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A SMEARFREE ACCORDION CCD IMAGER

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Abstract

A modified accordion clocking system offers an on-chip electronic method for the elimination of smear. The method is insensitive to spot movement. For Frame Transfer CCD imagers the clocking system provides an electronic shutter function as well. The smear suppression is also applicable to Interline CCD imagers.

Introduction

Charge Coupled Device (CCD) imagers have shown their merits in Solid State Imaging. The Frame Transfer (FT) and Interline Transfer (IL) CCD imagers are used not only in the consumer area but recently for broadcast applications as well.

Both the FT and IL systems have overcome the blooming problem by a Vertical AntiBlooming (VAB) structure[1,2]. However both systems suffer from "smear", a "blooming like" phenomenon occuring during the vertical shift of the charge packets. It shows up in most cases as an unsaturated vertical line pattern above and below a spot.

Smear can be reduced for the IL imager by means of an extra field memory, a combination of an FT and IL imager, the FIT imager[3]. For the FT imager the smear can be totally avoided by closing the lens during the I-to-S[a] shift e.g. by means of a rotating fan-type shutter[4].

In this paper a new on-chip solution applicable to both types of CCD imager is presented. It is based on the accordion principle[5] and will be discussed for the FT imager.

Description

The FT imager concept is shown in figure 1. During the I-to-S transfer after integration of a field, the empty virtual B pixel (above the I-section) is shifted to the place denoted by SmB[b] in the image section I. When it passes the spot smear is added. Thus the pixel contains only smear just before integration of a new field. The SmB smear packets can be eliminated by draining them e.g. via a VAB structure and the pixels in the I-section below the spot become smearfree. After integration the pixels below the spot arrive at their place in the S-section containing only their pixel information (V). The A pixel however collects smear SmA[c] in addition to its picture information during the passage through the spot.

First we will briefly describe the accordion transfer principle[5], that is depicted in figure 2. It gives the highest vertical pixel density but the pixel charges cannot be shifted to the S-section simultaneously. The transfer proceeds as follows. At t=0 under every second gate a pixel charge is collected in the image section I. At time instant t=1 the first pixel charge enters the storage section S. At t=2 a barrier of two gates has been formed between the first and the second pixel. Then both the first and second pixels are transferred simultaneously and so on. When the first pixel line reaches the bottom of the S-section the accordion is fully stretched (t=5) and the last pixel row starts its I-to-S transfer. The transfer takes place in a conventional four-phase mode. From t=5 to t=11 the closing action is performed and by the end of it all pixel lines are stored in the S-section. During this I-to-S transfer smear SmA is added to the pixel charges from above the spot (V+SmA, figure 1).

Characteristic of the accordion is the generation of an extra potential barrier to enable the transfer of the succeeding line (t=2,3). Characteristic of the smear (SmA) compensation method is that after the generation of an extra barrier an extra potential well is generated (figure 3). This well follows its corresponding video well and collects the same quantity of smear SmA, as they are transferred about 1μsec after each other. All video lines and their respective smear lines are stored and read out in pairs. After read-out they are subtracted and a smearfree picture is obtained. Because the smear in the video signal and the compensating signal are generated so shortly after each other, this compensation method works even for images of fast-moving spots. Smear correction holds good for image movements up to 0.1 of the pixel width in 1 μsec, which means an allowed movement of 3 times the image width in one field for an imager with 700 pixels/line and 50 fields per second.

Figure 4 shows schematically the I-to-S transfer of a field (t=1-23) and the start of the integration of a succeeding field (t=43). At t=1,7,13 the three successive pixel lines finish their integration and start their I-to-S shift. At t=4,10,16 their corresponding SmA wells are generated and transferred to the S-section.

If at t=23 all the SmB-smear were drained via a VAB structure all the lines of the new field would simultaneously start their integration time. Since the lines finish the integration 6 time instants after each other (t=1,7,13) a gradually increasing integration time with the line number would be found. This is unacceptable for short integration times. To guarantee a uniform integration period a closing action of the accordion is performed (t=31-43) together with a reversal of the transfer direction (t=24-41) so that the SmB is shifted to the top of the I-section where it is drained by an n^+drain (not drawn). By varying the start of the depicted procedure from a few μsecs up to a field time before the I-to-S shift starts an equivalent electronic shutter time is obtained.

Figure 5 shows a photograph of an experimental smearfree FT-CCD imager chip with electronic shutter. It contains 580 V x 712 H pixels, 1/2" format, total chip area 75.6 mm^2 including 17.6 mm^2 for additional storage lines needed for smear compensation.

If the modified accordion clocking for the I-section of

[a]Image section to Storage section
[b]Smear Before integration
[c]Smear After integration

figure 4 is applied to an IL-CCD imager and an extra SmA serial output register for smear subtraction is added then a smearfree IL-CCD imager can be obtained which saves the extra memory of the FIT sensor.

Conclusion

The modified accordion clocking system eliminates completely the smear (SmB) from above the displayed spot, while the smear (SmA) from below the spot is compensated up to very high speeds of the spot at the display. The modified accordion clocking can be applied to frame transfer and interline transfer CCD imagers. For frame transfer imagers the method allows a combination of smear suppression and electronic shutter function.

Acknowledgement

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References

1. M.J.H. van de Steeg et al,"A Frame Transfer CCD Color Imager with Vertical Antiblooming", IEEE Trans. on Electron Devices, ED-32,8, August 1985, pp 1430-1438

2. Yasuo Ishihara et al,"Interline CCD Image Sensor with an Antiblooming Structure",February 1982, IEEE Intl. Solid-State Circuits Conf., San Francisco, pp 168,169,314

3. Kenju Horii et al,"A New Configuration of CCD Imager with a Very Low Smear Level FIT-CCD Imager", IEEE Trans. on Electron Devices, ED-31,7, July 1984, pp 904-909

4. H. Griffioen and F.J. van Roessel,"Application of Frame Transfer CCD Sensors in a Newly Designed Lightweight Camera System", March 1987, NAB Engineering Conference Proceedings, Dallas, pp 182-187

5. A.J.P. Theuwissen et al,"The Accordion Imager: an Ultra High Density Frame Transfer CCD", IEEE Intl. Electron Devices Meeting, San Francisco, December 1984, pp 40-43

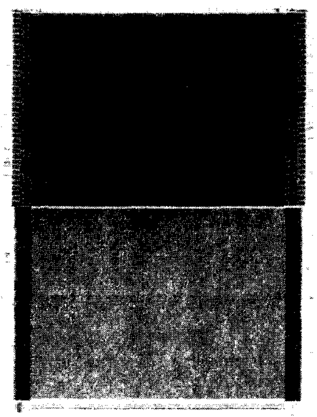

Figure 5. Experimental smearfree FT accordion CCD imager chip with electronic shutter. Chip area 75.6 mm², 580 V × 712 H pixels, ½" format.

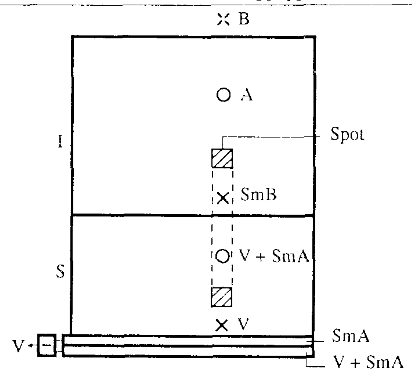

Figure 1. Schematic lay-out of the smearfree frame transfer accordion CCD imager. During the I-to-S transfer the virtual pixel B collects smear SmB, which is drained before the integration of the corresponding field is started (fig.4). During the next I-to-S transfer the A pixel collects smear SmA in addition to its picture sample V. The SmA is compensated by its copy that is collected in an extra generated transferring well (fig.3, t ≥4).

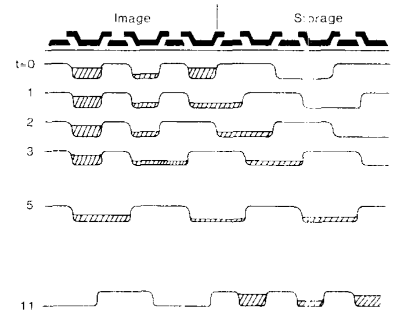

Figure 2. Accordion Transfer.

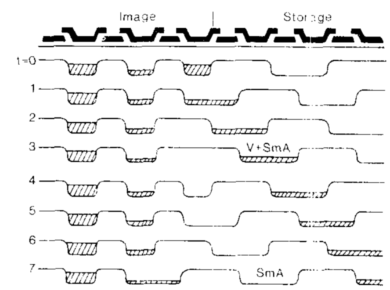

Figure 3. Modified Accordion Transfer, by which extra transferring wells for the collection of smear (SmA) are generated.

Figure 4. The Modified Accordion Transfer for the FT-imager. The position of the video (V) and smear packets (SmA,SmB) in between two successive field integration periods is shown. The Smear Before integration is drained at t=28 and the pixels of the succeeding field start their respective integration smearfree at t=31,37,43. Extra wells are generated at t=4,10,16 and transferred for the collection of a copy of the Smear After integration to compensate the smear SmA collected in the corresponding pixel wells (V+SmA).