EEE251

Logic Design and Circuits

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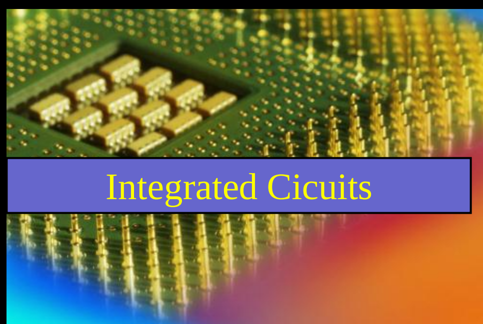


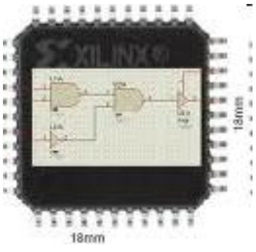
Integrated Cicuits

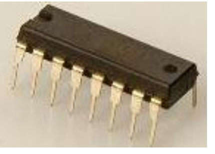
December 6, 2013

INTRODUCTION

- Logic gates and memory devices are fabricated as integrated circuits (ICs) because the components used are the integral parts of the chip
- ICs can be classified according to;
  - The type of components they have,
  - Number of logic gates and transistors they contain
  - The technology used to fabricate IC

INTRODUCTION (Cont.)





INTRODUCTION (Cont.)

- According to the IC fabrication process;
  - Bipolar ICS; DTL, TTL, HTL, ECL, etc.
  - Metal oxide semiconductor (MOS)-logic ICs; NMOS, PMOS, CMOS
- According to the number of transistors ;
  - Small-scale integration (SSI),
  - Medium-scale integration (MSI),
  - Large-scale integration (LSI),
  - Very large-scale integration (VLSI),
  - Ultra-large-scale integration,
  - Giga-scale integration,

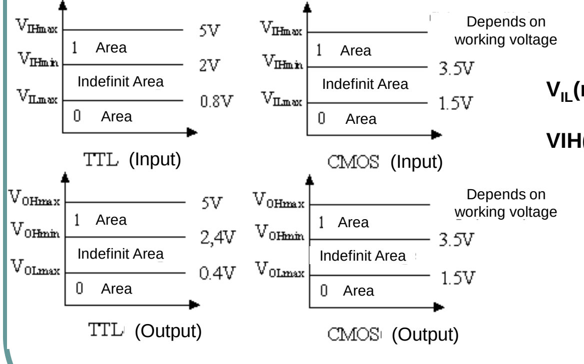
I- Terms and Parameters of ICs

Terms and Parameters of ICs;

- Definition of Logic Voltage / Current,
- Fan Out,
- Noise Immunity–Noise Margin,
- Propagation Delay and Propagation Speed,
- Power Dissipation,
- Speed-Power Product,
- Current Sourcing and Current Sinking,
- Power supply requirement and Operating temperature

1.1. Logic Voltage Levels

Voltage Levels;

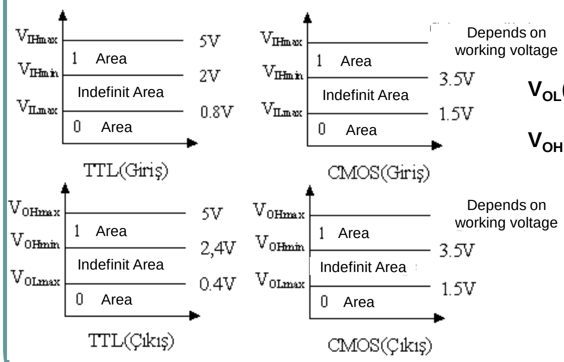


V_{IL}(max) = V input **l**ow **max**imum

VIH(min) = **V i**nput **h**igh **min**imum

1.1. Logic Voltage Levels (Cont.)

Voltage Levels;



V_{OL}(max) = V output low maximum

V_{OH}(min) = V output high minimum

1.2. Fan Out

- Refers to the maximum number of standard loads that the output of the gate can drive without any impairment or degradation of its normal operation.
- Varies according to the type of IC
- Calculated using input and output currents of an IC

1.2. Fan Out (Cont.)

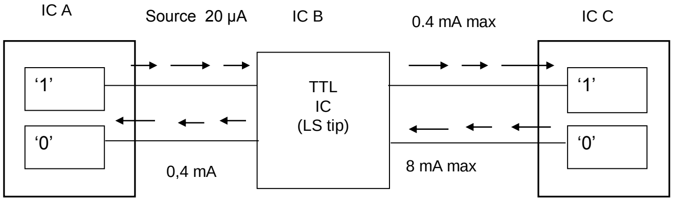
- Example; Current values for type LS TTL ICs;

Output current;	logic 1	0.4 mA	(toward load)
	logic 0	8 mA	(toward IC)
Input current;	logic 1	20 μA	(toward IC)
	logic 0	0.4 mA	(toward load)

1.2. Fan Out (Cont.)

If the input of IC B is connected to output of IC A which has the value of 1; 20 μA current flows from every input toward IC B. Since max output current of IC A is 0.4 mA ;

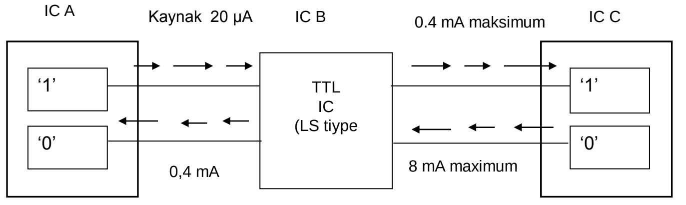
Fan Out = 0.4mA / 20 μA = 20 load it can drive



1.2. Fan Out (Cont.)

If the input of IC B is connected to output of IC A which has the value of 0; 0.4 mA current flows from input of IC B toward IC A. Since max input current of IC B is 8 mA the number of max load is ;

Fan Out = 8 mA / 0.4 mA = 20



1.2. Fan Out (Cont.)

- If there are two different numbers calculated the small one is taken
- The maximum number of inputs that can be connected to a logic gate without any impairment of its normal operation is referred to as **'fan in'**

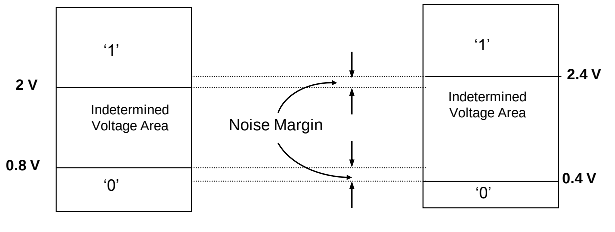
1.3. Noise Immunity or Noise Margin

Noise immunity or the noise margin is the limit of noise Voltage that may appear at the input of the logic gate without any impairment of its proper logic operation.

For Example; For a TTL IC to become logic ‘1’ it needs 2.4V , 0.4 V of this is for noise margin

1.3. Noise Immunity - Noise Margin

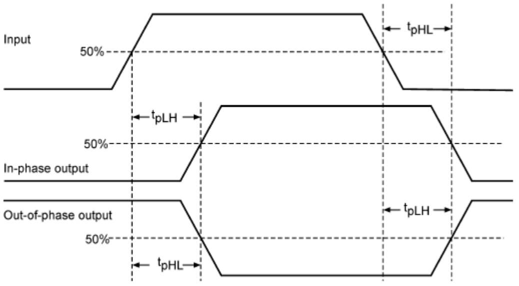
The difference between the operating input logic voltage level and the threshold voltage is the **‘noise margin’** of the circuit



1.4. Propagation Delay-tpd and Propagation Speed

The time taken for the output of a logic gate to change after the inputs have changed in nanosecond

Propagation Speed is the speed of procees in MHz



t_{pHL} is the propagation delay time for a signal to change from logic 1 to 0

t_{pLH} is the propagation delay time for a signal to change from logic 0 to 1

t_{pd} is the avarage ofg tp_{HL} and tp_{LH}

1.5. Power Dissipation

- Measure of the power consumed by logic gates when fully driven by all inputs in ‘mW’
- IC’s end which is connected to the power source is called **‘V_{CC}**’ in bipolar ICs and **‘V_{DD}**’ in CMOS ICs
- It varies according to the value of logic gate (0 or 1)

1.6. Speed - Power Product

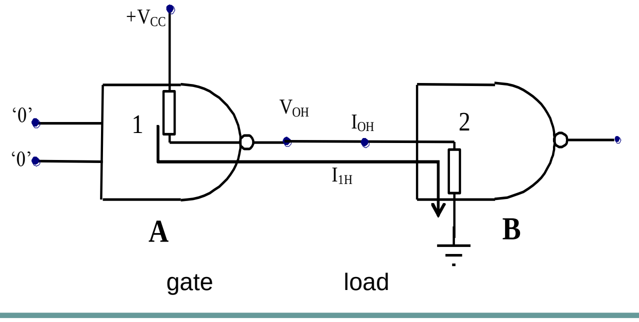
- This is a product of the propagation delay and the power dissipation measured in picojoules (pJ)

  Example; Propagation delay of an IC is 10 ns and avarage power dissipation is 50 mW;

  Speed-Power Product= 10 ns*50 mW = 500 pico watt-sn (500 pico joule)

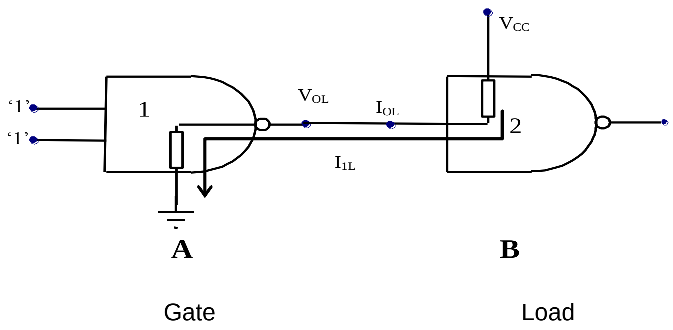
1.7. Current Sourcing

- When the output of a gate is high, it provides current to the input of the gate being driven, and in this situation, the output is said to act as the *current source*



1.7. Current Sinking

- When the output of a TTL gate is at low level, it acts as a *current sink*, because it sinks current from the gate inputs, which are driven to low



1.8. Power Supply Requirement and Operating Temperature

- The amount of power and supply voltage required for an IC is called **power supply requirement**

- **The operating temperature** ranges of an IC vary from 0°C to + 70°C for commercial and industrial application, and from –55°C to 125°C for military application

II – Clasification of Ics According to the number transistors they Contain

Density of IC	Number of Functions	Number of Component	Number of Gates
Zero Scale İntegration – ZSI			
Small Scale İntegration – SSI	2-20	100	1-12
Medium Scale İntegration-MSI	20-100	500	13-99
Large Scale İntegration – LSI	100-500	100000	100-9999
Very Large Scale İnteg.-VLSI	500-100000	250000	10000-99999
Ultra Large Scale İnteg.ULSI	100000 $\leq$	$10^7 - 10^9$	$10^5 - 10^8$
Giga Scale İntegration - GSI	-	$10^9 \leq$	$10^8 \leq$?

III - Clasification of Ics According to the number transistors their Components

- **Bipolar Logic Family**
  - **Resistor Diode Logic - RDL**
  - **Resistor Transistor Logic - RTL**
  - **Diode Transistor Logic - DTL**
  - **High Threshold Logic - HTL**
  - **Transistor Transistor Logic - TTL**
  - **Emiter Coupled Logic - ECL**
  - **Integrated Injection Logic –IIL - I2L**
- **MOS Logic Family**
  - **Metal Oxide Semiconductor-MOS**
    - **N - MOS**
    - **P - MOS**
  - **Complementary MOS-CMOS**

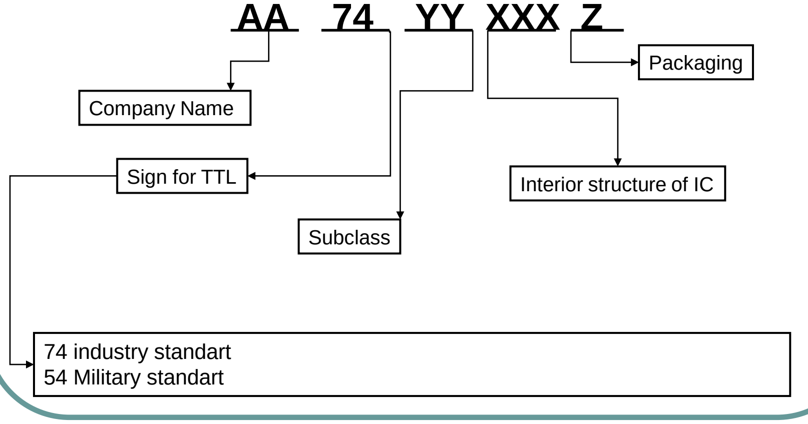
3.1. Bipolar Transistor Logic (Cont.)

TTL ICs

- Standart TTL – TTL - 74XX
- Low power TTL – LTTL – 74LXX
- High speed TTL – HTTL – 74HXX
- Schottky TTL – STTL –74SXX
- Low power schottky TTL – LSTTL – 74LSXX
- Advanced Schottky and Advanced – Low Power Schottky TTL- 74ASXX and 74ALSXX
- Fast – Advanced Schottky TTL – FASTTL – 74FXX

3.1. Bipolar Transistor Logic (Cont.)

- **Tansistor Transistor Logic IC Symbols**;



3.1.1 Comparison of TTL ICs

PERFORMANCE COMPARISON	74	74L	74H	74S	74LS	74AS	74ALS
Propagation Delay (ns)	9	33	6	3	9.5	1.7	4
Power Dissipation (mW)	90	33	138	60	19	13.6	4.8
Hız – Güç Üretimi (pj)	35	3	50	125	45	200	70
Max. Switching Speed (MHz)	10	20	10	20	20	40	20
Fan – Out							
VOLTAGE/CURRENT RATIO							
V_{OH} (min)	2,4	2,4	2,4	2,7	2,7	2,5	2,5
V_{OL} (max)	0,4	0,4	0,4	0,5	0,5	0,5	0,4
V_{IH} (min)	2,0	2,0	2,0	2,0	2,0	2,0	2,0
V_{IL} (max)	0,8	0,7	0,8	0,8	0,8	0,8	0,8
I_{OH} (min) - mA	1,6	0,16	2	2	0,4	0,3	0,2
I_{OL} (max) - mA	16	3,6	20	20	8	8	10
I_{IH} (min) - mA	0,04	0,01	0,05	0,05	0,02	0,02	0,02
I_{IL} (max) - mA	0,4	0,2	0,5	1	0,4	0,4	0,4

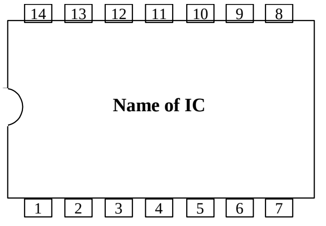
Values in the chart is for'NAND' Gate Except Max. Switching Rate

3.1.2 TTL IC Parameters

- **Electrical Parameters:**
  - **V_{IH}** : This implies that any voltage from 2 V to 5 V is recognized by the TTL gates as the high input level range without changing the output. (V_{IHmin}=2,0V).
  - **V_{IL}** : Any voltage from 0 V to 0.8 V is recognized by the TTL gates as the low input level range without changing the output. (V_{ILmax}=0,8V).
  - **V_{OH}**: This means that logic high output voltage level must be within 2.4 Vto 5 V.V_{OHmin}=2,4V).
  - **V_{OL}**: This implies that logic low output voltage level must be within 0 V to 0.4 V. (V_{OLmax}=0,4V).
  - **I_{IH}**: Current consumed by input when it's '1' (For TTL 40 µA/input).
  - **I_{IL}**: Current consumed by input when it's '0' If current flows trough out of the gate it's taken (-), otherwise it's taken (+). It's 1,6mA for a gate.
  - **I_{OH}**: Current value when output is '1' (For TTL 0,4 mA/gate).
  - **I_{OL}**: Current value when output is '1. It's into gate and 16mA

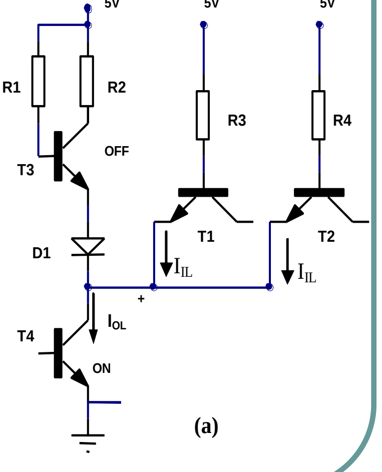
3.1.2 TTL IC Parameters

- **Dual inline package - DIP'**
- Pin numbers…
- Data sheets…



3.1.2 TTL IC Parameters

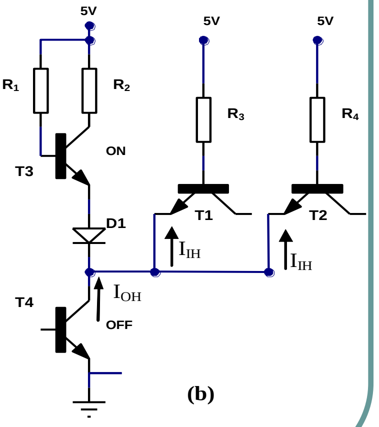
- **Operation Parameters**:
  - **Loading Drive and Fan-Out:**



(a)

3.1.2 TTL IC Parameters

- **Operation Parameters** :
  - **Loading Drive and Fan-Out**



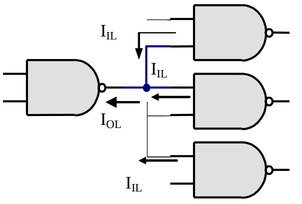
(b)

3.1.2 TTL IC Parameters

- **Loading Drive and Fan-Out):**

Example: How many of 7400 ‘ANDNOT’ gate can a 7400 ‘ANDNOT’ drive?

$I_{OL(max)}$=16mA ve $I_{IL(max)}$=1,6mA



a) Driver output and load input is ‘0’

3.1.2 TTL IC Parameters

When output is '0'

Fan out = $I_{OL(max)}$ / $I_{IL(max)}$ = 16mA/1,6mA = 10

When output is '1'
From the catalog;

$I_{OH(max)}$ = 0,4 mA = 400 μA and I_{IH}(max) = 40 μA

Then;

Fan out(1) = $I_{OH(max)}$ / $I_{IH(max)}$ = 400 μA/40 μA = 10

.

3.1.2 TTL IC Parameters

- **Unused Inputs:**
  - First they may be left as floating. The floating input of TTL family devices behaves as if logic HIGH has been applied to the input
  - Second They mat connect to +V
  - For 'OR' and 'ORNOT' gates, unused inputs shouldn't be floating or connected to +5 V. They should be connected to '0' or one of the inputs

3.2. MOS ICs

- **P-MOS and N-MOS**
  - **i- P-MOS logic**
  - **ii- N-MOS logic**
  - **iii- CMOS logic**

3.2.1 P-MOS and N-MOS Characteristics

- **Process Speed:** for a N-MOS ‘ANDNOT’ gate propagation delay is 50 ns.
- **Noise Margin:** N-MOS noise margin, for V_{DD}= 5 V is around 1.5 V
- **Fan-Out:** They are assumed to have infinite ‘Fan out’ capacity because of their very high input resistivity
- **Power Dsiispation:** Very low
- **Process Density:** The easiet produced logic gates

3.2.1 P-MOS and N-MOS Characteristics

- Must not be touched by bare hand
- Unused pins shouldn't be left floating. Should be connected to + V or ground

3.2.3 CMOS Characteristics

- **Series in CMOS ICs:** 74C and 54C CMOS IC serias are competible with TTL ICs
- **Supply Voltage and Voltage Elevels:** 4000 and 74C IC series operate between 3-15 V, 74HC and 74HCT series operate between 2-6 V

3.2.3 CMOS Characteristics

- **Noise Immunity:** DC noise immunity is; $V_{NH} = V_{NL} = \%30\ V_{DD}$
- **Power Dissipation:** It's very low. When $V_{DD} = +5$ V
  2.5 nW for each gate
- **Fan - Out:** There is a capacitive effect on each input for 5pF.
  That limits the fan out

IV - Interfacing

The output(s) of a circuit or a system should match the input(s) of another circuit or system that has different electrical characteristics.

In modular design technique,different circuit modules may be realized with the devices of different logic families.

It is always necessary to match the driver circuit module or system with the load circuit in terms of electrical parameters.

V – Displays Operated with TTL and CMOS ICs

- Dgital displays are used to display data produced by TTL and CMOS logic circuits

5.1 7 Segment Displays

- 7 segment displays are used for most of the digital display circuits
- 7 segment displays are made of either Light Emitting Diodes or Incondescent Flaments

5.1 7 Segment Displays - LED

- Two types of seven-segment display modules are available—*common cathode* type and *common anode* type

5.2 Incasdescent Filament 7 Segment Displays

- Incasdescent Filament Displays emit light when there is a current running through the filament. It heats up and starts to emit laight

5.3 Liquid Crystal Displays - LCD

- LCDs operate at low voltage (3-15 V_{eff}) and low frequency signals (25-60 Hz), they use very little current
- LCDs generally used with CMOS ICs. Because CMOS Ics use very little energy and TTL Ics produce 0.4V for logic ‘0’. This voltage makes LCD’s life shorter