GEARFLOW LAB PRODUCTION SRE RUNBOOK 04 | MACOS WINDOWSERVER + VESA DSC

macOS HiDPI Scaling, 5K2K Backing Store VRAM & DP/TB Bandwidth

Open PPI Calculator ->

Architecture Context: macOS `WindowServer` removed subpixel antialiasing in Mojave and renders fractional UI scales by supersampling an offscreen `2x HiDPI` (`backingScaleFactor = 2.0`) RGBA framebuffer before downsampling to panel timing. Choosing non-integer scaling impacts glyph sharpness, unified memory (UMA) framebuffer allocation, and DisplayPort / Thunderbolt DSC link negotiation.

1. macOS Pixel Density Zones & `WindowServer` 2x Backing Store VRAM Formulas

- **Physical Pixel Density:** `PPI = sqrt(W_native^2 + H_native^2) / Diagonal_inches` (e.g., `5120x2160` at `40.0"` = `138.92 PPI`; `5120x2880` at `27.0"` = `217.57 PPI`).
- **2x HiDPI Backing Framebuffer:** `W_fb = 2 * W_looks`, `H_fb = 2 * H_looks`. At 32-bit RGBA (`4 bytes/px`) with double-buffering (`2x-buf`): `VRAM_2x_buf_MiB = (W_fb * H_fb * 4 * 2) / 1,048,576` -> **40” 5K2K (`5120x2160`) at “Looks like `3840x1620`” renders `7680x3240` = `189.84 MiB` (1x frame) / `379.69 MiB` (`2x-buf`)!**

Panel Class	Native PPI	macOS Scaling Zone	Backing Store & Visual Behavior
`27" 5K` (`5120x2880`) / `32" 6K`	`~218 PPI`	**2x Retina Sweet Spot**	`Looks like 2560x1440` -> `5120x2880` (`1:1` integer pixel mapping, `225.00 MiB` 2x-buf, zero blur).
`27" QHD` (`2560x1440`) / `34" UWQHD`	`~109 PPI`	**1x Non-Retina Zone**	`1:1` native logical size (`2560x1440`), low DPI glyph fringes unless forced to `2x` HiDPI via BetterDisplay.
`40" 5K2K` (`5120x2160` at 120Hz)	`138.9 PPI`	**Fractional 2x Downsample**	`Looks like 3840x1620` -> `7680x3240` backing store (`379.69 MiB` 2x-buf) downsampled `1.5x` to `5120x2160`.
`27" 4K` (`3840x2160` at 120/144Hz)	`163.2 PPI`	**Fractional 2x Downsample**	`Looks like 2560x1440` -> `5120x2880` backing store (`225.00 MiB` 2x-buf) downsampled `1.33x` to `3840x2160`.

2. DisplayPort / Thunderbolt / HDMI Link Payload vs `5K2K 120Hz 10-bit` (`42.81 Gbps` CVT-RBv2)

Interface / Cable Standard	Raw Signaling	Max Data Payload	`5120x2160 @ 120Hz 10-bit` (`42.81 Gbps`) Support
DisplayPort 1.4a (HBR3, 4-lane)	`32.40 Gbps`	`25.92 Gbps`	**Requires VESA DSC 1.2a** (3:1 lossless compression, `14.3 Gbps` stream); capped at 60Hz without DSC.
Thunderbolt 4 (DP 1.4a Tunnel)	`40.00 Gbps`	`25.92 Gbps` (1x DP)	**Requires VESA DSC 1.2a** over single DP 1.4 HBR3 tunnel (Apple Silicon M1 Pro/Max through M4).
HDMI 2.1 (FRL6, 4x 12 Gbps)	`48.00 Gbps`	`42.67 Gbps`	Borderline uncompressed (`42.81 > 42.67 Gbps`); engages DSC 1.2a on M2 Pro+/M3/M4 HDMI 2.1 ports (M1/M2 base HDMI 2.0 = `14.4 Gbps` max!).
Thunderbolt 5 / DP 2.1 (UHBR20)	`80 / 120 Gbps`	`77.37 Gbps`	**Uncompressed Native Fit** (`42.81 < 77.37 Gbps` on M4 Pro / M4 Max TB5 with certified UHBR20 sink).

3. macOS Font Dilation (`CGFontRenderingFontSmoothingDisabled`) & HiDPI Verification CLI

On `109-140 PPI` external displays, macOS synthetic stem dilation (`AppleFontSmoothing`) makes terminal monospace fonts look overly bold or muddy. Tune and verify active `WindowServer` framebuffer dimensions with these reversible commands:

```
# 1. Inspect live physical pixel output vs UI "Looks like" HiDPI resolution & Retina status
system_profiler SPDisplaysDataType | grep -E "Resolution|UI Looks like|Retina|Mirror|Connection Type"

# 2. Disable heavy synthetic glyph stem thickening on 110-140 PPI external monitors (log out/in to apply)
defaults -currentHost write -g AppleFontSmoothing -int 0
defaults write -g CGFontRenderingFontSmoothingDisabled -bool YES

# 3. Alternative light smoothing (value 1) or full factory reset to macOS Sonoma/Sequoia defaults
defaults -currentHost write -g AppleFontSmoothing -int 1
defaults write -g CGFontRenderingFontSmoothingDisabled -bool NO
# Factory reset: defaults -currentHost delete -g AppleFontSmoothing && defaults delete -g
CGFontRenderingFontSmoothingDisabled
```

Quick Prefill Presets: 40” 5K2K 120Hz 10-bit | 27” 4K 144Hz 10-bit | 27” QHD 120Hz Non-Retina | All GearFlow Lab Engineering Tools (/tools/)