Contents

Introduction

Jim Peterson from Lumagen® posted the slide deck for a webinar presentation he gives to dealers and calibrators. I used the text from the webinar along with information from the Radiance™ Pro manual, as well as posts from AVS Forum to create this guide to help me understand setup and calibration of the Radiance™ Pro. Please note this is not an official Lumagen® document; it is an aggregation of information. – AVS Forum member giomania

Maximum Performance Recommendations

The following recommendations provide the best switching speed and video performance:

- All sources switched by the Radiance™ Pro for more reliable and faster video switching. In addition, this allows access to new features (i.e. HLG) that might not be supported in the AVR.
  - The disadvantage is you lose access to the AVR OSD, but you can generally connect the AVR output to an unused input on the Pro, to be able to select it to see the AVR OSD. There is a chance this will cause an HDMI HDCP authentication loop, which is the output of the Pro to the AVR authenticating HDCP, which causes the AVR to authenticate its output going to the Pro, which can then cause the Pro to again authenticate the connection to the AVR, etc... This is not a product fault, but a result of the timing and function of the HDMI HDCP authentication process.
  - Alternatively, you can switch with the Radiance™ Pro, and output through the AVR to the display. Since we recommend sending “HDR in a SDR container", the AVR only needs to support SDR modes. Switching is a little slower this way, but you get to use the AVR OSD.
- Finally, Lumagen® strongly recommends 18 GHz Certified HDMI cables for all connections, including any "audio only" output connections, even though it is running at an HD rate. This is because transmission-line theory says it is the edge rate that matters most for required cable quality, rather than video rate (which does matter, but not as much).
- Also avoid passive HDMI cables less than 2 meters long (especially for audio) as the signal can be too hot due to cable EQ.
- When sending HDMI over category cable (Cat 6, 7), avoid (non-fiber) baluns for 4k.
- Avoid using active cables on source outputs as often sources do not have enough HDMI Output Standby Power to reliably drive active cables.
- For 18 GHz dual-input cards connect commonly used sources to different input cards for faster switching. These cards only keep one input active at a time, which means switching between inputs on a card takes longer than switching between cards where the most recently used input is already selected.
  - For example, a 4446 with all 18 GHz inputs should have inputs connected from most to least used as input 1, 3, 5, 7, 8, 6, 4, 2.
- Use manual output mode selection (see below) to minimize output rate changes.

Audio Performance Information

Lumagen® has improved audio on the Radiance™ Pro line, first with the addition of microwave capacitors in the 4XXX models 2019, and then with the introduction of a new model (the 5348) in January, 2021; it was announced in this post.

For the 4XXX models, units shipped since ~January 2019 should have the microwave capacitors on the 18 GHz output card. We added microwave caps to the main board, 18 GHz input card, and 9 GHz output card, in critical locations shortly after that. Any new (non-B-Stock) 4XXX units purchased since about March 2020 should have the microwave capacitors throughout. When we switched to the new version, we still had some of the old I/O cards, so if you bought a B-stock unit in 2020, it may have the older boards.

To check for the presence of the newer boards, take the cover off and look for a revision number labels on the boards: I/O daughter cards (18 GHz in and out, or 9 GHz out) that have the microwave capacitors should have a small "Rev 1.3" label. The Radiance Pro 444X, and Radiance Pro 424X, main boards that have the microwave capacitor should have a small label that says "Rev 2.2" on them. I think some boards with the microwave capacitors shipped without labels, so if the purchase details suggest it should have them, that would explain the missing label.

The Radiance™ Pro 5348, uses the same HDMI chips and FPGA, as the 4XXX series, but features several electrical design improvements. The 5348 uses linear regulators for 28 critical power supplies and an HDMI de-jitter output buffer to dramatically reduce output jitter and noise. It also has Faraday cages for all nine DC-to-DC switching-regulators to dramatically reduce EMI.

As an example, the current 18 GHz Rev 1.4 output card in a 4446 has a HDMI data jitter of about 80 pS (HDMI specification requires 102 pS or less for 18 GHz). In comparison the measured HDMI output data jitter on the Radiance Pro 5348 is 45 pS. For audio, the HDMI output clock jitter has been measured at ~10 pS, which is a nearly ideal clock to send to the audio processor.

I get calls on a fairly regular basis asking why audio sounds better when it is running through the Radiance™ Pro? The difference is lower jitter and reduced electrical noise. The Radiance™ Pro 4XXX output jitter and electrical noise are already dramatically better than other products we know about, but 5348 takes jitter and noise reduction to the ultimate audiophile level.

Some have said that a high-end audio processor's de-jitter circuit can handle higher jitter levels. In my experience, audio processor de-jitter circuits can improve the jitter as the signal works toward the DAC's, but there is a limit to the improvement. The advantages the Radiance™ Pro has compared to traditional de-jitter circuits are: It completely regenerates the HDMI audio output using a very low jitter crystal clock chip for the HDMI audio clock, and then passes the HDMI signal through two stages of PLL de-jitter circuits. Using linear regulators for internal power supplies also helps maintain low jitter by isolating the noise from the digital circuits from the HDMI integrated circuits.

The lower jitter of the 5348 should not result in any visible difference in the video, as the data reaching the projector/TV should be identical. Since the 4XXX series already has output jitter well below specification, the 5348 going from 80 pS down to 45 pS for the data is not likely going to improve the Bit-Error-Rate (BER) on the HDMI connection.

Jim expanded on the Radiance™ Pro audio design in this post, which is summarized below.

Sending the HDMI audio through all Radiance™ Pro models before being sent to the audio processor sounds better than sending the HDMI audio directly from the source to the audio processor. HDMI audio passed through the Radiance™ Pro 5348 sounds better the Radiance™ Pro 4XXX models, based upon the electrical design improvements noted below.

All Radiance™ Pro units decode the HDMI audio to an I2S audio stream, and then create a new HDMI audio stream using a very low jitter clock. Therefore, the Radiance™ Pro output jitter is not correlated to the jitter in the source jitter in the HDMI stream, which makes the Radiance™ Pro dejitter function fundamentally different than what is used in audio processors. I cannot stress enough that this levels the playing field for source audio.

Audio processors decode the audio to an I2S stream and then use PLL's to try to reduce jitter. The jitter at the DACs in the audio processor is corelated to the amount of jitter in the source HDMI stream. A source with higher jitter leads to higher jitter at the DACs and a source with lower jitter leads to lower jitter at the DACs.

The goal of the design enhancements made to the Radiance™ Pro 4XXX models in early 2019 (microwave capacitors) was to provide the lowest jitter possible to the input of the audio processor. The jitter reduction of these 4XXX models is significantly lower than what comes in. In fact, the jitter coming out of the Radiance™ Pro 4XXX is not corelated to the jitter on the HDMI audio coming into the 4XXX unit since it is only dependent on the low-jitter clock used to create the HDMI audio from the I2S audio stream. The Radiance™ Pro 4XXX Rev 1.4 18 GHz output data jitter has been measured at 80 pS; the prior revision was ~150 pS. Note: The clock jitter is the more important jitter measurement, but we do not have this for the 4XXX models.

The goal of the Radiance™ Pro 5348 design enhancements is to further reduce jitter. It uses an even lower clock jitter source to create an HDMI audio stream with extremely low jitter, and then it runs the HDMI audio stream through PLL dejitter circuits for an even lower output jitter. In addition, the use of only linear power supplies for the HDMI output circuitry significantly reduces the noise on the output HDMI chips power rails, which has less negative impact on jitter than the digital power supplies used in the 4XXX series.

The Radiance™ Pro 5348 output data jitter has been measured at 45 pS, which is ~half that of the 4XXX models, and ~one-tenth from some source devices, so it is a significant reduction from the source. The clock jitter on the Radiance™ Pro 5348 output has been measured ~10 pS. This is an extremely low amount of clock jitter, and gives the audio processor a pristine clock to run through its dejitter circuitry.

Why HDMI Issues Exist

Customers often think the Lumagen® should not have HDMI issues given the cost of the product. It is often mentioned that various inexpensive source devices, AVRs, or displays have fewer compatibility issues than the Radiance™ Pro. While these concerns and statements are valid, the compatibility issues are due to three primary factors.

First, the Radiance™ Pro is properly designed to follow the HDMI specifications, and this can be problematic with the many consumer electronics devices that do not, resulting in intermittent audio dropout issues with source devices and/or processors / receivers. Anthem also experienced this first-hand as noted in this post.

Second, the HDMI chip vendor does not allow Lumagen® to control the output edge rate, as noted in this post, which limits this potential mitigation path for compatibility issues. During development of the Radiance™ Pro, Panasonic was the preferred HDMI chip vendor for Lumagen®. However, Panasonic declined to sell HDMI chips to Lumagen® due to their niche market, as noted in this post. The only other HDMI chip vendor available at the time was Silicon Image (Now Lattice), and changing HDMI chips in the product at this point is not feasible.

Third, Lumagen® has noted that HDMI edge rates out of the Lumagen are on the high side, meaning that cable selection and length are very important. They recommend HDMI cable lengths of at least 2 meters to allow greater attenuation of these HDMI signals.

Mitigating Audio Dropout Issues

The Radiance Pro can exhibit intermittent audio dropout issues with source devices and/or processors / receivers when the Radiance Pro is used (as recommended) as the HDMI switching device (Source devices → Radiance Pro → Processor / Receiver → Display).

While it can be frustrating to set up the Radiance Pro in the recommended configuration, only to experience these audio dropouts, Jim Peterson has responded with many posts over the years, including a very detailed response concerning these issues in this post.

It can be challenging to troubleshoot these issues in a complex system. If you are having issues, first try different cables, longer cables, if necessary. If you are unable to resolve it, reach out to Lumagen support if you are unable to resolve the issue. It is recommended to make a diagram of your HDMI device interconnection, as troubleshooting via email or via telephone can be challenging, and a system diagram may be the fastest way to explain a particular setup.

Mitigating HDMI Issues with Older Devices

The first step to attempt to mitigate HDMI issues is to disconnect and reconnect each HDMI cable on all source devices, displays, and the Lumagen®. This has the effect of cleaning the HDMI contacts, and can result in greater surface contact area for the 19 individual HDMI pins.

Do you have HDMI audio or video issues with an older device with a maximum output rate of 1080i / 1080p? Lumagen® advised they have seen a number of 1080 devices where the EDID parsers were not written with consideration of future changes required for 18 GHz bandwidth. One such device family is the DirecTV 1080 receivers. For these types of devices, there is a manual Input Memory setting to reduce the EDID back to what they can process. Note that generally audio is most affected by the EDID parser issue in these devices. Here are the instructions to enable this setting in the Radiance Pro:

MENU → Input → Option → HDMI Setup → Video EDID: Change Video Limit to 1080p, press OK to accept and then save the configuration.
The save command is: MENU → Save → Save → OK → OK
There is also a way to change the setting of the output board so it is limited to 9 GHz, if you have the 18 GHz output board. The command is:

MENU → Output → Styles → Style # → HDMI Format → Type → Auto 9GHz

Dynamic Dimming Recommendations

Dynamic Dimming (DD), either with a dynamic iris, or laser dimming, is not recommended by Lumagen® as explained in this post. Below is an edited version of the reasoning in the post.

For residential theaters, the 100% white target for SDR is 14 foot-Lamberts (fL) / 48 Nits: For commercial theaters, SDR is 106 Nits. The 14 fL standard was probably selected because it was achievable as a "minimum acceptable brightness", not because it is the optimal brightness. Therefore, a brighter image that more closely matches the commercial theater standard may be preferred. The commercial theater SDR target of 106 nits makes it feasible to have a good DD system. However, I have not seen DD that works well enough for SDR content that I would use.

HDR Dynamic Tone Mapping (DTM) with frame-by-frame adaptation, is *not* optimal for DD. The Radiance Pro outputs "HDR in an SDR container", so the projector thinks it is getting SDR content. The dimming is applied as if the content is straight SDR; the DD system does not comprehend it is getting DTM processed HDR in an SDR container. The DTM is doing the "grading" as is done with SDR content, but to the light capability of the projector, and the preferences of the viewer as set with the HDR Parameter menu, on a frame-by-frame basis. The DTM frame-by-frame "adaptation" makes this an even more untenable problem for DD systems.

Here are some alternative solutions if dark scenes are not dark enough. Consider increasing the effective Gamma via the Radiance Pro Gamma factor, **before calibration**. Reduce light output using a manual iris, if available. Change bulb power to low. For projectors with laser light engines, if your black gets blacker when the laser is turned down (not true for all projectors) you can try that.

More light is of course a good thing, but to me black is more important. Human vision adapts if the white is not as bright. However, in my opinion, black is more absolute and a blacker black is more important than a brighter white.

For the starfield scenes I have looked at, the background is almost never true black (level 64 in10-bit HDR mode). For these, if you like, you can have a memory with the Lumagen input Black level adjusted down to the point where the background looks black. This crushes levels near black to black, but this is IMO a better option than DD for movies with these types of scenes. This is because DD tends to make everything in the scene darker. Mid-brightness objects that are, say 25 nits without DD, should stay at 25 nits with DD on. However, this is not the case for DD I have evaluated. Using the Black Level, the small level change keeps mid-tones about where they should be and does not cause the detail-crush I see with DD systems.

Mitigating Set Top Box (STB) Scaling & Resolution Switching

Most STBs do not have a source direct feature, and usually scale all content up to 4K UHD when used with a 4K UHD display. When watching SDR content on such devices, the Radiance™ Pro should perform the scaling, not the STB. Fortunately, as noted in this multi-quote post on AVS Forum, there is a solution using HDMI EDID settings and input memories that allows seamless switching between SDR and HDR, depending upon the content.

With this solution, any given STB in a system will use two input memories; for example, one for HDR (Mem A), and one for SDR (Mem B). The only difference between the two input memories is that Mem B (SDR) has the video EDID set to 1080p, which forces the STB to send out 1080p, not 4K HDR.

For reference, below are the video and audio EDID settings I have established, which work in my system for the Apple TV 4K, 2017 Nvidia Shield TV Pro, and 2019 Roku Ultra. The Video Limit setting forces the STB to send 1080p, so the Radiance™ Pro can perform the scaling. Note the audio EDID setting may have an impact on the functionality of this tip.

For video EDID: Input → Options → HDMI Setup → Video EDID

--Src Video Formats (EDID)—

Interlaced: Use global	The options are: Use global, Auto, No, Yes
Rec2020: Use global	The options are: Use global, Auto, No, Yes
HDR: Use global	The options are: Use global, Auto, No, Yes
Video Limit: 1080p	The options are: Max(18 Ghz), 1080p, and 9 Ghz
HLG: Use global	The options are: Use global, Auto, No, Yes

For audio EDID: Input -> Options → HDMI Setup → Audio EDID, this is set to "Common".

Specific STB observations

When using the above mitigation technique, the following observations were made:

Apple TV 4K: It forces the ATV 4K to use “1080p SDR” resolution when using this memory. By default, upon detection of a new EDID, it disables rate switching, so you have to enable it for each EDID.

2017 Nvidia Shield TV Pro: No issues.

2019 Roku Ultra: When the resolution is forced to 1080p, it uses Chroma 4:4:4.

Apple TV 4K Setup Tips

In this multi-quote post on AVS Forum, the following tips are discussed about the Apple TV 4K:

Prevent the ATV 4K automatically switching resolution from 4K SDR to 4K HDR

The Apple TV Ensure the video and audio EDID settings do not cause an HDMI resync. I am using the following options:

For video EDID: Input → Options → HDMI Setup → Video EDID

--Src Video Formats (EDID--

Interlaced: Use global	The options are: Use global, Auto, No, Yes
Rec2020: Use global	The options are: Use global, Auto, No, Yes
HDR: Yes	The options are: Use global, Auto, No, Yes
Video Limit: Max(18 Ghz)	The options are: Max(18 Ghz), 1080p, and 9 Ghz
HLG: Use global	The options are: Use global, Auto, No, Yes

For audio EDID: Input -> Options → HDMI Setup → Audio EDID
This is set to "Common"

Nvidia Shield TV Setup Tips

AVS Forum member sjschaff reported issues with an Nvidia Shield TV sending YCbCr 4:2:2 video to the Radiance™ Pro with 9 GHz input cards.

While playing HDR files, the Nvidia Shield advanced HDMI settings presented an option for YUV 422 12-bit Rec. 709, never let me "keep" this setting. It reverts back to YUV 422 8-bit Rec. 709. Using OK button on the Lumagen remote shows that the source color space and Lumagen are different. Input shows RGB-HDR709 and output 422-SDR2020. By the way, this is for using CMS1 for all HDR source. Also, not using Auto-Convert for either CMS0 or CMS1.

The only way I can get this option in the Nvidia to "stick" is to alter the Lumagen Pro's input setting for Video Limit. Changing from 9ghz or 9ghz Max to 1080p. When I now pick the YUV 422 12-bit Rec. 709 the Nvidia asks if I want to keep it. By the way, I have enabled colorimetry in the Nvidia via the developer options, as described in prior posts for Nvidia Shield for color space switching.

Roku Ultra Setup Tips

In the Roku, ensure the following options are set in Settings → System → System Settings → Advanced System Settings → Advanced display settings.

"Auto-adjust display refresh rate" is set to "On".
"HDR subsampling" is set to "4:2:2".

Initial Setup Guidance

Don't be afraid to experiment with any given feature / setting. In most menu areas, if you press the HELP button, there are useful tips for that specific menu item. Since all changes must be saved prior to turning off the Radiance™ Pro, if you changed something that causes a bad result, just place the unit into standby, and the changes are not saved. Also, there is a useful "Radiance Configuration Utility" on the Lumagen site here that allows for saving the configuration to a PC.

Audio Setup

By default, the audio portion of the EDID for the device on Output 1 is passed back to sources. Manually programming EDID can help with power up order and issues with obtaining the proper sound formats. See the shortcut commands outlined in the Initial Settings Walkthrough below.

Video Setup

By default, the Radiance™ Pro output mode is set to "Auto" followed by the output number (1, 2, 3, or 4). With this setting, the Extended Display Identification Data (EDID) is read from the display device. This causes longer HDMI sync times due to the forced use of frame rate matching, which automatically selects the output rate based upon the input rate. If there is 24.00 or 60.00 content from a player make sure the Radiance Pro has Rate Match = On in output Style0. Otherwise, the Radiance Pro will output at 23.98 or 59.94. This could cause issues with video and possibly with audio.

To reduce HDMI sync times for all sources, manually set all input resolutions / rates to the same output resolution / rate (e.g. 3840 x 2160). Avoiding output restarts for framerate changes will reduce HDMI switching times with the default settings, but there are some unavoidable motion penalties, as 24p content is converted to 60 p via 3/2 pulldown. Another negative is the loss of accurate matching of 59.94 vs 60p, and 23.976p vs 24p. Setting to a fixed 60p output causes a dropped frame every 41 seconds and lip sync that cycles on a 0-1 frame gap. Video purists or those not bothered by the HDMI sync delays may choose to keep the default settings.

Setting to a fixed output is accomplished by turning "Rate Match" off to allow 23.98, 25, 50, 59.94 output, and manually selecting the output rates via the Output Setup menu or the shortcut commands. Another solution to unstable HDMI sync times it to disable Genlock, but this causes 23.976 stutter. See the section on Genlock for more information on that feature.

Now, Netflix, and others, are providing content at 60.00, and 24.00. I think OSDs and content should be 59.94 (or 23.98) because of the historical standard. Because of this we recently changed the MENU 0873 and MENU 0874 to *enable* Rate Match.

If you notice frame drops, press OK to bring up Info Pg 1. See if the source is 60.00 (or 24.00), and if so see if the output is the same rate or not. If not, go into the Output Style0 menu under HDMI Setup and Rate Match and enable Rate Match. Make sure to Save any changes.

4096 x 2160 Output

The imaging chips in 4K projectors are 4096 x 2160, while consumer content is 3840 x 2160. When you send 4096 x 2160 signal, the physical aspect ratio is 1.90. Therefore, if you have a ≥ 1.90 aspect ratio screen there will be extra light output when setting the Radiance Pro to send out 4096 x 2160. If you have a 1.78 screen and are not using lens shift, there is no reason to send 4096 x 2160 since you would end up over-scanning too much on the sides once you filled the screen height. If you have a 1.78 screen and are using lens shift, there may be a benefit to send 4096 x 2160, as noted in the example below.

The light output gain equation for 4096 output versus 3840 wide output is: (4096/3840)^2 = 1.138 or 13.8% gain. This is because you have 4096/3840 = 1.067 of 6.7% more pixels horizontally, but when you reduce the zoom to just fill the screen width, you have the same percentage of extra pixels vertically, and the extra light output is the product of the ratio of the two dimensions.

2.40 Screen example – Paladin DCR lens: The lens is designed for 4096 x 2160 on a 2.40 screen. Radiance Pro output resolution = 4096 x 2160, and output aspect = 2.40.

2.40 Screen example – No Anamorphic lens: Radiance Pro output resolution = 4096 x 2160 and output aspect = 2.40. Use the Radiance Pro output "Shrink" to adjust the active projector raster height.

1.78 Screen example – With lens shift: Radiance Pro output resolution = 4096 x 2160, output aspect = 1.78. Then you select 16:9 source aspect and use the projector zoom and shift to fill the height of the screen, with just a bit of overscan. Then you use the Radiance Pro output "Shrink" to reduce the width to fit the screen with just a bit of overscan.

MENU → Output → Styles → Style # → Mask/Shrink → Shrink

Using lens shift in projectors causes the height/width ratio of the image to increase. For example, a flashlight perpendicular to the wall casts a circular spot on the wall. As you angle the flashlight down the spot becomes elliptical; the height over width ratio increases. In this example, the benefit of 4096 output is dependent upon the amount of lens shift. Even if you cannot use the entire 4096 output width, the "Output Shrink" will reduce the active width (between 3840 and 4096, but still upscaling) and might provide a 1.78 image. This would provide more light output, and, eliminate the need to down-scale vertically.

There are direct command codes useful for implementing the above. First set the output rate:
MENU 0873: Set maximum output rate to 9 GHz
MENU 0847: Set maximum output rate to 18 GHz

Then add 24 Hertz to the output list:
MENU 0872: For 3840 x 2160 2160 @ 24, 25, 50, 60 Hz framerates
MENU 0877: For 4096 x 2160 @ 24, 25, 50, 60 Hz framerates

Then Save the changes.

Input & Output Rate Matching

The Rate Match setting can be used to alter the output rate to match the input rate if supported by the display. When the output mode is set to "Auto", the default Rate Match setting is (Yes) to make initial setup easier and reduce HDMI sync times. When the output mode is NOT set to "Auto", the default rate match setting is 'No', in case the display will not accept all refresh rates. Refresh rates of source material varies; some material may be 24.00/60.00 Hz instead of the standard 23.98/59.94 Hz rates. Refresh rates for User Interfaces also vary; most source devices use 59.94 Hz, not 23.98 Hz.

The Rate Match setting can be changed in the Output Setup Menu, under 2D select All inputs, All Memories, and All input resolutions and then select the output mode as 2160p60 (3840 x 2160). Then change the "Rate Match" setting to "No" in the Style menu.
The command is: MENU → Output → Styles → [Style#] → HDMI Format → Rate Match → (No, Yes)

Input & Output Rate Matching Using Memories

The Jim Peterson provided a Tech Tip on reducing HDMI sync times for some sources using two output profiles in this post: MEMB follows the input rate (23.98 or 59.94) for all sources. MEMA follows the input rate for DirecTV and Roku, but only outputs 23.98 for the Kaleidescape Strato or OPPO UDP-203. The OPPO OSD output is set at 24 Hertz (Setup → Video Output → Set Output Resolution: Custom, and then Custom Resolution to UHD 24Hz).

When I select the OPPO or Kaleidescape on MEMA, the projector re-syncs due to switching to 23.98 Hz. When starting a movie on either source device, there is no output rate change or HDMI re-sync due to the use of SDR2020 output for both SDR and HDR content. If choosing 59.94 Hz content from either source device, selecting MEMB changes the output to 59.94 Hz.

Many prefer to watch movies at their original 24 Hertz rate. However, for those who prefer faster switching times, fixing the output at 60 Hz can eliminate display output restarts. These commands set Scale-Bias = Off

To avoid output restarts for color format changes, set both the SDR CMS (i.e. CMS0) and the HDR CMS (i.e. CMS1) to SDR2020 output mode. With these changes, video from an OPPO should be visible in ~3-4 seconds. For a display with only a REC. 709 color gamut, set it to SDR709.

HDMI Operations and Microcode Information

HDMI can be very finicky, and issues can be caused by cables or components with HDMI interfaces. The Radiance™ Pro uses a Field Programmable Gate Array (FPGA), which allows greater control over the HDMI interface. Jim Peterson advised in this post that every FPGA is slightly different than every other FPGA. Therefore, while not common, there is a small chance an FPGA does not "like" a particular update, and cause HDMI issues.

Lumagen® has an embedded HDMI output microcode in the Radiance™ Pro. The microcode for 18 GHz output models was updated in the 110817 software release. This new output microcode was a significant improvement from earlier output microcode, but it created issues in some users' systems, so it was reverted in a subsequent software release. To clarify, the subsequent software release just made the original microcode the default, but the new microcode is still available for selection.

If you have an 18 GHz output, try both the new 18 GHz output microcode (MENU 0851) and the original (MENU 0850). No need to Save after these selections, as the Pro will reboot if you ask for the version not currently loaded. It is recommended to power-cycle your AVR and/or display after changing the microcode. To a degree, these two options have different HDMI characteristics. Not all products work with the newer 18 GHz output microcode (for example Sony projectors), but if it works your display, there will be slightly less jitter on the Pro output. Note that the Pro output has very low jitter with either original or new 18 GHz output microcode.

Jim Peterson provided the following information on jitter in this post. Every HDMI connection will have a statistical probability of a non-zero Bit-Error-Rate (BER). This is in the nature of the non-return-to-zero (NRZ) data interface used, and the need for using PLLs to generate clocks for the NRZ signals.

The error rate is never zero. However, in the Radiance Pro design I strive for as low an output jitter (and electrical noise. More on this below) as reasonably possible. Jitter above the HDMI specification limit will likely lead to a higher bit-error rate, which can degrade the image.

From a viewer's perspective, low jitter, is really all about eliminating bit-errors, to get accurate pixels on the screen. In general, you cannot see any picture difference unless a source has so much jitter there is a higher bit error rate. In the "1080 days" you would see bit errors as "sparkles" on the screen. The 4K HDMI chips have "error masking." This pretty much eliminates the sparkles. Bit-errors still degrade the picture, but now this is more in a loss of fine details as the masking filters neighboring pixels to hide the bit errors. This is a subtle but real issue for 4k video.

I get questions frequently of "I see a picture quality improvement when I use XXX cable versus YYY cable, am I imagining this?" HDMI cables can, and do, make a difference in picture quality. Output jitter, and projector/TV HDMI input design, are also a key part of accurate pixel data, and of course to getting a reliable connection in the first place.

HDMI connections must always be considered as a system. Each part has a role to play in getting the pixels to the projector/TV screen accurately. Having a low jitter output, and certainly one that meets the HDMI specification, is essential to accurate pixels on the screen. Then you need a cable with reasonable attenuation profile, correct single-ended and differential impedances, and as few "transmission line discontinuities" as possible. Finally, you need an HDMI input on the projector/TV that not only has few discontinuities, but also that follows the best practices for microwave circuit design techniques. This last seems to be the Achilles heel of many projectors.

So, what about electrical noise on an HDMI output? How does it affect the HDMI signal? Simply stated, electrical noise increases the jitter at the receiving device. Even though HDMI signaling is differential, the noise is not perfectly balanced and so increases jitter. It can also cause a complete loss of signal seen as a video dropout in some cases. Another issue is that the electrical noise is injected into the circuitry of the connected device. For a projector or TV that uses an analog display technology, such as LCOS and DILA, this can cause noise in the image. While many consumer DLP projectors suffer from low contrast, they are digital display devices and not significantly impacted by this injected noise.

In the Radiance Pro design, we not only have the best features, and DTM, we also have the best electrical performance. The HDMI connection matters a lot if you want the best image on the screen. From the HDMI specification, I calculated the jitter requirement for 18 GHz as 101 pS, or less, for data channels. The current Radiance Pro release as I write this (011119) was measured on a Tektronix HDMI tester at 90 pS for data channels running at 18 GHz and had a low electrical noise level. Note that different FPGA loads may have slightly different jitter, but likely within about 10% or so. For comparison, a high-end PC HDMI output recently measured at 450 pS of jitter at 18 GHz and had over a volt of electrical noise. This jitter and electrical noise is enough that the Tektronix had issues recognizing and locking on to the PC's HDMI signal. The PCs 4.5 times spec jitter and extreme noise IMO will degrade image quality.

At Lumagen we have always strived to have the best video processing, but also to be the reference standard for electrical design. I have not really discussed these electrical requirements much and hope this post helps everyone understand this extremely important aspect of design, and how much it affects audio quality and image quality. There was some subsequent discussion in this post and then Jim advised there were hardware changes for further jitter reduction in early 2019 in this post and this post.

Initial Settings Walkthrough

1. Update the software to the latest release and perform a Factory Reset (MENU 0999 and a Save).

2. The Radiance™ Pro automatically selects an appropriate output rate based on the input rate.

3. There are optional setup optimizations you can make to improve user experience, like EDID settings, power on order, and the connection order recommendations noted above.

4. EDID is reported back to sources as follows:
   - Audio EDID from device on Output 1; By default, the Audio EDID is set to "passback", which only works when you connect Audio output from Output 1 to an AVR.
   - Video EDID from device on highest numbered Output
   - Manual selection of EDID reporting back to the sources is also possible as follows:
     - Audio EDID:
       - MENU 0943: All audio formats
       - MENU 0944: Basic audio (2 CH PCM + DD5.1)
       - MENU 0745: 2 channel 44.1k and 2 channel 48k
       - MENU 0746: 2 channel 44.1k, 2 channel 48k, plus DD5.1
       - MENU 0747: Common formats without ATMOS, or DTS X
       - MENU 0748: Common formats with ATMOS and DTS X
       - "Common formats" include all HDMI 2.0 audio formats
     - Video EDID:
       - Report HDR, Rec. 2020
         - The command is: MENU → Global → Video → Src Format → Rec. 2020: Yes
         - The command is: MENU → Global → Video → Src Format → HDR: Yes
       - Report 3D Capability
         - The command is: MENU → Output → 3D Options → Out? Is 3D Capable: Yes

5. Manual output mode selection
   - This will speed up input switching, as the outputs restart less often.
     - Allow 3840 x 2160 @ 50 or 60 Hz framerates only:
       - The command is: MENU 0873 (9 GHz max)
       - The command is: MENU 0874 (18 GHz max)
     - Allow 3840 x 2160 @ 24, 25, 50, 60 Hz framerates
       - The command is: MENU 0872
     - Allow 3840 x 2160 @ 24, 25 Hz framerates or 1920 x 1080 @ 50, 60 Hz framerates
       - The command is: MENU 0871
     - Allow 4096 x 2160 @ 24, 25, 50, 60 Hz framerates

- The command is: MENU 0877

Video Input

- The Video Input Menu is used to configure independent settings for each input, input memory, and input resolution. Often no changes are needed using the Input Menu.

Input Setup

- The Input Setup Menu is used to select input settings based on the input resolution and vertical rate. For each Input, Input Memory, and Input Resolution, there are 8 input configuration memories.

- The Video Input Select Menu does not affect the audio settings. See the Audio Configuration section for information on configuring audio modes. "4k" is the most common 4k format and is 3840 x 2160. "Cin4k" refers to Cinema 4k and is 4096 x 2160.

- First highlight the '2D' or '3D' row and press "Ok" to edit.

Input Condition			->	Input Config Selection
	In	Mode		Config
*2D:	1A	1080	->	1080-0
3D:	1A	1080	->	1080-0
^ Selects 2D or 3D setup, press OK to edit				

- Next highlight the input condition entry that you want to edit.

2D Input Condition			->	2D Input Config Selection
In#	Mem	Mode		Config
1	A	1080	->	1080-0
(Input to edit output settings of)				
<> Select, ^v Change, OK to set, Exit quits				

- The ◄ and ► buttons change the active column. The ▲ and ▼ buttons select the input number, input memory, and input mode. In each Input Condition column one of the selections is "All."

Input Configuration

- The Base Input Resolutions are 480, 576, 720, 1080, 4K, Cin4K, Other. The 4K mode is automatically selected for 3840 x 2160 sources, and the Cin4K mode is automatically selected for 4096 x 2160 sources. Each Base Input Resolutions has 8 user programmable configuration memories 0 to 7.
- For each input sub-memory, adjustments include various Picture, Size, Control, and Enhance settings.

Black and White Levels

- Black Range: **0 to 64** White Range: **-128 to +128**
- Used to set the input's black-level (aka brightness) and white-level (aka contrast) using the Lumagen® controls and a PLUGE test pattern from the source device.
- Use a test pattern generator or a test pattern disc sent through the source device.
- These controls are intended to compensate for variations in video source levels, after calibration of the display.
- The command is: MENU → Input → In Configs → [Resolution] → [#] → Picture → (Black, White)

Colorspace

- The "Auto" mode is recommended, but some upscaling sources do not convert the color format to Bt.709 when programmed to output HD formats, so "Bt.601" would be manually selected.
- The colorspace selection options are: **Auto**, **Bt.601** (Standard-Definition), **Bt.709** (High-Definition), Bt.709 (Ultra-High Definition), and **Bt.2020** (High Dynamic Range).
- The command is: MENU → Input → In Configs → [Resolution] → [#] → Picture → Colorspace

Color Decoder

- Normally not used if the Color-Gamut is calibrated using the Radiance™ CMS system, unless the source has an error in its color decoder.
- If needed, use color-bar pattern to set color, Hue, color, and Hue offsets, via the Lumagen® internal test pattern, an external pattern generator, or a test disc.
- The command is: MENU → Input → In Configs → [Resolution] → [#] → Picture → Color Decoder

Y/C Delay

Range: +/- 1.9375 pixels in 1/16 steps

- Adjusts the horizontal Chroma timing in relation to Luma using a Y/C-delay calibration image. The CB and CR channels are adjusted independently.
- Use a test pattern generator or a test pattern disc sent through the source device.
- The command is: MENU → Input → In Configs → [Resolution] → [#] → Picture → YC Delay

CUE Filter

- Minimizes Chroma issues for sources with a Chroma up-sample error.
- The command is: MENU → Input → In Configs → [Resolution] → [#] → Picture → CUE Filter

Input Aspect Ratio Selection

- The input source aspect ratio can be selected by pressing one of the **4:3**, **LBOX**, **16:9**, **1.85**, or **2.35** aspect buttons.
  - Use **4:3** for standard definition full-screen material.
  - Use **LBOX** for "letterbox" standard definition material, with black bars above and below the image.
  - Use **16:9** for material labeled as "Enhanced for 16:9 televisions".
  - Use **1.85** for material labeled as "Aspect ratio 1.85".
  - Use **'Alt' 1.85** for material that is "Aspect ratio 1.85 letterboxed in a 16:9 (1.78) window".
  - Use **2.35** for material labeled as "Aspect ratio 2.35".
  - Use **'Alt' 2.35** for material labeled as "Aspect ratio 2.40".
  - Use **NLS** to apply a horizontal non-linear stretch, to stretch 4:3 to 16:9, or 16:9 or 1.85 to 2.35 or 2.40.
    - To use the **NLS** feature, press "**4:3, NLS**", "**16:9, NLS**", or "**1.85, NLS**".
- Ensure the "display aspect ratio" setting is 16:9 in the setup menu of all video sources, even if the display is not 16:9.
- The command is: MENU → Input → Options → Aspect Setup → Auto Aspect, and Aspect Set

Non-linear Stretch

- Non-linear-stretch (NLS) is used to horizontally stretch a 4:3 aspect ratio source to fit a 16:9 aspect-ratio display or to stretch a 16:9/1.85 source to fit a 2.35 aspect-ratio display. The image is stretched by a constant amount in the center section, and by an increasing amount approaching the left and right edges. This eliminates the black sidebars normally seen when viewing smaller aspect material on a higher aspect display. To use non-linear stretch press the “4:3”, “16:9” or “1.85” button and then press the “NLS” button.
- The goal is to stretch the image to fill the screen in a way that looks as natural as possible. The Lumagen® NLS command is very flexible and allows the image to be adjusted to user preferences to achieve this goal. The NLS adjustments are center width, center stretch, top cropping and bottom cropping. The center section of the image is stretched by a constant ratio from 0% to 24%. The width of the center section can be set from 15% to 70% of the display width. By programming the center section width and stretch amount, the amount of non-linear stretch in the left and right sections can be optimized. In addition, the top and bottom cropping can be set from 0 to 12%. Increasing the amount of cropping reduces the amount of stretch near the left and right edges of the image. When setting the cropping parameters, check the satellite/cable-box menu to ensure that critical information remains visible.
- Some 4:3 sources fill the entire source image (e.g. DVD 16:9 movies), but other sources place a 4:3 image in the center of a 16:9 image (e.g. HDTV with up-scaled SD source). This latter case is seen as a “pillar-boxed” image with black bars on the left and right. The “PILLARBOXED” parameter must be enabled for this case. The Radiance™ Pro will then crop the pillbox bars and stretch the active 4:3 image.
- For a 16:9 display, when 4:3 NLS is enabled, the image will fill the screen with a 4:3 (1.33) source for any output aspect ratio up to 1.85. If the output aspect ratio is greater than 1.85, software limits the maximum width to the equivalent of 1.78 and adds left and right sidebars.
- For a 2.35 display, when 16:9 NLS is enabled, the image will fill the screen with a 16:9 or 1.85 source for any output aspect ratio up to 2.40. If the output aspect ratio is greater than 2.40, software limits the maximum width to the equivalent of 2.40 and adds left and right sidebars.
- The command is: MENU → Input → In Configs → [Resolution] → [#] → Size → [Aspect Ratio] → NLStretch
  - Select the parameter to adjust using the ▲ and ▼ arrows and change the value of the selected parameter using the ◄ and ► arrows.

Alternative To Non-linear Stretch

Courtesy of Jim Peterson from this post.

For 16:9 content on a 2.35 screen the NLS center section stretch is 18%. This is noticeable, but many do not find it to be objectionable. If you are like me, this is a bit much, and that does not take into consideration the sides with even more stretch. If you agree with me, there is a middle ground.

If you like NLS, or you always want perfectly square pixels, you can stop reading here. If you are intrigued, please read on.

Rather than using NLS, use the "output aspect per input aspect" feature (Output->Style->Style0>Aspect->Output Aspect per Input Aspect) to program a modest linear stretch that to most people is not noticeable. You can pity my friends who I have used as unknowing test subjects to determine what is a reasonable horizontal stretch and what is too much.

At 18% linear I have had people note the image did not look quite right. However, when I dropped to 10% horizontal linear stretch, no one has ever commented, even when asked pointblank if they noticed anything "different." Even knowing there is a 10% horizontal stretch, I find typical content looks good.

As an example, a 10% stretch for 16:9 content on a 2.35 screen can be achieved by telling the Radiance Pro that when the input aspect is 16:9, the output aspect is 2.13 (even though the screen really is 2.35). This uses a linear stretch (which I prefer to NLS), uses more of the screen area for a larger more immersive image, and has smaller black side-bars. You can experiment for the 16:9 input case with 2.1 for a bit more stretch, or 2.16 for a bit less.

See if you like it, or not. If you do, you can also try:

Content Programmed output aspect
4:3 2.13
16:9 2.13
1.90 2.14
2.00 2.15
2.20 2.20 (so 2.20 fills the 2.35 screen with a 7% stretch)
2.35 2.35
2.40 2.40

In addition, it is nice that this works with Image Based Auto Aspect.

Another option if you have not choosen your screen yet, and you are okay with some stretch, and a bit of side cropping for 2.35 and 2.40 content, choose a 2.1 aspect screen. I have now convinced a few people who split their time equally between 16:9 content, and movies, that a 2.1 aspect screen is a reasonable choice. Let's do the math:

Content Programmed output aspect
4:3 1.90
16:9 1.90
1.90 1.90
2.00 2.00
2.20 2.20 (about 5% vertical stretch)

2.35 2.35 (but crop some off the left and right to keep vertical stretch smaller)
2.40 2.40 (but crop some off the left and right to keep vertical stretch smaller)

This mixes horizontal stretch, with vertical stretch and cropping of the sides. I considered a 2.1 aspect screen for the Lumagen Demo theater. However, since I am 95% movies, I went with a 2.40 Stewart StudioTek 130.

If you want to mix in NLS for the 16:9 content to fill the 2.1 screen, using auto-aspect, select "NLS when applicable," and set the output aspect to the actual 2.10 aspect ratio for 16:9 content in the output Style0 aspect menu. Then make sure to adjust the center section stretch to about 10% for the 16:9 content.

I completely understand videophiles wanting square pixels to stay square, and in fact that is how I currently have the Lumagen Demo Theater configured. However, I also understand wanting to "fill the screen" with minimal compromise and this is the reason for my post here.

2.1 Aspect Ratio Screens

Videophiles like the pixels to stay at their correct aspect, but if you want to "fill the screen" and since you like bot 16:9 and 2.40 content you might want to consider the following:

If you are okay with some stretch, and a bit of side cropping for 2.35 and 2.40 content, choose a 2.1 aspect screen. If content is split between 16:9 content, and movies, a 2.1 aspect screen is a reasonable choice. Let's do the math:

Content Programmed output aspect in Lumagen Output Style Style0 menu:
4:3 1.90
16:9 1.90
1.90 1.90
2.00 2.00 (about 5% horizontal stretch)
2.20 2.20 (about 5% vertical stretch)
2.35 2.35 (but crop some off the left and right to keep vertical stretch smaller)
2.40 2.40 (but crop some off the left and right to keep vertical stretch smaller)

This mixes horizontal stretch, with vertical stretch and cropping of the sides. If you want to mix in NLS for the 16:9 content to fill the 2.1 screen, using auto-aspect, select "NLS when applicable," and set the output aspect to the actual 2.10 aspect ratio for 16:9 content in the output Style0 aspect menu. Then make sure to adjust the center section stretch to about 10% for the 16:9 content.

Image Zoom

- After the input aspect ratio has been selected, the image can be zoomed in to better fit the screen. The zoom function uses the ▲ and ▼ arrow buttons. When the menu is off, by default, the ▲ arrow button zooms in by about 15% and the ▼ arrow button zooms out by about 15%.
  The Zoom amount can be changed to 5% steps.

Letter Box Zoom

- By default, the LBOX and 2.35 input aspect ratio button zoom the image to fill the height of the output. For example, for a 16:9 output aspect ratio, pressing the 2.35 will zoom the 2.35 letter box image to the height of the screen and crop the left and right edges to fit the screen. If the Output Aspect Per Input Aspect feature is used this may not be the correct behavior. The Letter Box Zoom command can disable the Zoom for these input aspect ratio selections.
- The command is: MENU → Input → In Configs → [Resolution] → [#] → Size → [Aspect Ratio] → LBox Zoom

Input Enhancement – Darbee Visual Presence

- The Darbee Visual Presence (DVP™) feature can improve the perceived visual quality of an image. It does this by adding definition and contrast to the image. Darbee DVP can be used with the other Radiance™ video enhancements, especially the edge enhancement "Sharpness" control, to further enhance the image. Darbee DVP supports sources up to 1080p60.
- By default, the Darbee video enhancement is turned on at a normal level. You can experiment to find the appropriate level, for your video source and display. Many users find that "HD" mode with a "Gain" setting in the range of 25, to 55, provide the best overall results.
- DVP is automatically turned off when a Radiance™ test pattern is displayed. When using an external test pattern, turn off DVP by setting "Enabled" to "No" in the Darbee menu.
- There are two ways to access the Darbee menu.
  - With Factory Settings the ► button is a short cut to bring up the Darbee menu.
  - The command is: MENU → Input → In Configs → [Resolution] → [#] → Enhance → Darbee

Darbee menu control

- Press ◄, or ►, arrow buttons as needed to select the setting to modify. Press the ▲ and ▼ arrow buttons to change the selected setting. Press the **EXIT** button to leave.
- **Gain** Range: 0 to 120
  - Most people prefer a gain from 25-55, but the optimum setting varies based on the video source, display, and personal preference. A gain setting of 0 effectively turns Darbee off and has the same effect as setting "Enabled" to "Off".
- **Mode**
  - **HD** The "High Def" mode can be used for watching high definition video. It has the least aggressive processing and is virtually free from processing artifacts. This is also a good general-purpose mode to use for all types of video content.
  - **Full** The "Full-Pop" mode can be used for watching low-resolution or lower-quality video. It has the most aggressive processing, and artifacts may be more noticeable.
  - **Game** The "Game" mode can be used for playing video games. It is also a good mode to use for watching Computer Generated Imagery (CGI) and clean video sources.
- **Enabled**
  - Set "Enabled" to "Yes" or "No" to turn the Darbee video enhancement on or off. Use this control to compare an image with and without the Darbee video processing.
- **View**
  - Set "View" to "Full" for normal viewing with Darbee processing. Set "View" to "Split" to display a split-screen image, with Darbee processing on the right half of the screen. The split-screen can be used to demonstrate or evaluate Darbee DVP processing.

Input Enhancement – Sharpness

- The sharpness feature can improve the perceived visual quality of an image. Sharpness can be used with the other Radiance™ video enhancements to further enhance the image. The sharpness control supports resolution up to 4K.
- By default, the sharpness video enhancement is turned off. You can experiment with the level setting to find the appropriate level, for your video source and display. This setting is applied on a per input, per input memory, and per resolution basis, so you can have different settings as required by a given source device and content resolution.
- Kris Deering made the following recommendation in this post: I've mainly stuck to evaluating 1080 and 4K content. With 1080p, I find a value of 2-4 to be ideal IMHO. I mainly stick to 2-3 with 3 probably being a safe default for those that want a balance of a nice uptick in noticeable sharpness but minimal artifacts (some REALLY sharp 1080 material may be better at 2). Same goes for 4K as well, I'm finding 3 a good place for most content without looking exaggerated or adding noticeable noise/ringing.

  I tend to evaluate with the sharpest transfers and set my levels for those because soft movies are going to look soft and compensating for them as the mainstay can make good looking transfers look over done. This is obviously season to taste, so set wherever you prefer! You can also turn it on and off from the same menu instantly, so it makes it easy to compare.

  I also found that if you use Darbee you may want to reduce the setting on that so the two don't combine and create an exaggerated image. I find 20-25 a good balance point.
- Jim Peterson added in this post: One additional detail I would like to add is for 4K UHD and / or HDR content: I use a slightly higher setting for content shot or mastered at 2k than for content shot and mastered at 4k or higher. So, you might use 2-3 for true 4k content and a setting of 3-4 for UHD content shot/mastered at 2k.

  I recommend leaving the setting one click down from "very noticeable." For me personally I would rather error on the side of less sharpness rather risk over-sharpening. Of course, some content looks fine with a higher setting than other content. Completely up to you and your preference.

  In summary, I have to say I like our sharpness feature, which is completely different than my feelings about other sharpness features. If you don't overdo it, the Radiance Pro sharpness features gives a nice step up in detail without looking artificial. We really worked hard recover detail lost in mastering and compression but avoid the "artificial" and "over processed" look some have noted with other sharpness features.
-

- There are two ways to access the sharpness menu.
  - With Factory Settings the ▶ button is a short cut to bring up the sharpness menu.
  - The command is: MENU → Input → In Configs → [Resolution] → [#] → Enhance → Sharpness

Sharpness menu control

- Press ◀, or ▶, arrow buttons as needed to select the setting to modify. Press the ▲ and ▼ arrow buttons to change the selected setting. Press the **EXIT** button to leave the Sharpness menu.
- **Level** Range: 1 to 5
  - A setting of 3 is a good set and forget point for both 1080p and 4K UHD content.
  - If you use Darbee you may want to reduce the setting to 20-25.
- **Sensitivity** Range: Norm, High
  - This setting mitigates dither, noise or compression artifacts in content with encoding issues. When artifacts are noticeable, try the High setting, as that does a better job of reducing artifacts that are inherent in the source but exaggerated by the sharpness feature. The HIGH setting provides a nice bump in perceived image sharpness without emphasizing grain, artifacts, etc. NORM still looks really good, but is not as much of a set it and forget it option.
  - Changing the setting in one input changes all inputs because by default the input configuration per resolution settings are shared; the default input config “<resolution>-0” is set for all inputs.
    - There are 8 memories per resolution (*-0 through *-7) available, which can be assigned to ensure all inputs have independent input configuration settings per resolution.
    - To assign a config to a specific input, go into input -> Input setup and then change the config selection based on the input mode.
    - So, for example, if you wanted your 1080p settings for input 1 to be different than input 2, you can assign 1080-0 to input 1 and 1080-1 to input 2.

Input Options

HDMI Setup

- Often the HDMI Input setup features are not required. However, for special cases or non-conforming sources, they are available to optimize each input. If required input setup should occur after the output setup is complete. The menu options are Physical In, Video EDID, Audio EDID, HDCP, Type, and Level.

  - **Video EDID**
    - The "--Src Video Formats (EDID)--" options are: **Interlaced, Rec2020, HDR, Video Limit, and HLG**.
    - The command is: MENU → Input → Options → HDMI Setup → Video EDID → (Interlaced, Rec2020, HDR, Video Limit, and HLG)
    - The options for each of these parameters is: Use Global, Auto, No, Yes

  - **Audio EDID**
    - The "--Src Audio Formats (EDID)--" options are: **PassbackOut1**, **Basic**, **Common**, **CommonNoAtmos**, **PassbackOut2**, **PassbackOut3**, **PassbackOut4**, **2Ch48**, **2Ch48,DD**.

  - **HDCP**
    - An HDCP 2.2 capable source is required to output using HDCP 2.2 encryption because the Radiance™ Pro supports HDCP 2.2. If the output of the Radiance™ Pro is connected to a HDCP 1.X TV, or projector, the video will be disabled because the TV, or projector, is not HDCP 2.2.
    - Generally, if an HDCP 2.2 capable set-top box or UHD Blu-ray player sees a HDCP 1.X device on its output, it will downgrade the video resolution and output as HDCP 1.X.
    - This command allows the Radiance™ Pro to report only HDCP 1.X capability back to the source, so a downgraded video format (vice disabling the video) will be output from the set-top box or UHD Blu-ray player for 4k sources.
    - The command is: MENU → Input → Options → HDMI Setup → HDCP

  - **Type**
    - By default, the HDMI input format is detected automatically using the HDMI Info Frame. For DVI sources, the Auto mode selects RGB format. For sources that do not report their format correctly, the input format can be selected manually.
    - The options are: **Auto**, **YCbCr 444**, **YCbCr 422**, and **RGB**
      - Set to "Auto" for YCbCr 420.
    - The command is: MENU → Input → Options → HDMI Setup → Type

Aspect Setup

- **Auto Aspect**
  - For HDMI sources, aspect information may be sent from the source. Enabling HDMI Auto-Aspect allows the source to select the input aspect ratio using the HDMI Info Frame aspect ratio information. The Radiance™ Pro can also automatically detect the input aspect ratio by analyzing the image to see if it fills the height of the source raster.
  - If the user manually selects an aspect ratio, by default, that aspect ratio will be used until the next aspect ratio change is detected by the Radiance™ Pro. If enabled, the Sticky Aspect Override feature will disable the image-based aspect ratio detection, and the new aspect will be used until the input is reselected, the **Input** button is pressed, or a memory button is pressed.
  - The command is: MENU → Input → Options → Aspect Setup → Auto Aspect
    - The following shortcut commands temporarily disable/re-enable auto aspect detection: **Alt + Clr** temporarily disables auto-aspect and **Alt + NLS** re-enables it.
  - The menu options are: **Auto Aspect Control, Sticky aspect override, NLS when applicable, Letterbox Zoom, and Merge to 1.78**.
    - The **Auto Aspect Control** options are: **Off** (default), **HDMI** (only), or **HDMI + Image** based auto aspect.
      - Since the image-based auto aspect analyzes the video, it is possible in rare cases that one aspect ratio might be mistaken for another.
    - The **Sticky aspect override** options are: **Off** (default), **On**
      - When you select a specific aspect ratio with this option on, it will stay at the selected aspect ratio, even if a different aspect is detected.
    - The **NLS when applicable** options are: **Off** (default), **On**
      - Often users prefer that, for example, 16:9 sources use the NLS function to stretch the image to fill an anamorphic screen. If the NLS when applicable feature is enabled, when the Radiance™ Pro detects 4:3, 16:9, or 1.85 as the source aspect, the NLS features is automatically applied.
    - The **Letterbox Zoom** options are: **Norm** (default), **Off**
      - Select whether the automatic aspect ratio detection applies Letterbox Zoom to letterboxed sources.
    - The **Merge to 1.78** options are: **Off** (default), **On**
      - Merges 1.85 to 1.78 to prevent miss-queues given how close these are.
    - The **Merge to 2.35 / 2.40** options are: **Off** (default), **On**
      - Merges 2.35 or 2.40 to prevent miss-queues given how close these are.
-

- **Aspect Set**
  - Set Input Aspect Same **No (Default), Yes**
  - This command controls whether the input aspect is common to all input resolutions for a given configuration memory, or if each input resolution has a unique aspect ratio.
  - By default, the input aspect ratio can be unique for each input resolution. When a control system is used to control the input aspect ratio it may be desirable to have a common aspect ratio for a given configuration memory and allow the control system to select it without regard to the input resolution.
  - The command is: MENU → Input → Options → Aspect Setup → Aspect Set

- **Custom Setup Information**
  - In this post, Jim Peterson outlined a setup for a customer who wanted all content to fill his 16:9 screen.
  - This approach is not for everyone, as it requires changing the content aspect ratio.
-

Genlock

- **Genlock**
  - Genlock is used to provide a constant video delay from input to output, which avoids intermittent dropped or repeated frames. It has been designed to mitigate switching delays for channel changes and can be enabled for set-top boxes.
  - Genlock incurs some delay as it must sync up the "flywheel" (PLL) attached to the video output clock to the input clock to avoid dropped / duplicate frames.
    Genlock Normal and Fast vary in how aggressively they attack the flywheel (braking / accelerating it). Once the clock is considered valid, the display then has re-sync to it.
  - Another advantage of the Radiance™ Pro Genlock is that the input to output video delay is within a few milliseconds and is independent of the input and output mode. For example, with Genlock on, the input to output delay for 1080i in to 4k60 out is similar to 24p in to 24p out.
  - There are two Genlock modes, Normal and Fast. Normal uses the input video clock as the clock source for the Genlock PLL. Fast mode uses an internally generated clock for Genlock and steps this clock rate up or down by small increments to keep the input and output clock to the same delay. Some displays will work better with one or the other, but this needs to be determined by experimenting with each.
  - Due to additional switching delay Lumagen® suggests not enable Genlock for 50 / 60 Hertz sources for faster “channel surfing.” If you choose to use Genlock.
  - April, 2019 Update: We are now suggesting Genlock be left off. It has created issues with a couple of displays. We think this is because the Digital PLL step size causes some devices issues. So unless it is really needed we recommend it be left off. If you want to us Genlock we then recommend using it only for 24 Hertz in and out where its benefit is the greatest. We also recommend the audio output to the audio processor be set to “Audio only” if genlock is enabled. The Digital PLL clock step can increase jitter if video is enabled.
  - Jim Peterson posted some additional information in this post.
  - The command is: MENU → Input → Options → Genlock
    - The options are: **Off** (default), **Auto24-Normal**, **Auto24-Fast**, **Auto-Normal**, **Auto-Fast**
    - Genlock can be set to off for all input rates, on for only 24p / 25p, or on for all input rates.
    - For 24p source material, choose between **Auto24-Normal**, and **Auto24-Fast**.

Scale Bias

- **Scaling Bias**
  - The options are Normal and Off.

HDR Setup

- The HDR Setup Menu contains the adjustment parameters for the HDR Tone Mapping options. The ADTM algorithms have improved to a point where you should only need to set the "Display Max Light," and optionally adjust "Dynamic Pad" (DynPad).
- The sub-menu items are: HDR Mapping, Crossover Pt, Max Default, and DynamicCtrls.
- This section is covered in detail after the calibration section**.**

A/V Delay

- **A/V Delay Controls**
  - These controls are used to fix lip sync issues in sources.
  - The command is: MENU → Input → Options → A/V Delay
  - The menu options are:
    - **Game Mode** (No, Yes)
    - **Add internal video delay** (enter value in ms)
    - **Enable EDID delay reporting** (Yes, No)
    - **Video delay to report** (enter value in ms)
    - **Audio delay to report** (enter value in ms)

Unfortunately, the devices we have seen do not correctly deal with the HDMI EDID lip-sync info. It is best to not use the delay reporting and only use the "**Add internal video delay**", in conjunction with the audio delay in the audio processor to fine tune.

Set the Radiance Pro for video delay longer than needed. Then set the audio delay to match for the most critical lip-sync source. If you have sources that have a different lip-sync timing, you can reduce, or lengthen, the video delay in the Radiance Pro for each source. The input memories can be used for multiple settings for a specific source, if different apps have different lip-sync delays.

This is a frame-time adjustment and so a course adjustment. However, for 60 Hz sources the 16.7 mS steps work pretty well. What this implies is if you have a primary 24 Hz movie source, set its lip-sync in the audio processor first after setting the video delay. Then you can use the video frame delay adjustment in the Radiance Pro for 60 Hz sources and get good results.

Enabling Genlock for 24 Hz content may provide better lip sync for 24 Hz content.

Video Output

Overview

- By default, the output is set to "Auto 2" (424X) or "Auto 4" (444X). "Auto 2" means the Radiance™ automatically reads the video EDID from the devices connected to Output 2, and automatically selects the appropriate output resolution.
- For "Auto" modes the output vertical rate is selected based on the input vertical rate. For example, input formats 480i60, 720p60, and 1080i60 automatically select a vertical output rate of 60 Hertz. Input formats 576i50, 720p50, and 1080i50 automatically select a vertical output rate of 50 Hz. For a 24p input formats, a 24p output vertical rate is selected, if the display supports a 24p vertical rate, otherwise a 60 Hz output rate is selected.

Video Output Setup Menu

- The Video Output Setup menu displays the input conditions and output selections and is used to select output settings (Mode, CMS, and Style) based on the input number, input memory, and input video resolution and rate. Parameters for Mode, CMS, and Style are changed using a different menu.
  - The command for the Video Output menu is: MENU → Output Setup → Ok

Input Conditions
Input: 1A Mode: Other, 2D, Rec601
Output Selections
Mode: Custom0(Auto 4) CMS: CMS0 Style: Style0 Out Enables: ABBV (1-4)

- Once the above menu appears, press "**Ok**" again to display the Video Output Select Menu.

In Condition			-	Video Output Selection					
	In	Mode		Mode	3D Type	601/709 CMS	HDR/2020 CMS	Style	Enable 1 2 3 4
*2D:	1A	1080p24	-	Custom0 (Auto 4)		CMS0	CMS1	Style0	A V B V
3D:	1A	1080p24	-	Auto 4	Auto	CMS0	CMS1	Style0	A V B V

  - Press the ▲ and ▼ arrow buttons to Highlight the **'2D' or '3D'** row and press "**Ok"** to edit.

2D In Condition			-	2D Video Output Selection				
In#	Mem	Mode		Mode	601/709 CMS	HDR/2020 CMS	Style	Enable 1 2 3 4
1	A	1080p24	-	Custom0 (Auto 4)	CMS0	CMS1	Style0	A V B V

- The above menu is navigated as follows:
  - Press the ◀ or ▶ arrow buttons to highlight the input condition entry to edit.
    - Press the ▲ and ▼ arrow buttons to set the input number, input memory, and input mode.
      - To allow application of the output setup to multiple input conditions, press "4" to select 'All' as the condition.
      - When making settings that apply to multiple input conditions, you can leave any of the output settings unchanged by selecting the '---' option for that output setting.
      - The 9 GHz Video Output cards have selections for:
        - "A" = audio only
        - "B" = both audio and video
        - "V" = video only
        - "N" = no output
        - "-" = to leave unchanged
      - The 18 GHz output cards have varying selections that are inter-dependent:
        - The odd-numbered outputs (1,3)
          - "A" = audio only
          - "N" = no output
        - The even-numbered outputs (2,4)
          - "B" = both audio and video

    - "V" = video only (If the odd-numbered outputs are off)

Color Management System (CMS) Menu

The Color Management System (CMS) stores settings used to calibrate the color of the display. There are menus to calibrate the following: Gamma curve, color gamut, colorspace, grayscale and gamma tracking, color decoder, black level, white level, and HDR Intensity Mapping.

- **Gamma Factor** adjusts the gamma curve of the Radiance™ video output.
  - Changing the Gamma Factor allows for a "coarse correction" control for display Gamma. The default setting of 1.00 leaves the output gamma unchanged.
  - It should be set to (Desired_Gamma / Measured_Gamma).
  - The command is: MENU → Output → CMS's → [CMS] → Gamma Factor

- **Color Gamut** allows for color calibration with measurement tools and equipment.
  - The color calibration options are: Primary and secondary color point, 125 (5x5x5), 729 (9x9x9), or 4913 (17x17x17) points throughout the RGB color cube, and 3D color lookup table (3D LUT) CMS
  - The command is: MENU → Output → CMS's → [CMS] → Color Gamut

- **Colorspace** allows for changing the output colorspace.
  - The sub-menu options are: **Colorspace**, **HDR Flag**, and **2020 <-> 601/709**.
  - For **Colorspace**, the choices are: Auto, HDR2020, SDR2020, SDR709, and SDR601. Auto (default) sets the output color space to match the input colorspace.
    - HDR2020 is used to output Rec. 2020, to an HDR display.
    - SDR2020 is used to output Rec. 2020, to a non-HDR display when HDR Intensity Mapping is active; see the HDR Intensity Mapping sections.
    - "SDR601" is generally not used because SD input sources are converted to Rec. 709.
  - The **HDR Flag** setting is used to manually force a display into HDR mode.
  - The **2020 <-> 601/709** setting is used to convert REC. 709 to REC. 2020; the choices are: Auto Convert and Off.
  - The command is: MENU → Output → CMS's → [CMS] → Colorspace

- **Grayscale and Gamma** allows the parametric adjustment of 2, 5, 11, 12 or 21 color temperature points to adjust the grayscale and gamma for the display.
  - The command is: MENU → Output → CMS's → [CMS] → Gray/Gamma

- **Color Decoder** allows correction of color decoder errors in the display that have red and/or green push.
  - This is generally not used in conjunction with Color Gamut 3D LUT calibration.

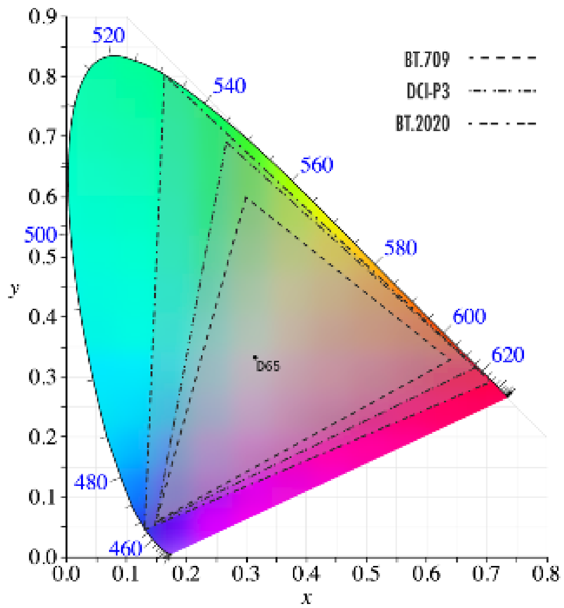
  - The command is: MENU → Output → CMS's → [CMS] → Color Decoder
- **Black** is used to set the black level for the display.
  - Normally the "Brightness" (or "Black Level") control in the display is used to set the black background level (see Calibrating Display Optical Black), but this allows for accurate calibration when the display controls are not adequate.
  - The Radiance™ Pro Adjustable Contrast 2 pattern is used to set the black video reference. (see Calibrating Lumagen® Digital Black Level)
  - This control is also useful when a second black level is desired (using a second output CMS) for a "day" or "night" mode.
  - The command is: MENU → Output → CMS's → [CMS] → Black

- **White** is used to set the white level for the display.
  - Normally the "Contrast" control on the display is used to set the white level, but this allows for accurate calibration when the display controls are not adequate.
  - It is recommended that the Radiance™ Contrast Pattern 1 (White and Black squares pattern) be used to set the display's white level.
  - The command is: MENU → Output → CMS's → [CMS] → White

- The CMS **HDR Intensity Mapping** setup is covered in the HDR Intensity Mapping CMS Setup section on page 63.

Color Management System (CMS) Overview

- Color space standards / specifications for video displays are managed by the International Telecommunication Union Recommendations (ITU-R). The ITU-R color space recommendations are:
  - Standard Definition (SD) displays use Rec. 601 / BT.601 color.
  - High Definition (HD) and Ultra-High Definition (UHD) displays use Rec. 709 / BT.709 color.
  - Ultra-High Definition-High Dynamic Range (UHD-HDR) displays use Rec. 2020 / BT.2020 color.
- The Radiance™ Pro video processor supports the HDR10 UHD-HDR standard, along with Rec. 2020 and DCI-P3 color space standards. DCI-P3 is a digital cinema display standard used in commercial theaters. Here is a representation of the BT.709, DCI-P3, and BT.2020 Color Spaces in the CIE diagram.



- Many displays have over-saturated colors, where the primary and secondary color coordinates lie outside the CIE color triangle. Often, displays either lack the proper controls to correct the problem, or they use an inappropriate method, which leads to color errors most noticeable in flesh-tones and natural colored objects, such as grass.
  - Color/Hue/Offset should not be used to try to correct the primary colors, because they operate in a nonlinear color space and provide incorrect results.
  - Hue/Lightness/Saturation (HLS) color space controls should not be used to try to correct the primary colors, because they operate in a nonlinear color space and provide incorrect results.
  - Set displays with these nonlinear controls to neutral before starting a new calibration.
- Lumagen® uses a linear-Gamma RGB color palette for CMS correction. Linear-Gamma RGB color space is the native color space for displays, and therefore allows the primary and secondary colors to be corrected, while maintaining correct color interpolation.

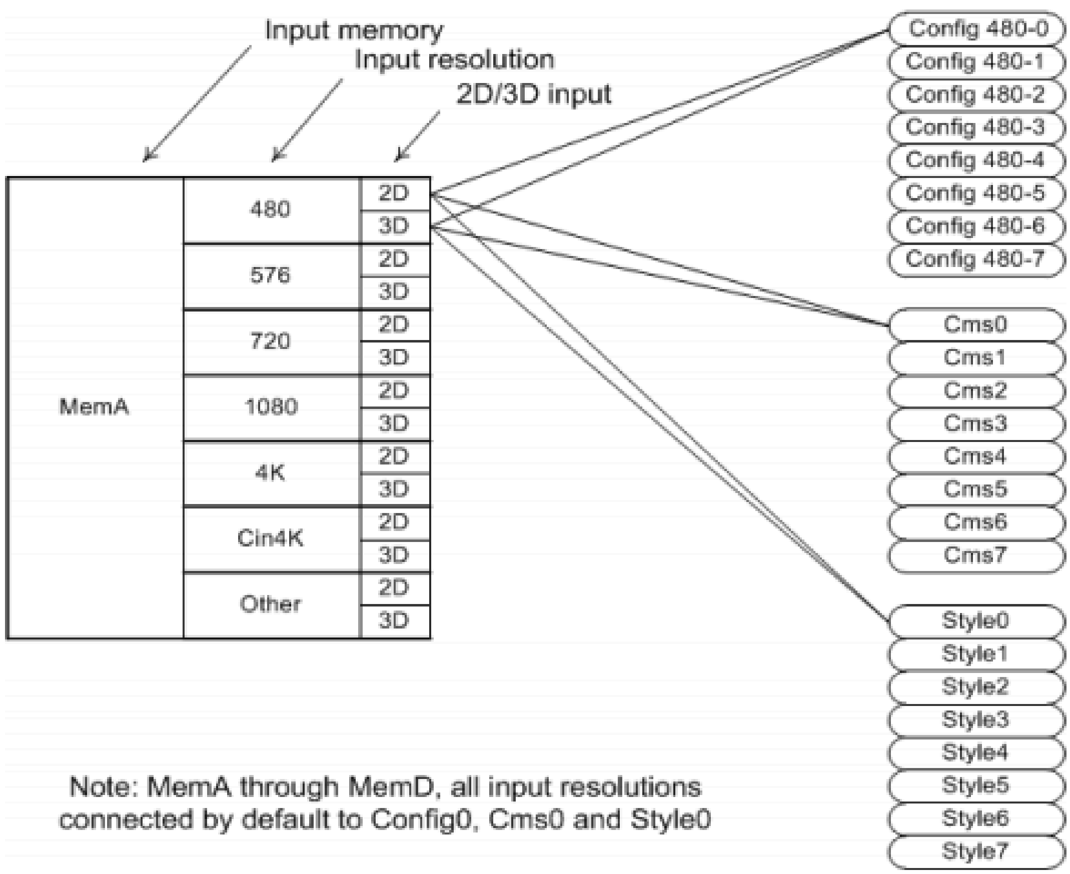
- The Lumagen® Color Management System (CMS) uses a 3D RGB color-palette that allows both the primary and secondary color points to be independently calibrated for (x,y) and Y values. The CMS can accurately correct colors, providing a linear response, including mitigating the non-linear response exhibited by many displays. The Radiance™ video processor models have some CMS variances.
  - The Radiance™ Mini/XS/XD/XE series CMS uses a 125-point (5x5x5 array of points) 3D Look Up Table (LUT) RGB color cube.
  - The Radiance™ 20XX series CMS uses a 729-point (9x9x9 array of points) 3D Look Up Table (LUT) RGB color cube.
  - The Radiance™ Pro series CMS uses a 4913-point (17x17x17 array of points) 3D Look Up Table (LUT) RGB color cube.
- The **HDR** standard supports display brightness up to 10,000 Nits, and the Rec. 2020 color standard, which has a much larger color Gamut than Rec. 709. Current display technologies are unable to obtain these brightness and color standards, so adaptation of the UHD-HDR source material to the actual display capabilities is a critical aspect of HDR viewing. This adaptation process is known as “tone mapping” and is implemented in the Radiance™ Pro in two parts.
  - The color portion of tone mapping is managed by calibrating using the Radiance™ Pro 3D Look-Up-Table (LUT) for color.
  - The brightness portion of tone mapping is managed by the **HDR Intensity Mapping** feature. See the **HDR Intensity Mapping Control** section for additional information.
- When properly calibrated, the tone mapping allows watching HDR10/Rec. 2020 sources on non-HDR Rec. 709 displays. The Radiance™ Pro can drive your display to its full capabilities, allowing a wider color Gamut and less image noise than Rec. 709 sources.

Color Management System (CMS) Memories

- The Radiance™ Pro has 8 CMS memories, labeled CMS0 through CMS7. By default, all Rec. 709 sources are pointed at CMS0 and all Rec. 2020 sources at CMS1.
- If using multiple displays, use different input memories and CMS memories for the various displays. For example: MemA for display 1 using CMS0 (SDR) CMS1 (HDR). MemB for display 2 using CMS2 (SDR) and CMS3 (HDR).
- This image from the manual is a good representation of the flexible memory system.

NOTE:
By default, for a Rec 709 source, all sub-memories point to Auto output mode CMS0 and Style0. For a HDR/Rec2020 source, all sub-memories point to Auto output mode, CMS1 and Style0. For the majority of systems this default set of configuration pointers does not need to be changed.

NOTE:
Changes must be Saved. If changes are not Saved the Radiance Pro will revert to the previously Saved settings when turned off. So, if you make a configuration mistake you can revert to Saved settings with a Power Cycle.



Input memory to output configuration block diagram

DCI-P3 Matrix Conversion Calibrations

The Radiance™ Pro features a DCI-P3 Matrix Conversion feature. This feature can be used with two different methodologies, dependent upon the display capabilities. The first method only works if your display supports the DCI-P3 (RGB) Colorspace AND honors the HDMI Info Frame P3 flag. This method requires the Radiance™ Pro be set to output P3 in the RGB format and does NOT require a 3D LUT calibration. While this method is preferred, most displays are not compliant with the requirements.

The second method supports displays that do not have a specific P3 D65 mode, or do not honor the HDMI Info Frame P3 flag. This method requires the Radiance™ Pro output be set at YCbCr 4:2:2 and requires a 3D LUT calibration. In the display, select the Colorspace that is closet to DCI-P3 Colorspace.

For both methods, the calibration software must support the DCI-P3 Colorspace, and (ideally allow) for changing the white point to D65.

Below is more information on the Radiance™ Pro DCI-P3 (P3) matrix conversion posted by Jim Peterson on AVS Forum:

The P3 matrix conversion comes before the 3D LUT in the video pipeline, and is in the same "RGB Linear Gamma" portion where the HDR Intensity Mapping resides. When the Radiance™ Pro output is set to P3, it enables the matrix conversion from the source format. The P3 output is set to target a Gamma of 2.4, which matches the Gamma we use for HDR-to-SDR2020 output. It allows one "P3 D65 Gamma 2.4" CMS to be used for a 709 source with an HDR output of "SDR P3 D65."

The only color format defined for P3 is RGB. If your display supports P3, honors the HDMI Info Frame P3 flag, AND the Radiance™ Pro is set to output P3 in the RGB color format, there is no need for a 3D LUT calibration. For displays that do not have a specific P3 D65 mode, or If the Radiance™ Pro is NOT set to output P3 in RGB, a 3D LUT calibration is required. There is no standard for the conversion of P3 to YCbCr, but if you plan on a 3D LUT you can actually use YCbCr. In this case the Pro converts from RGB to YCbCr using 709 matrix and projector converts back to RGB using the inverse 709 matrix. So, you can put the projector in it “nearest to P3” mode and then do a 3D LUT using LightSpace.

Prior to calibration, set the Radiance™ Pro output "Colorspace" to P3, and output color format (typically RGB for P3, as noted above) since these settings affect the calibration. Also disable the color space "Auto convert" option prior to calibration; it is re-enabled after calibration. This is crucial, because if the points were converted by the Radiance™ Pro, the calibration would be incorrect: The data points should be passed to the display without alteration (except any required format conversion to 4:2:2 or 4:4:4, if applicable). The 2020 <-> 601/709 setting is used to convert REC. 709 to REC. 2020; the choices are: Auto Convert and Off.

The command is: MENU → Output → CMS’s → [CMS] → Colorspace

For output of HDR as 709, or 709 as 2020, the matrix conversion is optional. For best results, we recommend turning it on versus just using the 3D LUT to do the conversion, especially if you plan to do a calibration. If you have already done a calibration and turn matrix conversion on your calibration will be voided.

For the calibration software, set it to target the primary points for the appropriate color space i.e. "DCI P3 D65" mode and a Gamma of 2.4. For the white point, select D65, if given a choice between D65 and DCI.

If you want P3 output for both 709 and 2020, calibrate for "DCI P3 D65" for CMS0, and then copy to CMS1. This allows you to tweak the CMS's differently for SDR and for HDR sources while using the same 1D and 3D LUT. The calibration process for this example is to have the Radiance™ Pro set to CMS0; it generates SDR patterns while the calibration software measures to the selected P3 targets (with a Gamma of 2.4) and adjusts the Pro 1D and 3D LUT as needed. You then copy CMS0 to CMS1 for use with HDR. For HDR in CMS1, enable the color space (already set to SDRP3) auto convert, enable HDR Mapping, and set the Display Max Light. Make sure to Save. You can use the calibration left in CMS0 for SDR and HDR sources assuming no issues with the display.

Here is another post by Jim Peterson on using the P3 output mode.

HDMI Output Type

- You can specify the digital output range as "RGB-PC level" (e.g. for 8-bit 0 to 255) or "RGB-Video level" (e.g. for 8-bit 16 to 235). "YCbCr 422" is the recommended output format. For the HDMI RGB output, setting the level as video allows blacker-than-black and whiter-than-white video levels to be output from the Radiance™. The Dual Output mode uses two connections to the display with the 12 LSB's on Output 1 and the 24 MSB's on Output 2.

  - The command is: MENU → Output → Styles → [Style] → HDMI Format → Type
  - The various options are: Auto, RGB/Level=Vid, RGB/Level=PC, RGB/36bpp Dual Out/Level=Vid, RGB/36bpp Dual Out/Level=Vid YCbCr444, YCbCr422
  - Note that for some output rates (e.g. 4k60 using 9 GHz output cards) the mode may not be programmable. For reference the 4k60 output mode using 9 GHz I/O cards is always 4:2:0, 8-bit.
  - Lumagen® recommends setting the **HDMI Output Type** to 4:2:2 (12-bit) HDMI output format.

Calibration

Calibration Process Overview

- The Radiance™ Pro has a Color Management System (CMS) that supports creation of Look-Up Table (LUT) calibrations when used with calibration software. The calibration can create both 1D LUTs (Greyscale) and 3D LUTs (color). When a color falls outside the native gamut of a display, it implies that the display just cannot physically output that color. Ideally, the display should properly map the gamut of the input colors to its native gamut.
- If the display does not properly map the gamut, the Radiance™ Pro can be set up to perform this task. In addition, the gamut mapping can be used to target color spaces other than Rec. 79 or Rec. 2020. For example, a 3D LUT can be created for DCI-P3 D65 target, with the projector color space set to the native gamut, and the Radiance™ Pro performs the gamut mapping instead of the projector.
- The Radiance™ Pro CMS that supports separate calibrations for SDR (CMS0) and HDR (CMS1) sources with the default settings. For example, up to four calibrations variations can be stored for each SDR and HDR CMS using the eight CMS memories available. It is important to understand how this works to ensure you have the correct CMS selected for the desired calibration type.
- For multiple displays, use different input memories and CMS memories for the various displays. For example: MemA for display 1 using CMS0 (SDR) CMS1 (HDR). MemB for display 2 using CMS2 (SDR) and CMS3 (HDR).
- Lumagen® recommends using the Radiance™ Pro tone mapping to "output HDR in an SDR container" by calibrating for HDR sources in "SDR Rec. 2020" color space. This recommendation is regardless of the calibration software's ability to successfully create an HDR 3DLUT.
- Prior to calibration, here are some recommended steps:
  1. Print this guide and the manual for your calibration software.
  2. Perform Initial Settings noted above.
  3. Determine the optimal display Colorspace and pre-calibration settings for the intended calibration type. Since other AVS Forum members may have already performed much of the research, reading / searching the dedicated thread for your display device may prove useful.
  4. Ensure you have a solid understanding of the CMS memories in the Radiance™ Pro to avoid saving a calibration in the incorrect CMS.
  5. Make sure you remember to save the calibration in the Radiance™ Pro, as noted in the step-by-step instructions.

Calibration Tips

- It is recommended to allow the display and the probe to warm up for 20-30 minutes prior to taking any measurements.
- While hiring a professional calibrator is recommended, the picture can be improved by using the Lumagen® test patterns and measurement equipment. Using the Radiance™ internal test patterns to calibrate the output configuration eliminates the effect of variances between sources, as the test patterns are generated in Source-Gamma space for all source formats.
  - The most important step is proper adjustment of the Black Level in the display's menu, as noted in the "Calibrating Display Black Level" section.
- The Radiance™ setup and calibration parameters are split into "input memories" and "output configurations."
  - Input memories are for source-specific setup and adjustment.
  - Output configurations are for display setup and calibration.
- By default, the Radiance™ Pro uses the HDR/Rec. 2020 Info Frame flags from the source to select either a Rec. 709 CMS memory (CMS0) or a HDR/Rec. 2020 CMS memory (CMS1). These defaults can be changed using the **Output Setup** menu.
  - When using multiple displays with separate calibrations, these defaults would be changed. For example, display 1 can utilize CMS 0 (SDR) and CMS 1 (HDR), while display 2 can utilize CMS 2 (SDR) and CMS 3 (HDR).
- When viewing HDR source material on non-HDR displays (CMS0), the output HDR Info-Frame is not used. To ensure the best performance, ensure the non-HDR display is optimized by selecting a wide color gamut and a bright output mode with excellent black levels.
- When using a non-HDR display, set the Radiance™ Pro video EDID to report support for HDR and Rec. 2020 to the video source.
  - The command is: MENU → Global → Video
    - Select the "Yes" options for HDR and Rec. 2020 and then save the configuration.
    - Setting this to "Yes" can help with power-on order dependencies for HDR displays.
    - Some 4k HDR players do not read the EDID/HDR information as they are supposed to when Hotplug is toggled, making them power-on order dependent. By manually enabling HDR and Rec. 2020, the HDR display can be off, or even disconnected, and the Radiance™ Pro will still report HDR and Rec. 2020 back to the video sources.
- The calibration pipeline consists of Color/Hue controls (generally not used), and a 3D Look-Up-Table (LUT) for color, followed by a 1D LUT for grayscale/Gamma.
- The recommended Lumagen® calibration sequence for SDR, Rec.709 is discussed in Tech Tip 2 – Gamut Calibration. The Tech Tip 2 instructions are incorporated in Calibration Process section.
-

- Calibrating Black Level is the most important calibration step. Displays will have different black levels depending on the APL of the image. The Radiance "Contrast 1" pattern with a –4% and a +4% vertical bar on the sides is a high APL image. It is better to use the low APL Radiance "Contrast 2" pattern, which has -4% to 4% vertical bars in 1% steps in the center, and the "Black Ramp" pattern to ensure that dark scenes have a correct black level setting.
  - Select reasonable display settings, including appropriate lamp/backlight level, and then calibrate the Display Optical Black Level, the Display Black Level, and (if necessary) the Lumagen® Digital Black Level prior to calibration (1D/3D LUT); the processes for these adjustments is outlined below.
  - Calibrate Black Level for individual SDR sources via the input memories.
  - Calibrate Black Level for individual HDR sources via the input memories.
- Lumagen® recommends using the 4:2:2 color format for HDR (and SDR) for both the input and output.
  - The 4:2:2 HDMI format supports 12-bit pixel depth, including 4k60 for 18 GHz I/O cards.
  - The only exception would be if there is an I/O speed limitation (e.g. 4k60 on a 9 GHz card).
- The Gamma for an SDR calibration (SDR input to SDR output) should be determined by the display, and this occurs with the default settings.
- The Gamma for an HDR calibration (HDR input to SDR2020) should be set to 2.4 in the display, as the Intensity Mapping EOTF expects either a display Gamma = 2.4, or a LUT calibration of Gamma = 2.4.
- Lumagen® recommends selecting the output format and any conversion and then do a calibration to the specified Gamma.
- Calibrate on an unused input with no active source to mitigate the time it takes for the test patterns to draw, as noted in this post.
- Typically, the calibration software makes two sets of measurements: One in the display mode that will be used for SDR/Rec. 709 material and one in the mode that will be used for HDR/Rec. 2020 material.
  - For HDR calibration there are three distinct calibration procedures to choose from. Two of these are for an SDR display (or an HDR display in SDR mode), and one for HDR displays using HDR output mode. The default is CMS1 for HDR and/or Rec. 2020 sources.
  - Alternately it is possible to use a single bright mode with a large Gamut for both HDR and SDR sources. After initial measurements the calibration software creates a 1D LUT, and a 3D LUT for SDR/Rec. 709, plus a separate 1D LUT and 3D LUT for HDR/Rec. 2020.

SDR Calibration Tips

- SDR for commercial theaters is generally targeted at 14 foot-lamberts (16 foot-lamberts open-gate). This is 48 nits, which matches your target.

  However, commercial content mastering targets 106 nits (-ish. I have heard numbers from 100 to 108 nits). While the human eye adapts to the 50% gain commercial theaters use, I prefer a brighter image that more closely matches the master target level. I suspect that 14 foot-Lamberts was selected because it was achievable and worked as a "minimum acceptable brightness" and not because it is the optimal brightness.

  I suppose this is personal taste, but if I had a projector anywhere in the 50 to 100 nit range I would set the brightness for SDR equal to maximum brightness. I expect others disagree.

  If you disagree, I recommend you at least do a test to see. For your 97 nits maximum output, allow SDR maximum to be 97 nits. Then if this appears too bright see if changing the Gamma to 2.6, from Bt.1886 or 2.4, makes the image look better. Many year ago I was installing a VisionPro HDP in a large screening room for a studio. I learned the studio targets 2.6 Gamma for viewing their SDR content. While I tend to target Gamma = 2.4, I also like SDR movie content at Gamma = 2.6 if there is enough brightness out of the projector. Again this is personal preference, but might be worth testing.

- If you want a Gamma of 2.6, if you have Gamma = 2.4 in the projector you can set the CMS1->Gamma_factor to 2.6/2.4 = 1.08. Do this before you calibrate the 1D LUT and check your Black Level after this change.

  Alternately you can target a Gamma of 2.6 in the 1D LUT calibration.

HDR Calibration Tips

- HDR Intensity Mapping must be disabled during calibration.
- The process is to do a 3D/1D LUT calibration to Gamma = 2.4 and target Rec. 2020 primaries using SDR calibration software. unless using the DCI-P3 matrix conversion option.
  - The 3D/1D LUT calibration process is very similar to SDR Rec. 709 and uses SDR patterns generated in source-Gamma space.
  - Most calibration software can perform a 3D/1D LUT calibration for SDR.
  - If the calibration software cannot successfully perform a 3D/1D LUT HDR calibration, try performing only 1D LUT calibration for Grayscale. If the display has fairly accurate color, this may be an acceptable compromise with excellent results.
- Select an SDR source (will select CMS0)
- Set CMS0 *Colorspace* = SDR709
- In the calibration software, select Rec. 2020 primaries (even if *Colorspace* set to SDR709), Gamma = 2.4 (not Bt.1886). Select Radiance™ Pro 21-point Grayscale mode
- Calibrate CMS0 1D and 3D LUT as "SDR Rec. 2020"
  - When performing SDR2020 or SDR709 calibrations, set CMS0 and CMS1 to the same "Colorspace" and do 3D LUT calibration for both, unless using ColourSpace, which can upload LUTS to the chosen CMS.
- Note that you have to make sure your display input modes match up with what the Lumagen is outputting - so if you output SDR2020 you need to use 2020 or HDR modes on the projector, but with Gamma to match the Lumagen (i.e. 2.4).
- Check Grayscale near black and adjust if necessary
- Copy CMS0 (SDR) to CMS1 (HDR), enable CMS1 *HDR Mapping*, set *Gamma to 3D LUT* = SDR and set CMS1 *Display Max Light* as appropriate (acts as coarse contrast control)
- Calibrate Rec. 709 as normal (CMS0). Set CMS0 *Colorspace* = SDR709 (Note: You can use *Colorspace* = SDR2020 and still create a Rec. 709 3D LUT)
- Some projectors move a color filter in place for Rec. 2020 mode. This enlarges the Color Gamut but can significantly reduce light output. You may want to consider using CMS1 Colorspace = SDR709 output mode and selecting a wide Gamut in the projector for this mode. The 3D LUT calibration then moves the points as close to where they should be as possible for the Rec. 2020 source. Given many projectors in Rec. 709 have a Gamut that is much larger than Rec. 709, this can provide an excellent representation of the HDR content at a brighter luminance level than using Rec. 2020 mode.
- Calibrating "HDR" with Colorspace = SDR2020 puts the 5% point for the 21-point 1D LUT farther from Black than is optimal. Lumagen® is considering a 129-point 1D LUT mode to control points closer to Black for HDR sources. Currently you can manually move the 21-point Grayscale points to 0.5%, 1%, 2%, 3%, 4%, 5%, 6%, 7%, 10%, 13%, 17%, 20%, 25%, 30%, 40%, 50%, 60%, 70%, 80%, 90% an 100%. For this optimization you would do the 21-point grayscale auto-calibration, then write down the values for each point and move the points. Measure the new points and adjust the settings for these and enter the appropriate data from the 21- point auto calibration points already done.
- There are a number of HDR movies that do not report (i.e. leave the Infoframe field

= 0), or incorrectly report Maximum Mastering Monitor Light, and/or Maximum Content Light Level (MaxCLL).

- Many HDR Games do not report Monitor Max, or MaxCLL, but use the full 10000 nit range. For these select MENU → Input → Options → HDR Mapping → Max Default = 10,000, then Save
  - These significant errors can prevent tone mapping from working correctly. Lumagen® is looking at ways to automatically correct for these errors.
- The Info Page 2 reports downstream device capabilities. For HDR sources, the Mastering Monitor Max/Min, and MaxCLL are also reported.
  - There are some source devices that report incorrect MaxCLL levels.
- Here is a tech tip on projector calibration from JRP; see this post:
  - In the typical projector system setup, CMS0 is used for SDR content and would be set to Colorspace = SDR709. CMS1 is used for HDR content and would be set to Colorspace = SDR2020.
  - Many displays do not honor the Rec 2020 Info Frame Flag, requiring changing of the picture mode color format depending on whether it is SDR or HDR source material. Bi-directional RS232 control systems (i.e. Crestron, Control4, etc.) can make this an automatic process. Otherwise, manual intervention is required.
  - For (presumably recent model) JVC projectors), Kris Deering provided the following advice in this post to a LightSpace user: If you are going to use the HDR color profile in the JVC, do your calibration to 2020 with LightSpace using the decatenated LUT. I find that a LUT is not needed with the JVCs if the pre-calibration is done properly and grayscale/white point are correct. Just some minor tweaks to the PJ's CMS is typically all that is needed.
  - For projectors with an accurate Rec 2020 mode (e.g. Sony 4k models, but not JVC), an alternative solution is to use SDR2020 for both CMS0 (SDR) and CMS1 (HDR), negating the need for a picture mode color format change. There are two changes required in the Radiance™ Pro prior to calibration.
    - First, set CMS0 to SDR2020 (with "Auto Convert" of color data enabled), "2020 <--> 601/709" = Auto Convert. Since SDR2020 is the same format used for "HDR output in a SDR container", there is no need to change the projector color mode regardless of the source format (SDR or HDR).
    - Second, reduce the "White Level" for CMS0 to reduce the brightness for SDR. Normally, the projector would be calibrated higher light output for HDR versus SDR, usually by manipulating the lamp and/or iris settings.
- If you have questions on setup, HDR, or calibration, please contact us at:
  - Support: 503-574-2211 Monday through Friday 9 to 5
  - Support@Lumagen.com

Calibration Types

For SDR (non-HDR) displays that support a wide (Rec. 2020) color gamut, it is recommended to perform an HDR calibration using SDR display mode (**Colorspace** = SDR2020).

- This option uses **Colorspace** = SDR2020 and **Gamma to 3D LUT** = SDR. The **HDR Intensity Mapping** adapts the HDR EOTF output so the image looks correct on an SDR display.
  - The process is to perform the 3D/1D LUT calibration to Gamma = 2.4 and target Rec. 2020 primaries using SDR calibration software. The 3D/1D LUT calibration process is very similar to SDR Rec. 709 and uses SDR patterns. HDR Intensity Mapping must be disabled during 3D/1D LUT calibration.
  - This method requires calibration of **CMS1** in SDR mode by changing the **Output Setup** menu to select CMS1 for SDR input modes, as instructed in step 3C below.
  - The calibration is performed with CMS1 at SDR Rec. 2020 using the Radiance™ Pro SDR Test Pattern Mode. In the calibration software, select the following:
    - Rec. 2020 primaries (even if Colorspace set to SDR709), unless using the DCI-P3 matrix conversion option.
    - Gamma = 2.4 (not BT.1886)
    - Radiance™ Pro 21-point Grayscale mode
  - After the calibration is complete, CMS0 for SDR sources must be re-selected in the **Output Setup** menu, as instructed in step 13 below.

For HDR displays that support a wide (Rec. 2020) color gamut, but have insufficient light output, like projectors, it is recommended to perform a calibration using the SDR2020 Colorspace. The 3D LUT color calibration is performed with Rec. 2020 primaries and an HDR Gamma.

- This option uses **Colorspace** = SDR2020 and **Gamma to 3D LUT** = Auto. The calibration software generates the 3D/1D LUT to adapt the source HDR EOTF to the display SDR EOTF. The **HDR Intensity Mapping** adapts the HDR EOTF output so the image looks correct on an SDR display.
  - If possible, in the calibration software, reduce the HDR 10,000-Nit limit to ~3,000- 5,000 Nits.
    - This allows setting the Display Max Light at ~2,000-5,000 Nits, allowing more room for the HDR Intensity Mapping to improve the image.
    - In ColourSpace, use Manage Spaces, Colour Spaces (preset) section, and modify the "ST2084 Rec2020" preset. Select the display profile as the Target Profile, and in the Soft roll off, change the Target Max (nits), and save. It will appear in the Colour Spaces (user) section. The below video demonstrates this concept.

      - ColourSpace ST2084 PQ HDR
      - 0:00:00 – 0:01:27 Reducing luminance to compensate for color shift.
      - 0:01:28 – 0:04:18 Generating a new ST2084 color space targeting profiled display.
      - 0:06:00 – 0:08:09 Modifying Rec. 2020 with soft roll off or Tone mapping.

- 0:08:10 – 0:09:14 Generating the LUT.
- 0:09:15 – 0:10:10 Limit Luminance option demonstration.
- 0:10:11 – 0:11:59 Reducing LUT target Nits for sub-optimal viewing conditions.
- 0:12:00 – 0:15:36 Using multipliers to compensate for projection light output.

HDR displays have internal HDR tone mapping, some with significant clipping, and poor tone mapping. This makes calibration difficult, and one of the above SDR output mode options may be preferred.

- If the output is in HDR mode, the **Display Max Light** needs to be set to match the expected level of the HDR source, rather than the display brightness, to account for the internal tone mapping.
- If possible, when generating the 3D LUT, set up the calibration software roll-off parameters for Gamut and intensity to ~3,000- 5,000 Nits maximum, instead of the normal HDR 10,000-Nit limit.
- Reducing the expected brightness will allow you to set the Display Max Light at ~2,000-5,000 Nits, which allows more room for the HDR Intensity Mapping to improve the image.

Tip: Projectors using the same mode for HDR & SDR

As detailed in this post and this post, Jim Peterson recommends using CMS0 and CMS1 Colorspace = SDR2020 for projectors that have a color gamut exceeding REC. 709, and accurate for REC. 2020. Note that with the same Iris and lamp settings for both SDR and HDR, you will lose contrast in SDR. With most projection systems, low lamp and smaller iris settings are sufficient to reach the 50 Nits / 14 Footlamberts SDR brightness level, with increased contrast.

CMS0 is used for SDR 709 content, and would normally be set to Colorspace = SDR709. However, since typically CMS1 (HDR content) is set to Colorspace = SDR2020, and since TVs/projectors apparently do not pay attention to the Rec 2020 Info Frame Flag, this means you have to somehow change the color format to get accurate colors. A bidirectional control system (e.g. Crestron, Control4, et. al.) can switch automatically; otherwise, you have to switch manually. If you have a JVC NX series projector, see the tip below.

By setting CMS0 to SDR2020 with "Auto Convert" of color data enabled (“2020 <--> 601/709” = Auto Convert), this is the same format as the Pro would use for "HDR output in a SDR container." So, if you set both CMS0 and CMS1 output to SDR2020, you do not need to change the projector color mode when switching to or from HDR. Then you won't forget to change it, and you do not need to train others in your family to make the change.

Set CMS0 Colorspace = SDR2020, and enable Auto Convert in the 2020 <-> 601/709 setting in the Output CMS during calibration (and while watching content). In the calibration software, perform an SDR Rec 709 calibration for CMS0.

In addition, if you want HDR to be brighter than SDR, you can turn the "White Level" down in CMS0 and leave the lamp mode and iris settings the same as for HDR. These two changes together mean you would not have to make a manual change in the projector switching SDR to or from HDR.

If the image appears too bright, try changing the Gamma to 2.6, as it makes the image look better if there is sufficient brightness in the projector. This is personal preference, but it might be worth testing. To change to Gamma 2.6 without using an extra user mode in the display, there are two options: If you have Gamma = 2.4 in the projector you can set the CMS1 -> Gamma factor to 1.08 (2.6/2.4 = 1.08). Check the black level after this change, adjust as needed, run a new grayscale profile of the display, and generate a new 1D LUT. Alternately, target a Gamma of 2.6 during the 1D LUT calibration.

Changing HDR Gamma in JVC NX series projectors with firmware ≥ v3.50

Lumagen recommends using a Gamma of 2.4 for greater precision near black, which is not possible to select on the NX series of projectors when sending an HDR signal. However, as of firmware 3.50, the NX Series supports importing Gamma, so this is easy to change to 2.4 using JVC AutoCal. The procedure is noted in this post.

The benefit of this was noted by Jim Peterson in this post: You can also use the HDR flag to select a different memory in the JVC NX series for SDR and HDR, with both using a Gamma of 2.4. This would allow you to use the JVC's manual iris to dial back the maximum light and increase contrast ratio further. If there are different manual iris settings between SDR and HDR, two 3D LUT calibrations are needed. Since the Pro "outputs HDR in an SDR container", they both calibrations would be to Rec 2020 color space and Gamma 2.4.

1. Select the "Content Type" as HDR10 content.
2. Select the "Picture Mode" as one of the User options, and rename it if desired.
3. Select the "Tone Mapping" as one of the Custom options.
4. In the "Tone Mapping" menu, set the "Correction Value" to "Import".
5. In the JVC AutoCal software, select "Gamma" from the main menu to open the Gamma Data Adjustment menu.
6. In the "Gamma" setting, select the Custom Gamma chosen in step 3.
7. In the "Correction Value" setting, choose "2.4".
    a. This post noted this caveat: when I chose 2.4 as the import gamma, the measured value is 2.26. So I ended up choosing 2.6, which measured 2.45, and then calibrated it to 2.4. Note: This change requires calibration to correct the errors in the lower Nits, as noted in this post.
8. Select "Save".
    a. A Gamma data file with a .jgd extension is saved to your computer.
9. Exit to the JVC AutoCal main menu.
10. Select "Import / Export" from the main menu to open the Import / Export menu.
11. Select the *.jgd file saved in step 8.
12. In the "Gamma" setting, select the Custom Gamma chosen in step 3.
13. Select "Import".

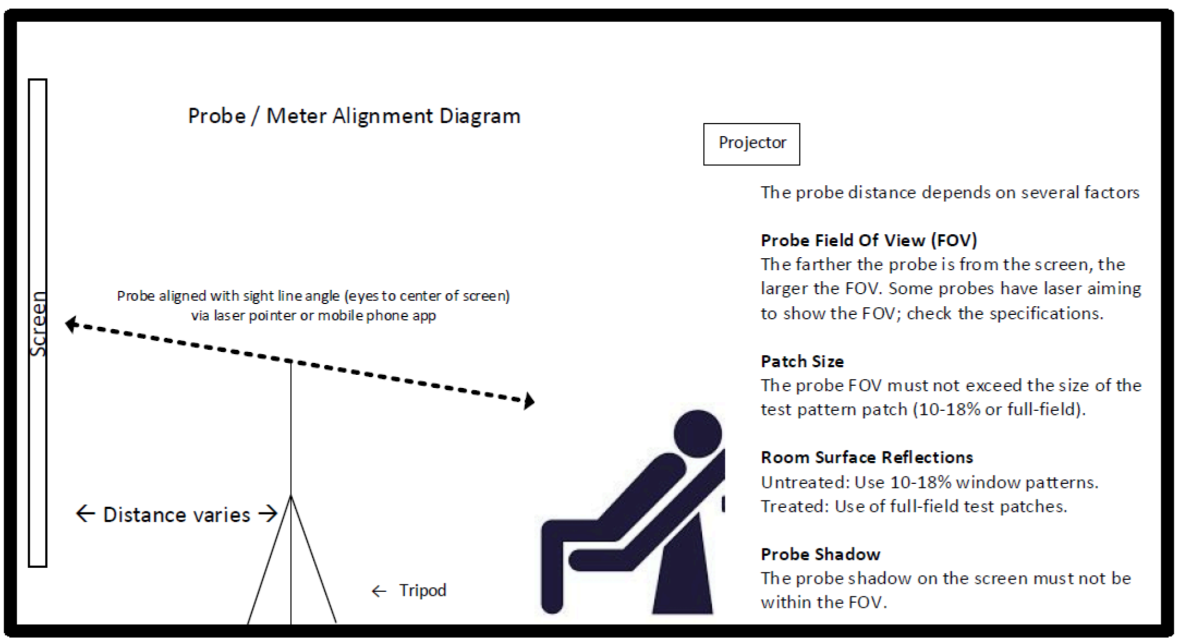
Positioning the Colorimeter / Probe

It is recommended to allow the display and the probe to warm up for 20-30 minutes prior to taking any measurements; this step is critical to obtaining accurate results.

Probe Placement

For flat panels, the Colorimeter should be placed in the center of the panel surface without the diffuser in the light path. For displays that are influenced by mechanical pressure (i.e., LCDs), ensure the probe is touching the screen lightly enough to avoid any changes in the measurement results from mechanical contact. Additionally, any stray light entering the colorimeter from the surrounding area must be eliminated.

For projection systems, AVS Forum member ConnecTEDDD provided substantive advise in this post. The probe is positioned in between the seated position and the projection screen, aligned with the sight line angle formed between your eyes and the center of the screen, as illustrated below. This recommendation ensures the measurements are taken from the same angle as the viewing position to the center of the screen, with the same level of reflected light seen by the viewer, which is different for each screen.



Probe Distance

The SMPTE recommendation is to measure from the viewing position, but this requires high-end spectroradiometers with very narrow (~2.0°) field of view equipped with viewing optics (PhotoResearch/Konica-Minolta) or with laser aiming (JETI).

For regular consumer-level probes, position it as close to the screen as possible to mitigate inaccuracies as detailed below.

Probe Field of View (FOV)

Each probe has different Field of View (FOV) specifications, as the optics see a different diameter area of pixels that varies based upon distance from the projection screen. If the measurement field is too large, the probe may measure light from too wide an area where by viewing-angle deviations can influence the measurement. It is also critical to prevent measurement of the area surrounding the test pattern patch. It is beneficial to ensure alignment of the measurement system to a small fraction of a degree. most consumer colorimeters have field of view limitations that prevent measurement from the viewing position.

For more information, see this article: [SpectraCAL - Why Viewing Angle is Important]
Notes: The i1Display is the same as C6, and the i1PRO is the same as i1PRO2. SpectraCAL measured the FOV only from 1 ft. and multiplied for different feet of distance.

			i1 Pro	K-10	C6	Discus	Hubble	C5
		FWHM (Degrees)	8.0	9.1	10.5	11.2	13.3	19.8
		TLT (Degrees)	8.0	10.6	15.9	24.1	15.4	23.6
		Shape	Plateau	Gaussian	Gaussian	Gaussian	Gaussian	Gaussian
Diameter of the Read Area at Given Distances	1 Ft	FWHM (Inches)	1.7	1.9	2.2	2.4	2.8	4.2
		TLT (Inches)	1.7	2.2	3.4	5.1	3.2	5.0
	2 Ft	FWHM (Inches)	3.4	3.8	4.4	4.7	5.6	8.4
		TLT (Inches)	3.4	4.5	6.7	10.2	6.5	10.0
	3 Ft	FWHM (Inches)	5.0	5.7	6.6	7.1	8.4	12.6
		TLT (Inches)	5.0	6.7	10.1	15.4	9.7	15.0
	4 Ft	FWHM (Inches)	6.7	7.6	8.8	9.4	11.2	16.8
		TLT (Inches)	6.7	8.9	13.4	20.5	13.0	20.1
	5 Ft	FWHM (Inches)	8.4	9.5	11.0	11.8	14.0	20.9
		TLT (Inches)	8.4	11.1	16.8	25.6	16.2	25.1
	6 Ft	FWHM (Inches)	10.1	11.5	13.2	14.1	16.8	25.1
		TLT (Inches)	10.1	13.4	20.1	30.7	19.5	30.1
	7 Ft	FWHM (Inches)	11.7	13.4	15.4	16.5	19.6	29.3
		TLT (Inches)	11.7	15.6	23.5	35.9	22.7	35.1
	8 Ft	FWHM (Inches)	13.4	15.3	17.6	18.8	22.4	33.5
		TLT (Inches)	13.4	17.8	26.8	41.0	26.0	40.1
	9 Ft	FWHM (Inches)	15.1	17.2	19.8	21.2	25.2	37.7
		TLT (Inches)	15.1	20.0	30.2	46.1	29.2	45.1
	10 Ft	FWHM (Inches)	16.8	19.1	22.1	23.5	28.0	41.9
		TLT (Inches)	16.8	22.3	33.5	51.2	32.4	50.1

Full Width Half Max Angle (FWHM) – This is the width of the Gaussian curve halfway between its minimum and maximum. It is the most relevant number when determining meter position because most of its sensitivity is within this angle. Typically, 85 to 90 percent of the light read by the meter will be within this angle.

Total Light Termination Angle (TLT) – The angle at which the meter stops reading light. This can be a fairly large angle and should be considered in meter placement but it is not as important as the FWHM.

Patch Size

The probe FOV must not exceed the size of the test pattern patch. For an untreated room, use 10-18% patches. For a treated room, use full-field patches.

Room Surface Reflections

A treated room has non-reflective surfaces within the field of view that limit light scattering. When this is achieved, the probe distance from the screen is only limited by the FOV and the shadow. Some options are using a matte, non-reflective paint (i.e., Rosco TV Video Black and Munsell N5 Neutral Grey, or covering the surfaces with special cloth like Triple Velvet Black.

Probe Shadow

Ensure the probe shadow is not within the probe field of view.

Probe positioning in untreated rooms

When there are light, reflective surfaces within the field of view that result in light scattering, it is best to use a small patch and measurements to determine optimal probe placement.

1. Project a 10-18% full white window test pattern size that will be used during the calibration process.

2. Position the probe on a tripod, centered close to the width of the screen, in between the seated position and the projection screen, aligned with the sight line angle formed between your eyes and the center of the screen, as illustrated above. Ensure the diffuser is not in the light path.

3. If the Probe used is listed in the chart above, measure the size of the window test pattern projected on screen and use the data in the table to set the Probe's distance from the screen.

   A. If no Probe measurement data is available, position the Probe about 1-3 feet away from the screen.

4. Adjust the angle of the probe so it is aligned with the sight line angle formed between your eyes and the center of the screen, and avoiding the probe shadow within the FOV.

5. Take a full-field white measurement using the calibration software and make note of it.

6. Move the Probe back towards the viewing position, re-adjust the angle, and re-measure.

7. When the recorded luminance level starts to fall off from the maximum reading obtained, the probe is starting to measure the dark area surrounding the test pattern patch.

8. Move it forward to the last position, and measure again to ensure it is correct.

1.

Calibration Process

Lumagen® recommends using automatic calibration software for a 125-point (or greater) calibration. If not using automatic calibration software, perform the Manual Gamma Calibration, as outlined below. Before you start, ensure you have a solid understanding of the Lumagen® memory system, because the calibrations are stored in the CMS that is in use when the calibration is started. You don't want to make the mistake of accidentally over-writing a prior calibration because the incorrect CMS was selected. While calibration may be tedious, and there is a steep learning curve for the novice, this process outline should have most of the steps and information required.

1. **Factory Default** - Lumagen® recommends updating the Radiance™ software to the newest release and performing a factory reset. If you are concerned about losing settings, take pictures of the various menu structures to capture them. If you are performing a new calibration on a previously calibrated display, just reset the particular output mode CMS settings and recalibrate.

   A. The command for a factory reset is:

      MENU → Save → Factory Reset → <**Select Reset Type**> → OK → OK

      i. The factory reset types are:

         All settings
         All settings except CMS
         Current input memory settings
         All input memory settings
         Current output mode settings
         Current output mode CMS settings
         Current output mode Style settings
         All output mode settings
         All output mode CMS settings
         All output mode Style settings
         All settings in Other menu
         All audio settings

   B. After performing the desired reset, save the settings: MENU → Save → Save → OK → OK

2. **Set Input & Output Formats** - The Radiance™ HDMI output parameters are set by default via HDMI EDID, but they can be changed.

   A. Lumagen® recommends using the 4:2:2 color format for HDR (and SDR) for both the input and output.

      i. The 4:2:2 HDMI format supports 12-bit pixel depth, including 4k60 for 18 GHz I/O cards.

      ii. The only exception is if there is an I/O speed limitation (e.g. 4k60 on a 9 GHz card).

   B. The command to change the HDMI input format is:

      i. MENU → Input → Input Setup → Options → HDMI Setup → Type

   C. The command to change the HDMI ouput format is:

      i. MENU → Output → Styles → [Style] → HDMI Format → Type

   D. If any parameters are changed, save the configuration before proceeding with the calibration.

3. **Select the desired CMS** - In the Radiance™, ensure the desired output Color Management System (CMS) memory is selected. The current CMS is displayed in the information OSD, page 2, or in the video output setup menu. This is an important step, because you must ensure the Radiance™ is configured to use the CMS for the intended calibration session.

   A. With factory settings on the Radiance™ Pro, SDR sources use memory CMS0 for all SDR, non-Rec. 2020 sources, and HDR sources uses CMS1. For an HDR calibration, have HDR source material playing so that CMS 1 is selected, and ensure the display is in HDR mode.

   B. The Video Output Setup Menu is accessed via the command: MENU → Output Setup → Ok.

      i. If changes are required, use the instructions in the Video Output Setup Menu section on page 24.

4. **Select the output Colorspace** - In the Radiance™, ensure the desired output Colorspace is selected in the Color Management System (CMS) memory. This is an important step, because you must ensure the Radiance™ is configured to use the desired CMS parameters prior to calibration.

   A. The command is: MENU → Output → CMS → [CMS] → Colorspace → Colorspace

   B. For an SDR calibration, ensure the Colorspace is set to SDR709 or SDR2020.

      i. SDR2020 can be used for projectors that have a color gamut exceeding REC. 709, and accurate for REC. 2020. This eliminates output restarts, and makes life with HDMI simpler.

         a. The **2020 <-> 601/709** setting in the Output CMS is used to convert REC. 709 to REC. 2020; it must be set to "Auto Convert" prior to an SDR2020 calibration, and turned off prior to an SDR709 calibration.

   C. For an HDR calibration, ensure HDR Intensity Mapping is turned off.

      i. The command: MENU → Output → CMS → [CMS] → HDR Setup → Intensity Mapping

   D. For an HDR calibration with an HDR-capable flat panel display, ensure the Colorspace is set to HDR2020.

   E. For an HDR calibration <u>with projectors and SDR displays</u> (to view HDR source material on a non-HDR capable display), ensure the Colorspace is set to SDR2020.

      i. You can use *Colorspace* = SDR2020 and still create a Rec. 709 3D LUT by choosing the Gamma to 3D LUT = SDR setting.

      ii. If using this calibration method, you need to select CMS1 for the 601/709 CMS setting in the Output Setup Menu. Both the "601/709 CMS" and the "HDR/2020 CMS" need to be set to CMS1; this is a temporary setting. The instructions to accomplish this are below.

         a. The command is: MENU → Output Setup → Ok

         b. Press **Ok** again to put the menu into edit mode.

         c. Press the ► arrow button and move to the "601/709 CMS" column, and press ▼ once to change from the default value of CMS0 to CMS1.

         d. Press OK and ensure the changes desired are listed correctly.

         e. Press **Exit** to confirm the change and close the menu.

5. **Initialize the Colorimeter**.

   A. It is recommended to allow the display and the probe to warm up for 20-30 minutes prior to taking any measurements.
   B. Select the desired operating mode for the display setup; some Colorimeters only have one mode.

6. **Set up the Lumagen® as the test pattern generator**.

   A. Connect the Radiance to the computer running the calibration software. If the Radiance will not connect when using a USB extender, try using a USB to Ethernet adapter.

   B. Below are some general setting recommendations:

   Choose the **Pattern Size**:

   Fields – These are best for Projectors and LCD/LED flat panels.
   Standard Windows – These are best for plasma and OLED flat panels.
   APL Windows – These are best for plasma and OLED flat panels.
   Small Windows – These are best for plasma and OLED flat panels.
   For 2017 LG OLED displays, the manufacturer provided specific recommendations:

   For an SDR calibration, use ≤ 18% area pattern window with a black background.

   For an HDR calibration, use ≤ 10% area pattern window with a black background.

7. Choose the appropriate application settings in the calibration software.

   A. This will be changed as the display is set up and evaluated in the next step.

8. **Prepare the display for calibration** - Consider performing a factory default or settings reset to ensure the display adjustment parameters are at default.

   A. Set the Gamma curve in the display.

      i. Specifications call for a Gamma of 2.2 for SDR, however many professionals prefer a Gamma of 2.4, so consider changing the Gamma prior to calibration. With the HDMI interface from the Radiance™ Pro to the display at a higher Gamma, this can provide additional precision near black. The output Gamma will be correct after the calibration of the Radiance™ Pro 1D grayscale LUT and 3D color cube LUT.

      ii. As described in this post, for SDR, the Gamma curve is used as transfer function where the display black level and peak white level are used to generate the digital luminance levels based upon the selected Gamma. For HDR, the PQ Curve transfer function has fixed numbers from 0-10.000 Nits which cannot be replaced with other values.

   B. Measure the selected Gamma curve of the display using the calibration software.

      i. If the display has a 1D LUT for grayscale calibration, you can even calibrate it to increase the display Gamma to 3, or 4. Depending on the internal precision of the display, it may result in lower noise near black for HDR material.

   C. Set the display to a the most accurate SDR or HDR picture mode (dependent upon the calibration type), with a reasonable color Gamut, unless using the DCI-P3 matrix conversion option, discussed on page 30.

      i. The best choice is a bright output mode with excellent black levels.

      ii. If using calibration software, most have a **Color Gamut module** that can be used to test the display's picture presets for accuracy.

      iii. For LG OLED displays, optimal color tracking is achieved when the OLED light and Contrast settings are at their default values, which affects the peak output. Source

   D. Turn off all the "special" display features that are intended to enhance the image, such as noise reduction and edge enhancement.

      i. For LG 2017 OLED displays, set the 'Dynamic Contrast' setting to 'Off' in the Expert Picture Mode settings while viewing HDR content. This is an 'Active HDR', dynamic tone mapping feature.

      ii. For LG 2017 OLED displays, disable the 'Edge Enhancer' feature by setting it to 'On' in the Expert Picture Mode Settings. This is the default (bypass) setting, as it does not increase sharpness.

   E. For projectors, disable any dynamic iris, laser dimming, or dynamic contrast features.

9. **Measure the pre-calibration values for Grayscale and Color Gamut** in the calibration software

10. **Manually calibrate white balance** at 100% in the calibration software while using the display RGB controls.

    A. Use the display controls to achieve adjust the "Y" value (Luminance) according to the calibration type. Manual Iris adjustments on a projector adjustment light output, while some OLED displays have an OLED light adjustment option.

        a. For SDR and HD calibrations for projection systems, 49.98 cd/m2 (candelas per Colorimeter squared) or 14.59 fL (Foot Lamberts) is the cinema standard.

        b. For SDR and HD calibrations for flat panel displays, 120 cd/m2 (candelas per Colorimeter squared) or 35 fL (Foot Lamberts) is common.

        c. For HDR calibrations, no display technology can achieve the light output standards, so adjust the display to the maximum light output capable.

    B. Use the display RGB controls to calibrate the color of white.

        a. The process varies depending upon the calibration software.
        b.

11. **For projectors, calibrate the "Optical Black Level"**, as outlined in Calibrating Projector Optical Black Level on page 49.

12. **Calibrate the "Display Black Level"**, as outlined in Calibrating Display Black Level on page 50.

    A. For HDR-capable flat panel displays, consider leaving the default brightness setting, as this is will typically affect the display color gamut and tone mapping.

13. **Calibrate the "Display White Level"**, as outlined in Calibrating Display White Level on page 51.

    A. For HDR-capable flat panel displays, consider leaving the default contrast setting, as this is will typically affect the display color gamut and tone mapping. When the contrast test patterns are displayed in HDR mode, you may not be able to see any of the white bars, and the contrast adjustment may not have any affect. As explained in this post, this behavior is be expected.

    B. If you have an LG OLED display, optimal color tracking is achieved with the OLED Light and Contrast at their default settings of 100, as recommended in this post.

14. **Calibrate the "Lumagen® Digital Black Level"** (if necessary), as outlined in Calibrating Lumagen® Digital Black Level on page 52.

    A. If the display controls are too coarse, or lack the proper range, you can use the Radiance output configuration "Black" control to adjust the black output level.

15. **Calibrate the "Lumagen® Digital White Level"** (if necessary), as outlined in Calibrating Lumagen® Digital White Level on page 54.

    A. If the display controls are too coarse, or lack the proper range, you can use the Radiance output configuration "White" control to adjust the white output level.

16. Profile the display using the calibration software.

17. Create the 1D and 3D LUT profiles using the calibration software, and upload it to the Radiance.

18. **Copy the CMS** - If you want to move the completed calibration to an un-used CMS for either safe-keeping or comparison purposes, use the copy command.

    A. The command is: MENU → Output → Copy → OK.

19. **Save the calibration values**.

    A. The command is: MENU → Save → Save → OK → OK

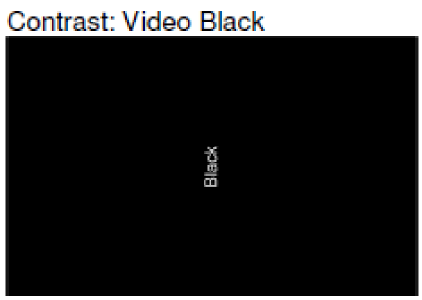
20.

21. Check after calibration to ensure the 3D Color Gamut options were updated in the Radiance™ according to the calibration session performed.
    A. The command is: Menu → Output → CMS's → [CMS] → Color Gamut → Options
        i. In this menu, the “Points:” indicate the type of calibration
        ii. The default setting is: “Points: 8 pts”.
        iii. For a 125-Point calibration, the following is shown: “Points: 5x5x5”.
        iv. For a 729-Point calibration, the following is shown: “Points: 9x9x9”.
        v. For a 4913-Point calibration, the following is shown: “Points: 17x17x17”.
22. **Measure the post-calibration values for Grayscale and Color Gamut** In the calibration software.
23. **Run a post-calibration report** in the calibration software.
24. If you completed an HDR calibration, ensure CMS 1 is selected and enable HDR Intensity Mapping and set the display maximum brightness; see the HDR Intensity Mapping CMS Setup section on page 63.
25. For LG 2017 OLED displays, set the ‘Dynamic Contrast’ setting to ‘Low’ in the Expert Picture Mode settings while viewing HDR content, if not using the Radiance Pro™ IM or ADTM features.
    A. This is an ‘Active HDR’, dynamic tone mapping feature, so evaluate this feature with and without the Radiance™ Pro HDR Adaptive Dynamic Tone Mapping (ADTM) while viewing some paused HDR material scenes noted on page 79.
26. Save any additional changes made.
    A. The command is: MENU → Save → Save → OK → OK

Calibrating Projector Optical Black Level

This process uses a combination of the projector "Brightness" or "Black Level" control and Iris control (if applicable), as well as the Radiance™ Pro CMS Black Level control to set the black background level while viewing the **Reference, Contrast: Video Black** pattern (a full raster black field).

- Display the **Reference, Contrast: Video Black** test pattern:
  - The command is: MENU → Other → Test Pattern → Reference
  - Use ◄or► to select test pattern Group 2 (Contrast).
  - Press digit 4 to step forward through group test patterns until the **Video Black** pattern is displayed.



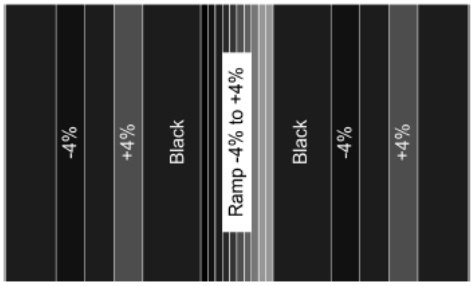
- With the **Video Black** test pattern displayed, make the following adjustments:
  - Raise the display brightness until the black field is visible.
  - Lower the display brightness until a down-click does not make black darker.
  - The black field should just be visible.
- For recent model JVC Projectors, the brightness control has the correct digital black setting when set at "0", but the iris setting affects this adjustment.
  - Lumagen® recommends trying different iris settings.
    - Start with the iris closed, and check when you start to see the black field is visible.
    - If the projector does not seem like it is set correctly for black, perform the following:
      - In the current output CMS, increase the CMS "Black" level from 0 to 1.0, then perform the Optical Black adjustment.
      - In the current output CMS, decrease the CMS "Black" level from 1.0 to -1.0, then perform the Optical Black adjustment again.
      - If there is a difference between the two setting combinations, decide which is better (CMS Black of -1.0, 0, or +1.0) and use that as the initial CMS Black level setting.
  - The best iris setting is often a trade-off between black, HDR brightness, and preference.
- When the adjustment is completed, press CLR to exit the test pattern mode.

Calibrating Display Black Level

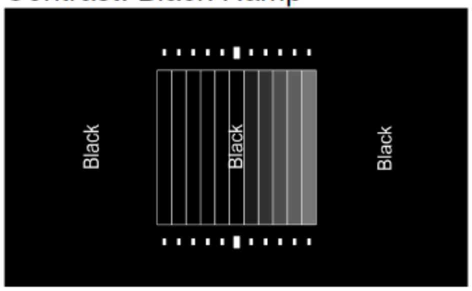
This process uses the display "Brightness" or "Black Level" control to set the black background level while viewing the **Reference, Contrast: Contrast 2** and **Black Ramp** test patterns (low-APL ramps).

- Display the **Reference, Contrast: Contrast 2** test pattern:
  - The command is: MENU → Other → Test Pattern → Reference
  - Use ◀or▶ to select test pattern Group 2 (Contrast).
  - Press digit 4 to step forward to the **Contrast 2** test pattern.
  - The below test pattern examples are from the Radiance Tech Tip 5, Using Test Patterns (2013), and the test patterns have evolved since that time. For example, the Black Ramp has more vertical lines and the bottom half flashes on and off now.

Contrast: Contrast 2



Contrast: Black Ramp

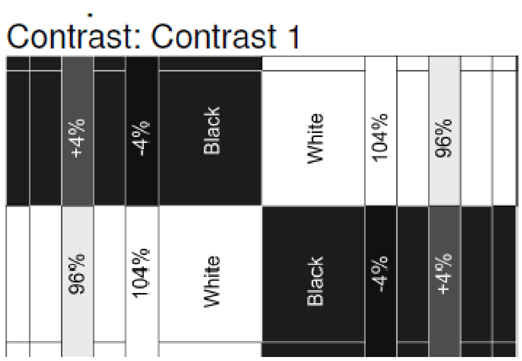


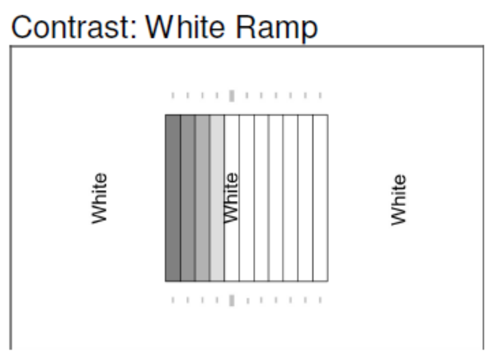
- With the **Contrast 2** test pattern displayed, and utilizing the center ramp in the middle of the test pattern, make the following adjustments to the display brightness or black level control:
  - The 1% & 4% bars to right of center are barely visible verses the 0% black background.
    - The 1% bar may not be visible, depending upon the display.
  - The -1% & -4% bars to left of center look same as the 0% black background.
    - Setting black slightly too dark is better than setting black slightly too bright.
- Press digit 4 to step forward to the **Black Ramp** test pattern and make the following adjustments to the display brightness or black level control:
  - The 1% & 4% bars to right of center are barely visible verses the 0% black background.
    - The 1% bar may not be visible, depending upon the display.
  - The -1% & -4% bars to left of center look same as the 0% Black background.
    - Setting black slightly too dark is better than setting black slightly too bright.
  - This test pattern has 11 vertical bars, from -5% to +5% bars in 1% increments.
  - This test pattern is used to compare the results of the adjustments made with the Contrast 2 test pattern and make any necessary adjustments. In a well-designed display, this test pattern will reveal the following:
    - The -1% bar cannot be differentiated from the 0% black background.
    - The +1% bar can be differentiated from the 0% black background.
- Press digits 1 and 4 to step back and forth between the **Contrast 2** and the **Black Ramp** test patterns to compare the results and adjust as needed.
- When the adjustment is completed, press CLR to exit the test pattern mode.

Calibrating Display White Level

This process uses the display "Contrast" or "White Level" control to set the white background level while viewing the **Reference, Contrast: Contrast 1** and **White Ramp** test patterns.

- Display the **Reference, Contrast: Contrast 1** test pattern:
  - The command is: MENU → Other → Test Pattern → Reference
  - Use ◀or▶ to select test pattern Group 2 (Contrast).
  - The below test pattern examples are from the Radiance Tech Tip 5, Using Test Patterns (2013), and the test patterns have evolved since that time. For example, the White Ramp has more vertical lines and the bottom half flashes on and off now.



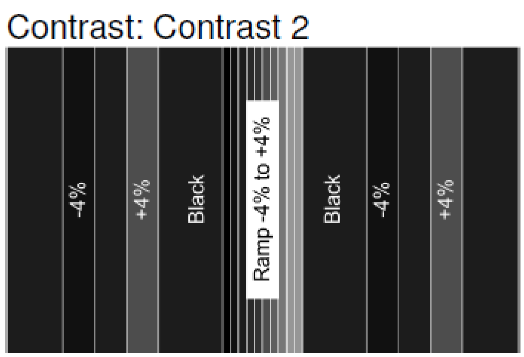


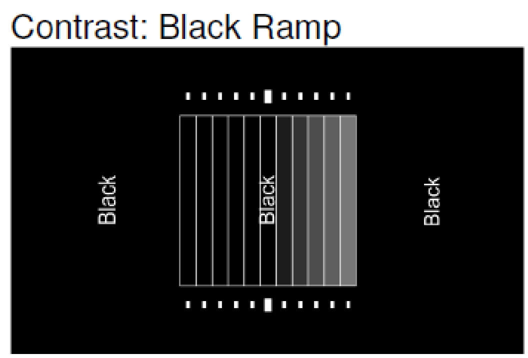
- With the **Contrast 1** test pattern displayed, make the following adjustments to the display Contrast or white level control:
  - The 96% & 104% bars should be differentiable from the 100% white background.
  - The 104% bar should not be "crushed".
    - This may show as a color change in the 104% bar verses the 100% and 96% bars.
- Press digit 4 to step forward to the **White Ramp** test pattern and make the following adjustments to the display Contrast or white level control:
  - The 96% & 104% bars should be differentiable from the 100% white background.
  - The 104% bar should not be "crushed".
    - This may show as a color change in the 104% bar verses the 100% and 96% bars.
  - This test pattern has 11 vertical bars, from 96% to 106% bars in 1% increments.
  - It is used to compare the results of the adjustments made with the Contrast 1 test pattern and make any necessary adjustments.
- Press digits 1 and 4 to step back and forth between the **Contrast 1** and the **White Ramp** test patterns to compare the results and adjust as needed.
- When the adjustment is completed, press CLR to exit the test pattern mode.

Calibrating Lumagen® Digital Black Level

This process uses the Radiance™ CMS "Black" control to set the black video reference level while viewing the **Adjustable, Contrast: Contrast 2** and **Black Ramp** low-APL test patterns. Normally the "Brightness" / "Black Level" control in the display is used to set the black background level (see Calibrating Display Black Level), but this adjustment allows for accurate calibration when the display controls are not adequate. This control is also useful when a second black level is desired (using a second output CMS) for a "day" or "night" mode.

- Display the **Adjustable, Contrast: Contrast 2** test pattern:
  - The command is: MENU → Other → Test Pattern → Adjustable
  - Use ◄or► to select test pattern Group 2 (Contrast).
  - Press digit 4 to step forward to the **Contrast 2** test pattern.
    - Press MENU → Black → OK to modify Black Adjust
      - If the Black control does not appear, access it manually via the command:
        - MENU → Output → CMS's → [CMS] → Black
    - The below test pattern examples are from the Radiance Tech Tip 5, Using Test Patterns (2013), and the test patterns have evolved since that time. For example, the Black Ramp has more vertical lines and the bottom half flashes on and off now.





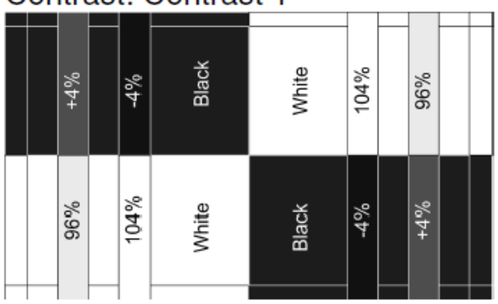
- The Contrast 2 test pattern has nine vertical bars in the middle of the screen. There is a black (0%) vertical bar in the very center of the image, four vertical bars (1%, 2%, 3%, and 4%) to the right of this center black bar, and four vertical bars (-1%, -2%, -3%, -4%) to the left of the center black bar.
- With the **Contrast 2** test pattern displayed, and utilizing the center ramp in the middle of the test pattern, make the following adjustments to the Lumagen® "Black" control:
  - The 1% & 4% bars to right of center are barely visible verses the 0% center black background; here is a video of Jim discussing this test pattern.
    - The 1% bar may not be visible, depending upon the display.
  - The -1% & -4% bars to left of center are not visible verses the 0% center black background.
    - Sometimes the -1% and +1% bars are either both visible, or both not visible.
    - It is most important that the -1% bar is not visible as compared to the center black bar.
    - Setting black slightly too dark is better than setting black slightly too bright.

- Press digit 4 to step forward to the **Black Ramp** test pattern and make the following adjustments to the Lumagen® "Black" control:
  - The 1% & 4% bars to right of center are barely visible verses the 0% black background.
    - The 1% bar may not be visible, depending upon the display.
  - The -1% & -4% bars to left of center look same as the 0% Black background.
    - Setting black slightly too dark is better than setting black slightly too bright.
  - This test pattern has 11 vertical bars, from -5% to +5% bars in 1% increments.
  - This test pattern is used to compare the results of the adjustments made with the Contrast 2 test pattern and make any necessary adjustments. In a well-designed display, this test pattern will reveal the following:
    - The -1% bar cannot be differentiated from the 0% black background.
    - The +1% bar can be differentiated from the 0% black background.
- Press digits 1 and 4 to step back and forth between the **Contrast 2** and the **Black Ramp** test patterns to compare the results and adjust as needed.
- When the adjustment is completed, press OK to accept any changes made.
- Press CLR to exit pattern mode.
- Remember the Black setting and go into the other active CMS memories and change the Black setting to the same number and press OK.
- Save these adjustments made in the Lumagen® CMS controls via the command:
  - MENU → Save → Save → OK → OK

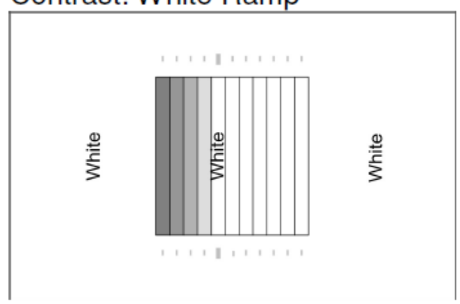
Calibrating Lumagen® Digital White Level

1. Normally the "Contrast" / "White Level" control in the display is used to set the white background level (see Calibrating Display White Level), but this adjustment allows for accurate calibration when the display controls are not adequate.
2. This control is also useful when a second white level is desired (using a second output CMS) for a "day" or "night" mode.
3. This process uses the Radiance™ CMS "White" control to set the black video reference level while viewing the **Adjustable, Contrast: Contrast 1** pattern.
   - Display the **Adjustable, Contrast: Contrast 1** and **White Ramp** test patterns:
     - The command is: MENU → Other → Test Pattern → Adjustable
     - Use ◄or► to select test pattern Group 2 (Contrast).
     - Press MENU → OK for White Adjust
       - If the White control does not appear, access it manually via the command:
         - MENU → Output → CMS's → [CMS] → White
     - The below test pattern examples are from the Radiance Tech Tip 5, Using Test Patterns (2013), and the test patterns have evolved since that time. For example, the White Ramp has more vertical lines and the bottom half flashes on and off now.

Contrast: Contrast 1



Contrast: White Ramp



   - With the **Contrast 1** test pattern displayed, make the following adjustments to the Lumagen® "White" control:
     - The 96% & 104% bars should be differentiable from the 100% white background.
     - The 104% bar should not be "crushed".
       - This may show as a color change in the 104% bar verses the 100% and 96% bars.
   - Press digit 4 to step forward to the **White Ramp** test pattern and make the following adjustments to the Lumagen® "White" control:
     - The 96% & 104% bars should be differentiable from the 100% white background.
     - The 104% bar should not be "crushed".
       - This may show as a color change in the 104% bar verses the 100% and 96% bars.
     - This test pattern has 11 vertical bars, from 96% to 106% bars in 1% increments.
     - It is used to compare the results of the adjustments made with the Contrast 1 test pattern and make any necessary adjustments.
   - When the adjustment is completed, press OK to accept any changes made.
   - Press CLR to exit pattern mode.
   - Save these adjustments made in the Lumagen® CMS controls via the command:

MENU → Save → Save → OK → OK

LG OLED Calibration Challenges

For LG OLED displays, the PQ-EOTF Tone-Mapping can't be disabled, as noted in this post. The PQ-EOTF Tone-Mapping can't be disabled using any LG OLED Model (2015/2016/2017/2018/2019), when the TV will enter to the HDR10 mode, the PQ-EOTF and gamut mapping will be enabled.

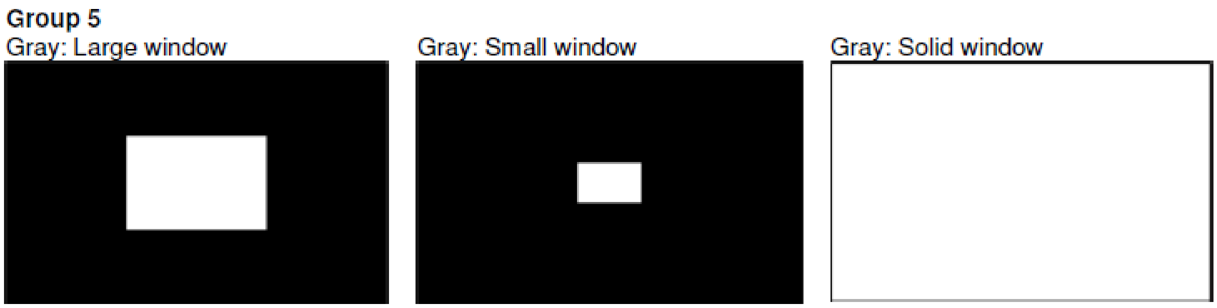
When the display is not working in HDR10 mode, but in SDR mode, with colorspace setting @ Wide, you can have wide gamut (native) and gamma based panel response, but you can't have the same peak output as you have to HDR10 mode.

So for your display, the only you can do is by not send metadata so the HDR mode to not be enabled, while to trick your player that you have active HDR10 connection with the TV, to be able to output the HDR10 content. (but you will not have max peak output, expect 300-350 nits)

For 2019 LG OLED's, a Peak Brightness setting has been added, where its enabling the White sub-pixel boost to SDR mode also, so you can able to reach similar peak output you have to HDR10 mode to the SDR mode..

Lumagen® Manual Gamma Calibration

1. Check the default Gamma curve of the display.
    - A. Specifications call for a Gamma of 2.2, however many professionals prefer a Gamma of 2.4.
    - B. Flat-panel displays may have a measured Gamma as low as 1.8 to 1.9, which is intended to mask dark-area noise issues. When this display flaw exists, calibrating for a correct Gamma of 2.2 is likely to expose this dark-area noise. In this case, there is a trade-off between correct Gamma and minimizing the visibility of the dark-area noise.
2. For displays with grayscale calibration controls, adjust the 100%-point grayscale using these controls.
    - A. On some display's, it may be necessary to also use the Radiance™ parametric adjustment of 2, 5, 11, 12 or 21-point Grayscale/Gamma function to correct for non-linearity in the display Gamma.
    - B. The command is: MENU → Output → CMS's → [CMS] → Gray/Gamma.
        - i. If you have an auto-calibration program, this can be done automatically.
3. Use the Radiance™ Gamma-Factor control to do an initial coarse calibration of Gamma as outlined in step 4.
    - A. Use either the internal Radiance™ test patterns or an external test pattern generator.
    - B. Measure the Gamma curve of the display in either 5% or 10% increments and **record the results**.
        - i. The recorded results will be used to calculate the Gamma-Factor control entry.
4. The Gamma calibration using the Radiance™ test patterns is accomplished by measuring the "Gray: Window" test patterns in various IRE increments.
    - A. The "Gray: Window" test patterns can be set to large, small, and solid (full-screen) window.
        - i. The <u>small window pattern works best on displays with power supply limitations</u>.
            - a. Displays with power supply limitations may cause variations in the results, dependent on the area covered by the window pattern. Plasma displays exhibit this issue.
        - ii. The <u>large window pattern works best for displays without power supply limitations</u>.
    - B. The command is: MENU → Other → Test Pattern → Adjustable
        - i. Use ◄or► to select test pattern Group 5 (Gray); the Gray: Large window test pattern will be visible.
        - ii. Press "4" to select between the patterns in the group.
        - iii. Press "2" to show/hide the menu.
        - iv. Use the ▲ or ▼ buttons to adjust the IRE on the test patterns.



5. Calculate the average Gamma **from the recorded measurements taken above**.
6. Use the Lumagen® Gamma-Factor to approximate the desired display Gamma.
   A. The Lumagen® Gamma-Factor adjustment range includes the entire range of values in the Gamma curve in order to support whiter-than-white and blacker-than-black.
      i. The adjustment range is 0 to 4095 (12-bit pixel depth), where black = 256.
      ii. Due to the wide adjustment range, changes to the Gamma-Factor also change the black and white levels, so they should be recalibrated after any changes to the Gamma-Factor.
   B. Set the Gamma-Factor equal to the Desired Gamma / Measured Gamma.
   C. The command is: MENU → Output → CMS's → [CMS] → Gamma-Factor
7. <u>If</u> adjustments to the Lumagen® Gamma-Factor are made, re-calibrate the items noted below; otherwise, skip this step.
   A. The "Display Optical Black Level", as outlined above.
   B. The "Display Black Level", as outlined above.
   C. The "Display White Level", as outlined above.
   D. The "Lumagen® Digital Black Level" (if it was necessary), as outlined above.
   E. The "Lumagen® Digital White Level" (if it was necessary), as outlined above.
8. <u>If</u> any adjustments are made as noted in step 7, re-calibrate Grayscale/Gamma using the new black and white levels; otherwise, skip this step.
9. The above steps must be performed before the color gamut calibration below, and ensure any grayscale calibration settings or Gamma-Factor entries are changed.
10. The Radiance™ Color-Gamut control adjusts the display color points toward the center (i.e. toward the white point) of the CIE diagram, within its physical capability.
    A. Display color temperature selections (e.g. default, warm, natural, etc.) generally affect the primary and secondary (x,y) points.
    B. Before starting the color-gamut calibration, select a color mode for which all the primary and secondary points are at, or outside, the CIE color triangle for the desired color space.
       i. Some displays have under-saturated colors requiring a compromise.
11. When taking measurements with an uncalibrated / corrected device, slight over-saturation of the primary or secondary points is recommended, rather than to allow potential under-saturation.
    A. Due to variations in measurement devices, and the potentially unknown error(s) in the (x,y) point reading, having readings slightly outside the CIE triangle will provide better visual results than (inaccurate) readings that exactly match the CIE chart.
    B. If you have a calibrated / corrected measurement device, this does not apply.

12. Measure the (x,y) and "Y" values for all the primary and secondary colors.
    A. Use the Radiance™ test patterns, groups 7-13, with the large or small window.
    B. Enter the measured white "Y" values into a luminance calculator, which is available on the Lumagen® website (http://www.lumagen.com/testindex.php?module=utilities). This calculator will output the expected (x,y) and "Y" values for each primary and secondary point.
    C. Automatic calibration software takes the readings and calculates the results automatically.
13. The luminance ("Y" value) for white may need to be reduced to have enough luminance in the primary and secondary colors.
    A. This is a common failure point in displays, which is easily overcome using the Radiance™.
    B. Between the primary and secondary colors, find the color with a Y, which has a measured value that is the smallest percentage of the calculated value.
        i. If this is above the calculated value, there is no need to adjust the white-point Y value.
        ii. Otherwise, reduce the Y of white, by the same percentage as the percentage the selected primary/secondary color is below its calculated Y value
        iii. Control the R, G, B balance to maintain the correct (x,y) point for white.
        iv. The command is: MENU → Output → CMS's → [CMS] → Color Gamut
14. Make adjustments to the RGB color values to get the (x,y) and Y values for each primary and secondary color to match their respective target points.
    A. Start with the points farthest from their target values.
    B. The RGB calibration color-space does not align with the (x,y) and Y of the CIE diagram, so there is a bit of art in this adjustment process.
        i. The process requires repeatedly adjusting (x,y) and Y, for each point.
    C. This step can be done using calibration software, to simplify the task.
15. Save the settings or you will lose your work, when the unit powers down!
    A. The command is: MENU → Save → Save → OK → OK by pressing "Menu, Save, OK, OK, OK".
16. Take post-calibration readings to make sure you are within target error values (dE's).
17. Watch - and judge - real video material. It is possible for a calibration to measure well, but provide poor image quality. This is always a good idea and a way to enjoy the great image quality you've achieved.

HDR Explained

- High Dynamic Range (HDR) is designed to increase the contrast ratio from the brightest to the darkest objects. Several formats have been developed to accomplish the goal.

  A. HDR-10 is a royalty-free open standard that uses static metadata and 10-bit color depth.
  B. HDR-10+ is a royalty-free open standard that uses dynamic metadata and 10-bit color depth.
     i. Dynamic metadata is used to more accurately adjust brightness levels on a scene-by-scene or frame-by-frame basis.
  C. Hybrid Log Gamma (HLG) is a royalty-free standard that uses dynamic metadata and is compatible with Standard Dynamic Range (SDR) displays with 10-bit color depth.
  D. Dolby Vision (DV) is a **royalty-required** proprietary standard that uses dynamic metadata and 12-bit color depth.
  E. SL-HDR1 (aka Technicolor HDR) is a royalty-free??? standard that uses static and dynamic metadata to reconstruct an HDR signal from a single-layer SDR video stream that can be distributed with existing SDR distribution networks and services. It allows for HDR rendering on HDR devices and SDR rendering on SDR devices using the single-layer video stream.

HDR10 Format Details

- All HDR10 sources are encoded with a 0 to 10,000 nit range, even if the material uses only a fraction of this range.

- The source reports content information via metadata in the HDMI Info Frame:
  A. Mastering monitor primary coordinates, and minimum / maximum brightness.
  B. Maximum Content Light Level (MaxCLL)
     i. Maximum video level encoded in the source material.
  C. Maximum Frame Average Light Level (MaxFALL)
     i. Maximum average level encoded in the source material.

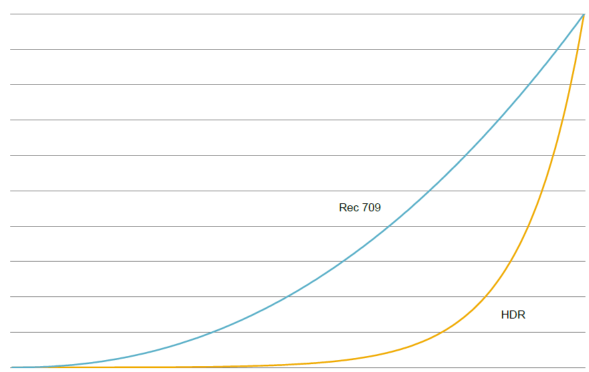
- The Radiance™ Pro adjusts the CMS output parameter based upon the HDMI Info Frame metadata.
  A. If HDR (Rec. 2020) is reported in the HDMI Info Frame, CMS1 is selected (factory setting).
  B. If SDR (Rec 601/709) is reported in the HDMI Info Frame, CMS0 is selected (factory setting).
  C. These default parameters can be changed in the Output Setup Menu for each User Memory.
  D. The Radiance™ Pro can report HDR and Rec. 2020 modes as Auto, *On*, or *Off.*
     i. “On” is the recommended setting.

-

- All HDR10 material uses the Rec. 2020 color Gamut.
  A. Rec. 2020 has a much larger Gamut than Rec. 709 and different primary/secondary targets.
  B. No current consumer display achieves Rec. 2020.
  C. Independent of source Gamut, HDR10 material is put into a "Rec. 2020 container"

- Consumer HDR10 is encoded as 10-bit 4:2:0 YCbCr using Bt.2084 (PQ) Gamma
  A. HDR (PQ) Gamma is much higher than SDR Gamma, as illustrated in the chart below.

HDR (PQ) Verses SDR Display Gamma



- Films are mastered using DCI-P3 color Gamut, but the industry is moving to the Academy Color Coding System (ACES). The Radiance™ Pro supports DCI-P3 color Gamut matrix conversion.
  A. HDMI does not support the P3/DCI format, so calibrate HDR using either DCI-P3 or Rec. 2020 primary targets. More information here.

Radiance™ Pro HDR Intensity Mapping & Adaptive Dynamic Tone Mapping

This section covers the HDR Intensity Mapping feature. In the Radiance™ Pro manual, the material below is covered in various parts of the manual but is combined below for ease of reference. Information from the Radiance™ Pro training slides (01/05/2020) is also included.

Overview

- HDR10 material varies significantly, making a single "one size fits all" approach to HDR impossible, so tone mapping has become a key ingredient to more consistent HDR picture quality.
- The Radiance™ Pro performs both HDR *tone mapping* for both HDR and non-HDR displays. The device performs both static **HDR Intensity Mapping** as well as intra-scene-based **Adaptive Dynamic Tone Mapping (ADTM)**. These features adapt HDR source material to HDR, Non-HDR (smaller color gamut, lower intensity), and SDR displays. It is disabled for SDR sources.
- The **HDR** standard supports display brightness up to 10,000 Nits, and the Rec. 2020 color Gamut. Current display technologies are unable to obtain these brightness and color standards, so adaptation of the UHD-HDR source material to the actual display capabilities is a critical aspect of HDR viewing. This adaptation process is known as "tone mapping" and is implemented in the Radiance™ Pro in two parts.
    A. The color portion of tone mapping is managed by calibrating using the Radiance™ Pro 3D Look-Up-Table (LUT) for color.
    B. The brightness portion of tone mapping is managed by the **HDR Intensity Mapping** and **Adaptive Dynamic Tone Mapping (ADTM)** features.
- When properly calibrated, the tone mapping allows viewing HDR10/Rec. 2020 sources on non-HDR Rec. 709 displays. The Radiance™ Pro can drive displays to their full capabilities, allowing a wider color Gamut and less image noise than Rec. 709 sources.
- Even though current display technologies are not able to obtain very high brightness levels of HDR, an experienced professional calibrator advised in this post that ~30 fL (100 nits) is sufficient headroom for HDR. Once this level of maximum brightness is obtained, it is best to concentrate on getting more contrast out of the image, as higher light output only helps HDR if you are not sacrificing black and contrast performance.
- The HDR Intensity Mapping has output conversion curves for HDR and an SDR Electro-Optical Transfer Function (EOTF) output modes, for displaying HDR on SDR displays.
    A. The CMS Colorspace can be selected as an SDR (CMS0) or HDR (CMS1) output mode.
    B. The CMS **Colorspace** selection, along with the **Gamma2LUT** is then used by **HDR Intensity Mapping** to select the appropriate output EOTF.
    C. In HDR output mode, the Radiance™ Pro tone mapping dynamically changes the EOTF based on the HDR Info Frame data and the HDR Intensity Mapping user settings to mitigate the variance in HDR sources and provide the best possible image.

D. In SDR output mode (3D LUT=SDR2020), the HDR tone mapping modifies the data so the image looks as correct as possible on an SDR display.

Sending HDR in an SDR Rec. 2020 Container

- A key concept to understand for HDR sources and HDR Intensity Mapping is that data manipulation in the pipeline does not always have to be in an "HDR EOTF / Gamma." Just as movies using the DCI-P3 color Gamut are put into a "Rec. 2020 container" for UHD HDR, it is possible to put the HDR Gamma into a "SDR container". As long this is accounted for such that the on-screen image is correct, the result is a correct HDR image. This is not somehow converting the HDR to SDR but is putting the HDR data into a "SDR container."

- Input to the camera is in "Linear Light", and output from the display is in "Linear Light".
  - If the above is maintained with good Signal-To-Noise-Ratio (SNR), what happens in between is "implementation detail" and does not affect the image.
  - The EOTF / Gamma is used to optimize SNR for a given encoding and transmission scheme.

- The Radiance™ Pro converts the HDR signal to "Linear Light".
  - HDR Intensity Mapping is performed with "Linear Light", maintaining signal integrity.

- The Radiance™ Pro then converts HDR Intensity Mapping's Linear EOTF / Gamma output to either HDR (PQ) EOTF, or Gamma = 2.4, based on the **Gamma2LUT** setting.
  A. HDR2020 is converted to HDR (PQ) EOTF, and the display applies the inverse HDR curve to the HDR signal, and outputs Linear Light.
  B. SDR2020 is converted to Gamma = 2.4, and the display applies the inverse SDR curve to the SDR signal, and outputs Linear Light.

HDR Intensity Mapping CMS Setup

The Radiance™ Pro **HDR Intensity Mapping** feature is disabled by default; it is covered in the Radiance™ Pro manual, page 13. The initial setup process requires setting the Display Maximum Brightness (Display Max Light), (a.k.a. LMax) in the Output CMS menu under **CMS HDR Mapping**, **MaxLight** value.

1. Enable HDR Intensity Mapping and set the display maximum brightness in the output CMS.

   A. The command is: MENU → Output → CMSs → [CMS] → HDR Mapping

   B. In the HDR Intensity Mapping menu, the options are **Enable**, **MaxLight**, and **Gamma2LUT**.

      i. Set **Enable** = On

      ii. Set **MaxLight** (Display Max Light) to reflect the display maximum light output capability.

         a) The Range is 100 to 9900, in 100-Nit increments (default = 500), and it is set as a multiple of measured Nits. Use the number keys to enter a value or the arrow keys to adjust up or down.

            1) This adjusts the source to display light ratio and is useful as a coarse "brightness" control when the HDR Intensity Mapping controls are at the default values.

            2) When MaxLight is set lower, scenes will be brighter but color saturation in bright objects will be reduced which can reduce the detail in bright saturated colors.

            3) When MaxLight is set higher, scenes will be darker but color saturation in bright objects is better preserved which can improve the detail in bright saturated colors.

            4) The user can choose to either maximize brightness (Luma), or maximize bright color saturation (Chroma), or balance these two objectives.

         b) As of 12/09/2020, Lumagen® recommends setting this as follows:

            1) For projectors: Four to Five times (4-5x) the measured Nits; 4x has slightly more brightness, and 5x has slightly more color saturation. Some users may prefer 3-4x; this is a personal choice and can also help to brighten images on a lower light output projector.

            2) For flat panel displays ≥ 1500 Nits: One to two times (1-2x) the measured Nits.

         c) To prevent reduction of the parameter's effective range, set this higher than the actual display brightness capability for displays with internal tone mapping.

            1) Displays with internal tone mapping reduce the HDR input to match the actual light output of the display, which has the effect of reducing the HDR Intensity Mapping

effective range, as it has much less range to work with.

d) Make the adjustment while viewing (paused) HDR source material. Choose a very bright scene; see the HDR Content Examples section for further details on the scene example below.

1) Example 1: The Meg™ (2018) at 1:08:30 where people are swimming around a capsized boat.
   i. Adjust to balance brightness and color saturation: A lower Max Light makes the scene brighter, and a higher Max Light may improve color saturation.

iii. Set **Gamma2LUT** = Auto, HDR, or SDR

a) The **Gamma2LUT** and the CMS Colorspace settings are used to adjust the Electro Optic Transfer Function (EOTF) of the HDR Intensity Mapping output. This selection is active even when HDR Intensity Mapping is disabled.

1) The valid combinations for the CMS memory **Gamma2LUT** and CMS **Colorspace** for HDR sources are shown in the following table.

Gamma2LUT Setting	CMS Colorspace	Test Pattern Mode	3D LUT Color Gamut	Input EOTF	Output EOTF	Comments
Auto or HDR	HDR2020	HDR	Rec. 2020	BT.2084	BT.2084	Optional
HDR	SDR2020	HDR	Rec. 2020	BT.2084	BT.1886	Required
Auto or SDR	SDR2020	SDR	Rec. 2020	BT.709	2.4 out.	Optional

2) When Gamma2LUT = Auto or HDR, and Colorspace = HDR2020, the calibration process uses HDR test patterns and uses the PQ / ITU-R BT.2020 / SMPTE ST.2084 HDR EOTF.
3) When Gamma2LUT = HDR, and Colorspace = SDR2020, the calibration uses HDR test patterns and uses the PQ / ITU-R BT.2020 / SMPTE ST.2084 HDR EOTF for the source input, and the SDR BT.1886 EOTF for the output.
4) When Gamma2LUT = Auto or SDR, and Colorspace = SDR2020 or SDR709, the calibration uses SDR test patterns and uses the BT.709 EOTF for the source input, and the Gamma of 2.4 for the output.

   i. You can calibrate the 3D/1D LUT's to SDR Rec. 2020 specifications and let the HDR Intensity Mapping "adapt" the HDR EOTF to SDR EOTF.
   ii. Even if HDR Intensity Mapping is off, this EOTF adaptation is applied for HDR sources.

b) For more details on EOTF, see the Electro-Optical Transfer Function (EOTF) Options section.

C. Save the changes via the command: MENU → Save → Save → OK → OK

2. Make changes to the HDR Intensity Mapping Control Parameters, if desired.

   A. After the initial setup, the HDR Intensity Mapping parameters are adjusted via the input options to adjust the response to your preference.

      i. The command is: MENU → Input → Options → HDR Mapping → OK

         1) Alternatively, with no OSD visible, press ◄ to bring up the HDR Mapping.

         2) Navigating via the OSD allows changing either the active or inactive parameters.

      ii. You must press *OK* to accept changes.

   B. Save the changes via the command: MENU → Save → Save → OK → OK

Adaptive Dynamic Tone Mapping Overview

- The Radiance™ Pro performs intra-scene **Adaptive Dynamic Tone Mapping (ADTM)**. ADTM maximizes the image quality for the varying brightness in every scene, like how the iris in your eye constricts for bright conditions and opens for dark conditions. ADTM results in visible improvement versus the (static) HDR Intensity Mapping (HIM) tone mapping, especially for source material incorrectly reporting MaxCLL.
- ADTM detects scene changes and dynamically adjusts both the scene Max Light (a.k.a. Lw), and the display Max Light target (a.k.a. LMax) by calculating and changing the effective MaxCLL (the brightest pixels) for the scene, and setting the ADTM transfer function based on this new MaxCLL.
- ADTM can change the effective MaxCLL on any frame, but it changes it at the beginning of a scene, because changing it mid-scene would cause a visible change in the background intensity of the picture, which would be distracting.
- ADTM uses the calculated MaxCLL for the scene and the “Low-set” and “High-set” parameters as reference points to calculate a percentage value used in the equation to adjust the EOTF.
  - The value entered for the Display Maximum Brightness (Display Max Light), (a.k.a. LMax) in the Output CMS menu under **CMS HDR Mapping**, **MaxLight** value is used to set the default “Low-set” and “High-set” parameters.
  - Jim Peterson advised he “designed the low to high tone mapping blend equations to allow the current Frame MaxCLL to be well below the low-curve-nit-point, and to also be able to be well above the high-curve-nit-point”. This works well for displays in the <700 Nits range, which represents the majority of displays currently on the market.
  - The Crossover Pt. parameter is not used when ADTM is enabled because the ADTM “Low-set” and “High-set” parameters, along with the current MaxCLL for a frame, are used to calculate a percentage value that is used for ADTM, eliminating the need for the (fixed, hard cut-off) Crossover Pt. setting.
- Note that the control parameters for HIM work with ADTM, except the Crossover Pt., as noted above. ADTM adds an additional control parameter called “DTM Pad” via the command: MENU → Input → Options → HDR Setup → DynamicCtrls
- For a practical example of ADTM, consider a 100 Nit projector. For a 100-Nit scene, ADTM will change to use the 100 Nit range of the projector, which maximizes image quality. For scenes greater than 100 Nits, ADTM changes the transfer function so that the brightest object in the scene maps to 100 Nits, and then uses the HIM and ADTM parameters to make the appropriate trade-offs for all other intensities from black to the brightest objects, to maximize image quality.
- Although It is not possible to get perfect results for every scene using ADTM, but for most scenes, the ADTM results should be better. Tone mapping is all about trade-offs, and the controls to “season to tasted” are available.

HDR Tone Mapping Controls Overview

- The HDR Intensity Mapping (HIM) Control Parameters are covered in the Radiance™ Pro manual, page 18.
- Prior to using the HDR Intensity Mapping control parameters, you must enable HDR Intensity Mapping and set the Display Maximum Brightness, as noted in the HDR Intensity Mapping Initial Setup section. Ideally, a calibration should be accomplished first, but is not necessary.
- As noted in the HDR Intensity Mapping Initial Setup section, for the first scene you adjust, it is recommended you change Display Max Light, which is a coarse "brightness" setting. The Display Ratio Adjust parameter should be at the default settings.
- After the initial setup, there are adjustments available for **Adaptive Dynamic Tone Mapping (ADTM)** designed to optimize the experience. The adjustment parameters are covered in the HDR Setup Menu section below. The parameters are specific to the active input, and input memory, so preferences can be set for each input and input memory or copied as desired.
- The ADTM algorithm and the default settings have both been refined and working very well for most program material. Typically, the only adjustment needed is the "Display Max Light" in the CMS upon initial setup. While almost all users will be very happy with the default settings, the default settings can still be adjusted for personal preferences and/or differences in source material. The parameters are interactive, so spend time trying different settings for each control. The Display Ratio Adjust parameter is useful for compensating for differences between sources.
- The effect of the parameters may vary based upon the Display Max Light setting, the MaxCLL, and the individual setting parameters. Typically, HDR material with higher MaxCLL titles will result in greater visible changes as settings are adjusted.

  - When viewing HDR with a display that has more range then the source needs, then no tone mapping is needed since the display can render the entire range of the source. As an example, if you have a 1000 Nit TV and a 1000 Nit source, you can render the source without tone mapping, but for a 4000 Nit source, you would need tone mapping.

  - Adjust the HDR Intensity Mapping control parameters while viewing (paused) HDR source material. Choose a scene with both dark and bright areas or a scene with a very bright object; see the HDR Content Examples section for further details.

HDR Setup Menu

- The HDR Setup Menu contains the adjustment parameters for the HDR Tone Mapping options. The ADTM algorithms have improved to a point where you should only need to set the "Display Max Light," and optionally adjust "Dynamic Pad" (DynPad).
- The sub-menu items are: **HDR Mapping**, **Crossover Pt**, **Max Default**, and **DynamicCtrls**.

HDR Mapping Menu

- The **HDR Mapping** menu parameters adjust the overall operation of the Tone Mapping transfer function. As of firmware version beta 120419, what you are able to see in this menu depends upon the user interface mode (User or Service). The parameters in the next section are available in the service mode. Lumagen® recommends most users stay in user mode to prevent making adjustments that negatively affect performance.
- Lumagen® recommends the default settings for HDR Adaptive Dynamic Tone Mapping (ADTM) which can be enabled via the command: MENU → Input → Options → HDR Setup → Set Defaults.
- The command is: MENU → Input → Options → HDR Setup → HDR Mapping
  - Once in this menu, and a parameter is selected, the menu switches to an abbreviated strip at the bottom of the display, so it is easy to see the effect of changes.
  - Press "**Alt**" to switch between the adjustments for "High" and "Low".
  - Press **OK** to accept changes or **EXIT** to discard changes.
  - Save any changes made.
  - You can also access the input **HDR Mapping** parameters by pressing the ◄ key.

Low Display Ratio **Range:** 0 to +63 (default = 31)

- The parameter adjusts brightness for dark scenes via a ratio between the HDR source to Display Max Light. Since the source to display intensity ratio is the primary factor in the **HDR Intensity Mapping** transfer function, **Ratio** has the largest effect.
- Note: Max Light must be set prior to any adjustments to this parameter.
- The default setting of 31 results in roughly "1X" measured light (assuming Max Light is in the 4-5x range) for dark scenes.
- *Display Max Light* is used to calculate the ratio of 10000/*DisplayMaxLight* for HDR Intensity Mapping.
  - Allows this calculated ratio to be adjusted for the current Input and Input Memory.
- Increasing *Ratio* increases image brightness.
- To determine the effective Max Light for the Low-set value:
  - While on the LowRatio column, the "Effective Max Light" value is displayed, and changes as the parameter is adjusted. Adjust for the given display as recommended below, and press OK to accept changes.
- As of 10/09/2020, Lumagen® recommends setting this as follows:
  - Projectors in the 70-140 Nit Range:
    - Adjust the Low-set ratio so that it is 1-2 times the measured maximum (HDR) light output. For a projector with 100 Nits maximum (HDR) brightness, set this to 100-200.
  - OLED Panels:
    - Adjust the Low-Set ratio so that it is 2 times the measured maximum (HDR) light output.

High Luminance DeSat **Range:** Auto, Low, Med, High (default = Auto)

- This parameter only effects the color of the very brightest highlights.
- Higher settings desaturate the color of very bright highlights, there is little need for it on lower peak MaxCLL titles, as it has no effect on moderate or dark scenes.
- Content evaluation example: **Mad Max Fury Road™ (2015)**
  - Chapter 03 / 00:28:29 Sand Storm: Car exploding in the air.
- As of 10/09/2020, Lumagen® recommends leaving this at the default setting.

HDR Mapping Menu (Service Mode)

- The following **HDR Mapping** menu parameters are available in the service mode. Lumagen® recommends most users stay in user mode to prevent making adjustments that negatively affect performance.
- While in service mode, some adjustment parameters have two different range values to cover both dark content via the "Low" (aka Low-set) settings, as well as bright content via the "High" (aka High-set) settings. The adjustment range for the two sets varies dependent upon the adjustment parameter.
  - The ADTM Low and High parameters are derived from the value entered for the Display Maximum Brightness (Display Max Light), (a.k.a. LMax) in the Output CMS menu under **CMS HDR Mapping**, **MaxLight**.
  - The ADTM Low and High parameters are used to calculate a percentage value that is used with the (scene by scene calculated) MaxCLL to automatically adjust the ADTM EOTF. This eliminates the need for the (fixed, hard cut-off) Crossover Pt. used in static HDR Intensity Mapping. As a result, the HDR Intensity Mapping parameters for "Crossover Pt." (MaxCLL ≤ Crossover and MaxCLL > Crossover) are not used when ADTM is enabled.
    - The **Low** range adjustments affect content that is ≤ the Display Max Light (a.k.a. LMax).
      - If changes are made, use a dark scene from Blade Runner 2049.
    - The **High** range adjustments affect content that is > the Display Max Light (a.k.a. LMax).
      - If changes are made, use a very bright scene, like Mad Max™ Fury Road at 0:28:29.
  - See the HDR Content Examples section on page 80 for further details on the scene examples above.
  - The Low and High Shape and Transition parameters also play a key role. It then dynamically interpolates, the low/high Display Max Light (LMax), Shape, Transition, and of course the dynamically calculated scene max light (a.k.a. Lw), and so takes user settings/preferences into account appropriately for each scene's brightness. Stated more explicitly display target max is not the same for dark scenes and bright scenes.

Display Ratio Adjust (High/Low) **Range:** 0 to +63 (default for High = 0, Low = 31)

- The **Display Ratio Adjust** parameter adjusts the HDR source to Display Max Light ratio. Since the source to display intensity ratio is the primary factor in the **HDR Intensity Mapping** transfer function, **Ratio** has the largest effect.
- The default setting of 31 results in roughly "1X" measured light (assuming Max Light is in the 5x range) for dark scenes.
- *Display Max Light* is used to calculate the ratio of 10000/*DisplayMaxLight* for HDR Intensity Mapping, which allows this calculated ratio to be adjusted for the current Input and Input Memory
- Use to adjust contrast for MaxCLL ≤ *Crossover* sources (or any HDR source) if needed.
- Increasing *Ratio* increases image brightness.

Shape (High/Low) **Range:** 0 to 7 (default for High = 4, Low = 3)

- The **Shape** parameter controls how smoothly the transfer function changes from the lower intensity range (where the goal is to "match nit-for-nit") to the higher intensities.
- This effect of this parameter varies based upon MaxCLL.
- Suggested value is from 2 to 5, with 3 (the default) being a common choice.
- A smaller curve (lower setting) increases the size of the "nit-for-nit" range.
- A smoother curve (higher setting) reduces the rate of change in input-to-output slope. A large *Shape* value effectively reduces the *Transition* point intensity.

- Note that the effect of the **Shape** parameter changes based on **Display Max Light**, and **Transition** parameters.

Transition (High/Low) **Range:** 0 to 15 (default for High = 9, Low = 7)

- The **Transition** parameter controls the percentage of the range that HDR Intensity Mapping tries to match "nit for nit."
- Reducing **Transition**, or increasing **Shape**, both have the effect of reducing the "nit for nit" range, so they are very interactive.
- Larger values increase nit-for-nit range and reduce range available for highlights.
- Suggested values are
  - Low: 6 to 8 (default = 7)
  - High: 8 to 13 (default = 9)
- *Transition* is the parameter most likely to change for different systems.
  - It depends the TV or projector brightness and content.
  - A 1500 nit TV will likely use a larger *Transition* value than an 80-nit projector.

Gamma Adjust **Range:** -10 to +10 (default = 0)

- The **Gamma Adjust** parameter modifies the effect of the “Gamma Factor” in the CMS menu.
- Increasing **Gamma** increases the resulting Gamma and can help make the image appear to have a higher contrast ratio.
- Selecting a negative number for **Gamma** can increase the brightness of dark areas if they are too dark.
- A positive value will make dark areas even darker and can sometimes be used to increase perceived contrast ratio.

Black Adjust **Range:** -15 to +15 (default = 0)

- The **Black Adjust** parameter adjusts the black level before the **HDR Intensity mapping** in the pipeline (the CMS memory **Black** is in the 1D LUT that is after the 3D LUT).
- Reducing the **Black** level may improve the perceived contrast ratio of the image, but may “crush” portions of the image near black if reduced too much.
- A negative number reduces Black Level and sometimes can improve the perceived contrast ratio.
- A positive number raises the Black Level.

Crossover Pt Menu

- This parameter is not used when Adaptive Dynamic Tone Mapping (ADTM) is enabled. The ADTM "Low" and "High" parameters are used to calculate a percentage value, which is used with the ADTM MaxCLL calculated for the scene to automatically adjust the ADTM EOTF. This eliminates the need for the (fixed, hard cut-off) Crossover Pt. settings.

- The adjustment parameters are **MaxCLL > Crossover** and **MaxCLL ≤ Crossover**.
  - **MaxCLL > Crossover** should be adjusted using known source material with specular highlights.
  - **MaxCLL ≤ Crossover** should be adjusted using known source material with low levels.
- The command is: MENU → Input → Options → HDR Setup → Crossover Pt

Max Default Menu

- The **Max Default** menu contains parameters for adjusting HDR Source MaxCLL; it is used when MaxCLL is not valid.
- The command is: MENU → Input → Options → HDR Setup → Max Default
- The adjustment range is 200 to 10,000 (Default = 4000).

DynamicCtrls Menu

- The **DynamicCtrls** menu contains parameters for adjusting the Adaptive Dynamic Tone Mapping (ADTM) function, which is enabled by default.
- The command is: MENU → Input → Options → HDR Setup → DynamicCtrls
  - Press the ▲ and ▼ arrow buttons to select the parameters. Press the ◀ and ▶ arrow buttons to change the selected setting. Press the **OK** button to accept the changes made. Press the **EXIT** button to leave the menu.
  - Press the “ALT” key to show an abbreviated menu at the bottom of the screen, which is useful for making adjustments with program material. Press ‘OK’ to get back to the normal menu screen.
- You can also quickly access the abbreviated menu **DynamicCtrls** by pressing the ◀ key.
  - Once in this menu press **OK** to accept changes or **EXIT** to discard changes.
- The **DynamicCtrls** menu options are **DTM Enabled**, **DTM Pad**, and **Adaptive**.
- The parameters are per-input and per-input-memory, except for "Global Max Light", which is "global" to all inputs and input memories that use the currently active HDR CMS.
- Note: If you want the settings (excepting Max Light) to apply to other inputs or input memories, use the "Input Copy" command to copy to the other inputs and/or memories and then save any changes you want to be permanent.

DTM Enabled **Options: No, Yes, Default:** Press ‘OK’ to make the selection.

DTMPad **Range:** 0 to 7 (default = 3)

- **Dynamic HDR Tonemapping Pad (aka DTMPad, DPad / DynPad)** adjusts the transfer-function headroom is selected at the first frame of each scene. This parameter makes ADTM a user-adjustable "dynamic" tone mapping solution. Since its introduction, subsequent firmware releases have resulted in improvements to the algorithm, so the recommended settings have also changed over time.
- As of 12/09/2020, Lumagen® recommends setting this at 2, but in this post encourages experimentation with 3, 4, and 5 to determine user preference.
  - DTMPad remains a trade-off between higher scene brightness (2) and more detail in very bright objects (5), as the intra-scene “Adaptation” adjusts the transfer-function during each scene.
- As explained in this post, the parameter adjusts aggressiveness of the "pad", allowing more highlight pop at the expense of some possible artifacts.
  - This is similar to how a dynamic iris works, as more aggressive modes can show occasional artifacts but provide better results with blacks.
- In this post, Kris Deering advises keeping DTMPad at 2-3 for most users.
-

Adaptive **Range:** N / Y (default = Y)

- As explained in this post, the **Adaptive** parameter is an adaptive PER FRAME adjustment designed to eliminate artifacts, as each frame is much closer to a static tone map for that specific frame. This feature is a key reason why changes when adjusting parameters are much harder to see.
- While in the menu to turn this on or off, press the 'ALT' key to show an abbreviated menu at the bottom of the screen. This is useful for seeing the effect of this feature. Press 'OK' to get back to the normal menu screen.
- The default level is limited to a single adjustment per frame which significantly reduces the instances where artifacts may appear.
  - There is a custom menu code that allows for a more aggressive setting, but I will leave that to Jim to decide if he wants to share that at this time. Pat advised in this post that with each step it would allow one bit of information to change. The default allows one. That said, moving to the next setting up (two adjustments per frame) does cause some very minor flickering at times depending on the scene (very similar to a quick flicker from a gamma adjustment in a dynamic contrast system).

- To make the changes made to the HDR Setup section permanent, so they survive a power-cycle, be sure to save them via the command: MENU → Save → Save → OK → OK:

Abbreviated DynamicCtrls Menu

- The abbreviated **DynamicCtrls** menu contains key parameters for adjusting the Adaptive Dynamic Tone Mapping (ADTM) function. While these adjustment parameters are covered elsewhere in this guide, they are provided below for reference, in edited form.
- You can also quickly access the abbreviated menu **DynamicCtrls** by pressing the ◀ key.
  - Once in this menu press **OK** to accept changes or **EXIT** to discard changes.
- The abbreviated **DynamicCtrls** menu options are **LowRatio**, **DynPad**, **DeSat**, and **Global MaxLight**.

- The parameters are per-input and per-input-memory, except for "Global Max Light", which is "global" to all inputs and input memories that use the currently active HDR CMS.
- Note: If you want the settings (excepting Max Light) to apply to other inputs or input memories, use the "Input Copy" command to copy to the other inputs and/or memories and then save any changes you want to be permanent.

Low Ratio **Range:** 0 to +63 (default = 31)

- The name was shortened from **Low Display Ratio** for this abbreviated menu. The parameter adjusts brightness for dark scenes via a ratio between the HDR source to Display Max Light. Since the source to display intensity ratio is the primary factor in the **HDR Intensity Mapping** transfer function, **Ratio** has the largest effect.
- Note: Max Light must be set prior to any adjustments to this parameter.
- The default setting of 31 results in roughly "1X" measured light (assuming Max Light is in the 4-5x range) for dark scenes.
- Increasing *Ratio* increases image brightness.
- To determine the effective Max Light for the Low-set value:
  - While on the LowRatio column, the "Effective Max Light" value is displayed, and changes as the parameter is adjusted. Adjust for the given display as recommended below, and press OK to accept changes.
- As of 10/09/2020, Lumagen® recommends setting this as follows:
  - Projectors in the 70-140 Nit Range:
    - Adjust the Low-set ratio so that it is 1-2 times the measured maximum (HDR) light output. For a projector with 100 Nits maximum (HDR) brightness, set this to 100-200.
  - Flat Panels:
    - Adjust the Low-Set ratio so that it is 2 times the measured maximum (HDR) light output.

DynPad **Range:** 0 to 7 (default = 3)

- The name was shortened from **Dynamic HDR Tonemapping Pad** for this abbreviated menu.
- As of 12/09/2020, Lumagen® recommends setting this at 2, but in this post encourages experimentation with 3, 4, and 5 to determine user preference.
    - DTMPad remains a trade-off between higher scene brightness (2) and more detail in very bright objects (5), as the intra-scene "Adaptation" adjusts the transfer-function during each scene.
- In this post, Kris Deering advises keeping DTMPad at 2-3 for most users.

DeSat **Range:** Auto, Low, Med, High (default = Auto)

- The name was shortened from **High Luminance DeSat** for this abbreviated menu.
- This parameter only effects the color of the very brightest highlights.
- Higher settings desaturate the color of very bright highlights, there is little need for it on lower peak MaxCLL titles, as it has no effect on moderate or dark scenes.
- As of 10/09/2020, Lumagen® recommends leaving this at the default setting.

Global MaxLight **Range:** 100 to 9900 (default = 500)

- It is duplicated from the Output CMS menu under HDR Intensity Mapping CMS Setup, MaxLight.
- This parameter should be se to reflect the display maximum light output capability.
- As of 12/09/2020, Lumagen® recommends setting this as follows:
    - For projectors: Four to Five times (4-5x) the measured Nits.
    - For flat panel displays ≥ 1500 Nits: One to two times (1-2x) the measured Nits.

- To make the changes made to the HDR Setup section permanent, so they survive a power-cycle, be sure to save them via the command: MENU → Save → Save → OK → OK:

HDR Content Examples

- Due to inconsistent HDR content and mastering techniques, and critical errors in the source metadata, such as incorrectly reporting MaxCLL, display manufacturers have implemented proprietary dynamic tone mapping solutions to mitigate these issues.

- Over time, specific scenes in HDR material have been used to illustrate inconsistencies with HDR content, as well as to evaluate the various dynamic tone mapping solutions. Some scenes are also useful to evaluate certain display properties. I have collected some scenes I have learned about. There may not be specific guidance on what to look for in a given scene, but the information provided allows quick access to it.

- Even though the mastered level of the film (Max Mon) may differ (1,000 or 4,000 Nits), a tone-mapped scene at the same maximum light level (MaxCLL) should look the same.
  - The Radiance Pro ADTM analyzes each scene, so for a given set of parameters a 500 Nit scene in a 1,000 Nit movie will look similar to a 500 Nit scene in a 4,000 Nit movie, but a 100 Nit scene in the 4,000 Nit movie can look darker than a 500 Nit scene in a 1,000 Nit movie.

- Content useful for setting up and evaluating dynamic tone mapping.

Mad Max Fury Road™ (2015) Max Mon = 4000, MaxCLL = 9919
- Examples of bright (specular) highlights in an overall low-APL scene.
  - Chapter 03 / 00:28:37 Sand Storm: Fireball in the upper left; lightning in the upper right.
- Examples of extremely bright (specular) highlights.
  - Chapter 03 / 00:28:29 Sand Storm: Car exploding in the air.
  - Chapter 03 / 00:38:13 Muzzle flash; a couple pixels in the 4400 Nit range.
  - Chapter 11 / 01:46.59 Sunset in the desert.

The Martian™ (2015) Max Mon = 1100, MaxCLL = 0
- Examples of bright (specular) highlights in an overall low-APL scene.
  - Chapter 02 / 00:33:35 Storm approaching.
  - Chapter 21 / 01:19:08 Large setting sun with character sitting on a rock.
  - Chapter 24 / 01:37:35 Sun peeking around dark mountains.

The Magnificent 7™ (2016) Max Mon = ????, MaxCLL = ????
- Examples of bright (specular) highlights in an overall low-APL scene.
  - Chapter 3 / 00:12:01 Horseback rider cresting hill with sun in the background.
    - MaxCLL = 1113, MaxY = 1752
    - Post about DTM issues with this scene.
  - Chapter 03 / 00:16:00 Dimly lit bar with bright windows & doorway.

- <u>Content useful for evaluating dynamic tone mapping.</u>

Blade Runner 2049 (2018) Max Mon = ????, MaxCLL = 480

- A very dark movie with a MaxCLL = 480 Nits (Disc metadata incorrectly reports 182 Nits)

Darkest Hour™ (2017) Max Mon = ????, MaxCLL = ????

- Examples of bright (specular) highlights in an overall low-APL scene.
  - Chapter 02 / 00:06:10 – 00:08:46 Dimly lit room with bright windows in the background.
  - Look for details in the curtains.

Greatest Showman™ (2017)

- Examples of specular highlights.
  - Chapter 11 / 00:48:56 – 00:53:01 Singing Never Enough on stage.

Hacksaw Ridge™ (2017)

- Examples of specular highlights.
  - Chapter xx / 01:38:xx – 01:3x:xx A bright explosion.

Insurgent™ (2015)

- Examples of ???.
  - Chapter 12 / 01:13:52 – 01:18:33 Tris in VR simulation.

The Meg™ (2018) Max Mon = ????, MaxCLL = ????

- Examples of bright (specular) highlights in an overall low-APL scene.
  - Chapter 07 / 00:58:01 – 00:58:01 Cage in water with sunlight above it.
- Example of a very bright scene
  - Chapter ?? / 1:08:30 – 1:08:?? People are swimming around a capsized boat.

Passengers™ (2016)

- Examples of specular highlights.
  - Chapter 14 / 01:34:46 – 01:35:47 Aurora vents the overheated chamber.

The Revenant™ (2015)

- Examples of DTM Performance.
  - Chapter 06 / 00:35:58 – 00:36:58 Men carrying a “stretcher”.

- Content useful for evaluating dynamic tone mapping.

Spears & Munsil UHD HDR Benchmark™ (2019) Max Mon = ????, MaxCLL = ????

- The Montage has examples of non-stylized content in various high-APL and low-APL scenes.
    - Chapter 02 / 00:00:33 – 00:00:38 Horses in the snow.
        - With the HDR10 1000 nit version, you can turn the dynamic tone mapping on and off and see changes. With LG OLED's, with Dynamic Contrast off, there is clipping in the snow. With Dynamic Contrast on, the detail in the snow is revealed. Contrast will have no impact at all on this.
    - Chapter 03 / 00:00:54 Snow around the lake.
        - There is detail in the near-white, if it is not clipped.
    - Chapter 04 / 00:01:41 – 00:01:45 Sunrise on the far right.
        - There is detail in the near-white, if it is not clipped.
    - Chapter 11 / 00:07:15 - 00:07:21 Chicks' feathers on the right side.
        - There is detail in the near-white, if it is not clipped.

- Content useful for evaluating display uniformity.

Arrival™ (2016)

- Examples of display uniformity?
    - Chapter 03 / 00:18:49 – 00:19:23 Aerial pan of base near object.

Star Trek Beyond™ (2016)

- Examples of display uniformity?
    - Chapter 06 / 00:52:22 – 00:52:40 Small ship flying past object.

- Content useful for bass demonstrations.

Alita: Battle Angel™ (2019) **4K version with Dolby Atmos**

- Chapter 04 / 00:11:00 – 00:11:18 Giant bot walking down the street.
- Chapter 07 / 00:18:04 – 00:19:55 Playing Motorball on the street.
- Chapter 09 / 00:27:00 – 00:31:35 Alita battles in an alley.
- Chapter 14 / 00:42:20 – 00:43:24 Watching Motorball in the arena.
- Chapter 16 / 00:51:35 – 00:52:30 Alita in the space ship.
- Chapter 19 / 01:02:55 – 01:09:50 Alita battles Grewishka in the bar and down.
- Chapter 28 / 01:30:50 – 01:36:05 Alita plays Motorball.
- Chapter 32 / 01:45:24 – 01:46:18 Alita enters the temple.
- Chapter 33 / 01:48:16 – 01:49:10 Alita destroys Grewishka.

HDR Intensity Mapping Debugging Command

- The debugging command allows for seeing pixels brighter than a set value blink red, profile the video, and show a live MaxCLL (and MaxY) calculation. You can use "Live" or "Profile" options without the image degrading. Upon entering the command, the "live MaxCLL" display is shown. The “Live” option only works if Adaptive Dynamic Tone Mapping (ADTM) is enabled.
- The command is MENU 0532; Use the ◄ and ► buttons to move to the left column where you can change to the other three options:
  - "**Filt**" is how many pixels need to be above the reported level for it to be considered the MaxCLL. You can change the size of the filter area, but it seems you need to arrow away from the column for this, and then back, before it will allow the change. You change the kernel size with the ▲ and ▼ buttons.
  - "**MaxCLL**" is the calculated MaxCLL for a single frame, reported at about a frame per second.
  - "**MaxY**" is the calculated maximum Luma value ("Y" which is the weighted R, G, B value) for a single frame; reported at about a frame per second.
    - MaxCLL and MaxY both report on the same frame (and pixels).
    - If MaxCLL and MaxY are nearly the same, the brightest pixels are near the Gray Vector.
    - If MaxCLL and MaxY are significantly different, the pixels for the reported MaxCLL are more saturated.
  - Jim Peterson uses this feature during testing to judge the image brightness and then see if the Adaptive Dynamic Tone Mapping (ADTM) decisions seemed reasonable.

Electro-Optical Transfer Function (EOTF) Options

- An Electro-Optical Transfer Function (EOTF) is a mathematical equation or set of instructions that translate voltages or digital values into brightness values. It is the opposite of the *Optical-Electro Transfer Function*, (*OETF)*, that defines how to translate brightness levels into voltages or digital values. Traditionally, the OETF and EOTF were incidental to the behavior of the cathode ray tube, which could be approximated by a 0-1 exponential curve with a power value (gamma) of 2.4. Now they are defined values like 'Linear", "Gamma 2.4" or any of the various LOG formats.

  A. OETF's are used by the camera to convert brightness values into voltages/digital values.
  B. EOTF's are used by displays to convert voltages/digital values into brightness values for each pixel.
  C. Source: https://www.mysterybox.us/blog/2016/10/19/hdr-video-part-3-hdr-video-terms-explained

- The Radiance™ Pro converts the incoming signals to various HDR EOTF's, dependent upon the options set in the output CMS and the HDR Intensity Mapping settings. For "HDR in an SDR container", Gamma = 2.4 is used, as it is essentially Bt.1886 for displays that have good black levels. A calibration with Gamma = BT.1886 may be better for a display with poor black levels. Most likely, only a professional level color probe (e.g. CR-100) will result in noticeably different for Gamma 2.4 versus BT.1886 using calibration software.

  A. The Perceptual Quantizer (PQ) / ITU-R BT.2020 / SMPTE ST.2084 EOTF allows for the display of high dynamic range (HDR) video with a luminance level of up to 10,000 Nits and can be used with the Rec. 2020 color space.
     i. It is designed to allocate bits as efficiently as possible with respect to how the human vision perceives changes in light levels.
     ii. It is based on the Recommendation ITU-R BT.2020-2 (10/2015).
     iii. It was previously standardized as SMPTE ST.2084 / **BT.2084** (08/2014)
  B. The ITU-R **BT.1886** EOTF is 2.40, with an offset to compensate for how good the black level is for a particular display or projector.
     i. It is designed more closely match the characteristics of a CRT.
     ii. It is based on the Recommendation ITU-R BT.1886 (03/2011).
  C. The ITU-R **BT.709** EOTF.
     i. It is designed to standardize the format of high-definition television, having 16:9 (widescreen) aspect ratio.
     ii. It is based on the Recommendation ITU-R BT.709 (06/2015).
  D. There are other HDR EOTF standards not currently supported by the Radiance™ Pro.
     i. Recommendation ITU-R BT.2100-2 (07/2018).
     ii. Hybrid Log Gamma (09/2015).
     iii. Are there others?

Test Patterns

- While hiring a professional calibrator is recommended, the picture can be improved by using the Lumagen® test patterns and measurement equipment. Using the Radiance™ internal test patterns to calibrate the output configuration eliminates the effect of any variance between sources on the calibration, as they are generated in Source-Gamma space for all source formats.
  - The most important step is proper adjustment of the Black Level in the display's menu, as noted in the "Calibrating Display Black Level" section.
- The Radiance™ has a large selection of internally generated, high accuracy test patterns. The test patterns can be generated at the same horizontal and vertical resolution as the current output mode, or with various user-specified parameters. The test patterns can be used for calibrating displays as well as for troubleshooting issues.
- The command is: MENU → Other → Test Pattern → (Reference, Adjustable, Warm up, Ref w/Mode, Adj w/Mode, Test Mode)

Test Pattern Modes

- **Reference** – Uses the current output mode. These patterns are affected *only* by the Output PC/Video level settings and can be used to calibrate the display controls. These are the same as the patterns produced by a video test pattern generator.
- **Adjustable** – Uses the current output mode. These patterns are affected by all the Output Color Management settings and can be used to calibrate the Radiance™ controls.
- **Warm up** – Displays a full-field gray test pattern of 20 IRE to 50 IRE and can be used to warm up a display for calibration. This pattern is safe for long-term use on a plasma or OLED display.
  - Use the ▲ and ▼ buttons to change the IRE level.
- **Ref w/Mode** – Uses the specified Test Mode. These patterns are affected only by the Output PC/Video level settings and can be used to calibrate the display controls.
  - **A/R Indicator** – In the lower-right corner, a small black "R" is displayed to indicate it's a Reference pattern. The indicator has a negligible effect on the average picture level.
- **Adj w/Mode** – Uses the specified Test Mode. These patterns are affected by all the Output Color Management settings and can be used to calibrate the Radiance™ controls.
  - **A/R Indicator** – In the lower-right corner, a small black "A" is displayed to indicate it's an Adjustable pattern. The indicator has a negligible effect on the average picture level.

- **Test Mode** – User-specified test mode that can be used to display test patterns in a user defined output mode, 2D/3D type, CMS and Style.
  - Allows a display to be calibrated without the need to switch to video sources to generate a specific video mode. You must select "Ref w/Mode" or "Adj w/Mode" to generate patterns with test mode settings.
  - The specific test mode selection options for the **Ref w/Mode** & **Adj w/Mode** test patterns are:
    - Input colorspace (Rec.709 or Rec.2020)
    - HDR (On, Off)
    - Output mode (480p60 through 2160p60)
    - 3D type (Off, SbyS, TopB, FrmP)
    - CMS
    - Style

Test Pattern Control

Use the below commands to control the test patterns.

- ◄ or ► Selects the pattern group.
- ▲ or ▼ Adjusts IRE on some patterns.
- "1" Steps backward through the patterns within a group.
- "2" Hides / displays the menu.
- "4" Steps forward through the patterns within a group.
- "CLR" Completely exit the test patterns.
- "Ok" Leaves the test pattern up and display the menu.
- "PRV" Toggles between video input and test pattern.
- "ALT" Exits the menu.

Test Pattern Timeout

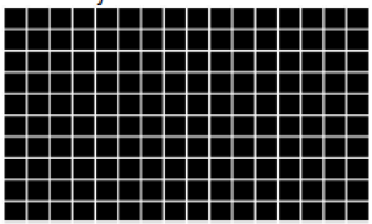
- The test pattern timeout setting controls the length of time the test patterns are displayed.
  - In the "Normal" setting the test patterns are displayed for 3 minutes. In the "Slow" setting the test patterns are displayed for 30 minutes.
  - The command is: MENU → Other → Menu Control → Timeouts → Test Pattern Timeout → [Normal, Slow]

Test Pattern Groups

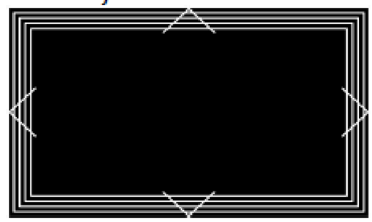
- The test patterns are arranged in thirteen pattern groups
- Group 1 (Geometry) contains the following test patterns: Crosshatch, Overscan, Overscan 2.35, and Aspect Squares.

Group 1

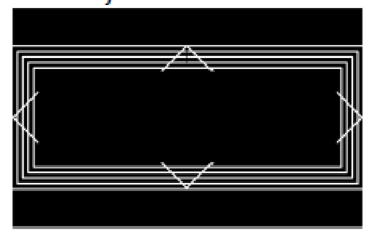
Geometry: Crosshatch



Geometry: Overscan



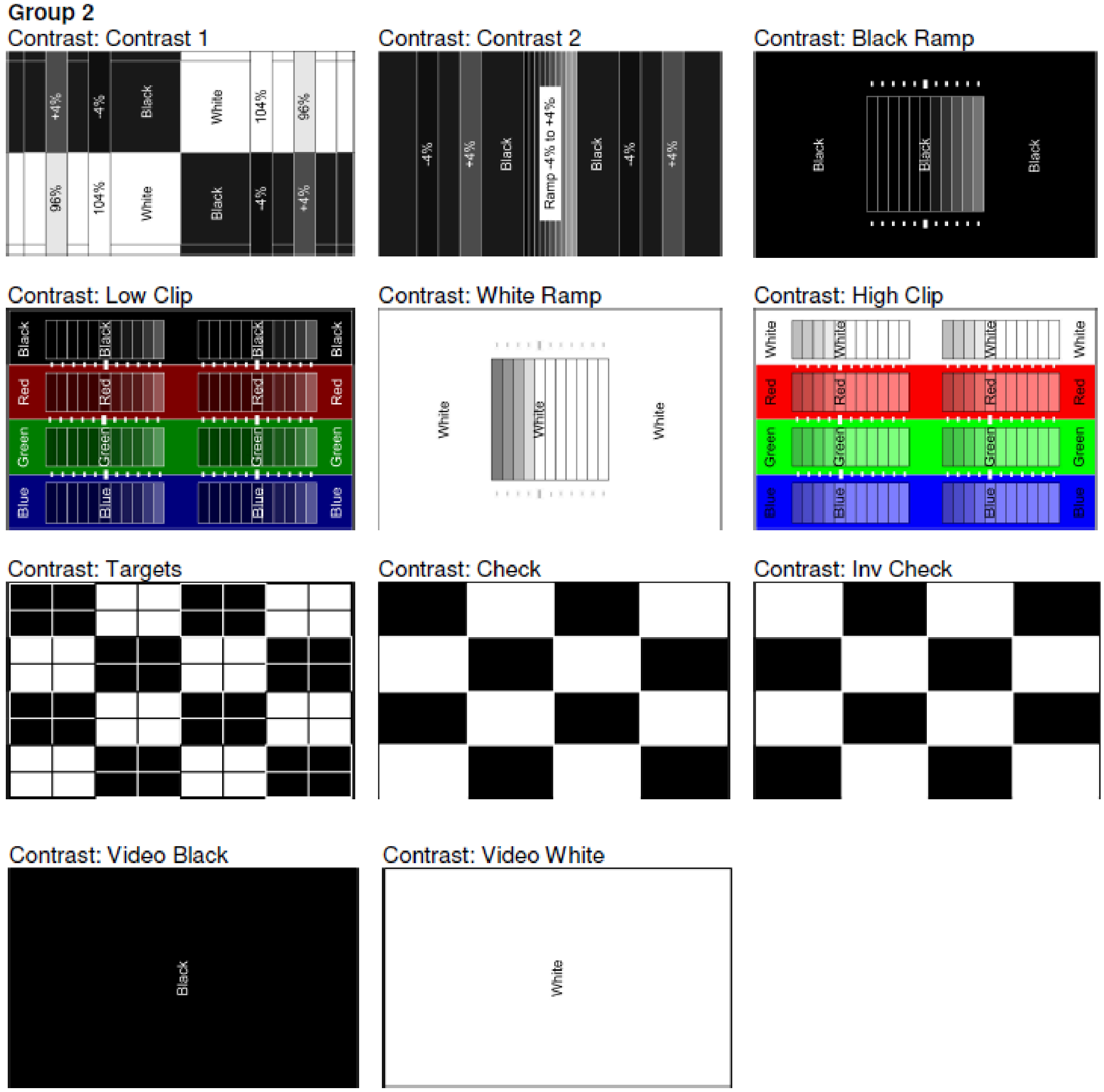
Geometry: Overscan 2.35



Geometry: Aspect Squares

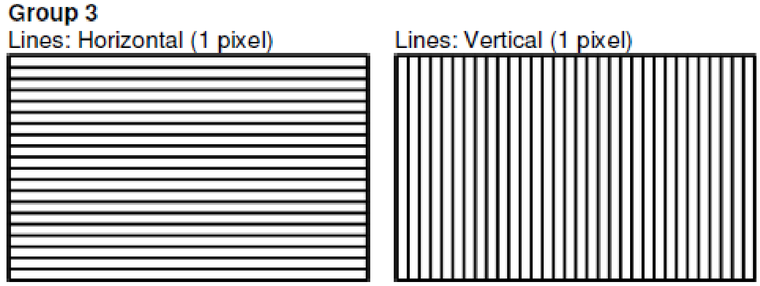
- Group 2 (Contrast) contains the following test patterns: Contrast 1, Contrast 2, Black Ramp, Low, Clip, White Ramp, High Clip, Targets, Check, Inverted Check, Video Black, and Video White.

Group 2



- Group 3 (Lines) contains the following test patterns: Horizontal and Vertical.

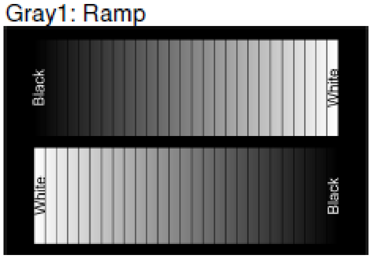
Group 3



- Group 4 (Gray1) contains the following test patterns: Ramp.

Group 4

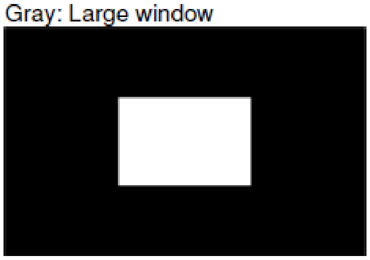
Gray1: Ramp



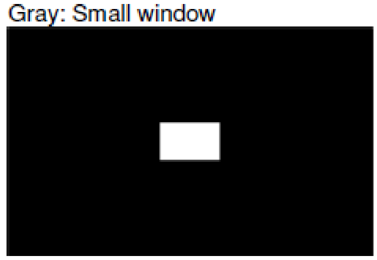
- Group 5 (Gray2) contains the following test patterns: Large Window, Small Window, Solid Window, Medium 50% APL, and Small 50% APL.

Group 5

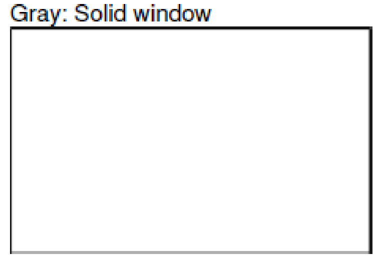
Gray: Large window



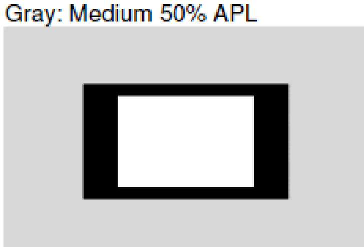
Gray: Small window



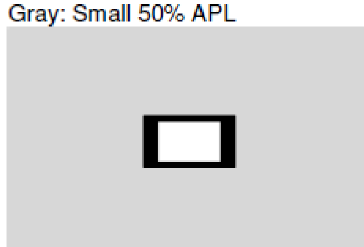
Gray: Solid window



Gray: Medium 50% APL



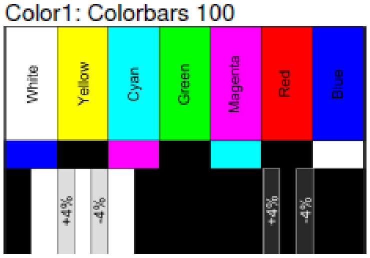
Gray: Small 50% APL



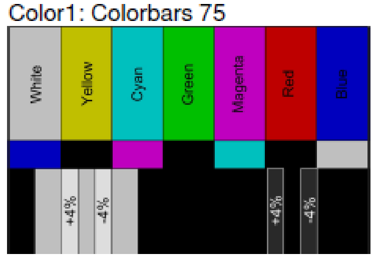
- Group 6 (Color1) contains the following test patterns: Colorbars 100 and Colorbars 75.

Group 6

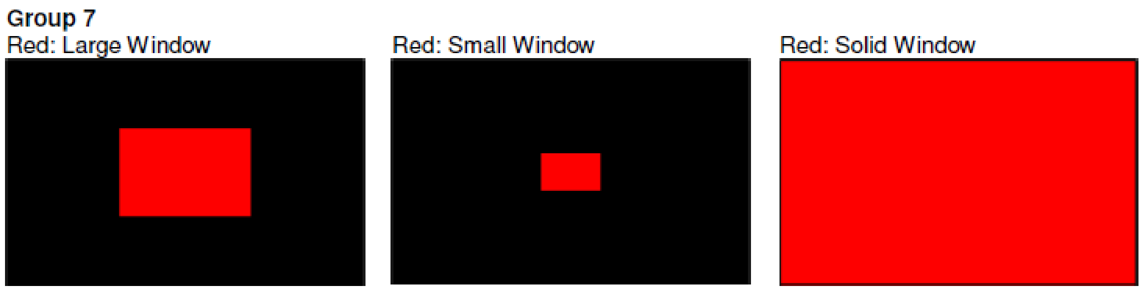
Color1: Colorbars 100



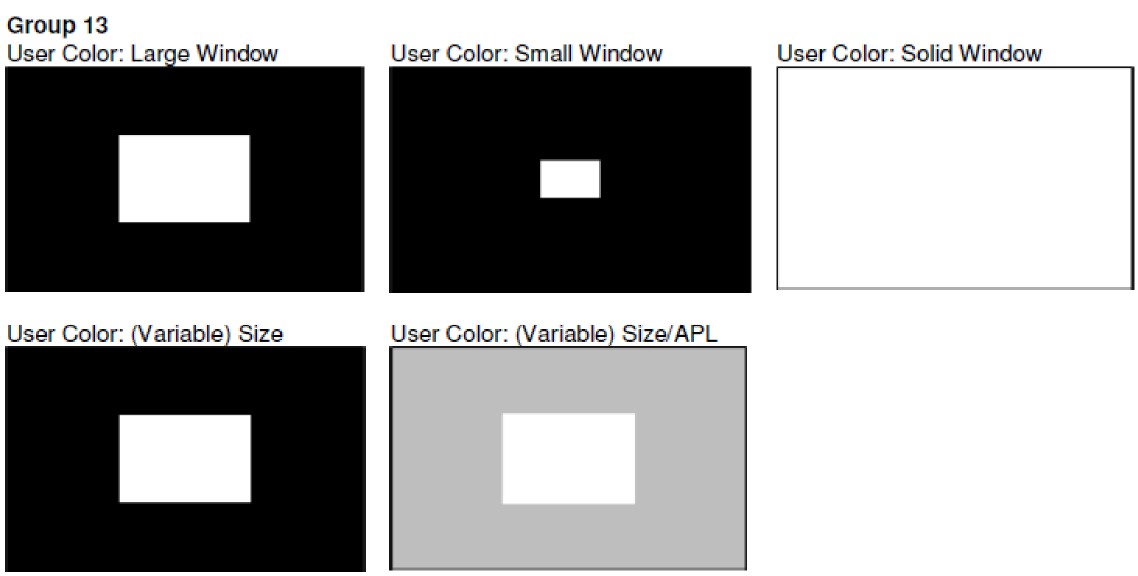
Color1: Colorbars 75



- Group 7 (Red) contains the following test patterns: Large Window, Small Window, and Solid Window.



- Group 8 (Green) contains the following test patterns: Large Window, Small Window, and Solid Window, just like the Group 7 examples above.
- Group 9 (Blue) contains the following test patterns: Large Window, Small Window, and Solid Window, just like the Group 7 examples above.
- Group 10 (Yellow) contains the following test patterns: Large Window, Small Window, and Solid Window, just like the Group 7 examples above.
- Group 11 (Cyan) contains the following test patterns: Large Window, Small Window, and Solid Window, just like the Group 7 examples above.
- Group 12 (Magenta) contains the following test patterns: Large Window, Small Window, and Solid Window, just like the Group 7 examples above.
- Group 13 (User Color) contains the following test patterns: Large Window, Small Window, Solid Window, Size, and Size APL.



Test Pattern Use Examples

- Specific examples of test pattern use are provided below.

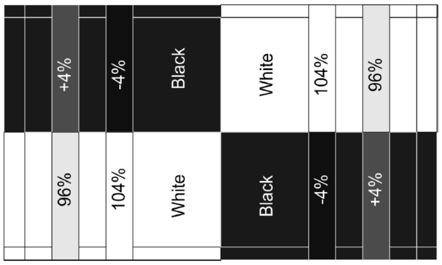
Using the Contrast 1, Contrast 2, and Black Ramp Test Patterns

- Displays will have different black levels, depending on the average picture level (APL) of the image, therefore, the Radiance™ has two contrast patterns.
- The "**Contrast 1**" pattern is a high APL image with -4% and +4% vertical bars in the corners.
- The "**Contrast 2**" pattern is a low APL image with -4% to 4% vertical bar ramp in 1% steps in the center, with -4% & 4% vertical bars surrounded by black on each side of the center ramp.
- The "**Black Ramp**" pattern is a low APL image with -4% to 4% vertical bars in 1% steps in the center.
- It is better to use the low APL "Contrast 2" and "Black Ramp" test patterns to ensure that dark scenes have a correct black level setting.
- Setting black slightly too dark is better than slightly too bright. Setting black is too bright will cause the image to look "softer" than it should.
- Use the Radiance™ 'Reference' test patterns for setting the display controls.
  - Menu → Other → Test Pattern → Reference → Ok

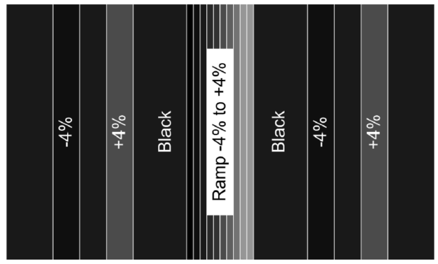
1. Set the black-level (brightness) and white-level (contrast) using the display controls.
   a. When black is properly calibrated, while viewing the **Contrast 2** pattern:
      i. The -4% bar cannot be differentiated from the 0% black background.
      ii. The +4% bar can be barely seen against the 0% black background.
   b. When black is properly calibrated on a well-designed display, while viewing the **Black Ramp** pattern:
      i. The -1% bar cannot be differentiated from the 0% black background.
      ii. The +1% bar can be barely seen against the 0% black background.

2. If the display controls are too coarse, or lack the proper range, you can use the Radiance™ output–configuration black-level and white-level to adjust the black, or white, output level via the command:
   a. Menu → Output → Styles → [style] → HDMI Format → Type

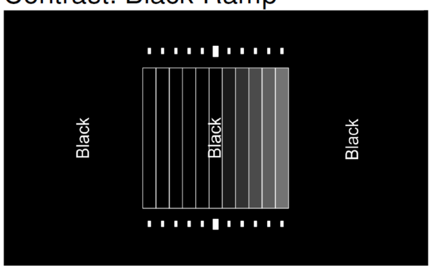
Contrast: Contrast 1



Contrast: Contrast 2



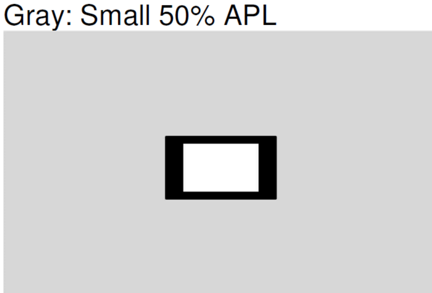
Contrast: Black Ramp



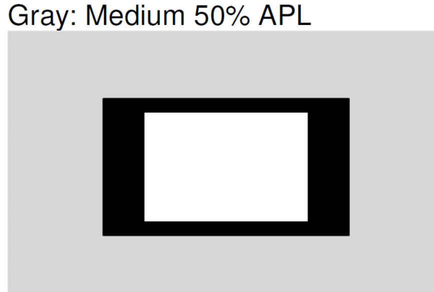
Using the 50% APL Test Patterns

- The Gray Window test patterns, “**Gray: Small 50 APL**” and “**Gray: Medium 50 APL**” are composed of three elements that add up to a constant 50% Average Picture Level (APL).
- The three elements of the test patterns are a central, white adjustable measurement window, a black, adjustable boarder, and a gray background.
    - The central, white, adjustable measurement window can be adjusted from 0 to 100 IRE, in 5 IRE increments.
    - The black, adjustable boarder is of equal area to the central window, and is adjusted automatically from 100 to 0 IRE, in 5 IRE increments.
    - The gray background is 50 IRE.
- To operate the test patterns, follow these steps:
    - Display the test patterns via the command: MENU → Other → Test Pattern → Ref/Adj → Ok
    - Press the ◀ or ▶ arrow buttons to display the “Gray” test pattern.
    - Press “1” or “4” to display the “Gray: SmlAPL” or “Gray: MedAPL” pattern.
    - Press the ▲ and ▼ arrow buttons to adjust the central measurement window, from 0
    - to 100 IRE.
    - Press “2” to turn the menu display on and off.

Gray: Small 50% APL



Gray: Medium 50% APL

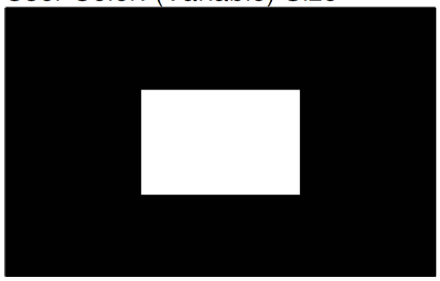


Using the Variable Size and APL Test Patterns

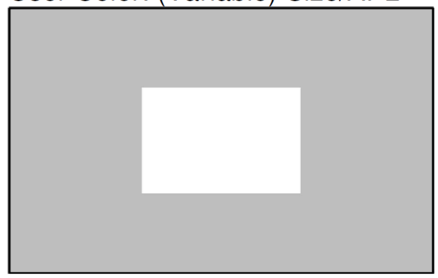
- The Group 13 User Color Window test patterns, "**User Color: (Variable) Size**" and "**User Color: (Variable) Size/APL**" allow you to set the size and Average Picture Level (APL) of the test pattern measurement window.

- To operate the test patterns, follow these steps:
  - Display the test patterns via the command: MENU → Other → Test Pattern → Ref/Adj → Ok
  - Press the ◄ or ► arrow buttons to display the "User Color" test patterns (Group 13).
  - Press "1" or "4" to display the "**User Color: (Variable) Size**" or "**User Color: (Variable) Size/APL**" pattern.
  - These patterns use the RGB levels set in the first three patterns in the group (Group 13): "Gray: Large window", "Gray: Small window", and "Gray: Solid window".
  - For the "**User Color: (Variable) Size**" pattern, adjust the central measurement window size.
    - Press the ▲ and ▼ arrow buttons to highlight the "Size" setting.
    - Enter three digits for the desired window size, between 0.00% to 99.5%, in steps of 0.1%.
  - For the "**User Color: (Variable) Size/APL**", adjust the central measurement window APL.
    - Press the ▲ and ▼ arrow buttons to highlight the "Size" setting.
    - Enter two digits for the desired window APL, between 0 to 100% APL, in steps of 1%.
      - The central measurement window size and the gray background level are automatically adjusted according to the desired APL.
      - The test pattern window size for small = 1.56%, medium = 11.1% and large = 100%.
      - In the event the desired APL cannot be achieved, a greater-than (>) or less-than (<) sign is displayed next to APL to indicate the difference.
        - For example, setting RGB = 240,240,240, the custom size to 90.0%, and the APL to 30% would result in > next to the APL.
  - Press "2" to turn the menu display on or off.

User Color: (Variable) Size



User Color: (Variable) Size/APL



Using the Adjustable Test Patterns

- The Radiance™ allows viewing the adjustable test pattern or an external video input while making adjustments to the Radiance™ input and output controls. This can be very useful when you are doing a video calibration. The process is as follows:
  1. Enable the “Service mode” via the command:
     a. Menu → Other → Menu control → Menu Mode → Ok → Service mode → Ok
  2. Display the adjustable test pattern via the command:
     a. Menu → Other → Test Pattern → Adjustable → Ok
  3. Press the ◀ or ▶ buttons to choose Group 4, “Gray1: Ramp” test pattern.
  4. Press “Ok” to leave the test pattern displayed and return to the menu.
  5. Change the Gamma Factor via the command:
     a. Menu → Output → CMS’s → [*CMS] → Gamma Factor → Ok
  6. Use the ▲ and ▼ buttons to adjust the gamma factor of the output.
     a. Notice the effect on the displayed test pattern.
  7. Press “PREV” to display the input video.
  8. Use the ▲ and ▼ buttons to adjust the gamma factor of the output.
     a. Notice the effect on the displayed video content.
  9. Press “PREV” again to return to the test pattern display.
  10. Press “ALT” to return to the test pattern command menu.
  11. Press the ◀ or ▶ buttons to choose a different test pattern group.
  12. Press “CLR” to clear the test pattern.
  13. Power-cycle the Radiance™ to reload the last saved configuration.