Active Pixel Sensors vs. CCDs

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ABSTRACT

Active pixel sensors are an emerging alternative image sensor technology to the charge-coupled device (CCD). Active pixel sensors contain one or more active transistors within each pixel. These transistors buffer the readout signal and provide access to the pixel data over metallic wires. This eliminates the need for nearly perfect charge transfer and increases the radiation hardness of the image sensor. The APS also permits non-destructive readout and random accessibility. However, the fill-factor of the APS is generally smaller than that of the CCD.

This paper will introduce the APS concept. A review of published literature on APS devices including the charge-modulation device (CMD), the bulk charge-modulation device (BCMD), the bipolar image sensor (BASIS), the static induction transistor image sensor (SIT), and other APS technologies will be presented. A comparison the advantages and disadvantages of the APS compared to the CCD for various applications will be presented. Some preliminary (and controversial) conclusions regarding the future competiveness of the CCD vs. the APS technology will be made.

It is expected that this paper will lead to a wide discussion of APS vs. CCD technology and further illuminate the topic during the course of the workshop.

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CHARGE COUPLED DEVICES (CCDs)

ADVANTAGES

1. Incumbent technology
2. Large formats demonstrated
3. Very small pixels possible
4. Noiseless charge domain processing (e.g. binning, TDI)

DISADVANTAGES

1. Need for nearly perfect charge transfer efficiency
   - Signal fidelity ~ η^m, η=CTE, m=# of stages
2. Radiation softness
   - bulk silicon damage
3. Difficult to integrate on-chip electronics
   - Large capacitances to drive
   - Many voltages required
   - Large voltage swings (power ~ CV^2f, electroluminescence)
   - Incompatible for practical CMOS signal chain integration

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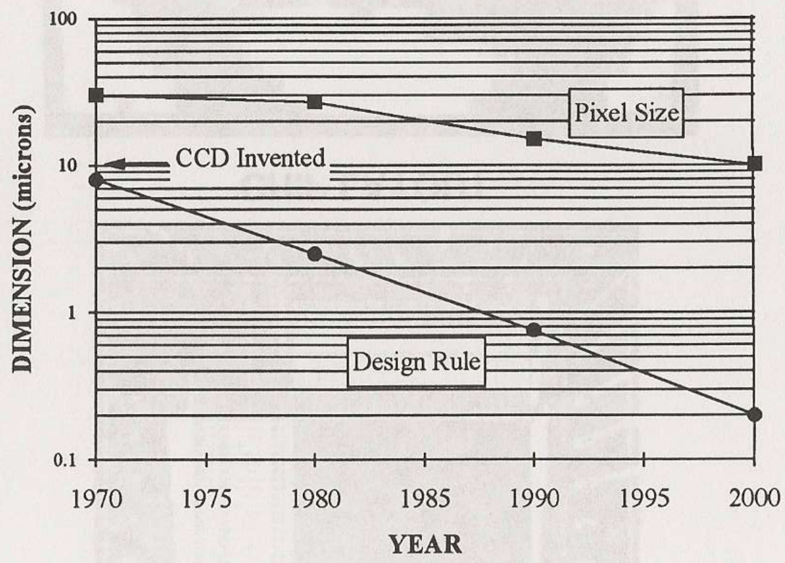
ACTIVE PIXEL SENSOR CONCEPT

One or more active transistors in the pixel.

- Buffer the output signal
- Provides high sensitivity (low C)
- Provides current drive capability
- Eliminates the need for charge transfer
- Provides random access capability

Evolution Of Photolithographic Feature Size Vs. Pixel Size



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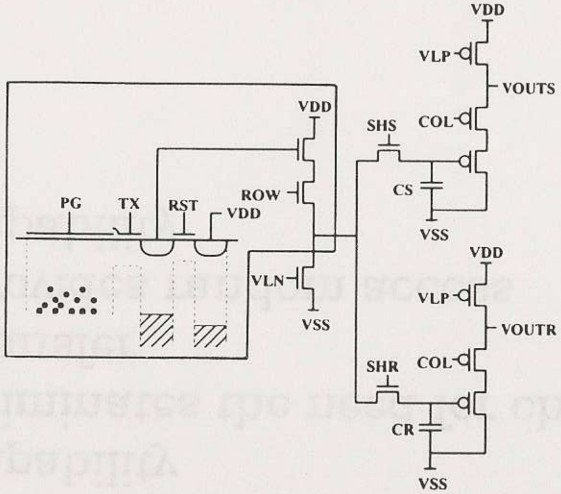
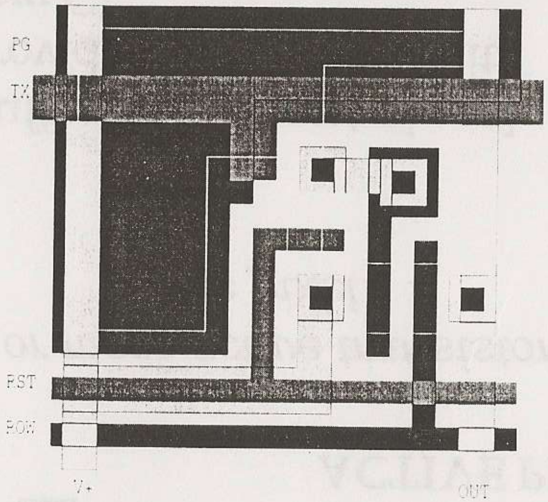
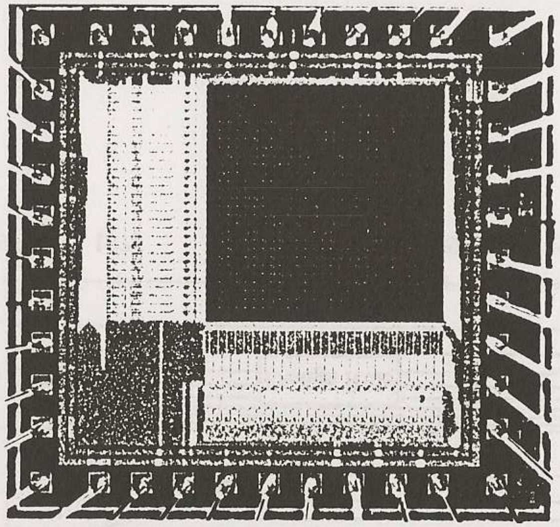
JPL CMOS ACTIVE-PIXEL-SENSOR



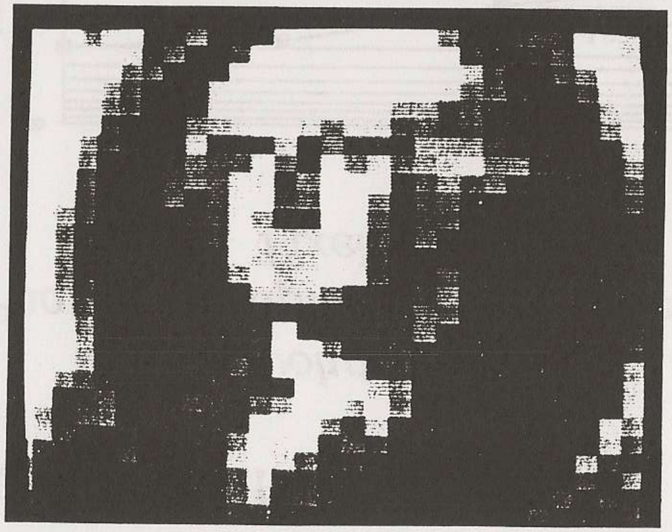
APS UNIT CELL AND OUTPUT CIRCUIT



APS UNIT CELL LAYOUT



CHIP LAYOUT



"GEORGE"

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SUMMARY OF STATE OF THE ART

	DGFSPT	CMD	BCMD	BASIS	SIT	AMI	CMOS
Developer	Toshiba	Olympus	Texas Instr.	Canon	Olympus	NHK	JPL/ Caltech
APS Type	Lateral	Vertical	Vertical	Vertical	Lateral	Lateral	Lateral
Output	Lateral	Lateral	Lateral	Vertical	Vertical	Lateral	Lateral
Pixel Size (μm)	13 x 13	7.3 x 7.6	10 x 10*	13.5 x 13.5	17 x 13.5	17.3x13.5	40 x 40
Sensitivity	200 μV/e-	250 pA/e+	15.4 μV/e-	3.5 μV/e+	3.0 μV/e+		4.0 μV/e-
Input-Noise	0.8 e- rms	20 e+ rms	15 e- rms	60 e+ rms	69 e+ rms		22 e- rms
Dynamic Range	75 dB	70 dB	72 dB	76 dB	86.5 dB	77 dB	82 dB
FPN (p-p)	10 %	5 %	2 %	0.03 %	1.1 %	0.2 %	< 2 %
Anti-blooming	vertical	vertical	vertical	none*	none*	lateral	lateral
Lag	0	0	0	<0.1 %	70 %	0	0