

# **An Overview on Signal Integrity**

**Dr. José Ernesto Rayas Sánchez**

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## Outline

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- Review of market and technology trends
- A Signal Integrity (SI) definition
- An introduction to SI terminology

## Technology Trends

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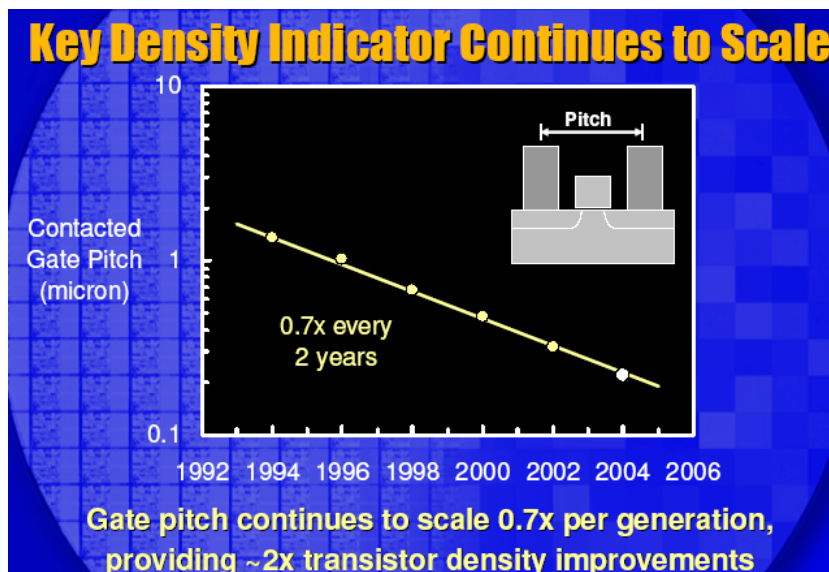
- The minimum dimension of transistors has been continuously decreasing: 25  $\mu\text{m}$  in 1960 to 0.13 $\mu\text{m}$  in 2005
- The number of transistors per chip has continue to double every 1.5 year (Moore's law)
- CPU operating frequency has continuously increase
- Denser and faster buses have appeared
- Faster memories are required
- Cost of interconnects remain a small fraction (<5%) of the system cost

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## Decreasing Dimension of Transistors

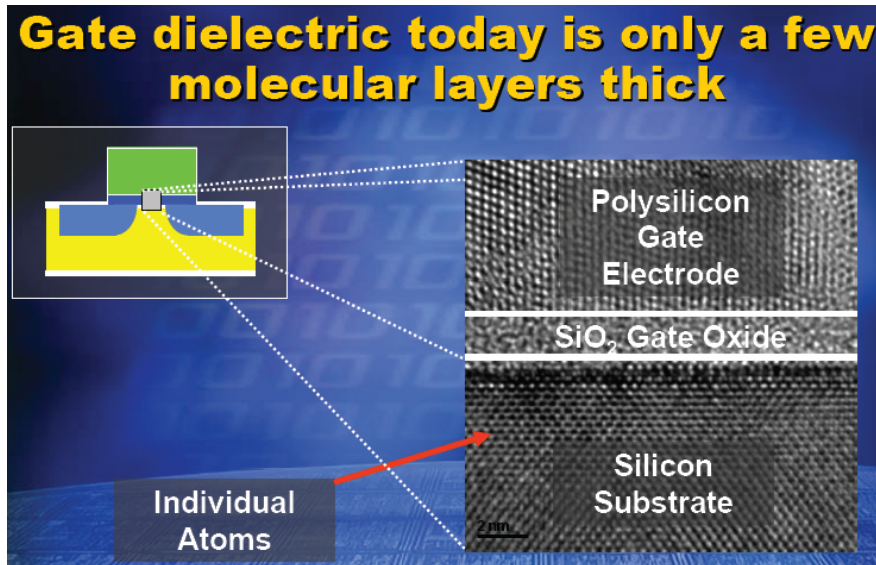
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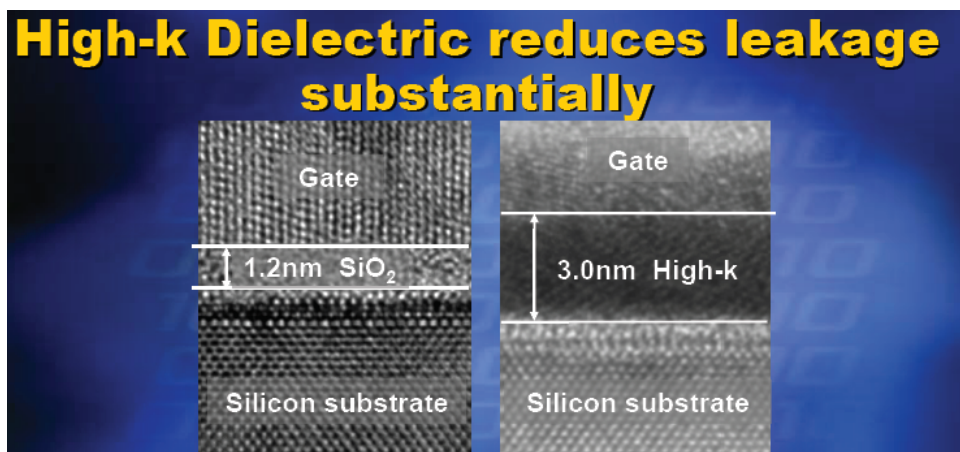
## Decreasing Dimension of Transistors (cont)



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## Decreasing Dimension of Transistors (cont)

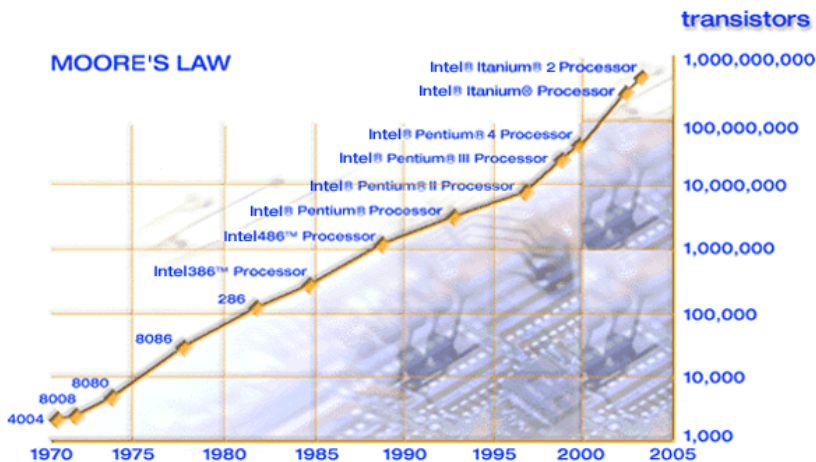


State-of-the-art silicon transistors can operate above 1 THz

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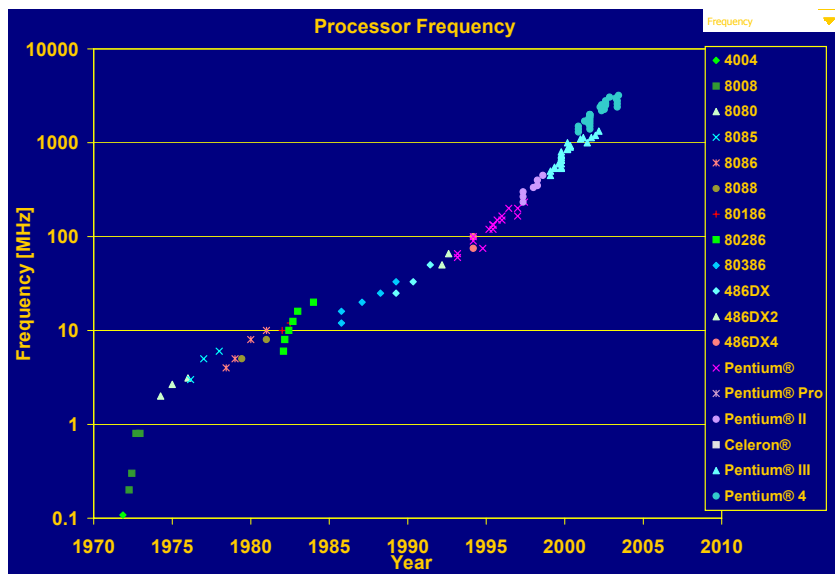
## Moore's Law



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## CPU Operating Frequency



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(H. Heck, 2005)<sub>8</sub>

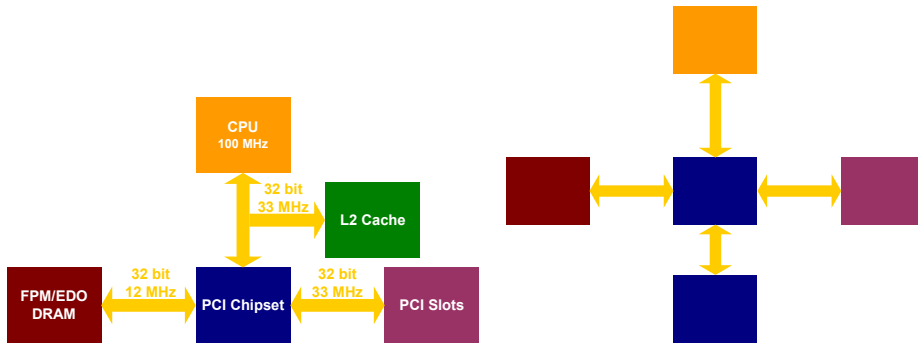
## Denser and Faster Buses

### 486DX2 Processor (~1992)

- 3 major buses
- 33 MHz max frequency
- 4 byte bus width

### Pentium® 4 Processor (2003)

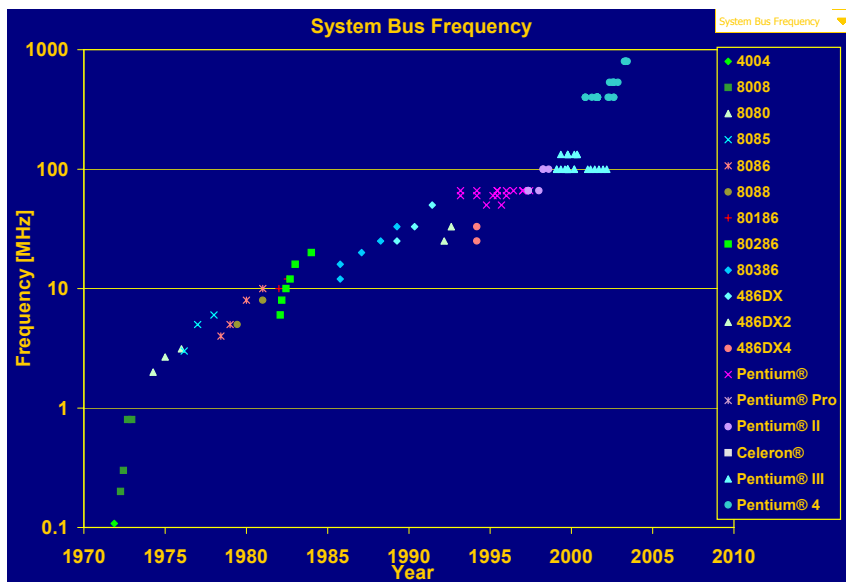
- 4 major buses
- 66-800 MHz max frequency
- 4-16 byte bus width



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(H. Heck, 2005),

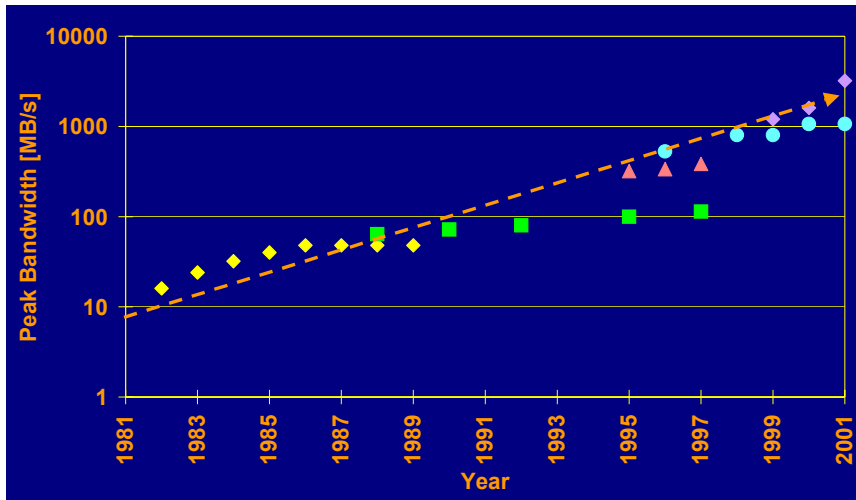
## Denser and Faster Buses (cont)



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(H. Heck, 2005),<sub>10</sub>

## Faster and Denser Memories



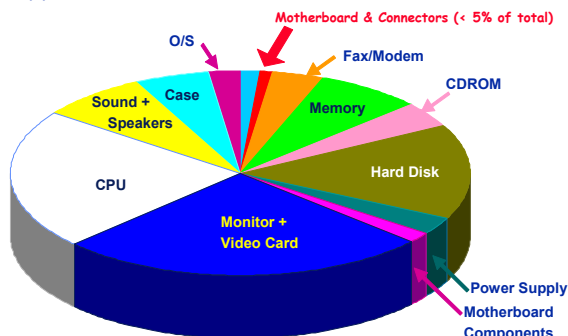
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(H. Heck, 2005)<sub>11</sub>

## Cost of Interconnects

- Interconnect makes up < 5% of the system cost
  - Most technical problems can be solved with \$
  - High volume PC market can't afford extra cost
- Designing Multi-GHz interconnects to fit in sub \$1000 PCs is a huge challenge

### Approximate Cost Breakdown of a PC



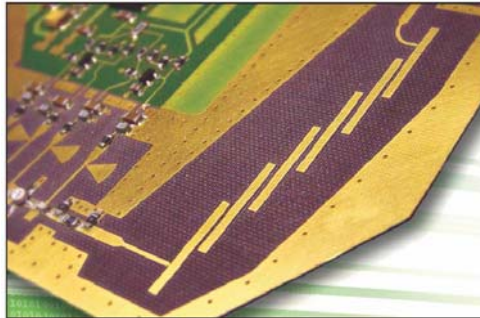
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(H. Heck, 2005)<sub>12</sub>

## Cost of Interconnects (cont)

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- FR4 has been the standard choice for PCBs in the last four decades
- Other dielectrics have better performance: polyethylene (PE), polytetrafluoroethylene (PTFE)
- PTFE-based laminates can cost up to US\$100 per squared foot
- FR4 is US\$2/sq ft



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(D. Reed, 2003)<sub>13</sub>

## High-Speed Digital Design

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- Physical design becomes crucial: connectors, backplanes, packages, PCB structures, material properties, etc.
- Analog techniques (analog electronics, RF and microwave engineering) are used to solve most signal integrity problems



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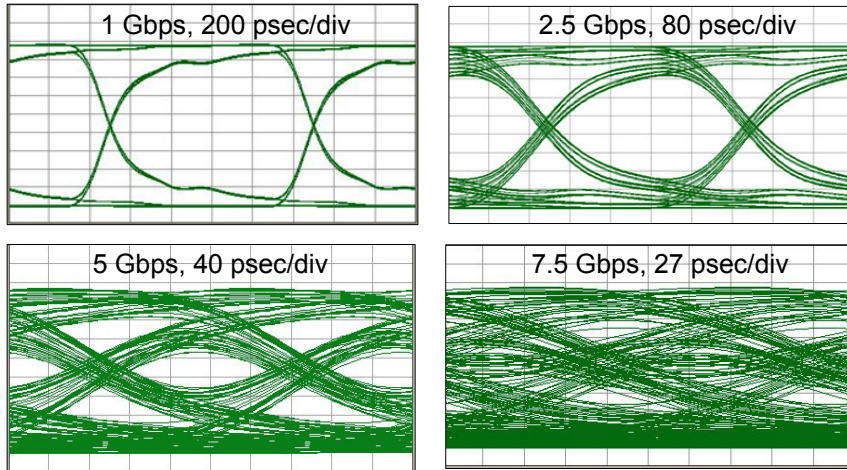
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## High-Speed Digital Design (cont)

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### Eye Diagrams (for a 25-inch channel)



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## What is Signal Integrity (SI)?

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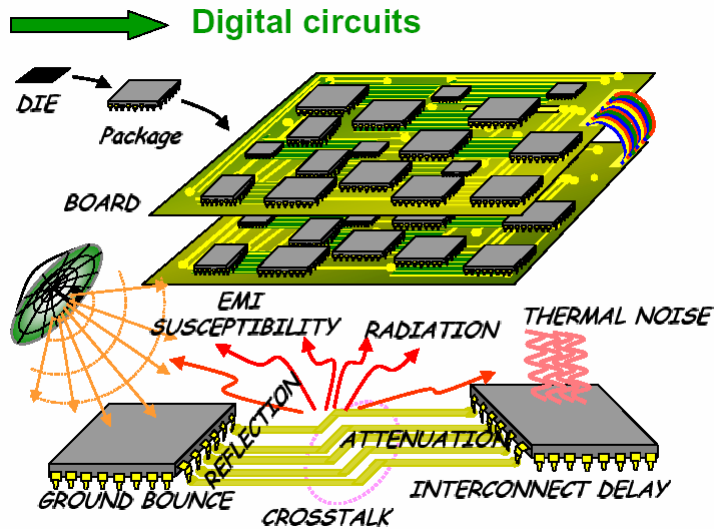
- It is an engineering practice that aims at ensuring reliable high-speed data transmission and reception, without polluting the electromagnetic spectrum and without damaging any device
- SI effectively combines concepts and techniques from the following disciplines:
  - microwave and RF engineering
  - electromagnetics
  - physical design
  - analog electronics
  - communications, and
  - digital design

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## SI Problems Appear at Different Levels



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(M. Nakhla, 2004)<sub>17</sub>

## SI Problems Appear at Different Levels (cont)

The diagram shows a 3D perspective of the hierarchy: "On-chip" (a die), "Package" (a package on a board), and "PCB" (a printed circuit board). To the right, a table provides parameters for different interconnection types.

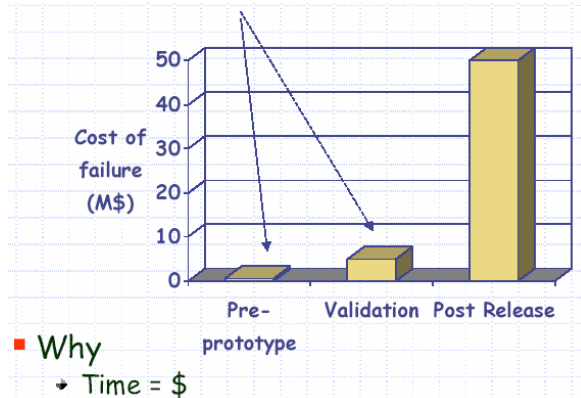
Inter-connection Type	Line Width ( $\mu\text{m}$ )	Line Thickness ( $\mu\text{m}$ )	Max. Length (cm)
On-Chip	0.5-2	0.5-2	0.3-1.5
Thin-Film	10-25	5-8	20-45
Ceramic	75-100	16-25	20-50
PCB	60-100	8-70	40-70

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(A. Weisshaar, 2004)<sub>18</sub>

## Effective Signal Integrity Practices

- Tracking down the cause of signal integrity problems after the hardware has been created can be extremely complicated
  - It costs less here.



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(R. Mellitz, 2003)<sub>19</sub>

## Signal Integrity Issues



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## Tools and Concepts for Signal Integrity Issues

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## CAD Tools for SI

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- CAD tools allow addressing many signal integrity issues during simulation
- Appropriate simulation strategies improve the understanding of highly complex signal integrity phenomena
- If the simulation is accurate enough, many signal integrity problems can be solved before they actually exist

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## Conclusions

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- System performance and functionality increase over time
- In the PC market, sales decrease sharply when the price exceeds the volume desktop price barrier
- Interconnect components account for < 5% of system cost
- Interconnects impose severe limitations in system performance
- Interconnect engineers must satisfy increased performance demands without increasing the cost of the solution
- SI problems are challenging, but many tools and concepts can be used to alleviate them