Digital Logic Families

LECTURE 2

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Logic Gates

- A logic gate is an idealized device implementing a **Boolean function**, a logical operation performed on one or more binary inputs that produces a single binary output.

- Universal logic gates are NAND gate and NOR gate.

- Logic gates are primarily implemented using diodes or transistors acting as electronic switches, but can also be constructed using vacuum tubes, electromagnetic relays (relay logic), fluidic logic, pneumatic logic, optics, molecules, or even mechanical elements like ball-pipe system.

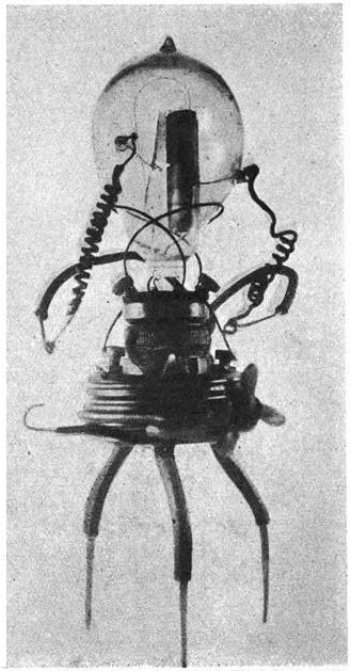
History and Development

Gottfried Wilhelm Leibniz
Binary Number System
(1705)

Charles Sanders Peirce
(1886)

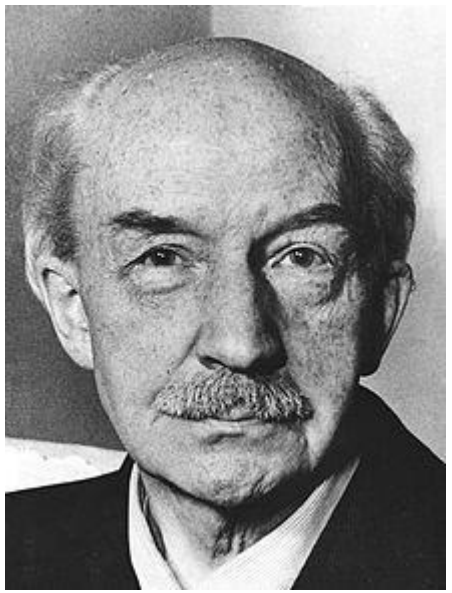
Vacuum Tube

History and Development



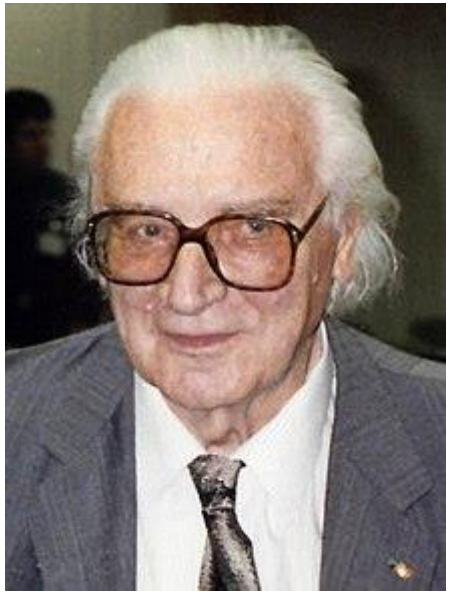
Fleming Valve (1907)

Ludwig Wittgenstein (1921)



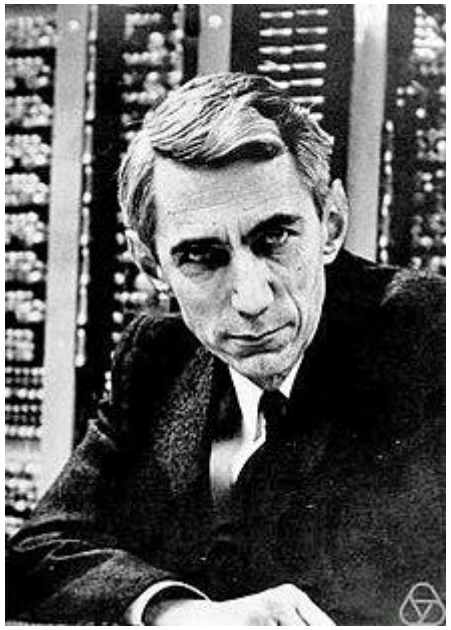
Walther Bothe (1924)

History and Development



Konrad Zuse
(1935-38)

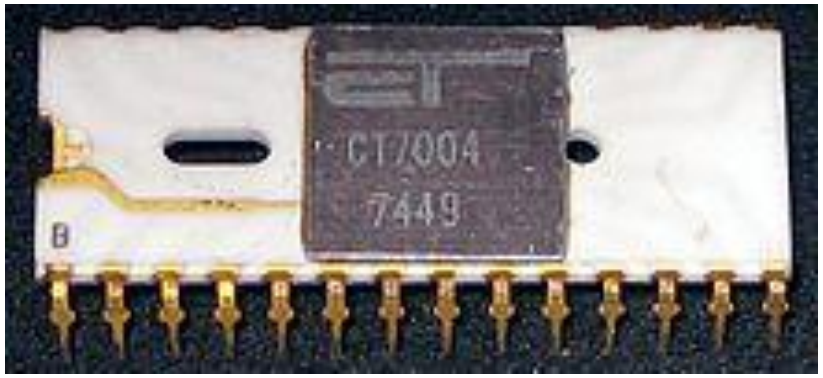
Akira Nakashima
(1934-36)



Claude Shannon
(1937)

History and Development

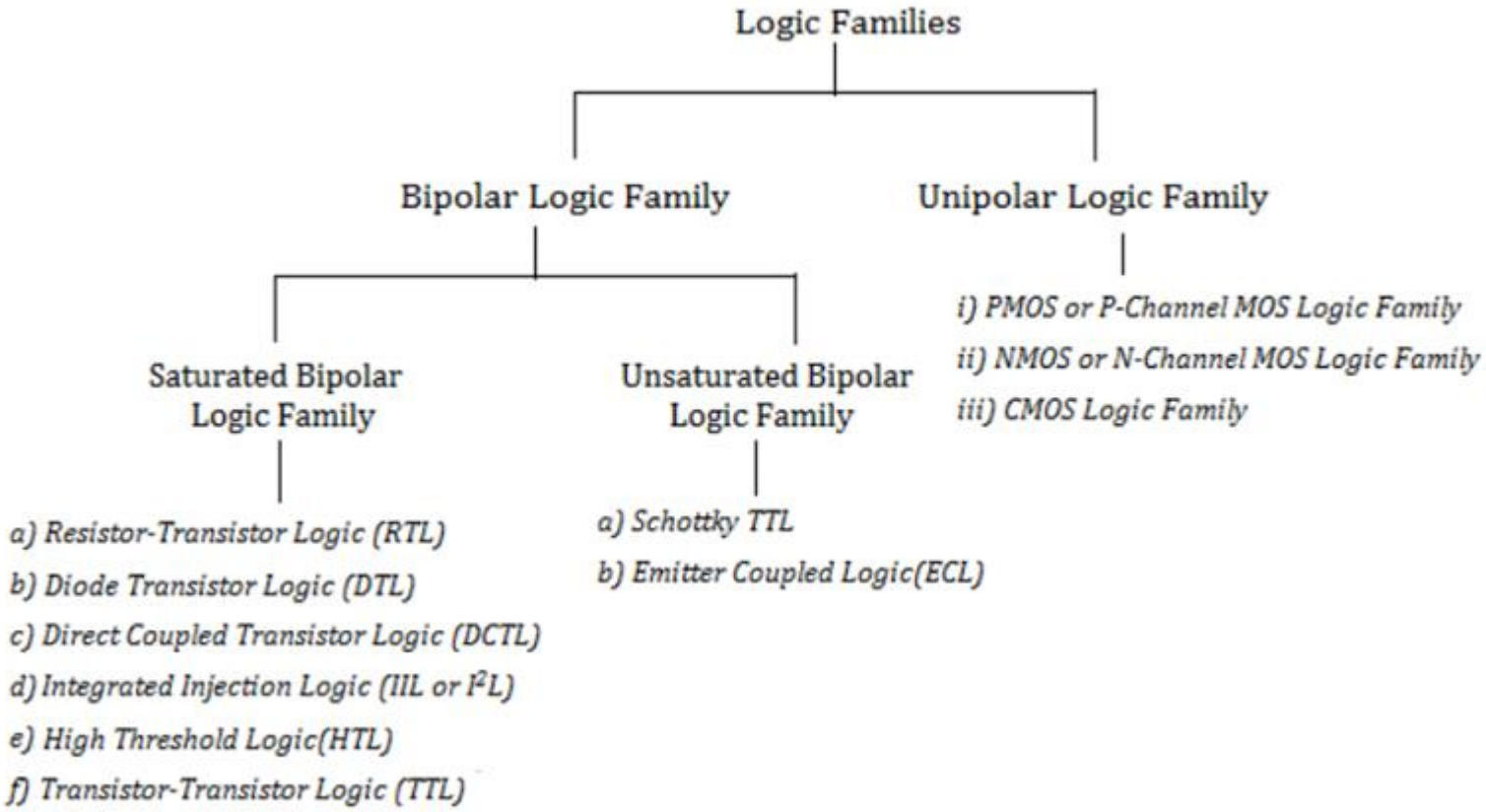
Mohamed M Atalla (1959)



PMOS clock IC, 1974

Dawon Kahng (1959)

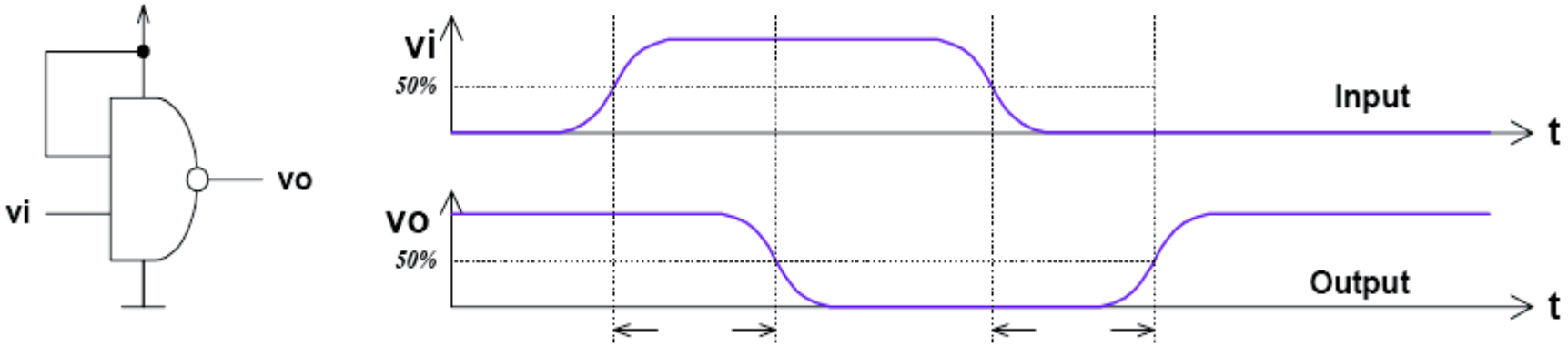
Digital Logic Families



Characteristics of Digital ICs

- Speed of operation
- Power dissipation
- Figure of merit
- Current and voltage parameters
- Fan-out
- Noise margins
- Operating temperature range
- Power supply requirements
- Flexibilities available.

Speed of Operation



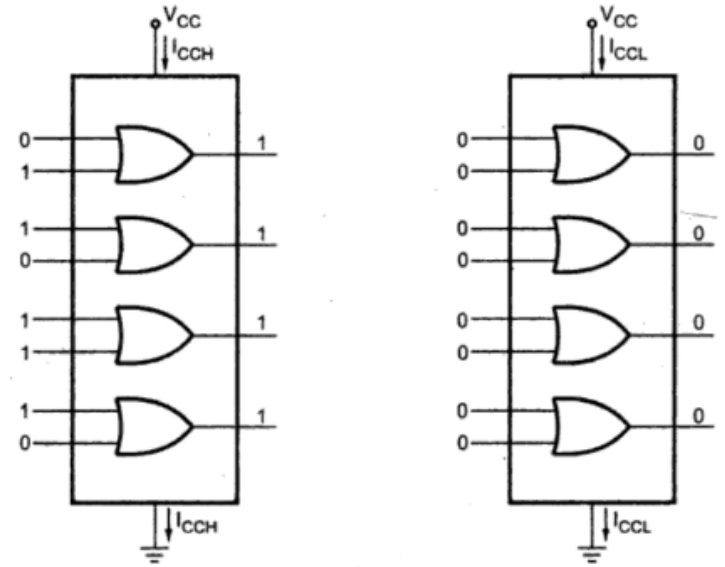
$T_{PD,HL}$ – input-to-output propagation delay from HI to LO output

$T_{PD,LH}$ – input-to-output propagation delay from LO to HI output

Characteristics of Digital ICs

- Power Dissipation

$$P = V_{cc} \times I_{cc}$$

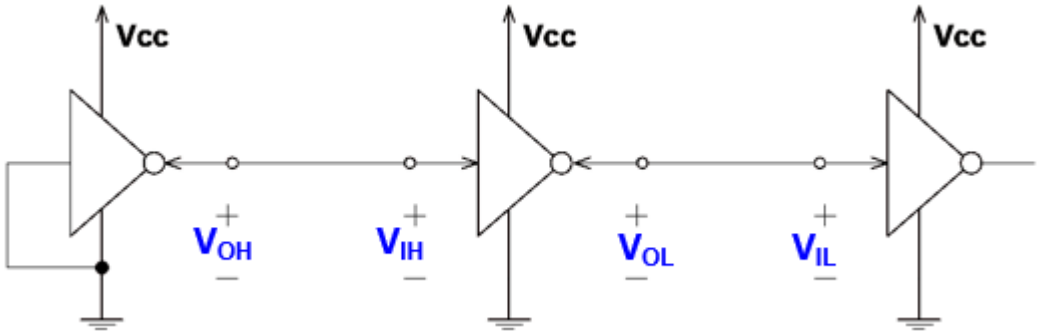


- Figure of Merit

$$FoM\ (pJ) = propagation\ delay\ time\ (ns) \times power\ (mW)$$

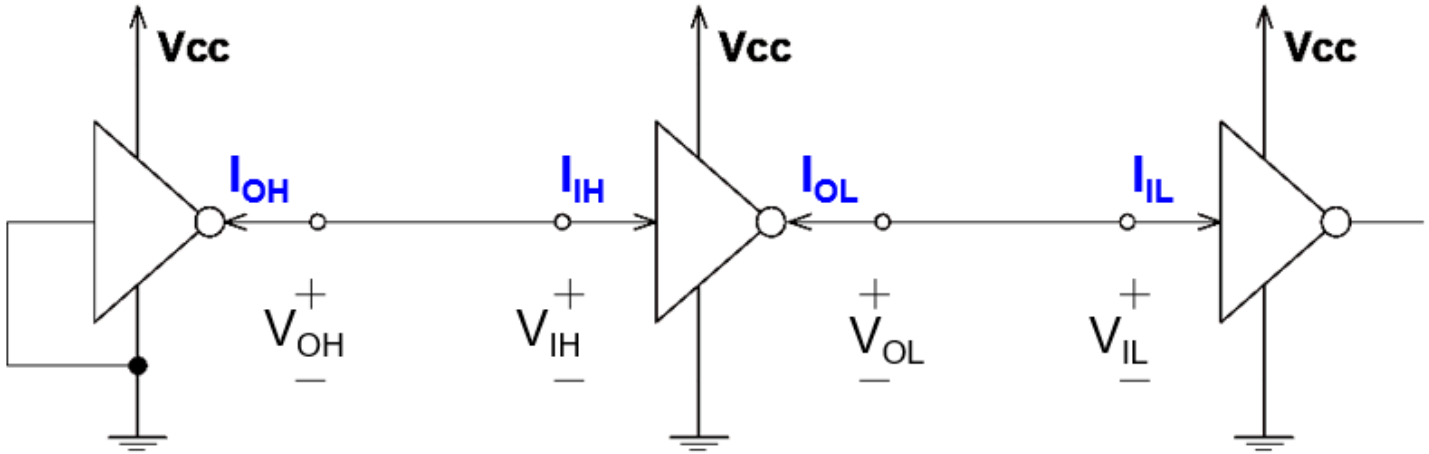
Current and Voltage Parameters

- V_{OH}(min) – The minimum voltage level at an output in the logical “1” state under defined load conditions
- V_{OL}(max) – The maximum voltage level at an output in the logical “0” state under defined load conditions
- V_{IH}(min) – The minimum voltage required at an input to be recognized as “1” logical state
- V_{IL}(max) – The maximum voltage required at an input that still will be recognized as “0” logical state



Current and Voltage Parameters

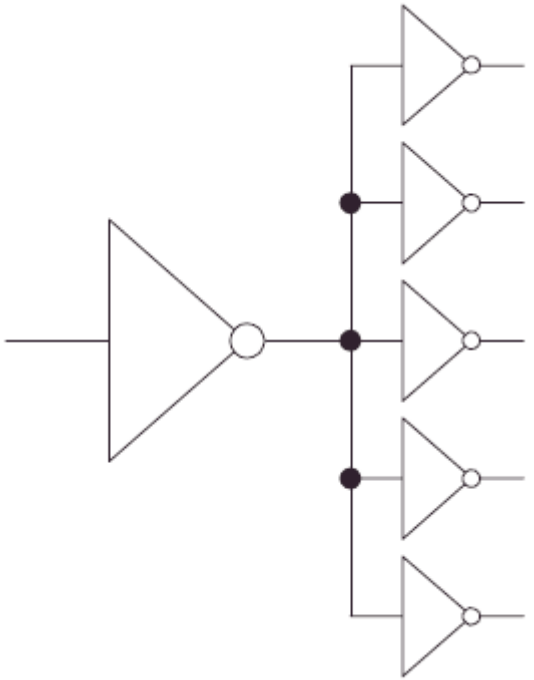
- I_{OH} – Current flowing into an output in the logical “1” state under specified load conditions
- I_{OL} – Current flowing into an output in the logical “0” state under specified load conditions
- I_{IH} – Current flowing into an input when a specified HI level is applied to that input
- I_{IL} – Current flowing into an input when a specified LO level is applied to that input



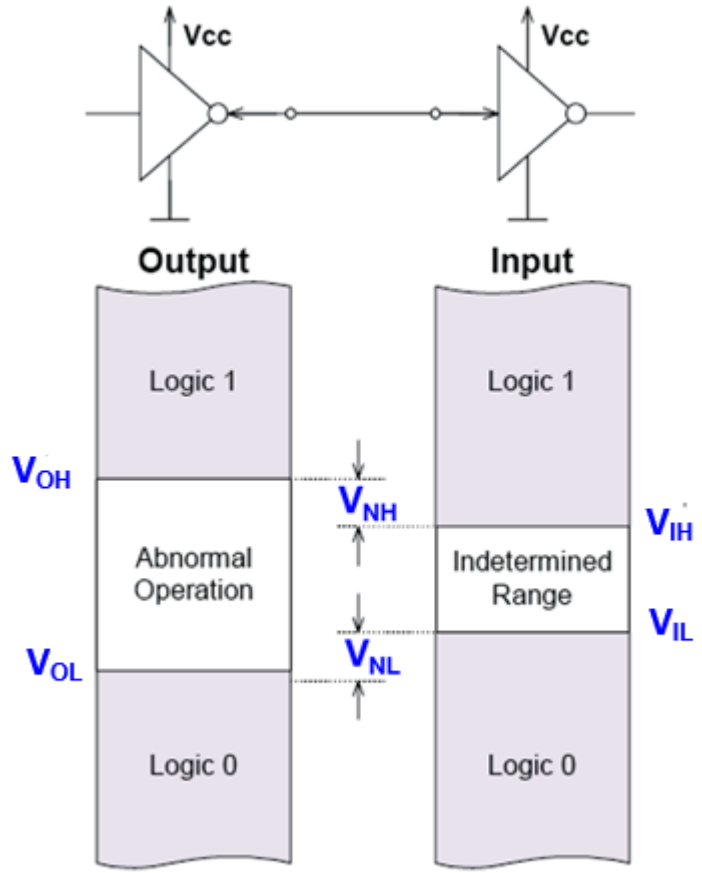
Fan Out

Fanout: the maximum number of logic inputs (of the same logic family) that an output can drive reliably.

$$\textbf{DC fanout} = \min\left(\frac{I_{OH}}{I_{IH}}, \frac{I_{OL}}{I_{IL}} \right)$$



Noise Margin



HIGH state noise margin:

$V_{NH} = V_{OH}(min) – V_{IH}(min)$

LOW state noise margin:

$V_{NL} = V_{IL}(max) – V_{OL}(max)$

Noise margin:

$V_N = min(V_{NH},V_{NL})$

Characteristics of Digital ICs

- Operating Temperature
- Power Supply Requirements
- Flexibilities Available:

1. The breadth of the series
2. Popularity of the series
3. Wired-logic capability
4. Availability of complement outputs
5. Type of output

Summary

- History of digital logic
- Classification of digital logic families
- Important characteristics of digital ICs

Reference

- Modern digital electronics, by Jain, Rajendra Prasad. Tata McGraw-Hill Education, 2003.
- Digital Electronics (Digital Logic Design) by Godse, A. P., and D. A. Godse . Technical Publications, 2009.