Chapter 1

MICROELECTRONIC INTERCONNECTIONS

The research topic known as Signal Integrity, or also, as recently proposed, Electrical Modeling of Interconnects and Packages [1], is a very important part of the electronic system design process. Its objective is to obtain a model of the physical phenomenon of signal propagation that can be used by electronic designers to predict any distortion of the information transmitted. Thus, the extracted model can either be electrical, for use with electrical design using currents and voltages as observable variables, or it can be logical, for use with higher level description tools.

The problems concerning signal propagation through interconnects are briefly explained in the first section. After this, the main technological characteristics of microelectronic interconnections, inside the chip and at package level, are also explained.

1. Signal transmission in interconnects

Any electronic system, at any level, is composed of functional blocks (transistors, gates, sub-circuits, IPs, cores, processors, boards...) interconnected with each other; that is, capable of transmitting information from one part to another. This information is in the form of a voltage or a current value.

Ideally, the communication between two interconnected blocks should be instantaneous and without any distortion. Under these conditions, the system is completely described by its building blocks and the way they are connected. However, this ideal picture cannot be achieved in practice. The reason is that physically, there is always a propagation time for transmitting the information from one point to the other. If the signals vary very slowly compared to this propagation time, the transmission may be considered instantaneous and the ideal picture is valid. If, on the other hand, the signals vary rapidly compared to the propagation time, several effects may be observed:
Signal Delay. This fact must be taken into account when designing the system to ensure that all blocks receive the information at the expected time.

- Reflections coming from the end of the interconnection and interfering with the signal sent.

- Interference between nearby interconnections (crosstalk).

All these non-ideal effects may influence the behavior of the system and they represent a limitation on performance. If not properly addressed at the design stage, they may be large enough to completely distort the transmitted information and therefore cause a system malfunction.

1.1 The problem with interconnections

The evolution of electronic technology, as dictated by Moore’s law, is towards denser, more complex, and faster systems. All three trends imply a larger interconnection effect, once considered only from the functional point of view. Today, a microelectronic design that does not consider interconnection effects from the beginning of the design process is most probably condemned to a large number of trial and error iterations, with the associated increase in cost and time to market.

The reason for the ever-increasing importance of interconnections can be understood using electrical models of the interconnections. The physical foundations of the electrical models will be fully justified in Chapter 2, but let us for the moment use them as an introductory explanation.

The electrical parameters that characterize an interconnection are resistance ($R$), capacitance ($C$) and inductance ($L$). The interconnection response to a certain voltage or current excitation can be derived from the relative values of those parameters. Roughly speaking, one can consider that the delay is mostly dependent on $R$ and $C$ (although $L$ is also important for high frequency signals). On the other hand, crosstalk interference depends on mutual $C$ and $L$ between close lines. Let us qualitatively analyze the influence of technology trends on parameters and their effect on signal integrity.

1.1.1 Increase in integration

As the number of devices per unit area increases, the interconnections between them must evolve towards a reduced cross-sectional dimension and a greater number of vertical conductor layers.

The reducing cross-sectional dimension leads to more tightly coupled interconnections, and therefore a higher probability of unwanted crosstalk interference between them.