

Xen to KVM Migration Guide

SUSE Linux Enterprise Server 15 SP1

As the KVM virtualization solution is becoming more and more popular among server administrators, many of them need a path to migrate their existing Xen based environments to KVM. As of now, there are no mature tools to automatically convert Xen VMs to KVM. There is, however, a technical solution that helps convert Xen virtual machines to KVM. The following information and procedures help you to perform such a migration.

Publication Date: February 01, 2024

Contents

- 1 Migration to KVM Using **virt-v2v** 2
- 2 Xen to KVM Manual Migration 9
- 3 For More Information 18
- 4 Legal Notice 18
- 5 GNU Free Documentation License 18



Important: Migration Procedure Not Supported

The migration procedure described in this document is not fully supported by SUSE. We provide it as a guidance only.

1 Migration to KVM Using **virt-v2v**

This section contains information to help you import virtual machines from foreign hypervisors (such as Xen) to KVM managed by libvirt.



Tip: Microsoft Windows Guests

This section is focused on converting Linux guests. Converting Microsoft Windows guests using virt-v2v is the same as converting Linux guests, except in regards to handling the Virtual Machine Driver Pack (VMDP). Additional details on converting Windows guests with the VMDP can be found in the separate Virtual Machine Driver Pack documentation at <https://documentation.suse.com/sle-vmdp/>.

1.1 Introduction to **virt-v2v**

virt-v2v is a command line tool to convert VM Guests from a foreign hypervisor to run on KVM managed by libvirt. It enables paravirtualized virtio drivers in the converted virtual machine if possible. A list of supported operating systems and hypervisors follows:

SUPPORTED GUEST OPERATING SYSTEMS

- SUSE Linux Enterprise Server
- openSUSE
- Red Hat Enterprise Linux
- Fedora
- Microsoft Windows Server 2003 and 2008

SUPPORTED SOURCE HYPERVISOR

- Xen

SUPPORTED TARGET HYPERVISOR

- KVM (managed by `libvirt`)

1.2 Installing `virt-v2v`

The installation of `virt-v2v` is simple:

```
> sudo zypper install virt-v2v
```

Remember that `virt-v2v` requires `root` privileges, so you need to run it either as `root`, or via `sudo`.

1.3 Preparing the Virtual Machine



Note: Conditions for Skipping This Step

If running `virt-v2v` on SLES 12 SP1 or before, this step can be safely skipped. This step can also be ignored if the virtual machine is fully virtualized or if it runs on SLES 12 SP2 or later.

The Xen virtual machine must have default kernel installed. To ensure this, run `zypper in kernel-default` on the virtual machine.

1.4 Converting Virtual Machines to Run under KVM Managed by `libvirt`

`virt-v2v` converts virtual machines from the Xen hypervisor to run under KVM managed by `libvirt`. To learn more about `libvirt` and `virsh`, see *Book "Virtualization Guide"*. Additionally, all `virt-v2v` command line options are explained in the `virt-v2v` manual page (`man 1 virt-v2v`).

Before converting a virtual machine, make sure to complete the following steps:

PROCEDURE 1: PREPARING THE ENVIRONMENT FOR THE CONVERSION

1. Create a new local storage pool.

virt-v2v copies the storage of the source virtual machine to a local storage pool managed by **libvirt** (the original disk image remains unchanged). You can create the pool either with Virtual Machine Manager, or **virsh**. For more information, see *Book "Virtualization Guide", Chapter 12 "Managing Storage", Section 12.1 "Managing Storage with Virtual Machine Manager"* and *Book "Virtualization Guide", Chapter 12 "Managing Storage", Section 12.2 "Managing Storage with virsh"*.

2. Prepare the local network interface.

Check that the converted virtual machine can use a local network interface on the VM Host Server. It is usually a network bridge. If it is not defined yet, create it with *YaST > System > Network Settings > Add > Bridge*.



Note: Mappings of Network Devices

Network devices on the source Xen host can be mapped during the conversion process to corresponding network devices on the KVM target host. For example, the Xen bridge **br0** can be mapped to the KVM network default. Sample mappings can be found in `/etc/virt-v2v.conf`. To enable these mappings, modify the XML rule as necessary and ensure the section is not commented out with `<!--` and `-->` markers. For example:

```
<network type='bridge' name='br0'>
  <network type='network' name='default' />
</network>
```



Tip: No Network Bridge

If there is no network bridge available, Virtual Machine Manager can optionally create it.

virt-v2v has the following basic command syntax:

```
virt-v2v -i INPUT_METHOD -os STORAGE_POOL SOURCE_VM
```

input_method

There are two input methods: `libvirt` or `libvirtxml`. See the `SOURCE_VM` parameter for more information.

storage_pool

The storage pool you already prepared for the target virtual machine.

source_vm

The source virtual machine to convert. It depends on the `INPUT_METHOD` parameter: For `libvirt`, specify the name of a libvirt domain. For `libvirtxml`, specify the path to an XML file containing a libvirt domain specification.



Note: Conversion Time

Conversion of a virtual machine takes a lot of system resources, mainly for copying the whole disk image for a virtual machine. Converting a single virtual machine typically takes up to 10 minutes, although virtual machines using very large disk images can take much longer.

1.4.1 Conversion Based on the libvirt XML Description File

This section describes how to convert a local Xen virtual machine using the `libvirt` XML configuration file. This method is suitable if the host is already running the KVM hypervisor. Make sure that the `libvirt` XML file of the source virtual machine, and the `libvirt` storage pool referenced from it are available on the local host.

1. Obtain the `libvirt` XML description of the source virtual machine.



Tip: Obtaining the XML Files

To obtain the `libvirt` XML files of the source virtual machine, you must run the host OS under the Xen kernel. If you already rebooted the host to the KVM-enabled environment, reboot back to the Xen kernel, dump the `libvirt` XML file, and then reboot back to the KVM environment.

First identify the source virtual machine under `virsh`:

```
# virsh list
Id      Name                               State
-----
[...]
 2     sles12_xen                         running
```

```
[...]
```

`sles12_xen` is the source virtual machine to convert. Now export its XML and save it to `sles12_xen.xml`:

```
# virsh dumpxml sles12_xen > sles12_xen.xml
```

2. Verify all disk image paths are correct from the KVM host's perspective. This is not a problem when converting on one machine, but may require manual changes when converting using an XML dump from another host.

```
<source file='/var/lib/libvirt/images/XenPool/SLES.qcow2' />
```



Tip: Copying Images

To avoid copying an image twice, manually copy the disk image(s) directly to the `libvirt` storage pool. Update the source file entries in the XML description file. The `virt-v2v` process will detect the existing disks and convert them in place.

3. Run `virt-v2v` to convert to KVM virtual machine:

```
# virt-v2v sles12_xen.xml ❶ \  
-i LIBVIRTXML ❷ \  
-os remote_host.example.com:/exported_dir ❸ \  
--bridge br0 ❹ \  
-on sles12_kvm ❺
```

- ❶ The XML description of the source Xen-based virtual machine.
- ❷ `virt-v2v` will read the information about the source virtual machine from a `libvirt` XML file.
- ❸ Storage pool where the target virtual machine disk image will be placed. In this example, the image will be placed on an NFS share `/exported_dir` on the `remote_host.example.com` server.
- ❹ The target KVM-based virtual machine will use the network bridge `br0` on the host.
- ❺ The target virtual machine will be renamed to `sles12_kvm` to prevent name collision with the existing virtual machine of the same name.

1.4.2 Conversion Based on the libvirt Domain Name

This method is useful if you are still running `libvirt` under Xen, and plan to reboot to the KVM hypervisor later.

1. Find the `libvirt` domain name of the virtual machine you want to convert.

```
# virsh list
Id      Name                State
-----
[...]
 2      sles12_xen          running
[...]
```

`sles12_xen` is the source virtual machine to convert.

2. Run `virt-v2v` to convert to KVM virtual machine:

```
# virt-v2v sles12_xen ① \
-i libvirt ② \
-os storage_pool ③ \
--network eth0 ④ \
-of qcow2 ⑤ \
-oa sparse ⑥ \
-on sles12_kvm
```

- ① The domain name of the Xen-based virtual machine.
- ② `virt-v2v` will read the information about the source virtual machine directly from the active `libvirt` connection.
- ③ The target disk image will be placed in a local `libvirt` storage pool.
- ④ All guest bridges (or networks) will be connected to a locally managed network.
- ⑤ Format for the disk image of the target virtual machine. Supported options are `raw` or `qcow2`.
- ⑥ If the converted guest disk space will be `sparse` or `preallocated`.

1.4.3 Converting a Remote Xen Virtual Machine

This method is useful if you need to convert a Xen virtual machine running on a remote host. As `virt-v2v` connects to the remote host via `ssh`, ensure that SSH service is running on the host.



Note: Passwordless SSH Access

Starting with SLES 12 SP2, `virt-v2v` requires a passwordless SSH connection to the remote host. This means a connection using an SSH key added to the `ssh-agent`. See `man ssh-keygen` and `man ssh-add` for more details on this. More information is also available at Book “Security and Hardening Guide”, Chapter 21 “Securing network operations with OpenSSH”.

To connect to a remote `libvirt` connection, construct a valid connection URI relevant for your remote host. In the following example, the remote host name is `remote_host.example.com`, and the user name for the connection is `root`. The connection URI then looks as follows:

```
xen+ssh://root@remote_host.example.com/
```

For more information on `libvirt` connection URIs, see <https://libvirt.org/uri.html>.

1. Find the `libvirt` domain name of the remote virtual machine you want to convert.

```
# virsh -c xen+ssh://root@remote_host.example.com/ list
Id      Name                State
-----
 1      sles12_xen          running
[...]
```

`sles12_xen` is the source virtual machine to convert.

2. The `virt-v2v` command for the remote connection looks like this:

```
# virt-v2v sles12_xen \
-i libvirt \
-ic xen+ssh://root@remote_host.example.com/ \
-os local_storage_pool \
--bridge br0
```

1.5 Running Converted Virtual Machines

After `virt-v2v` completes successfully, a new `libvirt` domain will be created with the name specified with the `-on` option. If you did not specify `-on`, the same name as the source virtual machine will be used. The new guest can be managed with standard `libvirt` tools, such as `virsh` or Virtual Machine Manager.



Tip: Rebooting the Machine

If you completed the conversion under Xen as described in [Section 1.4.2, “Conversion Based on the libvirt Domain Name”](#), you may need to reboot the host machine and boot with the non-Xen kernel.

2 Xen to KVM Manual Migration

2.1 General Outline

The preferred solution to manage virtual machines is based on [libvirt](#); for more information, see <https://libvirt.org/>. It has several advantages over the manual way of defining and running virtual machines—[libvirt](#) is cross-platform, supports many hypervisors, has secure remote management, has virtual networking, and, most of all, provides a unified abstract layer to manage virtual machines. Therefore the main focus of this article is on the [libvirt](#) solution.

Generally, the Xen to KVM migration runs in the following basic steps:

1. Make a backup copy of the original Xen VM Guest.
2. OPTIONAL: Apply changes specific to paravirtualized guests.
3. Obtain information about the original Xen VM Guest and update it to KVM equivalents.
4. Shut down the guest on the Xen host, and run the new one under the KVM hypervisor.



Warning: No Live Migration

The Xen to KVM migration cannot be done live while the source VM Guest is running. Before running the new KVM-ready VM Guest, you are advised to shut down the original Xen VM Guest.

2.2 Back Up the Xen VM Guest

To back up your Xen VM Guest, follow these steps:

1. Identify the relevant Xen guest you want to migrate, and remember its ID/name.

```
> sudo virsh list --all
Id Name                State
-----
 0 Domain-0            running
 1 SLES11SP3           running
[...]
```

2. Shut down the guest. You can do this either by shutting down the guest OS, or with `virsh`:

```
> sudo virsh shutdown SLES11SP3
```

3. Backup its configuration to an XML file.

```
> sudo virsh dumpxml SLES11SP3 > sles11sp3.xml
```

4. Backup its disk image file. Use the `cp` or `rsync` commands to create the backup copy. Remember that it is always a good idea to check the copy with the `md5sum` command.

5. After the image file is backed up, you can start the guest again with

```
> sudo virsh start SLES11SP3
```

2.3 Changes Specific to Paravirtualized Guests

Apply the following changes if you are migrating a paravirtualized Xen guest. You can do it either on the running guest, or on the stopped guest using `guestfs-tools`.

Important

After applying the changes described in this section, the image file related to the migrated VM Guest will not be usable under Xen anymore.

2.3.1 Install the Default Kernel

Warning: No Booting

After you installed the default kernel, do not try to boot the Xen guest with it, the system will not boot.

Before cloning the Xen guest disk image for use under the KVM hypervisor, make sure it is bootable *without* the Xen hypervisor. This is very important for paravirtualized Xen guests as they usually contain a special Xen kernel, and often do not have a complete GRUB 2 boot loader installed.

1. For SLES 11 update the `/etc/sysconfig/kernel` file. Change the `INITRD_MODULES` parameter by removing all Xen drivers and replacing the with virtio drivers. Replace

```
INITRD_MODULES="xenblk xennet"
```

with

```
INITRD_MODULES="virtio_blk virtio_pci virtio_net virtio_balloon"
```

For SLES 12 search for `xenblk xennet` in `/etc/dracut.conf.d/*.conf` and replace them with `virtio_blk virtio_pci virtio_net virtio_balloon`

2. Paravirtualized Xen guests are running a specific Xen kernel. To run the guest under KVM, you need to install the default kernel.



Note: Default Kernel Is Already Installed

You do not need to install the default kernel for a fully virtualized guests as it is already installed.

Enter `rpm -q kernel-default` on the Xen guest to find out if the default kernel is installed. If not, install it with `zypper in kernel-default`.

The kernel we are going to use to boot the guest under KVM must have *virtio* (paravirtualized) drivers available. Run the following command to find out. Do not forget to replace `3.8.9-4` with your kernel version:

```
> sudo find /lib/modules/3.8.9-4-default/kernel/drivers/ -name virtio*
/lib/modules/3.8.9-4-default/kernel/drivers/net/virtio_net.ko
/lib/modules/3.8.9-4-default/kernel/drivers/scsi/virtio_scsi.ko
/lib/modules/3.8.9-4-default/kernel/drivers/block/virtio_blk.ko
/lib/modules/3.8.9-4-default/kernel/drivers/char/virtio_console.ko
/lib/modules/3.8.9-4-default/kernel/drivers/char/hw_random/virtio_rng.ko
/lib/modules/3.8.9-4-default/kernel/drivers/virtio
/lib/modules/3.8.9-4-default/kernel/drivers/virtio/virtio.ko
/lib/modules/3.8.9-4-default/kernel/drivers/virtio/virtio_pci.ko
/lib/modules/3.8.9-4-default/kernel/drivers/virtio/virtio_balloon.ko
```

```
/lib/modules/3.8.9-4-default/kernel/drivers/virtio/virtio_ring.ko
/lib/modules/3.8.9-4-default/kernel/drivers/virtio/virtio_mmio.ko
```

3. Update `/etc/fstab`. Change any storage devices from `xvda` to `vda`.
4. Update the boot loader configuration. Enter `rpm -q grub2` on the Xen guest to find out if GRUB 2 is already installed. If not, install it with `zypper in grub2`.

Now make the newly installed default kernel the default for booting the OS. Also remove/update the kernel command line options that may refer to Xen-specific devices. You can do it either with YaST (*System > Boot Loader*), or manually:

- Find the preferred Linux boot menu entry by listing them all:

```
> cat /boot/grub2/grub.cfg | grep 'menuentry '
```

Remember the order number (counted from zero) of the one you newly installed.

- Set it the default boot menu entry:

```
> sudo grub2-set-default N
```

Replace `N` with the number of the boot menu entry you previously discovered.

- Open `/etc/default/grub` for editing, and look for `GRUB_CMDLINE_LINUX_DEFAULT` and `GRUB_CMDLINE_LINUX_RECOVERY` options. Remove/update any reference to Xen-specific devices. In the following example, you can replace

```
root=/dev/xvda1 disk=/dev/xvda console=xvc
```

with

```
root=/dev/vda1 disk=/dev/vda
```

Note that you need to remove all references to `xvc`-type consoles (such as `xvc0`).

5. Update `device.map` in one of `/boot/grub2` or `/boot/grub2-efi` directories. Change any storage device from `xvda` to `vda`.
6. To import new default settings, run

```
grub2-mkconfig -o /boot/grub2/grub.cfg
```

2.3.2 Update the Guest for Boot under KVM

1. Update the system to use default serial console. List the configured consoles, and remove symbolic links to `xvc?` ones.

```
> sudo ls -l /etc/systemd/system/getty.target.wants/  
getty@tty1.service -> /usr/lib/systemd/system/getty@.service  
getty@xvc0.service -> /usr/lib/systemd/system/getty@xvc0.service  
getty@xvc1.service -> /usr/lib/systemd/system/getty@xvc1.service  
  
# rm /etc/systemd/system/getty.target.wants/getty@xvc?.service
```

2. Update the `/etc/securetty` file. Replace `xvc0` with `ttyS0`.

2.4 Update the Xen VM Guest Configuration

This section describes how to export the configuration of the original Xen VM Guest, and what particular changes to apply to it so it can be imported as a KVM guest into `libvirt`.

2.4.1 Export the Xen VM Guest Configuration

First export the configuration of the guest and save it to a file. A typical one may look like this:

```
> sudo virsh dumpxml SLES11SP3  
<domain type='xen'>  
  <name>SLES11SP3</name>  
  <uuid>fa9ea4d7-8f95-30c0-bce9-9e58ffcabeb2</uuid>  
  <memory>524288</memory>  
  <currentMemory>524288</currentMemory>  
  <vcpu>1</vcpu>  
  <bootloader>/usr/bin/pygrub</bootloader>  
  <os>  
    <type>linux</type>  
  </os>  
  <clock offset='utc' />  
  <on_poweroff>destroy</on_poweroff>  
  <on_reboot>restart</on_reboot>  
  <on_crash>restart</on_crash>  
  <devices>  
    <emulator>/usr/lib/xen/bin/qemu-dm</emulator>  
    <disk type='file' device='disk'>  
      <driver name='file' />  
      <source file='/var/lib/libvirt/images/SLES_11_SP2_Je0S.x86_64-0.0.2_para.raw' />
```

```

    <target dev='xvda' bus='xen' />
</disk>
<interface type='bridge'>
  <mac address='00:16:3e:2d:91:c3' />
  <source bridge='br0' />
  <script path='vif-bridge' />
</interface>
<console type='pty'>
  <target type='xen' port='0' />
</console>
<input type='mouse' bus='xen' />
<graphics type='vnc' port='-1' autoport='yes' keymap='en-us' />
</devices>
</domain>

```

You can find detailed information on the libvirt XML format for VM Guest description at <https://libvirt.org/formatdomain.html>.

2.4.2 General Changes to the Guest Configuration

You need to make a few general changes to the exported Xen guest XML configuration to run it under the KVM hypervisor. The following applies to both fully virtualized and paravirtualized guests. Note that not all of the following XML elements need to be in your specific configuration.



Tip: Conventions Used

To refer to a node in the XML configuration file, an XPath syntax will be used throughout this document. For example, to refer to a <name> inside the <domain> tag

```

<domain>
  <name>sles11sp3</name>
</domain>

```

an XPath equivalent /domain/name will be used.

1. Change the type attribute of the /domain element from xen to kvm.
2. Remove the /domain/bootloader element section.
3. Remove the /domain/bootloader_args element section.
4. Change the /domain/os/type element value from linux to hvm.

5. Add `<boot dev="hd"/>` under the `/domain/os` element.
6. Add the `arch` attribute to the `/domain/os/type` element. Acceptable values are `arch="x86_64"` or `arch="i686"`
7. Change the `/domain/devices/emulator` element from `/usr/lib/xen/bin/qemu-dm'` to `/usr/bin/qemu-kvm`.
8. For each disk associated with the paravirtualized (PV) guest, change the following:
 - Change the `name` attribute of the `/domain/devices/disk/driver` element from `file` to `qemu`, and add a `type` attribute for the disk type. For example, valid options include `raw` or `qcow2`.
 - Change the `dev` attribute of the `/domain/devices/disk/target` element from `xv-da` to `vda`.
 - Change the `bus` attribute of the `/domain/devices/disk/target` element from `xen` to `virtio`.
9. For each network interface card, do the following changes:
 - If there is `model` defined in `/domain/devices/interface`, change its `type` attribute value to `virtio`

```
<model type="virtio">
```

- Delete all `/domain/devices/interface/script` sections.
- Delete all `/domain/devices/interface/target` elements if the `dev` attribute starts with `vif` or `vnet` or `veth`. If using a custom network then change the `dev` value to that target.

10. Remove the `/domain/devices/console` element section if it exists.
11. Remove the `/domain/devices/serial` element section if it exists.
12. Change the `bus` attribute on the `/domain/devices/input` element from `xen` to `ps2`.
13. Add the following element for memory ballooning features under the `/domain/devices` element.

```
<memballoon model="virtio"/>
```



Tip: Device Name

`<target dev='hda' bus='ide' />` controls the device under which the disk is exposed to the guest OS. The `dev` attribute indicates the "logical" device name. The actual device name specified is not guaranteed to map to the device name in the guest OS. Therefore you may need to change the disk mapping on the boot loader command line. For example, if the boot loader expects a root disk to be `hda2` but KVM still sees it as `sda2`, change the boot loader command line from

```
[...] root=/dev/hda2 resume=/dev/hda1 [...]
```

to

```
[...] root=/dev/sda2 resume=/dev/sda1 [...]
```

In the case of paravirtualized `xvda` devices, change it to

```
[...] root=/dev/vda2 resume=/dev/vda1 [...]
```

Otherwise the VM Guest will refuse to boot in the KVM environment.

2.4.3 The Target KVM Guest Configuration

After having applied all the modifications mentioned above, you end up with the following configuration for your KVM guest:

```
<domain type='kvm'>
  <name>SLES11SP3</name>
  <uuid>fa9ea4d7-8f95-30c0-bce9-9e58ffcabeb2</uuid>
  <memory>524288</memory>
  <currentMemory>524288</currentMemory>
  <vcpu cpuset='0-3'>1</vcpu>
  <os>
    <type arch="x86_64">hvm</type>
    <boot dev="hd"/>
  </os>
  <clock offset='utc' />
  <on_poweroff>destroy</on_poweroff>
  <on_reboot>restart</on_reboot>
  <on_crash>restart</on_crash>
  <devices>
    <emulator>/usr/bin/qemu-kvm</emulator>
```

```

<disk type='file' device='disk'>
  <driver name='qemu' type="raw"/>
  <source file='/var/lib/libvirt/images/SLES_11_SP2_Je0S.x86_64-0.0.2_para.raw' />
  <target dev='vda' bus='virtio' />
</disk>
<interface type='bridge'>
  <mac address='00:16:3e:2d:91:c3' />
  <source bridge='br0' />
</interface>
<input type='mouse' bus='usb' />
<graphics type='vnc' port='5900' autoport='yes' keymap='en-us' />
<memballoon model="virtio" />
</devices>
</domain>

```

Save the configuration to a file in your home directory. After you later import it, it will be copied to the default `/etc/libvirt/qemu`. Suppose you save the file as `SLES11SP3.xml`.

2.5 Migrate the VM Guest

After you updated the VM Guest configuration, and applied necessary changes to the guest OS, shut down the original Xen guest, and run its clone under the KVM hypervisor.

1. Shut down the guest on the Xen host by running `shutdown -h now` as `root` from the console.
2. Copy the disk files associated with the VM Guest if needed. A default configuration will require the Xen disk files to be copied from `/var/lib/xen/images` to `/var/lib/kvm/images`. The `/var/lib/kvm/images` directory may need to be created (as `root`) if you have not previously created a VM Guest.
3. Create the new domain, and register it with `libvirt`:

```

> sudo virsh define SLES11SP3.xml
Domain SLES11SP3 defined from SLES11SP3.xml

```

4. Verify that the new guest is seen in the KVM configuration:

```

> virsh list --all

```

5. After the domain is created, you can start it:

```

> sudo virsh start SLES11SP3

```

3 For More Information

For more information on libvirt, see <https://libvirt.org>.

You can find more details on `libvirt` XML format at <https://libvirt.org/formatdomain.html>.

For more information on virtualization with Xen and KVM, see the SUSE Linux Enterprise Server documentation at <https://documentation.suse.com/>.

4 Legal Notice

Copyright© 2006– 2024 SUSE LLC and contributors. All rights reserved.

Permission is granted to copy, distribute and/or modify this document under the terms of the GNU Free Documentation License, Version 1.2 or (at your option) version 1.3; with the Invariant Section being this copyright notice and license. A copy of the license version 1.2 is included in the section entitled “GNU Free Documentation License”.

For SUSE trademarks, see <https://www.suse.com/company/legal/>. All other third-party trademarks are the property of their respective owners. Trademark symbols (®, ™ etc.) denote trademarks of SUSE and its affiliates. Asterisks (*) denote third-party trademarks.

All information found in this book has been compiled with utmost attention to detail. However, this does not guarantee complete accuracy. Neither SUSE LLC, its affiliates, the authors, nor the translators shall be held liable for possible errors or the consequences thereof.

GNU Free Documentation License

Copyright (C) 2000, 2001, 2002 Free Software Foundation, Inc. 51 Franklin St, 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 functional and useful 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 non-commercially. Secondly, 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 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, in any medium, that contains a notice placed by the copyright holder saying it can be distributed under the terms of this License. Such a notice grants a world-wide, royalty-free license, unlimited in duration, to use that work under the conditions stated herein. The “Document”, below, refers to any such manual or work. Any member of the public is a licensee, and is addressed as “you”. You accept the license if you copy, modify or distribute the work in a way requiring permission under copyright law.

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. (Thus, 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. If a section does not fit the above definition of Secondary then it is not allowed to be designated as Invariant. The Document may contain zero Invariant Sections. If the Document does not identify any Invariant Sections then there are none.

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 Front-Cover Text may be at most 5 words, and a Back-Cover Text may be at most 25 words.

A "Transparent" copy of the Document means a machine-readable copy, represented in a format whose specification is available to the general public, that is suitable for revising the document 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, or absence of markup, has been arranged to thwart or discourage subsequent modification by readers is not Transparent. An image format is not Transparent if used for any substantial amount of text. 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, PostScript or PDF designed for human modification. Examples of transparent image formats include PNG, XCF and JPG. Opaque formats include 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, PostScript or PDF 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.

A section "Entitled XYZ" means a named subunit of the Document whose title either is precisely XYZ or contains XYZ in parentheses following text that translates XYZ in another language. (Here XYZ stands for a specific section name mentioned below, such as "Acknowledgements", "Dedications", "Endorsements", or "History".) To "Preserve the Title" of such a section when you modify the Document means that it remains a section "Entitled XYZ" according to this definition.

The Document may include Warranty Disclaimers next to the notice which states that this License applies to the Document. These Warranty Disclaimers are considered to be included by reference in this License, but only as regards disclaiming warranties: any other implication that these Warranty Disclaimers may have is void and has no effect on the meaning of this License.

2. VERBATIM COPYING

You may copy and distribute the Document in any medium, either commercially or non-commercially, 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 (or copies in media that commonly have printed covers) 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 computer-network location from which the general network-using public has access to download using public-standard network protocols a complete Transparent copy of the Document, free of added material. 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:

- A. 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 fewer than five), unless they release you from this requirement.
- 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", Preserve 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. For any section Entitled "Acknowledgements" or "Dedications", Preserve the Title of the section, 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 retile any existing section to be Entitled "Endorsements" or to conflict in title with any Invariant Section.
- O. Preserve any Warranty Disclaimers.

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, and that you preserve all their Warranty Disclaimers.

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, is called an "aggregate" if the copyright resulting from the compilation is not used to limit the legal rights of the compilation's users beyond what the individual works permit. When the Document is included in an aggregate, this License does not apply to the other works in the aggregate which 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 half of the entire aggregate, the Document's Cover Texts may be placed on covers that bracket the Document within the aggregate, or the electronic equivalent of covers if the Document is in electronic form. Otherwise they must appear on printed covers that bracket 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, and all the license notices in the Document, and any Warranty Disclaimers, provided that you also include the original English version of this License and the original versions of those notices and disclaimers. In case of a disagreement between the translation and the original version of this License or a notice or disclaimer, the original version will prevail.

If a section in the Document is Entitled "Acknowledgements", "Dedications", or "History", the requirement (section 4) to Preserve its Title (section 1) will typically require changing the actual title.

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 <http://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

```
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 1.2  
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 have Invariant Sections, Front-Cover Texts and Back-Cover Texts, replace the "with...Texts." line with this:

```
with the Invariant Sections being LIST THEIR TITLES, with the  
Front-Cover Texts being LIST, and with the Back-Cover Texts being LIST.
```

If you have Invariant Sections without Cover Texts, or some other combination of the three, merge those two alternatives to suit the situation.

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.