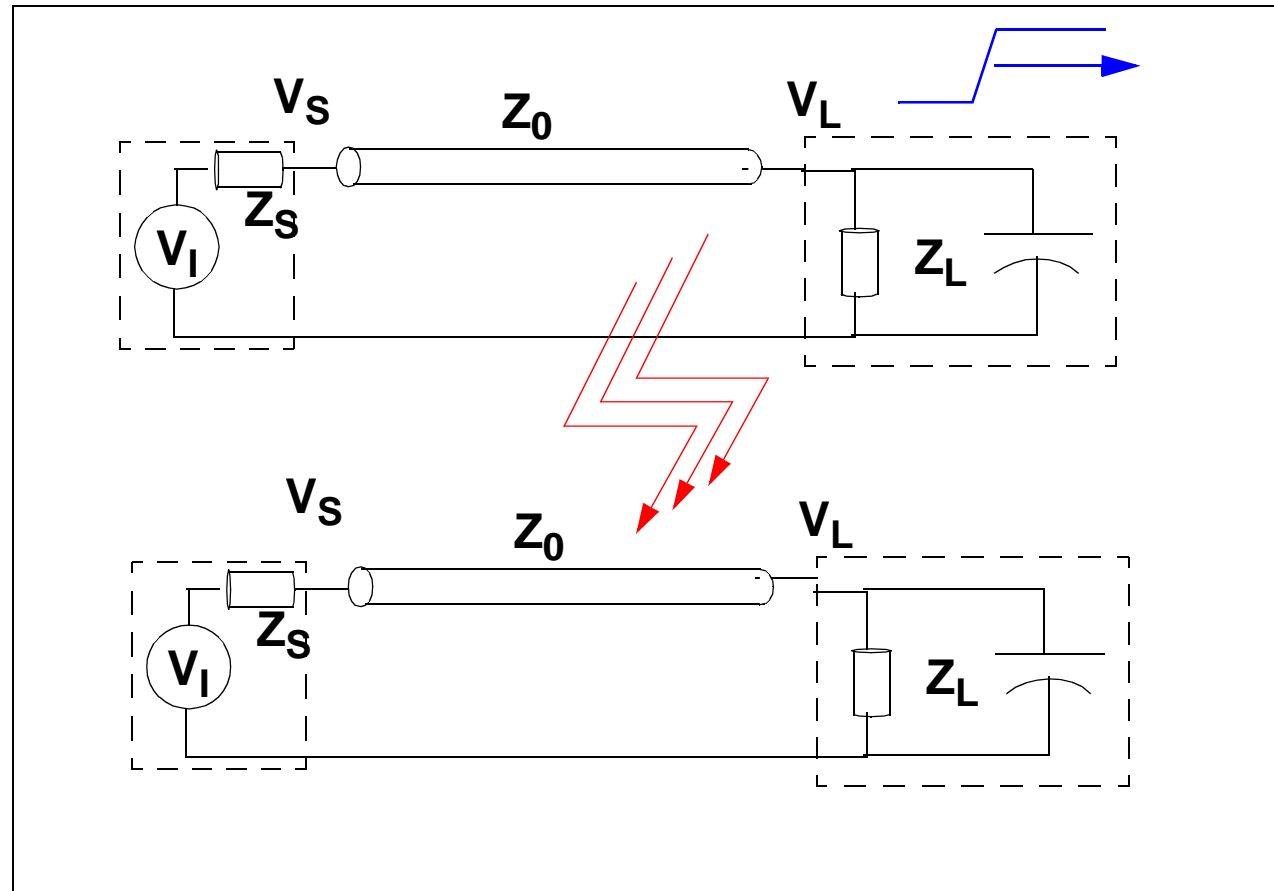
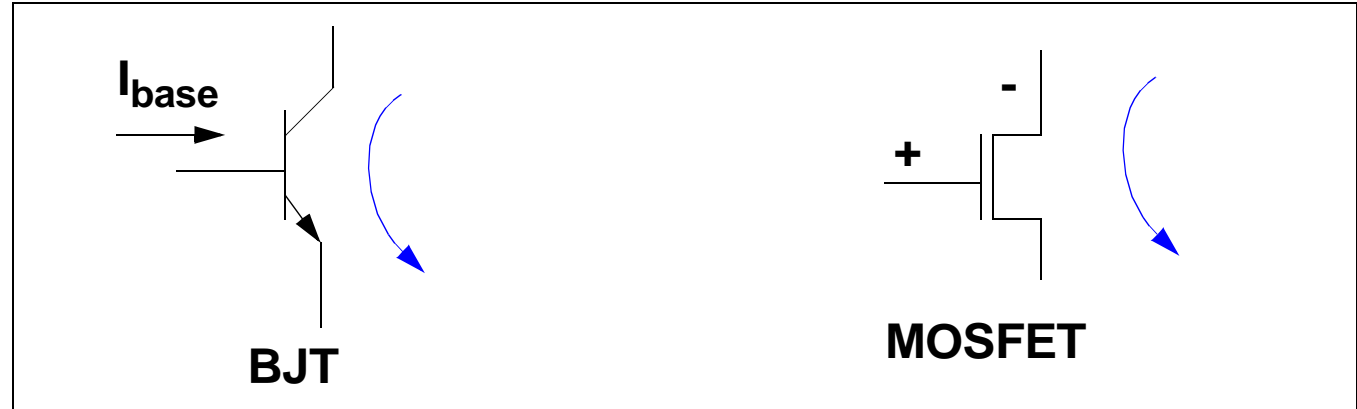


Wires Part II and Signalling



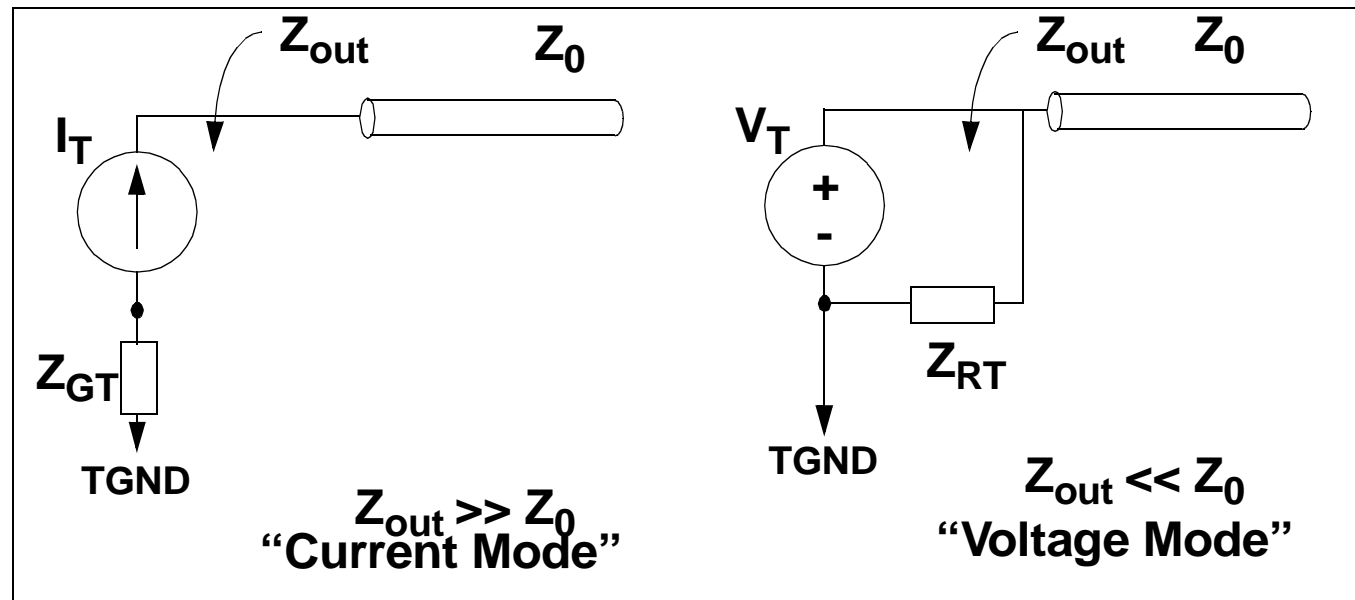
- More on transmission lines
- Termination
- Crosstalk

Voltage and Current Mode I



- **BJT: Current controlled current source**
- **MOSFET: Voltage controlled current source**
- **Current and voltages at output controlled by careful design of resistors values**
- **“On resistance” of MOSFET is low. “Off resistance” of MOSFET is high**
- **“resistance” through BJT is always high**

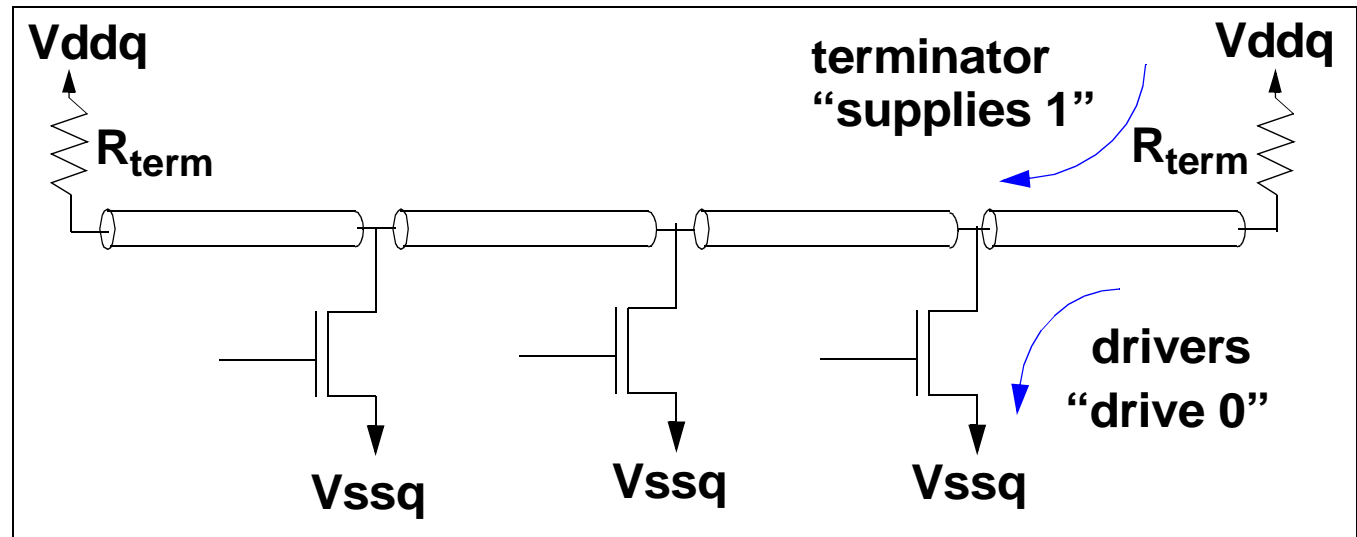
Voltage and Current Mode II



$$V_T = I_T Z_0$$

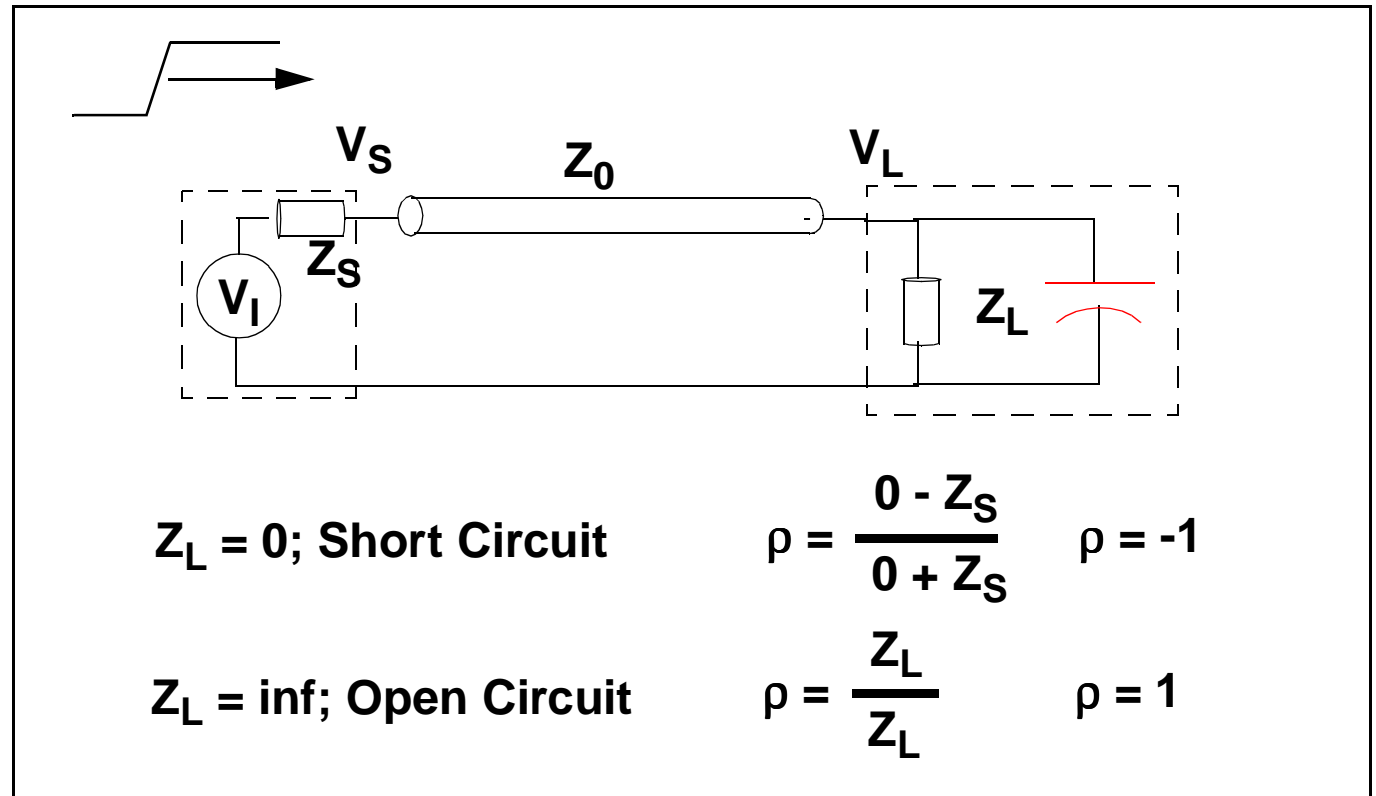
- “1” and “0” represented by +/- of voltage or current from transmitter perspective
- Receiver sees voltage differential.
- No “pure” voltage-mode or current mode.
- Z_{GT} is high. Isolates circuit from noise on power planes.
- If $Z_{out} \gg Z_0$, current mode. $Z_{out} \ll Z_0$, voltage mode

“Wired Or” Bus



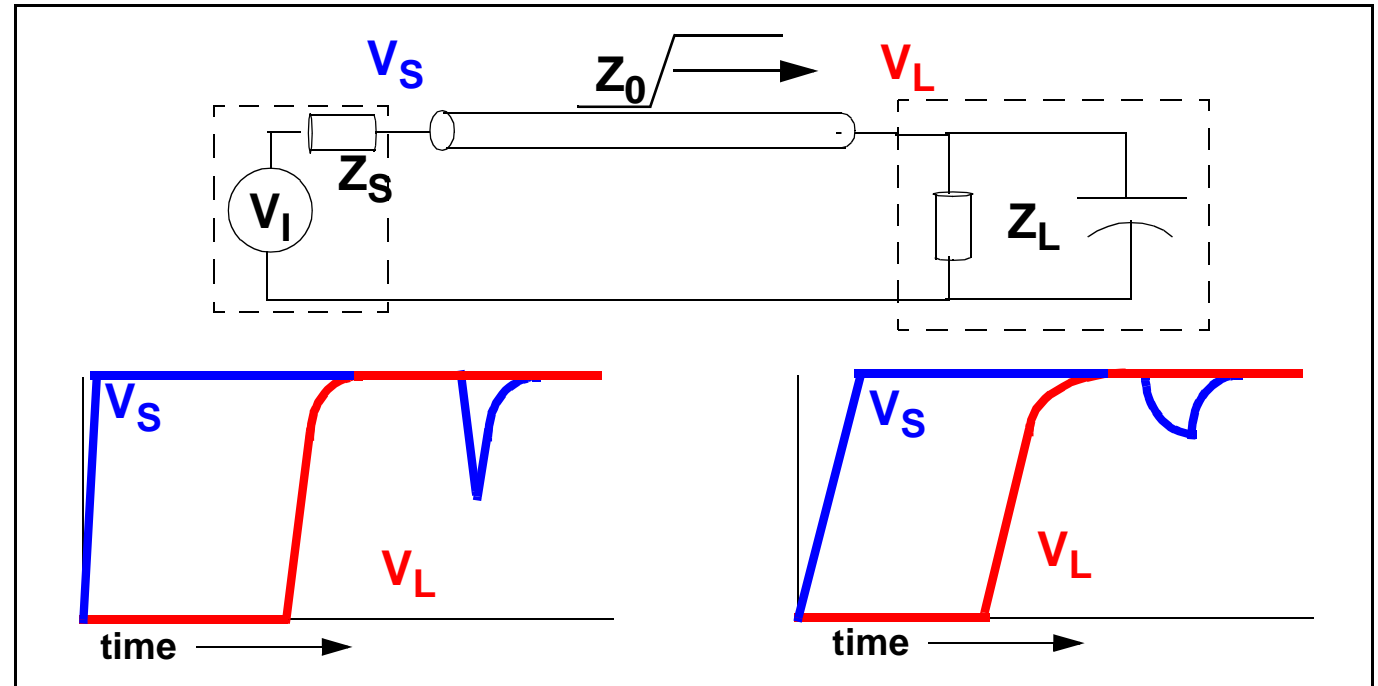
- Terminating resistor supplies “1”, voltage on bus is equal to V_{ddq} when no driver is active
- Driver sinks current to V_{ssq} when it needs to drive “0”
- Power consumed when “driving 0” and active current sinks

Capacitive Termination I



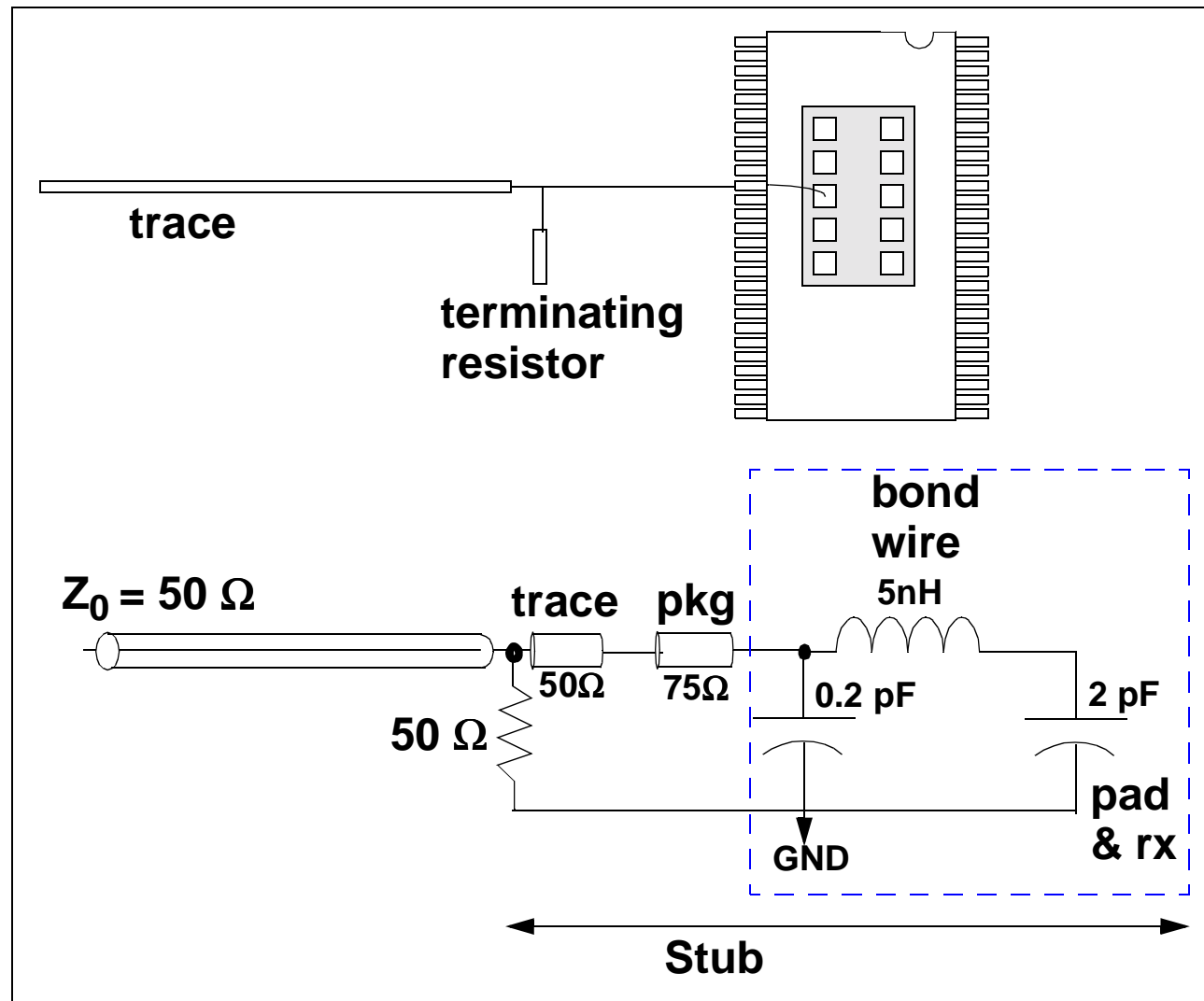
- Capacitors behave like short circuit when not charged. Once charged, behaves like open circuit.

Capacitive Termination II



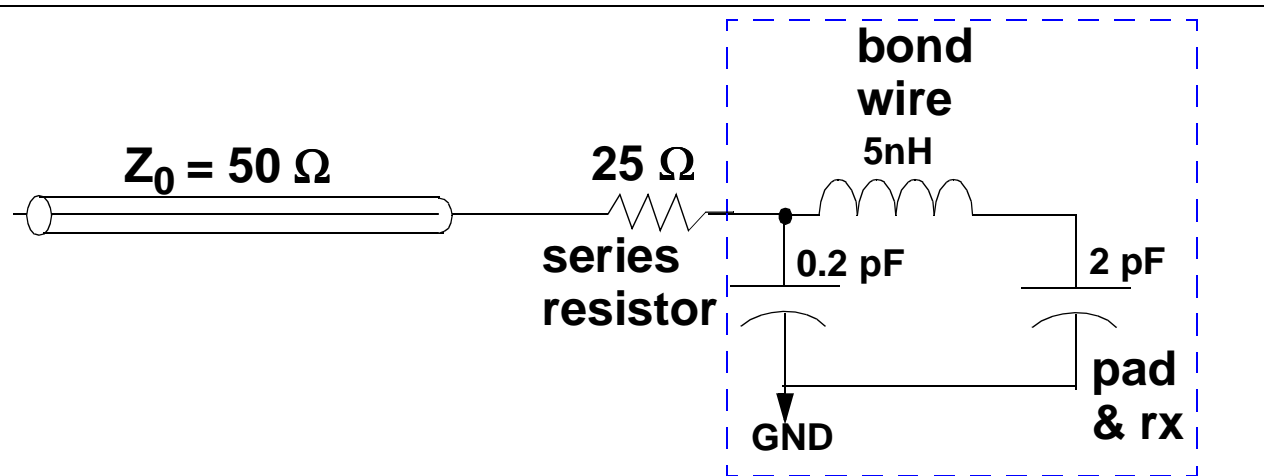
- When “shorted”, V_S is reflected with the same magnitude back toward source.
- The “magnitude” here is the “magnitude” of rise time.
- To minimize glitch, limit slew rate.

What is a Stub?



- Signal path inside of package also significant

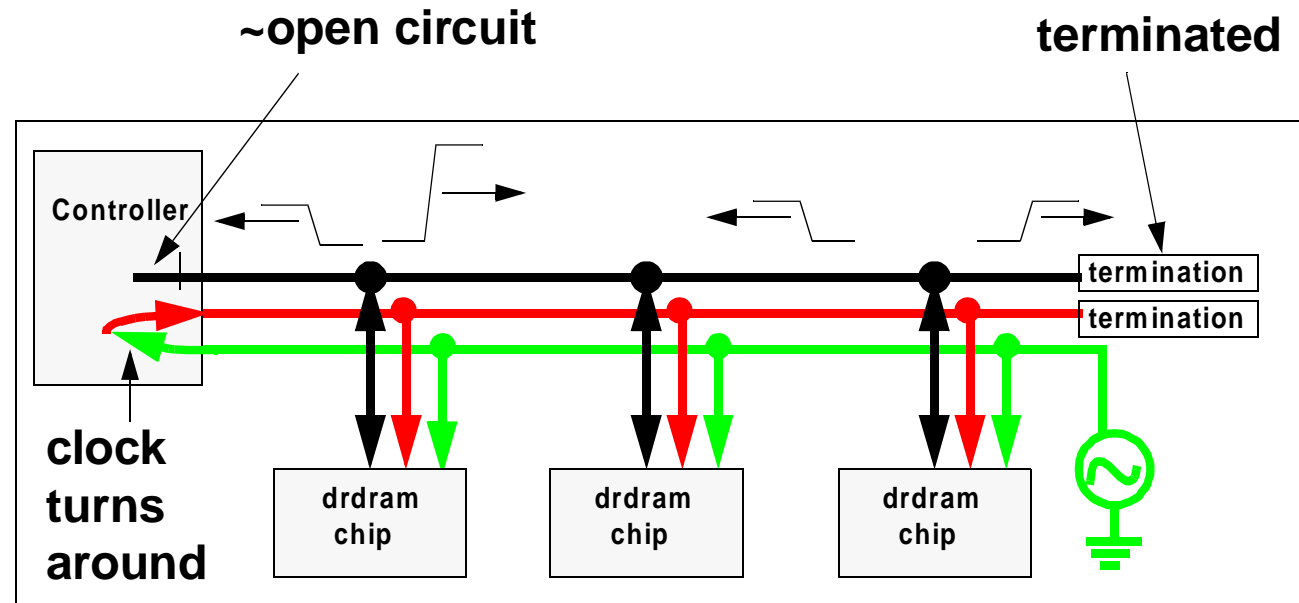
Series Stub Terminated Logic



$$\text{Reflection Coefficient} = \rho = \frac{Z_L - Z_S}{Z_L + Z_S}$$
$$\rho = \frac{25 - 50}{25 + 50}$$
$$= -0.3333$$

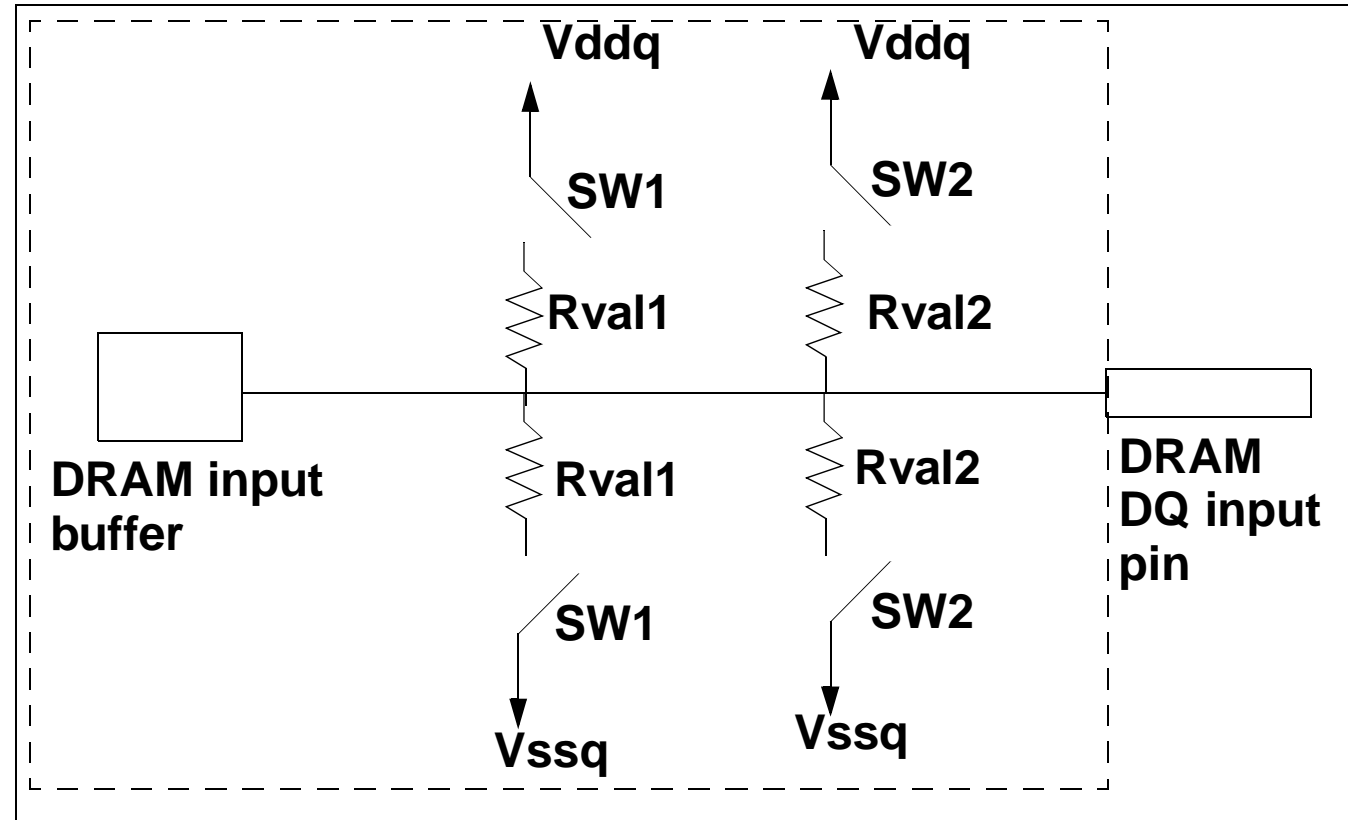
- Series resistor isolates stub from line
- reduces ringing
- reduces power

Rambus Signalling



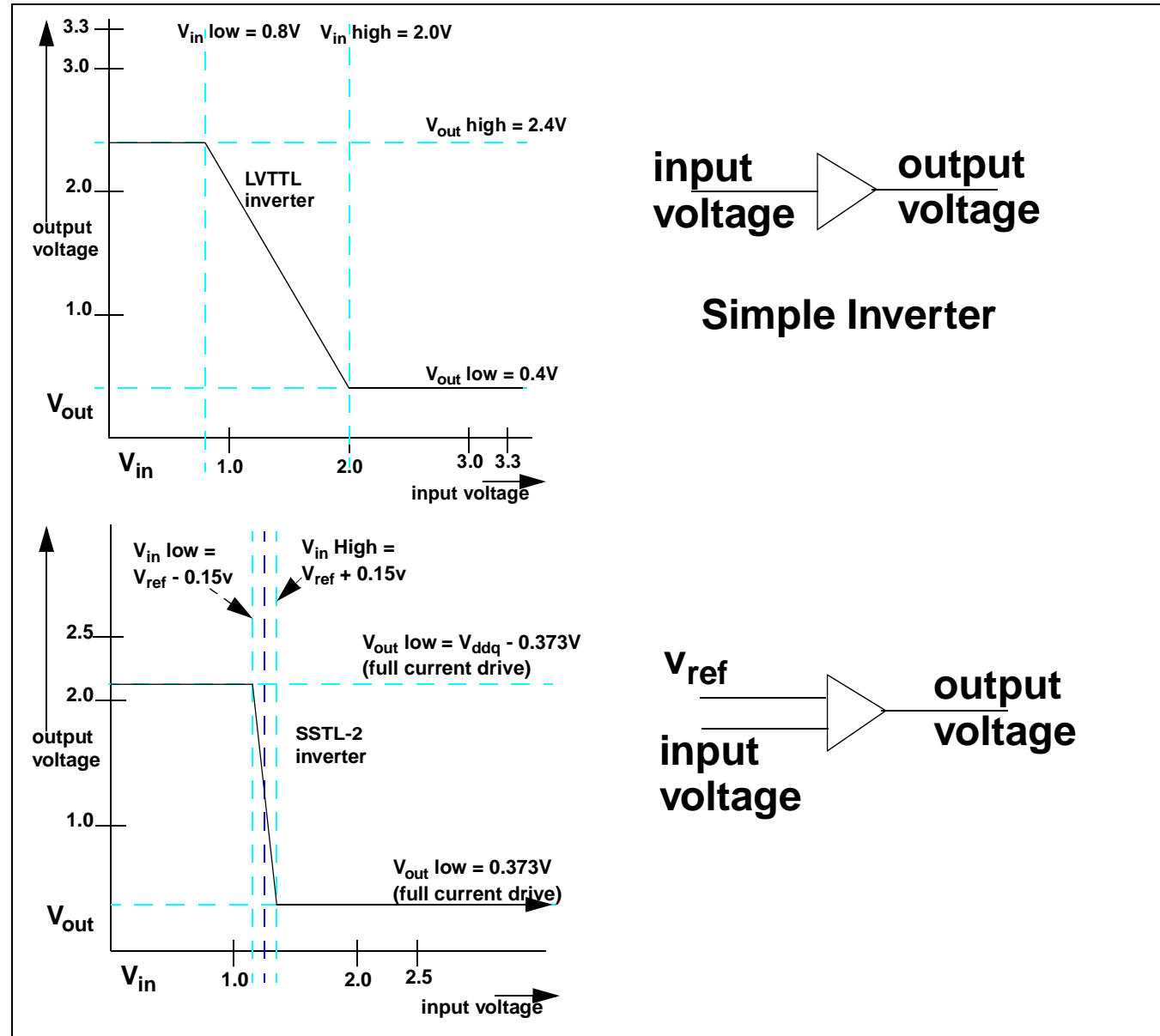
- Current mode
- Controller sends full height signal swings
- DRAM chips send half height signal swings
- Reflection off of controller driver creates full height signal swing
- Current control and voltage slewrate control

ODT: On Die Termination

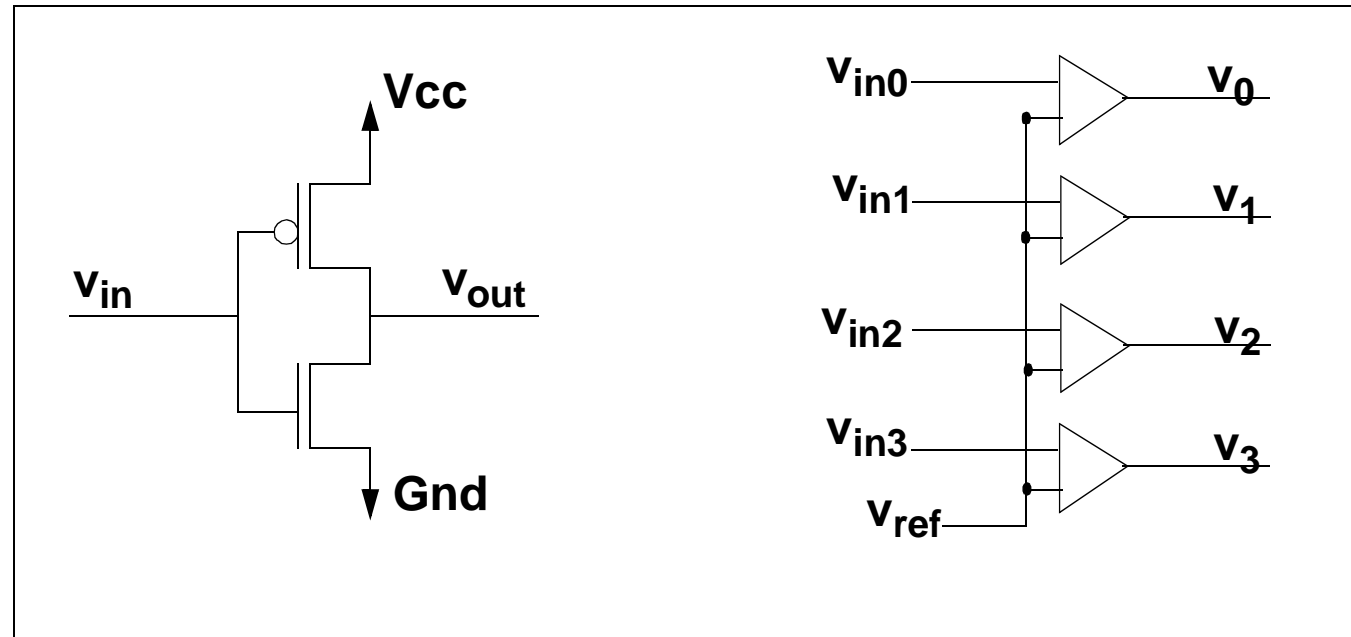


- Active, dynamic termination, depending on R/W, and number of loads on electrical bus
- Can be turned on/off in 2 cycles, off in 2.5 cycles
- Designed into DDR II

Input Buffering - References I

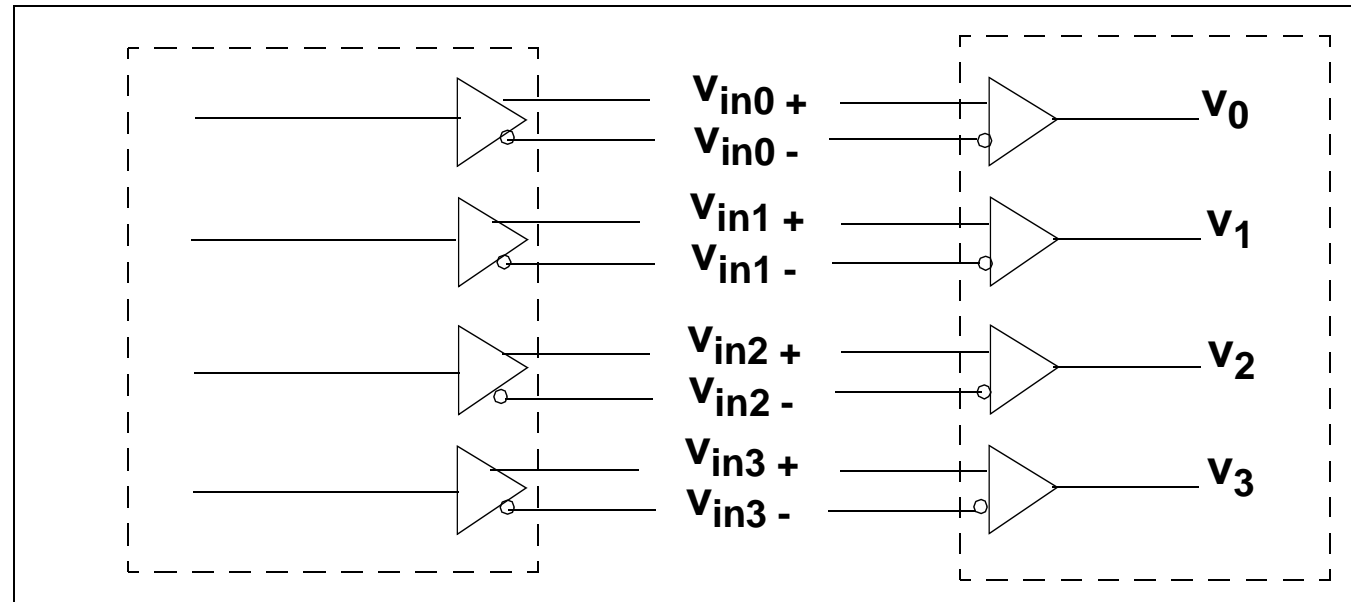


Input Buffering - References II



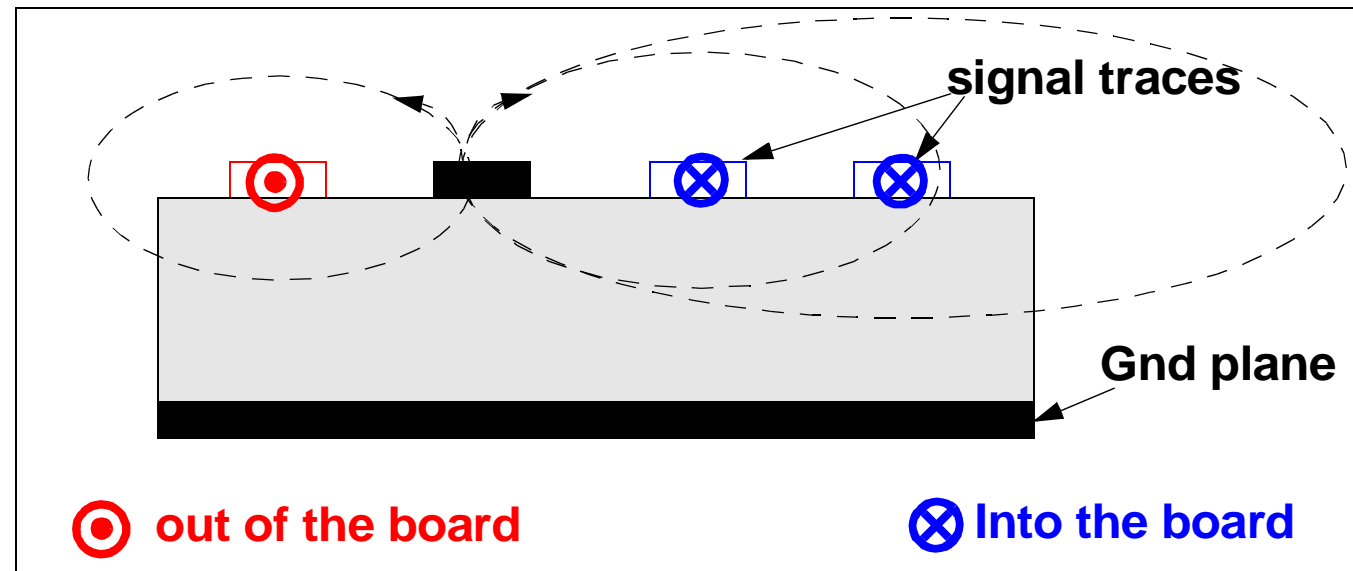
- Inverters aren't very good for high frequency signalling
- Local or remote reference?

Differential Signalling



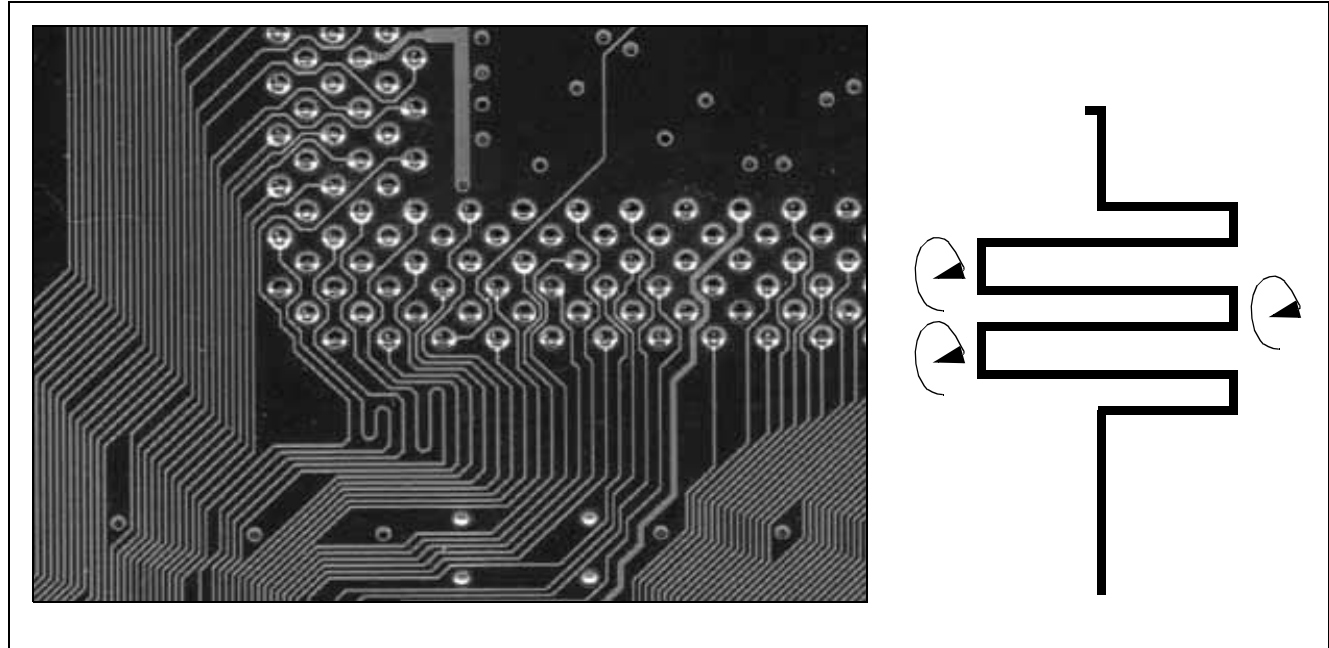
- Send the signal and its complement
- The complement signal path is the current return path
- Signal pairs must be routed closely together
- Signalling scheme can reject common mode noise quite well

Crosstalk I



- Signals should couple to ground to minimize EM.
- If EM fields do not cancel, could induce voltage/current excitation in nearby victim line.
- Magnitude of crosstalk depends on current magnitude current loop area(s) AND signal patterns on “aggressor” lines

Crosstalk II



- Routing of wires done for path length matching may in fact have slightly different “electrical distance” due to segments of the wire coupling to itself