Media controller

Harnessing the full power of tomorrow's video devices

FOSDEM 2010

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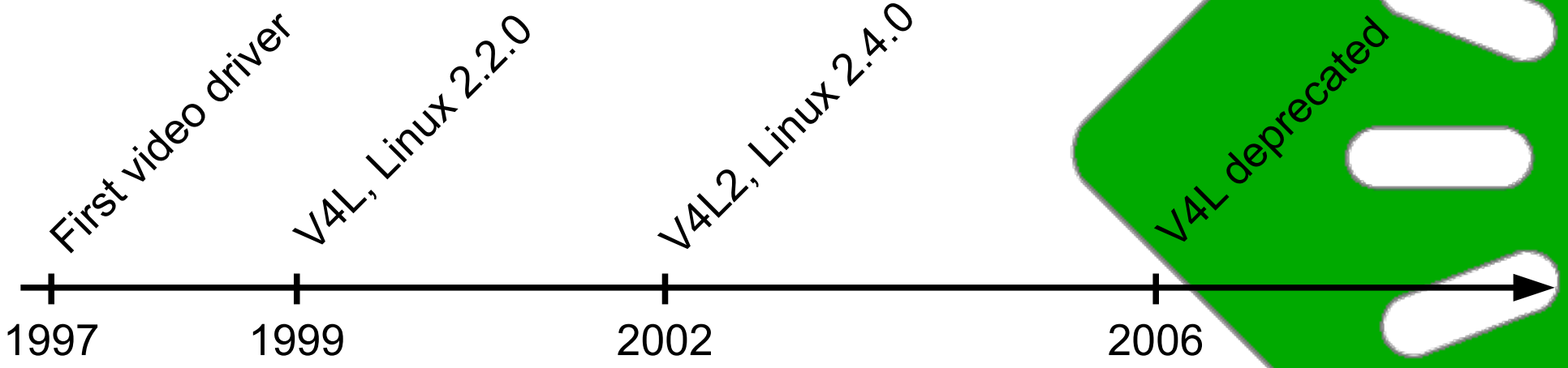
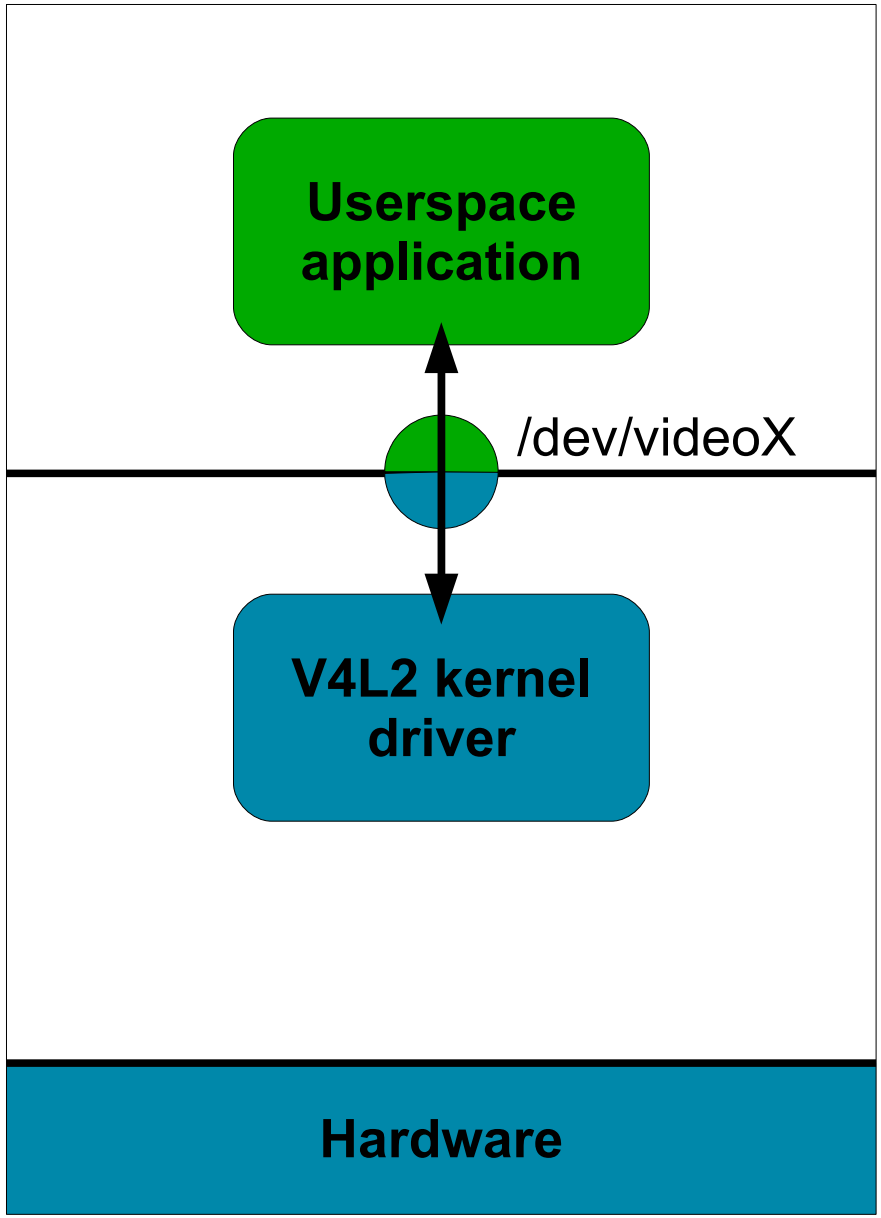
- Video acquisition in Linux
- Embedded cameras
- Tomorrow's devices
- Problems
- And solutions

Topics

Yesterday

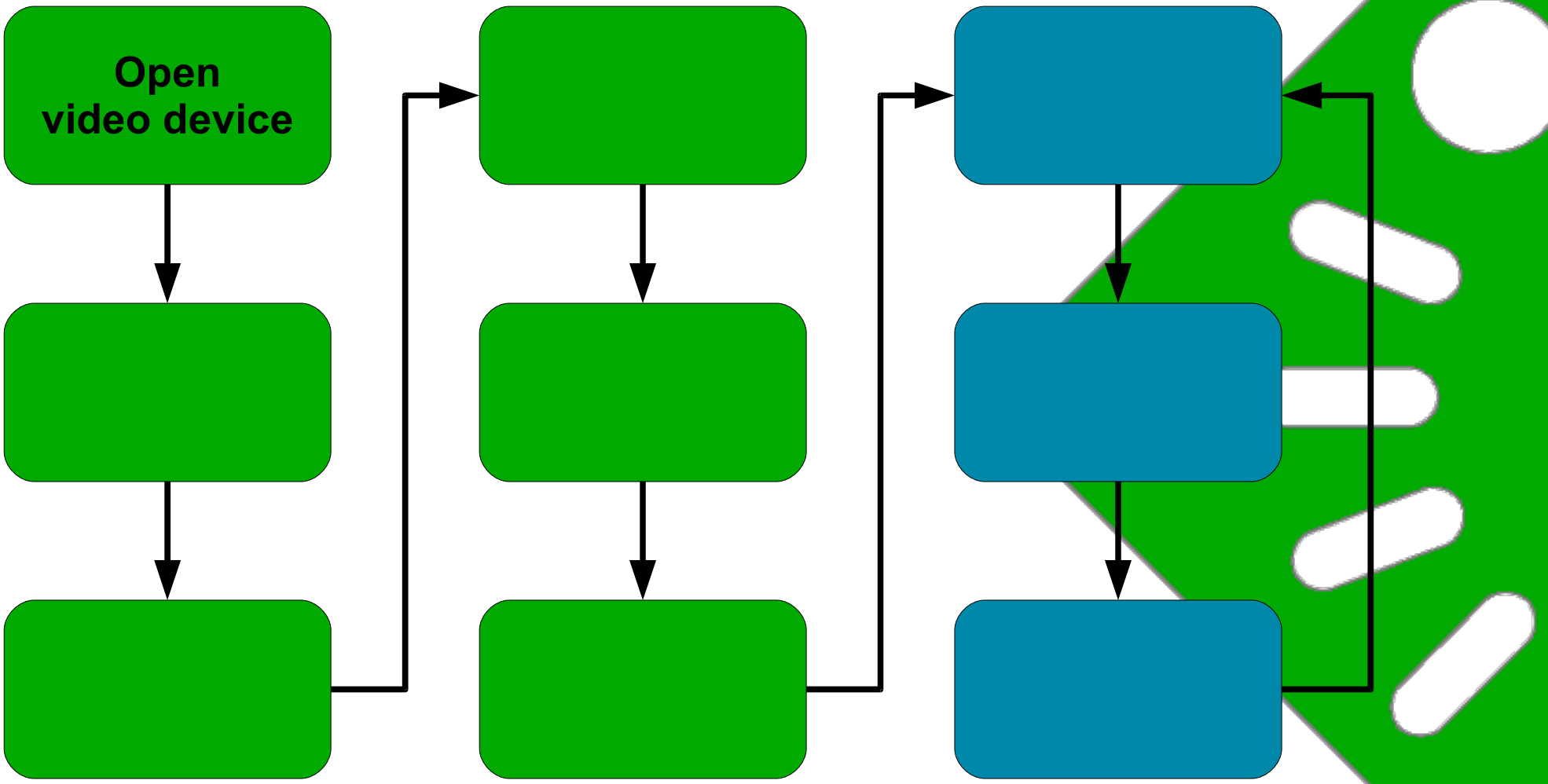


The (recent) past



V4L2 API

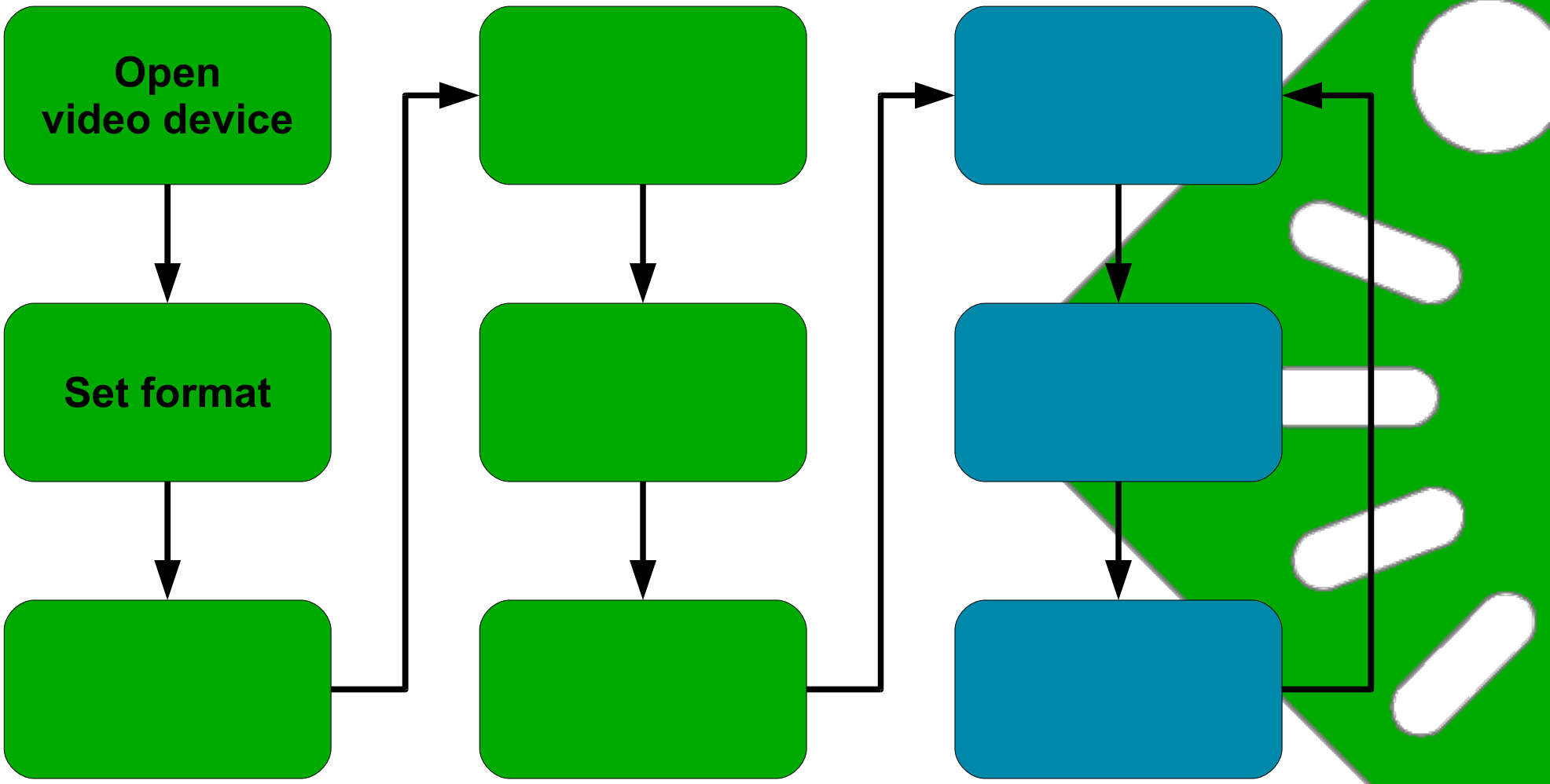
- Controls
- Video format
- Memory management
- Video streaming



V4L2 userspace API

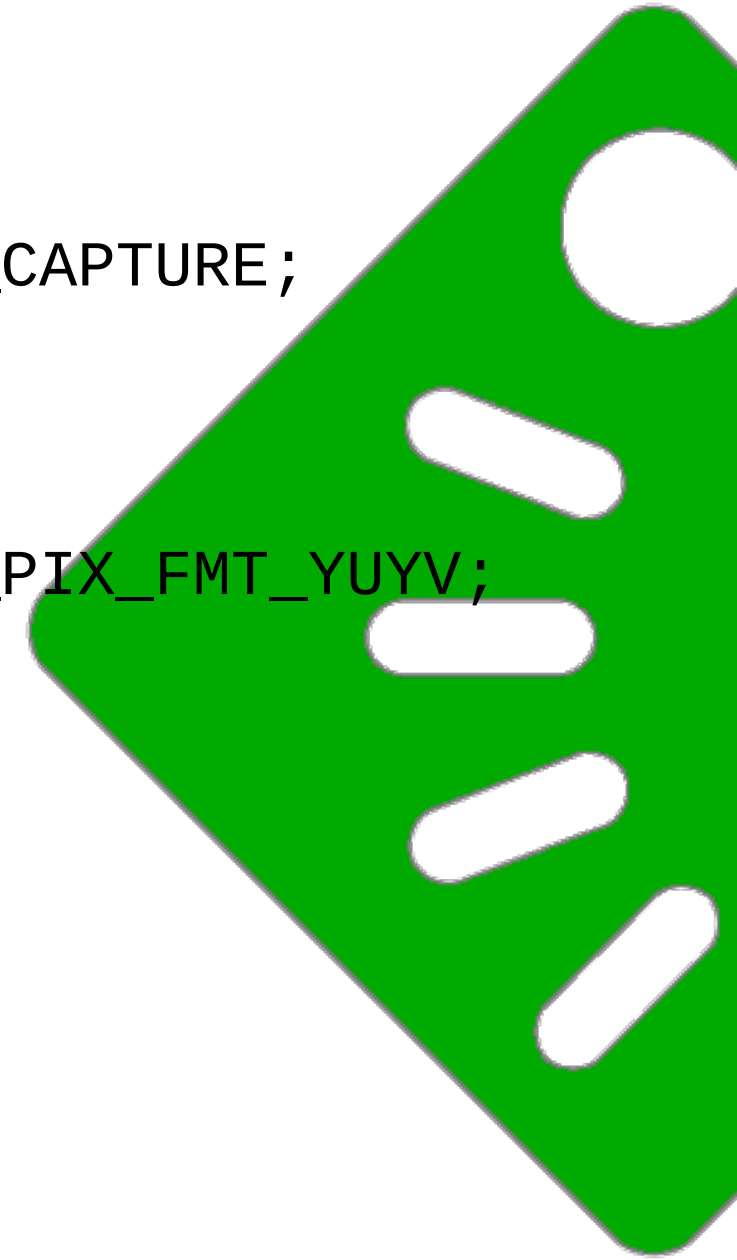
```
struct v4l2_capability cap;
int fd;

fd = open(“/dev/video0”, O_RDWR);
ioctl(fd, VIDIOC_QUERYCAP, &cap);

printf(“Device %s opened\n”, cap.card);
```

V4L2 – Open video device

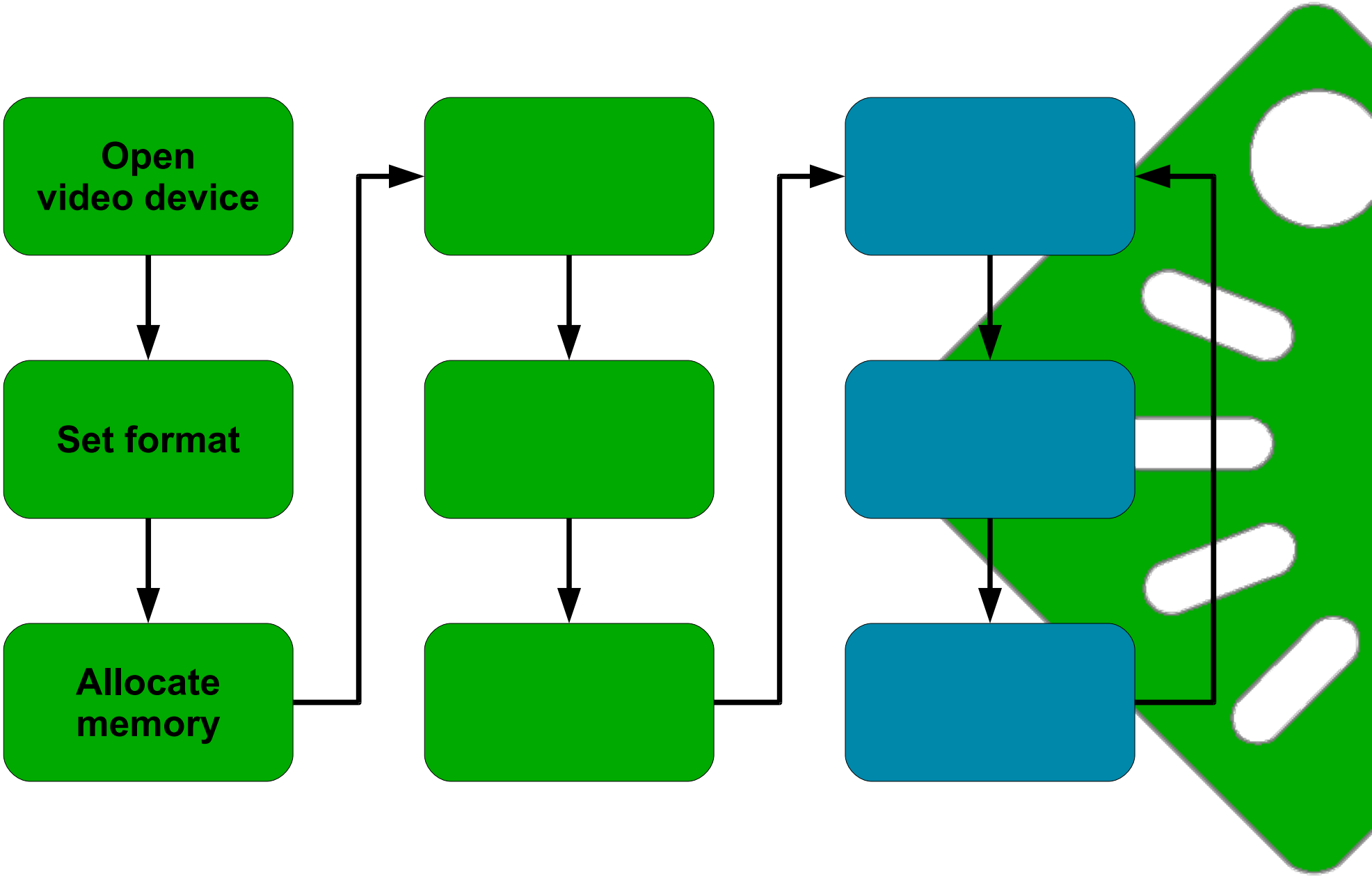


V4L2 userspace API

```
struct v4l2_format format;


format.type = V4L2_BUF_TYPE_VIDEO_CAPTURE;
format.fmt.pix.width = 1920;
format.fmt.pix.height = 1080;
format.fmt.pix.pixelformat = V4L2_PIX_FMT_YUYV;
ioctl(fd, VIDIOC_S_FMT, &format);
```



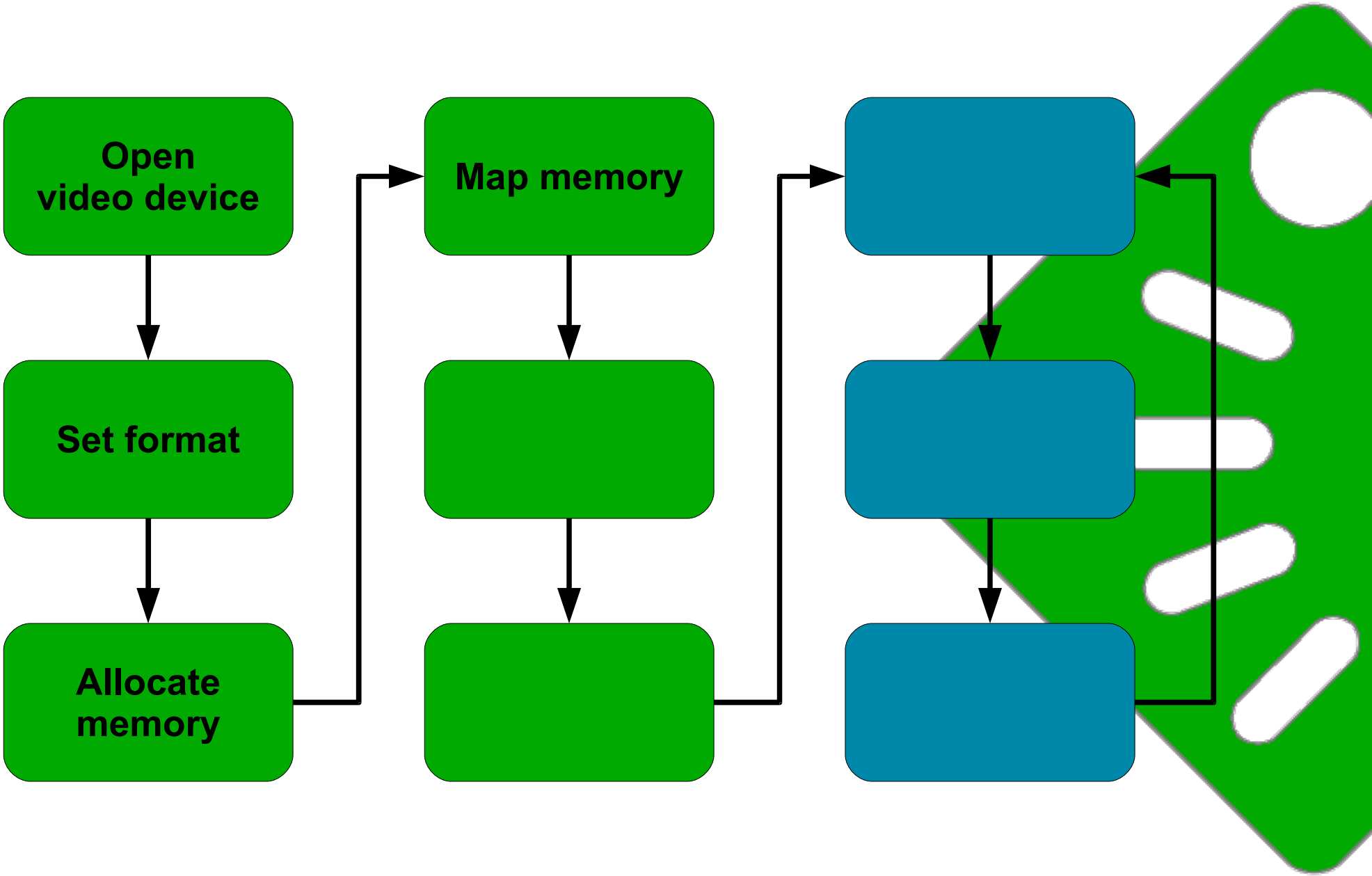
V4L2 – Set format



V4L2 userspace API

```
struct v4l2_requestbuffers req;
void **mem;

req.type = V4L2_BUF_TYPE_VIDEO_CAPTURE;
req.count = 4;
req.memory = V4L2_MEMORY_MMAP;
ioctl(fd, VIDIOC_REQBUFS, &req);

printf("Driver allocated %u buffers\n", req.count);
mem = malloc(req.count, sizeof *mem);
```

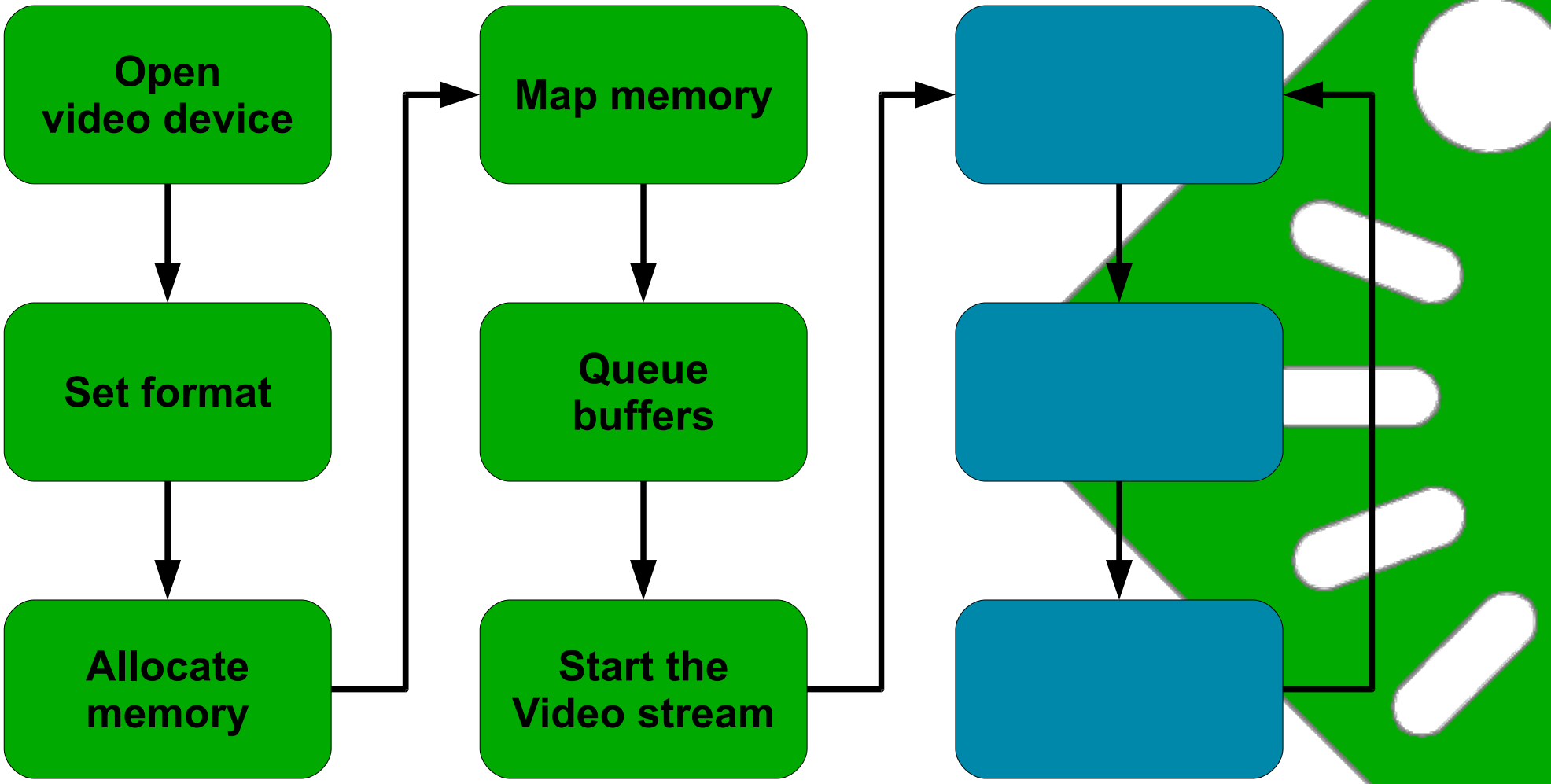
V4L2 – Allocate memory



V4L2 userspace API

```
struct v4l2_buffer buffer;
unsigned int i;

for (i = 0; i < req.count; ++i) {
    buffer.type = V4L2_BUF_TYPE_VIDEO_CAPTURE;
    buffer.memory = V4L2_MEMORY_MMAP;
    buffer.index = i;
    ioctl(fd, VIDIOC_QUERYBUF, &buffer);
    mem[i] = mmap(0, buffer.length,
                  PROT_READ|PROT_WRITE,
                  MAP_SHARED, fd, buffer.m.offset);
}
```

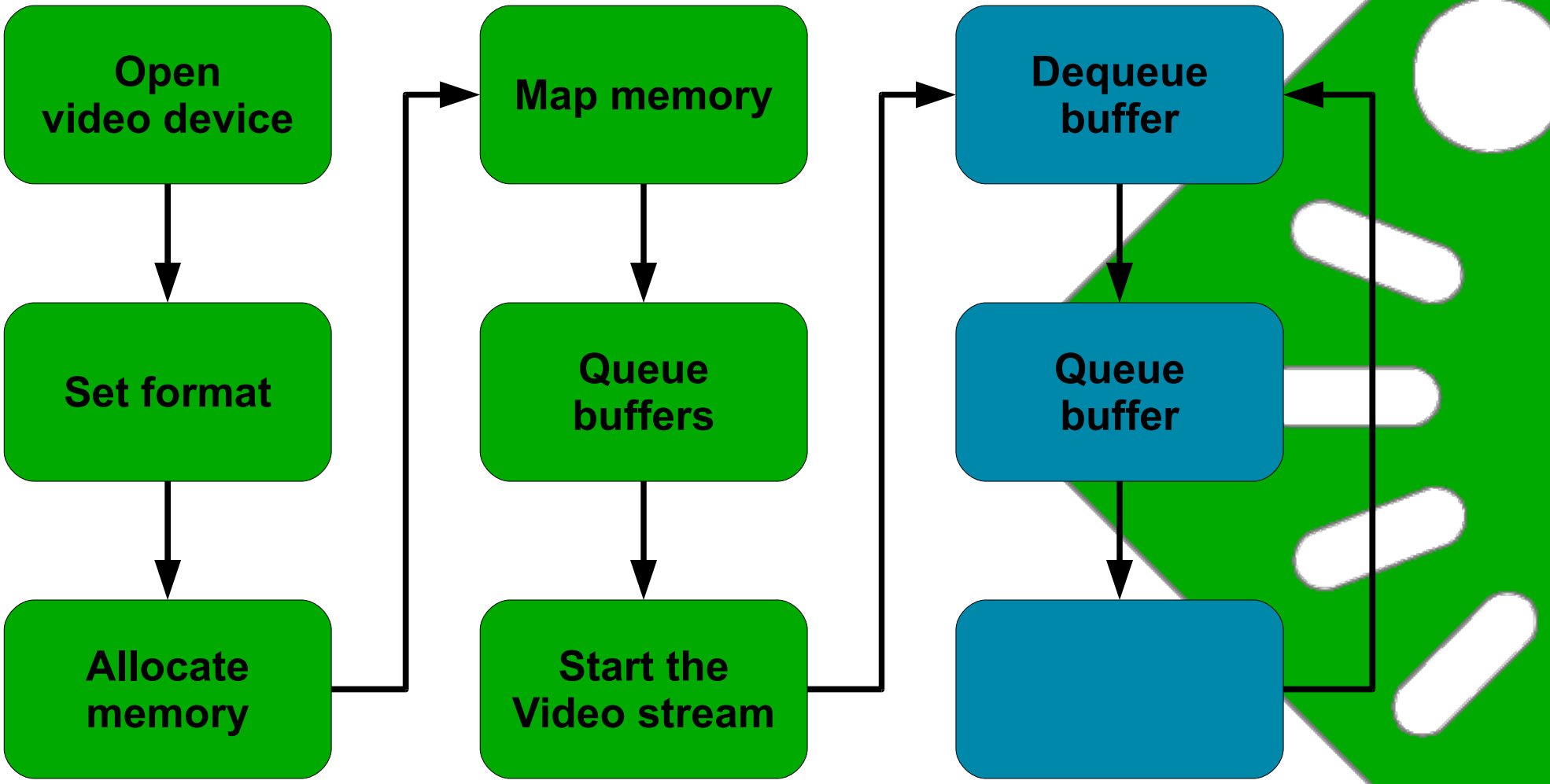
V4L2 – Map memory



V4L2 userspace API

```
struct v4l2_buffer buffer;
int type = V4L2_BUF_TYPE_VIDEO_CAPTURE;
unsigned int i;

for (i = 0; i < req.count; ++i) {
    buffer.type = V4L2_BUF_TYPE_VIDEO_CAPTURE;
    buffer.memory = V4L2_MEMORY_MMAP;
    buffer.index = i;
    ioctl(fd, VIDIOC_QBUF, &buffer);
}

ioctl(fd, VIDIOC_STREAMON, &type);
```

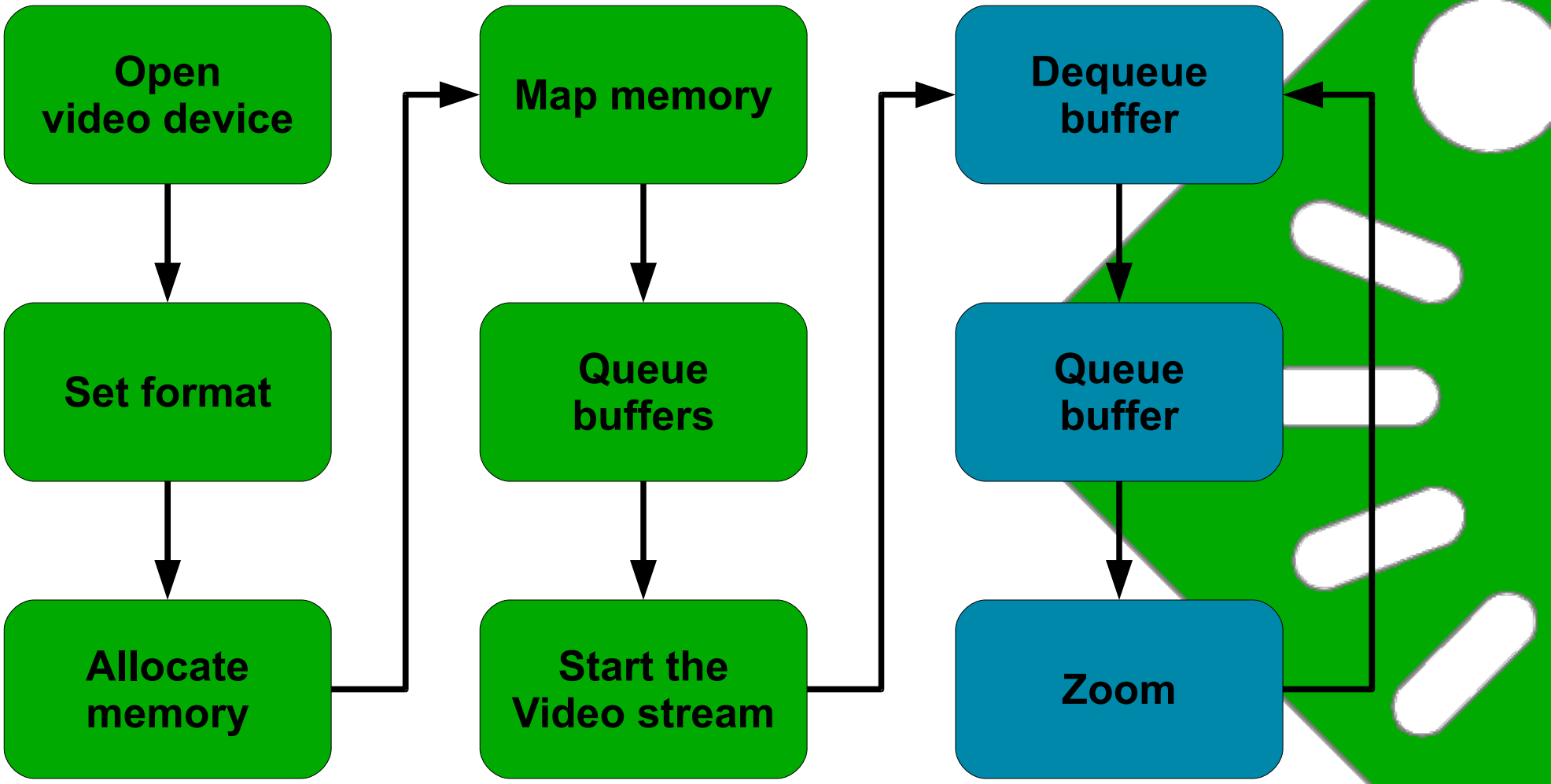
V4L2- Queue buffers and stream



V4L2 userspace API

```
struct v4l2_buffer buffer;


While (1) {
    buffer.type = V4L2_BUF_TYPE_VIDEO_CAPTURE;
    buffer.memory = V4L2_MEMORY_MMAP;
    ioctl(fd, VIDIOC_DQBUF, &buffer);
    process_buffer(buffer, mem[buffer.index]);
    ioctl(fd, VIDIOC_QBUF, &buffer);
}
```

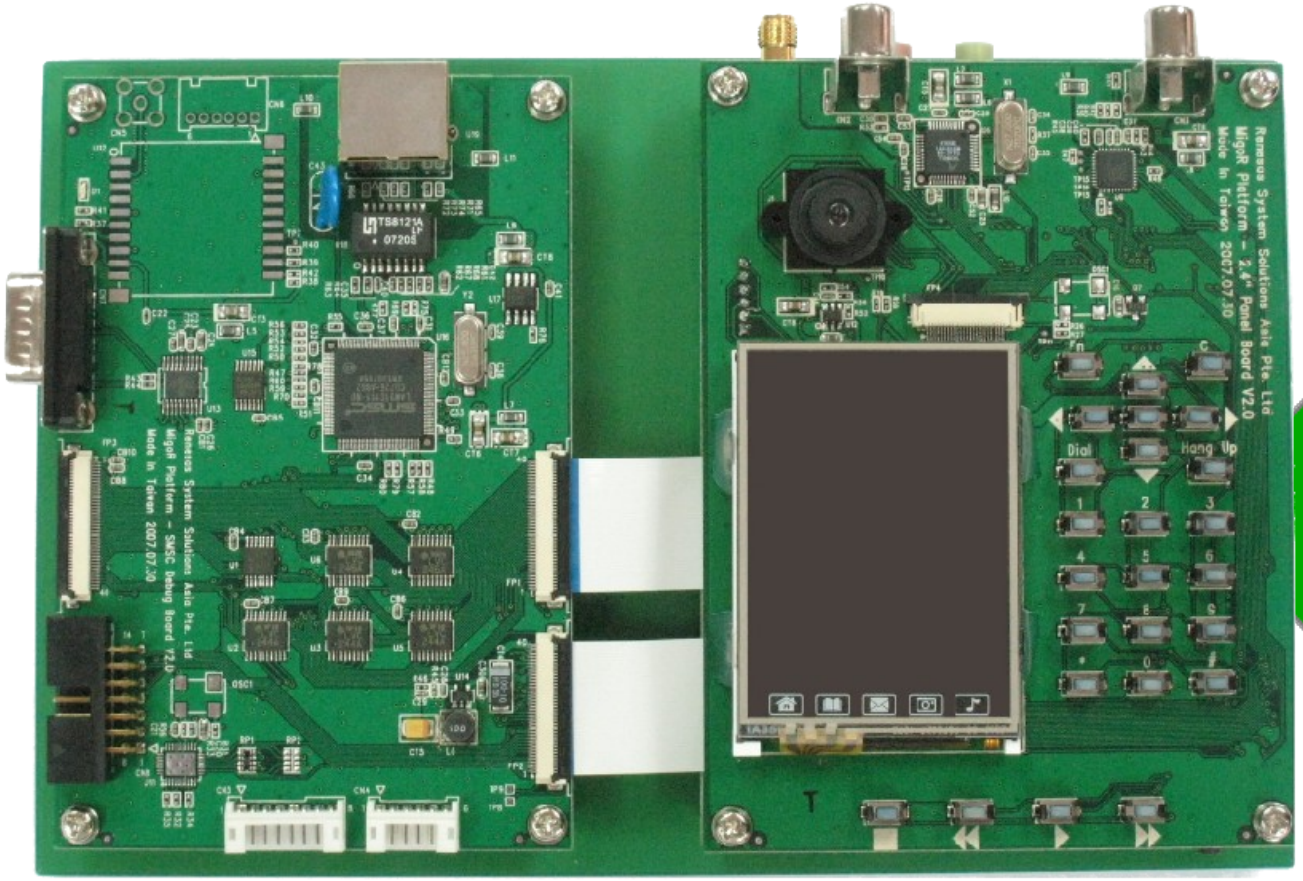
V4L2 – Capture video



V4L2 userspace API

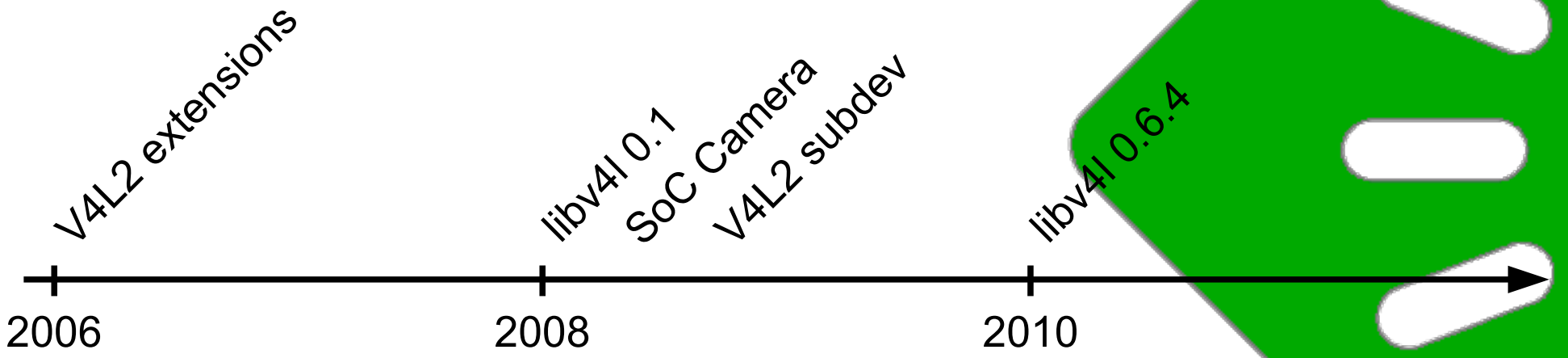
```
struct v4l2_crop crop;


crop.type = V4L2_BUF_TYPE_VIDEO_CAPTURE;
crop.bounds.left = (2592 – 1280) / 2;
crop.bounds.top = (1968 – 720) / 2;
crop.bounds.width = 1280;
crop.bounds.height = 720;
ioctl(fd, VIDIOC_S_CROP, &crop);
```

V4L2 – And zoom and more

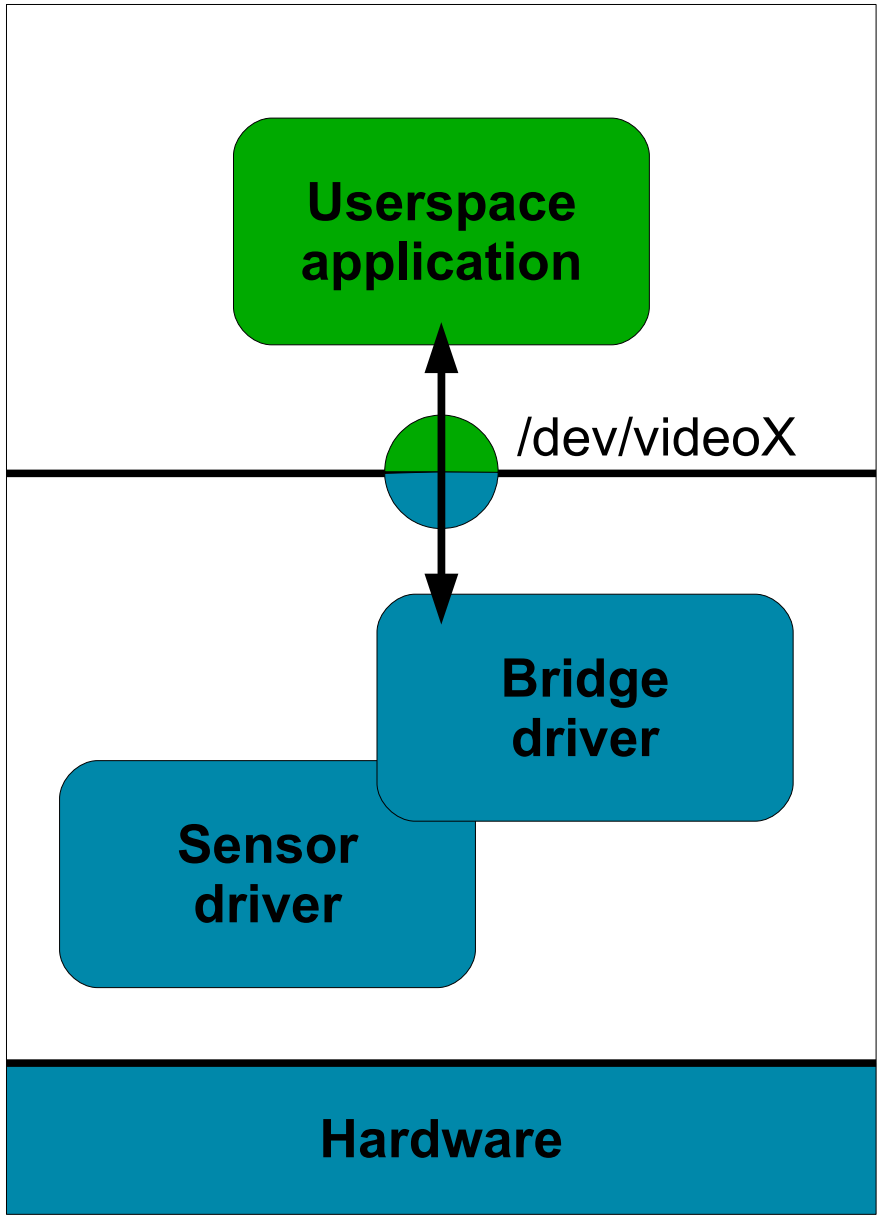


SH 7722 MIGO-R
Renesas Technology

Today


V4L2 extensions
libv4l 0.1
SoC Camera
V4L2 subdev
libv4l 0.6.4
2006
2008
2010

The present



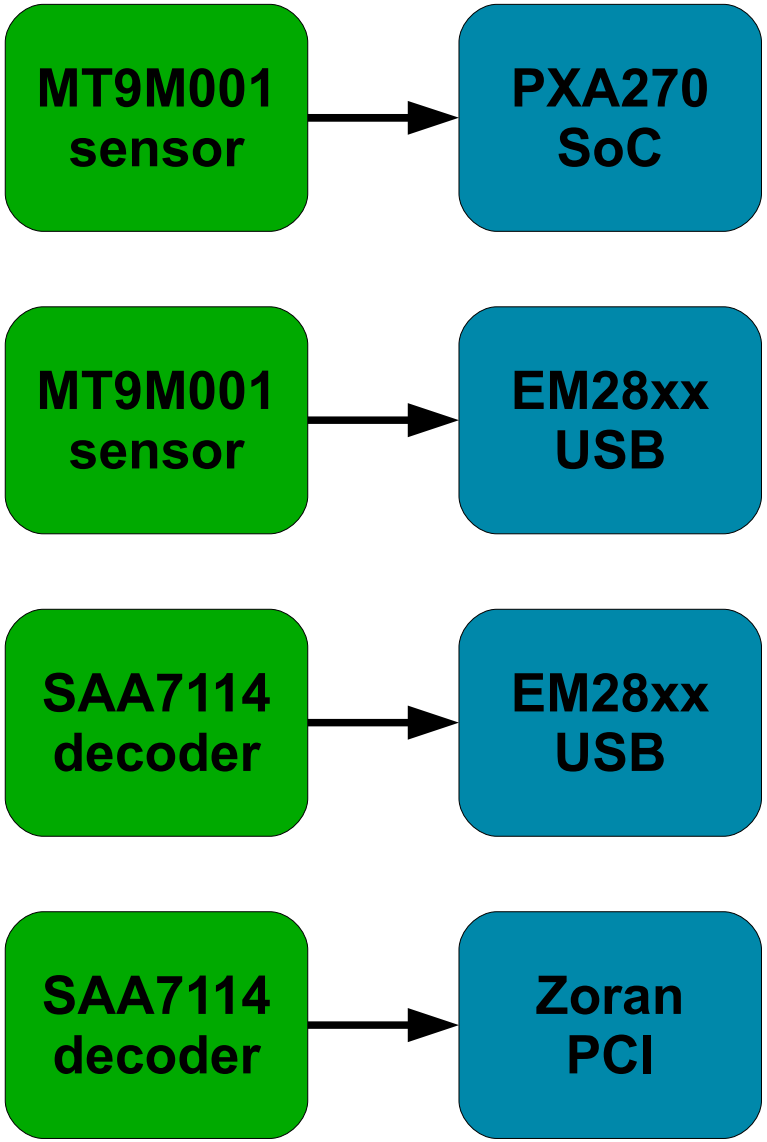
Embedded SoC camera

- soc_camera
- v4l2_device
- v4l2_subdev

Userspace library

- Format conversion
- Post-processing

Embedded camera



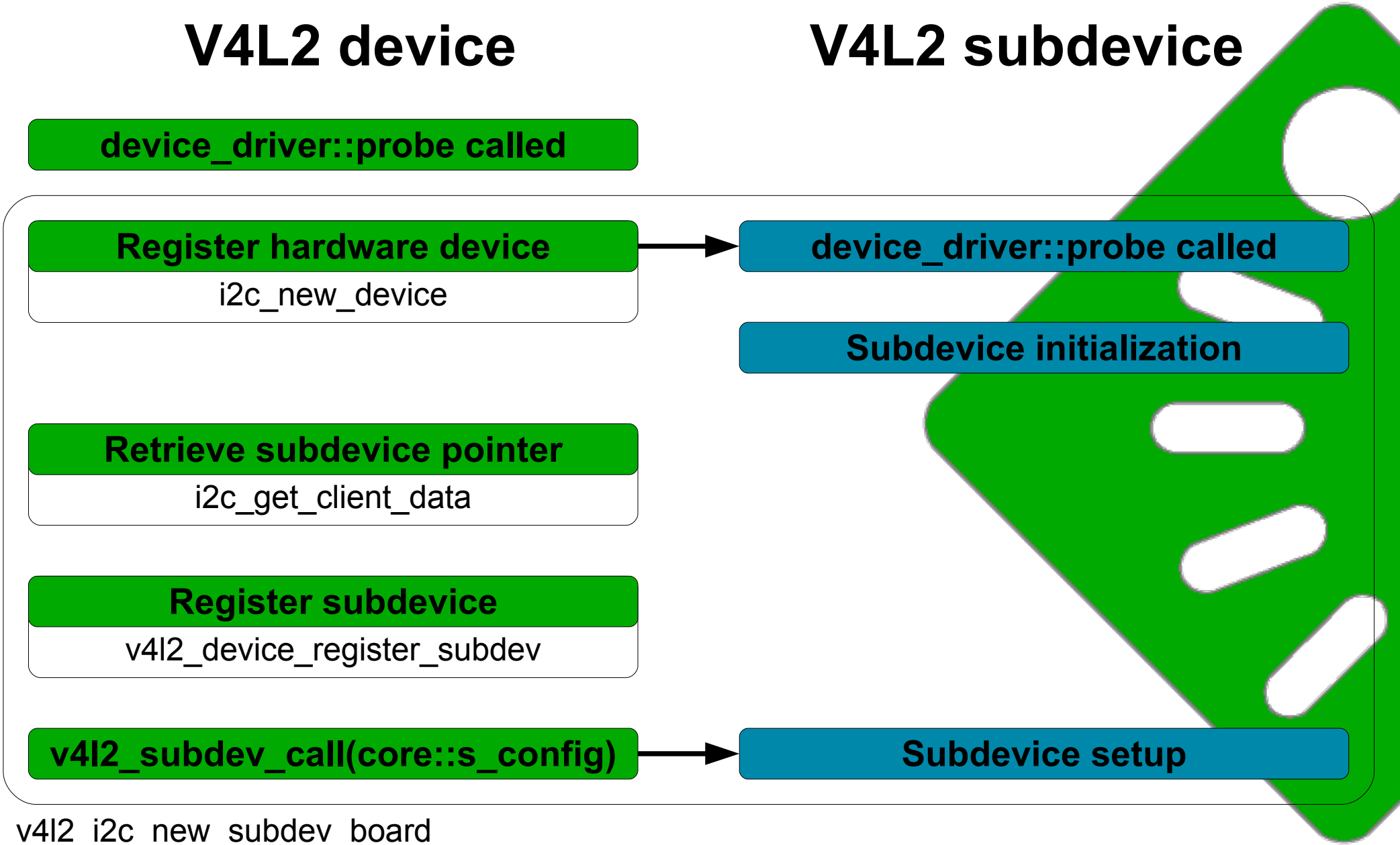
- In-kernel functional abstraction layer developed by Hans Verkuil
- Designed for on-board external devices (sensors, tuners, audio codecs, …)
- Reusability, Reusability, Reusability

V4L2 subdevice

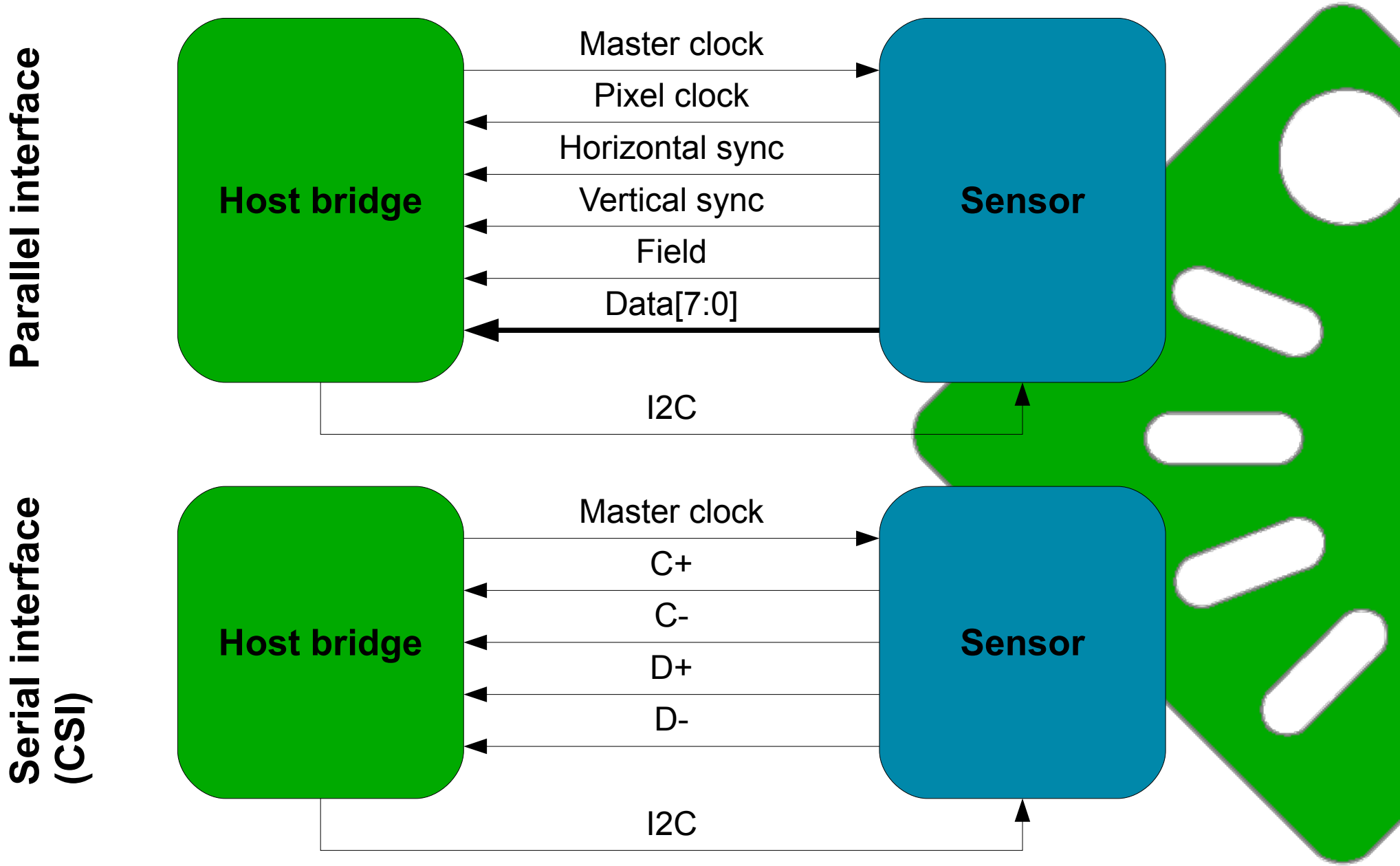
```
struct v4l2_subdev_ops {
    const struct v4l2_subdev_core_ops   *core;
    const struct v4l2_subdev_tuner_ops  *tuner;
    const struct v4l2_subdev_audio_ops  *audio;
    const struct v4l2_subdev_video_ops  *video;
    const struct v4l2_subdev_ir_ops     *ir;
    const struct v4l2_subdev_sensor_ops *sensor;
};
```

- Hardware independent
- Bus type independent

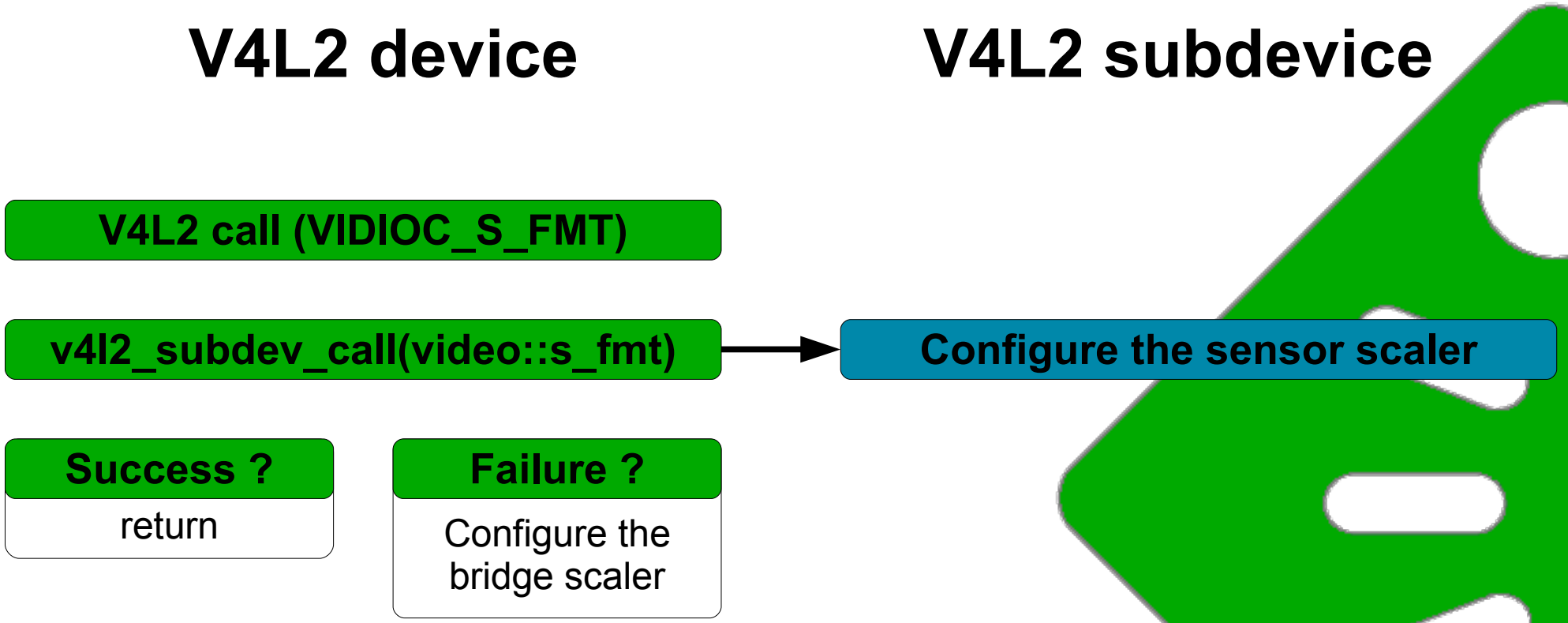
V4L2 subdevice operations



V4L2 subdevice registration


Parallel interface
Host bridge
Master clock
Pixel clock
Horizontal sync
Vertical sync
Field
Data[7:0]
Sensor
I2C
Serial interface (CSI)
Host bridge
Master clock
C+
C-
D+
D-
Sensor
I2C

SoC Camera



- **How do we decide where to perform scaling ?**
  - On the sensor side for higher frame rates ?
  - On the host side for better quality ?

V4L2 subdevice usage

- Cheap hardware rely on software image enhancement

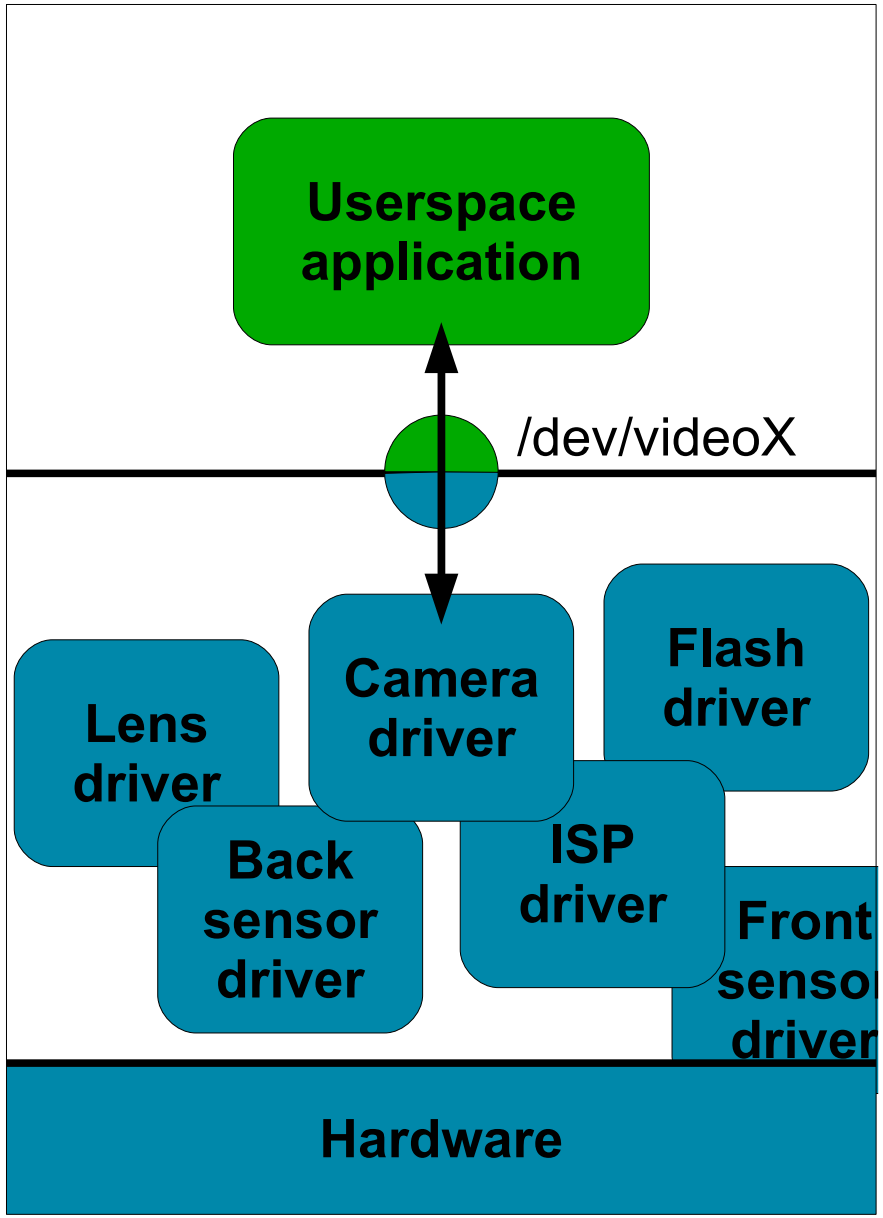
- High resolution on low bandwidth requires compression

- Userspace library developed by Hans de Goede
- http://people.fedoraproject.org/~jwrdegoede/
- Format conversion
  - Convert from any (known) format to BGR24 or YUV420, including compressed proprietary formats
  - Transparent format emulation
- Software image processing
  - Rotation
  - Auto-exposure
  - White balance
- CPU intensive but CPU is cheap. Or is it ?

libv4l

Camera 2.0
Stanford Computer Graphics Laboratory
Nokia Research Center Palo Alto Laboratory

Tomorrow

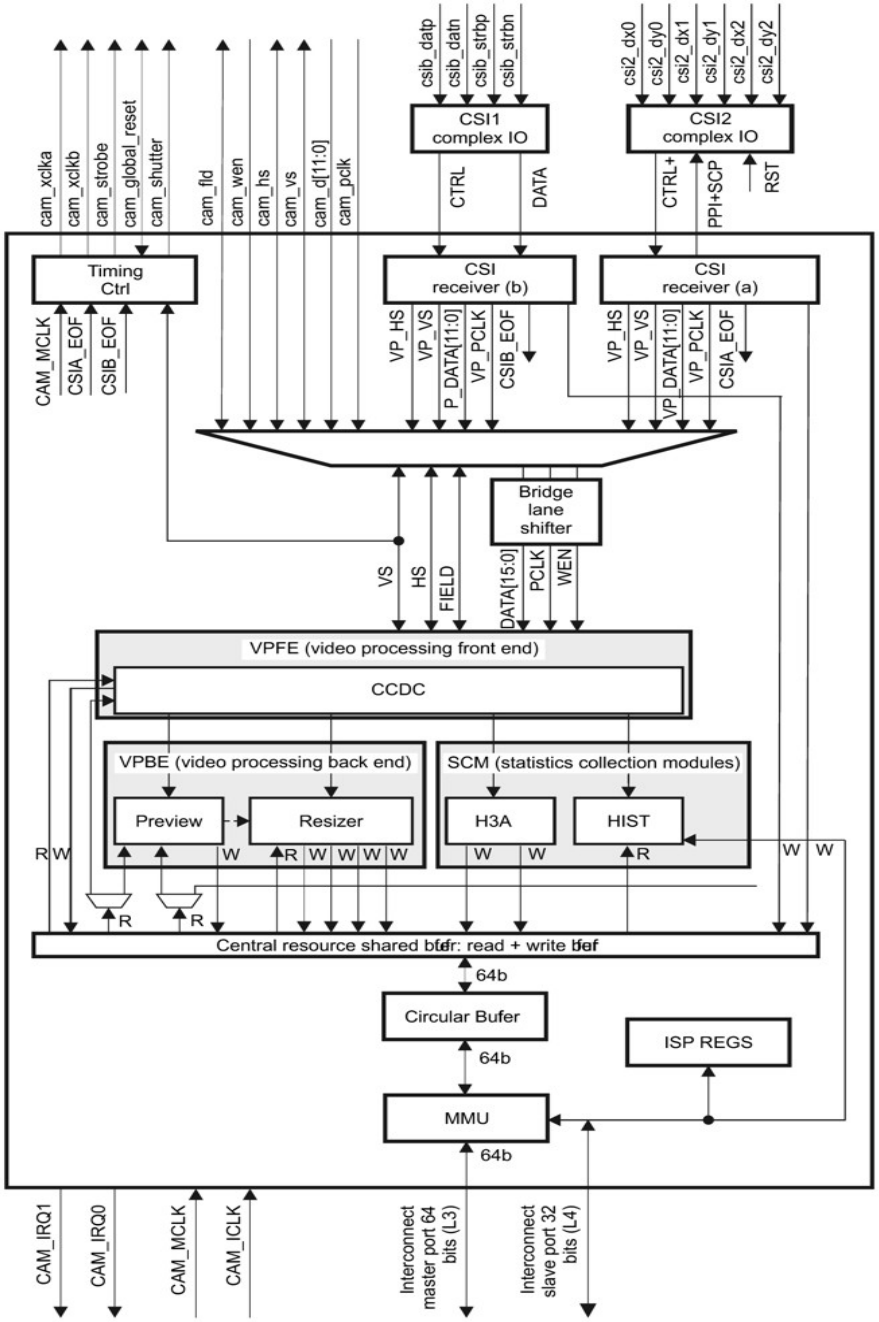


Highly complex devices

- Multiple inputs
- Multiple streams
- Configurable pipeline

Embedded mess

OMAP3430 ISP

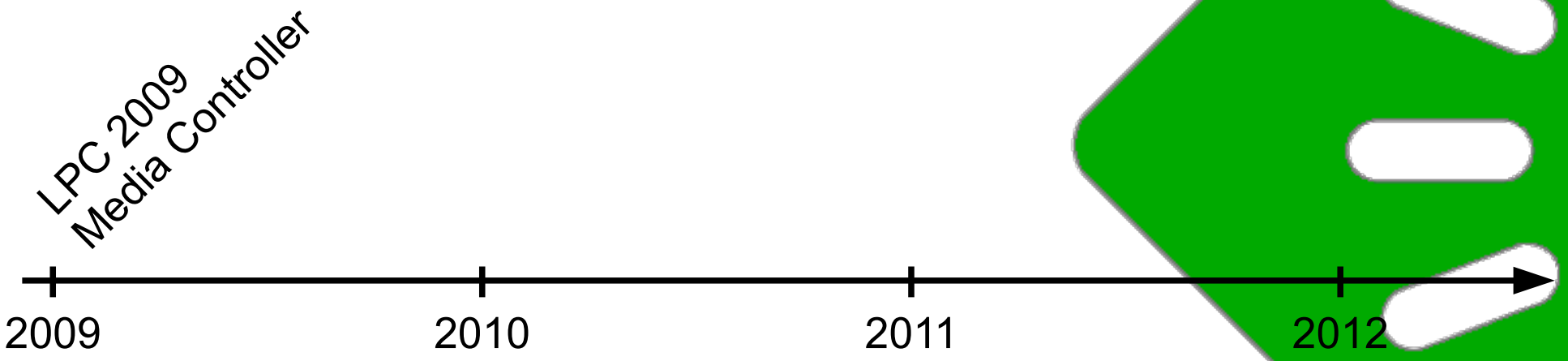


- Reconfigurable pipeline
- Parallel processing
- Memory-to-memory paths
- Fine-grain parameters

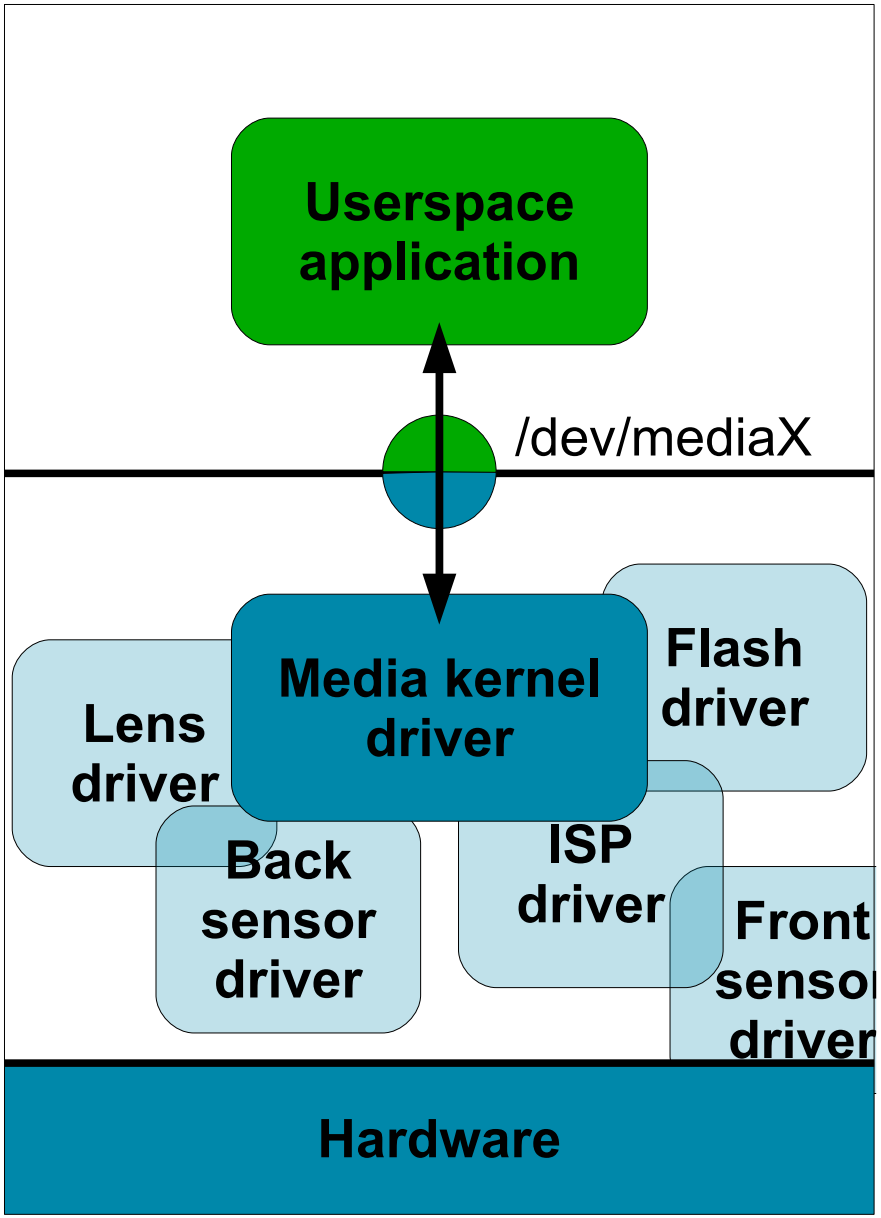
How do we handle the zillion configuration options through a single video device ?

Drawing is © Texas Instrument

OMAP3430 ISP



The (past) future



What ?

- Just a device. Similar to v4l2_device, but more abstract.

Why ?

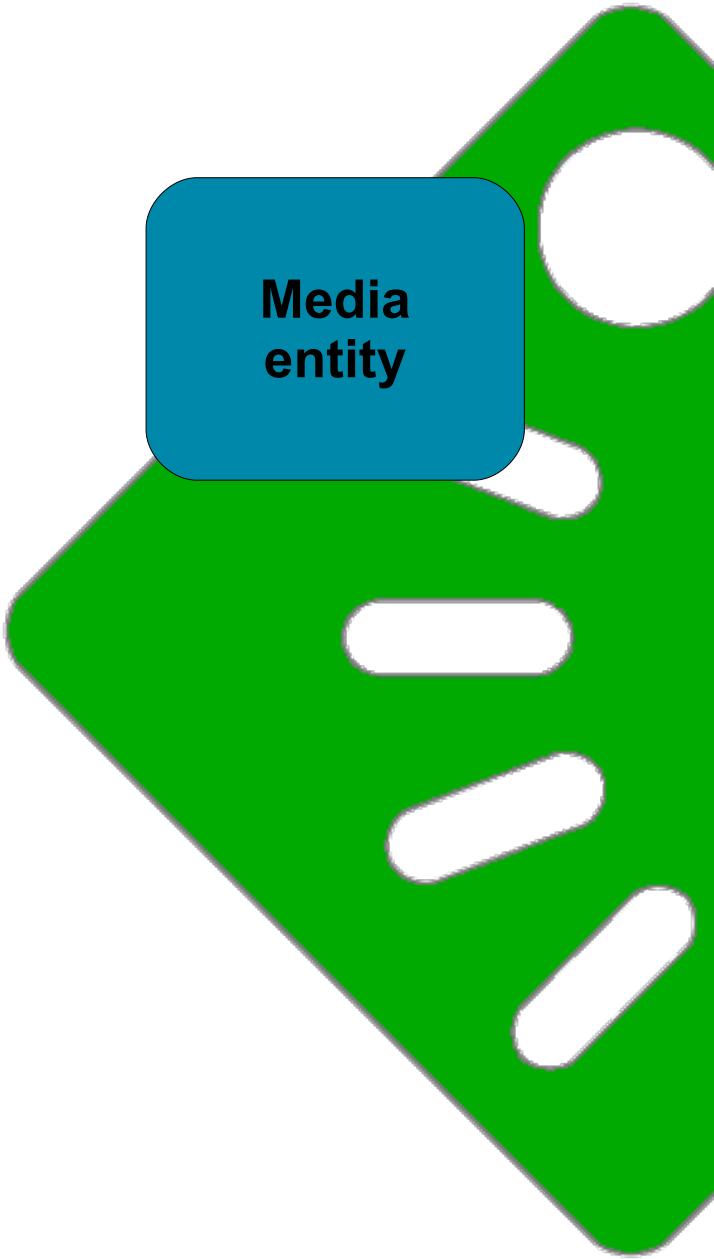
- To let userspace applications have fine grain control over all the media device parameters.

Media controller – What and why

How ?

- Expose the media device topology to userspace as a graph of building blocks called **entities** connected through **pads**.
- Create/break **connections** from userspace.
- Give access to entitites **internal parameters** through read/write/ioctl calls.
- Configure image **streaming parameters** at each pad.

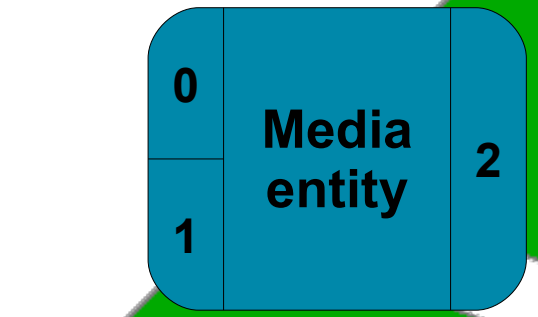
```
struct media_entity
{
    u32 id;
    const char *name;
    u32 type;
    u32 subtype;
    ...
};
```



- media_entity::type
  - MEDIA_ENTITY_TYPE_NODE
  - MEDIA_ENTITY_TYPE_SUBDEV

Media entity

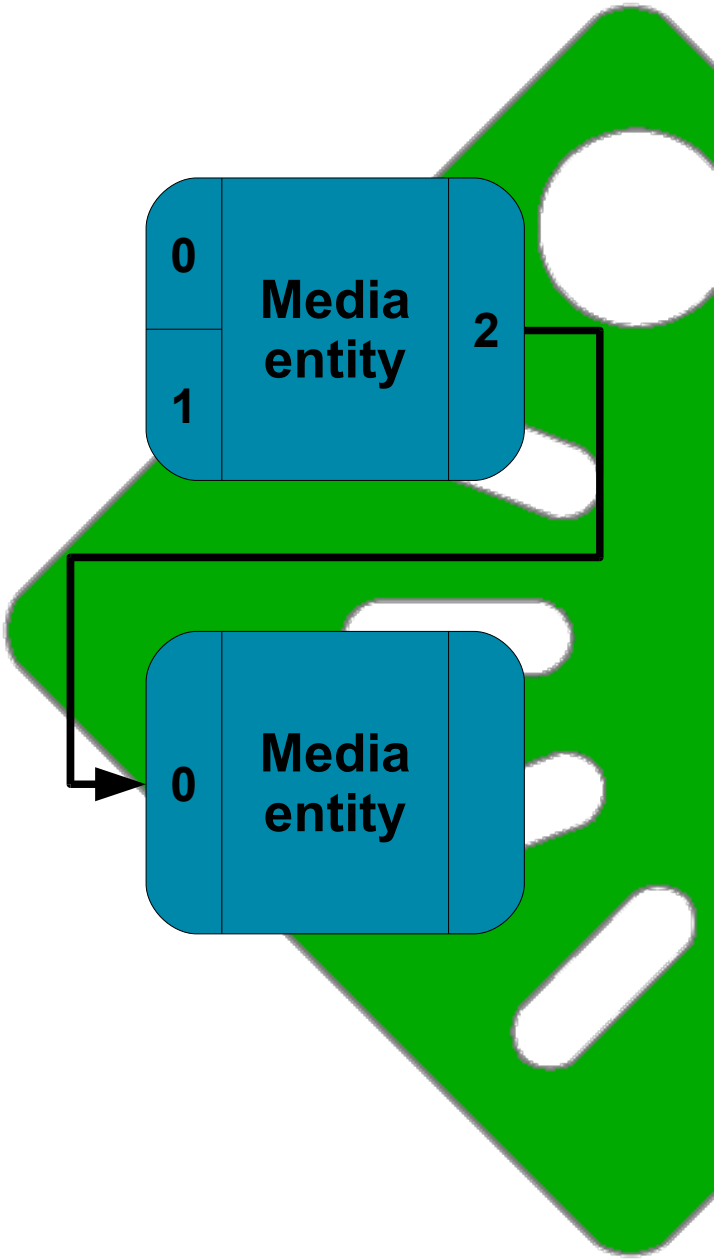
```
struct media_entity
{
    ...
    u8 num_pads;
    struct media_entity_pad *pads;
    ...
};

struct media_entity_pad
{
    u32 type;
    u32 index;
};
```



- media_entity_pad::type
  - MEDIA_PAD_TYPE_INPUT
  - MEDIA_PAD_TYPE_OUTPUT

Media entity - Pads

```
struct media_entity
{
    ...
    u32 num_links;
    struct media_entity_link *links;
    ...
};

struct media_entity_link
{
    struct media_entity_pad *source;
    struct media_entity_pad *sink;
    u32 flags;
};
```



- media_entity_link::flags
  - MEDIA_LINK_FLAG_ACTIVE
  - MEDIA_LINK_FLAG_IMMUTABLE

Media entity - Links

Media entity

Initialize entity

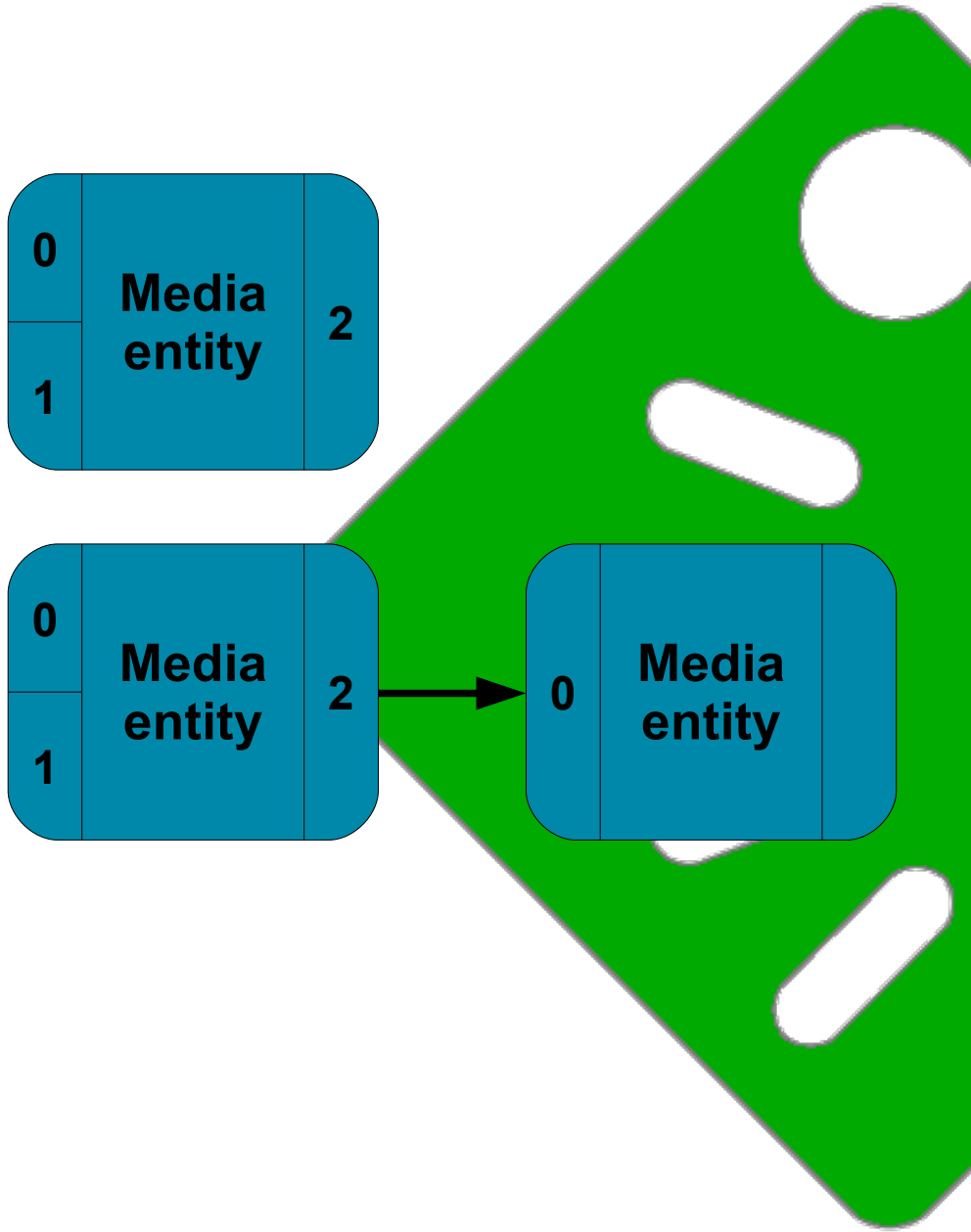
media_entity_init

Create links

media_entity_create_link

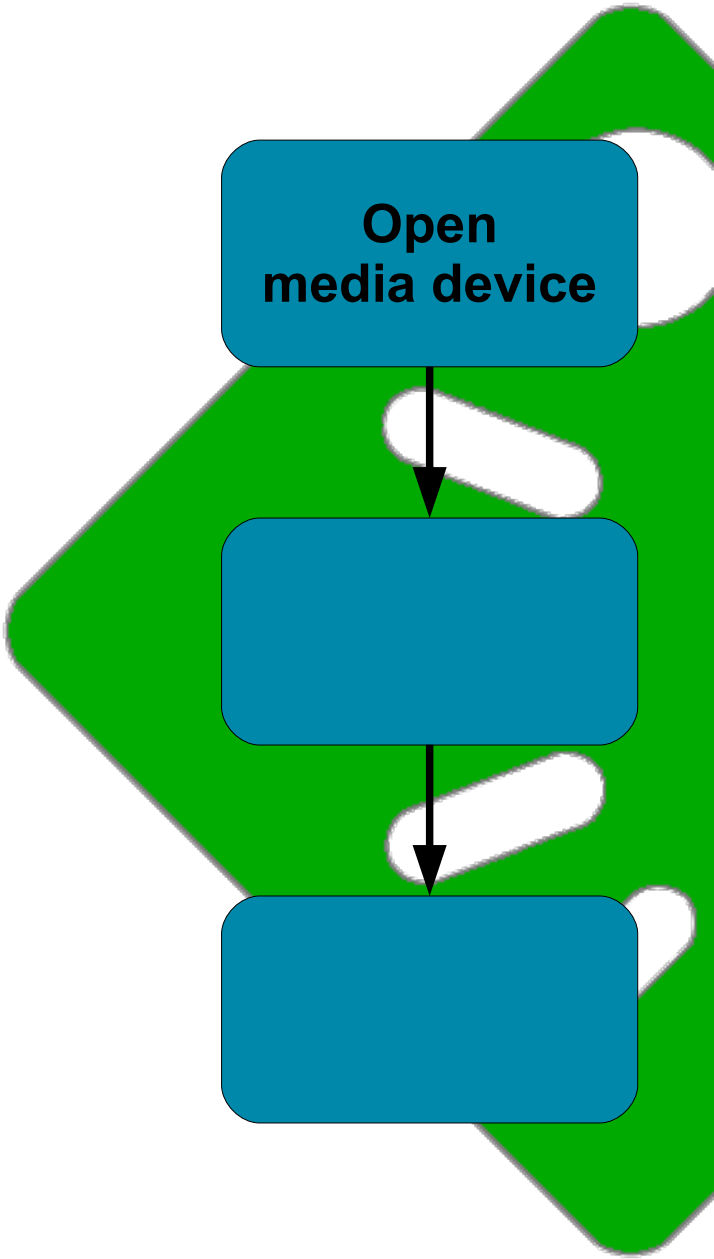
Register entity

media_device_register_entity



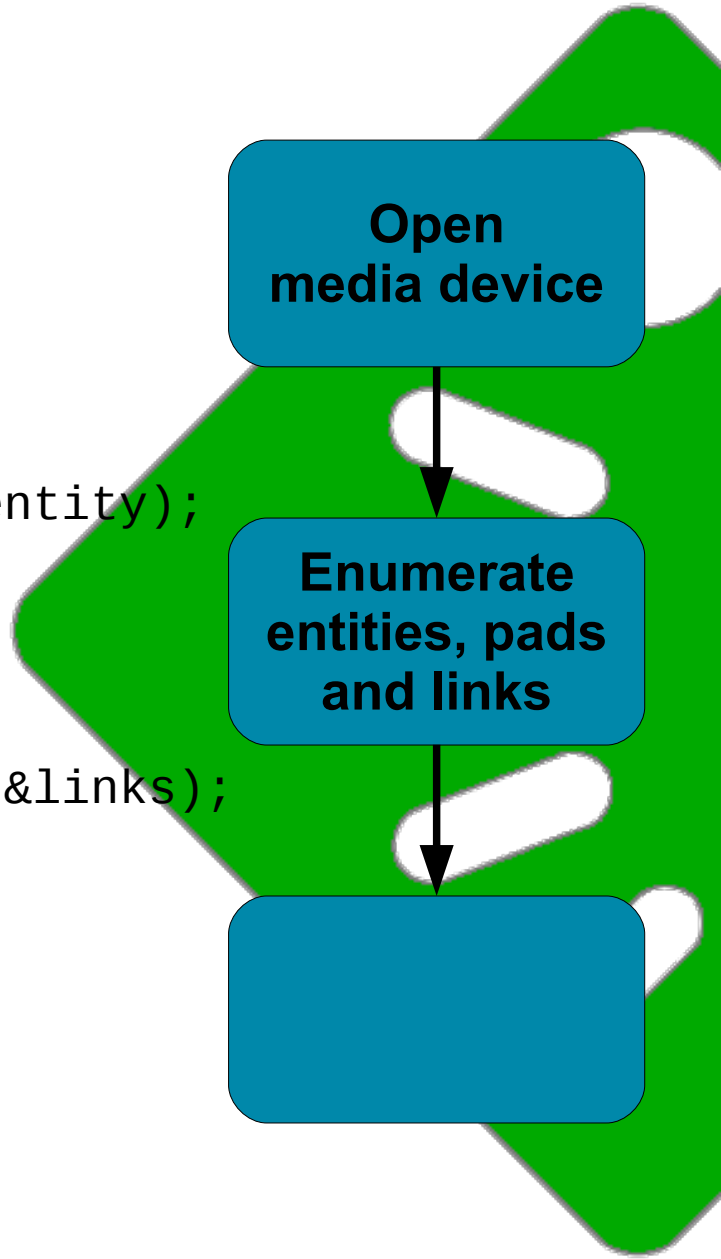
Media entity registration

```
int fd;

fd = open(“/dev/media0”, O_RDWR);
```

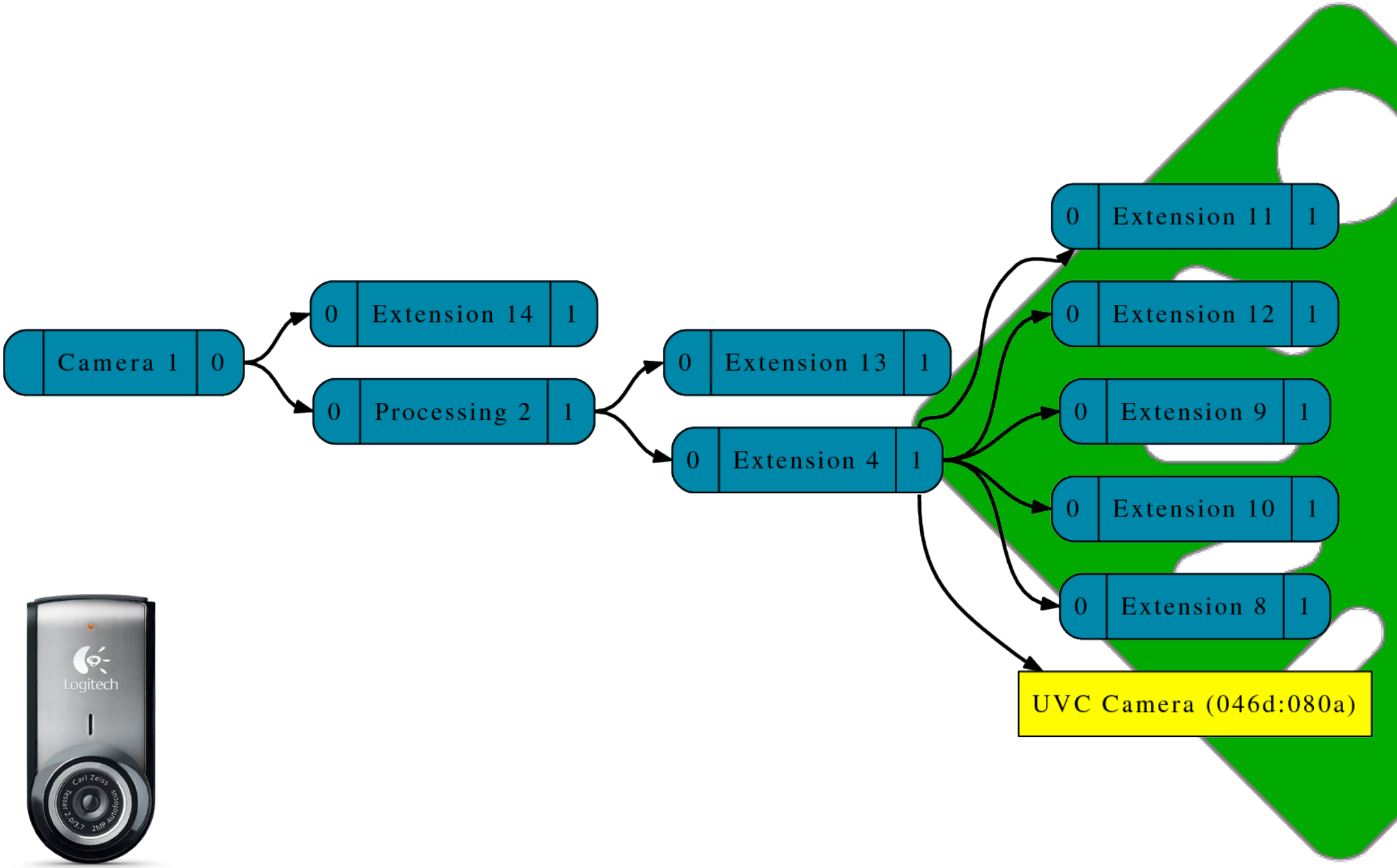


Media controller – Userspace API

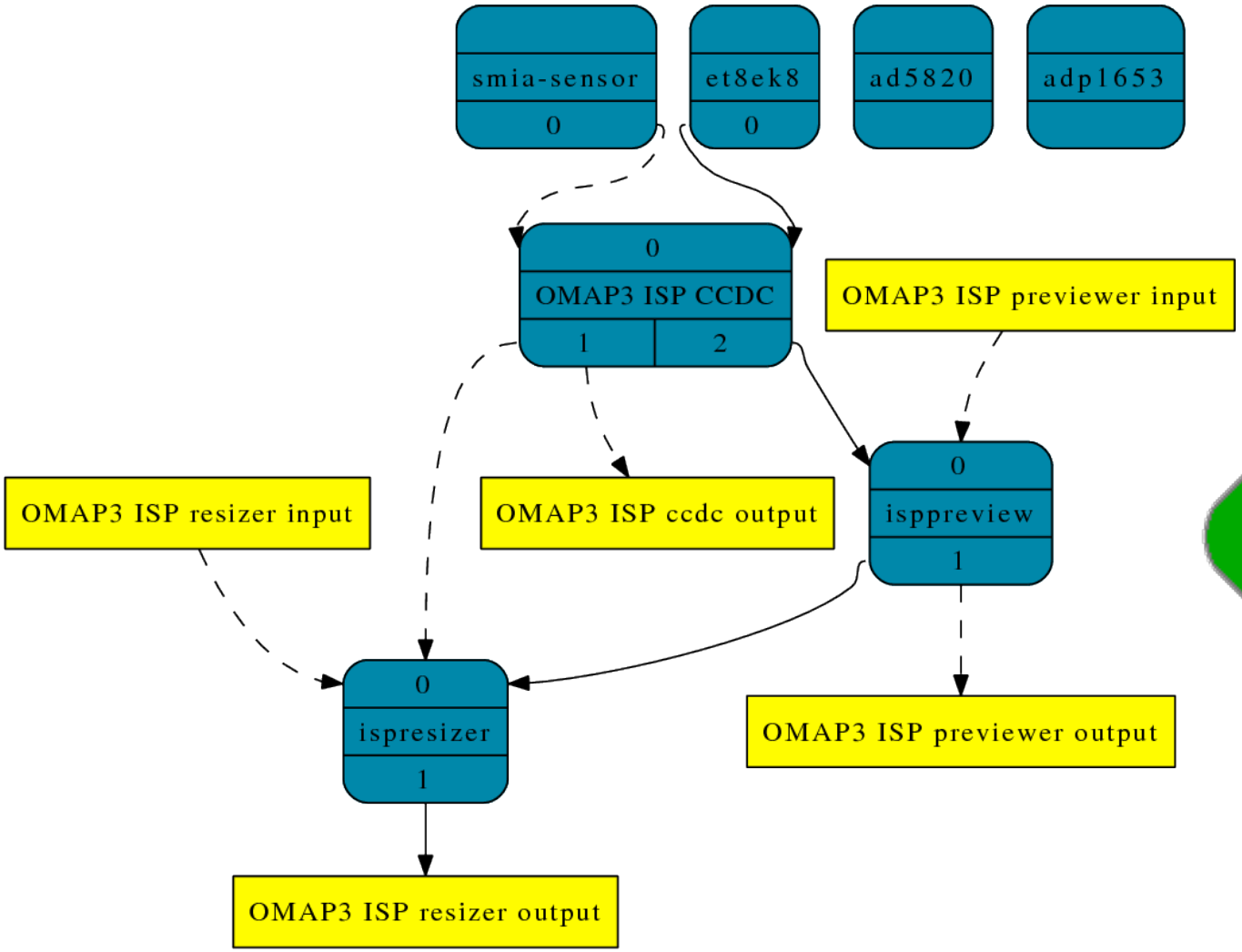
```
int fd;

fd = open(“/dev/media0”, O_RDWR);

while (1) {
    struct media_user_entity entity;
    struct media_user_links links;

    ret = ioctl(fd, MEDIA_IOC_ENUM_ENTITES, &entity);
    if (ret < 0)
        break;

    while (1) {
        ret = ioctl(fd, MEDIA_IOC_ENUM_LINKS, &links);
        if (ret < 0)
            break;
    }
}
```



Media controller – Userspace API



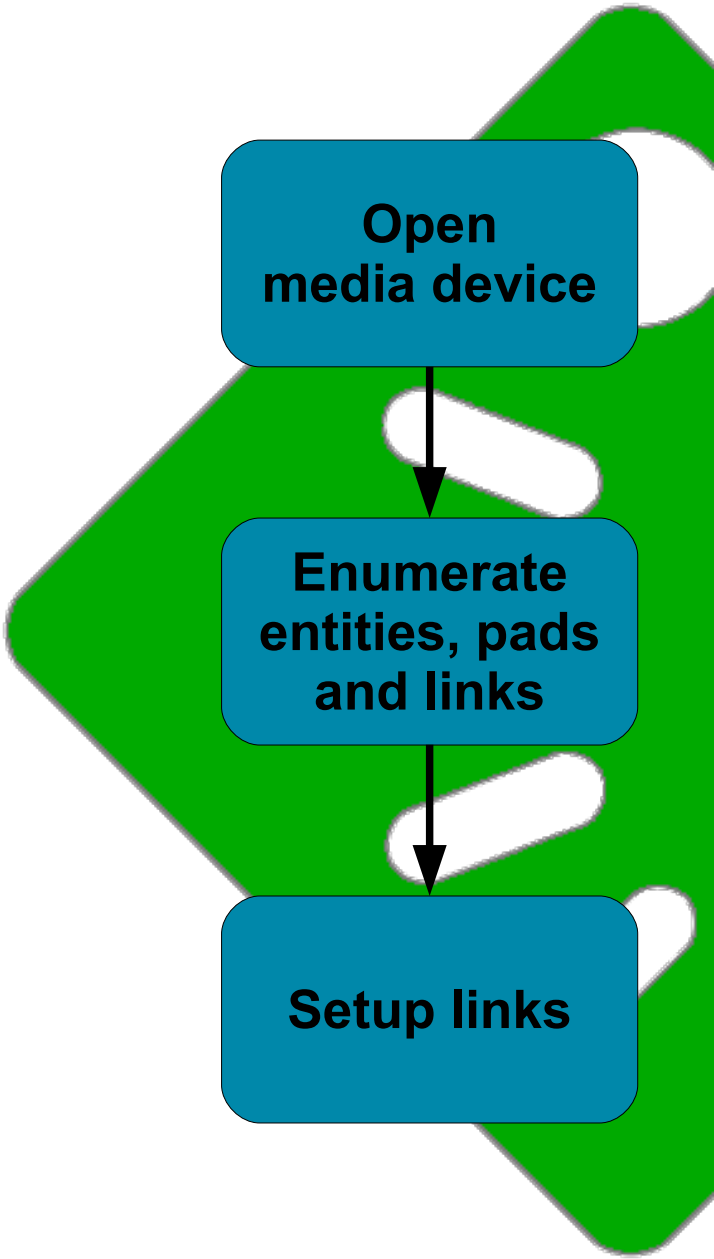
Logitech Portable Webcam C905


smia-sensor
0
et8ek8
0
ad5820
adp1653
0
OMAP3 ISP CCDC
1
2
OMAP3 ISP previewer input
OMAP3 ISP resizer input
OMAP3 ISP ccdc output
0
isppreview
1
0
ispresizer
1
OMAP3 ISP previewer output
OMAP3 ISP resizer output

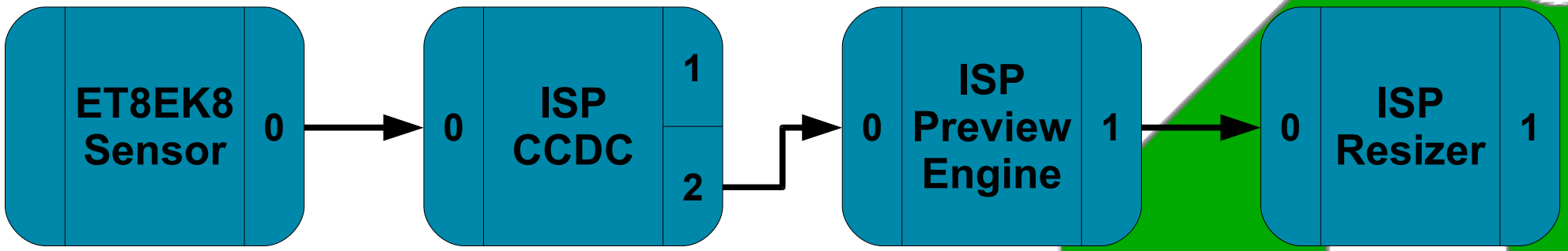

NOKIA
Marina
Maemo

Nokia N900

```
struct media_user_link link;

link.source.entity = OMAP3_ISP_ENTITY_CCDC;
link.source.index = 2;
link.sink.entity = OMAP3_ISP_ENTITY_PREVIEW;
link.sink.index = 0;
link.flags = 0;

ioctl(fd, MEDIA_IOC_SETUP_LINK, &link);

link.source.entity = OMAP3_ISP_ENTITY_CCDC;
link.source.index = 1;
link.sink.entity = OMAP3_ISP_ENTITY_CCDC_OUT;
link.sink.index = 0;
link.flags = MEDIA_LINK_FLAG_ACTIVE;


ioctl(fd, MEDIA_IOC_SETUP_LINK, &link);
```



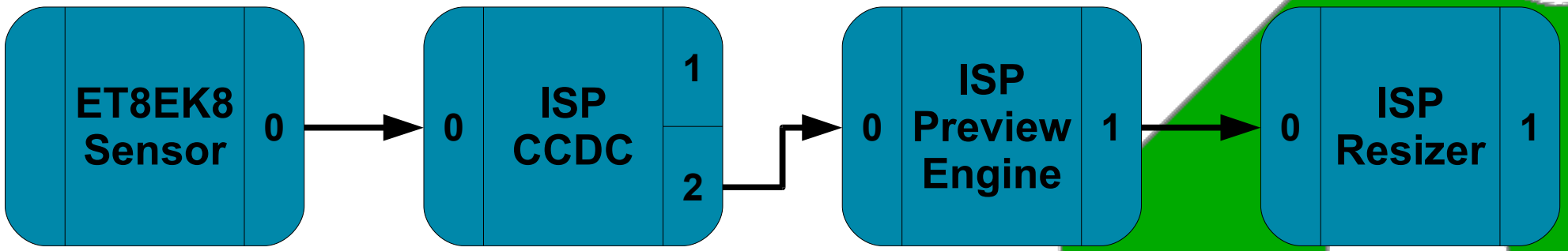
Media controller – Userspace API



- White balance
- Faulty pixels correction
- White balance
- Faulty pixels correction

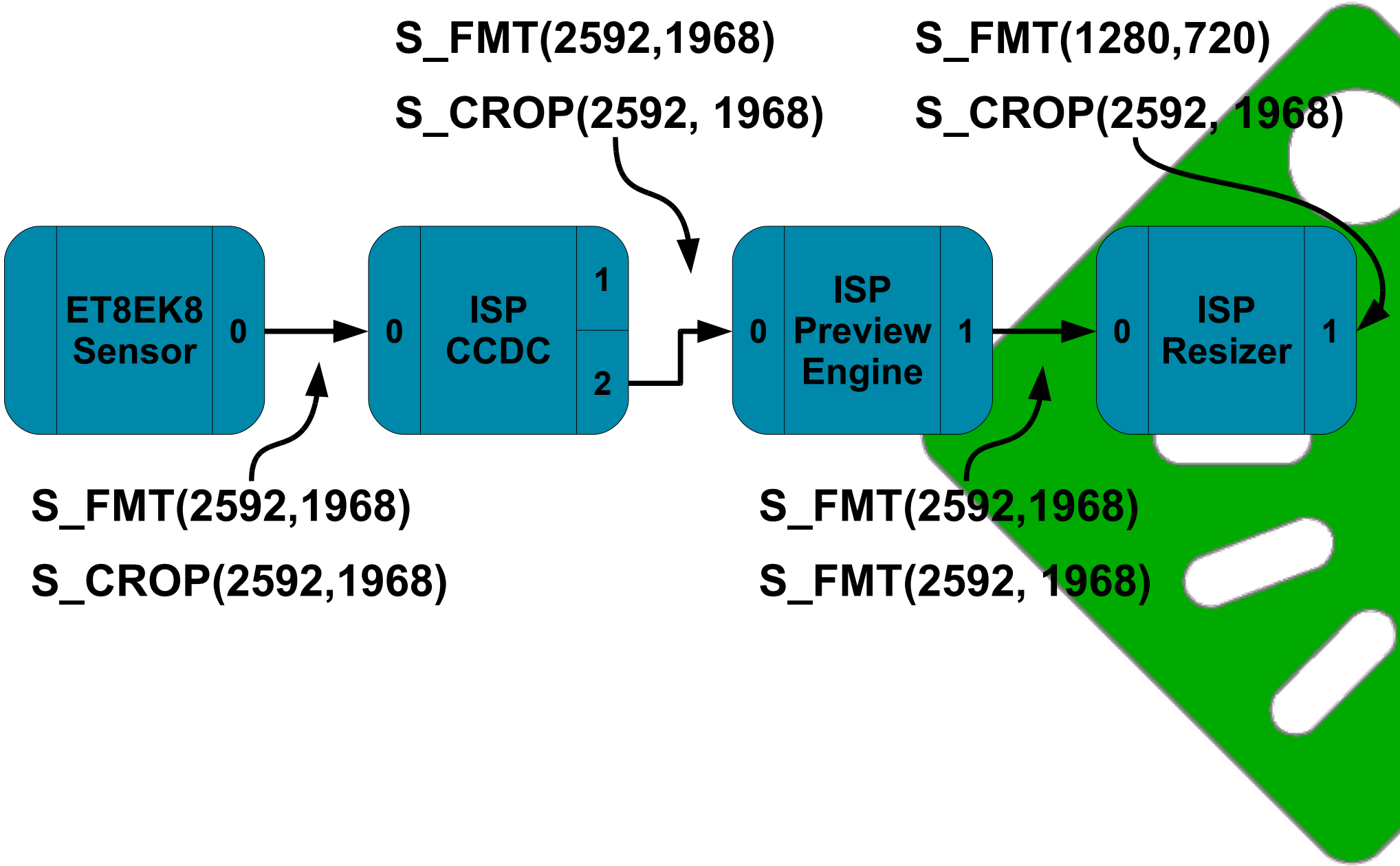
The S_CTRL API is not up to the job.

OMAP3430 ISP - Controls

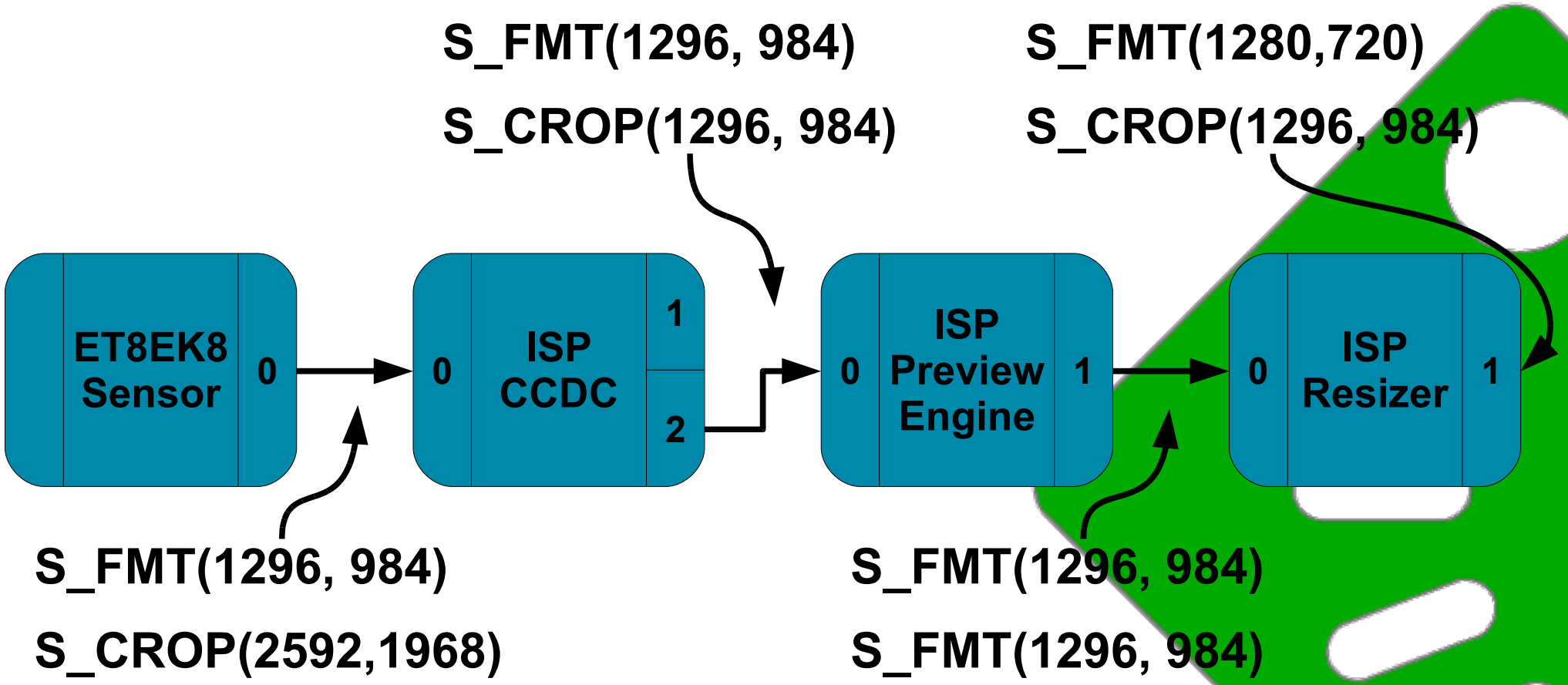


- Binning
- Horizontal averaging
- Polyphase filter

OMAP3430 ISP - Resizing

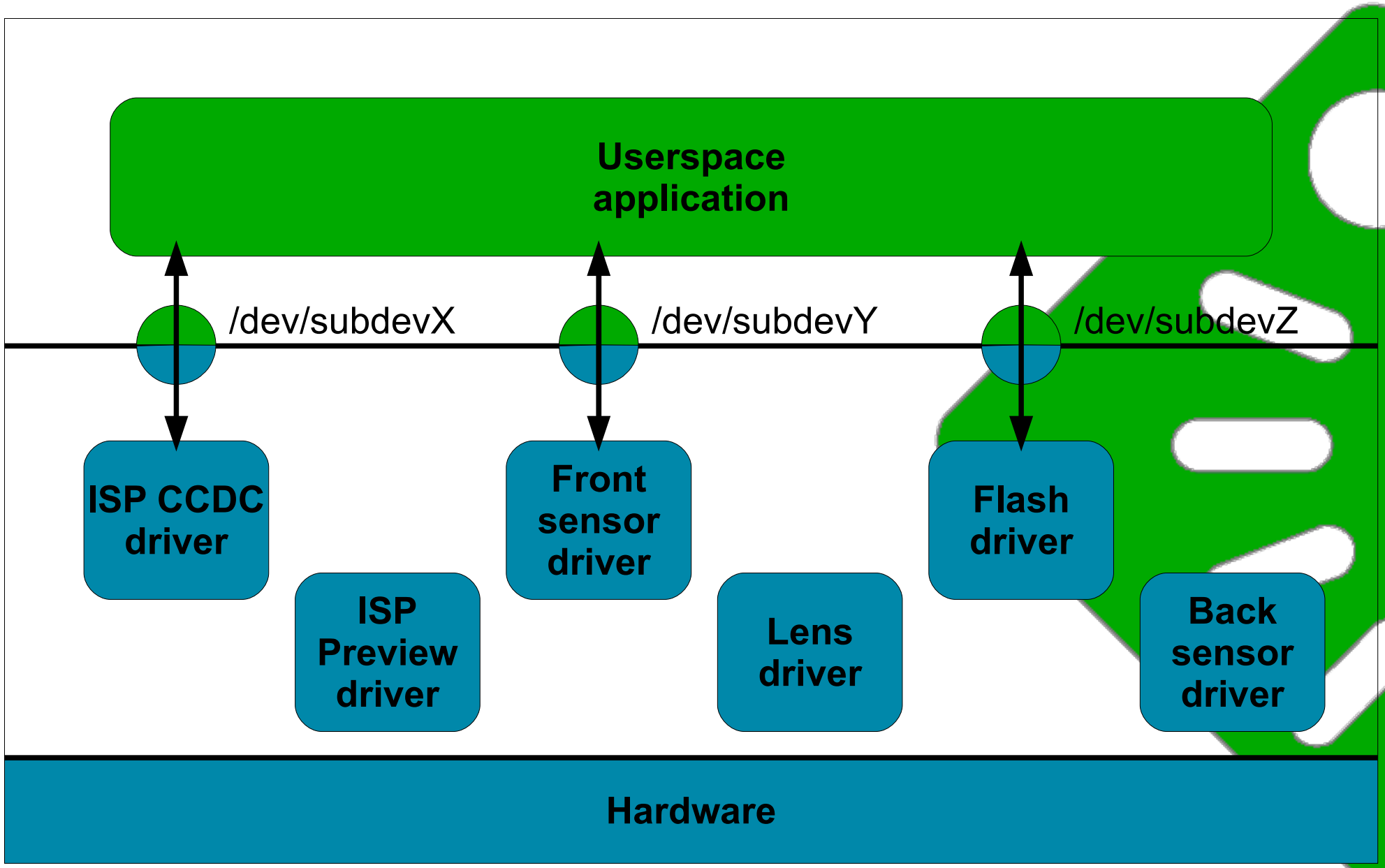


OMAP3430 ISP – High quality



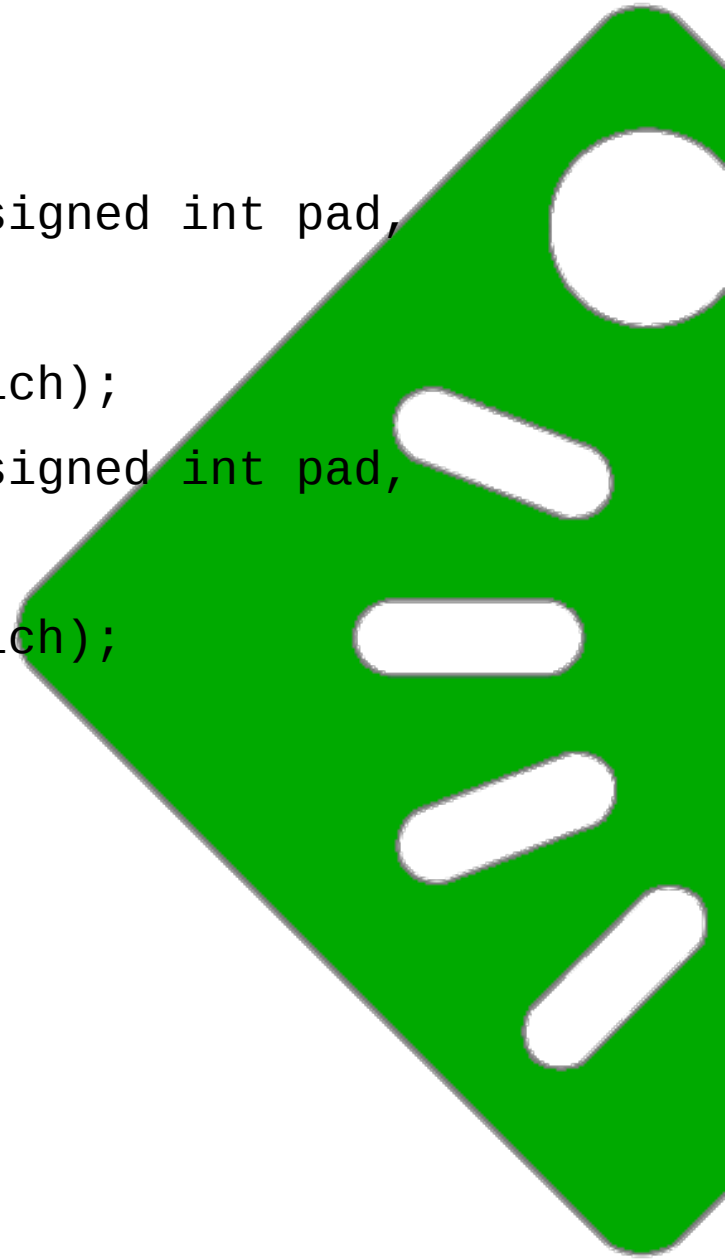
The S_FMT/S_CROP API is not up to the job.

OMAP3430 ISP – High speed



V4L2 subdev userspace API

```
struct v4l2_subdev_pad_ops {
    ...
    int (*get_fmt)(struct v4l2_subdev *sd, unsigned int pad,
                   struct v4l2_format *fmt,
                   enum v4l2_subdev_format which);
    int (*set_fmt)(struct v4l2_subdev *sd, unsigned int pad,
                   struct v4l2_format *fmt,
                   enum v4l2_subdev_format which);
    ....
};

struct v4l2_subdev_ops {
    ...
    const struct v4l2_subdev_pad_ops  *pad;
};
```



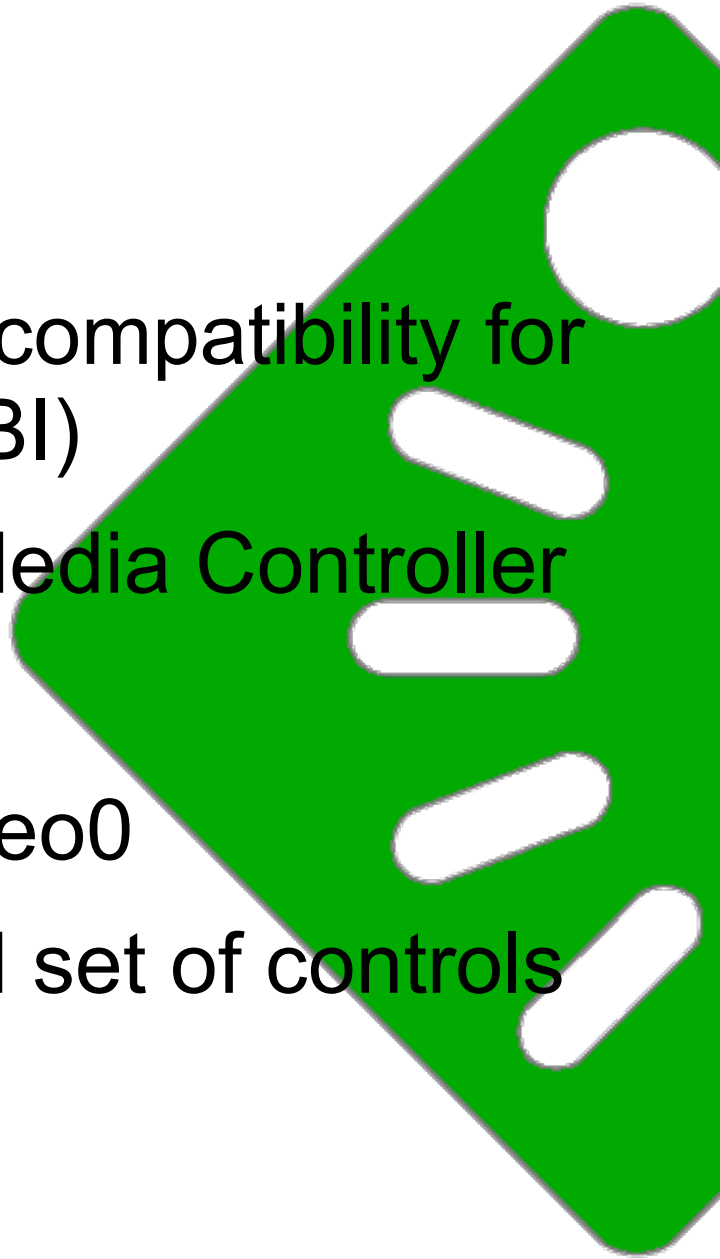
V4L2 subdevice pad operations

Is this V4L3 ?

- No, V4L2 is still alive and well
- Best effort to provide V4L2-only compatibility for existing applications (API and ABI)
- Advanced features will require Media Controller

OMAP3430 ISP

- Default pipeline through /dev/video0
- Limited set of resolutions, limited set of controls



V4L2 plain API

Retrieve statistics

V4L2 events API

Compute parameters

Host-side software algorithm

Set parameters

VIDIOC_S_CTRL

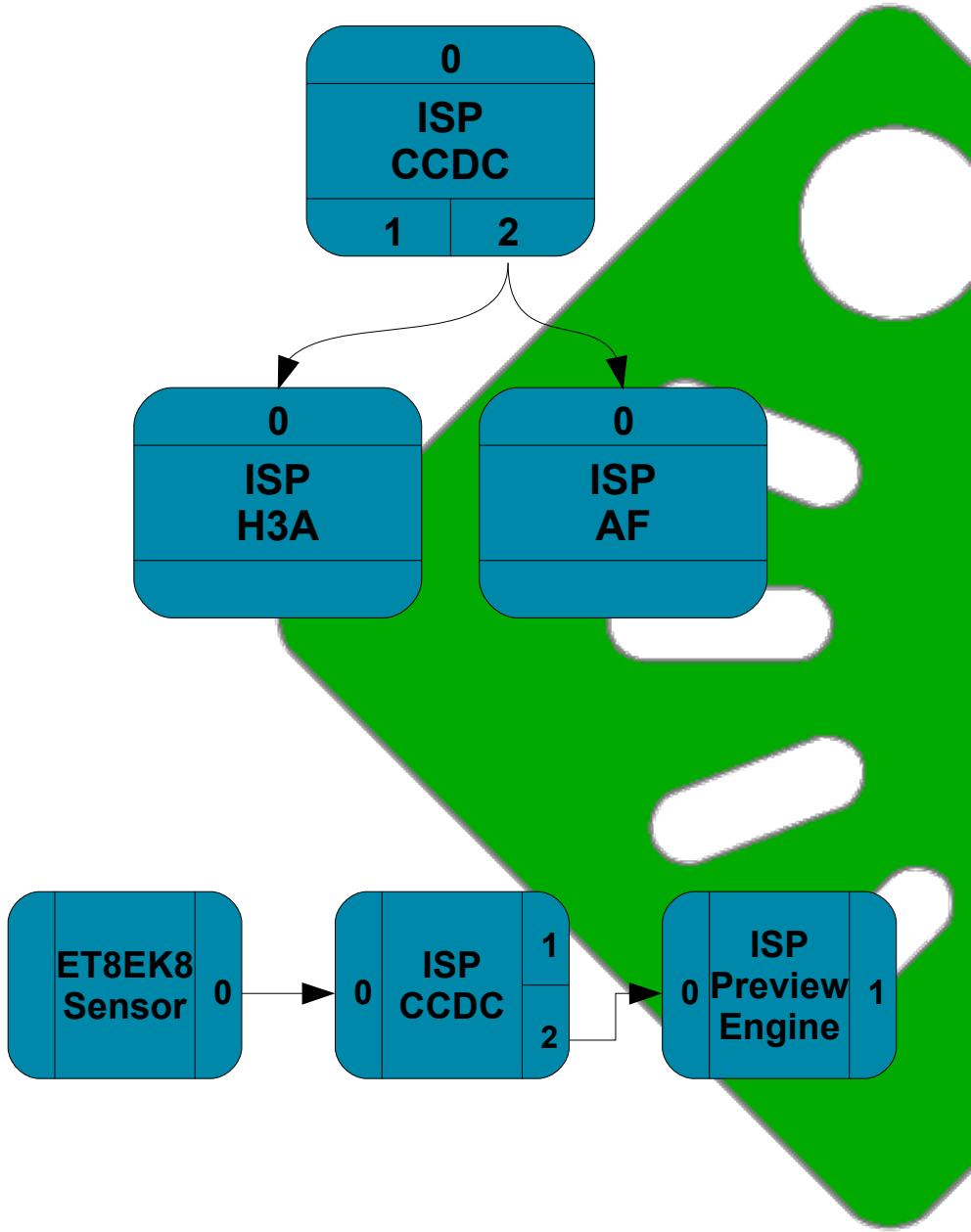
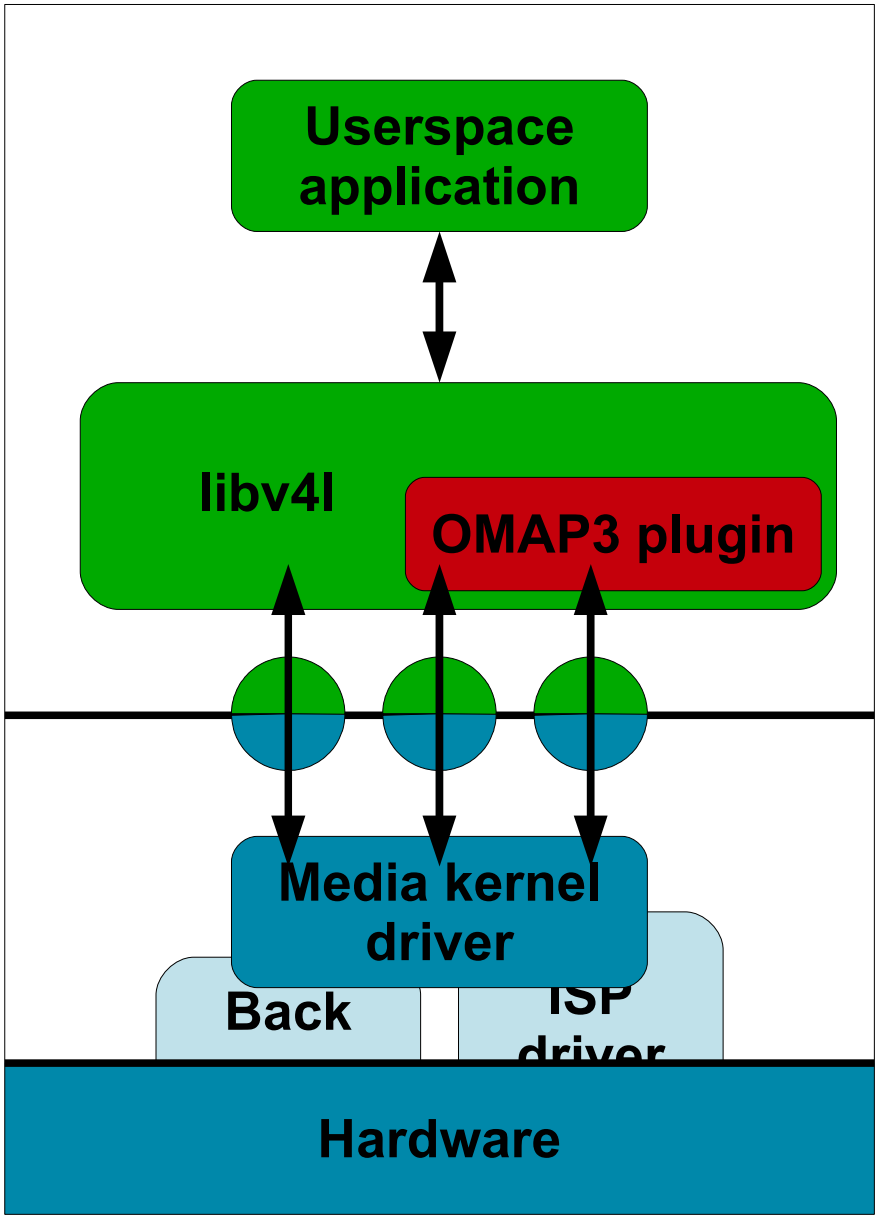
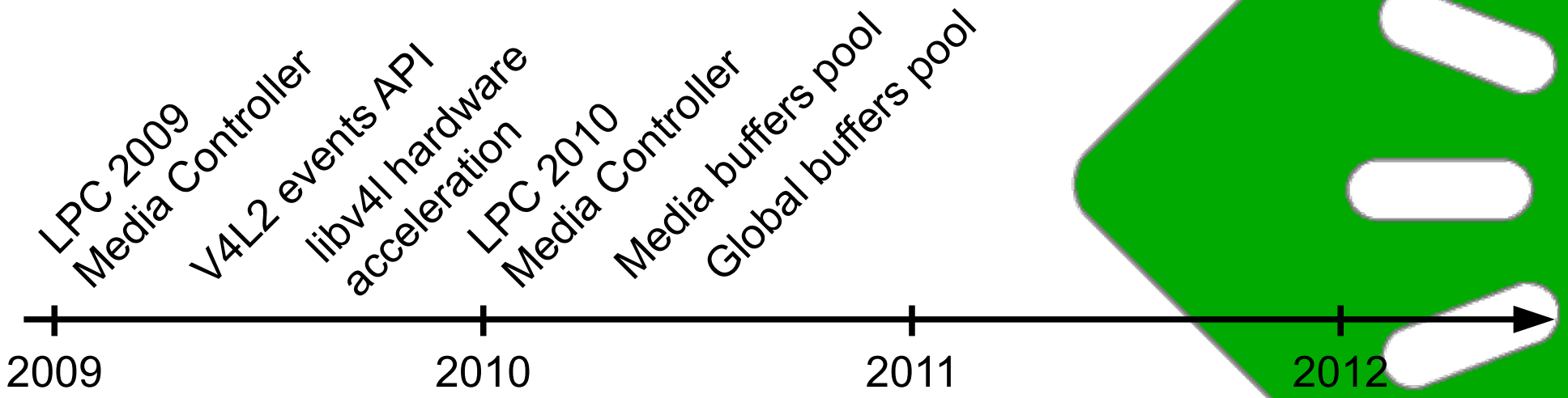


Image quality

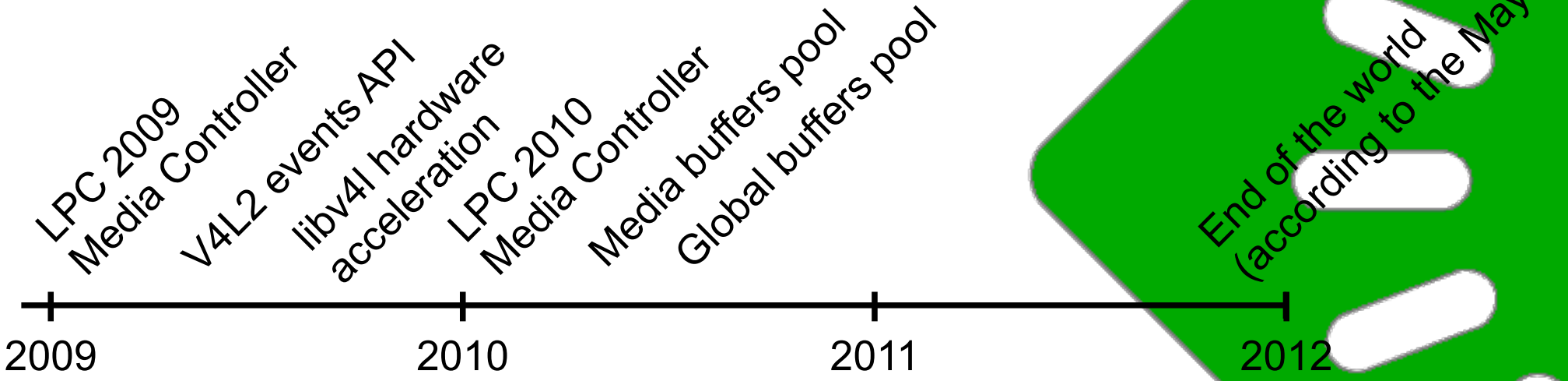


- Image enhancement algorithms
- Hardware-specific acceleration
- Transparent for applications

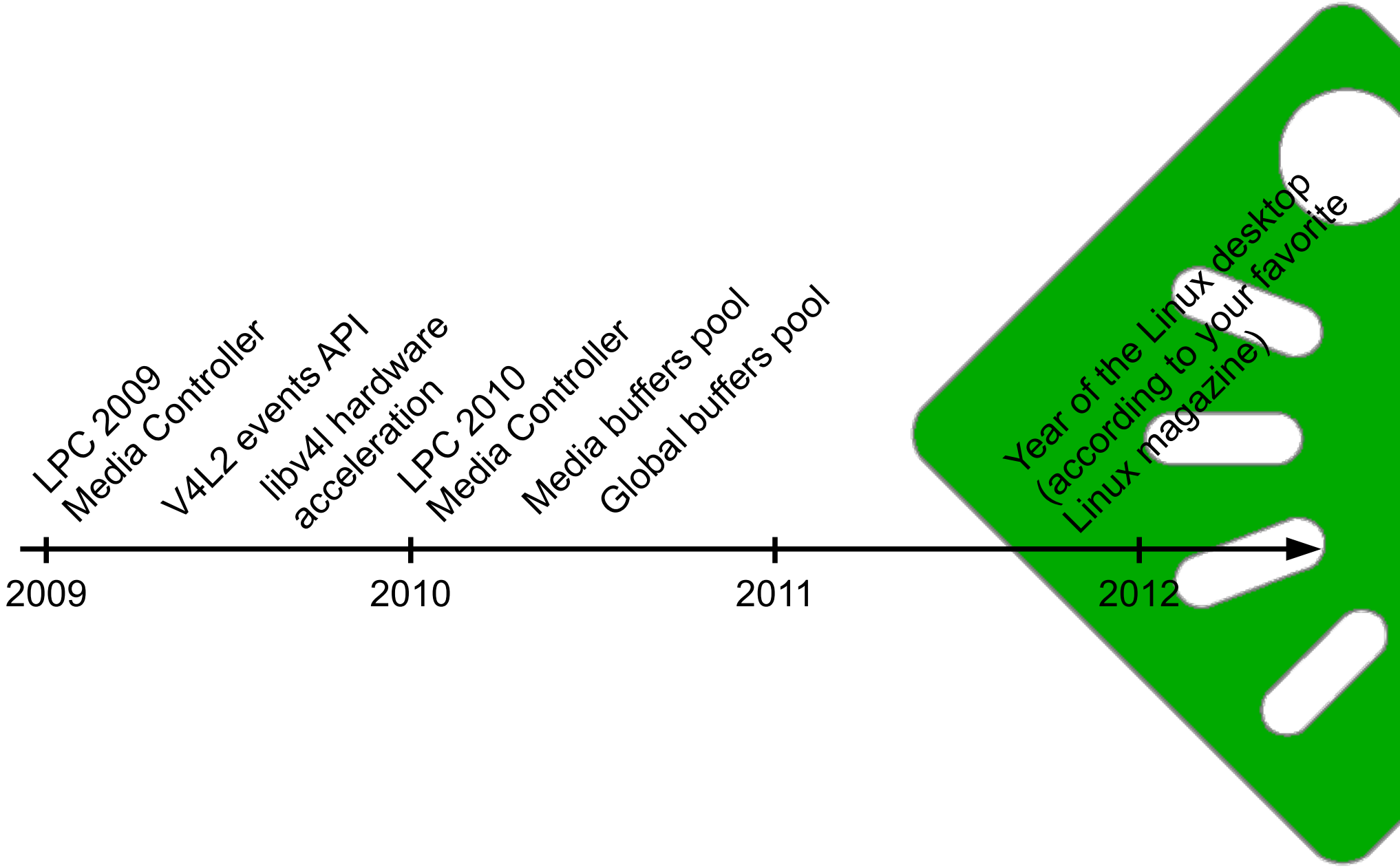
libv4l


LPC 2009
Media Controller
V4L2 events API
libv4l hardware acceleration
LPC 2010
Media Controller
Media buffers pool
Global buffers pool
2009
2010
2011
2012

The future



The future - V2



The future - V3

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Thanks

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