TPAC1.2 FDR

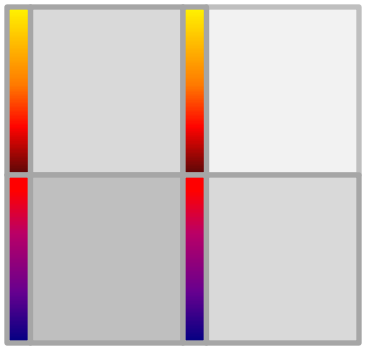
JC/Feb 27th

TPAC1.2 FDR Overview

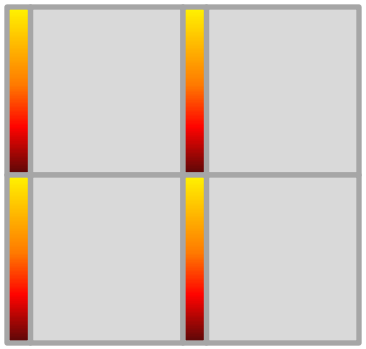
- The TPAC design will be re-submitted with two mask changes to fix to key bugs in the design:
  1. Non-unique address codes in each half of the array
  2. Oscillation of the in-pixel comparator at very low thresholds
- These errors are fixed by changes to
  1. Mask CS
  2. Mask M2
- Problem reports 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

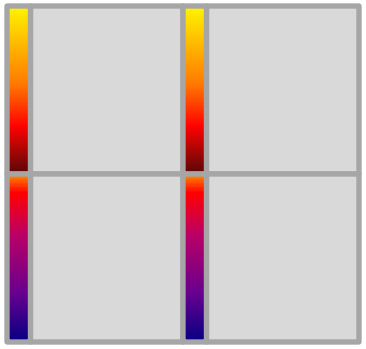
- Original TPAC1.0
  - Different pixel variants
  - Full 168-code row addresses, implemented as two halves
- TPAC1.1
  - Same pixel variants
  - Duplicated half of row addresses
    - Ambiguous hit locations!
    - Clumsy workaround
- TPAC1.2
  - Re-instates the unique row-address half removing the duplicated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



TPAC1.0



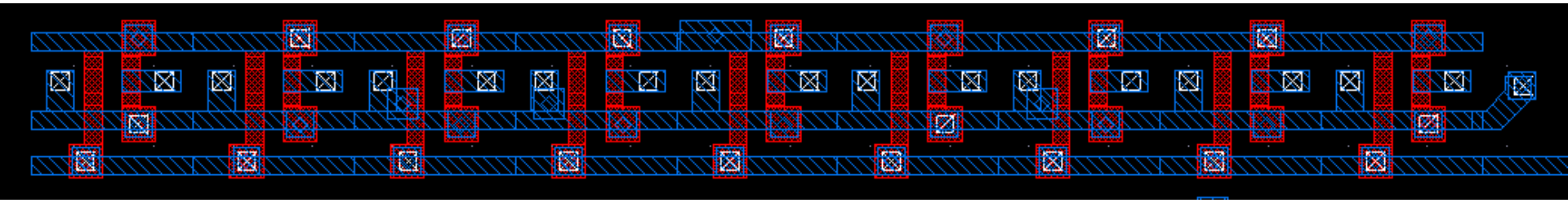
TPAC1.1



TPAC1.2

Addresses Implementation

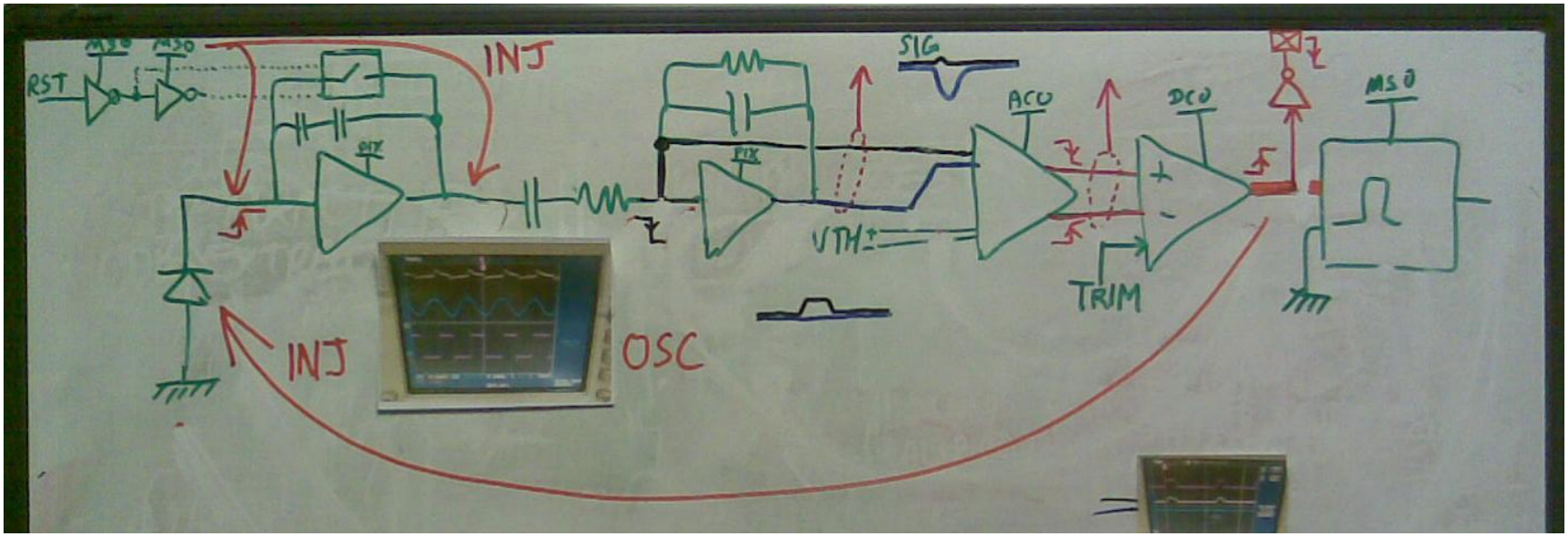
- Address of each row is set by placing contacts to either VDD or ground
- Layout is the same for each row, the contacts are placed by a different cell which makes each row unique
- Simple to modify the addressing, by changing CS only



Single bit selects VDD

Single bit selects GND

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…

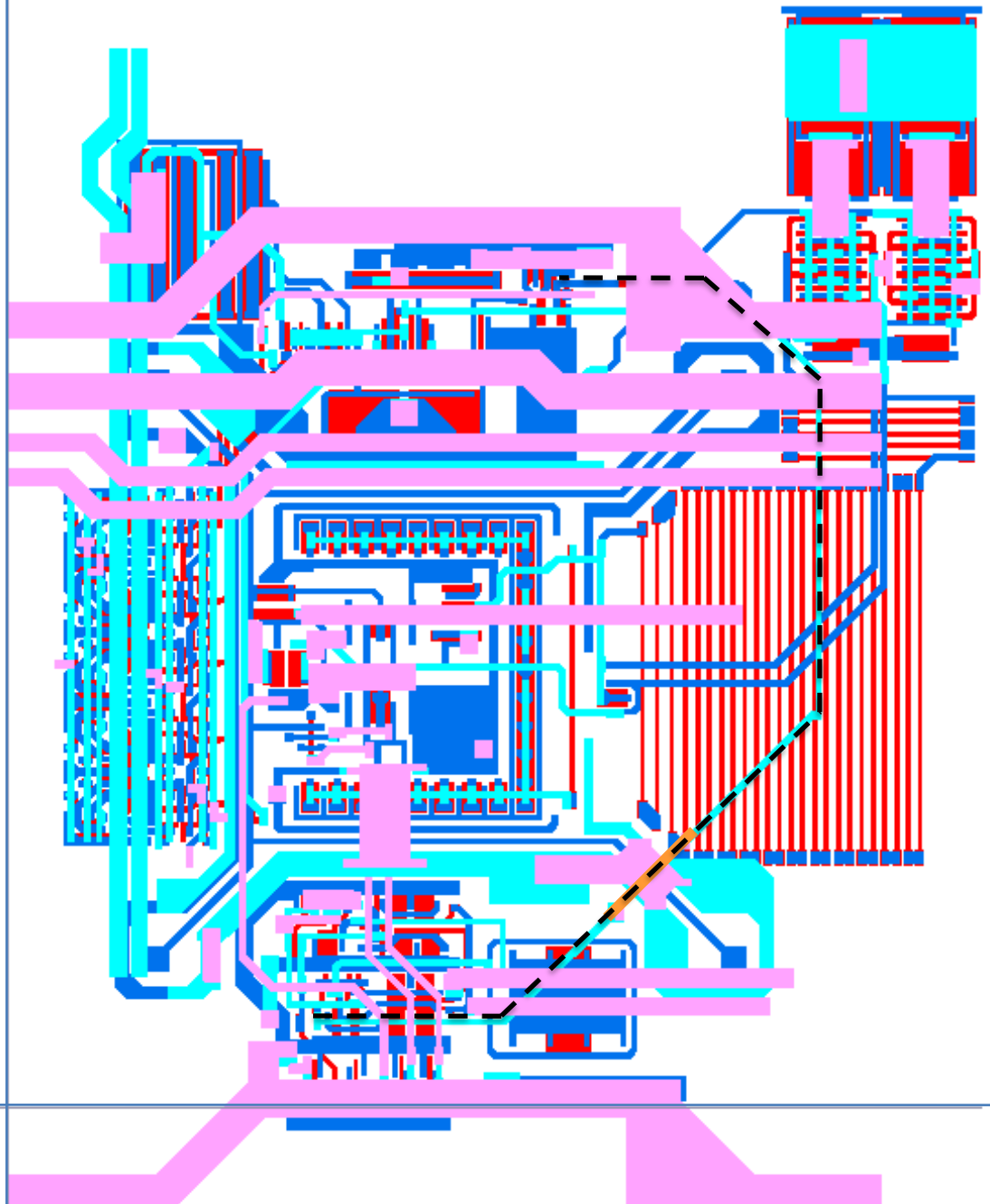
Consider a switching 1.8v signal coupling through a 30aF capacitor…

$Q = 30 \times 10^{-18} * 1.8$ $= 5.4 \times 10^{-17}$ C

= 337 electrons

Circuit charge gain is ~140uV/e- so… = 47mV signal

!

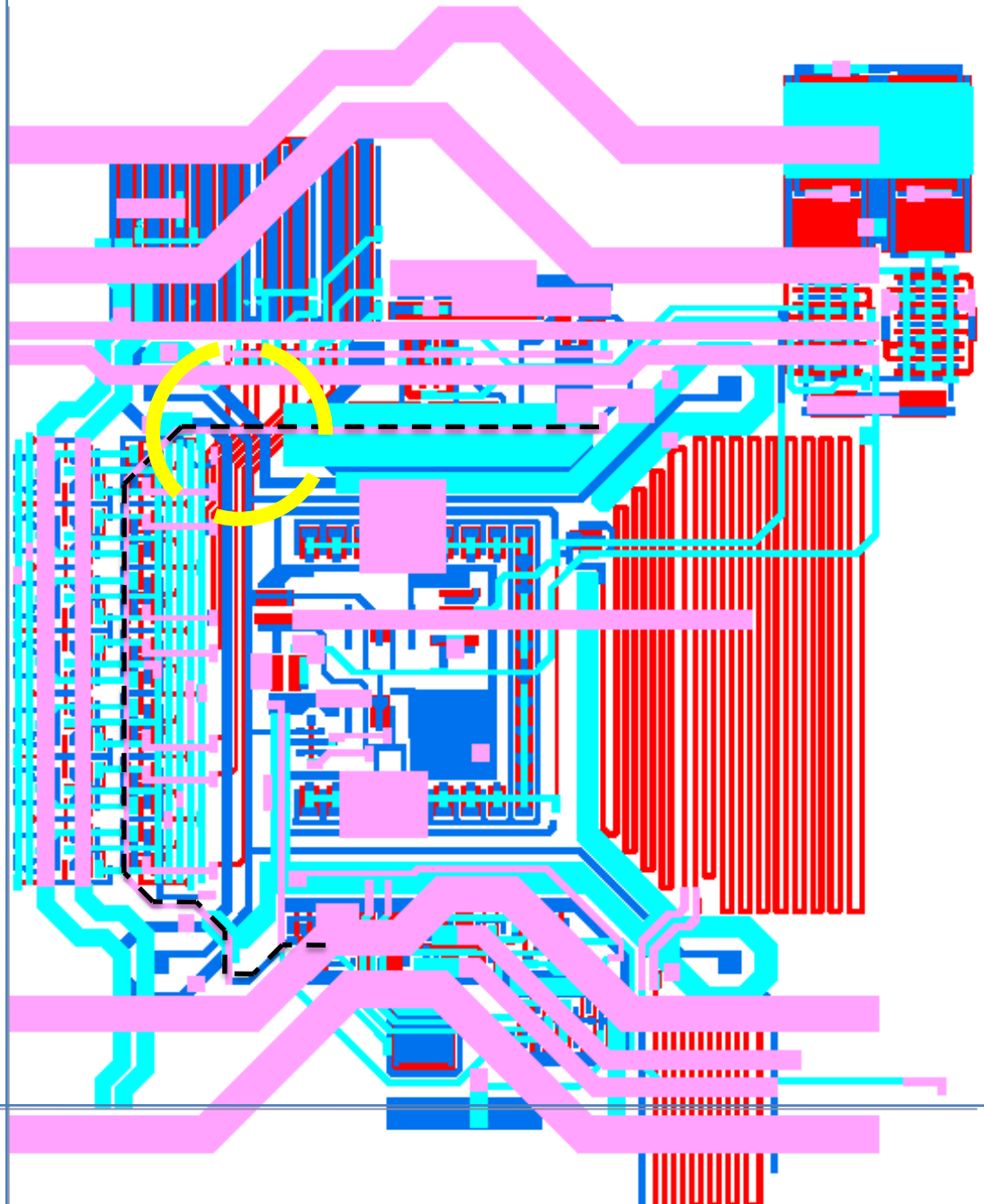


TPAC1.0 preShape pixel layout

Comparator output - - - - -

M1 M2 M3 M4

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



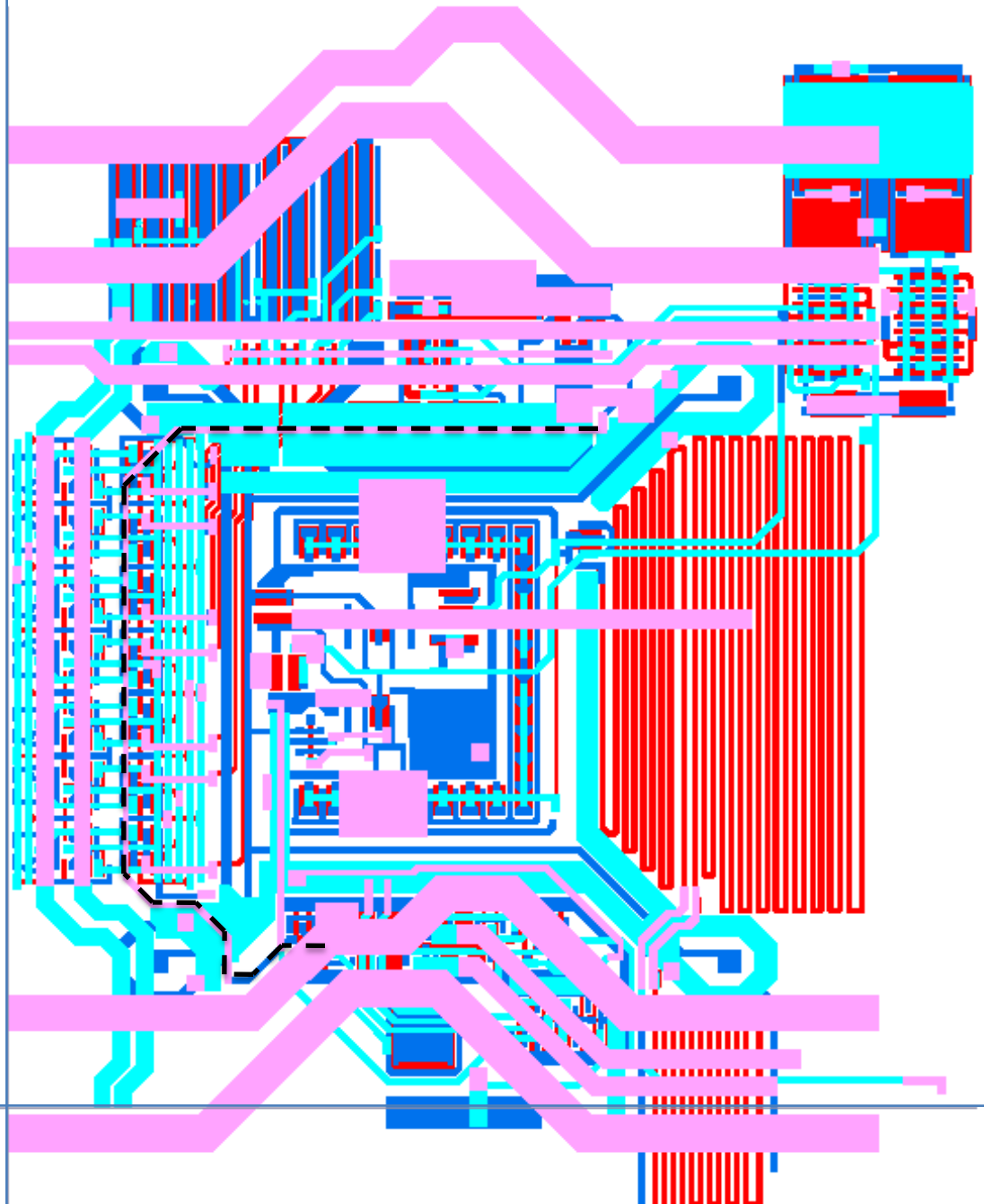
TPAC1.1 preShape pixel layout

Comparator output - - - - -

M1 M2 M3

Comparator output was re-routed 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

Comparator output - - - - -

M1 M2 M3

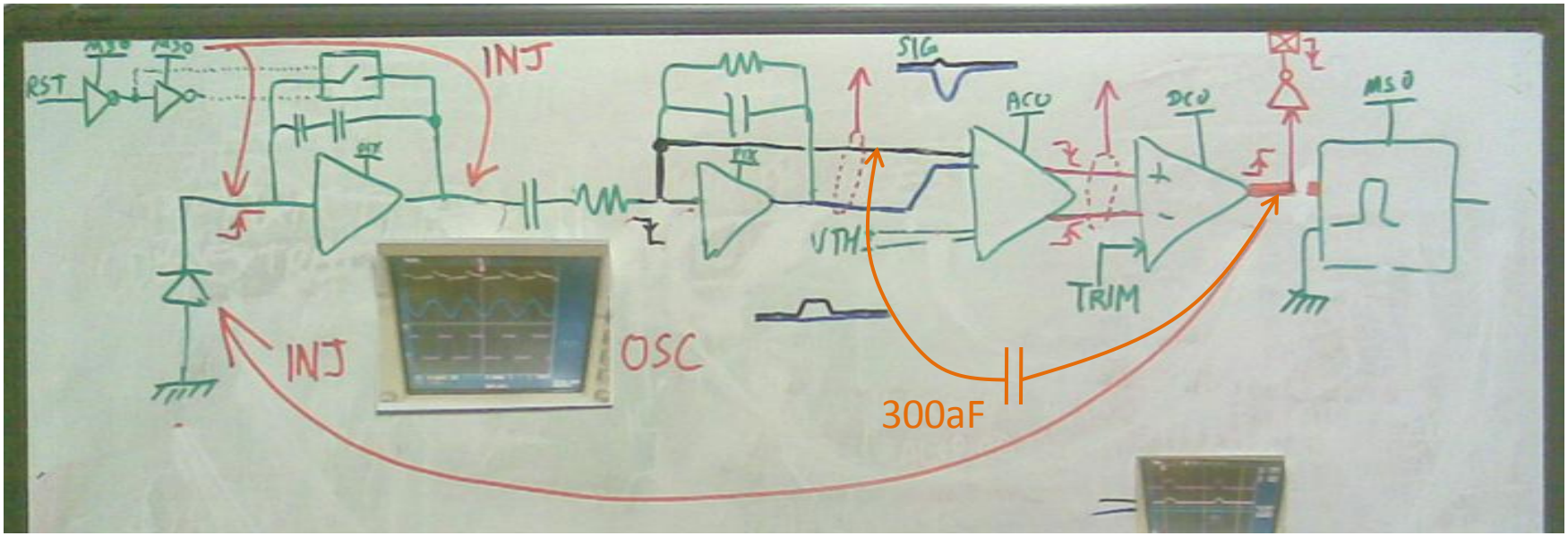
Single mask change (M2)
Extended shielding (ground)

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 1.1	Schematic	0	14 (est)	136	
	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 TPAC1.0 pixel as shown
  - This injection has the opposite polarity compared with that discussed so far
  - Due to altered signal routing, this is not 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^{-18})
  - 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

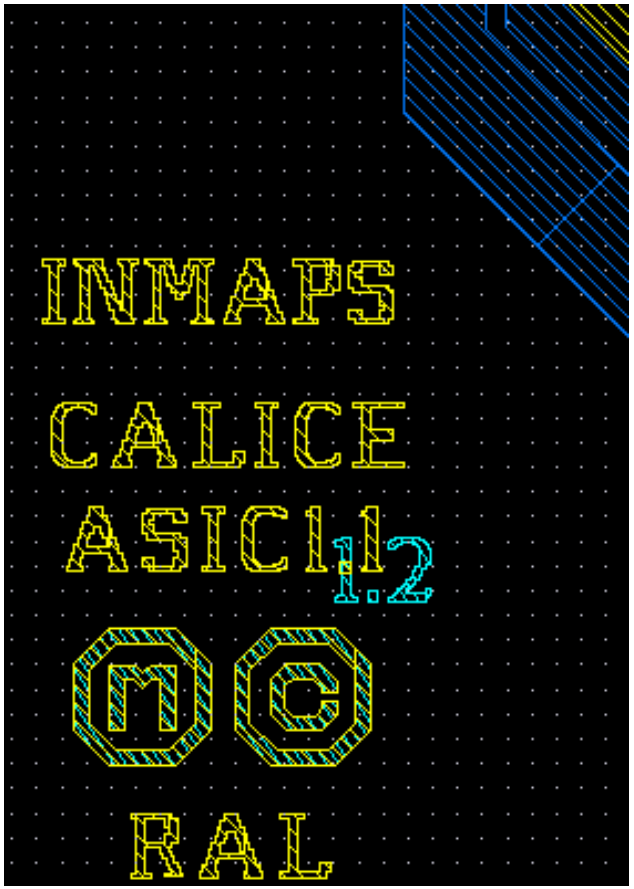
- Cross check size of injected signal with predicted coupling capacitance
  - Charge gain known from marcel's ^{55}Fe test pixel results
  - Can observe signals at two points in analog chain

- Induced signal on shaper output
  - Varies, in range 17→24mV
    - Note: Corresponding injection on shaper input will be too small to see on scope (<1mV)
  - Applying a gain of 150uV/e-
  - Injection varies in range 113→160e-
    - Right order of magnitude! ✓

Other Changes for TPAC1.2

M2

Logo

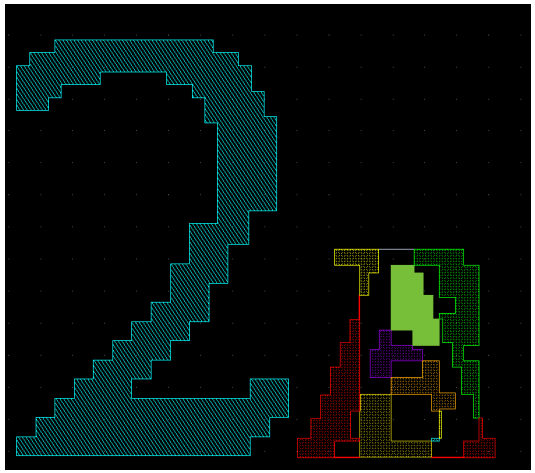


M2 & CS

Mask revision codes

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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READING  layer  1  from  ../TPAC1.2_submission/compare/ASIC1_2_tcp.gds  ...  Original Geometry Count = 876498
MERGING  layer  1  from  ../TPAC1.2_submission/compare/ASIC1_2_tcp.gds  ...  Merged Geometry Count = 4
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```

Layer	Name	# XOR geoms	check
34	CS	3271	= 7 (revB) + 4 (cols) * **816** (changes)
42	M2	141179	= 11 (revB) + 3 (logo) + **5** (changes) * ((168 * 168) (total bulk pixels) + 9 (test pix))

Progress

- ✓ Top level LVS
- ✓ Calibre DRC
- ✓ Compare
- ✓ Stream Out
- ✓ Stream In
- ✓ LVS
- ✓ Calibre DRC
- ✓ DPW DRC

Spare slides

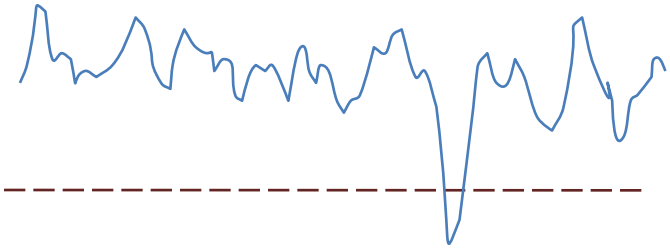
- Signals during oscillation
  - Triggered by noise
  - Oscillation
  - Similar scope trace

Signals

Diode

Preamp out

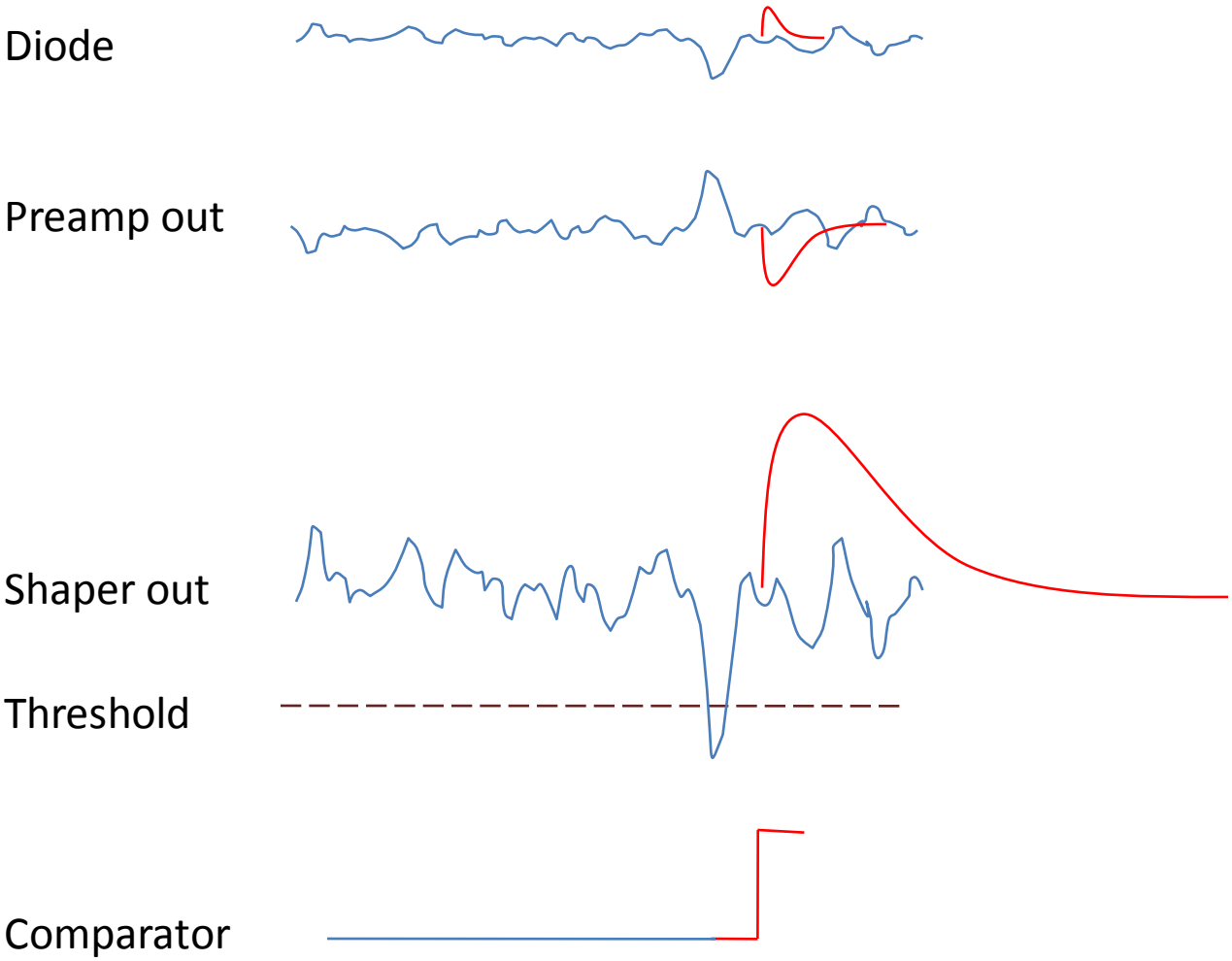
Shaper out



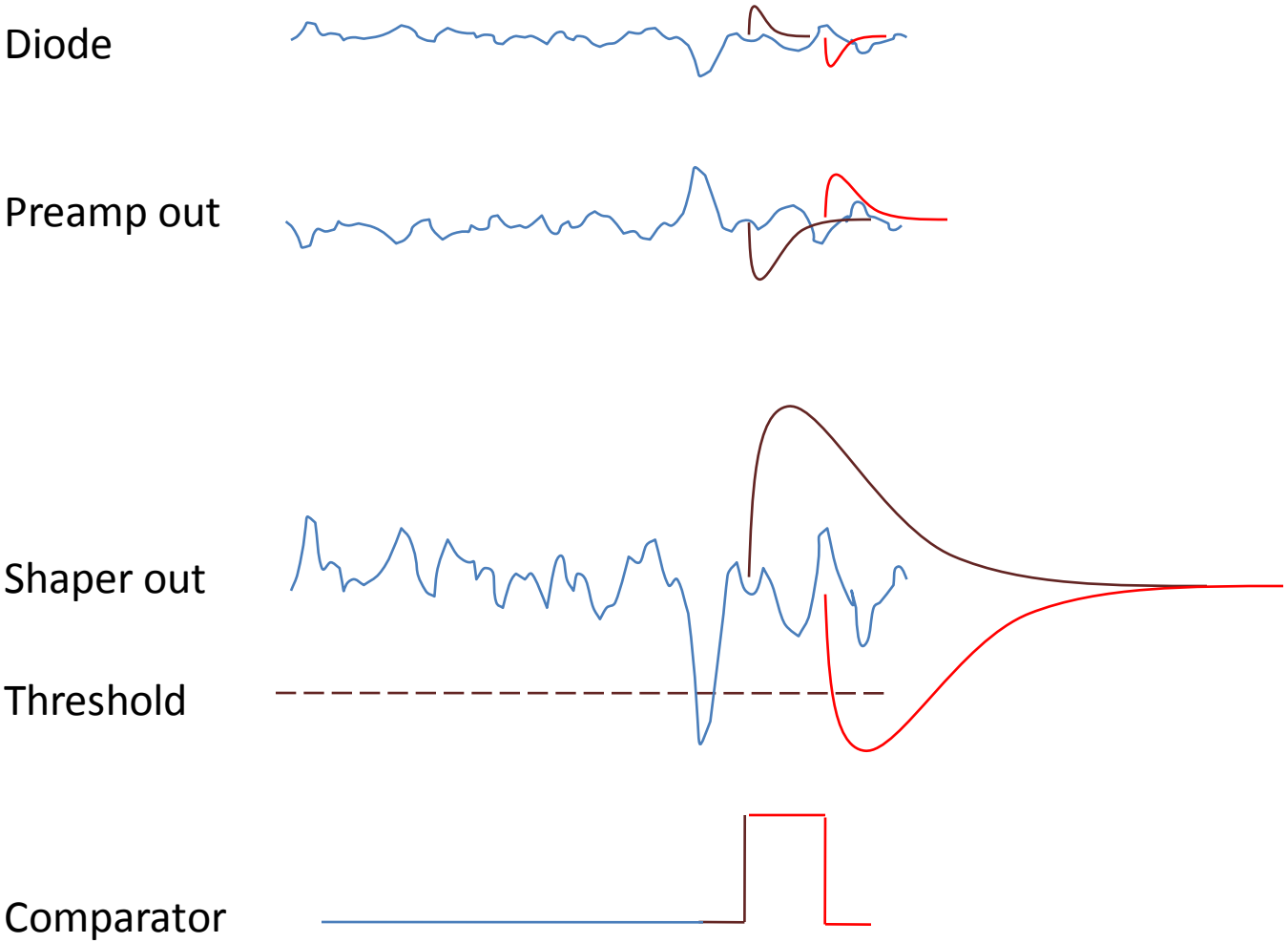
Threshold

Comparator

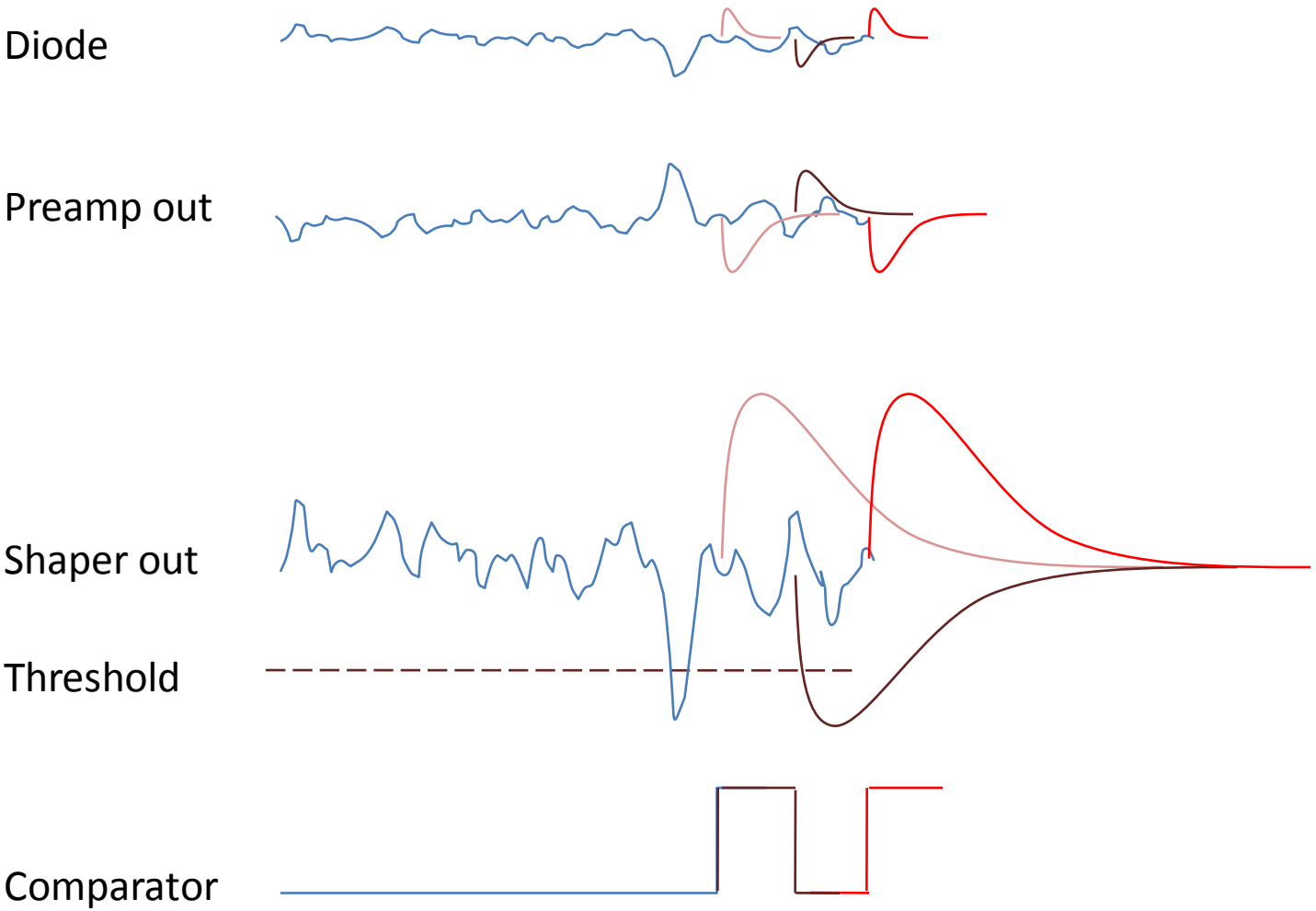
Signals



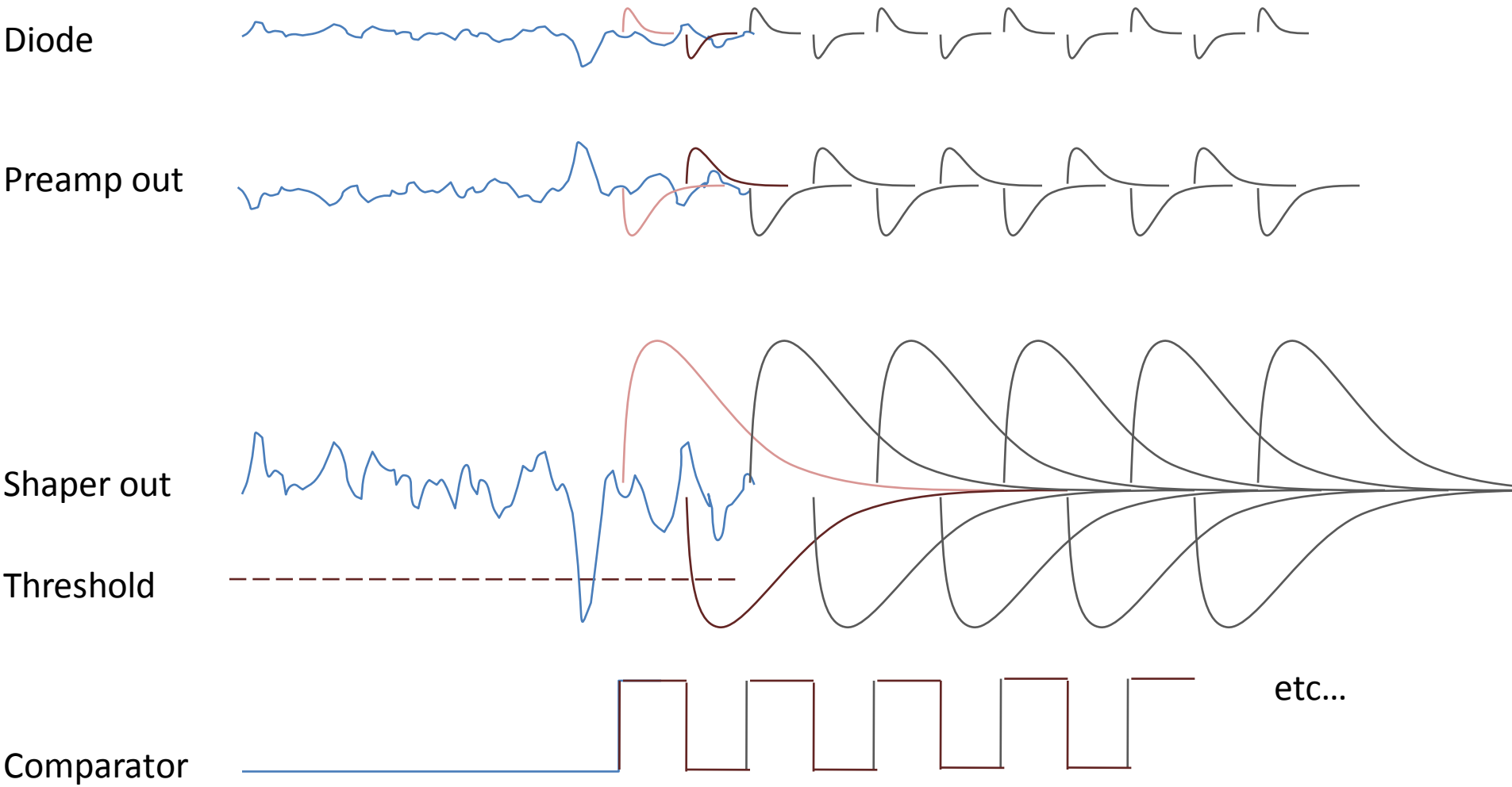
Signals



Signals

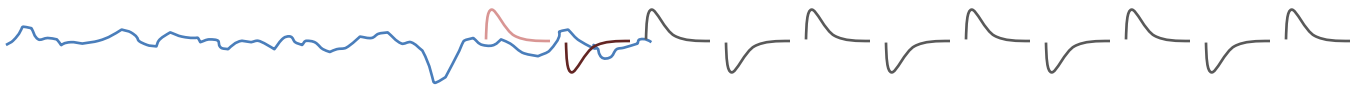


Signals

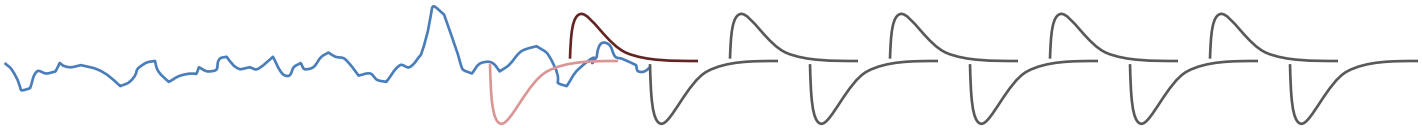


Signals

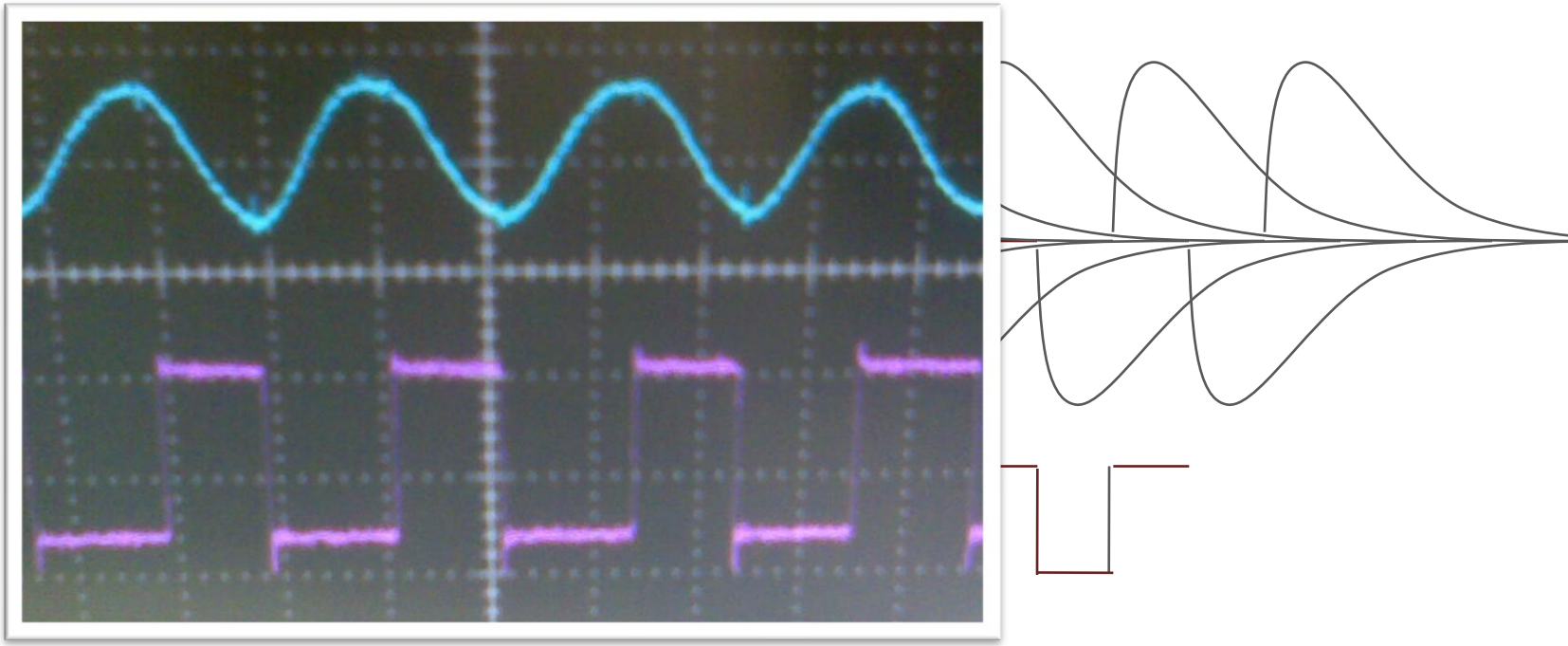
Diode



Preamp out



Shaper out



Comparator

Signals