

Floating Transfer Gate-based CMOS pixel for low noise imager

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Scientific imaging applications in space and ground-based astronomy require image sensors with read noise below $0.3 \text{ e}^-_{\text{RMS}}$ to ensure true single-photon detection [1]. Several device and circuit techniques have been reported before [2].

We present the Floating Transfer Gate (FTG) concept, a CMOS pixel capable of non-destructive multiple sampling, similar to that of a Skipper CCD [2]. The FTG pixel contains a pinned photodiode (PPD) and one or two FTGs on top of it. An NMOS source follower senses the charge under the FTG. Photo charges can be shuffled between the FTG and a second non-floating transfer gate (NFTG) for multiple CDS-like non-destructive readouts. Multiple CDS samples are averaged off-chip, reducing read noise to an arbitrarily low level.

An “FTG2” test chip with single pixels and readout periphery was fabricated in XFAB’s 180nm CIS process.

We report electro-optical and noise results of the FTG2 prototype. The noise of a single FTG non-destructive read is close to $5\text{ e}^-_{\text{RMS}}$ at room temperature. 1024 times oversampling reduces this to a theoretical $0.15\text{ e}^-_{\text{RMS}}$. The only significant noise source, dark-current shot noise (DCSN), does not improve with oversampling. One needs to cool below $-60\text{ }^{\circ}\text{C}$ to ensure that DCSN is negligible relative to the read noise. Issues related to cooling will be discussed.

Other useful operation modes of an FTG pixel are “sampling on the ramp”, similar to the old “non-destructive readout” of 3T pixels. FTG pixel can thus facilitate rejection of cosmic-ray-corrupted frames.

References

[1] N. Teranishi, Electron Devices, 2012

[2] P. Wakale, *et al.*, 20 C08003, JINST, 2025

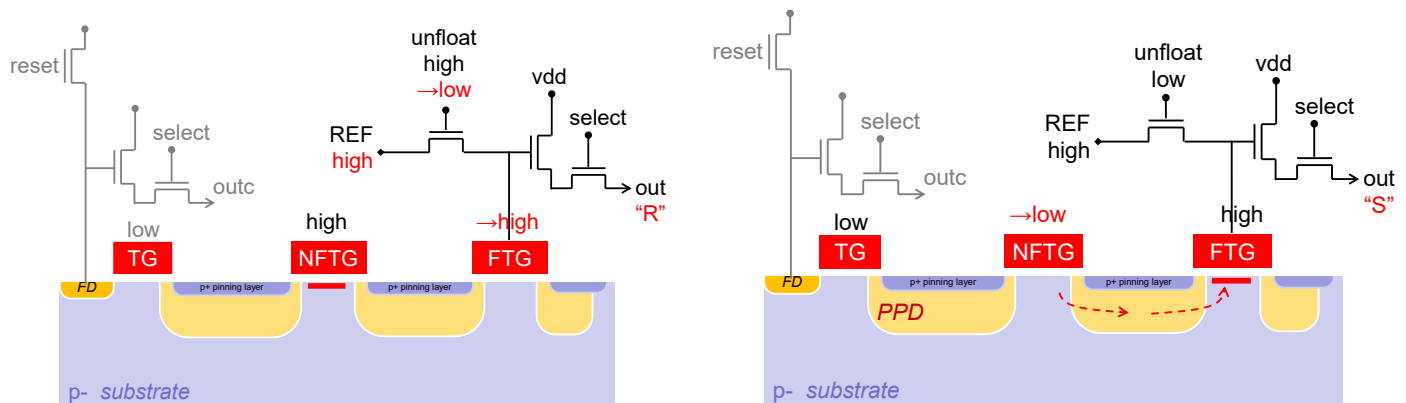


Figure 1: Operation of FTG: charge originally contained below NFTG is transferred to FTG, where the empty state “R” and the filled state “S” are sensed. The difference R-S is a CDS-like signal.