Getting ready for high frame rates in Digital Cinema

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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 high 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?”

Note that the frame rate is just one of the many parameters contributing to a good overall image quality on the cinema screen. Others parameters such as brightness, contrast, color and resolution impact image quality even more. When selecting a digital cinema setup, don’t get distracted too much by the ongoing discussion on frame rates, but consider all parameters that contribute to the creation of the best possible image on your screen(s).

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 – will have to evolve to make maximum 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’ means everything above 24 fps but usually refers 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.

What is implicitly assumed – but seldom explicitly mentioned – in the high frame rates discussion in the cinema industry, is that we are talking about high-frame-rate 3D. Producing 2D content at a frame rate higher than 24 fps has been possible for many years on a standard digital cinema setup (projector and standalone server). But the novelty and technological gap is introduced when going for 48 or 60 fps in 3D - i.e. 48 or 60 fps per eye - without extra compression. In the next paragraph, we will describe where this technological gap comes from.
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 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. In a standard digital cinema setup - as defined by the DCI standard - content is transferred from the server to the projector at 250 Mbps (megabits per second). This is true for 2K 2D at 24 fps and 4K 2D at 24 fps. The connection is designed to support this bandwidth, but not a higher one.

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.)

When introducing the new high-frame-rate 3D content and storage, the server-projector connection needs to support 450 Mbps or more. This is the case for 2K 3D 48 fps and 2K 3D 60 fps content (per eye, so actually running at double the frame rate. And in the case of 48 fps including frame repetition to avoid flicker). In order to support this increased bandwidth, you need to upgrade your digital cinema setup: the projector, the server and the connection in between them.
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). HFR 3D is only possible with a setup that uses an IMB; it’s not possible over the HD-SDI link that exists between standalone servers and the projector. A software upgrade of the IMB might be needed to fully enable this, but this new functionality is becoming more and more standard.

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. For Barco Series 2 projectors, this firmware is built in since December 2011 (on 2K projectors, since April 2012 on 4K projectors). For older units, a free software upgrade package is available online. With that new firmware, Barco supports all high frame rates:

- 2K 2D: 48, 50, 60, 96, 100, 120 fps
- 2K 3D: 48, 50, 60 fps

The situation is similar for all other DLP-based digital cinema projectors: enabling high frame rates is available to all OEMs via an upgrade offered by Texas Instruments, the only thing they need to do is give their customers access to the upgrade package for the specific projector brand.

Important to remember: only 2 upgrades are required: one to the IMB software, and one to the TI formatter firmware. However, as we mentioned, the high frame rates discussion implicitly assumes high-frame-rate 3D. So a third component that needs to be ready for high frame rates is the 3D system that is incorporated (Dolby 3D) or put in front of (MasterImage, RealD, Xpand...) the projector. All of the 3D manufacturers upgraded their product in time for the first releases, although not all of them are supporting the frame repetition (where 48 fps per eye is double flashed to net 192 fps to avoid image flicker). Be sure to check with your 3D supplier for the latest specs and updates.

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.
Series I vs. Series II

Everything we have described above applies to a Series II projector. Due to an inherent difference in electronics, the upgrade is not possible on Series I projectors.

2K vs. 4K

High-frame-rate 3D is possible on all Barco Series 2 projectors; both the 2K and 4K models. However, it is only possible for 2K content. Both from a technology (processing bandwidth) and from a content availability (no titles planned) perspective, high-frame-rate 3D 4K is currently out of scope.

Feature film vs. alternative content

The situation is also different for alternative content (coming in via the projector’s DVI or HDMI 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.

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REFERENCES

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