Signal Integrity and Crosstalk effect

Errors Can Break Your ASIC!

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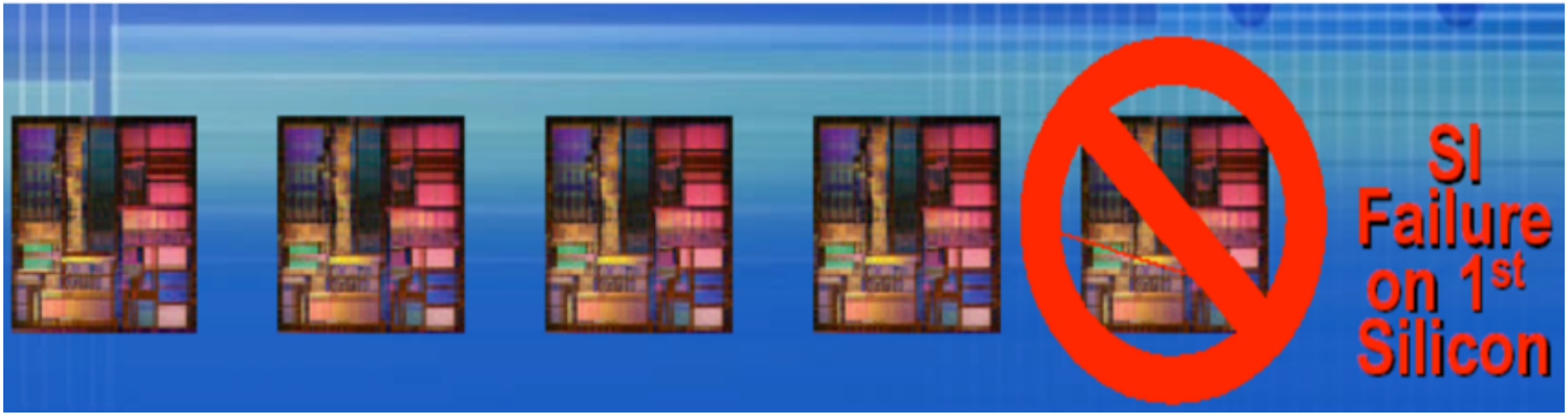
Introduction

According to the research conducted by Collett International Research Inc., in the year 2000, one in five chips fail because of the signal integrity issue as illustrated in Figure



This is really a significant effect on the yield of the chip production

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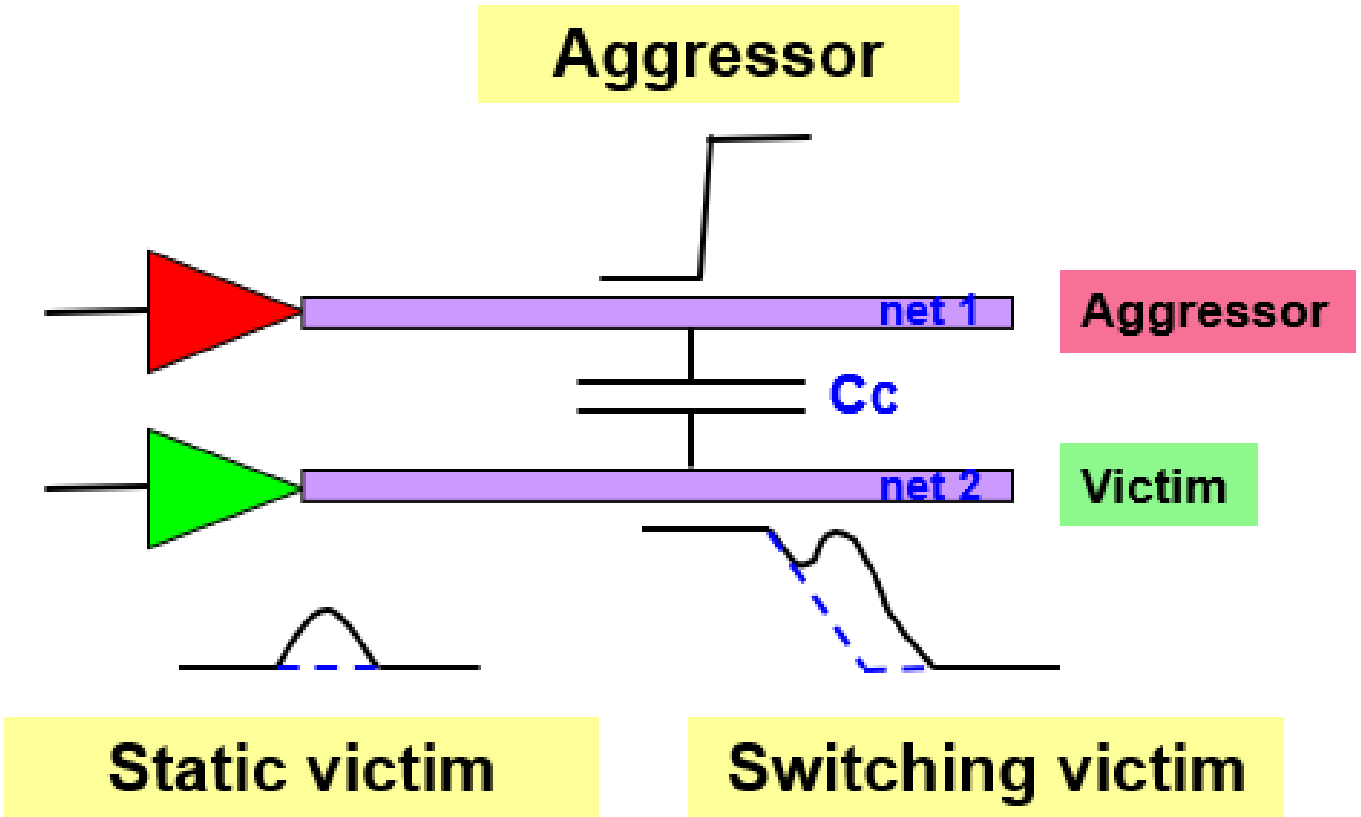
What is Crosstalk?

Crosstalk is the transfer of a voltage transition from one switching net (aggressor) to another static or switching net (victim) through a coupling capacitance (Cc)



Crosstalk mechanism

Crosstalk is a very severe effect especially in lower technology node and high-speed circuits and it could be one of the main reason of chip failure.

Crosstalk mechanism

Crosstalk occurs via two mechanisms:

- Inductive Crosstalk
- Electrostatic crosstalk

Inductive Crosstalk

- Inductive crosstalk occurs due to mutual inductance between two nets.
- A varying current in a net creates a varying magnetic field around the net.
- A varying magnetic field can either radiate energy by launching radio frequency waves or it can couple to adjacent nets.
- Such coupling of the magnetic field is called inductive crosstalk.

Electrostatic crosstalk

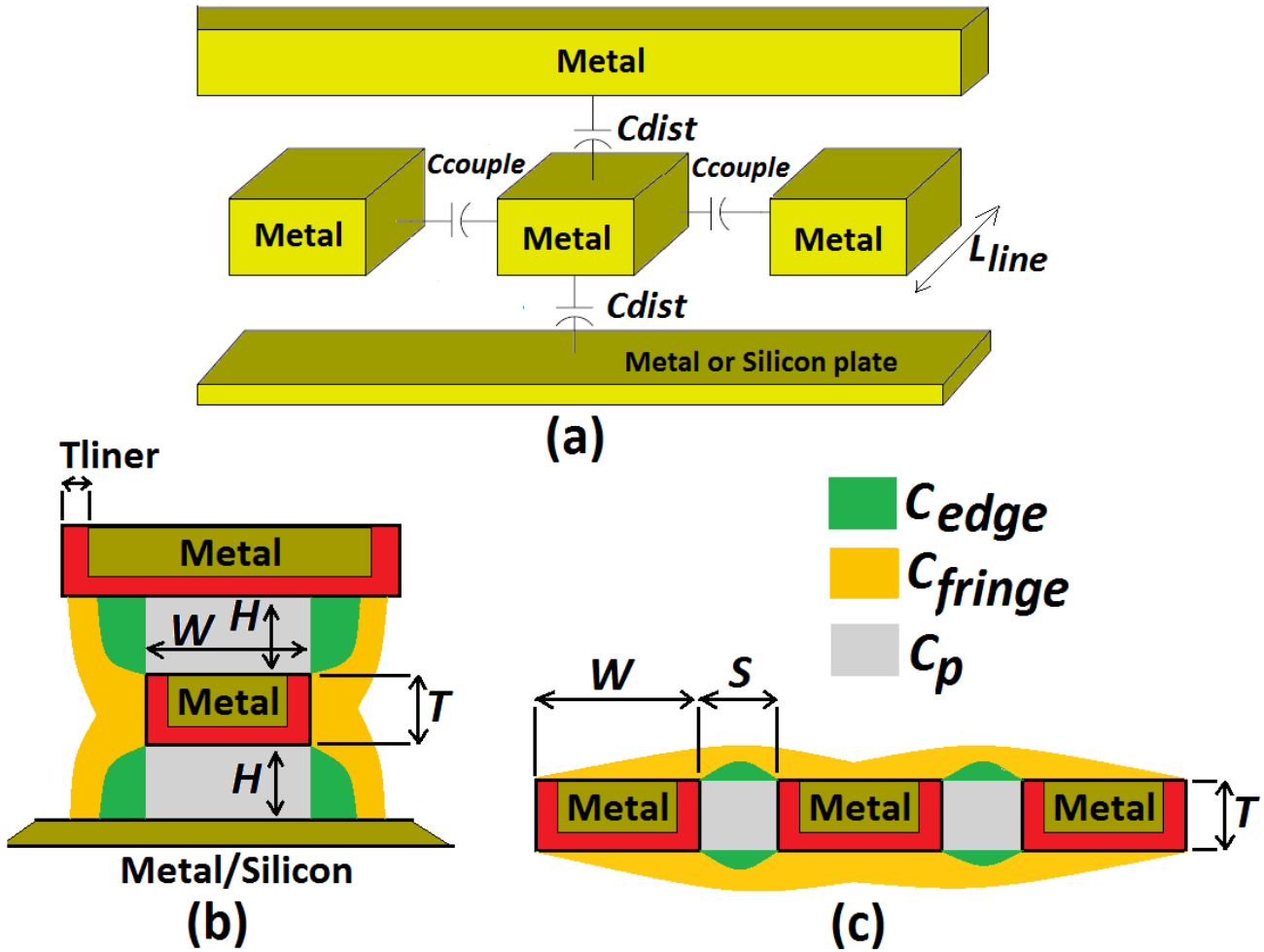
- Electrostatic crosstalk occurs due to mutual capacitance between two nets.
- The electric voltage in a net creates an electric field around it.
- If the electric field is changing, It can either radiate the Radio waves or can couple capacitively to the adjacent net.
- Such coupling of the electric field is called electrostatic crosstalk

Remark

Electrostatic Crosstalk mechanism is more significant and problematic than Inductive crosstalk. So, we will talk about Electrostatic crosstalk.

Parasitic capacitances related to Interconnects

The main reason of crosstalk is the capacitance between the interconnects.



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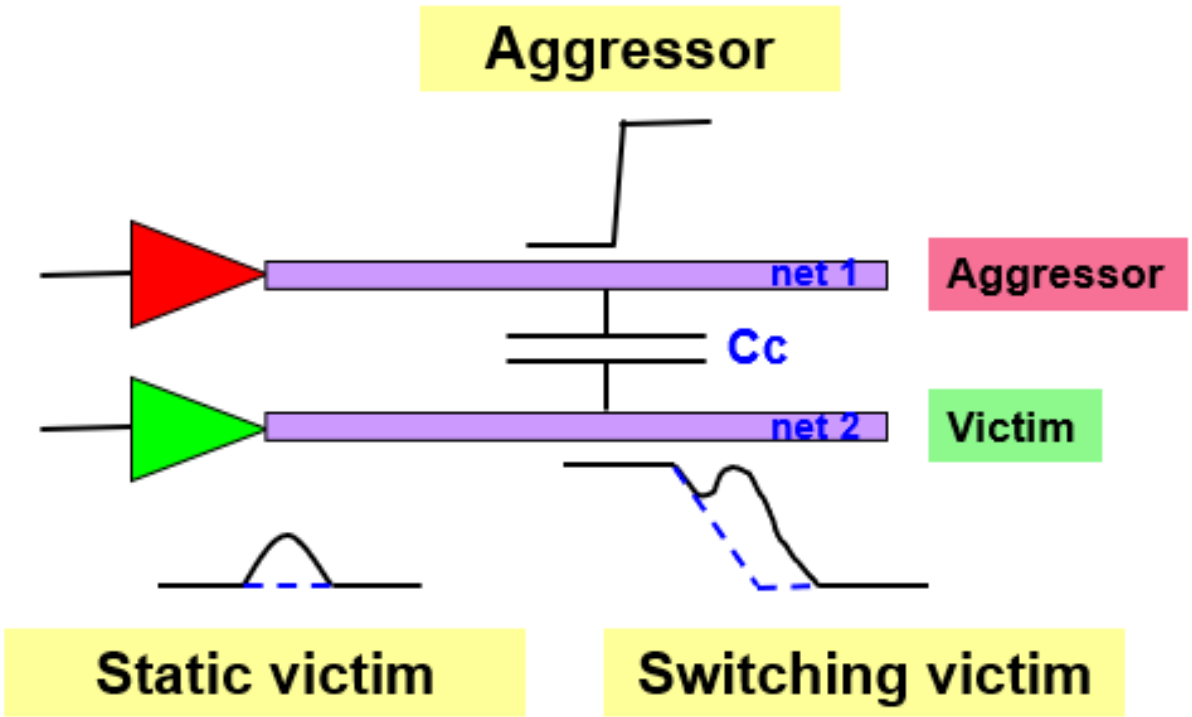
introduction

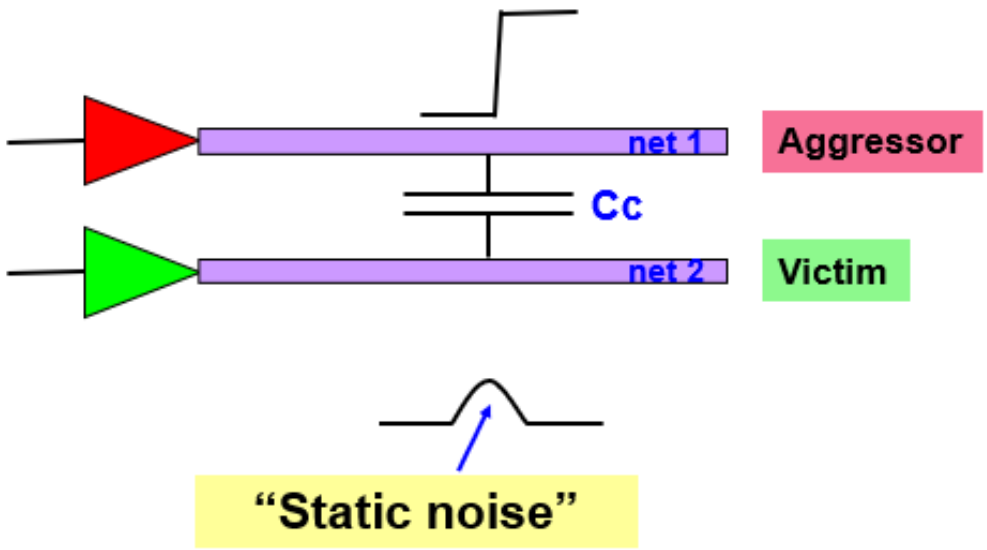
Crosstalk has two major effects

- Crosstalk glitch or crosstalk noise
- Crosstalk delta delay or crosstalk delay



Crosstalk-Induced Noise (aka Glitches)

Aggressor nets can create crosstalk-induced noise on static victim nets, also called "static noise"



Glitches types

Crosstalk glitch can be classified as below

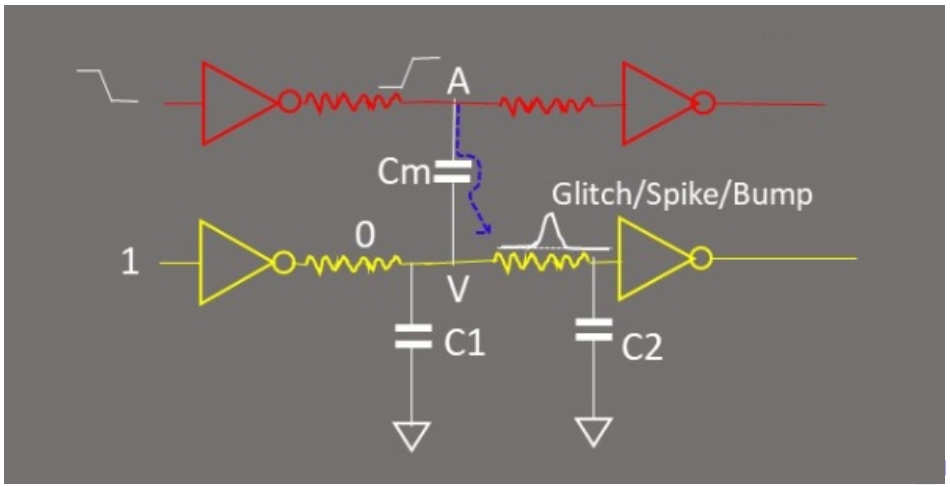
Glitches types

- Raising Glitch
- Failing Glitch
- Overshoot Glitch
- Undershoot Glitch

- **Rise glitch**: Raising aggressor net induces a rise glitch on a steady low
- **Fall glitch**: Falling aggressor net induces a fall glitch on a steady high
- **Overshoot glitch**: Raising aggressor net induces overshoot glitch on a steady high This takes the victim net voltage above its steady high value.
- **Undershoot glitch**: Falling aggressor net induces an undershoot glitch on a steady low This takes the victim net voltage below its steady low value.

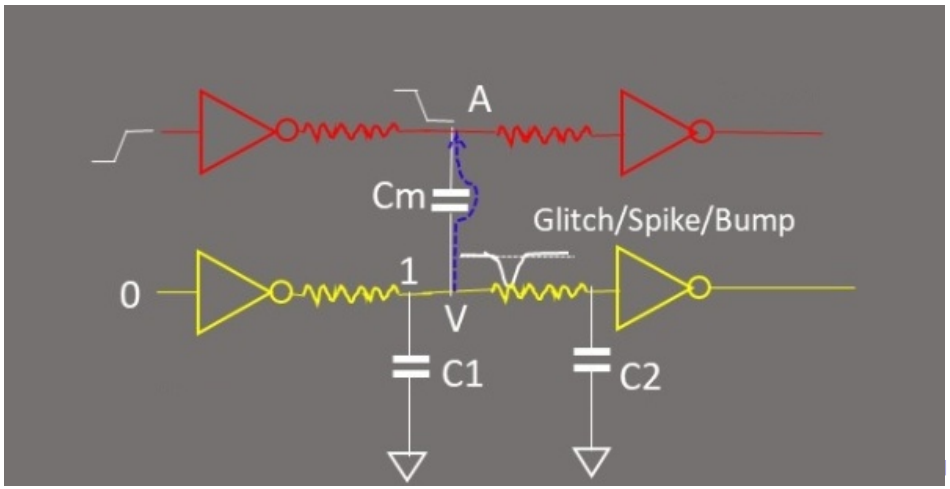
Rise glitch

- In this case, the aggressor net switches from logic 0 to logic 1 and the victim net is at constant zero as shown in the figure.
- As node A start switching from low to high, a potential difference across the mutual capacitance gets developed and the mutual capacitor Cm starts charging.
- During this event, there is some leakage current which starts flowing from node A to node V through the mutual capacitance Cm due to the leaky nature of mutual capacitance.
- This leakage current will raise the potential of node V, which creates a raising spike or raising glitch on the victim net as shown in figure.



Fall glitch

- In this case, the aggressor net switches from logic 1 to logic 0 and the victim net is at constant high as shown in the figure.
- As node A start switching from low to high, a potential difference across the mutual capacitance gets developed and the mutual capacitor Cm starts charging.
- During this event, there is some leakage current which starts flowing from node A to node V through the mutual capacitance Cm due to the leaky nature of mutual capacitance.
- This leakage current will drop the potential of node V, which creates a falling spike or falling glitch on the victim net as shown in figure

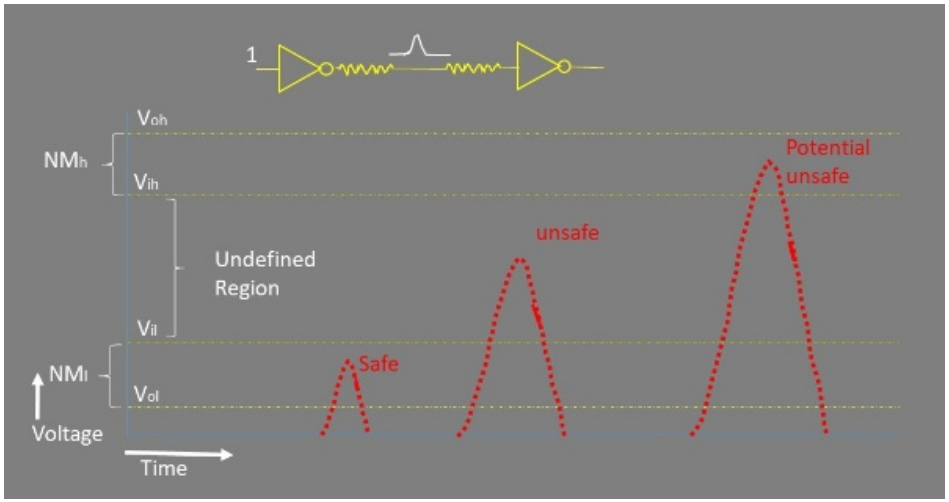


Effects of crosstalk glitch

Does every glitch unsafe?

The answer is it depends on the height of the glitch and the logical connection of the victim net.

- If the height of the glitch is within the noise margin low (NML), Such a glitch is considered a safe glitch.
- If the glitch height is above the noise margin high (NMH), such a glitch is considered a potentially unsafe glitch.
- In the case of a glitch, height is in between NMH and NML, this is an unpredictable case.



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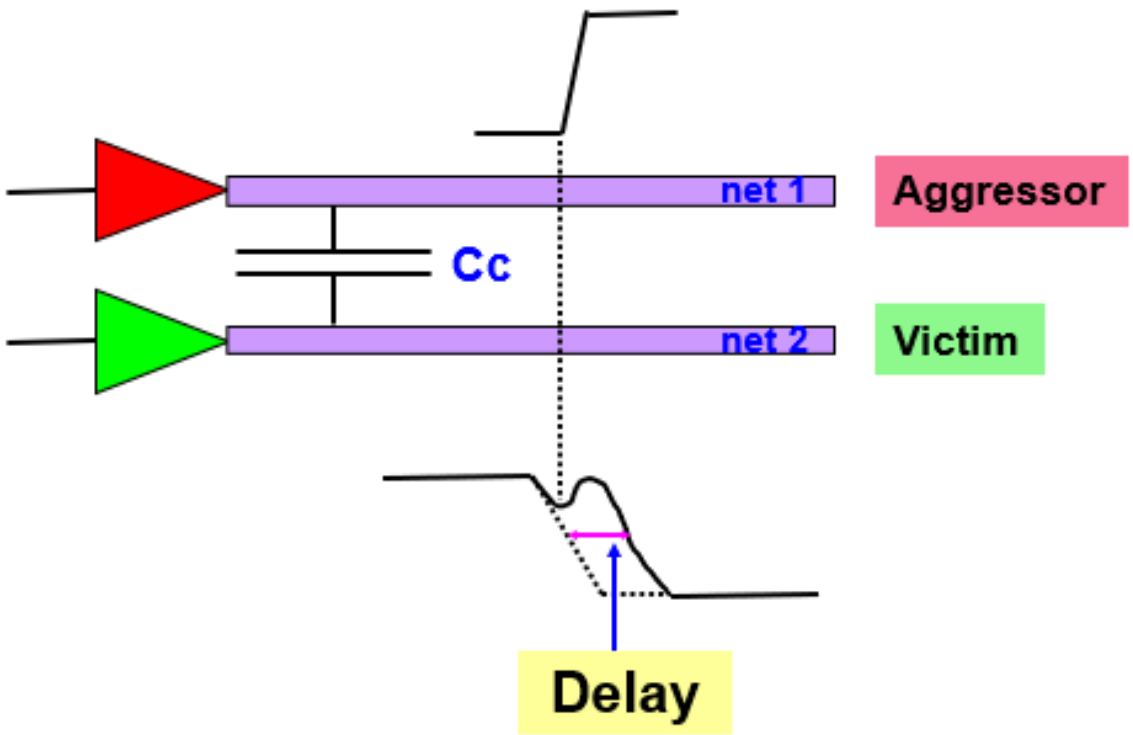
Crosstalk-Induced Delay

Aggressor/victim nets with overlapping timing windows can cause "crosstalk-induced delay" on victim nets.
This can lead to a speed-up or a slow-down of the victim net



Crosstalk Delay

Crosstalk Delay can be classified as below

Crosstalk Delay types

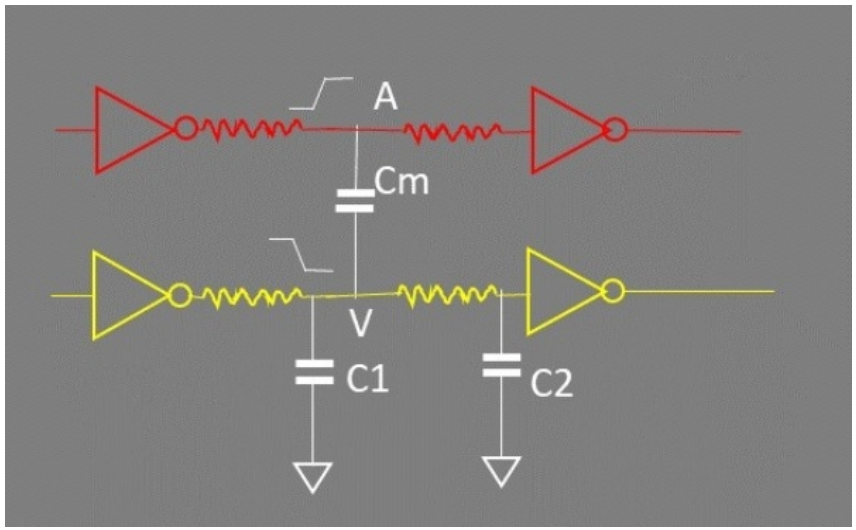
- Negative crosstalk delay
- Positive crosstalk delay

Notes

- Crosstalk delay may cause setup and hold timing violation.
- Crosstalk could either increase or decrease the delay of a cell depending upon the switching direction of aggressor and victim nets.

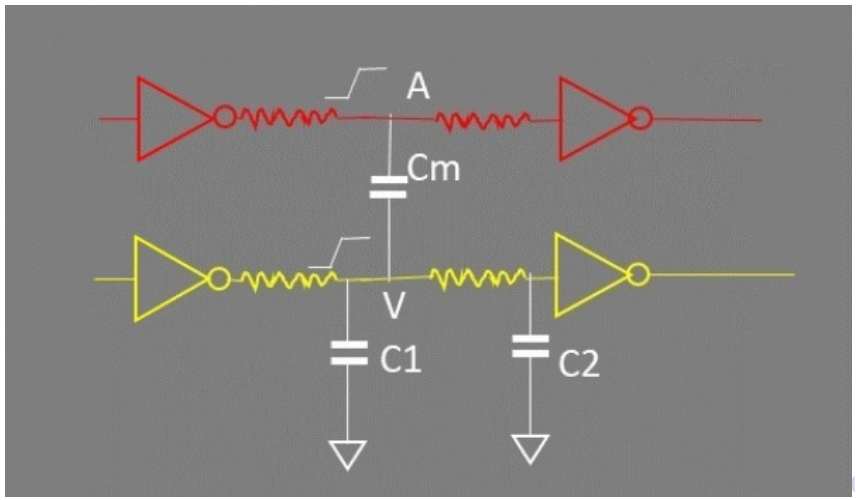
Positive crosstalk delay

- Let's consider aggressor net switches from low to high logic and victim net switches from high to low (opposite). as shown in figure.
- As node A starts to transition from low to high at the same time, node V starts switching from high to low.
- There is a coupling capacitance between A and V so the aggressor node will try to pull up the victim node.
- This will affect the smooth transition of the victim node from high to low and will have a bump after half of the transition and this will result in an increase in the transition time of the victim net.



Negative crosstalk delay

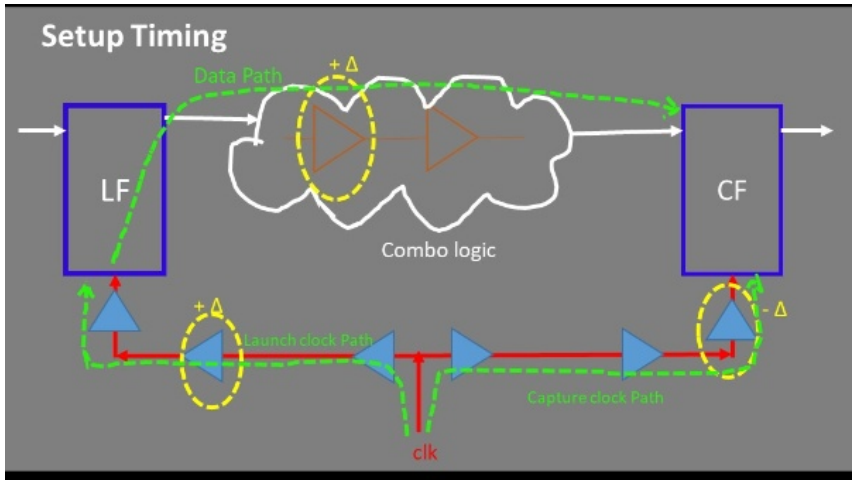
- Let's consider the aggressor net switches from low to high logic and the victim net also switches from low to high (same direction). as shown in the figure.
- As node A starts to transition from low to high at the same time, node V also starts switching from low to high.
- There is a coupling capacitance between A and V so the aggressor node will try to fast pull up the victim node.
- This will affect the smooth transition of the victim node from low to high and will have a bump after half of the transition and this will result in a decrease in the transition time of the victim net.



Effect on setup and hold timing

Crosstalk delay can violate the setup timing. Figure, shows the data path, launch clock path and capture clock path.

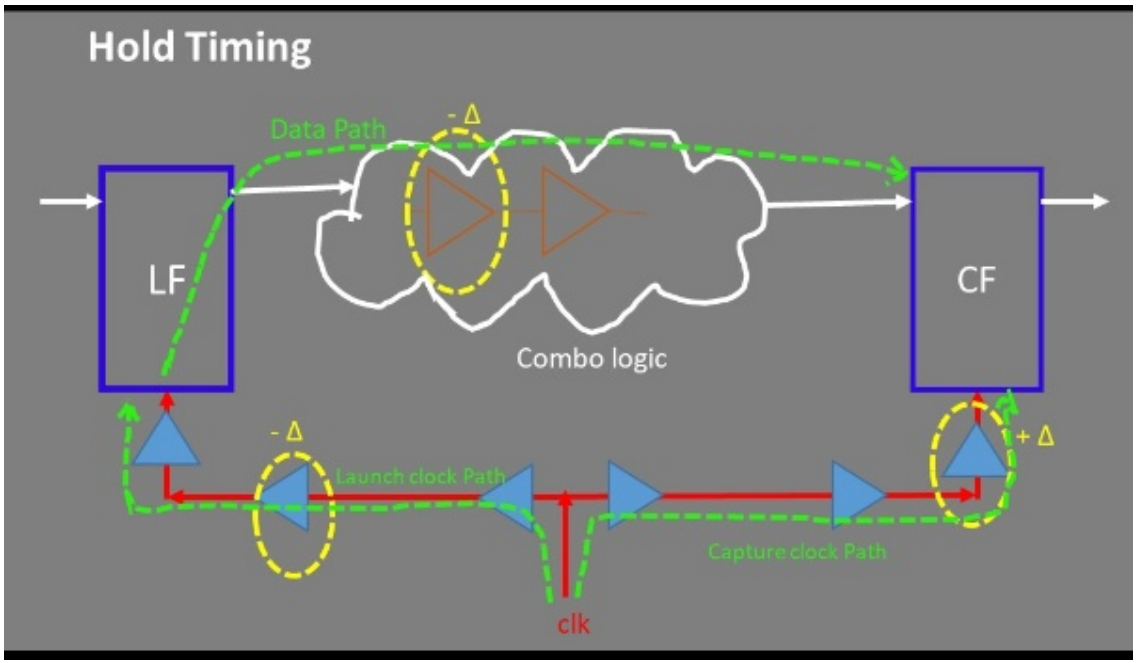
- For setup timing, data should reach the capture flop before the required time of capture flop.
- if there is an increase of delay in the data path or launch clock path it may cause a setup violation.
- Setup violation may also happen if there is a decrease in delay on the capture clock path.



Effect on setup and hold timing

Crosstalk delay can violate the hold timing. Figure, explains the situations where the hold time could violate due to crosstalk delay.

- If there is a decrease in the delay of any cells in the data path and launch clock or there is an increase of delay of cells in the capture clock path due to crosstalk delay, It may result in the hold timing violation. ecrease in delay on the capture clock path.



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prevention techniques

Increase the spacing between aggressor and victim net

ncreasing the spacing between aggressor and victim net we are ultimately reducing the coupling capacitance between them as the capacitance is inversely proportional to the distance between them. So by increasing the spacing crosstalk will decrease.

Shielding of nets

By shielding a net the two things will happen, one is the direct coupling capacitance between the aggressor and victim net will vanish and secondly the shielding net will remain at a constant logic so there are no chances of crosstalk.

prevention techniques

Upsizing the victim cell

If we increase the drive strength of the victim cell it will not be easy to affect by the aggressor net

Downsize the aggressor cell

Higher the drive strength of aggressor cell, higher is the impact of crosstalk on the victim. So by reducing the drive strength we can reduce the crosstalk effect.

Wrap up

بِسْمِ اللَـهِ الرَحمَـن الرَحيمِ

وَمَا أُوتِيتُمْ مِنَ الْعِلْمِ إِلَّا قَلِيلً