FRAME RATE CONVERSION IC FOR FULL HD 120 HZ LCD FLAT PANEL DISPLAYS

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Abstract

New display technologies including LCD and plasma panels and Digital Light Projection (DLP) systems all offer large screens and impressive picture quality. However, flat-panel displays require a sophisticated picture processing to let these panels perform at their optimum levels. This paper explains why motion compensating techniques combined with frame rate conversion and quasi-impulse driving reduces motion blur and film judder for flat panel displays and presents the IC and its system application using this technique.

1. Introduction

The LCD is a hold type display that always emits light. Therefore, even if the response time speed of the liquid crystal is improved, motion blur will remain due to afterimage in the observers' retina. On the other hand, motion blur is not generated from the impulse type display CRT due to cancellation of the retina afterimage influence within the 50/60 Hz refresh time. In case of film sources with 24/25/30 Hz refresh rates, this assumption is not still valid, even for CRTs ([1], [2], [3], [5]).
The reduction of motion-blur and film judder is therefore essential for large screen LCD displays. One key for motion-blur reduction are high refresh rate LCD panels, which are available now also for Full-HD resolution ([7]). Another key is the video processing IC for converting the video content with 24/25/30/50/60Hz to 100/120Hz. Most of the existing motion compensated solutions don't care about video (50/60) or film (24/25/30) content, where our solution is explicitly optimized for the different input formats ([4-7]). Only the direct conversion from 24/25/30 Hz to 100/120 Hz can remove the film judder and reduce the motion blur. Furthermore it can be shown, that the combination of motion compensation and quasi-impulse driving still can improve the motion blur reduction. The latter combination can be realized completely using digital signal processing and no special backlight technology is needed.

2. Experimental

The hold-type nature of the LCD technique is the major reason for the motion blur. In figure 1 a moving object is used in order to explain the problem of motion blur [1] and its solution. The object (white bar, black background) is moving from right to left with a constant speed. The human eye follows this movement. Due to the eye's integration function the brightness is integrated over the time. The figure 1 illustrates the human perception watching a CRT and an LCD at a video source. Due to the short impulse the CRT motion is perceived as sharp. In contrast the LCD holds the picture. The brightness is integrated and the object seems to be blurring.

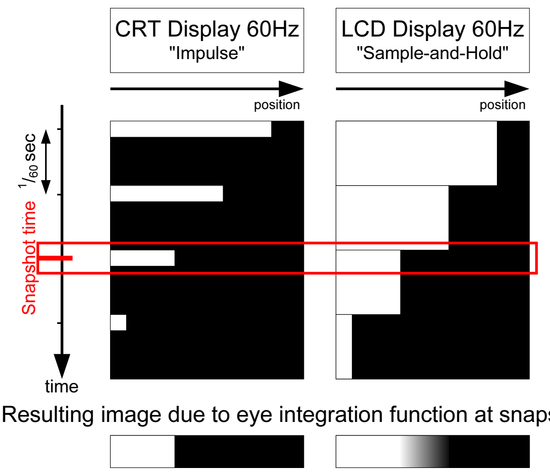

Fig. 1. Comparison between CRT display and LCD, video source.

The example above deals with a video source. Even more critical is a film source. Film sources are normally transmitted using pull-down techniques. Most common are the 2-2 pull-down and the 3-2 pull-down. The source material is sampled at a lower rate, on 2-2 pull-down at 25Hz for 50Hz or at 30Hz for 60Hz displays, on 3-2 pull-down at 24Hz for 60Hz displays. Then, each sampled picture is multiple displayed to fit the video frame rates of the target display.

The human eye tracks the object. Due to the non-continuous motion the CRT display shows some artifacts.

Indeed the impulses are sent with 60Hz, but on 2-2 pull-down the motion changes only with 30Hz. This causes a motion judder, potentially shown as doubled contour or slight blur. However, the picture is perceived sharply. In contrast to the CRT the LCD holds a value over the time. But the 2-2 pull-down causes a doubled hold time compared to video sources. Due to the integration function of the human eye the brightness is integrated over the doubled time, like illustrated in figure 2.

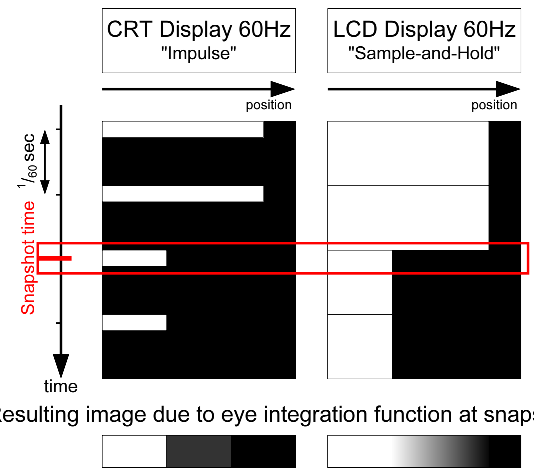

Fig. 2. Comparison between CRT display and LCD, film source.

To improve the motion blur, some articles propose to approximate the behavior of the CRT (for a comprehensive overview see [5]). A simple approach is to double the frame rate of the picture e.g. from 60 to 120 Hz and to insert black pictures or to switch off the backlight for a certain time (*High Refresh Rate Driving combined with Impulse Driving,* see figure 3). So the motion blur will be reduced due to less integration time during the increased black phase. But also the overall brightness and contrast will be reduced and ghosting will happen. To keep the same overall brightness and contrast, the intensity of the backlight has to be increased for the same ratio. This may be possible in the future with LED backlight. But the picture frame rate stays still nearly at 60 Hz and with increased brightness the large area flicker will be more visible.
In case of 50 Hz input signals large area flicker is much more annoying using the techniques described before.

More advanced techniques use motion adaptive processing methods to generate 120 frames out of 60 frames [3, 4, 5]. Figure 4 shows the so called *Quasi Impulse Driving* method (also called alternate frame driving or flexible data insertion). The same data is presented twice in each input interval (e.g. 60 Hz), once at bright gamma or luminance and again at dark gamma or luminance, mixing each to achieve the target gamma or luminance. Its main advantage is that it does not require a source of motion interpolated frames. Its disadvantage is an inability to eliminate motion blur in cases where there is significant high luminance content. Some publications mention a decreasing factor of motion blur of 26% [6]. A big drawback for this approach is that quasi-impulse driving does not work for film sources.

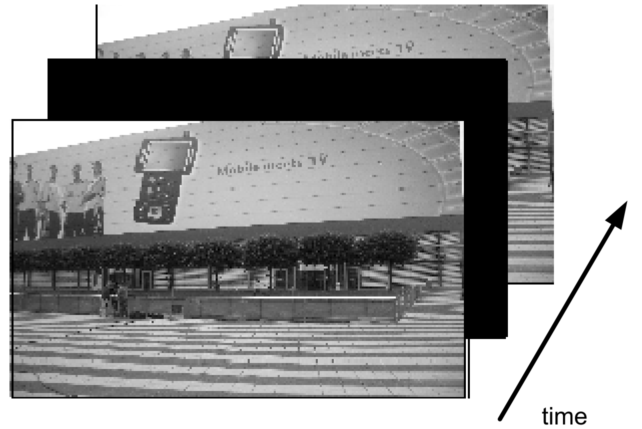

Fig. 3. Black Frame Insertion.

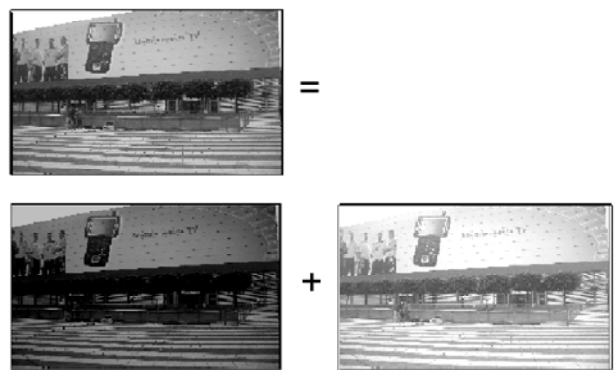

Fig. 4. Quasi Impulse Driving

Up to now only video sources were taken into account. If film sources are investigated, which may transmitted by using pull down techniques (2-3 for 24 Hz sources to 60 Hz or 2-2 for 25/30 Hz to 50/60 Hz), the above techniques will be less useful.

But only a frame rate conversion process with insertion of motion compensated pictures at the right position can solve the problem independent of the source frame rate. The achievable results of this technique will be described in the next section.

3. Results and discussion

Motion compensated frame rate techniques are well known from 100Hz interlaced Television systems ([8, 9]). This technique was developed for double scan CRTs to remove the motion blur and double contour effect resulting from the frame rate conversion from 50 fields to 100 fields. Here the motion blur occurred due to showing the same field at the same position twice (simple conversion from 50 to 100 fields by repeating).

The motion compensation system can generate new images to give true frame-rate conversion, yielding for example 100/120 unique frames per second. With these unique frames the motion blur can be removed for CRT displays, but for hold type displays, too.

Applying the motion compensation to a conventional display when displaying a video source has no advantage to the motion blur. No new image positions must be created. But if the frame rate is doubled, the hold time of the images is halved using frame rate conversion (120 frames are generated out of 60). Furthermore the generated images show true motion due to the motion compensation technique, which reduces the eye integration effect. This altogether reduces the motion blur and improves the overall sharpness of the display.

Even more visible is the effect for film sources, like shown in figure 5. Already when applying the motion compensation to a conventional 60Hz LCD display the integration time can be halved. The 30 motion steps per second are doubled to full 60 motion steps per second. The motion blur is reduced to the same level like on video sources. Using advanced 120Hz LCD displays the motion compensation converts the available 30 frames per second to full 120 frames per second. So the eye integration time is reduced dramatically by factor 4 compared to conventional display techniques.

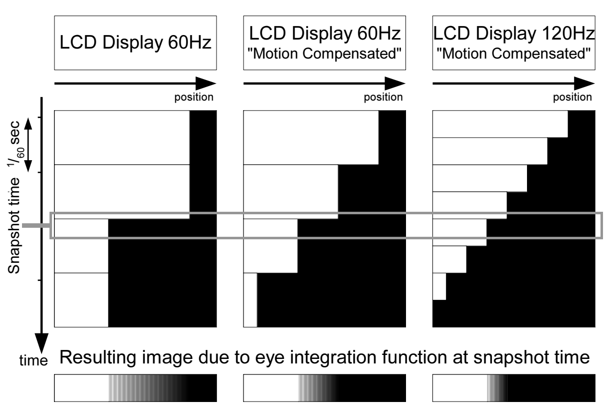

Fig. 6. Motion compensation on conventional 60Hz and advanced 120Hz LCD's, film source.

By combining the motion compensated 100/120Hz signal with the quasi-impulse driving approach, the result of the motion compensated algorithm can again be improved and finally it works also for film sources. In our approach the changing of the gamma or luminance is not constant, but depends on global motion of the images objects (G-QID, Global QID). A further big advantage is that the approach does not require sophisticated and fast switching backlight technology, because the complete processing is done with digital signal processing. A further development of the approach takes local impulse driving into account (L-QID). In this approach, only for the motion area the impulse driving scheme is applied. The concept will be explained in figure 6. First the input signal is frame rate converted. Second the image is applied to a non-linear transfer curve. The transfer curve is frame-periodically changed between the upper and lower curve. The gain of the curves depends on the motion values in the input image.

TABLE 1. Comparison of different methods

Technology (all for High Refresh Rate Panels)	Black Frame Insertion [5]	Black Band Cycling [5]	Global Quasi Impulse Driving [5]	Motion compensation + Global-Quasi Impulse Driving
Difficulty	Moderate	Moderate	Moderate	Difficult
Effectiveness	Good	Better	Better	Best
Disadvantage	Luminance Lost Flickering & Ghost No film sources	Luminance Loss Flickering & Ghost No film sources	Luminance Loss Not working for film sources	Very good motion compensation techniques required

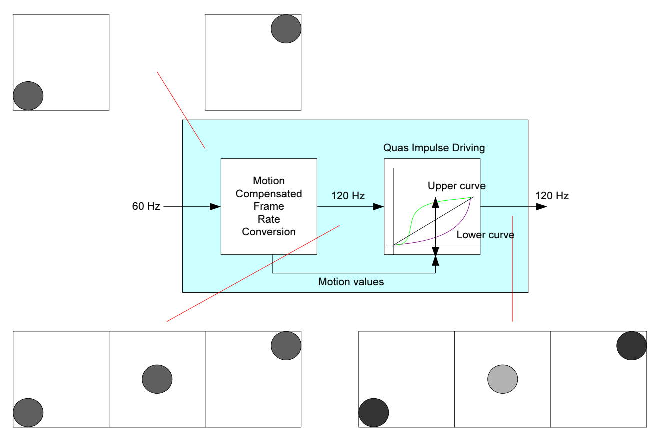

Fig. 6. MC+G-QID/L-QID concept.

4. Architecture and application of the IC

The IC is available now and its working up to Full-HD, 1920x1080p@100/120 Hz signals. In fact this means an output pixel clock of 297 MHz, which is a challenging task for the current submicron technologies. The IC has a dual LVDS receiver for accepting 1920x1080p@50/60Hz input signal and a quad (2 times dual) LVDS-TX to drive the latest high refresh rate panels. So the existing TV chassis applications can be easily upgraded from Full-HD 50/60 Hz panel to Full-HD 100/120 Hz panels.

A further advantage of the IC is the separate graphics input. The graphic is mixed to the video signal after the motion compensation process. This offers better overall performance, because transparent graphic is very difficult for the video algorithm.

The architecture of the IC consists of the conceptual blocks (see figure 7):

- LVDS RX

- Memory Manager
- Motion Compensation, Frame Rate Converter and De-interlacer/Scaler
- Picture Improvements and Graphic Mixer
- LVDS TX

The IC supports the input sources at frame rates 24p, 25p, 30p, 50p, 60p, 50i, 60i up to HDTV resolution with 1920x1080 pixels.

The motion compensation and frame rate conversion technique can be applied to all these formats to convert them e.g. to 1920x1080@120p for advanced LCD's, respectively. The IC needs only one external DDR memory.

So the IC fits very well in existing chassis concepts, which target on LCD's with 1920x1080 panel resolution. Figure 8 explains how to design the IC into an existing chassis concept. The approach can be chosen for any conventional LCD with resolutions up to 1920x1080 pixels.

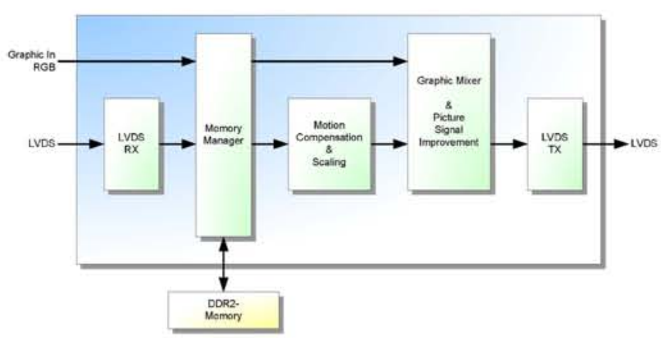

Fig. 7. IC architecture concept.

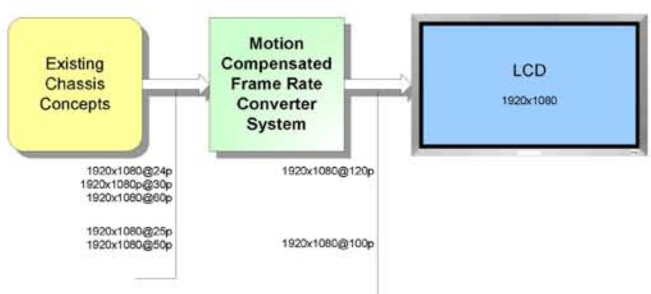

Fig. 8. Application of the IC within existing chassis concept.

5. Summary

Flat-panel displays today challenge the superiority of CRTs on many levels, and some of the latest and largest models deliver eye-popping high-definition images. Getting the best picture from these panels requires the very best upstream electronics. Motion compensation together with frame rate conversion technology and motion adaptive global or local quasi-impulse driving seeks to provide a sophisticated methodology to reduce the motion blur, still a major draw back compared to CRT displays. This is a difficult algorithm to realize, due to the known problems of occlusion for motion compensated solutions. We could solve this problem satisfyingly for TV customer applications. Especially for large displays the film judder effect is also a disadvantage. With the same approach for reducing the motion blur effect, we can solve the film judder problem.

6. References

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