Graphic Testing without hardware: discovering the power of VKMS!

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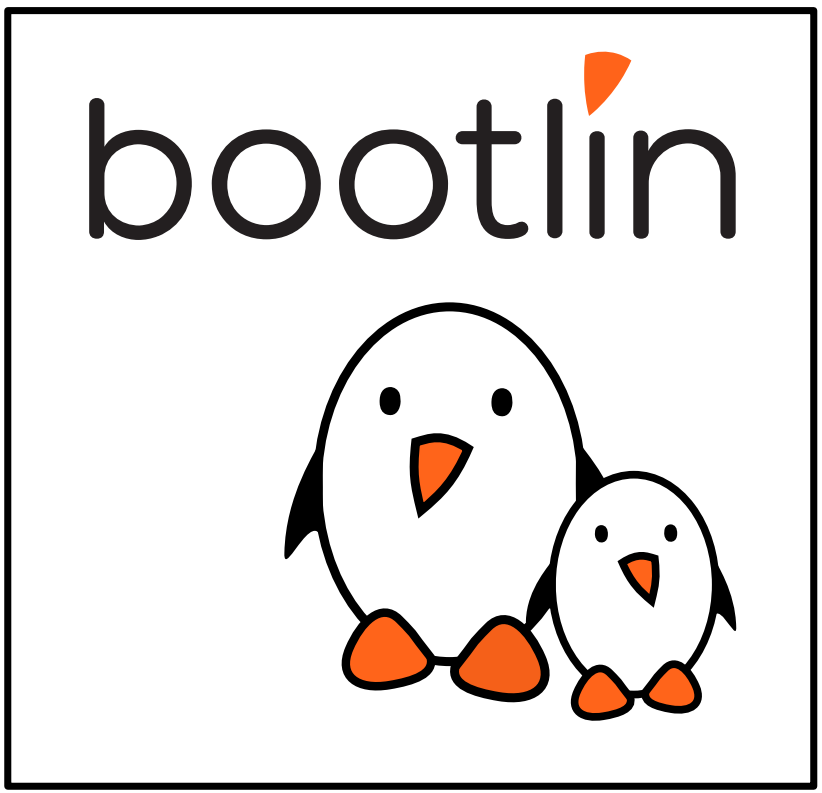
Louis Chauvet

- Embedded Linux engineer at Bootlin
  - Embedded Linux expertise
  - Development, consulting and training
  - Strong open-source focus
- VKMS Maintainer
- Living in **Toulouse**

Display testing

- What do we want to test?
- How to do it?



What do we want to test?

- Anything with a screen
- App which don't know exactly what is the hardware it will be ran on

How to do it?

Without VKMS	With VKMS

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1. Buy boards 2. Setup board 3. Debug 4. Go to step 1.	

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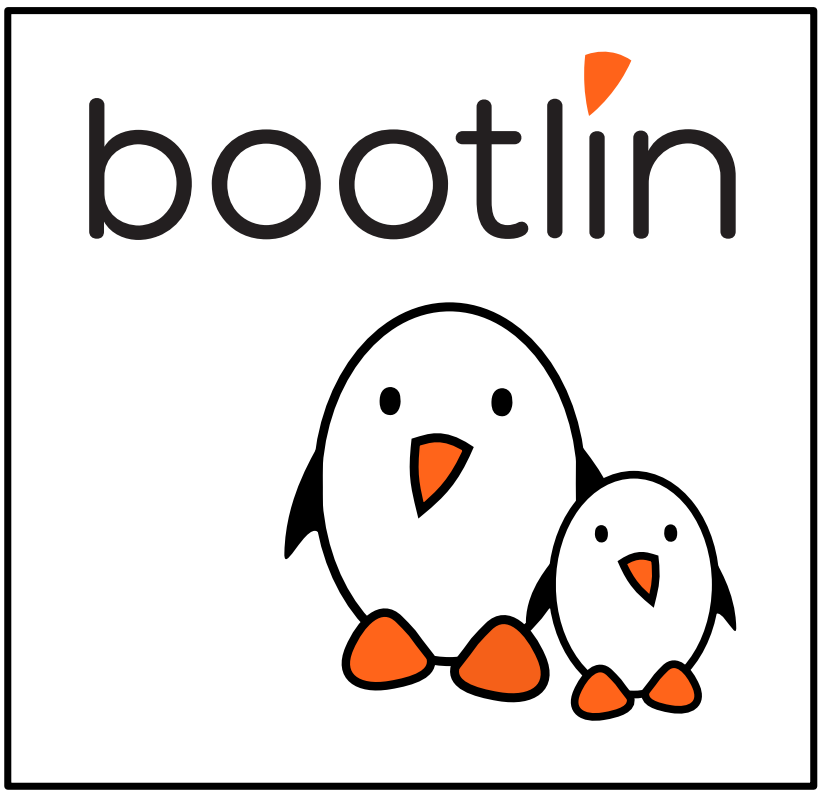
1. Buy boards 2. Setup board 3. Debug 4. Go to step 1.	1. Run VM 2. Set VKMS config 3. Debug 4. Go to step 1.
Pros: Real hardware **Cons**: Expensive, physical manipulations, hard to integrate in CI	**Pros**: Free, easy to automate **Cons**: Not the real hardware

VKMS, what it is?



VKMS, what it is?

VKMS: **V**irtual **K**ernel **M**ode **S**etting

> VKMS is a software-only model of a KMS driver that is useful for testing and for running X (or similar) on headless machines. VKMS aims to enable a virtual display with no need of a hardware display capability, releasing the GPU in DRM API tests.
>
> — Documentation/gpu/vkms.rst

VKMS, what it is?

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Main goal: Testing userspace without hardware

Quick overview of display pipeline

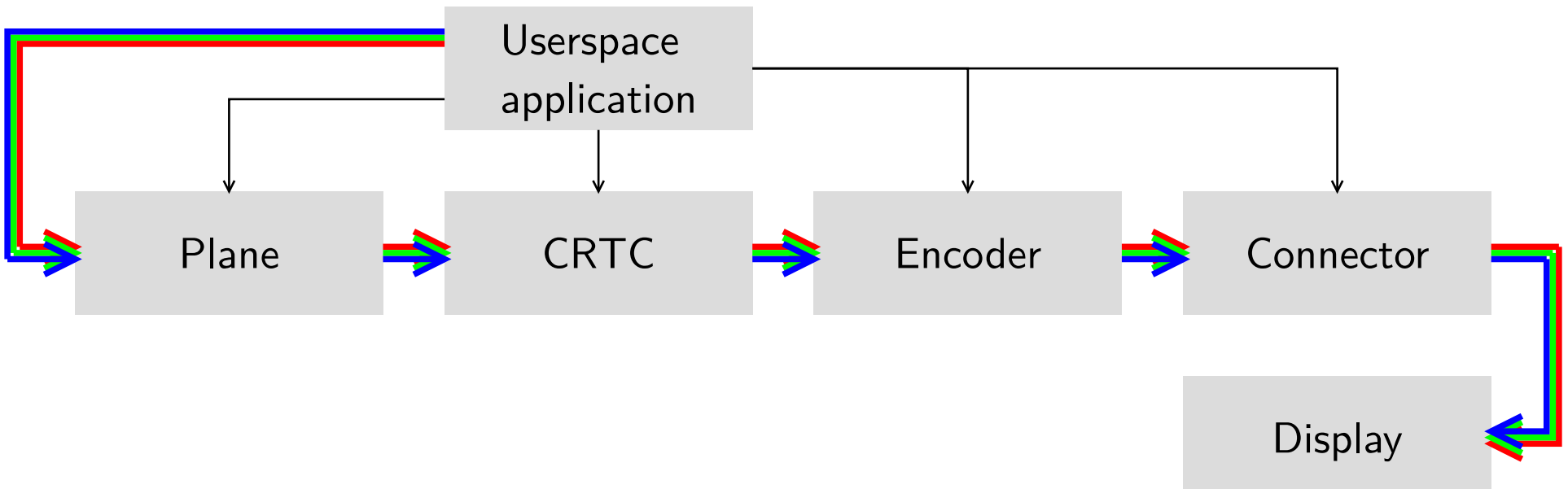
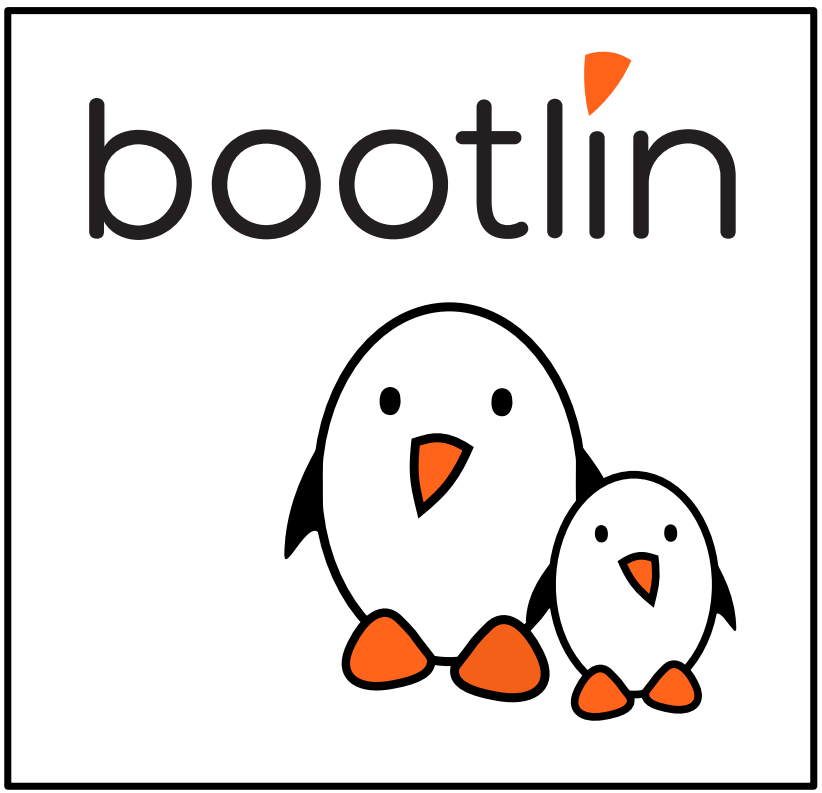


Figure 1: Overview of a display pipeline

Current VKMS Capabilities

- Plane composition
- Color conversion
- Writeback
- Kernel arguments
- Minimal configuration
- Maximal configuration



Plane composition

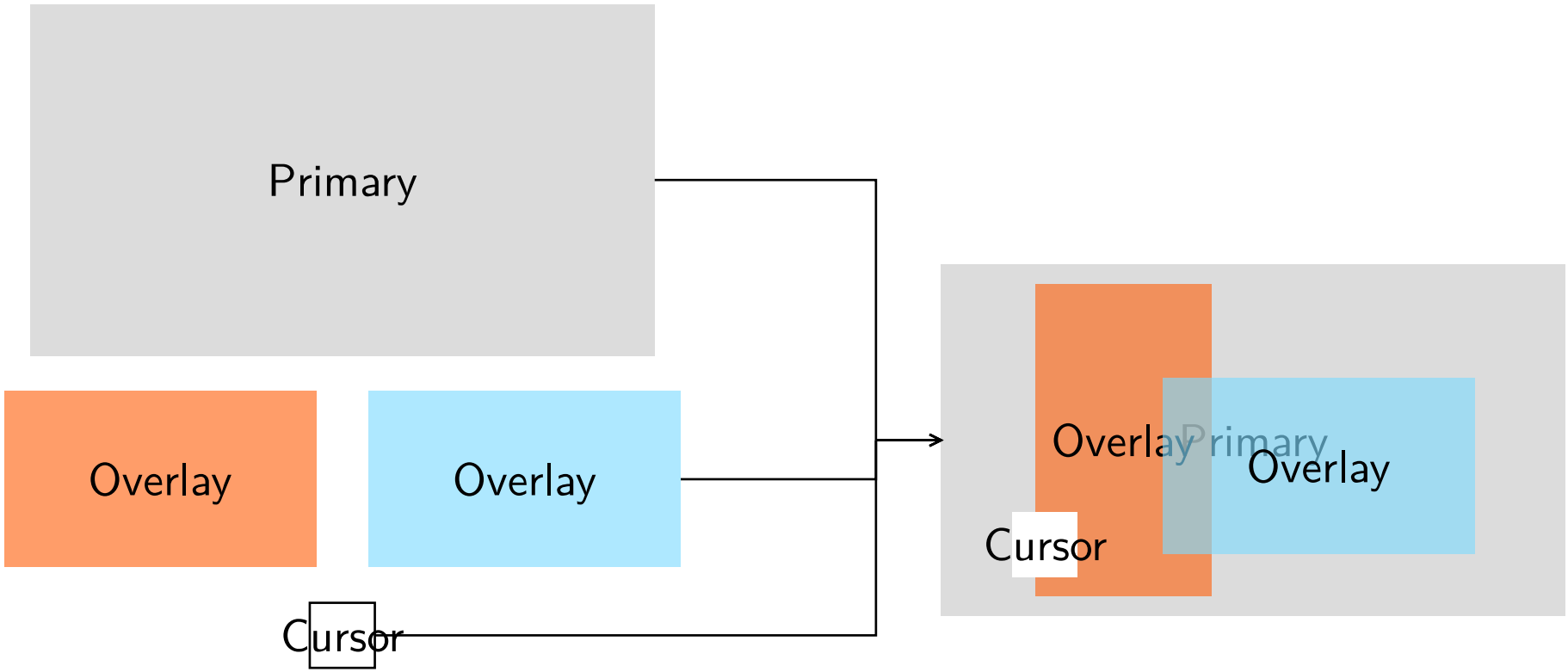


Figure 2: Plane composition

Color conversion

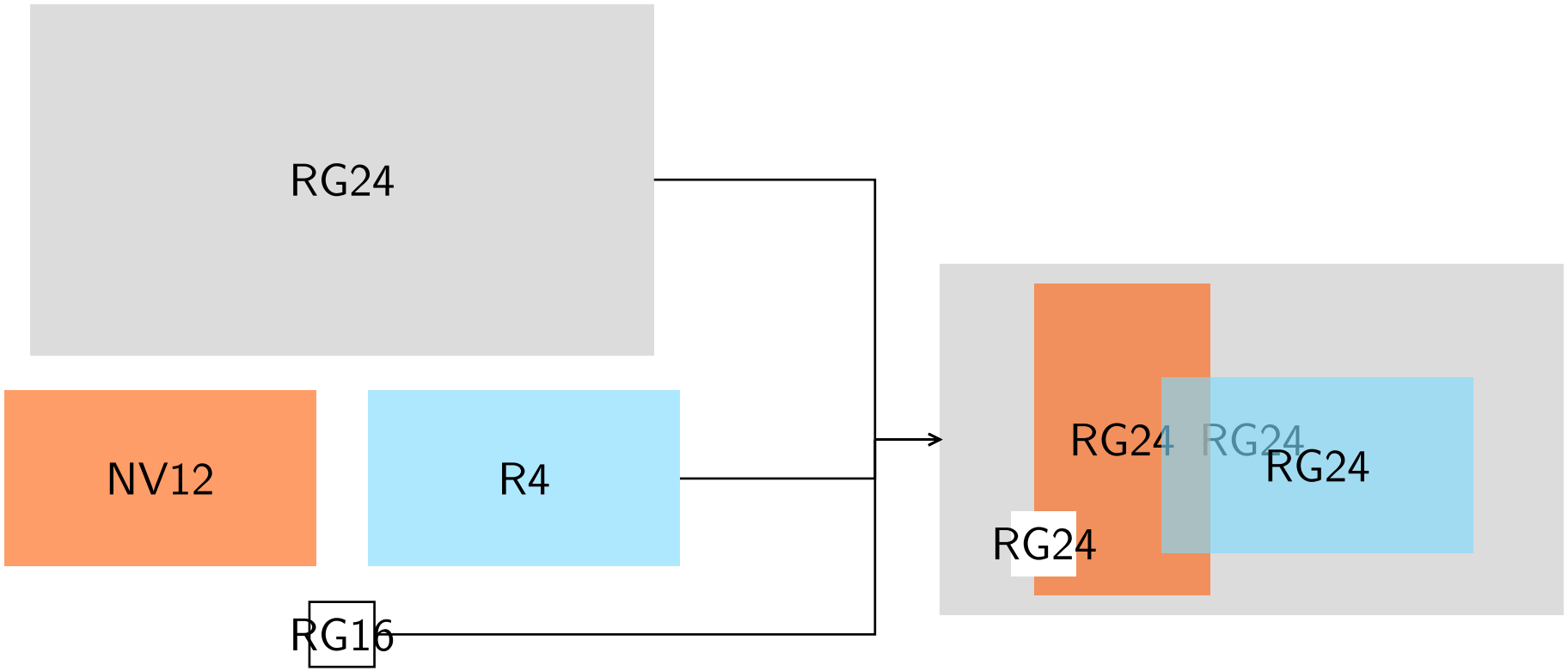


Figure 3: Plane composition

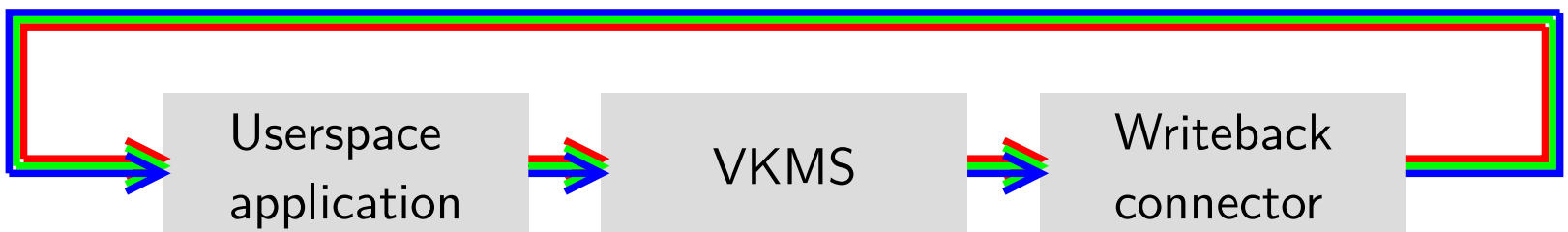


Figure 4: Writeback connector

Kernel arguments

- `enable_cursor` - `true`

  Add a cursor plane
- `enable_writeback` - `true`

  Add a writeback connector
- `enable_overlay` - `false`

  Add multiple planes

Minimal configuration

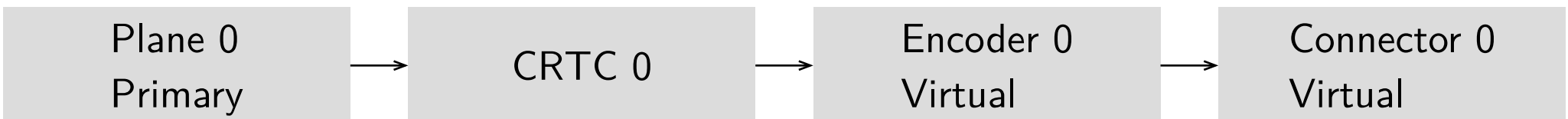


Figure 5: `enable_cursor=false`, `enable_writeback=false`, `enable_overlay=false`

Maximal configuration

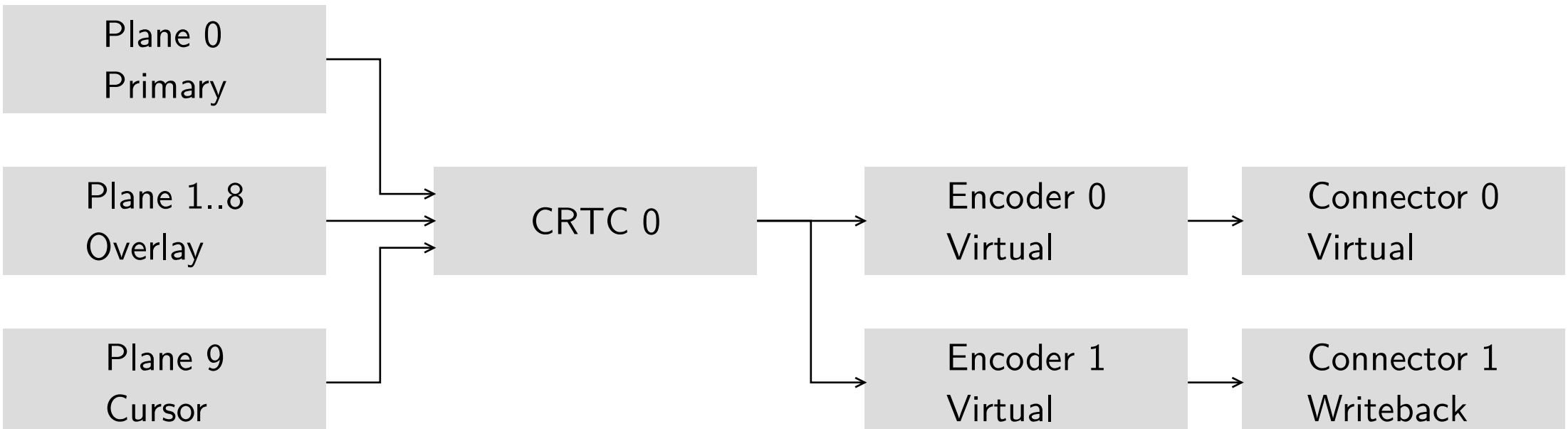
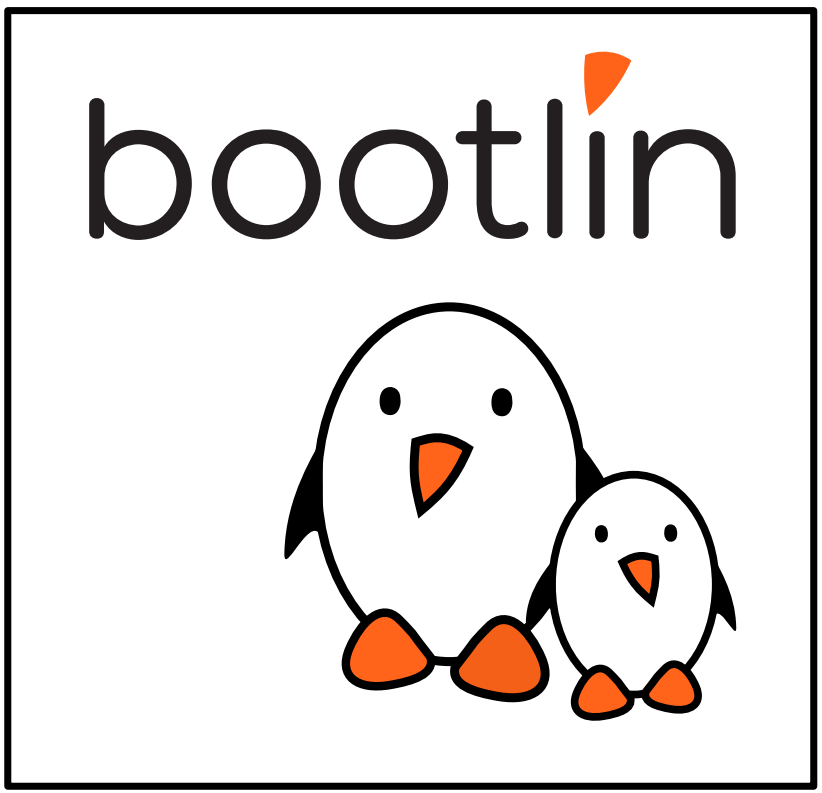


Figure 6: `enable_cursor=true`, `enable_writeback=true`, `enable_overlay=true`

Real life examples

- Texas Instrument - AM6232
- Framework 13 - intel



Real life examples - AM6232

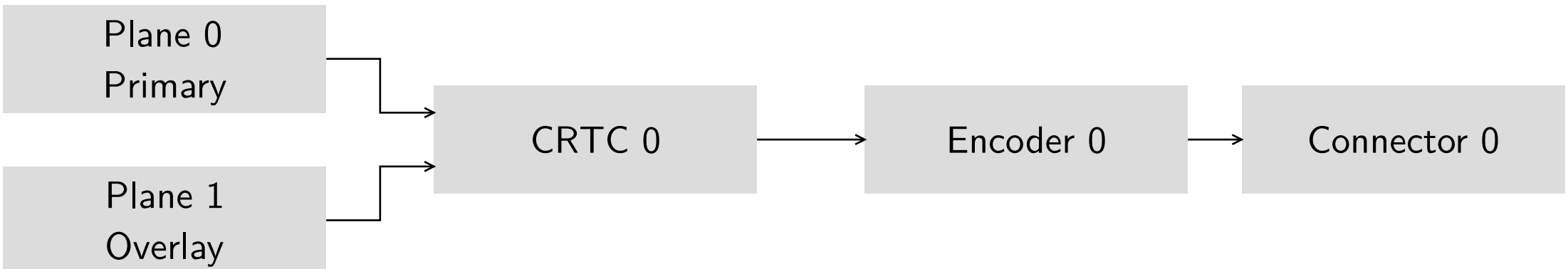


Figure 7: AM6232

Real life examples - Framework 13 - intel

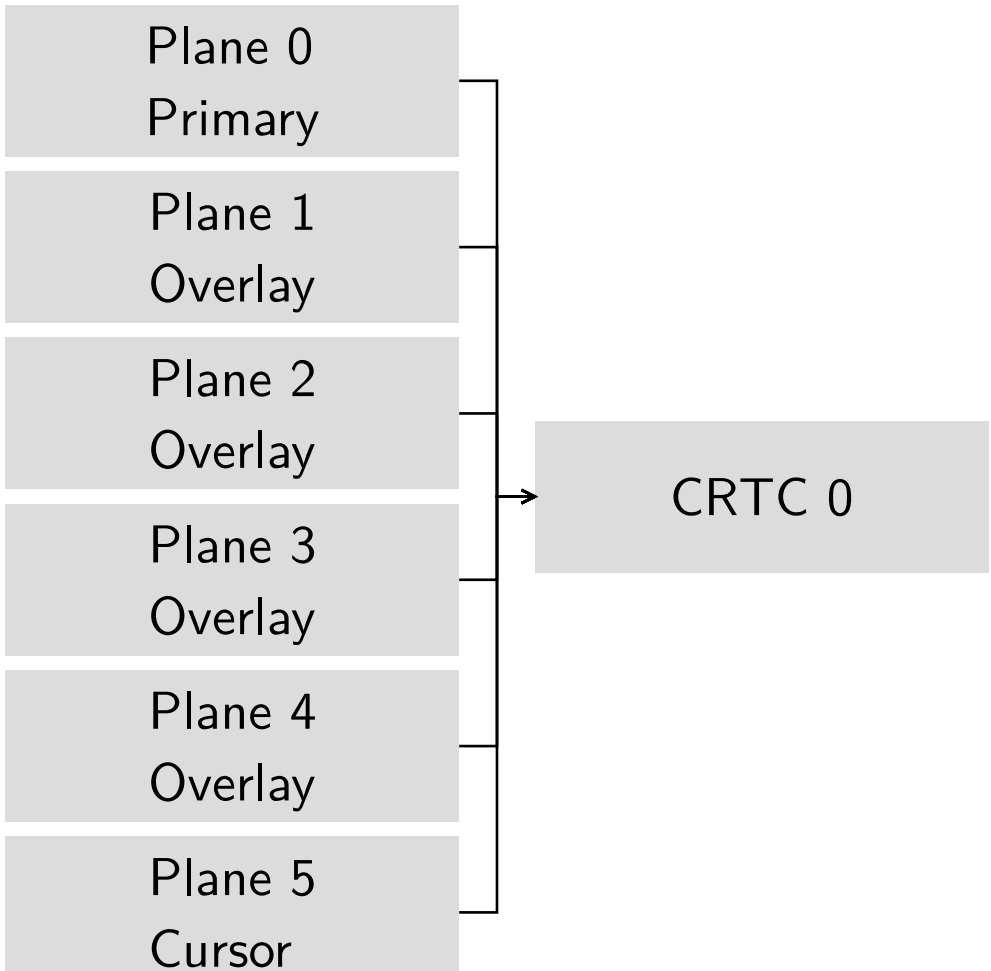


Figure 8: Framework 13

Real life examples - Framework 13 - intel

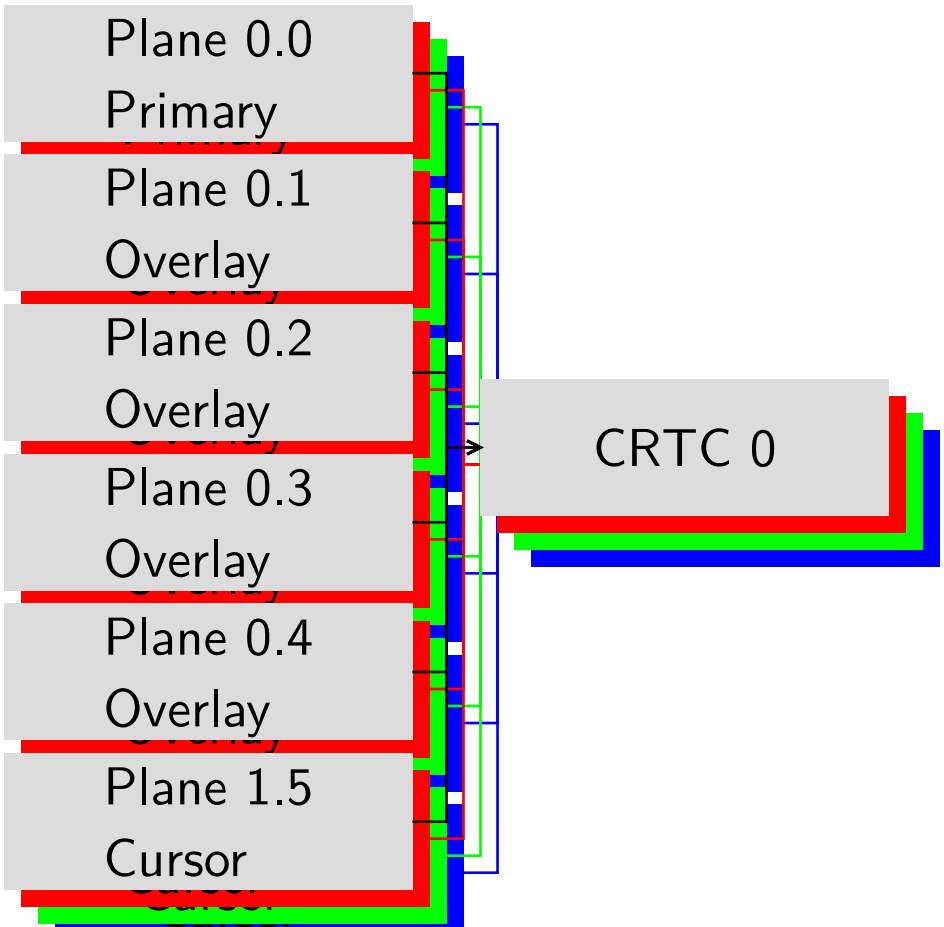


Figure 9: Framework 13

Real life examples - Framework 13 - intel

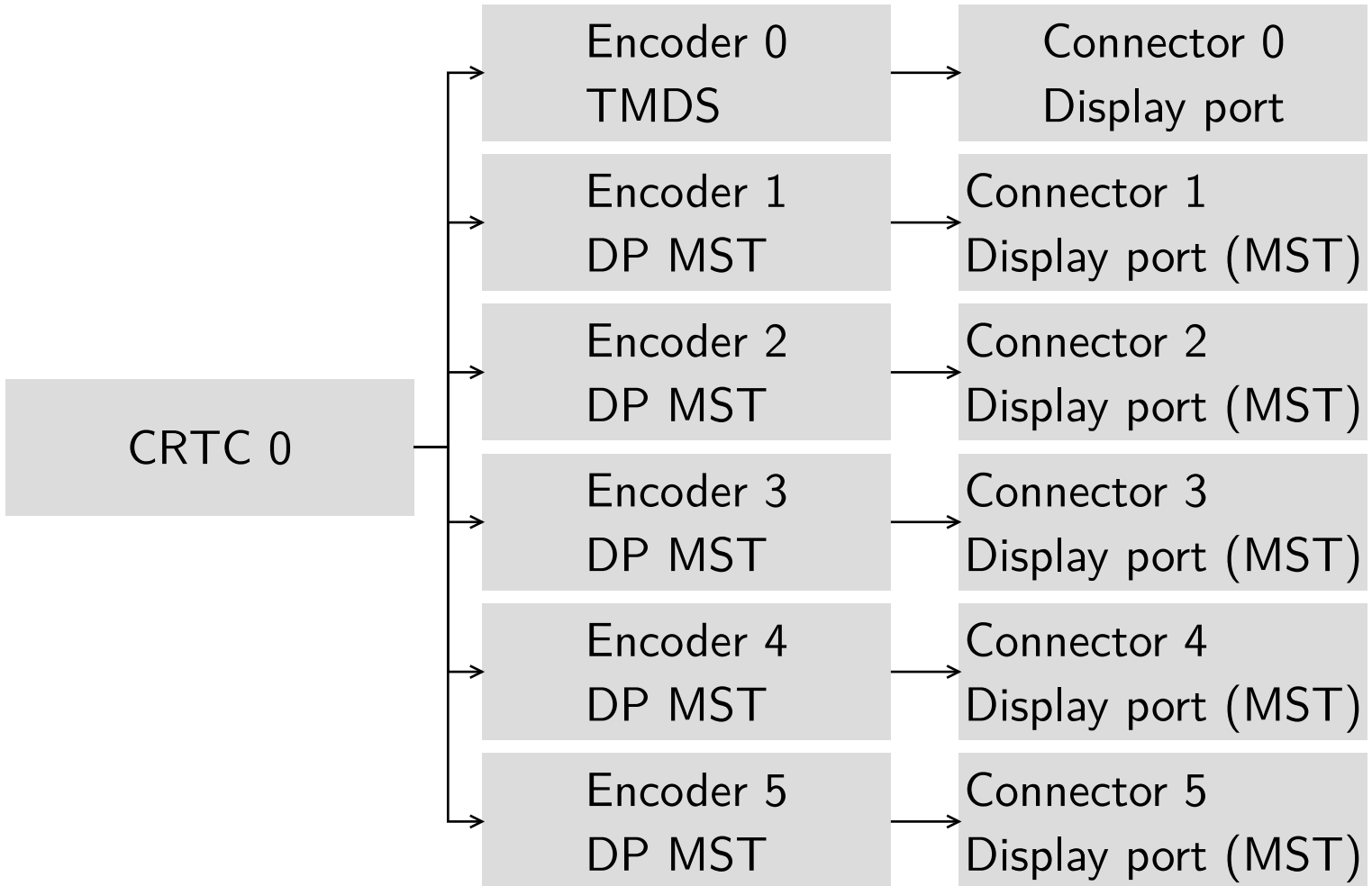


Figure 10: Framework 13

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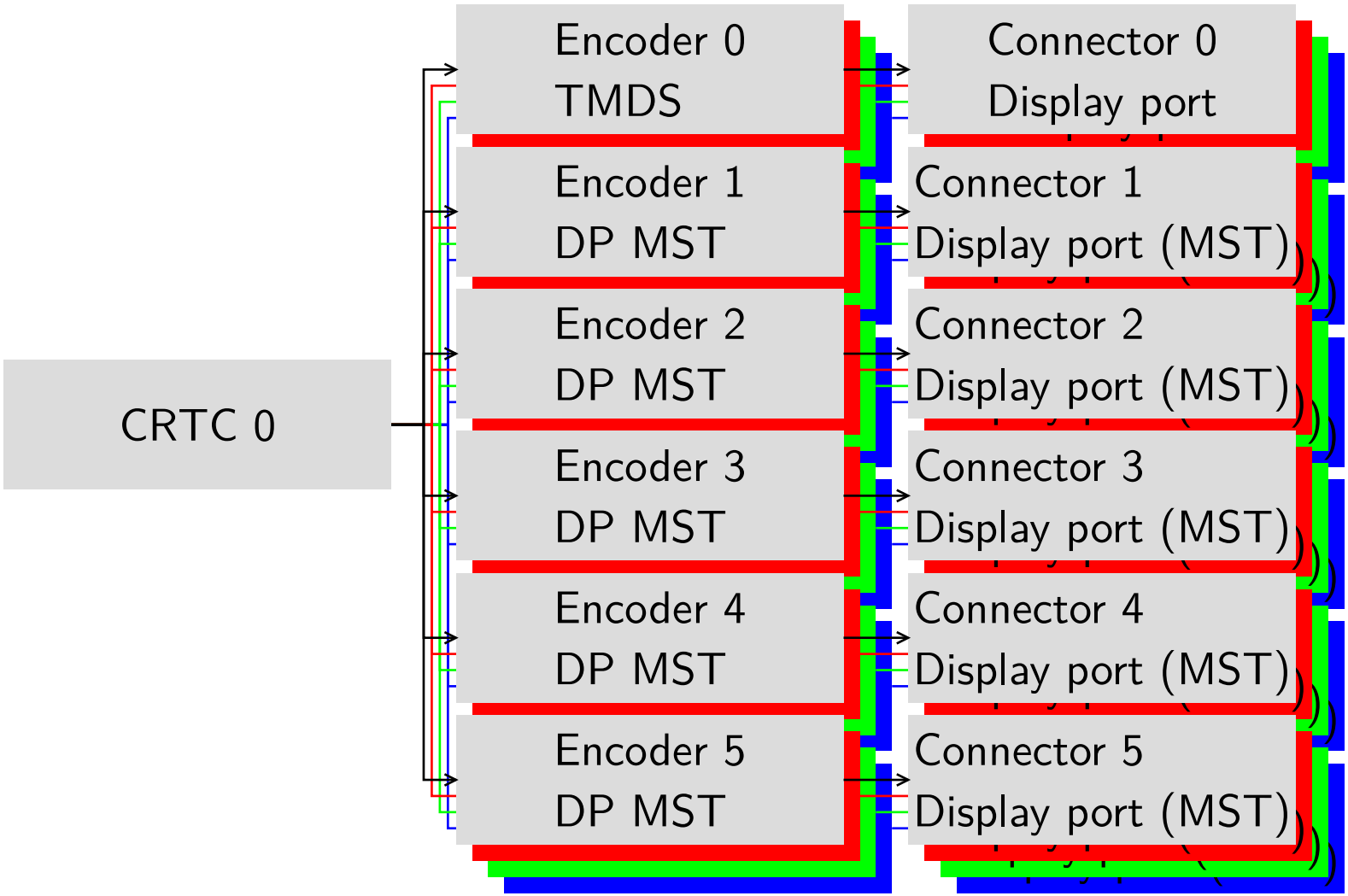

Figure 11: Framework 13

ConfigFS interface

- Upstreaming status

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- Internal VKMS modifications done

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- First set of configurations proposed by José Exposito and me

Upstreaming status

- Internal VKMS modifications done
- First set of configurations proposed by José Exposito and me

Last iteration: 20250507135431.53907-1-jose.exposito89@gmail.com

Repository: github.com/Fomys/linux/tree/review/20250507135431.53907-1-jose.exposito89@gmail.com

Demo time - probing

- New kernel argument: `create_default_dev`, disable or enable the creation of the default device to ensure backwards compatibility

```
$ modprobe vkms create_default_dev=0
```

Demo time - Creating a device

- Creating a device is as simple as creating a folder in ConfigFS:

```
$ mkdir /sys/kernel/config/vkms/MY_DEV
```

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```
$ mkdir /sys/kernel/config/vkms/MY_DEV
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```
$ tree /sys/kernel/config/vkms/MY_DEV
/sys/kernel/config/vkms/DEV_1/
├── connectors/
├── crtcs/
├── enabled
├── encoders/
└── planes/
```

Demo time - Enabling a device

- Enabling a device is done using the enabled file:

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$ echo 1 > /sys/kernel/config/vkms/MY_DEV/enabled
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Demo time - Enabling a device

- Enabling a device is done using the enabled file:

```
$ echo 1 > /sys/kernel/config/vkms/MY_DEV/enabled
(NULL device *): [drm] The number of planes must be between 1 and 31
```

But currently we did not configure it yet, DRM is complaining about missing planes

Demo time - Creating a plane

- Again, creating a plane only requires to create a folder:

```
$ mkdir /sys/kernel/config/vkms/MY_DEV/planes/PLA_1
```

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$ mkdir /sys/kernel/config/vkms/MY_DEV/planes/PLA_1

$ tree /sys/kernel/config/vkms/MY_DEV/planes
/sys/kernel/config/vkms/MY_DEV/planes
└── PLA_1
    ├── possible_crtcs
    └── type
```

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```

- **possible_crtcs** - Folder containing the connected CRTC
- **type** - Plane type configuration: 0 = Overlay, 1 = Primary, 2 = Cursor

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We want it to be a primary plane:

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/sys/kernel/config/vkms/MY_DEV/planes
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```

```
$ echo 1 > /sys/kernel/config/vkms/MY_DEV/enabled
(NULL device *): [drm] The number of CRTCs must be between 1 and 31
```

Demo time - Creating a CRTC

- And again, just create a folder

```
$ mkdir /sys/kernel/config/vkms/MY_DEV/crtcs/CRTC_1
```

Demo time - Creating a CRTC

- And again, just create a folder

```
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```

```
$ tree /sys/kernel/config/vkms/MY_DEV/crtcs
/sys/kernel/config/vkms/MY_DEV/crtcs
└── CRTC_1
    └── writeback
        └── writeback
```

Demo time - Creating a CRTC

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$ mkdir /sys/kernel/config/vkms/MY_DEV/crtcs/CRTC_1
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- **writeback** - create a writeback connector for this CRTC

Demo time - Creating a CRTC

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└── CRTC_1
    └── writeback
        └── writeback
```

- **writeback** - create a writeback connector for this CRTC

```
$ echo 1 > /sys/kernel/config/vkms/MY_DEV/enabled
(NULL device *): [drm] The number of encoders must be between 1 and 31
```

This time we need an encoder

Demo time - Creating an encoder

- You guessed it, just a new folder!

```
$ mkdir /sys/kernel/config/vkms/MY_DEV/encoders/ENC_1
```

```
$ tree /sys/kernel/config/vkms/MY_DEV/encoders
/sys/kernel/config/vkms/MY_DEV/encoders
└── ENC_1
    └── possible_crtcs
```

Demo time - Creating an encoder

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    └── possible_crtcs
```

- **possible_crtcs** - Folder containing the connected CRTC

Demo time - Creating an encoder

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    └── possible_crtcs
```

- **possible_crtcs** - Folder containing the connected CRTC

```
$ echo 1 > /sys/kernel/config/vkms/MY_DEV/enabled
(NULL device *): [drm] The number of connectors must be between 1 and 31
```

And last, a connector!

Demo time - Creating a connector

The last folder to create!

```
$ mkdir /sys/kernel/config/vkms/MY_DEV/connectors/CON_1
```

Demo time - Creating a connector

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$ mkdir /sys/kernel/config/vkms/MY_DEV/connectors/CON_1
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$ tree /sys/kernel/config/vkms/MY_DEV/connectors
/sys/kernel/config/vkms/MY_DEV/connectors
└── CON_1
    ├── possible_encoders
    └── status
```

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- **possible_encoders** - Folder containing the connected encoders
- **status** - Set the connection status of the connector: 1 = connected, 2 = disconnected, 2 = unknown

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- **possible_encoders** - Folder containing the connected encoders
- **status** - Set the connection status of the connector: 1 = connected, 2 = disconnected, 2 = unknown

```
$ echo 1 > /sys/kernel/config/vkms/MY_DEV/enabled
(NULL device *): [drm] All planes must have at least one possible CRTC
```

It is time to wire all those items together

Demo time - connect everything

Item in the graphic pipeline are connected together using symlinks. In our case:

```
$ ln -s /sys/kernel/config/vkms/MY_DEV/crtcs/CRTC_1/ /sys/kernel/config/vkms/
MY_DEV/planes/PLA_1/possible_crtcs/
$ ln -s /sys/kernel/config/vkms/MY_DEV/crtcs/CRTC_1/ /sys/kernel/config/vkms/
MY_DEV/encoders/ENC_1/possible_crtcs/
$ ln -s /sys/kernel/config/vkms/MY_DEV/encoders/ENC_1/ /sys/kernel/config/vkms/
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$ ln -s /sys/kernel/config/vkms/MY_DEV/encoders/ENC_1/ /sys/kernel/config/vkms/
MY_DEV/connectors/CON_1/possible_encoders/
```

```
$ echo 1 > /sys/kernel/config/vkms/MY_DEV/enabled
```

Demo time - Some experimentations

- `$ modetest -M vkms`

  `[...]`

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- `$ drm_info /dev/dri/card0`
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- `$ modetest -M vkms`
  `[...]`
- `$ drm_info /dev/dri/card0`
  `[...]`
- `$ modetest -M vkms -s 40:#0`

```
opened device `Virtual Kernel Mode Setting` on driver `vkms` (version
1.0.0 at 0)
setting mode 1024x768-60.00Hz on connectors 40, crtc 38
```

Demo time - Some experimentations

- `$ modetest -M vkms`
  `[...]`
- `$ drm_info /dev/dri/card0`
  `[...]`
- `$ modetest -M vkms -s 40:#0`
  `opened device `Virtual Kernel Mode Setting` on driver `vkms` (version 1.0.0 at 0)`
  `setting mode 1024x768-60.00Hz on connectors 40, crtc 38`
- Disconnection of the connector:

```
$ echo 2 > /sys/kernel/config/vkms/MY_DEV/connectors/CON_1/status
$ modetest -M vkms -s 40:#0
opened device `Virtual Kernel Mode Setting` on driver `vkms` (version 1.0.0 at 0)
failed to find mode "#0" for connector 40
failed to create dumb buffer: Invalid argument
```

Pending patches

A lot of work is ready to go

- New color formats for planes and writeback
- More configuration for planes, connector, encoder

Repository: https://github.com/Fomys/linux/tree/configfs-everything

Demo time 2

For readers:

```
$ modprobe vkms create_default_dev=0
$ mkdir /sys/kernel/config/vkms/MY_DEV
$ mkdir /sys/kernel/config/vkms/MY_DEV/planes/PLA_1
$ mkdir /sys/kernel/config/vkms/MY_DEV/planes/PLA_2
$ mkdir /sys/kernel/config/vkms/MY_DEV/crtcs/CRTC_1
$ mkdir /sys/kernel/config/vkms/MY_DEV/encoders/ENC_1
$ mkdir /sys/kernel/config/vkms/MY_DEV/connectors/CON_1
$ mkdir /sys/kernel/config/vkms/MY_DEV/connectors/CON_2
```

Demo time 2 - continuation


```
$ ln -s /sys/kernel/config/vkms/MY_DEV/crtcs/CRTC_1/ /sys/kernel/config/vkms/
MY_DEV/planes/PLA_1/possible_crtcs/
$ ln -s /sys/kernel/config/vkms/MY_DEV/crtcs/CRTC_1/ /sys/kernel/config/vkms/
MY_DEV/planes/PLA_2/possible_crtcs/
$ ln -s /sys/kernel/config/vkms/MY_DEV/crtcs/CRTC_1/ /sys/kernel/config/vkms/
MY_DEV/encoders/ENC_1/possible_crtcs/
$ ln -s /sys/kernel/config/vkms/MY_DEV/encoders/ENC_1/ /sys/kernel/config/vkms/
MY_DEV/connectors/CON_1/possible_encoders/
$ ln -s /sys/kernel/config/vkms/MY_DEV/encoders/ENC_1/ /sys/kernel/config/vkms/
MY_DEV/connectors/CON_2/possible_encoders/
$ echo 1 > /sys/kernel/config/vkms/MY_DEV/planes/PLA_1/type
$ echo 0 > /sys/kernel/config/vkms/MY_DEV/planes/PLA_2/type
```

Demo time 2 - plane configuration


```
$ tree /sys/kernel/config/vkms/MY_DEV/planes/
/sys/kernel/config/vkms/MY_DEV/planes/
└── PLA_1
    ├── default_color_encoding      # default for color encoding
    ├── default_color_range         # default for color range
    ├── default_rotation            # default for rotation
    ├── possible_crtcs
    │   └── CRTC_1 -> ../../../../../vkms/MY_DEV/crtcs/CRTC_1
    ├── supported_color_encoding    # color encoding bitmask
    ├── supported_color_range       # color range bitmask
    ├── supported_formats           # +RG24 to enable RGB888, -RG24 to disable
    ├── supported_rotations         # rotation bitmask
    └── type                        # 0 = Overlay, 1 = Primary, 2 = Cursor
```

Demo time 2 - plane color format configuration

- Only support RGB888 for primary plane

```
$ echo '-*' > /sys/kernel/config/vkms/MY_DEV/planes/PLA_1/supported_formats
$ echo '+RG24' > /sys/kernel/config/vkms/MY_DEV/planes/PLA_1/supported_formats
```

- Support everything except RGB888 for overlay plane

```
$ echo '+*' > /sys/kernel/config/vkms/MY_DEV/planes/PLA_2/supported_formats
$ echo '-RG24' > /sys/kernel/config/vkms/MY_DEV/planes/PLA_2/supported_formats
```

Demo time 2 - encoder configuration


```
$ tree /sys/kernel/config/vkms/MY_DEV/encoders/
/sys/kernel/config/vkms/MY_DEV/encoders/
└── ENC_1
    ├── possible_crtcs
    │   └── CRTC_1 -> ../../../../../vkms/MY_DEV/crtcs/CRTC_1
    └── type            # 5 = virtual, 3 = LVDS, ...
```

Demo time 2 - connector configuration


```
$ tree /sys/kernel/config/vkms/MY_DEV/connectors/
/sys/kernel/config/vkms/MY_DEV/connectors/
└── CON_1
    ├── dynamic                 # 1 = dynamic connector (MST), 0 = static
    ├── edid                    # raw edid content
    ├── edid_enabled            # 1 = use the provided edid, 0 = use default
mode list
    ├── enabled                 # if dynamic, create/destroy this connector on
the fly
    ├── possible_encoders
    │   └── ENC_1 -> ../../../../../vkms/MY_DEV/encoders/ENC_1
    ├── status                  # 1 = connected, 2 = disconnected, 2 = unknown
    ├── supported_colorspace    # for HDR support (only for type=eDP, DP or
HDMI)
    └── type                    # 15 = virtual, 10 = DP, ...
```

Demo time 2 - dynamic connector


```
$ echo 1 > /sys/kernel/config/vkms/MY_DEV/connectors/CON_2/dynamic
$ echo 0 > /sys/kernel/config/vkms/MY_DEV/connectors/CON_2/enabled
$ echo 1 > /sys/kernel/config/vkms/MY_DEV/enabled
$ modetest -M vkms | grep connected
45  0 connected Virtual-1       0x0   34  44
$ echo 1 > /sys/kernel/config/vkms/MY_DEV/connectors/CON_2/enabled
$ modetest -M vkms | grep connected
45  0 connected Virtual-1       0x0   34  44
46  0 connected Virtual-2       0x0   34  44
```

Demo time 2 - Plane formats


```
$ modetest -M vkms -p
[...]
```

Visual demonstrations

Questions? Suggestions? Comments?

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https://bootlin.com/pub/conferences/2025/elce/chauvet-graphic-testing