#### TPAC1.2 FDR

JC/Feb 27<sup>th</sup>

# **TPAC1.2 FDR Overview**

- The TPAC design will be re-submitted with two mask changes to fix to key bugs in the design:
  - 1. Non-unique address codes in each half of the array
  - 2. Oscillation of the in-pixel comparator at very low thresholds
- These errors are fixed by changes to
  - 1. Mask CS
  - 2. Mask M2
- Problem reports for TPAC1.1 that will <u>not</u> be addressed in this re-run
  - 1. -----
  - 2. Injection from MSO power supply to preAmplifier
    - Not easily addressed with mask changes
    - Per-pixel masking offers work-around
  - 3. -----
  - 4. Injection from DEBUG\_HIT\_OUT onto DEBUG\_RSTVAL1
    - Only affects test pixels
    - Cosmetic (does not affect in-pixel performance of test pixels)
  - 5. Power droop in clock buffer power net for configuration load
    - Not easily addressed with mask changes
    - Adequate work-around with on-board power module

### **Row Addresses**

- Original TPAC1.0
  - Different pixel variants
  - Full 168-code row addresses, implemented as two halves
- TPAC1.1
  - Same pixel variants
  - Duplicated half of row addresses
    - Ambiguous hit locations!
    - Clumsy workaround
- TPAC1.2
  - Re-instates the unique rowaddress half removing the duplicated address codes
  - implemented by instantiating a pre-existing cell in one half of the array



# Addresses Implementation

- Address of each row is set by placing contacts to either VDD or ground
- Layout is the same for each row, the contacts are placed by a different cell which makes each row unique
- Simple to modify the addressing, by changing CS only



### **Comparator Circuit Analysis**



- Polarity of injection eliminates coupling between certain nodes
- Eventually found that a single parasitic capacitance between comparator output and diode node can cause oscillations at low thresholds
  - RCX extracts 30aF between these two nets in the 1.1 pixel design (v small!)
  - RCX extracts no parasitics between these two nets in the 1.0 design
  - Schematic simulation (no parasitics) with an additional 30aF between the two critical nodes shows oscillations at low thresholds.

# Sanity check

- Can 30aF *really* matter?
  - Would not normally consider such tiny parasitics!
  - But... diode node is sensitive to induced charge, with a large gain...

Consider a switching 1.8v signal coupling through a 30aF capacitor...

 $Q = 30 \times 10^{-18} * 1.8$  = 5.4 x10<sup>-17</sup> C = 337 electrons Circuit charge gain is ~140uV/e- so... = 47mV signal



# TPAC1.0 preShape pixel layout

Comparator output								
M1	M2	M3	M4					

Comparator output bridges diode node only once, on metal 4 with metal 3 shield.



# TPAC1.1 preShape pixel layout

Comparator output - - - - - - - - M1 M2 M3

Comparator output was rerouted in v1.1 over SRAMS but crossing diode node twice

No M2 shield at one crossing creates dominant capacitance between the two nets



# TPAC1.2 preShape pixel layout

Single mask change (M2) Extended shielding (ground)

RCX tool finds no parasitics between comparator output and diode node ✓

## **Simulation Summary**

Design	View	Cpara (HIT→ DIODE)	Cpara (DIODE→ GND)	Gain μV/e-	Simulation
Original 1.0	Schematic	0	14 (est)	118	
	Extracted (C only)	0	13	164	
	Extracted (sel RC)	0	13.3	164	
Revision	Schematic	0	14 (est)	136	
1.1	Extracted (C only)	30.25a	12.1	182	Oscillates at low Vth
	Extracted (sel RC)	27.9a	12.4	181	Oscillates at low Vth
Amended 1.2	Schematic	0	14 (est)	160	
	Extracted (C only)	0	12.5	180	
	Extracted (sel RC)	0	12.8	178	

### One more thing...



- RCX extraction and simulations report an additional coupling effect in the <u>TPAC1.0</u> pixel as shown
  - This injection has the opposite polarity compared with that discussed so far
  - Due to altered signal routing, this is <u>not</u> present in TPAC1.1 or TPAC1.2
  - I believe this is an improvement over TPAC1.0 pixels (ie closer to ideal simulations)
    - Has not been proven (previously masked by oscillations)
    - Injection is not obvious in testing the v1.0 test pixel

## Comments

- Suggested fix adds small additional parasitics to diode node, but acceptable within context of original design
- Unsure of reliability of parasitic extraction tools at this precision (10<sup>-18</sup>)
  - what error bars to apply?
- Small injection effects are seen in the v1.0 test pixel
  - which the RCX tool does not predict
  - but the pixel does operate properly

# **Measured Injection**

- Cross check size of injected signal with predicted coupling capacitance
  - Charge gain known from marcel's <sup>55</sup>Fe test pixel results
  - Can observe signals at two points in analog chain
- Induced signal on shaper output
  - Varies, in range  $17 \rightarrow 24 \text{mV}$ 
    - Note: Corresponding injection on shaper input will be too small to see on scope (<1mV)</li>
  - Applying a gain of 150uV/e-
  - Injection varies in range  $113 \rightarrow 160e$ -
    - Right order of magnitude! ✓

#### Other Changes for TPAC1.2



### **GDS DIFF**

• The TPAC1.1 GDS file submitted on 22/07/08 is compared (XOR) with the new GDS file using calibre

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42	M2	141179	= 11 + 3 + 5 * ((168 * 168) + 9) (revB) (logo) (changes) (total bulk pixels) (test pix)

## Progress

✓ Top level LVS  $\checkmark$  Calibre DRC ✓ Compare ✓ Stream Out ✓ Stream In ✓ LVS ✓ Calibre DRC ✓ DPW DRC

# Spare slides

- Signals during oscillation
  - Triggered by noise
  - Oscillation
  - Similar scope trace



Preamp out

Shaper out

Threshold

14~~

Comparator



Preamp out

Shaper out

Threshold











