image sensors:
real device implementations
my favorite (but now old) CCD ...

**CCD 222**

**488×380-Element Area Image Sensor**

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**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.

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**PIN NAMES**

*CCD222 488X380 Element Area Image Sensors are also included in Fairchild Weston's series of solid-state television camera systems.*
Kodak KAF-400 CCD specs

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

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)