Xilinx at Work in ISDN Modems

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Summary

This white paper gives an overview of ISDN modem technologies and how Xilinx high volume programmable devices can be used to implement complex system level glue in ISDN modem designs. Topics include:

- Introduction
- Overview
- ISDN Model
- ISDN in the Real World
- ISDN Enhancements
- ISDN ASSPs
- Design Example
- Conclusion

Xilinx Products

XC9500 CPLDs and Spartan FPGAs

Introduction

This white paper gives an overview of ISDN modem technologies and how Xilinx high volume programmable devices can be used to implement complex system level glue in ISDN modem designs. The Xilinx device families targeted at these high volume applications include XC9500 CPLDs and Spartan FPGAs.

The flow of this document will be start with an overview of ISDN technology and how ISDN modems are used. We will next examine the major functional blocks of an ISDN modem and give an overview of the Application Specific Standard Products (ASSPs) that implement ISDN functions. We will then illustrate the system level glue functions that are needed by way of a design example.

Overview

ISDN (Integrated Services Digital Network) is a technology that was originally defined in themid-80s as a means of delivering integrated voice, data, and video services to Bell system customers. Although the technology definitely shows its age, it is still one of the most widely deployed digital data services.

ISDN is a circuit switched technology. In circuit switching, a dedicated communications path is established between two stations. The process of establishing these dedicated paths is referred to as signaling, and is carried out over special channels referred to as D (Delta) channels. Signaling results in the establishment of one or more 64 kilobit-per-second (kbps) B (Bearer) channels between locations. Once established, these channels can be used for voice, data or video.

There are two main ISDN variants, Basic Rate ISDN (BRI) and Primary Rate ISDN (PRI). Primary Rate ISDN service is targeted at larger corporate customers. PRI service consists of 23 B channels in North America and is transported across a standard T1 physical layer interface. In Europe the service provides 30 B channels plus one 64 kbps D channel and uses an E1 physical layer. PRI requires two sets of twisted pair telephone lines.

Basic Rate ISDN services are targeted at home and small business users. BRI service is delivered over a single twisted pair, the same wiring that is used to deliver POTS (Plain Old Telephone Service). It provides 2 B channels and one 16 kbps D channel. For the rest of this paper the term ISDN will be used synonymously with Basic Rate ISDN.

ISDN Model

The CCITT documentation defines the overall model of ISDN in terms of Reference Points and Functional Groupings. Figure 1 illustrates the ISDN Reference Model.

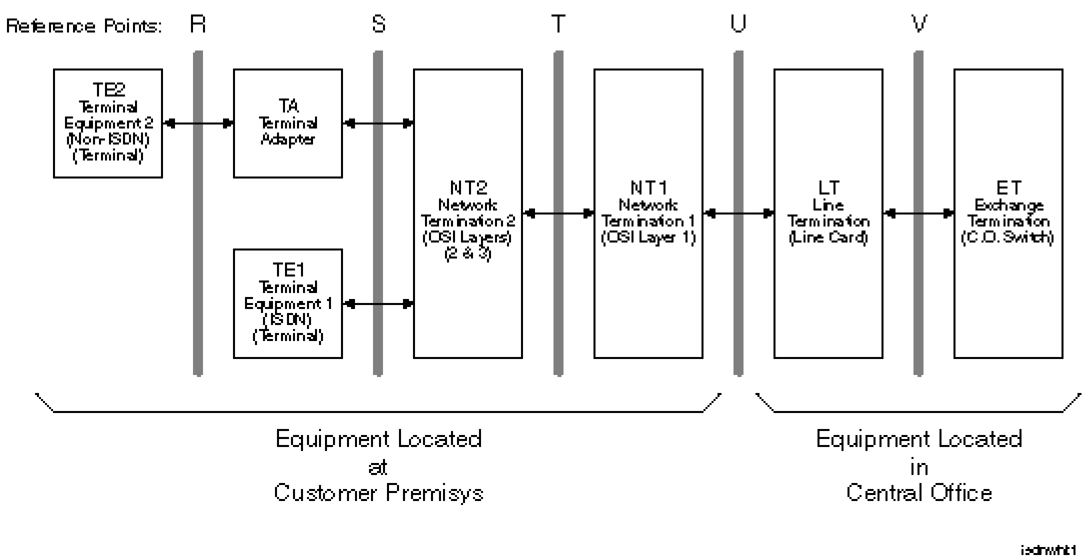

Figure 1: ISDN Reference Model

Functional Groupings define finite arrangements of physical equipment or combinations of equipment. ISDN defines the following Functional Groupings:

TE2 (Terminal Equipment 2): TE2 devices are non-ISDN terminal equipment such as personal computers. These devices interface to a TA by way of an R interface.

TA (Terminal Adapter): Adapts non-ISDN equipment to ISDN. A TA provides an R interface for the non-ISDN equipment and an S/T interface for connection to the ISDN network.

TE1 (Terminal Equipment 1): ISDN terminal equipment such as ISDN telephones. se devices interface to the ISDN network by way of an S interface.

NT1 (Network Termination Equipment for layer 1): Equipment that terminates the SDN network connection at OSI layer 1 (the physical layer). Specifically it terminates the interface and converts it into an S/T interface.

NT2 (Network Termination Equipment for layer 2): Equipment that terminates the SDN network interface at OSI layer 2, (the data link layer). An example would be a PBX that terminates a PRI connection and provides several BRI interfaces. An NT2 interfaces to a TA or TE1 via an S interface and to an NT1 via a T interface.

Reference Points are conceptual points used to separate groups of ISDN function. Some of these reference points are purely conceptual abstractions while others are defined as physical interfaces between functional blocks. ISDN defines the following Reference Points:

R: Provides a non-ISDN interface between user equipment that is not ISDN capable and ISDN adapter equipment. Examples include RS232, V.35, and X.21.

S: Interface between Terminal Adapters (TA) or terminal and Network termination.

T: The interface between an NT1 and NT2. It is functionally equivalent to the S interface.

U (User): The interface between the ISDN customer premises equipment and the public ISDN network. This interface defines a point to point connection using a single twisted pair and 2B1Q data coding.

Some of these Functional Groupings and Reference points apply to equipment located in the central office while others apply to equipment located on the customer premises. This paper will focus on the portion of the model that resides in the customer premises and are applicable to ISDN modems.

U Interface

The U (User) Interface is a point to point connection between subscribers and the service provider's central office. It consists of a single twisted pair that may be up to 5.5 km in length. Mid-span repeaters can double this distance.

In order to support transmission over these distances the U Interface uses some sophisticated transmission technology. A multilevel, 2B1Q (Two Binary, One Quaternary) line code (4B3T in Europe) is used as well as adaptive equalization and echo cancellation. In addition a scrambling polynomial is used to improve clock recovery and improve the spectral characteristics of the signal on the wire.

S/T Interface

The S/T Interface was defined for interconnecting ISDN customer premises equipment. As a result the technology employed differs significantly from that of the U Interface. The S/T Interface supports a bus topology with up to eight stations. Using four wires it supports a maximum distance of 1 km. The shorter distances involved, and full duplex transmission, simplify the line coding. An Alternate Space Inversion (ASI) coding scheme, also referred to as pseudo-ternary scheme, is used.

Proprietary TDM Interfaces

In addition to the interfaces defined in the ISDN specifications, vendors of ISDN ASSPs have defined several proprietary interfaces for tying together ISDN devices in a system. A typical application for such an interface is connecting an S/T interface ASSP to a U interface ASSP to create an NT1. These interfaces typically consist of four to seven signals. These signals include a transmission clock, serial data in, serial data out, and a start of frame indicator.

Several of the key TDM interfaces are as follows:

CHI: Concentration Highway Interface, defined by Lucent.

IOM-2: ISDN Oriented Modular Interface, defined by Infineon (formerly Siemens) and supported by AMD as part of a second source relationship.

IDL: Inter-chip Digital Link, defined by Motorola.

While several vendors support more than one of these interfaces on their device, using devices from different vendors often involves using glue logic to deal with the differences in these interfaces.

ISDN in the Real World

Now that we have had an overview of ISDN technology in the abstract, let's see how these technologies are packaged in the real world to create ISDN modems. Figure 2 illustrates how ISDN modems are typically deployed in Europe and North America.

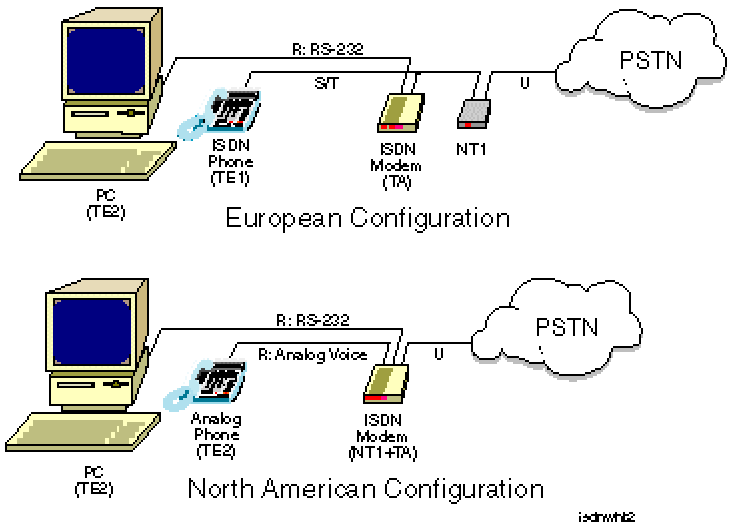

Figure 2: ISDN Modem Applications

In Europe the telephone companies do not let subscribers connect their own equipment directly to the Public Switched Telephone Network (PSTN). The Telco provides an NT1 to the customer as part of the service package. In this case the demarcation point between the subscriber and the PSTN is the S/T interface on the NT1, and the ISDN modem acts as a TA.

In North America, users can connect their own equipment directly to the PSTN and the demarcation point becomes the U interface. As a result, ISDN modems for the North American market typically include a built-in NT1. This lowers cost and simplifies installation.

Another difference between the European and North American configurations is how voice services are provided. In Europe there was reasonable acceptance of ISDN telephones. If an ISDN telephone is used it is simply connected to the S/T interface along with the modem. In North America ISDN phones are very rare and as a result ISDN modems include the circuitry necessary to convert digital voice signals into the analog form used by a standard telephone.

Anatomy of an ISDN Modem

The functional blocks that make up an ISDN modem are a function of whether the device is an add-in card for a personal computer or a stand-alone unit.

An external modem, or active TA, includes a processor for protocol processing, logic for the R Interface, and usually a voice COder/DECoder (CODEC). The inclusion of a CODEC lets the user plug in a standard analog phone and use it to make voice calls over one of the ISDN B channels. The R interface is typically RS-232, Ethernet or USB and is implemented using an ASSP. Figure 3 shows a block diagram for an external modem.

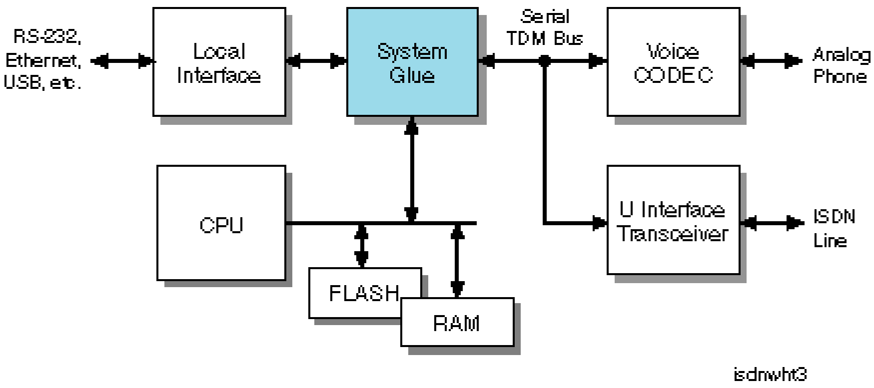

Figure 3: External ISDN Modem

The system glue has two functions within the architecture. The first is to normalize interface differences between the functional blocks. The second is to implement the required ISDN functional groupings. In this application this means the TA functions required to support the non-ISDN interfaces, specifically the R interface that embodies the local side of the modem and the CODEC. TA functions that must be implemented include Link Access Procedure D Channel (LAPD) framing functions that are used in signaling and Point to Point Protocol (PPP) or Multilink PPP functions that are used to transport data from the R interface across the ISDN network.

Internal modems, or Passive TAs, can eliminate hardware by moving functions to the host system. This reduces the system glue to providing interface glue functions for two interfaces: the host bus interface, and the serial TDM bus interface for the U-Interface transceiver. The TA functions included in the system glue are equivalent to those of the External modem. Figure 4 shows the block diagram for an internal modem.

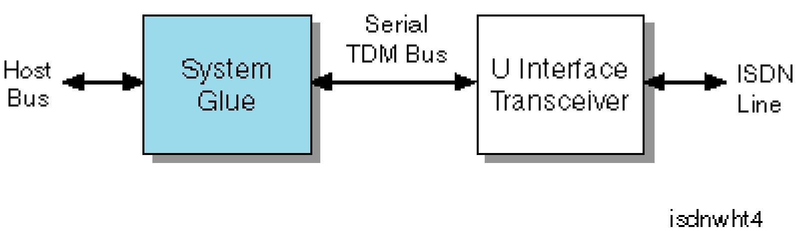

Figure 4: Internal ISDN Modem

ISDN Enhancements

The limited availability of DSL services has stimulated vendors to look for ways to provide DSL-like services using ISDN technology. While ISDN cannot compete with the bandwidth available from the newer DSL services, they have developed two approaches that give users the continuous availability that DSL provides.

Always On ISDN

The first of these approaches is called Always On ISDN. It does this by using the D channel not just for signaling but also for forwarding Internet Protocol (IP) traffic using the X.25 protocol. Since the D channel is always connected this provides the subscriber with up to 16 kbps of continuously available bandwidth. When the user traffic exceeds the bandwidth of the D channel, one or both of the B channels are connected.

Taking advantage of this requires that Always On support be provided by the user's Internet Service Provider (ISP), Phone Company, and the ISDN bridge or router that is used.

IDSL

A second approach to DSL-like ISDN service is IDSL. Originally developed by Ascend, IDSL takes a more radical approach in that it only uses the underlying infrastructure of ISDN and discards its higher level functions.

IDSL uses U Interface transmission technology to provide 144 kbps of bandwidth by way of the two B and one D channels. The channels are all continuously connected and therefore the ISDN signaling mechanisms are not used. All traffic is routed to the subscriber's ISP.

One downside to IDSL is that it does not support the ability to place circuit switched calls for voice or video conferencing applications. If the subscriber wishes to use the connection for voice traffic, a packet based voice technology such as Voice Over IP (VOIP) could be used.

ISDN ASSPs

The following table summarizes the ISDN ASSP offerings of several vendors.

Supplier	Device	Function
Motorola	MC145572	U Interface Transceiver
	MC145574	S/T Interface Transceiver
	MC145575	Passive ISDN Terminal adapter
	MC145576	Single-Chip NT1
AMD	Am79C30A/32A	Digital Subscriber Controller
Lucent	T7234	Single-Chip NT1
	T7256	Single Chip NT1 with Microprocessor and TDM interface
	T7237	U-Interface 2B1Q Transceiver
	T9000/T9001	ISDN Network Termination Node (NTN) devices
	T7250	S/T-interface with HDLC
National	TP3410	U Interface Device
	TP3420A	S/T Interface Device
Infineon	PEB 2091	U Interface Device
	PEB 2086	S/T Interface Device
	PEB 8090	Single Chip NT1
	PEB 8091	Single Chip NT1 with Microprocessor and TDM interface
Yamaha	YTD423	HDLC with Microprocessor Interface
	YTD421	S/T Interface Device
AKM	AK520S	Single Chip NT1

Most of these products fall into one of the following categories:

U Interface Transceiver: Includes the U interface logic and an interface to a TDM bus at the back end.

S/T Interface Transceiver: Includes the S/T interface logic and an interface to a TDM bus at the back end.

Single chip NT1: An S/T Interface Transceiver and a U Interface Transceiver connected back to back.

Terminal Adapter: These devices implement the LAPD and PPP framing functions that were previously mentioned and often include a host bus interface.

Design Example: An ISDN PCMCIA Modem

In order to illustrate how Spartan devices can be used to implement the system glue functions required to implement an ISDN modem, Xilinx has created an application note describing the architecture of a Spartan device based PCMCIA ISDN modem.

A key design objective for this application was the creation of a solution with the lowest possible cost. In this case the target was a semiconductor bill of materials for the PCMCIA interface that is significantly less than $20 in volume. A second objective was to simplify the design effort by utilizing as much commercially available Intellectual Property (IP) as possible.

Figure 5 gives an overview of the design. It consists of an ISDN U-Interface transceiver, the Spartan device, and external memory. The device that was chosen for the ISDN U-Interface in this application is a Motorola MC145572. The U-Interface connects to the rest of the design by way of two interfaces. The IDL interface is a five-wire TDM interface, defined by Motorola, and carries the B and D channel data. The PCP interface is an eight-bit microprocessor bus interface used to access the internal control and status registers of the U-Interface transceiver.

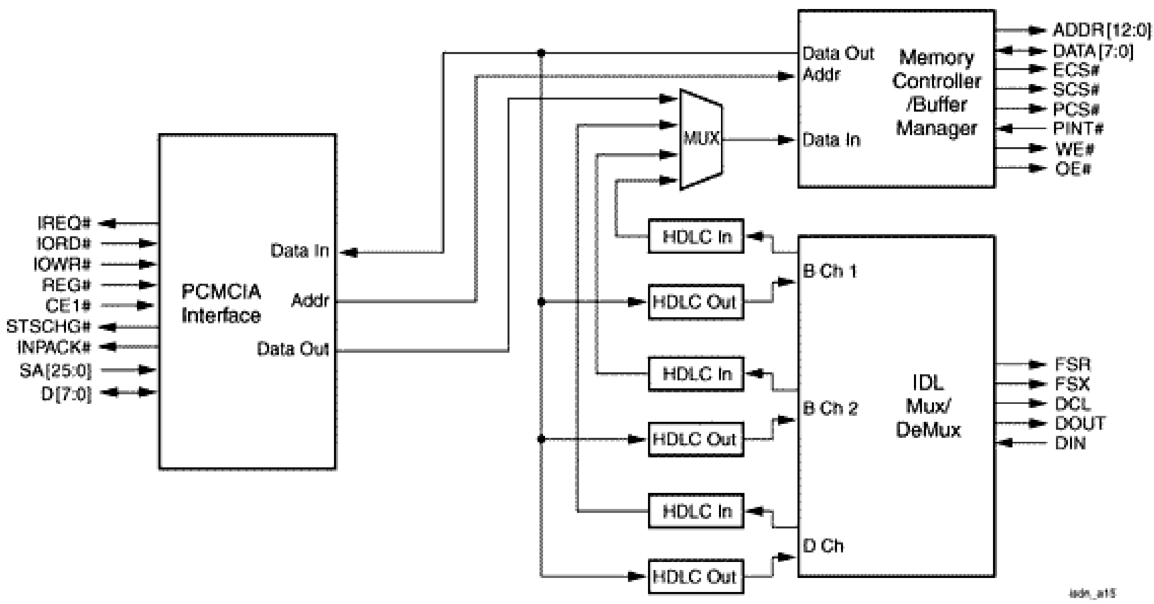

Figure 5: PCMCIA ISDN Modem Block Diagram

Three external memory devices are connected to the Spartan device. A serial configuration PROM is used for device initialization. A 2Kx8 EEPROM is used to store the PCMCIA CIS data structure. An 8Kx8 SRAM provides buffering for incoming and outgoing ISDN traffic.

Conclusion

Until digital 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.

References

- MC145572 ISDN U-Interface Transceiver Manual, Motorola