INTRODUCTION TO DATA COMMUNICATIONS & COMPUTER NETWORKS

ECE 422 – DATA COMMUNICATION & COMPUTER NETWORKS

SESSION I

Sunday, 16 February 2026

DATA COMMMUNICATIONS & COMPUTER NETWORKS SYLLABUS (1)

<u>Pre-requisites:</u>

ECE 416 – Digital Communication

<u>Course Purpose:</u>

To introduce students to basic concepts, theories and components in data communications and computer network and their applications in local area networks and industrial communication and control.

DATA COMMMUNICATIONS & COMPUTER NETWORKSSYLLABUS (2)

Expected Learning Outcomes:

Upon completion of this course, a student should be able to:

i. define data communications and telecommunications;
ii. define and diagram five network topologies;
iii. list the layers in the Internet and OSI models and describe their functions;
iv. list several standards organizations and identify several data communication standards;
v. describe the components of a data communication interface and relate it to a specific interface standard;
vi. list the advantages and disadvantages of common data communication media;
vii. identify several codes that are used for error detection and how error correction is accomplished;
viii. describe a data link protocol and define how it controls the transfer of frames;
ix. define multiplexing and switching and explain how and why each is used in data communications;
x. describe communication and control systems used in industrial plants.

DATA COMMMUNICATIONS & COMPUTER NETWORKS SYLLABUS (3)

Course Content:

Introduction: Overview of Data Communications and Networking.

Physical Layer: Analog and Digital, Analog Signals, Digital Signals, Analog versus Digital, Data Rate Limits, Transmission Impairment, More about signals.

Digital Transmission: Line coding, Block coding, Sampling, Transmission mode.

Analog Transmission: Modulation of Digital Data; Telephone modems, modulation of Analog signals.

Multiplexing: FDM, WDM, TDM.

Transmission Media: Guided Media, Unguided media (wireless).

Data Link Layer: Error Detection and correction - Types of Errors, Detection, Error Correction; Data Link Control and Protocols-Flow and Error Control, Stop-and-wait ARQ. Go-Back-N ARQ, Selective Repeat ARQ, HDLC. Point-to-Point Access- Point–to-Point Protocol (PPP), PPP Stack, Multiple Access Random Access, Controlled Access, Channelization.

Network Layer: Host to Host Delivery: Internetworking, addressing and Routing Network Layer Protocols: ARP, IPV4, ICMP, IPV6 and ICMPV6

Transport Layer: Process to Process Delivery: UDP; TCP congestion control and Quality of service.

Application Layer: Client Server Model, Socket Interface, Domain Name System (DNS): Electronic Mail (SMTP) and file transfer (FTP) HTTP and WWW.

Local area Network: Ethernet - Traditional Ethernet, Fast Ethernet, Gigabit Ethernet; Token bus, token ring; Wireless LANs - IEEE 802.11, Bluetooth virtual circuits: Frame Relay and ATM.

Industrial Communication and Control Networks: Transmission methods, Network topology, Contemporary networks – Profibus, Controller Area Network (CAN), DeviceNet, CANopen, Actuator Sensor Interface (AS-1),Industrial Ethernet.

DATA COMMMUNICATIONS & COMPUTER NETWORKS SYLLABUS (4)

Mode of Delivery

Lectures, Class discussions, e-learning and laboratory tests

Instructional Materials

Handouts, textbooks, lecture notes, e-materials, Chalkboard, Whiteboard, LCD/Overhead Projector

Course Assessment:

Continuous Assessment Tests (20%), Practicals 10%, End of semester Examination (70%)

DATA COMMMUNICATIONS & COMPUTER NETWORKS SYLLABUS (5)

Recommended books:

(i) Behrouz A. Forouzan, *Data Communications and Networking*, Tata McGraw-Hill

(ii) S. Tannenbum, D. Wetherall, *Computer Networks*, Prentice Hall, Imprint of Pearson 5th edition.

REFERENCE TEXTBOOKS

1. Behrouz Foruzan, *Data Communications and Networking*, McGraw Hill Higher Education.

WHAT IS DATA?

WEBSTER DICTIONARY

1. Information or facts used usually to calculate, analyze, or plan something.
2. Information that is produced or stored by a computer.

WIKIPEDIA

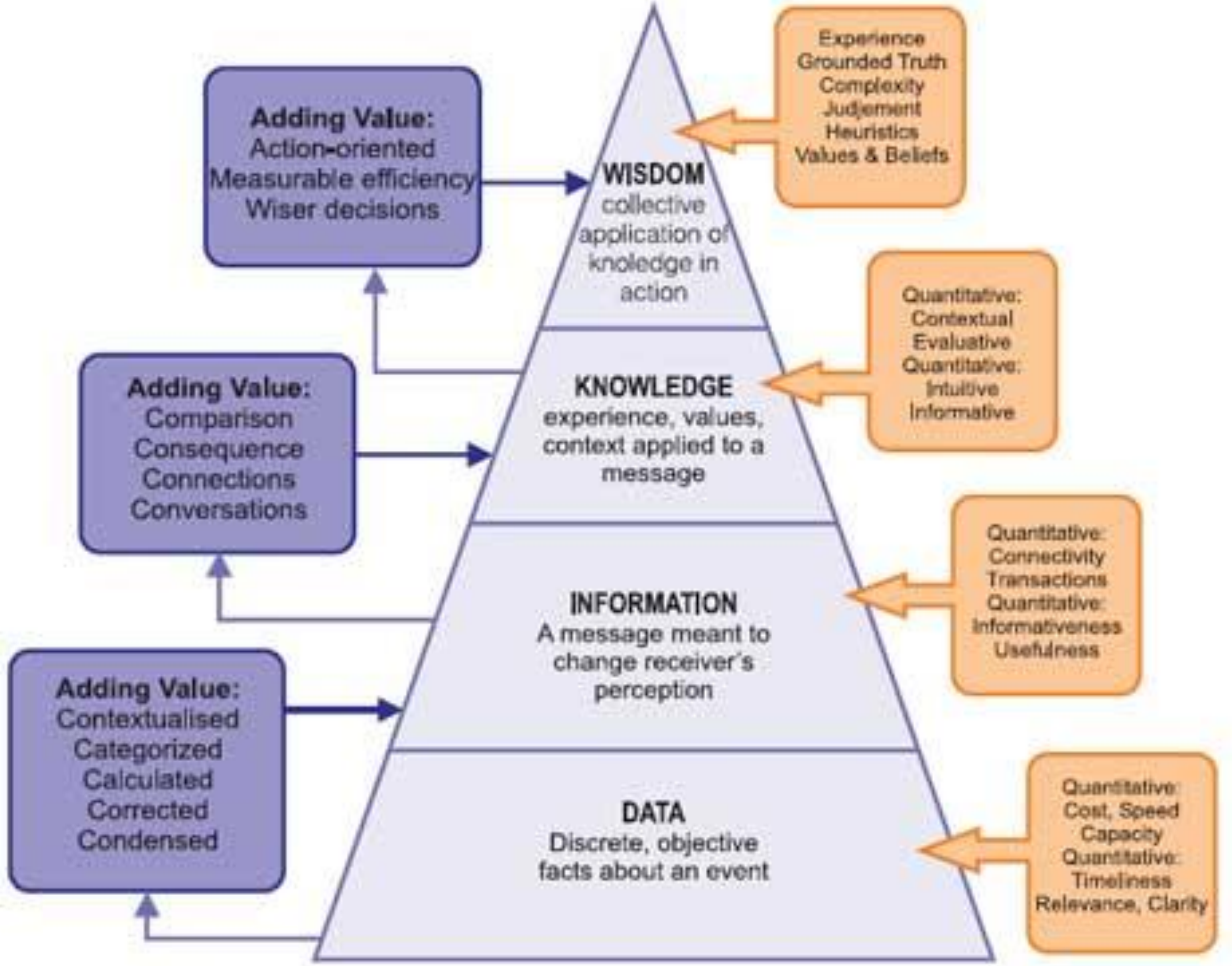
1. Data is a set of values of qualitative or quantitative variables.
2. Pieces of data are individual pieces of information. Data is measured, collected and reported, and analyzed, whereupon it can be visualized using graphs or images.
3. Data as an abstract concept can be viewed as the lowest level of abstraction, from which information and then knowledge are derived.

RELATION BETWEEN DATA, INFORMATION & KNOWLEDGE

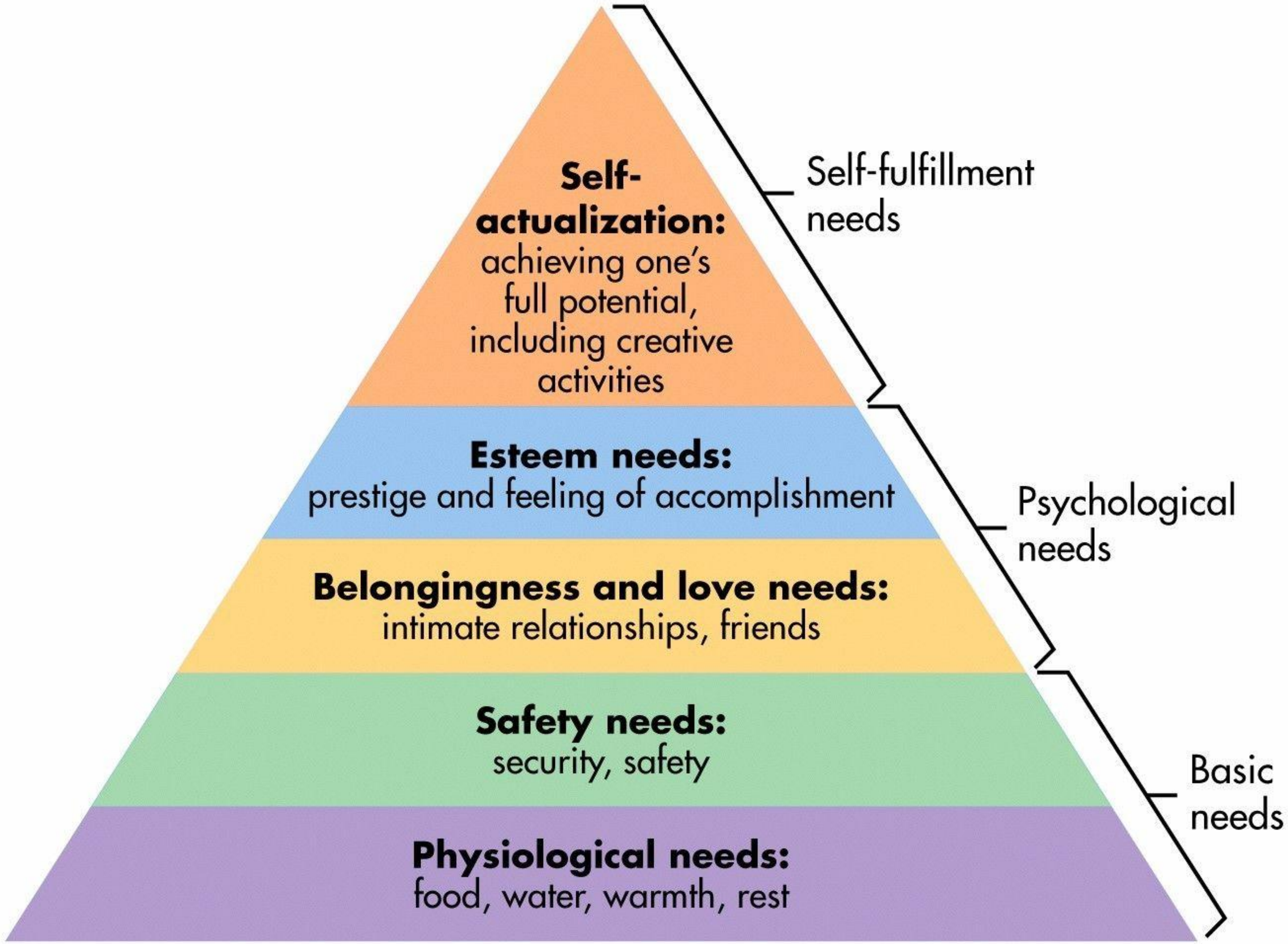
1. Data, information and knowledge are closely related terms.

2. **Data** is collected and analyzed to create information suitable for making decisions.
3. **Information** is facts provided or learned about something or someone

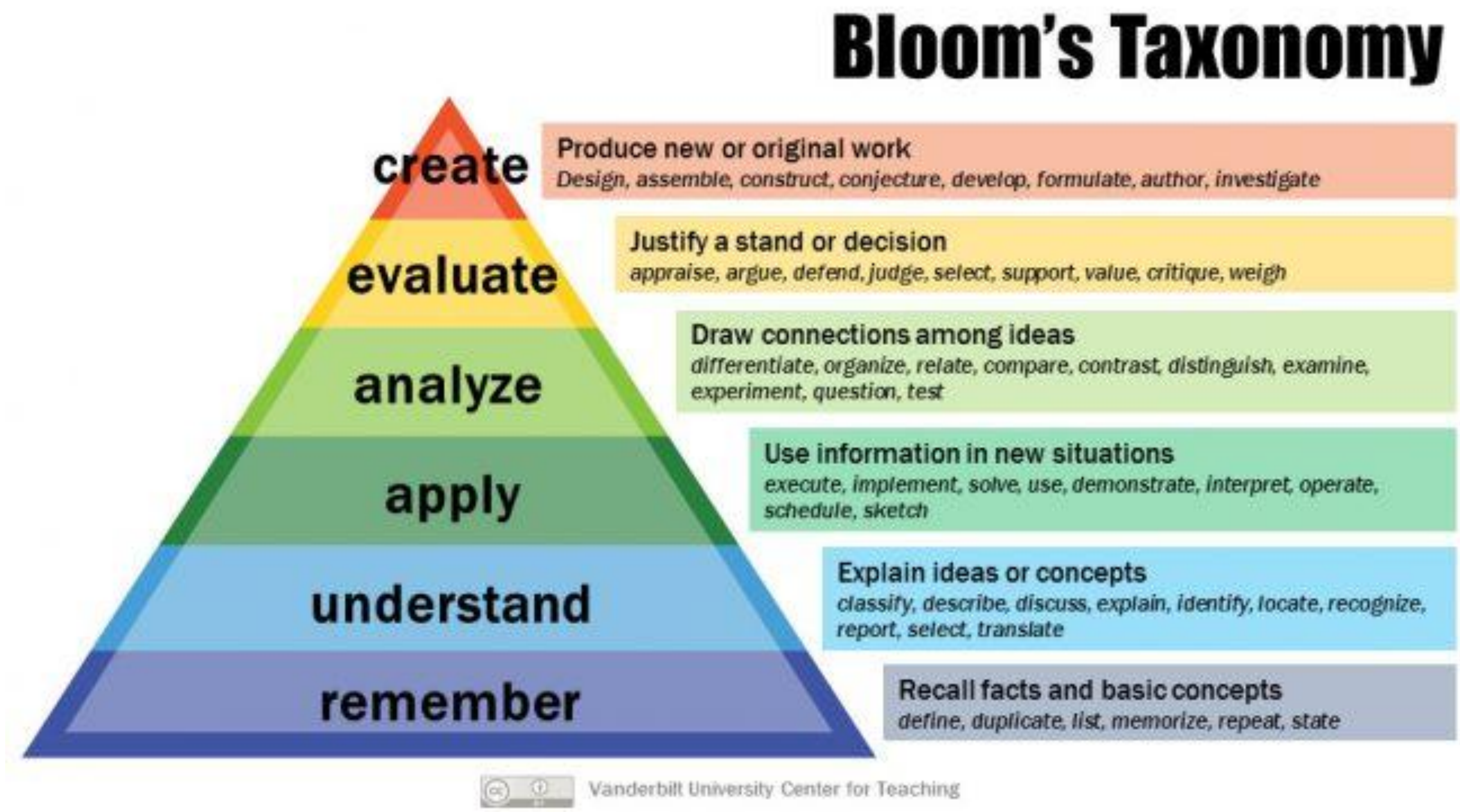
4. **Knowledge** is derived from extensive amounts of experience dealing with information on a subject.



HIERARCHY MODELS - For Those Who Will Move Into Management
Maslow's Hierarchy of Needs



HIERARCHY MODELS: For Those Who Will be Educationists /Trainers
Bloom's Taxonomy



TOPICS TO BE COVERED IN WEEK I

1. History of data communication.
2. Data communication codes.
3. Serial interfaces
4. Transmission media
5. Data modems.
6. Data protocols and standards.
7. Layered network architecture and open systems interconnection (ISO): layer 1 to 7.

HISTORY OF DATA COMMUNICATION

1838: **Samuel Morse & Alfred Veil** Invent Morse Code and Telegraph System

1876: Alexander Graham Bell invented Telephone.

1910: Howard Krum developed Start/Stop Synchronisation.

1930: Development of ASCII Transmission Code

1945: Allied Governments develop the First Large Computer

1950: IBM releases its first computer IBM 710

1960: IBM releases the First Commercial Computer IBM 360

HISTORY OF DATA COMMUNICATION

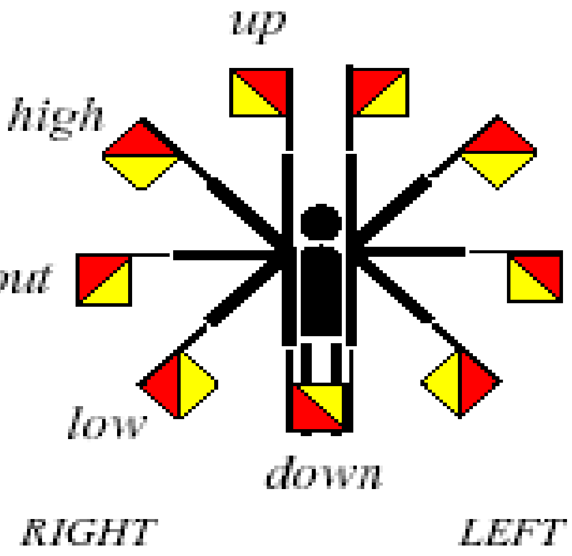
1967: ARPANET by Advanced Research Project Agency (ARPA) of U.S.

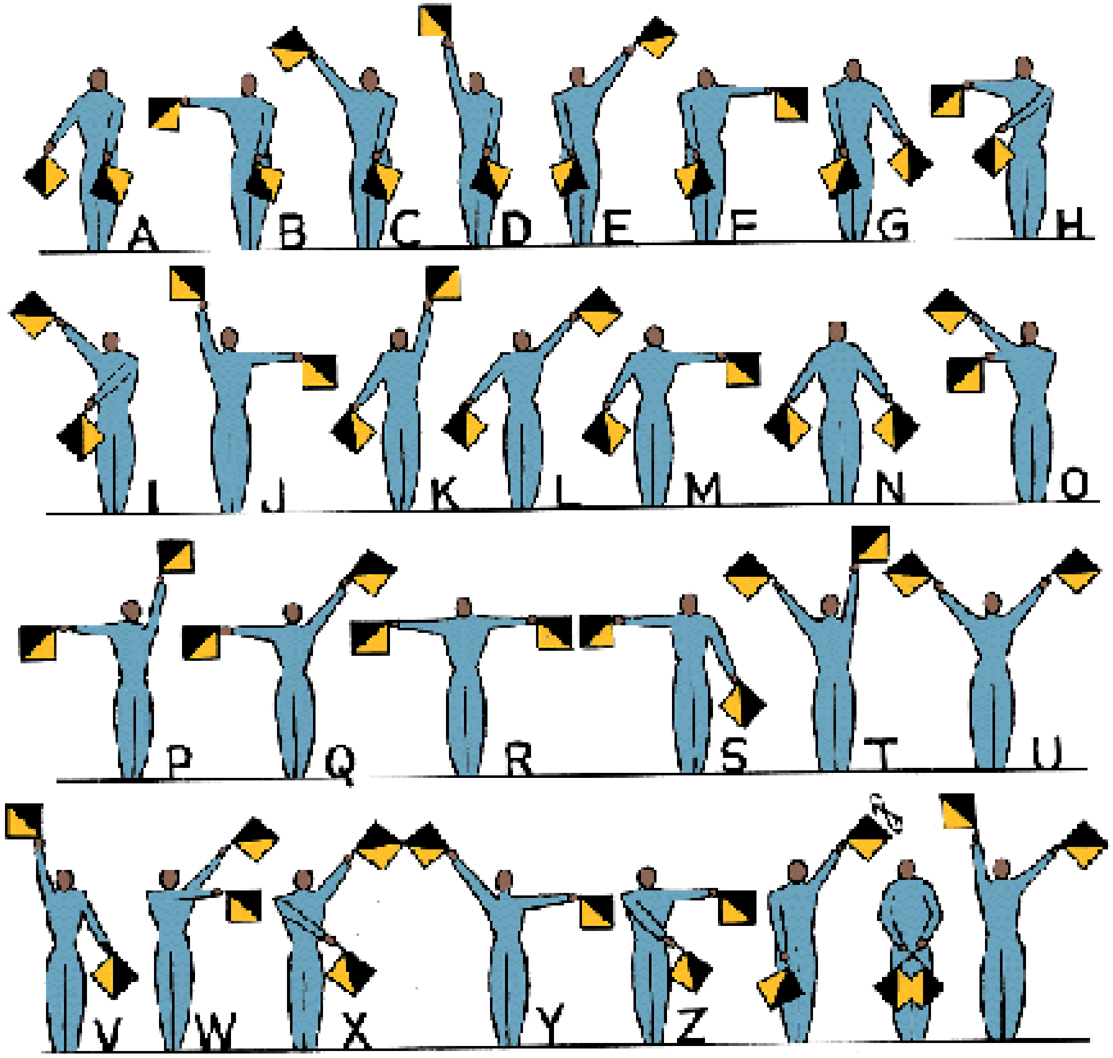
1975: TCP/IP protocol, DIX-Ethernet & IEEE 802 Networks

1976: ISO releases HDLC & CCITT releases X.25 (PSPDN)

PRE-TELEGRAPH DAYS - SEMAPHORE

Semaphore flag signalling system, designed by the Chappe brothers in France in the late 18th century was used to carry despatches between French army units, including those commanded by Napoleon, and was soon adopted by other European states.

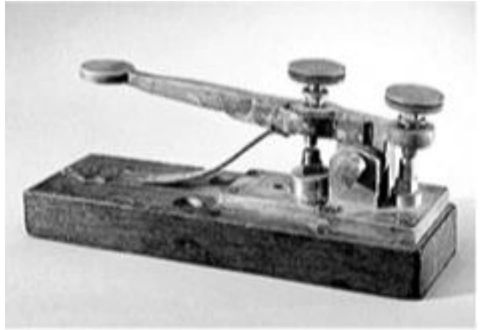


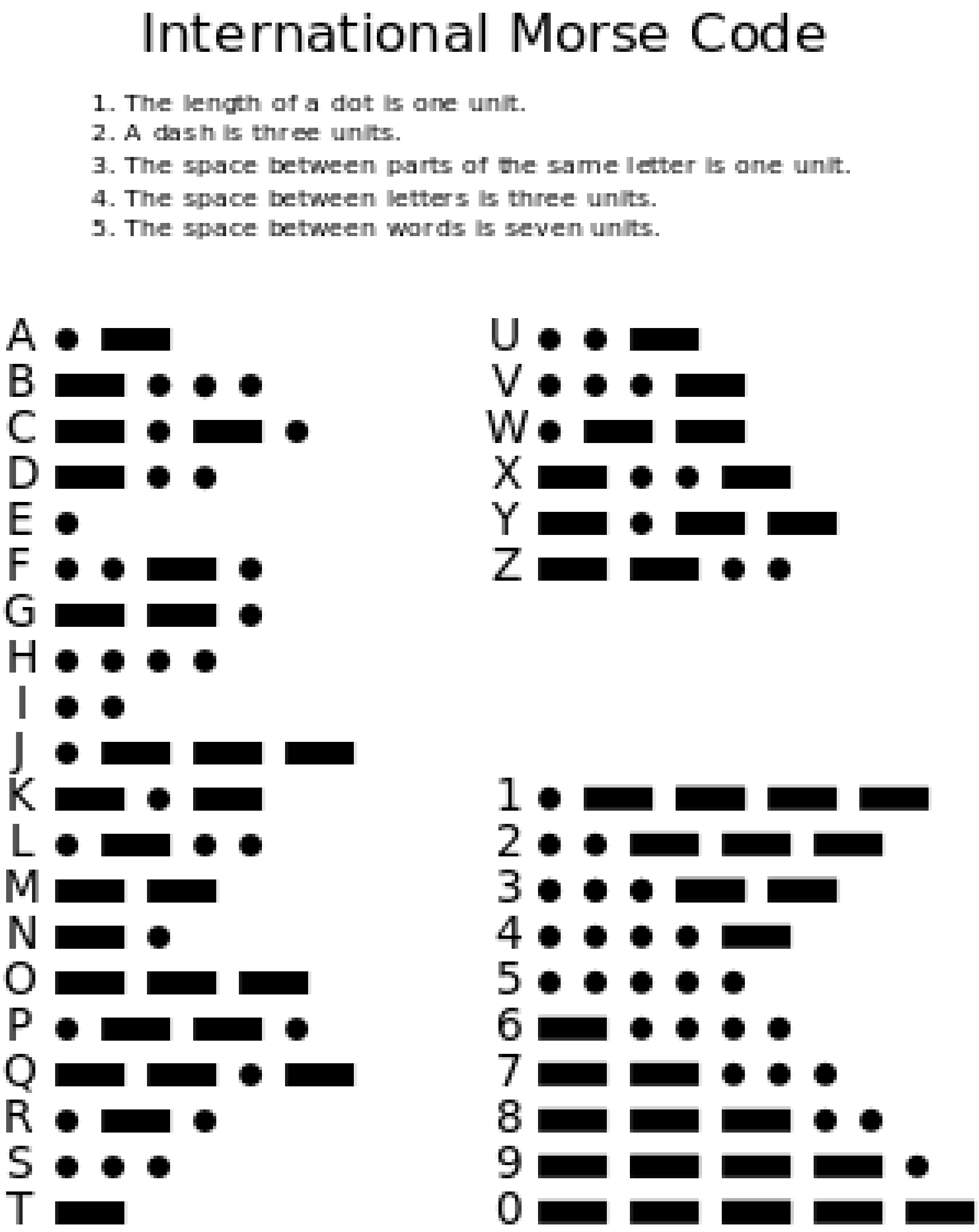


MORSE CODE

- **Morse Code** utilizes a series of dots, dashes and correlated spaces, signalled in either a visual (including light) or auditory (clicks) form to relay a message.

- Each letter of the alphabet has a different compilation of dots and dashes to help the end user decipher the words being



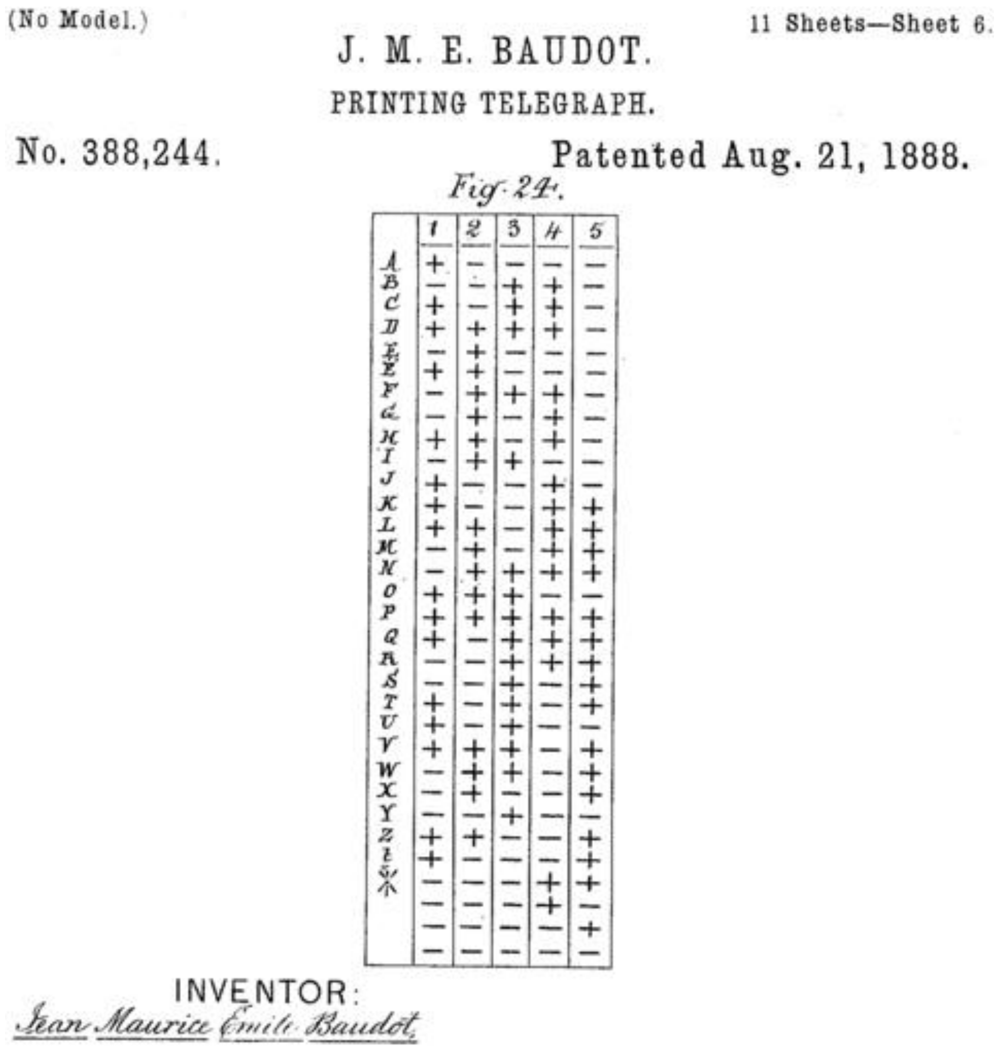


A di-dah	N dah-dit
B dah-di-di-dit	O dah-dah-dah
C dah-di-dah-dit	P di-dah-dah-dit
D dah-di-dit	Q dah-dah-di-dah
E dit	R di-dah-dit
F di-di-dah-dit	S di-di-dit
G dah-dah-dit	T dah
H di-di-di-dit	U di-di-dah
I di-dit	V di-di-di-dah
J di-dah-dah-dah	W di-dah-dah
K dah-di-dah	X dah-di-di-dah
L di-dah-di-dit	Y dah-di-dah-dah
M dah-dah	Z dah-dah-di-dit

Click Here to Watch Morse Code Video

BAUDOT TELETYPE CODE

1. **Baudot Teletype code** is a 5-bit code also known as International Telegraph Alphabet No. 2 (ITA2).
2. Basic ITA2 therefore supports $2^5 = 32$ codes
3. With the help of Letter shift & Figure shift key same code is used to represent two symbols. Then the maximum symbols is 58.
4. The International Telegraph Alphabet No. 2 (ITA2) was used in Telegraphy/Telex (now obsolete).



CODE SETS

1. A **code set** is the set of codes representing symbols.
2. Very common code sets are :
   a) *ASCII* : American Standards Institute's (ANSI's) 7-bit American Standard Code for Information Interchange

      ASCII code(7-bit) is often used with an 8th bit known as parity bit used for detecting errors. Parity bit is added to the Most Significant bit (MSB).

   a) Binary Coded Decimal Interchange Code *(BCDIC)* this is IBM's 8-bit Extended

AMERICAN STANDARD CODE FOR INFORMATION INTERCHANGE (ASCII) CODE

I. ASCII is defined in the American National Standards Institute (ANSI) as ANSI X3.4 but also adopted internationally as:
   a) ITU recommendation - International Alphabet No.5
   b) International Standards Organization (ISO) - ISO 646

II. ASCII has a total 128 codes
   a) 96 codes are graphic symbols (in Col. 2 to 7).
      i. 94 codes are printable
      ii. 2 codes viz. SPACE & DEL characters are non printable
   b) 32 codes control symbols (Col. 0 & 1)
      i. All the 32 are non printable

HISTORY OF ASCII

- **American Standard Code for Information Interchange (acronym: ASCII)** is a character-encoding scheme based on the ordering of the English alphabet.
- ASCII codes represent text in computers, communications equipment, and other devices that use text.
- **Work on ASCII formally began October 6, 1960**, with the first meeting of the American Standards Association's (ASA) X3.2 subcommittee.
- The first edition of the standard was published in 1963
- A major revision was published during 1967,
- The most recent ASCII update was carried out in 1986.

THE ASCII TABLE

Ascii	Char	Ascii	Char	Ascii	Char	Ascii	Char
0	Null	32	Space	64	@	96	`
1	Start of heading	33	!	65	A	97	a
2	Start of text	34	"	66	B	98	b
3	End of text	35	#	67	C	99	c
4	End of transmit	36	$	68	D	100	d
5	Enquiry	37	%	69	E	101	e
6	Acknowledge	38	&	70	F	102	f
7	Audible bell	39	'	71	G	103	g
8	Backspace	40	(	72	H	104	h
9	Horizontal tab	41	)	73	I	105	i
10	Line feed	42	*	74	J	106	j
11	Vertical tab	43	+	75	K	107	k
12	Form feed	44	,	76	L	108	l
13	Carriage return	45	-	77	M	109	m
14	Shift in	46	.	78	N	110	n
15	Shift out	47	/	79	O	111	o
16	Data link escape	48	0	80	P	112	p
17	Device control 1	49	1	81	Q	113	q
18	Device control 2	50	2	82	R	114	r
19	Device control 3	51	3	83	S	115	s
20	Device control 4	52	4	84	T	116	t
21	Neg. acknowledge	53	5	85	U	117	u
22	Synchronous idle	54	6	86	V	118	v
23	End trans. block	55	7	87	W	119	w
24	Cancel	56	8	88	X	120	x
25	End of medium	57	9	89	Y	121	y
26	Substitution	58	:	90	Z	122	z
27	Escape	59	;	91	[	123	{
28	File separator	60	<	92	\	124	|
29	Group separator	61	=	93	]	125	}
30	Record separator	62	>	94	^	126	~
31	Unit separator	63	?	95	_	127	Forward del.

EBCDIC CODE

1. Extended Binary Coded Decimal Interchange Code (EBCDIC) is an 8-bit code with 256 symbols
2. EBCDIC has no parity bit for error checking
3. The graphic symbols are almost same as ASCII
4. There are several differences in Control characters as compared to ASCII

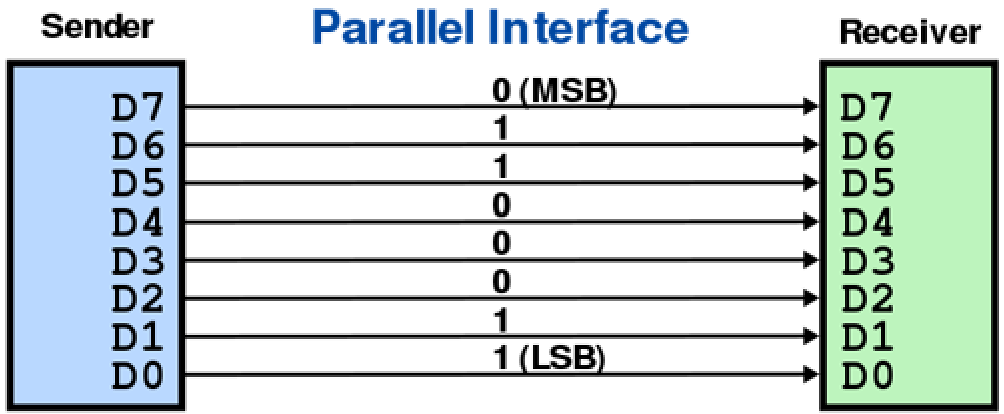
EBCDIC CODE

EBCDIC											
	Binary				Binary				Binary		
Char	Zone	Digit	Hex	Char	Zone	Digit	Hex	Char	Zone	Digit	Hex
blank	0100	0000	40	u	1010	0100	A4	P	1101	0111	D7
a	1000	0001	81	v	1010	0101	A5	Q	1101	1000	D8
b	1000	0010	82	w	1010	0110	A6	R	1101	1001	D9
c	1000	0011	83	x	1010	0111	A7	S	1110	0010	E2
d	1000	0100	84	y	1010	1000	A8	T	1110	0011	E3
e	1000	0101	85	z	1010	1001	A9	U	1110	0100	E4
f	1000	0110	86	A	1100	0001	C1	V	1110	0101	E5
g	1000	0111	87	B	1100	0010	C2	W	1110	0110	E6
h	1000	1000	88	C	1100	0011	C3	X	1110	0111	E7
i	1000	1001	89	D	1100	0100	C4	Y	1110	1000	E8
j	1001	0001	91	E	1100	0101	C5	Z	1110	1001	E9
k	1001	0010	92	F	1100	0110	C6	0	1111	0000	F0
l	1001	0011	93	G	1100	0111	C7	1	1111	0001	F1
m	1001	0100	94	H	1100	1000	C8	2	1111	0010	F2
n	1001	0101	95	I	1100	1001	C9	3	1111	0011	F3
o	1001	0110	96	J	1101	0001	D1	4	1111	0100	F4
p	1001	0111	97	K	1101	0010	D2	5	1111	0101	F5
q	1001	1000	98	L	1101	0011	D3	6	1111	0110	F6
r	1001	1001	99	M	1101	0100	D4	7	1111	0111	F7
s	1010	0010	A2	N	1101	0101	D5	8	1111	1000	F8
t	1010	0011	A3	O	1101	0110	D6	9	1111	1001	F9

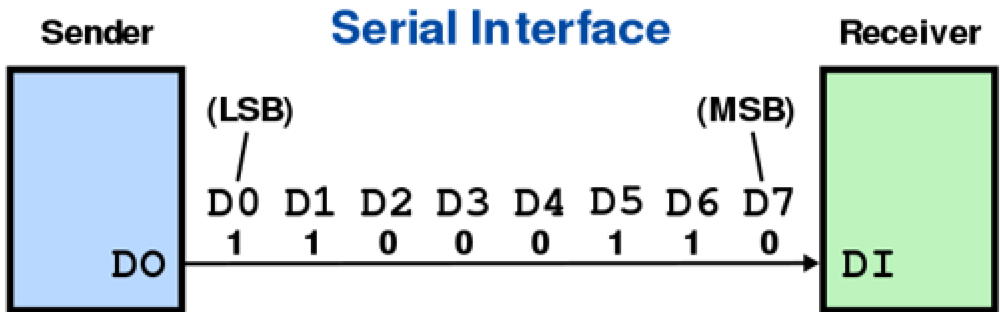
DATA TRANSMISSION

1. **Digital (binary) Data Transmission** means movement of the bits over a transmission medium connecting two devices.
2. Two types of Data Transmission are:

1. Parallel Transmission



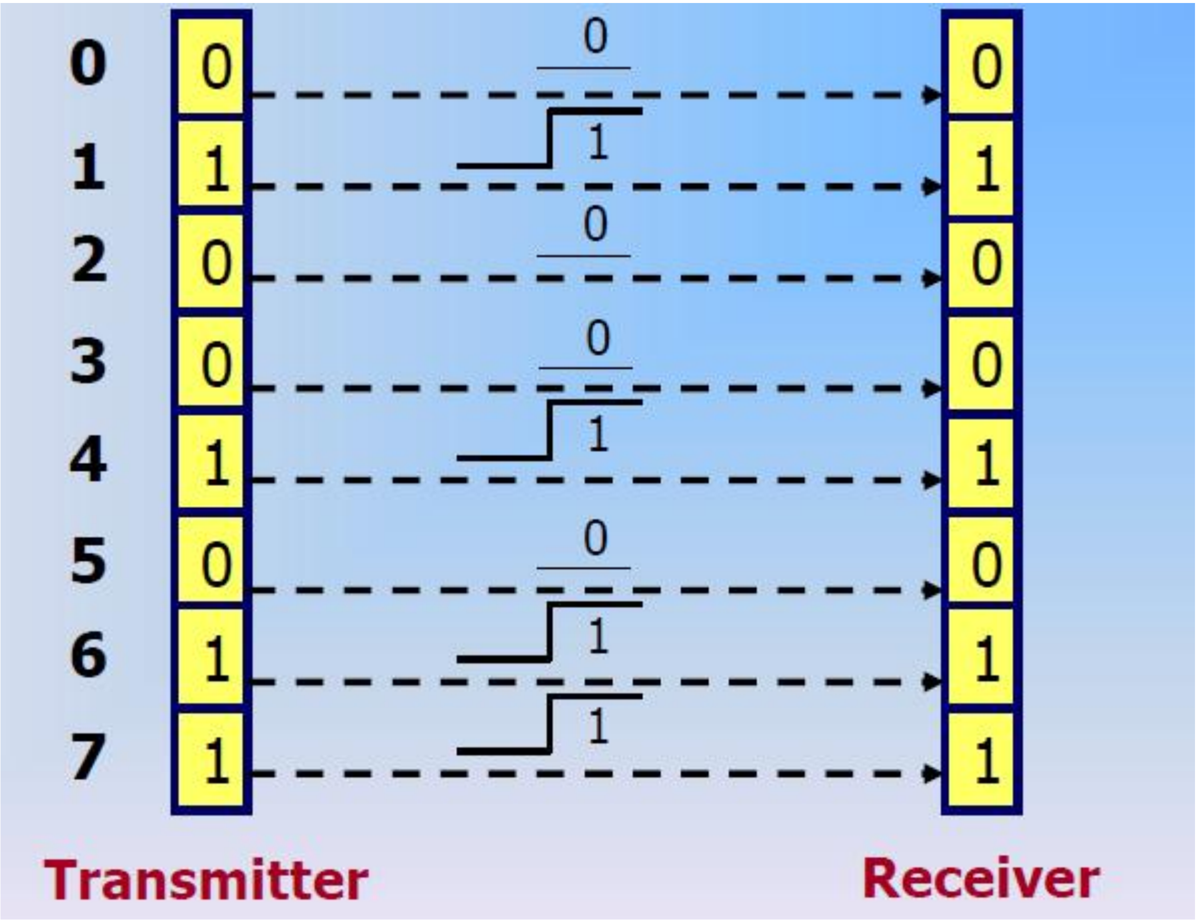
2. Serial Transmission



PARALLEL COMMUNICATION

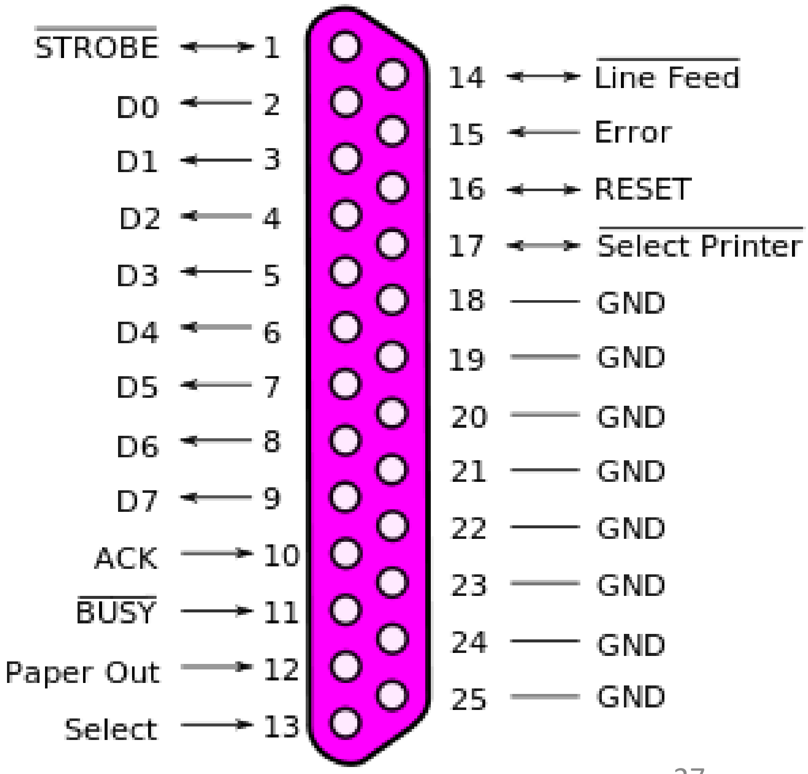
1. In **parallel communication** all the bits of a *byte* are transmitted simultaneously on separate wires.

2. Parallel Communication is practicable if two devices are close to each other e.g. Computer to Printer, or Communication within the Computer.



PARALLEL PRINTER CABLE

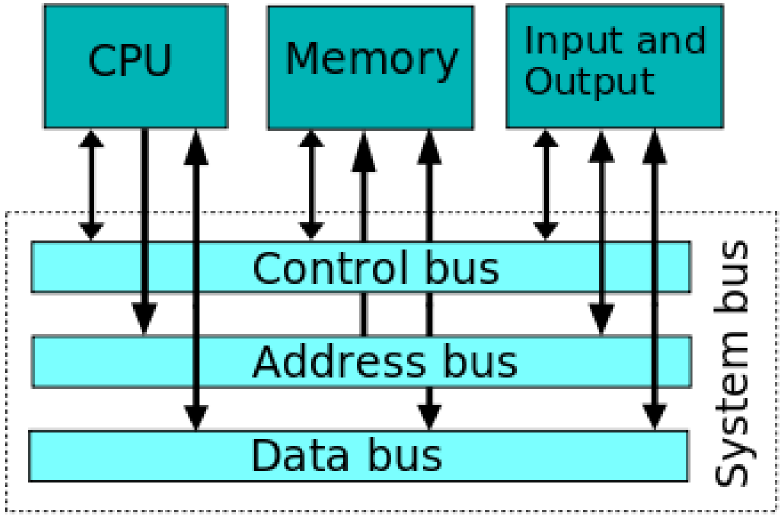
1. Before the invention of USB, the parallel printer cable was the most common method of connecting a printer to a computer.
2. The computer sends a byte of data in parallel to the printer on lines: D0 – D7
3. The printer can acknowledge, communicate busy status, paper out, etc as shown.
4. Data is read when STROBE is high or low.



DATA BUS

1. A data bus is a system within a computer or device, consisting of a connector or set of wires, that provides transportation for data.

2. A typical computer system will contain three buses, i.e
   a) Data bus
   b) Address bus
   c) Control bus



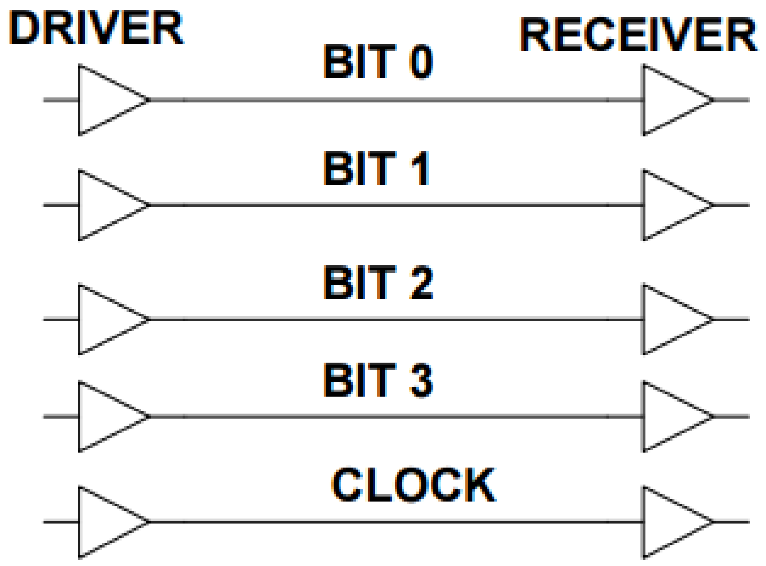
UNI-DIRECTIONAL DATA BUSES

1. Unidirectional data buses transmit data in only one direction.

2. Unidirectional data busses can range up to 512 bits wide.

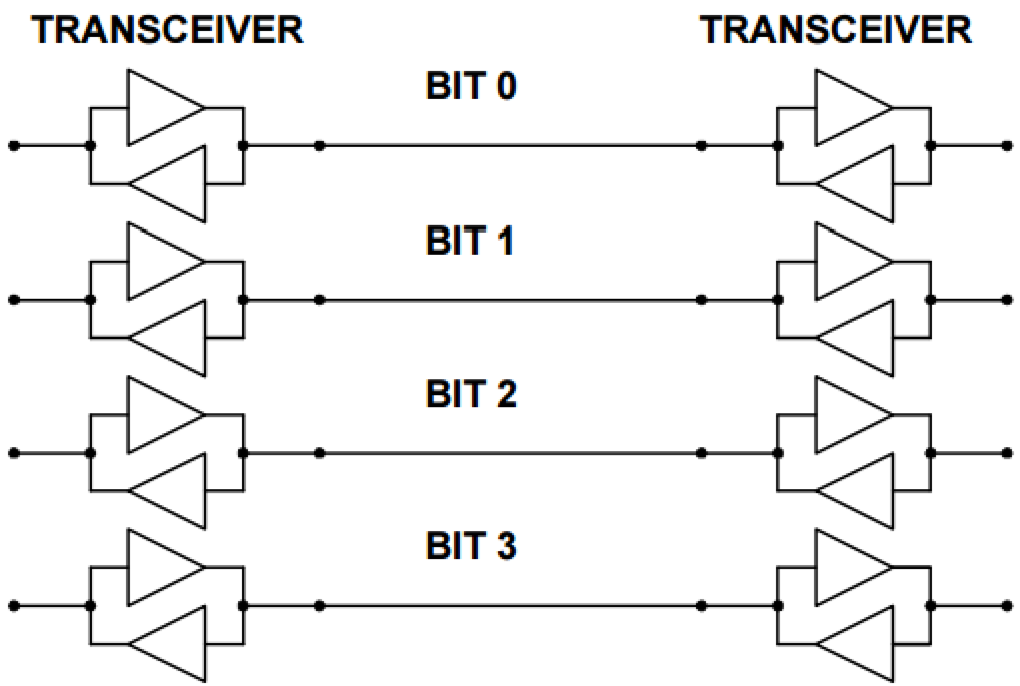
3. Examples of application areas for unidirectional data buses are:

   a) A/D and D/A converters
   b) Address bus for memory arrays.



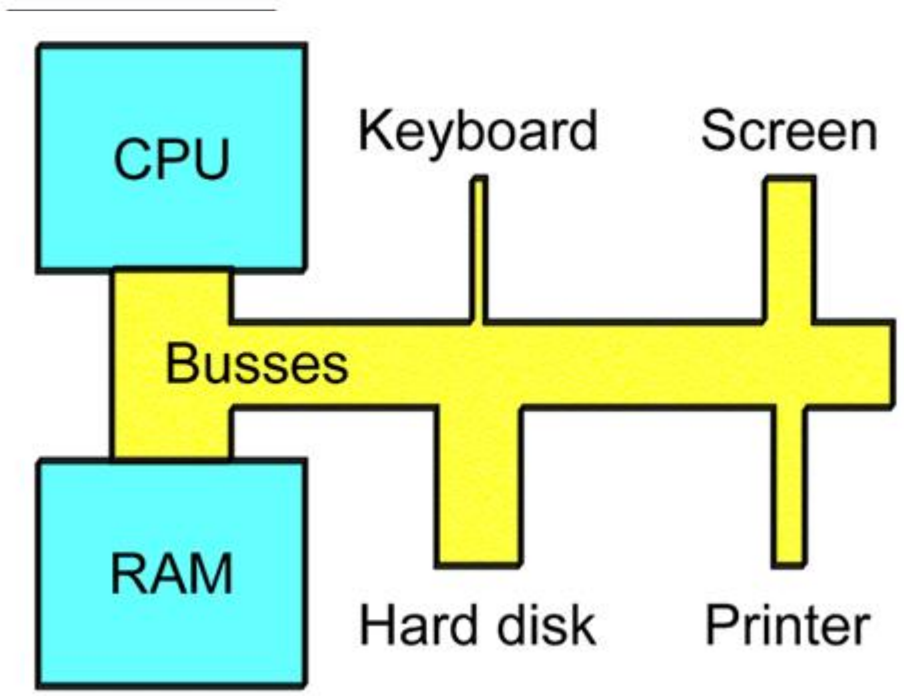
BIDIRECTIONAL DATA BUS

1. Bidirectional data bus transmits data in two directions.
2. A **bus supervisor circuit** is used to insure only one driver set is active at a time.
3. The bus supervisor creates the clock signals required by both the driver and receiver circuit.
4. The **Northbridge** and **Southbridge** ICs in a PC are examples of bus supervisor circuits.



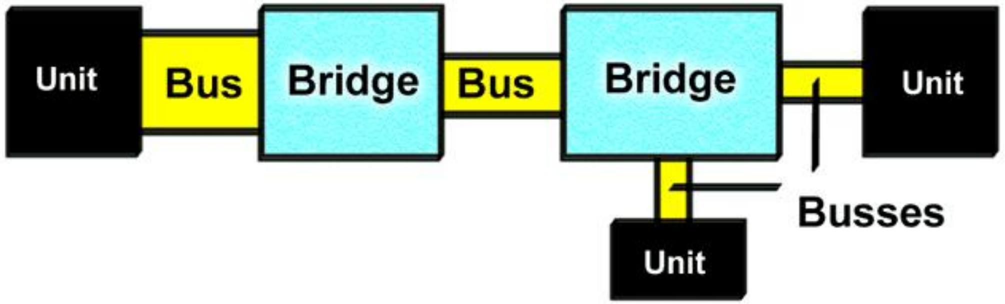
COMMUNICATION IN A PC

1. Data packets (of 8, 16, 32, 64 or more bits at a time) are constantly being moved back and forth between the CPU and all the other components (RAM, Hard Disk and Peripheral Devices).
2. These transfers are all done using *busses*.

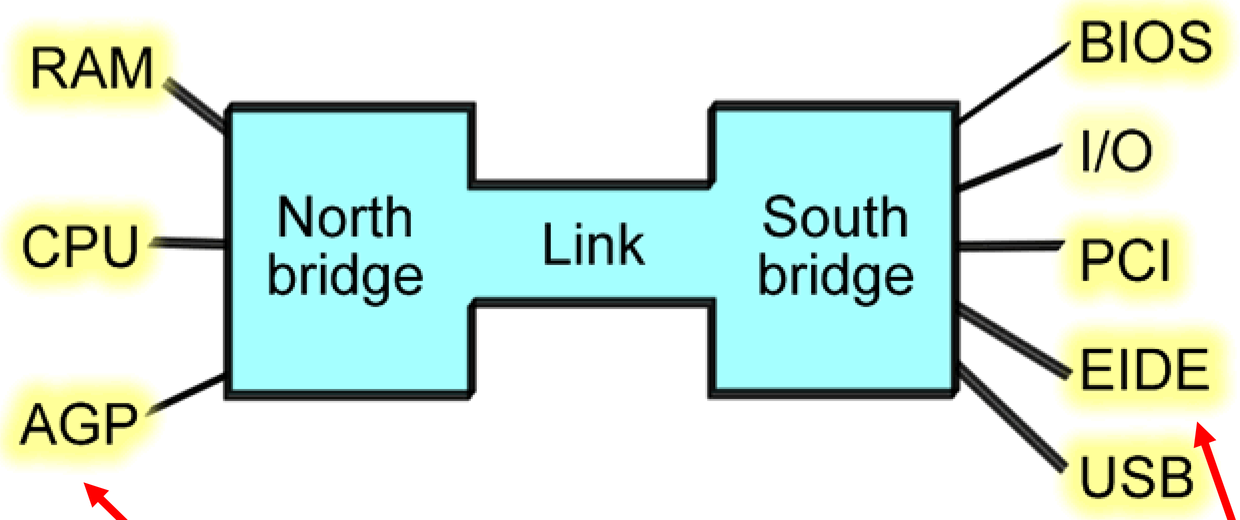


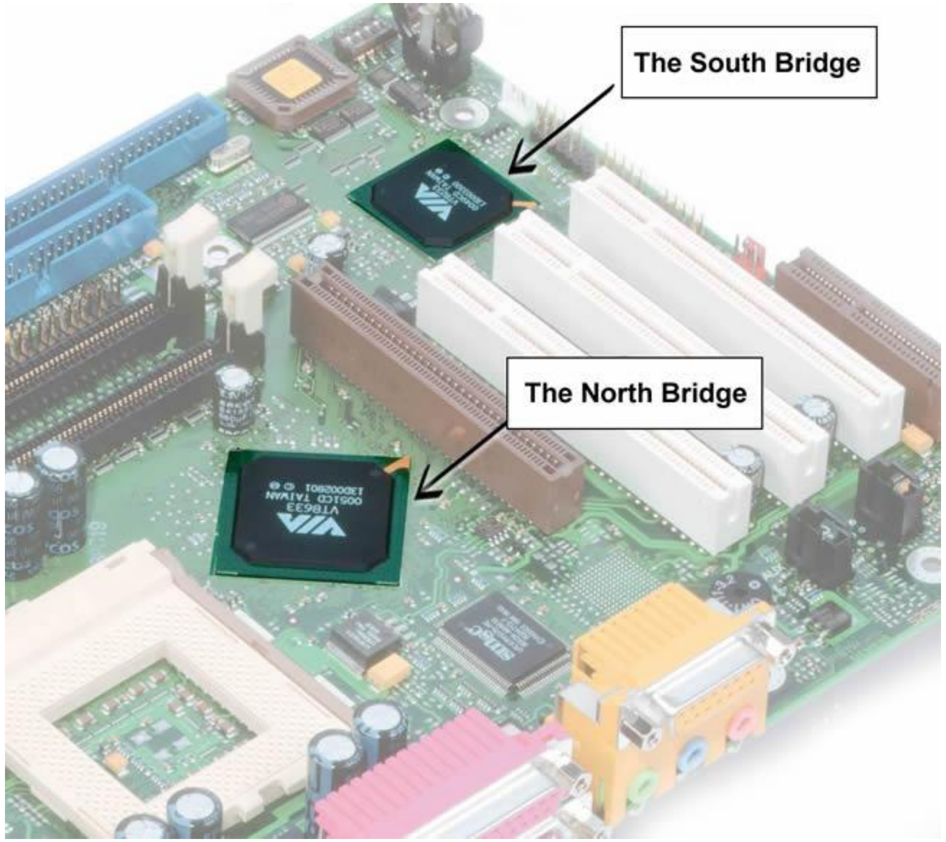
NEED FOR BRIDGES IN THE PC

1. PC bus system is subdivided into several branches.
2. Some of the PC components work with enormous amounts of data, while others manage with much less.
3. For example, the keyboard only sends very few bytes per second, whereas the RAM can send and receive several gigabytes per second.
4. **So you can't attach RAM and the keyboard to the same bus.**
5. Two busses with different capacities (data size and speed) can be connected if we place a controller between them.
6. **Such a controller is often called a *bridge***, since it functions as a link between the two different data speed systems.



NORTH BRIDGE & SOUTH BRIDGE





The **A**ccelerated **G**raphics **P**ort (often shortened to AGP) is a high-speed point-to-point channel for attaching a video card to a computer system to assist in the acceleration of 3D computer graphics.

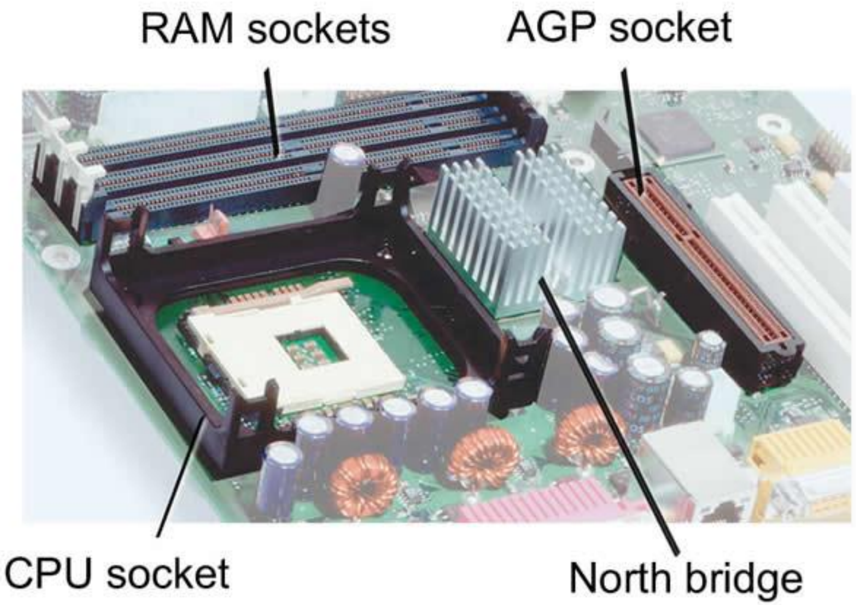
Extended Integrated Drive Electronics (IDE) interface

NORTH BRIDGE

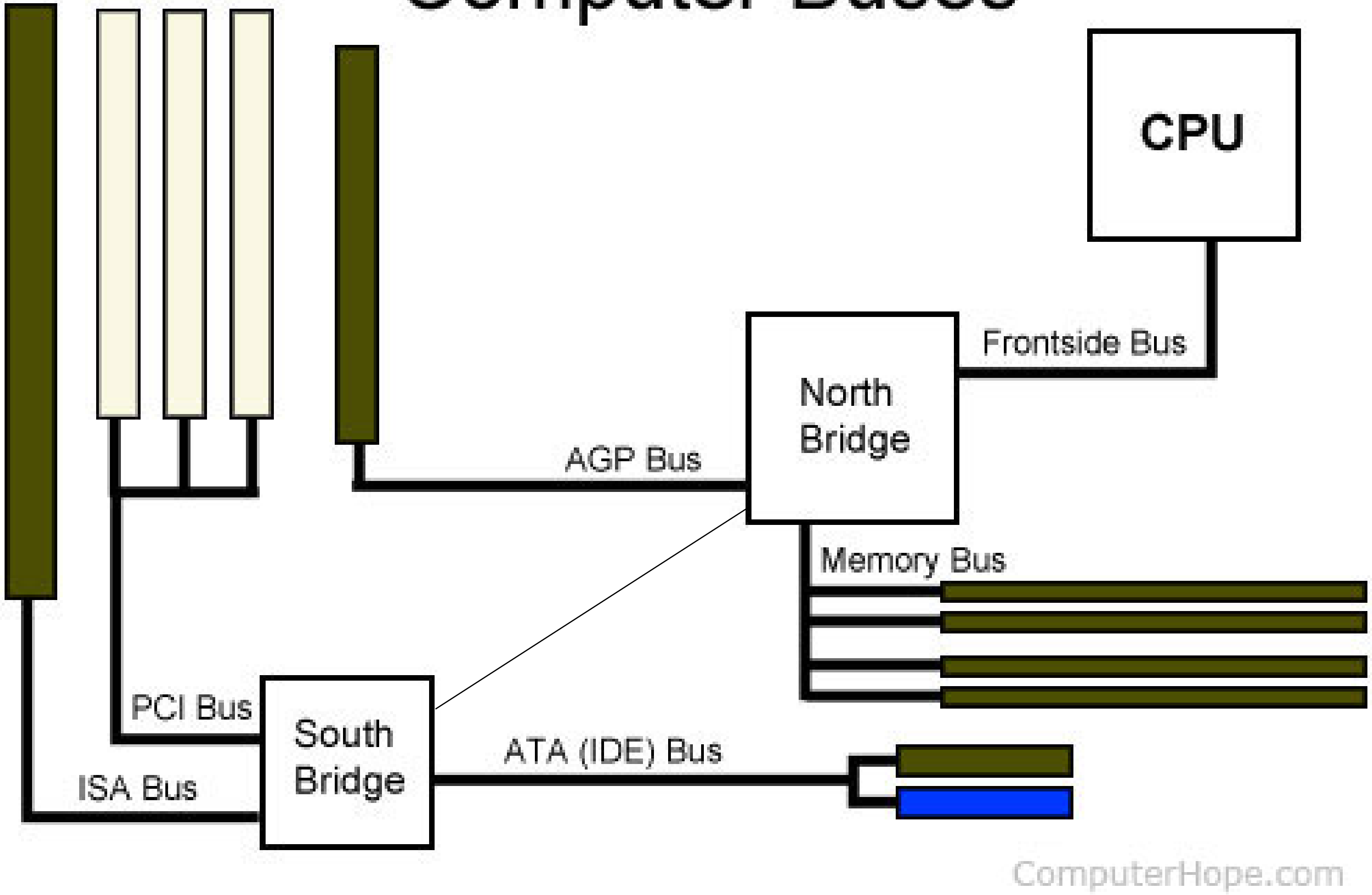
- The north bridge is a controller which controls the flow of data between the CPU and RAM, and to the Accelerated Graphics (AGP) port.

- In most cases, the north bridge has a large heat sink attached to it.

- It gets hot because of the very large amounts of data traffic which pass through it.

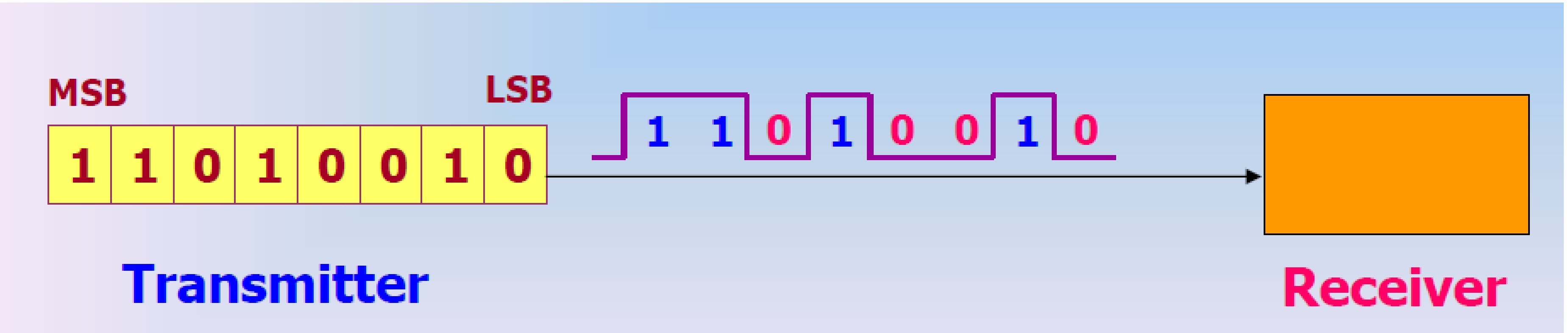


Computer Buses



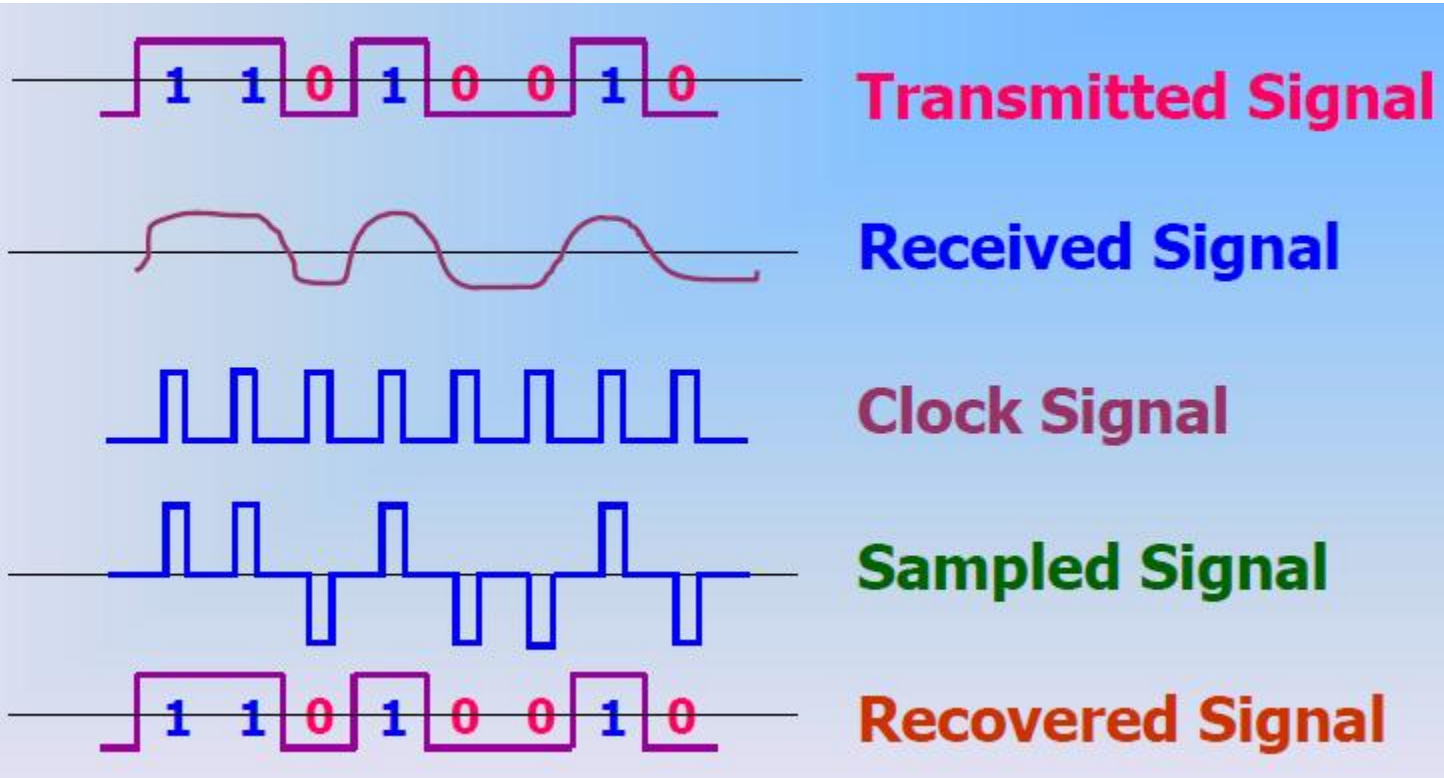
SERIAL COMMUNICATION

1. In a serial bus, bits are transmitted one after the other.
2. Usually the Least Significant Bit (LSB) is transmitted first
3. Serial Transmission requires only one pair of wires (or one carrier frequency in case of wireless) to interconnect two devices
4. Serial buses are preferred for Transmission over Long distance.



RECEIVING DATA BITS

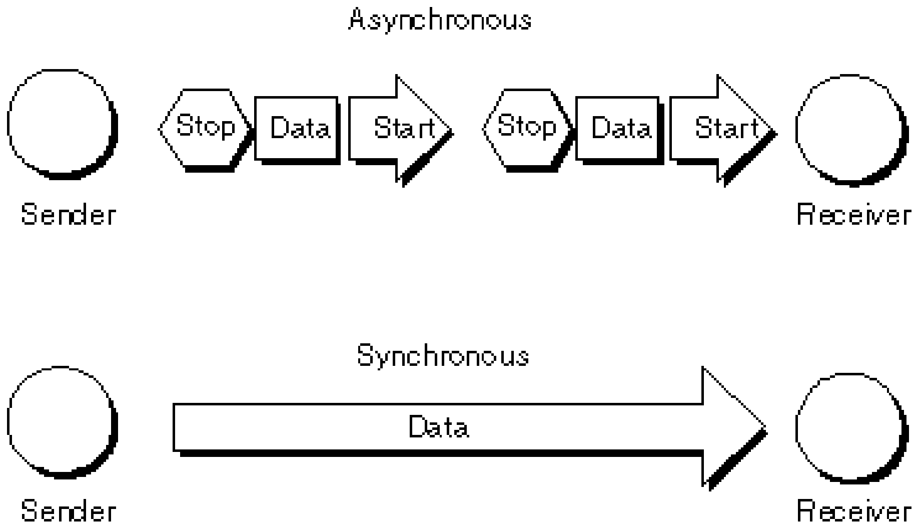
1. Received Signal is never same as transmitted due to line characteristics and interference.
2. Clock signal samples the signal and the receiver regenerates the original bits.
3. Received Signal should be sampled at right instant. Otherwise it will cause bit error.



TIMING & CONTROL OF SERIAL COMMUNICATION

Two methods for Timing control for receiving bits

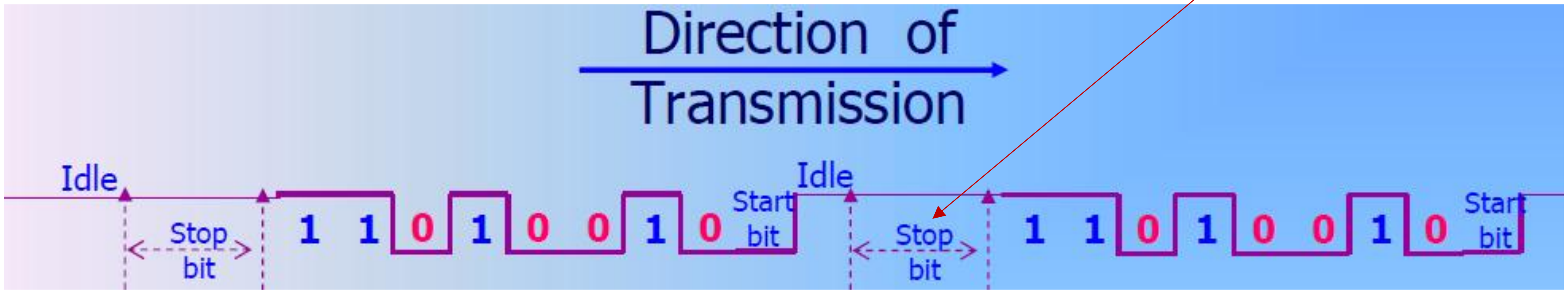
1. Asynchronous Transmission
   a) Transmitter commences the Transmission of bits at any instant of time
   b) No time relation between the consecutive bits
   c) During idle condition Signal '1' is transmitted
   d) "Start bit" before the byte and "Stop bit" at the end of the byte for Start/Stop synchronisation
2. Synchronous Transmission
   a) Transmission is carried out under the control of the timing signal.
   b) There are no Start/Stop bits
   c) Continuous block of Data are encapsulated with Header & Trailer along with Flags



ASYNCHRONOUS TRANSMISSION

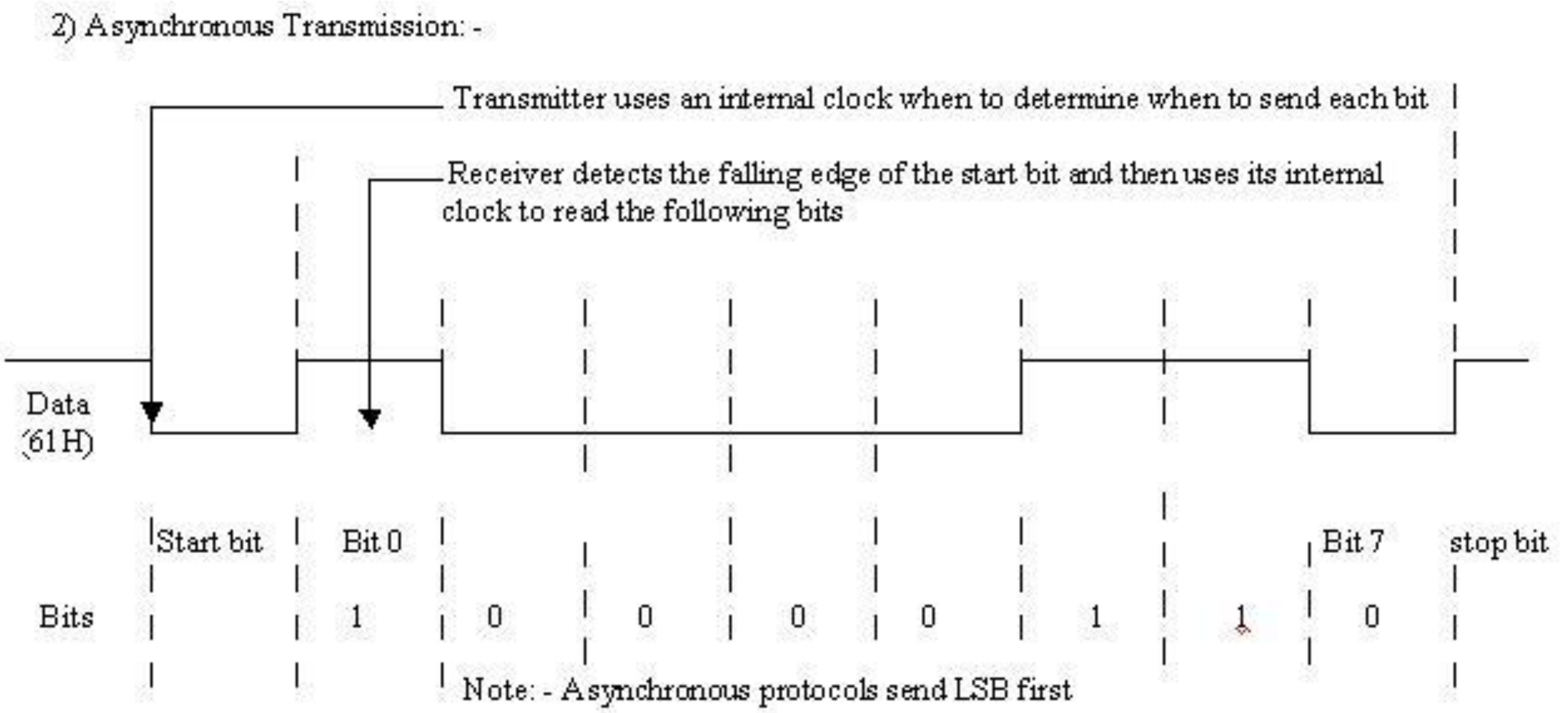
1. Asynchronous Transmission is synchronized using start-stop bits as shown below.

‘1’ is transmitted during idle time.



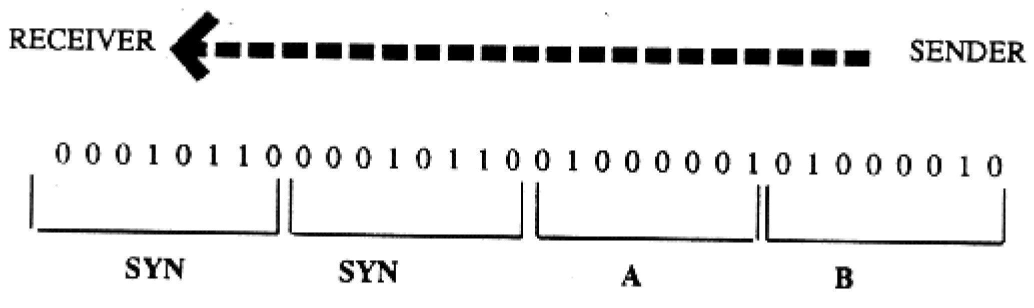
2. Asynchronous communication is useful for devices like computer keyboards which can be operated any time by the user. If a key of a keyboard is touched data flows from the keyboard to the computer. As soon as the key is released the data flow stops.

ASYNCHRONOUS COMMUNICATION



SYNCHRONOUS COMMUNICATION (1)

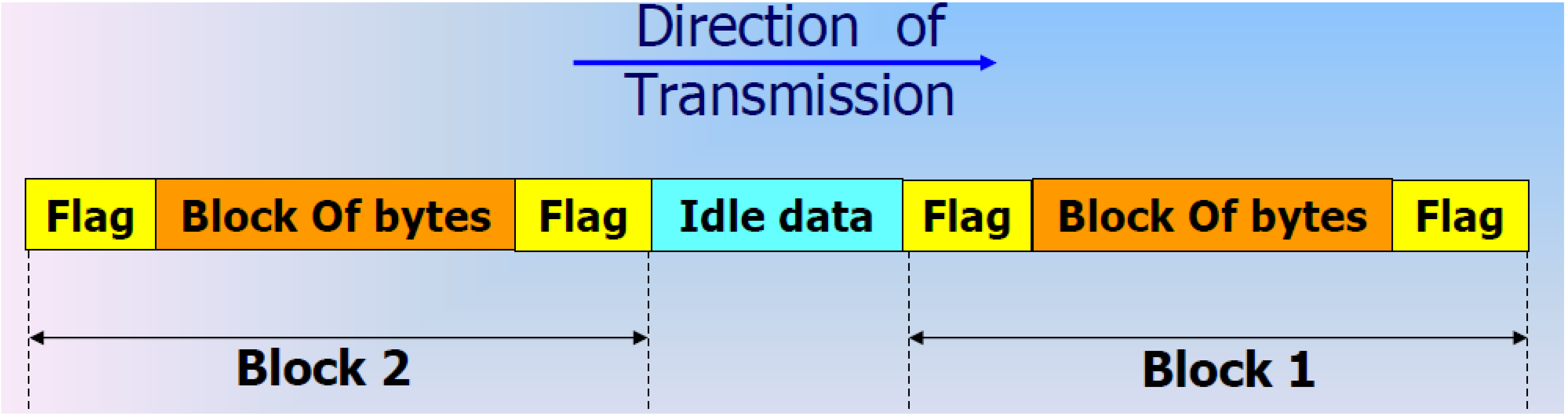
1. Characters/bytes are grouped together in blocks of some fixed size.
2. Each block transmitted is preceded by one or more special synchronisation characters, which can be recognised by the receiver.
3. ASCII provides a control character, SYN (ASCII code 22) for this unique purpose.



SYNCHRONOUS SERIAL TRANSMISSION

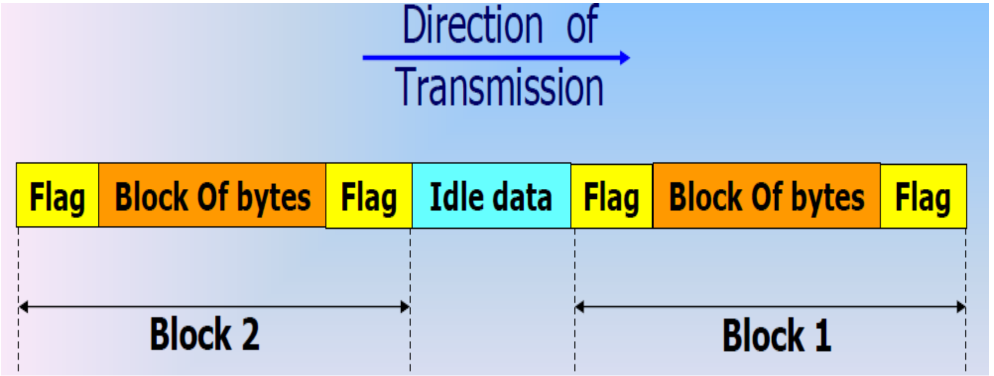
SYNCHRONOUS TRANSMISSION (2)

1. Flag identifies the Start and End of the block.
2. The Receiver first detects the Flag (usually a fixed pattern) and then detects the other bits/bytes in the data field.
3. Complete Block along with the Flags is called a FRAME.



FEATURES OF SYNCHRONOUS COMMUNICATION

1. Block of data transmitted without start or stop bits
2. Clocks must be synchronized
3. Can use separate clock line
   —Good over short distances
   —Subject to impairments
4. Embed clock signal in data
   —Manchester encoding
   —Carrier frequency (analog)
5. Need to indicate start and end of block
6. Use preamble and post-amble
   —e.g. series of SYN (hex 16) characters
   —e.g. block of 11111111 patterns ending in 11111110
7. More efficient (lower overhead) than async



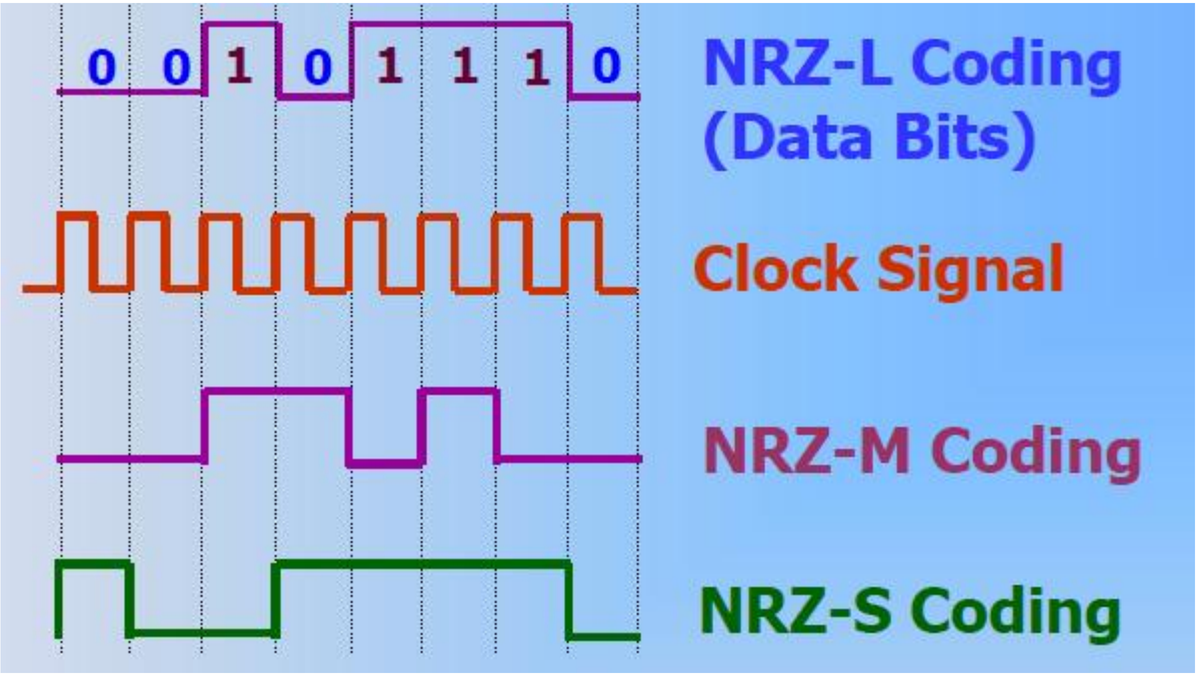
Further Reading:

LINE ENCODING

1. For transmission of bits into electrical signals for two binary states simple +ve and –ve voltages are not sufficient.
2. Sufficient Signal transition should be present to recover the clock properly at the receiving end.
3. Bandwidth of the signal should match with transmission medium.
4. Several ways to represent the bits as electrical signals. Two broad classes are:
   a) Non-Return to Zero (NRZ) and
   b) Return to Zero (RZ)

NRZ CODING

- **NRZ-L (Non-Return to Zero Level):** coded according to binary values of the Data bits).
- **NRZ-M (Non-Return to Zero on Mark):** Voltage Transition takes place on Mark (1).
- **NRZ-S (Non-Return to Zero on Space):** Voltage Transition takes place on Space (0)



RZ CODES

1. If there is continuous string of ‘0’s or ‘1’s in NRZ code it is very difficult to recover the clock signal
2. Hence **Return to Zero code (RZ)** was implemented Clock can be extracted from the Return to Zero code by the receiver using lot of transitions
3. RZ signals are the combination of “NRZ-L Signal + Clock Signal”
4. Examples of RZ codes are:
   - Manchester Code
   - Bi-phase-M Code
   - Bi-phase-S Code
   - Differential Manchester Code

FEATURES OF MANCHESTER CODING

1. Manchester coding (also known as phase encoding) is a line code in which the encoding of each data bit has at least one transition and occupies the same time.
2. It therefore
   a) has no DC component,
   b) can easily galvanically isolated using a network isolator.
3. A clock signal can be recovered from the encoded data.

ORIGIN & APPLICATIONS

1. **Manchester Code** was developed at the University of Manchester, where the coding was used to store data on the magnetic drum of the Manchester Mark 1 computer.

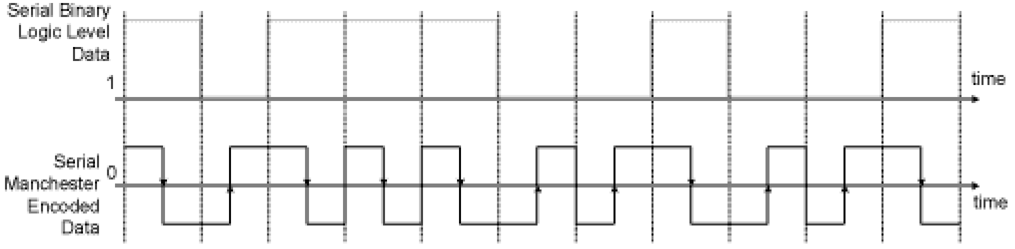
2. Manchester coding is currently used in:
   a) Ethernet - 10BASE-T (IEEE 802.3)
   b) Token Bus (IEEE 802.4) – Frozen standard
   c) Consumer IR devices e.g. remote controls
   d) RFID or near field communication.

MANCHESTER CODE

1. Manchester code embeds clock information with data as follows:
2. Each bit is transmitted with a transition in the middle of the bit time.

   a) For a ‘0’, transition is 0 to 1.

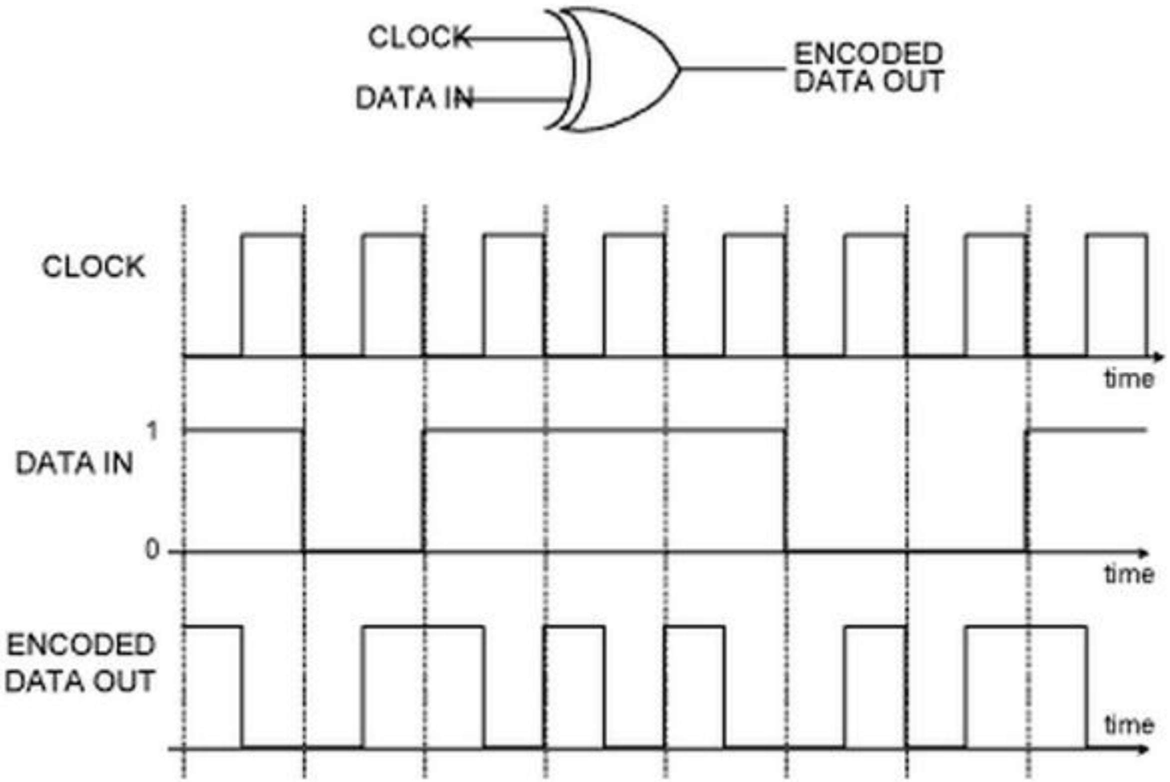
   b) For a ‘1’, transition is 1 to 0.



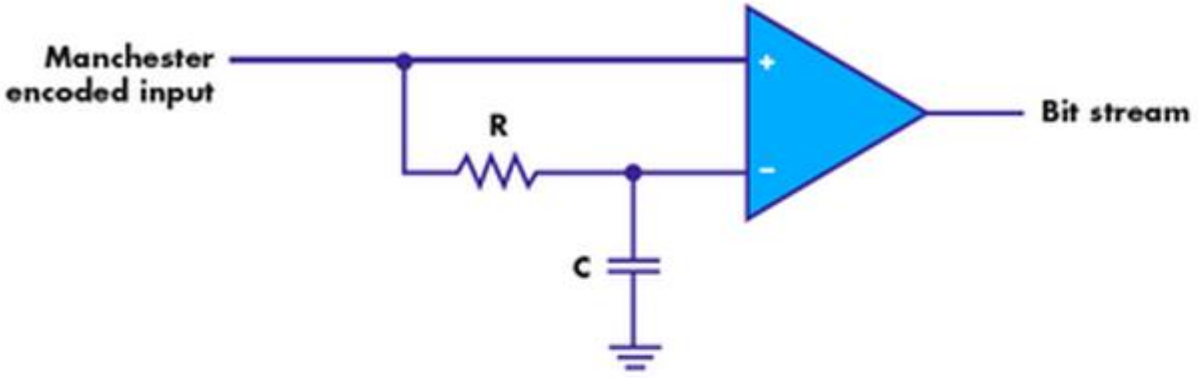
MANCHESTER ENCODING BY COMBINING DATA-RATE CLOCK AND SERIAL DATA BY XOR

1. Manchester data encoding is can be described as the process of a logical combining :
   a) the serial data to be encoded, and
   b) the clock used to establish the bit rate.

2. One commonly used method is by combining data-rate clock and serial data by XOR

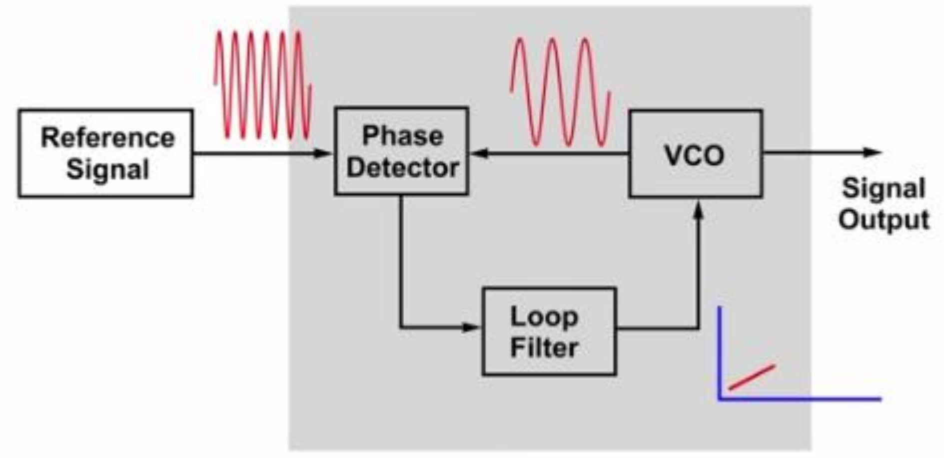


DECODING THE MANCHESTER CODED BITSTREAM USING A DATA SLICER

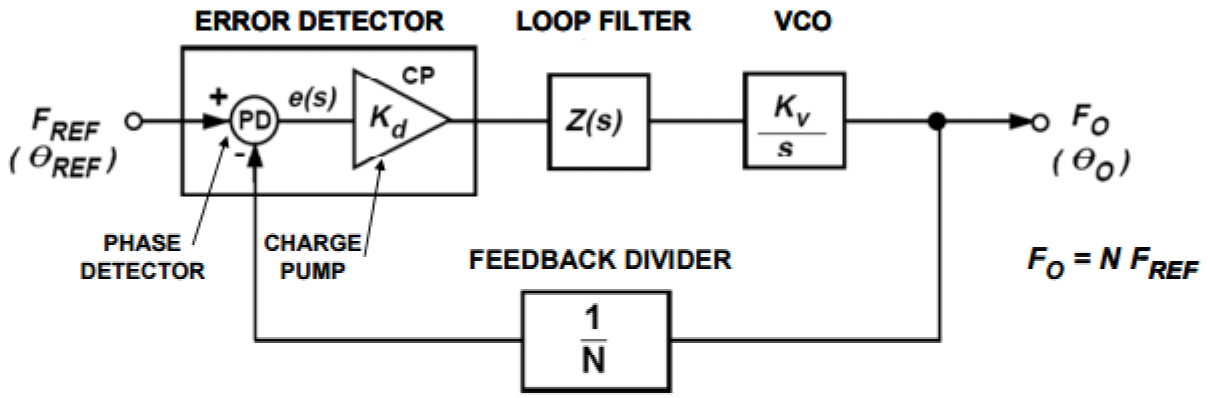


MANCHESTER CODE – CLOCK SYNCHRONIZATION

1. Another intrinsic value to Manchester encoding is the fact that the synchronizing clock is embedded within the signal.
2. This fact is exploited in **Ethernet**, which uses on-board circuitry to maintain clock synchronization.
   1. A Digital Phase Locked Loop (DPLL) circuit monitors the incoming Manchester-encoded signal
   2. The DPLL makes adjustments to its internal oscillator to keep it in constant synchronization with the transmitter's clock frequency.



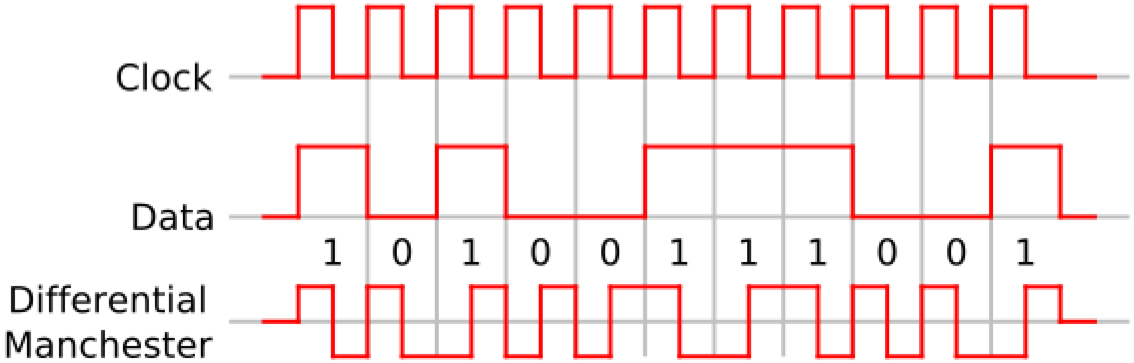
Analog Phase Locked Loop (PLL)



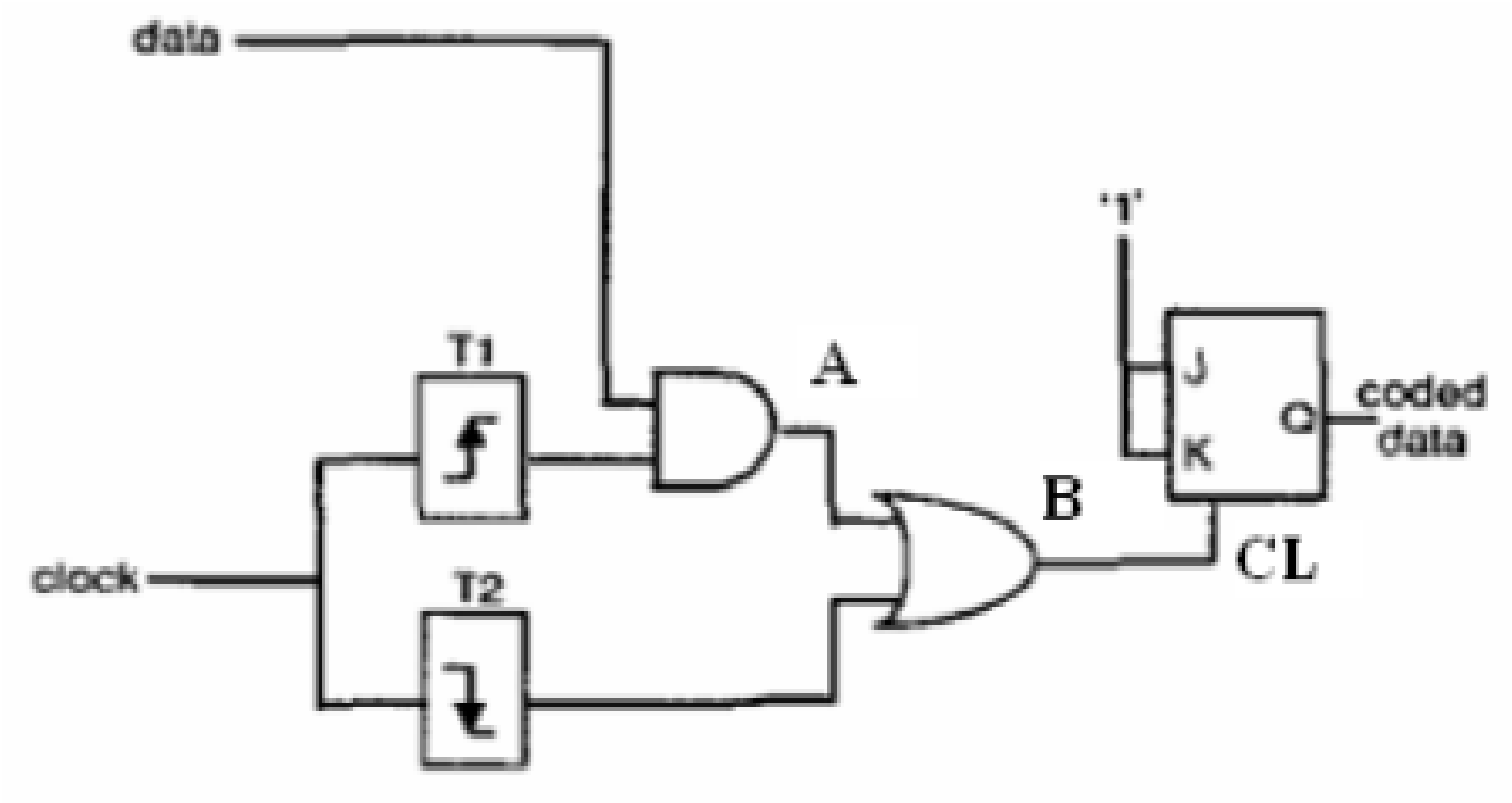
Digital Phase Locked Loop (PLL)

DIFFERENTIAL MANCHESTER CODING

- First introduced in 1998.
- It is a differential encoding, using the presence or absence of transitions to indicate logical value.
- It is not necessary to know the polarity of the received signal since the information is not kept in the actual values of the voltage but in their change
- In other words it does not matter whether a logical 1 or 0 is received, but only whether the polarity is the same or different from the previous value;



CIRCUIT FOR DIFFERENTIAL MANCHESTER CODING



ADVANTAGES OF DIFFERENTIAL MANCHESTER CODE

1. A transition is guaranteed at least once every bit, allowing the receiving device to perform clock recovery.
2. Unlike with Manchester encoding, only the presence of a transition is important, not the polarity. Detecting transitions is often less error-prone than comparing against a threshold in a noisy environment.
3. DMC Coded signals have zero average DC voltage, thus reducing the necessary transmitting power and minimizing the amount of electromagnetic noise produced by the transmission line.