Strategic Value Advisory Report

HD STANDARDS CONVERTERS PROJECT

(Version 1.4)

Prepared for:
NORTH AMERICAN BROADCASTERS ASSOCIATION (NABA)

On behalf of:
WORLD BROADCASTING UNIONS (WBU)

The purpose of this report was to evaluate high-quality standards converters primarily in preparation for the 2008 Olympic Games and other high-quality transmissions. The following document reports the results of testing that was conducted in 2007. As such, it reflects the state of the art for the products tested at the time of the testing. Additional development has occurred since the date of testing and products evaluated today will likely perform differently than at the time of these tests. This report, therefore, should be viewed as a guideline for the types of tests to be performed and possible artifacts that may be visible. The World Broadcasting Unions (WBU), the North American Broadcasters Association (NABA), and CBC/Radio-Canada do not endorse nor make any recommendation as to manufacturer or weighting of any type of artifact against another. The users of this report are therefore advised to take the information provided herein and evaluate for themselves the potential selections in conjunction with their own business needs.

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1 Scope

The scope of this investigation is to assess the technical and subjective quality of different High Definition motion compensated standard converters. The goal is to identify a suitable high definition standard converter for sports application and general use.

Criteria of performance:

- Video quality performance
- Ability to change frame rate standards without creating jerkiness (smooth motion) in video.
- Ability to transport audio in sync with video.
- Ability to conserve sharpness during camera movement on sport advertising / sponsorship.
- Ability to minimize motion-related artifacts
- Ability to perform with scene changes

2 Standard Conversion

Standard conversion is the process of converting video from different frame rate standard. This process can sometime require a conversion in the resolution of the video (ie: 525 to 625, 720p to 1080i). This process is now being used in many different applications that use high definition content, from converting soap to sports.

In the high definition domain, the amount of information has now increased significantly and put a lot more stress on the algorithms used by these units. The advantage is that there is more information to make the right motion estimation. High definition is also fixed in the color encoding and resolution. This means that there is no color encoding conversion and resolution change when converting two high definition signals (unless there is a cross conversion).

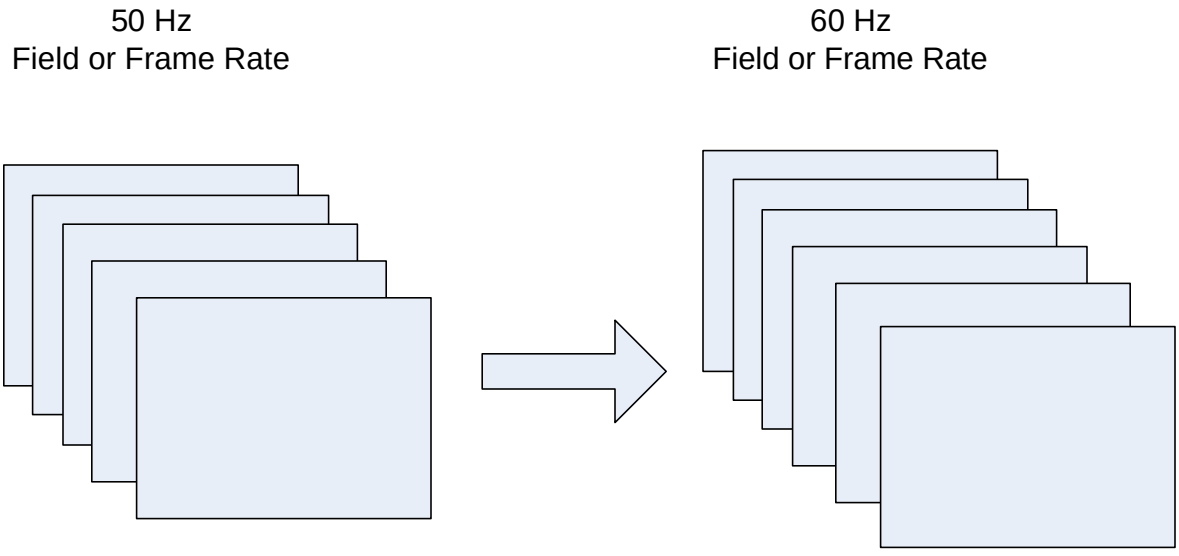


Figure 1: 50Hz to 60Hz frame rate conversion

3 Evaluated Manufacturers

The following four manufacturers were evaluated:

- [redacted]
- [redacted]
- [redacted]
- [redacted]

4 Test Sequences

4.1 Material submission

Many parties provided native format images (in all 4 HD formats) for the purpose of this evaluation. Material was very broad in content. From sports to drama including graphics and awards shows. The quality of the material was also excellent.

4.2 Test Sequence Editing:

The editing of the subjective viewing was done by using the ITU-500 standard as a reference point (major guidelines were followed). This means that 10-second clips were presented to the viewers separated by 3sec of mid grey. Clip A – 3s mid grey – Clip B – 3s mid grey – Clip C – 3s mid grey – Clip D. Each segment was separated by a 10sec mid-grey to allow voting time for the participant. The actual editing was done uncompressed on an AVID Symphony Nitris workstation.

Four tests sequences were created in the four following High definition formats with native material only.

- 1080i/25
- 1080i/29.97
- 720p/50
- 720p/60

Figure 2: Test sequence text overlay

Figure 3: Subjective viewing test sequence

The Clips where organized “random fashion” to enable 4 comparisons.

4.3 Subjective Viewing :

The viewing setup was always composed of 1-4 viewers sitting in a half circle at about 3 times the horizontal height of the monitor. The lighting was dimmed to a low level. The viewing monitor was a Sony professional BVM 24” HD monitor. 30 people attended the viewing. Each viewer was given written instructions and asked to identify the best subjective image.

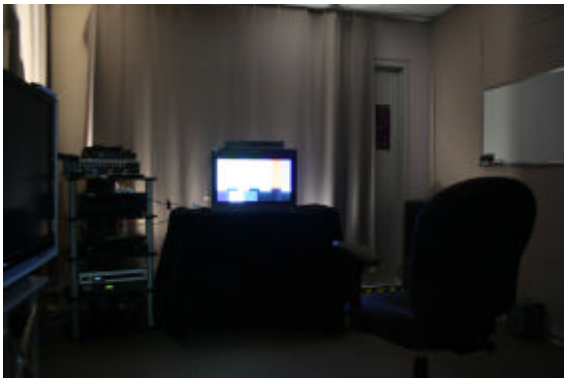
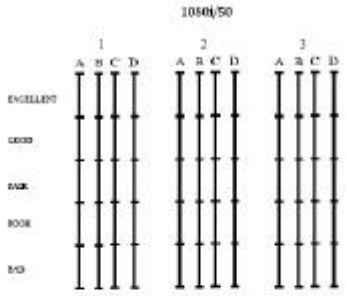


Figure 4: Viewing Room

5 Instructions and Voting Process

A copy of the instruction sheet that was provided to the viewers is available in Appendix, including the score sheet. A total of 32 segments were presented to the viewers. The duration of the viewing session was about 45 minutes.

Viewers were asked to rate the overall perceived picture quality.



6 Technical Evaluations

6.1 Introduction:

Each converter was evaluated technically for standards compliance and other technical aspects. These results were recorded on a result sheet for each manufacturer (available in the Appendix). Technical aspect such as power usage, rack space, standards converted and other technical specification were also noted. For each manufacturer, here under is a summary of this information (including problems that were noticed in the evaluation process).

6.2 Technical Specifications:

6.2.1 Manufacturer A:

The manufacturer A supports regular standard conversion formats. On the other hand, it does not support cross-conversion (in between 720 and 1080i). It was the only converter that supports 23.98psf to 59.94i motion compensated standard conversion. The user menu is very simple and easy to understand and it's controlled via a rotary button under the front panel. All technical aspects of the unit were in respect with industry standards including audio lip-sync.

			OUTPUT							
			1080i		720p		SD		psF	
			50i	59.94i	50p	59.94i	576/50i	480/59.94i	1080/23.98p	720/23.98p
INPUT	1080i	50i		MC	---	---	---	---	MC	---
		59.94i	MC		---	---	---	---	---	---
	720p	50p	---	---		MC	---	---	---	---
		59.94p	---	---	MC		---	---	---	---
	SD	576/50i	---	---	---	---		---	---	---
		480/59.94i	---	---	---	---	---		---	---
	psF	1080/23.98psF		MC						
		720/23.98psF								

Table 1: Manufacturer A conversion table (*MC: Motion Compensated)

6.2.2 Manufacturer B:

The manufacturer B supports all regular standard conversion formats and cross conversion. An interesting fact is that the unit will support dual conversion capabilities in future versions. This will permit both output to have different formats (SD and HD simultaneously without using an external downconverter). The user menu is controlled via a touch screen and has a very graphical approach. This menu system would be very easy to use in a post-production application where many changes of settings are required. All parameters can easily be verified on the display's main page.
The unit did not respect SMPTE return loss standards on both output (levels of -12db). The audio was out of sync by -25ms (not a significant error) and this was easily corrected by applying a delay in the audio delay setting of the unit (This was not tested for all conversion formats)

			OUTPUT							
			1080i		720p		SD		psF	
			50i	59.94i	50p	59.94i	576/50i	480/59.94i	1080/23.98p	720/23.98p
INPUT	1080i	50i		MC		MC	---	Future	---	---
		59.94i	MC		MC		Future	---	---	---
	720p	50p		MC		MC	---	Future	---	---
		59.94p	MC		MC		Future	---	---	---
	SD	576/50i	---	Future	---	Future	---	Future	---	---
		480/59.94i	Future	---	Future	---	Future	---	---	---
	psF	1080/23.98psF	---	---	---	---	---	---	---	---
		720/23.98psF	---	---	---	---	---	---	---	---

Table 2: Manufacturer B conversion table

6.2.3 Manufacturer C:

The manufacturer C supports all regular standard conversion formats and cross-conversion except for 720p50 (note: 720p50 is now fully supported by the unit since October 2007). At the time of evaluation, embedded audio was not supported (Embedded audio is now supported since October 2007). The interface requires the manufacturer remote's control panel to effectively control the unit. The unit is also a typical 3 RU rackmount card system that requires 3 cards (The converter, the motion compensation unit and the audio interface card). The unit did not respect SMPTE return loss standards on both output (levels of -10.6db & -11.5db). *note: 720p50 is now supported since October 2007*

			OUTPUT							
			1080i		720p		SD		psF	
			50i	59.94i	50p	59.94i	576/50i	480/59.94i	1080/23.98p	720/23.98p
INPUT	1080i	50i		MC	---	MC	---	MC	---	---
		59.94i	MC		---		MC	---	---	---
	720p	50p	---	---	---	---	---	---	---	---
		59.94p	MC		---		MC	---	---	---
	SD	576/50i	---	MC	---	MC	---	MC	---	---
		480/59.94i	MC	---	---	---	MC	---	---	---
	psF	1080/23.98psF	---	---	---	---	---	---	---	---
		720/23.98psF	---	---	---	---	---	---	---	---

Table 3: Manufacturer C Conversion table

6.2.4 Manufacturer D:

The manufacturer D supports all regular standard conversion formats and cross conversion. The unit does also support 720p50. The unit did not respect SMPTE return loss standards on both output and input (levels of -9.6257db/-11.208db for output and -10.27db for input).

			OUTPUT							
			1080i		720p		SD		psF	
			50i	59.94i	50p	59.94i	576/50i	480/59.94i	1080/23.98p	720/23.98p
INPUT	1080i	50i		MC	---	MC	---	MC	---	---
		59.94i	MC		MC		MC	---	---	---
	720p	50p	---	MC		MC	---	---	---	---
		59.94p	MC		MC		MC	---	---	---
	SD	576/50i	---	MC	---	MC		MC	---	---
		480/59.94i	MC	---	---	---	MC		---	---
	psF	1080/23.98psF	---	---	---	---	---	---		---
		720/23.98psF	---	---	---	---	---	---	---	

Table 4: manufacturer D conversion table

6.3 Motion Compensation Algorithms:

When working with motion compensation techniques, there is no “perfect” solution. All these methods give better results than a fixed interpolation technique (4 field averaging method) but the motion compensation still has to create new frames based on your best “estimation” of what a frame should have looked like. Each method will show signs of artifacts (different in nature from different algorithms) under specific conditions. Therefore, each motion compensation algorithm is a compromise for best quality.

6.3.1 Manufacturer D:

The manufacturer uses a motion vector algorithm for its motion compensation. A motion vector algorithm can either work globally to compensate for a dominant motion only or can be estimated separately for each pixels. A pixel based algorithm requires a significant amount of memory and processing power to properly identify each motion vectors. These vectors can have errors and will sometimes be corrected by statistical methods or by comparing neighbouring vectors.The limited memory size and speed of the chipsets from this product when it was developed a few years back limits the maximum usable motion vectors. The manufacturer recommends turning-off the scene detection mode in order to free up has much memory for the actual motion compensation (This should increase the quality of the video). This type of algorithm will create ghosting artifacts that are common on regular standard converter.

Figure 5: Ghosting artifact

6.3.2 Manufacturer A:

The manufacturer A uses a block matching method for its motion compensation algorithm. It can easily be compared to MPEG2 encoding with regards to working with blocks and applying motion vectors. The majority of the motion compensated systems use block matching motion estimator with added initial motion prediction to reduce the processing workload. This method works well with sequences where the motion is translational. These methods do not take into account multiple motions vectors in a single block resulting in motion artifacts. Motion block matching methods have been used for years in video compression and many different algorithms exist based on this technique. Techniques such as variable size block matching help increase the quality of such algorithm. For these types of motion estimators, most problems occur around the edges of moving objects. This is due to the fact that the object edges do not coincide with the block boundaries used in the motion estimator. This becomes more evident when an object is uncovering or covering another object. If they are not well corrected, the calculated motion vectors entropy will increase with objects that are periodic in nature or objects that increase in size with a non unidirectional motion vector (ie: race cars going around an hairpin turn).

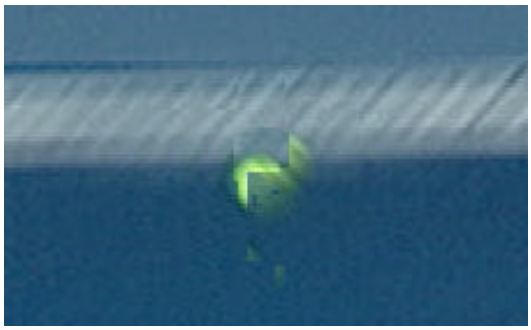


Figure 6: Blocking artifact

6.3.3 Manufacturer C:

The manufacturer C is based on a motion compensation designed by [redacted]. The motion compensation system is an added card into the frame that does motion estimation on the video and sends the data vector back to the converter card. This system is designed on a hierarchical block matching system. Instead of square blocks, the unit works with circular shapes of different sizes (hierarchical model). The estimate from the coarser block is first used to evaluate the general motion of the image structure; finer blocks are then used to correct the motion vectors creating a resolution pyramid. The approach can be used either as coarse to fine or vice versa. This method combined with a circular shape matching system will create artifacts that are circular in shape.

Figure 7: circular shape artifacts

6.3.4 Manufacturer B:

The manufacturer B uses an algorithm that works in the frequency domain (Phase Correlation). This technique was originally worked on in the 70s by the BBC R&D. An FFT is applied to the signal in order to retrieve a correlation surface to locate the motion vectors. The accuracy of the vectors can be as good as 1/10th of a pixel using proper interpolator (Other block matching techniques will have ½ or 1/4th of pixel). This method will actually measure the vector of moving objects instead of estimating the movement. Motion vectors still have to be corrected for appearing and disappearing objects. This method seems to work effectively well with high motion content. Unlike other motion vector calculating methods, the phase correlation technique is not easily fooled by objects that have rotational or spiraling motions. This method will create breaking artifacts (also common with other manufacturer).

Figure 8: Breaking artifact

6.4 Scene Change Detection:

The ability to detect a scene change and to recreate a clean cut from frame A to frame B is a very complicated and a processing intensive task. During the evaluation process we looked at each unit with respect to scene detection. For each standard converter, we looked at how the unit handled a clean cut from two distinctive content (All cuts were on Field 1 for the original interlaced material). We also looked at were the unit was inserting the scene cut (Field 1 or Field 2). A second test was also done using similar images with scene cut (17 camera changes using the snowboard scenes from the Olympics). This test is referred to as “intra sequence scene cut detection”.

Figure 9: Scene change overlap

Note on field dominance:
Special attention should be paid to post-production application of standard converter. Field dominance in interlaced material can become problematic. If your editing content on scene cuts that are a different field dominance than your editing station (Most, if not all, editing system will work with a Field 1 dominance) you can have flash frames. Manufacturer B is the only manufacturer that implemented a field dominance setting in their unit that would permit having all scene cuts on a specific field dominance (This feature was “turned on” during testing and we had scene cuts on both fields (this feature was therefore not functioning at the time of the evaluation). A field dominance feature is also directly related to it’s ability to detect the actual scene cuts. Avid proposes a lengthy work-around on their editing platform for field dominance problems when editing.

6.4.1 Scene cut results:

In order to analyse the scene cut detection performances of each converter, we took our original video content and looked at how each manufacturer performed for each scene cut. We only looked at cuts from different scenes (the content was very different in nature). Note: the version tested of manufacturer C did not support 720p50 at the time of the test.

1080i60 to 1080i50		
	Original	**detected**
Manufacturer A	16	16
Manufacturer B		15
Manufacturer D		9
Manufacturer C		15
1080i50 to 1080i 60		
	Original	**detected**
Manufacturer A	10	10
Manufacturer B		9
Manufacturer D		4
Manufacturer C		9
720p60 to 720p50		
	Original	**detected**
Manufacturer A	4	4
Manufacturer B		3
Manufacturer D		4
Manufacturer C		N/A
720p50 to 720p60		
	Original	**detected**
Manufacturer A	5	5
Manufacturer B		4
Manufacturer D		1
Manufacturer C		N/A

Table 5: Standard Converter scene cut detection performance table

6.4.2 Intra Sequence Scene Cut Detection:

In this second test, we used a clip at 1080i50 of a snow boarder going down a ski slop with 17 camera changes from the top of the hill to the bottom. This content was very similar from one scene cut to another, making it more difficult to detect.

Results:		
	Original	detected
Manufacturer A	17	17
Manufacturer B		15
Manufacturer D		0
Manufacturer C		8

Table 6: intra sequence scene cut performance

6.5 Film Material Detection:

All four manufacturers were tested for 24p material handling (24p material inside a 59.94 frame rate). None of the converters detected a 24p sequence correctly. All of them created severe artifacts when dealing with this type of material.

7 Viewing Analysis

7.1.1 General image content:

For general content, the standard converters evaluated gave comparable results. When differences where noticeable the results were very different and directly dependent to the type of images converted. Under very specific image conditions, theses results were completely different depending on the image content. What can be said for a specific condition might be the opposite on a different scene. This report refers to general type of content has image conditions that include graphics, beauty shots, slow to medium motion content, aerial shots and logo animation. This includes a significant portion of broadcast material. If differences could be noticed under freeze conditions, they were most of the time, unnoticeable at normal playing speed.

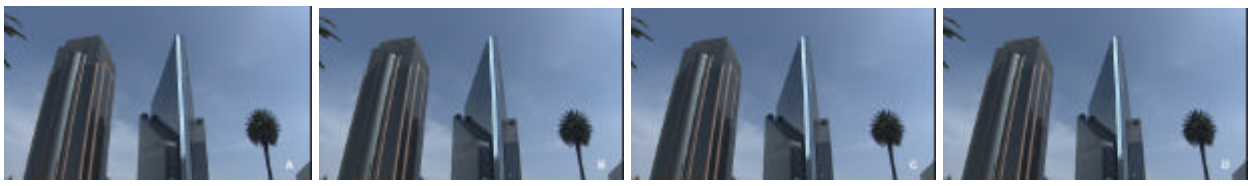


Figure 10: general content comparison

7.1.2 Sports / High Motion Content:

For sports and high motion images, the results from the different standard converter were very different. That being said, behavior was different based on the content processed. All four manufacturers showed problems with different type of conditions.

8 Issues & improvements

8.1 Downstream Video Compression Problem:

When dealing with video compression downstream of the standard converter (concatenation of standard converter and encoder), the overall image quality drops to a very poor level. This serious problem is not addressed by any of the manufacturer. The amount of information and motion vectors that the compression engine has to deal with requires its processing power. The encoder is dealing with such stressful images that it's relying mostly on image compression. The resulting video is marginal and very blocky.

Figure 11: Uncompressed converted video

Figure 12: Compressed converted video (ATSC encoding)

8.2 Manufacturer D:

8.2.1 Image Contouring Problem:

The unit will exhibit contouring problems when dealing with a very fast blurred moving background.

Figure 13: image contouring problem

8.2.2 Scene Cut Problem:

The unit will exhibit a vertical line when scene cut detection is turned on and when the algorithm is stressed by high motion.

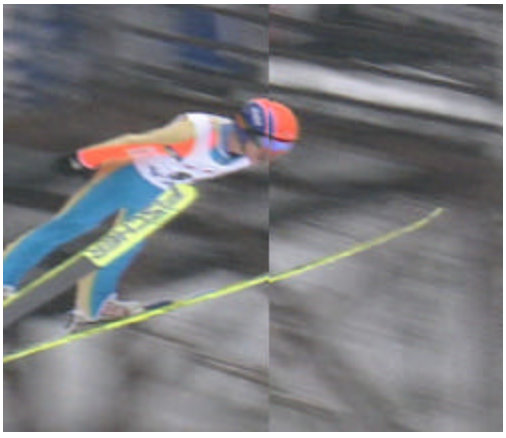


Figure 14: scene cut problem

8.3 Manufacturer B:

8.3.1 Buffer Management Problem:

The unit will go back 6 fields and jump back to the current frame. (happened 3 times over a 1 hour period)

Figure 15: buffer management problem

8.3.2 Noise Artifact Problem:

The unit will exhibit noise around objects with line patterns.

Figure 16: Noise artifact problem

8.3.3 Breaking artifacts problem:

The unit will exhibit breaking artifacts when an object is traveling across at a certain speed.

Figure 17: Breaking artifact problem

8.4 Manufacturer C:

8.4.1 Circular Artifacts Problem:

The unit will sometimes exhibit circular artifacts when stressed with high motion content.

Figure 18: Circular artifacts problem

8.5 Manufacturer A:

8.5.1 Flicker Problem:

The unit will exhibit flicker on certain scenes.

Figure 19: Flicker problem

8.5.2 Moving Background Problem:

The background will follow a moving object. (Happened once on specific scene)

9 Conclusion

The general conclusion that came out of this evaluation was that for general content, all four manufacturers are suitable for broadcast applications. When we are dealing with sports and high motion images, all four manufacturers show significant signs of problems. These problems will be directly linked to the content that the converter needs to process. Each manufacturer will respond differently to the same video when dealing with such content.

When dealing with video compression downstream of the standard converter (concatenation of standard converter and encoder), the overall image quality drops to a very poor level. This serious problem is not addressed by any of the manufacturer. The amount of information and motion vectors that the compression engine has to deal with requires its processing power. The encoder is dealing with such stressful images that it's relying mostly on image compression. The resulting video is marginal and very blocky.

Actions taken:

Manufacturers were informed of the different problems that were encountered during the evaluation process with their units. Manufacturers had already addressed some of these problems.

Manufacturer C now supports 720p/50 and has audio capabilities to support embedded audio. (Both these features were re-tested)
Manufacturer B claims that the buffer problem and the noise artifact problem have been addressed (This was not re-tested).

APPENDIX

Scoring example

1080i/50