LOW CURRENT AMPLIFIER (LCA) ASIC

Problem:

Read photo-current of a several Cooled Large Area Photodiodes (CLAP)

- with precision <0.1% and accuracy =0.2%
- in a focal plane environment and an optical bench environment
- from 10 pA range to 10 nA range
- with room temperature electronics

1000 e^-/pixel/s / 15x15 μ pixel

CLAP surface = 10^5 to $5x10^5$ pixels

→ minimum CLAP current = few picoamps

T.E. Cooled Photodiode (Hamamatsu S3477)

✣ Etienne Barrelet ✣ LPNHE ✣ Université Paris 6 & 7 ✣ IN2P3-CNRS ✣

Off-the-Shelf Solutions

1. **Keithley's** (617, 6514, 6517, 6430)

   electrometer (fA), not picoammeter (pA)

   input bias current **3 fA**, input noise **0.8 fA**

2. ***False solution***: OpAmps for Low Current Amplifier (NIST, Hamamatsu,...)
   cooled

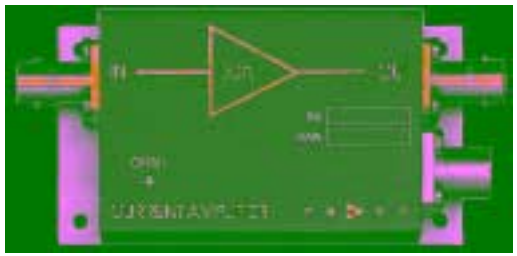
   JFets OpAmps: AD85xx(25pA), LT1793(10pA), LMP77xx(0.1pA) etc....

3. **Ultra Low Current Amplifier**

   Burr-Brown (TI) INA116: **3 fA**

   preamp DE-LCA-1-10T **10 fA**

   CMOS OpAmp LMC6064 (NS) **10 fA**



Preamp "Femto" DE-LCA-1-10T

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Why to look beyond off-the-shelf solutions?

- **Keithley's**:
  - ♦ not practical (and expensive) for a multichannel system in a focal plane position
  - ♦ 2% accuracy for 10 pA range insufficient

  Note: Keithley's input JFet not changed since the nineteen-eighties.

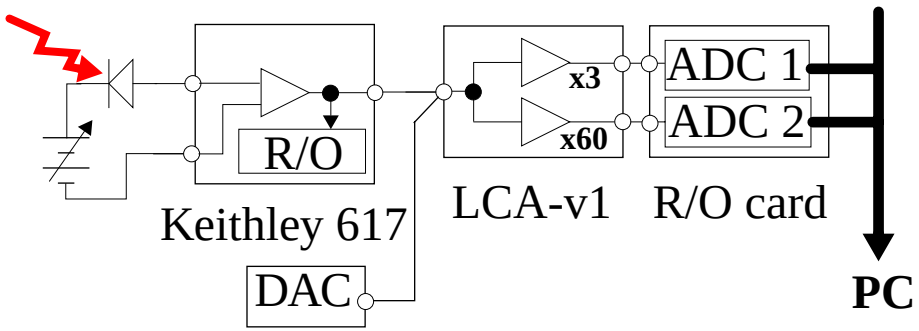
- **LCAs based on JFets**:
  - ♦ commercial low current preamps have one fixed gain
  - ♦ designing from scratch is not trivial and lacks modern ultra-low input bias opamps

- **CMOS ASIC design**:
  - ♦ SiO_2 favors ultra-low input bias current and CMOS don't yield excess noise anymore
  - ♦ our experience with AMS 0.35 µ process proves these minimal CMOS noise figures
  - ♦ our AMS 0.35 µ dual gain amplifier and its 2x16 bits readout offer a ready made solution for integrating a CMOS LCA with a pA plus a nA range photodiode readout.
  - ♦ compact amplifiers can be mounted near detectors to avoid pickup noise

LCA project at LPNHE: October 2006 status

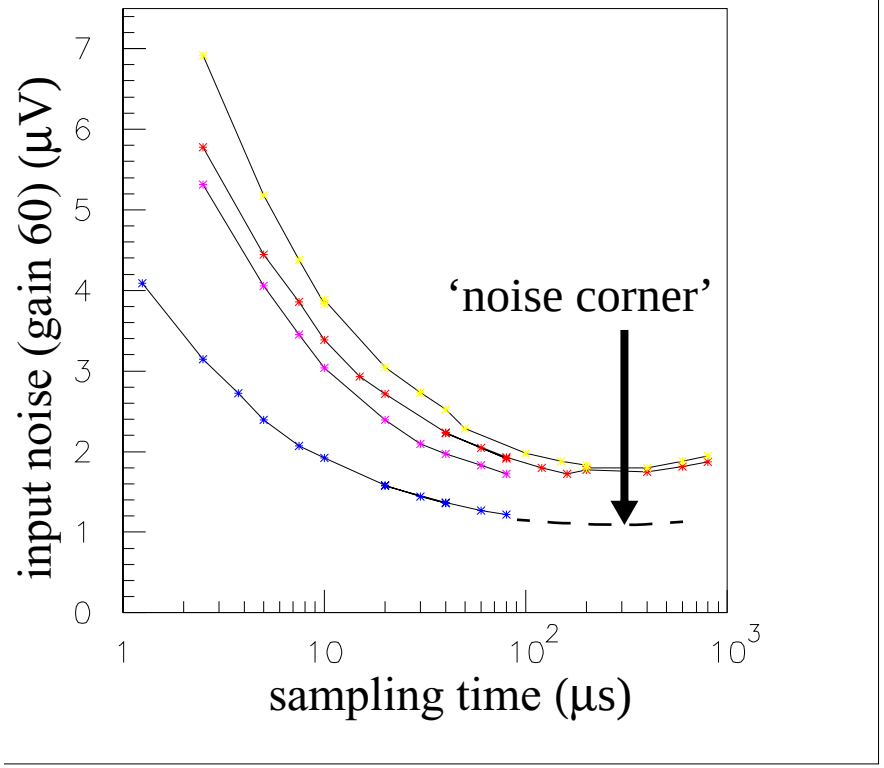
Test system with LCA-v1 (dual gain amp.) works on CCD test bench:

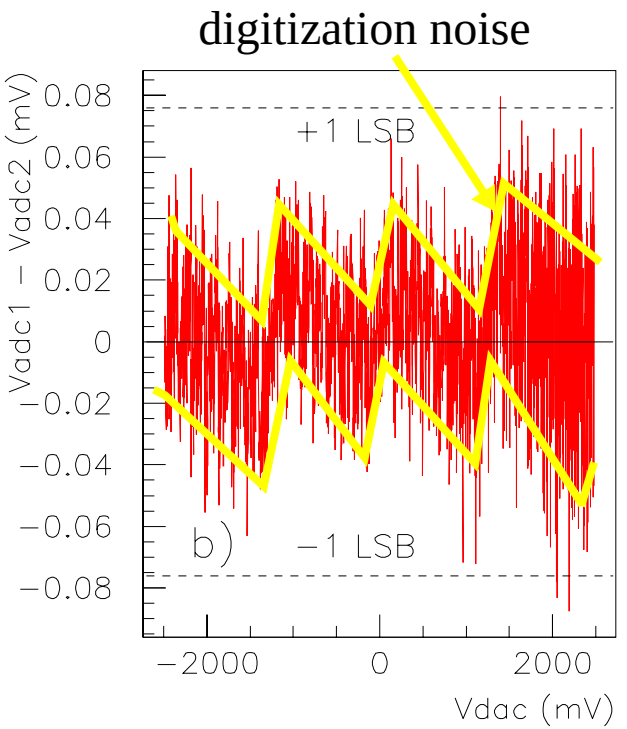
-overview:



-qualification of LCA-v1 (AMS 0.35 µ CMOS analog process):
Johnson noise = thermal min.value & 1/f noise corner at 300 µs (left[1])
inter-calibration of gain 3 and gain 60 channels better than 0.02% (right[1])

1. figures in next slide (cf. ASIC LPNHE 2004-11 & C.Juramy thesis)





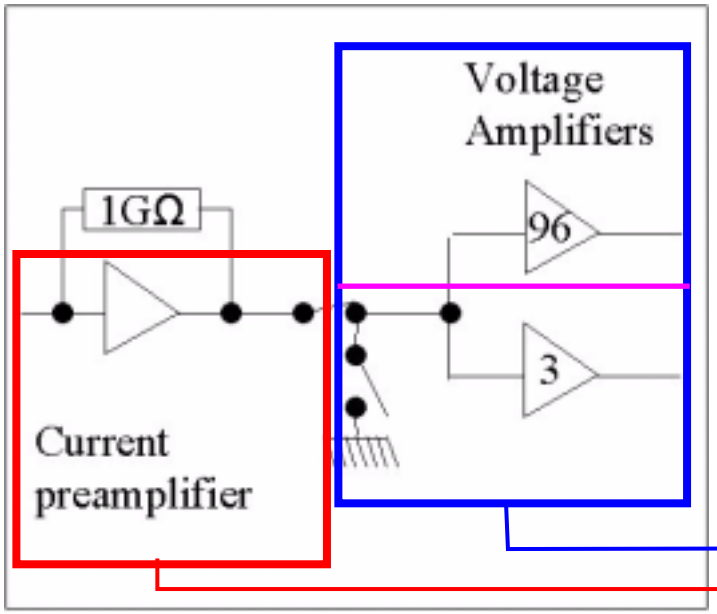
intercalibration of gain 3 and 60
(with a 20 bit DAC and two 16 bit ADCs)

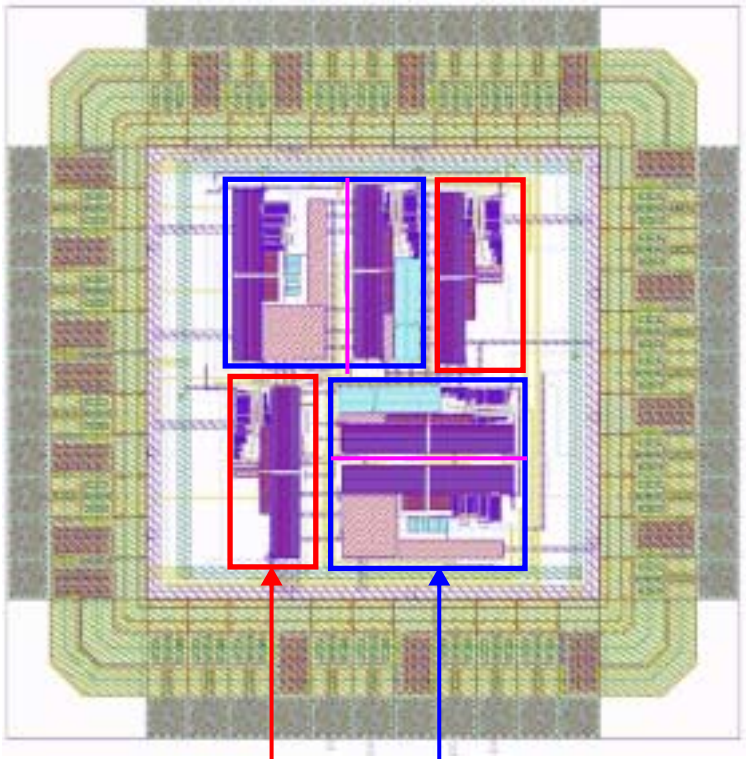
-a bug in LCA-v1 dual gain amplifier yields thermal drift of offset voltage.
It has to be corrected in LCA-v2. Then baseline stability should be excellent.

4. **Description of LCA-v2**:

Submitted 2006/10/30. Expected delivery january 2007

3 blocks: Current amplifier alone
Voltage amplifiers alone
Both amplifiers in line





5. Tests to do with LCA-v2

♦ current preamplifier: measure input bias, input noise and their thermal coefficients; check with AMS simulation package; understand the role of **input FET geometry** (see next slide) and vary trans impedance (feed back resistor) and input capacitance

♦ dual gain amplifier: measure both offsets, gains, noise and their thermal coefficients; check the inter calibration of both channels and its stability

♦ LCA (preamp+dual amp): complete functional check and compare with both components

We considered that purchasing a “calibrated current source” (Keithley Sourcemeter) was not justified. Tests will be conducted using photodiodes as current sources on the optical test bench. The ultimate calibration at low current should be the light distance method suggested in our report LPNHE 2006-2. It will validate the check standard method proposed in this paper, consisting in monitoring a LED light source with a calibrated “Cooled Large Area Photodiode” (CLAP). This CLAP is read either with a Keithley 6514 electrometer or with an electronic chain based on LCA-v2.

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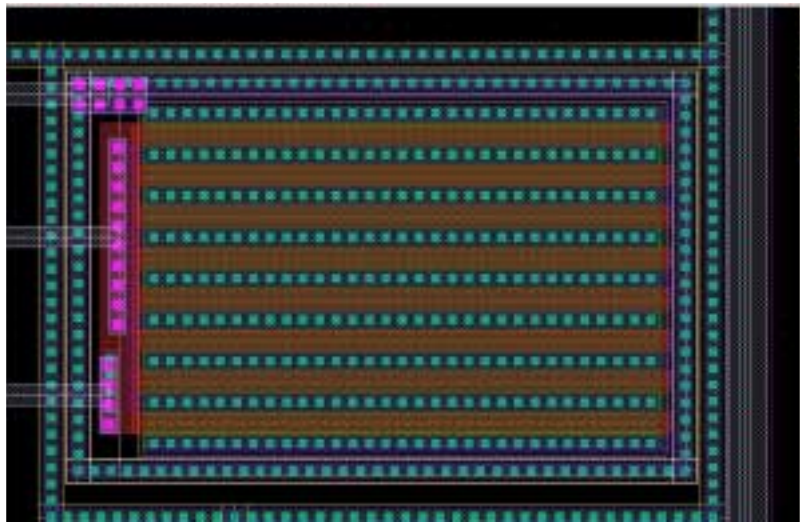
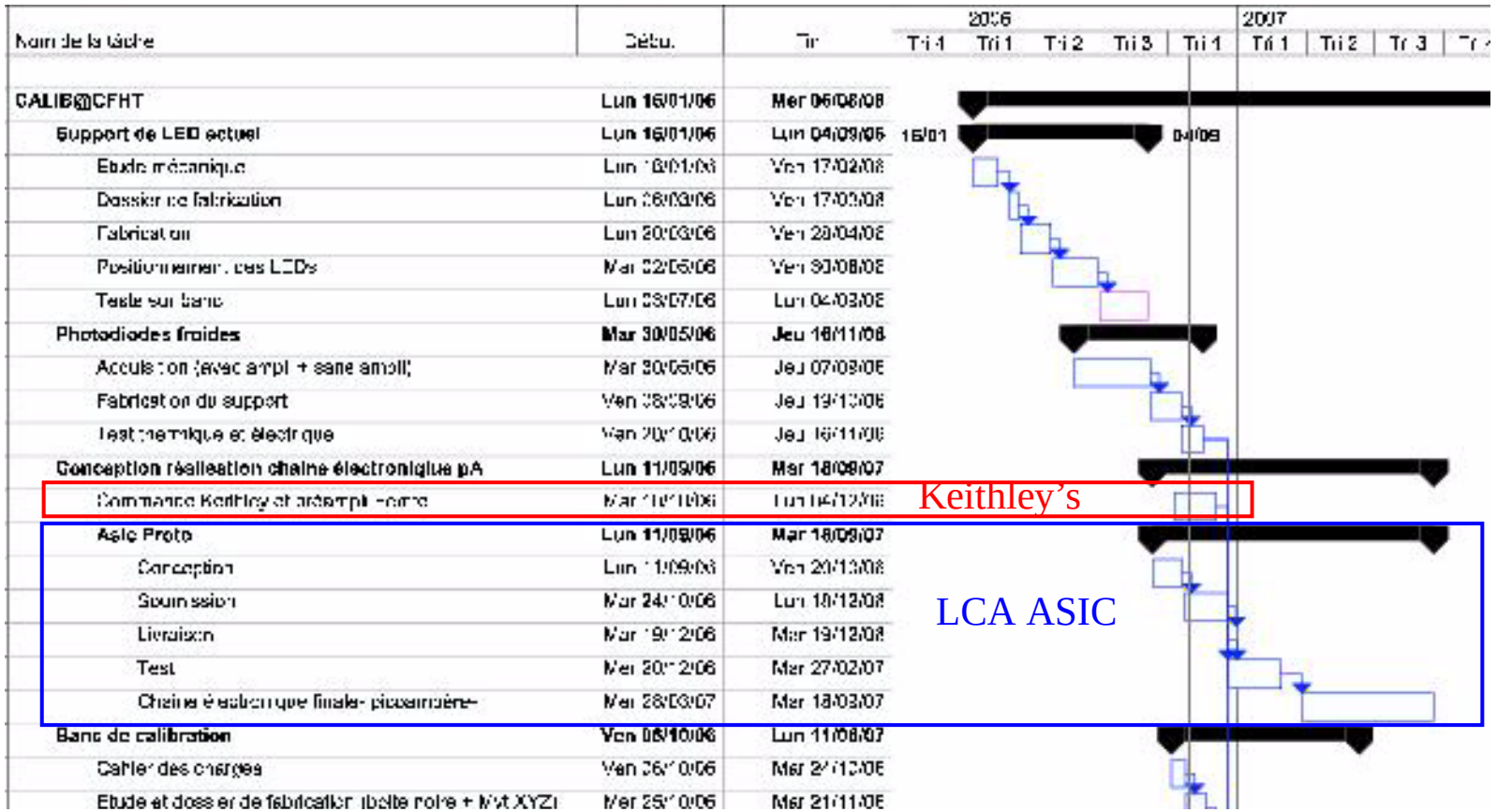


LCA input transistor

- the design of the input FET of LCA-v2 has been done with a special attention to noise optimizing properties (notice the two guard rings). Its properties will be measured and compared to the AMS 0.35 µ computer model in order to minimize input bias current and noise figures.

6. **Time Planning**::



This project is not on critical path for step 1 since Keithley's solution works.
It is r&d for step 2 (Cooled Large Area Photodiode on focal plane)