HOW THE COMPUTER WORKS

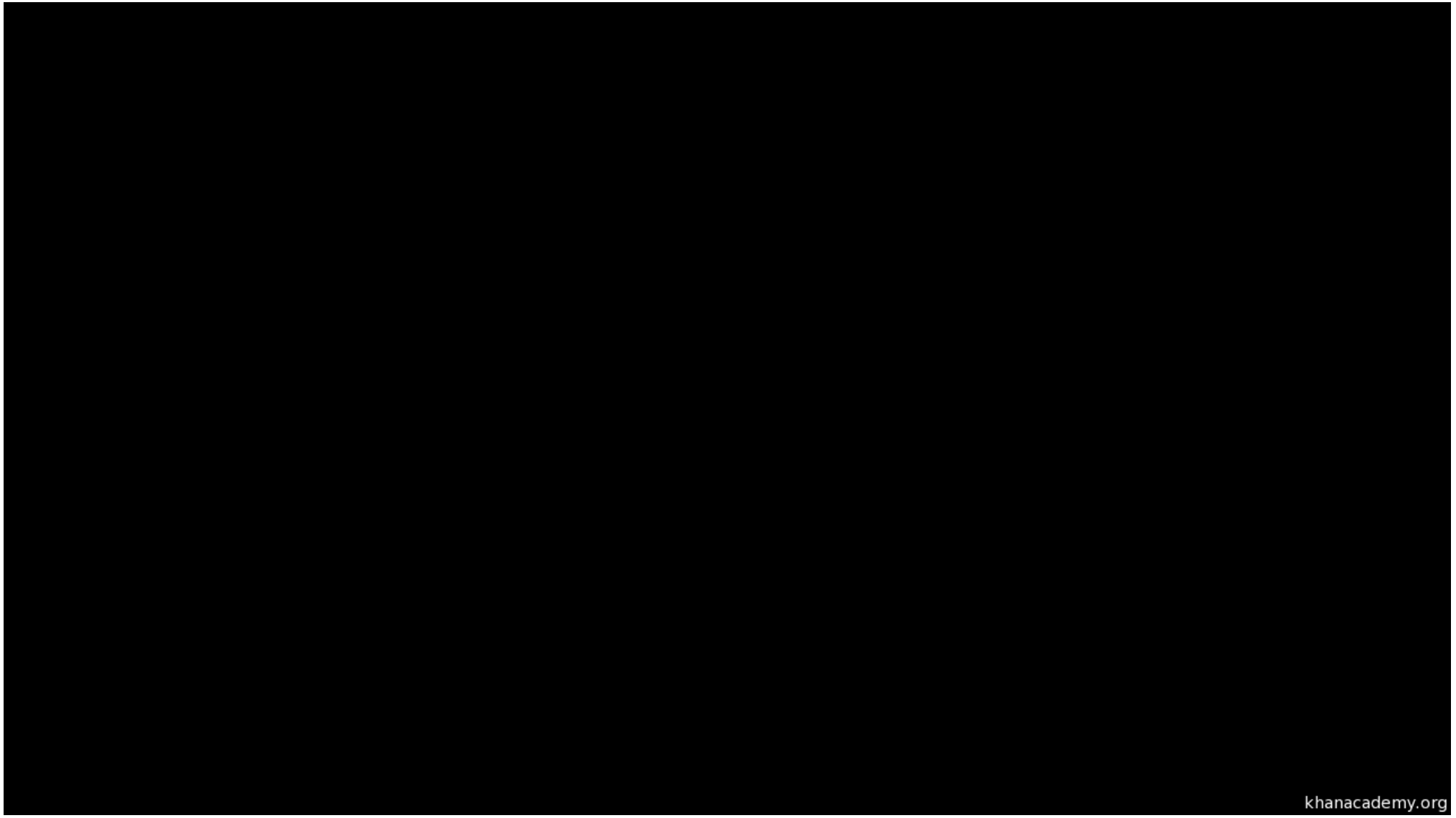
EGCO103 INFORMATION TECHNOLOGY IN THE DAILY LIFE

KANAT POOLSAWASD
DEPARTMENT OF COMPUTER ENGINEERING
MAHIDOL UNIVERSITY

UNDERSTANDING YOUR COMPUTER

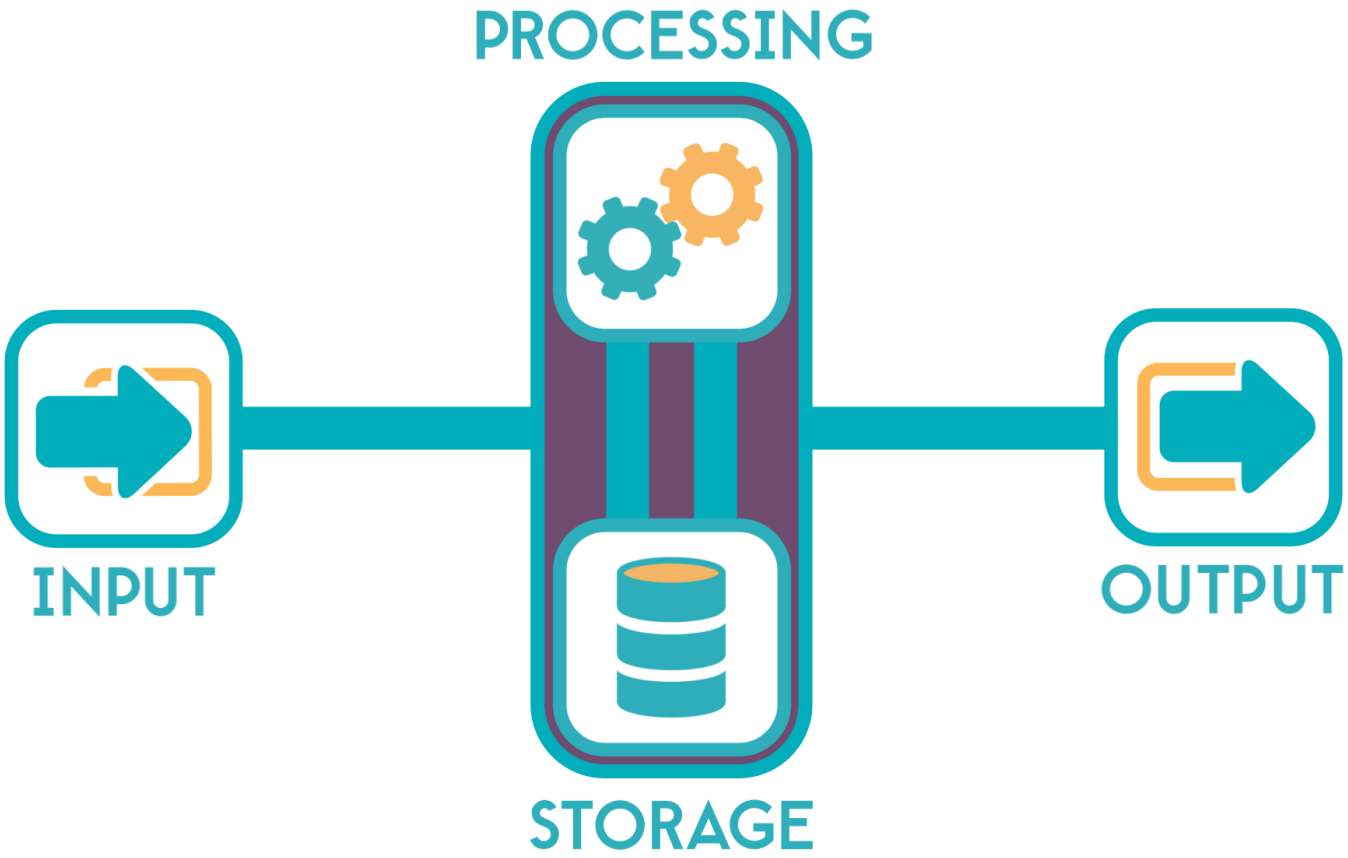
- Computer is a data processing device.
- Performs four major functions:
  - **Input:** Gathers data, allows users to input data.
  - **Process:** Manipulates, calculates, or organizes data into information.
  - **Output:** Displays data and information for user.
  - **Storage:** Saves data and information for later use.

WHAT MAKES A COMPUTER, A COMPUTER



* https://code.org and https://www.khanacademy.org

HOW THE COMPUTER WORKS ?



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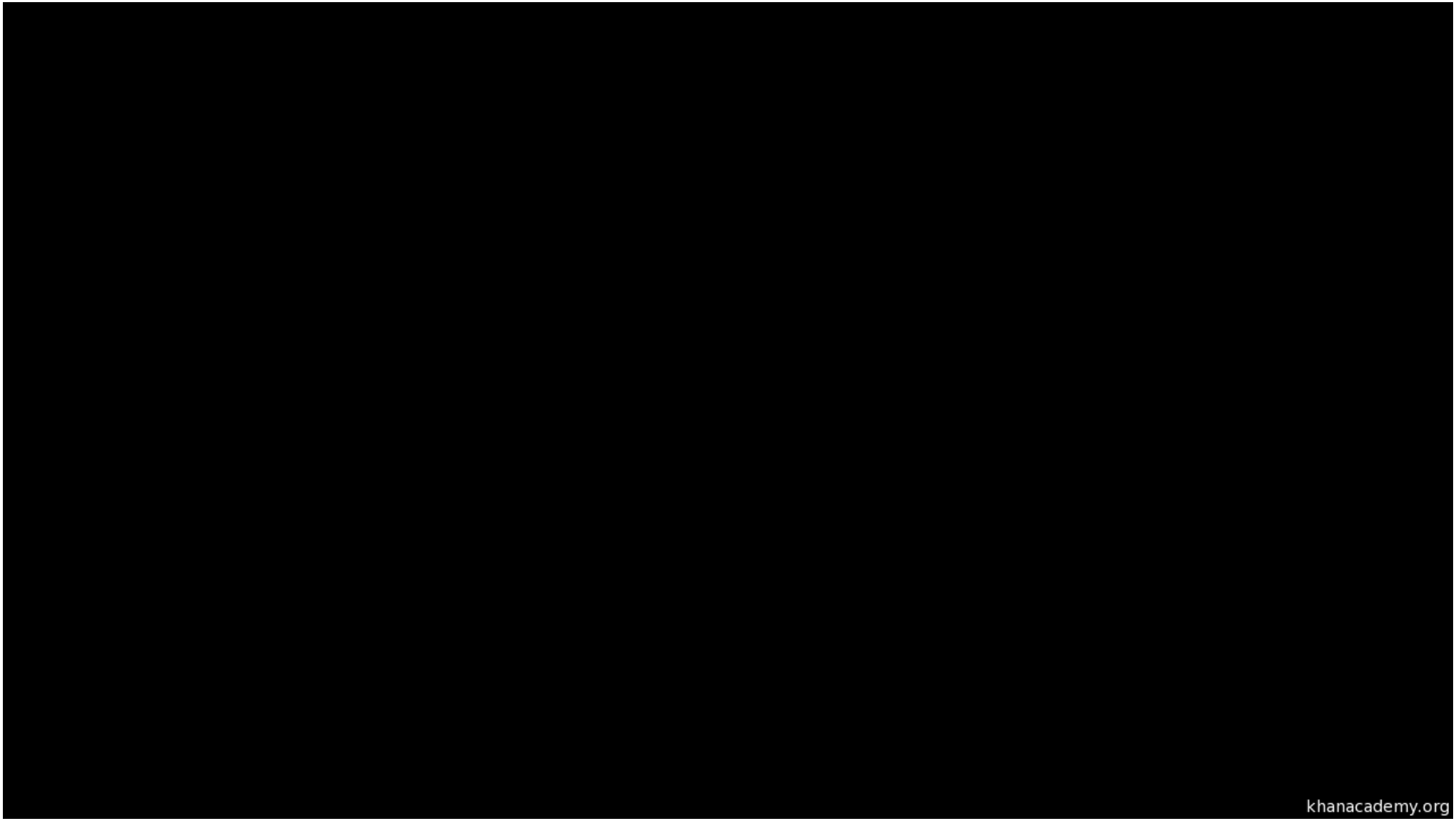
BINARY & INFORMATION



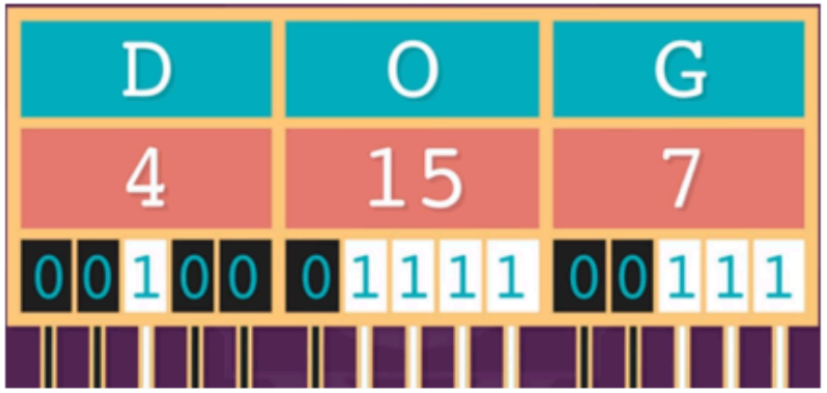
* https://code.org and https://www.khanacademy.org

BITS AND BYTES

- The language of computers
  - Bit (BInary digiT): 0 or 1
  - Byte = 8 bits
- See ‘b’ = bit, ‘B’ = Byte
- Each letter, number, or character is a unique combination of 8 bits of 0s and 1s

TEXT VIA BINARY NUMBERS

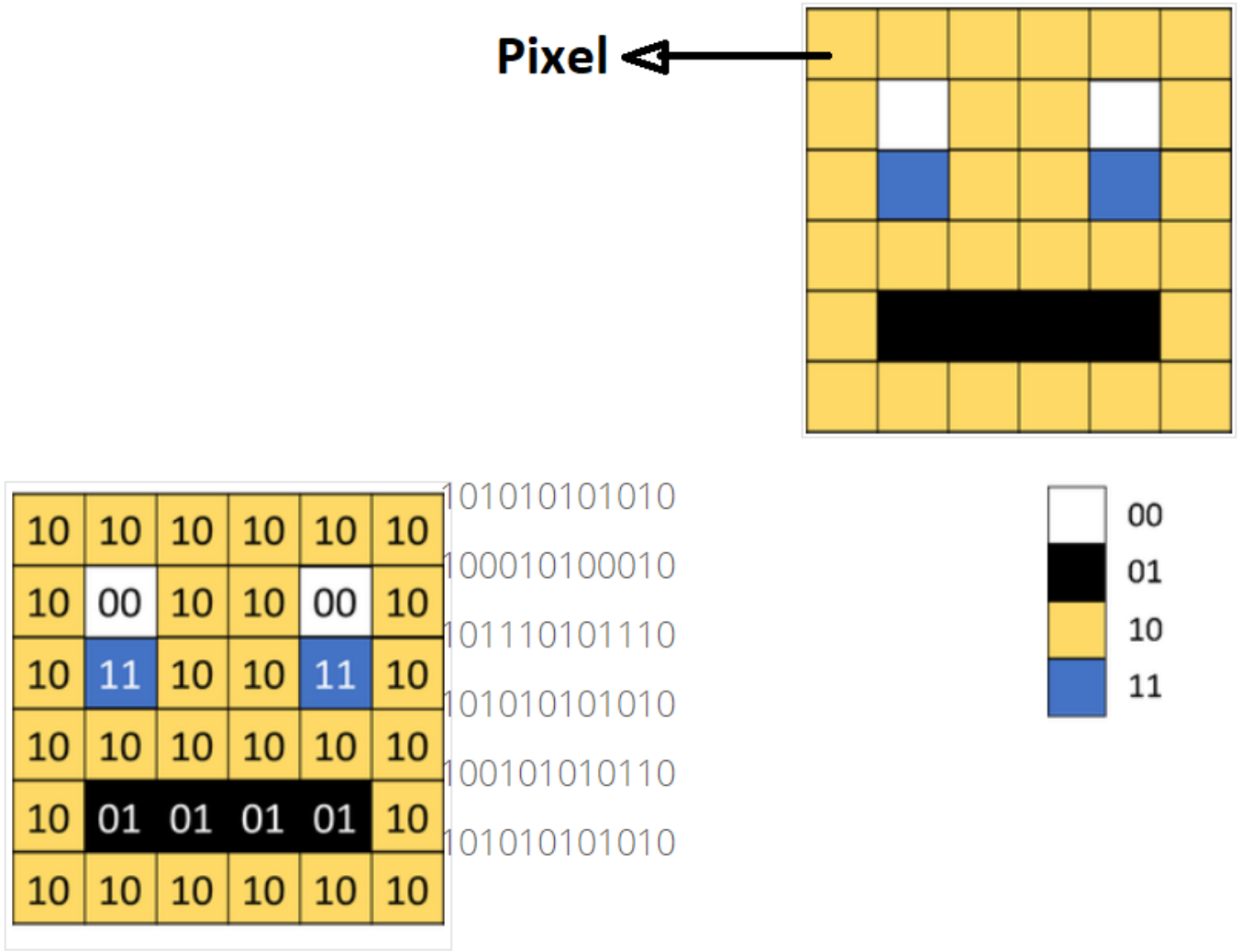
A	1	0 0 0 0 1
B	2	0 0 0 1 0
C	3	0 0 0 1 1
D	4	0 0 1 0 0
E	5	0 0 1 0 1
F	6	0 0 1 1 0
G	7	0 0 1 1 1



Decimal - Binary - Octal - Hex – ASCII Conversion Chart

Decimal	Binary	Octal	Hex	ASCII	Decimal	Binary	Octal	Hex	ASCII	Decimal	Binary	Octal	Hex	ASCII	Decimal	Binary	Octal	Hex	ASCII
0	00000000	000	00	NUL	32	00100000	040	20	SP	64	01000000	100	40	@	96	01100000	140	60	`
1	00000001	001	01	SOH	33	00100001	041	21	!	65	01000001	101	41	A	97	01100001	141	61	a
2	00000010	002	02	STX	34	00100010	042	22	"	66	01000010	102	42	B	98	01100010	142	62	b
3	00000011	003	03	ETX	35	00100011	043	23	#	67	01000011	103	43	C	99	01100011	143	63	c
4	00000100	004	04	EOT	36	00100100	044	24	$	68	01000100	104	44	D	100	01100100	144	64	d
5	00000101	005	05	ENQ	37	00100101	045	25	%	69	01000101	105	45	E	101	01100101	145	65	e
6	00000110	006	06	ACK	38	00100110	046	26	&	70	01000110	106	46	F	102	01100110	146	66	f
7	00000111	007	07	BEL	39	00100111	047	27	'	71	01000111	107	47	G	103	01100111	147	67	g
8	00001000	010	08	BS	40	00101000	050	28	(	72	01001000	110	48	H	104	01101000	150	68	h
9	00001001	011	09	HT	41	00101001	051	29	)	73	01001001	111	49	I	105	01101001	151	69	i
10	00001010	012	0A	LF	42	00101010	052	2A	*	74	01001010	112	4A	J	106	01101010	152	6A	j
11	00001011	013	0B	VT	43	00101011	053	2B	+	75	01001011	113	4B	K	107	01101011	153	6B	k
12	00001100	014	0C	FF	44	00101100	054	2C	,	76	01001100	114	4C	L	108	01101100	154	6C	l
13	00001101	015	0D	CR	45	00101101	055	2D	-	77	01001101	115	4D	M	109	01101101	155	6D	m
14	00001110	016	0E	SO	46	00101110	056	2E	.	78	01001110	116	4E	N	110	01101110	156	6E	n
15	00001111	017	0F	SI	47	00101111	057	2F	/	79	01001111	117	4F	O	111	01101111	157	6F	o
16	00010000	020	10	DLE	48	00110000	060	30	0	80	01010000	120	50	P	112	01110000	160	70	p
17	00010001	021	11	DC1	49	00110001	061	31	1	81	01010001	121	51	Q	113	01110001	161	71	q
18	00010010	022	12	DC2	50	00110010	062	32	2	82	01010010	122	52	R	114	01110010	162	72	r
19	00010011	023	13	DC3	51	00110011	063	33	3	83	01010011	123	53	S	115	01110011	163	73	s
20	00010100	024	14	DC4	52	00110100	064	34	4	84	01010100	124	54	T	116	01110100	164	74	t
21	00010101	025	15	NAK	53	00110101	065	35	5	85	01010101	125	55	U	117	01110101	165	75	u
22	00010110	026	16	SYN	54	00110110	066	36	6	86	01010110	126	56	V	118	01110110	166	76	v
23	00010111	027	17	ETB	55	00110111	067	37	7	87	01010111	127	57	W	119	01110111	167	77	w
24	00011000	030	18	CAN	56	00111000	070	38	8	88	01011000	130	58	X	120	01111000	170	78	x
25	00011001	031	19	EM	57	00111001	071	39	9	89	01011001	131	59	Y	121	01111001	171	79	y
26	00011010	032	1A	SUB	58	00111010	072	3A	:	90	01011010	132	5A	Z	122	01111010	172	7A	z
27	00011011	033	1B	ESC	59	00111011	073	3B	;	91	01011011	133	5B	[	123	01111011	173	7B	{
28	00011100	034	1C	FS	60	00111100	074	3C	<	92	01011100	134	5C	\	124	01111100	174	7C	|
29	00011101	035	1D	GS	61	00111101	075	3D	=	93	01011101	135	5D	]	125	01111101	175	7D	}
30	00011110	036	1E	RS	62	00111110	076	3E	>	94	01011110	136	5E	^	126	01111110	176	7E	~
31	00011111	037	1F	US	63	00111111	077	3F	?	95	01011111	137	5F	_	127	01111111	177	7F	DEL

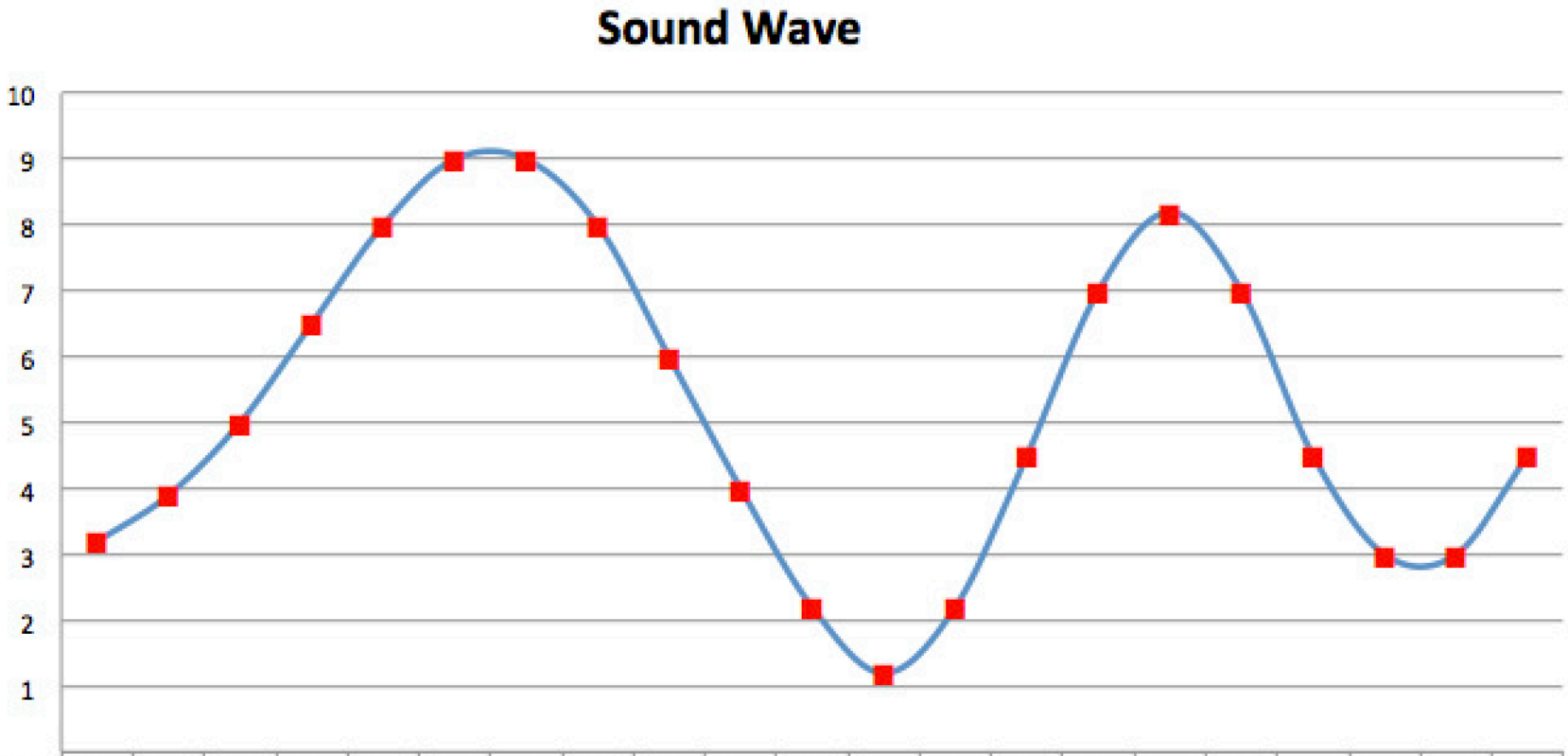
HOW IMAGES ARE STORED ON A COMPUTER ?



HOW IMAGES ARE STORED ON A COMPUTER ?

Color	Name	Bits Red	Bits Green	Bits Blue	Decimal
	Red	11111111	00000000	00000000	(255,0,0)
	Green	00000000	11111111	00000000	(0,255,0)
	Yellow	11111111	11111111	00000000	(255,255,0)

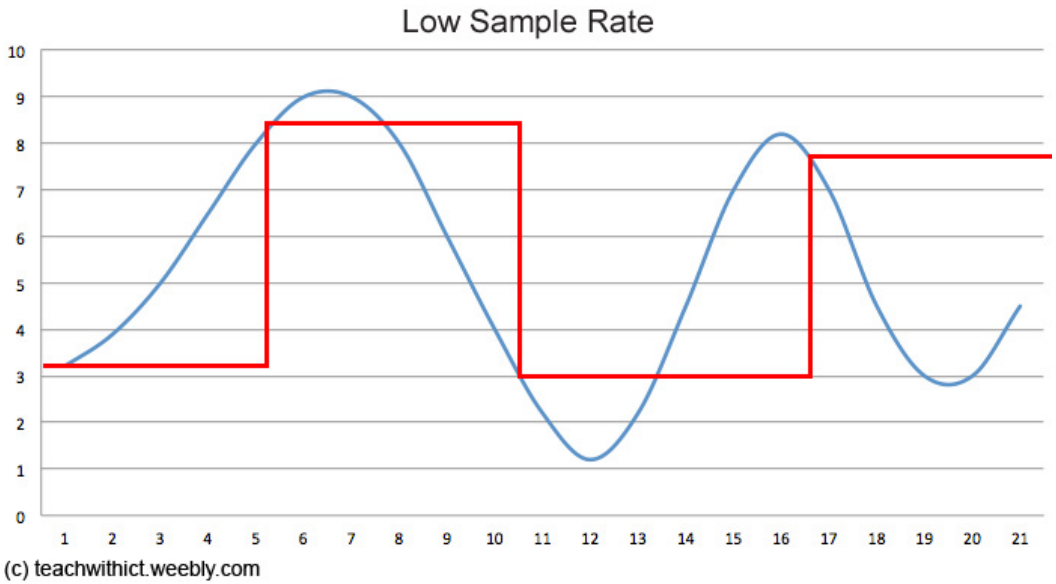
BINARY REPRESENTATION OF SOUND (1)

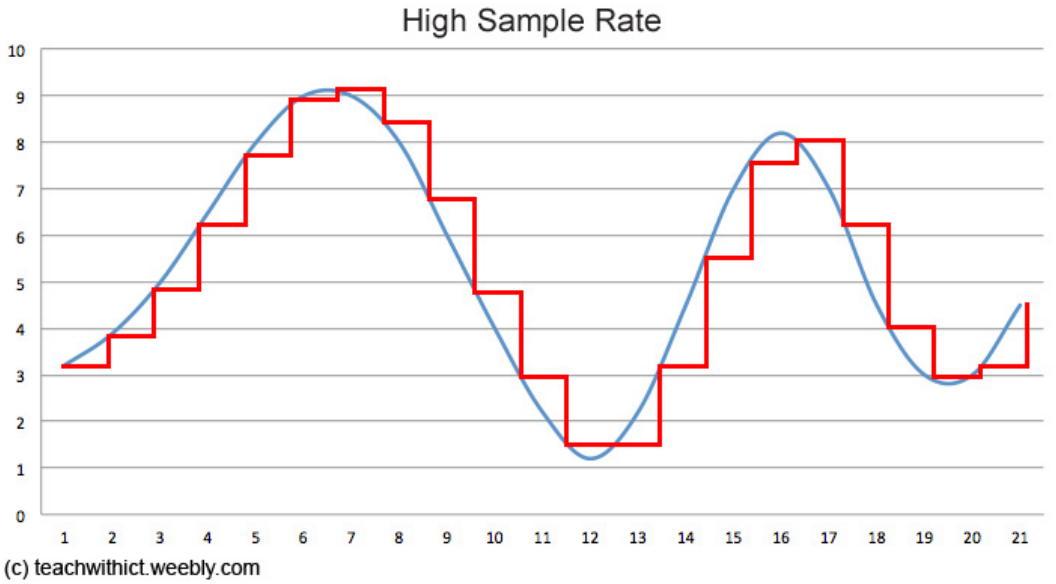


Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Sample	3.2	3.9	5	6.5	8	9	9	8	6	4	2.2	1.2	2.2	4.5	7	8.2	7	4.5	3	3	4.5

* https://www.teachwithict.com/binary-representation-of-sound.html

BINARY REPRESENTATION OF SOUND (2)



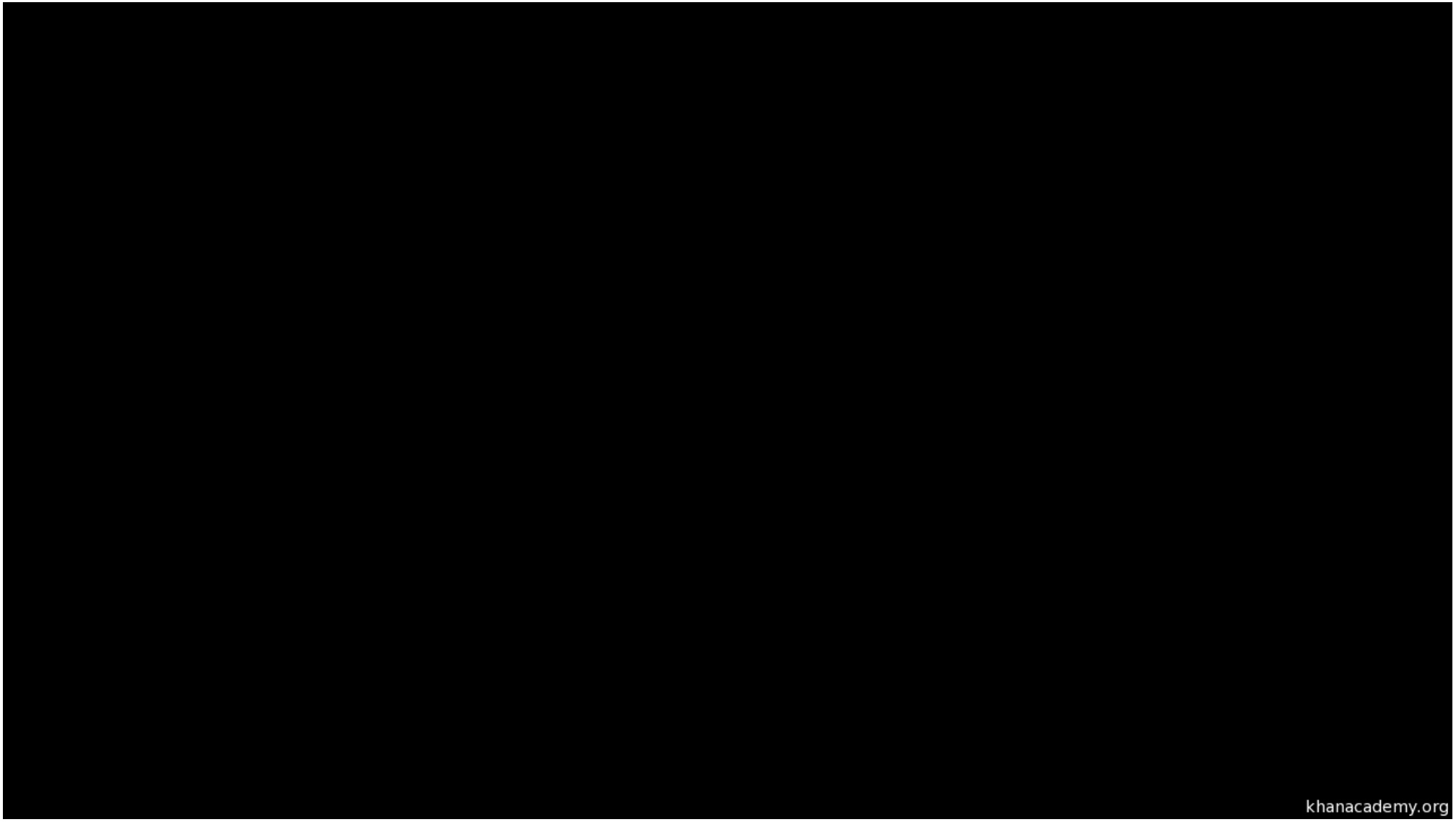


* https://www.teachwithict.com/binary-representation-of-sound.html

HOW MUCH IS A BYTE

Name	Abbreviation	Number of Bytes
Byte	B	1 byte
Kilobyte	KB	1,024 bytes (2^{10})
Megabyte	MB	1,048,576 bytes (2^{20} bytes)
Gigabyte	GB	1,073,741,824 bytes (2^{30} bytes)
Terabyte	TB	1,099,511,627,776 bytes (2^{40} bytes)
Petabyte	PB	1,125,899,906,842,62 bytes (2^{50} bytes)
Exabyte	EB	1,152,921,504,606,846,976 bytes (2^{60} bytes)
Zettabyte	ZB	1,180,591,620,717,411,303,424 bytes (2^{70} bytes)

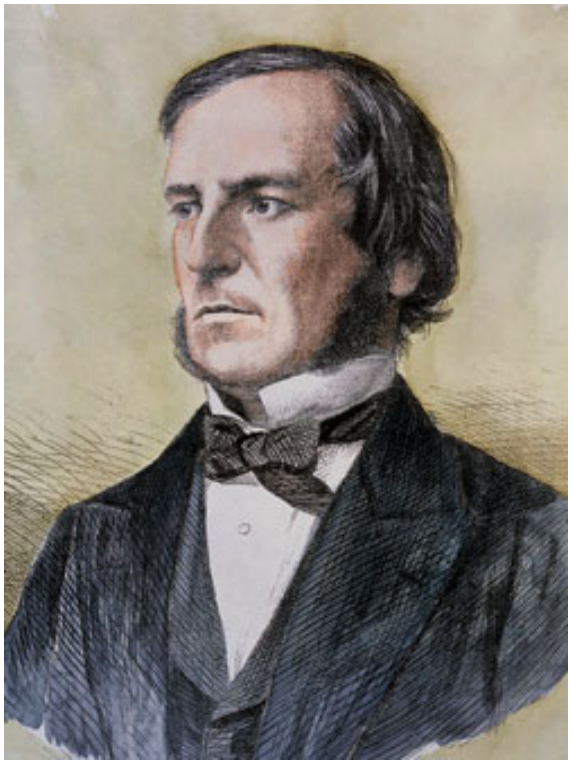
CIRCUITS & LOGIC



* https://code.org and https://www.khanacademy.org

GEORGE BOOLE & BOOLEAN ALGEBRA

- Boolean algebra was introduced by George Boole in his first book The Mathematical Analysis of Logic (1847), and set forth more fully in his An Investigation of the Laws of Thought (1854).



VALUES & BASIC OPERATIONS

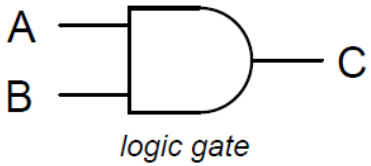
x	y	$x \wedge y$	$x \vee y$
0	**0**	0	0
1	**0**	0	1
0	**1**	0	1
1	**1**	1	1

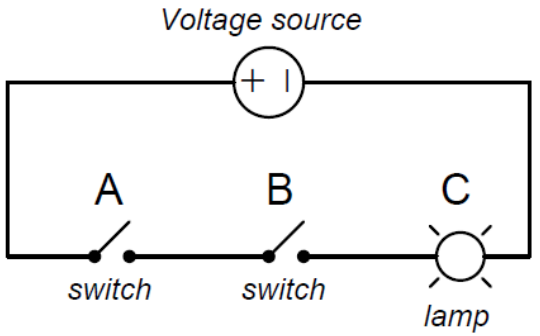
x	$\neg x$
0	1
1	0

- In Boolean algebra they denote the truth values false and true.
- The basic operations of Boolean algebra are as follows:
  - AND (Conjunction)
  - OR (Disjunction)
  - NOT (Negation)
- Alternatively the values of x ∧ y, x ∨ y, and ¬x can be expressed by tabulating their values with truth tables as follows:

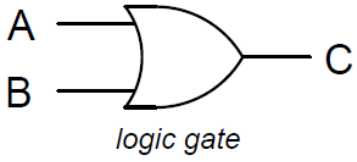
BOOLEAN ALGEBRA & LOGIC GATE

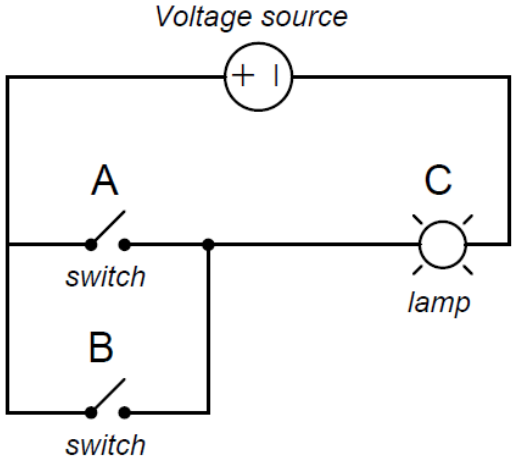
AND



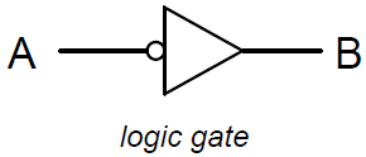


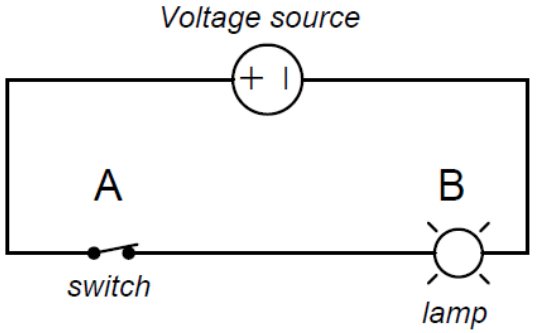
OR



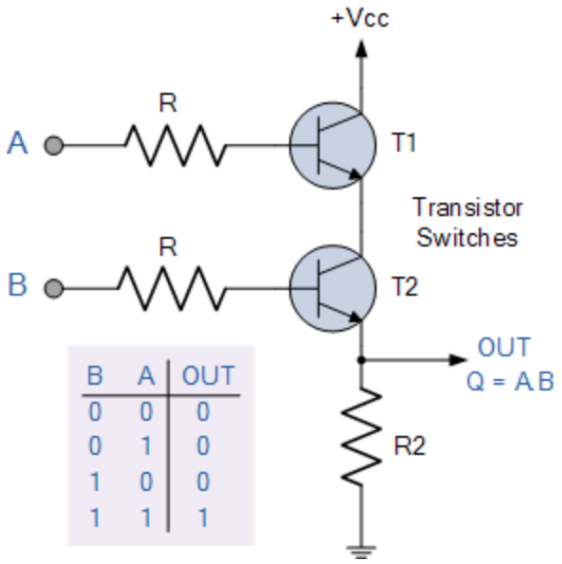


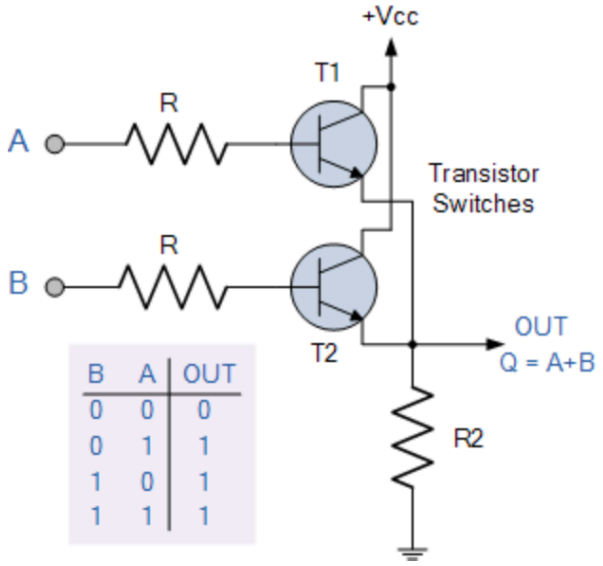
NOT

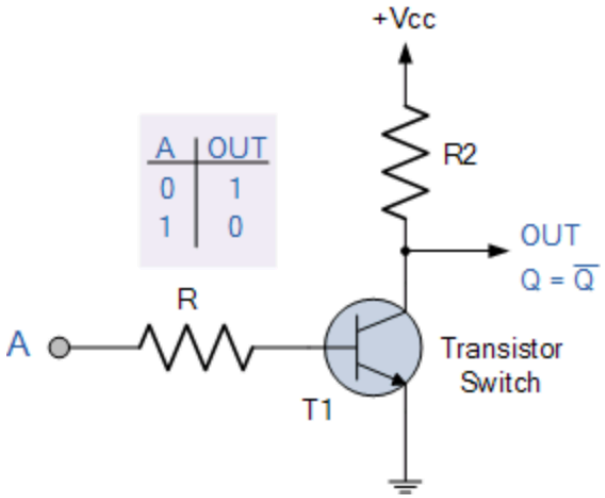




LOGIC GATE & TRANSISTER

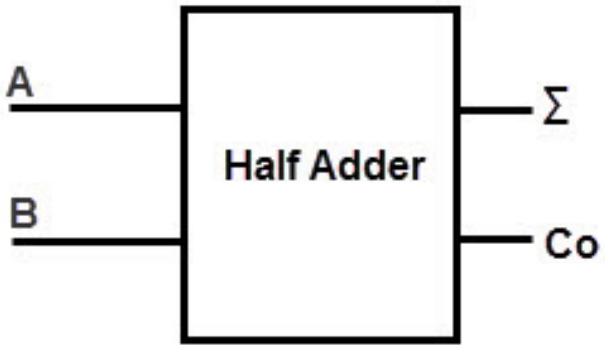






- Logic gate can be constructed using RTL Resistor-Transistor switches connected together.

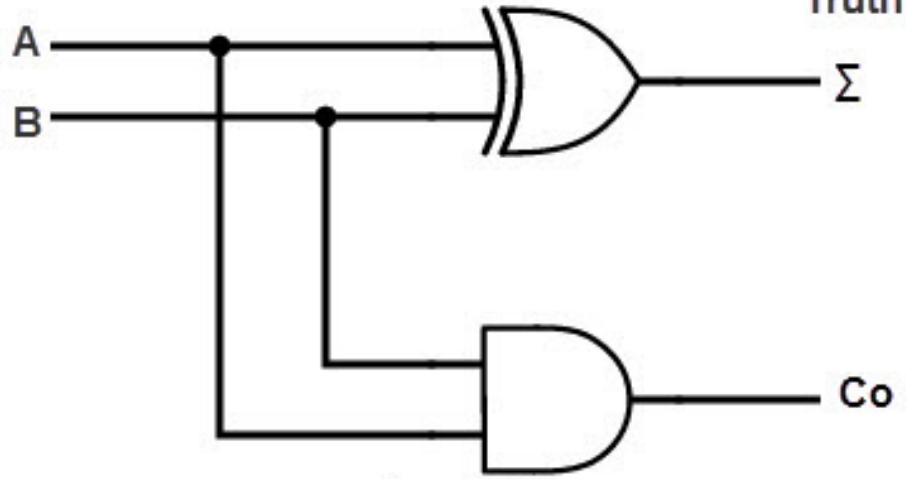
BINARY (HALF) ADDER CIRCUIT



Block Diagram

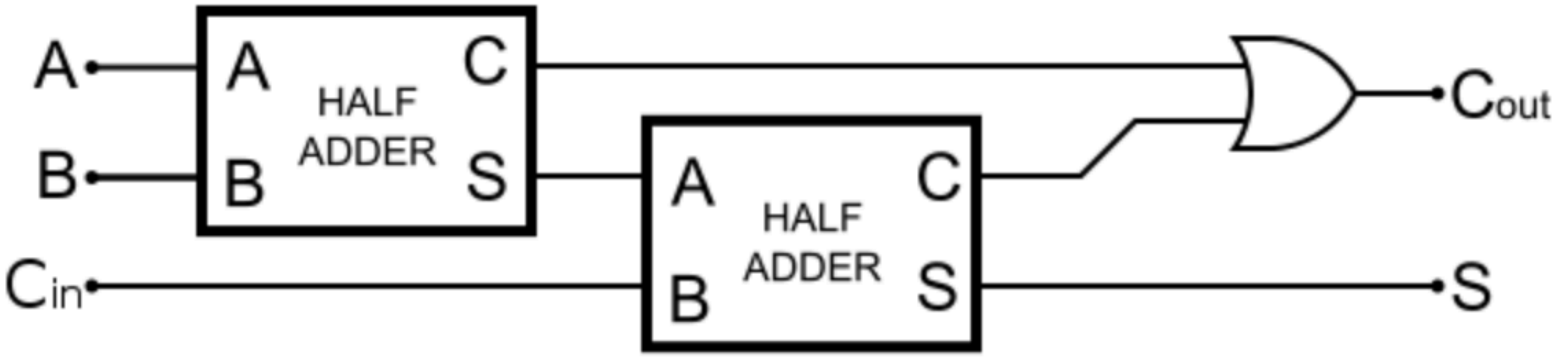
A	B	Sum (∑)	Carry Out (Co)
0	0	**0**	**0**
0	1	**1**	**0**
1	0	**1**	**0**
1	1	**0**	**1**

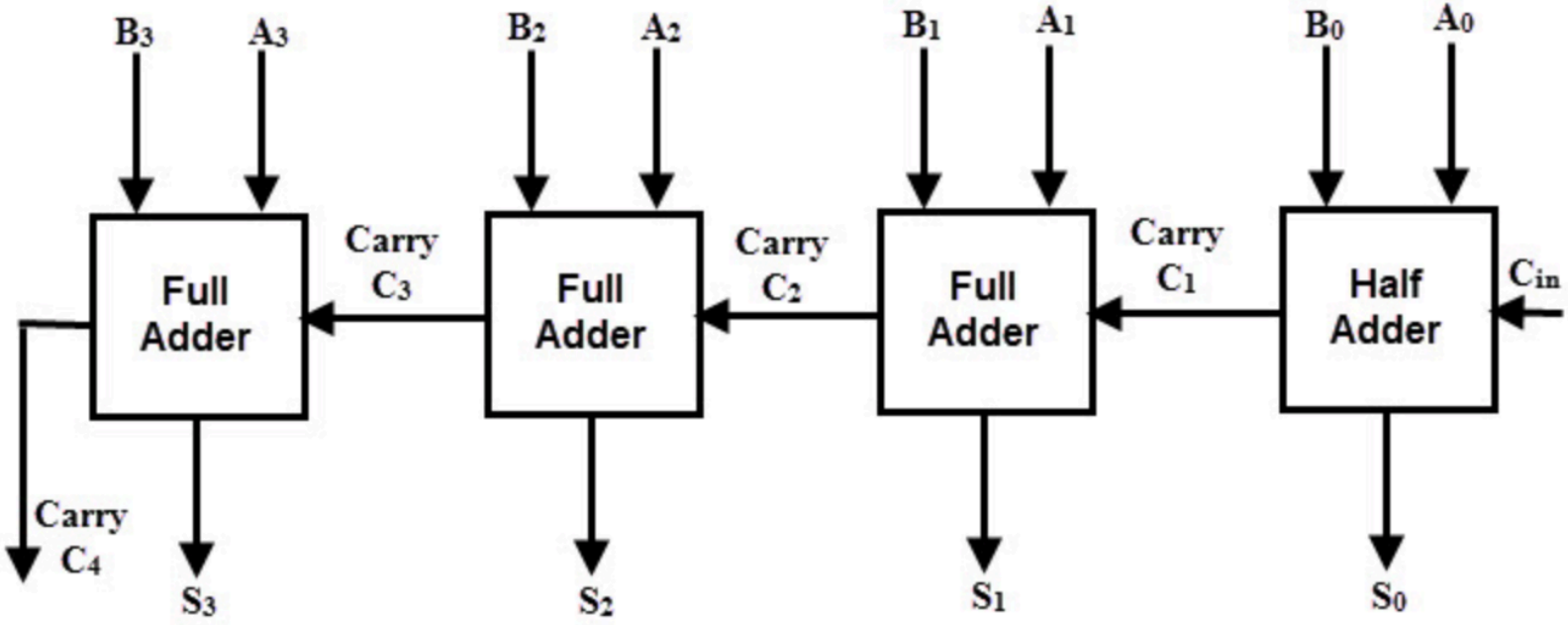
Truth Table



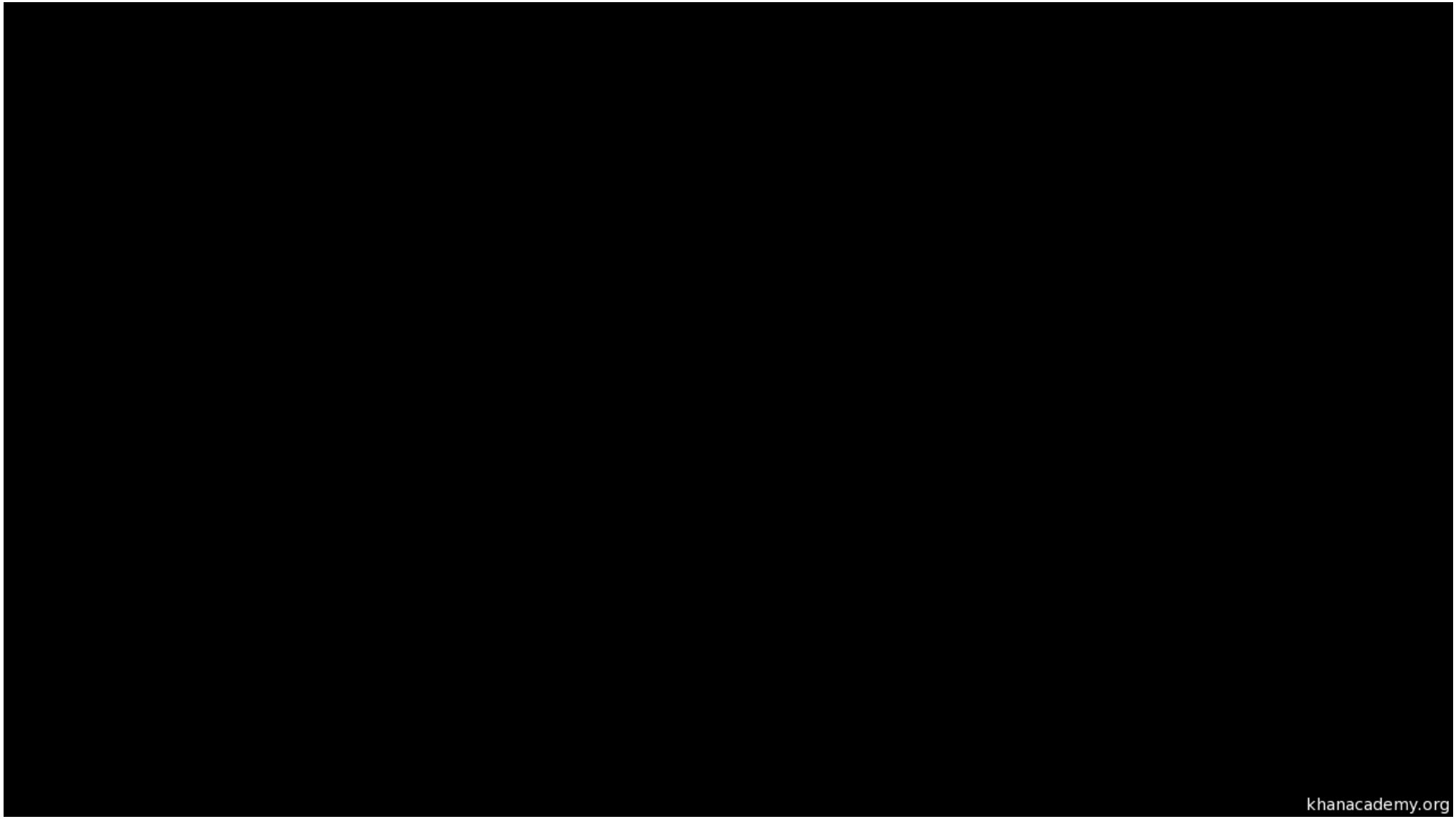
Logic Diagram

FULL ADDER CIRCUIT





CPU, MEMORY, INPUT & OUTPUT



* https://code.org and https://www.khanacademy.org

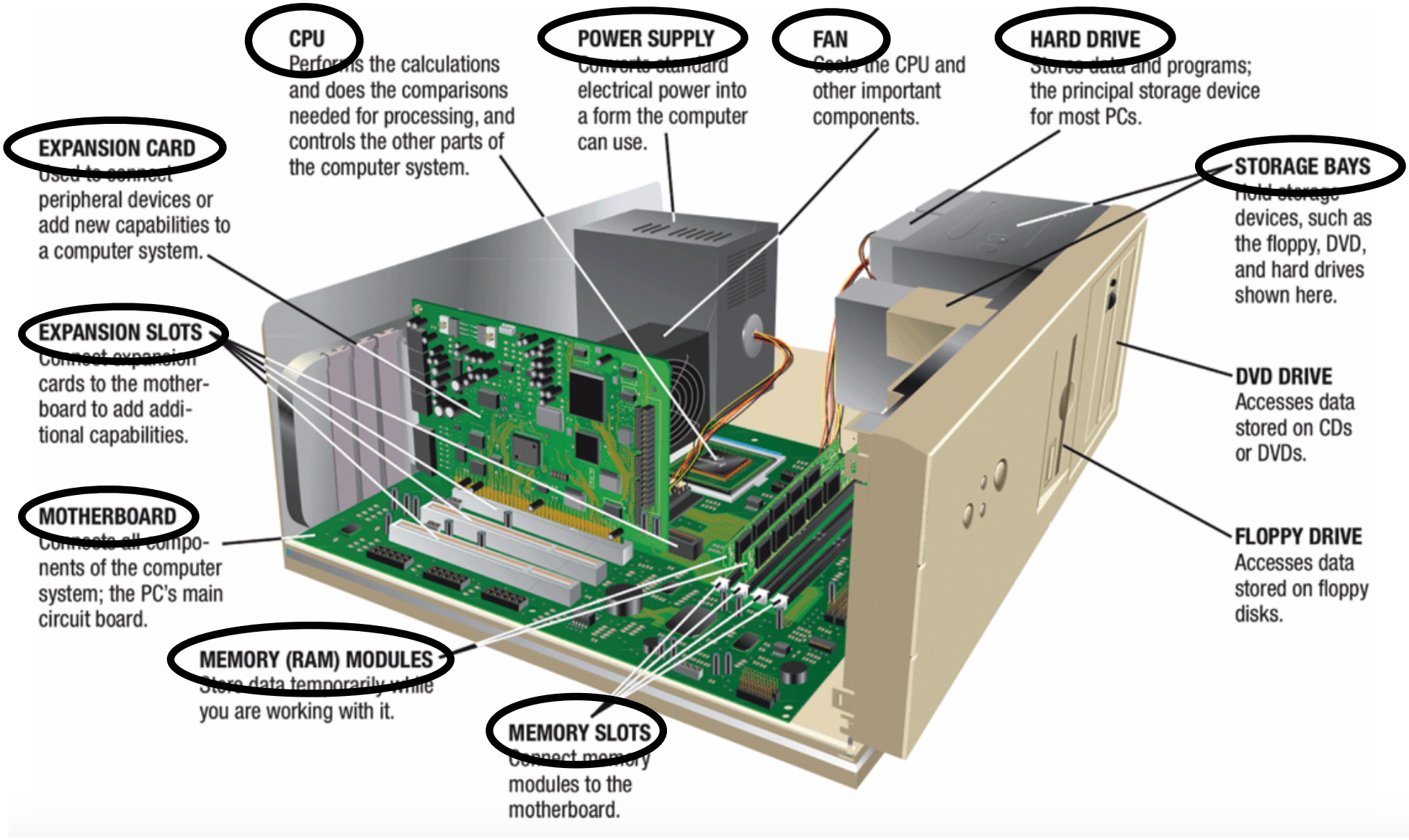
COMPUTER BOX (1)

Desktop

Laptop

* https://www.geeksfixitusa.com/all-blog-post/whats-inside-my-computer/

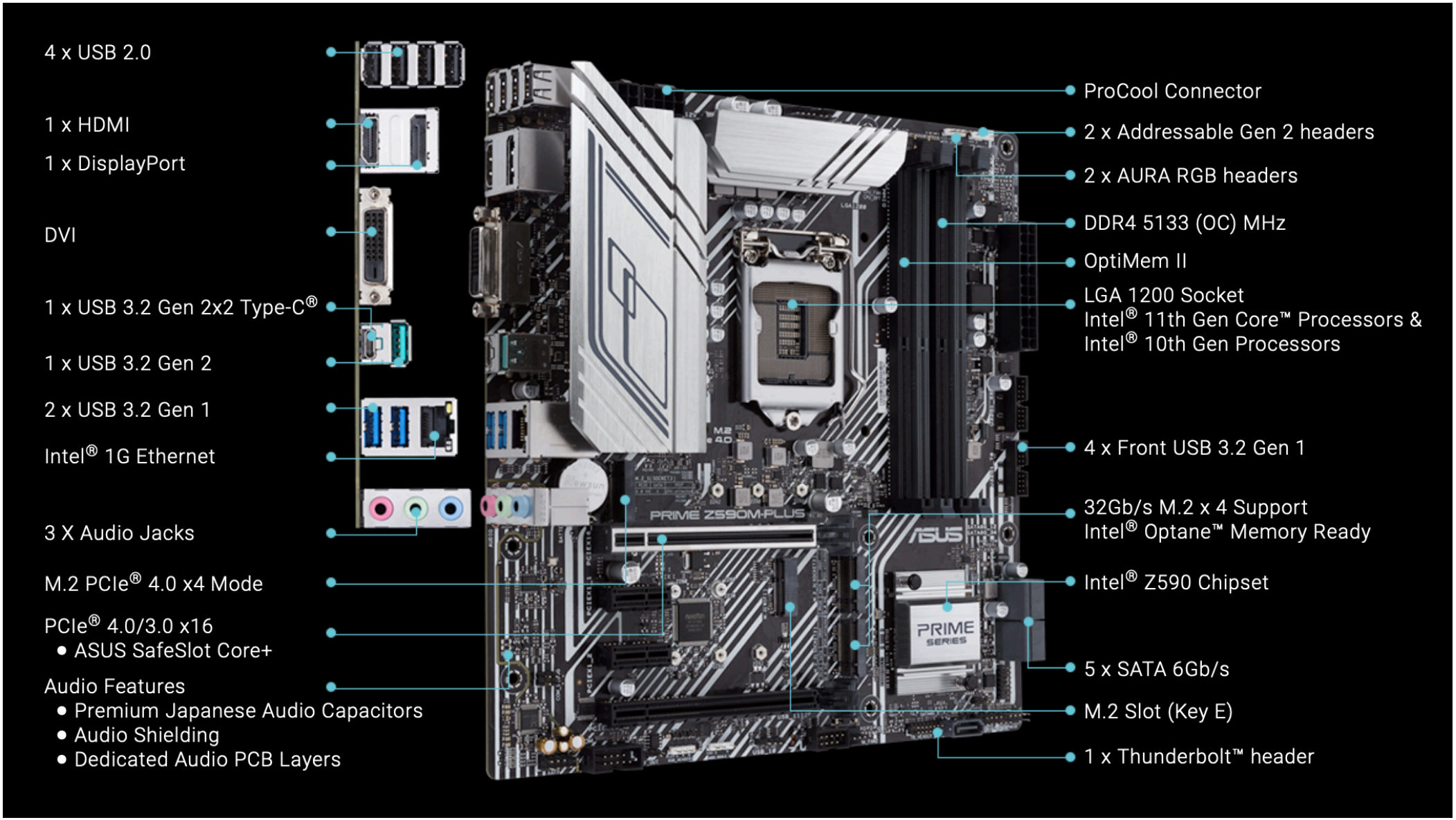
COMPUTER BOX (2)



MAINBOARD (1)

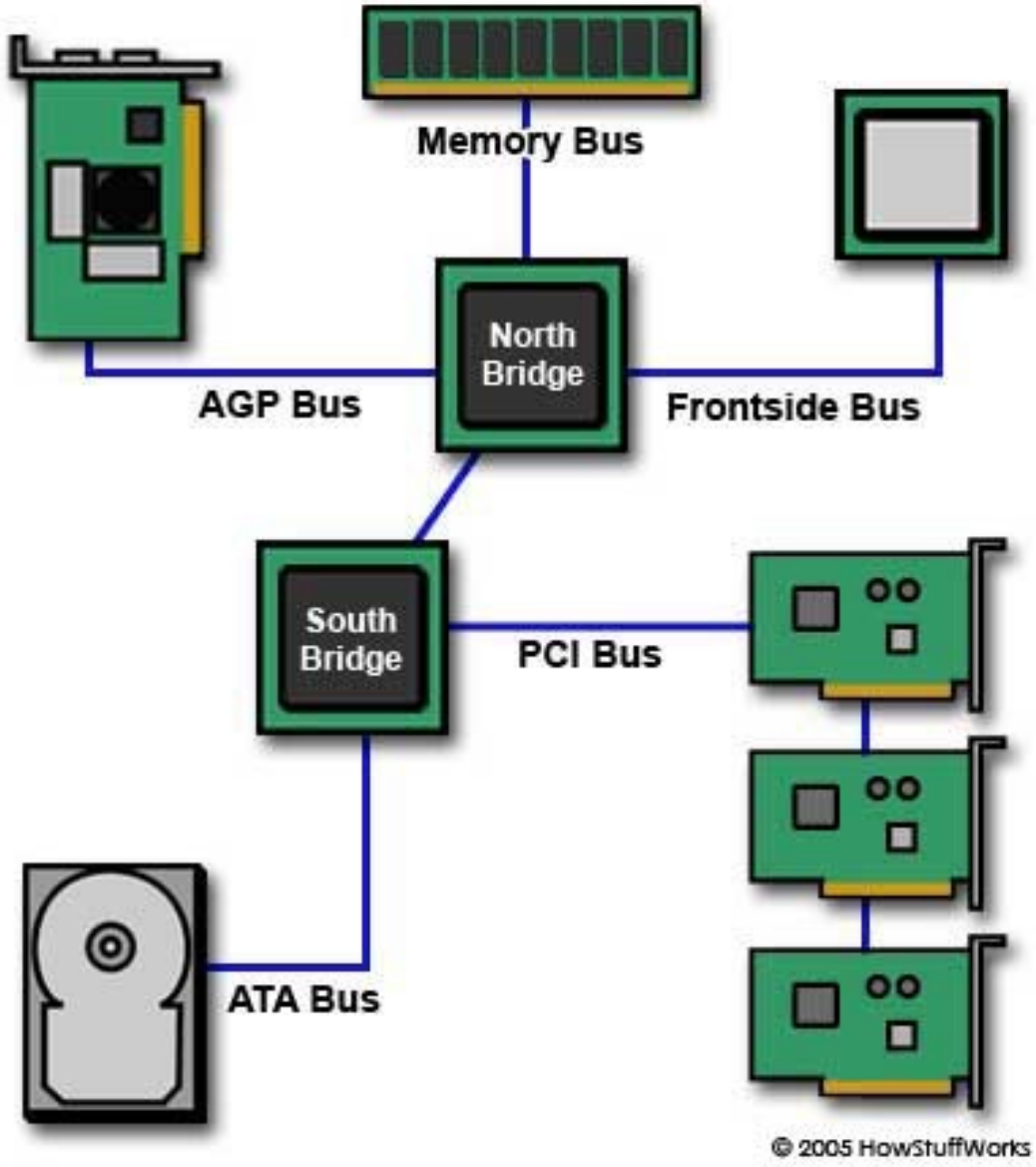
- Mainboard or Motherboard is the central part of a computer.
- Everything connects to the mother board.
- Famous brands: *Asus, Gigabyte, MSI, ASRock and etc.*

MAINBOARD (2)



* Asus Prime Z590M Plus (https://www.asus.com)

MAINBOARD (3)


Memory Bus
North Bridge
AGP Bus
Frontside Bus
South Bridge
PCI Bus
ATA Bus
© 2005 HowStuffWorks

FORM FACTOR

- The form factor is the specification of a motherboard – the dimensions, power supply type, location of mounting holes, number of ports on the back panel, etc.

Standard-ATX

Micro-ATX

Mini-ITX

Nano-ITX

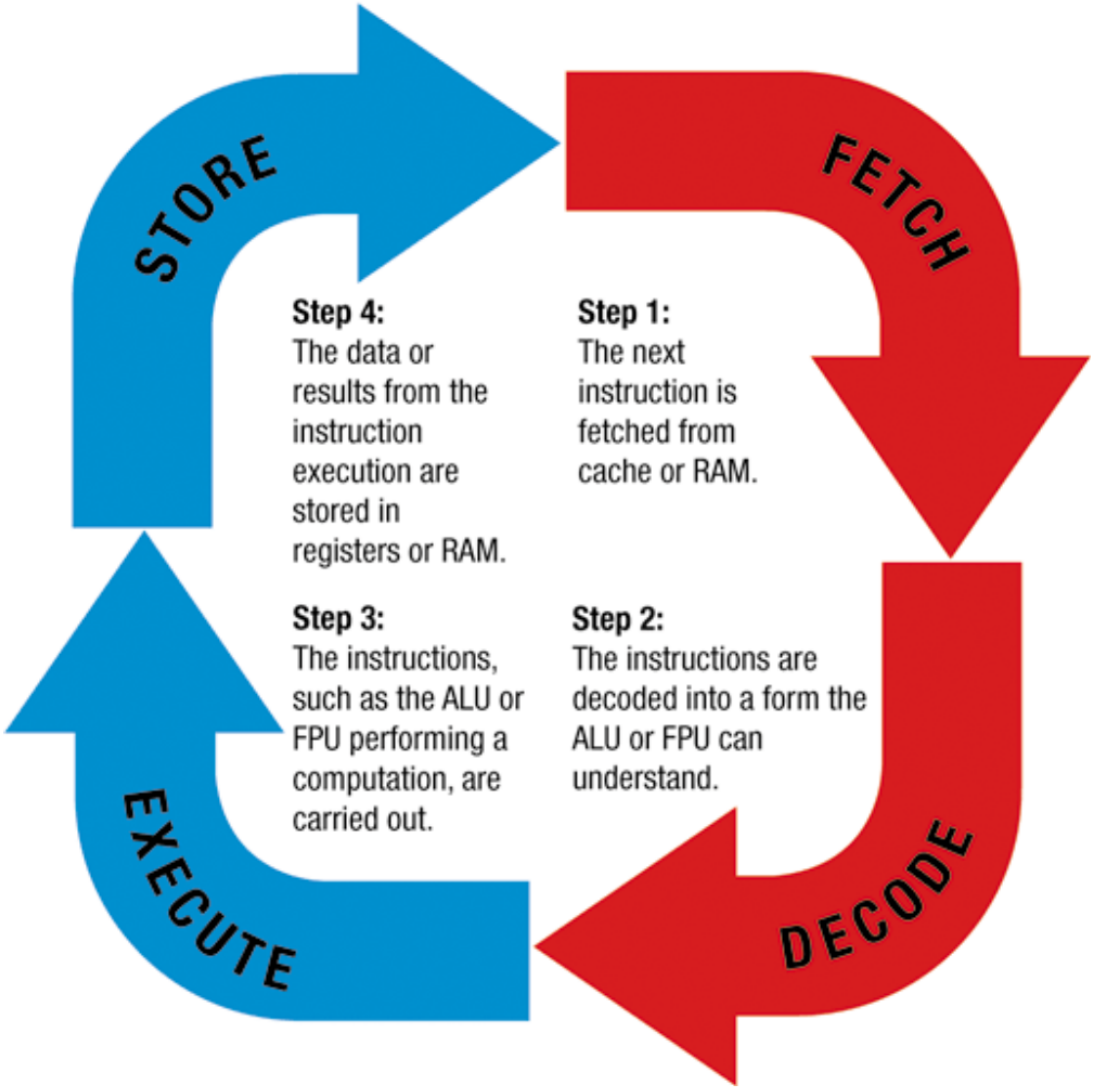
Pico-ITX

* http://en.wikipedia.org/wiki/Computer_form_factor

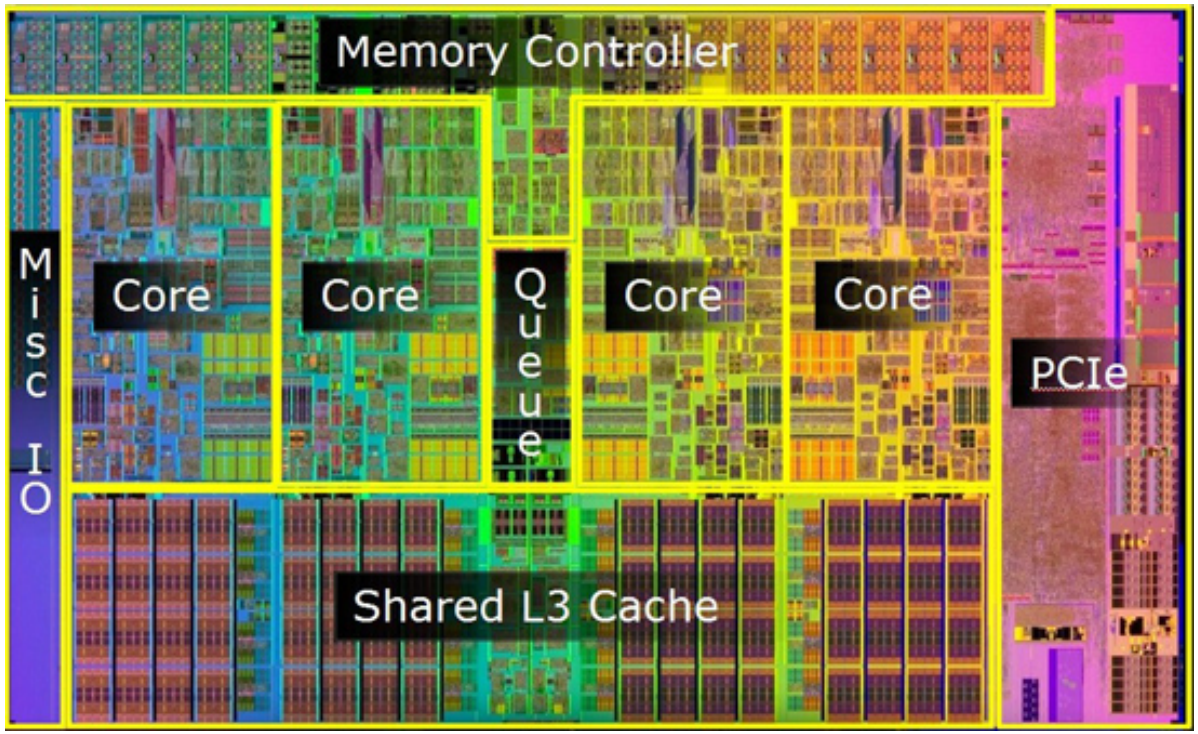
CENTRAL PROCESSING UNIT (CPU)

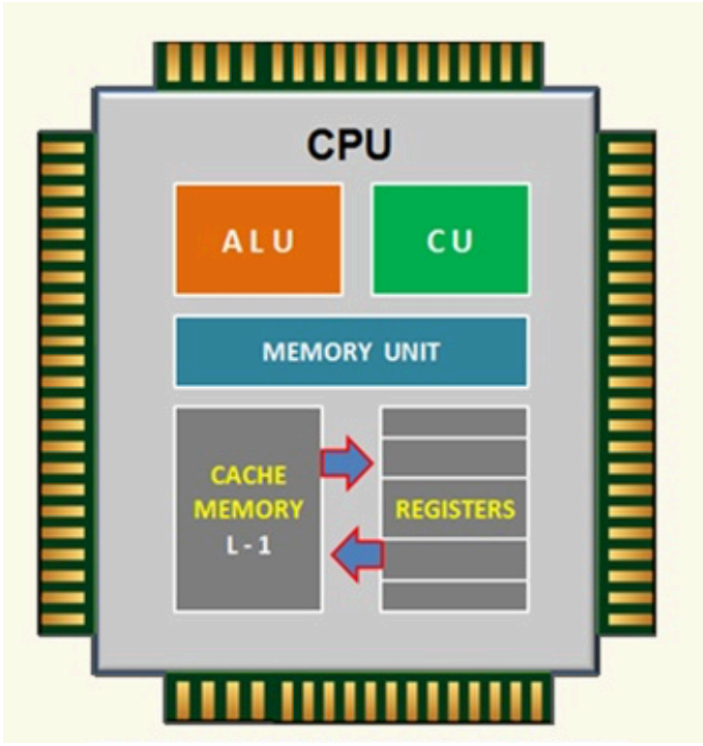
- Central Processing Unit (CPU)
- Does the most of processing for a computer
- Also called a processor or a microprocessor
- Quad-Core, Octa-Core
  - Pack 4/8 CPUs in one chip (Like having 4/8 computers)
- Often made by Intel or AMD
  - AMD is backing out from desktop and notebook
  - ARM is majority for mobile device (Phone, Pad). Now coming into desktop and notebook market.

HOW CPU WORKS ?

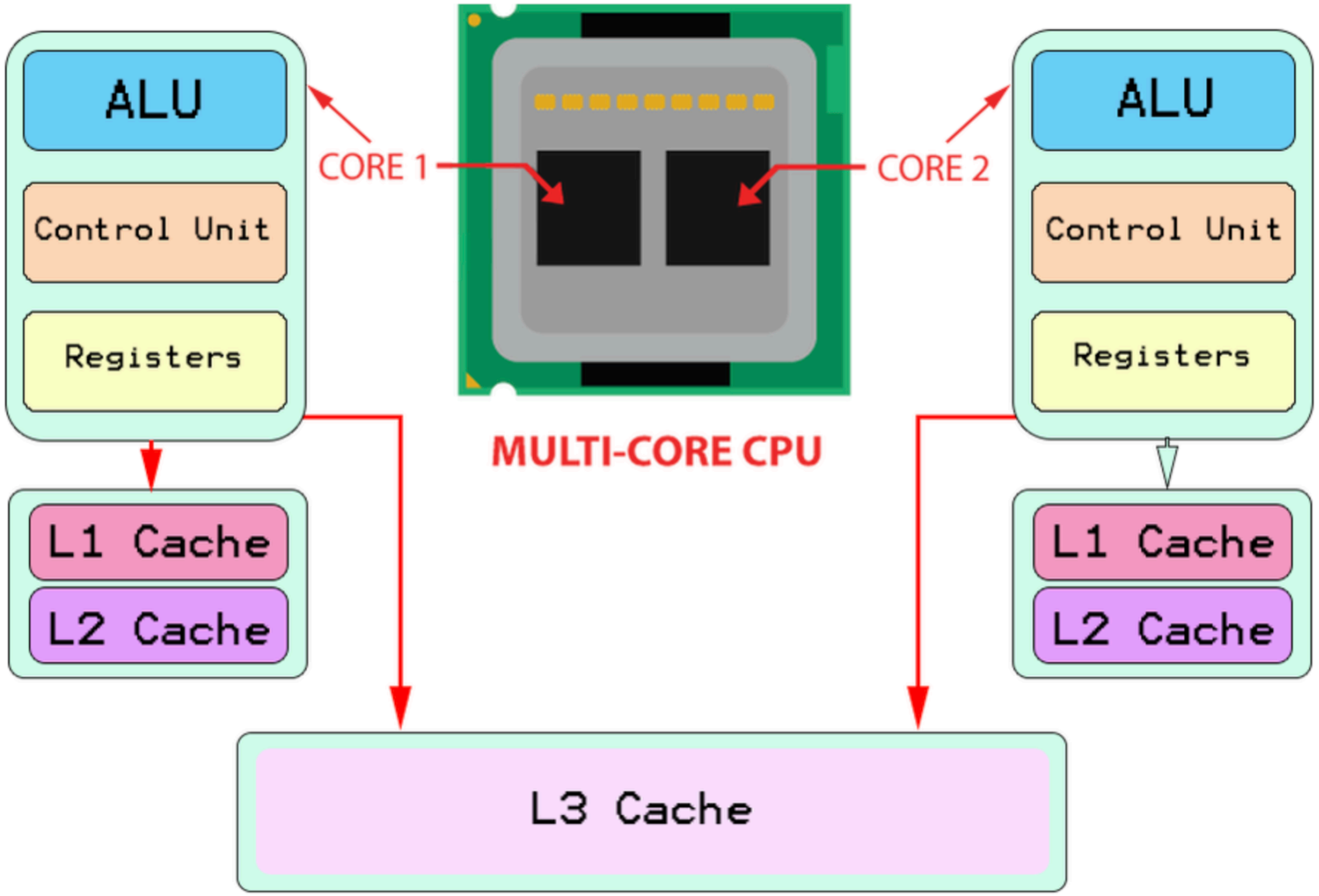


TYPICAL CPU COMPONENTS

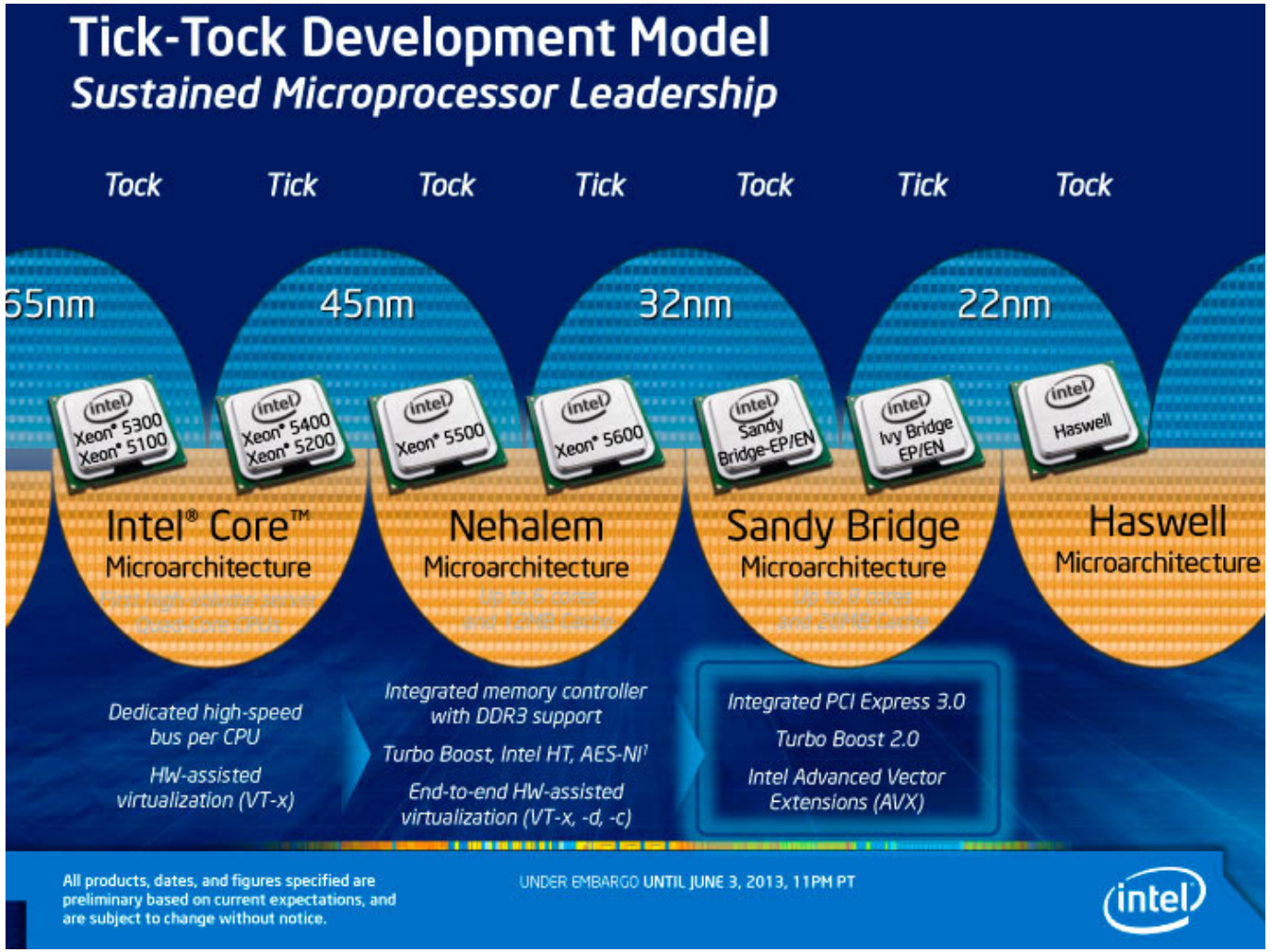




MULTI-CORE CPU



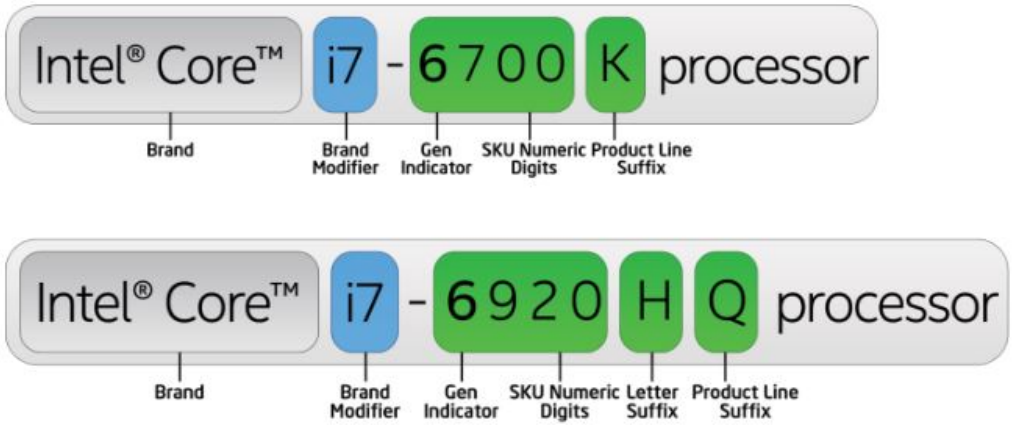
THE TICK-TOCK MODEL THROUGH THE YEARS



iPhone Tick-Tock

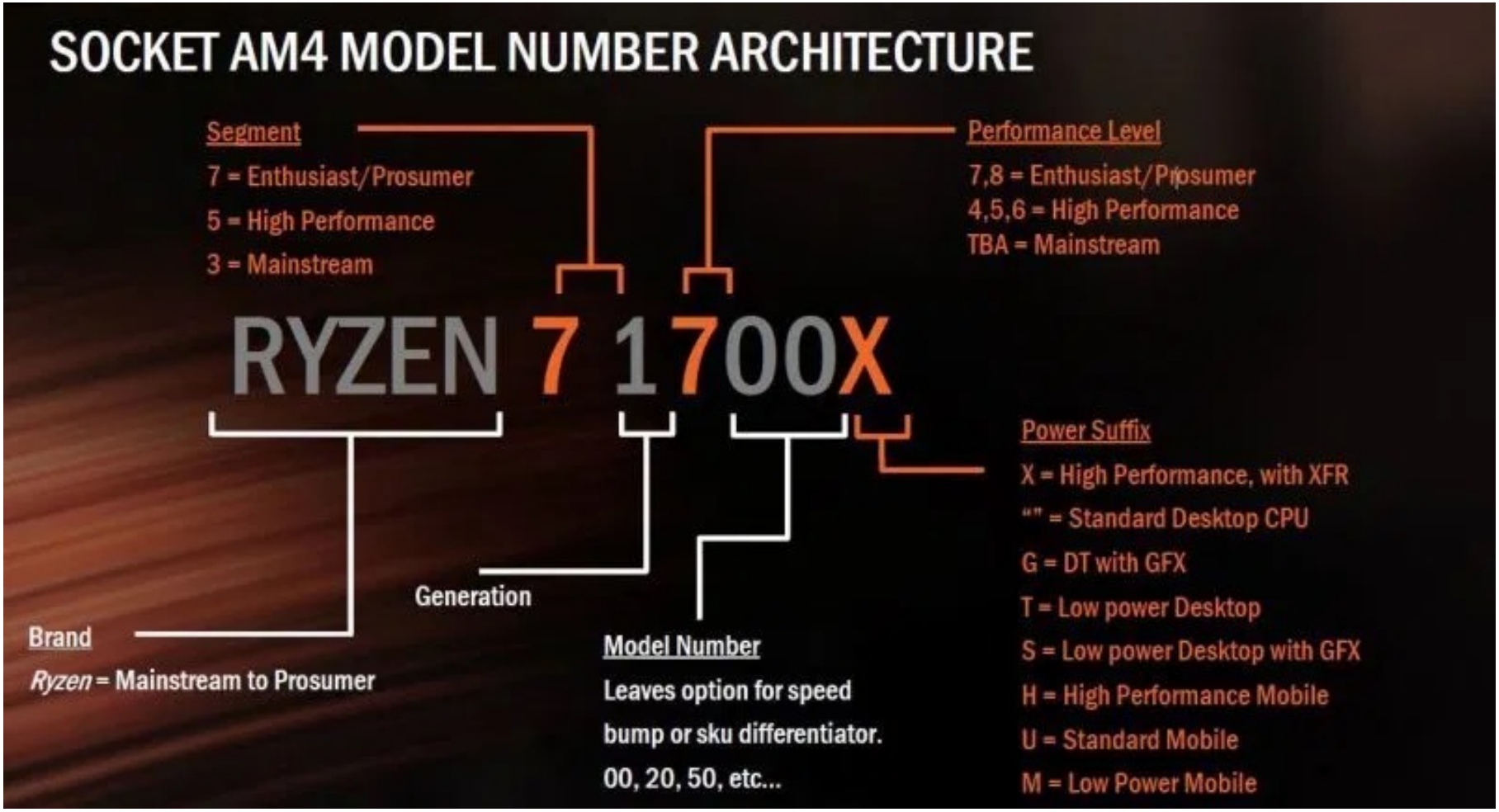
- iPhone 5 = Tick
- iPhone 5s = Tock
- iPhone 6 = Tick
- iPhone 6s = Tock

INTEL - ALPHA SUFFIX

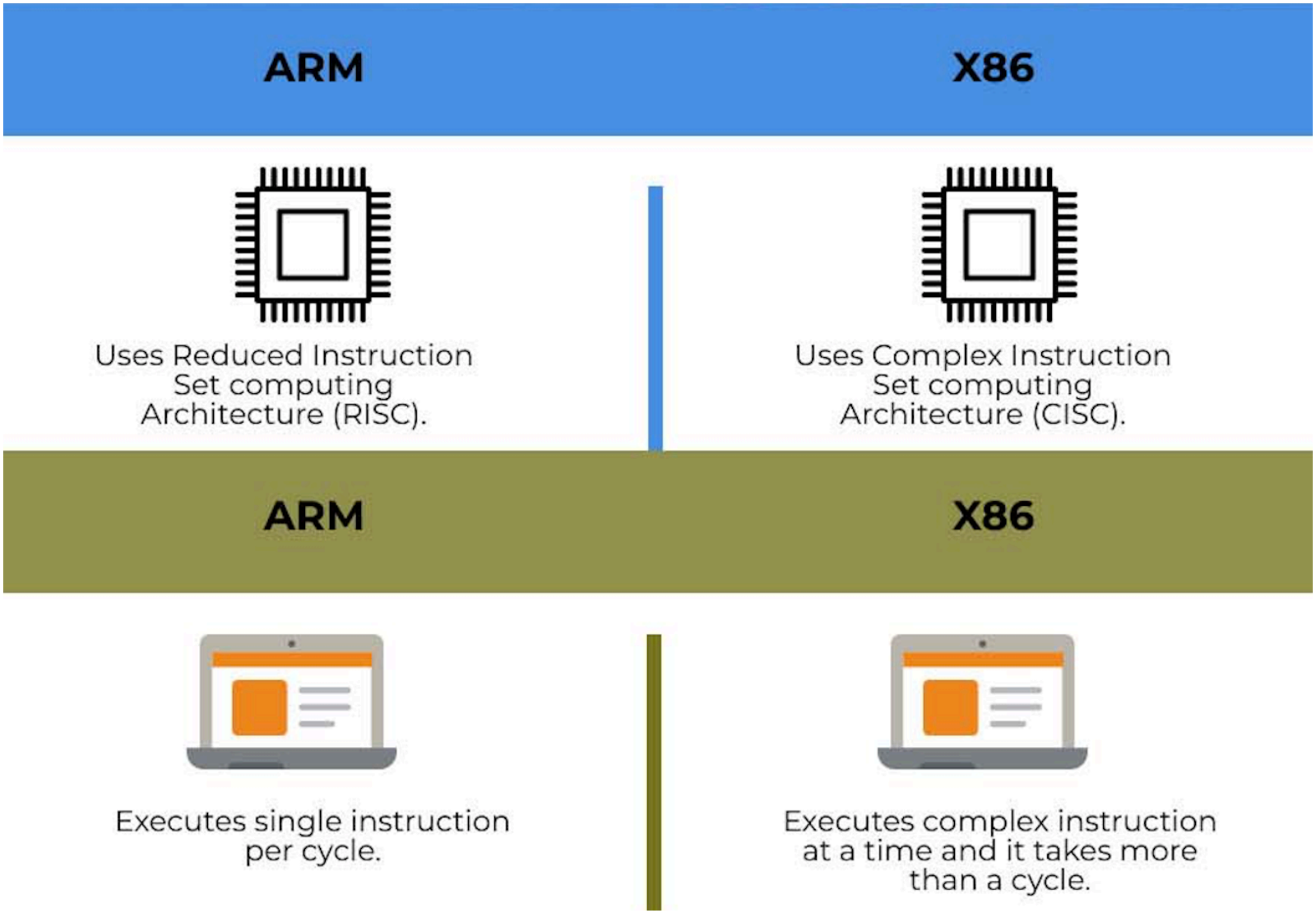


- K = Unlocked
- U = Ultra-low Power
- T = Power-optimised Lifestyle
- G = Includes Graphics
- H = High Performance Graphics
- HQ = High Performance Graphic, Quad-Core
- HK = High Performance Graphics, Unlocked
- Y = Extremely Low Power
- S = Performance-optimized Lifestyle

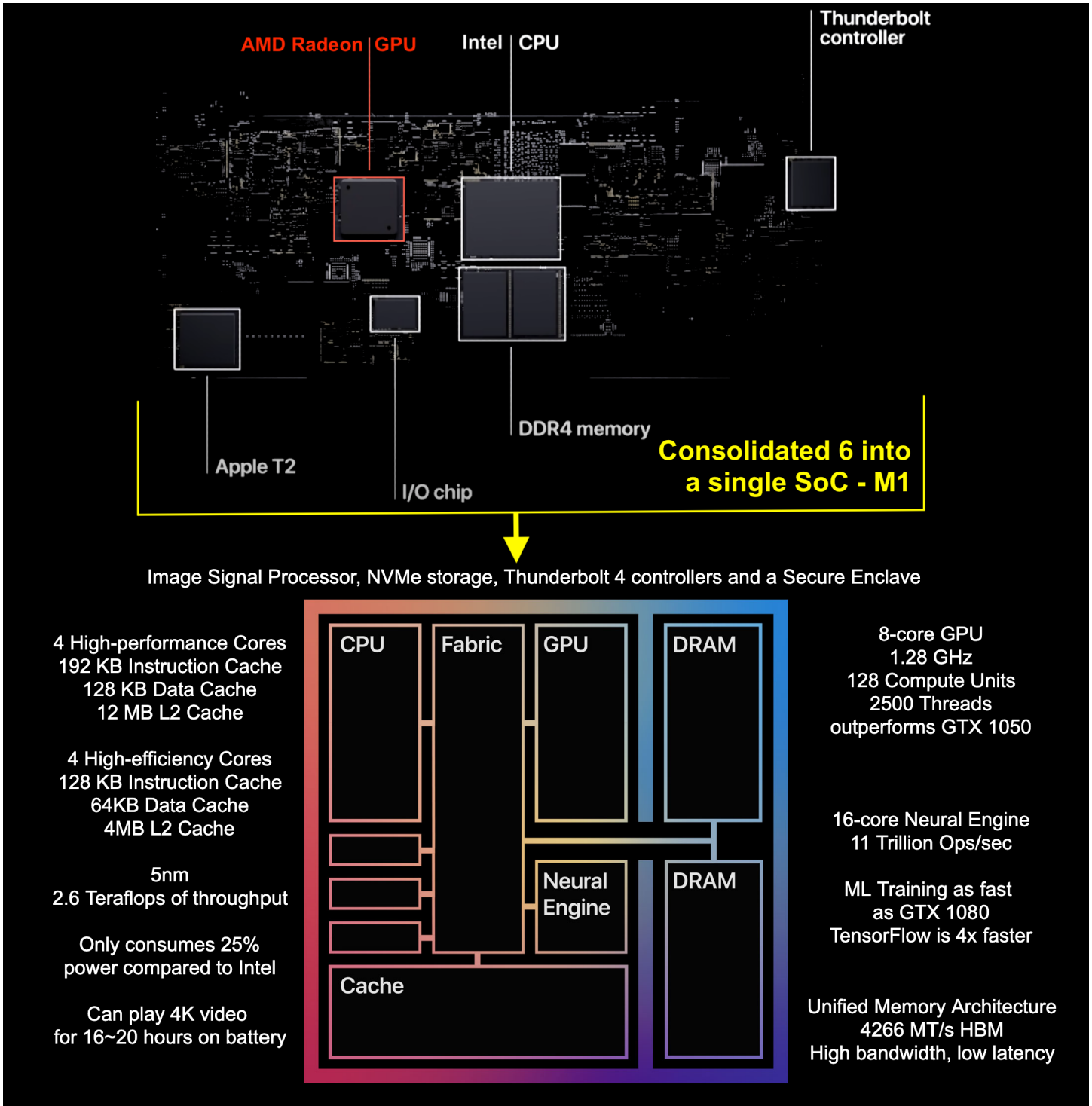
AMD - ALPHA SUFFIX



ARM VS X86


ARM
X86
Uses Reduced Instruction Set computing Architecture (RISC).
Uses Complex Instruction Set computing Architecture (CISC).
ARM
X86
Executes single instruction per cycle.
Executes complex instruction at a time and it takes more than a cycle.

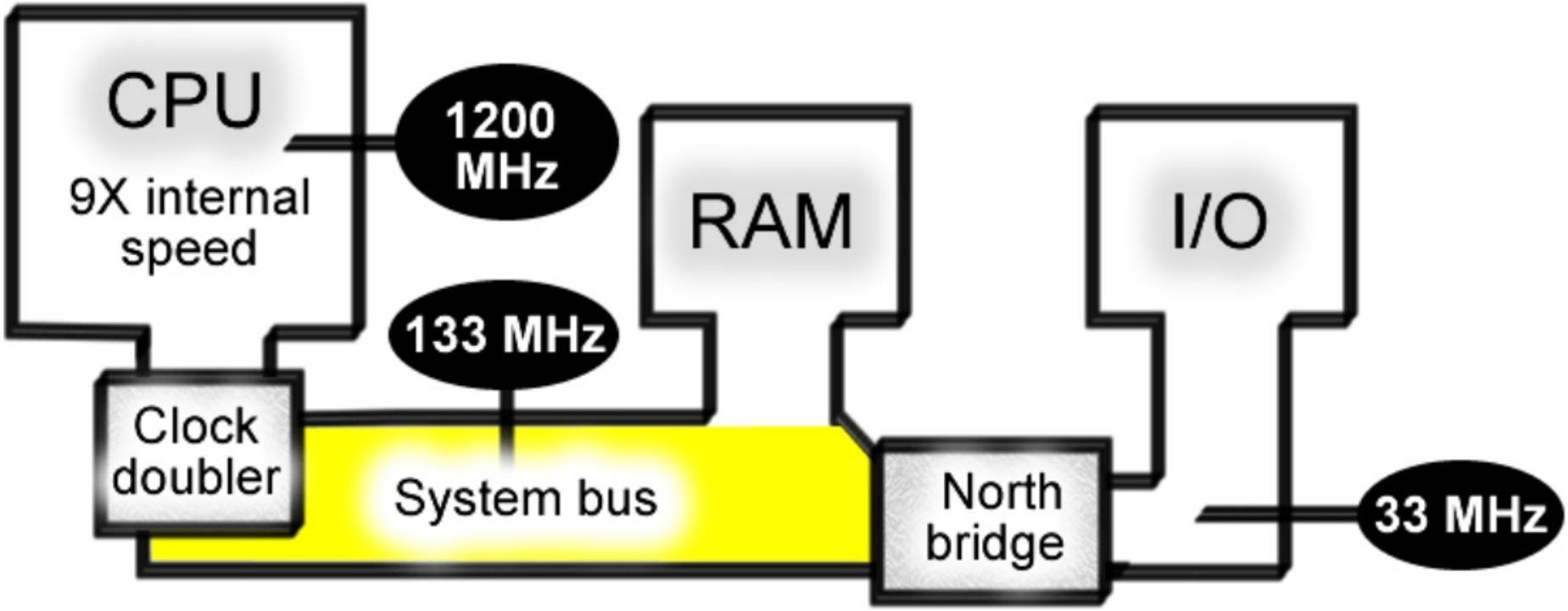
Apple M1 (SoC)


AMD Radeon GPU
Intel CPU
Thunderbolt controller
DDR4 memory
Apple T2
I/O chip
Consolidated 6 into a single SoC - M1
Image Signal Processor, NVMe storage, Thunderbolt 4 controllers and a Secure Enclave
4 High-performance Cores
192 KB Instruction Cache
128 KB Data Cache
12 MB L2 Cache
4 High-efficiency Cores
128 KB Instruction Cache
64KB Data Cache
4MB L2 Cache
5nm
2.6 Teraflops of throughput
Only consumes 25% power compared to Intel
Can play 4K video for 16~20 hours on battery
CPU
Fabric
GPU
DRAM
Neural Engine
DRAM
Cache
8-core GPU
1.28 GHz
128 Compute Units
2500 Threads
outperforms GTX 1050
16-core Neural Engine
11 Trillion Ops/sec
ML Training as fast as GTX 1080
TensorFlow is 4x faster
Unified Memory Architecture
4266 MT/s HBM
High bandwidth, low latency

CLOCK SPEED

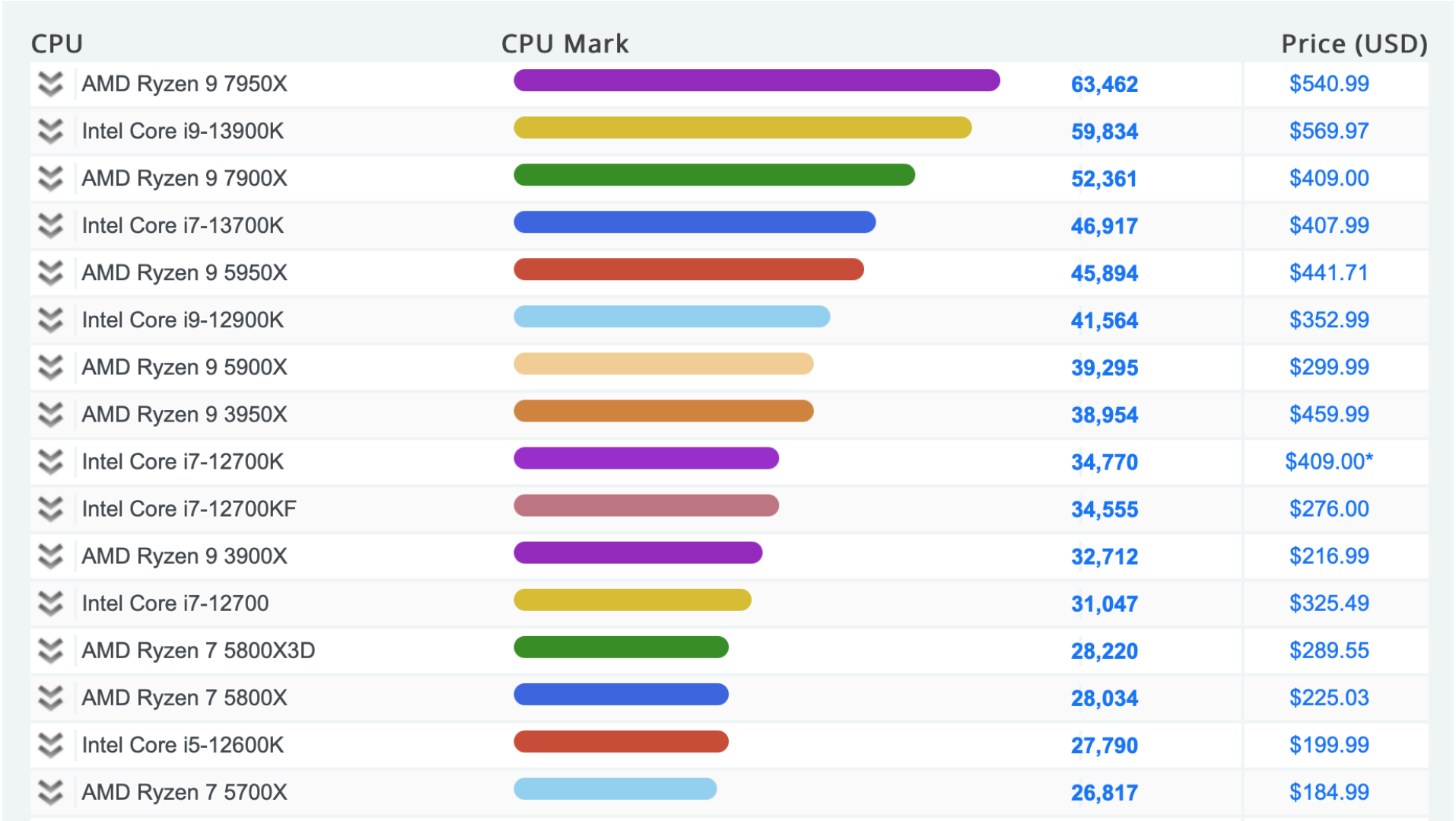
- A computer's system clock resides on the mother board.
- It sends out a signal to all other computer components in sync.
- Every action in the computer is timed by these clock cycles and takes a certain number of cycle to perform.

THE SYSTEM CLOCK AND THE MACHINE CYCLE



The bus system for a Pentium III processor.

PERFORMANCE



CPU	CPU Mark	Price (USD)
AMD Ryzen 9 7950X	63,462	$540.99
Intel Core i9-13900K	59,834	$569.97
AMD Ryzen 9 7900X	52,361	$409.00
Intel Core i7-13700K	46,917	$407.99
AMD Ryzen 9 5950X	45,894	$441.71
Intel Core i9-12900K	41,564	$352.99
AMD Ryzen 9 5900X	39,295	$299.99
AMD Ryzen 9 3950X	38,954	$459.99
Intel Core i7-12700K	34,770	$409.00*
Intel Core i7-12700KF	34,555	$276.00
AMD Ryzen 9 3900X	32,712	$216.99
Intel Core i7-12700	31,047	$325.49
AMD Ryzen 7 5800X3D	28,220	$289.55
AMD Ryzen 7 5800X	28,034	$225.03
Intel Core i5-12600K	27,790	$199.99
AMD Ryzen 7 5700X	26,817	$184.99

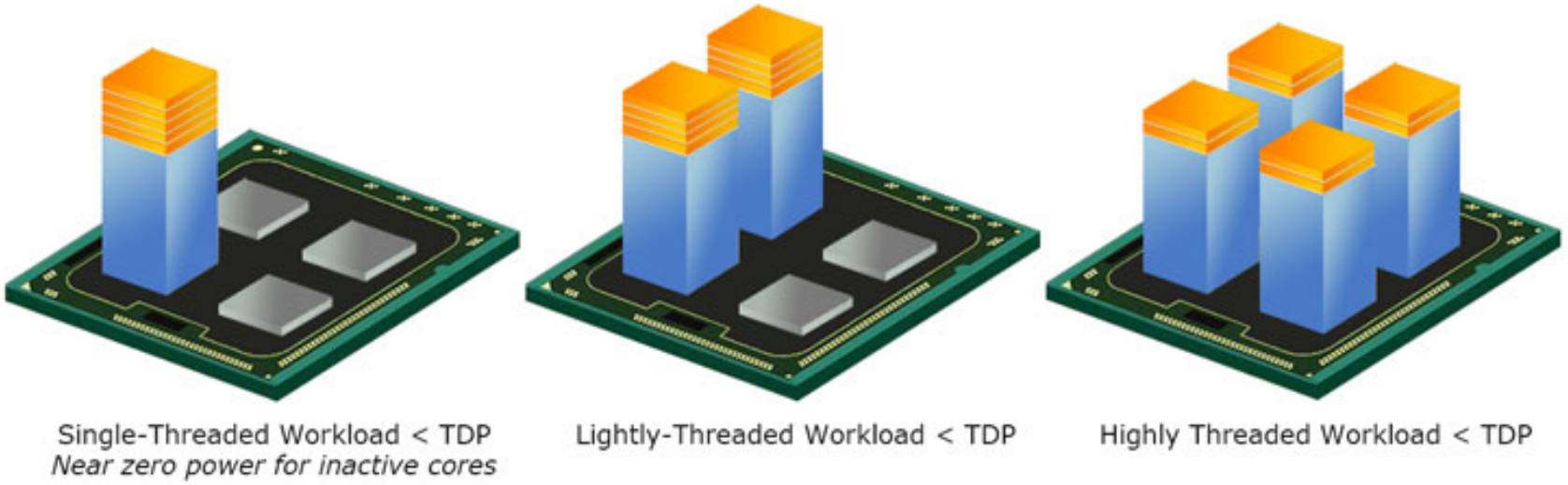
* https://www.cpubenchmark.net/common_cpus.html

32-BIT VS. 64-BIT

32-bit processors	64-bit processors
Addressable space of 4 GB	Addressable space of 16 TB
64-bit applications won't work.	Most 32-bit applications will work.
Not recommend for multitasking	Ideal for multitasking
Requires 32-bit operating system.	Both 32-bit & 64-bit OS will work.

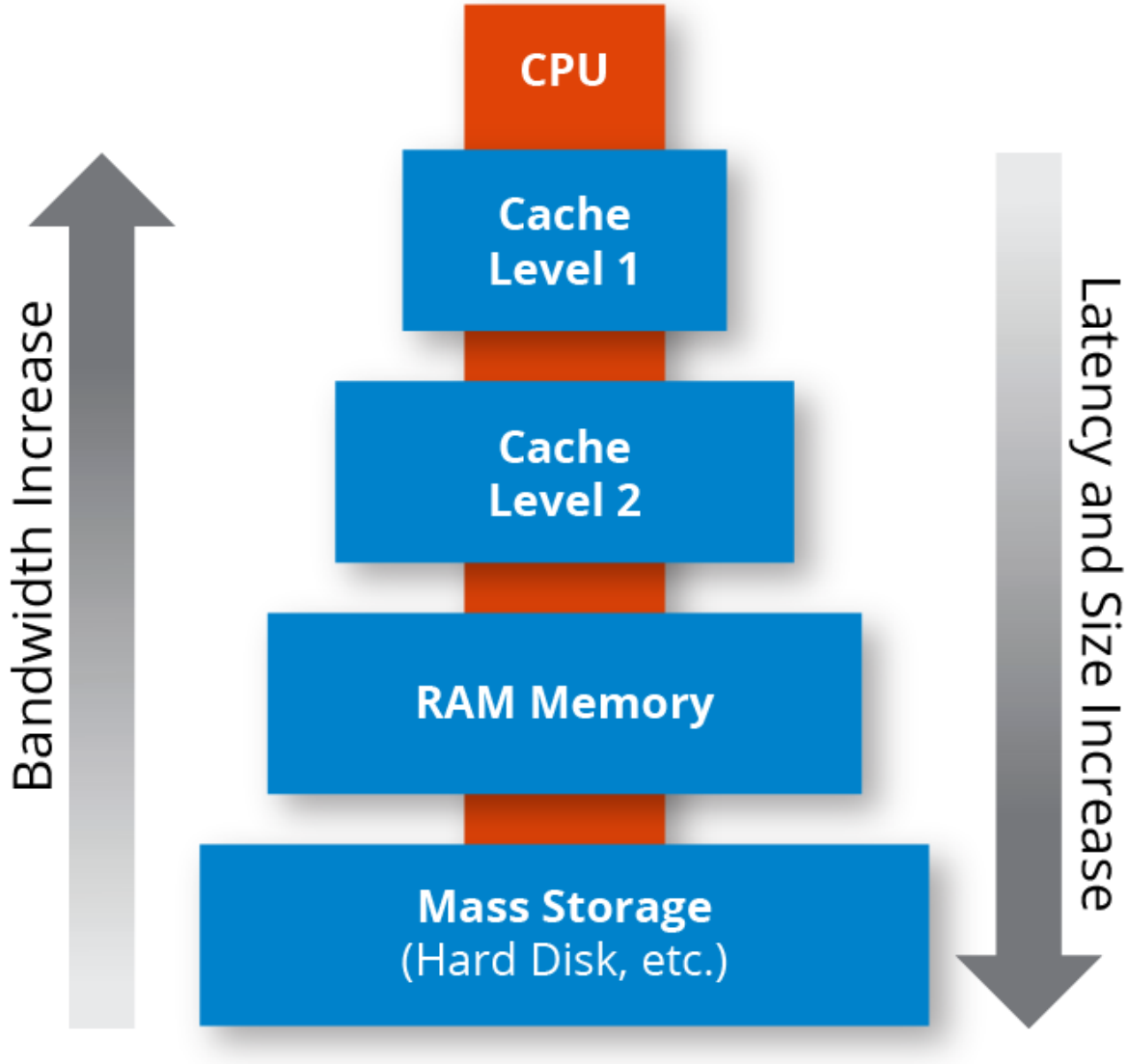
THREAD/CORE

- More core = more work can be done at the same time.
- More thread = more work can be done at the same time (but with slight limitation)



Multithreading in one core

CACHE MEMORY



EXPANSION SLOTS

- Expand functionality of the computer.
- Graphic Card -> Better graphic or more display
- Sound Card -> Better sound
- Network Card -> More/Faster network connections
- Controller Card -> Control Robot and etc.
- Many type
  - ISA, EISA, PCI, PCIe (PCI-E)
- Current trend = PCIe (PCI Express)

PCI EXPRESS (PCI-E)

- A single PCI Express lane can handle 200 MB of traffic in each direction per second.
- A x16 can handle 6.4 GB of data per second in each direction.

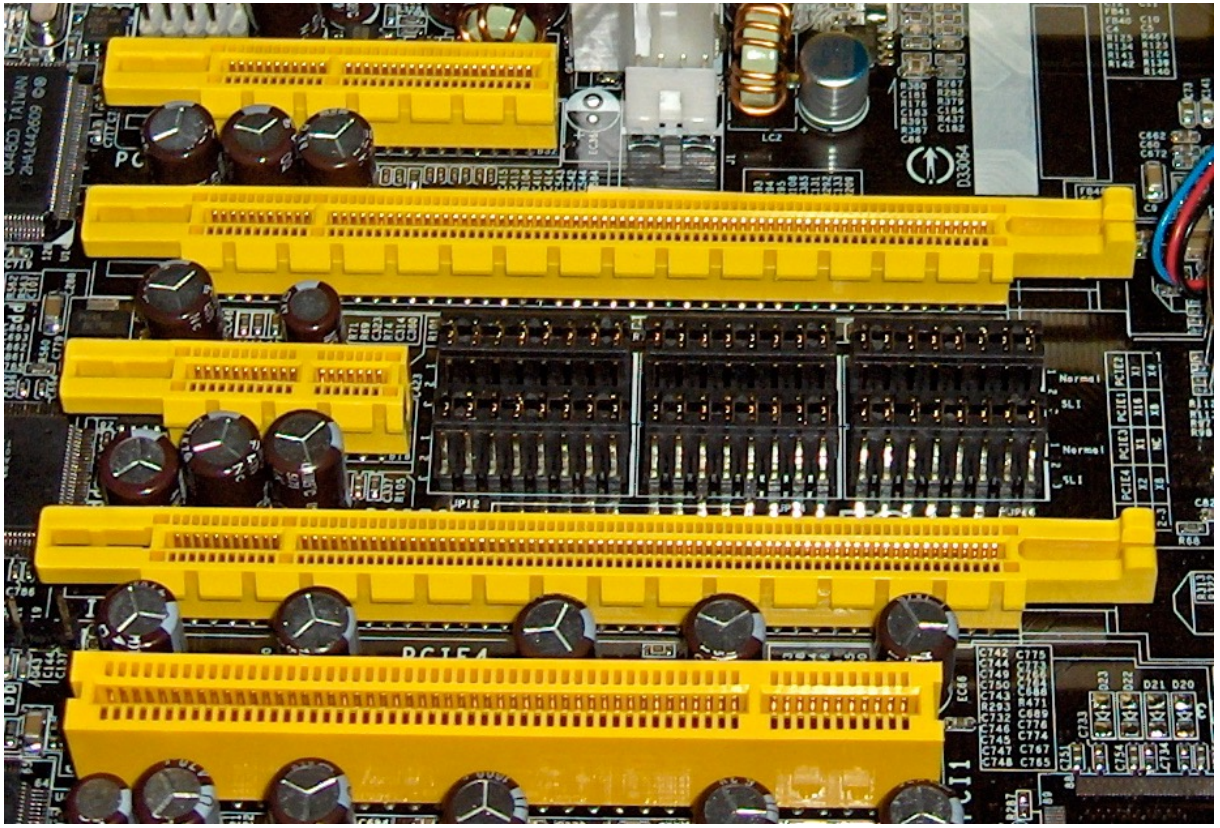
PCIx4

PCIx16

PCIx1

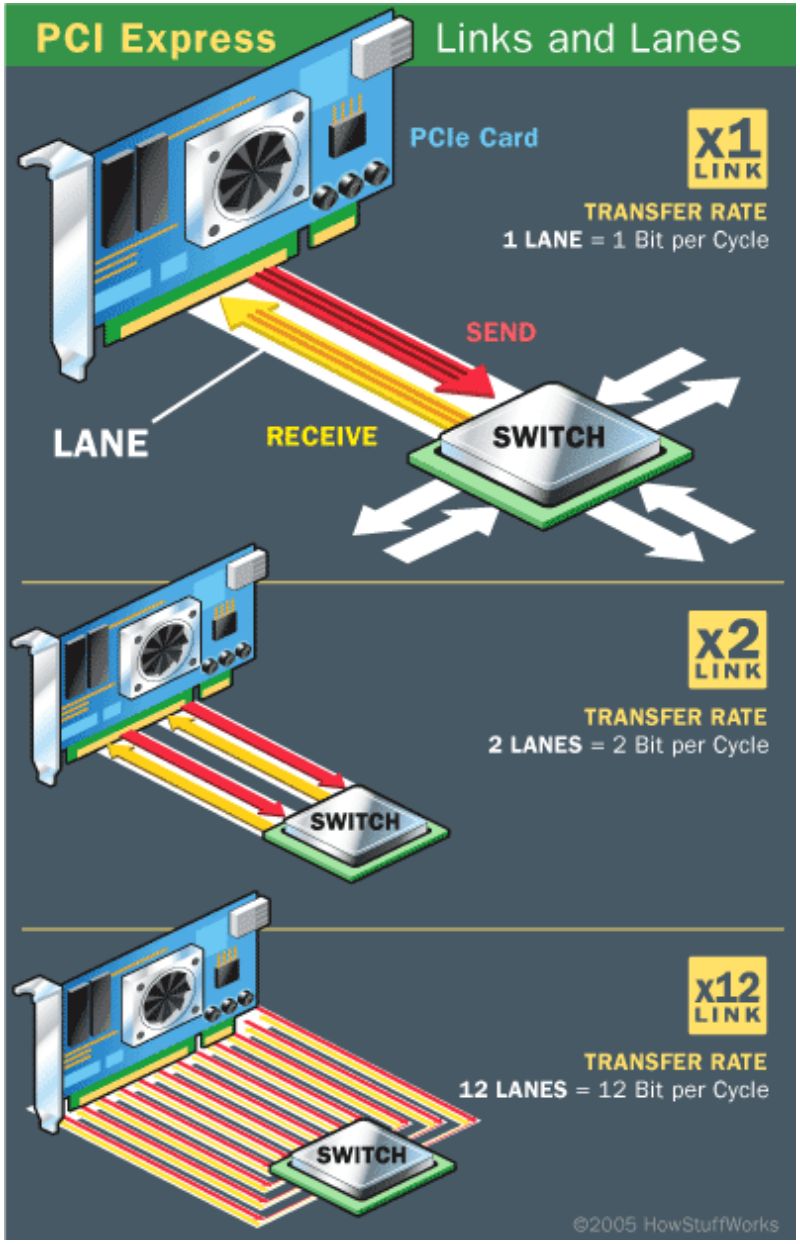
PCIx16

Legacy



From top to bottom: PCI Express ×4 | PCI Express ×16 | PCI Express ×1 | PCI Express ×16 | Legacy PCI (32-bit)

PCI EXPRESS LINKS AND LANES

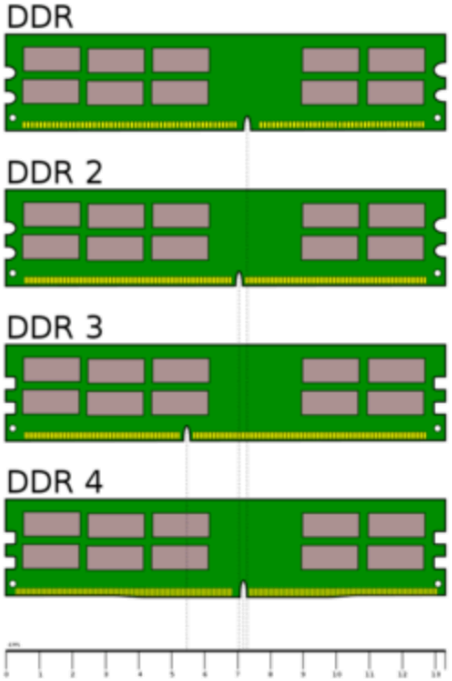


MEMORY (1)

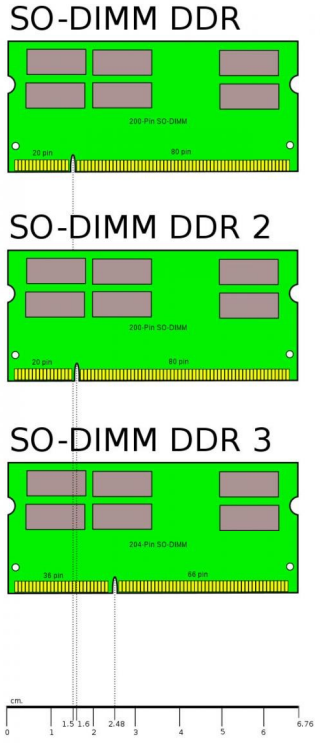
- Short term memory to help working
- Must be supported by motherboard and CPU
  - Double Data Rate Synchronous Dynamic Random-Access Memory (DDR SDRAM) is a class of memory integrated circuits used in computers.
  - Small Outline Dual In-line Memory Module (SODIMM) is a type of computer memory. SODIMM is often used in systems that have limited space, such as notebooks, small footprint PCs (such as those with a Mini-ITX motherboard)
- More is better. (current good spot is 8 GB)

MEMORY (2)

DDR SDRAM Standard	Bus clock (MHz)	Internal rate (MHz)	Prefetch (min burst)	Transfer Rate (MT/s)	Voltage	DIMM pins	SO-DIMM pins	MicroDIMM pins
DDR	100–200	100–200	2n	200–400	2.5/2.6	184	200	172
DDR2	200–533⅓	100–266⅔	4n	400–1066⅔	1.8	240	200	214
DDR3	400–1066⅔	100–266⅔	8n	800–2133⅓	1.5	240	204	214
DDR4	1066⅔–2133⅓	100–266⅔	8n	2133⅓–4266⅔	1.05/1.2	288	256	—



Schematic of the physical design of DDR2, DDR3 and DDR4 DIMMs.



MEMORY (3)

Features	DDR4	DDR5	DDR5 Advantages
Speed	1.6 to 3.2 GT/s 0.8 to 1.6 GHz clock	4.8 to 8.4 GT/s 1.6 to 4.2 GHz clock	Higher bandwidth
IO Voltage	1.2 V	1.1 V	Lower power
Power Management	On motherboard	On DIMM PMIC	Better power efficiency Better scalability
Channel Architecture	72-bit data channel (64 data + 8 ECC) 1 channel per DIMM	40-bit data channel (32 data + 8 ECC) 2 channels per DIMM	Higher memory efficiency Lower latency
Burst Length	BC4, BL8	BC8, BL16	Higher memory efficiency
Max. Die Density	16Gb	64Gb	Higher capacity DIMMs
More Intelligence	SPD (I^2C)	SPD Hub & Temperature Sensors (I^3C)	Enhanced system management Greater telemetry for thermal management

* https://www.rambus.com/blogs/get-ready-for-ddr5-dimm-chipsets/

HARD DRIVE / HARD DISK

- Permanent Storage for your computer
  - Talk more next time. (Data In and Data Out)
- Two types of Hard Disk
  - Solid State Drive (SSD)
    - Expensive
    - Durable
    - Fast
  - Spinning Disk
    - Cheap
    - Not so durable
    - Slower

HARD DRIVE / HARD DISK

- IDE (Integrated Drive Electronics) or PATA (Parallel-ATA)
  - Older + Slower
- SCSI (Small Computer System Interface)
  - SAS (Serial + SCSI)
- SATA (Serial ATA)
  - SATA1, SATA2, SATA3
  - Faster than above.
- M.2 (NVMe Protocol)
  - AHCI (SATA) vs. NVMe (PCIe)
  - M Key, B Key

B+M Key

M Key

NETWORK

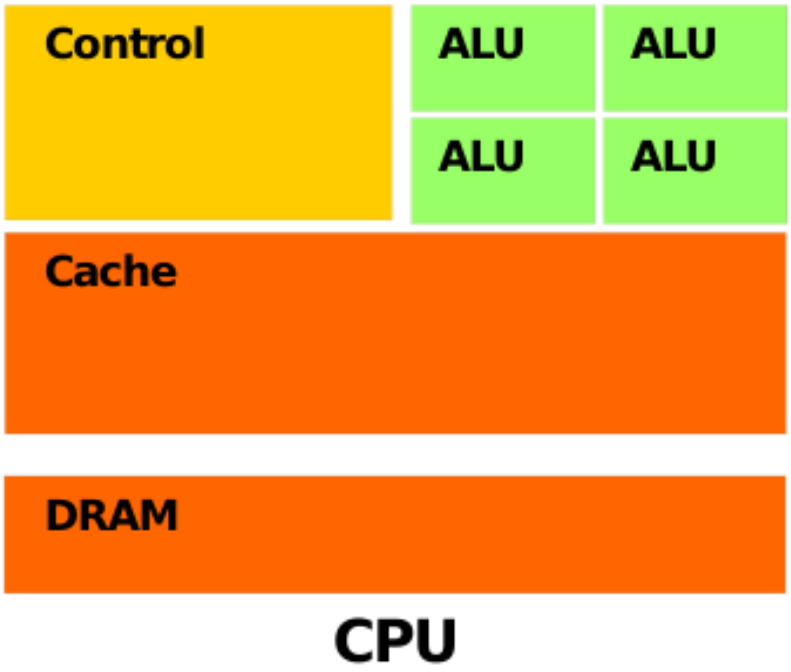
- Detail later. (Week 5)
- For now, wired cables are 3 speeds
  - 10 Mb/s, 100 Mb/s and 1000 Mb/s
- No big difference with network card brand.

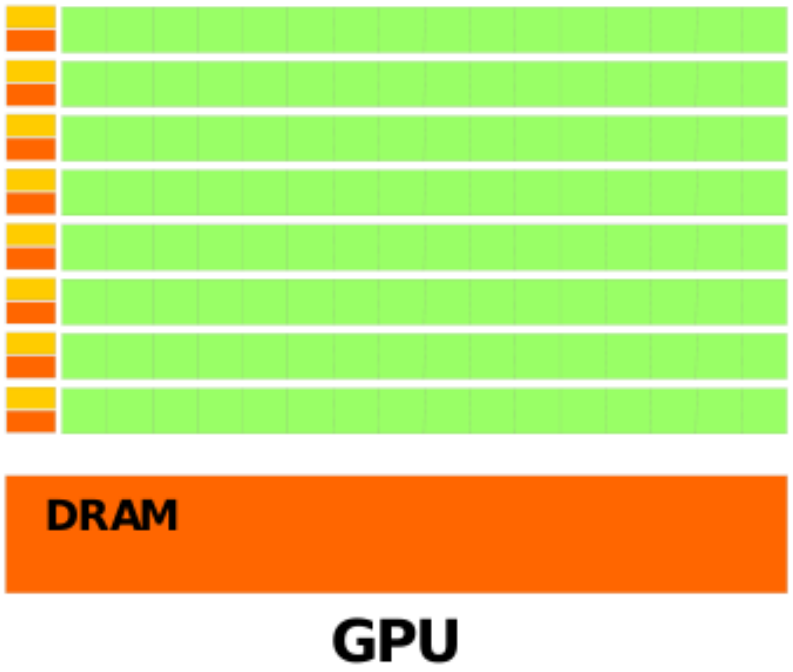
GRAPHICS CARD

- Additional card can be add to improve display quality.

- Nvidia and ATi are main players
  - They make chips then other companies use their chips to make a graphic card.

CPU & GPU

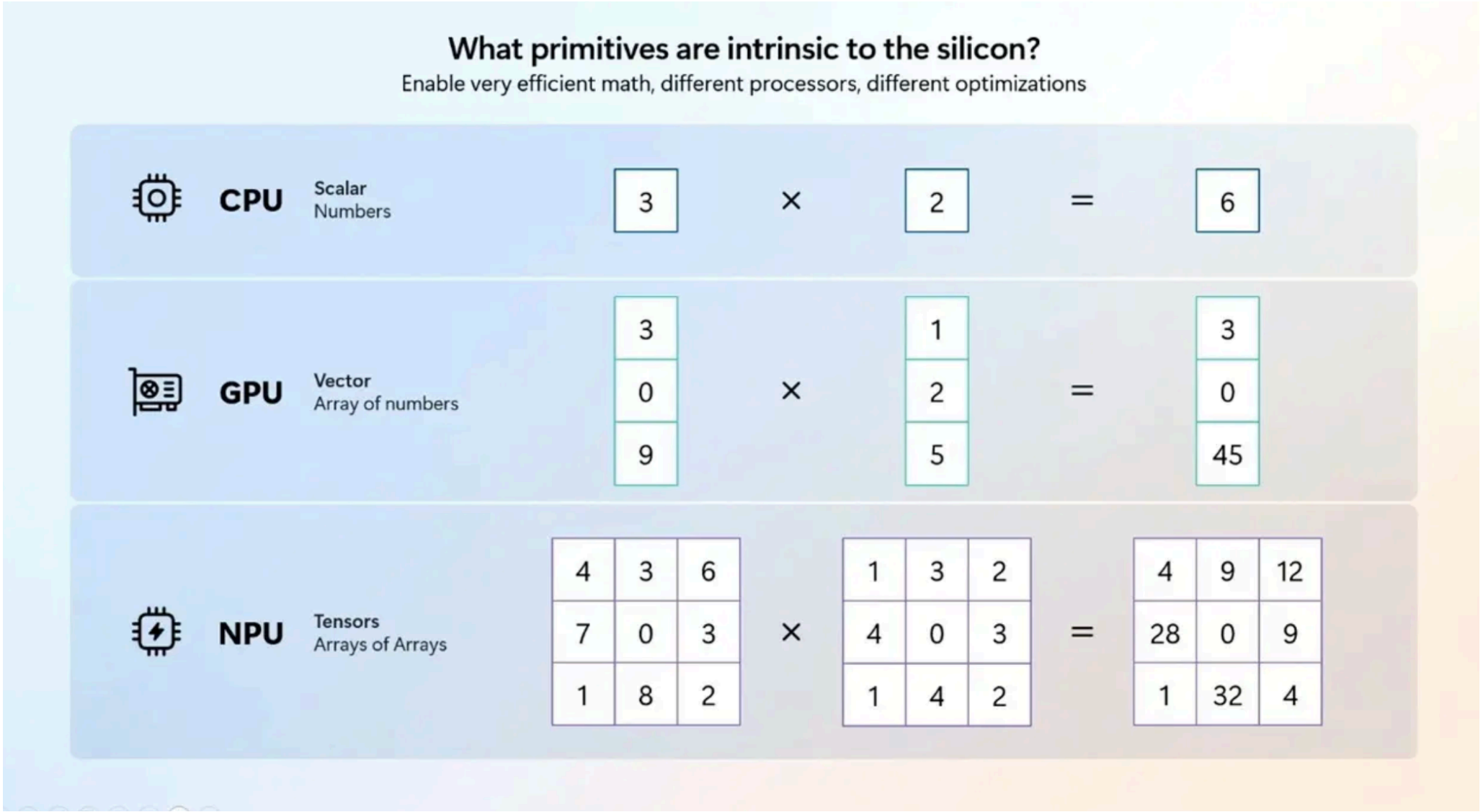




NPU (NEURAL PROCESSING UNIT)

- NPU stands for Neural Processing Unit, and it's specifically designed to perform AI-related tasks.
- When I say AI-related tasks, it means that NPU can process neural networks, machine learning tasks, and AI workloads.

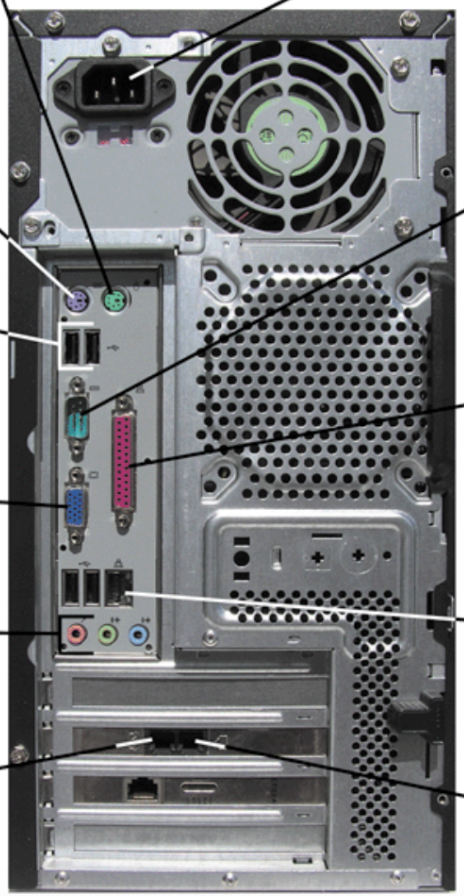
CPU & GPU & NPU



* Microsoft Corp.

PORTS & CONNECTORS

FIGURE 2-17
Typical ports found on the back of a desktop PC and examples of connectors.



MOUSE PORT
Connects a mouse.

POWER CONNECTOR
Connects the PC to a power outlet.

KEYBOARD PORT
Connects a keyboard.

SERIAL PORT
Connects a scanner or mouse.

USB PORTS
Connect a keyboard, mouse, scanner, flash memory drive, printer, digital camera, or other USB devices.

PARALLEL PORT
Connects a printer.

VGA MONITOR PORT
Connects a VGA monitor.

NETWORK PORT
Connects the PC to a network.

SOUND PORTS
Connect speakers, headphones, and a microphone.

PHONE PORT
Connects a telephone so you don't lose the use of your phone jack.

MODEM PORT
Connects the PC to a phone jack.

CONNECTORS


USB


FireWire


PS/2 (for mouse or keyboard)


Serial (DB-9)


Monitor (VGA)

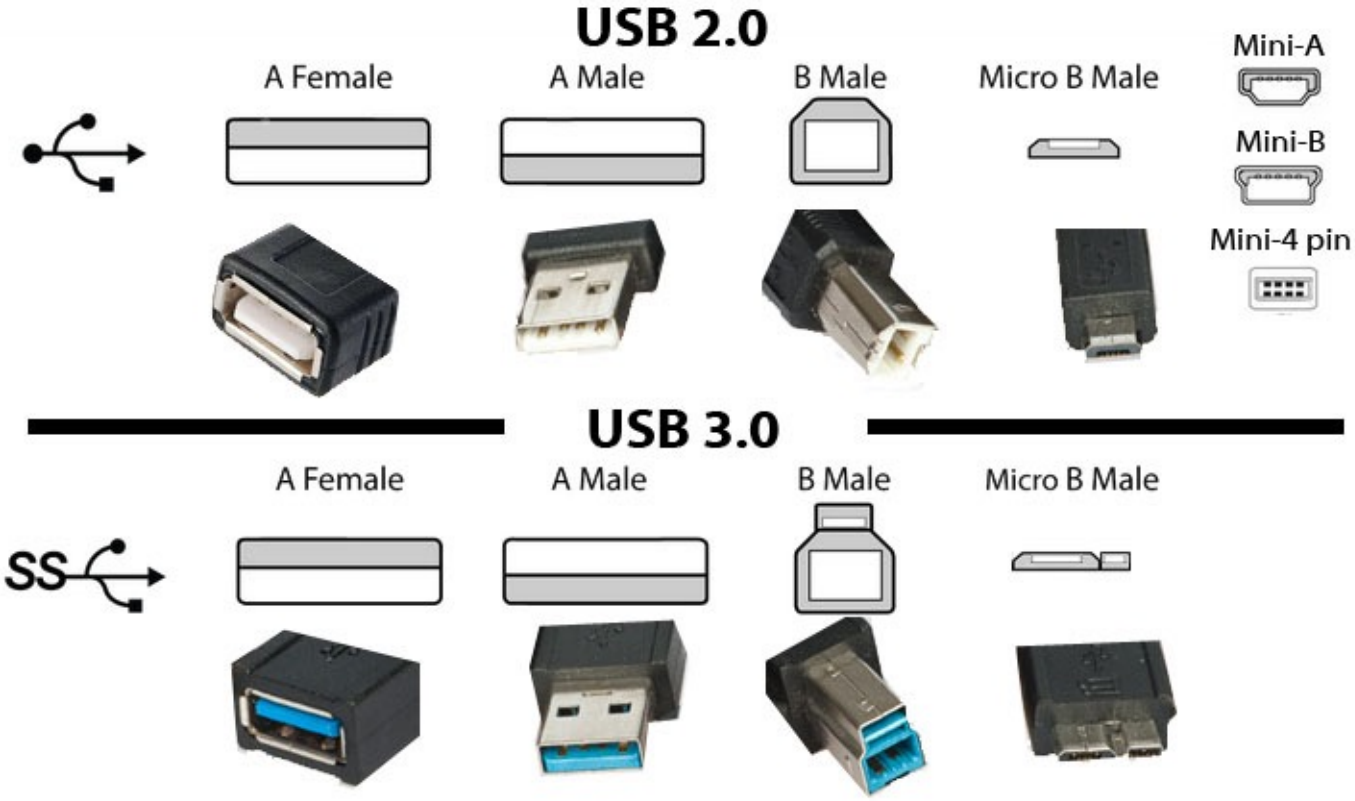

Parallel


Telephone (for modem and telephone)


Network (RJ-45)

USB (UNIVERSAL SERIAL BUS)

- USB 1 – 12 Mb/s or 1.5 Mb/s
- USB 2 (High Speed USB) – 480 Mb/s
- USB 3 (Super Speed USB) – 5 Gb/s



THUNDERBOLT AND USB-C

Thunderbolt 3 Cable

USB-C Cable

Thunderbolt 3
40Gb/s

USB 3.1 Gen 2
10Gb/s

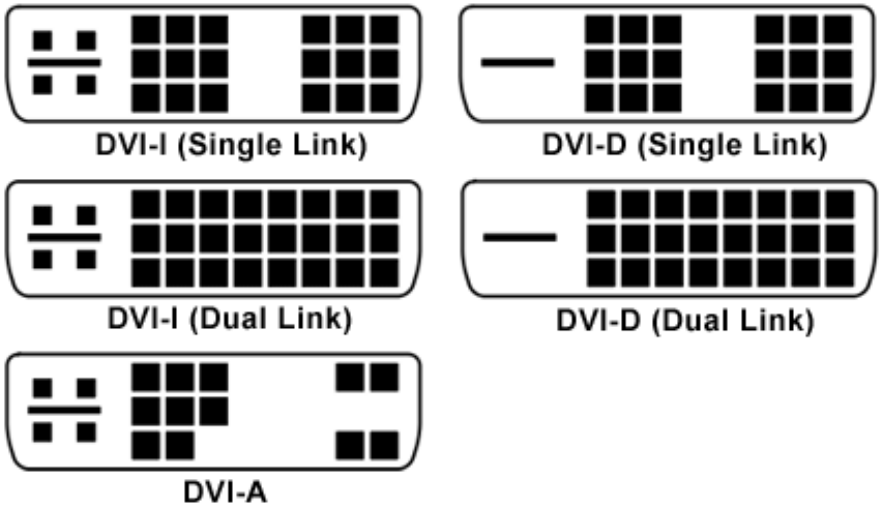
USB 3.1 Gen 1
5Gb/s

VGA (VIDEO GRAPHICS ARRAY)

- First introduced with the IBM PS/2 line of computers in 1987.
- Most common monitor connection.
- Analog Signal (Easy to get noise)
- Display only.

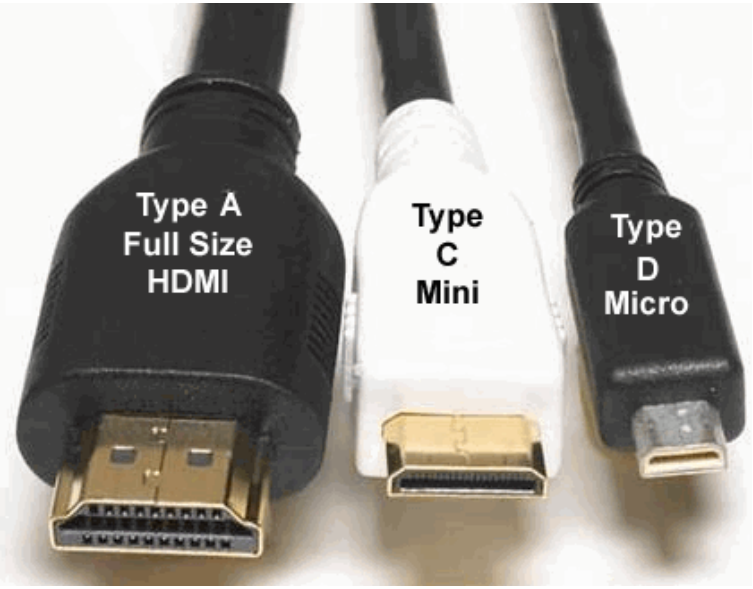
DVI (DIGITAL VISUAL INTERFACE)

- Common among new monitors.
- Digital Signal (Only some supports Analog)
- Display only



HDMI (HIGH-DEFINITION MULTIMEDIA INTERFACE)

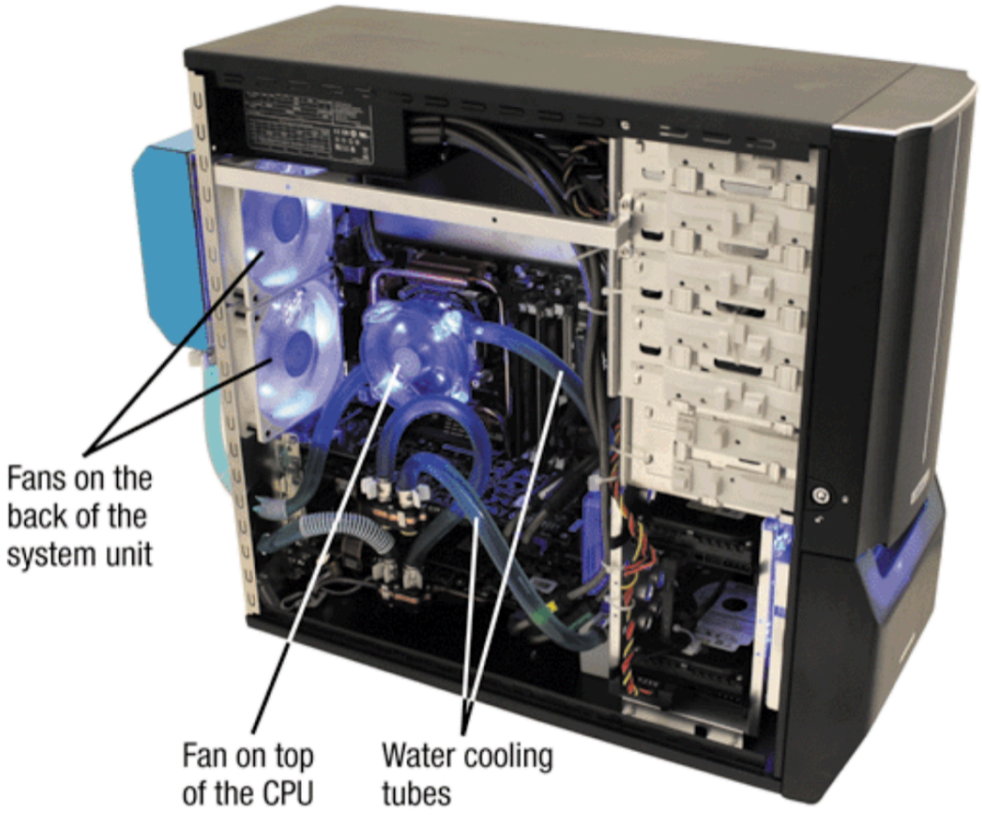
- Found on all new TV
- Display and Sound
- New version includes network data



POWER SUPPLY / UPS

- Need enough power (watt) to run
- Check here …
  - http://powersupplycalculator.net
- UPS (Uninterruptible Power Supply)
  - Form Factor - Tower or Rack-Mount
  - Power Factor (PF)
  - Watt = VA x PF

FANS, HEAT SINKS, AND OTHER COOLING COMPONENTS



WANT FASTER COMPUTER

- Better Hard Disk
  - SSD / Faster
- Better RAM
  - More / Faster
- Better Graphic Card
  - Only when you play 3D game or video rendering.
- Better CPU
  - If you have money to spare. Not so important

ASSIGNMENT 1

- ให้นักศึกษาแต่ละกลุ่มลองหาข้อมูลของคอมพิวเตอรข์องคุณว่ามีคุณสมบัติเป็นอย่างไรบ้าง โดยอย่างน้อยต้องมีข้อมูลดังต่อไปนี้
  - CPU
  - Memory
  - Hard Disk
  - Video Card
  - Operating System
  - Ports
- หาข้อมูลดังกล่าวมา 2 เครื่อง และลองเปรียบเทียบกันว่าถ้านำทั้ง 2 เครื่องใช้ในการตัดต่อวิดีโอ เครื่องใดจะทำงานได้มีประสิทธิภาพมากกว่ากัน และเพราะอะไร