Handset Design Techniques at the Package and System Level

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Silicon integration has delivered tremendous cost, space and power savings across a wide variety of consumer electronics products, enabling handset designers to meet strong demand for more highly integrated wireless semiconductor solutions capable of providing new voice, data and multimedia capabilities without increasing the size, cost or power requirements of next-generation mobile handsets. With the advent of advanced packaging techniques, designers can now bypass traditional steps on the integration curve while maintaining a high degree of flexibility, proven reliability, and guaranteed performance.

To meet the demand of more highly integrated wireless semiconductor solutions, innovation is accelerating along two parallel tracks - functional integration at both the die and package level, and the development of complete semiconductor system solutions for cellular handset applications.

On the functional integration track, designers are considering both SoC and SiP techniques. Although SoC integration has always been the ultimate goal of handset designers, it has presented design challenges that impact handset cost, size, design cycles and performance. Integration at the die level will eventually significantly reduce input/output count and deliver all the other traditional benefits of smaller process geometries; until then, however, many are finding that it is better to minimize SoC risks by using advanced packaging strategies that allow designers to focus on architectural partitioning trends, evolving standards, rapidly changing feature requirements, and increased system complexity. SiP techniques have enabled such innovations as single-chip DCRs, SPRs and 802.11b/g WLAN front-end modules. These packages surpass historical integration milestones to combine capabilities of multiple proven die into easy-to-test/assemble modules. Future opportunities include handsets that combine WLAN and cellular protocols in a single platform that can seamlessly roam between Wi-Fi and cellular networks.

On the system integration track, vendors have been able to quickly enter emerging markets with feature-rich phones by exploiting comprehensive cellular system solutions that provide all major integrated circuits, a full operator-qualified, network-approved protocol stack, all necessary development tools and customer support for building a complete platform. These phones include such advanced features as LCD color screens, ringtone melodies and multimedia features.

This paper will examine in detail the design techniques along both of these parallel tracks, and showcase early successes using both approaches.

Functional Integration: Die and Package Level

The current advanced packaging trend is toward low-cost chip-scale packages that can support digital, mixed-signal and RF applications. Only module-level integration and platform solutions help new players and shorten the development cycles for a diverse portfolio of products.

One of the most exciting first examples of this module-level integration approach is the SPR. The innovative SPR laminate module combines all of the radio circuitry required for a dual- or tri-band GSM/GPRS handset in one-third the footprint of alternative solutions created from discrete components. This eliminates tasks that can take up to nine months of development time. The SPR combines a transceiver, PA and associated controller, two SAW filters and a switchplexer module with switches and low-pass filters into a compact 40-pin 13x13 mm laminate MCM package with industry-leading insulation properties.
Before the advent of SPRs, handset manufacturers had to combine discrete components in a much larger area, while at the same time resolving challenging board and circuit-level RF design issues and bearing the costs of discrete-component integration tasks.

Laminate modules like the SPR deliver benefits in several key areas. In addition to enabling integration complexity, these packages are inexpensive and reliable. They deliver the same functionality at a comparable or only slightly higher price than discretes, while removing the individual purchasing, inventorying and packaging costs associated with each of the discrete components. Laminate modules allow multiple baseband die per package, and also provide a foundation for stacked-die and flipchip technology. For RF circuitry, they enable fully integrated radio systems like the CDMA MCM, which typically requires isolation between transmit and receive and high-quality passives. Semiconductor suppliers can place multiple die and surface-mount components on a laminate.

Also, unlike SoC solutions, the radio in a single-package approach maintains roadmap flexibility because the design is broken into digital and analog functions. Digital moves to the baseband die and analog to the transceiver die, thus eliminating the mixed-signal device. Each block can continuously shrink along the known roadmap of smaller geometries, unlike SoC approaches that lock RF, analog and baseband on the same die, making it difficult to quickly modify a design since the RF and analog blocks don't automatically scale. (See Fig. 1). This enables designers to leapfrog the limitations of silicon-based integration; for instance, in the RF section it is possible to achieve VCO integration, in the digital section one can combine both digital and RF together, and in PAs designers can merge HBT and CMOS die into the same package. Advanced packaging allows the designer to combine optimal process technologies, high-quality discrete passives and low-cost embedded.

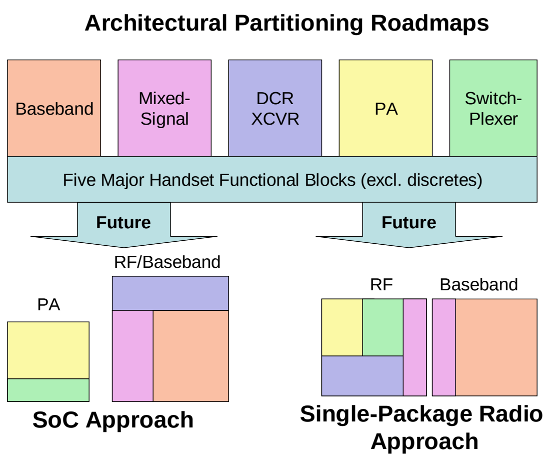

Fig. 1: SoC approach compared to SPR approach

Future development vectors for the SPR include improved integration in its two key components, the DCR and PA. During 2004, Skyworks reduced the footprint of the DCR to 6mm x 6mm and external component requirements from approximately 50 to less than 25. When paired with a transmit front-end module into an MCM, this DCR enabled the world's first sub-250-square-millimeter quad-band RF subsystem, paving the way for more cost-efficient and reliable infrastructure equipment such as 3G and 4G basestation transceivers. Similarly, Skyworks' latest-generation PA Plus reduced component count by 30 percent. Thanks to advances like these, SPR modules will continue to incorporate an increasing number of previously discrete components to further reduce customers' overall bill of materials.

Complete semiconductor system solutions for cellular handset applications

An increasingly popular alternative to SiP solutions is the complete cellular systems solution. This comprehensive approach has revolutionized the market-entry process, and fostered an entirely new breed of cellphone maker that focus their energies not on RF and other specialized design tasks, but on product differentiation and exciting new applications. Cellular system solution vendors supply the manufacturer with all of the devices from the baseband through the PA, as well as all of the software, and then collaborate with the handset manufacturer on board layouts. This gives the handset manufacturer more freedom to focus on the form factor, MMI, plastics and feature/performance definition. Time-to-market is greatly reduced as compared to the traditional model and, in many cases, the typical two-year design cycle can be cut to as little as 12 or 18 months with an aggressive form factor and extremely rich feature set.

Skyworks pioneered the concept of developing complete semiconductor system solutions for cellular handset applications. The hardware portion of Skyworks' cellular system solution includes all digital and analog baseband processing, multi-band/multi-slot power amplification, power management, battery charging and transceiver functions. Skyworks' protocol stack has been field tested, qualified and approved in more than 50 countries, and by more than 70 GSM network providers worldwide. These comprehensive solutions have enabled many new handset manufacturers to enter the marketplace over the past two years, giving consumers a much greater selection of phones, with significantly more features and capabilities, at substantially lower price points.

Conclusion

Moving forward, semiconductor manufacturers can further integrate the various die in each of the two individual packages. Each package follows its own integration path, using the optimal mix of available product and process technologies. The ultimate goal is still the fully integrated single-chip phone, of course. But by combining silicon integration with advanced packaging strategies, handset designers get the most flexible and risk-free development roadmap possible, while still realizing a good portion of tomorrow's cost, power and space savings by integrating at the package level.

ACRONYMS

CDMA: code division multiple access
CMOS: complementary metal-oxide semiconductor
DCR: direct conversion receiver
GSM: Global System for Mobile Communications
GPRS: General Packet Radio Service
HBT: heterojunction bipolar transistor
LCD: liquid-crystal display
MCM: multi-chip module
MMI: man machine interface
PA: power amplifier
RF: radio frequency
SAW: surface acoustic wave
SiP: system-in-package
SoC: system-on-chip
SPR: Single-Package Radio
VCO: voltage controlled oscillator
WLAN: wireless local area network