

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

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# 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>7</b>
3.1	MACHINE . . . . .	7
3.2	PACKAGE_INSTALL . . . . .	7
3.3	IMAGE_FSTYPES . . . . .	8
<b>4</b>	<b>build</b>	<b>9</b>
<b>5</b>	<b>install</b>	<b>11</b>
<b>6</b>	<b>run</b>	<b>12</b>
<b>7</b>	<b>outlook</b>	<b>13</b>

# 1 introduction

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

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 [5] 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>. The second directory to create is the <build\_directory>. This is where the build and build configuration live. I suggest that this one is not inside the <layer\_directory> to not mix *data* and *metadata*.

It might be necessary to install *Yocto* requirements[3] before running *bitbake*. Make sure to have the following command-line tools on your host machine: *chrpath*, *diffstat*, *lz4c*, *rpcgen*; Also have a look at the free space on the storage device. Fetched data requires 400 *Mb*, but the build hmmm.

I have a shell script to fetch *metadata* from public *github* repositories. This modification may serve people to build their own OS for *Raspberry  $\pi$  - 4 - model B*.

```
#!/usr/bin/env sh
# metafetch.sh
# fetch rpi metadata branch

BRANCH=kirkstone

while getopts ":l:b:r:h" option; do
    case $option in
        h) echo usage: $0 -l layerdir -b buildir -r branch;
        exit 420;;
        \?) echo minimal usage: $0 -l layerdir -b buildir; exit
        420;;
        l) LAYER=$OPTARG;;
        b) BUILD=$OPTARG;;
        r) BRANCH=$OPTARG;;
    esac
done

nodat() { echo $1; exit 111; }
nodir() {
    echo error: $1 is not a directory && mkdir $1 &&
    echo info: directory $1 created ||
    exit 111;
}

[ -n "$LAYER" ] || nodat 'specify layer directory'
[ -n "$BUILD" ] || nodat 'specify build directory'
[ -d $LAYER ] || nodir $LAYER
[ -d $BUILD ] || nodir $BUILD

LAYER=$(realpath $LAYER) && echo fetching $BRANCH in $LAYER
BUILD=$(realpath $BUILD) && echo fetching configuration in
    $BUILD

git clone -b $BRANCH git@github.com:yoctoproject/poky.git
```

```

$LAYER/poky
git clone -b $BRANCH git@github.com:openembedded/meta-
openembedded.git $LAYER/oe
git clone -b $BRANCH git@github.com:agherzan/meta-
raspberrypi $LAYER/rpi/meta-raspberrypi
git clone git@github.com:kaloyanski/meta-thc.git $LAYER/thc/
meta-thc
git clone git@github.com:TripleHelixConsulting/rpiconf.git
$BUILD/conf

sed -i s#/#home/yocto/layer#$LAYER#g $BUILD/conf/bblayers.
conf
source $LAYER/poky/oe-init-build-env $BUILD
bitbake-layers show-layers
# bitbake core-image-x11

exit 0

```

The script takes `<layer_directory>` and `<build_directory>` from the command-line. Download *metafetch.sh* [here](#). Use next commands to execute this *shell* script.

```
./metafetch -l <layer_directory> -b <build_directory>
```

The default *Yocto branch* is *kirkstone*. You may want to specify another *branch*.

```
./metafetch -l <layer_directory> -b <build_directory> -r <
branch_name>
```

## 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
```

If this is fine, the following command is going to build the OS image.

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

**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/raspb`  
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*[\[6\]](#). 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*

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