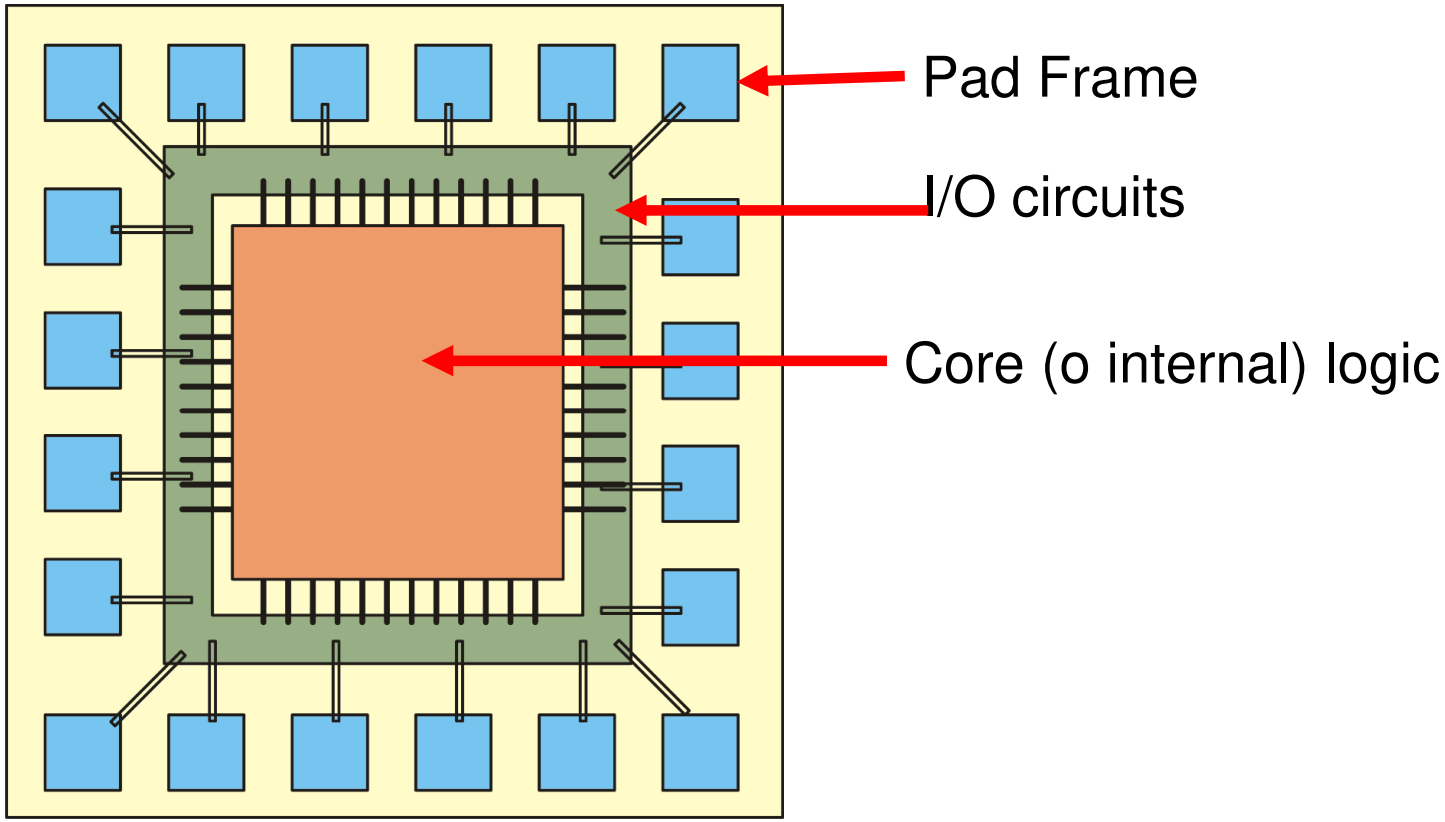
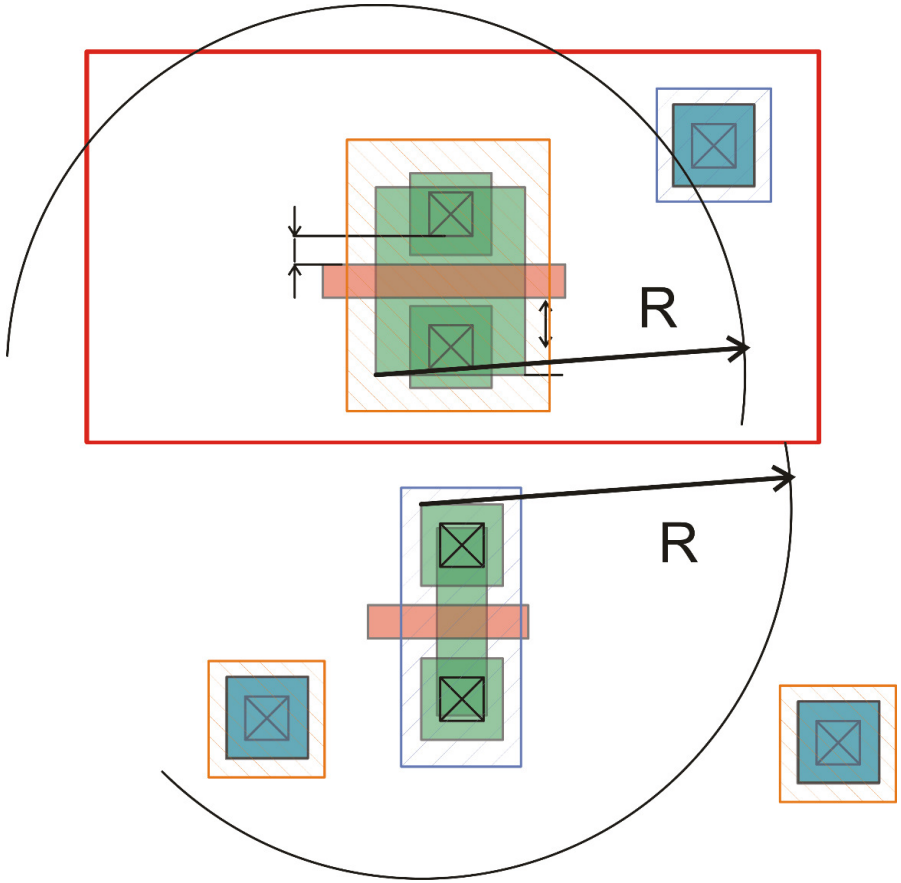
Typical structure of a digital chip



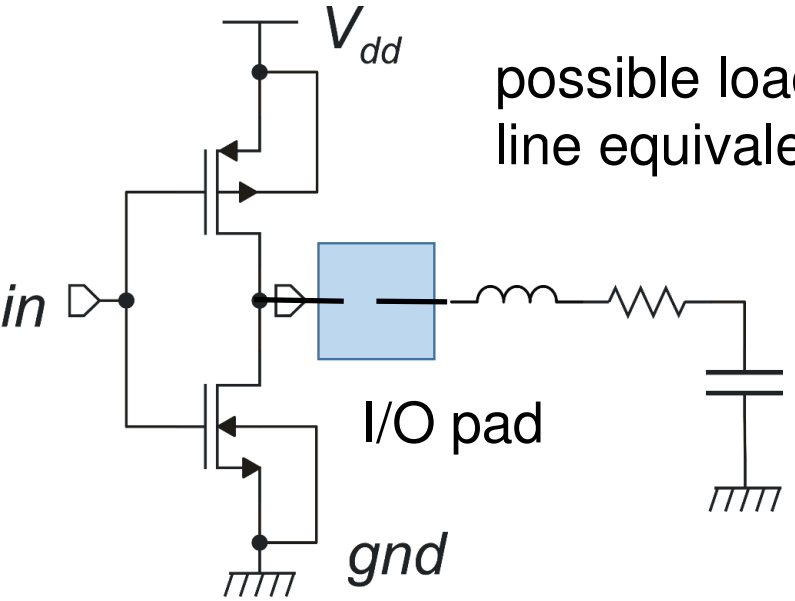
Latch-up layout rules: core logic



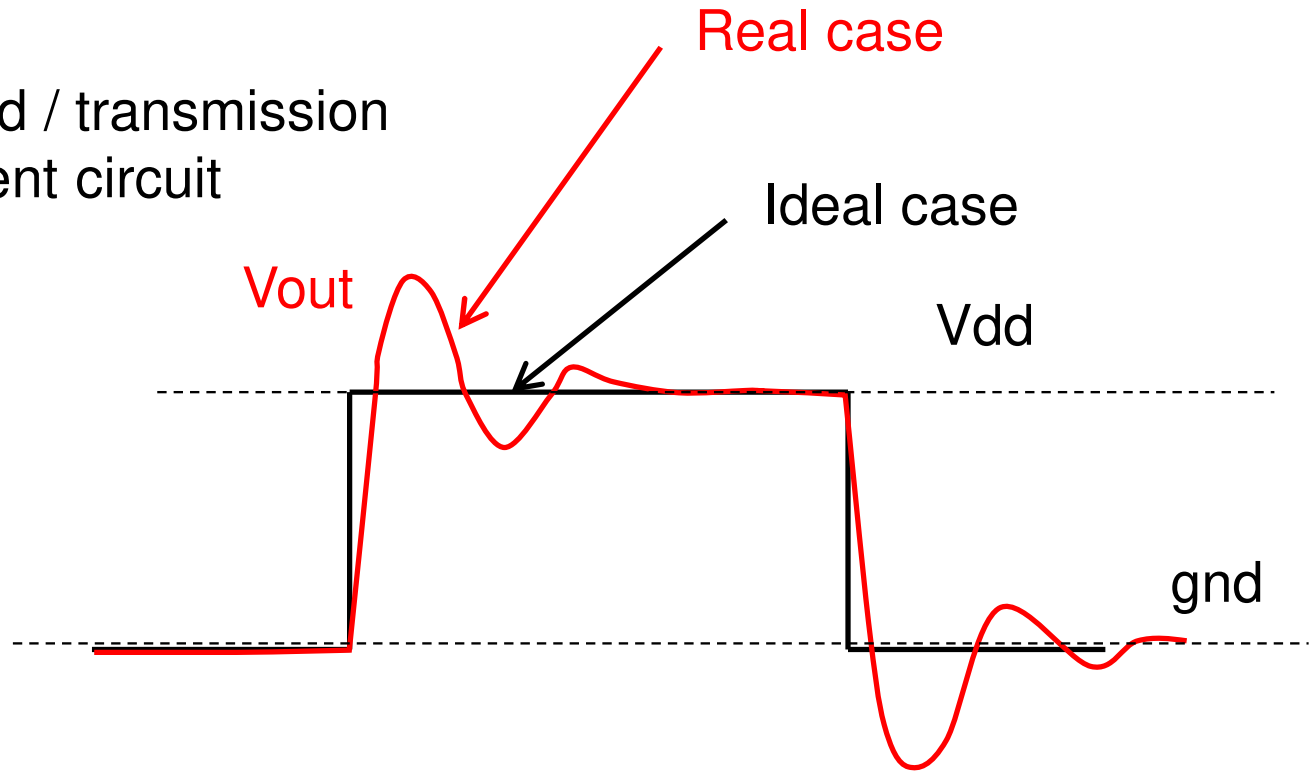
Every part of a p-active area in an n-well must "see" at least one well-tap with a maximum distance R

Every part of an n-active area in the substrate (p-well) must "see" at least one substrate-tap with a maximum distance R

I/O circuits: over-voltage risk



possible load / transmission line equivalent circuit

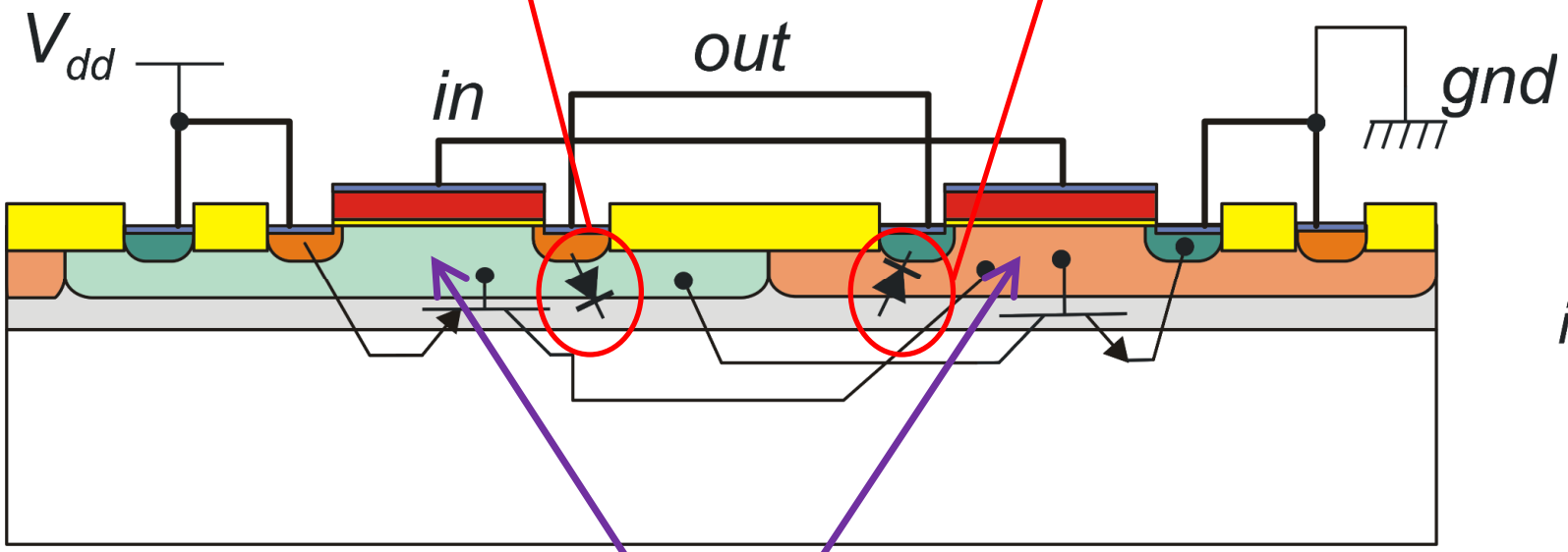


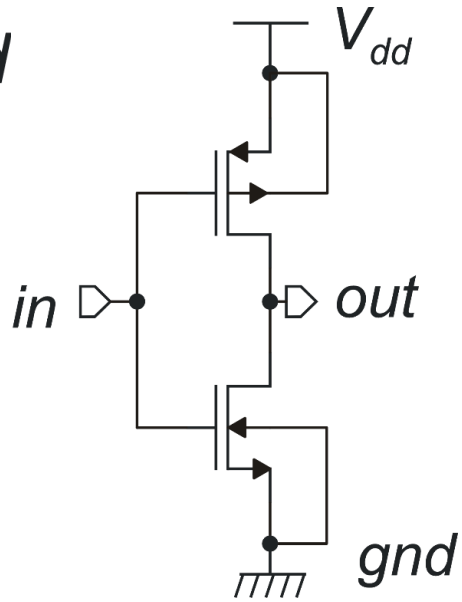
In I/O circuits, the output termination can exceed the Vdd or gnd rails. This introduces additional risk of latch-up

Injection of minority carriers

when Vout exceeds Vdd,
this diode is turned on

when Vout drops below gnd,
this diode is turned on

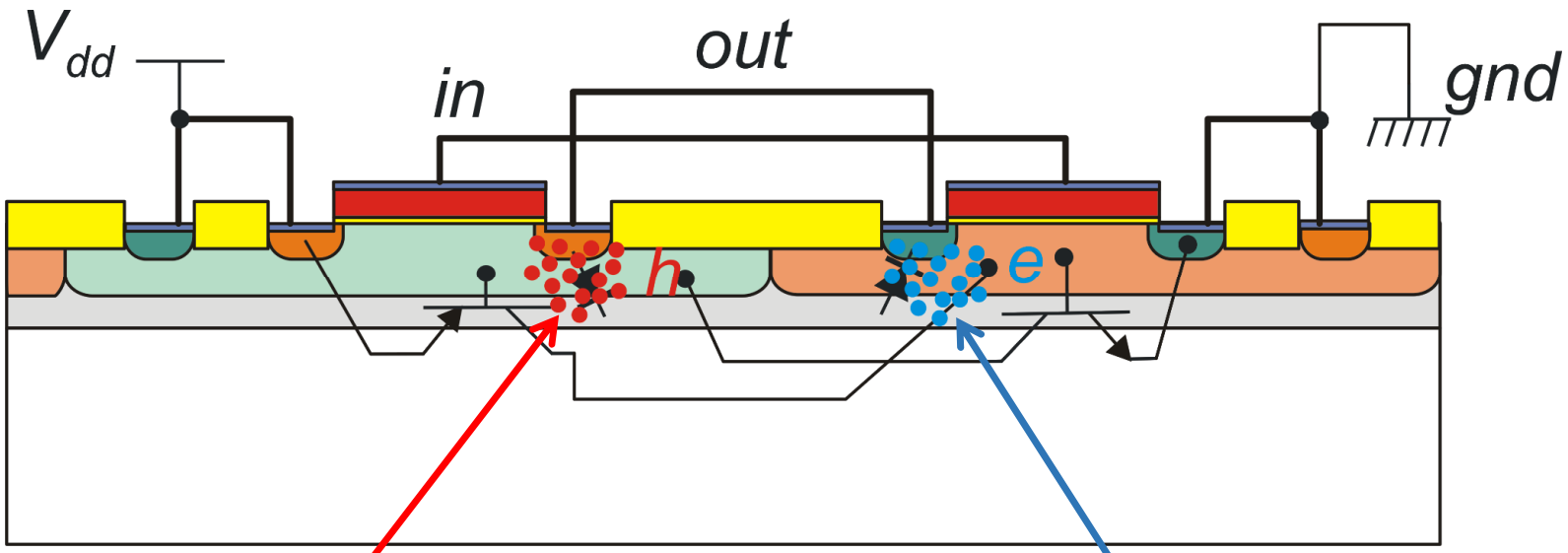




Well: bases of the pnp BJT (collector of npn BJT)
Substrate: bases of the npn BJT (collector of pnp BJT)

Injection of minority carriers

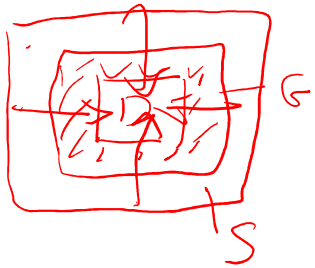
Injection of minority charge carriers into the parasitic BJTs bases may trigger the latch-up phenomenon



Hole injection into the n-well when $V_{out} > V_{dd}$

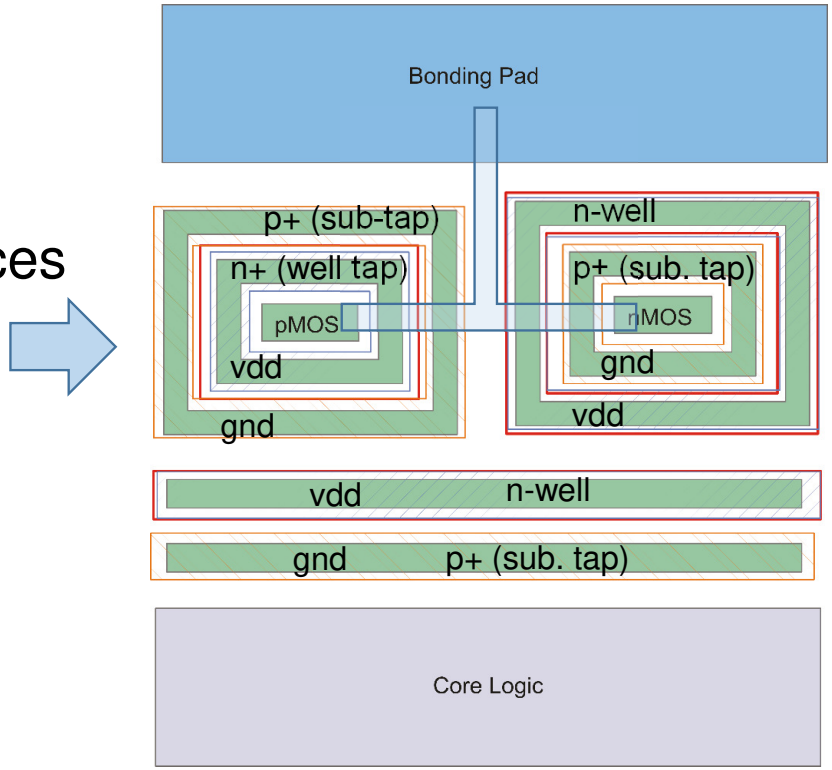
Electron injection into the substrate when $V_{out} < 0$

I/O devices: Guard Rings



I/O circuits require additional protection against latch-up

I/O devices



Guard rings are placed around the I/O devices in order to:

- Reduce the resistance between drain/body diffusions to gnd (nMOS) or Vdd (pMOS)
- Collect most of the minority carriers injected by one device before they reach neighboring devices

These guard rings further reduce the effects of the I/O devices on the core logic

Analog and mixed signal chips

- For the analog section of a System on a Chip, it is not convenient or even impossible to divide the circuit into a core section and an I/O section.
- However, the same rules illustrated for digital chips apply to the output devices of the analog cells (for example, operational amplifiers), which are connected to output pads. High density of substrate / well contacts, guard-rings and particular layout configurations are common practice for the output devices of analog circuits.