The CMOS Advantage

November 2005

Microwave Performance from Advanced CMOS

The emerging opportunity for high data rate wireless communications at 60 GHz has been dramatically enhanced by recent advances in the demonstration of excellent microwave performance from common digital CMOS[1]. Nonetheless, questions continue to be raised regarding the best process for semiconductor manufacturing: CMOS (Complementary Metal-Oxide Semiconductor) or SiGe BiCMOS (Silicon Germanium Bipolar Complementary Metal-Oxide Semiconductor). As outlined below, CMOS is inherently more advantageous in light of its design implications, efficient manufacturing process, impact to system cost, and overall reliability of design and performance.

Efficient Design

The enormous bandwidth available in the 60 GHz range require superb microwave performance from the devices and circuits being designed to exploit them. What may not be as well appreciated is the large amount of digital signal processing (DSP) that is also required in these circuits in order to implement error correction, channel selection and equalization, multi-path mitigation, and baseband signal processing. CMOS is by far the logic family with the highest device count and circuit density and is therefore the technology of choice for implementing wireless systems aimed at this portion of the spectrum.

In wireless communications electronics, low power operation is often of critical importance. Surprisingly, it is the receiver, not the transmitter, that consumes the most energy (transmitters may be turned off when not transmitting, but receivers typically have to be on all the time). Clever power control tricks can be implemented to reduce power consumption in the receiver, but only through the liberal use of logic gates. Sprinkling logic gates for power control in the areas surrounding a CMOS receiver is substantially easier than using the same approach in SiGe, where typically the analog circuitry is not amenable to hosting low-power logic gates.

The same approach can be used to correct non-idealities in analog circuit performance; in CMOS, compared to SiGe bipolar, this is easier to achieve by embedding complex correction electronics (A/D and D/A converters, for example) directly in the RF portions of the circuit.

In many ways, SiGe is a special technology option that changes the modeling and design methodology from CMOS to bipolar and thus will require a major restart if it ever became necessary to go to CMOS. Our approach is to view designs from the full system approach and to compensate for any compromises in analog performance with a superior

[1] C. H. Doan, S. Emami, A. M. Niknejad, and R. W. Brodersen, "Millimeter-wave CMOS design <http://bwrc.eecs.berkeley.edu/Research/RF/Publication/pubs/Doan_JSSC05.pdf>," *IEEE J. Solid-State Circuits*, vol. 40, pp. 144-155, Jan. 2005.

system design. We are confident that the right way to do this is to begin with CMOS and maintain an adherence to that technology throughout.
The breakdown voltage of SiGe bipolar transistors is thought to be higher than CMOS FETs. However, this comparison must be made at comparable technology nodes and minimum geometries. Where breakdown is important is in power amplifiers, and in that case it is the available output power (as well as power gain), the magnitude of nonlinearities, and the available dynamic range, that are most important, not voltage compliance alone.

Efficient Manufacturing Process

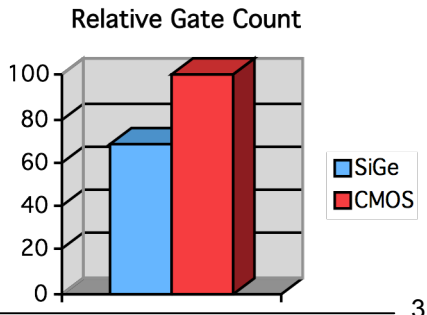
Production economies are a critical consideration as well. SiGe requires more specialized plants for production, and that serves to inflate costs. Moreover, as momentum toward high-volume, industry-standard CMOS continues to build and as CMOS continues to be better optimized for high yield processes than boutique SiGe bipolar processes, production costs for CMOS will decline. In other words, more production capacity and higher demand for CMOS solutions across the industry drives a bandwagon effect wherein cost and price are driven down across the board. The bottom line is that CMOS has an inherently lower manufacturing cost than SiGe BiCMOS by over 30%.

So why pursue SiGe? The rationalization for SiGe versus CMOS is typically that the rigor of the design challenge posed by an all-CMOS approach can be daunting. This is where SiBEAM has developed and offers to provide a unique advantage, having rigorously vetted our 60 GHz wireless communications building blocks over 5 years, thereby eliminating risks traditionally associated with CMOS. As such, the opportunity from CMOS provides the highest level of integration, yielding the lowest cost solution.

Taking this one step further, the soundness of our 60 GHz model has permitted SiBEAM to look beyond the core function and take into consideration the entire system's cost and performance, providing additional rationale for choosing SiBEAM's unique CMOS implementation over SiGe.

Cost Optimized Design

CMOS furthers its value proposition relative to SiGe with respect to lower total system cost. First, the design characteristics of SiGe lend themselves to a more costly process. The geometries of SiGe lag significantly behind standard CMOS processes. Since an overall wireless system (SoC) implementation (chip area) is dominated by digital logic, the implications for SiGe mean increased die area due to the number and size of SiGe gates required to realize a given logic function. Today, CMOS can be realized in a 130 nm, 90 nm, or even a 65 nm process, whereas SiGe geometries remain around 180 nm or greater. Currently, while 130 nm



CMOS is more common, 90 nm processes are expected to take over by late 2007 to early 2008. At that time, 90 nm would become the lowest-cost process on the market since less chip area and die size drive down price given that less space per wafer is required. Further, SiGe uses smaller wafers, which lowers relative production volume per run. With regard to yield considerations, there is every reason to believe the two technologies would be comparable since device count and wafer size would be dominated by the digital electronics, accomplished in CMOS in both processes. However, on the whole CMOS exhibits a more efficient design, leading to significant cost advantages.

Reliable Design, Reliable Performance, Best Price

Based on SiBEAM's experience of numerous experimental runs in which we have compared modern, advanced (but standard) CMOS (down to 0.13 microns), to a SiGe BiCMOS process, we have concluded that more accurate, reproducible models are available at microwave frequencies in CMOS than in SiGe. That capability allows designers to *predictably* exploit more of the available bandwidth inherent in advanced CMOS technologies (130 nm and beyond) than in SiGe. This predictability and reproducibility has been demonstrated in our 60 GHz wireless communications building blocks. The combination of this characteristic along with the efficient design and economical manufacturing process make CMOS the best process for semiconductor manufacturing for 60 GHz wireless communications.

Variable	CMOS	SiGe
Process	0.13 um 0.09 um	0.18 um
Power	Low	High
Process Availability	Widely	Limited
Cost	Low	Higher

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