Digital Electronics

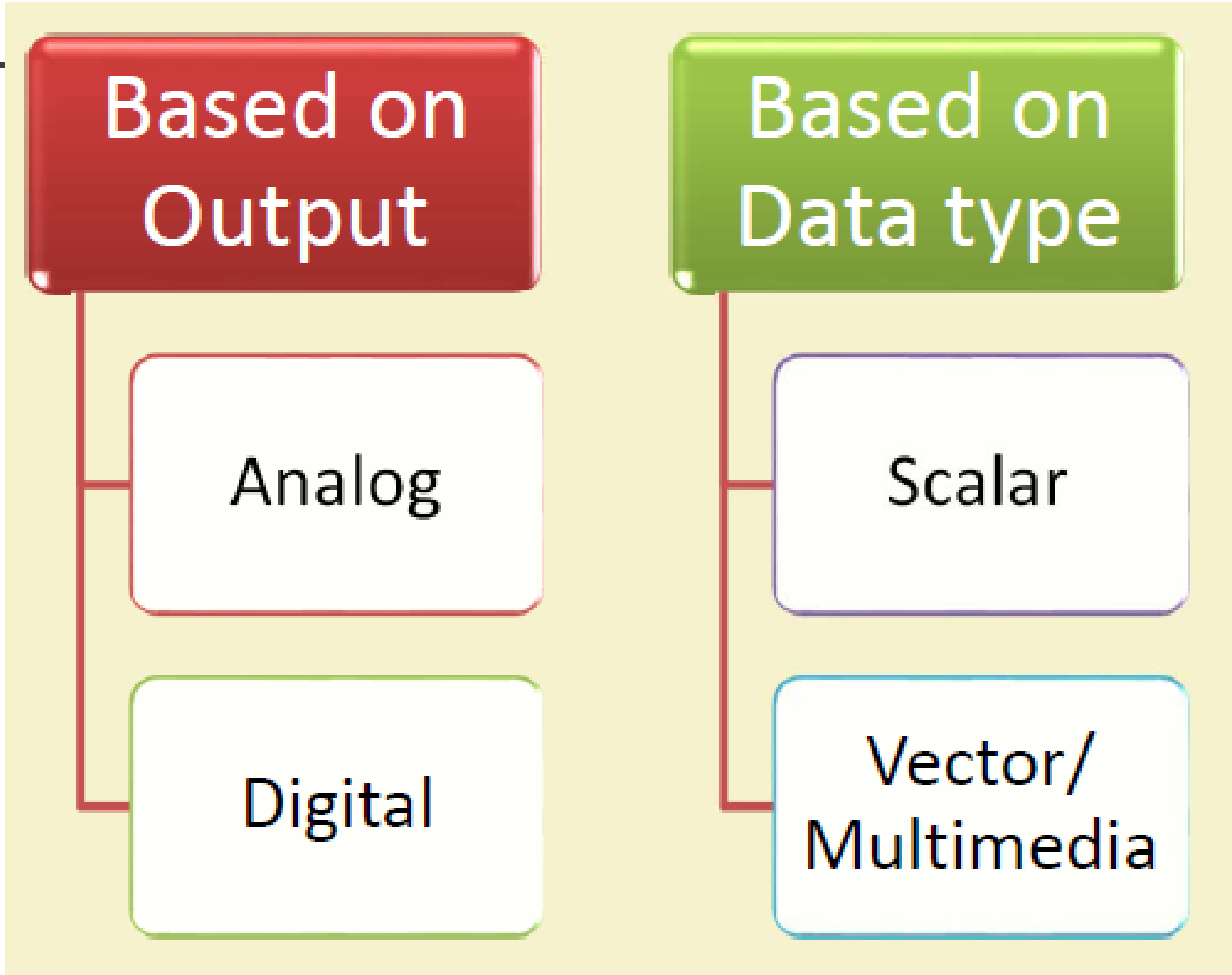
(Second Year B. Tech program in Computer Engineering)

Introduction to Sensors

- A sensor is a device, module, machine, or subsystem that detects events or changes in its environment and sends the information to other electronic devices.
- Sensor is the device which changes physical parameter to electrical signal.
- Sensors are applied to input port to take the input.
- People use sensors to measure temperature, gauge distance, detect smoke, regulate pressure and several other purposes.
- Different types of sensors are temperature & humidity, pressure, touch, sound, soil & moisture, ultrasonic, IR sensor etc.

Introduction to Sensors

Types of Sensors



Types of Sensors (Based on Output)

- Analog Sensors produce a continuous output signal or voltage which is generally proportional to the quantity being measured.

- Physical quantities such as Temperature, Speed, Pressure, Displacement, Strain etc. are all analog quantities as they tend to be continuous in nature.

- For example, the temperature of a liquid can be measured using a thermometer or thermocouple (e.g. in geysers) which continuously responds to temperature changes as the liquid is heated up or cooled down.

Types of Sensors (Based on Output)

- Digital Sensors produce discrete digital output signals or voltages that are a digital representation of the quantity being measured.

- Digital sensors produce a binary output signal in the form of a logic "1" or a logic "0", ("ON" or "OFF").

- Digital signal only produces discrete (non-continuous) values, which may be output as a single "bit" (serial transmission), or by combining the bits to produce a single "byte" output (parallel transmission).

Types of Sensors (Based on Data Type)

- Scalar Sensors produce output signal or voltage which is generally proportional to the magnitude of the quantity being measured.

- Physical quantities such as temperature, color, pressure, strain, etc. are all scalar quantities as only their magnitude is sufficient to convey an information.

- For example, the temperature of a room can be measured using a thermometer or thermocouple, which responds to temperature changes irrespective of the orientation of the sensor or its direction.

Types of Sensors (Based on Data Type)

- Vector Sensors produce output signal or voltage which is generally proportional to the magnitude, direction, as well as the orientation of the quantity being measured.

- Physical quantities such as sound, image, velocity, acceleration, orientation, etc. are all vector quantities, as only their magnitude is not sufficient to convey the complete information.

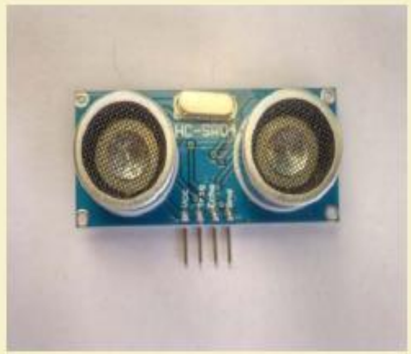
- For example, the acceleration of a body can be measured using an accelerometer, which gives the components of acceleration of the body with respect to the x,y,z coordinate axes.

Types of Sensors

Light	• Light Dependent resistor • Photo-diode
Temperature	• Thermocouple • Thermistor
Force	• Strain gauge • Pressure switch
Position	• Potentiometer, Encoders • Opto-coupler
Speed	• Reflective/ Opto-coupler • Doppler effect sensor
Sound	• Carbon Microphone • Piezoelectric Crystal
Chemical	• Liquid Chemical sensor • Gaseous chemical sensor

Examples of Sensors

Pressure Sensor
Source: Wikimedia Commons

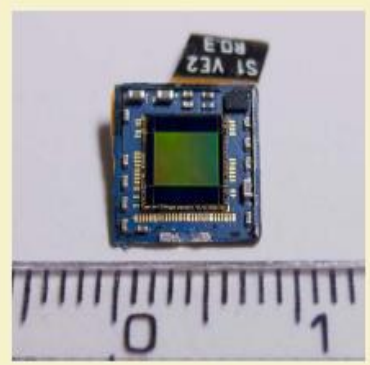


Ultrasonic Distance Sensor
Source: Wikimedia Commons

Tilt Sensor
Source: Wikimedia Commons

Infrared Motion Sensor
Source: Wikimedia Commons

Analog Temperature Sensor
Source: Wikimedia Commons



Camera Sensor
Source: Wikimedia Commons

SENSOR	ACTUATOR
A device that detects events or changes in the environment and sends that information to other electronic devices	A component of a machine that is responsible for moving and controlling mechanism
Connected to the input ports of the system	Connected to the output ports of the system
Help to monitor the changes in the environment	Helps to control the environment or physical changes
Output is an electrical signal	Output is a movement
Ex: biosensors, image sensors, motion sensors, chemical sensors	Ex: electric motors, stepper motors, comb drives, and hydraulic cylinders

Programming Logic Devices (PLDs)

Fixed Function ICs:

Advantages :

- Low development cost
- Fast turn around of design
- Relatively easy to test the circuit

Disadvantages :

- Large board space requirement
- Large power requirement
- Lack of security i.e. the circuit can be copied by others
- Additional cost, space, power requirements etc. required to modify the design or to introduce more features.

Programming Logic Devices (PLDs)

Application Specific Integrated Circuits (ASICs) :

Advantages :

- Reduce space requirement
- Reduce power requirement
- If produce in large volume, cost is considerably reduced
- Large reduction in size through the use of high level of integration
- Design implemented in this form are almost impossible to copy

Disadvantages :

- Initial development cost may be enormous
- Testing methods may have to be developed which may also increase the cost and efforts.

Programmable Logic Devices (PLDs) :

Advantages of fixed function ICs :

- Short design cycle
- Low development cost

Advantages over fixed function ICs :

- Reduction in board space requirement
- Reduction in power requirement
- Design security
- Compact circuitry
- Higher switching speed

Advantages of ASICs :

- Reduction in board space requirement
- Reduction in power requirement
- Design security
- Lower quantity production cost
- Higher densities

Programming Logic Arrays (PLAs)

- A Programmable Logic Device (PLD) usually consist of programmable array of logic gates and interconnections with array inputs and outputs connected to the device pins through fixed logic elements, such as inverting/non-inverting buffers and FLIP-FLOPs.
- The logic gates used may be two-level AND-OR, NAND-NAND or NOR-NOR configuration. In some cases, AND-OR-EX-OR configuration is also used.
- Basically, there are two types of PLDs:

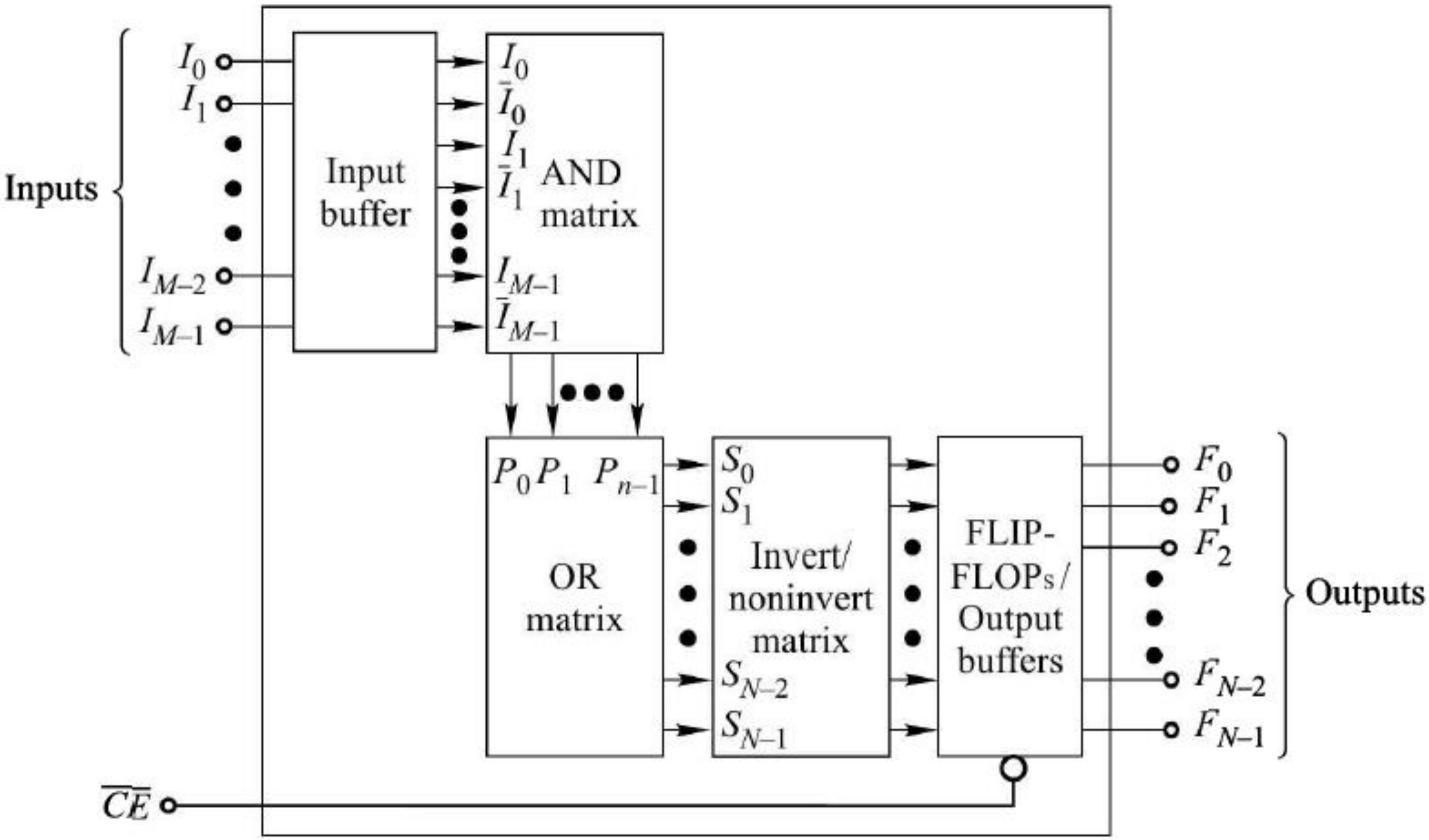
1. Programmable Logic Array (PLA)
2. Programmable Array Logic (PAL)

Programming Logic Arrays (PLAs)

- PLAs can be used to implement combinational and sequential logic circuits.
- PLA consist of two level AND-OR circuit on single chip.
- The number of AND gates and OR gates and their inputs are fixed for a given PLA chip.
- The AND gates are used to form the product terms and the OR gates are used to produce the logical sum of product terms and thereby generates logical expression in SOP form.
- It has M inputs, n product terms and N outputs with $n < 2^M$ and can be used to implement a logic function of M variables with N outputs.
- The PLA contains NOT, AND and OR gates fabricated on the chip. It passes every input by a NOT gate which makes each input and its complement available to every AND gate.
- The output of each AND gate is given to the each OR gate. At last, the OR gate output produces chip output.

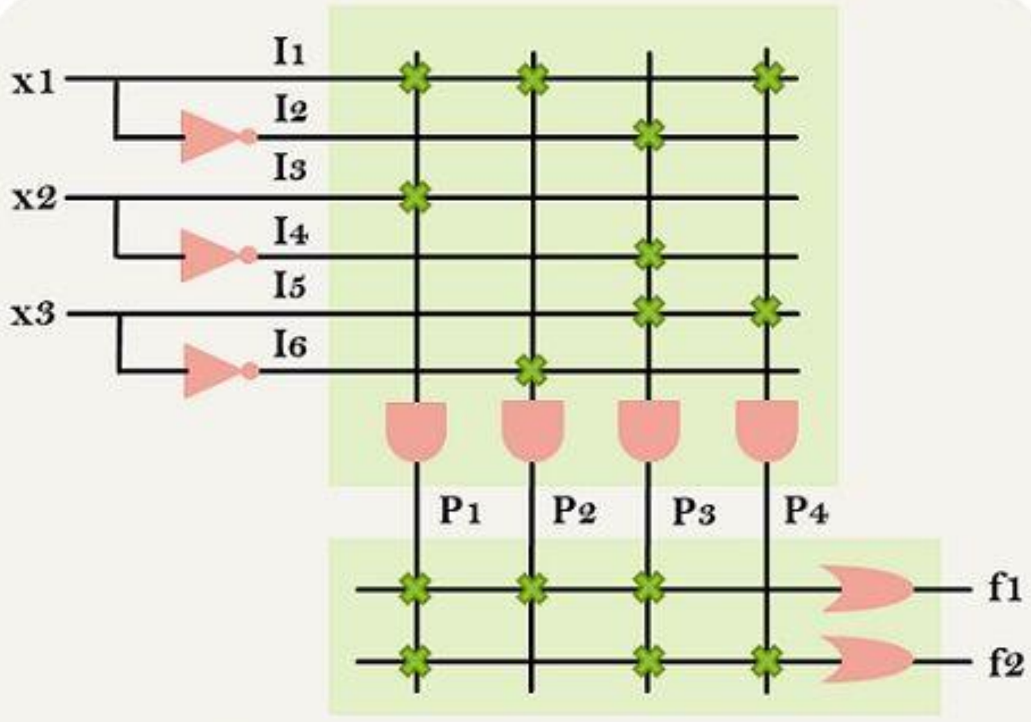
Programming Logic Arrays (PLAs)

The internal architecture of a PLA is shown in block diagram



Block Diagram of a PLA Device

Programming Logic Arrays (PLAs)



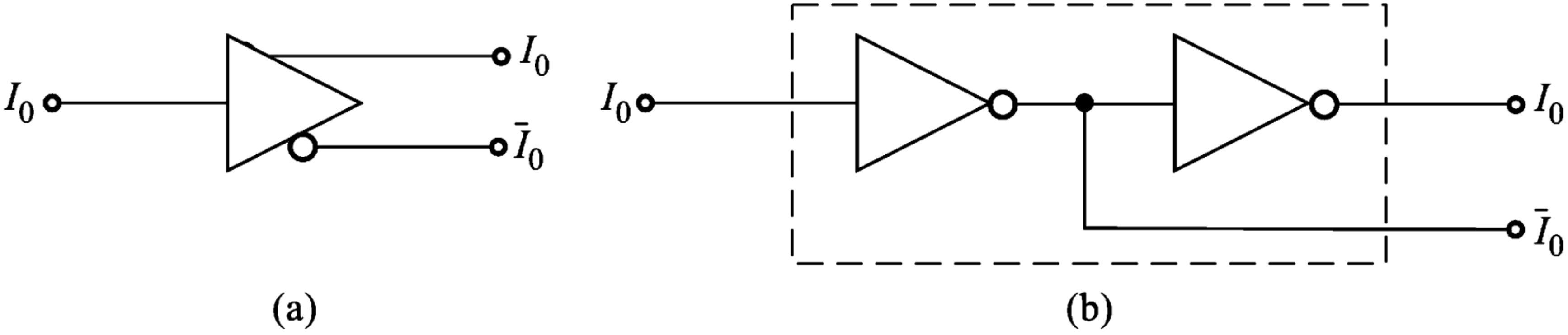
$$f_1 = x_1x_2 + x_1x'_3 + x'_1x'_2x_3$$

$$f_2 = x_1x_2 + x'_1x'_2x_3 + x_1x_3$$

Programmable Logic Array

Programming Logic Arrays (PLAs)

Input Buffers – Basically buffers at the input are **used to reduce the loading of the sources**. The buffer generates the inverted and non-inverted input as its output. Input buffers are basically a combination of NOT gates.



An Input Buffers

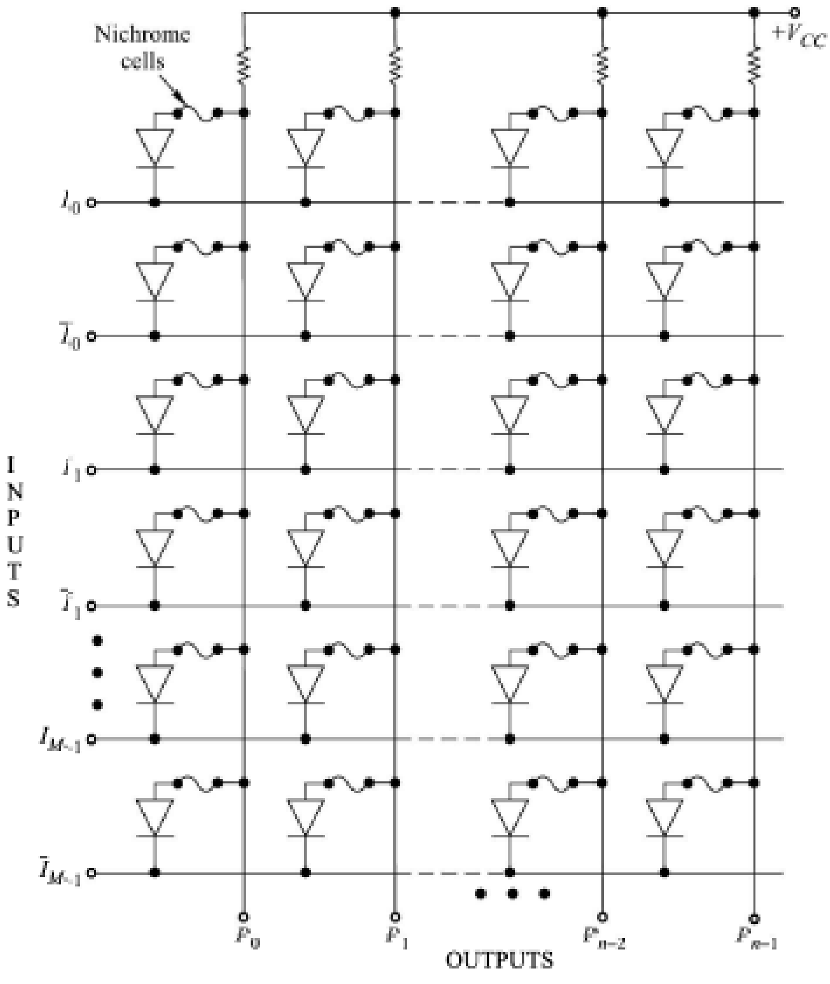
Programming Logic Arrays (PLAs)

AND Matrix– It is used to form a product terms. It has n AND gates with outputs P_0 to P_{n-1} and 2M inputs (I_0 to I_{M-1} and I'_0 to I'_{M-1} for each AND gate. This shows that each AND gate has all the input variables in complemented and Uncomplemented form.

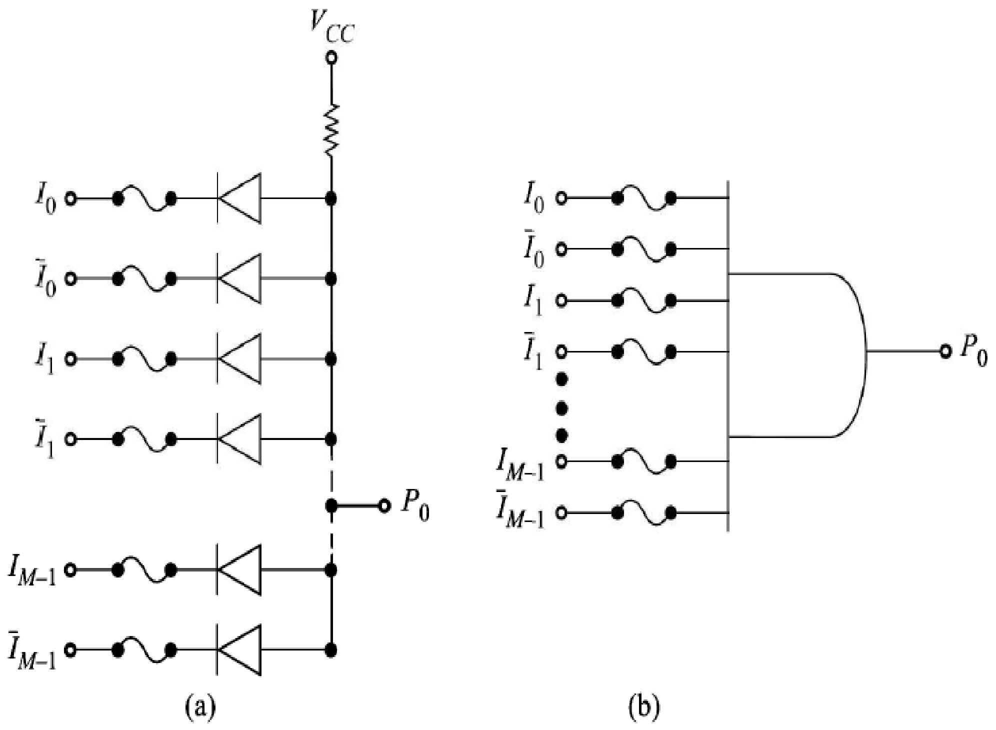
Each AND gate generates one product term which is given by

$$P = I_0 \cdot \bar{I}_0 \cdot I_1 \cdot \bar{I}_1 \ldots I_{M-1} \cdot \bar{I}_{M-1}$$

Programming Logic Arrays (PLAs)

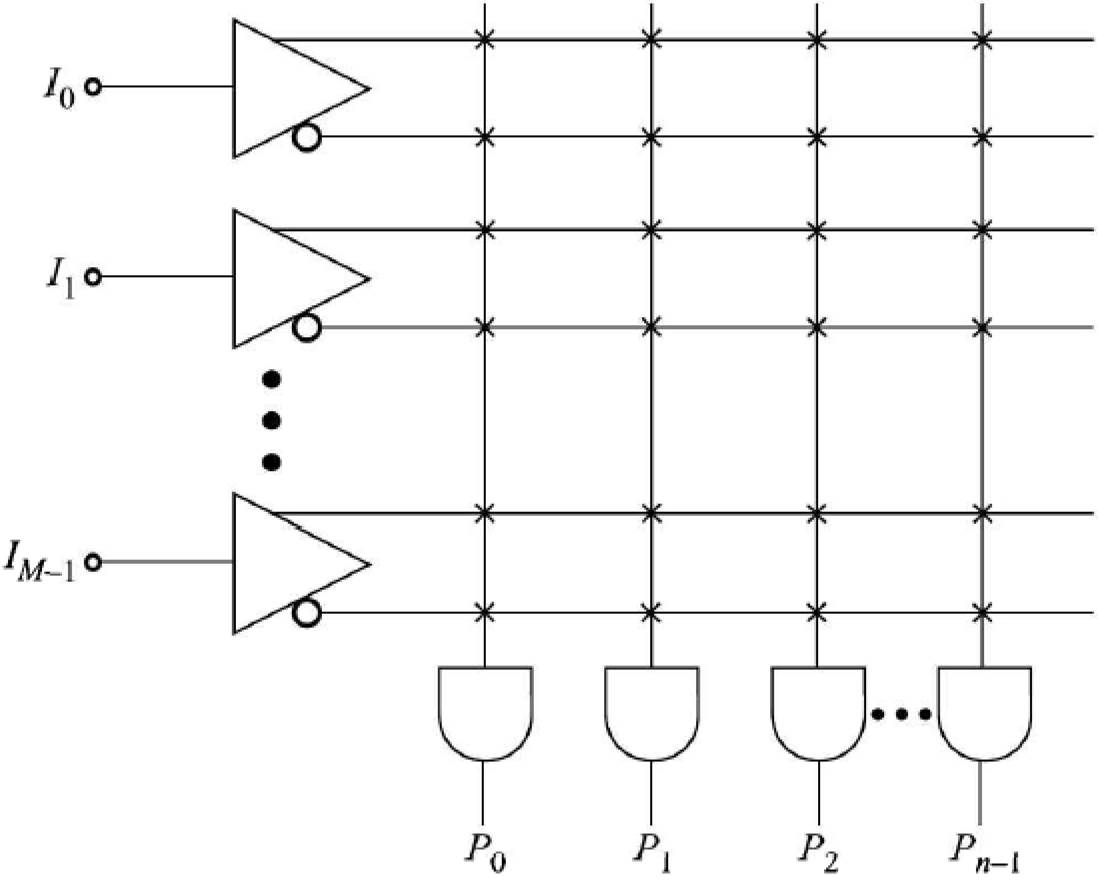


An AND *Matrix*



A Section of the AND *Matrix*

Programming Logic Arrays (PLAs)

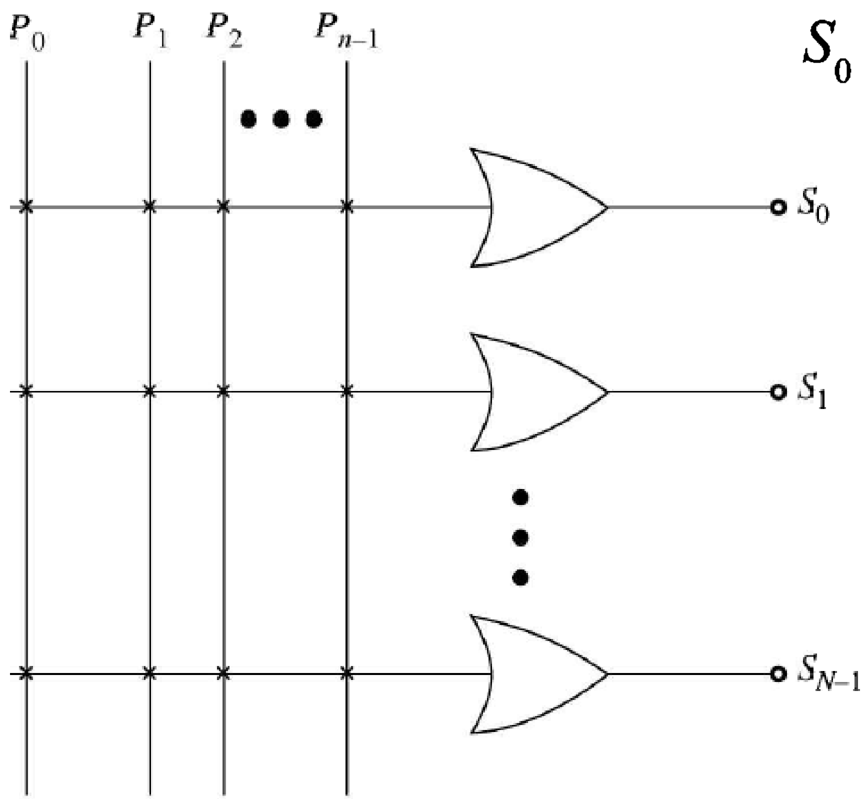


Representation of Input Buffers and* AND *Matrix

Programming Logic Arrays (PLAs)

OR Matrix– It is used to produce the logical sum of product terms outputs of AND matrix.

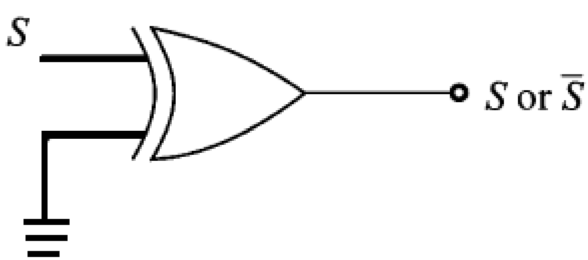
$$S_0 = P_0 + P_1 + \ldots + P_{n-1}$$

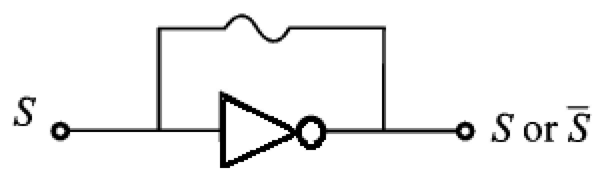


Representation of* OR *Matrix

Programming Logic Arrays (PLAs)

Inverting / Non Inverting Matrix – This is programmable buffer that can be set for **Inverting** and **Non Inverting** operations corresponding to active-low or active-high output, respectively.

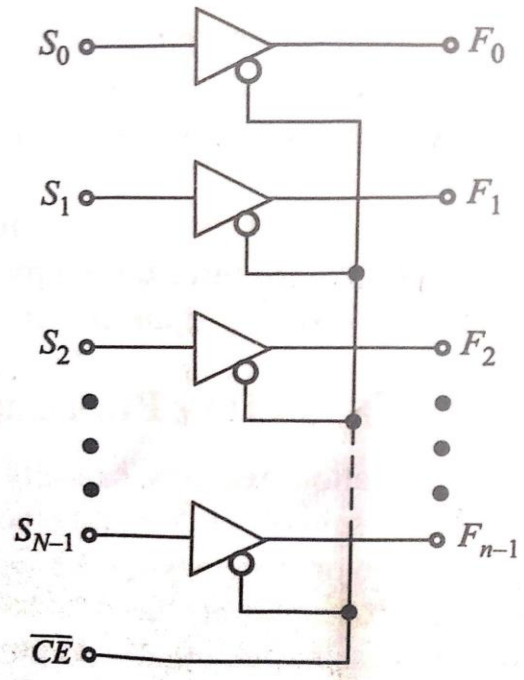




Inverting and Non Inverting Circuits

Programming Logic Arrays (PLAs)

Output Buffer – Output buffers are required to increase the driving capability of the PLA. Usually, the outputs are TTL compatible. The outputs may be totem-pole, open- collector, or three-state.

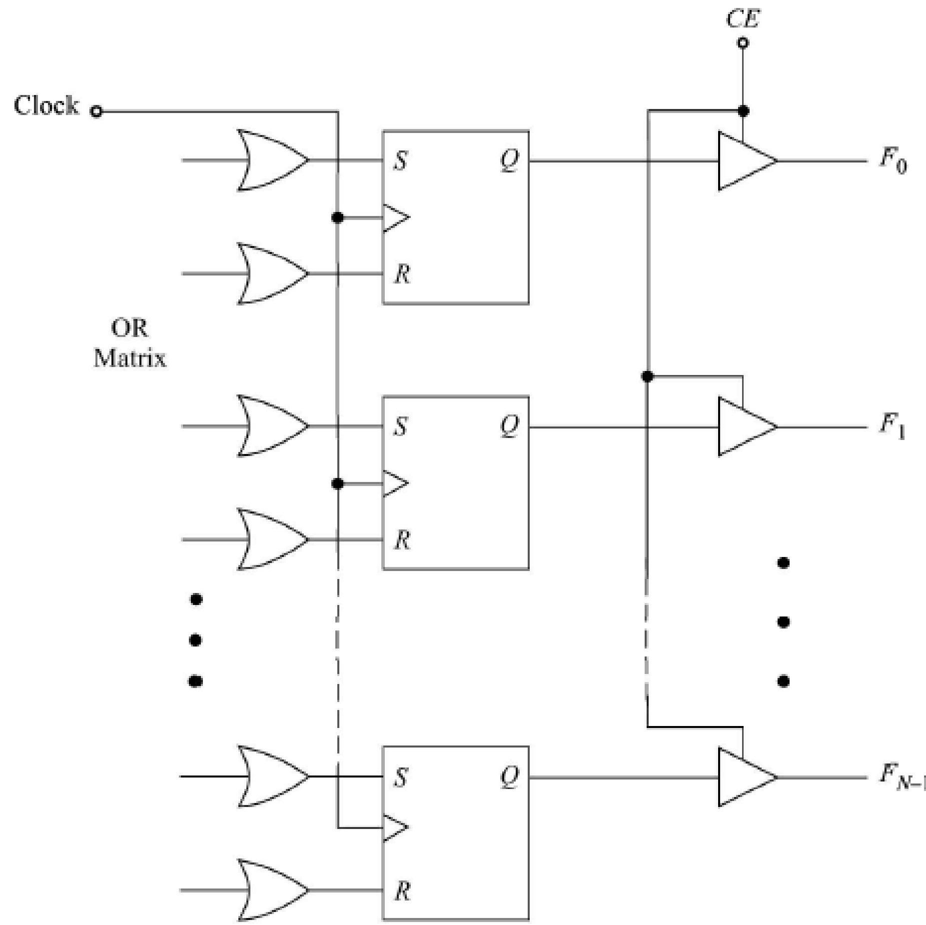


Output Buffers

Programming Logic Arrays (PLAs)

Output through FLIP-FLOPs and Buffers – PLA device suitable for state machine applications have FLIP-FLOPs and buffer in the output circuitry.

In this positive-edge triggered S-R FFs are connected at the outputs of the OR gates and the device outputs are available through tristate buffers.



A Section of PLA with FLIP-FLOPs *in the Output*

Programming Logic Arrays (PLAs)

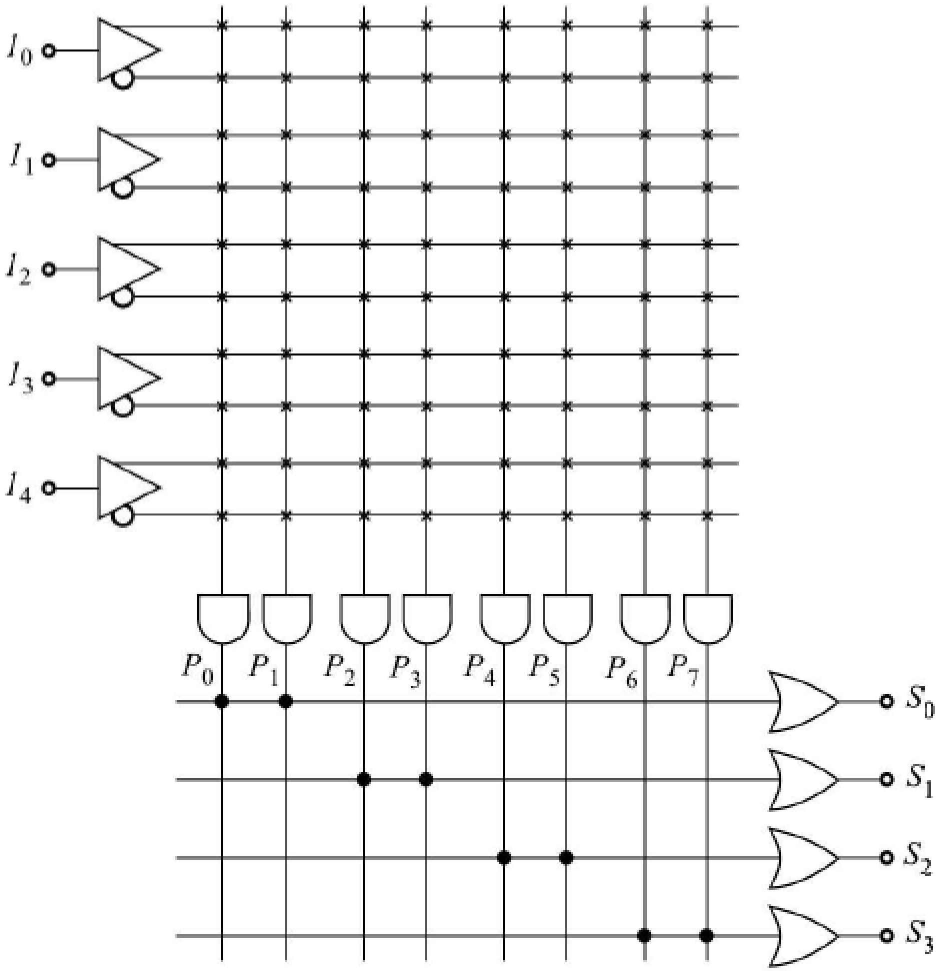
Steps for implementing combinational logic circuits:

1. Prepare the truth table.
2. Write the Boolean equations in SOP form.
3. Simplify the equations to obtain minimum SOP form. The main criterion is to minimize the number of product terms.
4. Determine the input connections of AND matrix to generate the required product terms.
5. Determine the input connections of OR matrix to generate the required sum terms.
6. Determine the connections required for INVERT/NON-INVERT matrix to set the active logic levels of the outputs.
7. Program the PLA.

Programming Array Logic (PALs)

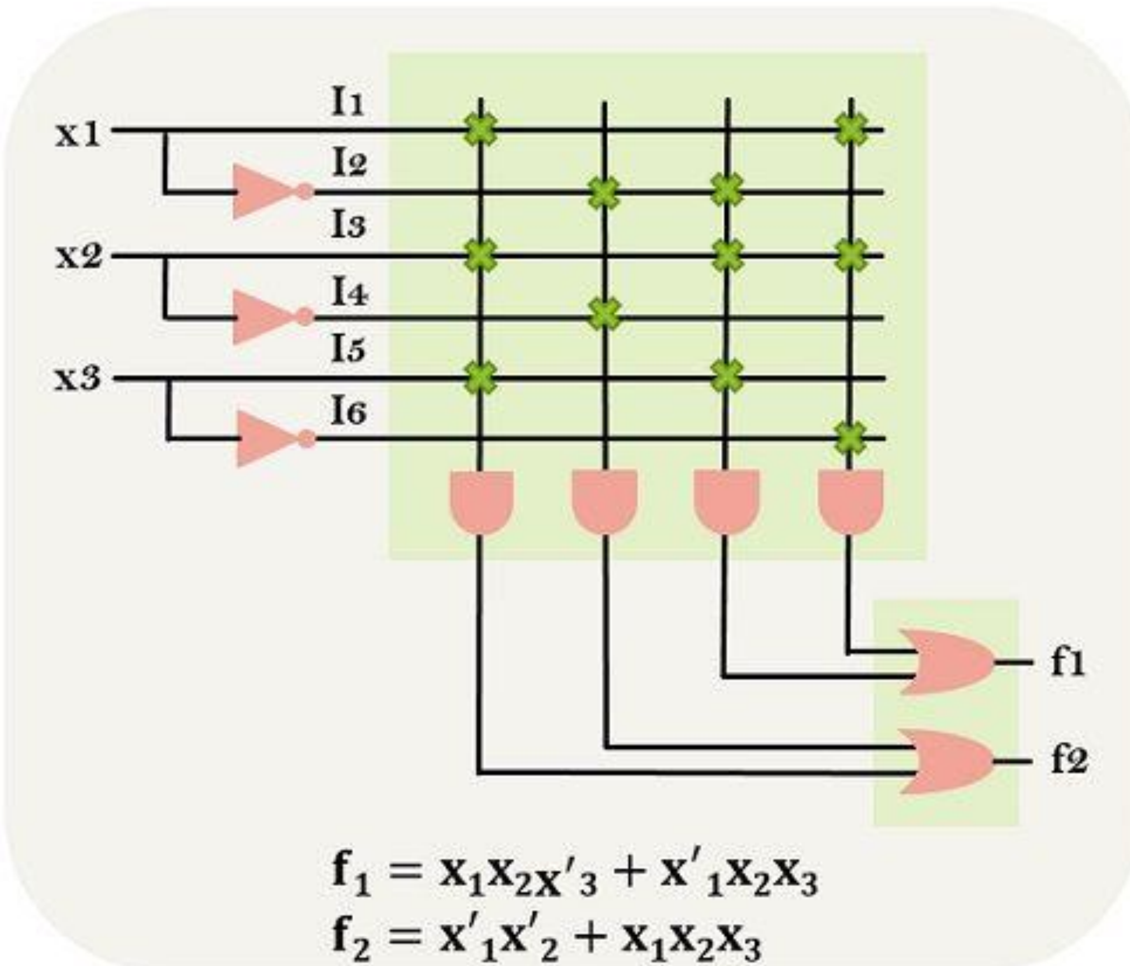
- PAL is the programmable array of logic gates on a single chip in AND-OR configuration.
- In contrast to PLA, it has programmable AND array and a fixed OR array in which some of the AND gates are connected as inputs to OR gate i.e. outputs of all AND gates are not connected to any OR gate.
- Below figure illustrates the configuration of AND and OR arrays for PAL with 5 inputs, 8 programmable AND gates and 4 fixed OR gates.
- Each AND gate has all the 10 inputs (both complemented and Uncomplemented form) with fusible links intact which can be programmed to generate 8 product terms.
- Each OR gate gets the input from the outputs of only two AND gates shown by ●
- Input and output circuits of PALs are similar to those of PLAs.
- The number of fusible links in a PAL is the product of 2M and n, where M is the number of input variable and n is the number of product terms.

Programming Array Logic (PALs)



Programmable Array Logic

Programming Array Logic (PALs)



Programmable Array Logic

PLAs Vs PALs

BASIS FOR COMPARISON	PLA	PAL
Stands for	Programmable Logic Array	Programmable Array Logic
Construction	Programmable array of AND and OR gates.	Programmable array of AND gates and fixed array of OR gates.
Availability	Less prolific	More readily available
Flexibility	Provides more programming flexibility.	Offers less flexibility, but more likely used.
Cost	Expensive	Intermediate cost
Number of functions	Large number of functions can be implemented.	Provides the limited number of functions.
Speed	Slow	High