Imagers

Last modified 4/14/20

Imagers

src: Nikon

- MOS Capacitor Photodetector

- Photo transparent polysilicon gate

- P-type silicon bulk (PMOS Capacitor)

- Biased in depletion mode (holes have been moved out of surface region)
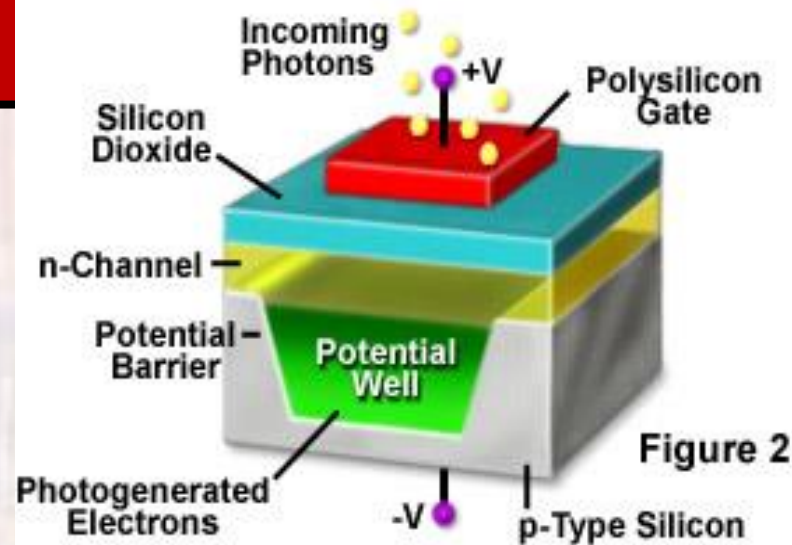
- Incident light creates hole-electron pairs
  - Holes are swept away
  - Electrons are trapped under the gate

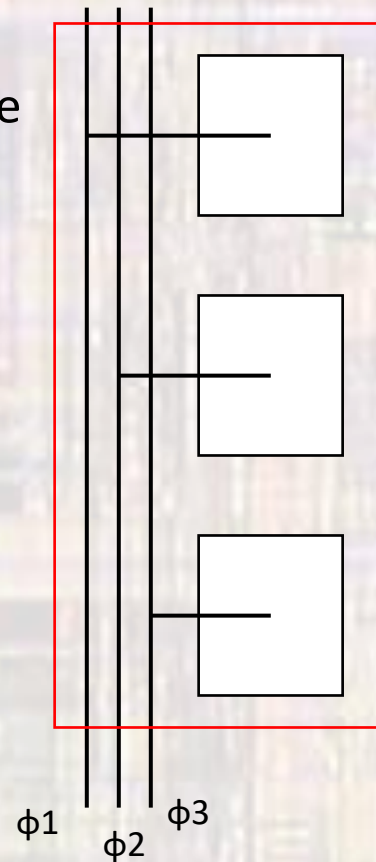- Total charge trapped is proportional to the intensity of the incident light

Imagers

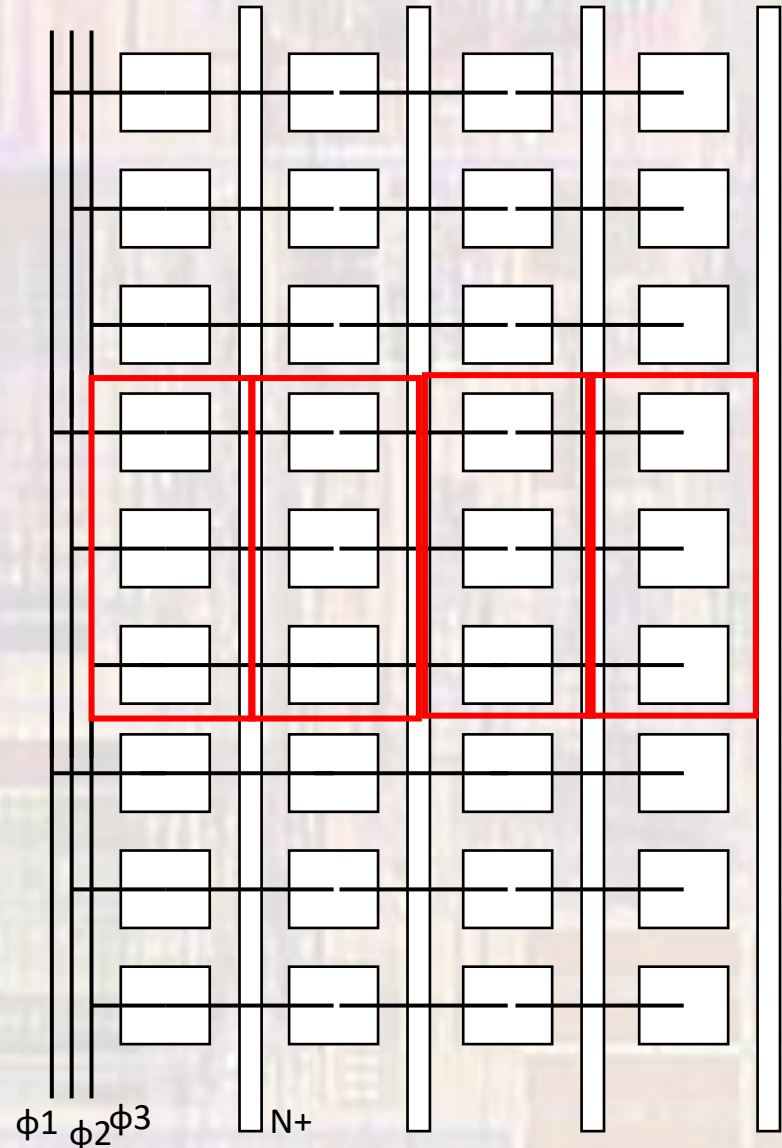- ## CCD Pixel Structure

  - Each pixel is configured as 3 gates
  - Each gate as a separate control line

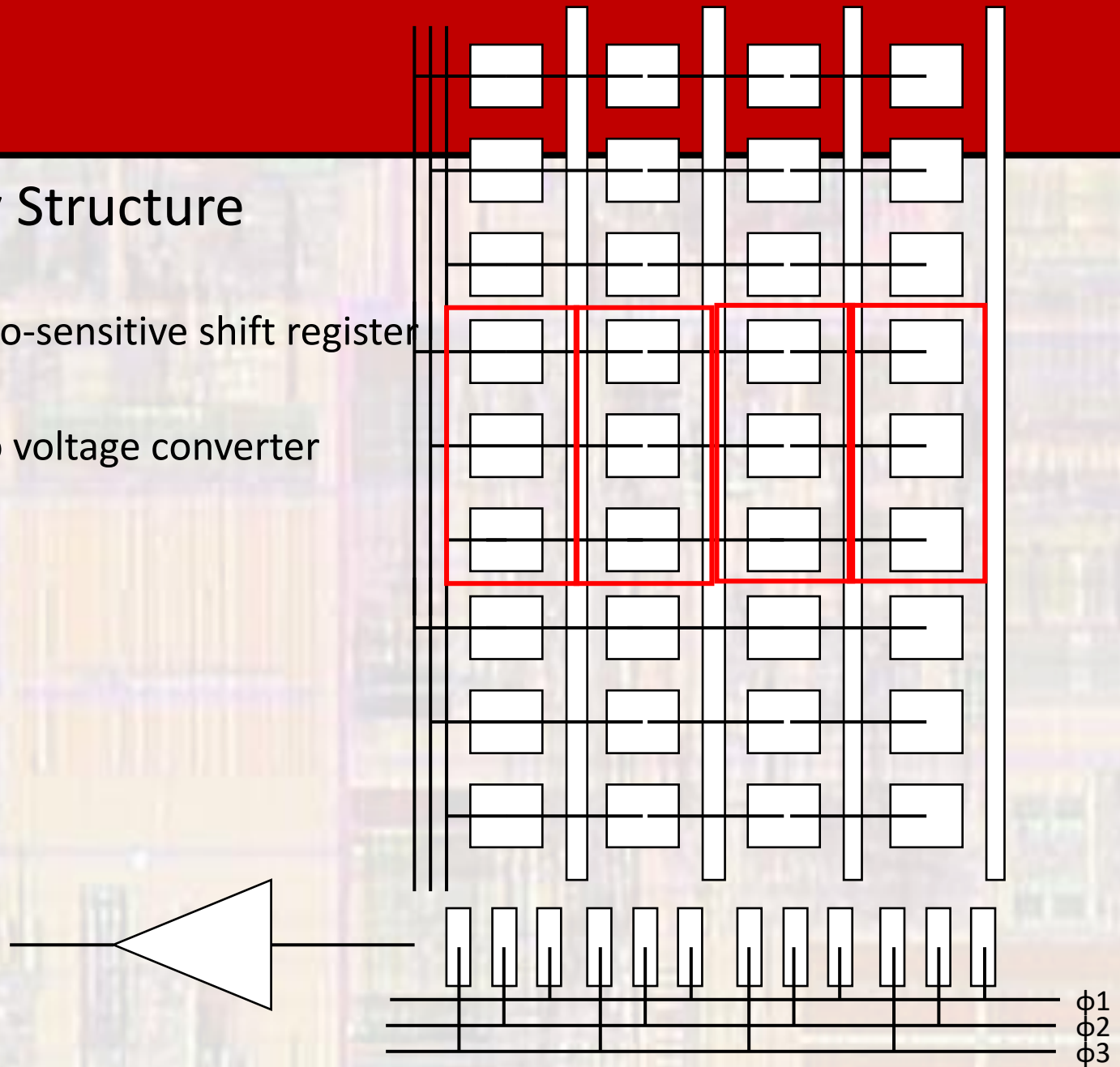φ1   φ2   φ3

Imagers

- CCD Array Structure

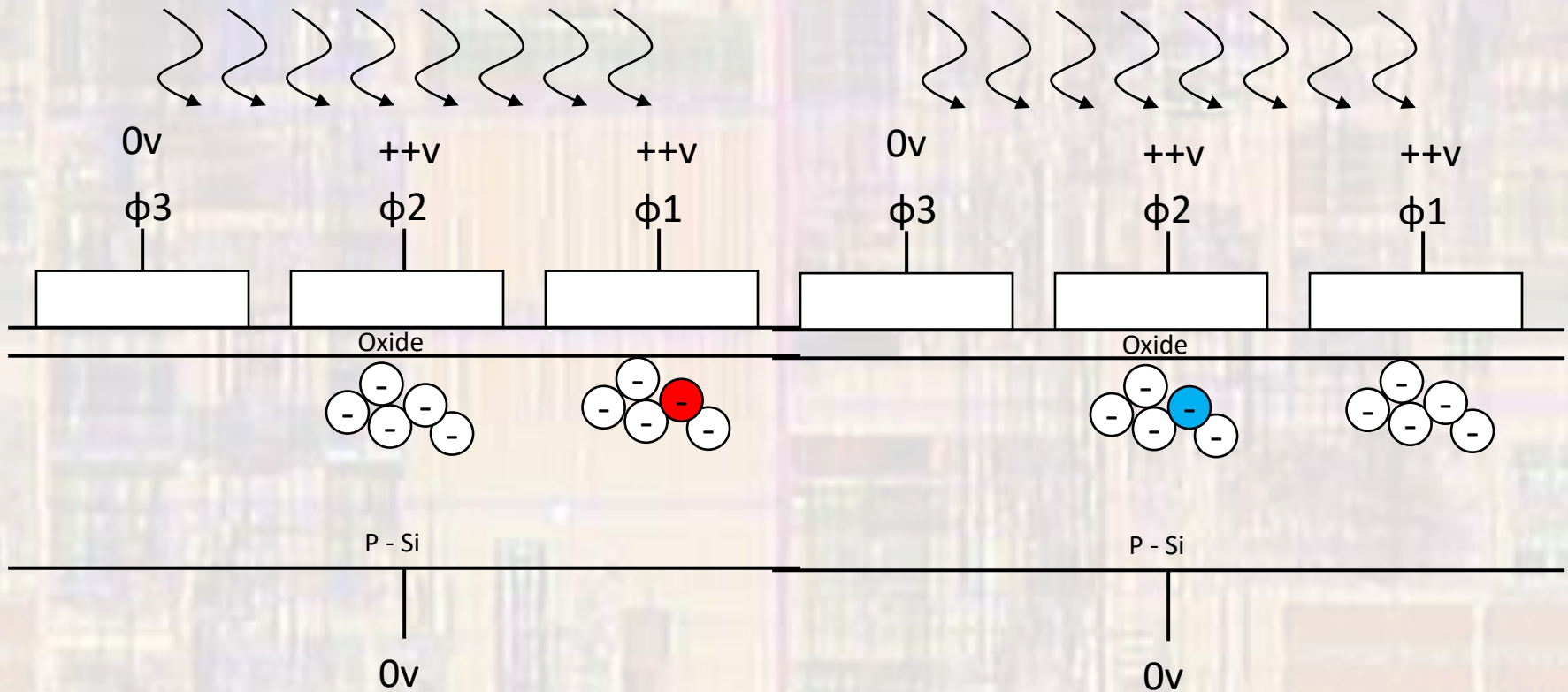 - Columns of pixels
    - Separated by barrier stops

φ1 φ2 φ3   N+

Imagers

- CCD Array Structure

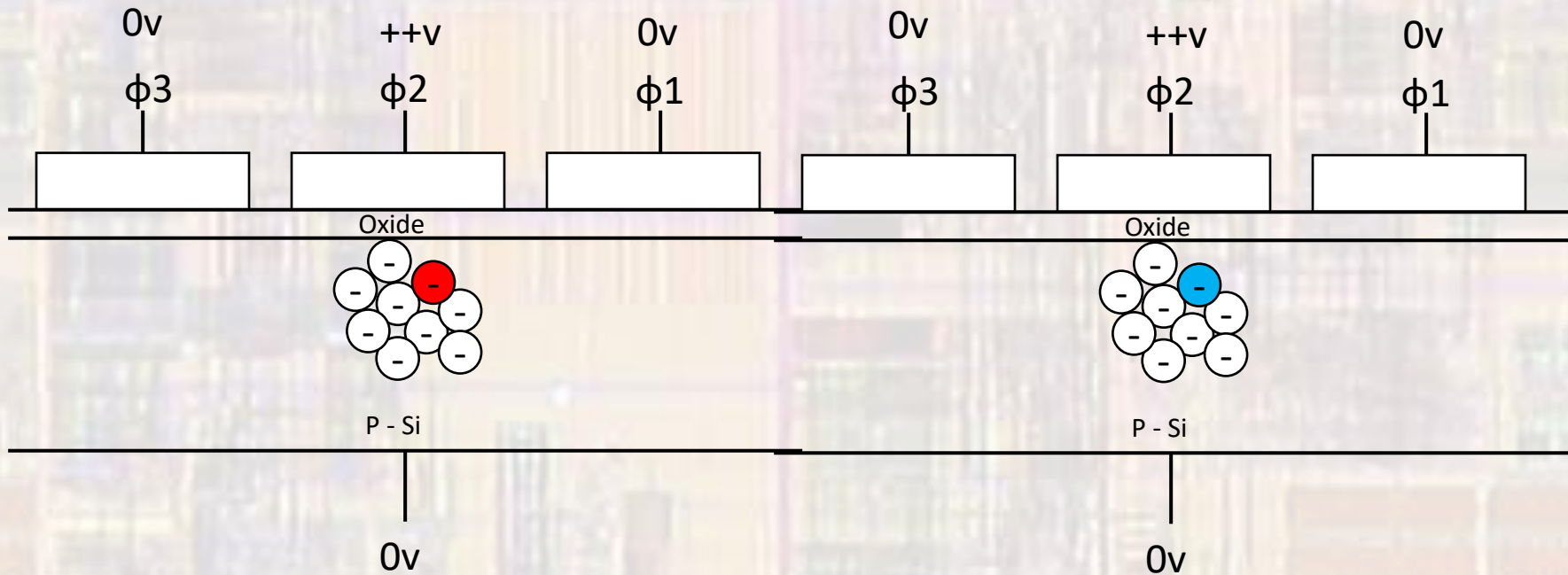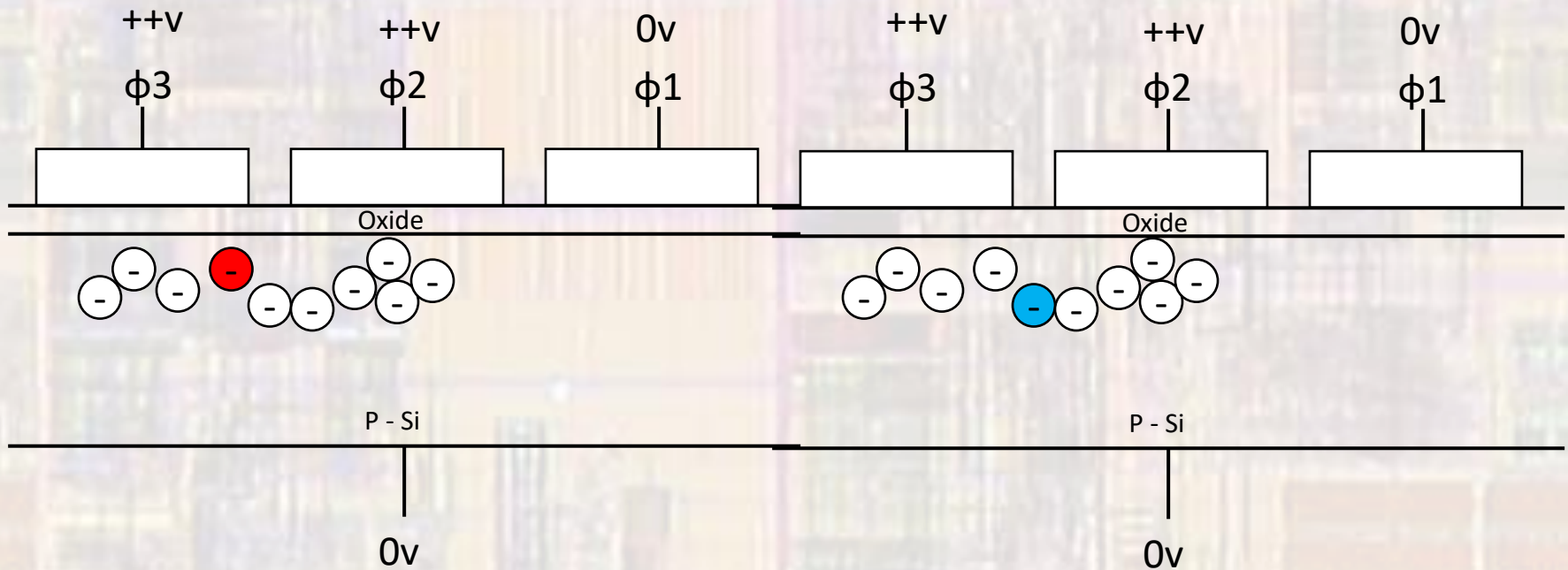 - Non photo-sensitive shift register

  - Charge to voltage converter

φ1
φ2
φ3

5

Imagers

- CCD Operation

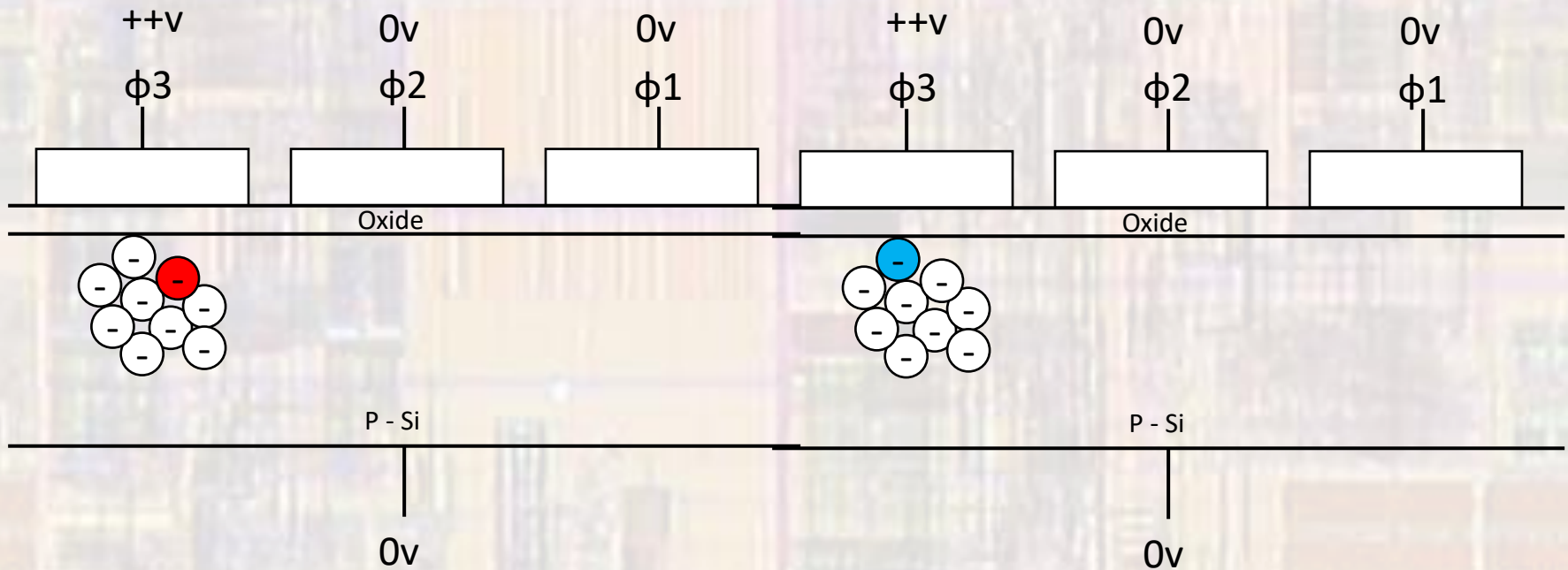# Imagers

- CCD Operation

  - Shutter light - off

0v	++v	0v	0v	++v	0v
φ3	φ2	φ1	φ3	φ2	φ1

Oxide

P - Si

Oxide

P - Si

0v

0v

Imagers

- CCD Operation

++v　　　　　++v　　　　　0v　　　　　　++v　　　　　++v　　　　　0v

φ3　　　　　φ2　　　　　φ1　　　　　　φ3　　　　　φ2　　　　　φ1

Oxide　　　　　　　　　　　　　　　　Oxide

P - Si　　　　　　　　　　　　　　　P - Si

0v　　　　　　　　　　　　　　　　0v

Imagers

- CCD Operation

++v   0v   0v   ++v   0v   0v

φ3   φ2   φ1   φ3   φ2   φ1

Oxide   Oxide

P - Si   P - Si

0v   0v

Imagers

- CCD Operation

++v	0v	++v	++v	0v	++v
φ3	φ2	φ1	φ3	φ2	φ1

Oxide   Oxide

P - Si   P - Si

0v   0v

Imagers

- CCD Operation

0v	0v	++v	0v	0v	++v
φ3	φ2	φ1	φ3	φ2	φ1

Oxide

Oxide

P - Si

P - Si

0v

0v
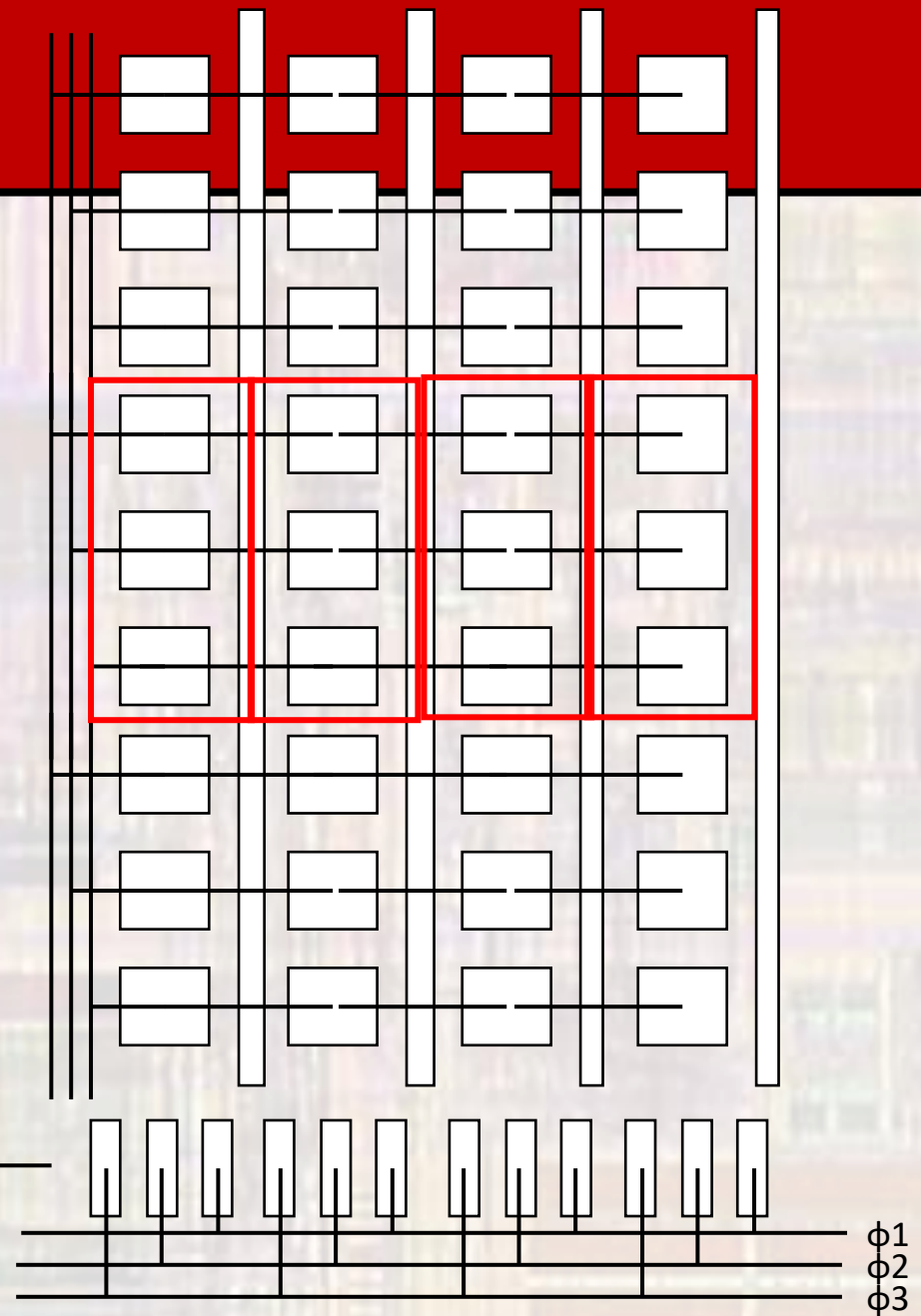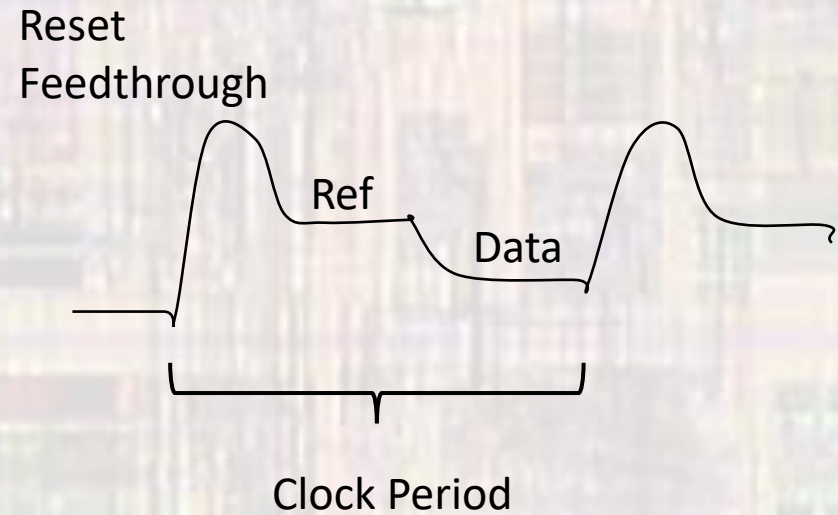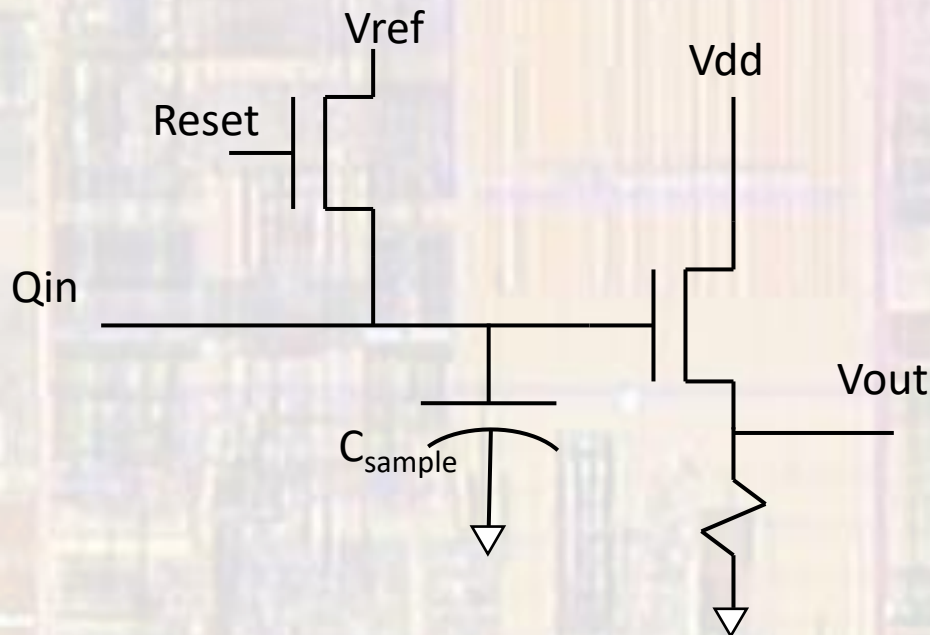
Imagers

- CCD Array Structure

  - One row transferred down to the shift register

  - Entire shift register transfer out to the charge converter

  - Next row transferred down
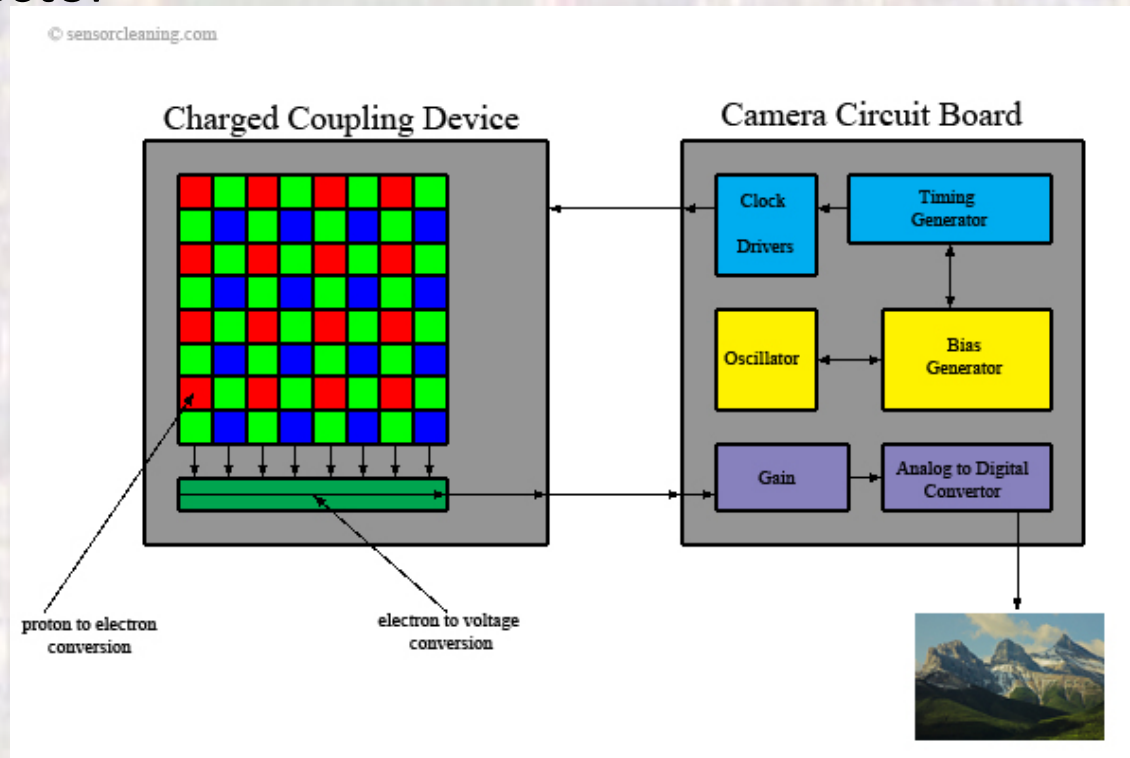
  - …

φ1
φ2
φ3

Imagers

- CCD Array Structure

  - Sense amplifier

Imagers

- CCD - color

  - RGB filters used to allow only 1 color to reach the detector

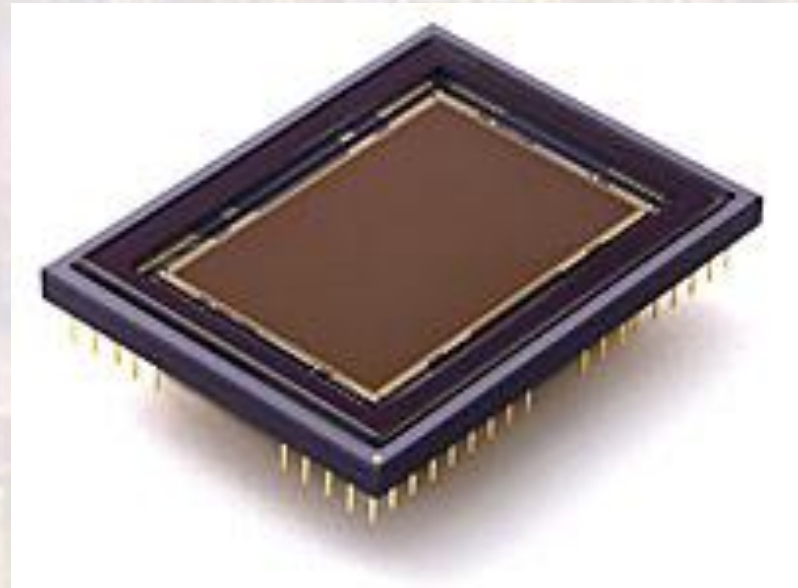
© sensorcleaning.com

Charged Coupling Device

Camera Circuit Board

Clock Drivers

Timing Generator

Oscillator

Bias Generator

Gain

Analog to Digital Convertor

proton to electron conversion

electron to voltage conversion

Imagers

- CCD

  - Dominant structure until 1990+

  - Lowest noise

  - Slow readout

  - Dominates scientific, military applications
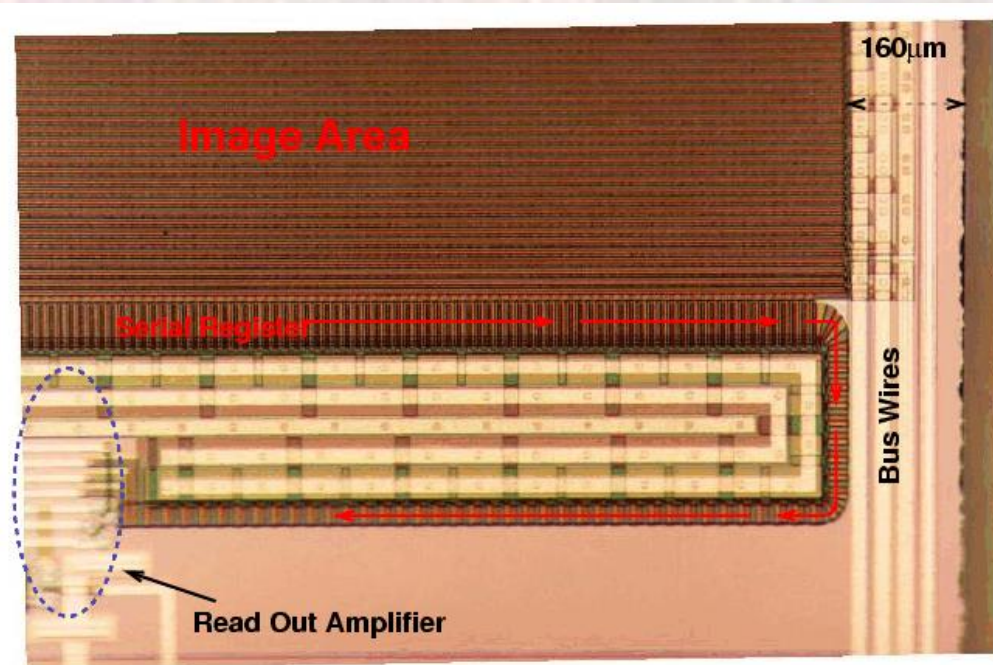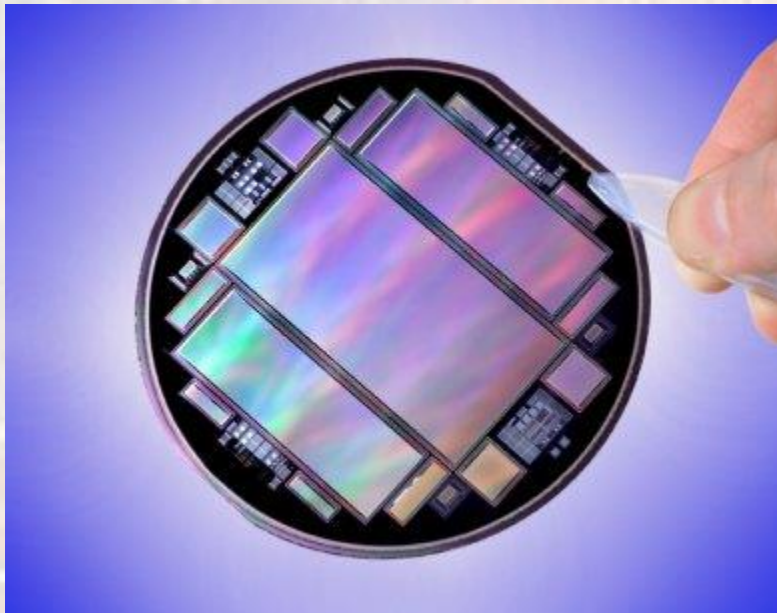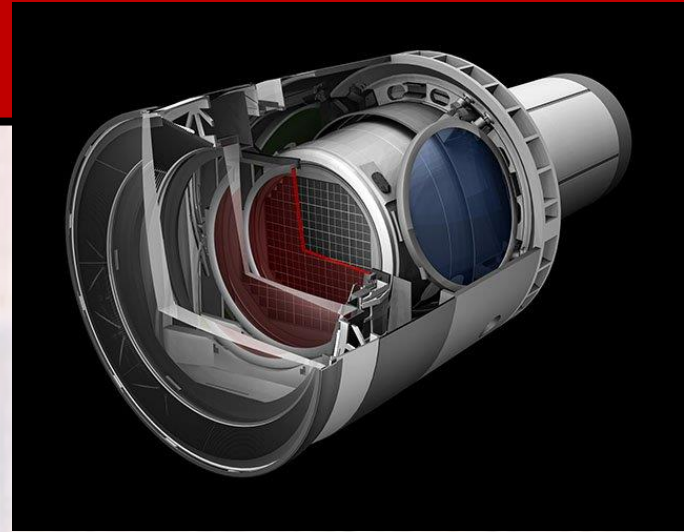 - Common in medical, industrial systems, very high end photography

Imagers

- CCD

  - Teledyne FTF9168C

    - 60Mpixel
    - 8956 x 6708
    - 6um x 6um pixel
    - 95% fill factor

Imagers

- CCD Sensors

  - Largest single – 111Mpixel
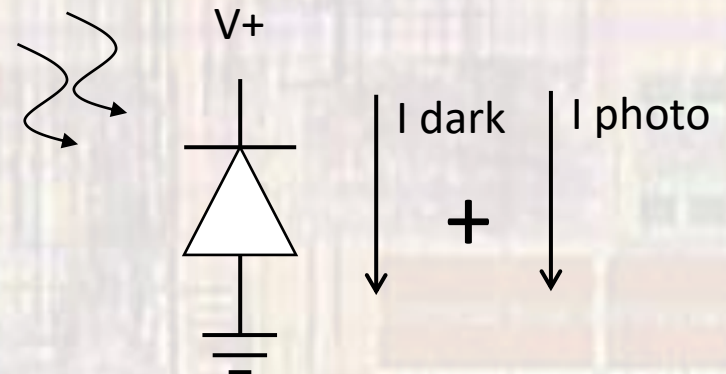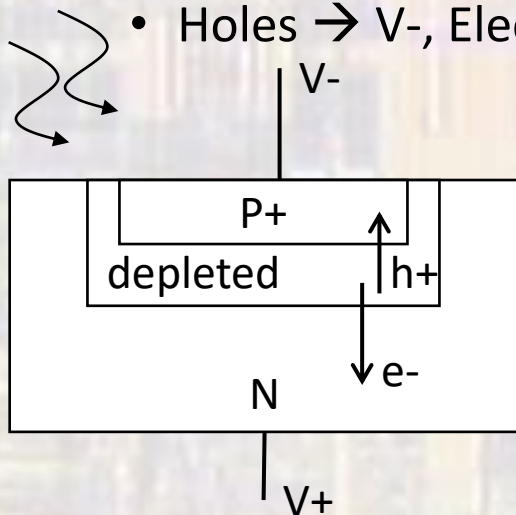 - Largest array – 3.2Gpixel
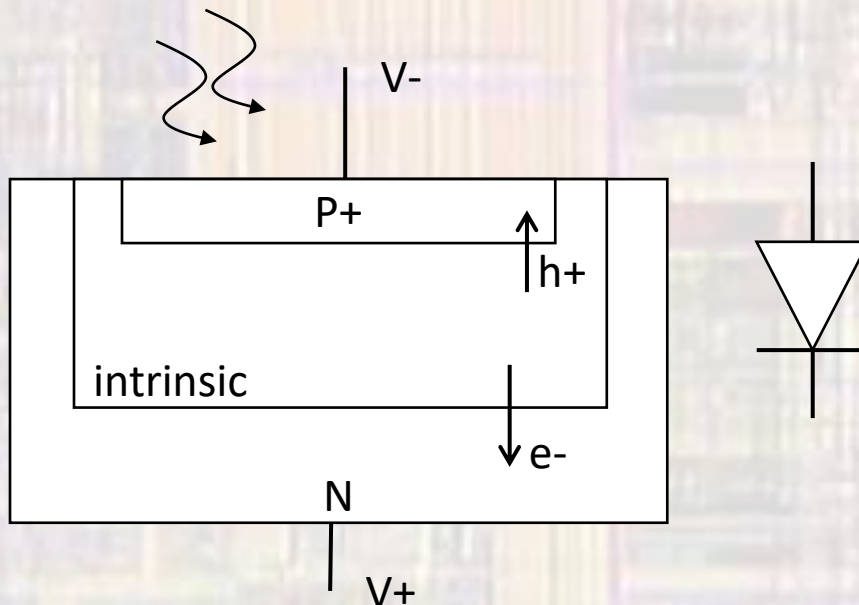
Imagers

- Photo-diode

  - Reverse bias the junction (leakage current == dark current)
  - Light creates hole-electron pairs
  - h-e pairs immediately recombine in P+ and N regions
  - h-e pairs in the depletion region are swept to the P+ and N regions
    - Holes → V-, Electrons → V+ → increase in reverse current

Imagers

- Photo-diode

  - Depletion region is not very large $\rightarrow$ limited performance

  - PIN diode
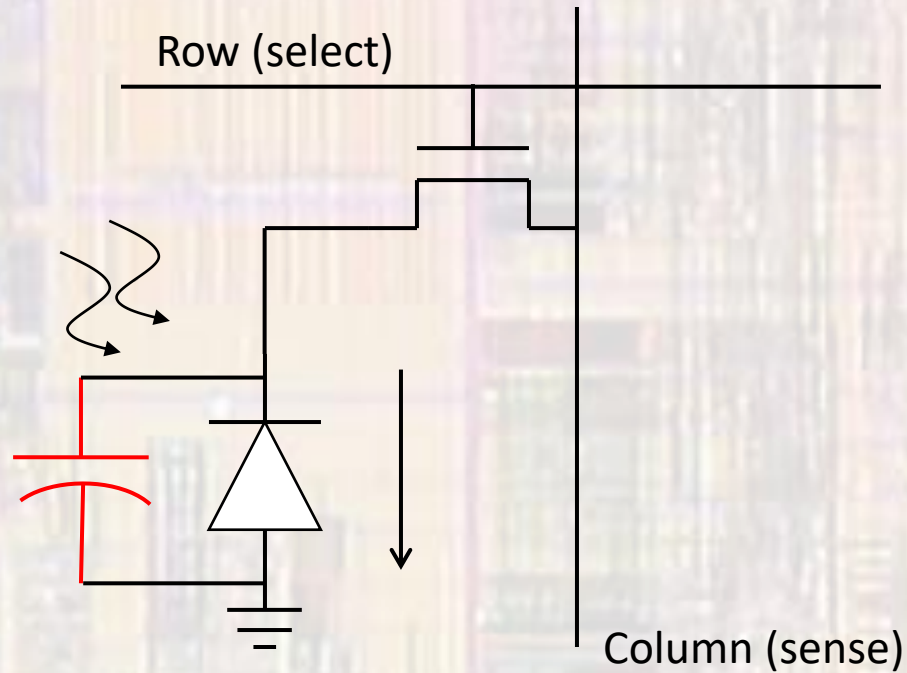   - Add an intrinsic region to increase the h-e generation volume

Imagers

- Photo-diode

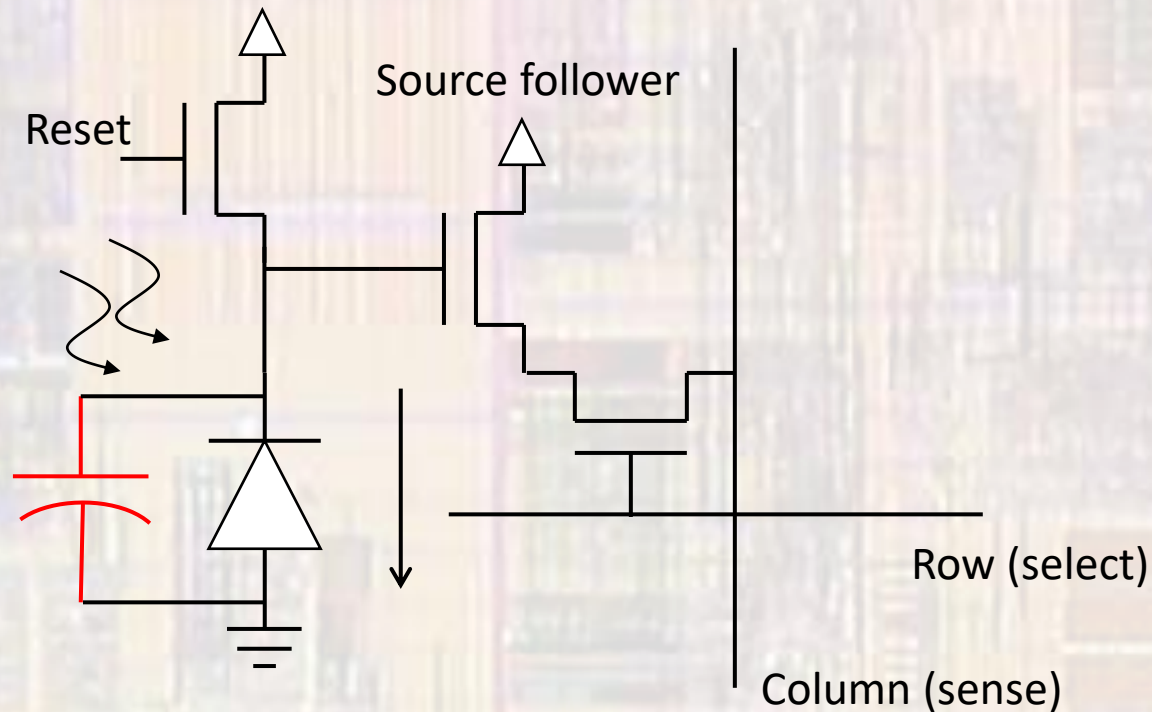| Material	Properties	Sensitivity	Usage
Silicon	low dark current, high speed	400 and 1000 nm	visible
Germanium	high dark current, slow speed	900 and 1600 nm	infrared
Indium Gallium Arsenide Phosphide	low dark current, high speed	1000 and 1400 nm	
Indium Gallium Arsenide	low dark current, high speed	900 and 1700 nm	

Imagers

- Passive Pixel Sensor

  - Simple and small
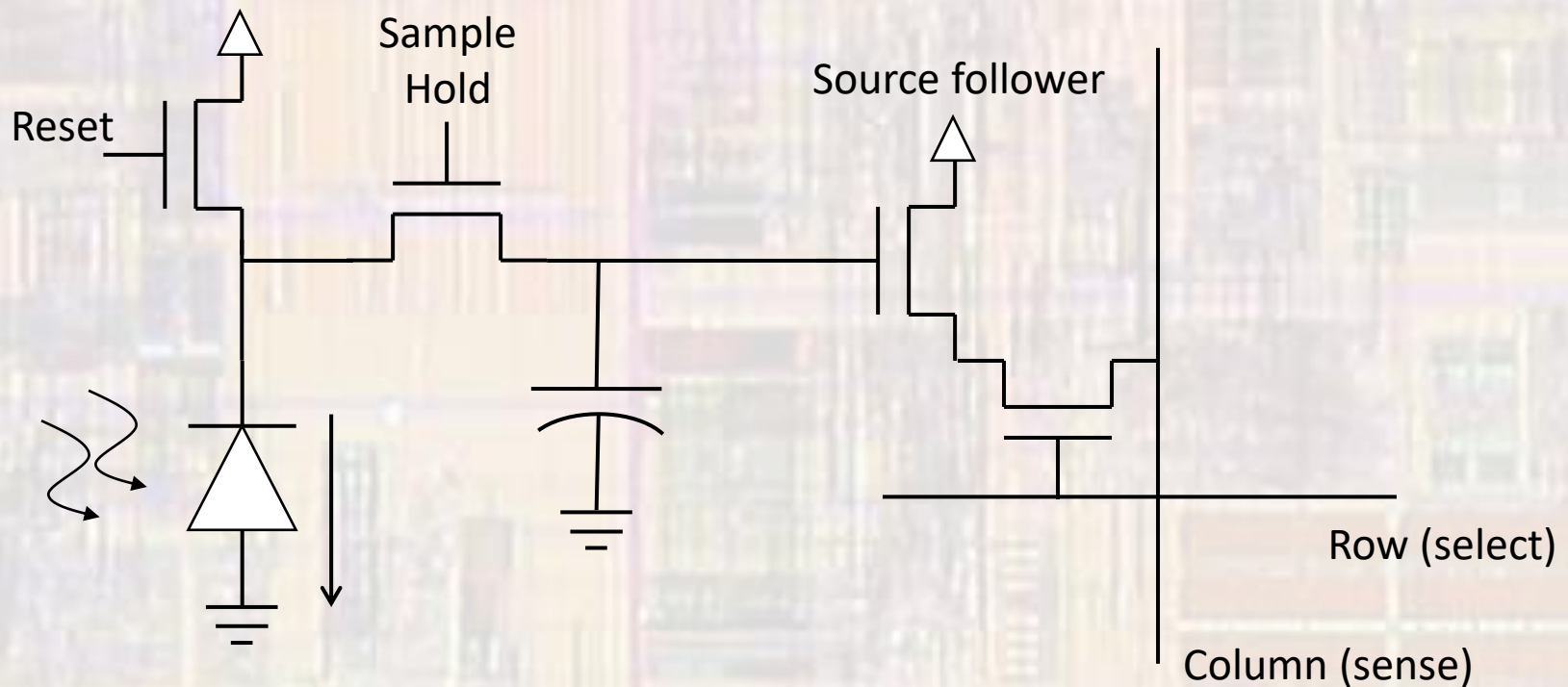 - Poor performance

Row (select)

Column (sense)

Imagers

- Active Pixel Sensor (APS)

  - Reset – fully charges the parasitic capacitance
  - Light – discharges proportional to the intensity and length of exposure
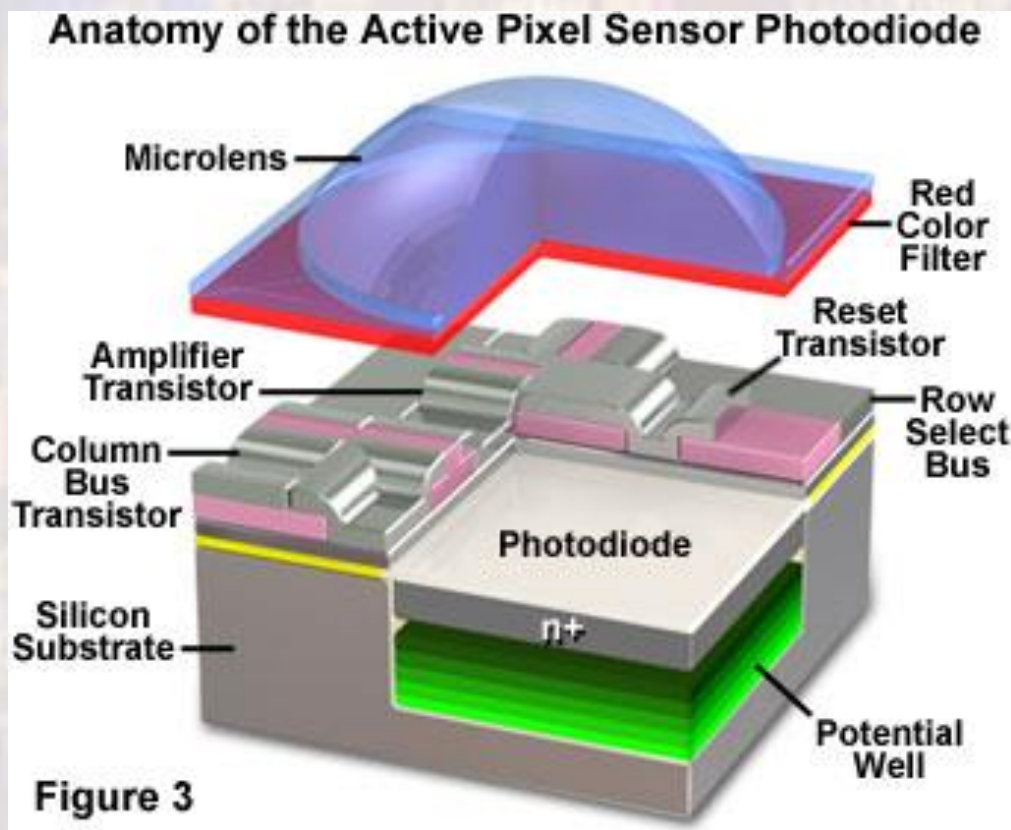

Source follower

Reset

Row (select)

Column (sense)

Imagers

- Active Pixel Sensor (APS)

  - 4T structure
  - Allows an electronic shutter (S/H)

Reset

Sample Hold

Source follower

Row (select)

Column (sense)

Imagers

- Active Pixel Sensor (APS)

Src: http://micro.magnet.fsu.edu/

Imagers

- Active Pixel Sensor (APS)

Bayer Color Filter Mosaic Array and Underlying Photodiodes

Src: http://micro.magnet.fsu.edu/

Imagers

- Active Pixel Sensor (APS)

Src: http://micro.magnet.fsu.edu/
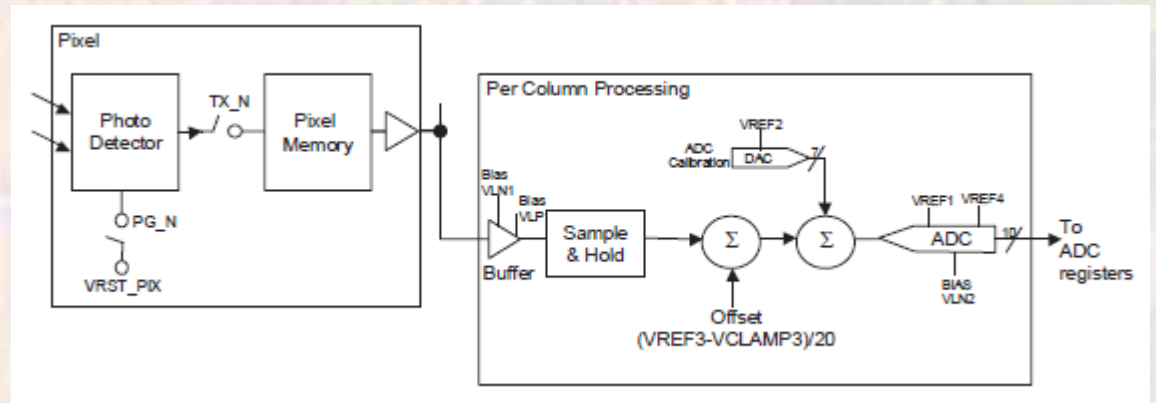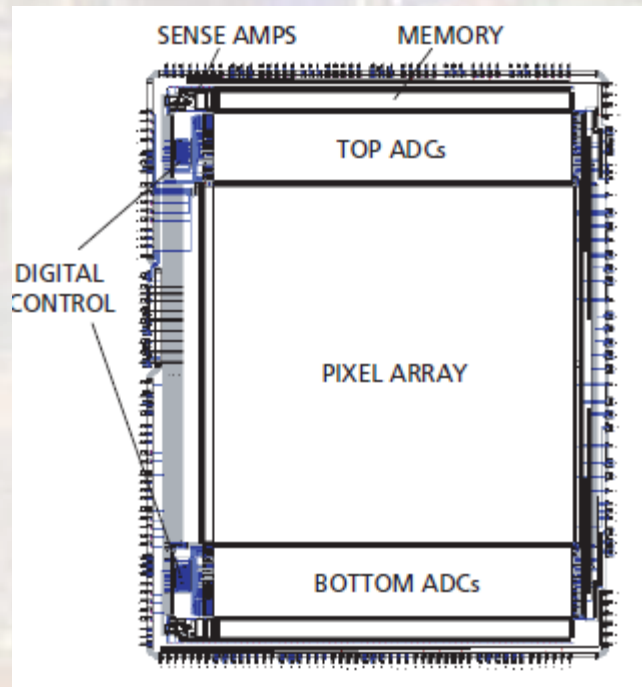
Imagers

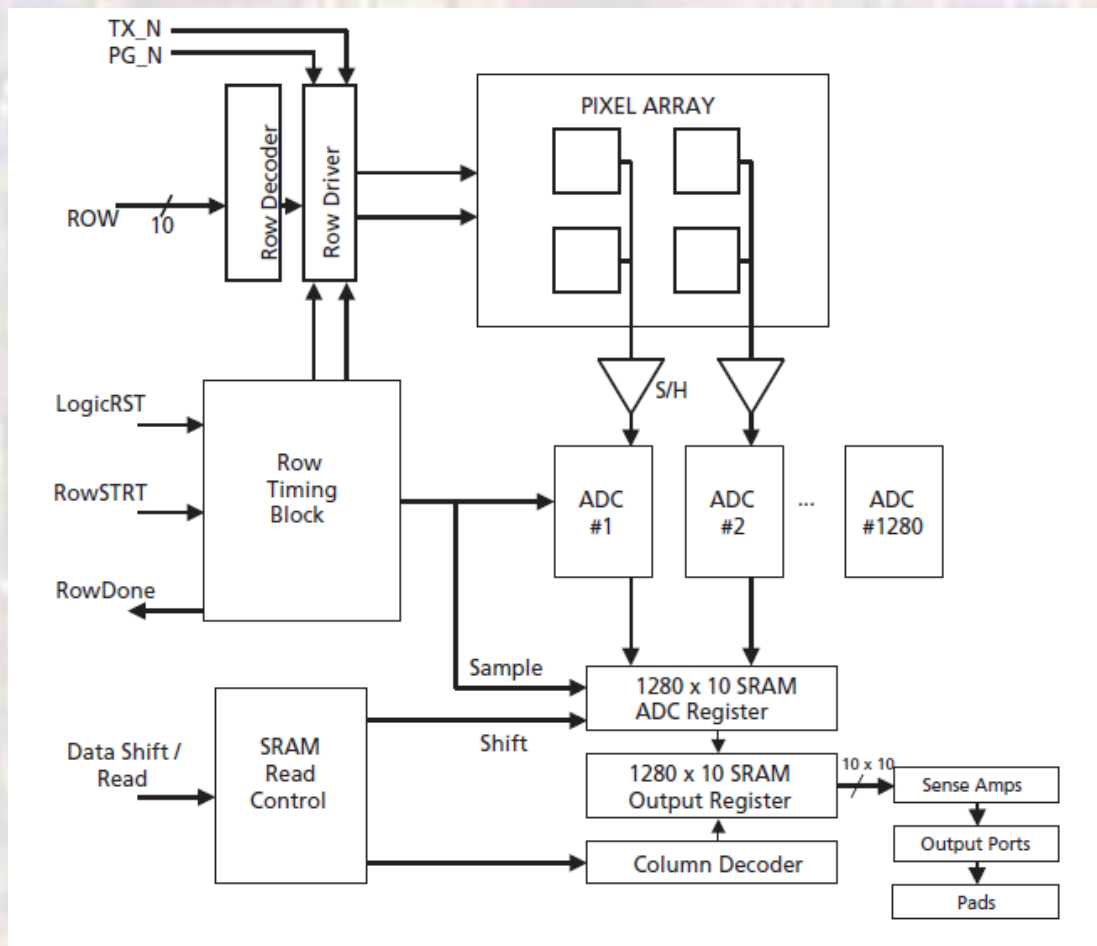- Active Pixel Sensor (APS)

Src: micron

Imagers

- Active Pixel Sensor (APS)

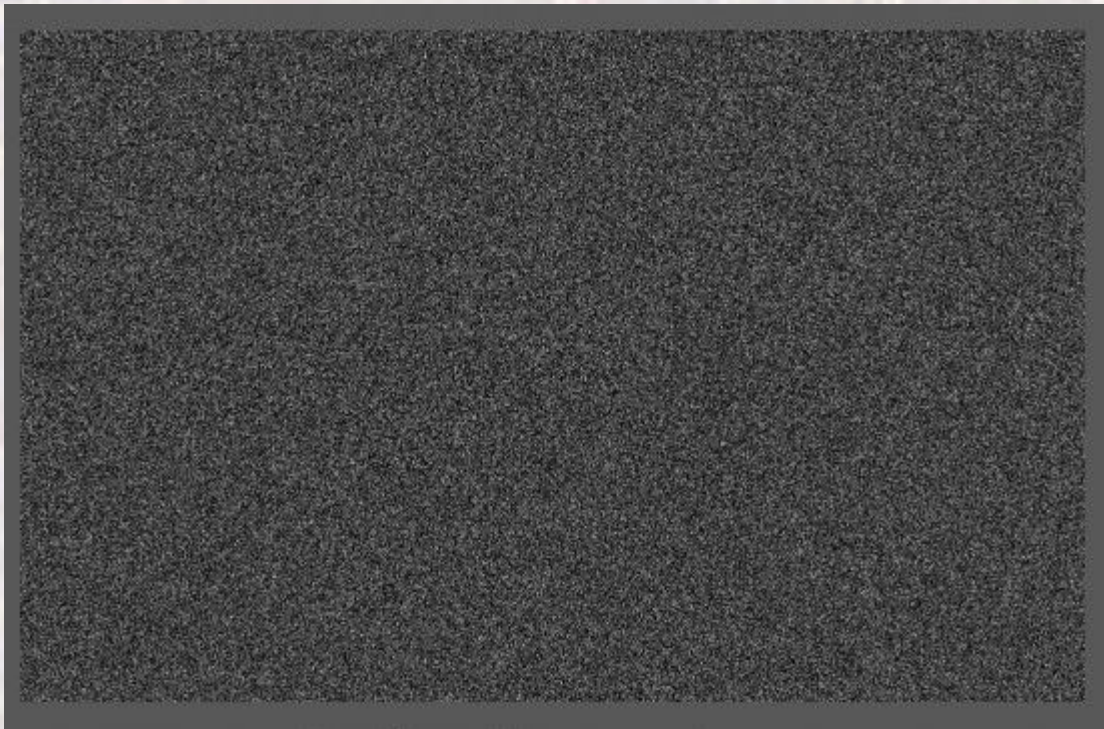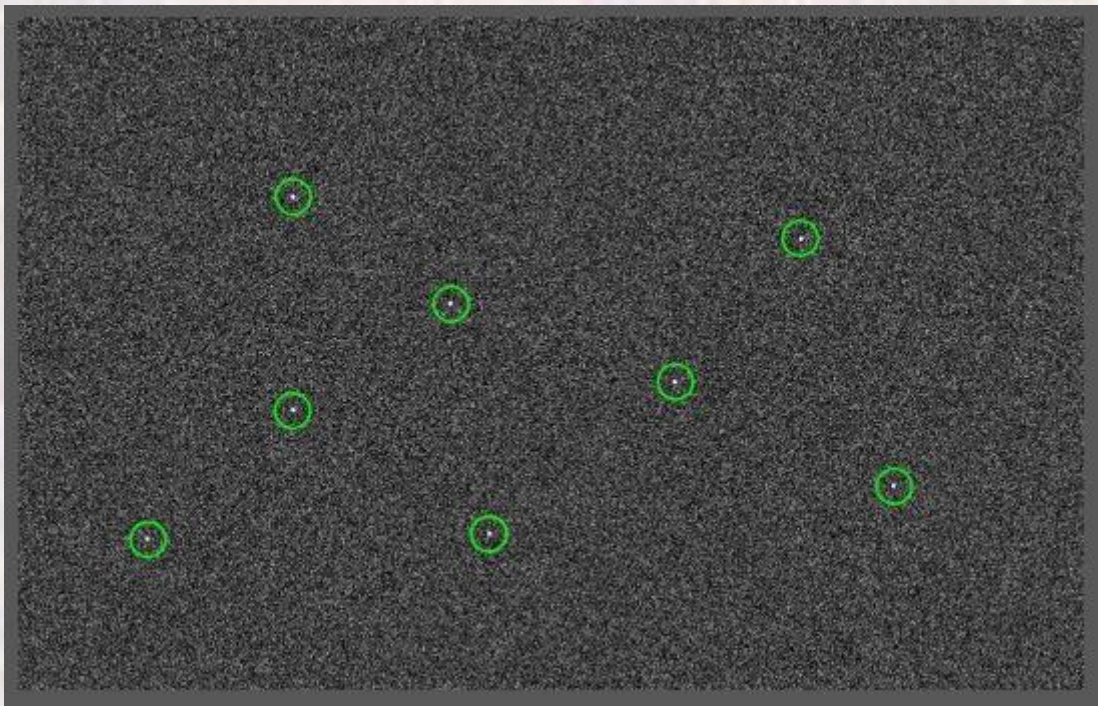Src: micron   © tj

Imagers

- Active Pixel Sensor (APS)

  - Dark Noise

Src: exclusive architecture
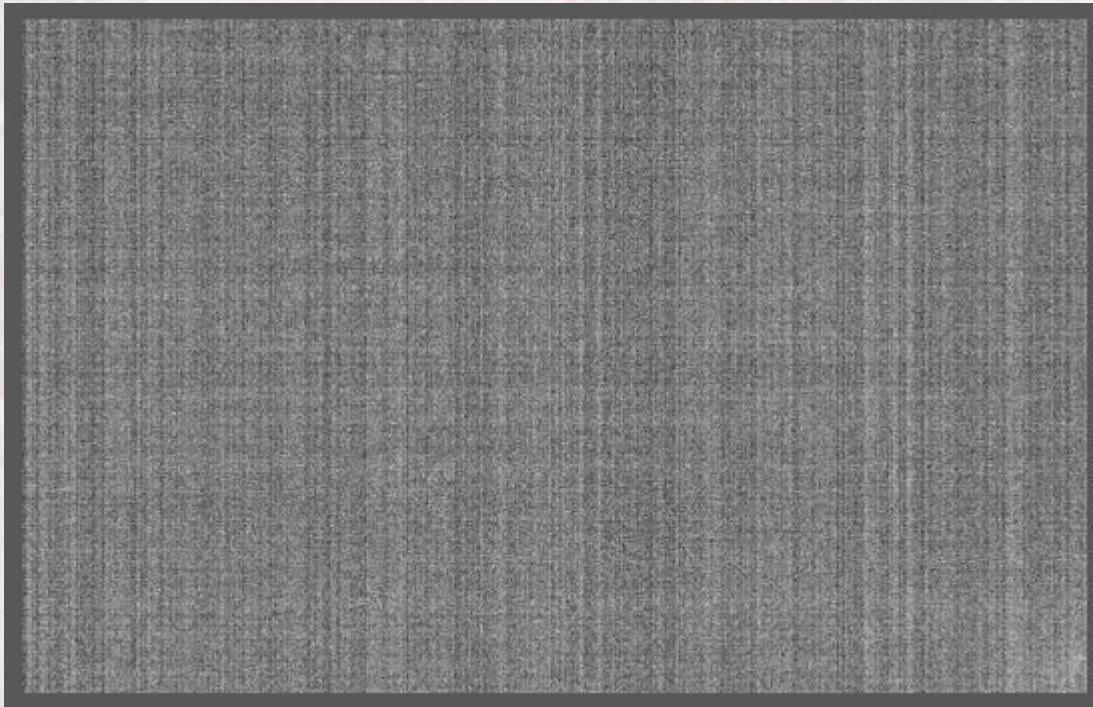
© tj

Imagers

- Active Pixel Sensor (APS)

  - Fixed Pattern Noise
    - Especially sensitive diodes

Src: exclusive architecture

Imagers

- Active Pixel Sensor (APS)

  - Banding Noise
    - Readout electronics patterns
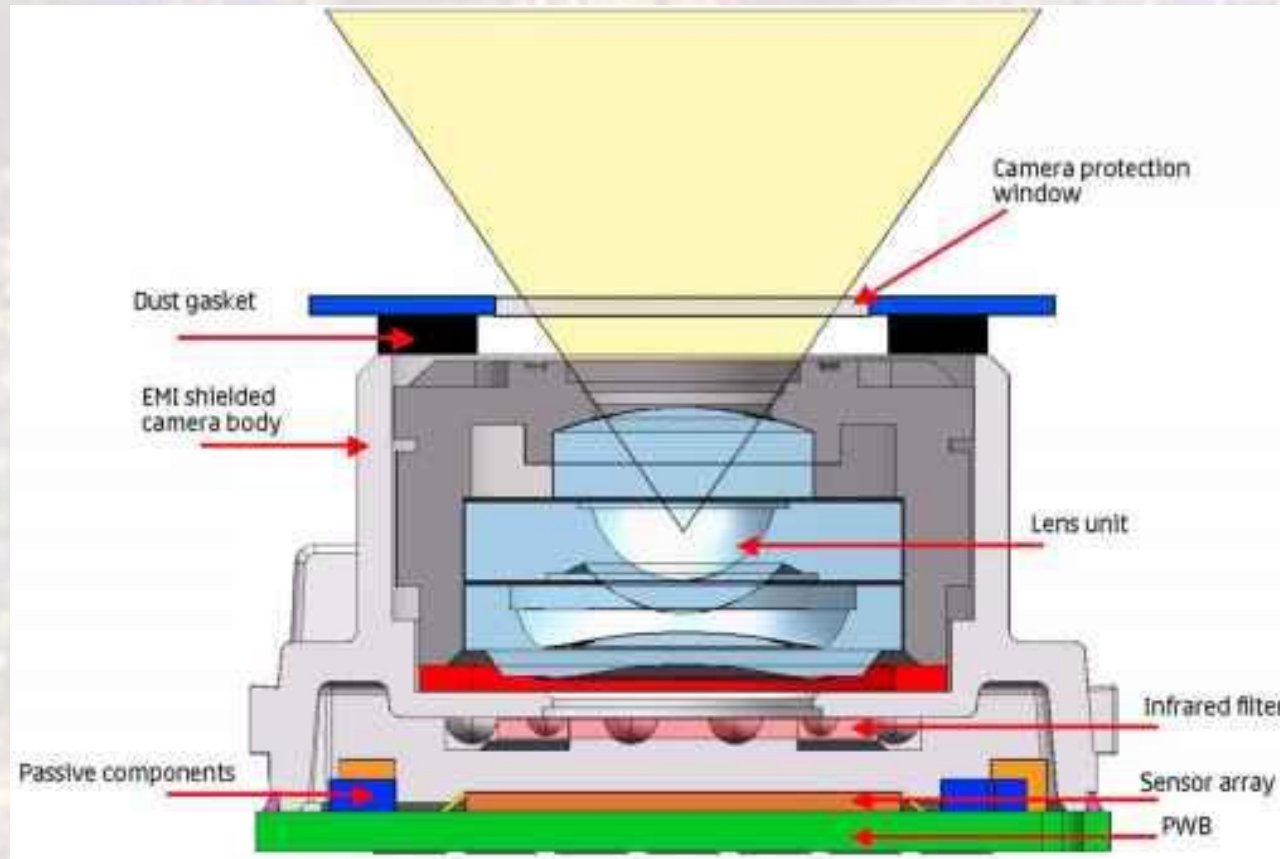

Src: exclusive architecture

Imagers

- 120Mpixel Imager

Src: smarttechnologynow
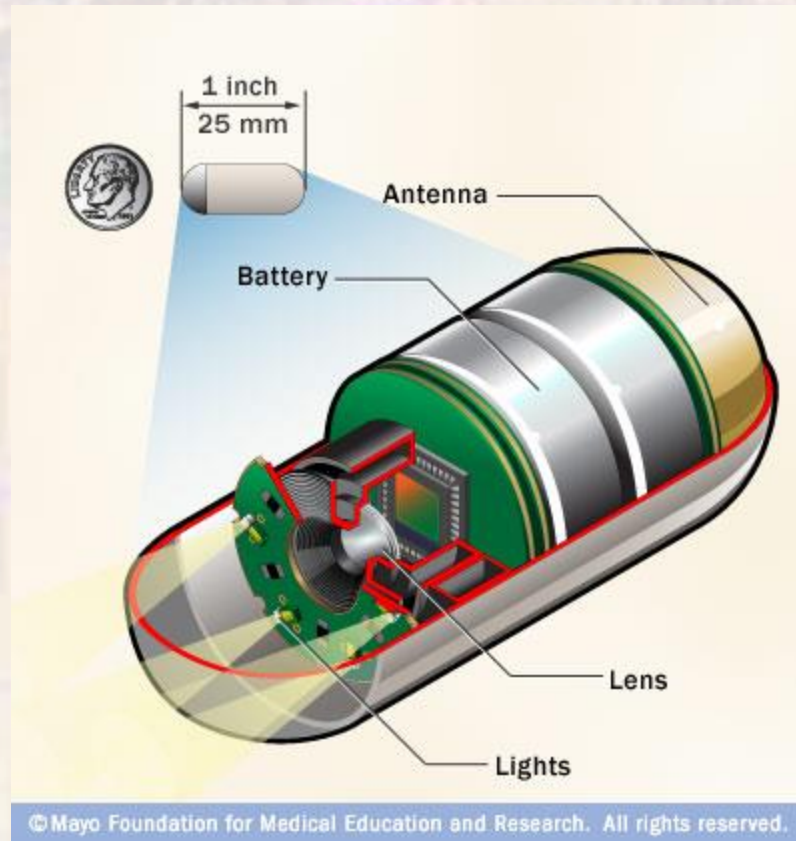
Imagers

- Camera Module

Src: Nokia

Imagers

- D-SLR

Src: smarttechnologynow

Imagers

- Pill Camera

Src: mayo clinic