Data Representation

15-110 – Friday 09/04

Learning Objectives

Understand how different number systems can represent the same information

Translate binary numbers to decimal, and vice versa

 Interpret binary numbers as abstracted types, including colors and text

Number Systems

Computers Run on 0s and 1s

Computers represent everything by using 0s and 1s. You've likely seen references to this before.

How can we represent text, or images, or sound with 0s and 1s? This brings us back to **abstraction**.

Abstraction is About Representation

Recall our definition of abstraction from the first lecture:

Abstraction is a technique used to make complex systems manageable by reducing the amount of detail used to **represent** or interact with the system.

We'll use abstraction to translate 0s and 1s to decimal numbers, then translate those numbers to other types.

Number Systems – Coins

A **number system** is a way of representing numbers using symbols.

One example of a number system is US currency. How much is each of the following symbols worth?









Penny 1 cent

Nickel 5 cents

Dime 10 cents

Quarter 25 cents

Number Systems – Dollars

Alternatively, we can represent money using **dollars and cents**, in decimal form.

For example, a medium coffee at Tazza is \$2.65.



Converting Coins to Dollars

We can **convert between number systems** by translating a value from one system to the other.

For example, the coins on the left represent the same value as \$0.87

Using pictures is clunky. Let's make a new representation system for coins.



Coin Number Representation

To represent coins, we'll make a number with four digits.

The first represents quarters, the second dimes, the third nickels, and the fourth pennies.

$$c.3.1.0.2 =$$

$$3*$0.25 + 1*$0.10 + 0*$0.05 + 2*$0.01 =$$

\$0.87













	Q	D	N	P
С	3	1	0	2

Converting Dollars to Coins

In recitation, you created an algorithm to convert money from dollars to coins, minimizing the number of coins used.

How did your algorithm work?

Conversion Example

What is \$0.59 in coin representation?

$$$0.59 = 2*$0.25 + 0*$0.10 + 1*$0.05 + 4*$0.01 = c.2.0.1.4$$

Activity: Coin Conversion

Now try the following calculations with your discussion group:

What is c.1.1.1.2 in dollars?

What is \$0.61 in coin representation?

Number Systems – Binary

Now let's go back to computers. We can represent numbers using only 0s and 1s with the **binary number system**.

Instead of counting the number of 1s, 5s, 10s, and 25s in coins you need, count the number of 1s, 2s, 4s, and 8s.

Why these numbers? They're **powers of 2**. This is a number in **base 2**. In contrast, our usual decimal system uses base 10.

²³ 8	²² 4	²¹ 2	2º 1
1	1	0	1

Bits and Bytes

When working with binary and computers, we often refer to a set of binary values used together to represent a number.

A single binary value is called a **bit**.

A set of 8 bits is called a **byte**.

We commonly use some number of bytes to represent data values.

Counting in Binary

$$O = \begin{bmatrix} 128 & 64 & 32 & 16 & 8 & 4 & 2 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$2 = \begin{bmatrix} 128 & 64 & 32 & 16 & 8 & 4 & 2 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \end{bmatrix}$$

$$4 = \begin{bmatrix} 128 & 64 & 32 & 16 & 8 & 4 & 2 & 1 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \end{bmatrix}$$

$$6 = \begin{bmatrix} 128 & 64 & 32 & 16 & 8 & 4 & 2 & 1 \\ 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 \end{bmatrix}$$

$$1 = \begin{bmatrix} 128 & 64 & 32 & 16 & 8 & 4 & 2 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$$3 = \begin{bmatrix} 128 & 64 & 32 & 16 & 8 & 4 & 2 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 \end{bmatrix}$$

$$5 = \begin{bmatrix} 128 & 64 & 32 & 16 & 8 & 4 & 2 & 1 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 \end{bmatrix}$$

$$7 = \begin{bmatrix} 128 & 64 & 32 & 16 & 8 & 4 & 2 & 1 \\ 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 \end{bmatrix}$$

Converting Binary to Decimal

To convert a binary number to decimal, just add each power of 2 that is represented by a 1.

For example, 00011000 = 16 + 8 = 24

128	64	32	16	8	4	2	1
0	0	0	1	1	0	0	0

Another example:

128	64	32	16	8	4	2	1
1	0	0	1	0	0	0	1

Converting Decimal to Binary

Converting decimal to binary uses the **same process** as converting dollars to coins.

Look for the largest power of 2 that can fit in the number and subtract it from the number. Repeat with the next-largest power of 2, etc., until you reach 0.

For example, 36 = 32 + 4 = 00100100

128	64	32	16	8	4	2	1
0	0	1	0	0	1	0	0

Another example:

$$103 = 64 + 32 + 4 + 2 + 1$$

128	64	32	16	8	4	2	1
0	1	1	0	0	1	1	1

Activity: Converting Binary

Now try converting numbers on your own.

First: what is **01011011** in decimal?

Second: what is **75** in binary?

Abstracted Types

Binary and Abstraction

Now that we can represent numbers using binary, we can represent everything computers store using binary.

We just need to use **abstraction** to interpret bits or numbers in particular ways.

Let's consider numbers, images, and text.

Discussion: Representing Advanced Numbers

It can be helpful to think logically about how to represent a value before learning how it's done in practice. Let's do that now.

Discuss: We can convert binary directly into positive numbers, but how do we represent negative numbers?

Discuss: What about floating-point numbers? How do we represent π ?

Answer: Representing Advanced Numbers

Negative Numbers

Possible Approach: reserve one bit to represent whether the number is positive or negative. Convert the rest normally.

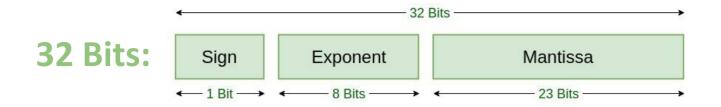
Actual Approach: any integer can be viewed as either signed or unsigned. The value 11111111 is 255, but it's also -1 because 11111111 + 1 = 100000000, which becomes 00000000 if we only have 8 bits. So 11111110 is -2 (or 254), and so on.

Floating-Point Numbers

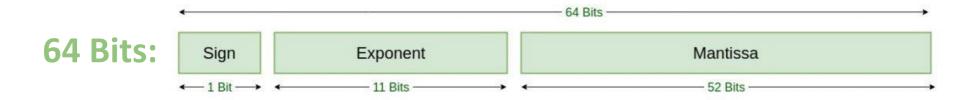
Possible Approach: use two bytes to represent digits before the decimal point, and two bytes to represent digits after.

Actual Approach: use scientific representation (0.8e+10) to move the decimal point. Some bits are for the exponent and some are for the number value (called the "mantissa").

Sidebar: 32 and 64 Bit Floating-Point Numbers



Single Precision
IEEE 754 Floating-Point Standard



Double Precision IEEE 754 Floating-Point Standard

Size of Integers

Your machine is either classified as 32-bit or 64-bit. This refers to the size of integers used by your computer's operating system.

The largest integer that can be represented with N bits is $2^{N}-1$ (why?). This means that...

Largest int for 32 bits: 4,294,967,295 (or 2,147,483,647 with negative numbers)

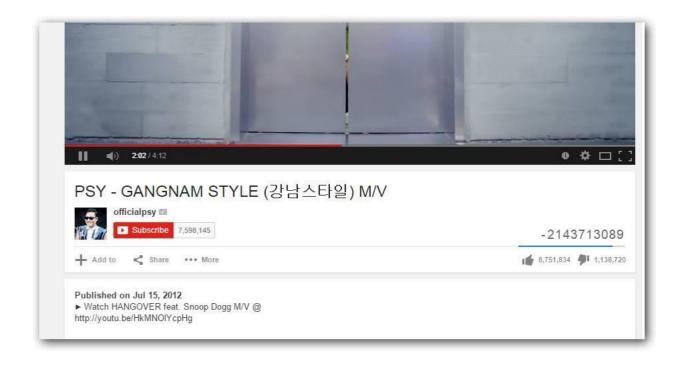
Largest int for 64 bits: 18,446,744,073,709,551,615 (18.4 quintillion)

Integer Overflow

Why does this matter?

By late 2014, the music video Gangnam Style received more than **2 billion** views. When it passed the largest positive number that could be represented with 32 bits, YouTube showed the number of views as **negative** instead!

Now YouTube uses a 64-bit counter instead.



Represent Images as Grids of Colors

What if we want to represent an image? How can we convert that to numbers?

First, break the image down into a grid of colors, where each square of color has a distinct hue. A square of color in this context is called a **pixel**.



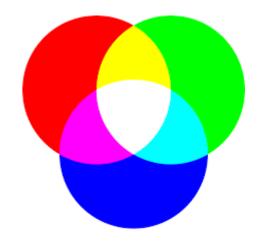
Representing Colors in Binary

Now we just need to represent a single color (a pixel) as a number.

There are a few ways to do this, but we'll focus on **RGB**. Any color can be represented as a combination of Red, Green, and Blue.

Red, green, and blue intensity can be represented using one **byte** each, where 00000000 (0) is none and 11111111 (255) is very intense. So each pixel will require 3 bytes to encode.

Try it out here: w3schools.com/colors/colors_rgb.asp



Example: Representing Beige

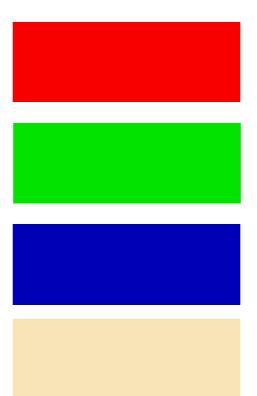
To make the campus-building beige, we'd need:

Red = 249 = 11111001

Green= 228 = 11100100

Blue = 183 = 10110111

Which makes beige!





Represent Text as Individual Characters

Next, how do we represent text?

First, we break it down into smaller parts, like with images. In this case, we can break text down into individual **characters**.

For example, the text "Hello World" becomes H, e, l, l, o, space, W, o, r, l, d

Use a Lookup Table to Convert Characters

Unlike colors, characters don't have a natural connection to numbers.

Instead, we can use a **lookup table** that maps each possible character to an integer.

As long as every computer uses the same lookup table, computers can always translate a set of numbers into the same set of characters.

ASCII is a Simple Lookup Table

For basic characters, we can use the encoding system called ASCII. This maps the numbers 0 to 255 to characters. Therefore, one character is represented by one byte.

Check it out here: www.asciitable.com

Dec Hex	Oct Chr	Dec Hex	Oct	HTML	Chr	Dec	Hex	Oct	HTML	Chr	Dec	Hex	Oct	HTML	Chr
0 0	000 NULL	32 20	040		Space	64	40	100	@	@	96	60	140	`	,
1 1	001 Start of Header	33 21	041	!	!	65	41	101	A	A	97	61	141	a	a
2 2	002 Start of Text	34 22	042	"	n	66	42	102	B	В	98	62	142	b	b
3 3	003 End of Text	35 23	043	#	#	67	43	103	C	C	99	63	143	c	C
4 4	004 End of Transmission	36 24	044	\$	\$	68	44	104	D	D	100	64	144	d	d
5 5	005 Enquiry	37 25	045	%	%	69	45	105	E	E	101	65	145	e	e
6 6	006 Acknowledgment	38 26	046	&	&	70	46	106	F	F	102	66	146	f	f
7 7	007 Bell	39 27	047	'	1	71	47	107	G	G	103	67	147	g	g
88	010 Backspace	40 28	050	((72	48	110	H	H	104	68	150	h	h
9 9	011 Horizontal Tab	41 29	051))	73	49	111	I	I	105	69	151	i	i
10 A	012 Line feed	42 2A	052	*	*	74	4A	112	J	J	106	6A	152	j	j
11 B	013 Vertical Tab	43 2B	053	+	+	75	4B	113	K	K	107	6B	153	k	k
12 C	014 Form feed	44 2C	054	,	1	76	4C	114	L	L	108	6C	154	l	1
13 D	015 Carriage return	45 2D	055	-	_	77	4D	115	M	M	109	6D	155	m	m
14 E	016 Shift Out	46 2E	056	.		78	4E	116	N	N	110	6E	156	n	n
15 F	017 Shift In	47 2F	057	/	/	79	4F	117	O	0	111	6F	157	o	0
16 10	020 Data Link Escape	48 30	060	0	0	80	50	120	P	P	112	70		p	р
17 11	021 Device Control 1	49 31	061	1	1	81	51	121	Q	Q	113	71		q	q
18 12	022 Device Control 2	50 32	062	2	2	82	52	122	R	R	114	72	162	r	r
19 13	023 Device Control 3	51 33	063	3	3	83	53	123	S	S	115	73	163	s	5
20 14	024 Device Control 4	52 34	064	4	4	84	54	124	T	T	116	74	164	t	t
21 15	025 Negative Ack.	53 35	065	5	5	85	55	125	U	U	117	75	165	u	u
22 16	026 Synchronous idle	54 36	066	6	6	86	56	126	V	V	118	76	166	v	V
23 17	027 End of Trans. Block	55 37	067	7	7	87	57	127	W	W	119	77	167	w	W
24 18	030 Cancel	56 38	070	8	8	88	58	130	X	X	120	78	170	x	X
25 19	031 End of Medium	57 39	071	9	9	89	59	131	Y	Y	121	79		y	У
26 1A	032 Substitute	58 3A	072	:	:	90	5A	132	Z	Z	122	7A	172	z	Z
27 1B	033 Escape	59 3B	073	;	;	91	5B	133	[[123	7B	173	{	{
	034 File Separator	60 3C	074	<	<	92		134	\	\	124		174		i
29 1D	035 Group Separator	61 3D	075	=	=	93]	ĺ	125			}	}
30 1E	036 Record Separator	62 3E	076	>	>	94	5E	136	^	^	126		176	~	~
31 1F	037 Unit Separator	63 3F		?	?	95	5F		_		127				Del
	•			*				- narodis						asciichars	

Translating Text to Numbers

Dec Hex Oct Chr Dec Hex Oct HTML Chr Dec Hex Oct HTML Chr Oct TML Chr Chr Oct TML Chr Ch													
1 1 001 Start of Header 33 21 041 ! ! 65 41 101 A Å 97 61 141 a a 2 2 002 Start of Text 34 22 042 " " 66 42 102 B B 98 62 142 b b 33 003 End of Text 35 23 043 # # 67 43 103 C C 99 63 143 c c 4 4 004 End of Transmission 36 24 044 \$ \$ 68 44 104 B D 100 64 144 d d 5 5 005 Enquiry 37 25 045 % % 69 45 105 E E 101 65 145 e e 6 6 006 Acknowledgment 38 26 046 & & 70 46 106 ʞ F 102 66 146 f f 7 7 007 Bell 39 27 047 ' ' 71 47 107 G G 103 67 147 g g 8 8 010 Backspace 40 28 050 ((72 48 110 I I 105 69 151 i i 10 A 012 Line feed 42 2A 052 * * 74 4A 112 I I 105 69 151 i i 11 B 013 Vertical Tab 41 29 051 (* 74 4A 112 L L 106 6A 152 j I 13 D 015 Carriage return 45 2D 055 , , 76 4C 114 L L 108 6C 154 l I 13 D 015 Carriage return 45 2D 055 / - 77 4D 115 M M 109 6D 155 l I 10 61 65 hiff Out 46 62 056 . . 78 4E 116 N N 110 6E 155 e n 15 F 017 Shift In 47 2F 057 / / 79 4F 117 O O 111 6F 157 o o 16 10 020 Data Link Escape 48 30 060 0 0 80 50 120 P P 112 70 160 p p 113 023 Device Control 2 50 32 062 2 2 82 52 122 R R 114 72 162 r r 19 13 023 Device Control 3 51 33 063 3 3 83 53 123 S U 117 75 165 u u 22 16 026 Synchronous idle 54 36 066 7 7 87 51 122 W W 119 77 164 48 #116; t 21 15 025 Negative Ack. 53 35 065 7 7 87 57 127 W W 119 77 167 w W 24 18 030 Cancel 56 38 070 7 ; 9 35 50 135 c C 125 77 175 z } 27 18 033 Escape 59 38 073 ; ; 9 15 8 133 [[123 78 173 z 2 2 2 2 122 & 124 77 & 173 z 2 2 2 125 & 124 50 603; I 125 70 175 z I 125 70 175	Dec Hex	Oct Chr	Dec Hex	Oct HTML	Chr	Dec Hex	Oct H	TML C	hr De	Hex	Oct	HTML	Chr
2 2 002 Start of Text	0 0	000 NULL	32 20	040	Space	64 40	100 &	#064; @) (6 60	140	`	S.,
3 3 003 End of Text 35 23 043 # # 67 43 103 C C 99 63 143 c c 4 4 004 End of Transmission 36 24 044 \$ \$ 68 44 104 D D 100 64 144 d d 5 5 005 Enquiry 37 25 045 % % 69 45 105 E E 101 65 145 e e 6 6 006 Acknowledgment 38 26 046 & & 70 46 106 F F 102 66 146 f f 7 7 007 Bell 39 27 047 ' ' 71 47 107 G G 103 67 147 g g 8 8 010 Backspace 40 28 050 ((72 48 110 H H 104 68 150 h h 9 9 011 Horizontal Tab 41 29 051)) 73 49 111 I I 105 69 151 i i 10 A 012 Line feed 42 2A 052 * * 74 4A 112 J J 106 6A 152 j j 11 B 013 Vertical Tab 43 2B 053 , , 76 4C 114 L L 108 6C 154 j j 13 D 015 Carriage return 45 2D 055 . - 77 4D 115 M M 109 6D 155 m m 14 E 016 Shift Out 46 2E 056 . - 78 4E 116 N N 110 6E 156 n n 15 F 017 Shift In 47 2F 057 Ɣ / 79 4F 117 O O 111 6F 157 o o 16 10 020 Data Link Escape 48 30 060 0 0 80 50 120 P P 112 70 160 p p 17 11 021 Device Control 1 49 31 061 1 1 81 51 121 Q O 113 71 161 q q 18 12 022 Device Control 4 52 34 064 _ 5 85 55 122 V V 117 75 165 u u 22 16 026 Synchronous idle 55 23 40 064 7 7 87 57 127 W W 119 77 167 u u 24 18 030 Cancel 56 30 048 7 7 87 57 127 Y J 117 75 165 u u 25 16 026 Synchronous idle 55 63 47 047 < < 92 5C 134 Z D 112 77 178 y p 26 1A 032 Substitute 58 3A 072 7 9 89 59 131 c J 125 7D 175 z z 27 18 033 Escape 59 3B 073 B < 92 5C 134 Z J 125 7D 175 z J	1 1	001 Start of Header	33 21		!	65 41	101 &	.#065; A	9	7 61			a
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9 9 011 Horizontal Tab 41 29 051)) 73 49 111 I I 105 69 151 i i 10 A 012 Line feed 42 2A 052 * * 74 4A 112 J J 106 6A 152 j j 11 B 013 Vertical Tab 43 2B 053 + + 75 4B 113 K K 107 6B 153 k k 12 C 014 Form feed 44 C 054 , , 76 4C 114 L L 108 6C 154 l I 13 D 015 Carriage return 45 2D 055 - - 77 4D 115 M M 109 6D 155 m m 14 E 016 Shift Out 46 2E 056 . . 78 4E 116 N N 110 6E 156 n n 15 F 017 Shift In 47 2F 057 / / 79 4F 117 O O 111 6F 157 o o 16 10 020 Data Link Escape 48 30 060 0 0 80 50 120 P P 112 70 160 p p 17 11 021 Device Control 1 49 31 061 1 1 81 51 121 Q Q 113 71 161 q q 18 12 022 Device Control 2 50 32 062 2 2 82 52 122 R R 114 72 162 r r 19 13 023 Device Control 4 52 34 064 4 4 84 54 124 T T 116 74 164 t t 21 15 025 Negative Ack. 53 35 065 5 5 85 55 125 U U 117 75 165 u u 22 16 026 Synchronous idle 54 36 066 6 6 86 56 126 V V 118 76 166 v v 23 17 027 End of Trans. Block 55 37 067 7 7 87 57 127 W W 119 77 167 w w 24 18 030 Cancel 56 38 070 7 7 87 57 127 W W 119 77 167 w w 24 18 030 Cancel 56 38 070 7 9 89 59 131 Y Y 121 79 171 y y 26 1A 032 Substitute 58 A 072 : : 90 5A 132 Z Z 122 7A 172 z z 27 1B 033 Escape 59 3B 073 ; ; 91 5B 133 [[123 7B 173 { { 28 1C 034 File Separator 60 3C 074 < < 92 5C 134 Z \ 124 7C 174 125 7D 175 } \}	7 7	007 Bell	39 27	047 '	1	71 47	107 &	.#071; G	10	3 67	147	g	g
10 A 012 Line feed 42 2A 052 * * 74 4A 112 J J 106 6A 152 j j 11 8 013 Vertical Tab 43 2B 053 + + 75 4B 113 K K 107 6B 153 k k 12 C 014 Form feed 44 2C 054 , , 76 4C 114 L L 108 6C 154 l I 13 D 15 Carriage return 45 2D 055 - - 77 4D 115 M M 109 6D 155 l I 14 E 016 Shift Out 46 2E 056 . . 78 4E 116 N N 110 6E 156 n n 15 F 017 Shift In 47 2F 057 / / 79 4F 117 O O 111 6F 157 o o 16 10 020 Data Link Escape 48 30 060 0 0 80 50 120 P P 112 70 160 p p 17 11 021 Device Control 1 49 31 061 1 1 81 51 121 Q Q 113 71 161 q q 18 12 022 Device Control 2 50 32 062 2 2 82 52 122 R R 114 72 162 r r 19 13 023 Device Control 4 52 34 064 4 4 84 54 124 T T 116 74 164 t t 21 15 025 Negative Ack. 53 35 065 5 5 85 55 125 U U 117 75 165 u u 22 16 026 Synchronous idle 54 36 066 6 6 88 059; 37 027 End of Trans. Block 55 37 067 7 5 87 57 127 W W 119 77 167 w w 24 18 030 Cancel 56 38 070 7 9 89 59 131 Y Y 121 79 171 y y 26 1A 032 Substitute 58 3A 072 7 9 89 59 131 Y Y 121 79 171 y y 26 1A 032 Substitute 58 3A 072 7 9 9 89 59 131 Y Y 121 79 171 y y 26 1A 032 Substitute 58 3A 072 7 9 9 89 59 131 Y Y 121 79 171 y y 26 1C 034 File Separator 60 3C 074 < < 92 5C 134 Z L 123 7B 173 } }	88	010 Backspace	40 28	050 ((110 &	.#072; H	10	4 68	150	h	h
11 B	9 9	011 Horizontal Tab	41 29	051))	73 49	111 &	#073; I	10	5 69	151	i	i
12 C 014 Form feed 44 2C 054 , , 76 4C 114 L L 108 6C 154 l I 13 D 015 Carriage return 45 2D 055 - - 77 4D 115 M M 109 6D 155 m m 14 E 016 Shift Out 46 2E 056 . . 78 4E 116 N N 110 6E 156 n n 15 F 017 Shift In 47 2F 057 / / 79 4F 117 O O 111 6F 157 o o 16 10 020 Data Link Escape 48 30 060 0 O 80 50 120 P P 112 70 160 p p 17 11 021 Device Control 1 49 31 061 1 1 81 51 121 Q Q 113 71 161 q q 18 12 022 Device Control 2 50 32 062 2 2 82 52 122 R R 114 72 162 r r 19 13 023 Device Control 3 51 33 063 3 3 83 53 123 S S 115 73 163 s s 20 14 024 Device Control 4 52 34 064 4 4 84 54 124 T T 116 74 164 t t 21 15 025 Negative Ack. 53 35 065 5 5 85 55 125 U U 117 75 165 u u 21 16 026 Synchronous idle 54 36 066 6 6 86 56 126 V V 118 76 166 v v 23 17 027 End of Trans. Block 55 37 067 7 7 87 57 127 W W 119 77 167 w w 24 18 030 Cancel 56 38 070 8 8 88 58 130 X X 120 78 170 x x 25 19 031 End of Medium 57 39 071 9 9 89 59 131 Y Y 121 79 171 y y 26 1A 032 Substitute 58 3A 072 ; ; 91 58 133 [[123 7B 173 z z 27 18 033 Escape 59 3B 073 ; ; 91 58 133 [[123 7B 173 z z 28 10 035 Group Separator 60 3C 074 < < 92 5C 134 \ \ 125 7D 175 } \}	10 A	012 Line feed	42 2A	052 *	*	74 4A	112 &	.#074; J	10	6 6A	152	j	j
13 D 015 Carriage return		013 Vertical Tab	43 2B	053 +	+	75 4B			10	7 6B	153	k	k
14 E 016 Shift Out 46 2E 056 . . 78 4E 116 N N 110 6E 156 n n 15 F 017 Shift In 47 2F 057 / / 79 4F 117 O O 111 6F 157 o o 16 10 020 Data Link Escape 48 30 060 0 0 80 50 120 P P 112 70 160 p p 17 11 021 Device Control 1 49 31 061 1 1 81 51 121 Q Q 113 71 161 q q 18 12 022 Device Control 2 50 32 062 2 2 82 52 122 R R 114 72 162 r r 19 13 023 Device Control 3 51 33 063 3 3 83 53 123 S S 115 73 163 s s 20 14 024 Device Control 4 52 34 064 4 4 84 54 124 T T 116 74 164 t t 21 15 025 Negative Ack. 53 35 065 5 5 85 55 125 U U 117 75 165 u u	12 C	014 Form feed	44 2C	054 ,	1	76 4C	114 &	.#076; L	10	8 6C	154	l	1
15 F 017 Shift In 47 2F 057 / / 79 4F 117 O O 111 6F 157 o O 16 10 020 Data Link Escape 48 30 060 0 O 80 50 120 P P 112 70 160 p p 17 11 021 Device Control 1 49 31 061 1 1 81 51 121 Q Q 113 71 161 q q 18 12 022 Device Control 2 50 32 062 2 2 82 52 122 R R 114 72 162 r r 19 13 023 Device Control 3 51 33 063 3 3 83 53 123 S S 115 73 163 s s 20 14 024 Device Control 4 52 34 064 4 4 84 54 124 T T 116 74 164 t t 21 15 025 Negative Ack. 53 35 065 5 5 85 55 125 U U 117 75 165 u u 22 16 026 Synchronous idle 54 36 066 6 6 86 56 126 V V 118 76 166 v v 23 17 027 End of Trans. Block 55 37 067 7 7 87 57 127 W W 119 77 167 w w 24 18 030 Cancel 56 38 070 7 7 87 57 127 W W 119 77 167 w w 24 18 030 Cancel 56 38 070 8 8 88 58 130 X X 120 78 170 x x 25 19 031 End of Medium 57 39 071 9 9 89 59 131 Y Y 121 79 171 y y 26 1A 032 Substitute 58 3A 072 : : 90 5A 132 Z Z 122 7A 172 z z 27 18 033 Escape 59 3B 073 ; ; 91 5B 133 [[123 7B 173 { { 28 1C 034 File Separator 60 3C 074 < < 92 5C 134 \ \ 124 7C 174 29 1D 035 Group Separator 61 3D 075 = = 93 5D 135]] 125 7D 175 } }	13 D	015 Carriage return	45 2D	055 -	-	77 4D	115 &	.#077; N	1 10	9 6D	155	m	m
16 10 020 Data Link Escape 48 30 060 0 0 80 50 120 P P 112 70 160 p p 17 11 021 Device Control 1 49 31 061 1 1 81 51 121 Q Q 113 71 161 q q 18 12 022 Device Control 2 50 32 062 2 2 82 52 122 R R 114 72 162 r r 19 13 023 Device Control 3 51 33 063 3 3 83 53 123 S S 115 73 163 s s 20 14 024 Device Control 4 52 34 064 4 4 84 54 124 T T 116 74 164 t t 21 15 025 Negative Ack. 53 35 065 5 5 85 55 125 U U 117 75 165 u u 22 16 026 Sync	14 E	016 Shift Out	46 2E	056 .		78 4E	116 &	.#078; N	13	0 6E	156	n	n
17 11 021 Device Control 1	15 F	017 Shift In	47 2F	057 /	/	79 4F	117 &	.#079; C	13	.1 6F	157	o	0
18 12 022 Device Control 2 50 32 062 2 2 82 52 122 R R 114 72 162 r r 19 13 023 Device Control 3 51 33 063 3 3 83 53 123 S S 115 73 163 s s 20 14 024 Device Control 4 52 34 064 4 4 84 54 124 T T 116 74 164 t t 21 15 025 Negative Ack. 53 35 065 5 5 85 55 125 U U 117 75 165 u u 22 16 026 Synchronous idle 54 36 066 6 6 86 56 126 V V 118 76 166 v v 23 17 027 End of Trans. Block 55 37 067 7 7 87 57 127 W W 119 77 167 w w 24 18 030 Cancel 56 38 070 8 8 88 58 130 X X 120 78 170 x x 25 19 031 End of Medium 57 39 071 9 9 89 59 131 Y Y 121 79 171 y y 26 1A 032 Substitute 58 3A 072 : : 90 5A 132 Z Z 122 7A 172 z z 27 1B 033 Escape 59 3B 073 ; ; 91 5B 133 [[123 7B 173 { { 28 1C 034 File Separator 60 3C 074 < 92 5C 134 \ \ 124 7C 174 29 1D 035 Group Separator 61 3D 075 = = 93 5D 135]] 125 7D 175 } }	16 10	020 Data Link Escape	48 30	060 0	0		120 &	.#080; P			160	p	p
19 13 023 Device Control 3 51 33 063 3 3 83 53 123 S S 115 73 163 s s 20 14 024 Device Control 4 52 34 064 4 4 84 54 124 T T 116 74 164 t t 21 15 025 Negative Ack. 53 35 065 5 5 85 55 125 U U 117 75 165 u u 22 16 026 Synchronous idle 54 36 066 6 6 86 56 126 V V 118 76 166 v v 23 17 027 End of Trans. Block 55 37 067 7 7 87 57 127 W W 119 77 167 w w 24 18 030 Cancel 56 38 070 8 8 88 58 130 X X 120 78 170 x x 25 19 031 End of Medium 57 39 071 9 9 89 59 131 Y Y 121 79 171 y y 26 1A 032 Substitute 58 3A 072 : : 90 5A 132 Z Z 122 7A 172 z Z 27 1B 033 Escape 59 3B 073 ; ; 91 5B 133 [[123 7B 173 { { 28 1C 034 File Separator 60 3C 074 < < 92 5C 134 \ \ 125 7D 175 } }	17 11	021 Device Control 1	49 31	061 1	1		121 &	.#081; Q	1.	.3 71	161	q	q
20 14 024 Device Control 4 52 34 064 4 4 84 54 124 T T 116 74 164 t t 21 15 025 Negative Ack. 53 35 065 5 5 85 55 125 U U 117 75 165 u u 22 16 026 Synchronous idle 54 36 066 6 6 86 56 126 V V 118 76 166 v v 23 17 027 End of Trans. Block 55 37 067 7 7 87 57 127 W W 119 77 167 w w 24 18 030 Cancel 56 38 070 8 8 88 58 130 X X 120 78 170 x x 25 19 031 End of Medium 57 39 071 9 9 89 59 131 Y Y 121 79 171 y y 26 1A 032 Substitute 58 3A 072 : : 90 5A 132 Z Z 122 7A 172 z Z 27 1B 033 Escape 59 3B 073 ; ; 91 5B 133 [[123 7B 173 { { 28 1C 034 File Separator 60 3C 074 < < 92 5C 134 \ \ 125 7D 175 } }	18 12	022 Device Control 2	50 32	062 2	2	82 52	122 &	.#082; R	13	4 72	162	r	r
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23 17 027 End of Trans. Block 55 37 067 7 7 87 57 127 W W 119 77 167 w w 24 18 030 Cancel 56 38 070 8 8 88 58 130 X X 120 78 170 x x 25 19 031 End of Medium 57 39 071 9 9 89 59 131 Y Y 121 79 171 y y 26 1A 032 Substitute 58 3A 072 : : 90 5A 132 Z Z 122 7A 172 z z 27 1B 033 Escape 59 3B 073 ; ; 91 5B 133 [[123 7B 173 { { 28 1C 034 File Separator 60 3C 074 < <	21 15	025 Negative Ack.	53 35	065 5	5	85 55	125 &	.#085; U	13	7 75	165	u	u
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25 19 031 End of Medium 57 39 071 9 9 89 59 131 Y Y 121 79 171 y y 26 1A 032 Substitute 58 3A 072 : : 90 5A 132 Z Z 122 7A 172 z Z 27 1B 033 Escape 59 3B 073 ; ; 91 5B 133 [[123 7B 173 { { 28 1C 034 File Separator 60 3C 074 < <	23 17	027 End of Trans. Block	55 37	067 7	7	87 57	127 &	.#087; V	/ 13	9 77	167	w	W
26 1A 032 Substitute 58 3A 072 : : 90 5A 132 Z Z 122 7A 172 z Z 27 1B 033 Escape 59 3B 073 ; ; 91 5B 133 [[123 7B 173 { { 28 1C 034 File Separator 60 3C 074 < <	24 18	030 Cancel	56 38	070 8	8	88 58	130 &	#088; X	12	20 78	170	x	X
27 1B 033 Escape 59 3B 073 ; ; 91 5B 133 [[123 7B 173 { { 28 1C 034 File Separator 60 3C 074 < <	25 19	031 End of Medium	57 39	071 9	9	89 59	131 &	.#089; Y	12	1 79	171	y	У
28 1C 034 File Separator 60 3C 074 < < 92 5C 134 \ \ 29 1D 035 Group Separator	26 1A	032 Substitute	58 3A	072 :	:	90 5A	132 &	#090; Z	12	2 7A	172	z	Z
29 1D 035 Group Separator 61 3D 075 = = 93 5D 135]] 125 7D 175 })	27 1B	033 Escape	59 3B	073 ;	;	91 5B	133 &	.#091; [12	3 7B	173	{	{
	28 1C	034 File Separator	60 3C	074 <	<	92 5C	134 &	#092; \	12	4 7C	174		
	29 1D		61 3D	075 =	=	93 5D	135 &	#093;]	12	5 7D	175	}	}
	30 1E		62 3E	076 >	>	94 5E	136 &	.#094; ^	12	6 7E	176	~	~
31 1F 037 Unit Separator 63 3F 077 ? ? 95 5F 137 _ _ 127 7F 177 Del	31 1F	037 Unit Separator	63 3F	077 ?	?	95 5F	137 &	.#095; _	12	7 7F	177		Del

Activity: Binary to Text

You do: translate the following binary into ASCII text.

010110010110000101111001

0 0 000 NULL 1 1 001 Start of Header 3 3 21 040 Space 64 40 100 ʘ ② 96 60 140 _ \ 1 1 0 001 Start of Header 3 3 21 041 ! ! 65 41 101 A A 97 61 141 a a 2 2 002 Start of Text 3 4 22 042 " " 66 42 102 B B 98 62 142 b b 3 3 003 End of Text 3 5 23 043 # # 67 43 103 C C 99 63 143 c c 4 4 004 End of Transmission 3 6 24 044 \$ S 68 44 104 ʜ D 100 64 144 d d 5 5 005 Enquiry 3 7 25 045 % % 69 45 105 E E 101 65 145 e e 6 6 006 Acknowledgment 3 8 26 046 & & 70 46 106 F F 102 66 146 f f 7 7 007 Bell 3 9 27 047 ' ' 71 47 107 G G 103 67 147 g g 8 8 010 Backspace 40 28 050 ((72 48 110 I I 105 69 151 i i 10 A 012 Line feed 42 2A 052 * * 74 44 112 J J 106 6A 152 j j 11 B 013 Vertical Tab 43 2B 053 + + 75 4B 113 K K 107 6B 153 i i 11 B 013 Vertical Tab 44 2C 054 , , 76 4C 114 L L 108 6C 154 l L 12 C 014 Form feed 44 2C 055 . - 77 4D 115 M M 109 6D 155 m n 14 E 016 Shift Out 46 2E 056 . - 78 4E 116 N N 110 6E 156 n n 15 F 017 Shift In 47 2F 057 / / 79 4F 117 O O 111 6F 156 n n 15 F 017 Shift In 47 2F 057 / / 79 4F 117 P O 111 6F 157 o o 18 12 022 Device Control 1 49 31 061 1 1 81 51 121 Q O 113 71 161 q q 18 12 022 Device Control 2 50 36 68 4055; 3 85 51 22 R R 114 72 166 n n 16 10 020 Data Link Escape 48 30 060 0 0 80 50 120 P P 112 70 160 p p 17 11 021 Device Control 3 51 33 063 3 3 83 53 123 S S 115 73 163 s s 20 14 024 Device Control 4 50 38 66 68 6 6 86 56 126 V V 118 76 166 v V 21 17 07 End of Trans. Block 50 38 070 8 8 88 59 131 Y V 127 71 71 71 y V 21 60 60 59 postparator 60 30 070 8 8 88 59 131 c I 127 71 71 74 y V 21 61 035 Group Separator 61 30 073 B 9 25 C 134 c I 127 71 71 74 y V 22 16 16 036 Record Separator 61 30 073 B 9 9 5 C 134 c I 126 7E 176 z	Dec Hex	Oct Chr	Dec Hex	Oct HTML	Chr	Dec Hex	Oct HTML	Chr	Dec I	Hex Oct	HTML	Chr
2 2 002 Start of Text	0 0	000 NULL	32 20	040	Space	64 40	100 @	@	96 (60 14	0 `	
3 3 003 End of Text 3 5 23 043 # # 67 43 103 C C 99 63 143 c c 4 4 004 End of Transmission 3 6 24 044 \$ \$ 68 44 104 B E 101 65 145 e e 6 6 006 Acknowledgment 3 8 26 046 & & 70 46 106 C F 102 66 146 f f 7 7 007 Bell 3 9 27 047 ' ' 71 47 107 H G 103 67 147 g g 8 8 010 Backspace 40 28 050 ((72 48 110 H H 104 68 150 h h 9 9 011 Horizontal Tab 41 29 051)) 73 49 111 I I 105 69 151 i i 10 A 012 Line feed 42 2A 052 ƒ * 74 4A 112 K K 107 68 153 k k 11 B 013 Vertical Tab 43 2B 053 Ɠ + 75 4B 113 K K 107 6B 153 k k 12 C 014 Form feed 44 2C 054 , , 76 4C 114 L L 108 6C 154 l I 13 D 015 Carriage return 45 2D 055 . - 77 4D 115 M M 109 6D 155 m m 14 E 016 Shift Out 46 2E 056 . - 78 4E 116 N N 110 6E 156 n n 15 F 017 Shift In 47 2F 057 / / 79 4F 117 O O 111 6F 157 o o 16 10 020 Data Link Escape 48 30 060 0 0 80 50 120 P P 112 70 160 p p 17 11 021 Device Control 1 19 3 023 Device Control 2 50 32 062 2 2 82 52 122 R R 114 72 162 r r 19 13 023 Device Control 4 51 33 063 3 3 83 53 123 S S 115 73 163 s s 20 14 024 Device Control 4 52 34 064 4 4 84 54 124 T V 118 76 166 s a 21 16 026 Synchronous idle 54 36 066 7 7 87 55 125 U V 118 76 166 w w 24 18 030 Cancel 55 70 67 2 9 95 51 13 c V 121 79 171 y y 26 1A 032 Substitute 58 3A 072 8 8 88 58 130 b V 121 79 171 y y 27 18 033 Escape 59 3B 073 2 9 15 B 133 c V 124 7C 174 z J 28 1C 034 File Separator 60 3C 074 < < 92 5C 134 c V 124 7C 174 z J 29 1D 035 Group Separator 61 3D 075 < < 92 5C 134 c V 124 7C 175 } J 30 1E 036 Record Separator 61 3D 075 < > 94 5E 136 c V 124 7C 175 } J 30 1E 036 Record Separator 61 3D 075 < > 94 5E 136 c V 124 7C 175 } J 30 1E 036 Record Separator 61 28 044 8052; P 45 E 136 c V 124 7C 175 } J 3	1 1	001 Start of Header	33 21	041 !	!	65 41	101 A	A	97 6	61 14	1 a	a
4 4 004 End of Transmission 36 24 044 \$ \$ 68 44 104 D D 100 64 144 d d 5 5 005 Enquiry 37 25 045 % % 69 45 105 E E 101 65 145 e e 6 6 006 Acknowledgment 38 26 046 & & 70 46 106 F F 102 66 146 f f 7 7 007 Bell 39 27 047 ' ' 71 47 107 G G 103 67 147 g g 8 8 010 Backspace 40 28 050 ((72 48 110 H H 104 68 150 i i 10 A 012 Line feed 42 2A 052 * * 74 4A 112 J J 106 6A 152 j j 11 B 013 Vertical Tab 43 2B 053 + + 75 4B 113 J J 106 6A 152 j j 11 B 013 Vertical Tab 43 2B 053 + + 75 4B 113 K K 107 6B 153 k k 12 C 014 Form feed 44 2C 054 , , 76 4C 114 L L 108 6C 154 l l 13 D 015 Carriage return 45 2D 055 . - 77 4D 115 M M 109 6D 155 m m 14 E 016 Shift Out 46 2E 056 . . 78 4E 116 N N 110 6E 156 n n 15 F 017 Shift In 47 2F 057 / / 79 4F 117 O O 111 6F 157 o o 16 10 020 Data Link Escape 48 30 060 0 0 80 50 120 P P 112 70 160 p p 17 11 021 Device Control 1 49 31 061 1 1 81 51 121 Q Q 113 71 161 q q 18 12 022 Device Control 2 50 32 062 5 5 85 55 125 U U 117 75 165 t x 101 117 117 117 117 117 117 117 117 117	2 2	002 Start of Text	34 22	042 "	n	66 42	102 B	В	98 6	62 14	2 b	b
5 5 005 Enquiry 6 6 006 Acknowledgment 7 7 007 Bell 38 26 046 & 8 70 46 106 F F 102 66 146 ϴ g 8 8 010 Backspace 40 28 050 ((72 48 110 H H 104 68 150 h h 9 9 011 Horizontal Tab 41 29 051 * * 74 4A 112 J J 106 6A 152 j j 11 B 013 Vertical Tab 43 2B 053 + + 75 4B 113 K K 107 6B 153 k k 12 C 014 Form feed 44 2C 054 , , 76 4C 114 L L 108 6C 154 l m 13 D 015 Carriage return 45 2D 055 . - 77 4D 115 M M 109 6D 155 ϲ m 14 E 016 Shift Out 46 2E 056 . - 78 4E 116 N N 110 6E 156 і n 15 F 017 Shift In 47 2F 057 / / 79 4F 117 O O 111 6F 157 o q 18 12 022 Device Control 1 49 31 061 1 1 81 51 121 Q Q 113 71 161 q q 18 12 022 Device Control 2 50 32 062 2 2 82 52 122 R R 114 72 162 t t 21 15 025 Negative Ack. 53 35 065 7 7 87 51 125 X V 117 75 165 u u 22 16 026 Synchronous idle 54 36 066 6 6 88 58 130 X X 120 78 v w 24 18 030 Cancel 55 37 067 7 ; 91 5B 133 [[123 7B 173 y y 25 19 031 End of Medium 57 39 071 7 ; 91 5B 133 [[123 7B 173 z y 27 1B 033 Escape 59 3B 073 8 > 94 5E 136 ^ ^ 124 7C 174 z y 28 1C 034 File Separator 60 36 Record Separator 60 28 50 68 6806; > 94 5E 136 ^ ^ 126 7E 176 z] 30 1E 036 Record Separator 60 28 50 66 B > 94 5E 136 ^ ^ 126 7E 176 z] 30 1E 036 Record Separator 60 28 50 66 B > 94 5E 136 ^ ^ 126 7E 176 z] 30 1E 036 Record Separator 60 28 50 68 68050; 2 94 5E 136 ^ ^ 126 7E 176 z] 30 1E 036 Record Separator 61 3D 075 B > 94 5E 136 ^ ^ 126 7E 176 Ӊ] 30 1E 036 Record Separator 61 3D 075 B > 94 5E 136 ^ ^ 126 7E 176 Ӊ] 30 1E 036 Record Separator 61 3D 075 B > 94 5E 136 ^ ^ 126 7E 176 Ӊ] 30 1E 036 Record Separator 61 3D 075 B > 94 5E 136 ^ ^ 126 7E 176 Ӊ]	3 3	003 End of Text		043 #	#	67 43	103 C	C	99 6	63 14	3 c	C
6 6 006 Acknowledgment 38 26 046 & 8 70 46 106 F F 102 66 146 f f 7 7 007 Bell 39 27 047 ' 71 47 107 G G 103 67 147 g g 8 8 010 Backspace 40 28 050 (72 48 110 H H 104 68 150 h g 10 A 012 Line feed 42 20 052 * 74 4A 112 J J 106 6A 152 j j 11 B 013 Vertical Tab 43 2B 053 + + 75 4B 113 K K 107 6B 153 k k 12 C 014 Form feed 44 2C 054 , - 76 4C 114 L L 108 6C 154 l l 13 D 015 Carriage return 45 2D 055 - - 77 4D 115 M M 109 6D 155 m m 14 E 016 Shift Out 46 2E 056 . - 78 4E 116 N N 110 6E 156 n n 15 F 017 Shift In 47 2F 057 / / 79 4F 117 O N 110 6E 156 o n 16 10 020 Data Link Escape 48 30 060 0	4 4	004 End of Transmission	36 24	044 \$	\$	68 44	104 D	D	100 6	64 14	4 d	d
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9 9 011 Horizontal Tab 41 29 051)) 73 49 111 I I 105 69 151 i i 10 A 012 Line feed 42 2A 052 * * 74 4A 112 J J 106 6A 152 j j 11 B 013 Vertical Tab 43 2B 053 + + 75 4B 113 K K 107 6B 153 k k 12 C 014 Form feed 44 2C 054 , , 76 4C 114 L L 108 6C 154 l I 13 D 015 Carriage return 45 2D 055 - - 77 4D 115 M M 109 6D 155 m m 14 E 016 Shift Out 46 2E 056 . . 78 4E 116 N N 110 6E 156 n n 15 F 017 Shift In 47 2F 057 / / 79 4F 117 O O 111 6F 157 o o 16 10 020 Data Link Escape 48 30 060 0 0 80 50 120 P P 112 70 160 p p 17 11 021 Device Control 1 49 31 061 1 1 81 51 121 Q Q 113 71 161 q q 18 12 022 Device Control 2 50 32 062 2 2 82 52 122 R R 114 72 162 r r 19 13 023 Device Control 3 51 33 063 3 3 83 53 123 S S 115 73 163 s a 163 s a 164 t t 165 025 Negative Ack. 53 35 065 5 5 85 55 125 U U 117 75 165 o u 17 75 165 o u 18 025 Negative Ack. 53 35 065 5 5 85 55 125 U U 117 75 165 o u 18 025 Negative Ack. 53 35 065 7 7 87 57 127 W W 119 77 167 w w 12 160 026 Synchronous idle 54 36 066 6 6 86 56 126 V V 118 76 166 v v 12 160 026 Synchronous idle 54 36 066 6 6 86 56 126 V V 118 76 166 v v 12 160 026 Synchronous idle 54 36 066 7 7 87 57 127 W W 119 77 167 w w 12 160 026 Synchronous idle 54 36 066 7 7 87 57 127 W W 119 77 167 w w 12 17 9 171 y y 12 17 9 171 y y 12 17 9 171 y y 12 18 12 Q I 18 12 Q I 18 12 Q I 18 76 166 v v 12 17 9 171 y y 12 17 9 171 { { 12 18 033 Escape 59 38 073 7 9 15 8 133 [[123 78 173 { { 124 036 Record Separator 61 30 075 B > 94 5E 136 ^ ^ 126 7E 176 ~ > 176 ~ > 176 ~ > 176	7 7	007 Bell	39 27	047 '	1	71 47	107 G	G	103 6	67 14	7 g	g
9 9 011 Horizontal Tab 41 29 051)) 73 49 111 I I 105 69 151 i i 10 A 012 Line feed 42 2A 052 * * 74 4A 112 J J 106 6A 152 j j 11 B 013 Vertical Tab 43 2B 053 + + 75 4B 113 K K 107 6B 153 k k 12 C 014 Form feed 44 2C 054 , , 76 4C 114 L L 108 6C 154 l I 13 D 015 Carriage return 45 2D 055 - - 77 4D 115 M M 109 6D 155 m m 14 E 016 Shift Out 46 2E 056 . . 78 4E 116 N N 110 6E 156 n n 15 F 017 Shift In 47 2F 057 / / 79 4F 117 O O 111 6F 157 o o 16 10 020 Data Link Escape 48 30 060 0 0 80 50 120 P P 112 70 160 p p 17 11 021 Device Control 1 49 31 061 1 1 81 51 121 Q Q 113 71 161 q q 18 12 022 Device Control 2 50 32 062 2 2 82 52 122 R R 114 72 162 r r 19 13 023 Device Control 4 52 34 064 3 3 83 53 123 S S 115 73 163 s a 167 4 164 t t 21 15 025 Negative Ack. 53 35 065 5 5 85 55 125 U U 117 75 165 u u 22 16 026 Synchronous idle 54 36 066 6 6 86 56 126 V V 118 76 166 v v 23 17 027 End of Trans. Block 55 37 067 7 7 87 57 127 W W 119 77 167 w w 24 18 030 Cancel 56 38 070 7 7 87 57 127 W W 119 77 167 w w 24 18 033 Escape 59 38 073 7 9 89 59 131 Y Y 121 79 171 z z 27 18 033 Escape 59 38 073 7 9 15 58 133 c I 125 7D 175 z 2 27 18 033 Escape 59 38 073 7 9 15 58 133 c I 125 7D 175 z 5 30 1E 036 Record Separator 60 3C 074 < < 92 5C 134 \ \ 125 7D 175 z \ 126 7E 176 z \ 127 77 77 88 705; \ 126 7E 176 z \ 127 77 77 88 705; \ 127 88 709; \ 125 7D 175 88 725; \ 127 88 709; \ 125 7D 175 88 725; \ 127 88 709; \ 125 7D 175 88 725; \ 127 88 709; \ 125 7D 175 88 725; \ 127 88 709; \ 125 7D 175 88 725; \ 127 88 709; \ 127 77 77 77 77 77 77 77 77 77 77 77 77 7	88	010 Backspace	40 28	050 ((72 48	110 H	H	104 6	68 15	0 h	h
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13 D 015 Carriage return 45 2D 055 - - 77 4D 115 M M 109 6D 155 m m 14 E 016 Shift Out 46 2E 056 . . 78 4E 116 N N 110 6E 156 n n 15 F 017 Shift In 47 2F 057 / / 79 4F 117 O O 111 6F 157 o o 10 020 Data Link Escape 48 30 060 0 0 80 50 120 P P 112 70 160 p p 17 11 021 Device Control 1 49 31 061 1 1 81 51 121 Q Q 113 71 161 q q 18 12 022 Device Control 2 50 32 062 2 2 82 52 122 R R 114 72 162 r r 19 13 023 Device Control 3 51 33 063 3 3 83 53 123 S S 115 73 163 s s 20 14 024 Device Control 4 52 34 064 4 4 84 54 124 T T 116 74 164 t t 21 15 025 Negative Ack. 53 35 065 5 5 85 55 125 U U 117 75 165 u u 22 16 026 Synchronous idle 54 36 066 6 6 86 56 126 V V 118 76 166 v v 23 17 027 End of Trans. Block 55 37 067 7 7 87 57 127 W W 119 77 167 w w 24 18 030 Cancel 56 38 070 7 7 88 55 132 X X 120 78 170 x x 25 19 031 End of Medium 57 39 071 9 9 89 59 131 Y Y 121 79 171 y y 26 1A 032 Substitute 58 3A 072 : : 90 5A 132 Z Z 122 7A 172 z Z 27 1B 033 Escape 59 3B 073 ; ; 91 5B 133 [[123 7B 173 { { 28 10 034 File Separator 60 3C 074 < < 92 5C 134 \ \ 10 035 Group Separator 61 3D 075 = = 93 5D 135]] 125 7D 175 } } 30 1E 036 Record Separator 62 3E 076 > > 94 5E 136 ^ ^ 126 7E 176 ~ ~	11 B	013 Vertical Tab	43 2B	053 +	+	75 4B	113 K	K	107 6	6B 15	3 k	k
14 E 016 Shift Out 46 2E 056 . . 78 4E 116 N N 110 6E 156 n n 15 F 017 Shift In 47 2F 057 / / 79 4F 117 O O 111 6F 157 o o 16 10 020 Data Link Escape 48 30 060 0 O 80 50 120 P P 112 70 160 p p 17 11 021 Device Control 1 49 31 061 1 1 81 51 121 Q Q 113 71 161 q q 18 12 022 Device Control 2 50 32 062 2 2 82 52 122 R R 114 72 162 r r 19 13 023 Device Control 3 51 33 063 3 3 83 53 123 S S 115 73 163 s s 20 14 024 Device Control 4 52 34 064 4 4 84 54 124 T T 116 74 164 t t 21 15 025 Negative Ack. 53 35 065 5 5 85 55 125 U U 117 75 165 u u 22 16 026 Synchronous idle 54 36 066 6 6 86 56 126 V V 118 76 166 v v 23 17 027 End of Trans. Block 55 37 067 7 7 87 57 127 W W 119 77 167 w w 24 18 030 Cancel 56 38 070 7 7 87 57 127 W W 119 77 167 w w 24 18 030 Cancel 56 38 070 7 8 88 58 130 X X 120 78 170 x x 25 19 031 End of Medium 57 39 071 9 9 89 59 131 Y Y 121 79 171 y y 26 1A 032 Substitute 58 3A 072 : : 90 5A 132 Z Z 122 7A 172 z Z 27 1B 033 Escape 59 3B 073 ; ; 91 5B 133 [[123 7B 173 { { 28 1C 034 File Separator 60 3C 074 < < 92 5C 134 \ \ 10 035 Group Separator 61 3D 075 = = 93 5D 135]] 125 7D 175 } } 30 1E 036 Record Separator 62 3E 076 > > 94 5E 136 ^ ^ 126 7E 176 ~ ~	12 C	014 Form feed	44 2C	054 ,	,	76 4C	114 L	L	108	6C 15	4 l	1
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18 12 022 Device Control 2 50 32 062 2 2 82 52 122 R R 114 72 162 r r 19 13 023 Device Control 3 51 33 063 3 3 83 53 123 S S 115 73 163 s s 20 14 024 Device Control 4 52 34 064 4 4 84 54 124 T T 116 74 164 t t 21 15 025 Negative Ack. 53 35 065 5 5 85 55 125 U U 117 75 165 u u 22 16 026 Synchronous idle 54 36 066 6 6 86 56 126 V V 118 76 166 v v 23 17 027 End of Trans. Block 55 37 067 7 7 87 57 127 W W 119 77 167 w w 24 18 030 Cancel 56 38 070 8 8 88 58 130 X X 120 78 170 x x 25 19 031 End of Medium 57 39 071 9 9 89 59 131 Y Y 121 79 171 y y 26 1A 032 Substitute 58 3A 072 : : 90 5A 132 Z Z 122 7A 172 z Z 27 1B 033 Escape 59 3B 073 ; ; 91 5B 133 [[123 7B 173 { { 28 1C 034 File Separator 60 3C 074 < < 92 5C 134 \ \ 126 7E 176 ~ ~	17 11	021 Device Control 1	49 31	061 1	1	81 51	121 Q	Q	113	71 16	1 q	q
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21 15 025 Negative Ack. 53 35 065 5 5 85 55 125 U U 117 75 165 u u 22 16 026 Synchronous idle 54 36 066 6 6 86 56 126 V V 118 76 166 v v 23 17 027 End of Trans. Block 55 37 067 7 7 87 57 127 W W 119 77 167 w w 24 18 030 Cancel 56 38 070 8 8 88 58 130 X X 120 78 170 x x 25 19 031 End of Medium 57 39 071 9 9 89 59 131 Y Y 121 79 171 y y 26 1A 032 Substitute 58 3A 072 : : 90 5A 132 Z Z 122 7A 172 z z 27 18 033 Escape 59 3B 073 ; ; 91 5B 133 [[123 7B 173 { { 28 1C 034 File Separator 60 3C 074 < < 92 5C 134 \ \ 124 7C 174 29 1D 035 Group Separator 61 3D 075 = = 93 5D 135 ^ \ 126 7E 176 ~ \sigma	19 13	023 Device Control 3	51 33	063 3	3	83 53	123 S	S	115	73 16	3 s	S
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22 16 026 Synchronous idle 23 17 027 End of Trans. Block 24 18 030 Cancel 25 19 031 End of Medium 26 1A 032 Substitute 27 1B 033 Escape 27 1B 033 Escape 28 1C 034 File Separator 29 1D 035 Group Separator 30 1E 036 Record Separator 30 16 08 436 066 6 6 86 56 126 V V 118 76 166 v V 119 77 167 w w 110 78 170 x x 120 78 170 y y 121 79 171 y y 122 7A 172 z z 123 7B 173 { { 124 7C 174 125 7D 175 } } 126 7E 176 ~ ~	21 15	025 Negative Ack.	53 35	065 5	5	85 55	125 U	U	117	75 16	5 u	u
24 18 030 Cancel 56 38 070 8 8 88 58 130 X X 120 78 170 x x 25 19 031 End of Medium 57 39 071 9 9 89 59 131 Y Y 121 79 171 y y 26 1A 032 Substitute 58 3A 072 : : 90 5A 132 Z Z 122 7A 172 z Z 27 1B 033 Escape 59 3B 073 ; ; 91 5B 133 [[123 7B 173 { { 28 1C 034 File Separator 60 3C 074 < < 92 5C 134 \ \ 124 7C 174 29 1D 035 Group Separator 61 3D 075 = = 93 5D 135]] 125 7D 175 } } 30 1E 036 Record Separator 62 3E 076 > > 94 5E 136 ^ ^ 126 7E 176 ~ ~	22 16		54 36	066 6	6	86 56	126 V	V	118 7	76 16	6 v	V
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26 1A 032 Substitute 58 3A 072 : : 90 5A 132 Z Z 122 7A 172 z Z 27 1B 033 Escape 59 3B 073 ; ; 91 5B 133 [[123 7B 173 { { 28 1C 034 File Separator 60 3C 074 < <	24 18	030 Cancel	56 38	070 8	8	88 58	130 X	X	120 7	78 17	0 x	X
26 1A 032 Substitute 58 3A 072 : : 90 5A 132 Z Z 122 7A 172 z Z 27 1B 033 Escape 59 3B 073 ; ; 91 5B 133 [[123 7B 173 { { 28 1C 034 File Separator 60 3C 074 < <	25 19	031 End of Medium	57 39	071 9	9	89 59	131 Y	Y	121 7	79 17	1 y	V
27 1B 033 Escape 59 3B 073 ; ; 91 5B 133 [[123 7B 173 { { 28 1C 034 File Separator 60 3C 074 < <	26 1A	032 Substitute	58 3A	072 :	:	90 5A	132 Z	Z	122	7A 17	2 z	1-700
28 1C 034 File Separator 60 3C 074 < < 92 5C 134 \ \ 124 7C 174 29 1D 035 Group Separator 61 3D 075 = = 93 5D 135]] 30 1E 036 Record Separator 62 3E 076 > > 94 5E 136 ^ ^ 126 7E 176 ~ ~	27 1B		59 3B	073 ;	;	91 5B	133 [[123	7B 17	3 {	{
29 1D 035 Group Separator 61 3D 075 = = 93 5D 135]] 125 7D 175 } } 30 1E 036 Record Separator 62 3E 076 > > 94 5E 136 ^ ^ 126 7E 176 ~ ~	28 1C		60 3C	074 <	<	92 5C	134 \	1				Ì
30 1E 036 Record Separator 62 3E 076 > > 94 5E 136 ^ ^ 126 7E 176 ~ ~	29 1D		61 3D		=	93 5D	135]	ĺ	125	7D 17	5 }	}
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31 1F U3/ Unit Separator	31 1F	037 Unit Separator	63 3F	077 ?	?	95 5F	137 _	_	127		7	Del

For More Characters, Use Unicode

There are plenty of characters that aren't available in ASCII (characters from non-English languages, advanced symbols, emoji...).

The Unicode system represents every character that can be typed into a computer. It uses up to 5 bytes, which can represent up to 1 trillion characters!

Find all the Unicode characters here: www.unicode-table.com

Sidebar: Fun Facts

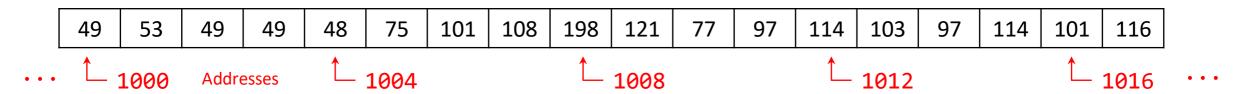
Fun Fact #1: .txt and .py files are encoded using just ASCII (or Unicode). But .docx and .pdf files have extra encoding information, since they are more than just text.

Fun Fact #2: the Unicode Consortium gets to decide which new Emoji are added to the table. Anyone can submit a request for a new Emoji!

Computer Memory is Stored as Binary

Your computer keeps track of saved data and all the information it needs to run in its **memory**, which is represented as binary. You can think about your computer's memory as a really long list of bits, where each bit can be set to 0 or 1. But usually we think in terms of bytes, which are groups of 8 bits.

Every byte in your computer has an **address**, which the computer uses to look it up.



Binary Values Depend on Interpretation

When you open a file on your computer, the application reads the associated binary and **interprets** the binary values based on the file encoding it expects.

You can attempt to open **any file** using **any program**, if you change the filetype extension to fool the program. Some programs may crash, and others will show nonsense, because the binary isn't being interpreted correctly.

Example: try changing a .docx filetype to .txt, then open it in a plain text editor.

We Use Lots of Bytes!

In modern computing, we use a **lot** of bytes to represent information.

Smartphone Memory: 64 gigabytes = 64 **billion** bytes

Google databases: Over 100 million gigabytes = 100 quadrillion bytes!

CMU Wifi: 15 million bytes per second

Sidebar: Compression Reduces Size

Transferring bytes between computers takes time. To save time, we often apply compression algorithms, which reduce the number of bytes needed to represent a thing. This can be done in two ways: lossless or lossy.

In **lossless** compression, no information is lost. When you undo the compression, you get back exactly the same data as the original version. This is done by mapping short keys to longer patterns.

Images, videos, and music often use **lossy** algorithms to get much greater compression, to as little as 10% of the original size! These algorithms reduce information by removing details that we can't perceive. However, adding more compression reduces the quality of the image, video, or audio recording.

JPEG (images), MPEG (video), and MP3 (audio) are common file formats that use lossy compression. GIF files use lossless compression.

Learning Objectives

 Understand how different number systems can represent the same information

• Translate binary numbers to decimal, and vice versa

Interpret binary numbers as abstracted types, including colors and text

Feedback form: https://bit.ly/110-feedback