

# Computer Organization and Architecture

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# iClicker

How many minimum number of bits do we need to identify 6 types of bagels uniquely?

- A 2
- B 3
- C 4
- D 6
- E 64



# Truth Table

What's your favorite ?

| Bagels           | A | B | C | F(A, B, C) |
|------------------|---|---|---|------------|
| Plain            | 0 | 0 | 0 | 0          |
| Everything       | 0 | 0 | 1 | 0          |
| Sesame           | 0 | 1 | 0 | 0          |
| Cinnamon         | 0 | 1 | 1 | 1          |
| Raisin           | 1 | 0 | 0 | 0          |
| Jalapeno-Cheddar | 1 | 0 | 1 | 1          |

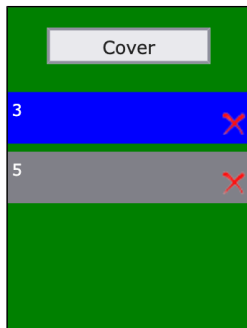


# Truth Table

| Bagels           | A | B | C | F(A, B, C) |
|------------------|---|---|---|------------|
| Plain            | 0 | 0 | 0 | 0          |
| Everything       | 0 | 0 | 1 | 0          |
| Sesame           | 0 | 1 | 0 | 0          |
| Cinnamon         | 0 | 1 | 1 | 1          |
| Raisin           | 1 | 0 | 0 | 0          |
| Jalapeno-Cheddar | 1 | 0 | 1 | 1          |
|                  | 1 | 1 | 0 | ?          |
|                  | 1 | 1 | 1 | ?          |



# Truth Table

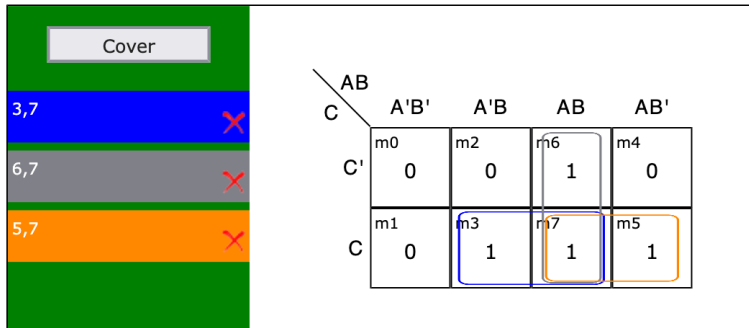


|   |    | AB      |         |         |         |
|---|----|---------|---------|---------|---------|
|   |    | A'B'    | A'B     | AB      | AB'     |
| C | C' | m0<br>0 | m2<br>0 | m6<br>0 | m4<br>0 |
|   | C  | m1<br>0 | m3<br>1 | m7<br>0 | m5<br>1 |

$$A'BC + AB'C$$



# Truth Table



$$AB + BC + AC$$



# Truth Table

| Bagels           | A | B | C | F(A, B, C) |
|------------------|---|---|---|------------|
| Plain            | 0 | 0 | 0 | 0          |
| Everything       | 0 | 0 | 1 | 0          |
| Sesame           | 0 | 1 | 0 | 0          |
| Cinnamon         | 0 | 1 | 1 | 1          |
| Raisin           | 1 | 0 | 0 | 0          |
| Jalapeno-Cheddar | 1 | 0 | 1 | 1          |
|                  | 1 | 1 | 0 | X          |
|                  | 1 | 1 | 1 | X          |



# Truth Table

|       |  |  |  |  |  |
|-------|--|--|--|--|--|
| Cover |  |  |  |  |  |
| 3,7   |  |  |  |  |  |
| 5,7   |  |  |  |  |  |
|       |  |  |  |  |  |

|    |    | AB   |     |    |     |
|----|----|------|-----|----|-----|
| C  | AB | A'B' | A'B | AB | AB' |
|    |    | m0   | m2  | m6 | m4  |
| C' |    | 0    | 0   | X  | 0   |
| C  |    | 0    | 1   | X  | 1   |

$$AC + BC$$



# K-Map: 3 variables

$F(A, B, C) = m1, m3, m4, m5$  and  
don't care =  $m0, m7$



# K-Map: 3 variables

$F(A, B, C) = m1, m3, m4, m5$  and  
don't care =  $m0, m7$

| A B |  |                              |         |         |         |
|-----|--|------------------------------|---------|---------|---------|
| C   |  | A' B'    A' B    A B    A B' |         |         |         |
|     |  |                              |         |         |         |
| C'  |  | m0<br>X                      | m2<br>0 | m6<br>0 | m4<br>1 |
|     |  | m1<br>1                      | m3<br>1 | m7<br>X | m5<br>1 |



# K-Map: 3 variables

$F(A, B, C) = m1, m3, m4, m5$  and  
don't care =  $m0, m7$

| A B |  |       |      |     |      |
|-----|--|-------|------|-----|------|
| C   |  | A' B' | A' B | A B | A B' |
|     |  | m0    | m2   | m6  | m4   |
| C'  |  | X     | 0    | 0   | 1    |
| C   |  | 1     | 1    | X   | 1    |
|     |  | m1    | m3   | m7  | m5   |

$$F(A, B, C) = B' + C$$



# K-Map: 3 variables

$F(A, B, C) = m_4, m_5, m_6, m_7$  and  
don't care =  $m_0, m_2$



# K-Map: 3 variables

$F(A, B, C) = m_4, m_5, m_6, m_7$  and  
don't care =  $m_0, m_2$

| A B |  |       |      |     |      |
|-----|--|-------|------|-----|------|
| C   |  | A' B' | A' B | A B | A B' |
|     |  | m0    | m2   | m6  | m4   |
| C'  |  | X     | X    | 1   | 1    |
| C   |  | 0     | 0    | 1   | 1    |



# K-Map: 3 variables

$F(A, B, C) = m_4, m_5, m_6, m_7$  and  
don't care =  $m_0, m_2$

| A B |  |         |         |         |         |
|-----|--|---------|---------|---------|---------|
| C   |  | A' B'   | A' B    | A B     | A B'    |
|     |  | m0      | m2      | m6      | m4      |
| C'  |  | X       | X       | 1       | 1       |
| C   |  | m1<br>0 | m3<br>0 | m7<br>1 | m5<br>1 |

$$F(A, B, C) = A$$



## iClicker

$$F(A, B, C) = m_3, m_7$$

Don't care =  $m_5, m_6$

| A B |    |       |      |     |      |
|-----|----|-------|------|-----|------|
| C   |    | A' B' | A' B | A B | A B' |
| C'  | m0 | 0     | 0    | X   | 0    |
| C   | m1 | 0     | 1    | 1   | X    |

BC



# K-Map: 4 variables

$F(A, B, C, D) = m_2, m_4, m_6, m_8, m_{11}, m_{12}, m_{13}, m_{15}$   
Don't care =  $m_0, m_9, m_{10}$



# K-Map: 4 variables

$F(A, B, C, D) = m_2, m_4, m_6, m_8, m_{11}, m_{12}, m_{13}, m_{15}$

Don't care =  $m_0, m_9, m_{10}$

| AB   |  |         |         |          |          |
|------|--|---------|---------|----------|----------|
| CD   |  | A'B'    | A'B     | AB       | AB'      |
|      |  | m0      | m4      | m12      | m8       |
| C'D' |  | X       | 1       | 1        | 1        |
| C'D  |  | m1<br>0 | m5<br>0 | m13<br>1 | m9<br>X  |
| CD   |  | m3<br>0 | m7<br>0 | m15<br>1 | m11<br>1 |
| CD'  |  | m2<br>1 | m6<br>1 | m14<br>0 | m10<br>X |



# K-Map: 4 variables

$F(A, B, C, D) = m_2, m_4, m_6, m_8, m_{11}, m_{12}, m_{13}, m_{15}$

Don't care =  $m_0, m_9, m_{10}$

| AB   |  |         |         |          |          |
|------|--|---------|---------|----------|----------|
| CD   |  | A'B'    | A'B     | AB       | AB'      |
|      |  | m0      | m4      | m12      | m8       |
| C'D' |  | X       | 1       | 1        | 1        |
| C'D  |  | m1<br>0 | m5<br>0 | m13<br>1 | m9<br>X  |
| CD   |  | m3<br>0 | m7<br>0 | m15<br>1 | m11<br>1 |
| CD'  |  | m2<br>1 | m6<br>1 | m14<br>0 | m10<br>X |

$$F(A, B, C, D) = A'D' + AD + C'D'$$



## iClicker

$$F(A, B, C, D) = m_0, m_1, m_2, m_3, m_5, m_{12}, m_{13}, m_{14}$$

Don't care =  $m_4, m_8, m_9, m_{10}, m_{15}$

| AB   |  |      |     |     |     |
|------|--|------|-----|-----|-----|
| CD   |  | A'B' | A'B | AB  | AB' |
|      |  | m0   | m4  | m12 | m8  |
| C'D' |  | 1    | X   | 1   | X   |
| C'D  |  | 1    | 1   | 1   | X   |
| CD   |  | 1    | 0   | X   | 0   |
| CD'  |  | 1    | 0   | 1   | X   |

$$C' + A'B' + AD$$



## iClicker

$$F(A, B, C, D) = m_0, m_1, m_2, m_3, m_5, m_{12}, m_{13}, m_{14}$$

Don't care =  $m_4, m_8, m_9, m_{10}, m_{15}$

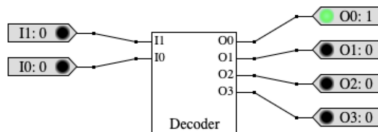
| AB   |    |      |     |    |     |
|------|----|------|-----|----|-----|
| CD   |    | A'B' | A'B | AB | AB' |
| C'D' | m0 | 1    | X   | 1  | X   |
| C'D  | m1 | 1    | 1   | 1  | X   |
| CD   | m3 | 1    | 0   | X  | 0   |
| CD'  | m2 | 1    | 0   | 1  | X   |

$$C' + A'B' + AB$$



# Decoder

- A decoder recognizes which encoded value is the input to the circuit
- Input:  $n$
- Output:  $2^n$
- One of the  $2^n$  outputs is asserted, based on which encoded value is input.



# Decoder

| $I_1$ | $I_0$ | $O_3$ | $O_2$ | $O_1$ | $O_0$ |
|-------|-------|-------|-------|-------|-------|
| 0     | 0     | 0     | 0     | 0     | 1     |
| 0     | 1     | 0     | 0     | 1     | 0     |
| 1     | 0     | 0     | 1     | 0     | 0     |
| 1     | 1     | 1     | 0     | 0     | 0     |



# Decoder

|   |    | A       |         |
|---|----|---------|---------|
|   |    | A'      | A       |
| B | B' | m0<br>1 | m2<br>0 |
|   | B  | m1<br>0 | m3<br>0 |

$$O_0 = A'B' = I_1'I_0'$$

|   |    | A       |         |
|---|----|---------|---------|
|   |    | A'      | A       |
| B | B' | m0<br>0 | m2<br>0 |
|   | B  | m1<br>1 | m3<br>0 |

$$O_1 = A'B = I_1'I_0$$

|   |    | A       |         |
|---|----|---------|---------|
|   |    | A'      | A       |
| B | B' | m0<br>0 | m2<br>1 |
|   | B  | m1<br>0 | m3<br>0 |

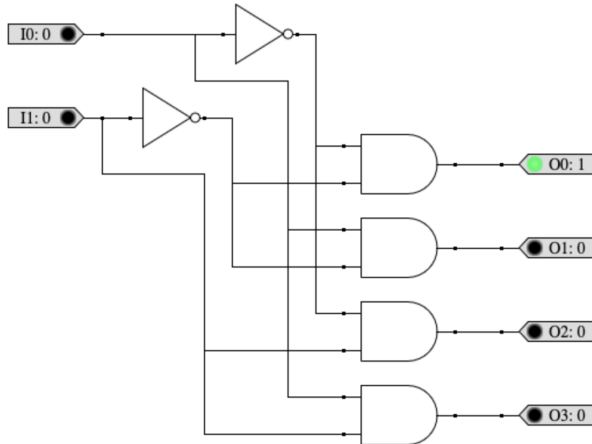
$$O_2 = AB' = I_1I_0'$$

|   |    | A       |         |
|---|----|---------|---------|
|   |    | A'      | A       |
| B | B' | m0<br>0 | m2<br>0 |
|   | B  | m1<br>0 | m3<br>1 |

$$O_3 = AB = I_1I_0$$

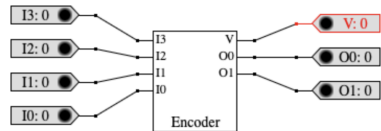


# Decoder



# Encoder

- Input:  $2^n$
- Output:  $n$



# Encoder

| $I_3$ | $I_2$ | $I_1$ | $I_0$ |  | $O_1$ | $O_0$ |
|-------|-------|-------|-------|--|-------|-------|
| 0     | 0     | 0     | 0     |  | ?     | ?     |
| 0     | 0     | 0     | 1     |  | ?     | ?     |
| 0     | 0     | 1     | 0     |  | ?     | ?     |
| 0     | 0     | 1     | 1     |  | ?     | ?     |
| 0     | 1     | 0     | 0     |  | ?     | ?     |
| 0     | 1     | 0     | 1     |  | ?     | ?     |
| 0     | 1     | 1     | 0     |  | ?     | ?     |
| 0     | 1     | 1     | 1     |  | ?     | ?     |

| $I_3$ | $I_2$ | $I_1$ | $I_0$ |  | $O_1$ | $O_0$ |
|-------|-------|-------|-------|--|-------|-------|
| 1     | 0     | 0     | 0     |  | ?     | ?     |
| 1     | 0     | 0     | 1     |  | ?     | ?     |
| 1     | 0     | 1     | 0     |  | ?     | ?     |
| 1     | 0     | 1     | 1     |  | ?     | ?     |
| 1     | 1     | 0     | 0     |  | ?     | ?     |
| 1     | 1     | 0     | 1     |  | ?     | ?     |
| 1     | 1     | 1     | 0     |  | ?     | ?     |
| 1     | 1     | 1     | 1     |  | ?     | ?     |



# Encoder

| $I_3$ | $I_2$ | $I_1$ | $I_0$ |  | $O_1$ | $O_0$ |
|-------|-------|-------|-------|--|-------|-------|
| 0     | 0     | 0     | 0     |  | ?     | ?     |
| 0     | 0     | 0     | 1     |  | 0     | 0     |
| 0     | 0     | 1     | 0     |  | 0     | 1     |
| 0     | 0     | 1     | 1     |  | ?     | ?     |
| 0     | 1     | 0     | 0     |  | 1     | 0     |
| 0     | 1     | 0     | 1     |  | ?     | ?     |
| 0     | 1     | 1     | 0     |  | ?     | ?     |
| 0     | 1     | 1     | 1     |  | ?     | ?     |

| $I_3$ | $I_2$ | $I_1$ | $I_0$ |  | $O_1$ | $O_0$ |
|-------|-------|-------|-------|--|-------|-------|
| 1     | 0     | 0     | 0     |  | 1     | 1     |
| 1     | 0     | 0     | 1     |  | ?     | ?     |
| 1     | 0     | 1     | 0     |  | ?     | ?     |
| 1     | 0     | 1     | 1     |  | ?     | ?     |
| 1     | 1     | 0     | 0     |  | ?     | ?     |
| 1     | 1     | 0     | 1     |  | ?     | ?     |
| 1     | 1     | 1     | 0     |  | ?     | ?     |
| 1     | 1     | 1     | 1     |  | ?     | ?     |



# Encoder

| $l_3$ | $l_2$ | $l_1$ | $l_0$ | $V$ | $O_1$ | $O_0$ |
|-------|-------|-------|-------|-----|-------|-------|
| 0     | 0     | 0     | 0     | 0   | ?     | ?     |
| 0     | 0     | 0     | 1     | 1   | 0     | 0     |
| 0     | 0     | 1     | 0     | 1   | 0     | 1     |
| 0     | 0     | 1     | 1     | 0   | ?     | ?     |
| 0     | 1     | 0     | 0     | 1   | 1     | 0     |
| 0     | 1     | 0     | 1     | 0   | ?     | ?     |
| 0     | 1     | 1     | 0     | 0   | ?     | ?     |
| 0     | 1     | 1     | 1     | 0   | ?     | ?     |

| $l_3$ | $l_2$ | $l_1$ | $l_0$ | $V$ | $O_1$ | $O_0$ |
|-------|-------|-------|-------|-----|-------|-------|
| 1     | 0     | 0     | 0     | 1   | 1     | 1     |
| 1     | 0     | 0     | 1     | 0   | ?     | ?     |
| 1     | 0     | 1     | 0     | 0   | ?     | ?     |
| 1     | 0     | 1     | 1     | 0   | ?     | ?     |
| 1     | 1     | 0     | 0     | 0   | ?     | ?     |
| 1     | 1     | 0     | 1     | 0   | ?     | ?     |
| 1     | 1     | 1     | 0     | 0   | ?     | ?     |
| 1     | 1     | 1     | 1     | 0   | ?     | ?     |



# Encoder

| $l_3$ | $l_2$ | $l_1$ | $l_0$ | $V$ | $O_1$ | $O_0$ |
|-------|-------|-------|-------|-----|-------|-------|
| 0     | 0     | 0     | 0     | 0   | X     | X     |
| 0     | 0     | 0     | 1     | 1   | 0     | 0     |
| 0     | 0     | 1     | 0     | 1   | 0     | 1     |
| 0     | 0     | 1     | 1     | 0   | X     | X     |
| 0     | 1     | 0     | 0     | 1   | 1     | 0     |
| 0     | 1     | 0     | 1     | 0   | X     | X     |
| 0     | 1     | 1     | 0     | 0   | X     | X     |
| 0     | 1     | 1     | 1     | 0   | X     | X     |

| $l_3$ | $l_2$ | $l_1$ | $l_0$ | $V$ | $O_1$ | $O_0$ |
|-------|-------|-------|-------|-----|-------|-------|
| 1     | 0     | 0     | 0     | 1   | 1     | 1     |
| 1     | 0     | 0     | 1     | 0   | X     | X     |
| 1     | 0     | 1     | 0     | 0   | X     | X     |
| 1     | 0     | 1     | 1     | 0   | X     | X     |
| 1     | 1     | 0     | 0     | 0   | X     | X     |
| 1     | 1     | 0     | 1     | 0   | X     | X     |
| 1     | 1     | 1     | 0     | 0   | X     | X     |
| 1     | 1     | 1     | 1     | 0   | X     | X     |



# Encoder

| AB \ CD | A'B'    | A'B     | AB       | AB'      |
|---------|---------|---------|----------|----------|
| C'D'    | m0<br>0 | m4<br>1 | m12<br>0 | m8<br>1  |
| C'D     | m1<br>1 | m5<br>0 | m13<br>0 | m9<br>0  |
| CD      | m3<br>0 | m7<br>0 | m15<br>0 | m11<br>0 |
| CD'     | m2<br>1 | m6<br>0 | m14<br>0 | m10<br>0 |

$$\begin{aligned}
 V &= AB'C'D' + \\
 &A'BC'D' + \\
 &A'B'CD' + A'B'C'D \\
 &= \\
 &l_3l_2l_1l_0' + l_3l_2l_1'l_0 + \\
 &l_3l_2l_1l_0' + l_3l_2l_1'l_0
 \end{aligned}$$

| AB \ CD | A'B'    | A'B     | AB       | AB'      |
|---------|---------|---------|----------|----------|
| C'D'    | m0<br>X | m4<br>1 | m12<br>X | m8<br>1  |
| C'D     | m1<br>0 | m5<br>X | m13<br>X | m9<br>X  |
| CD      | m3<br>X | m7<br>X | m15<br>X | m11<br>X |
| CD'     | m2<br>0 | m6<br>X | m14<br>X | m10<br>X |

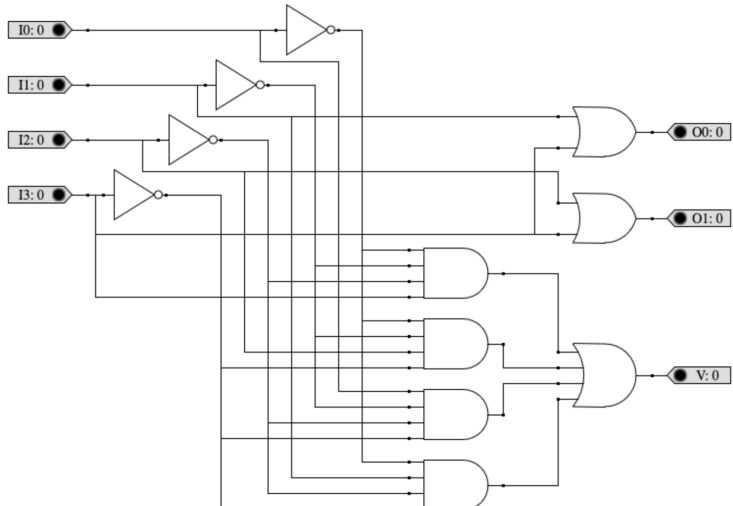
$$\begin{aligned}
 O_1 &= A + B = \\
 &l_3 + l_2
 \end{aligned}$$

| AB \ CD | A'B'    | A'B     | AB       | AB'      |
|---------|---------|---------|----------|----------|
| C'D'    | m0<br>X | m4<br>0 | m12<br>X | m8<br>1  |
| C'D     | m1<br>0 | m5<br>X | m13<br>X | m9<br>X  |
| CD      | m3<br>X | m7<br>X | m15<br>X | m11<br>X |
| CD'     | m2<br>1 | m6<br>X | m14<br>X | m10<br>X |

$$\begin{aligned}
 O_0 &= A + C = \\
 &l_3 + l_1
 \end{aligned}$$

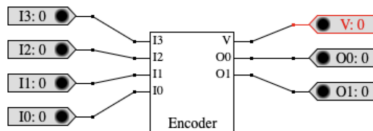


# Encoder



# Priority Encoder

- Priority Encoder acts like an encoder, but there is a priority established to handle more than one input being asserted
- Input:  $2^n$
- Output:  $n$
- One or more of the  $2^n$  inputs is asserted, highest priority value is encoded
- Priority Order:  
 $I_3 > I_2 > I_1 > I_0$



# Priority Encoder

| $I_3$ | $I_2$ | $I_1$ | $I_0$ | $V$ | $O_1$ | $O_0$ |
|-------|-------|-------|-------|-----|-------|-------|
| 0     | 0     | 0     | 0     |     | ?     | ?     |
| 0     | 0     | 0     | 1     | 1   | 0     | 0     |
| 0     | 0     | 1     | 0     | 1   | 0     | 1     |
| 0     | 0     | 1     | 1     |     | ?     | ?     |
| 0     | 1     | 0     | 0     | 1   | 1     | 0     |
| 0     | 1     | 0     | 1     |     | ?     | ?     |
| 0     | 1     | 1     | 0     |     | ?     | ?     |
| 0     | 1     | 1     | 1     |     | ?     | ?     |

| $I_3$ | $I_2$ | $I_1$ | $I_0$ | $V$ | $O_1$ | $O_0$ |
|-------|-------|-------|-------|-----|-------|-------|
| 1     | 0     | 0     | 0     | 1   | 1     | 1     |
| 1     | 0     | 0     | 1     |     | ?     | ?     |
| 1     | 0     | 1     | 0     |     | ?     | ?     |
| 1     | 0     | 1     | 1     |     | ?     | ?     |
| 1     | 1     | 0     | 0     |     | ?     | ?     |
| 1     | 1     | 0     | 1     |     | ?     | ?     |
| 1     | 1     | 1     | 0     |     | ?     | ?     |
| 1     | 1     | 1     | 1     |     | ?     | ?     |



# Priority Encoder

| $l_3$ | $l_2$ | $l_1$ | $l_0$ | $V$ | $O_1$ | $O_0$ |
|-------|-------|-------|-------|-----|-------|-------|
| 0     | 0     | 0     | 0     |     | ?     | ?     |
| 0     | 0     | 0     | 1     | 1   | 0     | 0     |
| 0     | 0     | 1     | 0     | 1   | 0     | 1     |
| 0     | 0     | 1     | 1     | 1   | 0     | 1     |
| 0     | 1     | 0     | 0     | 1   | 1     | 0     |
| 0     | 1     | 0     | 1     |     | ?     | ?     |
| 0     | 1     | 1     | 0     |     | ?     | ?     |
| 0     | 1     | 1     | 1     |     | ?     | ?     |

| $l_3$ | $l_2$ | $l_1$ | $l_0$ | $V$ | $O_1$ | $O_0$ |
|-------|-------|-------|-------|-----|-------|-------|
| 1     | 0     | 0     | 0     | 1   | 1     | 1     |
| 1     | 0     | 0     | 1     |     | ?     | ?     |
| 1     | 0     | 1     | 0     |     | ?     | ?     |
| 1     | 0     | 1     | 1     |     | ?     | ?     |
| 1     | 1     | 0     | 0     |     | ?     | ?     |
| 1     | 1     | 0     | 1     |     | ?     | ?     |
| 1     | 1     | 1     | 0     |     | ?     | ?     |
| 1     | 1     | 1     | 1     |     | ?     | ?     |



# Priority Encoder

| $I_3$ | $I_2$ | $I_1$ | $I_0$ | $V$ | $O_1$ | $O_0$ |
|-------|-------|-------|-------|-----|-------|-------|
| 0     | 0     | 0     | 0     |     | ?     | ?     |
| 0     | 0     | 0     | 1     | 1   | 0     | 0     |
| 0     | 0     | 1     | 0     | 1   | 0     | 1     |
| 0     | 0     | 1     | 1     | 1   | 0     | 1     |
| 0     | 1     | 0     | 0     | 1   | 1     | 0     |
| 0     | 1     | 0     | 1     | 1   | 1     | 0     |
| 0     | 1     | 1     | 0     | 1   | 1     | 0     |
| 0     | 1     | 1     | 1     | 1   | 1     | 0     |

| $I_3$ | $I_2$ | $I_1$ | $I_0$ | $V$ | $O_1$ | $O_0$ |
|-------|-------|-------|-------|-----|-------|-------|
| 1     | 0     | 0     | 0     | 1   | 1     | 1     |
| 1     | 0     | 0     | 1     |     | ?     | ?     |
| 1     | 0     | 1     | 0     |     | ?     | ?     |
| 1     | 0     | 1     | 1     |     | ?     | ?     |
| 1     | 1     | 0     | 0     |     | ?     | ?     |
| 1     | 1     | 0     | 1     |     | ?     | ?     |
| 1     | 1     | 1     | 0     |     | ?     | ?     |
| 1     | 1     | 1     | 1     |     | ?     | ?     |



# Priority Encoder

| $l_3$ | $l_2$ | $l_1$ | $l_0$ | $V$ | $O_1$ | $O_0$ |
|-------|-------|-------|-------|-----|-------|-------|
| 0     | 0     | 0     | 0     |     | ?     | ?     |
| 0     | 0     | 0     | 1     | 1   | 0     | 0     |
| 0     | 0     | 1     | 0     | 1   | 0     | 1     |
| 0     | 0     | 1     | 1     | 1   | 0     | 1     |
| 0     | 1     | 0     | 0     | 1   | 1     | 0     |
| 0     | 1     | 0     | 1     | 1   | 1     | 0     |
| 0     | 1     | 1     | 0     | 1   | 1     | 0     |
| 0     | 1     | 1     | 1     | 1   | 1     | 0     |

| $l_3$ | $l_2$ | $l_1$ | $l_0$ | $V$ | $O_1$ | $O_0$ |
|-------|-------|-------|-------|-----|-------|-------|
| 1     | 0     | 0     | 0     | 1   | 1     | 1     |
| 1     | 0     | 0     | 1     | 1   | 1     | 1     |
| 1     | 0     | 1     | 0     | 1   | 1     | 1     |
| 1     | 0     | 1     | 1     | 1   | 1     | 1     |
| 1     | 1     | 0     | 0     | 1   | 1     | 1     |
| 1     | 1     | 0     | 1     | 1   | 1     | 1     |
| 1     | 1     | 1     | 0     | 1   | 1     | 1     |
| 1     | 1     | 1     | 1     | 1   | 1     | 1     |



# Priority Encoder

| $l_3$ | $l_2$ | $l_1$ | $l_0$ | $V$ | $O_1$ | $O_0$ |
|-------|-------|-------|-------|-----|-------|-------|
| 0     | 0     | 0     | 0     | 0   | X     | X     |
| 0     | 0     | 0     | 1     | 1   | 0     | 0     |
| 0     | 0     | 1     | 0     | 1   | 0     | 1     |
| 0     | 0     | 1     | 1     | 1   | 0     | 1     |
| 0     | 1     | 0     | 0     | 1   | 1     | 0     |
| 0     | 1     | 0     | 1     | 1   | 1     | 0     |
| 0     | 1     | 1     | 0     | 1   | 1     | 0     |
| 0     | 1     | 1     | 1     | 1   | 1     | 0     |

| $l_3$ | $l_2$ | $l_1$ | $l_0$ | $V$ | $O_1$ | $O_0$ |
|-------|-------|-------|-------|-----|-------|-------|
| 1     | 0     | 0     | 0     | 1   | 1     | 1     |
| 1     | 0     | 0     | 1     | 1   | 1     | 1     |
| 1     | 0     | 1     | 0     | 1   | 1     | 1     |
| 1     | 0     | 1     | 1     | 1   | 1     | 1     |
| 1     | 1     | 0     | 0     | 1   | 1     | 1     |
| 1     | 1     | 0     | 1     | 1   | 1     | 1     |
| 1     | 1     | 1     | 0     | 1   | 1     | 1     |
| 1     | 1     | 1     | 1     | 1   | 1     | 1     |



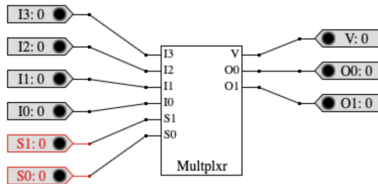
# Priority Encoder

## Expression and Circuit: Quiz !



# Multiplexer

- A multiplexer is used to select one input (out of several inputs) to be the circuit output
- Input:  $2^n$
- Selection input:  $n$
- Output: 1
- The  $n$  selection bits determine which of the  $2^n$  data inputs is routed to the output



# 2-to-1 Multiplexer

| $S$ | $O$   |
|-----|-------|
| 0   | $I_0$ |
| 1   | $I_1$ |

| $S$ | $I_1$ | $I_0$ | $O$ |
|-----|-------|-------|-----|
| 0   | 0     | 0     | 0   |
| 0   | 0     | 1     | 1   |
| 0   | 1     | 0     | 0   |
| 0   | 1     | 1     | 1   |
| 1   | 0     | 0     | 0   |
| 1   | 0     | 1     | 0   |
| 1   | 1     | 0     | 1   |
| 1   | 1     | 1     | 1   |



# 2-to-1 Multiplexer

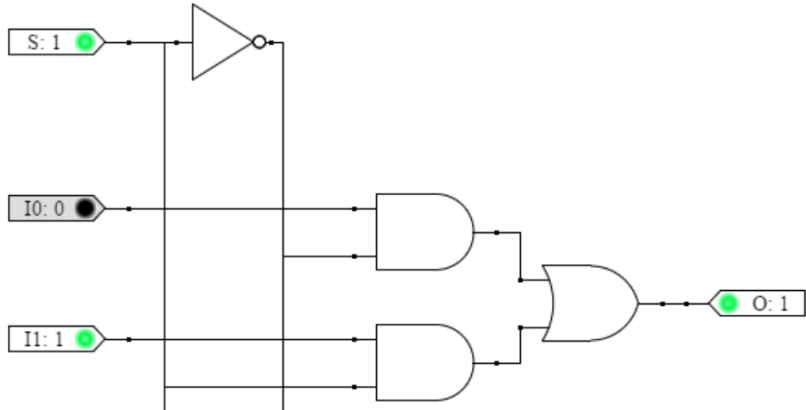
| $S$ | $I_1$ | $I_0$ | $O$ |
|-----|-------|-------|-----|
| 0   | 0     | 0     | 0   |
| 0   | 0     | 1     | 1   |
| 0   | 1     | 0     | 0   |
| 0   | 1     | 1     | 1   |
| 1   | 0     | 0     | 0   |
| 1   | 0     | 1     | 0   |
| 1   | 1     | 0     | 1   |
| 1   | 1     | 1     | 1   |

| $S \ I_1$<br>$I_0$ | $S' I_1'$ | $S' I_1$ | $S I_1'$ | $S I_1$ |
|--------------------|-----------|----------|----------|---------|
|                    | $I_0'$    | $I_0'$   | $I_0'$   | $I_0'$  |
| $I_0'$             | m0<br>0   | m2<br>0  | m6<br>1  | m4<br>0 |
| $I_0$              | m1<br>1   | m3<br>1  | m7<br>1  | m5<br>0 |

$$S I_1 + S' I_0$$



# 2-to-1 Multiplexer



# 4-to-1 Multiplexer

| $S_1$ | $S_0$ | $O$   |
|-------|-------|-------|
| 0     | 0     | $I_0$ |
| 0     | 1     | $I_1$ |
| 1     | 0     | $I_2$ |
| 1     | 1     | $I_3$ |

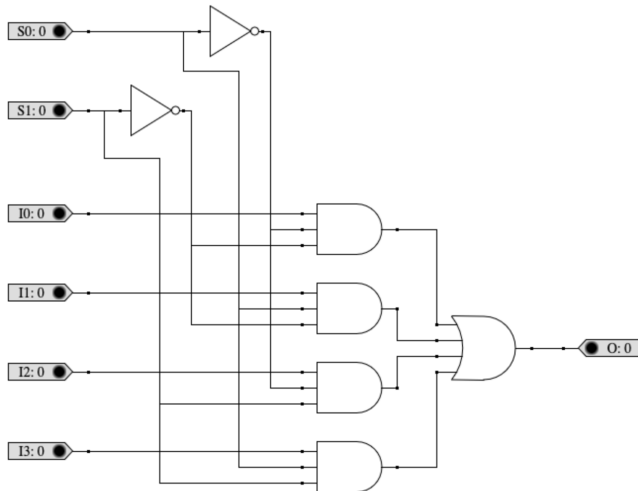


## 4-to-1 Multiplexer

6-inputs, so the characteristic table will contain  $2^6 = 64$  entries



# 4-to-1 Multiplexer



# Demultiplexer

| $S_1$ | $S_0$ | $O_3$ | $O_2$ | $O_1$ | $O_0$ |
|-------|-------|-------|-------|-------|-------|
| 0     | 0     | 0     | 0     | 0     | 1     |
| 0     | 1     | 0     | 0     | 1     | 0     |
| 1     | 0     | 0     | 1     | 0     | 0     |
| 1     | 1     | 1     | 0     | 0     | 0     |

