ASPECT RATIO SWITCHING WITH EQUAL HORIZONTAL PIXEL COUNT

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ABSTRACT.

A new generation Frame Transfer sensor is presented which is switchable from 4:3 into 16:9 and vice versa. In both modes this new sensor 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.

INTRODUCTION.

Many schemes have been proposed for incorporating 4:3 and 16:9 aspect ratio in one camera, Lacoste et al (1).
The first generation of switchable 4:3 and 16:9 cameras uses the "side panel method", figure 1. Here 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 "thrown away" in the line blanking to generate a picture with aspect ratio 4:3 from a 16:9 source, Steeg et al (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 resolution and reduced viewing angle in the 4:3 mode.

Of course, throwing away the side panels is the trivial way of generating a 4:3 picture out of a 16:9 picture.

This new generation Frame Transfer sensor which is vertical swichable is also equipped with horizontal scan reversal for those shots which are made looking through a mirror, or for effects.

THE NEW SWITCHABILITY.

With the SDTV/EDTV experience (2) in 1/2" format, and the HDTV experience in 1" format Theuwissen et al (3) the development was started of a 2/3" image sensor. 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 lines vertically with exactly 4/3. The excess lines not required by the standard as defined in 625-norm or the 525-norm are not used, figure 2. The optical centre is the same in both 4:3 and 16:9 mode.

ADDRESSING AN IMAGE CELL.

The definition of an image cell is very flexible in a Frame Transfer type sensor. 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. Fixed are the gates running from left to right. In the 625-norm the number of gates is approximately 1152, so when 288 lines per field are needed one image cell is vertically addressed with 4 gates.

Addressing in 4:3 mode.

The image cell in the FT-sensors used for standard definition television is a so called 4-phase image cell, figure 5. This means that 3 gates are positively and 1 gate, the blocking gate , is negatively biased. Even though all gates are almost equally sensitive, the charge is stored only underneath the three positively biased gates. The blocking gate determines the spatial separation between neighbouring image cells.

In general the definition of an image cell, in vertical direction, is therefore not hardware but software

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defined through the application of positive and negative voltages. Hence the possibility for dynamic pixel management (DPM) is created.

Addressing in 16:9 mode.

In a 3-phase image cell 2 gates are positively biased and 1 gate negatively, figure 6. 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.

An image area with image cells which are 3-phase driven needs only 3 bond pads.

With a 3-phase driven image area with 1152 gates, one creates 384 lines vertically per field, of which 288 lines are within the 16:9 aspect ratio and the remaining 96 lines are outside the format. In the vertical blanking interval, the handling of the lines is such that only the 288 lines are readout in such a way as to leave the optical centre unchanged.

Even though the outlook is 'Letter Box' there is no reduction of the number of lines within the 16:9 aspect ratio nor any interpolation: they are real TV-lines.

The 12-phase image part.

A way has been found to address the array of gates in such a way as to have a 4-phase or a 3-phase image cell, then a 4:3 and 16:9 switchable sensor can be made.
This clocking is done by making a 12-phase gate interconnect, figure 7. Now 12ΦA clocks are needed and are driven in such a way as to provide 3-phase or 4-phase.

In the 4-phase mode the combinations are:

4-phase clock	12-phase sensor input
ΦA1	A1
ΦA2	A2
ΦA3	A3
ΦA4	A4
ΦA1	A5
ΦA2	A6
ΦA3	A7
ΦA4	A8
....	....
ΦA4	A12

and in the 3-phase mode:

3-phase clock	12-phase sensor input
ΦA1	A1
ΦA2	A2
ΦA3	A3
ΦA1	A4
ΦA2	A5
ΦA3	A6
...	....
ΦA3	A12

Of course other modes are possible with the 12-phase imager but these are non-standard modes.

To ease the burden on the electronics, a demultiplexing ASIC was integrated into the same CCD-process that the new generation image sensor was made in. This IC demultiplexes in the 16:9 mode the 3-phase, supplied by the driving electronics, into a 12-phase clock for the image sensor. In the 4:3 mode the 4-phase clock is demultiplexed into a 12-phase clock.

INTERLACING

Interlacing in an FT-image sensor is accomplished by shifting every even field vertically by half an image cell with respect to the odd field.

In a 4-phase image cell, where 4-gates are used, this is easily accomplished by a two-gate shift, figure 4.

This is called static interlacing.

In a 3-phase imager the half image cell (one line) shift converts to a 1.5 gate shift. This is accomplished by what is called dynamic interlacing. This technicue was at first applied to an other type of FT-sensor, Stekelenburg (4).

The odd field is generated by the summation of two fields one of which has a vertical offset of one-gate, figure 8 and figure 9, and where the offset field is added with a weighting factor.

Similarly the even field is generated by the summing of two fields which also have a vertical offset of one-gate, figure 10 and figure 11, but now in the opposite direction. These two fields are also added with a weighting factor.

The weighting factors are chosen such that effectively a spatial offset of 1.5*gate=image cell/2 is created.

The weighted addition of two fields, as in dynamic interlacing, helps in reducing line flicker effects and vertical aliasing artifacts as are inherent to the 625-norm and the 575-norm.

MTF and aliasing.

With a mathematical model the MTF, figure 12, and aliasing behaviour, figure 13, for static images can be predicted. Due to the interlacing the foldback frequency is doubled from 288 cpph to 576 cpph.

In the case that interlacing is not effective for example, when zooming in or out, the foldback frequency reduces to 288 cpph, figure 14.

Now, a reduction of aliasing artifacts can be expected for the dynamic interlaced mode as is shown in figure 14.

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 uneffected 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.

Using the benefits of SDTV, first generation 4:3 and 16:9 switching, and HDTV experience in FT-sensor imaging, leads to a new generation FT-sensor with very good signal to noise performance and dynamic range.

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.

ACKNOWLEDGEMENT.

We would like to thank the FABWAG group of Philips Imaging Technology for their fast production of this new FT-image sensor.
Further, we would like to thank the following people of BTS for their contribution in making the new FT-sensor a reality in the new BTS LDK10/10P series:

W. Haar, K. Damstra, A. Dekkers.

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DEVICE PARAMETERS.

The newly developed FT-sensor has the following parameters.

TABLE 1 -Device parameters.

Image area	
Sensitivity without IR filter	In 4:3 39nA/Lux PAL, 38nA/Lux NTSC
Dynamic range	In 4:3 340nA PAL, 390nA NTSC
Number of active pixels horizontal	1000 in both 4:3 or 16:9 PAL or NTSC
Number of active lines 2:1	594 PAL 498 NTSC
Aspect ratio	switchable 4:3 or 16:9
Horizontal register	
Cross over frequency 1/f-noise	0.4MHz
Bandwidth at 3dB point	100MHz
Gain when loaded with 4k7	0.72
Output impedance	300 Ohm
Conversion factor at Floating Diffusion	15μV/e
Noise electron density (NED)	1.7e/$\sqrt{}$MHz
Horizontal clock frequency	18MHz
Number of image sensor outputs	2- to include horizontal scan reversal

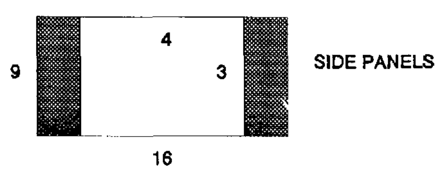

Figure 1: Generation of a 4:3 picture from a 16:9 source, by removing the side panels.

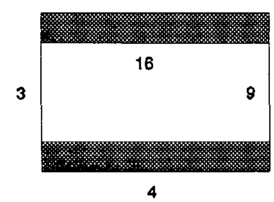

Figure 2: Generation of a 16:9 picture from a 4:3 source.

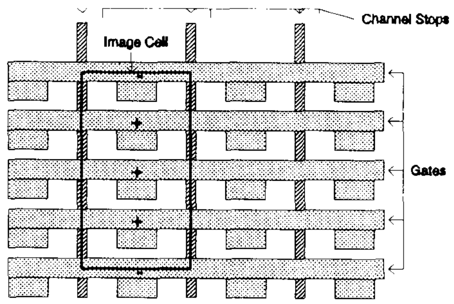

Figure 3: The bold lines show the definition of one 4-phase image cell in the odd field. One gate is negatively biased and the three other gates positively.

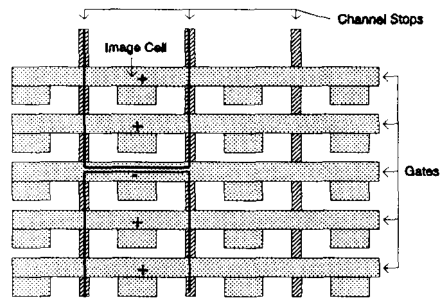

Figure 4: The image cell in the even fields, with half image cell offset with respect to the odd field. The bold lines show the borders of two half image cells.

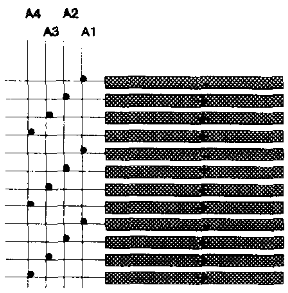

Figure 5: The 4-phase adressing of the image area.

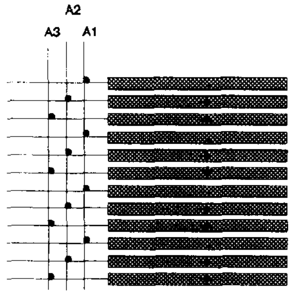

Figure 6: The 3-phase adressing of the image area.

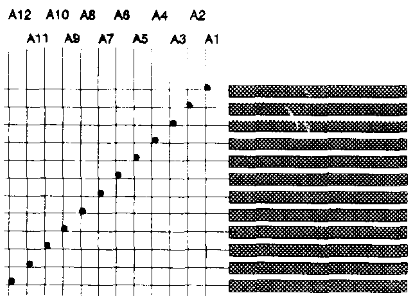

Figure 7: The 12-phase addressing of the image area.

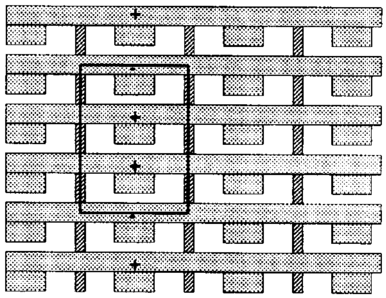

Figure 8: During part of the odd field the image cell is defined as above.

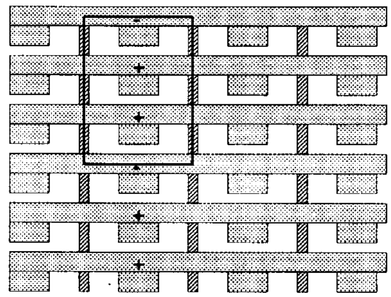

Figure 9: The odd field is an weighted addition of the charge collected with the image cell defined in figure 8 and in this figure 9.

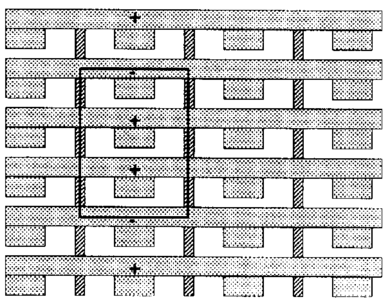

Figure 10: During part of the even field the image cell is defined as depicted.

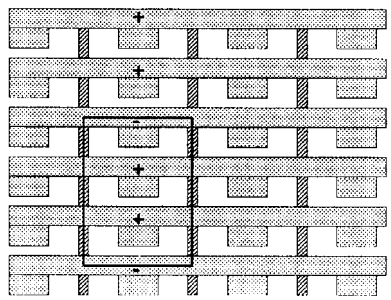

Figure 11: The even field is the weighted addition of the image cell as defined in figure 10 and the definition shown here.

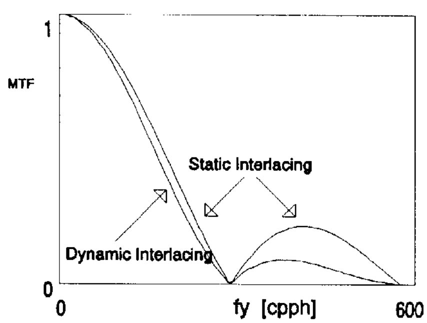

Figure 12: The MTF (n=0) as a function of spatial frequeny fy in cycles per picture height [cpph] for the ideal Static Interlaced case and the Dynamic Interlaced one. The first zero occurs at fy=288 cpph.

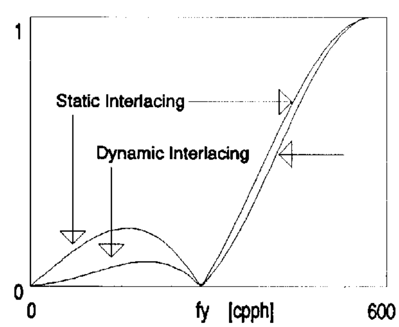

Figure 13: The second aliasing component at 2*fsv=576 cpph for the traditional Static Interlacing case and the Dynamic Interlaced case. The horizontal axis is the spatial frequency fy in [cpph].

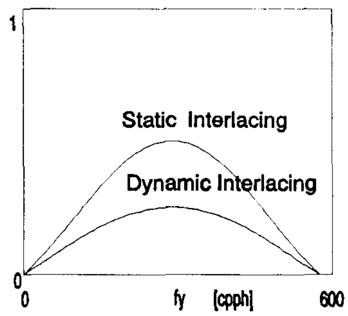

Figure 14: The aliasing component (n=1) around the sample frequency fsv=288 cpph in the case that the scene content is changing and interlacing is not effective any more. The horizontal axis is the spatial frequency fy in [cpph].