DYNAMIC PIXEL MANAGEMENT

FOR

SECOND GENERATION ASPECT RATIO SWITCHING.

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ABSTRACT.

A second generation aspect ratio switchable camera has been developed using a new Frame Transfer sensor. In both 4:3 and 16:9 modes this new camera maintains equal vertical and horizontal resolution. It has the same horizontal angle of view and therefore no need for a lens convertor. The performance in both modes is optimal. The key to the second generation aspect ratio switching lays in dynamic pixel management (DPM) which is intimately related to the Frame Transfer principle.

INTRODUCTION.

Many schemes have been proposed for incorporating 4:3 and 16:9 aspect ratio in one camera (1).
The first generation of switchable 4:3 and 16:9 cameras uses the "side panel method", figure 1. The 4:3 imager is inside the 16:9 imager and the remaining parts left and right from the 4:3 format are called side panels. In such a Frame Transfer image sensor the side panels are disposed off in the line blanking to generate a picture with aspect ratio 4:3 from a 16:9 source (2). This way of approaching the 4:3 and 16:9 switching issue yields a camera which is optimal designed for use in 16:9 and has reduced horizontal resolution and reduced horizontal viewing angle in the 4:3 mode.

Of course, removing the side panels is the electronic and trivial way of generating a 4:3 picture out of a 16:9 picture. The DPM-principle is a creative approach to the aspect ratio switching problem.

FIRST GENERATION ASPECT RATIO SWITCHING.

The first generation aspect ratio switching utilized a so called 1000 pixel-per-line sensor. In reality for 625-norm this is about 936 pixels within the aspect ratio (18MHz clock and 52μs active line time). In 4:3 the number of pixels reduces to 702 per line and the clock frequency to 13.5MHz. Also the horizontal angle of view is changed like the MTF and aliasing performance.
Within the aspect ratio the vertical number of image cells is 576 in an interlaced fashion.

Aspect Ratio	16:9	4:3
Number of pixels	936*576=539k	702x576=404k
Diagonal	12mm	9.81mm
Width	10.46mm	7.84mm
Heigth	5.88mm	5.88mm
F_{clock}	18MHz	13.5MHz

The horizontal angle of view is changed by a factor of 1.33 and the diagonal in 4:3 is 18% smaller with respect to the optimal value of 12mm.

MTF at 5MHz	16:9	4:3
Optical low pass filter	91%	84%
Aperture image cell	88%	79%
Electrical Sample and Hold	88%	79%
Total	70%	52%

SECOND GENERATION ASPECT RATIO SWITCHING.

With the SDTV/EDTV experience (2) in 1/2" format, and the HDTV experience in 1" format (3) the development was started of a 2/3" image sensor. This new generation 2/3" Frame Transfer sensor (4) is vertical switchable and is also equipped with horizontal scan reversal for those shots which are made looking through a mirror, or for other effects.
The 16:9 image is now inside the 4:3 format. It is generated, not by removing the side panels, but by increasing the number of image cells vertically with exactly 4/3. The excess of image cells not required by the standard as defined in the 625-norm are not used, figure 2.
Even though the outlook is 'Letter Box' there is no reduction of the number of TV-lines within the 16:9 aspect ratio nor any interpolation: they are real TV-lines.

The optical centre is the same in both 4:3 and 16:9 mode.

The second generation aspect ratio switching also utilizes a 1000 pixel-per-line sensor but the number of pixels per line is the same in both 4:3 and in 16:9. As is the clock frequency, the horizontal angle of view, the MTF and the aliasing behaviour. Also the number of image cells in the vertical direction is 576 in an interlaced fashion in both 4:3 and 16:9.

Aspect Ratio	16:9	4:3
Number of pixels	936*576=539k	936x576=539k
Diagonal	11mm	12mm
Width	9.2mm	9.2mm
Heigth	5.4mm	7.2mm
F_{clock}	18MHz	18MHz

The horizontal angle of view is the same and the diagonal in 16:9 is about 8% smaller with respect to the optimal value of 12mm.

MTF at 5MHz	16:9	4:3
Optical low pass filter	91%	91
Aperture image cell	88%	88%
Electrical Sample and Hold	88%	88%
Total	70%	70%

DYNAMIC PIXEL MANAGEMENT.

With IL and FIT imagers an image cell consists of two vertical photo diode's. In Frame Transfer imagers usually one image cell consists of 4-gates each of which behaves as one photo diode. So one image cell is equivalent with four vertical photo diode's.
In the horizontal direction the image cell is defined by its channel stoppers, figure 3. The image cell is vertically defined only by the voltages applied to the gates, figure 3 and figure 4. This makes the definition of a Frame Transfer image cell very flexible. Hence the possibility for dynamic pixel management, or DPM. In the 625-norm the number of gates vertically is approximately 1152, so when 288 TV-lines (image cells) per field are needed the gates are biased with a 4-phase pattern. In the 16:9 mode, bias pattern is 3-phase resulting in a total of 384 image cells of which 288 are within the aspect ratio.

In the 4:3 mode the basic image cell is 4-phase, figure 3. This means that 3 gates are positively and 1 gate, the blocking gate, is negatively biased. The 4 gates of the image cell are light sensitive and the charge generated under these 4 gates is stored under the three-positive biased gates. The blocking gate determines the spatial separation between neighbouring image cells.

In a 3-phase image cell 2 gates are positively biased and 1 gate negatively, figure 5. This is the basic image cell in the 16:9 mode. The 3 gates of the image cell are light sensitive and the charge generated under these 3 gates is stored under the two-positive biased gates.

The pixel sensitivity profile determines MTF but most of all aliasing properties. With dynamic pixel management the sensitivity profile is shaped in such a way to achieve excellent aliasing properties.

INTERLACING

Interlacing in a FT-image sensor is accomplished by shifting every even field vertically by half an image cell with respect to the odd field. It is a kind of vertical 'half pixel offset'.

In a 4-phase image cell, where 4-gates define an image cell, this is easily accomplished by a two-gate shift, figure 4. This is called static interlacing.

In a 3-phase imager a half image cell shift equals a 1.5 gate shift. But statically one can only shift an integer number of gates, like 1 or 2 gates. To arrive at the needed 1.5 gate shift dynamic interlacing is applied. This technique was at first used in an other type of FT-sensor (5).

Presently the dynamic interlacing has been refined to such a level that it out performs the earlier scheme's.

A nice way to judge interlacing is looking at the Siemens wedges. Photo 1 shows interlacing performance when the offset between the two fields is 1-gate (=1/3 image cell) and photo 2 when interlacing by dynamic pixel management is active.

ALIASING.

A way of judging aliasing performance is by viewing a two-dimensional spatial frequency sweep. The zone-chart contains such a sweep. One sees at a glance the aliasing frequencies and the amount the aliasing is suppressed. A block zone-chart was used for taking the photo's. Care must be taken in interpreting the folds since such a block chart contains higher harmonics. For example a 6MHz block also contains 18MHz giving rise to folds around the position of 6MHz at the zone-chart.

In photo 3 and photo 4 the 288 cpph corresponds to 60 lp/mm and 576 cpph with 120 lp/mm, along the horizontal axis the 18MHz resembles 111 lp/mm.
Photo 3 shows the aliasing performance when the two fields are displayed with a 1-gate vertical offset (=1/3 image cell offset) and photo 4 with dynamic pixel management active.
As one can see, there is no aliasing at 288 cpph -a minimum requirement for proper interlacing- and even the aliasing at 576 cpph is highly suppressed.

Due to the use of dynamic pixel management a superior vertical aliasing behaviour is obtained. The aliasing performance is electronically controlled with high precision. There is no need for a vertical optical low pass filter, with its inherent .

CONCLUSION

The new generation for merging the 4:3 and 16:9 aspect ratios into one solid state image sensor is shown to be possible with an FT-image sensor and is introduced in the LDK10-series camera products from BTS.

This new BTS approach leaves the performance in 4:3 mode unaffected and at a high level. At the same time it maintains equal vertical and horizontal resolution in 16:9, with no change in horizontal viewing angle.

Since this FT-sensor is switched vertically, the camera settings need not be changed when going from 4:3 to 16:9, and the sample rate is constant at 18MHz, giving top performance in both modes of operation.

The vertical aliasing and interlacing performance is outstanding due to the application of the Dynamic Pixel Management.

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4. Centen, P., et al, 1994, "Aspect ratio switching with equal horizontal pixel count", *Proceedings of the International Broadcast Convention 1994*, 488-491.

5. Stekelenburg, M., 1993, Private communications.

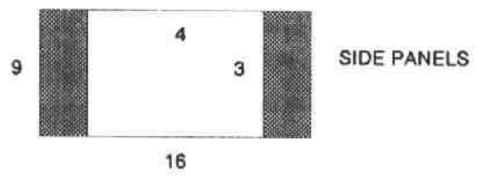

Figure 1: Generation of a 4:3 picture from a 16:9 source, by removing the side panels.

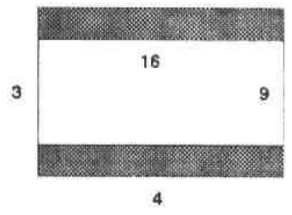

Figure 2: Generation of a 16:9 picture from a 4:3 source.

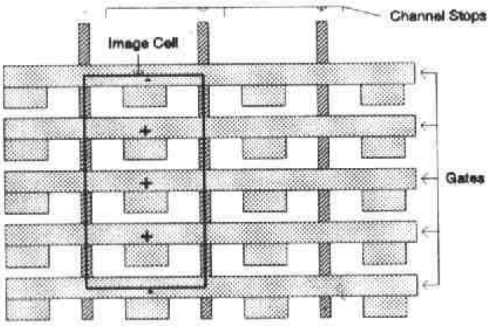

Figure 3: The bold lines show the definition of one 4-phase image cell in the odd field. One gate is negatively biased and the three other gates positively.

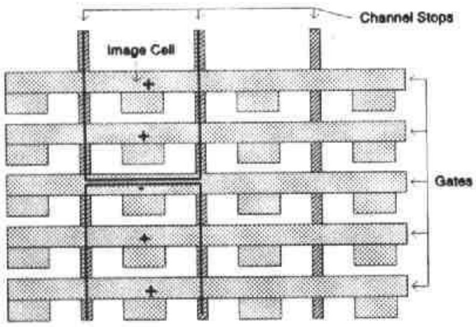

Figure 4: The image cell in the even fields, has a half image cell offset with respect to the odd field. The bold lines show part of the borders of two image cells.

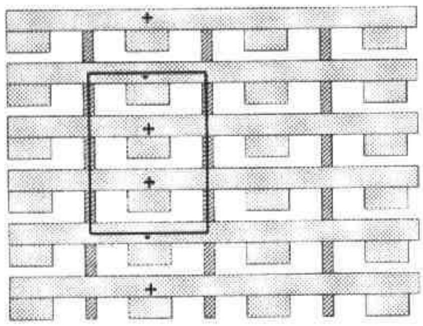

Figure 5: The bold lines show the 3-phase basic image cell. One gate is negatively biased and the two other gates positively.

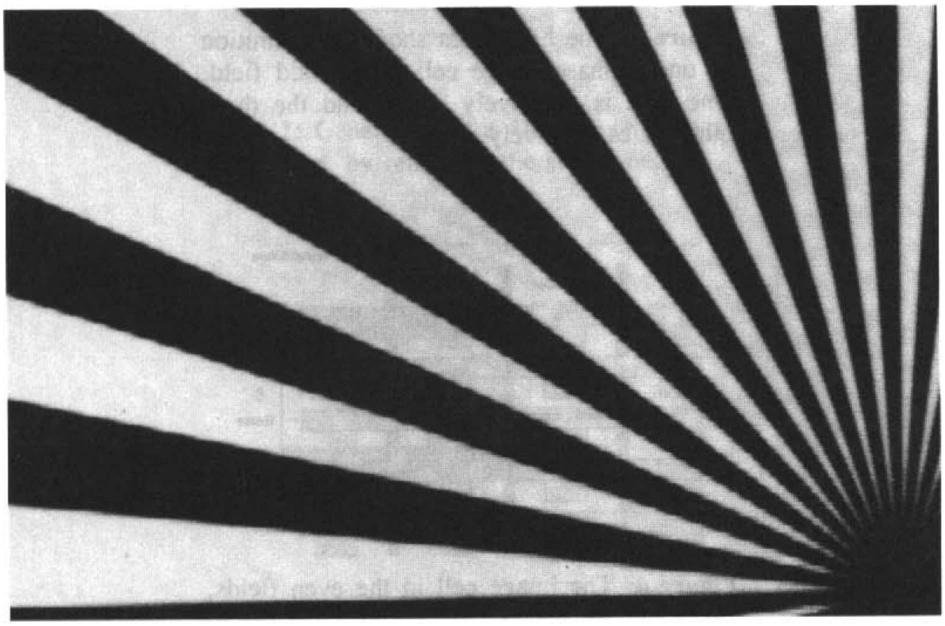

Photo 1: Siemens wedge showing the effect when interlacing with 1/3 image cell offset between odd and even field.

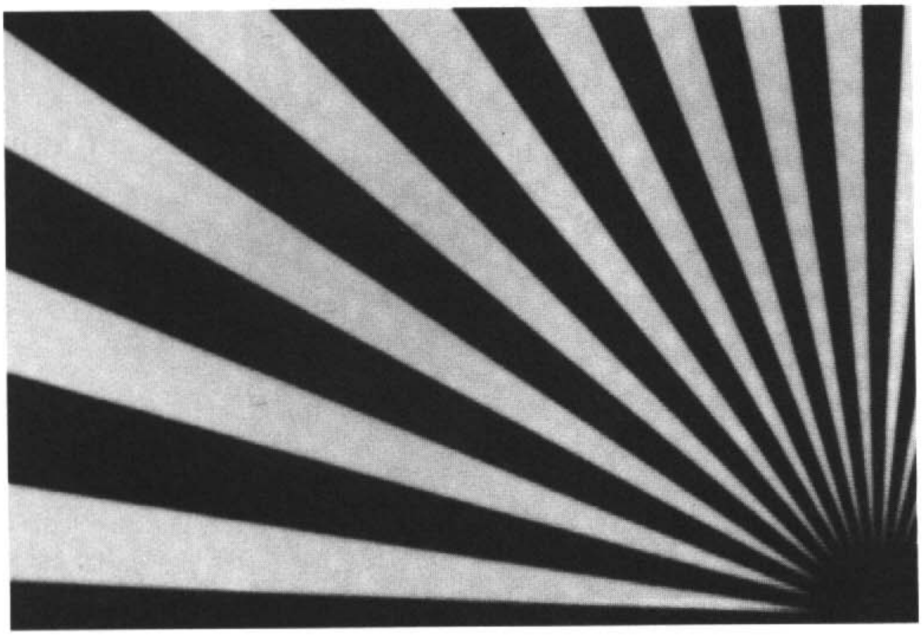

Photo 2: Siemens wedge showing the effect when dynamic pixel management is active. The vertical offset between the odd and even field is 1/2-image cell.

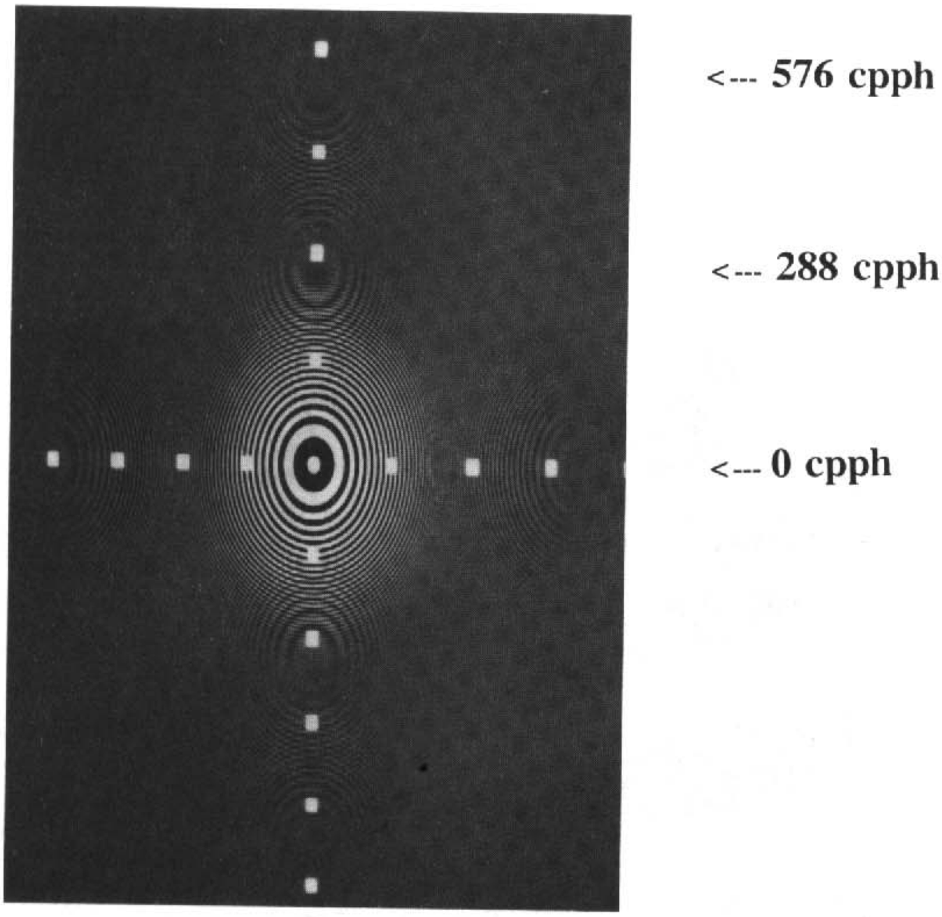

Photo 3: Zone-chart showing the effect when interlacing with 1/3-image cell offset between odd and even field. Clearly visible are the folds at 288 cpph and 576 cpph, showing non-proper interlacing. The horizontal markers to the right of the origin have a spacing of 5.3MHz and the vertical markers above the origin have a spacing of 160 cpph.

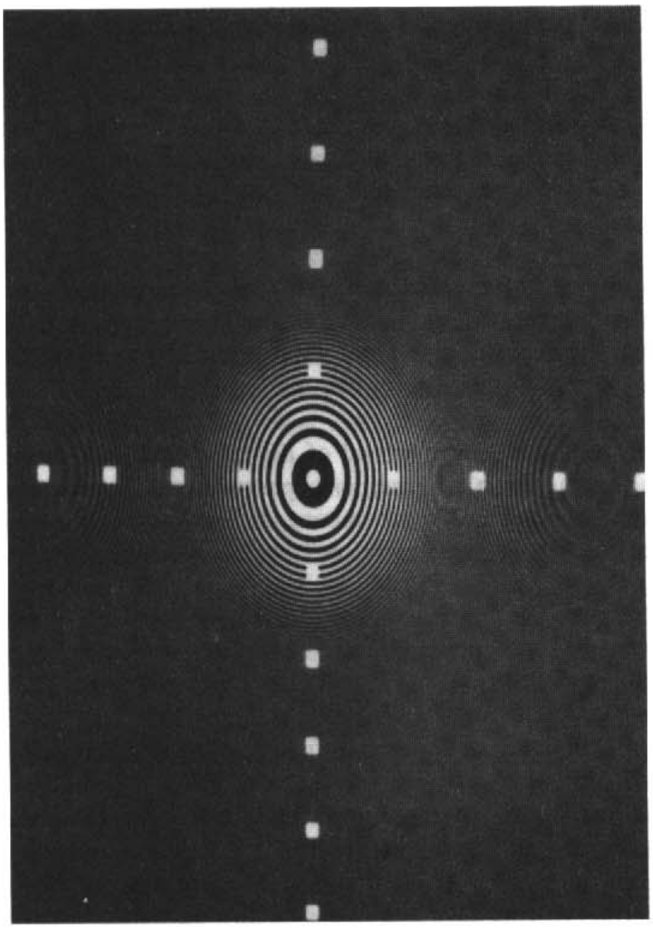

Photo 4: Zone-chart showing the effect when interlacing with dynamic pixel management generating an offset of 1/2-image cell between odd and even field. Clearly the folds at 288 cpph and 576 cpph have vanished, showing proper aliasing suppression.
The horizontal markers to the right of the origin have a spacing of 5.3MHz and the vertical markers above the origin have a spacing of 160 cpph.