

ICC Technical Note

Guidelines on the use of negative PCSXYZ values

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Introduction

In ICC.1 specifications (for all ICC v2 and v4 profiles), the PCS is encoded as normalized, media-relative XYZ with an encoding range of [0,1]. In some situations valid CIE XYZ values result in negative PCSXYZ values after chromatic adaptation and this document provides recommendations on how to handle such situations.

PCSXYZ encoding

PCS XYZ values are obtained by linearly scaling CIE XYZ tristimulus values and encoding as 16-bit or floating point numbers. PCSXYZ values are encoded as XYZNumber, which can be u1Fixed15Number, s15Fixed16Number or float32Number (ICC.1:2010 6.3.4.2). A PCSXYZ value of [0,0,0] corresponds to a perfect absorber (ICC.1:2010 6.4.3), while a PCSXYZ value of [0.9642, 1.0, 0.8249] corresponds to the media white point. (ICC.1:2010 3.1.24). When converting from PCSXYZ to PCSLAB, negative PCSXYZ values are clipped on a per-component basis to values in the PCSLAB range (ICC.1:2010 6.4).

In the case of the u1Fixed15Number, only values in the range [0, 1+ 32767/ 32768] can be encoded (ICC.1:2010 6.4.3.2). Both s15Fixed16Number and float32Number permit a larger range of values to be encoded.

Negative PCSXYZ values

A valid spectral radiance factor or spectral reflectance factor cannot be negative, and so when calculated from spectral radiances according to CIE Publication 15 XYZ, tristimulus values must also be ≥ 0 . However, negative XYZ values can result from applying a chromatic adaptation matrix to a set of valid CIE XYZ values. This issue has been observed for the chromatic adaptation transform used in CIECAM02, for example, and can also arise when using the ICC-recommended modified Bradford transform (ICC.1:2010 Annex E), particularly for chromaticities that lie close to the spectral locus. The chromaticities specified for ITU BT.2020 and the DCI P3, for example, lead to negative XYZ values for the Z tristimulus value for the red primary.

Where negative CIE XYZ values are present in the profile and clipped by the CMM to the range [0,1], such colours will not round trip accurately when converted back to the original illuminant by the inverse chromatic adaptation transform. Although negative values are not permitted in the ICC.1 specification, in practice many existing profiles use the signed 16-bit PCSXYZ encoding to include such values.

ICC.2

In ICC.2 (iccMAX), XYZNumber and PCSXYZ encodings are as defined in ICC.1:2010. In ICC.2 there is no requirement to clip to the range [0,1], and luminance scaling can be performed to map source luminance to destination luminance (ICC.2:2017 A.1.10).

Recommendations

The following recommendations are made for profiles created according to either ICC.1 or ICC.2, and for CMMs that read and apply such profiles.

- By using an s15Fixed16Number or a float32Number it is possible to encode a negative PCSXYZ value, and profile builders are encouraged to do so where such values arise in order to preserve the accuracy of round trip calculations.
- CMMs are encouraged to accept negative PCSXYZ values as valid and to use them in subsequent computations without clipping where possible.
- On conversion to PCSLAB, negative PCSXYZ values should be clipped on a per-component basis to values in the PCSLAB range, as described in ICC.1:2010 6.4.