MICRO-523: Optical Detectors

Week Nine: CMOS Cameras: Advanced Systems and Technical Aspects/1 – Exercises

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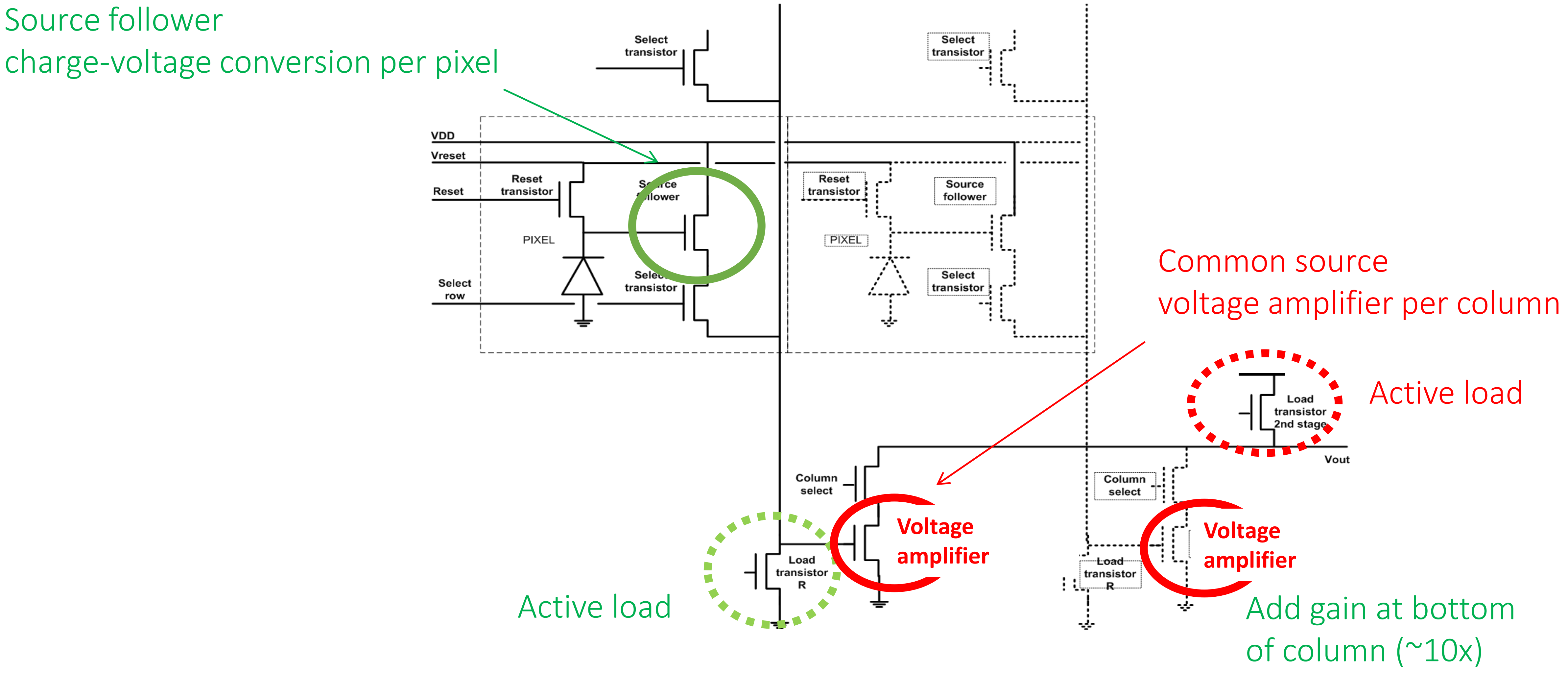
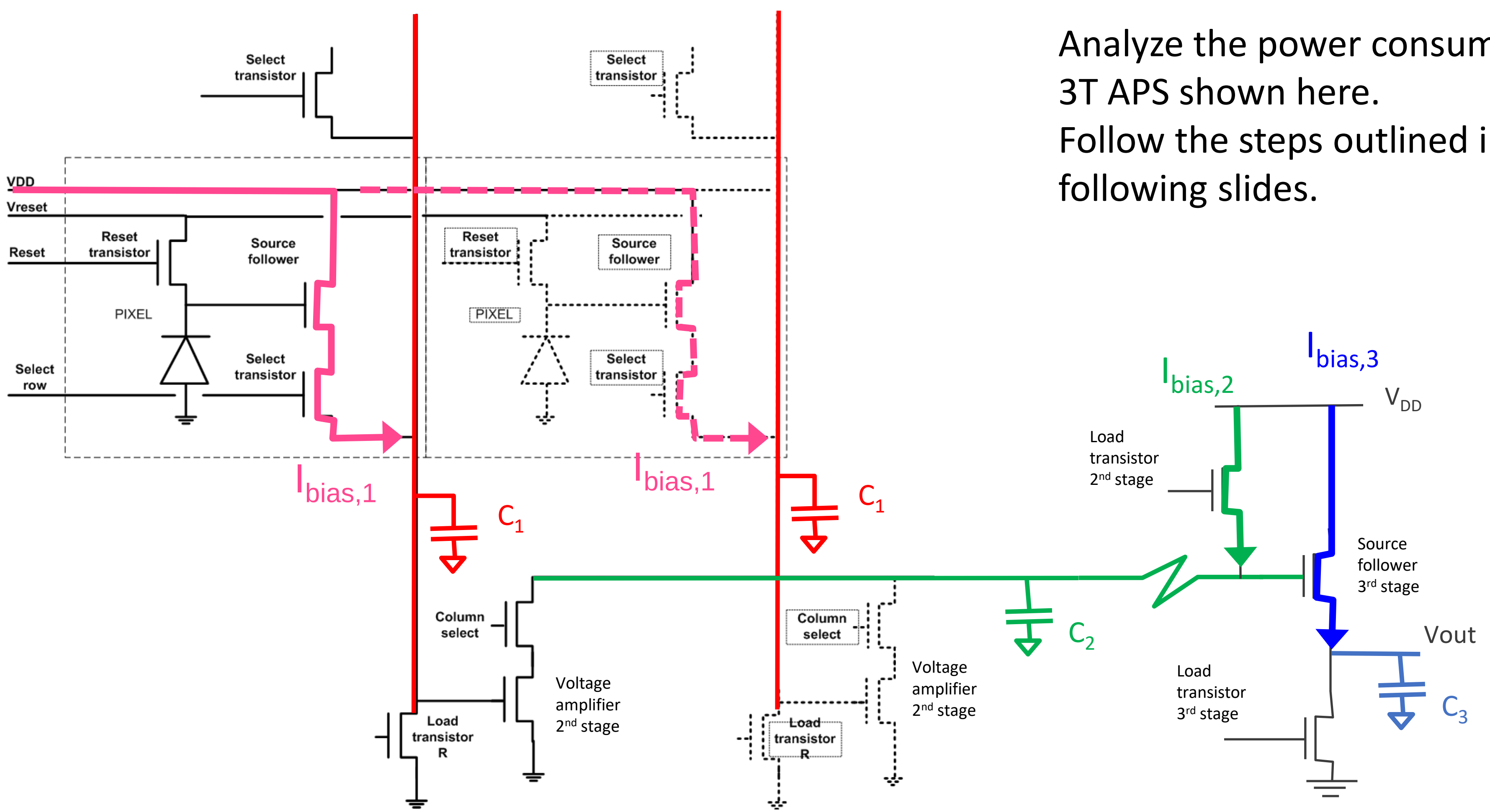
Outline

Exercise 9.1: Power Consumption of a 3T APS with 3 Output Stages



Exercise 9.1: Power Consumption of a 3T APS with 3 Output Stages

3T APS: Bias Currents for Analog Signals



Analyze the power consumption of the 3T APS shown here.
Follow the steps outlined in the following slides.

Exercise 9.1: Power Consumption of a 3T APS with 3 Output Stages

Consider a CMOS 3T APS camera with 3 output stages: one voltage (source) follower per pixel, one voltage amp per column, and one output buffer. The voltage gain of the 1st and 3rd stages are $G_1=G_3=1$, the 2nd stage has a gain G_2. In each pixel, the photodiode has a capacitance of 0.4fF/μm^2. The parasitic capacitances of the output lines are C_1=4pF and C_2=10pF. At the output, consider a capacitance of C_3=40pF, which corresponds to the contacts (pads, bonding wires) to the outside.

The camera has NxM pixels (N=1000 lines, M=1000 columns). The frame rate is r=25 images/s. Each pixel is 10x10μm^2 and the fill factor is 50%. The voltage bias is $V_{DD}=V_{reset}$=3.3V.

a) What are the working frequencies of each amplification stage?

b) Estimate the full well capacitance and the corresponding number of electrons

Exercise 9.1: Power Consumption of a 3T APS with 3 Output Stages

c) We are looking for a design that gives a variation of ΔV_{out}=2V at the output for 25'000 generated photoelectrons per pixel. To achieve this, what does the gain G_2 at the 2nd amplification have to be?

d) Considering a quantum efficiency of 80%, what illuminance is required at λ=550nm to collect 25'000 photoelectrons ? (in W/m^2 and in Lux).

e) The dark current density is 1nA/cm^2. How long does it take to collect 25'000 electrons from thermal generation?

f) As a compromise between speed, dynamic range, and pixel size, the bias current at the 1st follower stage is I_{bias1}=10mA. Is this enough to avoid a "slew-rate" problem on the C_1 capacitance? (The bias current has to allow the C_1 capacitance to charge quickly enough).

Exercise 9.1: Power Consumption of a 3T APS with 3 Output Stages

g) Determine the bias current I_{bias2} in the 2^{nd} amplification stage that allows charging the capacitance C_2 quickly enough (avoiding a “slew rate” problem).

h) Determine the bias current I_{bias3} in the 3^{rd} amplification stage that allows charging the capacitance C_3 quickly enough (avoiding a “slew rate” problem).

i) In a line, the “reset” and “row sel” capacitances for digital control signals have a total value of C_{row}=10pF. In each column, the “column sel” capacitance for digital signals is C_{col}=50fF. Calculate how much current is consumed for digital signals.

j) The “reset” voltage has to be such that photocharges are evacuated. What current is required if each pixel collects 25’000 photoelectrons per image?

k) Deduce this camera’s total consumption in terms of current and power (watts).

Exercise 9.2: APS Camera Sensitivity

An APS image sensor with a pixel size of d=10μm and an analogue output is illuminated with an optical power of 200μW/cm^2 at a wavelength of 600nm.

Can you estimate the output signal [in V] if the exposure time is set to 1ms?

$$V_{out} = N_\gamma \cdot F \cdot \eta \cdot \frac{q}{C}$$

FF: Fill Factor
η: Quantum efficiency
C_{PD} Photodiode capacitance
N_γ: Number of photons on one pixel in 1 ms: