T02 Tutorial Slides for Week 7

ENEL 353: Digital Circuits — Fall 2019 Term

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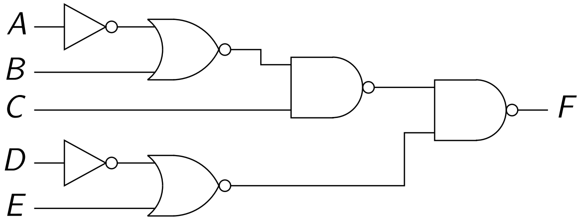
Topics for today

"Bubble-pushing" and De Morgan's Theorem.

Tristate buffers and X and Z values for circuit nodes.

K-map exercises.

Exercise 1: Bubble pushing

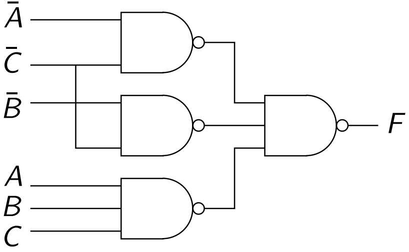


Find an SOP expression for F by "bubble-pushing".

Find the same expression by algebraic manipulation, including use of De Morgan's Theorem.

Exercise 2: Two-level NAND logic

Use bubble-pushing to find an SOP expression to describe this circuit:



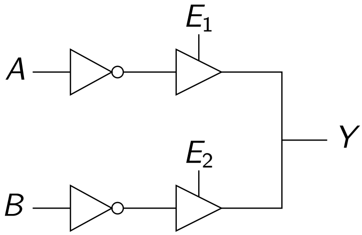
This is just an example of a general fact about two-level NAND logic. *What is that fact?*

A related fact: In CMOS technology, a NAND gate tends to be smaller and to switch faster than an AND or OR gate with the same number of inputs.

Exercise 3: Tristate buffers

In each row of the table, give the state of Y as one of 0, 1, X (for unknown/illegal value), or Z (for floating/ high-impedance).

Give brief reasons for each of your six answers.



A	B	E_1	E_2	Y
0	1	0	0	
0	1	0	1	
0	1	1	0	
1	0	0	1	
1	0	1	1	
1	1	1	1	

Exercise 4

Simplify $F = A\bar{B}\bar{C} + A\bar{B}C + AB\bar{C} + ABC$ *using a K-map.*

Repeat the simplification using Boolean algebra, particularly the Combining Theorem: $D\bar{E} + DE = D$.

Exercise 5

Draw a K-map for $F(A,B,C) = A + \bar{A}B$.

Review: A *prime implicant* is a rectangle of 1, 2, 4, or 8 1-cells that can't be doubled in size without collecting some 0-cells.

Circle the prime implicants of F.

Exercise 5, continued

Review: An *implicant* is any rectangle of 1, 2, 4, or 8 1-cells. Equivalently, the implicants of F are **all** the products that appear in **all** of the valid SOP expressions for F.

How many implicants does F have that are not prime implicants?

(The definitions of *prime implicant* and *implicant* on this slide and the previous one apply to functions with 2–4 input variables. Things are more complicated with 5 or more variables.)

Exercise 6

Draw a K-map for
$G(A,B,C,D) = \bar{A}CD + B\bar{C}D + AC + \bar{A}\bar{B}C\bar{D} + AD + BC\bar{D}$.

Review: A *distinguished 1-cell* is a 1-cell that is covered by only one prime implicant.

More review: An *essential prime implicant* is a prime implicant that covers at least one distinguished 1-cell.

Find the essential prime implicants of G.

Do the essential prime implicants of G give us a minimal SOP expression for G?

Essential versus *non-essential*

It's important to understand that in discussion of K-maps, *non-essential* does **not** mean the same thing as *unnecessary* or *not useful*.

A minimal SOP expression for a function F must use all of the **essential** PI's.

However, in some but not all K-map problems, one or more **non-essential** PI's must be used to complete the cover of all the 1-cells.

Exercise 7

Draw K-maps for the two functions of a 1-bit full adder.

Use the K-maps to find minimal SOP expressions for the two functions.

A	B	C_{IN}	C_{OUT}	S
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1