XFEL Read-out Amplifier Design

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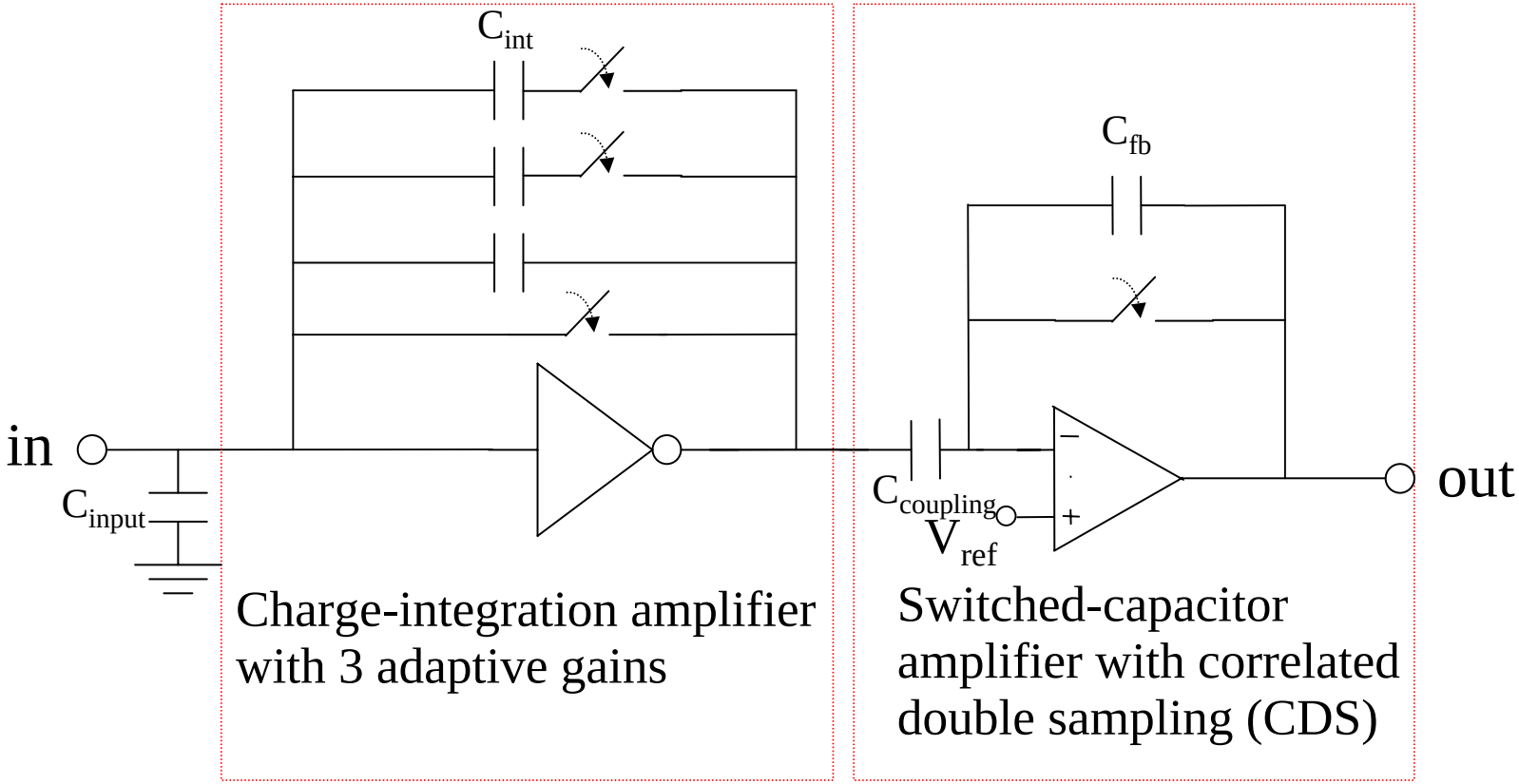
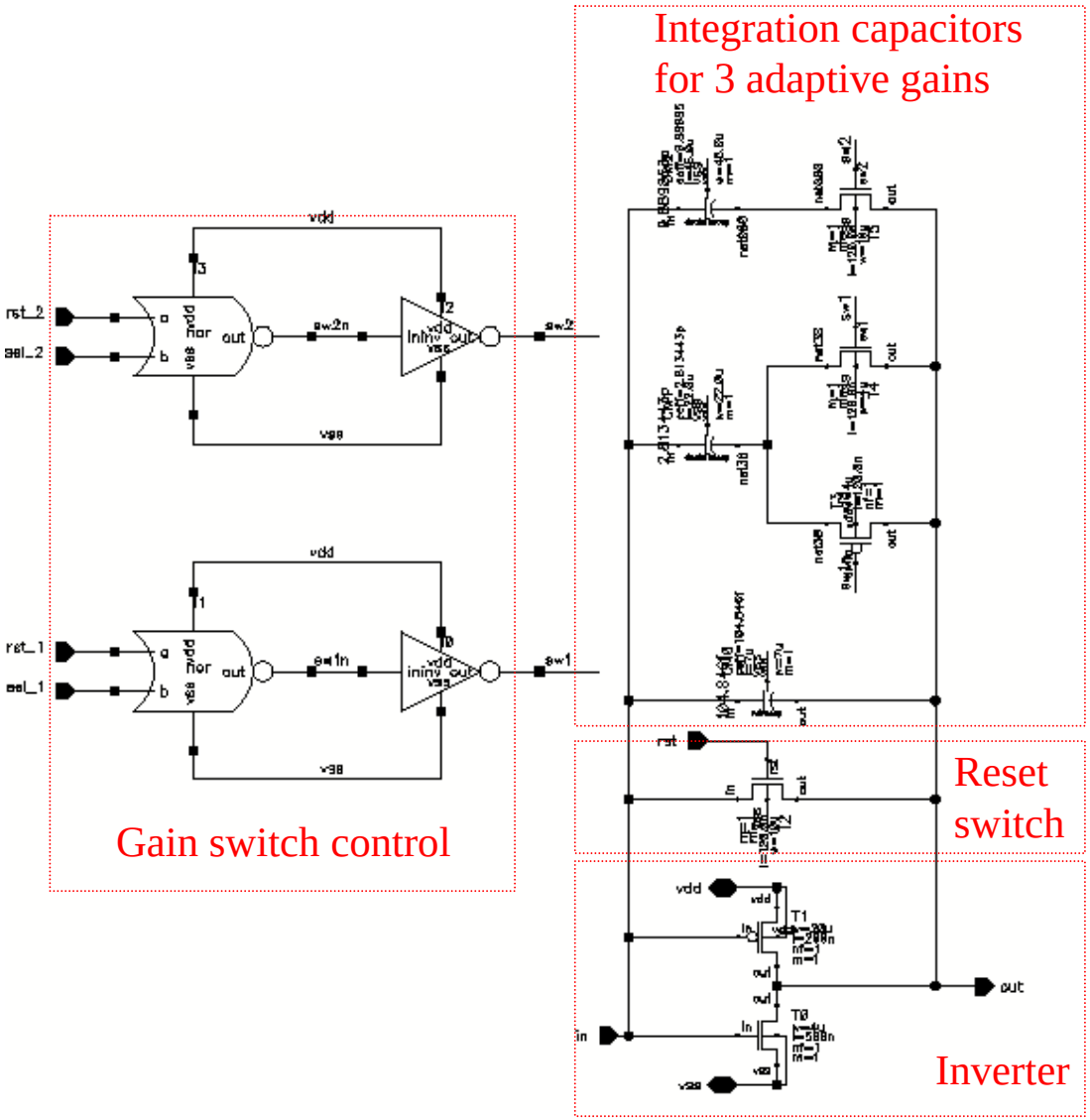
Concept of the read-out Amplifier



Input Charge Integration Amplifier



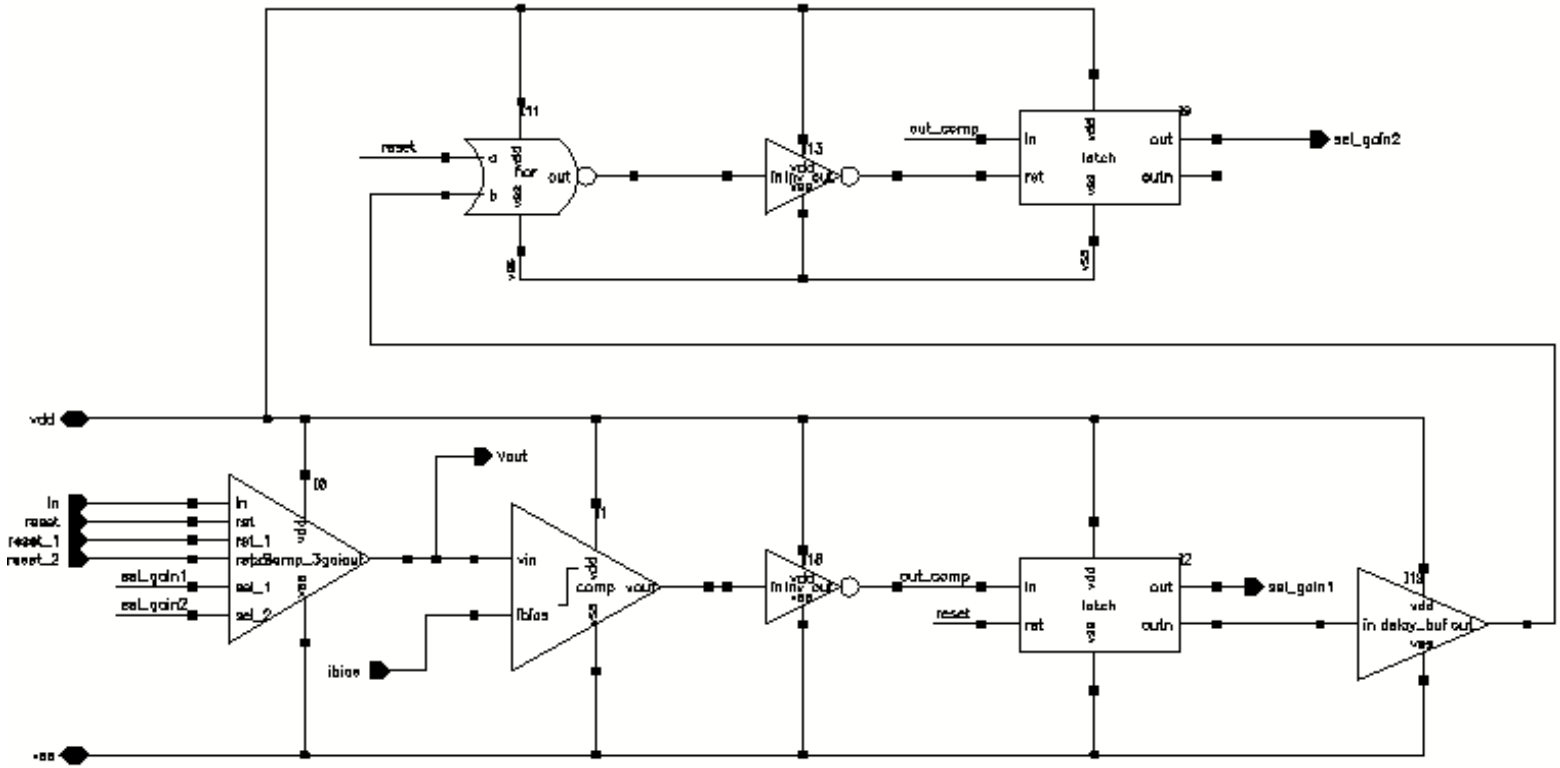
Voltage to charge gain:

$$\Delta V / Q = A_{dc} / (C_{input} + C_{int} + A_{dc}C_{int})$$

Main problems and solutions:

- Charge injection => CDS
- Input voltage peak => transmission gate as the switch for the intermediate gain stage.

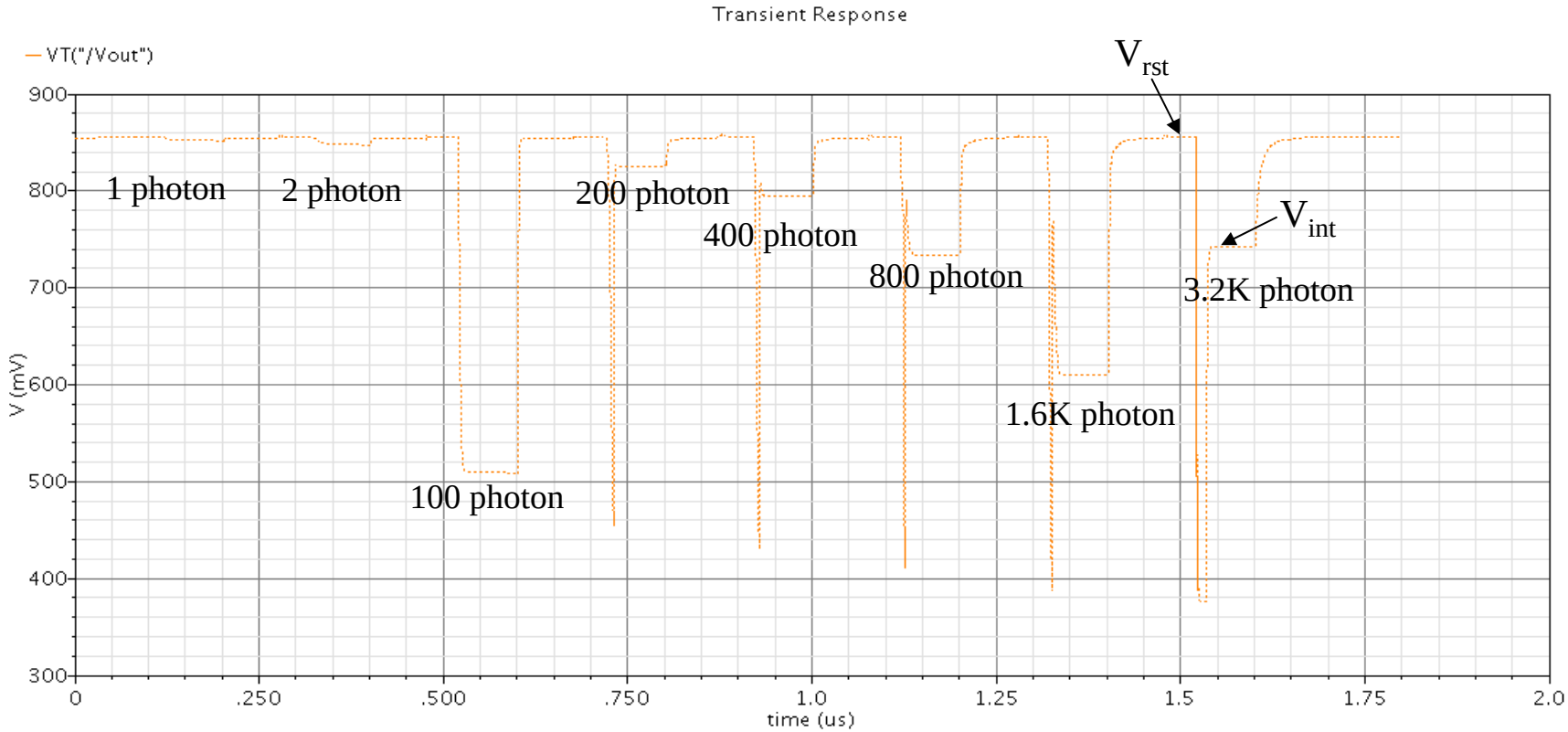
Adaptive Gain Control



No accidental switching-on of the highest gain stage.

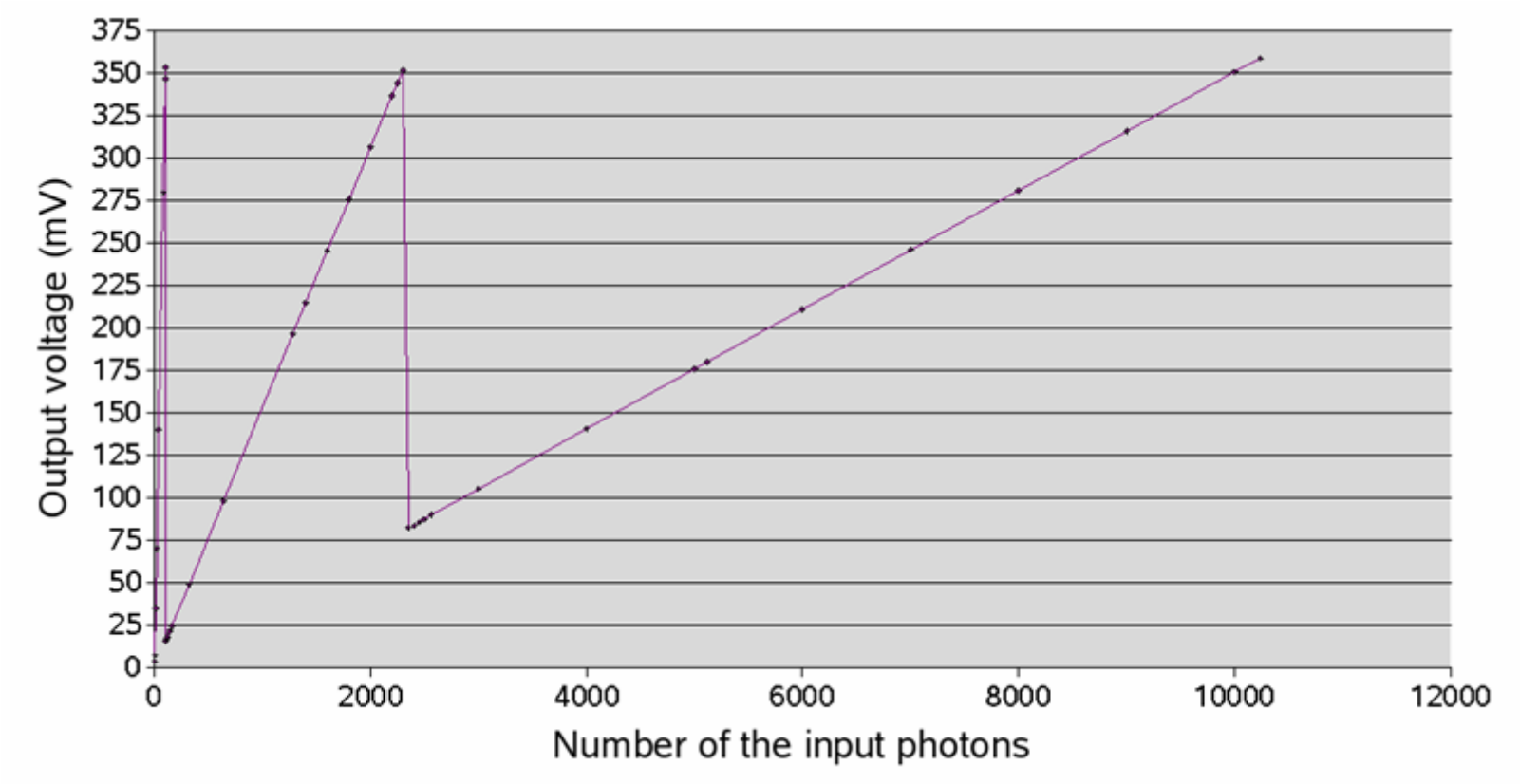
Simulation of the Input Amplifier

The output voltage waveform for different numbers of input photons



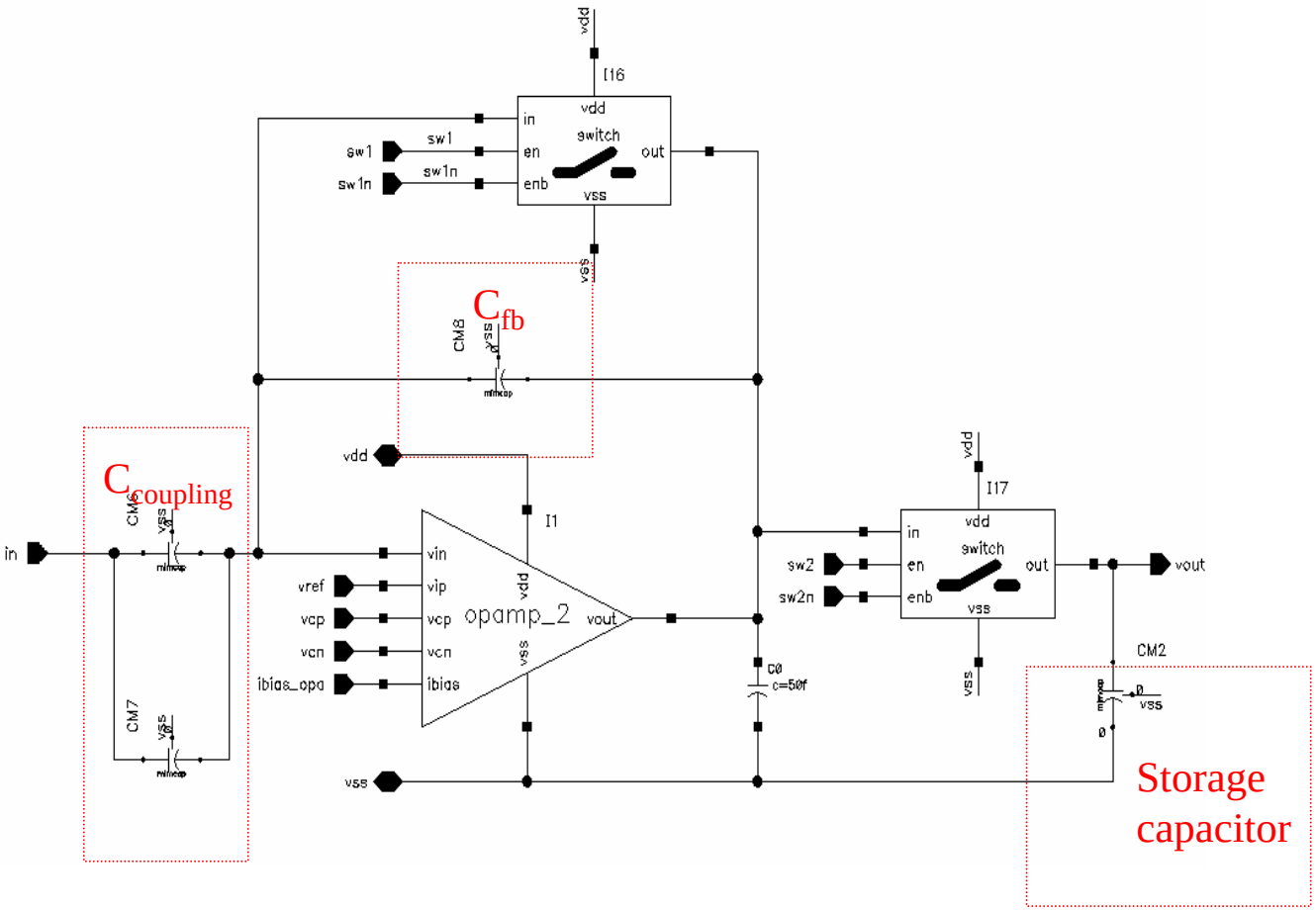
- The maximal conversion gain: ~ 3.5 mV / photon (with 3k electron / photon).
- Output noise: ~ 0.3 mV.

Simulation of the Input Charge Amplifier



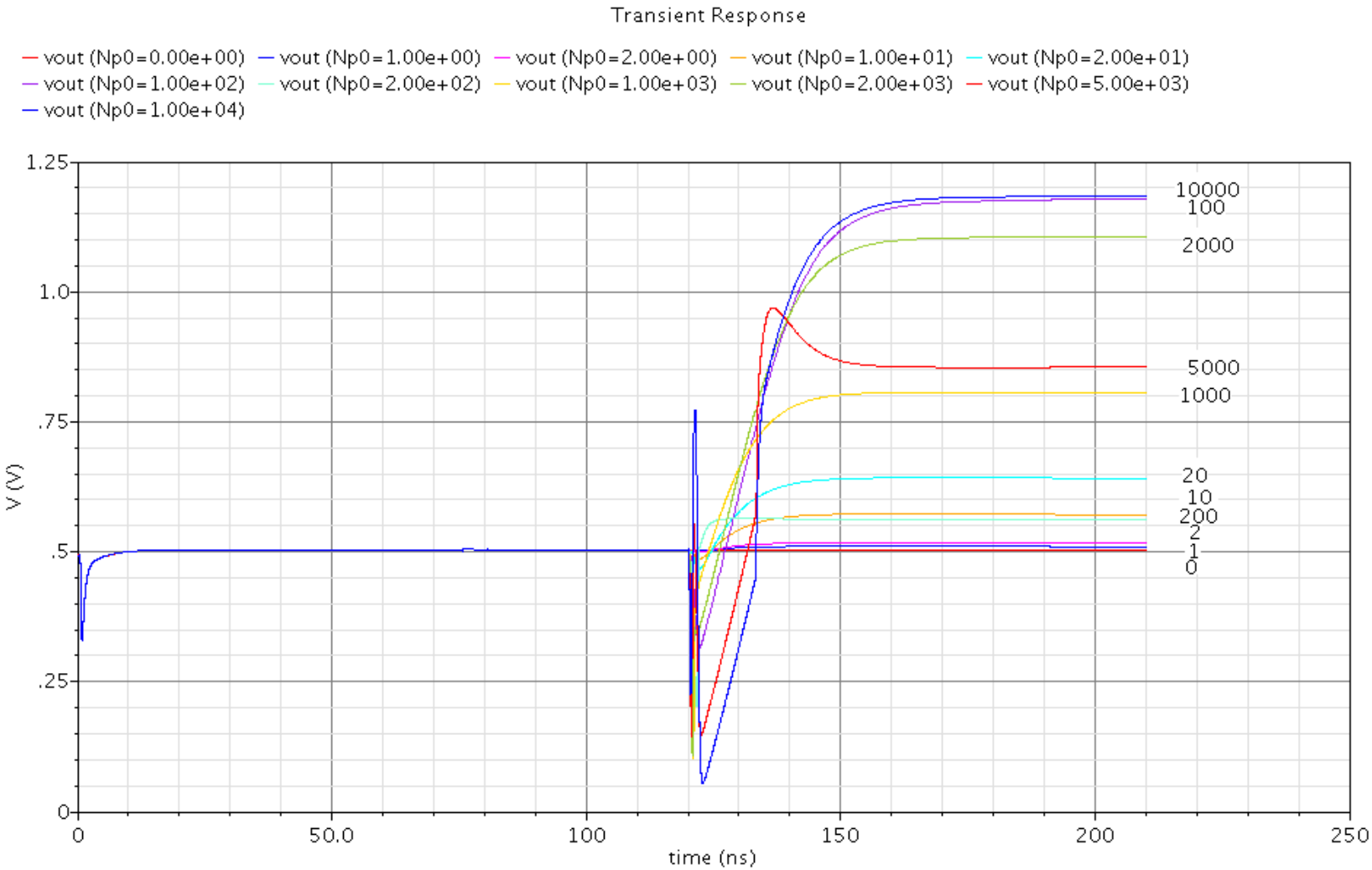
- The highest gain : ~ 3.5 mV / photon 1 – 102 photons.
- The medium gain: ~ 0.15 mV / photon 103 – 2300 photons.
- The lowest gain: ~ 0.035 mV / photon 2300 – 10000 photons.

Output Amplifier with CDS

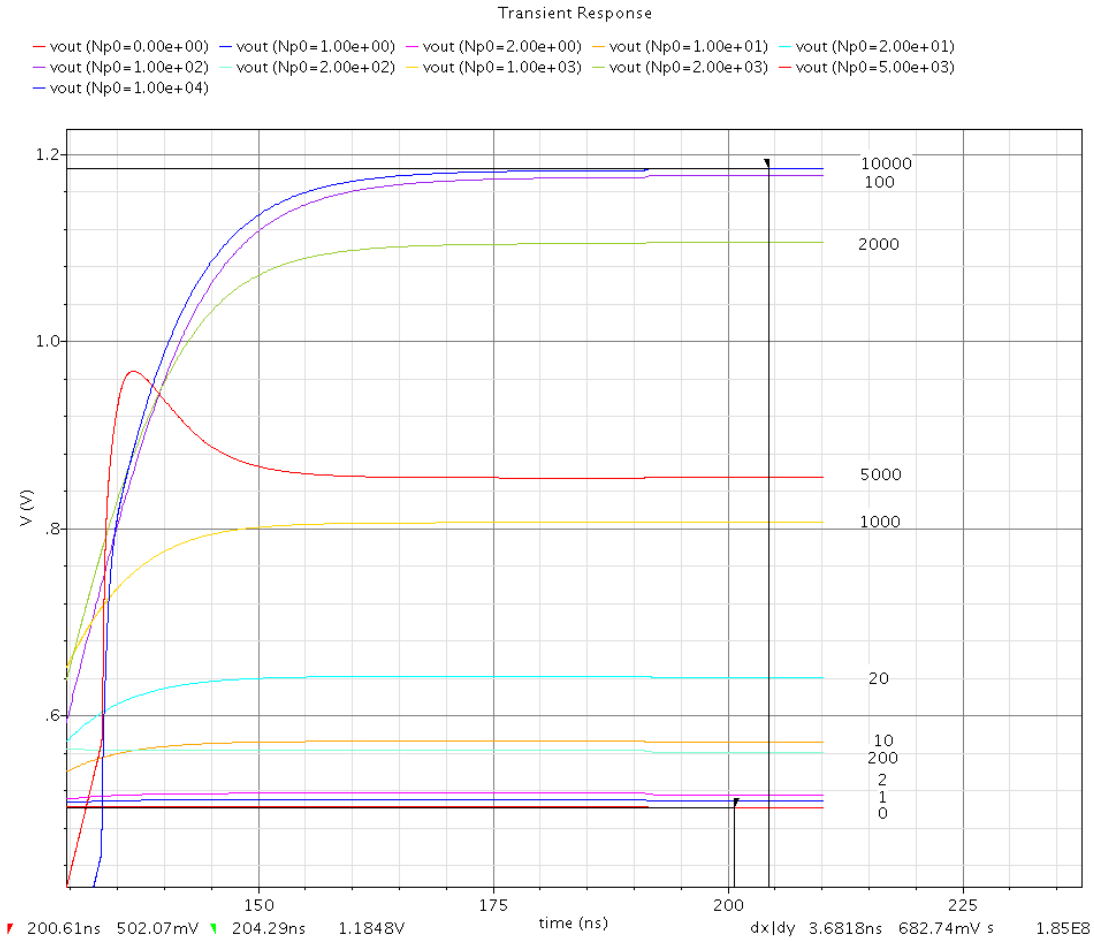


$$V_{out} = V_{ref} + (V_{rst} - V_{int})\, C_{coupling} / C_{fb}$$

Simulation of the Output Amplifier



Simulation of the Output Amplifier



No. of Photon (mV)	V_{out} (mV)
1	6.95
2	13.91
10	69.62
20	139.46
100	675.19
200	59.48
1000	304.7
2000	604.35
5000	352.83
10000	682.47

Conclusions

- A read-out circuit is designed and simulated at the schematic level.
- The input stage is an charge-integration amplifier with 3-adptive gain.
- The output stage performs correlated double sampling (CDS).
- Thanks to the adaptive gain, the input photon range can be 1 – 10^4.
- The CDS operation effectively reduces the offset and low frequency noise.

Future works

- Optimize the circuit for minimizing the noise.
- Extensive simulations for process, supply and temperature variation.
- Layout design with radiation tolerant technique, e.g. Enclosed layout transistor (ELT).

Questions ?