Texas Instruments

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Planning for PCS:
The TI Strategy for Upbanded GSM

Tomorrow's applications will depend on system solutions that collect, process and display real-world analog information on a real-time, ongoing basis. This ability to work with these real-world signals in the digital domain is vital for creating a range of low-cost interactive and responsive new applications as well as adding flexibility and intelligence to existing products. Digital Signal Processing Solutions from Texas Instruments provide a portfolio of products, including industry-leading hardware, software, system expertise and development tools that enable customers to create these applications.

Technology Brief

Introduction

Personal Communications Systems (PCS), the new wireless technology for voice and messaging, is one of the most dynamic and is projected to be one of the fastest growing market areas in telecommunications. In a short time, the multibillion-dollar market for PCS services, terminals and base stations has spawned a worldwide industry of service providers, original equipment manufacturers (OEMs) and semiconductor suppliers.

Because PCS is based on the transmission of compressed digital information, digital signal processors (DSPs) play a major role in the technology. Texas Instruments, the world's leading supplier of DSPs, is well positioned to provide competitive DSP solutions for PCS equipment. TI's leadership technology continues to help lower system costs through high levels of integration in digital and mixed-signal devices. Integration also lowers chip counts for smaller, lighter-weight systems; lowers power consumption for longer battery life; and makes design easier, so that OEMs can bring their products to market faster and achieve economies of scale sooner, helping to bring down terminal and base station prices and drive market demand.

The growing GSM standards

Among the standards that are rapidly emerging in the PCS environment is PCS1900 in North America and Digital Cellular System 1800 (DCS1800) in Europe and other emerging markets. Both of these standards are based on the Global System for Mobile (GSM) communications standard that has been successfully implemented throughout Europe and Asia for digital cellular telephones. Both of the PCS standards have been modified for use in the 1900-MHz (U.S.) and 1800-MHz (Europe) frequency bands reserved for PCS, as opposed to the 900-MHz frequency band used for GSM cellular transmission. In the following discussion, the phrase “GSM standards” refers to GSM, PCS1900 and DCS1800 as a group.

After a decade of development culminating in the commercial deployment of GSM in 1992, growth of the standard has been rapid. By early 1996, 124 GSM networks were in use worldwide with more than 13 million subscribers, and licenses for many more networks have been issued. By 1995, GSM-based wireless local loops were appearing for the use of wireless telephones in homes and offices where the wired telephone infrastructure was poor or non-existent.

While cellular usage of the base GSM standard has grown rapidly, usage of the PCS1900 derivative standard may grow just as fast. In early 1996, the first North American PCS1900 service was launched in the Washington D.C./Baltimore area, and plans for other services were announced.

Meeting the requirements of PCS

For suppliers of PCS systems, trends in design start with the demands of consumers or subscribers, as Figure 1 shows. In general, wireless telephone users are concerned about cost, size, weight, talk and standby time, voice quality, channel availability, ease of use and security. These demands are filtered through the business constraints of service providers, who need to provide as many channels as they can within a limited bandwidth, keep their costs and service offerings competitive, and provide instruments that comply with enough standards to allow customers to roam from service area to service area — perhaps from PCS to cellular services as well.

Demand drives PCS design requirements

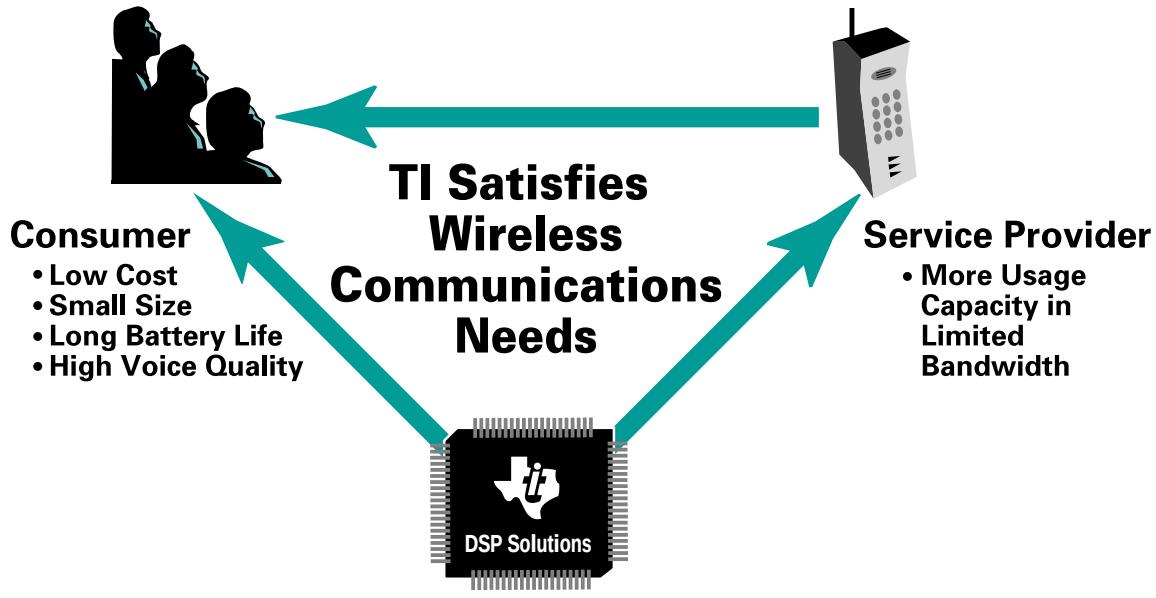

Figure 1. The requirements of subscribers and service providers drive OEM designs for PCS systems. As an IC solutions provider, TI meets the needs of all these groups

PCS instruments may eventually include not only wireless telephones but also messengers, mobile computers, personal digital assistants (PDAs), geographic locators, and other types of equipment. For any of these instruments, OEMs need to balance their own needs with the demands of end users and service providers (carriers). The OEM needs include having an upgrade path for new products, securing a volume supplier of reliable components, keeping their options open with flexible hardware and software in case standards change, manufacturing and testing their products easily, and getting to market quickly.

Although TI's direct customers are the OEMs building PCS instruments and infrastructure equipment, TI products must indirectly meet the needs of the service providers and users who are the OEMs' customers. Among the many capabilities TI has that allow it to offer leadership IC solutions for PCS are the following:

- IC products designed for low system costs, low power and battery management
- Software and system expertise for faster development (time to market) and high voice quality
- Roadmaps for long-term, multi-generation product integration
- Multiple, large-capacity manufacturing plants worldwide for fast ramp-up to volume production
- Small packages for small, light-weight systems
- Testability to help OEMs improve the quality of their products and lower overall costs of manufacturing

Evolving standards require programmable solutions

In general terms, as market size increases and standards mature for an end equipment, IC vendors offer more comprehensive solutions for the standards. At the same time, applications become more robust in features, requiring the introduction of new functions. For PCS and cellular instruments, an important new feature will be the ability to roam from one geographic region or one wireless service to another. Roaming will require that the instrument support multiple transmission standards and frequency bands — support that requires many additional hardware and software functions. The bottom line for wireless OEMs is that more comprehensive IC solutions will eventually relieve them from having to implement the basic transmission standards. At the same time, though, more feature-rich applications will continue to add complexity to wireless phone designs. Figure 2 illustrates these trends graphically.

In the early days of GSM, many people believed that the standard would quickly become frozen and that a full-custom solution or a plug-and-play chip set would be appropriate for the market. Today, however, the market in its relatively early stage is better served by a programmable hardware and software solution in which both the digital and mixed-signal components are partitioned to optimize cost and performance.

Programmability is important in a solution because the GSM standards are still evolving. Algorithms to implement the standards remain complex and diverse, and are therefore likely to change as new techniques emerge. With continual incremental change in the standards and algorithms, as well as changing market conditions and new applications, the product redesign cycle must be short, as often as once every year. A flexible solution with reprogrammable hardware allows OEMs to respond quickly to changes in the technology with minimal redesign, and also offers various ranges of phones based on the same platform.

Solution Expertise vs. Market Maturity

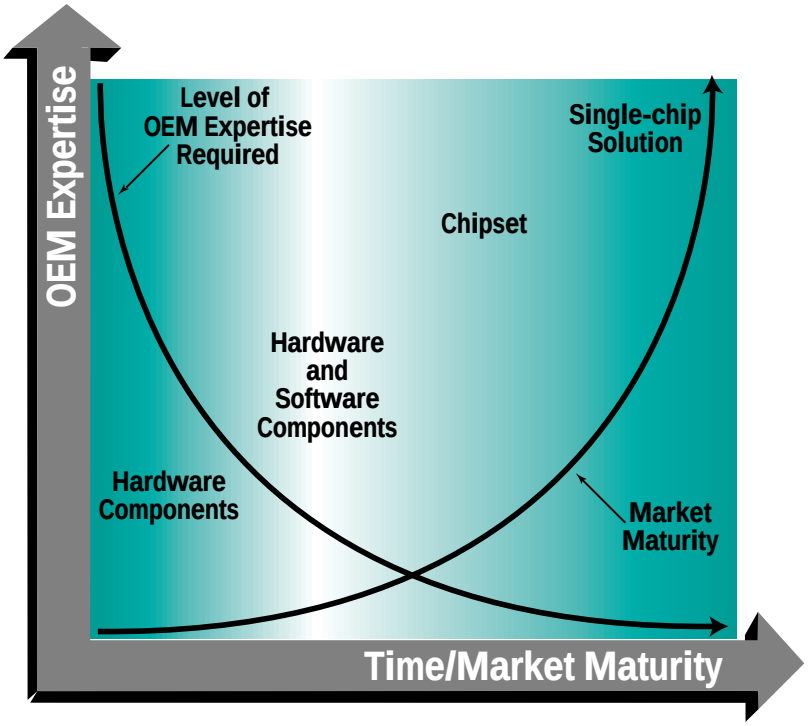

Figure 2. As the GSM/PCS1900/DCS1800 market grows and these standards mature, IC solutions will become more comprehensive. As a result, OEMs will need to know less about the operation of the standards in order to design their products. Products based on the GSM standards are currently in the stage where programmable hardware and software solutions are most beneficial.

A flexible DSP architecture

The architecture and powerful instruction set, together with low-power features, have made the 'C54x family the DSP of choice for many manufacturers of wireless terminals and base stations.

Several years ago when TI entered the market for digital wireless communications ICs, it recognized that a flexible programmable architecture provides a sound basis for helping OEMS meet the requirements of evolving wireless standards. Since then, TI has leveraged its industry-leading DSP technology to create a family of low-power, high-performance DSPs specifically crafted for wireless applications. This family is based on a highly efficient DSP core that is integrated with other low-power functions using ASIC methodologies for rapid response to market demand.

The first products resulting from the TI strategy are the TMS320C54x DSPs, a family of processors tailored to the requirements of wireless systems supporting a variety of digital standards, including GSM. Unlike standard-specific chip sets that remain frozen in features, 'C54x DSPs can be programmed to support a range of standards, including those like GSM, PCS1900 and DCS1800 that are still evolving, as well as features that allow the OEM to differentiate their phone. The architecture and powerful instruction set, together with low-power features, have made the 'C54x family the DSP of choice for many manufacturers of wireless terminals and base stations. TI has worked closely with these manufacturers to define the 'C54x architecture to better meet the market's needs.

Important features of the 'C54x architecture include:

- 66 MIPS performance with a roadmap to 100 MIPS in 1997
- 2.7-V and 5-V versions
- Three power-down modes for low power dissipation and longer battery life
- Integrated RAM and ROM configurations for fast program and data access
- Auto-buffered serial port to speed data I/O
- Glueless host port interface to standard 8-bit processors and TMS320 DSPs for ease of design
- Ultra-thin packaging for small systems, light weight
- DSP number-crunching enhancements:
    - Integrated Viterbi operation for faster channel decoding
    - Four internal buses and dual address generators to minimize memory bottlenecks
    - 40-bit adder, two 40-bit accumulators for single-cycle parallel instructions
    - Single-cycle 16-bit signed or 17-bit unsigned multiplication for efficient vocoding
    - New single-cycle instructions for efficient execution of common DSP tasks such as FIR filters

Four buses and two address generators in ‘C54x DSPs allow enhanced parallelism and data memory operand access. Two single cycle, and one dedicated bus enables stores from the CPU. When the program bus is being used for coefficient access, three operands can be read simultaneously. The two address generation units and up to 16 indirect modifiers are available for single data operand reads and writes, 32-bit long operand read and writes, dual operand reads, and single operand reads with parallel stores.

The arithmetic logic unit (ALU) enables a number of powerful instructions, in addition to providing a very efficient implementation of Viterbi-based operations such as equalization and channel coding and decoding. The program address generator enables block repeats for faster subroutine execution. The ‘C54x multiple bus architecture not only enables powerful multiple operand instructions, but also reduces memory program access demand for lower power consumption.

TMS320C54x Block Diagram

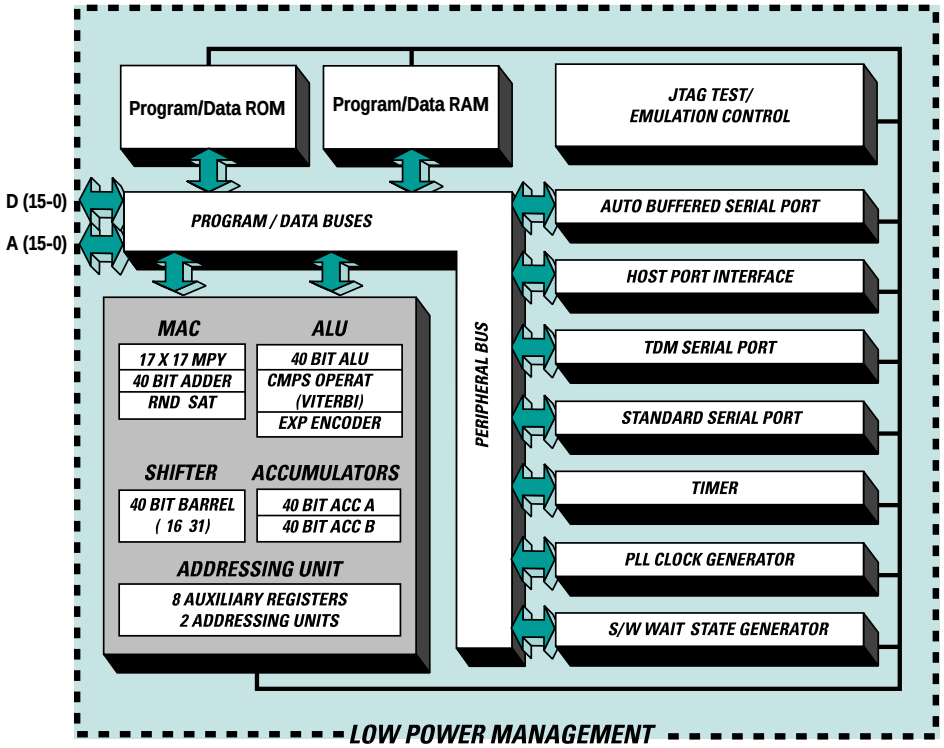

Figure 3. TMS320C54x DSPs are optimized to meet the performance, cost and low power needs of wireless communications systems.

TMS320C54x Performance in Full- and Half-Rate GSM Vocoding

Half-Rate GSM				Full-Rate GSM		
Total RAM	ROM	Avg. MIPS	GSM Software Modules	Total RAM	ROM	Avg. MIPS
0	2900	2.5	Modem (normal burst)	0	2900	4.9
16	576	1.8	A5	16	576	3.6
2101	21323	18.4	Voice Coder/Decoder	526	3750	2.5
992	7356	6.3	Channel Encoder/Decoder	992	4447	4.2
0	747	0.1	Frequency Burst Detection	0	747	0.1
19	385	0.1	Signalling and Key Beep Tones	19	385	0.1
1050	6000	0	Miscellaneous (control, power management, etc.)	1050	4056	0
6100**	39287	29.2	TOTALS	3923*	16861	15.4

*Includes static RAM above plus 1320 words of working RAM
**Includes static RAM above plus 1922 words of working RAM

Table 1. The GSM Half-Rate and Full-Rate baseband modules have been implemented on a 'C54x platform. The highly efficient architecture of the 'C54x allows the full-rate software to be implemented in only 15.4 MIPS and the half-rate software in only 29.2 MIPS.

TI has implemented the complete GSM baseband functionality, both full-rate and half-rate, on a single 'C54x. TI also plans an enhanced full-rate vocoder for GSM and PCS1900 that will operate with the full-rate software modules on a single 'C54x. Table 1 shows the efficiency of the 'C54x in executing GSM software. Only 15.4 MIPS are required to implement full-rate GSM; only 29.2 to implement half-rate GSM. For the full-rate codec, only 2.5 MIPS are required, or only 5.6 mW of dissipated power, giving the 'C54x one of the lowest milliwatts per function ratings in the market. For wireless systems, the combination of high performance and high efficiency offered by 'C54x DSPs can provide better voice quality and longer battery life at the same time. Efficient, powerful processing also allows OEMs to put unused MIPS to work with enhanced features such as voice dialing in order to differentiate their products in the market.

Since TMS320C54x DSPs deliver 66 MIPS at 3V today, there is sufficient remaining processing power for other features such as echo cancellation and dual-mode functionality. In base stations, either a RAM-based TMS320C542 or 'C548, both of which include a buffered serial port and a host-port interface, is ideally suited to implement several channels in the base station transcoder and transceiver.

Complete DSP Solutions

While ‘C54x DSPs provide an efficient high-performance engine for GSM product design, they are not the whole story. TI will soon release a single mixed-signal chip that will combine various baseband interface functions such as audio and digital control and voice band audio processing. The new chip will boost system performance and eliminate the need for separate devices to perform each of these functions. Figure 4 shows how the new device will integrate components in an existing GSM system.

In addition to enhancing baseband components, TI is also developing solutions to minimize the number of components required for the RF section of wireless systems. Other hardware and software enhancements that TI is well positioned to create, depending on customer demand, include a single-chip DSP and MCU, an enhanced full-rate vocoder for PCS1900, a complete software portfolio for the range of GSM standards, and dual-mode and dual-band hardware and software for joint PCS-cellular operation.

For all wireless communications ICs, greater integration goes hand-in-hand with ever-decreasing voltages. Add to these new power management techniques and the greater processing efficiencies of new algorithms, as shown in Figure 5. The result is lower power consumption for future products, helping prolong battery life and making it possible to use fewer batteries for smaller, lighter-weight systems.

GSM/PCS1900/DCS1800 System Block Diagram

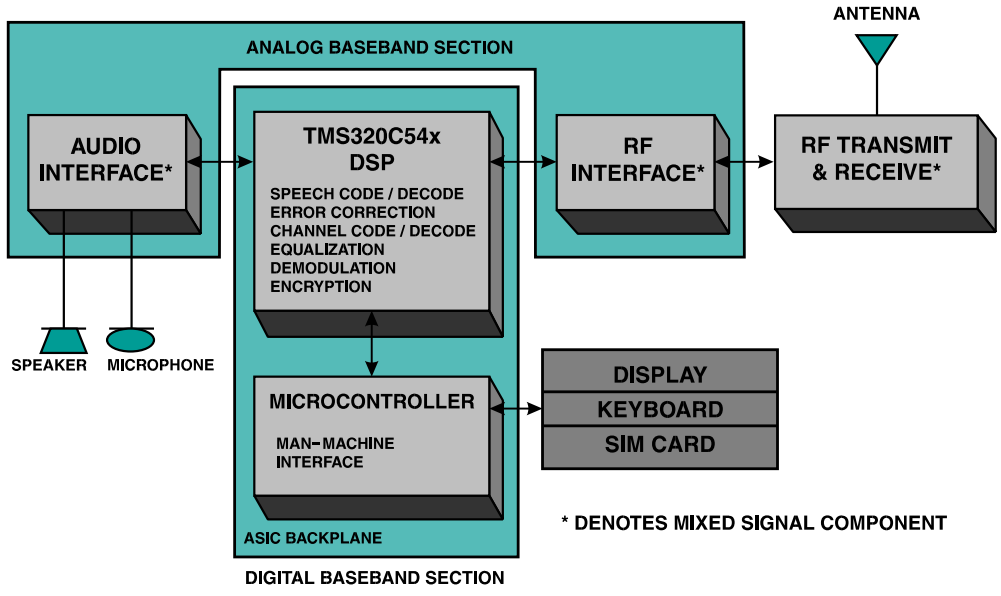

Figure 4. TMS320C54x DSPs and mixed-signal devices can provide a highly-integrated baseband solution for GSM cellular phones. The same technology is easily adaptable for use in PCS1900 systems.

Trends to Longer Battery Life

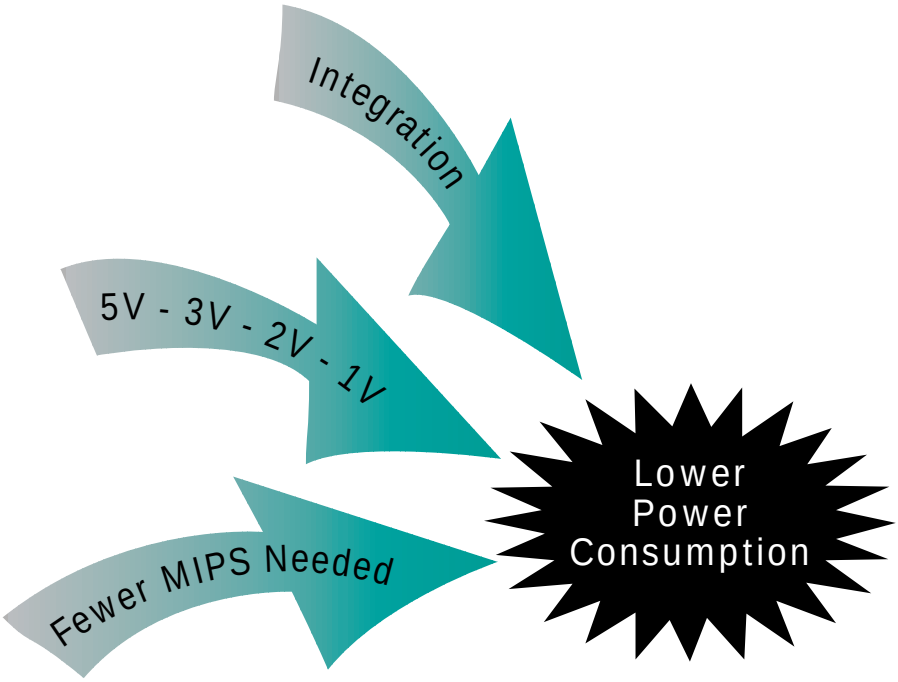

Figure 5. IC advances will allow the PCS and other wireless systems of tomorrow to consume less power for longer battery life.

To round out the solution TI offers its wireless customers, the company has taken other steps in its wireless business to complement its advances in components. For several years, TI has developed internal GSM expertise in order to be free of reliance on third parties for key software and to have full ownership and understanding of the solutions it offers its customers. The company has also dedicated manufacturing facilities to the wireless communications market in order to keep production capacity high. Since wireless OEMs are located in many countries, and since optimum solutions for their products come from several of TI's product entities, TI has formed a worldwide Wireless Communications Business Unit that is dedicated to serving its wireless customers.

Putting the pieces together for PCS

TI's flexible design strategy has already produced a family of DSPs and several mixed-signal devices that provide baseband solutions for a variety of wireless transmission standards. Since the principal difference between cellular and PCS technology is in the frequency, most of the design differences will be in the RF transceiver section. There are other potential hardware and software differences in areas such as modulation which may require the modification of the baseband section. Cellular baseband solutions are not drop-in solutions for PCS, even though the functions are nearly the same.

For PCS1900 and DCS1800 designers, TI has all the technology for complete baseband solutions. TI's flexible design approach will support rapid development of PCS1900/DCS1800 baseband hardware. TI's software modules provide an implementation baseline that system designers can customize to fit into their own PCS proprietary solutions, and which they can upgrade quickly as the GSM standards evolve. Rather than forcing system designers to conform to a strict, quickly outdated architecture, the TI programmable architecture puts system designers in charge of their own development destinies.

PCS, like cellular before it, promises a wealth of opportunity for OEMs and service providers — as long as they build the systems that users want. Ultimately, it is up to IC vendors like Texas Instruments to provide the component technologies that enable OEMs to build tomorrow's systems. For PCS1900 and DCS1800, the technology development is just beginning. Fortunately, TI's manufacturing strength and design methodologies, coupled with the systems and software expertise the company has gained from developing a portfolio of GSM system-level technologies, make it possible to create solutions that will enable PCS1900/DCS1800 OEMs to reduce the cost, size and power requirements of their systems quickly and get them to market fast.

Printed in the U.S.A. by Dallas, TX. SPRY004