FreeSync™, Adaptive Sync & VRR

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AGENDA

Static and dynamic refresh rates

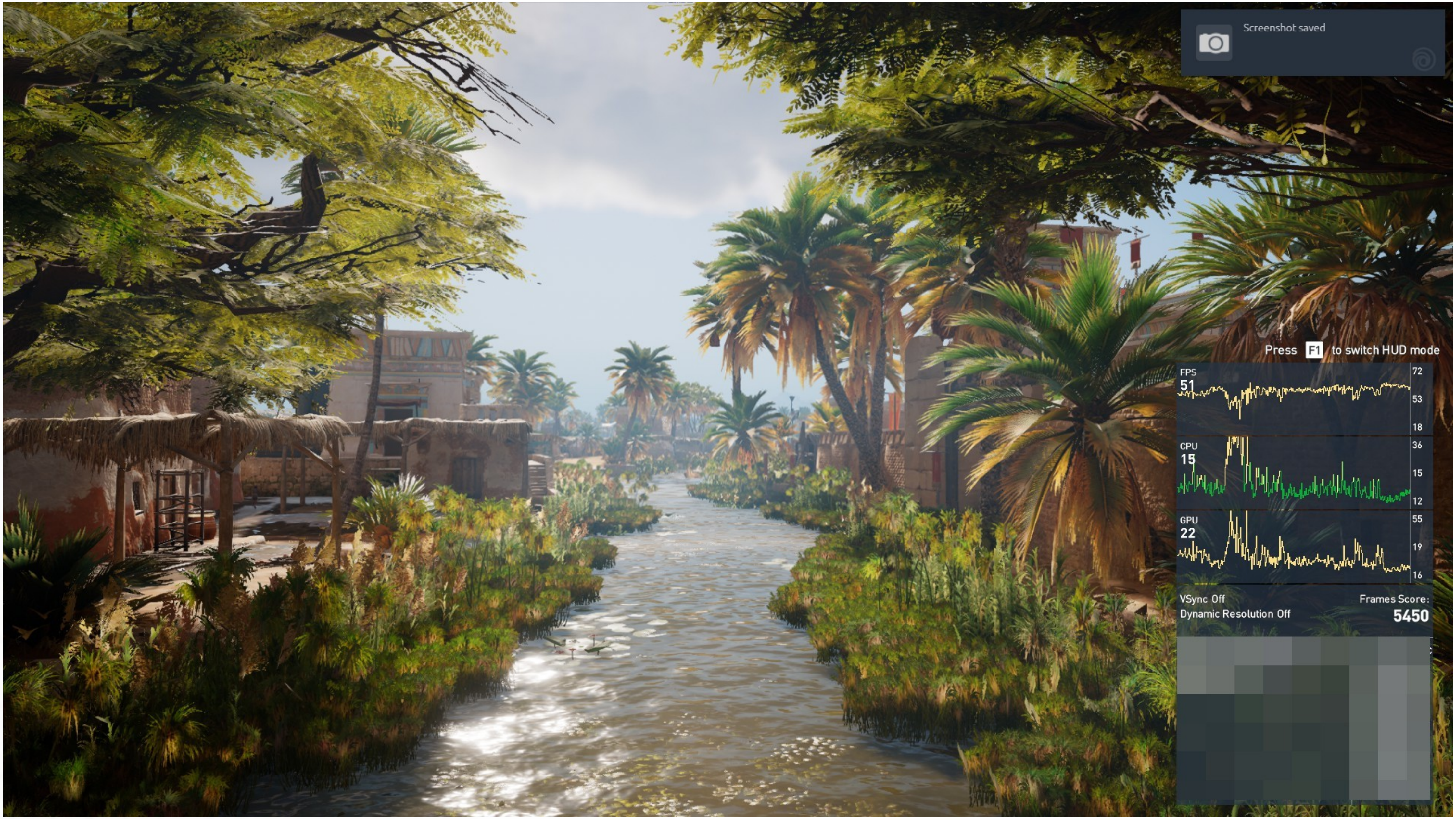
DP Adaptive Sync, HDMI™ VRR, FreeSync™

VRR in DRM & Mesa

Next Steps

Conclusion & Questions

Static and dynamic refresh rates

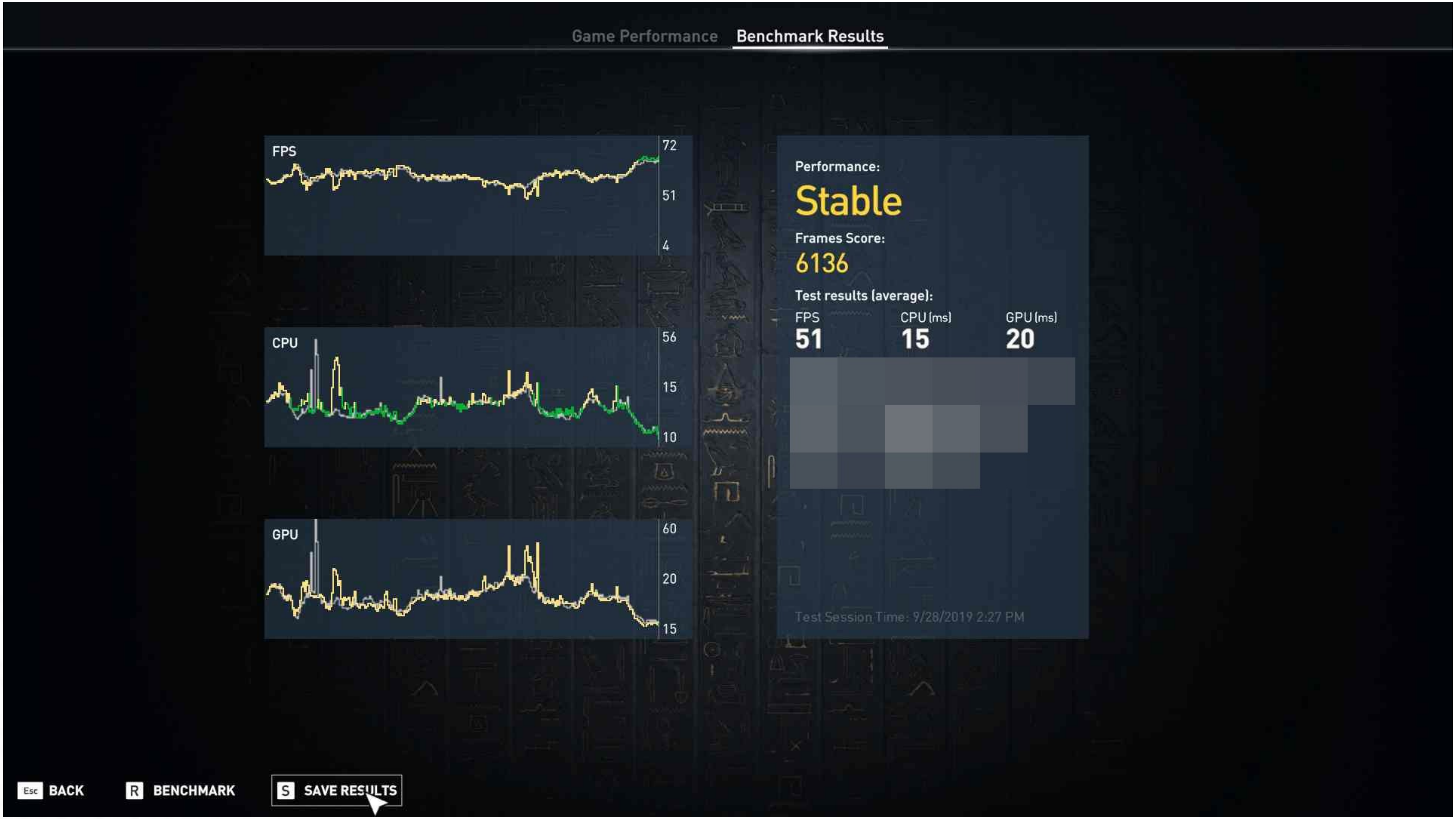


Screenshot saved

Press F1 to switch HUD mode

VSync Off
Dynamic Resolution Off

Frames Score:
5450



Performance:

Stable

Frames Score:

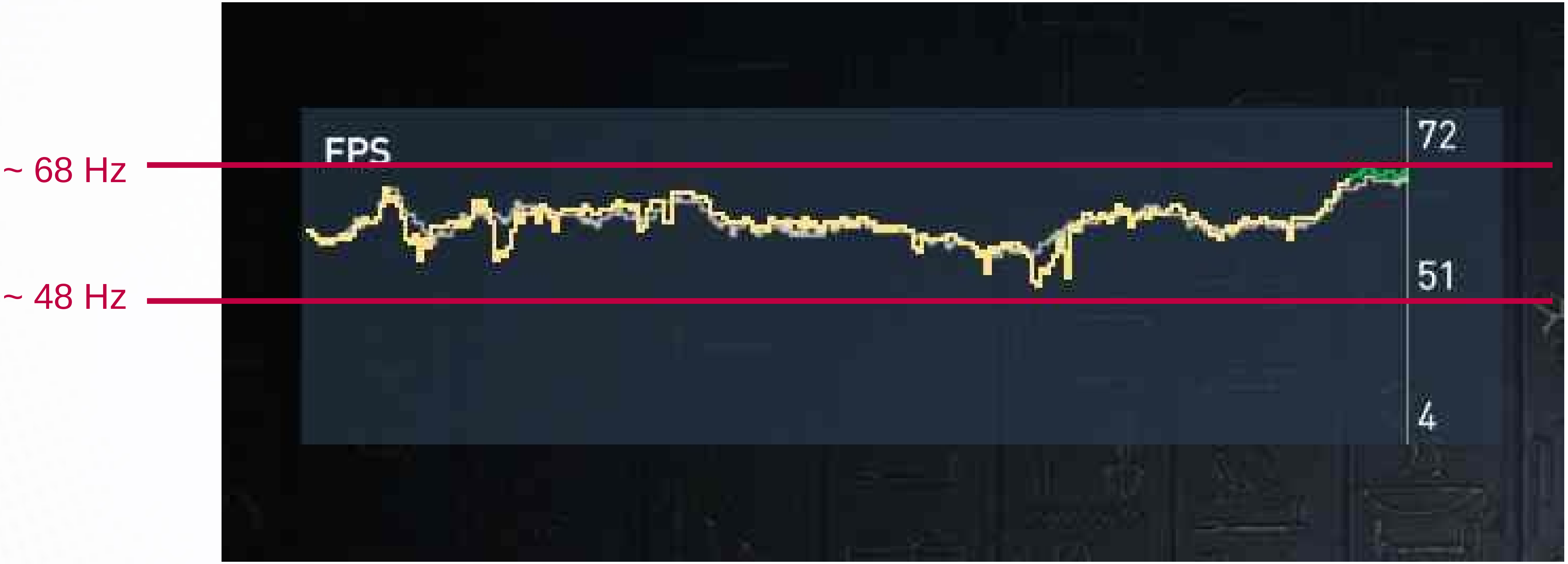
6136

Test results (average):

FPS	CPU (ms)	GPU (ms)
51	15	20

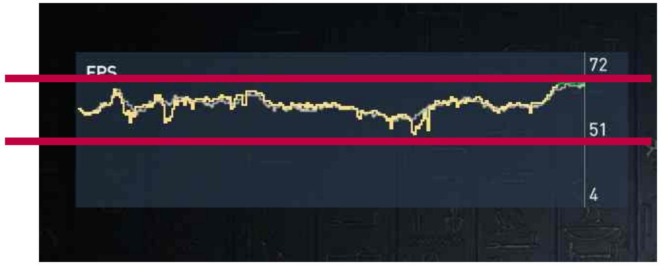
[redacted]

Test Session Time: 9/28/2019 2:27 PM


~ 68 Hz
~ 48 Hz
FPS
72
51
4

Dynamic refresh rates for gaming

- Render rate varies with content
- Latency between render and display matters

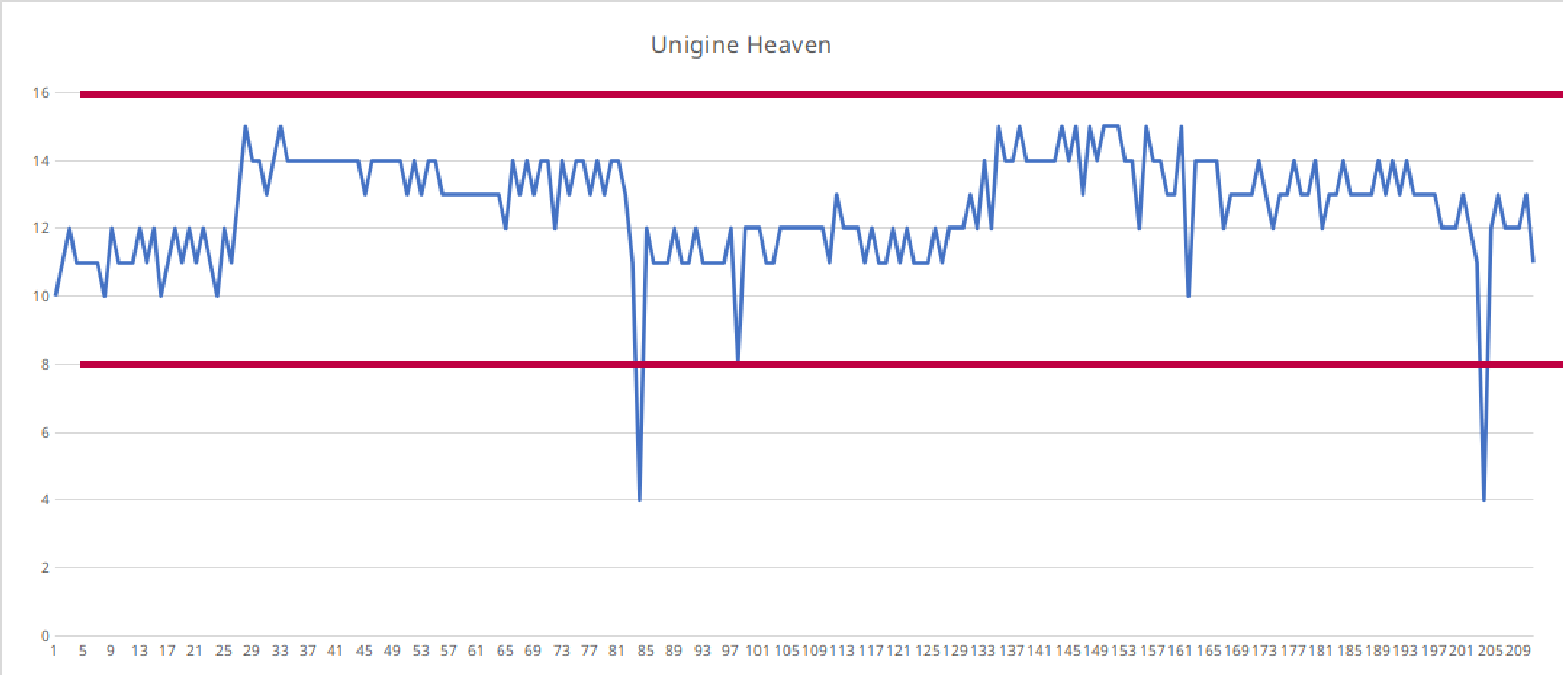


~ 68 Hz

~ 48 Hz

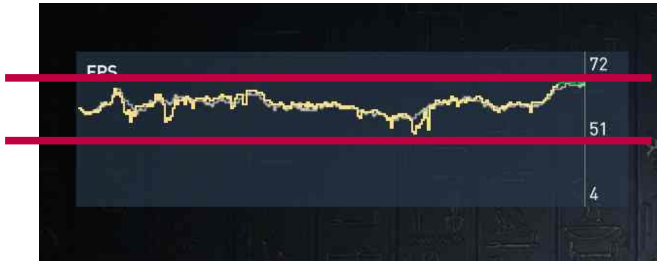
60 Hz

120 Hz



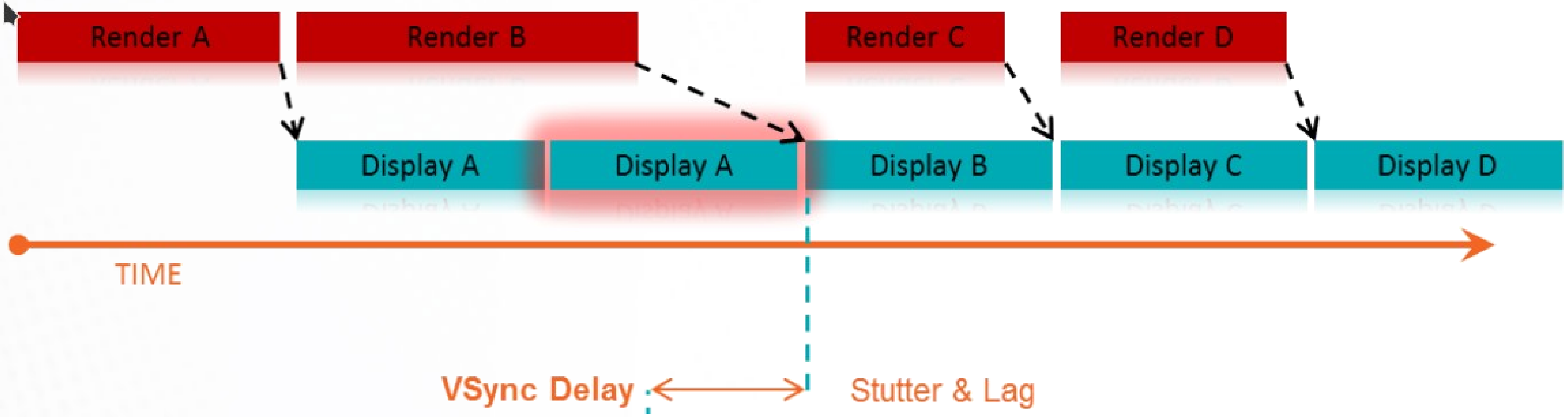
Dynamic refresh rates for gaming

- Mismatch between render rate & refresh rate leads to stutter & lag



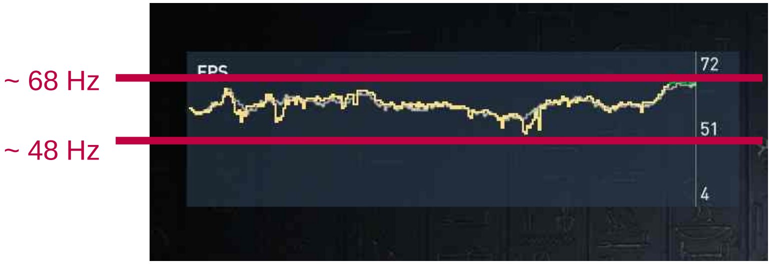
~ 68 Hz

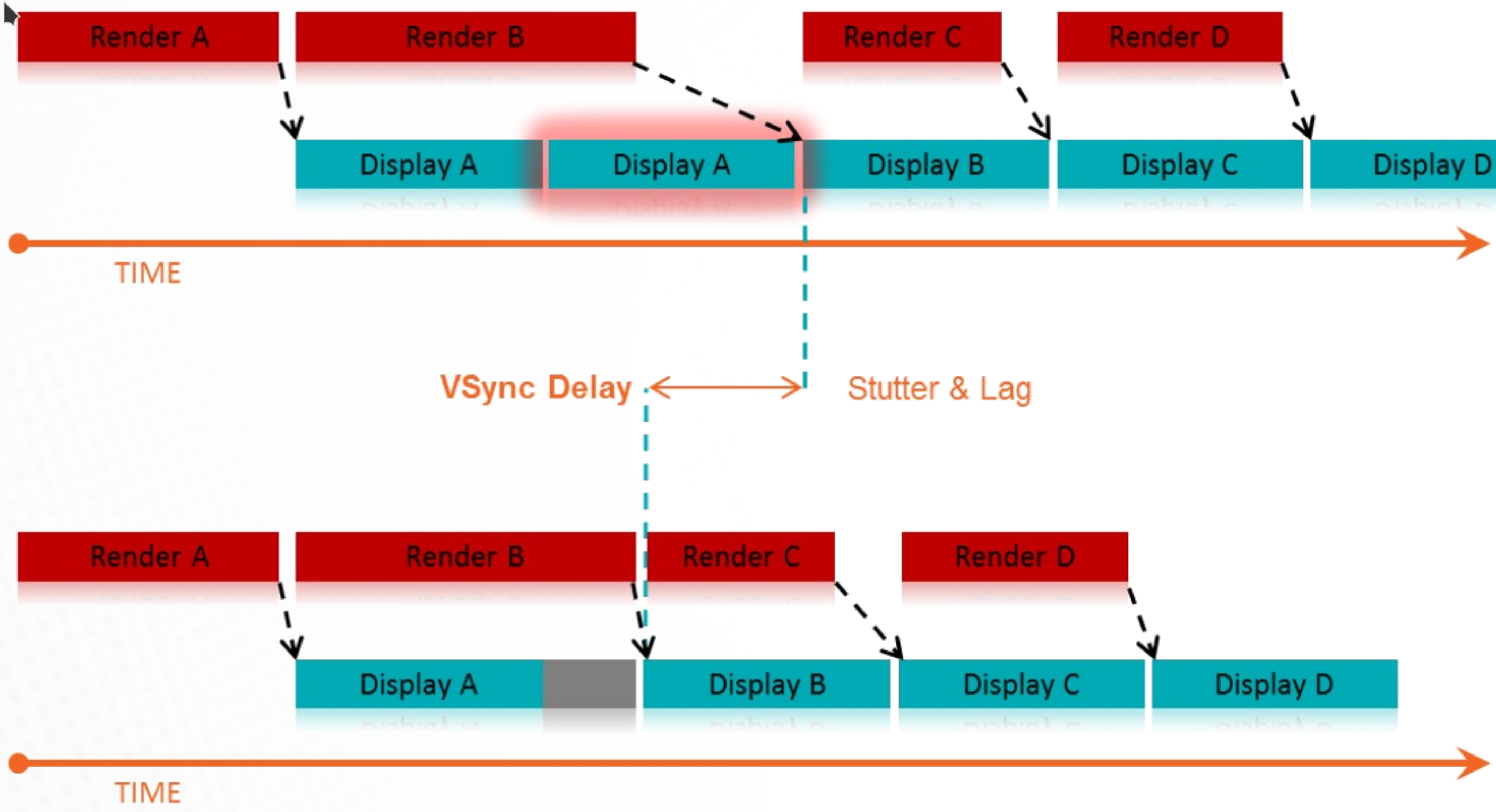
~ 48 Hz



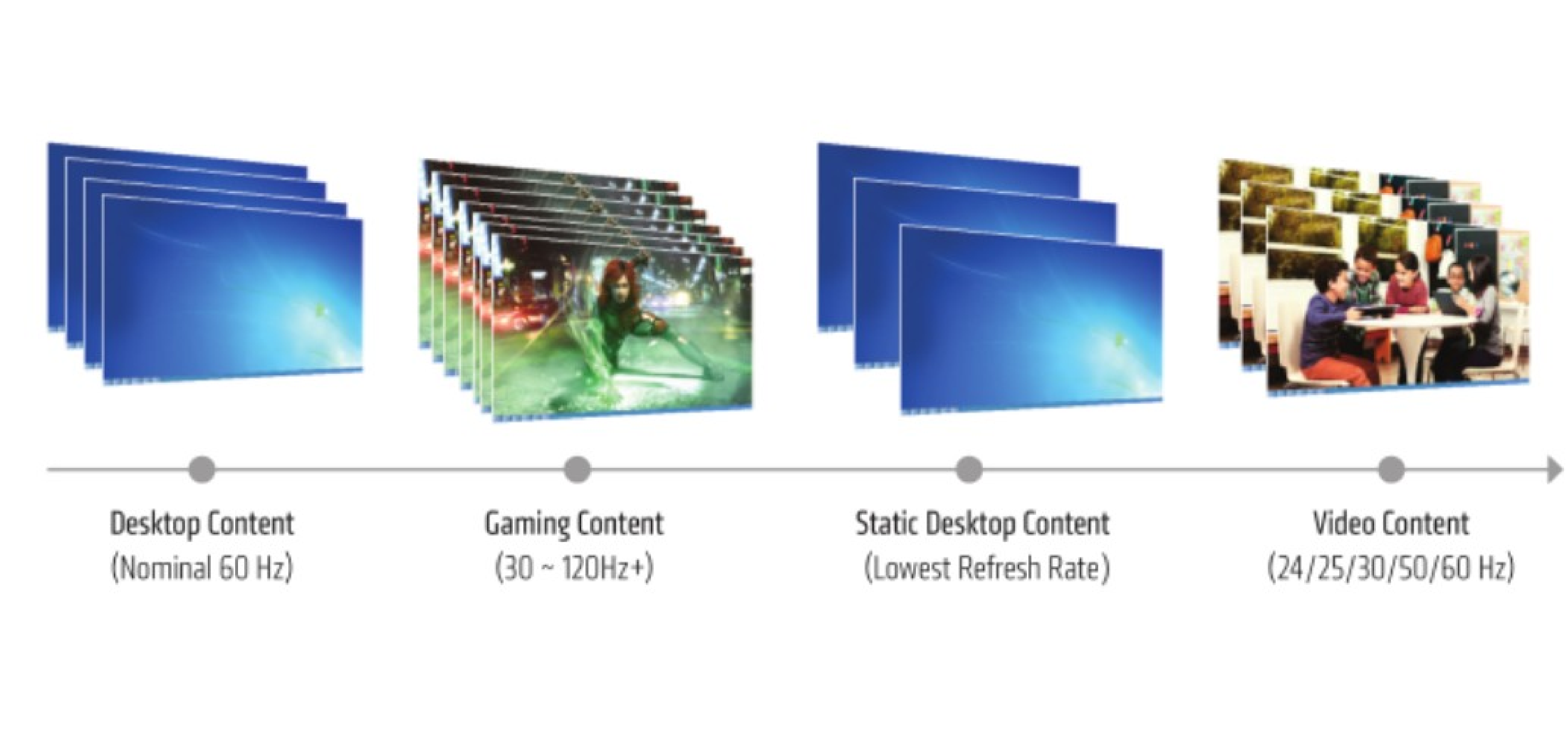
Dynamic refresh rates for gaming

- Syncing render & refresh rates reduces lag and eliminates stutter





Other dynamic refresh rate use cases

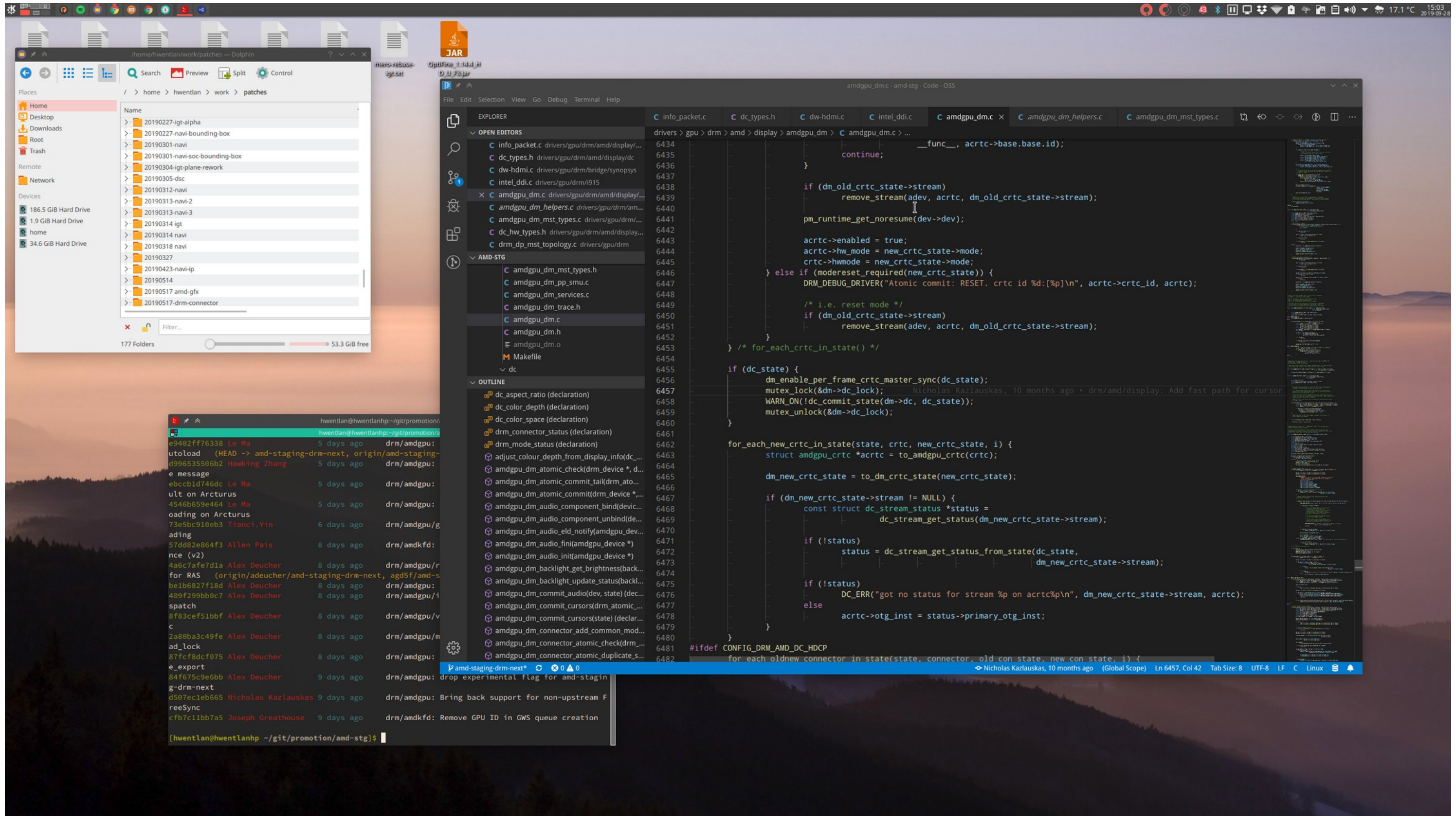


Benefits of Adaptive Sync - Video

- Video frame rates rarely match display refresh rate
- Common video frame rates: 24, 25
- Common display refresh rates: 60, 120
- Would be nice to switch to 24 Hz without a mode change
- With dynamic refresh rates we can seemlessly adjusted to video’s frame rate
- We can save power running at lower refresh rate

Benefits of Adaptive Sync – Power Saving

- Desktop content is mostly static in many cases
- Using adaptive sync system can switch to a lower refresh rate for static content
- Power Savings



/home/hwentlan/work/patches — Dolphin
amdgpu_dm.c - amd-stg - Code - OSS
info_packet.c
dc_types.h
dw-hdmi.c
intel_ddi.c
amdgpu_dm.c
amdgpu_dm_helpers.c
amdgpu_dm_mst_types.c
drivers > gpu > drm > amd > display > amdgpu_dm > amdgpu_dm.c > ...
OUTLINE
amd-staging-drm-next*

```c
                                        __func__, acrtc->base.base.id);
                                continue;
                        }

                        if (dm_old_crtc_state->stream)
                                remove_stream(adev, acrtc, dm_old_crtc_state->stream);

                        pm_runtime_get_noresume(dev->dev);

                        acrtc->enabled = true;
                        acrtc->hw_mode = new_crtc_state->mode;
                        crtc->hwmode = new_crtc_state->mode;
                } else if (modereset_required(new_crtc_state)) {
                        DRM_DEBUG_DRIVER("Atomic commit: RESET. crtc id %d:[%p]\n", acrtc->crtc_id, acrtc);

                        /* i.e. reset mode */
                        if (dm_old_crtc_state->stream)
                                remove_stream(adev, acrtc, dm_old_crtc_state->stream);
                }
        } /* for_each_crtc_in_state() */

        if (dc_state) {
                dm_enable_per_frame_crtc_master_sync(dc_state);
                mutex_lock(&dm->dc_lock);       Nicholas Kazlauskas, 10 months ago • drm/amd/display: Add fast path for cursor
                WARN_ON(!dc_commit_state(dm->dc, dc_state));
                mutex_unlock(&dm->dc_lock);
        }

        for_each_new_crtc_in_state(state, crtc, new_crtc_state, i) {
                struct amdgpu_crtc *acrtc = to_amdgpu_crtc(crtc);

                dm_new_crtc_state = to_dm_crtc_state(new_crtc_state);

                if (dm_new_crtc_state->stream != NULL) {
                        const struct dc_stream_status *status =
                                        dc_stream_get_status(dm_new_crtc_state->stream);

                        if (!status)
                                status = dc_stream_get_status_from_state(dc_state,
                                                                         dm_new_crtc_state->stream);

                        if (!status)
                                DC_ERR("got no status for stream %p on acrtc%p\n", dm_new_crtc_state->stream, acrtc);
                        else
                                acrtc->otg_inst = status->primary_otg_inst;
                }
        }
#ifdef CONFIG_DRM_AMD_DC_HDCP
        for_each_oldnew_connector_in_state(state, connector, old_con_state, new_con_state, i) {
```

```
Nicholas Kazlauskas, 10 months ago   (Global Scope)   Ln 6457, Col 42   Tab Size: 8   UTF-8   LF   C   Linux
```

```
e9402ff76338 Le Ma              5 days ago    drm/amdgpu:
utoload   (HEAD -> amd-staging-drm-next, origin/amd-staging-
d996535506b2 Hawking Zhang      5 days ago    drm/amdgpu:
e message
ebccb1d746dc Le Ma              5 days ago    drm/amdgpu:
ult on Arcturus
4546b659e464 Le Ma              5 days ago    drm/amdgpu:
oading on Arcturus
73e5bc910eb3 Tianci.Yin         6 days ago    drm/amdgpu/g
ading
57dd82e864f3 Allen Pais         8 days ago    drm/amdkfd:
nce (v2)
4a6c7afe7d1a Alex Deucher       8 days ago    drm/amdgpu/r
for RAS   (origin/adeucher/amd-staging-drm-next, agd5f/amd-s
be1b6827f18d Alex Deucher       8 days ago    drm/amdgpu:
409f299bb0c7 Alex Deucher       8 days ago    drm/amdgpu/i
spatch
8f83cef51bbf Alex Deucher       8 days ago    drm/amdgpu/v
c
2a80ba3c49fe Alex Deucher       8 days ago    drm/amdgpu/m
ad_lock
87fcf8dcf075 Alex Deucher       8 days ago    drm/amdgpu:
e_export
84f675c9e6bb Alex Deucher       9 days ago    drm/amdgpu: drop experimental flag for amd-stagin
g-drm-next
d507ec1eb665 Nicholas Kazlauskas 9 days ago   drm/amdgpu: Bring back support for non-upstream F
reeSync
cfb7c11bb7a5 Joseph Greathouse  9 days ago    drm/amdkfd: Remove GPU ID in GWS queue creation

[hwentlan@hwentlanhp ~/git/promotion/amd-stg]$
```

DP Adaptive Sync, HDMI™ VRR, FreeSync™

What is Adaptive Sync

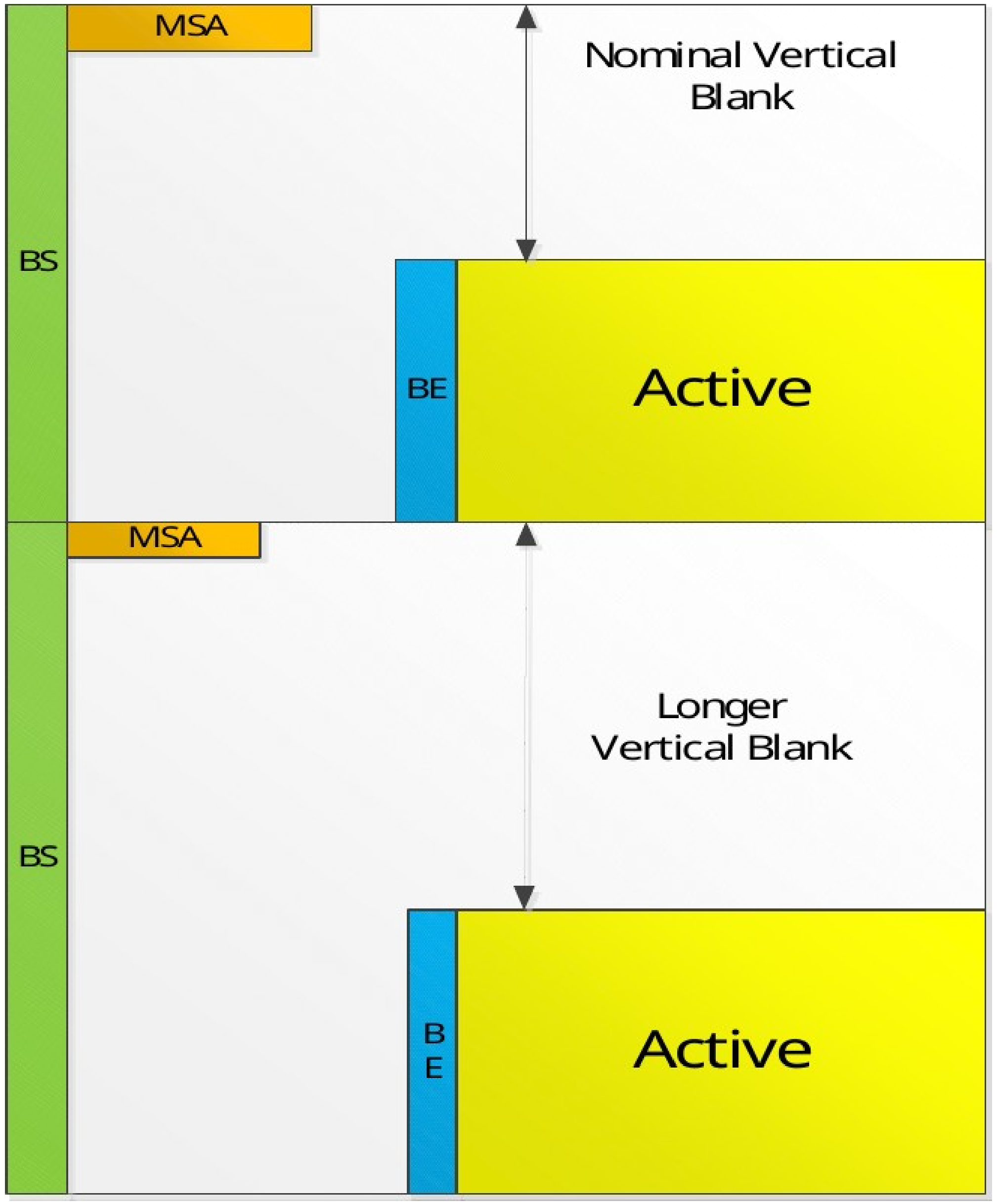
- VESA spec introduced variable refresh rate framework called “ignore MSA” with initial eDP spec
- Rolled out to DP and branded as ‘Adaptive-Sync’ with DP 1.2a in 2014
- Protocol to seamlessly vary framerate by changing blank duration and keeping pixel rate the same
- VESA press release addressed three main use cases
  - Seamless variable frame change for smooth gaming use case
  - Seamless change of frame rate to match video rate for judder free video playback
  - Reduce frame rate for power saving in battery

1) https://vesa.org/featured-articles/vesa-adds-adaptive-sync-to-popular-displayport-video-standard/

How does adaptive sync work?

- Tx (Transmitter) reads range limits from EDID
- When enabling the display
  - Tx writes ignore_msa bit in DPCD
- When user indicates content is suitable for adaptive sync
  - Set up Tx with range limits
  - Tx will extend vertical blank
  - For low latency use case (i.e., gaming) Tx shall end frame immediately once new frame is presented

Adaptive Sync DP Symbols



What is HDMI™ VRR

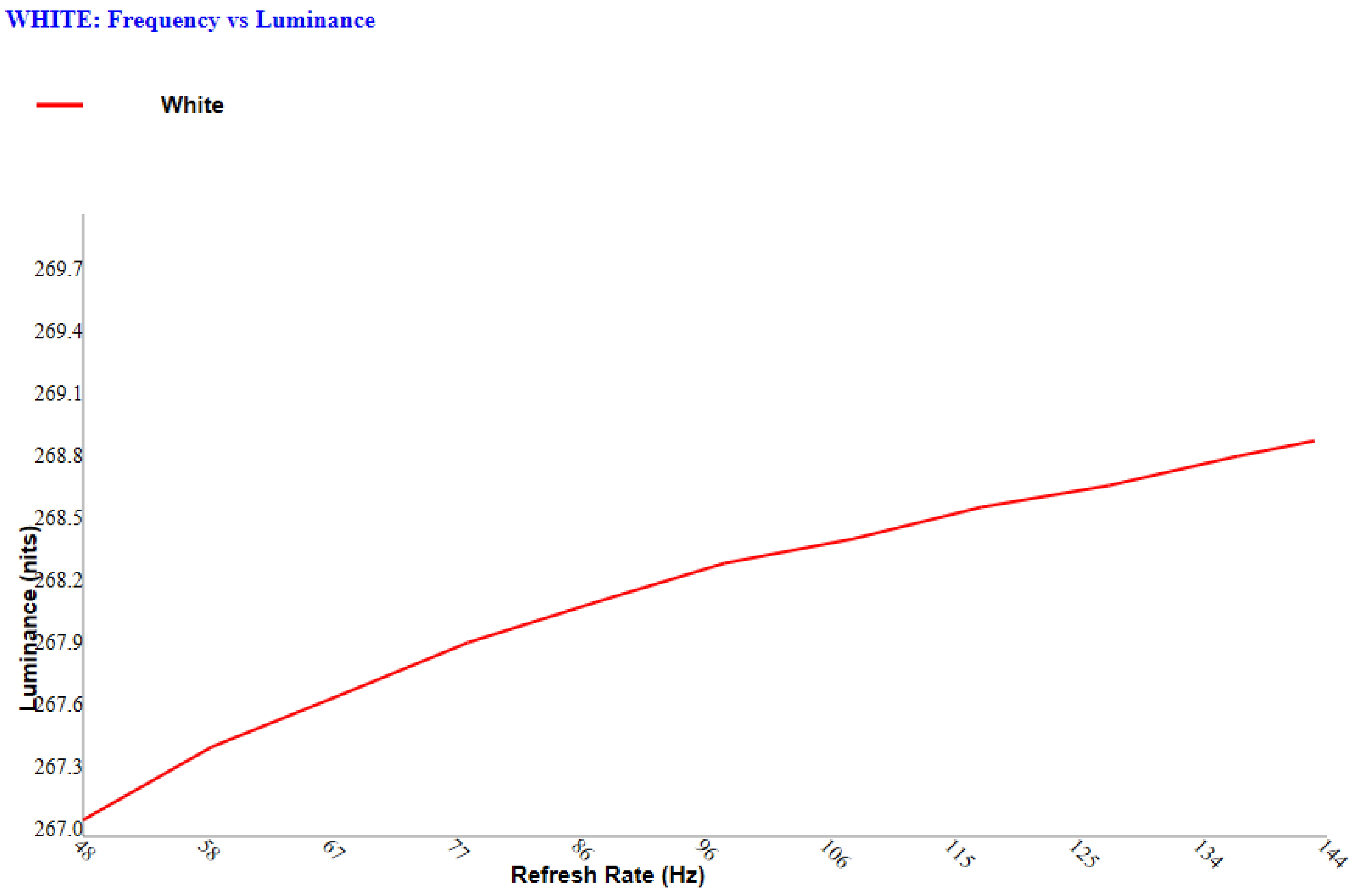
- Part of HDMI™ 2.1 spec
- AMD currently doesn’t enable HDMI™ VRR pending HDMI™ VRR CTS
- AMD enables FreeSync™ on HDMI™ via AMD proprietary protocol (Windows only)

What is FreeSync™

- AMD implementation of adaptive sync and VRR
- DP supported via
  - Adaptive Sync spec
  - Proprietary protocol
- HDMI™ supported via
  - Proprietary protocol
- FreeSync™ certification and logo
- FreeSync™ 2
  - Adaptive sync
  - HDR
  - Stricter certification requirements

Physical Limitations

- Static flicker
  - At very low refresh rates some displays will exhibit flicker due to luminance drop in between frames
- Dynamic flicker
  - When switching between short and long frame durations average brightness changes due to larger luminance drop for longer frames



VRR in DRM & Mesa

DRM/KMS VRR interface

CRTC Property

vrr_enabled

Indicates if variable refresh rate should be enabled for the CRTC. Support for the requested vrr state will depend on driver and hardware capabiltiy - lacking support is not treated as failure.

Connector Property

vrr_capable_property

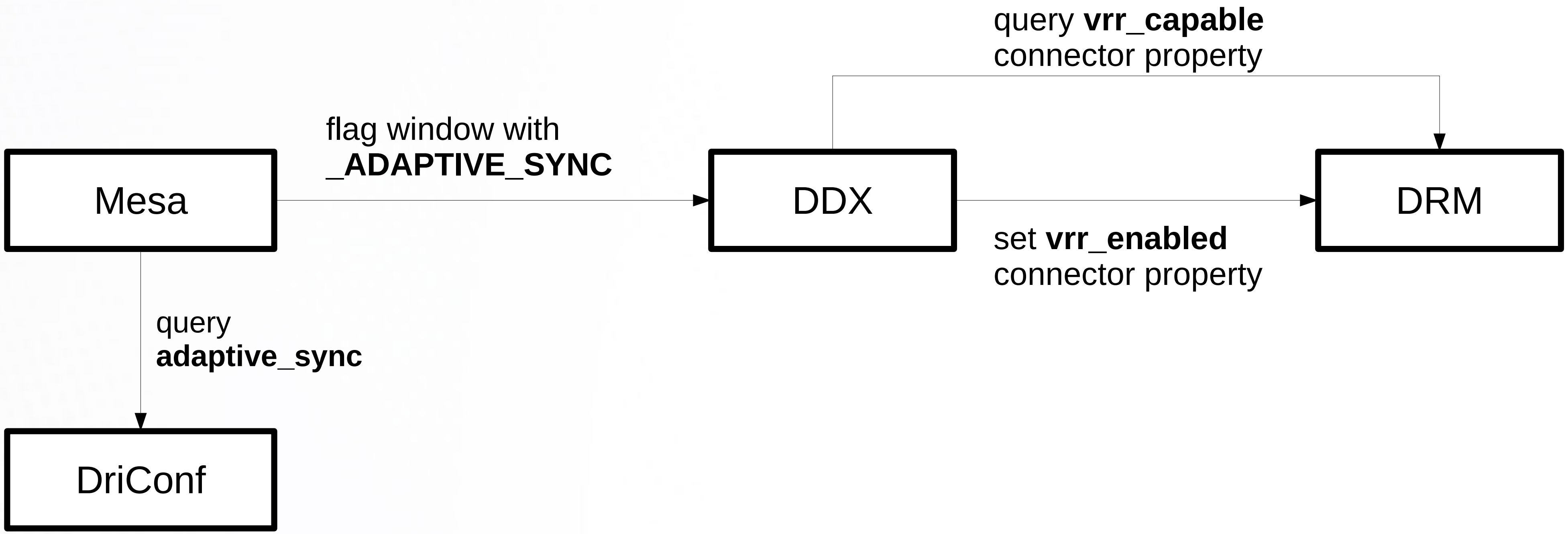
Optional property to help userspace query hardware support for variable refresh rate on a connector. connector. Drivers can add the property to a connector by calling drm_connector_attach_vrr_capable_property().

This should be updated only by calling drm_connector_set_vrr_capable_property().

VRR in Userland (X)

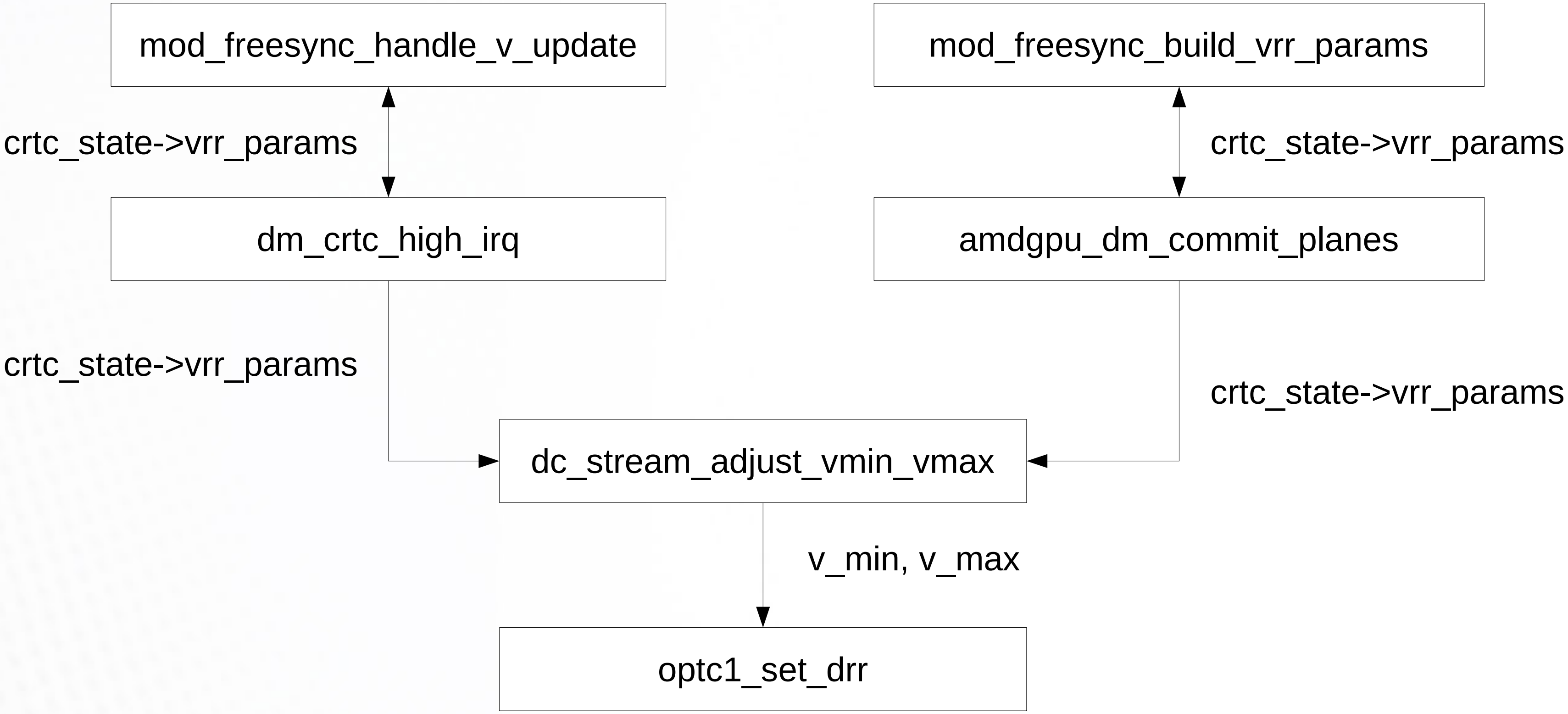
- VRR is supported by
  - radeonsi GL
  - orca GL (proprietary AMD GL driver)
  - radv Vulkan
- A free-running variable refresh rate is not suited for all rendered content, such as current implementations of web browsers, compositors, video players
- Mesa has a blacklist through DriConf for such applications: 00-mesa-defaults.conf
- VRR is enabled for GL/Vulkan rendered applications that use the Present extension and are not blacklisted
- Requires xf86-video-amdgpu
- X doesn’t support present flipping unless the application covers the entire X screen, which means VRR generally won’t enable on multi-monitor setups

VRR with Mesa in X



- Adaptive Sync Patches
  - **Mesa**: https://patchwork.freedesktop.org/series/51388/
  - **xf86-video-amdgpu**: https://gitlab.freedesktop.org/xorg/driver/xf86-video-amdgpu/merge_requests/5
  - **Kernel**: https://patchwork.freedesktop.org/series/49487/

FreeSync™ in DC



Next Steps

Enabling VRR beyond X, what is needed?

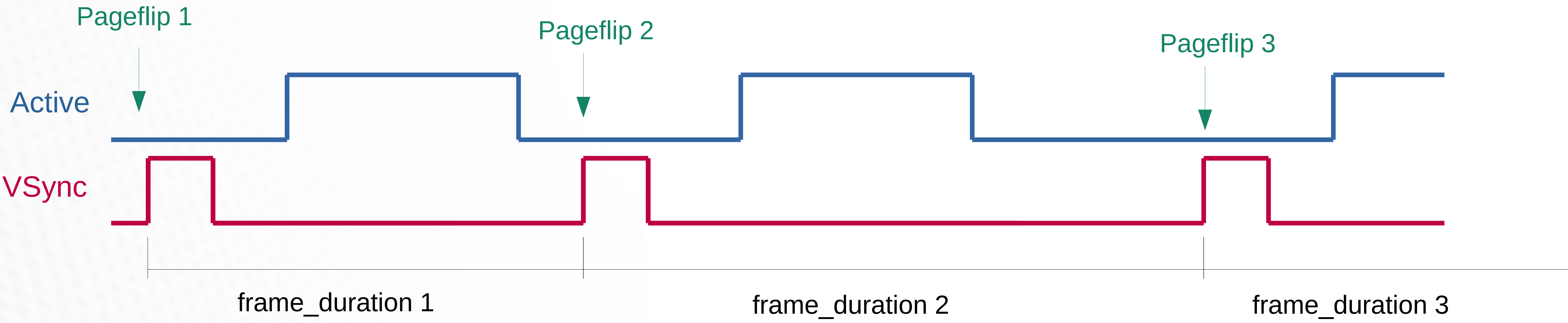
- Currently VRR is only enabled on X
- Good candidates to start adopting VRR would be
  - Wayland
    - Weston
    - Plasma
    - Gnome
  - ChromeOS
  - Etc.
- Looking for community engagement and input here

Enabling more use cases on Linux

- Current solution only covers gaming
- Smooth video playback requires refresh rate to match the content rate
  - With adaptive sync we can dynamically switch the refresh rate without requiring a mode set
- When the desktop is static there is no need to output at full refresh rate
  - Lowering the refresh rate can provide power savings
- Etc…. would love to see what other use cases the community comes up with

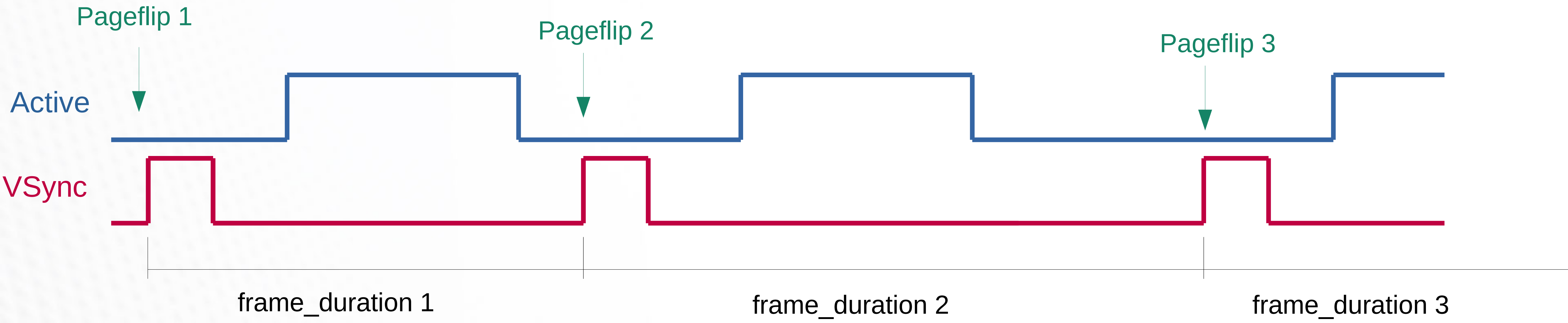
A frame duration time

- DRM/KMS exposes a frame duration time
- If userland provides it the kernel driver will program HW to refresh at rate calculated from frame_duration_time



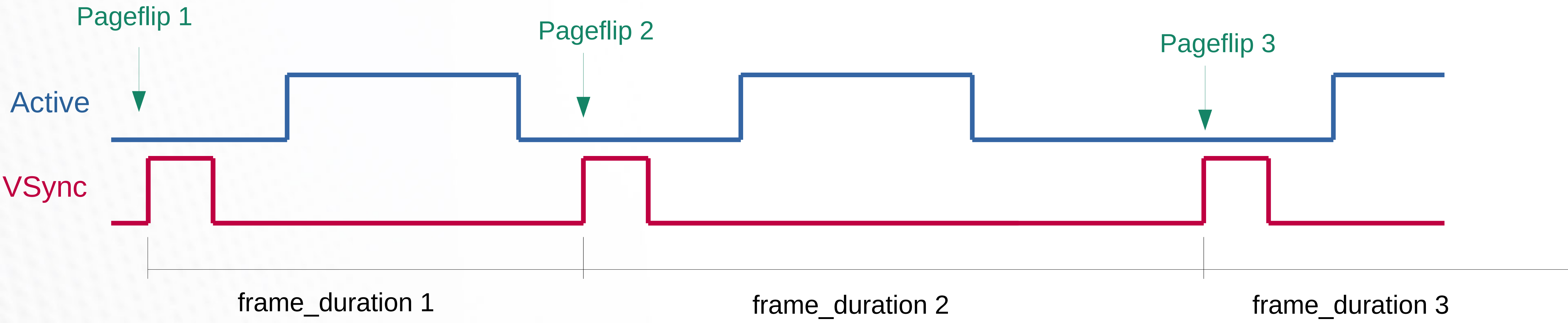
A frame duration time

- Video players can
  - Target the presentation duration, e.g. 1000 / 24 ms
  - Fudge the presentation duration up or down if audio playback drifts
- Compositors can
  - Target a larger presentation time on static screen



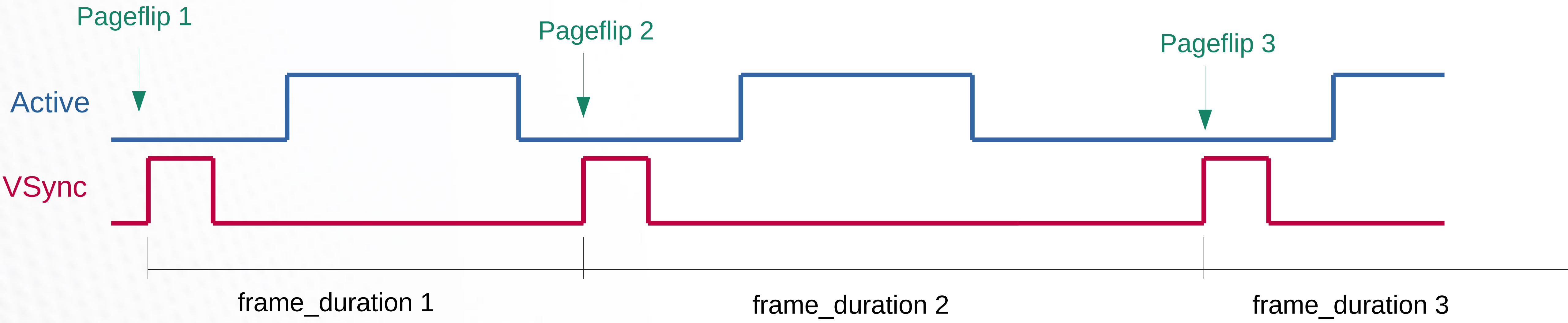
A frame duration time – pros and cons

- Pros
  - Programming length of frame we're submitting → can use HW to adjust frame
  - No need to recalculate frame time every frame for fixed rates
  - No need to calculate frame duration in driver



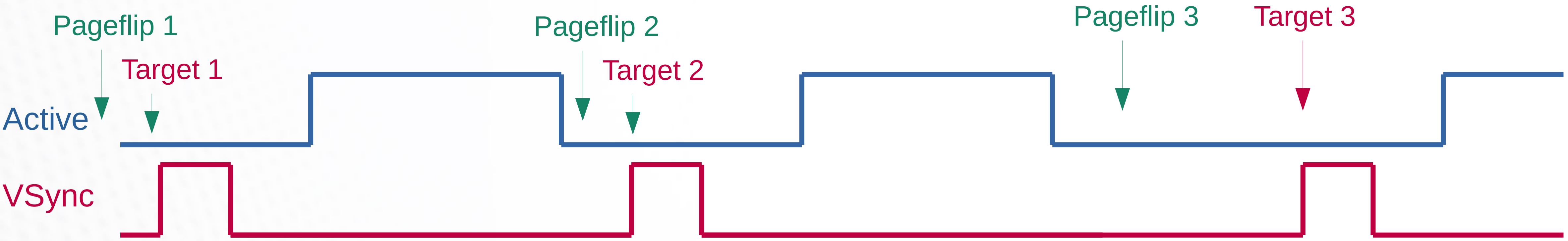
A frame duration time – pros and cons

- Cons
  - Potential for dynamic flicker
  - Userspace has to be aware of frame presentation time (vsync)
  - If flip is programmed too late results won't be as expected



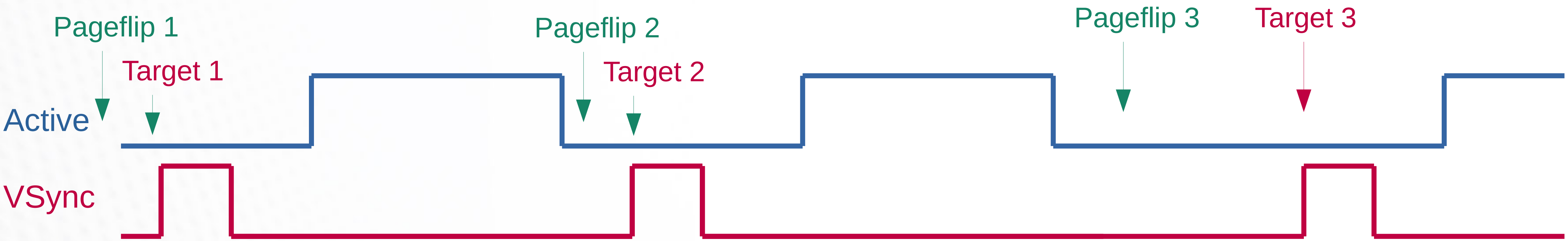
An absolute presentation target

- DRM/KMS exposes an presentation target timestamp
- If userland provides it the kernel driver will program HW in such a way that the start of scanout is no sooner than the timestamp



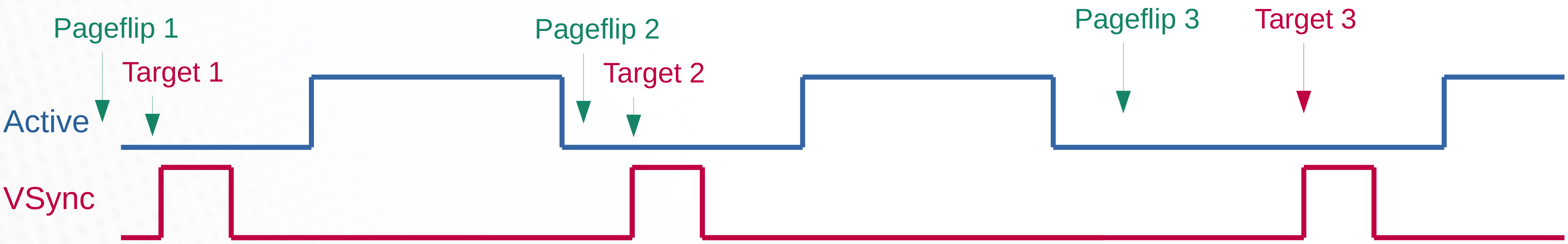
An absolute presentation target

- Video players can
  - Target the presentation time to be current_time_in_ms + (1000/24)
  - Fudge the presentation time up or down if audio playback drifts
- Compositors can
  - Target a larger presentation time on static screen



An absolute presentation target – pros & cons

- Pros
  - Aligns with existing vdpau interface[1] (earliest_presentation_time)
  - Aligns with existing vulkan extension[2] VK_GOOGLE_display_timing
  - Allows SW synchronization of all displays if they all support adaptive sync
  - Userspace doesn't need to be aware of range limits (vmin/vmax) or vsync
  - Might be useful for VR cases

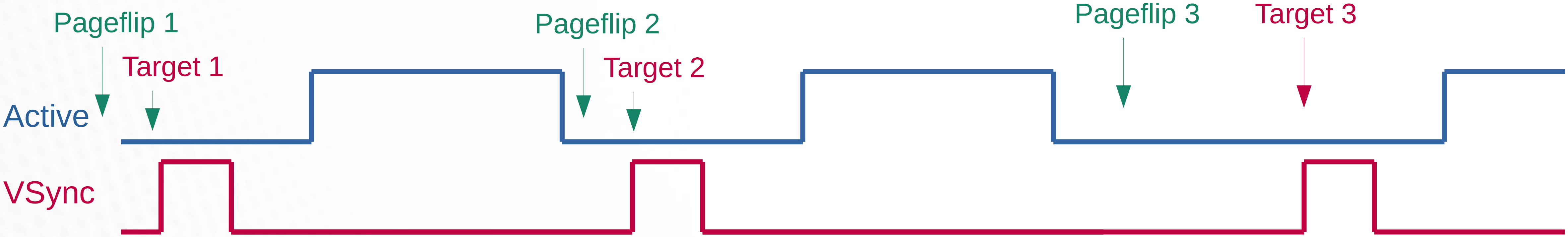


1) https://http.download.nvidia.com/XFree86/vdpau/doxygen/html/group__vdp_presentation_queue.html#ga5bd61ca8ef5d1bc54ca6921aa57f835a

2) https://github.com/KhronosGroup/Vulkan-Docs/blob/master/appendices/VK_GOOGLE_display_timing.txt

An absolute presentation target – pros & cons

- Cons
  - Potential for dynamic flicker
  - Userspace has to calculate new target presentation time with each flip
  - Display can't use HW to target presentation – has to schedule this in SW
  - Need to limit how far in the future presentation target can be



Conclusions

Conclusions

- Dynamic refresh rates greatly improve the gaming experience by reducing
  - Lag
  - Stutter
- There are many displays on the market that support dynamic refresh
- Dynamic/variable refresh rate support is availabe on X
- Wayland compositors still lack support
- A more explicit interface might be useful to enable other use cases

Questions

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