Chapter Contents

_____ Notes _____

4.0 ISDN

Objectives

This section will:

- Examine the ISDN reference model
- Review the borscht functions as they apply to ISDN
- Discuss the various ways ISDN terminals can be configured
- Consider the 2B+D basic access rate access channel
- Consider the 23B+D basic primary rate access channel
- Review the need for echo cancellation

Minimum Reading

An ISDN Tutorial by National Semiconductor

For Advanced Students

http://www.ralphb.net/ISDN/

http://www.microsoft.com/windows/getisdn/whatis.htm

http://www1.pfu.edu.ru/telesys/studwork/telfut96/Isdn/result.html

http://www.esoft.com/service/isdn_whitepaper.html

Telecommunications networks were initially optimized to handle analog voice signals, and provided relatively few services. As computer technology advanced, it became possible to offer CLASS and CMS services to the home, and centrex services to business. These advances however, did not affect the subscriber loop, which still operates in the analog domain.

A unique feature of ISDN† is the digital customer loop. Digitizing the loop, has a profound impact on all aspects of telecommunications. At the lowest level, it impacts the BORSCHT functions, and at the user level it opens up a whole new realm of possibilities. It should be remembered that the twisted pair copper loop is ubiquitous, and telcos have spent billions of dollars in its deployment. Therefor ISDN must perform its magic over the existing cable. This is quite a challenge!

† Integrated Services Digital Network

Notes

ISDN Penetration

For ISDN to provide near universal access to communications services, a competitive and imaginative environment must be established. It is believed this will sponsor the creation and deployment of new cost effective services. It is therefor not surprising to witness the trend toward deregulation in the communications industry running parallel to the development of ISDN.

In order to develop ISDN products, it is necessary to standardize certain interfaces, and identify certain tasks. To this end the CCITT reference model has been developed. However, it should be noted that although equipment vendors make the claim to be compliant to the standards, there is enough room for interpretation to guarantee a certain degree of incompatibility. This is highlighted by the fact that until recently AT&T and Nortel ISDN telephone sets were not compatible with each other's central office equipment. This absurdity has been addressed in a new agreement known as ISDN-1.

Narrowband ISDN was introduced in Europe in 1988. But it wasn't widely available in the United States until 1992[1] with the introduction of N1-1[†].

It is expected that by 1995, ISDN should be available to 70% of the U.S. population with more than 400,000 ISDN circuits installed. The average monthly cost of a BRI[†] is 54$US, and the cost of a PRI [†] is 1050$US.

4.1 ISDN Reference Model

The CCITT ISDN framework is universally accepted in the industry and specifies both the subscriber and network interfaces with varying topologies. Future services such as B-ISDN using advanced techniques such as ATM, will use the CCITT reference models.[2]

Bellcore has also developed common generic criteria for SONET transport systems implementing ISDN but it is less comprehensive than the CCITT version.[3]

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1 Expanding the Market for ISDN Access, Telecommunications, vol. 28 no. 10, October 1994

† National ISDN-1

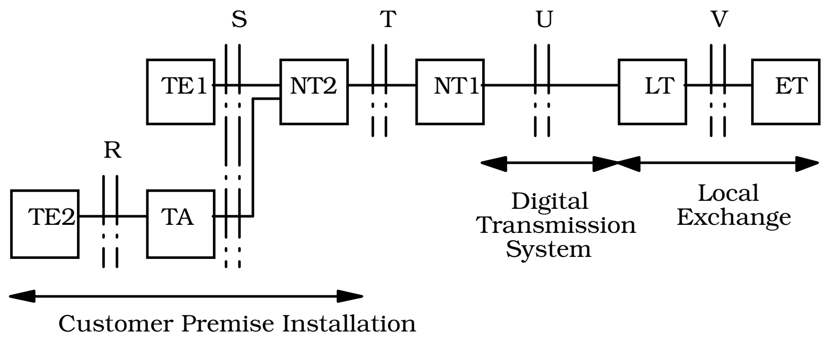
† Basic Rate Access [2B+D]

† Primary Rate Access [23B+D]

2 *Access to a Broadband ISDN,* British Telecom Technology Journal, vol 9 no 2, April 1991

3 *Synchronous Optical Network (SONET) Transport Systems: Common Generic Criteria,* Bellcore Technical Advisory TA-NWT-000253 issue 6, Sept 1990

Basic subscriber access network reference configuration[4]



There are five conceptual reference points in this model. They may correspond to a physical interface, but quite often, they are virtual interfaces since several of the blocks in the above diagram may be combined into a single entity.

The basic functional group definitions are:

- TE1 Terminal Equipment 1: such as telephones, PCs, work stations etc. which conforms to ISDN standards.
- TE2 Terminal Equipment 2: which does not conform to ISDN standards but may meet RS-232, X.21, X.25, or some other standard or proprietary protocol.
- TA Terminal Adapters: are necessary to make TE2 type equipment appear as TE1 equipment to the network.
- NT1 Network Termination 1: performs the electrical conversion between the customer's equipment and the digital transmission facilities. It also provides the power feed and performs some low-level diagnostic functions.
- NT2 Network Termination 2: provides multiplexing, concentration or switching functions such as found in a PABX, LAN, or mux.
- LT Line Termination: powers or otherwise provides the electrical interface necessary to maintain the loop.
- ET Exchange Termination: performs the signaling, code conversion, frame alignment and so on.

The following reference points may or may not represent physical boundaries between identifiable pieces of equipment, but they at least represent a logical functional partitioning:

- R A non ISDN interface, requiring a TA to bring it into conformity with ISDN standards
- S Provides the logical and perhaps physical boundary between the end user equipment and the beginning of the network
- T A theoretical interface which allows the partitioning of the network terminating equipment into two components.
- U This marks the boundary between the networking terminating equipment and the transmission facilities.

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[4] CCITT Blue Book, vol III.8, 1988

V This separates the physical and logical aspects of the user access network at the network premise. There are four versions of this boundary, simply referred to as V1 to V4.

The CCITT reference model provides a good place to start designing an ISDN device, as it clearly shows the functional requirements and possible configurations at each interface. Unfortunately, this model has not been universally implemented.

Europeans and North Americans interpret these interface definitions slightly differently. In Europe, the T interface represents the boundary between the network and the end-user. In North America, this demarcation is defined at the U interface.

It remains to be seen how quickly the international community can devise a comprehensive reference acceptable to all parties concerned. ISDN essentially means full digital connectivity. For example, voice/data terminals, fax machines, printers, automated banking machines, PCs etc. can be directly connected to the telephone network without the use of modems.

The benefits that are envisioned by this development are:

- More sophisticated calling features
- Equipment interconnect flexibility
- Reduced maintenance costs

There are three different types of channels in an ISDN system:

- B channel – 64 Kbps
- D channel – 16 or 64 Kbps
- H channel – 384, 1536, and 1920 Kbps

These channels can be combined into several different access structures. The two most common of these are the basic access rate and the primary access rate.

4.2 ISDN Applications

There are many potential applications for ISDN, but whether they become very popular depends largely on the cost of peripheral equipment and the willingness of Telcos to provide the service. Some applications include:

Internet access or large file transfer at 128 Kbps.

Telecommuting – end users can simultaneously link to LAN and voice facilities.

Desktop videoconferencing – ISDN can support 2 P channels in the Px64 standard.

Distance learning.

ACD database and simultaneous voice access.

4.3 Basic Access Rate [2B+D]

This is sometimes referred to as narrow band ISDN and will be the most widely used rate. One of its principle advantages is its ability to be conveyed over an existing telephone loop. This means that the outside plant, which is the most expensive component in the telecommunications systems, will not have to be replaced in order to provide advanced services.

The BORSCHT functions are modified as follows:

B Since the phone contains a considerable amount of electronics, it is no longer practical to provide power from the central office. This may mean that power means phone failure. However, ISDN sets that incorporate a fail to POTS mode, will still provide basic service.

O The standard telephone is made with robust components and therefore needs relatively little over voltage protection. Placing microelectronic components in the set changes this.

R there is no need to provide high voltage ringing over a digital loop, and some sort of messaging scheme is more suitable.

S The nature of supervision is changed considerably. The traditional hook switch, drawing loop current is still used to determine if the line has gone active, but the signaling method is a digital voltage pulse rather than a tone or current pulse.

C Since the loop is digital, the coding function must be done at the subscriber set, instead of in the central office. This means one codec per set rather than one codec per line as in the DMS system, or group codecs in the #5ESS.

H The hybrid function becomes difficult to provide, since transformers which can maintain a good balance over the voice band, are ineffective at the high frequencies digital links require. Consequently, transversal equalizers and echo cancellers are used.

T Testing complexity increases as the customer set becomes more complex.

With all of the difficulties associated with creating a digital loop, one might wonder: why bother? The answer lies with the development of personal computers.

PCs have become an indispensable part of business and home life. The internal workings of these machines are inherently digital in nature and it is therefor reasonable to provide digital links to connect them together. The usual method of using modems to format digital signals as analog tones, and then pass them through the PSTN is somewhat crude, and slow. This becomes increasingly annoying as PC processors become faster.

But what can one do with a digital telephone line?

Connecting a PC to the PSTN via a high-speed digital link facilitates new services:

- Telecommuting - For those people whose livelihood depends upon PCs, there is little if any need for them to go to the office, if they can be interconnected on high speed links via the PSTN.

- Remote file sharing - PCs connected over a LAN can share information or even the same screen. ISDN would allow this to be extended to anywhere in the world.
- Videophone
- Fax and E-mail - Either of these could be much more cost effective than the postal system.
- etc.

In majority of the world's telephone networks, a 2B+D channel is offered as the basic access. The aggregate bit rate for this type of link is 144 Kbps. In those areas where the networks cannot support such high data rates, two lower rate access structures have been defined:

- B+D [64 Kbps + 16 Kbps]
- B [64 Kbps]

4.3.1 B Channel Applications [64 Kbps]

- Digital voice
- High speed data [circuit or packet switched]
- Facsimile or slow-scan video

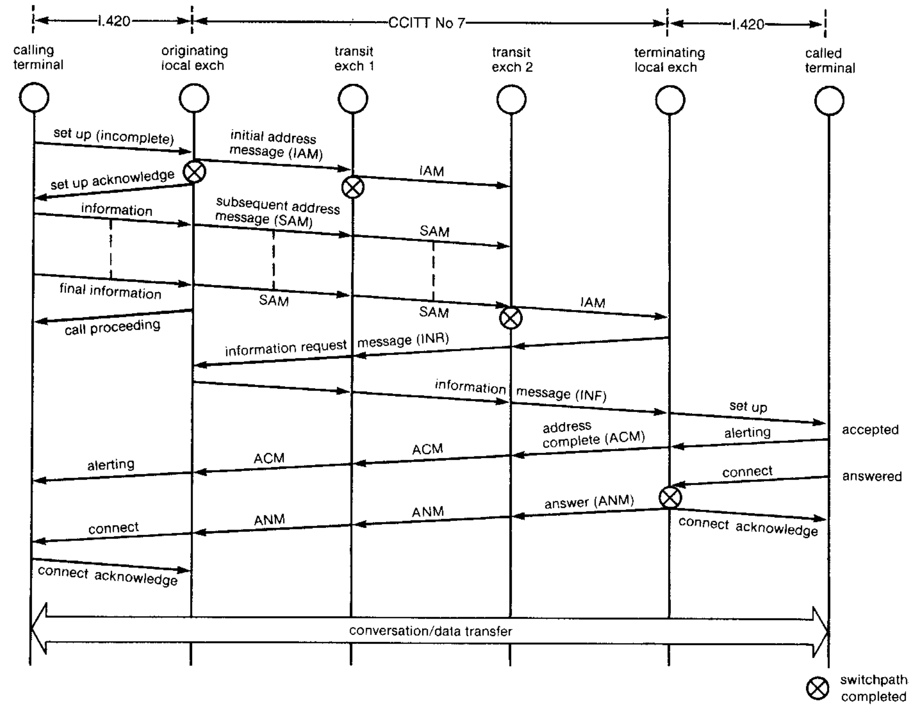
4.3.2 D Channel Applications [16 Kbps]

- Signaling [basic or enhanced]
- Low speed data [videotex, teletex, terminal]
- Telemetry [emergency services]

These rate are what is available to the user, the actual system or link bit rate is in fact higher, since synchronization, framing, and other overhead information must be transmitted. The 2B+D link therefor actually runs at 160 Kbps. An even more stringent requirement is that this bit rate is in each direction.

- 2B = 2 x 64 Kbps channels for voice/data
- D = 1 x 16 Kbps data/signaling channel
- 48 Kbps for framing and synchronization
- Full duplex at 144 Kbps
- Total bit rate is 192 Kbps
- Can support up to 8 terminals
- Implemented over standard twisted pair

An ISDN Call[5]



4.3.3 Frame Structure

The bits transacted at the S and T interfaces are organized into a 48-bit frame lasting 250 µSec. Consequently, the transmission rate is 4000 frames per second or 192 Kbps. The remaining 48 Kbps are used for overhead and control.

The bit definitions within a frame change slightly according to the signal direction. The four D bits in positions 12, 25, 36, and 47 form the D channel with an effective bit rate of 16 Kbps.

5 *ISDN Explained* (2nd ed), John M Griffiths, John Wiley & Sons, 1992, Figure 5.22

2B+D Frame Composition		
Bit	TE to NT	NT to TE
1 & 2	Framing bit	Framing bit
3 - 10	B1 Channel 1st octet	B1 Channel 1st octet
11	Balancing bit	E, D-echo channel bit
12	D Channel bit	D Channel bit
13	Balancing Bit	Bit A, used for activation
14	F_A auxiliary framing bit	F_A auxiliary framing bit
15	Balance bit	N bit
16 - 23	B2 Channel 1st octet	B2 Channel 1st octet
24	Balancing bit	E, D-echo channel bit
25	D Channel bit	D Channel bit
26	Balancing bit	M multiframing bit
27 - 34	B1 Channel 2nd octet	B1 Channel 2nd octet
35	Balancing bit	E, D-echo channel bit
36	D Channel bit	D Channel bit
37	Balance bit	S bit, future
38 - 45	B2 Channel 2nd octet	B2 Channel 2nd octet
46	Balancing bit	E, D-echo channel bit
47	D Channel bit	D Channel bit
48	Balance bit	Frame balance bit

Since multiple terminals can share the same network appearance, it is necessary to have a peer-to-peer protocol, which performs various functions such as:

- Activation and deactivation of terminal units
- D channel resource allocation
- Diagnostic and maintenance functions
- Coding, multiplexing and synchronization of peer-to-peer signaling

Information States

Signal	Comment
I0	An absence of signal denotes deactivation between NT and TE
I1	a pattern +-000000 from TE to request activation of NT
I2	Signals activation of NT or request activation of TE. All B, D, and echo bits, plus A are set to logical zero
I3	A properly synchronized frame with operational data in the B and D location transmitted from TE to NT
I4	The same as I3 but in the opposite direction. The A bit is set to zero.

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Terminal States

Signal	Comment
F1	Inactive. TE is powered down
F2	SENSING. POWERED UP BUT NOT RECEIVING
F3	Deactivated
F4	Awaiting signal. TE has responded to an activation request.
F5	Identifying Input. An unidentified signal has been received
F6	Synchronized. TE is active and waiting for normal frames
F7	Activated. Normal operating mode.
F8	Lost Framing.

Network States

Signal	Comment
G1	Deactivated
G2	Pending Activation
G3	Active
G4	Pending Deactivation

4.3.4 Basic Rate Line Code [2B+D]

Multi-level Line Codes

A number of baud rate reduction codes have been developed to reduce the number of symbols transmitted across the local loop. These codes are referred to as mBnL codes. This means that *m* binary bits are encoded into *n* different levels. These codes can reduce the error rates by:

- Increasing the number of bits per baud
- Narrowing the power spectral density, thus reducing crosstalk
- Introducing redundancy, which can be used for error control

The code redundancy is given by: $\log_2 L - \frac{m}{n}$ bits per symbol

North America [2B1Q]

This line code has come to be the North American standard. Two binary symbols are mapped into a single quaternary symbol or quat. The quat can take the values of ±1 and ±3. This arrangement does not provide any redundancy, but does lower the baud rate by 50%.

Binary Value	Quat Level
00	-3
01	-1
10	3
11	1

Frames consist of 120 quats. Groups of 8 frames are called super frames. The first 9 quats in the super frame contain a synchronization pattern known as the ISW or inverted synchronization word:

ISW = -3 -3 +3 +3 +3 -3 +3 -3 -3

The first 9 quats of all other frames in the super frame contain a synchronization word:

SW = +3 +3 -3 -3 -3 +3 -3 +3 +3

Europe [4B3T]

This line code has been selected by CCITT as the international standard for basic access digital lines. It is also known as MMS 43† and maps 4 binary symbols into 3 ternary ones, resulting in a 25% reduction in baud rate. Since 3 ternary symbols [+, -, 0] corresponds to $3^3 = 27$ different possible states, but 4 binary symbols correspond to $2^4 = 16$ possible states, there is a surplus of 11 states. Some of these are not used but others are used by the system to support control or supervision functions.

To prevent a long string of zeros from causing loss of lock, and increasing interference, the B and D channels are scrambled prior to line encoding. The scrambling polynomials are:

LT to NT1 $s(x) = 1 + x^{-5} + x^{-23}$

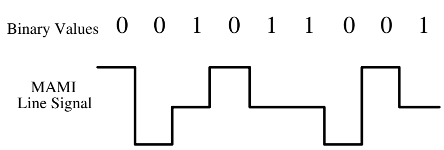
NT1 to LT $s(x) = 1 + x^{-18} + x^{-23}$

Data are arranged in frames of 120 ternary symbols. Frames synchronization is provided by word SW1 from the end-user terminal to the network and SW2 from the network:

SW1 - + - - + - - - + + +

SW2 + + + - - - + - - + -

The S and T interfaces require a balanced line format. It has been defined as a pseudo-ternary or MAMI† code. Transmission pulses have a peak voltage of ±2.5 V and duration of 5.21 µSec. Logical ones are represented by 0 volts and logical zeros are represented by alternate polarity pulses.



† Modified Monitoring State 4B3T

† Modified Alternate Mark Inversion

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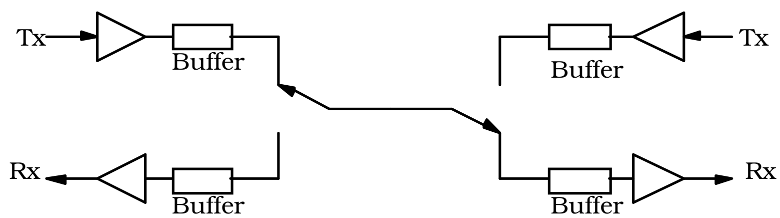
4.3.5 Basic Rate Line Interfaces

For Advanced Students

Half Duplex TCM

In the past, digital signals could be sent through the PSTN down a 4-wire loop where each pair is operating in the simplex mode. However, one of the principle objectives of ISDN is to use the existing 2 wire lines to support digital transmission. Digital half-duplex operation, also known as TCM† or ping pong is one possible solution.

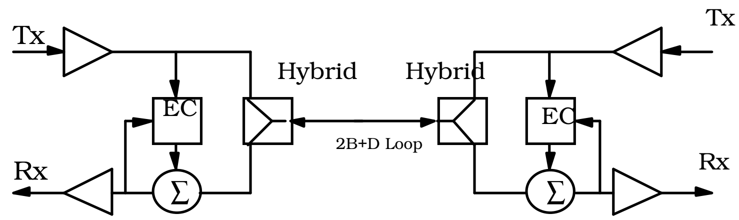
Data is compressed to a higher bit rate, and the loop switches directions. Since some switchover time would be needed to let the loop stabilize, the actual line data rate would be about 2.25 times the channel rate, or approximately 360 Kbps.



This approach requires bit rates, which a standard 2-wire loop cannot support. However, this technique is used inside of switching systems to save tracks on PCB back planes. An example of this is the A-link found in the DMS AccessNode.

Full Duplex Loop Interface

Traditionally analog signals are sent bidirectionally in a 2-wire copper loop. To transmit digital information bidirectionally on a 2-wire loop, a hybrid and an echo canceller is employed.



The transmitted pulses have a peak amplitude of 2.5 V while the minimum received pulse may be as low as 1.5 mV. The loop operates bi-directionally at 144 Kbps. The baud rate is only half of this since 2B1Q AMI line format is used. The loop attenuation increases with frequency and is about 50 dB at 89 KHz.

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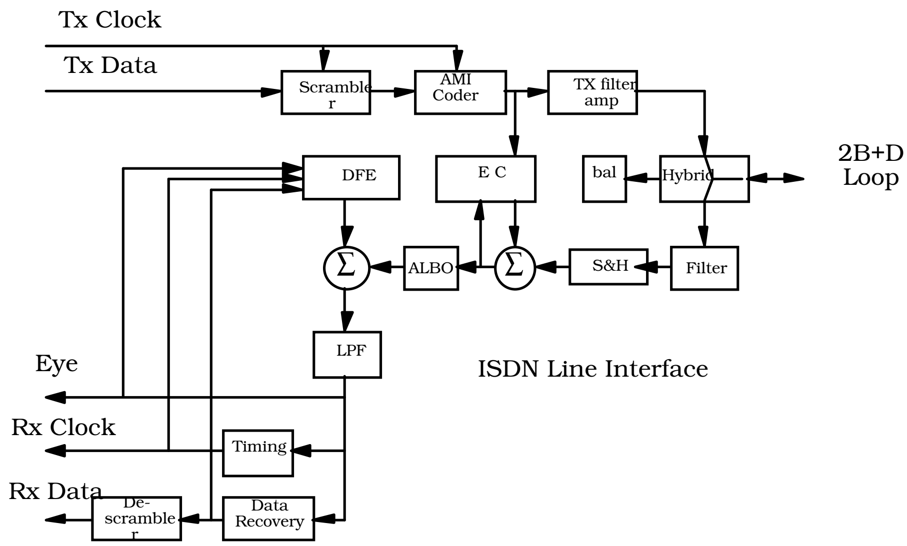
† Time Compression Multiplexing

2B1Q Interface Details[6]



For Advanced Students

Echo Cancellation

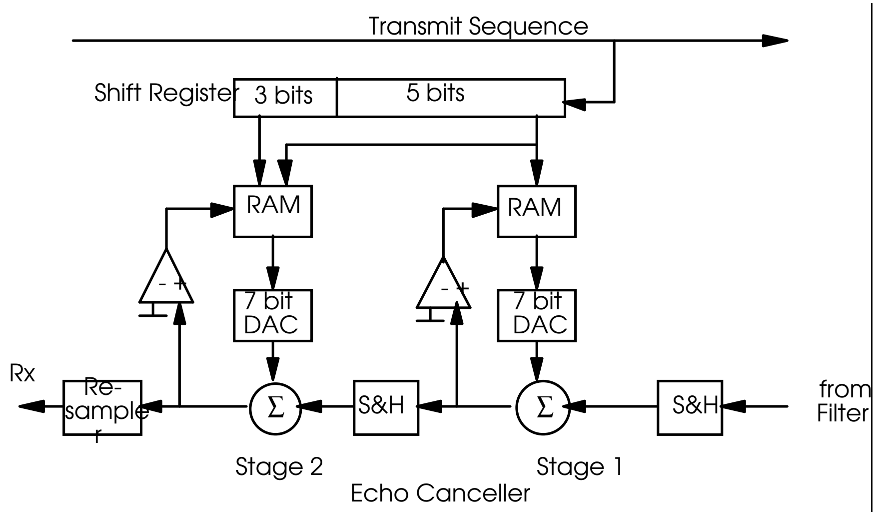
Echo Cancellation by Tellabs

The ISDN line interface must have many of the features common to any BORSCHT circuit. A hybrid is required to separate the two and four wire paths. A small transformer can be used to provide about 10 dB of THL while matching the loop impedance and providing some measure of isolation.

The incoming signal is then passed to a filter that reduces the pulse tail length and thus minimizes intersymbol interference. It also helps to ease some of the design requirements of the echo canceller.

In order to make 160 Kbps bidirectional signal transmissions possible, about 70 dB of cancellation is required on a loop with 50-dB loss.

6 Telesis, Three, 1986



The echo canceller consists of two stages each containing a 7-bit DAC. This requires less memory and has a faster convergence time than using a single 14-bit DAC.

The first stage handles the high amplitude echoes and operates on the first 5 bits in the shift register, providing 33 dB of cancellation. The second stage operates over the entire 8-bit sample and over the pulse. This provides about another 33 dB of cancellation. The total convergence time varies from 2 to 4 seconds.

Any sampling circuit creates transients at the sampling instant. These transients can be up to 30 dB greater than the cancellation signal. Consequently, the signals are resampled after cancellation and prior to entering the data recovery circuit.

Equalization

After the echo is canceled, digital pulses are reformed, reshaped through equalization. This is done via the prefilter, ALBO†, post equalizer, and decision feedback equalizer. Overall channel shaping is by a 100% RACOS† filter at the receiver output.

The ALBO consists of 2 stages and covers a range of 0 - 50 dB at 89 KHz. The combination of the fixed pre and post equalizer response approximates the inverse response of 6,858 m [22.5K ft] of 24-gauge plastic insulated cable.

The DFE† uses a 4 tap transversal equalizer to compensate for the effects of bridged taps and operates at 160 Kbps. The output feeds a 7 bit DAC, which generates a correction signal. This variable amplitude pulse is subtracted from the far end signal. The result is then shaped by the 100% RACOS filter to provide an eye pattern. The convergence time for this entire process is less than 100 mSec.

† Automatic Line Build Out

† RAised COSine

† Decision Feedback Equalizer

Timing Recovery

- Clock sampling edge is aligned to the center of the data pulse
- At the CO, a stable clock decides the transmitter and echo canceller i.e., only recovered data needs a regenerated clock
- A PLL with a 12 Hz bandwidth is used
- A voltage controlled crystal oscillator running 5.12 MHz
- Digitized phase detector
- Active loop filter

Initialization

- Requires no training sequences, startup protocols or spiral data context.
- At start up, both ends transmit random data [enabling echo cancellers to converge].
- At the CO, the canceller operates from the stable office clock.
- The terminal operates on a free running VCO.
- As the echo to signal ratio reaches 0 dB, the ALBO adjusts to peak the level of the far end signal [a coarsely equalized far end signal is now available].
- The terminal PLL locks onto the CO signal.
- the decision feedback equalizer fine tunes the signal.
- The CO PLL now converges on the terminal signal.
- Fully operational - 2 to 3 seconds.

Normally, initialization occurs only:

- At installation
- After a deliberate restart at the switch [i.e. testing]
- After dead loop operation

Ohio Bell announced the first trial of ISDN centrex in a residential area. The services to be offered include:[7]

- 5 digit local calling
- Electrical energy management [offered by local utility]
- Simultaneous voice and data communications
- Voice mail
- Security monitoring
- Up to 9 different incoming telephone numbers
- Numerous CLASS features
- Utilizes AT&T's Home Network Controller

7 *ISDN moves into the Home,* TE&M, September 15, 1991

4.4 Primary Access Rate [23B+D]

This is sometimes referred to as B-ISDN or Broadband ISDN and occurs at the U interface.

The primary access link will eventually displace the 24 channel DS–1 format. It has the same bit rate as DS–1, and is therefor somewhat backward compatible with existing facilities. However, the S bit is redefined as an F bit and has a increased functionality. Since A & B bit signaling is not employed, a clear 64 Kbps channel can be given to the end-user.

F Bit Designation	Frame	Use
m	all odd frames	Operation & Maintenance
e1, e2, e3, e4, e5, e6	2, 6, 10, 14, 18, 22	Error checking
FAS [001011]	4, 8, 12, 16, 20, 24	Frame Alignment Signal

North American version: 23B+D

- 23 x 64 Kbps B channels
- 1 x 64 Kbps D channel
- 8 Kbps for framing bits
- Total bit rate 1.544 Mbps
- Uses B8ZS coding

European version: 30B+D

Channel 0	64 Kbps for framing and synchronization
Channels 1 - 30	64 Kbps B channels
Channel 31	64 Kbps D channel
Total bit rate	2.048 Mbps
Coding	HDB3†

The European ISDN access structure is nearly identical to the level 1 scheme currently used. Sixteen 32 channel frames are organized into a multiframe.

Channel 0 is used for framing and synchronization, and has the following assignments:

† High Density Bipolar of order 3

	Channel 0 Bit Assignments							
Frame	1	2	3	4	5	6	7	8
0	C1	0	0	1	1	0	1	1
1	0	1	A	Sa	Sa	Sa	Sa	Sa
2	C2	0	0	1	1	0	1	1
3	0	1	A	Sa	Sa	Sa	Sa	Sa
4	C3	0	0	1	1	0	1	1
5	1	1	A	Sa	Sa	Sa	Sa	Sa
6	C4	0	0	1	1	0	1	1
7	0	1	A	Sa	Sa	Sa	Sa	Sa
8	C1	0	0	1	1	0	1	1
9	1	1	A	Sa	Sa	Sa	Sa	Sa
10	C2	0	0	1	1	0	1	1
11	1	1	A	Sa	Sa	Sa	Sa	Sa
12	C3	0	0	1	1	0	1	1
13	Si	1	A	Sa	Sa	Sa	Sa	Sa
14	C4	0	0	1	1	0	1	1
15	Si	1	A	Sa	Sa	Sa	Sa	Sa

Bits	Comments
C1, C2, C3, C4	Cyclic redundancy check bits
A	Remote alarm indication
Si	Spare bits for international use
Sa	Additional spare bits

Applications for BISDN center on video conferencing and high-speed data transfer. There are numerous opportunities for providing both connection and connectionless services.

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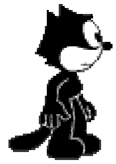
Assignment Questions



Quick Quiz

1. In order to connect a standard 500 set to an ISDN facility, a [NT2, TA] interface is required.
2. The ISDN T interface [cannot, may] be a virtual interface.
3. Modified alternate mark inversion is also known as pseudo ternary. [True, False]
4. Echo cancellation [is, is not] required on a 2B1Q loop.
5. The European 30B+D primary rate is actually composed of 32 channels. [True, False]

Composition Questions

1. Why is echo cancellation in ISDN basic access loops preferable to time compression multiplexing?
2. Suggest applications for 2B+D basic access loop.
3. Describe how ISDN basic access loops are initialized.
4. Discuss the differences between the North American and European implementations of PRA.

Notes

For Further Research

Freeman, Roger L., Telecommunication Transmission Handbook [3rd ed.], John Wiley & Sons, New York, 1991

Hermann, J. Helgert, Integrated Services Digital Networks Architectures, Protocols, Standards, Addison-Wesley, 1991

Pramode, K. Verma, ed., ISDN Systems Architecture, Technology, and Applications, Prentice Hall, 1990

Stallings, William, ISDN An Introduction, Macmillan Publishing Company, New York, 1989

http://public.pacbell.net/ISDN/connect.html

http://alumni.caltech.edu/~dank/isdn/

http://www.teles-usa.com/teles.www/isdn/e_isdn.htm

http://public.pacbell.net/ISDN/connect.html

http://www.cisco.com/univercd/cc/td/doc/cisintwk/idg4/idgisdn.htm

http://www.3com.com/nsc/500606.html

ISDN

http://www.ziplink.net/~ralphb/ISDN/

http://www.comstar.net/getStarted/tutorials/ISDNTutorial.html

http://public.pacbell.net/ISDN/connect.html

http://www.philmck.demon.co.uk/tutorial.htm

http://www.csis.gvsu.edu/~erickson/NetworkingArchives/ISDN/BradOverbeek/ISDN_main.html

http://mot-sps.com/solutions/isdn/isdn-tutorial.html

http://www.isdnzone.com/default.asp

http://www.via-isdn.org/resource.htm

http://www.niuf.nist.gov/

http://www-spires.slac.stanford.edu/comp/net/isdn.html

http://www.ralphb.net/ISDN/

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http://www.csis.gvsu.edu/~erickson/NetworkingArchives/ISDN/BradOverbeek/ISDN_main.html

http://www.looksmart.com/eus1/eus65300/eus65317/eus67401/eus70294/eus271798/eus154678/eus154682/eus590209/r?l&pin=000811x347482af0b24fc7fde1&