P22: CCD and APS – Both together to the comet P/Wirtanen

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Introduction

The Sensor Electronics Department of the DLR Institute of Space Sensor Technology and Planetary Exploration is developing a miniaturized modular sensor electronics including a flexible mechano-optical interface in the framework of the future ESA mission ROSETTA. The ROLIS CCD-camera is a descent and downlooking imager on the ROSETTA Lander ROLIS (**RO**SETTA **L**ander **I**maging **S**ystem). This line of development runs under the acronym MOSES, Modular Sensor Electronics System.

The technical concept is based on a rigid-flex 3D-interconnection between the functional electronic boards (CCD head, focal plane assembly, clock driver, signal chain, and interface). The technical solution allows to operate the complete electronics at temperatures down to 130K. Baseline is the FT 1Kx1K CCD THX7888 manufactured by THOMSON. Figure 1 shows block diagram of the CCD camera

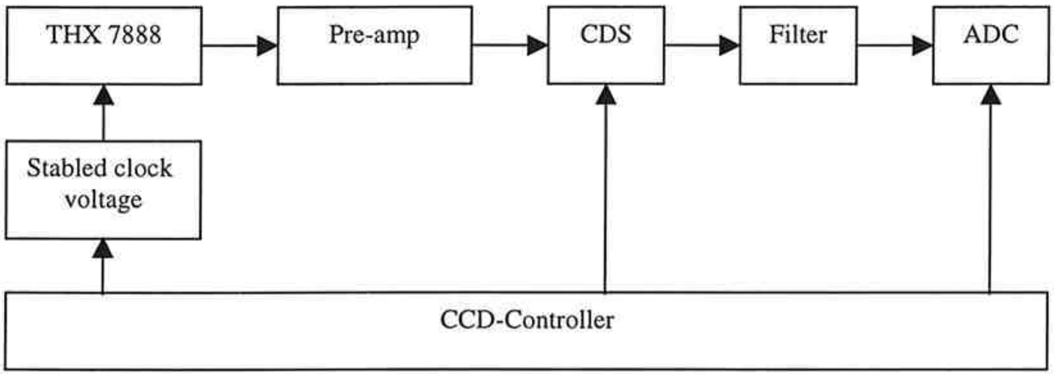


Figure 1

Signal chain conditioning

Low noise and high resolution designs comprises the limitation of the useful analog bandwidth of a CCD readout channel. Design driver are maximal signal slew rate between to pixels and acquisition time. The relationship between input signal $e(t)$ and output signal $a(t)$ can be described using transfer function.

$$a(t) = L^{-1}[H(p) * L[e(t)]] \qquad \text{L=Laplace Operator} \tag{1}$$

For a step function (0->1) as input signal (worst case) equation (1) can be written to:

$$a(t) = L^{-1}[H(p) * 1V * \frac{1}{p}] \tag{2}$$

Using a transfer function (third order low pass filter) with H(p):

$$H(p) = \frac{1}{(1+\frac{p}{\omega_{01}})(1+p\frac{2\rho}{\omega_{02}}+(\frac{p}{\omega_{02}})^2)} \tag{3}$$

we obtain for ω_0 after few operation and inverse Laplace transformation:

$$1-\Delta = 1-(\frac{w_0^2 * t^2}{2}+\omega_0 t+1) * e^{-\omega_0^2 t} \quad \text{with} \tag{4}$$

$$\Delta = rest \cdot error$$

$$\omega_0 = 2\pi f$$

$$t = acqusition \cdot time$$

At given acquisition time t and defined rest error after signal sampling the needed bandwidth can be calculated.

For example, if $\Delta = \frac{1}{10.000}$ *and t=500ns a bandwidth of 4.43 MHz will be necessary.*

Performance evaluation

For measure the electronics noise without CCD a technique is used, to determine the rms noise of an A/D converter (including all components), referred to the input due to histogram evaluation at fixed input signal. An important assumption is, that the model for the noise generation is a Gaussian noise source added to the input of the electronics. The probability density function (PDF) of an input shows that the majority of the output codes will occur in a single bin, but there must be additional codes corresponding to the tails of the distribution. The fraction that occurs outside the main code depends on the spread, or standard deviation σ, of the noise distribution. For a symmetrical Gaussian PDF, the equation

$$P = \frac{2}{\sigma\sqrt{2\pi}} \int_{-\infty}^{-0.5LSB} e^{-x^2/2\sigma^2} dx \tag{5}$$

expresses the probability of getting a code outside the main bin for that PDF. The terms inside the integral are simply the expression for a Gaussian distribution with unit area and standard deviation, σ. Integrate from $-\infty$ to –0.5LSB to find the area under one tail, and from +0.5LSB to $+\infty$ for the other. By symmetry, one can simply multiply the area under one tail by 2. To ultimately determine the noise equation (5) must be solved for σ, with P determined from the histogram as the fractional portion of code hits outside the main bin. Unfortunately, the integral has no closed form solution in terms of σ. One option is to iterate σ and numerically evaluate equation (5) until the solution equals the fraction determined from the histogram. Alternatively, we can fix σ, iterate the upper limit of integration, plot the result as a graph, and use it to find the upper limit that corresponds to any value of P. Since we already know the value of P from the histogram, we can simply find the x-axis point, x_0, corresponding to P. This value is equivalent to having evaluated equation (5) from $-\infty$ to –0.5LSB, had we know the correct value for σ. To calculate the rms noise, simply solve the equation

$$-x_0\sigma = 0.5LSB \qquad (6)$$

For example, if we have a measurement with n samples (n should be large) and k code hits outside the main bin, the value k/n represents $F = \frac{2}{\sigma\sqrt{2\pi}} \int_{-\infty}^{x} e^{-z^2/2\sigma^2} dz$. *Using a standard normal curve, or z-Table we found* x_0 *and calculate* σ *(equation 6).*

With application of limited resources concerning mass, volume, power, and high reliability of components for space instrumentation we get the following key parameters of the CCD-camera (table 1):

Parameters	**Value**	**Remarks**
Pixel readout time	3.2 µs	
Resolution	14 bit	
Total noise in darkness	13 e$^-$	@200°K
CCD noise	12 e$^-$	@200°K
Electronic noise	5 e$^-$	
Responsivity	7 µV/e$^-$	
System gain	20 e$^-$/DN	
Dark current	1700 e$^-$/sec 1100 e$^-$/sec 2000 e$^-$	Image section @ 10°C Memory section @10°C Serial register
Antiblooming control	Yes	
Peak QE	18%	

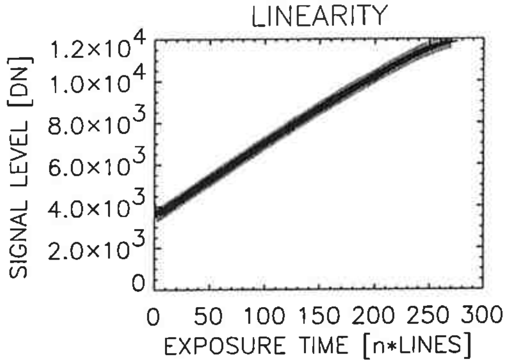
Table 1: Parameters of the THX7888 1Kx1K FT CCD and readout electronics

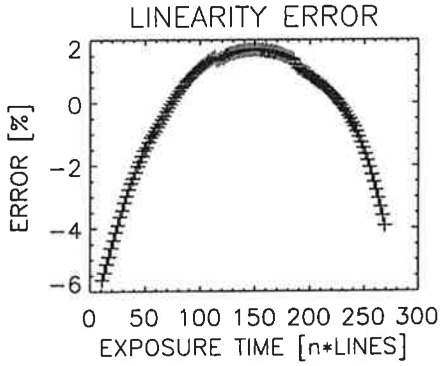
Application of an APS detector for a miniaturized imager

To increase science return of the Lander the Alpha-Proton-X-ray Spectrometer will be combined with a CMOS-imager. First tests were done with the IBIS1a detector manufactured by IMEC. Key parameters are listed in table 2.

Resolution	386x290
Pixel size	14x14 µm^2
Responsivity	9µ V/e$^-$
Full well charge	142000 e$^-$
Noise	52 e$^-$
Fill factor	70 %
Peak QE	28 %
Pixel type	3 transistor active pixel

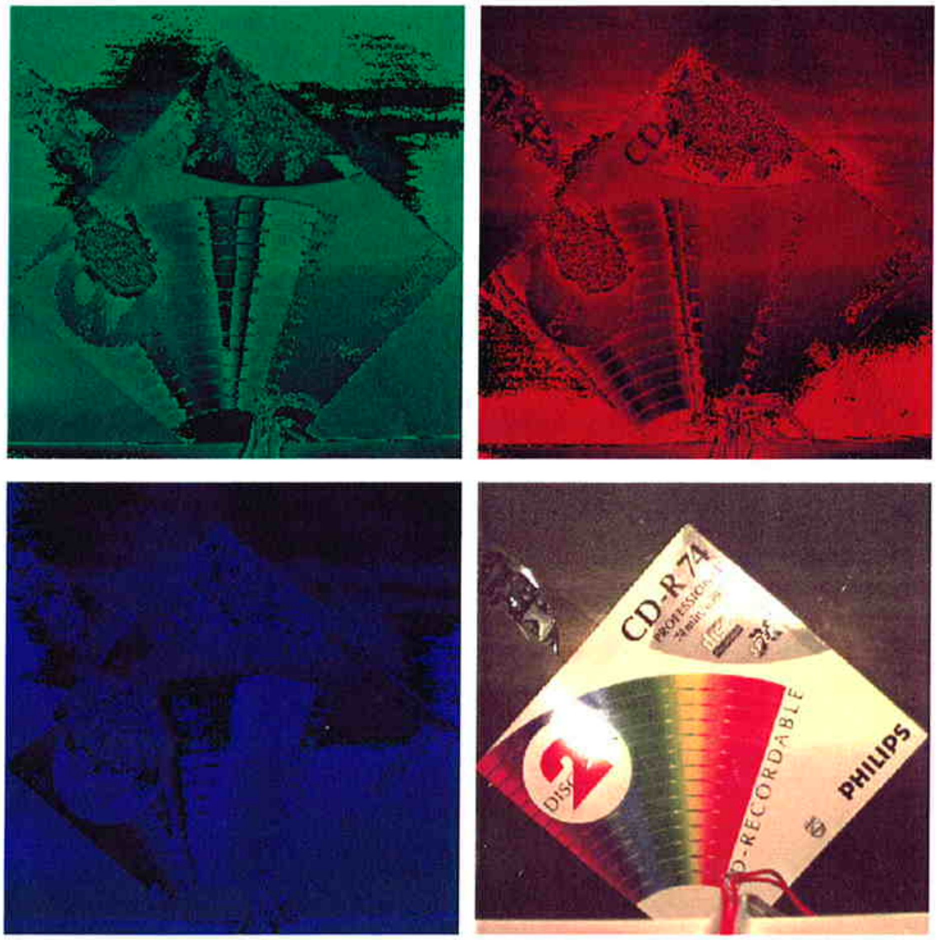
Table 2: IBIS1a Parameters

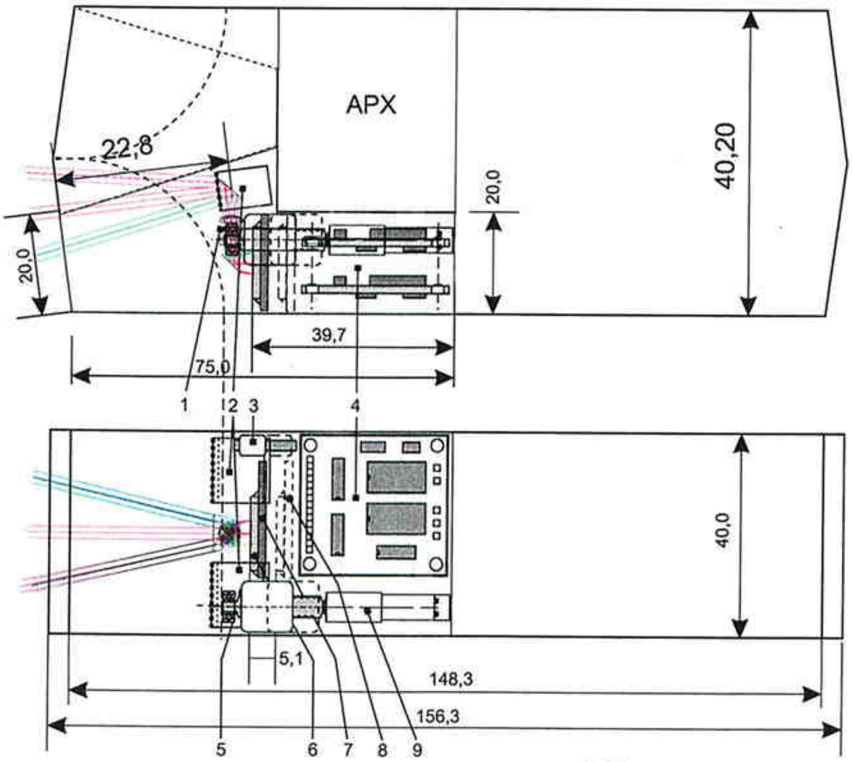




ROSETTA LANDER IMAGER

LED illuminated images and color composite image with THX7888





Close-up Imager for the Instrument Deployment Device

Infinity mode

1 Lens
2 LEDs (b, g, r, ir)
3 Linear ball bearing
4 Electronics
5 Ball screw
6 IMEC CMOS CCD
7 FPA board
8 Close-up position of FPA
9 Brushless dc motor with gear and rotation decoder