image sensors:
real device implementations

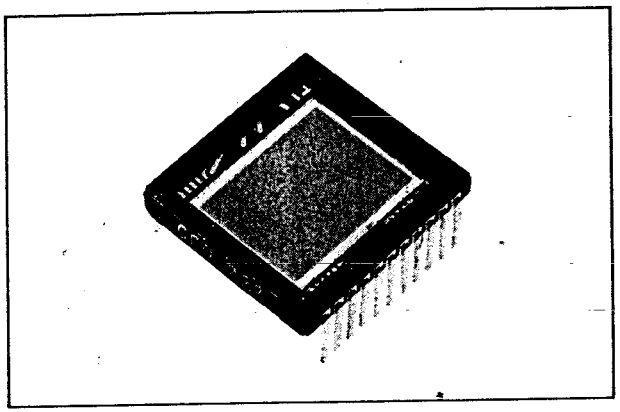
my favorite (but now old) CCD …

FAIRCHILD
WESTON
SYSTEMS
CCD IMAGING DIVISION

CCD 222
488×380-Element
Area Image Sensor

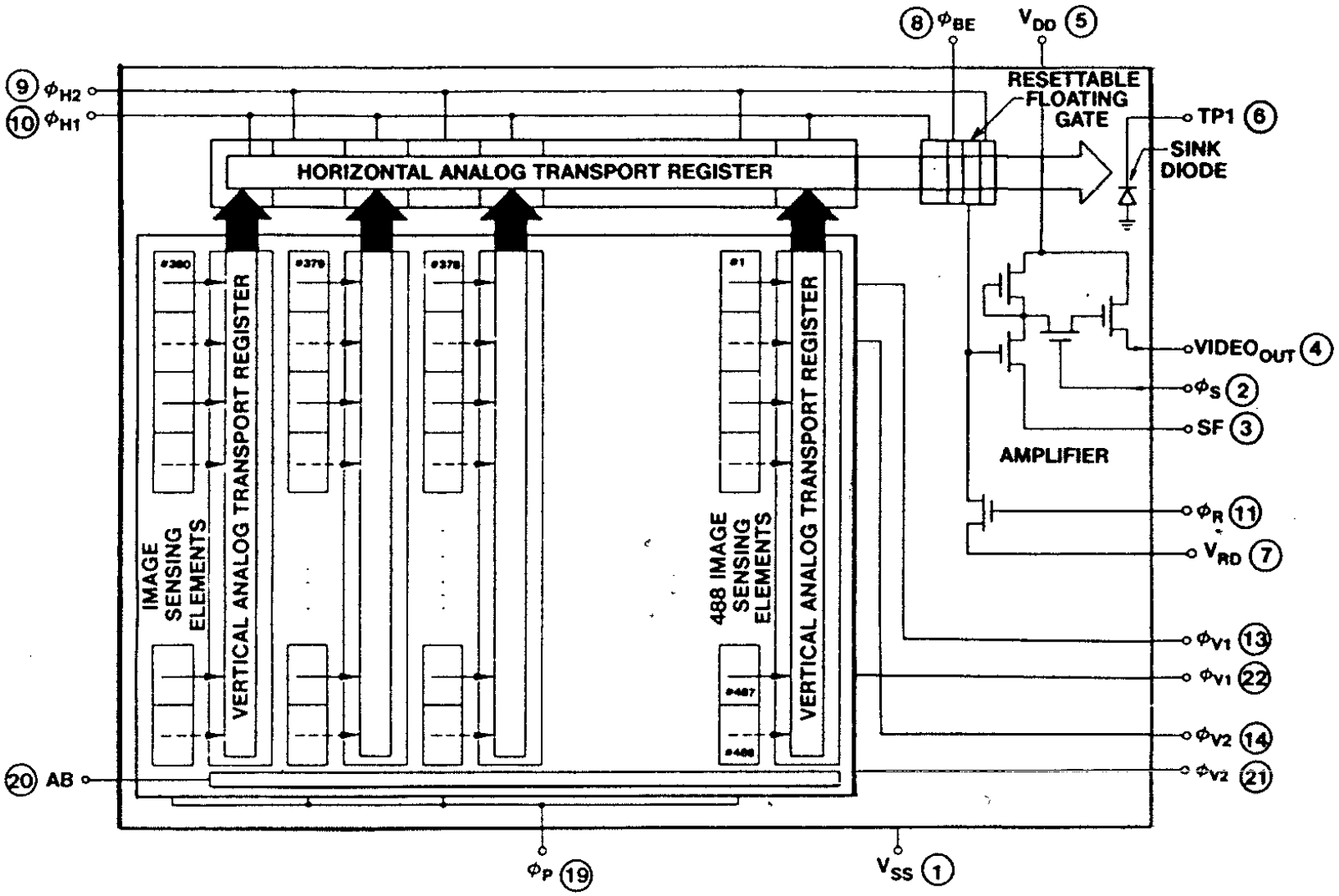
FEATURES

- 185,440 sensing elements on a single chip
- Available horizontal resolution: 380 elements per line
- Available vertical resolution: 488 lines
- No lag, no geometric distortion
- A gamma of unity
- High dynamic range — typically > 1,000:1 at 25°C (excluding dark signal non-uniformity)
- Low light level capability, low noise equivalent exposure
- Video data rates up to 20 MHz, frame rates to 90 Hz
- Sample-and-hold video output
- Low power dissipation, solid-state reliability and small size
- Standard TV aspect ratio (4:3)
- Satisfies NTSC resolution standards
- Two-phase register clocking
- Digitally-controlled readout
- Special selections available — consult factory.



CCD222 488X380 Element Area Image Sensors are also included in Fairchild Weston's series of solid-state television camera systems.

PIN NAMES


8 ϕ_{BE}
V_{DD} 5
9 ϕ_{H2}
10 ϕ_{H1}
RESETTABLE FLOATING GATE
TP1 6
SINK DIODE
HORIZONTAL ANALOG TRANSPORT REGISTER
#380
#379
#378
#1
IMAGE SENSING ELEMENTS
VERTICAL ANALOG TRANSPORT REGISTER
488 IMAGE SENSING ELEMENTS
#487
#488
VERTICAL ANALOG TRANSPORT REGISTER
$VIDEO_{OUT}$ 4
ϕ_S 2
SF 3
AMPLIFIER
ϕ_R 11
V_{RD} 7
ϕ_{V1} 13
ϕ_{V1} 22
ϕ_{V2} 14
ϕ_{V2} 21
20 AB
ϕ_P 19
V_{SS} 1

Kodak KAF-400 CCD specs

PARAMETER	NOMINAL FIGURE
Optical form factor	100%
Sensitivity @ 550 nm	740000 e^-/μJ/cm2
"	37000 e^-/μW/cm2
"	146 mA/W
"	44.5 ke^-/lux
Output Charge to Voltage Conversion Factor (CVF)	10 μV/e^-
Blue quantum efficiency @ 400 nm	0.03
Green quantum efficiency @ 550 nm	0.33
Red quantum efficiency @ 700 nm	0.40
Near IR quantum efficiency @100 nm	0.08
Reading noise	13 electrons
Dark current density @ 25°C	10 pA/cm^2
Dark signal	50 e^-/pixel/s
Signal level at saturation	0.11 μJ/cm2
Dynamic range	76 dB
Non-linearity	1%

must mean for 1/20 second exposure time

pixel size, signal, & signal-to-noise

- charge accumulates at a rate proportion to light intensity per unit area of pixel
- capacitance is proportional to pixel area
- so for a given light intensity, exposure time, and cell depth, the **signal voltage** (accumulated charge / cell capacitance) is **independent of cell area**
- but **signal-to-noise improves** with larger accumulated charge, hence **with cell area**

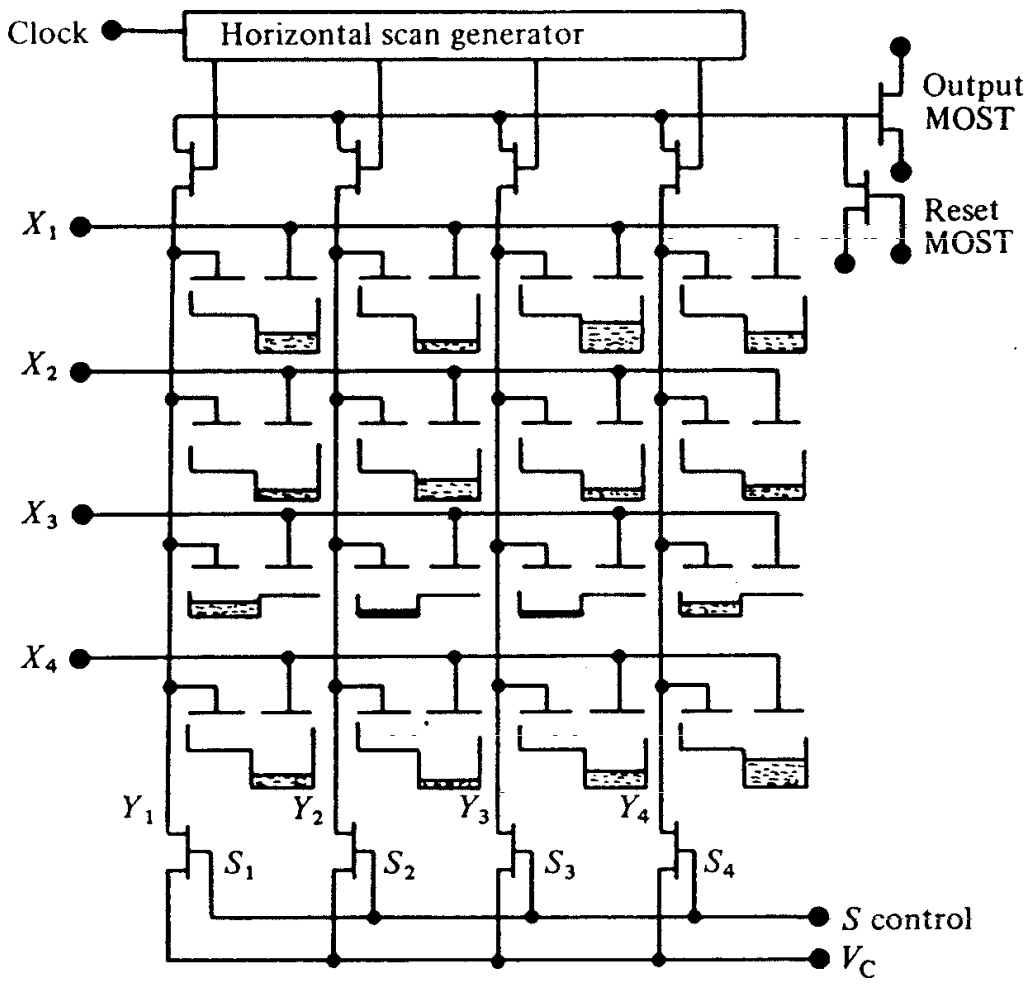
additional reading

in our AFS *readings* directory:

- *SENSORS02_05-image_sensors.pdf*
  - apparently from somebody's course
  - encompasses biological and electronic systems
  - I found it on the web
  - I don't remember where & can't find it again …
- *sensorsCaptureAttention.pdf*
  - comprehensive article on CMOS image sensors

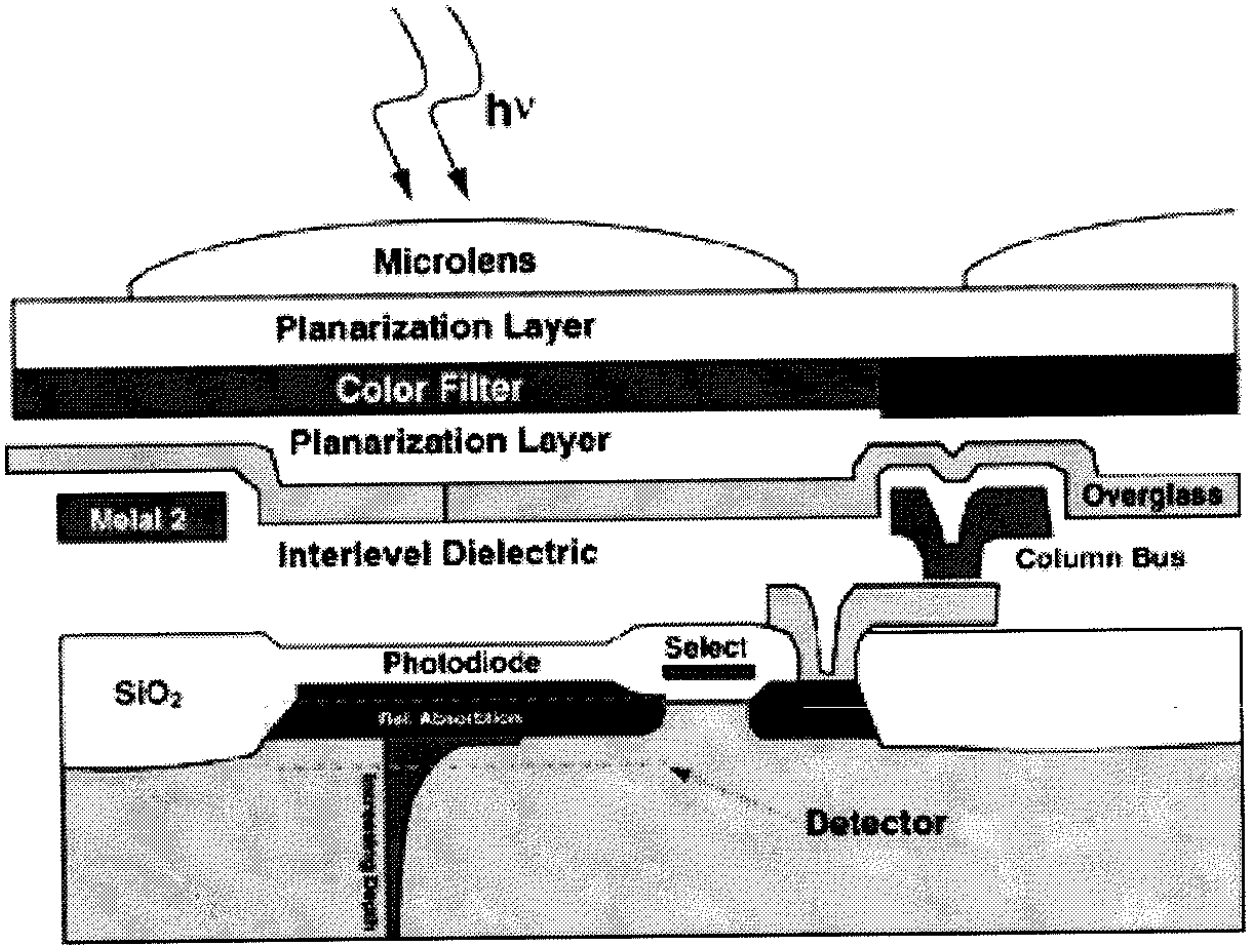
other (not CCD) kinds of modern image sensors

CID: charge injection device



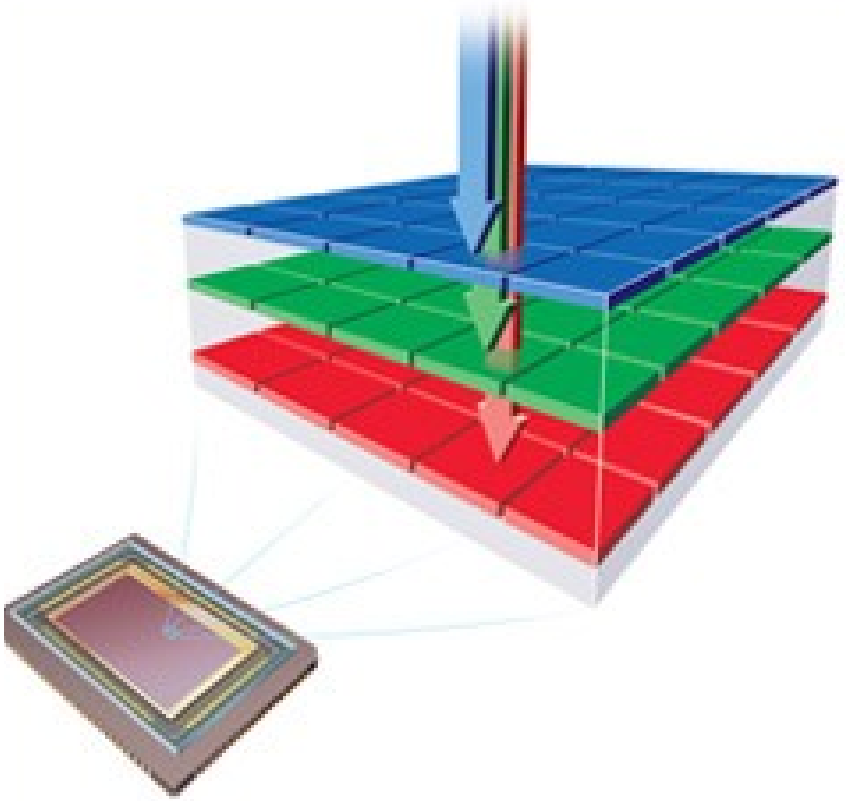
- CCDs are inherently serial readout: no way to address an individual pixel
- could realize better dynamic range, electronic zooming, etc., if could address individual pixels
- CID has been promising "around the corner" possibility for ~20 years

CMOS image sensors



- uses same technology as standard memory chips
- economical: uses highly-tuned high-volume production
- allows high degree of integration between imaging and image processing

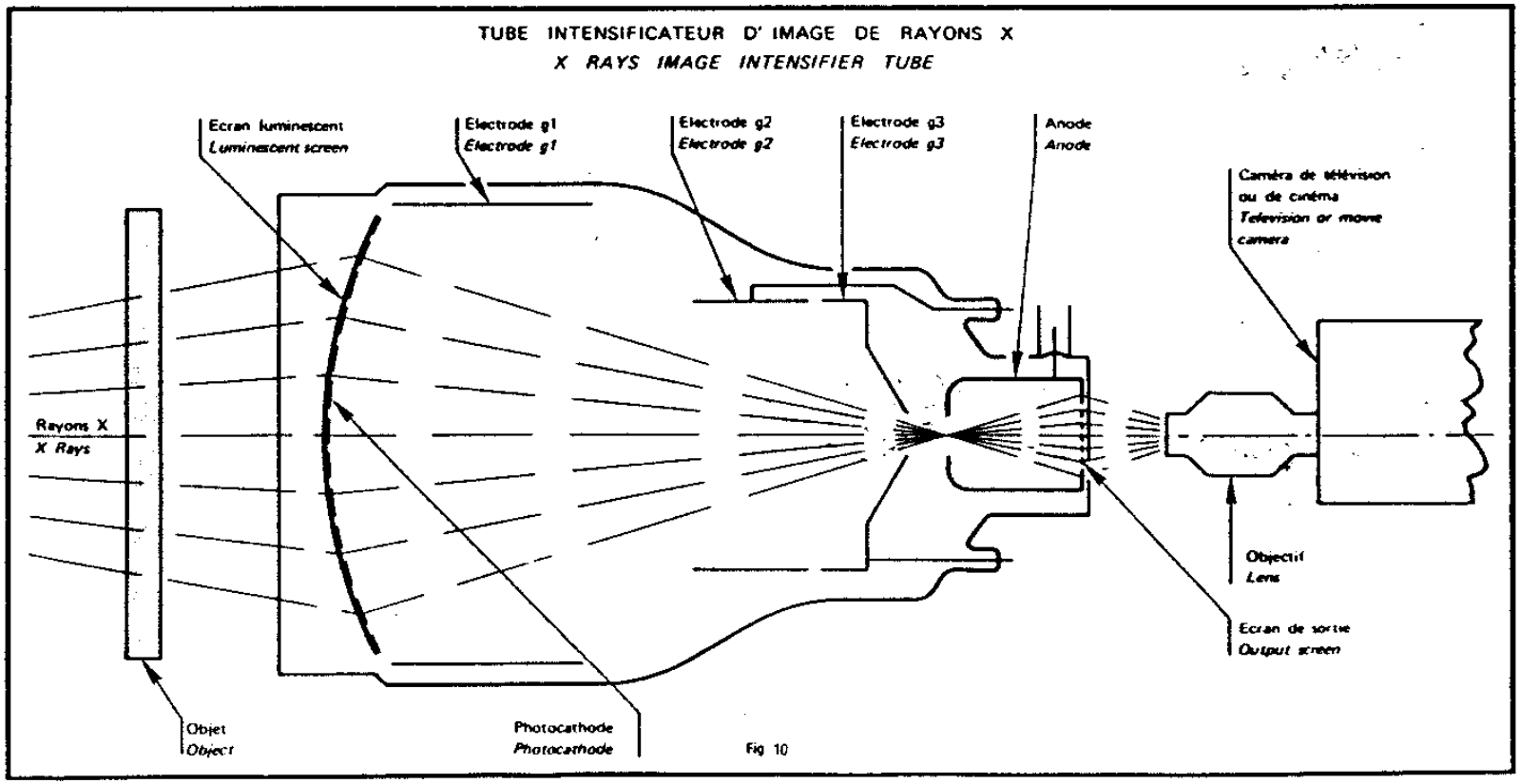
Foveon: color-film in silicon



(with lots of material processing compromises to achieve correct filtering and decent transmission)

special purpose
hybrid devices
e.g., “night vision”,
“image intensifiers”
etc

X-ray image intensifier



similar hybrid methods used in “night vision scopes” (Russian → cheap)