20ITT41 & PRINCIPLES OF COMMUNICATION

Unit - IV Data Communication

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Preamble This course explains the concepts of Analog and Digital communication systems that are used for the transmission of information from source to destination. A detailed quantitative framework for analog and digital transmission techniques is addressed.

Unit - I Amplitude Modulation: 9+3

Principles of amplitude modulation – AM envelope - Frequency spectrum and bandwidth - Modulation index and percentage modulation - AM power distribution - AM modulator circuits – Low level AM modulator - AM transmitters – Low level transmitter - AM receivers – Super heterodyne receivers

Unit - II Angle Modulation: 9+3

Angle Modulation – FM and PM waveforms - Phase deviation and modulation index - Frequency deviation - Direct FM and PM demodulators - Frequency spectrum of angle modulated waves - Bandwidth requirement - Narrowband FM and Broadband FM -Average power - FM and PM modulators, Direct FM transmitter - Angle modulation Vs. Amplitude modulation –Indirect FM transmitter.

Unit - III Digital Modulation: 9+3

Sampling - Time Division Multiplexing - Digital T-carrier System – Pulse code modulation – Amplitude shift keying – Frequency and phase shift keying – Modulator and demodulator - bit error rate calculation.

Unit - IV Data Communication: 9+3

Data communication codes: ASCII - BAR codes - Error Control - Error Detection - Redundancy checking - Error Correction -Hamming – Line coding: AMI – NRZ - RZ - Serial interfaces : RS232 - RS485 - Data communication circuits – Data communication modems - Public Switched Telephone Network(PSTN) – ISDN.

Unit - V Spread Spectrum: 9+3

PN sequence code and its properties- Direct sequence spread spectrum system - Processing gain- Frequency hopping spread spectrum.

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TEXT BOOK:

1. Wayne Tomasi, “Electronic Communications Systems: Fundamentals through Advanced”, 5th Edition, Pearson Education,
2008.

REFERENCES:

1. Michael Moher and Simon Haykin, “Communication System”, 5th Edition, Wiley India Pvt. Ltd., New Delhi, 2011.
2. Frenzel and Louis E., “Principles of Electronic Communication Systems”, 3rd Edition, Tata McGraw Hill Publishing Company,
New Delhi, 2008.
3. Anokh Singh, “Principles of Communication Engineering”,S. Chand & Co., New Delhi, 2006.

COURSE OUTCOMES:

On completion of the course, the students will be able to

CO1 illustrâtes amplitude modulation techniques Applying (K3)

CO2 use the different angle modulation schemes Applying (K3)

CO3 apply the concepts of digital modulation techniques Applying (K3)

CO4 detect and correct the errors introduced in the channel using error control coding schemes Applying (K3)

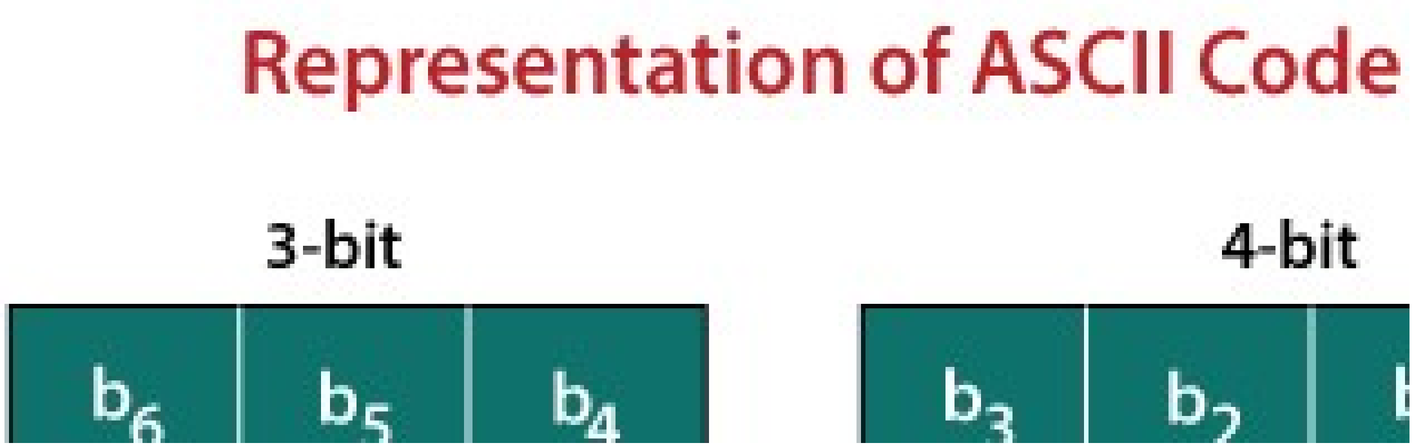
CO5 illustrate the spread spectrum techniques for modern communication Applying (K3)

Data communications codes

- *Data communications codes are often used to represent characters and symbols, such as letters,* digits, and punctuation marks. Therefore, data communications codes are called *character codes, character sets, symbol codes, or character languages.*
- **Baudot Code-** *fixed-length character code*
- **ASCII Code -** ***United States of America Standard Code for Information Exchange*** *(US**ASCII**)*
- **EBCDIC Code-** *extended binary-coded decimal interchange code*
- **BAR CODES -** *Bar codes are those omnipresent black-and-white striped stickers*

Data communications codes- ASCII- 7 bit

- ASCII is the standard character set for source coding the alphanumeric character set that humans understand but computers do not (computers only understand 1s and 0s).
- The ASCII is a 7-bit code capable of representing 2^7 or 128 number of different characters.
- The ASCII code is made up of a three-bit group, which is followed by a four-bit code.
- ASCII is a **seven-bit fixed-length character set**.



Data communications codes- ASCII- 8 bit

- The **8-bit code** holds ASCII, which supports 256 symbols where math and graphic symbols are added.
- The range of the extended ASCII is 80h to FFh.

For example, the ASCII encoding for the lowercase letter "m" is represented in the following ways:

Character	Hexadecimal	Octal	Decimal	Binary (7 bit)	Binary (8 bit)
m	0x6D	/155	109	110 1101	0110 1101

Data communications codes- ASCII

Table 2 ASCII-77: Odd Parity

Bit	Binary Code								Hex	Bit	Binary Code								Hex
	7	6	5	4	3	2	1	0			7	6	5	4	3	2	1	0	
NUL	1	0	0	0	0	0	0	0	00	@	0	1	0	0	0	0	0	0	40
SOH	0	0	0	0	0	0	0	1	01	A	1	1	0	0	0	0	0	1	41
STX	0	0	0	0	0	0	1	0	02	B	1	1	0	0	0	0	1	0	42
ETX	1	0	0	0	0	0	1	1	03	C	0	1	0	0	0	0	1	1	43
EOT	0	0	0	0	0	1	0	0	04	D	1	1	0	0	0	1	0	0	44
ENQ	1	0	0	0	0	1	0	1	05	E	0	1	0	0	0	1	0	1	45
ACK	1	0	0	0	0	1	1	0	06	F	0	1	0	0	0	1	1	0	46

ENQ	1	0	0	0	0	1	0	1	05	E	0	1	0	0	0
ACK	1	0	0	0	0	1	1	0	06	F	0	1	0	0	0
BEL	0	0	0	0	0	1	1	1	07	G	1	1	0	0	0
BS	0	0	0	0	1	0	0	0	08	H	1	1	0	0	1
HT	1	0	0	0	1	0	0	1	09	I	0	1	0	0	1
NL	1	0	0	0	1	0	1	0	0A	J	0	1	0	0	1
VT	0	0	0	0	1	0	1	1	0B	K	1	1	0	0	1

Data communications codes- ASCII

Table 2 ASCII-77: Odd Parity

Bit	Binary Code 7	6	5	4	3	2	1	0	Hex	Bit	Binary Code 7	6	5	4	3	2	1	0	Hex
DLE	0	0	0	1	0	0	0	0	10	P	1	1	0	1	0	0	0	0	50
DC1	0	0	0	1	0	0	0	1	11	Q	0	1	0	1	0	0	0	1	51
DC2	1	0	0	1	0	0	1	0	12	R	0	1	0	1	0	0	1	0	52
DC3	0	0	0	1	0	0	1	1	13	S	1	1	0	1	0	0	1	1	53
DC4	1	0	0	1	0	1	0	0	14	T	0	1	0	1	0	1	0	0	54
NAK	0	0	0	1	0	1	0	1	15	U	1	1	0	1	0	1	0	1	55
SYN	0	0	0	1	0	1	1	0	16	V	1	1	0	1	0	1	1	0	56
ETB	1	0	0	1	0	1	1	1	17	W	0	1	0	1	0	1	1	1	57

Bit	7	6	5	4	3	2	1	0	Hex	Bit	7	6	5	4	3
DC3	0	0	0	1	0	0	1	1	13	S	1	1	0	1	0
DC4	1	0	0	1	0	1	0	0	14	T	0	1	0	1	0
NAK	0	0	0	1	0	1	0	1	15	U	1	1	0	1	0
SYN	0	0	0	1	0	1	1	0	16	V	1	1	0	1	0
ETB	1	0	0	1	0	1	1	1	17	W	0	1	0	1	0
CAN	1	0	0	1	1	0	0	0	18	X	0	1	0	1	1

Data communications codes- ASCII

Table 2 ASCII-77: Odd Parity

Bit	Binary Code 7	6	5	4	3	2	1	0	Hex	Bit	Binary Code 7	6	5	4	3	2	1	0	Hex
!	1	0	1	0	0	0	0	1	21	a	0	1	1	0	0	0	0	1	61
"	1	0	1	0	0	0	1	0	22	b	0	1	1	0	0	0	1	0	62
#	0	0	1	0	0	0	1	1	23	c	1	1	1	0	0	0	1	1	63
$	1	0	1	0	0	1	0	0	24	d	0	1	1	0	0	1	0	0	64
%	0	0	1	0	0	1	0	1	25	e	1	1	1	0	0	1	0	1	65
&	0	0	1	0	0	1	1	0	26	f	1	1	1	0	0	1	1	0	66
'	1	0	1	0	0	1	1	1	27	g	0	1	1	0	0	1	1	1	67
(	1	0	1	0	1	0	0	0	28	h	0	1	1	0	1	0	0	0	68
)	0	0	1	0	1	0	0	1	29	i	1	1	1	0	1	0	0	1	69

(	1	0	1	0	1	0	0	0	28	h	0	1	1	0	1
)	0	0	1	0	1	0	0	1	29	i	1	1	1	0	1
*	0	0	1	0	1	0	1	0	2A	j	1	1	1	0	1
+	1	0	1	0	1	0	1	1	2B	k	0	1	1	0	1
,	0	0	1	0	1	1	0	0	2C	l	1	1	1	0	1
-	1	0	1	0	1	1	0	1	2D	m	0	1	1	0	1
.	1	0	1	0	1	1	1	0	2E	n	0	1	1	0	1
/	0	0	1	0	1	1	1	1	2F	o	1	1	1	0	1
0	1	0	1	1	0	0	0	0	30	p	0	1	1	1	0
1	0	0	1	1	0	0	0	1	31	q	1	1	1	1	0
2	0	0	1	1	0	0	1	0	32	r	1	1	1	1	0
3	1	0	1	1	0	0	1	1	33	s	0	1	1	1	0
4	0	0	1	1	0	1	0	0	34	t	1	1	1	1	0
5	1	0	1	1	0	1	0	1	35	u	0	1	1	1	0

Data communications codes- ASCII

Table 2 (*Continued*)

	Binary Code										Binary Code				
Bit	7	6	5	4	3	2	1	0	Hex	Bit	7	6	5	4	3
9	1	0	1	1	1	0	0	1	39	y	0	1	1	1	1
:	1	0	1	1	1	0	1	0	3A	z	0	1	1	1	1
;	0	0	1	1	1	0	1	1	3B	{	1	1	1	1	1
<	1	0	1	1	1	1	0	0	3C	|	0	1	1	1	1
=	0	0	1	1	1	1	0	1	3D	}	1	1	1	1	1
>	0	0	1	1	1	1	1	0	3E	~	1	1	1	1	1
?	1	0	1	1	1	1	1	1	3F	DEL	0	1	1	1	1

NUL = null
SOH = start of heading
STX = start of text
ETX = end of text
EOT = end of transmission
ENQ = enquiry
ACK = acknowledge

VT = vertical tab
FF = form feed
CR = carriage return
SO = shift-out
SI = shift-in
DLE = data link escape
DC1 = device control 1

SYN = synchronous
ETB = end of transmission block
CAN = cancel
SUB = substitute
ESC = escape
FS = field separator
GS = group separator

Data communications codes- ASCII

Character Group	Range		
	Decimal	Hexadecimal	
Control characters	0 - 31	00 – 1F	0000
Punctuation	32 - 47	20 – 2F	0010
Digits: 0 1 2 3 4 5 6 7 8 9	48 - 57	30 – 39	0011
Punctuation: : ; < = > ?	58 - 64	3A – 40	0011
Upper case letters: "A" through "Z"	65 - 90	41 – 5A	0100
Punctuation: [\ ] ^ _	91 - 96	5B – 60	0101
Lower case letters: "a" through "z"	97 - 122	61 – 7A	0110

		Binary Digit								Hex Code	
Letter	Decimal	128	64	32	16	8	4	2	1	Hex	Code
A	65	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**1**	**4**	**1**
z	122	0	1	1	1	1	0	1	0	7	A

Data communications codes- ASCII

Converting the text “hope” into binary

Characters:	h	o	p	e
ASCII Values:	104	111	112	101
Binary Values:	01101000	01101111	01110000	01100101
Bits:	8	8	8	8

ASCII advantages and disadvantages

- **Advantages**
- **Universally accepted.** ASCII character encoding is universally understood.
- **Compact character encoding.** Standard codes can be expressed in 7 bits. This means data that can be expressed in the standard ASCII character set requires only as many bytes to store or send as the number of characters in the data.
- **Efficient for programming.** The character codes for letters and numbers are well adapted to programming techniques for manipulating text and using numbers for calculations or storage as raw data.

Disadvantages

Limited character set. Even with extended ASCII, only 255 distinct characters can be represented. The characters in a standard character set are enough for English language communications.

But even with the diacritical marks and Greek letters supported in extended ASCII, it is difficult to accommodate languages that do not use the Latin alphabet.

Inefficient character encoding. Standard ASCII encoding is efficient for English language and numerical data.

Representing characters from other alphabets requires more overhead such as escape codes.

Data communications codes- **BAR CODES**

- A **barcode** or **bar code** is a method of representing data in a visual, machine-readable form.
- Initially, barcodes represented data by varying the widths, spacing and sizes of parallel lines.

Data communications codes- **BAR CODES**

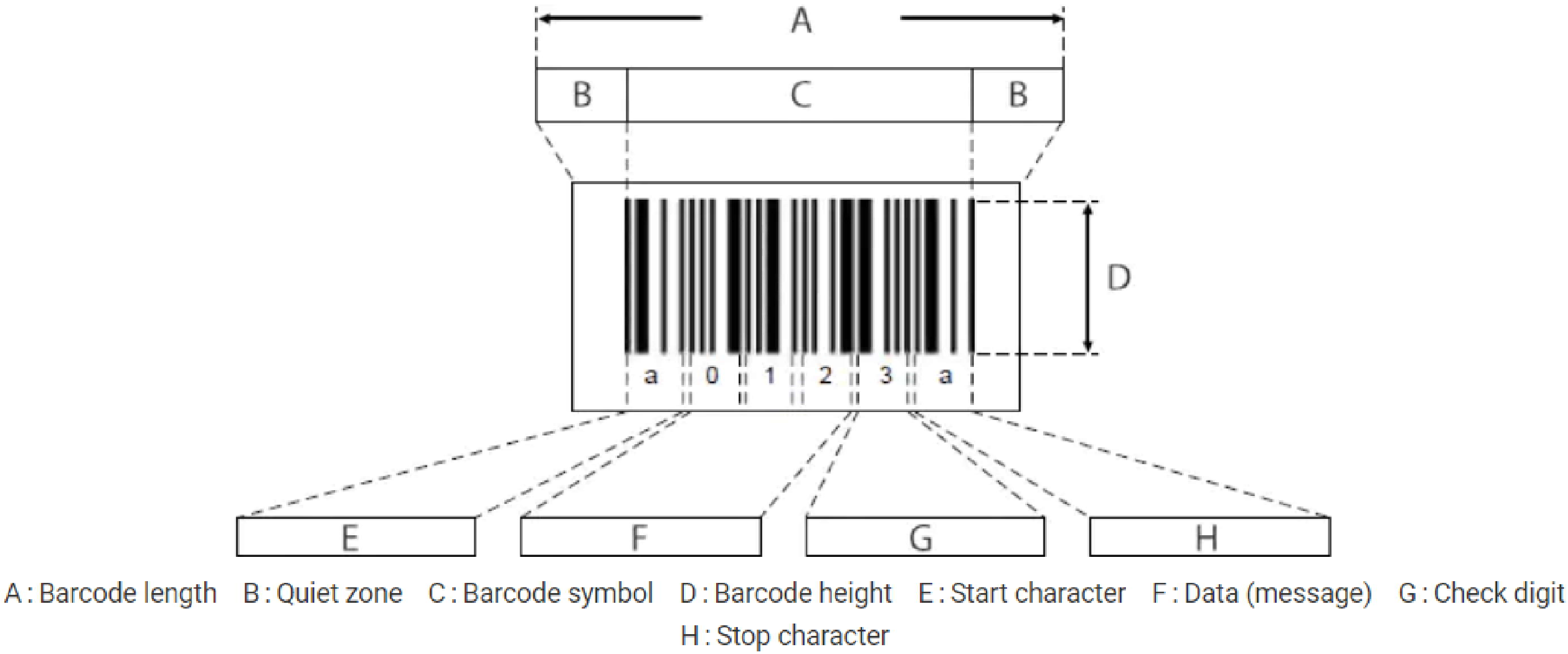
- There are several standard bar code formats. The format selected depends on what types of data are being stored, how the data are being stored, system performance, and which format is most popular with business and industry.
- Bar codes are generally classified as being discrete, continuous, or two-dimensional (2D).

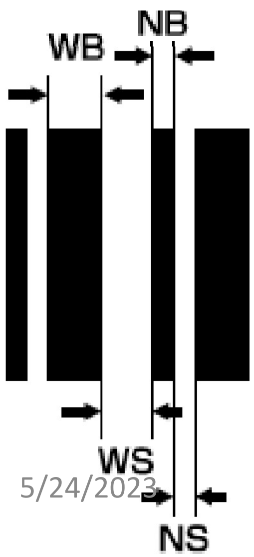
Discrete code*. A discrete bar code has spaces or gaps between characters. Therefore,* each character within the bar code is independent of every other character. **Code 39 is an example of a discrete bar code.**

Continuous code. *A continuous bar code does not include spaces between characters.* An example of a continuous bar code is the **Universal Product Code (UPC).**

2D code. *A 2D bar code stores data in two dimensions in contrast with a conventional* linear bar code, which stores data along only one axis. 2D bar codes have a larger storage capacity than one-dimensional bar codes (typically 1 kilobyte or more per data symbol).

Data communications codes- **BAR CODES**

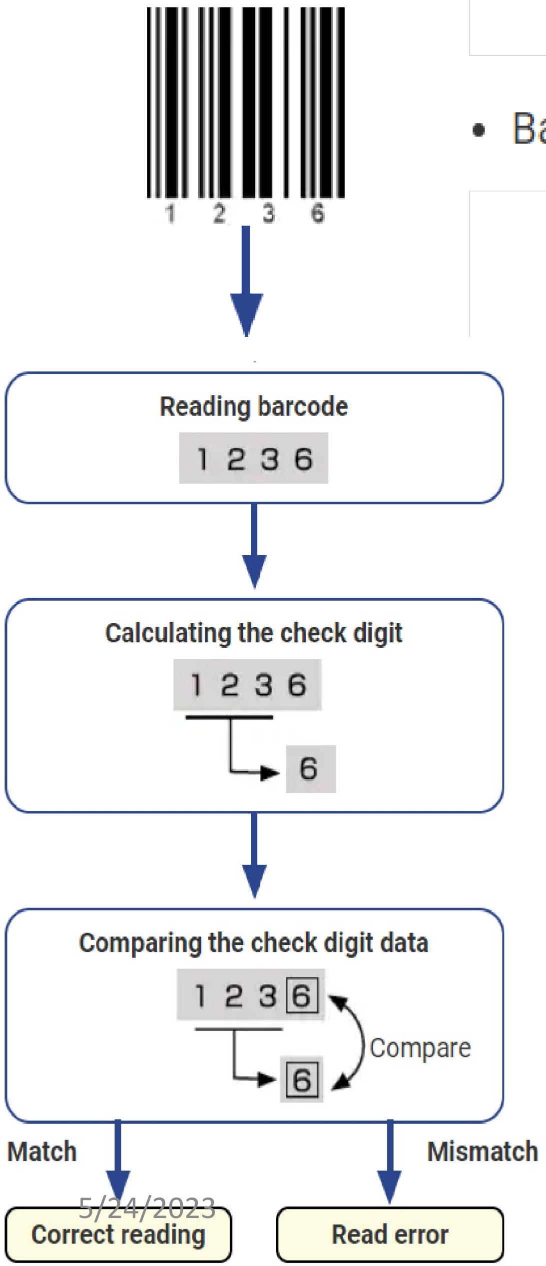




Narrow and wide widths are determined at the following ratio:
NB:WB = NS:WS =1:2 to 1:3

NB	Narrow bar
WB	Wide bar
NS	Narrow space
WS	Wide space

Data communications codes- **BAR CODES**



- Barcode with data “123”and check digit “6”.

- Barcode is read.
- Check digit is calculated from the data.
- The calculated check digit is compared with
- If they do not match, a read error occurs.

A check digit is a numeric value calculated to check for read error.

Data communications codes- **BAR CODES**

Calculating the check digit

The following explains how to calculate the check digit, taking Modulus 10/3 Weight as an example, which is applied for EAN and ITF.
①Number the code value sequentially starting from the right.
②Multiply each odd numbered value by 3 and each even numbered value by 1.
③Total the multiplied values and then subtract the last digit value of the total value from 10 to get the check digit.

12	11	10	9	8	7	6	5	4	3	2	1
4	9	7	1	2	3	4	5	6	7	8	9
x	x	x	x	x	x	x	x	x	x	x	x
1	3	1	3	1	3	1	3	1	3	1	3
॥	॥	॥	॥	॥	॥	॥	॥	॥	॥	॥	॥

4 + 27 + 7 + 3 + 2 + 9 + 4 + 15 + 6 + 21 + 8 + 27
= 133

10-3（the last digit value of 133）＝7
Thus, the check digit is calculated to be 7.

BAR CODES – CODE 39

Table 4 Code 39 Character Set

Character	Binary Code b_8	b_7	b_6	b_5	b_4	b_3	b_2	b_1	b_0	Bars $b_8b_6b_4b_2b_0$	Spaces $b_7b_5b_3b_1$	Check Sum Value
0	0	0	0	1	1	0	1	0	0	00110	0100	0
1	1	0	0	1	0	0	0	0	1	10001	0100	1
2	0	0	1	1	0	0	0	0	1	01001	0100	2
3	1	0	1	1	0	0	0	0	0	11000	0100	3
4	0	0	0	1	1	0	0	0	1	00101	0100	4
5	1	0	0	1	1	0	0	0	0	10100	0100	5
6	0	0	1	1	1	0	0	0	0	01100	0100	6
7	0	0	0	1	0	0	1	0	1	00011	0100	7
8	1	0	0	1	0	0	1	0	0	10010	0100	8

6	0	0	1	1	1	0	0	0	0	01100	010
7	0	0	0	1	0	0	1	0	1	00011	010
8	1	0	0	1	0	0	1	0	0	10010	010
9	0	0	1	1	0	0	1	0	0	01010	010
A	1	0	0	0	0	1	0	0	1	10001	001
B	0	0	1	0	0	1	0	0	1	01001	001
C	1	0	1	0	0	1	0	0	0	11000	001
D	0	0	0	0	1	1	0	0	1	00101	001
E	1	0	0	0	1	1	0	0	0	10100	001

BAR CODES- CODE 39

Table 4 Code 39 Character Set

Character	Binary Code b_8	b_7	b_6	b_5	b_4	b_3	b_2	b_1	b_0	Bars $b_8b_6b_4b_2b_0$	Spaces $b_7b_5b_3b_1$	Check Sum Value
K	1	0	0	0	0	0	0	1	1	1 0 0 0 1	0 0 0 1	20
L	0	0	1	0	0	0	0	1	1	0 1 0 0 1	0 0 0 1	21
M	1	0	1	0	0	0	0	1	0	1 1 0 0 0	0 0 0 1	22
N	0	0	0	0	1	0	0	1	1	0 0 1 0 1	0 0 0 1	23
O	1	0	0	0	1	0	0	1	0	1 0 1 0 0	0 0 0 1	24
P	0	0	1	0	1	0	0	1	0	0 1 1 0 0	0 0 0 1	25
Q	0	0	0	0	0	0	1	1	1	0 0 0 1 1	0 0 0 1	26
R	1	0	0	0	0	0	1	1	0	1 0 0 1 0	0 0 0 1	27
S	0	0	1	0	0	0	1	1	0	0 1 0 1 0	0 0 0 1	28
T	0	0	0	0	1	0	1	1	0	0 0 1 1 0	0 0 0 1	29

S	0	0	1	0	0	0	1	1	0	0 1 0 1 0	0 0
T	0	0	0	0	1	0	1	1	0	0 0 1 1 0	0 0
U	1	1	0	0	0	0	0	0	1	1 0 0 0 1	1 0
V	0	1	1	0	0	0	0	0	1	0 1 0 0 1	1 0
W	1	1	1	0	0	0	0	0	0	1 1 0 0 0	1 0

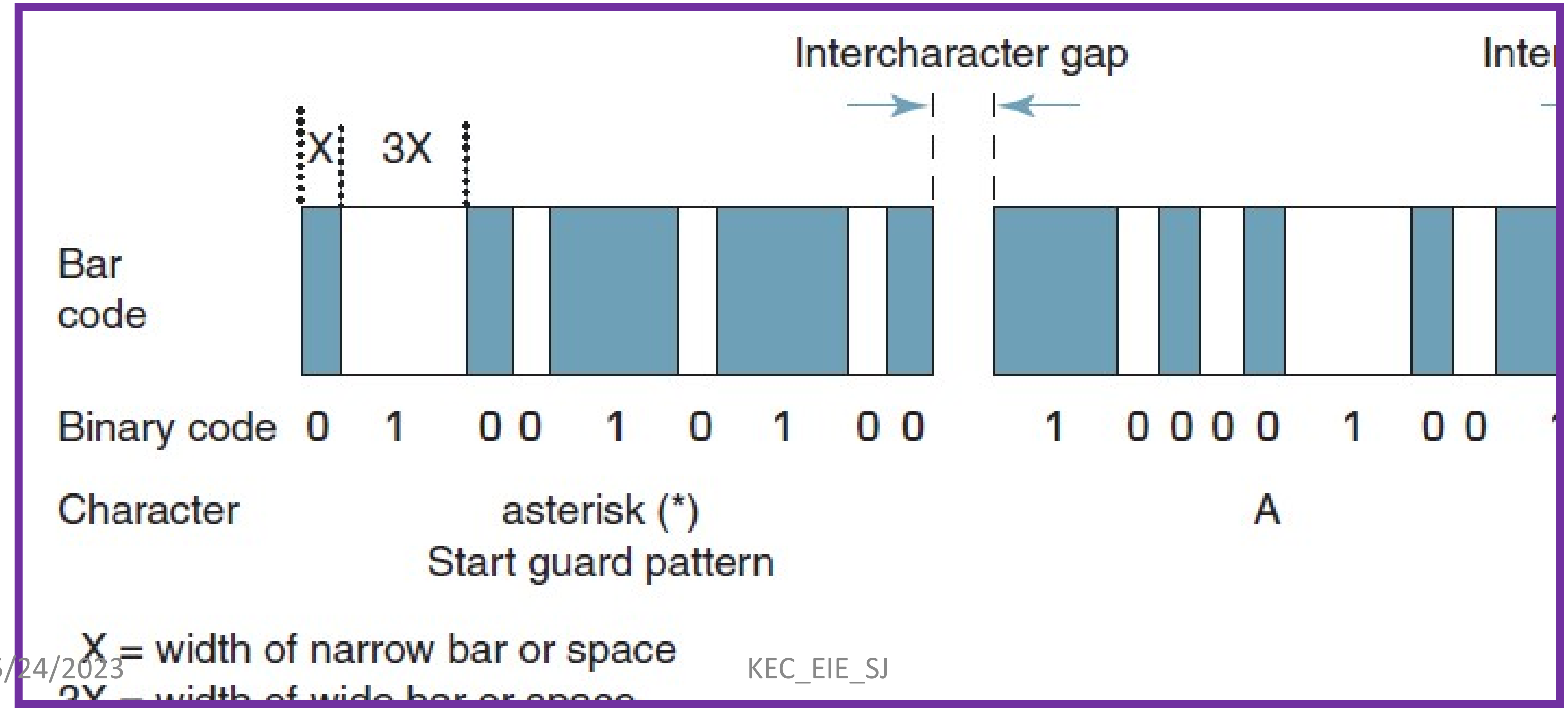
BAR CODES- CODE 39 Type

Symbology number:	8
Valid characters:	“0”..”9”, “A”..”Z”, “-“, “.”, Space, “*”, “$”, “/”, “+”, “%”
Quiet zone:	left/right: 10X, min. ¼ inch
Module width:	X >= 0.19 mm
Standard print ratio:	1:3:1:3
Ratio format:	1B:2B:1S:2S
Default check digit:	None (eCDNone)
Possible check digits:	Modulo 43 (eCDMod43), Modulo 11 Weight 7 (eCDMod11W7)
Symbol size:	H>=15% of L (H>=6.3 mm!) H: Height of the barcode without human readable text L: width of the barcode
Print control:	C=39

BAR CODES- CODE 39

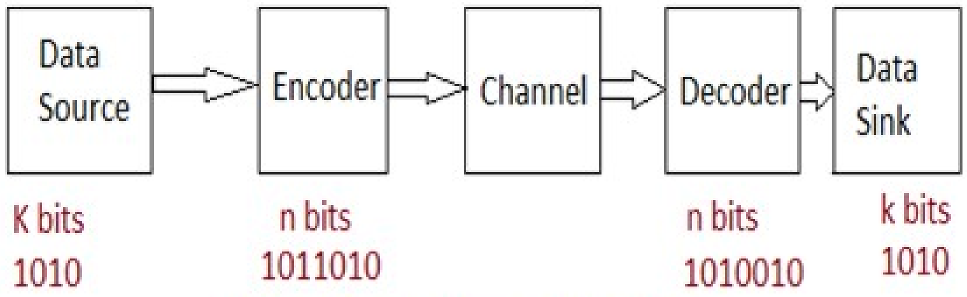
Table 4 Code 39 Character Set

Character	Binary Code b_8	b_7	b_6	b_5	b_4	b_3	b_2	b_1	b_0	Bars $b_8b_6b_4b_2b_0$	Spaces $b_7b_5b_3b_1$	Check Sum Value
–	0	1	0	0	0	0	1	0	1	0 0 0 1 1	1 0 0 0	36
.	1	1	0	0	0	0	1	0	0	1 0 0 1 0	1 0 0 0	37
space	0	1	1	0	0	0	1	0	0	0 1 0 1 0	1 0 0 0	38
*	0	1	0	0	1	0	1	0	0	0 0 1 1 0	1 0 0 0	—
$	0	1	0	1	0	1	0	0	0	0 0 0 0 0	1 1 1 0	39
/	0	1	0	1	0	0	0	1	0	0 0 0 0 0	1 1 0 1	40
+	0	1	0	0	0	1	0	1	0	0 0 0 0 0	1 0 1 1	41
%	0	0	0	1	0	1	0	1	0	0 0 0 0 0	0 1 1 1	42



ERROR DETECTION

- *Error detection is the **process of monitoring data transmission and determining** when errors* have occurred.
- Error-detection techniques neither correct errors nor identify which bits are in error—they indicate only when an error has occurred.
- The purpose of error detection is not to prevent errors from occurring but to prevent undetected errors from occurring.
- **1. Redundancy Checking**
  - ✓ **1 Vertical redundancy checking**
  - ✓ **2 Checksum**
  - ✓ **3 Longitudinal redundancy checking**
  - ✓ **4 Cyclic redundancy checking.**
- **ERROR CORRECTION**
  - ✓ **1 Retransmission**
  - ✓ **2 Forward Error Correction**
    - o **2-1 Hamming code.**



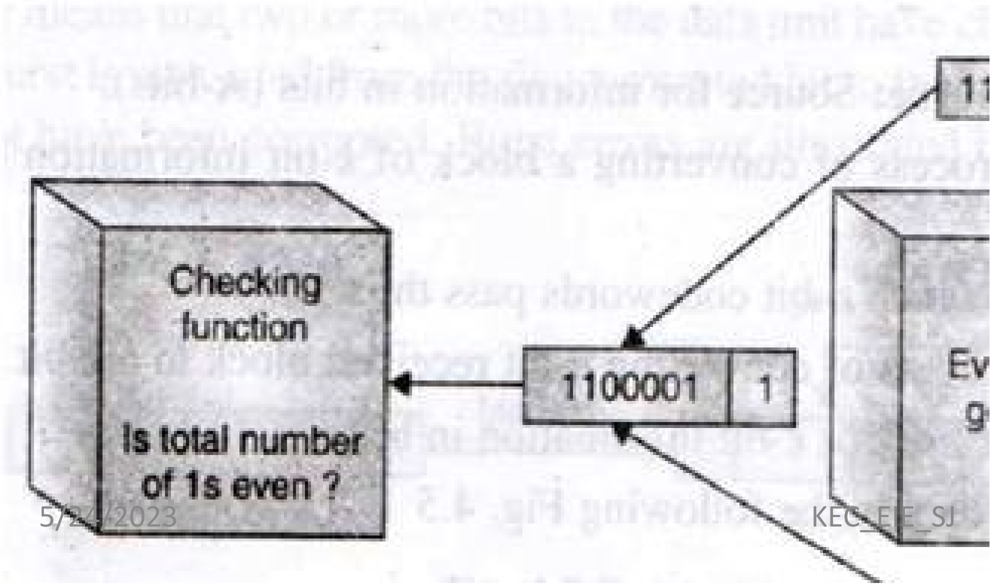
Principle of Error Detection

Error Detection: Redundancy Checking

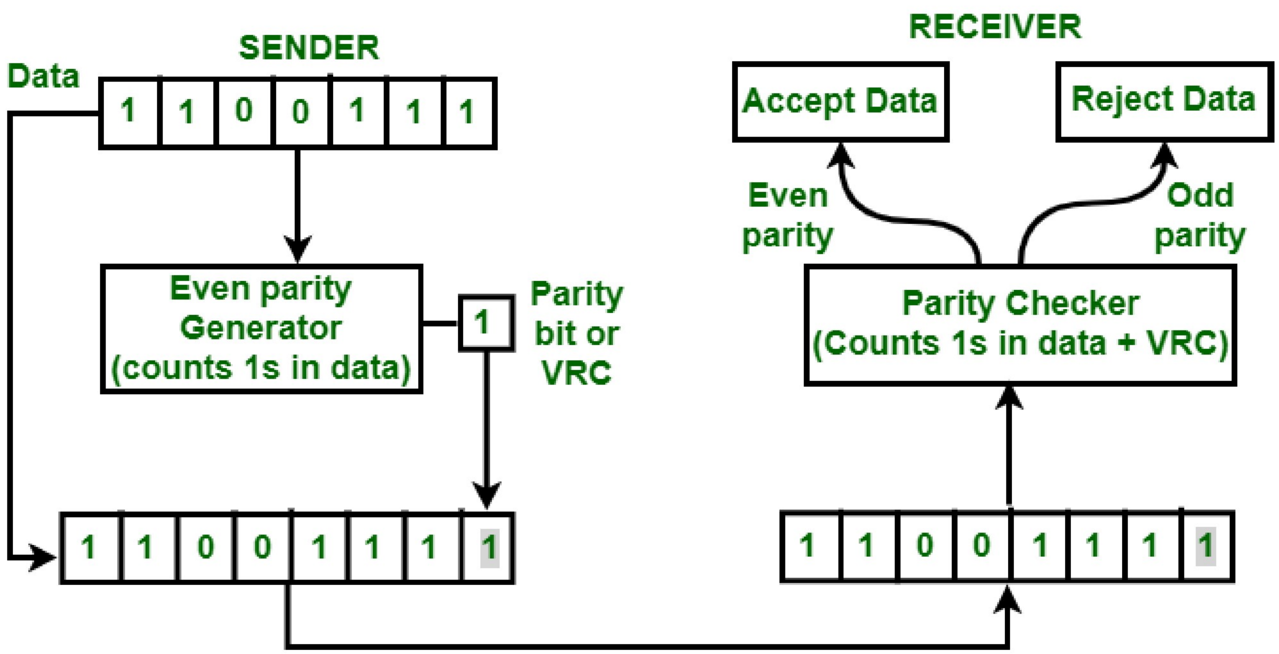
- Duplicating each data unit for the purpose of detecting errors is a form of error detection called *redundancy*
- Adding bits for the sole purpose of detecting errors is called *redundancy checking.*
- *Four Types of redundancy checking*
  - ✓ **1 Vertical redundancy checking**
  - ✓ **2 Checksum**
  - ✓ **3 Longitudinal redundancy checking**
  - ✓ **4 Cyclic redundancy checking.**

Error Detection: 1. Vertical Redundancy Checking

- *Vertical redundancy checking (VRC) is* probably the simplest error-detection scheme and is generally referred to as *character parity* or simply *parity.*
- *With character parity, each character has its own error-detection bit* called the *parity bit.*
- *Since the parity bit is not actually part of the character, it is considered* a redundant bit.
- An ***n-character*** *message would have* ***n redundant parity bits.***
- *Therefore, the* **number of error-detection** bits is directly proportional to the **length of the message**.



Error Detection: 1. Vertical Redundancy Checking



Parity generator will count number of 1s in data unit and will add parity bit. In the above example,
number of 1s in data unit is 5, parity generator appends a parity bit 1 to this data unit making the total number of 1s even i.e 6 .
Data along with parity bit is then transmitted across the network. In this case, 11001111 will be transmitted.
At the destination, This data is passed to parity checker at the destination. The number of 1s in data is counted by parity checker.

Sources: https://www.geeksforgeeks.org/vertical-redundancy-check-vrc-or-parity-check/

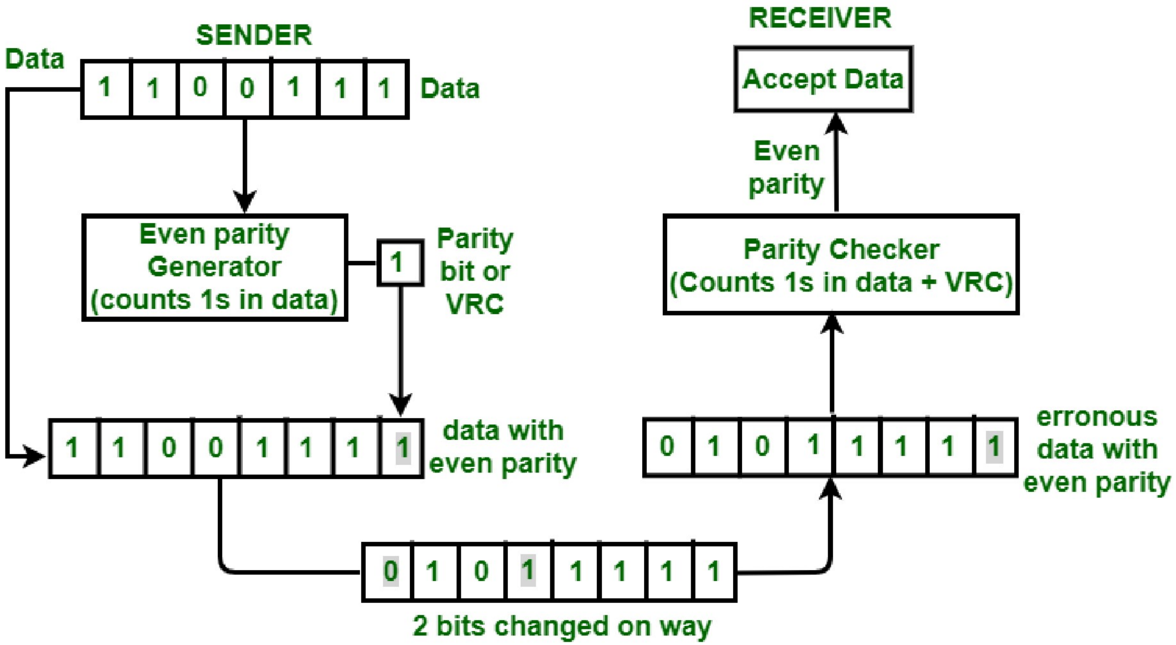
Error Detection: 1. Vertical Redundancy Checking

Advantages :

- VRC can detect all single bit error.
- It can also detect burst errors but only in those cases where number of bits changed is odd, i.e. 1, 3, 5, 7, …….etc.

Disadvantages :

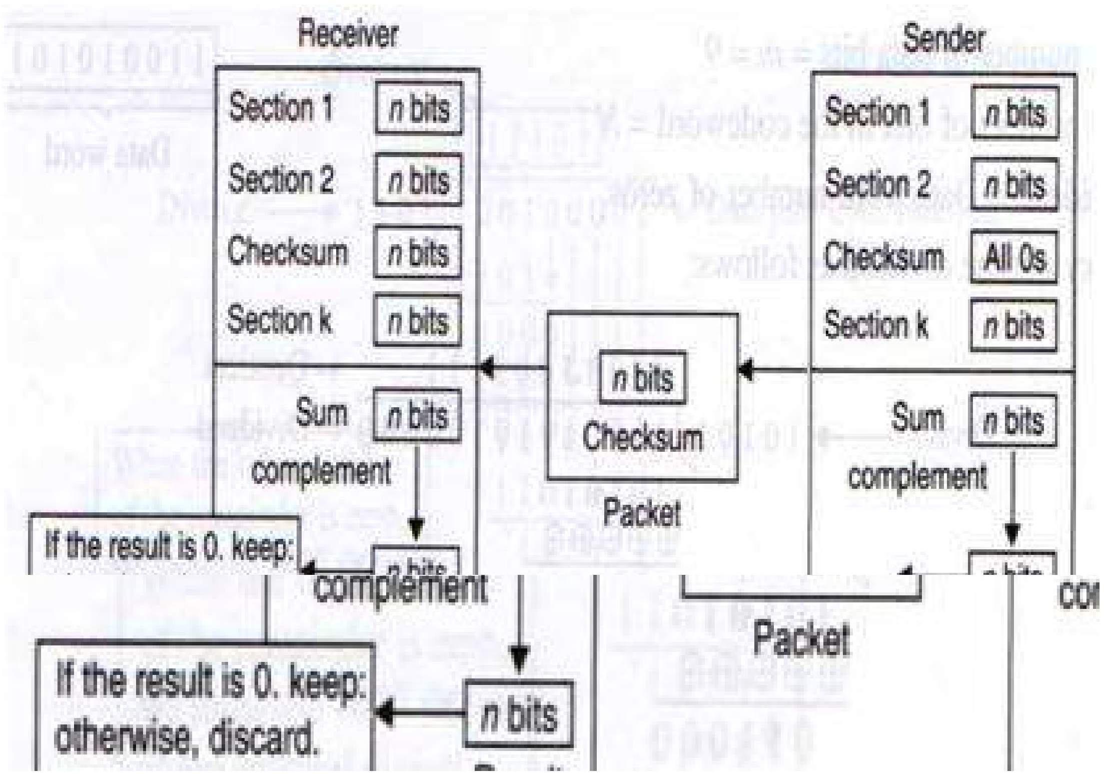
The major disadvantage of using this method for error detection is that it is not able to detect burst error if the number of bits changed is even, i.e. 2, 4, 6, 8, …….etc.



Sources: https://www.geeksforgeeks.org/vertical-redundancy-check-vrc-or-parity-check/

Error Detection: 2. Checksum method

- There are two modules in this error detection method viz. checksum generator and checksum checker.
- In the transmitter, checksum generator subdivides data unit into equal segments of n bits (usually 16).



These segments are added together using one's complement arithmetic in such a way that total is also n bits long.
The total (i.e. sum) is then complemented and **appended to the end of the original data unit as redundancy bits, called checksum field.**
The extended data unit is transmitted across the network. So it sum of data segment is equal to T, checksum will be -T.

https://www.rfwireless-world.com/Terminology/Error-Detection-basics-and-techniques.html

Error Detection: 2. Checksum method

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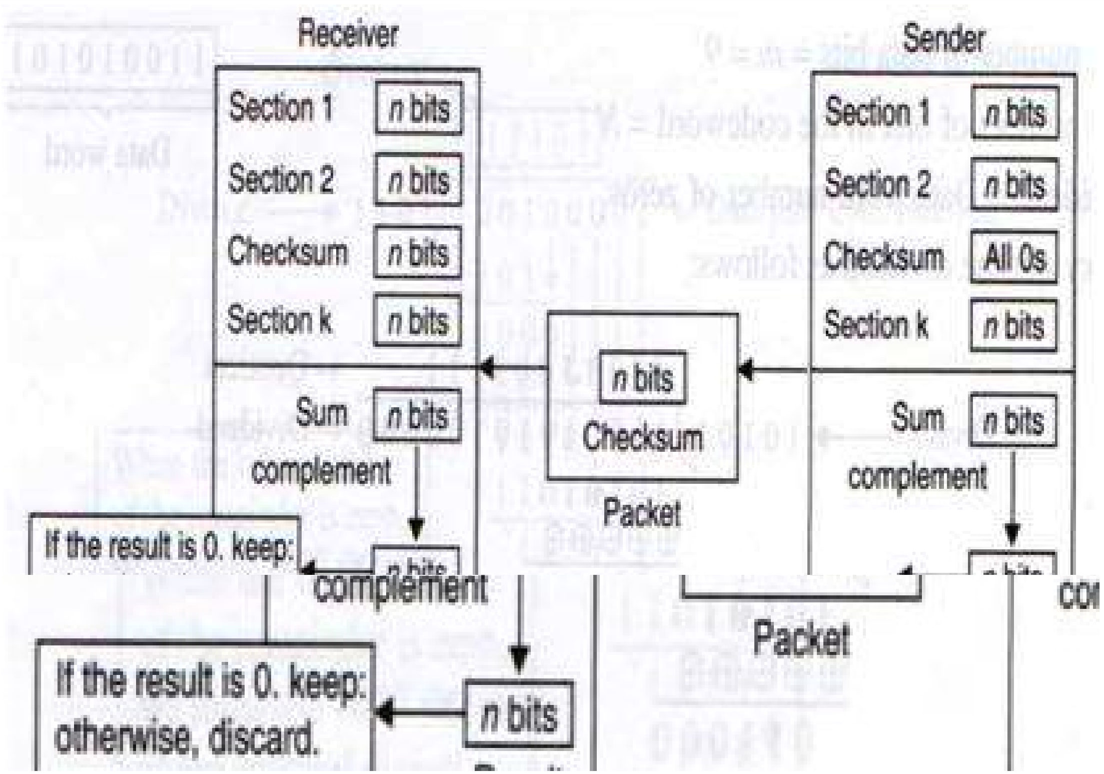


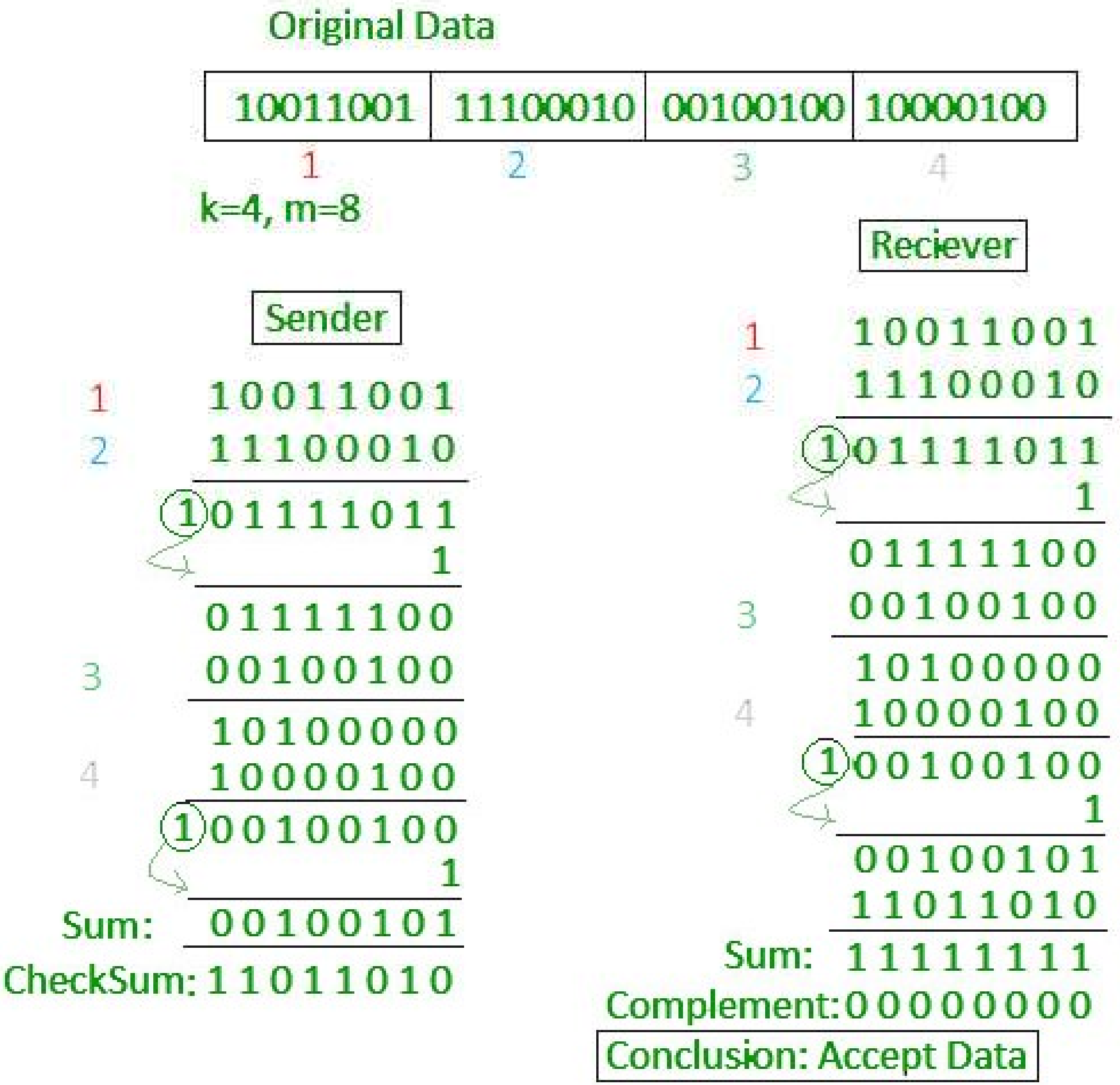
The **receiver subdivides** the data unit as above and adds all segments together and complements the result.

If the extended data unit is intact, the total value found by adding all data segments and checksum **field should be zero.**

If the result is not zero, the packet contains error and receiver rejects the packet.

https://www.rfwireless-world.com/Terminology/Error-Detection-basics-and-techniques.html

Error Detection: 2. Checksum method



https://www.rfwireless-world.com/Terminology/Error-Detection-basics-and-techniques.html

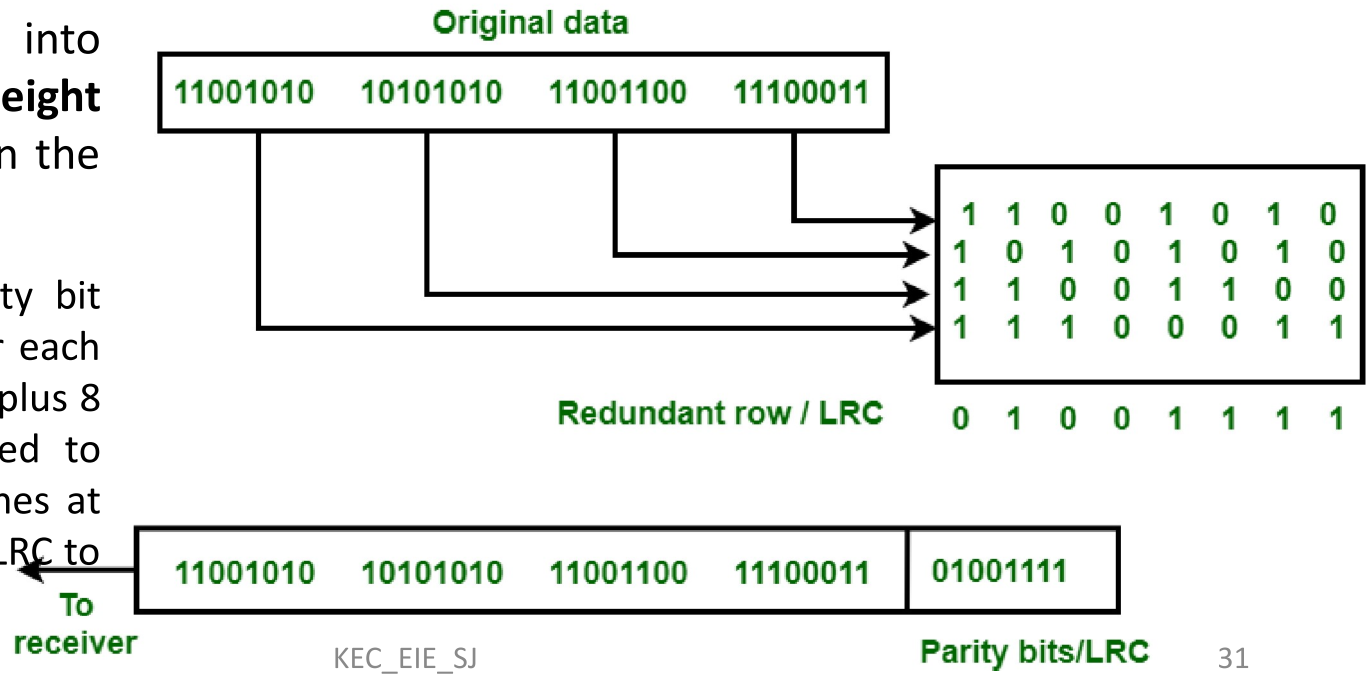
Error Detection: 3. Longitudinal redundancy checking

- Longitudinal Redundancy Check (LRC) is also known as 2-D parity check.
- In this method, data which the user want to send is organized into tables of rows and columns.
- A block of bit is divided into table or matrix of rows and columns.
- In order to detect an error, a redundant bit is added to the whole block and this block is transmitted to receiver.
- The receiver uses this redundant row to detect error. After checking the data for errors, receiver accepts the data and discards the redundant row of bits.

Example :

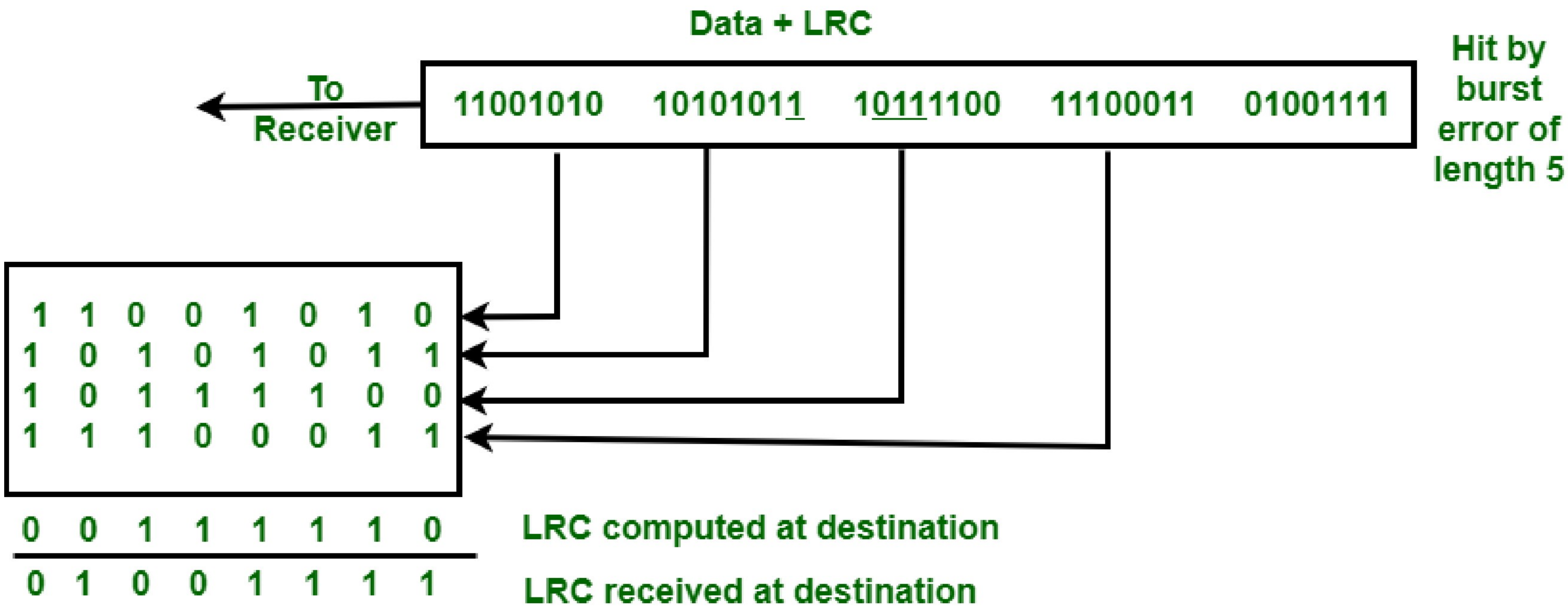
If a block of 32 bits is to be transmitted, it is divided into matrix of **four rows** and **eight columns** which as shown in the following figure

In this matrix of bits, a parity bit (odd or even) is calculated for each column. It means 32 bits data plus 8 redundant bits are transmitted to receiver. Whenever data reaches at the destination, receiver uses LRC to detect error in data.



Error Detection: 3. Longitudinal redundancy checking

Advantages : LRC is used to detect burst errors.



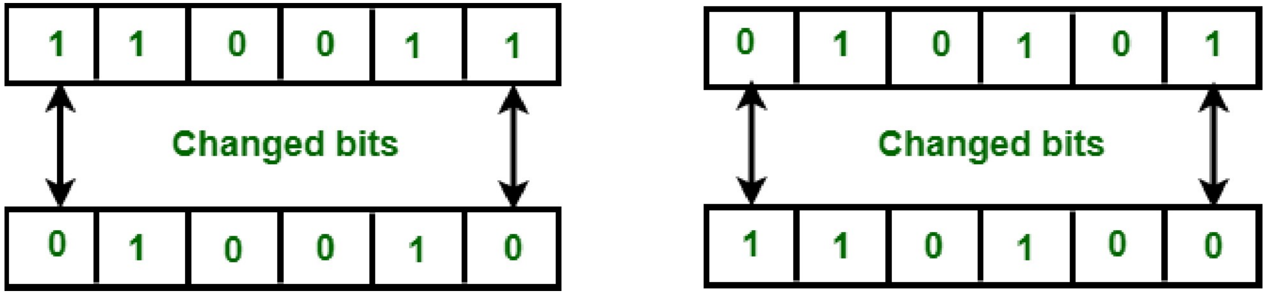
Example : Suppose 32 bit data plus LRC that was being transmitted is hit by a burst error of length 5 and some bits are corrupted as shown in the following figure :

The LRC received by the destination does not match with newly corrupted LRC. The destination comes to know that the data is erroneous, so it discards the data

Sources: https://www.geeksforgeeks.org/vertical-redundancy-check-vrc-or-parity-check/

Error Detection: 3. Longitudinal redundancy checking

Disadvantage : The main problem with LRC is that, it is not able to detect error if two bits in a data unit are damaged and **two bits in exactly the same position** in other data unit are also damaged.



Example : Example : If data 110011 010101 is changed to 010010110100.

In this example 1st and 6th bit in one data unit is changed . Also the 1st and 6th bit in second unit is changed.

Sources: https://www.geeksforgeeks.org/vertical-redundancy-check-vrc-or-parity-check/

Error Detection: 4. Cyclic redundancy checking

The most reliable redundancy checking technique for error detection is a convolutional coding scheme called *cyclic redundancy checking (CRC). With CRC, approximately 99.999% of all transmission errors are detected.*

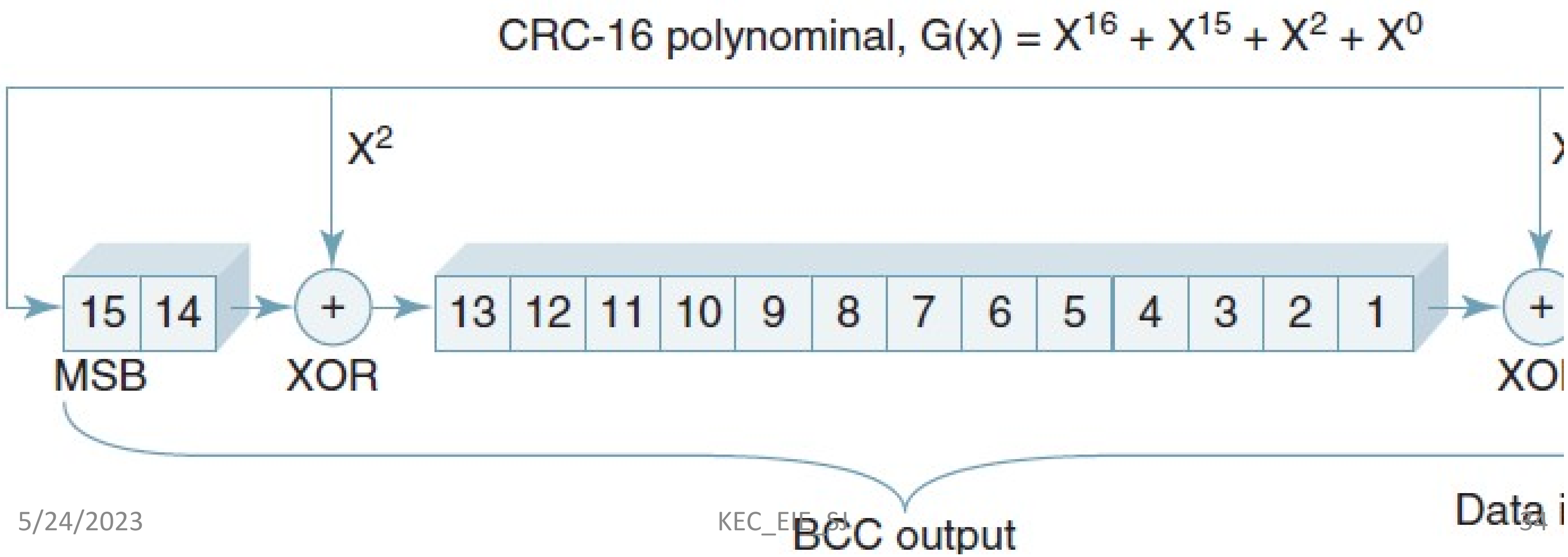
With CRC-16, 16 bits are used for the block check sequence. With CRC, the entire data stream is treated as a long continuous binary number.

Cyclic block codes are often written as (*n, k) cyclic codes*

where n= bit length of transmission and

k =bit length of message.

Therefore, the length of the BCC in bits is **BCC =*n*- *k***



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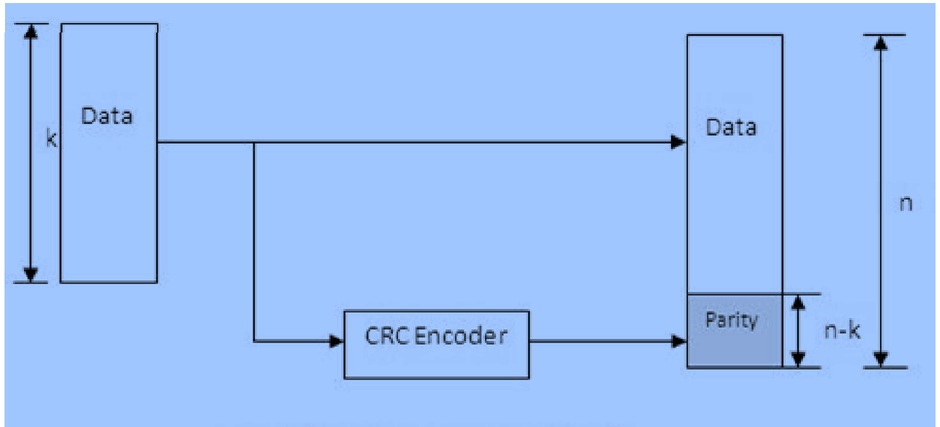
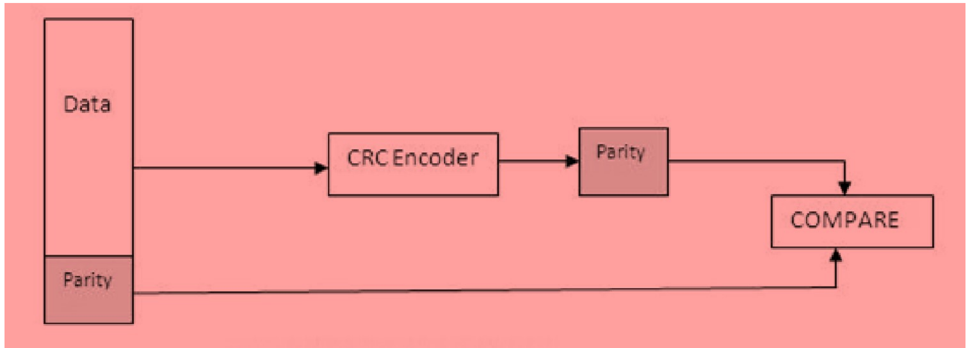


Error detection at transmitter end

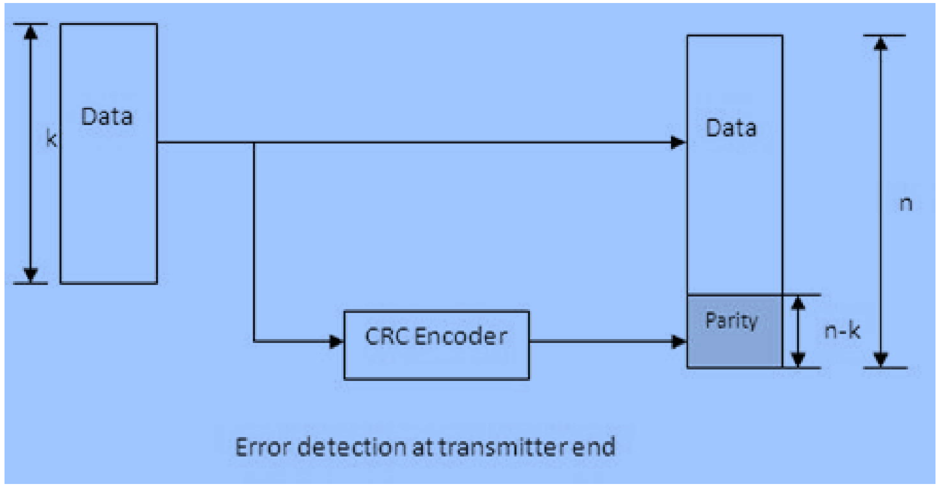


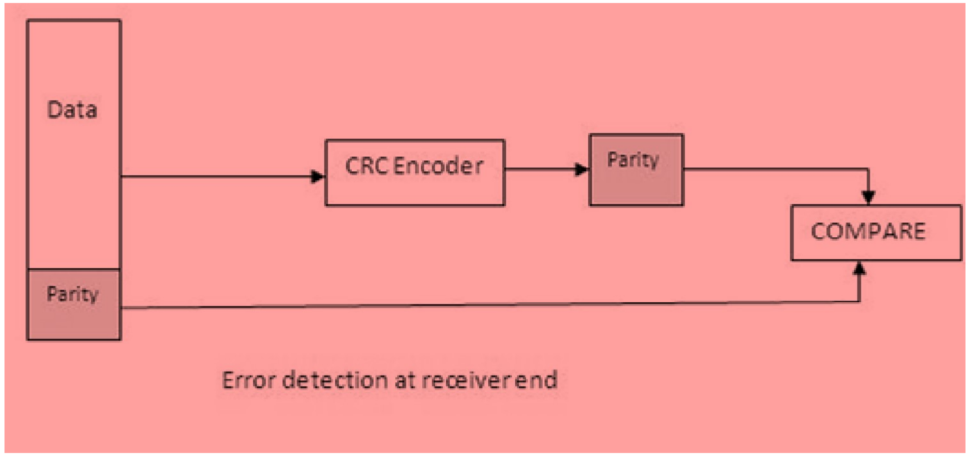
Error detection at receiver end

CRC is calculated based on received block and compared with CRC appended by transmitter. When calculated CRC and original CRC is equal, frame is considered to be **error free. When calculated CRC and original CRC is not equal, frame is said to be erroneous.**

Error Detection: 4. Cyclic redundancy checking

As shown in the figure, k bits are passed to the encoder block to generate parity bits. **This parity bits are added to input data bits and are transmitted as n bits. Hence n-k are parity bits. This happens at the transmitter.**





As shown in the figure at the receiver, parity bits along with data bits of total length n bits are passed to the encoder. **From the data part CRC is again computed and will be compared with the received CRC bits and based on this data is corrupted or not is decided. This process is called error detection and correction.**

Error Detection: 4. Cyclic redundancy checking

original message

1 0 1 0 0 0 0

@ means X-OR

Generator polynomial

x^3+1

$1.x^3+0.x^2+0.x^1+1.x^0$

CRC generator

1 0 0 1   4-bit

If CRC generator is of n bit then append (n-1) zeros in the end of original message

Sender

```
1001 | 1010000000
      @1001
       0011000000
        @1001
          01010000
         @1001
           0011000
           @1001
             01010
            @1001
              0011
```

Message to be transmitted

```
 1010000000
      + 011
 ----------
 1010000011
```

Receiver

```
1001 | 1010000011
      @1001
       0011000011
        @1001
          01010011
         @1001
           0011011
            @1001
              01001
             @1001
               0000
```

Zero means data is accepted

Error Detection: 4. Cyclic redundancy checking

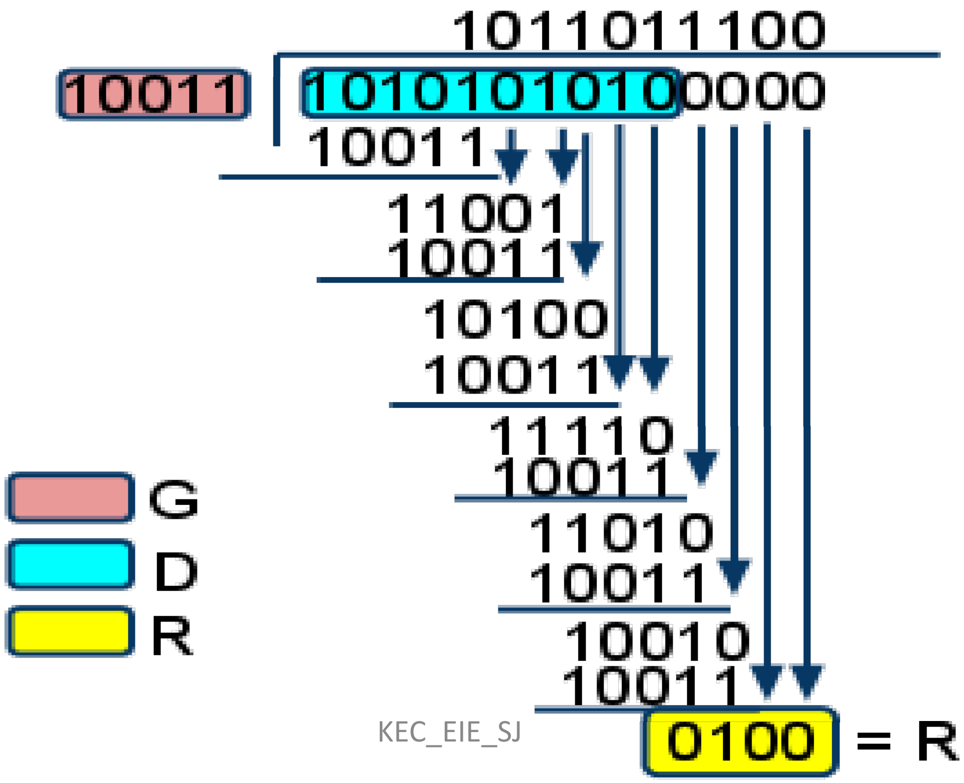
Suppose G = 10011 and D = 1010101010

Since G is an agreed upon from both nodes, it will be given. Since G is 5 bits long, then r is |G|-1=4, r=4.

D will be now shifted left by 4-bits and zero will be inserted into those places, and the new pattern will be denotes by D' = 10101010100000

Now we will divide G into D' using an “exclusive or” operation. This is shown in Figure 1.

The remainder from the division, R, will be the bit pattern need to add to D' such that the resulting bit pattern will be exactly divisible with G.



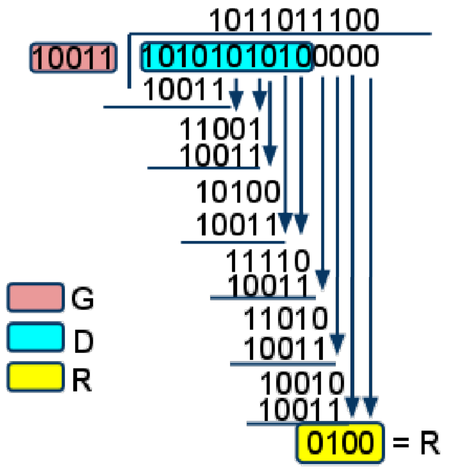
Error Detection: 4. Cyclic redundancy checking

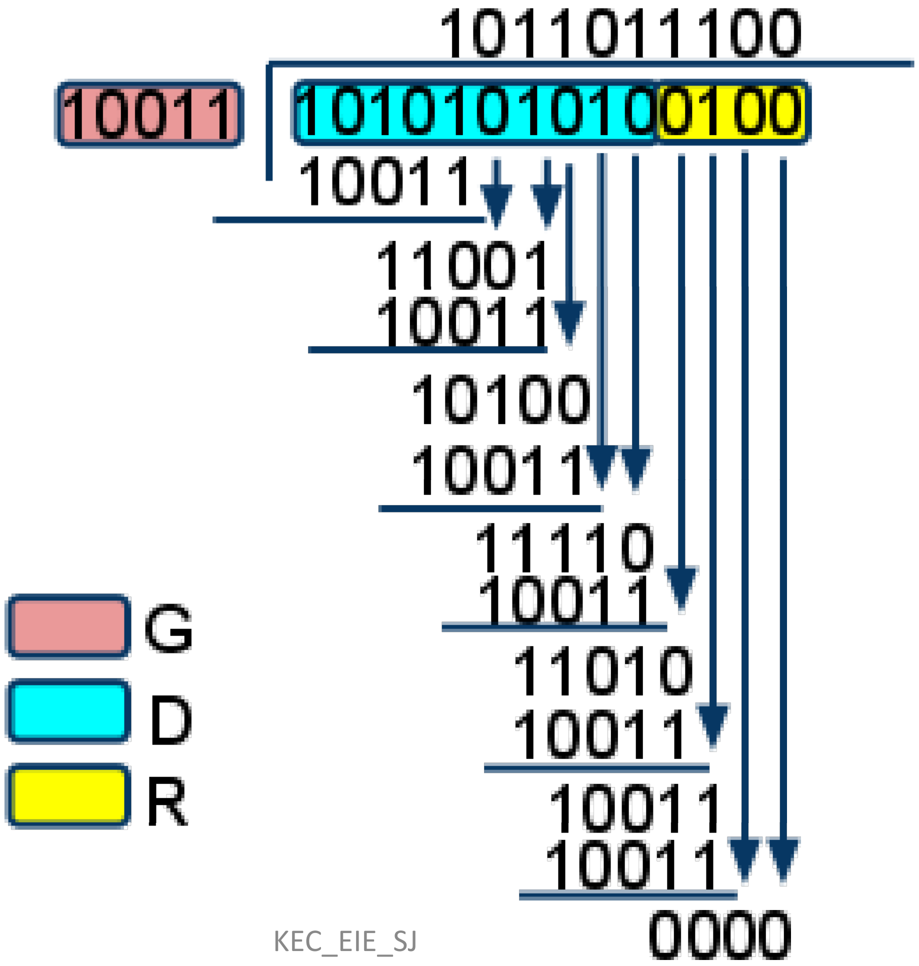
This is a simple way to check your work.

From the example about the resulting bit pattern when R is added to D' is D'' = **1010101010100**

Then divide G into D''.

If you computed the correct R then the resulting remainder will be 0. This is shown in Figure 2.





Difference between VRC and LRC

No.	Vertical Redundancy Check (VRC)	Longitudinal Redundancy Check (LRC)
1.	It stands for Vertical Redundancy Check.	It stands for Longitudinal Redundancy Check.
2.	In this redundant bit called parity bit is added to each data unit.	In this redundant row of bits is added to the whole block.
3.	VRC can detect single bit errors.	LRC can detect burst errors.
4.	It is also known as parity checker.	It is also known as 2-D parity checker.
5.	The advantage of using VRC is that it can checks all single bit errors but can check odd parity only in the case of change of odd bits.	The advantage of using LRC over VRC is that it can check all the burst errors.
6.	It is not capable of checking the burst error in case of change of bits is even.	If two bits in data unit is damaged and also in other data unit the same bits are damaged at same position, then it is not capable of detecting such kind of error.

Error Correction

- **Hamming code** is a set of error-correction codes that can be used to **detect and correct the errors** that can occur when the data is moved or stored from the sender to the receiver.
- It is a **technique developed by R.W. Hamming for error correction**.
- The Hamming code will correct only single-bit errors. It cannot correct multiple-bit errors or burst errors, and it cannot identify errors that occur in the Hamming bits themselves.
- The Hamming code, as with all FEC codes, requires the addition of overhead to the message, consequently increasing the length of a transmission.

Error Correction

- *Hamming bits (sometimes called error bits) are* ***inserted into a character*** *at* ***random locations****.*
- The combination of the data bits and the Hamming bits is called the Hamming code.
- The only stipulation on the placement of the Hamming bits is that both the sender and the receiver must agree on where they are placed.
- **Redundant bits –** Redundant bits are extra binary bits that are generated and added to the information-carrying bits of data transfer to ensure that no bits were lost during the data transfer.
- The number of redundant bits can be calculated using the following formula:
- $2^r \geq m + r + 1$ where, r = redundant bit, m = data bit

Error Correction – Hamming Codes

- For a 12-bit data string of 101100010010, determine the number of Hamming bits required, arbitrarily place the Hamming bits into the data string, determine the logic condition of each Hamming bit, assume an arbitrary single-bit transmission error, and prove that the Hamming code will successfully detect the error.
- **Solution:**
- **Substituting *m = 12 into Equation 2, the number of Hamming bits is***

for $n = 4$, $2^4 = 16 \geq 12 + 4 + 1 = 17$

Because 16 < 17, four Hamming bits are insufficient:

for $n = 5$, $2^5 = 32 \geq 12 + 5 + 1 = 18$

Because 32 > 18, five Hamming bits are sufficient, and a total of 17 bits make up the data stream (12 data plus five Hamming).

Error Correction – Hamming Codes

Arbitrarily placing five Hamming bits into bit positions 4, 8, 9, 13, and 17 yields

bit position	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
	H	1	0	1	H	1	0	0	H	H	0	1	0	H	0	1	0

To determine the logic condition of the Hamming bits, express all bit positions that contain a logic 1 as a five-bit binary number and XOR them together:

Bit position	Binary number	
2	00010	
6	00110	
XOR	00100	
12	01100	
XOR	01000	
14	01110	
XOR	00110	
16	10000	
XOR	10110	= Hamming bits

$h_{17} = 1$ $h_{13} = 0$ $h_9 = 1$ $h_8 = 1$ $h_4 =$

Error Correction – Hamming Codes

Assume that during transmission, an error occurs in bit position 14. The received data stream is

$$1 \quad 1 \quad 0 \quad \underbrace{\underline{0}}_{\text{error}} \quad 0 \quad 1 \quad 0 \quad 0 \quad 1 \quad 1 \quad 0 \quad 1 \quad 0 \quad 0 \quad 0 \quad 1 \quad 0$$

At the receiver, to determine the bit position in error, extract the Hamming bits and XOR them with the binary code for each data bit position that contains a logic 1:

Bit position	Binary number
Hamming bits	10110

Hamming bits	10110
2	00010
XOR	10100
6	00110
XOR	10010
12	01100
XOR	11110

Line coding

- A **line code** is the code used for data transmission of a digital signal over a transmission line.
- This process of coding is chosen so as to avoid overlap and distortion of signal such as inter-symbol interference.

Properties of Line Coding

- As the coding is done to make more bits transmit on a single signal, the bandwidth used is much reduced.
- For a given bandwidth, the power is efficiently used.
- The probability of error is much reduced.
- Error detection is done and the bipolar too has a correction capability.
- Power density is much favorable.
- The timing content is adequate.
- Long strings of **1s** and **0s** is avoided to maintain transparency.

https://www.tutorialspoint.com/digital_communication/digital_communication_line_codes.htm

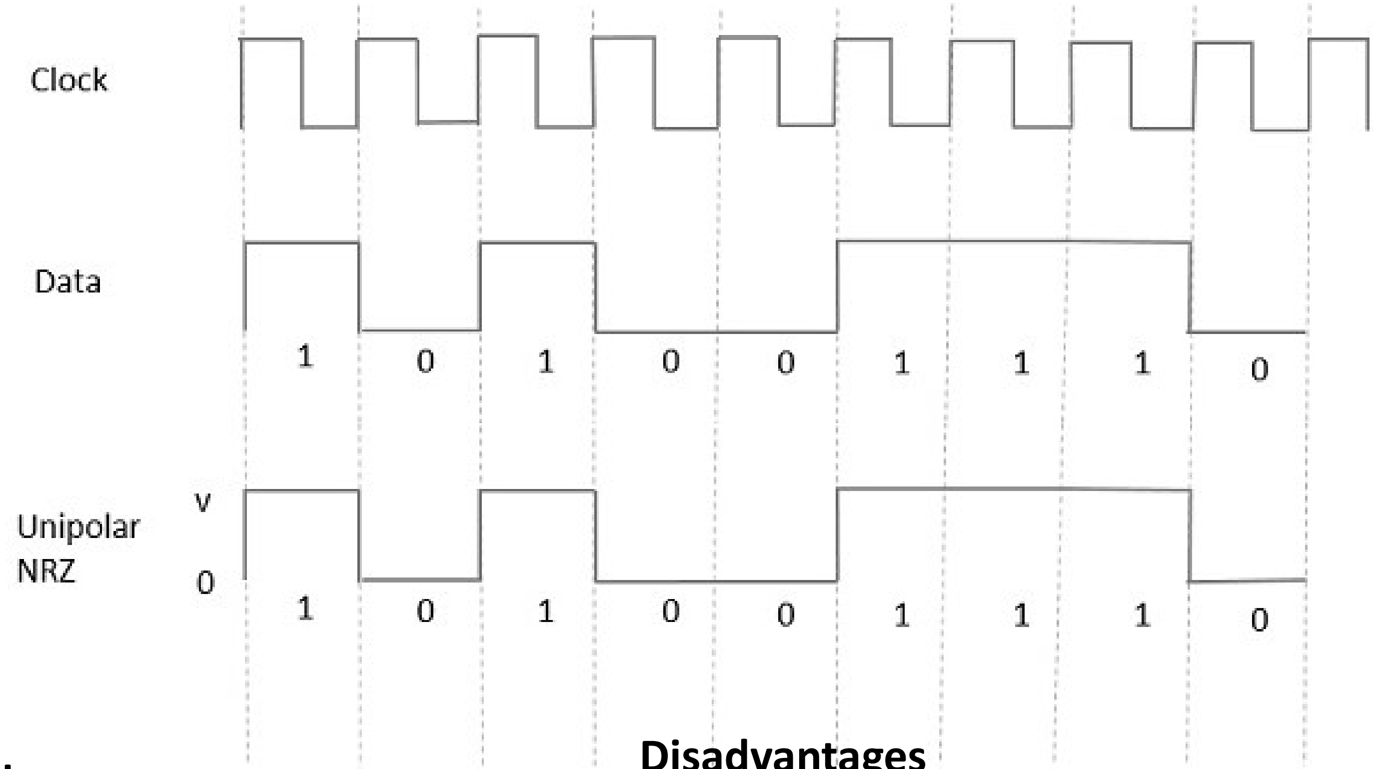
Types of Line Coding

- There are 3 types of Line Coding

1. Unipolar
   - Unipolar NRZ
   - Unipolar RZ
2. Polar
   - Polar NRZ
   - Polar RZ
3. Bi-polar
   - Bipolar NRZ
   - Bipolar RZ

Unipolar Non-Return to Zero NRZ

- In this type of unipolar signaling, a High in data is represented by a positive pulse called as **Mark**, which has a duration $\mathbf{T_0}$ equal to the symbol bit duration. A Low in data input has no pulse.



Advantages

It is simple.

A lesser bandwidth is required.

Disadvantages

✓No error correction done.

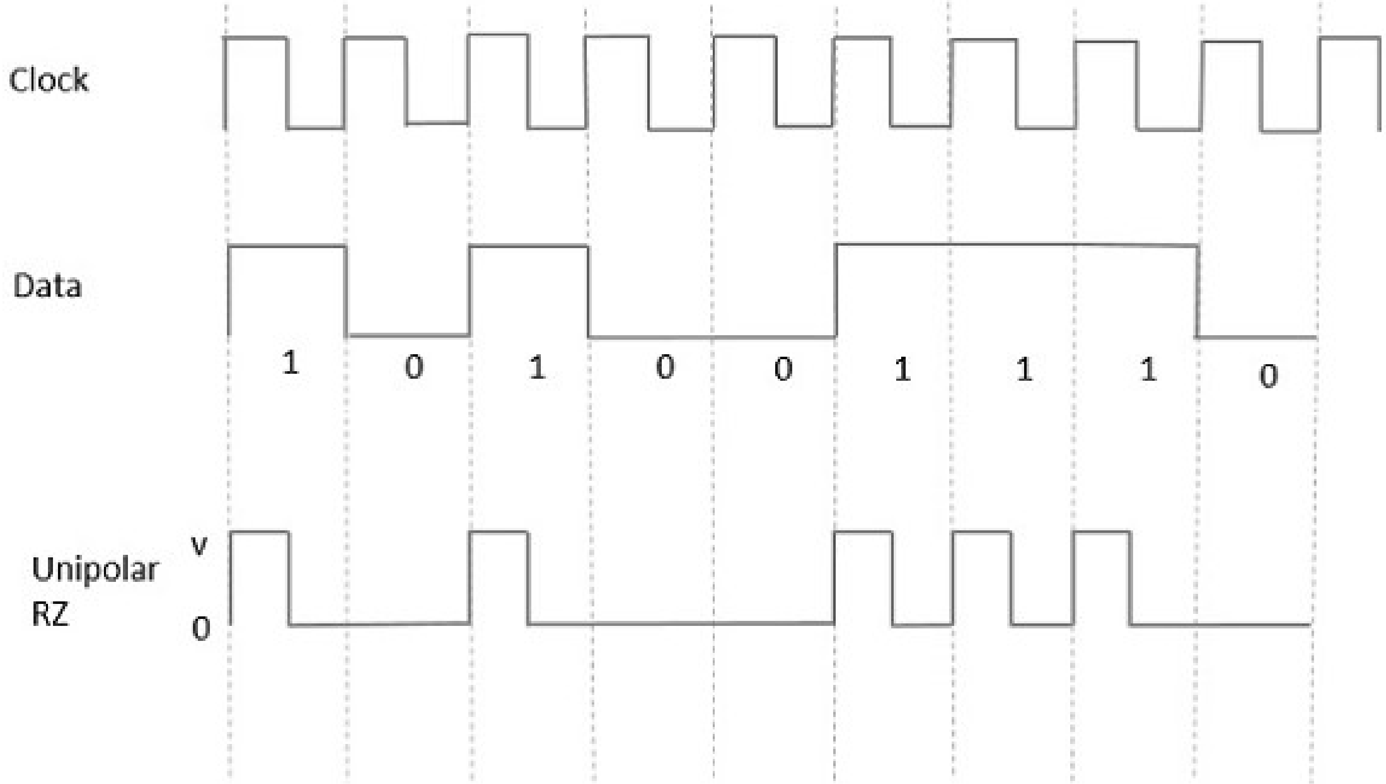
✓Presence of low frequency components may cause the signal droop.

✓No clock is present.

✓Loss of synchronization is likely to occur (especially for long strings of **1s** and **0s**).

Unipolar Return to Zero RZ

- In this type of unipolar signaling, a High in data, though represented by a **Mark pulse**, its duration $\mathbf{T_0}$ is less than the symbol bit duration. Half of the bit duration remains high but it immediately returns to zero and shows the absence of pulse during the remaining half of the bit duration.



Advantages

It is simple.

The spectral line present at the symbol rate can be used as a clock.

Disadvantages

No error correction.

Occupies twice the bandwidth as Unipolar NRZ.

The signal droop is caused at the places where signal is non-zero at 0 Hz.

Polar NRZ

- In this type of Polar signaling, a High in data is represented by a positive pulse, while a Low in data is represented by a negative pulse. The following figure depicts this well.

Advantages

➢It is simple.

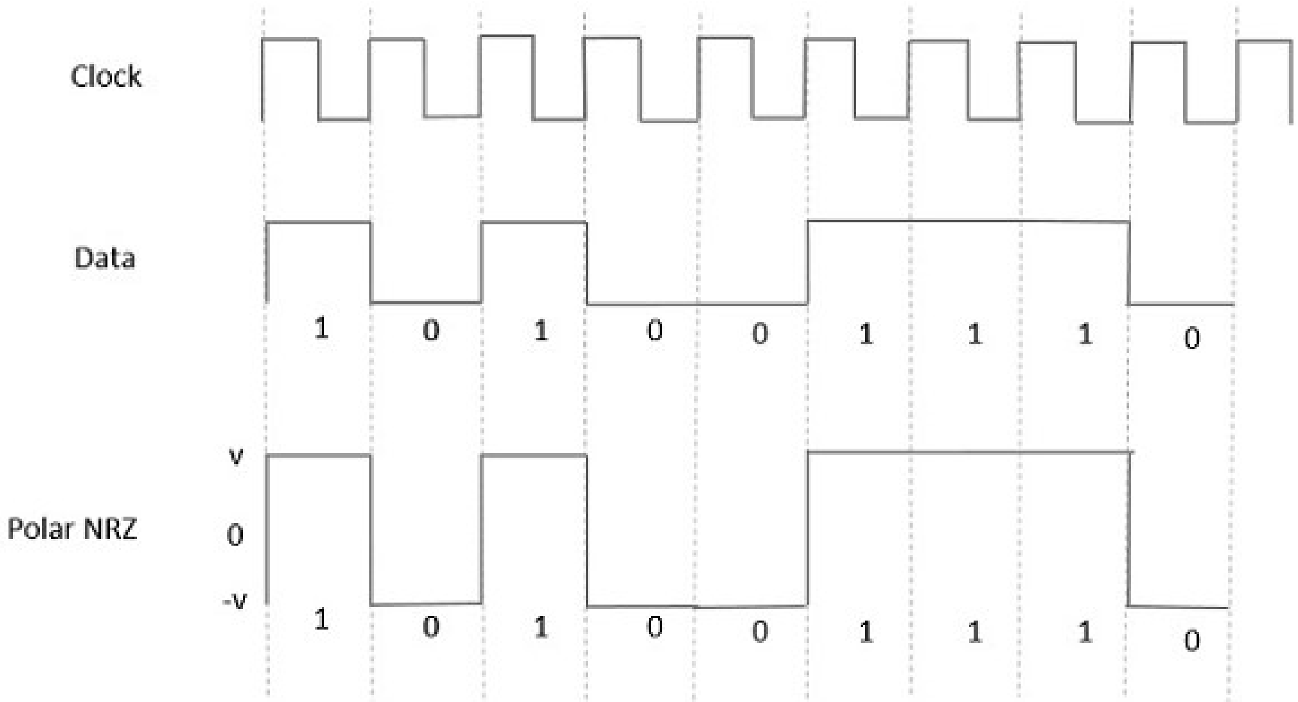
➢No low-frequency components are present.

Disadvantages

✓No error correction.

✓No clock is present.

✓The signal droop is caused at the places where the signal is non-zero at **0 Hz**.



Polar RZ

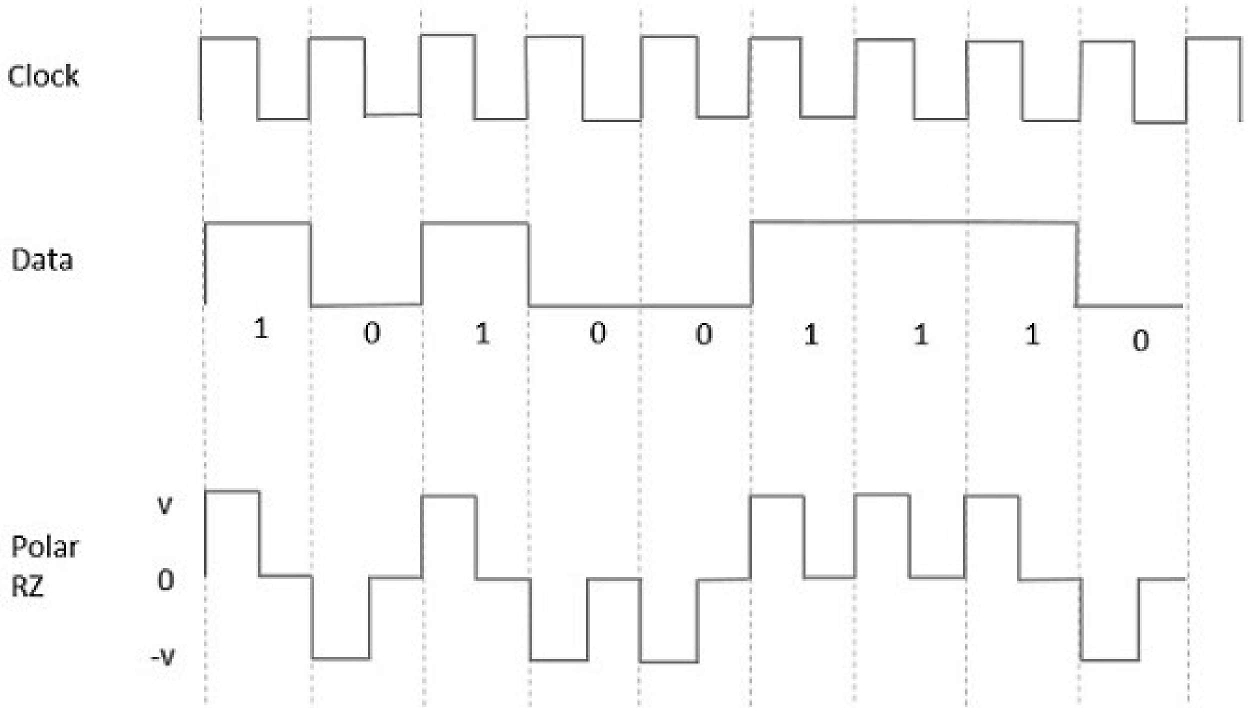
- In this type of Polar signaling, a High in data, though represented by a **Mark pulse**, its duration $\mathbf{T_0}$ is less than the symbol bit duration. Half of the bit duration remains high but it immediately returns to zero and shows the absence of pulse during the remaining half of the bit duration.
- However, for a Low input, a negative pulse represents the data, and the zero level remains same for the other half of the bit duration.

Advantages

- ➢It is simple.
- ➢No low-frequency components are present.

Disadvantages

- ➢No error correction.
- ➢No clock is present.
- ➢Occupies twice the bandwidth of Polar NRZ.
- ➢The signal droop is caused at places where the signal is non-zero at **0 Hz**.



Bipolar Signaling: NRZ and RZ

- This is an encoding technique which has three voltage levels namely **+, -** and **0**. Such a signal is called as **duo-binary signal**.
- An example of this type is **Alternate Mark Inversion** AMI.
- For a **1**, the voltage level gets a transition from + to – or from – to +, having alternate **1s** to be of equal polarity. A **0** will have a zero voltage level.
- Even in this method, we have two types. Bipolar NRZ and Bipolar RZ

Advantages

✓It is simple.

✓No low-frequency components are present.

✓Occupies low bandwidth than unipo and polar NRZ schemes.

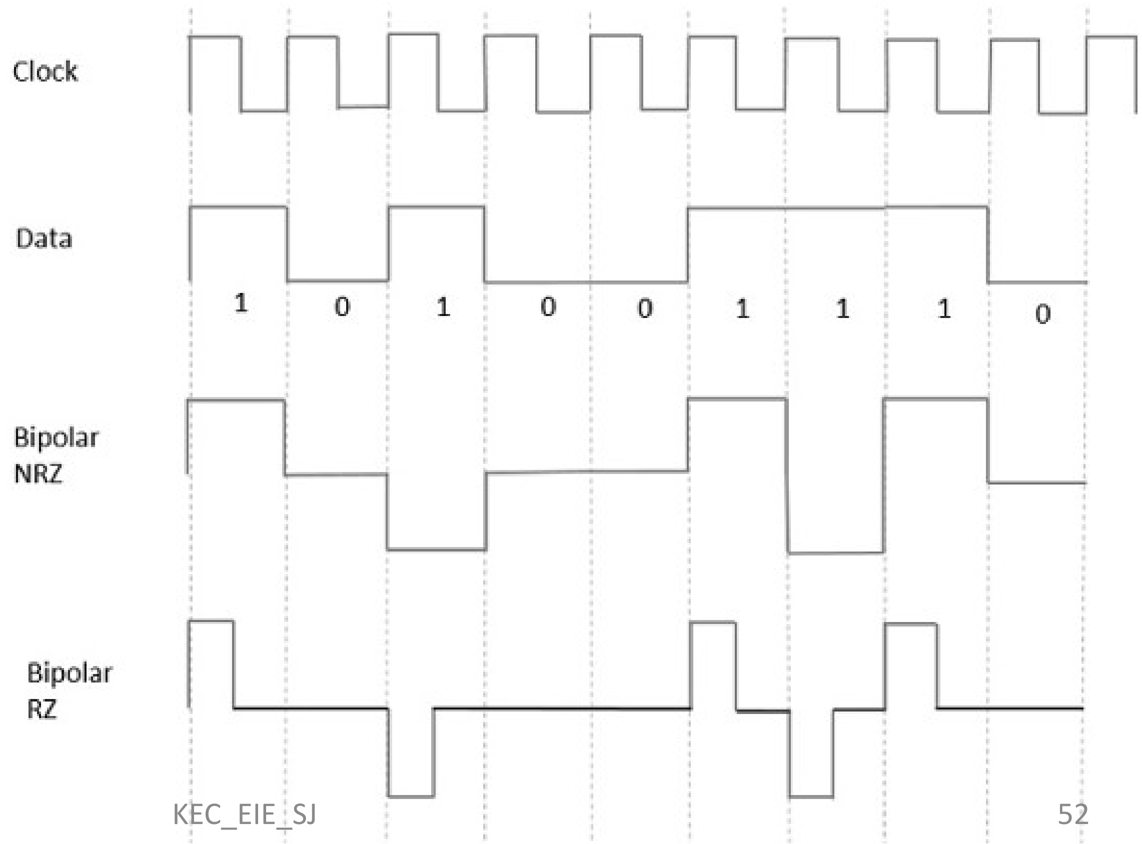
✓This technique is suitable for transmission over AC coupled lines, as signal drooping doesn't occur here.

✓A single error detection capability is present in this.

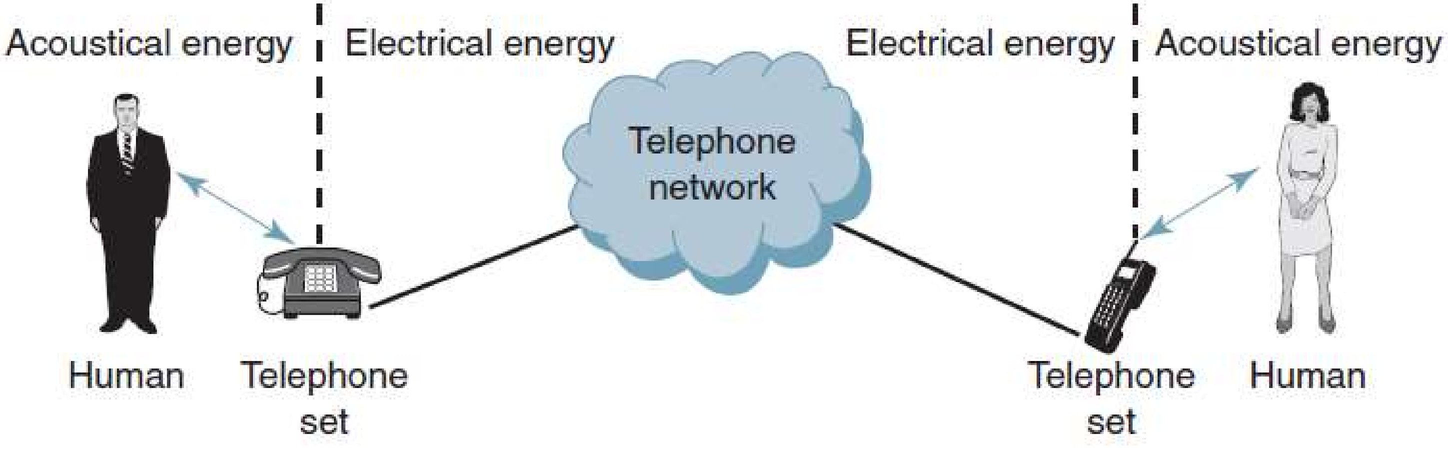
Disadvantages

No clock is present.

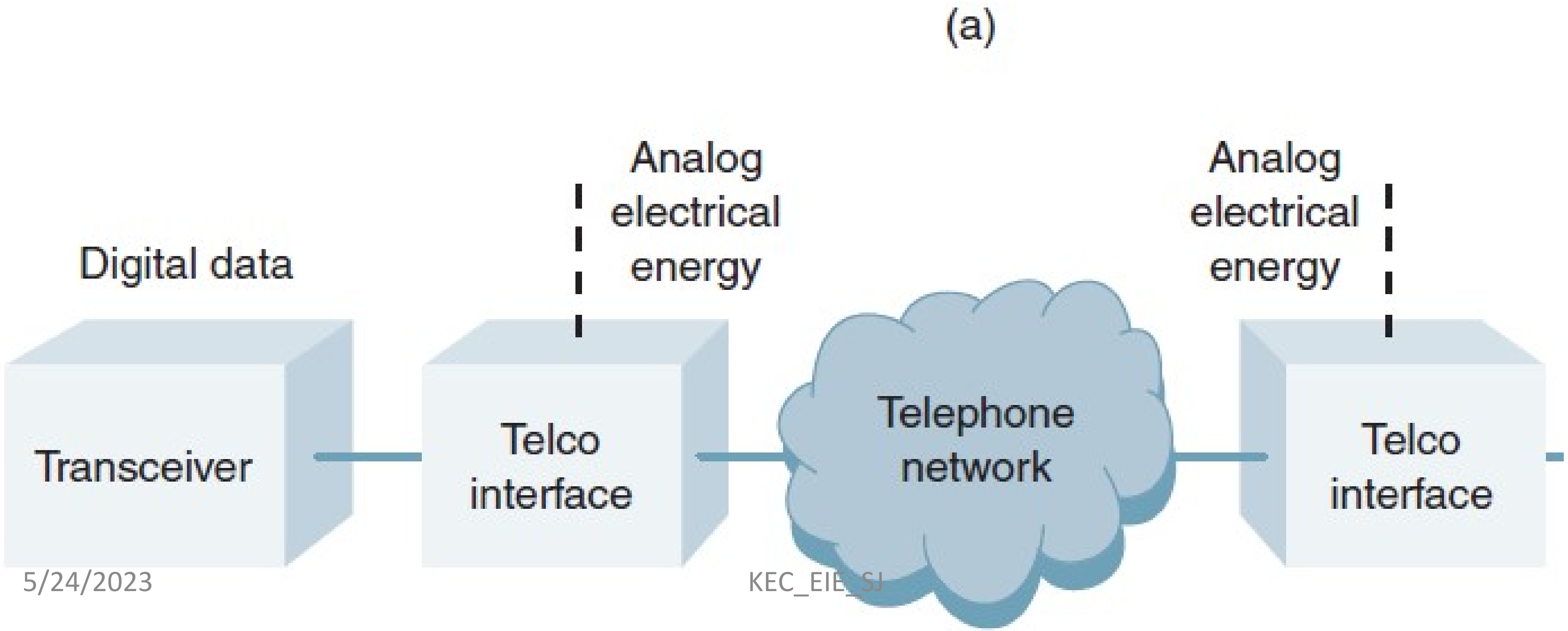
Long strings of data causes loss of synchronization



DATA COMMUNICATIONS CIRCUITS



(a)

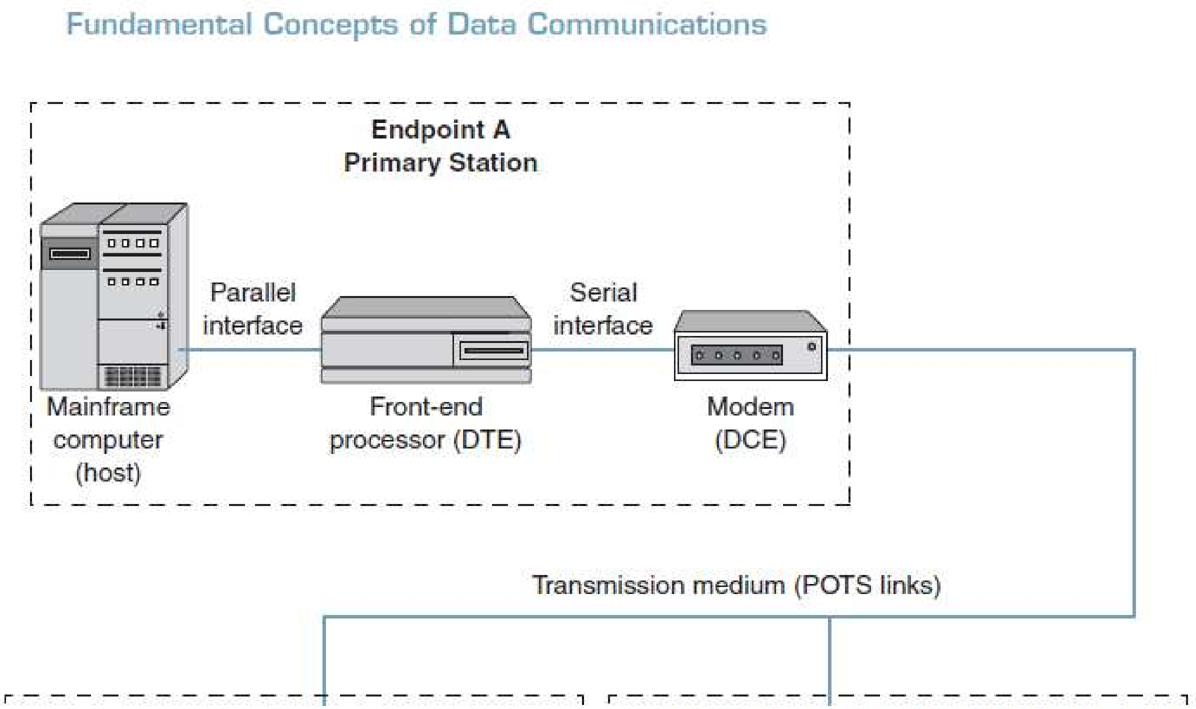


DATA COMMUNICATIONS CIRCUITS

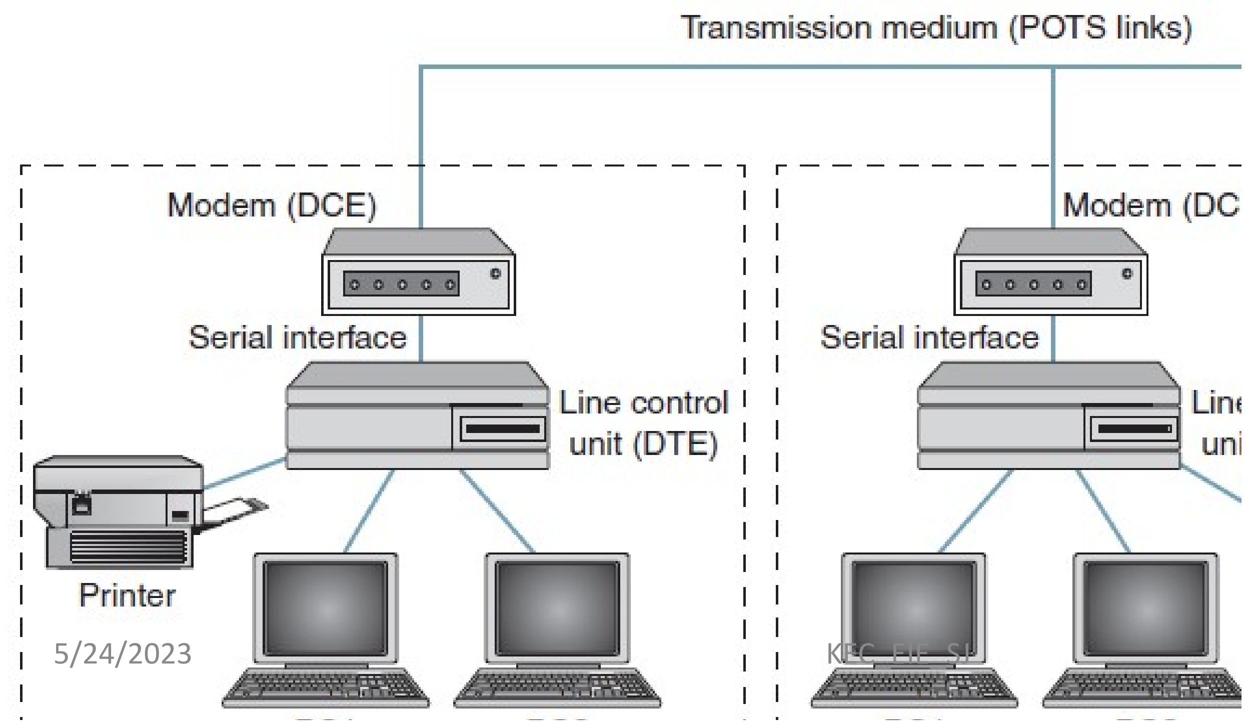
- **Data Terminal Equipment**
- *Data terminal equipment (DTE) can be virtually any binary digital device that generates,* transmits, receives, or interprets data messages.
- In essence, a DTE is where information originates or terminates.
- DTEs are the data communications equivalent to the person in a telephone conversation.
- Example: Telephone , Printers and personal computers

Data Communications Equipment

- *Data communications equipment (DCE) is a general term used to describe equipment that interfaces* data terminal equipment to a transmission channel, such as a digital T1 carrier or an analog telephone circuit.
- In essence, a DCE is a *signal conversion device, as it converts signals from a DTE* to a form more suitable to be transported over a transmission channel. A DCE also converts those signals back to their original form at the receive end of a circuit.



DATA COMMUNICATIONS CIRCUITS



SERIAL INTERFACES

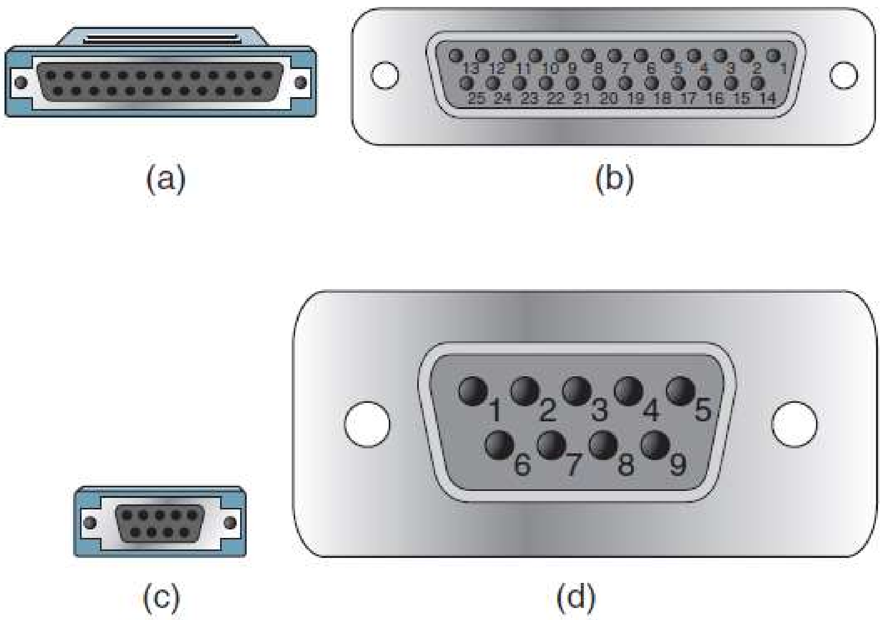
A serial interface standard should provide the following:

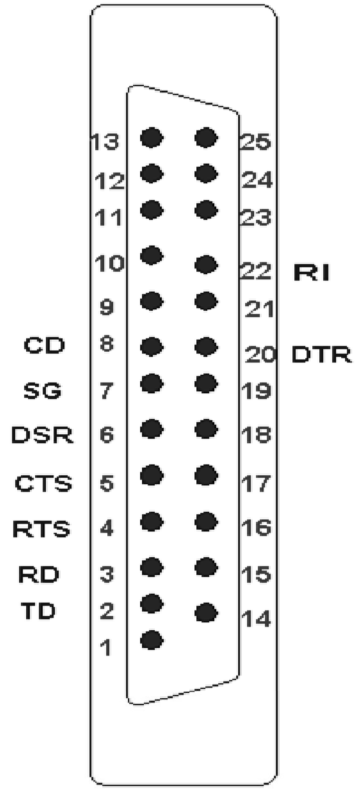
1. **A specific range of voltages for transmit and receive signal levels**
2. **Limitations for the electrical parameters of the transmission line, including source and load impedance, cable capacitance, and other electrical characteristics outlined later in this chapter**
3. **Standard cable and cable connectors**
4. **Functional description of each signal on the interface**

RS-232

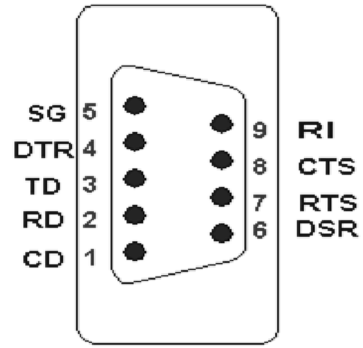
- In 1962, the Electronics Industries Association (EIA), in an effort to standardize interface equipment between data terminal equipment and data communications equipment, agreed on a set of standards called the *RS-232 specifications (RS meaning "recommended* standard").
- The official name of the RS-232 interface is *Interface Between Data Terminal Equipment and Data Communications Equipment Employing Serial Binary Data Interchange*

RS-232





DB 25 Male Connecter



DB 9 Male Connecter

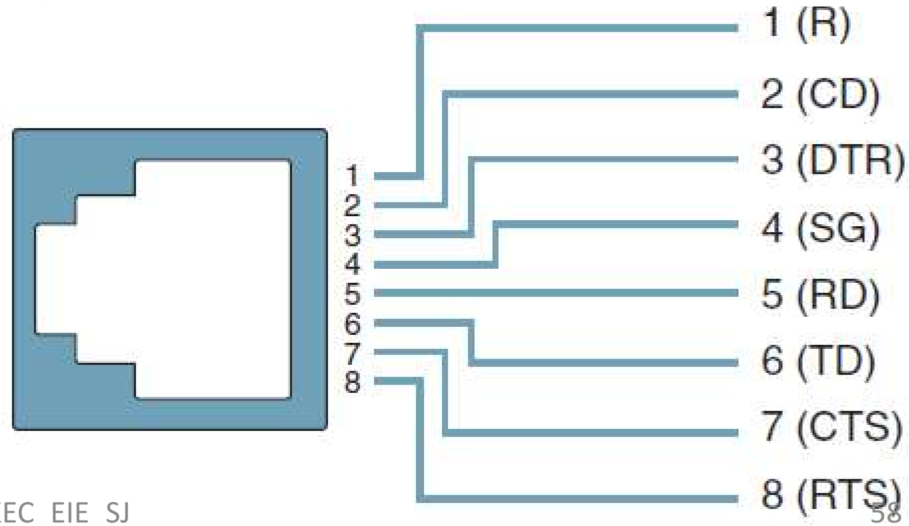
RS-232 serial interface connector:

(a) DB25P;

(b) DB25S;

(c) DB9P;

(d) DB9S



EIA-561 modular connector

RS-232

Table 7 RS-232 Voltage Specifications

	Data Signals		Control Signals	
	Logic 1	Logic 0	Enable (On)	Disable (Off)
Driver (output)	−5 V to −15 V	+5 V to +15 V	+5 V to +15 V	−5 V to −15 V
Terminator (input)	−3 V to −25 V	+3 V to +25 V	+3 V to +25 V	−3 V to −25 V

D-Type-25 Pin No.	D-Type-9 Pin No.	Abbreviation	Full Name
Pin 2	Pin 3	TD	Transmit Data
Pin 3	Pin 2	RD	Receive Data
Pin 4	Pin 7	RTS	Request To Send
Pin 5	Pin 8	CTS	Clear To Send
Pin 6	Pin 6	DSR	Data Set Ready
Pin 7	Pin 5	SG	Signal Ground
Pin 8	Pin 1	CD	Carrier Detect
Pin 20	Pin 4	DTR	Data Terminal Ready
Pin 22	Pin 9	RI	Ring Indicator

RS-232

TxD	The TXD (Transmit Data) signal is the data signal from the DTE device to the DCE device, a PC to a modem for example.
RxD	The RXD (Receive Data) signal is the data input signal to the DTE device, a PC receives data from a modem on this signal.
DTR	Data Terminal Ready is activated by the DTE device when it is ready for communications. A PC normally activates this line when some type of terminal program, like Procomm, is run. When the program is terminated, the DTR signal goes inactive. This signal is the compliment of the DSR signal.
DSR	Data Set Ready is driven by the modem and goes active when the modem is powered and ready to receive data. This line is the compliment of the DTR signal.
RTS	Request To Send is activated by the DTE device when it is ready to receive data. This line is the compliment of the CTS signal.
CTS	Clear To Send is activated by the DCE device when it is ready to receive data. This line is the compliment of the RTS signal. A PC and modem using hardware flow control will handshake with these two lines to prevent internal data buffers from overrunning.
RI	Ring Indicator will go active as a modem is receiving a phone call. The modem sends this signal to the DTE device, which may or may not use it. A PC running a terminal emulation program may detect this signal and print a “RING” message to the screen.
DCD	Carrier Detect will go active when one modem is receiving a signal from another modem over the phone line. When 2 modems establish a communication link, a carrier signal is transmitted between the 2 modems. As long as this carrier signal is present, the CD signal will be active.
GND	A ground connection is always required. It is used as the reference for both the data lines and the handshaking lines.

RS-232

PIN No.	Pin Name	Pin Description
1	CD (Carrier Detect)	Incoming signal from DCE
2	RD (Receive Data)	Receives incoming data from DTE
3	TD (Transmit Data)	Send outgoing data to DCE
4	DTR (Data Terminal Ready)	Outgoing handshaking signal
5	GND (Signal ground)	Common reference voltage
6	DSR (Data Set Ready)	Incoming handshaking signal
7	RTS (Request to Send)	Outgoing signal for controlling flow
8	CTS (Clear to Send)	Incoming signal for controlling flow
9	RI (Ring Indicator)	Incoming signal from DCE

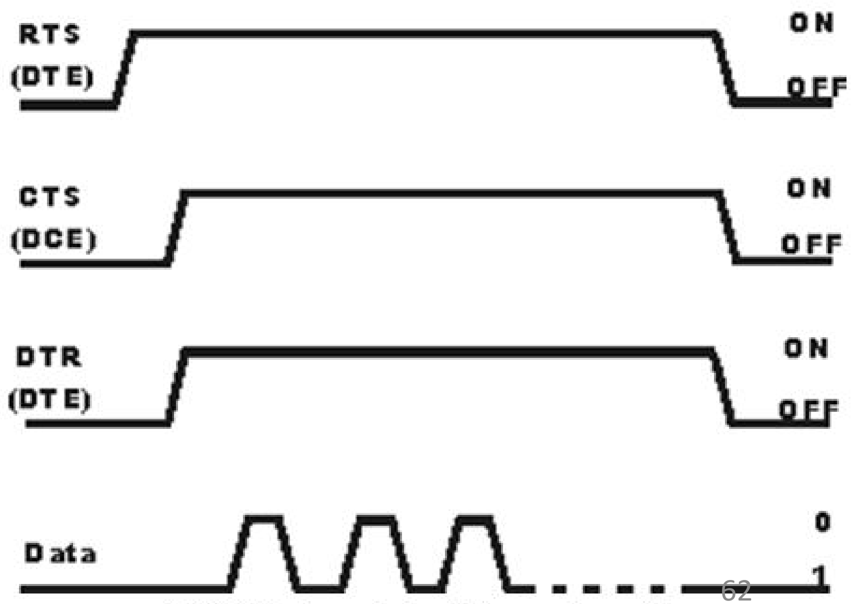
RS-232 Hand shake

- The handshaking exchange to start the data flow is quite straightforward and can be seen as a number of distinct stages:
- RTS is put in the ON state by the DTE.
- The DCE then put the CTS line into the ON state.
- The DTE then responds by placing the DTR line into the ON state.
- The DTR line remains on while data is being transmitted.

•At the end of the transmission, DTR and RTS are pulled to the OFF state and then the DCE pulls the CTS line to the OFF state.

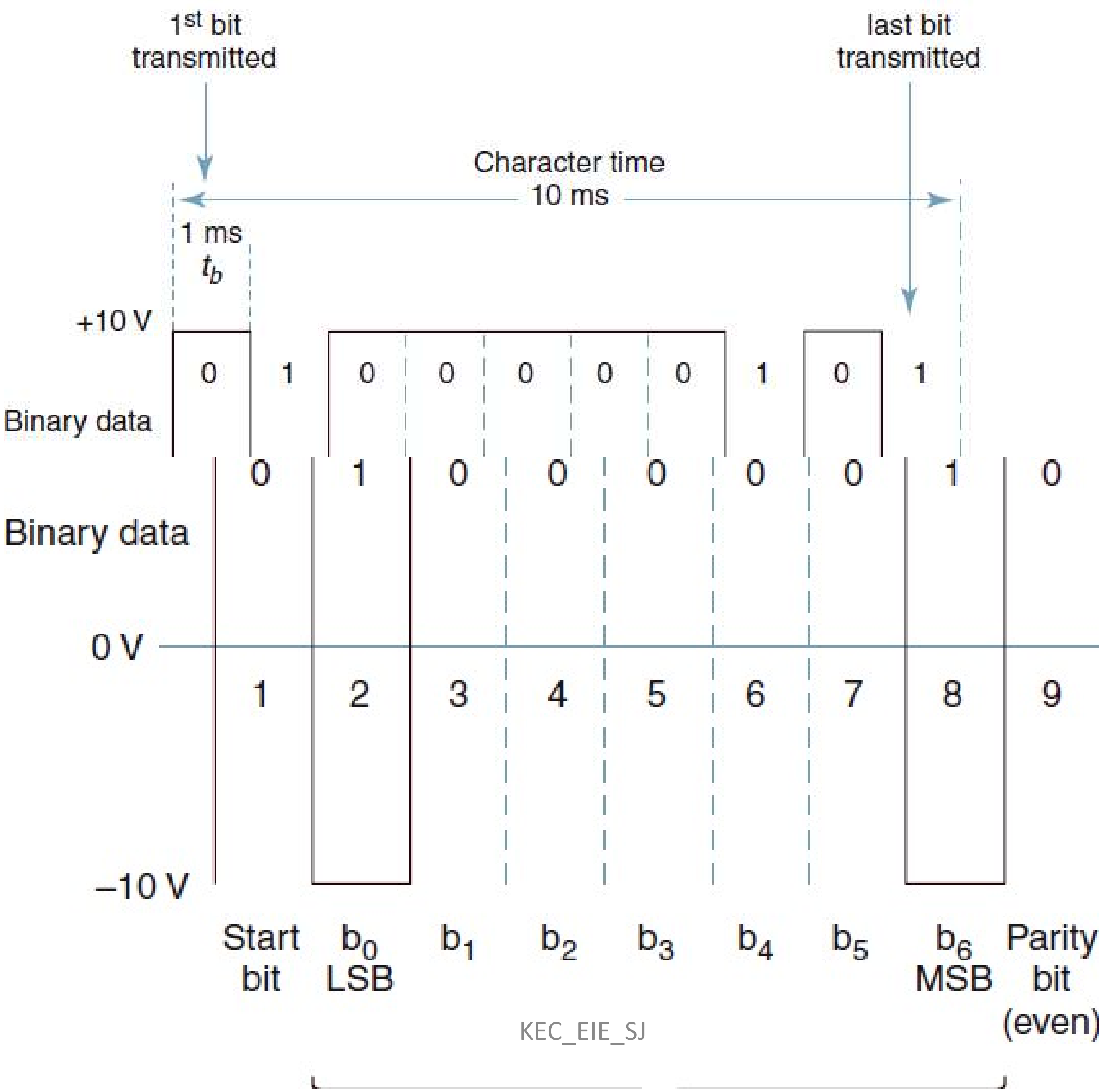
• This series of handshake controls was devised to allow the DTE to request control of the communications link from the related modem, and then to let the modem inform the terminal equipment that the control has been acquired.

•In this way the communications will only take place when both ends of the link are ready.

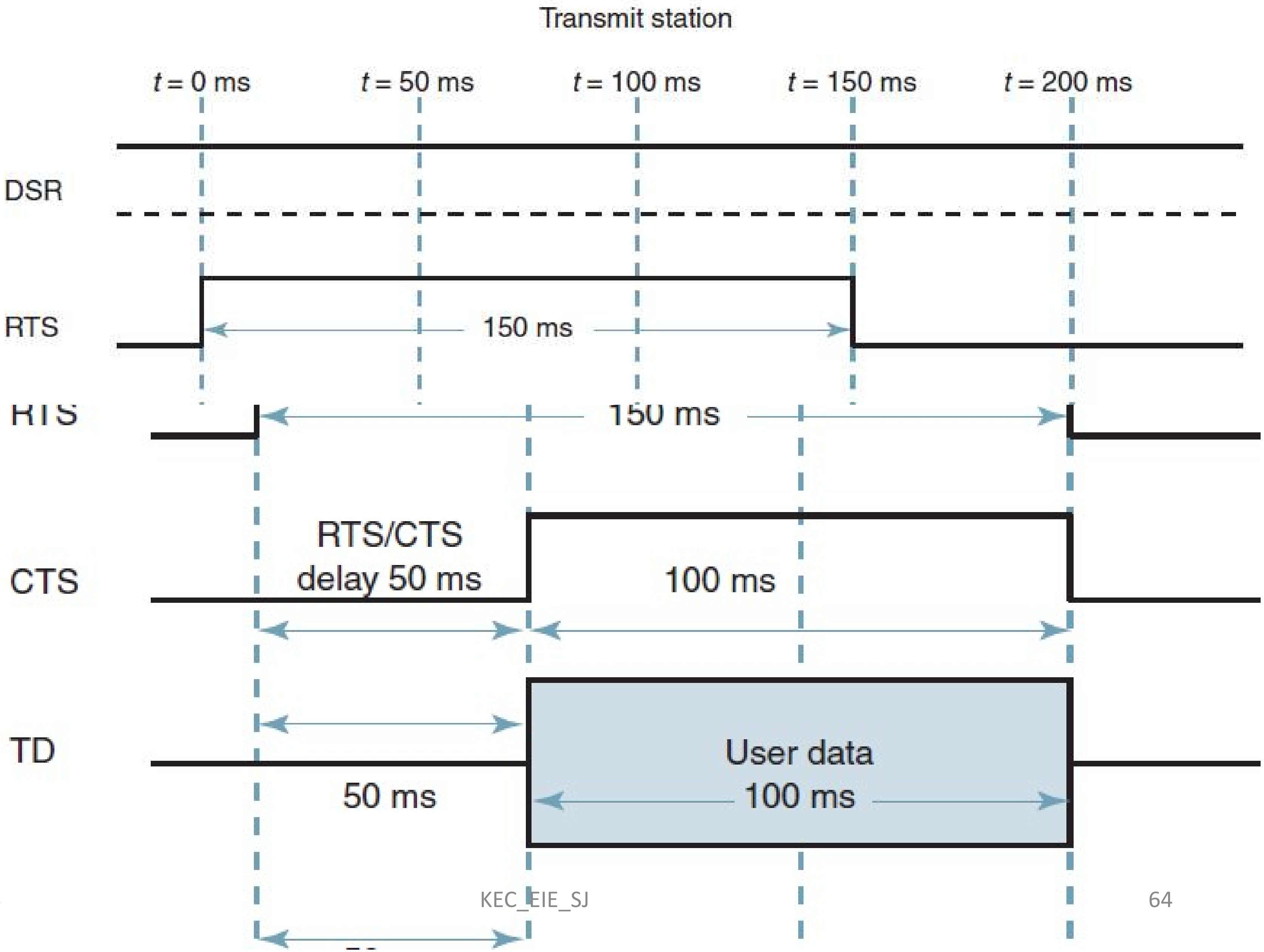


RS232 handshaking signals

RS-232 Hand shake



RS-232 Hand shake



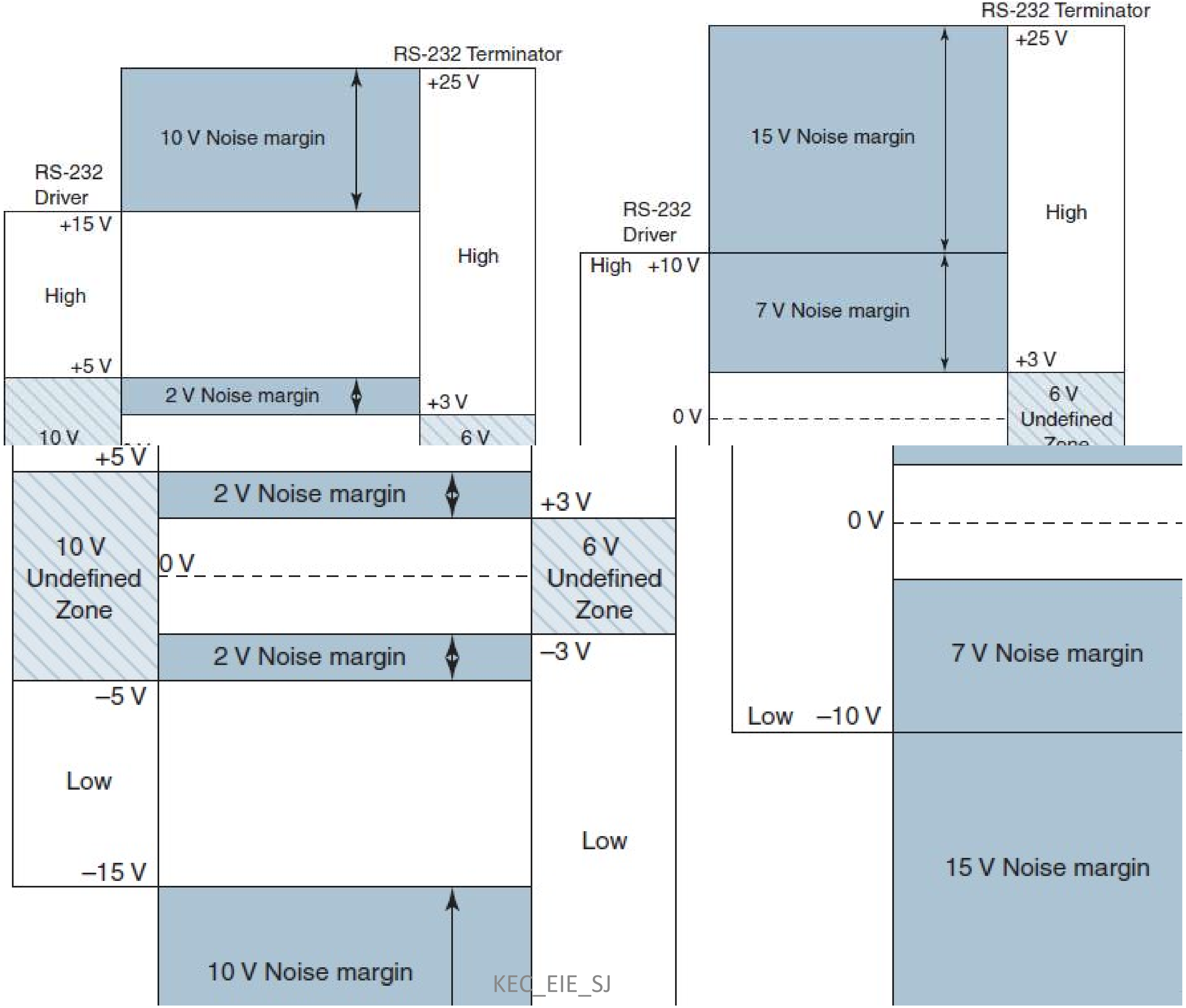
RS-232 Noise Margin

Table 7 RS-232 Voltage Specifications

	Data Signals		Control Signals	
	Logic 1	Logic 0	Enable (On)	Disable (Off)
Driver (output)	−5 V to −15 V	+5 V to +15 V	+5 V to +15 V	−5 V to −15 V
Terminator (input)	−3 V to −25 V	+3 V to +25 V	+3 V to +25 V	−3 V to −25 V

- The difference in the voltage levels between the driver output and the terminator input is called *noise margin (NM).*
- *The noise margin reduces the susceptibility* to interface caused by noise transients induced into the cable.
- The minimum noise margin of 2 V is called the ***implied noise margin.***

RS-232 Noise Margin



RS-232 Noise Margin

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Determine the noise margins for an RS-232 interface with driver signal voltages of ±6 V.

Solution :

The noise margin is the difference between the driver signal voltage and the terminator receive voltage, or

NM =6- 3= 3 V or NM = 25 - 6 = 19 V

The minimum noise margin is 3 V

RS-232 Noise Margin

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	Data Signals		Control Signals	
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12. Determine the noise margins for an RS-232 interface with driver output signal voltages of ±12V.

13. Determine the noise margins for an RS-232 interface with driver output signal voltages of ±11 V.

RS 485

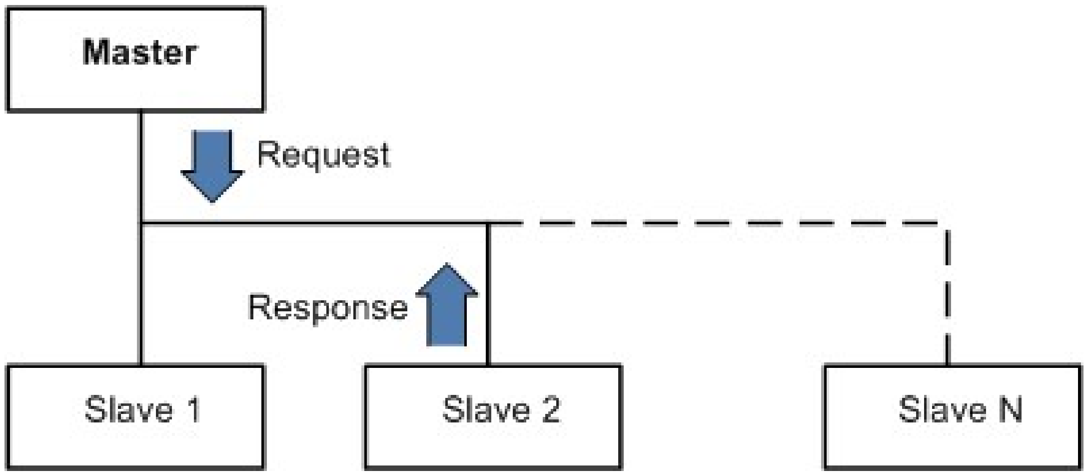
- **RS485** is the most versatile communication standard in the standard series defined by the EIA
- **RS485** is a serial communication bus for computers and devices.
- **RS232** is an interface to connect one **DTE**, *data terminal equipment* to one **DCE**, *data communication equipment* at a maximum speed of 20 kbps with a maximum cable length of 50 feet.

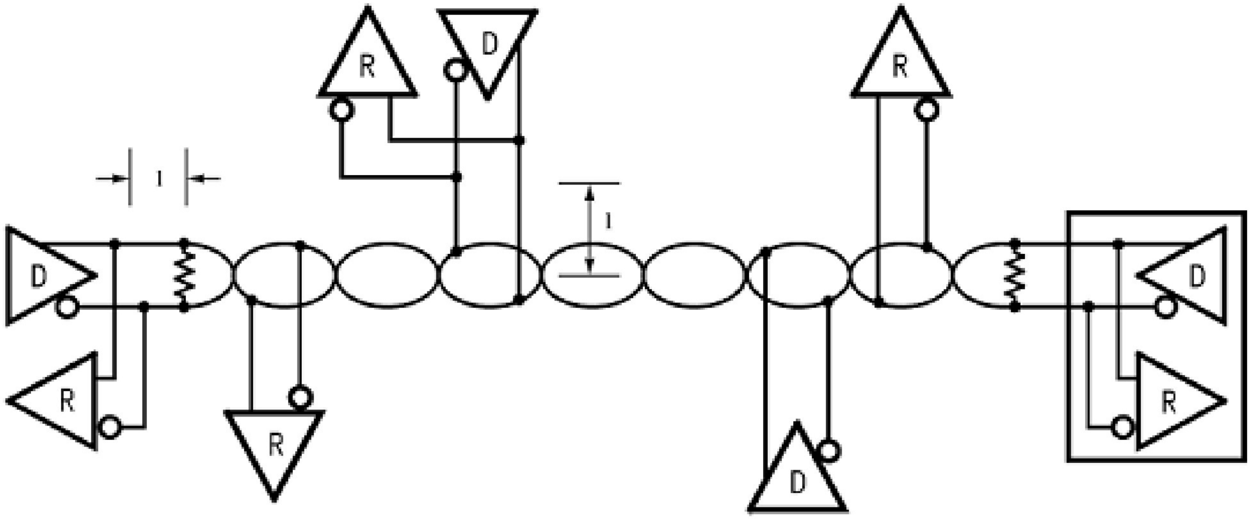
Features:

- Connect DTE's directly without the need of modems
- Connect several DTE's in a network structure
- Ability to communicate over longer distances
- Ability to communicate at faster communication rates

RS 485

- Multimode
- Half/ Full Duplex





Characteristics of RS232, RS485

	RS232	**RS485**
Cabling	single-ended	differential
Max number of drivers	1	32
Max number of receivers	1	32
Modes of operation	half duplex full duplex	half duplex
Network topology	point-to-point	multipoint
Max distance (acc. standard)	15 m	1200 m
Max speed at 12 m	20 kbs	35 Mbs
Max speed at 1200 m	(1 kbs)	100 kbs
Max slew rate	30 V/µs	n/a
Receiver input resistance	3..7 kΩ	≧ 12 kΩ
Driver load impedance	3..7 kΩ	54 Ω
Receiver input sensitivity	±3 V	±200 mV
Receiver input range	±15 V	–7 to 12 V
Max driver output voltage	±25 V	–7 to 12 V
Min driver output voltage (with load)	±5 V	±1.5 V

THE PUBLIC TELEPHONE NETWORK

- The public telephone network (PTN) accommodates two types of subscribers: *public and private.*
- The public telephone companies are sometimes called *service providers, as they lease equipment* and provide services to other private companies, organizations, and government agencies.
- subscribers to the public network are interconnected only temporarily through switches, the network is often appropriately called the *public switched telephone network* (PSTN) and sometimes simply as the ***dial-up network***

THE PUBLIC TELEPHONE NETWORK

- Telephone network equipment can be broadly divided into four primary classifications:
- **1. Instruments**

An *instrument is any device used to originate and terminate calls and to transmit and receive* signals into and out of the telephone network

- **2. local loops**

The *local loop is simply the dedicated cable facility used to connect an instrument at a subscriber's* station to the closest telephone office.

- **3. trunk circuits.**

A *trunk circuit is similar to a local loop except trunk circuits are used to interconnect two* telephone offices.

4. exchanges

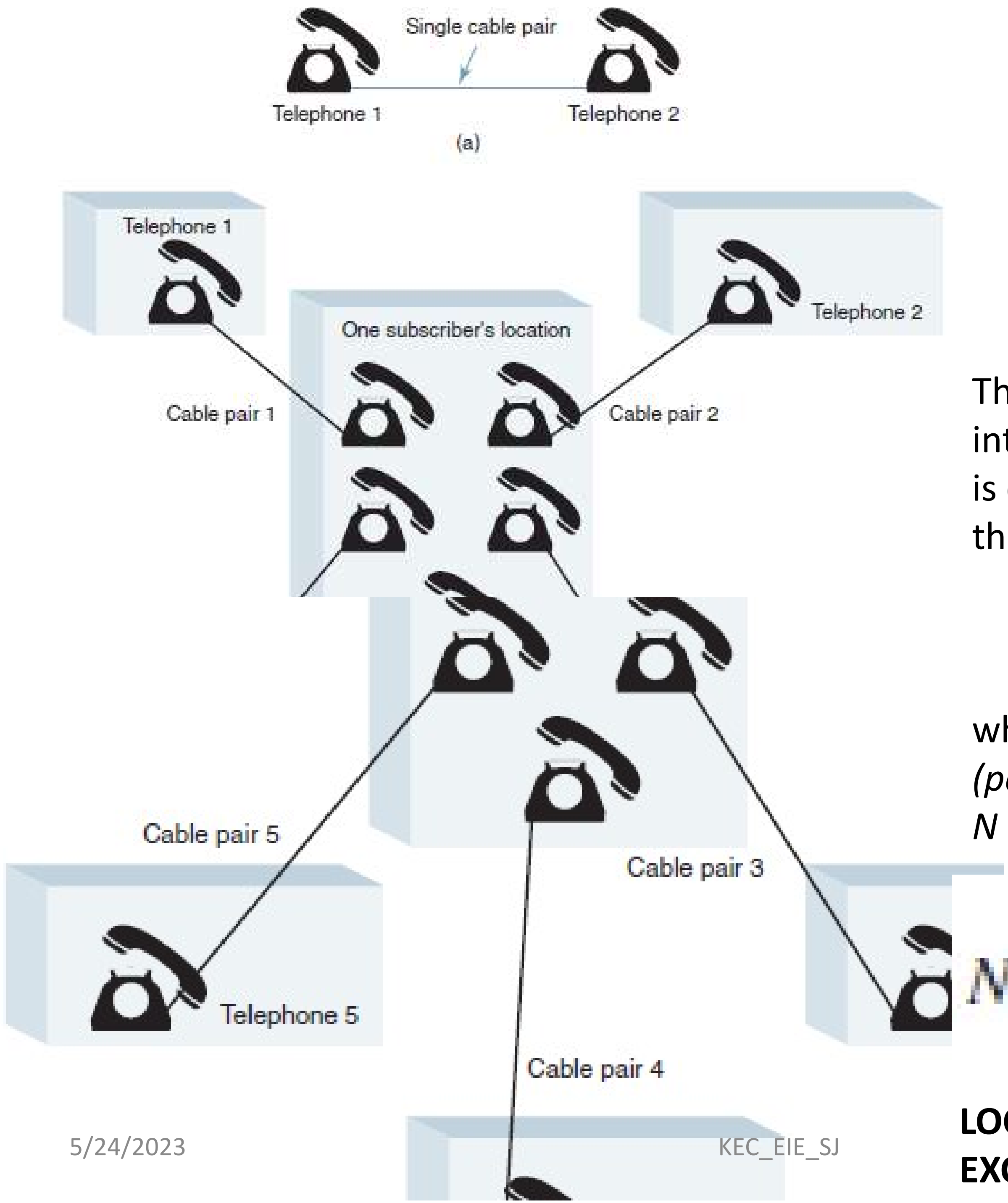
- An *exchange is a central location where subscribers are interconnected, either temporarily* or on a permanent basis.

The purpose of a telephone exchange is to provide a path for a call to be completed between two parties. To process a call, a switch must provide three primary functions:

1.Identify the subscribers

2.Set up or establish a communications path

3.Supervise the calling processes



THE PUBLIC TELEPHONE NETWORK

The number of lines required to interconnect any number of stations is determined by
the following equation:

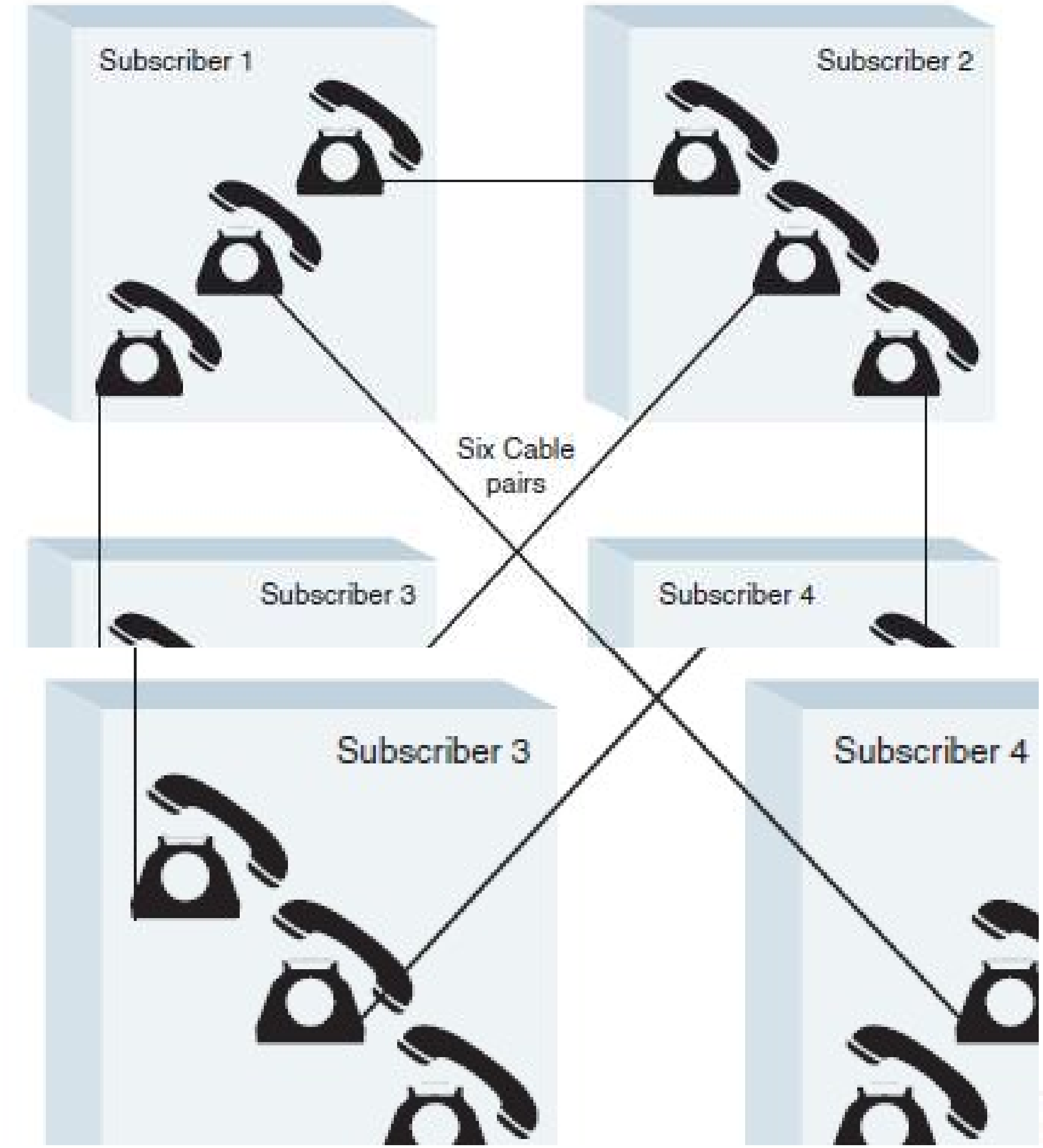
$$N = \frac{n(n-1)}{2}$$

where *n- number of stations (parties)*
N - number of interconnecting lines

$$N = \frac{100(100-1)}{2} =$$

LOCAL CENTRAL OFFICE TELEPHONE EXCHANGES

THE PUBLIC TELEPHONE NETWORK



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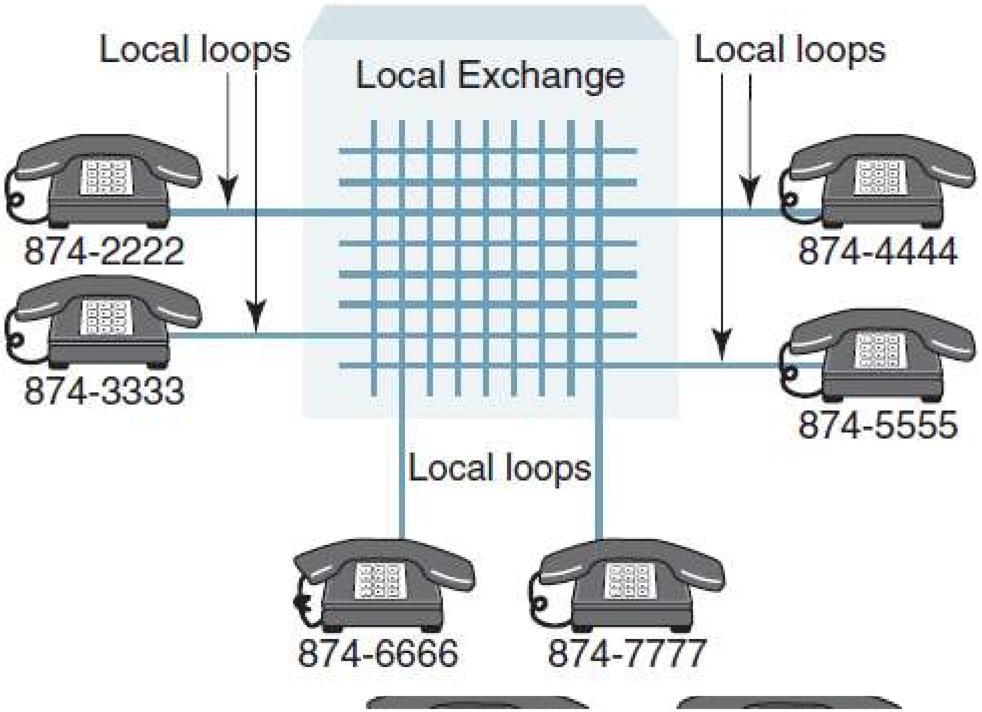
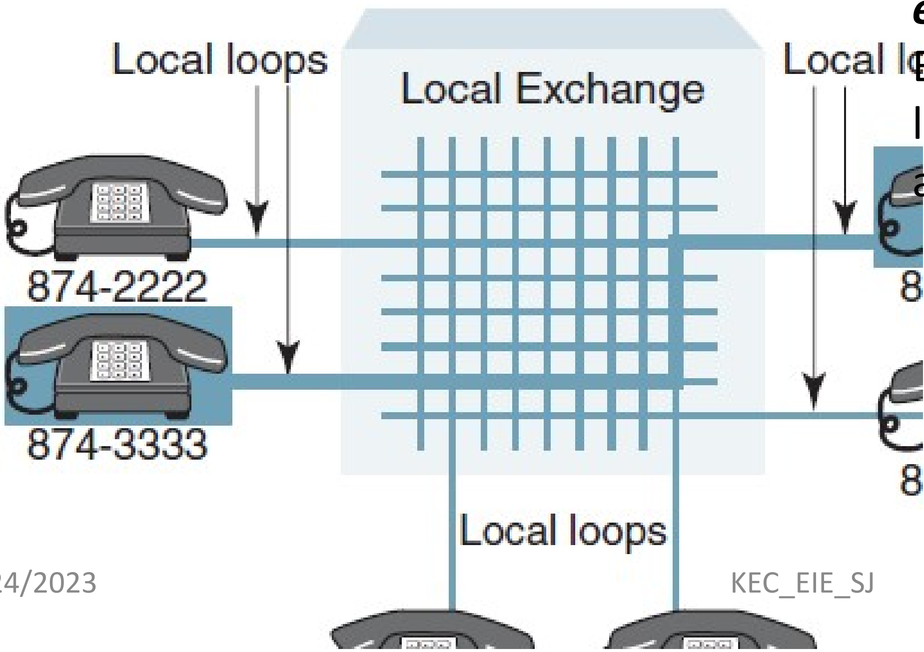
THE PUBLIC TELEPHONE NETWORK



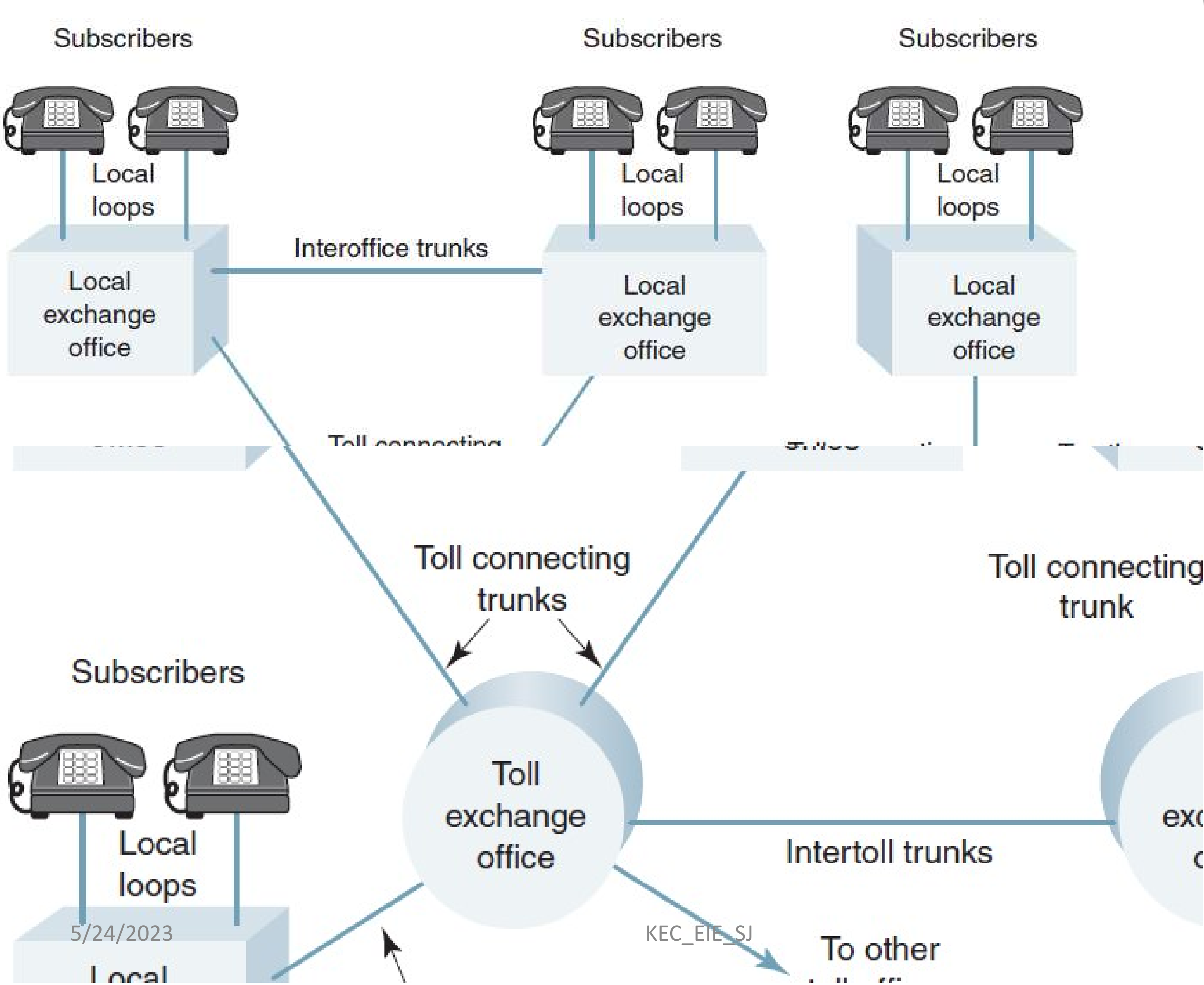


Local Telephone Exchanges and Exchange Areas

Exchanges connected directly to local loops are appropriately **called *local exchanges.***

Because local exchanges are centrally located within the area they serve, they are often called ***central offices (CO).***

THE PUBLIC TELEPHONE NETWORK



INTEGRATED SERVICES DIGITAL NETWORK(ISDN)

- The ***Integrated Services Digital Network (ISDN)*** *is a proposed network designed* by the major telephone companies in conjunction with the (**International Telecommunication Union**)ITU-T with the intent of providing worldwide telecommunications support of voice, data, video, and facsimile information within the same network (in essence, ISDN is the integrating of a wide range of services into a single multipurpose network).
- ISDN is a network that proposes to interconnect an unlimited number of independent users through a common communications network.

INTEGRATED SERVICES DIGITAL NETWORK(ISDN)

- The main feature of the ISDN concept is to support a wide range of voice (telephone) and non-voice (digital data) applications in the same network using a limited number of standardized facilities.
- Customers gain access to the ISDN system through a local interface connected to a digital transmission medium called a *digital pipe. There are several sizes of pipe available with* varying capacities (i.e., bit rates), depending on customer need.

ISDN Services

- **ISDN Services**
- **Bearer Services :**

  Transfer of information (voice, data, and video) between users without the network manipulating the content of that information is provided by the bearer network.
- **Teleservices :**

  Teleservices rely on the facilities of the bearer services and are designed to accommodate complex user needs. The user need not be aware of the details of the process. Teleservices include telephony, teletex, telefax, videotex, telex, and teleconferencing.
- **Supplementary Service:**

  Additional functionality to the bearer services and teleservices are provided by supplementary services. Reverse charging, call waiting, and message handling are examples of supplementary services which are all familiar with today's telephone company services.

ISDN Principle

- The ISDN works based on the standards defined by ITU-T (formerly CCITT). The Telecommunication Standardization Sector (ITU-T) coordinates standards for telecommunications on behalf of the **International Telecommunication Union (ITU)** and is based in Geneva, Switzerland. The various principles of ISDN as per ITU-T recommendation are:

I. To support switched and non-switched applications

II. To support voice and non-voice applications

III. Reliance on 64-kbps connections

IV. Intelligence in the network

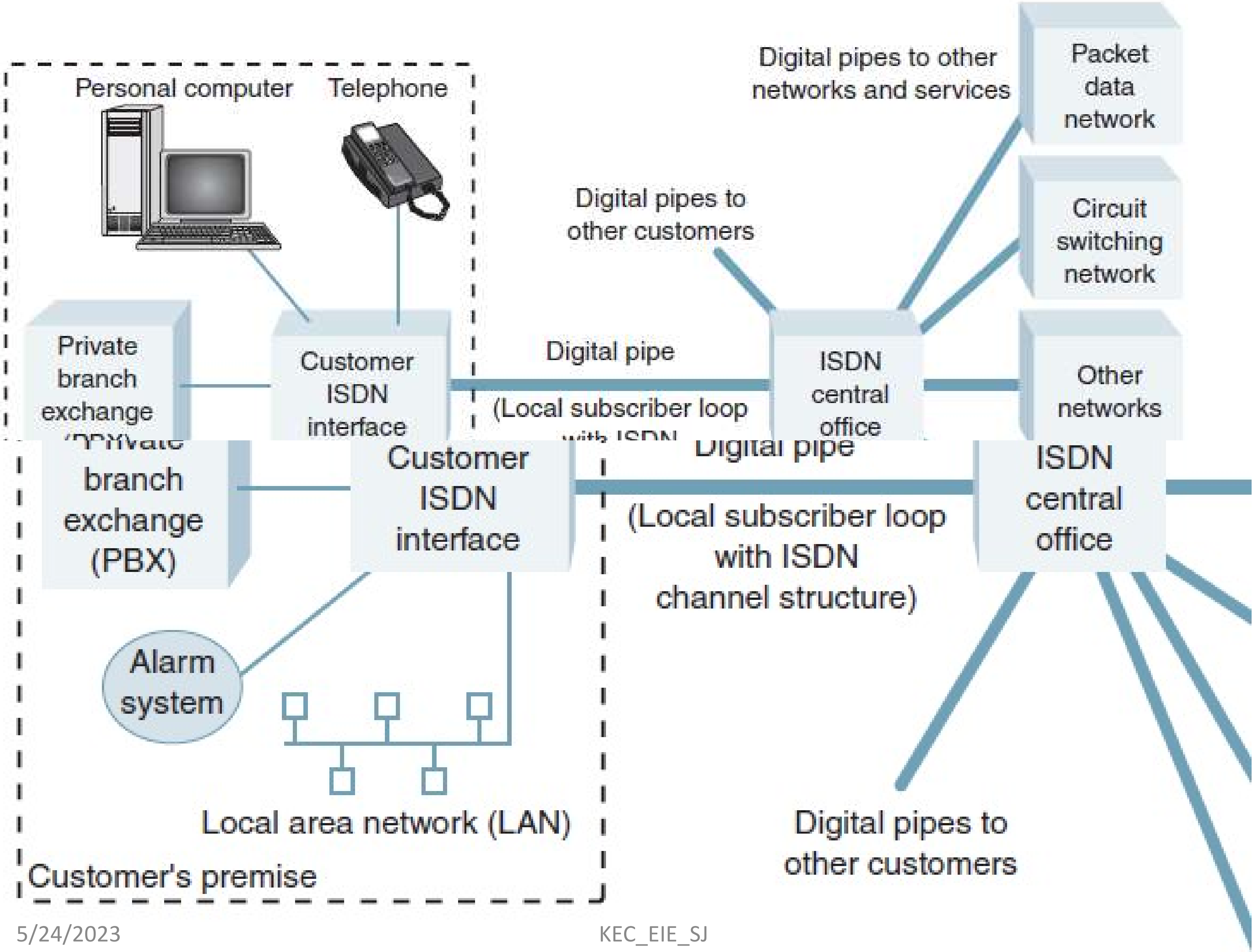
V. Layered protocol architecture

VI. Variety of configurations

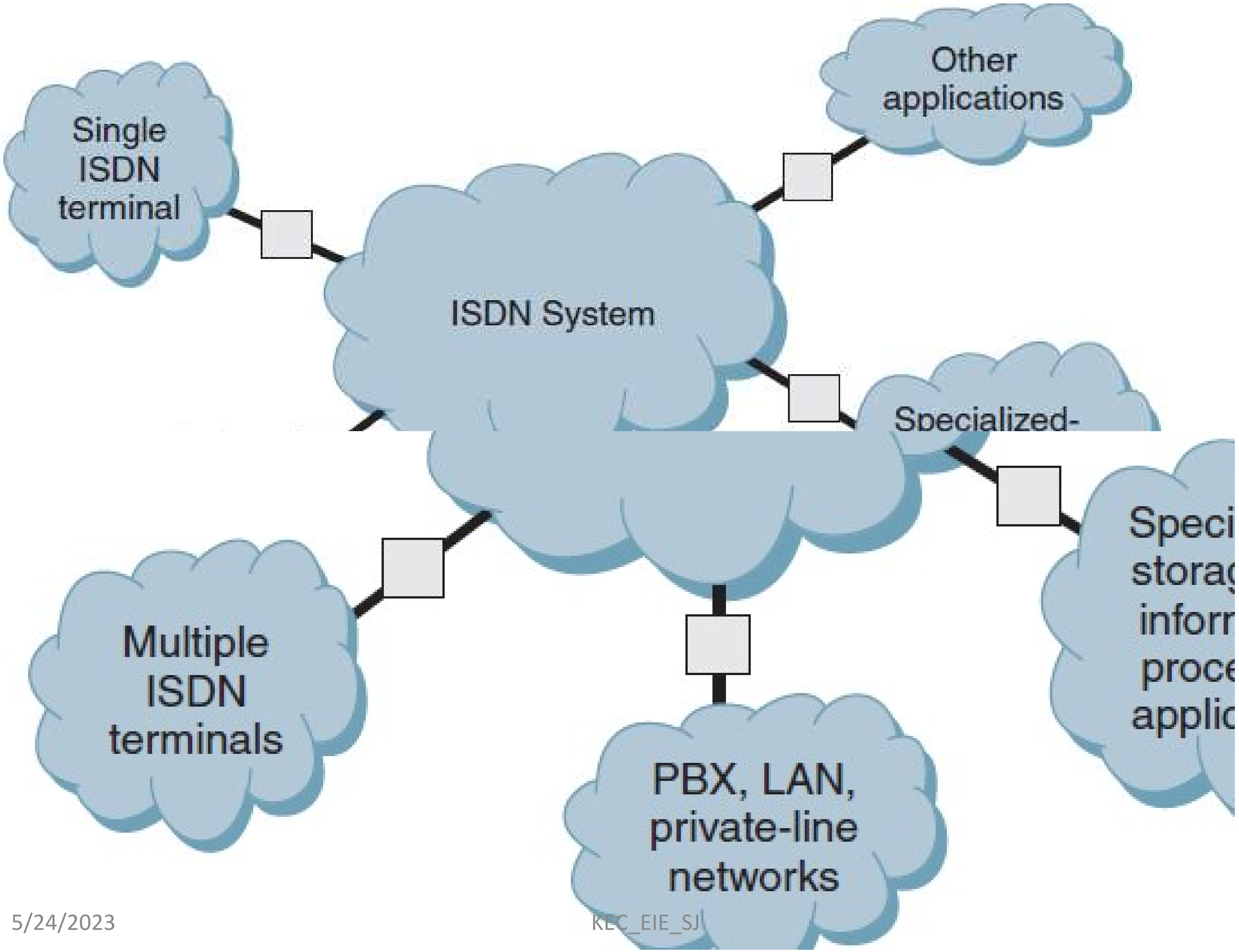
Types of ISDN

1. **Primary Rate Interface**
2. **Basic Rate Interface**
3. **B-channel ISDN -** Bearer Channel
4. **D-channel ISDN-** Delta channel
5. **Narrowband ISDN**
6. **Broadband ISDN**
7. **H-channel ISDN**

INTEGRATED SERVICES DIGITAL NETWORK(ISDN)



INTEGRATED SERVICES DIGITAL NETWORK(ISDN)

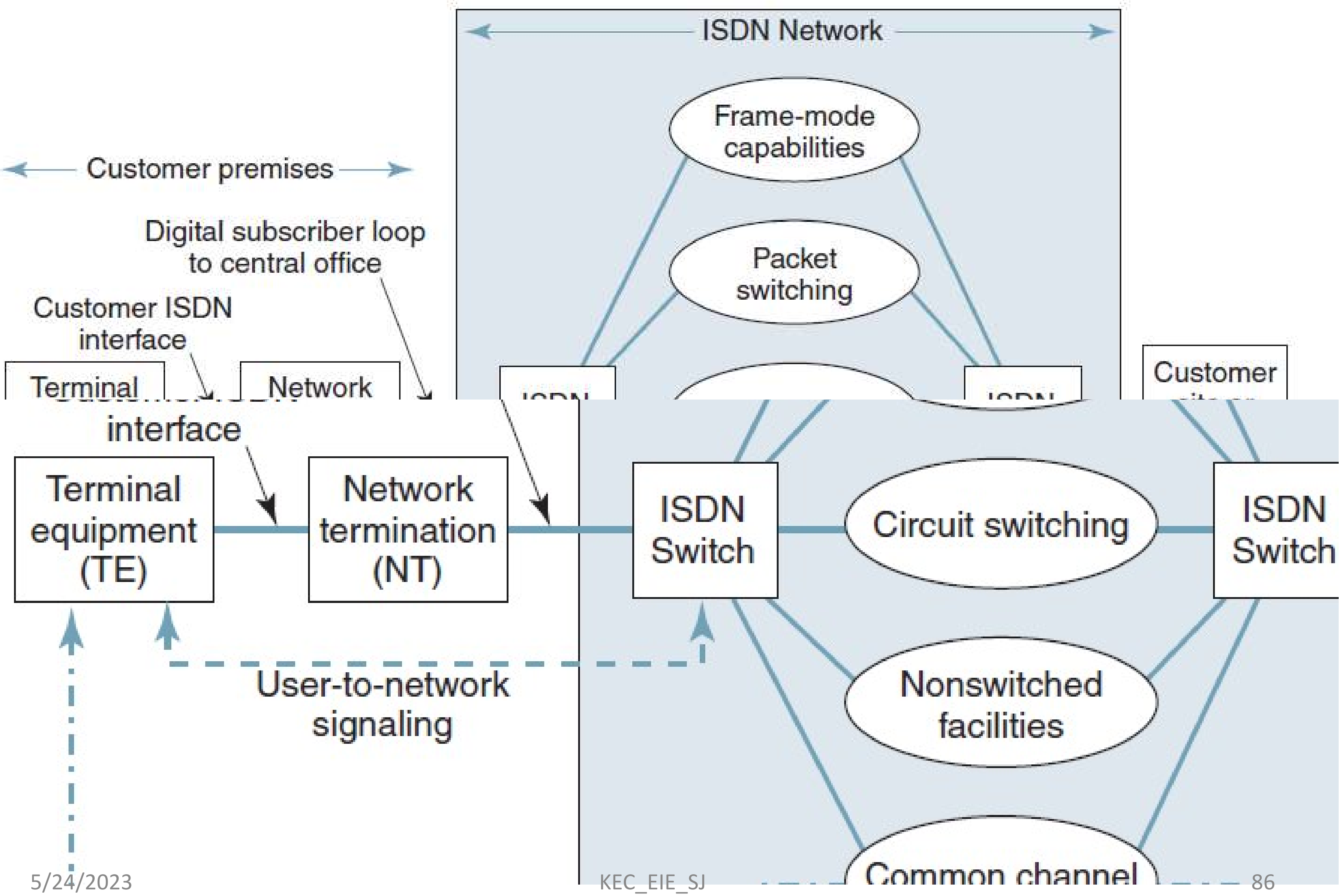


INTEGRATED SERVICES DIGITAL NETWORK(ISDN)

- **ISDN Objectives**

1. ***System standardization***. *Ensure universal access to the network.*
2. ***Achieving transparency***. *Allow customers to use a variety of protocols and applications.*
3. ***Separating functions***. *ISDN should not provide services that preclude competitiveness.*
4. ***Variety of configurations***. *Provide private-line (leased) and switched services.*
5. ***Addressing cost-related tariffs***. *ISDN service should be directly related to cost and* independent of the nature of the data.
6. ***Migration***. *Provide a smooth transition while evolving.*
7. ***Multiplexed support***. *Provide service to low-capacity personal subscribers as well* as to large companies.

ISDN Architecture



ISDN Architecture

Table 7 ISDN Services

Service	Transmission Rate	Channel
Telephone	64 kbps	BC
System alarms	100 bps	D
Utility company metering	100 bps	D
Energy management	100 bps	D

Utility company metering	100 bps
Energy management	100 bps
Video	2.4–64 kbps
Electronic mail	4.8–64 kbps

ISDN

Advantages of ISDN:

- ISDN channels have a reliable connection.
- ISDN is used to facilitate the user with multiple digital channels.
- It has faster data transfer rate.
- Efficient use of bandwidth
- Improved call quality
- Greater flexibility
- Integrated services

Disadvantages of ISDN:

- ✓ ISDN lines costlier than the other telephone system.
- ✓ It requires specialized digital devices.
- ✓ It is less flexible.
- ✓ Limited coverage
- ✓ High installation and maintenance costs
- ✓ Obsolescence
- ✓ Limited features