# WHITEPAPER

## COMPARING SINGLE-SPEED AND DUAL-SPEED ACQUISITION FOR SLOW-MOTION REPLAYS VERSUS TRIPLE-SPEED SUPER SLOW-MOTION

Klaus Weber, *Director, Imaging Technology*
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Triple-speed super slow-motion acquisition delivers a completely different level of performance for slow-motion replays when compared to single-speed and dual-speed acquisition. The various approaches address different production requirements, and in many cases a combination of them are used during the same production. This document looks at the differences between the different types of slow-motion acquisition methods.

## INTRODUCTION

For many years, slow-motion (SM) and super slow-motion (SSM) replays have been an important part of the storytelling in nearly all live sports productions. There has also been increasing use in entertainment productions such as game shows, reality shows, dance competitions, and similar types of productions typically found in studio environments. The main driver of this is for producers to deliver a new level of emotional imagery to these types of programs.

There are several options for both the speed of the image acquisition and the replay. Every option has its unique strengths but comes with some limitations as well.

What are the typical requirements for the different applications, and why have only a very limited number of the possible scenarios been widely accepted?

This document helps to explain these points in more detail, and assists the reader in choosing the right technology for specific applications.

In recent years a trend has developed that sees many productions also using ultra slow-motion replay capability besides the regular slow-motion and triple-speed super slow-motion replays. These ultra-slow-motion cameras with replay systems have a completely different workflow and offer a completely different set of features and limitations. These topics will not be covered here, but are available in a separate document from Grass Valley®: "Comparing Triple-Speed Super Slow-Motion Camera Systems with Ultra Slow-Motion Camera Systems."

## WHY TRIPLE-SPEED?

Single-speed (1X) and dual-speed (2X) cameras when compared to triple-speed (3X) super slow-motion camera systems each deliver a different level of performance. Besides this, each of the different solutions has its own specific limitations. Which approach offers the best solution depends on the application and/or the speed of the action.

In nearly all slow-motion applications the replays are done in 1/3 the real-time speed and this speed has been the de facto standard for many years. The reason is that the three-times slower than real-time speed offers the best balance between the speed needed to see detailed motion, and the additional time needed for replays.

To reduce the replay speed further (i.e., to 4-times or 5-times slower than real time) would not offer the viewer any additional motion information but would consume too much time for the replay itself. To reduce the replay speed to a lesser amount (i.e., to 2-times) would not offer enough detailed visual information for the viewer to see additional motion information and the replay would not look even close to "real" slow-motion as viewers expect.

If slow-motion replays are done in 1/3 real-time and the cameras are operating in regular speed, which means capturing 50 or 59.94 fields or frames per second, each field or frame will be played back three times. While this offers the viewer additional time to follow the action, it does not generate sharper or more detailed individual images for smooth slow-motion playback. The advantages of this operational mode is that every camera in the production can be used to its full performance and sensitivity as a regular camera and at the same time can be used for slow-motion replays whenever needed from that camera position.

When the single-speed camera is operating in an interlace mode, such as 1080i50 or 1080i59.94, there is a very specific problem in slow-motion replay systems: The same field is replayed three times and the even and odd fields from the camera cannot be played in the correct order during slow-motion replays. The conversion of an even field into an odd field or the other way around is not possible without losing some of the vertical resolution which is especially painful since interlace formats do not offer good vertical resolution to start from.

To have more pictures with a shorter exposure time available for playback, the camera needs to operate at a higher speed. Ideally the speed of the image acquisition is directly related to the slow-motion replay speed. So if the slow-motion replay speed is 1/3 real-time, the camera needs to operate three times faster than real-time mode. In this case the camera generates three times as many pictures with each having a 3-times shorter exposure time. During the 1/3 real-time speed slow-motion playback each of the pictures generated by the camera will be shown once.

Of special note: there is no problem if the camera is operating in an interlace mode since each field is played just once in the correct order. This offers the most perfect quality match possible with this speed, in combination with the best possible compromise in sensitivity and resolution. This mode still needs to take into account that the exposure time for each field or frame is only 1/3 compared to single-speed operation and so the sensitivity of the camera will be reduced by at least 1.5 f-stops.

The main problem with this operation is associated with artificial lighting and depending on the lighting conditions, there can be very severe problems with flicker in the images (see Picture 1). The reason for this is interference between the pictures captured by the camera, 150 or 179.82, and the AC operated light sources. Simply speaking, it can be said that the light varies its brightness 100 times per second at 50 Hz AC (or 120 times per second at 60 Hz AC).

This means that on a single-speed camera each field or frame will "see" exactly two of these variations and therefore the effect is the same for every field or frame. However, on a triple-speed camera, some fields or frames will be affected more by these variations and some will be affected less. In almost all applications the different lights used in a production will be connected to different power phases, and the interference seen by the cameras will be different from different light sources. That has been the most limiting problem for the use of super slow-motion cameras in all studio type applications and many sporting events occurring at night. With the introduction of AnyLight™ technology in the LDK 8300 triple-speed camera system, Grass Valley has completely solved this problem and flicker-free images under any type of lighting conditions can be expected.

## WHY TRIPLE-SPEED? (CONT.)

Where does that leave dual-speed operation—which means an image acquisition with 100 or 119.88 fields or frames per second? As explained earlier, a replay of 1/2 real time is not acceptable in nearly all live applications, which means the direct 1:1 replay of the recorded images will not be feasible. A replay in the regular slow-motion speed of 1/3 real time would mean that one image would need to be replayed two times and the following picture only one time.

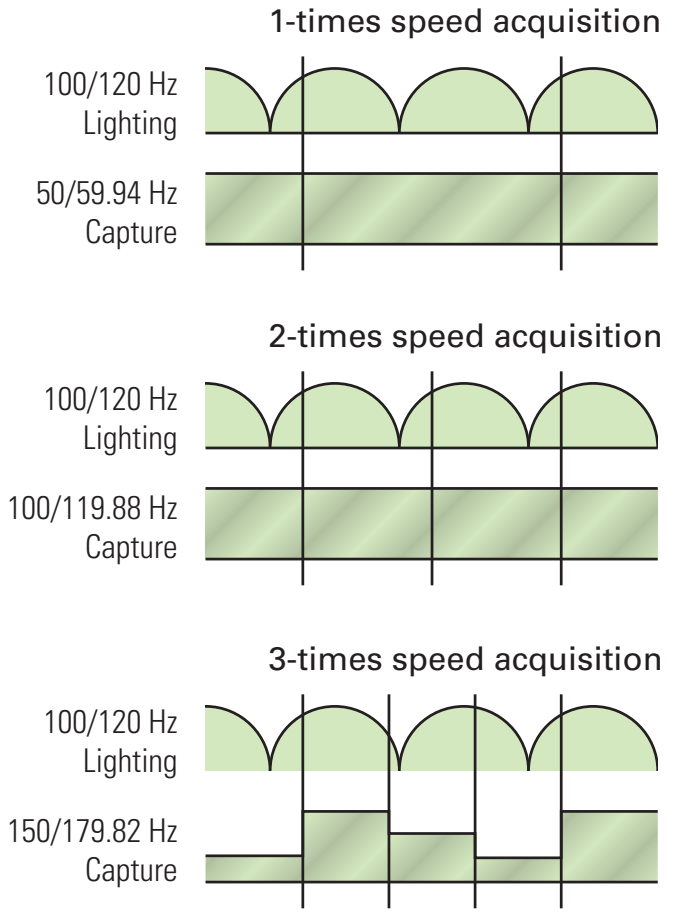
This generates a strange motion judder, and the problem with the wrong order of the even and odd fields in 1080i remains. As an alternative, new images could be calculated out of the dual-speed images but for a reasonably good result that would need quite demanding processing and still would not deliver dependable results for many applications. With triple-speed super slow-motion cameras widely available why should anyone accept all these compromises?

So why is dual-speed operation available? It actually goes back a few years to the early days of HD camera systems. At that time, triple-speed was already the de facto standard for SD applications, as the technology for triple-speed operation of HD cameras was not yet available. This was true from both an imaging technology aspect, and a camera head to base station signal transmission aspect. In addition, AnyLight technology was not yet available to deliver flicker-free images under all conditions where artificial lighting is used. Dual-speed acquisition in HD—which was introduced by Grass Valley with the LDK 6200 camera system—was an acceptable compromise at the time, until real triple-speed HD cameras became available. For a short time, dual-speed mode was the only way to produce slow-motion pictures in HD that were somewhat better than with a regular single-speed camera system.

As soon as the LDK 8300 became available, dual-speed camera systems were no longer in demand and the LDK 6200 was soon discontinued.

With the recent introduction of 1080p50/59.94-capable cameras, dual-speed operation in 1080i returned as a production tool, as 2X operation became available with some of these cameras. This was not based on demand from users but because these dual-speed modes have been included since they use the same 3G bandwidth as 1080p formats. As explained previously, there are no real applications for this operational mode and triple-speed cameras offer much better slow-motion performance for all most typical applications.

The Grass Valley LDK 8300 is still the only camera system available which offers the selection of 1X/2X/3X-speed in 1080i and 720p formats. In combination with the unique AnyLight technology, they offer the best possible super slow-motion images in any condition. A live, single-speed output—which can be used as a regular camera source during a production—is always available in addition to the selected dual- or triple-speed operational mode. Therefore, with the exception of the lower sensitivity and a different S/N ratio caused by the reduced exposure time, the picture quality is almost indistinguishable from Grass Valley single-speed cameras with the same matrix, gamma, and detail.




***Picture 1:*** *Flicker by artificial lighting.*

Also since the camera control system is identical to any Grass Valley single-speed camera system, a seamless integration into the C2IP camera control solution is an easy task.

As a consistent leader in slow-motion image acquisition, expect that Grass Valley will always be setting the bar to even higher standards.

## ABOUT GRASS VALLEY

Grass Valley is changing the way live television is made and delivered. Recognized with 18 Emmy® awards for technology innovation, Grass Valley's product portfolio—from image acquisition to playout—offers a complete end-to-end workflow of flexible, forward thinking solutions which enable broadcasters and content owners to build multiscreen, multiplatform futures. By simplifying and enhancing the way content is produced and distributed, Grass Valley gives customers the freedom they need to be creative in the studio, the field, and the newsroom. Merging optimizations of IT technologies with best-in-breed media systems, Grass Valley's next generation solutions deliver higher quality and greater efficiencies. Customers include world-leading broadcasters, teleproduction facilities, service providers, government, religious, educational, corporate, and independent video professionals. Grass Valley is headquartered in Hillsboro, OR, and maintains local presence across the globe with offices throughout North and Latin America, Europe, the Middle East, and Asia-Pacific regions.

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