Reduction of motion blur in CMOS linear arrays and TDI imagers

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Purpose

→ Reduce the motion blur that arises in CMOS line or TDI type image sensors.
→ Rival the MTF in the direction of scanning of CCD based TDI.
→ Not incur noise due to larger number of sub-pixels
→ Applies also to regular, single line image sensors

Introduction

TDI image sensors are used in remote sensing or earth observation, various fields of scientific imaging, and in various application of industrial imaging. These are essentially linear sensors, for which the sensitivity and SNR are enhanced by re-imaging and summing the same scene multiple times while the imager line scans orthogonally over the image.

The original and perfect TDI = CCD "move and add" charge packets.

CMOS equivalents of TDI [1-3]:
"OK, but…"
✓ one cannot freely move charge packets
✓ TDI is emulated by summing signals of two dimensional array
✓ Read noise increases * SQRT(lines)
✓ Pixel step motion blur ←***this work***

How to realize sub-pixel motion:
→ Obvious in a 3 or 4 phase CCD
→ In CMOS?

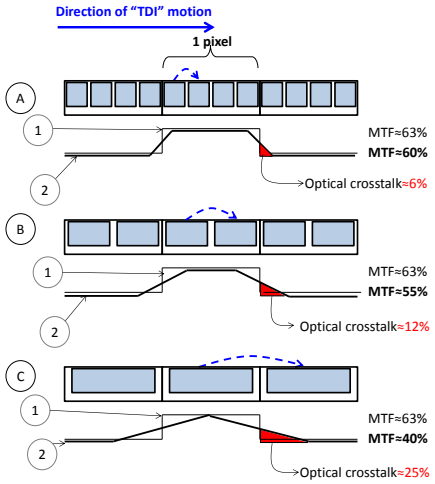

Fig 1 the effect of sub-pixel motion on optical crosstalk and MTF. Representation of TDI pixels subdivided in 4 (A), 2 (B) and 1 or none (C) sub pixels. In each case we plotted the effective pixel shape when the pixel is static or not moving (1), or when the pixel is moving in TDI fashion (2).

Concept

CMOS sub-pixel motion concept, not having the noise disadvantage for reading the sub-pixels:

- By using shared photodiode sub-pixels inside one "TDI pixel" (fig.2), and accumulating the charges of these sub-pixels on a shared sense node, such as the shared floating diffusion or other charge amplifiers (fig.4).
- Charges of the sub-pixels are acquired according to the desired sub-pixel motion (fig.3). The effective integration times of the different sub-pixels are relatively shifted in time.

References

[1] B. Pain et al. "CMOS image sensors capable of Time-delayed Integration", NASA Tech. Brief, vol.25 no.4 (2001)
[2] E. Fox, "CMOS TDI Image sensor", US Patent 6,906,749 (2005)
[3] G. Lepage et al., "CMOS long linear array for space application", Proc. of SPIE-IS&T Electronic Imaging, SPIE Vol 6068 (2006)

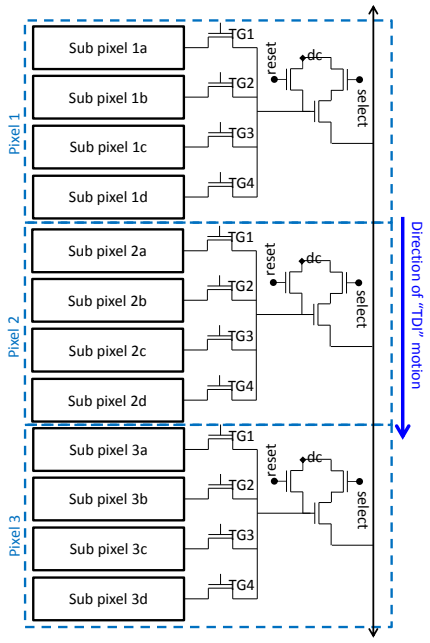

Fig 2 implementation using shared pinned photodiode sub-pixels

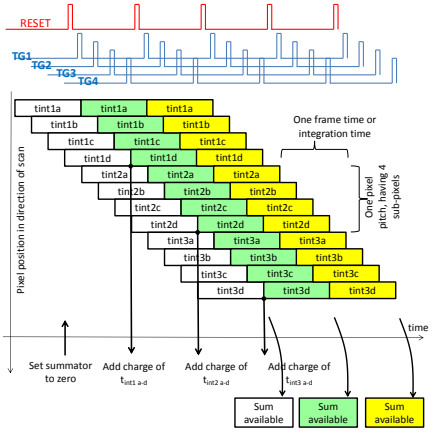

Fig 3 effective integration times of the sub-pixels of previous figure.

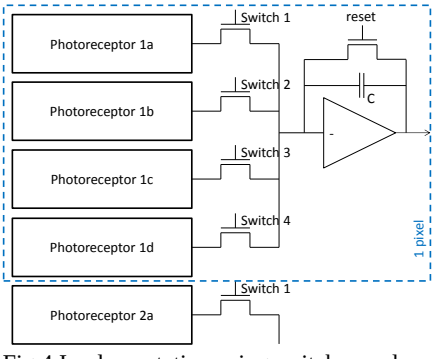

Fig 4 Implementation using switches and a CTIA