Designing in 45 nm technology using Microwind

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This article describes the improvements related to the CMOS 45 nm technology and the implementation of this technology in Microwind3 CMOS layout tool. We will observe how the main novelties related to the 45 nm technology such as the high-k gate oxide, metal-gate and very low-K interconnect dielectric effects the circuit operations & power consumptions.
The example taken here is ring inverter chain, which can give us good overview of the speed vs power characteristics of 45nm technology.

Ring Inverter Simulation

The ring oscillator made from 5 inverters has the property of oscillating naturally. We observe in the circuit of figure 1 the oscillating outputs and measure their corresponding frequency.

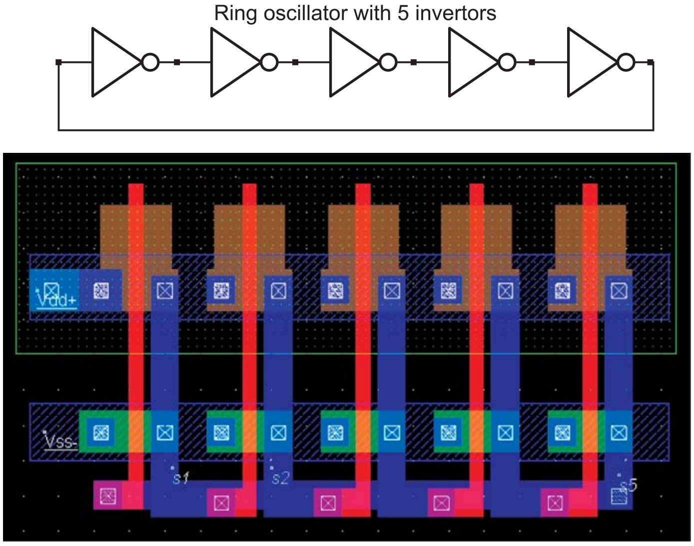


Figure 1: Schematic diagram and layout of the ring oscillator used for simulation (INV5.MSK)

The ring oscillator circuit can be simulated easily at layout level with Microwind using various technologies.

The time-domain waveform of the output is reported in figure 2 for 0.8, 0.12µm and 45nm technologies. Although the supply voltage (VDD) has been reduced (VDD is 5V in 0.8µm, 1.2V in 0.12µm, and 1.0 V in 45nm), the gain in frequency improvement is significant.

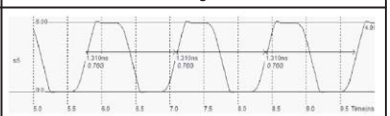
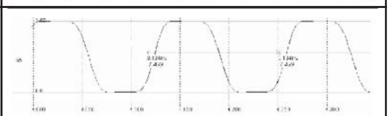
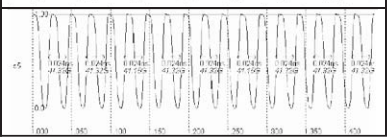
Technology	Supply	Oscillation	Chronograms
0.8 µm	5 V	0.76GHz	
0.18 µm	2 V	7.5 GHz	
45 nm	1.0 V	41 GHz	

Figure 2: Oscillation frequency improvement with the technology scale down (Inv5.MSK)

Use the command **File Select Foundry** to change the configuring technology. Select sequentially the **cmos08.RUL** rule file which corresponds to the CMOS 0.8-µm technology, the **cmos018.RUL** rule file (0.18µm technology), and eventually **cmos45nm.RUL** which configures Microwind to the CMOS 45-nm technology. When you run the simulation, observe the change of VDD and the significant change in oscillating frequency.

High Speed vs Low leakage

Let us consider the ring oscillator with an enable circuit, where one inverter has been replaced by a NAND gate to enable or disable oscillation (Inv5Enable.MSK). The schematic diagram is shown in figure 3, as well as its layout implementation. We analyze the switching performances in high speed and low leakage mode.

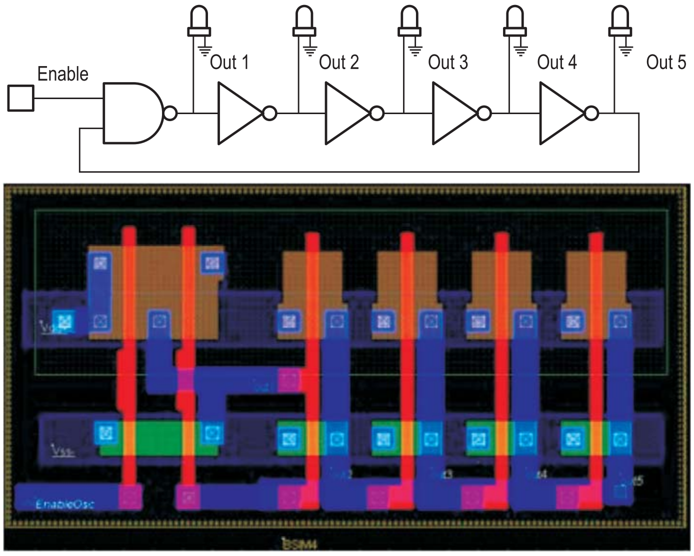


Figure 3 : The schematic diagram and layout of the ring oscillator used to compare the analog performances in high speed and low leakage mode (INV5Enable.MSK)

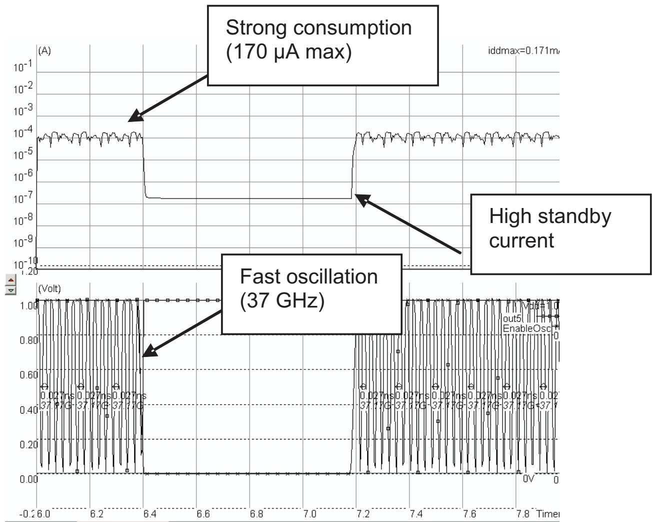
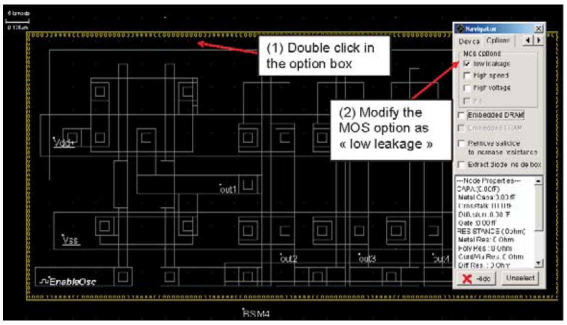


Figure 4: Simulation of the ring oscillator in high speed mode. The oscillating frequency is faster in the case of high-speed mode but the standby current is high (Inv5Enable.MSK)

The option layer which surrounds all the oscillator devices is set to high speed mode first by a double click inside that box, and by selecting "high speed" (Fig. 5). The analog performances of both options are summarized in table 1. In high speed mode, the circuit works fast (37 GHz) but consumes a lot of power when ON, and a significant standby current when off (more than 200 nA), as shown in the simulation of the voltage and current given figure 4. Notice the tick in front of "Scale I in log" to display the current in logarithmic scale.

After changing the properties of the option layer to “low leakage” as shown in Fig. 5, the simulation is performed again. In contrast to “high speed”, the low leakage mode features slower oscillation (29 GHz shown in fig 6, that is approximately a 30 % speed reduction), with 40 % less current when ON, and more than one decade less standby current when off (5 nA). In summary, low leakage MOS devices should be used as default devices whenever possible. High speed MOS should be used only when switching speed is critical.



Parameter	High Speed Mode	Low Leakage Mode
Maximum Current	170 µA	100 µA
Leakage Current	>200 µA	<5 nA
Oscillating Frequency	37 GHz	29GHz

Table 1 : Comparative performances of the ring oscillator (Inv5Enable.MSK)

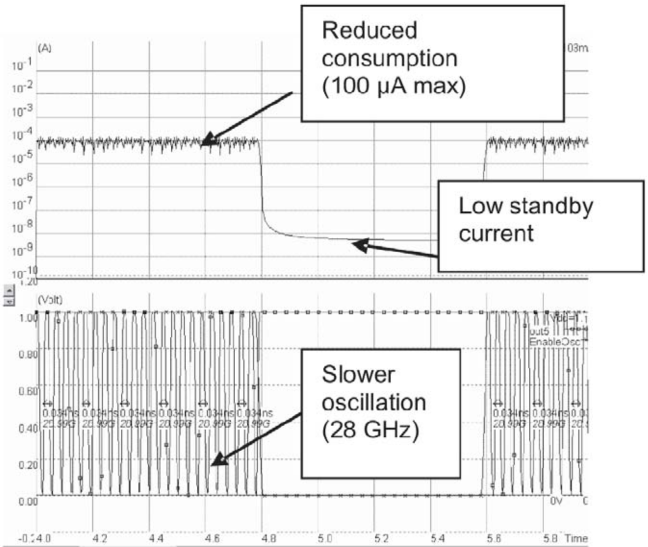


Figure 6: Simulation of the ring oscillator in low leakage mode. The oscillating frequency is faster in the case of high-speed mode but the standby current is also high (Inv5Enable.MSK)

Conclusion

Ring inverter oscillation with various technologies gives impressive results for comparing high speed performances to low leakage, with the impact on speed and leakage current.

45nm is truly low leakage current technology and is revolutionizing the electronic gadget market faster than its previous generations.