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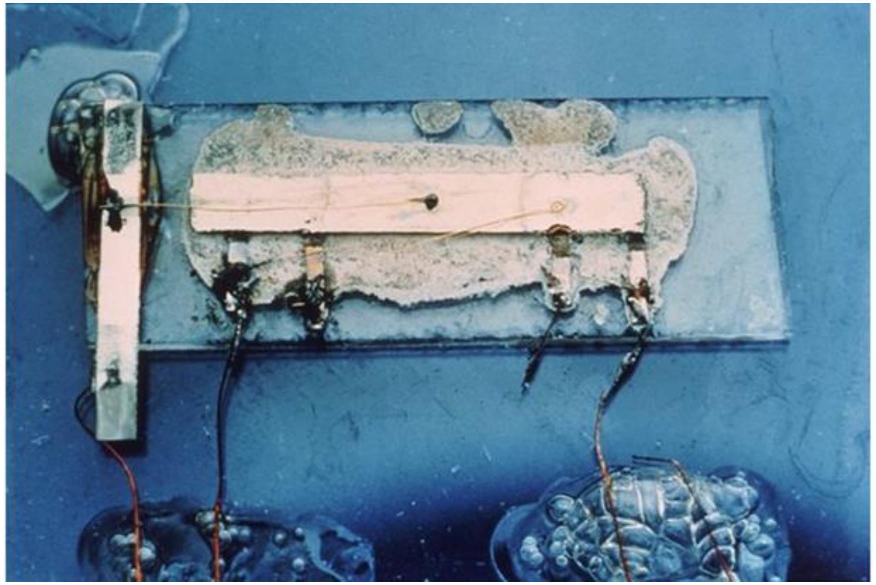
Faculty of Transportation Engineering and Vehicle Engineering
Department of Control for Transportation and Vehicle Systems

IC TECHNOLOGY

Lecture 2.

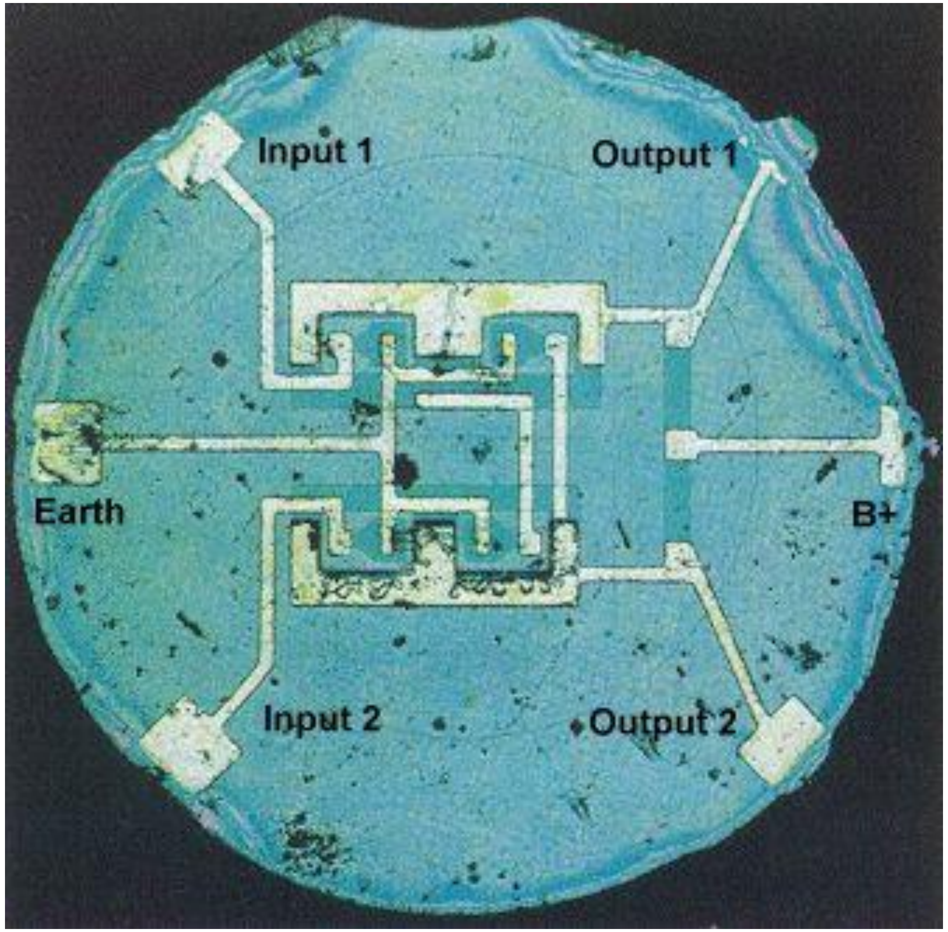
IC – Integrated Circuit – Technology

- Integrated Circuit: An integrated circuit (IC, a chip, or a microchip) is a set of electronic circuits on one small flat piece (or "chip") of semiconductor material, normally silicon.
- First IC had created by Jack Kilby – researcher of Texas Instruments - in 1958.
- Basic elements of ICs:
  - resistor,
  - capacitor,
  - diode,
  - transistor.



IC – Integrated Circuit – Technology

- First silicon IC: Robert Noyce, 1961



IC – Integrated Circuit – Technology

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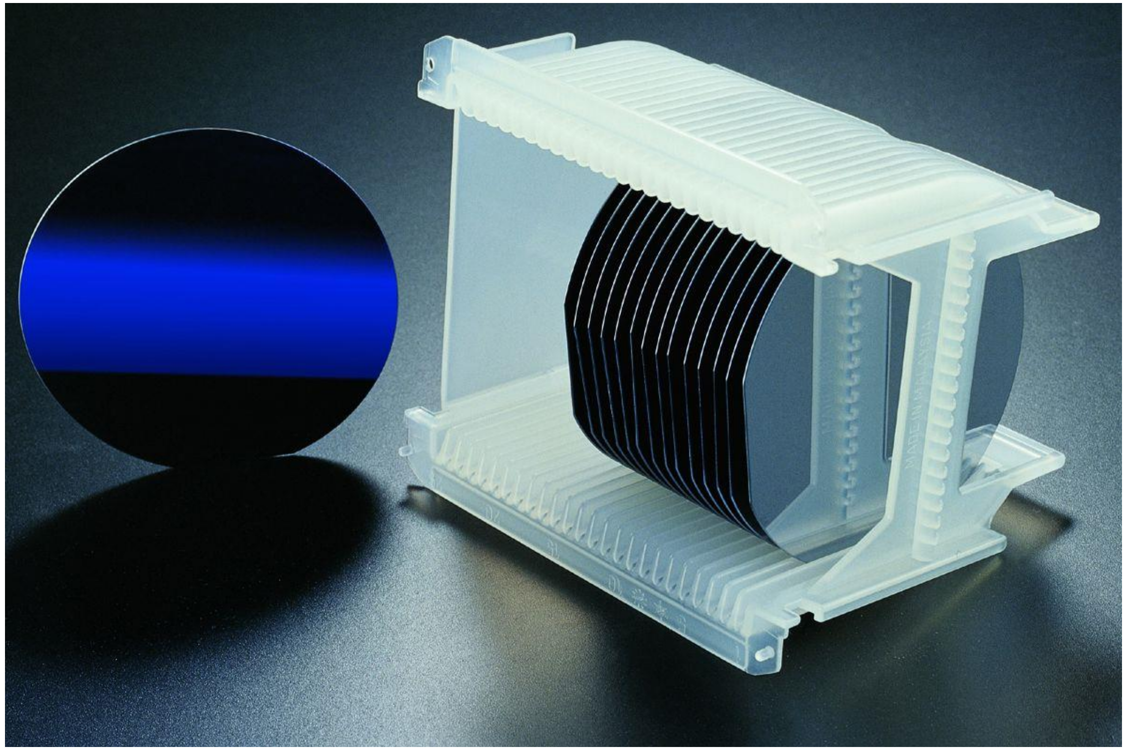
- Digital integrated circuits can contain anywhere from one to billions of logic gates, flip-flops, multiplexers, and other circuits in a few square millimeters.
- Planar process (several times in a row), from slices of a silicon single crystal rod, called wafer:
  - creation of a layer,
  - lithography,
  - doping.



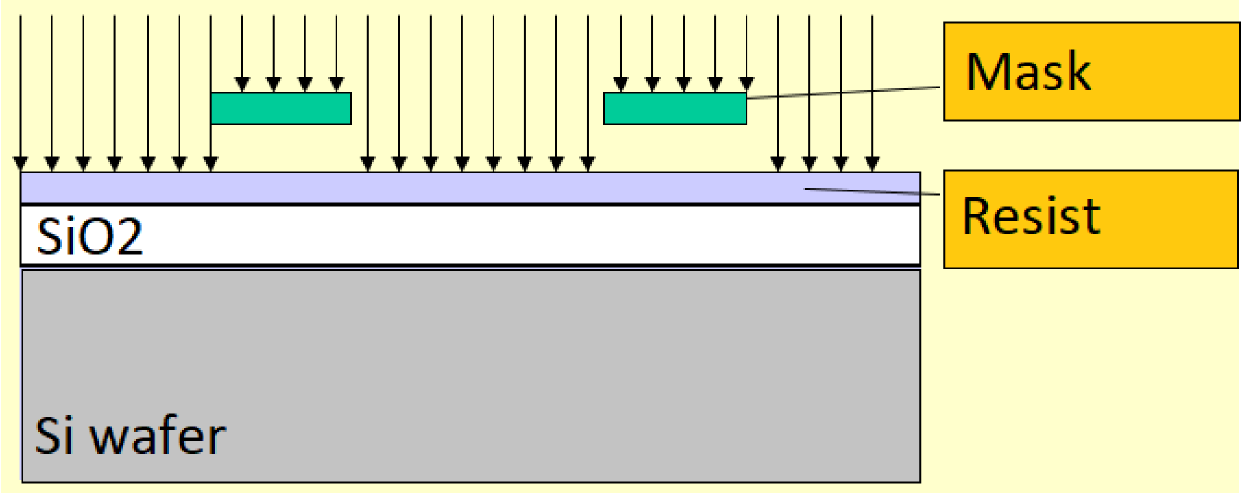
IC – Integrated Circuit – Technology

- Planar means, that the production of ICs take place in planar layout.
- Creation of a layer: chemical or physical methods in order to create a contigous layer on the wafer:
    - oxidation, epitaxial growth, chemical vapor deposition, physical vapor deposition,
    - SiO_2 layer: masks and insulates

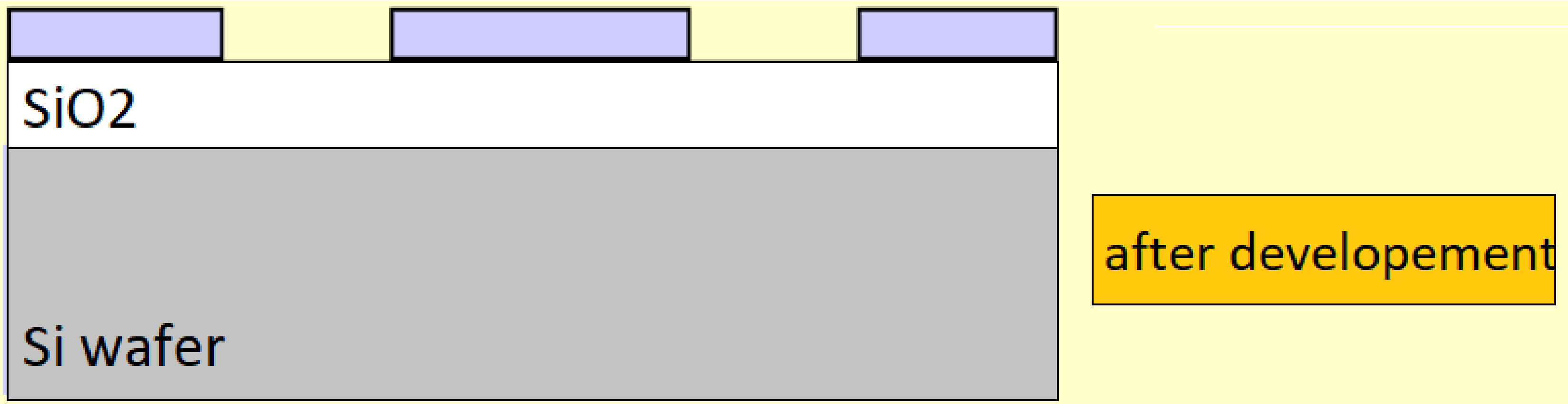
IC – Integrated Circuit – Technology

- Litography process: the purpose is to create the pattern,
- Steps of the litography process:
  - applying fotoresist material to the wafer,
  - pattern mapping,:
    - the wafer is illuminated through a mask belonging to the given layer,
    - where light penetrates the material, it will polymerize, so it will be resistant to some solvents.
  - oxide milling.

IC – Integrated Circuit – Technology



source: www.mems.hu



source: www.mems.hu

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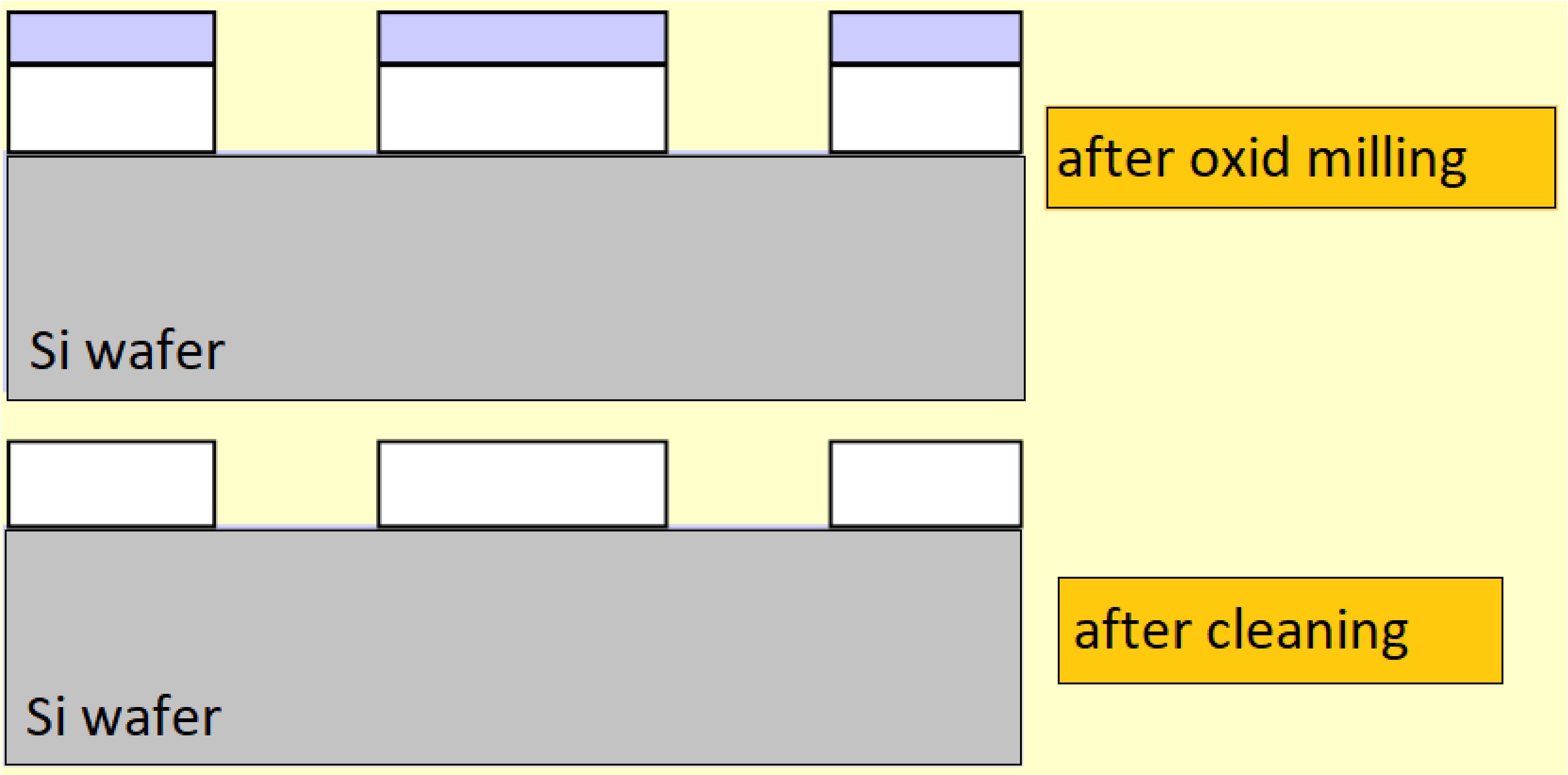
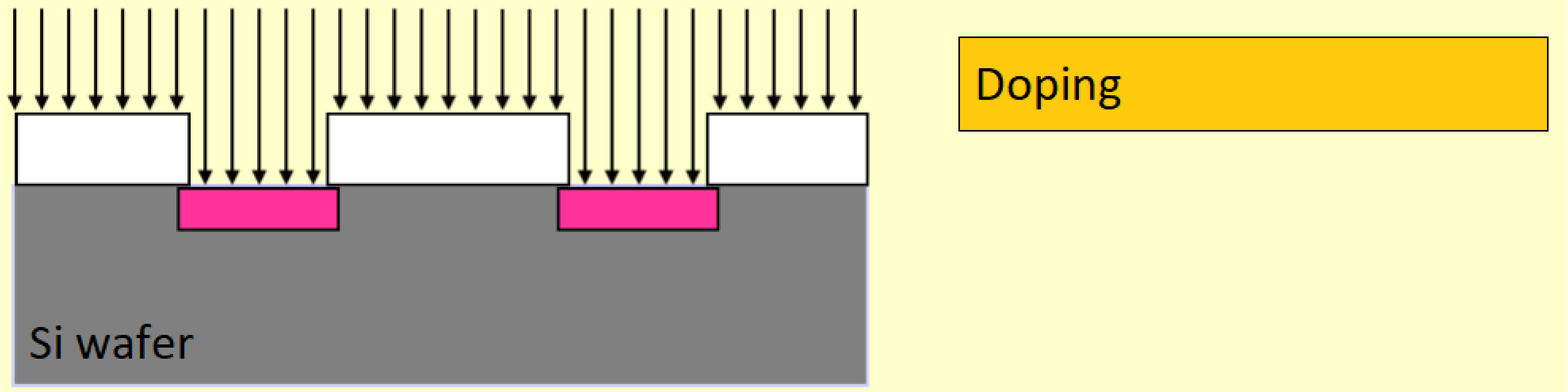


source: www.mems.hu

IC – Integrated Circuit – Technology

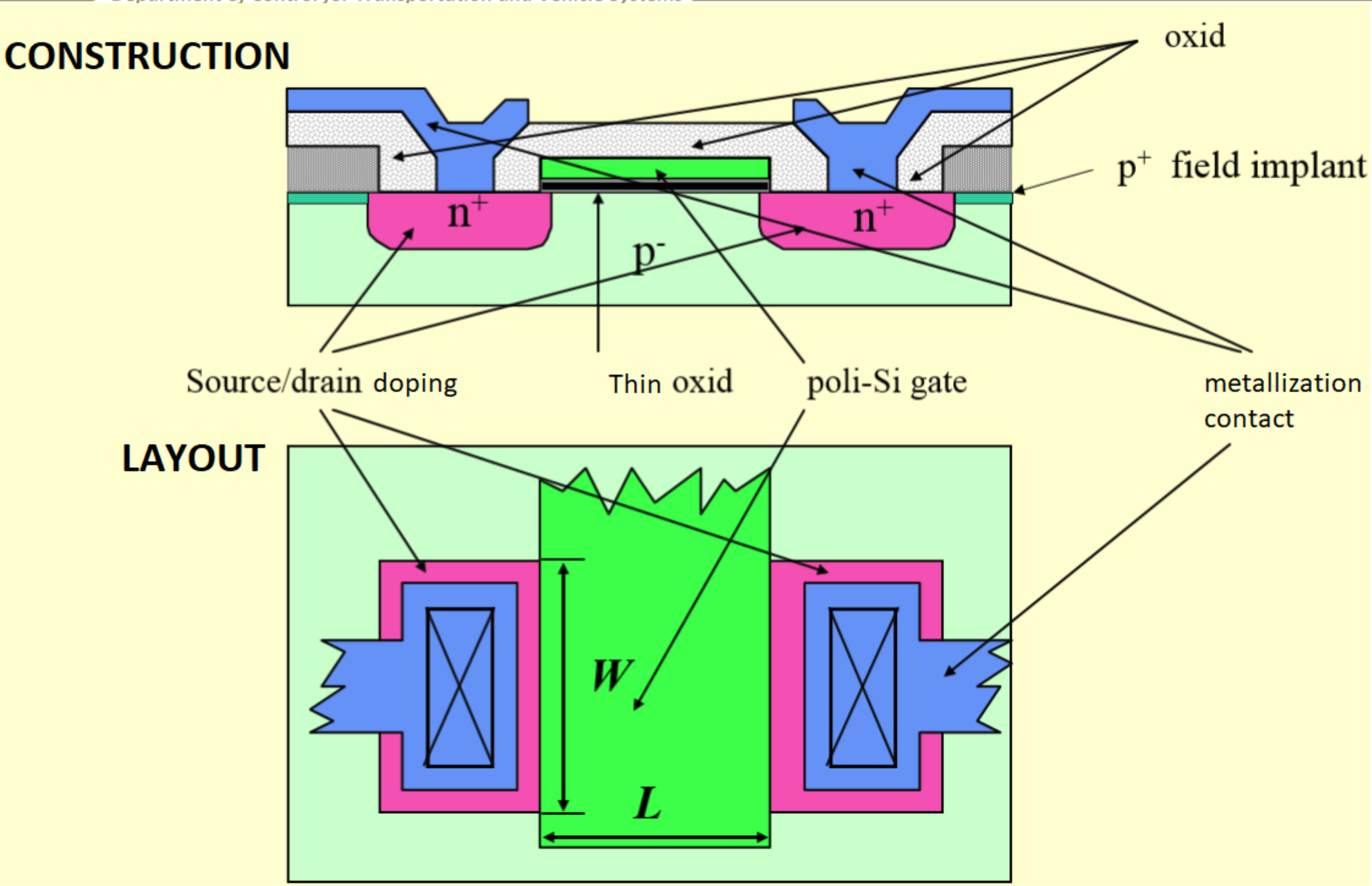
- Doping: with n or p type materials:
  - diffusion and ion implantation



source: www.mems.hu

IC – Integrated Circuit – Technology

- MOS FET IC, eg:



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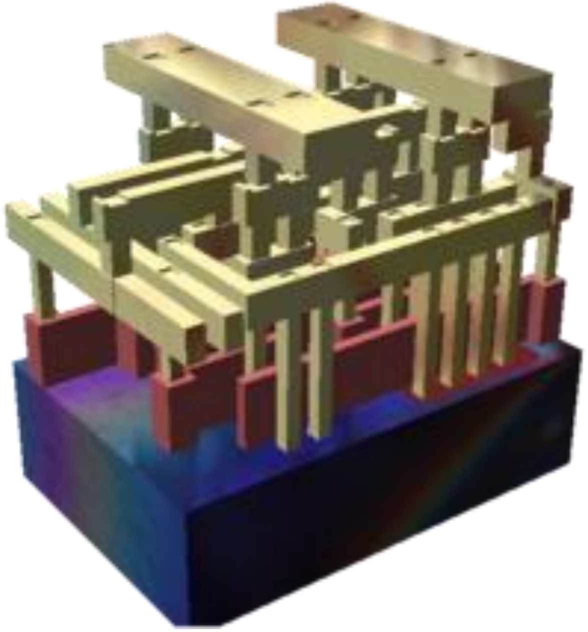

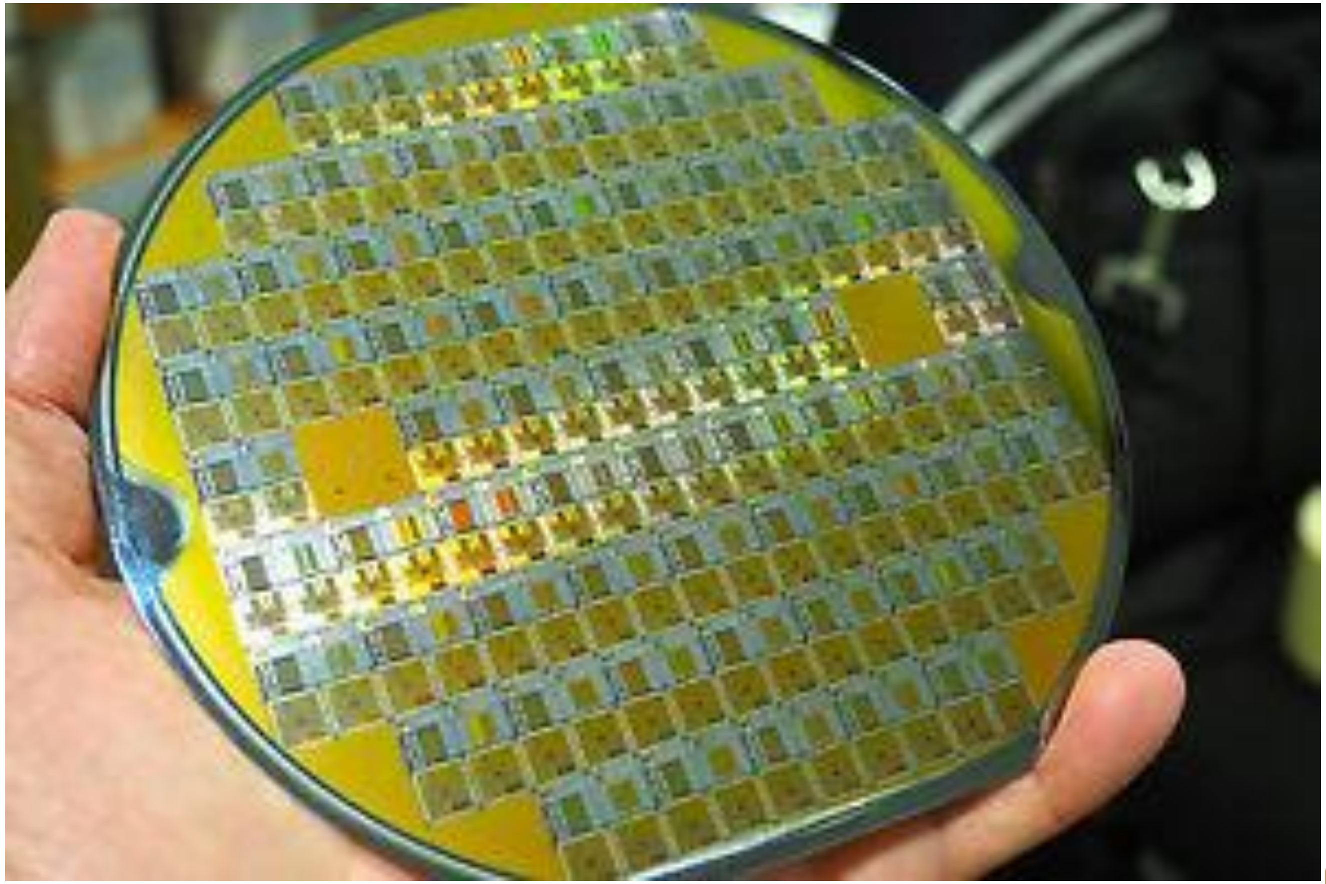

IC – Integrated Circuit – Technology

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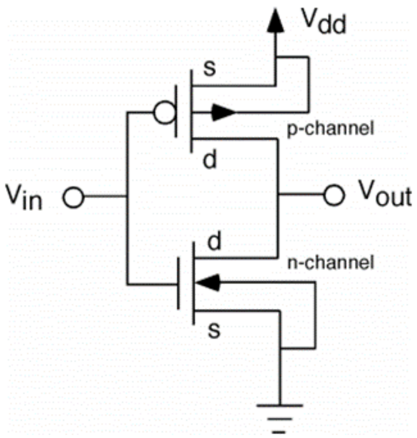
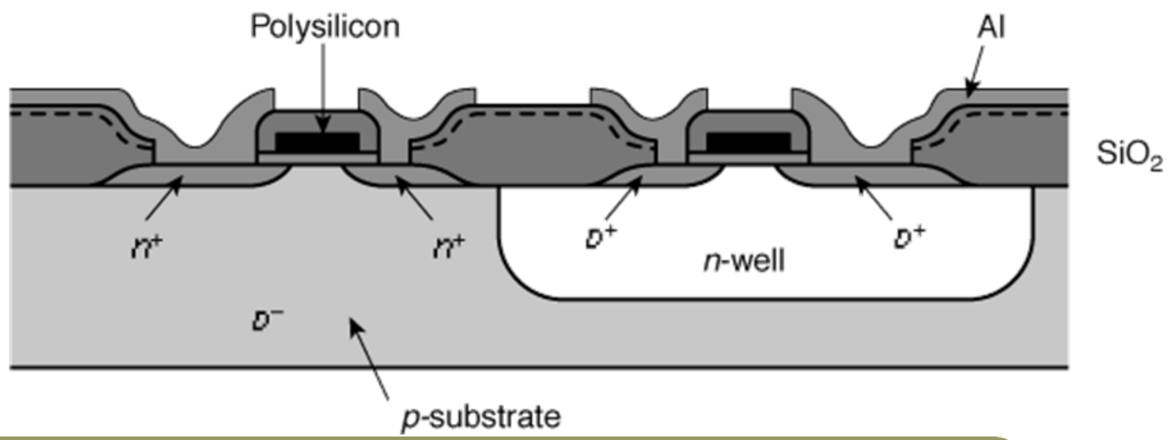
- CMOS type inverter:
  - p and n type layers by masks – these are the layers of the source and the drain of the transistors, with aluminum outlet,
  - gate of the transistor is made by polycrystalline silicon, beneath a thin layer of SiO_2, above it is also a thicker insulating layer.





IC – Integrated Circuit – Technology

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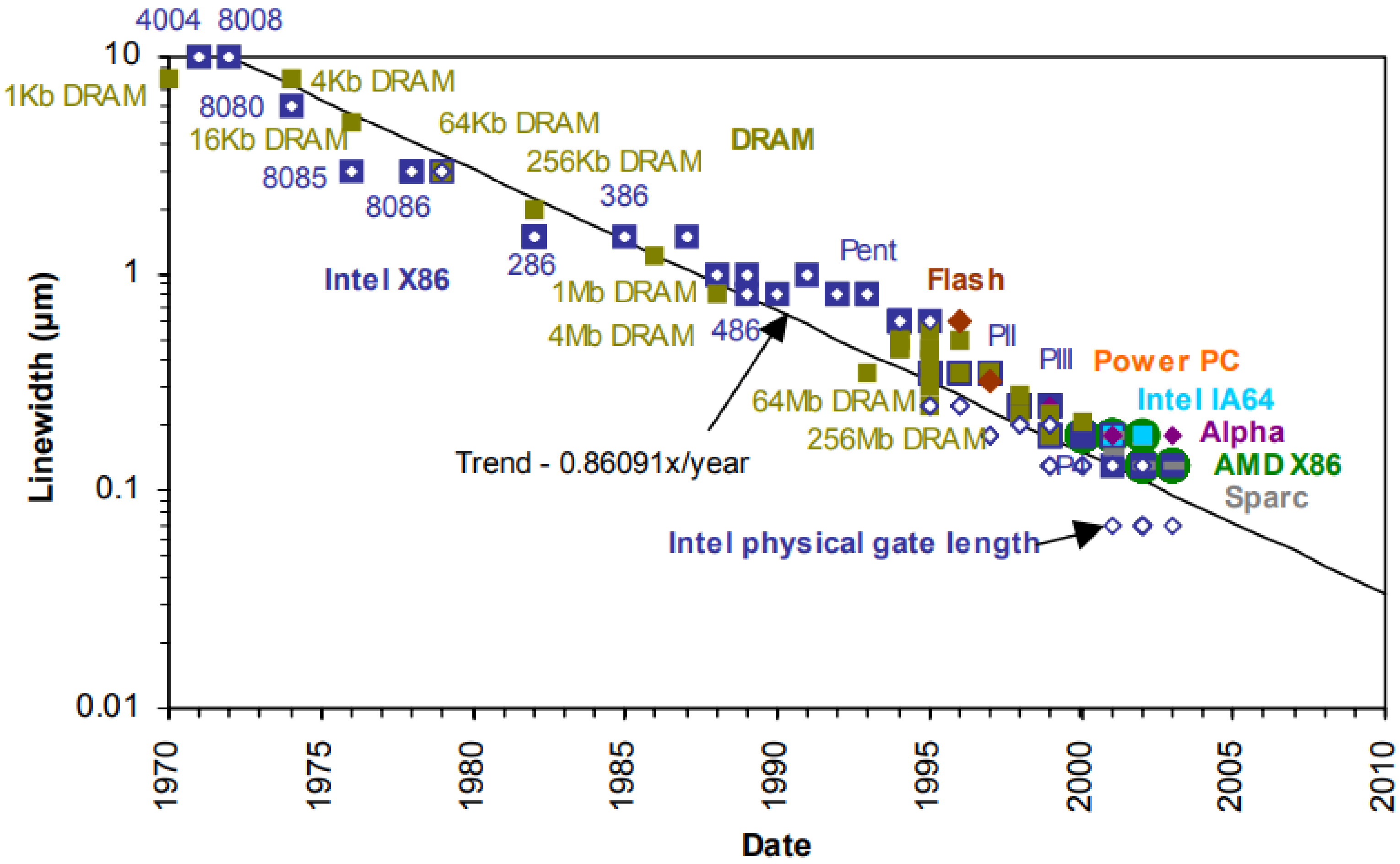
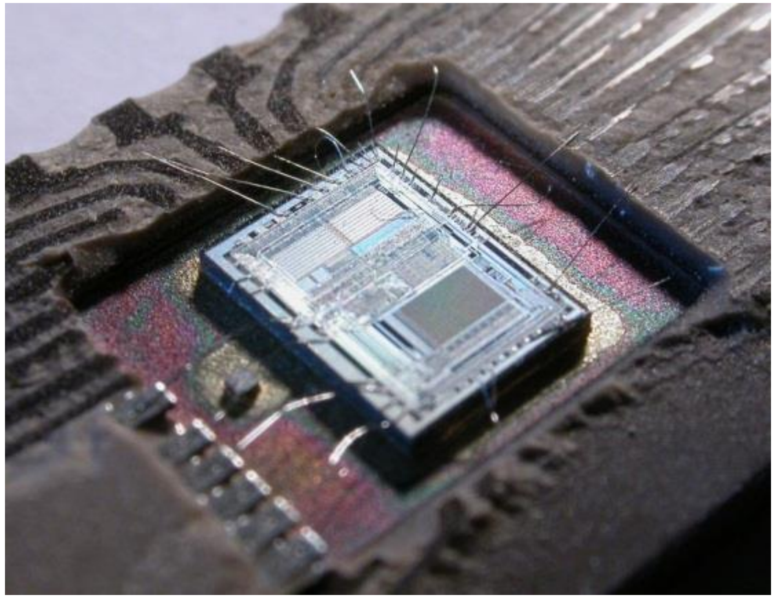


source: Scotten W. Jones, Introduction to Integrated CircuitTechnology, Third Edition, 2004

IC – Integrated Circuit – Technology

- IC enclosures:
  - according to assembling technology:
    - through-hole,
    - surface-mounted:
      - dual,
      - quad,
      - ball grid array,
    - contactless,
  - according to the material used:
    - plastic,
    - ceramic,
    - metal and power.



IC – Integrated Circuit – Technology

SOP (Small Outline Package)

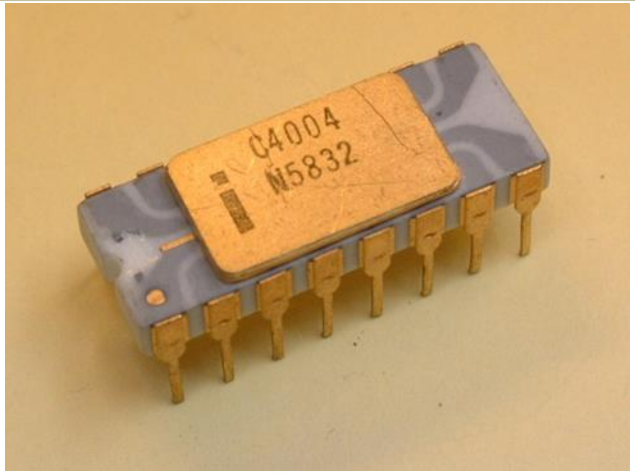
DIP (Dual In Line)

SSOP (Small Schrink Outline Package)

PLCC (Plastic Leaded Chip Carrier)

IC – Integrated Circuit – Technology

- Generation of ICs:
- ICs – number of transistors:
  - SSI (Small-Scale Integration): 10x
  - MSI (Medium-Scale Integration): 100x
  - LSI (Large-Scale Integration): 10000x
  - VLSI (Very Large-Scale Integration): 100000x
  - ULSI (Ultra Large-Scale Integration): 1000000x
  - SoC (System on Chip): a „whole computer" integrated in a single IC. (E.g.: motherboard of smart phones)
  - Intel 4004 (1971): 2300
  - Intel Core i7 (2008): 781 million
  - Intel Core i9 (2017): about 7 billion
- Line width in the chip:
  - Intel 4004 (1971): 10 μm
  - Intel Core i7 (2008): 45 nm
  - Intel Core i9 (2017): 10 nm



Memories

- Memories:
- Volatile:
  - RAM (Random – Access Memory):
    - Dynamic RAM,
    - Static RAM.
- Non – Volatile:
  - ROM (Read-Only Memory),
  - PROM (Programmable ROM),
  - EPROM (Erasable Programmable ROM),
  - EEPROM (Electrically Erasable Programmable ROM),
  - Flash.

Memories

- RAM:
  - Dynamic RAM:
    - one cell consists of one transistor and one capacitor,
    - it has to refresh time to time, because the capacitor is discharged due to the trickle current,
    - slow, smaller size, cheap.
  - Static RAM:
    - one cell consists of more transistors (flip-flop),
    - it stores the data for any length of time, if there is a power supply,
    - fast, small energy consumption, expensive.

Memories

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- ROM
  - Programmed by the manufacturer, the user can only read it.
- PROM
  - User can program it once, than he can only read it.

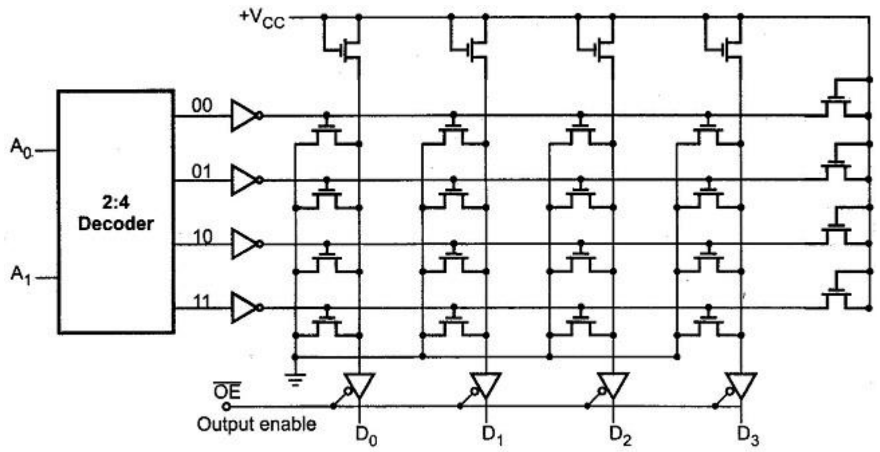


Fig. 3.70 Simple four half-byte ROM

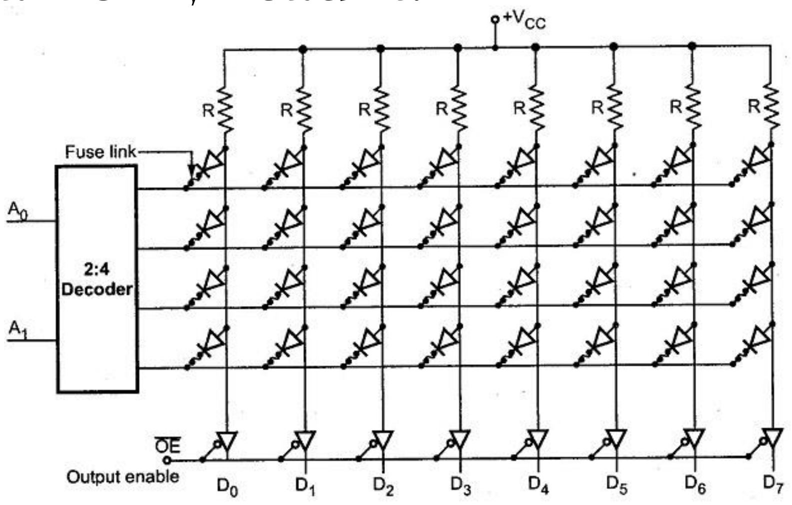
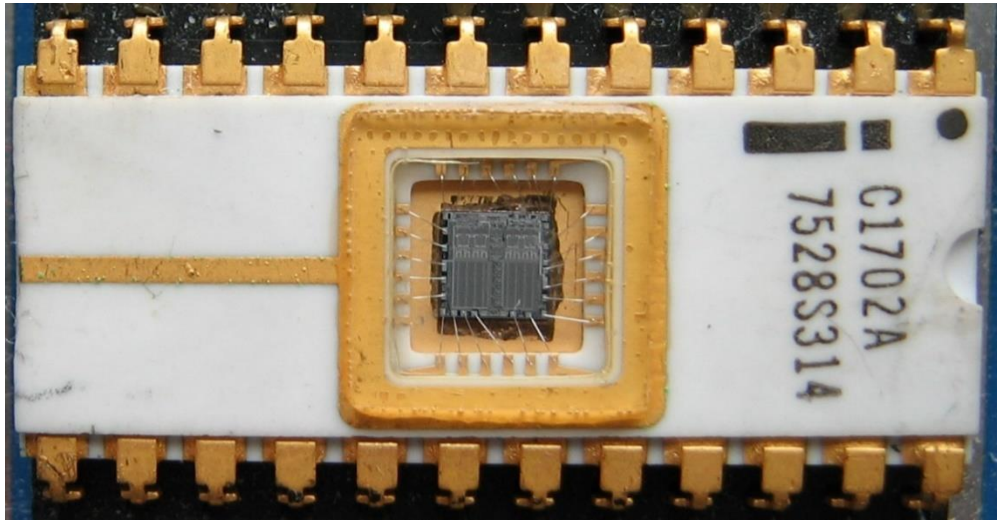


Fig. 3.71 Four byte PROM

Memories

- EPROM
  - Cleared by UV light, programmed by special equipment.
- EEPROM
  - Programmed and cleared by special equipment.
- Flash
  - Type of EEPROM, programmed and cleared by the computer.



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LOGICAL NETWORKS

Lecture 2.

Boolean Algebra

- Logical connectives:

$$0 \cdot 0 = 0 \cdot 1 = 1 \cdot 0 = 0; \qquad 1 \cdot 1 = 1$$

$$0 + 1 = 1 + 0 = 1 + 1 = 1; \qquad 0 + 0 = 0$$

$$\overline{0} = 1; \quad \overline{1} = 0; \quad \overline{\overline{0}} = 0; \quad \overline{\overline{1}} = 1$$

Boolean Algebra

- commutativity:

$$A + B = B + A$$
$$A \cdot B = B \cdot A$$

- associavity:

$$A + B + C = A + (B + C)$$
$$A \cdot B \cdot C = A \cdot (B \cdot C)$$

- absorption:

$$A + A \cdot B + A \cdot B \cdot C + \cdots = A$$
$$A \cdot A + B \cdot A + B + C \cdot \cdots = A$$

- distibutivity:

$$A \cdot (B + C) = A \cdot B + A \cdot C$$
$$A + (B \cdot C) = (A + B) \cdot (A + C\ )$$
$$A \cdot A + A \cdot C + B \cdot A + B \cdot C = A \cdot (1 + C + B) + BC$$

- De Morgan's laws:

$$\overline{\boldsymbol{A} + \boldsymbol{B}} = \overline{\boldsymbol{A}} \cdot \overline{\boldsymbol{B}}$$
$$\overline{\boldsymbol{A} \cdot \boldsymbol{B}} = \overline{\boldsymbol{A}} + \overline{\boldsymbol{B}}$$

Realization of Logical Networks

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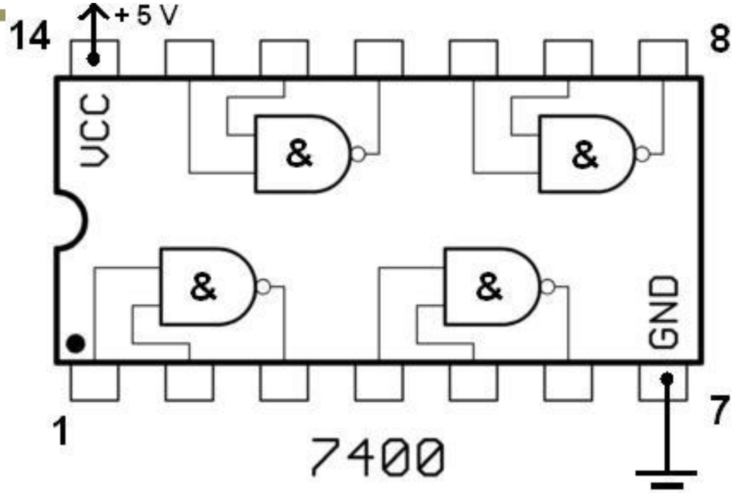
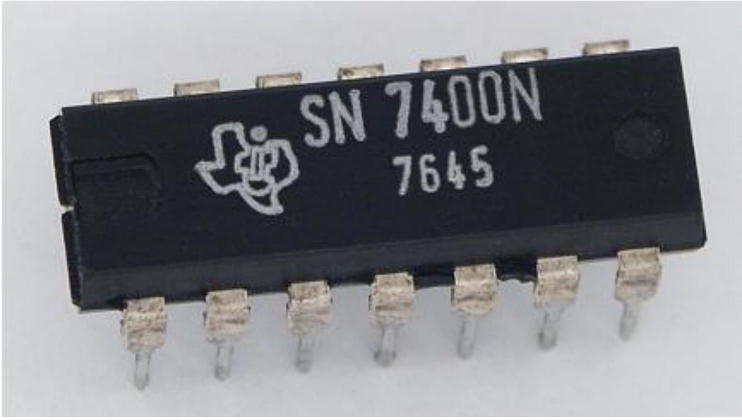
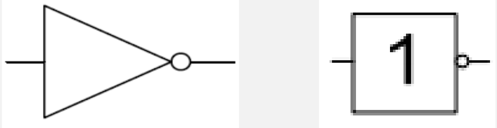
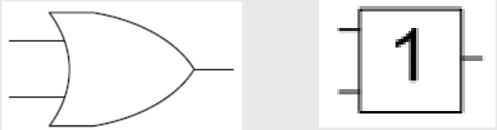
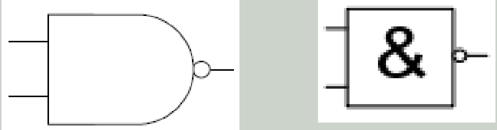
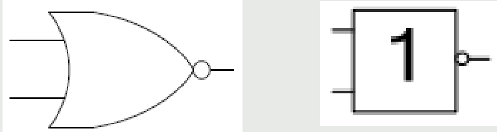
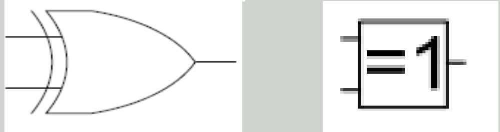
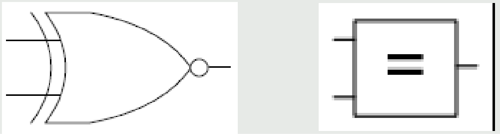


- logical gates:
  - basic functions
    - AND, OR, NOT
  - complex functions
    - NAND, NOR, XOR (exclusive OR), XNOR (exclusive NOR)
- relay
- computers
- pneumatic networks
- …



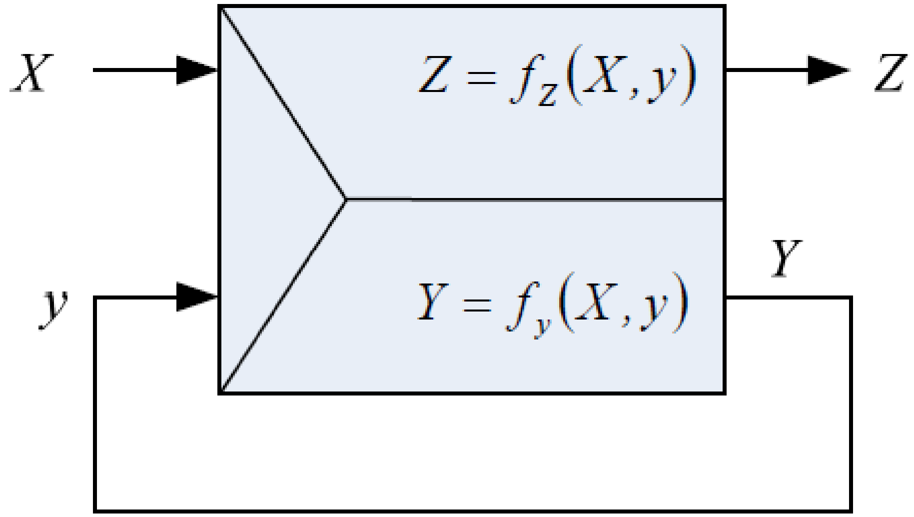
Realization of Logical Networks

Realization of Logical Networks

NOT	
AND	
OR	
NAND	
NOR	
XOR	
XNOR	

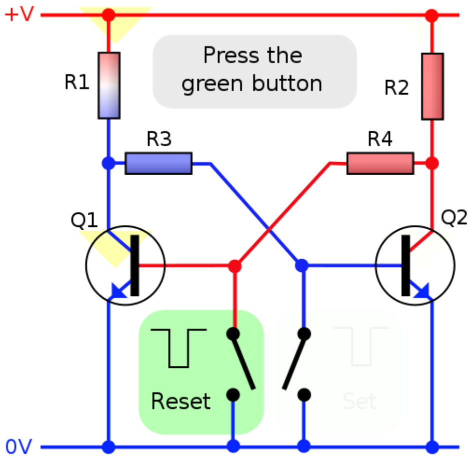
Sequential Networks

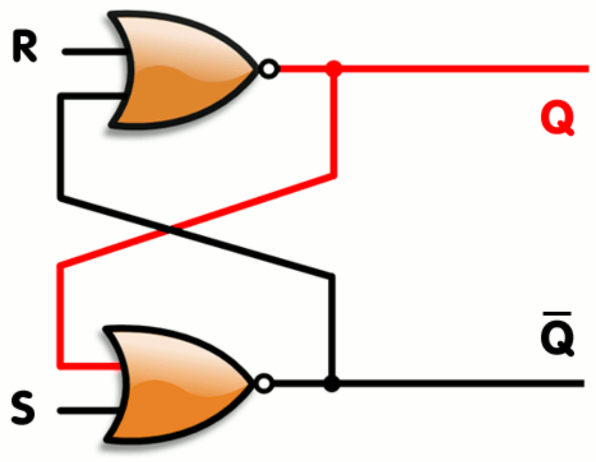
- sequential networks: a network, whose output depends on the actual inputs and past inputs (the order of the inputs) – a network with memory

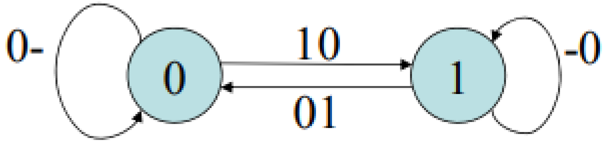


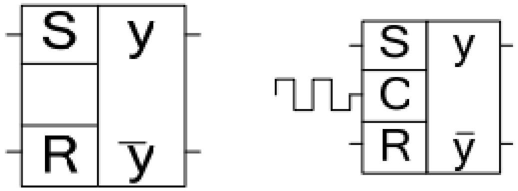
Sequential Networks

- realization with flip-flops (finite state machine):
  - flip flop: a circuit, that has two stable states to store a one bit information, it is a bistable multivibrator, can be synchronous (clock controlled) or asynchronous (event driven),
- SR flip-flop:









Sequential Networks

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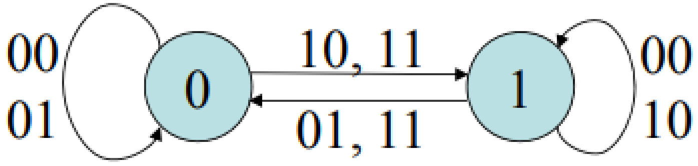
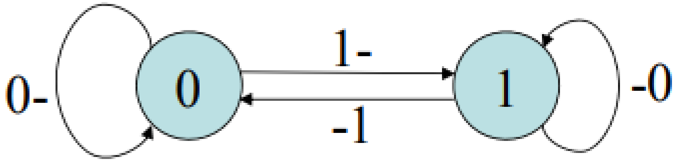
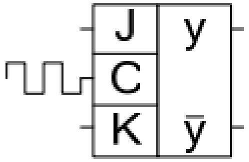
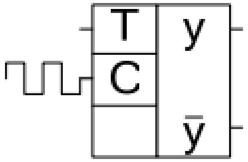
- JK flip-flop:

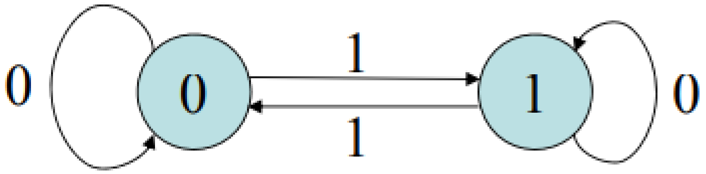




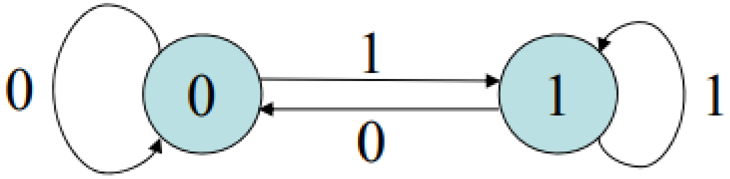


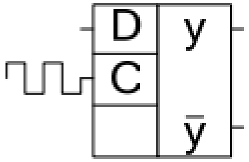
- T flip-flop:



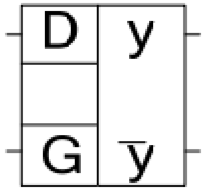


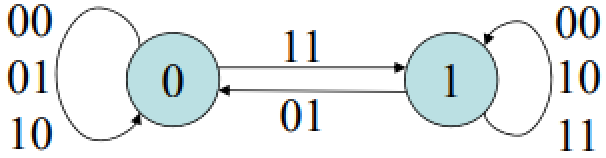
- D flip-flop:

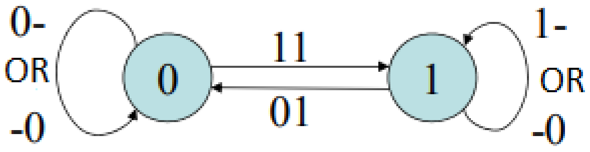




- DG flip-flop:







Sequential Networks

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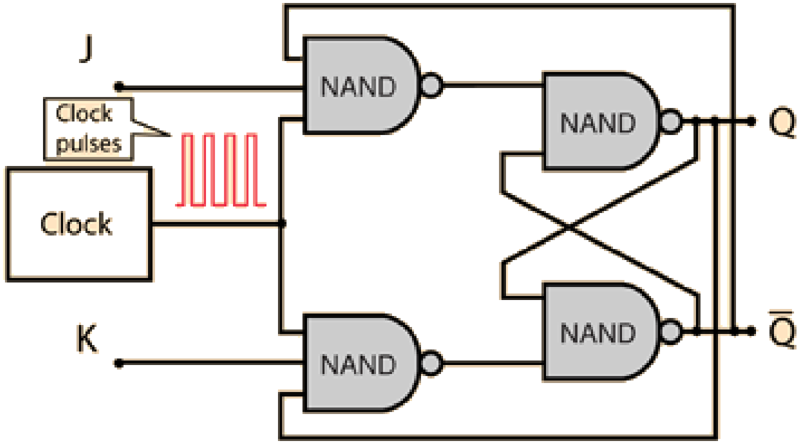
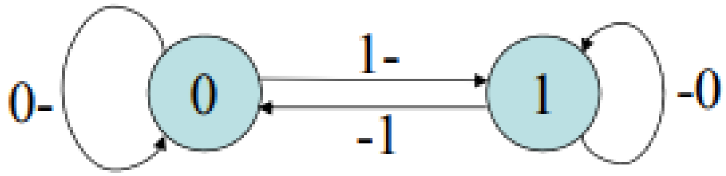
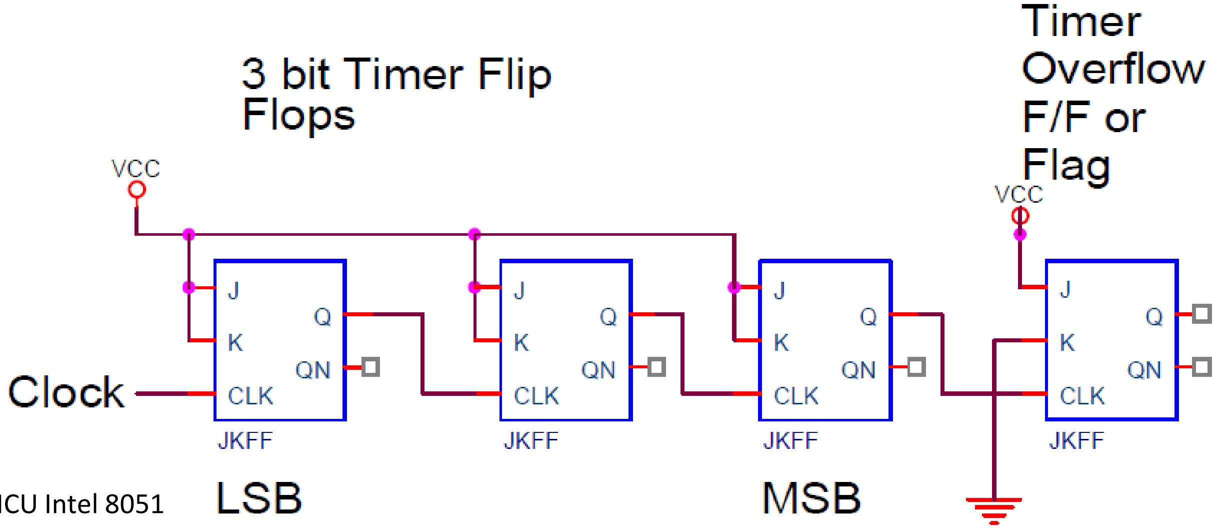
- timer, eg.:



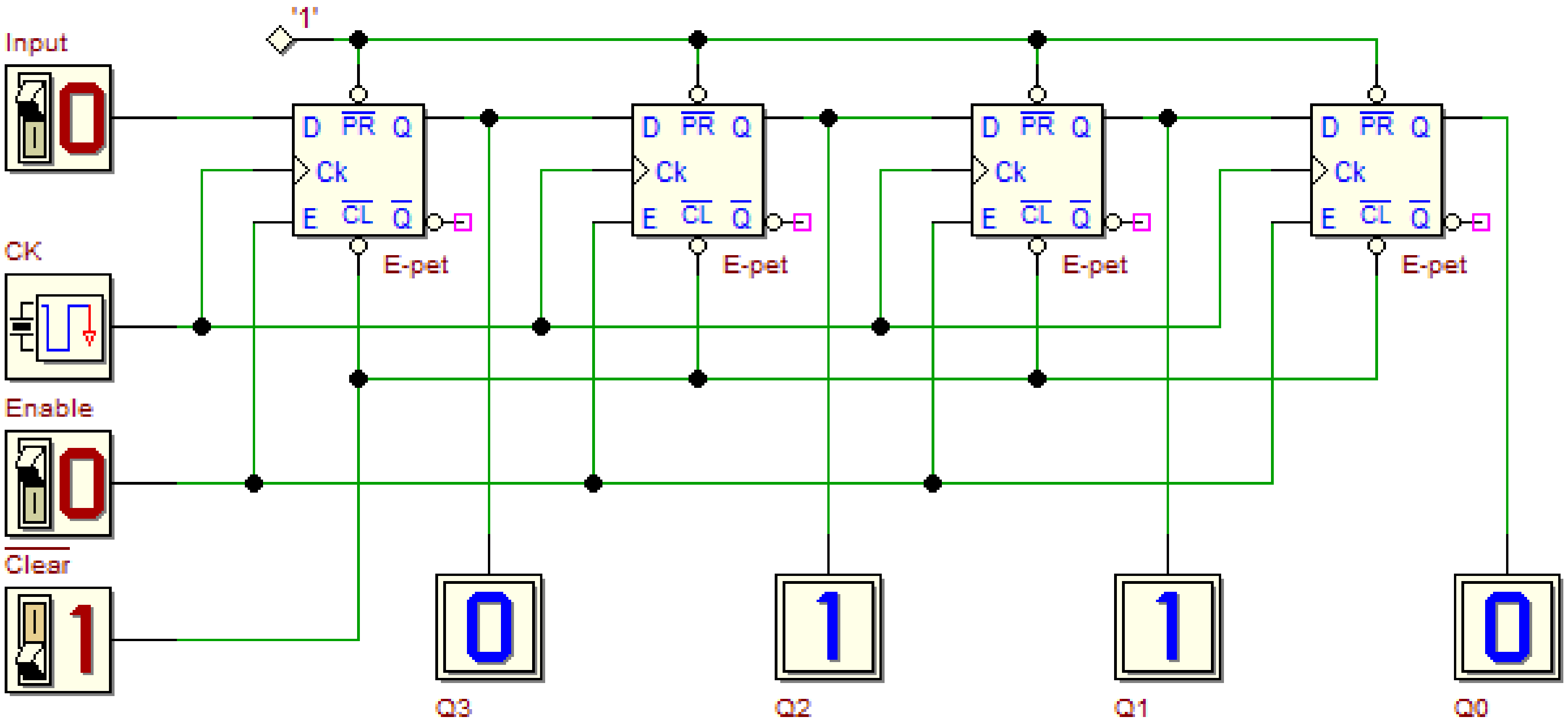




realization of a timer in the MCU Intel 8051

Sequential Networks

- shift register, eg.:



source: https://www.digitalelectronicsdeeds.com/demos/demopage_seq.html

Sequential Networks

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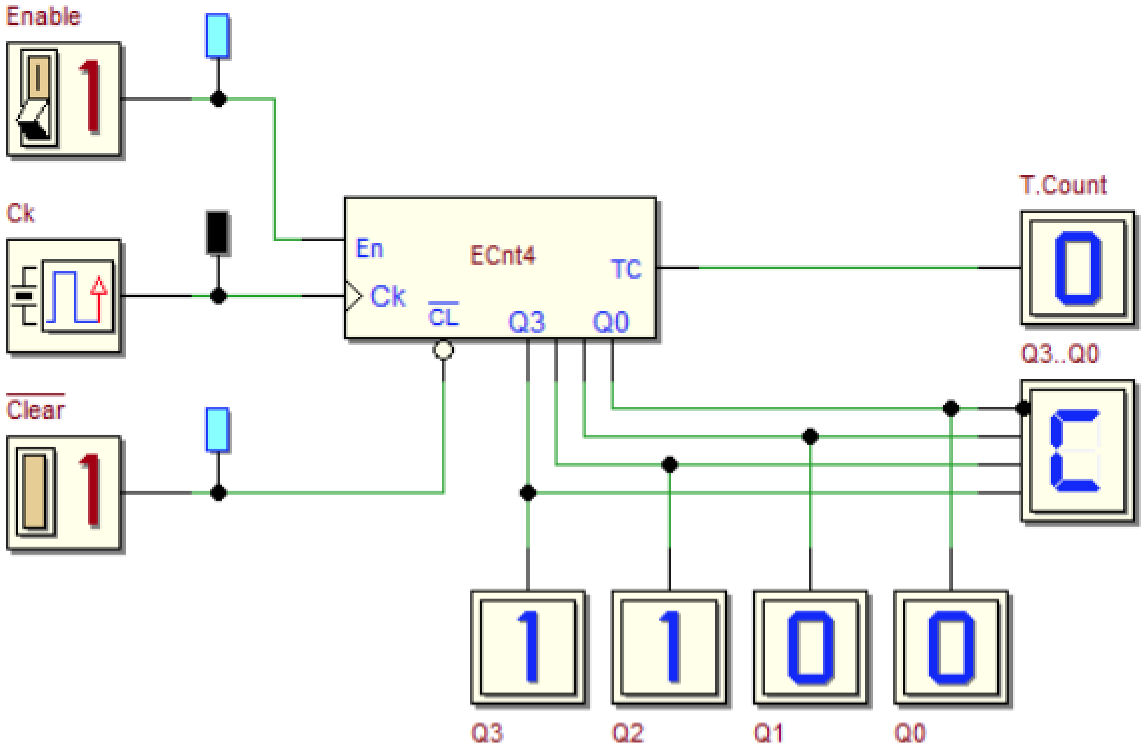
- binary up counter, eg.:



source: https://www.digitalelectronicsdeeds.com/demos/demopage_seq.html

Sequential Networks

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- more examples:
- https://www.allaboutcircuits.com/textbook/digital/chpt-11/finite-state-machines/
- https://www.youtube.com/watch?v=dV8PTOZ2-gQ
- https://www.youtube.com/watch?v=kNlGHmsfp40
- https://www.youtube.com/watch?v=YW-_GkUguMM
- https://www.youtube.com/watch?v=F1OC5e7Tn_o

End of Lecture 2.

Thank you for your attention!