

# Building Embedded Operating System with IMGUI Demo for *Raspberry $\pi$ - 4 - model B* with *Yocto*

Kaloyan Krastev\*

October 20, 2023

---

\*Triple Helix Consulting[6]

# table of contents

|          |                           |           |
|----------|---------------------------|-----------|
| <b>1</b> | <b>introduction</b>       | <b>3</b>  |
| <b>2</b> | <b>metadata</b>           | <b>4</b>  |
| <b>3</b> | <b>configuration</b>      | <b>5</b>  |
| 3.1      | MACHINE . . . . .         | 6         |
| 3.2      | PACKAGE_INSTALL . . . . . | 6         |
| 3.3      | IMAGE_FSTYPES . . . . .   | 7         |
| <b>4</b> | <b>build</b>              | <b>8</b>  |
| <b>5</b> | <b>install</b>            | <b>9</b>  |
| <b>6</b> | <b>run</b>                | <b>11</b> |
| <b>7</b> | <b>outlook</b>            | <b>12</b> |

# 1 introduction

These instructions[3] follow the configuration and build of a Linux-based operating system for *Raspberry  $\pi$  - 4 - model B*[5] with *Yocto*[2]. Find project overview in [4].

The *operating system* (OS) build is done in several steps organized in corresponding sections as follows. Read in Section 2 how to fetch *metadata*. Section 3 shows how to configure the OS build. In Section 4 learn how to build the OS *image* and see how to copy *image* to *SD* card in Section 5. Section 6 is dedicated to post-install issues like the configuration of the WiFi interface from the command line.

## 2 metadata

*Metadata* is a set of instructions to build targets. It is organized in *recipe* files with the *.bb* suffix. Further there are *class* files with the suffix *.bbclass* with information shared between *recipes*. Finally, there are configuration files with the extension *.conf*. These define configuration variables to control the build process. *Metadata* is organized in *layers*. Layers logically separate information of a project. *OpenEmbedded*[1] defines the following layer types.

- base layers contain base *metadata* for the build
- machine aka *board support package* (BSP) layers include *hardware* (HW) support
- distribution layers hold the policy configuration
- *software* (SW) layers are used for additional SW
- miscellaneous layers do not fall in upper categories

The complete list of *github* SW *metadata* repositories used in this project includes *Yocto* layers, the *Raspberry  $\pi$  - 4 - model B* BSP layer, a SW layer with custom recipes, and the build configuration itself. Please refer [4] for details.

In short, users fetch *metadata* in contrast to the *real data* fetched by *bitbake* during OS build. See Section 4 for details. It is an user decision where to put fetched *metadata*. However, it is nice to have all layer sub-directories in one location. In these instructions this location is referred as <layer\_directory>. Execute next script to fetch layers from public *github* repositories. This shell script takes <layer\_directory> as argument. You may [download metafetch.sh here](#).

```
#!/usr/bin/env sh
# metafetch.sh
# fetch rpi metadata
error() { echo $1; exit 111; }
if [ ! $# -eq 1 ]; then error "usage: $0 <directory>"; fi
if [ ! -d $1 ]; then error "error: $1 not a directory"; fi

echo fetching metadata in $1 ...

exit 1

git clone -b kirkstone \
    git@github.com:yoctoproject/poky.git \
    $1/poky
git clone -b kirkstone \
    git@github.com:openembedded/meta-openembedded.git \
    $1/oe
git clone -b kirkstone \
    git@github.com:agherzan/meta-raspberrypi \
    $1/rpi/meta-raspberrypi
git clone \
    git@github.com:kaloyanski/meta-thc.git \
    $1/thc/meta-thc

exit 0
```

## metafetch.sh

The second directory to create is the `<build_directory>` and I suggest that this one is not inside the `<layer_directory>` to not mix *data* and *metadata*. Fetch the project build configuration with the command that follows.

```
git clone git@github.com:TripleHelixConsulting/rpiconf.git \
    <build_directory>/conf
```

## 3 configuration

After the last command from the previous section there should be two files in `<build_directory>/conf`, namely *local.conf* and *bblayers.conf*.

The path to *Yocto* layers is specified in *bblayers.conf*. Layer locations are wrong because most probably your `<layer_directory>` is not */home/yocto/layer*. Change this to correspond layers system path.

The build configuration is in *local.conf*. This should work as it is. Variables in this file control the build. I call them directives to avoid repetitions. Many directives are not covered in these instructions. Please refer *bitbake* documentation for details. It is not always easy to understand the meaning and the relations between different directives. What is more, *bitbake* syntax is pretty complicated. In short, your life can easily become unbearable if the build configuration is too long.

### 3.1 MACHINE

No doubt, this is the most important directive, set here to *raspberrypi4-64*. You may want to change this value if you build an [OS](#) for a different [HW](#). If you want to examine [OS](#) built for *Raspberry  $\pi$  - 4 - model B* on your host machine with *qemu*, set *MACHINE* to *qemuarm64*. I confirm that this works although I did not find this approach very useful to test a *graphical user interface* ([GUI](#)).

### 3.2 PACKAGE\_INSTALL

This is where to specify additional [SW](#) packages. This is useful for packages not included in the *image* by default. In my experience, the default [OS](#) has all necessary programs or compact alternatives. However this is the directive used to append *imgui*.

### 3.3 IMAGE\_FSTYPES

This is another important directive. Here I have removed archived *images* that I do not need to decrease the built time and added the *wic* format to have an *image* file ready to be copied to the *SD* card immediately after the build. See [Section 5](#) for details.

## 4 build

*Yocto* provides a list of image types. For obvious reasons, I have chosen *core-image-x11*<sup>[2]</sup> - a very basic X11 image with a terminal.

The primary build tool of *OpenEmbedded* based projects, such as the *Yocto* project, *bitbake*, works in the `<build_directory>`. Here is a list of the most important sub-directory names by default. These are configurable but usually there is no need to change their default names.

- `<build_directory>/conf` - build (*local.conf*) and layer (*bblayers.conf*) configuration files
- `<build_directory>/downloads` - fetched source code archives
- `<build_directory>/tmp/work` - working directory where source code is extracted, configured, compiled and installed
- `<build_directory>/tmp/deploy/ipk` - final [SW](#) packages in *ipk* format
- `<build_directory>/tmp/deploy/images/raspberrypi4-64` - boot files, compiled kernels and [OS images](#).

First, you need to initialize build environment.

```
source <layer_directory>/poky oe-init-build-env <build_directory>
```

This will change your system path to `<build_directory>`. You may run now next command to check the project layers.

```
bitbake-layers show-layers
```



| task                 | description                    |
|----------------------|--------------------------------|
| do_fetch             | fetch the source code          |
| do_unpack            | unpack the source code         |
| do_patch             | apply patches to the source    |
| do_configure         | source configuration           |
| do_compile           | compile the source code        |
| do_install           | copy files to the holding area |
| do_package           | analyse holding area           |
| do_package_write_ipk | create <i>ipk</i> package      |
| do_package_qa        | quality checks on the package  |

Table 1: A list of *bitbake* tasks

If this is fine, the following command is going to build the [OS image](#).

```
bitbake core-image-x11
```

Be patient because, unless your host machine is a supercomputer, this will take hours. Find a list of tasks performed by *bitbake* for a typical [SW](#) package in Table 1.

## 5 install

The [OS](#) includes a kernel *ARM*, 64 *bit* boot executable *image* of 23MB, a *Raspberry  $\pi$  - 4 - model B* configuration of Linux 5.15. The total size of kernel modules is 21MB. Happily this kernel release has a *long – term support* ([LTS](#)).

*Yocto* provides multiple package and *image* formats. Further, different ways exist to install *images* on *SD* card. The result is an [OS](#) with two partitions - */root* and */boot*. There are not *swap* and *home*

partitions. I recommend the classic command-line tool *dd* to copy data. It works fine with different *image* formats like *rpi - sdimg*, *hddimg* and *wic*. The last format is recommended. Find the card device name, usually */dev/sda*, unmount it with *umount* if mounted, and do copy data with a simple command

```
dd if=core-image-x11-raspberrypi4-64.wic of=/dev/sda status=progress
```

note 1: run this command in `<build_directory>/tmp/deploy/images/raspberrypi4-64`

note 2: run this command with *root* privileges

note 3: be careful to not specify the device name of your hard drive (see note 2)

The transfer is going to take a while. Once it is over, put the card in you *Raspberry  $\pi$  - 4 - model B* and turn it on. That's it.

## 6 run

Connected embedded systems can communicate to one another and to cloud-based *platform-as-a-service* (PaaS) solutions. In addition, a remote control may be required. An *secure shell* (SSH) server is a standard solution for both problems.

Wireless connection is established via classic command-line tools like *ip*, *iw*, *dhcpcd*, and *wpa\_supplicant*. Custom shell scripts are installed in */usr/bin*, as well as a running GUI example to demonstrate the usage of the *Dear ImGui* library. Once an *internet protocol* (IP) address is assigned, the SSH server by *Dropbear* allows for a secured remote login, remote control and file transfer.

## 7 outlook

This reports the progress in the development of a custom Linux-based OS for *Raspberry  $\pi$  - 4 - model B*[\[5\]](#). The kernel version of this embedded OS is Linux release 5.15. An example GUI application using the *Dear ImGui* library is built as a part of the OS image. In addition, an SSH server provides remote connection, data transfer and device control. As the OS is now functional, performance and real-time tests are ongoing.

## acronyms

**BSP** *board support package*

**SSH** *secure shell*

**GUI** *graphical user interface*

**SW** *software*

**HW** *hardware*

**OS** *operating system*

**IP** *internet protocol*

**PaaS** *platform-as-a-service*

**LTS** *long – term support*

# bibliography

- [1] Yocto Project community. *OpenEmbedded*. 2017.  
URL: <https://www.openembedded.org> (visited on 2023).
- [2] Yocto Project community. *Yocto Project*. 2023.  
URL: <https://www.yoctoproject.org> (visited on 2023).
- [3] Kaloyan Krastev. *Building Embedded Operating System with IMGUI Demo for Raspberry  $\pi$  - 4 - model B with Yocto*. 2023. URL:  
<https://kaloyanski.github.io/meta-thc/thchowto.html>  
(visited on 2023).
- [4] Kaloyan Krastev. *Embedded Operating System for Raspberry  $\pi$  - 4 - model B with Yocto*. 2023. URL:  
<https://kaloyanski.github.io/meta-thc/thcport.html>  
(visited on 2023).
- [5] Raspberry  $\pi$  Ltd. *Raspberi  $\pi$* . 2023.  
URL: <https://www.raspberrypi.com> (visited on 2023).
- [6] Atanas Rusev. *Triple Helix Consulting*. 2023. URL:  
<https://triplehelix-consulting.com> (visited on 2023).