Digital Integrated circuits

Almost all of the digital circuits used in modern digital systems are integrated circuits (ICs).

An integrated circuits is a complete electronic circuit in which both active and passive elements are fabricated on an extremely tiny single chip of silicon.

Digital ICs are categorized according to the number of basic gates or gate-equivalent circuits that they contain. The commonly used categories and the range of gates of each category are as follows

Number of gates	Integrated ccts Category Name	Abbreviation
1 - 12	Small-scale Integration	SSI
13 - 99	Medium-scale "	MSI
100 - 9999	Large-scale "	LSI
10,000 - 99,999	Very large-scale "	VLSI
over 100,000	Ultra-high scale "	UHSI

SSI ——→ simple logic gates
MSI ——→ Counters, code converters
LSI/VLSI ——→ Microprocessors ICs used as "brains" in computers
UHSI ——→ gates array

logic families

Many Integrated logic families exist - The most commonly used ones are: TTL and CMOS

- TTL (Transistor-Transistor logic) which uses Bipolar Transistor as its main circuit element

- CMOS (complementary Metal oxide Semiconductor) uses the enhancement-mode MOSFET as its principal circuit element - other also exist:
- RTL (Resistor - Transistor logic) uses Resistor and transistors
- DTL (Diode Transistor logic) uses Diode and Resistor etc....

TTL logic families

Devices in the standard TTL family are identified by numbers that start with 74 or, for military specification 54. Two or three digits after the 74 are used to identify the logic function performed by the device.

Table below shows the identifing numbers and the logic function performed by several commonly available TTL devices

Device number	Description of Device	Number of gates
7400	Quadruple 2-input NAND gates	4
7402	Quadruple 2 input NOR gates	4
7404	Hex Inverters	6
7408	Triple - 2 - input NAND gates	4
7410	Triple - 3 - input NAND gates	3
7420	Dual 4-input NAND gates	2
7430	8 - input NAND gates	1
7432	Quadruple 2-input OR gates	4
7486	Quadruple 2-input XOR gates	4
7493	4-bit binary counter	1

Numbers and letters on IC Packages identify the logic family and the logic function they performed In addition an IC may also have numbers and letters which indicate which indicate company made the device, the year and month, the package type and a code which indicate how thoroughly the device was tested

Exple

74 HCT 00 N

74 ↑ Commercial Temperature range.

HCT ↑ Type, HCT = High speed CMOS, TTL lev

00 ↑ Device number, identifies function

N ↑ Package Type
N = Plastic Dip

XXX XXX X ← layout identification

XXX ↑ Factory Identification

↳ Date code

Here are some Company Codes for the most Common IC manufacturers

Code	Manufacturer
AM	Advanced Micro devices
CD	GE/ RCA
DM	National Semiconductor
F	Fairchild
GD	Gold star
H	Harris
HD	Hitachi
IM	Intersil

KS	Samsung
LR	Sharp
M	SGS
MC	Motorola
MM	Monolithic Memories
MN	Panasonic
N	Signetics
P	intel
SN	Texas Instruments
SP	SPI
US	sprague
TC	Toshiba

Some letters code for common Package typ
are :

N — Plastic DIP
J — Ceramic DIP
D — Glass |metal DIP
W — flat Pack

Exple

SN 74 LS 10 N

- SN → Texas Instrument
- 74 → Temperature range
- LS → Large scale
- 10 → Device w/ identification
- N → Plastic DIP

A DM74LS08J can be replaced if faulty by SN74LS08J.
In other words, quality considerations aside - you care only about the function of a device not the manufacturer.

CMOS Logic families

The advantage of logic gates made with MOS transistors is that they dissipate very little power when operated at low frequencies.

Here are some TTL-compatible subfamilies to help you identify the device you find on a circuit board.

74C00 – First TTL-compatible CMOS family. Microwatt power dissipation at low frequencies but very slow compared to TTL

74HC00: High speed CMOS. Low power dissipation at low frequency operation, but almost as fast as Standard TTL

74HCT00: Another high speed CMOS. Has input and output voltage levels that are more compatible with TTL.

The first CMOS logic subfamily to be developed was the 4000A series. The family include logic functions such as those shown for TTL in the table above, but the devices are numbered differently – For exple 4001A contains four-2-input NOR gates etc....

Characteristics of logic families.

The characteristics are:

- speed
- fan in
- fan out → fan out low: $\frac{I_{OL(max)}}{I_{IL(max)}} = \frac{I_{OH(max)}}{I_{IH(max)}}$ (high)
- noise immunity
- Power dissipation

↓

$V_{NH} = V_{OH(min)} - V_{IH(min)}$

$V_{NL} = V_{IL(max)} - V_{OL(max)}$

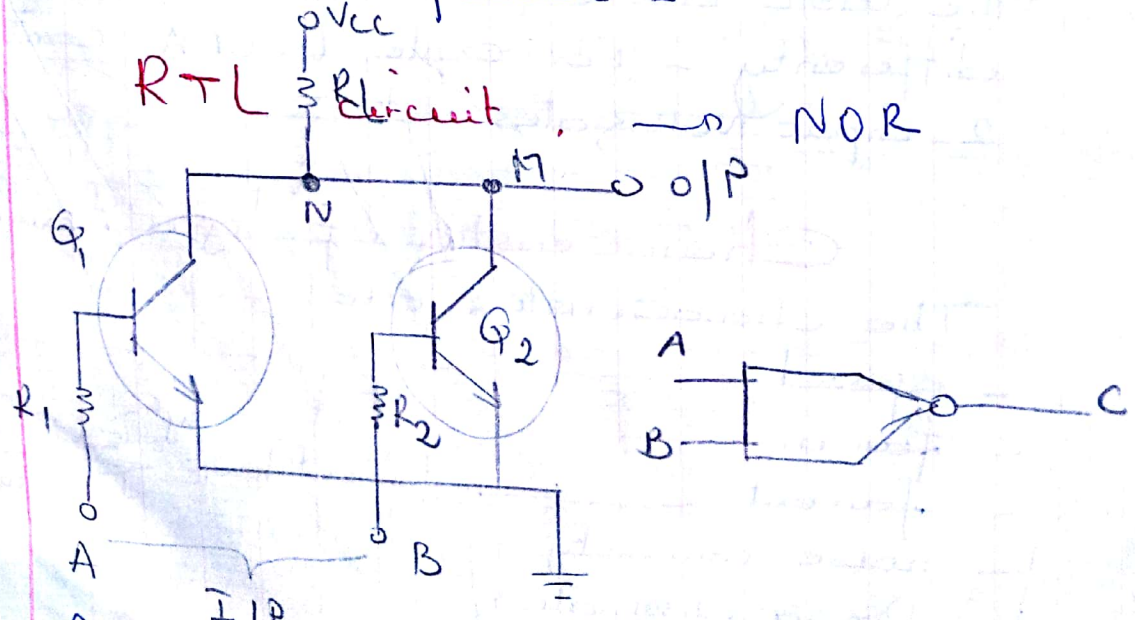
Speed: of a logic gate is the time that elapse between the application of a signal to an input terminal and the resulting change in logical state at the output.

Fan-in: of a logic gate is the number of inputs (coming from similar circuits) that logic gate can handle property.

Fan-out: of a logic gate is the maximum number of similar circuits that this gate can drive reliably.

noise immunity is represented by the maximu indicated noise voltage a logic circuit ca withstand without a false change in its outp state. It is also called Noise margin.

Power dissipation: is the power dissipated in a circuit as it switches from one state to another and also within all-current carrying resistors. Power dissipation of a gate should be as small as possible.



If A = B = 0.V (logic 0) both Transistors are off

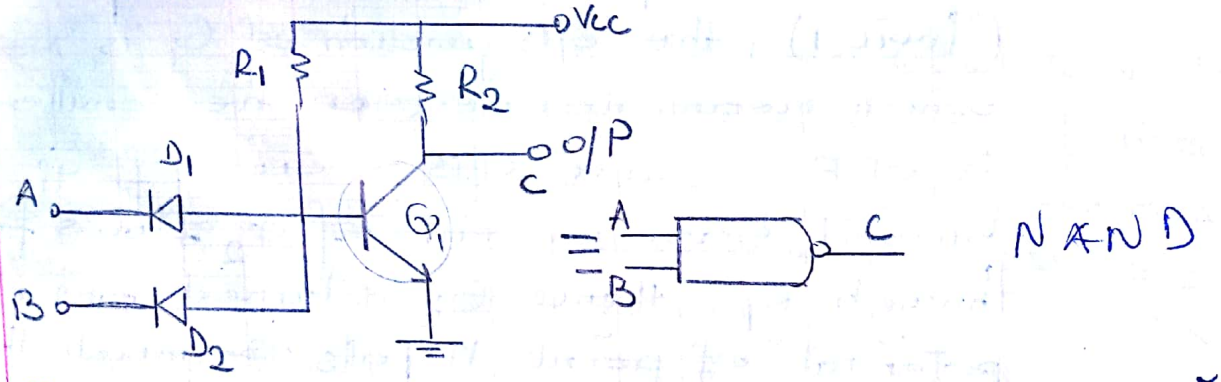
hence point M goes to +Vcc so that the output is at logic 1.

If either B or A or both terminals are at +Vcc i.e if are high logic (1) both transistors will be fully ON (i.e) Saturate thereby reducing the voltage at point N to 0V. Hence output would be at logic 0

RTL has the following disadvantages

1) low speed
2) low fan out — poor noise immunity ....

DTL circuit

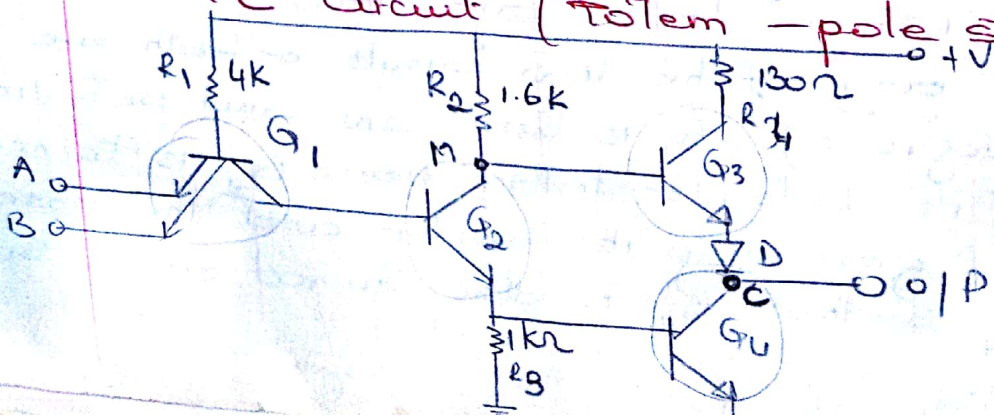


If A = B = 1 (+Vcc) D_1 and D_2 are reverse biased and Q_1 is ON so that C = 0

If either A or B or both are at 0V (logic 0), a conducting diode with cut-off Q_1 and therefore the output should be at logic 1.

DTL has a better noise immunity than RTL because of the 0.7V VBG of the diodes.

TTL Circuit (Totem-pole stage).



The TTL (Totem-pole) is the most widely used circuit Line because of its speed, good fanout and fan in and easy interface with other digital circuitry.

Circuit operation

Q_3, D and Q_4 is often known as totem-pole stage because the three output components are stacked on top of the other in the manner of a totem-pole.

When Input is high.

When the input terminals have positive voltage, (logic 1), the E/B junction of Q_1 is reversed biased which means no current at the emitter hence Q_1 is OFF. Since C/B junction of Q_1 is forward biased base current of Q_2 flows from Vcc through R_1 - Hence Q_2 is turned ON. As a result potential of point M falls so much that Q_3 is turned OFF. At the same time Q_4 is turned ON by the voltage drop across R_3 - when Q_4 is turn ON, its collector potential (potential at point c) is nearly that of its emitter - Hence output is low (at logic 0).

In short when inputs are at logic 1, Q_1 is OFF, Q_2 is ON, Q_3 is OFF and Q_4 is ON and output is at logic 0

When Inputs are low

If any of the two inputs or both are low (logic 0), Q_1 is turn ON and potential of its collector falls - Hence Q_2 is turned off grounding its emitter and the base of Q_4 so that Q_4 is also turned OFF - Since

M is at Vcc, it turns Q_3 ON. The potential of point C is Vcc minus drop in R_4, Q_3 and D. which is not much hence output is at logic 1. It may be noted that when even-numbered transistors are ON, the odd-numbered are OFF and vice-versa.

The function of D is to prevent Q_3 and Q_4 from being turn ON simultaneously.

Input/outputs Voltages and currents

The figure below is the manufacturer's data sheet for 5400/7400 NAND gate IC of the standard TTL series showing the recommended operating conditions, electrical characteristics and switching characteristics.