Submicron CMOS technology

Speed and smaller device dimensions are closely interrelated and we have already touched on the fact that the foreseeable limits on channel length for MOS transistors is in the region of 0.14 micro meters, after which further scaling down results in unworkable transistor geometry.

In CMOS devices we have also seen that the p-transistors have inherently slower performance than similar n-transistors. This is primarily due to the lower mobility of holes compared with that of electrons. Typically

$\mu_p = 240\ cm^2/V.sec$

$\mu_n = 650\ cm^2/V.sec$

In long-channel devices this means a difference in current drive transition times of about 2.5:1. However, as the channel lengths are scaled down, the influence of mobility starts to diminish as the effects of velocity saturation begin to be felt.

For long-channel MOS transistors, the current/voltage relationship below saturation can be approximated by

$I_{ds} = [W\mu C_{OX}/L][(V_{gs}-V_t)Vds - 0.5Vds^2]$

Where, C_{OX} = gate/channel capacitance per unit area

$= (\varepsilon_{ins}. E_0)/D$

This implies that current drive is proportional to mobility and inversely proportional to channel length.

Transconductance g_m is similarly influenced. When velocity saturation occurs along the entire channel length, then the current/voltage relationship is given by

$I_{dsat} = WC_{OX}\ v_{sat}\ (V_{gs} - V_t)$

Where v_{sat} is the saturation velocity. Current is now independent of both mobility and channel length but dependent on the saturation velocity. Transconductance is constant and thus independent of channel length.

It should be noted that velocity saturation occurs at lower electric field strengths in n-devices owing to their higher mobility when compared with p-devices. Thus, as dimensions are scaled down, the current drive from n-transistors tends to a constant value independent of channel length while the current drive from p-transistors does not tend to a constant value until, at a shorter channel length, the holes start to run into velocity saturation. We must therefore look to other than silicon-based MOS technology to provide for the faster devices which will undoubtedly be required as the sophistication of our system design capabilities increases. An alternative technology is based on gallium arsenide.

Gallium Arsenide (GaAs) VLSI Technology

Silicon Metal Oxide Semiconductor technology has been the main medium for computer and electronic applications for the past few years and will continue to fill this role in the coming future. However, technologies using silicon logic has speed limitations that are already becoming apparent in high speed digital system design. When compared with silicon technology, some very interesting results have emerged for gallium arsenide (GaAs)-based technology. Gallium arsenide will not displace silicon in any of its technology, but it is being used in conjunction with silicon in order to obtain the need for very high speed integrated (VHSI) technology in many new and innovative systems.

Much of the development work in high speed technology that has paralleled that in silicon has been from group II to group VI and also from group III to group V compounds. When it comes to gallium arsenide, groups III—V compounds are the ones that have shown the most promise.

The compound gallium arsenide was first discovered in 1926. However, its application as a high speed semiconductor was not known until the 1960's. Both Gallium Arsenide and Silicon need the same lithographic process. Some of the advantages in using Gallium Arsenide when compared to Silicon are

- The high speed electron mobility of gallium arsenide with respect to silicon.
- A semi-insulating substrate with consequent lower parasitics.
- An improvement factor of 1.4 for carrier saturation velocity of GaAs over silicon.
- Better opto-electrical properties
- Less power dissipation than silicon and radiation hardness

The developments in Integrated Circuit Fabrication Technology in the 1970s made such Gallium Arsenide products a possibility and finally, as the result of significant advances in Ion Implantation in the 1980's, GaAs VLSI technology is a commercial reality for the 1990's.

Therefore, in the posts to follow we are going to concentrate on this new material and explore the various possibilities that exist to design circuits and systems using an appropriate class of logic together with suitable design methodology for this technology.