Chapter 1

The Importance of Interconnect Design

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Outline

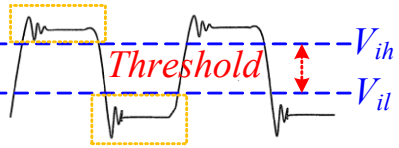
- The Basics
- The Past and the Future

The Basics

- Basic Concepts
  - Trace Length Compared with Wavelength
    - In 100 ps, the light in free space travels about 30 mm (1.2 inches).
    - Since the traces on the PCBs or on the Silicon level may be larger than or comparable with this length, the speed of light is just too slow.
    - When the lengths of the traces are larger than or comparable with the wavelength, they should be considered as transmission lines to incorporating wave effects, not merely considered as simple connecting wires.
    - If these transmission lines are not handled properly, the system timing could be unintentionally ruined.

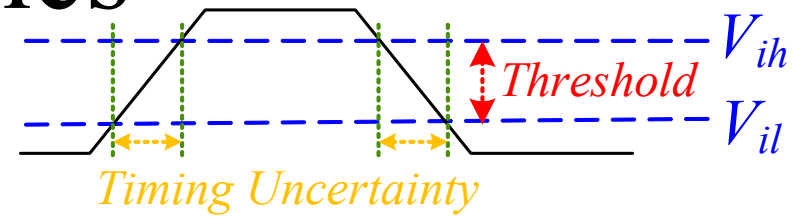
The Basics

- Basic Concepts
  - Interconnect and Its Influence on Waveform
    - The conductive paths carrying the digital signals are known as ***interconnects***.
    - The interconnect includes the chip packages, connectors, sockets, as well as a myriad of additional structures.
    - A group of interconnects is referred to as a ***bus***.
    - The designer must guarantee that the system can, under all conditions, deliver high voltages that do not fall below *Vih*, and low voltages that remain below *Vil*, in order to ensure the integrity of the data.



    - ***Threshold region***: Level could not be determined.

The Basics

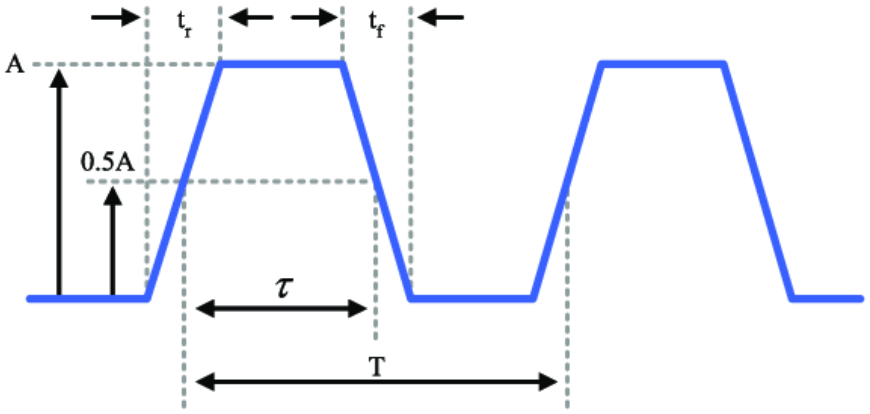


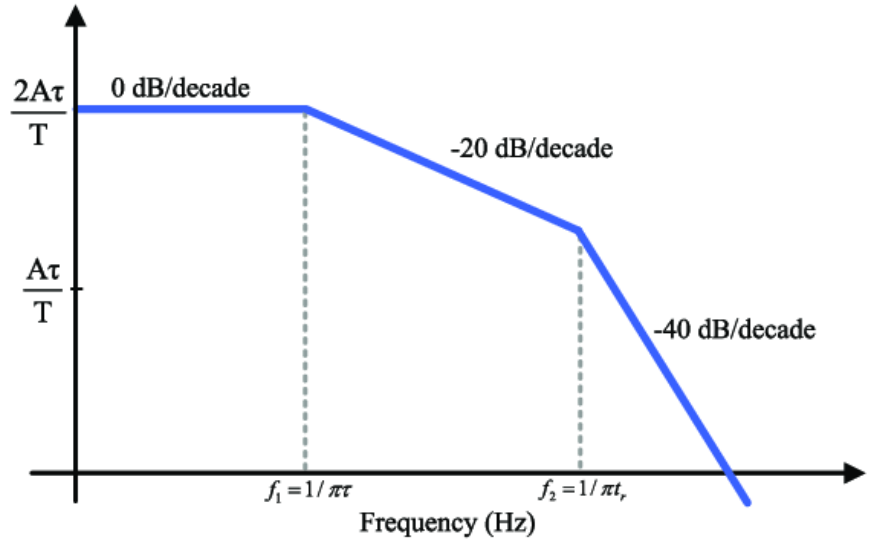
- Basic Concepts
  - Limitations of Rise and Fall Times
    - In order to maximize the speed of operation of a digital system, the timing uncertainty of a transition through the threshold region must minimized.
    - This means that the rise or fall time of the digital signal must be as fast as possible.
    - But the faster rise or fall times will result in higher spectrum, which in turn causes the capacitance, inductance, and frequency-dependent resistance of a wire to be considered.
    - The wire will then have a delay and transient impedance that can cause distortions and glitches on the waveform.

The Basics

τ_r: rise time, generally 10~90%
τ_f: fall time, generally 10~90%
τ: pulse width, generally midpoints

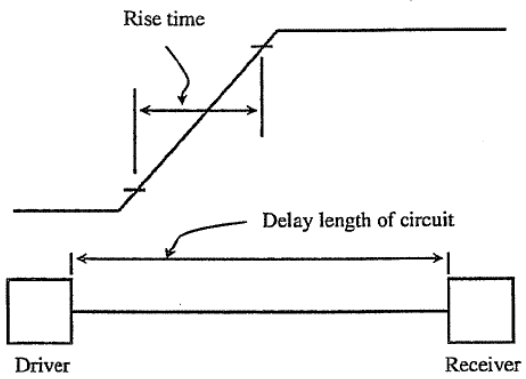
- Basic Concepts
  - Spectrum of Trapezoidal (Clock) Waveforms
    - Periodic, Trapezoidal Pulse Train (τ_r=τ_f)





- τ or τ_r determines the highest frequency of interest?
- $f_2 = 1/(\pi\tau_r) = 0.32/\tau_r$

The Basics



- Basic Concepts
  - When Conductors be Considered TX Lines
    - In general, this must be done when the physical size of the circuit approaches the wavelength of the highest frequency of interest in the signal.
    - In other words, any circuit length at least 1/10th of the edge rate must be considered as a transmission line.
    - One of the most difficult aspects of high-speed design is the fact that there are a large number codependent variables that affect the outcome of a digital design.

For the signal with rise time t_r

$f=0.35/t_r$

$\lambda=c/f$

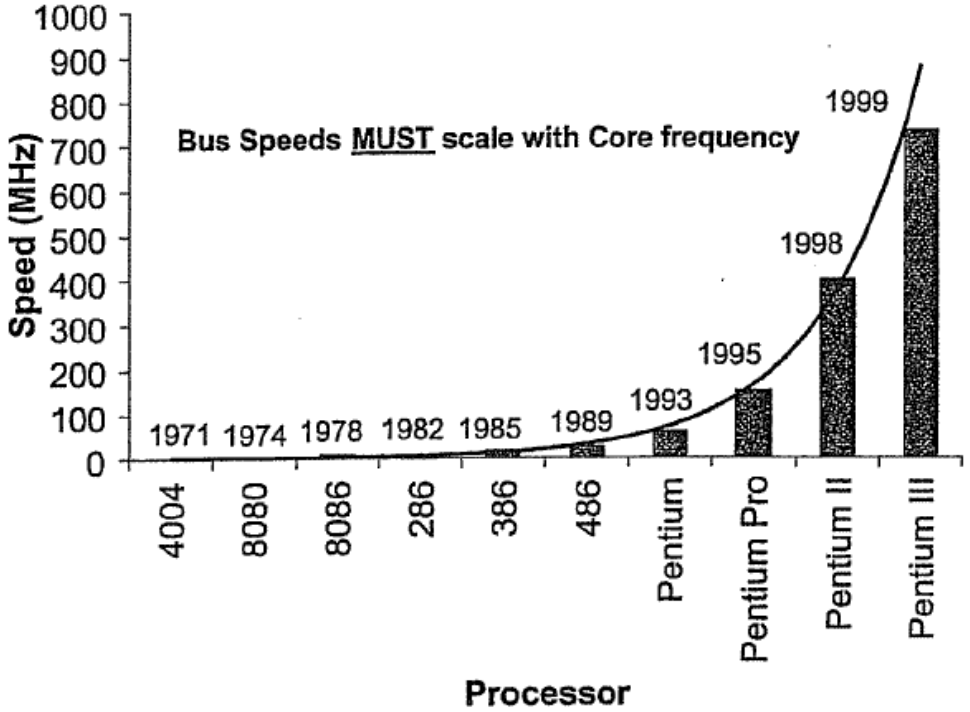
For the circuit with time delay TD_l

$f_l=0.35/TD_l=0.35/(1/10t_r)=10(0.35/t_r)=10f$

$\lambda_l=c/f_l=c/(10f)=(c/f)/10=\lambda/10$

The Past and the Future

- Moore's Law
  - Only CPU Speed
    - Gordon Moore, co-founder of Intel Corporation, predicted that the performance of computers will double every 18 months.



The Past and the Future

- Revised Law
  - Bus Speed is the Bottleneck
    - As core frequency increases, faster data rates will be demanded from the buses that feed information to the processor.
    - Decreased timing budgets mean that it is even more important to properly account for the effects of buses.

At high frequencies, new variables and new effects will arise, which are challenging problems concerning the design of the digital system.