LG Electronics

Colour Management Configuration in macOS and Windows

for LG EP950 UltraFine OLED Pro Displays

v1.05-J 06/25/2021

Neil Robinson – LG Electronics, Zenith R&D

Contents

Background

The EP950 display is a professional quality display, factory calibrated to a high level of accuracy for all picture modes when used as a stand-alone device. All displays however, require a source device to produce 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.

A common expected use case for the EP950 display is with a computer running macOS or Windows. This document details configuration of the colour management systems in these operating systems to match each picture mode available on the EP950 display, thereby providing accurate colour reproduction.

macOS

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 display connection, or can be manually applied by the user through the macOS ColorSync application.

The EP950 default EDID at the time of writing (v3.4.0 firmware) signals to macOS that sRGB is the default display colour space. EP950 models feature an sRGB accurate picture mode, resulting in accurate colour with no additional configuration required. If you would like to make use of the wider colour gamut capabilities of the EP950 display, as well as HDR, other picture modes may be used, but additional macOS configuration is needed at the time of writing this document.

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.

ICC Profile Usage

As stated above, ICC Profiles can be used to configure macOS colour management for SDR picture modes on both Intel and M1 based Mac computers; this approach is not affective for HDR picture modes.

macOS provides built in ICC Profiles that already accurately describe the expected colour space for the following EP950 SDR picture modes[1] [2]:

- AdobeRGB Picture mode = Adobe RGB (1998) ICC Profile
- sRGB Picture mode = sRGB IEC61966-2.1 ICC Profile[3]

LG has provided additional ICC Profiles which accurately describe the standards based colour spaces for the following EP950 picture modes:

- BT.2020 Picture mode = ITU-R BT.2020 2.4 Gamma
- BT.709 Picture mode = ITU-R BT.709 2.4 Gamma
- P3-D65 Picture mode = P3-D65 2.6 Gamma

To install an ICC Profile, copy the .icc files to either the `/Library/ColorSync/Profiles` folder if you would like the changes applied to all users, or the `~/Library/ColorSync/Profiles` folder if you would like the changes to apply only to the current user. ICC Profiles may be copied individually, or the entire set of provided ICC Profiles may be copied in to this folder, including the 'LG EP950' sub folder. It may be necessary to input your macOS user password to grant access to this protected folder structure. The result should look as shown in Figure 1.

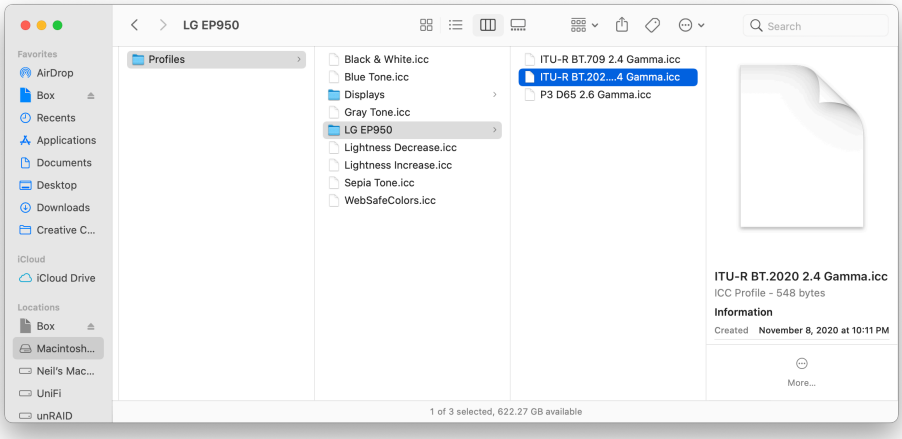

Figure 1: macOS ICC Profile folder location with LG supplied ICC profiles shown

Once copied to the `/Library/ColorSync/Profiles` folder, the appropriate ICC profile needed to match the display picture mode should be selected. To do this, open System Preferences, and select Displays; new windows will appear if multiple displays are connected. Select the Color tab in the window representing the EP950 settings, and un-check the box beside 'Show profiles for this display only'. You should now see a list of all of the ICC profiles available to macOS, including the newly copied LG provided profiles. Selecting the profile which should be used with the display is as simple as clicking on the profile in the list. macOS will remember this choice whenever this monitor is connected in the future.

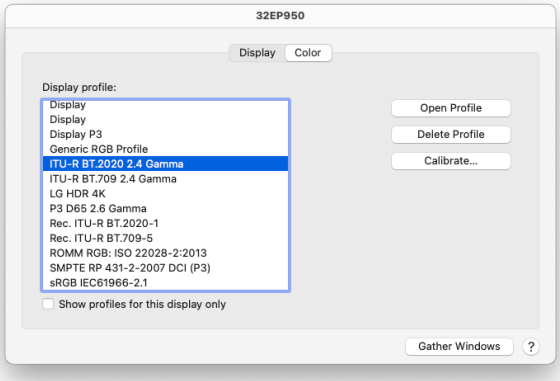

Figure 2: LG supplied ITU-R BT.2020 2.4 Gamma ICC Profile selected

Each ICC profile should only be used with the corresponding picture mode on the EP950. If the EP950 picture mode is changed for any reason, so too should the ICC profile be changed to match the new chosen picture mode.

macOS ICC Profile Usage Notes

1. *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 provided by LG*
2. *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 P3-D65 picture mode, because the 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 provided by LG*
3. *The EP950 factory calibration target for the sRGB picture mode includes a transfer function of 2.2 power. End users can calibrate the sRGB picture mode with the parametric transfer function using the LG Calibration Studio software, or utilize the provided sRGB 2.2 Gamma ICC Profile with the factory calibration*

EDID Override Usage

As stated above, EDID Override files can be used to configure macOS colour management for SDR and HDR picture modes on Intel based Mac computers[1]; this is the only effective approach for configuring macOS for HDR picture modes because ICC Profiles do not yet support the necessary data for HDR colour management.

Unfortunately, at the time of writing, EDID override functionality only works on Intel based Macs, and does not work on M1 based Macs[2].

To install an EDID Override file, create the
`/Library/Displays/Contents/Resources/Overrides/DisplayVendorID-1e6d`
folder structure if it does not already exist. It may be necessary to input your macOS user password to gain access to this protected folder structure.

Select the EP950 picture mode that you intend to use with macOS, and find the appropriate EDID Override file provided by LG. Shown below are the EP950 picture modes and matching EDID Override files:

- BT.2020 Picture mode = BT.2020 2.4 Gamma
- BT.709 Picture mode = BT.709 2.4 Gamma
- P3-D65 Picture mode = P3-D65 2.6 Gamma
- AdobeRGB Picture mode = AdobeRGB
- sRGB Picture mode = sRGB[3]
- (HDR) BT.2100 PQ Picture mode, Normal Peak Luminance = HDR BT.2100 PQ Normal[4]
- (HDR) BT.2100 PQ Picture mode, High Peak Luminance = HDR BT.2100 PQ High[4]
- (HDR) P3-D65 PQ Picture mode, Normal Peak Luminance = HDR P3-D65 PQ Normal[4]
- (HDR) P3-D65 PQ Picture mode, High Peak Luminance = HDR P3-D65 PQ High[4]

Copy the appropriate EDID override folder in to the `DisplayVendorID-1e6d` sub-folder and rename the file according to the input type that you are using with the display as follows:

- For HDMI Inputs – DisplayProductID-7762
- For DisplayPort Inputs – DisplayProductID-7763
- For USB-C Inputs – DisplayProductID-7764

As before, it may be necessary to input your macOS user password to gain access to this protected folder structure. The result should look as shown in Figure 3.

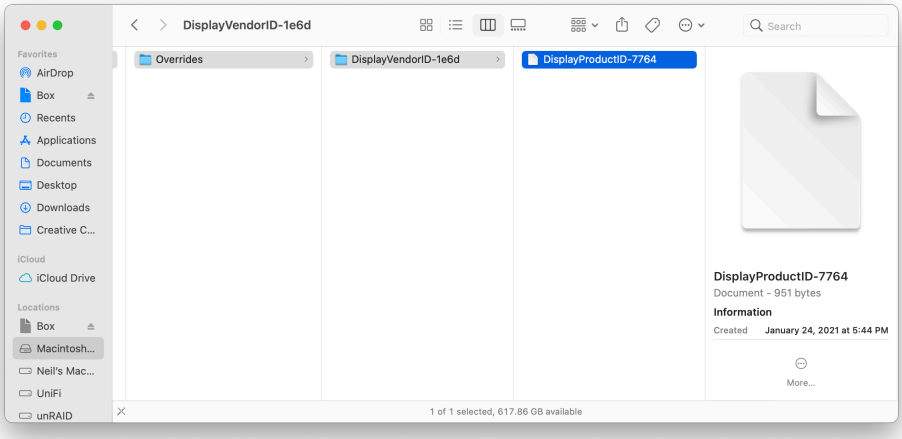

Figure 3: macOS EDID Override folder with LG supplied EDID Override for USB-C Input shown

Disconnect and re-connect the EP950 display, and the EDID override should be active. To confirm that the EDID override is active, open System Preferences, and select Displays; new windows will appear if multiple displays are connected. The window representing the EP950 settings should now be named 'Pic_[Picture Mode]' as shown in Figure 4[5]. The High Dynamic

Range check box should also be checked to enable macOS to render in HDR on the selected display.

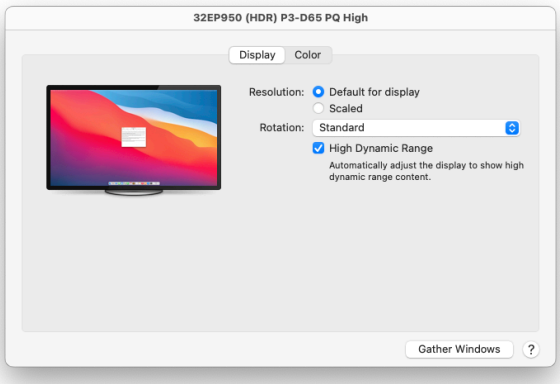

Figure 4: EP950 Picture Mode shown in the Display pane of Displays System Preferences signifying EDID Override successfully applied High Dynamic Range checkbox showing macOS in High Dynamic Range colour processing mode

Using an EDID Override causes macOS to automatically generate an ICC Profile which is used to configure SDR and HDR colour management. If you had previously manually selected an ICC Profile for use with the EP950, this should be de-selected to ensure that the automatically generated profile data is now in use. To do this, select the Color tab in the System Preferences window representing the EP950 settings, and check the box beside 'Show profiles for this display only'. Once checked, the list of ICC profiles shown should reduce. Select the top ICC Profile matching the name of the display as shown in the Displays System Preferences window.

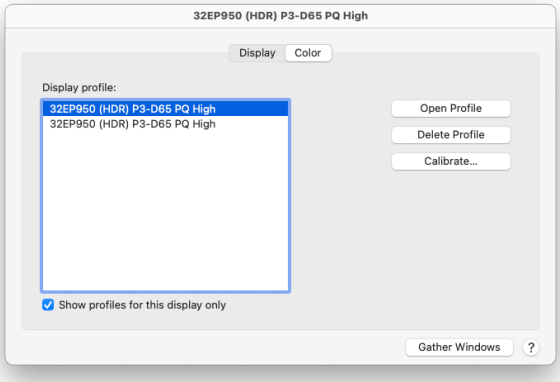

Figure 5: macOS Generated ICC Profile matching monitor name selected in the Color pane of Displays System Preferences

Each EDID Override should only be used with the corresponding picture mode on the EP950. If the EP950 picture mode is changed for any reason, so too should the EDID Override be changed to match the new chosen picture mode. Due to the file naming requirements, only one EDID Override file can be used at one time, and must be named as described above. It is however possible to have different EDID overrides active for each input type.

macOS EDID Override Usage Notes

1. *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.*
2. *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 to reflect changes in EP950 behaviour, but cannot guarantee the continued accuracy of information relating to third party hardware and software.*
3. *The EP950 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.*
4. *macOS makes use of Peak Luminance data in the EDID to configure HDR colour management, therefore, a different EDID Override file is needed for the Normal and High Peak Luminance settings*
5. *As described earlier, at the time of writing, EDID override functionality only works on Intel based Macs, and does not work on M1 based Macs. If an EDID override is used with an M1 Mac, the Displays System Preferences window representing the EP950 settings will be updated with the picture mode name, but colour configuration will not be applied.*

Windows

SDR

In SDR mode, 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 possible on Windows when the display is operating in sRGB mode with no additional configuration required. The EP950 features an sRGB accurate picture mode[1], and this is therefore the suggested 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. Please note that the Windows desktop and most Windows applications are not colour managed; using any picture mode other than sRGB will therefore result in over-saturated colours for these unmanaged applications.

Some Windows applications use their own colour management and must be configured separately from the operating system settings. Configuration of these applications is beyond the scope of this document.

To change the system configuration for the display ICC profiles in Windows, launch the Color Management control panel. Make sure that the EP950 is the active display in the drop down at the top of the Devices tab, tick the ‘Use my settings for this device’ tick box, and then click ‘Add…’ to associate an ICC Profile file. To add one of the LG supplied ICC Profiles, click ‘Browse…’ and select the file from your download location.

Once the ICC Profile is associated with the display, it can be selected, and set as default as required. Multiple ICC Profiles can be associated with each display, and switched between by using the Color Management control panel.

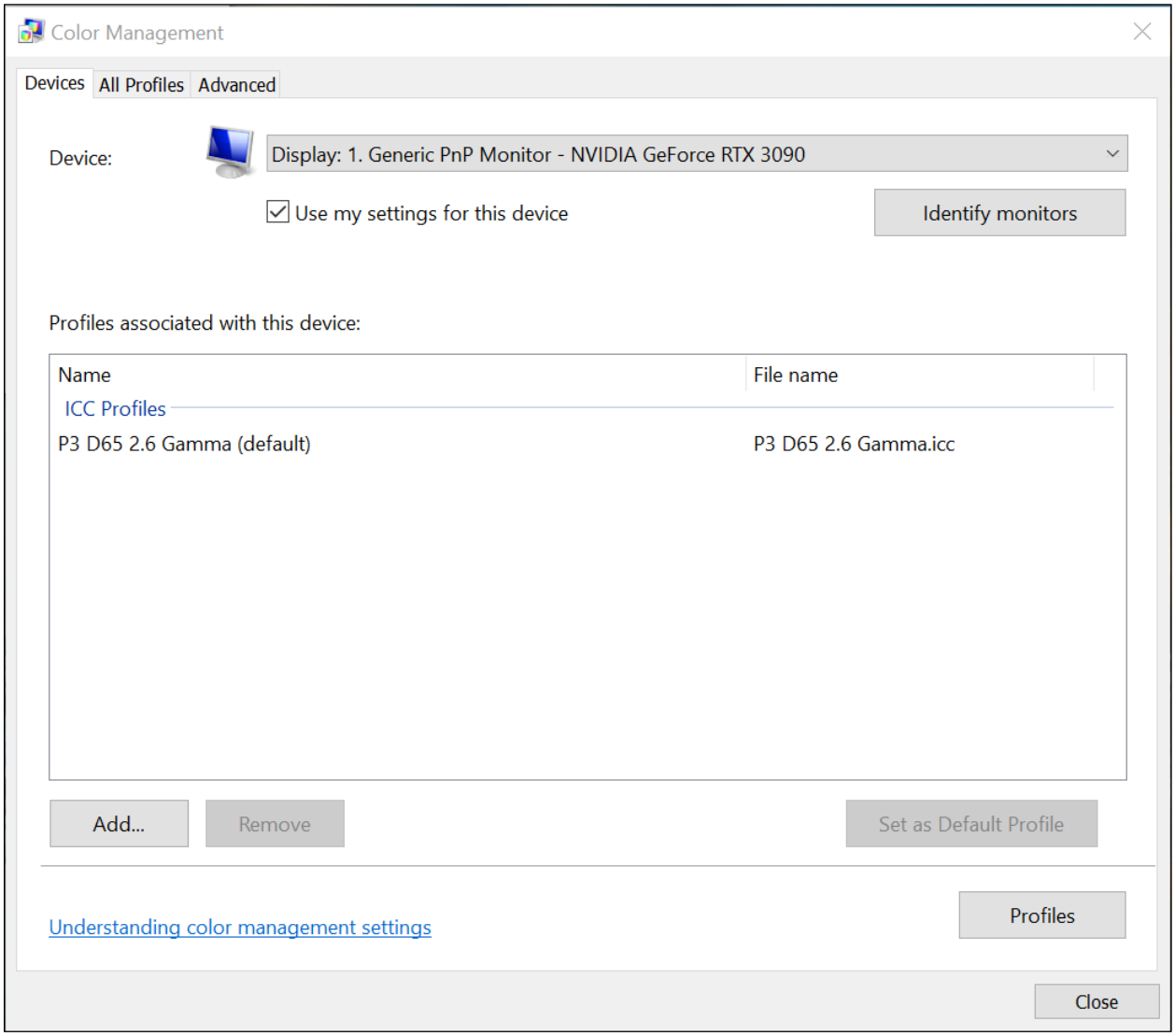

Figure 6: Windows 10 Color Management Control Panel showing user installed P3-D65 2.6 Gamma ICC Profile selected

Windows SDR Usage Notes

1. *The factory calibration target for the sRGB picture mode includes a transfer function of 2.2 Power. End users can calibrate the sRGB picture mode with the parametric transfer function using the LG Calibration Studio software, or utilize the provided sRGB 2.2 Gamma ICC Profile with the factory calibration.*

HDR

In HDR mode, Windows assumes that the connected display is rendering the BT.2020 PQ HDR colour space, and signals this colour space to the display accordingly. 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. No additional configuration is needed to achieve accurate colour for HDR content in Windows when the EP950 (HDR) BT.2100 PQ picture mode is used.

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' window[1] shown in Figure 7.

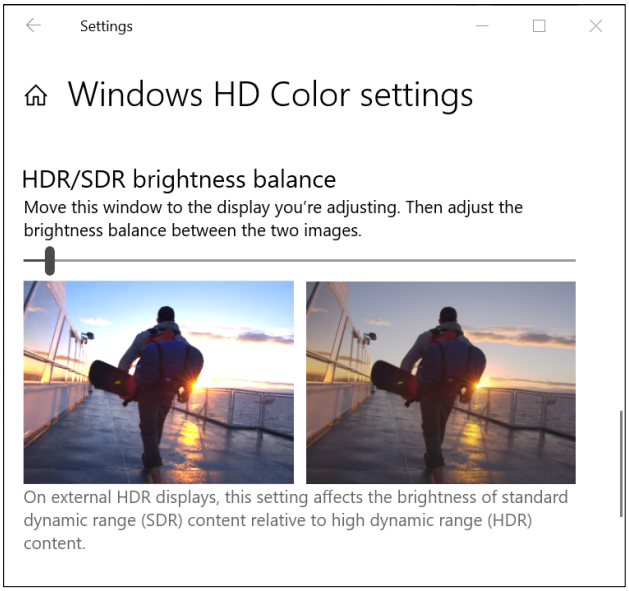

Figure 7: Windows 10 HD Color Settings 'HDR/SDR brightness balance' slider

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 video[2]. Values greater than a setting of '4' will increase the peak luminance of SDR content above the standards for these colour spaces.

Windows HDR Usage Notes

1. *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).*
2. *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