Setup Camera with V4L2, FFmpeg, and PiCamera

Enable Camera module on Raspberry Pi. Install drivers and applications to capture image or video from the camera. Compare the performance of some encoders used in ffmpeg and python picamera package.

#pi #camera #v4l2 #ffmpeg #python #picamera

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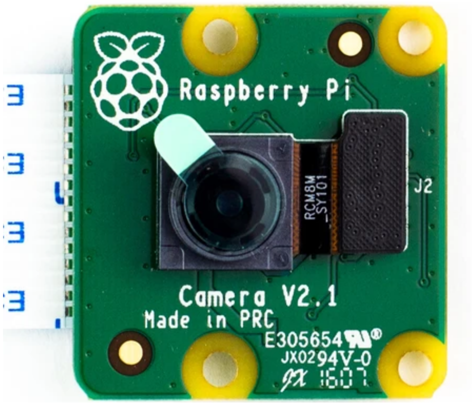


RaspberryPi Camera Module

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

1. Enable Camera module

Run `raspi-config` configuration tool:

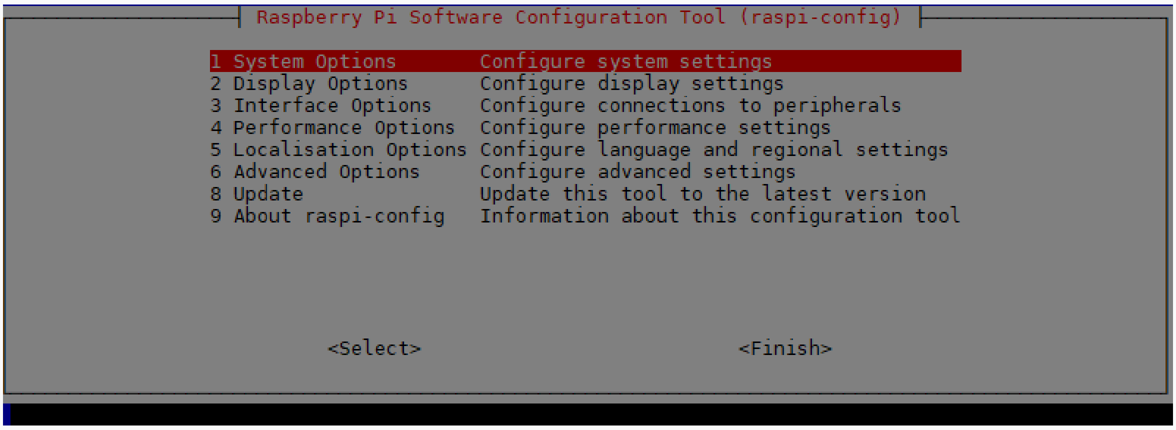
```
sudo raspi-config
```

Select **Interfacing Options** > **Camera** > **Yes**.

This method does the same thing with setting up `start_x=1` in */boot/config.txt*.

raspi-config

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

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**
>
> **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 in to Raspbian 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
```

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 RPi already enables hardware accelerator support, with OpenMAX IL H.264 video encoder (`h264_omx`).

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

Compile FFmpeg

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`. For example:

```
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.

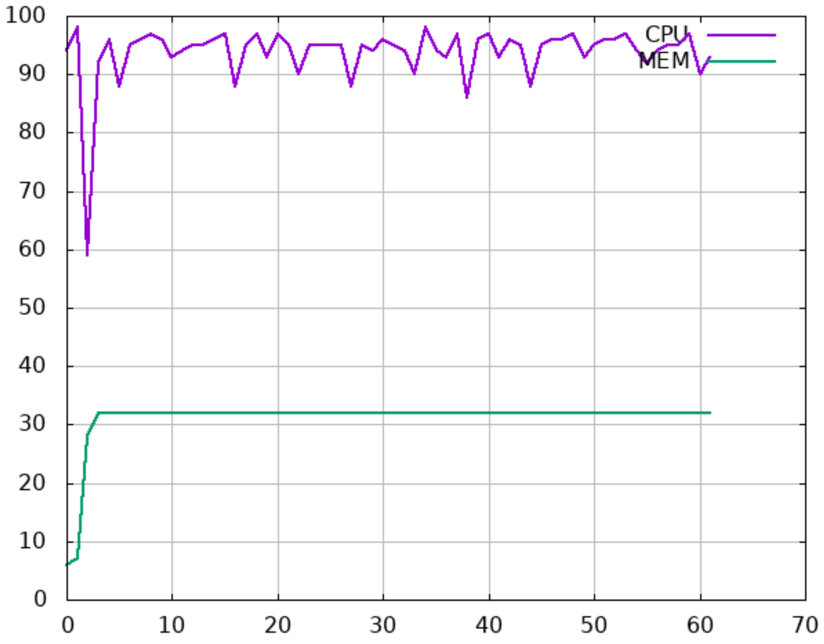
Video settings

> Video side: **1024x768**
> Framerate: **30** fps
> Input Length: **60** seconds
> Note that `ffmpeg` uses `v4l2` driver!

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

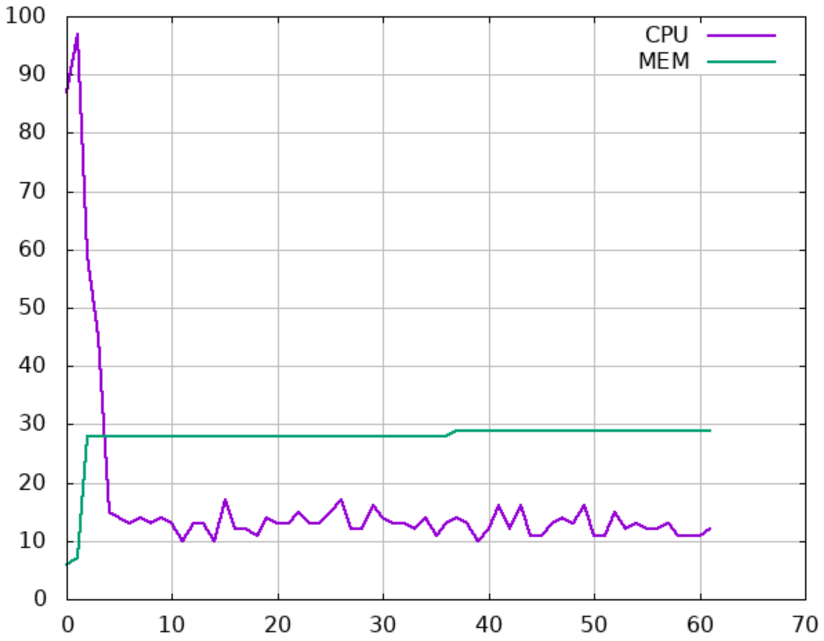


Raw to MJPEG

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

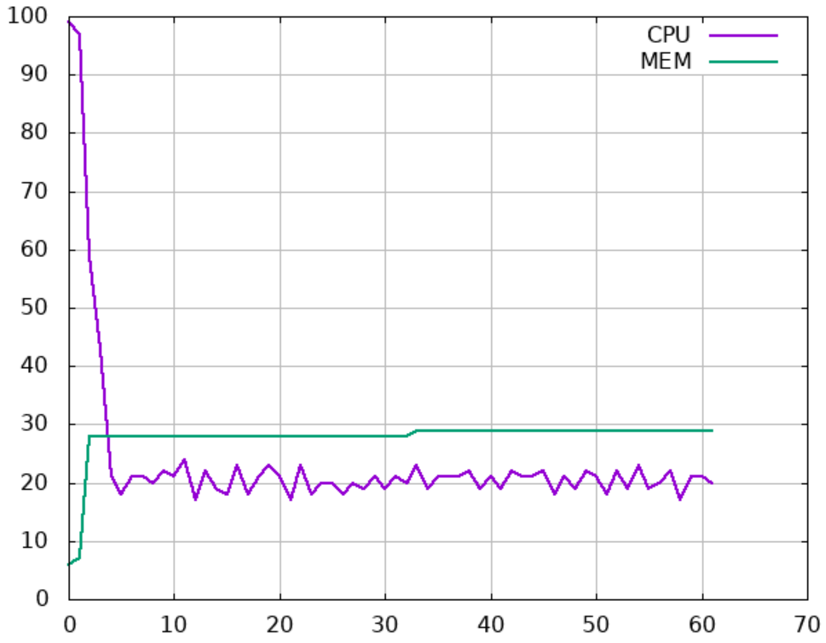


Raw to H264_OMX @8Mbps

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

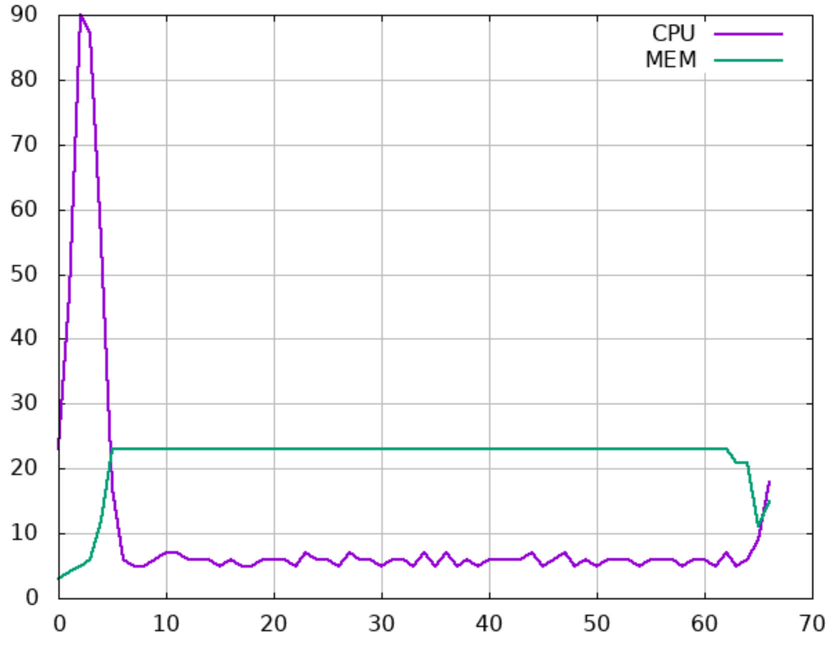


Raw to H264_V4L2M2M @8Mbps

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)*

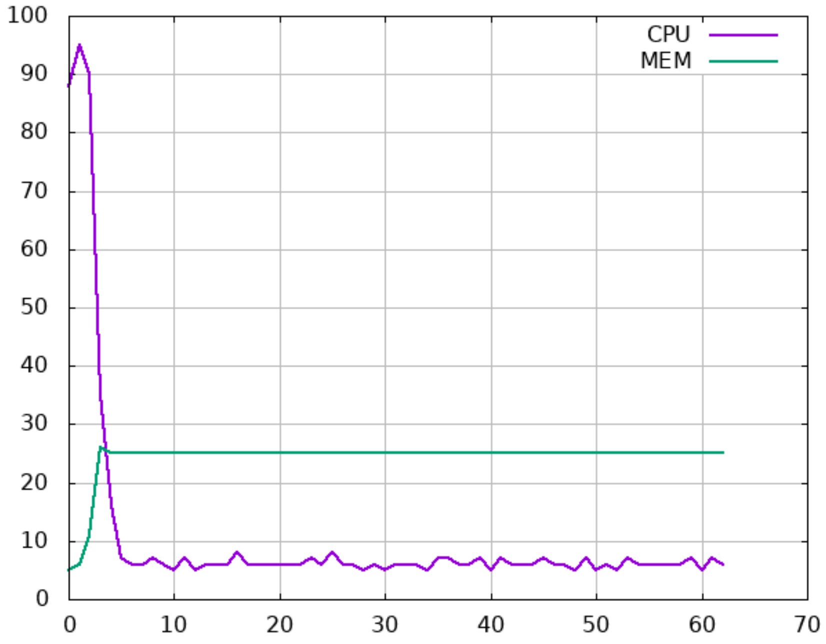


Save V4L2 MJPEG strem

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

After above tests, it says 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. Homepage is at https://picamera.readthedocs.io/en/latest/install.html.

If using the Raspbian distro, probably it has picamera installed by default. Run a test:

```
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 example in the official guide of Picamera at https://picamera.readthedocs.io/en/latest/recipes1.html.

Get maximum resolution of the camera:

```python
import picamera

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

Take a snapshot:

```python
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 testing. record a 60-second video from camera and measure resource usage with `monitor`, then use `ffmpeg` to convert raw h264 to mp4:

6.1. Picamera H264 (.h264)

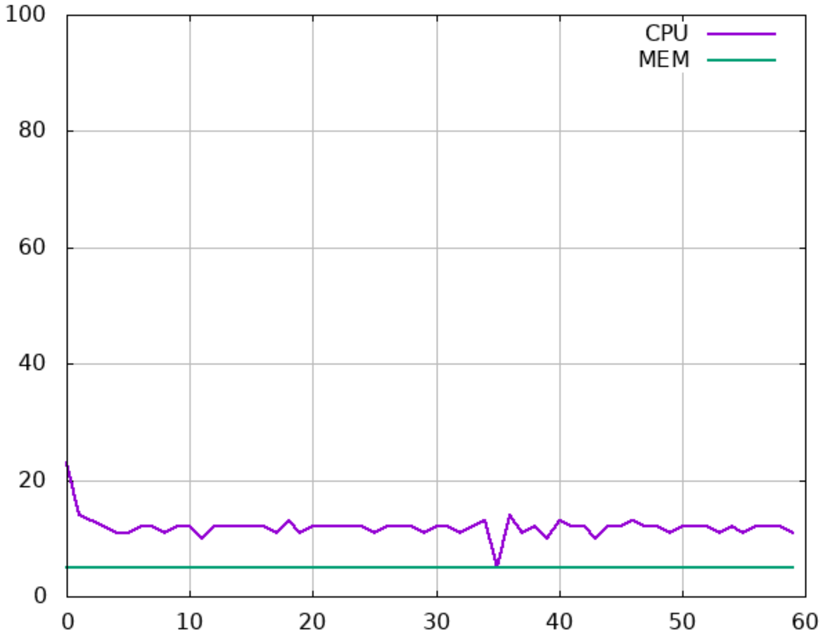
```python
from picamera import PiCamera

# 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()
```

```
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)*



Picamera

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

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

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

```
camera.resolution = (1024, 768)
camera.annotate_text = datetime.datetime.now().strftime(TIMEFMT)

# 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(TIMEFMT)
  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.

Comments