libcamera: The Future of Cameras on Linux is Now

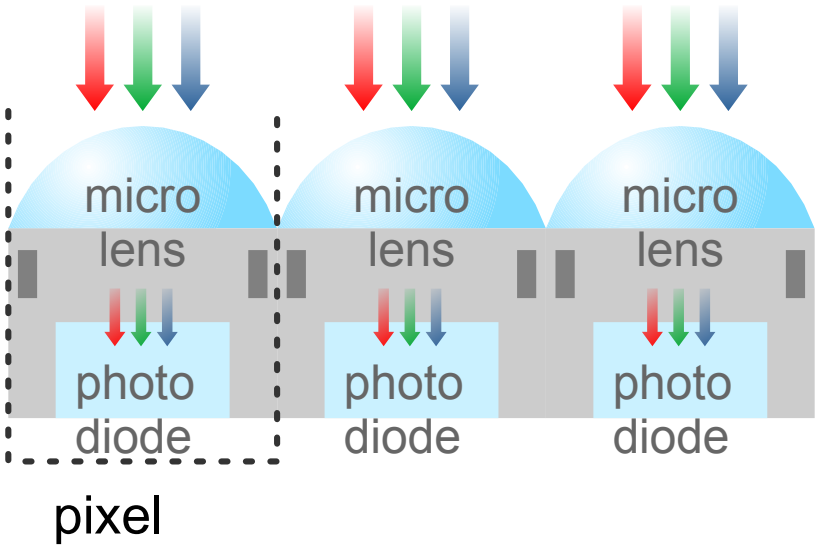
Open Source Summit Japan 2021
2021-12-14

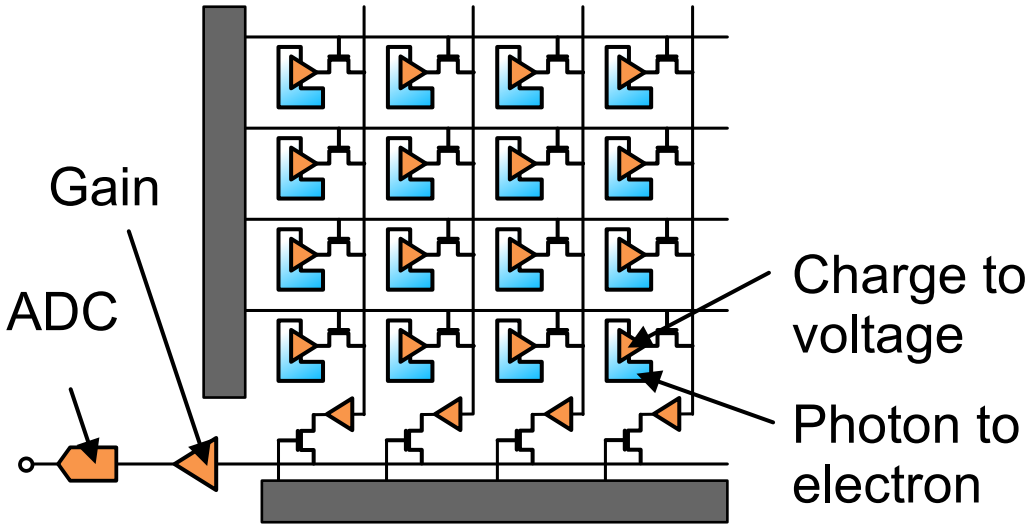
Paul Elder
paul.elder@ideasonboard.com

IDEAS ON BOARD

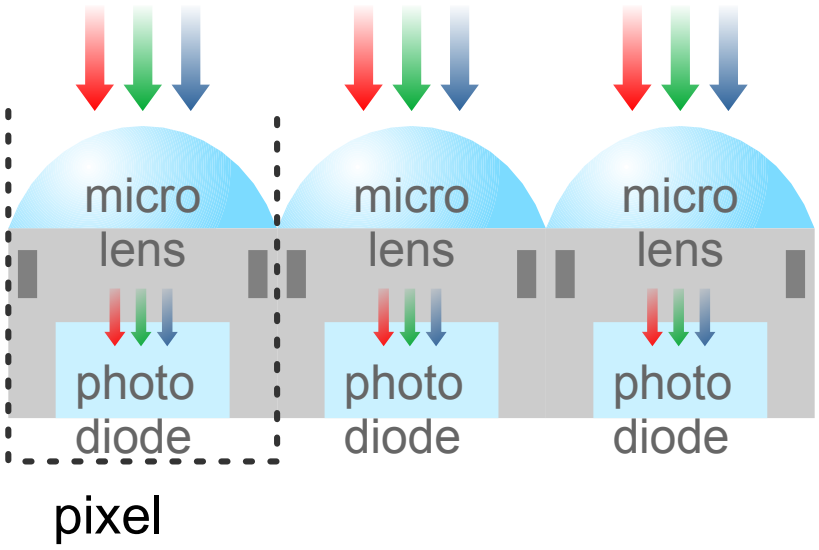
What is a camera?

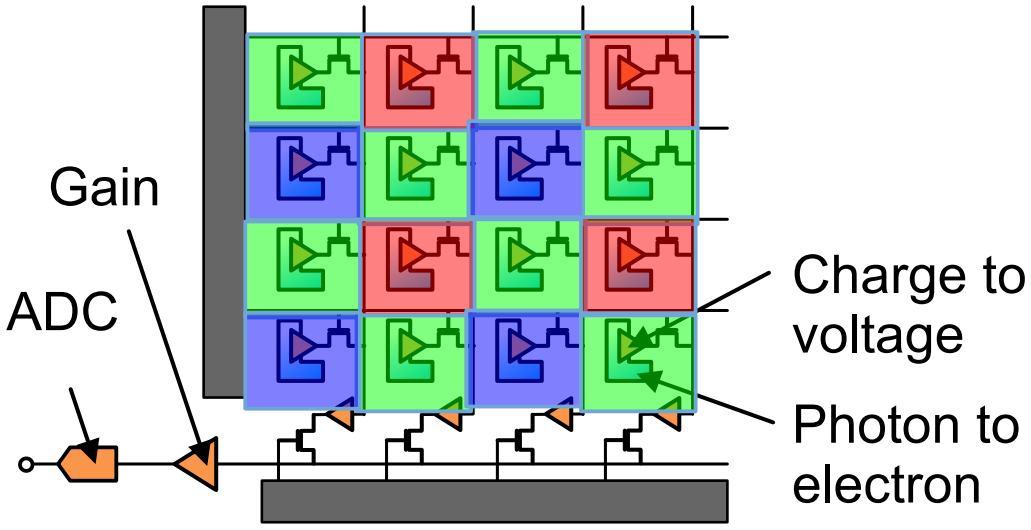
IDEAS ON BOARD


micro lens
micro lens
micro lens
photo diode
photo diode
photo diode
pixel

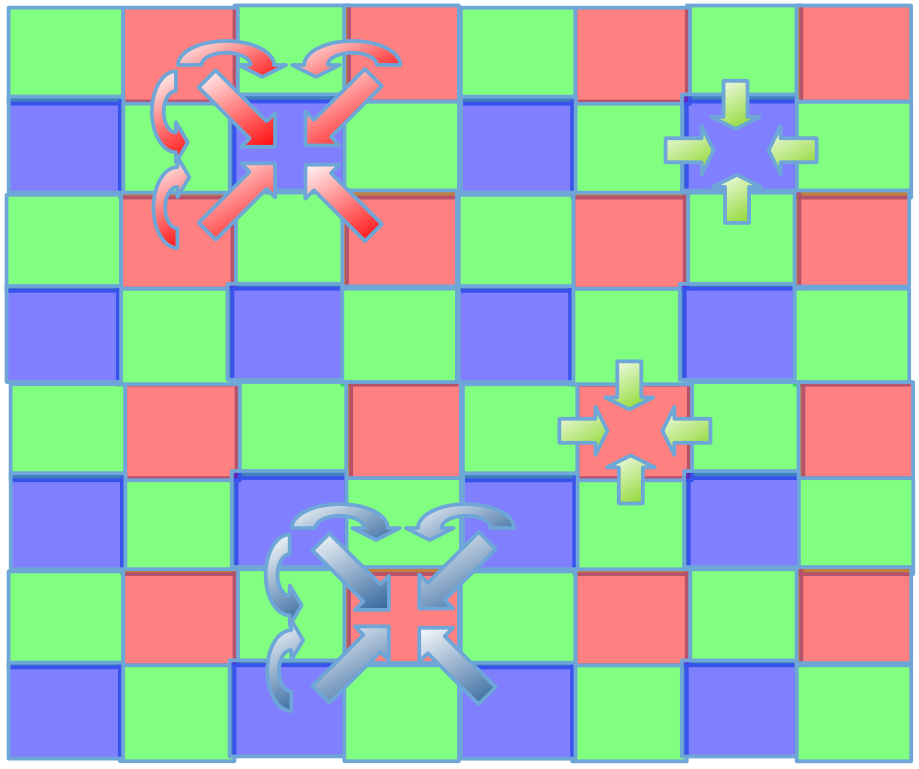

Gain
ADC
Charge to voltage
Photon to electron

CMOS Sensor


micro lens
micro lens
micro lens
photo diode
photo diode
photo diode
pixel


Gain
ADC
Charge to voltage
Photon to electron

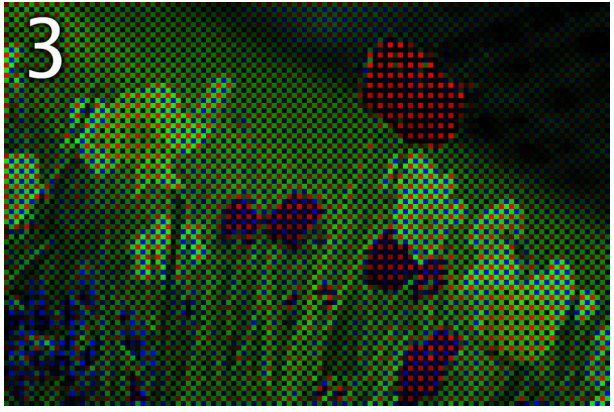
CMOS Sensor



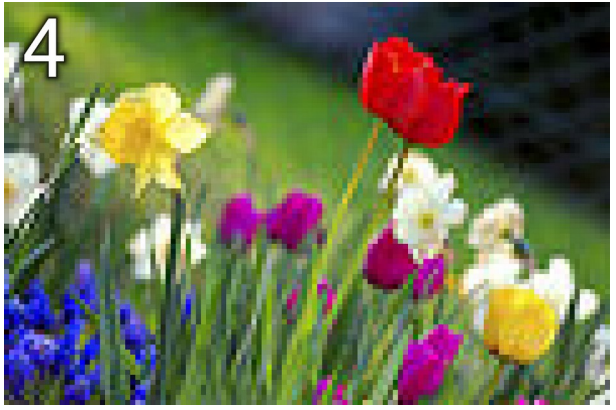
Color Filter Array Interpolation

Original

120x80 Bayer image



Colour-coded



Colour interpolation

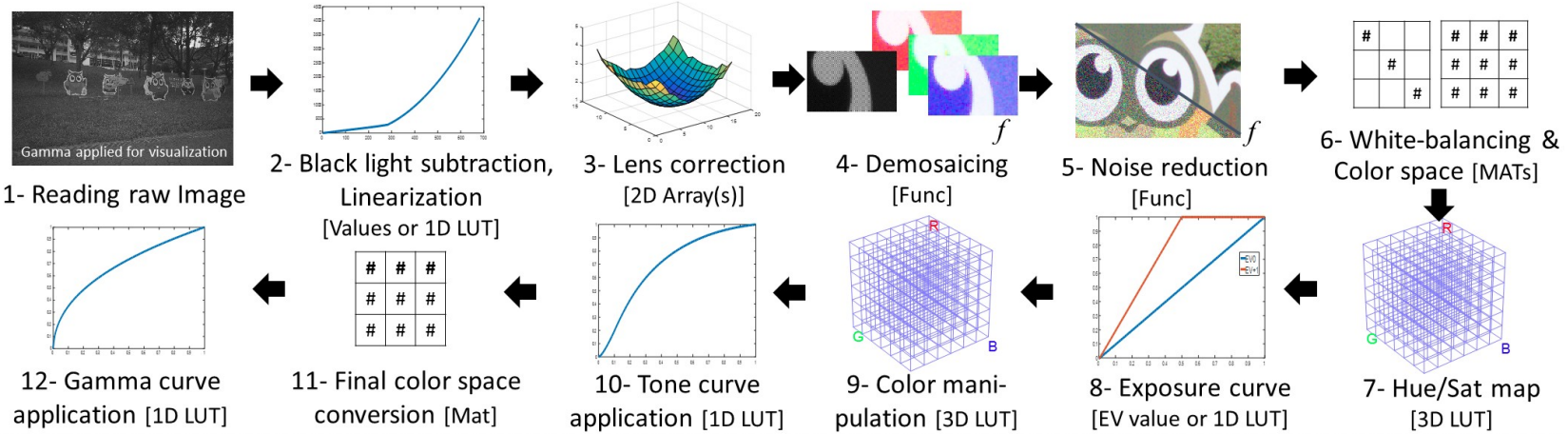
IDEAS ON BOARD

CFA Interpolation

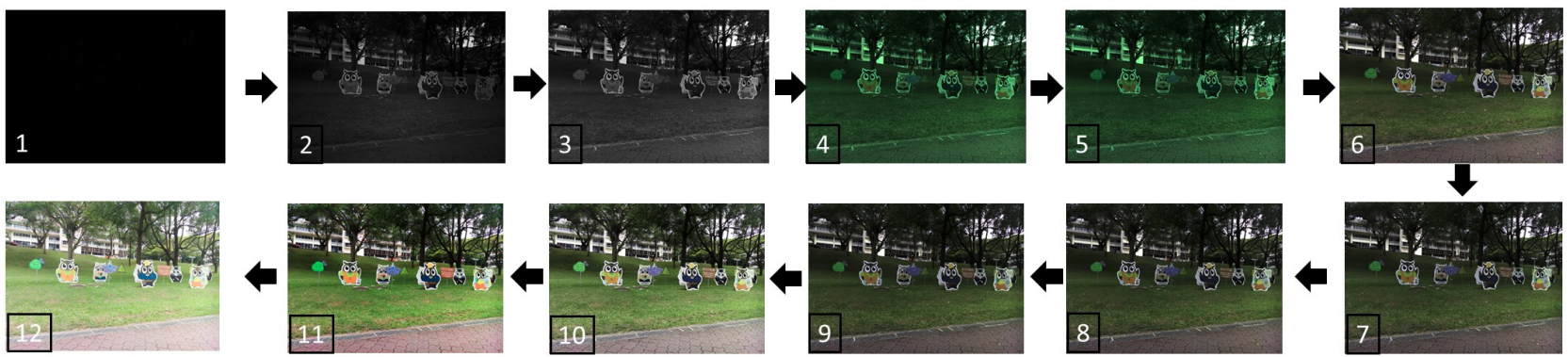
source: https://en.wikipedia.org/wiki/Bayer_filter

Lens Shading

Stages of the camera imaging pipeline and associated parameters

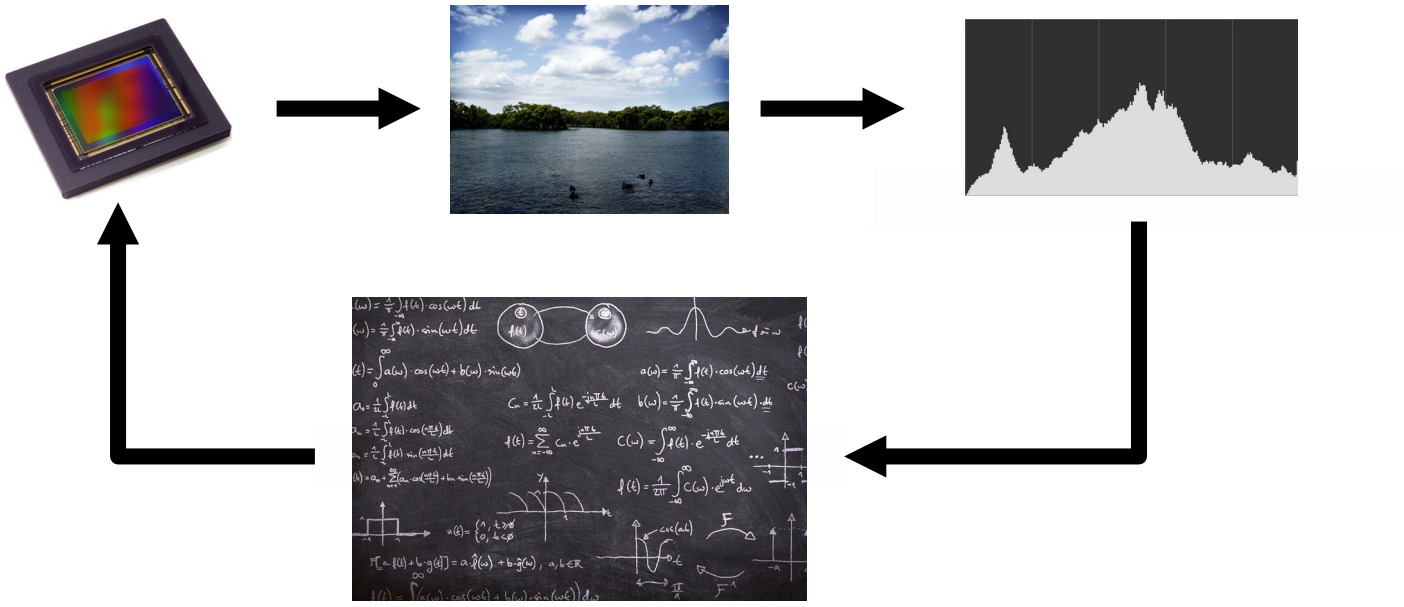


Intermediate images for each stage

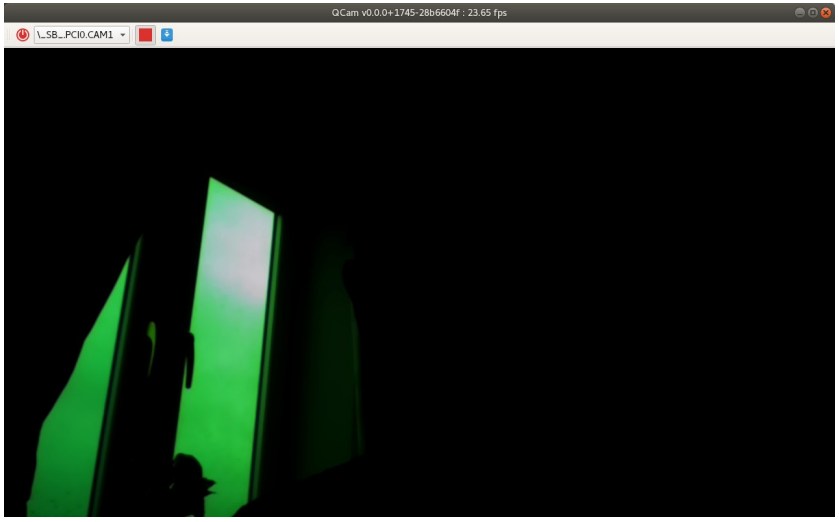


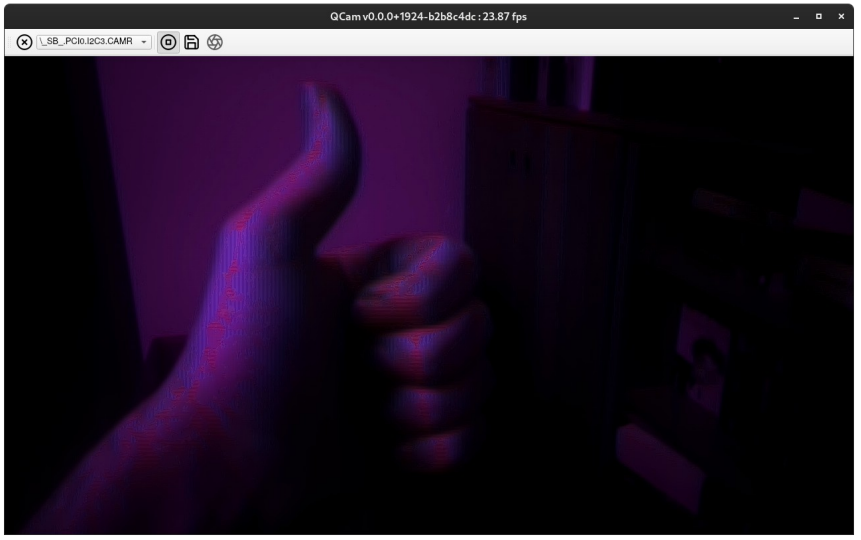
Camera Pipeline

source: https://karaimer.github.io/camera-pipeline/

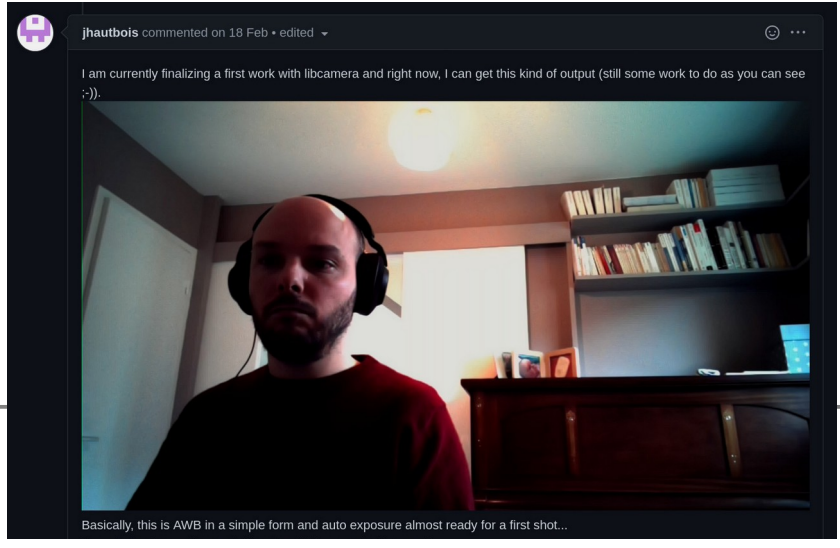


Auto Algorithms (a.k.a. 3A)





Initial support status with work on kernel drivers from djrscally, kitakar5525 and qzed



IDEAS ON BOARD

linux-surface

IQ Tuning

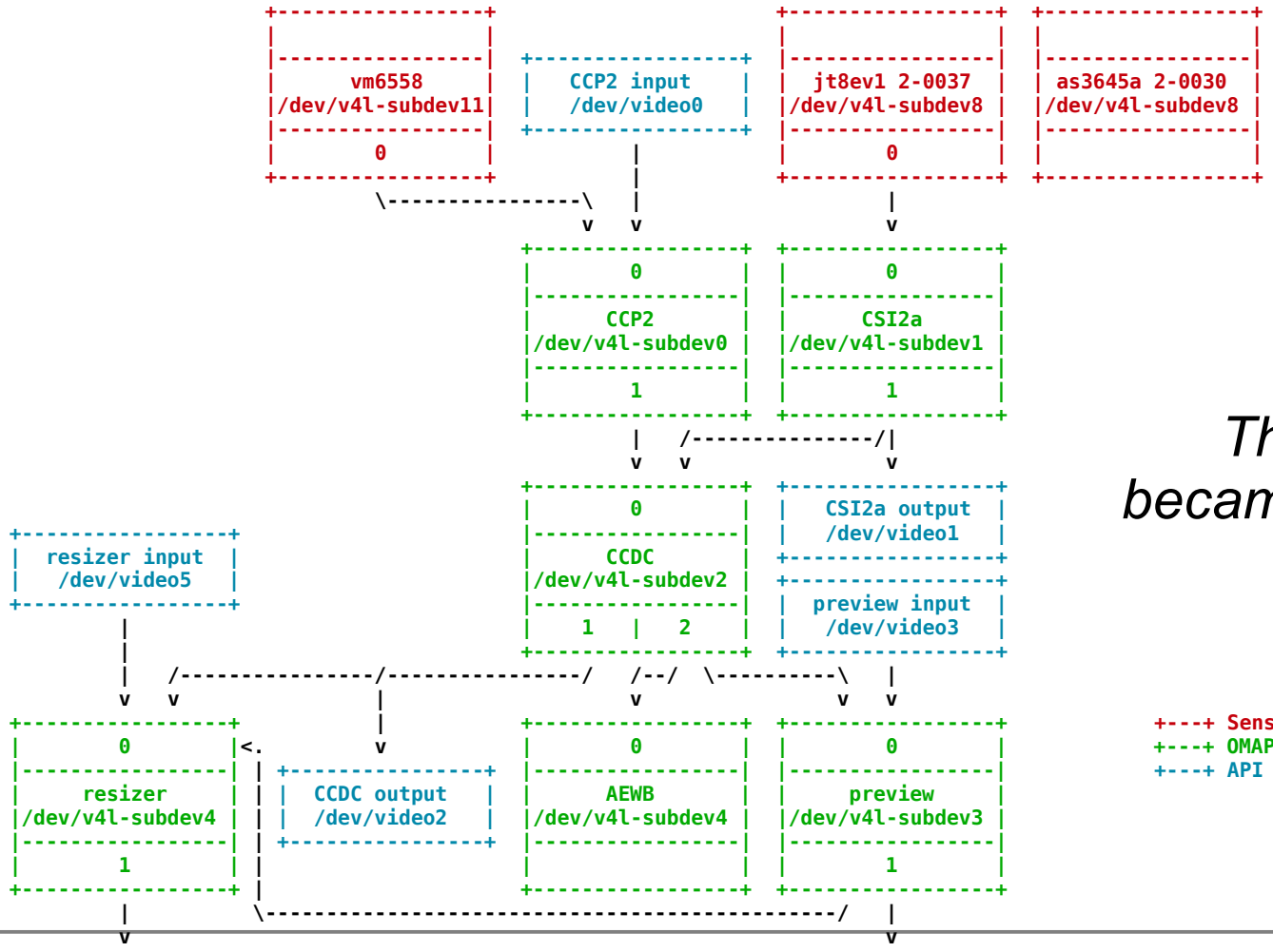
source: https://www.flickr.com/photos/davedugdale/15043975135

History of cameras on Linux


```
A    /  +-----------------+
P    |  |     capture     |
I    |  |  /dev/video0    |
     \  +-----------------+
```

Logitech Quickcam Express For Notebooks

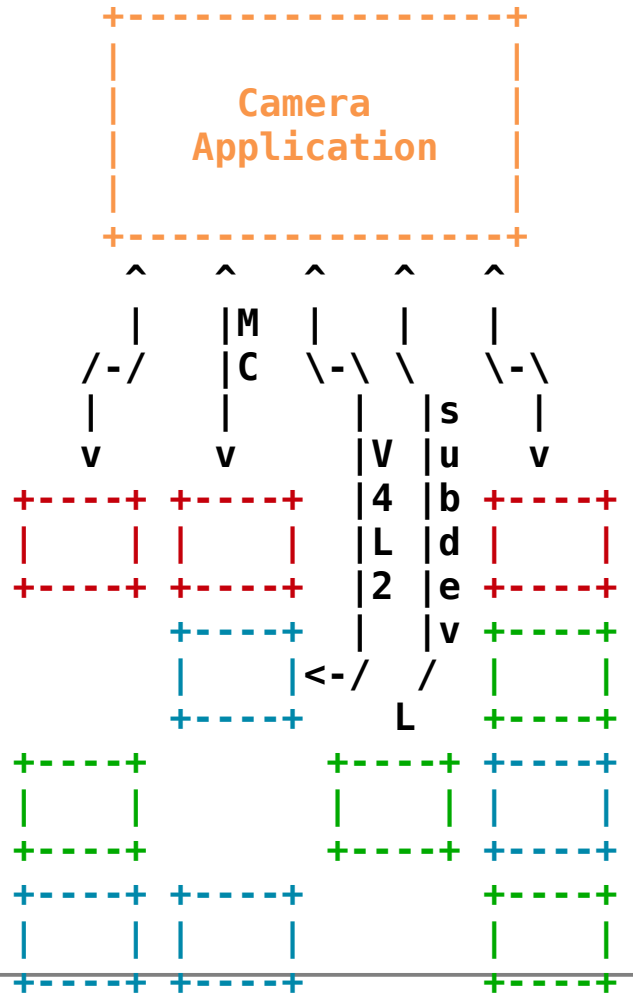
UVC Camera - V4L2



Then the world became complex...

Complex cameras

… and application developers were left suffering.

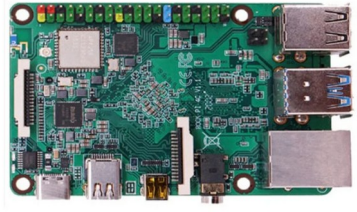


Microsoft Surface devices

Raspberry Pi 4

Dell Latitude 7285

Acer Chromebook Tab 10



ROCK
PI 4

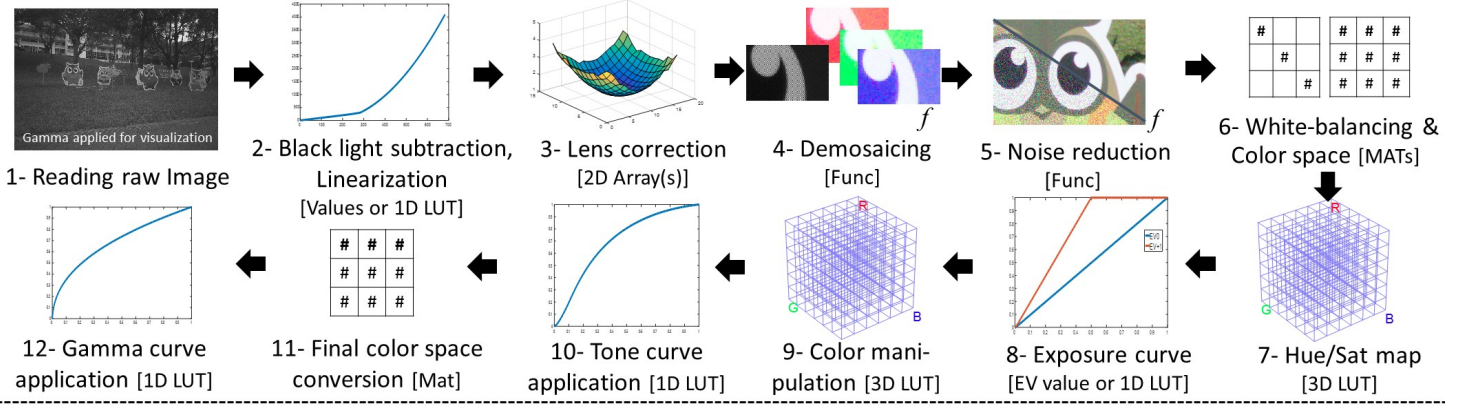
HP Chromebook x2

IDEAS ON BOARD

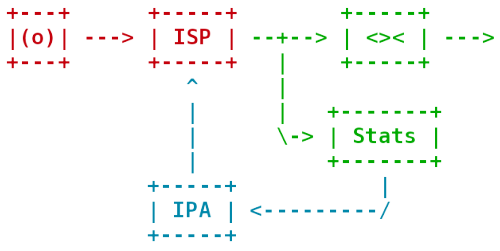
Some devices with complex cameras

```
obs
- plugins
  - linux-v4l2
  - mac-capture
  - win-capture
  ...
```

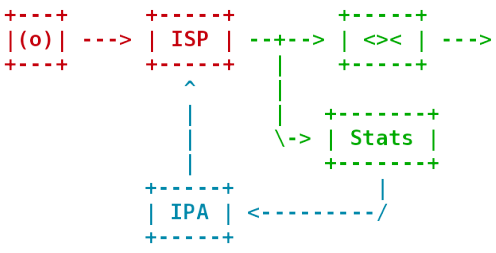
```
obs
- plugins
  - linux-v4l2
  - mac-capture
  - win-capture
  ...
  - ipu3
```

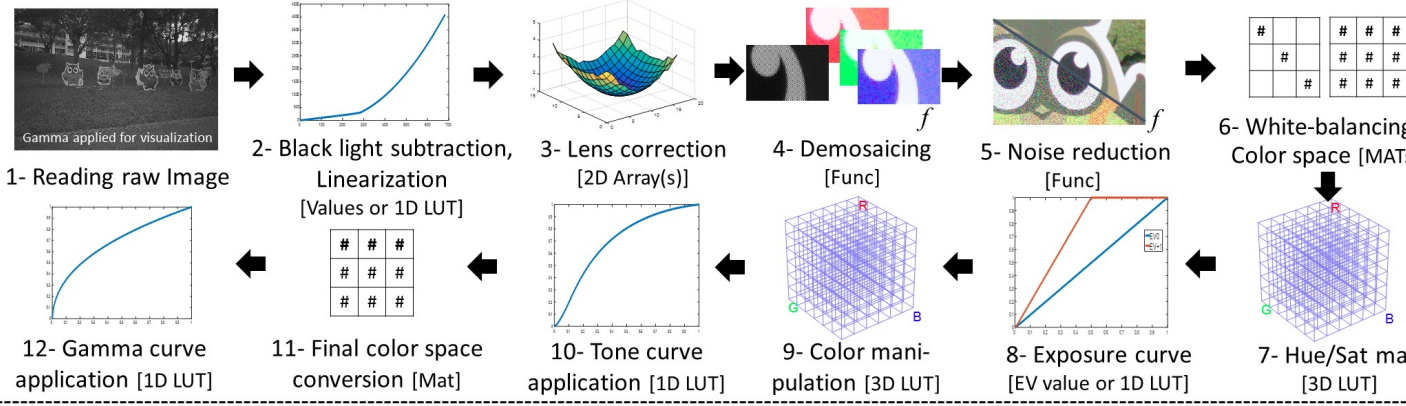


IPU3 pipeline



```
obs
- plugins
   - linux-v4l2
   - mac-capture
   - win-capture
   ...
   - ipu3
   - rkisp1
```

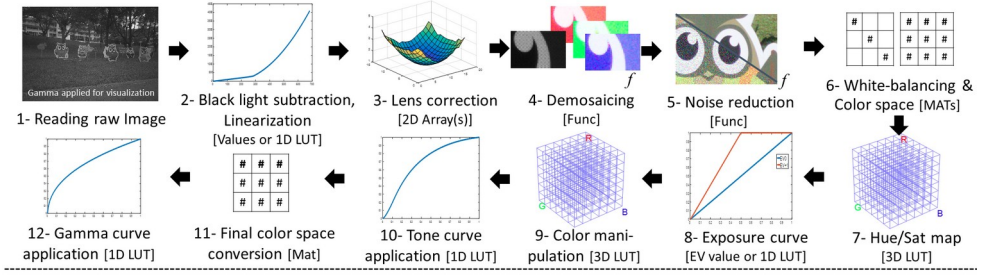




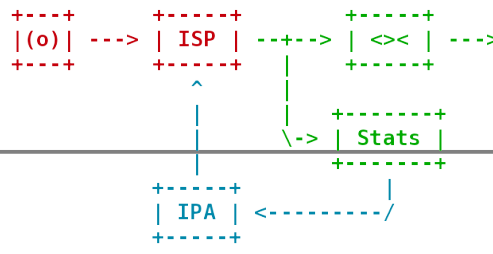
rkisp1 pipeline

IDEAS ON BOARD

```
obs
- plugins
  - linux-v4l2
  - mac-capture
  - win-capture
  ...
  - ipu3
  - rkisp1
  - raspberrypi
```

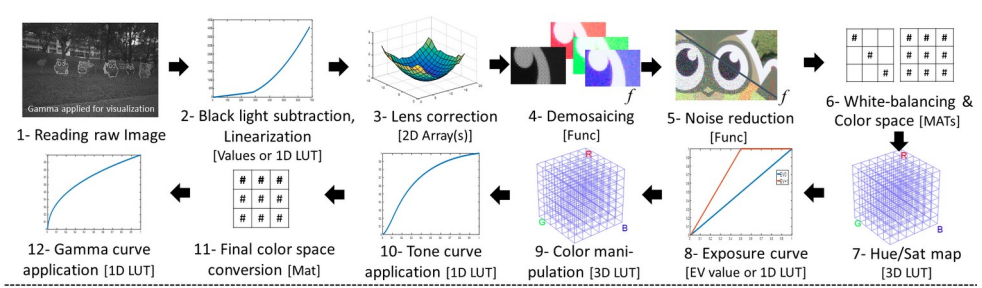


Raspberry Pi pipeline

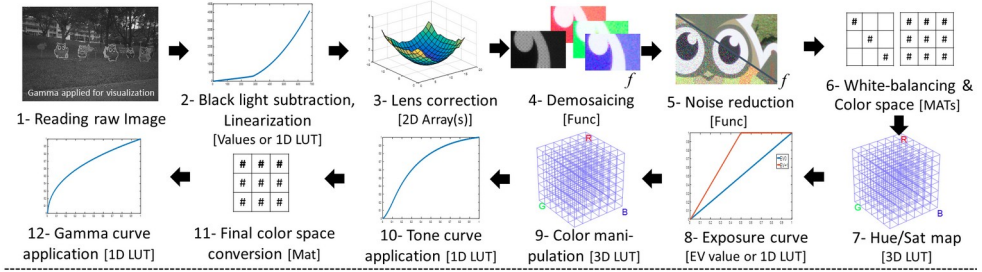


IDEAS ON BOARD

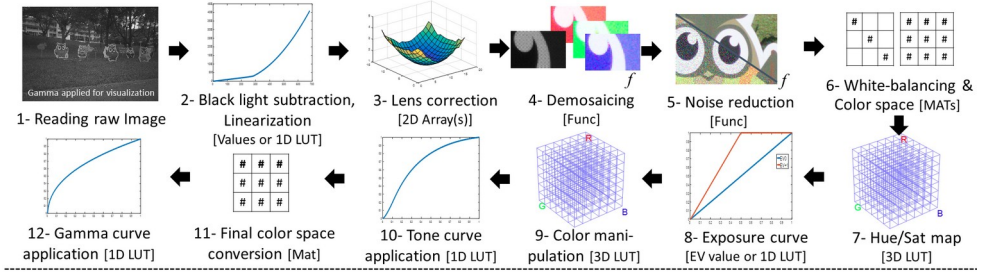
```
obs
- plugins
  - linux-v4l2
  - mac-capture
  - win-capture
  ...
  - ipu3
  - rkisp1
  - raspberrypi
  - vimc
  - imx8
  - qcom
  ...
```



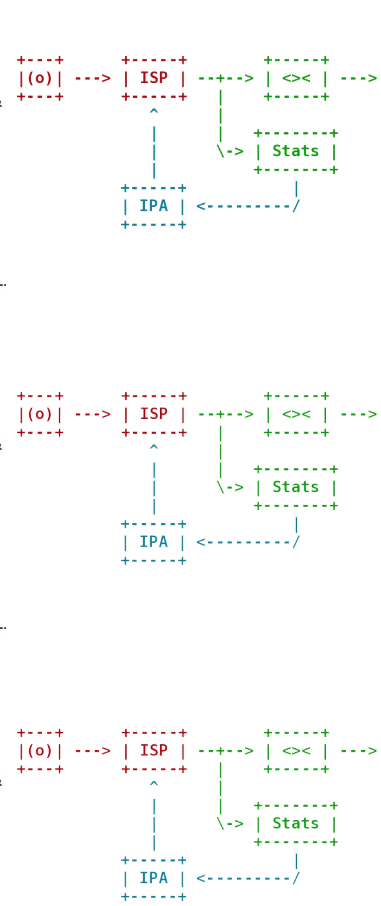
vimc pipeline



imx8 pipeline



qcom pipeline

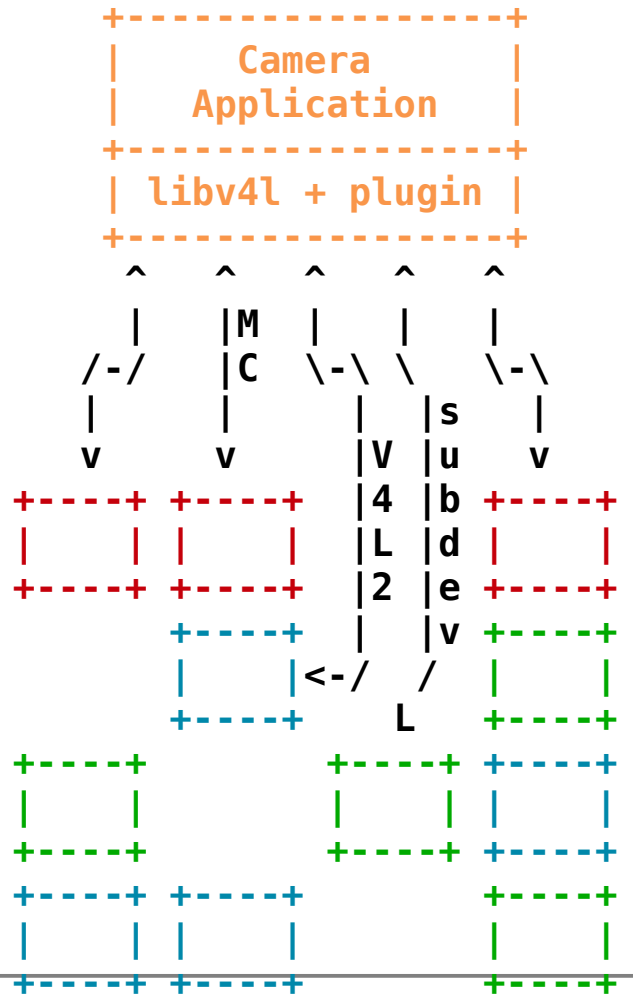


```
obs
- plugins
  - linux-v4l2
  - mac-capture
  - win-capture
  ...
  - ipu3
  - rkisp1
  - raspberrypi
  - vimc
  - imx8
  - qcom
  ...
```

```
firefox
- video_capture
  - linux-v4l2
  - mac-capture
  - win-capture
  ...
  - ipu3
  - rkisp1
  - raspberrypi
  - vimc
  - imx8
  - qcom
  ...
```

```
acme video conferencing sw
- media
  - linux-v4l2
  - mac-capture
  - win-capture
  ...
  - ipu3
  - rkisp1
  - raspberrypi
  - vimc
  - imx8
  - qcom
  ...
```

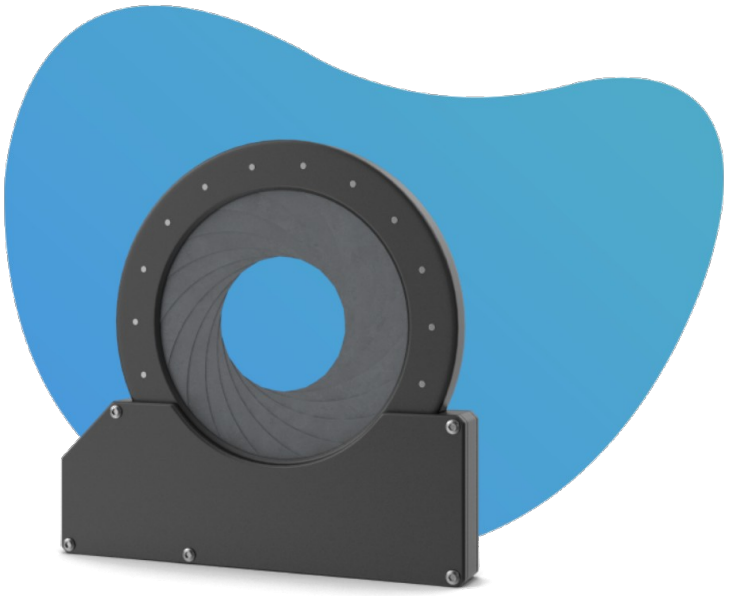
Solutions were proposed...



… but never implemented.

The world turned dark...

...then hope came back.



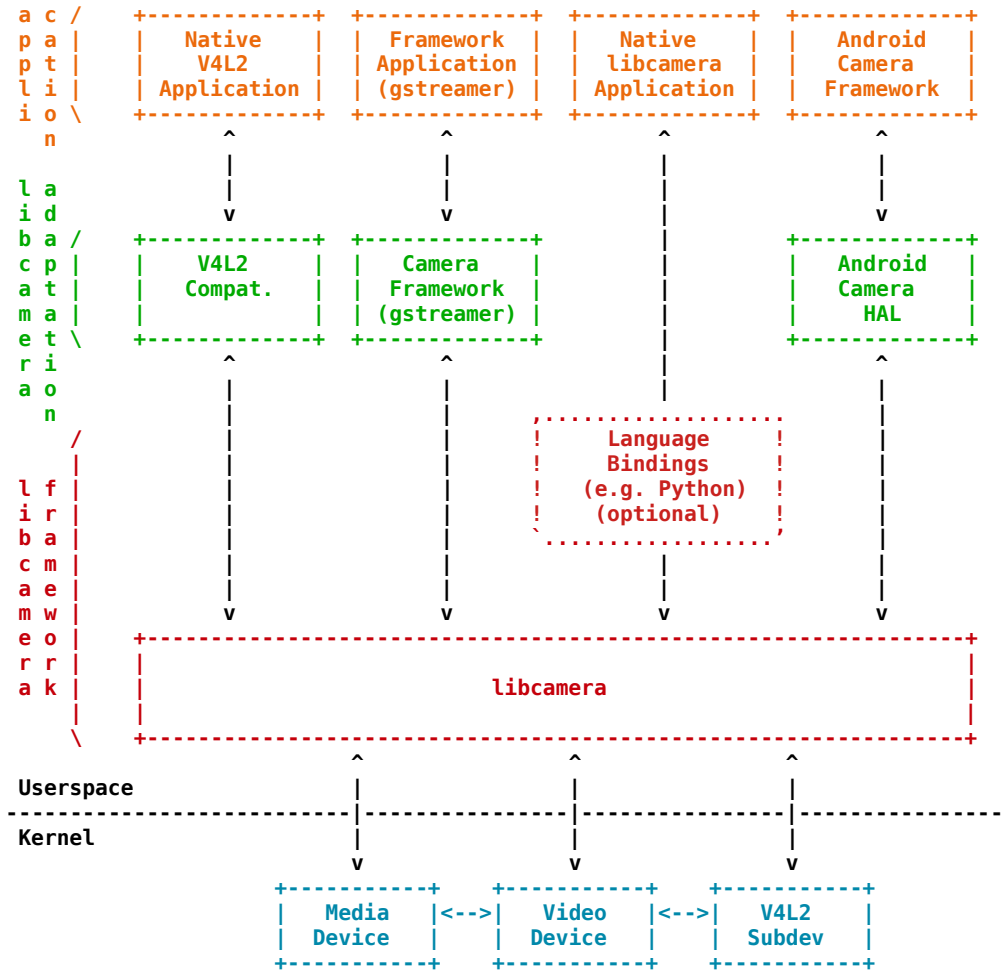
Hi, we're libcamera.

An open source camera stack and framework for Linux, Android, and ChromeOS

Getting Started

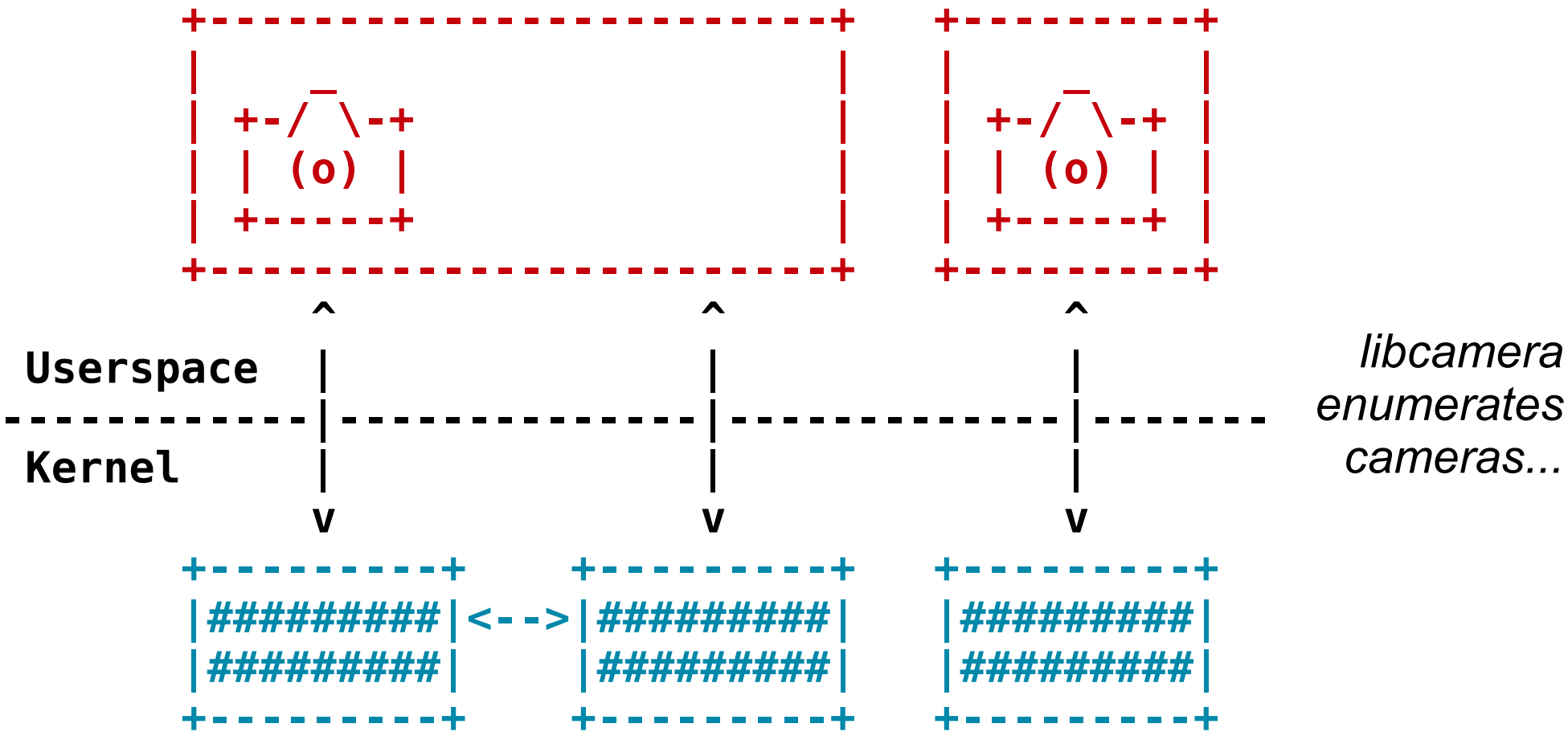
IDEAS ON BOARD

libcamera provides a complete userspace camera stack.

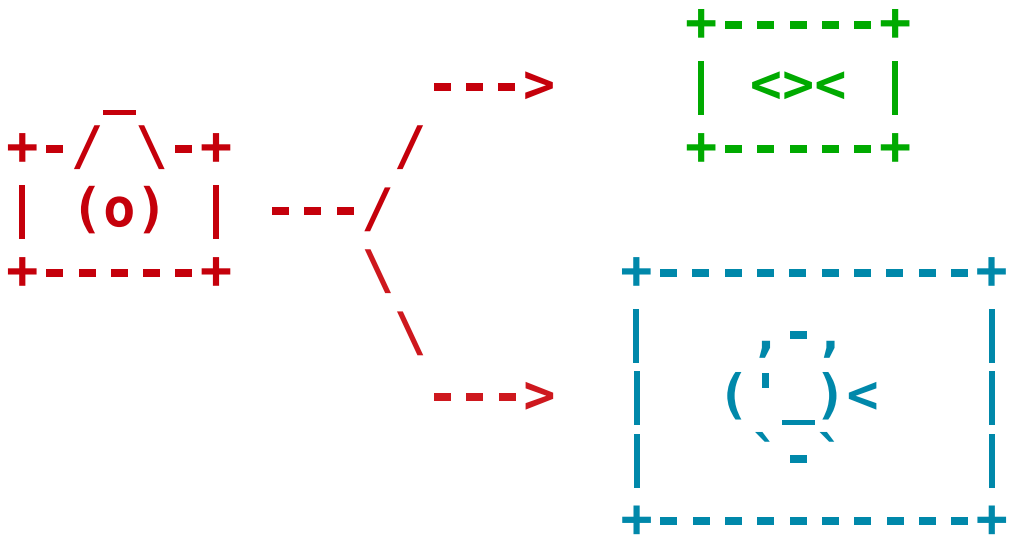


The 'Mesa' of the camera world.

Camera Stack

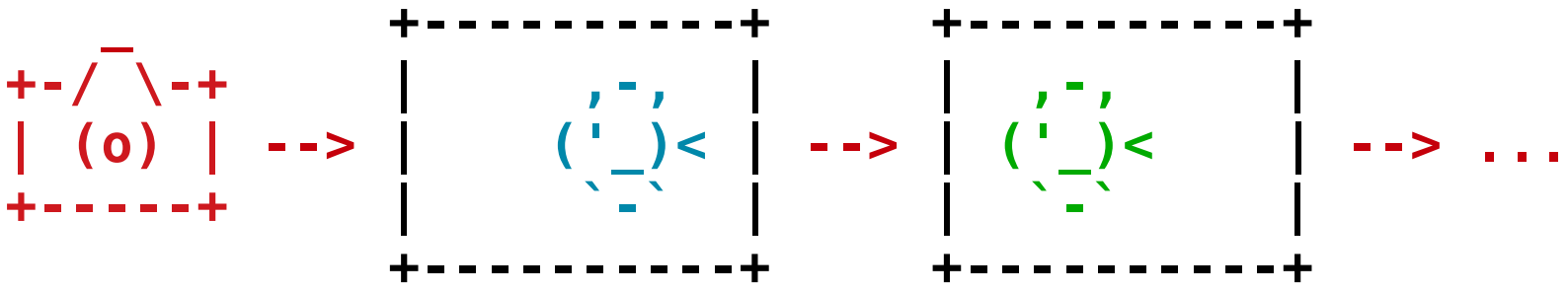


Camera Devices & Enumeration



It supports multiple concurrent streams for the same camera...

Streams



… and per-frame controls.

Per-Frame Controls

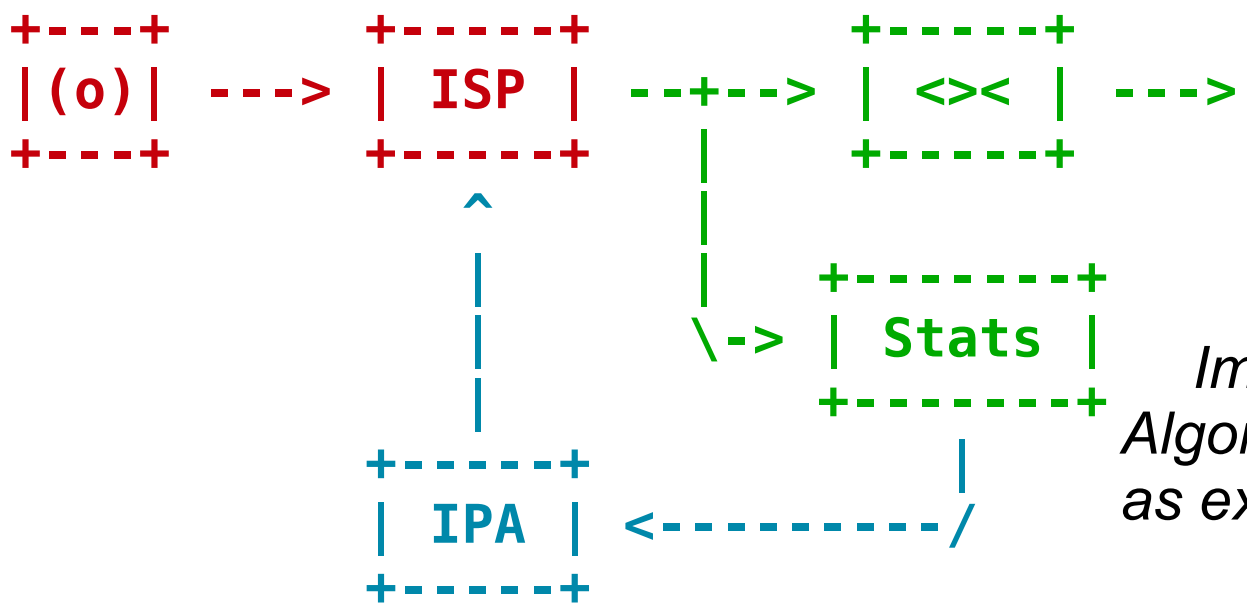
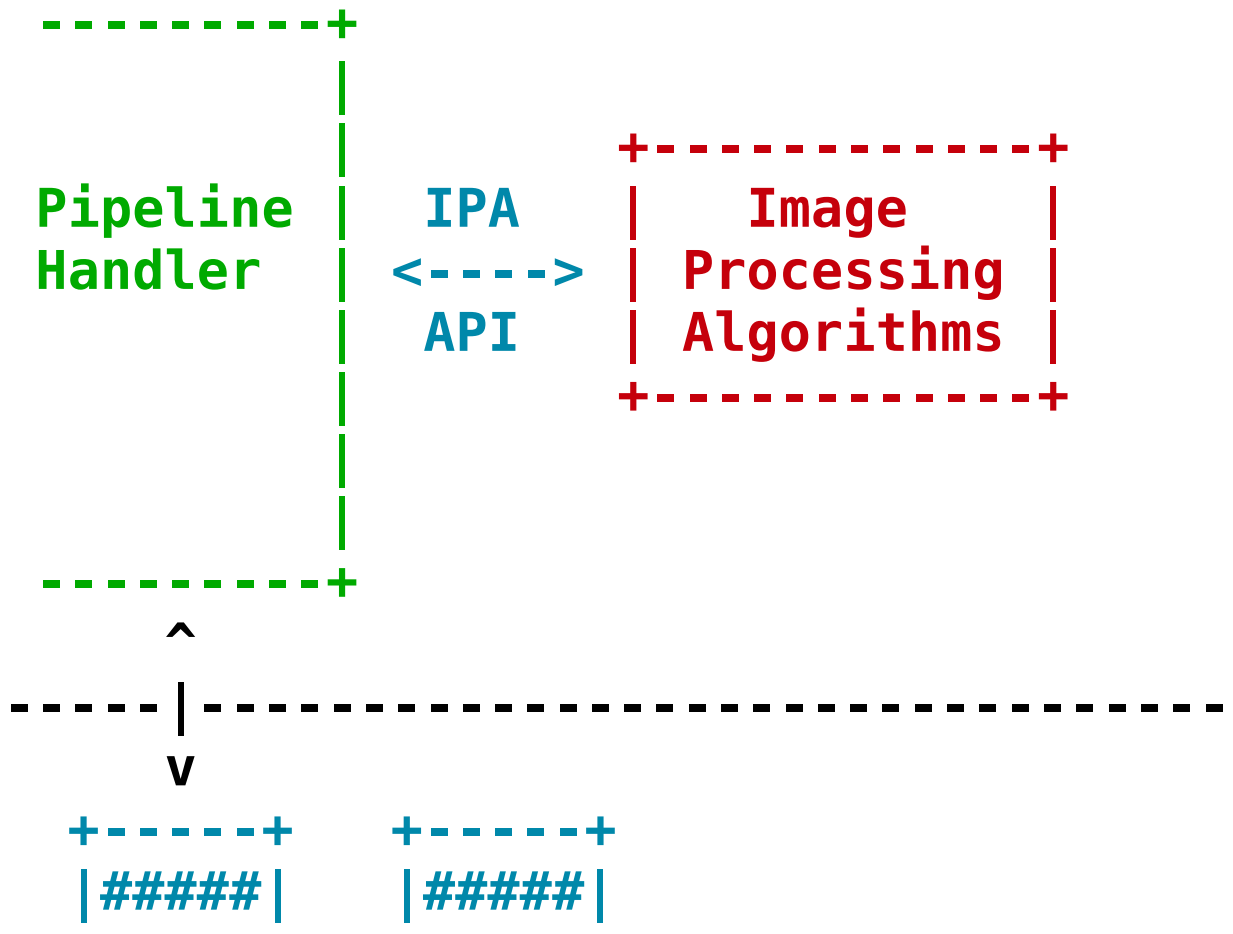


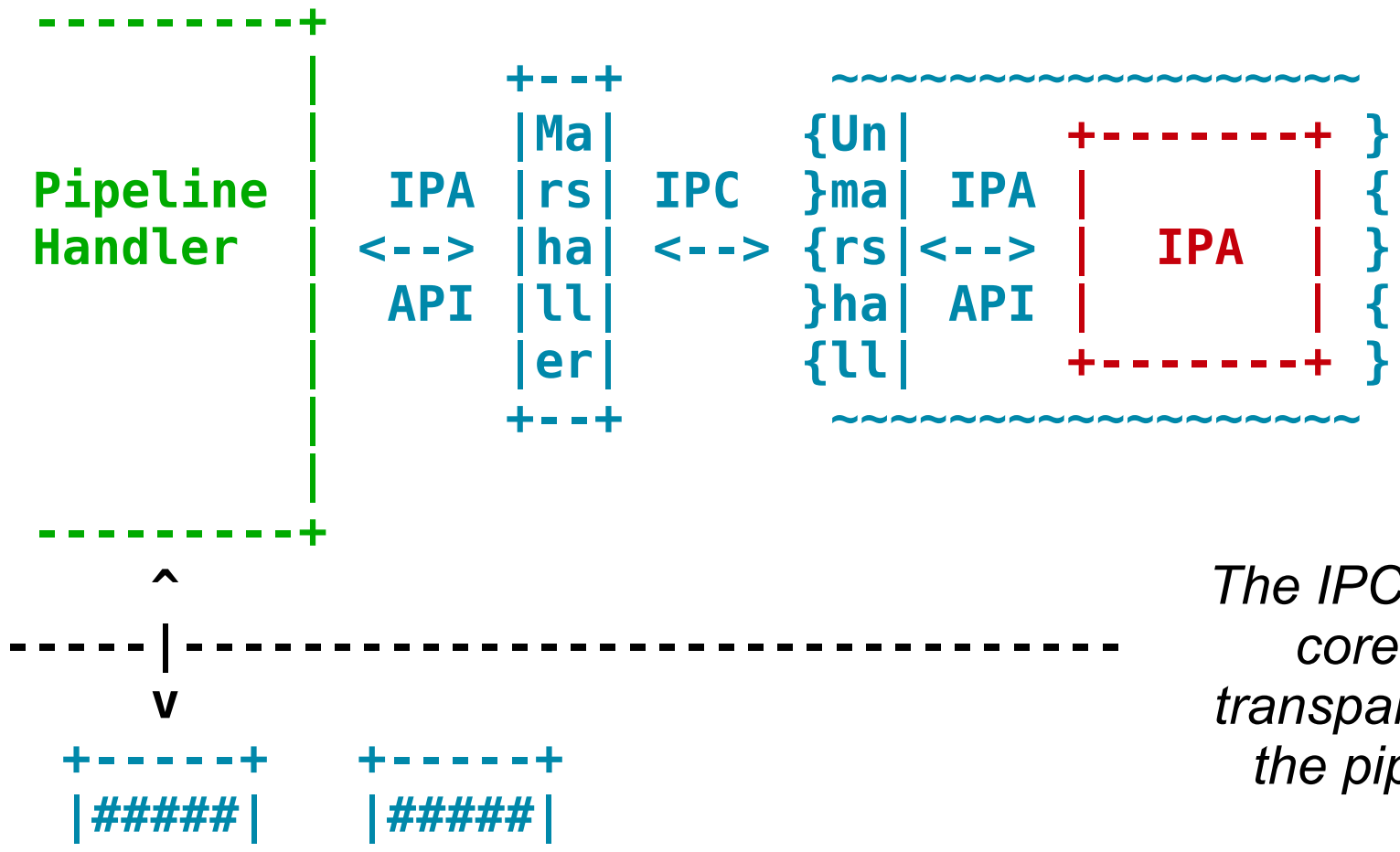
Image Processing Algorithm are loaded as external modules.

Image Processing Algorithms (3A)



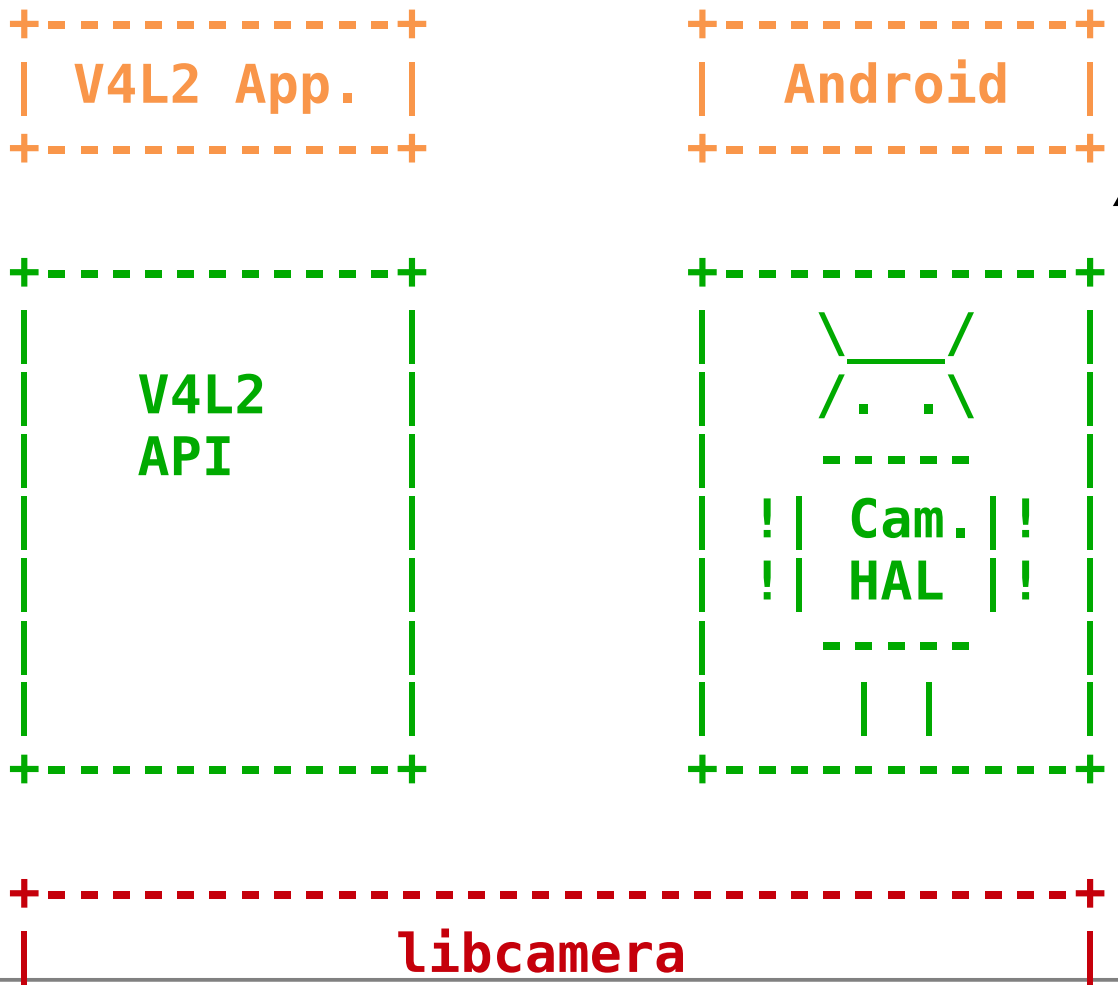
IPAs are separate modules that don't access kernel devices directly. They only have access to their pipeline handler through the IPA API.

The Image Processing Algorithms



The IPC is handled in core components, transparently for both the pipeline handler and the IPA.

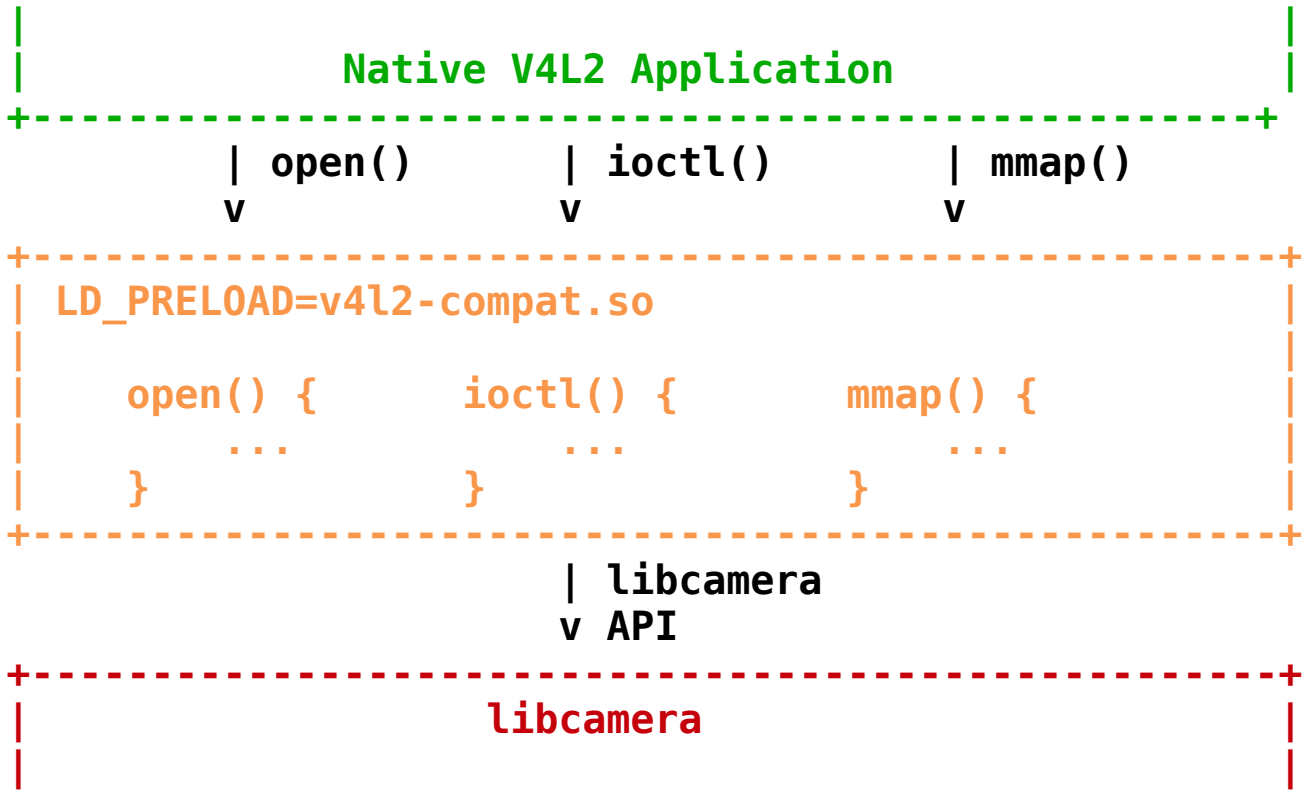
The Image Processing Algorithms



Adaptation layers offer backward compatibility with existing APIs

and integrate libcamera with other operating systems.

Adaptation



Native V4L2 applications are supported through a transparent compatibility layer.

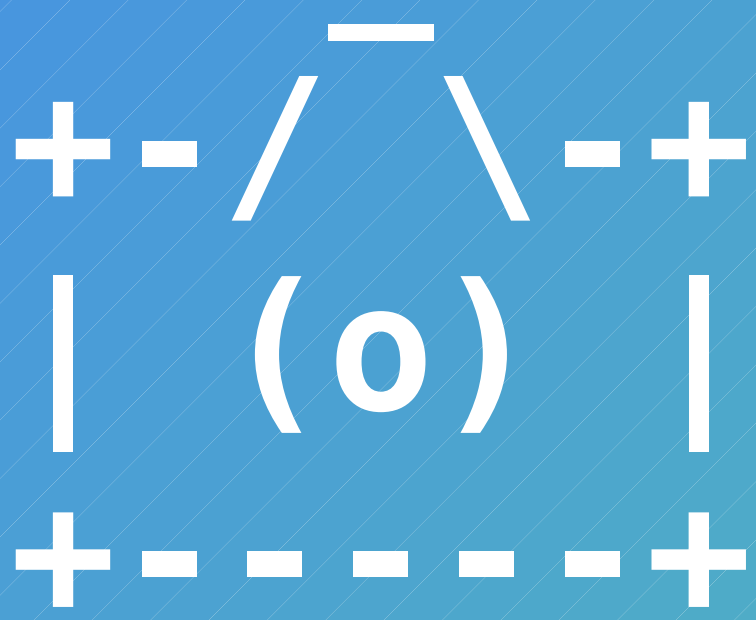
Native V4L2 Compatibility

“libcamerasrc” offers a multi-stream source element for GStreamer applications.

GStreamer

pipewire

More adaptation layers



For users

IDEAS ON BOARD

```
$ cam -l
[33:09:16.400961063] [2921096]  INFO IPAManager ipa_manager.cpp:138 libcamera is not installed. Adding
'/home/epaul/dev/iob/libcamera/build/gcc/src/ipa' to the IPA search path
[33:09:16.415141039] [2921096]  INFO Camera camera_manager.cpp:293 libcamera v0.0.0+3266-cb1de399
Available cameras:
1: 'Logitech Webcam C930e' (\_SB_.PCI0.XHC_.RHUB.HS03-3.1:1.0-046d:0843)
2: 'Integrated Camera: Integrated C' (\_SB_.PCI0.XHC_.RHUB.HS08-8:1.0-04f2:b6cb)
3: 'Integrated Camera: Integrated I' (\_SB_.PCI0.XHC_.RHUB.HS08-8:1.2-04f2:b6cb)
```

Use libcamera

```
$ gst-launch-1.0 libcamerasrc camera-name="\\\_SB_.PCI0.XHC_.RHUB.HS08-8:1.0-04f2:b6cb" name=src
src.src ! video/x-raw,width=1280,height=720 ! queue ! videoconvert ! Ximagesink
Setting pipeline to PAUSED ...
[33:14:24.969515306] [2939470]  INFO IPAManager ipa_manager.cpp:138 libcamera is not installed. Adding
'/home/epaul/dev/iob/libcamera/build/clang/src/ipa' to the IPA search path
[33:14:24.971012306] [2939470]  INFO Camera camera_manager.cpp:293 libcamera v0.0.0+3307-9d6f591a
Pipeline is live and does not need PREROLL ...
Pipeline is PREROLLED ...
Setting pipeline to PLAYING ...
New clock: GstSystemClock
[33:14:25.197789380] [2939492]  INFO Camera camera.cpp:945 configuring streams: (0) 1280x720-YUYV
^Chandling interrupt.
Interrupt: Stopping pipeline ...
Execution ended after 0:00:02.612884344
Setting pipeline to NULL ...
Freeing pipeline ...
```

Via gstreamer

```
obs
- plugins
  - linux-v4l2
  - mac-capture
  - win-capture
  ...
  - ipu3
  - rkisp1
  - raspberrypi
  - vimc
  - imx8
  - qcom
  ...
```

```
firefox
- video_capture
  - linux-v4l2
  - mac-capture
  - win-capture
  ...
  - ipu3
  - rkisp1
  - raspberrypi
  - vimc
  - imx8
  - qcom
  ...
```

```
acme video conferencing sw
- media
  - linux-v4l2
  - mac-capture
  - win-capture
  ...
  - ipu3
  - rkisp1
  - raspberrypi
  - vimc
  - imx8
  - qcom
  ...
```

Add it to your application

```
obs
- plugins
  - linux-v4l2
  - mac-capture
  - win-capture
  - linux-libcamera
```

```
firefox
- video_capture
  - linux-v4l2
  - mac-capture
  - win-capture
  - linux-libcamera
```

```
acme video conferencing sw
- media
  - linux-v4l2
  - mac-capture
  - win-capture
  - linux-libcamera
```

Add it to your application

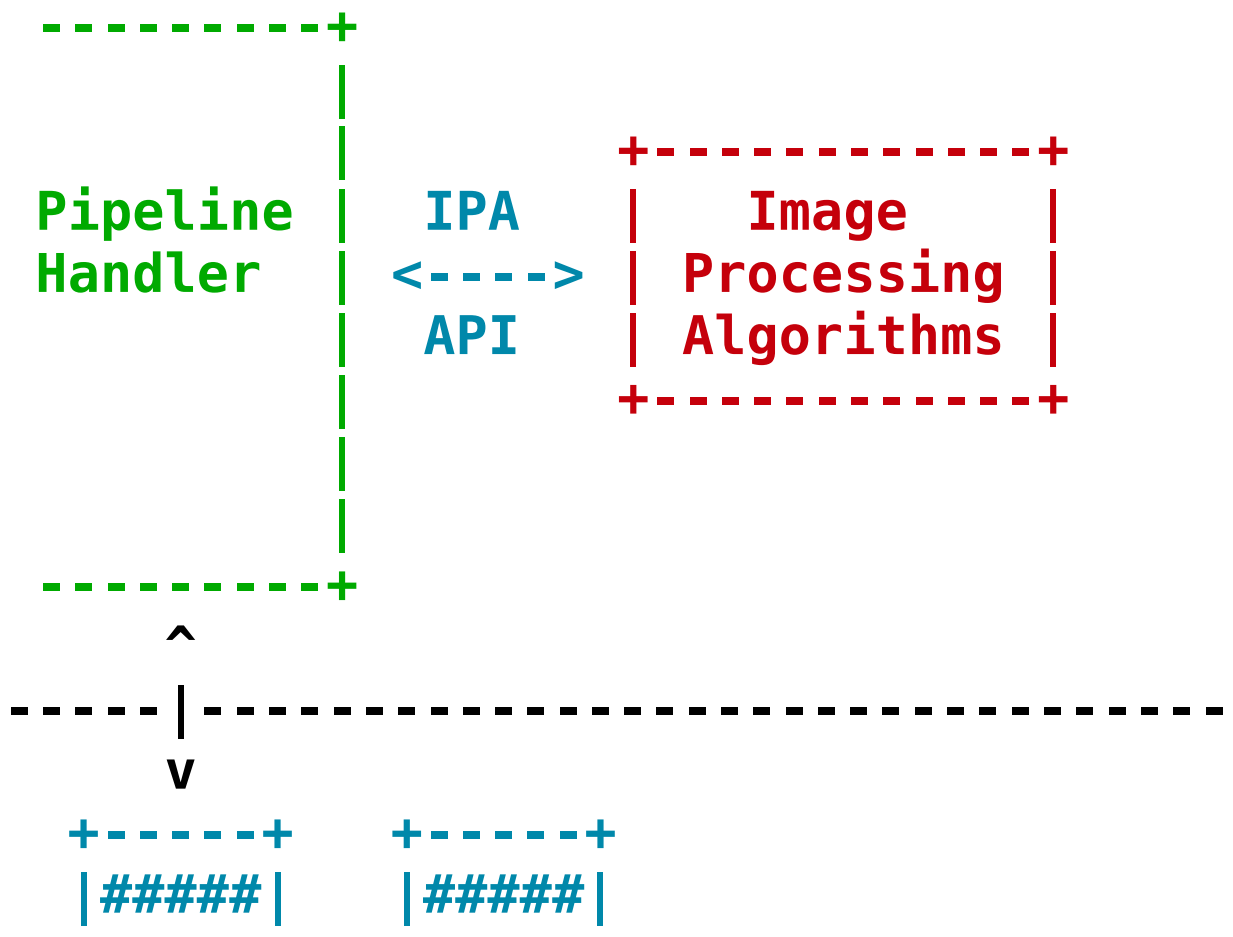
Chromium (on MS Surface Go 2)

“Live” demo

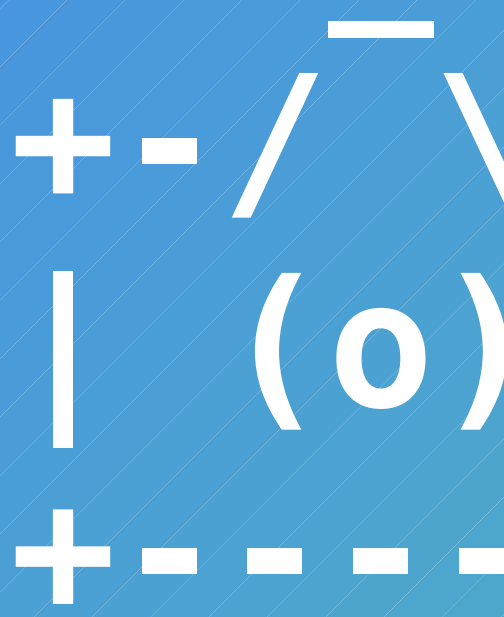
source: https://github.com/Rahi374/obs-studio/tree/libcamera-demo

- OBS
- PipeWire
- OpenCV
- Qt Multimedia
- Chromium
- Firefox
- <insert your app or framework here>

Add it to your application

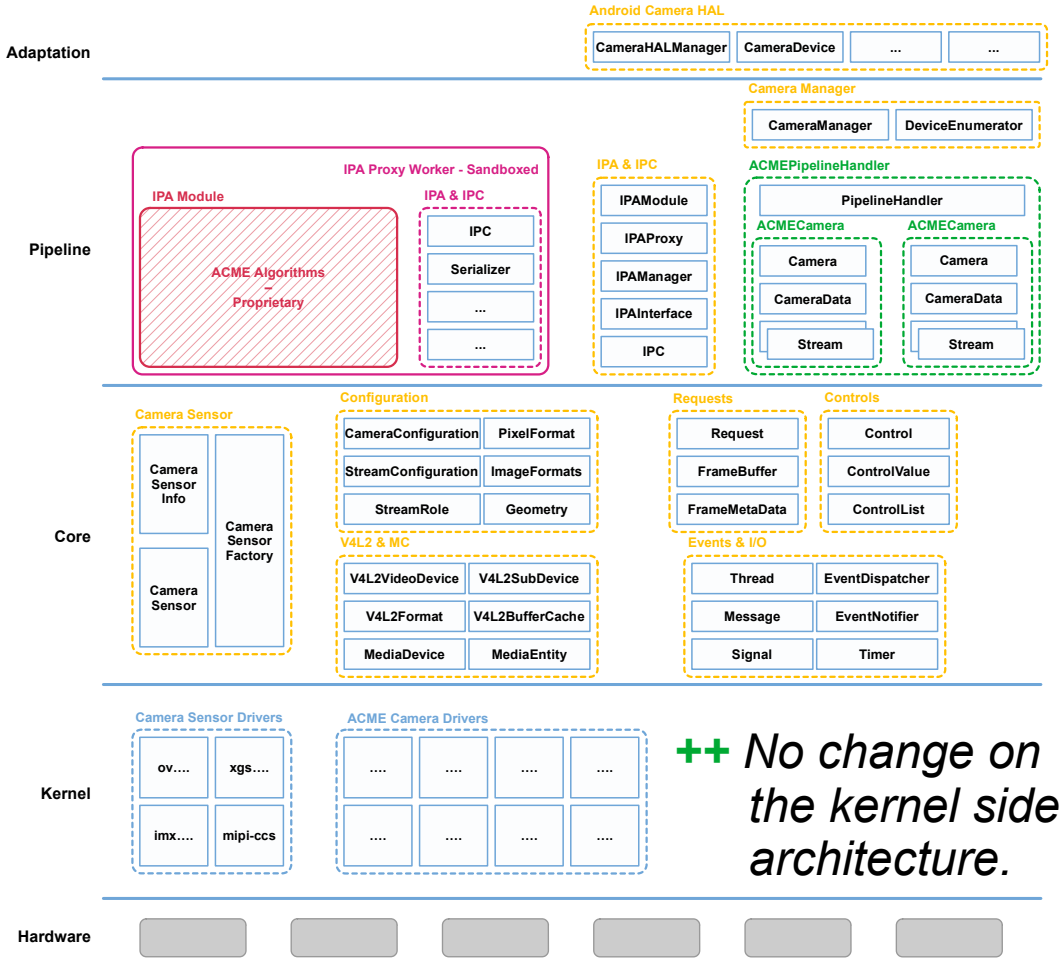


Experiment with IPAs?



For Camera Vendors

IDEAS ON BOARD



Platform Enablement

We drive MC and V4L2 standardization and extensions development according to our needs.

libcamera is a userspace framework, not a hostile takeover of kernel development.

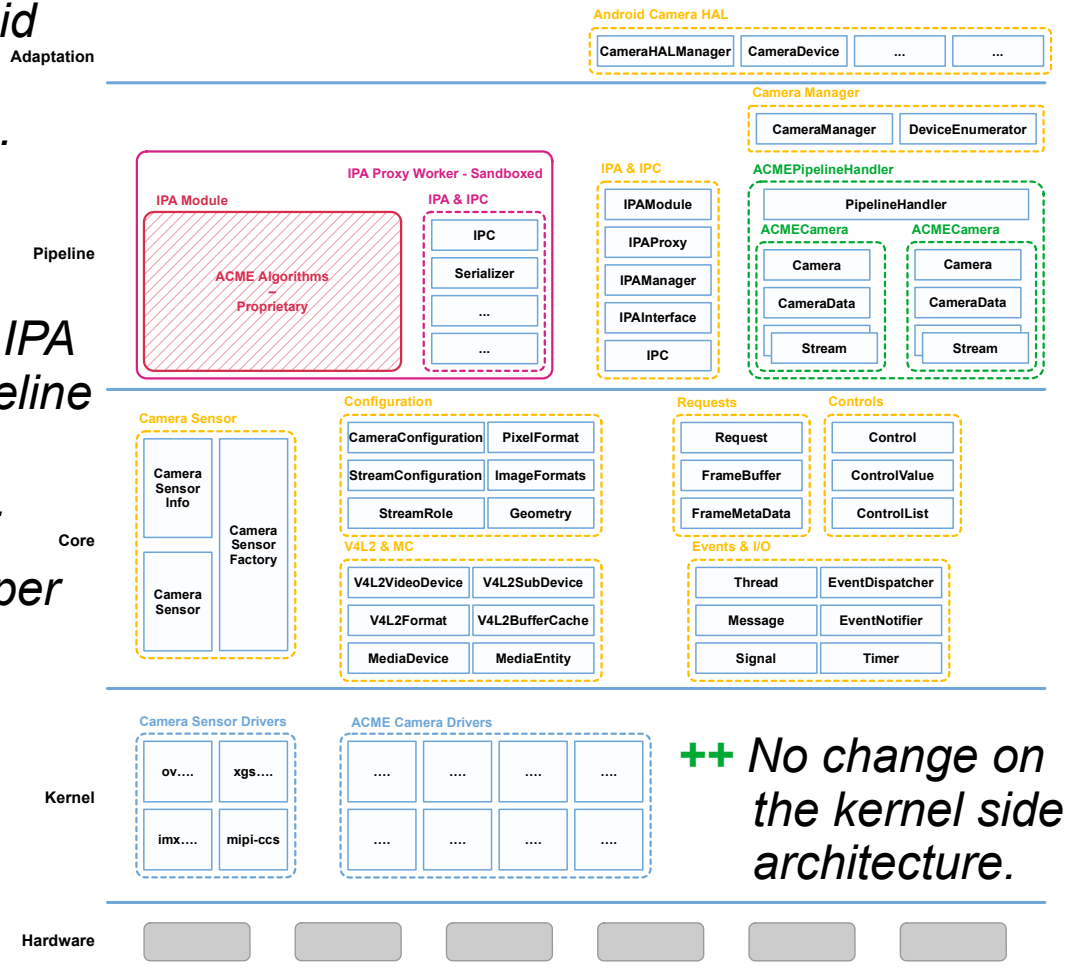
Kernel APIs

++ *Standard Android Camera HAL Implementation.*

++ *GStreamer, V4L2, ...*

/!\ *Custom API for IPA module <-> pipeline handler communication.*

++ *libcamera wrapper classes reduce custom code.*



++ *No change on the kernel side architecture.*

/!\ *Pipeline handler is ACME-specific development.*

++ *Development support available.*

/!\ *Implementation changes may be required to mainline drivers.*

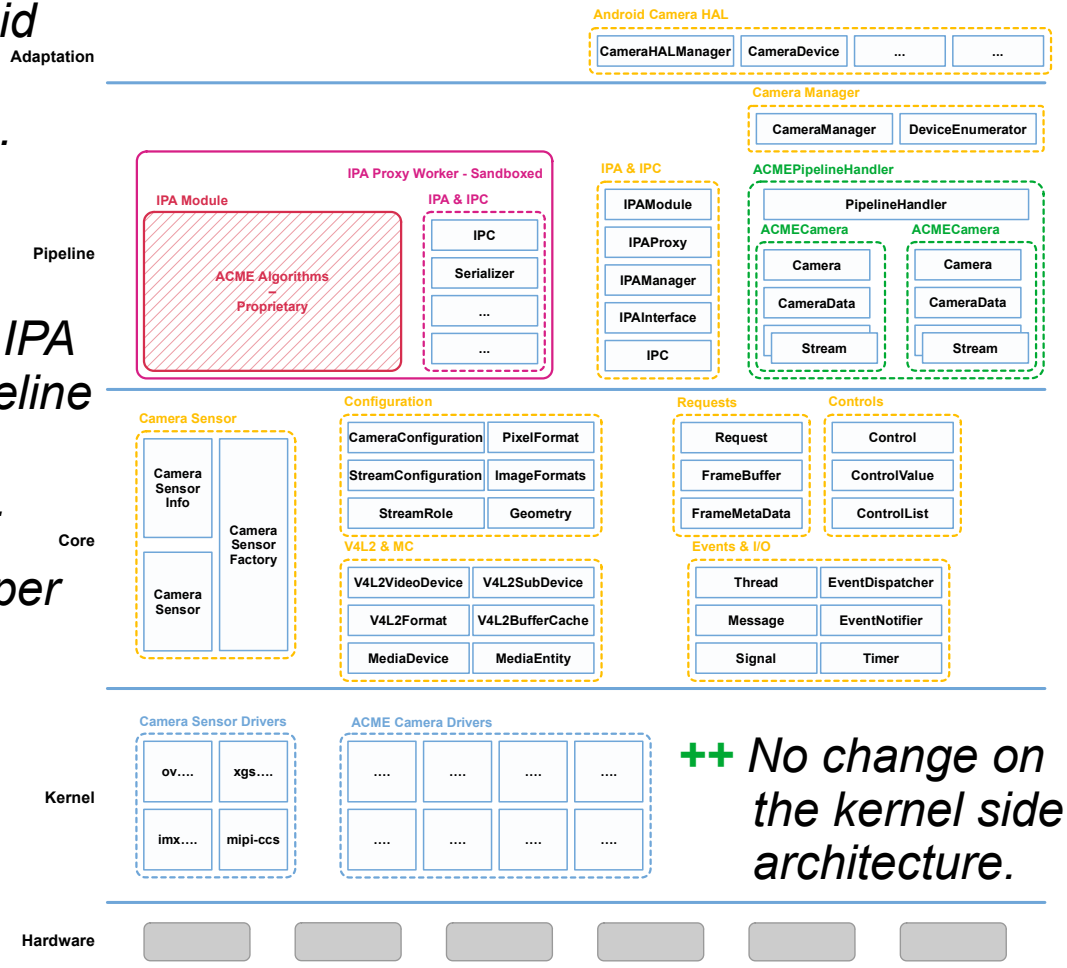
Platform Enablement

++ *Standard Android Camera HAL Implementation.*

++ *GStreamer, V4L2, ...*

/!\ *Custom API for IPA module <-> pipeline handler communication.*

++ *libcamera wrapper classes reduce custom code.*



++ *No change on the kernel side architecture.*

/!\ *Pipeline handler is ACME-specific development.*

++ *Development support available.*

/!\ *Implementation changes may be required to mainline drivers.*

Platform Enablement

The libcamera core is licensed under the LGPL v2.1 or later.

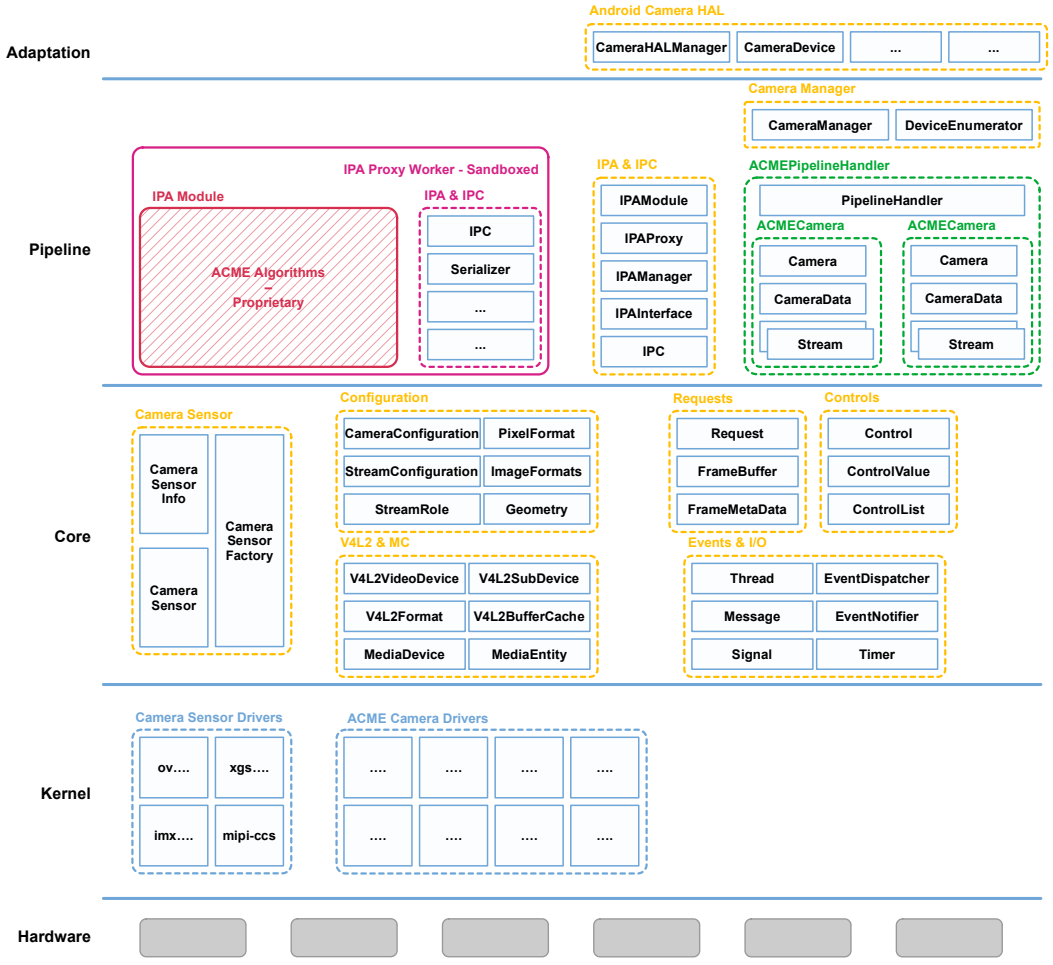
Changes need to be published according to the license. This includes pipeline handlers.

Upstreaming is not mandatory but highly recommended (forks are costly to maintain).

Licensing

Closed-source IPA modules are fully supported.

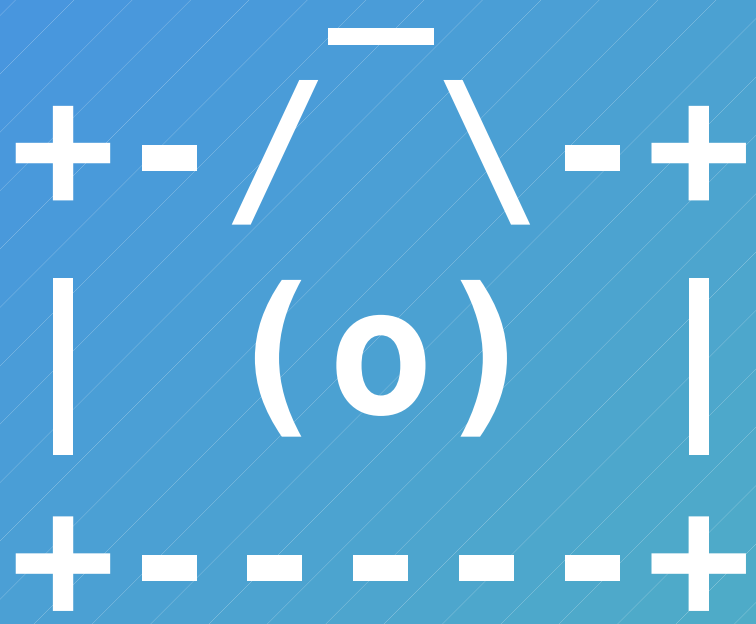
Pipeline handlers and IPA modules can link to third-party libraries.



The libcamera core, pipeline handlers and adaptation are licensed under LGPL v2.1 or later

Kernel code is licensed under GPL v2.0.

Licensing



libcamera

libcamera-devel@lists.libcamera.org
irc://irc.oftc.net/#libcamera

paul.elder@ideasonboard.com

Contact

Thank you.