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UltraCMOS™ Leads Toward Ultra-Integration

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In today's high volume markets, integration is playing a key role in the never-ending quest to reduce size, component count and cost. Integration has taken many forms, but recently has had the greatest impact on size when reducing the number of passive components used in a system. This is typically accomplished by utilizing a myriad of integrated passive technologies or by eliminating the passive function through semiconductor integration.

For high volume markets such as WLAN and cellular phones, passive devices account for 75 to 85% of all components used. In the cellular handset market, this ratio holds true across all air interface standards and handset providers. As a quantitative example, the widely available Nokia 3300 music phone utilizes a total of 406 components with 355 of them passives – capacitors, inductors and resistors.

Integrated passive technologies have been the key enablers to lowering overall component count in the RF section, especially within RF modules. Several different integrated passive technologies exist today, but the most widely available include Low Temperature Co-Fired Ceramic (LTCC), Thin Film Silicon and conventional thin dielectric materials used as a PCB. The measure of value of these integrated passives is typically reported as the passive density, available values, quality factor and tolerances.

Little known is that integrated passives are typically cost effective only when implemented at the module level. This is due to the interconnection and test costs as well as the design effort all best handled at the module level. Although modules can be cost effective compared to discrete solutions, the issues of multiple suppliers, margin stacking and multiple test costs preclude modules as just a step in the effort to true integration.

History has shown that true integration comes through semiconductor technologies. CMOS has traditionally dominated in baseband, recently in RF transceivers, and now in front ends. As a case study, most GSM handsets incorporate LTCC as the technology of choice for passive integration in ASMs (antenna-switch modules). ASMs perform the front-end RF signal routing and power-amplifier harmonic filtering. While the current high-volume ASM solutions use a combination of mounted PIN diodes and passives integrated into the substrate for dual and triple-band phones, ASM designers have turned to more integrated technology options, such as UltraCMOS™, to meet the requirements of quad-band GSM handsets. These ASMs have traditionally integrated multiple technologies on the surface of the LTCC to achieve the overall functionality, but market pressures on size, cost, and added functions have continuously driven ASM manufacturers to reduce the component count added to the LTCC.

Quad-band GSM front-ends have six RF paths – two dual-band TX paths and four dedicated RX paths. PIN diodes have not scaled to this quad-band application as at least one PIN diode is required for each path and each PIN diode requires a transmission line and a set of biasing passives. While LTCC manufacturers have made astounding technical strides in increasing their density of integration, the size and height requirements today preclude PIN diodes from being a solution.

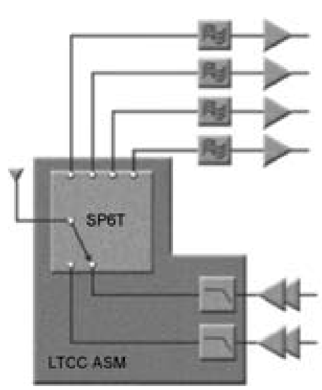

Figure 1: Example of front-end architectures for quad-band GSM

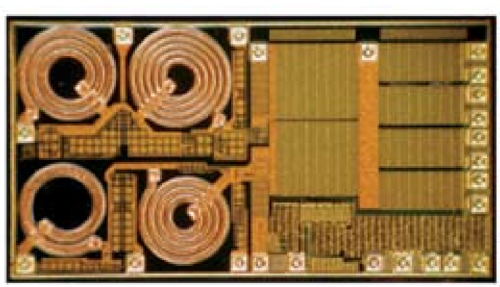

Figure 2: Monolithic SP6T Antenna Switch and PA Filters enabled by UltraCMOS™ Process Technology

Monolithic switching solutions eliminate the PIN diodes along with the associated transmission lines and passives. **Figure 1** shows an ASM implementation with an UltraCMOS SP6T switch. By reducing component count to one and eliminating several LTCC layers by integrating matching and harmonic filters, the ASM footprint is reduced by more than 60% while keeping the overall ASM height below the critical requirement of 1.2 mm. What is intriguing, however, is that further integration is possible.

Using UltraCMOS technology, Peregrine Semiconductor has demonstrated the world's first monolithic semiconductor replacement for an ASM in only 1.2 x 2.2 mm (See **Figure 2**). This ASM monolithically combines CMOS RF technology with integrated passive devices for the ultimate in true integration. The device performs the high-power SP6T switching and PA harmonic filter functions required for quad-band GSM. It also delivers industry-leading linearity; TX insertion loss of 1.2 dB at 900 MHz and 1.4 dB at 1900 MHz; and RX insertion loss of 0.8 dB and 1.0 dB for 900 and 1900 MHz, respectively.

In the WLAN market, chipset providers have also made great strides in lowering component count, size and cost through integration. As an example, 802.11a/b/g reference designs published in 2003 from the leading chipset providers require approximately 300 components. Today the reference designs have shed 200 components and the typical implementations have no more than 100 components on a single-sided printed wiring board. (See **Figure 3**)

Also using UltraCMOS technology, Peregrine Semiconductor has demonstrated the world's first monolithic semiconductor replacement for a WLAN front end (See **Figure 4**). This FEM monolithically integrates CMOS RF technology with integrated passive devices for the ultimate in true integration. The device performs the linear DPDT switching, as well as four bandpass filters, a digital attenuator, two baluns and a LNA.

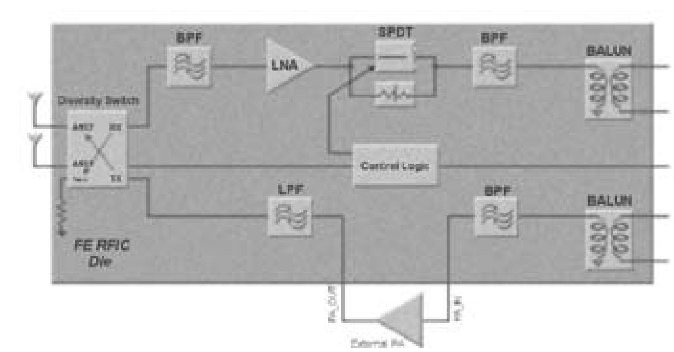

Figure 3: Example of front-end architectures for WLAN

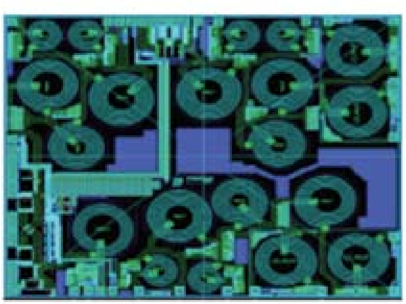

Figure 4: UltraCMOS™ Monolithic WLAN Front End

Because the UltraCMOS process utilizes a highly insulating sapphire substrate, high-Q passives – comparable to those found on LTCC and thin-film silicon solutions – can be integrated into a monolithic die with unprecedented RF performance. Unlike LTCC-based passives, which are plagued with repeatability problems associated with poor control of the shrinking process, UltraCMOS-based passives enjoy the repeatability of semiconductor processing with inductor tolerances on the order of 2% and capacitor tolerances of 5%. Unlike thin-film silicon, UltraCMOS is a monolithic solution, therefore eliminating costly packaging and die-to-die interconnect issues. Biasing is internally generated, eliminating the need for external DC-blocking capacitors. The integrated CMOS decoder also reduces the number of required control lines to three, and naturally accepts the control levels provided by other CMOS devices. By placing this component into a standard QFN package, a finished device height could be as low as 0.5 mm, dramatically lower than its LTCC counterpart. Further, because UltraCMOS is a standard CMOS process, it carries all of the semiconductor advantages – repeatability, small size, and cost-effectiveness – while maintaining the functionality of digital CMOS. This state-of-the-art technology enables the world's smallest and simplest RF front-end solutions and the ultimate in integration.

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