Technology Trends
Display-Use ICs

A Frame Rate Conversion IC for 120Hz Flat Panel Displays

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New display technologies including LCD, plasma and Digital Light Projection (DLP) all offer large screens and impressive picture quality. However, flat-panel displays require sophisticated picture processing to let these panels perform at their optimum levels. This article explains why motion compensation techniques combined with frame rate conversion reduce motion blur in flat-panel displays. It presents an IC, the FRC 9449H, that implements this technique for high-quality de-interlacing and frame rate conversion, including picture scaling and improvement capabilities for HDTV panels.

Introduction

Video images are usually transmitted in interlaced format. Each field contains only the even or the odd lines of the picture. Unlike traditional CRTs, which display these interlaced fields exactly, modern flat-panel displays, especially LCDs and DLP screens, show only progressive-scan images. This requires an efficient de-interlacing algorithm. Micronas previously has presented a short overview of de-interlacing methods[1].

Another essential difference arises from the kind of pixel illumination. A CRT lights each pixel briefly with an electron beam. The period of persistence depends on the residual glow of the phosphor when stimulated. The illumination can be described mathematically by an impulse function.

Pixels on LCD panels are illuminated digitally. Simply put, they are set to a specific intensity, and they hold this value until the value is changed again. Ideally, this behavior is identical to a "sample-and-hold" or box function. Of interest is the hold time – the duration that a pixel is being lit. Other aspects of a non-ideal behavior like the response time will not be discussed here.

Differences in the behaviors of displays are evident in their frequency responses (Fig. 1). The CRT’s short impulse has a wider frequency response than the wide, rectangular pulse of the flat panel. Thus, CRTs have a higher potential than flat panels for presenting sharp moving images.

It is obvious that the LCD’s image becomes sharper as the hold time gets shorter. The hold time influences the image's edge sharpness for all time-variant picture material containing motion. This article will focus on the resulting motion blur of edges for moving objects.

Figure 2 shows a moving object, to explain the problem of motion blur and its solution. The magnified part of a moving object, resulting in a white vertical bar, is moving from right to left at constant speed over time. The camera’s sampling process produces a series of discrete pictures that show the bar at varying positions. The human eye follows this movement. Due to the eye’s integration function, the brightness is integrated over time.

Figure 3 illustrates the difference in effect on human perception between watching the same video source on a CRT and on an LCD. Because of the short impulse, the CRT motion is perceived as sharp. In contrast, the LCD holds the picture. The brightness is integrated by the eye and the object seems to be blurring.

The example above deals with a video source. Film sources are even more critical. Film is usually shot at 24fps, and must be adapted to the 25Hz or 30Hz broadcast frame rate using pull-down techniques. The most common techniques are 2:2 pull-down and 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, or on 3:2 pull-down at 24Hz for 60Hz displays. Then each sampled picture is multiply displayed to fit the video frame rates of the target display.

Figure 4 shows that for a 2-2 pull-down and for the same average object speed as the previous example, the differences between neighboring object positions are twice as big.

The human eye tracks the object. Because of the non-continuous motion, the CRT display shows some artifacts. Indeed the impulses are sent at 60Hz, but on 2-2 pull-down, the motion changes only at 30Hz. This causes motion judder, typically shown as doubled contour or slight blur. However, the picture is perceived sharply. In contrast to the CRT, the LCD holds a value over time, but the 2-2 pull-down doubles the hold time compared to video sources. The integration function of the human eye integrates the brightness over the doubled time, as illustrated in Figure 5.

To improve the motion blur, some design techniques approximate the behavior of the CRT. A simple approach is to double the frame rate of the picture e.g. from 60 to 120Hz and to insert black pictures, or to switch off the backlight for a certain time. Thus, the motion blur will be reduced because of the shorter integration time during the increased black phase.

However, the overall brightness and contrast will be reduced, which is not acceptable. To keep the same overall brightness and contrast, the intensity of the backlight has to be increased by the same ratio. This may be possible in the future with LED backlights, but in any case, the picture frame rate still stays at 60Hz. With increased brightness, the large-area flicker will be more visible. When using 50Hz input signals, large-area flicker is much more annoying using the techniques described before.

Therefore, this technique does not help for 50Hz sources at all. That is the reason some solutions simply convert 50Hz signals to 60Hz using frame repetition methods. This does not help because the integration time is increased and the motion blur and the motion judder will be increased too, as explained before. For film sources, which are transmitted by using pull-down techniques (2-3 for converting 24Hz sources to 60Hz or 2-2 for converting 25 or 30Hz to 50 or 60Hz), the above techniques will be even less useful.

More advanced techniques use motion-adaptive processing methods to generate 120 frames out of 60 frames. However, only a frame rate conversion process that inserts motion-compensated pictures at the right position can solve the problem independently of the source frame rate. This technique will be described in the next section.

Motion Compensation

Motion compensation techniques are well known from 100Hz interlaced television systems. These techniques were 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 occurs when showing the same field at the same position twice, the result of 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 or 120 unique frames per second. With these unique frames, the motion blur can be removed not only for CRT displays, but for LCD and DLP displays, too.

Figure 6 compares the conventional display technique with the motion-compensated technique applied to a 60Hz display, and with motion compensation in combination with an advanced 120Hz LCD. Applying the motion compensation to a conventional display when displaying a video source does not reduce the motion blur, because no new image positions need to be created. However, if the frame rate is doubled, the hold time of the images is halved using frame rate conversion (120 frames are generated from 60). Furthermore, the generated images show true motion with the motion compensation technique, which reduces the eye integration effect. Altogether, this reduces the motion blur and improves the overall sharpness of the display.

Even more apparent is the effect for film sources (Fig. 7). When applying the motion compensation to a conventional 60Hz LCD, the integration time can be halved. The 30 motion steps per second are doubled to a full 60 motion steps per second. The motion blur is reduced to the same level as on video sources. Using advanced 120Hz LCDs, the motion compensation converts the available 30 frames per second into a full 120 frames per second. Thus, the eye integration time is reduced by a factor of four compared to conventional display techniques.

This method of motion compensation is implemented in a single IC, the Micronas FRC 9449H. Some aspects of the implementation and application of the IC are discussed in the next section.

Architecture and Application

The architecture of the IC consists of the following conceptual blocks (Fig. 8):

Input Formatter

Memory Manager

Motion Compensation, Frame Rate Converter and Scaling

Picture Improvements and Graphic Mixer

Output Formatter.

The FRC 9449H supports input sources at frame rates of 24p, 25p, 30p, 50p, 60p, 50i, and 60i, and resolutions up to HDTV at 1,920 **x** 1,080 pixels.

The motion compensation and frame rate conversion technique can be applied to all these formats to convert them, for example to 1,920 x 1,080 at 60p for conventional LCDs or 1,280 x 720 at 120p for advanced LCDs. The IC is optimized for use with only one external DDR memory device. Graphics can be inserted through an additional on-screen-display interface. The graphics will be added on top of the video layer after the video frame rate conversion process, at full resolution.

The IC fits very well in existing TV chassis designs that target LCDs with 1,280 x 720, WXGA or even 1,920 x 1,080 panel resolution. Figure 9 shows how the FRC 9449H can be designed into an existing TV chassis architecture. This serial approach works for any conventional LCD with resolutions up to 1,920 x 1,080 pixels, and advanced 100 or 120Hz LCDs up to WXGA resolution.

Conclusion

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 provides a sophisticated method to eliminate motion blur. The technique presented here enables excellent reproduction of moving images, including precise reproduction of clean lines and edges, regardless of the format of the original source material. The technique also neutralizes shutter effects, generates more unique frames per second from film sources, and offers one of the best de-interlacing performances of any method developed so far. It has been implemented in the mass-produced Micronas FRC 9449H video processor IC.

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About this article:

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Captions

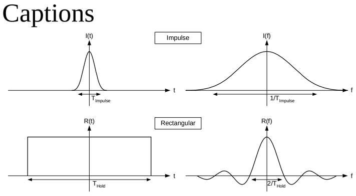

Fig. 1: Impulse (CRT) and rectangular sample-and-hold (LCD) behaviors and their corresponding frequency spectra

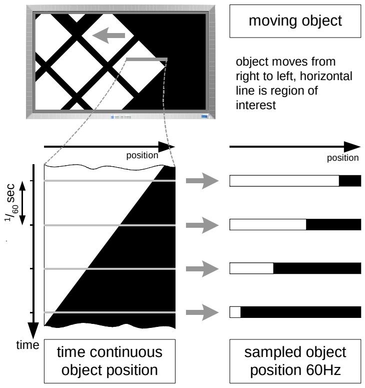

Fig. 2: Moving object with time-continuous and video camera-sampled positions

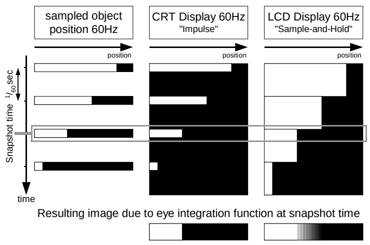

Fig. 3. Comparison of video source appearance on CRT display and LCD

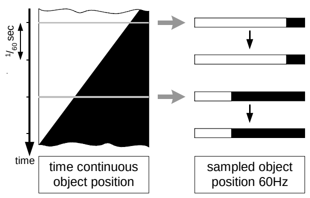

Fig. 4: Moving object with time-continuous and film camera-sampled positions (2-2 pull-down)

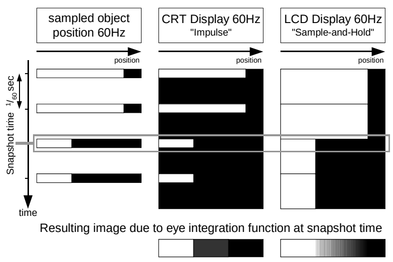

Fig. 5: Comparison of film-source appearance on CRT display and LCD

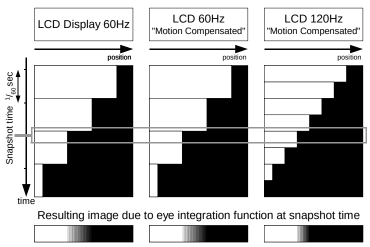

Fig. 6: Motion compensation for video sources on conventional 60Hz and advanced 120Hz LCDs

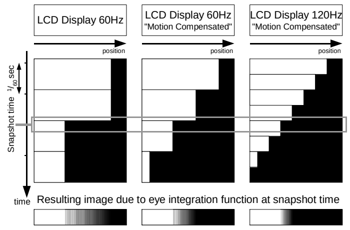

Fig. 7: Motion compensation for film sources on conventional 60Hz and advanced 120Hz LCDs

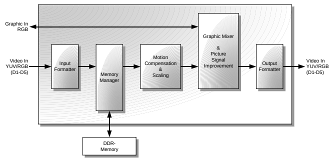

Fig. 8: FRC 9449H architectural concept

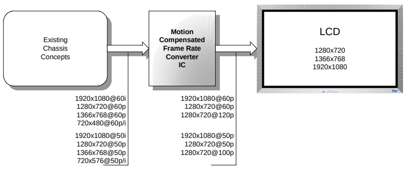

Fig. 9: Serial-mode use of the IC within an existing chassis