Sustainability of Digital Formats: Planning for Library of Congress Collections

Camera Raw Formats (Group Description)

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Format Description Properties

- ID: fdd000241
- Short name: CAM_RAW
- Content categories: still-image
- Format Category: encoding, file-format
- Other facets: unitary, binary, unstructured, sampled
- Last significant FDD update: 2023-04-25
- Draft status: Full

Identification and description

Full name	Camera Raw Formats
Description	Collective description of a group of proprietary formats employed by digital cameras that use a color filter array or Fovean sensor to capture image data. Several examples are listed in File type signifiers below. Raw files contain data captured by the sensors in the array. The data generally receives a very modest amount of processing before being output by the camera. The production of usable images requires additional processing after the data files have been transferred to a computer. Some information about this pre- and post-processing is provided in the Notes below. Raw files permit the creator-editor to interpret the image as the various post-processing steps are applied, tailoring an outcome that suits the subject matter and intended use. This outcome may be contrasted to the production of "finished" images in a camera—typically formatted as TIFF_UNC_EXIF or JPEG_EXIF—for which algorithms built into the camera make the post-processing decisions for the photographer. The proprietary nature of raw formats, however, means that there is a risk that any given format will not be supported for the long term, especially if the manufacturer goes out of business. In at least one instance, data

	elements have been encrypted within a raw format, forcing the use of the manufacturer's own software for post-processing. The proprietary and undocumented nature of raw formats has been the subject of complaint by professionals; one outlet for their ideas is the OpenRAW organization. Meanwhile, formats that normalize camera raw data, like Adobe's DNG_1_1, are intended to mitigate this risk. (DNG may also contain a copy of the raw file as created.)
Production phase	Used for content in the initial state.
Relationship to other formats	
Used by	DNG_1_1, Adobe Digital Negative (DNG), Version 1.1
Used by	DNG_1_6, Adobe Digital Negative (DNG), Version 1.6
Used by	Apple_ProRAW, Apple ProRAW

Local use

LC experience or existing holdings	The Library has many Camera Raw files in its digital collections - over 5.5 TB in 2023 - across numerous collections.
LC preference	The Library of Congress Recommended Formats Statement (RFS) includes Camera Raw Formats as an accepted format for digital photographs and other graphic images in digital form.

Sustainability factors

Disclosure	There is very little disclosure of raw format specifications by manufacturers and this is a contentious issue for some photographers; see, for example, Michael Reichmann and Juergen Specht's The Raw Flaw (2005). Available through Internet Archive.
Documentation	
Adoption	Varied, depends upon the extent of use of specific cameras. Several of the camera brands listed by Adobe are very popular.
Licensing and patents	Not investigated at this time.
Transparency	All raw formats require special software to convert them into usable images. Some raw formats are exported from the camera in a compressed mode.
Self-documentation	Most formats include metadata, both for the interpretation of the data (e.g., about white balance) and to provide the types of additional information specified by EXIF_2_2. Professionals in the field report, however, that raw files do not support the widely used IPTC structure for descriptive metadata, or do so in a non-standard and imperfect way.
External dependencies	None
Technical protection considerations	Not investigated at this time.

Quality and functionality factors

Still Image	
Normal rendering	Provided when files are opened in special software.
Clarity (high image resolution)	High levels of image quality are *latent* in each raw file. The data must be processed to yield an image; the processing can adjust images for a number of desired outcomes.

Color maintenance	See professional photographer Richard Anderson's comments headed *Accurate Rendering* in Notes below. The specification for DNG_1_1 has a brief outline for mapping camera color space to CIE XYZ color space (pp. 47-48).
Support for vector graphics, including graphic effects and typography	Not relevant
Functionality beyond normal rendering	Raw files are highly malleable; see Notes below.

File type signifiers and format identifiers

Tag	Value	Note
Filename extension	cr2	Produced by Canon cameras
Filename extension	crw	Produced by Canon cameras
Magic numbers	Hex: 49 49 1A 00 00 00 48 45 41 50 43 43 44 52 02 00 01 ASCII: II [null] HEAPCCDR	For *crw*; from The File Extension Source; see also The Canon RAW (CRW) File Format
Pronom PUID	fmt/592	See https://www.nationalarchives.gov.uk/pronom/fmt/592 for Canon RAW File Formats with the .cr2 extension.
Pronom PUID	fmt/593	See https://www.nationalarchives.gov.uk/pronom/fmt/593 for Canon RAW File Formats with the .crw extension.
Wikidata Title ID	Q4033406	See https://www.wikidata.org/wiki/Q4033406 for Wikidata entry for Adobe Camera Raw formats. Specific raw file formats and extensions are linked from this Wikidata entry.
Wikidata Title ID	Q26791581	See https://www.wikidata.org/wiki/Q26791581.
Tag	**Value**	**Note**
Filename extension	dcr	Produced by Kodak cameras
Filename extension	kdc	Produced by Kodak cameras
Wikidata Title ID	Q28205367	See https://www.wikidata.org/wiki/Q28205367 for Wikidata entry for Kodak Raw files with the .dcr extension.
Wikidata Title ID	Q28205363	See https://www.wikidata.org/wiki/Q28205363 for Wikidata entry for Kodak Raw files with the .kdc extension.
Tag	**Value**	**Note**
Filename extension	mrw	Produced by Minolta cameras
Internet Media Type	image/x-minolta-mrw	See Cross-desktop interoperability standards Gitlab.
Magic numbers	Hex: 00 4D 52 4D ASCII: .MRM	For *mrw*; from The File Extension Source
Pronom PUID	fmt/669	See https://www.nationalarchives.gov.uk/pronom/fmt/669.
Wikidata Title ID	Q1937473	See https://www.wikidata.org/wiki/Q1937473.

Tag	Value	Note
Filename extension	nef	Produced by Nikon cameras
Internet Media Type	image/x-nikon-nef	See https://www.wikidata.org/wiki/Q3341814.
Pronom PUID	fmt/202	See https://www.nationalarchives.gov.uk/pronom/fmt/202.
Wikidata Title ID	Q3341814	See https://www.wikidata.org/wiki/Q3341814.
Tag	**Value**	**Note**
Filename extension	orf	Produced by Olympus cameras
Internet Media Type	image/x-olympus-orf	See libopenraw documentation.
Magic numbers	See note.	According to Exifprobe documentation, "Olympus has taken the unusual step of marking their formats with unique 'magic numbers' in the header (a different magic number for each flavor). . . . One of the formats (magic=0x5352='RS') contains primary image data in 'packed' 12 bit CFA format. The other (magic=0x4f52='RO') provides 12 bit 'unpacked' (16 bits per sample) CFA data."
Pronom PUID	fmt/668	See https://www.nationalarchives.gov.uk/pronom/fmt/668.
Wikidata Title ID	Q7072922	See https://www.wikidata.org/wiki/Q7072922.
Tag	**Value**	**Note**
Filename extension	pef	Produced by Pentax cameras
Internet Media Type	image/x-pentax-pef	See libopenraw documentation.
Pronom PUID	fmt/1781	See https://www.nationalarchives.gov.uk/PRONOM/fmt/1781.
Wikidata Title ID	Q3964876	See https://www.wikidata.org/wiki/Q3964876.
Tag	**Value**	**Note**
Filename extension	raf	Produced by Fuji cameras
Pronom PUID	fmt/642	See https://www.nationalarchives.gov.uk/PRONOM/fmt/642.
Tag	**Value**	**Note**
Filename extension	srf	Sony Raw Image. Produced by Sony cameras
Filename extension	arw	Sony Alpha Raw. Produced by Sony cameras
Internet Media Type	image/x-sony-srf	Not registered with IANA but listed in https://www.wikidata.org/wiki/Q112796519 for SRF (Sony Raw Image).
Pronom PUID	See note.	No PRONOM entry for SRF as of June 2023.
Pronom PUID	fmt/191	See http://www.nationalarchives.gov.uk/PRONOM/fmt/191 for the ARW format
Wikidata Title ID	Q112796519	See https://www.wikidata.org/wiki/Q112796519 for SRF.
Wikidata Title ID	Q28205439	See https://www.wikidata.org/wiki/Q28205439 for ARW.
Tag	**Value**	**Note**
Filename extension	x3f	Produced by Sigma cameras

Magic numbers	Hex: 46 4F 56 62 ASCII: FOVb	For *x3f*; from The File Extension Source
Pronom PUID	fmt/661	See https://www.nationalarchives.gov.uk/pronom/fmt/661.
Wikidata Title ID	Q28205445	See https://www.wikidata.org/wiki/Q28205445.
Tag	**Value**	**Note**
Filename extension	iiq	Phase One RAW Image. See https://fileinfo.com/extension/iiq
Filename extension	cap	Phase One Raw Image or Capture One Raw Image. See https://www.nationalarchives.gov.uk/pronom/fmt/1060
Filename extension	capture	Phase One Raw Image or Capture One Raw Image. See https://www.nationalarchives.gov.uk/pronom/fmt/1060
Pronom PUID	See note.	No PRONOM PUID for .iiq as of June 2023.
Pronom PUID	fmt/1060	See https://www.nationalarchives.gov.uk/pronom/fmt/1060 for both .cap and .capture
Wikidata Title ID	See note.	No Wikidata entry for .iiq as of June 2023.
Wikidata Title ID	Q50604600	See https://www.wikidata.org/wiki/Q50604600 for both .cap and .capture.

Notes

General	**Regarding processing of raw files in the camera prior to export:** The *Wikipedia* article "Raw Image Format" (as of August 17, 2006) reports, "In general, this processing is limited to algorithms that require direct access to the camera's hardware. This includes 'long exposure noise reduction' (aka 'dark frame subtraction') and the mapping out of 'hot' (too bright) or 'dead' (too dim) pixels. It also often includes rudimentary noise reduction." For a discussion of dead pixels, see https://web.archive.org/web/20070513082749/http://www.cs.wisc.edu/~jduffy/699/. **Regarding post-processing:** Most digital camera color filter arrays employ the Bayer pattern (an array with twice the number of green elements than red or blue, to produce sufficient green information to satisfy the needs of human perception). The conversion of this data to the familiar red, blue, and green channels of an RGB image is called *demosaicing*. Bruce Fraser's excellent white paper "Understanding Digital Raw Capture" names the other post-processing actions typically entailed in the conversion of a raw file: • White balance • Colorimetric interpretation • Gamma correction • Noise reduction, anti-aliasing, and sharpening It is worth noting that the Fovean sensor used in Sigma, Polaroid, and HanVision cameras employs a structure that is drastically different from the Bayer array and produces raw images comprised of RGB data. Fovean raw files from Sigma cameras can be processed using Adobe software. **Regarding accurate rendering:** From a paper by the professional photographer Richard Anderson for a 2006 symposium at the I3A (International Imaging Industry Association, apparently disbanded as of October 2013): "In color management theory, completely accurate rendering from scene through camera to computer to finished print requires profiling of all devices. There is some debate as to whether cameras can and should be profiled, and how those profiles

	should be used by a RAW processing software. I use the solution provided by the Adobe Camera RAW calibrate tab, where a MacBeth 24 color checker can be photographed, and a script can be run that essentially creates a camera profile unique to each camera body. Others prefer treating the camera as essentially a scanner, where they shoot a color target, measure it and create a camera profile. Whether this profile works under all lighting conditions, or just the specific condition under which the target was shot is the subject of some debate. There is the issue of how the profile should be applied, before or after rendering for instance. Also, not all software has the ability to apply profiles in the rendering process."
History	

Format specifications

- Proprietary RAW formats evolve as camera manufacturers bring out new models; they are not usually openly documented. Some specifications or approximations to specifications can be found under Useful References, below:

Useful references

URLs

- General References
  - Understanding Digital Raw Capture (https://www.adobe.com/digitalimag/pdfs/understanding_digitalrawcapture.pdf). By Bruce Fraser
  - Exifprobe documentation: Supported file formats. (https://web.archive.org/web/20080303102012/http://www.virtual-cafe.com/~dhh/tools.d/exifprobe.d/exifprobe_output002.html). Information about various raw formats is included. As of March 2012, the page could not be found; link here is to Internet Archive.
  - Wikipedia on Raw Image Format (https://en.wikipedia.org/wiki/Raw_image_format).
  - OpenRAW organization (https://www.openraw.org/).
  - Documentation of the Canon CIFF wrapper format (http://xyrion.org/ciff/CIFFspecV1R04.pdf). The basis for the Canon crw format. (A comment from a reader indicated that the Canon cr2 format is TIFF-based.)
  - About the crw format (https://exiftool.org/canon_raw.html).
  - X3F Tools (https://www.proxel.se/x3f.html).
  - X3F SIGMA RAW documentation project (https://web.archive.org/web/20131126184040/http://www.photofo.com/x3f-raw-format/). From photofo.com. Available through Internet Archive.
  - About X3F format (https://web.archive.org/web/20070317042320/http://www.x3f.info/technotes/FileDocs/X3F_Format.pdf). Via Internet Archive Wayback Machine
  - The Raw Flaw (https://web.archive.org/web/20061023105559/https://www.luminous-landscape.com/TheRawFlaw.pdf). About issues related to proprietary raw formats
  - Lists camera brands supported by the Adobe Camera Raw plugin for Photoshop. (https://helpx.adobe.com/camera-raw/using/supported-cameras.html).
  - Specification for dng format (https://helpx.adobe.com/photoshop/digital-negative.html).
  - Discussion of dead pixels (https://web.archive.org/web/20070513082749/http://www.cs.wisc.edu/~jduffy/699/).
- Wikidata Entries for Various Camera Raw Formats
  - Wikidata entry for Q4033406 (https://www.wikidata.org/wiki/Q4033406). Information in Wikidata about Adobe Camera RAW formats.
  - Wikidata entry for Q26791581 (https://www.wikidata.org/wiki/Q26791581). Information in Wikidata about Canon Original RAW format.
  - Wikidata entry for Q3341814 (https://www.wikidata.org/wiki/Q3341814). Information in Wikidata about Nikon Electronic RAW format.
  - Wikidata entry for Q112796519 (https://www.wikidata.org/wiki/Q112796519). Information in Wikidata about Sony RAW Image format.

- Wikidata entry for Q1937473 (https://www.wikidata.org/wiki/Q1937473). Information in Wikidata about Minolta RAW format.
- Wikidata entry for Q3964876 (https://www.wikidata.org/wiki/Q3964876). Information in Wikidata about Pentax Electronic RAW format.
- Wikidata entry for Q7072922 (https://www.wikidata.org/wiki/Q7072922). Information in Wikidata about Olympus RAW format.
- Wikidata entry for Q28205445 (https://www.wikidata.org/wiki/Q28205445). Information in Wikidata about X3F Sigma RAW format.

- PRONOM Entries for Various Camera Raw Formats
  - PRONOM entry for fmt/593 (https://www.nationalarchives.gov.uk/pronom/fmt/593). Information in PRONOM for Canon RAW Version 2.0 files with .crw extensions.
  - PRONOM entry for fmt/592 (https://www.nationalarchives.gov.uk/pronom/fmt/592). Information in PRONOM for Canon RAW Version 1.0 files with .cr2 extensions.
  - PRONOM entry for fmt/669 (https://www.nationalarchives.gov.uk/pronom/fmt/669). Information in PRONOM for Minolta RAW format.
  - PRONOM entry for fmt/202 (https://www.nationalarchives.gov.uk/pronom/fmt/202). Information in PRONOM for Nikon Digital SLR Camera Raw Image File Format.
  - PRONOM entry for fmt/668 (https://www.nationalarchives.gov.uk/pronom/fmt/668). Information in PRONOM for Olympus RAW format.
  - PRONOM entry for fmt/1781 (https://www.nationalarchives.gov.uk/PRONOM/fmt/1781). Information in PRONOM for Pentax PEF Image File Format.
  - PRONOM entry for fmt/642 (https://www.nationalarchives.gov.uk/PRONOM/fmt/642). Information in PRONOM for Fujifilm RAW Image Format.
  - PRONOM entry for fmt/661 (https://www.nationalarchives.gov.uk/pronom/fmt/661). Information in PRONOM for Sigma RAW Image Format.

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