

**School of Computer Science**

**Faculty of Science**

**COMP-2650: Computer Architecture I: Digital Design**

**Fall 2020**

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| Lab# | Date | Title | Due Date | Grade Release Date |
| Lab 06 | Nov 02-04, 2020 | **L06: Boolean Algebra and Logic Gates** | Nov. 18, 2020  Wednesday Midnight [AoE](https://www.timeanddate.com/time/zones/aoe) | Nov. 25, 2020 |

The 6th lab's objectives will be to master the topics in logic circuit design by implementing the algorithms with a programming language, herein, C/C++.

**Step 1. Environment Setup**

Our programming environment is the same as the first lab (Lab 01). In this lab, we want to start a new series of labs about designing a logic circuit. Particularly, in this lab, we want to create a truth table for a given number of input binary variables and output binary variables.

1. As we discussed in the lectures, the first step in designing a logic circuit is to build a truth table with columns for input binary variables and columns for output binary variables. Also, we have to create rows for different values of the input binary variables, either 0 or 1 for each input binary variable. For example, given 3 input binary variables and 1 output binary variable, the truth table would have 4 columns and 23=8 rows.
2. Next, we have to pick names for the input and output binary variables. For instance, for 3 input binary variables, we can choose Z, Y, X and for the single output binary variable we can choose F.
3. Then, we have to look at those rows that make the output binary variable 1 and write the output binary variable as a Boolean function (expression) of the input binary variables in form of a sum of minterms (canonical sum of products). For instance, F = ∑m(0,2,3) = Z’Y’X’ + Z’YX’ + Z’YX.
4. Finally, we sketch the logic circuit using the schematic symbols of the NOT, AND and OR logic gates.

In this lab, we want to write a program that does the 1st and 2nd steps. That is, we want to write a program that outputs the truth table. In the following code, I assume that there are 3 input binary variables (line#04), there are 1 output binary variables (line#05), and as a result, the truth table is going to have 2^(#input variables) = 23=8.

I defined the truth table as a 2-D array of integer values with size 8 rows × 4 columns (line#15). Please pay attention that in C/C++ the '^' symbol is reserved for bitwise XOR operator and cannot be used for power operator (line#11,12). In C/C++, we can use the pow(a, b) function available in math.h library to return a to the power of b as shown in line#14. Also, note that the format specifier for char is "%c".

01 **#include** <stdio.h>

02 **#include** <math.h>

03

04 **#define** INPUT\_VARIABLE\_COUNT 3

05 **#define** OUTPUT\_VARIABLE\_COUNT 1

06

07 **int** **main**(**void**) {

08

09 **setbuf**(stdout, NULL);

10

11 //Wrong! ^ operator in C/C++ is the bitwise XOR logic operator.

12 //int TRUTH\_TABLE\_ROW\_COUNT = 2^INPUT\_VARIABLE\_COUNT;

13

14 **int** TRUTH\_TABLE\_ROW\_COUNT = (**int**)pow(2, INPUT\_VARIABLE\_COUNT);

15 **int** truth\_table[TRUTH\_TABLE\_ROW\_COUNT][INPUT\_VARIABLE\_COUNT + OUTPUT\_VARIABLE\_COUNT] = {0};

16 **const** **char** variables[INPUT\_VARIABLE\_COUNT + OUTPUT\_VARIABLE\_COUNT] = {'Z', 'Y', 'X', 'F'};

17

18 //printing the header of truth table with variable names for inputs and outputs

19

20 //printing the header for input variables

21 **for**(**int** i = 0; i < INPUT\_VARIABLE\_COUNT; i = i + 1){

22 **printf**("%c, ", variables[i]);

23 }

24 **printf**(" : ");

25

26 //printing the header for output variables

27 **for**(**int** i = INPUT\_VARIABLE\_COUNT; i < INPUT\_VARIABLE\_COUNT + OUTPUT\_VARIABLE\_COUNT; i = i + 1){

28 **printf**("%c", variables[i]);

29 }

30 **printf**("\n");

31

32 //printing the content of each row

33 **for**(**int** i = 0; i < TRUTH\_TABLE\_ROW\_COUNT; i = i + 1){

34

35 //printing the content of each row regarding the input variables

36 **for**(**int** j = 0; j < INPUT\_VARIABLE\_COUNT; j = j + 1){

37 **printf**("%d, ", truth\_table[i][j]);

38 }

39 **printf**(" : ");

40

41 //printing the content of each row regarding the output variables

42 **for**(**int** j = INPUT\_VARIABLE\_COUNT; j < INPUT\_VARIABLE\_COUNT + OUTPUT\_VARIABLE\_COUNT; j = j + 1){

43 **printf**("%d", truth\_table[i][j]);

44 }

45 **printf**("\n");

46 }

47 **return** 0;

48}

In the above code, first, we output the header of the truth table (line#18-30) given the names of variables are defined in an array of chars (line#16). Then, we output the content of the truth table. If you run the code you would see the following result:

Z, Y, X, : F

0, 0, 0, : 0

0, 0, 0, : 0

0, 0, 0, : 0

0, 0, 0, : 0

0, 0, 0, : 0

0, 0, 0, : 0

0, 0, 0, : 0

0, 0, 0, : 0

As you can see, the code has two problems: *i)* it outputs only one possibility in the input binary variables: Z=0, Y=0, X=0, *ii)* it does not ask or determine where the output binary variable should be 1.

To fix the previous code, first, I have to create all the possibilities of the input binary variables on the left side of the truth table such that the output looks like the following:

Z, Y, X, : F

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, : 0

As seen, if I put the different possibilities of the input variables in increasing order of binary numbers, they look like incrementing the previous possibility, that is, 000 → 001 → … → 110 → 111. I can use either the signed-magnitude addition or the signed-2’s-complement addition functions in arithmetic\_tools.h that I wrote in lab04 and lab05 to do an increment. Or I can add a new function that does an increment to a given unsigned binary:

**arithmetic\_tools.h**

**void** func\_increment(**int** a[], **int** result[]);

**arithmetic\_tools.cpp**

**#define** MAX 8//Byte = 8 bits

**void** func\_increment(**int** a[], **int** result[]){...}

Then, I can change my code to fix the input binary variable part of the truth table.

**void** build\_left\_side(**int** truth\_table[]){

**for**(**int** i = 0; i < TRUTH\_TABLE\_ROW\_COUNT - 1; i = i + 1){

**int** row[INPUT\_VARIABLE\_COUNT] = {0};

**int** result[INPUT\_VARIABLE\_COUNT] = {0};

//accessing the elements of the i-th row

...

//increment

func\_increment(row, result);

//put into the next row: (i+1)-th row

...

}

}

Regarding the second problem, we can ask the user for the value of the output binary variable ('F').

**void** build\_right\_side(**int** truth\_table[]){

**for**(**int** i = 0; i < TRUTH\_TABLE\_ROW\_COUNT; i = i + 1){

//for each output variable F, ...

**for**(**int** j = 0; j < OUTPUT\_VARIABLE\_COUNT; j = j + 1){

**printf**("output value for row# %d of %c output variable:", i, ...);

**...**

}

}

}

A sample run would look like the following then:

output value for row# 0 of F output variable:1

output value for row# 1 of F output variable:0

output value for row# 2 of F output variable:0

output value for row# 3 of F output variable:0

output value for row# 4 of F output variable:1

output value for row# 5 of F output variable:1

output value for row# 6 of F output variable:0

output value for row# 7 of F output variable:0

Z, Y, X, : F

0, 0, 0, : 1

0, 0, 1, : 0

0, 1, 0, : 0

0, 1, 1, : 0

1, 0, 0, : 1

1, 0, 1, : 1

1, 1, 0, : 0

1, 1, 1, : 0

**Lab Assignment**

You should complete the above program under the name of a project COMP2650\_Lab06\_{UWinID} that

asks for the value of output variable F1 as follows:

output value for row# 0 of F output variable:1

output value for row# 1 of F output variable:0

output value for row# 2 of F output variable:0

output value for row# 3 of F output variable:0

output value for row# 4 of F output variable:1

output value for row# 5 of F output variable:1

output value for row# 6 of F output variable:0

output value for row# 7 of F output variable:0

When the user enters the values, the program should print out the truth as shown below:

Z, Y, X, : F

0, 0, 0, : 1

0, 0, 1, : 0

0, 1, 0, : 0

0, 1, 1, : 0

1, 0, 0, : 1

1, 0, 1, : 1

1, 1, 0, : 0

1, 1, 1, : 0

Please restrict the user to enter inputs within the range {0,1} for the value of the output variable. For instance, if the user enters 2, -1, …, print out an error message and come back to ask for correct inputs.

It is required to write a *modular* program:

1. For increment, you can re-use the function in arithmetic\_tools.h or write a new function called func\_increment().
2. Put the part of the code that completes the left part of the truth table in a new function called build\_left\_side() inside the main.c file.
3. Put the part of the code that asks for the values of the output variable in a new function called build\_right\_side() inside the main.c file.

**Deliverables**

You will prepare and submit the program in one single zip file COMP2650\_Lab06\_{UWinID}.zip containing the following two items:

1. The entire project folder COMP2650\_Lab06\_{UWinID}, including the code (source) files and executable file.
2. The result of the commands in the file COMP2650\_Lab06\_Results\_{UWinID}.jpg/pdf. Simply make a screenshot of the results and save it. If multiple images, please print them all into a single pdf file.
3. A lab report document in the PDF file COMP2650\_Lab06\_Report\_{UWinID}.pdf. It should include:
4. Your name, UWinID, and student number
5. One paragraph describes the program that you attached, along with any prerequisites needed to build and run the program. *Please note that if your program cannot be built and run on our computer systems, you will lose marks.*

In sum, your final zip file for the submission includes 1 folder (entire project folder), 1 image/pdf (results snapshot), and 1 pdf (report). *Please follow the naming convention as you lose marks otherwise.* Instead of {UWinID}, use your own UWindsor account name, e.g., mine is [hfani@uwindsor.ca](mailto:hfani@uwindsor.ca), so,

COMP2650\_Lab06\_hfani.zip

* COMP2650\_Lab06\_hfani
  + src
    - arithmetic\_tools.cpp
    - arithmetic\_tools.h
    - main.cpp
  + COMP2650\_Lab06\_hfani [.exe in MS-Windows]
* COMP2650\_Lab06\_Report\_hfani.pdf
* COMP2650\_Lab06\_Results\_hfani.jpg or COMP2650\_Lab06\_Results\_hfani.pdf