AIDA-WP9

Status and Plans @PM12

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OUTLINE

1) Design flow

2) Technology selection

3) Functional model of a channel

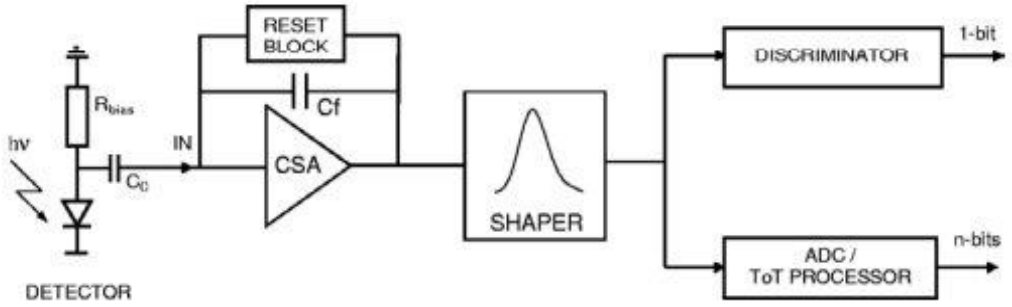
4) Noise analysis

5) Amplifier design

6) Basic biasing current source

7) Future work

Low energy detectors (X-ray)



* Pawel Grybos, “Fast binary readout front-end electronics for silicon strip detectors for low energy x-ray imaging applications.

High energy detectors (particle physics)

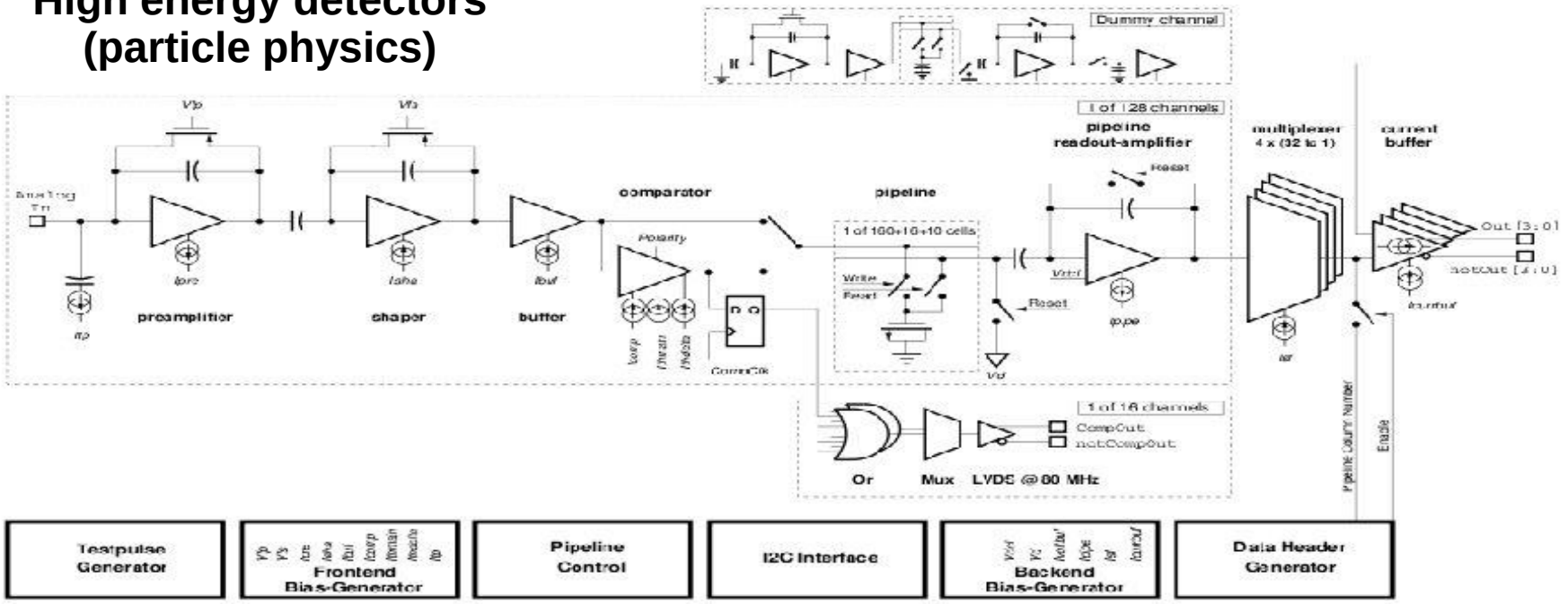


Figure 1: Schematic block diagram of the *Beetle* readout chip.

Design flow strategy

1- Technology analysis and selection (130nm IBM, 65nm TSMC)

- Intrinsic transistor gain
- Noise spectral density

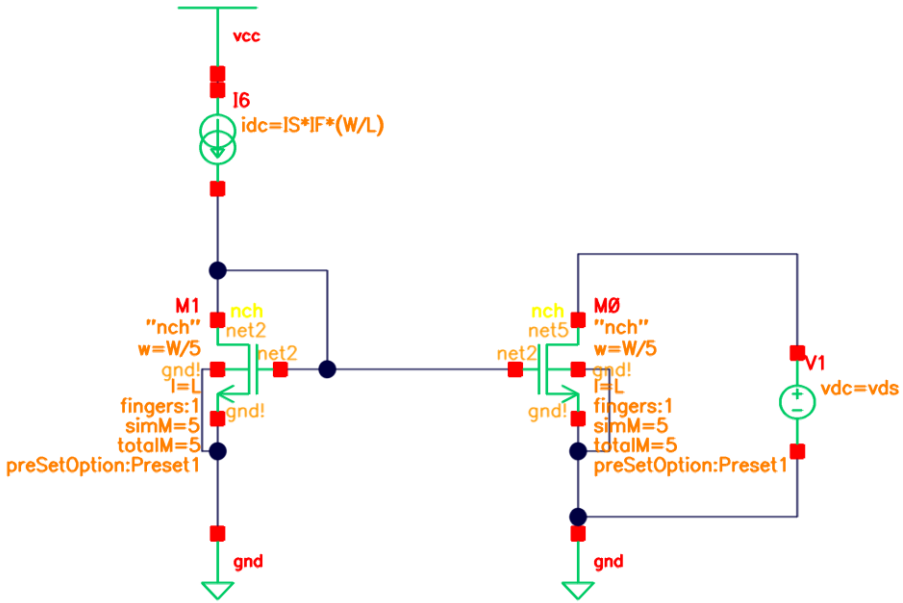
Choosen technology: TSMC 65nm

2- Functional models of an entire channel

3- Design of the LNA / preamplifier

- Ideal amplifier with a pole and limited output
  - Amplifier specifications
- Choosen amplifier: Folded cascode
- Noise analysis
  - Input transistor size and bias

Technology analysis: Intrinsic gain



Intrinsic gain analysis:

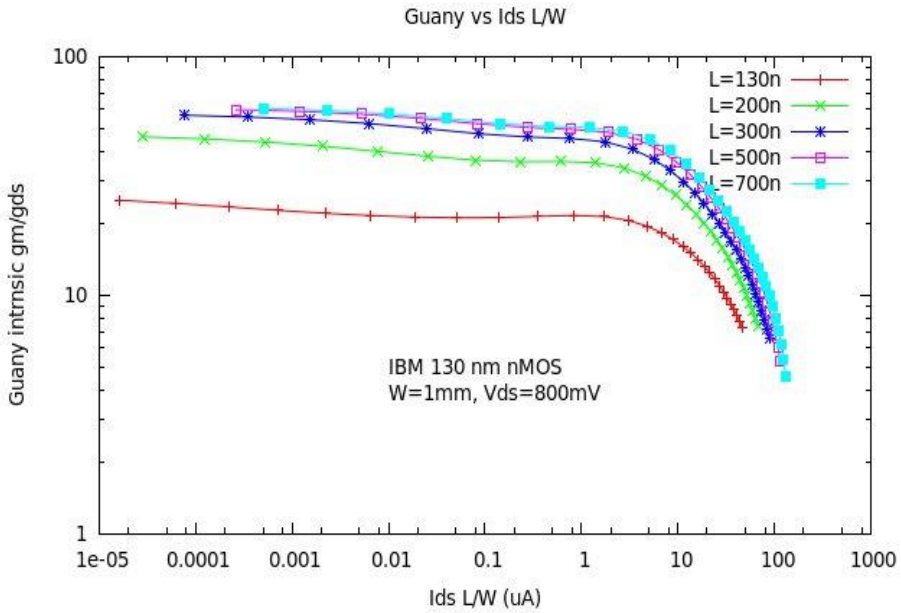
- The DUT is biased (current mirror configuration) with an inversion factor IF and a fixed Vds.

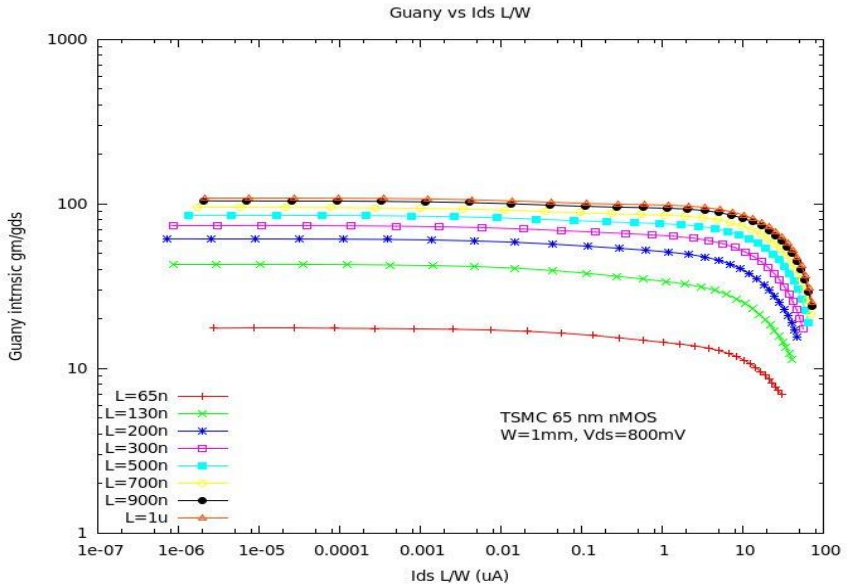
- A parametric sweep is done for the inversion factor, from w.i. (10e-7) to s.i. (10e2)

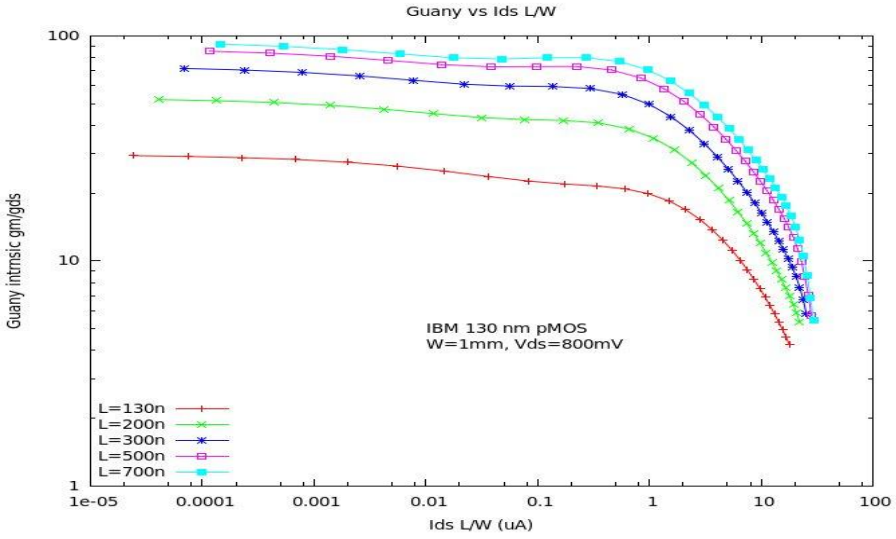
- The intrinsic gain, taken as gm/gds is plotted against Ids·L/W.

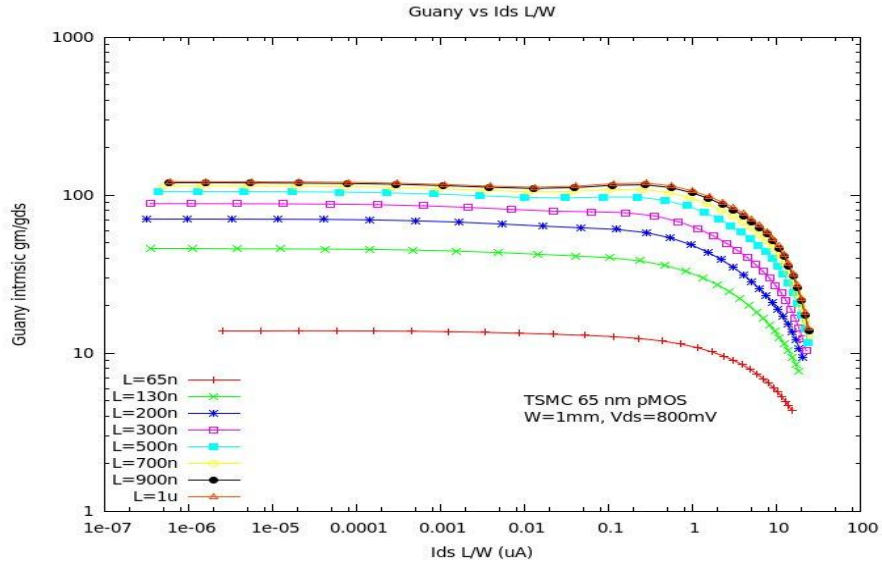
- The procedure is repeated for different L.

Technology analysis: Intrinsic gain

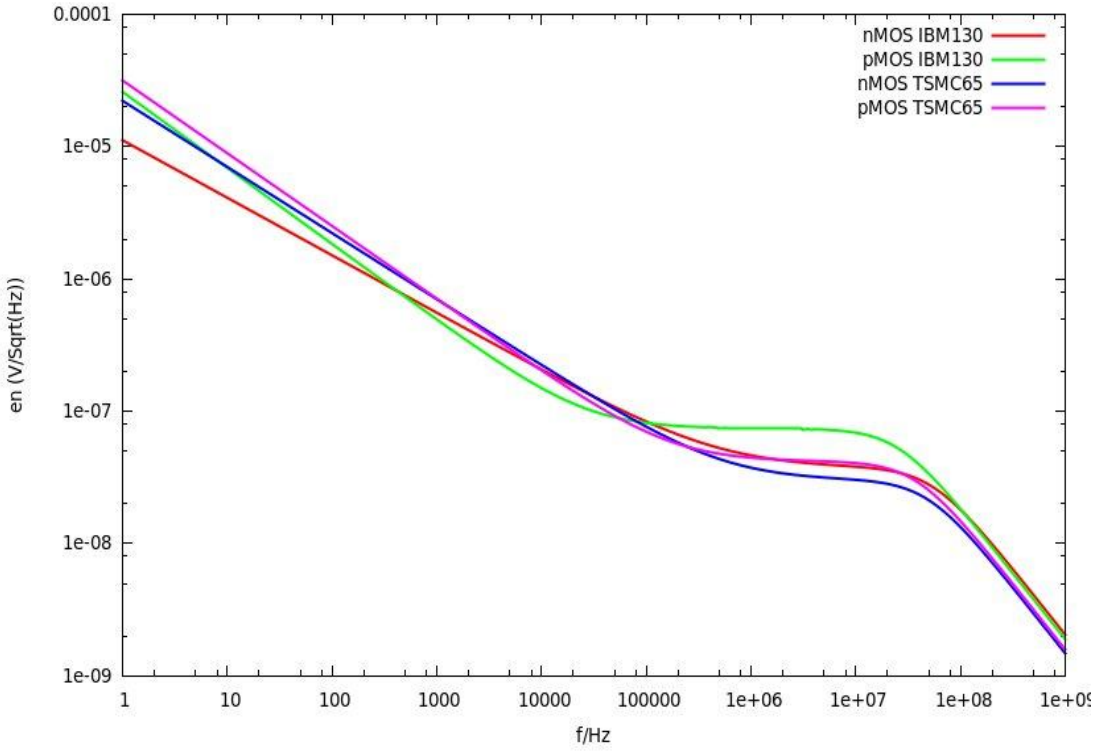








Technology analysis: Noise Spectral Density



* Graphic obtained with Cadence simulations (BSIM4 model).

TSMC: Higher flicker noise
IBM: Higher thermal noise

Technology selection

TSMC 65nm

- **Higher intrinsic gain**

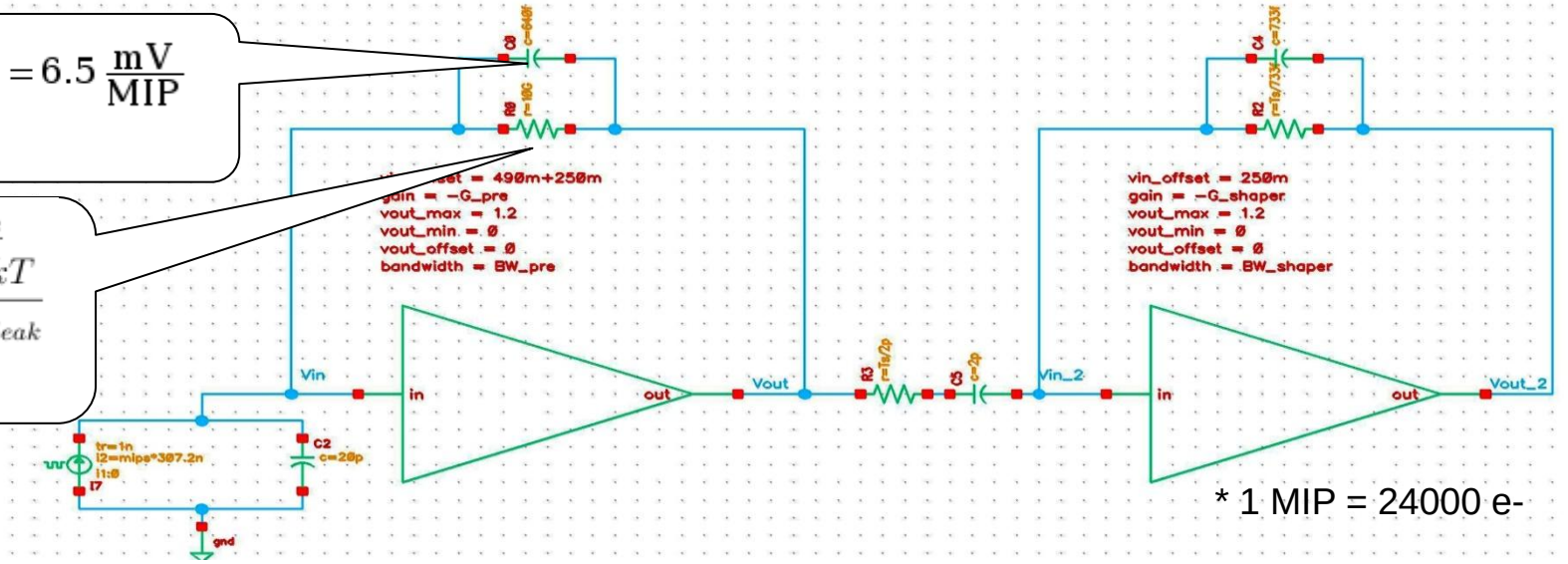
- **Similar noise compared to IBM**

- **Fits more electronics**

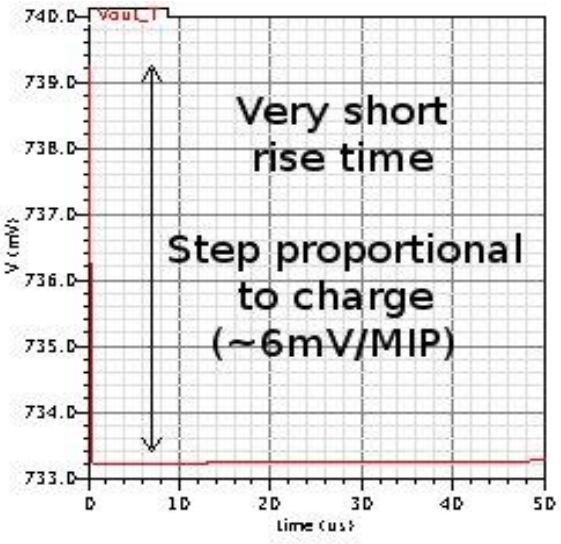
Functional model: Preamplifier + Shaper

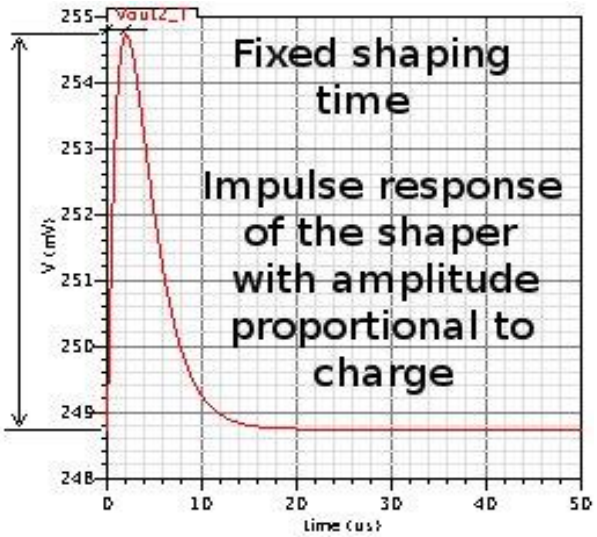
$$G = \frac{1}{Cf} = 6.5\ \frac{mV}{MIP}$$

$$R > \frac{2kT}{eI_{leak}}\ \text{noise}$$



* 1 MIP = 24000 e-





This functional model provides the minimum requirements.
Front-end amplifier:

Minimum gain:
60dB
Minimum BW @ 60dB
~ 100kHz

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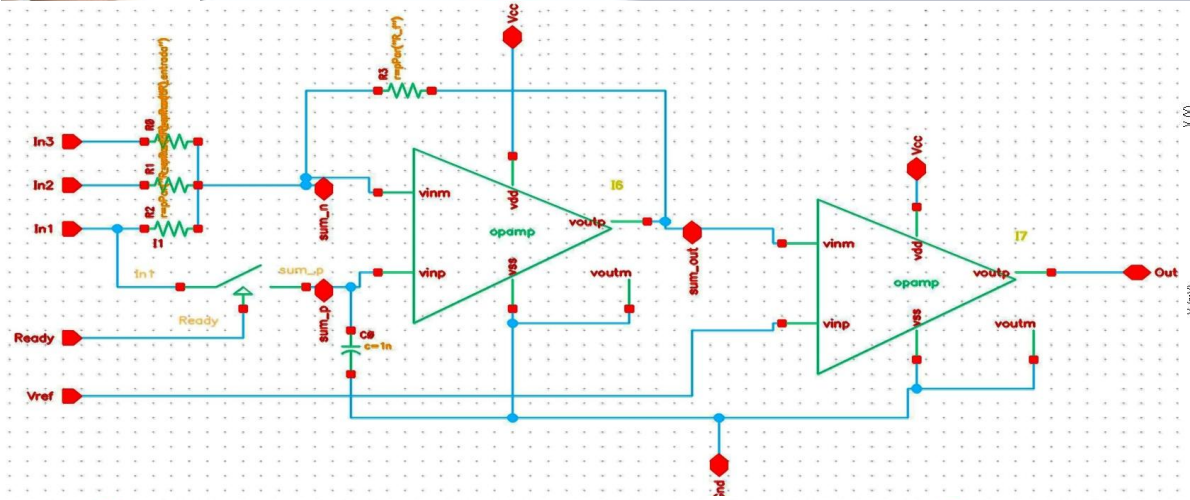
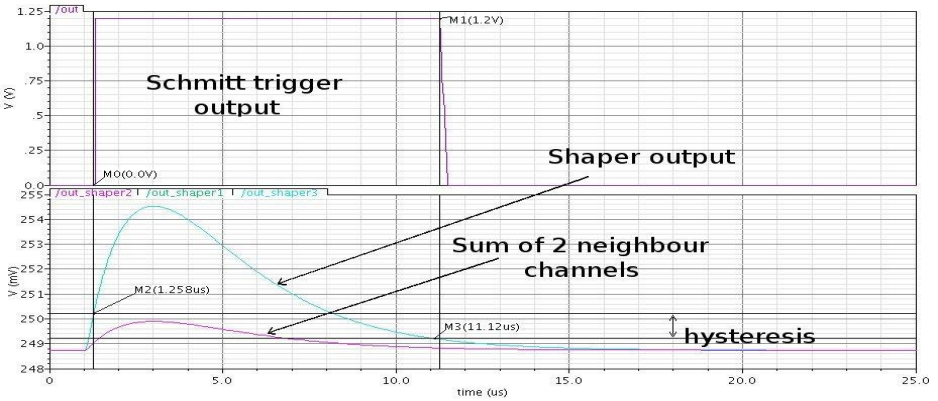
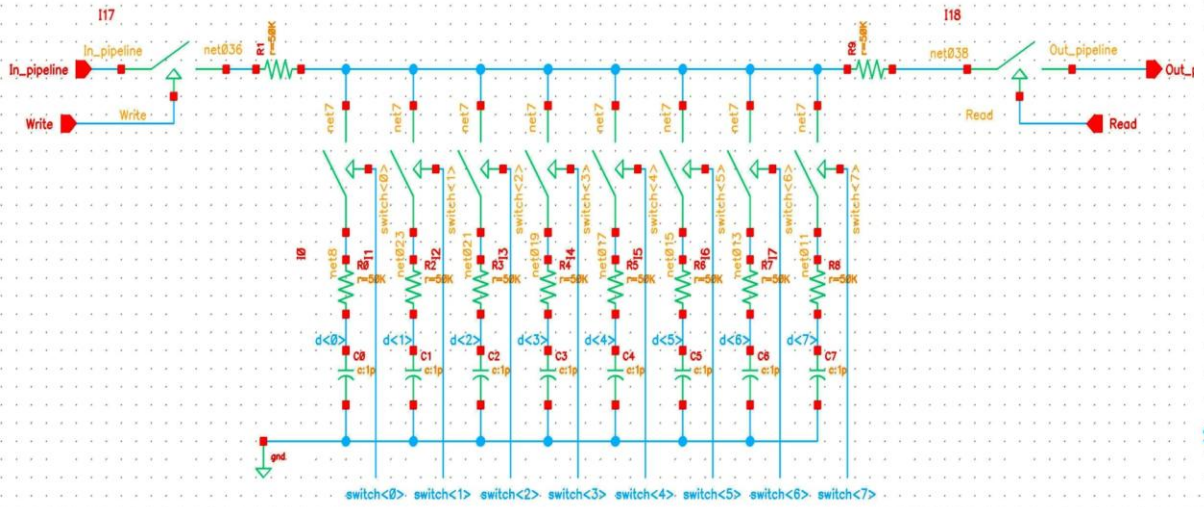
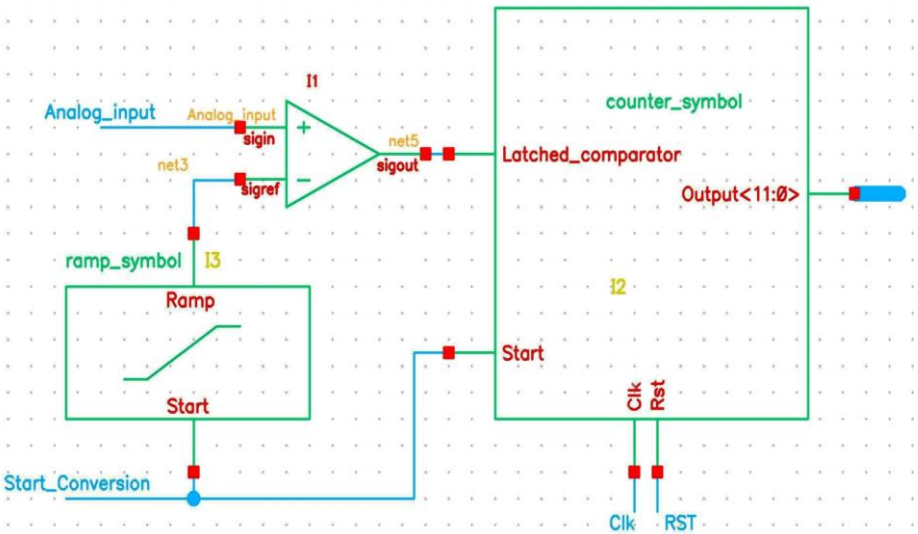
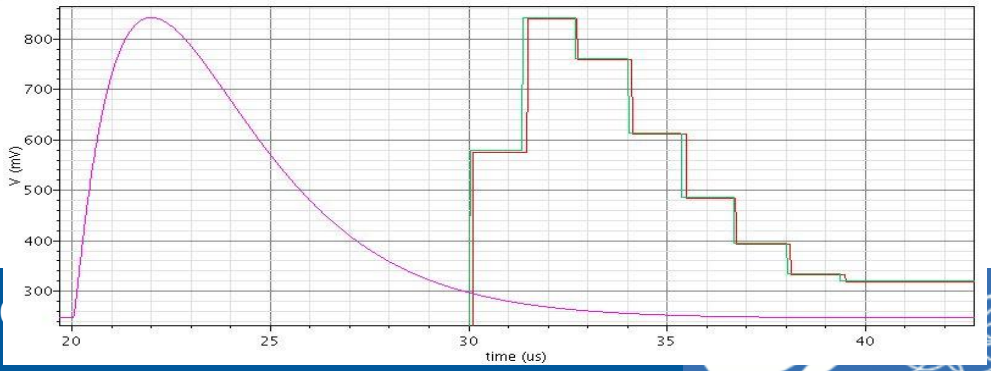
Functional model: Sparsifier + Comparator, analog sampler, Wilkinson ADC (single ramp)



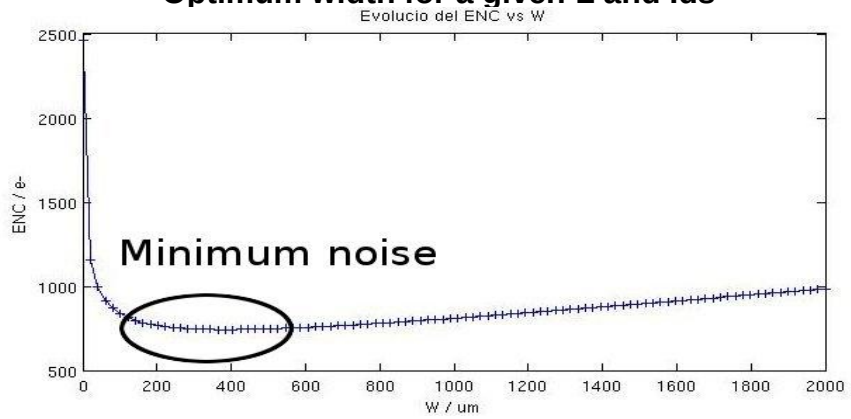








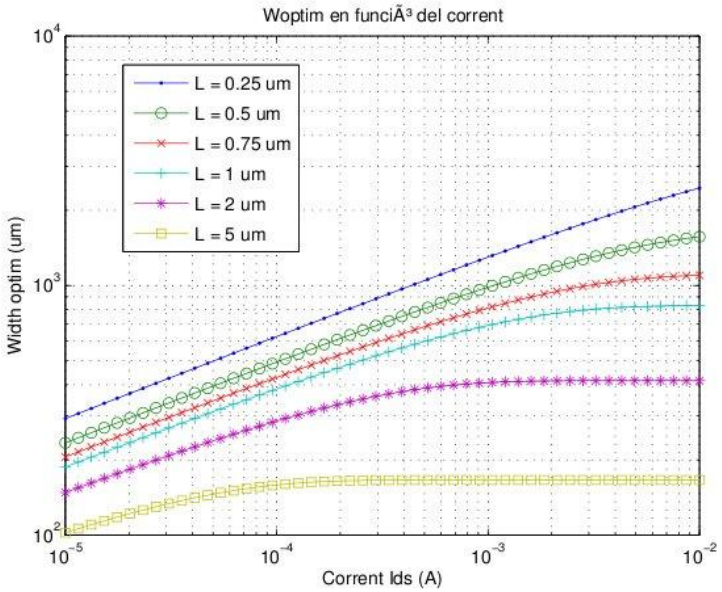
Optimum width for a given L and Ids

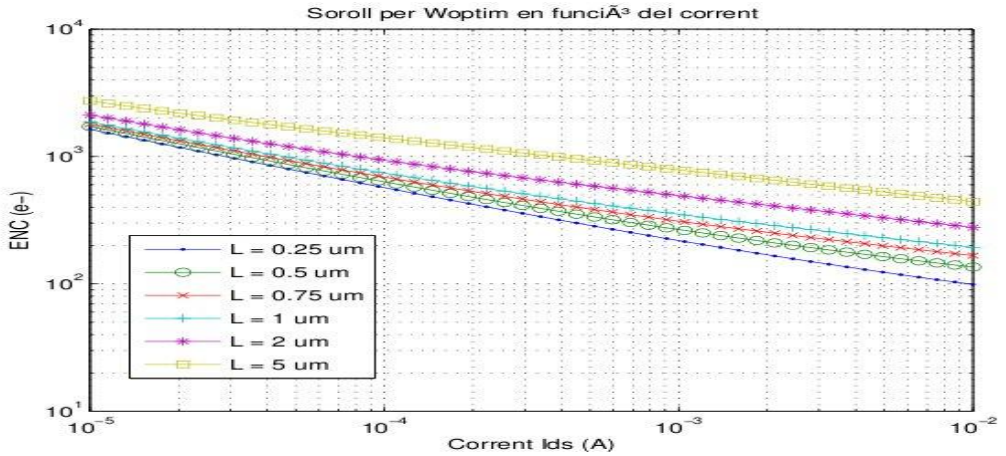


Característiques de soroll per diferents L i I_{ds}

L	I_{ds}	a	b	$ENC\ 20pF$	W_{optima}	$Consum$	IF
$0.25\mu m$	$100\mu A$	$47e^-$	$26.2e^-$	$570e^-$	$624\mu m$	$120\mu W$	0.27
$0.25\mu m$	$200\mu A$	$40e^-$	$19.1e^-$	$422e^-$	$781\mu m$	$240\mu W$	0.42
$0.25\mu m$	$300\mu A$	$37e^-$	$15.9e^-$	$355e^-$	$890\mu m$	$360\mu W$	0.56
$0.25\mu m$	$500\mu A$	$34e^-$	$12.7e^-$	$288e^-$	$1046\mu m$	$600\mu W$	0.79
$0.50\mu m$	$100\mu A$	$71e^-$	$28.1e^-$	$633e^-$	$493\mu m$	$120\mu W$	0.70
$0.50\mu m$	$200\mu A$	$63e^-$	$20.8e^-$	$479e^-$	$613\mu m$	$240\mu W$	1.12
$0.50\mu m$	$300\mu A$	$59e^-$	$17.6e^-$	$410e^-$	$694\mu m$	$360\mu W$	1.49
$0.50\mu m$	$500\mu A$	$54e^-$	$14.3e^-$	$340e^-$	$808\mu m$	$600\mu W$	2.13
$0.75\mu m$	$100\mu A$	$94e^-$	$29.8e^-$	$689e^-$	$428\mu m$	$120\mu W$	1.25
$0.75\mu m$	$200\mu A$	$84e^-$	$22.4e^-$	$532e^-$	$528\mu m$	$240\mu W$	2.02
$0.75\mu m$	$300\mu A$	$79e^-$	$19.1e^-$	$460e^-$	$594\mu m$	$360\mu W$	2.70
$0.75\mu m$	$500\mu A$	$74e^-$	$15.7e^-$	$387e^-$	$683\mu m$	$600\mu W$	3.90
$1.00\mu m$	$100\mu A$	$115e^-$	$31.4e^-$	$743e^-$	$385\mu m$	$120\mu W$	1.89
$1.00\mu m$	$200\mu A$	$104e^-$	$23.8e^-$	$581e^-$	$470\mu m$	$240\mu W$	3.10
$1.00\mu m$	$300\mu A$	$98e^-$	$20.4e^-$	$507e^-$	$525\mu m$	$360\mu W$	4.16
$1.00\mu m$	$500\mu A$	$92e^-$	$17.0e^-$	$432e^-$	$596\mu m$	$600\mu W$	6.11

ENC ~ a + b·Cd

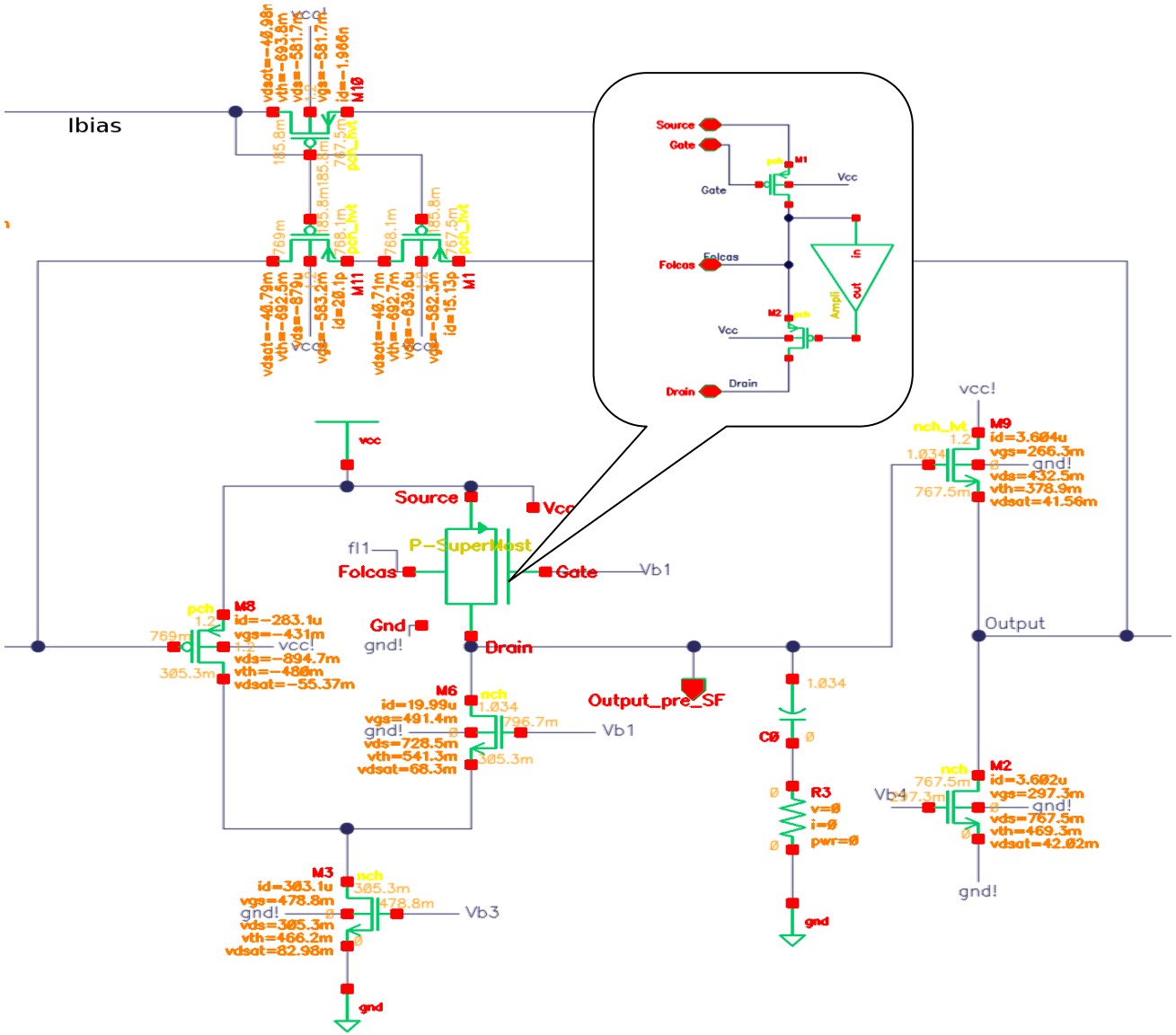




$$ENC = \sqrt{\frac{2}{3}kT\frac{1}{g_m}\,1.57\,\frac{C_t^2 e^2}{\pi q^2 \tau} + \frac{K_f}{C_{ox}^2 WL}\frac{C_t^2 e^2}{2q^2} + I_{\text{leak}}\,1.57\,\frac{e^2\tau}{2\pi q} + \frac{kT}{R}\,1.57\,\frac{e^2\tau}{\pi q^2}}$$

Hans-Günther Moser, “Silicon detector systems in high energy physics”, 2009

Amplifier design: Folded cascode with gain-boosting



Power supply:
1.2V

Power consumption:
< 380 µW

Noise @ 2µs shaping time:
A ~ 35,7 e-
B ~ 16,5 e-/pF
[< 400 e- (20pF)]

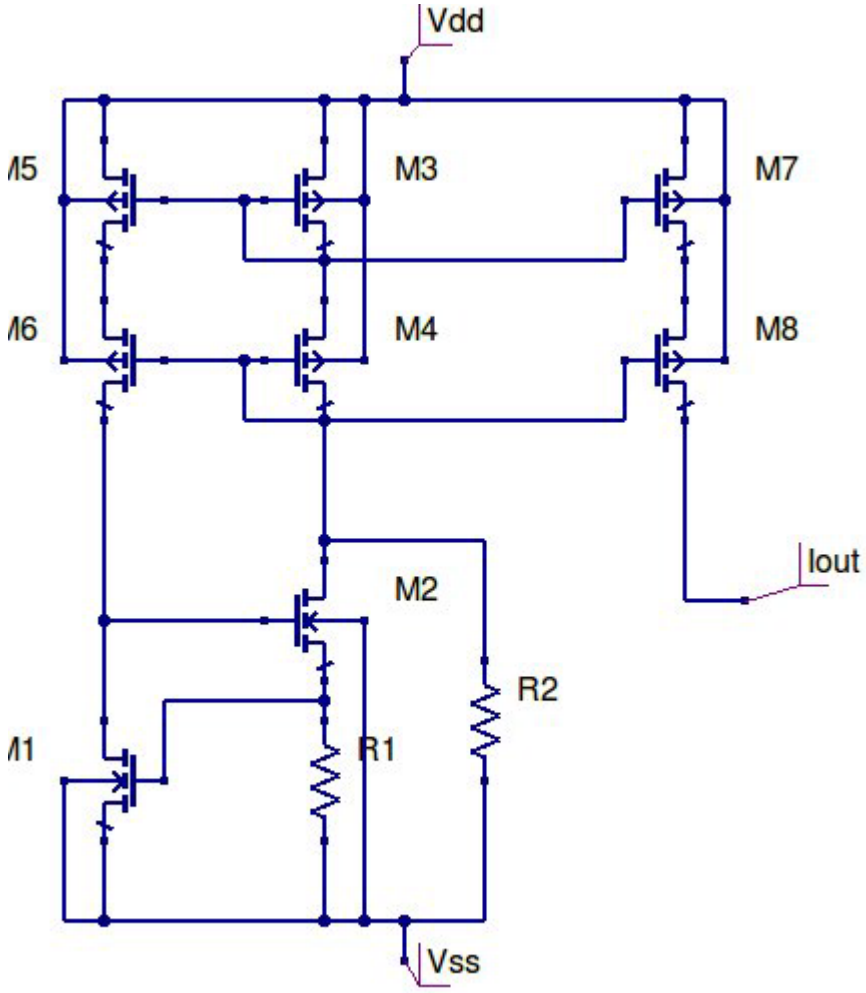
Full scale:
100 MIP

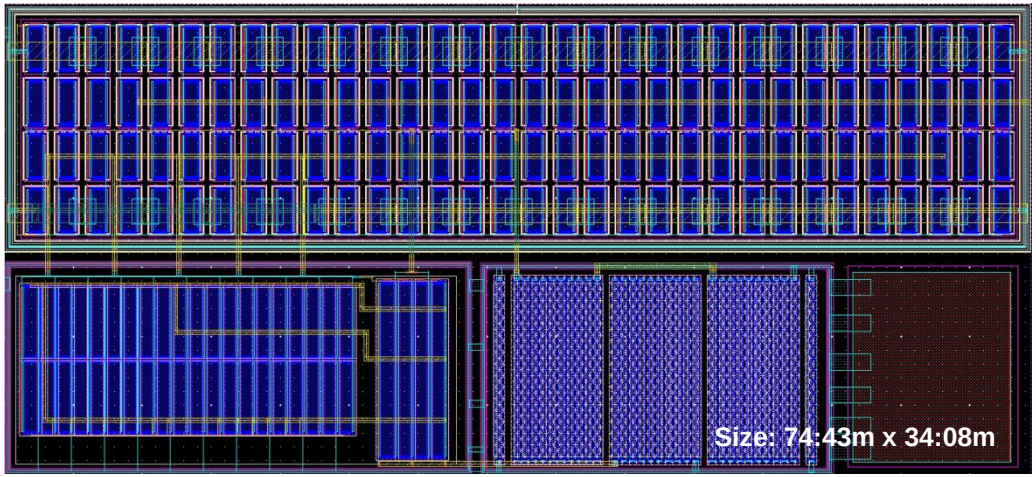
Charge gain:
~ 6.5 mV/MIP

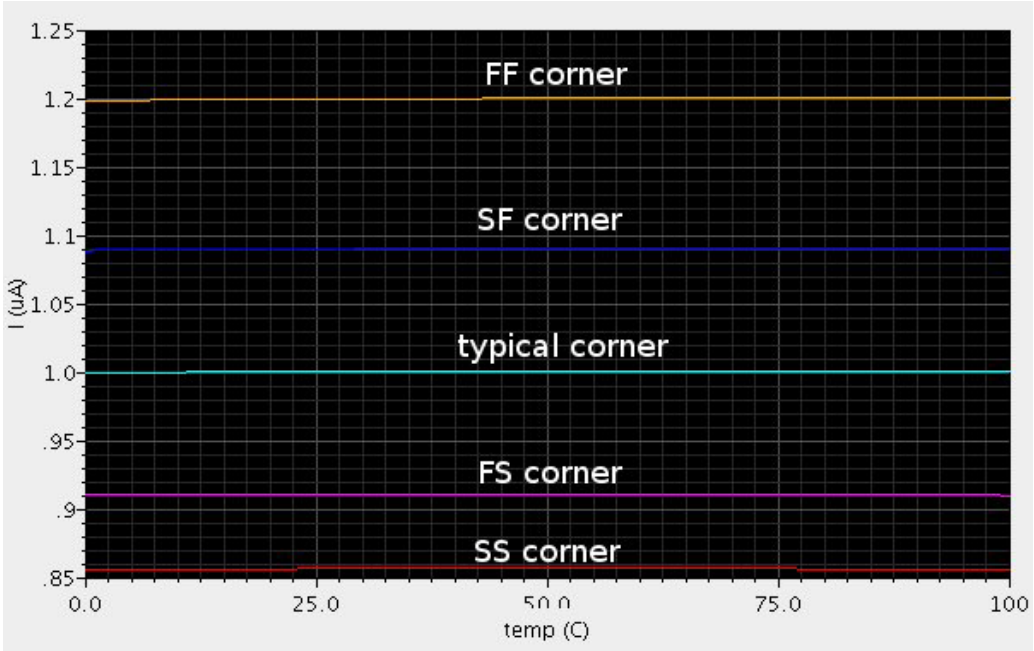
Amplifier:
Gain ~ 69 dB
3dB-BW: ~ 55kHz
PM ~ 66 º

*** 1 MIP = 24000 e-**

T independent current source design







I=1uA, TC < 30ppm [0:100ºC]
P=6uW

Future work:

- **Design of 1 channel:**
  - Shaper and sparsifier amplifiers
  - Comparator
  - Analog pipeline
  - ADC
  - Biasing DACs
  - Digital electronics
- **Multichannel design**
- **Look for interest in other groups for the design to accelerate the design**
- **Obtain more specifications: sensor characteristics, pitch, ..., readout requirements (for example number of pipelines required)**
- **Find budget to prototype**