



Understanding and Managing Conversion Delays in Live Production Systems



New production and display technology allows a wide variety of picture formats (*including SD, 720p, 1080i*) to be mixed together. They do this by converting the various picture formats to one common format. The processing time required to convert between picture formats can often add substantial signal delay. It is important to understand delay because if not managed it can cause some very undesirable results.

For example, in IMAG* applications if delays are significant the audience will become distracted because the subjects movements on the large screen will lag behind live subject and the associated audio.

*(*IMAG refers to Image Magnification, which is used at live events to magnify the live subject on a large screen so that a larger audience can see the action.)*

Unfortunately, identifying the source of delay is often very difficult as many devices do not specify their processing delays. Moreover, many devices have inherent delays that may not be initially apparent.

The following paper will identify the most common sources of delays and provide examples and tips on how to reduce the overall delay in your system.

Where are the delays?

Conversion/Converters:

Converting from one picture format to another will always result in some form of delay and the amount of delay depends on the quality of the conversion.

For example, a simple converter that converts from interlaced to progressive or vice versa would only analyze 1 frame of data to perform the conversion, thus resulting in a 1 frame delay. However, a higher quality converter that mathematically analyzes multiple frames of video will result in a greater delay equivalent to the number of frames used for the analysis.

In short, better quality conversions result in greater processing delay.

Displays:

LCD, LED, DLP and Plasma displays (*including projectors*) will reprocess incoming data to accommodate the nuances of the technology used. If the input format is the same as the displays native resolution then the reprocessing will be minimized typically to 1 frame of delay. However if the picture format does not match the native resolution, then the image must be “scaled” to match the displays native resolution. Additionally, most new displays have been designed to accommodate sophisticated processing technology such as noise reduction and cadence detection (*used to improve the movie watching experience by removing 24 frame film conversion artifacts*). These advanced processes require at least two frames of delay and often more, even if the native resolution of the input matches the display capability.

For example, A 720 picture displayed on a 1080 display must be converted from 1280x720 to 1920x1080 and depending on the scaling technology used could take several frames to reprocess.

Cameras:

Cameras are designed around fixed size imaging devices even though they output a variety of formats.

If the output of the camera is set for a picture format that is not the same size as the imaging device, then internal conversion must be used. This conversion will add delay. The amount of delay depends on the design architecture and chosen signal format.

For example, a video camera that has an imager of 1920x1080 pixels should output a 1080 HD signal without delay. If however the output of that camera is set to 720 HD or 525/625 SD then the picture must be converted from progressive to interlaced and the image must be re-sized to achieve the desired resolution. Moreover choosing additional options like "film mode" or "24 frame mode" will require additional processing resulting in additional delay.

Fortunately cameras are better able to manage delays as the camera controls how the imager is scanned but typically there will be a delay of 1 frame or more depending on the settings chosen.

Multiviewers:

Multiviewer technology allows multiple sources and effects busses to be monitored on a single display, which offers tremendous cost savings and reduced complexity. However, the images in multiviewer windows are scaled representations of the original pictures, which of course adds delay. Multiviewers not only convert from interlaced to progressive but they also position multiple pictures on a single display. This requires a substantial amount of processing and the resulting delay varies with design and is typically between 1 to 3 frames.

Synchronous vs. Asynchronous systems:

An important first step to any form of picture processing is identifying the frame boundary (*where a picture frame starts and where it ends*). In a synchronous system all of the equipment in the system shares a common reference (*genlock*). Sharing a common reference means that all of the equipment is locked together and the video outputs will have frame boundaries that coincide. An asynchronous system has no timing references and so the output of each product has no video framing relationship. In order to mix or perform effects on these signals it is necessary to realign them using a device called a frame synchronizer, which will add 1 frame of delay.

Adding Up the Delays:

We have seen the various sources of delay in a typical system and you may have noticed that the delay at each component is only a small number of frames. However, processing delays accumulate as they pass through the system and the cumulative delay can be unacceptable. It is therefore crucial to understand where the delays can occur so that they can be avoided or minimized.

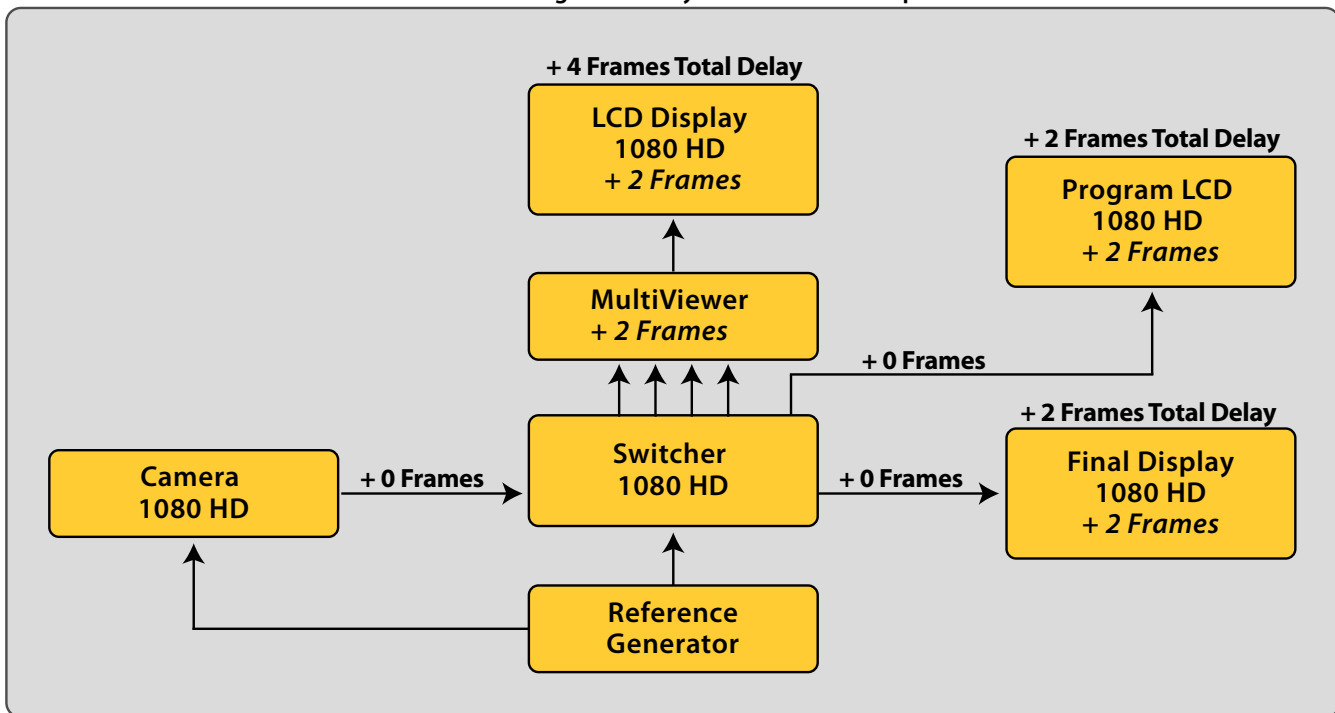
Best Practices to Minimize Delays

- If possible always synchronize the entire production system to a master reference.
- Try to match the native processing resolutions of all your equipment to that of the final display. For example if your final display has a native resolution of 720p then try and choose a camera that also has a 720p native resolution and set your switcher's processing format to 720p. Remember that switching a 1080 camera to 720 results in less of a delay than playing 1080 video on a 720 display.
- When choosing displays, try to identify the inherent processing delay and the true native resolution. Unfortunately this is often unpublished information and so it may be necessary to surf the web forums and blogs to collect information from other users.
- If it is necessary to combine existing standard definition cameras in a high definition system avoid using these cameras on the primary subjects.
- If your sources and outputs are primarily standard definition, then consider switching the processing mode of all equipment in the system to standard definition.
- Some delays are inherent. However knowing where they are will help you to avoid them or minimize their effect.

Following are a few diagrams of example systems and a calculation of the delay in that system. By comparing the various examples you should be able to get a better idea of how overall system delay can increase or decrease.

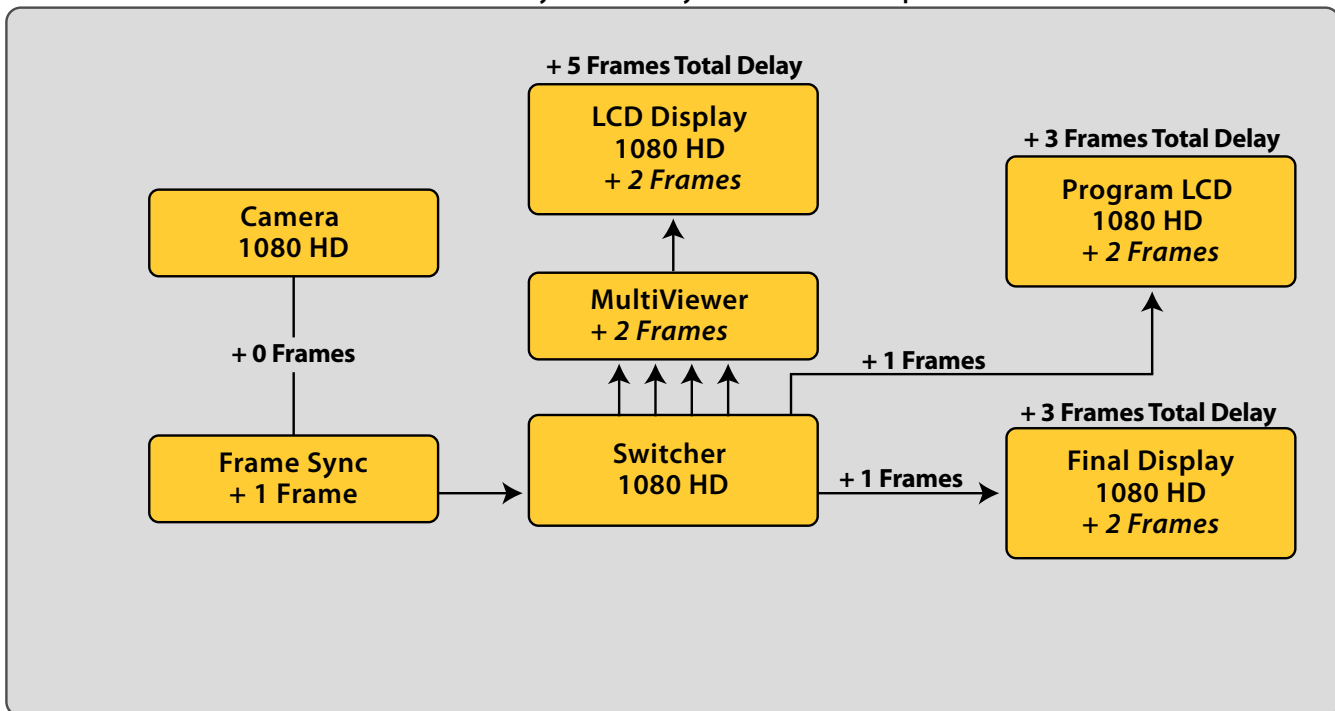
Example 1.

A genlocked system where all components have the same native resolution



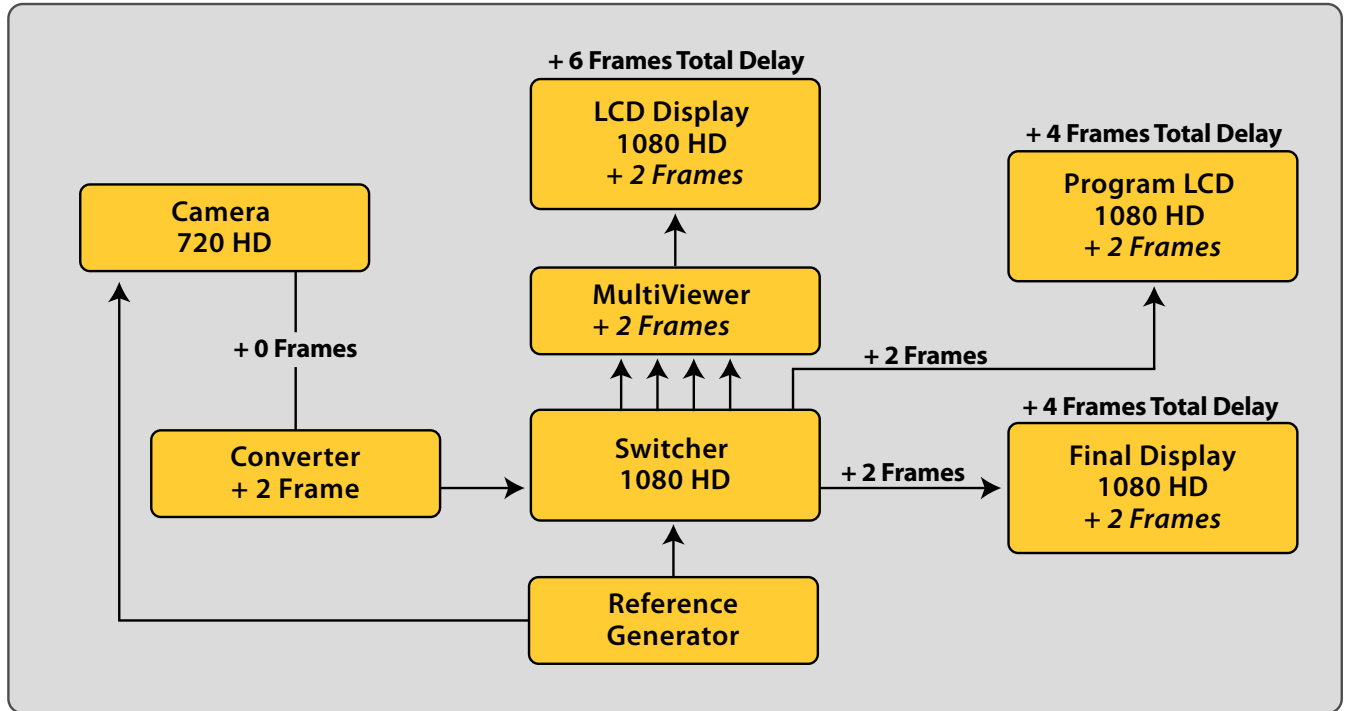
Example 2.

An asynchronous system where all components have the same native resolution



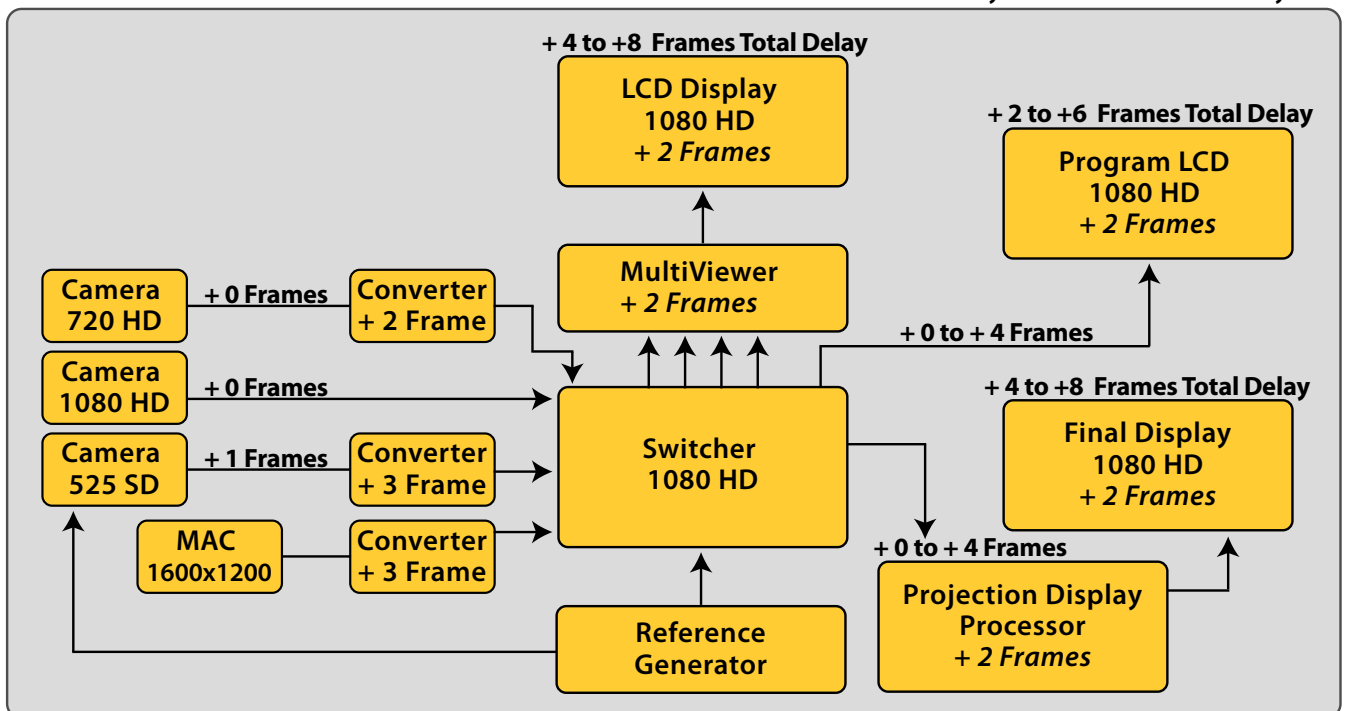
Example 3.

A synchronous system where some components have dissimilar native resolutions



Example 4.

A synchronous multi-format system



ATEM CONVERSION DELAY TABLES

Internal Operating Standard 1080i (50 or 60Hz)				Internal Operating Standard 720p (50 or 60Hz)				Internal Operating Standard 525i/60 or 625i/50			
Input Format	Input Delay	Native Output	Total Delay	Input Format	Input Delay	Native Output	Total Delay	Input Format	Input Delay	Native Output	Total Delay
1080p	+1	+0	+1	1080p	+1	+0	+1	525i/625i (S)	+0	+0	+0
1080i (S)	+0	+0	+0	1080i	+1	+0	+1	525i/625i (A)	+1	+0	+1
1080i (A)	+1	+0	+1	720p (S)	+0	+0	+0	Computer	+1	+0	+1
720p	+1	+0	+1	720p (A)	+1	+0	+1	Input Format	Input Delay	Aux 4 & 5	Total Delay
525i/625i	+1	+0	+1	525i/625i	+1	+0	+1	525i/625i (S)	+0	+1	+1
Computer	+1	+0	+1	Computer	+1	+0	+1	525i/625i (A)	+1	+1	+2
Input Format	Input Delay	Aux 4 & 5	Total Delay	Input Format	Input Delay	Aux 4 & 5	Total Delay	Computer	+1	+1	+2
1080p	+1	+1	+2	1080p	+1	+1	+2	Input Format	Input Delay	MultiViewer	Total Delay
1080i (S)	+0	+1	+1	1080i	+1	+1	+2	525i/625i (S)	+0	+2	+2
1080i (A)	+1	+1	+2	720p (S)	+0	+1	+1	525i/625i (A)	+1	+2	+3
720p	+1	+1	+2	720p (A)	+1	+1	+2	Computer	+1	+2	+3
525i/625i	+1	+1	+2	525i/625i	+1	+1	+2				
Computer	+1	+1	+2	Computer	+1	+1	+2				
Input Format	Input Delay	MultiViewer	Total Delay	Input Format	Input Delay	MultiViewer	Total Delay				
1080p	+1	+2	+3	1080p	+1	+2	+3				
1080i (S)	+0	+2	+2	1080i	+1	+2	+3				
1080i (A)	+1	+2	+3	720p (S)	+0	+2	+2				
720p	+1	+2	+3	720p (A)	+1	+2	+3				
525i/625i	+1	+2	+3	525i/625i	+1	+2	+3				
Computer	+1	+2	+3	Computer	+1	+2	+3				

Notes:

The Delay Numbers given are in Video Frames

(S) = Synchronous (Genlocked) Input

(A) = Asynchronous (non - Genlocked) Input

Native Outputs = Program, Preview, Aux1, Aux2, and Aux3 - the output standard is that of the operating standard selected

Aux 4 & 5 are multiformat outputs and can be set for any valid standard

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