7.10 Decoders

Basics

A **decoder** is a combinational circuit that converts N inputs to a 1 on one of 2^N outputs. A **2x4 decoder**, spoken as "2 to 4 d converts two inputs to a 1 on exactly one of four outputs.

PARTICIPATION ACTIVITY   7.10.1: A 2x4 decoder.

Start   ☐ 2x speed

i1	i0	y3	y2	y1	y0
0	0	0	0	0	1
0	1	0	0	1	0
1	0	0	1	0	0
1	1	1	0	0	0

Circuit block:
- 1 → i1
- 1 → i0
- y3 → 1
- y2 → 0
- y1 → 0
- y0 → 0

PARTICIPATION ACTIVITY   7.10.2: 2x4 decoder.

Consider a 2x4 decoder.

1) If i1i0 = 00, then y1 = _____ .

Check   **Show answer**

2) If i1i0 = 01, then y1= _____ .

Check   **Show answer**

3) i1i0 = _____ configures the decoder to output y0 = 0, y1 = 0, y2 = 0, and y3 = 1.

Check   **Show answer**

4) How many outputs are set to 1 at any given time?
Type: 0, 1, 2, 3, or 4

Check   **Show answer**

5) i1i0 = _____ configures the decoder to output y0 = 0, y1 = 0, y2 = 1, and y3 = 1.
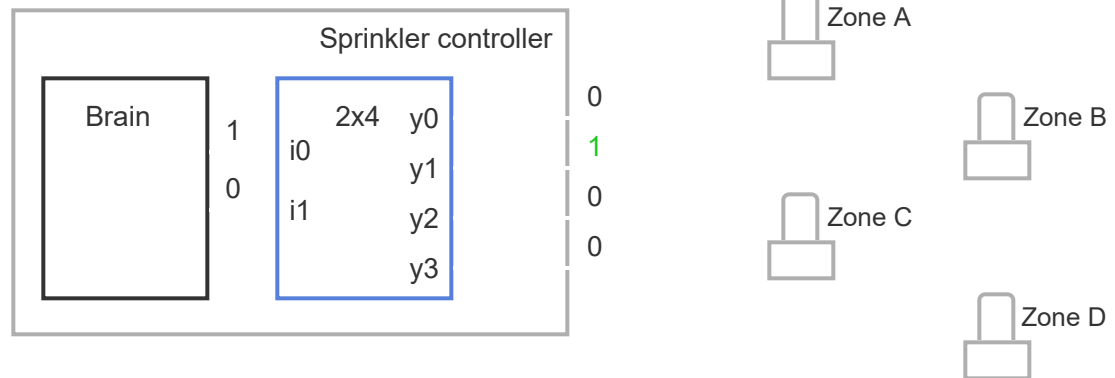Type: 00, 01, 10, 11, or ** if not possible.

Check   **Show answer**

Example: Lawn sprinkler controller

A lawn sprinkler system may have multiple zones. A sprinkler controller activates only one zone at a time, due to limited inc
The brain of the controller, typically a small computer, may encode the active zone in binary on output pins, to save pins: If a
zones, only 3 pins are needed, while 4 zones need only 2 pins. A decoder can convert the binary encoded zone into the acti
appropriate zone.

PARTICIPATION ACTIVITY 7.10.3: Lawn sprinkler example using a decoder.

Start ☐ 2x speed

```
                Sprinkler controller
    ┌──────────────────────────────────────┐
    │                                    0   │      Zone A
    │  ┌────────┐  ┌──────────────┐          │
    │  │ Brain  │  │  2x4    y0   │      1   │      Zone B
    │  │      1 │  │ i0           │          │
    │  │      0 │  │         y1   │      0   │      Zone C
    │  │        │  │ i1           │          │
    │  │        │  │         y2   │      0   │      Zone D
    │  │        │  │         y3   │          │
    │  └────────┘  └──────────────┘          │
    └──────────────────────────────────────┘
```

PARTICIPATION ACTIVITY 7.10.4: Lawn sprinkler system with a decoder.

Consider the example above.

1) If the brain outputs 11, what zone is activated?

○ A

○ D

2) What brain output values will activate all
   zones at once?

   ○ 11

   ○ No such values

3) If a system has 32 zones instead of 4,
   how many outputs would the brain
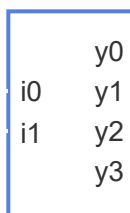   need?

   ○ 4

   ○ 5

   ○ 32

Decoder equation and circuit

A 2x4 decoder has four outputs. Each output's behavior is easily converted to an equation and then to a circuit.

PARTICIPATION ACTIVITY	7.10.5: Each decoder output is easily converted to an equation and circuit.

Start ☐ 2x speed

i1	i0	y3	y2	y1	y0
0	0	0	0	0	1
0	1	0	0	1	0
1	0	0	1	0	0

$y0 = i1'i0'$

$y1 = i1'i0$

$y2 = i1i0'$

$$1 \quad 1 \quad 1 \quad 0 \quad 0 \quad 0 \qquad y3 = i1i0$$

PARTICIPATION ACTIVITY   7.10.6: Decoder design.

1) How many inputs does a 2x4 decoder have?

> [ ]

Check   **Show answer**

2) How many outputs does a 2-input decoder have?

> [ ]

Check   **Show answer**

3) How many AND gates does a 2x4 decoder require?

> [ ]

Check   **Show answer**

4) How many OR gates does a 2x4 decoder require?

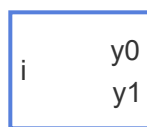> [ ]

Check   **Show answer**

Decoder sizes

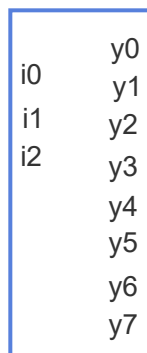Other size decoders can be designed similarly.

PARTICIPATION
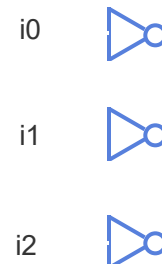ACTIVITY   7.10.7: Designing other sized decoders.

Start   ☐ 2x speed

i   y0   i   ▷o   y0
         y1   y1

y0 = i'
y1 = i

i0   y0
         y1   i0   ▷o   y0
i1   y2
i2   y3   y1
         y4   i1   ▷o
         y5   y2
         y6
         y7   i2   ▷o   y3

                              y4
y0 = i2'i1'i0'
y1 = i2'i1'i0   y5
y2 = i2'i1i0'
y3 = i2'i1i0   y6
y4 = i2i1'i0'
y5 = i2i1'i0   y7
y6 = i2i1i0'
y7 = i2i1i0

PARTICIPATION ACTIVITY   7.10.8: Various sized decoders.

1) How many inputs are required for a decoder with 8 outputs?

[   ]

Check   **Show answer**

2) How many inputs are required for a decoder with 2 outputs?

[   ]

Check   **Show answer**

3) How many outputs does a 2-input decoder have?

[   ]

Check   **Show answer**

4) How many outputs does a 4-input decoder have?

[   ]

Check   **Show answer**

5) How many AND gates does a 3x8 decoder require?

Check   **Show answer**

6) How many OR gates does a 5x32
   decoder require?

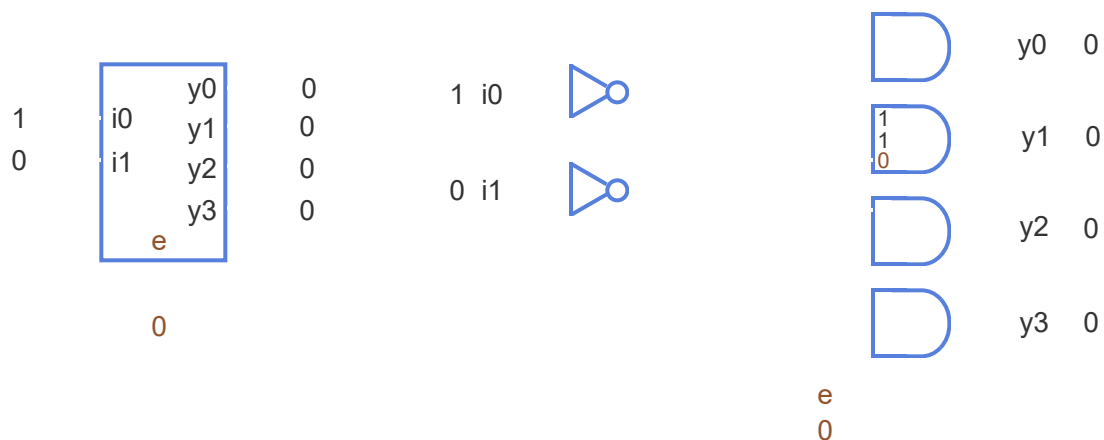Check   **Show answer**

Decoder with enable

Some decoders have an additional input called an **enable input** that when 0 sets all outputs to 0s, and when 1 enables the normal behavior.

A decoder's equations and circuit are easily extended for an enable input by including the enable in each AND.

PARTICIPATION
ACTIVITY   7.10.9: A decoder with an enable input.

Start   ☐ 2x speed

1   i0   y0   0   1 i0   y0   0
0   i1   y1   0   1
           y2   0   0 i1   1   y1   0
           y3   0   0
     e   y2   0

     0   y3   0
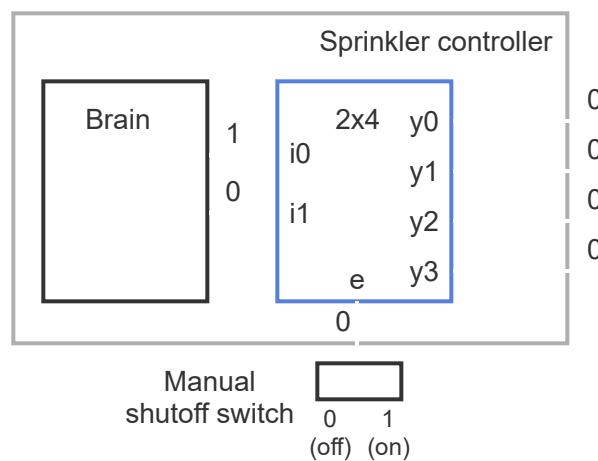
                                             e
                                             0

PARTICIPATION
ACTIVITY   7.10.10: Lawn sprinkler example using a decoder.

Start   ☐ 2x speed

Sprinkler controller

Brain   1   2x4   y0   0
             i0   0
             0   i1   y1
                             y2   0
                      e   y3   0
                      0

Zone A

Zone B

Zone C

Zone D

Manual   ┌──────┐
shutoff switch   0   1
                (off) (on)

PARTICIPATION
ACTIVITY   7.10.11: Decoders with enable.

1) If i1i0 = 01 and enable = 1, then y1 =
    _____ .

    ┌──────────────────────┐
    │   │
    └──────────────────────┘

    Check   Show answer

2) If i1i0 = 00 and enable = 1, then y1 =
_____ .

[   ]

Check   **Show answer**

3) If i1i0 = 11 and enable = 0, then y3 =
_____ .

[   ]

Check   **Show answer**

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