercising rights under this License with respect to the covered work, and you disclaim any intention to limit operation or modification of the work as a means of enforcing, against the work's users, your or third parties' legal rights to forbid circumvention of technological measures.

4. Conveying Verbatim Copies.

   You may convey verbatim copies of the Program's source code as you receive it, in any medium, provided that you conspicuously and appropriately publish on each copy an appropriate copyright notice; keep intact all notices stating that this License and any non-permissive terms added in accord with section 7 apply to the code; keep intact all notices of the absence of any warranty; and give all recipients a copy of this License along with the Program.

You may charge any price or no price for each copy that you convey, and you may offer support or warranty protection for a fee.

5. Conveying Modified Source Versions.

   You may convey a work based on the Program, or the modifications to produce it from the Program, in the form of source code under the terms of section 4, provided that you also meet all of these conditions:

   a) The work must carry prominent notices stating that you modified it, and giving a relevant date.

   b) The work must carry prominent notices stating that it is released under this License and any conditions added under section 7. This requirement modifies the requirement in section 4 to "keep intact all notices".

   c) You must license the entire work, as a whole, under this License to anyone who comes into possession of a copy. This License will therefore apply, along with any applicable section 7 additional terms, to the whole of the work, and all its parts, regardless of how they are packaged. This License gives no permission to license the work in any other way, but it does not invalidate such permission if you have separately received it.

   d) If the work has interactive user interfaces, each must display Appropriate Legal Notices; however, if the Program has interactive interfaces that

do not display Appropriate Legal Notices, your work need not make them do so.

A compilation of a covered work with other separate and independent works, which are not by their nature extensions of the covered work, and which are not combined with it such as to form a larger program, in or on a volume of a storage or distribution medium, is called an "aggregate" if the compilation and its resulting copyright are not used to limit the access or legal rights of the compilation's users beyond what the individual works permit. Inclusion of a covered work in an aggregate does not cause this License to apply to the other parts of the aggregate.

6. Conveying Non-Source Forms.

   You may convey a covered work in object code form under the terms of sections 4 and 5, provided that you also convey the machine-readable Corresponding Source under the terms of this License, in one of these ways:

   a) Convey the object code in, or embodied in, a physical product (including a physical distribution medium), accompanied by the Corresponding Source fixed on a durable physical medium customarily used for software interchange.

   b) Convey the object code in, or embodied in, a physical product (including a physical distribution medium), accompanied by a written offer, valid for at least three years and valid for as long

as you offer spare parts or customer support for that product model, to give anyone who possesses the object code either (1) a copy of the Corresponding Source for all the software in the product that is covered by this License, on a durable physical medium customarily used for software interchange, for a price no more than your reasonable cost of physically performing this conveying of source, or (2) access to copy the Corresponding Source from a network server at no charge.

c) Convey individual copies of the object code with a copy of the written offer to provide the Corresponding Source. This alternative is allowed only occasionally and noncommercially, and only if you received the object code with such an offer, in accord with subsection 6b.

d) Convey the object code by offering access from a designated place (gratis or for a charge), and offer equivalent access to the Corresponding Source in the same way through the same place at no further charge. You need not require recipients to copy the Corresponding Source along with the object code. If the place to copy the object code is a network server, the Corresponding Source may be on a different server (operated by you or a third party) that supports equivalent copying facilities, provided you maintain clear directions next to the object code saying where to find the

Corresponding Source. Regardless of what server hosts the Corresponding Source, you remain obligated to ensure that it is available for as long as needed to satisfy these requirements.

e) Convey the object code using peer-to-peer transmission, provided you inform other peers where the object code and Corresponding Source of the work are being offered to the general public at no charge under subsection 6d.

A separable portion of the object code, whose source code is excluded from the Corresponding Source as a System Library, need not be included in conveying the object code work.

A "User Product" is either (1) a "consumer product", which means any tangible personal property which is normally used for personal, family, or household purposes, or (2) anything designed or sold for incorporation into a dwelling. In determining whether a product is a consumer product, doubtful cases shall be resolved in favor of coverage. For a particular product received by a particular user, "normally used" refers to a typical or common use of that class of product, regardless of the status of the particular user or of the way in which the particular user actually uses, or expects or is expected to use, the product. A product is a consumer product regardless of whether the product has substantial commercial, industrial or non-consumer uses, unless such uses represent the only significant mode of use of the product.

"Installation Information" for a User Product means any methods, procedures, authorization keys, or other information required to install and execute modified versions of a covered work in that User Product from a modified version of its Corresponding Source. The information must suffice to ensure that the continued functioning of the modified object code is in no case prevented or interfered with solely because modification has been made.

If you convey an object code work under this section in, or with, or specifically for use in, a User Product, and the conveying occurs as part of a transaction in which the right of possession and use of the User Product is transferred to the recipient in perpetuity or for a fixed term (regardless of how the transaction is characterized), the Corresponding Source conveyed under this section must be accompanied by the Installation Information. But this requirement does not apply if neither you nor any third party retains the ability to install modified object code on the User Product (for example, the work has been installed in ROM).

The requirement to provide Installation Information does not include a requirement to continue to provide support service, warranty, or updates for a work that has been modified or installed by the recipient, or for the User Product in which it has been modified or installed. Access to a network may be denied when the modification itself materially and adversely affects the

operation of the network or violates the rules and protocols for communication across the network.

Corresponding Source conveyed, and Installation Information provided, in accord with this section must be in a format that is publicly documented (and with an implementation available to the public in source code form), and must require no special password or key for unpacking, reading or copying.

7. Additional Terms.

"Additional permissions" are terms that supplement the terms of this License by making exceptions from one or more of its conditions. Additional permissions that are applicable to the entire Program shall be treated as though they were included in this License, to the extent that they are valid under applicable law. If additional permissions apply only to part of the Program, that part may be used separately under those permissions, but the entire Program remains governed by this License without regard to the additional permissions.

When you convey a copy of a covered work, you may at your option remove any additional permissions from that copy, or from any part of it. (Additional permissions may be written to require their own removal in certain cases when you modify the work.) You may place additional permissions on material, added by you to a covered work, for which you have or can give appropriate copyright permission.

Notwithstanding any other provision of this License, for material you add to a covered work, you may (if authorized by the copyright holders of that material) supplement the terms of this License with terms:

a) Disclaiming warranty or limiting liability differently from the terms of sections 15 and 16 of this License; or

b) Requiring preservation of specified reasonable legal notices or author attributions in that material or in the Appropriate Legal Notices displayed by works containing it; or

c) Prohibiting misrepresentation of the origin of that material, or requiring that modified versions of such material be marked in reasonable ways as different from the original version; or

d) Limiting the use for publicity purposes of names of licensors or authors of the material; or

e) Declining to grant rights under trademark law for use of some trade names, trademarks, or service marks; or

f) Requiring indemnification of licensors and authors of that material by anyone who conveys the material (or modified versions of it) with contractual assumptions of liability to the recipient, for any liability that these contractual assumptions directly impose on those licensors and authors.

All other non-permissive additional terms are considered "further restrictions" within the meaning of section 10. If the Program as you received it, or any part of it, contains a notice stating that it is governed by this License along with a term that is a further restriction, you may remove that term. If a license document contains a further restriction but permits relicensing or conveying under this License, you may add to a covered work material governed by the terms of that license document, provided that the further restriction does not survive such relicensing or conveying.

If you add terms to a covered work in accord with this section, you must place, in the relevant source files, a statement of the additional terms that apply to those files, or a notice indicating where to find the applicable terms.

Additional terms, permissive or non-permissive, may be stated in the form of a separately written license, or stated as exceptions; the above requirements apply either way.

8. Termination.

   You may not propagate or modify a covered work except as expressly provided under this License. Any attempt otherwise to propagate or modify it is void, and will automatically terminate your rights under this License (including any patent licenses granted under the third paragraph of section 11).

However, if you cease all violation of this License, then your license from a particular copyright holder is reinstated (a) provisionally, unless and until the copyright holder explicitly and finally terminates your license, and (b) permanently, if the copyright holder fails to notify you of the violation by some reasonable means prior to 60 days after the cessation.

Moreover, your license from a particular copyright holder is reinstated permanently if the copyright holder notifies you of the violation by some reasonable means, this is the first time you have received notice of violation of this License (for any work) from that copyright holder, and you cure the violation prior to 30 days after your receipt of the notice.

Termination of your rights under this section does not terminate the licenses of parties who have received copies or rights from you under this License. If your rights have been terminated and not permanently reinstated, you do not qualify to receive new licenses for the same material under section 10.

9. Acceptance Not Required for Having Copies.

   You are not required to accept this License in order to receive or run a copy of the Program. Ancillary propagation of a covered work occurring solely as a consequence of using peer-to-peer transmission to receive a copy likewise does not require acceptance. However, nothing other than this License grants you permission to propagate or modify any covered work.

These actions infringe copyright if you do not accept this License. Therefore, by modifying or propagating a covered work, you indicate your acceptance of this License to do so.

10. Automatic Licensing of Downstream Recipients.

    Each time you convey a covered work, the recipient automatically receives a license from the original licensors, to run, modify and propagate that work, subject to this License. You are not responsible for enforcing compliance by third parties with this License.

    An "entity transaction" is a transaction transferring control of an organization, or substantially all assets of one, or subdividing an organization, or merging organizations. If propagation of a covered work results from an entity transaction, each party to that transaction who receives a copy of the work also receives whatever licenses to the work the party's predecessor in interest had or could give under the previous paragraph, plus a right to possession of the Corresponding Source of the work from the predecessor in interest, if the predecessor has it or can get it with reasonable efforts.

    You may not impose any further restrictions on the exercise of the rights granted or affirmed under this License. For example, you may not impose a license fee, royalty, or other charge for exercise of rights granted under this License, and you may not initiate litigation (including a cross-claim or counterclaim in a lawsuit)

alleging that any patent claim is infringed by making, using, selling, offering for sale, or importing the Program or any portion of it.

11. Patents.

    A "contributor" is a copyright holder who authorizes use under this License of the Program or a work on which the Program is based. The work thus licensed is called the contributor's "contributor version".

    A contributor's "essential patent claims" are all patent claims owned or controlled by the contributor, whether already acquired or hereafter acquired, that would be infringed by some manner, permitted by this License, of making, using, or selling its contributor version, but do not include claims that would be infringed only as a consequence of further modification of the contributor version. For purposes of this definition, "control" includes the right to grant patent sublicenses in a manner consistent with the requirements of this License.

    Each contributor grants you a non-exclusive, worldwide, royalty-free patent license under the contributor's essential patent claims, to make, use, sell, offer for sale, import and otherwise run, modify and propagate the contents of its contributor version.

    In the following three paragraphs, a "patent license" is any express agreement or commitment, however denominated, not to enforce a patent (such as an express permission to practice a patent or covenant not

to sue for patent infringement). To "grant" such a patent license to a party means to make such an agreement or commitment not to enforce a patent against the party.

If you convey a covered work, knowingly relying on a patent license, and the Corresponding Source of the work is not available for anyone to copy, free of charge and under the terms of this License, through a publicly available network server or other readily accessible means, then you must either (1) cause the Corresponding Source to be so available, or (2) arrange to deprive yourself of the benefit of the patent license for this particular work, or (3) arrange, in a manner consistent with the requirements of this License, to extend the patent license to downstream recipients. "Knowingly relying" means you have actual knowledge that, but for the patent license, your conveying the covered work in a country, or your recipient's use of the covered work in a country, would infringe one or more identifiable patents in that country that you have reason to believe are valid.

If, pursuant to or in connection with a single transaction or arrangement, you convey, or propagate by procuring conveyance of, a covered work, and grant a patent license to some of the parties receiving the covered work authorizing them to use, propagate, modify or convey a specific copy of the covered work, then the patent license you grant is automatically ex-

tended to all recipients of the covered work and works based on it.

A patent license is "discriminatory" if it does not include within the scope of its coverage, prohibits the exercise of, or is conditioned on the non-exercise of one or more of the rights that are specifically granted under this License. You may not convey a covered work if you are a party to an arrangement with a third party that is in the business of distributing software, under which you make payment to the third party based on the extent of your activity of conveying the work, and under which the third party grants, to any of the parties who would receive the covered work from you, a discriminatory patent license (a) in connection with copies of the covered work conveyed by you (or copies made from those copies), or (b) primarily for and in connection with specific products or compilations that contain the covered work, unless you entered into that arrangement, or that patent license was granted, prior to 28 March 2007.

Nothing in this License shall be construed as excluding or limiting any implied license or other defenses to infringement that may otherwise be available to you under applicable patent law.

12. No Surrender of Others' Freedom.

If conditions are imposed on you (whether by court order, agreement or otherwise) that contradict the conditions of this License, they do not excuse you

from the conditions of this License. If you cannot convey a covered work so as to satisfy simultaneously your obligations under this License and any other pertinent obligations, then as a consequence you may not convey it at all. For example, if you agree to terms that obligate you to collect a royalty for further conveying from those to whom you convey the Program, the only way you could satisfy both those terms and this License would be to refrain entirely from conveying the Program.

13. Use with the GNU Affero General Public License.

    Notwithstanding any other provision of this License, you have permission to link or combine any covered work with a work licensed under version 3 of the GNU Affero General Public License into a single combined work, and to convey the resulting work. The terms of this License will continue to apply to the part which is the covered work, but the special requirements of the GNU Affero General Public License, section 13, concerning interaction through a network will apply to the combination as such.

14. Revised Versions of this License.

    The Free Software Foundation may publish revised and/or new versions of the GNU General Public License from time to time. Such new versions will be similar in spirit to the present version, but may differ in detail to address new problems or concerns.

Each version is given a distinguishing version number. If the Program specifies that a certain numbered version of the GNU General Public License "or any later version" applies to it, you have the option of following the terms and conditions either of that numbered version or of any later version published by the Free Software Foundation. If the Program does not specify a version number of the GNU General Public License, you may choose any version ever published by the Free Software Foundation.

If the Program specifies that a proxy can decide which future versions of the GNU General Public License can be used, that proxy's public statement of acceptance of a version permanently authorizes you to choose that version for the Program.

Later license versions may give you additional or different permissions. However, no additional obligations are imposed on any author or copyright holder as a result of your choosing to follow a later version.

15. Disclaimer of Warranty.

THERE IS NO WARRANTY FOR THE PROGRAM, TO THE EXTENT PERMITTED BY APPLICABLE LAW. EXCEPT WHEN OTHERWISE STATED IN WRITING THE COPYRIGHT HOLDERS AND/OR OTHER PARTIES PROVIDE THE PROGRAM "AS IS" WITHOUT WARRANTY OF ANY KIND, EITHER EXPRESSED OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND

FITNESS FOR A PARTICULAR PURPOSE. THE ENTIRE RISK AS TO THE QUALITY AND PERFORMANCE OF THE PROGRAM IS WITH YOU. SHOULD THE PROGRAM PROVE DEFECTIVE, YOU ASSUME THE COST OF ALL NECESSARY SERVICING, REPAIR OR CORRECTION.

16. Limitation of Liability.

    IN NO EVENT UNLESS REQUIRED BY APPLICABLE LAW OR AGREED TO IN WRITING WILL ANY COPYRIGHT HOLDER, OR ANY OTHER PARTY WHO MODIFIES AND/OR CONVEYS THE PROGRAM AS PERMITTED ABOVE, BE LIABLE TO YOU FOR DAMAGES, INCLUDING ANY GENERAL, SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING OUT OF THE USE OR INABILITY TO USE THE PROGRAM (INCLUDING BUT NOT LIMITED TO LOSS OF DATA OR DATA BEING RENDERED INACCURATE OR LOSSES SUSTAINED BY YOU OR THIRD PARTIES OR A FAILURE OF THE PROGRAM TO OPERATE WITH ANY OTHER PROGRAMS), EVEN IF SUCH HOLDER OR OTHER PARTY HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

17. Interpretation of Sections 15 and 16.

    If the disclaimer of warranty and limitation of liability provided above cannot be given local legal effect according to their terms, reviewing courts shall apply local law that most closely approximates an absolute

waiver of all civil liability in connection with the Program, unless a warranty or assumption of liability accompanies a copy of the Program in return for a fee.

END OF TERMS AND CONDITIONS

How to Apply These Terms to Your New Programs

If you develop a new program, and you want it to be of the greatest possible use to the public, the best way to achieve this is to make it free software which everyone can redistribute and change under these terms.

To do so, attach the following notices to the program. It is safest to attach them to the start of each source file to most effectively state the exclusion of warranty; and each file should have at least the "copyright" line and a pointer to where the full notice is found.

```
<one line to give the program's name and a brief idea
of what it does.>

Copyright (C) <textyear> <name of author>

This program is free software:  you can redistribute
it and/or modify it under the terms of the GNU General
Public License as published by the Free Software
Foundation, either version 3 of the License, or (at
your option) any later version.

This program is distributed in the hope that it will
be useful, but WITHOUT ANY WARRANTY; without even the
implied warranty of MERCHANTABILITY or FITNESS FOR A
PARTICULAR PURPOSE. See the GNU General Public License
for more details.

You should have received a copy of the GNU General
Public License along with this program.  If not, see
<http://www.gnu.org/licenses/>.
```

Also add information on how to contact you by electronic and paper mail.

If the program does terminal interaction, make it output a short notice like this when it starts in an interactive mode:

```
<program> Copyright (C) <year> <name of author>

This program comes with ABSOLUTELY NO WARRANTY; for
details type ‘show w’.  This is free software, and
you are welcome to redistribute it under certain
conditions; type ‘show c’ for details.
```

The hypothetical commands `show w` and `show c` should show the appropriate parts of the General Public License. Of course, your program's commands might be different; for a GUI interface, you would use an "about box".

You should also get your employer (if you work as a programmer) or school, if any, to sign a "copyright disclaimer" for the program, if necessary. For more information on this, and how to apply and follow the GNU GPL, see http://www.gnu.org/licenses/.

The GNU General Public License does not permit incorporating your program into proprietary programs. If your program is a subroutine library, you may consider it more useful to permit linking proprietary applications with the library. If this is what you want to do, use the GNU Lesser General Public License instead of this License. But first, please read http://www.gnu.org/philosophy/why-not-lgpl.html.