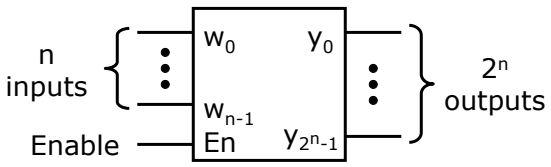
ECE380 Digital Logic

Combinatorial Circuit Building Blocks:

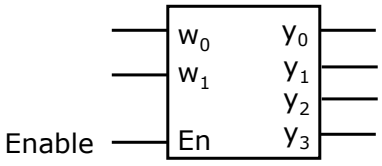
Decoders, Demultiplexers, Encoders and Code Converters

Decoders

- Decoder circuits: decode encoded information
- A binary decoder has ***n*** data inputs and $\mathbf{2^n}$ outputs
- Only one output is asserted at any time (***one-hot encoded***) and each output corresponds to one valuation of the inputs
- An enable input (En) is used to disable the outputs
  - If En=0, none of the decoder outputs is asserted
  - If En=1, one of the outputs is asserted according to the valuation of the inputs

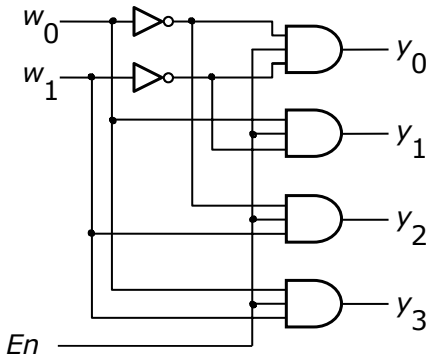


2-to-4 decoder circuit

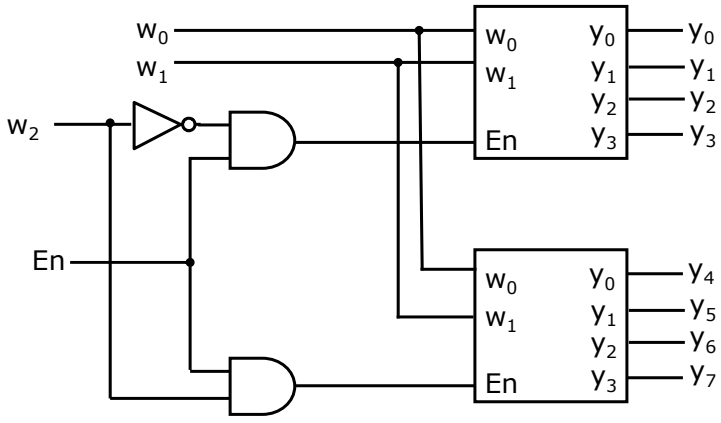


En	w_1	w_0	y_0	y_1	y_2	y_3
1	0	0	1	0	0	0
1	0	1	0	1	0	0
1	1	0	0	0	1	0
1	1	1	0	0	0	1
0	X	X	0	0	0	0

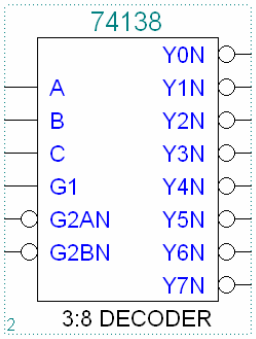
Truth table



3-to-8 decoder



74138 3-to-8 decoder



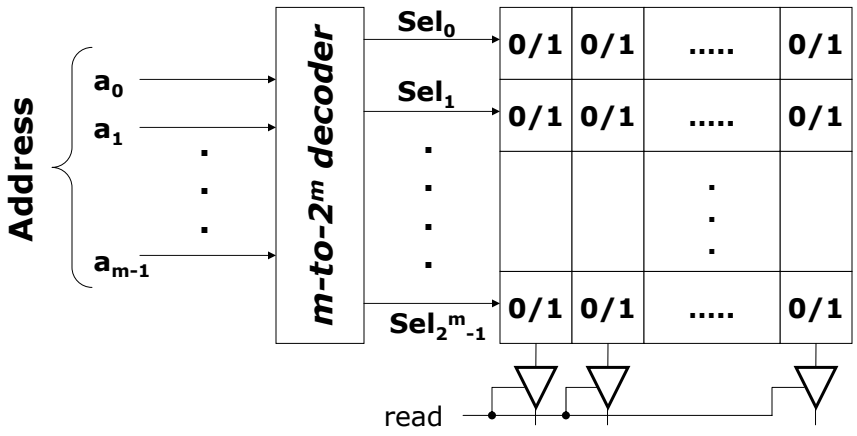
Inputs					Outputs							
Enable		Select										
G1	G2*	C	B	A	Y0N	Y1N	Y2N	Y3N	Y4N	Y5N	Y6N	Y7N
X	H	X	X	X	H	H	H	H	H	H	H	H
L	X	X	X	X	H	H	H	H	H	H	H	H
H	L	L	L	L	L	H	H	H	H	H	H	H
H	L	L	L	H	H	L	H	H	H	H	H	H
H	L	L	H	L	H	H	L	H	H	H	H	H
H	L	L	H	H	H	H	H	L	H	H	H	H
H	L	H	L	L	H	H	H	H	L	H	H	H
H	L	H	L	H	H	H	H	H	H	L	H	H
H	L	H	H	L	H	H	H	H	H	H	L	H
H	L	H	H	H	H	H	H	H	H	H	H	L

* G2 = G2AN + G2BN

Note the 'active low' outputs

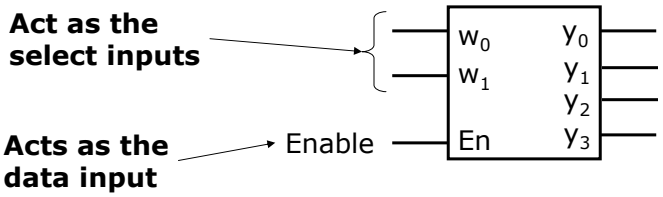
Decoder application

- A common decoder application is the decoding of address lines for memory chips



Demultiplexers

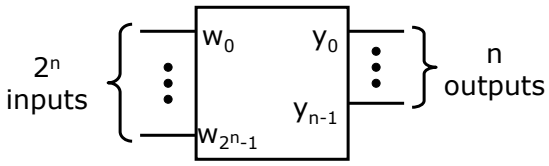
- A multiplexer multiplexed *n* data inputs to a single output
- A circuit that performs the opposite, placing the value of a single input onto one for multiple outputs is called a ***demultiplexer***
- An *n*-to-2^n decoder implements a 1-to-*n* demultiplexer



Encoders

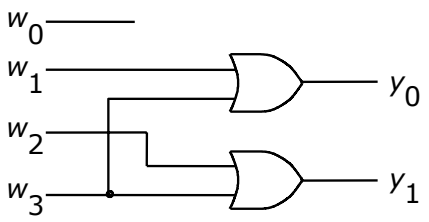
- An ***encoder*** performs the opposite function of a decoder
- A ***binary encoder*** encodes information (data) from 2^n inputs into an *n*-bit code (output)
  - Exactly one of the inputs should have a value of one
  - The outputs represent the binary number that identifies which input is equal to 1
- Encoders reduce the number of bits needed to represent given information
- Practical use: transmitting information in a digital system

Encoders



A 2^n-to-n binary encoder

w_3	w_2	w_1	w_0	y_1	y_0
0	0	0	1	0	0
0	0	1	0	0	1
0	1	0	0	1	0
1	0	0	0	1	1



Priority encoders

- Another useful class of encoders is based on the ***priority*** of the input signals
- In a priority encoder, each input has a priority level associated with it
- The encoder outputs indicate the active input that has the highest priority
  - When an input with a high priority is asserted, the other lower priority inputs are ignored

Priority encoders

- Assume that w_0 has the lowest priority and w_3 has the highest
- The output ***z*** indicates when none of the inputs are 1
- Letting
  - $i_0 = w_3' w_2' w_1' w_0$
  - $i_1 = w_3' w_2' w_1$
  - $i_2 = w_3' w_2$
  - $i_3 = w_3$

$y_0 = i_1 + i_3$, $y_1 = i_2 + i_3$
$z = i_1 + i_2 + i_3 + i_4$

w_3	w_2	w_1	w_0	y_1	y_0	z
0	0	0	0	D	D	0
0	0	0	1	0	0	1
0	0	1	X	0	1	1
0	1	X	X	1	0	1
1	X	X	X	1	1	1

4-to-2 priority encoder truth table

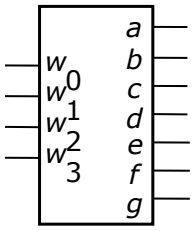
Code converters

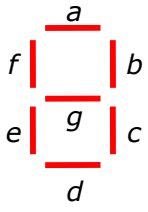
- The purpose of ***code converter*** circuits is to convert from one type of input encoding to another type of output encoding
- For example:
  - A 3-to-8 decoder converts from a binary number to a one-hot encoding at the output
  - A 8-to-3 encoder performs the opposite
- Many different types of code converter circuits can be constructed
  - One common example a a BCD-to7-segment decoder

BCD-to-7-segment decoder

- Converts one binary-coded decimal (BCD) digit into information suitable for driving a digit-oriented display
  - A vending machine display is an example
- The circuit converts a BCD digit into 7 signals that are used to drive (activate) the segments in the display
  - Each segment is a small light-emitting diode (LED), which glows when driven by an electrical signal

BCD-to-7-segment decoder





w_3	w_2	w_1	w_0	a	b	c	d	e	f	g
0	0	0	0	1	1	1	1	1	1	0
0	0	0	1	0	1	1	0	0	0	0
0	0	1	0	1	1	0	1	1	0	1
0	0	1	1	1	1	1	1	0	0	1
0	1	0	0	0	1	1	0	0	1	1
0	1	0	1	1	0	1	1	0	1	1
0	1	1	0	1	0	1	1	1	1	1
0	1	1	1	1	1	1	0	0	0	0
1	0	0	0	1	1	1	1	1	1	1
1	0	0	1	1	1	1	1	0	1	1

BCD-to-7-segment decoder