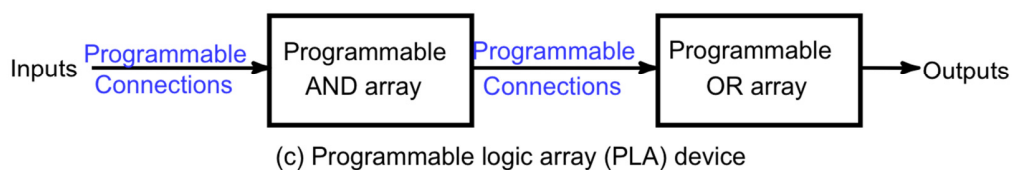
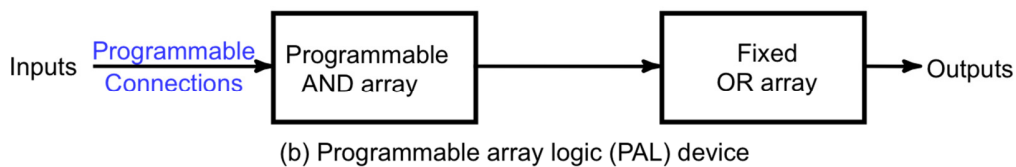
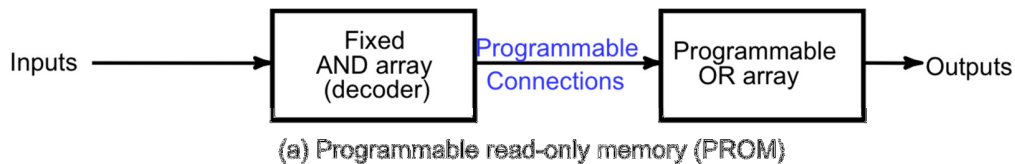


PROGRAMMABLE LOGIC DEVICES

- **Read Only Memory (ROM)** - a fixed array of AND gates and a programmable array of OR gates
- **Programmable Array Logic (PAL)** - a programmable array of AND gates feeding a fixed array of OR gates.
- **Programmable Logic Array (PLA)** - a programmable array of AND gates feeding a programmable array of OR gates.
- **Complex Programmable Logic Device (CPLD) / Field- Programmable Gate Array (FPGA)** - complex enough to be called “architectures”



READ ONLY MEMORY

- Read Only Memories (ROM) or Programmable Read Only Memories (PROM) have:
 - N input lines,
 - M output lines, and
 - 2^N decoded minterms.
- Fixed AND array with 2^N outputs implementing all N-literal minterms.
- Programmable OR Array with M outputs lines to form up to M sum of minterm expressions.
- A program for a ROM or PROM is simply a multiple-output truth table
 - If a 1 entry, a connection is made to the corresponding minterm for the corresponding output
 - If a 0, no connection is made
- Can be viewed as a *memory* with the inputs as *addresses of data* (output values), hence ROM or PROM names!

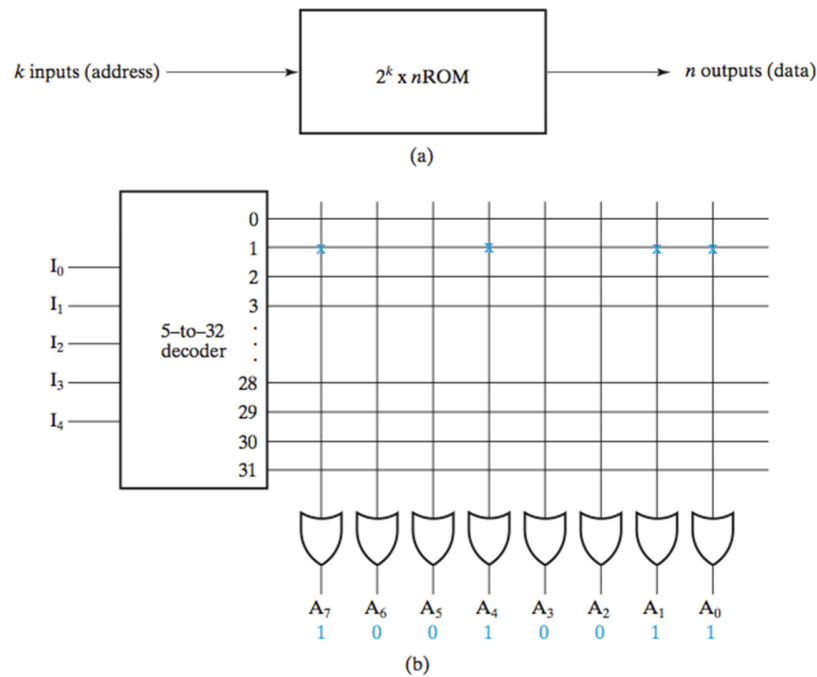
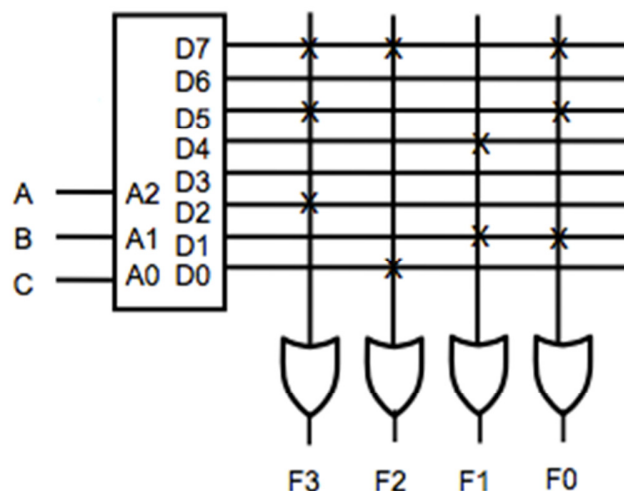


Figure: Block diagram and Internal Logic of a ROM

- Depending on the programming technology and approaches, read-only memories have different names
 1. ROM – mask programmed
 2. PROM – fuse or antifuse programmed
 3. EPROM – erasable floating gate programmed
 4. EEPROM or E²PROM – electrically erasable floating gate programmed
 5. FLASH memory: electrically erasable floating gate with multiple erasure and programming modes.
- Example: A 8 X 4 ROM (N = 3 input lines, M= 4 output lines)
 - The fixed "AND" array is a "decoder" with 3 inputs and 8 outputs implementing minterms.
 - The programmable "OR" array uses a single line to represent all inputs to an OR gate. An "X" in the array corresponds to attaching the minterm to the OR
 - Read Example: For input $(A_2, A_1, A_0) = 011$, output is $(F_3, F_2, F_1, F_0) = 0011$.
 - What are functions F_3, F_2, F_1 and F_0 in terms of (A_2, A_1, A_0) ?



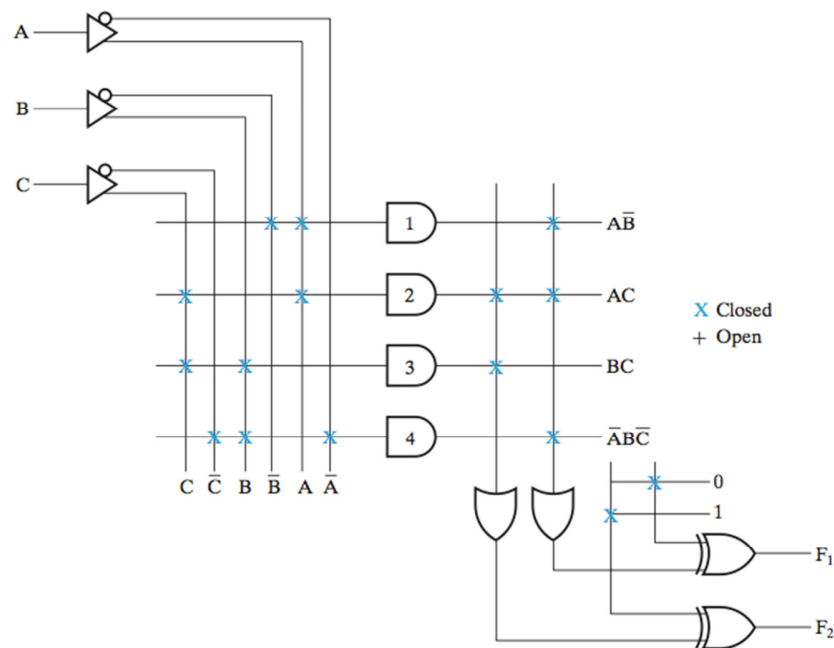
PROGRAMMABLE LOGIC ARRAY (PLA)

- Compared to a ROM and a PAL, a PLA is the most flexible having a programmable set of ANDs combined with a programmable set of ORs.
- Advantages
 - A PLA can have large N and M permitting implementation of equations that are impractical for a ROM (because of the number of inputs, N, required)
 - A PLA has all of its product terms connectable to all outputs, overcoming the problem of the limited inputs to the PAL Ors
 - Some PLAs have outputs that can be complemented, adding POS functions
- Disadvantages
 - Often, the product term count limits the application of a PLA.
 - Two-level multiple-output optimization is required to reduce the number of product terms in an implementation, helping to fit it into a PLA.
 - Multi-level circuit capability available in PAL not available in PLA. PLA requires external connections to do multi-level circuits.

Programmable Logic Array Example

$$F_1 = AB' + AC + A'BC'$$

$$F_2 = (AC + BC)'$$

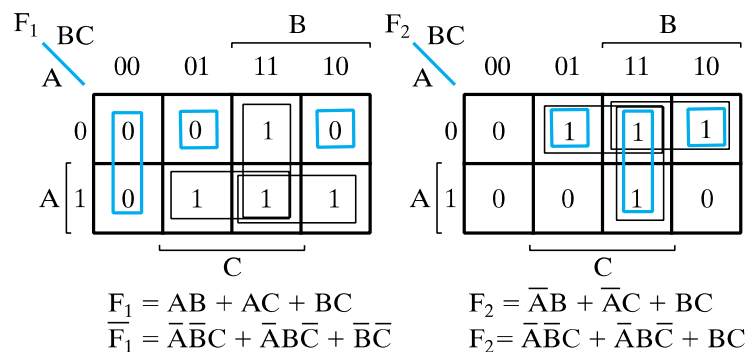


- What are the equations for F₁ and F₂?
- Could the PLA implement the functions without the XOR gates?
- 3-input, 3-output PLA with 4 product terms

Example 6-3 from Mano: Implementing a Combinational Circuit Using a PLA

$$F_1(A,B,C) = \Sigma m(3,5,6,7)$$

$$F_2(A,B,C) = \Sigma m(1,2,3,7)$$



The solution is:

$$F_1 = \overline{A}\overline{B}C + \overline{A}B\overline{C} + \overline{B}\overline{C}$$

$$F_2 = \overline{A}\overline{B}C + \overline{A}B\overline{C} + BC$$

PROGRAMMABLE ARRAY LOGIC (PAL)

- The PAL is the opposite of the ROM, having a programmable set of ANDs combined with fixed ORs.
- Disadvantage
 - ROM guaranteed to implement any M functions of N inputs. PAL may have too few inputs to the OR gates.
- Advantages
 - For given internal complexity, a PAL can have larger N and M
 - Some PALs have outputs that can be complemented, adding POS functions
 - No multilevel circuit implementations in ROM (without external connections from output to input). PAL has outputs from OR terms as internal inputs to all AND terms, making implementation of multi-level circuits easier.

Programmable Array Logic Example

- 4-input, 3-output PAL with fixed, 3-input OR terms
- What are the equations for F1 through F4?

$$W(A,B,C,D) = \Sigma m(2,12,13)$$

$$X(A,B,C,D) = \Sigma m(7,8,9,10,11,12,13,14,15)$$

$$Y(A,B,C,D) = \Sigma m(0,2,3,4,5,6,7,8,10,11,15)$$

$$Z(A,B,C,D) = \Sigma m(1,2,8,12,13)$$

Simplifying the four function to a minimum number of terms results in the following Boolean functions

$$W = ABC' + A'B'CD'$$

$$X = A + BCD$$

$$Y = A'B + CD + B'D'$$

$$Z = ABC' + A'B'CD' + AC'D' + A'B'C'D = W + AC'D' + A'B'C'D$$

