Various analog electronic components are commonly used in designing the hardware of an embedded system. The role of some of these components is explained as follows,

1. **Resistor**

   Resistor is a current limiting device and is commonly used to interface LEDs and buzzers with the port pins of a microcontroller in an embedded application.

2. **Transistor**

   Transistors are popularly used in embedded applications for performing switching and amplification functions. When transistor acts as a switch, it remains either in ON or in OFF state. Whereas, in amplification application, a transistor always remains in ON state. For switching and driving circuits in embedded systems, NPN transistor in common emitter configuration is used extensively. Examples of such circuits are relays, buzzers and stepper motor driving circuits.

3. **Capacitor**

   Capacitors are generally used in signal filtering and resonating circuits for performing implementation of reset circuits, matching of circuits for RF designs, decoupling of power supply in embedded applications. Various types of capacitors that are widely used in embedded hardware design are electrolytic capacitors, ceramic capacitors and tantalum capacitors.

4. **Diode**

   The most commonly used diodes in embedded hardware circuits are P-N junction diodes, Schottky diodes and Zener diodes. A Schottky diode acts similar to a P-N junction diode, but has low forward voltage drop of the order of 0.15 V to 0.45 V when compared to a P-N junction diode whose forward voltage drop is of the order of 0.7 V to 1.7 V, also it has a very small current switching time when compared to a P-N junction diode. A zener diode in forward biased condition acts as P-N junction diode and is used in voltage clamping applications. Various other functions performed by a diode in an embedded system are reverse polarity protection, voltage rectification, free-wheeling of current produced in inductive circuits etc.

The various digital electronic components used in embedded system development are as follows,

1. Open collector and tri-state output
2. Logic gates
3. Buffer
4. Latch
5. Decoder
6. Encoder
7. Multiplexer
8. De-multiplexer
9. Combinational circuits
10. Sequential circuits.

1. Open Collector and Tri-state Output

In digital system design, open collector is referred as an IC output and is used as source of interface to connect IC with other components. Figure (1) illustrates the output of an IC interfaced with base of an NPN transistor.

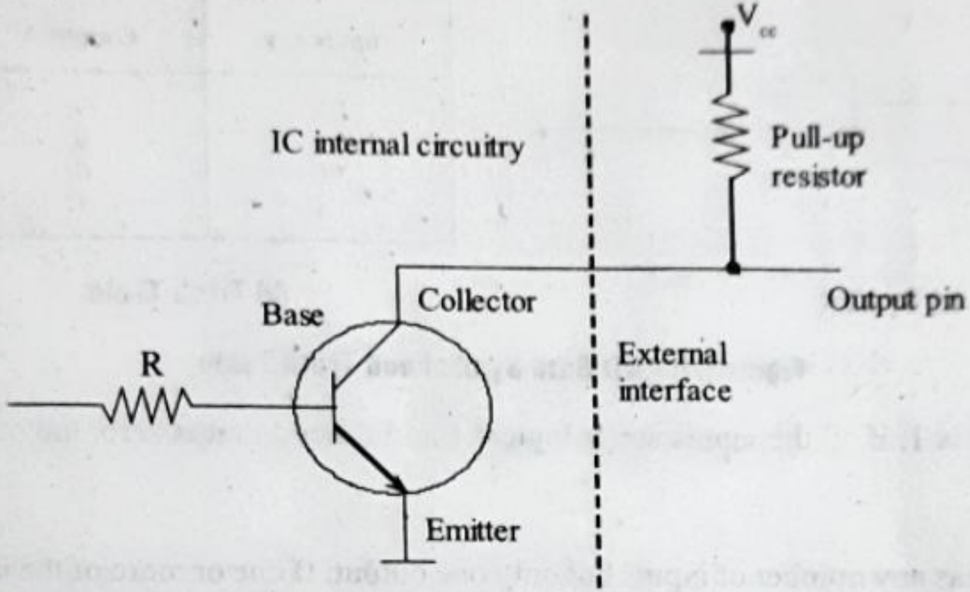

Figure (1): Configuration of Open Collector

2. Logic Gates

In a digital communication system, some basic operations such as arithmetic and logical operations has to be performed. For this, logic gates or circuits for implementing boolean algebraic equations are required.

A logic gate is an electronic circuit which monitors several binary inputs to perform a logical function based on the conditions and produces an output when the required input condition is obtained.

These logic gates are AND gate, OR gate, NOT gate, NOR gate, NAND gate, Exclusive-OR gate and Exclusive-NOR gate. Among these the basic gates are the AND gate, OR gate and NOT gate. The NAND gate is derived from AND gate and NOR gate is derived from OR gate.

3. **Buffer**

A buffer is used to amplify the power or current. Due to this, the driving capability of a logic circuit increases. The figures (9) and (10) shows unidirectional or bidirectional buffer.

1. **Decoder**

A combinational circuit, containing 'n' number of input lines, 2^n number of output lines where particular combination of the input is responded only by one of 2^n output lines is known as decoder.

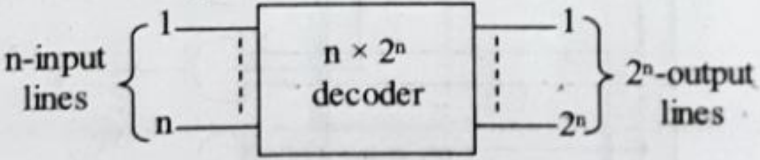

Figure (1): Representation of n × 2^n Decoder

Encoder

An encoder is a digital circuit that converts one form of binary information to another form. A general encoder has 2^n input lines and n output lines and is represented as shown in figure (3).

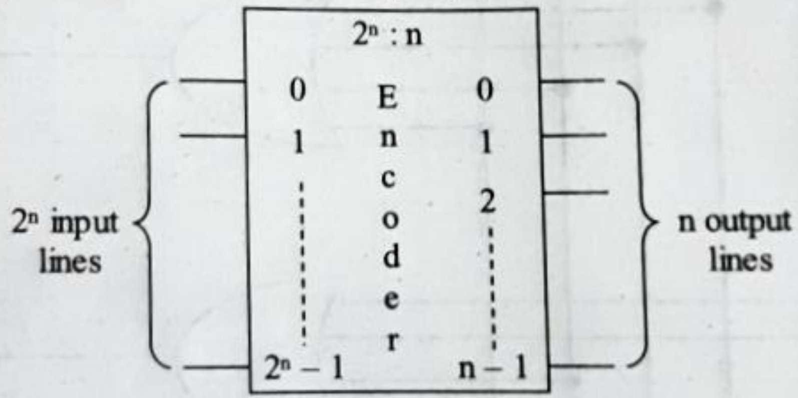

Figure (3)

The block schematic and truth table of a 4 to 2 encoder is shown figure (4).

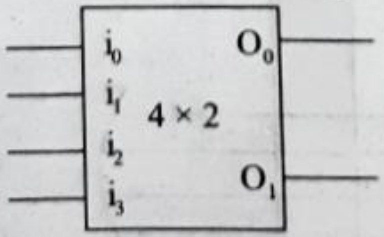

Figure (5)

3. Multiplexer

Multiplexing means transmitting a large number of information units over a small number of channels are lines. "A digital multiplexer is a combinational circuit that selects binary information from one of many input lines and direct it to a single output line. The selection of a particular line is controlled by a set of selection lines. Normally, there are 2^n input lines and n selection lines whose bit combinations determine which input is selected as shown in figure (6).

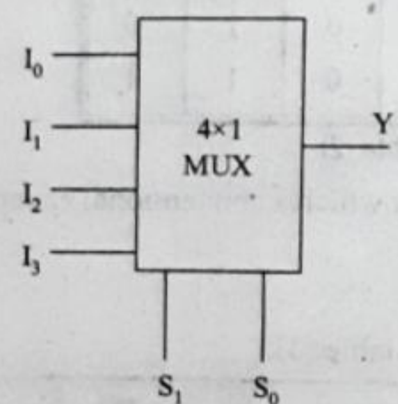

Figure (6): 4 × 1 Mux

Input		Output
S_0	S_1	Y
0	0	I_0
0	1	I_1
1	0	I_2
1	1	I_3

Table (4)

4. Demultiplexer

A decoder with enable input acts as a demultiplexer. "A demultiplexer is a circuit that receives information on a single line and transmits that information on one of 2^n possible output line. The selection of specific output line is controlled by the bit values of n selection lines as shown in figure (7).

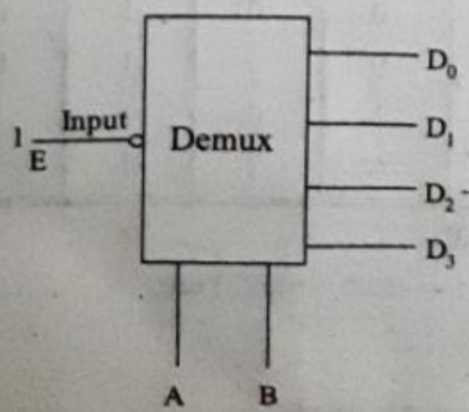

Figure (7): Demultiplexer

Inputs			Outputs			
E	A	B	D_0	D_1	D_2	D_3
1	x	x	0	0	0	0
0	0	0	1	0	0	0
0	0	1	0	1	0	0
0	1	0	0	0	1	0
0	1	1	0	0	0	1

Table (5)

9. Combinational Circuits

A combinational circuit is a combination of logic gates. Examples are adder circuits, comparators etc., output values depend on present state only.

K-map is used to simplify the logic.

Figure shows K-map for XOR gate.

B \ A	0	1
0	0	1
1	0	1

Figure (12): XOR Gate K Map

10. Sequential Circuits

Sequential circuit has memory element output value depends on present and past inputs. A combinational circuit with memory forms a sequential circuit. Synchronous and asynchronous sequential circuits are the two kinds of sequential circuits. Figure (13) represents a sequential circuit.

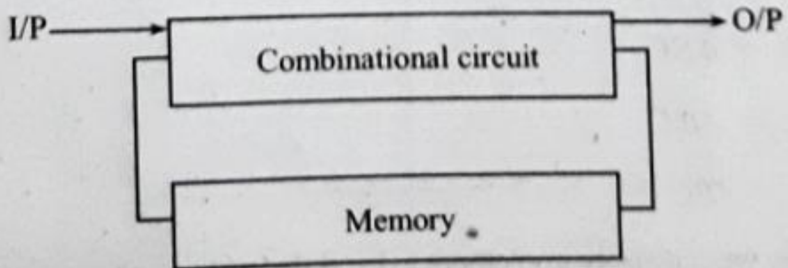

Figure (13): Sequential Circuit

Figure (13): Sequential Circuit