

Audiovisuelle Dateiformate

Reto Kromer • AV Preservation by reto.ch

Weiterführender Memoriav-Workshop

**Qualitätskontrolle
von audiovisuellen Dateien**

Lichtspiel, Bern, 26. Januar 2023

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Inhalt

- digitaler Ton und digitales Bild
- Container, Codec, Rohdaten
- verschiedene Formate für unterschiedliche Zwecke
- audiovisuelle Dateiumwandlungen

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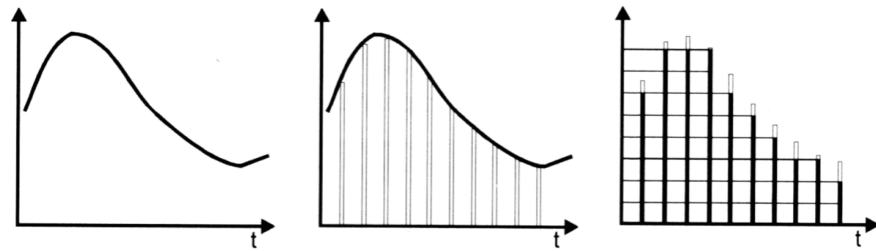
Digitaler Ton

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Digitaler Ton

- Abtastung
- Quantisierung
- Kompression

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Digitalisierung = Abtastung + Quantisierung

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Abtastung

- 44.1 kHz
- 48 kHz
- 96 kHz
- 192 kHz
- 500 kHz

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Quantisierung

- 16 bit ($2^{16} = 65\,536$)
- 24 bit ($2^{24} = 16\,777\,216$)
- 32 bit ($2^{32} = 4\,294\,967\,296$)

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Digitales Bild

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Digitales Bild

- Auflösung
- Quantisierungsauflösung
- linear, Potenzfunktion, logarithmisch
- Farbraum
- Kompression und Farbunterabtastung
- Normlicht

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Auflösung

- SD 480i / SD 576i
- HD 720p / HD 1080i
- 2K / HD 1080p
- 4K / UHD-1
- 8K / UHD-2

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Quantisierungsauflösung

- 8 bit ($2^8 = 256$)
- 10 bit ($2^{10} = 1\,024$)
- 12 bit ($2^{12} = 4\,096$)
- 16 bit ($2^{16} = 65\,536$)
- 24 bit ($2^{24} = 16\,777\,216$)

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Linear, Potenz, Logarithmus

«Mittelgrau»

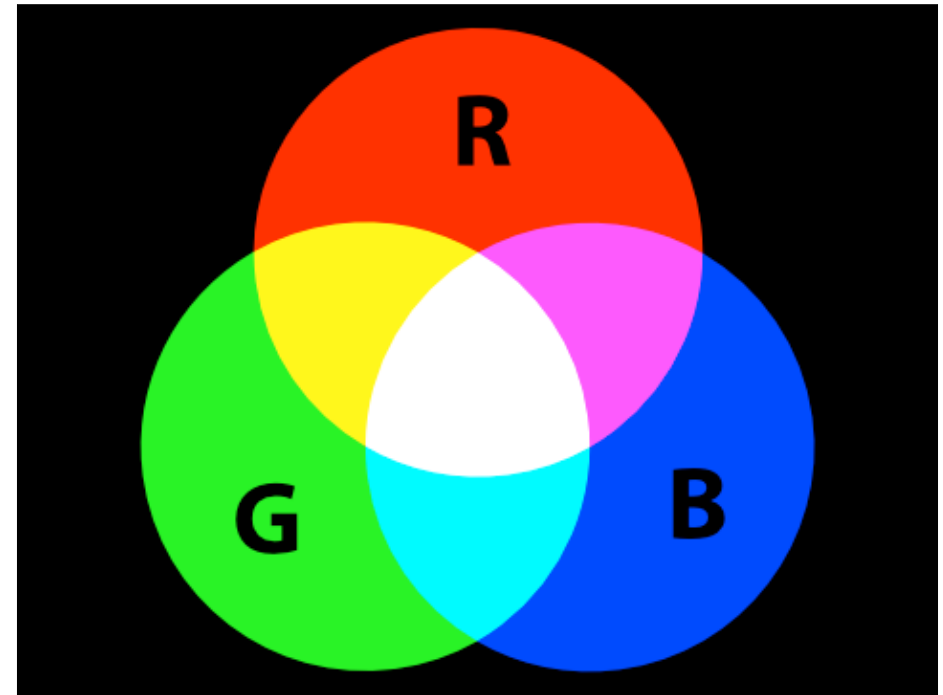
- lineare Funktion: etwa 18 %
- Potenzfunktion: 50 %
- Logarithmusfunktion: 50 %

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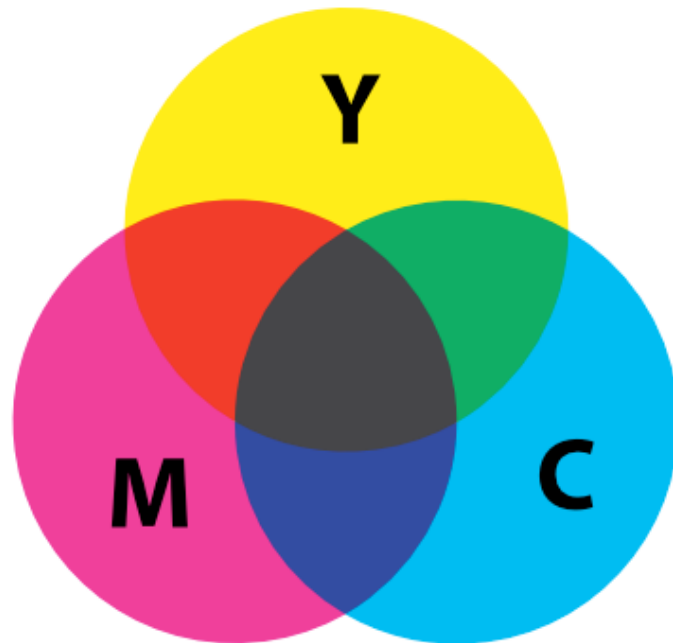
Farbraum

- XYZ, $L^*a^*b^*$
- RGB / $R'G'B'$ / CMY / $C'M'Y'$
- $Y'IQ$ / $Y'UV$ / $Y'D_BD_R$
- $Y'C_BC_R$ / $Y'CoC_G$
- $Y'P_BP_R$

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$$\begin{pmatrix} R' \\ G' \\ B' \end{pmatrix} = \begin{pmatrix} 1 & 0 & 1.396523 \\ 1 & -0.342793 & -0.711348 \\ 1 & 1.765078 & 0 \end{pmatrix} \begin{pmatrix} Y' \\ C_B \\ C_R \end{pmatrix}$$

$$\begin{pmatrix} Y' \\ C_B \\ C_R \end{pmatrix} = \begin{pmatrix} 0.299 & 0.587 & 0.114 \\ -0.168074 & -0.329965 & 0.498039 \\ 0.498039 & -0.417947 & -0.080992 \end{pmatrix} \begin{pmatrix} R' \\ G' \\ B' \end{pmatrix}$$

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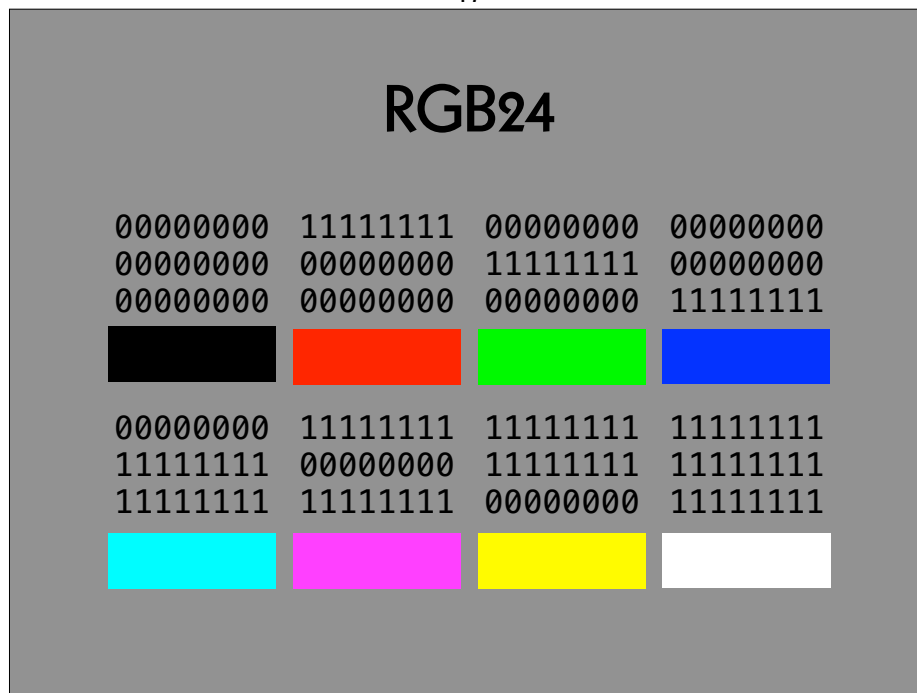
$$\begin{pmatrix} R' \\ G' \\ B' \end{pmatrix} = \begin{pmatrix} 1 & 1 & -1 \\ 1 & 0 & 1 \\ 1 & -1 & -1 \end{pmatrix} \begin{pmatrix} Y' \\ C_O \\ C_G \end{pmatrix}$$

$$\begin{pmatrix} Y' \\ C_O \\ C_G \end{pmatrix} = \begin{pmatrix} \frac{1}{4} & \frac{1}{2} & \frac{1}{4} \\ \frac{1}{2} & 0 & -\frac{1}{2} \\ -\frac{1}{4} & \frac{1}{2} & -\frac{1}{4} \end{pmatrix} \begin{pmatrix} R' \\ G' \\ B' \end{pmatrix}$$

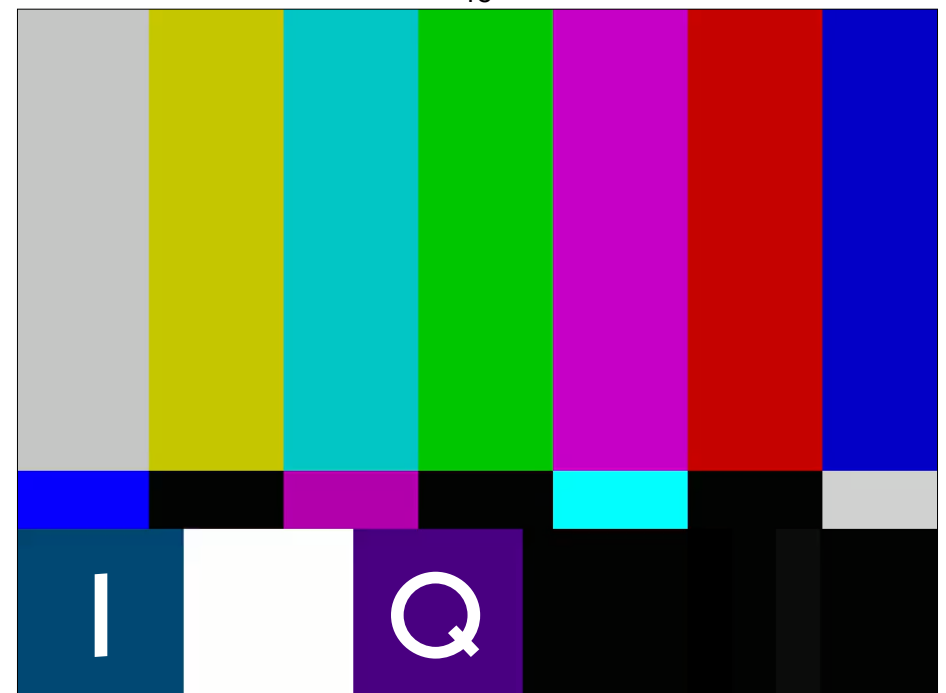
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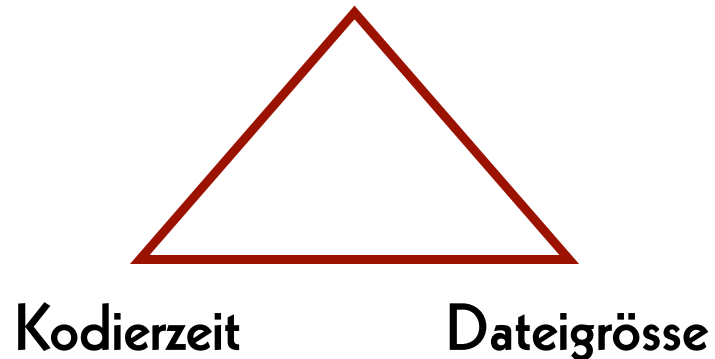


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Bildqualität



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Kompression

- nicht komprimiert
- verlustfrei komprimiert
- verlustbehaftet komprimiert
- Farbunterabtastung
- komprimiert generiert

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Nicht komprimiert

- + Daten sind leichter zu bearbeiten
- + Software läuft schneller
- grössere Dateien
- langsames Schreiben, Übermitteln und Lesen der Dateien

Beispiele: TIFF, DPX, DNG, OpenEXR

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Verlustfrei komprimiert

- + kleinere Dateien
- + schnelleres Schreiben, Übermitteln und Lesen der Dateien
- Daten sind komplexer zu bearbeiten
- Software läuft langsamer

Beispiele: JPEG 2000, FFV1

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Verlustbehaftet komprimiert

- optimiert für Aufnahme und/oder Postproduktion
- optimiert für Zugang und Distribution

Beispiele (Mezzanine): ProRes 422, ProRes 4444; DNxHD, DNxHR

Beispiele (Zugang): H.264 (AVC), H.265 (HEVC), H.266 (VVC); AV1

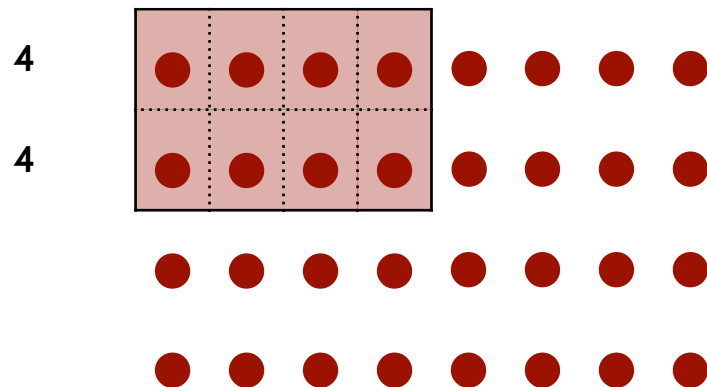
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Farbunterabtastung

- 4:4:4
- 4:2:2
- 4:2:0 / 4:1:1

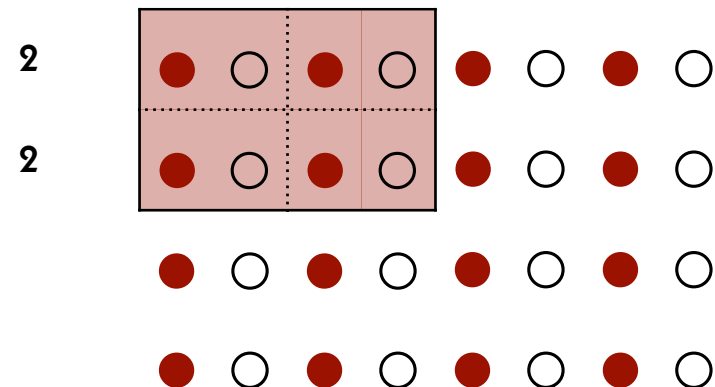
26

4:4:4



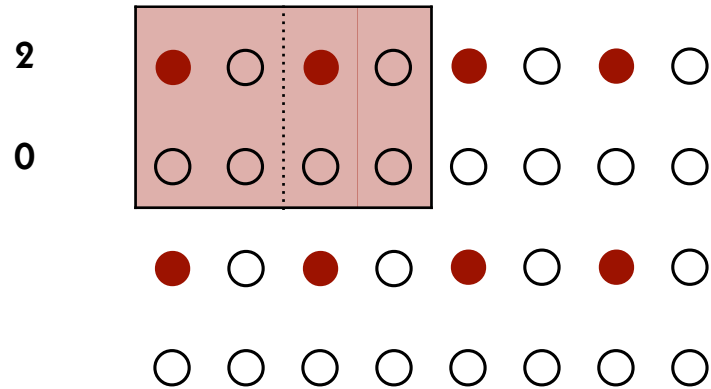
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4:2:2



28

4:2:0



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Komprimiert generiert

- sowohl für Aufnahme als auch für Postproduktion optimiert

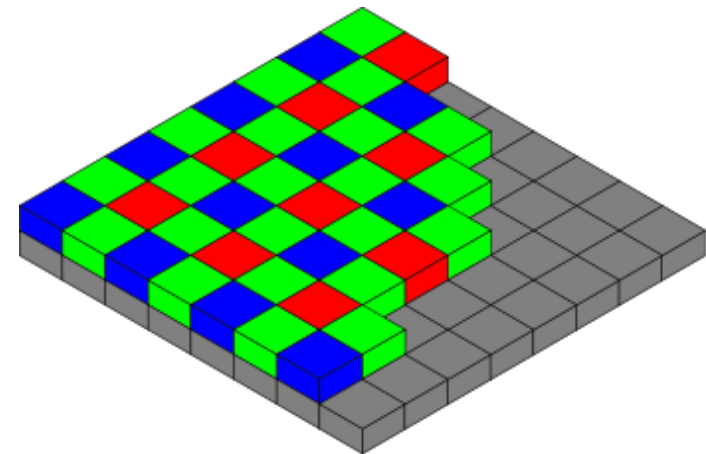
Beispiele: CineForm RAW, ProRes RAW, Blackmagic RAW

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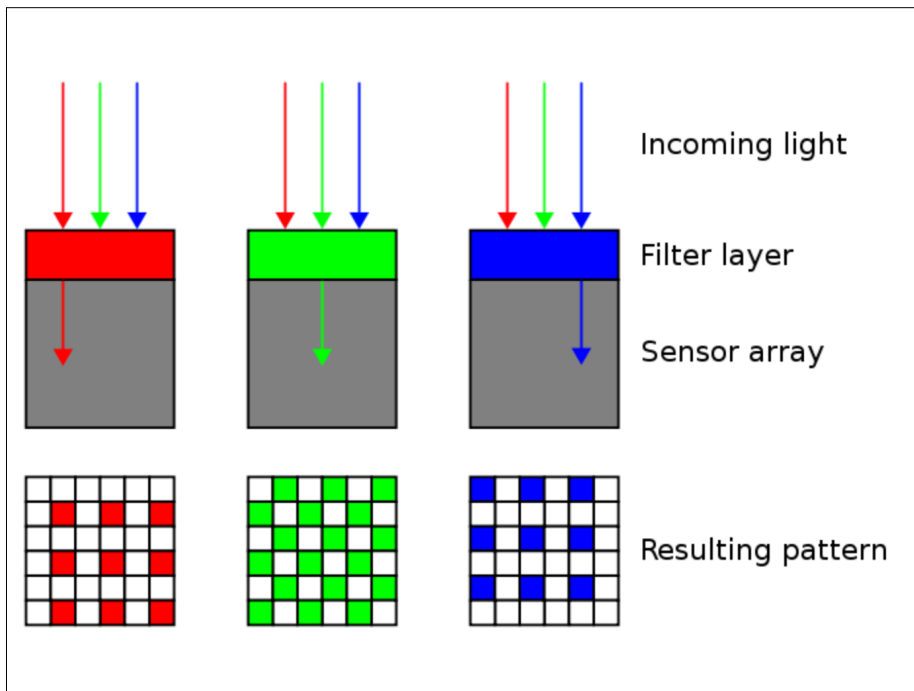
Unbequeme Wahrheiten

- Sensoren sind farbenblind
- Bayer-Sensoren erzeugen kein vollständiges RGB-Bild

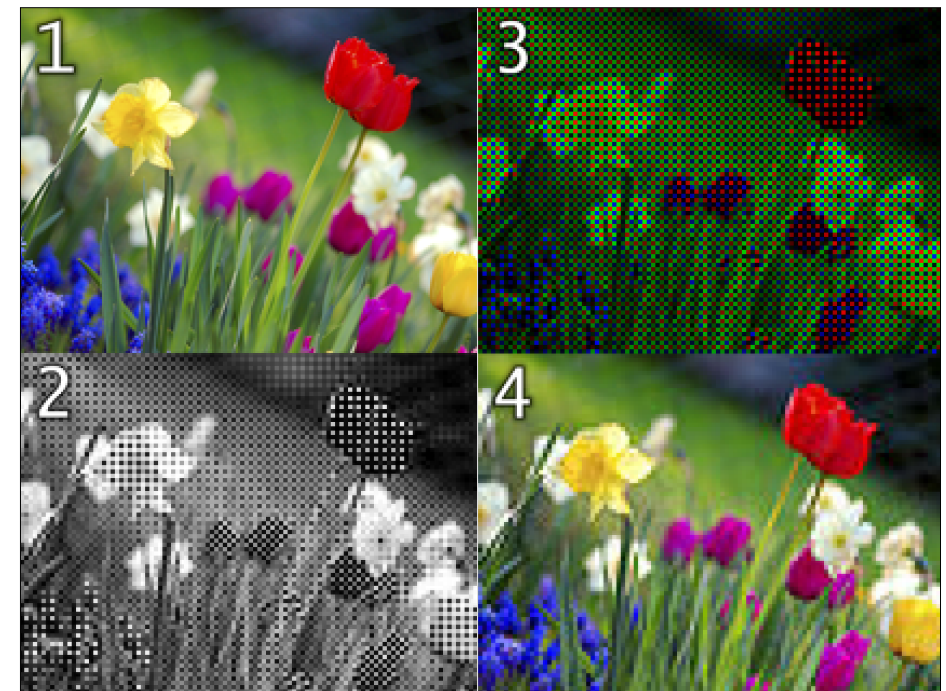
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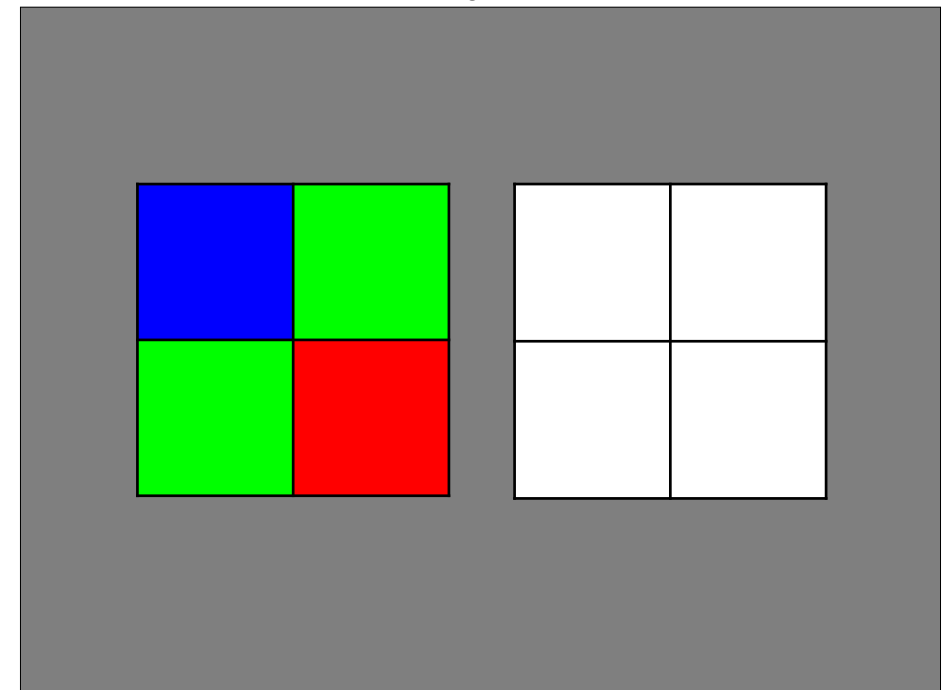
34

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110101 010101	010100 001011		
101010 011010	101001 010101		

37

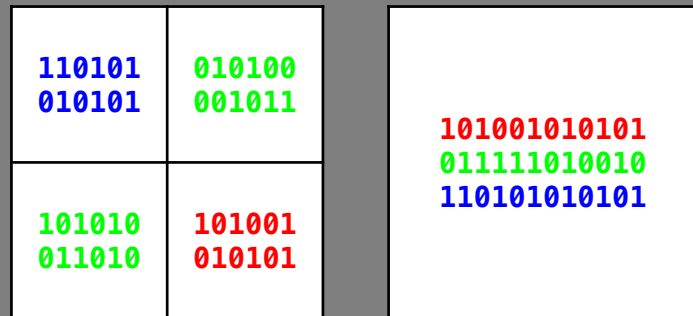
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000000000000 101010011010 000000000000	101001010101 000000000000 000000000000	011000111001 101010011010 100001010111	101001010101 010011011110 010100010111

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0 0 B	0 G ₁ 0	R G B	R G ₁ B
0 G ₂ 0	R 0 0	R G ₂ B	R G B

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Zwei Möglichkeiten, Bayer-Daten zu speichern

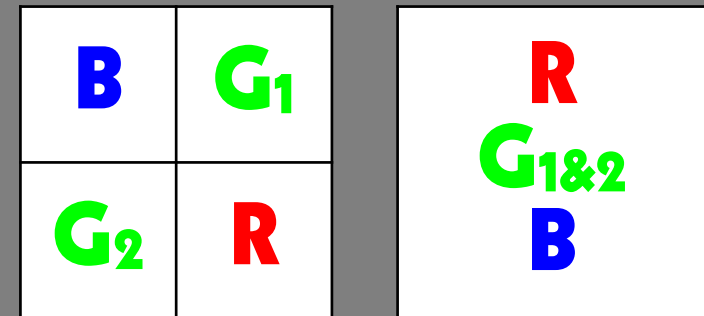
digitales Aufblasen auf **RGB**

- die generierten Daten werden verdreifacht
- die Datei hat die volle Sensorauflösung
- nur die Hälfte der Daten ist real

digitale Reduktion auf **RGB**

- drei Viertel der generierten Daten sind gespeichert
- die Datei hat die halbe Sensorauflösung
- die gesamten Daten sind real

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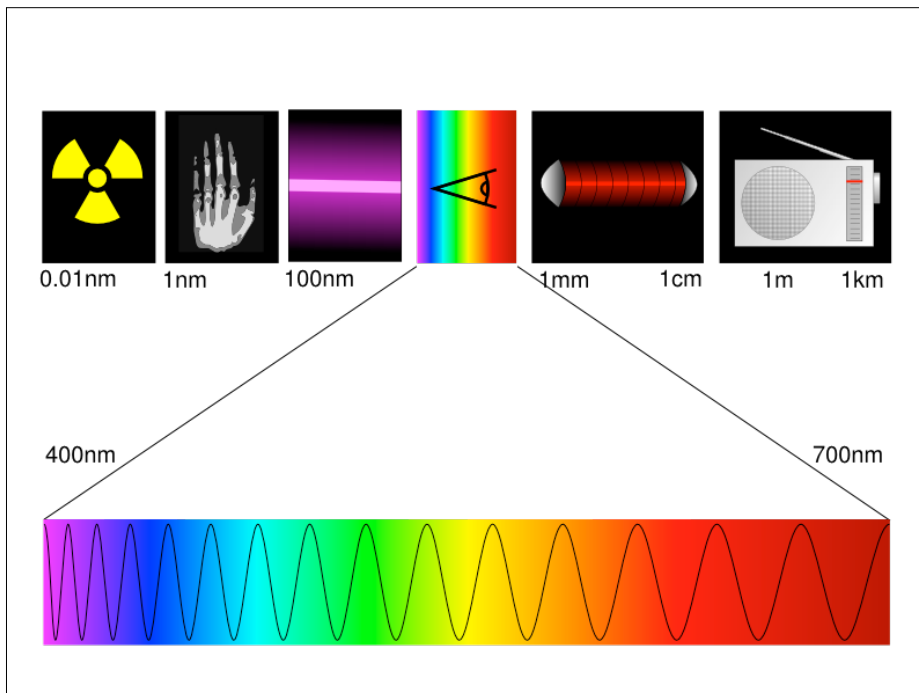


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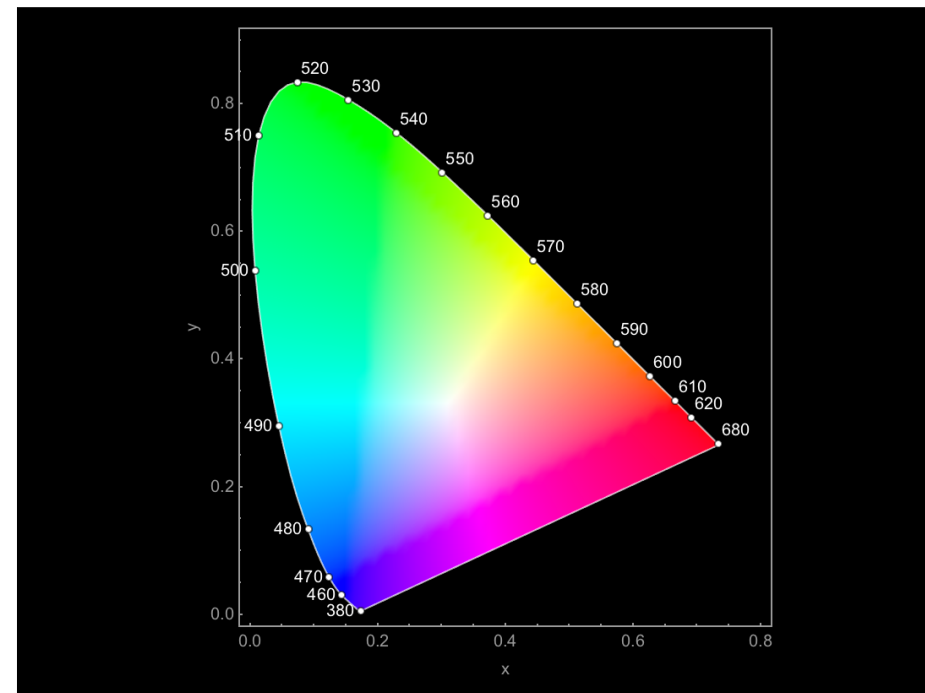
Normlicht

- D50
- D55
- D65
- D75

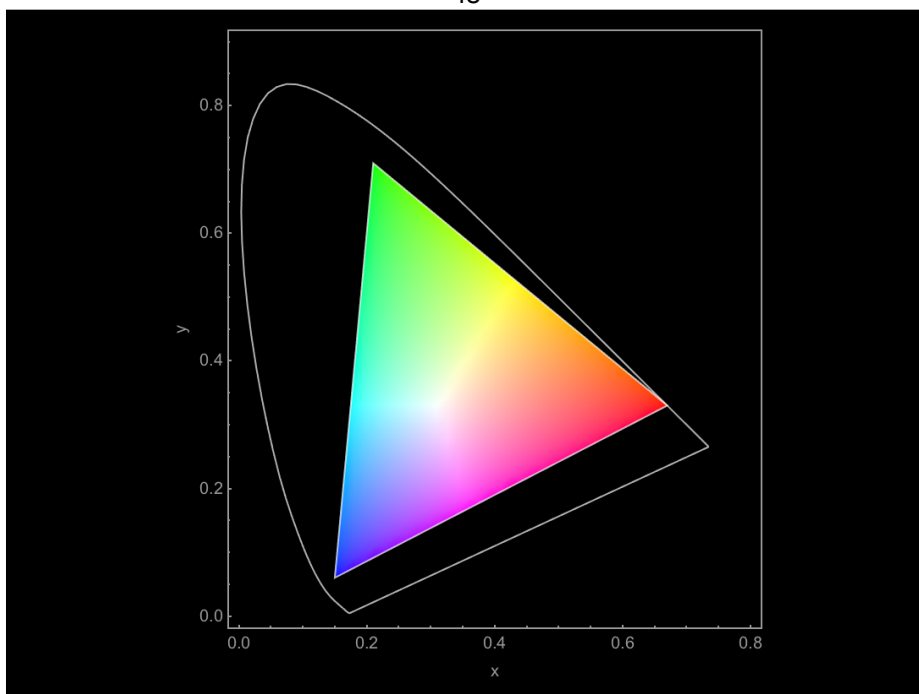
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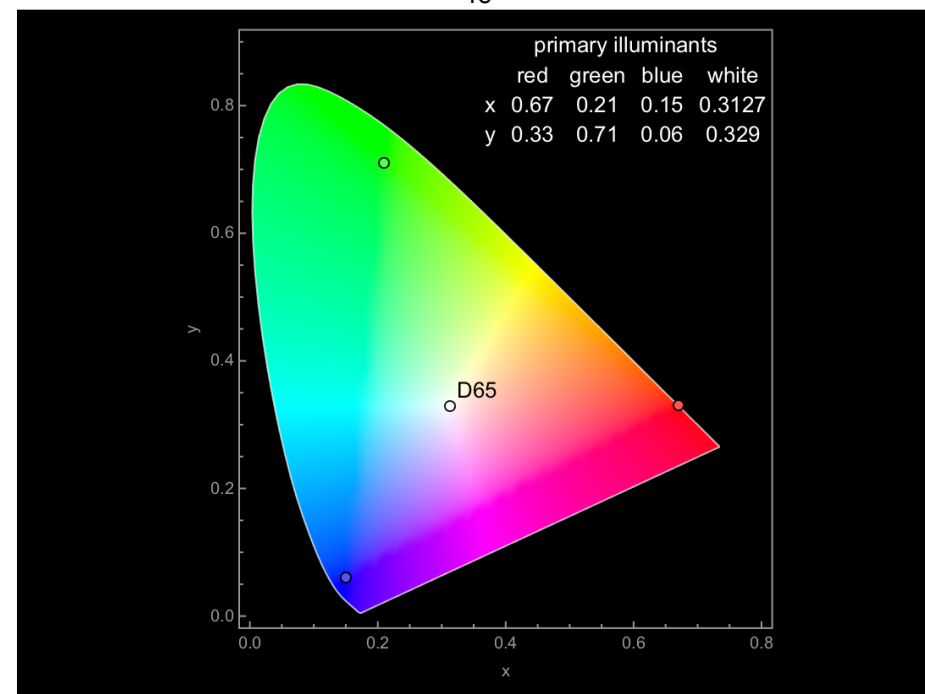
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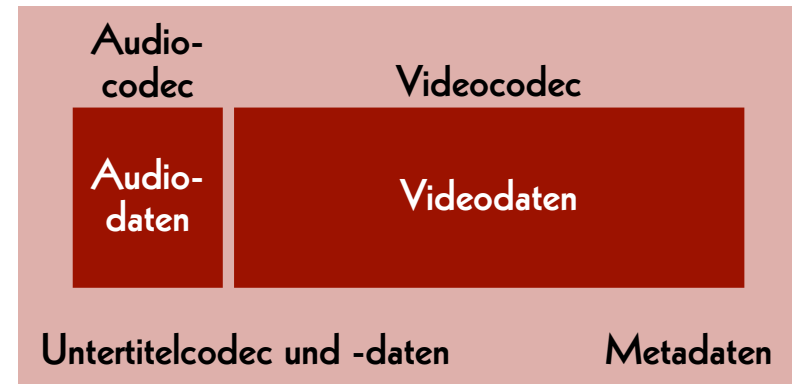
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Dateiaufbau

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Dateiaufbau

Container (Wrapper)



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Container für Datenfluss

- MP4
- QuickTime (.mov)
- AVI
- Flash
- MXF
- Matroska (.mkv)

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Container für Einzelbilder

- Ordner
- TAR
- ZIP
- MXF
- Matroska (.mkv)
- CinemaDNG
- Motion JPEG

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Audiocodec

- WAVE
- BWF
- AAC
- MP3
- FLAC

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Videocodec (Master)

Einzelbilder

- TIFF
- DPX
- JPEG 2000
- OpenEXR
- DNG

Datenfluss

- 8 bit raw
- 10 bit raw
- HuffYUV
- FFV1

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Videocodec (Mezzanine)

- ProRes 422, ProRes 4444, ProRes RAW
- DNxHD, DNxHR
- CineForm RAW
- Blackmagic RAW

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Videocodec (Zugang)

- H.264 (AVC)
- H.265 (HEVC)
- H.266 (VVC)
- AV1

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Data is anything
but «raw».

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Audiodaten

- pcm_s16le
- pcm_s24le
- pcm_s32le

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Videodaten

- | | |
|------------------|---------------|
| • rgb48le | • yuv444p16le |
| • rgb24 | • yuv422p10le |
| • rgb72le | • uyvy422 |
| | • yuv420p |
| • bayer_bggr16le | • yuv444p24le |
| • bayer_bggr24le | |

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Dateiformate

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Grundsätze

- **Ein Archiv muss seine Dateien pflegen und handhaben können.**
- Open Source
- einfache Bedienung und ausführliche Dokumentation
- weite Verbreitung

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Formate für verschiedene Anwendungszwecke

Archivmasterformat

→ zur Erhaltung und Archivierung

Mezzanine-Format

→ zur Bearbeitung und Postproduktion

Distributionsformat

→ zur Verbreitung und Zugänglichmachung

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Elena Rossi-Snook:

**Archiving without access
isn't preservation,
it's hoarding.**

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Archivmaster (heute)

«Film» (Einzelbilder)

- Ordner, TIFF, 2K oder 4K, RGB, 16 bit
- MXF, DPX, 2K oder 4K, R'G'B', 10 bit

«Video» (Datenfluss)

- AVI, «raw», HD, Y'C_BC_R 4:2:2, 10 bit
- Matroska, FFV1, HD, Y'C_BC_R 4:2:2, 10 bit

Ton

- BWF, 96 kHz, 24 bit
- FLAC, 96 kHz, 24 bit

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Mezzanine (heute)

Bild

- ProRes 4444, 2K
- DNxHR, 2K
- ProRes 422 HQ, HD
- DNxHD 175x, HD

Ton

- BWF, 48 kHz, 24 bit
- WAVE, 48 kHz, 24 bit

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Archivmaster und Mezzanine

«Film» (Einzelbilder)

- Matroska, FFV1, 4K oder 2K, RGB, 16 bit

«Video» (Datenfluss)

- Matroska, FFV1, «HD», $Y'CbCr$ 4:2:2, 10 bit

Ton

- Matroska, FLAC, 192 kHz, 24 bit

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Zugang (heute)

MP4

Bild

- H.264, SD, $Y'CbCr$ 4:2:0, 8 bit, lossy
- H.264, «HD», $Y'CbCr$ 4:2:0, 8 bit, lossy

Ton

- AAC, 44.1 kHz, 16 bit
- AAC, 48 kHz, 16 bit

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Zugang

MP4

Bild

- H.265, «HD», $Y'CbCr$ 4:2:0, 8 bit, lossy
- H.266, «HD», $Y'CbCr$ 4:2:0, 8 bit, lossy
- AV1, «HD», $Y'CbCr$ 4:2:0, 8 bit, lossy

Ton

- AAC, 96 kHz, 16 bit

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Bibliografie

Reto Kromer: **Matroska and FFV1: One File Format for Film and Video Archiving?**, in «Journal of Film Preservation», Nr. 96 (April 2017), FIAF, Brüssel, Belgien, S. 41–45

→ https://retokromer.ch/publications/JFP_96.html

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Container:

- Ordner
- TAR
- ZIP
- MXF
- Matroska

Codec:

- TIFF
- DPX
- JPEG 2000
- FFV1
- OpenEXR
- CineForm RAW
- ProRes RAW
- Blackmagic RAW

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Vor- und Nachteile

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	Vorteile	Nachteile
TIFF DPX OpenEXR	Daten leichter zu bearbeiten	grössere Dateien
JPEG 2000 FFV1	kleinere Dateien	Daten komplexer zu bearbeiten

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MXF-Container (.mxf)

Videocodec

- DPX
- JPEG 2000
- DNxHD, DNxHR
- ProRes 422, ProRes 4444

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MXF / DPX

MXF

→ SMPTE RDD 48:2018

DPX

→ SMPTE ST 268M:2015

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SMPTE RDD 48:2018

SMPTE REGISTERED DISCLOSURE DOCUMENT



MXF Archive and Preservation Format Registered Disclosure Document

Page 1 of 113

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Every attempt has been made to ensure that the information contained in this document is accurate. Errors in this document should be reported to the proponent identified below, with a copy to eng@smpte.org.

All other inquiries in respect of this document, including inquiries as to intellectual property requirements that may be attached to use of the disclosed technology, should be addressed to the proponent identified below.

Proponent Contact Information:

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Library of Congress
101 Independence Ave, S.E.
Washington, DC 20540-1300

Email: kmur@loc.gov

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MXF / JPEG 2000

MXF

→ SMPTE RDD 48:2018

JPEG 2000

→ ISO/IEC 15444-1:2019

→ usw.

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MXF / DNx

MXF

→ SMPTE RDD 48:2018

DNxHD, DNxHR

→ nicht veröffentlicht

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MXF / ProRes

MXF

→ SMPTE RDD 48:2018

ProRes 422, ProRes 4444

→ SMPTE RDD 36:2015

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SMPTE REGISTERED DISCLOSURE DOCUMENT

SMPTE RDD 36:2015

Apple ProRes Bitstream Syntax and Decoding Process



Page 1 of 39 pages

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Proponent contact information:

ProRes Program Office
Apple Inc.
1 Infinite Loop, MS: 77-2YAK
Cupertino, CA 95014
USA

Email: ProRes@apple.com

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Matroska-Container (.mkv)

Videocodec

- FFV1
- ProRes 422, ProRes 4444

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Matroska / FFV1

Matroska (.mkv)

→ IETF Internet Draft

FFV1

→ IETF RFC 9043

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Matroska / ProRes

Matroska (.mkv)

→ IETF Internet Draft

ProRes 422, ProRes 4444

→ SMPTE RDD 36:2015

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Stream: Internet Engineering Task Force (IETF)
RFC: 9043
Category: Informational
Published: August 2021
ISSN: 2070-1721
Authors: M. Niedermayer D. Rice J. Martinez

RFC 9043

FFV1 Video Coding Format Versions 0, 1, and 3

Abstract

This document defines FFV1, a lossless, intra-frame video encoding format. FFV1 is designed to efficiently compress video data in a variety of pixel formats. Compared to uncompressed video, FFV1 offers storage compression, frame fixity, and self-description, which makes FFV1 useful as a preservation or intermediate video format.

Status of This Memo

This document is not an Internet Standards Track specification; it is published for informational purposes.

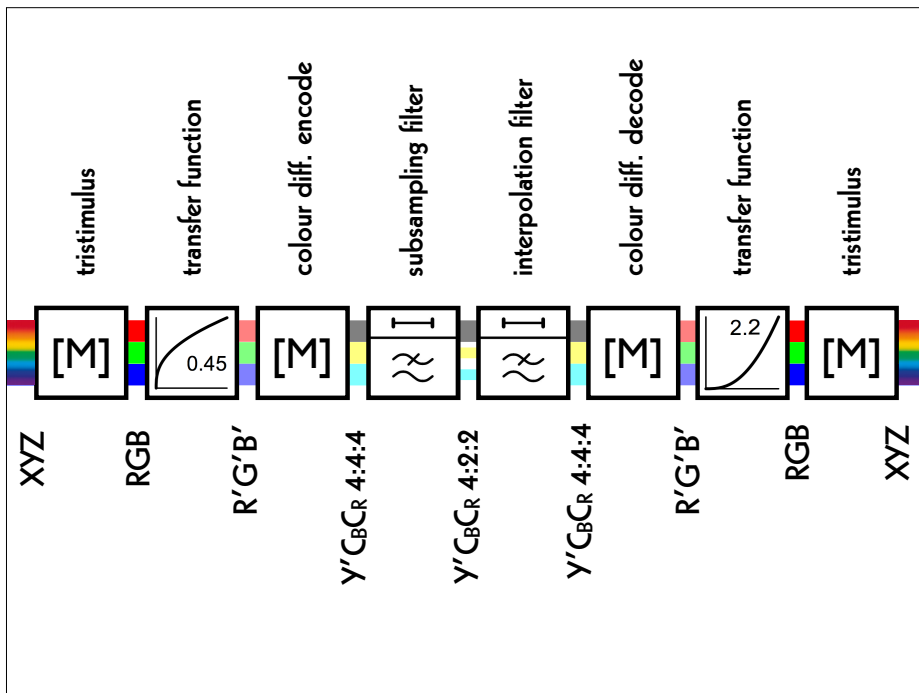
This document is a product of the Internet Engineering Task Force (IETF). It represents the consensus of the IETF community. It has received public review and has been approved for publication by the Internet Engineering Steering Group (IESG). Not all documents approved by the IESG are candidates for any level of Internet Standard; see Section 2 of RFC 7841.

Information about the current status of this document, any errata, and how to provide feedback on it may be obtained at <https://www.rfc-editor.org/info/rfc9043>.

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Umwandlungen

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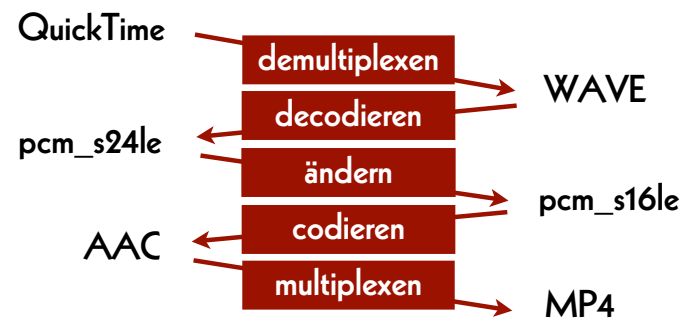
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Dateiumwandlungen



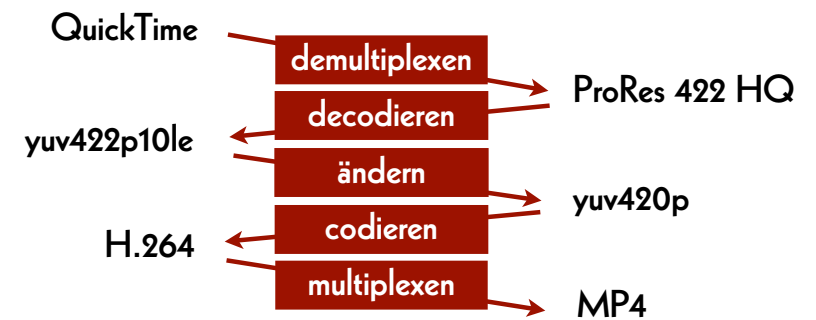
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Beispiel: Ton



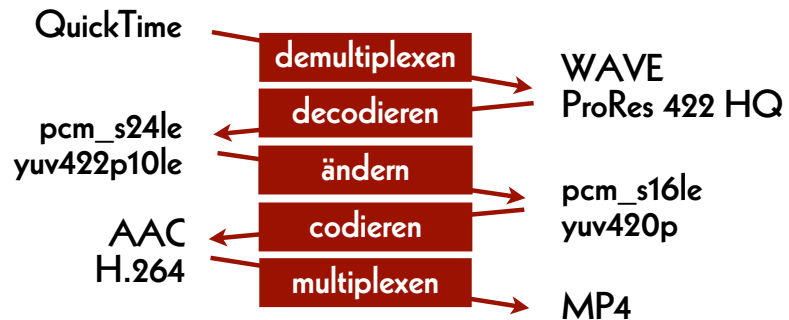
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Beispiel: Bild



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Beispiel: Bild und Ton



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Danksagung (1)

- Eidgenössische Technische Hochschule
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- Kinemathek Lichtspiel, Bern
- Charles Poynton
- Dave Rice und Misty De Meo
- Agathe Jarczyk und David Pfluger

90

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- Claudio Weidmann
- Jim Lindner
- Carl Eugen Hoyos
- Peter Bubestinger-Steindl
- Jérôme Martinez
- Michael Niedermayer

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