FULL RESOLUTION 2K DIGITAL PROJECTION - by EDCF CEO Dave Monk

1.0 Introduction

This paper is intended to familiarise the reader with the issues associated with the projection of images from D Cinema equipment in practical theatrical venues.

The topic arises from the different shape (Aspect Ratio, or AR) of images chosen by producers to present their cinematic work and the shape of the image forming device in the projector.

The electronic imaging device in a D Cinema projector has a fixed shape necessitating different settings of the electronics and /or optics to produce images in the correct aspect ratio on the screen. Different methods of achieving the correct on-screen aspect ratio have advantages and disadvantages in cost, quality and operational simplicity.

The paper describes the technical alternatives and also proposes the method preferred by the industry (DCI, EDCF, SMPTE,...) for the best possible on-screen image quality for a given projector and auditorium situation.

2.0 Historical Background

Over the years various film gauges and formats have been developed to improve the presentation of movies for public presentation. In general, image quality relates to the size of the film stock, but there are various ways of formatting the projectable area. Today, mainstream movies are predominantly presented in one of two formats: ‘Flat’ or ‘Cinemascope’. Both formats are produced for exhibition on 35mm gauge film. Film projectors deliver these two formats by use of different lenses which are, usually automatically, selected at show time.

3.0 The Two Standard Formats

3.1 The ‘Flat’ format is printed onto the film stock in the same shape that it is presented on to the screen. There is no expansion of the shape – hence ‘flat’.

The on-screen ratio of the width to the height is 1.85:1.

3.2 The ‘Cinemascope’ or ‘Scope’ format is printed onto the film stock in a horizontally compressed or ‘squeezed’ form. The film projector has a lens which projects the image onto the screen with greater (2x) horizontal magnification than vertical, in order to correct the squeezed image on the film.

The on screen ratio of the width to the height is 2.39:1.

The ‘scope’ picture is the widest format.

3.3 It is a matter of artistic choice which format is used by the film maker. Wide screen images were developed to match the AR of the human visual field which is wider than it is high. There are economic as well as artistic considerations relating to the capture of the two image formats.

3.4 Screen Format & Masking

In order to present the image at the maximum size, either the screen height or width must be adjusted for each format. This is usually done with moveable black masks/curtains which are selected with the change in film format.

3.4.1 Constant Height Screens.

If screen height is constant, then side masking is required for 'flat' presentations. This method is most common as the focal length of the lens is constant and only a width stretching adaptor (anamorphic lens) is required for 'scope' presentations.

3.4.2 Constant Width Screens

If screen width is constant, then top/bottom masking is required for 'scope' presentations. This method offers the largest 'flat' image but requires a different focal length lens for each format plus the anamorphic adapter for 'scope'.

4.0 <u>The Digital Projector Image Formats</u>

The DCI specification images sizes are 2048 x 1080 pixels (2K) or 4096 x 2160 pixels (4K). The pixels are square shape in both cases so the AR of the projectors is approx 1.9 in both cases. Note that this is not exactly equal to the AR of either film format but is a compromise to enable both formats to be shown effectively.

4.1 Imager Formatting.

In the same way that film can be formatted so it is with electronic imagers. The 'Active Area' is the part shown on the screen and this can be determined by which part of the imager is 'loaded' with image data.

D Cinema projectors also have the capability to transform image data from its input version (resolution and aspect ratio) to output (resolution and aspect ratio). This allows the electronic format to be matched to the physical imager. The scaler or 'resizer' can enlarge or reduce the format in either or both of the horizontal and vertical dimensions. It can thus stretch or squeeze the image to make it correct on the screen.

This provides operators with a unique flexibility which is electronically programmable and almost continuously variable. Although the scalers in today's 2K projectors are very high quality they inevitably reduce the integrity of the original image. This reduction in quality manifests itself as a softening of the image. Nonetheless, they do allow the imager the maximum number of pixels which form the image. The more pixels that are used the smaller the pixels become, which reduces their visibility specially for those seats within one screen height of the screen.

4.2 Best Image Quality

The best image quality for a given source is obtained when the maximum number of pixels are used to create the on-screen image. Coincidentally, this also delivers the highest possible brightness to the screen.
There are trade offs between the use of the maximum number of pixels and the minimum intervention of the scaler. Ideally, there would always be a one to one correspondence between the input resolution and the imager resolution but this is not always practical and the most efficient way of conveying light to the screen.

4.3 Optimal 'Flat' Image Format.

The optimal format for flat presentations is to format the image onto 1998 x 1080 imager pixels. This uses 98% of the resolution and brightness efficiency of the imager. It also avoids image scaling.

4.4 Optimal 'Scope' Image Format.

4.4.1 The optimal format for scope presentations is to use the full imager resolution and an anamorphic lens of 1.25:1. This uses the full 2K imager resolution (2048 x 1080) and light efficiency for the brightest and highest quality images. The intervention of the scalar is compensated by the higher imager resolution. (see alternative below without the anamorphic lens). Some optical resolution is lost in the anamorphic lens but this is minor with qualified lenses. The economic considerations are the fixed cost of the extra lens and change over mechanism versus the ongoing gains in optical efficiency which translates to lamp running and replacement costs.

4.4.2 An alternative format is to format the image onto 2048 x 857 [4096 x 1714]. This uses 79% of the resolution and brightness efficiency of the imager. The advantages of this approach are that there is no image scaling and no anamorphic lens (which avoids cost and minor image degradation. The disadvantages are that the on screen pixels are larger vertically and the optical efficiency is 20% lower. This can be a limiting factor for illumination of the largest screens where maximum brightness is critical to achieving the SMPTE standard.

4.5 Matching the Masking and Imager Formats

4.5.1 Constant Height Presentations (Side Masking).

	Imager Format	Efficiency	Scaling	Optics Required
4.5.1.1	Flat @ 1998 x 1080	98%	N	
	Scope @ 2048 x 1080	100%	Y	1.25 Anamorph
4.5.1.2	Flat @ 1998 x 1080	98%	N	
	Scope @ 2048 x 857	80%	Y	Zoom Lens or 2 FF
4.5.1.3	Flat @ 1586 x 857	61%	Y	
	Scope @ 2048 x 857	80%	Y	Single Lens only.

4.5.2 Constant Width Presentations (Top/Bottom Masking).

	Imager Format	Efficiency	Scaling	Optics Required
4.5.2.1	Flat @ 1998 x 1080	98%		
	Scope @ 2048 x 1080	100%		Ana + (Zoom or 2FF)
4.5.2.2	Flat @ 1998 x 1080	98%		
	Scope @ 2048 x 857	80%		Zoom Lens or 2FF.
4.5.2.3	Flat @ 1998 x 1080	98%	N	
	Scope @ 1998 x 836	76%	Y	Single Lens Only.

4.6 Other Considerations

4.6.1 Focal Length Considerations

The theoretical calculation of required focal length for a particular auditorium may not be available. The screen area can be filled by scaling the image accordingly. This reduces the on screen quality if the focal length is too short as the image would have to be scaled down electronically.

4.6.2 Off-Centre Projection

When the projector lens is not aligned with the horizontal and or vertical axial centre of the screen a geometric distortion occurs called ‘keystone’. This can be geometrically corrected by an optical correction using lens offsetting or it can be cosmetically trimmed by electronic masking. In the latter case only the edges are trimmed to horizontal and or vertical. The fundamental image distortion remains. This process should only be used for minor corrections as the result only makes the picture look rectangular. This sort of cropping is either at the expense of the image resolution or the image area. While this seems unacceptable the same system is used in film projection with metallic ‘shims’ which are cut to suit each auditorium rake and horizontal offset. The best solution is to position the projector on the central axes of the screen or second best to use an optical correction. Cropping should be a last resort.

5.0 Summary

Digital Cinema images are created at the maximum practical resolution. Installers and exhibitors should strive to deliver as much of this native quality as possible. After all the transition to D Cinema is founded on its capability of delivering visibly superior image quality to the cinema going patron.

5.1 Lamp Efficiency

Maximum use of the the imager coincidentally delivers the best image quality and brightness. Lamp power should be adjusted to deliver the SMPTE spec brightness of 16FL (Open Gate equivalent). When the imager is running at maximum efficiency, lower operating power is required which extends lamp life and lowers utility running costs. This should be considered when making decisions to configure the optical elements and screen formats.

5.2 Constant Height Screen Theatres.

Best quality is obtained with a single prime lens and anamorphic adapter for scope presentations.

Second best option is to use two prime lenses.

Third best option is to use a zoom lens which is adjusted between format changes.

Lowest cost and lowest quality option is to use a single lens. This solution compromises both flat and scope quality and offers lowest lamp efficiency. Allowed but not recommended.

5.3 Constant Width Theatres

Best quality and efficiency is obtained with two lenses and an anamorphic adapter for scope presentations.

The most practical solution is for a single lens solution which is optimal for flat presentations and still reasonably efficient for scope. A small gain in resolution and efficiency could be obtained with a second lens for scope presentations but this has to be set against the operational disadvantage of lens changing and the additional cost.

5.4 Image Quality

In the report we refer to image quality in terms of available pixel usage. This needs to be carefully qualified to avoid misunderstanding.

Image Quality should relate to the Human Visual System and this is a highly complex process of perception – not at all linear or one dimensional. More than half of the human brain is used to do this task.

Image quality is not just about spatial resolution (or pixel counting). This is a very incomplete proxy for image quality. It is about sharpness (related to spatial resolution but also to contrast), colour accuracy, uniformity and consistency. Early versions of the currently deployed 2K technology produced surprisingly good pictures. These '1.3K' projectors used fewer pixels than today's projectors but were judged almost universally as acceptable by cinemagoers and for the most part vastly superior to the normal film experience.
This perception was driven by the contrast, colour and consistency of the image. A technology that can deliver its native contrast from pixel to adjacent pixel enables more image detail than one with more pixels and less adjacent pixel contrast. Sharpness is about the black to white transitions and this is how the high frequency detail in an image is delivered. Many projector elements stand in the way of this capability – principally the optical elements which disperse the light and reduce the delivery of the native capability of the imager. It is therefore very important to consider the optical performance of the technology and only use properly qualified lenses that are designed to translate the contrast and colour performance to the screen. Fully qualified lenses trade cost, brightness and zoom range for contrast, colour and geometric distortion. These latter points have more bearing on image quality than pixel quantity.

The resolving power of the observer is principally a function of the angle of the detail subtended at the observer's position. When fewer pixels are used their visibility naturally increases closer to the screen. If an economic choice is made about use of a single fixed focal length lens, the effect can be at least partly mitigated by moving the first row of seats further from the screen. This removes pixel visibility and makes for a more comfortable viewing experience.

In recent tests the single lens format with image scaling produced surprisingly less inferior results than might have been predicted from the math shown above. This is a tribute to the scaler, the system design and the human visual system!

Proper projector maintenance and lamp alignment will also ensure that the image delivered to the customer is both pleasing and cost effective for the operator.

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