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**Title: Clarifying interpolation of colors in ISO/IEC 14496-22 AMD2**

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During the break-out group discussion at the last SC29/WG3 meeting in January 2021 (see report in **m56219**), the group concluded that the interpolation of colors was not sufficiently specified. This was one of the topics that was deferred for additional discussions.

This contribution summarizes the results of the discussions and proposes new updates to clarify the specific approach to color interpolation defined as part of the ISO/IEC 14496-22:2019/AMD2, and resolves the issues outlined by the BoG report.

*5.7.11.1.2.1 “Color lines”*

*Replace the fourth paragraph with the following text:*

Color gradation is defined over the interval from the first color stop, through the successive color stops, to the last color stop. Between numerically-adjacent color stops, color values are linearly interpolated. See *Interpolation of Colors* in 5.7.12 for requirements on how colors are interpolated.

For example, a gradient color line could be defined with two color stops at 0.2 and 1.5. The gradient color line is positioned in the design grid by aligning stop offsets 0 and 1 to design grid positions, as defined for each gradient type, using an extrapolated color of stop offset 0 at one position and an interpolated color of stop offset 1 at the other position. Colors for offsets between 0.5 and 1.5 are interpolated. Colors for offsets above 1.5 and below 0.2 are defined and determined by the color line’s *extend mode*, described below.

*5.7.11.2.5.11 “PaintComposite”*

*Replace the third paragraph [immediately following the “CompositeMode enumeration” table] with the following text:*

The graphic compositions are defined by the source and backdrop paint tables and their respective sub-graphs. Conceptually, they are rendered into bitmaps, and the source is composited or blended into the backdrop using the specified composite mode. Details on each mode, including specifications of the required calculations using pixel color and alpha values, are provided in the Compositing and Blending Level 1 specification [33].

While color values obtained from the CPAL table are represented in sRGB using the non-linear transfer function defined in the sRGB specification, the compositing and blending calculations are done after applying the inverse transfer function to derive linear-light RGB values. For more information regarding the non-linear and linear-light representations for sRGB, see *Interpolation of Colors* in 5.7.12.

*5.7.12 “CPAL – Palette Table”*

*Replace the second paragraph with the following text:*

Palettes are defined by a set of color records. Each color record specifies a color in the sRGB color space using 8-bit BGRA (blue, green, red, alpha) representation. The sRGB color space is specified in IEC 61966-2-1. Details on the specification for the sRGB color space, including the color primaries and “gamma” transfer function, are also provided in [CSS Color Module Level 4, section 10.2](https://www.w3.org/TR/css-color-4/#predefined) [34].

All palettes have the same number of color records, specified by numColorRecords. All color records for all palettes are arranged in a single array, and the color records for any given palette are a contiguous sequence of color records within that array. The first color record of each palette is provided in the colorRecordIndices array.

*Insert the following paragraphs at the end of the sub clause 5.7.12 with the heading “Interpolation of colors”:*

**Interpolation of Colors**

The SVG table and version 1 of the COLR table both support color gradient fills. The gradients are defined using color stops to specify color values at specific positions along a color line, with color values for other positions on the color line derived by interpolation.

When interpolating color values, linear interpolation between color stop positions is used. For example, suppose adjacent color stops are specified for positions 0.5 and 0.9 on a color line, and a color value is being calculated for position 0.8. The color value of the first color stop will contribute 75% of the value ((0.8 - 0.5) / (0.9 - 0.5)), and the color value of the second color stop will contribute 25% of the value. Interpolated values at each position of the color line are computed in this way for each of the R, G and B color components.

When interpolating color values, specific aspects of the representation of colors as well as handling of alpha need to be considered.

Representations of sRGB color values are expressed as levels of red, green and blue color “primaries” with specific, absolute chromaticity values, which are defined in the sRGB specification. Color-primary levels can potentially be expressed using a linear-light scale that correlates directly to light energy. (On a linear-light scale, for example, a doubling of a color value would correspond to a doubling of display luminance.) For sRGB, however, standard practice is to represent levels using a scale defined by a non-linear transfer function, sometimes referred to as “gamma”. This transfer function is also defined in the sRGB specification. (See [CSS Color Module Level 4, section 10.2](https://www.w3.org/TR/css-color-4/#predefined) [34] for details.) In the CPAL table, sRGB color values are always specified in terms of the non-linear, sRGB transfer function.

NOTE An advantage of representing colors using a non-linear scale is that it allows more effective use of limited bit depth when color-primary levels are represented as integers: smaller differences in light energy can be represented for lower levels than for higher levels. This is beneficial since the human visual system is more sensitive to differences at low luminance levels than to differences at high luminance levels.

When interpolating colors, different results will be obtained if the interpolation is computed using the non-linear scale for color levels than if using the linear-light scale. For interoperable results, whether the non-linear or linear-light scale is to be used needs to be specified.

For gradient color values in the SVG table, the required interpolation behavior is defined in the SVG 1.1 specification: the [‘color-interpolation’ property](https://www.w3.org/TR/SVG11/painting.html#ColorInterpolationProperty) can be used in an SVG document to declare whether interpolation is done using the non-linear sRGB scale (the default), or using a linear-light scale by applying the inverse sRGB transfer function.

For gradient color values in the COLR table, interpolation shall be computed using linear-light values (i.e., after applying the inverse sRGB transfer function).

After an interpolated color value is computed, whether or not the non-linear sRGB transfer function needs to be re-applied is determined by the requirements of the implementation context.

For both the COLR and SVG tables, interpolation shall be done with alpha pre-multiplied into each linearized R, G and B component. For alpha specified in a CPAL ColorRecord, the value is converted to a floating value in the range [0, 1.0] by dividing by 255, then multiplied into each R, G and B component. For ColorIndex records in the COLR table, the alpha value from the ColorIndex record (with variation, in a variable font) is multiplied into the R, G and B components as well. Interpolated values are then calculated by linear interpolation using these pre-multiplied, linear-light R, G and B values.

NOTE Alpha components use a linear scale and can be directly interpolated apart from the R, G and B components without any linearization step.

Once interpolation of the pre-multiplied red, green and blue values and of the alpha value is complete, the red, green and blue results are then un-premultiplied by dividing each interpolated value by the corresponding interpolated alpha.

While color values are specified as 8-bit integers, the interpolation computations will require greater precision in each of the linearization, pre-multiply, and interpolation steps. Also, when rendered results are to be presented on an imaging device with known characteristics, visual banding artifacts in a gradient can be minimized by taking full advantage of the color bit depth supported by the device. For instance, if a display supports 10- or 12-bit quantization per color channel, then ideally the ramp of color values in a gradient would use that level of quantization. Other factors from the presentation context may, however, also affect the available capabilities. Therefore, no minimum level of precision is specified as a requirement

**Bibliography**

*Add a new entry 34 as follows:*

[34] CSS Color Module Level 4. W3C Working Draft Recommendation, 12 November 2020.
<https://www.w3.org/TR/css-color-4/>