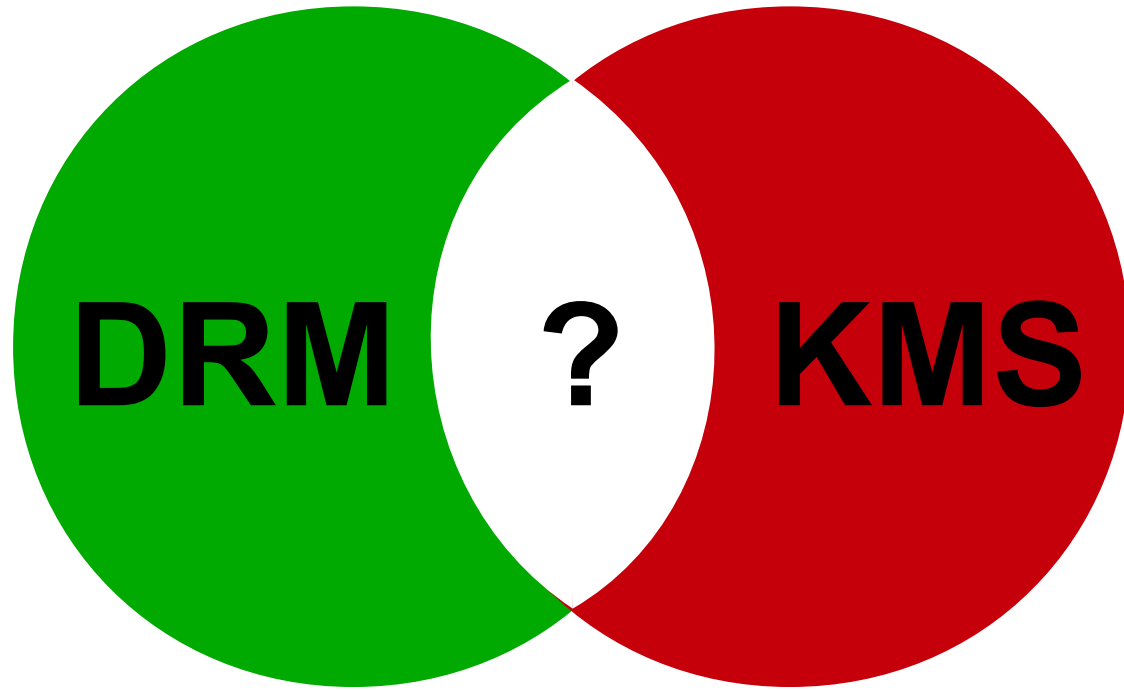


Anatomy of an Atomic KMS Driver

Embedded Linux Conference Europe 2015
Dublin

Laurent Pinchart
laurent.pinchart@ideasonboard.com



APIs

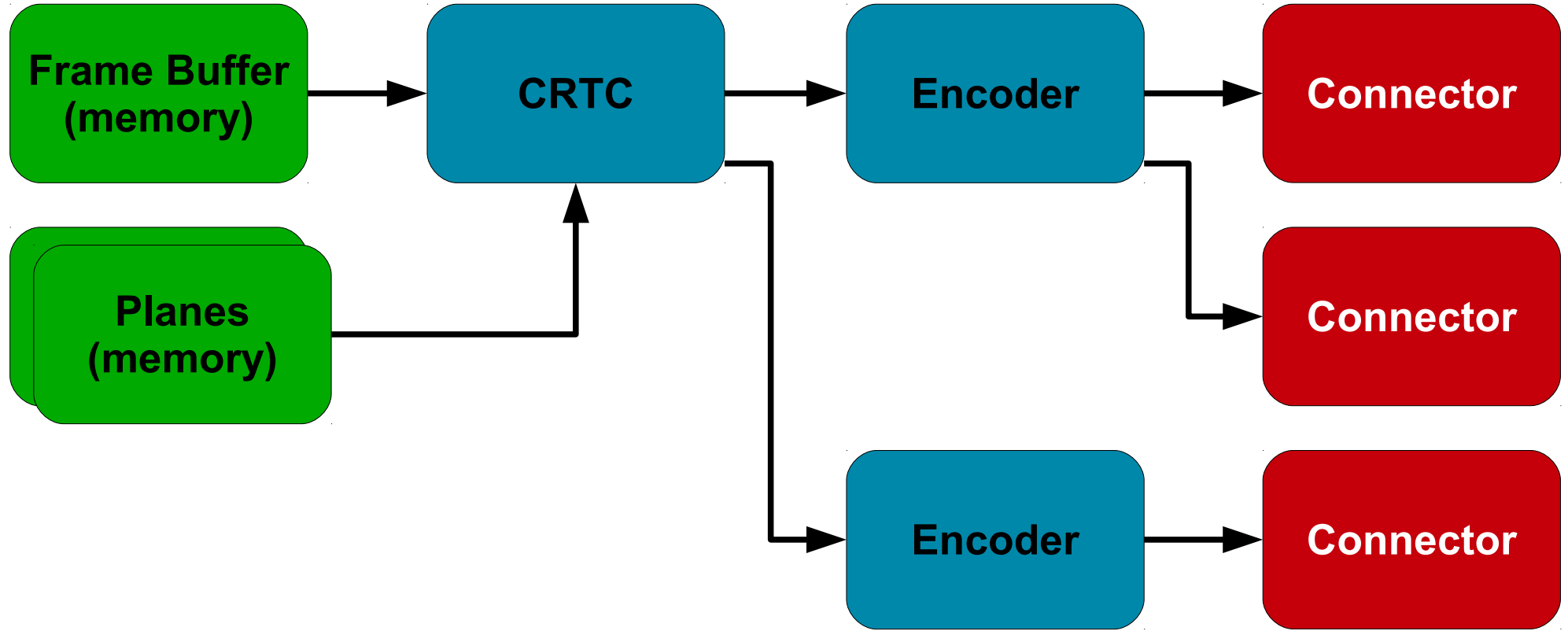
- Memory Management
- Vertical Blanking
- Version, Authentication, Master, ...



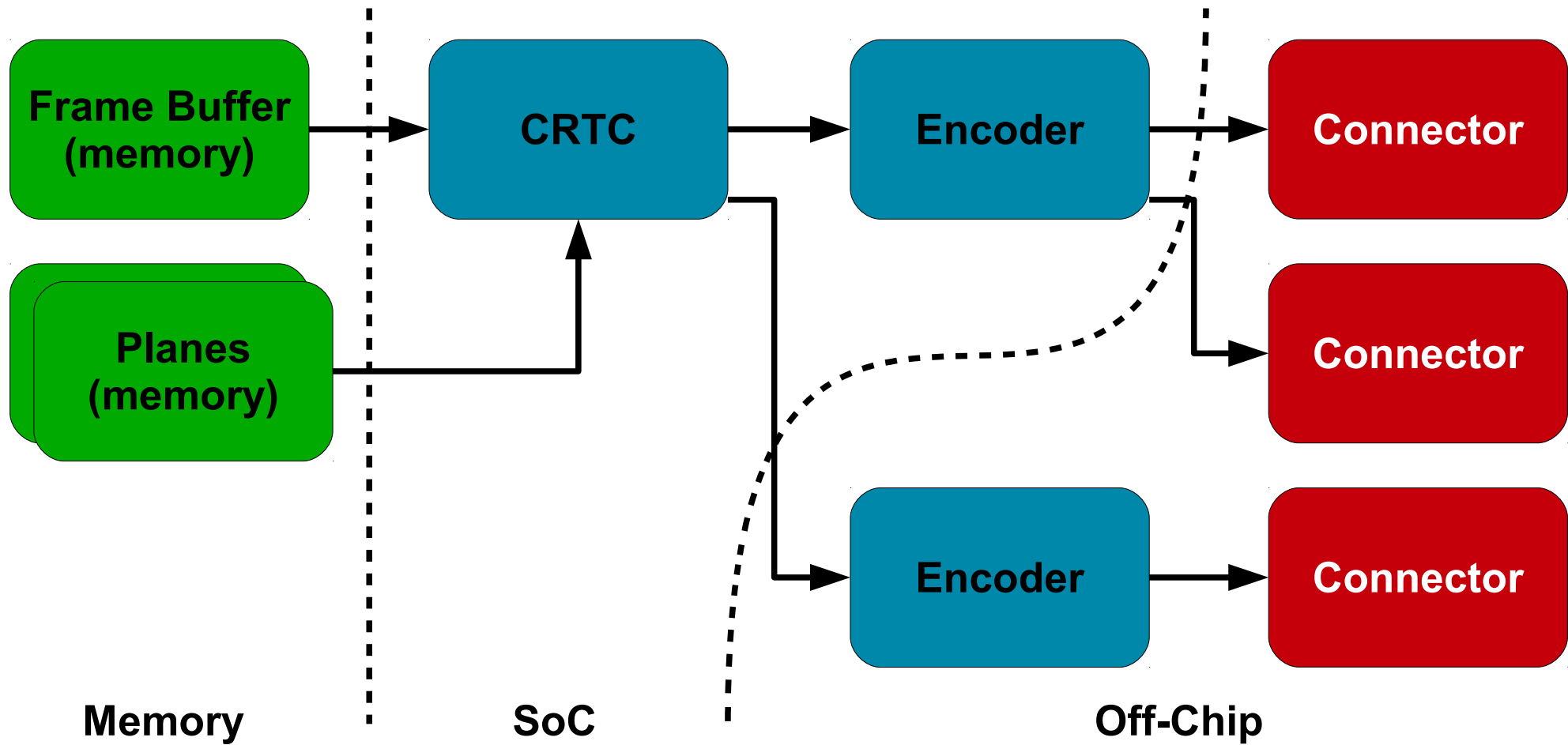
DRM

- Device Model
- Frame Buffer
- Modes
- Page Flip
- Planes
- Cursor, Gamma, ...





Device Model



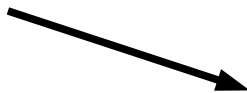
Device Model

Frame Buffer

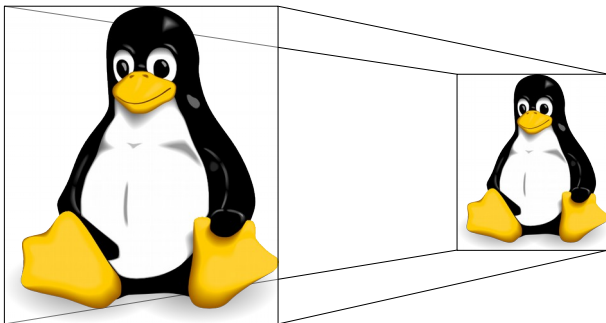


KMS – Scanout

CRTC



Plane(s)

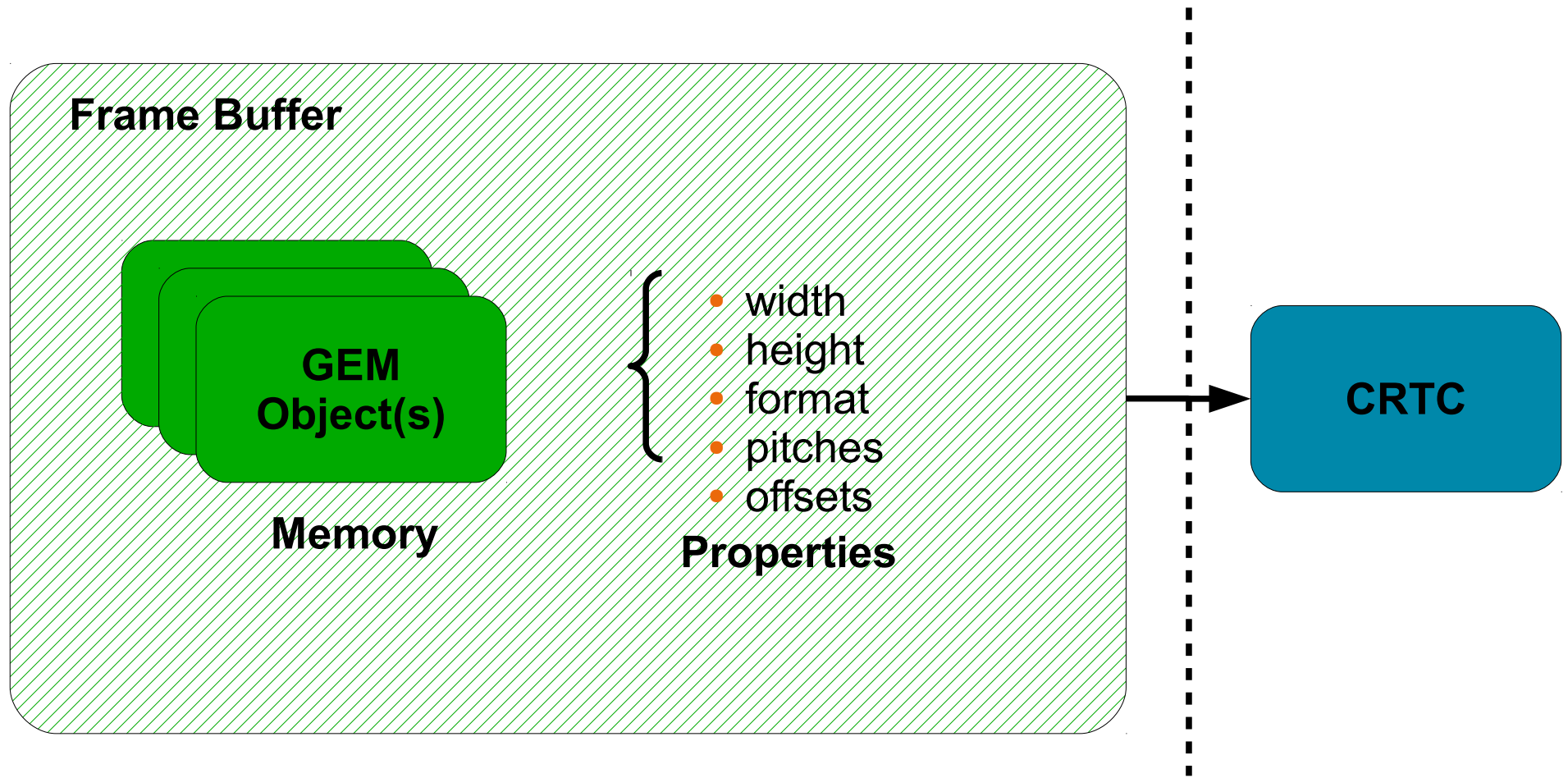


Composition

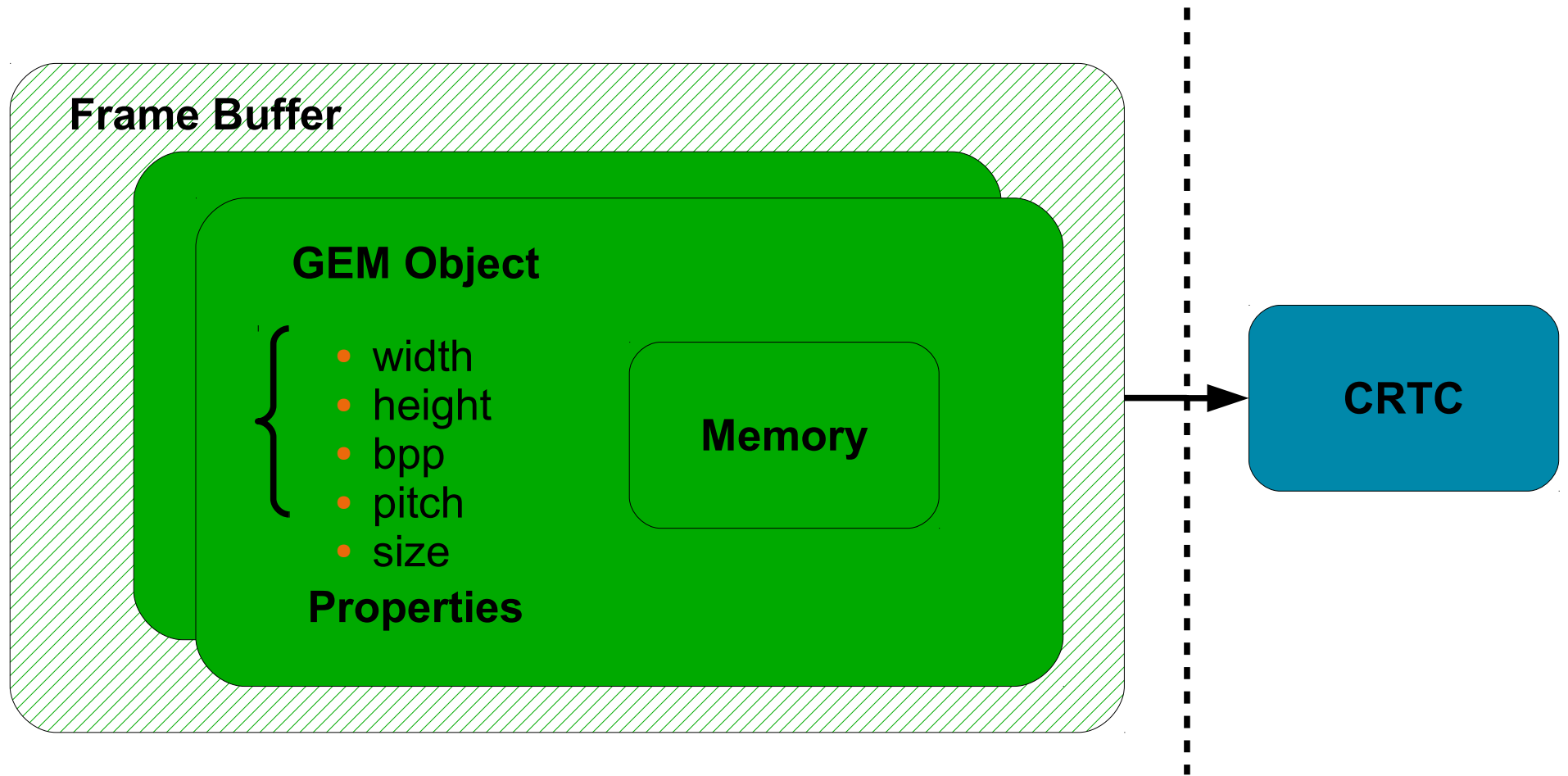


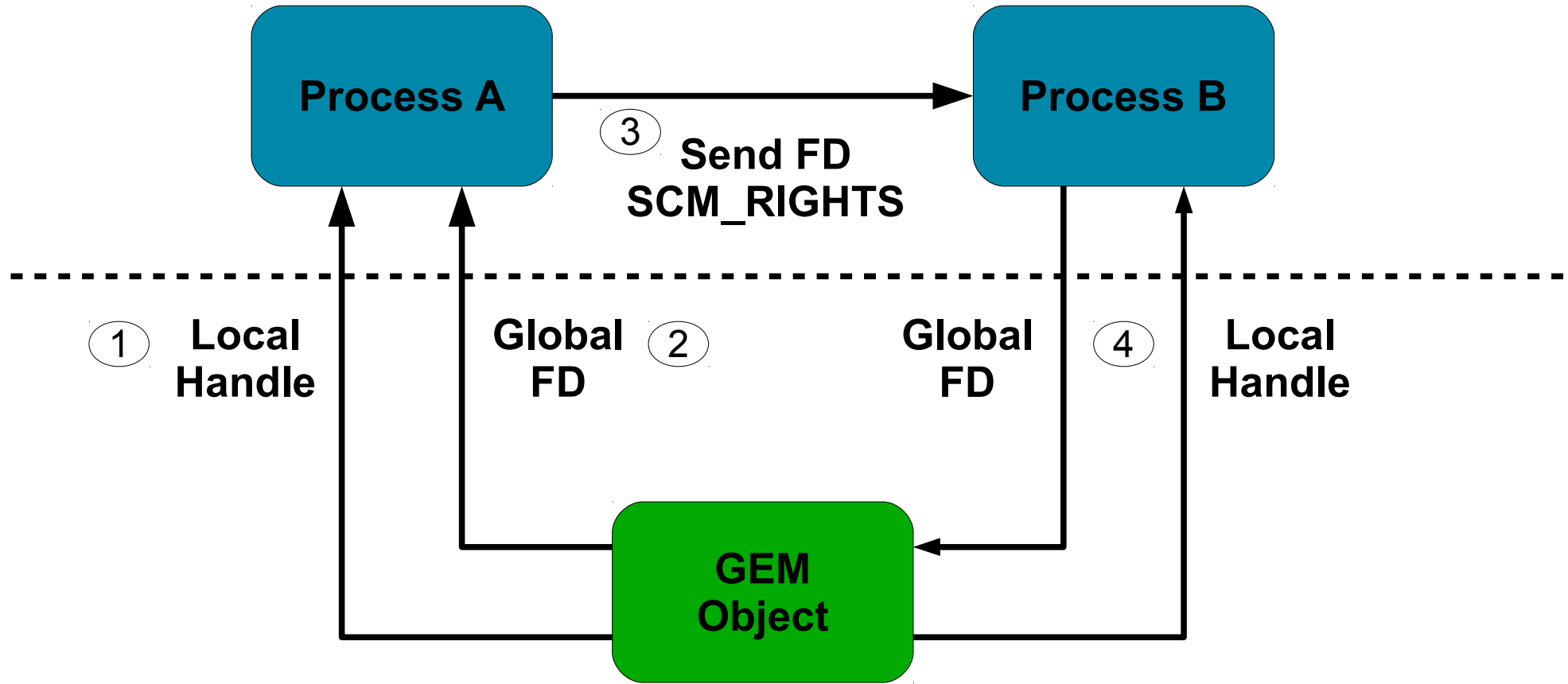
KMS – Composition

**IDEAS
ON BOARD**

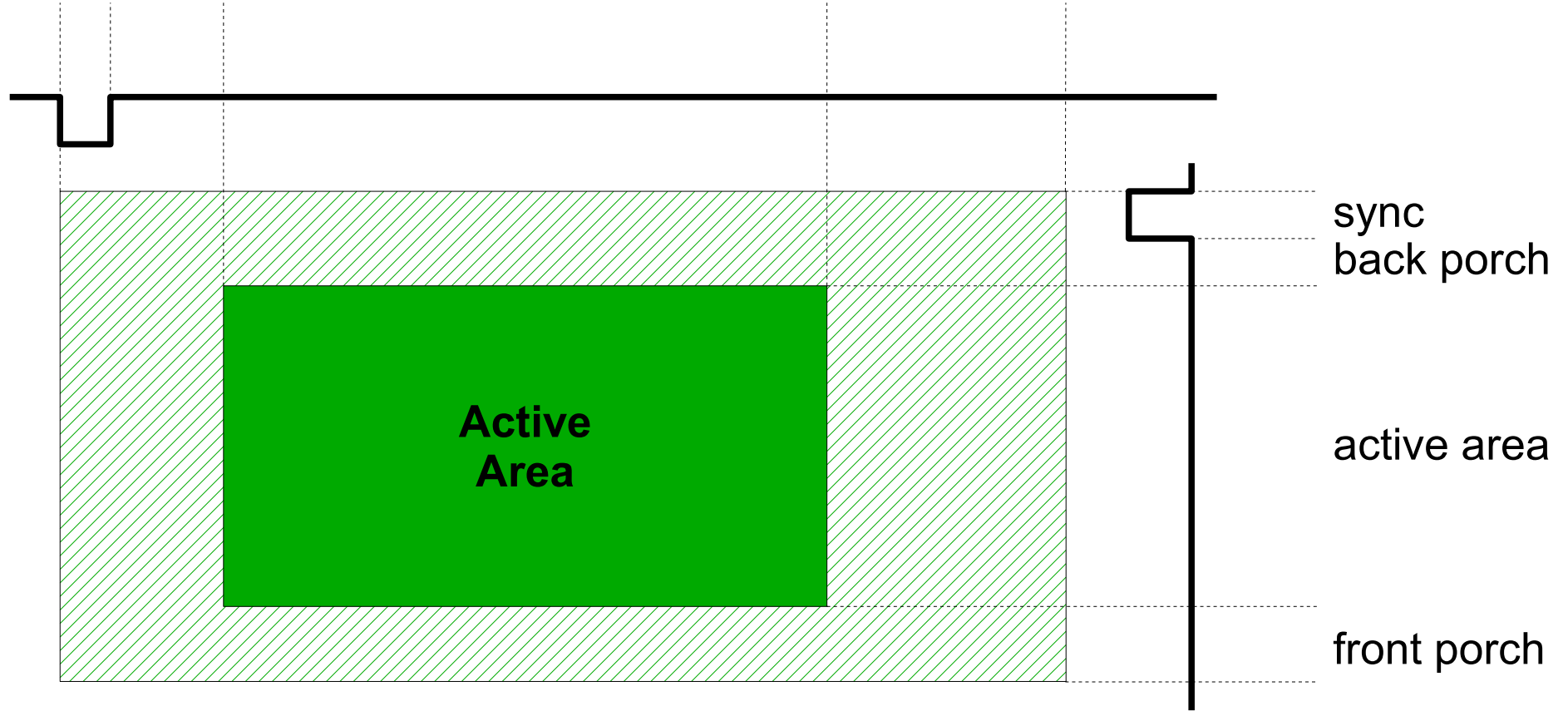


KMS – Frame Buffer

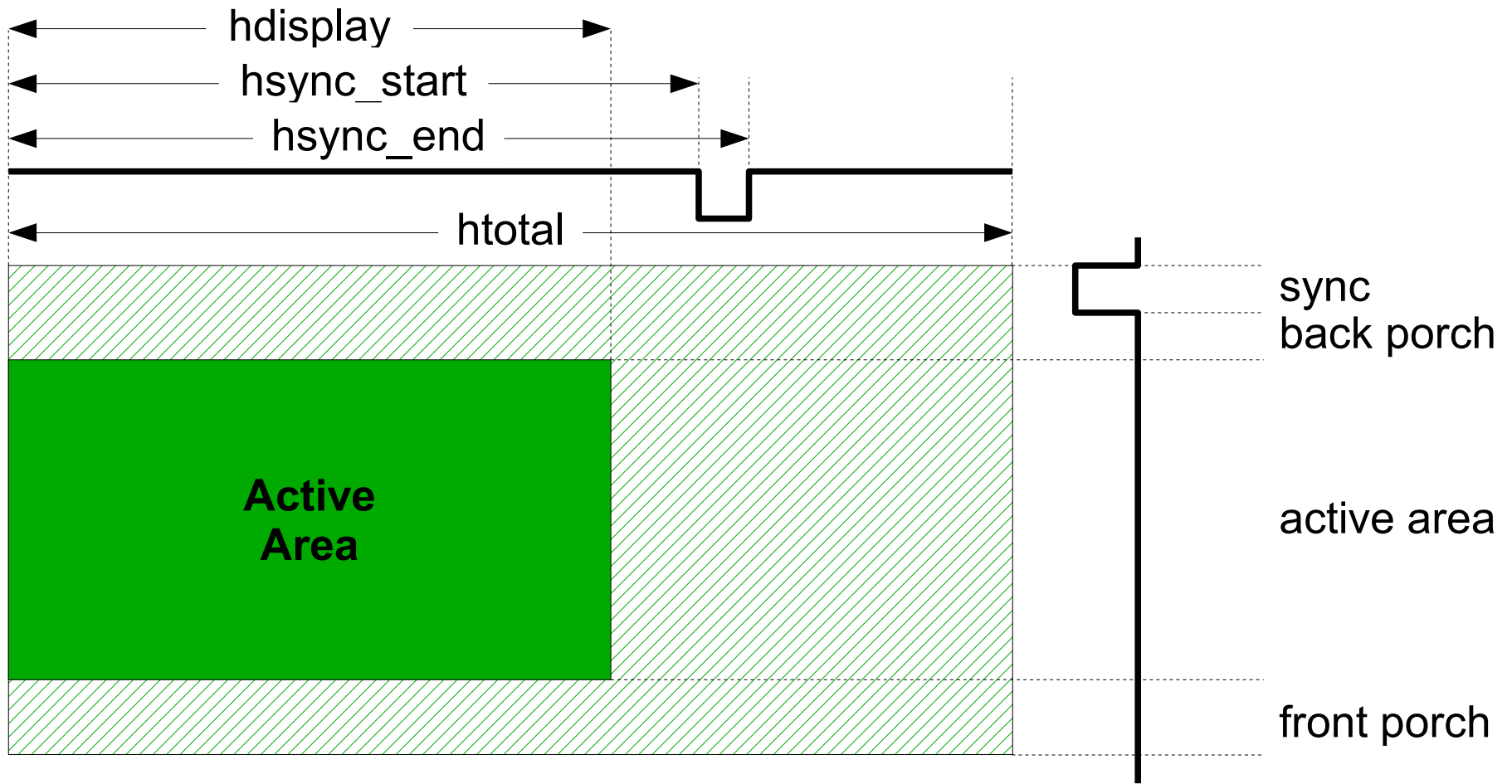




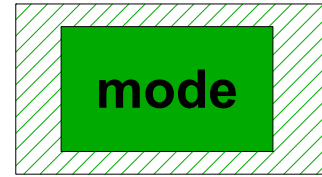
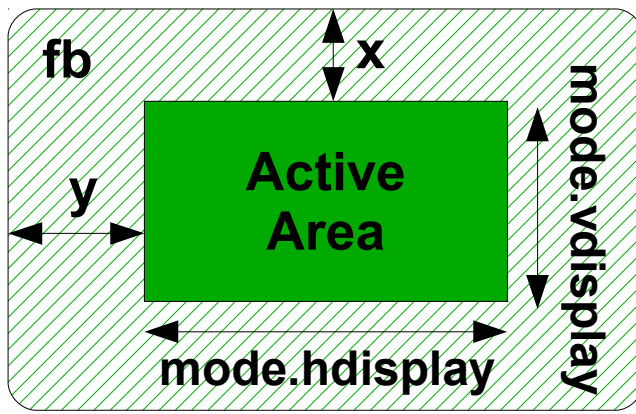
DRM – Handles



KMS – Modes (1/2)



KMS – Modes (2/2)

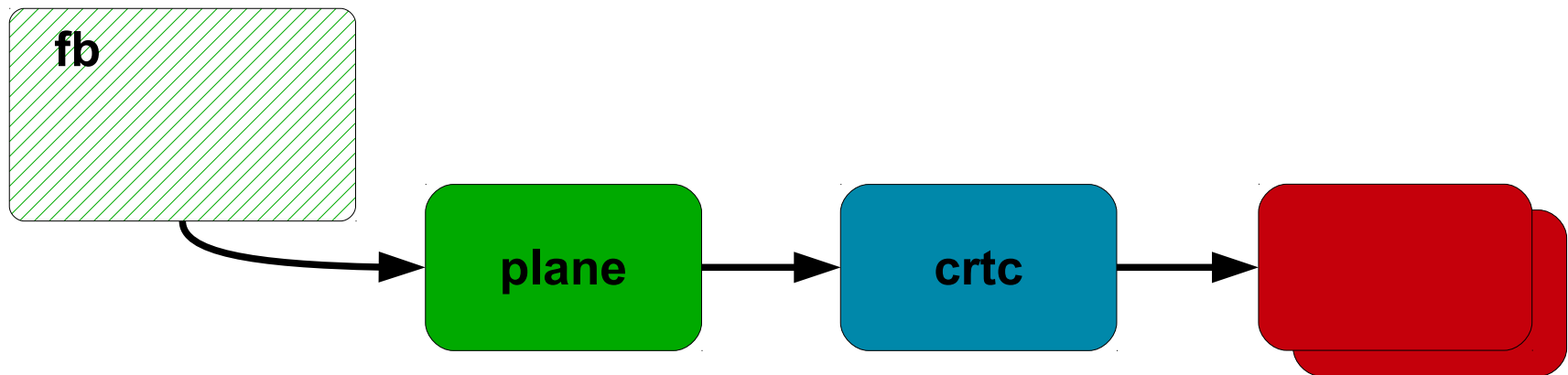


```
struct drm_mode_set {  
    struct drm_framebuffer *fb;  
    struct drm_crtc *crtc;  
    struct drm_display_mode *mode;  
    uint32_t x;  
    uint32_t y;  
    struct drm_connector **connectors;  
    size_t num_connectors;  
};
```

***connectors**
num_connectors

KMS – Mode Setting

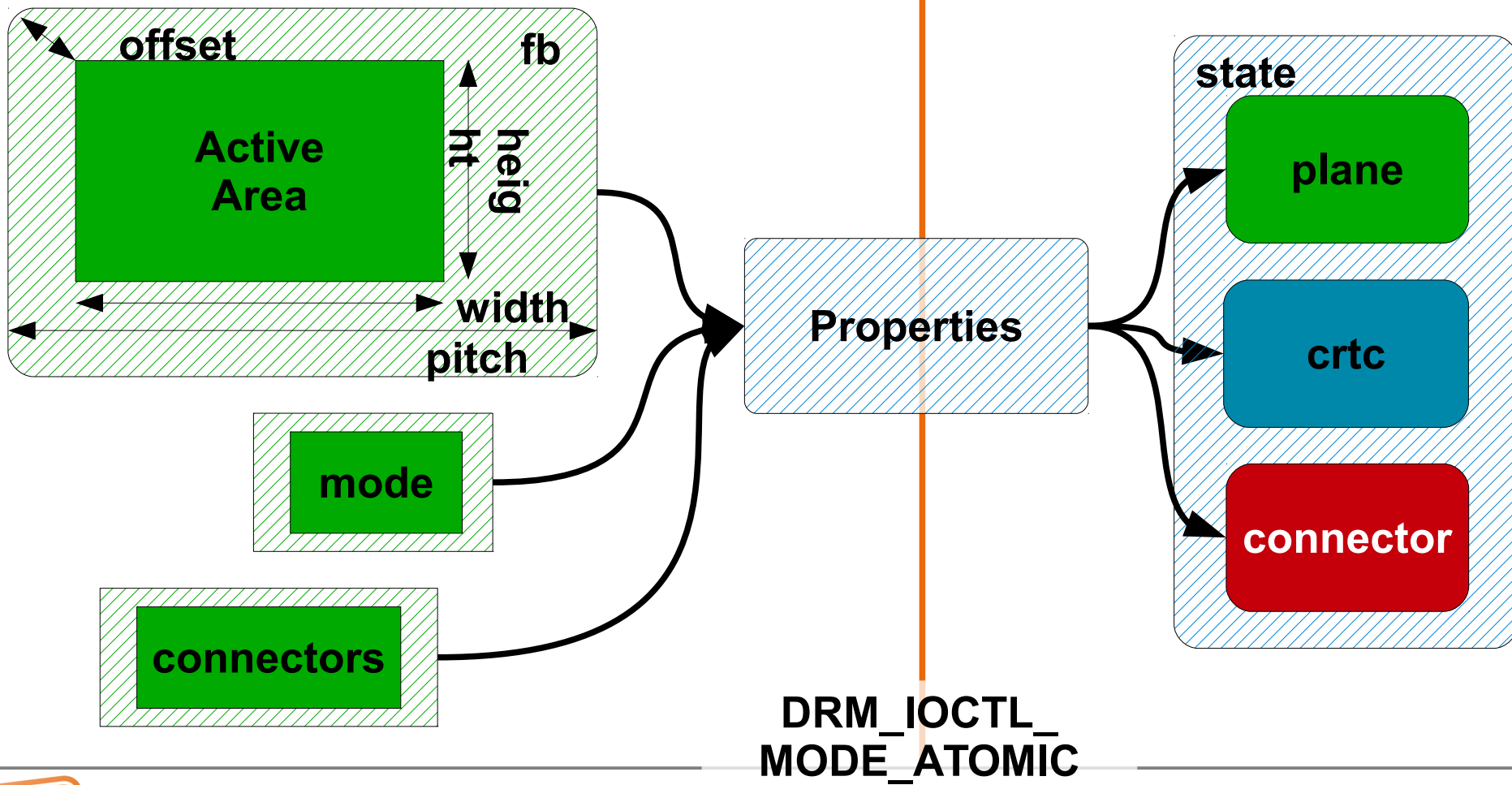




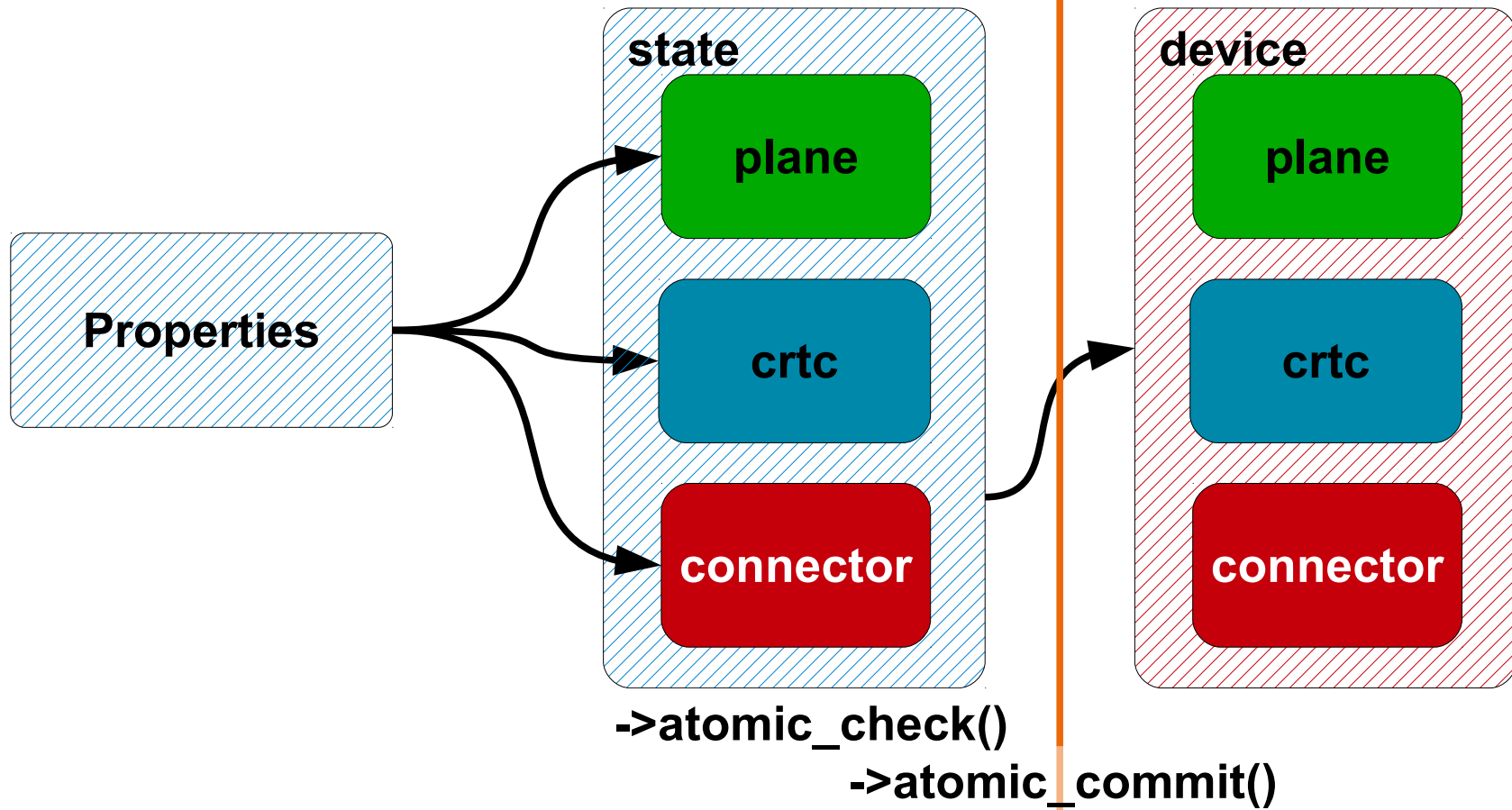
```
struct drm_mode_crtc_page_flip {  
    __u32 crtc_id;  
    __u32 fb_id;  
    __u32 flags;  
    __u32 reserved;  
    __u64 user_data;  
};
```



KMS – Page Flipping



KMS – Atomic Update



KMS – Atomic Update

```
struct drm_mode_atomic {  
    __u32 flags;  
    __u32 count_objs;  
    __u64 objs_ptr;  
    __u64 count_props_ptr;  
    __u64 props_ptr;  
    __u64 prop_values_ptr;  
    __u64 reserved;  
    __u64 user_data;  
};
```

```
#define DRM_MODE_PAGE_FLIP_EVENT      0x01  
#define DRM_MODE_PAGE_FLIP_ASYNC     0x02  
#define DRM_MODE_ATOMIC_TEST_ONLY    0x0100  
#define DRM_MODE_ATOMIC_NONBLOCK     0x0200  
#define DRM_MODE_ATOMIC_ALLOW_MODESET 0x0400
```



KMS – Atomic Update

**kerneldoc
drivers/gpu/drm/***

**Documentation/
DocBook/drm.tmpl**

Please contribute

Documentation



Code Ahead

Locking and error handling
omitted for readability



Disclaimer

drm_* = core
(rcar_du_)* = driver



Initialization & Cleanup

Frame Buffer & Memory

Mode Discovery

State Management

Atomic Update

Vertical Blanking



Atomic KMS Driver Anatomy

```
struct drm_driver rcar_du_driver = {  
    ...  
};  
  
int rcar_du_probe(struct platform_device *pdev)  
{  
    struct drm_device *dev;  
  
    ...  
    dev = drm_dev_alloc(&rcar_du_driver,  
                        &pdev->dev);  
    ...  
}
```



Device Probe (1/2)

```
int rcar_du_probe(struct platform_device *pdev)
{
    struct rcar_du_device *rcdu;
    struct drm_device *dev;

    ...
    rcdu = kzalloc(sizeof(*rcdu), GFP_KERNEL);
    dev->dev_private = rcdu;

    /* Memory, clocks, regulators, ... */
    ...

    drm_dev_register(dev, 0);
    ...
}
```



Device Probe (2/2)


```
int rcar_du_remove(struct platform_device *pdev)
{
    struct rcar_du_device *rcdu =
        platform_get_drvdata(pdev);
    struct drm_device *dev = rcdu->ddev;

    drm_dev_unregister(dev);

    ...

    drm_dev_unref(dev);

    return 0;
}
```



Device Removal

```
struct drm_driver rcar_du_driver = {  
    .driver_features = DRIVER_HAVE_IRQ |  
        DRIVER_GEM | DRIVER_MODESET |  
        DRIVER_PRIME | DRIVER_ATOMIC,  
    .name  = "rcar-du",  
    .desc  = "Renesas R-Car Display Unit",  
    .date  = "20130110",  
    .major = 1,  
    .minor = 0,  
    .patchlevel = 0,  
    ...  
};
```



Driver Information

```
struct file_operations rcar_du_fops = {  
    .owner          = THIS_MODULE,  
    .open           = drm_open,  
    .release        = drm_release,  
    .unlocked_ioctl = drm_ioctl,  
    .compat_ioctl   = drm_compat_ioctl,  
    .poll           = drm_poll,  
    .read           = drm_read,  
    .fasync         = drm_fasync,  
    .llseek         = no_llseek,  
    .mmap           = ...,  
};  
  
struct drm_driver rcar_du_driver = {  
    .fops           = &rcar_du_fops,  
};
```



File Operations

```
int rcar_du_probe(struct platform_device *pdev)
{
    ...
    drm_irq_install(dev);
    /* Behind the scene:
     * request_irq(platform_get_irq(..., 0))
     */
    ...
}

struct drm_driver rcar_du_driver = {
    /* .irq_preinstall */
    .irq_handler = rcar_du_irq,
    /* .irq_postinstall */
};
```



IRQ Installation

```
struct drm_mode_config_funcs modecfg_funcs = {
    .fb_create = ...,
};

int rcar_du_probe(struct platform_device *pdev)
{
    ...
    drm_mode_config_init(dev);

    dev->mode_config.min_width = 0;
    dev->mode_config.min_height = 0;
    dev->mode_config.max_width = 4095;
    dev->mode_config.max_height = 2047;
    dev->mode_config.funcs =
        &rcar_du_modecfg_funcs;
    ...
}
```

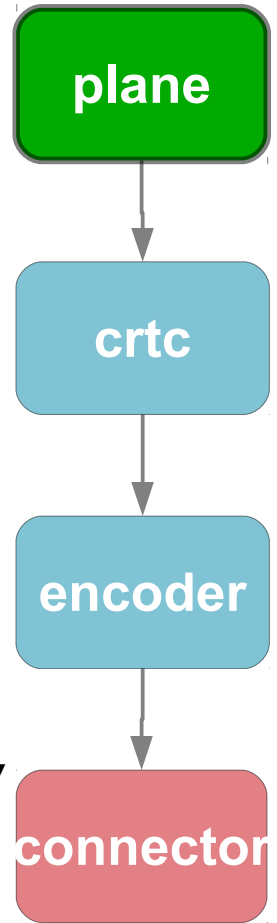


Mode Config

```
struct drm_plane_funcs plane_funcs = {
    .destroy = drm_plane_cleanup,
};

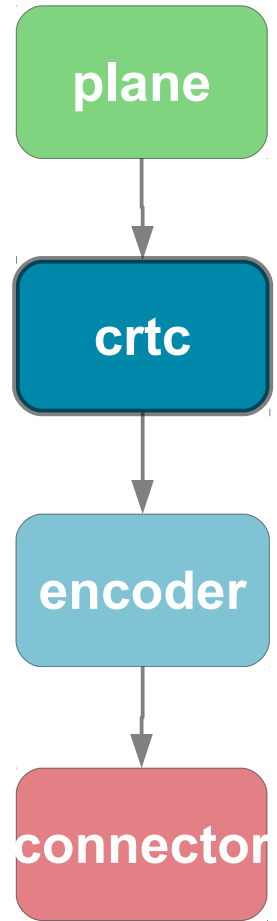
uint32_t formats[] = {
    DRM_FORMAT_RGB565, ...
};

int rcar_du_probe(struct platform_device *pdev)
{
    struct drm_plane *plane = ...;
    ...
    drm_universal_plane_init(dev, plane, crtcs,
                            &plane_funcs, formats, ARRAY_SIZE(formats),
                            DRM_PLANE_TYPE_PRIMARY);
    /* DRM_PLANE_TYPE_OVERLAY */
}
```



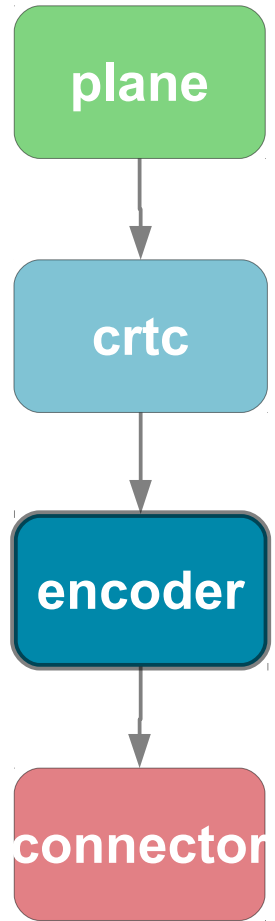
Initialization – Plane

```
struct drm_crtc_funcs crtc_funcs = {  
    .destroy = drm_crtc_cleanup,  
    ...  
};  
  
int rcar_du_probe(struct platform_device *pdev)  
{  
    struct drm_device *dev;  
    struct drm_crtc *crtc;  
    ...  
    drm_crtc_init(dev, crtc, &crtc_funcs);  
    ...  
}
```



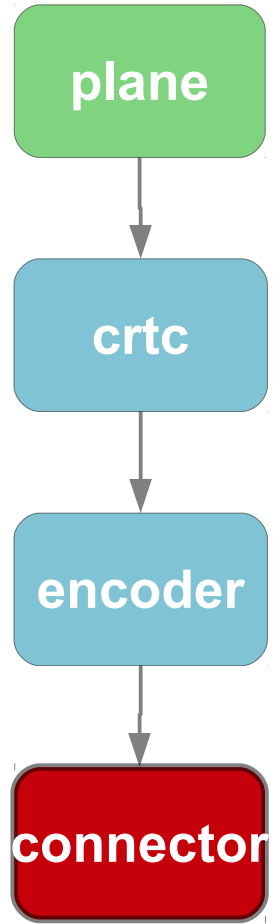
Initialization – CRTC

```
struct drm_encoder_funcs encoder_funcs = {  
    .destroy = drm_encoder_cleanup,  
};  
  
int rcar_du_probe(struct platform_device *pdev)  
{  
    struct drm_device *dev;  
    struct drm_encoder *encoder;  
    ...  
    encoder->possible_crtcs = 1 << crtc;  
    drm_encoder_init(dev, encoder, &encoder_funcs,  
                     DRM_MODE_ENCODER_DAC);  
    ...  
}
```



Initialization – Encoder


```
struct drm_connector_funcs connector_funcs = {  
    .destroy = drm_connector_cleanup,  
};  
  
int rcar_du_probe(struct platform_device *pdev)  
{  
    struct drm_device *dev;  
    struct drm_connector *connector;  
    ...  
    connector->display_info.width_mm = ...;  
    connector->display_info.height_mm = ...;  
  
    drm_connector_init(dev, connector,  
        &connector_funcs, DRM_MODE_CONNECTOR_VGA);  
    drm_connector_register(connector);  
    drm_mode_connector_attach_encoder(connector, encoder);  
}
```



Initialization – Connector

Initialization & Cleanup

Frame Buffer & Memory

Mode Discovery

State Management

Atomic Update

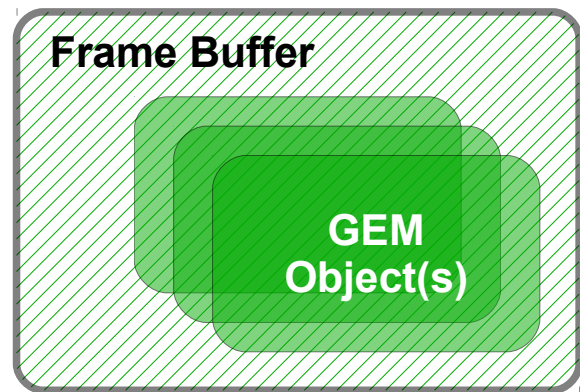
Vertical Blanking



Atomic KMS Driver Anatomy

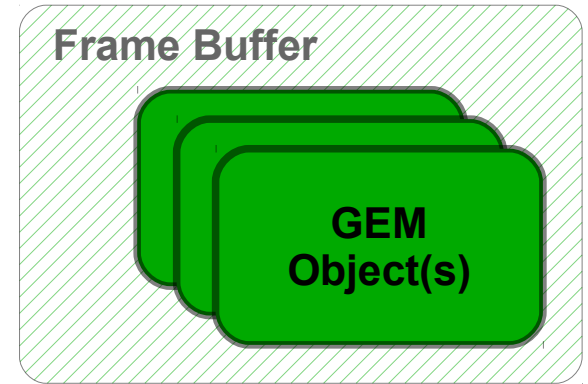
```
drm_framebuffer *
rcar_du_fb_create(struct drm_device *dev,
                  struct drm_file *file_priv,
                  struct drm_mode_fb_cmd2 *mode_cmd)
{
    /* Validate the pixel format, size and pitches */
    ...
    return drm_fb_cma_create(dev, file_priv,
                             mode_cmd);
}

struct drm_mode_config_funcs
rcar_du_modecfg_funcs = {
    .fb_create = rcar_du_fb_create,
};
```

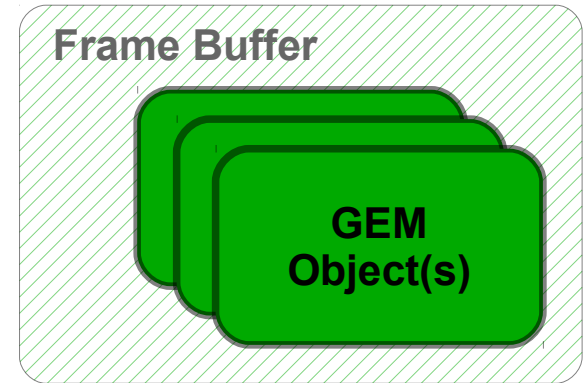


Frame Buffer

```
struct file_operations rcar_du_fops = {  
    .mmap                = drm_gem_cma_mmap,  
};  
  
struct drm_driver rcar_du_driver = {  
    .gem_free_object      = drm_gem_cma_free_object,  
    .gem_vm_ops           = &drm_gem_cma_vm_ops,  
};
```



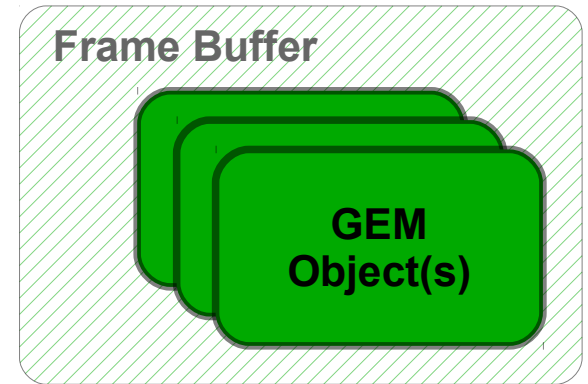
```
struct drm_driver rcar_du_driver = {  
    .dumb_create      = drm_gem_cma_dumb_create,  
    .dumb_map_offset  = drm_gem_cma_dumb_map_offset,  
    .dumb_destroy     = drm_gem_cma_dumb_destroy,  
};
```



GEM – Dumb Objects



```
struct drm_driver rcar_du_driver = {  
    .prime_handle_to_fd = drm_gem_prime_handle_to_fd,  
    .prime_fd_to_handle = drm_gem_prime_fd_to_handle,  
    .gem_prime_import    = drm_gem_cma_dmabuf_import,  
    .gem_prime_export    = drm_gem_cma_dmabuf_export,  
};
```



GEM – PRIME



Initialization & Cleanup
Frame Buffer & Memory

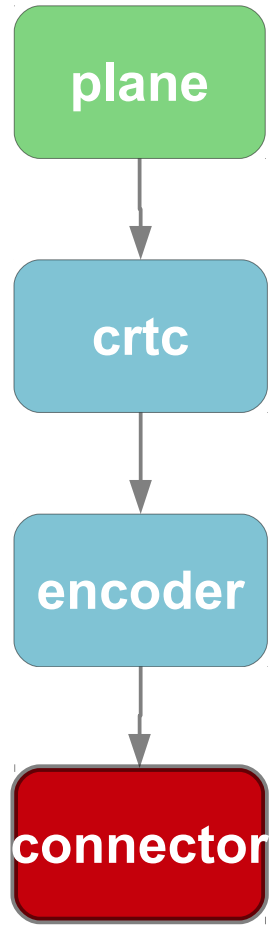
Mode Discovery

State Management
Atomic Update
Vertical Blanking



Atomic KMS Driver Anatomy

```
struct drm_connector_funcs connector_funcs = {  
    .fill_modes = ...,  
};  
  
int (*fill_modes)(struct drm_connector *connector,  
    uint32_t max_width, uint32_t max_height);
```



Modes Discovery (1/2)


```
struct drm_connector_funcs connector_funcs = {  
    .fill_modes = drm_helper_probe_single_connector_modes,  
};
```

Core

```
struct drm_connector_helper_funcs connector_helper_funcs = {  
    .get_modes = rcar_du_vga_connector_get_modes,  
    .mode_valid = rcar_du_vga_connector_mode_valid,  
};
```

Helpers



Modes Discovery (2/2)

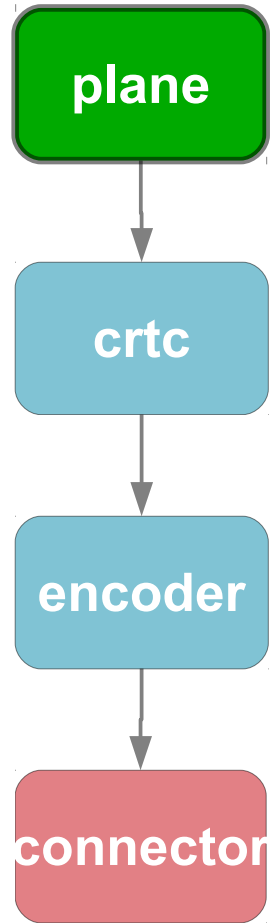
Initialization & Cleanup
Frame Buffer & Memory
Mode Discovery
State Management
Atomic Update
Vertical Blanking



Atomic KMS Driver Anatomy

```
struct drm_plane_funcs plane_funcs = {  
    .reset = rcar_du_plane_reset,  
    .atomic_duplicate_state =  
        rcar_du_plane_atomic_duplicate_state,  
    .atomic_destroy_state =  
        rcar_du_plane_atomic_destroy_state,  
};
```

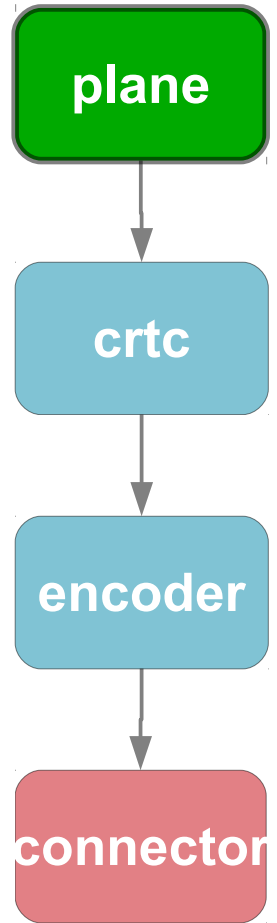
```
struct drm_plane_state {  
    struct drm_plane *plane;  
    struct drm_crtc *crtc;  
    struct drm_framebuffer *fb;  
  
    int32_t crtc_x, crtc_y;  
    uint32_t crtc_w, crtc_h;  
    ...  
};
```



State – Plane (1/5)



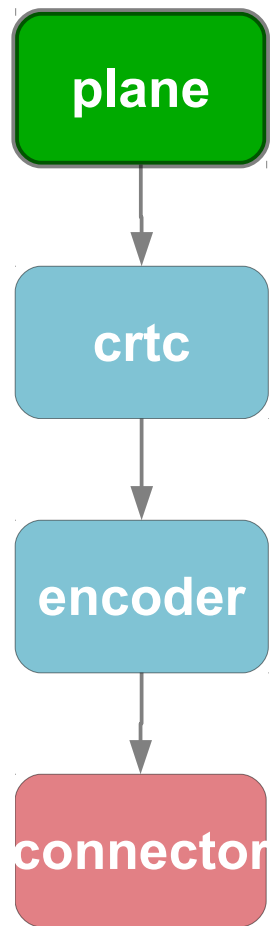
```
struct rcar_du_plane_state {  
    struct drm_plane_state state;  
  
    const struct rcar_du_format_info *format;  
    int hwindex;  
  
    unsigned int alpha;  
    unsigned int colorkey;  
    unsigned int zpos;  
};
```



```
void rcar_du_plane_reset(struct drm_plane *plane)
{
    struct rcar_du_plane_state *state;

    if (plane->state) {
        rcar_du_plane_atomic_destroy_state(
            plane, plane->state);
        plane->state = NULL;
    }

    state = kzalloc(sizeof(*state), GFP_KERNEL);
    state->alpha = 255;
    state->colorkey = RCAR_DU_COLORKEY_NONE;
    ...
    plane->state = &state->state;
    plane->state->plane = plane;
}
```



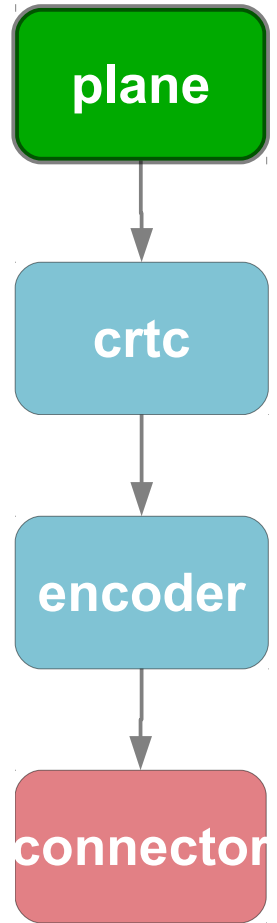
State – Plane (3/5)

```
struct drm_plane_state *
rcar_du_plane_atomic_duplicate_state(
    struct drm_plane *plane)
{
    struct rcar_du_plane_state *state;
    struct rcar_du_plane_state *copy;

    state = to_rcar_plane_state(plane->state);
    copy = kmemdup(state, sizeof(*state),
                   GFP_KERNEL);

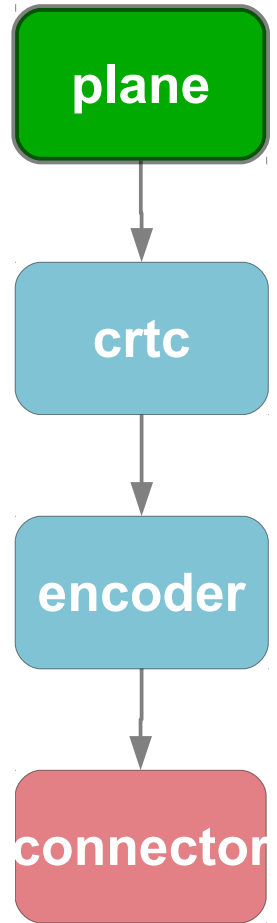
    __drm_atomic_helper_plane_duplicate_state(
        plane, &copy->state);

    return &copy->state;
}
```



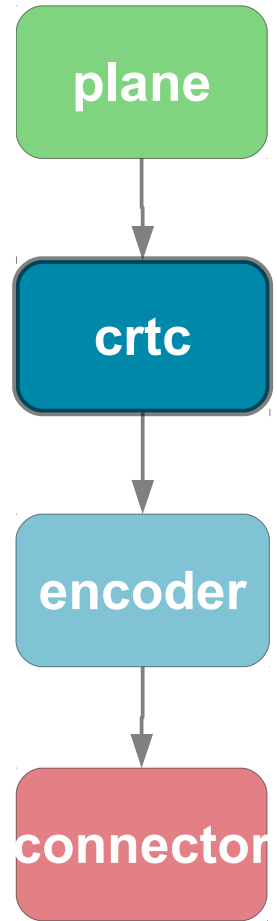
State – Plane (4/5)

```
void rcar_du_plane_atomic_destroy_state(  
    struct drm_plane *plane,  
    struct drm_plane_state *state)  
{  
    __drm_atomic_helper_plane_destroy_state(  
        plane, state);  
    kfree(to_rcar_plane_state(state));  
}
```



State – Plane (5/5)

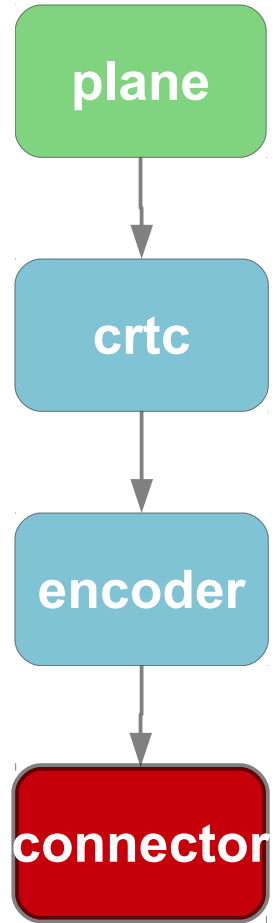
```
struct drm_crtc_funcs crtc_funcs = {  
    .reset = drm_atomic_helper_crtc_reset,  
    .atomic_duplicate_state =  
        drm_atomic_helper_crtc_duplicate_state,  
    .atomic_destroy_state =  
        drm_atomic_helper_crtc_destroy_state,  
};  
  
struct drm_crtc_state {  
    struct drm_crtc *crtc;  
  
    bool enable;  
  
    bool planes_changed : 1;  
    bool mode_changed : 1;  
    ...  
};
```



State – CRTC




```
struct drm_connector_funcs connector_funcs = {  
    .reset = drm_atomic_helper_connector_reset,  
    .atomic_duplicate_state =  
        drm_atomic_helper_connector_duplicate_state,  
    .atomic_destroy_state =  
        drm_atomic_helper_connector_destroy_state,  
};  
  
struct drm_connector_state {  
    struct drm_connector *connector;  
  
    struct drm_crtc *crtc;  
  
    struct drm_encoder *best_encoder;  
  
    struct drm_atomic_state *state;  
};
```



State – Connector



```
int drm_atomic_set_crtc_for_plane(
    struct drm_plane_state *plane_state,
    struct drm_crtc *crtc);

void drm_atomic_set_fb_for_plane(
    struct drm_plane_state *plane_state,
    struct drm_framebuffer *fb);

int drm_atomic_set_crtc_for_connector(
    struct drm_connector_state *conn_state,
    struct drm_crtc *crtc);

...
```



State Manipulation

Initialization & Cleanup
Frame Buffer & Memory
Mode Discovery
State Management
Atomic Update
Vertical Blanking



Atomic KMS Driver Anatomy

```
struct drm_mode_config_funcs mode_config_funcs = {  
    .atomic_check = ...,  
    .atomic_commit = ...,  
};  
  
int (*atomic_check)(struct drm_device *dev,  
                    struct drm_atomic_state *a);  
int (*atomic_commit)(struct drm_device *dev,  
                     struct drm_atomic_state *a,  
                     bool async);
```



Atomic Update – KMS (1/2)

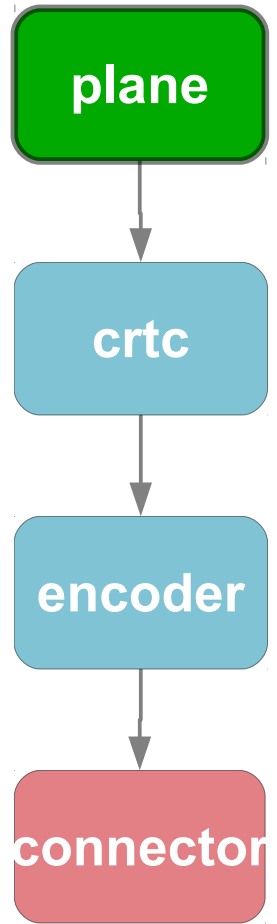
```
struct drm_mode_config_funcs mode_config_funcs = {  
    .atomic_check = drm_atomic_helper_check,  
    .atomic_commit = drm_atomic_helper_commit,  
};
```

```
int rcar_du_load(struct drm_device *dev,  
                unsigned long flags)  
{  
    ...  
    drm_crtc_helper_add(crtc, &crtc_helper_funcs);  
    drm_connector_helper_add(connector,  
                             &connector_helper_funcs);  
    drm_encoder_helper_add(encoder,  
                           &encoder_helper_funcs);  
    ...  
}
```



Atomic Update – KMS (2/2)

```
struct drm_plane_helper_funcs plane_helper_funcs = {  
    .prepare_fb = ...,  
    .cleanup_fb = ...,  
};  
  
int (*prepare_fb)(struct drm_plane *plane,  
                  struct drm_framebuffer *fb,  
                  const struct drm_plane_state *new_state);  
void (*cleanup_fb)(struct drm_plane *plane,  
                   struct drm_framebuffer *fb,  
                   const struct drm_plane_state *old_state);
```

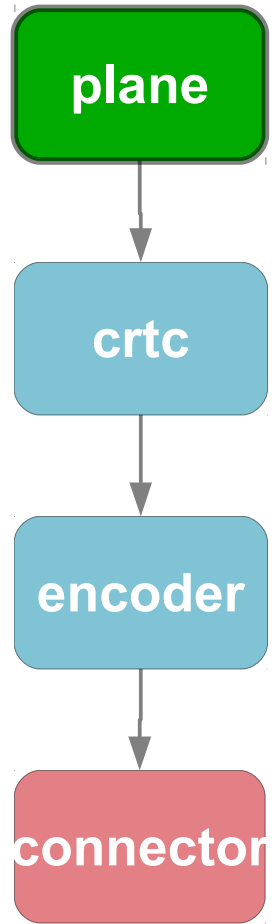


Atomic Update – Plane (1/2)

```
struct drm_plane_helper_funcs plane_helper_funcs = {  
    .atomic_check = rcar_du_plane_atomic_check,  
    .atomic_update = rcar_du_plane_atomic_update,  
    /* .atomic_disable = ..., */  
};
```

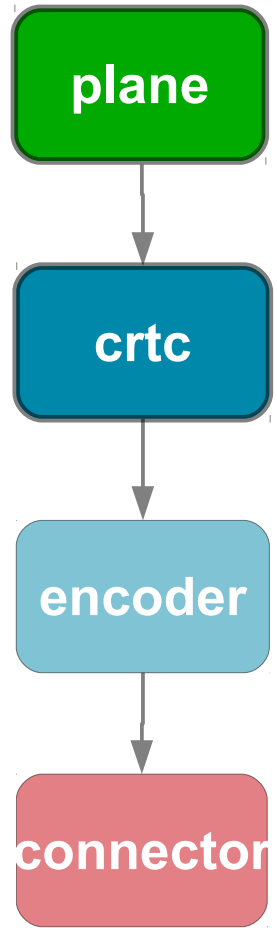
```
int rcar_du_plane_atomic_check(  
    struct drm_plane *plane,  
    struct drm_plane_state *state)  
{ ... }
```

```
void rcar_du_plane_atomic_update(  
    struct drm_plane *plane,  
    struct drm_plane_state *old_state)  
{ ... }
```



Atomic Update – Plane (2/2)

```
struct drm_crtc_helper_funcs crtc_helper_funcs = {  
    .atomic_begin = rcar_du_crtc_atomic_begin,  
    .atomic_flush = rcar_du_crtc_atomic_flush,  
};  
  
void rcar_du_crtc_atomic_begin(struct drm_crtc *crtc,  
                               struct drm_crtc_state *old_crtc_state)  
{  
    /* Enable vblank processing */  
    drm_crtc_vblank_get(crtc);  
}  
  
void rcar_du_crtc_atomic_flush(struct drm_crtc *crtc,  
                               struct drm_crtc_state *old_crtc_state)  
{  
    /* Set the GO bit */  
}
```



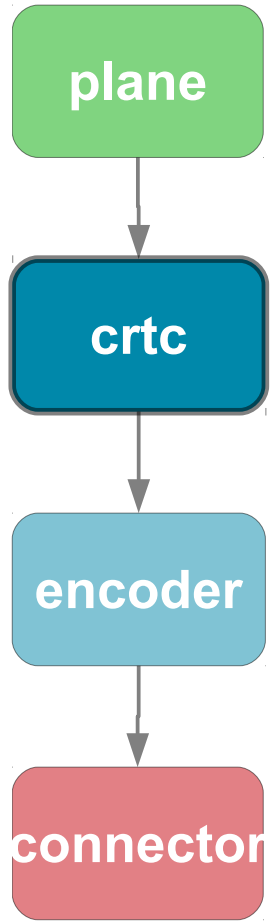
Atomic Update – CRTC + Plane


```
struct drm_crtc_helper_funcs crtc_helper_funcs = {
    .mode_fixup = rcar_du_crtc_mode_fixup,
    /* .mode_set_nofb = ..., */
    .disable = rcar_du_crtc_disable,
    .enable = rcar_du_crtc_enable,
};

bool rcar_du_crtc_mode_fixup(struct drm_crtc *crtc,
                             const struct drm_display_mode *mode,
                             struct drm_display_mode *adjusted_mode)
{
    ...
}

void rcar_du_crtc_disable(struct drm_crtc *crtc)
{
    ...
}

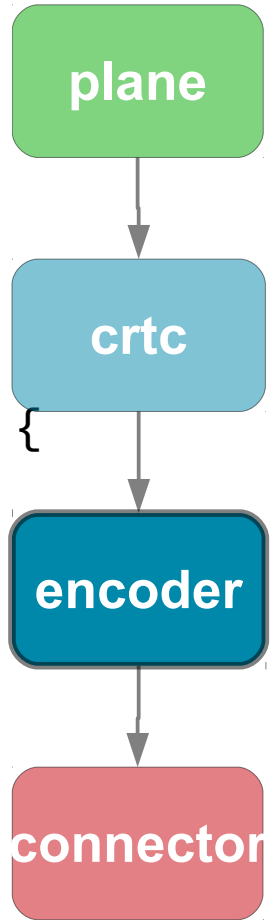
void rcar_du_crtc_enable(struct drm_crtc *crtc)
{
    ...
}
```



Atomic Update – CRTC

```
struct drm_encoder_helper_funcs encoder_helper_funcs = {  
    .mode_set = rcar_du_encoder_mode_set,  
    .disable = rcar_du_encoder_disable,  
    .enable = rcar_du_encoder_enable,  
    .atomic_check = rcar_du_encoder_atomic_check,  
};
```

```
struct drm_connector_helper_funcs connector_helper_funcs = {  
    .atomic_best_encoder =  
        rcar_du_connector_best_encoder,  
    /* .best_encoder still used for FBDEV emulation */  
};
```



Atomic Update – Encoder

Initialization & Cleanup
Frame Buffer & Memory
Mode Discovery
State Management
Atomic Update
Vertical Blanking



Atomic KMS Driver Anatomy

```
int rcar_du_probe(struct platform_device *pdev)
{
    ...
    drm_vblank_init(dev, 1);
    ...
}

irqreturn_t rcar_du_irq(int irq, void *arg)
{
    struct drm_device *dev = arg;

    drm_handle_vblank(dev, 0);
}
```



Vertical Blanking (1/4)

```
int rcar_du_enable_vblank(struct drm_device *dev,
                          int crtc)
{
    /* Enable the vblank interrupt for the CRTC */
}

void rcar_du_disable_vblank(struct drm_device *dev,
                             int crtc)
{
    /* Disable the vblank interrupt for the CRTC */
}

struct drm_driver rcar_du_driver = {
    .get_vblank_counter = drm_vblank_count,
    .enable_vblank      = rcar_du_enable_vblank,
    .disable_vblank     = rcar_du_disable_vblank,
};
```



Vertical Blanking (2/4)

```
irqreturn_t rcar_du_crtc_irq(int irq, void *arg)
{
    struct rcar_du_crtc *rcrtc = arg;
    ...

    drm_handle_vblank(rcrtc->crtc.dev, rcrtc->index);
    rcar_du_crtc_finish_page_flip(rcrtc);

    return IRQ_HANDLED;
}
```



Vertical Blanking (3/4)

```
void rcar_du_crtc_finish_page_flip(struct rcar_du_crtc *rcrtc)
{
    struct drm_pending_vblank_event *event;
    ...
    spin_lock_irqsave(&dev->event_lock, flags);
    event = rcrtc->event;
    rcrtc->event = NULL;
    spin_unlock_irqrestore(&dev->event_lock, flags);

    if (event == NULL)
        return;

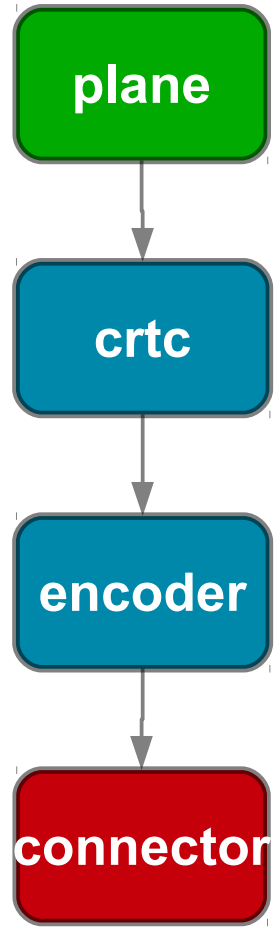
    spin_lock_irqsave(&dev->event_lock, flags);
    drm_send_vblank_event(dev, rcrtc->index, event);
    wake_up(&rcrtc->flip_wait);
    spin_unlock_irqrestore(&dev->event_lock, flags);

    drm_crtc_vblank_put(&rcrtc->crtc);
}
```



Vertical Blanking (4/4)

```
struct drm_crtc_funcs crtc_funcs = {  
    .set_config = drm_atomic_helper_set_config,  
    .page_flip = drm_atomic_helper_page_flip,  
};  
  
struct drm_connector_funcs connector_funcs = {  
    .dpms = drm_atomic_helper_connector_dpms,  
};
```



Legacy

- properties
- connector status poll
- FBDEV emulation
- ...



And Much More...



Source: <http://www.flickr.com/photos/buckarooobay/3721809183/>

- suspend/resume helpers
- atomic fbdev
- active only plane update
- better runtime PM support



Ongoing Work

- vblank rework
- bridge vs. slave encoder
- write back
- live sources
- fences
- validation
- fastboot
- generic async commit



Future Work

- Conversion HOWTO for legacy drivers
<http://blog.ffwll.ch/2014/11/atomic-modeset-support-for-kms-drivers.html>
- Atomic mode setting design overview (LWN)
<https://lwn.net/Articles/653071/>
<https://lwn.net/Articles/653466/>
- DRM DocBook
<https://01.org/linuxgraphics/gfx-docs/drm/>



Resources

- 
- dri-devel@lists.freedesktop.org
 - laurent.pinchart@ideasonboard.com

?

!

thx.

