

CSE 140 Lecture 11

Standard Combinational Modules

CK Cheng
CSE Dept.
UC San Diego

Part III - Standard Combinational Modules

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

Part III - Standard Combinational Modules

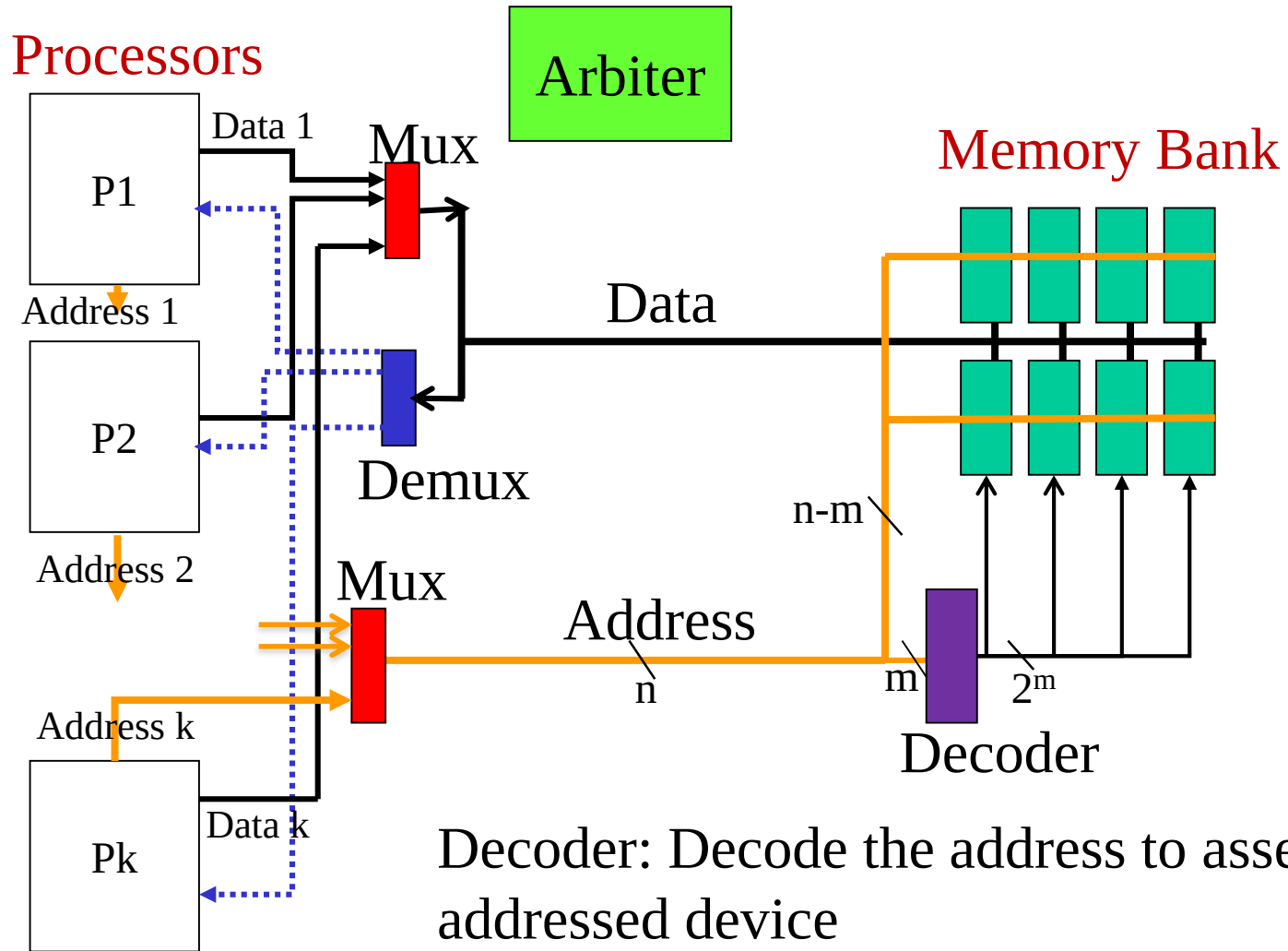
Signal Transport

- 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

Interconnect: Decoder, Encoder, Mux, DeMux



Decoder: Decode the address to assert the addressed device

Mux: Select the inputs according to the index addressed by the control signals 4

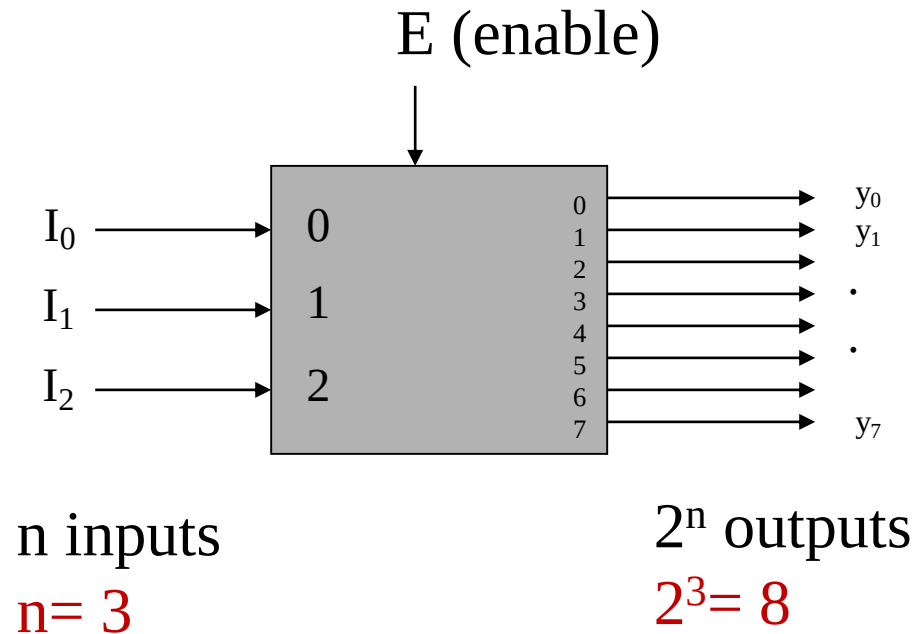
1. Decoder

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

iClicker: 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

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

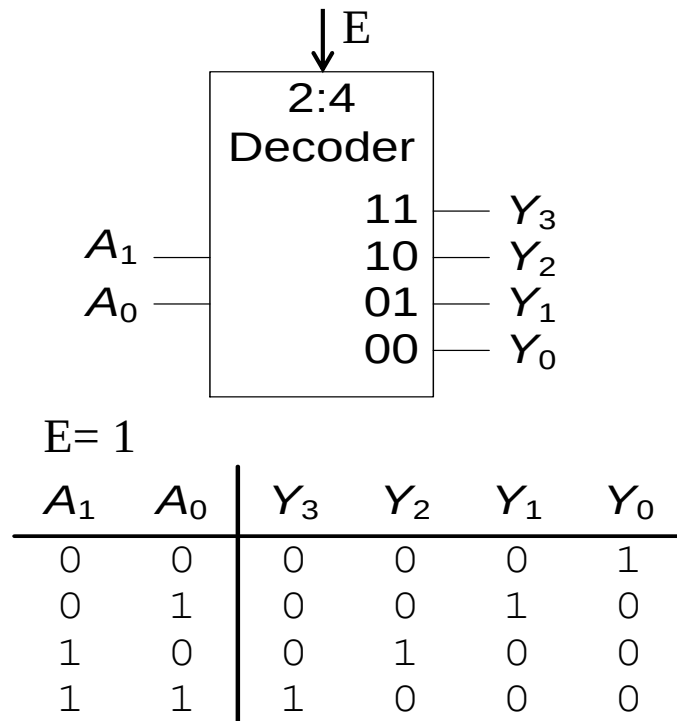


n to 2^n decoder
function:

$$y_i = 1 \text{ if } E=1 \text{ \& } (I_2, I_1, I_0) = i$$
$$y_i = 0 \text{ otherwise}$$

1. Decoder: Definition

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

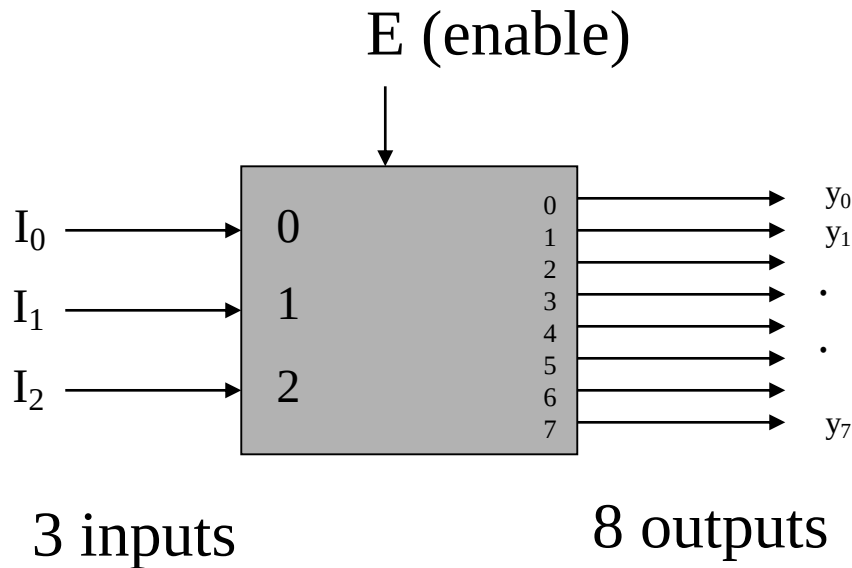


1. Decoder: Definition

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

- A. 2 outputs
 - B. 4 outputs
 - C. 8 outputs
 - D. 10 outputs
- ↓^E

Decoder Definition

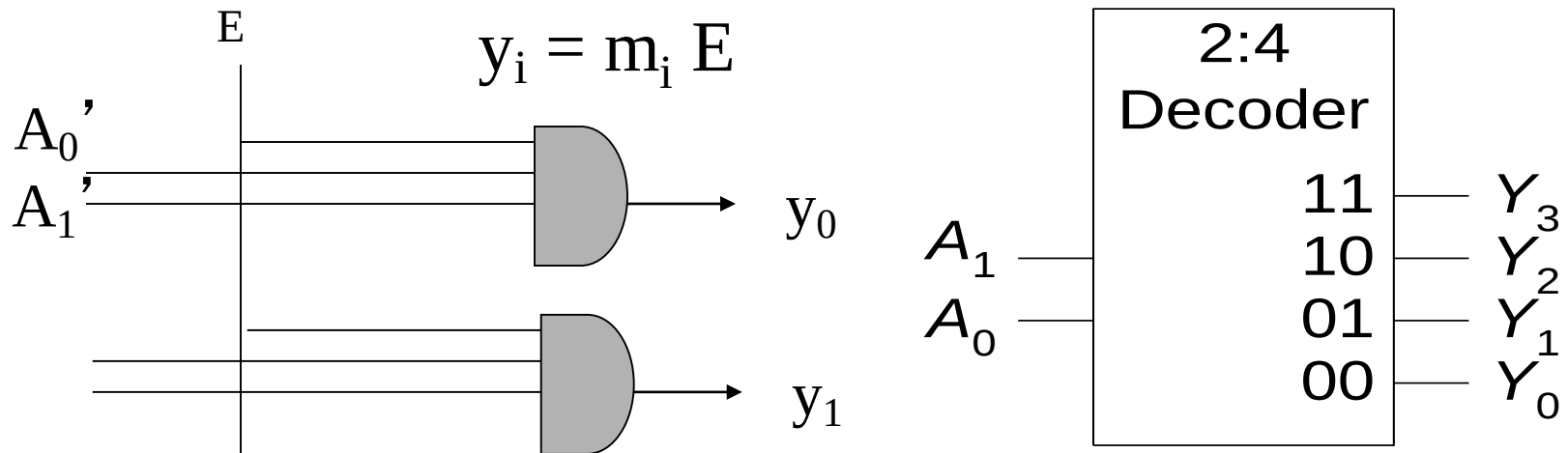


iClicker: For a 3-input decoder, suppose $(E, I_2, I_1, I_0) = (1, 0, 0, 0)$, then $(y_7, y_6, \dots, y_0)$ is equal to:

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

Decoder: Logic Diagram (Inside a decoder)

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



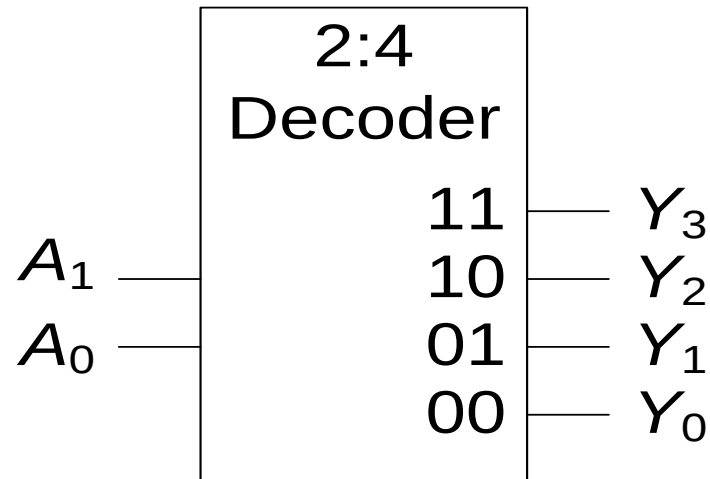
A_1	A_0	Y_3	Y_2	Y_1	Y_0
0	0	0	0	0	1
0	1	0	0	1	0
1	0	0	1	0	0
1	1	1	0	0	0

$$y_3 = A_1 A_0 E$$

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)



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

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.

Decoder Application: universal set {Decoder, OR}

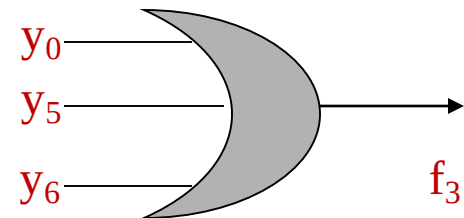
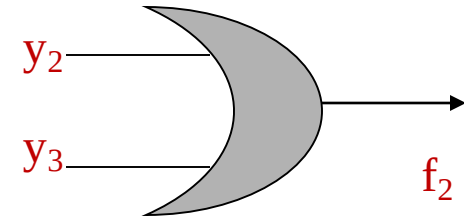
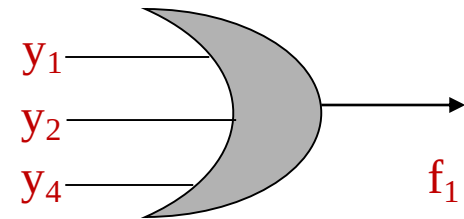
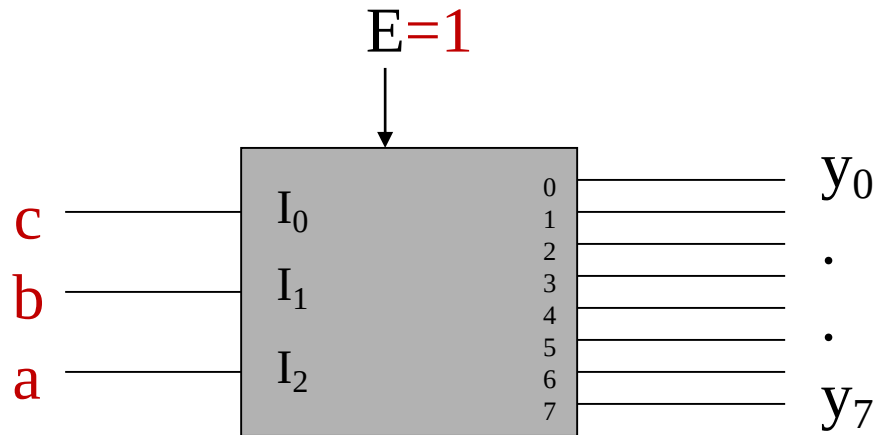
Example: Implement functions

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

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

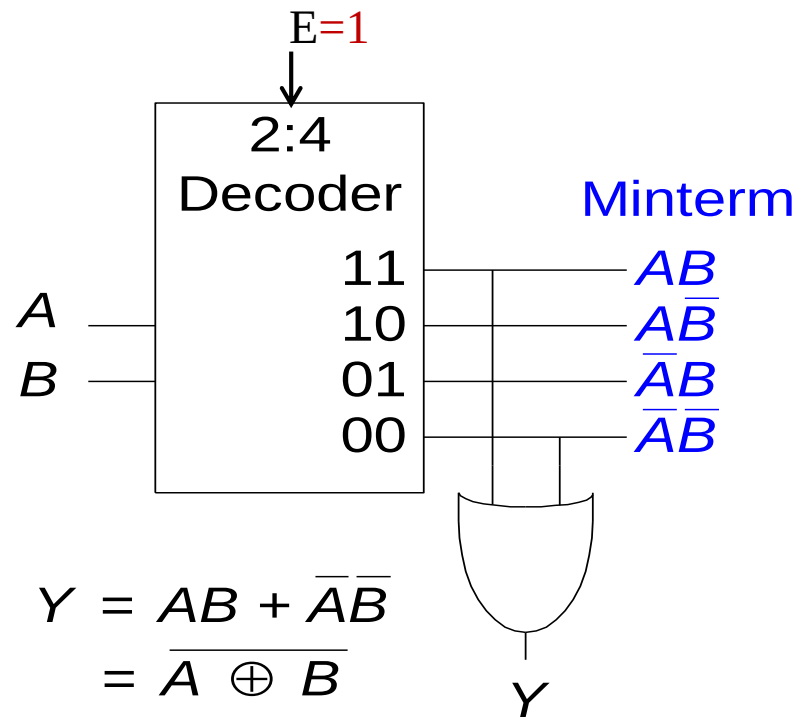
iii) $f_3(a,b,c) = \Sigma m(0,5,6)$

with a 3-input decoder and OR gates.



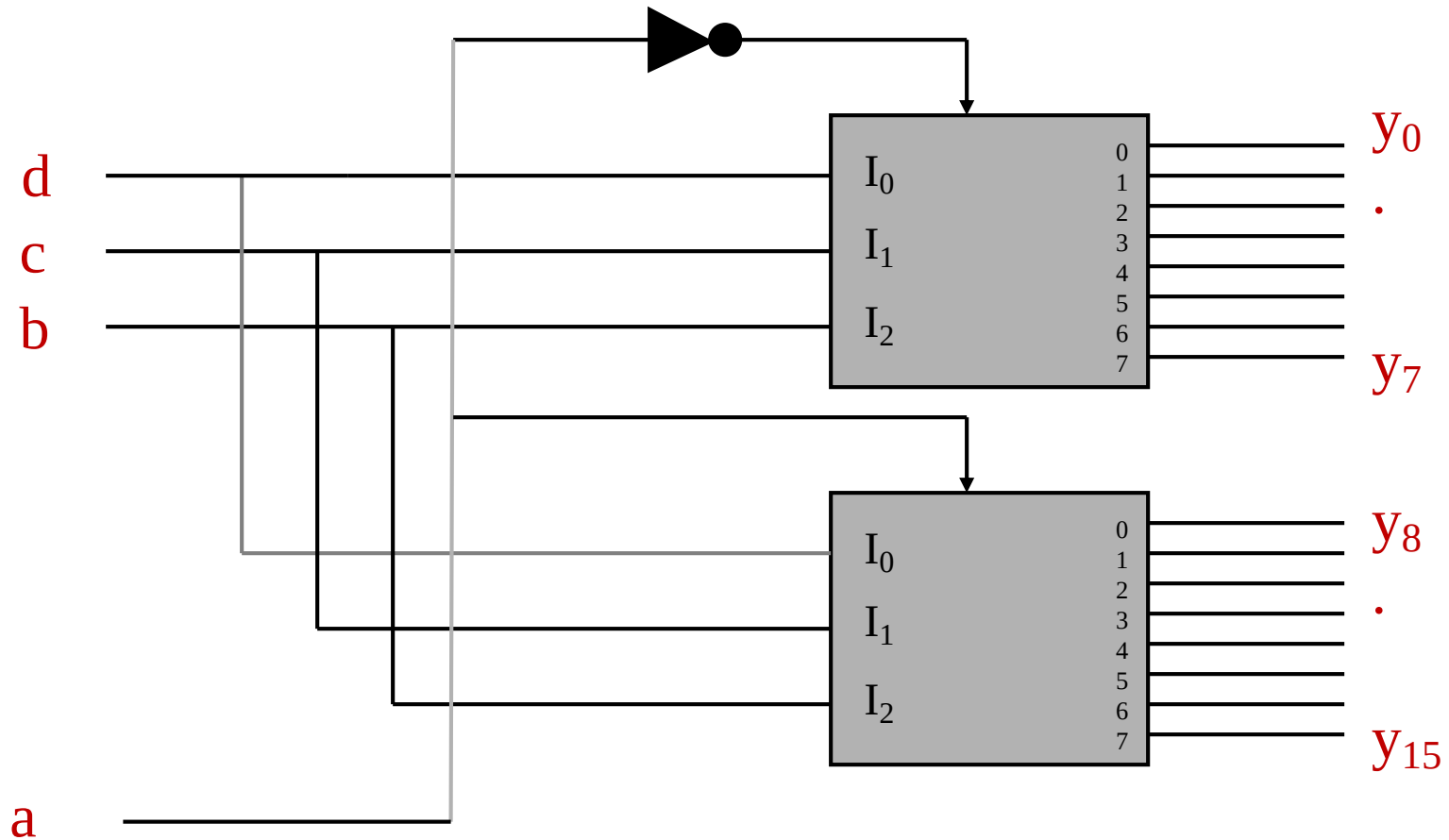
Decoders

- OR minterms



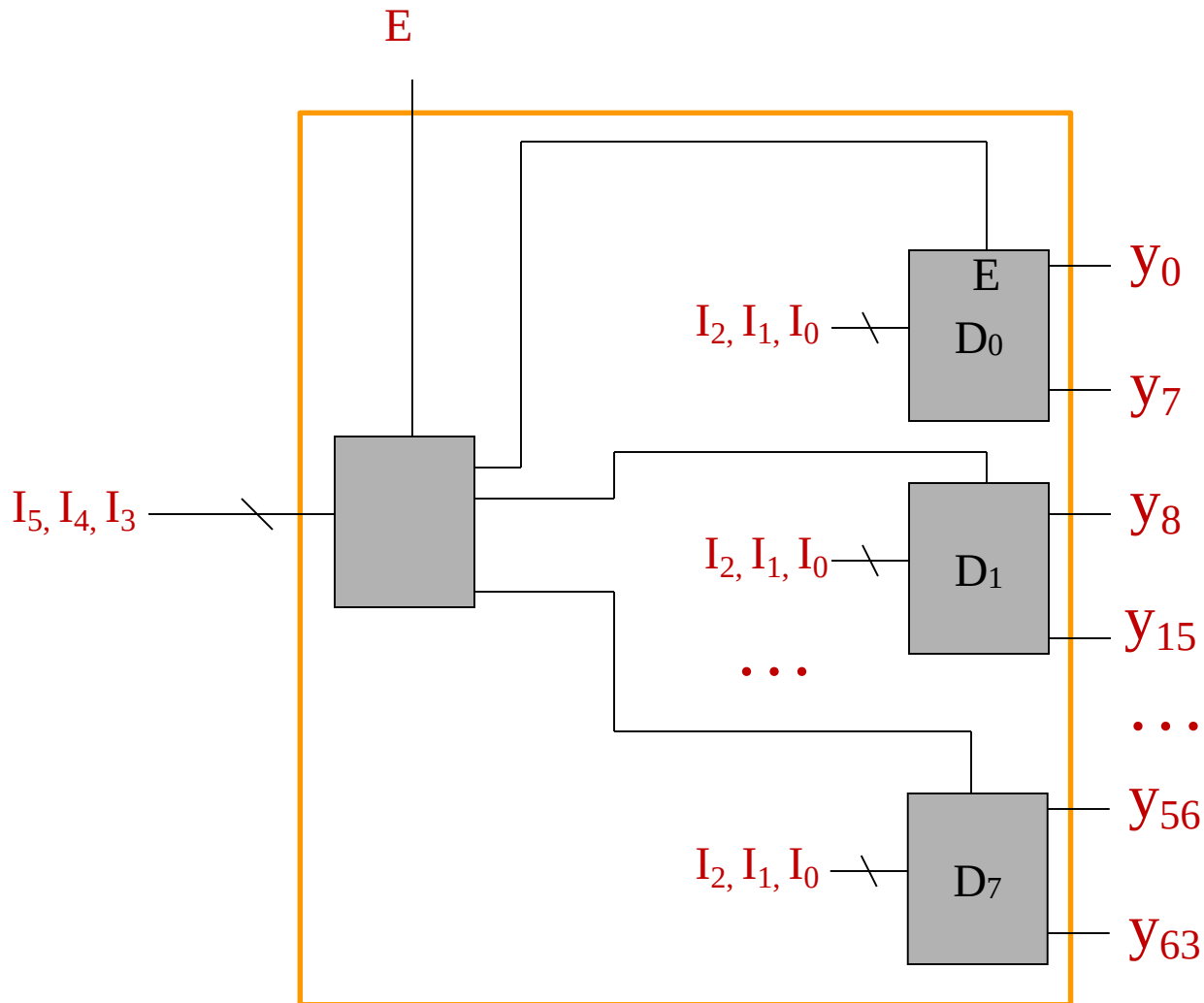
Tree of Decoders: Scale up the size of the decoders using a tree structure

Implement a $4\text{-}2^4$ decoder with $3\text{-}2^3$ decoders.



Tree of Decoders

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



PI Q: 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

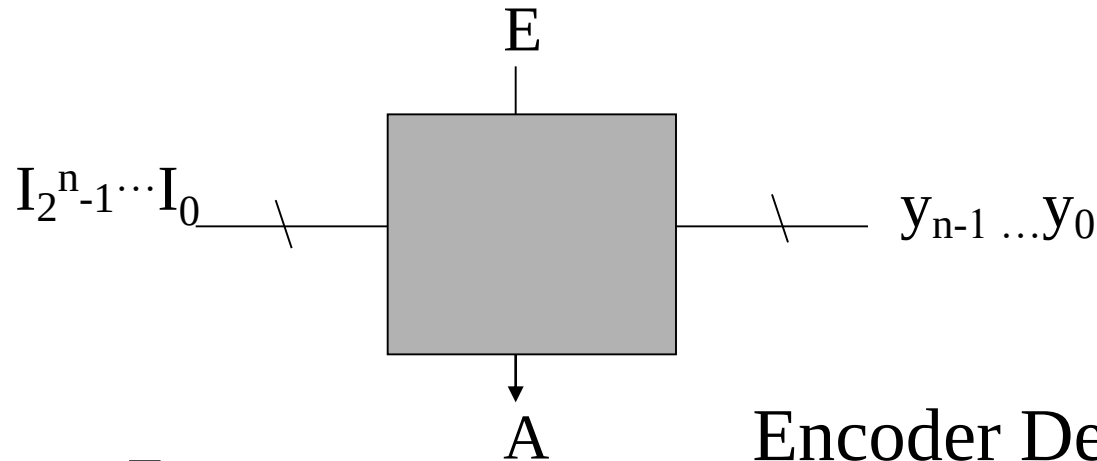
2. Encoder

- Definition
- Logic Diagram
- Priority Encoder

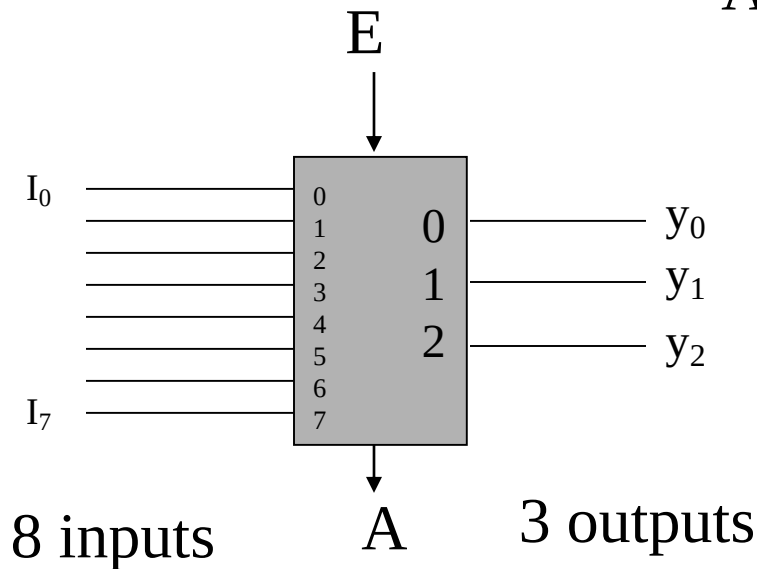
iClicker: Definition of Encoder

- 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

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



Encoder Description:



At most one $I_i = 1$.

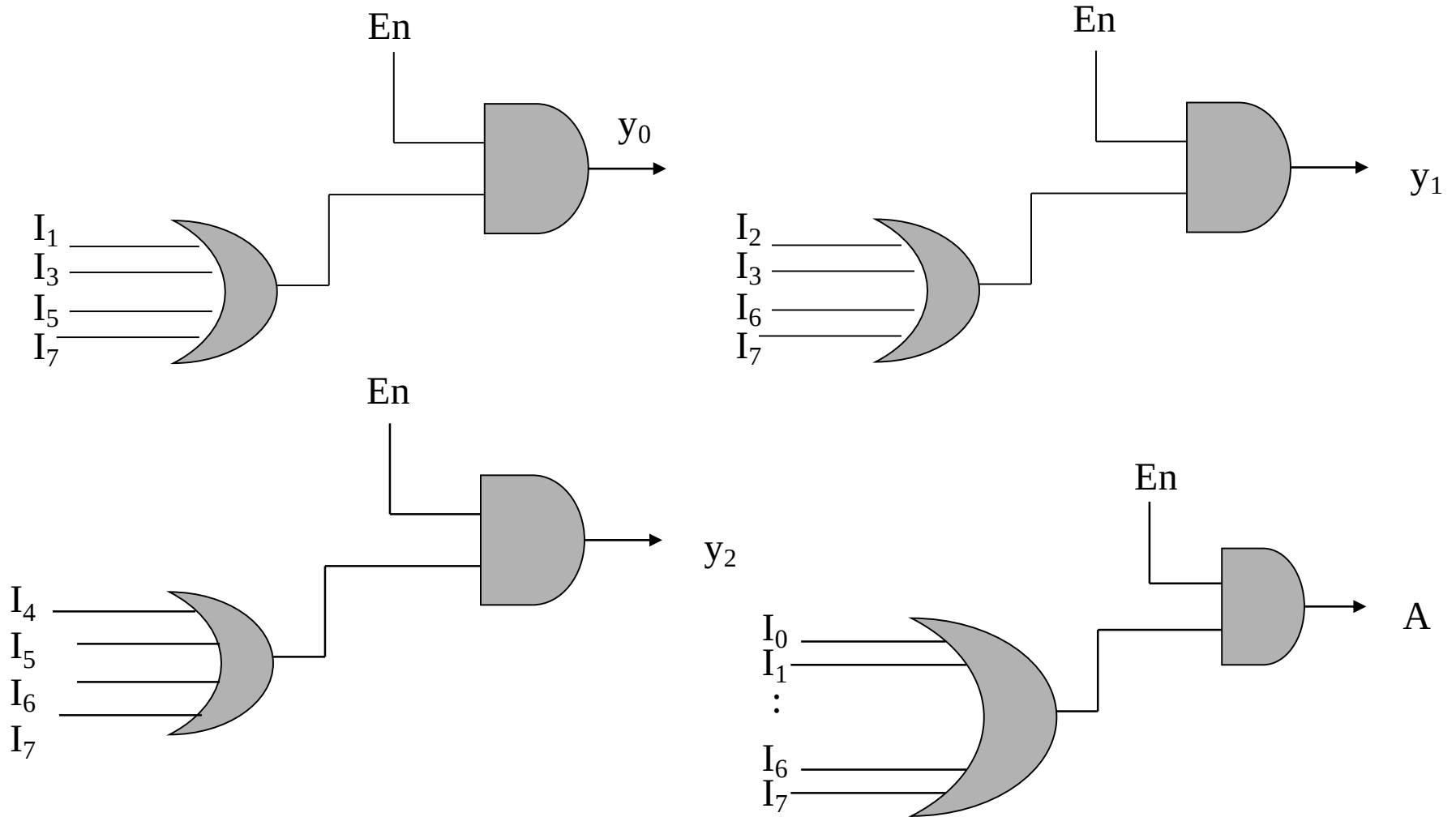
$(y_{n-1}, \dots, y_0) = i$ if $I_i = 1$ & $E = 1$

$(y_{n-1}, \dots, y_0) = 0$ otherwise.

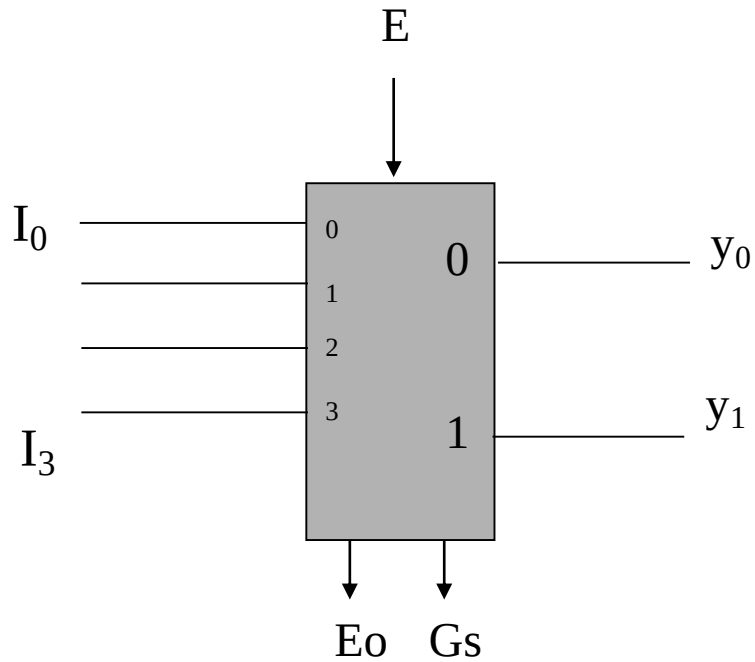
$A = 1$ if $E = 1$ and one i s.t. $I_i = 1$

$A = 0$ otherwise.

Encoder: Logic Diagram



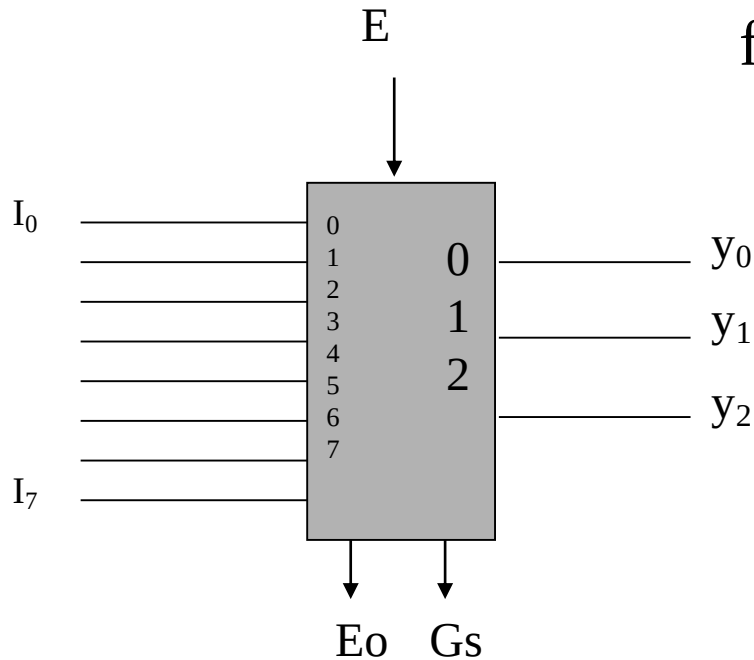
Priority Encoder:



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).



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

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

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

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

