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

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# 1 introduction

These instructions[5] follow the configuration and build of a Linux-based operating system for *Raspberry* $\pi$ - 4 - *model B*[7] with *Yocto*[2]. Find project overview in [6].

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

# 2 download

*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 layer
  base *metadata* for the build
- machine aka *board support package* (BSP) layer
  *hardware* (HW) support
- distribution layer
  policy configuration
- *software* (SW) layer
  additional SW
- miscellaneous layer
  for layers that 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 [6] for details.

It is up to users to decide where to download *metadata*. It is a good idea to have all layer sub-directories in one location. In these instructions this is referred as <layer-directory>. Once you have it created execute next lines to get layer *metadata*.

```
git clone -b kirkstone \
git@github.com:yoctoproject/poky.git \
<layer-directory>

git clone -b kirkstone \
git@github.com:openembedded/meta-openembedded.git \
<layer-directory>

git clone -b kirkstone \
git@github.com:agherzan/meta-raspberrypi \
<layer-directory>/rpi

git clone git@github.com:kaloyanski/meta-thc.git \
<layer-directory>/thc/meta-thc
```

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*. Further, to get the project build configuration use the command that follows.

```
git clone git@github.com:TripleHelixConsulting/rpiconf.
<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. No doubt, the most important is $MACHINE$, set to *raspberrypi*4-64. You may want to change this value only it if you build an OS for a different HW. Another important directive is $IMAGE\_FSTYPES$. 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. Further there are many directives 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.

In the main build configuration, apart from *Dear ImGui* and *GLFW*, I have added the following packages;

- $os-release$
  OS identification

- *Dropbear*
  Compact *secure shell* (SSH) server[4]

- *dhcpcd*
  *dynamic host configuration protocol* (DHCP) client[8]

- *thcp*
  OS post-configuration scripts

## 3.1 layers

Here is a list of *Yocto* layers. The project reference distribution is *poky*.

- *meta*
  user-space data and standard licenses

- *meta – poky*
  *Yocto* reference distribution policy

- *meta – raspberrypi*
  This[3] is the general HW specific BSP overlay for the *RaspberryPi* device. The core BSP part of *meta – raspberrypi* works with different *OpenEmbedded/ Yocto* distributions and layer stacks. In short, the recipes to build the kernel and kernel modules are in this layer. For details see the package *linux-raspberrypi*. In addition, here is the HW specific firmware. By chance, the build configuration corresponds the specific HW, in this case *Raspberry π - 4 - model B*.

- *meta – thc*
  I have introduced a new *Yocto* SW layer to control the build of *Dear ImGui* and *GLFW*. As long as the source codes have a standard build configuration, the *bitbake* recipes are straightforward. Both instructions inherit *cmake*.

# 4 build

*Yocto* provides a list of image types. For obvious reasons, I have chosen $core-image-x11$[2] - 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 - downloaded source code archives, usually fetched from github.com
- <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*.

Keeping this in mind, type following commands to build the OS *image*.

```
source <layer-directory>/poky oe-init-build-env <build-
bitbake core-image-x11
```

The first command is needed to initialise the environment. The second one gonna do the actual build. Be patient because, unless your

| 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 *ipk* package |
| do_package_qa | quality checks on the package |

Table 1: A list of packages in *core-image-x11-raspberrypi4-64*

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=progre*

note 1: run this command in <build-directory>/tmp/deploy/images/raspbe
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 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 *graphical user interface* (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*[7]. 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*

**DHCP** *dynamic host configuration protocol*

**IP** *internet protocol*

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

**LTS** *long – term support*

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