AGH University of Science and Technology

SALT simulations

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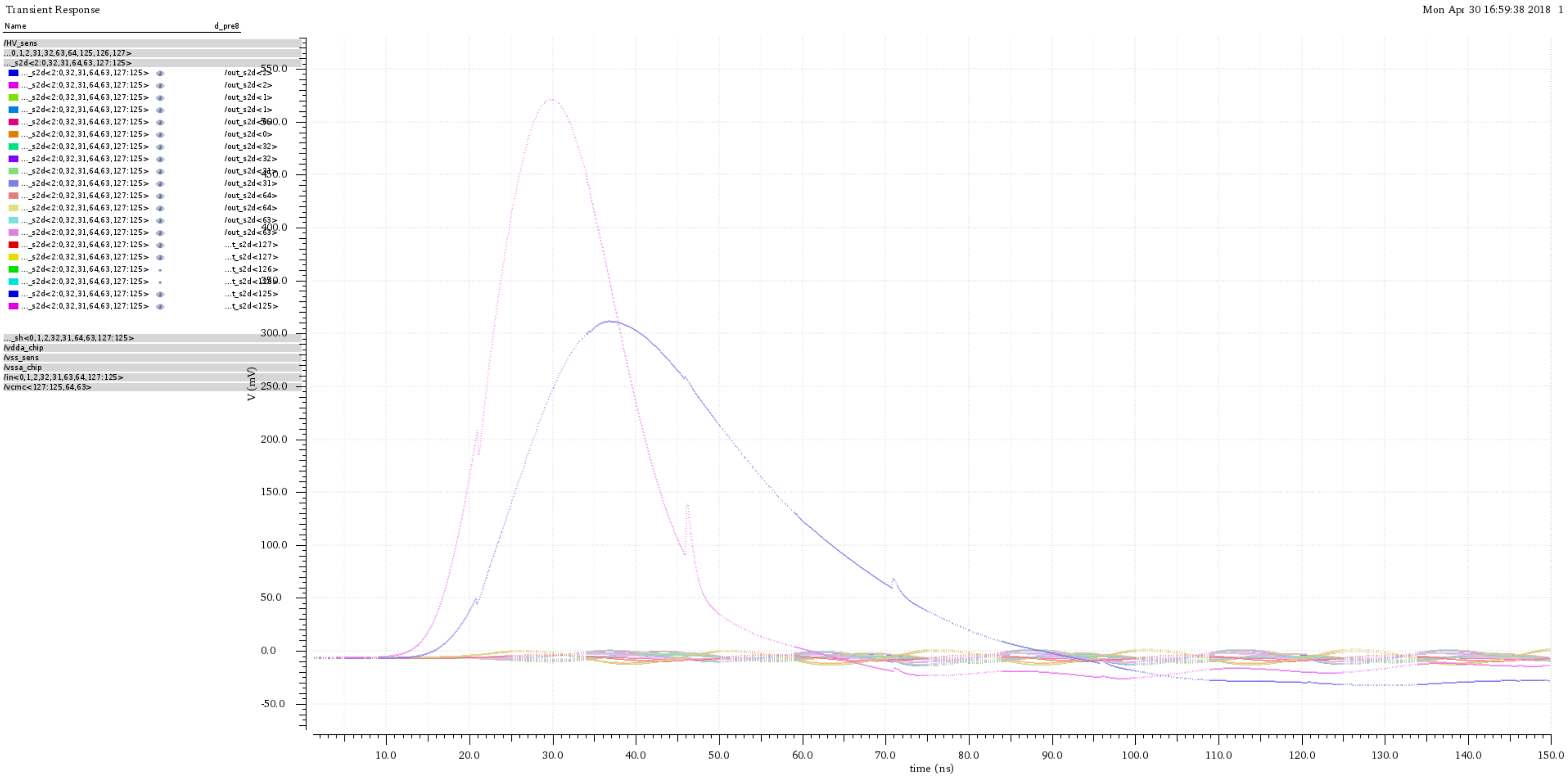
LHCb UT May 2018

Schematic simulations
Transient

Simulations of SALT 2.5
Schematic plus main resistances

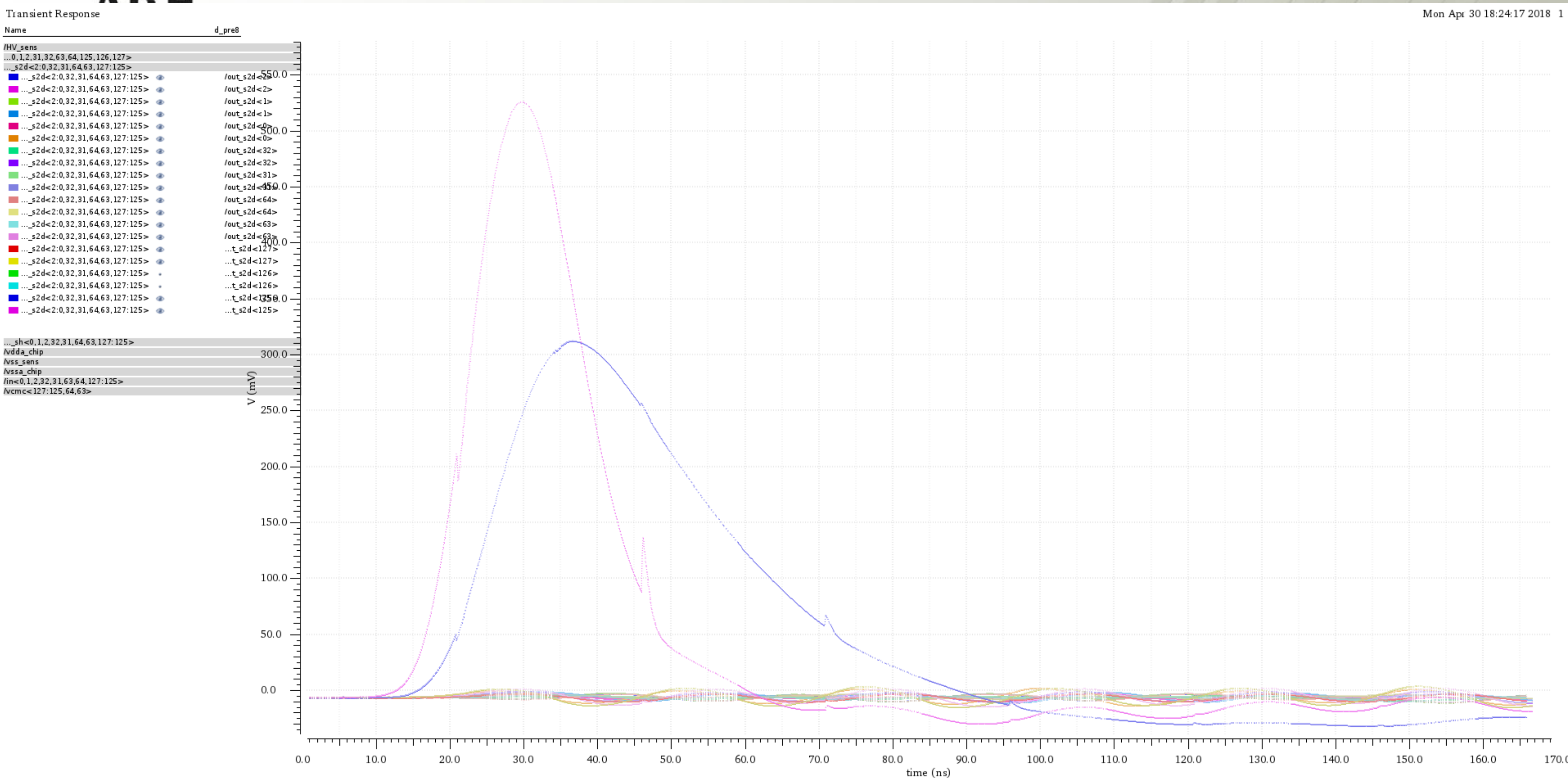
- Simulations of 128 mixed-mode channels (FE+ADC), Digital part not included. Simulator used ++APS(Sampled), conservative
- Simulated configurations of Preamp gnd:
  - Default, with Out_gnd (vssa_pre)
  - With Out_gnd(vssa_pre) and In_gnd(vssai)
  - With In_gnd(vssai)
- In simulations the resistances of power/gnd network are added artificially
- Added resistances:
  - General network (common for all channels, horizontal in layout) – res_vdda_presh=200m, res_vdda_adc=200m, res_vdda_ref=200m, res_vssa_pre=100m, res_vdda_sh=100m, res_vdda_adc=300m)
  - Inter-channel power network (additive to general, in layout vertical going up/down from the middle) – r_vdda=1m, r_vdds2d=8m, r_vddadc=3m, r_vrefd=14.5m, r_vssai=2m, r_vssa=2m, r_vsss2d=8m, r_vssadc=3m)

Schematic Simulations of SALT 2.5
S2d out (Only Out_gnd, Cdet 12pF, Ipre 4/15)



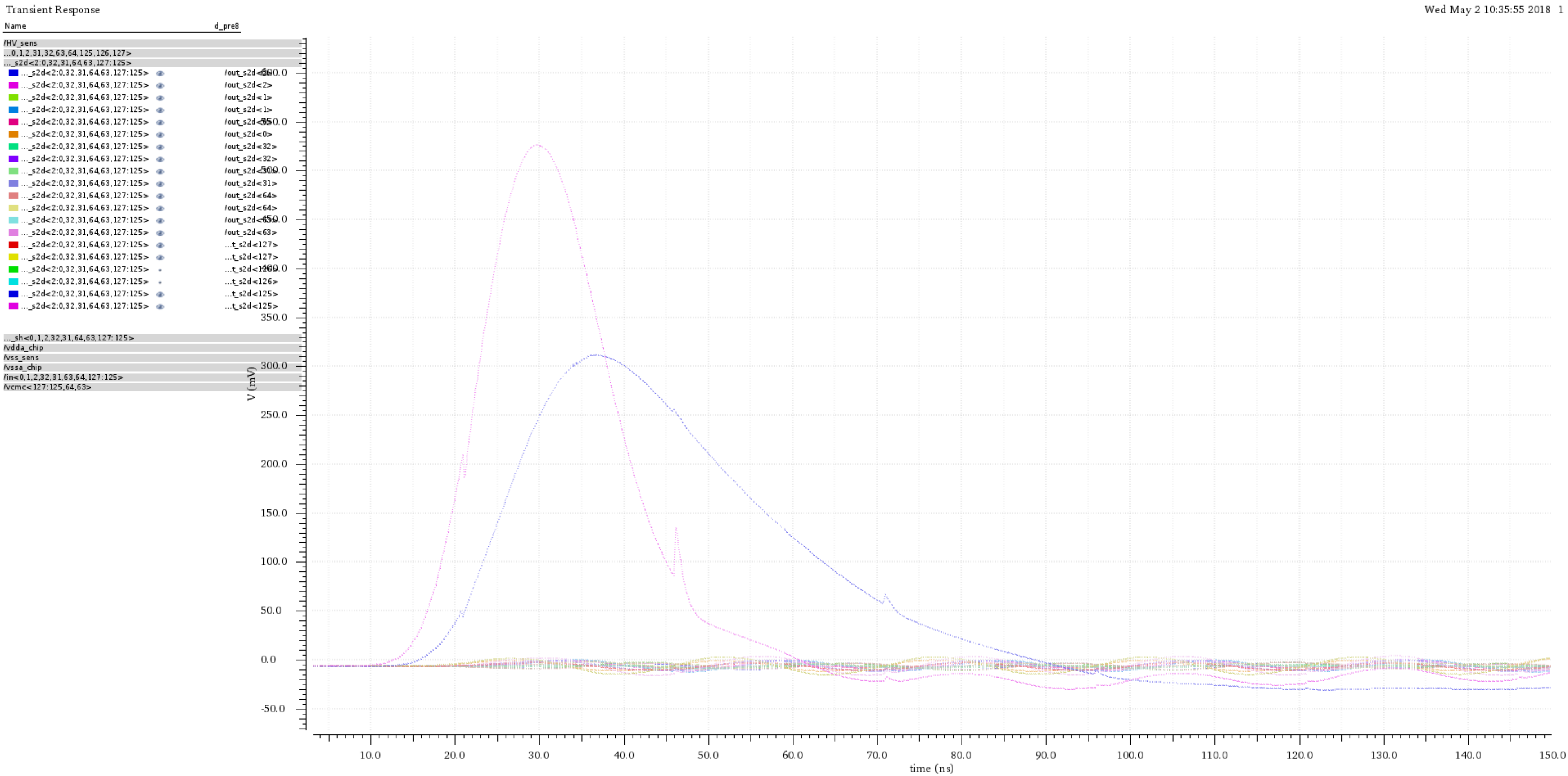
- Two pulses for Ipre=4/15
- Other channels with baseline oscillations within ~1LSB

Schematic Simulations of SALT 2.5
S2d out (Out_gnd&In_gnd, Cdet 12pF, Ipre 4/15)



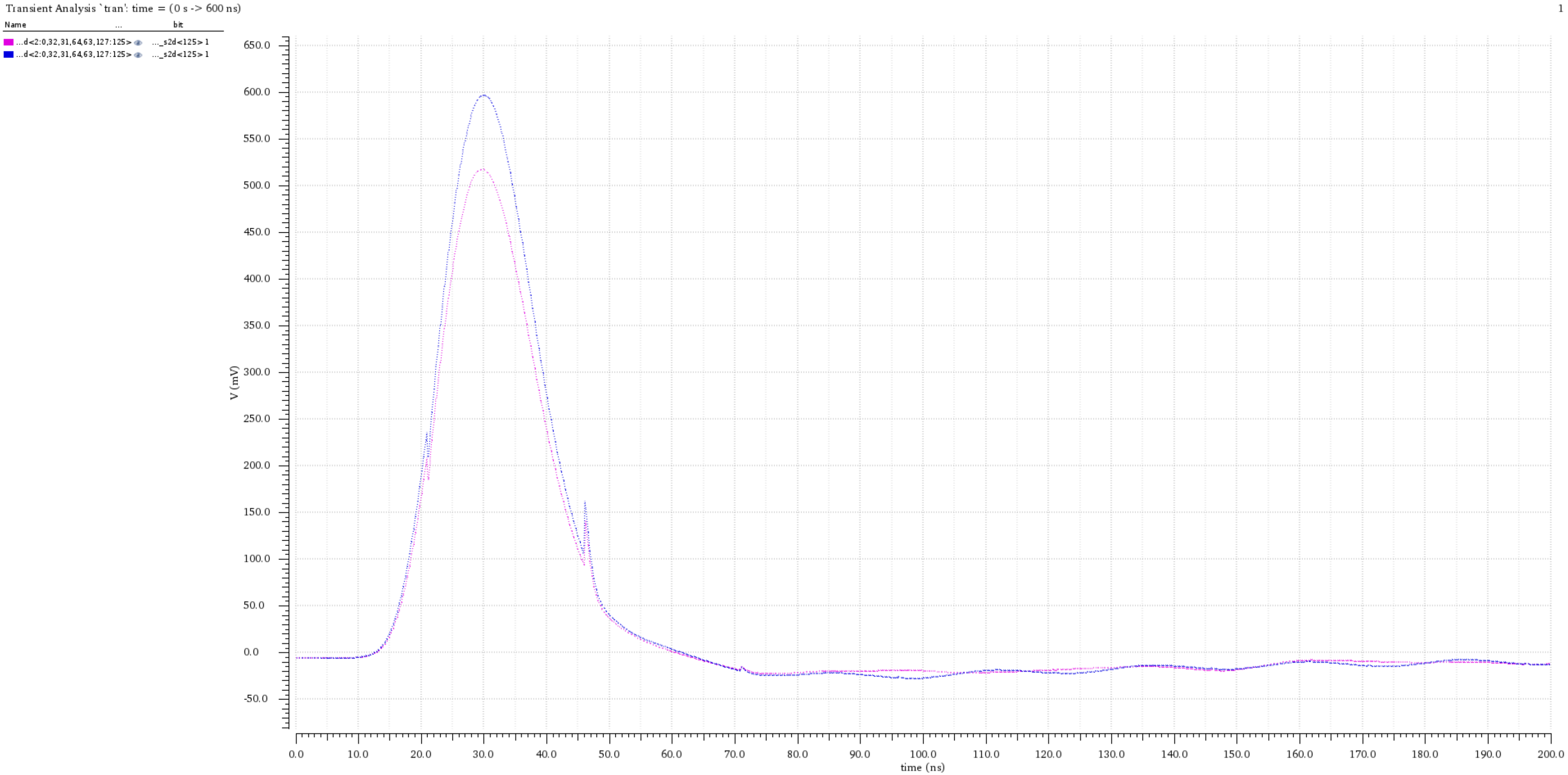
- Two pulses for Ipre=4/15
- Other channels with baseline oscillations within ~1LSB

Schematic Simulations of SALT 2.5
S2d out (Only In_gnd, Cdet 12pF, Ipre 4/15)



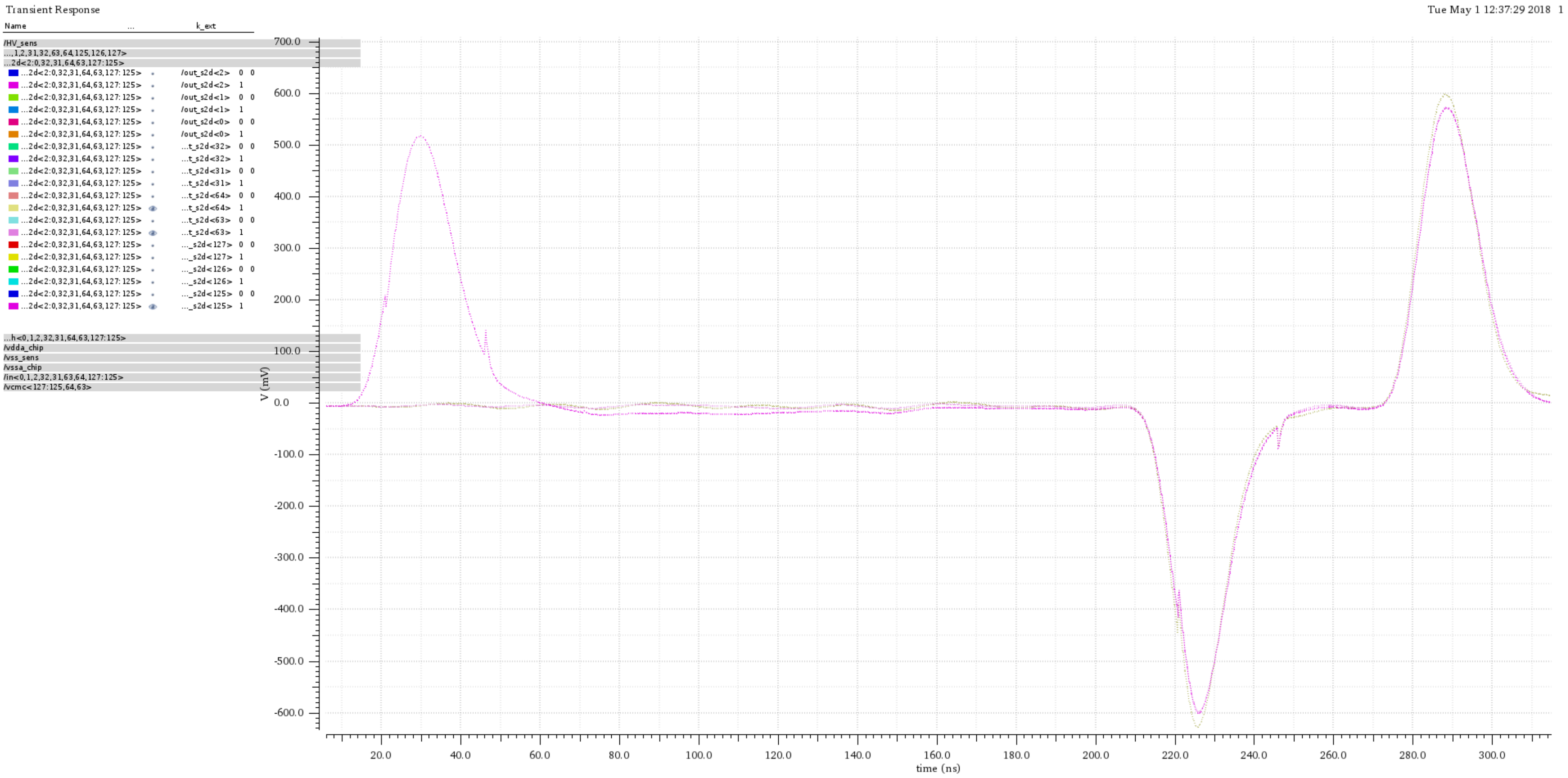
- Two pulses for Ipre=4/15
- Other channels with baseline oscillations within ~1LSB

Schematic Simulations of SALT 2.5
S2d out (Only Out_gnd, Cdet 12pF, Ipre 15)
Comparison: ++APS_Sampled vs APS



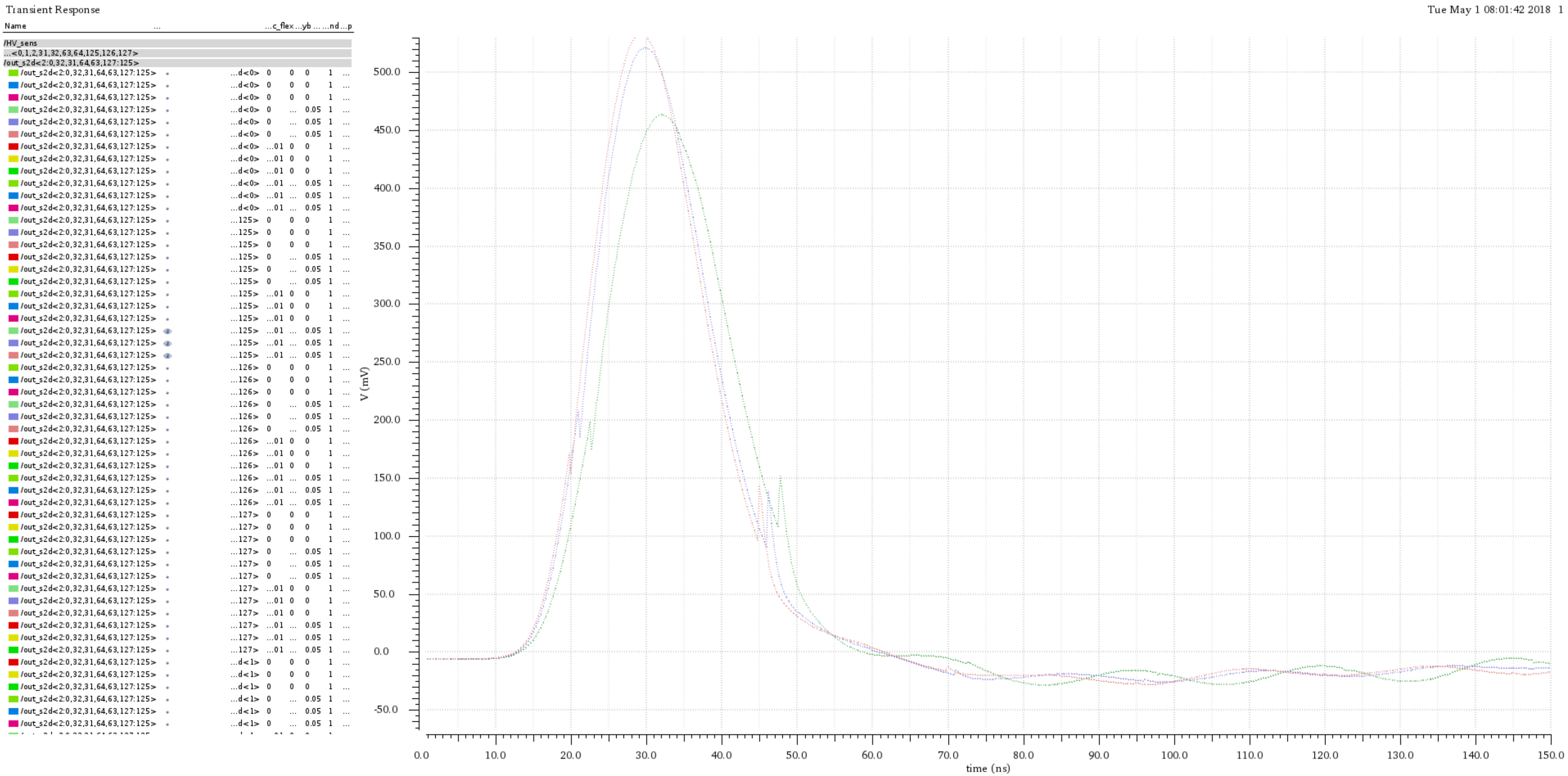
- Blue with APS, Pink with ++APS_Sampled
- Visible difference in pulse amplitude but not in baseline oscillations

Schematic Simulations of SALT 2.5
S2d out (Only Out_gnd, Cdet 12pF, Ipre 15)
Pulse injection: External vs Calibration



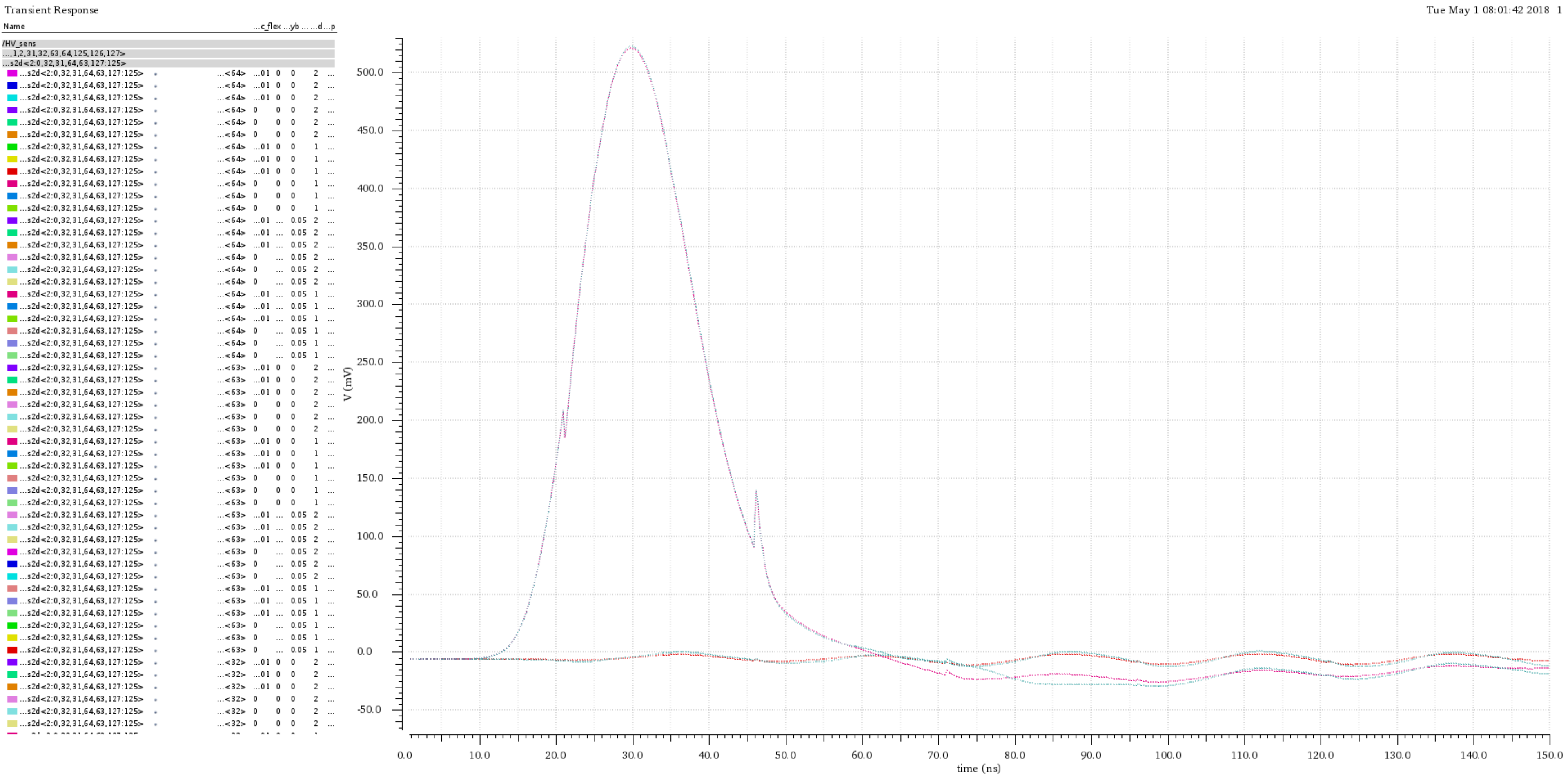
- First pulse injected externally, next two from Calibration

Schematic Simulations of SALT 2.5
S2d out (Only Out_gnd, Cdet 12pF, Ipre 15)
Power supply 1.1 V, 1.2V, 1.3V



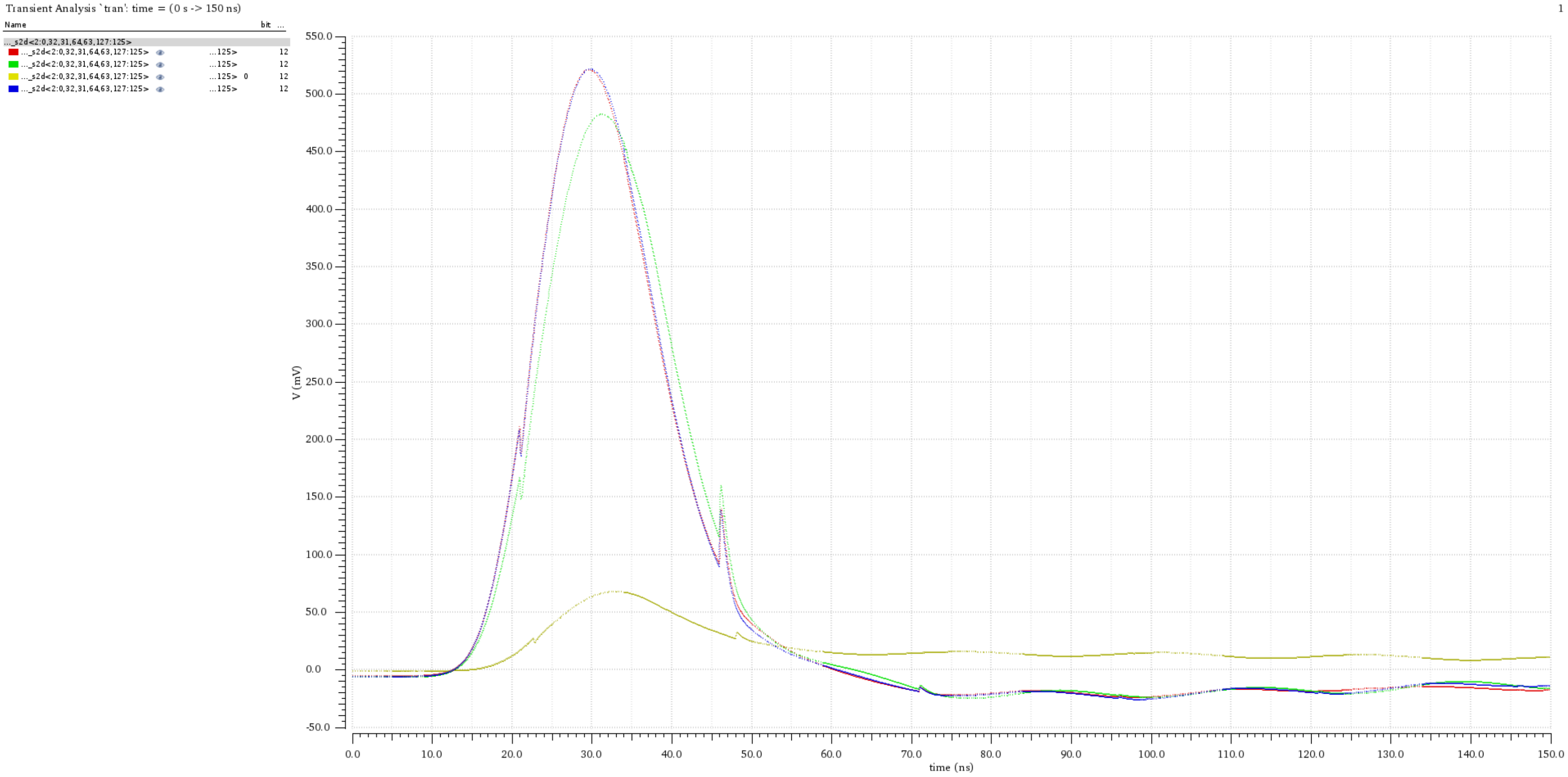
- Higher supply higher amplitude (and faster)
- Baseline oscillations similar

Schematic Simulations of SALT 2.5
S2d out (Only Out_gnd, Cdet 12pF, Ipre 15)
Inductance per power supply bond 2nH, 4nH



- No significant difference between 2nH and 4nH

Schematic Simulations of SALT 2.5
S2d out (Only Out_gnd, Cdet 12pF)
vcm = 0,16,32,63



- For 16,32 ok, lower for 63, very low for 0

Schematic Simulations of SALT 2.5 Preamp out (Only Out_gnd, Cdet 12pF) Ipre = 4,8,15,30

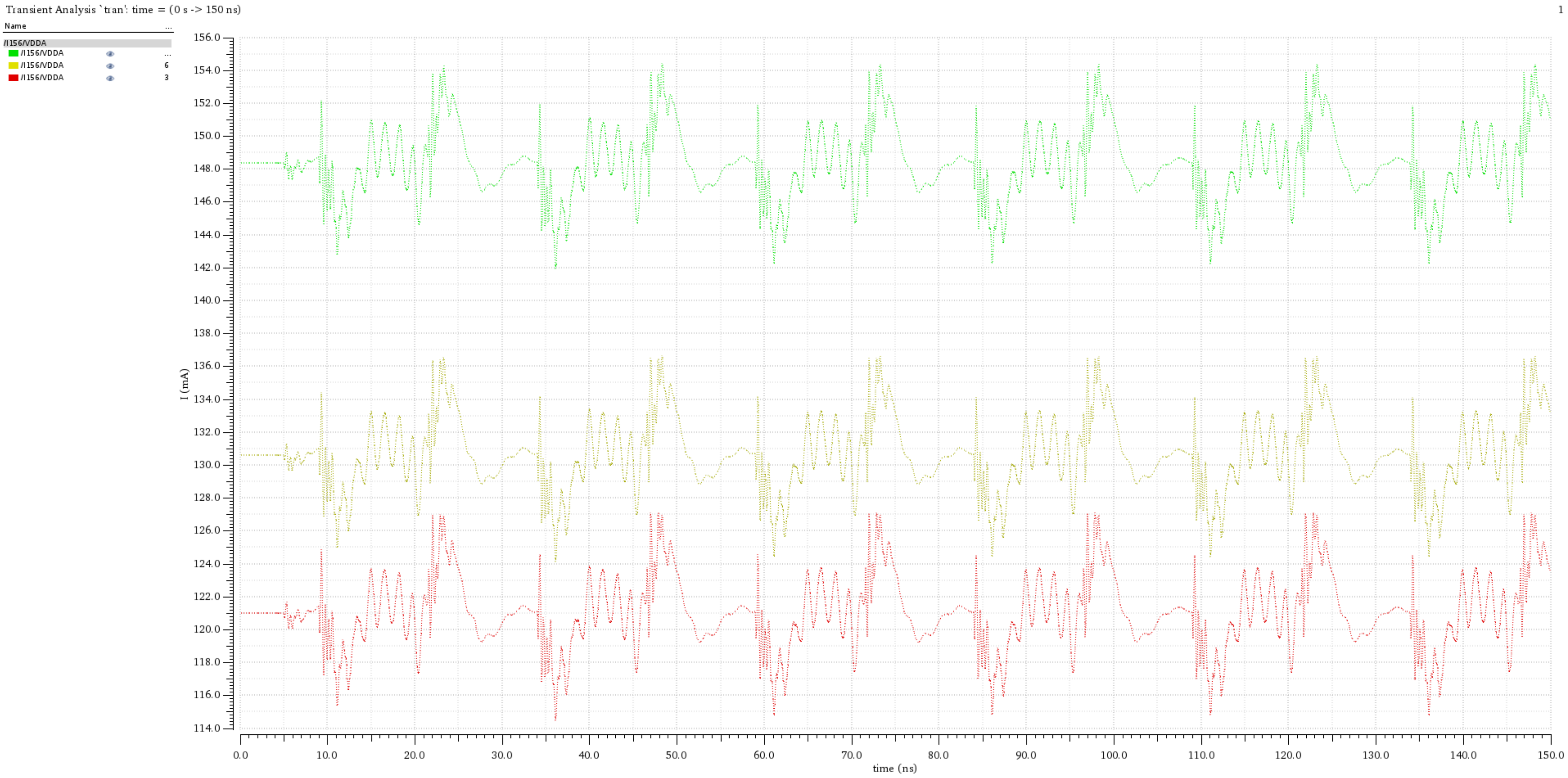
- Faster pulse for higher Ipre
- Baseline DC change of 1-2mV

Simulations of SALT 2.5
Schematic plus main resistances
DC measurements

- Default settings are:
  - Ipre=15
  - Ikrum=4
  - Ivcm=32
  - Ish=12
  - Is2d=12
  - Ibase=128
  - Ipulse=15
- ..

Schematic Simulations of SALT 2.5 Ivdda (Only Out_gnd, Cdet 12pF) Ipre=4,8,15,30, other settings default

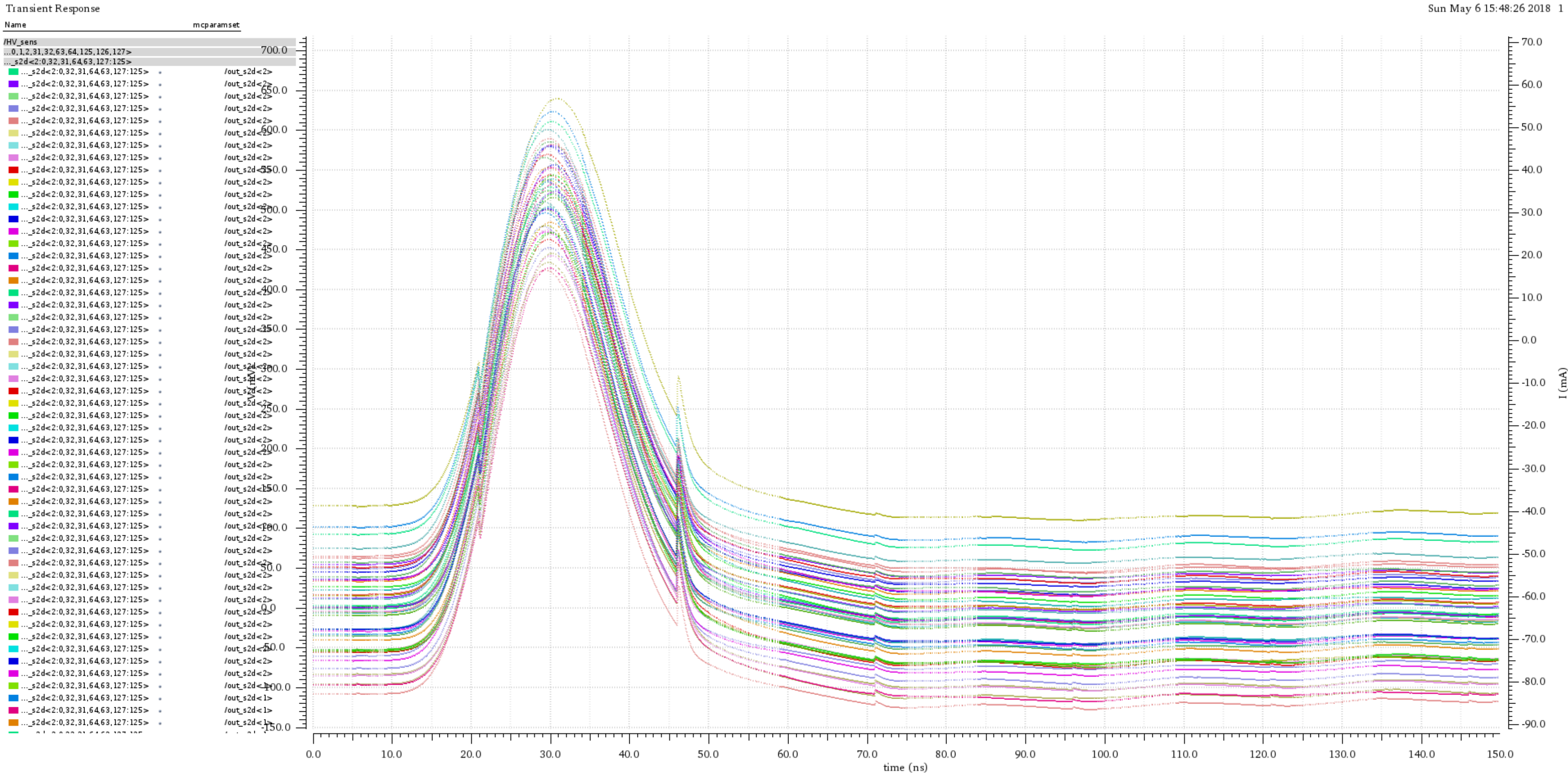
Schematic Simulations of SALT 2.5 Ivdda (Only Out_gnd, Cdet 12pF) Ish=3,6,12, other settings default



Schematic Simulations of SALT 2.5 Ivdda (Only Out_gnd, Cdet 12pF) Ivcm=0,16,32,63, other settings default

- Highest current for highest (63) setting

Schematic Simulations of SALT 2.5 S2d out MC (Cdet 12pF, Ipre 15)



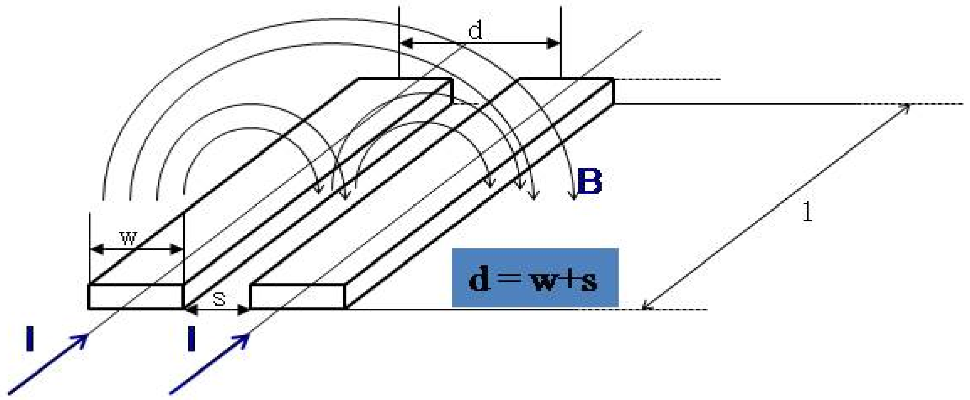
- The S2D(differentially) DC baseline stays in the range +-130mV

Simulations of SALT 2.5
Effects of internal inductances and their couplings

- The main effect of internal inductances may come from long (~2.5mm) horizontal lines of ADC power supply and Preamp ground which are placed in parallel, have widths of 100-200um and are separated by less than 50um.
- First order estimation of the inductance of ADC power or Preamp gnd line is about 1.5-1.7nH for each of them.
- First order estimation of coupling between ADC power and Preamp gnd lines is huge, of about 50%. The estimation is based on the figure/equation from next slide. We suspect that in reality, because there are many other metal lines around, it is significantly less.

Mutual Inductance between Lines

Since some of the flux generated in one line is "coupled" to the adjacent line, "mutual" inductance is introduced between the two lines.

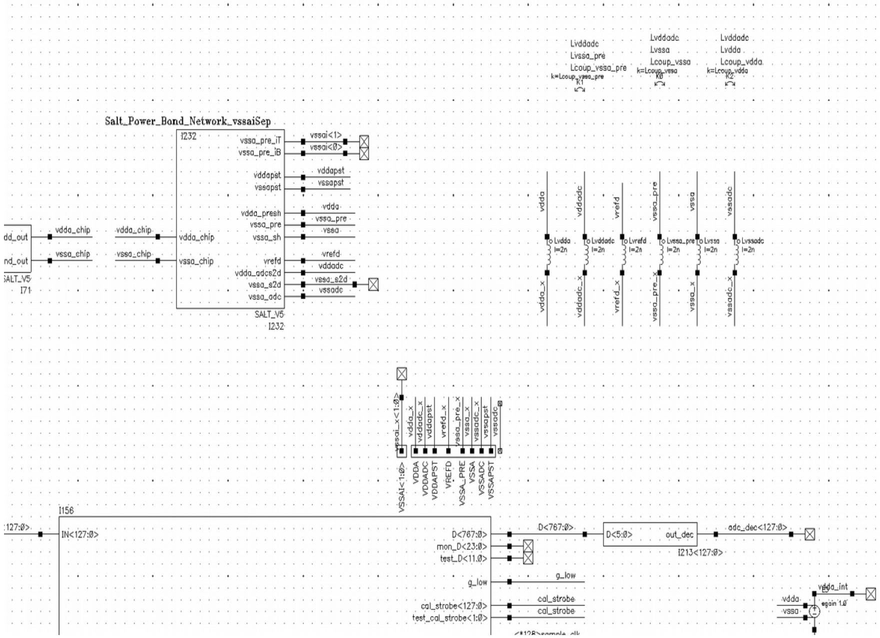


$$M = \frac{\mu_0}{2\pi} l \left(\ln\left(\sqrt{1+\left(\frac{l}{d}\right)^2} + \frac{l}{d}\right) - \sqrt{1+\left(\frac{d}{l}\right)^2} + \frac{d}{l}\right)[H]$$

Dimensions in m

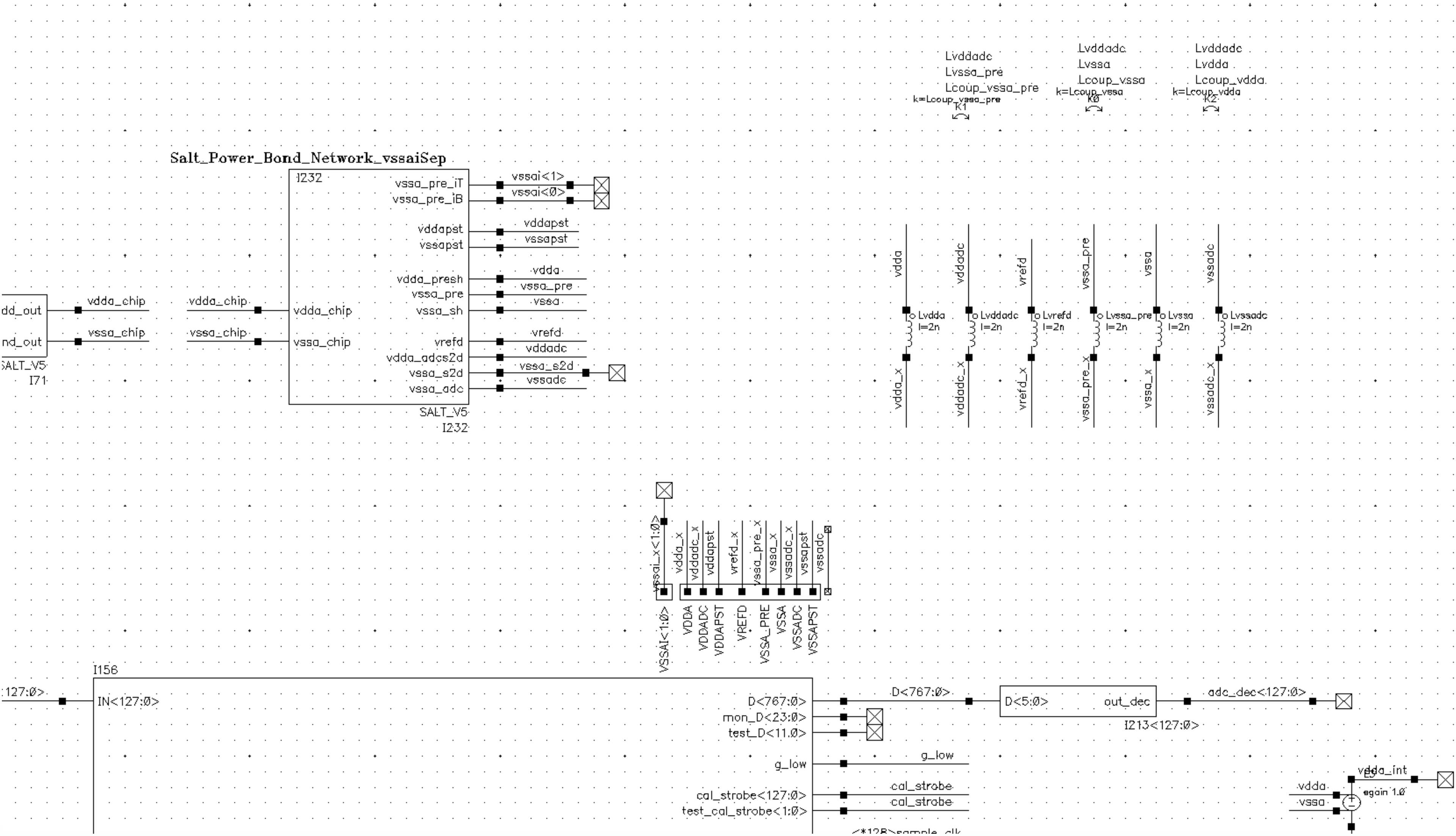
Mutual inductance can be positive or negative depending on current direction.

Schematic Simulations of SALT 2.5
How inductances and their couplings are simulated

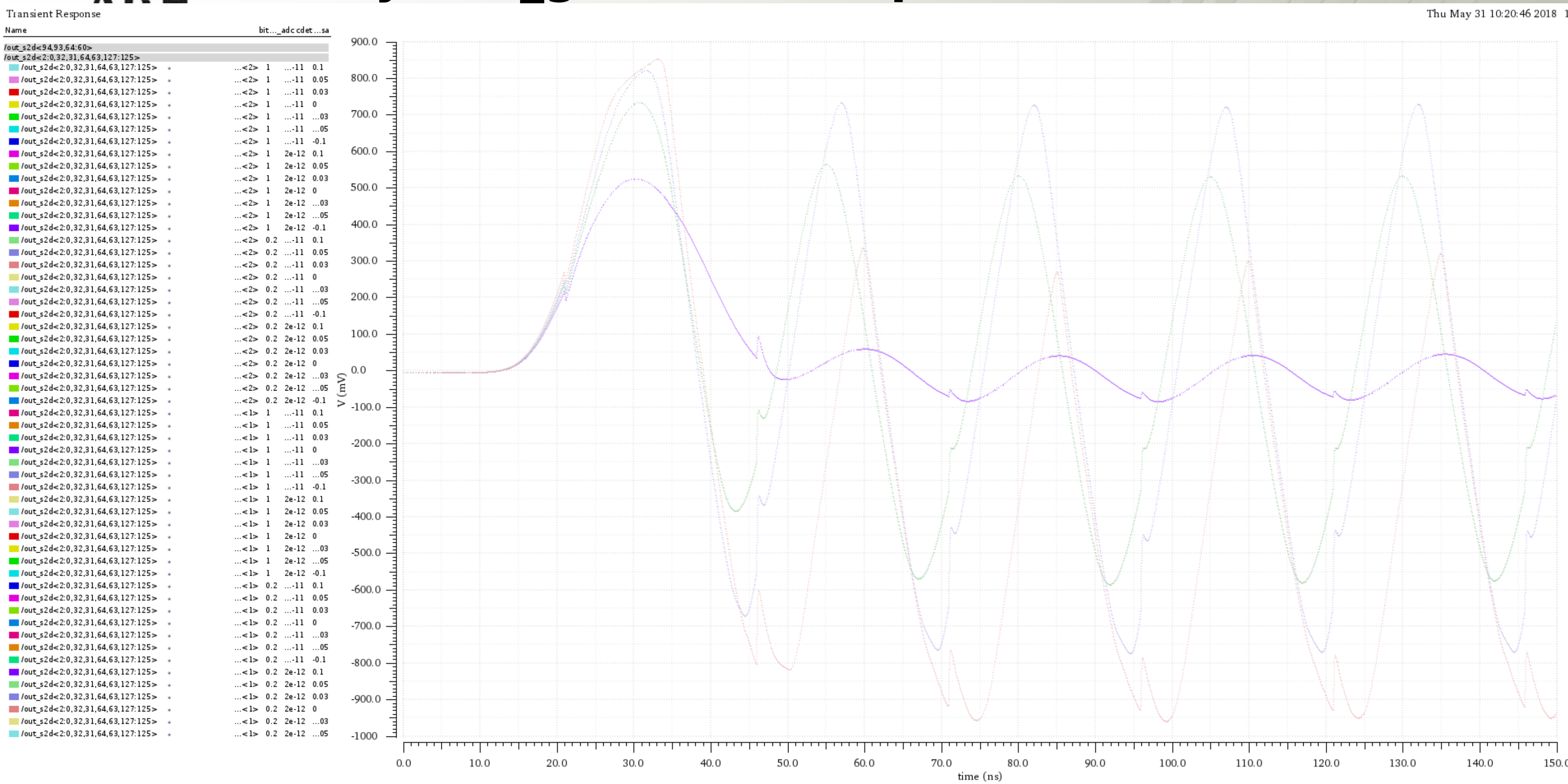


- Top left (Salt_Power_Bond…) block contains bond inductances and series resistances of long power/gnd lines in SALT2.5.
- Bottom - SALT2.5 (only the side with power supply network is seen)
- Inductances Lvdda, Lvddadc, …, simulate internal inductances (e.g. horizontal power/gnd lines). For 1st appr. 2nH was used.
- Top right - Lcouplings. 3 are seen here: vddadc-vssa_pre, vddadc-vssa, vddadc-vdda. Each of them may be set between -1,+1. For 1st simulation only vddadc-vssa_pre was used.
- Next slide shows the zoom of this schematic…

Schematic Simulations of SALT 2.5
How inductances and their couplings are simulated

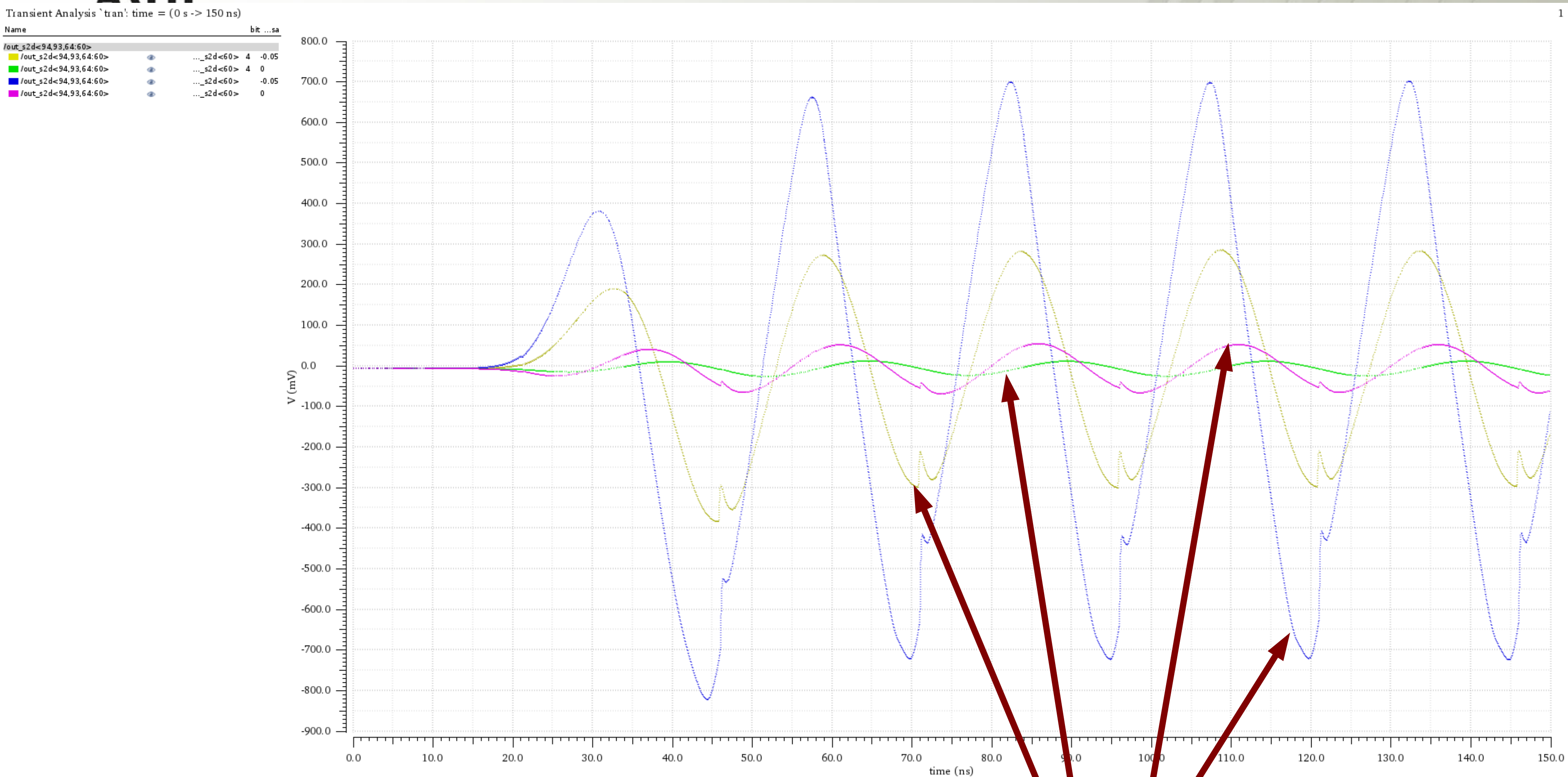


Schematic Simulations of SALT 2.5 S2Diff out vs Lcoup (Vdd_ADC, Vssa_Pre) (Only Out_gnd, Cdet 12pF)



- Internal inductance of 2nH for Vdd_ADC and Vss_Pre added
- Lcoupling between Vdd_ADC and Vss_Pre -0.1, -0.05, -0.03, 0.0

Schematic Simulations of SALT 2.5 S2Diff out vs Lcoup (Vdd_ADC, Vssa_Pre) vs Ipre (Only Out_gnd, Cdet 12pF)

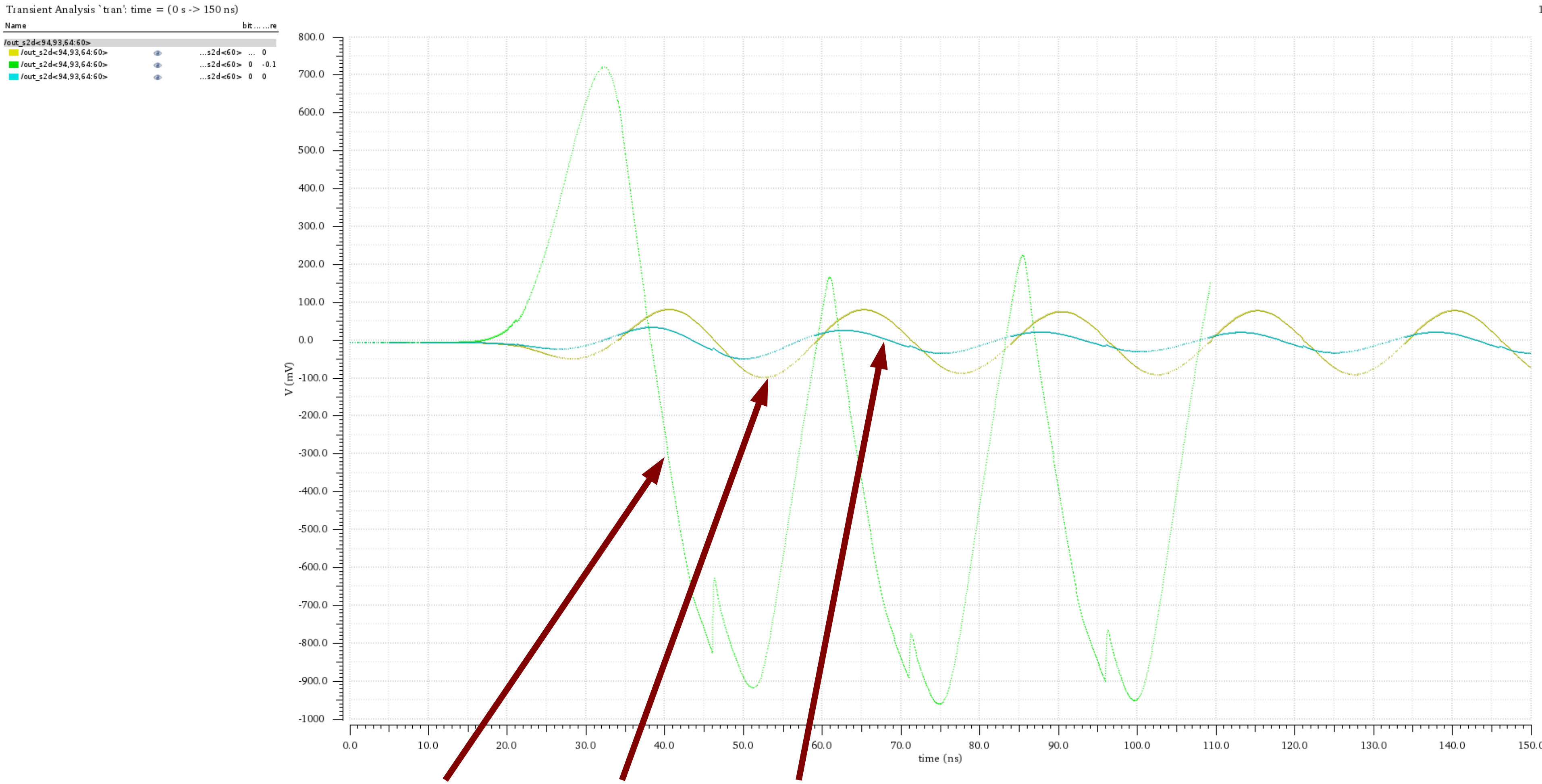


- Internal inductance of 2nH for Vdd_ADC and Vss_Pre added
- Lcoupling Vdd_ADC and Vss_Pre -0.05, 0.0, Ipre 4, 15
- Ipre has big effect on oscillations amplitude!

Simulations of SALT 2.5
Effects of internal inductances and their couplings

- In addition to previous simulations, the 2nH internal inductance has been added to all power/gnd lines: Vdda_ADC, Vrefd, Vssa_adc, Vdda, Vssa, Vssa_Pre
- Different coupling configurations will be studied...

Schematic Simulations of SALT 2.5 S2Diff out (Lcoup -0.1,0, Cdet 12pF) (Vdd_ADC coupled to Vssa_Pre or Vssa)

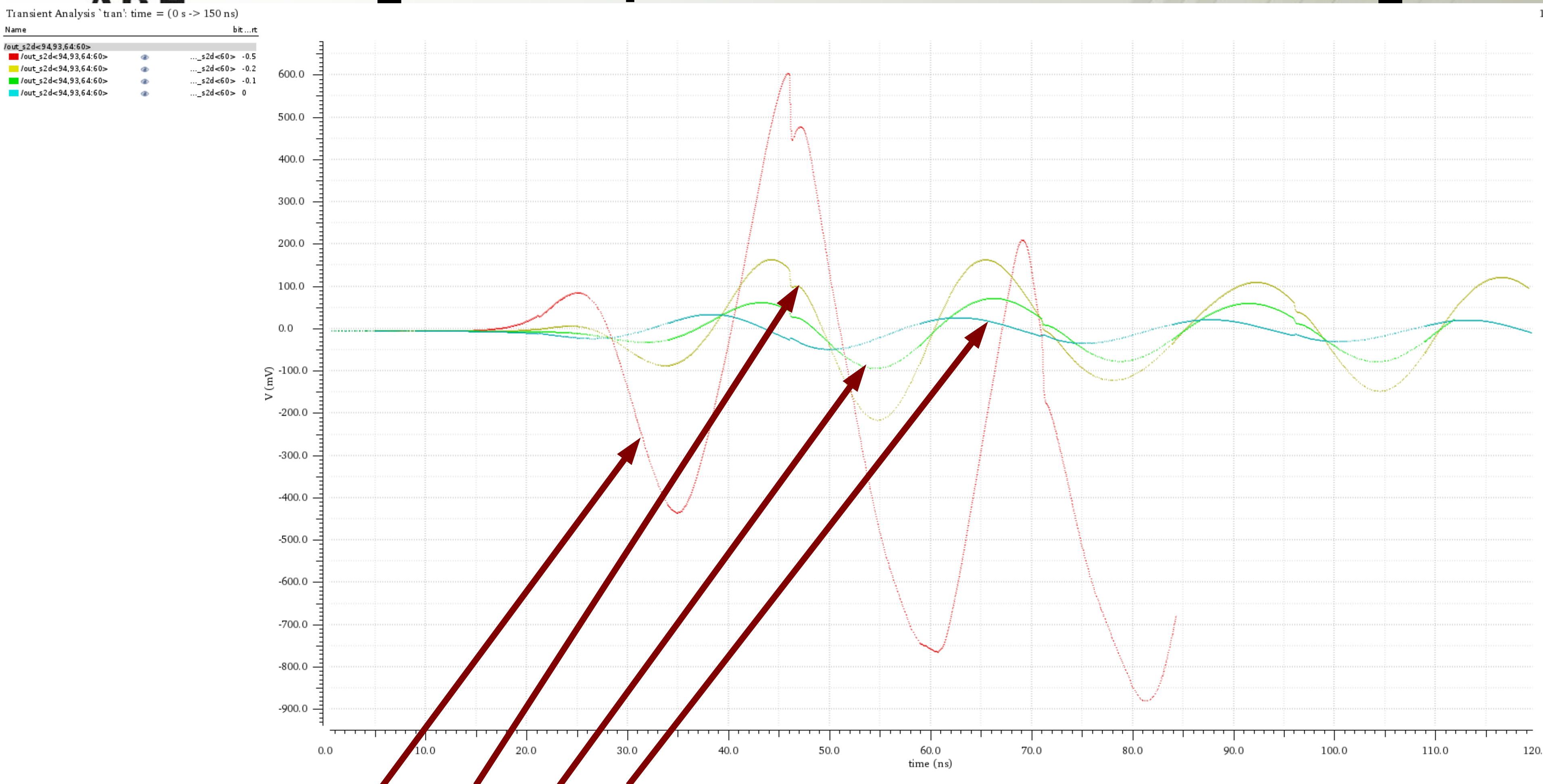


- Lcoupling to: Vssa_Pre, Vssa, No coupling
- Coupling to Vssa_pre is dominant!

Simulations of SALT 2.5
Effects of internal inductances and their couplings

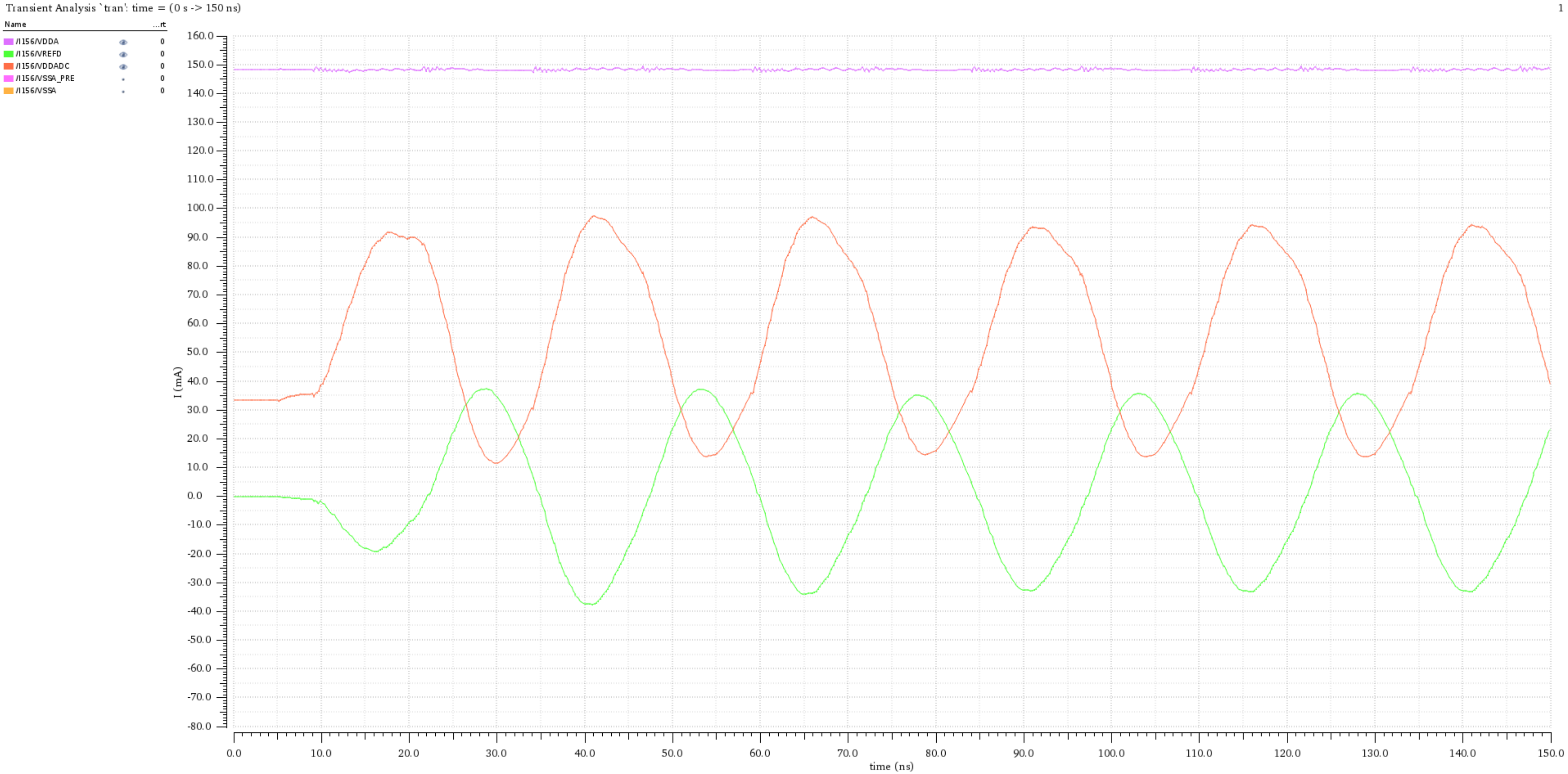
- An attempt to estimate the effect of inductive coupling between vertical power/gnd lines was made…
- The same as before 2nH inductances were used for vertical lines, although vertival length is about 1cm (4 x more than horizontal). On the other hand not whole ADC current flows through the whole length…
- In the layout the lines (from the left) go in order: Vssa_pre, Vdda, Vssa, Vdda, ADC power and gnd lines
- Since the dominant effect comes from Vssa_pre sensitivity, it was assumed that Vdda_ADC couples to Vdda and then Vdda to Vssa_pre. The same coupling strength for both pairs was used.
- In these simulations horizontal coupling/inductances were OFF (zero).

Schematic Simulations of SALT 2.5 S2Diff out (Cdet 12pF) Vdd_ADC coup. to Vdda and Vdda to Vssa_Pre



- Lcoupling: -0.5, -0.2,-0.1,0
- Effect is still there but higher coupling (>0.2) is needed

Simulations of SALT 2.5
Why we see the effects of internal L/Lcouplings while others do not ?



- Ivddadc current changes by ~90mA during 25ns period !
- Effect of Lcoupling is multiplied by huge current changes !