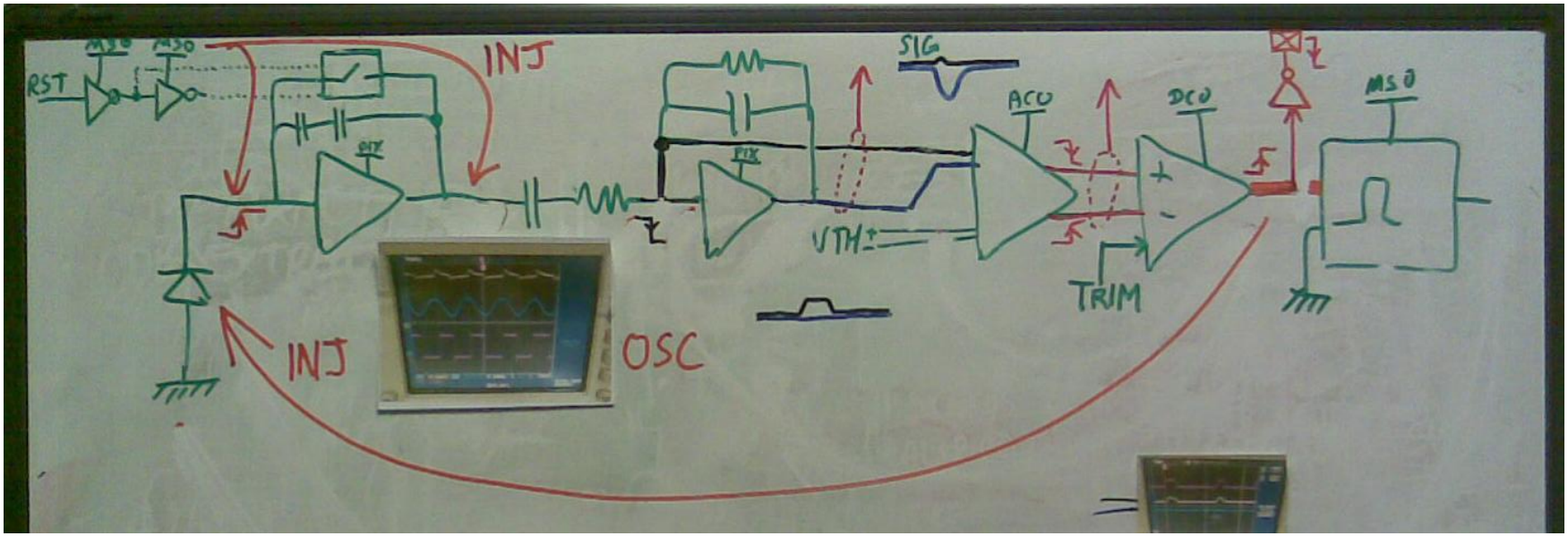
TPAC1.1 Testing

JC/Jan 16th

Comparator Investigations

- Two (related) symptoms were observed
  - Non-gaussian threshold scans, with steep sides and flat tops
  - Test pixel comparator oscillates for very low thresholds
- Coupling (positive feedback) in the pixel design
  - Not present (or significantly diminished) in old pixel design
  - Dominant in new pixel design causing oscillations
  - Schematic is fundamentally the same, so must be due to layout → parasitic capacitance
- Full RCX simulation
  - Fixed a bug (previously caused full pixel RCX to fail)
  - Setting a very low threshold shows oscillations!
    - Good → any fix should be possible to prove in simulation
    - Previously all RCX simulations had not checked the very low threshold case, which is necessary to cause oscillation
    - Pixel performs ok at higher thresholds, although some injection can be seen that might have identified a potential problem
  - Doesn't actually identify the problem, just confirms that one exists
- Analysis of circuit and observed behaviour is required to understand what is going on

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…

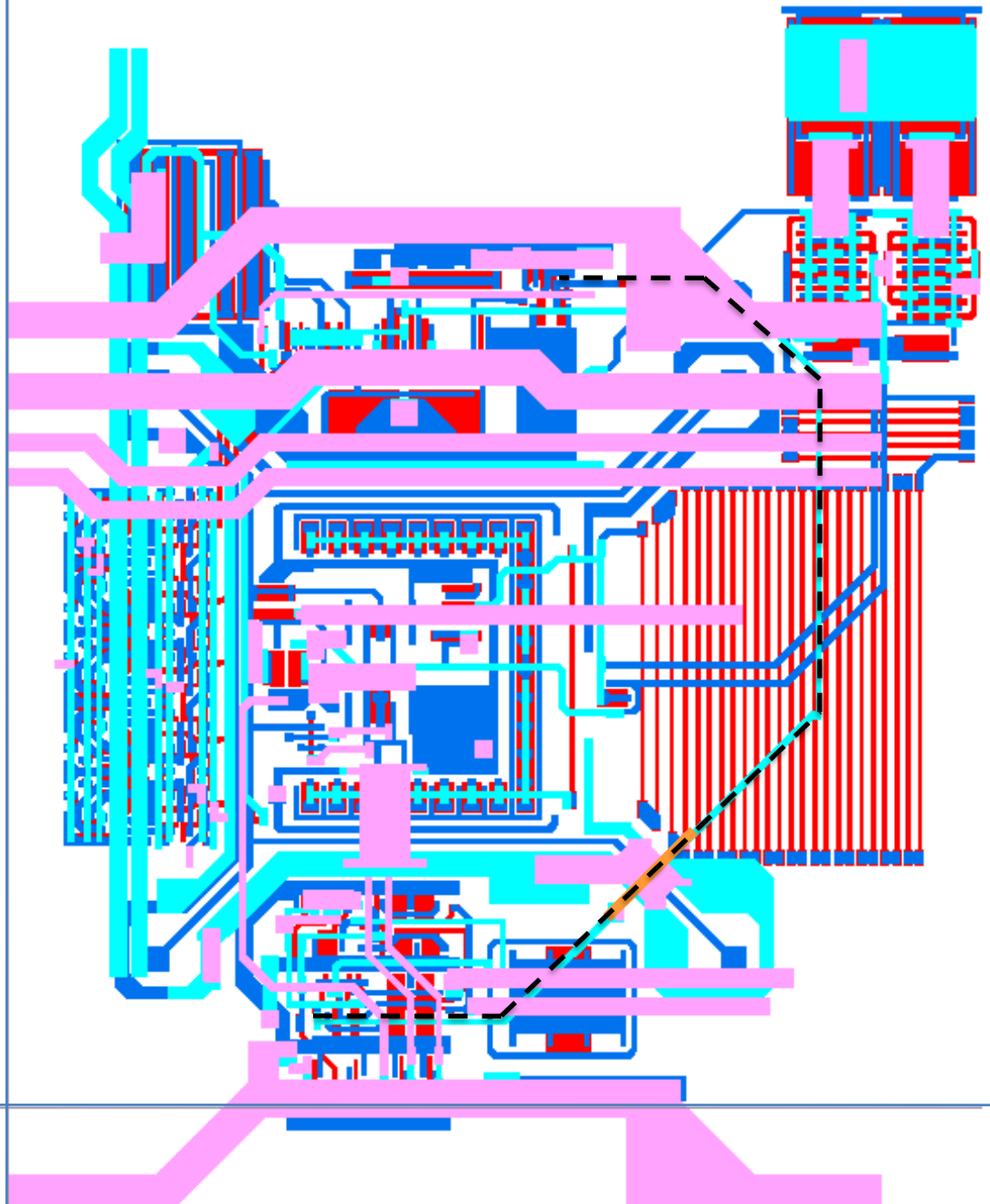
Consider a switching 1.8v signal coupling through a 30aF capacitor…

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

= 337 electrons

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

!

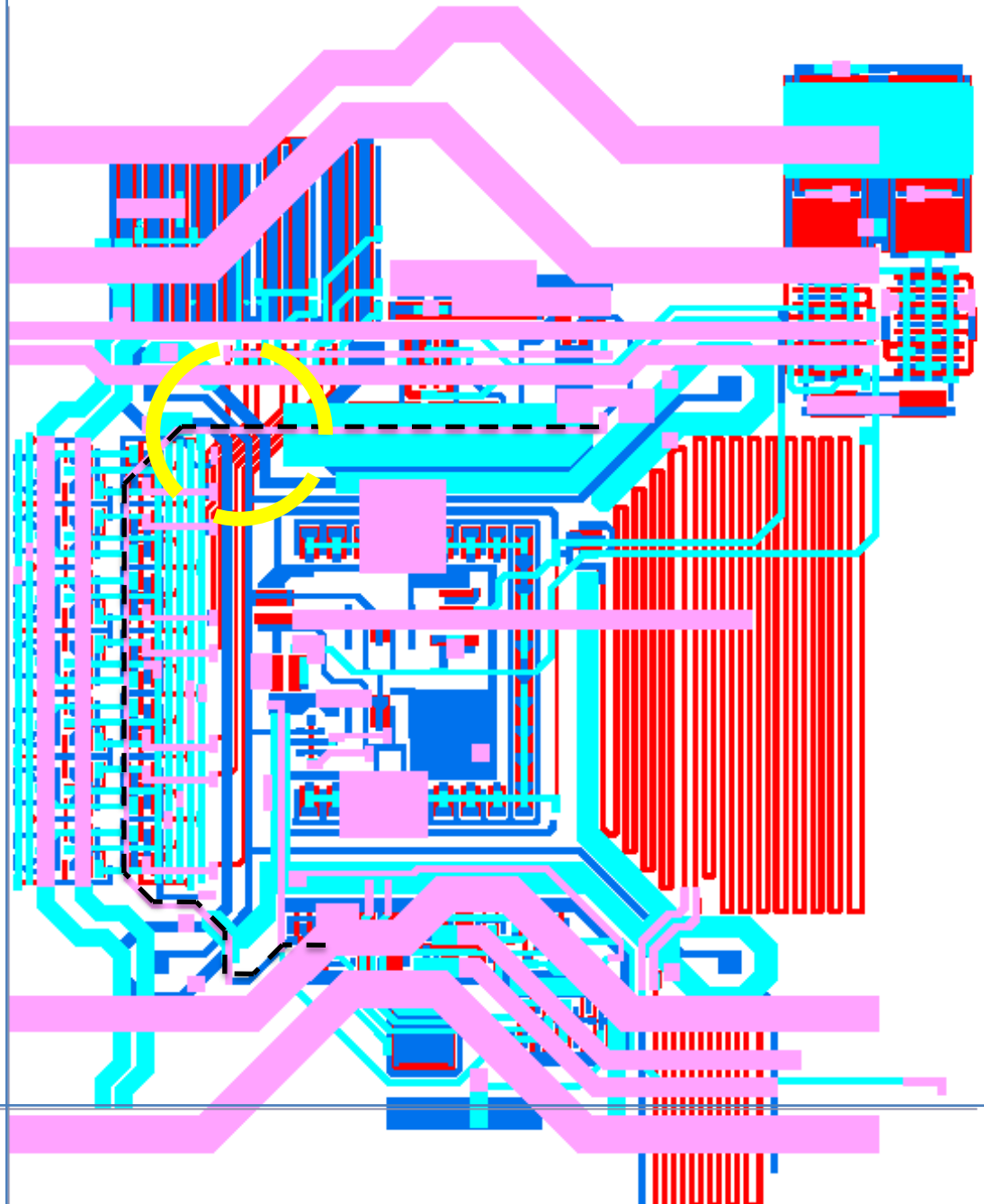


TPAC1.0 preShape pixel layout

Comparator output - - - - -

M1 M2 M3 M4

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



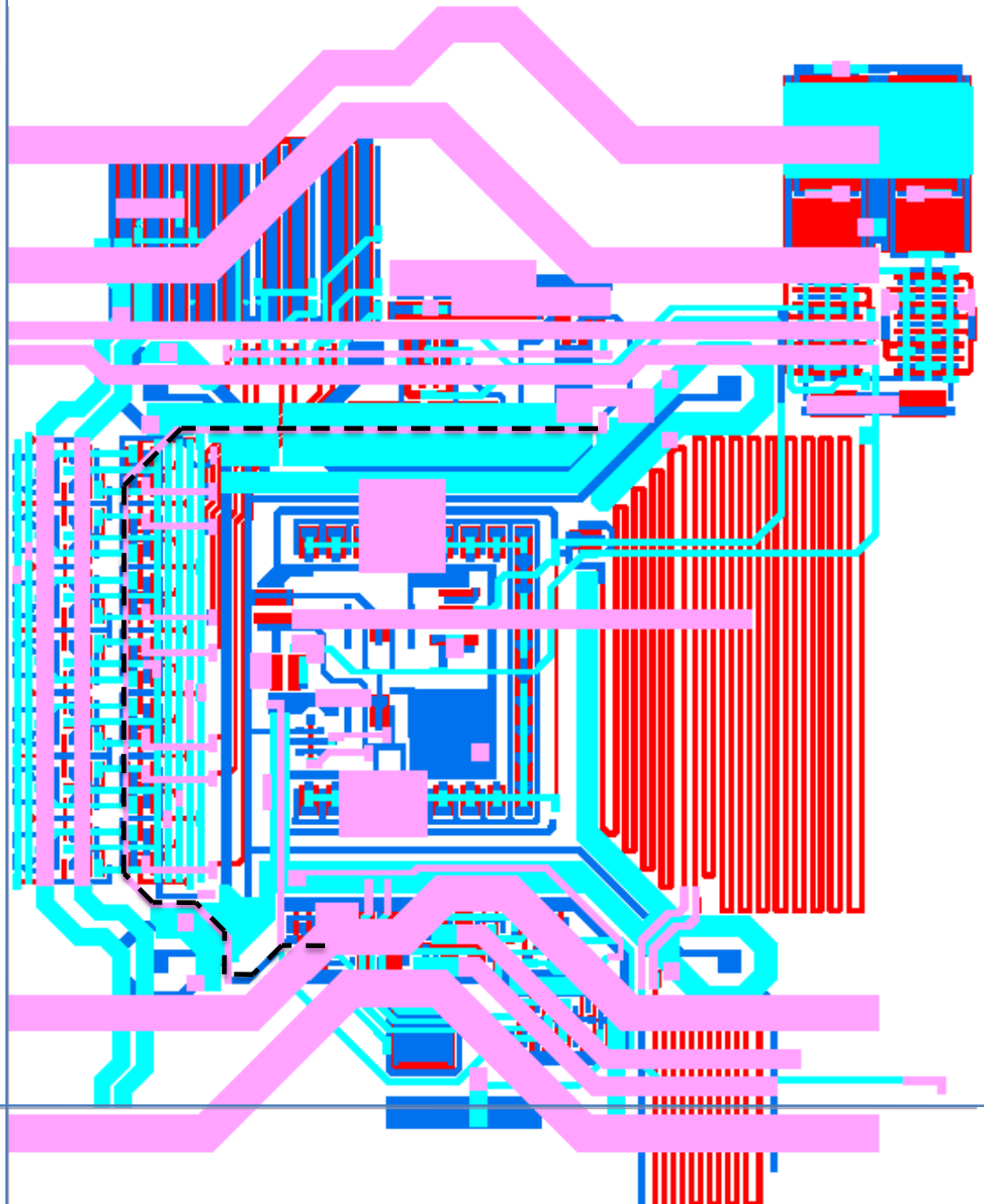
TPAC1.1 preShape pixel layout

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	

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! ✓

Mask change costs

- M2 required to fix parasitic capacitance
- CS required to fix address repettition

- $$…

Spare slides

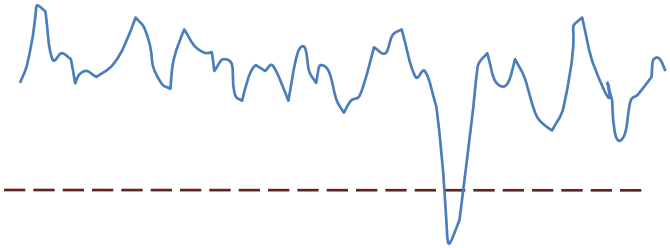
- Signals during oscillation
  - Triggered by noise
  - Oscillation
  - Similar scope trace

Signals

Diode

Preamp out

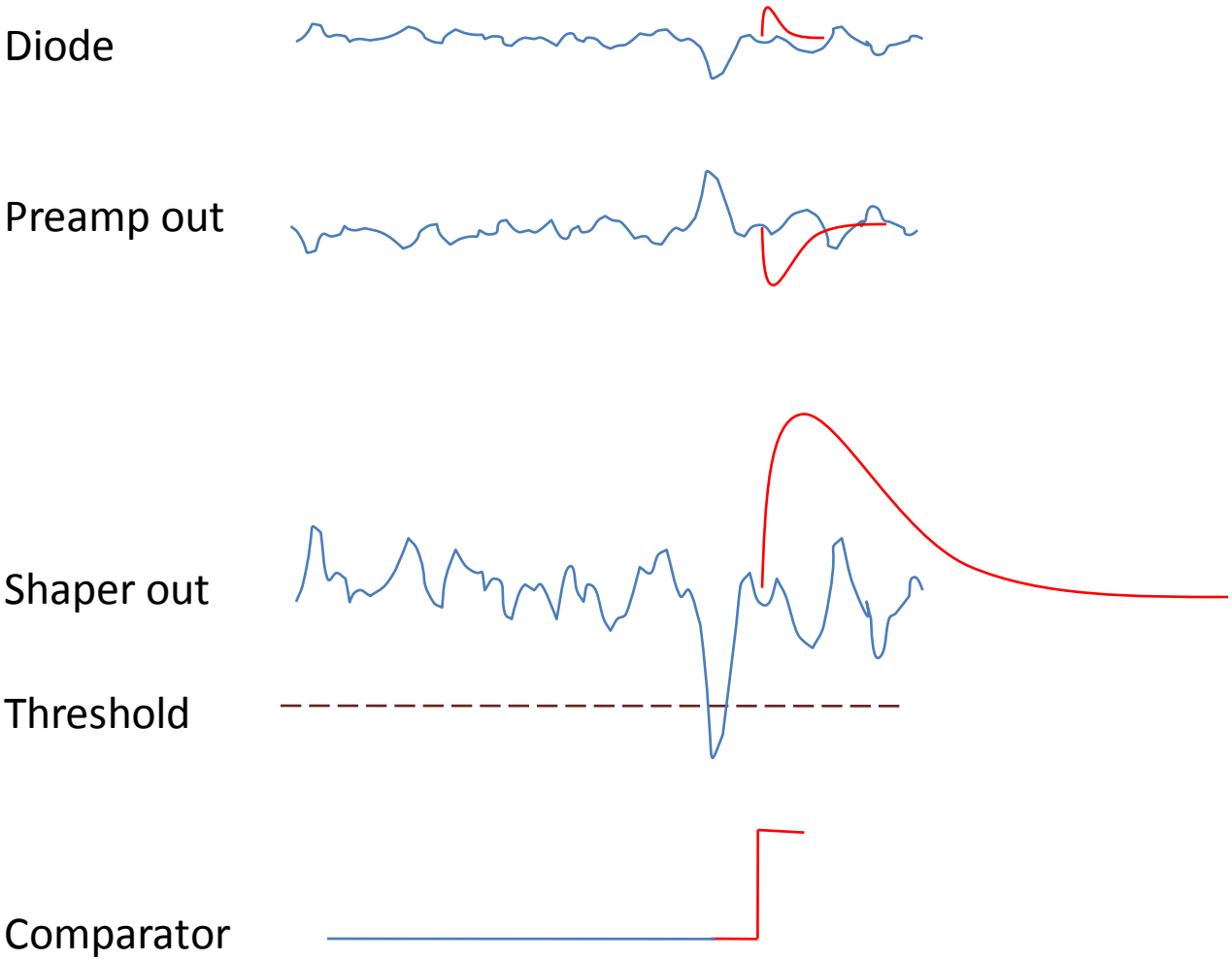
Shaper out



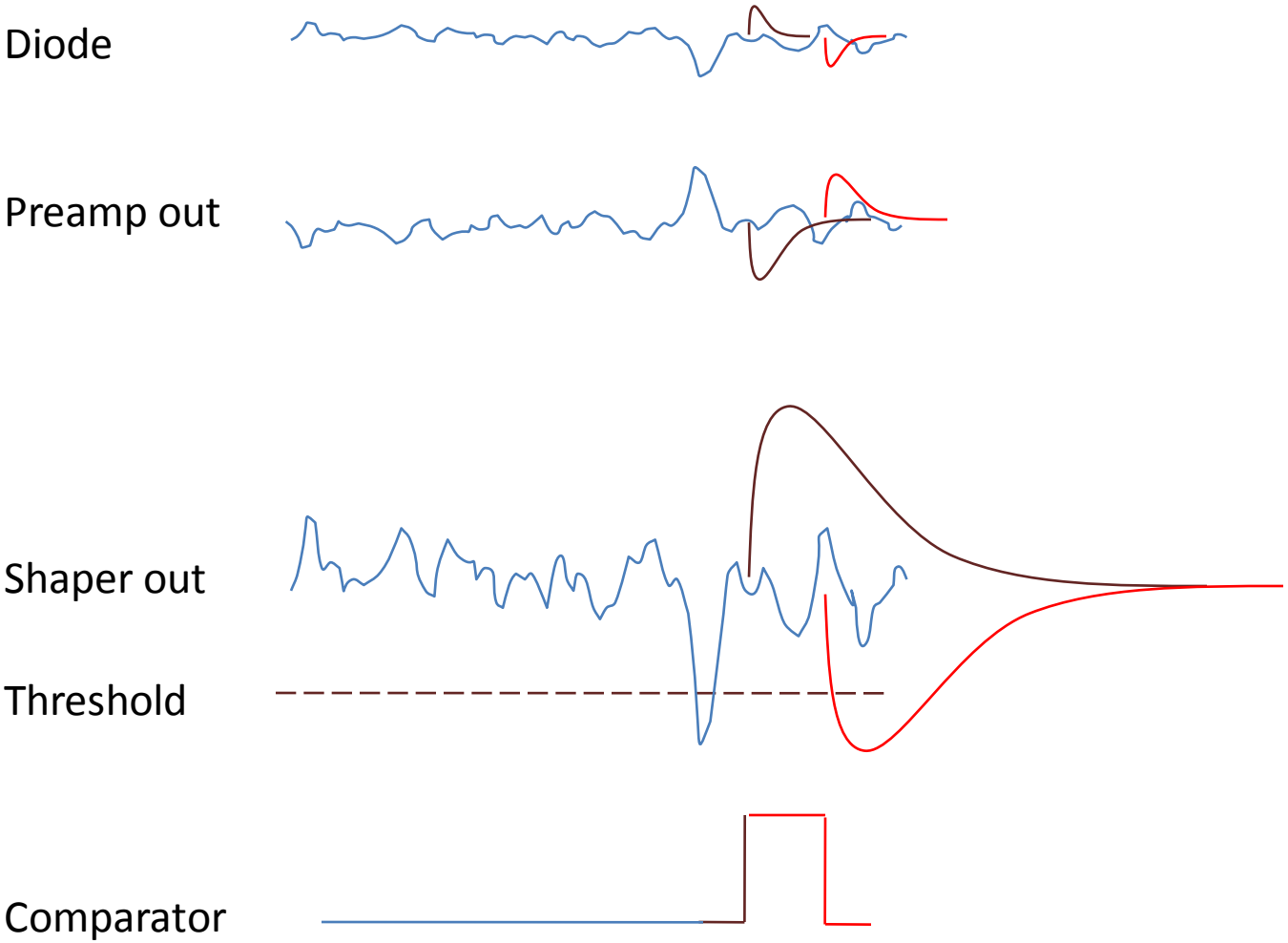
Threshold

Comparator

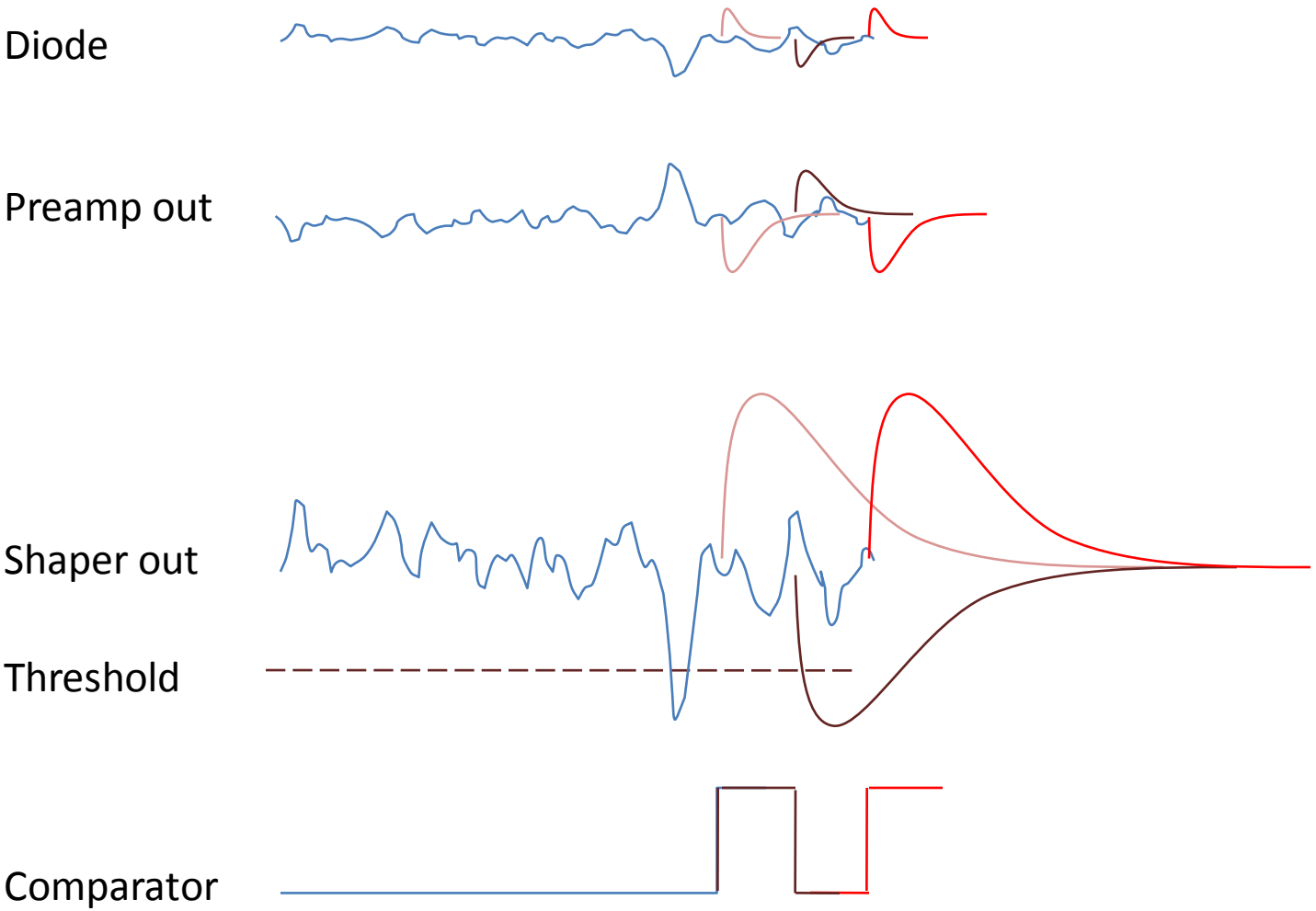
Signals



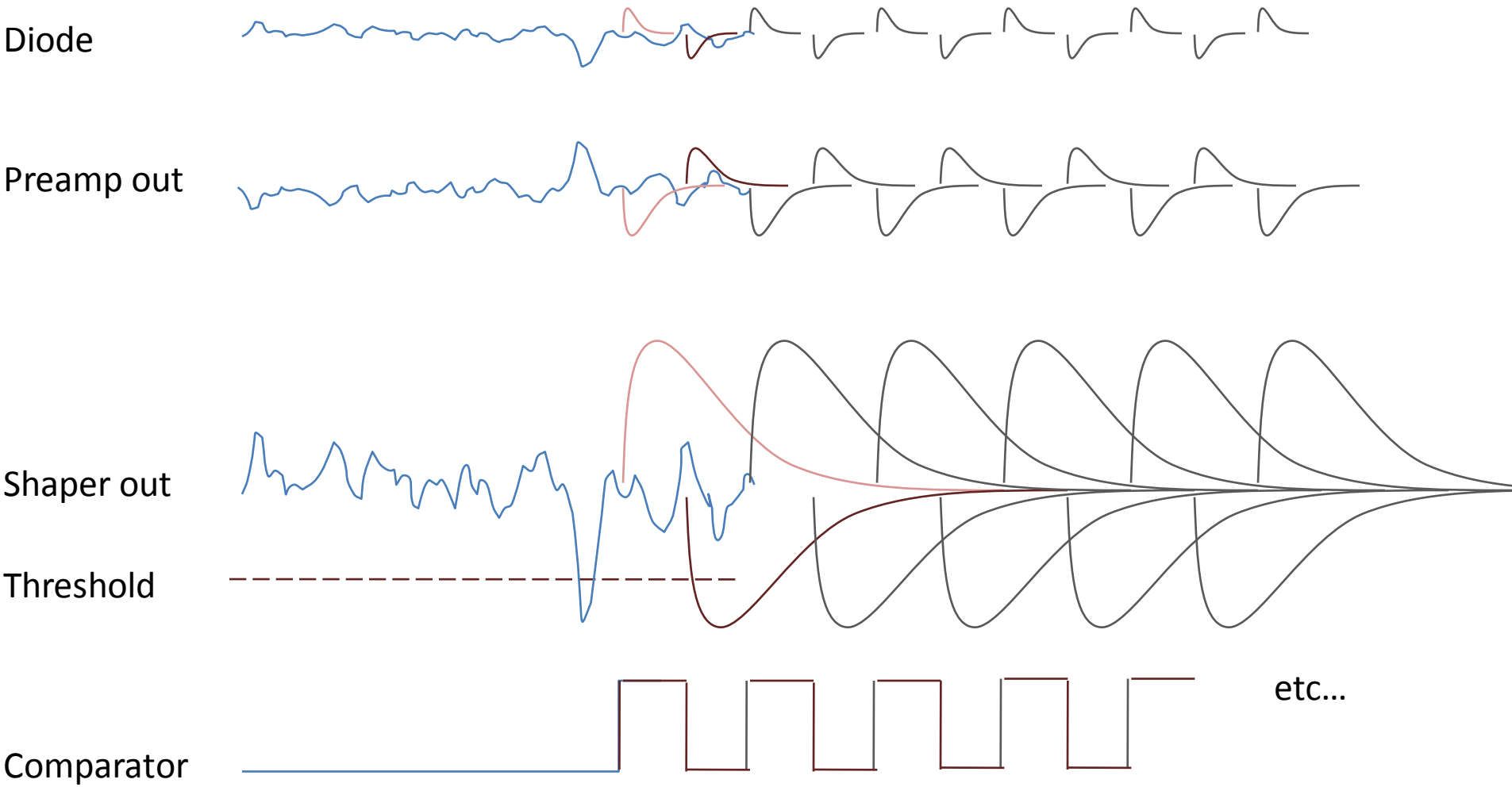
Signals



Signals

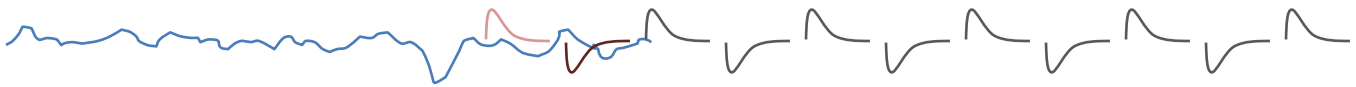


Signals

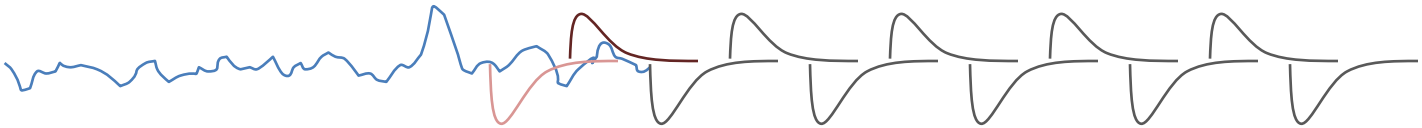


Signals

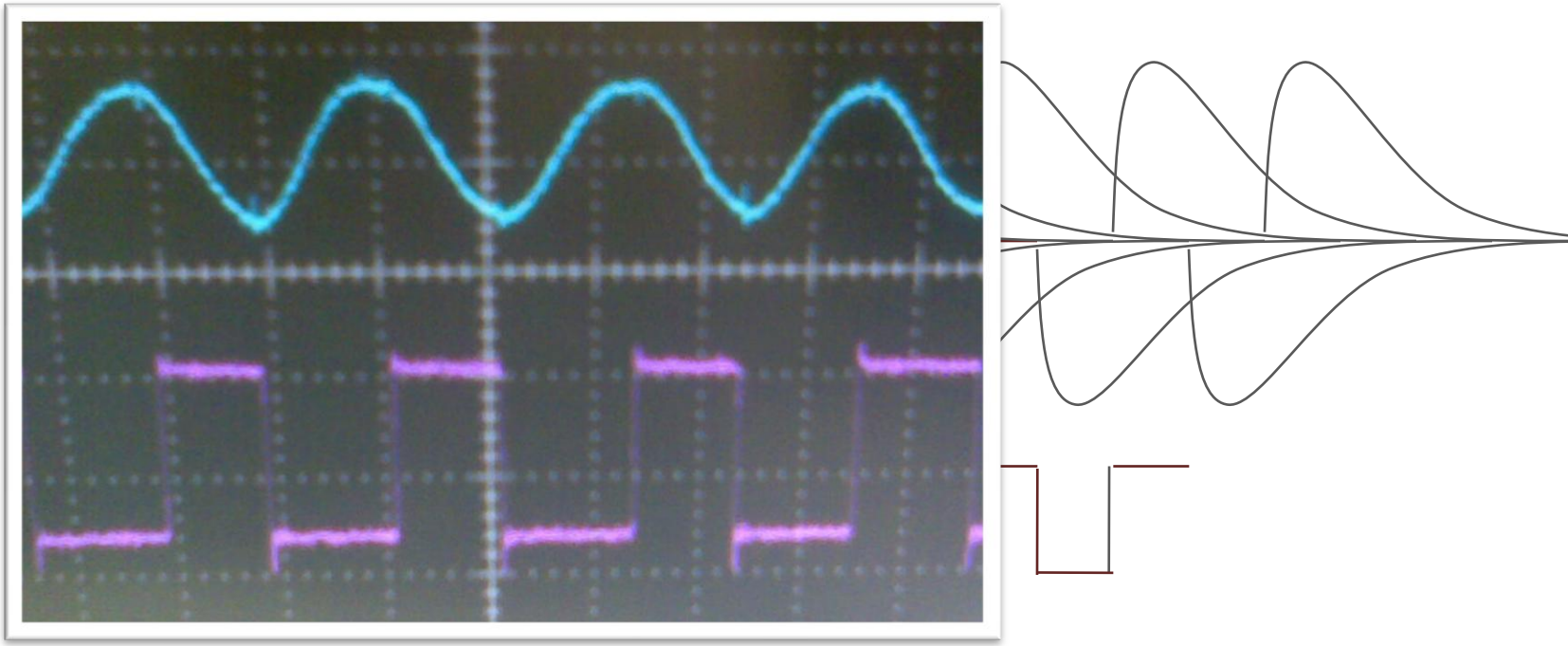
Diode



Preamp out



Shaper out



Comparator