WEEK01 – COMPUTER HARDWARE

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OUTLINE

1. **History of Calculator**
2. **History of Computer**
3. **Semiconductor Manufacturing Technology**
4. Types of Computers
5. Logic Gates and TTL Signals

HISTORY OF CALCULATOR

Calculator – A machine can process the addition, subtraction, multiplication and division of numbers.

3000 years ago – Chinese abacus

1673, 1694 Step Reckoner – a digital mechanical calculator by Gottfried Leibniz (1646-1716, German). The design is expanded on Pascal's idea.

1842 Arithmaurel – a mechanical calculator by Timoleon Maurel (France)

1883 Circular Calculator invented by Joseph Edmondson (the British)
1948 Curta – portable calculator by Curt Herzstark (1902-1988, Austrian)

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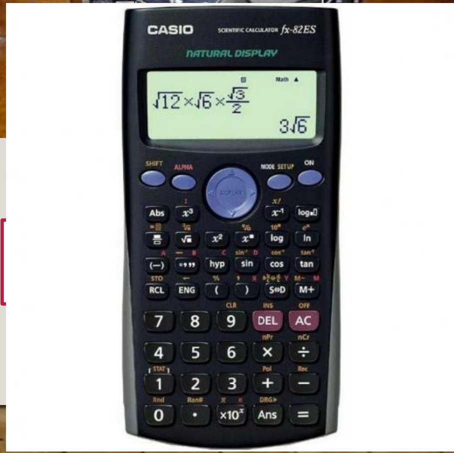


Ref1: http://www.gwleibniz.com/calculator/calculator.html
Ref2: https://en.wikipedia.org/wiki/Leibniz_wheel
Ref3: https://history-computer.com/MechanicalCalculators/19thCentury/Edmondson.html
Ref4: http://www.vcalc.net/cu.htm

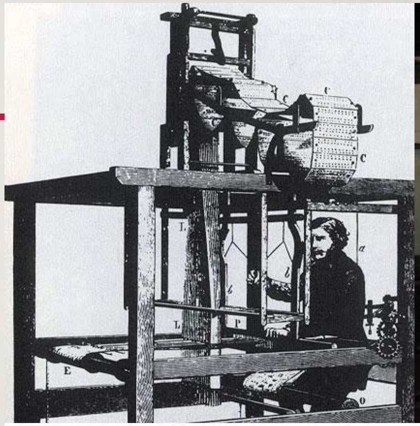
HISTORY ABOUT CODING & CALCULATION

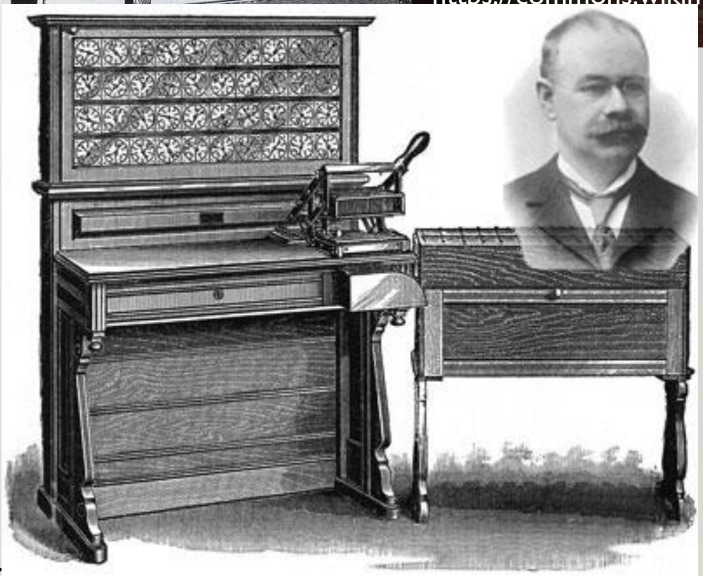
Coding – A sequence of commands that can be executed one by one by a machine

1804 programmable loom by Joseph Marie Jacquard (1752-1834, France)

1821 difference engine – tabulate polynomial functions (Taylor expansion), analytical engine (1834), new difference engine (1840) by Charles Babbage (1791-1871, the British)

1890 tabulated machine to summarize information stored in punched cards, invented by Herman Hollerith (1860-1929, American)





Ref1: http://history.computer.org/pioneers/index.html
Ref2: https://www.scienceandindustrymuseum.org.uk/objects-and-stories/jacquard-loom
Ref3: https://history-computer.com/ModernComputer/Basis/TabulatingMachine_Hollerith.html

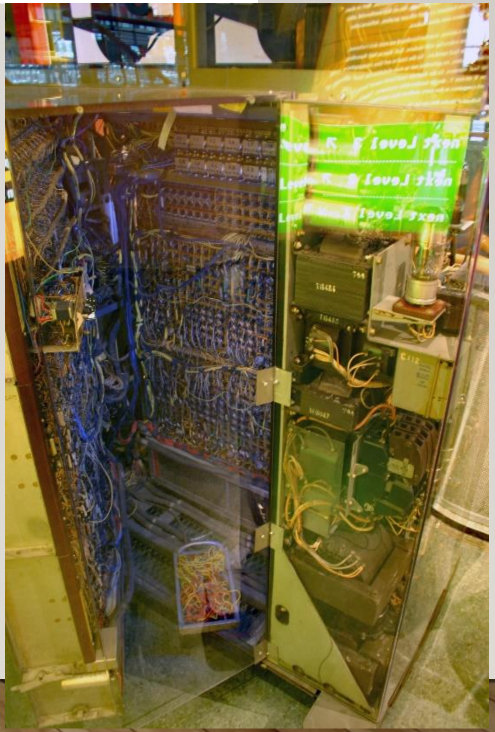
HISTORY OF COMPUTER

Computer – machine calculation with codes of pre-installed sequences

1944 IBM ASCC - Aiken-IBM Automatic Sequence Controlled Calculator Mark I (assembled using switches, relays, rotating shafts, and clutches) by Howard Aiken (American). The first program was installed by John von Neumann.

1946 ENIAC - Electronic Numerical Integrator and Computer (a Turing-complete machine, containing 20,000 vacuum tubes) with clock speed of 5 kHz, designed by John Mauchly and J. Presper Eckert of the University of Pennsylvania

1st generation



1955 Harwell CADET (Europe) & IBM 604 (United States) – transistor computer with clock speed of 58 kHz. The IBM 604 consists of 2,000 transistors.

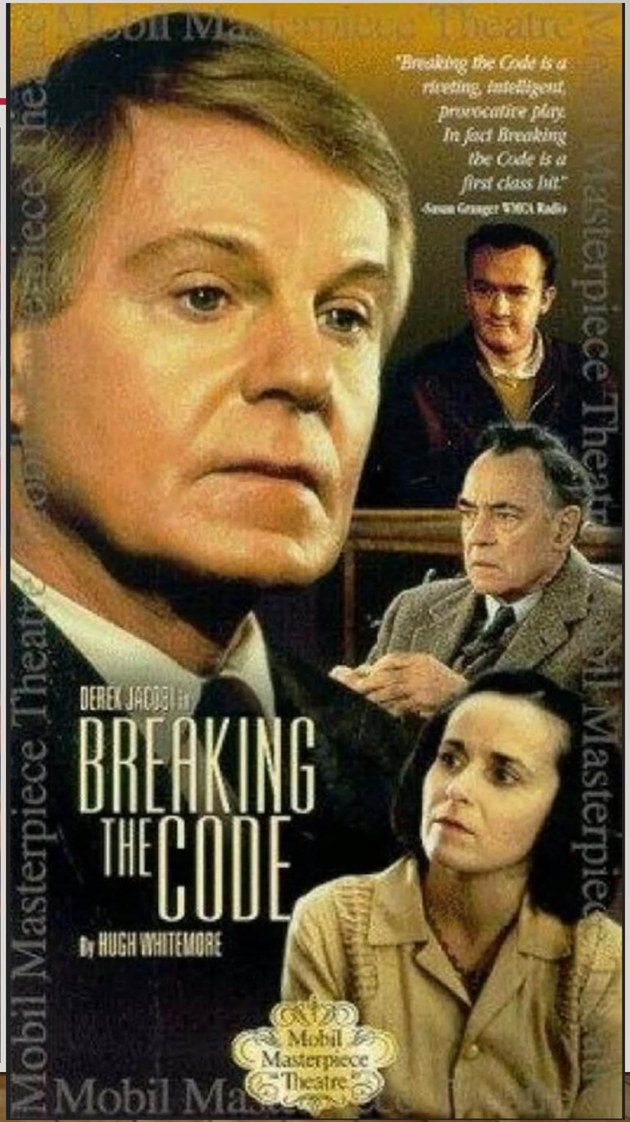
2nd generation

Ref1: https://www-03.ibm.com/ibm/history/exhibits/markI/markI_intro.html
Ref2: https://en.wikipedia.org/wiki/ENIAC
Ref3: https://en.wikipedia.org/wiki/IBM_604

HISTORY OF COMPUTER

The Imitation Game (2014) – A Story about Alan Turing

Breaking The Code – released in 1987



A TURING MACHINE CONSISTS OF:

- A tape divided into cells, one next to the other. Each cell contains a symbol from some finite alphabet. The alphabet contains a special blank symbol (here written as '0') and one or more other symbols.
- A head that can read and write symbols on the tape and move the tape left and right one (and only one) cell at a time.
- A state register that stores the state of the Turing machine, one of finitely many.
- A finite table of instructions that, given the state(q_i) the machine is currently in and the symbol(a_j) it is reading on the tape, tells the machine to do the following in sequence ……

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

HISTORY OF COMPUTER

Computer – machine calculation with codes of pre-installed sequences

1964 IBM System/360, memory 8, 64, 256, 1024 k Bytes, peripheral: random-access magnetic disk storage devices, magnetic tape storage, visual display units, card readers and punches, printers, an optical character reader … (made by Integrated Circuit, IC) 3rd generation

1971 Intel 4004 4 bit central processing unit (CPU) with clock speed of 108-740 kHz (made by Very Large Scale Integrated Circuit, VLSI)

1972 Intel 8008 8 bit CPU with clock speed of 0.5 or 0.8 MHz

1974 Intel 8080 16 bit CPU with clock speed of 2 MHz, containing 6,000 transistors, 10 μm fabrication – RCS, IBM, Moto 6800, AMD … 4th generation

Ref1: https://ethw.org/IBM_System/360
Ref2: https://www.ibm.com/developerworks/library/pa-microhist/index.html
Ref3: http://www.mynikko.com/CPU/8080.html

HISTORY OF COMPUTER

Computer – machine calculation with codes of pre-installed sequences

5th generation

The 5th generation computer was initiated by Japan's Ministry of International Trade and Industry since 1982.

It is supposed to be made by Super Large Scale Integrated Circuit (SLSI).

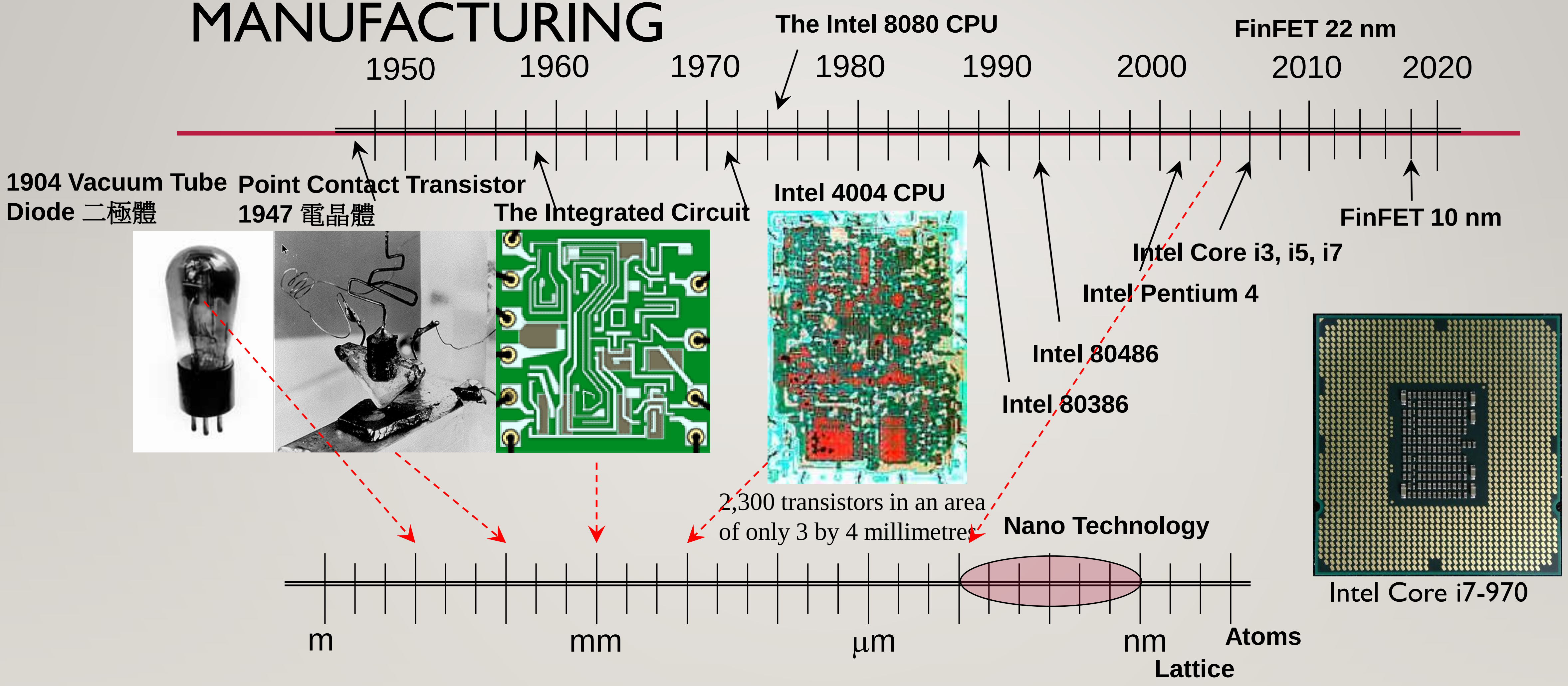
The concepts of artificial intelligence and deep learning might be integrated in it.

What will be the future? Back to The Future 2 – 30 years later to see the self-lacing sneakers

Demolition Man 超級戰警

Ref1: https://en.wikipedia.org/wiki/Fifth_generation_computer

MANUFACTURING



Making a transistor as small as possible is the way to assemble more transistors in the CPU. The final size of materials with periodic lattice structures is nano meter. That could be the smallest size while maintaining thermal stability for making electronic devices.

OUTLINE

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5. **Logic Gates and TTL Signals**

TYPES OF COMPUTERS

Super Computer – Server – Personal Computer

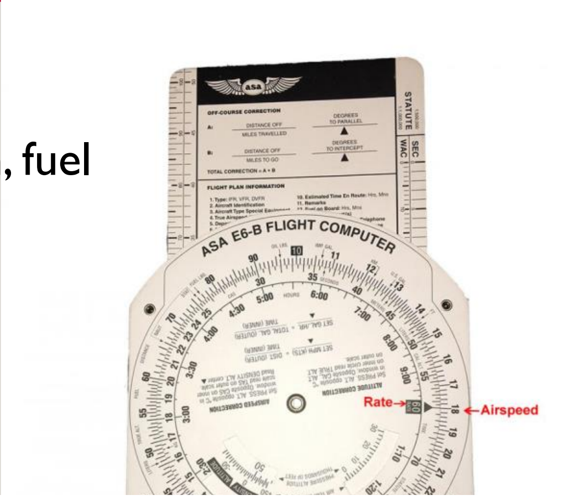
- Supercomputer – e.g. more than 40 k CPUs each with 256 processing cores
- Mainframe (PC clusters) – processing is done centrally and users are dumb terminals
- Server – file server, application server, mail server (could be executed by one or more than one computers)
- Cloud Computing – cloud computing are done on the internet at somewhere and files are stored at some other places
- Workstation – for complex procedures execute in one high-end computer
- Personal Computer
- Smart Phones
- Microcomputer – Intel 8051, Arduino

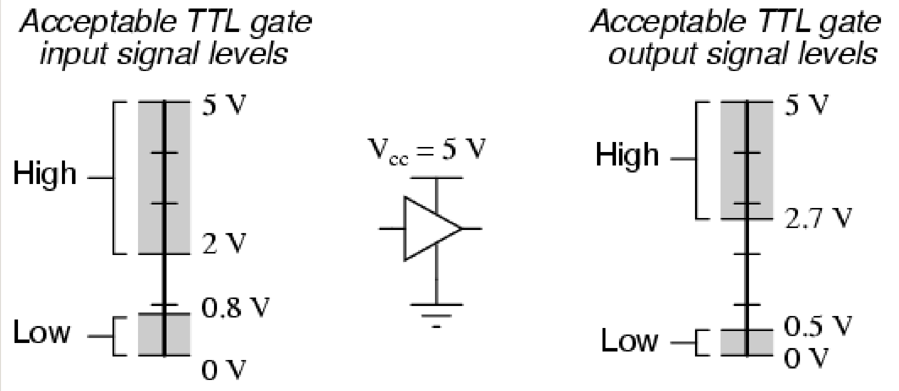
Ref1: http://cs.sru.edu/~mullins/cpsc100book/module02_introduction/module02-02_introduction.html

TYPES OF COMPUTERS

Analog? Digital?

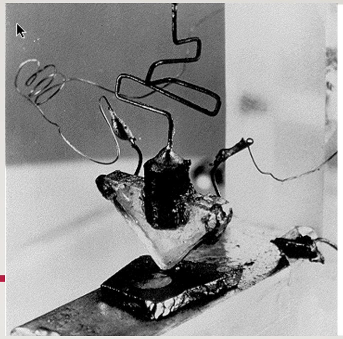
- Analog Computer
  - For example, the E6B flight computer was used to calculate wind correction, fuel burn, time and distance, and ground speed. It was invented by Navy Lt. Philip Dalton in 1930s. Hamilton KHAKI X-WIND
  - Artificial neural network uses analog signals.
- Digital Computer
  - **TTL (Transistor-Transistor Logic)**
  - The signal 0 is a voltage in the range between 0 and 0.5 V.
  - The signal 1 is a voltage in the range between 2.7 and 5 V.

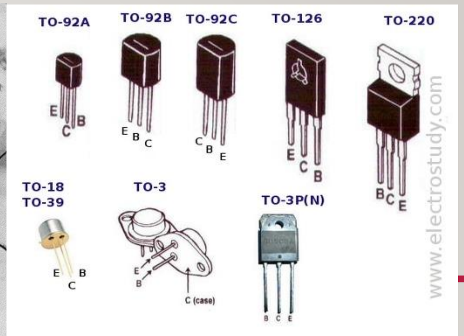




Ref1: https://www.gleimaviation.com/e6b-flight-computer-instructions/
Ref2: https://www.allaboutcircuits.com/textbook/digital/chpt-3/logic-signal-voltage-levels/

LOGIC **GATES**



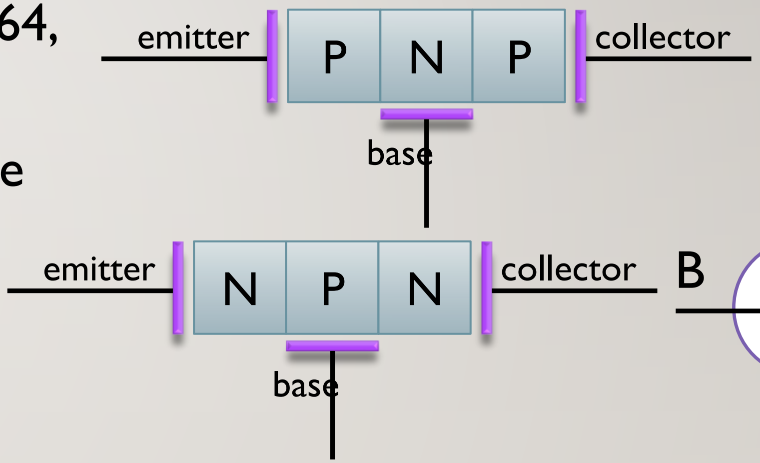


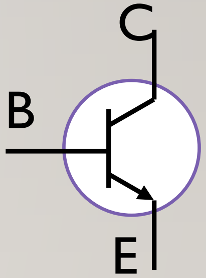
1847 The Mathematical Analysis of Logic, George Boole (1815-1864, the British)

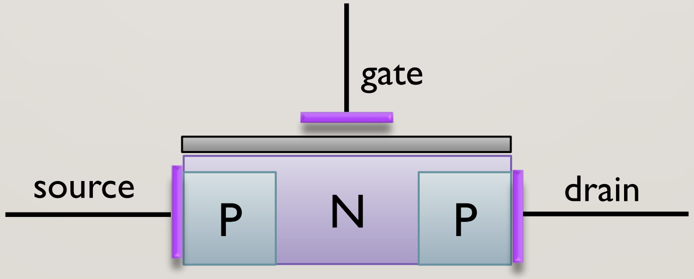
The calculation can be realized by the transistor and now it can be easily materialized by using field-effect transistors.

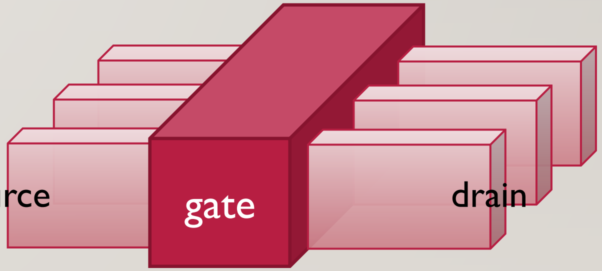
The modern structures are named as Insulated Gate Field Effect Transistors (IGFET) or Metal Oxide Semiconductor Field Effect Transistors (MOSFET).

Here the **gate** electrode is used to control and to turn on/off the current flow between the source and drain electrodes.



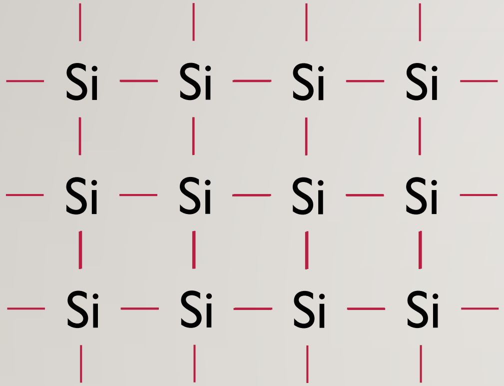


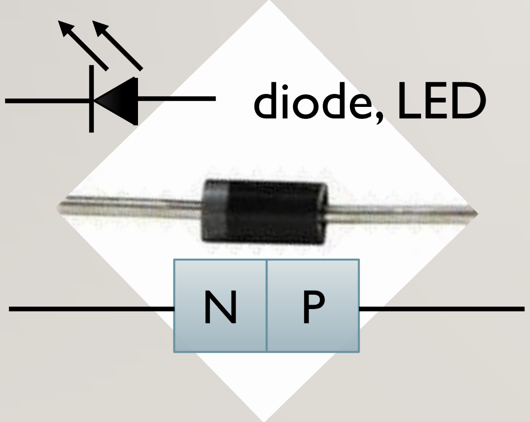


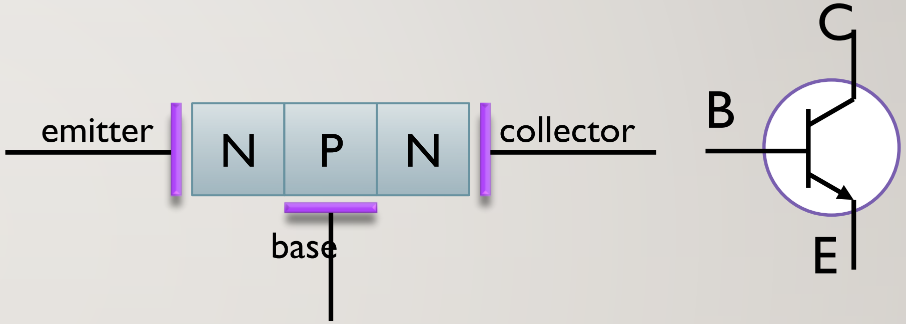


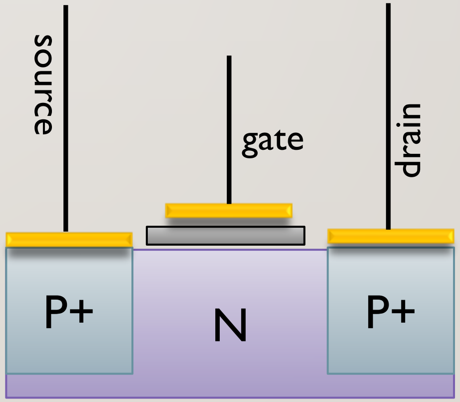
FinFET

SEMICONDUCTORS & TRANSISTORS







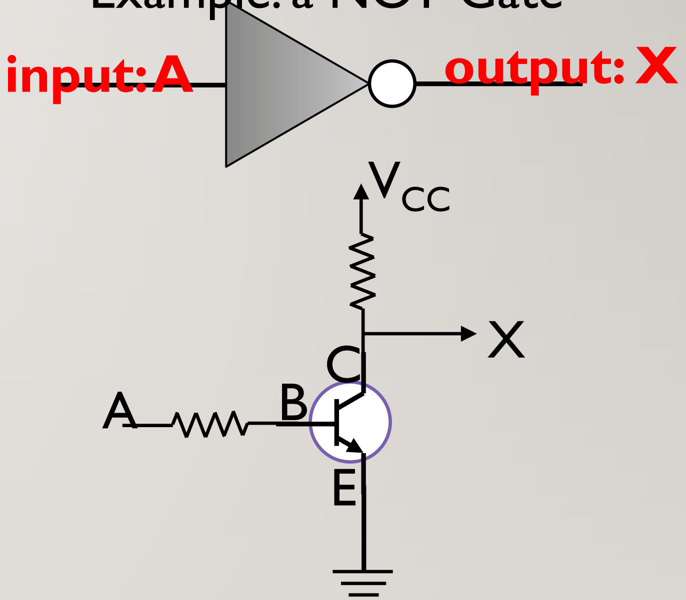


LOGIC **GATES**

Boolean Operations: 1 = TRUE = 5.0 V, 0 = FALSE = 0 V (ideal value)

Example: a NOT Gate

Logic Diagram: Symbols to Express The Circuit and Signal Operation



Truth Table:

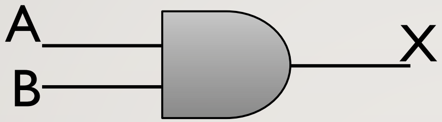
A	X
0	1
1	0

Basic Logic Gates: NOT, AND, OR, XOR, NAND, NOR

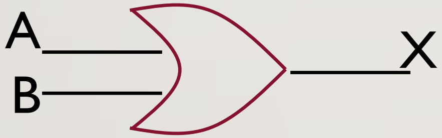
Combinational Logic Gates: Distributive Law A (B + C), Addition A + B, Multiplexer, Memory

LOGIC **GATES**

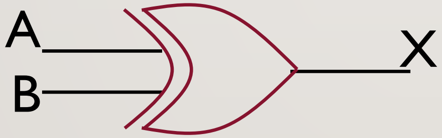
AND Gate: $X = A \cdot B$



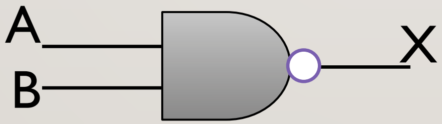
OR Gate: $X = A + B$



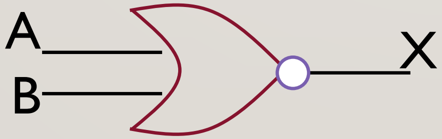
XOR Gate: $X = A \oplus B$



NAND Gate: $X = \overline{A \cdot B}$



NOR Gate: $X = \overline{A + B}$



A	B	X
0	0	0
1	0	0
0	1	0
1	1	1

A	B	X
0	0	0
1	0	1
0	1	1
1	1	1

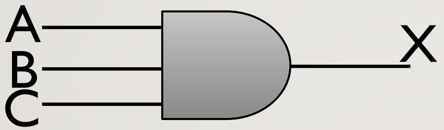
A	B	X
0	0	0
1	0	1
0	1	1
1	1	0

A	B	X
0	0	1
1	0	1
0	1	1
1	1	0

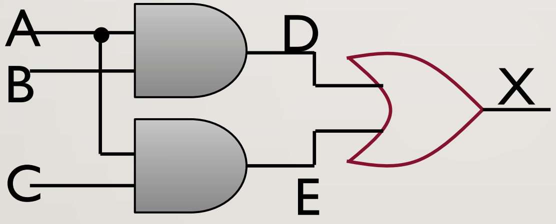
A	B	X
0	0	1
1	0	0
0	1	0
1	1	0

LOGIC **GATES**

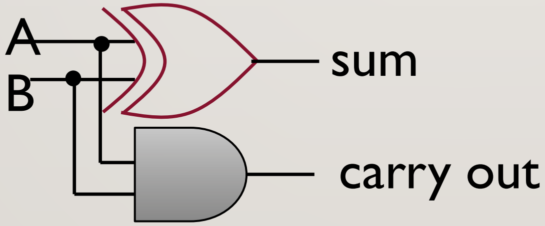
AND Gate: $X = A \cdot B \cdot C$



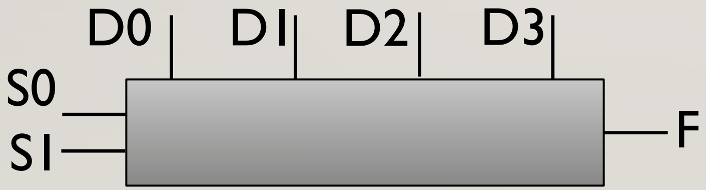
Combinational Logic Gates:



Combinational Logic Gates - Adder



Combinational Logic Gates - Multiplexer



A	B	C	X
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

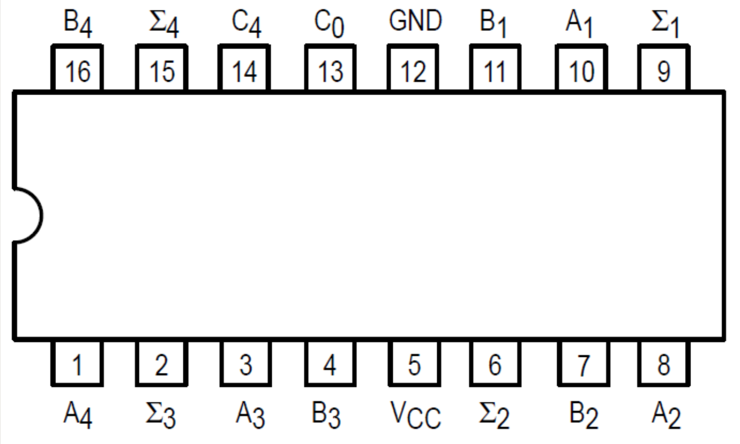
A	B	C	D	E	X
0	0	0	0	0	0
0	0	1	0	0	0
0	1	0	0	0	0
0	1	1	0	0	0
1	0	0	0	0	0
1	0	1	0	1	1
1	1	0	1	0	1
1	1	1	1	1	1

A	B	sum	carry
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

S1	S0	F
0	0	D0
0	1	D1
1	0	D2
1	1	D3

DIGITAL SIGNAL & NUMBER OF BITS IN PROCESSING

TTL signal processing, for example, Motorola 74LS83, a 4-bit adder



1 bit – 2 bits – 4 bits – 8 bits – 16 bits – 32 bits

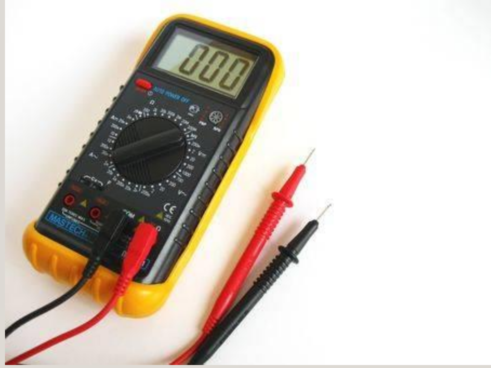
Vcc: power, 5-V voltage source; GND: common ground

A1-A4: 4-bit input A, B1-B4: 4-bit input B

C0: carry in; C4: carry out.

$\Sigma 1 - \Sigma 4$: 4-bit output

0101 + 0110 = ? What will you get from the $\Sigma 1 - \Sigma 4$ pin by using a voltage meter?



0101 = ?

Units used in computer: bits & bytes, 1 byte = 8 bit, 1 KB = 1024 bytes rather than 1000 bytes

Ref1: Motorola 74LS83 Datasheet

OPERATION OF TTL LOGIC GATES

Power: V_{CC} and GND

TTL Logic Gate: 74LS04, 6 NOT Gates

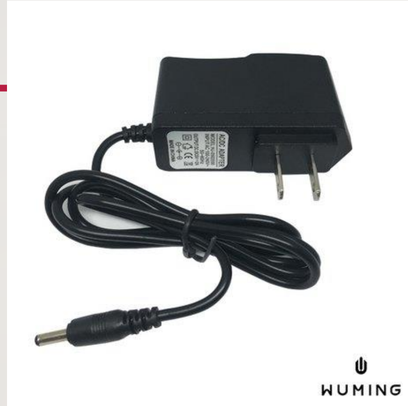
Board For Integrated Circuits: Breadboard

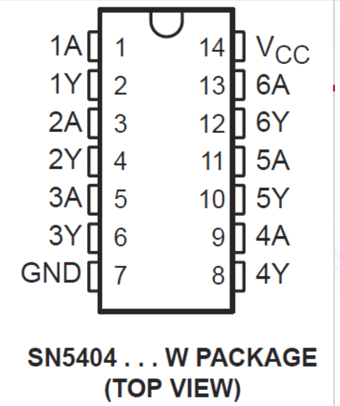
The power and the ground can be used as signal 1 & 0.

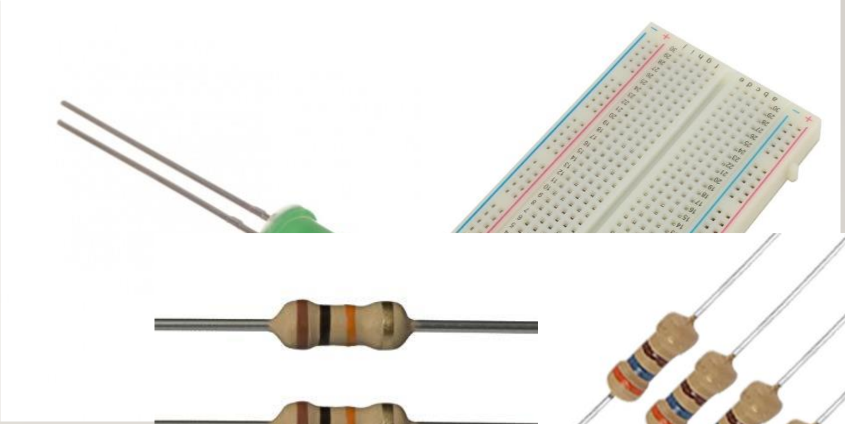
The pull-up resistor of 10-100 kΩ for signal 1 shall be used.

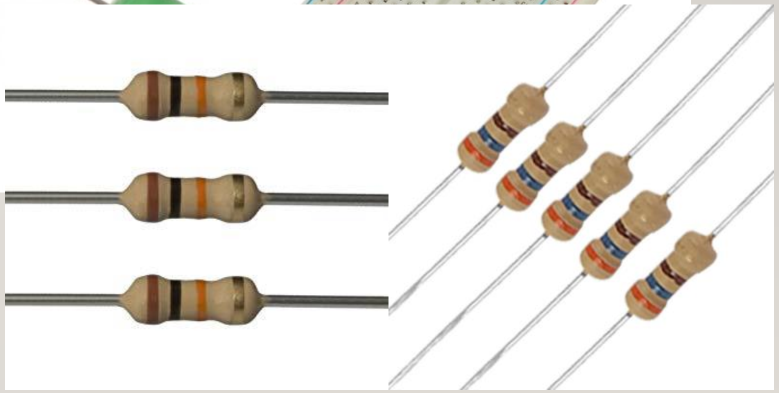
See your output by using a LED. Parameters: 5V, 13 mA -> R=385 Ω

Power limitation of the resistor, e.g. ¼ W. What are high and low precision resistors?









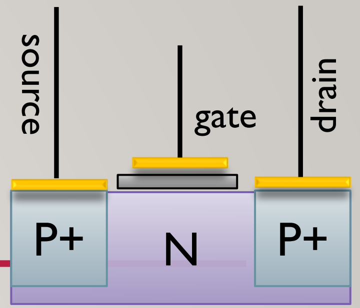
EXERCISE

1. What are the innovative technologies used in the 1st, 2nd, and 3rd generations of computers?
2. What are those invented machines in history related to the computer coding?
3. Which computer generation is Intel 8088 attributed to?
4. Use one paragraph to introduce Turing and his achievements.
5. What's the correct prediction in the movie of "Demolition Man", released in 1993?
6. What are Moore's law and Huang's law (Nvidia Corp.)?

EXERCISE

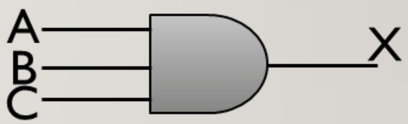
- The vacuum tube diode was invented in 1904. Can you tell us its size? Can you draw a current-voltage behavior to show the diode operation?
- When was vacuum tube diode invented? Which computer generation was it used? When was the point contact transistor invented? Which computer generation was it implemented?
- Leibniz wheel was an ancient mechanical calculator. What number system was used in the Leibniz calculator? (binary, octal, decimal, or hexadecimal number system)
- What is the number system used in the Intel 4004 CPU (the 4th computer)?

EXERCISE



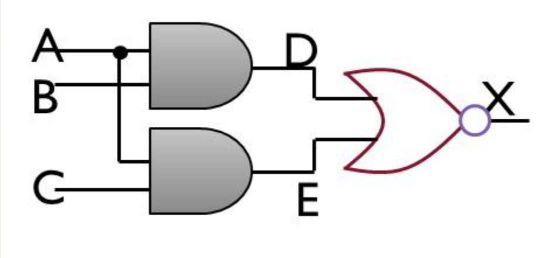
- Could you simply explain how to operate the n-type field-effect transistor shown in the right figure?

- Please write a true table for the logic gate shown in the right.

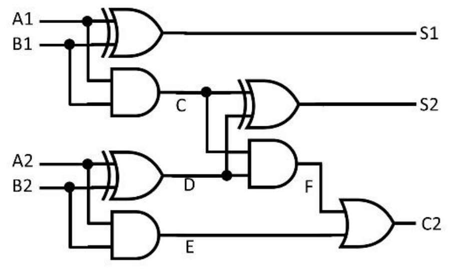


EXERCISE

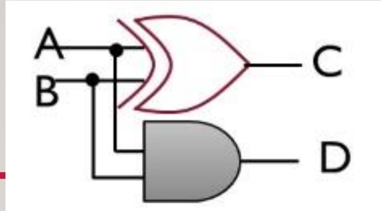
1. Please use logic gates to design a two-bit adder and give a detail descriptions of the signals in true tables.
2. Please draw the truth table for the combined gates.



3. Please draw a truth table of the following 2-bit adder. Mark the value of either 0 or 1 on the terminals of A_1, A_2, B_1, B_2, C, D, E, F, S_1, S_2, and C_2. Note that the A_1, A_2, B_1, and B_2 are terminals for input.



EXERCISE



- Please write the truth table of the right combinational logic gates. Please explain that which output pin (C or D) can be used as a summation result of a one-bit adder and which pin can be a carry out pin.