

Raspberry Pi - Setup Camera and test the performance of different video encoders

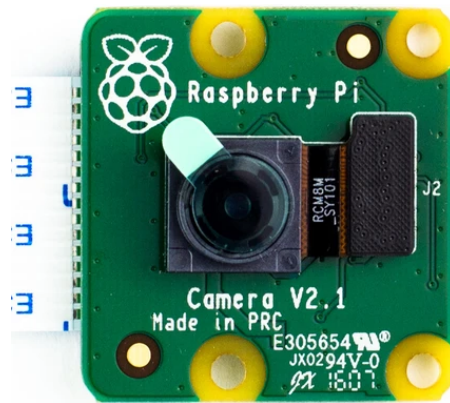
Camera module on Raspberry Pi needs to be enabled manually before it can be used by applications. There are some methods to access to the camera with different encoders, but popular drivers include Video For Linux 2, and OMX H264 hardware encoder. This post runs some tests using FFmpeg and PiCamera package to measure the performance of different encoders.

[#rasberry-pi](#) [#camera](#) [#v4l2](#) [#ffmpeg](#) [#python](#) [#picamera](#)

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RaspberryPi Camera Module

i This tutorial is for setting up the official Raspberry Pi Camera module which is attached with a CSI cable. Other types of USB Camera should work on Pi out-of-the-box.

1. Enable Camera module

Run `raspi-config` configuration tool:

```
sudo raspi-config
```

then select **Interfacing Options** → **Camera** → **Yes**.

This method will automatically set `start_x=1` in `/boot/config.txt` file.

i `raspi-config` is a Raspberry Pi configuration command-line tool, to enable or disable some features in Pi OS. This tool requires root permission, therefore, it must be run with the super user right using `sudo`.

```

Raspberry Pi Software Configuration Tool (raspi-config)

1 System Options      Configure system settings
2 Display Options     Configure display settings
3 Interface Options   Configure connections to peripherals
4 Performance Options Configure performance settings
5 Localisation Options Configure language and regional settings
6 Advanced Options    Configure advanced settings
8 Update              Update this tool to the latest version
9 About raspi-config  Information about this configuration tool

<Select>                                <Finish>

```

User interface of `raspi-config`

2. Increase GPU memory

Some video encoders need a big buffer to process video encoding or decoding. To increase the memory reserved for video processor, in the `raspi-config` configuration tool, go to **Performance Options** → **GPU Memory** then fill in `256` and select **OK**.


This method does the same thing with setting up `gpu_mem=256` in `/boot/config.txt`.

3. Test Camera

Detect the camera connection by running the checking tool:

```
vcgencmd get_camera
```

which should print out `supported=1 detected=1` telling that the camera is supported and connected.

 **vcgencmd** is a command line utility that can get various pieces of information from the VideoCore GPU on the Raspberry Pi. Check more detail in [Raspberry Pi/vcgencmd](#)

[Raspicam commands](#) has a set of tools to work with the camera module: `raspistill`, `raspivid`, and `raspiyuv`.

- Capture an image: `raspistill -o cam.jpg`
- Record an video: `raspivid -o vid.h264`

4. Video for Linux 2 - V4L2

Under Linux, the standard APIs for cameras (including webcams) is **V4L** (Video for Linux), and a number of applications have been written that support any camera with a V4L driver. An independent developer has now written an user space V4L driver for the Raspberry Pi camera but it is closed sourced, and can be a little slow because it runs as a user program rather than a kernel driver.

Recognizing that a V4L driver is needed, the Raspberry Pi Foundation reported that they were working with Broadcom to develop an official kernel V4L driver. As a kernel driver, it should be faster than the user space driver.

Finally, V4L2 was released under the name `bcm2835-v4l2` which is included Raspberry Pi OS by default. Use `v4l2-ctl` utility tool to capture from the camera.

4.1. List devices

```
v4l2-ctl --list-devices
```

```
bcm2835-codec-decode (platform:bcm2835-codec):
    /dev/video10
    /dev/video11
    /dev/video12

bcm2835-isp (platform:bcm2835-isp):
    /dev/video13
    /dev/video14
    /dev/video15
    /dev/video16

mmal service 16.1 (platform:bcm2835-v4l2):
    /dev/video0
```

4.2. Driver info

```
v4l2-ctl -d /dev/video0 --all
```

```
Driver Info:
  Driver name      : bcm2835 mmal
  Card type        : mmal service 16.1
  Bus info         : platform:bcm2835-v4l2
  Driver version   : 5.4.79
  Capabilities     : 0x85200005
                    Video Capture
                    Video Overlay
                    Read/Write
                    Streaming
  ...
```

4.3. Supported formats

```
v4l2-ctl --list-formats
```

```
ioctl: VIDIOC_ENUM_FMT
  Type: Video Capture

[0]: 'YU12' (Planar YUV 4:2:0)
[1]: 'YUYV' (YUYV 4:2:2)
[2]: 'RGB3' (24-bit RGB 8-8-8)
[3]: 'JPEG' (JFIF JPEG, compressed)
[4]: 'H264' (H.264, compressed)
[5]: 'MJPG' (Motion-JPEG, compressed)
[6]: 'YVYU' (YVYU 4:2:2)
[7]: 'VYUY' (VYUY 4:2:2)
[8]: 'UYVY' (UYVY 4:2:2)
[9]: 'NV12' (Y/CbCr 4:2:0)
[10]: 'BGR3' (24-bit BGR 8-8-8)
```

```
[11]: 'YV12' (Planar YVU 4:2:0)
[12]: 'NV21' (Y/CrCb 4:2:0)
[13]: 'RX24' (32-bit XBGR 8-8-8-8)
```

Please take a note for **RGB3** , **JPEG** , **H264** , and **MJPEG** , which can be used in OpenCV, or streaming directly.

4.4. Capture JPEG Image

```
v4l2-ctl --set-fmt-video=width=2592,height=1944,pixelformat=3 && \
v4l2-ctl --stream-mmap=3 --stream-count=1 --stream-to=somefile.jpg
```

4.5. Record H264 Video


 Note the value *height=1088*, not 1080.

```
v4l2-ctl --set-fmt-video=width=1920,height=1088,pixelformat=4 && \
v4l2-ctl --stream-mmap=3 --stream-count=100 --stream-to=somefile.264
```

5. FFmpeg

The pre-built **ffmpeg** package of Pi already enables hardware accelerator support, with OpenMAX IL H.264 video encoder (**h264_omx**).

```
sudo apt-get install ffmpeg -y
```

 An FFmpeg version with a specific library can be built by following this topic [Compile FFmpeg with Hardware Accelerator](#).

5.1. Encoders

To see all available encoders:

```
ffmpeg -encoders
```

If interested in **h264** and **mjpeg** , use **grep** to search for the specific encoders:

```
ffmpeg -hide_banner -encoders | grep -E "h264|mjpeg"
```

```
V..... libx264                libx264 H.264 / AVC / MPEG-4 AVC / MPEG-4 part 10 (codec
h264)
V..... libx264rgb             libx264 H.264 / AVC / MPEG-4 AVC / MPEG-4 part 10 RGB
(codec h264)
```

```
V..... h264_omx          OpenMAX IL H.264 video encoder (codec h264)
V..... h264_v4l2m2m       V4L2 mem2mem H.264 encoder wrapper (codec h264)
VFS... mjpeg               MJPEG (Motion JPEG)
```

Check encoder options

Before using an encoder, check its options by **help** command in **ffmpeg**.

```
ffmpeg -h encoder=<format>
```

Here is the list of formats supported by OpenMAX IL H.264 video encoder (h264_omx):

```
ffmpeg -h encoder=h264_omx
```

```
Encoder h264_omx [OpenMAX IL H.264 video encoder]:
  General capabilities: delay
  Threading capabilities: none
  Supported pixel formats: yuv420p
h264_omx AVOptions:
  -omx_libname      <string>      ED.V..... OpenMAX library name
  -omx_libprefix    <string>      ED.V..... OpenMAX library prefix
  -zerocopy         <int>         E..V..... Try to avoid copying input frames if
possible (from 0 to 1) (default 1)
  -profile          <int>         E..V..... Set the encoding profile (from -99 to
100) (default -99)
    baseline        66           E..V.....
    main            77           E..V.....
    high            100          E..V.....
```

5.2. Performance

Next, try to record some short video (60 seconds) with H264 format using different encoders. To measure the performance, use a small tool to check CPU and Memory Usage in [monitor - Script to check performance](#).

 Note that **ffmpeg** will use **v4l2** driver if user does not specify the driver!"

Video settings

Video side: **1024x768**

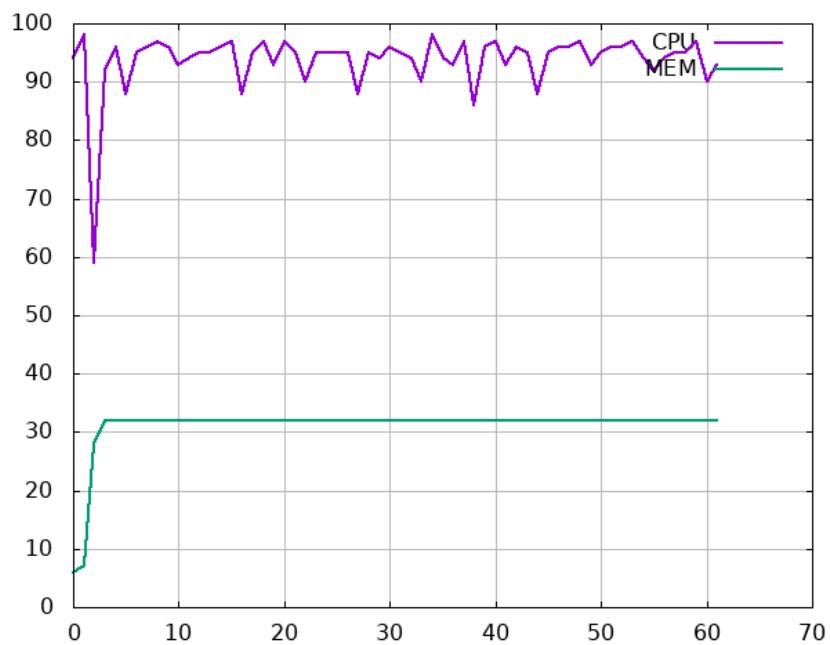
Framerate: **30** fps

Input Length: **60** seconds

5.2.1. Raw to MJPEG (.avi)

```
ffmpeg -y -hide_banner \
  -use_wallclock_as_timestamps 1 \
  -t 60 \
  -i /dev/video0 \
  -c:v mjpeg \
  raw_mjpeg.avi
```

- Performance:
 - Total time: 63 seconds
 - Average CPU: *93 (too high)*
 - Average MEM: 31
 - Input FPS: *4.8 (dropped input)*
 - Output FPS: 30
- Quality:
 - Format: JPEG
 - Codec ID: MJPG
 - Bit rate: 839 kb/s



Raw to MJPEG

5.2.2. Raw to H264_OMX @8Mbps (.mp4)

```
ffmpeg -y -hide_banner \  
  -use_wallclock_as_timestamps 1 \  
  -t 60 \  
  -i /dev/video0 \  
  -c:v h264_omx \  
  -b:v 8M \  
  raw_h264omx.mp4
```

- Performance:
 - Total time: 63 seconds
 - Average CPU: **16 (OK)**
 - Average MEM: 27
 - Input FPS: 30
 - Output FPS: 30
- Quality:
 - Format: AVC (GOP: M=1, N=12)
 - Codec ID: avc1
 - Bit rate: 2 877 kb/s

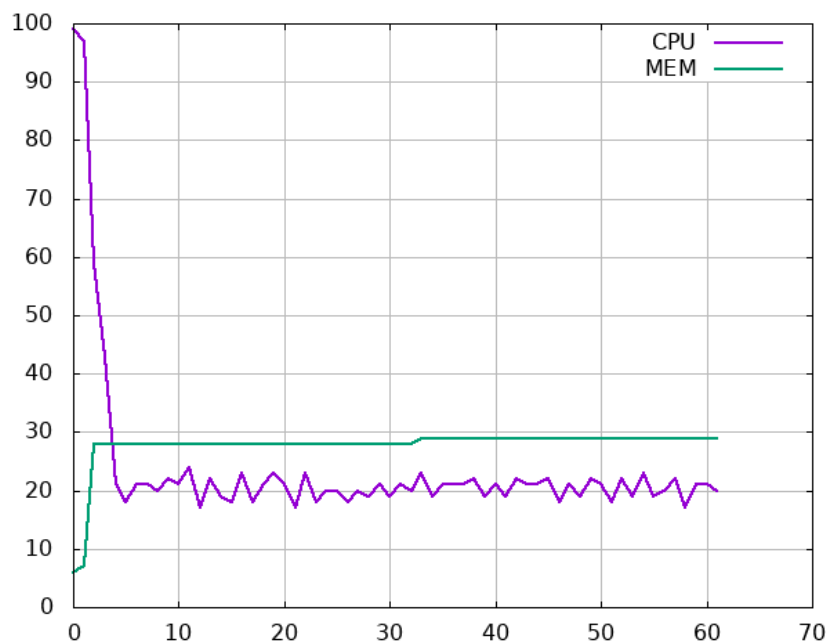


Raw to H264_OMX @8Mbps

5.2.3. Raw to H264_V4L2M2M @8Mbps (.mp4)

```
ffmpeg -y -hide_banner \
  -use_wallclock_as_timestamps 1 \
  -t 60 \
  -i /dev/video0 \
  -c:v h264_v4l2m2m \
  -b:v 8M \
  raw_h264v4l2m2m.mp4
```

- Performance:
 - Total time: 62 seconds
 - Average CPU: 23
 - Average MEM: 27
 - Input FPS: 30
 - Output FPS: 30
- Quality:
 - Format: AVC (GPO: M=1, N=60)
 - Codec ID: avc1
 - Bit rate: 1 783 kb/s

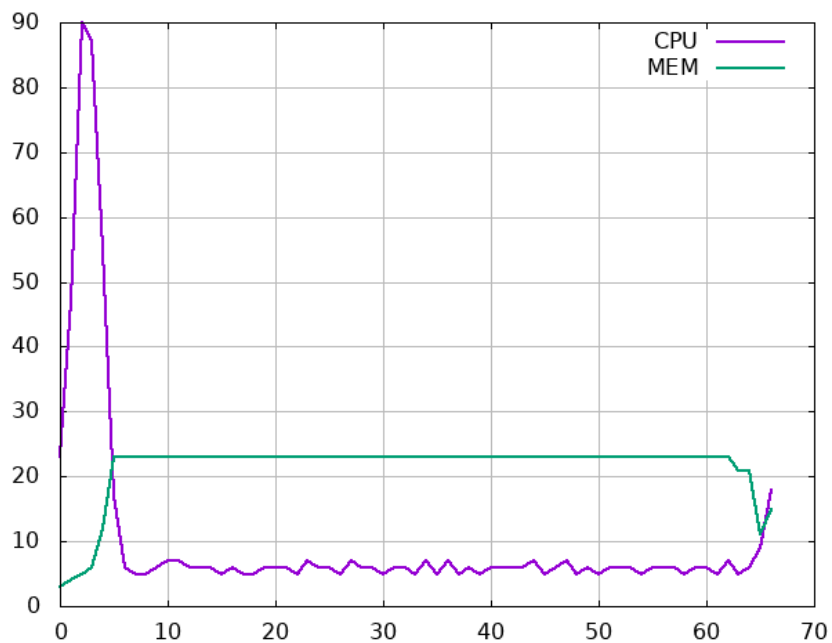


Raw to H264_V4L2M2M @8Mbps

5.2.4. V4L2 MJPEG direct copy (.avi)

```
ffmpeg -y -hide_banner \
  -use_wallclock_as_timestamps 1 \
  -t 60 \
  -input_format mjpeg \
  -i /dev/video0 \
  -c:v copy \
  -t 60 \
  mjpeg.avi.avi
```

- Performance:
 - Total time: 67 seconds
 - Average CPU: **10 (Good)**
 - Average MEM: 21
 - Input FPS: 30
 - Output FPS: 30
- Quality:
 - Format: JPEG
 - Codec ID: MJPG
 - Bit rate: *10.2 Mb/s (very high bandwidth)*

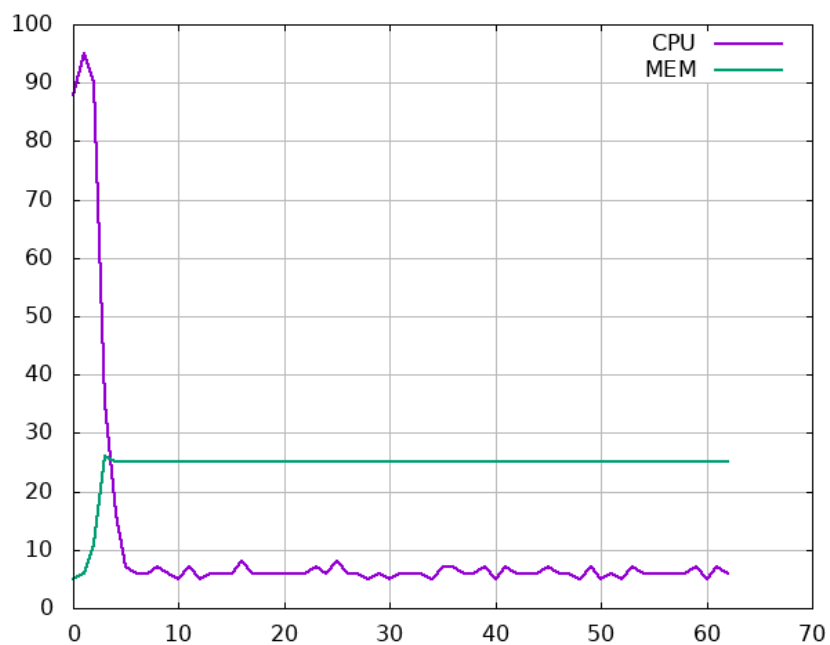


Save V4L2 MJPEG stream

5.2.5. V4L2 H264 direct copy (.mp4)

```
ffmpeg -y -hide_banner \
  -use_wallclock_as_timestamps 1 \
  -t 60 \
  -input_format h264 \
  -i /dev/video0 \
  -c:v copy \
  -t 60 \
  h264_mp4.mp4
```

- Performance:
 - Total time: 67 seconds
 - Average CPU: **10 (Good)**
 - Average MEM: 24
 - Input FPS: 30
 - Output FPS: 30
- Quality:
 - Format: AVC (GPO: M=1, N=60)
 - Codec ID: avc1
 - Bit rate: **5 506 kb/s (OK)**



Save V4L2 H264 stream

5.2.6. Conclusion

After above tests, it can be said that using compressed input format from **v4l2** is much more effective than compressing by an software encoder.

Let's add some timestamp to video by using **drawtext** filter with built-in expandable **localtime** variable in **Text-expansion** option.

```
ffmpeg -y -hide_banner \
  -use_wallclock_as_timestamps 1 \
  -t 10 \
  -i /dev/video0 \
  -vf "drawtext=text='{localtime}':fontcolor=white:x=100:y=100" \
  -c:v h264_omx \
  -b:v 8M \
  raw_h264omx_text.mp4
```

✗ Filter and stream-copy cannot be used together

Text needs inserted and each frame needs re-encoded, therefore, stream-copy is unavailable.

```
# this will not work
ffmpeg -y -hide_banner \
  -use_wallclock_as_timestamps 1 \
  -t 10 \
  -input_format h264 \
  -i /dev/video0 \
  -vf "drawtext=text='{localtime}':fontcolor=white:x=100:y=100" \
  -c:v copy \
  -t 10 \
  h264_mp4_text.mp4
```

6. Install **picamera**

The **picamera** package is a pure Python interface to the Raspberry Pi camera module for Python language. If using the **Raspbian** distro, probably it has **picamera** installed by default. Run a test to check it is installed or not:

```
python -c "import picamera"
python3 -c "import picamera"
```

If no module found, install **picamera** from the system's package manager:

```
sudo apt-get install python-picamera python3-picamera
```

There are a lot of examples in the **official guide**. Here are some starting points:

Get maximum resolution of the camera

```
import picamera

with picamera.PiCamera() as cam:
    print(cam.MAX_RESOLUTION)
```

Take a snapshot

```
from time import sleep
from picamera import PiCamera

# setup a camera
camera = PiCamera()
camera.resolution = (1024, 768)

# camera warm-up time
sleep(2)

# capture an image
camera.capture('snapshot.jpg')
```

Now, for the testing purpose, let's record a 60-second video from the camera and measure the resource usage with `monitor`, then use `ffmpeg` to convert raw h264 to mp4:

6.1. Picamera H264 (.h264)

Recode a raw H264 video file

```
from picamera import PiCamera

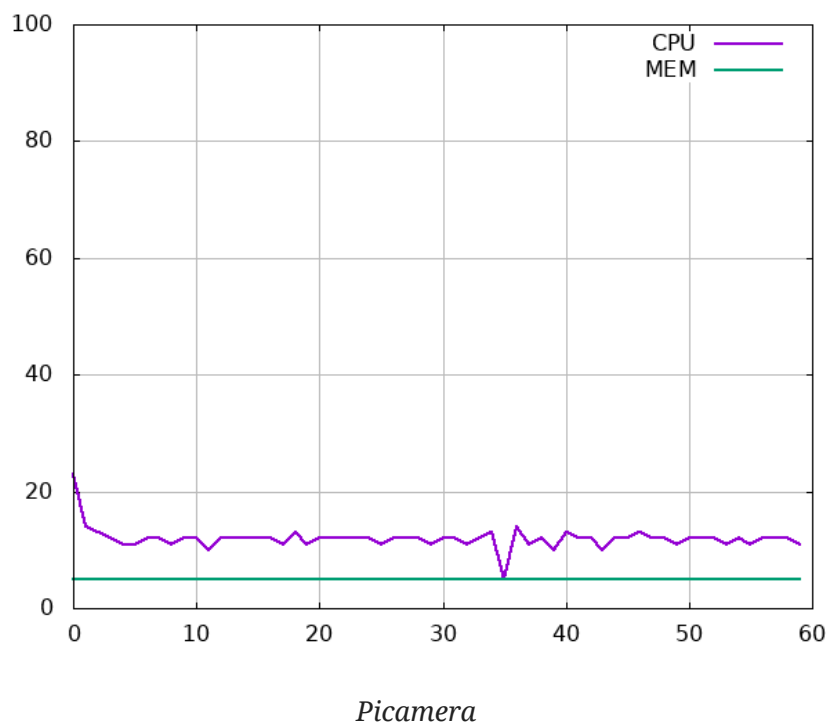
# setup a camera
camera = PiCamera()
camera.resolution = (1024, 768)
camera.framerate = 30

# record a video
camera.start_recording('picamera.h264')
camera.wait_recording(60)
camera.stop_recording()
```

Convert to MP4 video file

```
ffmpeg -i picamera.h264 \
    -c:v copy picamera.mp4
```

- Performance:
 - Total time: 61 seconds
 - Average CPU: **11 (Good)**
 - Average MEM: **5 (Good)**
 - Input FPS: 30
 - Output FPS: 25
- Quality:
 - Format: AVC (GPO: M=1, N=60)
 - Codec ID: avc1
 - Bit rate: **3 302 kb/s (Good)**



6.2. Picamera H264 (.h264) with Text overlay

Now, try to detect how `picamera` can draw text on output video. Here is the test code:

```
from picamera import PiCamera
import datetime

TIMEFMT = '%Y-%m-%d %H:%M:%S.%f'

# setup a camera
camera = PiCamera()
```

```
camera.resolution = (1024, 768)
camera.annotate_text = datetime.datetime.now().strftime('%Y-%m-%d %H:%M:%S')

# record a video
camera.start_recording('picamera_text.h264')
start = datetime.datetime.now()

while (datetime.datetime.now() - start).seconds < 60:
    camera.annotate_text = datetime.datetime.now().strftime('%Y-%m-%d %H:%M:%S')
    camera.wait_recording(0.04) # 25fps

# stop it
camera.stop_recording()
```

Using `picamera` shows an impressive CPU and MEM usage, comparing to using FFmpeg. The result shows that the CPU uses twice as much as it does in non-overlay text, while the MEM keeps the same percentage.