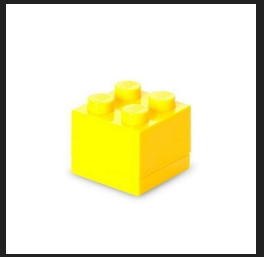
Bits and Bytes

Derrick Modified by Aidan

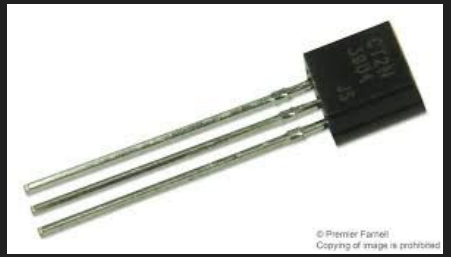
Transistors



-The smallest building block of computing

-A switch that can be in either an ON or OFF position

-State is changed by electrical current



-Solid State (no moving parts)

-A collection of transistors etched on to a piece of Silicon is called a Chip

Data

At the smallest scale in the computer, information is stored as bits (and bytes).

“Single bit of information”

On / off

Yes / No

True / False

1 / 0

Number Systems

Decimal (Base 10)

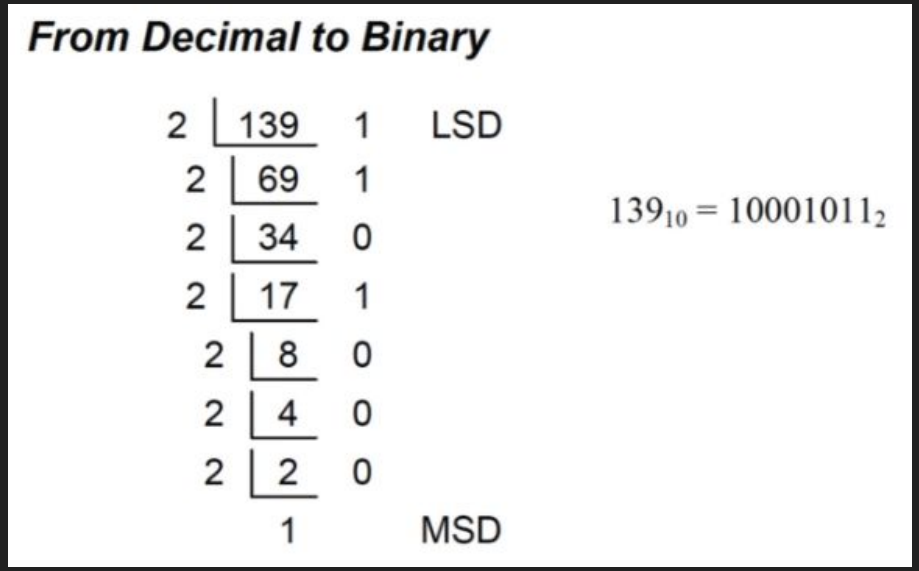
Binary (Base 2)

Octal (Base 8)

Hexadecimal (Base 16)

Number Conversion

- Using Successive Division, we can easily convert decimal numbers to binary, octal, or hexadecimal



Converting Back

Convert the 8 bit binary number 00011010

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

16 + 8 + 2 = 26

$00011010_2 = 26_{10}$

Bits

Bit - the smallest unit of storage

A bit stores just a 0 or 1

“Computer is all 0’s and 1’s” … bits

Anything with two separate states can store 1 bit

Bytes and Words

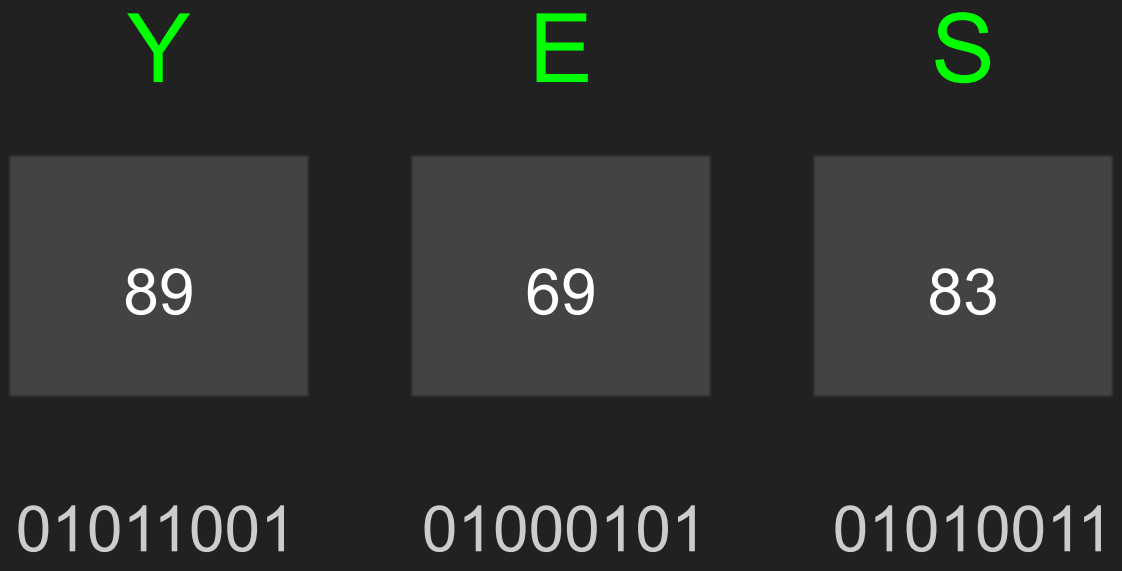
- Individual bits aren't that useful
- Solution: group 8 bits together into bytes
  - Optimized to handle bytes instead of bits
- How much exactly can one byte hold?
  - 1 bit: 2, 2 bits: 4, 3 bits: 8, 4 bits: 16…
  - Mathematically: n bits yields 2^n patterns
- Group 4 or 8 bytes together to make a word
  - Number of bits the CPU reads from memory at a time
  - Part of the architecture

Representing Data: Character

- Plain text uses ASCII (a numbering system for characters)
  - Each character is represented by one byte (8 bits)
- Unicode
  - Used for representing “special” characters and emojis
  - Controlled by The Unicode Consortium
  - Represented with one to four bytes based on an encoding scheme
  - UTF-8 (most commonly used in web pages, emails etc.)
- Words are just a sequence of characters (computer use ASCII when possible)

ASCII TABLE

Decimal	Hex	Char	Decimal	Hex	Char	Decimal	Hex	Char	Decimal	Hex	Char
0	0	[NULL]	32	20	[SPACE]	64	40	@	96	60	`
1	1	[START OF HEADING]	33	21	!	65	41	A	97	61	a
2	2	[START OF TEXT]	34	22	"	66	42	B	98	62	b
3	3	[END OF TEXT]	35	23	#	67	43	C	99	63	c
4	4	[END OF TRANSMISSION]	36	24	$	68	44	D	100	64	d
5	5	[ENQUIRY]	37	25	%	69	45	E	101	65	e
6	6	[ACKNOWLEDGE]	38	26	&	70	46	F	102	66	f
7	7	[BELL]	39	27	'	71	47	G	103	67	g
8	8	[BACKSPACE]	40	28	(	72	48	H	104	68	h
9	9	[HORIZONTAL TAB]	41	29	)	73	49	I	105	69	i
10	A	[LINE FEED]	42	2A	*	74	4A	J	106	6A	j
11	B	[VERTICAL TAB]	43	2B	+	75	4B	K	107	6B	k
12	C	[FORM FEED]	44	2C	,	76	4C	L	108	6C	l
13	D	[CARRIAGE RETURN]	45	2D	-	77	4D	M	109	6D	m
14	E	[SHIFT OUT]	46	2E	.	78	4E	N	110	6E	n
15	F	[SHIFT IN]	47	2F	/	79	4F	O	111	6F	o
16	10	[DATA LINK ESCAPE]	48	30	0	80	50	P	112	70	p
17	11	[DEVICE CONTROL 1]	49	31	1	81	51	Q	113	71	q
18	12	[DEVICE CONTROL 2]	50	32	2	82	52	R	114	72	r
19	13	[DEVICE CONTROL 3]	51	33	3	83	53	S	115	73	s
20	14	[DEVICE CONTROL 4]	52	34	4	84	54	T	116	74	t
21	15	[NEGATIVE ACKNOWLEDGE]	53	35	5	85	55	U	117	75	u
22	16	[SYNCHRONOUS IDLE]	54	36	6	86	56	V	118	76	v
23	17	[ENG OF TRANS. BLOCK]	55	37	7	87	57	W	119	77	w
24	18	[CANCEL]	56	38	8	88	58	X	120	78	x
25	19	[END OF MEDIUM]	57	39	9	89	59	Y	121	79	y
26	1A	[SUBSTITUTE]	58	3A	:	90	5A	Z	122	7A	z
27	1B	[ESCAPE]	59	3B	;	91	5B	[	123	7B	{
28	1C	[FILE SEPARATOR]	60	3C	<	92	5C	\	124	7C	|
29	1D	[GROUP SEPARATOR]	61	3D	=	93	5D	]	125	7D	}
30	1E	[RECORD SEPARATOR]	62	3E	>	94	5E	^	126	7E	~
31	1F	[UNIT SEPARATOR]	63	3F	?	95	5F	_	127	7F	[DEL]

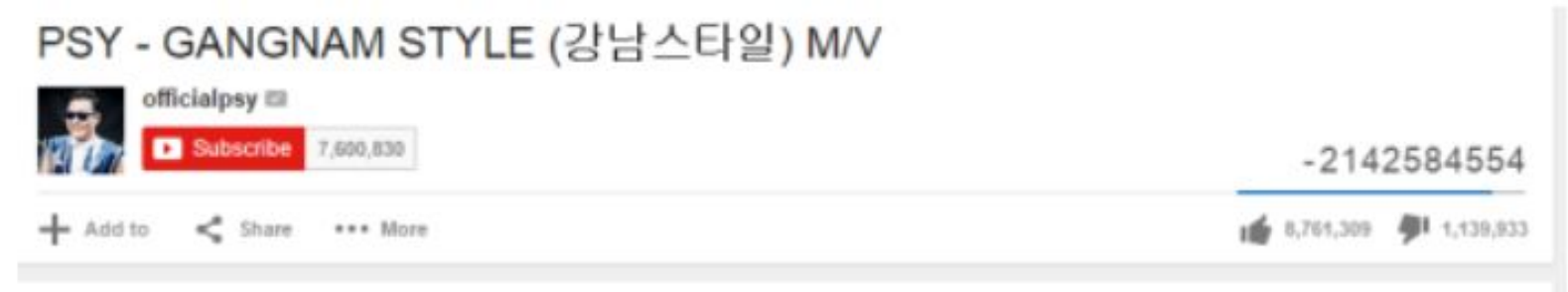

Y
E
S
89
69
83
01011001
01000101
01010011

Emojis (Face with Tears of Joy)

128514

Representing Data: Integers

- Represented with one computer word (32 or 64 bits)
- Problems with 32 bits:
  - Not enough options to label all computers in the world
  - Gangnam Style “overflow”



Representing Data: Real Numbers

- Usually called doubles
- Represented with one computer word (8 bytes)
- Much like scientific notation (IEEE Floating Point)
- Keeps track of the sign, the exponent, and the fractional part
- Idea: `7.5` can be represented as `1.875 * 2^2`
- Tradeoff: fixed number of bytes means not perfectly precise

Representing Data: Colors

- RGB (Red, Green, Blue)

8 bits 8 bits 8 bits

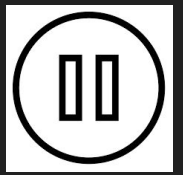
Representing Data: Images

Represented using a set of three numbers for each pixel.

Provides an RGB value set for every pixel, so the data for an image is a collection of pixel colour values.

Representing Data: Animation (Videos)

- *“It’s just a sequence of images flying past the screen, very quickly”*
- FPS (Frame Per Second)
- Movies - “moving pictures”



Lots of Bytes

- Fact: 2^10 is 1024 (about 1000)
- 1 kilobyte (KB) = 1024 bytes
  - About the size of a 1000 characters
  - Measures emails and text documents
- 1 megabyte (MB) = 1024 KB (about 1 mil bytes)
  - MP3 audio is about 1 MB per minute
  - Used to measure audio clips and image sizes
- 1 gigabyte (GB) = 1024 MB (about 1 bil bytes)
  - 1 hour of video is about 2 GB
  - Used to measure video sizes and computer storage space
- 1 terabyte (TB) = 1024 GB (about 1 tril bytes)
  - Used to measure computer storage spaces
  - Sometimes used in the context of “big data”, along with petabytes (1024 TB)

Storage space practice

- Alice has 600 MB of data. Bob has 700 MB of data. Will it all fit on Alice's 2 GB thumb drive?
  - Yes, 1300 MB is about 1.3 GB
- Alice has 100 small images, each of which is 500 KB. How much space do they take up overall in MB?
  - 100 times 500 KB is 50000 KB which is about 50 MB
- Your ghost hunting group is recording the sound inside a haunted Stanford classroom for 20 hours as MP3 audio files. About how much data will that be, expressed in GB?
  - MP3 usually takes up about 1 MB per min. 60 mins * 20 = 1200 mins which is about 1200 MB, 1.2 GB

Megabytes vs Mebibytes

- Marketers like to interpret a megabyte as 1 mil bytes (1000 KB) - less memory to make

- Mebibyte is the actual 1024 * 1024 bytes (1024KB)
- For more about kibibytes

Extra resources

- https://www.electronics-tutorials.ws/binary/bin_1.html
- https://www.electronics-tutorials.ws/binary/bin_2.html
- https://www.electronics-tutorials.ws/binary/bin_3.html
- https://www.electronics-tutorials.ws/binary/bin_4.html
- https://www.electronics-tutorials.ws/binary/bin_5.html
- https://www.electronics-tutorials.ws/binary/signed-binary-numbers.html
- https://www.electronics-tutorials.ws/binary/binary-coded-decimal.html
- https://www.electronics-tutorials.ws/binary/binary-fractions.html