How to setup a VC MIPI MODULE on a Raspberry PI Compute IO Board 3

Hardware and Software Setup

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Image symbols used in this document

Symbol	Meaning
	The Light bulb highlights hints and ideas that may be helpful for a development.
	This warning sign alerts of possible pitfalls to avoid. Please pay careful attention to sections marked with this sign.
?!	This is a sign for an example.

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ESD sensitivity

Warning

The components are very sensitive to electrostatic discharge (ESD)! Please take all the precautions necessary to avoid ESD!

ESD

The electronic components and circuits are sensitive to ElectroStatic Discharge (ESD). When handling any circuit board assemblies, it is necessary that ESD safety precautions be observed.

ESD safe best practices include, but are not limited to:

- **Leaving circuit boards in their antistatic packaging until they are ready to be installed.**
- **Using a grounded wrist strap when handling circuit boards.**
- **Working on a grounded ESD table mat.**
- **Only handling circuit boards in ESD safe areas, which may include ESD floor and table mats, wrist strap stations and ESD safe lab coats.**
- **Avoiding handling circuit boards in carpeted areas.**
- **Try to handle the board by the edges, avoiding contact with components.**

This note is not an exhaustive information about the protection against electrostatic discharge (ESD).

Table of Contents

1 Hardware Setup

Note

The power supply must at least provide 2.5A at 5V.

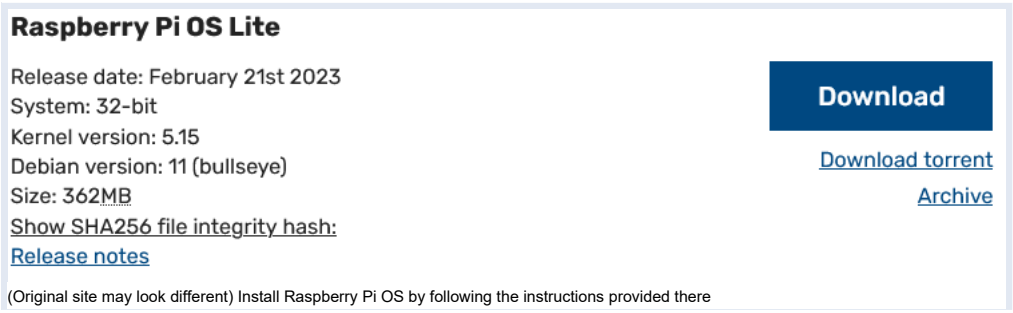
1.1 Hardware Pre-Check: Install Raspbian

First step is to install Raspberry Pi OS from

https://www.raspberrypi.com/software/operating-systems/

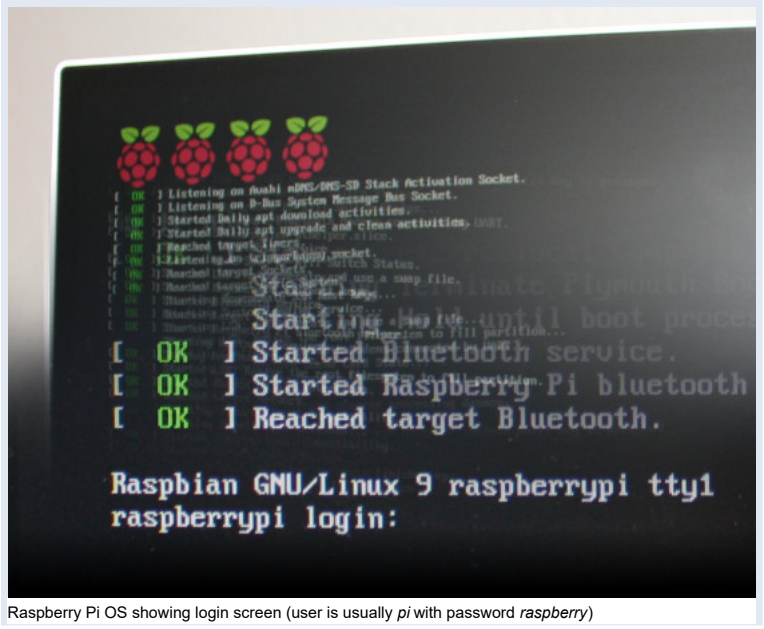
The driver is compatible with kernel versions 5.4, 5.10, 5.15 and 6.1 (32-bit and 64-bit), so download the appropriate Raspberry Pi OS version. *Raspberry Pi OS Buster Lite* is sufficient, and this guide expects this version to be installed not only for the framebuffer output handling.

For more installation instructions see the Raspberry Pi OS Installation Manual; the procedure depends on the platform type where the OS is going to be installed.



(Original site may look different) Install Raspberry Pi OS by following the instructions provided there

The display shows a login prompt after successful installation. If this is not the case, you have to check your Raspberry Pi OS installation. The most relevant information to succeed can be found at the Raspberry Pi OS website or on the web.



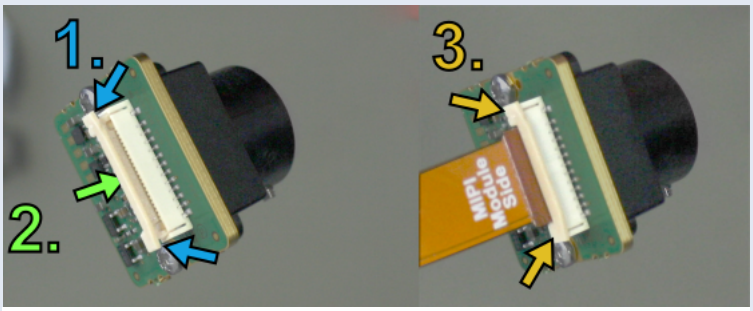
Raspberry Pi OS showing login screen (user is usually *pi* with password *raspberry*)

1.2 Connect the MIPI module

Warning

Always disconnect all cables before connecting or disconnecting the MIPI module!

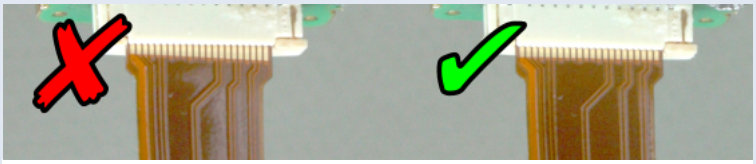
The ends of the MIPI module connector cable is marked with the hardware to connect to. Open the socket connectors first by raising their lid, insert the cable and press their lid back when mounted correctly. You should then not be able to pull the cable out.



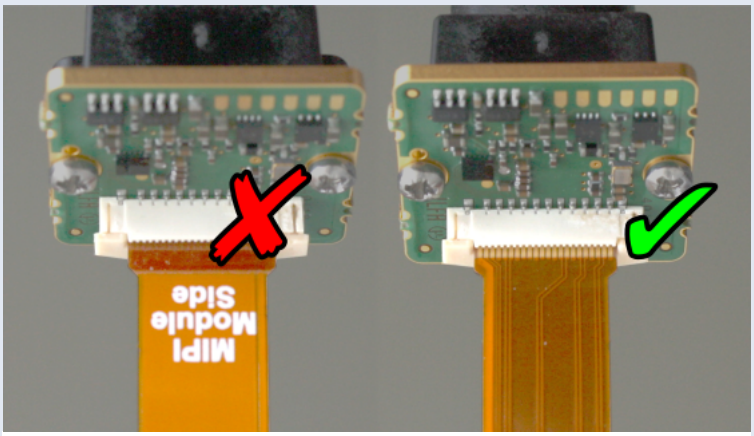
Open the MIPI module socket, put in the cable, close the MIPI module socket

Warning

The connection at this type of socket is not protected against bad alignment, so always check the orthogonality, and if it is bent, correct it! Also watch out for the right orientation of the cable! The MIPI module or the board connected on the other side can be irrevocably damaged if the cable is not inserted the right way, and warranty is lost!

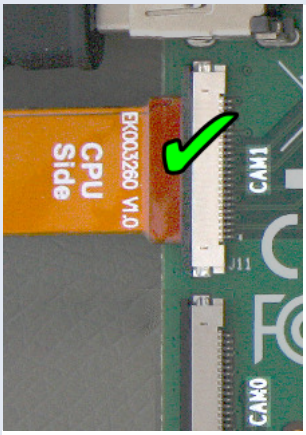

Harmfully angled (left) and good (right) cable fixation

The socket type is also not protected against wrong orientation, so compare your setup to the figures below before switching the power on.



Watch the orientation of the cable (left: bad, right: good)

Connect the MIPI sensor to the socket named *CAM1*.

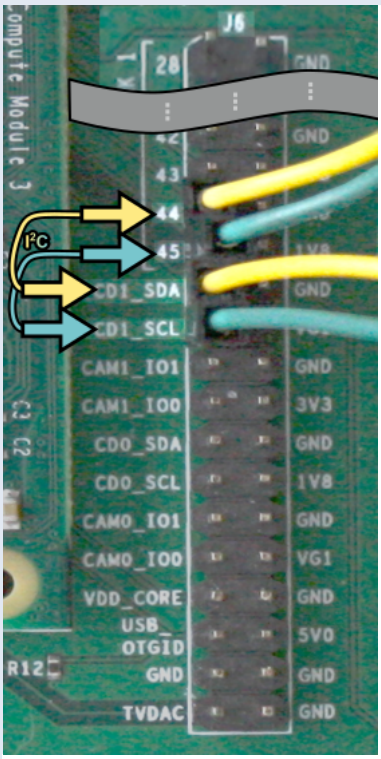


Connect the cable to the *CAM1* socket and watch out for the cable orientation

The I²C bus named *VC* is used for sensor communication and must be connected by a cable bridge to the *CAM1* socket's I²C bus pins.
Therefore connect the

- **pin named *44* with the pin named *CD1_SDA* as well as the**
- **pin named *45* with the pin named *CD1_SCL***

at the *J6* GPIO connector.



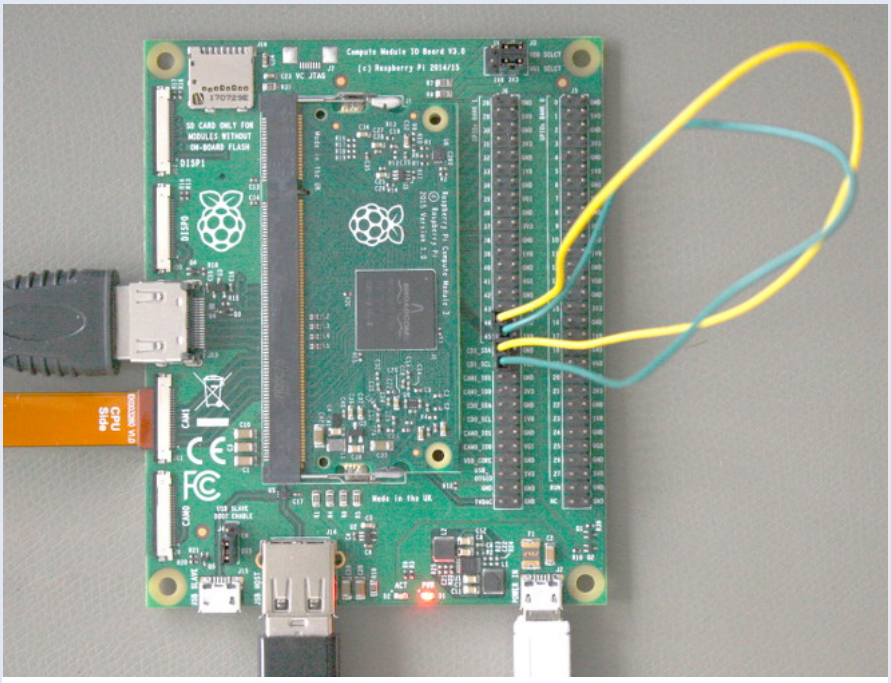
At the *J6* connector: I²C cable bridge to the *CAM1* socket.

Warning

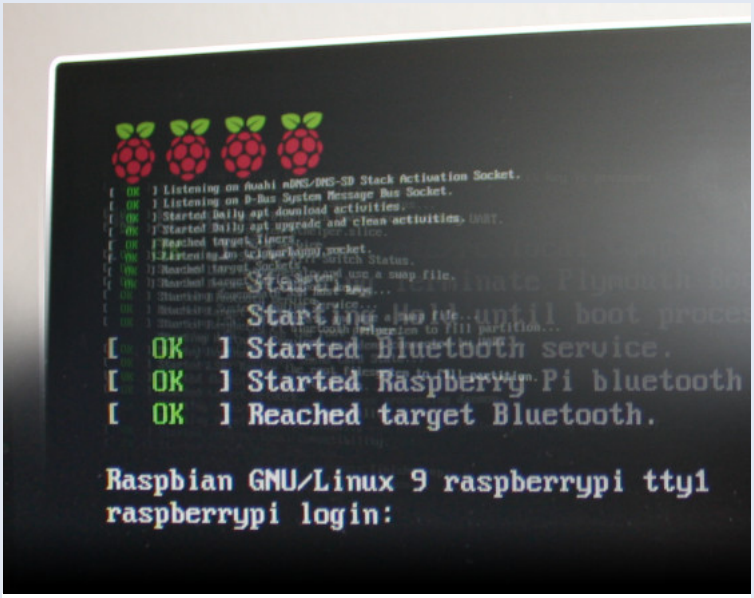
Do not connect other devices to the I²C bus named *VC*, since it can affect the communication between the camera sensor and the driver!
For example, running the touch screen of the Raspberry PI 7 inch display will lead to communication problems between driver and camera sensor. The display may work with the following line appended to the */boot/config.txt*, but test first without connecting it to the Raspberry PI to be sure everything works so far:

```
disable_touchscreen=1
```

Reconnect the other peripherials to the Raspberry Pi.


Connection setup for the first image acquisition test.

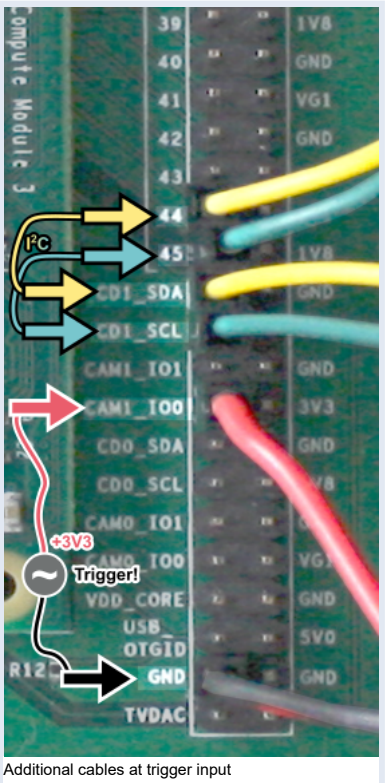
You should have the login prompt back after switching the system on.



Raspbian showing login screen (user is usually *pi* with password *raspberry*)

1.3 Optional: Trigger input (if supported)

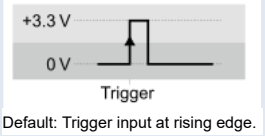
If the MIPI sensor supports it, you can trigger it externally for an image capture. To do so, connect - for example - a frequency generator between *CAM1_IO0* and *GND*.



Additional cables at trigger input

To trigger the sensor,

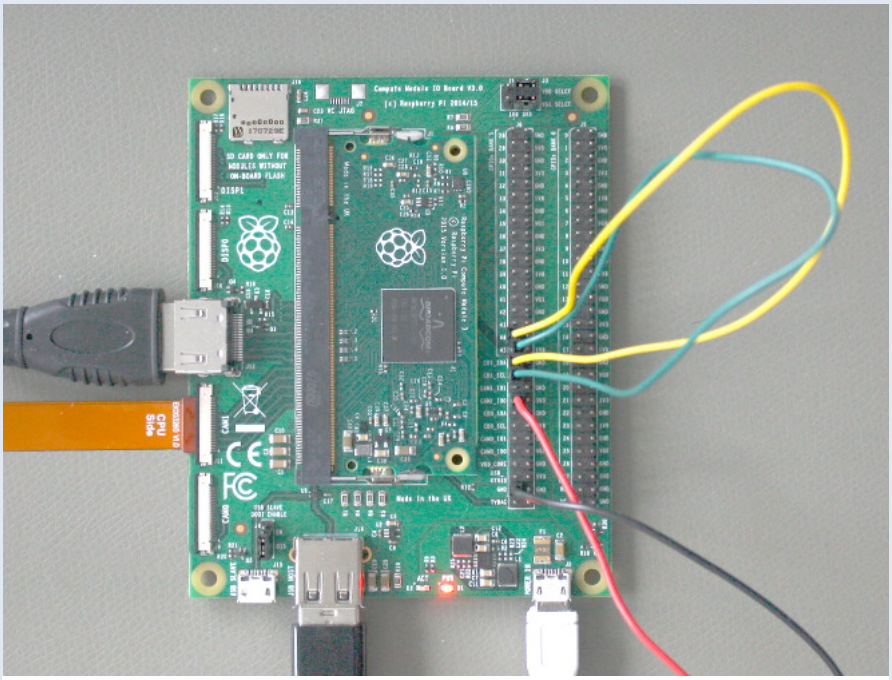
1. **choose an appropriate sensor mode which supports external triggering (see the driver's setmode), and**
2. **give a +3.3V impulse on the *CAM1_IO0* pin**



Default: Trigger input at rising edge.

Warning

The impulse voltage may not exceed +3.3V, or the hardware will be damaged and warranty is lost!



Connection setup with an external trigger source.

1.4 Optional: Connect a second MIPI module

We assume that the same type of sensor is connected to the other port, but this is no limitation. You may connect a different sensor to the other socket.

Note

It is best practice to start with one single sensor first, and if it works to come back here.
You have to understand how the I²C bus is configured and how the CSI port is selected as well as how to edit and handle device tree overlays to get the second MIPI module working – see the Driver Knowledge section for that.

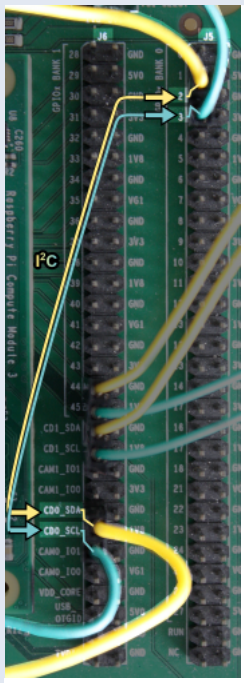
1.4.1 Additional cable setup

The second sensor will be connected to the socket named *CAM0*. Its corresponding I²C pins at the *J6* GPIO connector are *CD0_SDA* and *CD0_SCL*. We will use the second I²C bus *i2c_arm* to connect to the second sensor. Its data lane is at pin *2* while its clock signal resides at pin *3* of the *J5* GPIO connector.

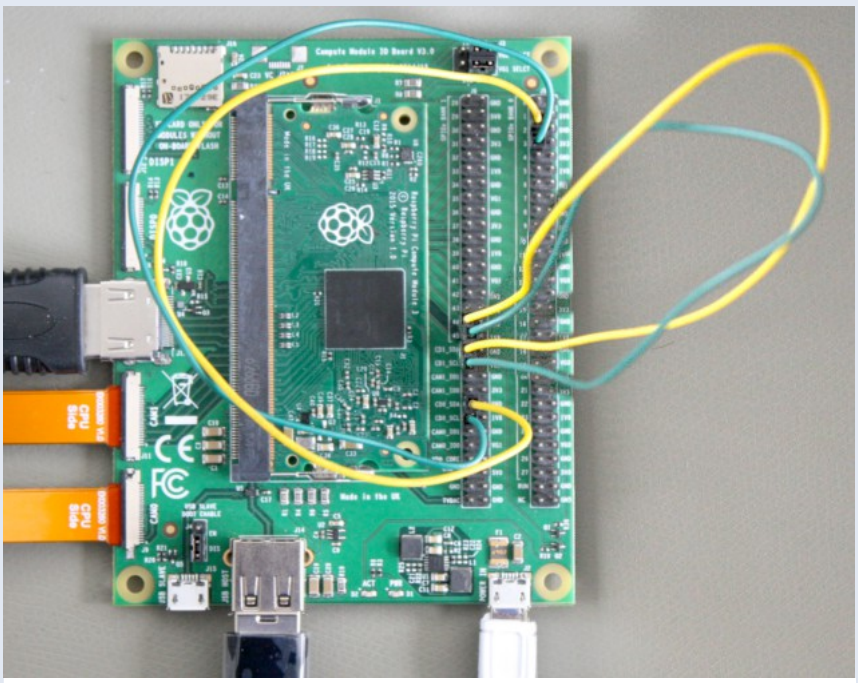
Therefore connect the *J5* GPIO connector's

- pin named *2* with the pin named *CD0_SDA* as well as the
- pin named *3* with the pin named *CD0_SCL*

at the *J6* GPIO connector.



I²C cable bridge to the CAM1 socket.


Connected second sensor to *CAM0* and

2 Software Setup

2.1 Get the driver and demo code

You can download the driver and demo code from the following links.

- Driver: vc-mipi-driver-bcm2835-dkms_0.2.7_all.zip
- Demo code: vcmipidemo_0.7.0.zip

2.2 Install necessary Raspberry PI OS packages

Before beginning with the installation, do the following steps first. This requires your Raspberry PI to already have an internet connection; otherwise you have to install the packages mentioned manually, search the web for the procedure needed.

1. Update the *raspberrypi-kernel* package and your system by calling:

   ```
   sudo apt-get update && sudo apt-get upgrade
   ```

2. **Reboot**.
3. Install the *raspberrypi-kernel-headers* and *device-tree-compiler* package by using the following command:

   ```
   sudo apt-get install raspberrypi-kernel-headers device-tree-compiler
   ```

4. Test if the version of the running kernel matches the version of the kernel headers, the following command should show the directory for compiling the sensor module kernel module driver:

   ```
   ls "/usr/src/linux-headers-$(uname -r)"
   ```

5. Install the *dkms* package with:

   ```
   sudo apt-get install dkms
   ```

2.3 Driver Installation

Note

If you already installed an older version of the driver, an update will not modify the device tree files and the configuration files, in case customers made their own changes. If you wish to update the device tree files and the configuration files together with the driver it is necessary to deinstall the driver first and to delete the device tree files with the following commands:

```
sudo apt-get purge vc-mipi-driver-bcm2835-dkms
sudo rm -rf /boot/config_vc*
sudo rm -rf /boot/overlays/vc-mipi*
```

Warning

It is important that the date and time of your Raspberry Pi are set correctly! You can set the date and time using NTP:

```
sudo apt-get install ntpdate
ntpdate ip_address_of_ntp_server
```

Or you can use the command "date":

```
sudo date -s "2021-08-20 09:41:00"
```

In both cases store the time and date in the hardware clock:

```
sudo hwclock -w
```

1. Copy the driver debian package (*vc-mipi-driver-bcm2835-dkms_x.x.x_armhf.deb*) to the /tmp folder on the Raspberry Pi.
2. Install the driver package by calling (replace x.x.x by the current version number):

   ```
   sudo dpkg -i /tmp/vc-mipi-driver-bcm2835-dkms_x.x.x_armhf.deb
   ```

3. Edit the file */boot/config_vc-mipi-driver-bcm2835.txt* (for example with nano with the command: *sudo nano /boot/config_vc-mipi-driver-bcm2835.txt*).
   - choose the correct platform by uncommenting the corresponding line
   - choose the correct overlay according to your MIPI module and platform by uncommenting the corresponding line (for the IMX565, IMX566, IMX567, IMX568 please activate the overlay for the IMX568.)
   - choose the desired sensor mode (see chapter Sensor modes below for mode description)
   - change the IO configuration if necessary (see chapter IO configuration below for IO description)
   - activate the self-triggered mode (see chapter Self-triggered mode below)

   All these settings can be done for cam0 and cam1 in case you are using a Raspberry Pi CMIO or a VC CMIO.

```
###############################################################################
# platform ####################################################################
##
###
### Choose your platform here
### WRONG SETTINGS MAY LEAD TO MALFUNCTION OR DAMAGE YOUR SYSTEM!
###

include  config_vc-mipi-driver-bcm2835-raspi3Bplus.txt
#include  config_vc-mipi-driver-bcm2835-raspi4B.txt
#include  config_vc-mipi-driver-bcm2835-vccmi10.txt
#include  config_vc-mipi-driver-bcm2835-raspiCM3IO.txt
#include  config_vc-mipi-driver-bcm2835-raspiCM4IO.txt
#include  config_vc-mipi-driver-bcm2835-raspiZero.txt


###############################################################################
# cam0 ########################################################################
##
###
### Choose the overlay corresponding to your platform and sensor here.
### For the 'raspiCM3IO' platform choose 'vccmi10'
### For the 'raspiCM4IO' platform choose 'vccmi10'
### For the 'raspi4B'    platform choose 'raspi3Bplus'
### For the 'raspiZero'  platform choose 'raspi3Bplus'
###

# dtoverlay=vc-mipi-bcm2835-raspi3Bplus-cam0-ov7251
dtoverlay=vc-mipi-bcm2835-raspi3Bplus-cam0-ov9281
# dtoverlay=vc-mipi-bcm2835-raspi3Bplus-cam0-imx178
# dtoverlay=vc-mipi-bcm2835-raspi3Bplus-cam0-imx183
# dtoverlay=vc-mipi-bcm2835-raspi3Bplus-cam0-imx226
# dtoverlay=vc-mipi-bcm2835-raspi3Bplus-cam0-imx250
# dtoverlay=vc-mipi-bcm2835-raspi3Bplus-cam0-imx252
# dtoverlay=vc-mipi-bcm2835-raspi3Bplus-cam0-imx264
# dtoverlay=vc-mipi-bcm2835-raspi3Bplus-cam0-imx265
# dtoverlay=vc-mipi-bcm2835-raspi3Bplus-cam0-imx273
# dtoverlay=vc-mipi-bcm2835-raspi3Bplus-cam0-imx290
# dtoverlay=vc-mipi-bcm2835-raspi3Bplus-cam0-imx296
# dtoverlay=vc-mipi-bcm2835-raspi3Bplus-cam0-imx327
# dtoverlay=vc-mipi-bcm2835-raspi3Bplus-cam0-imx335
# dtoverlay=vc-mipi-bcm2835-raspi3Bplus-cam0-imx392
# dtoverlay=vc-mipi-bcm2835-raspi3Bplus-cam0-imx412
# dtoverlay=vc-mipi-bcm2835-raspi3Bplus-cam0-imx415

# dtoverlay=vc-mipi-bcm2835-vccmi10-cam0-ov7251
# dtoverlay=vc-mipi-bcm2835-vccmi10-cam0-ov9281
# dtoverlay=vc-mipi-bcm2835-vccmi10-cam0-imx178
# dtoverlay=vc-mipi-bcm2835-vccmi10-cam0-imx183
# dtoverlay=vc-mipi-bcm2835-vccmi10-cam0-imx226
# dtoverlay=vc-mipi-bcm2835-vccmi10-cam0-imx250
# dtoverlay=vc-mipi-bcm2835-vccmi10-cam0-imx252
# dtoverlay=vc-mipi-bcm2835-vccmi10-cam0-imx264
# dtoverlay=vc-mipi-bcm2835-vccmi10-cam0-imx265
# dtoverlay=vc-mipi-bcm2835-vccmi10-cam0-imx273
# dtoverlay=vc-mipi-bcm2835-vccmi10-cam0-imx290
# dtoverlay=vc-mipi-bcm2835-vccmi10-cam0-imx296
# dtoverlay=vc-mipi-bcm2835-vccmi10-cam0-imx327
# dtoverlay=vc-mipi-bcm2835-vccmi10-cam0-imx335
# dtoverlay=vc-mipi-bcm2835-vccmi10-cam0-imx392
# dtoverlay=vc-mipi-bcm2835-vccmi10-cam0-imx412
# dtoverlay=vc-mipi-bcm2835-vccmi10-cam0-imx415
```


Part 2:

```
### Select the sensor mode for the camera connected to cam0;
### see output of the driver for more information about the modes.
###

dtparam=cam0_sensor_mode_0          <-- Set the desired sensor mode here

###
### Select the sensor I/O configuration for the sensor connected to cam0.
### WRONG SETTINGS MAY LEAD TO MALFUNCTION OR DAMAGE YOUR SYSTEM!
### READ THE DOCUMENTATION OF YOUR VC MIPI SENSOR TYPE BEFORE MANIPULATION!
### For example on a RaspberryPi3B+ two output drivers operate against each other.
### A value of 0 or 8 is safe.
###

dtparam=cam0_io_config=9            <-- Set the desired IO configuration here

###
### Select the optional sensor trigger configuration for the sensor connected to cam0.
### WRONG SETTINGS MAY LEAD TO MALFUNCTION OR DAMAGE YOUR SYSTEM!
### READ THE DOCUMENTATION OF YOUR VC MIPI SENSOR TYPE BEFORE MANIPULATION!
###
### OPTIONAL overwrite register 0x108
###
### enable only when you need special trigger features
### !!! NORMALLY THE VALUE OF THIS REGISTER IS AUTOMATICALLY SET BY SENSOR_MODE !!!

#dtparam=cam0_external_trigger_mode_overwrite=1
```

Example of configuration file for the OV9281 MIPI module on a Raspberry Pi 3B+ in sensor mode 0.

4. **Reboot**.

Note

For the IMX565, IMX566, IMX567, IMX568 please activate the overlay for the IMX568.

2.4 First Image Acquisition Test

A sensor device should be listed as *Video input* at the following command output (from the Video4Linux-Control):

```
v4l2-ctl --all
```

The following command dumps sensor data:

```
v4l2-ctl --stream-mmap --stream-count=-1 -d /dev/video0 --stream-to=/dev/null
```

It will output subsequent lines ending with a frames-per-second information (in the example named *[number]*) until pressing CTRL-C:

```
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<< [number] fps
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<< [number] fps
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<< [number] fps
<<<<<<<<<<<<<<<<<<<<<<<^C
```

2.5 Running the Demo

The demo itself is a program named *vcmipidemo* and its source code is mainly in the file *vcmipidemo.c*. However more programs are provided, namely the *vcimgnetsrv*, a network image server, and its counterpart *vcimgnetclient.py*. The *vcimgnetsrv* is started as background service, and the *vcmipidemo* connects to it. Then you can use the *vcimgnetclient.py* on your PC to view live captured images.

But for the first run it is better to just run the *vcmipidemo* and check if it shows the ascii representation. This works without any network cable attached. You can then output the captured image to the framebuffer of the display by using the *-f* command line switch.

2.5.1 Compile the programs

1. **Unpack the previously downloaded archive *vcmipidemo_x.x.x.zip* and copy the folder *vcmipidemo* to the Raspberry Pi (for example to */home/pi/*)**

1. **Change to the subdirectory named *vcmipidemo/src*.**
2. **The source directory contains a Makefile to compile the driver. Do so by calling:**

```
make clean all
```

2.5.2 Execute the demo

Just run the demo itself:

```
./vcmipidemo
```

or with framebuffer output:

```
./vcmipidemo -f
```

or with live view over ethernet:

```
./vcimgnetsrv &
./vcmipidemo
```

For live view over ethernet, execute the *vcimgnetclient.py* at the client. This needs Python 2 and PyGTK. Install both following packages in this order (Windows):

- Python 2: https://files.vision-components.com/ImageTransfer/python-2.7.11.msi
- PyGTK: https://files.vision-components.com/ImageTransfer/pygtk-all-in-one-2.24.2.win32-py2.7.msi

Note

You can change exposure and gain values by vcmipidemo command line arguments. To get a listing of possible parameters, just call it with a *-?*:

```
./vcmipidemo -?
```

2.6 Switching Sensor Configuration

2.6.1 Sensor modes

The sensor driver provides different modes which support several features. They can be switched by changing values of sensor driver parameters.
To list available parameters of the sensor driver kernel module, you can use the following command:

```
dmesg
```

You can also check the table below (Sensor modes description) for a complete list of available sensor modes.

```
[    7.612957] vc_mipi_modules_0 0-0060: VC_SEN_FPGA found!
[    7.612971] vc_mipi_modules_0 0-0060: [ MAGIC  ] [ mipi-module ]
[    7.612987] vc_mipi_modules_0 0-0060: [ MANUF. ] [ Vision Components ] [ MID=0x0427 ]
[    7.613000] vc_mipi_modules_0 0-0060: [ SENSOR ] [ OM OV9281 ]
[    7.613014] vc_mipi_modules_0 0-0060: [ MODULE ] [ ID=0x9281 ] [ REV=0x0002 ]
[    7.613026] vc_mipi_modules_0 0-0060: [ MODES  ] [ NR=0x0004 ] [ BPM=0x0010 ]
[    7.613038] vc_mipi_modules_0 0-0060: [ COLOR  ] [ NO  ]
[    7.613053] vc_mipi_modules_0 0-0060: [ MODE 0 ]   format: RAW 10 Bit, type: IntTrig, data lanes: 2, lane data rate:  800000000
[    7.613068] vc_mipi_modules_0 0-0060: [ MODE 1 ]   format: RAW  8 Bit, type: IntTrig, data lanes: 2, lane data rate:  800000000
[    7.613082] vc_mipi_modules_0 0-0060: [ MODE 2 ]   format: RAW 10 Bit, type: ExtTrig, data lanes: 2, lane data rate:  800000000
[    7.613095] vc_mipi_modules_0 0-0060: [ MODE 3 ]   format: RAW  8 Bit, type: ExtTrig, data lanes: 2, lane data rate:  800000000
[    7.613112] vc_mipi_modules_0 0-0060: read property flash-output = 9
[    7.613126] vc_mipi_modules_0 0-0060: read property external-trigger-mode = 1
[    7.613139] vc_mipi_modules_0 0-0060: read property sensor-mode = 3
[    7.613159] vc_mipi_modules_0 0-0060: read property clock-frequency = 25000000
[    7.613183] vc_mipi_modules_0 0-0060: read property data-lanes = 2
[    7.613199] vc_mipi_modules_0 0-0060: read property link-frequencies[0] = 800000000
[    7.613217] vc_mipi_modules_0 0-0060: VC Sensor device-tree has configured 2 data-lanes! [ sensor_mode = 3 ]
```

Example of the dmesg command for an OV9281 MIPI module, showing the available sensor modes.

To set the desired mode, edit the file */boot/config_vc-mipi-driver-bcm2835.txt* (for example with nano with the command: *sudo nano /boot/config_vc-mipi-driver-bcm2835.txt*). Change the sensor mode by modifing dtparam:

```
dtparam=cam0_sensor_mode_1
```

The number after the underscore is the sensor mode. For mode 0 the correct setting would be *dtparam=cam0_sensor_mode_0*.

```
###
### Select the sensor mode for the camera connected to cam0;
### see output of the driver for more information about the modes.
###

dtparam=cam0_sensor_mode_1
```

Example of setting the sensor mode to 1 for cam0.

2.6.2 Sensor modes description

This table lists the available modes for all mipi modules.

VC MIPI OV7251	Mode	Image format (bits)	Lanes	Capture mode	Resolution
	0	10	2	Streaming	640x480
	1	8	2	Streaming	640x480
	2	10	2	External trigger	640x480
	3	8	2	External trigger	640x480

VC MIPI OV9281	Mode	Image format (bits)	Lanes	Capture mode	Resolution
	0	10	2	Streaming	1280x800
	1	8	2	Streaming	1280x800
	2	10	2	External trigger	1280x800
	3	8	2	External trigger	1280x800

VC MIPI IMX178	Mode	Image format (bits)	Lanes	Capture mode	Resolution
	0	8	2	Streaming	3104x2076
	1	10	2	Streaming	3104x2076
	2	12	2	Streaming	3104x2076
	3	14	2	Streaming	3104x2076
	4	8	2	External trigger	3104x2076
	5	10	2	External trigger	3104x2076
	6	12	2	External trigger	3104x2076
	7	14	2	External trigger	3104x2076
	8	8	4	Streaming	3104x2076
	9	10	4	Streaming	3104x2076
	10	12	4	Streaming	3104x2076
	11	14	4	Streaming	3104x2076
	12	8	4	External trigger	3104x2076
	13	10	4	External trigger	3104x2076
	14	12	4	External trigger	3104x2076
	15	14	4	External trigger	3104x2076

VC MIPI IMX183	Mode	Image format (bits)	Lanes	Capture mode	Resolution
	0	8	2	Streaming	5440x3648
	1	10	2	Streaming	5440x3648
	2	12	2	Streaming	5440x3648
	3	8	2	External trigger	5440x3648
	4	10	2	External trigger	5440x3648
	5	12	2	External trigger	5440x3648
	6	8	4	Streaming	5440x3648
	7	10	4	Streaming	5440x3648
	8	12	4	Streaming	5440x3648
	9	8	4	External trigger	5440x3648
	10	10	4	External trigger	5440x3648
	11	12	4	External trigger	5440x3648

VC MIPI IMX226	Mode	Image format (bits)	Lanes	Capture mode	Resolution
	0	8	2	Streaming	3840x3046
	1	10	2	Streaming	3840x3046
	2	12	2	Streaming	3840x3046
	3	8	2	External trigger	3840x3046
	4	10	2	External trigger	3840x3046
	5	12	2	External trigger	3840x3046
	6	8	4	Streaming	3840x3046
	7	10	4	Streaming	3840x3046
	8	12	4	Streaming	3840x3046
	9	8	4	External trigger	3840x3046
	10	10	4	External trigger	3840x3046
	11	12	4	External trigger	3840x3046

VC MIPI IMX250	Mode	Image format (bits)	Lanes	Capture mode	Resolution
	0	8	2	Streaming	2432x2048
	1	10	2	Streaming	2432x2048
	2	12	2	Streaming	2432x2048
	3	8	2	External trigger	2432x2048
	4	10	2	External trigger	2432x2048
	5	12	2	External trigger	2432x2048
	6	8	4	Streaming	2432x2048
	7	10	4	Streaming	2432x2048
	8	12	4	Streaming	2432x2048
	9	8	4	External trigger	2432x2048
	10	10	4	External trigger	2432x2048
	11	12	4	External trigger	2432x2048

VC MIPI IMX252	Mode	Image format (bits)	Lanes	Capture mode	Resolution
	0	8	2	Streaming	2048x1536
	1	10	2	Streaming	2048x1536
	2	12	2	Streaming	2048x1536
	3	8	2	External trigger	2048x1536
	4	10	2	External trigger	2048x1536
	5	12	2	External trigger	2048x1536
	6	8	4	Streaming	2048x1536
	7	10	4	Streaming	2048x1536
	8	12	4	Streaming	2048x1536
	9	8	4	External trigger	2048x1536
	10	10	4	External trigger	2048x1536
	11	12	4	External trigger	2048x1536

VC MIPI IMX264	Mode	Image format (bits)	Lanes	Capture mode	Resolution
	0	8	2	Streaming	2432x2048
	1	10	2	Streaming	2432x2048
	2	12	2	Streaming	2432x2048
	3	8	2	External trigger	2432x2048
	4	10	2	External trigger	2432x2048
	5	12	2	External trigger	2432x2048

VC MIPI IMX265	Mode	Image format (bits)	Lanes	Capture mode	Resolution
	0	8	2	Streaming	2048x1536
	1	10	2	Streaming	2048x1536
	2	12	2	Streaming	2048x1536
	3	8	2	External trigger	2048x1536
	4	10	2	External trigger	2048x1536
	5	12	2	External trigger	2048x1536

VC MIPI IMX273	Mode	Image format (bits)	Lanes	Capture mode	Resolution
	0	8	2	Streaming	1440x1080
	1	10	2	Streaming	1440x1080
	2	12	2	Streaming	1440x1080
	3	8	2	External trigger	1440x1080
	4	10	2	External trigger	1440x1080
	5	12	2	External trigger	1440x1080
	6	8	4	Streaming	1440x1080
	7	10	4	Streaming	1440x1080
	8	12	4	Streaming	1440x1080
	9	8	4	External trigger	1440x1080
	10	10	4	External trigger	1440x1080
	11	12	4	External trigger	1440x1080
	12	8	2	Streaming	720x540 (binning)
	13	10	2	Streaming	720x540 (binning)
	14	12	2	Streaming	720x540 (binning)
	15	8	2	External trigger	720x540 (binning)
	16	10	2	External trigger	720x540 (binning)
	17	12	2	External trigger	720x540 (binning)
	18	8	4	Streaming	720x540 (binning)
	19	10	4	Streaming	720x540 (binning)
	20	12	4	Streaming	720x540 (binning)
	21	8	4	External trigger	720x540 (binning)
	22	10	4	External trigger	720x540 (binning)
	23	12	4	External trigger	720x540 (binning)

VC MIPI IMX290	Mode	Image format (bits)	Lanes	Capture mode	Resolution
	0	10	2	Streaming	1920x1080
	1	10	4	Streaming	1920x1080

VC MIPI IMX296	Mode	Image format (bits)	Lanes	Capture mode	Resolution
	0	10	1	Streaming	1440x1080
	1	10	1	External trigger	1440x1080
	2	10	1	Streaming	720x540 (binning)
	3	10	1	External trigger	720x540 (binning)

VC MIPI IMX296 C	Mode	Image format (bits)	Lanes	Capture mode	Resolution
	0	10	1	Streaming	1440x1080
	1	10	1	External trigger	1440x1080

VC MIPI IMX297	Mode	Image format (bits)	Lanes	Capture mode	Resolution
	0	10	1	Streaming	720x540
	1	10	1	External trigger	720x540

VC MIPI IMX327 C	Mode	Image format (bits)	Lanes	Capture mode	Resolution
	0	10	2	Streaming	1920x1080
	1	10	4	Streaming	1920x1080

VC MIPI IMX335	Mode	Image format (bits)	Lanes	Capture mode	Resolution
	0	10	2	Streaming	2560x1964
	1	10	2	Streaming	2560x1964
	2	12	2	Streaming	2560x1964
	3	12	2	Streaming	2560x1964
	4	10	4	Streaming	2560x1964
	5	10	4	Streaming	2560x1964
	6	12	4	Streaming	2560x1964
	7	12	4	Streaming	2560x1964

VC MIPI IMX392	Mode	Image format (bits)	Lanes	Capture mode	Resolution
	0	8	2	Streaming	1920x1200
	1	10	2	Streaming	1920x1200
	2	12	2	Streaming	1920x1200

VC MIPI IMX392	Mode	Image format (bits)	Lanes	Capture mode	Resolution
	3	8	2	External trigger	1920x1200
	4	10	2	External trigger	1920x1200
	5	12	2	External trigger	1920x1200
	6	8	4	Streaming	1920x1200
	7	10	4	Streaming	1920x1200
	8	12	4	Streaming	1920x1200
	9	8	4	External trigger	1920x1200
	10	10	4	External trigger	1920x1200
	11	12	4	External trigger	1920x1200

VC MIPI IMX412 C	Mode	Image format (bits)	Lanes	Capture mode	Resolution
	0	10	2	Streaming	4056x3040
	1	10	4	Streaming	4056x3040

VC MIPI IMX415 C	Mode	Image format (bits)	Lanes	Capture mode	Resolution
	0	10	2	Streaming	3864x2192
	1	10	4	Streaming	3864x2192

VC MIPI IMX462 C	Mode	Image format (bits)	Lanes	Capture mode	Resolution
	0	10	2	Streaming	1920x1080
	1	10	4	Streaming	1920x1080

VC MIPI IMX565	Mode	Image format (bits)	Lanes	Capture mode	Resolution
	0	8	2	Streaming	4128x3008
	1	10	2	Streaming	4128x3008
	2	12	2	Streaming	4128x3008
	3	8	2	External trigger	4128x3008
	4	10	2	External trigger	4128x3008
	5	12	2	External trigger	4128x3008
	6	8	4	Streaming	4128x3008
	7	10	4	Streaming	4128x3008
	8	12	4	Streaming	4128x3008
	9	8	4	External trigger	4128x3008
	10	10	4	External trigger	4128x3008
	11	12	4	External trigger	4128x3008

VC MIPI IMX566	Mode	Image format (bits)	Lanes	Capture mode	Resolution
	0	8	2	Streaming	2848x2840
	1	10	2	Streaming	2848x2840
	2	12	2	Streaming	2848x2840
	3	8	2	External trigger	2848x2840
	4	10	2	External trigger	2848x2840
	5	12	2	External trigger	2848x2840
	6	8	4	Streaming	2848x2840
	7	10	4	Streaming	2848x2840
	8	12	4	Streaming	2848x2840
	9	8	4	External trigger	2848x2840
	10	10	4	External trigger	2848x2840
	11	12	4	External trigger	2848x2840

VC MIPI IMX567	Mode	Image format (bits)	Lanes	Capture mode	Resolution
	0	8	2	Streaming	2432x2048
	1	10	2	Streaming	2432x2048
	2	12	2	Streaming	2432x2048
	3	8	2	External trigger	2432x2048
	4	10	2	External trigger	2432x2048
	5	12	2	External trigger	2432x2048
	6	8	4	Streaming	2432x2048
	7	10	4	Streaming	2432x2048
	8	12	4	Streaming	2432x2048
	9	8	4	External trigger	2432x2048
	10	10	4	External trigger	2432x2048
	11	12	4	External trigger	2432x2048

VC MIPI IMX568	Mode	Image format (bits)	Lanes	Capture mode	Resolution
	0	8	2	Streaming	2432x2048
	1	10	2	Streaming	2432x2048
	2	12	2	Streaming	2432x2048
	3	8	2	External trigger	2432x2048
	4	10	2	External trigger	2432x2048
	5	12	2	External trigger	2432x2048
	6	8	4	Streaming	2432x2048
	7	10	4	Streaming	2432x2048
	8	12	4	Streaming	2432x2048
	9	8	4	External trigger	2432x2048
	10	10	4	External trigger	2432x2048
	11	12	4	External trigger	2432x2048

2.6.3 IO configuration

Some sensors can be triggered externally and also provide a flash output. These two features can be switched using the *cam0_io_config* parameter.

```
###
### Select the sensor I/O configuration for the sensor connected to cam0.
### WRONG SETTINGS MAY LEAD TO MALFUNCTION OR DAMAGE YOUR SYSTEM!
### READ THE DOCUMENTATION OF YOUR VC MIPI SENSOR TYPE BEFORE MANIPULATION!
### For example on a RaspberryPi3B+ two output drivers operate against each other.
### A value of 0 is safe.
###

dtparam=cam0_io_config=8
```

Example of setting the IO configuration to 8 for cam0.

This parameter corresponds to the value written to register 3 on the MIPI module. A value of 0x08 activates the trigger input. A value of 0x09 activates the trigger input and the flash output.

After modifying the sensor mode or the IO configuration, save the changes and **reboot**.

2.6.4 Self-triggered mode

On some modules the streaming mode does not allow a flash output signal. In this case it is necessary to activate the so-called self-triggered mode (from the user point of view it behaves like the streaming mode). This is done by choosing one of the external trigger modes and additionally overriding the value of the register 0x0108 of the mipi controller.

```
###
### Select the optional sensor trigger configuration for the sensor connected to cam0.
### WRONG SETTINGS MAY LEAD TO MALFUNCTION OR DAMAGE YOUR SYSTEM!
### READ THE DOCUMENTATION OF YOUR VC MIPI SENSOR TYPE BEFORE MANIPULATION!
###
### OPTIONAL overwrite register 0x108
###
### enable only when you need special trigger features
### !!! NORMALLY THE VALUE OF THIS REGISTER IS AUTOMATICALLY SET BY SENSOR_MODE !!!

dtparam=cam0_external_trigger_mode_overwrite=4
```

Register 0x108 configuration: set to 4 for self-triggered mode.

A detailed documentation of the mipi controller registers is available on request.

3 Troubleshooting and Background Information

3.1 Q/A

Problem:

Running *make* fails with an error:

```
⋮
make[1]: *** /lib/modules/4.14.79-v7+/build: No such file or directory.  Stop.
⋮
```

Solution:

The system needs the build tools of the kernel to build the sensor driver (which itself is a kernel module). They can be obtained by installing the RaspberryPi Kernel Headers package named *raspberrypi-kernel-headers*, see https://www.raspberrypi.org/documentation/linux/kernel/headers.md

---

Problem:

The sensor module driver cannot be started, it shows an error:

```
⋮
[ 4.773298] imx296 0-0060: Error -5 setting default controls
[ 4.773346] imx296: probe of 0-0060 failed with error -5
⋮
```

Solution:

Be sure no other device is connected to the I²C bus 0! For example, the touch screen controller of the Raspberry PI display may not be connected.

Check the orientation of the cable at the sensor side as well as at the cpu side. Also check if the cable and the sockets are orthogonal.

3.2 Driver Knowledge

The following tasks have to be done to do an image acquisition with the camera sensor:

- Information about the new sensor hardware and its connector must be provided to the kernel by adding it to the so-called kernel device tree as overlay.
- This device tree overlay must be applied to the kernel device tree.
- For the driver to communicate with the sensor the I²C bus must be set up to connect between the CPU and the MIPI socket.
- The driver itself must be installed as kernel modules.
- Contiguous memory must be reserved for the captured image.

The driver is separated into parts exclusive for the platform, e.g. the Raspi3BPlus as well as generic parts.

The main configuration file for the driver is named:

```
config_vc-mipi-driver-bcm2835.txt
```

It should include the platform specific configuration, here the file:

```
config_vc-mipi-driver-bcm2835-raspi3Bplus.txt
```

and also refer to the sensor overlays (see the following) you would like to use. Overlays can be found relative to the configuration file at the *./overlays/* directory.

3.2.1 Providing device tree overlays

The so-called kernel device tree overlay contains information about the socket and periphery where the mipi module is connected to.

Here are the steps to compile a device tree overlay by yourself:

We assume to compile an example overlay file named

```
example123-overlay.dts
```

1. Install the *device-tree-compiler* package via:

   ```
   sudo  apt-get install  device-tree-compiler
   ```

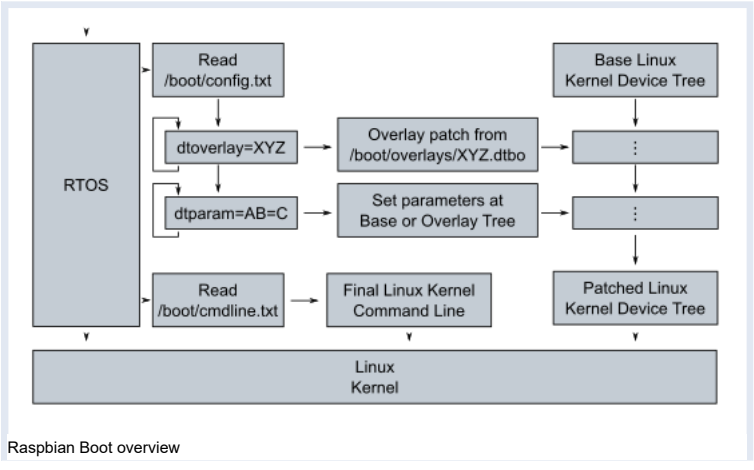
2. Compile the dtbo kernel device tree overlay binary representation by using the following command:

   ```
   dtc -@ -I dts -O dtb -o example123.dtbo example123-overlay.dts
   ```

3. Copy the binary to

   ```
   /boot/overlays/example123.dtbo
   ```

3.2.1.1 Telling the RTOS to use the device tree overlay



Raspbian Boot overview

Before starting the linux kernel, the Raspberry Pi first boots a real-time operating system (RTOS) on the GPU. This RTOS looks into the file */boot/config.txt*. It loads a default Kernel device tree and patches it by overlaying the device tree parts listed by the *dtoverlay* entries at the file */boot/config.txt*. To add new information to the device tree this config-file (or a therein included file) needs the following entry:

```
dtoverlay=example123
```

The device tree will then be modified by the overlay at

```
/boot/overlays/example123.dtbo
```

before the linux kernel is run.

To check the behaviour of the RTOS one can look at the output by the following command:

```
sudo vcdbg log msg
```

Example

After reboot the applied overlays can be shown by executing the following command:

```
sudo vcdbg log msg  2>&1 | grep '^[0-9\.]\+: Loaded overlay'
```

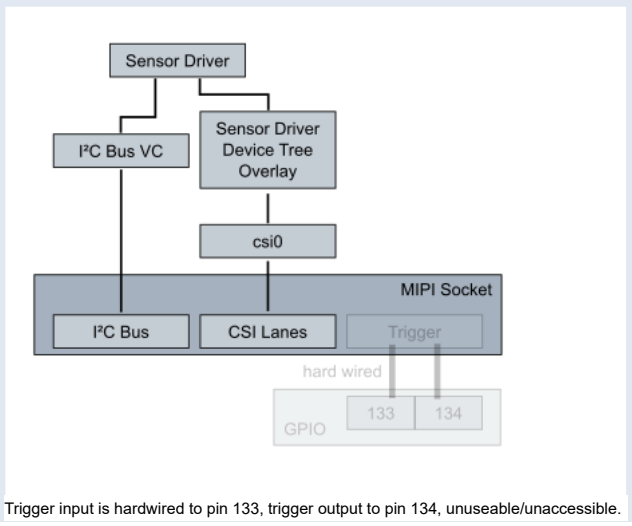
Here is a sample output:

```
002143.555: Loaded overlay 'example123'
```

A deeper insight into the device tree overlays and parameters can be found at https://www.raspberrypi.org/documentation/configuration/device-tree.md

3.2.2 Set up the I²C bus for driver-sensor communication

For the RaspberryPi 3B+ there is only one socket available, so there is no need to change the CSI port information at a device tree overlay provided.



Trigger input is hardwired to pin 133, trigger output to pin 134, unuseable/unaccessible.

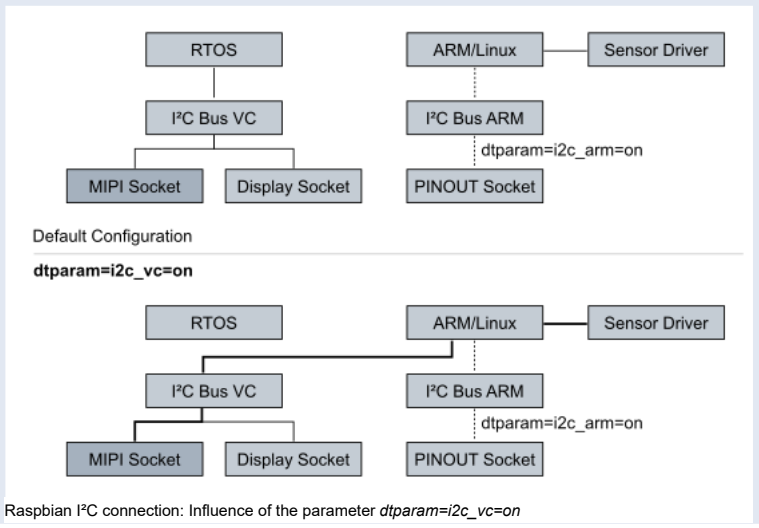
Note

On this Raspberry PI model the pins used for trigger input and output are hard-wired to some GPIO, so external triggering is not possible (no access).

Warning

Hardware will be damaged and warranty lost if you use pins as outputs where the sensor has its own flash output, so double-check before you (if you are able to) access the trigger gpio pins! Don't activate sensor flash or sync output (e.g via the dtparam *cam*_io_config*) if the wires are connected to an output, for example at a RaspberryPi3B+!

The sensor driver needs to communicate via the I²C Bus named *VC*. To be able to access it, assigning it to the CPU is mandatory.



Raspbian I²C connection: Influence of the parameter *dtparam=i2c_vc=on*

The I²C bus is assigned by the RTOS. So the file */boot/config_vc-mipi-driver-bcm2835-raspi3Bplus.txt* has an entry:

```
dtparam=i2c_vc=on
```

It changes the physical I²C bus *VC* accessor from the default, the GPU, to the CPU. The referred overlay *vc-mipi-bcm2835-raspi3Bplus-i2c0* makes it accessible for linux over GPIO pins.

Note

Some hardware like the touch display demands exclusiveness over the I²C Bus *VC* or their drivers assume the I²C Bus *VC* is connected to the RTOS. Since the sensor driver must communicate with the sensor module connected to the MIPI socket, neither the exclusiveness nor the RTOS connectedness is given. So the I²C bus *VC* cannot

be used for other purposes when the sensor is attached.

Example

After reboot the *dtparam* line can be shown by executing the following command:

```
sudo vcdbg log msg  2>&1 | grep '^[0-9\.]\+: dtparam:'
```

Here is a sample output:

```
002077.358: dtparam: audio=on
002096.467: dtparam: i2c_vc=on
```

3.2.3 Providing the sensor driver as kernel module

Here are the steps to compile the kernel modules by yourself:

1. After installation of the DKMS module the driver will be found at a subdirectory of the folder */usr/src/*:

   vc-mipi-driver-bcm2835-*versionnumber*

2. Copy it to a new place and change to that new place, since the previous mentioned subdirectory is part of the DKMS package management! Be aware, that after a new kernel version installation, the DKMS will rebuild the driver. Check where the sources for that rebuild lies to have your customized setup after the kernel update.
3. The source directory contains a Makefile to compile the driver. Do so by calling:

   ```
   make clean all
   ```

4. The directory then contains the driver as several modules. They must be copied to their place
   - **.ko* to */lib/modules/$(uname -r)/kernel/drivers/media/i2c/*
   - **.txt* to */boot/*
   - *overlays/*.dtbo* to */boot/overlays/*

   Afterwards the new modules must be registered by calling *depmod -a* and the main configuration file must be included at the */boot/config.txt*.

   All this can be also done by calling:

   ```
   make install
   debian/postinst
   ```

The module drivers will then be loaded by calling the following commands in that order (or automatically at boot):

```
modprobe vc_mipi_modules_0
modprobe bcm2835-unicam
```

Example

After reboot you can display the output of the vc_mipi_imx296 kernel module by executing the following command:

```
dmesg | grep '^[^]]*\] vc_mipi_modules_0'
```

Here is a sample output **which will be different at your setup**:

```
[ 13.260918] vc_mipi_modules_0 0-001a: VC_SEN_FPGA found!
[ 13.260930] vc_mipi_modules_0 0-001a: [ MAGIC ] [ mipi-module ]
[ 13.260941] vc_mipi_modules_0 0-001a: [ MANUF. ] [ Vision Components ] [ MID=0x0427 ]
...
[ 13.464166] vc_mipi_modules_0 0-001a: VC_SEN_MODE=0 PowerOn STATUS=0x80 try=2
...
```

3.2.4 Reserving Contiguous Memory for the Image Captures

In contrast to the normally used non-contiguous memory the capture hardware needs a contiguous memory region to transfer pixel data to by using direct memory access (DMA).

To reserve other than 128MByte of memory for capturing images, edit the overlay file named

vc-mipi-common-memory-contiguous-overlay.dts

and change its *size* entry, for example to use 64MiB:

```
size = <0x4000000>; /* 64MiB */
```

Compile the *.dts* file and copy its *.dtbo* file to */boot/overlays/*.

After reboot the kernel message line beginning with *Memory:* will show an updated entry (last one):

[0.000000] Memory: 881620K/970752K available (8192K kernel code, 653K rwdata, 2220K rodata, 1024K init, 822K bss, 23596K reserved, 65536K cma-reserved)

Example

After reboot you can show the line by executing the following command:

```
dmesg | grep '^[^]]*\] Memory:'
```

Here is a sample output which will look slightly different at your setup:

```
[    0.000000] Memory: 817108K/970752K available (7168K kernel code, 576K rwdata, 2076K rodata, 1024K init, 698K bss, 22572K reserved, 131072K cma-reserved)
```

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