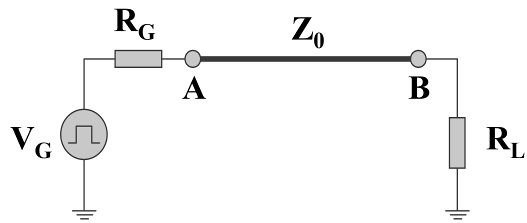
Chapter 4_2
Signal Integrity in Digital Design

Reflexion



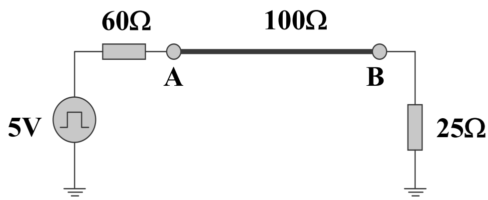
$$\rho = \frac{Z - Z_0}{Z + Z_0}$$

$$\rho_A = \frac{R_G - Z_0}{R_G + Z_0}$$

$$\rho_B = \frac{R_L - Z_0}{R_L + Z_0}$$

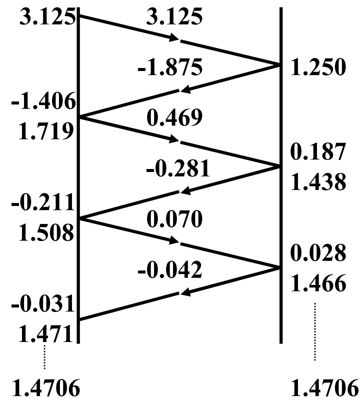
At any discontinuity in the signal path there is a reflexion. Also at the ends (generator and load) in case they are not adapted. Reflexion coefficient varies between +1 and -1. It is zero when impedance is adapted (no change)

Reflexion: An example (1)

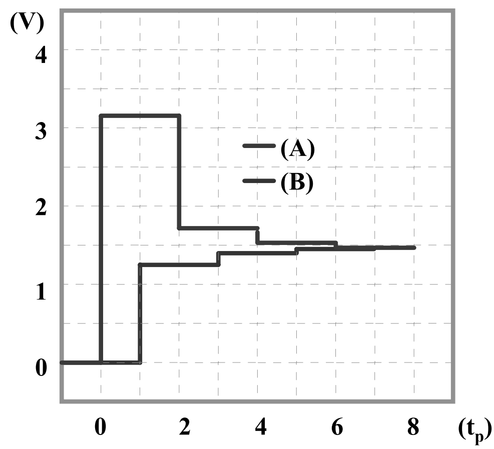


$$\rho_A = \frac{R_G - Z_0}{R_G + Z_0} = -0.25$$

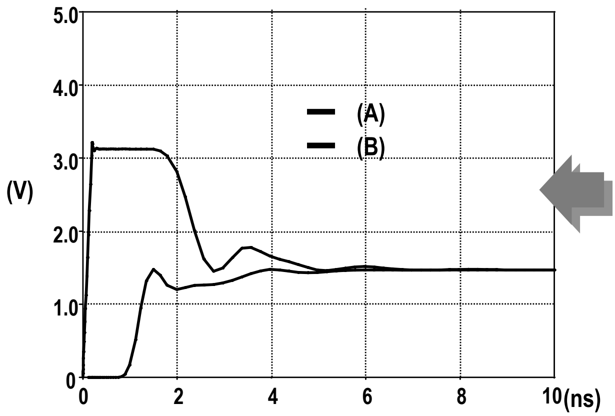
$$\rho_B = \frac{R_L - Z_0}{R_L + Z_0} = -0.6$$



Reflexion: An example (2)

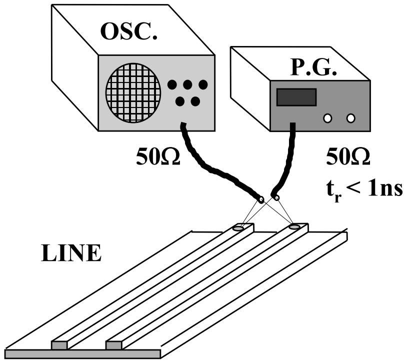


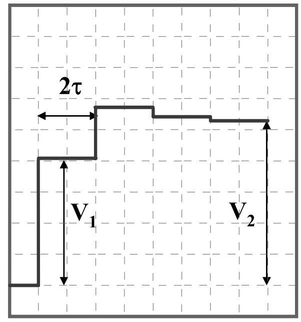
Reflexion: Simulation (3)



DATA:
l = 10 cm
$Z_0 = 100\ \Omega$
t_0 = 10 ns/m
t_r = 0.2 ns
t_r/t_0 = 2 cm
n = 32 elem.

TDR

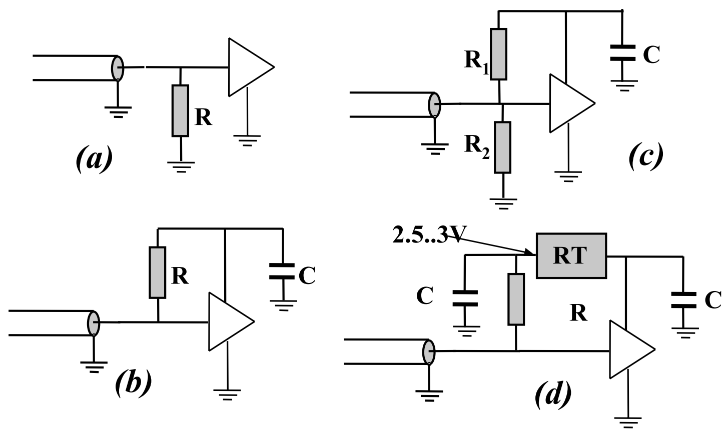




Resolution: $x_{min} = \frac{t_r}{t_0}$

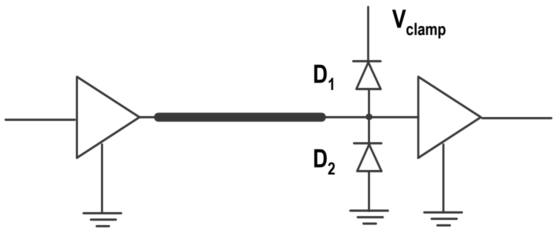
$$Z_0 = \frac{25}{V_2/V_1 - 1}\Omega\ ;L' = \tau \cdot Z_0\ ;C' = \tau / Z_0$$

Line Terminations (1)



Clamping Diodes

Clamping diodes to absorb reflexions

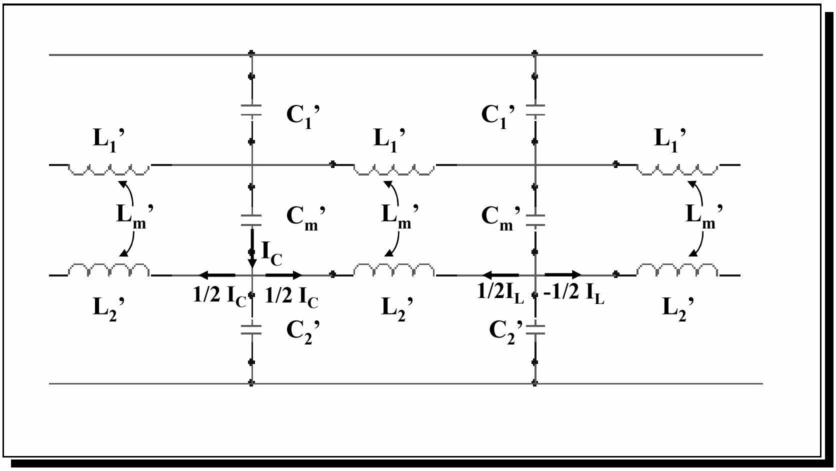


D_1 clips above $V_{clamp} + V_D$

D_2 clips below $-V_D$

- Internal diodes are sometimes unable to absorb the current
- External diodes must be fast enough. Usually *Schottky* type

Coupled lines (1)



Coupled lines (2)

- In most of practical situations coupling is week.
  In that case, line Impedance changes only slightly.

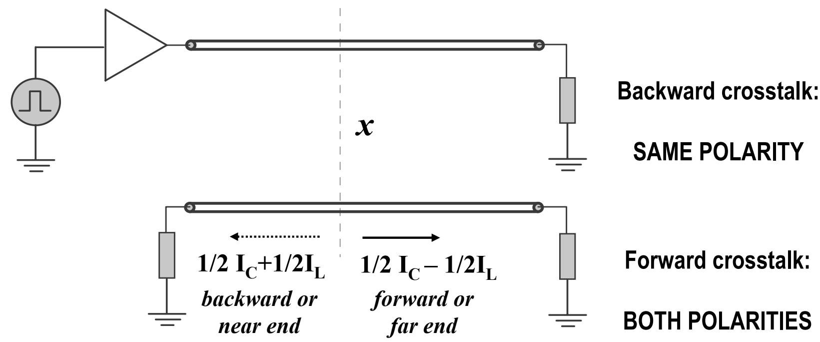
$$Z_1 = \sqrt{\frac{L'_1}{C'_1}} \qquad k_m = \frac{L'_m}{\sqrt{L'_1 L'_2}}$$

magnetic copupling

$$Z_2 = \sqrt{\frac{L'_2}{C'_2}} \qquad k_c = \frac{C'_m}{\sqrt{C'_1 C'_2}}$$

electrostatic coupling

Crosstalk (1)

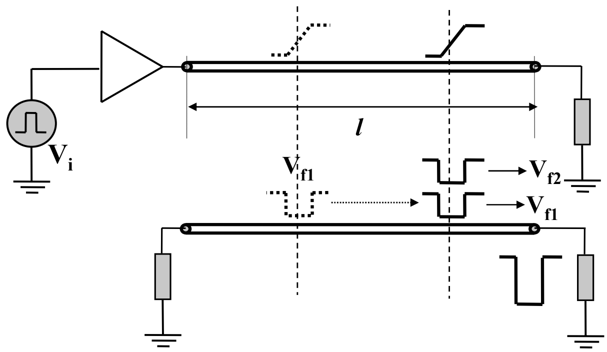


The two induced currents, capacitive and inductive, add with sign to produce two types ot Crosstalk: Backward and Forward

Backward or near end Crosstalk happens at the passive line end corresponding to active line generator end. It has always the same polarity as the active line signal.

Forward or far end Crosstalk happens at the passive line end corresponding to the load end of active line. It may have any polarity or even cancel.

Crosstalk (2)



FORWARD

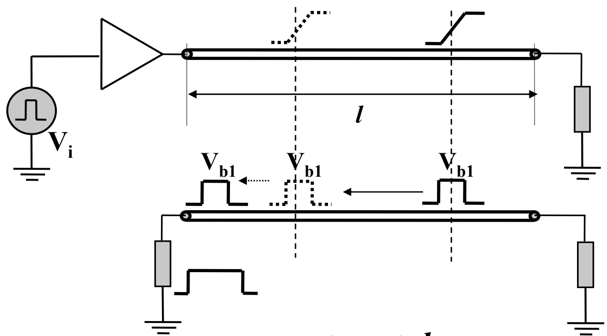
$$t_{dd} \propto t_r\,(t_f)$$

$$V_{dd} \propto l_{par}\frac{dV_i(t)}{dt}$$

In forward crosstalk, both interfering and interference signals travel at the same speed and direction, thus interference signal amplitude increases while propagating, adding in phase.

This means that induced signal time span is independent of coupled length, depending only on interferent signal edge duration. On the contrary, amplitude depends on both dV/dt and coupled length.

Crosstalk (3)



$$t_{par} = t_0\, l$$

BACKWARD

$$t_{di} = 2\, t_{par}$$

$$V_{di} \propto \frac{dV_i(t)}{dt}$$

In backward crosstalk, interfering and interference signals travel at the same speed and opposite direction, thus interference signal time span increases while propagating.

This means that induced signal amplitude is independent of coupled length, depending only on interferent signal dV/dt. On the contrary, duration depends on coupled length.

Crosstalk (4)

$$k_m = \frac{L'_m}{\sqrt{L'_1 L'_2}} \Rightarrow k_m = \frac{L'_m}{L'_1}$$

$$k_c = \frac{C'_m}{\sqrt{C'_1 C'_2}} \Rightarrow k_c = \frac{C'_m}{C'_1}$$

SYMMETRIC LINE

TO DECREASE CROSSTALK:

- **DECREASE MUTUAL COUPLING (L_m' & C_m')**
- **INCREASE DOWN COUPLING (L_1' & C_1')**

MULTIPLY BY $(1+\rho)$ AT LINE ENDS !

Switching Noise (1)

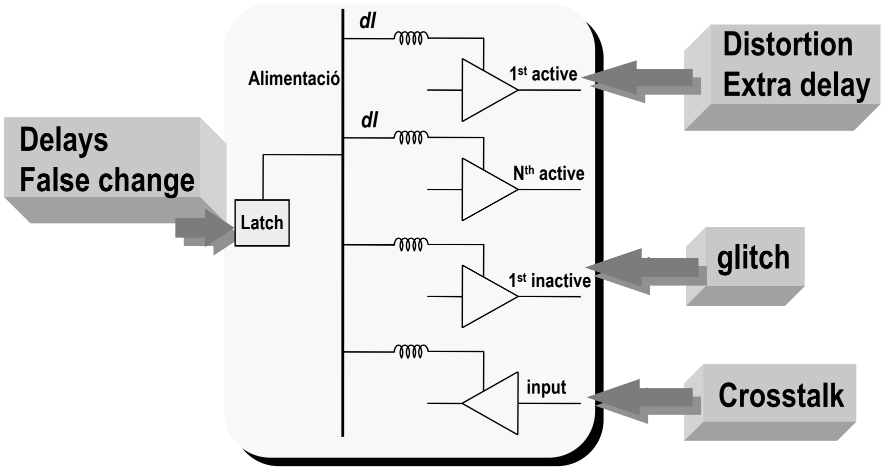
"inductive" noise caused by simultaneous switching of currents

$$V_c = N \cdot L_{eq} \cdot \frac{dI}{dt}$$

Depending on:

- Geometry (L_{eq}) and distribution (I) of SUPPLY's
- Geometry (L_{eq}) and distribution (I) of DATA lines
- Simultaneity factor (N)

Switching Noise (2)



Switching Noise (3)

NOISE	COUPLING	CAUSE
Switching	Supply lines	Inductive
Crosstalk	Signal lines	Inductive and Capacitive

Crostalk and Switching Noise are similar and sometimes difficult to separate

How to decrease Switching Noise: