

“Intuitive ISDN”— An ISDN Tutorial

WHAT IS ISDN?

The Integrated Services Digital Network, commonly called ISDN, is simply an all digital communications network which offers its users a variety of different capabilities. In due time, the ISDN will change the way that many, if not all of us communicate, be it through voice, data or video communication. To that end, the ISDN is an invisible rebuilding of the existing telephone network that will allow simultaneous voice and data communication over ordinary telephone lines.

What are the advantages that an integrated services digital network will offer? In order for ISDN to be successful, customers must see an economic payoff associated with ISDN. That payoff is perceived as an increased use of data communications without a linear increase in costs. For users of the network this means that anyone can take either a telephone, personal computer or any other form of data communications equipment and plug them directly into a standard phone jack and gain immediate access to a number of high speed data pipelines. The user will be able to dynamically allocate different 64 kbps channels to each of up to 8 pieces of terminal equipment. By terminal equipment we mean telephones, personal computers, facsimile machines, printers, thermostats, water and gas meters . . . and the list goes on. This revolutionary change will occur without changing the existing installed base of copper wire.

CCITT, the governing body of telecommunications standards defines the ISDN as:

A network evolved from the telephony integrated digital network that provides end-to-end digital connectivity to support a wide variety of services, to which users have access by a limited set of standard multipurpose customer interfaces.

National Semiconductor
Application Note 492
Doug Gremel
Bob Poniatowski
December 1991

THE CASE FOR ISDN

Without a doubt the past decade has brought us a one hundred fold increase in the utilization of data processing. Unfortunately, that increase has come at the cost of not being able to effectively communicate and share our individual data. We have created isolated islands of data processing.

For years now, telephone exchanges throughout the world have taken advantage of the capabilities of digital central office switching. This is due in great part to help from products such as National's COMBO™ family, which does the analog to digital conversion of voice signals. If one's voice conversation can be converted to a series of 1's and 0's it can be added, or multiplexed with other voice channels and several conversations can be carried simultaneously at high speed over a single phone wire. Presently this analog to digital conversion takes place at the central office switch.

The logical basis for the ISDN is simply to move the point of analog to digital conversion from the central office to the subscriber and make the transmitted signal a digital one. If this were accomplished, the subscriber would be able to take advantage of the ability to send digital data directly over the phone line. Since the phone network would not be able to distinguish between digital voice generated and digital computer generated data, a common access point for both types of services is created.

With a common access point created, the phone companies, among others, will be able to provide new services which customers will pay for. Although it is difficult to measure quantitatively, a resounding increase in productivity should be enjoyed by ISDN's subscribers.



ISDN GOAL: Global Connectivity

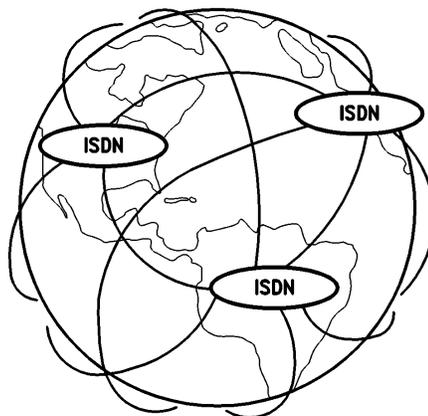


FIGURE 1. Islands of Data Processing

TL/H/9318-1

COMBO™ is a trademark of National Semiconductor Corporation.

It's easy to understand why the phone companies are so anxious to implement ISDN. From their point of view, the ISDN represents a new, revenue generating service which takes advantage of their large capital investment in their existing Telecom network. In addition, ISDN will help them keep customers. The RBOC's (Regional Bell Operating Companies) are presently faced with the competitive threat of a host of bi-pass schemes. In addition to the Telecommunications industry, there are also other proponents of ISDN.

The data processing industry has the vested interest in making sure that its equipment can communicate with other pieces of equipment. Many computer manufacturers have, in the past, intentionally tried to lock their customers into buying their equipment by maintaining a proprietary communications architecture. This strategy was sound while the industry was in its infancy, but users are beginning to consider the benefits of an open networking scheme. If there were a common communications backbone, computer manufacturers would benefit by selling more equipment as well as new services.

The proponents of ISDN have many different motivating factors for supporting a worldwide voice/data communications network. A common thread binding all ISDN supporters is the work of the standardization committees. Standards act to ensure inter-operability among a large set of similar equipment. They act for the benefit of three distinct groups. For the users of the network, the primary advantage is one of not being locked into the purchase of one type of equipment. For the service provider, standards guarantee a large user base, thus they encourage the service provider to make the investment necessary to reap any benefits. To manufacturers, building to a specification enables them to produce products of wide appeal and reduces the proprietary nature of equipment.

Along these lines, it has been said that there are 4 cornerstones to ISDN and 4 reasons for companies to invest in ISDN technologies.

Cornerstones

1. ISDN will reduce telephone companies costs by integrating more services over a single access line.
2. ISDN represents increased revenue for telephone companies.
3. ISDN will help proliferate intelligence within and beyond the network.
4. ISDN supports national and international standards.

FIGURE 3. Cornerstones of ISDN

ISDN IMPLEMENTATION ISSUES

The concept of a single access point for voice and data communication has a great deal of appeal. Many experts are saying that the dawn of the true information age will not be at hand until data communications can flow freely. Before we can begin to dream of what the information age will hold, there are several prerequisites that need to be fulfilled. The evolution of ISDN will actually occur in phases. In the first phase, a complete deployment of digital local switching must be in place. The digital central office represents the backbone of the network. Also, ISDN loop terminations will be required for each potential ISDN subscriber. In a second phase of deployment, ISDN capabilities will be extended between switching offices. This requires the deployment of CCITT's common channel signalling called signalling system #7. A third major phase will be the extension of ISDN services between networks. This would mean that a single world wide network would be operational. These prerequisites are outlined in *Figure 4*.

PHASE I	PHASE II	PHASE III
Digital CO's	SS #7	Inter-Networking
Loop Terminations	Digital Trunks	
ISDN Terminal Adaptors		

FIGURE 4. Evolution to ISDN

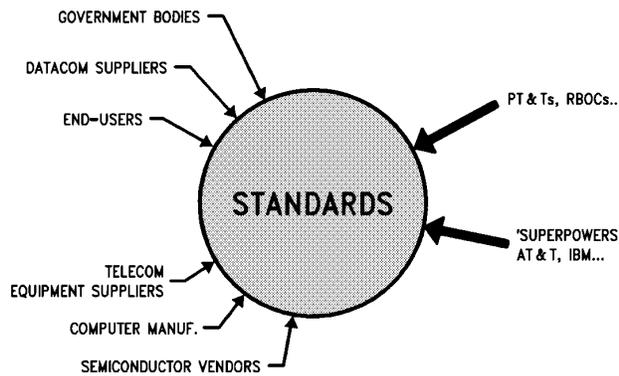


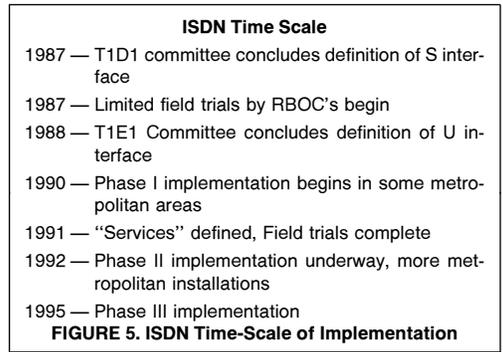
FIGURE 2. Proponents of ISDN

TL/H/9318-2

Without compliance to a set of standards laid out by CCITT, the goal of ISDN will not be realized. The standards that are of most interest to vendors are those dealing with the S and U interfaces. At this point in time, the S interface is the most solidly defined interface. A complete description of the S interface function is outlined in CCITT's document I.430.

Most of the work in the U.S. standardization body, T1D1 is presently focused on the U interface.

Until the time that T1D1 standards are complete, no vendors can legitimately announce products which are "ISDN compatible". Rather, ISDN exists more in the press than it does in reality. Even Bell Operating companies are in the decision making process as to what services will be marketed and how their ISDN networks will be implemented. For this reason, Bell Operating companies are presently undertaking limited field trials using "psuedo-ISDN" services in a very limited manner. These field trials will supply user feedback and will greatly help define new services. In *Figure 5*, a time scale of ISDN implementation events is outlined.



ISDN TERMINOLOGY/DEFINITIONS

In order to convert a subscribers connection from an analog signal to a digital one, the termination at each end of the copper loop must be changed slightly. Upon this conversion, one of two connection types will be offered, Basic or Primary access. Under the **Basic Access** rate, each subscriber will be entitled to the use of 2 B channels and 1 D channel, (**2B + 1D**). For Basic Access each **B Channel** (B for Bearer) represents a 64 kbps channel and the **D Channel** (D for Delta) represents a 16 kbps channel. A minimum transmission rate of 144 kbps full duplex transmission is therefore required for basic access transport. Typically, a basic access subscriber will be a specific, individual subscriber as opposed to a multi-user subscriber such as a corporation, which will require several primary access lines.

Under the **Primary Access** rate, each subscriber in the United States and Japan will be able to transmit and receive over 23 B channels and 1 D channel (**23B + 1D**). This data rate is compatible with the 1.536 Mbps rate for T1 carriers for these countries. For the rest of the world the primary access rate offers users 30 B channels and 1 D channel. However, unlike the basic access rate the D channel in primary access represents a 64 Kbps channel.

In *Figure 6* we see the ISDN reference model for a basic access connection. The reference model shows a block diagram of how the communications link is established. In the diagram, blocks represent equipment or physical, tangible points along the phone line.

In *Figure 6* the **TE or Terminal Equipment** can represent either a digital telephone, a personal computer, a facsimile machine, a printer, a thermostat, gas meter etc. As you can see there are two types of terminal equipment. The **TE1** is a terminal which is synchronized to the ISDN network. This simply means that the terminal equipment was manufac-

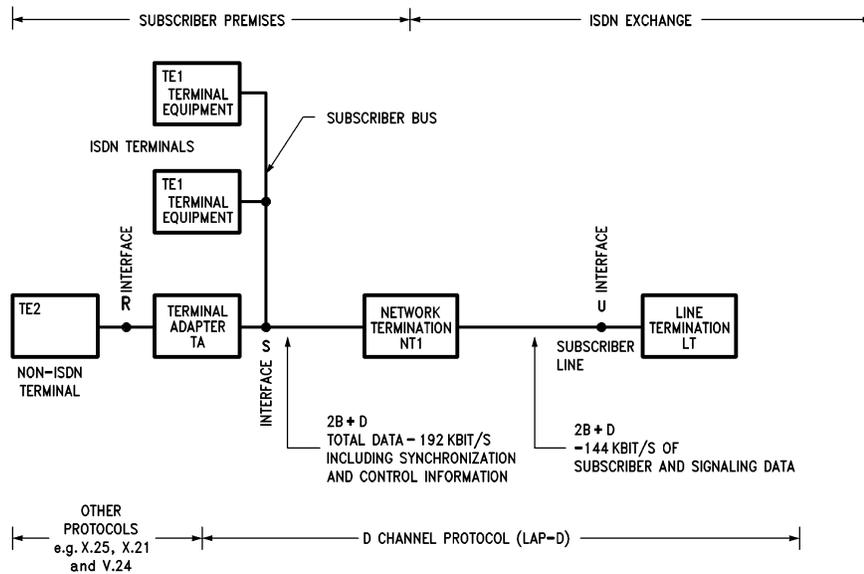


FIGURE 6. ISDN Basic Access Reference Model

TL/H/9318-3

tured with the intention of being compatible with the ISDN network. The **TE2** on the other hand is a terminal which might not now be compatible with the ISDN network. Because TE2's are made before the existence of ISDN, it is the function of the **TA or Terminal Adaptor** to convert either asynchronous or synchronous data from non-ISDN terminals into data which is synchronized with ISDN B or D channels. The data rate must be adapted by stuffing extra bits into the bit stream in a prescribed pattern.

The next block in the model is the **Network Termination or NT**. The NT terminates the network at the user's end of the 2 wire loop (on the subscribers premises). It converts the "U" interface to the "S" and "T" interface and acts as the master end of the user's line. Just like the terminal equipment, the NT is also Customer Premises Equipment (CPE) and will be sold through retail outlets (except in Europe and Canada).

Further along the model is the **LT or Line Termination**. Typically, the LT consists of the "U" interface transceiver and power feeding functions on the ISDN line card.

In addition to the various blocks in the reference point model, the interfaces between the blocks are also of great interest. From the users point of view these interfaces can be considered pieces of copper wire. However, its in the interface between the blocks that the "intelligence" resides which enables the signal to be transmitted down the line. The intelligence is actually a transceiver device which is named appropriately after the interface function it accomplishes.

There are several functions that the **S Interface** fulfills. In addition to electrically connecting (in parallel) up to 8 TE's with the NT, what other functions does the S interface accomplish? For a basic access rate of 2B + D, 3 channels are available for use by 8 pieces of terminal equipment. Part of the S function is to arbitrate the use of these channels to however many TE's reside on the line. Fortunately, chances are good that no one will have more than 1 voice phone hanging on a 2B + D line. Since computers and the like don't need to be operated in real time, the S interface can control the use of the phone connection (always a circuit switched connection) and the 7 other pieces of terminal equipment can share the other 2 channels (packet switched connections). A user can maintain a voice connection on one of the B channels and simultaneously transmit data on the other B and D channels.

In order to get access to a B channel, certain formalities or protocols must be granted. These protocols are all regulated in the D channel. Thus, the term **LAPD for Link Access Protocol in the D Channel** is used to describe the process of attaining a connection via the D channel. LAPD is typically implemented in a software routine rather than being a hardware function.

When transmitted signals pass through the S interface, they are traveling over a 4 wire connection. This is due in part to the fact that the S interface function is required to do all the arbitration and control functions. As such, the distance over which the S interface can function is limited in distance. For a point to point configuration, in which only one TE is connected to the NT, the S interface is specified to have a range of 1 Km. If the S interface is fully burdened by all 8 TE's, a loop length of only 200m can be attained.

In contrast, signals transmitted over the **U interface** are carried over only 2 wires. This is due to the fact that the

phone company supplies only 2 wires to any given subscriber. If you will remember, the NT is considered Customer Premises Equipment (CPE) and physically resides at the end of the 2 wire loop. Now that the transmitted signal travels over only 2 wires rather than 4, the signal must be transmitted in both directions simultaneously. This transmission technique is called **Echo Cancellation**. In an echo cancellation based transmission, signals from the transmitted point are effectively cancelled from the receiver of the transmitted point, therefore the receiver will only hear what the transmitter at the far end of the line is sending. This is a very complex transmission scheme. But none the less, such a scheme is needed to transport the digital signals the required length of as much as 18 kft.

NATIONAL SEMICONDUCTORS ROLE IN THE ISDN

Obviously, the concept of the ISDN would not be possible if not for the technological accomplishments of these past 5 years. At the heart of these advances are the implementation of VLSI integrated circuit technology.

National Semiconductor will play a key role in the evolution towards an Integrated Services Digital Network, VLSI devices which are cost effective solutions must be used if ISDN is going to become a wide scale economic reality.

Because so much of the system itself is becoming integrated into standard devices, National does play a key role in the definition of standards for the ISDN. Along with this participation in standard setting goes the willingness to comply wholeheartedly with those standards.

As the Semiconductor industries' leading supplier of dedicated Telecom IC's, National is in an excellent position to take advantage of its years of experience when implementing new ISDN devices. Key to this success are the relationships built over the years with customers and the ongoing dialog necessary to define successful products.

National is driving standards through T1E1 involvement

National is providing basic silicon blocks which will make ISDN practical

National is providing a silicon architecture which will become a de-facto standard

FIGURE 7. National's Role in the ISDN

In developing the architecture of its ISDN chip set, National's major objective has been to create a flexible set of building blocks which provide elegant and cost-effective solutions for a wide range of applications. With just a few highly integrated devices, a broad spectrum of ISDN equipment can be designed, ranging from Central Office and PBX line cards to X.25 and ISDN Terminals and telephones, PC terminal adaptors, NT's and more.

National's ISDN Chip-Set

TP3401 DASL	TP3076 COMBO II
TP3420 SID	
TP3410 Echo Canceller	
HPC16400 Protocol Controller	

The first device from National is the TP3420 S Interface Device (SID). The SID implements entirely the functions outlined in the CCITT I.430 document (which is the worldwide standard). In addition, the SID includes noise filtering and a high resolution digital phase locked loop to provide transmission performance in excess of that specified in the standard. All activation and D channel access sequences are handled automatically by the SID. The TP3421, a GCI version of the SID (GCI is an interchip protocol popular in Europe) is also available.

The second National transceiver is the TP3401 Digital Adapter for Subscriber Loops (DASL). The DASL is a low cost burst-mode transceiver for 2 wire PBX and private network loops up to 6 kft in length. The DASL functions as a U interface for networks that don't have the long loop lengths of the Central Office.

The TP3410 U Interface Device is the third transceiver offered by National. The TP3410 is a full feature, single chip 2B1Q Echo Canceller which is capable of transmitting data over a 18 kft loop. Features include a fully automatic adaptive receiver, maintenance channel processing, and a programmable time slot assigner. This has resulted in a flexible transceiver solution which is highly integrated with superior transmission performance. The National U Interface complies in full with the ANSI T1.601-1988 standard.

National has also developed a 16-bit microcontroller specifically for use in ISDN applications, the HPC16400. This microcontroller is ideally suited for ISDN. In addition to the HPC 16-bit microcontroller "core", it contains 2 HDLC controllers (used in message processing), an on board UART (for rate adaption), and 4 full DMA channels.

The TP3076 COMBO II™ is a Programmable PCM CODEC/Filter. This device features programmable channel gains, time slot assignment, and interface latches to support applications requiring voice channels.

National's ISDN development boards, the TP3500 and TP3515, allow today's designers to prototype their ISDN system quickly and efficiently. Both data and voice calls are supported, with the ability to individually exercise each of National's ISDN components. The systems can be controlled from a standard VT100 terminal, and access is provided for a protocol analyzer.

National also provides customers with access to its ISDN Applications Laboratory, a state of the art ISDN development center. The ISDN lab allows customers to review and debug their design with the assistance of National's application engineers. All of the tools necessary to evaluate prototype products are available.

All of National's ISDN software has been developed in conjunction with Telenetworks, an independent software vendor specializing in telecommunications software. The complete software package is supported by Telenetworks, and includes training and technical support. The code has been developed in C, and is structured around the MTEX real time operating system.

National has also formed an alliance with SGS Thomson Microelectronics. This means that a second source is available for all of National's ISDN products now and in the future. All of the NSC/ST ISDN products are developed jointly but manufactured separately by both companies. This results in the ability to quickly respond to market trends and standards updates while providing our customers with the advantages of a true second source.

In short, National Semiconductor has the experience, resources, and products to help you develop products for ISDN today.

LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform, when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.



National Semiconductor Corporation
 1111 West Bardin Road
 Arlington, TX 76017
 Tel: 1(800) 272-9959
 Fax: 1(800) 737-7018

National Semiconductor Europe
 Fax: (+49) 0-180-530 85 86
 Email: onjwge@tevm2.nsc.com
 Deutsch Tel: (+49) 0-180-530 85 85
 English Tel: (+49) 0-180-532 78 32
 Français Tel: (+49) 0-180-532 93 58
 Italiano Tel: (+49) 0-180-534 16 80

National Semiconductor Hong Kong Ltd.
 19th Floor, Straight Block,
 Ocean Centre, 5 Canton Rd.
 Tsimshatsui, Kowloon
 Hong Kong
 Tel: (852) 2737-1600
 Fax: (852) 2736-9960

National Semiconductor Japan Ltd.
 Tel: 81-043-299-2309
 Fax: 81-043-299-2408

National does not assume any responsibility for use of any circuitry described, no circuit patent licenses are implied and National reserves the right at any time without notice to change said circuitry and specifications.