Representation of information

UNIT 1: USE OF MICROCOMPUTING SYSTEMS. SECOND PART

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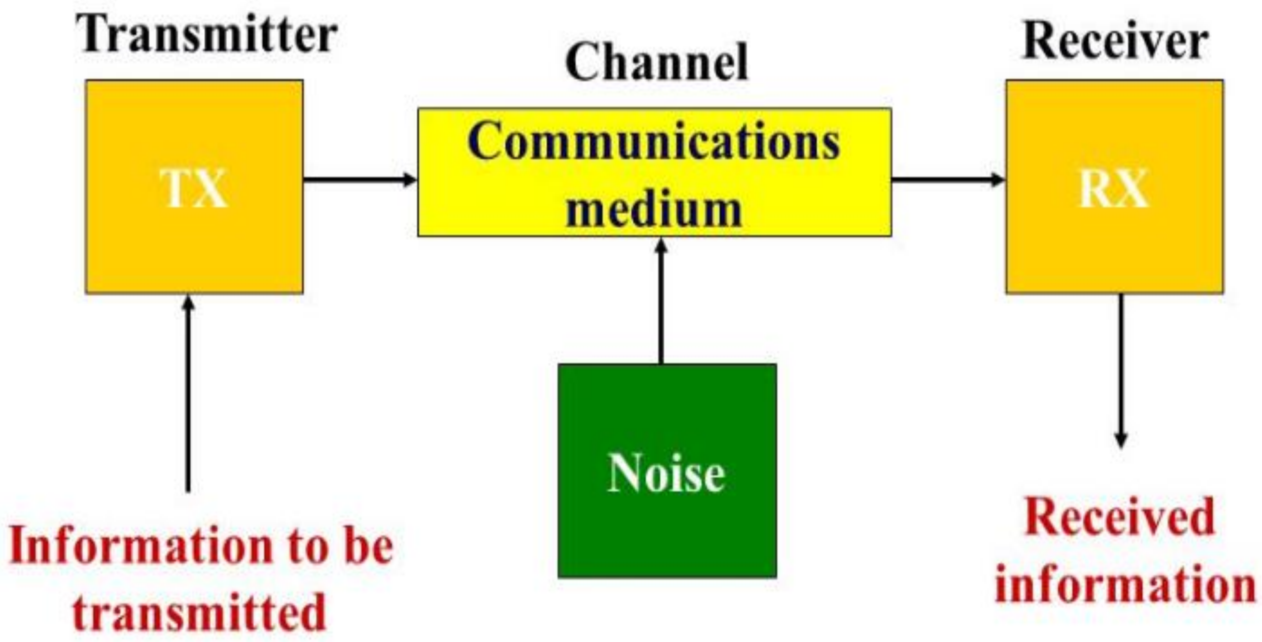
1. Introduction

- Computers basically get input data, transform this data and produce results.
- The purpose of computers is to automate work.
- Computer components understand neither letters nor numbers, but electric current and other physical magnitudes.
- We need codification systems, which convert letters and numbers to something understandable for computers.
- The OS, together with the hardware components, converts the information into electricity and vice versa.

1. Introduction

- Communication system:
  - Transmitter
  - Receiver
  - Channel
- Unidirectional or bidirectional



2. Encoding information

- Information broadcasting
  - Alphanumeric characters (a…z, A..Z, 0….9)
  - Sounds
  - Videos
  - Graphs and pictures

Each type of information works different and has its own way of representing data.

The existence of information requires a common code between transmitter and receiver.

2. Encoding information

- All the information in a computer is stored with two symbols: 1 and 0.
- These two numbers represent two electrical states, which make possible to build reliable internal computer circuits.
- It is necessary a clear correspondence between human symbols (characters, numbers, signs, etc.) and binary symbols (1 and 0),
- This process is called encoding, while decoding is the opposite one.

3. Numeral systems

- A numeral system (also known as system of numeration or number system) is a mathematical notation for representing numbers of a given set, using digits or other symbols, according to some rules.
- The common system uses 10 digits, but we have different bases depending on how many digits are used in a system of numeration to represent numbers
  - **Decimal system (base 10):** 0,1,2,3,4,5,6,7,8,9.
  - **Binary system (base 2):** 0,1
  - **Octal system (base 8):** 0,1,2,3,4,5,6,7
  - **Hexadecimal system (base 16):** 0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F

3. Numeral systems

- The most commonly used systems today are positional
- Value of numbers is determined by **weight** and **position** of each digit.
- The value of each digit position is the value of its digit, multiplied by a power of the base.
- In general, if b is the base, one writes a number in the numeral system of base b by expressing it in the form $a_n b^n + a_{n-1} b^{n-1} + a_{n-2} b^{n-2} + \ldots + a_0 b^0$ and writing the enumerated digits $a_n a_{n-1} a_{n-2} \ldots a_0$ in descending order.

3. Numeral systems

- Any numeral system can be summarized by the following relationship:

  $N = \sum b_i q^i$

  where: N is a real positive number
  b is the digit
  q is the base value
  and integer (i) can be positive, negative or zero

- So, in positional base-10 notation: 458 (base 10) = $4*10^2 + 5*10^1 + 8*10^0$
- And, in positional base-2 notation: 1110000 (base 2) = $1*2^6 + 1*2^5 + 1*2^4 + 0*2^3 + 0*2^2 + 0*2^1 + 0*2^0$

3.1. Binary system

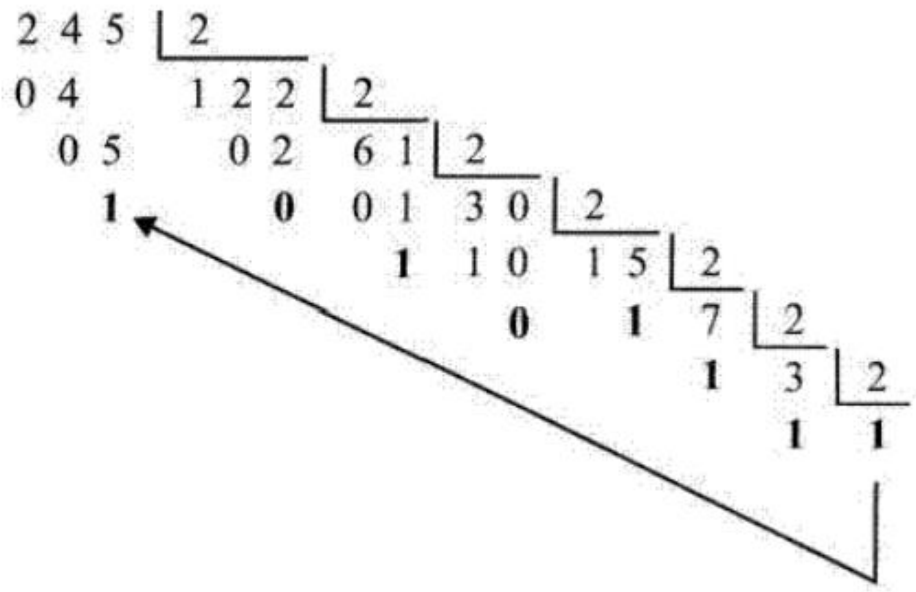
- It is composed of two symbols: 0,1
- Base 2
- Digital systems are based on binary numbers.

0	**0 volts**	**OFF**	**NO**
1	**5 volts**	**ON**	**YES**

- Ex: 1110000 (base 2) = $1*2^6 + 1*2^5 + 1*2^4 + 0*2^3 + 0*2^2 + 0*2^1 + 0*2^0$
- To convert a binary number to decimal, just add the final value of each power of two. According to the example: 1110000 (base 2) = 112 (base 10)

3.1. Binary system

- **To convert a decimal number to binary**:
  - ➢ Divide the input decimal number by 2.
  - ➢ Repeat this process till quotient becomes zero.
  - ➢ Equivalent binary number will be the remainders in above process in reverse order.
- Example: N = 245



- Result = 11110101

3.1. Binary system

- Having n bits, we can represent 2^n values
- Basic powers of 2:
  - $2^1 = 2$… Having 1 bit we represent 2 numbers
  - $2^2 = 4$… Having 2 bits we represent 4 numbers
  - $2^3 = 8$… Having 3 bits we represent 8 numbers
  - $2^4 = 16$… Having 4 bits we represent 16 numbers
- And so on…

3.1. Binary system

- Exercises:

1. Convert from decimal to binary
   - 517
   - 425
   - 315
2. Convert from binary to decimal
   - 1011
   - 10100110
   - 11011

3.2. Conversion between numeral systems

- We have studied how to transform a binary number into decimal and vice versa.
- To convert a binary number to decimal, the equivalent value is equal to the sum of binary digits (d_n) times their power of 2 (2^n). To convert from any numeral system to decimal, we can use the same method, replacing base-2 with the corresponding base.
- To convert a decimal number to binary, we divided and multiplied by 2. To convert from a decimal number to any other numeral system, we can divide and multiply in the same way, but using the corresponding base.
- So…

3.2. Conversion between numeral systems

- We can set a general rule to convert a base-a number to a base-b number:
  - Convert the original number to a decimal number (base 10).
  - Convert the decimal number obtained to the new base number.

  - $N_A \Rightarrow N_{10}$
  - $N_{10} \Rightarrow N_B$

3.2. Conversion between numeral systems

- Exercises:

1. Convert 5270_{10} to base 8
2. Convert 543_{10} to base 8.
3. Convert 3456_8 to binary.
4. Convert 243_{10} to base 5
5. Convert 531_6 to base 10

3.3. Octal and hexadecimal numbers

- Binary system becomes complicated because of the amount of digits used to represent numbers.
- Computers sometimes use base 8 and 16.
- This way, it is easier to convert from and to 2, 8 and 16 bases.
- Octal uses 8 symbols (0..7)
- Hexadecimal uses 16 symbols (0..9, A..F)
- **Let’s take a look on the conversion table in the next slide.**

3.3. Octal and hexadecimal numbers

Dec	Hex	Oct	Bin
0	0	000	0000
1	1	001	0001
2	2	002	0010
3	3	003	0011
4	4	004	0100
5	5	005	0101
6	6	006	0110
7	7	007	0111
8	8	010	1000
9	9	011	1001
10	A	012	1010
11	B	013	1011
12	C	014	1100
13	D	015	1101
14	E	016	1110
15	F	017	1111

3.3. Octal and hexadecimal numbers

- There is a shortcut method for conversions between octal and binary and vice versa.

1. Octal to binary

   - Convert each octal digit to a 3 digit binary number (the octal digits may be treated as decimal for this conversion), according to the previous table.
   - Combine all the resulting binary groups (of 3 digits each) into a single binary number.
     - ✓ $351)_8 = \underline{\mathbf{0}11}\ \underline{101}\ \underline{001})_2$ (we can pad zeros on the left)

3.3. Octal and hexadecimal numbers

2. Binary to octal

- Divide the binary digits into groups of three (starting from the right).
- Convert each group of three binary digits to one octal digit.
  - ✓ $\underline{010}\ \underline{101}\ \underline{100})_2 = 254)_8$ (if there are less than 3 numbers on the left, we pad with zeros)

3.3. Octal and hexadecimal numbers

- To convert from hexadecimal to binary and vice versa, we use the same method as before, but grouping in four.
- Each four numbers are equivalent to an hexadecimal digit.
  - ✓ $15F)_{16}$ = **000**1 0101 1111$)_2$ (we can pad zeros on the left)
  - ✓ 00**11** **1101**$)_2$ = $3D)_{16}$ (if there are less than 4 numbers on the left, we pad with zeros)

3.3. Octal and hexadecimal numbers

- Exercises:

1. Convert $5270)_{10}$ to octal.
2. Convert $3456)_{8}$ to binary.
3. Convert $5270)_{10}$ to hexadecimal
4. Convert $3456)_{16}$ to binary.
5. Convert $454)_{8}$ to hexadecimal.
6. Convert $1C)_{16}$ to octal.

4. Alphanumeric characters

- Computers not only process numbers, but also letters, special symbols or complex types of data such as sound and pictures.
- In computer science, **alphanumeric is a combination of letters and numbers**.
- Each character has a numeric representation, whose binary conversion allows to store data in a “human” format.
- We have different <u>character sets and encodings</u> to represent information.
- ASCII, EBCDIC, UNICODE or UTF-8 are four of the most important ones.

4.1. ASCII

- ASCII is the abbreviated from American Standard Code for Information Interchange
- The original ASCII table is encoded on 7 bits therefore it has 128 characters.
- Nowadays most computers use an **extended ASCII table** (from ISO 8859-1), which is encoded on 8 bits
- Current ASCII can represent 256 characters (including Á, Ä, Œ, é, è and other characters useful for European languages as well as mathematical glyphs and other symbols).

4.1. ASCII (7 bits)

ASCII Code Chart

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0	NUL	SOH	STX	ETX	EOT	ENQ	ACK	BEL	BS	HT	LF	VT	FF	CR	SO	SI
1	DLE	DC1	DC2	DC3	DC4	NAK	SYN	ETB	CAN	EM	SUB	ESC	FS	GS	RS	US
2		!	"	#	$	%	&	'	(	)	*	+	,	-	.	/
3	0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?
4	@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
5	P	Q	R	S	T	U	V	W	X	Y	Z	[	\	]	^	_
6	`	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
7	p	q	r	s	t	u	v	w	x	y	z	{	|	}	~	DEL

4.1. ASCII (8 bits)

128	Ç	144	É	160	á	176	░	193	┴	209	╤	225	ß	241	±
129	ü	145	æ	161	í	177	▒	194	┬	210	╥	226	Γ	242	≥
130	é	146	Æ	162	ó	178	▓	195	├	211	╙	227	π	243	≤
131	â	147	ô	163	ú	179	│	196	─	212	╘	228	Σ	244	⌠
132	ä	148	ö	164	ñ	180	┤	197	┼	213	╒	229	σ	245	⌡
133	à	149	ò	165	Ñ	181	╡	198	╞	214	╓	230	µ	246	÷
134	å	150	û	166	ª	182	╢	199	╟	215	╫	231	τ	247	≈
135	ç	151	ù	167	º	183	╖	200	╚	216	╪	232	Φ	248	°
136	ê	152	_	168	¿	184	╕	201	╔	217	┘	233	Θ	249	∙
137	ë	153	Ö	169	_	185	╣	202	╩	218	┌	234	Ω	250	·
138	è	154	Ü	170	¬	186	║	203	╦	219	█	235	δ	251	√
139	ï	156	£	171	½	187	╗	204	╠	220	▄	236	∞	252	_
140	î	157	¥	172	¼	188	╝	205	═	221	▌	237	φ	253	²
141	ì	158	_	173	¡	189	╜	206	╬	222	▐	238	ε	254	■
142	Ä	159	ƒ	174	«	190	╛	207	╧	223	▀	239	∩	255	
143	Å	192	└	175	»	191	┐	208	╨	224	α	240	≡		

4.2. EBDIC

- **Extended Binary Coded Decimal Interchange Code (EBCDIC)** is an 8-bit character encoding used mainly on IBM mainframe and IBM midrange computer operating systems.
- When moving information between EBCDIC machines and ASCII machines it is quite often necessary to convert the information.
- It is not a straightforward process, as EBCDIC put lowercase letters before uppercase letters and letters before numbers, exactly the opposite of ASCII.
- EBCDIC is used nowadays in modern mainframes only to provide backwards compatibility.

4.2. EBDIC

	0000 0	0001 1	0010 2	0011 3	0100 4	0101 5	0110 6	0111 7	1000 8	1001 9	1010 A	1011 B	1100 C	1101 D	1110 E	1111 F
0000 0	NUL 0	DLE 16	DS 32	48	SP 64	& 80	- 96	112	128	144	160	176	{ 192	} 208	\ 224	0 240
0001 1	SOH 1	DCI 17	SOS 33	49	65	/ 81	97	113	a 129	j 145	161	177	A 193	J 209	225	1 241
0010 2	STX 2	DC2 18	FS 34	SYN 50	66	82	98	114	b 130	k 146	s 162	178	B 194	K 210	S 226	2 242
0011 3	ETX 3	TM 19	35	51	67	83	99	115	c 131	l 147	t 163	179	C 195	L 211	T 227	3 243
0100 4	PF 4	RES 20	BYP 36	PN 52	68	84	100	116	d 132	m 148	u 164	180	D 196	M 212	U 228	4 244
0101 5	HT 5	NL 21	LF 37	RS 53	69	85	101	117	e 133	n 149	v 165	181	E 197	N 213	V 229	5 245
0110 6	LC 6	BS 22	ETB 38	UC 54	70	86	102	118	f 134	o 150	w 166	182	F 198	O 214	W 230	6 246
0111 7	DEL 7	IL 23	ESC 39	EOT 55	71	87	103	119	g 135	p 151	x 167	183	G 199	P 215	X 231	7 247
1000 8	8	CAN 24	40	56	72	88	104	120	h 136	q 152	y 168	184	H 200	Q 216	Y 232	8 248
1001 9	RLF 9	EM 25	41	57	73	89	105	\ 121	i 137	r 153	z 169	185	I 201	R 217	Z 233	9 249
1010 A	SMM 10	CC 26	SM 42	58	cent 74	! 90	| 106	: 122	138	154	170	186	202	218	234	250
1011 B	VT 11	CU1 27	CU2 43	CU3 59	. 75	$ 91	, 107	# 123	139	155	171	187	203	219	235	251
1100 C	FF 12	IFS 28	44	DC4 60	< 76	* 92	% 108	@ 124	140	156	172	188	204	220	236	252
1101 D	CR 13	IGS 29	ENQ 45	NAK 61	(77	) 93	_ 109	’ 125	141	157	173	189	205	221	237	253
1110 E	SO 14	IRS 30	ACK 46	62	+ 78	; 94	> 110	= 126	142	158	174	190	206	222	238	254
1111 F	SI 15	IUS 31	BEL 47	SUB 63	| 79	¬ 95	? 111	” 127	143	159	175	191	207	223	239	255

4.3. Unicode vs UTF-8

- **UTF-8 is an encoding - Unicode is a character set**
- A character set is a list of characters with unique numbers. For example, in the Unicode character set, the number for A is 41.
- Unicode is a standard that defines a superset of all existing characters required to represent practically all known languages.
- UTF-8 encodes each of the 1,112,064 valid code points in Unicode using one to four 8-bit bytes.
- The first 128 characters of Unicode, which correspond one-to-one with ASCII, are encoded using a single octet with the same binary value as ASCII.
- There are other encodings, such UTF-8, UTF-16, UTF-32, UTF-EBCDIC or GB 18030

5. Units of information

- A **bit** is a binary digit, the smallest increment of data on a computer. As we mentioned at the beginning, a bit can hold only one of two values: 0 or 1, corresponding to the electrical values of off or on, respectively.
- Several conventional names are used for collections or groups of bits:
  - Nibble = 4 bits
  - Byte = 8 bits
  - Kilobyte (KB) = 1000 bytes = 10^3 bytes
  - Megabyte (MB) = 1000 KB = 10^6 bytes
  - Gigabyte (GB) = 1000 MB = 10^9 bytes
  - Terabyte (TB) = 1000 GB = 10^{12} bytes
  - Petabyte (PB) = 1000 TB = 10^{15} bytes
  - Exabyte (EB) = 1000 PB = 10^{18} bytes
- <u>BE CAREFUL:</u> We do not use the "1024" equivalences anymore because the prefixes kilo and mega mean 1000 and 1000000 respectively in the in the International System of Units.

5. Units of information

- Computers count by base 2, so we commonly use “binary” units of information.
  - Nibble = 4 bits
  - Byte = 8 bits
  - Kibibyte (KiB) = 1024 bytes
  - Mebibyte (MiB) = 1024 KiB = 1,048,576 bytes
  - Gibibyte (GiB) = 1024 MiB = 1,048,576 bytes
  - Tebibyte (TiB) = 1024 GiB = 1,099,511,627,776 bytes
  - Pebibyte (PiB) = 1024 TiB = 1,125,899,906,842,624 bytes
  - Exbibyte (EiB) = 1024 PiB = 1,152,921,504,606,846,976 bytes

5. Units of information

- Computers count by base 2, so we use "binary" conversions.
  - 1 KiB = 1024 bytes = 2^{10} bytes = 2^{13} bits
  - 1 MiB = 1024 KiB = $2^{10} * 2^{10} = 2^{20}$ bytes = 2^{23} bits
  - 1 GiB = 1024 MiB = $2^{10} * 2^{10} * 2^{10} = 2^{30}$ bytes = 2^{33} bits
  - 1 TiB = 1024 GiB = $2^{10} * 2^{10} * 2^{10} * 2^{10} = 2^{40}$ bytes = 2^{43} bits
  - …..
- <u>Notice that:</u> **B represents bytes** and **b means bit**. For example:
  - 30 MB = 30 megabytes (used in storage devices)
  - 30 MiB = 30 mebibytes (used in storage devices)
  - 30 Mbs = 30 megabits per second (used in networking or devices bandwidth)
  - 30 Mibs = 30 mebibits per second (used in networking or devices bandwidth)

END