An Introduction to the Video4Linux Framework

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Features & Architecture

Features

- Video capture/output and tuning (/dev/videoX, streaming and control)
- Video capture and output overlay (/dev/videoX, control)
- Memory-to-Memory (aka codec) devices (/dev/videoX, streaming and control)
- Raw and Sliced VBI capture and output (/dev/vbiX, streaming and control)
- Radio tuning and modulating (/dev/radioX, control, ALSA for streaming)
- RDS receiver/transmitter (/dev/radioX, streaming and control)
- Upcoming in 3.15: Software Defined Radio (/dev/swradioX, streaming and control)
- Low-level sub-device control (/dev/v4l-subdevX, control)
- Device topology discovery/control (/dev/mediaX, control)

Driver architecture

- The bridge driver controls the platform/USB/PCI/... hardware that is responsible for the DMA transfers.
- Based on the board configuration (USB ID, PCI ID, kernel config, device tree, module options) the necessary *sub-device* drivers are loaded.
- The bridge driver finally registers the device nodes it needs.
- Consequences for the Device Tree model: sub-devices need to defer initialization until the bridge driver has been loaded. The bridge driver needs to postpone initializing sub-devices until all required sub-devices have been loaded (v4l2-async).

Resources

Resources

- Linux Media Infrastructure API: http://linuxtv.org/downloads/v4l-dvb-apis. Latest version: http://hverkuil.home.xs4all.nl/spec/media.html
- Documentation/video4linux/v4l2-framework.txt and v4l2-controls.txt
- include/media/videobuf2-core.h
- Upstream media git repository: http://git.linuxtv.org/media_tree.git
- v4l-utils git repository: http://git.linuxtv.org/v4l-utils.git
- linux-media mailinglist & irc channel: http://linuxtv.org/lists.php

V4L2 PCI Skeleton Driver Basics

struct v4l2_device (1)

```
#include <linux/videodev2.h>
#include <media/v4l2-device.h>

MODULE_DESCRIPTION("V4L2 PCI Skeleton Driver");
MODULE_AUTHOR("Hans Verkuil");
MODULE_LICENSE("GPL v2");
MODULE_DEVICE_TABLE(pci, skeleton_pci_tbl);

struct skeleton {
        struct pci_dev *pdev;
        struct v4l2_device v4l2_dev;
};

static const struct pci_device_id skeleton_pci_tbl[] = {
        { PCI_DEVICE(PCI_VENDOR_ID_FOO, PCI_DEVICE_ID_BAR) },
        { 0, }
};

<skeleton_probe>
<skeleton_remove>

static struct pci_driver skeleton_driver = {
        .name = KBUILD_MODNAME,
        .probe = skeleton_probe,
        .remove = skeleton_remove,
        .id_table = skeleton_pci_tbl,
};

module_pci_driver(skeleton_driver);
```

struct v4l2_device (2)

```
static int skeleton_probe(struct pci_dev *pdev, const struct pci_device_id *ent)
{
        struct skeleton *skel;
        int ret;

        pci_enable_device(pdev);
        pci_set_dma_mask(pdev, DMA_BIT_MASK(32));
        skel = devm_kzalloc(&pdev->dev, sizeof(struct skeleton), GFP_KERNEL);
        if (!skel)
                return -ENOMEM;
        skel->pdev = pdev;
        ret = v4l2_device_register(&pdev->dev, &skel->v4l2_dev);
        if (ret)
                goto disable_pci;
        dev_info(&pdev->dev, "V4L2 PCI Skeleton Driver loaded\n");
        return 0;

disable_pci:
        pci_disable_device(pdev);
        return ret;
}

static void skeleton_remove(struct pci_dev *pdev)
{
        struct v4l2_device *v4l2_dev = pci_get_drvdata(pdev);
        struct skeleton *skel = container_of(v4l2_dev, struct skeleton, v4l2_dev);

        v4l2_device_unregister(&skel->v4l2_dev);
        pci_disable_device(skel->pdev);
}
```

struct v4l2_device (3)

- Top level struct.
- Misnomer: a better name would have been v4l2_root.
- v4l2_device_(un)register should have been called v4l2_root_init/exit.
- Maintains list of sub-devices.
- Has notify() callback for sub-devices.
- Has release() callback called when the last device reference goes away.

struct video_device (1)

```
struct skeleton {
        struct pci_dev *pdev;
        struct v4l2_device v4l2_dev;
        struct video_device vdev;
        struct mutex lock;
};

static int skeleton_probe(struct pci_dev *pdev, const struct pci_device_id *ent)
{
        ...
        mutex_init(&skel->lock);
        vdev = &skel->vdev;
        strlcpy(vdev->name, KBUILD_MODNAME, sizeof(vdev->name));
        vdev->release = video_device_release_empty;
        vdev->fops = &skel_fops,
        vdev->ioctl_ops = &skel_ioctl_ops,
        vdev->lock = &skel->lock;
        vdev->v4l2_dev = &skel->v4l2_dev;
        /* Supported SDTV standards, if any */
        vdev->tvnorms = V4L2_STD_ALL;
        set_bit(V4L2_FL_USE_FH_PRIO, &vdev->flags);
        video_set_drvdata(vdev, skel);

        ret = video_register_device(vdev, VFL_TYPE_GRABBER, -1);
        if (ret)
                goto v4l2_dev_unreg;

        dev_info(&pdev->dev, "V4L2 PCI Skeleton Driver loaded\n");
        return 0;
        ...
}
```

struct video_device (2)

```
static int skeleton_querycap(struct file *file, void *priv,
                             struct v4l2_capability *cap)
{
        struct skeleton *skel = video_drvdata(file);

        strlcpy(cap->driver, KBUILD_MODNAME, sizeof(cap->driver));
        strlcpy(cap->card, "V4L2 PCI Skeleton", sizeof(cap->card));
        snprintf(cap->bus_info, sizeof(cap->bus_info), "PCI:%s",
                 pci_name(skel->pdev));
        cap->device_caps = V4L2_CAP_VIDEO_CAPTURE | V4L2_CAP_READWRITE |
                           V4L2_CAP_STREAMING;
        cap->capabilities = cap->device_caps | V4L2_CAP_DEVICE_CAPS;
        return 0;
}

static const struct v4l2_ioctl_ops skel_ioctl_ops = {
        .vidioc_querycap = skeleton_querycap,
};

static const struct v4l2_file_operations skel_fops = {
        .owner = THIS_MODULE,
        .open = v4l2_fh_open,
        .release = v4l2_fh_release,
        .unlocked_ioctl = video_ioctl2,
};
```

struct video_device (3)

- Represents a video/radio/vbi/v4l2_subdev node.
- Often represents a DMA engine as well: pointer to vb2_queue.
- Pointer to v4l2_ioctl_ops for ioctl operations.
- Pointer to v4l2_file_operations for the file operations.
- Core locking support: lock mutex, vb2_queue.lock:
  - If lock == NULL, then the driver does all locking.
  - If lock != NULL but vb2_queue.lock == NULL, then all ioctls are serialized through that lock, including the streaming ioctls.
  - If vb2_queue.lock is also != NULL then that lock is used for all the streaming ioctls: useful if other ioctls can hold the core lock for a long time (typical for USB drivers).
  - The driver always does all the locking for non-ioctl file operations.
- My personal recommendation: use core locking.

Input ioctls (1)

```
static int skeleton_enum_input(struct file *file, void *priv,
                               struct v4l2_input *i)
{
        if (i->index > 1)
                return -EINVAL;
        i->type = V4L2_INPUT_TYPE_CAMERA;
        if (i->index == 0) {
                i->std = V4L2_STD_ALL;
                strlcpy(i->name, "S-Video", sizeof(i->name));
                i->capabilities = V4L2_IN_CAP_STD;
        } else {
                i->std = 0;
                strlcpy(i->name, "HDMI", sizeof(i->name));
                i->capabilities = V4L2_IN_CAP_DV_TIMINGS;
        }
        return 0;
}

static const struct v4l2_ioctl_ops skel_ioctl_ops = {
        .vidioc_enum_input = skeleton_enum_input,
};
```

Input ioctls (2)

```
static int skeleton_s_input(struct file *file, void *priv, unsigned int i)
{
        struct skeleton *skel = video_drvdata(file);

        if (i > 1)
                return -EINVAL;
        skel->input = i;
        skel->vdev.tvnorms = i ? 0 : V4L2_STD_ALL;
        skeleton_fill_pix_format(skel, &skel->format);
        return 0;
}

static int skeleton_g_input(struct file *file, void *priv, unsigned int *i)
{
        struct skeleton *skel = video_drvdata(file);

        *i = skel->input;
        return 0;
}

static const struct v4l2_ioctl_ops skel_ioctl_ops = {
        .vidioc_g_input = skeleton_g_input,
        .vidioc_s_input = skeleton_s_input,
};
```

SDTV Standards ioctls (1)

```
static int skeleton_s_std(struct file *file, void *priv, v4l2_std_id std)
{
        struct skeleton *skel = video_drvdata(file);

        if (skel->input)
                return -ENODATA;
        if (std == skel->std)
                return 0;
        /* TODO: handle changing std */
        skel->std = std;
        skeleton_fill_pix_format(skel, &skel->format);
        return 0;
}

static int skeleton_g_std(struct file *file, void *priv, v4l2_std_id *std)
{
        struct skeleton *skel = video_drvdata(file);

        if (skel->input)
                return -ENODATA;
        *std = skel->std;
        return 0;
}

static const struct v4l2_ioctl_ops skel_ioctl_ops = {
        .vidioc_g_std = skeleton_g_std,
        .vidioc_s_std = skeleton_s_std,
};
```

SDTV Standards ioctls (2)

```
static int skeleton_querystd(struct file *file, void *priv,
                             v4l2_std_id *std)
{
        struct skeleton *skel = video_drvdata(file);

        if (skel->input)
                return -ENODATA;
        /* TODO: Query currently seen standard. */
        return 0;
}

static const struct v4l2_ioctl_ops skel_ioctl_ops = {
        .vidioc_querystd = skeleton_querystd,
};
```

DV Timings ioctls (1)

```
static const struct v4l2_dv_timings_cap skel_timings_cap = {
        .type = V4L2_DV_BT_656_1120,
        /* keep this initialization for compatibility with GCC < 4.4.6 */
        .reserved = { 0 },
        V4L2_INIT_BT_TIMINGS(
                720, 1920,              /* min/max width */
                480, 1080,              /* min/max height */
                27000000, 74250000,     /* min/max pixelclock*/
                V4L2_DV_BT_STD_CEA861,  /* Supported standards */
                /* capabilities */
                V4L2_DV_BT_CAP_INTERLACED | V4L2_DV_BT_CAP_PROGRESSIVE
        )
};

static int skeleton_dv_timings_cap(struct file *file, void *fh,
                                   struct v4l2_dv_timings_cap *cap)
{
        struct skeleton *skel = video_drvdata(file);

        if (skel->input == 0)
                return -ENODATA;
        *cap = skel_timings_cap;
        return 0;
}

static const struct v4l2_ioctl_ops skel_ioctl_ops = {
        .vidioc_dv_timings_cap = skeleton_dv_timings_cap,
};
```

DV Timings ioctls (2)

```
static int skeleton_s_dv_timings(struct file *file, void *_fh,
                                 struct v4l2_dv_timings *timings)
{
        struct skeleton *skel = video_drvdata(file);

        if (skel->input == 0)
                return -ENODATA;
        if (!v4l2_valid_dv_timings(timings, &skel_timings_cap, NULL,
NULL))
                return -EINVAL;
        if (!v4l2_find_dv_timings_cap(timings, &skel_timings_cap, 0, NULL,
NULL))
                return -EINVAL;
        if (v4l2_match_dv_timings(timings, &skel->timings, 0))
                return 0;
        /* TODO: Configure new timings */
        skel->timings = *timings;
        skeleton_fill_pix_format(skel, &skel->format);
        return 0;
}

static const struct v4l2_ioctl_ops skel_ioctl_ops = {
        .vidioc_s_dv_timings = skeleton_s_dv_timings,
};
```

DV Timings ioctls (3)

```
static int skeleton_g_dv_timings(struct file *file, void *_fh,
                                 struct v4l2_dv_timings *timings)
{
        struct skeleton *skel = video_drvdata(file);

        if (skel->input == 0)
                return -ENODATA;
        *timings = skel->timings;
        return 0;
}

static int skeleton_enum_dv_timings(struct file *file, void *_fh,
                                    struct v4l2_enum_dv_timings *timings)
{
        struct skeleton *skel = video_drvdata(file);

        if (skel->input == 0)
                return -ENODATA;
        return v4l2_enum_dv_timings_cap(timings, &skel_timings_cap, NULL, NULL);
}

static const struct v4l2_ioctl_ops skel_ioctl_ops = {
        .vidioc_g_dv_timings = skeleton_g_dv_timings,
        .vidioc_enum_dv_timings = skeleton_enum_dv_timings,
};
```

DV Timings ioctls (4)

```
static int skeleton_query_dv_timings(struct file *file, void *_fh,
                                     struct v4l2_dv_timings *timings)
{
        struct skeleton *skel = video_drvdata(file);

        if (skel->input == 0)
                return -ENODATA;

        /* TODO: Query currently seen timings. */
        detect_timings();
        if (no_signal)
                return -ENOLINK;
        if (cannot_lock_to_signal)
                return -ENOLCK;
        if (signal_out_of_range_of_capabilities)
                return -ERANGE;

        /* Useful for debugging */
        if (debug)
                v4l2_print_dv_timings(skel->v4l2_dev.name,
                                      "query_dv_timings:",
                                      timings, true);
        return 0;
}

static const struct v4l2_ioctl_ops skel_ioctl_ops = {
        .vidioc_query_dv_timings = skeleton_query_dv_timings,
};
```

Format ioctls (1)

```
static int skeleton_s_fmt_vid_cap(struct file *file, void *priv,
                                  struct v4l2_format *f)
{
        struct skeleton *skel = video_drvdata(file);
        int ret;

        ret = skeleton_try_fmt_vid_cap(file, priv, f);
        if (ret)
                return ret;
        /* TODO: change format */
        skel->format = f->fmt.pix;
        return 0;
}

static int skeleton_g_fmt_vid_cap(struct file *file, void *priv,
                                  struct v4l2_format *f)
{
        struct skeleton *skel = video_drvdata(file);

        f->fmt.pix = skel->format;
        return 0;
}

static const struct v4l2_ioctl_ops skel_ioctl_ops = {
        .vidioc_s_fmt_vid_cap = skeleton_s_fmt_vid_cap,
        .vidioc_g_fmt_vid_cap = skeleton_g_fmt_vid_cap,
};
```

Format ioctls (2)

```
static int skeleton_enum_fmt_vid_cap(struct file *file, void *priv,
                                     struct v4l2_fmtdesc *f)
{
        if (f->index != 0)
                return -EINVAL;
        strlcpy(f->description, "4:2:2, packed, UYVY", sizeof(f-
>description));
        f->pixelformat = V4L2_PIX_FMT_UYVY;
        f->flags = 0;
        return 0;
}

static const struct v4l2_ioctl_ops skel_ioctl_ops = {
        .vidioc_enum_fmt_vid_cap = skeleton_enum_fmt_vid_cap,
};
```

Format ioctls (3)

```
static void skeleton_fill_pix_format(struct skeleton *skel, struct v4l2_pix_format *pix)
{
        pix->pixelformat = V4L2_PIX_FMT_UYVY;
        if (skel->input == 0) {
                pix->width = 720;
                pix->height = (skel->std & V4L2_STD_525_60) ? 480 : 576;
                pix->field = V4L2_FIELD_INTERLACED;
                pix->colorspace = V4L2_COLORSPACE_SMPTE170M;
        } else {
                pix->width = skel->timings.bt.width;
                pix->height = skel->timings.bt.height;
                if (skel->timings.bt.interlaced)
                        pix->field = V4L2_FIELD_INTERLACED;
                else
                        pix->field = V4L2_FIELD_NONE;
                pix->colorspace = V4L2_COLORSPACE_REC709;
        }
        pix->bytesperline = pix->width * 2;
        pix->sizeimage = pix->bytesperline * pix->height;
        pix->priv = 0;
}

static int skeleton_try_fmt_vid_cap(struct file *file, void *priv, struct v4l2_format *f)
{
        struct skeleton *skel = video_drvdata(file);
        struct v4l2_pix_format *pix = &f->fmt.pix;

        if (pix->pixelformat != V4L2_PIX_FMT_UYVY)
                return -EINVAL;
        skeleton_fill_pix_format(skel, pix);
        return 0;
}

static const struct v4l2_ioctl_ops skel_ioctl_ops = {
        .vidioc_try_fmt_vid_cap = skeleton_try_fmt_vid_cap,
};
```

V4L2 PCI Skeleton Driver Streaming

Streaming Modes

- Read and Write
- Memory Mapped Streaming I/O: memory allocated by the driver, mmap()ed into userspace.
- User Pointer Streaming I/O: memory allocated by userspace, requires scatter-gather DMA support.
- DMABUF Streaming I/O: memory allocated by another device, exported as a DMABUF file handler and imported in this driver.

Streaming Support (1)

```
#include <media/videobuf2-dma-contig.h>

struct skeleton {
        ...
        struct vb2_queue queue;
        struct vb2_alloc_ctx *alloc_ctx;

        spinlock_t qlock;
        struct list_head buf_list;
        unsigned int sequence;
};

struct skel_buffer {
        struct vb2_buffer vb;
        struct list_head list;
};

static inline struct skel_buffer *to_skel_buffer(struct vb2_buffer *vb2)
{
        return container_of(vb2, struct skel_buffer, vb);
}
```

Streaming Support (2)

```
static int skeleton_probe(struct pci_dev *pdev, const struct pci_device_id *ent)
{
        ...
        q = &skel->queue;
        q->type = V4L2_BUF_TYPE_VIDEO_CAPTURE;
        q->io_modes = VB2_MMAP | VB2_DMABUF | VB2_READ;
        q->drv_priv = skel;
        q->buf_struct_size = sizeof(struct skel_buffer);
        q->ops = &skel_qops;
        q->mem_ops = &vb2_dma_contig_memops;
        q->timestamp_type = V4L2_BUF_FLAG_TIMESTAMP_MONOTONIC;
        q->lock = &skel->lock;
        q->gfp_flags = GFP_DMA32;
        ret = vb2_queue_init(q);
        if (ret)
                goto v4l2_dev_unreg;

        skel->alloc_ctx = vb2_dma_contig_init_ctx(&pdev->dev);
        if (IS_ERR(skel->alloc_ctx)) {
                dev_err(&pdev->dev, "Can't allocate buffer context");
                ret = PTR_ERR(skel->alloc_ctx);
                goto v4l2_dev_unreg;
        }
        INIT_LIST_HEAD(&skel->buf_list);
        spin_lock_init(&skel->qlock);
        ...
        vdev->queue = q;
        ...
}
```

Streaming Support (3)

```
static struct vb2_ops skel_qops = {
        .queue_setup            = queue_setup,
        .buf_prepare            = buffer_prepare,
        .buf_queue              = buffer_queue,
        .start_streaming        = start_streaming,
        .stop_streaming         = stop_streaming,
        .wait_prepare           = vb2_ops_wait_prepare,
        .wait_finish            = vb2_ops_wait_finish,
};

static const struct v4l2_ioctl_ops skel_ioctl_ops = {
        ...
        .vidioc_reqbufs = vb2_ioctl_reqbufs,
        .vidioc_querybuf = vb2_ioctl_querybuf,
        .vidioc_qbuf = vb2_ioctl_qbuf,
        .vidioc_dqbuf = vb2_ioctl_dqbuf,
        .vidioc_streamon = vb2_ioctl_streamon,
        .vidioc_streamoff = vb2_ioctl_streamoff,
};

static const struct v4l2_file_operations skel_fops = {
        .owner = THIS_MODULE,
        .open = v4l2_fh_open,
        .release = vb2_fop_release,
        .unlocked_ioctl = video_ioctl2,
        .read = vb2_fop_read,
        .mmap = vb2_fop_mmap,
        .poll = vb2_fop_poll,
};
```

Streaming Support (4)

```
static int queue_setup(struct vb2_queue *vq,
                       const struct v4l2_format *fmt,
                       unsigned int *nbuffers,
                       unsigned int *nplanes,
                       unsigned int sizes[],
                       void *alloc_ctxs[])
{
        struct skeleton *skel = vb2_get_drv_priv(vq);

        if (*nbuffers < 3)
                *nbuffers = 3;
        *nplanes = 1;
        sizes[0] = skel->format.sizeimage;
        alloc_ctxs[0] = skel->alloc_ctx;
        return 0;
}
```

Streaming Support (5)

```
static int start_streaming(struct vb2_queue *vq, unsigned int count)
{
        struct skeleton *skel = vb2_get_drv_priv(vq);

        if (count < 2)
                return -ENOBUFS;
        skel->sequence = 0;
        /* TODO: start DMA */
        return 0;
}

static int stop_streaming(struct vb2_queue *vq)
{
        struct skeleton *skel = vb2_get_drv_priv(vq);
        struct skel_buffer *buf, *node;
        unsigned long flags;

        /* TODO: stop DMA */
        /* Release all active buffers */
        spin_lock_irqsave(&skel->qlock, flags);
        list_for_each_entry_safe(buf, node, &skel->buf_list, list) {
                vb2_buffer_done(&buf->vb, VB2_BUF_STATE_ERROR);
                list_del(&buf->list);
        }
        spin_unlock_irqrestore(&skel->qlock, flags);
        return 0;
}
```

Streaming Support (6)

```
static int buffer_prepare(struct vb2_buffer *vb)
{
        struct skeleton *skel = vb2_get_drv_priv(vb->vb2_queue);
        unsigned long size = skel->format.sizeimage;

        if (vb2_plane_size(vb, 0) < size) {
                dev_err(&skel->pdev->dev, "buffer too small (%lu < %lu)\n",
                         vb2_plane_size(vb, 0), size);
                return -EINVAL;
        }
        vb2_set_plane_payload(vb, 0, size);
        vb->v4l2_buf.field = skel->format.field;
        return 0;
}

static void buffer_queue(struct vb2_buffer *vb)
{
        struct skeleton *skel = vb2_get_drv_priv(vb->vb2_queue);
        struct skel_buffer *buf = to_skel_buffer(vb);
        unsigned long flags;

        spin_lock_irqsave(&skel->qlock, flags);
        list_add_tail(&buf->list, &skel->buf_list);

        /* TODO: Update any DMA pointers if necessary */

        spin_unlock_irqrestore(&skel->qlock, flags);
}
```

Streaming Support (6)

```
static irqreturn_t skeleton_irq(int irq, void *dev_id)
{
        struct skeleton *skel = dev_id;

        /* TODO: handle interrupt */

        if (captured_new_frame) {
                ...
                spin_lock(&skel->qlock);
                list_del(&new_buf->list);
                spin_unlock(&skel->qlock);
                new_buf->vb.v4l2_buf.sequence = skel->sequence++;
                v4l2_get_timestamp(&new_buf->vb.v4l2_buf.timestamp);
                vb2_buffer_done(&new_buf->vb, VB2_BUF_STATE_DONE);
        }
        return IRQ_HANDLED;
}
```

Streaming Support (7)

Add this check:

```
        if (vb2_is_busy(&skel->queue))
                return -EBUSY;
```

to:

```
        skeleton_s_input()
        skeleton_s_std()
        skeleton_s_dv_timings()
        skeleton_s_fmt_vid_cap()
```

V4L2 PCI Skeleton Driver Control Framework

Control Support (1)

```
#include <media/v4l2-ctrls.h>
#include <media/v4l2-event.h>

struct skeleton {
        ...
        struct v4l2_ctrl_handler ctrl_handler;
        ...
};

static const struct v4l2_ctrl_ops skel_ctrl_ops = {
        .s_ctrl = skeleton_s_ctrl,
};

static const struct v4l2_ioctl_ops skel_ioctl_ops = {
        ...
        .vidioc_log_status = v4l2_ctrl_log_status,
        .vidioc_subscribe_event = v4l2_ctrl_subscribe_event,
        .vidioc_unsubscribe_event = v4l2_event_unsubscribe,
};
```

Control Support (2)

```
static int skeleton_probe(struct pci_dev *pdev, const struct pci_device_id *ent)
{
        ...
        struct v4l2_ctrl_handler *hdl;
        ...
        hdl = &skel->ctrl_handler;
        v4l2_ctrl_handler_init(hdl, 4);
        v4l2_ctrl_new_std(hdl, &skel_ctrl_ops,
                          V4L2_CID_BRIGHTNESS, 0, 255, 1, 127);
        v4l2_ctrl_new_std(hdl, &skel_ctrl_ops,
                          V4L2_CID_CONTRAST, 0, 255, 1, 16);
        v4l2_ctrl_new_std(hdl, &skel_ctrl_ops,
                          V4L2_CID_SATURATION, 0, 255, 1, 127);
        v4l2_ctrl_new_std(hdl, &skel_ctrl_ops,
                          V4L2_CID_HUE, -128, 127, 1, 0);
        if (hdl->error) {
                ret = hdl->error;
                goto free_hdl;
        }
        skel->v4l2_dev.ctrl_handler = hdl;
        ...

free_hdl:
        v4l2_ctrl_handler_free(&skel->ctrl_handler);
        v4l2_device_unregister(&skel->v4l2_dev);
disable_pci:
        pci_disable_device(pdev);
        return ret;
}
```

Control Support (3)

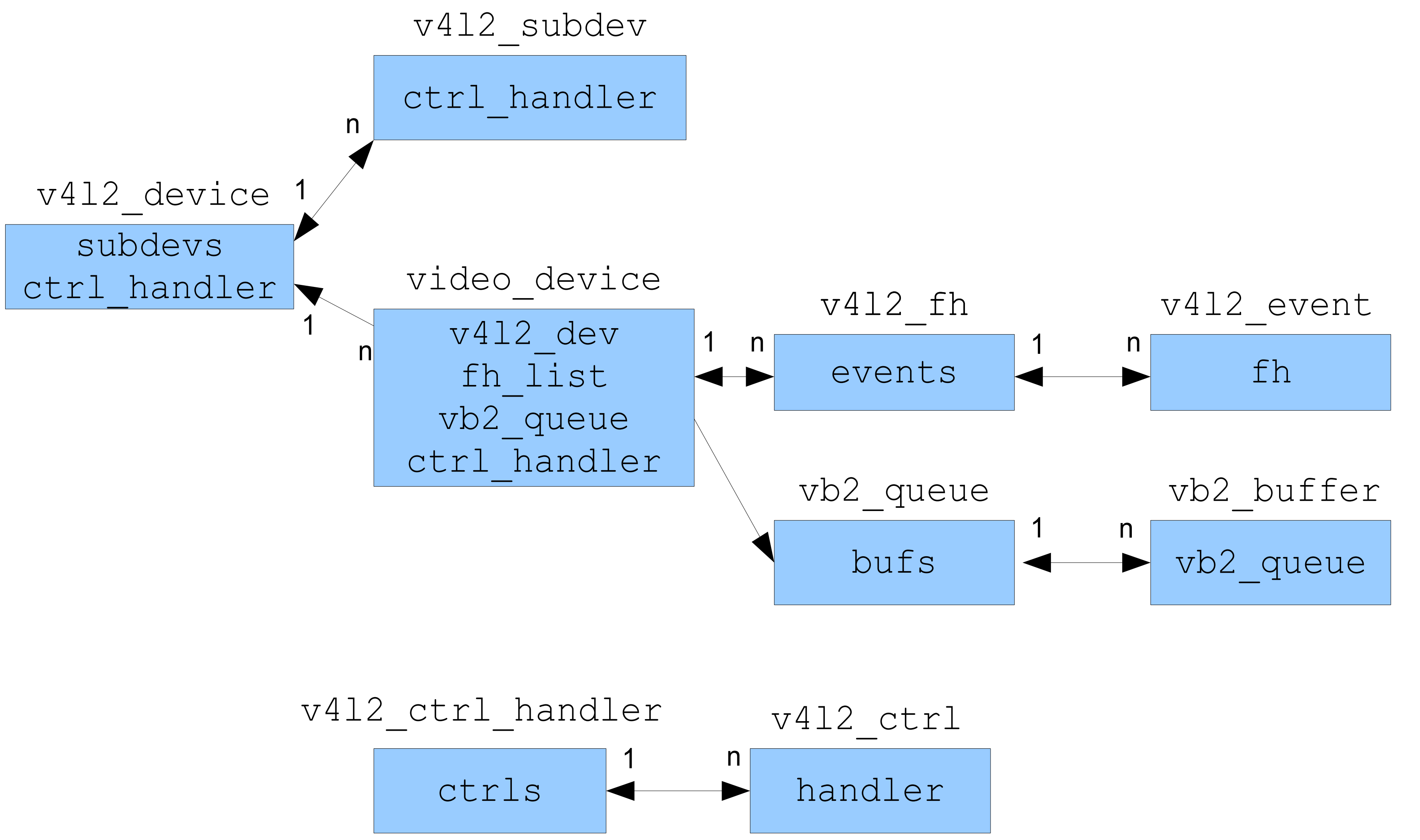
```
static int skeleton_s_ctrl(struct v4l2_ctrl *ctrl)
{
        struct skeleton *skel =
                container_of(ctrl->handler, struct skeleton, ctrl_handler);

        switch (ctrl->id) {
        case V4L2_CID_BRIGHTNESS:
                /* TODO: set brightness to ctrl->val */
                break;
        case V4L2_CID_CONTRAST:
                /* TODO: set contrast to ctrl->val */
                break;
        case V4L2_CID_SATURATION:
                /* TODO: set saturation to ctrl->val */
                break;
        case V4L2_CID_HUE:
                /* TODO: set hue to ctrl->val */
                break;
        default:
                return -EINVAL;
        }
        return 0;
}
```

Control Framework

- Can inherit controls from other control handlers, particularly from sub-devices.
- Controls can be combined to clusters if they have to be set together.
- Validation and atomicity is handled by the framework.
- Integrates with the event handling to allow control events (i.e. get an event when a control changes value or state).
- Bridge driver can be notified when a control of a sub-device changes.
- Support for auto-clusters. For example: AUTOGAIN and GAIN controls.
- It is possible to set a control handler at the v4l2_device level, at the video_device level or at the v4l2_fh level. In sub-devices the control handler is always at the v4l2_subdev level.

V4L2 Framework & Subdevices

V4L2 Framework



Sub-devices: v4l2_subdev struct

- Usually chips connected to the i2c or SPI bus, or controlled via GPIO pins, but they can also represent SoC/FPGA-internal blocks.
- Sub-device drivers can be used by different bridge drivers, so they cannot depend on any particular bridge driver.
- Probing is not possible, so the bridge driver must load subdev drivers explicitly.
- It must be possible to address one, a subset of, or all subdev drivers.
- API must be bus-independent.
- A wide range of hardware leads to a large API: how to keep this efficient?

Sub-devices

```
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_vbi_ops        *vbi;
    const struct v4l2_subdev_ir_ops         *ir;
    const struct v4l2_subdev_sensor_ops     *sensor;
    const struct v4l2_subdev_pad_ops        *pad;
};
struct v4l2_subdev_core_ops {
    int (*log_status)(struct v4l2_subdev *sd);
    int (*s_config)(struct v4l2_subdev *sd, int irq, void
*platform_data);
    int (*s_io_pin_config)(struct v4l2_subdev *sd, size_t n,
                           struct v4l2_subdev_io_pin_config *pincfg);
    …
};
#define v4l2_subdev_call(sd, o, f, args...) \
    (!(sd) ? -ENODEV : (((sd)->ops->o && (sd)->ops->o->f) ? \
     (sd)->ops->o->f((sd) , ##args) : -ENOIOCTLCMD))
ret = v4l2_subdev_call(sd, core, s_config, 0, &pdata);
```

Utilities

Utilities

- v4l2-ctl: Swiss army knife for v4l2.
- v4l2-compliance: V4L2 compliance driver testing.
- v4l2-dbg: allows access to DBG_G_CHIP_INFO, DBG_G/S_REGISTER.
- qv4l2: Qt test application.
- Core debugging: 'echo 1 >/sys/class/video4linux/video0/debug'.
  - 1: show ioctl name
  - 2: show arguments as well

Thank You!