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13 Black level

The subject of black has been raised before in previous issues of *Poynton's Vector.* In Issue 1, I discussed adjustment of BLACK LEVEL. In Issue 4, I discussed “legal” and “valid” codes and the footroom codes below reference black. In Issue 11, I computed the relative luminance levels to be expected around reference black. Several additional aspects of black deserve further discussion.

The term *setup* implies insertion of an offset such that the range of video levels from black to white is reduced so as to maintain the white level. The term *pedestal* implies insertion or alteration of an offset without this correction.

Let's start with “setup.” In ancient times – the 1940s, when vacuum tubes ruled electronics – raster scanning on a CRT was prone to cause retrace lines to be visible. Video signal levels drifted owing to temperature dependencies and component aging. Video engineers established *blanking level* of the video signal, intended to cause the beam to fully extinguish, and *black level,* taken as the lowest level of meaningful picture information on the way up to white. The blanking to white range was quantified in 100 units, later standardized by the Institute of Radio Engineers (IRE, the predecessor of the IEEE). Black level was established at 7.5 units, leaving 92.5 units for the picture range. That was 1941; colour television was still a decade away.

By 1964, at the introduction of 625-line video, European engineers decided that circuitry was sufficiently stable that separating blanking and black was no longer necessary. Setup was abolished for 625/50.

In the U.S., 7.5-unit setup was retained for compatibility reasons. Japan adopted the NTSC system, with its 525-line scanning and its 7.5-unit setup; however, Japanese television engineers soon realized that the 7.5-unit setup was useless. In about 1985, they undertook a country-wide effort to reconfigure the entire broadcasting infrastructure to eliminate setup. I suppose that many consumers adjusted BRIGHTNESS to compensate; I suppose that many didn't. But Japanese analog SD material from that era into the present day has zero setup.

The +16 interface offset of BT.601 provides signal processing “footroom.” It was not intended to mimic or provide for setup.

Upon establishment of the first studio digital interface standard – BT.601, in 1984 – setup was abolished from the digital domain. Eight-bit coding was agreed to have reference black at interface code 16 and reference black at interface code 235. The codes below 16 were provided for filter undershoot and accommodation of analog tolerances, but no provision was made – nor was it necessary – for setup.

When it became feasible to do substantial arithmetic processing of video in the digital domain, in order for black to stay black – say, upon multiplication by a gain factor – the interface offset had to be removed. The footroom region must be represented in digital arithmetic using negative numbers. I came to denote the reference black and white levels in terms of *processing levels* after removal of the interface offset. For me, eight-bit digital video has *processing* reference levels 0 and 219. If footroom codes are clipped – as is common in PC video – quality suffers. Reference black remains at processing code 0 even with increased bit depth such as 10 bits. The math of video is easiest using reference levels 0 and 1, again using negative numbers for the footroom region (and numbers up to about 1.09 for headroom).

If wide-gamut colour is ever to be deployed in content creation, it will almost certainly use the xvYCC (x.v.Color) scheme whereby wide-gamut colours are coded into values that reach below reference black or above reference white – that is, lie outside the range 0 to 1. In Issue 4, I commented that content creators – or more specifically, the "quality control" houses that they hire – should disable their clippers. Clipping was once necessary to avoid overmodulation in analog NTSC transmitters, but those transmitters have now been decommissioned.

In 1984, at the introduction of digital video in the studio, it was clear that analog interfaces would remain in use for quite some time, both in studios and in consumers' premises. In studios the situation was complicated because Sony and Panasonic introduced different ill-considered analog component interfaces that involved setup or vestigial setup elements. In the consumer domain, the S-video analog interface was introduced in 1987 for S-VHS videocassette recorders. It had 3 versions: an American version with 714 mV video and 7.5-unit setup, a Japanese version with 714 mV video and zero setup (NTSC-J), and a European version with 700 mV video and zero setup. When DVD was introduced in 1995, its SD component analog interface needed the same three versions; however, many DVD player manufacturers got the details wrong; consumer image quality suffered.

Standardization of HDTV followed the European lead: HD analog interfaces never had setup; digital HD followed the BT.601 example.

Computers are digital! Application software should not, in my opinion, mimic setup in the SD analog domain. If you have old-fashioned users, teach them that setup is obsolete.

Upon the introduction of DV consumer recording in about 1995, many camcorders incorrectly recorded black at interface codes below 16, apparently in a misguided attempt to "maximize dynamic range." I'll have more to say about dynamic range in a future issue.

The story so far has many false starts and premature optimizations. The correct way forward clearly has no setup! Reference black should be called 0 no matter what bit depth is in use, even in the abstract math domain where reference white is represented as the value 1. It is entirely reasonable to use percentages – refer to video levels as 0 percent and 100 percent, if you like – but with the sole exception of analog 525-line SD, black should be taken as zero, not 7.5 percent.

I'll leave you with one subtle aspect of studio mastering practice. BLACK LEVEL is set in the studio using PLUGE; the resulting luminance is about 0.03 nt: Reference black has nonzero luminance! Modelling the display EOCF as a pure 2.4-power function, reducing video level below reference black should drive down to theoretical zero luminance. In current studio practice, theoretical zero luminance is obtained at a negative 10-bit processing code, in the footroom region: –32. On the 10-bit 64-to-940 interface code scale, this is code 32. The capability to represent true, theoretical zero luminance is another reason for using footroom codes in video content.

Your comments are welcome!