CRT-02: Television Sets with Ultra-Slim Transposed Scan CRTs

R.J. van Wesenbeeck, M. Bosma, I. Heynderickx, M.P.C.M. Krijn, E. Mastenbroek

Philips Research Laboratories, Eindhoven, The Netherlands

Abstract

Transposed scan is an innovation that paves the road to ultra-slim CRTs with deflection angles up to 135°. We discuss the integration of video transposition with the other video processing functions in the television set. An in-place transposition algorithm which minimizes the amount of frame memory is proposed as a low-cost solution for transposed scan conversion. The difference in visual perception of transposed scan and normal scan depends on the frame rate and the line density of the video format. We found that for high frame rates and high line densities, no difference was perceived for both scan modes.

1. Introduction

To remain competitive with emerging flat and thin display technologies, the trend in CRT (Cathode Ray Tube) design is towards picture tubes with flat face plates and reduced depth. For CRT manufacturers, simultaneously meeting the demands on picture quality is a big challenge.

Transposed scan (TS) is considered to be indispensable for ultra-slim CRTs [3]. In opposition to normal scan (NS), the lines are scanned in the vertical instead of in the horizontal direction. In addition to a better spot uniformity – the spot size at the borders is about the same as in the center of the screen – , evident advantages of transposed scan are a better manufacturability (exposure, landing), a lower dynamic focussing voltage, and lower power dissipation in the DY [4].

Because pictorial data is broadcasted as consecutive horizontal lines, transposed scan conversion has to be performed completely within the set. Frame memories and digital signal processing equipment for functions such as picture rate up-conversion and scaling, which are present in modern television sets, are a prerequisite for transposed scan.

In this paper, the implication of transposed scan for the video processing chain is discussed. An efficient algorithm that performs video transposition at minimum hardware costs is introduced. Furthermore, the perception of transposed scan is compared with the perception of normal scan video.

2. Video path of a TS television set

On going to transposed scan, the deflection circuitry must be adapted for the changed line and frame scanning amplitudes and frequencies. Because transposed scan has a positive effect on power dissipation, no significant problems are to be expected related to the CRT driving electronics.

More complex will be the integration of the transposed scan conversion function with the other digital video processing functions. Efficient algorithms and architectures to perform this task next to other digital video processing algorithms, leading to a minimum amount of image artefacts, are required.

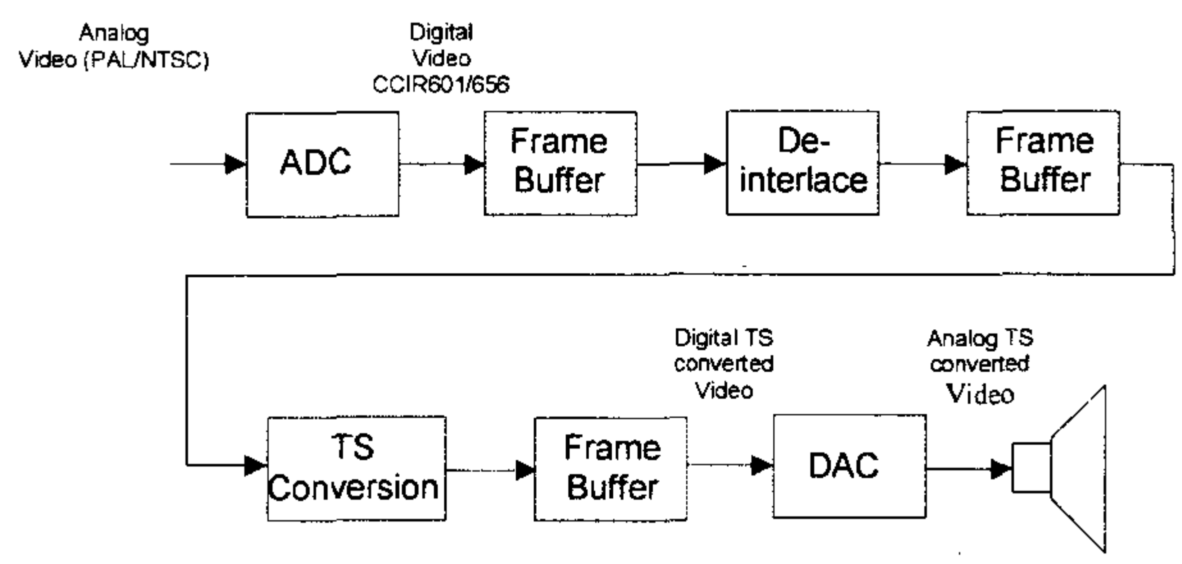

Figure 1. Basic processing steps to convert PAL or NTSC video to transposed scan.

The basic processing steps for transposed scan conversion are depicted in Figure 1. In case of PAL or NTSC interlaced input video, complete video frames must be reconstructed from the separate fields before transposition. This reconstruction process is called deinterlacing [2]. Two simple deinterlacing methods are field insertion and vertical temporal median filtering. More complex deinterlacing methods are based on motion compensation techniques.

In the television set, transposed scan conversion has to be integrated with the other digital video processing functions. In high-end and mid-range television sets, digital video processing functions such as motion estimated picture rate up-conversion, scaling, and split-window are common features. Teletext is present in nearly every European television set. In the end, the picture resulting from all these functions must be available in TS format.

The location of transposed scan conversion determines cost and complexity of the architecture embracing all the video processing functions. Digital memory is the main cost factor for the implementation of the transposition function. Therefore, transposition of the smallest possible frame size is preferred, which would imply immediate transposition of the incoming fields. Consequently, all subsequent video processing functions must be adapted for the transposed video format, leading to high re-design costs. As to re-design costs, the ideal location for transposition is at the end of the video chain. At this location however, the video signal may be HD, progressive, RGB, and at the double frame rate. Memory size and bandwidth are increased by a factor 12 and 24, respectively, increasing implementation costs.

Straightforward implementation of the transposition function requires two frame memories to store both an input and an output frame. In a so-called ping-pong configuration, into one memory a fresh frame is written, while another frame is read in transposed mode from the other memory. The roles of the memories are swapped for the next frame, and so on (Figure 2).

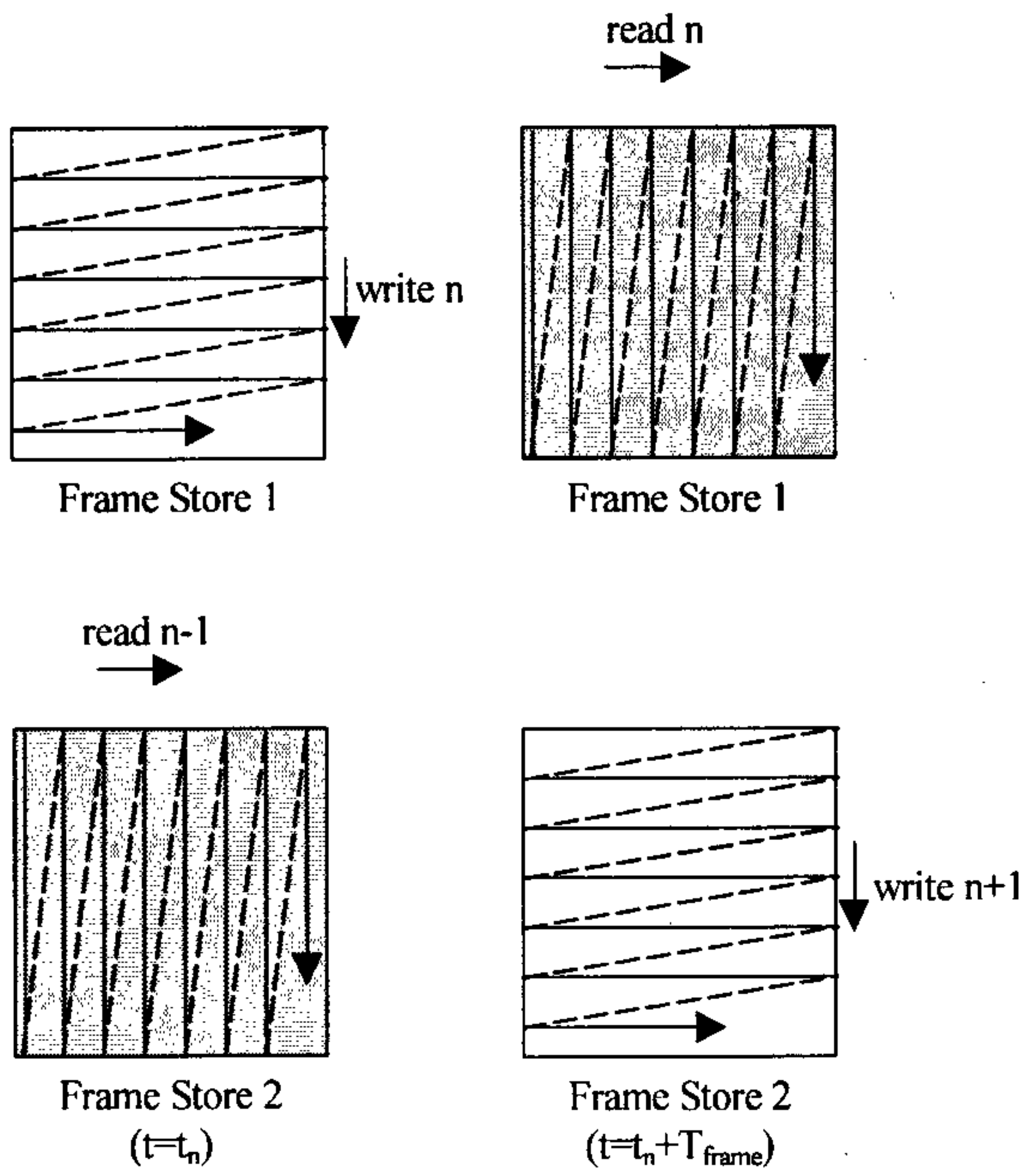

Figure 2. Straightforward ping-pong transposition

On the other hand, an efficient in-place transposition algorithm is feasible, exploiting the equal input and output data rates. At the expense of only some extra line buffers, 50% of memory can be saved.

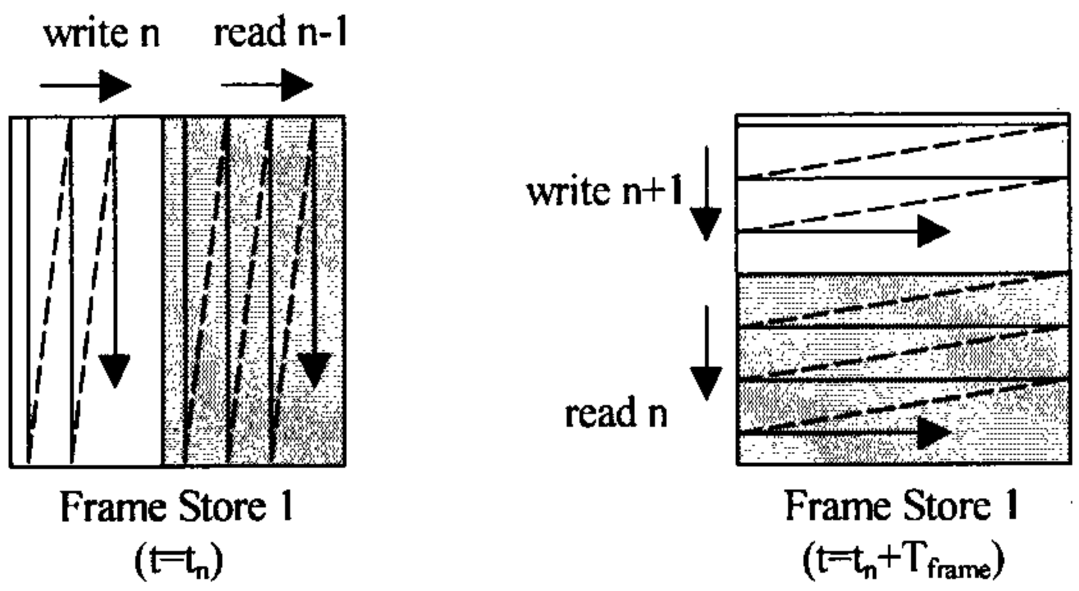

Figure 3. In-place transposition

The time relation of writing normal scan frames n and n+1 and reading transposed scan frames n-1 and n is depicted in Figure 3. After each frame period, the read and write directions change from horizontal to vertical, or vice versa. By re-using an existing frame memory in the video chain, implementation costs can be reduced dramatically. In this case, the ideal location for transposition will be after the last frame memory in the video chain, also minimizing re-design costs.

3. Perception issues

Before a television set with a TS CRT is developed, one should assess how video is perceived on such a display. It is well known that large-area flicker and line crawl determine the perceived quality of television pictures. Visibility of large-area flicker decreases with increasing frame rate. The term 'line crawl' denotes the loss in resolution of objects moving at an odd number of lines per field in case of interlaced video. Its visibility decreases with increasing resolution.

The majority of the viewers were considered to be naïve viewers. They were not aware of the aim of the test and were not informed about the video formats involved. On one CRT monitor, TS video was displayed, and the same video content was displayed in the corresponding NS format on another monitor of the same type. To imitate transposed scanning, the video pictures were rotated by 90°, and the CRT monitor was put on its side. The fronts of the monitors were masked while leaving a square image area at each of the CRTs, thus preventing the reconnaissance of the TS CRT.

Early experiments pointed out that at low frame rates (50Hz, 60Hz), the perceived quality of transposed scan is substantially worse than it is for normal scan. However, we should be aware that large-area flicker is predominant at these frequencies, and humans are accustomed to perceive it in NS rather than in TS orientation. Different perception of large-area flicker might explain the preference for normal to transposed scan at low frame rates.

In order to investigate how transposed scan is perceived with respect to normal scan at higher frame rates, a second set of tests has been carried out. Four combinations of resolution and TV format were applied for these tests:

- 540 visible scan lines (PAL resolution) at 75 Hz field frequency interlaced
- 720 visible scan lines (HD resolution) at 75 Hz field frequency interlaced
- 540 visible scan lines (PAL resolution) at 100 Hz field frequency interlaced
- 720 visible scan lines (HD resolution) at 100 Hz field frequency interlaced

The viewers judged each of these four formats for three different images: a still image, an image with horizontally moving lines of text and an image with vertically moving lines of text. So a total of twelve different situations had to be judged. Two different speeds were applied in the image content for the moving lines of text, text moving at one line and text moving at two lines per field. These speeds were considered to be critical for the visibility of line crawl artefacts.

More than 600 judgments were collected for the twelve situations. The number of subjects reporting artefacts such as flicker or line crawl could be neglected. The average annoyance level of these artefacts was also low.

Some trends in preference are visible for images with moving lines of text. Images with horizontally moving text gave a slight preference for normal scan mode CRTs, while for vertically moving lines of text the preference was in favour of transposed scan mode CRTs. However, a negligible number of subjects gave the visibility of typical scan artefacts such as large area flicker and line crawl as reason for their preference. The different preferences may be caused by other reasons than mentioned scan artefacts.

4. Conclusions

Acceptance of transposed scan by the set-maker will be determined by cost and complexity of integrating the transposition function in the video processing architecture. With in-place transposition, only a single frame memory is needed for transposition. By re-using a frame memory at the end of the video processing chain, implementation and re-design costs are minimized. Superior spot uniformity and reduced depth of the CRT must justify the modifications in the video processing path.

A perception study points out that for low frame rates, artefacts such as line crawl and large-area flicker are perceived differently for normal scan than for transposed scan. The reason for this might be the habituation of the spectators to the artefacts of normal scan. The perceived difference disappears for sufficiently high frame rates and line densities.

5. Acknowledgement

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6. References

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