A Current Overview of the DRM KMS Driver-Side APIs

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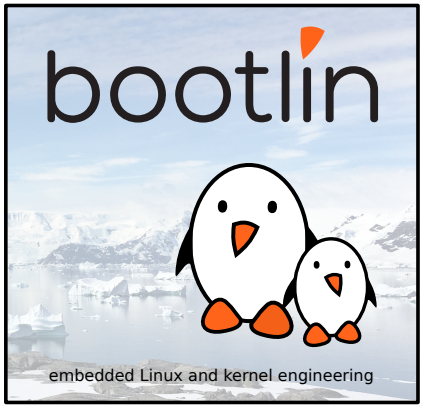

Paul Kocialkowski

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  - **Development**, consulting and training
  - Strong open-source focus
- Open-source contributor
  - Contributor to the **cedrus** Allwinner Video Engine V4L2 driver
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  - Contributor to the **sun4i-drm** and **vc4** DRM drivers
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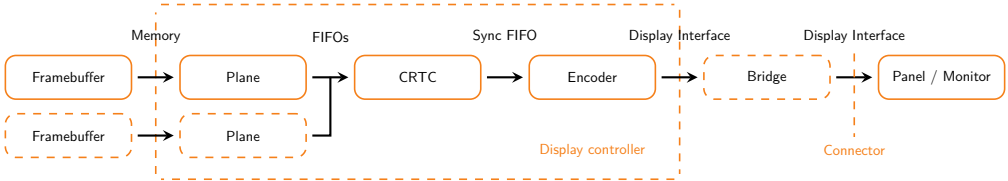
Introduction

Display Hardware Pipeline



- **Framebuffer**: Memory buffer(s) with pixel data
- **Plane**: Pixel mixing (rotation, scaling, format and more), layers
- **CRTC**: Timings generation and pixel streaming
- **Encoder**: Interface physical adaptation (protocol, signals)
- **Bridge**: Interface transcoding
- **Panel**: Display surface emitting/reflecting light
- **Monitor**: Peripheral integrating a panel

Display Hardware Overview

Typical hardware components:

- Display controller in (PCIe) graphics card (x86) or as unit in SoC (embedded)
- On-board and internal bridge(s)
- Display connector(s), always-connected panel(s)

Memory cases:

- Dedicated memory in graphics card (video RAM)
- Shared memory with the system
  - With IOMMU: general system pages, scatter-gather
  - Without IOMMU: reserved contiguous memory
- CPU access and cache management:
  - Automatic with cache-coherent interconnect
  - Manual cache invalidate/flush or cache disabled otherwise

Display Support in Linux and Userspace

Linux userspace APIs for display:

- **fbdev** interface: deprecated
  - Simple uAPI with pre-allocated memory
  - Very limited use-cases and configuration
  - Bad performance (no zero-copy)
  - No new drivers, will be removed eventually
- **DRM KMS**/**DRM mode** uAPI:
  - Proper pipeline configuration (planes, CRTC, connector)
  - Well-balanced abstraction of hardware complexity
  - DRM Atomic uAPI
  - DRM GEM/TTM memory management
  - DRM Prime for dma-buf zero-copy
  - DRM Sync Object for fences
  - Various drivers for graphics cards and embedded

Display Support in Linux and Userspace

Userspace software status:

- DRM KMS supported and used by most components
- fbdev still supported as fallback
- fbdev still used by quick-and-dirty projects (please stop)

Userspace software display support:

- **Display servers**: weston, sway, mutter, kwin, xorg
- **Graphics libraries**: SDL, Qt (eglfs), DirectFB2, LVGL, Mesa (GBM)
- **Media libraries**: GStreamer (kmssink), FFmpeg (kmsgrab), libcamera
- **Tools**: modetest, igt, kmscube, glmark2

DRM KMS Internals

DRM KMS Components Overview

Kernel hardware components:

- Drivers registered from bus infrastructure:
  - `pci` bus for graphics cards
  - `platform` bus for SoC units
  - `i2c`, `spi`, etc for bridges and panels
  - `platform` or `mipi_dsi` for panels
- Drivers register components to DRM KMS framework:
  - `struct drm_device`, for display controllers
  - `struct drm_bridge`, for bridges (internal or external)
  - `struct drm_panel`, for panels
- Drivers need to identify eachother:
  - Represent pipeline topology
  - Retrieve remote component structures for API use
  - Static description via device-tree graph with `port/endpoint` (or ACPI)
  - Node nesting for bus (DSI)

DRM KMS Components Integration (Device-Tree Example)

```
tcon0: lcd-controller@1c0c000 {
  compatible = "allwinner,sun50i-a64-tcon-lcd",
               "allwinner,sun8i-a83t-tcon-lcd";
  [...]

  ports {
    [...]

    tcon0_out: port@1 {
      reg = <1>;
      [...]

      tcon0_out_dsi: endpoint@1 {
        reg = <1>;
        remote-endpoint = <&dsi_in_tcon0>;
        allwinner,tcon-channel = <1>;
      };
    };
  };
};
```

```
dsi: dsi@1ca0000 {
  compatible = "allwinner,sun50i-a64-mipi-dsi";
  [...]

  port {
    dsi_in_tcon0: endpoint {
      remote-endpoint = <&tcon0_out_dsi>;
    };
  };

  panel@0 {
    compatible = "xingbangda,xbd599";
    reg = <0>;
    [...]
  };
};
```

DRM Display Controller: Base Driver

- Driver data static declaration: `struct drm_driver`,
  - `driver_features`: bitfield of `DRIVER_MODESET`, `DRIVER_ATOMIC`, `DRIVER_GEM`
  - `fops`: default definitions with `DEFINE_DRM_GEM_FOPS`,
  - `name`, `desc`, `date`/`major`/`minor` for information
  - Various operation callbacks, default definitions with `DRM_GEM_DMA_DRIVER_OPS`
- Device data: `struct drm_device`
  - Created by the DRM framework
  - Associated with character devices (`card`, `render`) for uAPI
- Setup at `probe()`:
  - Allocate `struct drm_device` from `struct drm_driver` with `drm_dev_alloc()`
    devm-managed with `devm_drm_dev_alloc()`, can allocate parent structure
  - Check if mode setting is allowed with `drm_firmware_drivers_only()`
    honor the `nomodeset` kernel command line parameter
  - Initialize display controller components
  - Register device with `drm_dev_register()`

DRM Display Controller: Base Driver

- Components registration typical order:
  - Planes with `struct drm_plane`
  - CRTC with `struct drm_crtc`, attach to planes
  - Encoder with `struct drm_encoder`, attach to CRTC
  - Connector with `struct drm_connector`, attach to encoder
- Cleanup at `remove()`:
  - Unregister with `drm_dev_unregister()`
  - Call shutdown helper `drm_atomic_helper_shutdown()` to stop CRTCs
  - Put reference (non-devm) with `drm_dev_put()`
- Power management at `suspend()`/`resume()`:
  - Pipeline configuration saved/disabled at suspend with: `drm_mode_config_helper_suspend()`
  - Pipeline configuration restored/enabled at resume with: `drm_mode_config_helper_resume()`

DRM Display Controller: Memory Management

- Translation Table Manager (TTM) memory manager:
  - Historic memory manager for DRM, big and complex
  - Supports both shared system memory and dedicated video memory, used by graphics card drivers
- Graphics Execution Manager (GEM) memory manager:
  - New design from Intel, focused on sharing code
  - Only supports shared system memory, used by most embedded drivers
  - Provides `struct drm_driver fops` and callbacks with `DEFINE_DRM_GEM_FOPS` and `DRM_GEM_DMA_DRIVER_OPS`
  - Supports driver-specific `dumb_create` operation with `DRM_GEM_DMA_DRIVER_OPS_WITH_DUMB_CREATE`
  - Allocates write-combined DMA buffers with `dma_alloc_wc()` contiguous or not depending on IOMMU presence, coherent
  - Also supports non-coherent (requires explicit sync)
  - Helper to get framebuffer DMA address: `drm_fb_dma_get_gem_addr()`

DRM Display Controller: Memory Management (CMA, Device-Tree)

- GEM can typically use the Contiguous Memory Allocator (CMA):
  - Meant for large contiguous buffer allocation
  - Uses reclaimable reserved pools of (DRAM) memory
  - Reserved early at boot with static size
- Default system pool available to every device:
  - Size configured with the `CONFIG_CMA_SIZE_MBYTES` option or with the `cma` kernel command line parameter
- Dedicated pool attached to specific devices:
  - Declared in device-tree with compatible `shared-dma-pool` under `reserved-memory` node
  - Attached to node in device-tree with `memory-region` property
  - Attached to `struct device` with `of_reserved_mem_device_init()`
  - Detached from `struct device` with `of_reserved_mem_device_release()`
  - DMA allocations with `struct device` then automatically use dedicated pool
  - Can be made default pool with `linux,cma-default;` in device-tree

DRM Display Controller: Memory Management (CMA, Device-Tree)

```
/ {
  [...]

  reserved-memory {
    #address-cells = <1>;
    #size-cells = <1>;
    ranges;

    gfx_memory: framebuffer {
      size = <0x01000000>;
      alignment = <0x01000000>;
      compatible = "shared-dma-pool";
      reusable;
    };
  };
};
```

```
gfx: display@1e6e6000 {
  compatible = "aspeed,ast2600-gfx", "syscon";
  [...]

  memory-region = <&gfx_memory>;
};
```

DRM Display Controller: Mode Config

- Mode config data: `struct drm_mode_config` from `struct drm_device`
  - `{min,max}_{width,height}`: framebuffer dimension limits
  - `preferred_depth`: default framebuffer pixel depth
  - `funcs`: driver-specific `struct drm_mode_config_funcs`
- Mode config functions: `struct drm_mode_config_funcs` (boilerplate)
  - `fb_create`: framebuffer creation with `drm_gem_fb_create()`
  - `atomic_check`: atomic commit validation with `drm_atomic_helper_check()`
  - `atomic_commit`: atomic commit entry point with `drm_atomic_helper_commit()`
- Setup at `probe()`:
  - Initialize mode config with `drmm_mode_config_init()`
    automatically calls `drm_mode_config_cleanup()` using `destroy` functions
  - Configure mode config data fields
  - Reset global pipeline state with `drm_mode_config_reset()` using `reset` functions
  - Register device with `drm_dev_register()`

DRM Display Controller: Atomic

- Atomic support:
  - Group batches of changes together as atomic commit
  - Provided by userspace as a list of property changes
  - Atomic state managed by the KMS framework
- Atomic state: `struct drm_atomic_state`
  - New/old configuration state for internal components
  - Derived to component-specific structures
  - Used to configure hardware registers
- Non-atomic is considered legacy and not covered here
  - Expected that new KMS drivers are atomic nowadays
  - Converting non-atomic drivers is welcome

DRM Display Controller: Planes

- Plane data: `struct drm_plane`
  - `type`: one of `DRM_PLANE_TYPE_PRIMARY`, `DRM_PLANE_TYPE_OVERLAY`, `DRM_PLANE_TYPE_CURSOR`
  - `possible_crtcs`: valid CRTCs with `drm_crtc_mask()`
  - `formats`: list of supported pixel formats
  - `modifiers`: list of supported pixel format modifiers (tiling, etc)
- Plane functions: `struct drm_plane_funcs` (boilerplate)
  - `reset`: plane state reset with `drm_atomic_helper_plane_reset()`
  - `destroy`: plane destruction with `drm_plane_cleanup()`
  - `atomic_{duplicate,destroy}_state`: plane state handling with `drm_atomic_helper_plane_duplicate_state()`, `drm_atomic_helper_plane_destroy_state()`
  - `{update,disable}_plane`: plane configuration with `drm_atomic_helper_update_plane()`, `drm_atomic_helper_disable_plane()`

DRM Display Controller: Planes

- Plane atomic state: `struct drm_plane_state`
  - New/old plane states available from `struct drm_atomic_state`: `drm_atomic_get_new_plane_state()`, `drm_atomic_get_old_plane_state()`
  - Associated CRTC: `struct drm_crtc`
  - Associated framebuffer: `struct drm_framebuffer`
  - Various base and optional properties
- Plane helper functions: `struct drm_plane_helper_funcs`
  - `atomic_check`: driver-specific atomic state validation
    can use `drm_atomic_helper_check_plane_state()` with scaling/position features
  - `atomic_update`: driver-specific plane configuration
    register configuration using plane (and crtc) atomic state
  - `atomic_disable`: driver-specific plane disable
- Setup at `probe()`:
  - Initialize and register `struct drm_plane` with `drm_universal_plane_init()`
  - Register plane helpers with `drm_plane_helper_add()`
  - Configure available plane properties

DRM Display Controller: Plane Properties

- Plane properties are exposed to userspace and used in configuration
- Base properties are registered with `drm_universal_plane_init()`
- Optional properties can be registered by driver:
  - Plane-wide alpha: `drm_plane_create_alpha_property()`
  - Plane stacking order: `drm_plane_create_zpos_property()`, `drm_plane_create_zpos_immutable_property()`
  - Rotation: `drm_plane_create_rotation_property()`
  - Blend mode: `drm_plane_create_blend_mode_property()`
  - Scaling filter: `drm_plane_create_scaling_filter_property()`
  - Custom driver-specific properties may also exist

DRM Display Controller: Metadata

- Display mode: `struct drm_display_mode`
  - Describes display timings and *some* signal characteristics (sync polarity, composite sync, double/half clock rate)
  - List provided by connector, with preferred indication
  - Chosen by userspace to configure CRTC with property
- Display information: `struct drm_display_info`
  - Describes pixel interface characteristics
  - `bus_formats`: list of `MEDIA_BUS_FMT_*` formats
  - `bus_flags`: bitfield of `DRM_BUS_FLAG_*` for signal characteristics
  - `{width,height}_mm`: physical surface dimensions
- Both are retreived either:
  - Dynamically with EDID (`struct edid`) via DDC for monitors
  - Statically with hardcoded definitions for panels

DRM Display Controller: Connector

- Connector data: `struct drm_connector`
  - `type`: display interface indication, `DRM_MODE_CONNECTOR_*`
  - `status`: one of `connector_status_connected`, `connector_status_disconnected`, `connector_status_unknown`
  - `possible_encoders`: valid encoders with `drm_encoder_mask()`
  - `modes`: list of available display interface modes
- Connector functions: `struct drm_connector_funcs` (boilerplate)
  - `reset`: connector state reset with `drm_atomic_helper_connector_reset()`
  - `destroy` connector destruction with `drm_connector_cleanup()`
  - `atomic_{duplicate,destroy}_state`: connector state handling with `drm_atomic_helper_connector_duplicate_state()`, `drm_atomic_helper_connector_destroy_state()`
  - `fill_modes`: get mode list from available sources with `drm_helper_probe_single_connector_modes()`

DRM Display Controller: Connector

- Connector atomic state: `struct drm_connector_state`
  - New/old connector states available from `struct drm_atomic_state`: `drm_atomic_get_new_connector_state()`, `drm_atomic_get_old_connector_state()`
  - Associated CRTC and encoder: `struct drm_crtc`, `struct drm_encoder`
  - Various base and optional properties
- Connector helper functions: `struct drm_connector_helper_funcs`
  - `get_modes`: retrieve list of modes with `drm_get_edid()` and `drm_add_edid_modes()` or `drm_panel_get_modes()`
  - `mode_{valid,fixup}`: validate/fixup proposed mode with hardware constraints
  - `detect`: detect connector status
- Setup at `probe()`:
  - Initialize and register `struct drm_connector` with `drm_connector_init()`
  - Register connector helpers with `drm_connector_helper_add()`
  - Attach encoder to connector with `drm_connector_attach_encoder()`

DRM Display Controller: Connector Hotplug

- Connector status detection:
  - Detect connector plug/unplug for monitors
  - Using dedicated pin or status, associated interrupt or not
  - Updates `struct drm_connector status` using `detect` helper function
  - Notify userspace via sysfs uevent `HOTPLUG=1` (and `CONNECTOR=*`)
- Interrupt-based detection:
  - Set `struct drm_connector polled` field to `DRM_CONNECTOR_POLL_HPD`
  - Event reported from IRQ handler with `drm_connector_helper_hpd_irq_event()` or `drm_helper_hpd_irq_event()` (global)
- Active polling (10 Hz):
  - Set `struct drm_connector polled` field to `DRM_CONNECTOR_POLL_CONNECT | DRM_CONNECTOR_POLL_DISCONNECT`
  - Dedicated worker started with `drm_kms_helper_poll_init()`
  - Dedicated worker stopped with `drm_kms_helper_poll_fini()`

DRM Display Controller: CRTC

- CRTC data: `struct drm_crtc`
  - `primary`, `cursor`: legacy planes for compatibility (replaced by atomic state)
  - `mode`: legacy mode for compatibility (replaced by atomic state)
- CRTC functions: `struct drm_crtc_funcs` (mostly boilerplate)
  - `reset`: crtc state reset with `drm_atomic_helper_crtc_reset()`
  - `destroy` crtc destruction with `drm_crtc_cleanup()`
  - `atomic_{duplicate,destroy}_state`: crtc state handling with `drm_atomic_helper_crtc_duplicate_state()`, `drm_atomic_helper_crtc_destroy_state()`
  - `set_config`: crtc configuration with `drm_atomic_helper_set_config()`
  - `page_flip`: crtc page flip with `drm_atomic_helper_page_flip()`
  - `enable_vblank`: driver-specific vblank interrupt enable
  - `disable_vblank`: driver-specific vblank interrupt disable

DRM Display Controller: CRTC

- CRTC atomic state: `struct drm_crtc_state`
  - New/old crtc states available from `struct drm_atomic_state`: `drm_atomic_get_new_crtc_state()`, `drm_atomic_get_old_crtc_state()`
  - Associated planes, connectors and encoders with `drm_plane_mask()`, `drm_connector_mask()`, `drm_encoder_mask()`
  - Adjusted and requested modes: `adjusted_mode`, `mode`
  - Pending vblank `event` with `struct drm_pending_vblank_event`
  - Various properties (gamma, scaling filter)
- CRTC helper functions: `struct drm_crtc_helper_funcs`
  - `mode_{valid,fixup}`: validate/fixup proposed mode with hardware constraints
  - `atomic_check`: driver-specific atomic state validation
  - `atomic_enable`: driver-specific crtc configuration using atomic state, enable vblank with `drm_crtc_vblank_on()`
  - `atomic_disable`: driver-specific crtc disable, disable vblank with `drm_crtc_vblank_off()`

DRM Display Controller: CRTC

- Setup at `probe()`:
  - Initialize and register `struct drm_crtc` with `drm_crtc_init_with_planes()`
  - Register CRTC helpers with `drm_crtc_helper_add()`
  - Provide `port` `struct device_node` with `of_graph_get_port_by_id()`, used by `drm_of_find_possible_crtcs()` with multiple device-tree nodes
- Vblank reporting with `drm_crtc_handle_vblank()` in interrupt handler
  - Wake-up any task waiting for vblank
- Vblank userspace event handling: `struct drm_pending_vblank_event`
  - Locked with `struct drm_device` `event_lock`
  - Grabbed at `atomic_enable` from atomic state `event` with `drm_crtc_vblank_get()` copied and removed from `struct drm_crtc_state`
  - Returned in interrupt handler with `drm_crtc_send_vblank_event()` and `drm_crtc_vblank_put()`

DRM Display Controller: Encoder

- Encoder data: `struct drm_encoder`
  - `type`: physical encoding indication, `DRM_MODE_ENCODER_*`
  - `possible_crtcs`: valid CRTCs with `drm_crtc_mask()`
- Encoder functions: `struct drm_encoder_funcs` (mostly boilerplate)
  - `reset`: encoder state reset (optional)
  - `destroy` encoder destruction with `drm_encoder_cleanup()`

DRM Display Controller: Encoder

- No encoder atomic state, using crtc and connector state
- Encoder helper functions: `struct drm_encoder_helper_funcs`
  - `mode_{valid,fixup}`: validate/fixup proposed mode with hardware constraints
  - `atomic_check`: driver-specific atomic state validation
  - `atomic_enable`: driver-specific encoder configuration using atomic state
  - `atomic_disable`: driver-specific encoder disable
- Setup at `probe()`:
  - Initialize and register `struct drm_encoder` with `drm_encoder_init()` or `drm_simple_encoder_init()` (boilerplate funcs)
  - Register encoder helpers with `drm_encoder_helper_add()`
  - Attach encoder to connector with `drm_connector_attach_encoder()`

DRM Bridge

- Bridge data: `struct drm_bridge`
  - `ops`: bitfield of `DRM_BRIDGE_OP_DETECT`, `DRM_BRIDGE_OP_EDID`, `DRM_BRIDGE_OP_HPD`, `DRM_BRIDGE_OP_MODES`
  - `type`: terminal connector type, `DRM_MODE_CONNECTOR_*`
  - `timings`: optional `struct drm_bridge_timings` with input bus flags
  - `chain_node`: list of `struct drm_bridge` for chaining bridges
  - `encoder`: `struct drm_encoder` currently attached to the bridge
  - Not tied to a specific `struct drm_device`
- Bridge functions: `struct drm_bridge_funcs` (boilerplate)
  - `atomic_{duplicate,destroy}_state`: bridge state handling with `drm_atomic_helper_bridge_duplicate_state()`, `drm_atomic_helper_bridge_destroy_state,()`
  - `atomic_reset`: bridge state reset with `drm_atomic_helper_bridge_reset()`
  - No `cleanup` callback since `drm_mode_config_cleanup()` relates to `struct drm_device`

DRM Bridge

- Bridge state: `struct drm_bridge_state` (useful for chaining)
  - New/old bridge states available from `struct drm_atomic_state`: `drm_atomic_get_new_bridge_state()`, `drm_atomic_get_old_bridge_state()`
  - Input/output bus configuration: `struct drm_bus_cfg` with `MEDIA_BUS_FMT_*` if available or `MEDIA_BUS_FMT_FIXED`
- Bridge functions: `struct drm_bridge_funcs`
  - `attach/detach`: create/destroy connector, unless `DRM_BRIDGE_ATTACH_NO_CONNECTOR` flag is specified or attach/detach next bridge with `drm_bridge_attach()`
  - `mode_{valid,fixup}`: validate/fixup proposed mode with hardware constraints
  - `atomic_get_{input,output}_bus_fmts`: report supported input/output bus formats for negotiation in bridge chains
  - `atomic_enable`: driver-specific bridge configuration using (crtc) atomic state
  - `atomic_disable`: driver-specific bridge disable
  - `atomic_check`: driver-specific atomic state validation

DRM Bridge

- Setup at `probe()` (dedicated driver):
  - Configure `type`, `ops`, `funcs`, `of_node` and possibly `timings`
  - Initialize and register `struct drm_bridge` with `drm_bridge_add()` devm-managed with `devm_drm_bridge_add()`
- Cleanup at `remove()`:
  - Unregister and cleanup with `drm_bridge_remove()`
- Display controller driver usage:
  - Identified via device-tree with `drm_of_find_panel_or_bridge()` or `devm_drm_of_get_bridge()`
  - Attached to encoder with `drm_bridge_attach()`,
  - Automatically detached during encoder cleanup
  - Connector is created by (final) bridge directly
  - Bridge functions are called automatically once attached with encoder

DRM Panel

- Panel data: `struct drm_panel`
  - `backlight`: `struct backlight_device` for the attached backlight
  - `connector_type`: display interface indication, `DRM_MODE_CONNECTOR_*`
  - Not tied to a specific `struct drm_device`
- Panel functions: `struct drm_panel_funcs`
  - `prepare`: Setup panel (typically power lines, configuration)
  - `enable`: Turn on panel, start expecting data
  - `disable`: Turn off panel, stop expecting data
  - `unprepare`: Cleanup panel
  - `get_{modes,timings}`: return list of supported modes/timings
- No panel atomic state:
  - Timings are known in advance with a single mode (typical)
  - Generally no need to configure timings explicity

DRM Panel

- Setup at `probe()` (dedicated driver):
  - Initialize panel with `drm_panel_init()` given `funcs` and `type`
  - Attach backlight via device-tree using `drm_panel_of_backlight()`
  - Register panel with `drm_panel_add()`
- Cleanup at `remove()`:
  - Unregister panel with `drm_panel_remove()`
- Display controller driver usage (deprecated):
  - Identified via device-tree with `drm_of_find_panel_or_bridge()`
  - Register encoder and connector for panel
  - Return panel modes in connector `get_modes` with `drm_panel_get_modes()`
  - Enable panel in encoder `atomic_enable` with `drm_panel_prepare()` and `drm_panel_enable()` (automatically enables backlight)
  - Disable panel in encoder `atomic_disable` with `drm_panel_unprepare()` and `drm_panel_disable()`

DRM Panel Bridge

- Differentiated handling for bridges and panels is painful:
  - Both are *in-fine* connected to an encoder
  - Panels require drm device to manage the connector
  - Bridges register their own connector
  - Provided functions are comparable (enable, disable, modes list)
- DRM Panel Bridge API closes the gap:
  - Unified API for both, using `struct drm_bridge`
  - Boilerplate connector registered transparently for panels
  - Calls back panel functions in bridge functions
- Display controller driver usage:
  - Use `devm_drm_of_get_bridge()` instead of `drm_of_find_panel_or_bridge()`
  - Use bridge normally, no particular difference

DRM Bridge and Panel Drivers

- Generic drivers provide static data and regulator/gpio integration
- Generic bridge drivers:
  - `simple-bridge`: static bridge timings with dedicated device-tree compatibles
  - `lvds-codec`: generic device-tree compatibles
  - `display-connector`: generic device-tree compatibles
- Generic panel drivers:
  - `panel-simple`: static modes list, panel-specific device-tree compatibles
  - `panel-lvds`: timings from device-tree properties
  - `panel-edp`: static modes list, panel-specific device-tree compatibles, edid fixup tables
- Specific drivers:
  - Generally require specific register configuration
  - Pitfall: panel and LCD controller confusion
  - Device-tree compatible must **not** be the LCD controller name
  - Having a common driver for a LCD controller is a good idea (with panel-specific compatibles)

DRM Bridge/Panel Generic Drivers: panel-simple

```
static const struct drm_display_mode
lemaker_bl035_rgb_002_mode = {
  .clock = 7000,
  .hdisplay = 320,
  .hsync_start = 320 + 20,
  .hsync_end = 320 + 20 + 30,
  .htotal = 320 + 20 + 30 + 38,
  .vdisplay = 240,
  .vsync_start = 240 + 4,
  .vsync_end = 240 + 4 + 3,
  .vtotal = 240 + 4 + 3 + 15,
};
```

```
static const struct panel_desc
lemaker_bl035_rgb_002 = {
  .modes = &lemaker_bl035_rgb_002_mode,
  .num_modes = 1,
  .size = {
    .width = 70,
    .height = 52,
  },
  .bus_format = MEDIA_BUS_FMT_RGB888_1X24,
  .bus_flags = DRM_BUS_FLAG_DE_LOW,
};
```

```
static const struct of_device_id platform_of_match[] = {
  [...]
  {
    .compatible = "lemaker,bl035-rgb-002",
    .data = &lemaker_bl035_rgb_002,
  },
  [...]
};
```

DRM Repositories and Lists

Repositories:

- DRM (top): https://cgit.freedesktop.org/drm/drm
  - Branches: drm-next, drm-fixes
  - Maintainer: Dave Airlie
- DRM Misc: https://cgit.freedesktop.org/drm/drm-misc
  - Branches: drm-misc-next, drm-misc-fixes
  - Maintainers: Maarten Lankhorst, Maxime Ripard, and Thomas Zimmermann
- Hardware-specific:
  - DRM Intel: https://cgit.freedesktop.org/drm/drm-intel
  - DRM AMD: https://gitlab.freedesktop.org/agd5f/linux.git
  - DRM Nouveau: https://gitlab.freedesktop.org/drm/nouveau

Patch submission and tracking:

- Patchwork: https://patchwork.freedesktop.org
- Mailing list: dri-devel@lists.freedesktop.org

Questions? Suggestions? Comments?

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