Red Hat Enterprise Linux 9

Packaging and distributing software

Packaging software by using the RPM package management system

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Abstract

Package software into an RPM package by using the RPM package manager. Prepare source code for packaging, package software, and investigate advanced packaging scenarios, such as packaging Python projects or RubyGems into RPM packages.

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PROVIDING FEEDBACK ON RED HAT DOCUMENTATION

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1. Log in to the Jira website.
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5. Click **Create** at the bottom of the dialogue.

CHAPTER 1. INTRODUCTION TO RPM

The RPM Package Manager (RPM) is a package management system that runs on Red Hat Enterprise Linux (RHEL), CentOS, and Fedora. You can use RPM to distribute, manage, and update software that you create for any of these operating systems.

The RPM package management system has the following advantages over distributing software in conventional archive files:

- RPM manages software in the form of packages that you can install, update, or remove independently of each other, which makes the maintenance of an operating system easier.
- RPM simplifies the distribution of software because RPM packages are standalone binary files, similar to compressed archives. These packages are built for a specific operating system and hardware architecture. RPMs contain files such as compiled executables and libraries that are placed into the appropriate paths on the filesystem when the package is installed.

With RPM, you can perform the following tasks:

- Install, upgrade, and remove packaged software.
- Query detailed information about packaged software.
- Verify the integrity of packaged software.
- Build your own packages from software sources and complete build instructions.
- Digitally sign your packages by using the GNU Privacy Guard (GPG) utility.
- Publish your packages in a DNF repository.

In Red Hat Enterprise Linux, RPM is fully integrated into the higher-level package management software, such as DNF or PackageKit. Although RPM provides its own command-line interface, most users need to interact with RPM only through this software. However, when building RPM packages, you must use the RPM utilities such as **rpmbuild(8)**.

1.1. RPM PACKAGES

An RPM package consists of an archive of files and metadata used to install and erase these files. Specifically, the RPM package contains the following parts:

GPG signature

The GPG signature is used to verify the integrity of the package.

Header (package metadata)

The RPM package manager uses this metadata to determine package dependencies, where to install files, and other information.

Payload

The payload is a **cpio** archive that contains files to install to the system.

There are two types of RPM packages. Both types share the file format and tooling, but have different contents and serve different purposes:

- Source RPM (SRPM)

An SRPM contains source code and a **spec** file, which describes how to build the source code into a binary RPM. Optionally, the SRPM can contain patches to source code.

Binary RPM

A binary RPM contains the binaries built from the sources and patches.

1.2. LISTING RPM PACKAGING UTILITIES

In addition to the **rpmbuild(8)** program for building packages, RPM provides other utilities to make the process of creating packages easier. You can find these programs in the **rpmdevtools** package.

Prerequisites

- The **rpmdevtools** package has been installed:

```
# dnf install rpmdevtools
```

Procedure

- Use one of the following methods to list RPM packaging utilities:
  - To list certain utilities provided by the **rpmdevtools** package and their short descriptions, enter:

```
$ rpm -qi rpmdevtools
```

  - To list all utilities, enter:

```
$ rpm -ql rpmdevtools | grep ^/usr/bin
```

Additional resources

- RPM utilities man pages

CHAPTER 2. CREATING SOFTWARE FOR RPM PACKAGING

To prepare software for RPM packaging, you must understand what source code is and how to create software.

2.1. WHAT IS SOURCE CODE

Source code is human-readable instructions to the computer that describe how to perform a computation. Source code is expressed by using a programming language.

The following versions of the **Hello World** program written in three different programming languages cover major RPM Package Manager use cases:

- **Hello World** written in Bash
  The *bello* project implements **Hello World** in Bash. The implementation contains only the **bello** shell script. The purpose of this program is to output **Hello World** on the command line.

  The **bello** file has the following contents:

  ```
  #!/bin/bash

  printf "Hello World\n"
  ```

- **Hello World** written in Python
  The *pello* project implements **Hello World** in Python. The implementation contains only the **pello.py** program. The purpose of the program is to output **Hello World** on the command line.

  The **pello.py** file has the following contents:

  ```
  #!/usr/bin/python3

  print("Hello World")
  ```

- **Hello World** written in C
  The *cello* project implements **Hello World** in C. The implementation contains only the **cello.c** and **Makefile** files. The resulting **tar.gz** archive therefore has two files in addition to the **LICENSE** file. The purpose of the program is to output **Hello World** on the command line.

  The **cello.c** file has the following contents:

  ```
  #include <stdio.h>

  int main(void) {
    printf("Hello World\n");
    return 0;
  }
  ```

NOTE

The packaging process is different for each version of the **Hello World** program.

2.2. METHODS OF CREATING SOFTWARE

You can convert the human-readable source code into machine code by using one the following methods:

- Natively compile software.
- Interpret software by using a language interpreter or language virtual machine. You can either raw-interpret or byte-compile software.

2.2.1. Natively compiled software

Natively compiled software is software written in a programming language that compiles to machine code with a resulting binary executable file. Natively compiled software is standalone software.

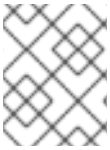
NOTE

Natively compiled RPM packages are architecture-specific.

If you compile such software on a computer that uses a 64-bit (x86_64) AMD or Intel processor, it does not run on a 32-bit (x86) AMD or Intel processor. The resulting package has the architecture specified in its name.

2.2.2. Interpreted software

Some programming languages, such as Bash or Python, do not compile to machine code. Instead, a language interpreter or a language virtual machine executes the programs' source code step-by-step without prior transformations.



NOTE

Software written entirely in interpreted programming languages is not architecture-specific. Therefore, the resulting RPM package has the **noarch** string in its name.

You can either raw-interpret or byte-compile software written in interpreted languages:

- Raw-interpreted software
  You do not need to compile this type of software. Raw-interpreted software is directly executed by the interpreter.
- Byte-compiled software
  You must first compile this type of software into bytecode, which is then executed by the language virtual machine.

NOTE

Some byte-compiled languages can be either raw-interpreted or byte-compiled.

Note that the way you build and package software by using RPM is different for these two software types.

2.3. BUILDING SOFTWARE FROM SOURCE

During the software building process, the source code is turned into software artifacts that you can package by using RPM.

2.3.1. Building software from natively compiled code

You can build software written in a compiled language into an executable by using one of the following methods:

- Manual building
- Automated building

2.3.1.1. Manually building a sample C program

You can use manual building to build software written in a compiled language.

A sample **Hello World** program written in C (**cello.c**) has the following contents:

```
#include <stdio.h>

int main(void) {
    printf("Hello World\n");
    return 0;
}
```

Procedure

1. Invoke the C compiler from the GNU Compiler Collection to compile the source code into binary:

```
$ gcc -g -o cello cello.c
```

2. Run the resulting binary **cello**:

```
$ ./cello
Hello World
```

2.3.1.2. Setting up automated building for a sample C program

Large-scale software commonly uses automated building. You can set up automated building by creating the **Makefile** file and then running the GNU **make** utility.

Procedure

1. Create the **Makefile** file with the following content in the same directory as **cello.c**:

```
cello:
 gcc -g -o cello cello.c
clean:
 rm cello
```

Note that the lines under **cello:** and **clean:** must begin with a tabulation character (tab).

2. Build the software:

```
$ make
make: 'cello' is up to date.
```

3. Because a build is already available in the current directory, enter the **make clean** command, and then enter the **make** command again:

```
$ make clean
rm cello

$ make
gcc -g -o cello cello.c
```

Note that trying to build the program again at this point has no effect because the GNU **make** system detects the existing binary:

```
$ make
make: 'cello' is up to date.
```

4. Run the program:

```
$ ./cello
Hello World
```

2.3.2. Interpreting source code

You can convert the source code written in an interpreted programming language into machine code by using one of the following methods:

- Byte-compiling
  The procedure for byte-compiling software varies depending on the following factors:
  - Programming language
  - Language's virtual machine
  - Tools and processes used with that language

  NOTE

  You can byte-compile software written, for example, in Python. Python software intended for distribution is often byte-compiled, but not in the way described in this document. The described procedure aims not to conform to the community standards, but to be simple. For real-world Python guidelines, see Software Packaging and Distribution.

  You can also raw-interpret Python source code. However, the byte-compiled version is faster. Therefore, RPM packagers prefer to package the byte-compiled version for distribution to end users.

- Raw-interpreting
  Software written in shell scripting languages, such as Bash, is always executed by raw-interpreting.

2.3.2.1. Byte-compiling a sample Python program

By choosing byte-compiling over raw-interpreting of Python source code, you can create faster software.

A sample **Hello World** program written in the Python programming language (**pello.py**) has the following contents:

```
print("Hello World")
```

Procedure

1. Byte-compile the **pello.py** file:

```
$ python -m compileall pello.py
```

2. Verify that a byte-compiled version of the file is created:

```
$ ls __pycache__
pello.cpython-311.pyc
```

Note that the package version in the output might differ depending on which Python version is installed.

3. Run the program in **pello.py**:

```
$ python pello.py
Hello World
```

2.3.2.2. Raw-interpreting a sample Bash program

A sample **Hello World** program written in Bash shell built-in language (**bello**) has the following contents:

```
#!/bin/bash

printf "Hello World\n"
```

NOTE

The **shebang** (**#!**) sign at the top of the **bello** file is not part of the programming language source code.

Use the **shebang** to turn a text file into an executable. The system program loader parses the line containing the **shebang** to get a path to the binary executable, which is then used as the programming language interpreter.

Procedure

1. Make the file with source code executable:

```
$ chmod +x bello
```

2. Run the created file:

```
$ ./bello
Hello World
```

CHAPTER 3. PREPARING SOFTWARE FOR RPM PACKAGING

To prepare a piece of software for packaging with RPM, you can first patch the software, create a LICENSE file for it, and archive it as a tarball.

3.1. PATCHING SOFTWARE

When packaging software, you might need to make certain changes to the original source code, such as fixing a bug or changing a configuration file. In RPM packaging, you can instead leave the original source code intact and apply patches on it.

A patch is a piece of text that updates a source code file. The patch has a *diff* format, because it represents the difference between two versions of the text. You can create a patch by using the **diff** utility, and then apply the patch to the source code by using the patch utility.

> **NOTE**
>
> Software developers often use Version Control Systems such as Git to manage their code base. Such tools offer their own methods of creating diffs or patching software.

3.1.1. Creating a patch file for a sample C program

You can create a patch from the original source code by using the **diff** utility. For example, to patch a **Hello world** program written in C (**cello.c**), complete the following steps.

Prerequisites

- You installed the **diff** utility on your system:

```
# dnf install diffutils
```

Procedure

1. Back up the original source code:

```
$ cp -p cello.c cello.c.orig
```

   The **-p** option preserves mode, ownership, and timestamps.

2. Modify **cello.c** as needed:

```
#include <stdio.h>

int main(void) {
    printf("Hello World from my very first patch!\n");
    return 0;
}
```

3. Generate a patch:

```
$ diff -Naur cello.c.orig cello.c
--- cello.c.orig        2016-05-26 17:21:30.478523360 -0500
+ cello.c     2016-05-27 14:53:20.668588245 -0500
```

```
@@ -1,6 +1,6 @@
 #include<stdio.h>

 int main(void){
-    printf("Hello World!\n");
+    printf("Hello World from my very first patch!\n");
     return 0;
 }
\ No newline at end of file
```

Lines that start with **+** replace the lines that start with **-**.

NOTE

Using the **Naur** options with the **diff** command is recommended because it fits the majority of use cases:

- **-N** (**--new-file**)
  The **-N** option handles absent files as empty files.
- **-a** (**--text**)
  The **-a** option treats all files as text. As a result, the **diff** utility does not ignore the files it classified as binaries.
- **-u** (**-U NUM** or **--unified[=NUM]**)
  The **-u** option returns output in the form of output NUM (default 3) lines of unified context. This is a compact and an easily readable format commonly used in patch files.
- **-r** (**--recursive**)
  The **-r** option recursively compares any subdirectories that the **diff** utility found.

However, note that in this particular case, only the **-u** option is necessary.

4. Save the patch to a file:

```
$ diff -Naur cello.c.orig cello.c > cello.patch
```

5. Restore the original **cello.c**:

```
$ mv cello.c.orig cello.c
```

IMPORTANT

You must retain the original **cello.c** because the RPM package manager uses the original file, not the modified one, when building an RPM package. For more information, see Working with spec files.

Additional resources

- **diff(1)** man page

3.1.2. Patching a sample C program

To apply code patches on your software, you can use the **patch** utility.

Prerequisites

- You installed the **patch** utility on your system:

```
# dnf install patch
```

- You created a patch from the original source code. For instructions, see Creating a patch file for a sample C program.

Procedure

The following steps apply a previously created **cello.patch** file on the **cello.c** file.

1. Redirect the patch file to the **patch** command:

```
$ patch < cello.patch
patching file cello.c
```

2. Check that the contents of **cello.c** now reflect the desired change:

```
$ cat cello.c
#include<stdio.h>

int main(void){
    printf("Hello World from my very first patch!\n");
    return 1;
}
```

Verification

1. Build the patched **cello.c** program:

```
$ make
gcc -g -o cello cello.c
```

2. Run the built **cello.c** program:

```
$ ./cello
Hello World from my very first patch!
```

3.2. CREATING A LICENSE FILE

It is recommended that you distribute your software with a software license.

A software license file informs users of what they can and cannot do with a source code. Having no license for your source code means that you retain all rights to this code and no one can reproduce, distribute, or create derivative works from your source code.

Procedure

- Create the **LICENSE** file with the required license statement:

```
$ vim LICENSE
```

Example 3.1. Example GPLv3 LICENSE file text

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

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

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

Additional resources

- Sorce code examples

3.3. CREATING A SOURCE CODE ARCHIVE FOR DISTRIBUTION

An archive file is a file with the **.tar.gz** or **.tgz** suffix. Putting source code into the archive is a common way to release the software to be later packaged for distribution.

3.3.1. Creating a source code archive for a sample Bash program

The *bello* project is a **Hello World** file in Bash.

The following example contains only the **bello** shell script. Therefore, the resulting **tar.gz** archive has only one file in addition to the **LICENSE** file.

> **NOTE**
>
> The **patch** file is not distributed in the archive with the program. The RPM package manager applies the patch when the RPM is built. The patch will be placed into the **~/rpmbuild/SOURCES/** directory together with the **tar.gz** archive.

Prerequisites

- Assume that the **0.1** version of the **bello** program is used.
- You created a **LICENSE** file. For instructions, see Creating a LICENSE file.

Procedure

1. Move all required files into a single directory:

```
$ mkdir bello-0.1
```

```
$ mv ~/bello bello-0.1/

$ mv LICENSE bello-0.1/
```

2. Create the archive for distribution:

```
$ tar -cvzf bello-0.1.tar.gz bello-0.1
bello-0.1/
bello-0.1/LICENSE
bello-0.1/bello
```

3. Move the created archive to the **~/rpmbuild/SOURCES/** directory, which is the default directory where the **rpmbuild** command stores the files for building packages:

```
$ mv bello-0.1.tar.gz ~/rpmbuild/SOURCES/
```

Additional resources

- Hello World written in bash

3.3.2. Creating a source code archive for a sample Python program

The *pello* project is a **Hello World** file in Python.

The following example contains only the **pello.py** program. Therefore, the resulting **tar.gz** archive has only one file in addition to the **LICENSE** file.

NOTE

The **patch** file is not distributed in the archive with the program. The RPM package manager applies the patch when the RPM is built. The patch will be placed into the **~/rpmbuild/SOURCES/** directory together with the **tar.gz** archive.

Prerequisites

- Assume that the **0.1.1** version of the **pello** program is used.
- You created a **LICENSE** file. For instructions, see Creating a LICENSE file.

Procedure

1. Move all required files into a single directory:

```
$ mkdir pello-0.1.1

$ mv pello.py pello-0.1.1/

$ mv LICENSE pello-0.1.1/
```

2. Create the archive for distribution:

```
$ tar -cvzf pello-0.1.1.tar.gz pello-0.1.1
pello-0.1.1/
```

```
pello-0.1.1/LICENSE
pello-0.1.1/pello.py
```

3. Move the created archive to the **~/rpmbuild/SOURCES/** directory, which is the default directory where the **rpmbuild** command stores the files for building packages:

```
$ mv pello-0.1.1.tar.gz ~/rpmbuild/SOURCES/
```

Additional resources

- Hello World written in Python

3.3.3. Creating a source code archive for a sample C program

The *cello* project is a **Hello World** file in C.

The following example contains only the **cello.c** and the **Makefile** files. Therefore, the resulting **tar.gz** archive has two files in addition to the **LICENSE** file.

> **NOTE**
>
> The **patch** file is not distributed in the archive with the program. The RPM package manager applies the patch when the RPM is built. The patch will be placed into the **~/rpmbuild/SOURCES/** directory together with the **tar.gz** archive.

Prerequisites

- Assume that the **1.0** version of the **cello** program is used.
- You created a **LICENSE** file. For instructions, see Creating a LICENSE file.

Procedure

1. Move all required files into a single directory:

```
$ mkdir cello-1.0

$ mv cello.c cello-1.0/

$ mv Makefile cello-1.0/

$ mv LICENSE cello-1.0/
```

2. Create the archive for distribution:

```
$ tar -cvzf cello-1.0.tar.gz cello-1.0
cello-1.0/
cello-1.0/Makefile
cello-1.0/cello.c
cello-1.0/LICENSE
```

3. Move the created archive to the **~/rpmbuild/SOURCES/** directory, which is the default directory where the **rpmbuild** command stores the files for building packages:

–

```
$ mv cello-1.0.tar.gz ~/rpmbuild/SOURCES/
```

Additional resources

- Hello World written in C

CHAPTER 4. PACKAGING SOFTWARE

4.1. SETTING UP RPM PACKAGING WORKSPACE

To build RPM packages, you must first create a special workspace that consists of directories used for different packaging purposes.

4.1.1. Configuring RPM packaging workspace

To configure the RPM packaging workspace, you can set up a directory layout by using the **rpmdev-setuptree** utility.

Prerequisites

- You installed the **rpmdevtools** package, which provides utilities for packaging RPMs:

```
# dnf install rpmdevtools
```

Procedure

- Run the **rpmdev-setuptree** utility:

```
$ rpmdev-setuptree

$ tree ~/rpmbuild/
/home/user/rpmbuild/
|-- BUILD
|-- RPMS
|-- SOURCES
|-- SPECS
`-- SRPMS

5 directories, 0 files
```

Additional resources

- RPM packaging workspace directories

4.1.2. RPM packaging workspace directories

The following are the RPM packaging workspace directories created by using the **rpmdev-setuptree** utility:

Table 4.1. RPM packaging workspace directories

Directory	Purpose
BUILD	Contains build artifacts compiled from the source files from the **SOURCES** directory.

Directory	Purpose
RPMS	Binary RPMs are created under the **RPMS** directory in subdirectories for different architectures. For example, in the **x86_64** or **noarch** subdirectory.
SOURCES	Contains compressed source code archives and patches. The **rpmbuild** command then searches for these archives and patches in this directory.
SPECS	Contains **spec** files created by the packager. These files are then used for building packages.
SRPMS	When you use the **rpmbuild** command to build an SRPM instead of a binary RPM, the resulting SRPM is created under this directory.

4.2. ABOUT SPEC FILES

A **spec** file is a file with instructions that the **rpmbuild** utility uses to build an RPM package. This file provides necessary information to the build system by defining instructions in a series of sections. These sections are defined in the *Preamble* and the *Body* part of the **spec** file:

- The *Preamble* section contains a series of metadata items that are used in the *Body* section.
- The *Body* section represents the main part of the instructions.

4.2.1. Preamble items

The following are some of the directives that you can use in the *Preamble* section of the RPM **spec** file.

Table 4.2. The *Preamble* section directives

Directive	Definition
Name	A base name of the package that must match the **spec** file name.
Version	An upstream version number of the software.
Release	The number of times the version of the package was released. Set the initial value to **1%{?dist}** and increase it with each new release of the package. Reset to **1** when a new **Version** of the software is built.
Summary	A brief one-line summary of the package.

Directive	Definition
License	A license of the software being packaged. The exact format for how to label the **License** in your **spec** file varies depending on which RPM-based Linux distribution guidelines you are following, for example, GPLv3+.
URL	A full URL for more information about the software, for example, an upstream project website for the software being packaged.
Source	A path or URL to the compressed archive of the unpatched upstream source code. This link must point to an accessible and reliable storage of the archive, for example, the upstream page, not the packager's local storage. You can apply the **Source** directive either with or without numbers at the end of the directive name. If there is no number given, the number is assigned to the entry internally. You can also give the numbers explicitly, for example, **Source0**, **Source1**, **Source2**, **Source3**, and so on.
Patch	A name of the first patch to apply to the source code, if necessary. You can apply the **Patch** directive either with or without numbers at the end of the directive name. If there is no number given, the number is assigned to the entry internally. You can also give the numbers explicitly, for example, **Patch0**, **Patch1**, **Patch2**, **Patch3**, and so on. You can apply the patches individually by using the **%patch0**, **%patch1**, **%patch2** macro, and so on. Macros are applied within the**%prep** directive in the *Body* section of the RPM**spec** file. Alternatively, you can use the **%autopatch** macro that automatically applies all patches in the order they are given in the **spec** file.
BuildArch	An architecture that the software will be built for. If the software is not architecture-dependent, for example, if you wrote the software entirely in an interpreted programming language, set the value to **BuildArch: noarch**. If you do not set this value, the software automatically inherits the architecture of the machine on which it is built, for example, **x86_64**.
BuildRequires	A comma- or whitespace-separated list of packages required to build the program written in a compiled language. There can be multiple entries of **BuildRequires**, each on its own line in the SPEC file.
Requires	A comma- or whitespace-separated list of packages required by the software to run once installed. There can be multiple entries of **Requires**, each on its own line in the **spec** file.
ExcludeArch	If a piece of software cannot operate on a specific processor architecture, you can exclude this architecture in the **ExcludeArch** directive.

Directive	Definition
Conflicts	A comma- or whitespace-separated list of packages that must not be installed on the system in order for your software to function properly when installed. There can be multiple entries of **Conflicts**, each on its own line in the **spec** file.
Obsoletes	The **Obsoletes** directive changes the way updates work depending on the following factors: ● If you use the **rpm** command directly on a command line, it removes all packages that match obsoletes of packages being installed, or the update is performed by an updates or dependency solver. ● If you use the updates or dependency resolver (**DNF**), packages containing matching **Obsoletes:** are added as updates and replace the matching packages.
Provides	If you add the **Provides** directive to the package, this package can be referred to by dependencies other than its name.

The **Name**, **Version**, and **Release** (**NVR**) directives comprise the file name of the RPM package in the **name-version-release** format.

You can display the **NVR** information for a specific package by querying RPM database by using the **rpm** command, for example:

```
# rpm -q bash
bash-4.4.19-7.el8.x86_64
```

Here, **bash** is the package name, **4.4.19** is the version, and **7.el8** is the release. The **x86_64** marker is the package architecture. Unlike **NVR**, the architecture marker is not under direct control of the RPM packager, but is defined by the **rpmbuild** build environment. The exception to this is the architecture-independent **noarch** package.

4.2.2. Body items

The following are the items used in the *Body* section of the RPM **spec** file.

Table 4.3. The Body section items

Directive	Definition
%description	A full description of the software packaged in the RPM. This description can span multiple lines and can be broken into paragraphs.

Directive	Definition
%prep	A command or series of commands to prepare the software for building, for example, for unpacking the archive in the **Source** directive. The **%prep** directive can contain a shell script.
%build	A command or series of commands for building the software into machine code (for compiled languages) or bytecode (for some interpreted languages).
%install	A command or series of commands that the **rpmbuild** utility will use to install the software into the **BUILDROOT** directory once the software has been built. These commands copy the desired build artifacts from the **%_builddir** directory, where the build happens, to the **%buildroot** directory that contains the directory structure with the files to be packaged. This includes copying files from **~/rpmbuild/BUILD** to **~/rpmbuild/BUILDROOT** and creating the necessary directories in **~/rpmbuild/BUILDROOT**. The **%install** directory is an empty **chroot** base directory, which resembles the end user's **root** directory. Here you can create any directories that will contain the installed files. To create such directories, you can use RPM macros without having to hardcode the paths. Note that **%install** is only run when you create a package, not when you install it. For more information, see Working with spec files.
%check	A command or series of commands for testing the software, for example, unit tests.
%files	A list of files, provided by the RPM package, to be installed in the user's system and their full path location on the system. During the build, if there are files in the **%buildroot** directory that are not listed in **%files**, you will receive a warning about possible unpackaged files. Within the **%files** section, you can indicate the role of various files by using built-in macros. This is useful for querying the package file manifest metadata by using the **rpm** command. For example, to indicate that the **LICENSE** file is a software license file, use the **%license** macro.
%changelog	A record of changes that happened to the package between different **Version** or **Release** builds. These changes include a list of date-stamped entries for each Version-Release of the package. These entries log packaging changes, not software changes, for example, adding a patch or changing the build procedure in the **%build** section.

4.2.3. Advanced items

A **spec** file can contain advanced items, such as Scriptlets or Triggers.

Scriptlets and Triggers take effect at different points during the installation process on the end user's system, not the build process.

4.3. BUILDROOTS

In the context of RPM packaging, **buildroot** is a chroot environment. The build artifacts are placed here by using the same file system hierarchy as the future hierarchy in the end user's system, with **buildroot** acting as the root directory. The placement of build artifacts must comply with the file system hierarchy standard of the end user's system.

The files in **buildroot** are later put into a **cpio** archive, which becomes the main part of the RPM. When RPM is installed on the end user's system, these files are extracted in the **root** directory, preserving the correct hierarchy.

NOTE

The **rpmbuild** program has its own defaults. Overriding these defaults can cause certain issues. Therefore, avoid defining your own value of the **buildroot** macro. Use the default **%{buildroot}** macro instead.

4.4. RPM MACROS

An rpm macro is a straight text substitution that can be conditionally assigned based on the optional evaluation of a statement when certain built-in functionality is used. Therefore, RPM can perform text substitutions for you.

For example, you can define *Version* of the packaged software only once in the **%{version}** macro, and use this macro throughout the **spec** file. Every occurrence is automatically substituted by *Version* that you defined in the macro.

NOTE

If you see an unfamiliar macro, you can evaluate it with the following command:

```
$ rpm --eval %{MACRO}
```

For example, to evaluate the **%{_bindir}** and **%{_libexecdir}** macros, enter:

```
$ rpm --eval %{_bindir}
/usr/bin

$ rpm --eval %{_libexecdir}
/usr/libexec
```

Additional resources

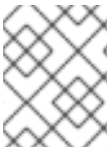
- More on macros

4.5. WORKING WITH SPEC FILES

To package new software, you must create a SPEC file.

You can create a SPEC file the following ways:

- Write the new SPEC file manually from scratch.
- Use the **rpmdev-newspec** utility.
  This utility creates an unpopulated SPEC file, where you fill in the necessary directives and fields.



NOTE

Some programmer-focused text editors pre-populate a new **.spec** file with their own SPEC template. The **rpmdev-newspec** utility provides an editor-agnostic method.

The following sections use the three example implementations of the **Hello World!** program:

Software Name	Explanation of example
bello	A program written in a raw interpreted programming language. It demonstrates when the source code does not need to be built, but only needs to be installed. If a pre-compiled binary needs to be packaged, you can also use this method because the binary would also just be a file.
pello	A program written in a byte-compiled interpreted programming language. It demonstrates byte-compiling the source code and installing the bytecode - the resulting pre-optimized files.
cello	A program written in a natively compiled programming language. It demonstrates a common process of compiling the source code into machine code and installing the resulting executables.

The implementations of **Hello World!** are the following:

- bello-0.1.tar.gz
- pello-0.1.2.tar.gz
- cello-1.0.tar.gz (cello-output-first-patch.patch)

As a prerequisite, these implementations need to be placed into the **~/rpmbuild/SOURCES** directory.

For more information about the **Hello World!** program implementations, see What is source code .

In the following section, learn how to work with SPEC files:

- Create a new SPEC file with rpmdev-newspec .
- Modify an original SPEC file for creating RPMs .
- Examine example SPEC files for programs written in bash, Python, and C.

4.5.1. Creating a new spec file for sample Bash, C, and Python programs

You can create a **spec** file for each of the three implementations of the **Hello World!** program by using the **rpmdev-newspec** utility.

Prerequisites

- The following **Hello World!** program implementations were placed into the **~/rpmbuild/SOURCES** directory:

- bello-0.1.tar.gz
- pello-0.1.2.tar.gz
- cello-1.0.tar.gz (cello-output-first-patch.patch)

Procedure

1. Navigate to the ~/**rpmbuild**/**SPECS** directory:

```
$ cd ~/rpmbuild/SPECS
```

2. Create a **spec** file for each of the three implementations of the **Hello World!** program:

```
$ rpmdev-newspec bello
bello.spec created; type minimal, rpm version >= 4.11.

$ rpmdev-newspec cello
cello.spec created; type minimal, rpm version >= 4.11.

$ rpmdev-newspec pello
pello.spec created; type minimal, rpm version >= 4.11.
```

   The ~/**rpmbuild**/**SPECS**/ directory now contains three **spec** files named **bello.spec**, **cello.spec**, and **pello.spec**.

3. Examine the created files.
   The directives in the files represent those described in About spec files. In the following sections, you will populate particular section in the output files of **rpmdev-newspec**.

4.5.2. Modifying an original spec file

The original output **spec** file generated by the **rpmdev-newspec** utility represents a template that you must modify to provide necessary instructions for the **rpmbuild** utility. **rpmbuild** then uses these instructions to build an RPM package.

Prerequisites

- The unpopulated ~/**rpmbuild**/**SPECS**/**<name>.spec spec** file was created by using the **rpmdev-newspec** utility. For more information, see Creating a new spec file for sample Bash, C, and Python programs.

Procedure

1. Open the ~/**rpmbuild**/**SPECS**/**<name>.spec** file provided by the **rpmdev-newspec** utility.

2. Populate the following directives of the **spec** file *Preamble* section:

   Name

   Name was already specified as an argument to **rpmdev-newspec**.

   Version

   Set **Version** to match the upstream release version of the source code.

   Release

Release is automatically set to **1%{?dist}**, which is initially **1**.

Summary

Enter a one-line explanation of the package.

License

Enter the software license associated with the source code.

URL

Enter the URL to the upstream software website. For consistency, utilize the **%{name}** RPM macro variable and use the **https://example.com/%{name}** format.

Source

Enter the URL to the upstream software source code. Link directly to the software version being packaged.

NOTE

The example URLs in this documentation include hard-coded values that could possibly change in the future. Similarly, the release version can change as well. To simplify these potential future changes, use the **%{name}** and **%{version}** macros. By using these macros, you need to update only one field in the **spec** file.

BuildRequires

Specify build-time dependencies for the package.

Requires

Specify run-time dependencies for the package.

BuildArch

Specify the software architecture.

3. Populate the following directives of the **spec** file *Body* section. You can think of these directives as section headings, because these directives can define multi-line, multi-instruction, or scripted tasks to occur.

%description

Enter the full description of the software.

%prep

Enter a command or series of commands to prepare software for building.

%build

Enter a command or series of commands for building software.

%install

Enter a command or series of commands that instruct the **rpmbuild** command on how to install the software into the **BUILDROOT** directory.

%files

Specify the list of files, provided by the RPM package, to be installed on your system.

%changelog

Enter the list of datestamped entries for each **Version-Release** of the package.
Start the first line of the **%changelog** section with an asterisk (*****) character followed by **Day-of-Week Month Day Year Name Surname <email> - Version-Release**.

For the actual change entry, follow these rules:

- Each change entry can contain multiple items, one for each change.
- Each item starts on a new line.
- Each item begins with a hyphen (**-**) character.

You have now written an entire **spec** file for the required program.

Additional resources

- Preamble items
- Body items
- An example spec file for a sample Bash program
- An example spec file for a sample Python program
- An example spec file for a sample C program
- Building RPMs

4.5.3. An example spec file for a sample Bash program

You can use the following example **spec** file for the **bello** program written in bash for your reference.

An example spec file for the bello program written in bash

```
Name:       bello
Version:    0.1
Release:    1%{?dist}
Summary:    Hello World example implemented in bash script

License:    GPLv3+
URL:        https://www.example.com/%{name}
Source0:    https://www.example.com/%{name}/releases/%{name}-%{version}.tar.gz

Requires:   bash

BuildArch:  noarch

%description
The long-tail description for our Hello World Example implemented in
bash script.

%prep
%setup -q

%build

%install

mkdir -p %{buildroot}/%{_bindir}
```

```
install -m 0755 %{name} %{buildroot}/%{_bindir}/%{name}

%files
%license LICENSE
%{_bindir}/%{name}

%changelog
* Tue May 31 2016 Adam Miller <maxamillion@fedoraproject.org> - 0.1-1
- First bello package
- Example second item in the changelog for version-release 0.1-1
```

- The **BuildRequires** directive, which specifies build-time dependencies for the package, was deleted because there is no building step for **bello**. Bash is a raw interpreted programming language, and the files are just installed to their location on the system.
- The **Requires** directive, which specifies run-time dependencies for the package, includes only **bash**, because the **bello** script requires only the **bash** shell environment to execute.
- The **%build** section, which specifies how to build the software, is blank, because the **bash** script does not need to be built.

NOTE

To install **bello**, you must create the destination directory and install the executable **bash** script file there. Therefore, you can use the **install** command in the **%install** section. You can use RPM macros to do this without hardcoding paths.

Additional resources

- What is source code

4.5.4. An example SPEC file for a program written in Python

Example SPEC file for the **pello** program written in the Python programming language follows.

An example SPEC file for the pello program written in Python

```
%global python3_pkgversion 3.11                    (1)

Name:          python-pello                        (2)
Version:       1.0.2
Release:       1%{?dist}
Summary:       Example Python library

License:       MIT
URL:           https://github.com/fedora-python/Pello
Source:        %{url}/archive/v%{version}/Pello-%{version}.tar.gz

BuildArch:     noarch
BuildRequires:  python%{python3_pkgversion}-devel   (3)

# Build dependencies needed to be specified manually
BuildRequires:  python%{python3_pkgversion}-setuptools
```

```
# Test dependencies needed to be specified manually
# Also runtime dependencies need to be BuildRequired manually to run tests during build
BuildRequires:  python%{python3_pkgversion}-pytest >= 3


%global _description %{expand:
Pello is an example package with an executable that prints Hello World! on the command line.}

%description %_description

%package -n python%{python3_pkgversion}-pello                    4
Summary:        %{summary}

%description -n python%{python3_pkgversion}-pello %_description


%prep
%autosetup -p1 -n Pello-%{version}


%build
# The macro only supported projects with setup.py
%py3_build                                                       5


%install
# The macro only supported projects with setup.py
%py3_install


%check                                                           6
%{pytest}


# Note that there is no %%files section for the unversioned python module
%files -n python%{python3_pkgversion}-pello
%doc README.md
%license LICENSE.txt
%{_bindir}/pello_greeting

# The library files needed to be listed manually
%{python3_sitelib}/pello/

# The metadata files needed to be listed manually
%{python3_sitelib}/Pello-*.egg-info/
```

1. By defining the **python3_pkgversion** macro, you set which Python version this package will be built for. To build for the default Python version 3.9, either set the macro to its default value **3** or remove the line entirely.

2. When packaging a Python project into RPM, always add the **python-** prefix to the original name of the project. The original name here is **pello** and, therefore, the **name of the Source RPM (SRPM)** is **python-pello**.

3. **BuildRequires** specifies what packages are required to build and test this package. In **BuildRequires**, always include items providing tools necessary for building Python packages:

4. When choosing a name for the binary RPM (the package that users will be able to install), add a versioned Python prefix. Use the **python3-** prefix for the default Python 3.9, the **python3.11-** prefix for Python 3.11, or the **python3.12-** prefix for Python 3.12. You can use the **%{python3_pkgversion}** macro, which evaluates to **3** for the default Python version 3.9 unless you set it to an explicit version, for example, **3.11** (see footnote 1).

5. The **%py3_build** and **%py3_install** macros run the **setup.py build** and **setup.py install** commands, respectively, with additional arguments to specify installation locations, the interpreter to use, and other details.

6. The **%check** section should run the tests of the packaged project. The exact command depends on the project itself, but it is possible to use the **%pytest** macro to run the **pytest** command in an RPM-friendly way.

4.5.5. An example spec file for a sample C program

You can use the following example **spec** file for the **cello** program that was written in the C programming language for your reference.

An example spec file for the cello program written in C

```
Name:        cello
Version:     1.0
Release:     1%{?dist}
Summary:     Hello World example implemented in C

License:     GPLv3+
URL:         https://www.example.com/%{name}
Source0:     https://www.example.com/%{name}/releases/%{name}-%{version}.tar.gz

Patch0:      cello-output-first-patch.patch

BuildRequires:  gcc
BuildRequires:  make

%description
The long-tail description for our Hello World Example implemented in
C.

%prep
%setup -q

%patch0

%build
make %{?_smp_mflags}

%install
%make_install

%files
%license LICENSE
```

```
%{_bindir}/%{name}

%changelog
* Tue May 31 2016 Adam Miller <maxamillion@fedoraproject.org> - 1.0-1
- First cello package
```

- The **BuildRequires** directive, which specifies build-time dependencies for the package, includes the following packages required to perform the compilation build process:
  - **gcc**
  - **make**
- The **Requires** directive, which specifies run-time dependencies for the package, is omitted in this example. All runtime requirements are handled by **rpmbuild**, and the **cello** program does not require anything outside of the core C standard libraries.
- The **%build** section reflects the fact that in this example the **Makefile** file for the **cello** program was written. Therefore, you can use the GNU make command. However, you must remove the call to **%configure** because you did not provide a configure script.

You can install the **cello** program by using the **%make_install** macro. This is possible because the **Makefile** file for the **cello** program is available.

Additional resources

- What is source code

4.6. BUILDING RPMS

You can build RPM packages by using the **rpmbuild** command. When using this command, a certain directory and file structure is expected, which is the same as the structure that was set up by the **rpmdev-setuptree** utility.

Different use cases and desired outcomes require different combinations of arguments to the **rpmbuild** command. The following are the main use cases:

- Building source RPMs.
- Building binary RPMs:
  - Rebuilding a binary RPM from a source RPM.
  - Building a binary RPM from the **spec** file.

4.6.1. Building source RPMs

Building a Source RPM (SRPM) has the following advantages:

- You can preserve the exact source of a certain **Name-Version-Release** of an RPM file that was deployed to an environment. This includes the exact **spec** file, the source code, and all relevant patches. This is useful for tracking and debugging purposes.
- You can build a binary RPM on a different hardware platform or architecture.

Prerequisites

- You have installed the **rpmbuild** utility on your system:

```
# dnf install rpm-build
```

- The following **Hello World!** implementations were placed into the **~/rpmbuild/SOURCES/** directory:
  - bello-0.1.tar.gz
  - pello-0.1.2.tar.gz
  - cello-1.0.tar.gz (cello-output-first-patch.patch)
- A **spec** file for the program that you want to package exists.

Procedure

1. Navigate to the **~/rpmbuild/SPECS/** directive, which contains the created **spec** file:

```
$ cd ~/rpmbuild/SPECS/
```

2. Build the source RPM by entering the **rpmbuild** command with the specified **spec** file:

```
$ rpmbuild -bs <specfile>
```

The **-bs** option stands for the *build source*.

For example, to build source RPMs for the **bello**, **pello**, and **cello** programs, enter:

```
$ rpmbuild -bs bello.spec
Wrote: /home/admiller/rpmbuild/SRPMS/bello-0.1-1.el8.src.rpm

$ rpmbuild -bs pello.spec
Wrote: /home/admiller/rpmbuild/SRPMS/pello-0.1.2-1.el8.src.rpm

$ rpmbuild -bs cello.spec
Wrote: /home/admiller/rpmbuild/SRPMS/cello-1.0-1.el8.src.rpm
```

Verification steps

- Verify that the **rpmbuild/SRPMS** directory includes the resulting source RPMs. The directory is a part of the structure expected by **rpmbuild**.

Additional resources

- Working with spec files
- Creating a new spec file for sample Bash, C, and Python programs
- Modifying an original spec file

4.6.2. Rebuilding a binary RPM from a source RPM

To rebuild a binary RPM from a source RPM (SRPM), use the **rpmbuild** command with the **--rebuild** option.

The output generated when creating the binary RPM is verbose, which is helpful for debugging. The output varies for different examples and corresponds to their **spec** files.

The resulting binary RPMs are located in the **~/rpmbuild/RPMS/YOURARCH** directory, where **YOURARCH** is your architecture, or in the **~/rpmbuild/RPMS/noarch/** directory, if the package is not architecture-specific.

Prerequisites

- You have installed the **rpmbuild** utility on your system:

```
# dnf install rpm-build
```

Procedure

1. Navigate to the **~/rpmbuild/SRPMS/** directive, which contains the source RPM:

```
$ cd ~/rpmbuild/SRPMS/
```

2. Rebuild the binary RPM from the source RPM:

```
$ rpmbuild --rebuild <srpm>
```

Replace *srpm* with the name of the source RPM file.

For example, to rebuild **bello**, **pello**, and **cello** from their SRPMs, enter:

```
$ rpmbuild --rebuild bello-0.1-1.el8.src.rpm
[output truncated]

$ rpmbuild --rebuild pello-0.1.2-1.el8.src.rpm
[output truncated]

$ rpmbuild --rebuild cello-1.0-1.el8.src.rpm
[output truncated]
```

NOTE

Invoking **rpmbuild --rebuild** involves the following processes:

- Installing the contents of the SRPM (the **spec** file and the source code) into the ~/**rpmbuild**/ directory.
- Building an RPM by using the installed contents.
- Removing the **spec** file and the source code.

You can retain the **spec** file and the source code after building either of the following ways:

- When building the RPM, use the **rpmbuild** command with the **--recompile** option instead of the **--rebuild** option.
- Install SRPMs for **bello**, **pello**, and **cello**:

```
$ rpm -Uvh ~/rpmbuild/SRPMS/bello-0.1-1.el8.src.rpm
Updating / installing…
   1:bello-0.1-1.el8              [100%]

$ rpm -Uvh ~/rpmbuild/SRPMS/pello-0.1.2-1.el8.src.rpm
Updating / installing…
…1:pello-0.1.2-1.el8              [100%]

$ rpm -Uvh ~/rpmbuild/SRPMS/cello-1.0-1.el8.src.rpm
Updating / installing…
…1:cello-1.0-1.el8              [100%]
```

4.6.3. Building a binary RPM from the spec file

To build a binary RPM from its **spec** file, use the **rpmbuild** command with the **-bb** option.

Prerequisites

- You have installed the **rpmbuild** utility on your system:

```
# dnf install rpm-build
```

Procedure

1. Navigate to the ~/**rpmbuild**/**SPECS**/ directive, which contains **spec** files:

```
$ cd ~/rpmbuild/SPECS/
```

2. Build the binary RPM from its **spec**:

```
$ rpmbuild -bb <spec_file>
```

For example, to build **bello**, **pello**, and **cello** binary RPMs from their **spec** files, enter:

```
$ rpmbuild -bb bello.spec
```

```
$ rpmbuild -bb pello.spec

$ rpmbuild -bb cello.spec
```

4.7. CHECKING RPMS FOR SANITY

After creating a package, you might want to check the quality of the package. The main tool for checking package quality is **rpmlint**.

With the **rpmlint** tool, you can perform the following actions:

- Improve RPM maintainability.
- Enable sanity checking by performing static analysis of the RPM.
- Enable error checking by performing static analysis of the RPM.

You can use **rpmlint** to check binary RPMs, source RPMs (SRPMs), and **spec** files. Therefore, this tool is useful for all stages of packaging.

Note that **rpmlint** has strict guidelines. Therefore, it is sometimes acceptable to skip some of its errors and warnings as shown in the following sections.

NOTE

In the examples described in the following sections, **rpmlint** is run without any options, which produces a non-verbose output. For detailed explanations of each error or warning, run **rpmlint -i** instead.

4.7.1. Checking a sample Bash program for sanity

In the following sections, investigate possible warnings and errors that can occur when checking an RPM for sanity on the example of the **bello spec** file and **bello** binary RPM.

4.7.1.1. Checking the bello spec file for sanity

Inspect the outputs of the following examples to learn how to check a **bello spec** file for sanity.

Output of running the rpmlint command on the bello spec file

```
$ rpmlint bello.spec
bello.spec: W: invalid-url Source0: https://www.example.com/bello/releases/bello-0.1.tar.gz HTTP
Error 404: Not Found
0 packages and 1 specfiles checked; 0 errors, 1 warnings.
```

For **bello.spec**, there is only one **invalid-url Source0** warning. This warning means that the URL listed in the **Source0** directive is unreachable. This is expected, because the specified **example.com** URL does not exist. Assuming that this URL will be valid in the future, you can ignore this warning.

Output of running the rpmlint command on the bello SRPM

```
$ rpmlint ~/rpmbuild/SRPMS/bello-0.1-1.el8.src.rpm
bello.src: W: invalid-url URL: https://www.example.com/bello HTTP Error 404: Not Found
```

```
bello.src: W: invalid-url Source0: https://www.example.com/bello/releases/bello-0.1.tar.gz HTTP Error
404: Not Found
1 packages and 0 specfiles checked; 0 errors, 2 warnings.
```

For the **bello** SRPM, there is a new **invalid-url URL** warning that means that the URL specified in the **URL** directive is unreachable. Assuming that this URL will be valid in the future, you can ignore this warning.

4.7.1.2. Checking the bello binary RPM for sanity

When checking binary RPMs, the **rpmlint** command checks the following items:

- Documentation
- Manual pages
- Consistent use of the filesystem hierarchy standard

Inspect the outputs of the following example to learn how to check a **bello** binary RPM for sanity.

Output of running the rpmlint command on the bello binary RPM

```
$ rpmlint ~/rpmbuild/RPMS/noarch/bello-0.1-1.el8.noarch.rpm
bello.noarch: W: invalid-url URL: https://www.example.com/bello HTTP Error 404: Not Found
bello.noarch: W: no-documentation
bello.noarch: W: no-manual-page-for-binary bello
1 packages and 0 specfiles checked; 0 errors, 3 warnings.
```

The **no-documentation** and **no-manual-page-for-binary** warnings mean that the RPM has no documentation or manual pages, because you did not provide any. Apart from the output warnings, the RPM passed **rpmlint** checks.

4.7.2. Checking a sample Python program for sanity

In the following sections, investigate possible warnings and errors that can occur when checking RPM sanity on the example of the **pello spec** file and **pello** binary RPM.

4.7.2.1. Checking the pello spec file for sanity

Inspect the outputs of the following examples to learn how to check a **pello spec** file for sanity.

Output of running the rpmlint command on the pello spec file

```
$ rpmlint pello.spec
pello.spec:30: E: hardcoded-library-path in %{buildroot}/usr/lib/%{name}
pello.spec:34: E: hardcoded-library-path in /usr/lib/%{name}/%{name}.pyc
pello.spec:39: E: hardcoded-library-path in %{buildroot}/usr/lib/%{name}/
pello.spec:43: E: hardcoded-library-path in /usr/lib/%{name}/
pello.spec:45: E: hardcoded-library-path in /usr/lib/%{name}/%{name}.py*
pello.spec: W: invalid-url Source0: https://www.example.com/pello/releases/pello-0.1.2.tar.gz HTTP
Error 404: Not Found
0 packages and 1 specfiles checked; 5 errors, 1 warnings.
```

- The **invalid-url Source0** warning means that the URL listed in the **Source0** directive is unreachable. This is expected, because the specified **example.com** URL does not exist. Assuming that this URL will be valid in the future, you can ignore this warning.

- The **hardcoded-library-path** errors suggest using the **%{_libdir}** macro instead of hard-coding the library path. For the sake of this example, you can safely ignore these errors. However, for packages going into production, check all errors carefully.

Output of running the rpmlint command on the SRPM for pello

```
$ rpmlint ~/rpmbuild/SRPMS/pello-0.1.2-1.el8.src.rpm
pello.src: W: invalid-url URL: https://www.example.com/pello HTTP Error 404: Not Found
pello.src:30: E: hardcoded-library-path in %{buildroot}/usr/lib/%{name}
pello.src:34: E: hardcoded-library-path in /usr/lib/%{name}/%{name}.pyc
pello.src:39: E: hardcoded-library-path in %{buildroot}/usr/lib/%{name}/
pello.src:43: E: hardcoded-library-path in /usr/lib/%{name}/
pello.src:45: E: hardcoded-library-path in /usr/lib/%{name}/%{name}.py*
pello.src: W: invalid-url Source0: https://www.example.com/pello/releases/pello-0.1.2.tar.gz HTTP
Error 404: Not Found
1 packages and 0 specfiles checked; 5 errors, 2 warnings.
```

The **invalid-url URL** error means that the URL mentioned in the **URL** directive is unreachable. Assuming that this URL will be valid in the future, you can ignore this warning.

4.7.2.2. Checking the pello binary RPM for sanity

When checking binary RPMs, the **rpmlint** command checks the following items:

- Documentation

- Manual pages

- Consistent use of the Filesystem Hierarchy Standard

Inspect the outputs of the following example to learn how to check a **pello** binary RPM for sanity.

Output of running the rpmlint command on the pello binary RPM

```
$ rpmlint ~/rpmbuild/RPMS/noarch/pello-0.1.2-1.el8.noarch.rpm
pello.noarch: W: invalid-url URL: https://www.example.com/pello HTTP Error 404: Not Found
pello.noarch: W: only-non-binary-in-usr-lib
pello.noarch: W: no-documentation
pello.noarch: E: non-executable-script /usr/lib/pello/pello.py 0644L /usr/bin/env
pello.noarch: W: no-manual-page-for-binary pello
1 packages and 0 specfiles checked; 1 errors, 4 warnings.
```

- The **no-documentation** and **no-manual-page-for-binary** warnings mean that the RPM has no documentation or manual pages because you did not provide any.

- The **only-non-binary-in-usr-lib** warning means that you provided only non-binary artifacts in the **/usr/lib/** directory. This directory is typically used for shared object files, which are binary files. Therefore, **rpmlint** expects at least one or more files in **/usr/lib/** to be binary.
  This is an example of an **rpmlint** check for compliance with Filesystem Hierarchy Standard. To ensure the correct placement of files, use RPM macros. For the sake of this example, you can safely ignore this warning.

- The **non-executable-script** error means that the **/usr/lib/pello/pello.py** file has no execute permissions. The **rpmlint** tool expects the file to be executable because the file contains the shebang (**#!**). For the purpose of this example, you can leave this file without execute permissions and ignore this error.

Apart from the output warnings and errors, the RPM passed **rpmlint** checks.

4.7.3. Checking a sample C program for sanity

In the following sections, investigate possible warnings and errors that can occur when checking RPM sanity on the example of the **cello spec** file and **cello** binary RPM.

4.7.3.1. Checking the cello spec file for sanity

Inspect the outputs of the following examples to learn how to check a **cello spec** file for sanity.

Output of running the rpmlint command on the cello spec file

```
$ rpmlint ~/rpmbuild/SPECS/cello.spec
/home/admiller/rpmbuild/SPECS/cello.spec: W: invalid-url Source0:
https://www.example.com/cello/releases/cello-1.0.tar.gz HTTP Error 404: Not Found
0 packages and 1 specfiles checked; 0 errors, 1 warnings.
```

For **cello.spec**, there is only one **invalid-url Source0** warning. This warning means that the URL listed in the **Source0** directive is unreachable. This is expected because the specified **example.com** URL does not exist. Assuming that this URL will be valid in the future, you can ignore this warning.

Output of running the rpmlint command on the cello SRPM

```
$ rpmlint ~/rpmbuild/SRPMS/cello-1.0-1.el8.src.rpm
cello.src: W: invalid-url URL: https://www.example.com/cello HTTP Error 404: Not Found
cello.src: W: invalid-url Source0: https://www.example.com/cello/releases/cello-1.0.tar.gz HTTP Error
404: Not Found
1 packages and 0 specfiles checked; 0 errors, 2 warnings.
```

For the **cello** SRPM, there is a new **invalid-url URL** warning. This warning means that the URL specified in the **URL** directive is unreachable. Assuming that this URL will be valid in the future, you can ignore this warning.

4.7.3.2. Checking the cello binary RPM for sanity

When checking binary RPMs, the **rpmlint** command checks the following items:

- Documentation
- Manual pages
- Consistent use of the filesystem hierarchy standard

Inspect the outputs of the following example to learn how to check a **cello** binary RPM for sanity.

Output of running the rpmlint command on the cello binary RPM

```
$ rpmlint ~/rpmbuild/RPMS/x86_64/cello-1.0-1.el8.x86_64.rpm
```

```
cello.x86_64: W: invalid-url URL: https://www.example.com/cello HTTP Error 404: Not Found
cello.x86_64: W: no-documentation
cello.x86_64: W: no-manual-page-for-binary cello
1 packages and 0 specfiles checked; 0 errors, 3 warnings.
```

The **no-documentation** and **no-manual-page-for-binary** warnings mean that the RPM has no documentation or manual pages because you did not provide any.

Apart from the output warnings, the RPM passed **rpmlint** checks.

4.8. LOGGING RPM ACTIVITY TO SYSLOG

You can log any RPM activity or transaction by using the System Logging protocol (**syslog**).

Prerequisites

- The **syslog** plug-in is installed on the system:

```
# dnf install rpm-plugin-syslog
```

> **NOTE**
>
> The default location for the **syslog** messages is the **/var/log/messages** file. However, you can configure **syslog** to use another location to store the messages.

Procedure

1. Open the file that you configured to store the **syslog** messages.
   Alternatively, if you use the default **syslog** configuration, open the **/var/log/messages** file.
2. Search for new lines including the **[RPM]** string.

4.9. EXTRACTING RPM CONTENT

In some cases, for example, if a package required by RPM is damaged, you might need to extract the content of the package. In such cases, if an RPM installation is still working despite the damage, you can use the **rpm2archive** utility to convert an **.rpm** file to a tar archive to use the content of the package.

> **NOTE**
>
> If the RPM installation is severely damaged, you can use the **rpm2cpio** utility to convert the RPM package file to a **cpio** archive.

Procedure

- Convert the RPM file to the tar archive:

```
$ rpm2archive <filename>.rpm
```

  The resulting file has the **.tgz** suffix. For example, to create an archive from the **bash** package, enter:

```
$ rpm2archive bash-4.4.19-6.el8.x86_64.rpm
$ ls bash-4.4.19-6.el8.x86_64.rpm.tgz
bash-4.4.19-6.el8.x86_64.rpm.tgz
```

CHAPTER 5. ADVANCED TOPICS

This section covers topics that are beyond the scope of the introductory tutorial but are useful in real-world RPM packaging.

5.1. SIGNING RPM PACKAGES

You can sign RPM packages to ensure that no third party can alter their content. To add an additional layer of security, use the HTTPS protocol when downloading the package.

You can sign a package by using the **--addsign** option provided by the **rpm-sign** package.

Prerequisites

- You have created a GNU Privacy Guard (GPG) key as described in Creating a GPG key .

5.1.1. Creating a GPG key

Use the following procedure to create a GNU Privacy Guard (GPG) key required for signing packages.

Procedure

1. Generate a GPG key pair:

```
# gpg --gen-key
```

2. Check the generated key pair:

```
# gpg --list-keys
```

3. Export the public key:

```
# gpg --export -a '<Key_name>' > RPM-GPG-KEY-pmanager
```

   Replace <Key_name> with the real key name that you have selected.

4. Import the exported public key into an RPM database:

```
# rpm --import RPM-GPG-KEY-pmanager
```

5.1.2. Configuring RPM to sign a package

To be able to sign an RPM package, you need to specify the **%_gpg_name** RPM macro.

The following procedure describes how to configure RPM for signing a package.

Procedure

- Define the **%_gpg_name** macro in your **$HOME/.rpmmacros** file as follows:

```
%_gpg_name Key ID
```

Replace *Key ID* with the GNU Privacy Guard (GPG) key ID that you will use to sign a package. A valid GPG key ID value is either a full name or email address of the user who created the key.

5.1.3. Adding a signature to an RPM package

The most usual case is when a package is built without a signature. The signature is added just before the release of the package.

To add a signature to an RPM package, use the **--addsign** option provided by the **rpm-sign** package.

Procedure

- Add a signature to a package:

```
$ rpm --addsign package-name.rpm
```

  Replace *package-name* with the name of an RPM package you want to sign.

NOTE

You must enter the password to unlock the secret key for the signature.

5.2. MORE ON MACROS

This section covers selected built-in RPM Macros. For an exhaustive list of such macros, see RPM Documentation.

5.2.1. Defining your own macros

The following section describes how to create a custom macro.

Procedure

- Include the following line in the RPM **spec** file:

```
%global <name>[(opts)] <body>
```

All whitespace surrounding **<body>** is removed. Name may be composed of alphanumeric characters, and the character _ and must be at least 3 characters in length. Inclusion of the **(opts)** field is optional:

- **Simple** macros do not contain the **(opts)** field. In this case, only recursive macro expansion is performed.
- **Parametrized** macros contain the **(opts)** field. The **opts** string between parentheses is passed to **getopt(3)** for **argc**/**argv** processing at the beginning of a macro invocation.

NOTE

Older RPM **spec** files use the **%define <name> <body>** macro pattern instead. The differences between **%define** and **%global** macros are as follows:

- **%define** has local scope. It applies to a specific part of a **spec** file. The body of a **%define** macro is expanded when used.
- **%global** has global scope. It applies to an entire **spec** file. The body of a **%global** macro is expanded at definition time.

IMPORTANT

Macros are evaluated even if they are commented out or the name of the macro is given into the **%changelog** section of the **spec** file. To comment out a macro, use **%%**. For example: **%%global**.

Additional resources

- Macro syntax

5.2.2. Using the %setup macro

This section describes how to build packages with source code tarballs using different variants of the **%setup** macro. Note that the macro variants can be combined. The **rpmbuild** output illustrates standard behavior of the **%setup** macro. At the beginning of each phase, the macro outputs **Executing(%...)**, as shown in the below example.

Example 5.1. Example %setup macro output

```
Executing(%prep): /bin/sh -e /var/tmp/rpm-tmp.DhddsG
```

The shell output is set with **set -x** enabled. To see the content of **/var/tmp/rpm-tmp.DhddsG**, use the **--debug** option because **rpmbuild** deletes temporary files after a successful build. This displays the setup of environment variables followed by for example:

```
cd '/builddir/build/BUILD'
rm -rf 'cello-1.0'
/usr/bin/gzip -dc '/builddir/build/SOURCES/cello-1.0.tar.gz' | /usr/bin/tar -xof -
STATUS=$?
if [ $STATUS -ne 0 ]; then
  exit $STATUS
fi
cd 'cello-1.0'
/usr/bin/chmod -Rf a+rX,u+w,g-w,o-w .
```

The **%setup** macro:

- Ensures that we are working in the correct directory.
- Removes residues of previous builds.
- Unpacks the source tarball.

- Sets up some default privileges.

5.2.2.1. Using the %setup -q macro

The **-q** option limits the verbosity of the **%setup** macro. Only **tar -xof** is executed instead of **tar -xvvof**. Use this option as the first option.

5.2.2.2. Using the %setup -n macro

The **-n** option is used to specify the name of the directory from expanded tarball.

This is used in cases when the directory from expanded tarball has a different name from what is expected (**%{name}-%{version}**), which can lead to an error of the **%setup** macro.

For example, if the package name is **cello**, but the source code is archived in **hello-1.0.tgz** and contains the **hello**/ directory, the **spec** file content needs to be as follows:

```
Name: cello
Source0: https://example.com/%{name}/release/hello-%{version}.tar.gz
…
%prep
%setup -n hello
```

5.2.2.3. Using the %setup -c macro

The **-c** option is used if the source code tarball does not contain any subdirectories and after unpacking, files from an archive fills the current directory.

The **-c** option then creates the directory and steps into the archive expansion as shown below:

```
/usr/bin/mkdir -p cello-1.0
cd 'cello-1.0'
```

The directory is not changed after archive expansion.

5.2.2.4. Using the %setup -D and %setup -T macros

The **-D** option disables deleting of source code directory, and is particularly useful if the **%setup** macro is used several times. With the **-D** option, the following lines are not used:

```
rm -rf 'cello-1.0'
```

The **-T** option disables expansion of the source code tarball by removing the following line from the script:

```
/usr/bin/gzip -dc '/builddir/build/SOURCES/cello-1.0.tar.gz' | /usr/bin/tar -xvvof -
```

5.2.2.5. Using the %setup -a and %setup -b macros

The **-a** and **-b** options expand specific sources:

- The **-b** option stands for **before**. This option expands specific sources before entering the working directory.

- The **-a** option stands for **after**. This option expands those sources after entering. Their arguments are source numbers from the **spec** file preamble.

In the following example, the **cello-1.0.tar.gz** archive contains an empty **examples** directory. The examples are shipped in a separate **examples.tar.gz** tarball and they expand into the directory of the same name. In this case, use **-a 1** if you want to expand **Source1** after entering the working directory:

```
Source0: https://example.com/%{name}/release/%{name}-%{version}.tar.gz
Source1: examples.tar.gz
…
%prep
%setup -a 1
```

In the following example, examples are provided in a separate **cello-1.0-examples.tar.gz** tarball, which expands into **cello-1.0/examples**. In this case, use **-b 1** to expand **Source1** before entering the working directory:

```
Source0: https://example.com/%{name}/release/%{name}-%{version}.tar.gz
Source1: %{name}-%{version}-examples.tar.gz
…
%prep
%setup -b 1
```

5.2.3. Common RPM macros in the %files section

The following table lists advanced RPM Macros that are needed in the **%files** section of a **spec** file.

Table 5.1. Advanced RPM Macros in the%files section

Macro	Definition
%license	The **%license** macro identifies the file listed as a**LICENSE** file and it will be installed and labeled as such by RPM. Example: **%license LICENSE**.
%doc	The **%doc** macro identifies a file listed as documentation and it will be installed and labeled as such by RPM. The %doc macro is used for documentation about the packaged software and also for code examples and various accompanying items. If code examples are included, care must be taken to remove executable mode from the file. Example: **%doc README**
%dir	The **%dir** macro ensures that the path is a directory owned by this RPM. This is important so that the RPM file manifest accurately knows what directories to clean up on uninstall. Example: **%dir %{_libdir}/%{name}**
%config(noreplace)	The **%config(noreplace)** macro ensures that the following file is a configuration file and therefore should not be overwritten (or replaced) on a package install or update if the file has been modified from the original installation checksum. If there is a change, the file will be created with **.rpmnew** appended to the end of the filename upon upgrade or install so that the pre-existing or modified file on the target system is not modified. Example: **%config(noreplace) %{_sysconfdir}/%{name}/%{name}.conf**

5.2.4. Displaying the built-in macros

Red Hat Enterprise Linux provides multiple built-in RPM macros.

Procedure

1. To display all built-in RPM macros, run:

```
rpm --showrc
```

> **NOTE**
>
> The output is quite sizeable. To narrow the result, use the command above with the **grep** command.

2. To find information about the RPMs macros for your system's version of RPM, run:

```
rpm -ql rpm
```

> **NOTE**
>
> RPM macros are the files titled **macros** in the output directory structure.

5.2.5. RPM distribution macros

Different distributions provide different sets of recommended RPM macros based on the language implementation of the software being packaged or the specific guidelines of the distribution.

The sets of recommended RPM macros are often provided as RPM packages, ready to be installed with the **dnf** package manager.

Once installed, the macro files can be found in the **/usr/lib/rpm/macros.d/** directory.

Procedure

- To display the raw RPM macro definitions, run:

```
rpm --showrc
```

The above output displays the raw RPM macro definitions.

- To determine what a macro does and how it can be helpful when packaging RPMs, run the **rpm --eval** command with the name of the macro used as its argument:

```
rpm --eval %{_MACRO}
```

Additional resources

- **rpm** man page

5.2.6. Creating custom macros

You can override the distribution macros in the ~/**.rpmmacros** file with your custom macros. Any changes that you make affect every build on your machine.

> **WARNING**
>
> Defining any new macros in the ~/**.rpmmacros** file is not recommended. Such macros would not be present on other machines, where users may want to try to rebuild your package.

Procedure

- To override a macro, run:

```
%_topdir /opt/some/working/directory/rpmbuild
```

You can create the directory from the example above, including all subdirectories through the **rpmdev-setuptree** utility. The value of this macro is by default ~/**rpmbuild**.

```
%_smp_mflags -l3
```

The macro above is often used to pass to Makefile, for example **make %{?_smp_mflags}**, and to set a number of concurrent processes during the build phase. By default, it is set to **-jX**, where **X** is a number of cores. If you alter the number of cores, you can speed up or slow down a build of packages.

5.3. EPOCH, SCRIPTLETS AND TRIGGERS

This section covers **Epoch**, **Scriptlets**, and **Triggers**, which represent advanced directives for RMP **spec** files.

All these directives influence not only the **spec** file, but also the end machine on which the resulting RPM is installed.

5.3.1. The Epoch directive

The **Epoch** directive enables to define weighted dependencies based on version numbers.

If this directive is not listed in the RPM **spec** file, the **Epoch** directive is not set at all. This is contrary to common belief that not setting **Epoch** results in an **Epoch** of 0. However, the **dnf** utility treats an unset **Epoch** as the same as an **Epoch** of 0 for the purposes of depsolving.

However, listing **Epoch** in a **spec** file is usually omitted because in majority of cases introducing an **Epoch** value skews the expected RPM behavior when comparing versions of packages.

> **Example 5.2. Using Epoch**
>
> If you install the **foobar** package with **Epoch: 1** and **Version: 1.0**, and someone else packages **foobar** with **Version: 2.0** but without the **Epoch** directive, the new version will never be considered an update. The reason being that the **Epoch** version is preferred over the traditional **Name-Version-Release** marker that signifies versioning for RPM Packages.

Using of **Epoch** is thus quite rare. However, **Epoch** is typically used to resolve an upgrade ordering issue. The issue can appear as a side effect of upstream change in software version number schemes or versions incorporating alphabetical characters that cannot always be compared reliably based on encoding.

5.3.2. Scriptlets directives

Scriptlets are a series of RPM directives that are executed before or after packages are installed or deleted.

Use **Scriptlets** only for tasks that cannot be done at build time or in an start up script.

A set of common **Scriptlet** directives exists. They are similar to the **spec** file section headers, such as **%build** or **%install**. They are defined by multi-line segments of code, which are often written as a standard POSIX shell script. However, they can also be written in other programming languages that RPM for the target machine's distribution accepts. RPM Documentation includes an exhaustive list of available languages.

The following table includes **Scriptlet** directives listed in their execution order. Note that a package containing the scripts is installed between the **%pre** and **%post** directive, and it is uninstalled between the **%preun** and **%postun** directive.

Table 5.2. Scriptlet directives

Directive	Definition
%pretrans	Scriptlet that is executed just before installing or removing any package.
%pre	Scriptlet that is executed just before installing the package on the target system.
%post	Scriptlet that is executed just after the package was installed on the target system.
%preun	Scriptlet that is executed just before uninstalling the package from the target system.
%postun	Scriptlet that is executed just after the package was uninstalled from the target system.
%posttrans	Scriptlet that is executed at the end of the transaction.

5.3.3. Turning off a scriptlet execution

The following procedure describes how to turn off the execution of any scriptlet using the **rpm** command together with the **--no_scriptlet_name_** option.

Procedure

- For example, to turn off the execution of the **%pretrans** scriptlets, run:

  ```
  # rpm --nopretrans
  ```

  You can also use the **-- noscripts** option, which is equivalent to all of the following:

- **--nopre**
- **--nopost**
- **--nopreun**
- **--nopostun**
- **--nopretrans**
- **--noposttrans**

Additional resources

- **rpm(8)** man page.

5.3.4. Scriptlets macros

The **Scriptlets** directives also work with RPM macros.

The following example shows the use of systemd scriptlet macro, which ensures that systemd is notified about a new unit file.

```
$ rpm --showrc | grep systemd
-14: __transaction_systemd_inhibit      %{__plugindir}/systemd_inhibit.so
-14: _journalcatalogdir /usr/lib/systemd/catalog
-14: _presetdir /usr/lib/systemd/system-preset
-14: _unitdir   /usr/lib/systemd/system
-14: _userunitdir       /usr/lib/systemd/user
/usr/lib/systemd/systemd-binfmt %{?*} >/dev/null 2>&1 || :
/usr/lib/systemd/systemd-sysctl %{?*} >/dev/null 2>&1 || :
-14: systemd_post
-14: systemd_postun
-14: systemd_postun_with_restart
-14: systemd_preun
-14: systemd_requires
Requires(post): systemd
Requires(preun): systemd
Requires(postun): systemd
-14: systemd_user_post  %systemd_post --user --global %{?*}
-14: systemd_user_postun        %{nil}
-14: systemd_user_postun_with_restart   %{nil}
-14: systemd_user_preun
systemd-sysusers %{?*} >/dev/null 2>&1 || :
echo %{?*} | systemd-sysusers - >/dev/null 2>&1 || :
systemd-tmpfiles --create %{?*} >/dev/null 2>&1 || :

$ rpm --eval %{systemd_post}

if [ $1 -eq 1 ] ; then
        # Initial installation
        systemctl preset  >/dev/null 2>&1 || :
fi

$ rpm --eval %{systemd_postun}
```

```
systemctl daemon-reload >/dev/null 2>&1 || :

$ rpm --eval %{systemd_preun}

if [ $1 -eq 0 ] ; then
        # Package removal, not upgrade
        systemctl --no-reload disable  > /dev/null 2>&1 || :
        systemctl stop  > /dev/null 2>&1 || :
fi
```

5.3.5. The Triggers directives

Triggers are RPM directives which provide a method for interaction during package installation and uninstallation.

> **WARNING**
>
> **Triggers** may be executed at an unexpected time, for example on update of the containing package. **Triggers** are difficult to debug, therefore they need to be implemented in a robust way so that they do not break anything when executed unexpectedly. For these reasons, Red Hat recommends to minimize the use of **Triggers**.

The order of execution on a single package upgrade and the details for each existing **Triggers** are listed below:

```
all-%pretrans
…
any-%triggerprein (%triggerprein from other packages set off by new install)
new-%triggerprein
new-%pre      for new version of package being installed
…           (all new files are installed)
new-%post     for new version of package being installed

any-%triggerin (%triggerin from other packages set off by new install)
new-%triggerin
old-%triggerun
any-%triggerun (%triggerun from other packages set off by old uninstall)

old-%preun    for old version of package being removed
…           (all old files are removed)
old-%postun   for old version of package being removed

old-%triggerpostun
any-%triggerpostun (%triggerpostun from other packages set off by old un
           install)
…
all-%posttrans
```

The above items are found in the **/usr/share/doc/rpm-4.*/triggers** file.

5.3.6. Using non-shell scripts in a spec file

The **-p** scriptlet option in a **spec** file enables the user to invoke a specific interpreter instead of the default shell scripts interpreter (**-p /bin/sh**).

The following procedure describes how to create a script, which prints out a message after installation of the **pello.py** program:

Procedure

1. Open the **pello.spec** file.
2. Find the following line:

```
install -m 0644 %{name}.py* %{buildroot}/usr/lib/%{name}/
```

3. Under the above line, insert:

```
%post -p /usr/bin/python3
print("This is {} code".format("python"))
```

4. Build your package as described in Building RPMs.
5. Install your package:

```
# dnf install /home/<username>/rpmbuild/RPMS/noarch/pello-0.1.2-1.el8.noarch.rpm
```

6. Check the output message after the installation:

```
Installing       : pello-0.1.2-1.el8.noarch                    1/1
Running scriptlet: pello-0.1.2-1.el8.noarch                    1/1
This is python code
```

NOTE

To use a Python 3 script, include the following line under **install -m** in a **spec** file:

```
%post -p /usr/bin/python3
```

To use a Lua script, include the following line under **install -m** in a SPEC file:

```
%post -p <lua>
```

This way, you can specify any interpreter in a **spec** file.

5.4. RPM CONDITIONALS

RPM Conditionals enable conditional inclusion of various sections of the **spec** file.

Conditional inclusions usually deal with:

- Architecture-specific sections

- Operating system-specific sections
- Compatibility issues between various versions of operating systems
- Existence and definition of macros

5.4.1. RPM conditionals syntax

RPM conditionals use the following syntax:

If *expression* is true, then do some action:

```
%if expression
…
%endif
```

If *expression* is true, then do some action, in other case, do another action:

```
%if expression
…
%else
…
%endif
```

5.4.2. The %if conditionals

The following examples shows the usage of **%if** RPM conditionals.

Example 5.3. Using the %if conditional to handle compatibility between Red Hat Enterprise Linux 8 and other operating systems

```
%if 0%{?rhel} == 8
sed -i '/AS_FUNCTION_DESCRIBE/ s/^/#/' configure.in
sed -i '/AS_FUNCTION_DESCRIBE/ s/^/#/' acinclude.m4
%endif
```

This conditional handles compatibility between RHEL 8 and other operating systems in terms of support of the AS_FUNCTION_DESCRIBE macro. If the package is built for RHEL, the **%rhel** macro is defined, and it is expanded to RHEL version. If its value is 8, meaning the package is build for RHEL 8, then the references to AS_FUNCTION_DESCRIBE, which is not supported by RHEL 8, are deleted from autoconfig scripts.

Example 5.4. Using the %if conditional to handle definition of macros

```
%define ruby_archive %{name}-%{ruby_version}
%if 0%{?milestone:1}%{?revision:1} != 0
%define ruby_archive %{ruby_archive}-%{?milestone}%{?!milestone:%{?revision:r%{revision}}}
%endif
```

This conditional handles definition of macros. If the **%milestone** or the **%revision** macros are set, the **%ruby_archive** macro, which defines the name of the upstream tarball, is redefined.

5.4.3. Specialized variants of %if conditionals

The **%ifarch** conditional, **%ifnarch** conditional and **%ifos** conditional are specialized variants of the **%if** conditionals. These variants are commonly used, hence they have their own macros.

The %ifarch conditional

The **%ifarch** conditional is used to begin a block of the **spec** file that is architecture-specific. It is followed by one or more architecture specifiers, each separated by commas or whitespace.

Example 5.5. An example use of the %ifarch conditional

```
%ifarch i386 sparc
…
%endif
```

All the contents of the **spec** file between **%ifarch** and **%endif** are processed only on the 32-bit AMD and Intel architectures or Sun SPARC-based systems.

The %ifnarch conditional

The **%ifnarch** conditional has a reverse logic than **%ifarch** conditional.

Example 5.6. An example use of the %ifnarch conditional

```
%ifnarch alpha
…
%endif
```

All the contents of the **spec** file between **%ifnarch** and **%endif** are processed only if not done on a Digital Alpha/AXP-based system.

The %ifos conditional

The **%ifos** conditional is used to control processing based on the operating system of the build. It can be followed by one or more operating system names.

Example 5.7. An example use of the %ifos conditional

```
%ifos linux
…
%endif
```

All the contents of the **spec** file between **%ifos** and **%endif** are processed only if the build was done on a Linux system.

5.5. PACKAGING PYTHON 3 RPMS

You can install Python packages on your system either from the upstream PyPI repository using the **pip** installer, or using the DNF package manager. DNF uses the RPM package format, which offers more downstream control over the software.

The packaging format of native Python packages is defined by Python Packaging Authority (PyPA) Specifications. Most Python projects use the **distutils** or **setuptools** utilities for packaging, and defined package information in the **setup.py** file. However, possibilities of creating native Python packages have evolved over time. For more information about emerging packaging standards, see pyproject-rpm-macros.

This chapter describes how to package a Python project that uses **setup.py** into an RPM package. This approach provides the following advantages compared to native Python packages:

- Dependencies on Python and non-Python packages are possible and strictly enforced by the **DNF** package manager.
- You can cryptographically sign the packages. With cryptographic signing, you can verify, integrate, and test content of RPM packages with the rest of the operating system.
- You can execute tests during the build process.

5.5.1. SPEC file description for a Python package

A SPEC file contains instructions that the **rpmbuild** utility uses to build an RPM. The instructions are included in a series of sections. A SPEC file has two main parts in which the sections are defined:

- Preamble (contains a series of metadata items that are used in the Body)
- Body (contains the main part of the instructions)

An RPM SPEC file for Python projects has some specifics compared to non-Python RPM SPEC files.

IMPORTANT

A name of any RPM package of a Python library must always include the **python3-**, **python3.11-**, or **python3.12-** prefix.

Other specifics are shown in the following SPEC file example for the **python3*-pello** package. For description of such specifics, see the notes below the example.

An example SPEC file for the pello program written in Python

```
%global python3_pkgversion 3.11                    (1)

Name:          python-pello                        (2)
Version:       1.0.2
Release:       1%{?dist}
Summary:       Example Python library

License:       MIT
URL:           https://github.com/fedora-python/Pello
Source:        %{url}/archive/v%{version}/Pello-%{version}.tar.gz

BuildArch:     noarch
BuildRequires:  python%{python3_pkgversion}-devel   (3)

# Build dependencies needed to be specified manually
BuildRequires:  python%{python3_pkgversion}-setuptools
```

```
# Test dependencies needed to be specified manually
# Also runtime dependencies need to be BuildRequired manually to run tests during build
BuildRequires:  python%{python3_pkgversion}-pytest >= 3


%global _description %{expand:
Pello is an example package with an executable that prints Hello World! on the command line.}

%description %_description

%package -n python%{python3_pkgversion}-pello                    4
Summary:        %{summary}

%description -n python%{python3_pkgversion}-pello %_description


%prep
%autosetup -p1 -n Pello-%{version}


%build
# The macro only supported projects with setup.py
%py3_build                                                       5


%install
# The macro only supported projects with setup.py
%py3_install


%check                                                           6
%{pytest}


# Note that there is no %%files section for the unversioned python module
%files -n python%{python3_pkgversion}-pello
%doc README.md
%license LICENSE.txt
%{_bindir}/pello_greeting

# The library files needed to be listed manually
%{python3_sitelib}/pello/

# The metadata files needed to be listed manually
%{python3_sitelib}/Pello-*.egg-info/
```

1. By defining the **python3_pkgversion** macro, you set which Python version this package will be built for. To build for the default Python version 3.9, either set the macro to its default value **3** or remove the line entirely.

2. When packaging a Python project into RPM, always add the **python-** prefix to the original name of the project. The original name here is **pello** and, therefore, the **name of the Source RPM (SRPM)** is **python-pello**.

3. **BuildRequires** specifies what packages are required to build and test this package. In **BuildRequires**, always include items providing tools necessary for building Python packages:

python3-devel (or **python3.11-devel** or **python3.12-devel**) and the relevant projects needed by the specific software that you package, for example, **python3-setuptools** (or **python3.11-setuptools** or **python3.12-setuptools**) or the runtime and testing dependencies needed to run the tests in the **%check** section.

4. When choosing a name for the binary RPM (the package that users will be able to install), add a versioned Python prefix. Use the **python3-** prefix for the default Python 3.9, the **python3.11-** prefix for Python 3.11, or the **python3.12-** prefix for Python 3.12. You can use the **%{python3_pkgversion}** macro, which evaluates to **3** for the default Python version 3.9 unless you set it to an explicit version, for example, **3.11** (see footnote 1).

5. The **%py3_build** and **%py3_install** macros run the **setup.py build** and **setup.py install** commands, respectively, with additional arguments to specify installation locations, the interpreter to use, and other details.

6. The **%check** section should run the tests of the packaged project. The exact command depends on the project itself, but it is possible to use the **%pytest** macro to run the **pytest** command in an RPM-friendly way.

5.5.2. Common macros for Python 3 RPMs

In a SPEC file, always use the macros that are described in the following *Macros for Python 3 RPMs* table rather than hardcoding their values. You can redefine which Python 3 version is used in these macros by defining the **python3_pkgversion** macro on top of your SPEC file (see Section 5.5.1, "SPEC file description for a Python package"). If you define the **python3_pkgversion** macro, the values of the macros described in the following table will reflect the specified Python 3 version.

Table 5.3. Macros for Python 3 RPMs

Macro	Normal Definition	Description
%{python3_pkgversion}	3	The Python version that is used by all other macros. Can be redefined to **3.11** to use Python 3.11, or to **3.12** to use Python 3.12
%{python3}	/usr/bin/python3	The Python 3 interpreter
%{python3_version}	3.9	The major.minor version of the Python 3 interpreter
%{python3_sitelib}	/usr/lib/python3.9/site-packages	The location where pure-Python modules are installed
%{python3_sitearch}	/usr/lib64/python3.9/site-packages	The location where modules containing architecture-specific extension modules are installed
%py3_build		Runs the **setup.py build** command with arguments suitable for an RPM package
%py3_install		Runs the **setup.py install** command with arguments suitable for an RPM package

Macro	Normal Definition	Description
% {py3_shebang_flags}	s	The default set of flags for the Python interpreter directives macro, **%py3_shebang_fix**
%py3_shebang_fix		Changes Python interpreter directives to **#! % {python3}**, preserves any existing flags (if found), and adds flags defined in the **% {py3_shebang_flags}** macro

Additional resources

- Python macros in upstream documentation

5.5.3. Using automatically generated dependencies for Python RPMs

The following procedure describes how to use automatically generated dependencies when packaging a Python project as an RPM.

Prerequisites

- A SPEC file for the RPM exists. For more information, see SPEC file description for a Python package.

Procedure

1. Make sure that one of the following directories containing upstream-provided metadata is included in the resulting RPM:
   - **.dist-info**
   - **.egg-info**
     The RPM build process automatically generates virtual **pythonX.Ydist** provides from these directories, for example:

     ```
     python3.9dist(pello)
     ```

     The Python dependency generator then reads the upstream metadata and generates runtime requirements for each RPM package using the generated **pythonX.Ydist** virtual provides. For example, a generated requirements tag might look as follows:

     ```
     Requires: python3.9dist(requests)
     ```
2. Inspect the generated requires.
3. To remove some of the generated requires, use one of the following approaches:
   a. Modify the upstream-provided metadata in the **%prep** section of the SPEC file.

b. Use automatic filtering of dependencies described in the upstream documentation.

4. To disable the automatic dependency generator, include the **%{?python_disable_dependency_generator}** macro above the main package's **%description** declaration.

Additional resources

- Automatically generated dependencies

5.6. HANDLING INTERPRETER DIRECTIVES IN PYTHON SCRIPTS

In Red Hat Enterprise Linux 9, executable Python scripts are expected to use interpreter directives (also known as hashbangs or shebangs) that explicitly specify at a minimum the major Python version. For example:

```
#!/usr/bin/python3
#!/usr/bin/python3.9
#!/usr/bin/python3.11
#!/usr/bin/python3.12
```

The **/usr/lib/rpm/redhat/brp-mangle-shebangs** buildroot policy (BRP) script is run automatically when building any RPM package, and attempts to correct interpreter directives in all executable files.

The BRP script generates errors when encountering a Python script with an ambiguous interpreter directive, such as:

```
#!/usr/bin/python
```

or

```
#!/usr/bin/env python
```

5.6.1. Modifying interpreter directives in Python scripts

Use the following procedure to modify interpreter directives in Python scripts that cause build errors at RPM build time.

Prerequisites

- Some of the interpreter directives in your Python scripts cause a build error.

Procedure

- To modify interpreter directives, complete one of the following tasks:
  - Use the following macro in the **%prep** section of your SPEC file:

    ```
    # %py3_shebang_fix SCRIPTNAME ...
    ```

    SCRIPTNAME can be any file, directory, or a list of files and directories.

    As a result, all listed files and all **.py** files in listed directories will have their interpreter

directives modified to point to **%{python3}**. Existing flags from the original interpreter directive will be preserved and additional flags defined in the **%{py3_shebang_flags}** macro will be added. You can redefine the **%{py3_shebang_flags}** macro in your SPEC file to change the flags that will be added.

- Apply the **pathfix.py** script from the **python3-devel** package:

```
# pathfix.py -pn -i %{python3} PATH ...
```

You can specify multiple paths. If a ***PATH*** is a directory, **pathfix.py** recursively scans for any Python scripts matching the pattern **^[a-zA-Z0-9_]+\.py$**, not only those with an ambiguous interpreter directive. Add the command above to the **%prep** section or at the end of the **%install** section.

- Modify the packaged Python scripts so that they conform to the expected format. For this purpose, you can use the **pathfix.py** script outside the RPM build process, too. When running **pathfix.py** outside an RPM build, replace **%{python3}** from the preceding example with a path for the interpreter directive, such as **/usr/bin/python3** or **/usr/bin/python3.11**.

Additional resources

- Interpreter invocation

5.7. RUBYGEMS PACKAGES

This section explains what RubyGems packages are, and how to re-package them into RPM.

5.7.1. What RubyGems are

Ruby is a dynamic, interpreted, reflective, object-oriented, general-purpose programming language.

Programs written in Ruby are typically packaged using the RubyGems project, which provides a specific Ruby packaging format.

Packages created by RubyGems are called gems, and they can be re-packaged into RPM as well.

NOTE

This documentation refers to terms related to the RubyGems concept with the **gem** prefix, for example .gemspec is used for the **gem specification**, and terms related to RPM are unqualified.

5.7.2. How RubyGems relate to RPM

RubyGems represent Ruby's own packaging format. However, RubyGems contain metadata similar to those needed by RPM, which enables the conversion from RubyGems to RPM.

According to Ruby Packaging Guidelines, it is possible to re-package RubyGems packages into RPM in this way:

- Such RPMs fit with the rest of the distribution.
- End users are able to satisfy dependencies of a gem by installing the appropriate RPM-packaged gem.

RubyGems use similar terminology as RPM, such as **spec** files, package names, dependencies and other items.

To fit into the rest of RHEL RPM distribution, packages created by RubyGems must follow the conventions listed below:

- Names of gems must follow this pattern:

```
rubygem-%{gem_name}
```

- To implement a shebang line, the following string must be used:

```
#!/usr/bin/ruby
```

5.7.3. Creating RPM packages from RubyGems packages

To create a source RPM for a RubyGems package, the following files are needed:

- A gem file
- An RPM **spec** file

The following sections describe how to create RPM packages from packages created by RubyGems.

5.7.3.1. RubyGems spec file conventions

A RubyGems **spec** file must meet the following conventions:

- Contain a definition of **%{gem_name}**, which is the name from the gem's specification.
- The source of the package must be the full URL to the released gem archive; the version of the package must be the gem's version.
- Contain the **BuildRequires:** a directive defined as follows to be able to pull in the macros needed to build.

```
BuildRequires:rubygems-devel
```

- Not contain any RubyGems **Requires** or **Provides**, because those are autogenerated.
- Not contain the **BuildRequires:** directive defined as follows, unless you want to explicitly specify Ruby version compatibility:

```
Requires: ruby(release)
```

  The automatically generated dependency on RubyGems (**Requires: ruby(rubygems)**) is sufficient.

5.7.3.2. RubyGems macros

The following table lists macros useful for packages created by RubyGems. These macros are provided by the **rubygems-devel** packages.

Table 5.4. RubyGems' macros

Macro name	Extended path	Usage
%{gem_dir}	/usr/share/gems	Top directory for the gem structure.
%{gem_instdir}	%{gem_dir}/gems/%{gem_name}-%{version}	Directory with the actual content of the gem.
%{gem_libdir}	%{gem_instdir}/lib	The library directory of the gem.
%{gem_cache}	%{gem_dir}/cache/%{gem_name}-%{version}.gem	The cached gem.
%{gem_spec}	%{gem_dir}/specifications/%{gem_name}-%{version}.gemspec	The gem specification file.
%{gem_docdir}	%{gem_dir}/doc/%{gem_name}-%{version}	The RDoc documentation of the gem.
%{gem_extdir_mri}	%{_libdir}/gems/ruby/%{gem_name}-%{version}	The directory for gem extension.

5.7.3.3. RubyGems spec file example

Example **spec** file for building gems together with an explanation of its particular sections follows.

An example RubyGems spec file

```
%prep
%setup -q -n  %{gem_name}-%{version}

# Modify the gemspec if necessary
# Also apply patches to code if necessary
%patch0 -p1

%build
# Create the gem as gem install only works on a gem file
gem build ../%{gem_name}-%{version}.gemspec

# %%gem_install compiles any C extensions and installs the gem into ./%%gem_dir
# by default, so that we can move it into the buildroot in %%install
%gem_install
```

```
%install
mkdir -p %{buildroot}%{gem_dir}
cp -a ./%{gem_dir}/* %{buildroot}%{gem_dir}/

# If there were programs installed:
mkdir -p %{buildroot}%{_bindir}
cp -a ./%{_bindir}/* %{buildroot}%{_bindir}

# If there are C extensions, copy them to the extdir.
mkdir -p %{buildroot}%{gem_extdir_mri}
cp -a .%{gem_extdir_mri}/{gem.build_complete,*.so} %{buildroot}%{gem_extdir_mri}/
```

The following table explains the specifics of particular items in a RubyGems **spec** file:

Table 5.5. RubyGems' spec directives specifics

Directive	RubyGems specifics
%prep	RPM can directly unpack gem archives, so you can run the **gem unpack** comamnd to extract the source from the gem. The **%setup -n %{gem_name}-%{version}** macro provides the directory into which the gem has been unpacked. At the same directory level, the **%{gem_name}-%{version}.gemspec** file is automatically created, which can be used to rebuild the gem later, to modify the **.gemspec**, or to apply patches to the code.
%build	This directive includes commands or series of commands for building the software into machine code. The **%gem_install** macro operates only on gem archives, and the gem is recreated with the next gem build. The gem file that is created is then used by **%gem_install** to build and install the code into the temporary directory, which is **./%{gem_dir}** by default. The **%gem_install** macro both builds and installs the code in one step. Before being installed, the built sources are placed into a temporary directory that is created automatically. The **%gem_install** macro accepts two additional options: **-n <gem_file>**, which allows to override gem used for installation, and **-d <install_dir>**, which might override the gem installation destination; using this option is not recommended. The **%gem_install** macro must not be used to install into the **%{buildroot}**.
%install	The installation is performed into the **%{buildroot}** hierarchy. You can create the directories that you need and then copy what was installed in the temporary directories into the **%{buildroot}** hierarchy. If this gem creates shared objects, they are moved into the architecture-specific **%{gem_extdir_mri}** path.

Additional resources

- Ruby Packaging Guidelines

5.7.3.4. Converting RubyGems packages to RPM spec files with gem2rpm

The **gem2rpm** utility converts RubyGems packages to RPM **spec** files.

The following sections describe how to:

- Install the **gem2rpm** utility

- Display all **gem2rpm** options
- Use **gem2rpm** to covert RubyGems packages to RPM **spec** files
- Edit **gem2rpm** templates

5.7.3.4.1. Installing gem2rpm

The following procedure describes how to install the **gem2rpm** utility.

Procedure

- To install **gem2rpm** from RubyGems.org, run:

```
$ gem install gem2rpm
```

5.7.3.4.2. Displaying all options of gem2rpm

The following procedure describes how to display all options of the **gem2rpm** utility.

Procedure

- To see all options of **gem2rpm**, run:

```
$ gem2rpm --help
```

5.7.3.4.3. Using gem2rpm to covert RubyGems packages to RPM spec files

The following procedure describes how to use the **gem2rpm** utility to covert RubyGems packages to RPM **spec** files.

Procedure

- Download a gem in its latest version, and generate the RPM **spec** file for this gem:

```
$ gem2rpm --fetch <gem_name> > <gem_name>.spec
```

The described procedure creates an RPM **spec** file based on the information provided in the gem's metadata. However, the gem misses some important information that is usually provided in RPMs, such as the license and the changelog. The generated **spec** file thus needs to be edited.

5.7.3.4.4. gem2rpm templates

The **gem2rpm** template is a standard Embedded Ruby (ERB) file, which includes variables listed in the following table.

Table 5.6. Variables in the gem2rpm template

Variable	Explanation
package	The **Gem::Package** variable for the gem.

Variable	Explanation
spec	The **Gem::Specification** variable for the gem (the same as format.spec).
config	The **Gem2Rpm::Configuration** variable that can redefine default macros or rules used in spec template helpers.
runtime_dependencies	The **Gem2Rpm::RpmDependencyList** variable providing a list of package runtime dependencies.
development_dependencies	The **Gem2Rpm::RpmDependencyList** variable providing a list of package development dependencies.
tests	The **Gem2Rpm::TestSuite** variable providing a list of test frameworks allowing their execution.
files	The **Gem2Rpm::RpmFileList** variable providing an unfiltered list of files in a package.
main_files	The **Gem2Rpm::RpmFileList** variable providing a list of files suitable for the main package.
doc_files	The **Gem2Rpm::RpmFileList** variable providing a list of files suitable for the **-doc** subpackage.
format	The **Gem::Format** variable for the gem. Note that this variable is now deprecated.

5.7.3.4.5. Listing available gem2rpm templates

Use the following procedure describes to list all available **gem2rpm** templates.

Procedure

- To see all available templates, run:

```
$ gem2rpm --templates
```

5.7.3.4.6. Editing gem2rpm templates

You can edit the template from which the RPM **spec** file is generated instead of editing the generated **spec** file.

Use the following procedure to edit the **gem2rpm** templates.

Procedure

1. Save the default template:

```
$ gem2rpm -T > rubygem-<gem_name>.spec.template
```

2. Edit the template as needed.

3. Generate the **spec** file by using the edited template:

```
$ gem2rpm -t rubygem-<gem_name>.spec.template <gem_name>-<latest_version.gem
> <gem_name>-GEM.spec
```

You can now build an RPM package by using the edited template as described in Building RPMs.

5.8. HOW TO HANDLE RPM PACKAGES WITH PERLS SCRIPTS

Since RHEL 8, the Perl programming language is not included in the default buildroot. Therefore, the RPM packages that include Perl scripts must explicitly indicate the dependency on Perl using the **BuildRequires:** directive in RPM **spec** file.

5.8.1. Common Perl-related dependencies

The most frequently occurring Perl-related build dependencies used in **BuildRequires:** are :

- **perl-generators**
  Automatically generates run-time **Requires** and **Provides** for installed Perl files. When you install a Perl script or a Perl module, you must include a build dependency on this package.

- **perl-interpreter**
  The Perl interpreter must be listed as a build dependency if it is called in any way, either explicitly via the **perl** package or the **%__perl** macro, or as a part of your package's build system.

- **perl-devel**
  Provides Perl header files. If building architecture-specific code which links to the **libperl.so** library, such as an XS Perl module, you must include **BuildRequires: perl-devel**.

5.8.2. Using a specific Perl module

If a specific Perl module is required at build time, use the following procedure:

Procedure

- Apply the following syntax in your RPM **spec** file:

```
BuildRequires: perl(MODULE)
```

> **NOTE**
>
> Apply this syntax to Perl core modules as well, because they can move in and out of the **perl** package over time.

5.8.3. Limiting a package to a specific Perl version

To limit your package to a specific Perl version, follow this procedure:

Procedure

- Use the **perl(:VERSION)** dependency with the desired version constraint in your RPM **spec** file:

For example, to limit a package to Perl version 5.30 and higher, use:

```
BuildRequires: perl(:VERSION) >= 5.30
```

WARNING

Do not use a comparison against the version of the **perl** package because it includes an epoch number.

5.8.4. Ensuring that a package uses the correct Perl interpreter

Red Hat provides multiple Perl interpreters, which are not fully compatible. Therefore, any package that delivers a Perl module must use at run time the same Perl interpreter that was used at build time.

To ensure this, follow the procedure below:

Procedure

- Include versioned **MODULE_COMPAT Requires** in RPM **spec** file for any package that delivers a Perl module:

```
Requires:  perl(:MODULE_COMPAT_%(eval `perl -V:version`; echo $version))
```

CHAPTER 6. NEW FEATURES IN RHEL 9

This section documents the most notable changes in RPM packaging between Red Hat Enterprise Linux 8 and 9.

6.1. DYNAMIC BUILD DEPENDENCIES

Red Hat Enterprise Linux 9 introduces the **%generate_buildrequires** section that enables generating dynamic build dependencies.

Additional build dependencies can now be generated programmatically at RPM build time, using the newly available **%generate_buildrequires** script. This is useful when packaging software written in a language in which a specialized utility is commonly used to determine run-time or build-time dependencies, such as Rust, Golang, Node.js, Ruby, Python, or Haskell.

You can use the **%generate_buildrequires** script to dynamically determine which **BuildRequires** directives are added to a SPEC file at build-time. If present, **%generate_buildrequires** is executed after the **%prep** section and can access the unpacked and patched source files. The script must print the found build dependencies to standard output using the same syntax as a regular **BuildRequires** directive.

The **rpmbuild** utility then checks if the dependencies are met before continuing the build.

If some dependencies are missing, a package with the **.buildreqs.nosrc.rpm** suffix is created, which contains the found **BuildRequires** and no source files. You can use this package to install the missing build dependencies with the **dnf builddep** command before restarting the build.

For more information, see the **DYNAMIC BUILD DEPENDENCIES** section in the **rpmbuild(8)** man page.

Additional resources

- **rpmbuild(8)** man page
- **yum-builddep(1)** man page

6.2. IMPROVED PATCH DECLARATION

6.2.1. Optional automatic patch and source numbering

The **Patch:** and **Source:** tags without a number are now automatically numbered based on the order in which they are listed.

The numbering is run internally by the **rpmbuild** utility starting from the last manually numbered entry, or **0** if there is no such entry.

For example:

```
Patch: one.patch
Patch: another.patch
Patch: yet-another.patch
```

6.2.2. %patchlist and %sourcelist sections

It is now possible to list patch and source files without preceding each item with the respective **Patch:** and **Source:** tags by using the newly added **%patchlist** and **%sourcelist** sections.

For example, the following entries:

```
Patch0: one.patch
Patch1: another.patch
Patch2: yet-another.patch
```

can now be replaced with:

```
%patchlist
one.patch
another.patch
yet-another.patch
```

6.2.3. %autopatch now accepts patch ranges

The **%autopatch** macro now accepts the **-m** and **-M** parameters to limit the minimum and maximum patch number to apply, respectively:

- The **-m** parameter specifies the patch number (inclusive) to start at when applying patches.
- The **-M** parameter specifies the patch number (inclusive) to stop at when applying patches.

This feature can be useful when an action needs to be performed in between certain patch sets.

6.3. OTHER FEATURES

Other new features related to RPM packaging in Red Hat Enterprise Linux 9 include:

- Fast macro-based dependency generators
- Powerful macro and **%if** expressions, including ternary operator and native version comparison
- Meta (unordered) dependencies
- Caret version operator (**^**), which can be used to express a version that is higher than the base version. This operator complements the tilde (~) operator, which has the opposite semantics.
- **%elif**, **%elifos** and **%elifarch** statements

CHAPTER 7. ADDITIONAL RESOURCES

References to various topics related to RPMs, RPM packaging, and RPM building follows.

- Mock
- RPM Documentation
- RPM 4.15.0 Release Notes
- RPM 4.16.0 Release Notes
- Fedora Packaging Guidelines