

Design of an Image Sensor with Well Photo Diode

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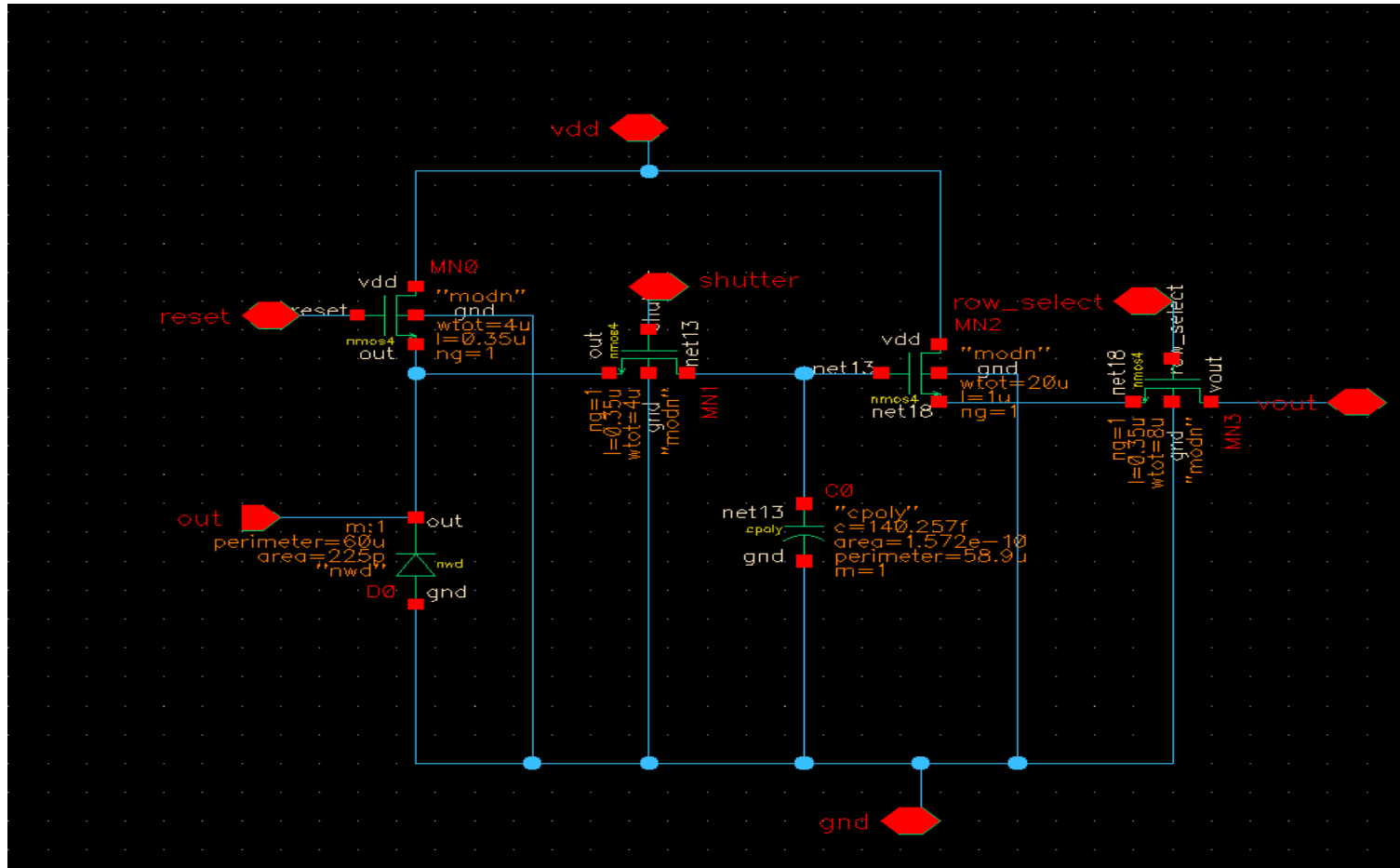
Introduction

➤ Aim:

Design of a 32x16 APS matrix with Well diode as photo diode. Achieve this goal through systematic approach from Single APS pixel design to the complete design and simulation of APS matrix.

➤ Technology used is 0.35 μm (4 metal layers) from Austriamicrosystems.

Single APS Pixel Schematic



se L: schSingleSelectPt()

M: schHiMousePopUp()

R: geScroll(nil "s" nil)

Design Parameters of a Single APS pixel

➤ Single APS pixel Components (Transistor)

Name	Component	Width (μm)	Length(μm)
Reset	N-MOS	4	0.35
Shutter	N-MOS	4	0.35
MN2	N-MOS	20	1
row_select	N-MOS	8	0.35

Design Parameters of a Single APS Pixel

- Transistor aspect ratios are kept accordingly as mentioned, such that a better readout time and output voltage level are achieved
- reset and shutter transistors are switches so I kept them in minimum dimension (tuning can be done for better readout time)
- row_select and MN2 have higher width because, it is observed that reducing the width of these transistors will effectively reduce the readout time and output voltage level

Design of Single APS pixel

➤ Other Components

1. Photo diode Features:

Area- $225 \text{ Sq.}\mu\text{m}$ ($15\mu \times 15\mu$)

Perimeter- $60\mu\text{m}$

2. Capacitor: **C**

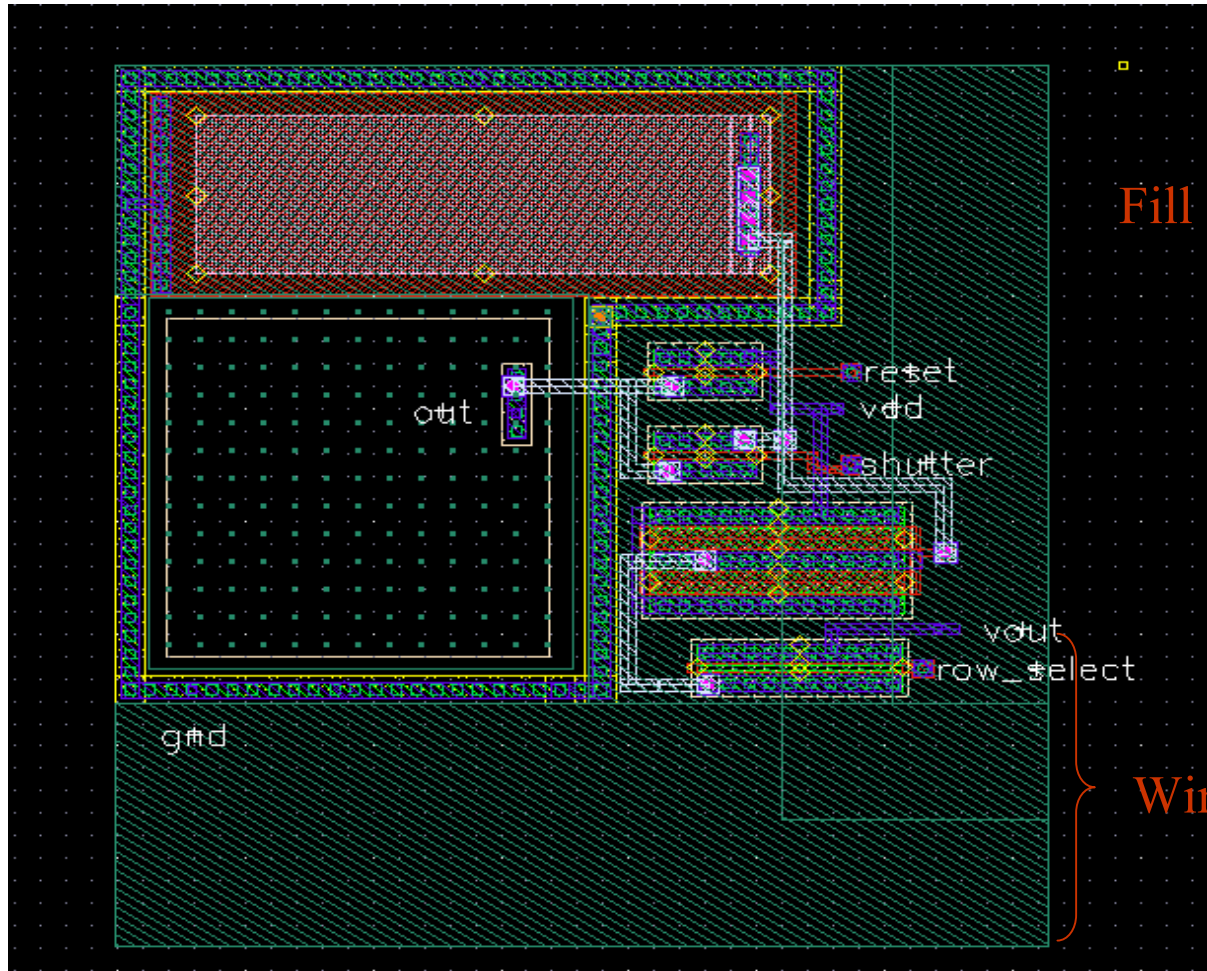
Value – 140fF

Area- 1.572×10^{-10}

Perimeter- $58.9 \mu\text{m}$

Note: Large value of **C** gives larger o/p volatge but lesser readout time. So a compromise between both are made

Single APS Pixel Layout



Fill factor = 22%

Wiring Channel

Single APS Pixel LVS Check

```
/export/users/sens9/LVS/si.log
File Help 24
Warning: Unknown device "rpoly1" on a permuteDevice command.
Warning: Unknown device "lat3" on a permuteDevice command.
Warning: Unknown device "vert15" on a permuteDevice command.
Warning: Unknown device "vert10" on a permuteDevice command.
Warning: Unknown device "vert5" on a permuteDevice command.
Warning: Unknown device "pmosm4" on a permuteDevice command.
Warning: Unknown device "rmosmh4" on a permuteDevice command.
Warning: Unknown device "rmosm4" on a permuteDevice command.
Warning: Unknown device "pmos4" on a permuteDevice command.
Warning: Unknown device "rmosh6" on a permuteDevice command.
Warning: Unknown device "rmosh4" on a permuteDevice command.
Warning: Unknown device "ng" on a permuteDevice command.
Warning: Unknown device "cvar" on a permuteDevice command.
Warning: Unknown device "csandwt" on a permuteDevice command.
Warning: Unknown device "zd2sm24" on a permuteDevice command.
Warning: Unknown device "pd" on a permuteDevice command.
Warning: Unknown device "nd" on a permuteDevice command.

The net-lists match.

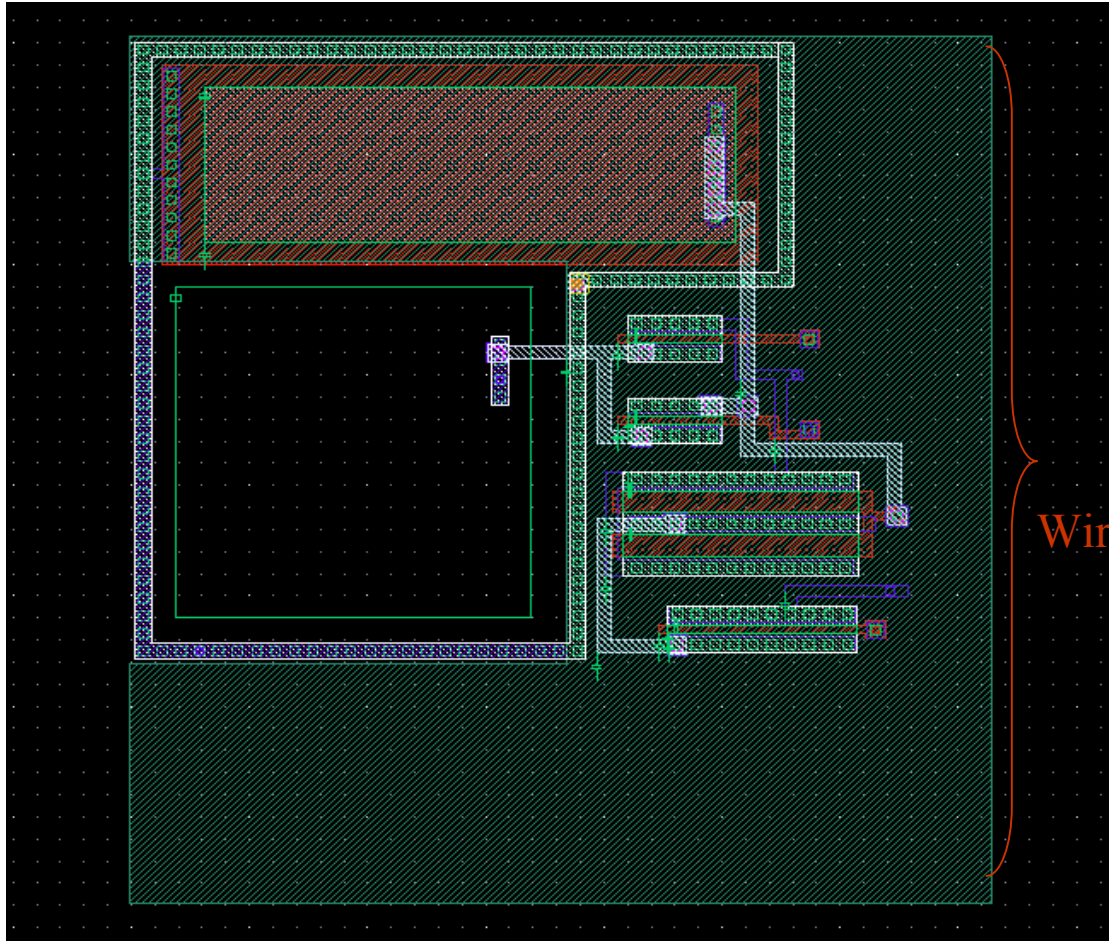
                layout schematic
                instances
un-matched      0      0
rewired         0      0
size errors     0      0
pruned         0      0
active          7      6
total          7      6

                nets
un-matched      0      0
merged          0      0
pruned         0      0
active          9      9
total          9      9

                terminals
un-matched      0      0
matched but
different type  0      0
total          7      7
End comparison:   Jul 30 16:50:05 2008

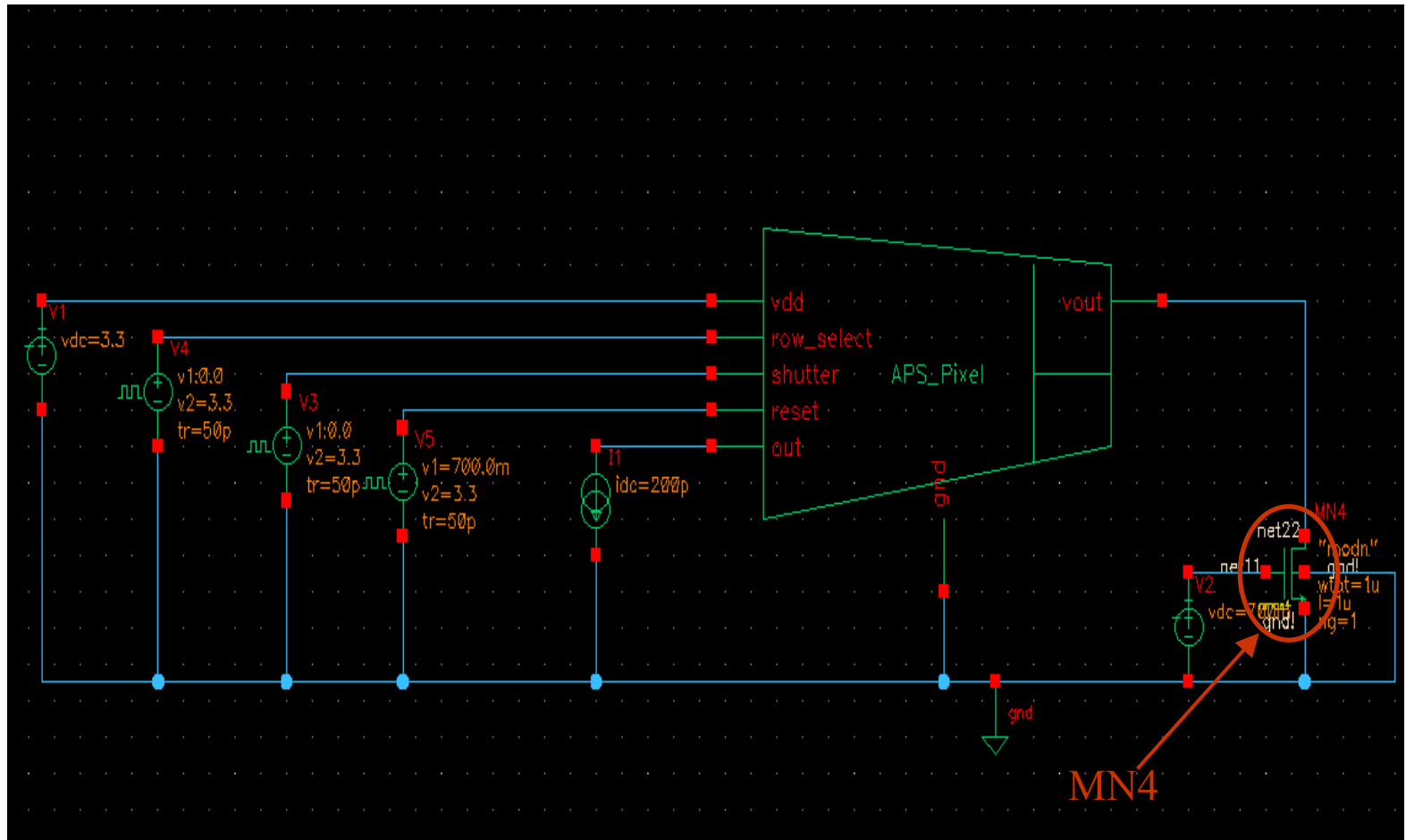
Comparison program completed successfully.
```

APS Single Pixel Analog Extracted



Wiring Channel

Single APS Pixel Simulation Set up



Simulation Set up for a APS Single pixel

Comp	V1	V2	tr(pSec)	tf(pSec)	PW(μ S)	Delay (mSec)
row_sel	0V	3.3V	50	50	500	0
shutter	0V	3.3V	50	50	700	0
reset	700mV	3.3V	50	50	500	1

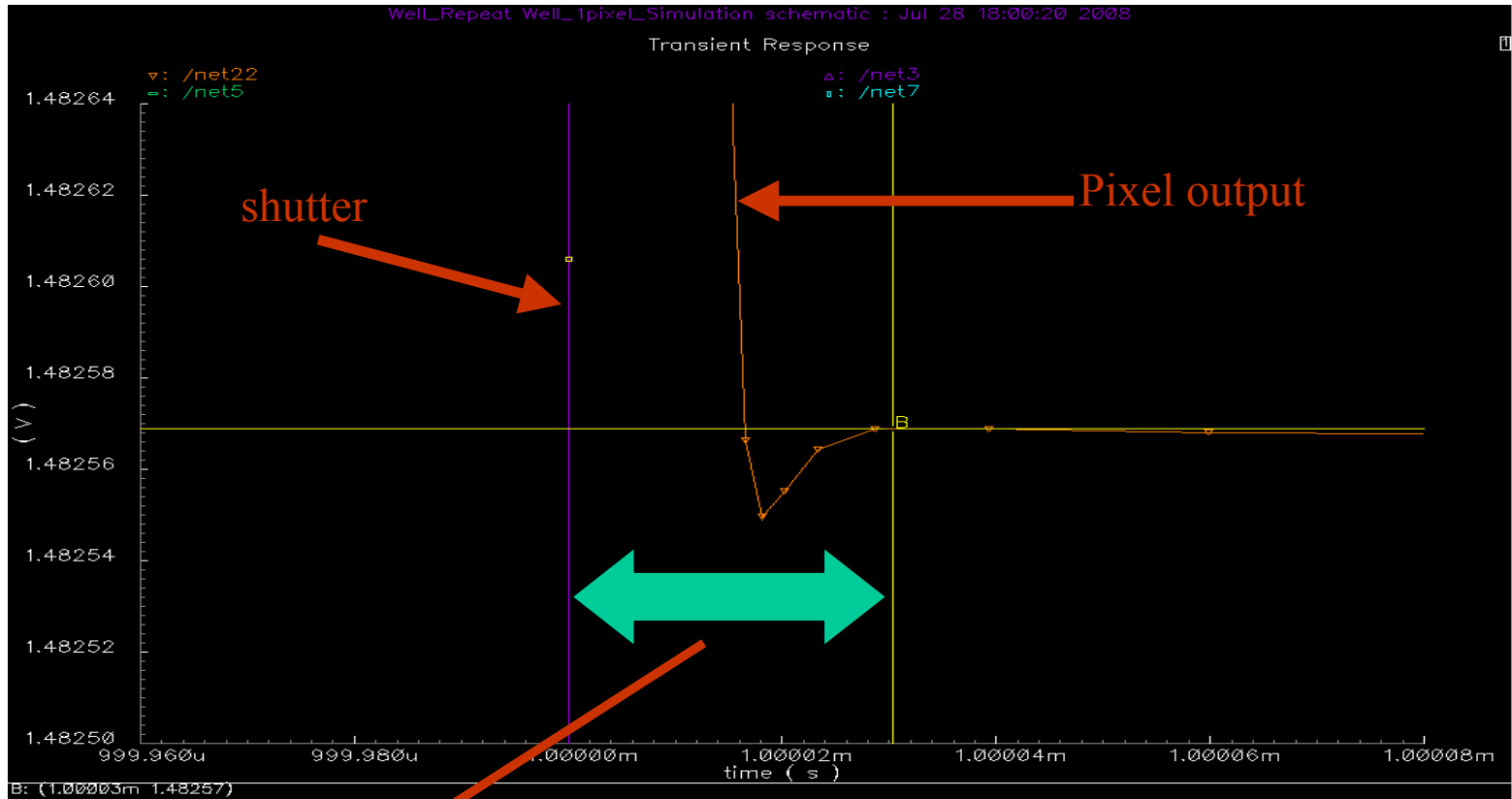
Load Transistor: MN4

Aspect Ratio: $(1/1)\mu\text{m}$ and $V_{\text{Bias}} = 750\text{mV}$

Simulation Set up for a APS Single pixel

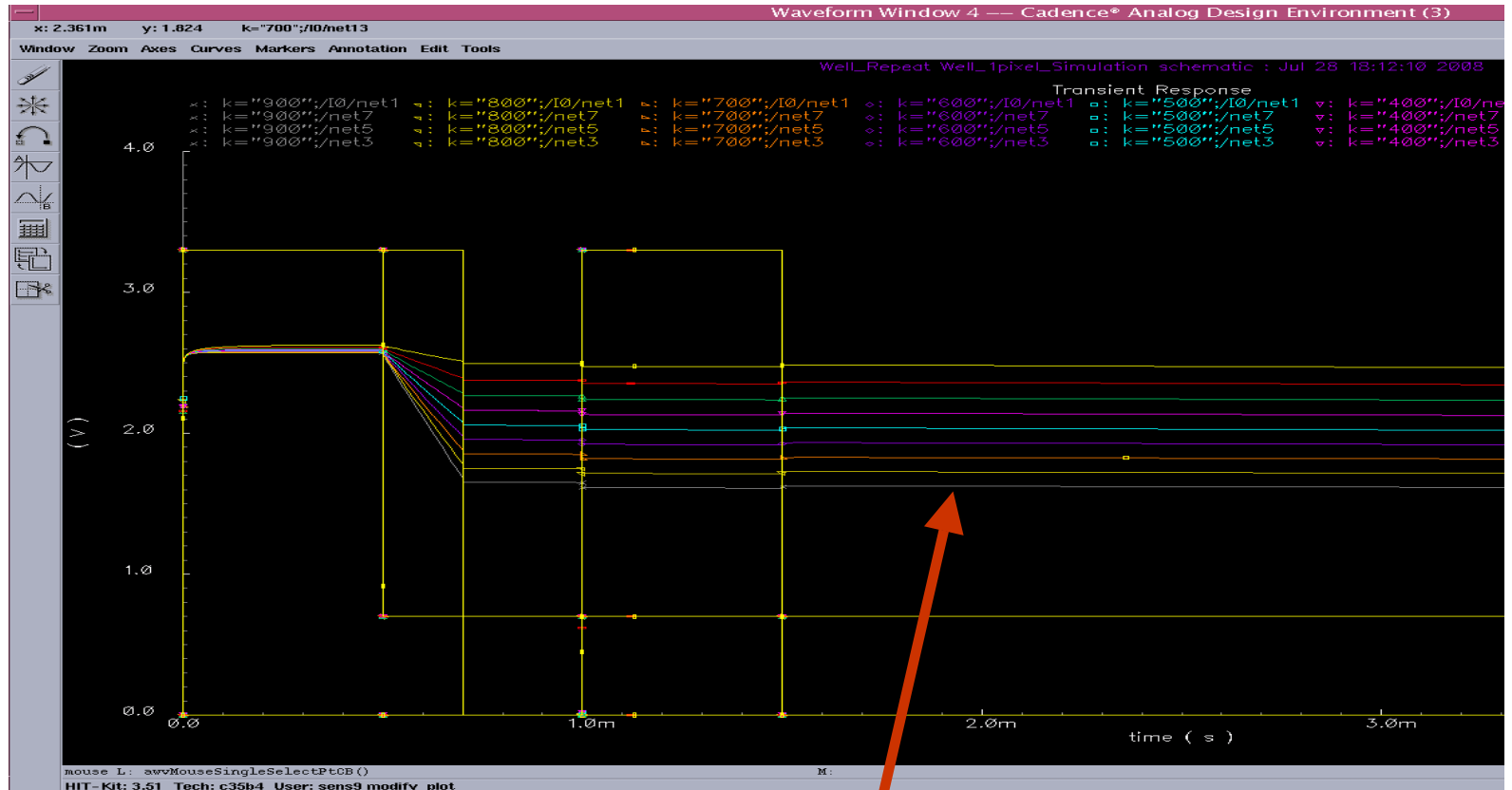
- Aspect ratio of MN4 is sized for better readout time
- Biasing voltage of MN4 has to be more than the threshold voltage (approx. 500mV)
- As width increases, o/p voltage decreases also readout time decreases with increase in Biasing voltage
- So I kept the biasing voltage little higher than the threshold voltage to ensure the proper working of the pixel to obtain better readout time and output voltage level
- V1 for reset transistor is 700mV to avoid driving the photo diode to forward biasing

Single APS Pixel Readout



Readout Time – 25nSec

APS Single pixel Parametric Analysis

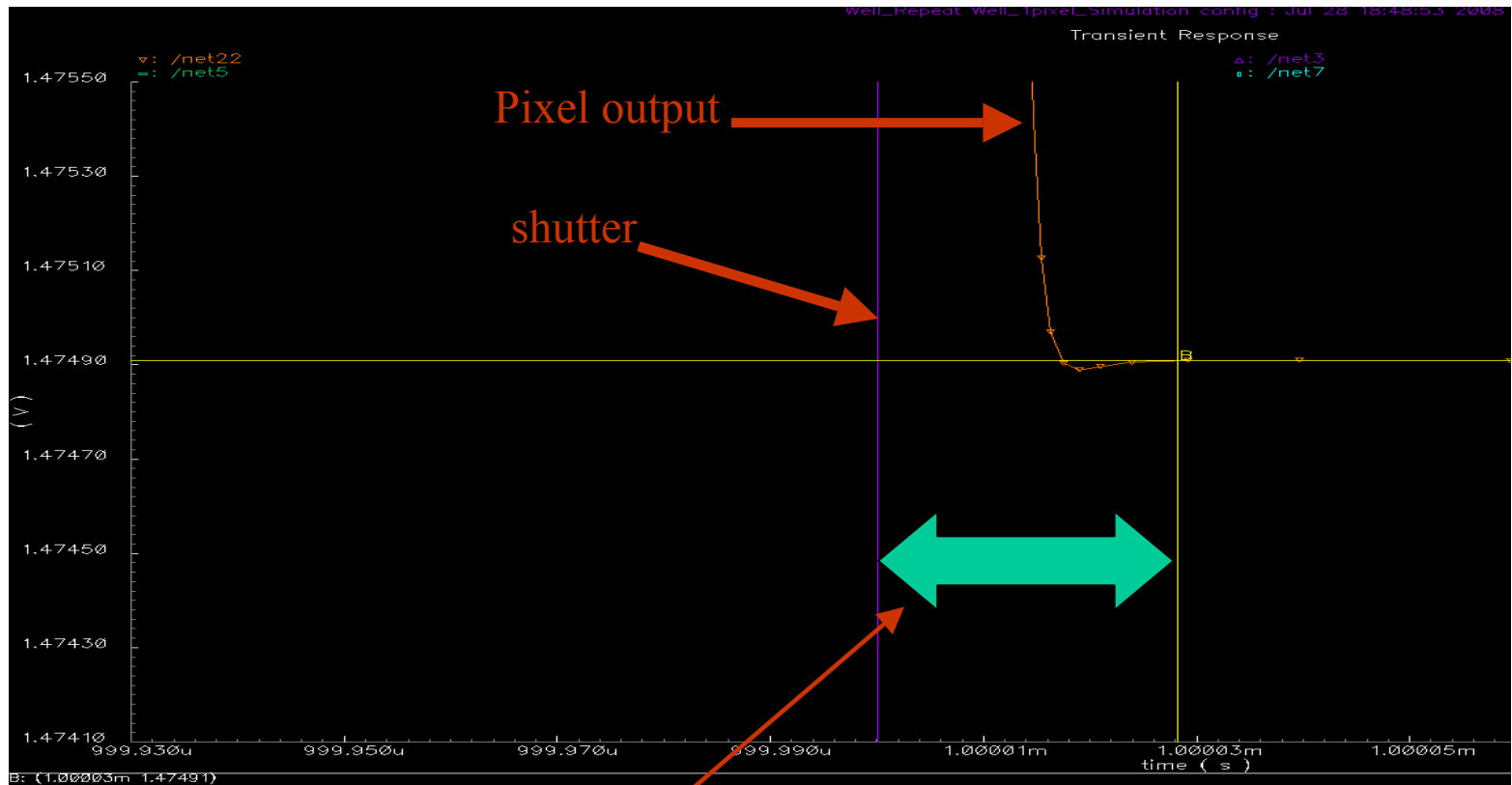


Transient analysis for dynamic range measurement

APS Single pixel Parametric Analysis

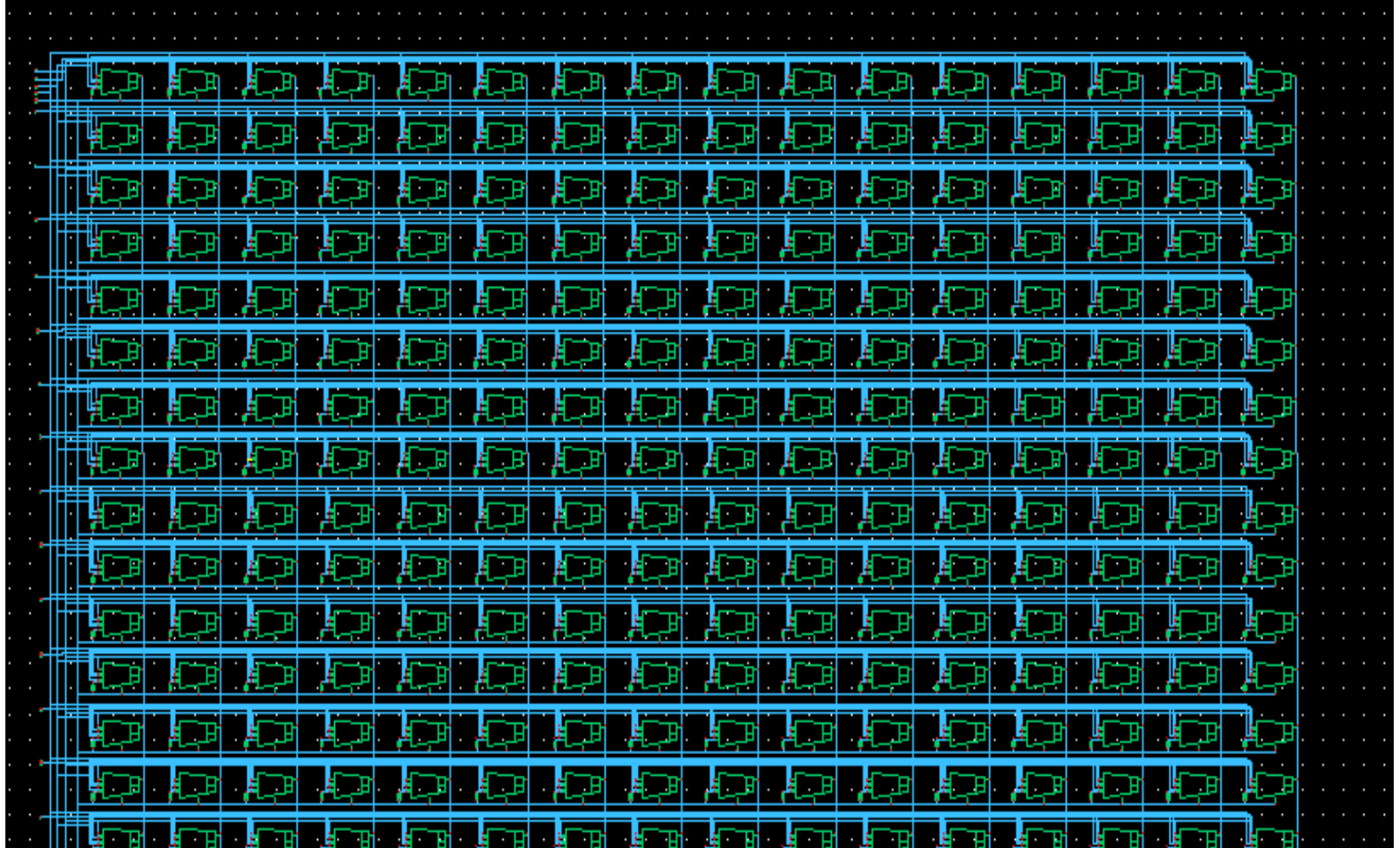
- A parametric analysis is performed with different values of photo current (I_{photo}) ranging from 1pA till 900 pA
- The ratio of max to minimum photo current in the operating region is used to measure the Dynamic range
- Dynamic range obtained is 40dB

APS Single Pixel Config Readout (Extracted)

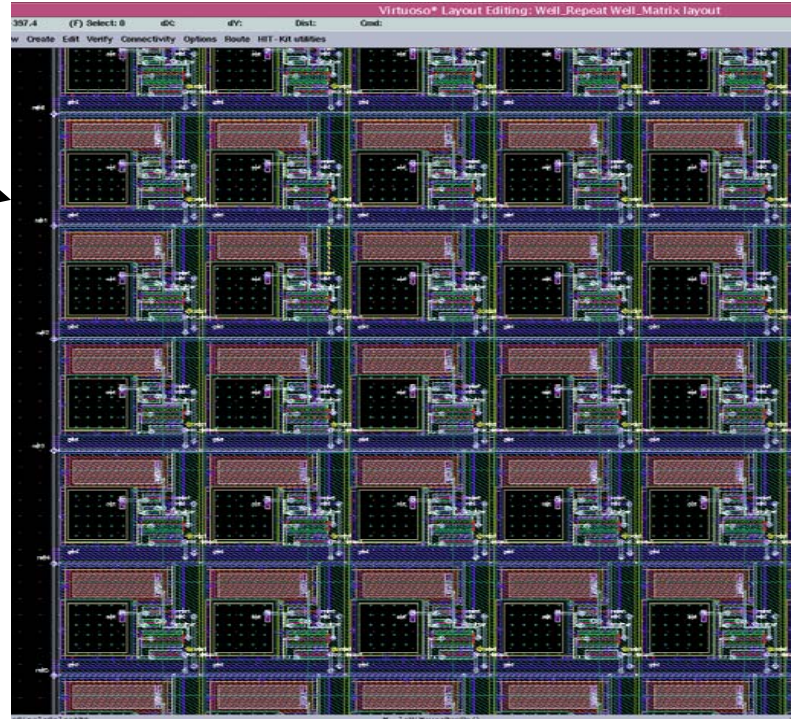


Readout Time – 29nSec

APS Matrix Design (Schematic)

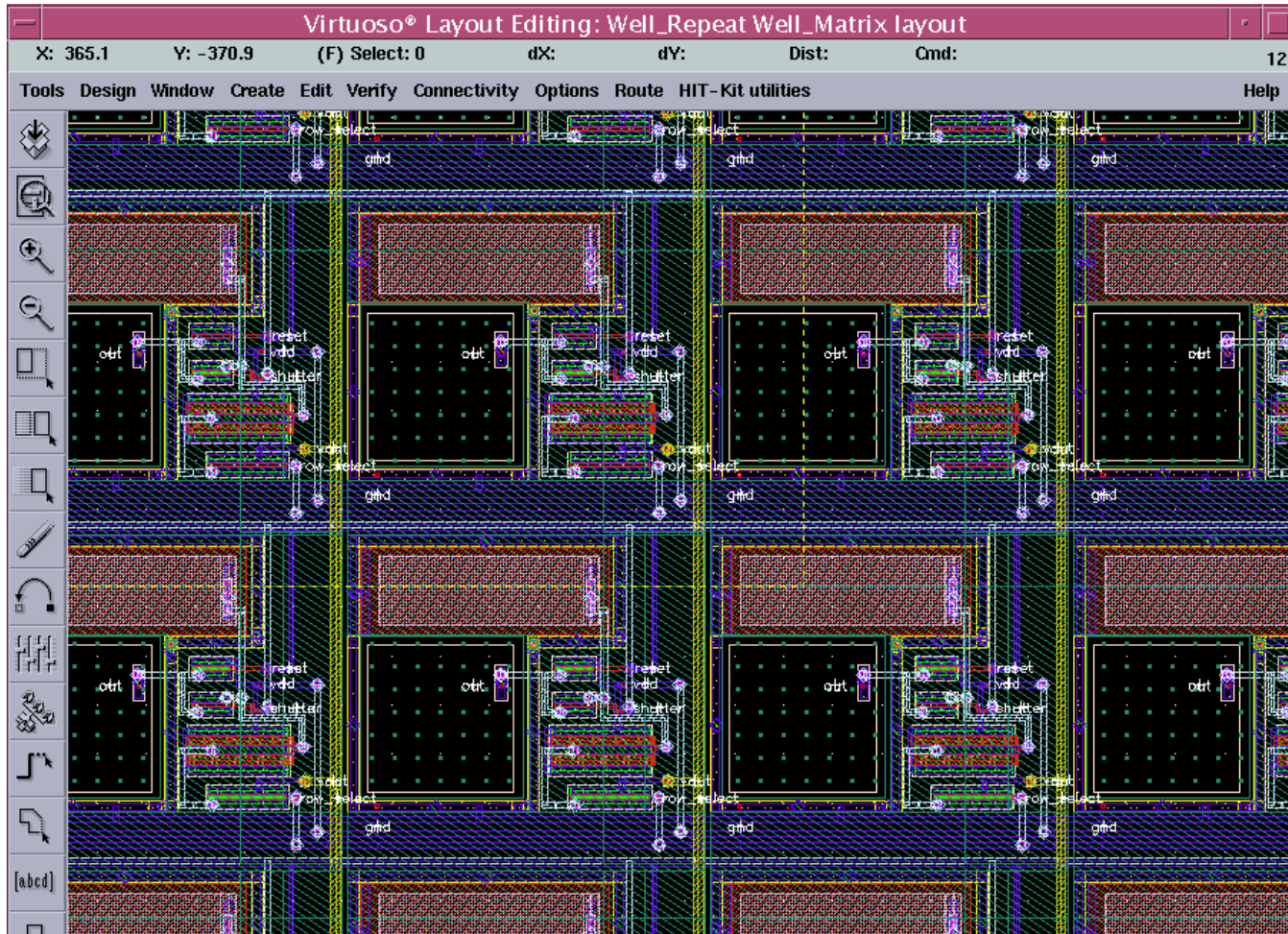


APS Matrix Layout



Matrix Size – $1092\mu \times 596.6\mu$

APS Matrix Layout (Close view)



APS Matrix LVS Check

```
File /export/users/sens9/LVS/si.log
Warning: Unknown device "rpoly1" on a permuteDevice command.
Warning: Unknown device "lat3" on a permuteDevice command.
Warning: Unknown device "vert15" on a permuteDevice command.
Warning: Unknown device "vert10" on a permuteDevice command.
Warning: Unknown device "vert5" on a permuteDevice command.
Warning: Unknown device "pmosm4" on a permuteDevice command.
Warning: Unknown device "rmosmh4" on a permuteDevice command.
Warning: Unknown device "rmosm4" on a permuteDevice command.
Warning: Unknown device "pmos4" on a permuteDevice command.
Warning: Unknown device "rmosh6" on a permuteDevice command.
Warning: Unknown device "rmosh4" on a permuteDevice command.
Warning: Unknown device "ng" on a permuteDevice command.
Warning: Unknown device "cvar" on a permuteDevice command.
Warning: Unknown device "csandwt" on a permuteDevice command.
Warning: Unknown device "zd2sm24" on a permuteDevice command.
Warning: Unknown device "pd" on a permuteDevice command.
Warning: Unknown device "nd" on a permuteDevice command.

The net-lists match.

                layout schematic
                instances
un-matched          0      0
rewired             0      0
size errors         0      0
pruned              0      0
active              3584   3072
total               3584   3072

                nets
un-matched          0      0
merged              0      0
pruned              0      0
active              1588   1588
total               1588   1588

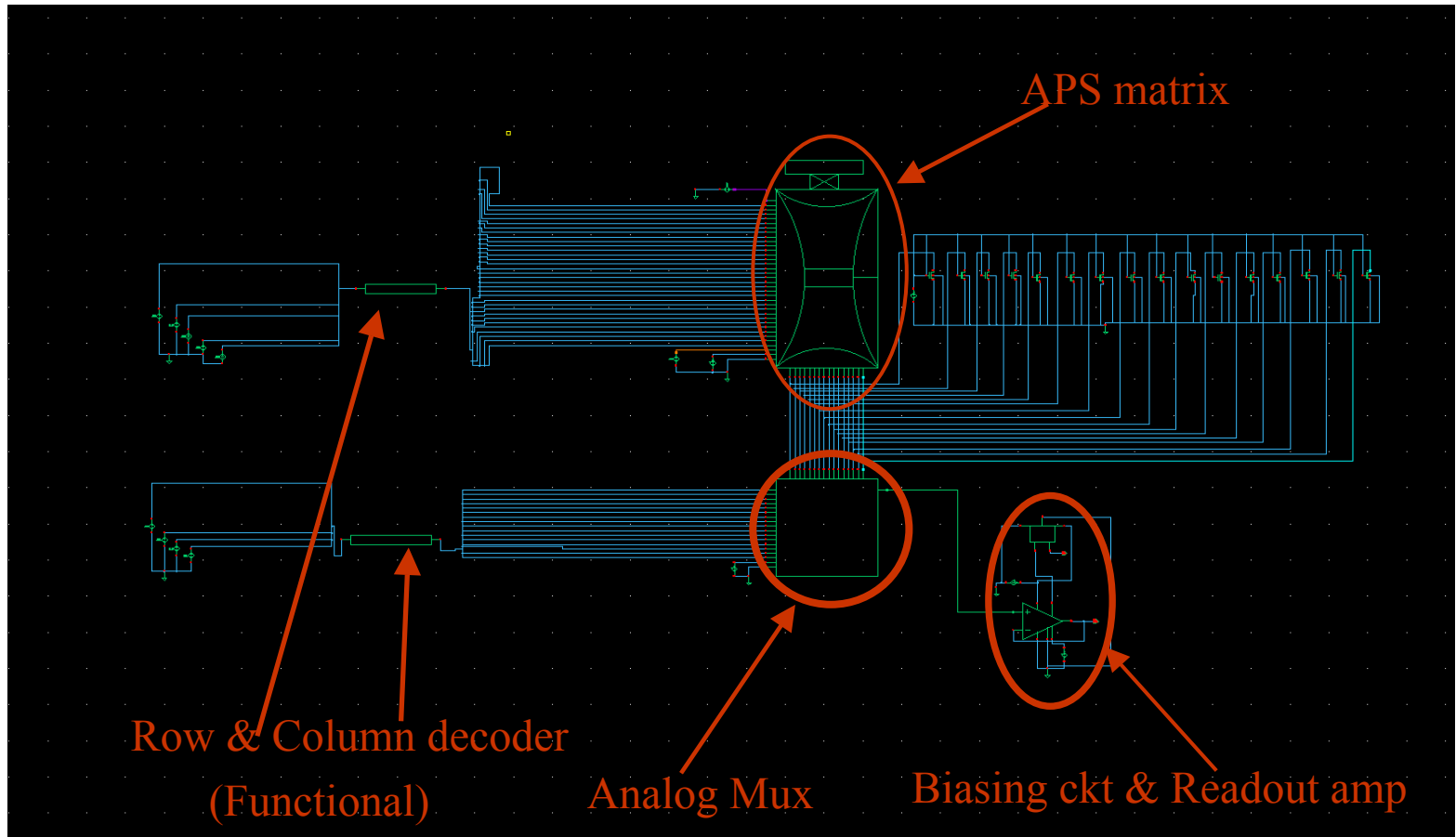
                terminals
un-matched          0      0
matched but
different type      0      0
total               52     52
End comparison:      Jul 30 16:28:44 2008

Comparison program completed successfully.
```

APS Matrix Analog Extracted View

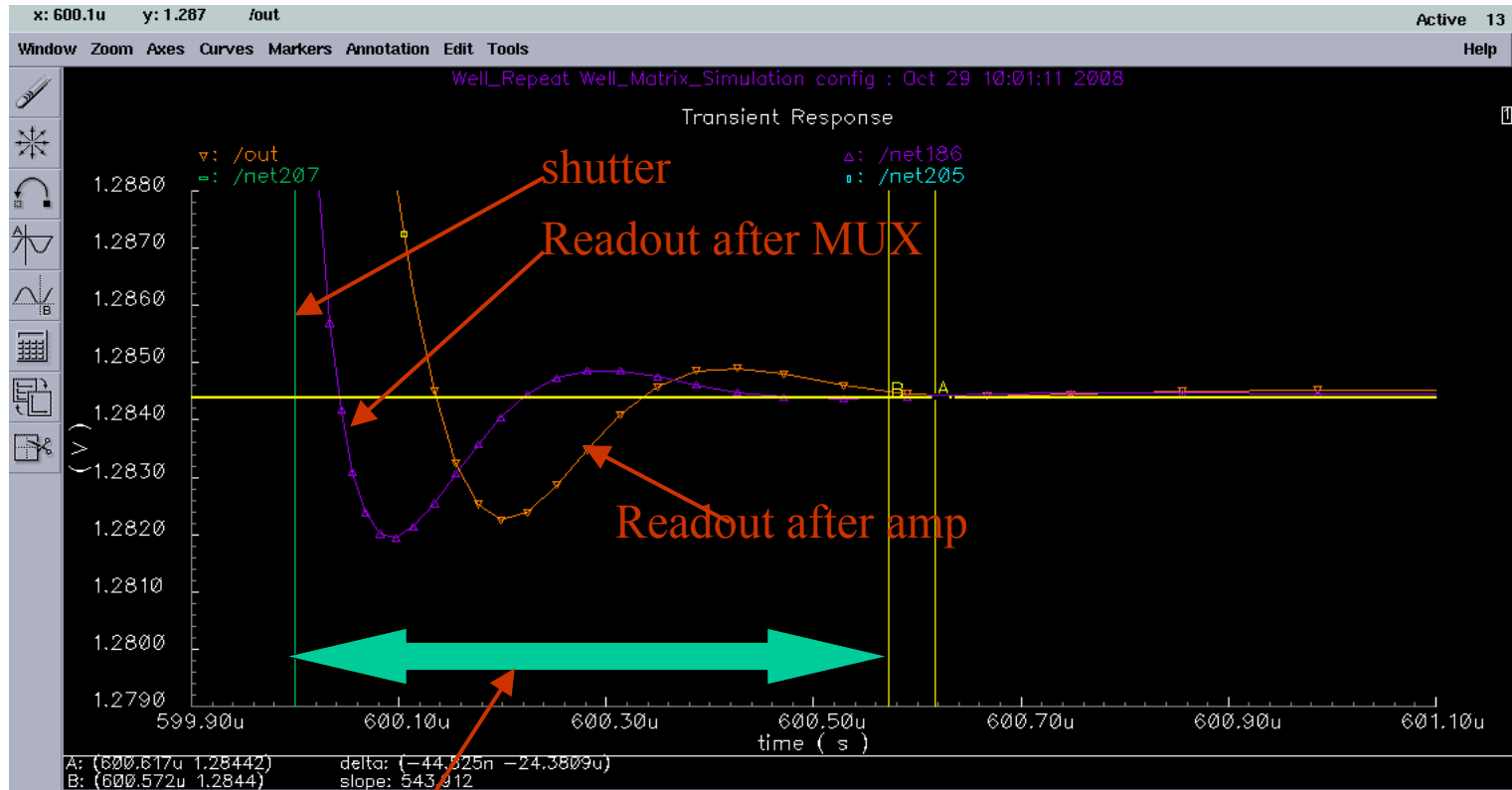


APS Matrix Config View (Extracted)



APS Matrix Config Read out (Extracted)

Pixel in 1st Row 1st Column



Read out After MUX- 480nS, Amplifier – 600nS

Results

- Pixel Size – $36.5\mu \times 28.4\mu$
- Fill Factor – 22%
- Readout time – 25nS (Schematic), 29nS (Extracted)
- Matrix Size – $1092\mu \times 596.6\mu$
- Matrix Readout for a Pixel - $0.48\mu\text{S}$ (MUX), 0.6nS (Amp)
- Dynamic Range – 40dB
- Frame rate approximately – 270.12FPS
- Output voltage = 1.23V (for $I_{\text{photo}} = 500\text{pA}$)

Conclusion

- Goal of designing a N-well photodiode APS matrix is successfully achieved
- Compactness of design may be improved by careful designing (routing of lines and component placing)
- Fill factor obtained is 22% , this is less compared to the commercially available APS sensors. Hence this may be improved
- Dimensioning of the components may provide much more efficient results

Reference

- HEIS Lecture Slides by Prof. Andreas Koenig (TU Kaiserslautern)
- CMOS Analog Circuit Design – P E. Allen & D R. Holberg
- Analysis and Design of Analog Integrated Circuit Design by, P R.Grey, S H. Lewis, P J. Hurst & R G.Meyer
- www.wikipedia.org

APS Matrix Design

“Thank You For Your Attention“