Integrated circuits

Active and passive components. Discrete components. Wafer. Chip. Advantage and drawbacks of ICs. Scale of integration: SSI, MSI, LSI and VLSI (basic idea and definitions only). Classification is of ICs. Example of linear and digital ICs.

ACTIVE COMPONENTS and PASSIVE COMPONENT

Active components include amplifying components such as transistors, triode vacuum tubes (valves), and tunnel diodes.

Passive components include two-terminal components such as resistors, capacitors, inductors, and transformers.

BASIS	ACTIVE COMPONENTS	PASSIVE COMPONENT
Function of the component	Devices which produce energy in the form of voltage or current.	Devices which stores energy in the form of voltage or current.
Power Gain	They are capable of providing power gain.	They are incapable of providing power gain.
Flow of current	Active components can control the flow of current.	Passive components cannot control the flow of the current.
Requirement of external source	They require an external source for the operations.	They do not require any external source for the operations.
Nature of energy	Active components are energy donor.	Passive components are energy acceptor.

DISCRETE COMPONENT

An elementary electronic device constructed as a single unit. Before the advent of integrated circuits (chips), all transistors, resistors, capacitors and diodes were discrete. Discrete components are widely used in amplifiers and other electronic products that use large amounts of current. On a circuit board, they are intermingled with the chips, and there is hardly any electronic product that does not have at least one or two discrete resistors or capacitors. See also discrete manufacturing.

WAFER

In electronics, a **wafer** (also called a **slice** or **substrate**) is a thin slice of semiconductor, such as a crystalline silicon (c-Si), used for the fabrication of integrated circuits and, in photovoltaics, to manufacture solar cells. The wafer serves as the substrate for microelectronic devices built in and upon the wafer. It undergoes many microfabrication processes, such as doping, ion implantation, etching, thin-film deposition of various materials, and photolithographic patterning. Finally, the individual microcircuits are separated by wafer dicing and packaged as an integrated circuit.

Wafers are formed of highly pure,] nearly defect-free single crystalline material, with a purity of 99.9999999%

CHIP

In electronics, a chip is comprised of semiconductor material cut from a larger wafer of material that is only a few millimeters on one side. On this chip, a transistor or integrated circuit may be etched but only occupy one-thousandth of an inch of the chip's surface.

The terms chip, microchip, integrated circuit (IC) and silicon chip are synonymous.

INTEGRATED CIRCUITS **-** The separately manufactured components like resistor, capacitor, diode, and transistor are joined by wires or by printed circuit board (PCB) to form circuits. These circuits are called discrete circuits and they have following disadvantages:

1. In a large electronic circuit, there may be very large number of components and as a result the discrete assembly will occupy a very large space. 2. They are formed by soldering which causes a problem of reliability.

To overcome these problems of space conservation and reliability, the integrated circuits were developed.

Integrated Circuit (IC): An IC comprises a number of circuit components like resistors, transistor etc. They are interconnected in a single small package to perform the desired electronic function. These components are formed and connected within a small chip of semiconductor material. In IC the following features are observed.

It combines both active elements like diodes and transistors with passive components like resistors and capacitors in a monolithic structure, so the complete unit in a monolithic circuit. Their size is very small.

To see connections between their various components, a microscope is needed.

All the components are formed within the chip and no components is seen projected above the surface of the chip.

Comparison of IC and Discrete Circuits Integrated circuits and discrete circuits can be compare as follows:

Integrated Circuits (IC's)	Discrete Circuits
1. I.C can work on low voltages.	1. Discrete circuits require comparatively more voltage.
2. They can handle limited amount of power.	2. Discrete circuits can handle much more power than
3. They are very small in size	3. Circuit with discrete components acquires large space.
4. They are cheap	4. Discrete circuits are costly than IC's.
5. Complex circuitry on a chip may be used to obtain improved performance characteristics.	5. The performance is not good.

ADVANTAGE OF ICs

1. The entire physical size of IC is extremely small than that of discrete circuit.
2. The weight of an IC is very less as compared entire discrete circuits.
3. It's more reliable.
4. Because of their smaller size it has lower power consumption.
5. It can easily replace but it can hardly repair, in case of failure.
6. Because of an absence of parasitic and capacitance effect it has increased operating speed.
7. Temperature differences between components of a circuit are small.
8. It has suitable for small signal operation.
9. The reduction in power consumption is achieved due to extremely small size of IC.

DIS-ADVANTAGE OF ICs

1. Coils or indicators cannot be fabricated.
2. It can be handle only limited amount of power.
3. High grade P-N-P assembly is not possible.
4. It is difficult to be achieved low temperature coefficient.
5. The power dissipation is limited to 10 watts.
6. Low noise and high voltage operation are not easily obtained.
7. Inductors and transformers are needed connecting to exterior to the semiconductor chip as it is not possible to fabricate inductor and transformers on the semiconductor chip surface.
8. Inductors cannot be fabricated directly.
9. Low noise and high voltage operation are not easily obtained.
10. the various components are integral part of a small semiconductor chip and the individual components cannot be removed for repair and replacement as in discrete circuits.

SCALE OF INTEGRATION:

The number of components fitted into a standard size IC represents its integration scale, in other words it's a density of components. It is classified as follows:

1. SSI – Small Scale Integration. It has less than 100 components (about 10 gates).

2. MSI – Medium Scale Integration. It contains less than 500 components or have more than 10 but less than 100 gates.

3. LSI – Large Scale Integration. Here number of components is between 500 and 300000 or have more than 100 gates.

4. VLSI – Very Large Scale Integration It contains more than 300000 components per chip

5. VVLSI - Very Very Large Scale Integration. It contains more than 1500000 components per chip.

Classification is of ICs: **Linear and digital integrated circuits**

Most integrated circuits (ICs) are classified as being either *linear* or *digital* devices. A linear circuit is one whose output signal has a linear relationship with the input signal. Linear ICs are also known as *Analogue* ICs because the signals that they handle may vary continuously over a range of values. Linear ICs include operational amplifiers (op-amps), audio-frequency power amplifiers and various radio and television circuits. Most linear ICs employ bipolar transistors throughout, although a few types of op-amp have either a JFET or a MOSFET input stage.

Digital ICs operate with Binary digital signals that are always in either of two possible states; namely logic 0 and logic 1. Digital ICs include gates, counters, memories and microprocessors. Some ICs include both Analogue and digital circuitry; three examples of these ICs are timer, Analogue-to-digital converters (ADC) and digital-to-Analogue converters (DAC).

Digital ICs

1. OR Gates, 7432

4 gates on this package, each with 2 input pins, 1 output pin. The output pin is high only when either one, or both, of the input pins are high.

2. NOR Gates, 7402

4 gates on this package, each with 2 input pins, 1 output pin. The output pin is low only when either one, or both, of the input pins are high.

3. XOR Gates, 7486

4 gates on this package, each with 2 input pins, 1 output pin. The output pin is low when both input pins are equal (both high or both low), and it is high when one of the input pins is high and at the same time the other input pin is low. This is called the "odd but not even gate" meaning that an odd number of inputs need to be high in order for the output to be high. The XNOR gate is just the opposite; called the "even but not odd gate".

4. AND Gates, 7408

4 gates on this package, each with 2 input pins, 1 output pin. The output pin is high only when all input pins are high at the same time.

5. Other AND Gates

7411 has 3 AND gates, each with 3 inputs and 1 output. 7421 has 2 AND gates, each with 4 inputs and 1 output.

6. NAND Gates, 7400, 74132

4 gates on this package, each with 2 input pins, 1 output pin. The output pin is low only when all input pins are high at the same time.

7. Other NAND Gates

7410 has 3 NAND gates, each with 3 inputs and 1 output. 7420 has 2 NAND gates, each with 4 inputs and 1 output. 7430 has 1 NAND gate, with 8 input pins, and 1 output pin.

8. Flip Flops

7474 has two D flip flops. Pin 14 is the 5V power pin; pin 7 is GND. 5474(W) and 54L74(W) has some differences. Pin 4 is Vcc (+5 volts) and pin 11 is GND. 7473 has two JK flip flops.

Linear ICs

Part number	Predecessor	Obsolete?	Description
555 timer IC		No	Timer, pulse generation, and oscillator applications.
78xx		No	Family of self-contained fixed linear voltage regulator integrated circuits.
Current conveyor			Electronic amplifier with unity gain. Three versions of generations of the idealised device, CCI, CCII and CCIII.[2]
Low-dropout regulator (LDO)			DC linear voltage regulator that can regulate the output voltage even when the supply voltage is very close to the output voltage.[3]

Hitachi HA12043		Yes	CX noise reduction system for phonograph records in the 1980s.
Hitachi HA12044		Yes	CX noise reduction system for phonograph records in the 1980s.
MK484			Fully functional AM radio detector on a chip. Constructed in a TO-92 case.[4][5]
NE612			Oscillator and a mixer. Used in ham radio applications.[6]
Operational amplifier			DC-coupled high-gain electronic voltage amplifier with a differential input and, usually, a single-ended output.[7]
Telefunken U401B		Yes	High quality High Com Analogue compander for audio in the 1970s.
Telefunken U401BG	Telefunken U401B	Yes	High quality High Com Analogue compander for audio in the 1970s.
Telefunken U401BR	Telefunken U401BG	Yes	High quality High Com Analogue compander for audio in the 1970s/1980s.
Telefunken U2141B		Yes	CX noise reduction system for phonograph records in the 1980s.
ZN414			Single-chip AM radio integrated circuit from 1972.
LM317			Adjustable 1.5 A positive voltage regulator (1.25 V-37 V)[8]
LM13700			Two current controlled operational transconductance amplifiers (OTA), each having differential inputs and a push-pull output.
LM393		No	Dual Differential Comparator[9]
LM358		No	Low power, wide supply range dual op-amps[10]
LM386			Low voltage audio power amplifier[11]
LM3875			High-performance 56 W audio power amplifier[12]

Digital circuits

Difference between Analogue and digital circuits. Binary numbers, decimal to Binary and Binary to decimal conversion. BCD, octal and hexadecimal numbers. And OR and NOT gates (realisation using diodes and transistor). NAND and NOR gates as universal gates. XOR and XNOR gates and applications as parity checkers.

<u>What are ANALOG CIRCUITS?</u>

conventional electric circuits are **used to process continuous signals** which can have any value within a limited range. Such signals are called **Analog signals** and the circuit handling them a call **Analog circuits.**

<u>What are DIGITAL CIRCUITS?</u>

There is another type of signals which can have **only two discrete values either low or high.** Here the actual magnitude of the signal is unimportant, as long as it within a specified range of low or high level of signal. This type of signal is known as **digital signal** and the circuits used to process such signal are known as **digital circuits.**

Analog circuits	Digital circuits
1. Analog circuits operate on continuously variable signals also known as Analog Signals.	1. Digital Circuits operate on discretely variable signals or Digital signals i.e. the signal exists only in two levels: 0 and 1 (Binary digital signalling).
2. Depending the efficiency and precision, it is quite difficult to design Analog Circuits.	2. Digital Circuits are relatively easy to design with many automated tools available for various stages of design and analysis.
3. When interacting with the physical world, Analog circuits can directly accept the signals from outside as the data is already Analog.	3. If a digital circuit has to acquire data from physical world, the Analog signals must be converted to digital signals first.
4. As there is no need for data conversion, there is ideally no loss of information.	4. During the process of converting Analog signals to digital signals, there might a significant amount of data loss, which can result in loss of information.
5. If precision and accuracy are not a criterion, then Analog circuits can be simple and inexpensive.	5. Even with simple design techniques and at low cost, the digital circuits can provide good accuracy and precision.
6. Due to the lack of skilled engineers and the complexity of the designs, Analog circuits can turn out to be quite expensive.	6. Advanced Integrated Circuits technologies and many other factors help the digital circuits to be reliable, lower in cost and smaller in size.

In mathematics and digital electronics, a **Binary number** is a number expressed in the **base-2 numeral system** or **Binary numeral system**, which uses only two symbols: typically "0" (zero) and "1" (one).

The base-2 numeral system is a positional notation with a radix of 2. Each digit is referred to as a bit. Because of its straightforward implementation in digital electronic circuitry using logic gates, the Binary system is used by almost all modern computers and computer-based devices.

<u>What is BINARY NUMBER SYSTEM?</u>

A number system consisting of two digits 0 & 1, only is known as **Binary number system.**

<u>What is this BASE or RADIX?</u>

The number of basic symbols or digits used in a number system is called the **base or radix.** Hence Binary number system is a **base two system.**

What do you mean by BIT, BYTE, LSB, MSB, NIBBLE, DOUBLE WORD?

Each Binary digit in short called a **bit.**

A group of 8 bit has been given the special name **bite(byte)**

the bit in the right most position in a Binary number is called least significant bit(LSB). Whereas the bit in the left most position is **the most significance bit(MSB).**

The group of 4-bit called a **nibble.**

A group of 32-bit is called a **double word.**

What is the advantage of using Binary number system in a digital computer?

In calculator, computer and other digital systems that input signal can have only two discrete values- either low or high. Hence the actual magnitude of the signal is unimportant, as long as it within a specific range of low or high level of the signal.

If we use Binary number system consisting of two digit 0 & 1, only two discrete distinct signal levels are necessary to represent them. This can be achieved with great accuracy. That is why digital systems use Binary number system extensively.

Why do mean by Binary codes?

Digital Systems process data in Binary form. The representation of various data like decimal numbers, alphabetic letters, and other special characters in Binary form to a strings of bits. This Binary forms are known as Binary codes.

Weighted and unweighted codes

when the absolute position of a digit in a number is important in a codes then this weighted codes

when the absolute position of a digit in a number is unimportant in a codes then this unweighted codes.

What do mean by Binary coded decimal(BCD) ?

Binary coded decimal is a class of Binary encoding of decimal number where each decimal digit is represented by a fixed number of bits, usually four or eight.

Among various BCD system the weighted 8421 code is most common, [note that the four bits used have weights $(2^3, 2^2, 2^1, 2^0)$]. For example,

$$\begin{array}{ccc} 5 & 6 & 3 \\ \downarrow & \downarrow & \downarrow \\ 0101 & 0110 & 0011 \end{array}$$

in many practical applications like frequency meters, digital voltmeters, digital calculators where output is decimal display, BCD is used.

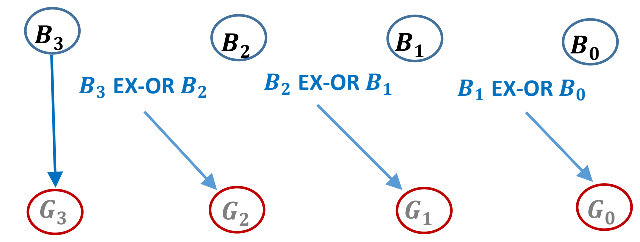
The case of conversion between 84210 numbers and familiar decimal numbers is the main advantage of this code.

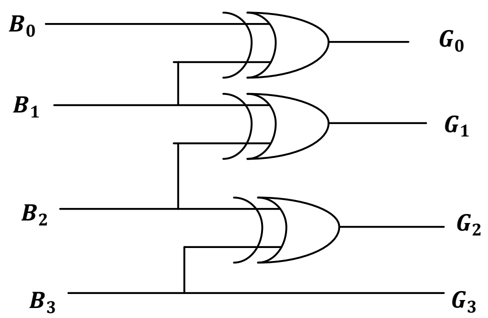
What is Gray code?

It is an un-weighted code. In this code in number differs from the preceding number only by one-bit position. The property makes it useful for many applications such as sequence counting.

Binary to Gray code conversion

The MSB of the Gray code will be exactly equal to the MSB of the given Binary number.

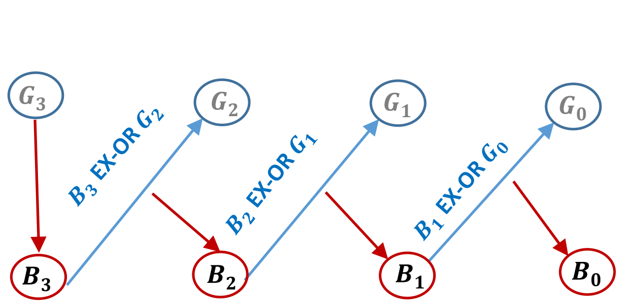


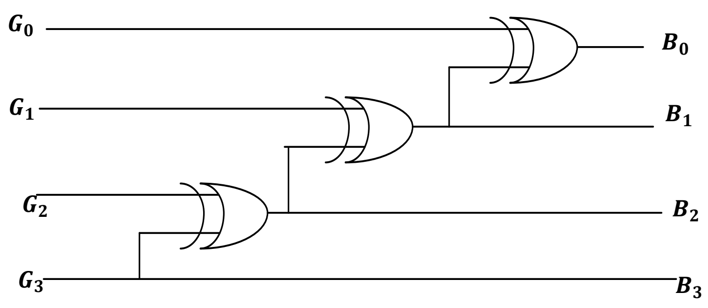


Circuit for Binary to Gray code

Gray code to Binary conversion

The MSB of the Binary number will be exactly equal to the MSB of the given Gray code number.





Circuit for Gray code to Binary number

Home Tasks: 1. convert Binary number 01001 to Gray code. 2. Gray code 01101 to Binary number.

Hints : The output of EX-OR gate for equal inputs is "0" and for unequal inputs is "1"

Decimal Number	Binary Code	Gray Code
0	0000	0000
1	0001	0001
2	0010	0011
3	0011	0010
4	0100	0110
5	0101	0111

Decimal Number	Binary Code	Gray Code
6	0110	0101
7	0111	0100
8	1000	1100
9	1001	1101
10	1010	1111

Decimal to Binary conversion

2^{11}	2^{10}	2^{9}	2^{8}	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}	2^{-1}	2^{-2}	2^{-3}	2^{-4}	2^{-5}
2048	**1024**	**512**	**256**	**128**	**64**	**32**	**16**	**8**	**4**	**2**	**1**	**0.5**	**0.25**	**0.125**	**0.0625**	**0.03125**

Here is an example of using repeated division to convert $(\mathbf{25.625})_{\mathbf{10}}$ decimal to Binary.

$\mathbf{25 = (16 + 8 + 0 + 0 + 1)}$ $\quad \mathbf{0.625 = (0.5 \ + 0.00 + 0.125)}$

$\mathbf{(25.625)_{10} = (11001.101)_{\,2}}$

Signed Binary number

$$(+50)_{10} = (00110010)_2 \qquad (-50)_{10} = (10110010)_2$$

$+\,\boldsymbol{sign}$ $\qquad -\,\boldsymbol{sign}$

The disadvantage here is that whereas before we had a full range n-bit unsigned Binary number, we now have an n-1 bit signed Binary number giving a reduced range of digits from: $\mathbf{-2^{(n-1)}}$ $\boldsymbol{to}$ $\mathbf{+2^{(n-1)}}$

1st 's Complement of a Signed Binary Number

$$(+50)_{10} = (00110010)_2 \qquad (-50)_{10} = (11001101)_2$$

1st complement of 00110010

2nd 's Complement of a Signed Binary Number

$$(+50)_{10} = (00110010)_2 \qquad (-50)_{10} = (11001101 + 1)_2 = (11001110)_2$$

1st complement of 00110010

The main advantage of two's complement over the previous one's complement is that there is no double-zero problem plus it is a lot easier to generate the two's complement of a signed Binary number. Therefore, arithmetic operations are relatively easier to perform when the numbers are represented in the two's complement format.

Decimal to Octal Here is an example of using repeated division to convert $(1792.513)_{10}$ decimal to octal:

Decimal Number	Operation	Quotient	Remainder	Octal Result
1792	÷ 8 =	224	0	0
224	÷ 8 =	28	0	00
28	÷ 8 =	3	4	400
3	÷ 8 =	0	3	3400
0	done.			

Again $0.513\times 8 = 4.104 \longrightarrow 4$

$0.104\times 8 = 0.832 \longrightarrow 0$

$0.832 \times 8 = 6.656 \longrightarrow 6$

$0.656 \times 8 = 5.248 \longrightarrow 5$

Hence $(1792.513)_{10} = (3400.4065 \ldots)_8$

Decimal to Hexadecimal The only addition to the algorithm when converting from decimal to hexadecimal is that a table must be used to obtain the hexadecimal digit if the remainder is greater than decimal 9.

Decimal	0	1	2	3	4	5	6	7
Hexadecimal	0	1	2	3	4	5	6	7
Decimal	8	9	10	11	12	13	14	15
Hexadecimal	8	9	A	B	C	D	E	F

Here is an example of using repeated division to convert $(1792.513)_{10}$ decimal to hexadecimal:

Decimal Number	Operation	Quotient	Remainder	Hexadecimal Result
1792	÷ 16 =	112	0	0
112	÷ 16 =	7	0	00
7	÷ 16 =	0	7	700
0	done.			

Again $0.513 \times 16 = 8.208 \rightarrow 8$

$0.208 \times 16 = 3.328 \rightarrow 3$

$0.328 \times 16 = 5.248 \rightarrow 5$

$0.248 \times 16 = 3.968 \rightarrow 3$

Hence $(1792.513)_{10} = (700.8353\ldots)_8$

The addition of letters can make for funny hexadecimal values. For example, 48879 decimal converted to Hex is:

Decimal Number	Operation	Quotient	Remainder	Hexadecimal Result
48879	÷ 16 =	3054	15	F
3054	÷ 16 =	190	14	EF
190	÷ 16 =	11	14	EEF
11	÷ 16 =	0	11	BEEF
0	done.			

Other fun hexadecimal numbers include: AD, BE, FAD, FADE, ADD, BED, BEE, BEAD, DEAF, FEE, ODD, BOD, DEAD, DEED, BABE, CAFE, C0FFEE, FED, FEED, FACE, BAD, F00D, and my initials DAC.

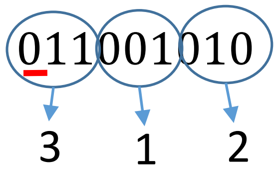
Binary to decimal:

Home task:

1. Convert signed Binary number in decimal
   A) $(00110010)_2$ B) $(10110010)_2$
2. Convert signed Binary number (in 1ST compliment representation) in decimal number.
   A) $(00110010)_2$ B) $(11001101)_2$
3. Convert signed Binary number (in 2nd compliment representation) in decimal number.
   A) $(00110010)_2$ B) $(11001110)_2$

Hints: Since positive sign-magnitude numbers always start with a zero (0), its complement will therefore always start with a one (1) to indicate a negative number.

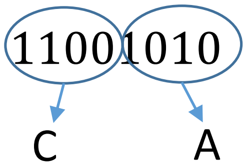
Binary to Octal: say for example $(11001010)_2 = (?)_8$



Binary to Octal

Hence $(11001010)_2 = (312)_8$

Binary to Hexadecimal: say for example $(11001010)_2 = (?)_{16}$



Binary to Hexadecimal

Hence $(11001010)_2 = (CA)_{16}$

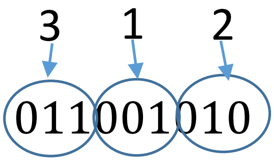
Octal to Decimal: Say for example $(312)_8 = (?)_{10}$

$$\boxed{3\times 8^2 + 1 \times 8^1 + 2 \times 8^0 = 202}$$

Octal to Decimal

Hence $(312)_8 = (202)_{10}$

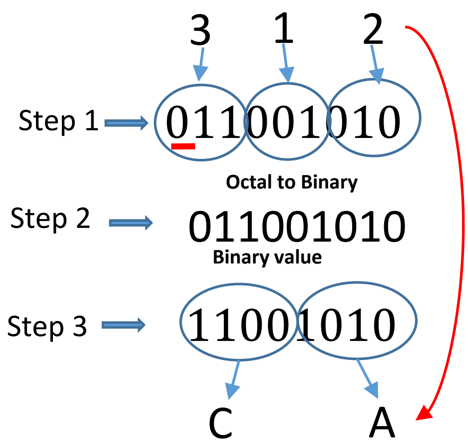
Octal to Binary: Say for example $(312)_8 = (?)_2$



Octal to Binary

Hence $(312)_8 = (011001010)_2$

Octal to Hexadecimnal:



Binary to Hexadecimal

Say for example $(312)_8 = (?)_{16}$

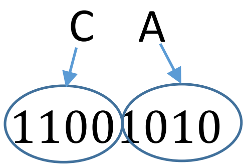
Hence $(312)_8 = (CA)_{16}$

Hexadecimal to Decimal: Say for example $(CA)_{16} = (?)_{10}$

$$\boxed{12\times 16^1 + 10 \times 16^0 = 202}$$

Hence $(CA)_{16} = (202)_{10}$

Hexadecimal to Binary:

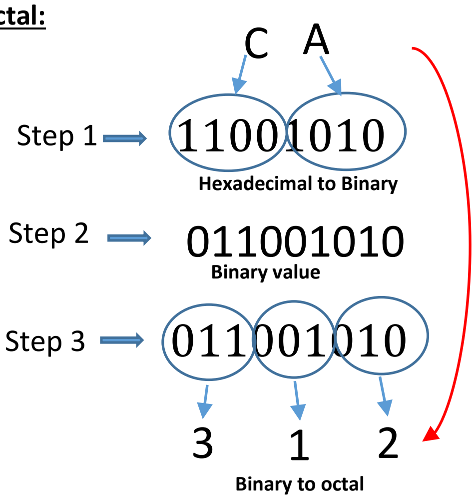


Hexadecimal to Binary

Say for example $(CA)_{16} = (?)_{10}$

Hence $(CA)_{16} = (11001010)_2$

Hexadecimal to Octal:



Say for example $(CA)_{16} = (?)_8$

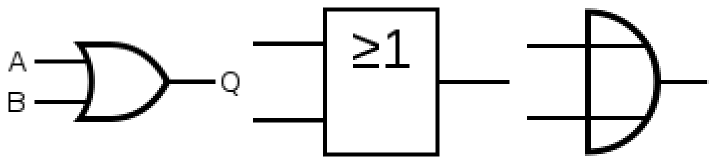
Hence $(CA)_{16} = (312)_8$

OR GATE

The **OR gate** is a digital logic gate that implements logical disjunction – it behaves according to the truth table to the right. A HIGH output (1) results if one or both the inputs to the gate are HIGH (1). If neither input is high, a LOW output (0) results. In another sense, the function of OR effectively finds the *maximum* between two binary digits, just as the complementary AND function finds the *minimum*.

Symbols

There are two symbols of OR gates: the American (ANSI or 'military') symbol and the IEC ('European' or 'rectangular') symbol, as well as the deprecated DIN symbo

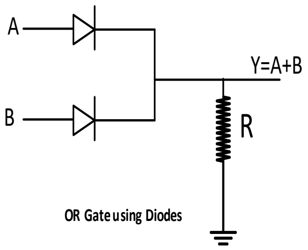


MIL/ANSI Symbol *IEC Symbol* *DIN Symbol*

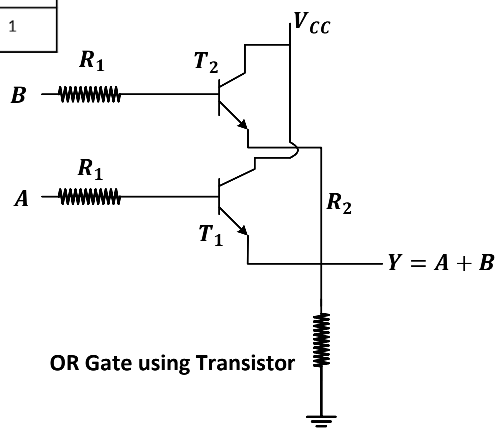
Truth Table OR gate

A	B	Y=A+B
0	0	0
0	1	1
1	0	1
1	1	1

The OR gate with inputs *A* and *B* and output *C* implements the logical expression $Y = A + B$



OR Gate using Diodes



OR Gate using Transistor

USING DIODE	USING TRANSISTOR
If one or both inputs are at logic “1” (5 volts), the current will flow through one or both diodes. This current passes through the resistor and causes the appearance of a voltage across its terminals, thereby obtaining logic “1” on the output. We only get logic “0” (0 volts) on the output when both inputs are in logic “0”. In this case, the diodes do not conduct, there is no current through the resistor R and there is no voltage across its terminals. As a result the voltage at V out is the same as ground (0 volts)	For the OR logic, the transistors are in parallel and the output is driven high if either of the transistors is conducting.

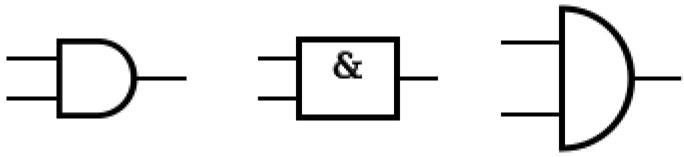
AND gate

The **AND gate** is a basic digital logic gate that implements logical conjunction - it behaves according to the truth table to the right. A HIGH output (1) results only if all the inputs to the AND gate are HIGH (1). If none or not all inputs to the AND gate is HIGH, a LOW output results. The function can be extended to any number of inputs.

The function of AND effectively finds the *minimum* between two binary digits, just as the complementary OR function finds the *maximum*.

Symbols

There are three symbols for AND gates: the American (ANSI or 'military') symbol and the IEC ('European' or 'rectangular') symbol, as well as the deprecated DIN symbol. Additional inputs can be added as needed.

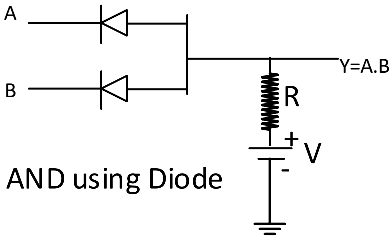


MIL/ANSI Symbol *IEC Symbol* *DIN Symbol*

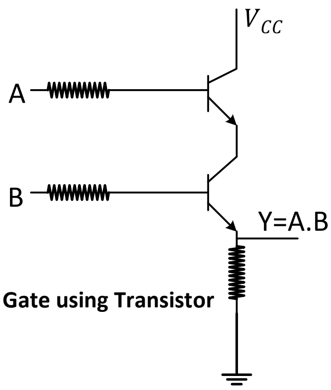
Truth Table AND gate

A	B	Y=A.B
0	0	0
0	1	0
1	0	0
1	1	1

The AND gate with inputs *A* and *B* and output *C* implements the logical expression $Y = A$.B



AND using Diode



AND Gate using Transistor

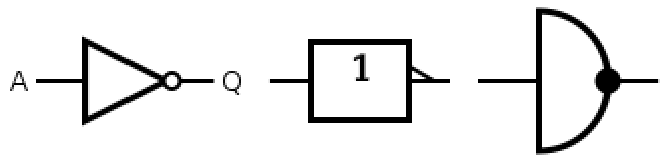
USING DIODE	USING TRANSISTOR
When both inputs are at logic “1”, the two diodes are reverse biased and there is no current flowing to ground. Therefore, the output is logic “1” because there is no voltage drop across the resistor R. If one of the inputs is logic “0”, the current will flow through the corresponding diode and through the resistor. Thus the diode anode (the output) will be logic “0”.	For the AND logic, the transistors are in series and both transistors must be in the conducting state to drive the output high.

NOT Gate

A **NOT gate** (also often called **Inverter**) is a logic gate. Each NOT gate has only one input signal. Logically with NOT gates, the input and the output swap, so if you input *1* it outputs as *0*; likewise, if you input *0* it outputs as *1*.

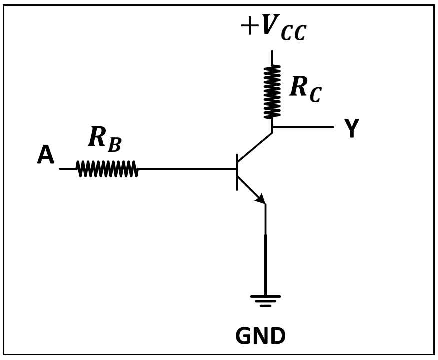
In the 20th century an inverter was often made of a discrete transistor with other components, or several inverters were packaged in an integrated circuit.

There are three symbols for the NOT gate:



MIL/ANSI Symbol *IEC Symbol* *DIN Symbol*

INPUT A	**OUTPUT** NOT A
0	1
1	0



We can design a NOT gate by using a NPN transistor as shown in below picture. The Base (B) of the NPN transistor is connected with the input signal A. we connect a supply voltage of V_{CC} =+5 V to the emitter (E) and the output Q is collected at the emitter. When the low level voltage 0 V is connected to the input, then the transistor will be OFF. So no current flows through it. This means the supply voltage +5 V will be measured at the output port, which is considered as HIGH state. Similarly, when the high level voltage +5 V is connected to the input, then the transistor will be ON. So the total supply current will be drawn by transistor. This means the no voltage is measured at the output port, which is considered as LOW state.

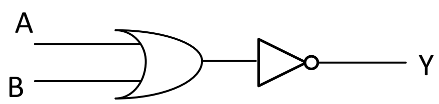
NOR GATE

The inclusive NOR (Not-OR) gate has an output that is normally at logic level “1” and only goes “LOW” to logic level “0” when **ANY** of its inputs are at logic level “1”. The **Logic NOR Gate** is the reverse or “*Complementary*” form of the inclusive OR gate we have seen previously.

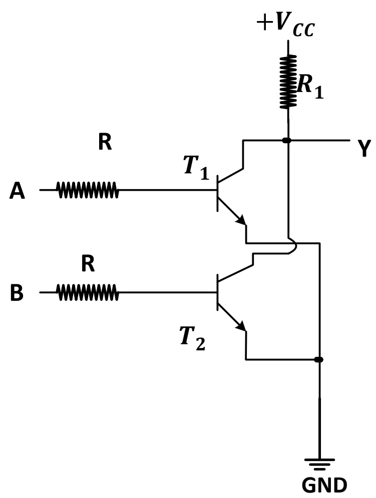
A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

Logic NOR Gate Equivalent

The logic or Boolean expression given for a logic NOR gate is that for *Logical Multiplication* which it performs on the *complements* of the inputs. Then we can define the operation of a 2-input digital logic NOR gate as being: “If both A and B are NOT true, then Y is true”

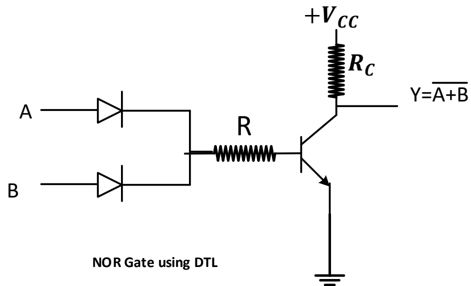


`USING RTL



For the NOR logic, the transistors are in parallel with the output above them so that if either or both of the inputs are high, then the transistors will be ON. So the total supply current will be drawn by transistor. This means the no voltage is measured at the output port, which is considered as LOW state, the output is driven low.

When the low level voltage 0 V is connected to the both input, then the both the transistors will be OFF. So no current flows through it. This means the supply voltage +5 V will be measured at the output port, which is considered as HIGH state.



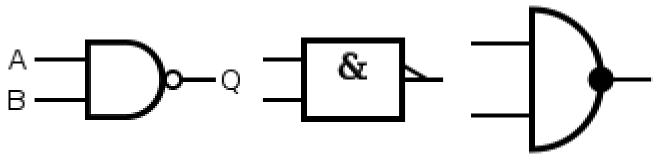
NOR Gate using DTL

NAND GATE

In digital electronics, a **NAND gate** (**NOT-AND**) is a logic gate which produces an output which is false only if all its inputs are true; thus its output is complement to that of an AND gate. A LOW (0) output results only if all the inputs to the gate are HIGH (1); if any input is LOW (0), a HIGH (1) output results. A NAND gate is made using transistors and junction diodes. By De Morgan's theorem, a two-input NAND gate's logic may be expressed as $\overline{AB} = \bar{A}+\bar{B}$, making a NAND gate equivalent to **inverters followed by an OR gate**.

The NAND gate is significant because any Boolean function can be implemented by using a combination of NAND gates. This property is called functional completeness. It shares this property with the NOR gate. Digital systems employing certain logic circuits take advantage of NAND's **functional completeness.**

There are three symbols for NAND gates: the MIL/ANSI symbol, the IEC symbol and the deprecated DIN symbol sometimes found on old schematics. For more information see logic gate symbols. The ANSI symbol for the NAND gate is a standard AND gate with an inversion bubble connected.



MIL/ANSI Symbol *IEC Symbol* *DIN Symbol*

A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

Logic NAND Gate Equivalent

The logic or Boolean expression given for a logic NAND gate is that for *Logical Addition*, which is the opposite to the AND gate, and which it performs on the *complements* of the inputs. Then we can define the operation of a 2-input digital logic NAND gate as being: "If either A or B are NOT true, then Q is true"