Barco

A pragmatic look at higher frame rates in Digital Cinema

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INTRODUCTION

The digitization of cinema projection started around the year 2000. Since then, multiple forces and sources have both accelerated and decelerated the conversion. For example, the release of Avatar, the most popular box-office hit in history, was an important driver for the success of 3D cinema and for the digitization of cinema in general. More recently, discussions and demonstrations are being held on higher frame rates in cinema. Again, multiple sources of information are flowing into the industry.

This paper, written in this context of an emerging technological development, is offered as an objective source of information for all those looking for more understanding. This paper has been written from the viewpoint of a projector manufacturer – Barco – and so it will take a more pragmatic approach than a scientific paper would. The goal of this paper is not to prove a link between frame rate and image quality, nor does it intend to promote (the standardization of) certain frame rate values. Its primary aim is to lower the implementation threshold for those that want to convert their digital cinema projection setup to higher frame rates (independent of any standardization). This paper will answer questions such as: "What do I need in order to play out higher frame rate content?" and "What is the difference between higher frame rates in 2D and 3D?"

Also note that a transition to higher frame rates impacts the entire workflow: from production, post-production and packaging, to distribution and exhibition. The industry – including DCI standards and SMPTE standards – may need to expand to make use of these higher frame rates.

WHAT ARE 'HIGHER FRAME RATES'?

Belgian scientist Joseph Plateau was the first person to produce the illusion of a moving image by presenting a rapid sequence of static images that contained small increments of motion. This illusion is based on a property of the human eye called 'persistence of vision'. Plateau used rotating disks to create his animation, calling his device of 1832 the phenakistoscope.

The same principle was used with the introduction of motion pictures on film. Moving picture film was originally shot and projected at various speeds using hand-cranked cameras and projectors. Research indicates that most films were shot between 16 frames per second (fps) and 23 fps and projected from 18 fps on up [1]. When sound was added to film in the late 1920s, a constant speed was required for the sound head to maintain synchronization with the film. 24 fps was chosen because that was the slowest (and thus cheapest) speed that allowed for adequate sound quality.

Today, in digital cinema projection, feature films are still being played back at 24 fps. Every 1/24th of a second, a new image is projected onto the screen. The image is no longer a physical frame on a film reel, but a digital picture representing each frame. This is not completely identical to digital television, which typically divides the picture into horizontal lines, first playing back odd-, and then even-, numbered lines. Digital cinema projectors play the complete picture in every frame.

'Higher frame rates' usually refer to speeds of 48 fps or 60 fps. In theory, rates even higher than these are possible (e.g. some television sets boast 240 fps), but then the entire chain – from camera to cinema – must support the rate. (In practice, the 240 fps televisions use 60 fps input and flash each image 4 times: the extra impact on image quality is negligible, but it looks good in marketing brochures.) The higher frame rates we discuss here do not repeat frames to achieve their speed but actually process and project different frames at the higher rate.

Based on current camera and post-production technology, we believe that 48 fps and 60 fps will be regarded as sufficient for DC projection for many years.

DO BARCO DIGITAL CINEMA PROJECTORS SUPPORT PLAYING OUT THESE HIGHER FRAME RATES?

The easy answer is: Yes. For example, we have up to 72 fps in our list of supported input formats in our installation manual.

The more correct, but complex, answer is: It depends on the bandwidth (the number of bits you can send from input to output per second). This bit-rate is impacted by the frame-rate (fps) and also by the size of each frame/image in bits. Higher resolution means more bits, higher image quality (linked to compression) means more bits, and so on. Each system (server + connections + projector) has a total bandwidth available for use.

The various components impacting the bandwidth in a 2K series II DC projector (the most-deployed model worldwide) and their respective available capacity (if no integrated server or IMB is used) are:

- Incoming dual HD-SDI connection: 2K @ 30Hz (high quality) or 2K @ 60Hz (compressed). [note that DCI specifies high quality for 2D content]
- HD-SDI board + enigma board: 2K @ 120Hz
- ICP and Formatter: 2K @ 120Hz (or 4K @ 30Hz)

It is clear that the limiting factor is not the projector's internal electronics, but the bandwidth that's available in the connection to the projector.

Note: it is possible to present more than 30Hz, if you're willing, and allowed, to compromise on the bits per image. This is what is being done in 3D and 'full panel triple flash' (sometimes called 'Brilliant 3D'): by encoding each image with a higher compression, it is possible to present 30Hz to each eye (60Hz in total). (Starting from 24Hz, together with the triple flash processing, the system actually runs at 144 fps. However, each frame is repeated 3 times.)

WHAT DO YOU NEED TO PROCESS HIGHER FRAME RATES ON YOUR PROJECTOR?

Just as in the conversion from 2K to 4K, the trick lies in circumventing the limitations of the connection between server and projector by integrating some of the server's intelligence into the projector's IMB (integrated media block). State-of-the-art 4K-ready IMBs can be enabled to output 2K @ 120Hz (DCI compliant quality). Today's situation requires a software upgrade to the IMB to enable this, but this new functionality will most likely be standard on future versions.

Another adaptation is programming the new and faster sequence into the formatter boards that drive the DMD chips in the projector. As mentioned above, the boards have the capacity to support this sequence, but a firmware upgrade is

required to activate it. Once again, it is to be expected that this new functionality will be standard on future versions of the formatter firmware.

Important to remember: only 2 upgrades are required: one to the IMB software, and one to the TI formatter firmware. Although no definite timeline has been confirmed, it is very likely that both upgrades will be standard in the future. No investment in new hardware or equipment is required.

Note that we haven't mentioned the most important requirement: the availability of content. As long as studios keep making movies at 24 fps, the higher frame rates do not impact image quality, because the projector will simply repeat certain frames to emulate the content's lower frame rate.

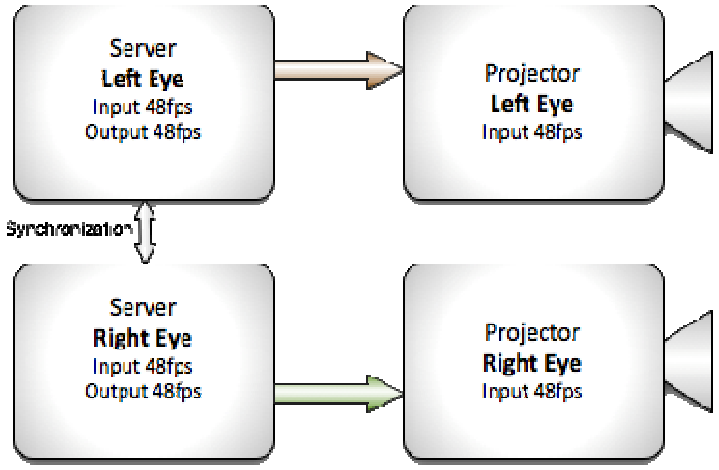
IS THE CONVERSION TO HIGHER FRAME RATES POSSIBLE IN ALL SETUPS?

2D vs. 3D

Everything we have described in the previous paragraph is valid for 2D content. 3D at higher frame rates is also possible, but there are more consequences. Once a projector has been upgraded to output 2K @ 120Hz, it can also show 3D @ 60Hz per eye. At these frame rates, the artifacts that triple flash tries to resolve are much less visible. Because triple flash is no longer needed, the content can be shown, just like that, in 3D @ 60Hz.

In the initial stage, the focus of the higher frame rate discussion lies on 3D content: this has to do with the margin for improvement of 3D image quality. The cinema market received some criticism from moviegoers and key opinion leaders as the number of 3D screenings increased following the release of Avatar. The criticism related to occurrences of insufficient image brightness [3], artifacts and visual discomfort. Increasing the frame rate can improve the perceived image quality in 3D – so, that's why the initial focus and trials are on 3D content. This improvement will be most noticeable on fast-moving scenes, camera pan-shots, and the like.

The first demos of digital cinema projection at higher frame rates were dual projector setups, thereby eliminating all potential temporal artifacts. For the 48 fps demonstration, two servers and two projectors were used: one server-projector combination dedicated to each eye. In-projector media blocks decoded incoming content at 48 fps [2].



The 60 fps demonstration was just as straightforward: two servers and two projectors were again used, with one server-projector combination dedicated to each eye [2].

Note that the previous comment on the availability of content applies here as well (probably even more so…).

Series I vs. Series II

Everything we have described above applies to a Series II 2K projector (Barco's DP2K models). Due to an inherent difference in electronics, the upgrade is not possible on Series I projectors. The dual projector setup as described in the example above could be a workaround here. It is currently (Q3 2011) being investigated how to enable the same functionality on 4K projectors (Barco's DP4K models) as well. This applies even when these projectors are showing 2K content.

Feature film vs. alternative content

The situation is also different for alternative content (coming in via the projector's DVI port). Here, the processing path is slightly different and frame rates up to 60Hz are more common. See our installation manual for an overview of supported DVI input formats.

Input	Source standard	Vertical rate	Scan type
Single DVI	VESA (1280x1024)	60	Progressive
Single DVI	1280x720	60	Progressive
Single DVI	1920x1080	60	Progressive
Single DVI	2048x1080	50/60	Progressive
Single DVI	1920x1080i	50/60	Interlaced
Twin DVI	ACS (2048x1080)	50/59.94	Progressive
Twin DVI	ACS (2048x1080)	50/59.94	Progressive
Twin DVI	3D (2048x1080)	24	Progressive
Twin DVI	3D (2048x1080)	25	Progressive
Twin DVI	3D (2048x1080)	30	Progressive

REFERENCES

[1] "Silent Film Speed". Cinemaweb.com

[2] "Cameron, Showscan, and 3-D". Mkpe.com

[3] "A movie lover's plea: Let there be light". Boston Globe, 22/05/2011