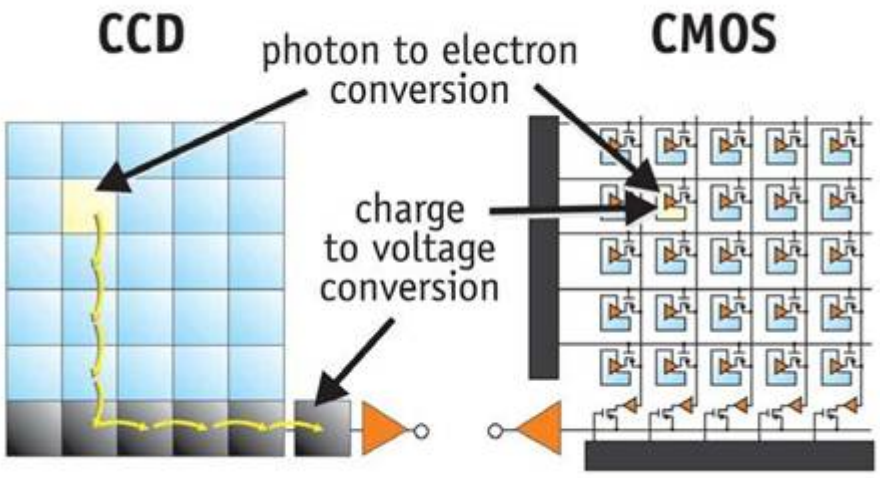
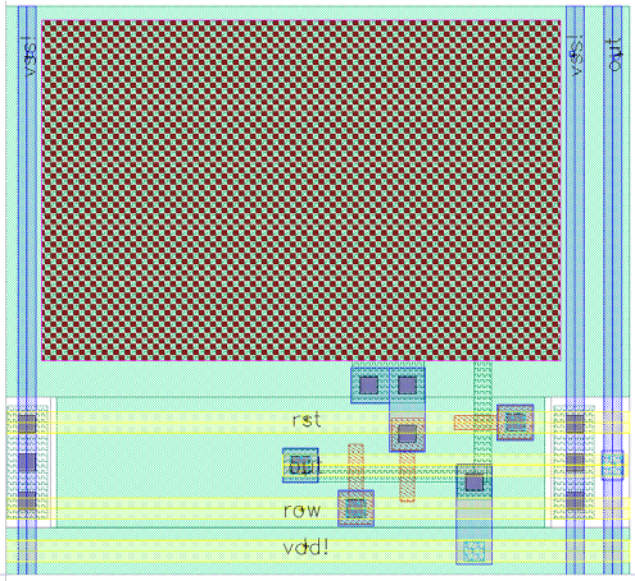
CCD Important Difference

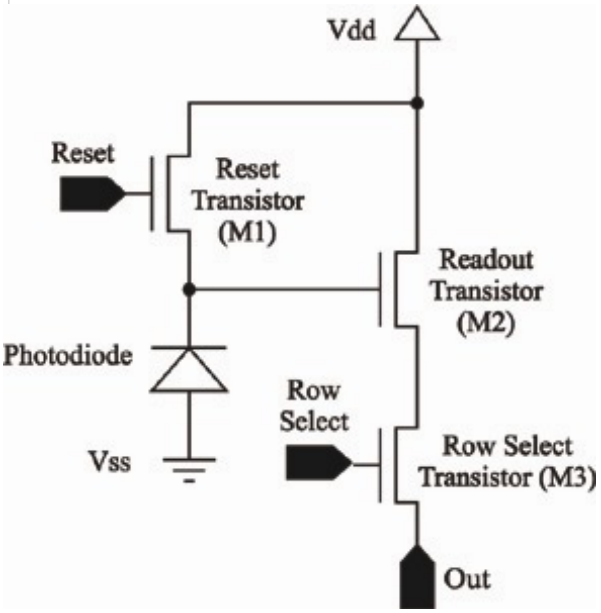
- CCDs have one important difference from CMOS sensors
- As CCD size changes sensitivity changes
- CCD collects photo electrons in CCD pixel area
- Thus as sensor shrinks sensitivity decreases
- Will see this is not true for CMOS sensors
- In CMOS sensitivity does not change with area.

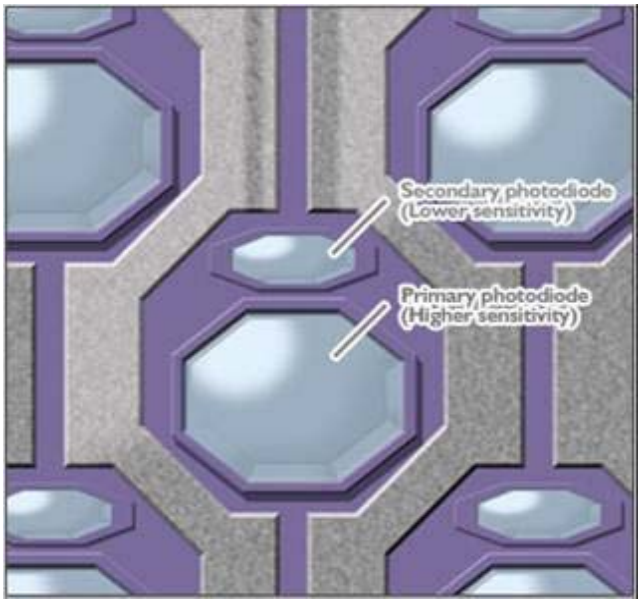


CMOS Active Pixel Sensor

- CMOS (Complementary MOS transistors)
- Is the dominant IC manufacturing process
- Active Pixel Sensor (APS) is the current dominant image sensor
- Proposed by Nobel at NASA in 1968
- Use photodiode as sensor – typically 25% of device
- Transistors to control output and reset
- But did not become important until late 1990's

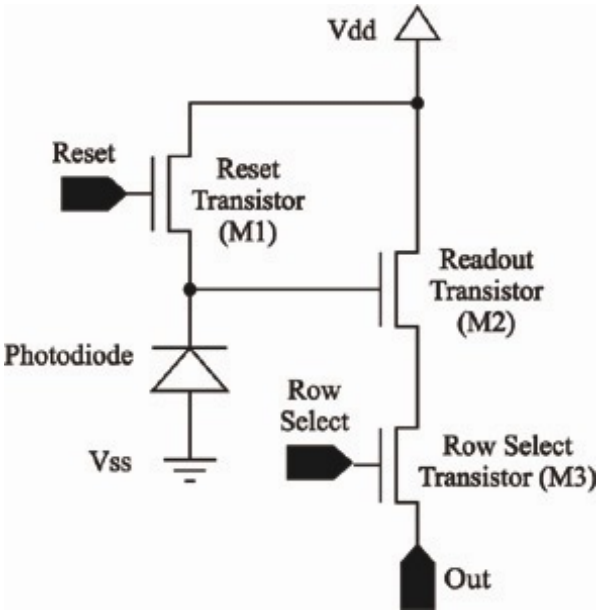


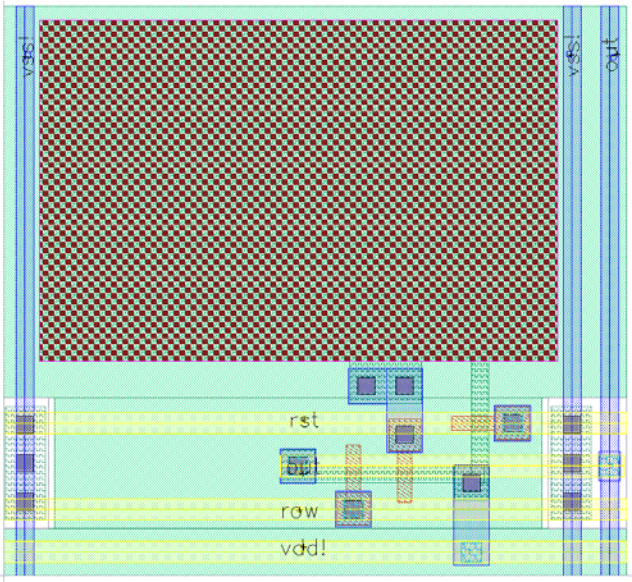




How APS Works

- Photodiode collects light
- C of Photodiode stores the e's
- Charge also collected on the readout (amplifier) transistor M2
- After exposure reset diode/M2 using transistor M1



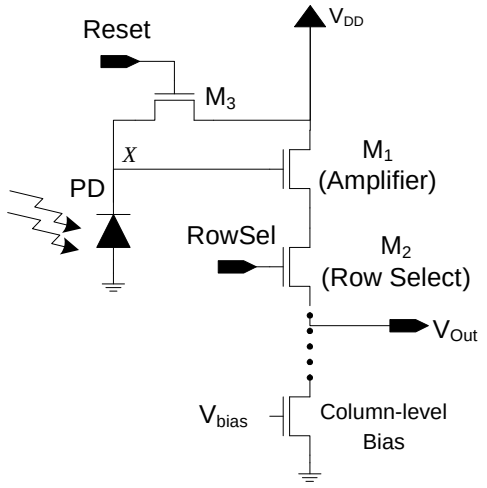


3 Transistor

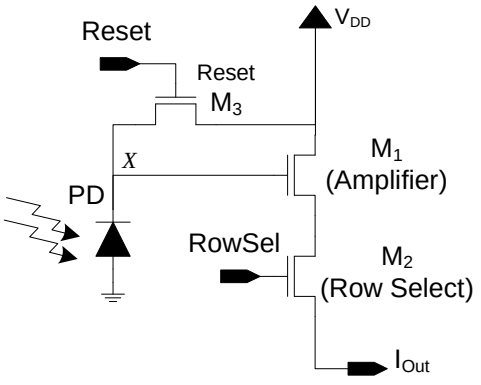
- Consider a single pixel in a column of pixels
- 3Transistor design PD = Photodiode
- M1 is output amplifier buffering the photodiode
- Photoelectrons collects on PD and M1 gate
- Actually PD and M1 are precharged to Vdd by reset M1
- PD actually discharges that charge
- V on point X changes depending on Charge

$$V(X) = \frac{Q_{reset} - T_{\text{int}}\left(I_{photo} + I_{dark}\right)}{C_X},$$

- Cx is combination of PD and M1 gate capacitance
- Row select (M2) selects a row of pixels to readout
- When M2 is turned full on
- Then M1 V controls the output



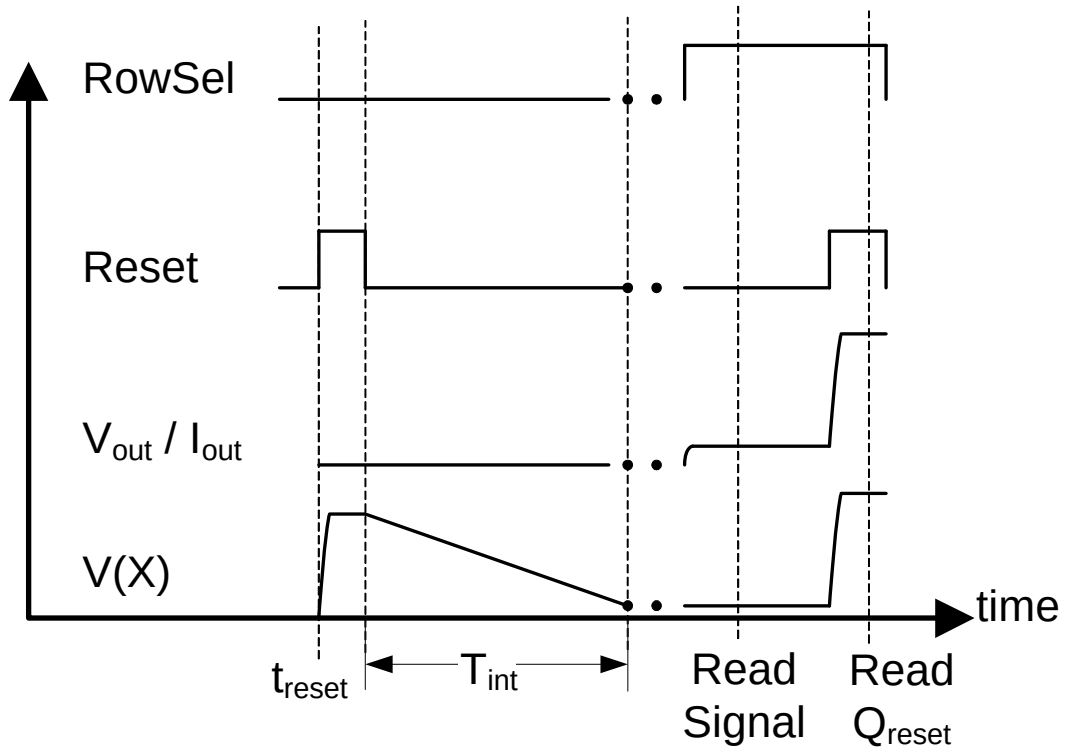
(a) Voltage domain.



(b) Current domain.

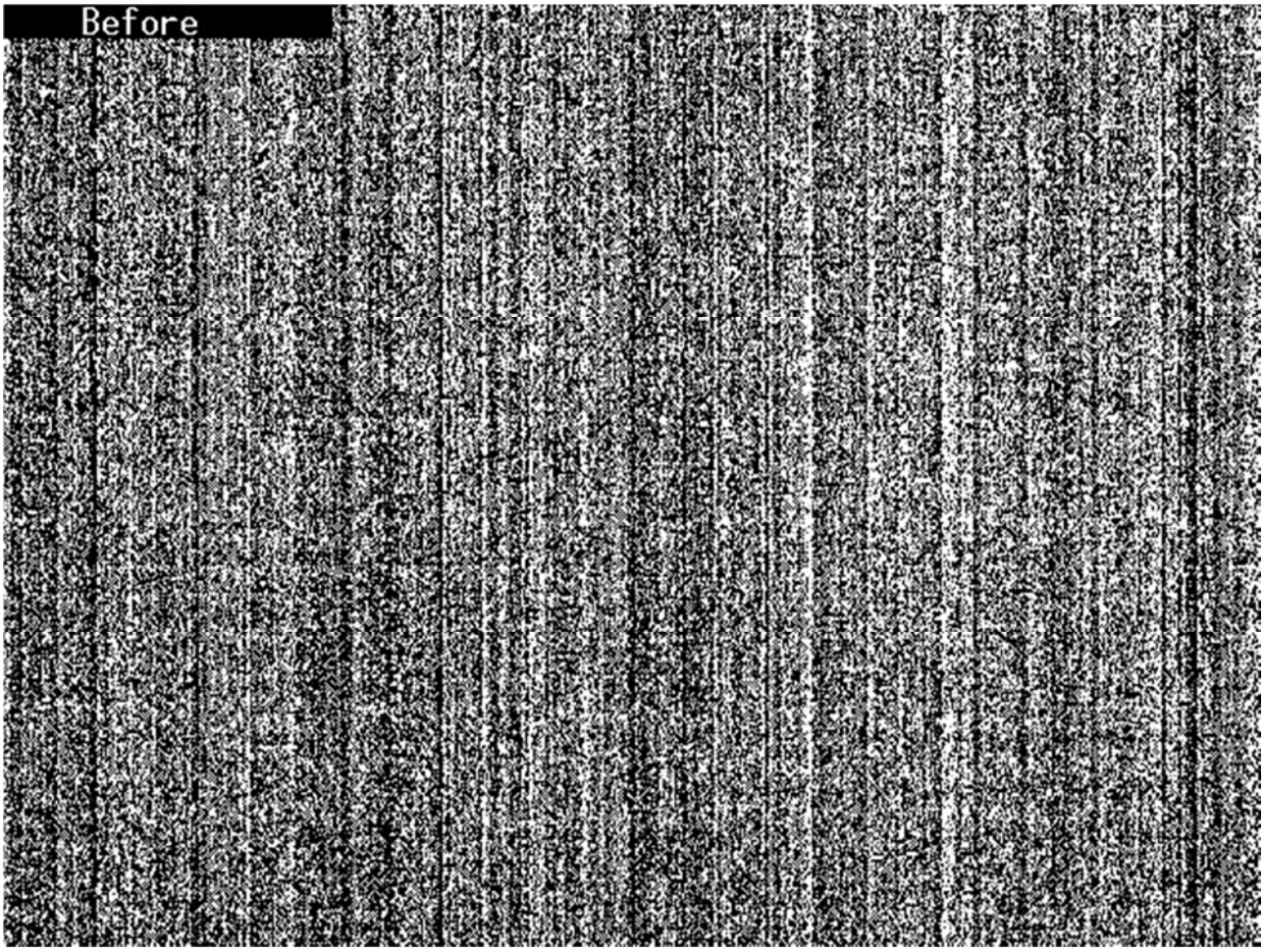
APS Cycle

- Reset photodiode PD through reset transistor M3 at time treset.
- Collect photogenerated carriers for Tint seconds (the integration period) on PD and get of amplifier M2.
- Transfer output signal to column line by activating row-select transistor, M2.
- Read and store output signal.
- Reset PD again.
- Read and store reset signal.
- Subtract measurements from 4 and 6 to calculate pixel value.



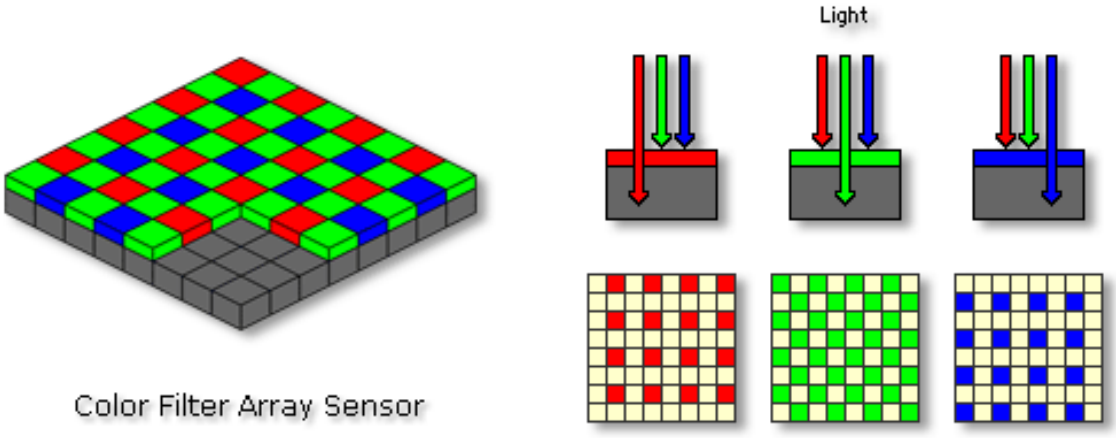
Why CMOS took so long

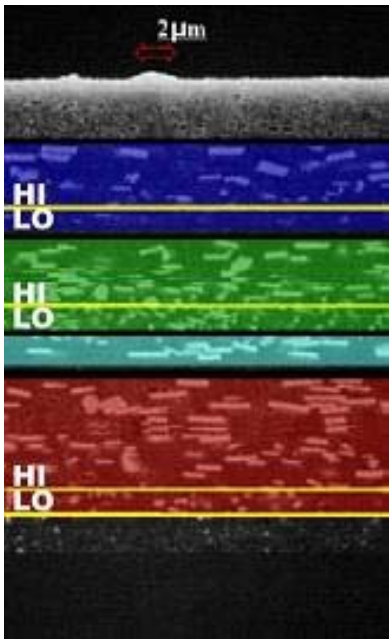
- Early days of CMOS transistor characteristics widely vary
- Gives Pattern Noise
- Every pixel had different response
- Hence really noisy image



Colour Limits

- Digital uses Bayer colour filter of Red, Green & Blue
- Algorithm interpolates colour between pixels called Demosaicing
- Eg for G pixel use neighboring R&B to estimate RGB values
- However if pattern changes rapidly produces colour error
- Film does all 3 colours at same spot- better colour resolution
- Also problem with colour balance: getting the whites correct
- In digital jpg colour balance calculated in camera but frozen in
- But may freeze in wrong balance and only 8 bits of colour
- Shoot Digital Raw (pure sensor data)
- Can do balance after for the light scene





Colour balance error