Getting Started V2.10.0-pre0-6375-g678d99c39d

2021-10-28

Table of Contents

The LinuxCNC Team

This handbook is a work in progress. If you are able to help with writing, editing, or graphic preparation please contact any member of the writing team or join and send an email to emc-users@lists.sourceforge.net.

Copyright © 2000-2025 LinuxCNC.org

Permission is granted to copy, distribute and/or modify this document under the terms of the GNU Free Documentation License, Version 1.1 or any later version published by the Free Software Foundation; with no Invariant Sections, no Front-Cover Texts, and no Back-Cover Texts. A copy of the license is included in the section entitled "GNU Free Documentation License".

If you do not find the license you may order a copy from:

```
Free Software Foundation, Inc.
51 Franklin Street
Fifth Floor
Boston, MA 02110-1301 USA.
```

(The English language version is authoritative)

LINUX® is the registered trademark of Linus Torvalds in the U.S. and other countries. The registered trademark Linux® is used pursuant to a sublicense from LMI, the exclusive licensee of Linus Torvalds, owner of the mark on a world-wide basis.

The LinuxCNC project is not affiliated with Debian®. *Debian* is a registered trademark owned by Software in the Public Interest, Inc.

The LinuxCNC project is not affiliated with UBUNTU®. *UBUNTU* is a registered trademark owned by Canonical Limited.

Chapter 1. About LinuxCNC

LinuxCNC (the Enhanced Machine Control) is a software system for computer control of machine tools such as milling machines and lathes, robots such as puma and scara and other computer controlled machines up to 9 axes. LinuxCNC is free software with open source code. Current versions of LinuxCNC are entirely licensed under the GNU General Public License and Lesser GNU General Public License (GPL and LGPL).

To lower the entry-hurdle, LinuxCNC provides:

- easy discovery and testing without installation with the Live Image,
- easy installation from the Live Image,
- easy to use graphical configuration wizards to rapidly create a configuration specific to the machine,
- directly availability as regular packages of recent releases of Debian (since Bookworm) and Ubuntu (since Kinetic Kudu).

LinuxCNC provides a graphical user interface with many flavours to choose from to match your personal preferences and technical needs. Advanced users may directly exploit

- graphical interface creation tools (Glade, Qt),
- the interpreter for *G-code* (the RS-274 machine tool programming language),
- operation of low-level machine electronics such as sensors and motor drives,
- an easy to use *breadboard* layer for quickly creating a unique configuration for your machine,
- a software PLC programmable with ladder diagrams.

Under the hood, LinuxCNC provides

- a realtime motion planning system with look-ahead,
- support for non-Cartesian motion systems is provided via custom kinematics modules. Available architectures include hexapods (Stewart platforms and similar concepts) and systems with rotary joints to provide motion such as PUMA or SCARA robots.
- support for a variety of hardware interfaces. The control can operate true servos (analog or PWM) with the feedback loop closed by the LinuxCNC software at the computer, or open loop with step-servos or stepper motors.
- Motion control features include: cutter radius and length compensation, path deviation limited to a specified tolerance, lathe threading, synchronized axis motion, adaptive feedrate, operator feed override, and constant velocity control.
- LinuxCNC runs on Linux using real-time extensions.

LinuxCNC expects G-code that if not entered manually is provided by another software, which supports CAM (Computer Automated Manufacturing) and determines what tool shall be used at what speed for what geometry. Many prominent CAD (Computer Automated Design) tools that determine the desired final shape of your work piece (or the assembly of multiple work pieces that area to be produced individually) offer a CAM module.

1.1. Architecture - Context diagram

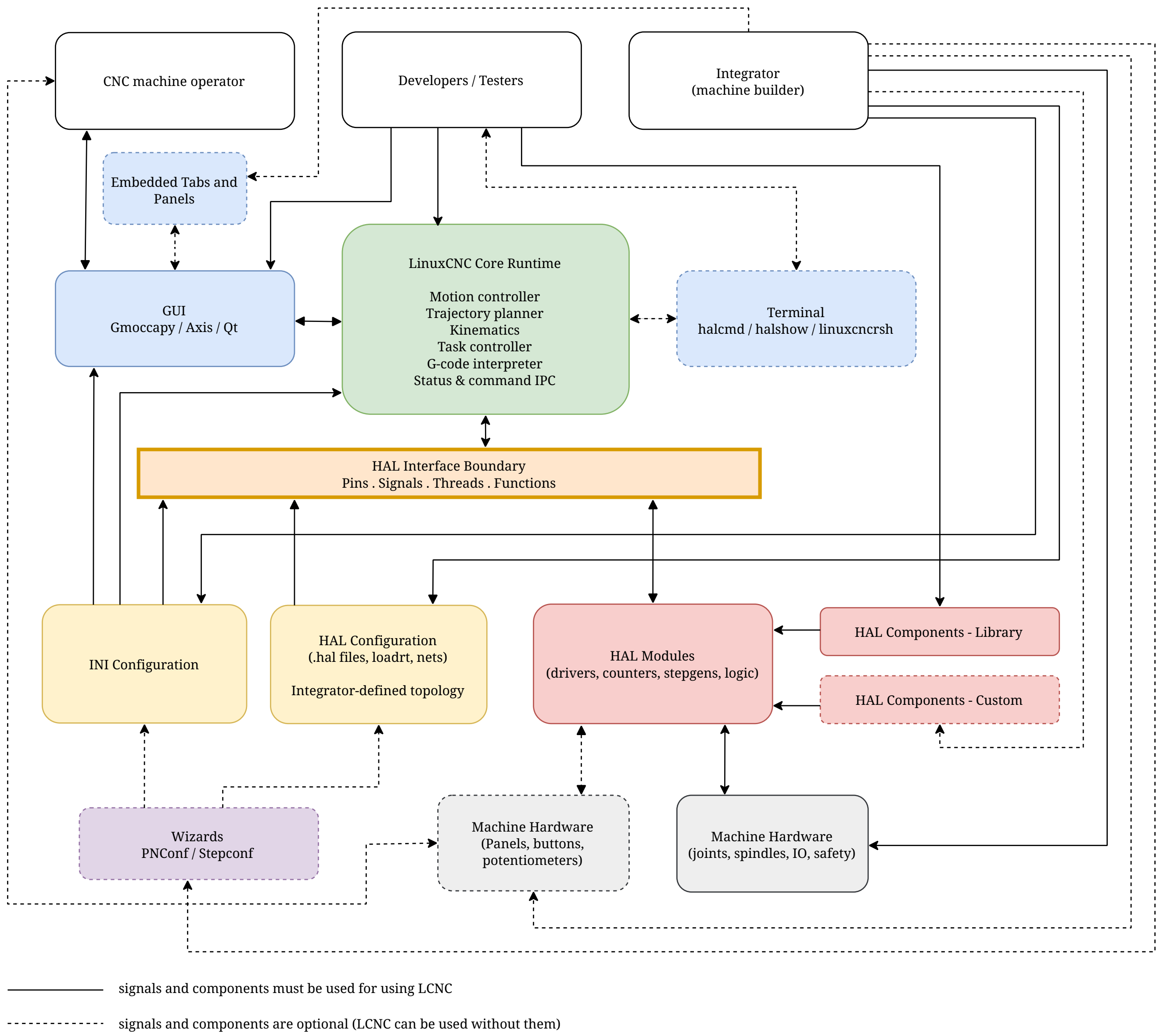

Figure 1. Roles of operators, integrators, developers and hardware

The diagram presents the components and players of the LinuxCNC ecosystem and how they interact. It is not intended to help you understand the functionality of LinuxCNC. Please refer to the following chapters for this.

Operator

One a machine is set up, its operator will only use one of the many graphical user interfaces that LinuxCNC and external groups are providing. The requirements for the operator are determined by how the integrator has set up the machine. The integrator has the option of setting up the machine so that the operator only presses one button to start the machining process, or leaves the GUI in its default state and the operator will fully control the CNC machine using the GUI functionality and G,M,O-codes. The integrator may or may not create a physical or virtual panel for the operator with various buttons and various indicators.

Integrator

It is on an integrator (machine builder) to ensure that the LinuxCNC configuration matches the hardware setup both in the wiring and the protocols spoken on those wires. The integrator can choose whether to set up the machine using the Wizard or to configure it manually. If the Wizard is used, the integrator's knowledge of LinuxCNC is minimal. It is enough to understand the machine hardware. If the integrator wants to use the maximum potential of LinuxCNC, he must be able to create or edit configuration files manually. To do this, it is enough to have knowledge of HAL, INI configuration and ideally the creation of custom HAL components or embedded panels. This knowledge will allow the connection of various hardware combinations with LCNC. Using INI, the integrator selects the GUI (Gmoccapy, Axis, Qt, …), kinematics, number of axes, parameters (velocities, acceleration, distance, …). Using HAL, the integrator selects the hardware control method (velocity mode / position mode, on-off control / analog control, without / with feedback, …). Using a suitable HAL module, various components can be controlled via various buses (PCI, USB, Ethernet, EtherCAT, Modbus RTU/TCP, Parallel port, …)

Developer

The LinuxCNC developers may be coming up with drivers for new hardware or other new features in the GUI and anything in between a mouse click and a motor turning. For testing, monitoring or possibly also the communication between multiple machines, also a text-based interface to LinuxCNC is available. Since LinuxCNC is an Open-source project, you can modify it in any way you like, provided you meet the very benevolent license conditions. You can create these modifications for the official LinuxCNC community, or for your own needs. Both paths have their advantages and disadvantages. If you offer your modification or improvement to the official developers, if they are interested, they can help you improve it even more and you will receive feedback. If you keep your modification to yourself, you do not have to worry about whether it will interest the official developers, but it may be a problem in the future if someone unfamiliar with these modifications were to maintain the machine you built (modifications, updates, fixes, …). Of course, the developers modify all the code that is part of LinuxCNC, but the diagram only shows the links for which the developer's skills are necessary (C, C++, Python, Bash, GTK, Glade, QT, Linux OS, GitHub, PC hardware, …)

Wizard

Wizards are standalone programs that LinuxCNC and external groups are providing. They can work without other LinuxCNC components. The main output of Wizards are configuration files (*.ini, *.hal and others). Therefore, it is possible to do your first machine setup using the Wizard and only later, after a deeper study of the LCNC configuration, can you edit the files generated by the Wizard.

1.2. The Operating System

LinuxCNC is available as ready-to-use packages for Debian distributions.

1.3. Getting Help

1.3.1. Web Forum

A web forum can be found at https://forum.linuxcnc.org or by following the link at the top of the linuxcnc.org home page.

This is quite active but the demographic is more user-biased than the mailing list. If you want to be sure that your message is seen by the developers then the mailing list is to be preferred.

1.3.2. IRC

IRC stands for Internet Relay Chat. It is a live connection to other LinuxCNC users. The LinuxCNC IRC channel is #linuxcnc on libera.chat.

The simplest way to get on the IRC is to use the embedded web client client from libera.

Some IRC etiquette

- Ask specific questions… Avoid questions like "Can someone help me?".
- If you're really new to all this, think a bit about your question before typing it. Make sure you give enough information so someone can answer your question or solve your problem.
- Have some patience when waiting for an answer. Sometimes it takes a while to formulate an answer, or everyone might be busy working or something.
- Set up your IRC account with your unique name so people will know who you are. If you use the java client, use the same name every time you log in. This helps people remember who you are. If you have been on before, many will remember past discussions with you which will save time on both ends.

Sharing Files

The most common way to share files on the IRC is to upload the file to one of the following or a similar service and paste the link:

- *For text*: https://pastebin.com/, https://gist.github.com/, https://0bin.net/, https://paste.debian.net/
- *For pictures*: https://imagebin.org/, https://imgur.com/, https://bayimg.com/
- *For files*: https://filedropper.com/, https://filefactory.com/, https://1fichier.com/

1.3.3. Mailing List

An Internet Mailing List is a way to put questions out for everyone on that list to see and answer at their convenience. You get better exposure to your questions on a mailing list than on the IRC but answers take longer. In a nutshell you e-mail a message to the list and either get daily digests or individual replies back depending on how you set up your account.

You can subscribe to the emc-users mailing list at: https://lists.sourceforge.net/lists/listinfo/emc-users.

1.3.4. Web Forum

A web forum can be found at https://forum.linuxcnc.org/ or by following the link at the top of the https://linuxcnc.org/ home page.

This is quite active but the demographic is more user-biased than the mailing list. If you want to be sure that your message is seen by the developers then the mailing list is to be preferred.

1.3.5. LinuxCNC Wiki

A Wiki site is a user maintained web site that anyone can add to or edit.

The user maintained LinuxCNC Wiki site contains a wealth of information and tips at: http://wiki.linuxcnc.org

1.3.6. Bug Reports

Report bugs on the LinuxCNC Github github bug tracker.

Chapter 2. System Requirements

2.1. Minimum Requirements

The minimum system to run LinuxCNC and Debian / Ubuntu may vary depending on the exact usage. Stepper systems in general require faster threads to generate step pulses than servo systems. You can use the Live CD to test the software before committing to a permanent installation on a computer. Keep in mind that the Latency Test numbers are more important than the processor speed for software step generation. More information on the Latency Test is here. In addition, LinuxCNC needs to be run on an operating system that uses a specially modified kernel, see Kernel and Version Requirements.

Additional information is on the LinuxCNC Wiki site: Hardware Requirements

LinuxCNC and Debian Linux should run reasonably well on a computer with the following minimum hardware specification. These numbers are not the absolute minimum but will give reasonable performance for most stepper systems.

- 1.2 GHz 64-bit x86 processor or Raspberry Pi 4 or better.
- 512 MB of RAM, 4 GB with GUI to avoid surprises
- No hard disk for Live CD, 8 GB or more for permanent installation
- Graphics card capable of at least 1024x768 resolution, which is not using the NVidia or ATI fglrx proprietary drivers. Modern onboard graphic chipsets seem to generally be OK.
- Internet connection (not strictly needed, but very useful for updates and for communicating with the LinuxCNC community)

Minimum hardware requirements change as Linux distributions evolve so check the Debian web site for details on the Live CD you're using. Older hardware may benefit from selecting an older version of the Live CD when available.

If you plan not to rely on the distribution of readily executable programs ("binaries") and/or aim at contributing to the source tree of LinuxCNC, then there is a good chance you want a second computer to perform the compilation. Even though LinuxCNC and your developments could likely be executed at the same time with respect to disk space, RAM and even CPU speed, a machine that is busy will have worse latencies, so you are unlikely to compile your source tree and produce chips at the same time.

2.2. Kernel and Version requirements

LinuxCNC requires a kernel modified for realtime use to control real machine hardware. However, it can run on a standard kernel in simulation mode for purposes such as checking G-code, testing config files and learning the system. To work with these kernel versions there are two versions of LinuxCNC distributed. The package names are "linuxcnc" and "linuxcnc-uspace".

The realtime kernel options are preempt-rt, RTAI and Xenomai.

You can discover the kernel version of your system with the command:

```
uname -a
```

If you see (as above) `-rt-` in the kernel name then you are running the preempt-rt kernel and should install the "uspace" version of LinuxCNC. You should also install uspace for "sim" configs on non-realtime kernels.

If you see `-rtai-` in the kernel name then you are running RTAI realtime. See below for the LinuxCNC version to install.

2.2.1. Preempt-RT with *linuxcnc-uspace* package

Preempt-RT is the newest of the realtime systems, and is also the version that is closest to a mainline kernel. Preempt-RT kernels are available as precompiled packages from the main repositories. The search term "PREEMPT_RT" will find them, and one can be downloaded and installed just like any other package. Preempt-RT will generally have the best driver support and is the only option for systems using the Mesa ethernet-connected hardware driver cards. In general preempt-rt has the worst latency of the available systems, but there are exceptions.

2.2.2. RTAI with *linuxcnc* package

RTAI has been the mainstay of LinuxCNC distributions for many years. It will generally give the best realtime performance in terms of low latency, but might have poorer peripheral support and not as many screen resolutions. An RTAI kernel is available from the LinuxCNC package repository. If you installed from the Live/Install image then switching kernel and LinuxCNC flavour is described in [Installing-RTAI].

2.2.3. Xenomai with *linuxcnc-uspace* package

Xenomai is also supported, but you will have to find or build the kernel and compile LinuxCNC from source to utilise it.

2.2.4. RTAI with *linuxcnc-uspace* package

It is also possible to run LinuxCNC with RTAI in user-space mode. As with Xenomai you will need to compile from source to do this.

2.3. Problematic Hardware

2.3.1. Laptops

Laptops are not generally suited to real time software step generation. Again a Latency Test run for an extended time will give you the info you need to determine suitability.

2.3.2. Video Cards

If your installation pops up with 800 x 600 screen resolution then most likely Debian does not recognize your video card or monitor. This can sometimes be worked-around by installing drivers or creating / editing Xorg.conf files.

Chapter 3. Getting LinuxCNC

This section describes the recommended way to download and make a fresh install of LinuxCNC. There are also Alternate Install Methods for the adventurous. If you have an existing install that you want to upgrade, go to the Updating LinuxCNC section instead.

> **NOTE**
> To operate machinery LinuxCNC requires a special kernel with real-time extensions. There are three possibilities here: preempt-rt, RTAI or Xenomai. In addition there are two versions of LinuxCNC which work with these kernels. See the table below for details. However for code testing and simulation it is possible to run the `linuxcnc-uspace` application on a stock kernel of the distribution.

Fresh installs of LinuxCNC are most easily created using the Live/Install Image. This is a hybrid ISO filesystem image that can be written to a USB storage device or a DVD and used to boot a computer. At boot time you will be given a choice of booting the "Live" system (to run LinuxCNC without making any permanent changes to your computer) or booting the Installer (to install LinuxCNC and its operating system onto your computer's hard drive).

The outline of the process looks like this:

1. Download the Live/Install Image.
2. Write the image to a USB storage device or DVD.
3. Boot the Live system to test out LinuxCNC.
4. Boot the Installer to install LinuxCNC.

3.1. Download the image

This section describes some methods for downloading the Live/Install image.

3.1.1. Normal Download

Software for LinuxCNC to download is presented on the project's Downloads page. Most users will aim for the disk image for Intel/AMD PCs, the URL will resemble https://www.linuxcnc.org/iso/linuxcnc_2.9.8-amd64.hybrid.iso.

For the Raspberry Pi, multiple images are provided to address differences between the RPi4 and RPi5.

> **NOTE**
> Do not use the regular Raspbian distribution for LinuxCNC that may have shipped with your RPi starter kit - that will not have the real-time kernel and you cannot migrate from Raspbian to Debian's kernel image.

3.1.2. Download using zsync

zsync is a download application that efficiently resumes interrupted downloads and efficiently transfers large files with small modifications (if you have an older local copy). Please note, it needs to use the http protocol, not https. Use zsync if your download of the image using the Normal Download method is frequently interrupted.

zsync in Linux

1. Install zsync using Synaptic or, by running the following in a terminal

   ```
   sudo apt-get install zsync
   ```

2. Then run this command to download the iso to your computer

   ```
   zsync https://www.linuxcnc.org/iso/linuxcnc_2.9.8-amd64.hybrid.iso
   ```

Please remember to confirm the checksum of the downloaded iso as described below, since the authenticity of the server is not guaranteed with the http protocol.

zsync in Windows

There is a Windows port of zsync. It works as a console application and can be downloaded from https://www.assembla.com/spaces/zsync-windows/documents .

3.1.3. Verify the image

(This step is unnecessary if you used zsync)

1. After downloading, verify the checksum of the image to ensure integrity.

```
md5sum linuxcnc-2.9.8-amd64.iso
```

or

```
sha256sum linuxcnc-2.9.8-amd64.iso
```

1. Then compare to these checksums

```
amd64 (PC)
md5sum: cf77d61fcba9641d7205ac33751e5f38
sha256sum: 72eab92d7c34c238b0429054dc52d240df8dc5f083e769a39194cfac3e4984e8
arm64 (Pi)
md5sum: 4547e8a72433efb033f0a5cf166a5cd2
sha256sum: ff3ba9b8dfb93baf1e2232746655f8521a606bc0fab91bffc04ba74cc3be6bf0
```

Verify md5sum on Windows or Mac

Windows does not come with an md5sum program, but there are alternatives. More information can be found at: How To MD5SUM

3.2. Write the image to a bootable device

The LinuxCNC Live/Install ISO Image is a hybrid ISO image which can be written directly to a USB storage device (flash drive) or a DVD and used to boot a computer. The image is too large to fit on a CD.

3.2.1. Raspberry Pi Image

The Raspbery Pi image is a complete SD card image and should be written to an SD card with the [Raspberry Pi Imager App](https://www.raspberrypi.com/software/). Note that the imager app can open the .zip file directly, no need to expand.

3.2.2. AMD-64 (x86-64, PC) Image using GUI tools

Download and install Balena Etcher from https://etcher.balena.io/#download-etcher (Linux, Windows, Mac) and write the downloaded image to a USB drive.

If your image fails to boot then please also try Rufus. It looks more complicated but seems to be more compatible with various BIOSes.

3.2.3. Command line - Linux

1. Connect a USB storage device (for example a flash drive or thumb drive type device).
2. Determine the device file corresponding to the USB flash drive. This information can be found in the output of `sudo dmesg` after connecting the device. `cat /proc/partitions` may also be helpful.
3. Use the `dd` command to write the image to your USB storage device. For example, if your storage device showed up as `/dev/sde`, then use this command:

```
dd if=linuxcnc_2.9.8-amd64.hybrid.iso of=/dev/sde bs=4k status=progress
```

3.2.4. Command line - MacOS

1. Open a terminal and type

```
diskutil list
```

2. Insert the USB and note the name of the new disk that appears, e.g. /dev/disk5.
3. Unmount the USB. The number found above should be substituted in place of the N.

```
diskutil unmountDisk /dev/diskN
```

4. Transfer the data with dd, as for Linux above. Note that the disk name has an added "r" at the beginning.

```
sudo dd if=linuxcnc_2.9.8-amd64.hybrid.iso of=/dev/rdiskN bs=1m status=progress
```

Writing the image to a DVD in Linux

1. Insert a blank DVD into your burner. A *CD/DVD Creator* or *Choose Disc Type* window will pop up. Close this, as we will not be using it.
2. Browse to the downloaded image in the file browser.

3. Right click on the ISO image file and choose Write to Disc.
4. Select the write speed. It is recommended that you write at the lowest possible speed.
5. Start the burning process.
6. If a *choose a file name for the disc image* window pops up, just pick OK.

Writing the image to a DVD in Windows

1. Download and install Infra Recorder, a free and open source image burning program: https://infrarecorder.org/ .
2. Insert a blank CD in the drive and select Do nothing or Cancel if an auto-run dialog pops up.
3. Open Infra Recorder, and select the *Actions* menu, then *Burn image*.

Writing the image to a DVD in Mac OSX

1. Download the .iso file
2. Right-click on the file in the Finder window and select "Burn to disc". (The option to burn to disc will only appear if the machine has an optical drive fitted or connected.)

3.3. Testing LinuxCNC

With the USB storage device plugged in or the DVD in the DVD drive, shut down the computer then turn the computer back on. This will boot the computer from the Live/Install Image and choose the Live boot option.

NOTE If the system does not boot from the DVD or USB stick, it may be necessary to change the boot order in the PC BIOS.

Once the computer has booted up you can try out LinuxCNC without installing it. You can not create custom configurations or modify most system settings in a Live session, but you can (and should) run the latency test.

To try out LinuxCNC: from the Applications/CNC menu pick LinuxCNC. A dialog box will open from which you can choose one of many sample configurations. At this point it only really makes sense to pick a "sim" configuration. Some of the sample configurations include onscreen 3D simulated machines, look for "Vismach" to see these.

To see if your computer is suitable for software step pulse generation run the Latency Test as shown here.

At the time of writing the Live Image is only available with the preempt-rt kernel and a matching LinuxCNC. On some hardware this might not offer good enough latency. There is an experimental version available using the RTAI realtime kernel which will often give better latency.

3.4. Installing LinuxCNC

To install LinuxCNC from the Live CD select *Install (Graphical)* at bootup.

3.5. Updates to LinuxCNC

With the normal install the Update Manager will notify you of updates to LinuxCNC when you go on line and allow you to easily upgrade with no Linux knowledge needed. It is OK to upgrade everything except the operating system when asked to.

WARNING Do not upgrade the operating system to a new version if prompted to do so. You should accept OS *updates* however, especially security updates.

3.6. Install Problems

In rare cases you might have to reset the BIOS to default settings if during the Live CD install it cannot recognize the hard drive during the boot up.

3.7. Alternate Install Methods

The easiest, preferred way to install LinuxCNC is to use the Live/Install Image as described above. That method is as simple and reliable as we can make it, and is suitable for novice users and experienced users alike. However, this will typically replace any existing operating system. If you have files on the target PC that you want to keep, then use one of the methods described in this section.

In addition, for experienced users who are familiar with Debian system administration (finding install images, manipulating apt sources, changing kernel flavors, etc), new installs are supported on following platforms: ("amd64" means "64-bit", and is not specific to AMD processors, it will run on any 64-bit x86 system)

Debian Trixie	amd64 & arm64	preempt-rt	linuxcnc-uspace	machine control & simulation
Debian Trixie	amd64	RTAI	linuxcnc	machine control
Distribution	Architecture	Kernel	Package name	Typical use
Debian Bookworm	amd64 & arm64	preempt-rt	linuxcnc-uspace	machine control & simulation
Debian Bookworm	amd64	RTAI	linuxcnc	machine control
Debian Bullseye	amd64	preempt-rt	linuxcnc-uspace	machine control & simulation
Any	Any	Stock	linuxcnc-uspace	simulation ONLY

NOTE LinuxCNC v2.9 is not supported on Debian 9 or older.

Preempt-RT kernels

The Preempt-rt kernels are available for Debian from the regular debian.org archive. The package is called `linux-image-rt-*`. Simply install the package in the same way as any other package from the Synaptic Package manager or with apt-get at the command-line.

RTAI Kernels

The RTAI kernels are available for download from the linuxcnc.org debian archive. The apt source is:

- Debian Trixie: `deb http://linuxcnc.org trixie base`
- Debian Bookworm: `deb http://linuxcnc.org bookworm base`
- Debian Bullseye: `deb http://linuxcnc.org bullseye base`
- Debian Buster: `deb http://linuxcnc.org buster base`

LinuxCNC and the RTAI kernel are now only available for 64-bit OSes but there are very few surviving systems that can not run a 64-bit OS.

3.7.1. Installing on Debian Trixie (with Preempt-RT kernel)

1. Install Debian Trixie (Debian 13), amd64 version. You can download the installer here: https://www.debian.org/distrib/
2. After burning the iso and booting up if you don't want Gnome desktop select *Advanced Options* > *Alternative desktop environments* and pick the one you like. Then select *Install* or *Graphical Install*.

   WARNING Do not enter a root password, if you do sudo is disabled and you won't be able to complete the following steps.

3. Run the following in a terminal to bring the machine up to date with the latest packages.

   ```
   sudo apt-get update
   sudo apt-get dist-upgrade
   ```

   NOTE It is possible to download a version of LinuxCNC directly from Debian (currently version 2.9.4) but a more up-to-date version (2.9.8) can be installed from the LinuxCNC repository.

4. Install the Preempt-RT kernel and modules

   ```
   sudo apt-get install linux-image-rt-amd64
   ```

5. Re-boot, and select the Linux 6.1.0-10-rt-amd64 kernel. The exact kernel version might be different, look for the "-rt" suffix. This might be hidden in the "Advanced options for Debian Bookworm" sub-menu in Grub. When you log in, verify that `PREEMPT RT`is reported by the following command.

   ```
   uname -v
   ```

6. Open Applications Menu > System > Synaptic Package Manager search for *linux-image* and right click on the original non-rt and select *Mark for Complete Removal*. Reboot. This is to force the system to boot from the RT kernel. If you prefer to retain both kernels then the other kernels need not be deleted, but grub boot configuration changes will be needed beyond the scope of this document.
7. Add the LinuxCNC Archive Signing Key to your apt keyring by downloading [the LinuxCNC installer

script](https://www.linuxcnc.org/linuxcnc-install.sh). You will need to make the script executable to run it:

```
chmod +x linuxcnc-install.sh
```

```
Then you can run the installer:
```

```
sudo ./linuxcnc-install.sh
```

3.7.2. Installing on Debian Trixie (with experimental RTAI kernel)

1. This kernel and LinuxCNC version can be installed on top of the Live DVD install, or alternatively on a fresh Install of Debian Trixie 64-bit as described above.
2. You can add the LinuxCNC archive signing key and repository information by downloading and running the installer script as described above. If an RTAI kernel is detected it will stop before installing any packages.
3. Update the package list from linuxcnc.org

   ```
   sudo apt-get update
   ```

4. Remove the existing uspace version of LinuxCNC and install the new realtime kernel, RTAI and the RTAI-version of LinuxCNC.

   ```
   sudo apt-get purge linuxcnc-uspace
   sudo apt-get purge linuxcnc-doc*
   sudo apt-get install linuxcnc
   ```

   Reboot the machine, ensuring that the system boots from the new 5.4.258-rtai kernel.

3.7.3. Installing on Raspbian 12

Don't do that. The latencies are too bad with the default kernel and the PREEMPT_RT (the RT is important) kernel of Debian does not boot on the Pi (as of 1/2024). Please refer to the .iso images provided online on the regular LinuCNC download page. You can create them yourself following the scripts provided online.

Chapter 4. Running LinuxCNC

4.1. Invoking LinuxCNC

After installation, LinuxCNC starts just like any other Linux program: run it from the terminal by issuing the command *linuxcnc*, or select it in the *Applications → CNC* menu.

4.2. Configuration Launcher

When starting LinuxCNC (from the CNC menu or from the command line without specifying an INI file) the Configuration Selector dialog starts.

The Configuration Selector dialog allows the user to pick one of their existing configurations (My Configurations) or select a new one (from the Sample Configurations) to be copied to their home directory. Copied configurations will appear under My Configurations on the next invocation of the Configuration Selector.

The Configuration Selector offers a selection of configurations organized:

- *My Configurations* - User configurations located in linuxcnc/configs in your home directory.
- *Sample Configurations* - Sample configurations, when selected, are copied to linuxcnc/configs. Once a sample configuration was copied to your local directory, the launcher will offer it as *My Configurations*. The names under which these local configurations are presented correspond to the names of the directories within the configs/ directory:
  - *sim* - Configurations that include simulated hardware. These can be used for testing or learning how LinuxCNC works.
  - *by_interface* - Configurations organized by GUI.
  - *by_machine* - Configurations organized by machine.
  - *apps* - Applications that do not require starting linuxcnc but may be useful for testing or trying applications like PyVCP or GladeVCP.
  - *attic* - Obsolete or historical configurations.

The sim configurations are often the most useful starting point for new users and are organized around supported GUIs:

- *axis* - Keyboard and Mouse GUI
- *craftsman* - Touch Screen GUI (no longer maintained ???)
- *gmoccapy* - Touch Screen GUI
- *gscreen* - Touch Screen GUI
- *pyvcp_demo* - Python Virtual Control Panel
- *qtaxis* - Touch Screen GUI, axis lookalike
- *qtdragon* - Touch Screen GUI

- *qtdragon_hd* - Touch Screen GUI, high definition
- *qtplasmac* - Touch Screen GUI, for plasma tables
- *qttouchy* - Touch Screen GUI
- *tklinuxcnc* - Keyboard and Mouse GUI (no longer maintained)
- *touchy* - Touch Screen GUI
- *woodpecker* - Touch Screen GUI

A GUI configuration directory may contain subdirectories with configurations that illustrate special situations or the embedding of other applications.

The *by_interface* configurations are organized around common, supported interfaces like:

- general mechatronics
- mesa
- parport
- pico
- pluto
- servotogo
- vigilant
- vitalsystems

Related hardware may be required to use these configurations as starting points for a system.

The *by_machine* configurations are organized around complete, known systems like:

- boss
- cooltool
- scortbot erIII
- sherline
- smithy
- tormach

A complete system may be required to use these configurations.

The *apps items* are typically either:

1. utilities that don't require starting linuxcnc
2. demonstrations of applications that can be used with linuxcnc
    - info - creates a file with system information that may be useful for problem diagnosis.
    - gladevcp - Example GladeVCP applications.
    - halrun - Starts halrun in an terminal.

  - latency - Applications to investigate latency
    - latency-histogram-1 - histogram for single servo thread
    - latency-histogram - histogram
    - latency-test - standard test
    - latency-plot - stripchart
  - parport - Applications to test parport.
  - pyvcp - Example pyvcp applications.
  - xhc-hb04 - Applications to test an xhc-hb04 USB wireless MPG

NOTE Under the Apps directory, only applications that are usefully modified by the user are offered for copying to the user's directory.

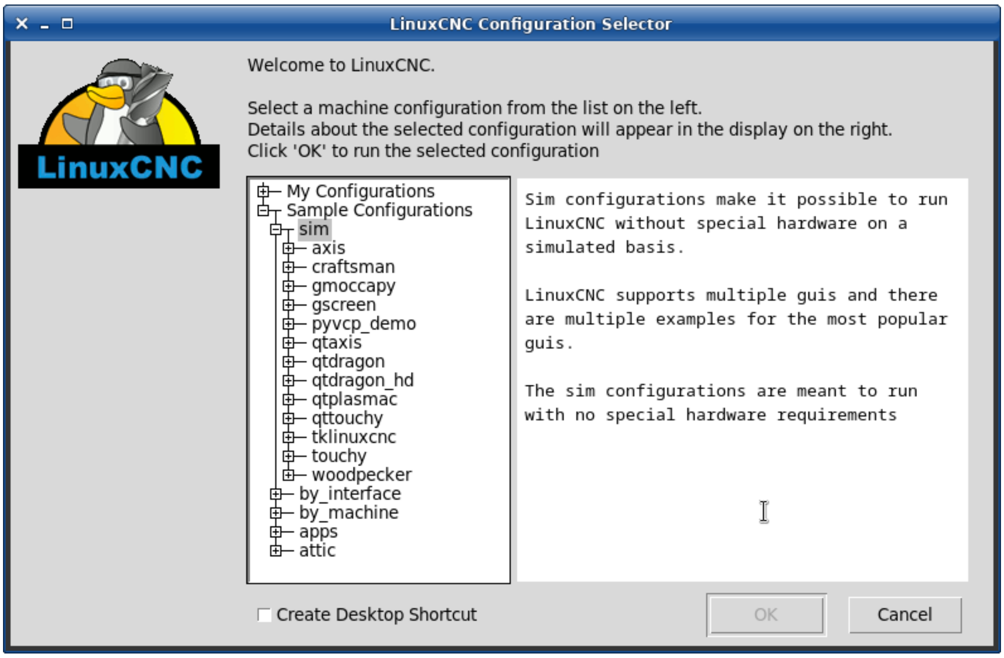

Figure 2. LinuxCNC Configuration Selector

Click any of the listed configurations to display specific information about it. Double-click a configuration or click OK to start the configuration.

Select *Create Desktop Shortcut* and then click *OK* to add an icon on the Ubuntu desktop to directly launch this configuration without showing the Configuration Selector screen.

When you select a configuration from the Sample Configurations section, it will automatically place a copy of that config in the ~/linuxcnc/configs directory.

4.3. Next steps in configuration

After finding the sample configuration that uses the same interface hardware as your machine (or a simulator configuration), and saving a copy to your home directory, you can customize it according to the details of your machine. Refer to the Integrator Manual for topics on configuration.

4.4. Simulator Configurations

All configurations listed under Sample Configurations/sim are intended to run on any computer. No specific hardware is required and real-time support is not needed.

These configurations are useful for studying individual capabilities or options. The sim configurations are organized according to the graphical user interface used in the demonstration. The directory for axis contains the most choices and subdirectories because it is the most tested GUI. The capabilities demonstrated with any specific GUI may be available in other GUIs as well.

4.5. Configuration Resources

The Configuration Selector copies all files needed for a configuration to a new subdirectory of ~/linuxcnc/configs (equivalently: /home/username/linuxcnc/configs). Each created directory will include at least one INI file (iniflename.ini) that is used to describe a specific configuration.

4.5.1. When the copy happens

For the following cases the Configuration Selector copies the chosen sample configuration to ~/linuxcnc/configs:

- **Package install (deb, rpm, distro packages)**: sample configurations live under a system path and are not writabe.
- **The file is not in the directory tree of `CONFIG_DIR`** (environmental variable)
- **The file is in a directory included in `LINUXCNC_AUX_EXAMPLES`** (environmental variable)

For **Run-In-Place (RIP) builds** the source tree is normally writable by the user who built it, so the selector runs the configuration directly from the source tree without copying. Edits made through the configuration apply to the files in the RIP tree.

4.5.2. Forcing a copy from a RIP build

To test the copy-and-run path from a RIP build (or to keep a personal copy of a sample configuration outside the source tree), set the `debug_pickconfig` environment variable before launching LinuxCNC:

```
debug_pickconfig=1 linuxcnc
```

With this set, the selector copies the chosen sample configuration to ~/linuxcnc/configs even though the RIP source tree is writable.

File resources within the copied directory will typically include one or more INI file (filename.ini) for related configurations and a tool table file (toolfilename.tbl). Additionally, resources may include HAL files (filename.hal, filename.tcl), a README file for describing the directory, and configuration specific information in a text file named after a specific configuration (inifilename.txt). That latter two files are displayed when using the Configuration Selector.

The supplied sample configurations may specify the parameter HALFILE (filename.hal) in the configuration INI file that are not present in the copied directory because they are found in the system HAL file library. These files can be copied to the user configuration directory and altered as required by the user for modification or test. Since the user configuration directory is searched first when finding HAL files, local modifications will then prevail.

The Configuration selector makes a symbolic link in the user configuration directory (named hallib) that points to the system HAL file library. This link simplifies copying a library file. For example, to copy the library core_sim.hal file in order to make local modifications:

```
cd ~/linuxcnc/configs/name_of_configuration
cp hallib/core_sim.hal core_sim.hal
```

Chapter 5. Updating LinuxCNC

Updating LinuxCNC to a new minor release (ie to a new version in the same stable series, for example from 2.9.7 to 2.9.8) is an automatic process if your PC is connected to the internet. You will see an update prompt after a minor release along with other software updates. If you don't have an internet connection to your PC see Updating without Network.

5.1. Upgrade to the new version

This section describes how to upgrade LinuxCNC from version 2.8.x to a 2.9.y version. It assumes that you have an existing 2.8 install that you want to update.

To upgrade LinuxCNC from a version older than 2.8, you have to first upgrade your old install to 2.8, then follow these instructions to upgrade to the new version.

If you do not have an old version of LinuxCNC to upgrade, then you're best off making a fresh install of the new version as described in the section Getting LinuxCNC.

Furthermore, if you are running Ubuntu Precise, Debian Wheezy or Debian Buster it is well worth considering making a backup of the "linuxcnc" directory on removable media and performing a clean install of a newer OS and LinuxCNC version as these releases were EOL in 2017, 2018 and 2022 respectively. If you are running on Ubuntu Lucid then you will have to do this, as Lucid is no longer supported by LinuxCNC (it was EOL in 2013).

To upgrade major versions like 2.8 to 2.9 when you have a network connection at the machine you need to disable the old linuxcnc.org apt sources in the file /etc/apt/sources.list and add a new linuxcnc.org apt source for 2.9, then upgrade LinuxCNC.

The details will depend on which platform you're running on. Open a terminal then type `lsb_release -ic` to find this information out:

```
lsb_release -ic
Distributor ID: Debian
Codename:       Trixie
```

You should be running on Debian Bullseye, Bookworm or Trixie or Ubuntu 20.04 "Focal Fossa" or newer. LinuxCNC 2.9.y will not run on older distributions than these.

You will also need to check which realtime kernel is being used:

```
uname -r
6.1.0-10-rt-amd64
```

If you see (as above) `-rt-` in the kernel name then you are running the preempt-rt kernel and should install the "uspace" version of LinuxCNC. You should also install uspace for "sim" configs on non-realtime kernels.

If you see `-rtai-` in the kernel name then you are running RTAI realtime. See below for the LinuxCNC version to install. RTAI packages are available for Bookworm and Buster but not currently for Bullseye.

5.1.1. Apt Sources Configuration

- Open the `Software Sources` window. The process for doing this differs slightly on the three supported platforms:
  - Debian:
    - Click on `Applications Menu`, then `System`, then `Synaptic Package Manager`.
    - In Synaptic, click on the `Settings` menu, then click `Repositories` to open the `Software Sources` window.
  - Ubuntu Precise:
    - Click on the `Dash Home` icon in the top left.
    - In the `Search` field, type "software", then click on the `Ubuntu Software Center` icon.
    - In the Ubuntu Software Center window, click on the `Edit` menu, then click on `Software Sources...` to open the `Software Sources` window.
  - Ubuntu Lucid:
    - Click the `System` menu, then `Administration`, then `Synaptic Package Manager`.
    - In Synaptic, click on the `Settings` menu, then click on `Repositories` to open the `Software Sources` window.
- In the `Software Sources` window, select the `Other Software` tab.
- Delete or un-check all the old linuxcnc.org entries (leave all non-linuxcnc.org lines as they are).
- Click the `Add` button and add a new apt line. The line will be slightly different on the different platforms:

Table 1. Tabular overview on variants of the Operating System and the corresponding configuration of the repository. The configuration can be performed in the GUI of the package manager or in the file /etc/apt/sources.list.

OS / Realtime Version	Repository
Debian Bullseye - preempt	`deb https://linuxcnc.org bullseye base 2.9-uspace`
Debian Bookworm - preempt	`deb https://linuxcnc.org bookworm base 2.9-uspace`
Debian Bookworm - RTAI	`deb https://linuxcnc.org bookworm base 2.9-rt`
Debian Trixie - preempt	`deb https://linuxcnc.org trixie base 2.9-uspace`
Debian Trixie - RTAI	`deb https://linuxcnc.org trixie base 2.9-rt`

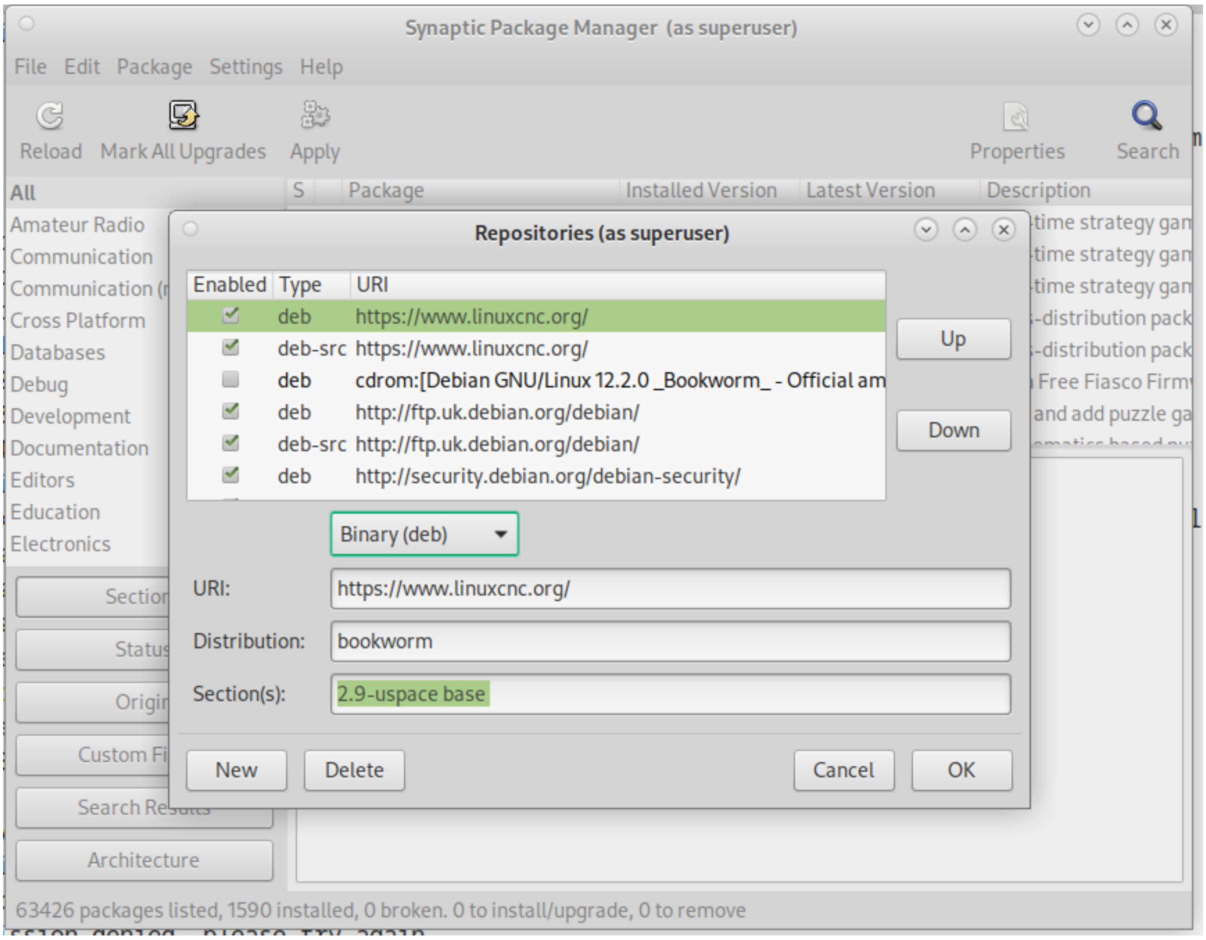

Figure 3. Figure with a screenshot of the repository configuration of the synaptic package manager.

- Click `Add Source`, then `Close` in the Software Sources window. If it pops up a window informing you that the information about available software is out-of-date, click the `Reload` button.

5.1.2. Upgrading to the new version

Now your computer knows where to get the new version of the software, next we need to install it.

The process again differs depending on your platform.

Debian Bullseye, Bookworm and Trixie

Debian uses the Synaptic Package Manager.

- Open Synaptic using the instructions in Setting apt sources above.
- Click the `Reload` button.
- Use the Search function to search for `linuxcnc`.
- The package is called "linuxcnc" for RTAI kernels and "linuxcnc-uspace" for preempt-rt.
- Click the check box to mark the new linuxcnc and linuxcnc-doc-* packages for upgrade. The package manager may select a number of additional packages to be installed, to satisfy dependencies that the new linuxcnc package has.
- Click the `Apply` button, and let your computer install the new package. The old linuxcnc package will

be automatically upgraded to the new one.

5.1.3. Ubuntu

- Click on the `Dash Home` icon in the top left.
- In the `Search` field, type "update", then click on the `Update Manager` icon.
- Click the `Check` button to fetch the list of packages available.
- Click the `Install Updates` button to install the new versions of all packages.

5.2. Updating without Network

To update without a network connection you need to download the .deb then install it with dpkg. The .debs can be found in https://linuxcnc.org/dists/ .

You have to drill down from the above link to find the correct deb for your installation. Open a terminal and type in *lsb_release -ic* to find the release name of your OS.

```
> lsb_release -ic
Distributor ID: Debian
Codename:       trixie
```

Pick the OS from the list then pick the major version you want like 2.9-rt for RTAI or 2.9-uspace for preempt-rt.

Next pick the type of computer you have: binary-amd64 for 64-bit PC or binary-arm64 (64bit) for Raspberry Pi.

Next pick the version you want from the bottom of the list like *linuxcnc-uspace_2.9.8_amd64.deb* (choose the latest by date). Download the deb and copy it to your home directory. You can rename the file to something a bit shorter with the file manager like *linuxcnc_2.9.8.deb* then open a terminal and install it with the package manager with this command:

```
sudo dpkg -i linuxcnc_2.9.8.deb
```

5.3. Updating Configuration Files for 2.9

5.3.1. Stricter handling of pluggable interpreters

If you just run regular G-code and you don't know what a pluggable interpreter is, then this section does not affect you.

A seldom-used feature of LinuxCNC is support for pluggable interpreters, controlled by the undocumented `[TASK]INTERPRETER` INI setting.

Versions of LinuxCNC before 2.9.0 used to handle an incorrect `[TASK]INTERPRETER` setting by automatically falling back to using the default G-code interpreter.

Since 2.9.0, an incorrect `[TASK]INTERPRETER` value will cause LinuxCNC to refuse to start up. Fix this condition by deleting the `[TASK]INTERPRETER` setting from your INI file, so that LinuxCNC will use the default G-code interpreter.

5.3.2. Canterp

If you just run regular G-code and you don't use the `canterp` pluggable interpreter, then this section does not affect you.

In the extremely unlikely event that you are using `canterp`, know that the module has moved from `/usr/lib/libcanterp.so` to `/usr/lib/linuxcnc/canterp.so`, and the `[TASK]INTERPRETER` setting correspondingly needs to change from `libcanterp.so` to `canterp.so`.

5.3.3. Spindle limits in the INI

It is now possible to add settings to the [SPINDLE] section of the INI file

MAX_FORWARD_VELOCITY = 20000 The maximum spindle speed (in rpm)

MIN_FORWARD_VELOCITY = 3000 The minimum spindle speed (in rpm)

MAX_REVERSE_VELOCITY = 20000 This setting will default to MAX_FORWARD_VELOCITY if omitted.

MIN_REVERSE_VELOCITY = 3000` This setting is equivalent to MIN_FORWARD_VELOCITY but for reverse spindle rotation. It will default to the MIN_FORWARD_VELOCITY if omitted.

INCREMENT = 200 Sets the step size for spindle speed increment / decrement commands. This can have a different value for each spindle. This setting is effective with AXIS and Touchy but note that some control screens may handle things differently.

HOME_SEARCH_VELOCITY = 100 - Accepted but currently does nothing

HOME_SEQUENCE = 0 - Accepted but currently does nothing

5.4. Updating Configuration Files for 2.10.y

Touchy: the Touchy MACRO entries should now be placed in a [MACROS] section of the INI rather than in the [TOUCHY] section. This is part of a process of commonising the INI setting between GUIs.

5.5. New HAL components

5.5.1. Non-Realtime

mdro mqtt-publisher pi500_vfd pmx485-test qtplasmac-cfg2prefs qtplasmac-materials qtplasmac-plasmac2qt qtplasmac-setup sim-torch svd-ps_vfd

5.5.2. Realtime

anglejog div2 enum filter_kalman flipflop homecomp limit_axis mesa_uart millturn scaled_s32_sums tof ton

5.6. New Drivers

A framework for controlling ModBus devices using the serial ports on many Mesa cards has been introduced. http://linuxcnc.org/docs/2.9/html/drivers/mesa_modbus.html

A new GPIO driver for any GPIO which is supported by the gpiod library is now included: http://linuxcnc.org/docs/2.9/html/drivers/hal_gpio.html

Chapter 6. Glossary

A listing of terms and what they mean. Some terms have a general meaning and several additional meanings for users, installers, and developers.

Acme Screw

A type of lead-screw that uses an Acme thread form. Acme threads have somewhat lower friction and wear than simple triangular threads, but ball-screws are lower yet. Most manual machine tools use acme lead-screws.

Axis

One of the computer controlled movable parts of the machine. For a typical vertical mill, the table is the X axis, the saddle is the Y axis, and the quill or knee is the Z axis. Angular axes like rotary tables are referred to as A, B, and C. Additional linear axes relative to the tool are called U, V, and W respectively.

AXIS(GUI)

One of the Graphical User Interfaces available to users of LinuxCNC. It features the modern use of menus and mouse buttons while automating and hiding some of the more traditional LinuxCNC controls. It is the only open-source interface that displays the entire tool path as soon as a file is opened.

GMOCCAPY (GUI)

A Graphical User Interfaces available to users of LinuxCNC. It features the use and feel of an industrial control and can be used with touch screen, mouse and keyboard. It support embedded tabs and hal driven user messages, it offers a lot of hal beens to be controlled with hardware. GMOCCAPY is highly customizable.

Backlash

The amount of "play" or lost motion that occurs when direction is reversed in a lead screw. or other mechanical motion driving system. It can result from nuts that are loose on leadscrews, slippage in belts, cable slack, "wind-up" in rotary couplings, and other places where the mechanical system is not "tight". Backlash will result in inaccurate motion, or in the case of motion caused by external forces (think cutting tool pulling on the work piece) the result can be broken cutting tools. This can happen because of the sudden increase in chip load on the cutter as the work piece is pulled across the backlash distance by the cutting tool.

Backlash Compensation

Any technique that attempts to reduce the effect of backlash without actually removing it from the mechanical system. This is typically done in software in the controller. This can correct the final resting place of the part in motion but fails to solve problems related to direction changes while in motion (think circular interpolation) and motion that is caused when external forces (think cutting tool pulling on the work piece) are the source of the motion.

Ball Screw

A type of lead-screw that uses small hardened steel balls between the nut and screw to reduce friction. Ball-screws have very low friction and backlash, but are usually quite expensive.

Ball Nut

A special nut designed for use with a ball-screw. It contains an internal passage to re-circulate the balls from one end of the screw to the other.

CNC

Computer Numerical Control. The general term used to refer to computer control of machinery. Instead of a human operator turning cranks to move a cutting tool, CNC uses a computer and motors to move the tool, based on a part program.

Halcompile

A tool used to build, compile and install LinuxCNC HAL components.

Configuration(n)

A directory containing a set of configuration files. Custom configurations are normally saved in the users home/linuxcnc/configs directory. These files include LinuxCNC's traditional INI file and HAL files. A configuration may also contain several general files that describe tools, parameters, and NML connections.

Configuration(v)

The task of setting up LinuxCNC so that it matches the hardware on a machine tool.

Coordinate Measuring Machine

A Coordinate Measuring Machine is used to make many accurate measurements on parts. These machines can be used to create CAD data for parts where no drawings can be found, when a hand-made prototype needs to be digitized for moldmaking, or to check the accuracy of machined or molded parts.

Display units

The linear and angular units used for onscreen display.

DRO

A Digital Read Out is a system of position-measuring devices attached to the slides of a machine tool, which are connected to a numeric display showing the current location of the tool with respect to some reference position. DROs are very popular on hand-operated machine tools because they measure the true tool position without backlash, even if the machine has very loose Acme screws. Some DROs use linear quadrature encoders to pick up position information from the machine, and some use methods similar to a resolver which keeps rolling over.

EDM

EDM is a method of removing metal in hard or difficult to machine or tough metals, or where rotating tools would not be able to produce the desired shape in a cost-effective manner. An excellent example is rectangular punch dies, where sharp internal corners are desired. Milling operations can not give sharp internal corners with finite diameter tools. A *wire* EDM machine can make internal corners with a radius only slightly larger than the wire's radius. A *sinker* EDM can make internal corners with a radius only slightly larger than the radius on the corner of the sinking electrode.

EMC

The Enhanced Machine Controller. Initially a NIST project. Renamed to LinuxCNC in 2012.

EMCIO

The module within LinuxCNC that handles general purpose I/O, unrelated to the actual motion of the axes.

EMCMOT

The module within LinuxCNC that handles the actual motion of the cutting tool. It runs as a real-time program and directly controls the motors.

Encoder

A device to measure position. Usually a mechanical-optical device, which outputs a quadrature signal. The signal can be counted by special hardware, or directly by the parport with LinuxCNC.

Feed

Relatively slow, controlled motion of the tool used when making a cut.

Feed rate

The speed at which a cutting motion occurs. In auto or MDI mode, feed rate is commanded using an F word. F10 would mean ten machine units per minute.

Feedback

A method (e.g., quadrature encoder signals) by which LinuxCNC receives information about the position of motors.

Feedrate Override

A manual, operator controlled change in the rate at which the tool moves while cutting. Often used to allow the operator to adjust for tools that are a little dull, or anything else that requires the feed rate to be "tweaked".

Floating Point Number

A number that has a decimal point. (12.300) In HAL it is known as float.

G-code

The generic term used to refer to the most common part programming language. There are several dialects of G-code, LinuxCNC uses RS274/NGC.

GUI

Graphical User Interface.

General

A type of interface that allows communications between a computer and a human (in most cases) via the manipulation of icons and other elements (widgets) on a computer screen.

LinuxCNC

An application that presents a graphical screen to the machine operator allowing manipulation of the machine and the corresponding controlling program.

HAL

Hardware Abstraction Layer. At the highest level, it is simply a way to allow a number of building blocks to be loaded and interconnected to assemble a complex system. Many of the building blocks are drivers for hardware devices. However, HAL can do more than just configure hardware drivers.

Home

A specific location in the machine's work envelope that is used to make sure the computer and the actual machine both agree on the tool position.

INI file

A text file that contains most of the information that configures LinuxCNC for a particular machine.

Instance

One can have an instance of a class or a particular object. The instance is the actual object created at runtime. In programmer jargon, the "Lassie" object is an instance of the "Dog" class.

Joint Coordinates

These specify the angles between the individual joints of the machine. See also Kinematics

Jog

Manually moving an axis of a machine. Jogging either moves the axis a fixed amount for each key-press, or moves the axis at a constant speed as long as you hold down the key. In manual mode, jog speed can be set from the graphical interface.

kernel-space

Code running inside the kernel, as opposed to code running in userspace. Some realtime systems (like RTAI) run realtime code in the kernel and non-realtime code in userspace, while other realtime systems (like Preempt-RT) run both realtime and non-realtime code in userspace.

Kinematics

The position relationship between world coordinates and joint coordinates of a machine. There are two types of kinematics. Forward kinematics is used to calculate world coordinates from joint coordinates. Inverse kinematics is used for exactly the opposite purpose. Note that kinematics does not take into account, the forces, moments etc. on the machine. It is for positioning only.

Lead-screw

An screw that is rotated by a motor to move a table or other part of a machine. Lead-screws are usually either ball-screws or acme screws, although conventional triangular threaded screws may be used where accuracy and long life are not as important as low cost.

Machine units

The linear and angular units used for machine configuration. These units are specified and used in the INI file. HAL pins and parameters are also generally in machine units.

MDI

Manual Data Input. This is a mode of operation where the controller executes single lines of G-code as they are typed by the operator.

NIST

National Institute of Standards and Technology. An agency of the Department of Commerce in the United States.

NML

Neutral Message Language provides a mechanism for handling multiple types of messages in the same buffer as well as simplifying the interface for encoding and decoding buffers in neutral format and the configuration mechanism.

Offsets

An arbitrary amount, added to the value of something to make it equal to some desired value. For example, G-code programs are often written around some convenient point, such as X0, Y0. Fixture offsets can be used to shift the actual execution point of that G-code program to properly fit the true location of the vice and jaws. Tool offsets can be used to shift the "uncorrected" length of a tool to equal that tool's actual length.

Part Program

A description of a part, in a language that the controller can understand. For LinuxCNC, that language is RS-274/NGC, commonly known as G-code.

Program Units

The linear and angular units used in a part program. The linear program units do not have to be the same as the linear machine units. See G20 and G21 for more information. The angular program units are always measured in degrees.

Python

General-purpose, very high-level programming language. Used in LinuxCNC for the Axis GUI, the StepConf configuration tool, and several G-code programming scripts.

Rapid

Fast, possibly less precise motion of the tool, commonly used to move between cuts. If the tool meets the workpiece or the fixturing during a rapid, it is probably a bad thing!

Rapid rate

The speed at which a rapid motion occurs. In auto or MDI mode, rapid rate is usually the maximum speed of the machine. It is often desirable to limit the rapid rate when testing a G-code program for the first time.

Real-time

Software that is intended to meet very strict timing deadlines. On Linux, in order to meet these requirements it is necessary to install a realtime kernel such as RTAI or Preempt-RT, and build the LinuxCNC software to run in the special real-time environment. Realtime software can run in the kernel or in userspace, depending on the facilities offered by the system.

RTAI

Real Time Application Interface, see https://www.rtai.org/, the real-time extensions for Linux that LinuxCNC can use to achieve real-time performance.

RTLINUX

See https://en.wikipedia.org/wiki/RTLinux, an older real-time extension for Linux that LinuxCNC used to use to achieve real-time performance. Obsolete, replaced by RTAI.

RTAPI

A portable interface to real-time operating systems including RTAI and POSIX pthreads with realtime extensions.

RS-274/NGC

The formal name for the language used by LinuxCNC part programs.

Servo Motor

Generally, any motor that is used with error-sensing feedback to correct the position of an actuator. Also, a motor which is specially-designed to provide improved performance in such applications.

Servo Loop

A control loop used to control position or velocity of an motor equipped with a feedback device.

Signed Integer

A whole number that can have a positive or negative sign. In HAL it is usually a s32, but could be also a s64.

Spindle

The part of a machine tool that spins to do the cutting. On a mill or drill, the spindle holds the cutting tool. On a lathe, the spindle holds the workpiece.

Spindle Speed Override

A manual, operator controlled change in the rate at which the tool rotates while cutting. Often used to allow the operator to adjust for chatter caused by the cutter's teeth. Spindle Speed Override assumes that the LinuxCNC software has been configured to control spindle speed.

StepConf

An LinuxCNC configuration wizard. It is able to handle many step-and-direction motion command based machines. It writes a full configuration after the user answers a few questions about the computer and machine that LinuxCNC is to run on.

Stepper Motor

A type of motor that turns in fixed steps. By counting steps, it is possible to determine how far the motor has turned. If the load exceeds the torque capability of the motor, it will skip one or more steps, causing position errors.

TASK

The module within LinuxCNC that coordinates the overall execution and interprets the part program.

Tcl/Tk

A scripting language and graphical widget toolkit with which several of LinuxCNCs GUIs and selection wizards were written.

Traverse Move

A move in a straight line from the start point to the end point.

Units

See "Machine Units", "Display Units", or "Program Units".

Unsigned Integer

A whole number that has no sign. In HAL it is usually a u32 but could be also a u64.

World Coordinates

This is the absolute frame of reference. It gives coordinates in terms of a fixed reference frame that is attached to some point (generally the base) of the machine tool.

Chapter 7. Legal Section

Translations of this file provided in the source tree are not legally binding.

7.1. Copyright Terms

Copyright (c) 2000-2022 LinuxCNC.org

Permission is granted to copy, distribute and/or modify this document under the terms of the GNU Free Documentation License, Version 1.1 or any later version published by the Free Software Foundation; with no Invariant Sections, no Front-Cover Texts, and no Back-Cover Texts. A copy of the license is included in the section entitled "GNU Free Documentation License".

7.2. GNU Free Documentation License

GNU Free Documentation License Version 1.1, March 2000

Copyright © 2000 Free Software Foundation, Inc. 51 Franklin Street, Fifth Floor, Boston, MA 02110-1301 USA. Everyone is permitted to copy and distribute verbatim copies of this license document, but changing it is not allowed.

0. PREAMBLE

The purpose of this License is to make a manual, textbook, or other written document "free" in the sense of freedom: to assure everyone the effective freedom to copy and redistribute it, with or without modifying it, either commercially or noncommercially. Secondarily, this License preserves for the author and publisher a way to get credit for their work, while not being considered responsible for modifications made by others.

This License is a kind of "copyleft", which means that derivative works of the document must themselves be free in the same sense. It complements the GNU General Public License, which is a copyleft license designed for free software.

We have designed this License in order to use it for manuals for free software, because free software needs free documentation: a free program should come with manuals providing the same freedoms that the software does. But this License is not limited to software manuals; it can be used for any textual work, regardless of subject matter or whether it is published as a printed book. We recommend this License principally for works whose purpose is instruction or reference.

1. APPLICABILITY AND DEFINITIONS

This License applies to any manual or other work that contains a notice placed by the copyright holder saying it can be distributed under the terms of this License. The "Document", below, refers to any such manual or work. Any member of the public is a licensee, and is addressed as "you".

A "Modified Version" of the Document means any work containing the Document or a portion of it, either copied verbatim, or with modifications and/or translated into another language.

A "Secondary Section" is a named appendix or a front-matter section of the Document that deals exclusively with the relationship of the publishers or authors of the Document to the Document's overall subject (or to related matters) and contains nothing that could fall directly within that overall subject. (For example, if the Document is in part a textbook of mathematics, a Secondary Section may not explain any mathematics.) The relationship could be a matter of historical connection with the subject or with related matters, or of legal, commercial, philosophical, ethical or political position regarding them.

The "Invariant Sections" are certain Secondary Sections whose titles are designated, as being those of Invariant Sections, in the notice that says that the Document is released under this License.

The "Cover Texts" are certain short passages of text that are listed, as Front-Cover Texts or Back-Cover Texts, in the notice that says that the Document is released under this License.

A "Transparent" copy of the Document means a machine-readable copy, represented in a format whose specification is available to the general public, whose contents can be viewed and edited directly and straightforwardly with generic text editors or (for images composed of pixels) generic paint programs or (for drawings) some widely available drawing editor, and that is suitable for input to text formatters or for automatic translation to a variety of formats suitable for input to text formatters. A copy made in an otherwise Transparent file format whose markup has been designed to thwart or discourage subsequent modification by readers is not Transparent. A copy that is not "Transparent" is called "Opaque".

Examples of suitable formats for Transparent copies include plain ASCII without markup, Texinfo input format, LaTeX input format, SGML or XML using a publicly available DTD, and standard-conforming simple HTML designed for human modification. Opaque formats include PostScript, PDF, proprietary formats that can be read and edited only by proprietary word processors, SGML or XML for which the DTD and/or processing tools are not generally available, and the machine-generated HTML produced by some word processors for output purposes only.

The "Title Page" means, for a printed book, the title page itself, plus such following pages as are needed to hold, legibly, the material this License requires to appear in the title page. For works in formats which do not have any title page as such, "Title Page" means the text near the most prominent appearance of the work's title, preceding the beginning of the body of the text.

2. VERBATIM COPYING

You may copy and distribute the Document in any medium, either commercially or noncommercially, provided that this License, the copyright notices, and the license notice saying this License applies to the Document are reproduced in all copies, and that you add no other conditions whatsoever to those of this License. You may not use technical measures to obstruct or control the reading or further copying of the copies you make or distribute. However, you may accept compensation in exchange for copies. If you distribute a large enough number of copies you must also follow the conditions in section 3.

You may also lend copies, under the same conditions stated above, and you may publicly display copies.

3. COPYING IN QUANTITY

If you publish printed copies of the Document numbering more than 100, and the Document's license notice requires Cover Texts, you must enclose the copies in covers that carry, clearly and legibly, all these Cover Texts: Front-Cover Texts on the front cover, and Back-Cover Texts on the back cover. Both covers must also clearly and legibly identify you as the publisher of these copies. The front cover must present the full title with all words of the title equally prominent and visible. You may add other material on the covers in addition. Copying with changes limited to the covers, as long as they preserve the title of the Document and satisfy these conditions, can be treated as verbatim copying in other respects.

If the required texts for either cover are too voluminous to fit legibly, you should put the first ones listed (as many as fit reasonably) on the actual cover, and continue the rest onto adjacent pages.

If you publish or distribute Opaque copies of the Document numbering more than 100, you must either include a machine-readable Transparent copy along with each Opaque copy, or state in or with each Opaque copy a publicly-accessible computer-network location containing a complete Transparent copy of the Document, free of added material, which the general network-using public has access to download anonymously at no charge using public-standard network protocols. If you use the latter option, you must take reasonably prudent steps, when you begin distribution of Opaque copies in quantity, to ensure that this Transparent copy will remain thus accessible at the stated location until at least one year after the last time you distribute an Opaque copy (directly or through your agents or retailers) of that edition to the public.

It is requested, but not required, that you contact the authors of the Document well before redistributing any large number of copies, to give them a chance to provide you with an updated version of the Document.

4. MODIFICATIONS

You may copy and distribute a Modified Version of the Document under the conditions of sections 2 and 3 above, provided that you release the Modified Version under precisely this License, with the Modified Version filling the role of the Document, thus licensing distribution and modification of the Modified Version to whoever possesses a copy of it. In addition, you must do these things in the Modified Version:

1. Use in the Title Page (and on the covers, if any) a title distinct from that of the Document, and from those of previous versions (which should, if there were any, be listed in the History section of the Document). You may use the same title as a previous version if the original publisher of that version gives permission. B. List on the Title Page, as authors, one or more persons or entities responsible for authorship of the modifications in the Modified Version, together with at least five of the principal authors of the Document (all of its principal authors, if it has less than five). C. State on the Title page the name of the publisher of the Modified Version, as the publisher. D. Preserve all the copyright notices of the Document. E. Add an appropriate copyright notice for your modifications adjacent to the other copyright notices. F. Include, immediately after the copyright notices, a license notice giving the public permission to use the Modified Version under the terms of this License, in the form shown in the Addendum below. G. Preserve in that license notice the full lists of Invariant Sections and required Cover Texts given in the Document's license notice. H. Include an unaltered copy of this License. I. Preserve the section entitled "History", and its title, and add to it an item stating at least the title, year, new authors, and publisher of the Modified Version as given on the Title Page. If there is no section entitled "History" in the Document, create one stating the title, year, authors, and publisher of the Document as given on its Title Page, then add an item describing the Modified Version as stated in the previous sentence. J. Preserve the network location, if any, given in the Document for public access to a Transparent copy of the Document, and likewise the network locations given in the Document for previous versions it was based on. These may be placed in the "History" section. You may omit a network location for a work that was published at least four years

before the Document itself, or if the original publisher of the version it refers to gives permission. K. In any section entitled "Acknowledgements" or "Dedications", preserve the section’s title, and preserve in the section all the substance and tone of each of the contributor acknowledgements and/or dedications given therein. L. Preserve all the Invariant Sections of the Document, unaltered in their text and in their titles. Section numbers or the equivalent are not considered part of the section titles. M. Delete any section entitled "Endorsements". Such a section may not be included in the Modified Version. N. Do not retitle any existing section as "Endorsements" or to conflict in title with any Invariant Section.

If the Modified Version includes new front-matter sections or appendices that qualify as Secondary Sections and contain no material copied from the Document, you may at your option designate some or all of these sections as invariant. To do this, add their titles to the list of Invariant Sections in the Modified Version’s license notice. These titles must be distinct from any other section titles.

You may add a section entitled "Endorsements", provided it contains nothing but endorsements of your Modified Version by various parties—for example, statements of peer review or that the text has been approved by an organization as the authoritative definition of a standard.

You may add a passage of up to five words as a Front-Cover Text, and a passage of up to 25 words as a Back-Cover Text, to the end of the list of Cover Texts in the Modified Version. Only one passage of Front-Cover Text and one of Back-Cover Text may be added by (or through arrangements made by) any one entity. If the Document already includes a cover text for the same cover, previously added by you or by arrangement made by the same entity you are acting on behalf of, you may not add another; but you may replace the old one, on explicit permission from the previous publisher that added the old one.

The author(s) and publisher(s) of the Document do not by this License give permission to use their names for publicity for or to assert or imply endorsement of any Modified Version.

5. COMBINING DOCUMENTS

You may combine the Document with other documents released under this License, under the terms defined in section 4 above for modified versions, provided that you include in the combination all of the Invariant Sections of all of the original documents, unmodified, and list them all as Invariant Sections of your combined work in its license notice.

The combined work need only contain one copy of this License, and multiple identical Invariant Sections may be replaced with a single copy. If there are multiple Invariant Sections with the same name but different contents, make the title of each such section unique by adding at the end of it, in parentheses, the name of the original author or publisher of that section if known, or else a unique number. Make the same adjustment to the section titles in the list of Invariant Sections in the license notice of the combined work.

In the combination, you must combine any sections entitled "History" in the various original documents, forming one section entitled "History"; likewise combine any sections entitled "Acknowledgements", and any sections entitled "Dedications". You must delete all sections entitled "Endorsements."

6. COLLECTIONS OF DOCUMENTS

You may make a collection consisting of the Document and other documents released under this License, and replace the individual copies of this License in the various documents with a single copy that is included in the collection, provided that you follow the rules of this License for verbatim copying of each of the documents in all other respects.

You may extract a single document from such a collection, and distribute it individually under this License, provided you insert a copy of this License into the extracted document, and follow this License in all other respects regarding verbatim copying of that document.

7. AGGREGATION WITH INDEPENDENT WORKS

A compilation of the Document or its derivatives with other separate and independent documents or works, in or on a volume of a storage or distribution medium, does not as a whole count as a Modified Version of the Document, provided no compilation copyright is claimed for the compilation. Such a compilation is called an "aggregate", and this License does not apply to the other self-contained works thus compiled with the Document, on account of their being thus compiled, if they are not themselves derivative works of the Document.

If the Cover Text requirement of section 3 is applicable to these copies of the Document, then if the Document is less than one quarter of the entire aggregate, the Document's Cover Texts may be placed on covers that surround only the Document within the aggregate. Otherwise they must appear on covers around the whole aggregate.

8. TRANSLATION

Translation is considered a kind of modification, so you may distribute translations of the Document under the terms of section 4. Replacing Invariant Sections with translations requires special permission from their copyright holders, but you may include translations of some or all Invariant Sections in addition to the original versions of these Invariant Sections. You may include a translation of this License provided that you also include the original English version of this License. In case of a disagreement between the translation and the original English version of this License, the original English version will prevail.

9. TERMINATION

You may not copy, modify, sublicense, or distribute the Document except as expressly provided for under this License. Any other attempt to copy, modify, sublicense or distribute the Document is void, and will automatically terminate your rights under this License. However, parties who have received copies, or rights, from you under this License will not have their licenses terminated so long as such parties remain in full compliance.

10. FUTURE REVISIONS OF THIS LICENSE

The Free Software Foundation may publish new, revised versions of the GNU Free Documentation 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. See https://www.gnu.org/copyleft/.

Each version of the License is given a distinguishing version number. If the Document specifies that a particular numbered version of this License "or any later version" applies to it, you have the option of following the terms and conditions either of that specified version or of any later version that has been published (not as a draft) by the Free Software Foundation. If the Document does not specify a version number of this License, you may choose any version ever published (not as a draft) by the Free Software Foundation.

ADDENDUM: How to use this License for your documents

To use this License in a document you have written, include a copy of the License in the document and put the following copyright and license notices just after the title page:

Copyright (c) YEAR YOUR NAME. Permission is granted to copy, distribute and/or modify this document under the terms of the GNU Free Documentation License, Version 1.1 or any later version published by the Free Software Foundation; with the Invariant Sections being LIST THEIR TITLES, with the Front-Cover Texts being LIST, and with the Back-Cover Texts being LIST. A copy of the license is included in the section entitled "GNU Free Documentation License".

If you have no Invariant Sections, write "with no Invariant Sections" instead of saying which ones are invariant. If you have no Front-Cover Texts, write "no Front-Cover Texts" instead of "Front-Cover Texts being LIST"; likewise for Back-Cover Texts.

If your document contains nontrivial examples of program code, we recommend releasing these examples in parallel under your choice of free software license, such as the GNU General Public License, to permit their use in free software.