EEE104 – Digital Electronics (I)

Lecture 6

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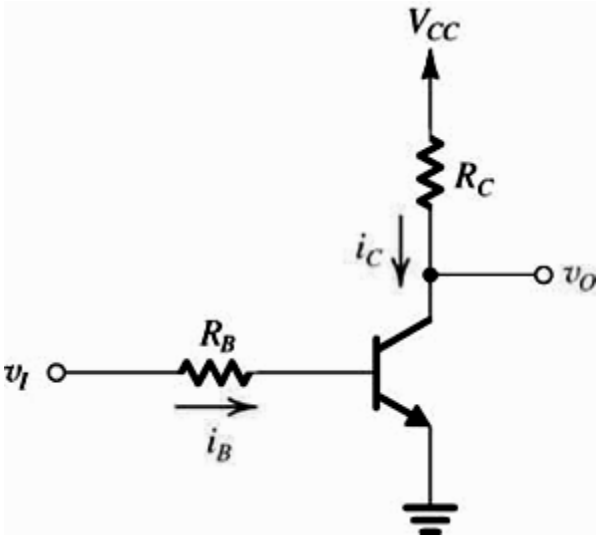
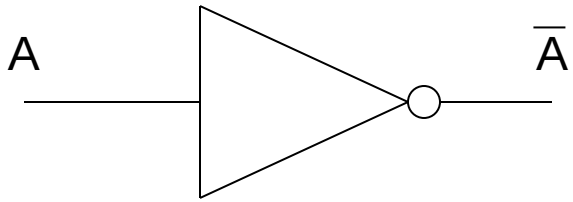
In This Session

- Transistors in a Gate
- Digital Integrated Circuits
- Integrated Circuit Logic Gates
  - Types and Series
  - Characteristics

Transistors in a Gate





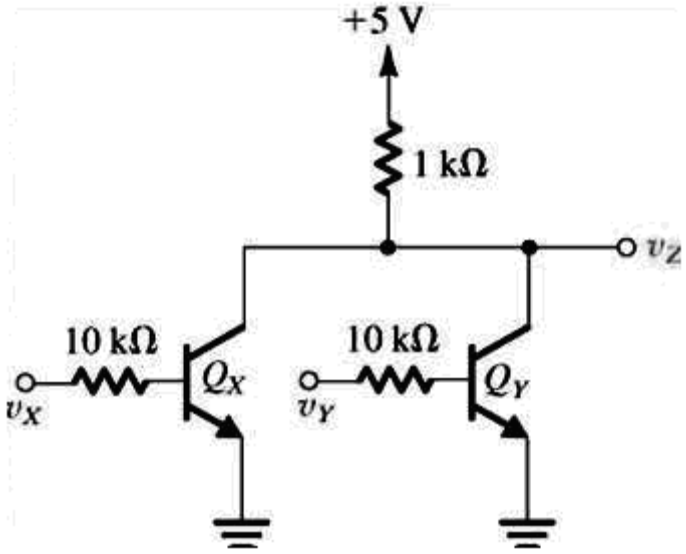
symbol

When a BJT is used as a switch, it operates between the cutoff and saturation modes.

1. If v_I is "0" or at a value close to ground, the BJT will be cutoff; $v_O = V_{CC}$ (logic "1").
2. If v_I is "1" or at a value close to V_{CC}, the BJT will be saturated; $v_O = V_{CEsat} \cong 0.2$ V (logic "0").
3. This is a logic inverter.

A	$\overline{A}$
0	1
1	0

Transistors in a Gate



v_X	v_Y	v_Z
0.2 V	0.2 V	5 V
0.2 V	5 V	0.2 V
5 V	0.2 V	0.2 V
5 V	5 V	0.2 V

X	Y	Z
0	0	1
0	1	0
1	0	0
1	1	0

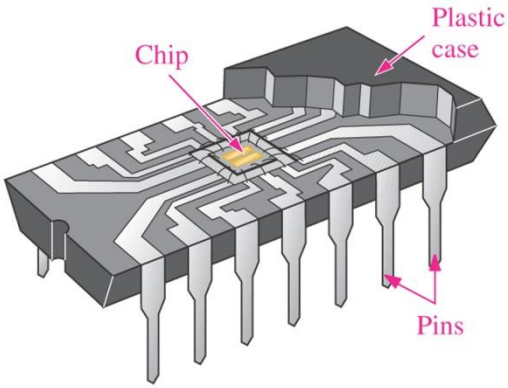
$$Z = \overline{X + Y}$$

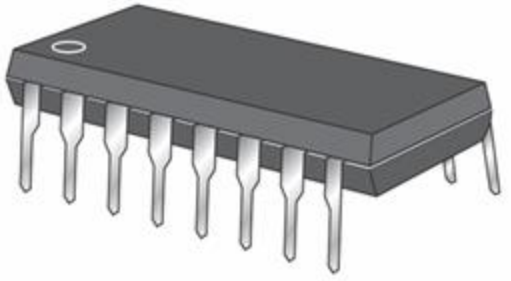
NOR Gate

Digital Integrated Circuits

The Integrated Circuit (IC)

- It is an electronic circuit that is constructed entirely on a single small chip of silicon.
- The **pins** connect the internal points to allow inputs and outputs.
- Dual-in-line package (DIP) is the common IC package for small or medium-scale ICs.

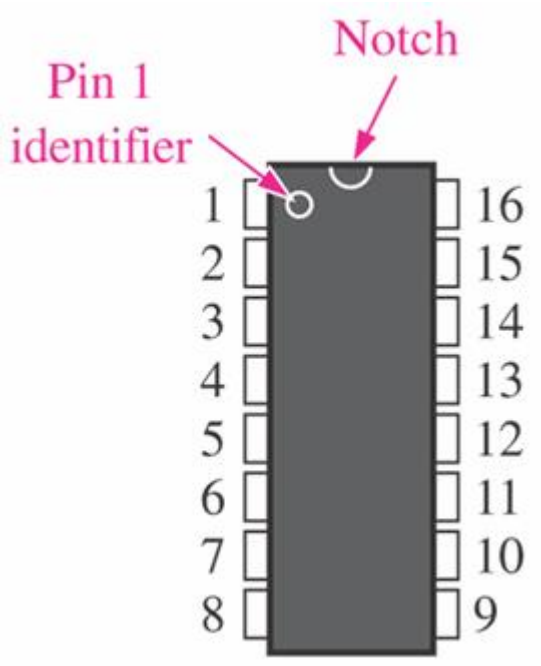




Digital Integrated Circuits

Pin Numbering for DIP

- Pin 1 is indicated by either a small dot or a notch.
- With the notch oriented upward, pin numbers increase as you go down, then across and up.
- The highest pin number is the top right pin.



Digital Integrated Circuits

Complexity Classification

1. **SSI**, small-scale integration, 1~12 gates, used for basic gates and flip-flops.
2. **MSI**, medium-scale integration, 13~99 gates, used for encoders, counters, registers, multiplexers, etc.
3. **LSI**, large-scale integration, 100~9,999 gates, used for memories.
4. **VLSI**, Very large-scale integration, 10,000~99,999 gates.
5. **ULSI**, ultra large-scale integration, 100,000 or more gates, used for microprocessors and large memories.

Digital Integrated Circuits

Technologies

- **Bipolar junction transistors**, such as TTL (transistor-transistor logic) and ECL (emitter-coupled logic).
- **MOSFETs**, such as CMOS (complementary MOS) and NMOS (n-channel MOS).
- SSI and MSI circuits are available in both TTL and CMOS.
- LSI, VLSI and ULSI are implemented with CMOS or NMOS, because *it is more compact and consumes less power*.

IC Logic Gates

Designation

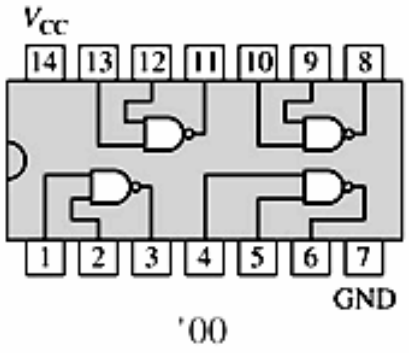
Prefix + series + type, e.g. 74LS04.

1. Prefix – 74 for commercial grade, 54 for military grade.
2. Series – a letter or letters to indicate the IC technology used, e.g. TTL or CMOS.
3. Type – a number to indicate the type of logic device.

IC Logic Gates

Types

Quad 2-Input NAND



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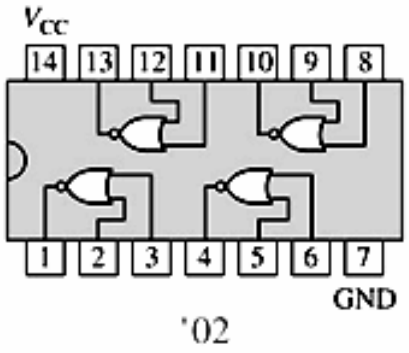

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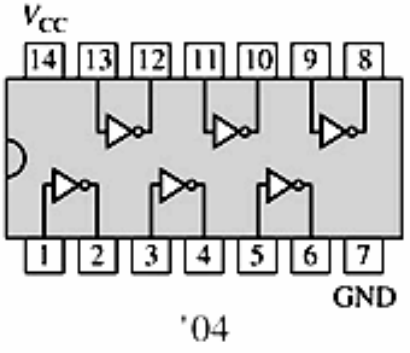
Quad 2-Input NOR

Hex Inverter



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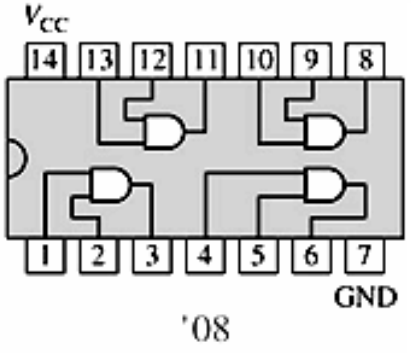

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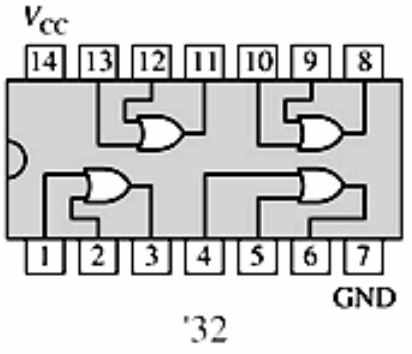
Quad 2-Input AND

Quad 2-Input OR



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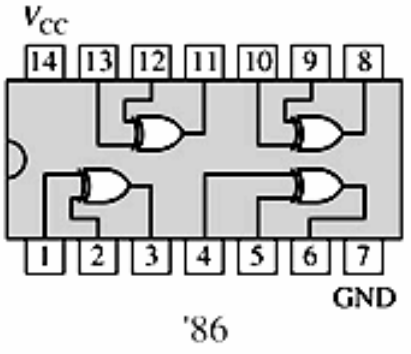

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Quad 2-Input XOR

IC Logic Gates

Series – TTL

74LS — Low-power Schottky TTL
74AS — Advanced Schottky TTL
74F — Fast TTL

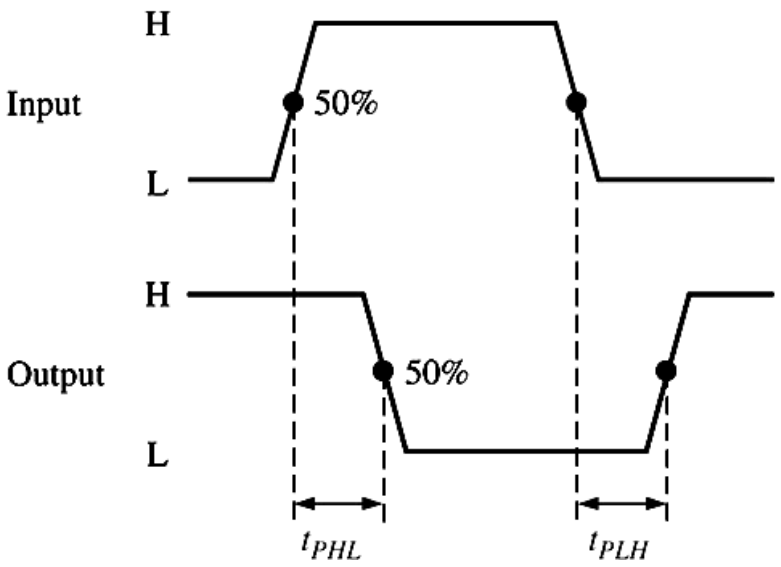
Series – CMOS

74HC — High-speed CMOS
74HCT — High-speed CMOS, TTL compatibility
74AC — Advanced CMOS
74LVC — Low-voltage CMOS

IC Logic Gates

Characteristics – Propagation Delay Time

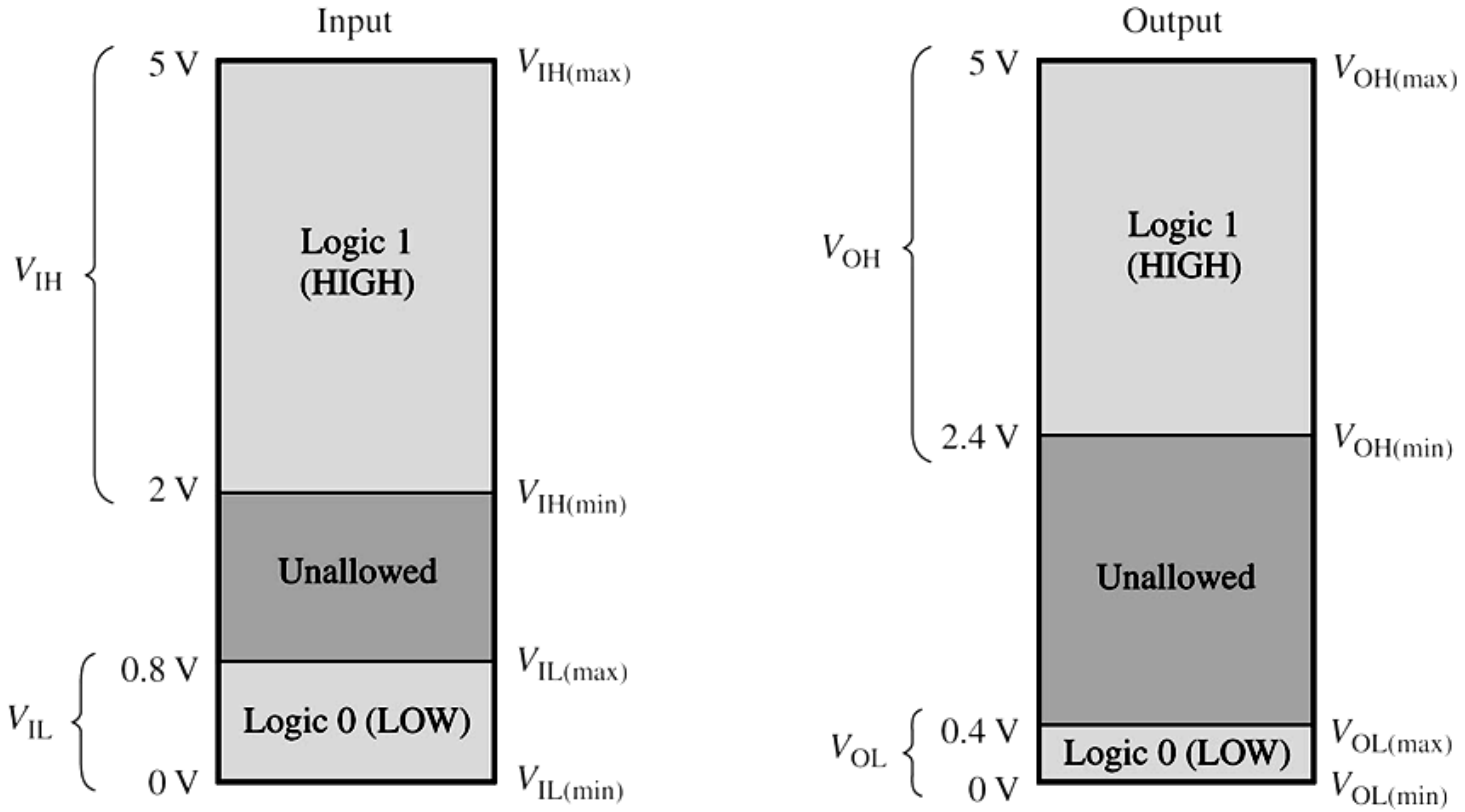
The time interval t_p between the application of an input pulse and the occurrence of the output pulse, e.g. t_{pHL} and t_{pLH}.



- The shorter t_p, the higher the speed.
- 74LS series 11 ns
  74F series 3.3 ns
  74HCT series 7 ns
  74AC series 5 ns

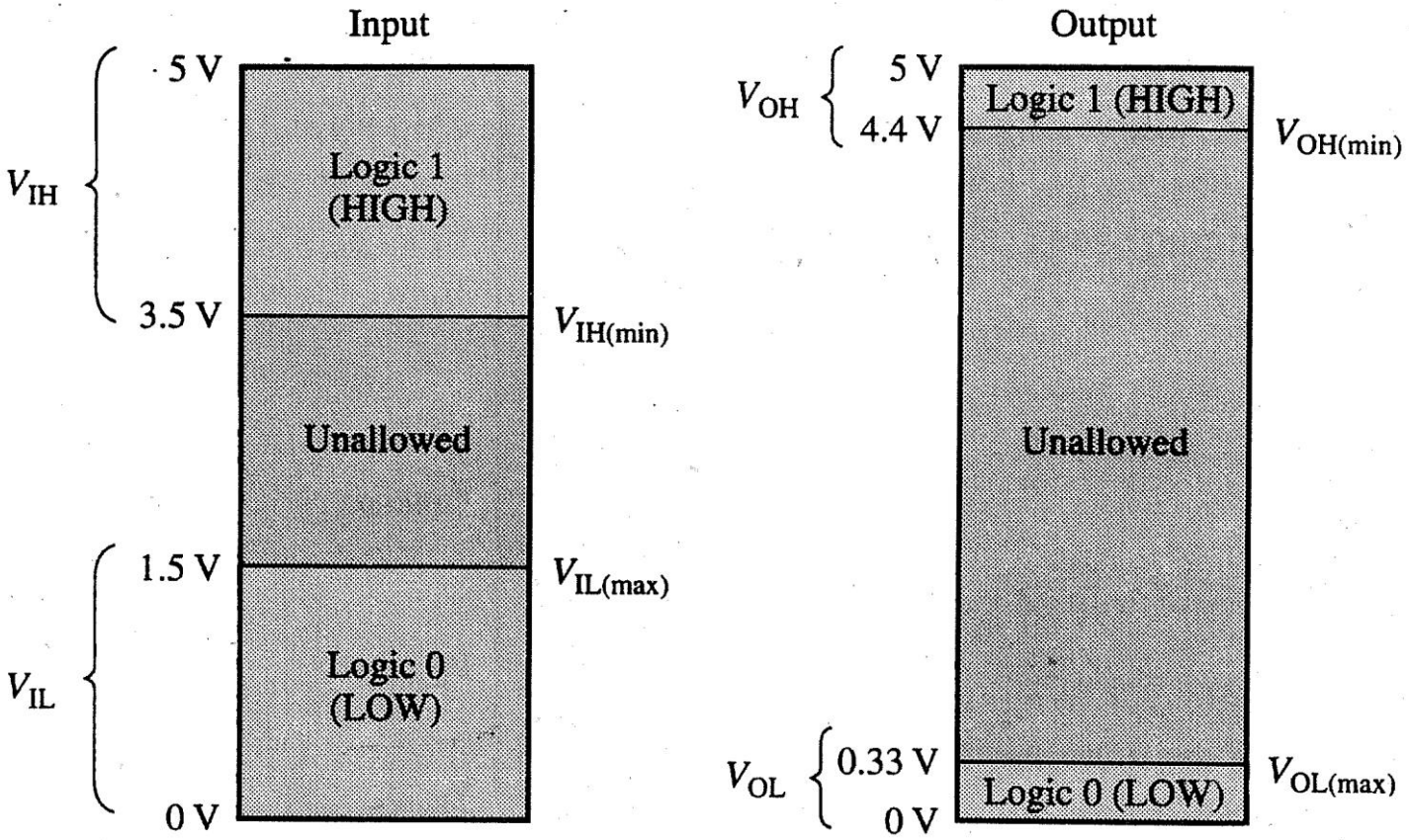
IC Logic Gates

Characteristics – Input and output Logic Levels (TTL)



IC Logic Gates

Characteristics – Input and Output Logic Levels (+5V CMOS)



IC Logic Gates

Characteristics – DC Supply Voltage (V_{CC})

- There are two categories of CMOS: 5V CMOS and 3.3V CMOS (less power dissipation).

	Minimum	Typical	Maximum
TTL	4.5 V	5.0 V	5.5 V
5V CMOS	2.0 V	5.0 V	6.0 V
3.3V CMOS	2.0 V	3.3 V	3.6 V

- The supply voltage of CMOS can vary over a wider range than for TTL.

IC Logic Gates

Characteristics – Fan-Out

- The **fan-out** is the maximum number of inputs that can be connected to a gate's output.
- Most TTL series, such as the 74LS, can drive 20 load gates.
- The fan-out for CMOS gates is very high.