

CSE 140 Lecture 11

Standard Combinational Modules

CK Cheng
CSE Dept.
UC San Diego

1

Part III - Standard Combinational Modules

- Introduction
- Decoder
 - Behavior, Logic, Usage
- Encoder
- Multiplexer (Mux)
 - Behavior, Logic, Usage
- Demultiplexier (DeMux)

2

Part III - Standard Combinational Modules

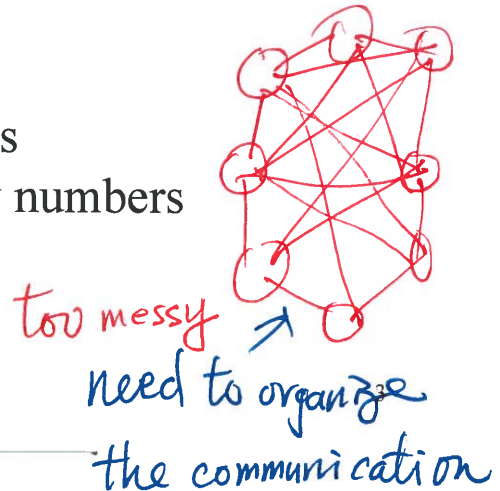
Signal Transport

- Decoder: Decode address
- Encoder: Encode address
- Multiplexer (Mux): Select data by address
- Demultiplexier (DeMux): Direct data by address
- Shifter: Shift bit location

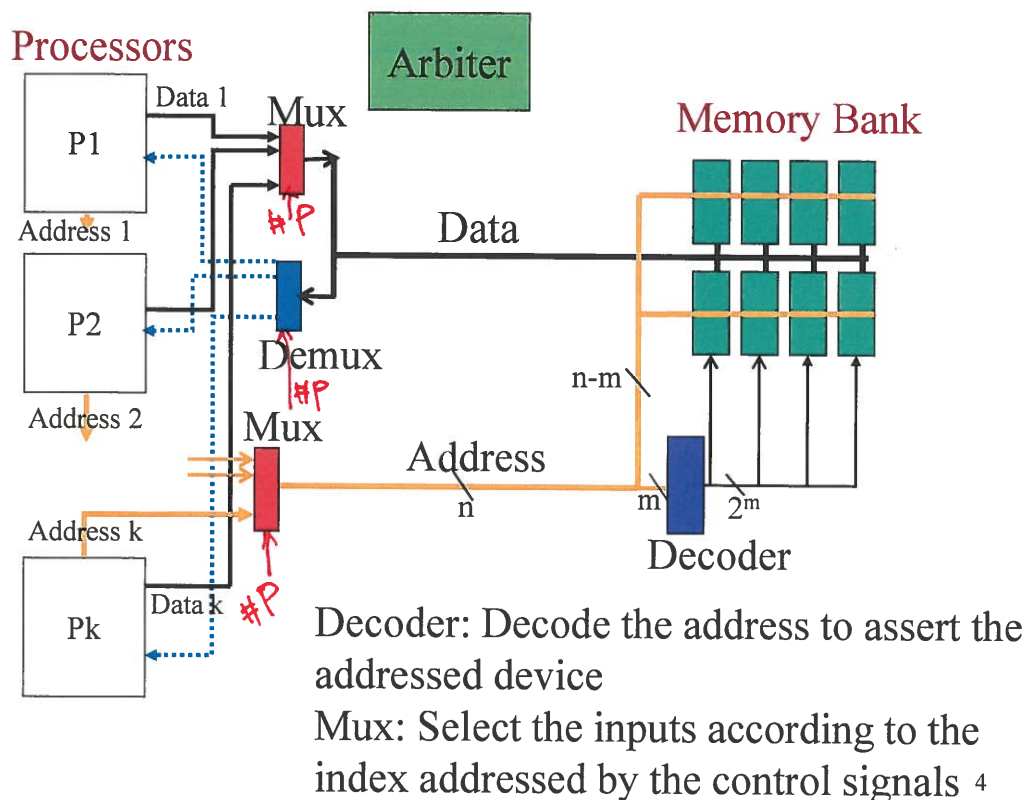
Data Operator

- Adder: Add two binary numbers
- Multiplier: Multiply two binary numbers

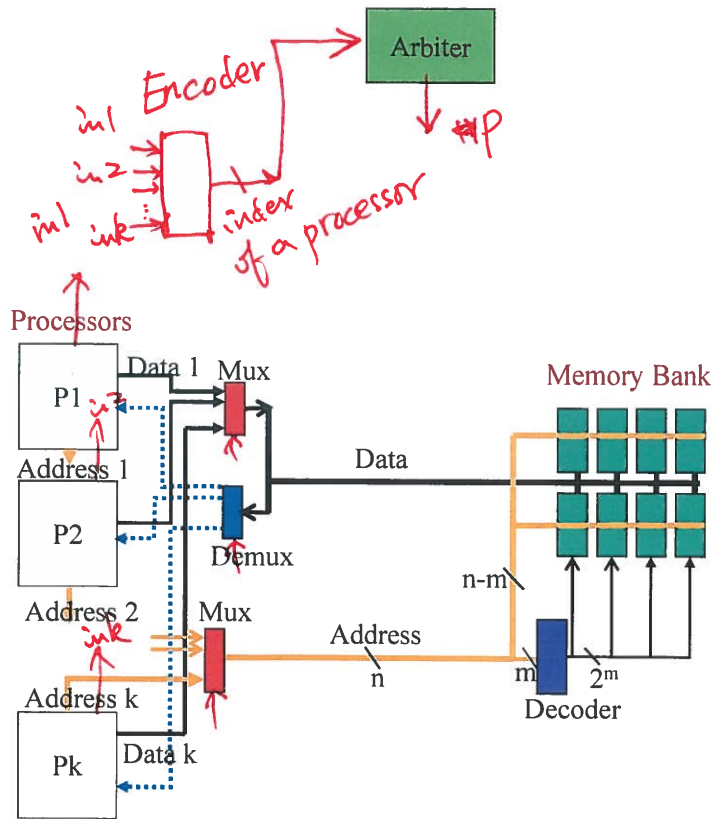
AIU, FFT, Image Conv.



Interconnect: Decoder, Encoder, Mux, DeMux



Interconnect: Decoder, Encoder, Mux, DeMux



5

1. Decoder

- Definition
- Logic Diagram
- Application (Universal Set)
- Tree of Decoders

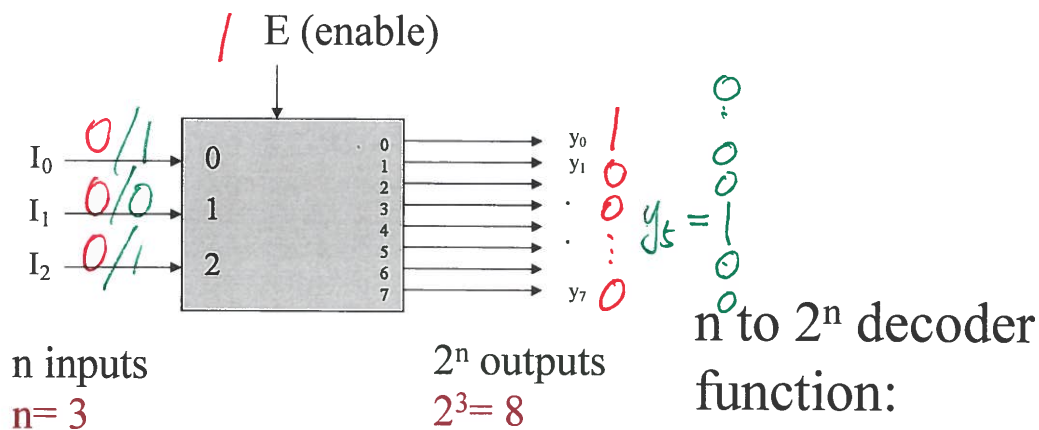
6

Decoder: Definition

- A. A device that decodes
- B. An electronic device that converts signals from one form to another
- C. A machine that converts a coded text into ordinary language
- D. A device or program that translates encoded data into its original format
- E. All of the above

7

Decoder Definition: A digital module that converts a binary **address** to the assertion of the addressed **device**



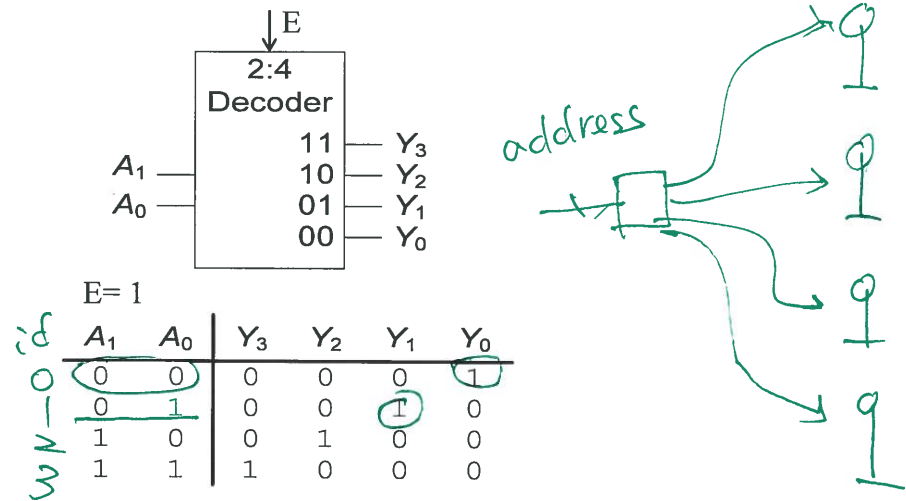
$$y_i = 1 \text{ if } E = 1 \text{ \& } (I_2, I_1, I_0) = i$$

$$y_i = 0 \text{ otherwise}$$

8

1. Decoder: Definition

- N inputs, 2^N outputs
- One-hot outputs: only one output HIGH at most



9

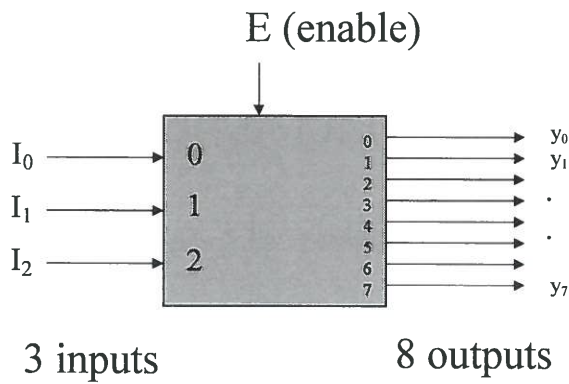
1. Decoder: Definition

Example: A 3-input decoder has how many outputs?

- A. 2 outputs
- B. 4 outputs
- C. 8 outputs
- D. 10 outputs

↓ E

Decoder Definition



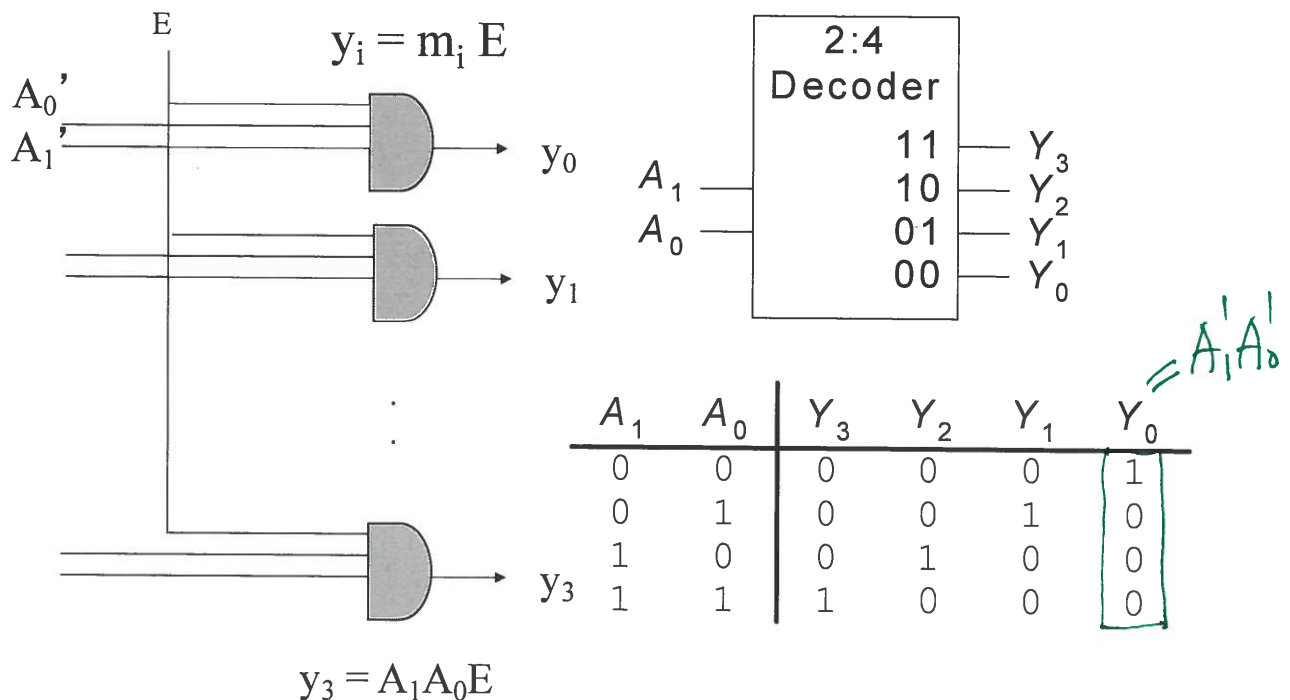
Example: For a 3-input decoder, suppose $(E, I_2, I_1, I_0) = (1, 0, 0, 0)$, then $(y_7, y_6, \dots, y_0)$ is equal to:

- A. (00000000)
- B. (00000001)
- C. (00000010)
- D. (01000000)
- E. (10000000)

11

Decoder: Logic Diagram (Inside a decoder)

$y_0 = 1$ if $(A_1, A_0) = (0, 0) \& E = 1$

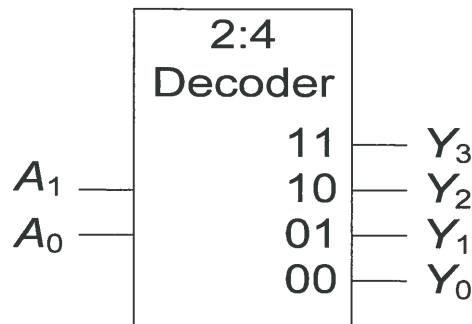


12

1. Decoder: Definition

PI Q: What is the output $Y_{3:0}$ of the 2:4 decoder for $(A_1, A_0) = (1, 0)$?

- A. (1, 1, 0, 0)
- B. (1, 0, 1, 1)
- C. (0, 0, 1, 0)
- D. (0, 1, 0, 0)



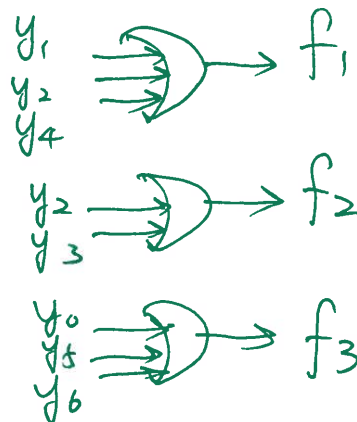
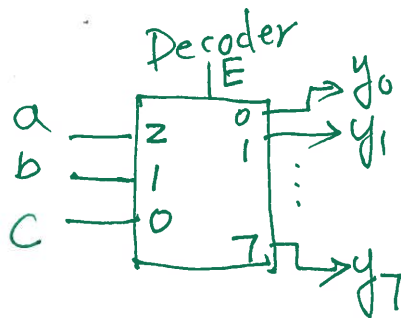
13

Decoder Application: universal set {Decoder, OR}

Example:

Implement the following functions with a 3-input decoder and OR gates.

- i) $f_1(a,b,c) = \Sigma m(1,2,4)$
- ii) $f_2(a,b,c) = \Sigma m(2,3)$
- iii) $f_3(a,b,c) = \Sigma m(0,5,6)$



14

Decoder Application: universal set {Decoder, OR}

Decoder produces minterms when $E=1$.

We can use an OR gate to collect the minterms to cover the On-set.

For the Don't Care-Set, we can just ignore the terms.

15

Decoder Application: universal set {Decoder, OR}

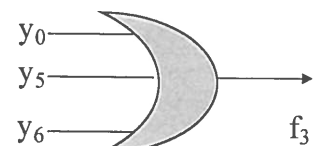
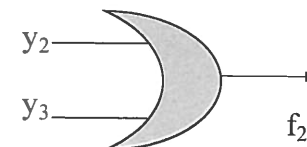
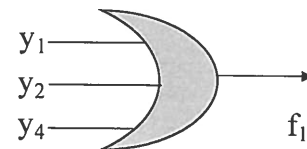
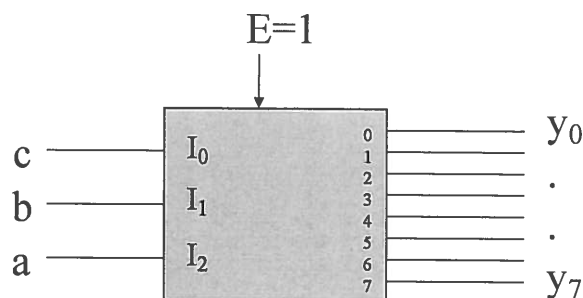
Example: Implement functions

i) $f_1(a,b,c) = \Sigma m(1,2,4) + \Sigma d(0,5)$,

ii) $f_2(a,b,c) = \Sigma m(2,3) + \Sigma d(1,4)$,

iii) $f_3(a,b,c) = \Sigma m(0,5,6)$

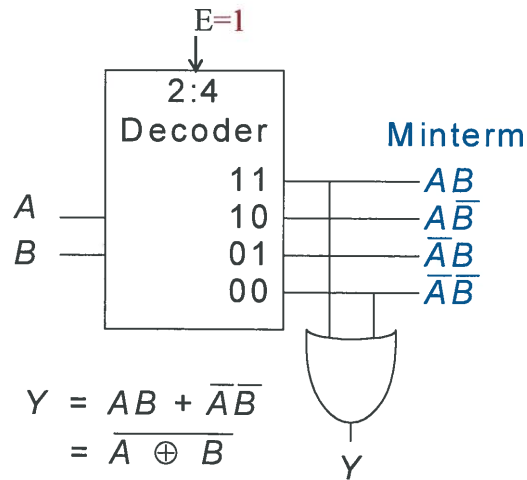
with a 3-input decoder and OR gates.



16

Decoders

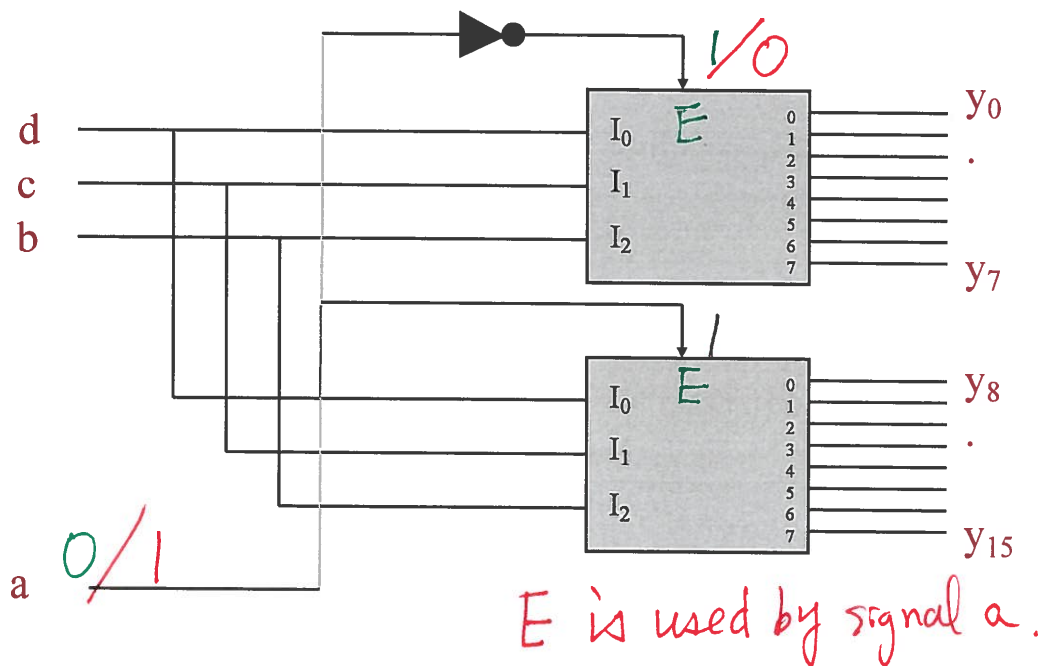
- OR minterms



17

Tree of Decoders: Scale up the size of the decoders using a tree structure

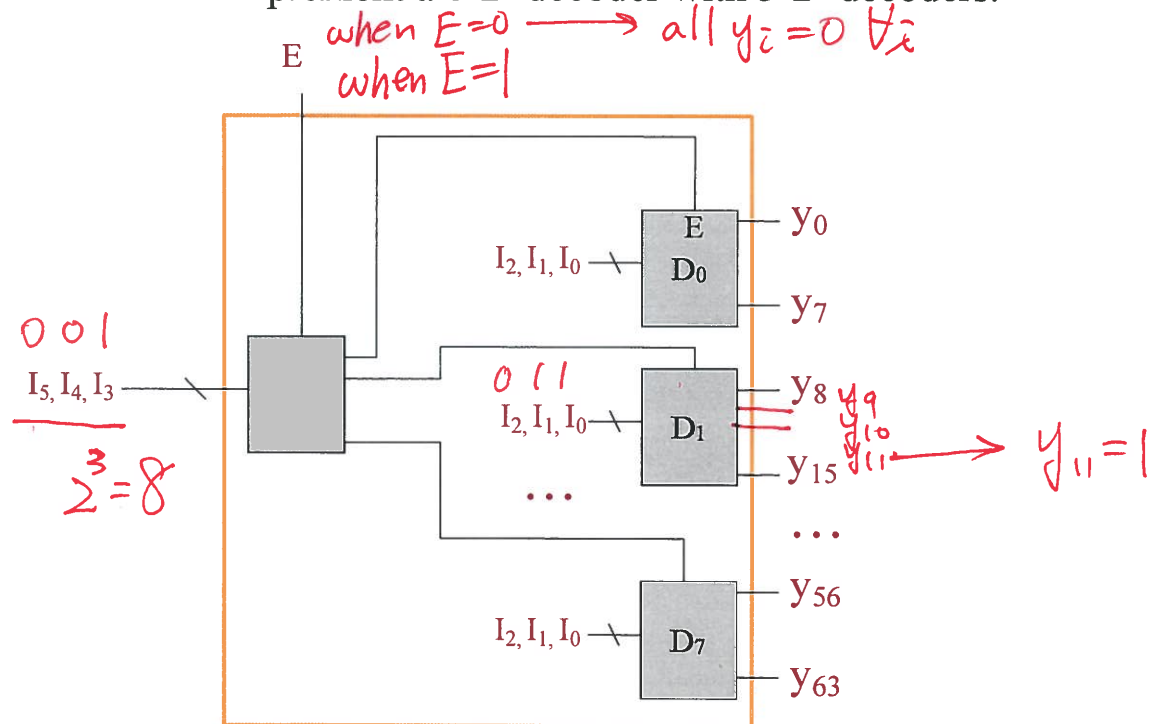
Implement a 4- 2^4 decoder with 3- 2^3 decoders.



18

Tree of Decoders

Implement a $6\text{-}2^6$ decoder with $3\text{-}2^3$ decoders.



$I_5 I_4 I_3 \quad I_2 I_1 I_0$
 $001 \quad 011$
 $32 \quad 16 \quad 8 \quad 4 \quad 2 \quad 1 \rightarrow 8+2+1 = 11$

Construction: A four variable switching function $f(a,b,c,d)$ can be implemented using which of the following?

- A. 1:2 decoders and OR gates
- B. 2:4 decoders and OR gates
- C. 3:8 decoders and OR gates
- D. All of the above
- E. None of the above

2. Encoder

- Definition
- Logic Diagram
- Priority Encoder

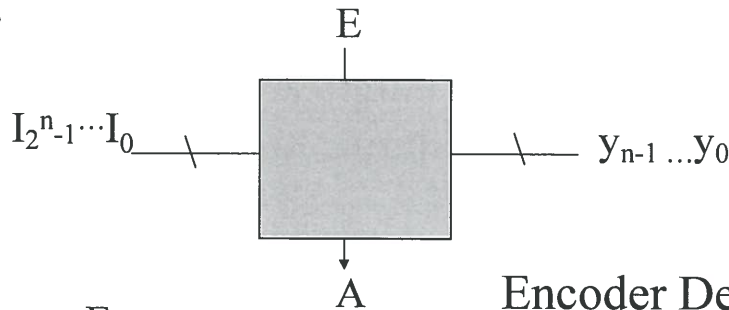
21

Definition of Encoder

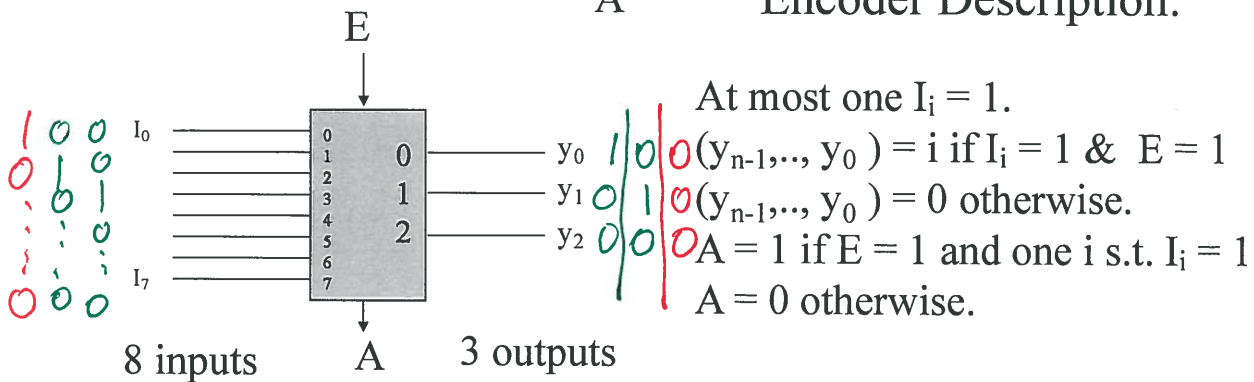
- A. Any program, circuit or algorithm which encodes
- B. In digital audio technology, an encoder is a program that converts an audio WAV file into an MP3 file
- C. A device that convert a message from plain text into code
- D. A circuit that is used to convert between digital video and analog video
- E. All of the above

22

Encoder Definition: A digital module that converts the assertion of a **device** to the binary **address** of the device.

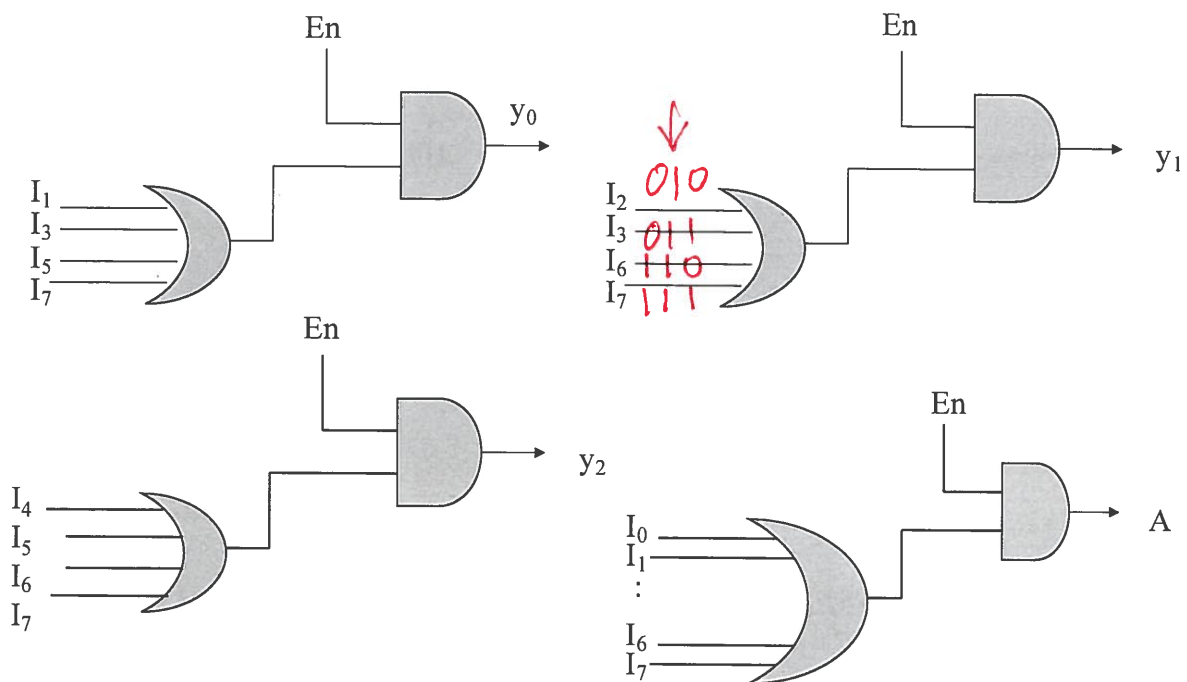


Encoder Description:



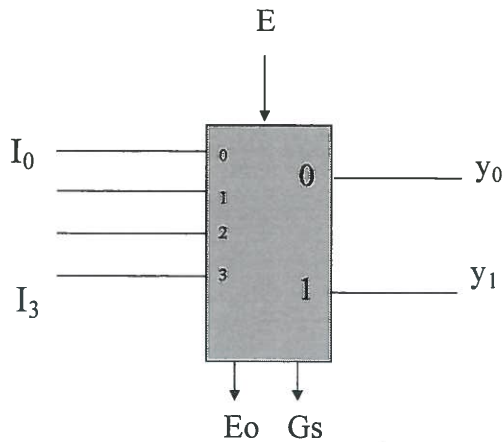
23

Encoder: Logic Diagram



24

Priority Encoder:

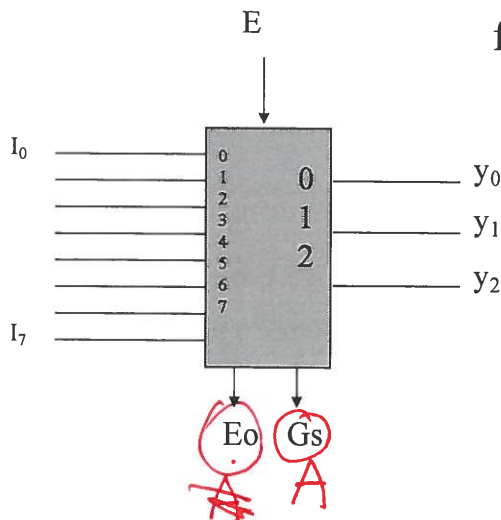


25

Priority Encoder: Definition

Description: Input $(I_{2^n-1}, \dots, I_0)$, Output $(y_{n-1}, \dots, y_0)$

$(y_{n-1}, \dots, y_0) = i$ if $I_i = 1$ & $E = 1$ & $I_k = 0$ for all $k > i$ (high bit priority) or for all $k < i$ (low bit priority).



② $E_o = 1$ if $E = 1$ & $I_i = 0$ for all i ,

③ $G_s = 1$ if $E = 1$ & $\exists i$ s.t. $I_i = 1$.

(G_s is like A, and E_o passes on enable).

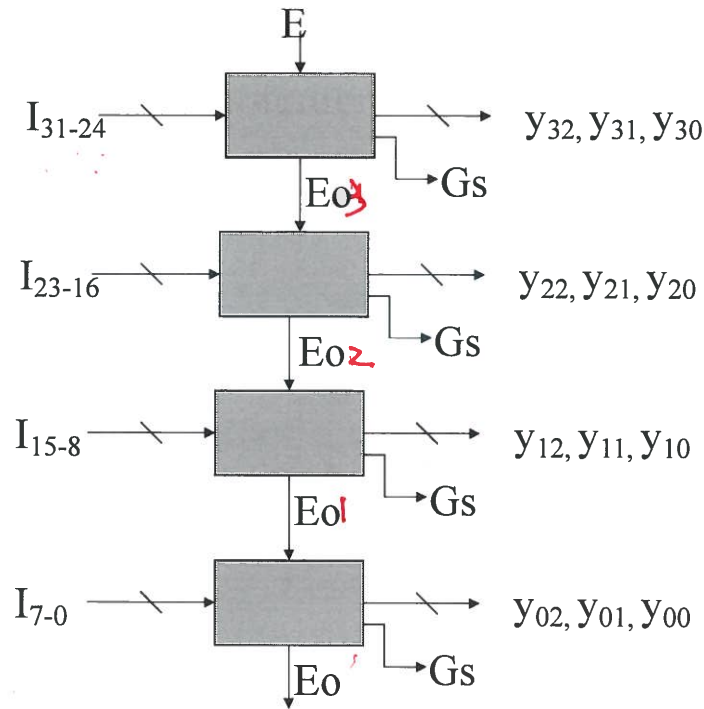
① $E = 0$

② $E = 1 \quad \forall I_i = 0$

③ $E = 1 \quad \exists i, I_i = 1$

26

Priority Encoder: Implement a 32-input priority encoder with 8 input priority encoders (high bit priority).



27

- A**
- ① If $E=0 \Rightarrow A=0 \Rightarrow$ Address is not valid.
 - ② If $E=1 \Rightarrow I_{31-24} \exists i \in 31-24, I_i=1$
 Then $G_s=1$, y_{32}, y_{31}, y_{30} show the index of input line.
 $\Rightarrow E_{03}=0$
 $\Rightarrow \forall i \in 31-24, I_i=0$
 $E_{03}=1 \Rightarrow$ Pass the token to the next encoder