## **Bits and Bytes**



How is information stored at the lowest level in a computer?



### Can you read this?



#### **Bits and bytes**

Fundamentally, digital computers are machines that convert high and low electrical signals into 0's and 1's.

- The lowest level of communication with a digital computer is 0's and 1's
- Let's learn to speak its native language!









### **Can you read this?**

00111111

#### **Binary Place-Value**





### **Can you read this?**

00111111





	et's	all 1	trans	late	this	 *
Decin	nal	Binary				
1		000001	9			
2		000010				
3		000011	15			
4	<u> </u>	000100				
5		000101	34			
6	<b>→</b> 000	000110				
7	<b>→</b> 000	000111	85			
8		001000				
Re	minder: 12	28 . 64 .	32 16	8 4	2 1	 

Car	ı you t	transl	ate th	nis?	*
Decimal <b>1</b>	00000001	12			:
2	0000010				
3	0000011	21			
4	00000100				
5	00000101	51			
6	00000110				
7	00000111	101			
8	00001000	255			
Reminder:					

Ascittable 33 $\frac{1}{1}$ $\frac{65}{65}$ $\frac{8}{A}$ $\frac{96}{7}$ $\frac{1}{33}$ $\frac{1}{1}$ $\frac{65}{65}$ $\frac{8}{A}$ $\frac{97}{9}$ $\frac{8}{9}$ $\frac{1}{9}$ $\frac{1}{65}$ $\frac{8}{5}$ $\frac{99}{6}$ $\frac{1}{33}$ $\frac{1}{7}$ $\frac{65}{6}$ $\frac{8}{69}$ $\frac{99}{2}$ $\frac{1}{101}$ $\frac{1}{61}$ $\frac{39}{39}$ $\frac{1}{7}$ $\frac{71}{10}$ $\frac{6}{101}$ $\frac{1}{201}$ $\frac{1}{21}$ $\frac{39}{100}$ $\frac{1}{710}$ $\frac{71}{1000}$ $\frac{1}{1000}$ $\frac{1}{10000}$ $\frac{1}{10000000000000000000000000000000000$	 Dec	Char	Dec	Char	Dec	Char
$63 \ 2 \ 95 \ - \ 100 \ 111111 \ 9 \ 1001111111 \ 9 \ 1001111111 \ 1001 \ 11000 \ 1100 \ 110$	32	SPACE	64	0	96	•
001111111 63 34 " 66 B 99 b 35 # 67 C 99 c 39 c 68 b 30 c 37 b 69 E 101 c 39 c 71 c 103 g 40 (72 H 104 h 105 i 42 c 74 J 106 j 43 + 75 K 107 k 44 , 76 L 108 l 44 , 76 L 108 l 45 - 77 M 109 m 46 . 78 N 110 n 47 / 79 0 111 0 113 q 50 2 82 R 114 r 51 3 83 S 115 s 52 4 84 T 116 t 53 5 85 U 117 u 48 0 80 P 112 p 48 0 80 P 112 p 116 t 53 5 85 U 117 u 55 7 87 W 119 w 56 8 88 X 120 x 56 7 97 9 11 (123 4 60 < 92 \ 122 1 95 ; 91 [ 122 2 59 ; 91 [ 122 2 124 ] 125 ] 127 DEL	33	1	65	A	97	a
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001111111 633 37 % 69 E 101 e 38 % 70 F 102 f 39 ' 71 G 103 g 40 ( 72 H 104 h 41 ) 73 I 105 i 42 * 74 J 106 j 43 + 75 K 107 k 44 , 76 L 108 l 45 - 77 M 109 m 46 . 78 N 110 n 47 / 79 0 111 0 48 0 80 P 112 p 49 1 81 0 113 q 50 2 82 R 114 r 51 3 83 S 115 s 52 4 84 T 116 t 53 5 85 U 117 u 54 6 86 V 118 v 55 7 87 W 119 w 56 8 88 X 120 x 57 9 89 Y 121 y 56 8 88 X 120 x 57 9 89 Y 121 y 56 8 98 X 120 x 57 9 89 Y 121 y 56 8 98 X 120 x 57 9 89 Y 121 y 56 8 90 z 122 z 59 ; 91 [ 123 { 60 < 92 \ 124 ] 61 = 93 1 125 ] 62 > 94 1 125 ] 62 > 94 1 125 ] 62 > 94 1 126 ~ 63 7 95 _ 127 DEL	36	\$	68	D	100	d
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63 + 44 + 7 + 76 + 1 + 108 + 109 + 108 +	43	+	75	ĸ	107	ĸ
63 - 78  N 100  n 46 - 78  N 110  n 46 - 78  N 110  n 47 / 79  O 111  o 48  O 80  P 112  p 49  1 81  O 113  q 50 2 82  R 114  r 51 3 83  S 115  s 52 4 84  T 116  t 53 5 85  U 117  u 54  6 86  V 118  v 55 7 87  W 119  w 55 7 87  W 119  w 55 8  s 99  v 121  v 55 7 87  W 119  w 55 8  s 99  v 121  v 55 7 9 89  v 121  v 55 7 9 89  v 121  v 55 8  s 99  v 121  v 56 8  s 99  v 121  v 56 8  s 99  v 122  v 57 9  s 9  s 9  v 121  v 55 8  s 93  s 115  s 57 9  s 9  v 121  v 55 8  s 93  s 1125  s 57 9  s 93  s 120  s 122  s 59  s 7 9  s 91  s 123  s 125  s 122  s	44	'	70	м	108	
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001111111       63         48       0       80       P       112       p         49       1       81       0       113       q         50       2       82       R       114       r         51       3       83       S       115       s         52       4       84       T       116       t         53       5       85       U       117       u         54       6       86       V       118       v         55       7       87       W       119       w         56       8       88       X       120       x         57       9       89       Y       121       y         58       90       Z       122       z         59       91       1       123       {         60       92       124       1         61       93       1       125       {         62       94       126       -       -         63       7       95       127       DEL	40	;	79	0	111	
001111111       63       81       0       113       9         50       2       82       R       114       r         51       3       83       S       115       s         52       4       84       T       116       t         53       5       85       U       117       u         54       6       86       V       118       v         55       7       87       W       119       w         56       8       88       X       120       x         57       9       89       Y       121       y         58       90       Z       122       z         59       ;       91       [       123       {         60       92       124                   61       93       1       125           62       94       126             63       2       95       127       DEL	 48	ó	80	р	112	n
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56       8       88       X       120       X         57       9       89       Y       121       Y         58       :       90       Z       122       z         59       ;       91       [       123       {         60       <       92       \       124                 61       =       93       ]       125       }         62       >       94       ^       126       ~         63       ?       95       _       127       DEL	55	7	87	W	119	w
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63 ? 95 127 DEL	62	>	94	<u>^</u>	126	~
	63	?	95	-	127	DEL



https://en.wikipedia.org/wiki/ASCII



#### From letters to ascii numbers to binary

We can encode our messages into binary just by reversing the operation.

Dec	Char	Dec	Char	Dec	Char
32	SPACE	64	6	96	``
33	1	65	A	97	a
34		66	в	98	b
35	#	67	С	99	С
36	\$	68	D	100	d
37	8	69	E	101	е
38	&	70	F	102	f
39		71	G	103	g
40	(	72	H	104	h
41	)	73	I	105	i
42	*	74	J	106	j
43	+	75	K	107	k
44	,	76	L	108	1
45	-	77	м	109	m
46		78	N	110	n
47	/	79	0	111	0
48	0	80	Р	112	р
49	1	81	Q	113	q
50	2	82	R	114	r
51	3	83	S	115	S
52	4	84	т	116	t
53	5	85	U	117	u
54	6	86	v	118	v
55	7	87	W	119	w
56	8	88	х	120	x
57	9	89	Y	121	У
58	:	90	Z	122	2
59	;	91	[	123	{
60	<	92	Λ	124	
61	=	93	]	125	}
62	>	94	^	126	~
63	?	95	_	127	DEL

	Dec	Char	Dec	Char	Dec	Char	
	32	SPACE	64	6	96	``	
	33	1	65	A	97	a	
	34		66	в	98	b	
	35	#	67	С	99	С	
	36	\$	68	D	100	d	
	37	8	69	Е	101	е	
	38	&	70	F	102	f	
	39	'	71	G	103	g	
	40	(	72	H	104	h	
	41	)	73	I	105	1	
	42	*	74	J	106	j	
	43	+	75	ĸ	107	ĸ	
	44	'	76	L	108	1	
	45	-	70	M	110	m	
01001100	40	;	70	N O	110	n	
	47	6	00	D	112	2	
	40	1	91	0	112	2	
	50	2	82	Ř	114	ч r	
	51	3	83	g	115	- e	
	52	4	84	Ϋ́	116	t	
Anowor:	53	5	85	Ū	117	ŭ	
Allswel.	54	6	86	v	118	v	
	55	7	87	W	119	w	
	56	8	88	х	120	x	
	57	9	89	Y	121	У	
	58	:	90	Z	122	z	
	59	;	91	[	123	{	
(Let's do the first number by hand)	60	<	92	Λ	124		
	61	=	93	1	125	}	
	62	>	94	^	126	~	
	63	?	95	_	127	DEL	.·
***************************************							4



#### We can convert using Python!

Let's convert from binary to decimal. How would we do that?

Assume that a binary number is represented by a string of 0's and 1's.

```
# Convert binary input string to decimal
 1
 2
     # Get binary input string (like "1011")
 3
     binary_str = input("Input a binary number: ")
 4
 5
     # Will add up place value of each '1' bit
 6
     decimal_value = 0
 7
 8
     # Loop through all characters
 9
     length = len(binary_str)
10
     for i in range(length):
11
12
         # Access the next character (bit) back-to-front)
         bit index = length - i - 1
13
         bit = binary_str[bit_index]
14
15
         # Add place-value of this bit
16
         if bit == '1':
17
             decimal value += 2**i
18
19
     # Print result in decimal
20
21
     print(f"That equals {decimal_value}")
```





#### Hexadecimal

Another numbering system important in CS is hexadecimal.

You may see it in **color representations**, for example: 00FFAA

0000 0000 <b>0</b>	1111 1111 <b>255</b>	1010 1010 <b>170</b>	
RED	GREEN	BLUE	

Decimal	Binary	Hexadecimal
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7
8	1000	8
9	1001	9
10	1010	A
11	1011	в
12	1100	С
13	1101	D
14	1110	E
15	1111	F



## More examples

All data (strings, numbers, colors, videos, music...) are expressed with bits.

Code	example	binary	hexadecimal
ASCII	"AB"	0100000101000010	4142
ASCII	"12"	0011000100110010	3132
ASCII (note: space is coded!)	"12 AB"	00110001001100100010000 00100000101000010	3132204142
Color (RGB)	Red color	111111110000000000000000000000000000000	FF0000
Integer number (fixed point notation) (ex with 2 bytes, typically more)	12	000000000001100	000C
Number with decimals (floating point notation)	123.45		

## **Colors in Hex**



Unicode

# Many languages, many characters, many encodings



**Unicode UTF-8** 



The maximum number of unique codes in a byte is 255 (11111111).

To type in other languages than English, we may need a lot more than 255 types of characters.

**Unicode** uses **up to 4 bytes** to handle more characters.







#### **Review**

Communicating with the computer directly in binary or hexadecimal would take a lot of time and would be quite hard to read :)

Python helps translate from binary or hex into something we understand!



#### **Grace Murray Hopper** Developer of FLOW-MATIC,

the first English-like programming language in 1955, predecessor to COBOL.





What are the numbering systems called which use:

- Only 0's and 1's?
- Digits 0-9,A-F?
- a) Binary & Decimal
- b) Decimal & Hexadecimal
- c) Binary & Hexadecimal
- d) Binary & UTF8

What is the value of the binary number below, in decimal? 0101

- <mark>a)</mark> 2
- b) 5
- <mark>c)</mark> 9
- <mark>d)</mark> 101

How many bits are in 2 bytes?



- <mark>b)</mark> 8
- <mark>c)</mark> 16
- <mark>d)</mark> 32

How would you write the decimal number below in binary?

14

- <mark>a)</mark> 0140
- b) 0111
- <mark>C)</mark> 1110
- d) 1111