UK Film Council
Digital Screen Network

DSN Content Specification

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Contents

Introduction

This is a specification for the format in which content may be submitted for ingestion to the Digital Screen Network (DSN).

To ensure consistent performance at each of the participating cinemas, content will be distributed throughout the DSN in a predetermined format. Content will be converted to this format during the process of ingestion. It is intended that the ingestion process should be, largely, mechanistic with little or no opportunity of adjustment for individual content. To support this objective, it is necessary to limit the range of formats in which content may be submitted for ingestion. This specification defines the formats for which the ingestion process has been designed.

Each aspect of the specification is explained with both acceptable and preferred options. Additional sections address recommended practices for some areas of the mastering process. The specification is shown in abbreviated form as an appendix.

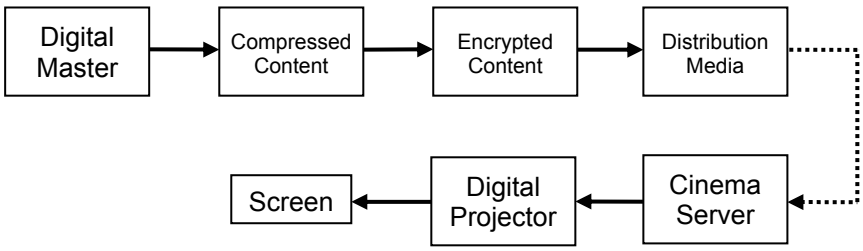
Overview of the Digital Screen Network

The Digital Screen Network has been designed for distribution and exhibition of content that was originally captured on film – or the electronic equivalent. The projectors used employ DLP Cinema technology with a resolution of 2048 x 1080 pixels. The image is projected as progressive frames at a rate of 23.98, 24 or 25 fps with a colour gamut similar to that of a 35mm film print. The projection system is designed to achieve a sequential contrast ratio of 2000:1.

DSN Distribution Model

Content is distributed to DSN cinemas in an encrypted, compressed form. The content is ingested from a Digital Master which includes both the image and soundtrack. During ingestion, the content is compressed using Quality Priority Encoding (QPE) by a QuVis Acuity. It is intended that the compression scheme will be changed to M-JPEG 2000 once that standard is ratified. The compressed content is encrypted using the 128-bit AES CBC algorithm before being copied to distribution media for shipment to the relevant cinemas. The type of distribution medium is flexible - removable hard-drives will be used initially. Keys to decrypt the content are distributed separately using 2048-bit RSA encryption.

When it arrives at a cinema, the encrypted content is copied from the distribution media to RAID storage on the DSN server (QuVis CinePlayer) – still in encrypted form. The server will only allow the content to be played when provided with a software key that is valid for the content, the server and the current date and time.



Suitable Content

Content should have originated on film - or have been captured electronically in a progressive form - at a frame-rate of 23.98, 24 or 25 fps.

Film-based content in the form of interlaced video may be suitable if it can be de-interlaced to the original frame-rate with accurate reversal of the pull-down sequence. Material that originated as interlaced video is not normally suitable unless it was shot cinematically avoiding fast subject and camera motion. Cinematically-shot, 50Hz interlaced content may be suitable if it is converted to a 25 fps progressive format. Video-based content at 59.94i or 60i is not currently supported even if converted to 29.98p or 30p.

The Digital Master

Content is submitted for DSN ingestion as a Digital Master. Initially, this can only be in the form of a videotape but it is expected that ingest from data files will be supported at a later stage.

The Digital Master should include all parts of the programme – including any required logos and stings – complete with the conformed soundtrack and should preferably be on a single tape. Where the programme is submitted on multiple tapes, each one must be in an identical format.

Delivery Medium

Currently acceptable tape formats are HDCam-SR, HD-D5, HDCam and Digital Betacam (with restrictions). The recommended format is HDCam-SR.

HDCam should only be employed for content where the reduced resolution can be tolerated. It would be most appropriate for content that had been up-converted from Standard-Definition video.

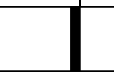
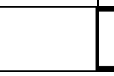
Digital Betacam should only be used for film-based content at 720 x 576 x 50i.

Image Coding

The Digital Screen Network supports both 4:4:4 and 4:2:2 coding through the entire distribution process including projection. 4:4:4 coding is recommended for best possible image reproduction but is currently only possible when the Digital Master is delivered on HDCam-SR tape.

Image Size

Digital Masters on HD videotape should be recorded with a frame size of 1920 x 1080 pixels. Images must be scaled to fill either the height or the width of the frame and be non-anamorphic (square pixels). Aspect ratios other than 1.78 should be symmetrically letter-boxed or pillar-boxed with black bars. The following table shows the recommended active image sizes for the range of supported aspect ratios.

Aspect Ratio	1.33	1.38	1.66	1.75	1.78	1.85	2.35
Horizontal Pixels	1440	1490	1800	1890	1920	1920	1920
Vertical Pixels	1080	1080	1080	1080	1080	1038	817
Framing							

The image size of SD Digital Masters on Digital Betacam tape can only be 720 x 576 pixels. Standard 1.33 (4:3) and 1.78 (16:9 anamorphic) aspect ratios can be accepted.

Frame Rate

HD images must be progressive and at a frame-rate of 23.98, 24 or 25 fps. The recording format may be either true progressive (P) or segmented-progressive (PsF or SF) as appropriate for the delivery medium. SD content can only be accepted at 50i.

Colour Space

The DSN supports both the HD standard Rec.709 and the digital cinema standard P7V2 colour spaces. P7V2 provides a colour gamut and white-point that closely matches that of projected 35mm film so is recommended for the best possible reproduction of film-originated content. The specification for P7V2 is shown below:

Colour	**x (CIE 1931)**	**y (CIE 1931)**
Red	0.6650	0.3120
Green	0.2650	0.6900
Blue	0.1400	0.0700
Cyan	0.1757	0.3371
Magenta	0.3732	0.1777
Yellow	0.4567	0.5220
White	0.3140	0.3510

Rec.709 colour specification is:

Colour	**x (CIE 1931)**	**y (CIE 1931)**
Red	0.6400	0.3300
Green	0.3000	0.6000
Blue	0.1500	0.0600
White	0.3127	0.3290

SD content will be assumed to use standard Rec.601 colour space and will be converted to Rec.709 during ingest.

Display Gamma

During projection, content will be linearized (de-gamma'd) for a fixed value of display gamma that depends on the colour space in which it is projected. Content projected in Rec.709 colour space is assumed to have been mastered for a display gamma of 2.45. The P7V2 colour space assumes a display gamma of 2.60.

It is recommended that content graded for P7V2 is also corrected for a display gamma of 2.60 to achieve the most cinematic reproduction.

Content mastered for a display gamma of 2.45 but projected with a de-gamma of 2.60 will lose detail in dark areas of the image and may have excessive "contrast". Conversely, content mastered for a gamma of 2.60 that is projected with a de-gamma of 2.45 will have an elevated black-level and lack "punch".

Soundtrack

The Digital Master should include the soundtrack accurately conformed to the image. The DSN supports six channels of primary audio in 5.1 format and two optional channels for Audio Description. Where the Digital Master is provided on HDCam or Digital Betacam tape – both of which are limited to four audio tracks – the soundtrack will be constrained to Mono (1.0), Stereo (2.0) or LCR (3.0) formats without the option for Audio Description. Mono soundtracks should be recorded on both left and right front channels at the same level.

Audio tracks should be recorded at 48KHz sampling with 16, 20 or 24 bits per sample. The soundtrack should be mixed for theatrical reproduction with a reference level of -20dBFS.

Each channel should be on a separate (discrete) track in the order shown in the table below. Encoded or matrixed audio (E.G. Dolby-E, AC3, Lt/Rt) cannot be accepted for ingest and should be decoded to discrete tracks on the Digital Master.

Audio Track	Channels for 5.1 Sound	Channels for Stereo/Mono
1	Left Front	Left or Mono
2	Right Front	Right or Mono
3	Centre	(Centre for LCR)
4	Sub-woofer	
5	Left Surround	
6	Right Surround	
7	Audio Description (option)	Audio Description (option)
8	Audio Description (option)	Audio Description (option)

Timecode

The Digital Master should include continuous timecode for the whole of the programme at the same frame-rate as the image. Timecode for 23.98 fps should be non drop-frame (NDF).

The programme should start at a clean, non-zero hour timecode (E.G. 01:00:00:00, 10:00:00:00, etc). This applies to each tape if the Digital Master requires more than one.

Labelling

The Digital Master label should include the following information:

- Active image size and aspect ratio (E.G. 1440 x 1080, 1.33)
- Frame rate and recording format (E.G. 24PsF)
- Image coding and colour space (E.G. 4:2:2, P7V2)
- Starting timecode and program duration (E.G. 01:00:00:00, 1h 40m 30s)
- Soundtrack format and bit-depth (E.G. 5.1, 24bit)

Subtitles

The Digital Screen Network includes the facility for subtitles to be inserted into projected content at the time of projection. This results in very clear subtitles and is cost-effective compared to other forms of titling. The subtitles are rendered in the projector in real-time with data supplied from a form of spotting list written in XML.

Subtitle data can be submitted for DSN ingest in the form of a CD or Floppy Disk containing either of two acceptable file types: DLP Cinema Subtitle (.xml) or EBU Subtitle (.stl). Subtitle timing should be at the same frame-rate as, and referenced to, the timecode on the Digital master.

Subtitles submitted as .xml files must conform to the DLP Cinema Subtitle specification (TI Document 2504760b). This can be achieved by the use of appropriate software tools to create the titles or to assist in converting them from an existing format.

It is essential that subtitles are accurately timed to the Digital Master timecode. The timing will not be adjusted during DSN content ingestion. It is strongly recommended that subtitles should be converted to .xml form, and rehearsed against the Digital Master using a DLP Cinema projector, before being submitted to the DSN.

Image Capture

The equipment used to distribute and project content for the Digital Screen Network is capable of reproducing clear, stable images with a resolution up to 2048 x 1080 pixels. To benefit from this capability, content should ideally be captured or scanned at a resolution of at least 2K horizontal pixels.

There is a visible improvement in the level of detail portrayed by a 2K down-conversion of a 4K Interpositive scan compared to that of a 2K scan – assuming the detail exists in the print. The content-owner must decide whether the content and the budget justify high-resolution scanning. Where possible, it is recommended that sample scans are performed and the results demonstrated by screening through a 2K DLP Cinema projector.

Dirt & Scratch Removal

The highly stable images reproduced by the DSN projection equipment tend to accentuate any imperfections in content. When content is captured from film, it is recommended that some degree of Dirt & Scratch Removal (DSR) is performed. In most cases, the type of automatic DSR typically used for DVD production would be sufficient. It would benefit the content-owner if the available options for image clean-up were demonstrated on projected sample clips.

Grading Content for Digital Cinema

Grading is often performed with the use of a colour-calibrated monitor as a visual reference. Experienced graders have achieved very good results using this method on both film and video content but it has rarely been successful when used in mastering for digital cinema. This may be partly because the P7V2 colour space uses, in effect, seven colour primaries rather than the usual three and performs very differently to a CRT monitor.

There are products that employ LUT-based colour-correction in an attempt to emulate the performance of one type of display technology when viewed on a different type. These products may be helpful but they cannot reproduce colours outside the natural gamut of the actual monitor. Digital cinema's P7V2 gamut is larger than any other current display technology so is difficult to emulate.

The best results will be obtained when P7V2 grading is performed with monitoring through a 2K DLP Cinema projector in viewing conditions similar to that of a cinema. When grading is performed in this way and with reference to projection of the 35mm original, the results can be virtually indistinguishable – except for improved image stability and consistency.

Projector Calibration

Accurate monitoring requires that the DLP Cinema projector is correctly calibrated for the viewing conditions. Calibration should include both colour-correction (through measurement of the MCGD) and peak-white luminance (typically 14 fL). The projector should be set to use the target colour space (TCGD) appropriate for the content – either "P7V2 Telecine" or "Rec.709". The projector's de-gamma coefficient should be set to the same value for all colours – 2.60 for P7V2 or 2.45 for Rec.709. Projector masking should be completely removed and the image size adjusted to be fully within the screen masking so that any erroneous parts of the image are visible. Projector scaling should be set to accurately reflect the active image size and aspect ratio of the content.

Projector Performance

When first installed and as part of periodic maintenance, the projector's performance should be verified by accurate measurement of the on-screen images of appropriate test patterns. The most important parameters are Colour Accuracy, Luminance Uniformity and Sequential Contrast.

Colour Accuracy should be checked, as a minimum, using red, green, blue and white test images with known target CIE chromaticity values. Measurements should be

made of the reflected light from the on-screen image using a spectro-radiometer or chroma-photometer with an accuracy of ± 0.002 CIE xy units. The measured values should be within ± 4 Delta-E (ΔE^*_{uv}) of the expected chromaticity co-ordinates. (See appendix 2 for calculation of ΔE^*_{uv}.)

Luminance Uniformity can be assessed by measuring the image luminance of a 100% white test image at the centre, in the corners and at the edges. The lowest luminance measurement should be at least 80% of the highest reading (typically at the centre of the image).

Sequential Contrast can be verified by measuring the screen-centre luminance of a 100% white test image and comparing that with the measurement of a 100% black test image. The white luminance value should be at least 1500 times that of the black measurement.

Screen Size

Experience has shown that images mastered on a screen of at least 10 feet high are reproducible on much larger screens. Smaller screens have been used successfully, but a review is always required on a larger screen, and usually the content is trimmed to correct some small differences. Screens smaller than 4 feet high are not recommended.

Viewing Conditions

The level of ambient light in the screening room should be reduced as much as possible. This may require equipment indicators and monitors to be masked or covered with ND material. The ambient light measured on the screen (with the projector off) should not exceed 1/5000th of the projector's peak-white level. For the nominal peak-white level of 14 fL, this requires ambient light to be less than 0.003 fL when measured as screen luminance (maximum illuminance of 0.03 lux if screen gain = 1).

The walls, ceiling, floor and furnishings of the screening room should be dark to avoid scattering light back onto the screen. Light scatter can be assessed by measuring the difference in screen illuminance for the black and white squares of a projected ANSI checkerboard pattern. The illuminance of the white squares should be at least 150 times that of the black ones. Content mastered in conditions with high ambient light or scatter may look "washed-out" when screened under theatrical conditions.

The ideal viewing position is 1.5 to 2 screen-heights back from the centre of the image. Viewing too near to the screen can result in mastered content looking "soft" whilst viewing from too far tends to produce content with a video-look.

Image Enhancement

The types of image enhancement often employed when mastering for video (E.G. Aperture correction, Coring, Contours) are not recommended for digital cinema content. These forms of enhancement can result in projected images that look "edgy" and obviously electronic. It is recommended that zero or negative enhancement is applied when mastering for digital cinema.

Up-Conversion of SD Content

There are occasions where it may be necessary to up-convert content from interlaced SD video to create a progressive HD Digital master. This should only be attempted if the content originated on film or was shot on video with cinematic constraint of subject and camera motion. The second case is also limited to video shot at 50Hz as the DSN does not currently support 29.98 or 30 fps content.

The magnification required to reproduce a 720 x 576 pixel image on a large screen will render even the smallest imperfection visible. The process of up-conversion can compound this by accentuating certain aspects of the SD image. Up-converted SD content should only be used when it is not feasible to obtain the material in HD or on film.

Recommendations for up-conversion of SD video to HD:

- Monitor the up-conversion process by viewing the projected HD image.
- Convert 50i film-based content to 25p with reverse 2:2 pulldown.
- Convert 59.94i film-based content to 23.98p with reverse 3:2 pulldown.
- Convert 50i video-based content to 25p with 2:1 motion-adaptive de-interlacing.
- Set enhancement to zero or negative to reduce visibility of artefacts.
- Apply de-ringing to reduce visible echoes on edge transitions.
- Set input image blanking to mask extraneous objects and ringing that can occur on the top, bottom, left and right edges.
- Crop the input image for a consistent size throughout the content.
- Delay audio tracks by a time equal to the latency of the up-conversion process so that they remain conformed.
- An up-converted image will always look soft. It is usually better to over-soften the image than it is to accentuate noise and imperfections by attempting to improve detail or sharpness.

Appendix 1 – Summary Digital Master Specification

This is a summary of the requirements for Digital Masters that can be accepted for ingest to the Digital Screen Network. Preferred options are underlined.

Content Origin: Film or Progressive Video capture

Physical Medium: HDCam-SR, HD-D5 or HDCam videotape

Frame-Rate: 23.98P, 23.98PsF, 24P, 24PsF, 25P or 25PsF

Image Coding: 4:4:4 or 4:2:2

Image Format: 1920 x 1080, non-anamorphic, full height or width

Aspect Ratio: 1.33, 1.38, 1.66, 1.75, 1.78, 1.85 or 2.35

Colour Space: P7V2 or Rec.709

Display Gamma: 2.6 (P7V2) or 2.45 (Rec.709)

Soundtrack: Eight channels (1=L, 2=R, 3=C, 4=Sw, 5=LS, 6=RS, 7=Desc, 8=Desc)

Audio Format: 16, 20 or 24 bit @ 48KHz

Audio Reference Level: -20dBFS

Audio Description: Videotape tracks 7 and 8

Timecode: At frame-rate, Non Drop-Frame, clean non-zero hour start

Subtitle Files: DLP Cinema (.xml) or EBU (.stl) on CD or Floppy-Disc

Subtitle Timecode: Referenced to digital master timecode and frame-rate

Other: Digital Betacam (720 x 576 @ 50i) for 1.33:1 or 1.78:1 film-based SD content.

Appendix 2 – Light and Colour Terminology

Delta-E (ΔE^*_{uv}) is a measurement of perceptible difference between two colours. A ΔE^*_{uv} difference of 1.0 would be unnoticeable to most observers. A ΔE^*_{uv} difference of 4.0 is often considered as "just perceptible" to most observers.

ΔE^*_{uv} is calculated as the square-root of the sum of the squares of the differences between two colours in CIE L*u*v* colour space. If luminance variations are ignored, a simplified form of ΔE^*_{uv} can be calculated for two colours in CIE u'v' colour space as follows:

If colour a = u'_a, v'_a and colour b = u'_b, v'_b:

$$\Delta E^*_{uv} = 1300 * \sqrt{ ((u'_b - u'_a)^2 + (v'_b - v'_a)^2)}$$

Chromaticity values in CIE xy colour space can be converted to perceptually uniform CIE u'v' values with the following calculations:

$$u' = 4x \div (3 - 2x + 12y)$$

$$v' = 9y \div (3 - 2x + 12y)$$

Illuminance is the intensity of light incident on a surface (screen) measured as luminous flux density in units of lumens per square meter (lm/m^2 = lux). This is the measurement obtained from an incident light meter positioned at the surface and directed at the primary light source.

Luminance is the intensity of light leaving a surface in a particular direction measured as candela per square meter (cd/m^2) or foot-Lamberts (fL). 1fL = 3.4263 cd/m^2. This is the measurement obtained with a reflected-light (spot) light meter directed at the surface. The luminance of an image on a screen is related to the illuminance by the relative gain of the screen at the angle of measurement: Luminance (cd/m^2) = Illuminance (lm/m^2) / π * Gain.

Luminous Flux is the total amount of visible light incident on a surface measured in lumens (lm). Luminous Flux is related to illuminance by the total area of the surface: Luminous Flux (lm) = Illuminance (lm/m^2) * Area (m^2)