# ECE380 Digital Logic

Optimized Implementation of Logic Functions:

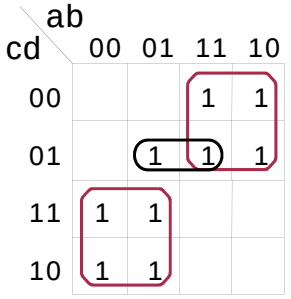
Multiple Output Circuits, NAND and NOR Logic Networks

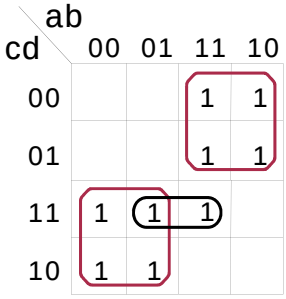


## Multiple output circuits

- In all previous examples we have considered only single output functions
- In practice, these functions may be part of some larger circuit that has many such functions
- Circuits that implement these functions may be combined into a less costly single circuit with multiple outputs by sharing some gates needed in the implementation of the single functions

# Multiple output circuit example



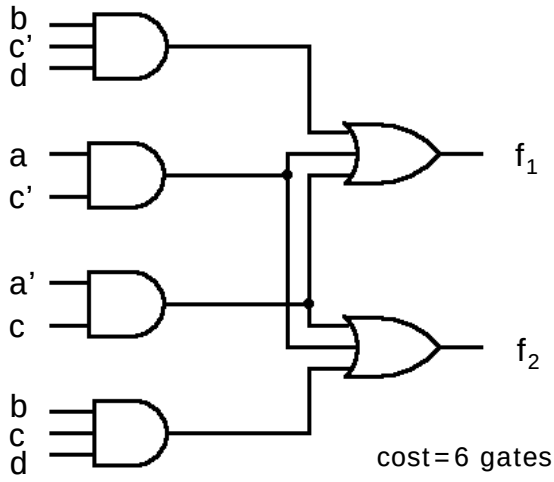

$f_1(a,b,c,d) = ac' + a'c + bc'd$ cost = 4 gates + 10 inputs

$f_2(a,b,c,d) = ac' + a'c + bcd$ cost = 4 gates + 10 inputs

NOTE: cost ignores NOT gates



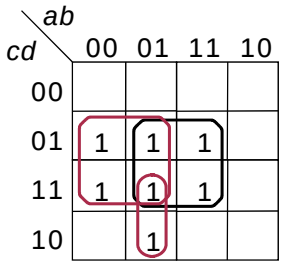
# Multiple output circuit example



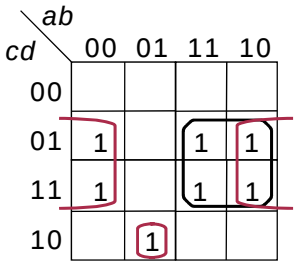

cost = 6 gates + 16 inputs

# Multiple output circuit example

- In this case, the minimum combined circuit was derived from the minimum circuit for each function ($f_1$ and $f_2$)
- This will not always be the case.
- Consider two functions $f_3$ and $f_4$.



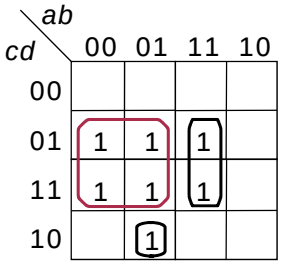

Optimal realization of $f_3$

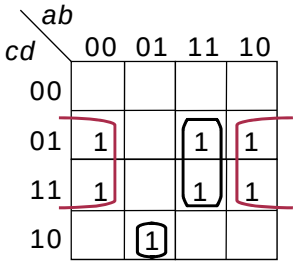



Optimal realization of $f_4$



# Multiple output circuit example

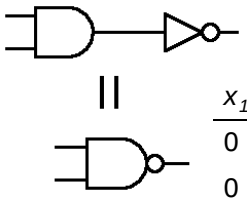



Optimal realization of $f_3$ and $f_4$ together

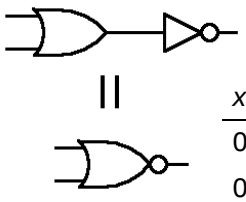
# NAND and NOR logic networks

- A ***NAND*** gate is a functional combination of an AND gate followed by a NOT gate



| $x_1$ | $x_2$ | $\overline{x_1 \cdot x_2}$ |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

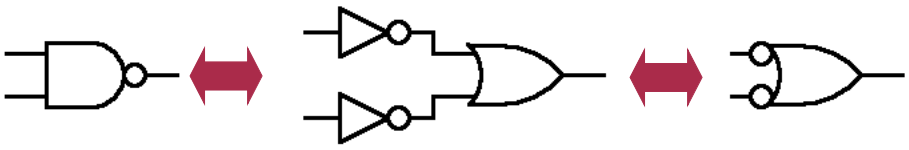
- A ***NOR*** gate is a functional combination of an OR gate followed by a NOT gate



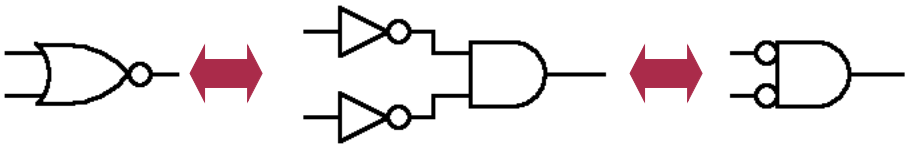
| $x_1$ | $x_2$ | $\overline{x_1 + x_2}$ |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 0 |



# DeMorgan's theorem in gate terms



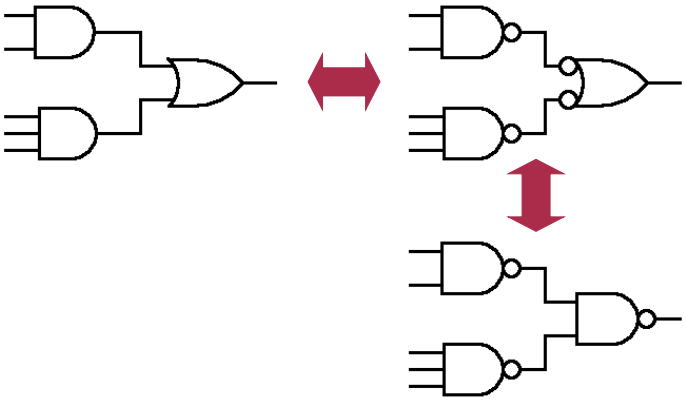
**(ab)'=a'+b'**



**(a+b)'=a'b'**

# AND-OR and NAND-NAND networks

- If we have a network in AND-OR (SOP) form, we can convert it to a NAND-NAND network





# OR-AND and NOR-NOR networks

- If we have a network in OR-AND (POS) form, we can convert it to a NOR-NOR network