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SpectraCal

# Poynton's Vector 15 Order-of-operations

It's an uncomfortable, unspoken truth of home theatre calibration, even in high-end products, that three-quarters of the effort is expended in dialing-out poorly chosen factory presets. Television receiver manufacturers are motivated to sell receivers, not to deliver accurate imagery. They deliver receivers that they think have the "wow" factor that may be necessary for the fluorescent-lit showroom, but produces garish, over-bright, over-colourful images in the living room or the den.

It's unfortunate that BT.709 does not establish gamma. I wrote about that issue in Issue 3. A new ITU-T standard is forthcoming. Until then, use 2.4 in a typical living room environment at about 100 $cd \cdot m^{-2}$.

Video content is mastered on displays that exhibit characteristics very close to those specified in BT.709. To deliver a visual experience comparable to the experience of the program creator, you seek a calibration as close as possible to BT.709. (It is a question for the next few years whether content creators will master content in wide-gamut colour. If that takes place, then the principle may change.)

Projectors are typically delivered with factory settings that produce images resembling BT.709 calibration. However, at least one manufacturer is promoting "personalization" as a strategic direction. In my view, this is a dead end. Consumer manufacturers are already inserting their own personalities, distorting the imagery from the creative intent. I see no advantage in high-end manufacturers doing so. Even home theatre calibrators have trouble understanding colour management systems on those devices in which CMS capability is provided. To my mind it is completely unrealistic to think that you could explain to a consumer how to adjust a CMS to personalize his video content. To me, the value proposition for home theatre remains faithful presentation, recreating the director's experience of his or her own movie.

What is the best order in which to make adjustments when calibrating a video display, projector, or and television receiver to BT.709?

You can get a good start by choosing an ISF or THX preset if one is available. (One disclaimer: Although I was intimately involved in the recent additions to ITU-T standards for studio reference displays, I am not entitled to read the ISF and THX "standards." We are left to wonder what's in those standards, and to what extent commercial considerations intrude into the certification process.)

To calibrate to BT.709, we hope that the receiver's signal path resembles the path implicit in BT.709. That path has these steps:

- NTSC/PAL/MPEG decode;
- $Y'C_BC_R$-to-$R'G'B'$ dematrix;
- gain and offset (CONTRAST and BRIGHTNESS);

- individual channel gain and offset, and GAMMA (EOCF) control;
- display (perhaps including BACKLIGHT control).

If we were able to able to access video data after processing, at the point where processed data is presented to the panel, it would be easy to establish signal path adjustments. For example, in all modern digital display technologies we expect the reference black video signal to present the all-zeros code to the display. But we don't have access to the panel data, so we have to measure the display's light output instead. My suggested order of adjustments is based upon the following principle: Measure the thinnest layer possible – the shortest signal path. Correct that, then add layers one-by-one until you reach the front end of the system and the longest possible path. Imagine the receiver block diagram with conventional left-to-right signal flow. At each step, insert your test signal into the signal flow as close to the display as possible, that is, as far to the right as possible.

Receiver design engineers are apparently instructed to provide lots of controls to users, but I don't think they deliberately set out to confound calibrators. In all likelihood each control's midscale setting is the "unity" setting where processing is effectively bypassed. So, unless otherwise indicated, set each adjustment to its midscale detent. In the absence of a detent, use the Poynton algorithm: Set each control to the numerical average of the lowest and highest presented values.

If you can inject computer *R′G′B′* (ranging 0–255), do so, to eliminate errors in CE-to-IT level conversion (16–235-to-0–255). Use a test signal that matches the native panel pixel count, to bypass resampling.

If the receiver has a BACKLIGHT control, this will be effected right at the display. Set it first, so as to achieve maximum required luminance.

Set individual *R′G′B′* BIAS if these controls are provided. (These may be called SCREEN, OFFSET, or RGB-LOW.) They are likely to be optimum at midscale.

Set individual *R′G′B′* GAIN if these controls are provided. (These may be called DRIVE or RGB-HIGH.) They are likely to be optimum at midscale. These may interact with COLOUR TEMPERATURE (WHITE REFERENCE).

Set BLACK LEVEL. For any modern digital display, it's likely to be optimum at midscale.

Set the poorly-named CONTRAST control to achieve the desired display luminance (e.g., 100 $cd \cdot m^{-2}$, representative of HD mastering).

Set GAMMA, if gamma adjustment is available.

The next block back toward the input is $Y'C_BC_R$-to-*R′G′B′* dematrix. This block effects the BT.601/BT.709 luma coefficient setting, and in all likelihood incorporates CHROMA and HUE. Set these to unity.

If the receiver or projector has a so-called colour management system (CMS), it is almost certainly implemented in the $Y'C_BC_R$ domain. Do your best to defeat it. If the native display primaries differ from BT.709, the correct approach to compensate is to apply 2.4-gamma, transform the primaries in a linear-light 3×3 matrix, then impose the inverse of the display's EOCF. If that sounds complicated, it is. Few manufacturers do it. Many manufacturers bury comparable correction in the CMS, but compensation there will never perfectly match proper BT.709 dematrixing, decoding, and display.

Good luck! Your comments are welcome!