SOC for Broadband Convergence

Trends and Implications for Silicon Technology and Design

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Communications & Entertainment Drive Electronics Growth

- Cell phone is key device platform
- Carrier subsidies encourage high replacement rates
- Global 3G rollout will encourage development of new services

Source: iSuppli, June 2005; Gartner, July 2005
Many new connected devices requiring content

Wireless and Consumer Electronics Converge Creating Huge Opportunity

Connected

Unconnected CE Devices

Wireless
Bluetooth®
Cellular
UWB
Wi-Fi
Digital TV

Digital camcorders
Digital still cameras
Internet audio players
Digital juke boxes
And more…

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Extending Entertainment......
Living Room experience; on Your Phone

**Display**
- CIF, VGA
- Up to D1

**Audio**
- Dolby audio and 3D audio effects

**Camera**
- 4 megapixel
- Up to 6 megapixel

**Video**
- VGA video
- Up to DVD quality

**TV**
- TV output
- Digital TV reception

**Games**
- 3D interactive Game-console quality soon
Mobile Entertainment Taking Off and Demanding Bandwidth

- **2 Mega-Pixel Camera**
  - Lenovo i717

- **Digital Music Player for MP3**
  - LG Cyon SV9140
  - Nokia N91

- **3D Gaming**
  - Sharp 902SH from Vodafone

- **Live TV**
  - LG Cyon SV9140

- **3D Surround Sound**
  - NTT DoCoMo FOMA™ F901i

- **Mobile Wallet**

- **Digital Music Player for MP3**
  - Nokia N91

- **Video Conferencing**
  - SonyEricsson Z1010
Silicon Innovations Fuel Wireless

- Single-chip GSM/GPRS Cell Phone: Enabling low-cost handsets, opening new markets

- OMAP™ 2 Application Processors: The living-room goes mobile: Camera, DVD, Dolby®, 3D Games

- Live Digital TV Chip – “Hollywood”: Mobile TV based on open standards and TI Digital RF
Conclusion #1—IC Technologies Converge

- Convergence means combining RF, analog, and digital into a single CMOS chip
  - New-generation silicon process technologies
  - Multi-$B investments in R&D favor large players with “all the pieces”

- Performance no longer defined by Mhz
  - Power consumption, size, cost are king
    - System-on-a-chip (SOC)
    - System-in-package (SIP) – multi-chip
    - Sophisticated multi-layer power management schemes

- Convergence demands programmability for multifunction devices
Example of Today’s Convergence
DVB-H Mobile TV: DTV1000/1001
The Future of Wireless…
The Converged Device

ANY DEVICES

ANY NETWORK

ANY WHERE

ANY TIME

SEAMLESS CONNECTIVITY

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Near Term MIMO-OFDM Trend

- World-wide standards have been evolving towards OFDM
  - ADSL, VDSL, digital TV (DVB, DMB, MediaFLO, ISDB-T), audio
  - 3.9G long-term evolution (LTE)
  - WiMAX, IEEE802.20
  - WLAN (802.11), WPAN (MB-OFDM/UWB)

- Multiple-Input, Multiple-Output
  - Increased spectral efficiency, increased reach / robustness
  - Increased throughput, cell capacity
  - 802.11n, WiMAX, 3.9G LTE, 802.20

- Semiconductor technology enables low-cost, energy efficient implementations
Conclusion #2……Bandwidth Demands Grow

• Applications like video consume high bandwidth on a per user basis

• New standards will have to evolve to handle these needs

• New regulations and spectrum allocations needed

• More flexible devices such as Software Defined Radio will be required
Applications Rule ……
New Complex Use Models Are Emerging

- Watching live TV broadcast when a phone call arrives
  - DVB-H radio tuner
  - H.264 or WMV decode
  - MIDI ring tone

- Video conference from hotel room
  - MPEG-4 or H.264 encode & decode
  - AAC+ encode & decode

- Stream and listen to music videos from the Internet via cellular or WiFi™
  - MP3 playback
  - Video playback
  - MPEG-4 or H.264
  - Optional WiFi™ download

UMTS cellular network

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Conclusion #3.....S/W based IC platforms enable multiple standards to converge

• Continuous innovation in Handsets
  – New functions enabled via S/W (vs. dedicated hardware)
  – Multiple programmable cores on single chip
    • Each optimized for specific jobs like Comms, Graphics, Video, Audio, etc

• Silicon Vendors expected to provide more/more of the core S/W functions
  – Communication functionality of chip
  – Applications software
  – More Engineers at TI with S/W job codes than IC designers!
The Longer Term, What is 4G?

3GPP Rel'5
HSDPA

- Deployment in 2006
- Rel'5 Features:
  - Up to 14.4 Mbps DL
  - 384 Kbps UL (QPSK)
  - AMC, HARQ, FDE, Turbo

3GPP Rel'6
HSUPA

- Deployment in 2007
- 5.8 Mbps UL
- MBMS broadcast/multicast
- Interference cancellation

3GPP Rel'7
(study only)

- 5 MHz FDD
- Focus on Rel'6 deployment issues
- MIMO

OFDMA

- 3GPP 3.9G Long Term Evolution
- High data rate, low latency, packet optimized
- Studies complete by summer 2006
- Features:
  - 100 Mbps DL, 50 Mbps UL
  - 2x-4x release'6 spectral efficiency
  - RAN latency < 10ms
  - MIMO (2x2 DL, 1x2 UL)
  - Freq. Scalability: 1.25, 2.5, 5.0, 10, 15, 20 MHz
  - FDD

Broadband Wireless WAN

IEEE 802.16e / OFDMA

- WiMax
  - Features:
    - Freq. Scalability: 1.25, 2.5, 5.0, 10, 15, 20 MHz
    - TDD (or FDD)

Non Cellular OFDM

WiFi/802 (40 MHz)

- UltraWideband (> 1 GHz)

- Digital Audio (1.5 MHz)

- Mobile Digital TV (8 MHz)

4G Communications

- Features:
  - 100 MHz bandwidth
  - FDD or TDD
  - > 20 bps/Hz
  - > 1 Gbps throughput
  - MIMO, advanced FEC, OFDM
  - Multistandard implementations
  - Best overall die area / power by intelligently sharing components

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TEXAS INSTRUMENTS
4G System Challenges

• **Spectrum availability?**
  – 3GPP LTE/3.9G and WiMAX support up to 20 MHz signal BW

• **4G:** need 20 – 100 MHz BW, > 20 bps/Hz spectral efficiency

• **Standardization**
  – Open standards (3GPP, IEEE, ETSI, ANSI, others)
  – Operators, OEM’s, semiconductor companies, content providers

• **Large Infrastructure capital expense:** technology must be disruptive to justify the investment

• **Large R&D investment for SoC design and verification**

• **Spectral efficiency > 20 bps/Hz ➔ > 1 Gbps**
  – Requires MIMO, OFDM, and advanced FEC
4G Implementation Challenges

- **Power Dissipation/integration/cost/performance**
  - 100 mW, 10M-100M gates/memory/RF, ~$10, 20 bps/Hz

- **Small board footprint, single chip with no external components**

- **Multi-standard operation** (LTE, WiMAX, WiFi, DVB-H, ISDB-T, others)

- **RF CMOS performance**
  - Noise, linearity, phase noise, jitter, ACI, co-located transmitters

- **Digital Baseband**
  - ~1 GMACS per MHz signal BW (multiply-accumulate operations per sec)
  - 8K FFT size → large memory requirements
  - Power management

- **Networking**
  - Seamless handoff between communications PHY/MAC, internetworking
  - Cross-layer optimization
Conclusion #4…..More and more systems capability required of IC Vendors

- System/silicon architects play a critical role
- Hardware designers know S/W
- S/W programmers know H/W
  - “close-to-the-metal” programming
- Analog Engineers “do” digital (aka “mixed signal ICs”)
- Marketing needs intimate knowledge of the technology
- Technologists need to understand “business”
- More focus on our “customer’s customer”
  - Relationships with carriers/service providers/content owners etc. give us early insight to new chip features
Summary

• Broadband communications offers an exciting future

• Many unsolved technology issues

• IC technology will provide incredible capabilities for the system technologist

• Connecting people with audio, video, data has and will continue to offer growth opportunities for the electronics industry
Thanks!