4K UHD-1 Frame Rate Conversion

Snell Advanced Media

Application Note

1. Introduction

Frame rate conversions are needed by any content broadcaster or distributor dealing with international program feeds where content arrives at a different frame rate than that required for transmission or distribution to end users. This is also true when dealing with UHD-1 4K content.

The same challenges faced previously with frame converting SD and HD material are still present with UHD-1 4K content and the quality of the source material is more important than ever before. Changing the frame rate of the content essentially means creating additional frames where none existed at the input and when that is done across four different links it also adds extra complexity to the process and can affect the quality of the result.

Linear vs Motion Compensated Conversion

It is a known fact that simple linear interpolation of new frames from those immediately preceding and following can give a very blurred result when the objects in the scene move, as shown in Figure 1.

Figure 1: motion compensated and simple linear standard conversion examples

Other effects can also arise such as motion judder, where objects no longer have smooth motion from frame to frame.

A motion compensated converter, calculates the motion between frames in the content, and works out where to move objects to when creating new frames in between, as shown in Figure 2.

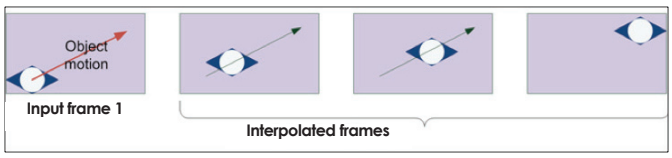


Figure 2: motion compensated interpolation

Accurate calculation of motion is very challenging and different motion vectors are required for different parts of the picture because typical video scenes contain multiple objects, of different sizes moving at different speeds, which could have very complex shapes. The objects may be passing across detailed backgrounds, and may cross each other all adding to the complexity.

Other factors

Motion estimation is only a part of the processing needed when frame rate converting video. Movies and TV programs are composed of multiple sequences which are edited together, with various effects such as cuts & fades etc, and often graphics, logos and text appear over the content for short periods of time (e.g. a scoreboard) then disappear. Scrolling captions are also very common, not just at the start or end of a program, but also during a program to provide instant updates e.g. a stock ticker at the foot of a news program.

In such cases, new content appears in the picture without any history, and as we explained above, the simple example of Figure 1 is not very common in practice. Therefore motion compensated frame rate converters also have to include processing which creates perfect picture content in areas where new objects appear, disappear or obscure each other.

Another area where motion estimators have problems is where the picture contains stationary repetitive patterns, which may be interpreted as a moving object. In the example shown in Figure 3a, a motion estimation algorithm examining the scene frame by frame by looking at an area about the size of one of the bridge supports (as could be the case for some block-based motion estimation methods) would have difficulty knowing whether to interpret the information as a static pattern or a moving object. The moving bridge support object in Figure 3b could give the same apparent motion analysis results as the bridge itself (Figure 3a) if it is moving exactly its own width each frame.

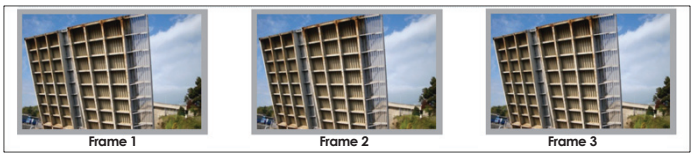


Figure 3a: stationary object containing repetitive patterns

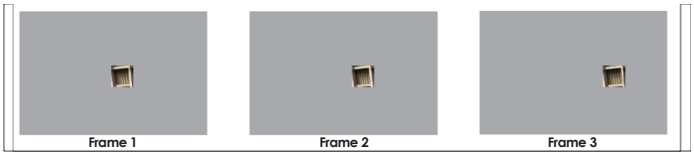


Figure 3b: object moving at its own width per frame

1.1 SAM's 4K-UHD-1 Frame Rate Solution

SAM offers a variety of existing motion compensated converters to meet the most challenging material even UHD-1 4K conversions:

- **Alchemist PH.C-HD** - World-leading format & frame rate converter offering Gold standard frame rate conversion, so much so, that content owners around the world demand Alchemist by name because it delivers the best quality, cleanest and most detailed conversions – even with highly dynamic content. Alchemist Ph.C-HD utilizes unique phase correlation-based motion estimation to produce images that are clear, sharp and free from motion artifacts.
- **KudosPro** is the compact and cost-effective image processing platform from SAM. Kudos Pro is still capable of punching well above it's size and price tag in delivering high-quality format and frame rate conversion in a format-flexible 19" x 1RU package.

Both product lines offer a superior quality conversion for a range of content. Usually many types of content such as news, drama, current affairs and talk shows contain relatively large objects with slow, regular motion, which does not challenge a frame rate converter. Where motion becomes faster, more complex, and where there are multiple small moving objects in the scene, the requirements placed on the frame rate converter become more demanding. Particularly difficult are fast action sports and music clips where there are rapid dance movements.

1.2 Solution 1: UHD-1 4K frame rate conversion with four Alchemist Ph.C-HD

Alchemist Ph.C-HD uses a highly accurate method called Phase Correlation for calculation of motion vectors.

This is a frequency domain method, which requires spectral analysis of the content followed by further processing. In Phase Correlation, the distance and direction of the motion is measured accurately, but the area of the screen in which it took place is not. So in practical systems the phase correlation stage is followed by a pixel-by-pixel assignment stage.

One reason why phase correlation is so accurate is that it uses frequency information to calculate the motion in the scene. In this way, small objects are not missed because they will generate high frequency components in the analysis. A further advantage of phase correlation is that it is sub-pixel accurate, meaning that object movement in fractions of pixels can be calculated. This leads to smoother motion profiles and higher quality results. In addition to highly accurate motion estimation, Alchemist Ph.C-HD integrates many additional steps to manage the difficult cases we described above such as obscured/revealed areas, stationary repetitive patterns, and highly complex motion. After calculation of the initial motion vectors, Alchemist Ph.C-HD applies processing to check for consistency of vectors, discarding those that appear to be erroneous or not fitting the pattern of vectors in the surrounding area. Through such techniques, Alchemist Ph.C-HD can avoid errors often associated with motion compensated frame rate converters such as blurring or introduction of the wrong content into an area of the scene.

As may be expected, the additional algorithms and methods used in Alchemist Ph.C-HD to get such accurate results require considerable processing resources, and as a result, the Alchemist Ph.C-HD is a relatively expensive solution. However, the investment cost in Alchemist Ph.C-HD is rapidly repaid through its unmatched quality of conversion and its handling of difficult program material.

1.3 Solution 2: MC2000 IQ fitted with two IQMCC30 modular cards

The KudosPro MC2000 IQ fitted with two additional IQMCC30 motion compensated converters offer cost-effective 4K UHD-1 conversion in a 1U frame. In order to reduce the amount and cost of components used, the KudosPro and IQMCC30 products (whilst having the same processing technology) use a different processing method to Alchemist Ph.C-HD.

They perform motion estimation using a special transform analysis which is proprietary. The transform is designed to detect the broad motion profile of a scene and is followed by further processing stages to maximise accuracy and reduce the impact of signal noise.

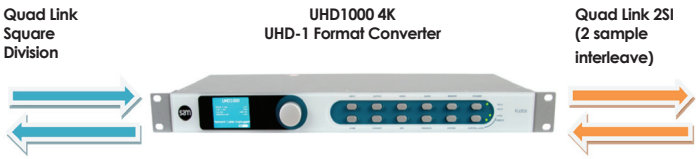
Their processing was designed to achieve high quality conversions while keeping the overall processing latency as low as possible. Even with challenging content they deliver optimal results whilst saving power and resources through the use of sophisticated analysis techniques.

1.4 Conclusions

Both Alchemist Ph.C-HD and KudosPro motion compensated frame rate converters offer state-of-the-art processing, with conversion quality unmatched by any other converter in the market. Incredibly accurate processing combined with years of refinement make Alchemist Ph.C-HD the true "gold standard" in frame rate conversion that can be applied in a 4k UHD-1 environment, where converted output is virtually indistinguishable from the input for most content.

KudosPro uses simpler processing in order to offer a cost-effective and compact alternative. Excellent quality results are obtained for most types of content, but for the most demanding content, such as sports and dance, Alchemist Ph.C-HD will give better results.

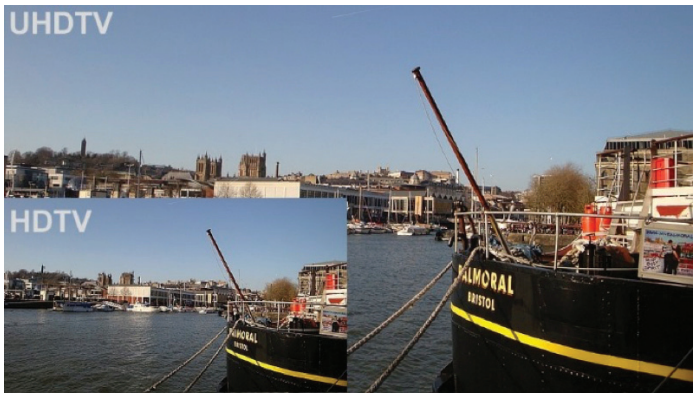
Our extensive tests have proven that using 2SI (2 sample interleave) quad link signals prior to frame rate conversion provides a superior result rather than using square division (quadrant mode). This is because the motion processing is still working across the whole frame even though the resolution is a lot lower, and so eliminates any artefacts that might occur at the edge of the quadrants if using square division mode. As most applications today use square division quad split links for 4K transport SAM offers a solution for translating between square division and 2SI modes (Kudos Pro UHD1000) to be combined with any of the above solutions.



2. Appendix A -Introduction to UHDTV1

UHDTV1 is a broadcast standard of picture dimensions 3840 pixels x 2160 lines, sometimes referred to as 2160p. Frame rates include 50Hz and 59.94Hz (lower and higher frame rates are also supported).

4K is a digital cinema standard of picture dimensions 4096 × 2160. Frame rates are typically 23.98, 24, 25 and 29.97Hz. Some institutions use 4K and UHDTV interchangeably, but usually mean UHDTV1 (UHD-1).

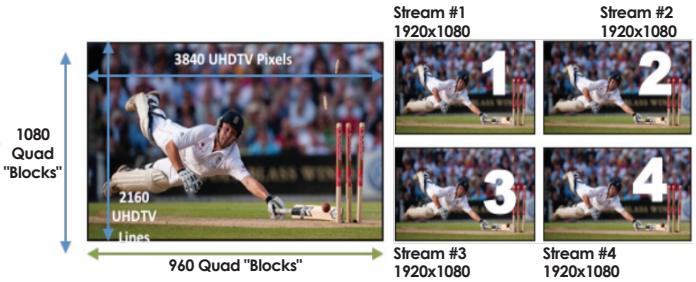


2.1 UHDTV1 Quad Link Uncompressed Workflows

Quad HD-SDI links at 3Gb/s are used to transport a UHD signal. Each link contains a 1920x1080 progressive video signal that represents one quarter (1/4) of the original image.

They are two formats to date used for transporting UHD-1 uncompressed quad link signals and are both commonly used across the industry:

- Quad link -> 2 sample interleave (2SI) (3840x2160p). Each stream contains a full image at quarter (1/4) of resolution.



- Quad Link -> Square division quad split SDI (3840x2160p). Each stream contains one quarter of the original image.

The two methods of transport are incompatible and cannot be mixed together in a production without translation e.g utilising the SAM UHD1000 4K format converter.

Comparison

Quad link -> 2 sample interleave (2SI) (3840x2160p) the 2SI method allows picture monitoring on standard 1080P displays as each link carries the whole image at ¼ of its original resolution.

Quad Link -> Square division quad split SDI (3840x2160p).

Using the square division quad split method it is necessary to reassemble the quad split in a 4K display for monitoring purposes.

Application Note

Facts

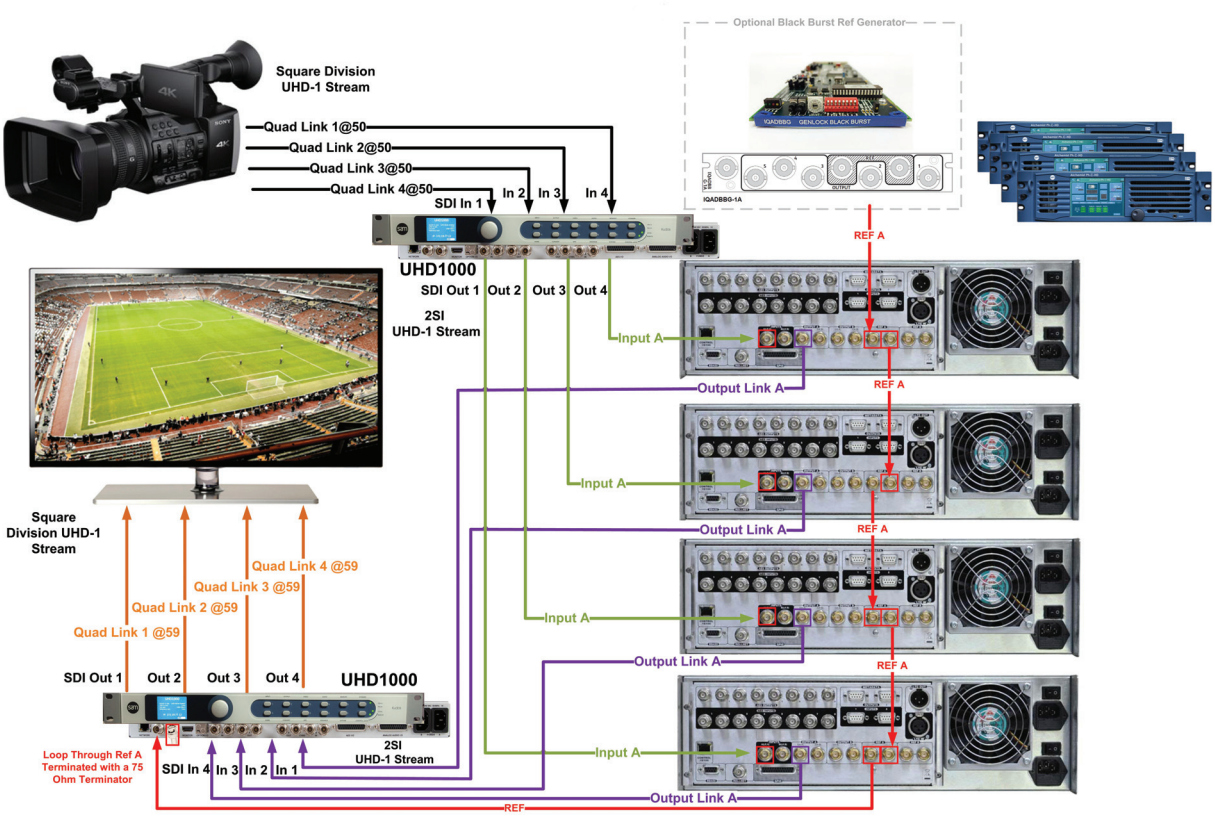
UHD -1 workflows are very sensitive to any timing differences between the paths and all four streams must end up perfectly lined up when they reach their destination. (Due to being composed of a quad split of the original image into four streams/links that need to be re-assembled to provide the full UHD resulting image).

Hence when utilising 3G capable products e.g distribution and processing devices, in such a workflow those devices MUST either:

- Be able to maintain a level of synchronization that prevents image artefacts from occurring when the four quadrants or quarters are assembled back together by the destination device.

Or

- The workflow includes suitable frame sync products at key points to remove any timing differences.



4K UHD-1 frame rate conversion with Alchemist PH.C-HD