Reduction of motion blur in CMOS linear arrays and TDI imagers

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Abstract

We present a concept to reduce the motion blur that arises in CMOS line or TDI type image sensors.

When applied to CMOS TDI imagers, one rivals the MTF in the direction of scanning of CCD based TDI. Also in regular, single line image sensors the method improves the MTF along the motion direction.

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 enhance by re-imaging and summing the same scene multiple times while the line scans orthogonally over the image.

The original and genuine TDI method makes use of a very specific feature of CCD, namely the capability to move and add charge packets. One has attempted to create CMOS image sensors equivalents of TDI, with various success [1-3]. As in a CMOS imager one cannot freely move charge packets, the TDI operation is emulated by summing signals obtained by pixels in a two dimensional array, in a way that it realizes geometrical synchronicity between the summed pixel signals and the motion of the optical image over the sensor.

Apart from the noise disadvantage (in CCD, the read noise happens once while in CMOS implementations, the acquisition and summation of each intermediate pixel signal incurs read noise), CCD has the advantage of sub-pixel motion of charge packets. A 4 or 3 phase CCD shifts the charge in steps of 1/4th or 1/3rd of a pixel, thus following accurately the optical image motion, and thus resulting in minor MTF degradation or motion blur (fig.1). In a typical CMOS TDI, there is no sub-pixel motion, or, if sub-pixel motion is implemented, it comes with a penalty in noise, as the number of elementary samples read and summed increases.

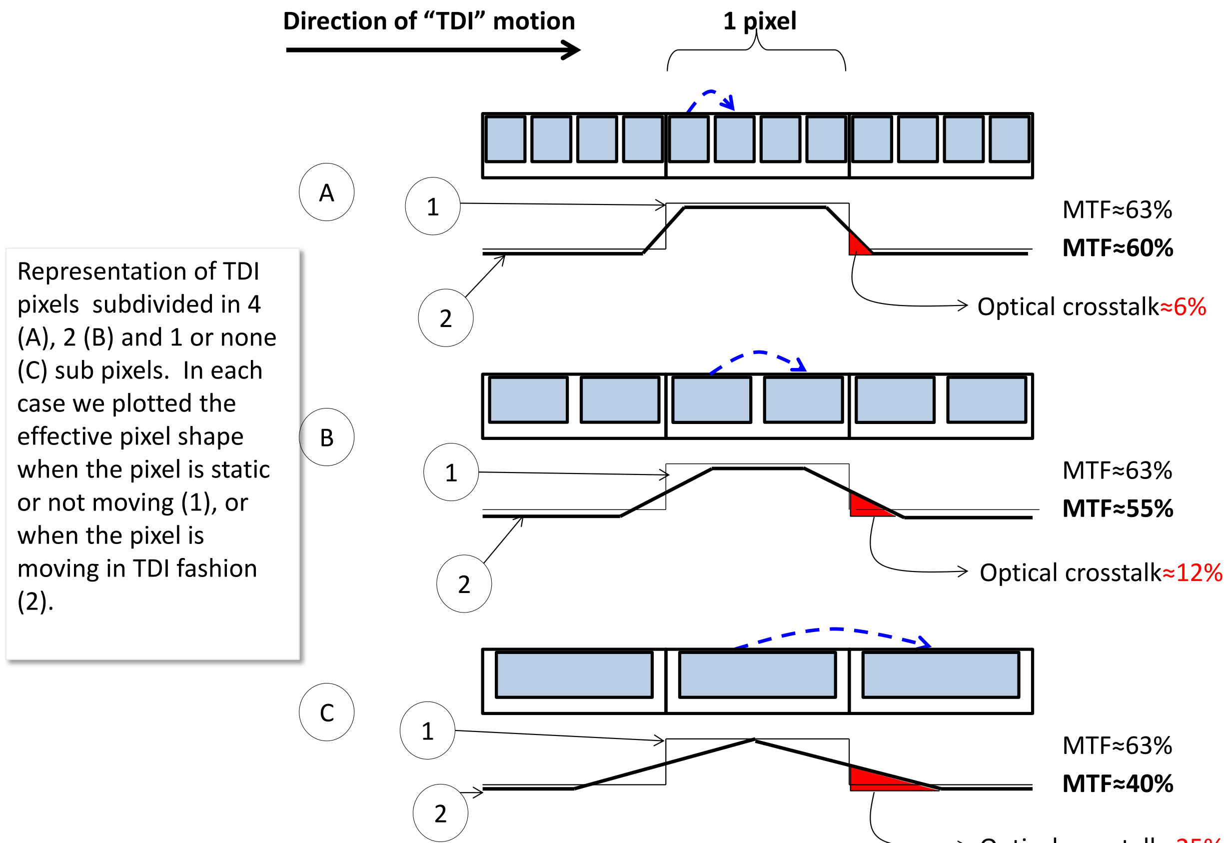

Fig 1 the effect of sub-pixel motion on optical crosstalk and MTF

We present a way to realize sub-pixel motion, while not having the noise disadvantage for reading the sub-pixels. This is realized 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), whereby the 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.

As a special case this sub-pixel motion benefits also a single pixel row linear image sensor. The sub pixel motion can nicely compensate the motion blur that is due to scanning motion.

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)

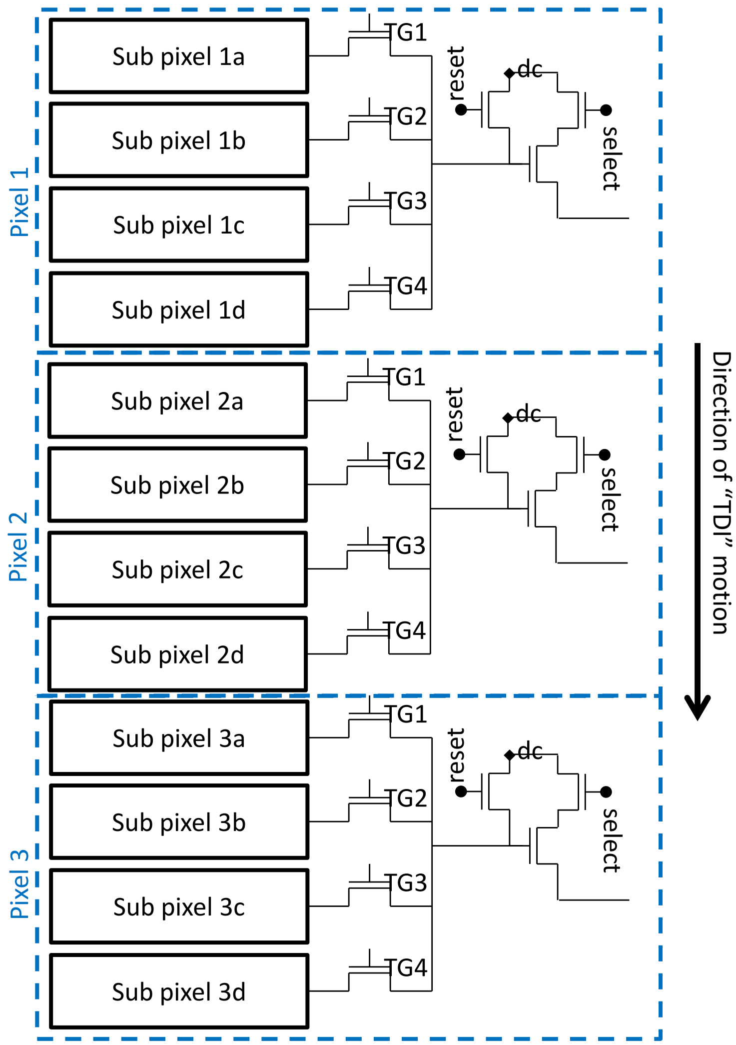

Fig 2 implementation using shared pinned photodiode sub-pixels

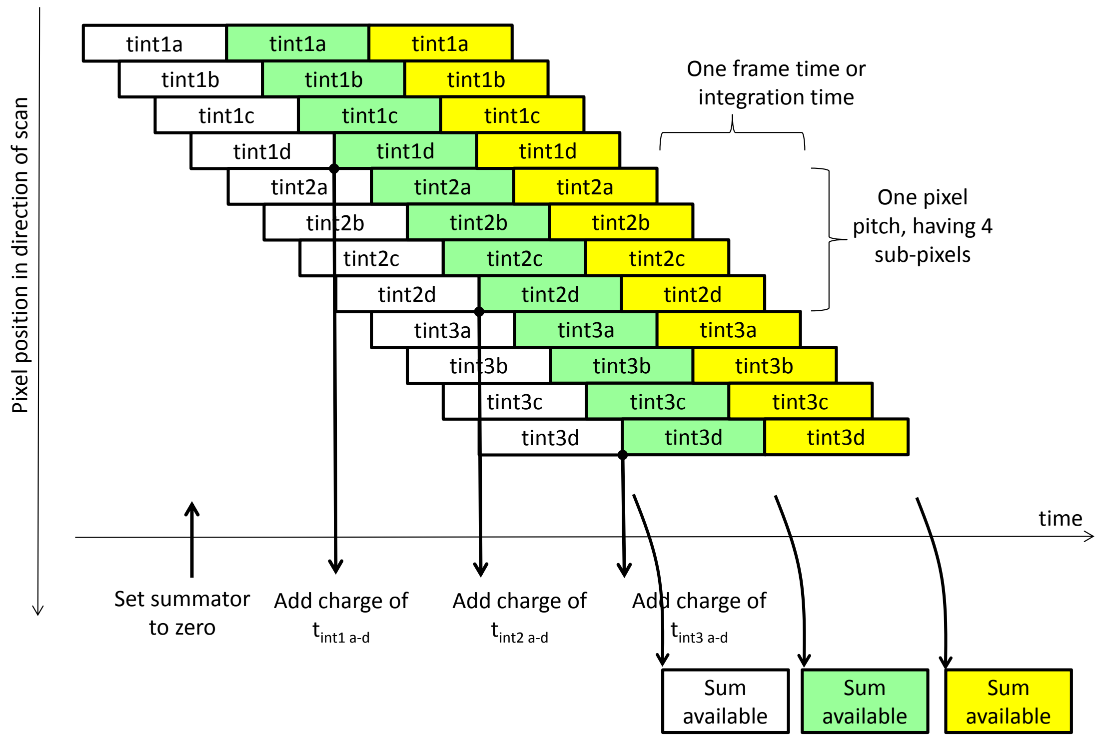

Fig 3 effective integration times of the sub-pixels of previous figure.

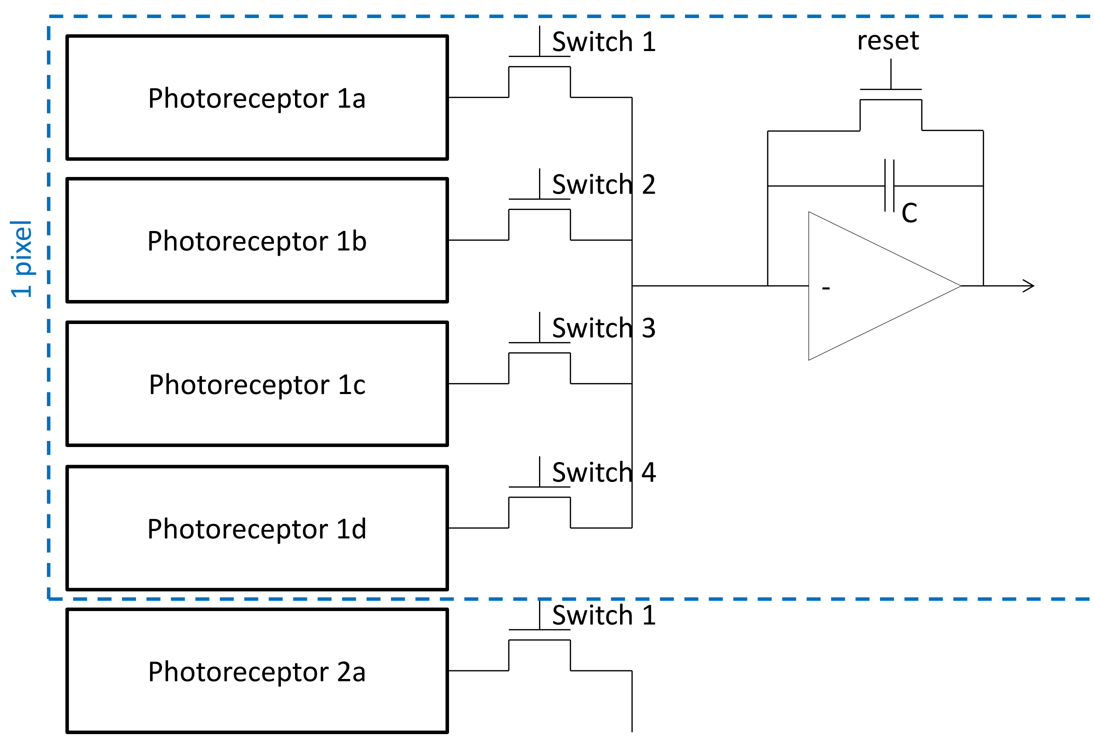

Fig 4 Implementation using switches and a CTIA