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Xilinx High-Volume Programmable Logic Applications in Satellite Modem Designs

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Summary

This paper provides an overview of satellite modem technologies and standards, and discusses how the Internet is driving the deployment of this technology. The major functional building blocks of a satellite modem are detailed, including an overview of the Application Specific Standard Products (ASSPs) that are typically used to implement the satellite interface. Finally, the paper illustrates how a Spartan device is used to implement complex system glue in a generic USB-interface satellite modem design. The Xilinx device families targeted at these high volume applications include XC9500 CPLDs and Spartan®-II FPGAs. Detailed information describing these families can be found on the web at www.xilinx.com.

Introduction

While this document focuses on satellite modem applications for Xilinx programmable logic devices, the examples discussed illustrate many of the issues found in other designs: specifically, how to cost-effectively interface complex ASSPs with incompatible interfaces. The ASIC vendors have abandoned the traditional solution for this class of problems, the small ASIC, as they move towards the system-on-a-chip market. Fortunately for system designers, new classes of low-cost PLDs, such as the Spartan-II family, have filled this void with devices that replace low-density ASICs and deliver the time-to-market advantages of FPGAs.

Overview

The Demand for High-Bandwidth Internet Connectivity

Driven by a new class of corporate Internet users and a host of new net services, demand for higher-bandwidth access continues to grow. High-bandwidth access to corporate computer resources is necessary to maintain the productivity of remote offices and telecommuters. Such corporate users are being brought to the Internet in large numbers as corporations choose Internet-based Virtual Private Network (VPN) technologies over costly private networks. In addition, home users of the newest online services benefit from a higher-bandwidth Internet connection as well. Streaming video and high-resolution graphical images, both integral components of many increasingly popular Web-based services, demand greater bandwidth than has been heretofore available.

In the face of this burgeoning demand, analog modem technology has hit the end of the road with the 56K generation of devices. Satellite modems address the need for increasing Internet access bandwidth by offering download speeds ranging from around 400 Kbps to 38 Mbps.

Direct Broadcast Satellite (DBS) Modems vs. DSL and Cable Modems

While cable modem and DSL connectivity have both received a lot of attention as the next generation of Internet access technology, they are currently limited in their deployment. DSL requires that the subscriber be within 18,000 wire-feet of the telco central office. Cable modem technology usually requires a significant upgrade to the head-end equipment within the cable system. Satellite (DBS) modem technology, on the other hand, requires only a clear line of site to the satellite, and a standard phone line for the return channel (upstream) data. For this reason, satellite modems represent not only a good option for high-speed Internet access; for many people they represent the *only* option.

Satellite Modem Technology and Standards

Existing Delivery Standards

Satellite modems employ the same infrastructure used to deliver digital television services such as DirecTV®. There are three major standards for delivering these services:

DSS (Digital Satellite System)

DSS is a proprietary, high-power, digital satellite video technology developed by Hughes. DirecTV, a DBS service provider owned by Hughes Electronics Corporation, utilizes DSS technology for distribution. As of Q1 1999, DirecTV had nearly 5 million subscribers.

DVB (Digital Video Broadcasting)

DVB is a consortium that has developed a set of open digital-video broadcast standards. All DVB systems are based on MPEG-2 audio and video compression. DVB adds to the MPEG transport stream the necessary elements to bring digital broadcast services to the home through cable, satellite, and terrestrial broadcast systems.

Primestar

Primestar is a DBS service provider utilizing proprietary medium-power technology. Hughes Electronics Corporation, the owner of DirecTV, acquired Primestar in early 1999. At the time of the acquisition, Hughes indicated that Primestar's 2.3 million subscribers would be migrated to DSS technology.

Internet Access via Satellite Modem

Figure 1 illustrates what is involved in providing Internet access via a satellite modem. The complexity of the dataflow within the network is due to the fact that the satellite provides a uni-directional data link.

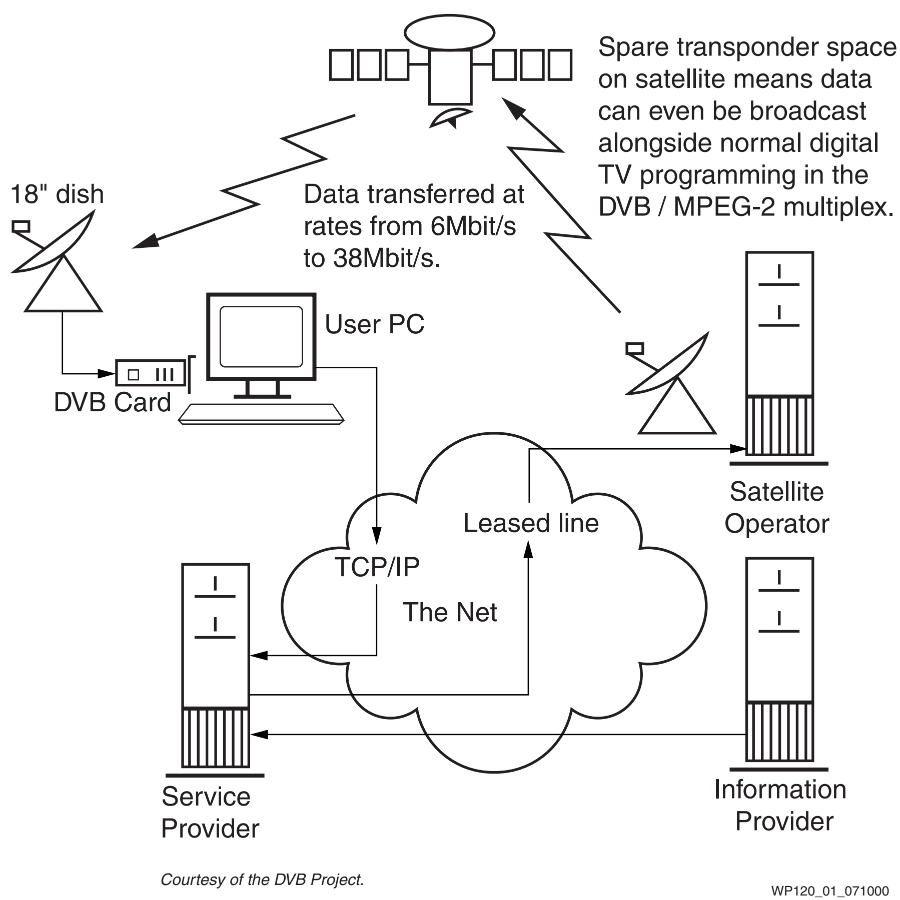

Figure 1: **Internet Access Network Architecture**

Definitions:

User PC: The *user PC* is a standard personal computer with two network connections. The satellite modem is used to transfer Internet data to the User PC. Data from the User PC destined for the Internet is transferred by way of a telephone connection to the Internet Service Provider.

Internet Service Provider (ISP): The *ISP* provides access and routing services for the subscriber. Data coming in from the subscriber over the dial-up phone connection is routed to the appropriate *information provider* by way of the Internet. Information coming from the information provider destined for the subscriber is forwarded to the *satellite operator* over leased lines.

Information Provider: The *information provider* is any site providing information resources via the Internet. The issues of satellite data flow are transparent to the information provider.

Satellite Operator: The *satellite operator* takes data from the ISP and transmits it to the satellite for delivery to the subscriber. This data may be transmitted via dedicated transponders or multiplexed with digital video data.

Satellite Modem Issues

There are two issues that impact the desirability of satellite modems as a means of Internet access:

1. Bandwidth available through the satellite is shared among a large number of users. While each transponder supports from 6 to 38 Mbps of data transfer capacity, the DirecPC service only guarantees 144 Kbps to each user.
2. Satellite modems are only capable of receiving data. Consequently, the subscriber must use a standard phone line for return data. This arrangement considerably complicates the network architecture, and provides only a comparatively slow upstream connection to the Internet information provider.

Satellite Modem Architecture

The functional blocks that make up a satellite modem are illustrated in Figure 2 and include:

A satellite interface containing the satellite-specific link functions.

A CPU complex consisting of the CPU plus RAM and ROM, responsible for configuring and managing the system.

A host interface used to connect a modem to the host computer (or to a local area network if the modem includes router functionality).

Each of these blocks is typically implemented by a small number of ASSPs. In most cases there are mismatches between the ASSPs used to implement each of these blocks. The system level glue needed to interface these blocks while delivering a product early to market is a key benefit of Xilinx's high-volume FPGA and CPLD products.

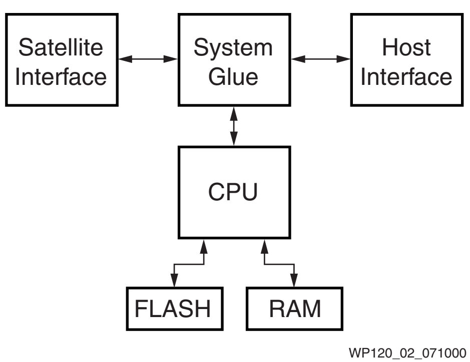

Figure 2: **Satellite Modem Architecture**

Satellite Interface

The satellite interface consists of two major functional blocks, the *tuner* and the *decoder*.

- The tuner consists of analog components typically packaged in module form in a shielded metal enclosure. The function of the tuner is to selectively filter and down-convert the satellite signal into a quadrature baseband signal. Again, note that all of this occurs in the analog domain.
- The decoder provides analog-to-digital conversion, decoding, and forward error correction functions. The decoder is typically implemented as a single ASSP. Figure 3 illustrates the major functional blocks included. The decoder is configured and managed by a microprocessor; as a result, these devices include a processor interface in the form of either an 8-bit microprocessor bus or a serial interface such as I^2C.

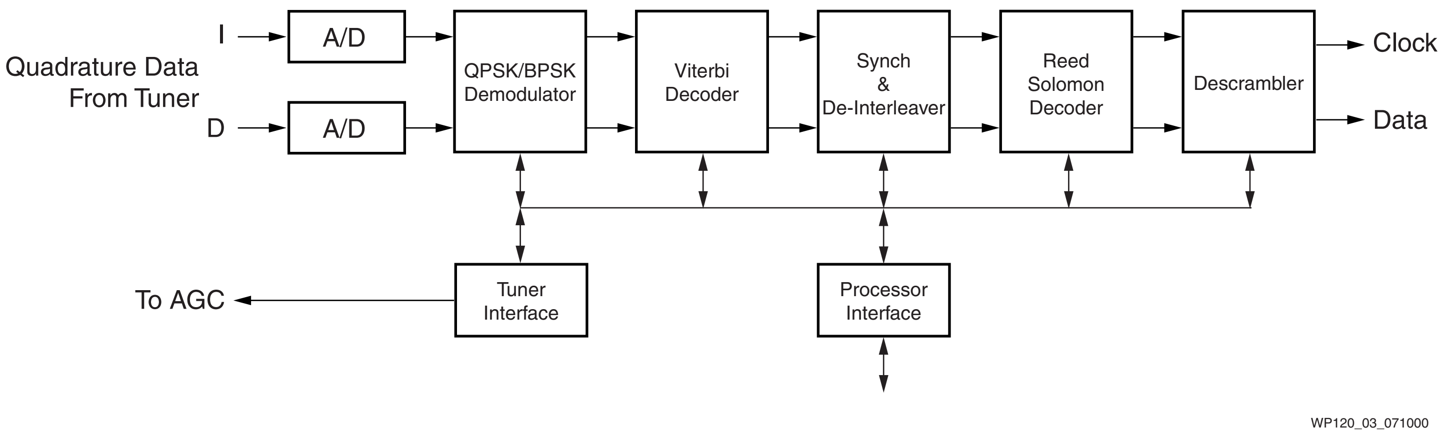

Figure 3: **Decoder Block Diagram**

Satellite decoder ASSPs are available from three major vendors as shown in Table 1. While there are minor differences in each of these products, they are all single-chip implementations and include all of the needed demodulation, forward error correction, and analog-to-digital conversion functions.

Table 1: **Satellite Decoder ASSPs**

Supplier	Components	Process Interface	Standards
Broadcom	BCM4201 Universal Satellite Receiver	I^2C, SPI	DSS, DVB, Primestar
Conexart	HM1211 Demodulator	Serial, Parallel	DVB, DSS
LSI Logic	L64724 Satellite Receiver	Serial, Parallel	DVB, DSS

Host Interfaces

The host interface, on the local side of the modem, is used to connect to the PC, server, or other networking equipment. For a PC internal modem, this interface is the I/O bus of the computer, typically ISA or PCI.

In the past, the most popular interface for external modems has been RS-232. Unfortunately, this interface is not fast enough to support the data rates provided by digital modems. As a result, manufacturers of satellite and most other high-speed modems have had to move to other interfaces.

The most popular choice for new external modem designs has been Universal Serial Bus (USB). A key advantage of this interface is that USB has been incorporated into PC core logic for over a year, and as a result is included as a standard feature in all new PCs. An external modem that provides a USB interface is attractive because it eliminates the need for users to open their systems, and also provides a means of supporting non-PC systems such as the popular iMac. For these reasons, USB is a popular approach for next-generation satellite modem designs.

For users who are not intimidated by opening up their computers and installing cards, an internal modem is still the most cost-effective solution. The cost of an internal modem will always be lower, since there is no need for a case or power supply. The internal satellite modem's host interface consists of the logic required to glue the CPU local bus and the satellite decoder's data stream interface to the computer's PCI bus.

A Xilinx Satellite Modem Design Win

The Xilinx Spartan series FPGAs were used in the Hughes Network Systems (HNS) DirecPC-USB satellite modem design.

HNS was faced with the challenge of how to quickly introduce an external satellite modem with a USB interface. Up to this point, DirecPC customers had been required to use an internal PCI modem for their network access. In order to reduce both time to market and development costs, HNS wanted to leverage an ASIC they had developed for the PCI card in this new external modem design.

They solved their design challenge with a Spartan XCS20, using it to implement the required system-level glue. The Spartan device interfaces the RISC CPU, satellite decoder, USB interface ASSP, and their own ASIC. Figure 4 shows a block diagram of their design.

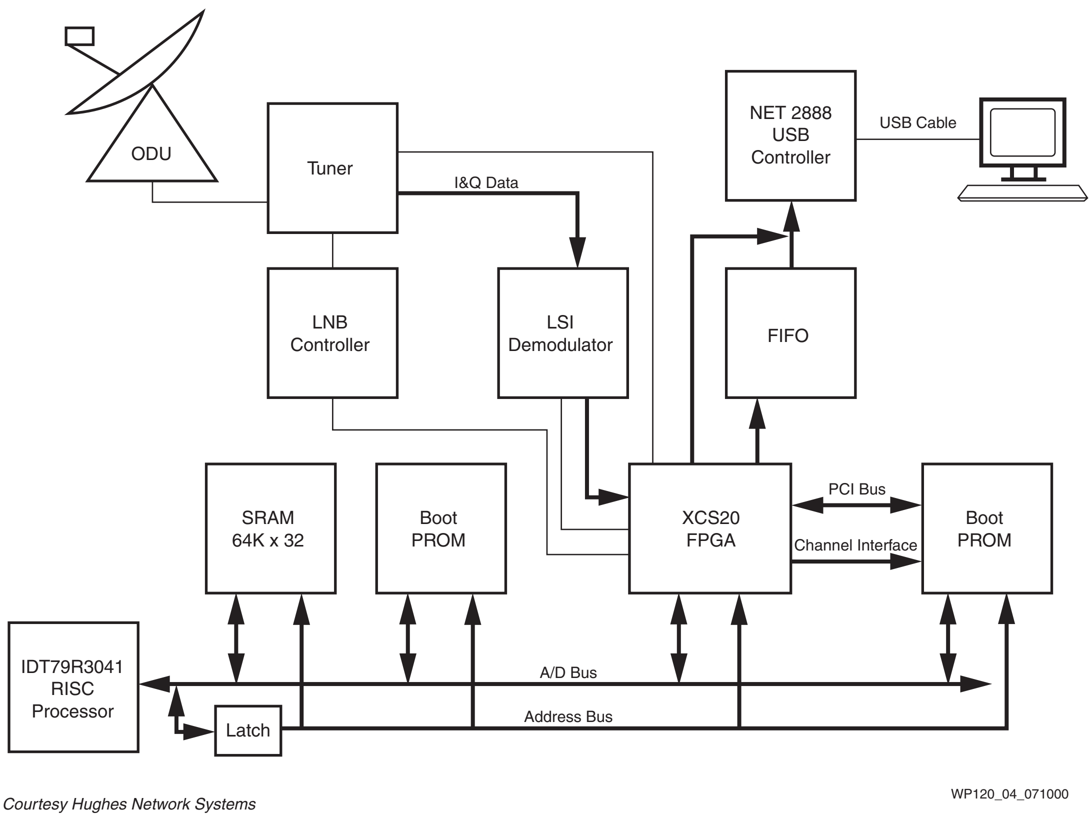

Figure 4: **HNS DirecPC®-USB Receiver Block Diagram**

Functions implemented within the Spartan device include:

Processor Interface: contains bus state machine logic, system control registers, and a watchdog timer.

Data Buffer: resides between the satellite decoder and the HNS ASIC.

CRC Check: checks incoming packets for errors using a 32-bit CRC polynomial.

USB Controller Interface: implements bus arbitration functions for USB DMA requests, control logic for the external data FIFO, and DMA control.

PCI interface: gives the RISC microcontroller access to the control registers within the HNS ASIC, and lets it take over the functions that were handled by the host processor in the original PCI card design.

Conclusion

Until satellite modem ASSP manufacturers deliver more highly integrated solutions, designers of these products will be faced with the task of interfacing a variety of devices with incompatible interfaces. Xilinx high-volume FPGA and CPLD technologies provide system designers with cost-effective solutions that retain the traditional PLD time-to-market advantage.

Revision History

The following table shows the revision history for this document.

Date	Version	Revision
07/21/00	1.0	Initial Xilinx release.