Camera software

This documentation describes how to use supported camera modules with our software tools. All Raspberry Pi cameras can record high-resolution photographs and full HD 1080p video (or better) with our software tools.

Raspberry Pi produces several official camera modules, including:

- the original 5-megapixel Camera Module 1 (discontinued)
- the 8-megapixel Camera Module 2, with or without an infrared filter
- the 12-megapixel Camera Module 3, with both standard and wide lenses, with or without an infrared filter
- the 12-megapixel High Quality Camera with CS and M12 mount variants for use with external lenses
- the 1.6-megapixel Global Shutter Camera for fast motion photography
- the 12-megapixel AI Camera uses the Sony IMX500 imaging sensor to provide low-latency, high-performance AI capabilities to any camera application

For more information about camera hardware, see the camera hardware documentation.

First, install your camera module. Then, follow the guides in this section to put your camera module to use.

`rpicam-apps`

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NOTE

> Raspberry Pi OS *Bookworm* renamed the camera capture applications from `libcamera-*` to `rpicam-*`. Symbolic links allow users to use the old names for now. **Adopt the new application names as soon as possible.** Raspberry Pi OS versions prior to *Bookworm* still use the `libcamera-*` name.

Raspberry Pi supplies a small set of example `rpicam-apps`. These CLI applications, built on top of `libcamera`, capture images and video from a camera. These applications include:

- `rpicam-hello`: A "hello world"-equivalent for cameras, which starts a camera preview stream and displays it on the screen.
- `rpicam-jpeg`: Runs a preview window, then captures high-resolution still images.
- `rpicam-still`: Emulates many of the features of the original `raspistill` application.
- `rpicam-vid`: Captures video.
- `rpicam-raw`: Captures raw (unprocessed Bayer) frames directly from the sensor.
- `rpicam-detect`: Not built by default, but users can build it if they have TensorFlow Lite installed on their Raspberry Pi. Captures JPEG images when certain objects are detected.

Recent versions of Raspberry Pi OS include the five basic `rpicam-apps`, so you can record images and videos using a camera even on a fresh Raspberry Pi OS installation.

Users can create their own `rpicam`-based applications with custom functionality to suit their own requirements. The `rpicam-apps` source code is freely available under a BSD-2-Clause licence.

libcamera

`libcamera` is an open-source software library aimed at supporting camera systems directly from the Linux operating system on Arm processors. Proprietary code running on the Broadcom GPU is minimised. For more information about `libcamera` see the `libcamera` website.

`libcamera` provides a C++ API that configures the camera, then allows applications to request image frames. These image buffers reside in system memory and can be passed directly to still image encoders (such as JPEG) or to video encoders (such as H.264). `libcamera` doesn't encode or display images itself: that that functionality, use `rpicam-apps`.

You can find the source code in the official libcamera repository. The Raspberry Pi OS distribution uses a fork to control updates.

Underneath the `libcamera` core, we provide a custom pipeline handler. `libcamera` uses this layer to drive the sensor and image signal processor (ISP) on the Raspberry Pi. `libcamera` contains a collection of image-processing algorithms (IPAs) including auto exposure/gain control (AEC/AGC), auto white balance (AWB), and auto lens-shading correction (ALSC).

Raspberry Pi's implementation of `libcamera` supports the following cameras:

- Official cameras:
    - OV5647 (V1)
    - IMX219 (V2)
    - IMX708 (V3)
    - IMX477 (HQ)
    - IMX500 (AI)
    - IMX296 (GS)
- Third-party sensors:
    - IMX290
    - IMX327
    - IMX378
    - IMX519
    - OV9281

To extend support to a new sensor, contribute to `libcamera`.

rpicam-hello

Edit this on GitHub

`rpicam-hello` briefly displays a preview window containing the video feed from a connected camera. To use `rpicam-hello` to display a preview window for five seconds, run the following command in a terminal:

```
$ rpicam-hello
```

You can pass an optional duration (in milliseconds) with the `timeout` option. A value of `0` runs the preview indefinitely:

```
$ rpicam-hello --timeout 0
```

Use `Ctrl+C` in the terminal or the close button on the preview window to stop `rpicam-hello`.

Display an image sensor preview

Most of the `rpicam-apps` display a preview image in a window. If there is no active desktop environment, the preview draws directly to the display using the Linux Direct Rendering Manager (DRM). Otherwise, `rpicam-apps` attempt to use the desktop environment. Both paths use zero-copy GPU buffer sharing: as a result, X forwarding is *not* supported.

If you run the X window server and want to use X forwarding, pass the `qt-preview` flag to render the preview window in a Qt window. The Qt preview window uses more resources than the alternatives.

NOTE

> Older systems using Gtk2 may, when linked with OpenCV, produce `Glib-GObject` errors and fail to show the Qt preview window. In this case edit the file `/etc/xdg/qt5ct/qt5ct.conf` as root and replace the line containing `style=gtk2` with `style=gtk3`.

To suppress the preview window entirely, pass the `nopreview` flag:

```
$ rpicam-hello -n
```

The `info-text` option displays image information on the window title bar using `%` directives. For example, the following command displays the current red and blue gain values:

```
$ rpicam-hello --info-text "red gain %rg, blue gain %bg"
```

For a full list of directives, see the `info-text` reference.

rpicam-jpeg

Edit this on GitHub

`rpicam-jpeg` helps you capture images on Raspberry Pi devices.

To capture a full resolution JPEG image and save it to a file named `test.jpg`, run the following command:

```
$ rpicam-jpeg --output test.jpg
```

You should see a preview window for five seconds. Then, `rpicam-jpeg` captures a full resolution JPEG image and saves it.

Use the `timeout` option to alter display time of the preview window. The `width` and `height` options change the resolution of the saved image. For example, the following command displays the preview window for 2 seconds, then captures and saves an image with a resolution of 640×480 pixels:

```
$ rpicam-jpeg --output test.jpg --timeout 2000 --width 640 --height 480
```

rpicam-still

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`rpicam-still`, like `rpicam-jpeg`, helps you capture images on Raspberry Pi devices. Unlike `rpicam-jpeg`, `rpicam-still` supports many options provided in the legacy `raspistill` application.

To capture a full resolution JPEG image and save it to a file named `test.jpg`, run the following command:

```
$ rpicam-still --output test.jpg
```

Encoders

`rpicam-still` can save images in multiple formats, including `png`, `bmp`, and both RGB and YUV binary pixel dumps. To read these binary dumps, any application reading the files must understand the pixel arrangement.

Use the `encoding` option to specify an output format. The file name passed to `output` has no impact on the output file type.

To capture a full resolution PNG image and save it to a file named `test.png`, run the following command:

```
$ rpicam-still --encoding png --output test.png
```

For more information about specifying an image format, see the `encoding` option reference.

Capture raw images

Raw images are the images produced directly by the image sensor, before any processing is applied to them either by the Image Signal Processor (ISP) or CPU. Colour image sensors usually use the Bayer format. Use the `raw` option to capture raw images.

To capture an image, save it to a file named `test.jpg`, and also save a raw version of the image to a file named `test.dng`, run the following command:

```
$ rpicam-still --raw --output test.jpg
```

`rpicam-still` saves raw images in the DNG (Adobe Digital Negative) format. To determine the filename of the raw images, `rpicam-still` uses the same name as the output file, with the extension changed to `.dng`. To work with DNG images, use an application like Dcraw or RawTherapee.

DNG files contain metadata about the image capture, including black levels, white balance information and the colour matrix used by the ISP to produce the JPEG. Use ExifTool to view DNG metadata. The following output shows typical metadata stored in a raw image captured by a Raspberry Pi using the HQ camera:

```
File Name                       : test.dng
Directory                       : .
File Size                       : 24 MB
File Modification Date/Time     : 2021:08:17 16:36:18+01:00
File Access Date/Time           : 2021:08:17 16:36:18+01:00
File Inode Change Date/Time     : 2021:08:17 16:36:18+01:00
File Permissions                : rw-r--r--
File Type                       : DNG
File Type Extension             : dng
MIME Type                       : image/x-adobe-dng
Exif Byte Order                 : Little-endian (Intel, II)
Make                            : Raspberry Pi
Camera Model Name               : /base/soc/i2c0mux/i2c@1/imx477@1a
Orientation                     : Horizontal (normal)
Software                        : rpicam-still
Subfile Type                    : Full-resolution Image
Image Width                     : 4056
Image Height                    : 3040
Bits Per Sample                 : 16
Compression                     : Uncompressed
Photometric Interpretation      : Color Filter Array
Samples Per Pixel               : 1
Planar Configuration            : Chunky
CFA Repeat Pattern Dim          : 2 2
CFA Pattern 2                   : 2 1 1 0
Black Level Repeat Dim          : 2 2
Black Level                     : 256 256 256 256
White Level                     : 4095
DNG Version                     : 1.1.0.0
DNG Backward Version            : 1.0.0.0
Unique Camera Model             : /base/soc/i2c0mux/i2c@1/imx477@1a
Color Matrix 1                  : 0.8545269369 -0.2382823821 -0.09044229197 -0.1890484985
1.063961506 0.1062747385 -0.01334283455 0.1440163847 0.2593136724
As Shot Neutral                 : 0.4754476844 1 0.413686484
Calibration Illuminant 1        : D65
Strip Offsets                   : 0
Strip Byte Counts               : 0
Exposure Time                   : 1/20
```

```
ISO                             : 400
CFA Pattern                     : [Blue,Green][Green,Red]
Image Size                      : 4056x3040
Megapixels                      : 12.3
Shutter Speed                   : 1/20
```

To find the analogue gain, divide the ISO number by 100. The Auto White Balance (AWB) algorithm determines a single calibrated illuminant, which is always labelled `D65`.

Capture long exposures

To capture very long exposure images, disable the Automatic Exposure/Gain Control (AEC/AGC) and Auto White Balance (AWB). These algorithms will otherwise force the user to wait for a number of frames while they converge.

To disable these algorithms, supply explicit values for gain and AWB. Because long exposures take plenty of time already, it often makes sense to skip the preview phase entirely with the `immediate` option.

To perform a 100 second exposure capture, run the following command:

```
$ rpicam-still -o long_exposure.jpg --shutter 100000000 --gain 1 --awbgains 1,1 --immedia
te
```

To find the maximum exposure times of official Raspberry Pi cameras, see the camera hardware specification.

Create a time lapse video

To create a time lapse video, capture a still image at a regular interval, such as once a minute, then use an application to stitch the pictures together into a video.

via `rpicam-still` time lapse mode

To use the built-in time lapse mode of `rpicam-still`, use the `timelapse` option. This option accepts a value representing the period of time you want your Raspberry Pi to wait between captures, in milliseconds.

First, create a directory where you can store your time lapse photos:

```
$ mkdir timelapse
```

Run the following command to create a time lapse over 30 seconds, recording a photo every two seconds, saving output into `image0000.jpg` through `image0013.jpg`:

```
$ rpicam-still --timeout 30000 --timelapse 2000 -o timelapse/image%04d.jpg
```

via `cron`

You can also automate time lapses with `cron`. First, create the script, named `timelapse.sh` containing the following commands. Replace the `<username>` placeholder with the name of your user account on your Raspberry Pi:

```
#!/bin/bash
DATE=$(date +"%Y-%m-%d_%H%M")
rpicam-still -o /home/<username>/timelapse/$DATE.jpg
```

Then, make the script executable:

```
$ chmod +x timelapse.sh
```

Create the `timelapse` directory into which you'll save time lapse pictures:

```
$ mkdir timelapse
```

Open your crontab for editing:

```
$ crontab -e
```

Once you have the file open in an editor, add the following line to schedule an image capture every minute, replacing the `<username>` placeholder with the username of your primary user account:

```
* * * * * /home/<username>/timelapse.sh 2>&1
```

Save and exit, and you should see this message:

```
crontab: installing new crontab
```

TIP

> To stop recording images for the time lapse, run `crontab -e` again and remove the above line from your crontab.

Stitch images together

Once you have a series of time lapse photos, you probably want to combine them into a video. Use `ffmpeg` to do this on a Raspberry Pi.

First, install `ffmpeg`:

```
$ sudo apt install ffmpeg
```

Run the following command from the directory that contains the `timelapse` directory to convert your JPEG files into an mp4 video:

```
$ ffmpeg -r 10 -f image2 -pattern_type glob -i 'timelapse/*.jpg' -s 1280x720 -vcodec libx
264 timelapse.mp4
```

The command above uses the following parameters:

- `-r 10`: sets the frame rate (Hz value) to ten frames per second in the output video
- `-f image2`: sets `ffmpeg` to read from a list of image files specified by a pattern
- `-pattern_type glob`: use wildcard patterns (globbing) to interpret filename input with `-i`
- `-i 'timelapse/*.jpg'`: specifies input files to match JPG files in the `timelapse` directory
- `-s 1280x720`: scales to 720p
- `-vcodec libx264` use the software x264 encoder.
- `timelapse.mp4` The name of the output video file.

For more information about `ffmpeg` options, run `ffmpeg --help` in a terminal.

rpicam-vid

`rpicam-vid` helps you capture video on Raspberry Pi devices. `rpicam-vid` displays a preview window and writes an encoded bitstream to the specified output. This produces an unpackaged video bitstream that is not wrapped in any kind of container (such as an mp4 file) format.

NOTE

When available, `rpicam-vid` uses hardware H.264 encoding.

For example, the following command writes a ten-second video to a file named `test.h264`:

```
$ rpicam-vid -t 10s -o test.h264
```

You can play the resulting file with VLC and other video players:

```
$ vlc test.h264
```

On Raspberry Pi 5, you can output to the MP4 container format directly by specifying the `mp4` file extension for your output file:

```
$ rpicam-vid  -t 10s -o test.mp4
```

Encoders

`rpicam-vid` supports motion JPEG as well as both uncompressed and unformatted YUV420:

```
$ rpicam-vid -t 10000 --codec mjpeg -o test.mjpeg
```

```
$ rpicam-vid -t 10000 --codec yuv420 -o test.data
```

The `codec` option determines the output format, not the extension of the output file.

The `segment` option breaks output files up into chunks of the segment size (given in milliseconds). This is handy for breaking a motion JPEG stream up into individual JPEG files by specifying very short (1 millisecond) segments. For example, the following command combines segments of 1 millisecond with a counter in the output file name to generate a new filename for each segment:

```
$ rpicam-vid -t 10000 --codec mjpeg --segment 1 -o test%05d.jpeg
```

Capture high framerate video

To minimise frame drops for high framerate (> 60fps) video, try the following configuration tweaks:

- Set the H.264 target level to 4.2 with `--level 4.2`.
- Disable software colour denoise processing by setting the `denoise` option to `cdn_off`.
- Disable the display window with `nopreview` to free up some additional CPU cycles.
- Set `force_turbo=1` in `/boot/firmware/config.txt` to ensure that the CPU clock does not throttle during video capture. For more information, see the `force_turbo` documentation.
- Adjust the ISP output resolution with `--width 1280 --height 720` or something even lower to achieve your framerate target.
- On Raspberry Pi 4, you can overclock the GPU to improve performance by adding `gpu_freq=550` or higher in `/boot/firmware/config.txt`. See the overclocking documentation for further details.

The following command demonstrates how you might achieve 1280×720 120fps video:

```
$ rpicam-vid --level 4.2 --framerate 120 --width 1280 --height 720 --save-pts timestamp.p
ts -o video.264 -t 10000 --denoise cdn_off -n
```

`libav` integration with `rpicam-vid`

`rpicam-vid` can use the `ffmpeg/libav` codec backend to encode audio and video streams. You can either save these streams to a file or stream them over the network. `libav` uses hardware H.264 video encoding when present.

To enable the `libav` backend, pass `libav` to the `codec` option:

```
$ rpicam-vid --codec libav --libav-format avi --libav-audio --output example.avi
```

rpicam-raw

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`rpicam-raw` records video as raw Bayer frames directly from the sensor. It does not show a preview window. To record a two second raw clip to a file named `test.raw`, run the following command:

```
$ rpicam-raw -t 2000 -o test.raw
```

`rpicam-raw` outputs raw frames with no formatting information at all, one directly after another. The application prints the pixel format and image dimensions to the terminal window to help the user interpret the pixel data.

By default, `rpicam-raw` outputs raw frames in a single, potentially very large, file. Use the `segment` option to direct each raw frame to a separate file, using the `%05d` directive to make each frame filename unique:

```
$ rpicam-raw -t 2000 --segment 1 -o test%05d.raw
```

With a fast storage device, `rpicam-raw` can write 18MB 12-megapixel HQ camera frames to disk at 10fps. `rpicam-raw` has no capability to format output frames as DNG files; for that functionality, use `rpicam-still`. Use the `framerate` option at a level beneath 10 to avoid dropping frames:

```
$ rpicam-raw -t 5000 --width 4056 --height 3040 -o test.raw --framerate 8
```

For more information on the raw formats, see the `mode` documentation.

rpicam-detect

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NOTE

> Raspberry Pi OS does not include `rpicam-detect`. However, you can build `rpicam-detect` if you have installed TensorFlow Lite. For more information, see the `rpicam-apps` build instructions. Don't forget to pass `-Denable_tflite=enabled` when you run `meson`.

`rpicam-detect` displays a preview window and monitors the contents using a Google MobileNet v1 SSD (Single Shot Detector) neural network trained to identify about 80 classes of objects using the Coco dataset. `rpicam-detect` recognises people, cars, cats and many other objects.

Whenever `rpicam-detect` detects a target object, it captures a full-resolution JPEG. Then it returns to monitoring preview mode.

See the TensorFlow Lite object detector section for general information on model usage. For example, you might spy secretly on your cats while you are away with:

```
$ rpicam-detect -t 0 -o cat%04d.jpg --lores-width 400 --lores-height 300 --post-process-f
ile object_detect_tf.json --object cat
```

Configuration

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Most use cases work automatically with no need to alter the camera configuration. However, some common use cases do require configuration tweaks, including:

- Third-party cameras (the manufacturer's instructions should explain necessary configuration changes, if any)

- Using a non-standard driver or overlay with an official Raspberry Pi camera

Raspberry Pi OS recognises the following overlays in `/boot/firmware/config.txt`.

Camera Module	**In `/boot/firmware/config.txt`**
V1 camera (OV5647)	`dtoverlay=ov5647`
V2 camera (IMX219)	`dtoverlay=imx219`
HQ camera (IMX477)	`dtoverlay=imx477`
GS camera (IMX296)	`dtoverlay=imx296`
Camera Module 3 (IMX708)	`dtoverlay=imx708`
IMX290 and IMX327	`dtoverlay=imx290,clock-frequency=74250000` or `dtoverlay=imx290,clock-frequency=37125000` (both modules share the imx290 kernel driver; refer to instructions from the module vendor for the correct frequency)
IMX378	`dtoverlay=imx378`
OV9281	`dtoverlay=ov9281`

To use one of these overlays, you must disable automatic camera detection. To disable automatic detection, set `camera_auto_detect=0` in `/boot/firmware/config.txt`. If `config.txt` already contains a line assigning an `camera_auto_detect` value, change the value to `0`. Reboot your Raspberry Pi with `sudo reboot` to load your changes.

Tweak camera behaviour with tuning files

Raspberry Pi's `libcamera` implementation includes a **tuning file** for each camera. This file controls algorithms and hardware to produce the best image quality. `libcamera` can only determine the sensor in use, not the module. As a result, some modules require a tuning file override. Use the `tuning-file` option to specify an override. You can also copy and alter existing tuning files to customise camera behaviour.

For example, the no-IR-filter (NoIR) versions of sensors use Auto White Balance (AWB) settings different from the standard versions. On a Raspberry Pi 5 or later, you can specify the the NoIR tuning file for the IMX219 sensor with the following command:

```
$ rpicam-hello --tuning-file /usr/share/libcamera/ipa/rpi/pisp/imx219_noir.json
```

NOTE

> Raspberry Pi models prior to Raspberry Pi 5 use different tuning files. On those devices, use the files stored in `/usr/share/libcamera/ipa/rpi/vc4/` instead.

`libcamera` maintains tuning files for a number of cameras, including third-party models. For instance, you can find the tuning file for the Soho Enterprises SE327M12 in `se327m12.json`.

Use multiple cameras

`rpicam-apps` has basic support for multiple cameras. You can attach multiple cameras to a Raspberry Pi in the following ways:

- For Raspberry Pi Compute Modules, you can connect two cameras directly to a Raspberry Pi Compute Module I/O board. See the Compute Module documentation for further details. With this method, you can *use both cameras simultaneously*.
- For Raspberry Pi 5, you can connect two cameras directly to the board using the dual MIPI connectors.

- For other Raspberry Pi devices with a camera port, you can attach two or more cameras with a Video Mux board such as this third-party product. Since both cameras are attached to a single Unicam port, *only one camera may be used at a time*.

To list all the cameras available on your platform, use the `list-cameras` option. To choose which camera to use, pass the camera index to the `camera` option.

NOTE

> `libcamera` does not yet provide stereoscopic camera support. When running two cameras simultaneously, they must be run in separate processes. This means there is no way to synchronise sensor framing or 3A operation between them. As a workaround, you could synchronise the cameras through an external sync signal for the HQ (IMX477) camera, and switch the 3A to manual mode if necessary.

Install `libcamera` and `rpicam-apps`

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Raspberry Pi provides two `rpicam-apps` packages:

- `rpicam-apps` contains full applications with support for previews using a desktop environment. This package is pre-installed in Raspberry Pi OS.
- `rpicam-apps-lite` omits desktop environment support, and only makes the DRM preview available. This package is pre-installed in Raspberry Pi OS Lite.

Dependencies

`rpicam-apps` depends on library packages named `library-name<n>`, where `<n>` is the ABI version. Your package manager should install these automatically.

Dev packages

You can rebuild `rpicam-apps` without building `libcamera` and `libepoxy` from scratch. For more information, see Building `rpicam-apps` without rebuilding `libcamera`.

Stream video over a network with `rpicam-apps`

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This section describes native streaming from `rpicam-vid`. You can also use the `libav` backend for network streaming.

UDP

To stream video over UDP using a Raspberry Pi as a server, use the following command, replacing the `<ip-addr>` placeholder with the IP address of the client or multicast address and replacing the `<port>` placeholder with the port you would like to use for streaming:

```
$ rpicam-vid -t 0 --inline -o udp://<ip-addr>:<port>
```

To view video streamed over UDP using a Raspberry Pi as a client, use the following command, replacing the `<port>` placeholder with the port you would like to stream from:

```
$ vlc udp://@:<port> :demux=h264
```

Alternatively, use the following command on a client to stream using `ffplay`:

```
$ ffplay udp://<ip-addr-of-server>:<port> -fflags nobuffer -flags low_delay -framedrop
```

TCP

You can also stream video over TCP. To use a Raspberry Pi as a server:

```
$ rpicam-vid -t 0 --inline --listen -o tcp://0.0.0.0:<port>
```

To view video streamed over TCP using a Raspberry Pi as a client, use the following command:

```
$ vlc tcp/h264://<ip-addr-of-server>:<port>
```

Alternatively, use the following command on a client to stream using `ffplay` at 30 frames per second:

```
$ ffplay tcp://<ip-addr-of-server>:<port> -vf "setpts=N/30" -fflags nobuffer -flags low_d
elay -framedrop
```

RTSP

To use VLC to stream video over RTSP using a Raspberry Pi as a server, use the following command:

```
$ rpicam-vid -t 0 --inline -o - | cvlc stream:///dev/stdin --sout '#rtp{sdp=rtsp://:8554/
stream1}' :demux=h264
```

To view video streamed over RTSP using a Raspberry Pi as a client, use the following command:

```
$ ffplay rtsp://<ip-addr-of-server>:8554/stream1 -vf "setpts=N/30" -fflags nobuffer -flag
s low_delay -framedrop
```

Alternatively, use the following command on a client to stream using VLC:

```
$ vlc rtsp://<ip-addr-of-server>:8554/stream1
```

To suppress the preview window on the server, use `nopreview`.

Use the `inline` flag to force stream header information into every intra frame, which helps clients understand the stream if they miss the beginning.

libav

You can use the `libav` backend as a network streaming source for audio/video. To stream video over TCP using a Raspberry Pi as a server, use the following command, replacing the `<ip-addr>` placeholder with the IP address of the client or multicast address and replacing the `<port>` placeholder with the port you would like to use for streaming:

```
$ rpicam-vid -t 0 --codec libav --libav-format mpegts --libav-audio -o "tcp://<ip-addr>:<
port>?listen=1"
```

You can stream over UDP with a similar command:

```
$ rpicam-vid -t 0 --codec libav --libav-format mpegts --libav-audio  -o "udp://<ip-addr>:
<port>"
```

GStreamer

GStreamer is a Linux framework for reading, processing and playing multimedia files. This section shows how to use `rpicam-vid` to stream video over a network.

This setup uses `rpicam-vid` to output an encoded h.264 bitstream to stdout. Then, we use the GStreamer `fdsrc` element to receive the bitstream, and extra GStreamer elements to send it over the network. On the server, run the following command to start the stream, replacing the `<ip-addr>` placeholder with the IP address of the client or multicast address and replacing the `<port>` placeholder with the port you would like to use for streaming:

```
$ rpicam-vid -t 0 -n --inline -o - | gst-launch-1.0 fdsrc fd=0 ! udpsink host=<ip-addr> p
ort=<port>
```

On the client, run the following command to receive the stream, replacing the `<ip-addr>` placeholder with the IP address of the client or multicast address and replacing the `<port>` placeholder with the port you would like to use for streaming:

```
$ gst-launch-1.0 udpsrc address=<ip-addr> port=<port> ! h264parse ! v4l2h264dec ! autovid
eosink
```

TIP

> To test this configuration, run the server and client commands in separate terminals on the same device, using `localhost` as the address.

RTP

To stream using RTP, run the following command on the server, replacing the `<ip-addr>` placeholder with the IP address of the client or multicast address and replacing the `<port>` placeholder with the port you would like to use for streaming:

```
$ rpicam-vid -t 0 -n --inline -o - | gst-launch-1.0 fdsrc fd=0 ! h264parse ! rtph264pay !
udpsink host=<ip-addr> port=<port>
```

To receive over RTP, run the following command on the client, replacing the `<ip-addr>` placeholder with the IP address of the client or multicast address and replacing the `<port>` placeholder with the port you would like to use for streaming:

```
$ gst-launch-1.0 udpsrc address=<ip-addr> port=<port> caps=application/x-rtp ! rtph264dep
ay ! h264parse ! v4l2h264dec ! autovideosink
```

If the client is not a Raspberry Pi it may have different GStreamer elements available. On an x86 device running Linux, you might run the following command instead:

```
$ gst-launch-1.0 udpsrc address=<ip-addr> port=<port> caps=application/x-rtp ! rtph264dep
ay ! h264parse ! avdec_h264 ! autovideosink
```

`libcamerasrc` GStreamer element

`libcamera` provides a `libcamerasrc` GStreamer element which can be used directly instead of `rpicam-vid`. To use this element, run the following command on the server, replacing the `<ip-addr>` placeholder with the IP address of the client or multicast address and replacing the `<port>` placeholder with the port you would like to use for streaming:

```
$ gst-launch-1.0 libcamerasrc ! capsfilter caps=video/x-raw,width=1280,height=720,format=
NV12 ! v4l2convert ! v4l2h264enc extra-controls="controls,repeat_sequence_header=1" ! 'vi
deo/x-h264,level=(string)4.1' ! h264parse ! rtph264pay ! udpsink host=<ip-addr> port=<por
t>
```

and on the client we use the same playback pipeline as previously.

`rpicam-apps` options reference

Edit this on GitHub

Common options

The following options apply across all the `rpicam-apps` with similar or identical semantics, unless otherwise noted.

To pass one of the following options to an application, prefix the option name with `--`. If the option requires a value, pass the value immediately after the option name, separated by a single space. If the

value contains a space, surround the value in quotes.
Some options have shorthand aliases, for example `-h` instead of `--help`. Use these shorthand aliases instead of the full option name to save space and time at the expense of readability.

help

Alias: `-h`

Prints the full set of options, along with a brief synopsis of each option. Does not accept a value.

version

Prints out version strings for `libcamera` and `rpicam-apps`. Does not accept a value.

Example output:

```
rpicam-apps build: ca559f46a97a 27-09-2021 (14:10:24)
libcamera build: v0.0.0+3058-c29143f7
```

list-cameras

Lists the detected cameras attached to your Raspberry Pi and their available sensor modes. Does not accept a value.

Sensor mode identifiers have the following form: `S<Bayer order><Bit-depth>_<Optional packing> : <Resolution list>`

Crop is specified in native sensor pixels (even in pixel binning mode) as `(<x>, <y>)/<Width>x<Height>`. `(x, y)` specifies the location of the crop window of size `width × height` in the sensor array.

For example, the following output displays information about an `IMX219` sensor at index 0 and an `IMX477` sensor at index 1:

```
Available cameras
-----------------
0 : imx219 [3280x2464] (/base/soc/i2c0mux/i2c@1/imx219@10)
    Modes: 'SRGGB10_CSI2P' : 640x480 [206.65 fps - (1000, 752)/1280x960 crop]
                             1640x1232 [41.85 fps - (0, 0)/3280x2464 crop]
                             1920x1080 [47.57 fps - (680, 692)/1920x1080 crop]
                             3280x2464 [21.19 fps - (0, 0)/3280x2464 crop]
           'SRGGB8' : 640x480 [206.65 fps - (1000, 752)/1280x960 crop]
                      1640x1232 [41.85 fps - (0, 0)/3280x2464 crop]
                      1920x1080 [47.57 fps - (680, 692)/1920x1080 crop]
                      3280x2464 [21.19 fps - (0, 0)/3280x2464 crop]
1 : imx477 [4056x3040] (/base/soc/i2c0mux/i2c@1/imx477@1a)
    Modes: 'SRGGB10_CSI2P' : 1332x990 [120.05 fps - (696, 528)/2664x1980 crop]
           'SRGGB12_CSI2P' : 2028x1080 [50.03 fps - (0, 440)/4056x2160 crop]
                             2028x1520 [40.01 fps - (0, 0)/4056x3040 crop]
                             4056x3040 [10.00 fps - (0, 0)/4056x3040 crop]
```

For the IMX219 sensor in the above example:

- all modes have an `RGGB` Bayer ordering
- all modes provide either 8-bit or 10-bit CSI2 packed readout at the listed resolutions

camera

Selects the camera to use. Specify an index from the list of available cameras.

config

Alias: `-c`

Specify a file containing CLI options and values. Consider a file named `example_configuration.txt` that contains the following text, specifying options and values as key-value pairs, one option per line, long (non-alias) option names only:

```
timeout=99000
verbose=
```

TIP

> Omit the leading `--` that you normally pass on the command line. For flags that lack a value, such as `verbose` in the above example, you must include a trailing `=`.

You could then run the following command to specify a timeout of 99000 milliseconds and verbose output:

```
$ rpicam-hello --config example_configuration.txt
```

`timeout`

Alias: `-t`

Default value: 5000 milliseconds (5 seconds)

Specify how long the application runs before closing. This applies to both video recording and preview windows. When capturing a still image, the application shows a preview window for `timeout` milliseconds before capturing the output image.

To run the application indefinitely, specify a value of `0`.

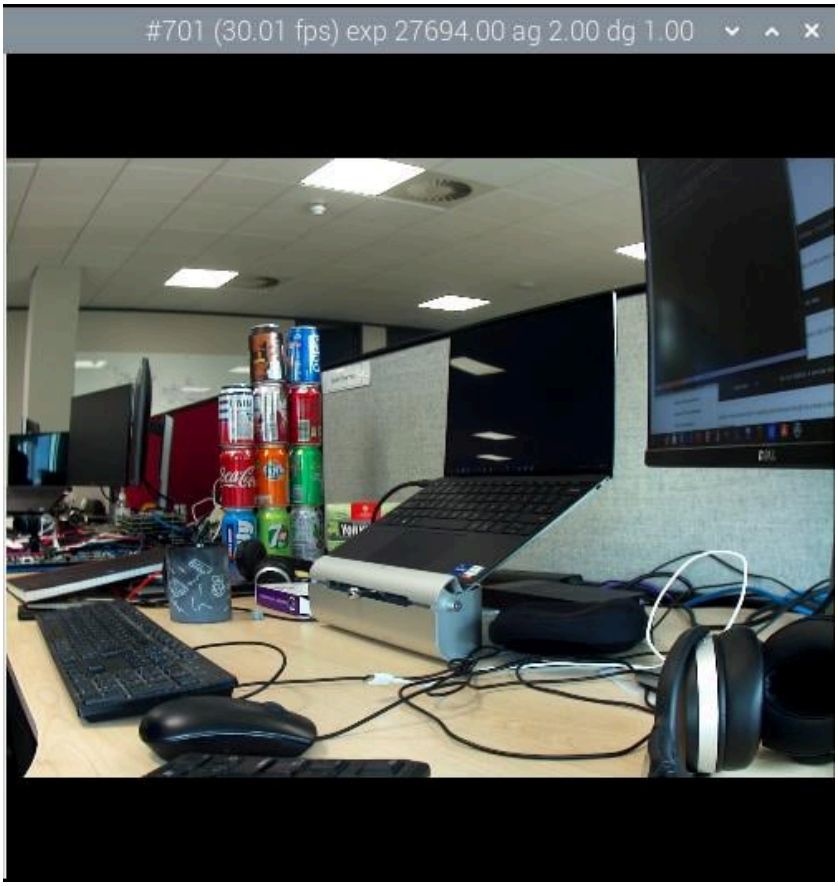
`preview`

Alias: `-p`

Sets the location (x,y coordinates) and size (w,h dimensions) of the desktop or DRM preview window. Does not affect the resolution or aspect ratio of images requested from the camera. Scales image size and pillar or letterboxes image aspect ratio to fit within the preview window.

Pass the preview window dimensions in the following comma-separated form: `x,y,w,h`

Example: `rpicam-hello --preview 100,100,500,500`



`fullscreen`

Alias: `-f`

Forces the preview window to use the entire screen with no border or title bar. Scales image size and pillar or letterboxes image aspect ratio to fit within the entire screen. Does not accept a value.

`qt-preview`

Uses the Qt preview window, which consumes more resources than the alternatives, but supports X window forwarding. Incompatible with the `fullscreen` flag. Does not accept a value.

`nopreview`

Alias: `-n`

Causes the application to *not* display a preview window at all. Does not accept a value.

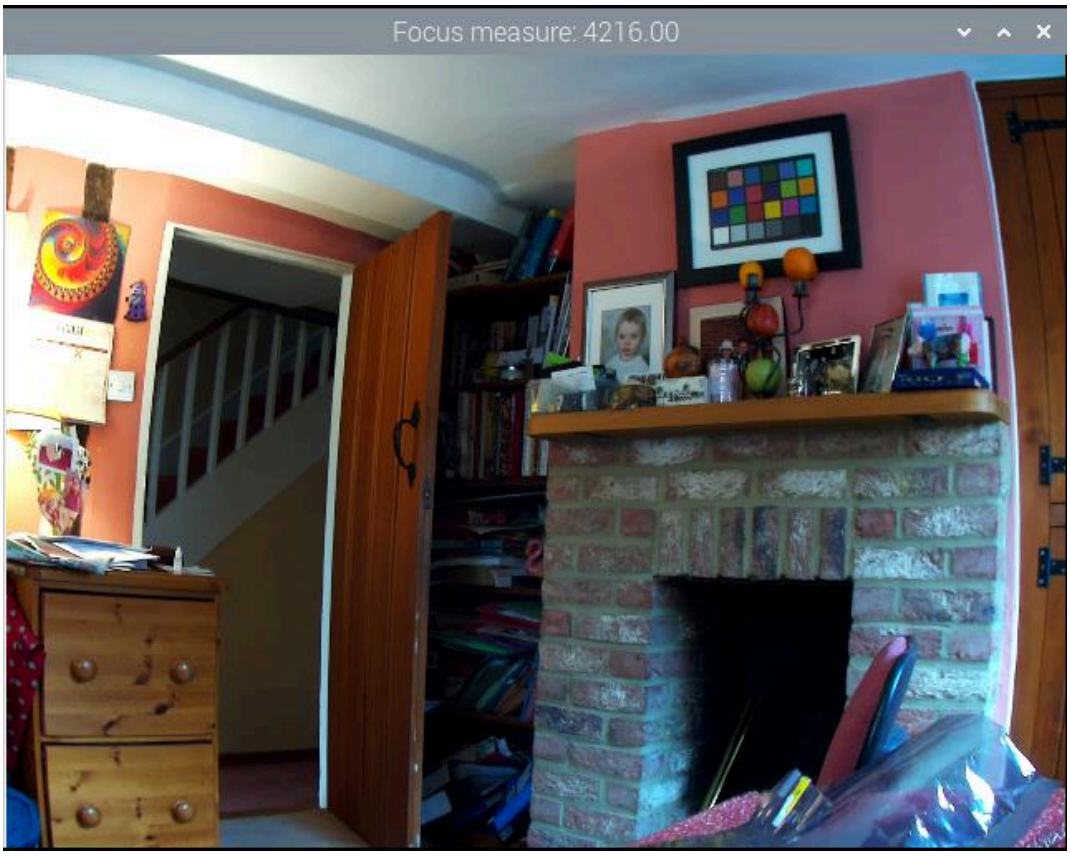
`info-text`

Default value: `"#%frame (%fps fps) exp %exp ag %ag dg %dg"`

Sets the supplied string as the title of the preview window when running in a desktop environment. Supports the following image metadata substitutions:

Directive	Substitution
`%frame`	Sequence number of the frame.
`%fps`	Instantaneous frame rate.
`%exp`	Shutter speed used to capture the image, in microseconds.
`%ag`	Analogue gain applied to the image in the sensor.

Directive	Substitution
`%dg`	Digital gain applied to the image by the ISP.
`%rg`	Gain applied to the red component of each pixel.
`%bg`	Gain applied to the blue component of each pixel.
`%focus`	Focus metric for the image, where a larger value implies a sharper image.
`%lp`	Current lens position in dioptres (1 / distance in metres).
`%afstate`	Autofocus algorithm state (`idle`, `scanning`, `focused` or `failed`).



`width` and `height`

Each accepts a single number defining the dimensions, in pixels, of the captured image.

For `rpicam-still`, `rpicam-jpeg` and `rpicam-vid`, specifies output resolution.

For `rpicam-raw`, specifies raw frame resolution. For cameras with a 2×2 binned readout mode, specifying a resolution equal to or smaller than the binned mode captures 2×2 binned raw frames.

For `rpicam-hello`, has no effect.

Examples:

- `rpicam-vid -o test.h264 --width 1920 --height 1080` captures 1080p video.
- `rpicam-still -r -o test.jpg --width 2028 --height 1520` captures a 2028×1520 resolution JPEG. If used with the HQ camera, uses 2×2 binned mode, so the raw file (`test.dng`) contains a 2028×1520 raw Bayer image.

`viewfinder-width` and `viewfinder-height`

Each accepts a single number defining the dimensions, in pixels, of the image displayed in the preview window. Does not effect the preview window dimensions, since images are resized to fit. Does not affect captured still images or videos.

`mode`

Allows you to specify a camera mode in the following colon-separated format: `<width>:<height>:<bit-depth>:<packing>`. The system selects the closest available option for the sensor if there is not an exact match for a provided value. You can use the packed (`P`) or unpacked (`U`) packing formats. Impacts the format of stored videos and stills, but not the format of frames passed to the preview window.

Bit-depth and packing are optional. Bit-depth defaults to 12. Packing defaults to `P` (packed).

For information about the bit-depth, resolution, and packing options available for your sensor, see `list-cameras`.

Examples:

- `4056:3040:12:P` - 4056×3040 resolution, 12 bits per pixel, packed.
- `1632:1224:10` - 1632×1224 resolution, 10 bits per pixel.
- `2592:1944:10:U` - 2592×1944 resolution, 10 bits per pixel, unpacked.
- `3264:2448` - 3264×2448 resolution.

Packed format details

The packed format uses less storage for pixel data.

On Raspberry Pi 4 and earlier devices, the packed format packs pixels using the MIPI CSI-2 standard. This means:

- 10-bit camera modes pack 4 pixels into 5 bytes. The first 4 bytes contain the 8 most significant bits (MSBs) of each pixel, and the final byte contains the 4 pairs of least significant bits (LSBs).
- 12-bit camera modes pack 2 pixels into 3 bytes. The first 2 bytes contain the 8 most significant bits (MSBs) of each pixel, and the final byte contains the 4 least significant bits (LSBs) of both pixels.

On Raspberry Pi 5 and later devices, the packed format compresses pixel values with a visually lossless compression scheme into 8 bits (1 byte) per pixel.

Unpacked format details

The unpacked format provides pixel values that are much easier to manually manipulate, at the expense of using more storage for pixel data.

On all devices, the unpacked format uses 2 bytes per pixel.

On Raspberry Pi 4 and earlier devices, applications apply zero padding at the **most significant end**. In the unpacked format, a pixel from a 10-bit camera mode cannot exceed the value 1023.

On Raspberry Pi 5 and later devices, applications apply zero padding at the **least significant end**, so images use the full 16-bit dynamic range of the pixel depth delivered by the sensor.

`viewfinder-mode`

Identical to the `mode` option, but it applies to the data passed to the preview window. For more information, see the `mode` documentation.

`lores-width` and `lores-height`

Delivers a second, lower-resolution image stream from the camera, scaled down to the specified dimensions.

Each accepts a single number defining the dimensions, in pixels, of the lower-resolution stream.

Available for preview and video modes. Not available for still captures. If you specify a aspect ratio different from the normal resolution stream, generates non-square pixels.

For `rpicam-vid`, disables extra colour-denoise processing.

Useful for image analysis when combined with image post-processing.

`hflip`

Flips the image horizontally. Does not accept a value.

`vflip`

Flips the image vertically. Does not accept a value.

`rotation`

Rotates the image extracted from the sensor. Accepts only the values 0 or 180.

`roi`

Crops the image extracted from the full field of the sensor. Accepts four decimal values, *ranged 0 to 1*, in the following format: `<x>,<y>,<w>,h>`. Each of these values represents a percentage of the available width and heights as a decimal between 0 and 1.

These values define the following proportions:

- `<x>`: X coordinates to skip before extracting an image
- `<y>`: Y coordinates to skip before extracting an image
- `<w>`: image width to extract
- `<h>`: image height to extract

Defaults to `0,0,1,1` (starts at the first X coordinate and the first Y coordinate, uses 100% of the image width, uses 100% of the image height).

Examples:

- `rpicam-hello --roi 0.25,0.25,0.5,0.5` selects exactly a half of the total number of pixels cropped from the centre of the image (skips the first 25% of X coordinates, skips the first 25% of Y coordinates, uses 50% of the total image width, uses 50% of the total image height).
- `rpicam-hello --roi 0,0,0.25,0.25` selects exactly a quarter of the total number of pixels cropped from the top left of the image (skips the first 0% of X coordinates, skips the first 0% of Y coordinates, uses 25% of the image width, uses 25% of the image height).

`hdr`

Default value: `off`

Runs the camera in HDR mode. If passed without a value, assumes `auto`. Accepts one of the following values:

- `off` - Disables HDR.

- `auto` - Enables HDR on supported devices. Uses the sensor's built-in HDR mode if available. If the sensor lacks a built-in HDR mode, uses on-board HDR mode, if available.
- `single-exp` - Uses on-board HDR mode, if available, even if the sensor has a built-in HDR mode. If on-board HDR mode is not available, disables HDR.

Raspberry Pi 5 and later devices have an on-board HDR mode.

To check for built-in HDR modes in a sensor, pass this option in addition to `list-cameras`.

Camera control options

The following options control image processing and algorithms that affect camera image quality.

`sharpness`

Sets image sharpness. Accepts a numeric value along the following spectrum:

- `0.0` applies no sharpening
- values greater than `0.0`, but less than `1.0` apply less than the default amount of sharpening
- `1.0` applies the default amount of sharpening
- values greater than `1.0` apply extra sharpening

`contrast`

Specifies the image contrast. Accepts a numeric value along the following spectrum:

- `0.0` applies minimum contrast
- values greater than `0.0`, but less than `1.0` apply less than the default amount of contrast
- `1.0` applies the default amount of contrast
- values greater than `1.0` apply extra contrast

`brightness`

Specifies the image brightness, added as an offset to all pixels in the output image. Accepts a numeric value along the following spectrum:

- `-1.0` applies minimum brightness (black)
- `0.0` applies standard brightness
- `1.0` applies maximum brightness (white)

For many use cases, prefer `ev`.

`saturation`

Specifies the image colour saturation. Accepts a numeric value along the following spectrum:

- `0.0` applies minimum saturation (grayscale)
- values greater than `0.0`, but less than `1.0` apply less than the default amount of saturation
- `1.0` applies the default amount of saturation
- values greater than `1.0` apply extra saturation

`ev`

Specifies the exposure value (EV) compensation of the image in stops. Accepts a numeric value that controls target values passed to the Automatic Exposure/Gain Control (AEC/AGC) processing algorithm along the following spectrum:

- `-10.0` applies minimum target values
- `0.0` applies standard target values
- `10.0` applies maximum target values

`shutter`

Specifies the exposure time, using the shutter, in *microseconds*. Gain can still vary when you use this option. If the camera runs at a framerate so fast it does not allow for the specified exposure time (for instance, a framerate of 1fps and an exposure time of 10000 microseconds), the sensor will use the maximum exposure time allowed by the framerate.

For a list of minimum and maximum shutter times for official cameras, see the camera hardware documentation. Values above the maximum result in undefined behaviour.

`gain`

Alias: `--analoggain`

Sets the combined analogue and digital gain. When the sensor driver can provide the requested gain, only uses analogue gain. When analogue gain reaches the maximum value, the ISP applies digital gain. Accepts a numeric value.

For a list of analogue gain limits, for official cameras, see the camera hardware documentation.

Sometimes, digital gain can exceed 1.0 even when the analogue gain limit is not exceeded. This can occur in the following situations:

- Either of the colour gains drops below 1.0, which will cause the digital gain to settle to 1.0/min(red_gain,blue_gain). This keeps the total digital gain applied to any colour channel above 1.0 to avoid discolouration artefacts.
- Slight variances during Automatic Exposure/Gain Control (AEC/AGC) changes.

`metering`

Default value: `centre`

Sets the metering mode of the Automatic Exposure/Gain Control (AEC/AGC) algorithm. Accepts the following values:

- `centre` - centre weighted metering
- `spot` - spot metering
- `average` - average or whole frame metering
- `custom` - custom metering mode defined in the camera tuning file

For more information on defining a custom metering mode, and adjusting region weights in existing metering modes, see the Tuning guide for the Raspberry Pi cameras and libcamera.

`exposure`

Sets the exposure profile. Changing the exposure profile should not affect the image exposure. Instead, different modes adjust gain settings to achieve the same net result. Accepts the following

values:

- `sport`: short exposure, larger gains
- `normal`: normal exposure, normal gains
- `long`: long exposure, smaller gains

You can edit exposure profiles using tuning files. For more information, see the Tuning guide for the Raspberry Pi cameras and libcamera.

`awb`

Sets the Auto White Balance (AWB) mode. Accepts the following values:

Mode name	Colour temperature range
`auto`	2500K to 8000K
`incandescent`	2500K to 3000K
`tungsten`	3000K to 3500K
`fluorescent`	4000K to 4700K
`indoor`	3000K to 5000K
`daylight`	5500K to 6500K
`cloudy`	7000K to 8500K
`custom`	A custom range defined in the tuning file.

These values are only approximate: values could vary according to the camera tuning.

No mode fully disables AWB. Instead, you can fix colour gains with `awbgains`.

For more information on AWB modes, including how to define a custom one, see the Tuning guide for the Raspberry Pi cameras and libcamera.

`awbgains`

Sets a fixed red and blue gain value to be used instead of an Auto White Balance (AWB) algorithm. Set non-zero values to disable AWB. Accepts comma-separated numeric input in the following format: `<red_gain>,<blue_gain>`

`denoise`

Default value: `auto`

Sets the denoising mode. Accepts the following values:

- `auto`: Enables standard spatial denoise. Uses extra-fast colour denoise for video, and high-quality colour denoise for images. Enables no extra colour denoise in the preview window.
- `off`: Disables spatial and colour denoise.
- `cdn_off`: Disables colour denoise.
- `cdn_fast`: Uses fast colour denoise.
- `cdn_hq`: Uses high-quality colour denoise. Not appropriate for video/viewfinder due to reduced throughput.

Even fast colour denoise can lower framerates. High quality colour denoise *significantly* lowers framerates.

`tuning-file`

Specifies the camera tuning file. The tuning file allows you to control many aspects of image processing, including the Automatic Exposure/Gain Control (AEC/AGC), Auto White Balance (AWB), colour shading correction, colour processing, denoising and more. Accepts a tuning file path as input.

For more information about tuning files, see Tuning Files.

`autofocus-mode`

Default value: `default`

Specifies the autofocus mode. Accepts the following values:

- `default`: puts the camera into continuous autofocus mode unless `lens-position` or `autofocus-on-capture` override the mode to manual
- `manual`: does not move the lens at all unless manually configured with `lens-position`
- `auto`: only moves the lens for an autofocus sweep when the camera starts or just before capture if `autofocus-on-capture` is also used
- `continuous`: adjusts the lens position automatically as the scene changes

This option is only supported for certain camera modules.

`autofocus-range`

Default value: `normal`

Specifies the autofocus range. Accepts the following values:

- `normal`: focuses from reasonably close to infinity
- `macro`: focuses only on close objects, including the closest focal distances supported by the camera
- `full`: focus on the entire range, from the very closest objects to infinity

This option is only supported for certain camera modules.

`autofocus-speed`

Default value: `normal`

Specifies the autofocus speed. Accepts the following values:

- `normal`: changes the lens position at normal speed
- `fast`: changes the lens position quickly

This option is only supported for certain camera modules.

`autofocus-window`

Specifies the autofocus window within the full field of the sensor. Accepts four decimal values, *ranged 0 to 1*, in the following format: `<x>,<y>,<w>,h>`. Each of these values represents a percentage of the available width and heights as a decimal between 0 and 1.

These values define the following proportions:

- `<x>`: X coordinates to skip before applying autofocus
- `<y>`: Y coordinates to skip before applying autofocus

- `<w>`: autofocus area width
- `<h>`: autofocus area height

The default value uses the middle third of the output image in both dimensions (1/9 of the total image area).

Examples:

- `rpicam-hello --autofocus-window 0.25,0.25,0.5,0.5` selects exactly half of the total number of pixels cropped from the centre of the image (skips the first 25% of X coordinates, skips the first 25% of Y coordinates, uses 50% of the total image width, uses 50% of the total image height).
- `rpicam-hello --autofocus-window 0,0,0.25,0.25` selects exactly a quarter of the total number of pixels cropped from the top left of the image (skips the first 0% of X coordinates, skips the first 0% of Y coordinates, uses 25% of the image width, uses 25% of the image height).

This option is only supported for certain camera modules.

`lens-position`

Default value: `default`

Moves the lens to a fixed focal distance, normally given in dioptres (units of 1 / *distance in metres*). Accepts the following spectrum of values:

- `0.0`: moves the lens to the "infinity" position
- Any other `number`: moves the lens to the 1 / `number` position. For example, the value `2.0` would focus at approximately 0.5m
- `default`: move the lens to a default position which corresponds to the hyperfocal position of the lens

Lens calibration is imperfect, so different camera modules of the same model may vary.

`verbose`

Alias: `-v`

Default value: `1`

Sets the verbosity level. Accepts the following values:

- `0`: no output
- `1`: normal output
- `2`: verbose output

Output file options

`output`

Alias: `-o`

Sets the name of the file used to record images or video. Besides plaintext file names, accepts the following special values:

- `-`: write to stdout.
- `udp://` (prefix): a network address for UDP streaming.

- `tcp://` (prefix): a network address for TCP streaming.
- Include the `%d` directive in the file name to replace the directive with a count that increments for each opened file. This directive supports standard C format directive modifiers.

Examples:

- `rpicam-vid -t 100000 --segment 10000 -o chunk%04d.h264` records a 100 second file in 10 second segments, where each file includes an incrementing four-digit counter padded with leading zeros: e.g. `chunk0001.h264`, `chunk0002.h264`, etc.
- `rpicam-vid -t 0 --inline -o udp://192.168.1.13:5000` streams H.264 video to network address 192.168.1.13 using UDP on port 5000.

`wrap`

Sets a maximum value for the counter used by the `output` `%d` directive. The counter resets to zero after reaching this value. Accepts a numeric value.

`flush`

Flushes output files to disk as soon as a frame finishes writing, instead of waiting for the system to handle it. Does not accept a value.

`post-process-file`

Specifies a JSON file that configures the post-processing applied by the imaging pipeline. This applies to camera images *before* they reach the application. This works similarly to the legacy `raspicam` "image effects". Accepts a file name path as input.

Post-processing is a large topic and admits the use of third-party software like OpenCV and TensorFlowLite to analyse and manipulate images. For more information, see post-processing.

Image options

Edit this on GitHub

The command line options specified in this section apply only to still image output.

To pass one of the following options to an application, prefix the option name with `--`. If the option requires a value, pass the value immediately after the option name, separated by a single space. If the value contains a space, surround the value in quotes.

Some options have shorthand aliases, for example `-h` instead of `--help`. Use these shorthand aliases instead of the full option name to save space and time at the expense of readability.

`quality`

Alias: `-q`

Default value: `93`

Sets the JPEG quality. Accepts a value between `1` and `100`.

`exif`

Saves extra EXIF tags in the JPEG output file. Only applies to JPEG output. Because of limitations in the `libexif` library, many tags are currently (incorrectly) formatted as ASCII and print a warning in the terminal.

This option is necessary to add certain EXIF tags related to camera settings. You can add tags unrelated to camera settings to the output JPEG after recording with ExifTool.

Example: `rpicam-still -o test.jpg --exif IDO0.Artist=Someone`

`timelapse`

Records images at the specified interval. Accepts an interval in milliseconds. Combine this setting with `timeout` to capture repeated images over time.

You can specify separate filenames for each output file using string formatting, e.g. `--output test%d.jpg`.

Example: `rpicam-still -t 100000 -o test%d.jpg --timelapse 10000` captures an image every 10 seconds for 100 seconds.

`framestart`

Configures a starting value for the frame counter accessed in output file names as `%d`. Accepts an integer starting value.

`datetime`

Uses the current date and time in the output file name, in the form `MMDDhhmmss.jpg`:

- `MM` = 2-digit month number
- `DD` = 2-digit day number
- `hh` = 2-digit 24-hour hour number
- `mm` = 2-digit minute number
- `ss` = 2-digit second number

Does not accept a value.

`timestamp`

Uses the current system Unix time as the output file name. Does not accept a value.

`restart`

Default value: `0`

Configures the restart marker interval for JPEG output. JPEG restart markers can help limit the impact of corruption on JPEG images, and additionally enable the use of multi-threaded JPEG encoding and decoding. Accepts an integer value.

`immediate`

Captures the image immediately when the application runs.

`keypress`

Alias: `-k`

Captures an image when the `timeout` expires or on press of the **Enter** key, whichever comes first. Press the `x` key, then **Enter** to exit without capturing. Does not accept a value.

`signal`

Captures an image when the `timeout` expires or when `SIGUSR1` is received. Use `SIGUSR2` to exit without capturing. Does not accept a value.

`thumb`

Default value: `320:240:70`

Configure the dimensions and quality of the thumbnail with the following format: `<w:h:q>` (or `none`, which omits the thumbnail).

`encoding`

Alias: `-e`

Default value: `jpg`

Sets the encoder to use for image output. Accepts the following values:

- `jpg` - JPEG
- `png` - PNG
- `bmp` - BMP
- `rgb` - binary dump of uncompressed RGB pixels
- `yuv420` - binary dump of uncompressed YUV420 pixels

This option always determines the encoding, overriding the extension passed to `output`.

When using the `datetime` and `timestamp` options, this option determines the output file extension.

`raw`

Alias: `-r`

Saves a raw Bayer file in DNG format in addition to the output image. Replaces the output file name extension with `.dng`. You can process these standard DNG files with tools like *dcraw* or *RawTherapee*. Does not accept a value.

The image data in the raw file is exactly what came out of the sensor, with no processing from the ISP or anything else. The EXIF data saved in the file, among other things, includes:

- exposure time
- analogue gain (the ISO tag is 100 times the analogue gain used)
- white balance gains (which are the reciprocals of the "as shot neutral" values)
- the colour matrix used by the ISP

`latest`

Creates a symbolic link to the most recently saved file. Accepts a symbolic link name as input.

`autofocus-on-capture`

If set, runs an autofocus cycle *just before* capturing an image. Interacts with the following `autofocus_mode` values:

- `default` or `manual`: only runs the capture-time autofocus cycle.

- `auto`: runs an additional autofocus cycle when the preview window loads.
- `continuous`: ignores this option, instead continually focusing throughout the preview.

Does not require a value, but you can pass `1` to enable and `0` to disable. Not passing a value is equivalent to passing `1`.

Only supported by some camera modules (such as the *Raspberry Pi Camera Module 3*).

Video options

Edit this on GitHub

The command line options specified in this section apply only to video output.

To pass one of the following options to an application, prefix the option name with `--`. If the option requires a value, pass the value immediately after the option name, separated by a single space. If the value contains a space, surround the value in quotes.

Some options have shorthand aliases, for example `-h` instead of `--help`. Use these shorthand aliases instead of the full option name to save space and time at the expense of readability.

`quality`

Alias: `-q`

Default value: `50`

Accepts an MJPEG quality level between 1 and 100. Only applies to videos encoded in the MJPEG format.

`bitrate`

Alias: `-b`

Controls the target bitrate used by the H.264 encoder in bits per second. Only applies to videos encoded in the H.264 format. Impacts the size of the output video.

Example: `rpicam-vid -b 10000000 --width 1920 --height 1080 -o test.h264`

`intra`

Alias: `-g`

Default value: `60`

Sets the frequency of Iframes (intra frames) in the H.264 bitstream. Accepts a number of frames. Only applies to videos encoded in the H.264 format.

`profile`

Sets the H.264 profile. Accepts the following values:

- `baseline`
- `main`
- `high`

Only applies to videos encoded in the H.264 format.

`level`

Sets the H.264 level. Accepts the following values:

- `4`
- `4.1`
- `4.2`

Only applies to videos encoded in the H.264 format.

`codec`

Sets the encoder to use for video output. Accepts the following values:

- `h264` - use H.264 encoder (the default)
- `mjpeg` - use MJPEG encoder
- `yuv420` - output uncompressed YUV420 frames.
- `libav` - use the libav backend to encode audio and video (for more information, see `libav`)

`save-pts`

WARNING

> Raspberry Pi 5 does not support the `save-pts` option. Use `libav` to automatically generate timestamps for container formats instead.

Enables frame timestamp output, which allow you to convert the bitstream into a container format using a tool like `mkvmerge`. Accepts a plaintext file name for the timestamp output file.

Example: `rpicam-vid -o test.h264 --save-pts timestamps.txt`

You can then use the following command to generate an MKV container file from the bitstream and timestamps file:

```
$ mkvmerge -o test.mkv --timecodes 0:timestamps.txt test.h264
```

`keypress`

Alias: `-k`

Allows the CLI to enable and disable video output using the **Enter** key. Always starts in the recording state unless specified otherwise with `initial`. Type the `x` key and press **Enter** to exit. Does not accept a value.

`signal`

Alias: `-s`

Allows the CLI to enable and disable video output using `SIGUSR1`. Use `SIGUSR2` to exit. Always starts in the recording state unless specified otherwise with `initial`. Does not accept a value.

`initial`

Default value: `record`

Specifies whether to start the application with video output enabled or disabled. Accepts the following values:

- `record`: Starts with video output enabled.

- `pause`: Starts with video output disabled.

Use this option with either `keypress` or `signal` to toggle between the two states.

`split`

When toggling recording with `keypress` or `signal`, writes the video output from separate recording sessions into separate files. Does not accept a value. Unless combined with `output` to specify unique names for each file, overwrites each time it writes a file.

`segment`

Cuts video output into multiple files of the passed duration. Accepts a duration in milliseconds. If passed a very small duration (for instance, `1`), records each frame to a separate output file to simulate burst capture.

You can specify separate filenames for each file using string formatting, e.g. `--output test%04d.h264`.

`circular`

Default value: `4`

Writes video recording into a circular buffer in memory. When the application quits, records the circular buffer to disk. Accepts an optional size in megabytes.

`inline`

Writes a sequence header in every Iframe (intra frame). This can help clients decode the video sequence from any point in the video, instead of just the beginning. Recommended with `segment`, `split`, `circular`, and streaming options.

Only applies to videos encoded in the H.264 format. Does not accept a value.

`listen`

Waits for an incoming client connection before encoding video. Intended for network streaming over TCP/IP. Does not accept a value.

`frames`

Records exactly the specified number of frames. Any non-zero value overrides `timeout`. Accepts a nonzero integer.

`framerate`

Records exactly the specified framerate. Accepts a nonzero integer.

`libav` options

Edit this on GitHub

The command line options specified in this section apply only to `libav` video backend.

To enable the `libav` backend, pass the `codec` option the value `libav`.

To pass one of the following options to an application, prefix the option name with `--`. If the option requires a value, pass the value immediately after the option name, separated by a single space. If the value contains a space, surround the value in quotes.

Some options have shorthand aliases, for example `-h` instead of `--help`. Use these shorthand aliases instead of the full option name to save space and time at the expense of readability.

`libav-format`

Sets the `libav` output format. Accepts the following values:

- `mkv` encoding
- `mp4` encoding
- `avi` encoding
- `h264` streaming
- `mpegts` streaming

If you do not provide this option, the file extension passed to the `output` option determines the file format.

`libav-audio`

Enables audio recording. When enabled, you must also specify an `audio-codec`. Does not accept a value.

`audio-codec`

Default value: `aac`

Selects an audio codec for output. For a list of available codecs, run `ffmpeg -codecs`.

`audio-bitrate`

Sets the bitrate for audio encoding in bits per second. Accepts numeric input.

Example: `rpicam-vid --codec libav -o test.mp4 --audio_codec mp2 --audio-bitrate 16384` (Records audio at 16 kilobits/sec with the mp2 codec)

`audio-samplerate`

Default value: `0`

Sets the audio sampling rate in Hz. Accepts numeric input. `0` uses the input sample rate.

`audio-device`

Select an ALSO input device for audio recording. For a list of available devices, run the following command:

```
$ pactl list | grep -A2 'Source #' | grep 'Name: '
```

You should see output similar to the following:

```
Name: alsa_output.platform-bcm2835_audio.analog-stereo.monitor
Name: alsa_output.platform-fef00700.hdmi.hdmi-stereo.monitor
Name: alsa_output.usb-GN_Netcom_A_S_Jabra_EVOLVE_LINK_000736B1214E0A-00.analog-stereo.mon
itor
Name: alsa_input.usb-GN_Netcom_A_S_Jabra_EVOLVE_LINK_000736B1214E0A-00.mono-fallback
```

`av-sync`

Shifts the audio sample timestamp by a value in microseconds. Accepts positive and negative numeric values.

Detection options

Edit this on GitHub

The command line options specified in this section apply only to object detection using `rpicam-detect`.

To pass one of the following options to `rpicam-detect`, prefix the option name with `--`. If the option requires a value, pass the value immediately after the option name, separated by a single space. If the value contains a space, surround the value in quotes.

Some options have shorthand aliases, for example `-h` instead of `--help`. Use these shorthand aliases instead of the full option name to save space and time at the expense of readability.

`object`

Detects objects with the given name, sourced from the model's label file. Accepts a plaintext file name as input.

`gap`

Wait at least this many frames between captures. Accepts numeric values.

Post-processing with `rpicam-apps`

Edit this on GitHub

`rpicam-apps` share a common post-processing framework. This allows them to pass the images received from the camera system through a number of custom image-processing and image-analysis routines. Each such routine is known as a *stage*. To run post-processing stages, supply a JSON file instructing the application which stages and options to apply. You can find example JSON files that use the built-in post-processing stages in the `assets` folder of the `rpicam-apps` repository.

For example, the **negate** stage turns light pixels dark and dark pixels light. Because the negate stage is basic, requiring no configuration, `negate.json` just names the stage:

```
{
    "negate": {}
}
```

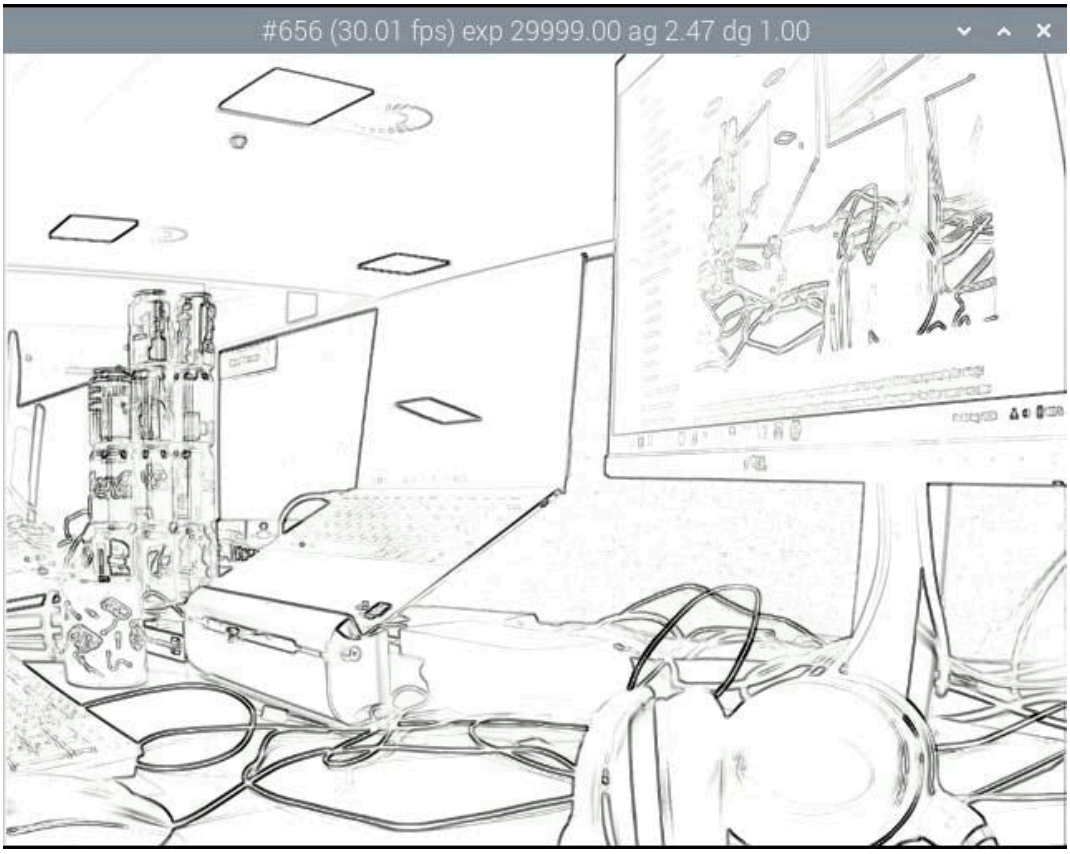
To apply the negate stage to an image, pass `negate.json` to the `post-process-file` option:

```
$ rpicam-hello --post-process-file negate.json
```

To run multiple post-processing stages, create a JSON file that contains multiple stages as top-level keys. For example, to the following configuration runs the Sobel stage, then the negate stage:

```
{
    "sobel_cv":
    {
        "ksize": 5
    },
    "negate": {}
}
```

The Sobel stage uses OpenCV, hence the `cv` suffix. It has a user-configurable parameter, `ksize`, that specifies the kernel size of the filter to be used. In this case, the Sobel filter produces bright edges on a black background, and the negate stage turns this into dark edges on a white background.



A negated Sobel filter.

Some stages, such as `negate`, alter the image in some way. Other stages analyse the image to generate metadata. Post-processing stages can pass this metadata to other stages and even the application.

To improve performance, image analysis often uses reduced resolution. `rpicam-apps` provide a dedicated low-resolution feed directly from the ISP.

NOTE

The `rpicam-apps` supplied with Raspberry Pi OS do not include OpenCV and TensorFlow Lite. As a result, certain post-processing stages that rely on them are disabled. To use these stages, re-compile `rpicam-apps`. On a Raspberry Pi 3 or 4 running a 32-bit kernel, compile with the `-DENABLE_COMPILE_FLAGS_FOR_TARGET=armv8-neon` flag to speed up certain stages.

Built-in stages

`negate` stage

This stage turns light pixels dark and dark pixels light.

The `negate` stage has no user-configurable parameters.

Default `negate.json` file:

```
{
    "negate" : {}
}
```

Run the following command to use this stage file with `rpicam-hello`:

```
$ rpicam-hello --post-process-file negate.json
```

Example output:

A negated image.

`hdr` stage

This stage emphasises details in images using High Dynamic Range (HDR) and Dynamic Range Compression (DRC). DRC uses a single image, while HDR combines multiple images for a similar result.

Parameters fall into three groups: the LP filter, global tonemapping, and local contrast.

This stage applies a smoothing filter to the fully-processed input images to generate a low pass (LP) image. It then generates the high pass (HP) image from the diff of the original and LP images. Then, it applies a global tonemap to the LP image and adds it back to the HP image. This process helps preserve local contrast.

You can configure this stage with the following parameters:

`num_frames`	The number of frames to accumulate; for DRC, use 1; for HDR, try 8
`lp_filter_strength`	The coefficient of the low pass IIR filter.
`lp_filter_threshold`	A piecewise linear function that relates pixel level to the threshold of meaningful detail
`global_tonemap_points`	Points in the input image histogram mapped to targets in the output range where we wish to move them. Uses the following sub-configuration: • an inter-quantile mean (`q` and `width`) • a target as a proportion of the full output range (`target`) • maximum (`max_up`) and minimum (`max_down`) gains to move the measured inter-quantile mean, to prevents the image from changing image too drastically
`global_tonemap_strength`	Strength of application of the global tonemap
`local_pos_strength`	A piecewise linear function that defines the gain applied to local contrast when added back to the tonemapped LP image, for positive (bright) detail
`local_neg_strength`	A piecewise linear function that defines the gain applied to local contrast when added back to the tonemapped LP image, for negative (dark) detail
`local_tonemap_strength`	An overall gain applied to all local contrast that is added back

`local_colour_scale`	A factor that allows the output colours to be affected more or less strongly

To control processing strength, changing the `global_tonemap_strength` and `local_tonemap_strength` parameters.

Processing a single image takes between two and three seconds for a 12MP image on a Raspberry Pi 4. When accumulating multiple frames, this stage sends only the processed image to the application.

Default `drc.json` file for DRC:

```
{
    "hdr" : {
                "num_frames" : 1,
                "lp_filter_strength" : 0.2,
                "lp_filter_threshold" : [ 0, 10.0 , 2048, 205.0, 4095, 205.0 ],
                "global_tonemap_points" :
                        [
                            { "q": 0.1, "width": 0.05, "target": 0.15, "max_up": 1.5, "ma
x_down": 0.7 },
                            { "q": 0.5, "width": 0.05, "target": 0.5, "max_up": 1.5, "max
_down": 0.7 },
                            { "q": 0.8, "width": 0.05, "target": 0.8, "max_up": 1.5, "max
_down": 0.7 }
                        ],
                "global_tonemap_strength" : 1.0,
                "local_pos_strength" : [ 0, 6.0, 1024, 2.0, 4095, 2.0 ],
                "local_neg_strength" : [ 0, 4.0, 1024, 1.5, 4095, 1.5 ],
                "local_tonemap_strength" : 1.0,
                "local_colour_scale" : 0.9
    }
}
```

Example:

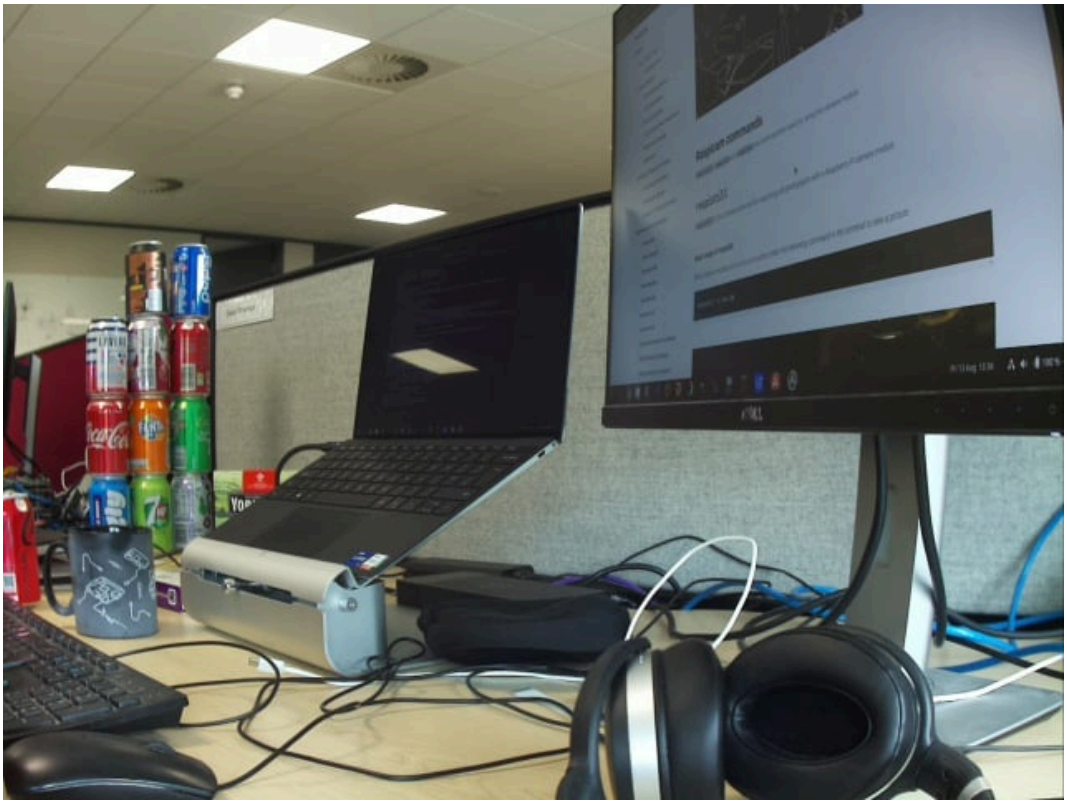


Image without DRC processing

Run the following command to use this stage file with `rpicam-still`:

```
$ rpicam-still -o test.jpg --post-process-file drc.json
```

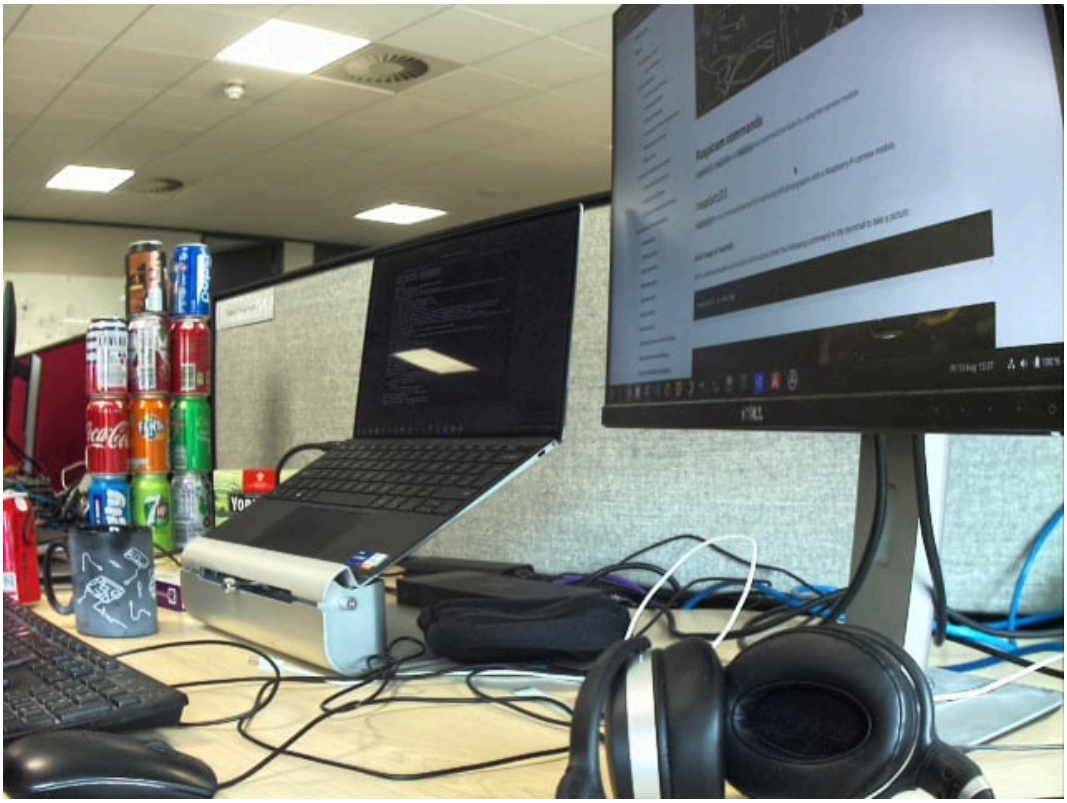


Image with DRC processing

Default **`hdr.json`** file for HDR:

```
{
    "hdr" : {
                "num_frames" : 8,
                "lp_filter_strength" : 0.2,
                "lp_filter_threshold" : [ 0, 10.0 , 2048, 205.0, 4095, 205.0 ],
                "global_tonemap_points" :
                        [
                            { "q": 0.1, "width": 0.05, "target": 0.15, "max_up": 5.0, "ma
x_down": 0.5 },
                            { "q": 0.5, "width": 0.05, "target": 0.45, "max_up": 5.0, "ma
x_down": 0.5 },
                            { "q": 0.8, "width": 0.05, "target": 0.7, "max_up": 5.0, "max
_down": 0.5 }
                        ],
                "global_tonemap_strength" : 1.0,
                "local_pos_strength" : [ 0, 6.0, 1024, 2.0, 4095, 2.0 ],
                "local_neg_strength" : [ 0, 4.0, 1024, 1.5, 4095, 1.5 ],
                "local_tonemap_strength" : 1.0,
                "local_colour_scale" : 0.8
    }
}
```

Example:

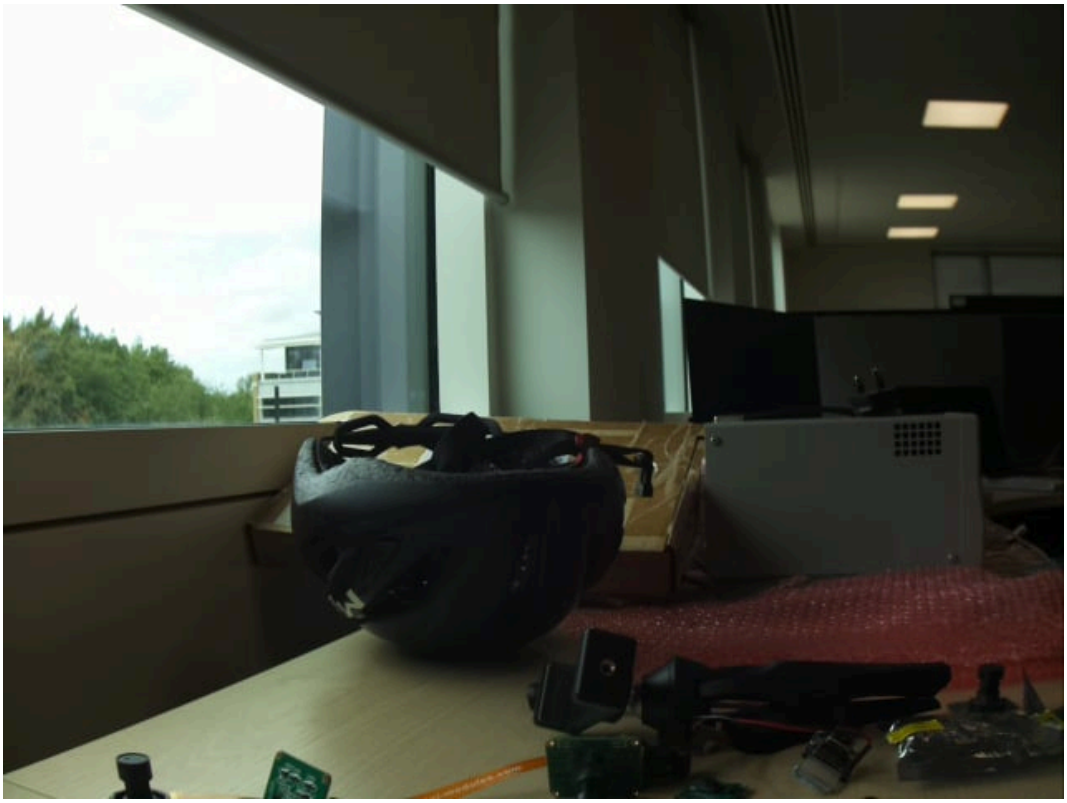


Image without HDR processing

Run the following command to use this stage file with `rpicam-still`:

```
$ rpicam-still -o test.jpg --ev -2 --denoise cdn_off --post-process-file hdr.json
```

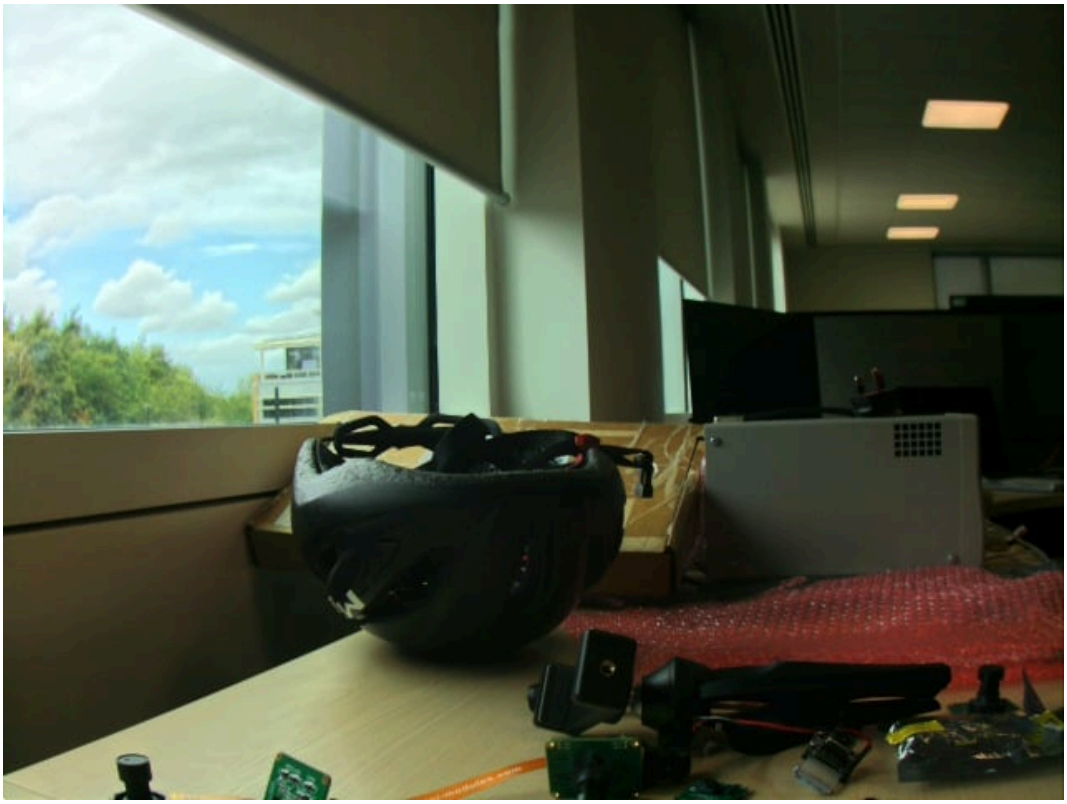


Image with HDR processing

`motion_detect` stage

The `motion_detect` stage analyses frames from the low-resolution image stream. You must configure the low-resolution stream to use this stage. The stage detects motion by comparing a region of interest (ROI) in the frame to the corresponding part of a previous frame. If enough pixels change between frames, this stage indicates the motion in metadata under the `motion_detect.result` key.

This stage has no dependencies on third-party libraries.

You can configure this stage with the following parameters, passing dimensions as a proportion of the low-resolution image size between 0 and 1:

`roi_x`	x-offset of the region of interest for the comparison (proportion between 0 and 1)
`roi_y`	y-offset of the region of interest for the comparison (proportion between 0 and 1)
`roi_width`	Width of the region of interest for the comparison (proportion between 0 and 1)
`roi_height`	Height of the region of interest for the comparison (proportion between 0 and 1)
`difference_m`	Linear coefficient used to construct the threshold for pixels being different
`difference_c`	Constant coefficient used to construct the threshold for pixels being different according to `threshold = difference_m * pixel_value + difference_c`
`frame_period`	The motion detector will run only this many frames
`hskip`	The pixel subsampled by this amount horizontally
`vksip`	The pixel subsampled by this amount vertically
`region_threshold`	The proportion of pixels (regions) which must be categorised as different for them to count as motion
`verbose`	Print messages to the console, including when the motion status changes

Default `motion_detect.json` configuration file:

```
{
    "motion_detect" : {
                "roi_x" : 0.1,
                "roi_y" : 0.1,
                "roi_width" : 0.8,
                "roi_height" : 0.8,
                "difference_m" : 0.1,
                "difference_c" : 10,
                "region_threshold" : 0.005,
                "frame_period" : 5,
                "hskip" : 2,
                "vskip" : 2,
                "verbose" : 0
    }
}
```

Adjust the differences and the threshold to make the algorithm more or less sensitive. To improve performance, use the `hskip` and `vskip` parameters.

Run the following command to use this stage file with `rpicam-hello`:

```
$ rpicam-hello --lores-width 128 --lores-height 96 --post-process-file motion_detect.json
```

Post-processing with OpenCV

Edit this on GitHub

NOTE

> These stages require an OpenCV installation. You may need to rebuild `rpicam-apps` with OpenCV support.

`sobel_cv` stage

This stage applies a Sobel filter to an image to emphasise edges.

You can configure this stage with the following parameters:

`ksize`	Kernel size of the Sobel filter

Default `sobel_cv.json` file:

```
{
    "sobel_cv" : {
        "ksize": 5
    }
}
```

Example:

Using a Sobel filter to emphasise edges.

`face_detect_cv` stage

This stage uses the OpenCV Haar classifier to detect faces in an image. It returns face location metadata under the key `face_detect.results` and optionally draws the locations on the image.

You can configure this stage with the following parameters:

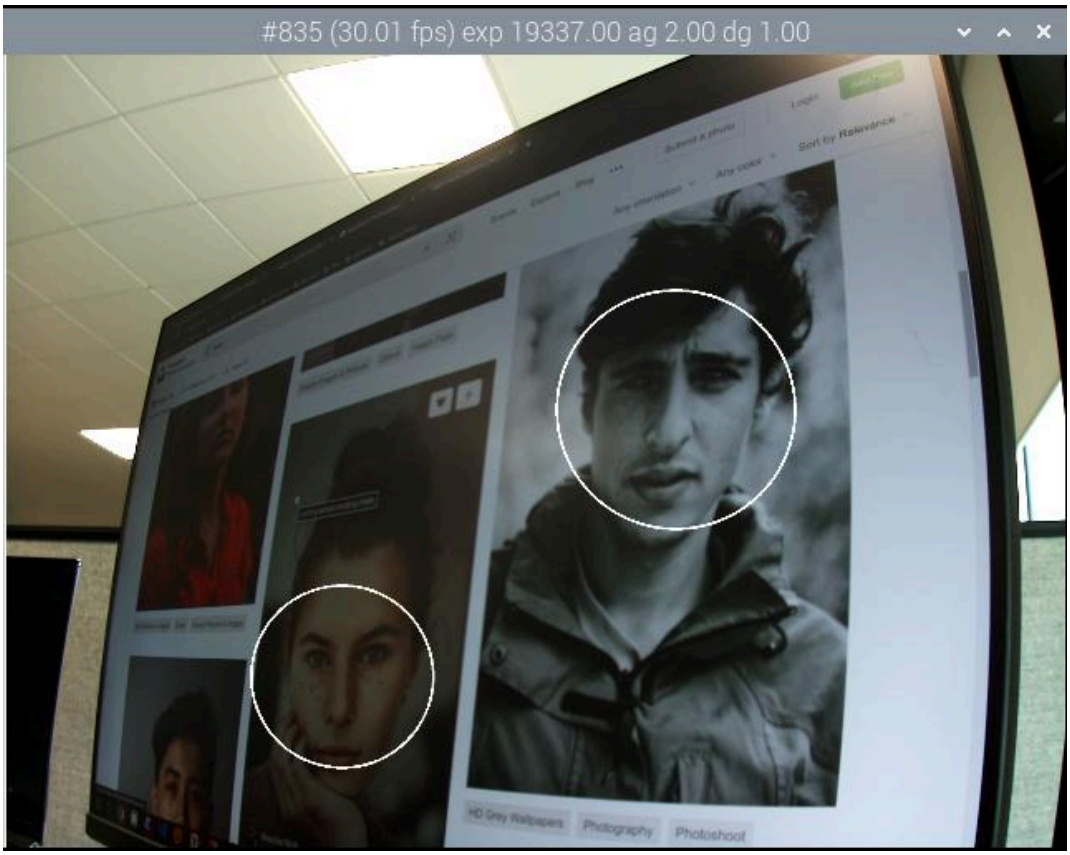
`cascade_name`	Name of the file where the Haar cascade can be found
`scaling_factor`	Determines range of scales at which the image is searched for faces
`min_neighbors`	Minimum number of overlapping neighbours required to count as a face
`min_size`	Minimum face size
`max_size`	Maximum face size
`refresh_rate`	How many frames to wait before trying to re-run the face detector
`draw_features`	Whether to draw face locations on the returned image

The `face_detect_cv` stage runs only during preview and video capture. It ignores still image capture. It runs on the low resolution stream with a resolution between 320×240 and 640×480 pixels.

Default `face_detect_cv.json` file:

```
{
    "face_detect_cv" : {
        "cascade_name" : "/usr/local/share/OpenCV/haarcascades/haarcascade_frontalface_alt.xml",
        "scaling_factor" : 1.1,
        "min_neighbors" : 2,
        "min_size" : 32,
        "max_size" : 256,
        "refresh_rate" : 1,
        "draw_features" : 1
    }
}
```

Example:



Drawing detected faces onto an image.

`annotate_cv` stage

This stage writes text into the top corner of images using the same `%` substitutions as the `info-text` option.

Interprets `info-text` directives first, then passes any remaining tokens to `strftime`.

For example, to achieve a datetime stamp on the video, pass `%F %T %z`:

- `%F` displays the ISO-8601 date (2023-03-07)
- `%T` displays 24h local time (e.g. "09:57:12")
- `%z` displays the timezone relative to UTC (e.g. "-0800")

This stage does not output any metadata, but it writes metadata found in `annotate.text` in place of anything in the JSON configuration file. This allows other post-processing stages to write text onto images.

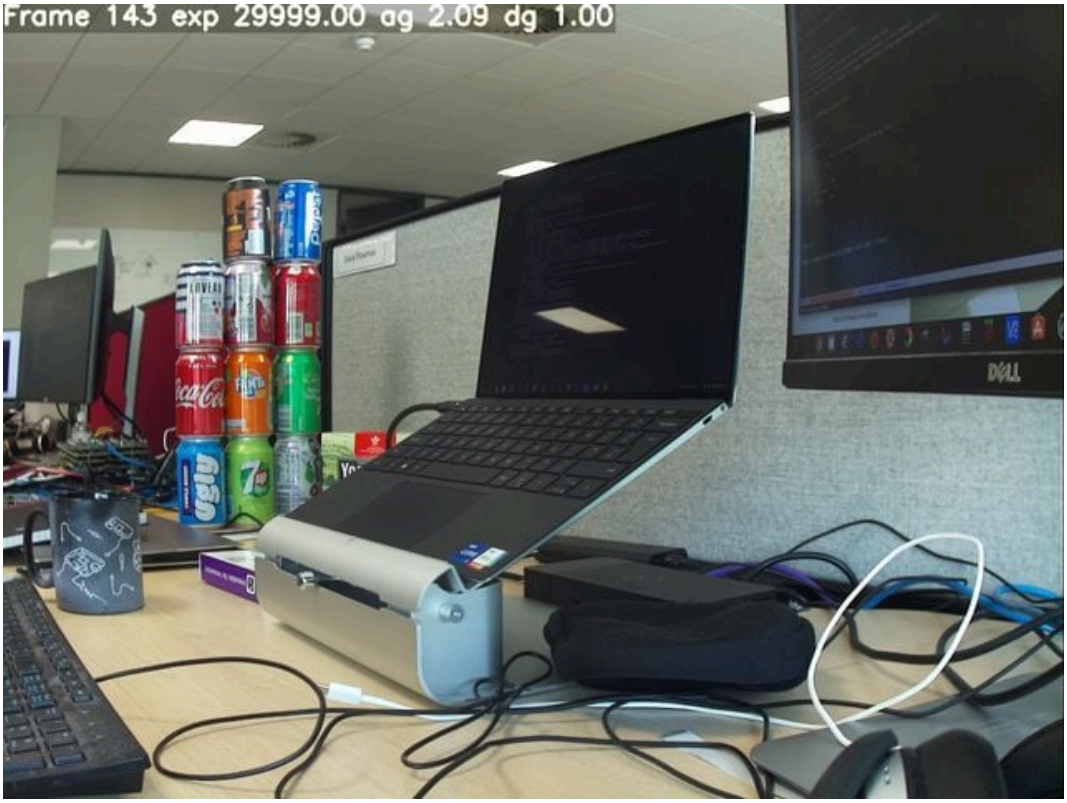
You can configure this stage with the following parameters:

`text`	The text string to be written
`fg`	Foreground colour
`bg`	Background colour
`scale`	A number proportional to the size of the text
`thickness`	A number that determines the thickness of the text
`alpha`	The amount of alpha to apply when overwriting background pixels

Default `annotate_cv.json` file:

```
{
    "annotate_cv" : {
        "text" : "Frame %frame exp %exp ag %ag dg %dg",
        "fg" : 255,
        "bg" : 0,
        "scale" : 1.0,
        "thickness" : 2,
        "alpha" : 0.3
    }
}
```

Example:



Writing camera and date information onto an image with annotations.

Post-Processing with TensorFlow Lite

Edit this on GitHub

Prerequisites

These stages require TensorFlow Lite (TFLite) libraries that export the C++ API. TFLite doesn't distribute libraries in this form, but you can download and install a version that exports the API from lindevs.com.

After installing, you must recompile `rpicam-apps` with TensorFlow Lite support.

`object_classify_tf` stage

Download:
https://storage.googleapis.com/download.tensorflow.org/models/mobilenet_v1_2018_08_02/mobilenet_v1_1.0_224_qu

`object_classify_tf` uses a Google MobileNet v1 model to classify objects in the camera image. This stage requires a `labels.txt` file.

You can configure this stage with the following parameters:

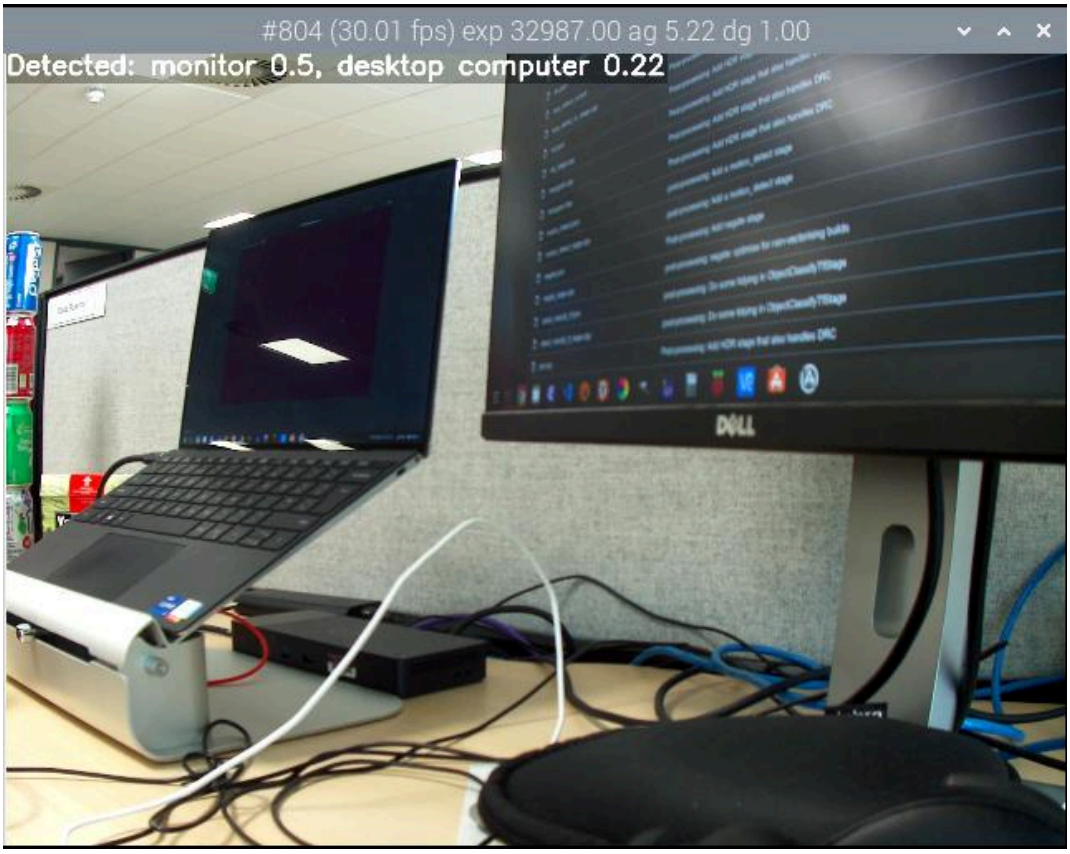
`top_n_results`	The number of results to show
`refresh_rate`	The number of frames that must elapse between model runs
`threshold_high`	Confidence threshold (between 0 and 1) where objects are considered as being present
`threshold_low`	Confidence threshold which objects must drop below before being discarded as matches
`model_file`	Filepath of the TFLite model file
`labels_file`	Filepath of the file containing the object labels
`display_labels`	Whether to display the object labels on the image; inserts `annotate.text` metadata for the `annotate_cv` stage to render
`verbose`	Output more information to the console

Example `object_classify_tf.json` file:

```
{
    "object_classify_tf" : {
        "top_n_results" : 2,
        "refresh_rate" : 30,
        "threshold_high" : 0.6,
        "threshold_low" : 0.4,
        "model_file" : "/home/<username>/models/mobilenet_v1_1.0_224_quant.tflite",
        "labels_file" : "/home/<username>/models/labels.txt",
        "display_labels" : 1
    },
    "annotate_cv" : {
        "text" : "",
        "fg" : 255,
        "bg" : 0,
        "scale" : 1.0,
        "thickness" : 2,
        "alpha" : 0.3
    }
}
```

The stage operates on a low resolution stream image of size 224×224. Run the following command to use this stage file with `rpicam-hello`:

```
$ rpicam-hello --post-process-file object_classify_tf.json --lores-width 224 --lores-heig
ht 224
```



Object classification of a desktop computer and monitor.

`pose_estimation_tf` stage

Download: https://github.com/Qengineering/TensorFlow_Lite_Pose_RPi_32-bits

`pose_estimation_tf` uses a Google MobileNet v1 model to detect pose information.

You can configure this stage with the following parameters:

`refresh_rate`	The number of frames that must elapse between model runs
`model_file`	Filepath of the TFLite model file
`verbose`	Output extra information to the console

Use the separate `plot_pose_cv` stage to draw the detected pose onto the main image.

You can configure the `plot_pose_cv` stage with the following parameters:

`confidence_threshold`	Confidence threshold determining how much to draw; can be less than zero

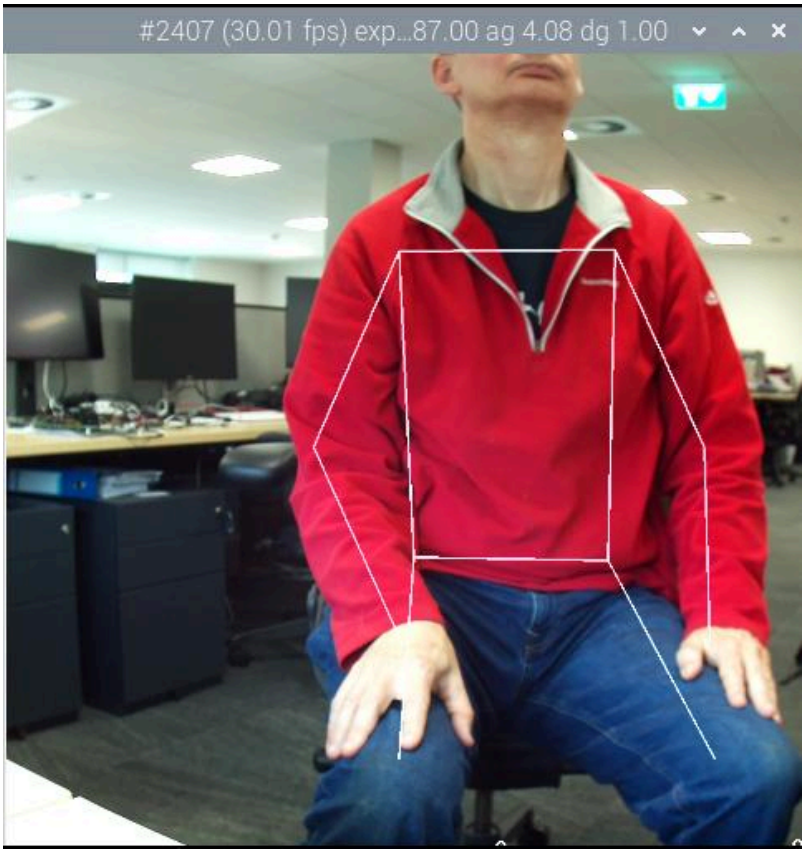
Example `pose_estimation_tf.json` file:

```
{
    "pose_estimation_tf" : {
        "refresh_rate" : 5,
        "model_file" : "posenet_mobilenet_v1_100_257x257_multi_kpt_stripped.tflite"
    },
    "plot_pose_cv" : {
       "confidence_threshold" : -0.5
    }
}
```

The stage operates on a low resolution stream image of size 257×257. **Because YUV420 images must have even dimensions, round up to 258×258 for YUV420 images.**

Run the following command to use this stage file with `rpicam-hello`:

```
$ rpicam-hello --post-process-file pose_estimation_tf.json --lores-width 258 --lores-heig
ht 258
```



Pose estimation of an adult human male.

`object_detect_tf` stage

Download:
https://storage.googleapis.com/download.tensorflow.org/models/tflite/coco_ssd_mobilenet_v1_1.0_quant_2018_06_29

`object_detect_tf` uses a Google MobileNet v1 SSD (Single Shot Detector) model to detect and label objects.

You can configure this stage with the following parameters:

`refresh_rate`	The number of frames that must elapse between model runs
`model_file`	Filepath of the TFLite model file
`labels_file`	Filepath of the file containing the list of labels
`confidence_threshold`	Confidence threshold before accepting a match
`overlap_threshold`	Determines the amount of overlap between matches for them to be merged as a single match.
`verbose`	Output extra information to the console

Use the separate `object_detect_draw_cv` stage to draw the detected objects onto the main image.

You can configure the `object_detect_draw_cv` stage with the following parameters:

`line_thickness`	Thickness of the bounding box lines
`font_size`	Size of the font used for the label

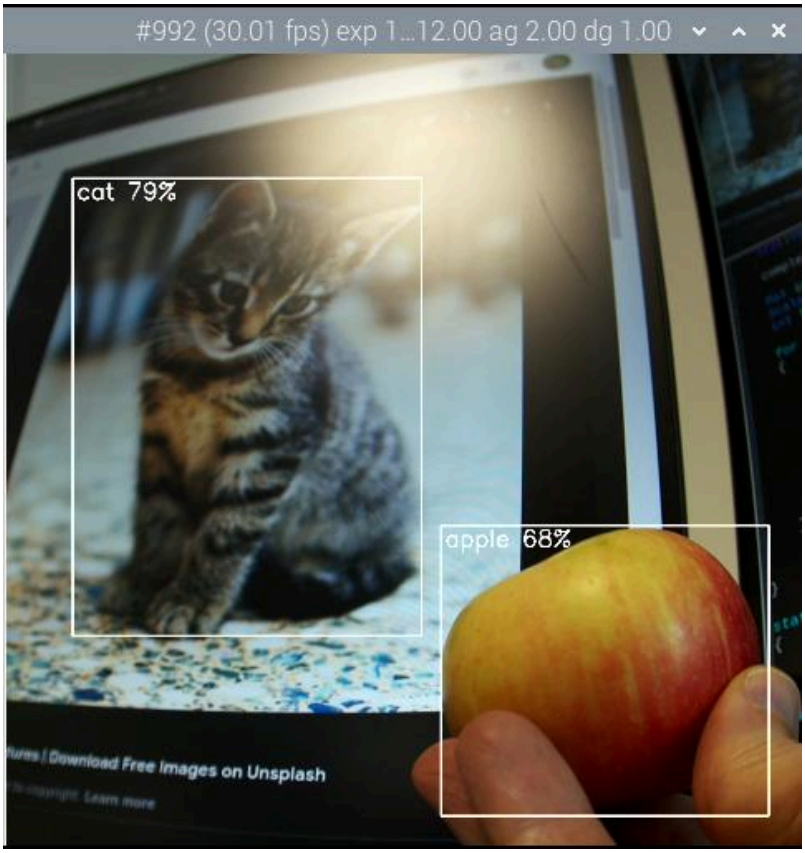
Example `object_detect_tf.json` file:

```
{
    "object_detect_tf" : {
        "number_of_threads" : 2,
        "refresh_rate" : 10,
        "confidence_threshold" : 0.5,
        "overlap_threshold" : 0.5,
        "model_file" : "/home/<username>/models/coco_ssd_mobilenet_v1_1.0_quant_2018_06_2
9/detect.tflite",
```

```
        "labels_file" : "/home/<username>/models/coco_ssd_mobilenet_v1_1.0_quant_2018_06_
29/labelmap.txt",
        "verbose" : 1
    },
    "object_detect_draw_cv" : {
       "line_thickness" : 2
    }
}
```

The stage operates on a low resolution stream image of size 300×300. Run the following command, which passes a 300×300 crop to the detector from the centre of the 400×300 low resolution image, to use this stage file with `rpicam-hello`:

```
$ rpicam-hello --post-process-file object_detect_tf.json --lores-width 400 --lores-height
300
```



Detecting apple and cat objects.

`segmentation_tf` stage

Download: https://tfhub.dev/tensorflow/lite-model/deeplabv3/1/metadata/2?lite-format=tflite

`segmentation_tf` uses a Google MobileNet v1 model. This stage requires a label file, found at the `assets/segmentation_labels.txt`.

This stage runs on an image of size 257×257. Because YUV420 images must have even dimensions, the low resolution image should be at least 258 pixels in both width and height. The stage adds a vector of 257×257 values to the image metadata where each value indicates the categories a pixel belongs to. You can optionally draw a representation of the segmentation into the bottom right corner of the image.

You can configure this stage with the following parameters:

`refresh_rate`	The number of frames that must elapse between model runs
`model_file`	Filepath of the TFLite model file
`labels_file`	Filepath of the file containing the list of labels
`threshold`	When verbose is set, prints when the number of pixels with any label exceeds this number

`draw`	Draws the segmentation map into the bottom right hand corner of the image
`verbose`	Output extra information to the console

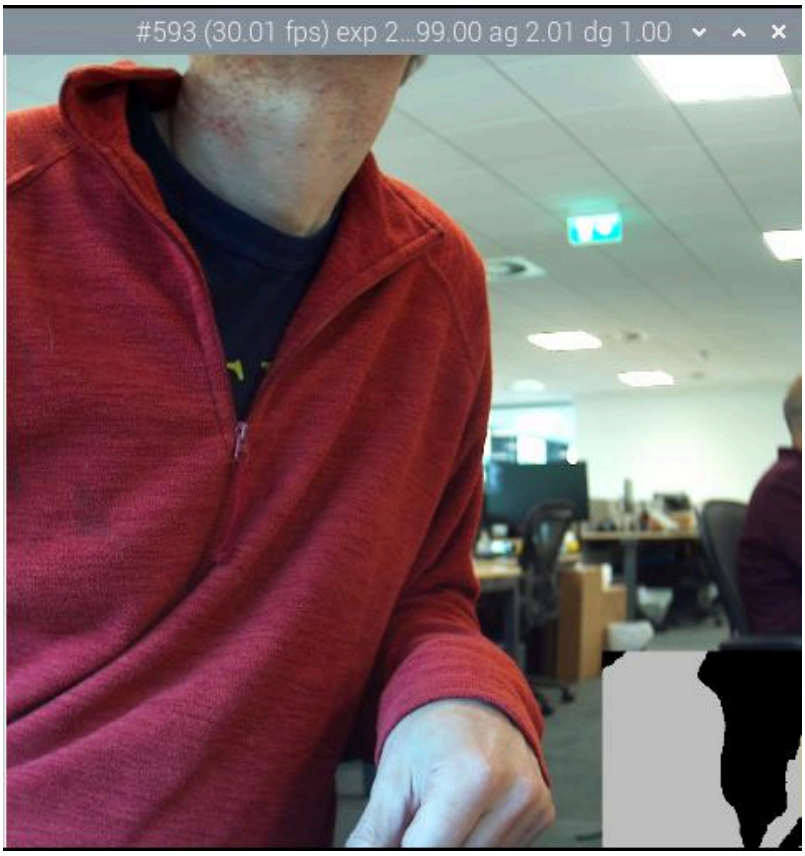
Example `segmentation_tf.json` file:

```
{
    "segmentation_tf" : {
        "number_of_threads" : 2,
        "refresh_rate" : 10,
        "model_file" : "/home/<username>/models/lite-model_deeplabv3_1_metadata_2.tflit
e",
        "labels_file" : "/home/<username>/models/segmentation_labels.txt",
        "draw" : 1,
        "verbose" : 1
    }
}
```

This example takes a camera image and reduces it to 258×258 pixels in size. This stage even works when squashing a non-square image without cropping. This example enables the segmentation map in the bottom right hand corner.

Run the following command to use this stage file with `rpicam-hello`:

```
$ rpicam-hello --post-process-file segmentation_tf.json --lores-width 258 --lores-height
258 --viewfinder-width 1024 --viewfinder-height 1024
```



Running segmentation and displaying the results on a map in the bottom right.

Write your own post-processing stages

Edit this on GitHub

With the `rpicam-apps` post-processing framework, users can create their own custom post-processing stages. You can even include algorithms and routines from OpenCV and TensorFlow Lite.

Basic post-processing stages

To create your own post-processing stage, derive a new class from the `PostProcessingStage` class. All post-processing stages must implement the following member functions:

`char const *Name() const`
: Returns the name of the stage. Matched against stages listed in the JSON post-processing configuration file.

`void Read(boost::property_tree::ptree const &params)`
: Reads the stage's configuration parameters from a provided JSON file.

`void AdjustConfig(std::string const &use_case, StreamConfiguration *config)`
: Gives stages a chance to influence the configuration of the camera. Frequently empty for stages with no need to configure the camera.

`void Configure()`
: Called just after the camera has been configured to allocate resources and check that the stage has access to necessary streams.

`void Start()`
: Called when the camera starts. Frequently empty for stages with no need to configure the camera.

`bool Process(CompletedRequest &completed_request)`
: Presents completed camera requests for post-processing. This is where you'll implement pixel manipulations and image analysis. Returns `true` if the post-processing framework should **not** deliver this request to the application.

`void Stop()`
: Called when the camera stops. Used to shut down any active processing on asynchronous threads.

`void Teardown()`
: Called when the camera configuration is destroyed. Use this as a deconstructor where you can de-allocate resources set up in the `Configure` method.

In any stage implementation, call `RegisterStage` to register your stage with the system.

Don't forget to add your stage to `meson.build` in the post-processing folder. When writing your own stages, keep these tips in mind:

- The `Process` method blocks the imaging pipeline. If it takes too long, the pipeline will stutter. **Always delegate time-consuming algorithms to an asynchronous thread.**
- When delegating work to another thread, you must copy the image buffers. For applications like image analysis that don't require full resolution, try using a low-resolution image stream.
- The post-processing framework *uses parallelism to process every frame*. This improves throughput. However, some OpenCV and TensorFlow Lite functions introduce another layer of parallelism *within* each frame. Consider serialising calls within each frame since post-processing already takes advantage of multiple threads.
- Most streams, including the low resolution stream, use the YUV420 format. You may need to convert this to another format for certain OpenCV or TFLite functions.
- For the best performance, always alter images in-place.

For a basic example, see `negate_stage.cpp`. This stage negates an image by turning light pixels dark and dark pixels light. This stage is mostly derived class boiler-plate, achieving the negation logic in barely half a dozen lines of code.

For another example, see `sobel_cv_stage.cpp`, which implements a Sobel filter in just a few lines of OpenCV functions.

TensorFlow Lite stages

For stages that use TensorFlow Lite (TFLite), derive a new class from the `TfStage` class. This class delegates model execution to a separate thread to prevent camera stuttering.

The `TfStage` class implements all the `PostProcessingStage` member functions post-processing stages must normally implement, *except for* `Name`. All `TfStage`-derived stages must implement the `Name` function, and should implement some or all of the following virtual member functions:

`void readExtras()`
: The base class reads the named model and certain other parameters like the `refresh_rate`. Use this function this to read extra parameters for the derived stage and check that the loaded model is correct (e.g. has right input and output dimensions).

`void checkConfiguration()`
: The base class fetches the low resolution stream that TFLite operates on and the full resolution stream in case the derived stage needs it. Use this function to check for the streams required by your stage. If your stage can't access one of the required streams, you might skip processing or throw an error.

`void interpretOutputs()`
: Use this function to read and interpret the model output. *Runs in the same thread as the model when the model completes*.

`void applyResults()`
: Use this function to apply results of the model (could be several frames old) to the current frame. Typically involves attaching metadata or drawing. *Runs in the main thread, before frames are delivered*.

For an example implementation, see the `object_classify_tf_stage.cpp` and `pose_estimation_tf_stage.cpp`.

Advanced `rpicam-apps`

Edit this on GitHub

Build `libcamera` and `rpicam-apps`

Build `libcamera` and `rpicam-apps` for yourself for the following benefits:

- You can pick up the latest enhancements and features.
- `rpicam-apps` can be compiled with extra optimisation for Raspberry Pi 3 and Raspberry Pi 4 devices running a 32-bit OS.
- You can include optional OpenCV and/or TFLite post-processing stages, or add your own.
- You can customise or add your own applications derived from `rpicam-apps`

Remove pre-installed `rpicam-apps`

Raspberry Pi OS includes a pre-installed copy of `rpicam-apps`. Before building and installing your own version of `rpicam-apps`, you must first remove the pre-installed version. Run the following command to remove the `rpicam-apps` package from your Raspberry Pi:

```
$ sudo apt remove --purge rpicam-apps
```

Building `rpicam-apps` without building `libcamera`

To build `rpicam-apps` without first rebuilding `libcamera` and `libepoxy`, install `libcamera`, `libepoxy` and their dependencies with `apt`:

```
$ sudo apt install -y libcamera-dev libepoxy-dev libjpeg-dev libtiff5-dev libpng-dev
```

TIP

If you do not need support for the GLES/EGL preview window, omit `libepoxy-dev`.

To use the Qt preview window, install the following additional dependencies:

```
$ sudo apt install -y qtbase5-dev libqt5core5a libqt5gui5 libqt5widgets5
```

For `libav` support in `rpicam-vid`, install the following additional dependencies:

```
$ sudo apt install libavcodec-dev libavdevice-dev libavformat-dev libswresample-dev
```

If you run Raspberry Pi OS Lite, install `git`:

```
$ sudo apt install -y git
```

Next, build `rpicam-apps`.

Building `libcamera`

NOTE

Only build `libcamera` from scratch if you need custom behaviour or the latest features that have not yet reached `apt` repositories.

NOTE

If you run Raspberry Pi OS Lite, begin by installing the following packages:

```
$ sudo apt install -y python3-pip git python3-jinja2
```

First, install the following `libcamera` dependencies:

```
$ sudo apt install -y libboost-dev
$ sudo apt install -y libgnutls28-dev openssl libtiff5-dev pybind11-dev
$ sudo apt install -y qtbase5-dev libqt5core5a libqt5gui5 libqt5widgets5
$ sudo apt install -y meson cmake
$ sudo apt install -y python3-yaml python3-ply
$ sudo apt install -y libglib2.0-dev libgstreamer-plugins-base1.0-dev
```

Now we're ready to build `libcamera` itself.

Download a local copy of Raspberry Pi's fork of `libcamera` from GitHub:

```
$ git clone https://github.com/raspberrypi/libcamera.git
```

Navigate into the root directory of the repository:

```
$ cd libcamera
```

Next, run `meson` to configure the build environment:

```
$ meson setup build --buildtype=release -Dpipelines=rpi/vc4,rpi/pisp -Dipas=rpi/vc4,rpi/p
isp -Dv4l2=true -Dgstreamer=enabled -Dtest=false -Dlc-compliance=disabled -Dcam=disabled
-Dqcam=disabled -Ddocumentation=disabled -Dpycamera=enabled
```

NOTE

You can disable the `gstreamer` plugin by replacing `-Dgstreamer=enabled` with `-Dgstreamer=disabled` during the `meson` build configuration. If you disable `gstreamer`, there is no need to install the `libglib2.0-dev` and `libgstreamer-plugins-base1.0-dev` dependencies.

Now, you can build `libcamera` with `ninja`:

```
$ ninja -C build
```

Finally, run the following command to install your freshly-built `libcamera` binary:

```
$ sudo ninja -C build install
```

TIP

> On devices with 1GB of memory or less, the build may exceed available memory. Append the `-j 1` flag to `ninja` commands to limit the build to a single process. This should prevent the build from exceeding available memory on devices like the Raspberry Pi Zero and the Raspberry Pi 3.

`libcamera` does not yet have a stable binary interface. Always build `rpicam-apps` after you build `libcamera`.

Building `rpicam-apps`

First fetch the necessary dependencies for `rpicam-apps`.

```
$ sudo apt install -y cmake libboost-program-options-dev libdrm-dev libexif-dev
$ sudo apt install -y meson ninja-build
```

Download a local copy of Raspberry Pi's `rpicam-apps` GitHub repository:

```
$ git clone https://github.com/raspberrypi/rpicam-apps.git
```

Navigate into the root directory of the repository:

```
$ cd rpicam-apps
```

For desktop-based operating systems like Raspberry Pi OS, configure the `rpicam-apps` build with the following `meson` command:

```
$ meson setup build -Denable_libav=enabled -Denable_drm=enabled -Denable_egl=enabled -Den
able_qt=enabled -Denable_opencv=disabled -Denable_tflite=disabled -Denable_hailo=disabled
```

For headless operating systems like Raspberry Pi OS Lite, configure the `rpicam-apps` build with the following `meson` command:

```
$ meson setup build -Denable_libav=disabled -Denable_drm=enabled -Denable_egl=disabled -D
enable_qt=disabled -Denable_opencv=disabled -Denable_tflite=disabled -Denable_hailo=disab
led
```

TIP

> - Use `-Dneon_flags=armv8-neon` to enable optimisations for 32-bit OSes on Raspberry Pi 3 or Raspberry Pi 4.
> - Use `-Denable_opencv=enabled` if you have installed OpenCV and wish to use OpenCV-based post-processing stages.
> - Use `-Denable_tflite=enabled` if you have installed TensorFlow Lite and wish to use it in post-processing stages.
> - Use `-Denable_hailo=enabled` if you have installed HailoRT and wish to use it in post-processing stages.

You can now build `rpicam-apps` with the following command:

```
$ meson compile -C build
```

TIP

> On devices with 1GB of memory or less, the build may exceed available memory. Append the `-j 1` flag to `meson` commands to limit the build to a single process. This should prevent the build from exceeding available memory on devices like the Raspberry Pi Zero and the Raspberry Pi 3.

Finally, run the following command to install your freshly-built `rpicam-apps` binary:

```
$ sudo meson install -C build
```

TIP

The command above should automatically update the `ldconfig` cache. If you have trouble accessing your new `rpicam-apps` build, run the following command to update the cache:

```
$ sudo ldconfig
```

Run the following command to check that your device uses the new binary:

```
$ rpicam-still --version
```

The output should include the date and time of your local `rpicam-apps` build.

Finally, follow the `dtoverlay` and display driver instructions in the Configuration section.

`rpicam-apps` meson flag reference

The `meson` build configuration for `rpicam-apps` supports the following flags:

`-Dneon_flags=armv8-neon`
: Speeds up certain post-processing features on Raspberry Pi 3 or Raspberry Pi 4 devices running a 32-bit OS.

`-Denable_libav=enabled`
: Enables or disables `libav` encoder integration.

`-Denable_drm=enabled`
: Enables or disables **DRM/KMS preview rendering**, a preview window used in the absence of a desktop environment.

`-Denable_egl=enabled`
: Enables or disables the non-Qt desktop environment-based preview. Disable if your system lacks a desktop environment.

`-Denable_qt=enabled`
: Enables or disables support for the Qt-based implementation of the preview window. Disable if you do not have a desktop environment installed or if you have no intention of using the Qt-based preview window. The Qt-based preview is normally not recommended because it is computationally very expensive, however it does work with X display forwarding.

`-Denable_opencv=enabled`
: Forces OpenCV-based post-processing stages to link or not link. Requires OpenCV to enable. Defaults to `disabled`.

`-Denable_tflite=enabled`
: Enables or disables TensorFlow Lite post-processing stages. Disabled by default. Requires Tensorflow Lite to enable. Depending on how you have built and/or installed TFLite, you may need to tweak the `meson.build` file in the `post_processing_stages` directory.

`-Denable_hailo=enabled`
: Enables or disables HailoRT-based post-processing stages. Requires HailoRT to enable. Defaults to `auto`.

`-Ddownload_hailo_models=true`
: Downloads and installs models for HailoRT post-processing stages. Requires `wget` to be installed. Defaults to `true`.

Each of the above options (except for `neon_flags`) supports the following values:

- `enabled`: enables the option, fails the build if dependencies are not available
- `disabled`: disables the option

- `auto`: enables the option if dependencies are available

Building `libepoxy`

Rebuilding `libepoxy` should not normally be necessary as this library changes only very rarely. If you do want to build it from scratch, however, please follow the instructions below.

Start by installing the necessary dependencies.

```
$ sudo apt install -y libegl1-mesa-dev
```

Next, download a local copy of the `libepoxy` repository from GitHub:

```
$ git clone https://github.com/anholt/libepoxy.git
```

Navigate into the root directory of the repository:

```
$ cd libepoxy
```

Create a build directory at the root level of the repository, then navigate into that directory:

```
$ mkdir _build
$ cd _build
```

Next, run `meson` to configure the build environment:

```
$ meson
```

Now, you can build `libexpoxy` with `ninja`:

```
$ ninja
```

Finally, run the following command to install your freshly-built `libepoxy` binary:

```
$ sudo ninja install
```

Write your own `rpicam` apps

Edit this on GitHub

`rpicam-apps` does not provide all of the camera-related features that anyone could ever need. Instead, these applications are small and flexible. Users who require different behaviour can implement it themselves.

All of the `rpicam-apps` use an event loop that receives messages when a new set of frames arrives from the camera system. This set of frames is called a `CompletedRequest`. The `CompletedRequest` contains:

- all images derived from that single camera frame: often a low-resolution image and a full-size output
- metadata from the camera and post-processing systems

`rpicam-hello`

`rpicam-hello` is the smallest application, and the best place to start understanding `rpicam-apps` design. It extracts the `CompletedRequestPtr`, a shared pointer to the `CompletedRequest`, from the message, and forwards it to the preview window:

```
CompletedRequestPtr &completed_request = std::get<CompletedRequestPtr>(msg.payload);
app.ShowPreview(completed_request, app.ViewfinderStream());
```

Every `CompletedRequest` must be recycled back to the camera system so that the buffers can be reused. Otherwise, the camera runs out of buffers for new camera frames. This recycling process happens automatically when no references to the `CompletedRequest` remain using C++'s *shared pointer* and *custom deleter* mechanisms.

As a result, `rpicam-hello` must complete the following actions to recycle the buffer space:

- The event loop must finish a cycle so the message (`msg` in the code), which holds a reference to `CompletedRequest`, can be replaced with the next message. This discards the reference to the previous message.
- When the event thread calls `ShowPreview`, it passes the preview thread a reference to the `CompletedRequest`. The preview thread discards the last `CompletedRequest` instance each time `ShowPreview` is called.

`rpicam-vid`

`rpicam-vid` is similar to `rpicam-hello` with encoding added to the event loop. Before the event loop starts, `rpicam-vid` configures the encoder with a callback. The callback handles the buffer containing the encoded image data. In the code below, we send the buffer to the `Output` object. `Output` could write it to a file or stream it, depending on the options specified.

```
app.SetEncodeOutputReadyCallback(std::bind(&Output::OutputReady, output.get(), _1, _2, _
3, _4));
```

Because this code passes the encoder a reference to the `CompletedRequest`, `rpicam-vid` can't recycle buffer data until the event loop, preview window, *and* encoder all discard their references.

`rpicam-raw`

`rpicam-raw` is similar to `rpicam-vid`. It also encodes during the event loop. However, `rpicam-raw` uses a dummy encoder called the `NullEncoder`. This uses the input image as the output buffer instead of encoding it with a codec. `NullEncoder` only discards its reference to the buffer once the output callback completes. This guarantees that the buffer isn't recycled before the callback processes the image.

`rpicam-raw` doesn't forward anything to the preview window.

`NullEncoder` is possibly overkill in `rpicam-raw`. We could probably send images straight to the `Output` object, instead. However, `rpicam-apps` need to limit work in the event loop. `NullEncoder` demonstrates how you can handle most processes (even holding onto a reference) in other threads.

`rpicam-jpeg`

`rpicam-jpeg` starts the camera in preview mode in the usual way. When the timer completes, it stops the preview and switches to still capture:

```
app.StopCamera();
app.Teardown();
app.ConfigureStill();
app.StartCamera();
```

The event loop grabs the first frame returned from still mode and saves this as a JPEG.

Use `libcamera` with Qt

Qt is a popular application framework and GUI toolkit. `rpicam-apps` includes an option to use Qt for a camera preview window.

Unfortunately, Qt defines certain symbols (such as `slot` and `emit`) as macros in the global namespace. This causes errors when including `libcamera` files. The problem is common to all platforms that use both Qt and `libcamera`. Try the following workarounds to avoid these errors:

- List `libcamera` include files, or files that include `libcamera` files (such as `rpicam-apps` files), *before* any Qt header files whenever possible.
- If you do need to mix your Qt application files with `libcamera` includes, replace `signals:` with `Q_SIGNALS:`, `slots:` with `Q_SLOTS:`, `emit` with `Q_EMIT` and `foreach` with `Q_FOREACH`.
- Add the following at the top of any `libcamera` include files:

```
#undef signals
#undef slots
#undef emit
#undef foreach
```

- If your project uses `qmake`, add `CONFIG += no_keywords` to the project file.
- If your project uses `cmake`, add `SET(QT_NO_KEYWORDS ON)`.

Use `libcamera` from Python with Picamera2

Edit this on GitHub

The Picamera2 library is a `rpicam`-based replacement for Picamera, which was a Python interface to Raspberry Pi's legacy camera stack. Picamera2 presents an easy-to-use Python API.

Documentation about Picamera2 is available on GitHub and in the Picamera2 manual.

Installation

Recent Raspberry Pi OS images include Picamera2 with all the GUI (Qt and OpenGL) dependencies. Recent Raspberry Pi OS Lite images include Picamera2 without the GUI dependencies, although preview images can still be displayed using DRM/KMS.

If your image did not include Picamera2, run the following command to install Picamera2 with all of the GUI dependencies:

```
$ sudo apt install -y python3-picamera2
```

If you don't want the GUI dependencies, you can run the following command to install Picamera2 without the GUI dependencies:

```
$ sudo apt install -y python3-picamera2 --no-install-recommends
```

NOTE

If you previously installed Picamera2 with `pip`, uninstall it with: `pip3 uninstall picamera2`.

Use a USB webcam

Edit this on GitHub

Most Raspberry Pi devices have dedicated ports for camera modules. Camera modules are high-quality, highly-configurable cameras popular with Raspberry Pi users.

However, for many purposes a USB webcam has everything you need to record pictures and videos from your Raspberry Pi. This section explains how to use a USB webcam with your Raspberry Pi.

Install dependencies

First, install the `fswebcam` package:

```
$ sudo apt install fswebcam
```

Next, add your username to the `video` group, otherwise you may see 'permission denied' errors:

```
$ sudo usermod -a -G video <username>
```

To check that the user has been added to the group correctly, use the `groups` command.

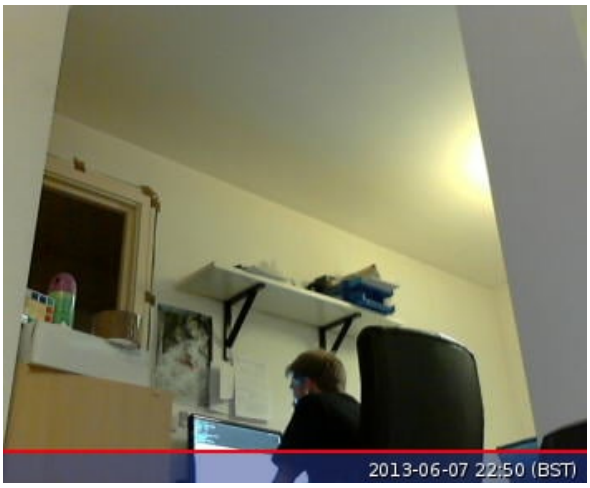
Take a photo

Run the following command to take a picture using the webcam and save the image to a filename named `image.jpg`:

```
$ fswebcam image.jpg
```

You should see output similar to the following:

```
--- Opening /dev/video0...
Trying source module v4l2...
/dev/video0 opened.
No input was specified, using the first.
Adjusting resolution from 384x288 to 352x288.
--- Capturing frame...
Corrupt JPEG data: 2 extraneous bytes before marker 0xd4
Captured frame in 0.00 seconds.
--- Processing captured image...
Writing JPEG image to 'image.jpg'.
```



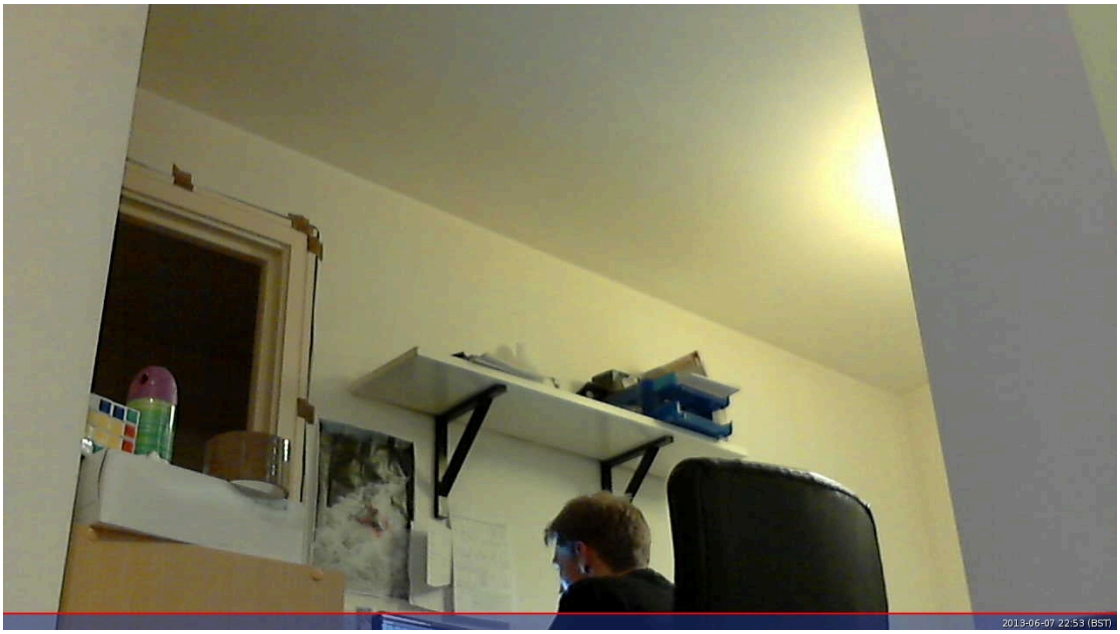
By default, `fswebcam` uses a low resolution and adds a banner displaying a timestamp.

To specify a different resolution for the captured image, use the `-r` flag, passing a width and height as two numbers separated by an `x`:

```
$ fswebcam -r 1280x720 image2.jpg
```

You should see output similar to the following:

```
--- Opening /dev/video0...
Trying source module v4l2...
/dev/video0 opened.
No input was specified, using the first.
--- Capturing frame...
Corrupt JPEG data: 1 extraneous bytes before marker 0xd5
Captured frame in 0.00 seconds.
--- Processing captured image...
Writing JPEG image to 'image2.jpg'.
```



Specify a resolution to capture a higher quality image.

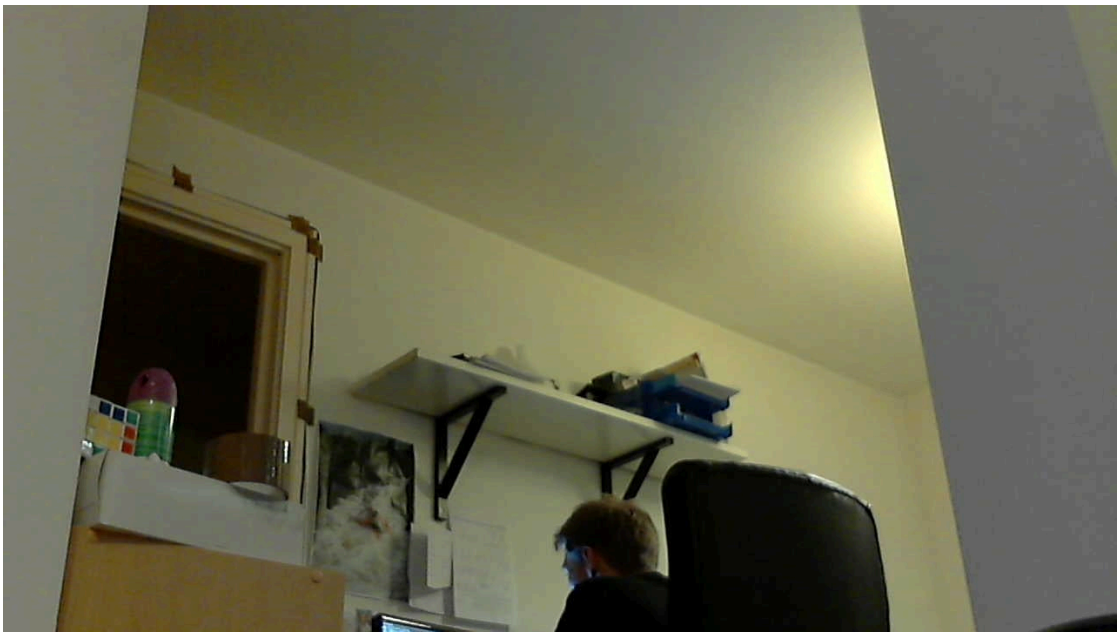
Remove the banner

To remove the banner from the captured image, use the `--no-banner` flag:

```
$ fswebcam --no-banner image3.jpg
```

You should see output similar to the following:

```
--- Opening /dev/video0...
Trying source module v4l2...
/dev/video0 opened.
No input was specified, using the first.
--- Capturing frame...
Corrupt JPEG data: 2 extraneous bytes before marker 0xd6
Captured frame in 0.00 seconds.
--- Processing captured image...
Disabling banner.
Writing JPEG image to 'image3.jpg'.
```



Specify `--no-banner` to save the image without the timestamp banner.

Automate image capture

Unlike `rpicam-apps`, `fswebcam` doesn't have any built-in functionality to substitute timestamps and numbers in output image names. This can be useful when capturing multiple images, since manually editing the file name every time you record an image can be tedious. Instead, use a Bash script to implement this functionality yourself.

Create a new file named `webcam.sh` in your home folder. Add the following example code, which uses the `bash` programming language to save images to files with a file name containing the year, month, day, hour, minute, and second:

```
#!/bin/bash

DATE=$(date +"%Y-%m-%d_%H-%M-%S")

fswebcam -r 1280x720 --no-banner $DATE.jpg
```

Then, make the bash script executable by running the following command:

```
$ chmod +x webcam.sh
```

Run the script with the following command to capture an image and save it to a file with a timestamp for a name, similar to `2024-05-10_12-06-33.jpg`:

```
$ ./webcam.sh
```

You should see output similar to the following:

```
--- Opening /dev/video0...
Trying source module v4l2...
/dev/video0 opened.
No input was specified, using the first.
--- Capturing frame...
Corrupt JPEG data: 2 extraneous bytes before marker 0xd6
Captured frame in 0.00 seconds.
--- Processing captured image...
Disabling banner.
Writing JPEG image to '2024-05-10_12-06-33.jpg'.
```

Capture a time lapse

Use `cron` to schedule photo capture at a given interval. With the right interval, such as once a minute, you can capture a time lapse.

First, open the cron table for editing:

```
$ crontab -e
```

Once you have the file open in an editor, add the following line to the schedule to take a picture every minute, replacing `<username>` with your username:

```
* * * * * /home/<username>/webcam.sh 2>&1
```

Save and exit, and you should see the following message:

```
crontab: installing new crontab
```

V4L2 drivers

V4L2 drivers provide a standard Linux interface for accessing camera and codec features. Normally, Linux loads drivers automatically during boot. But in some situations you may need to load camera drivers explicitly.

Device nodes when using `libcamera`

/dev/videoX	Default action
`video0`	Unicam driver for the first CSI-2 receiver
`video1`	Unicam driver for the second CSI-2 receiver
`video10`	Video decode
`video11`	Video encode
`video12`	Simple ISP, can perform conversion and resizing between RGB/YUV formats in addition to Bayer to RGB/YUV conversion
`video13`	Input to fully programmable ISP
`video14`	High resolution output from fully programmable ISP
`video15`	Low result output from fully programmable ISP
`video16`	Image statistics from fully programmable ISP
`video19`	HEVC decode

Use the V4L2 drivers

For more information on how to use the V4L2 drivers, see the V4L2 documentation.

Unicam

Edit this on GitHub

Raspberry Pi SoCs all have two camera interfaces that support either CSI-2 D-PHY 1.1 or Compact Camera Port 2 (CCP2) sources. This interface is known by the codename Unicam. The first instance of Unicam supports two CSI-2 data lanes, while the second supports four. Each lane can run at up to 1Gbit/s (DDR, so the max link frequency is 500MHz).

Compute Modules and Raspberry Pi 5 route out all lanes from both peripherals. Other models prior to Raspberry Pi 5 only expose the second instance, routing out only two of the data lanes to the camera connector.

Software interfaces

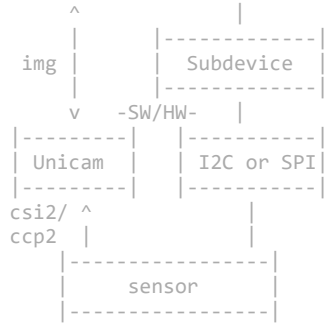
The V4L2 software interface is the only means of communicating with the Unicam peripheral. There used to also be firmware and MMAL rawcam component interfaces, but these are no longer supported.

V4L2

NOTE

> The V4L2 interface for Unicam is available only when using `libcamera`.

There is a fully open-source kernel driver available for the Unicam block; this kernel module, called `bcm2835-unicam`, interfaces with V4L2 subdevice drivers to deliver raw frames. This `bcm2835-unicam` driver controls the sensor and configures the Camera Serial Interface 2 (CSI-2) receiver. Peripherals write raw frames (after Debayer) to SDRAM for V4L2 to deliver to applications. There is no image processing between the camera sensor capturing the image and the `bcm2835-unicam` driver placing the image data in SDRAM except for Bayer unpacking to 16bits/pixel.



Mainline Linux contains a range of existing drivers. The Raspberry Pi kernel tree has some additional drivers and Device Tree overlays to configure them:

Device	Type	Notes
Omnivision OV5647	5MP Camera	Original Raspberry Pi Camera
Sony IMX219	8MP Camera	Revision 2 Raspberry Pi camera
Sony IMX477	12MP Camera	Raspberry Pi HQ camera
Sony IMX708	12MP Camera	Raspberry Pi Camera Module 3
Sony IMX296	1.6MP Camera	Raspberry Pi Global Shutter Camera Module
Toshiba TC358743	HDMI to CSI-2 bridge	
Analog Devices ADV728x-M	Analog video to CSI-2 bridge	No interlaced support
Infineon IRS1125	Time-of-flight depth sensor	Supported by a third party

As the subdevice driver is also a kernel driver with a standardised API, third parties are free to write their own for any source of their choosing.

Write a third-party driver

This is the recommended approach to interfacing via Unicam.

When developing a driver for a new device intended to be used with the `bcm2835-unicam` module, you need the driver and corresponding device tree overlays. Ideally, the driver should be submitted to the linux-media mailing list for code review and merging into mainline, then moved to the Raspberry Pi kernel tree; but exceptions may be made for the driver to be reviewed and merged directly to the Raspberry Pi kernel.

NOTE

> All kernel drivers are licensed under the GPLv2 licence, therefore source code must be available. Shipping of binary modules only is a violation of the GPLv2 licence under which the Linux kernel is licensed.

The `bcm2835-unicam` module has been written to try and accommodate all types of CSI-2 source driver that are currently found in the mainline Linux kernel. These can be split broadly into camera sensors and bridge chips. Bridge chips allow for conversion between some other format and CSI-2.

Camera sensors

The sensor driver for a camera sensor is responsible for all configuration of the device, usually via I2C or SPI. Rather than writing a driver from scratch, it is often easier to take an existing driver as a basis and modify it as appropriate.

The IMX219 driver is a good starting point. This driver supports both 8bit and 10bit Bayer readout, so enumerating frame formats and frame sizes is slightly more involved.

Sensors generally support V4L2 user controls. Not all these controls need to be implemented in a driver. The IMX219 driver only implements a small subset, listed below, the implementation of which is handled by the `imx219_set_ctrl` function.

- `V4L2_CID_PIXEL_RATE` / `V4L2_CID_VBLANK` / `V4L2_CID_HBLANK`: allows the application to set the frame rate
- `V4L2_CID_EXPOSURE`: sets the exposure time in lines; the application needs to use `V4L2_CID_PIXEL_RATE`, `V4L2_CID_HBLANK`, and the frame width to compute the line time
- `V4L2_CID_ANALOGUE_GAIN`: analogue gain in sensor specific units
- `V4L2_CID_DIGITAL_GAIN`: optional digital gain in sensor specific units
- `V4L2_CID_HFLIP / V4L2_CID_VFLIP`: flips the image either horizontally or vertically; this operation may change the Bayer order of the data in the frame, as is the case on the IMX219.
- `V4L2_CID_TEST_PATTERN` / `V4L2_CID_TEST_PATTERN_*`: enables output of various test patterns from the sensor; useful for debugging

In the case of the IMX219, many of these controls map directly onto register writes to the sensor itself.

Further guidance can be found in the `libcamera` sensor driver requirements, and in chapter 3 of the Raspberry Pi Camera tuning guide.

Device Tree

Device Tree is used to select the sensor driver and configure parameters such as number of CSI-2 lanes, continuous clock lane operation, and link frequency (often only one is supported).

The IMX219 Device Tree overlay for the 6.1 kernel is available on GitHub.

Bridge chips

These are devices that convert an incoming video stream, for example HDMI or composite, into a CSI-2 stream that can be accepted by the Raspberry Pi CSI-2 receiver.

Handling bridge chips is more complicated. Unlike camera sensors, they have to respond to the incoming signal and report that to the application.

The mechanisms for handling bridge chips can be split into two categories: either analogue or digital.

When using `ioctls` in the sections below, an *`S`* in the `ioctl` name means it is a set function, while *`G`* is a get function and *`ENUM`* enumerates a set of permitted values.

Analogue video sources

Analogue video sources use the standard `ioctls` for detecting and setting video standards. `VIDIOC_G_STD`, `VIDIOC_S_STD`, `VIDIOC_ENUMSTD`, and `VIDIOC_QUERYSTD` are available.

Selecting the wrong standard will generally result in corrupt images. Setting the standard will typically also set the resolution on the V4L2 CAPTURE queue. It can not be set via `VIDIOC_S_FMT`. Generally, requesting the detected standard via `VIDIOC_QUERYSTD` and then setting it with `VIDIOC_S_STD` before streaming is a good idea.

Digital video sources

For digital video sources, such as HDMI, there is an alternate set of calls that allow specifying of all the digital timing parameters: `VIDIOC_G_DV_TIMINGS`, `VIDIOC_S_DV_TIMINGS`, `VIDIOC_ENUM_DV_TIMINGS`, and `VIDIOC_QUERY_DV_TIMINGS`.

As with analogue bridges, the timings typically fix the V4L2 CAPTURE queue resolution, and calling `VIDIOC_S_DV_TIMINGS` with the result of `VIDIOC_QUERY_DV_TIMINGS` before streaming should ensure the

format is correct.
Depending on the bridge chip and the driver, it may be possible for changes in the input source to be reported to the application via `VIDIOC_SUBSCRIBE_EVENT` and `V4L2_EVENT_SOURCE_CHANGE`.

Currently supported devices

There are two bridge chips which are currently supported by the Raspberry Pi Linux kernel: the Analog Devices ADV728x-M for analogue video sources, and the Toshiba TC358743 for HDMI sources.

Analog Devices ADV728x(A)-M analogue video to CSI2 bridge chips convert composite S-video (Y/C), or component (YPrPb) video into a single lane CSI-2 interface, and are supported by the ADV7180 kernel driver.

Product details for the various versions of this chip can be found on the Analog Devices website: ADV7280A, ADV7281A, and ADV7282A.

Because of some missing code in the current core V4L2 implementation, selecting the source fails, so the Raspberry Pi kernel version adds a kernel module parameter called `dbg_input` to the ADV7180 kernel driver which sets the input source every time VIDIOC_S_STD is called. At some point mainstream will fix the underlying issue (a disjoin between the kernel API call s_routing, and the userspace call `VIDIOC_S_INPUT`) and this modification will be removed.

Receiving interlaced video is not supported, therefore the ADV7281(A)-M version of the chip is of limited use as it doesn't have the necessary I2P deinterlacing block. Also ensure when selecting a device to specify the -M option. Without that you will get a parallel output bus which can not be interfaced to the Raspberry Pi.

There are no known commercially available boards using these chips, but this driver has been tested via the Analog Devices EVAL-ADV7282-M evaluation board.

This driver can be loaded using the `config.txt` dtoverlay `adv7282m` if you are using the `ADV7282-M` chip variant; or `adv728x-m` with a parameter of either `adv7280m=1`, `adv7281m=1`, or `adv7281ma=1` if you are using a different variant.

```
dtoverlay=adv728x-m,adv7280m=1
```

The Toshiba TC358743 is an HDMI to CSI-2 bridge chip, capable of converting video data at up to 1080p60.

Information on this bridge chip can be found on the Toshiba website.

The TC358743 interfaces HDMI into CSI-2 and I2S outputs. It is supported by the TC358743 kernel module.

The chip supports incoming HDMI signals as either RGB888, YUV444, or YUV422, at up to 1080p60. It can forward RGB888, or convert it to YUV444 or YUV422, and convert either way between YUV444 and YUV422. Only RGB888 and YUV422 support has been tested. When using two CSI-2 lanes, the maximum rates that can be supported are 1080p30 as RGB888, or 1080p50 as YUV422. When using four lanes on a Compute Module, 1080p60 can be received in either format.

HDMI negotiates the resolution by a receiving device advertising an EDID of all the modes that it can support. The kernel driver has no knowledge of the resolutions, frame rates, or formats that you wish to receive, so it is up to the user to provide a suitable file via the VIDIOC_S_EDID ioctl, or more easily using `v4l2-ctl --fix-edid-checksums --set-edid=file=filename.txt` (adding the --fix-edid-checksums option means that you don't have to get the checksum values correct in the source file). Generating the required EDID file (a textual hexdump of a binary EDID file) is not too onerous, and there are tools available to generate them, but it is beyond the scope of this page.

As described above, use the `DV_TIMINGS` ioctls to configure the driver to match the incoming video. The easiest approach for this is to use the command `v4l2-ctl --set-dv-bt-timings query`. The driver does support generating the `SOURCE_CHANGED` events, should you wish to write an application to handle a changing source. Changing the output pixel format is achieved by setting it via

`VIDIOC_S_FMT`, but only the pixel format field will be updated as the resolution is configured by the DV timings.
There are a couple of commercially available boards that connect this chip to the Raspberry Pi. The Auvidea B101 and B102 are the most widely obtainable, but other equivalent boards are available.

This driver is loaded using the `config.txt` dtoverlay `tc358743`.

The chip also supports capturing stereo HDMI audio via I2S. The Auvidea boards break the relevant signals out onto a header, which can be connected to the Raspberry Pi's 40-pin header. The required wiring is:

Signal	B101 header	40-pin header	BCM GPIO
LRCK/WFS	7	35	19
BCK/SCK	6	12	18
DATA/SD	5	38	20
GND	8	39	N/A

The `tc358743-audio` overlay is required *in addition to* the `tc358743` overlay. This should create an ALSA recording device for the HDMI audio.

There is no resampling of the audio. The presence of audio is reflected in the V4L2 control `TC358743_CID_AUDIO_PRESENT` (audio-present), and the sample rate of the incoming audio is reflected in the V4L2 control `TC358743_CID_AUDIO_SAMPLING_RATE` (audio sampling-frequency). Recording when no audio is present or at a sample rate different from that reported emits a warning.

Differences between `rpicam` and `raspicam`

Edit this on GitHub

The `rpicam-apps` emulate most features of the legacy `raspicam` applications. However, users may notice the following differences:

- Boost `program_options` don't allow multi-character short versions of options, so where these were present they have had to be dropped. The long form options are named the same way, and any single-character short forms are preserved.
- `rpicam-still` and `rpicam-jpeg` do not show the captured image in the preview window.
- `rpicam-apps` removed the following `raspicam` features:
    - opacity (`--opacity`)
    - image effects (`--imxfx`)
    - colour effects (`--colfx`)
    - annotation (`--annotate`, `--annotateex`)
    - dynamic range compression, or DRC (`--drc`)
    - stereo (`--stereo`, `--decimate` and `--3dswap`)
    - image stabilisation (`--vstab`)
    - demo modes (`--demo`)

      Post-processing replaced many of these features.
- `rpicam-apps` removed `rotation` option support for 90° and 270° rotations.
- `raspicam` conflated metering and exposure; `rpicam-apps` separates these options.

- To disable Auto White Balance (AWB) in `rpicam-apps`, set a pair of colour gains with `awbgains` (e.g. `1.0,1.0`).
- `rpicam-apps` cannot set Auto White Balance (AWB) into greyworld mode for NoIR camera modules. Instead, pass the `tuning-file` option a NoIR-specific tuning file like `imx219_noir.json`.
- `rpicam-apps` does not provide explicit control of digital gain. Instead, the `gain` option sets it implicitly.
- `rpicam-apps` removed the `--ISO` option. Instead, calculate the gain corresponding to the ISO value required. Vendors can provide mappings of gain to ISO.
- `rpicam-apps` does not support setting a flicker period.
- `rpicam-still` does not support burst capture. Instead, consider using `rpicam-vid` in MJPEG mode with `--segment 1` to force each frame into a separate file.
- `rpicam-apps` uses open source drivers for all image sensors, so the mechanism for enabling or disabling on-sensor Defective Pixel Correction (DPC) is different. The imx477 driver on the Raspberry Pi HQ Camera enables on-sensor DPC by default. To disable on-sensor DPC on the HQ Camera, run the following command:

```
$ sudo echo 0 > /sys/module/imx477/parameters/dpc_enable
```

Troubleshooting

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If your Camera Module doesn't work like you expect, try some of the following fixes:

- On Raspberry Pi 3 and earlier devices running Raspberry Pi OS *Bullseye* or earlier:
    - To enable hardware-accelerated camera previews, enable **Glamor**. To enable Glamor, enter `sudo raspi-config` in a terminal, select `Advanced Options` > `Glamor` > `Yes`. Then reboot your Raspberry Pi with `sudo reboot`.
    - If you see an error related to the display driver, add `dtoverlay=vc4-fkms-v3d` or `dtoverlay=vc4-kms-v3d` to `/boot/config.txt`. Then reboot your Raspberry Pi with `sudo reboot`.
- On Raspberry Pi 3 and earlier, the graphics hardware can only support images up to 2048×2048 pixels, which places a limit on the camera images that can be resized into the preview window. As a result, video encoding of images larger than 2048 pixels wide produces corrupted or missing preview images.
- On Raspberry Pi 4, the graphics hardware can only support images up to 4096×4096 pixels, which places a limit on the camera images that can be resized into the preview window. As a result, video encoding of images larger than 4096 pixels wide produces corrupted or missing preview images.
- The preview window may show display tearing in a desktop environment. This is a known, unfixable issue.
- Check that the FFC (Flat Flexible Cable) is firmly seated, fully inserted, and that the contacts face the correct direction. The FFC should be evenly inserted, not angled.
- If you use a connector between the camera and your Raspberry Pi, check that the ports on the connector are firmly seated, fully inserted, and that the contacts face the correct direction.
- Check to make sure that the FFC (Flat Flexible Cable) is attached to the CSI (Camera Serial Interface), *not* the DSI (Display Serial Interface). The connector fits into either port, but only the CSI port powers and controls the camera. Look for the `CSI` label printed on the board near the port.

- Update to the latest software.
- Try a different power supply. The Camera Module adds about 200-250mA to the power requirements of your Raspberry Pi. If your power supply is low quality, your Raspberry Pi may not be able to power the Camera module.
- If you've checked all the above issues and your Camera Module still doesn't work like you expect, try posting on our forums for more help.

Getting help

Edit this on GitHub

For further help with `libcamera` and the `rpicam-apps`, check the Raspberry Pi Camera forum. Before posting:

- Make a note of your operating system version (`uname -a`).
- Make a note of your `libcamera` and `rpicam-apps` versions (`rpicam-hello --version`).
- Report the make and model of the camera module you are using.
- Report the software you are trying to use. We don't support third-party camera module vendor software.
- Report your Raspberry Pi model, including memory size.
- Include any relevant excerpts from the application's console output.

If there are specific problems in the camera software (such as crashes), consider creating an issue in the `rpicam-apps` GitHub repository, including the same details listed above.