Digital Subscriber Line (xDSL)
xDSSL Agenda

- Introduction
- Benefits & Applications
- Market Dynamics
- Technology & Equipment
- Xilinx Solutions
- Summary
Introduction
Broadband Access

• High speed connection to the Internet
  – Greater than 128Kbps
  – Always on!
  – Simultaneous up-Link and down-link communication
  – Overcomes Internet frustrations
  – Made possible by digital modems

• Leading broadband access technologies
  – xDSL, cable, satellite, ISDN digital modems
xDSL Introduction

• xDSL is the term for the Broadband Access technologies based on Digital Subscriber Line (DSL) technology
  – “x” signifies that there are various flavors of DSL
• Provides always-on, high-speed data services over existing copper wires to residences & businesses
  – POTS service and DSL coexist on same copper line
• Lower rate xDSL (up to 1.5 Mbps) is gaining popularity in the residential market; will get faster and cheaper
• High performance xDSL (up to 52 Mbps) targets business and high-end users
Benefits & Applications

Benefits
• High-speed data service
  – DSL typically >10x faster than 56-kbps analog modem
• Always on connection
  – No need to “dial-up”
• Uses existing copper wires
  – Co-exists w/ POTS service
• Reasonably priced today and getting cheaper

Applications
• High speed Internet access
• SOHO
• Multimedia, Long distance learning, gaming
• Video on Demand
• VPN
• VoDSL
## Speed Benefits

### Average Download Times

<table>
<thead>
<tr>
<th>Connection Speed</th>
<th>Web Page (30KBytes)</th>
<th>3 minute Music File (3MBytes)</th>
<th>30 second Video/Movie (50 MBytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>28.8 kbps</td>
<td>9 seconds</td>
<td>15 minutes</td>
<td>4 hours</td>
</tr>
<tr>
<td>56 kbps</td>
<td>4.5 seconds</td>
<td>7.5 minutes</td>
<td>2 hours</td>
</tr>
<tr>
<td>ISDN (144 kbps)</td>
<td>2 seconds</td>
<td>3 minutes</td>
<td>55 minutes</td>
</tr>
<tr>
<td>DSL (1.5Mbps)</td>
<td>&lt;1 seconds</td>
<td>15 seconds</td>
<td>5 minutes</td>
</tr>
</tbody>
</table>
xDSL Market

• Market Drivers
  – Increasing demand for high-speed internet
  – Decreasing component costs
  – Standardization for increased vendor interoperability
  – Competition from alternate access technologies

• Challenges
  – Speed, ease and cost of deployment
  – Applications and new services
  – Steep competition from other access technologies
    • Cable Modem, Satellite, Fixed Wireless and others
xDSL Market

- Worldwide xDSL equipment market is forecast to grow at a CAGR of 12% from 2000 to 2007
  - $4.8 B in 2000 => $10.4 B in 2007
  - Mostly asymmetric xDSL variety (83% of market)
- Leading equipment vendors
  - Alcatel owned 31% of 2000 market
  - Lucent, Cisco, & Efficient made up 32%
- Equipment market is divided into two subgroups
  - Central Office Equipment - DSLAMs
  - Customer Premises Equipment - DSL Modems, Gateways
Worldwide xDSL Equipment Market Forecast

Source: Frost & Sullivan, 12/2001

Revenue ($M)

2000 2001 2002 2003 2004 2005 2006 2007

Central Office Equipment  Customer Premises Equipment
xDSL Technology & Equipment
DSL Overview

A - Rack of xDSL Line Cards
B - Voice routed over PSTN
C - Multiplexed Internet access
Asymmetric xDSL

• “Asymmetric” => faster downstream rate vs. upstream
  – Suitable for applications such as web-browsing, MP3 downloading, Video on demand (VoD)

• Types of asymmetric DSL
  – Asymmetric DSL (ADSL)
    • The original and most popular
    • Other asymmetric DSL technologies derived from ADSL
  – Universal ADSL (UDSL), a.k.a. G.Lite or DSL Lite
    • Expedites and reduces cost of deployment process by moving the splitting process from the CP to the CO
    • Splitter-less nature slows the bit rate considerably
Asymmetric xDSL

- Rate-Adaptive DSL (RADSL)
  - Detects highest possible line rate & adjusts accordingly
- Very High Bit-rate DSL (VDSL)
  - Used to get high speed over short local loops
  - Typically used in conjunction with Fiber to the Curb (FTTC)
  - Still in development phase
Symmetric xDSL

- “Symmetric” => downstream & upstream rates are equal
  - Suitable for office type apps like Video conferencing
- Types of symmetric xDSL
  - Symmetric DSL (SDSL)
    - Based on HDSL but single pair
    - Spectral compatibility an issue (crosstalk & interference)
  - High bit-rate DSL (HDSL)
    - The first of the symmetric DSL technologies
    - Uses multiple wire pairs (2 or 3) to achieve high bit rates
Symmetric xDSL

- **HDSL 2**
  - Single-pair version of HDSL
  - More standards driven to improve interoperability and spectrally compatible with other loop services (ISDN, T1, HDSL)
  - Also takes into consideration diminishing amount of copper pairs

- **Single-pair HDSL (SHDSL)**
  - Similar to HDSL 2, but more generalized
  - Business class DSL for transporting T1/E1, ISDN, ATM, and IP

- **ISDN DSL (ISDL)**
  - DSL over ISDN; okay to pass through repeaters & DLCs
  - Always-on, flat rate billing, and transmit data over data network
## DSL Technologies

<table>
<thead>
<tr>
<th>DSL Type</th>
<th>Download</th>
<th>Upload</th>
<th>Distance (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADSL (Asymmetrical)</td>
<td>1.5 - 8 Mbps</td>
<td>16 kbps to 640 kbps</td>
<td>9K to 18K</td>
</tr>
<tr>
<td>UDSL (a.k.a. G.lite, DSL Lite)</td>
<td>1.5 Mbps</td>
<td>384 kbps</td>
<td>12K to 18K</td>
</tr>
<tr>
<td>RADSL (Rate Adaptive)</td>
<td>Variable to 7 Mbps</td>
<td>Variable to 640 kbps</td>
<td>16K to 25K</td>
</tr>
<tr>
<td>VDSL (Very High Bit Rate)</td>
<td>26 Mbps to 52 Mbps</td>
<td>3 Mbps to 6 Mbps</td>
<td>1K to 3K</td>
</tr>
<tr>
<td>IDSU (ISDN over DSL)</td>
<td>144 kbps</td>
<td>144 kbps</td>
<td>10K (more w/ repeater)</td>
</tr>
<tr>
<td>SDSL (Symmetrical)</td>
<td>144 kbps to 2 Mbps</td>
<td>144 kbps to 2 Mbps</td>
<td>11.5K to 22K</td>
</tr>
<tr>
<td>HDSL (High Bit Rate)</td>
<td>1.544 Mbps</td>
<td>1.544 Mbps</td>
<td>12K on 2 pairs</td>
</tr>
<tr>
<td>HDSL (High Bit Rate)</td>
<td>2.048 Mbps</td>
<td>2.048 Mbps</td>
<td>12K on 3 pairs</td>
</tr>
<tr>
<td>HDSL2</td>
<td>1.544 Mbps</td>
<td>1.544 Mbps</td>
<td>12K on 1 pair</td>
</tr>
<tr>
<td>SHDSL (Single-pair HDSL)</td>
<td>192 kbps to 2.312 Mbps</td>
<td>3 Mbps to 6 Mbps</td>
<td>1K to 3K</td>
</tr>
</tbody>
</table>
ADSL Broadcast Solution

Satellite, cable or terrestrial

Descrambler

Broadcast Translator

Scrambler

IP Router & ATM Switch

DSLAM

POTS Splitter

ADSL Modem CPE

PC

Set-top box, hard disk & TV

Smart Card

VoD Server & Software

Internet Proxy

Telephone

ADSL Central Office

Home
**ADSL Equipment**

- Two groups of equipment
  - Central Office - DSL Access Multiplexer (DSLAM), Repeaters
  - Customer Premise - DSL Modems, Gateways, Network Interface Card (NIC), splitters and filters
DSLAM

- DSLAM is usually found in a Central Office
- xDSL line cards are installed in a DSLAM to terminate incoming xDSL signals
- The DSLAM then combines multiple xDSL access lines into one high speed line
- The muxed traffic is converted into ATM cells which gets sent over an ATM backbone
Generic DSL Line Card for DSLAM Applications

- DSL Channels
- DSL Driver /Receiver Chip(s)
- HDLC Controller
- System Controller
- PCI Backplane Interface
- Processor
- Memory
- PLLs/ Clock Management
- Hot Swap Controllers
- SSTL-2/3 Translators
- GTL/GTL+ Transceivers
- High Performance Backplane
DSL Modem/Gateway

- A xDSL modem is the device found at the customer’s premise which is used to transmit & receive xDSL signals.
- Could be an external “box” or a network interface card placed inside a computer.
- An xDSL Gateway combines the functionality of a modem and a router.
DSL Modem Evolves to the Residential Gateway

- **Phase 1**: Broadband Access
  - High speed Internet access

- **Phase 2**: The Residential Gateway
  - Information distribution to multiple devices

- **Phase 3**: The Networked Home
  - Data, voice and video delivery around the home
DSL Modem
Residential Gateway

- HomePNA
- MII
- 10/100 Base-TX Ethernet MAC
- UTOPIA or ISA
- Expansion Bus Interface
- DRAM
- 32-bit Processor
- Network Interface Block
- PCI Bus Interface
- 8 KB Internal SRAM
- Hasher List Manager
- PCI
- 8 MHz Oscillator
- Clock Generator & DLLs
- UTOPIA I/F or ATM
- DSL Driver/Receiver Chipset

10/100 Base-TX Transceiver

10/100 Base-TX Ethernet MAC

10/100 Base-TX Ethernet MAC

10/100 Base-TX Ethernet MAC

PCI Bus Interface

8 KB Internal SRAM

Hasher List Manager

Network Interface Block

8 MHz Oscillator

Clock Generator & DLLs

UTOPIA I/F or ATM

DSL Driver/Receiver Chipset

10/100 Base-TX Transceiver
DSL Modem
Residential Gateway

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- 10/100 Base-TX Transceiver
- PCI
- HomePNA
- MII
- 10/100 Base-TX Ethernet MAC

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Xilinx Solutions
Xilinx Spartan-IIIE FPGAs

- **Differential I/O**
  - 400 Mbps
  - LVDS
  - Bus LVDS
  - LVPECL

- **Block RAM**
  - Up to 64Kbits
  - 200 MHz

- **System I/O™**
  - 19 signaling standards
  - Chip to Backplane
  - Chip to Memory
  - Chip to Chip

- **Delay Lock Loops**
  - 200+ MHz performance
  - 4 DLLs in every device
  - Deskew 4 system Clks
  - Zero-delay clock conv.

- **CLB Tiles**
  - Fast, predictable interconnect

- **Vector Based Interconnect**
  - 2 ns delay

- **Dual-Port 4Kbit BRAM**

- **Up to 64Kbits**

- **200 MHz**
Spartan-IIIE Clock Management

**Delay Locked Loops Lower Memory and Board Costs**
Spartan-IIIE Memory Solutions

- **Distributed RAM**
  - 16x1

- **DSP Coefficients**
  - Small FIFOs

- **Large FIFOs**
  - Video Line Buffers
  - Cache Tag Memory

- **Block RAM**
  - 4Kx1
  - 2Kx2
  - 1Kx4
  - 512x8
  - 256x16

- **External Memory Interface**
  - SDRAM
  - SGRAM
  - PB SRAM
  - DDR SRAM
  - ZBT SRAM
  - QDR SRAM

- **200 MHz Memory Continuum - Transparent Bandwidth**

- **Memory Corner**
  - Free Reference Designs

- **Xilinx**
  - Spartan-IIIE Memory Solutions
Spartan-IIIE Block RAM

- True Dual-port Static RAM - 4K bits
  - Independently configurable port data width
    - 4K x 1; 2K x 2; 1K x 4; 512 x 8; 256 x 16
  - Fast synchronous read and write
    - 2.5-ns clock-to-output with 1-ns input address/data setup

Data Flow

<table>
<thead>
<tr>
<th>Data Flow</th>
<th>Spartan-IIIE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A to B</td>
<td>Yes</td>
</tr>
<tr>
<td>B to A</td>
<td>Yes</td>
</tr>
<tr>
<td>A to A</td>
<td>Yes</td>
</tr>
<tr>
<td>B to B</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Memory Corner

• Collaboration between Xilinx and major memory vendors to provide comprehensive web-based memory solutions
  • Free reference designs (VHDL/Verilog)
  • SRAM, DRAM & embedded FPGA memory solutions
  • Data sheets, app notes, tutorials, FAQs, design guidelines
Generic DSL Line Card

- DSL Driver / Receiver Chip(s)
  - $10 - $120
- HDLC Controller
  - $16 - $65
- System Controller
  - $4
- Processor
  - $12 - $25
- Memory
  - $6
- PCI Backplane Interface
  - PCI9610
  - PCI9054
  - S5933
  - S5920
  - GT64115
- High Performance Backplane
  - xDSL
  - 34
Generic DSL Line Card

Logic and Interface Savings By Using Spartan-III E FPGAs

- DSL Channels
- DSL Driver/Receiver Chip(s)
- HDLC Controller
- XC2S100E $8.85
- System Controller
- PCI Backplane Interface
- Memory
- Processor
- PLLs/Clock Management
- Hot Swap Controllers
- SSTL-2/3 Translators
- GTL/GTL+ Transceivers
- PCI Backplane

xDSL 35
IP Solution for HDLC

- High Performance module for the HDLC protocol
- Support for up to 32 full duplex channels, total data rate >40Mb/s
- Low cost, fixed function netlist cores
  - Single-Channel Core: HDLC1
  - 32-Channel HDLC Core: HDLC32
  - Optimized for Virtex, Virtex-E, Virtex-II, Spartan-II, Spartan-IIIE
- Licensed from Amphion Semiconductor
- Spartan-IIIE + HDLC Controller IP = Programmable HDLC Controller Solution
HDLC Core Features

• Fully Compliant with ITU Q.921, X.25, ISO/IEC 3309, ISDN Channels B & D
• 8 or 16-bit address insertion and detection – selectable
• Programmable 16 & 32-bit CRC (FCS)
• Both cores suited for multiple HDLC scaling
• Full duplex operation, with 32 channel multiplex capability
• T1/E1 stream support using External mux/de-mux
• Generic 8 bit host interface for control and status registers
• Fully synchronized with bit-rate
HDLC Block Diagram

[Diagram of HDLC block diagram with various components and signal paths, including Transmit Control & Status Register, Transmit Frame Timer and Synchronization Logic, Receive Control & Status Registers, Receive Frame Timer and Synchronization Logic, Address Detect, FCS Calculator (CRC16), Zero Detection, and Flag Detection.]
Example Implementation

<table>
<thead>
<tr>
<th>Target Device HDLC1</th>
<th>Virtex XCV100-6</th>
<th>Virtex-E XCV100E-8</th>
<th>Virtex-II XC2V250-5</th>
<th>Spartan II XC2S100-6</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
<td>234 Slices</td>
<td>232 Slices</td>
<td>231 Slices</td>
<td>234 Slices</td>
</tr>
<tr>
<td><strong>Speed</strong></td>
<td>73 MHz</td>
<td>96.5 MHz</td>
<td>114.9 MHz</td>
<td>75 MHz</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Target Device HDLC32</th>
<th>Virtex XCV100-6</th>
<th>Virtex-E XCV100E-6</th>
<th>Virtex-II XC2V250-5</th>
<th>Spartan II XC2S100-6</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
<td>521 Slices</td>
<td>522 Slices</td>
<td>522 Slices</td>
<td>521 Slices</td>
</tr>
<tr>
<td><strong>Speed</strong></td>
<td>50 MHz</td>
<td>57.8 MHz</td>
<td>80.6 MHz</td>
<td>51 MHz</td>
</tr>
</tbody>
</table>

- No package restrictions
- No stringent place and route constraints
The Spartan-IIIE Advantage: Data Rate/Throughput

• HDLC controller solution data throughput
  – Spartan-IIIE
    • > 40 Mbps
  – Typical HDLC controller ASSP data throughput
    • ~ 2.5 - 8.192Mbps

• HDLC controller solution CRC
  – Spartan-IIIE
    • 16-bit and 32-bit provided
  – Typical HDLC controller ASSP
    • No flexibility
The Spartan-IIIE Advantage: 100k Unit Cost

- Typical HDLC controller ASSP
  - ~$4.56 (1 channel)
  - ~$60 - $120 (multi channel)

- Spartan-IIIE HDLC controller solution
  - ~$3.95 (1 channel)
  - ~$10 (multi channel)

The Spartan-IIIE Solution has a Clear Competitive Advantage over Stand-alone ASSPs
Real-PCI from Xilinx

• Real-Compliance
  – Guarantees Setup, Hold and Min/Max Clock-to-Out timing

• Real-Flexibility
  – Supports a wide range of Spartan-II and Virtex class devices allowing for easy device migration
  – Back-end decoupled from the PCI Interface to allow customization without affecting PCI timing

• Real Performance
  – Zero-wait state
  – Up to 132 MB/sec sustained throughput

• Real-Availability - Right Here Right Now!
LogiCORE PCI Block Diagram
# Spartan-IIIE PCI Solutions

<table>
<thead>
<tr>
<th>Spartan-IIIE Device</th>
<th>PCI Core</th>
<th>Speed</th>
<th>Available User Logic (system gates)</th>
<th>Available BlockRAM bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>2S50E</td>
<td>PCI32</td>
<td>33 MHz</td>
<td>30-35K</td>
<td>32,768</td>
</tr>
<tr>
<td></td>
<td></td>
<td>66 MHz*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2S100E</td>
<td>PCI32</td>
<td>33 MHz</td>
<td>70-75K</td>
<td>40,960</td>
</tr>
<tr>
<td></td>
<td></td>
<td>66 MHz*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2S150E</td>
<td>PCI32</td>
<td>33 MHz</td>
<td>130-135K</td>
<td>49,152</td>
</tr>
<tr>
<td></td>
<td>PCI64</td>
<td>66 MHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2S200E</td>
<td>PCI32</td>
<td>33 MHz</td>
<td>180-185K</td>
<td>57,344</td>
</tr>
<tr>
<td></td>
<td>PCI64</td>
<td>66 MHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2S300E</td>
<td>PCI32</td>
<td>33 MHz</td>
<td>280-285K</td>
<td>65,536</td>
</tr>
<tr>
<td></td>
<td>PCI64</td>
<td>66 MHz</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* PCI32: 66 MHz design available using Xilinx XPERTs or Design Services
PCI - A Successful Programmable Solution

Relative Component Cost

- External PLD 7K Gates
- External DLLs, memories, Controllers and translators
- PCI ASSP PCI Master and Slave I/F
- XC2S50E-5 PQ208
- 35K Gates Extra Logic

Spartan-IIIE FPGAs Lower Overall System Cost

Solution ≤$2 per silicon basis

Solution <$2 per silicon basis

PCI - A Successful Programmable Solution

Standard Chip

The Real-PCI™
Spartan-IIIE - System Integration
Other Advantages

- Time to market
- Flexibility
- Field upgradability
- Address lower volume strategic applications
- Distribution and inventory management
Summary
Summary

• Demand for greater Internet bandwidth is driving the need for digital modem solutions
  – Satellite, ISDN, cable, xDSL

• xDSL is one of the premier broadband access technologies of the future

• Digital modems will evolve into the next generation residential gateways to network your home
  – The digital revolution and the Internet are forcing broadband access to the home
  – Home networking will bridge the technology islands in the home
  – This gateway evolution could be part of a PC or set-top box
Summary

- Spartan-II FPGAs + Soft IP provide cost effective DSL solutions for the DSLAM and DSL residential gateway
  - Spartan-II FPGA provides higher densities, increased features and maximum flexibility at low costs
- Spartan-II FPGAs are ideal solutions
  - HDLC, PCI, microcontrollers, system interfaces, memory interfaces
  - Reprogrammability allows time-to-market