

LG Electronics

EP950 UltraFine OLED Pro Monitor Best Practices and Additional Usage Information

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Neil Robinson –LG Electronics, Zenith R&D

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Source Device Interoperability

The EP950 displays are factory calibrated to a high level of accuracy for all picture modes when used as a stand-alone device. All displays however, need to be connected to an active source device to render an image, and matching the configuration of the source device to the expected colour space of the display is critical to achieving an accurate colour response.

Signal Range

Matching the source device and display signal range is extremely important, and should be considered the first step in ensuring a correct configuration. 'Pluge', 'Brightness', and 'Contrast' patterns can help provide a visual indication that the correct configuration has been set.

The signal range configuration on the EP950 displays is performed using the 'Input Range' section of the user menu. **The Brightness and Contrast controls should not be used to configure the signal range.** If highlights and / or shadows are crushed, investigate the Input Range setting on the display and the equivalent settings on the source device first.

Colour Space

The EP950 has pre-set picture modes for many common colour spaces used for content creation. As with signal range, it is essential to ensure that the video data output from the source device is encoded in the same colour space that has been configured in the display.

For the most accurate colour response with content creation software such as DaVinci Resolve, Final Cut Pro, Foundry Nuke etc. LG recommends the use of a dedicated hardware video output device from manufacturers such as BlackMagic Design and AJA to eliminate additional superfluous signal processing by the host OS, and ease configuration of the output format to match the display.

Use with macOS¹

macOS is a fully colour managed operating system, and as such, is able to handle colour mapping from a diverse range of colour spaces to ensure accurate colour for all applications on screen at the same time. In order to achieve this, macOS needs accurate information for the target colour space that the display is expecting.

macOS uses ICC profiles to describe the display colour space, which are either automatically generated by macOS based on EDID data received from the display on connection, or can be manually applied by the user through the macOS ColorSync application.

The EP950 models support a number of different display colour spaces, and this can result in a mis-match between the colour space expected by the display, and the colour space output by macOS. For SDR picture modes, this mis-match can be corrected by manually applying an ICC profile to match the selected display picture mode, or by applying an EDID override that contains data to match the selected display picture mode². At this time, ICC does not support

HDR colour spaces, and therefore an EDID override matching the selected display picture mode is the only viable solution to ensure accurate HDR rendering.

LG has created a set of ICC profiles that describe the industry standard SDR colour spaces^{3 4} supported by the EP950 picture modes which can be used to configure macOS colour management when rendering SDR content on both Intel and M1 based Mac computers. Additionally, LG has created EDID override files which may also be used to configure macOS colour management when rendering SDR content, and these EDID override files are currently the only way of configuring macOS to accurately render HDR content. Unfortunately, at this time, EDID override functionality only works on Intel based Macs, and does not work on M1 based Macs.

Details for the use of ICC profiles and EDID overrides in macOS can be found with all necessary files at the following link [TBD].

For HDR rendering, macOS defines two approaches called ‘Display Techniques’ for application developers, details of which can be found in the Developer article linked [here](#). The major difference between these approaches is if the developer wishes macOS to perform automated tone mapping, or if the developer wishes to make their own decisions regarding tone mapping.

When following the above recommendations using the appropriate EDID override¹ file to match the selected display picture mode, accurate colour response for SDR and HDR can be achieved with macOS, with the following caveats when rendering HDR. These caveats are not specific to use with the EP950, and are behaviours exhibited by macOS:

HDR Behaviour in macOS

	Intel Based Macs HDMI connections	Intel Based Macs DisplayPort / USB-C connections	M1 Based Macs DP / USB-C & HDMI connections
General considerations	<ul style="list-style-type: none"> macOS always uses BT.2020 colour space in HDR mode; the P3D65 PQ HDR mode will not be accurate even with an EDID override 	<ul style="list-style-type: none"> None 	<ul style="list-style-type: none"> M1 based Macs do not support EDID override functionality macOS always uses BT.2020 colour space in HDR mode SDR peak luminance level is fixed at 200nits peak with no means of adjustment
Application Tone Mapping , e.g. <ul style="list-style-type: none"> DaVinci Resolve Foundry Nuke Final Cut Pro 	<ul style="list-style-type: none"> All data below 0.002 nits is crushed to black Poor low luminance quantisation 		<ul style="list-style-type: none"> PQ rendering tracks at 2.0x standard with no means of adjustment
System Tone Mapping , e.g. <ul style="list-style-type: none"> QuickTime 	<ul style="list-style-type: none"> All data below 0.005 nits is crushed to black PQ rendering tracks higher than standard from 0 ~ 8% PQ rendering tracks lower than standard from 8 ~ 30% Poor low luminance quantisation 	<ul style="list-style-type: none"> All data below 0.005 nits is crushed to black PQ rendering tracks lower than standard from 10 ~ 30% Poor low luminance quantisation 	<ul style="list-style-type: none"> PQ tracking is excellent without any highlight compression or scaling, but the output signal clips at ~7,000nits

Based on these caveats, at this time, there is no way to achieve an accurate response at all luminance levels in macOS. A reasonable level of accuracy down to 0.005 nits can be achieved with Intel based Macs with applications performing their own HDR processing. Unfortunately,

at the time of writing, M1 Macs render HDR luminance at 2.0x the standard with these kinds of applications, and we are unaware of any way to change this behaviour.

LG is actively working with Apple on an improved approach to ensure automated configuration and accurate rendering for all supported SDR and HDR colour spaces when the EP950 is used with macOS.

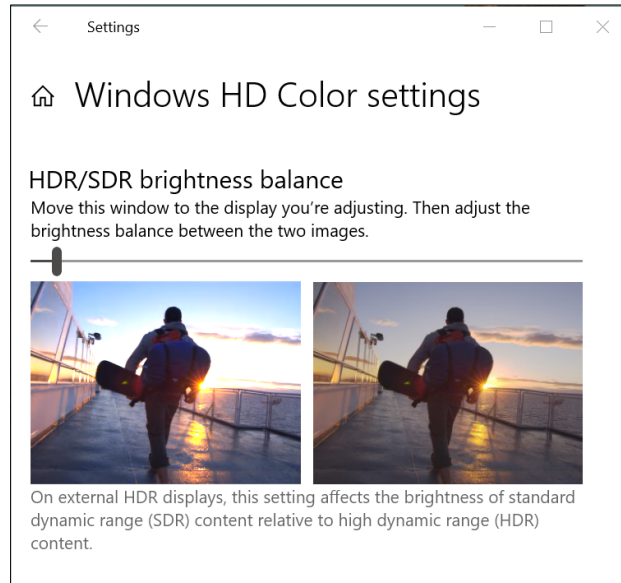
Use with Windows

Windows currently relies on applications to implement their own colour management, with much of the OS working under the assumption that the connected display renders the sRGB colour space. As a result, accurate colour across the entire desktop is only possible on Windows when the display is operating in sRGB mode. The EP950 models feature an sRGB accurate picture mode, and this is therefore the suggested EP950 mode of operation in SDR for Windows.

If you would like to make use of the wider colour gamut capabilities of the EP950 display, other picture modes may be used, and applications which support colour management may be able to render accurate colour when configured with an ICC profile to match the selected display picture mode. Details for the use of ICC profiles and all necessary files can be downloaded at the following link [TBD]. Please note that the Windows desktop and most Windows applications are not colour managed, and using any picture mode other than sRGB will therefore over-saturate colours.

When HDR is enabled in Windows, the colour space encoding is always BT.2020 with a PQ (ST 2084) EOTF. The BT.2100 PQ HDR picture mode is therefore the only picture mode that should be used on the EP950 for HDR in Windows. Depending on the application, highlight compression tone mapping may be applied, but no additional scaling of the HDR signal is performed and the PQ EOTF is tracked correctly.

When operating in HDR mode in Windows, SDR content, which makes up the majority of applications and content, is accurately mapped in to the PQ EOTF output to the display, and scaled in luminance according to the 'HDR/SDR brightness balance' slider control in the 'Windows HD Color Settings' window⁵ (shown below).



Windows 10 HD Color Settings 'HDR/SDR brightness balance' slider

Setting this slider control all the way to the left, will render SDR content with a peak luminance of 80nits, the standard for sRGB. A setting of '4' will render SDR content with a peak luminance of 100nits, the standard for SDR video⁶. Values greater than a setting of '4' will increase the peak luminance of SDR content above the standards for these colour spaces.

Source Device Interoperability Notes

1. Information on macOS in this section was accurate at the time of writing, with macOS 11.2.3 Big Sur on Intel and M1 platforms. Apple is continuously updating and improving macOS, and their hardware, so changes to this status are expected. LG will continue to update this document while relevant to reflect changes in EP950 behaviour, but cannot guarantee the continued accuracy of information relating to third party hardware and software.
2. Apple does not officially support the use of EDID override files, and could therefore disable or change this functionality at any time. Additionally, M1 based Macs do not make use of the necessary sections of the EDID override files used for this configuration approach.
3. macOS includes ICC profiles for Rec. ITU-R BT.709-5 and Rec. ITU-R BT.2020-1, but these profiles describe a different interpretation of the standards than that commonly used in the content creation industry, and used by the EP950. These ICC profiles should not be used with the EP950; please use the appropriate ICC profile or EDID override provided by LG
4. macOS includes an ICC profile for 'Display P3', which describes a colour space with P3 primaries, D65 white point, and an sRGB transfer function. This ICC profile should not be used with the EP950 P3D65 picture mode, because the standard display colour space expected by this picture mode uses the 2.6 power transfer function commonly used for theatrical content production which is different from that used in the Apple provided 'Display P3' ICC profile; please use the ICC profile or EDID override provided by LG
5. The human visual system is able to adapt to different diffuse white luminance levels, but will also often prefer brighter rendering. Whilst it might be tempting to move the 'HDR/SDR brightness balance' slider to the right to achieve a brighter overall desktop image, the difference in visual impact between SDR and HDR relies on there being a significant difference in dynamic range between SDR and HDR. Setting the SDR luminance level higher than the 80nit or 100nit standards will result in HDR

content looking dim and flat in comparison to Windows desktop SDR elements, and may also fail to preserve the creative intent of the SDR content shown on screen (see below).

6. *The ITU-R BT.2408 document describes a reference (i.e. diffuse) white level for HDR content of 203 nits. It might seem logical therefore to render SDR content at 203 nits peak, by simply scaling the luminance. Recent research suggests that this approach does not preserve the ‘look’ and ‘creative intent’ of SDR content. In addition, despite ITU recommendations, most theatrical and episodic HDR content does not have a diffuse white level of 203 nits. The diffuse white level in such content usually changes from scene to scene, and is far closer to the typical diffuse white level of SDR content of between 80 and 100 nits at most. LG therefore suggests setting the SDR peak luminance at SDR standards based levels using a value of < 4 on the ‘HDR/SDR brightness balance’ slider.*

Performance

APL Curve

Like most self-emissive displays, the EP950 models reduce luminance to meet maximum limits for on-screen average picture level, APL.

An ideal display should have a stable, consistent, predictable response to APL. When operating in SDR picture modes, the EP950 is able to maintain such a stable, consistent, predictable response at all APL levels.

When operating in HDR picture modes, the EP950 will maintain a stable, consistent, predictable response from the lowest APL level, such as a single illuminated pixel on a black screen, up to the APL limitation of the panel determined by the ‘Peak Luminance’ setting in the user menu as shown below:

- SDR Modes (< 250nits) – Totally flat APL response
- HDR Normal (~400nits peak) – Flat APL response from 0 ~ 75% APL
- HDR High (~540nits peak) – Flat APL response from 0 ~ 50% APL

The EP950 models illuminate the power LED in amber as a real time automatic brightness limiter (ABL) Indicator to signal to the user that APL dimming is occurring with the content currently shown on screen. The brightness of this indicator can be controlled in the user menu.

Calibration

The EP950 displays are factory calibrated to a high level of accuracy for all picture modes, pre-configured as shown below:

	sRGB	BT.709	BT.2020	P3D65	AdobeRGB	P3D65 PQ	BT.2100 PQ
RGB Primaries	sRGB	BT.709	BT.2020	P3	AdobeRGB	P3	BT.2020
White Point	D65 (0.3127x, 0.3290y – CIE 1931 2° standard observer)						
Transfer Function	2.2 Power ¹	2.4 Power	2.4 Power	2.6 Power	2.2 Power	ST 2084 (PQ)	ST 2084 (PQ)
Peak Luminance	80 nits	100 nits	100 nits	48 nits	160 nits	Set with ‘Peak Luminance’ UI Setting	

In addition to these factory calibrated picture modes, a further two picture modes are provided to allow for additional configuration.

The 'Custom' picture mode features no factory calibration at all, and therefore provides the panel native response. This can be further customised using the on-screen controls, but cannot be calibrated using end user calibration software.

The 'Calibration' picture mode is inactive initially, and is activated by end user calibration software. The targets for calibration of this picture mode can be completely customised to target any arbitrary colour space.

[LG Calibration Studio](#)

LG Calibration Studio is a software package available for Windows and macOS for automatically calibrating the display.

LG Calibration Studio works with many common colour measurement devices including, but not limited to the Colorimetry Research CR100, Klein Instruments K10-A, X-Rite i1DisplayPro, X-Rite i1Pro2, Gamma Scientific GS1160B.

At the time of writing, all SDR picture modes can be calibrated using LG Calibration Studio, with custom targets for white point, peak luminance and transfer function possible for all picture modes with pre-defined colour gamuts (sRGB, BT.709, BT.2020, P3-D65 and AdobeRGB), and custom targets for white point, peak luminance, transfer function and colour gamut for the 'Calibration' picture mode.

[Portrait Displays Calman](#)

LG is working with Portrait Displays to bring the power, functionality and flexibility of Calman calibration to the EP950. Calman support is expected at or very soon after EP950 availability in the market.

Menu Structure

The menu is accessed using the joystick nub control located in the bottom center of the display bezel. Clicking the joystick in displays the initial quick access menu, with 'Power Off' an up / back press, access to the full 'Settings' menu to the right, the 'Input' menu to the left, and a configurable quick access item defaulting to 'Picture Mode' down / forward.

Moving to the full 'Settings' menu provides three sub-menus: Input, Picture and General. The function of each of the controls in these menus is detailed below.

Input

Input List

Selection of the active input - USB-C, DisplayPort 1, DisplayPort 2, and HDMI

Aspect Ratio

Three settings for aspect ratio are defined, and these have different scaling behavior (when required) based on the input signal resolution. The table below shows this behaviour in detail:

	Full-Wide	Original	1:1
UHD	No scaling Required; signal matches display resolution		
HD (1920x1080)	Bicubic		Nearest Neighbour
DCI 2K (2048x1080)	Fit to screen	Bicubic + Letterbox	Nearest Neighbour + Center Crop
DCI 4K (4096x2160)	Fit to screen	Letterbox	Center Crop
Other 16:9	Bicubic		True 1:1 centered
Other non 16:9	Fit to screen	Letterbox / Pillarbox	True 1:1 centered

Input Range

The input range setting is used to configure the display to match the signal range used. 5 options are provided:

- Auto – Automatically sets between ‘Narrow’ and ‘Full’ range based on HDMI / DP InfoFrame signaling when present¹
- Narrow² - 10b 64-940
- Super White³ - 10b 64-1019
- Full² - 10b 0-1023
- SDI Range⁴ - 10b 4-1019

Input Settings Notes

1. Unfortunately, many source devices do not set the signal range bit at all, or set it incorrectly, resulting in undefined Auto behaviour
2. The terms 'Narrow' and 'Full' have been used because they are the terms defined in recent ITU documents. Many terms for this ITU 'Narrow' Range exist in common parlance, including SMPTE Range, Limited Range, Legal Range, Head Range etc.
3. Super White is a concept widely used in broadcast globally, where some highlight details remain in the region above 100% stimulus. In this mode, values between 100% [10b 940] and 109% [10b 1019] are preserved, values < 0% / 10b 64 (sub-black) however, are not
4. Many SDI sources can be configured to use 'Full' Range, but the SDI interface does not support true 'Full' range. It is important to understand if the SDI source attempted to fit a true 'Full' Range signal on to the SDI interface by scaling the signal to the maximum available range of 4-1019, or if the SDI source simply puts the signal to the SDI interface without scaling, cropping off the upper and lower values; The EP950 provides options for both configurations

Picture

Picture Mode

Allows selection of the picture mode. For details of the picture modes and the calibration targets used in the factory calibration, refer to the Performance sub-section on Calibration.

A 'Custom' picture mode is provided which is not factory calibrated, and is therefore set to panel native primaries, white point, transfer function (2.2 Power) and peak luminance. This picture mode can be fully customised using the UI system described below.

Finally, a 'Calibration' picture mode is provided which allows for custom calibration by end user software and a colour measurement probe; for more details, see the Performance sub-section on Calibration. Note that this picture mode cannot be selected until after it has been calibrated using such software; attempting to select this picture mode will result in the 'Custom' picture mode being activated.

Brightness

the Brightness control is a panel gain adjustment, allowing control of the peak luminance output of the display without sacrificing signal code values. This control can be thought of as equivalent in function to an LCD 'Backlight' control, or the 'OLED Light' control on LG OLED TVs.

In SDR picture modes, this setting is factory calibrated to achieve the peak luminance required for the picture mode, but can be adjusted by the user. In HDR picture modes, this setting will typically be set to 100 to achieve the highest peak luminance possible

This control is different from 'Brightness' controls found on some broadcast moniotrs where the lack leve is adjusted

Gamma (EOTF)

The Gamma setting may be adjusted in all picture modes from the defaults shown above. Power function EOTFs with varying gamma in 0.2 increment steps from 0.2 to 2.6 are provided, as well as the PQ (ST 2084) EOTF

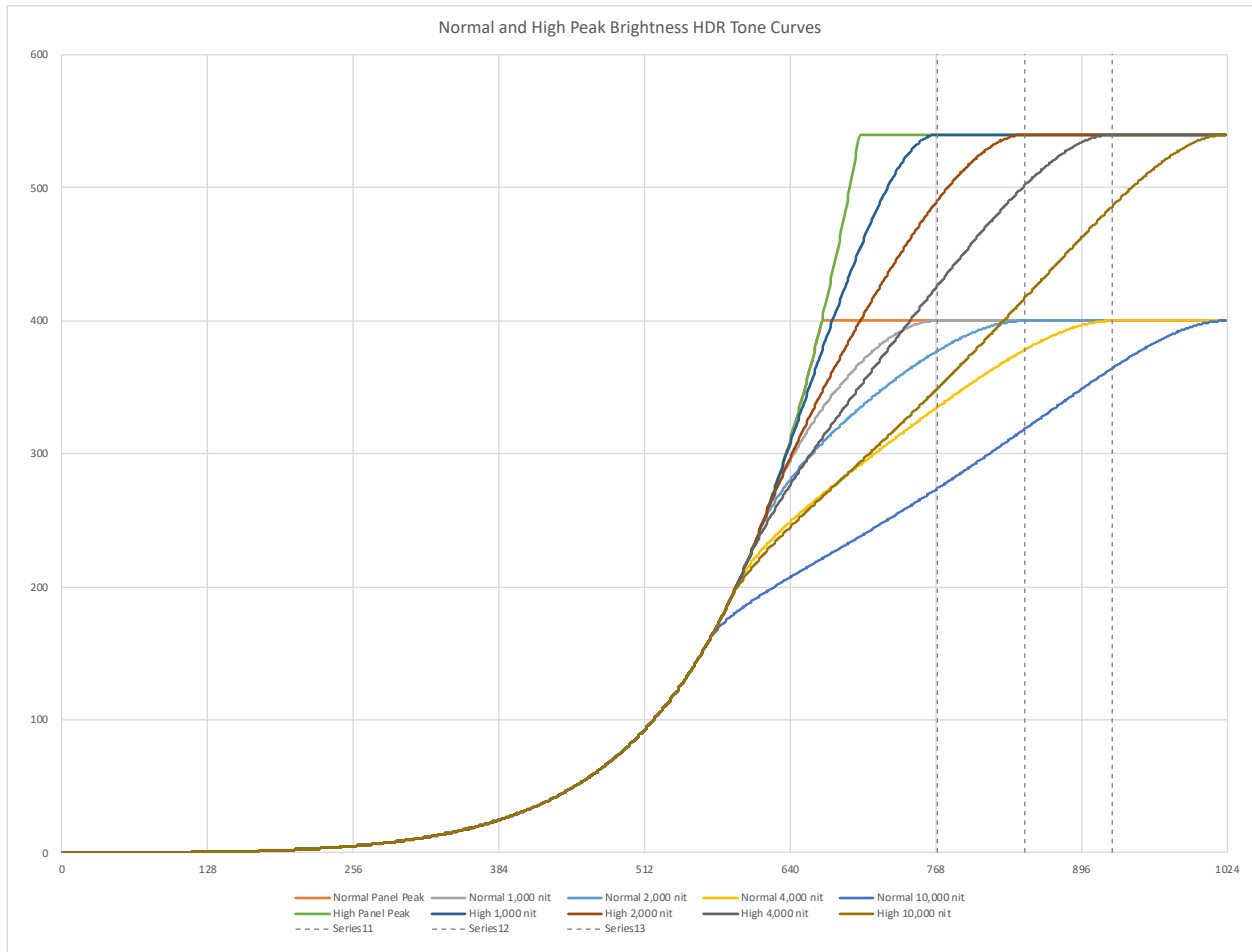
PQ Clip Point

When operating in a configuration with an PQ (ST 2084) EOTF, this setting allows configuration of the HDR processing and the resultant PQ EOTF tracking².

A setting for tracking the PQ EOTF up to the panel peak, often referred to as a 'PQ Hard Clip' is provided, labelled 'Panel Peak'.

Additionally, settings simulating the rendering of a brighter display by compressing highlights are provided, with options for simulating displays capable of, and therefore clipping at, 1,000 nits, 2,000 nits, 4,000 nits and 10,000 nits.

The charts below show the expected behavior of the EP950 in each of these settings for the 'Normal' peak brightness mode, and the 'High' peak brightness mode.



HDR Tone Curves for Normal and High Peak Brightness modes in response to PQ Clip Point settings

A further 'Auto' setting is provided, which configures the display to automatically select the most appropriate tone curve based on ST 2086 metadata often present with HDMI or DisplayPort video signals according to the following formula:

```

IF (MasteringDisplayPeak != '0')
  IF (MaxCLL != '0')
    IF (MasteringDisplayPeak > MaxCLL)
      Use MaxCLL
    ELSE IF (Mastering DisplayPeak < MaxCLL)
      Use MasteringDisplayPeak
  ELSE IF (MaxCLL == '0')
    Use MasteringDisplayPeak
    
```

```
ELSE IF (MasteringDisplayPeak == '0')
  IF (MaxCLL != '0')
    Use MaxCLL
  ELSE IF (MaxCLL == '0')
    Use Default
```

The Default tone curve in the 'Auto' mode and in the absence of ST 2086 metadata is the 1,000nit clip point.

Color Gamut

The Color Gamut setting allows selection between the different colour gamut mapping tables calibrated during the factory calibration process³

Color Temp

Allows selection from a pre-defined range of CCTs calculated during factory calibration, in addition to the default 'Custom' setting which uses an advanced factory calibration approach to achieve a highly accurate D65 result⁴

Red, Green, Blue

Adjustments for RGB Gain to adjust the 'Custom' white point of the display^{5 6}

Hue

A global hue adjustment for all colours on screen

Saturation

A global saturation adjustment for all colours on screen

Six Color

Provides adjustment for Hue and Saturation to primary and secondary colours, allowing for small adjustments to the factory gamut mapping calibration for the selected picture mode

Picture Reset

Resets all picture modes to the factory default state⁷

Picture Settings Notes

1. *At the time of writing, the factory calibration target for the sRGB picture mode includes a transfer function of 2.2 Gamma. End users can calibrate the sRGB picture mode with the parametric transfer function using the LG Calibration Studio software*
2. *A known bug in the current firmware at the time of writing (v3.4.0) results in additional sharpening applied to the image whenever a change to this setting is made. After making a change to this setting, please temporarily select an alternate picture mode and then return to the desired picture mode to deactivate this sharpening effect.*
3. *The Color Gamut setting is only active in the 'Custom' picture mode. In all other picture modes, the colour gamut is fixed to match the name of the picture mode*

4. *End user calibration performed with LG Calibration Studio or third party software will also store white point data in the 'Custom' setting*
5. *A known bug in the current firmware at the time of writing (v3.4.0) is that these controls have no effect in any picture mode except 'Custom'. This issue will be addressed in a future firmware update.*
6. *Adjusting RGB gain values too high can result in clipping of R, G or B channels. This will manifest itself as a white point shift at 100% stimulus. If this symptom occurs, adjust the white point by reducing, rather than increasing RGB gains to the proportions required.*
7. *Be cautious selecting this option because all calibration data and configurations for all picture modes will be lost and the display will revert to the factory defaults*

General

Language

Allows selection of UI language from 17 options

Peak Brightness¹

Allows setting of the panel peak luminance in HDR picture modes, choose from Normal (400nits), and High (540nits)

ABL Indicator

Allows adjustment of the brightness of the ABL indicator² which illuminates when ABL dimming occurs

HDMI Ultra HD Deep Color

Changes the bandwidth capabilities advertised by the display in the HDMI EDID between a maximum of 18 Gbps³ (On setting) and 10.2 Gbps⁴ (Off setting)

USB Selection

The EP950 display features an integrated USB Hub, and USB control functionality for settings and calibration. This setting allows the USB connection to the host PC to be configured to use the USB-C link combined with the video signal, or to use the separate USB-B input port on the display

Screen Saver

A screen saver function is provided to help reduce the risk of image retention. When active, the display will detect static images on screen, and initially dim, and then turn off the display, until motion is again detected. A pop-up message will appear on screen before the image dims, and the Power / ABL indicator will flash amber when the screen saver function is active

Screen Shift

This function shifts the image around the display by a few pixels periodically changing the location very slightly. No scaling is performed by this function because a small

number of additional active pixels are available on the panel to achieve this. Enabling this function therefore has no negative impact on the accuracy of the image.

24 / 48p⁵

By default, the EP950 panel operates with a refresh rate of 60 Hz regardless of input frame rate. This menu item configures the display to operate at 48 Hz with input frame rates of 24 Hz or 48 Hz. Integer multiples of the input frame rate will show more accurate motion, but may increase perceived flicker

Volume

Adjust the volume of the integrated headphone amplifier⁶

Power LED

Enables and disables the white front panel LED indicator indicating the power on condition

Automatic Standby

Enables a stand by timer after which time the display will automatically power off. Available options are 4, 6 or 8 hours, as well as Off (disabled)

DisplayPort Version

Changes the bandwidth capabilities advertised by the display in the DisplayPort and USB-C EDIDs between a maximum of 21.6 Gbps⁷ (1.2 setting) and 32.4 Gbps (1.4 setting)

Hot key Settings

Allows defining which menu item can be quickly accessed from the initial on-screen popup followed by a down press. Available options are Picture Mode, Peak Brightness, PQ Clip Point, Input Range and the Information screen.

OSD Lock

An OSD Lock is provided to prevent accidental changes to configurations, limiting access to only the Volume, Input List, Input Range, and the Information Screens.

The default behaviour of this control is that it can be enabled and disabled freely by the user, providing no additional security. The functionality of this feature can be modified by setting DDC/CI VCP Opcode 177 as follows:

VCP Value	Volume, Input, Input Range	OSD Lock / Unlock UI Setting	Picture Mode Selection	All Other Settings
0 (0x0000)	O	O	O	O
1 (0x0001)	O	O	X	X
2 (0x0002)	O	O	O	X
257 (0x0101)	O	X	X	X
258 (0x0102)	O	X	O	X

Options highlighted Blue in the table above, are identical to the default On/Off UI configurations for this setting.

Information

Provides information on the current status of the monitor, with details of the input signal format and timing, the configuration of image settings, the display firmware version and the usage hours

Reset to Initial Settings

Resets all settings to factory default, including any end user calibration data

General Settings Notes

1. *The Peak Luminance setting is only active when the display is operating in an HDR picture mode or when using the PQ EOTF*
2. *The EP950 has an ABL performance limiting characteristic when operating in HDR picture modes; as the average picture level increases, at some point, the peak luminance capability decreases. Details of this characteristic are provided in the Performance section of this document*
3. *The maximum bandwidth of HDMI 2.0 is 18 Gbps. UHD resolution at > 30p with 4:4:4 YCbCr sub-sampling / RGB is only possible at 8 bits per component within this bandwidth. If 10 (or 12) bits per component is a requirement, a lower resolution, frame-rate, or a different interface must be used; UHD 24p 10 bpc RGB is possible over HDMI 2.0.*
4. *A maximum bandwidth of 10.2 Gbps on HDMI limits UHD resolution to < 30p, 4:2:0 YCbCr sub-sampling and 8 bits per component. The use of UHD inputs is not recommended when this limitation is set.*
5. *The 24p / 48p menu will not be visible out of the box, and must be enabled before it can be used. To enable the 24p / 48p menu, starting with no on screen menu on screen, hold the joystick in the down / forward position for 10 seconds until the '24p / 48p: On' message appears on screen*
6. *The EP950 display does not have integrated speakers. The volume control only has an effect on the output to connected headphones and / or amplified external speaker systems*
7. *Although the DisplayPort bandwidth is reduced by setting 1.2 in this menu, UHD resolution at 60p 10 bpc RGB is still possible within this reduced bandwidth*