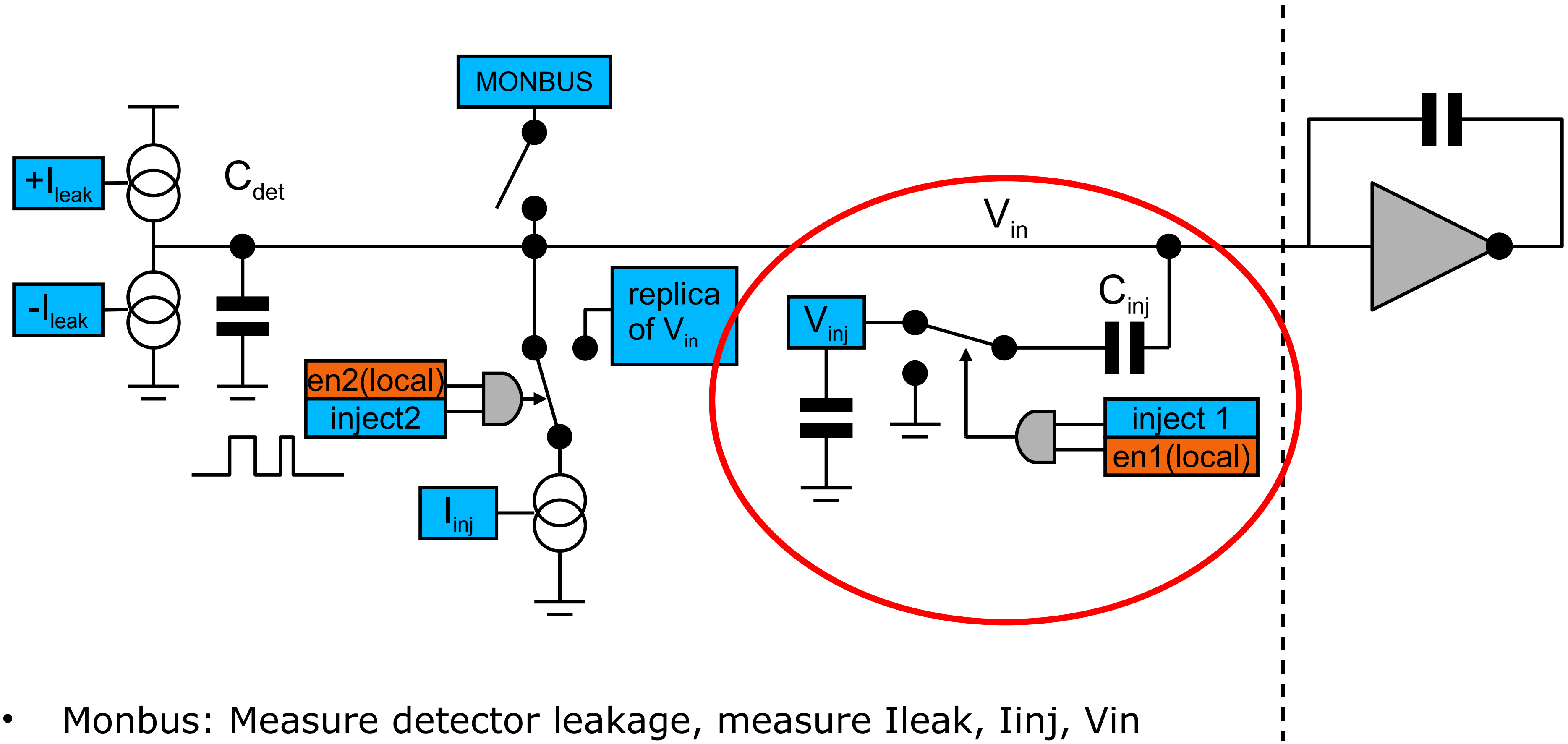
Design carefully: Injection Circuit

- Goals:
  - Full chip characterization without external components
  - Measure Noise
    - fine steps up to ~ ½ mip
    - calibrated charge
    - Inject known step through known injection capacitor C_{inj}: $Q_{inj} = C_{inj} \times dV$
  - Measure dynamic range and (linearity)
    - larger steps up to ~ 4 mip
  - Measure timing and double pulse behavior
    - requires more than one step or – better – current pulses: $Q_{inj} = I_{inj} \times dT$
  - Measure tricky details
    - i.e. measure crosstalk: inject one channel, measure thres/noise on neighbor
  - Inject leakage current, measure leakage current
    - Versatile Monitoring Bus

Possible Circuit

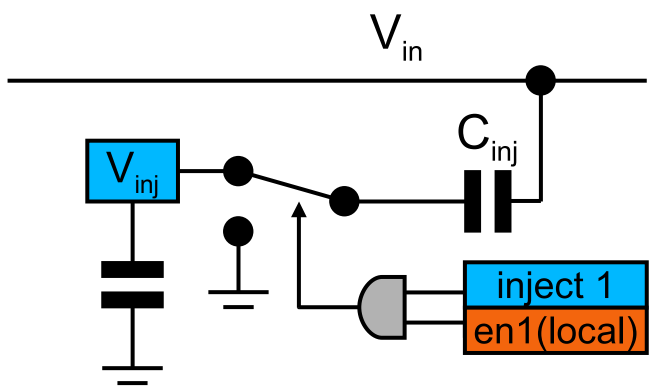


- Monbus: Measure detector leakage, measure Ileak, Iinj, Vin
- Add large array of Cinj with cap measurement on chip
- Cinj value: Cinj = Qmax / DVmax ~ 10fC / 1V ~ 10fF
- Red part is beeing designed by Mannheim

Circuit to measure C_{inj} precisely

Detail: Injection via Voltage Step

- Goals:
  - Bipolar pulses (pos. and neg. Charges)
  - Large voltage steps (less sensitive to noise in Vinj)
  - PMOS switches for radiation hardness
  - Switchable Cinj for adjustable range (2-10fC)
  - Short pulses (some ns)
- General Problems:
  - Charge injection
  - Bipolar pulses with PMOS
  - Need a good reference/ground voltage

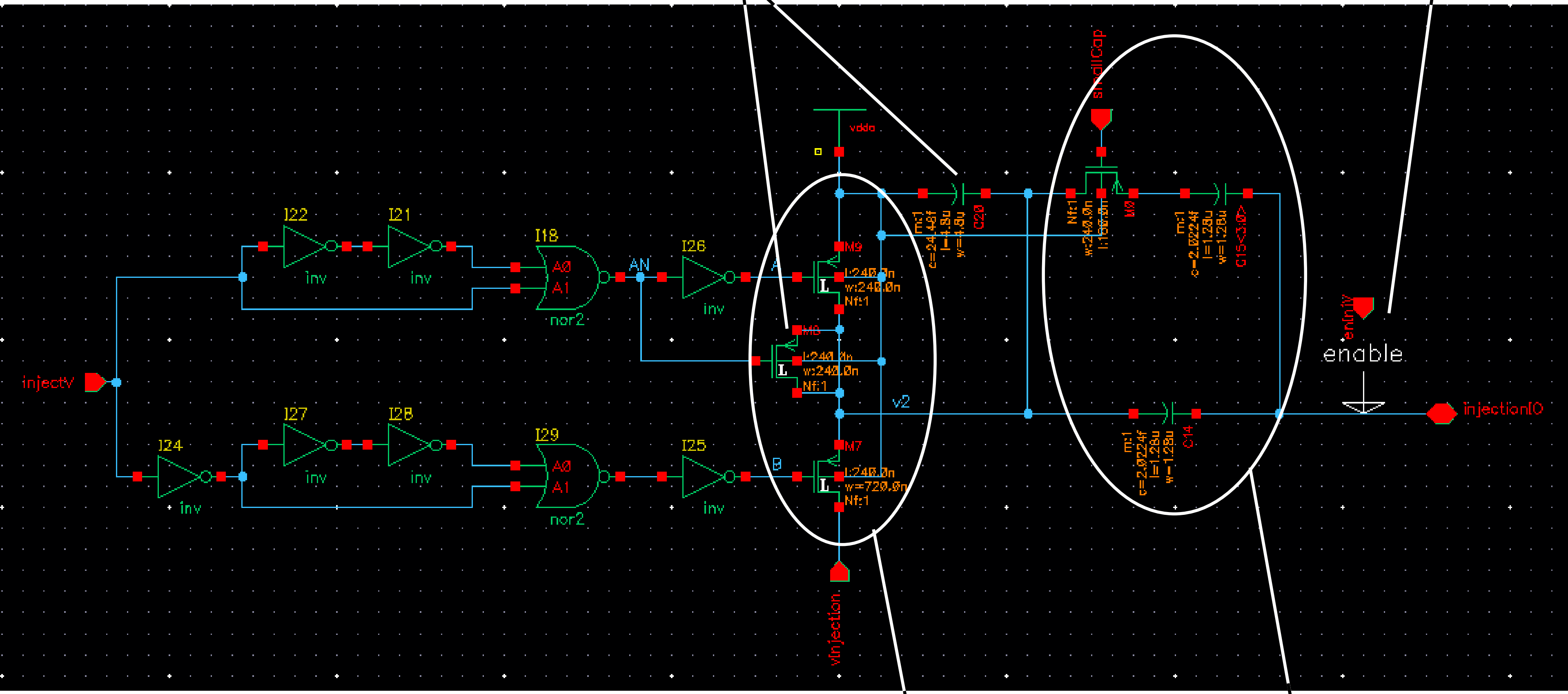


=> Switches tricky, design carefully

Schematic

Reduce/compensate charge injection

Type of MOS switch depends on input DC level of preamplifier

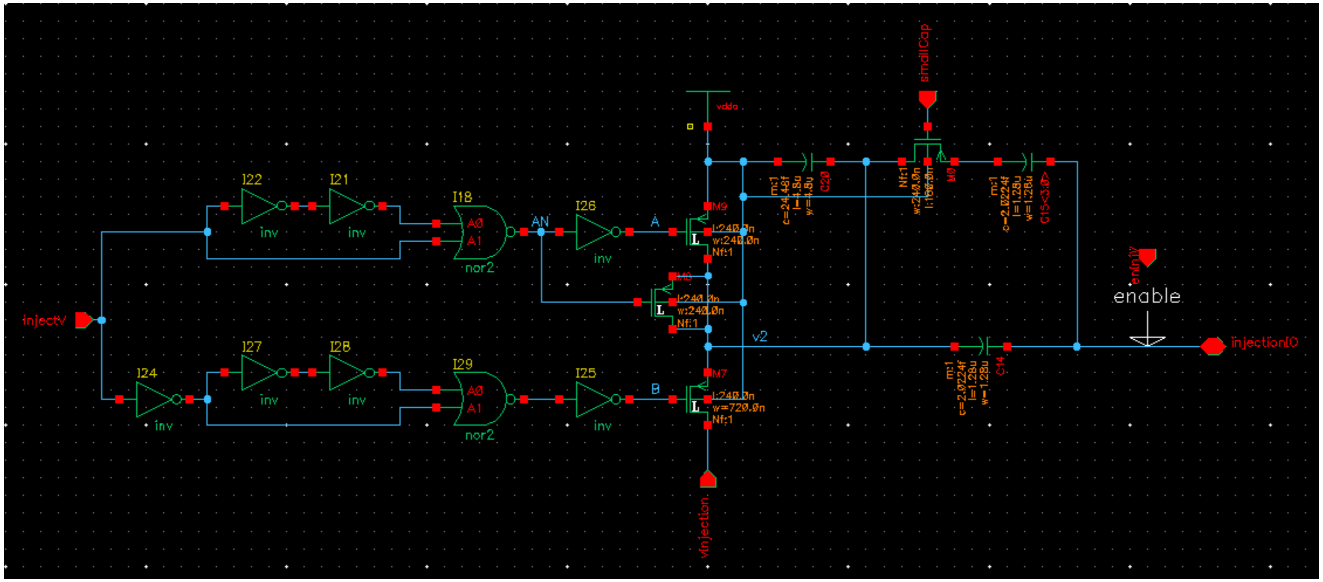


Rad-hard control logic

Switch between Vdda and vInjection

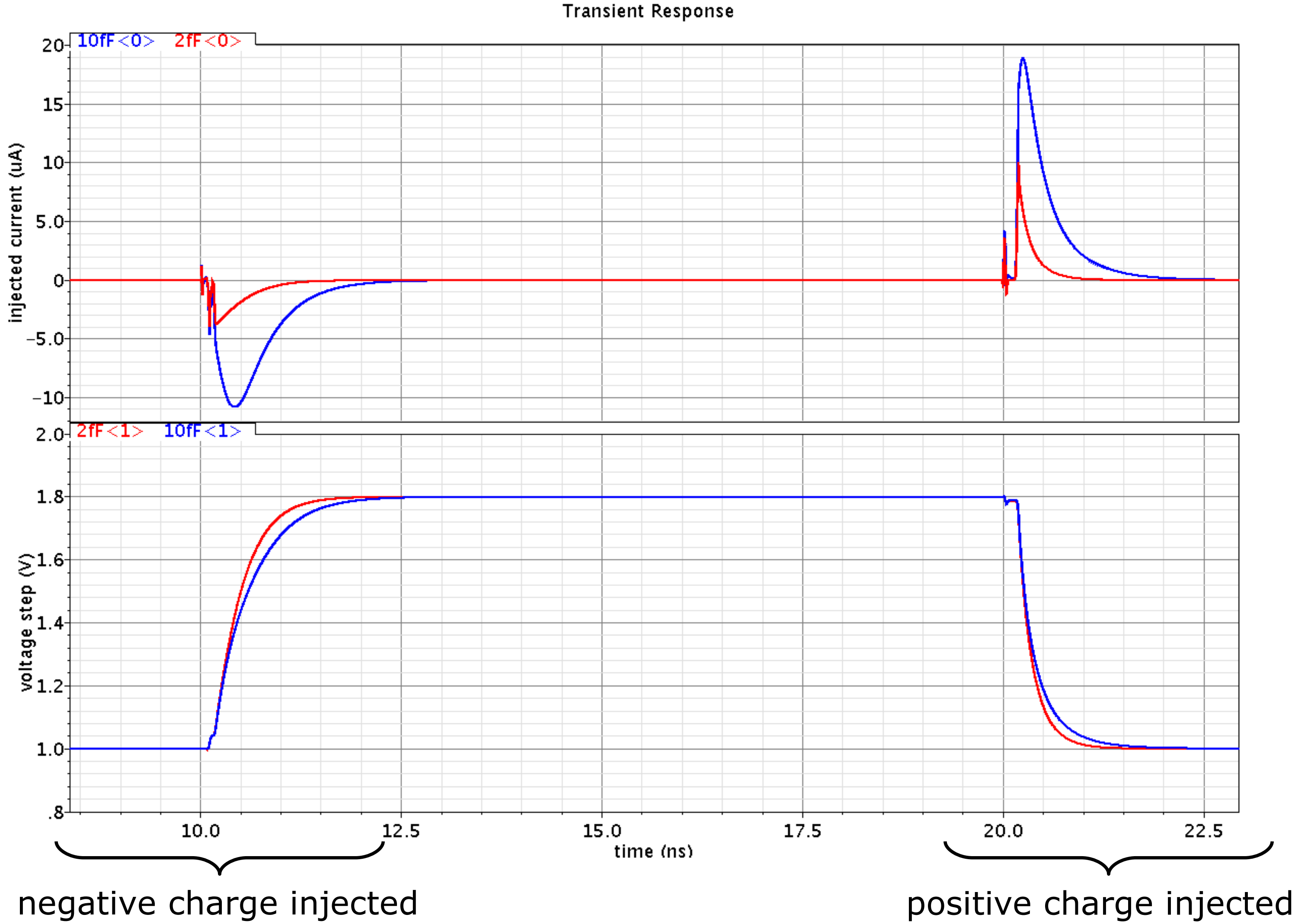
Switchable injection capacitance

Design Aspects



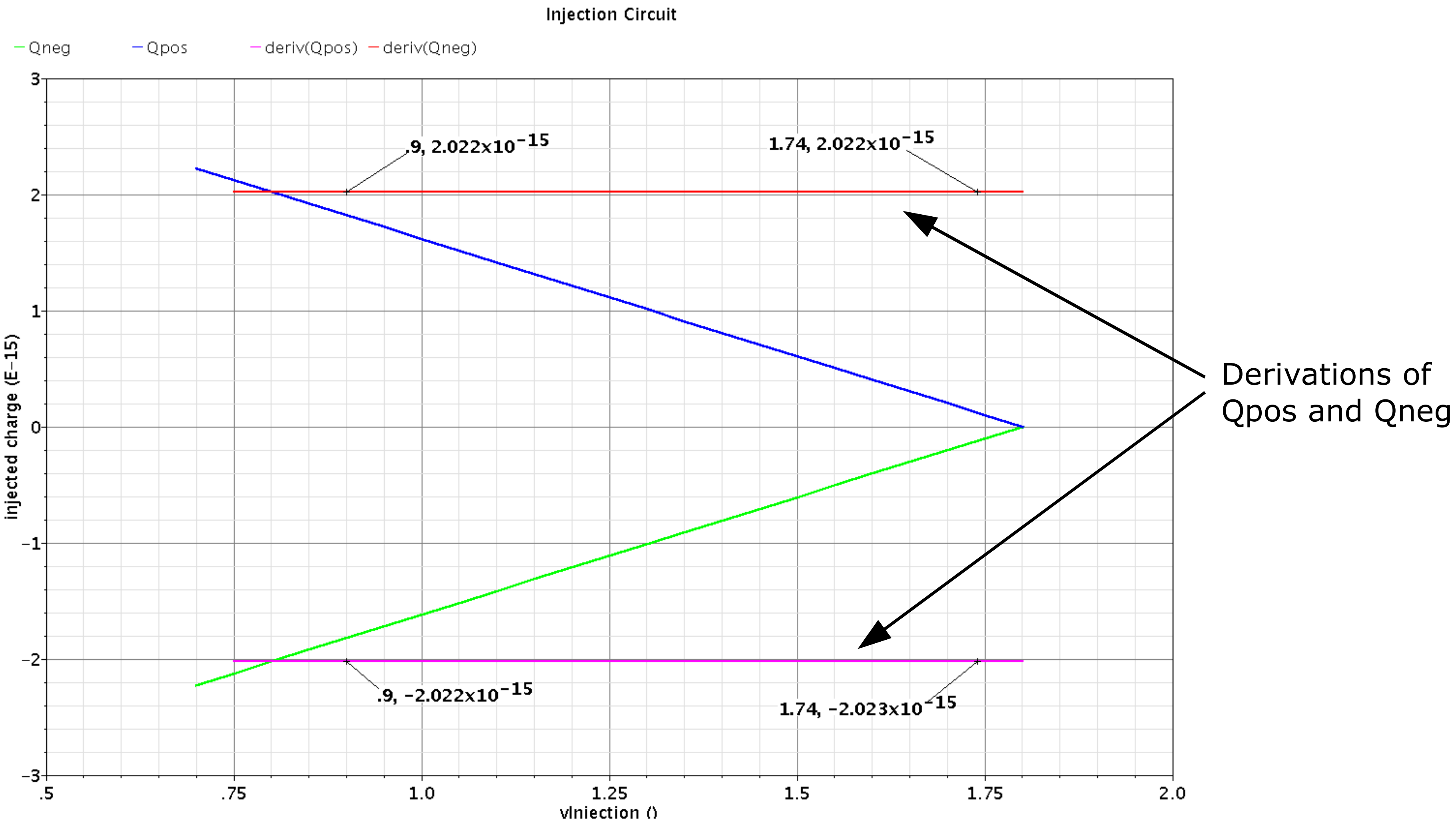
- Only PMOS switches
- Bipolar pulses possible
- Charge injection:
  - No problem with posedge (pos. charge injected doesn't matter).
  - Compensation for negedge (intentionally over-compensated)
- Especially delayed control signals needed
- Low threshold transistors for large output range
- Control logic can be actualized using rad-hard standard cells
- Critical point: Need a good reference voltage (here Vdda)
- Simulation results: Fast and exact (see next slices)

Transient Simulation



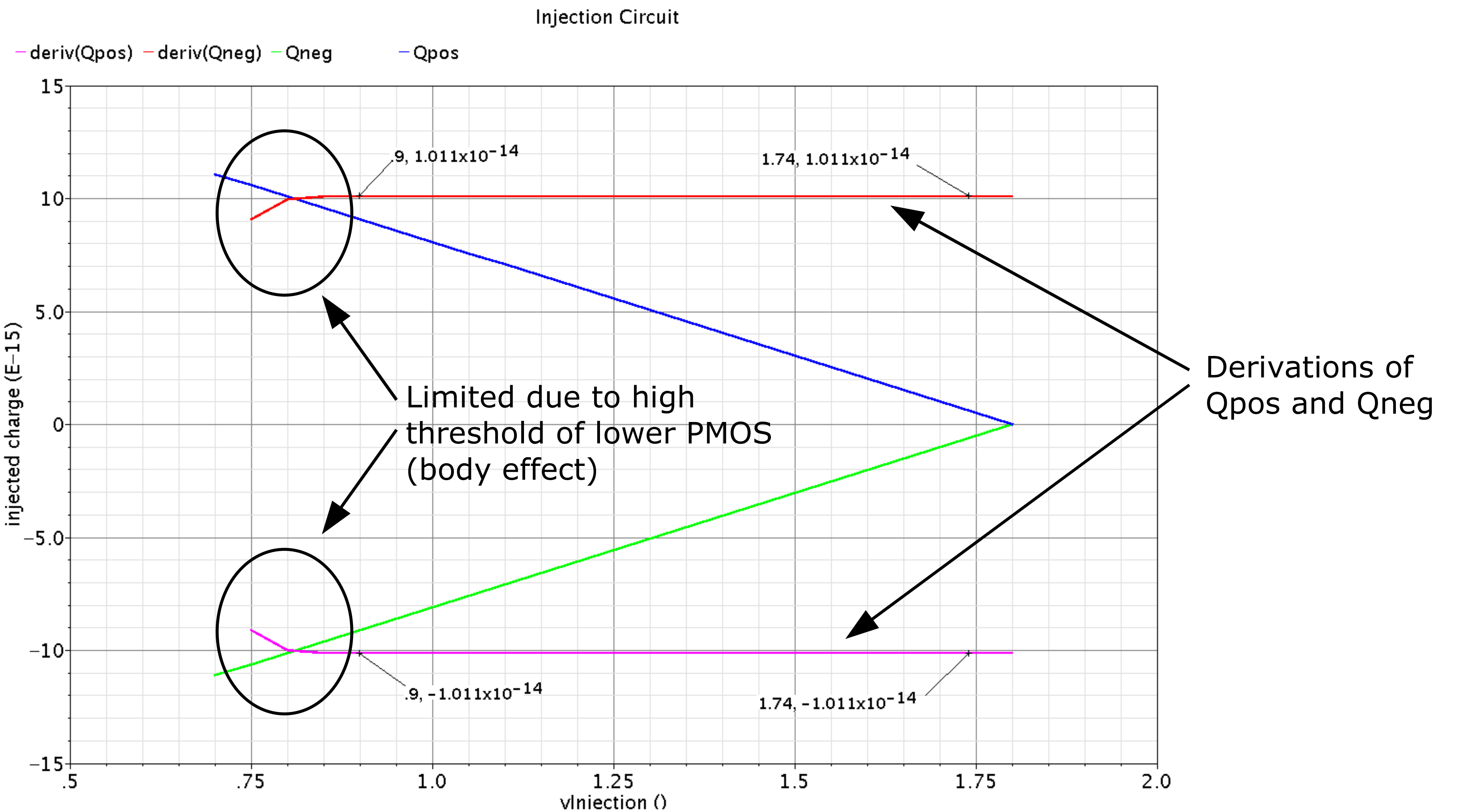
=> No over-/undershooting of voltage step due to charge injection, pulse length <3ns

Injected Charge: switch off - small capacitance



Capacitor 2.022fF => between 900mV and 1.74V simulated error <= 0.05%
(max. step 1.74V limited due to charge injection)

Injected Charge: switch on - large capacitance



Capacitor 10.11fF => between 900mV and 1.74V simulated error <= 0.09%

Summary

- **Bipolar** pulses
- **Rad-hard** design
- Possible **injection steps 0.06 - 900mV**
  - Fine steps: Qinjected = **±(0.03 – 1.8fC)**, resolution: 2fC/V
  - High range: Qinjected = **±(0.15 – 9.0fC)**, resolution: 10fC/V
  - Any other resolution in-between is easy realizable
- **Max. 0.1% (simulated) deviation** from ideal charge values
- **Fast pulses** (< 3ns)
- Most **critical point**: Good reference voltage needed