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The source-to-gate capacitance of the in-pixel source follower: a positive feedback during charge sensing which increases column settling time and noise voltage

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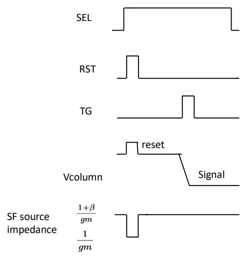
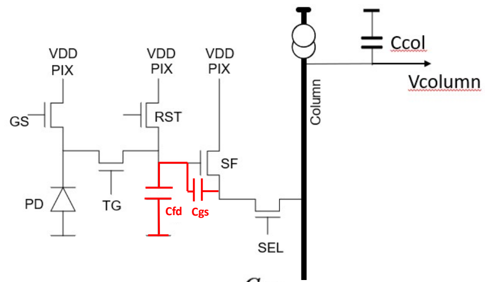


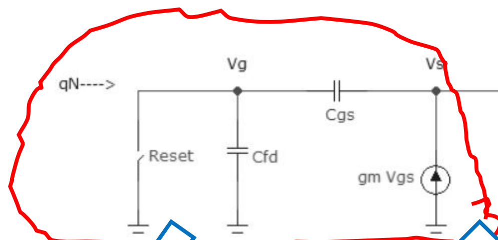


Feedbackfactor $\beta := \frac{Cgs}{Cfd}$

Abstract

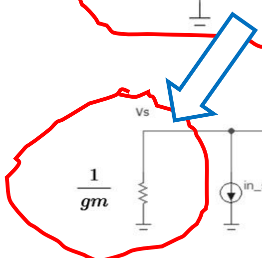
The gate-to-source capacitance of the in-pixel source follower, forms a capacitive attenuator with the floating diffusion capacitance. Voltage changes at the source are feedback to the gate: a positive feedback. It is effective when the resetfet is turned off. This is during charge sensing and reset level sensing for CDS. The positive feedback increases the output impedance at the source of the source follower and the noise voltage increases just as the settling time at the column.

publications

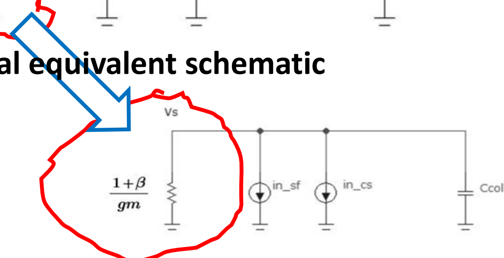


biography

Noise small signal equivalent schematic



Reset on



Reset off: charge sensing

Outputimpedance

In the charge sensing state (positive feedback Cgs,Cfd) the SF-source output impedance increases with (1+β), $\frac{1+\beta}{gm}$

Noise

Assuming that the resetnoise is suppressed with e.g. CDS, the noise at the column is mainly caused by the source follower (in_sf) and the current source CS (in_cs). The noise voltage at the SF source, due to the positive feedback, increases to:

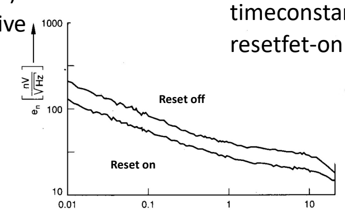
$$en^2 = \left(in\_sf^2 + in\_cs^2\right) \cdot \left(\frac{1+\beta}{gm}\right)^2$$

with β=1 the noise spectral density increases 4 times. Irrespective if the noise is thermal, 1/f, RTN etc!

$$en^2 = 4 \cdot kT \cdot \frac{2}{3} \cdot (gm + gcs) \cdot \left(\frac{1+\beta}{gm}\right)^2 = 4 \cdot kT \cdot \frac{2}{3} \cdot \left(1 + \frac{gcs}{gm}\right) \cdot \frac{1}{gm} \cdot (1+\beta)^2$$

after sampling

$$\sigma^2 = Bn \cdot en^2 = \frac{kT}{Ccol} \cdot \frac{2}{3} \cdot \left(1 + \frac{gcs}{gm}\right) \cdot (1+\beta) \quad \text{or} \quad \sigma^2 = 2\,\frac{kT}{Ccol}$$



Noisebandwidth

For a single pole network, the noise bandwidth Bn relates to the timeconstant. Due to the positive feedback the timeconstant is increased with (1+β) compared to the resetfet-on state

$$Bn := \frac{1}{4 \cdot \tau} = \frac{1}{4} \cdot \frac{gm}{1+\beta} \cdot \frac{1}{Ccol}$$

Timeconstant

with β=1 the RC-timeconstant for charging the column capacitor (Ccol) is doubled (1+ β=2),

$$\tau := \frac{Ccol}{gm} \cdot (1+\beta)$$

Conclusion

During charge sensing, the reset-off state, settling is (Cgs/Cfd+1) ~ 2 times slower than what one would intuitively expect when using only the SF-transconductance and the column capacitor value. The same holds for the noise voltage at the column.

The sampled thermal noise at the column is not the kT/Ccol but about (Cgs/Cfd+1)*kT/Ccol.

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