HDTV Image Sensors

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Abstract

State-of-the-art solid-state image sensors, suited for application in one-chip B/W HDTV-cameras or in three-chip HDTV colour cameras are discussed. It is shown that a frame-transfer imager yields an excellent image quality without the artifacts like image lag, smear, and light-nonuniformity of other types.

Introduction

Nowadays, all consumer and professional broadcast cameras are equipped with solid-state image sensors. Image sensors for the present television system (CCIR/EIA) require approximately 300k-450k image pixels. The future HDTV-television system offers a 16:9 aspect ratio and a double amount of details in horizontal and vertical direction, leading to a high data rate. This article will deal with the state-of-the-art image sensors for HDTV-application.

HDTV-issues

In this discussion restriction has been made to the three most important organization schemes: Interline Transfer (IL), Frame-Interline Transfer (FIT) and Frame Transfer (FT). The HDTV image sensors reported in literature have pixel numbers between 1.3M and 2.2M, which make them suited for both three-chip color and one-chip B/W HDTV-cameras. The imagers will be described focusing on the problems which are typical for HDTV-imagers.

Vertical transport

In IL/FIT/FT imagers, CCD-transport of the charge packets takes place by clocking of electrodes. Conventionally, the horizontally running polysilicon electrodes of the image (IL/FIT/FT) section and the storage (FIT/FT) section are contacted at their left and right sides only. Such electrodes in HDTV-imagers with their large optical format yield high RC-constants, leading to small maximum charge packets and hence to a low dynamic range. In all imagers except IL, this is solved by extra vertically running metal lines, contacting the electrodes many times within the image and storage section.

In IL/FIT imagers, the complicated electrode structure in the image section causes large overlap capacitances. Thus, the clocking of these electrodes leads to a very large power dissipation (ref. 9). Application of these imagers in an HDTV-camera needs (power consuming) active cooling. The FT-imagers with their simple electrode structure do not suffer from this problem.

Horizontal transport

A single horizontal output register in combination with the high pixel data rates for IL/FIT/FT HDTV-imagers, up to 74 MHz, becomes problematic: degradation of charge-transfer efficiency and requirement of a very large bandwidth of the output amplifier.

The solution is the division of the charge packets of odd and even columns over a dual horizontal CCD structure. A multi-channel structure was first reported in ref. 10. It requires a very careful design, otherwise a fixed vertical-line pattern results, especially visible at low illumination intensities. All companies using two horizontal registers (ref. 1, 3-8) claim to have solved this problem.

Sensitivity, smear and image lag

In IL/FIT imagers, both photodiode and vertical CCD-registers are integrated in the image section. This combination can cause image deterioration in the form of image lag (visibility of video information of prior TV-fields) and smear (bright vertical stripes above and below highlights). By making the photodiode size small, these artifacts can become worse, also the light sensitivity is going to decrease. To enhance the diminished light sensitivity, special structures on top of the photodiode are added.

Toshiba (ref. 6) uses an α-Si toplayer at the expense of even more image lag. Several companies (ref. 3,4 and 8) use microlenses on top of the photodiode. Both the α-Si toplayer and the microlenses enhance the light sensitivity more than at least two times and diminish smear. A disadvantage of microlenses is non-uniformity (ref. 9). Moreover, these microlenses are designed for optimal light conditions with small camera-lens openings. They are much less effective under conditions where you need them: low-light conditions with large lens openings.

The FIT/IL smear-values for the HDTV-imagers are less good than the typical values of -120dB, reported for traditional CCIR/EIA cameras with 1/2" image sensors. The FT-imager has a simple cell structure with large aperture. Image lag and, when a shutter is used, also smear are totally absent in FT-imagers.

Output stage

The high pixel data rate requires amplifiers with much higher bandwidth and lower noise than in consumer imagers, independent of the type of imager. In ref. 5 and 7, optimized three-stage amplifiers have been reported, in ref. 4 a hybrid amplifier has been used: three-stage on-chip with an extra off-chip bipolar amplifier within the package.

Discussion and Conclusions

Several imagers have been reported which are suited for application in a three-chips HDTV-camera (ref. 1-8). An overview, in alphabetic order, is included at the end of this paper. For each company the main characteristics of their imager are summarized in the table, a cross-section of the unit cell is shown and the device architecture is illustrated. (Remarks: (*) with NEC: measured with IR-filter, (*) with Philips: only valid in the camera, (*) with Toshiba: including a non-linear response part.) Up to now, only the Philips FT-sensor (ref. 5) is suited for the Eureka-proposed HDTV standard. To obtain good quality HDTV-pictures, a large number of pixels and a large optical format (1") is needed (ref. 1, 3-7). The recently announced 2/3" image sensor (ref. 2, 8) is still in the development phase, and needs higher sensitivity, larger dynamic range and less smear.

Compared to the IL and FIT-imagers, the Philips FT-sensor (ref. 5) is the type with a good HDTV-image quality without compromise to artifacts like image lag and smear, or non-uniformity due to microlenses. The FT-imagers have proven their high performance in commercially available HDTV-cameras in live broadcasting during the 1992 Olympic Winter in Albertville and the 1992 Summer Games in Barcelona.

References

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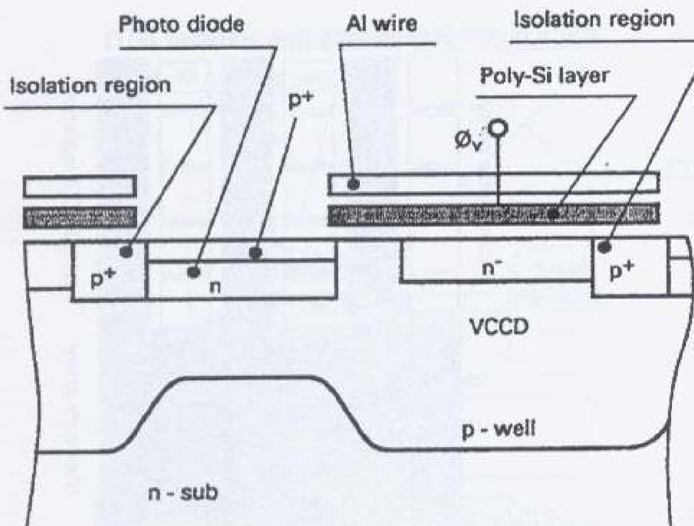
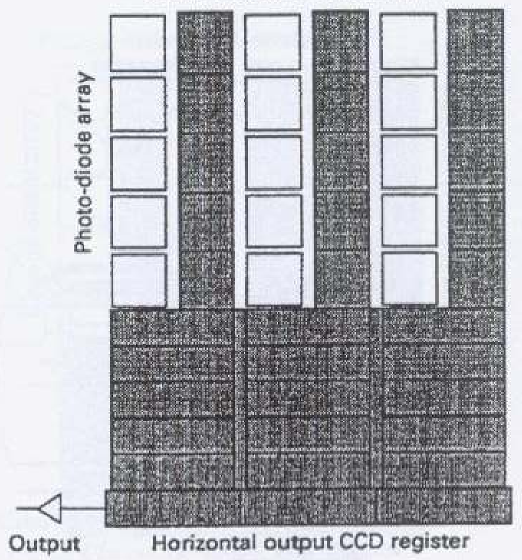
Matsushita

Sensor type		FIT	FIT
Image format		1"	2/3"
Pixel count	H	1258	1258
	V	1035	1035
Pixel size (μm)	H	10.8	7.6
	V	7.4	5.2
Sensitivity (nA/lux)		50	24
Dynamic range (dB)		72	70
Saturation (nA)		900	300
Smear (dB)		-100	-100
Lag (%)		<1	<1
Year		1989	1991

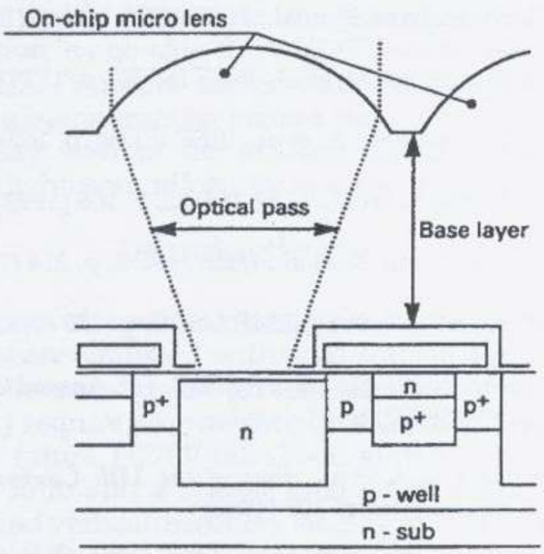


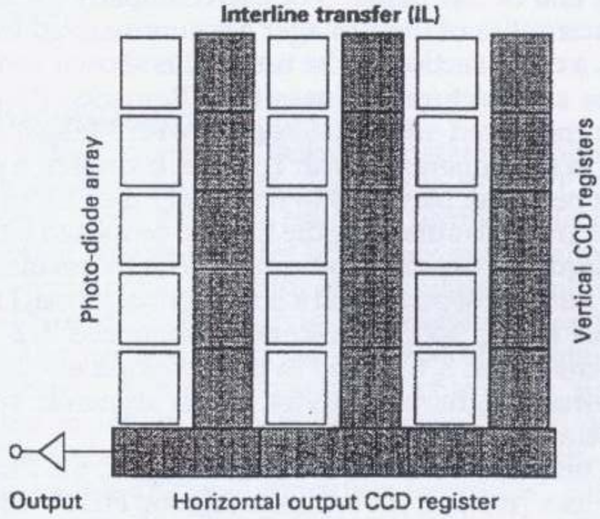
Frame interline transfer (FIT)



Mitsubishi

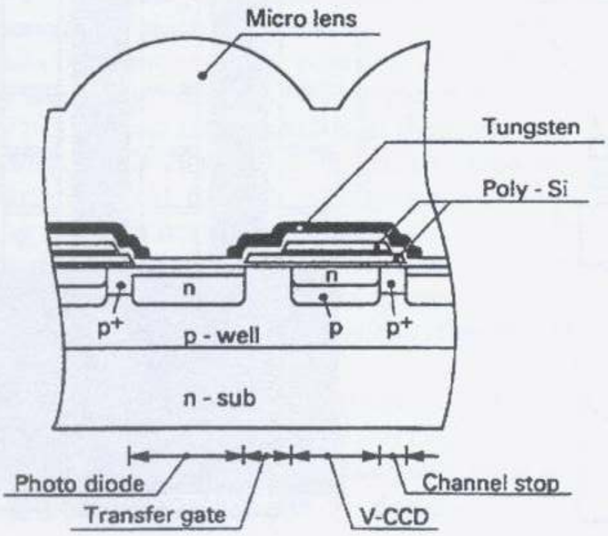
Sensor type		IL
Image format		1"
Pixel count	H	1440
	V	1035
Pixel size (µm)	H	9.7
	V	7.6
Sensitivity (nA/lux)		80
Dynamic range (dB)		73
Saturation (nA)		860
Smear (dB)		-90
Lag (%)		
Year		1991

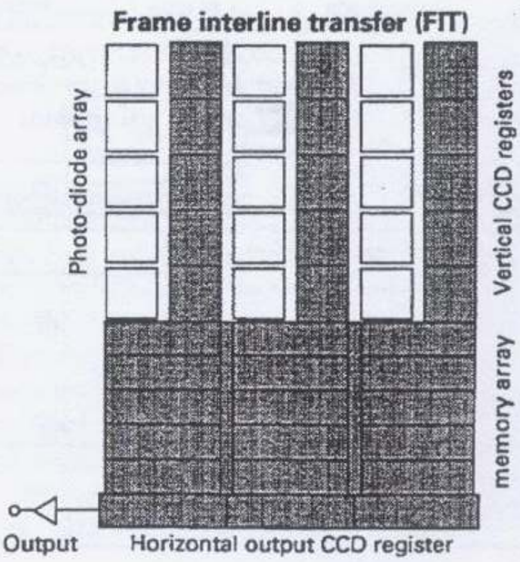




NEC

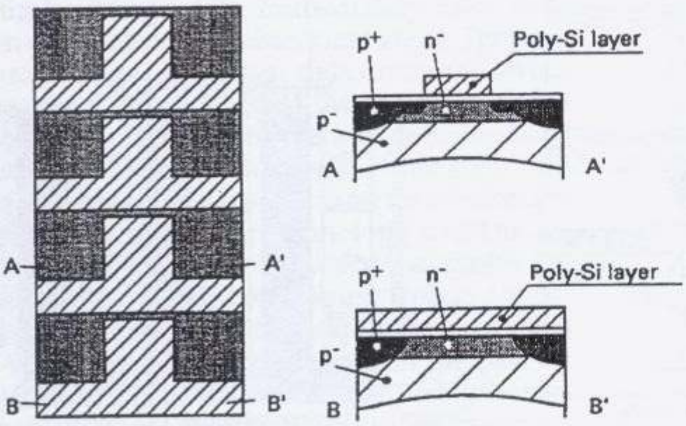
Sensor type		FIT
Image format		1"
Pixel count	H	1920
	V	1036
Pixel size (µm)	H	7.3
	V	7.6
Sensitivity (nA/lux)		23*
Dynamic range (dB)		75
Saturation (nA)		1150
Smear (dB)		-110
Lag (%)		
Year		1992



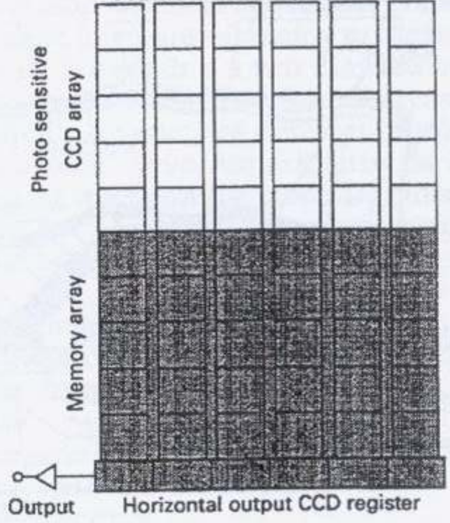


Philips

Sensor type	FT
Image format	1"
Pixel count H	1920
V	1152
Pixel size (μm) H	7.25
V	6.80
Sensitivity (nA/lux)	53
Dynamic range (dB)	74
Saturation (nA)	1100
Smear (dB)	none*
Lag (%)	none
Year	1991

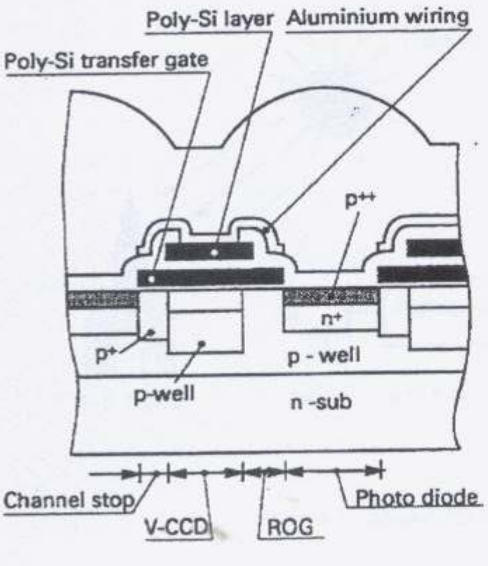


Frame transfer (FT)

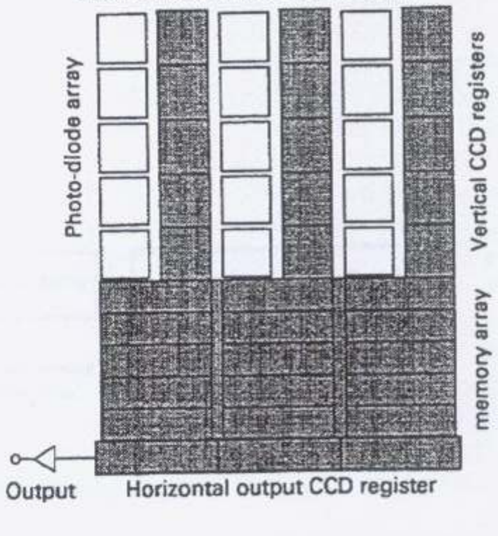


Sony

Sensor type	FIT	FIT
Image format	1"	2/3"
Pixel count H	1920	1920
V	1036	1036
Pixel size (μm) H	7.3	5.0
V	7.6	5.2
Sensitivity (nA/lux)	75	30
Dynamic range (dB)	72	70
Saturation (nA)	1000	380
Smear (dB)	-100	-90
Lag (%)	<0.1	<0.1
Year	1990	1992



Frame interline transfer (FIT)



Toshiba

Sensor type	α-Si IL
Image format	1"
Pixel count H	1920
V	1036
Pixel size (μm) H	7.3
V	7.6
Sensitivity (nA/lux)	210
Dynamic range (dB)	110*
Saturation (nA)	2000
Smear (dB)	-120
Lag (%)	0.5
Year	1992