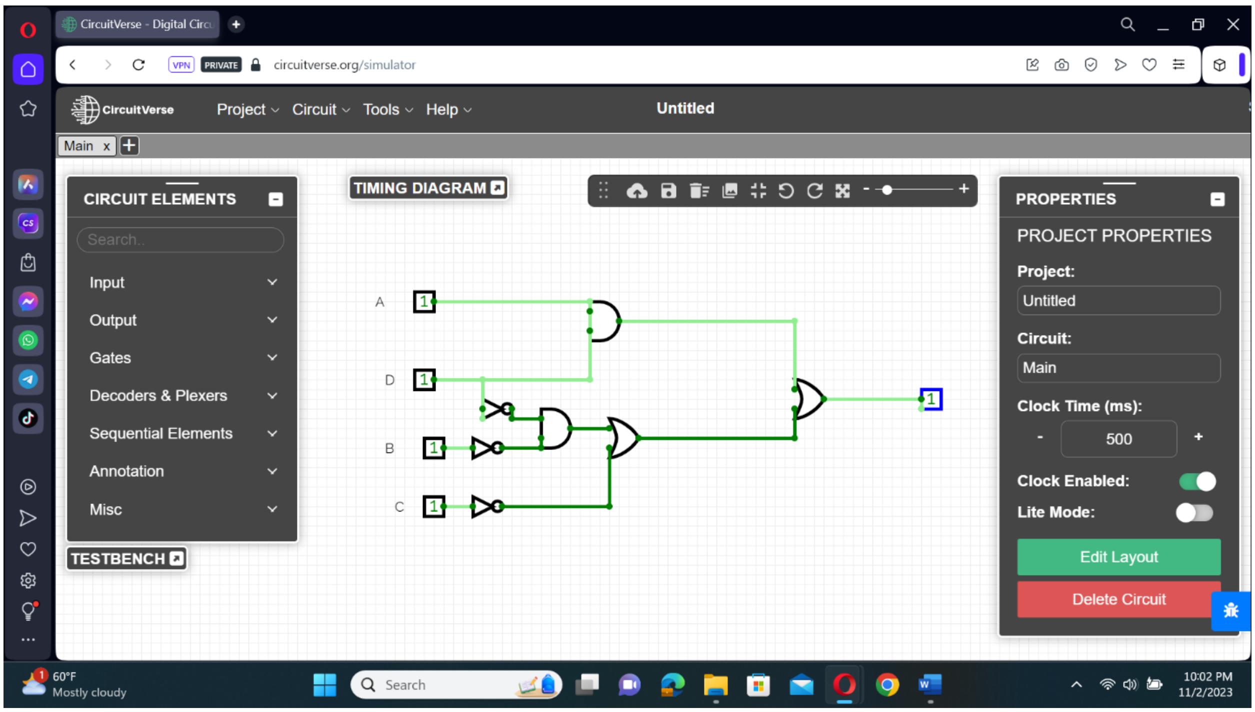
1. Simplify the following Boolean logic functions to the format in sum of product first and then create a truth table in Excel for each as the verification reference of the circuit design, finally implement by online tools at https://circuitverse.org/simulator

a. $f = (A + \bar{C} + \bar{D})(\bar{B} + \bar{C} + D)(A + \bar{B} + \bar{C})$

$= (A + \bar{C} + \bar{D})(\bar{B}\bar{C} + \bar{B}D + \bar{C}\bar{C} + \bar{C}D)$

$= (A\bar{B} + AD + \bar{C}\bar{D} + \bar{C}D)$

$= (A + \bar{C} + \bar{D})(\bar{B}\bar{C} + \bar{B}D + \bar{C}\bar{C} + \bar{C}D)$



b. f = (Z + X)($\bar{Z}$ + $\bar{Y}$)($\bar{Y}$ + X)

f = (Z + X)($\bar{Z}$ + $\bar{Y}$)($\bar{Y}$ + X)

= (Z$\bar{Z}$ + Z$\bar{Y}$ + X$\bar{Z}$ + X$\bar{Y}$)($\bar{Y}$ + X)

= (0 + Z$\bar{Y}$ + X$\bar{Z}$ + X$\bar{Y}$)($\bar{Y}$ + X)

= Z$\bar{Y}\bar{Y}$ + X$\bar{Z}\bar{Y}$ + X$\bar{Y}\bar{Y}$ + Z$\bar{Y}$X + XX$\bar{Z}$ + XX$\bar{Y}$

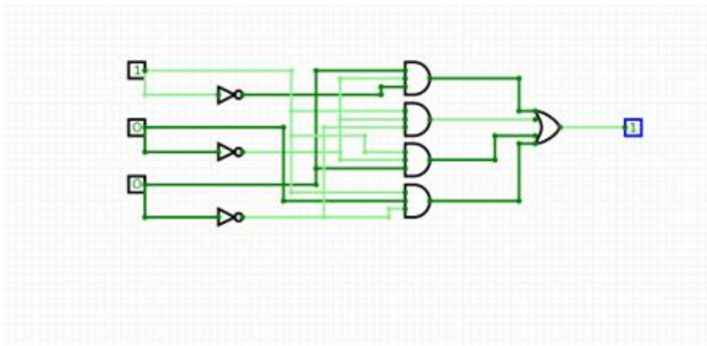
= Z$\bar{Y}$ + X$\bar{Z}\bar{Y}$ + Z$\bar{Y}$X + X$\bar{Z}$ + X$\bar{Y}$

From the truth table, we can see that the SOP form is $\overline{XY}$Z + X$\bar{Y}\bar{Z}$ + $\bar{X}$YZ + X$\bar{Y}$Z

X	Y	Z	X	~Y	~Z	Z~Y	X~Z~Y	Z~YX	X~Z	X~Y	f
0	0	0	1	1	1	0	0	0	0	0	0
0	0	1	1	1	0	1	0	0	0	0	1

0	1	0	1	0	1	0	0	0	0	0	0
0	1	1	1	0	0	0	0	0	0	0	0
1	0	0	0	1	1	0	1	0	1	1	1
1	0	1	0	1	0	1	0	1	0	1	1
1	1	0	0	0	1	0	0	0	1	0	1
1	1	1	0	0	0	0	0	0	0	0	0

Circuit



c. $(\overline{X} + \overline{Y})Z + \overline{X}\overline{Y}\overline{Z}$

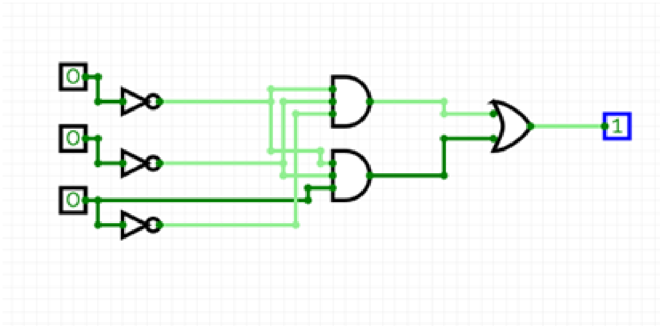
$= \overline{X}\overline{Y}Z + \overline{X}\overline{Y}\overline{Z}$

$= \overline{X}Z + Z(\overline{Y} + X)$

X	Y	Z	~X	~Y	~Z	~X~YZ	~X~Y~Z	f
0	0	0	TRUE	TRUE	TRUE	FALSE	TRUE	1
0	0	1	TRUE	TRUE	FALSE	TRUE	FALSE	1
0	1	0	TRUE	FALSE	TRUE	FALSE	FALSE	0
0	1	1	TRUE	FALSE	FALSE	FALSE	FALSE	0
1	0	0	FALSE	TRUE	TRUE	FALSE	FALSE	0
1	0	1	FALSE	TRUE	FALSE	FALSE	FALSE	0
1	1	0	FALSE	FALSE	TRUE	FALSE	FALSE	0
1	1	1	FALSE	FALSE	FALSE	FALSE	FALSE	0

From truth table SOP form is $\overline{X}\overline{Y}Z + \overline{X}\overline{Y}\overline{Z}$

Circuit is now:



2. Design signal bit full adder based on the truth table and circuit on chapter 3 lecture handouts first and then create 4-bit "Adder-Subtractor circuit" as follows to implement arithmetic addition and subtraction operations.

(a) A + B

= 7 + (-3) = 4

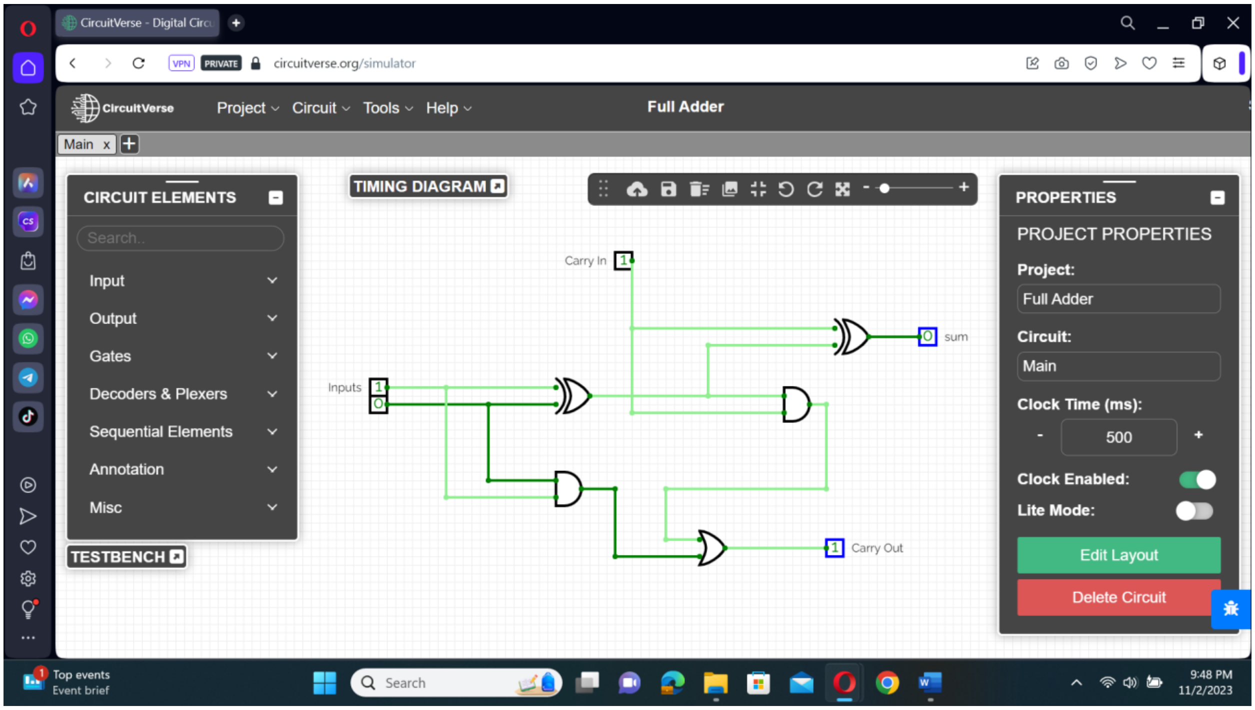
Here,

7 = 0111

-3 = 1101

4 = 0100

Circuit design is below:



(b) A - B

= -6 - (-1) = -5

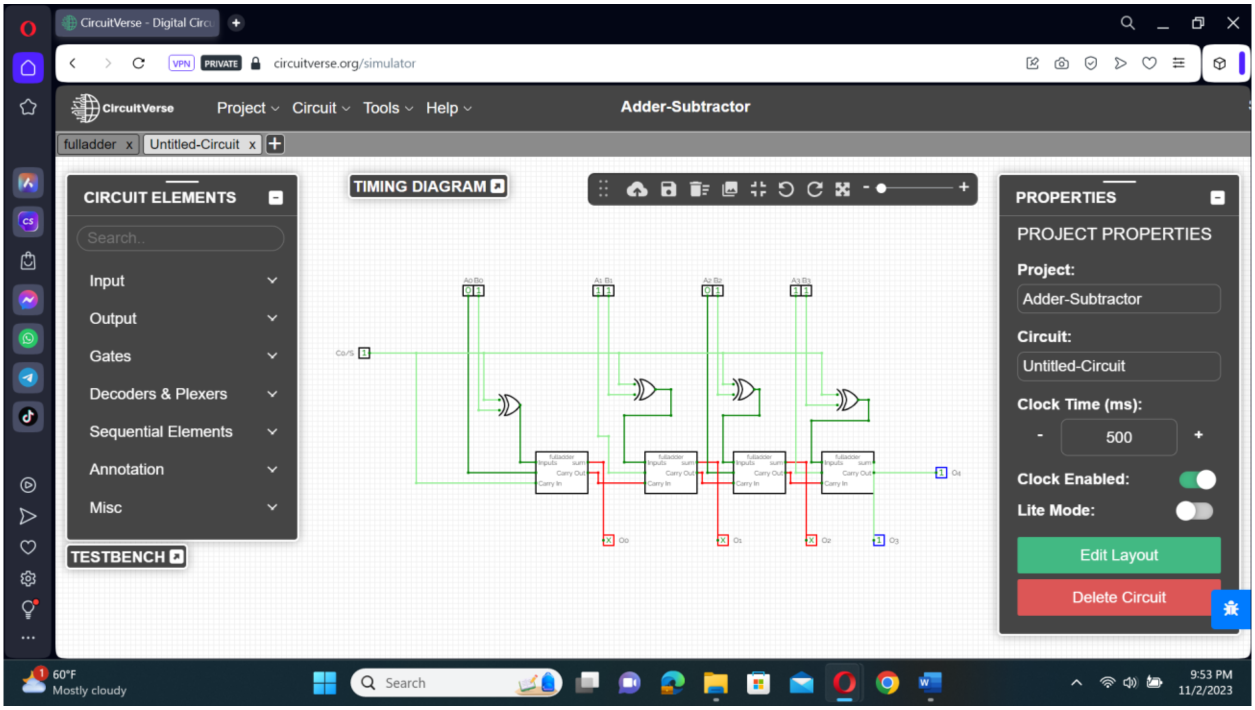
Here,

-6 = 1010

-1 = 1111

-5 = 1011

Circuit design is below:



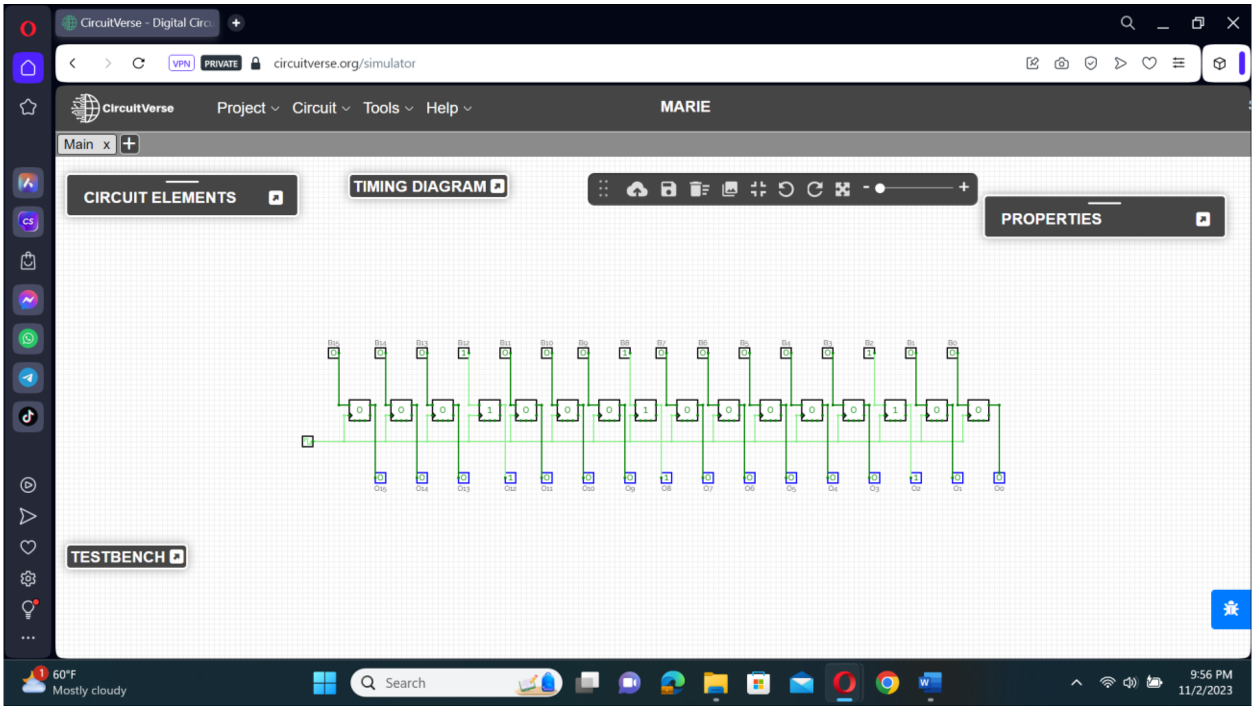
3. The following circuit is to simulate the MARIE assembly instruction "load 003", which means that it moves this instruction saved in the certain location of the memory to the instruction register (IR) using 16 D-Flip Flops within CPU.Based on the above circuit, please implement the following MARIE assembly instructions by translating assembly code to machine code depending on the given lookup table in chapter 4 lecture handouts.

Load 104

We know here that,

Load 104 = 0001000100000100

Circuit design is below:

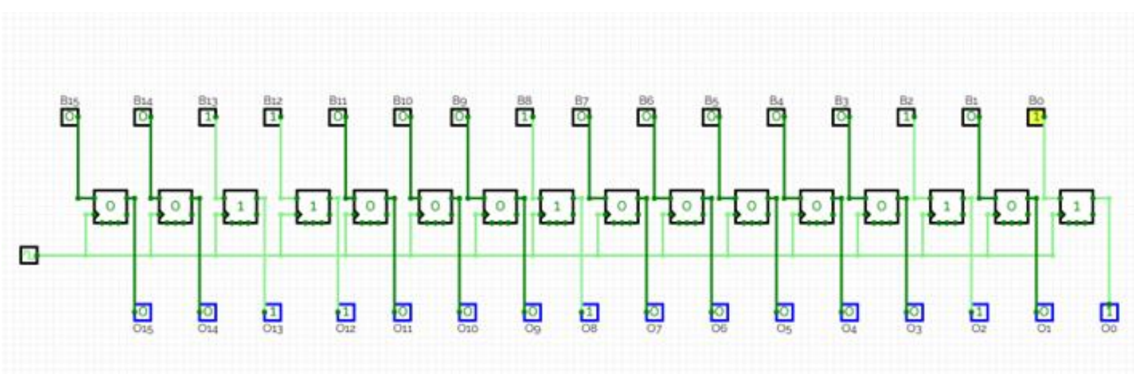


Next step is Adding 105

We know:

Add 105 = 0011000100000101

Circuit becomes then,

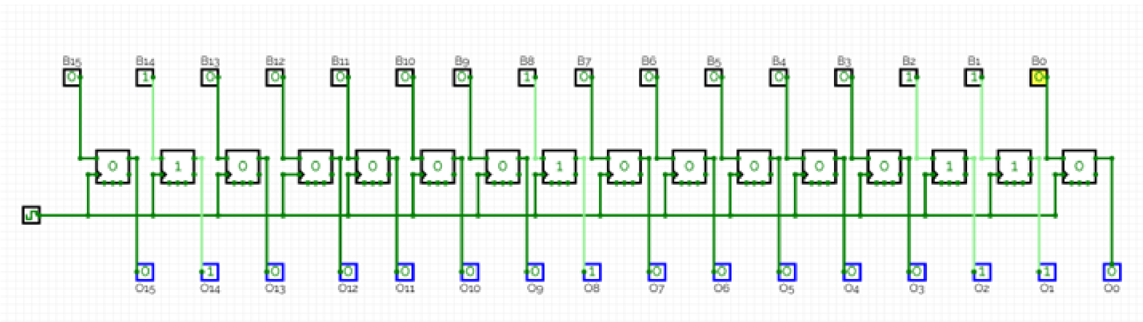


Next step is Storing 106

We know,

Store = 0100000100000110

Circuit becomes:



Finally, Halt = 0111000000000000

Circuit becomes: