Project Report Title

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1 Combinational Circuit: 2 Bit Multiplier

1.1 Description

A 2-bit binary multiplier is used to multiply two 2-bit binary numbers and provide the result as output. The binary numbers used in the binary multiplication are called the multiplicand and the multiplier. On multiplying the two 2-bit binary numbers A1A0 and B1B0, we obtain a binary output P3P2P1P0.

1.2 Implementation

For bit by bit multiplication, we use the following rules: 0X0=0, 0X1=0, 1X0=0, 1X1=1

		A1	A0
X		B1	B0
		B0A1	B0A0
	B1A1	B1A0	x
P3	P2	P1	P0

Boolean expressions:
P3 = A1*A0*B1*B0
P2 = A1*B1*(A0*B0)’
P1 = (A1*B0) xor (A0*B1)
P0 = A0*B0

Inputs (A1 A0)	Inputs (B1 B0)	Outputs (P3 P2 P1 P0)
00	00	0000
00	01	0000
00	10	0000
00	11	0000
01	00	0000
01	01	0001
01	10	0010
01	11	0011
10	00	0000
10	01	0010
10	10	0100
10	11	0110
11	00	0000
11	01	0011
11	10	0110
11	11	1001

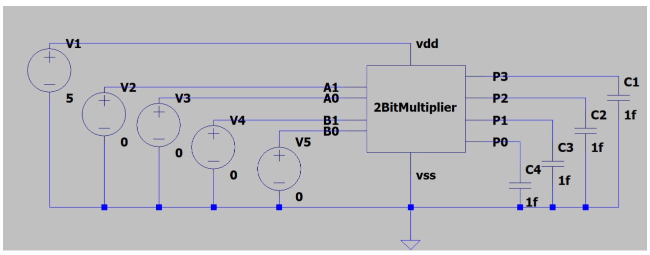


Figure 1: Testbench

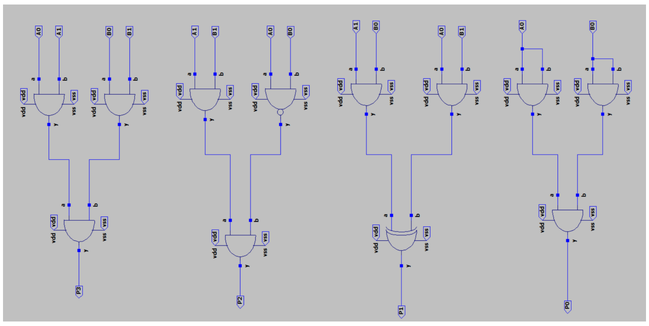


Figure 2: Subcircuit

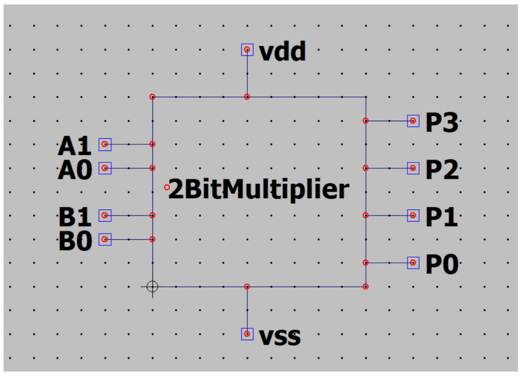


Figure 3: Symbol

1.3 Results

Logic-1 is represented by 5V and logic-0 is represented by 0V. The results obtained on passing different input voltages in the testbench circuit are as follows.
24.5 nV and 98.3 nV are negligible in comparison to 5V and thus can be approximated to 0 V. Hence, the outputs generated by the testbench match the values in the truth table of the 2-bit multiplier.

A1 (I/P) (V)	A0 (I/P) (V)	B1 (I/P) (V)	B0 (I/P) (V)	P3 (O/P)	P2 (O/P)	P1 (O/P)	P0 (O/P)
0	0	0	0	24.5 nV	24.5 nV	98.3 nV	24.5 nV
0	0	0	5	24.5 nV	24.5 nV	98.3 nV	24.5 nV
0	0	5	0	24.5 nV	24.5 nV	98.3 nV	24.5 nV
0	0	5	5	24.5 nV	24.5 nV	98.3 nV	24.5 nV
0	5	0	0	24.5 nV	24.5 nV	98.3 nV	24.5 nV
0	5	0	5	24.5 nV	24.5 nV	98.3 nV	5 V
0	5	5	0	24.5 nV	24.5 nV	5 V	24.5 nV
0	5	5	5	24.5 nV	24.5 nV	5 V	5 V
5	0	0	0	24.5 nV	24.5 nV	98.3 nV	24.5 nV
5	0	0	5	24.5 nV	24.5 nV	5 V	24.5 nV
5	0	5	0	24.5 nV	5 V	98.3 nV	24.5 nV
5	0	5	5	24.5 nV	5 V	5V	24.5 nV
5	5	0	0	24.5 nV	24.5 nV	98.3 nV	24.5 nV
5	5	0	5	24.5 nV	24.5 nV	5 V	5 V
5	5	5	0	24.5 nV	5 V	5 V	24.5 nV
5	5	5	5	5 V	24.5 nV	24.5 nV	5 V

2 Sequential Circuit: E.g., Mod-3 Up Counter

2.1 Description

A counter counts by one with each clock pulse. Counters which increase states when activated by a clock are said to operate in a “count-up” mode. MOD counters are based on the number of states that the counter will count before returning back to its original value.

2.2 Implementation

For example, a 2-bit counter that counts from 00 to 10 in binary, that is 0 to 2 in decimal, has a modulus value of 3 (00 $\rightarrow$ 01 $\rightarrow$ 10 , and return back to 00) so would therefore be called mod-3 counter.It has taken three clock pulses to get from 00 to 10. So, a Mod-3 counter will require 2 flip-flops connected together to count a single data bit while providing 3 different output states.

2.3 Results

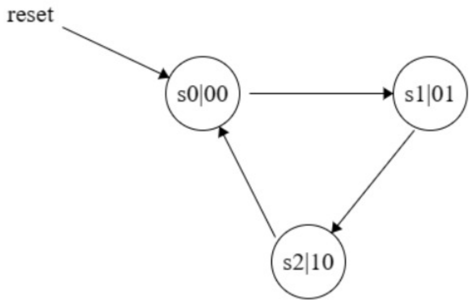
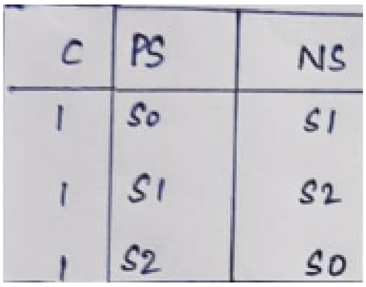
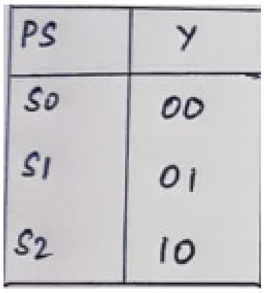


Figure 4: State transition Diagram



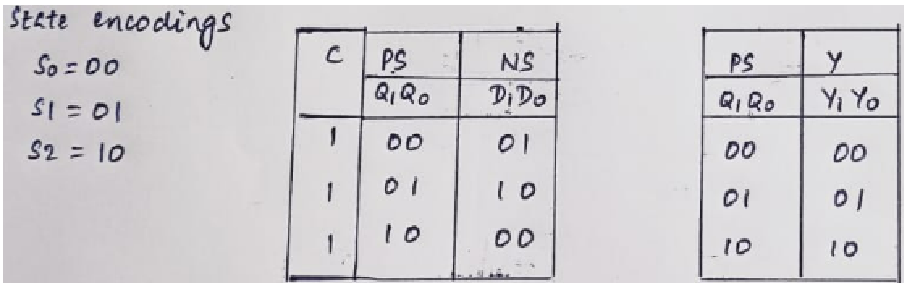
C	PS	NS
1	S0	S1
1	S1	S2
1	S2	S0

Figure 5: State trasnsition table (next state)



PS	Y
S0	00
S1	01
S2	10

Figure 6: State trasition table (next state)



State encodings
S0 = 00
S1 = 01
S2 = 10

C	PS Q_1Q_0	NS D_1D_0
1	00	01
1	01	10
1	10	00

PS Q_1Q_0	Y Y_1Y_0
00	00
01	01
10	10

Figure 7: Truth table with state encodings

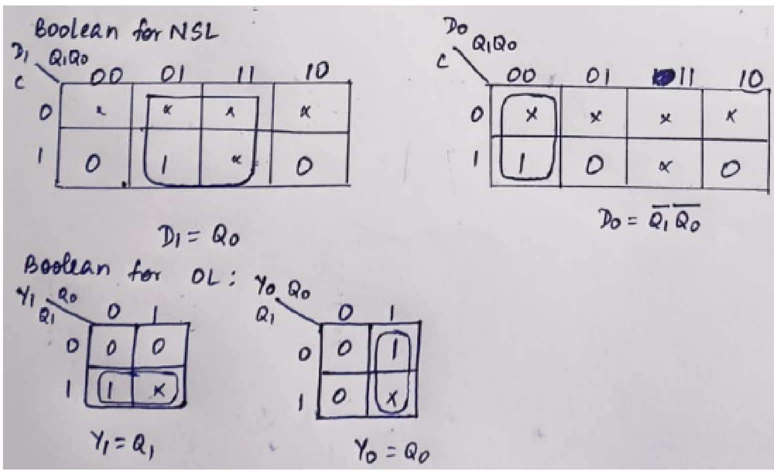


Figure 8: K-Maps

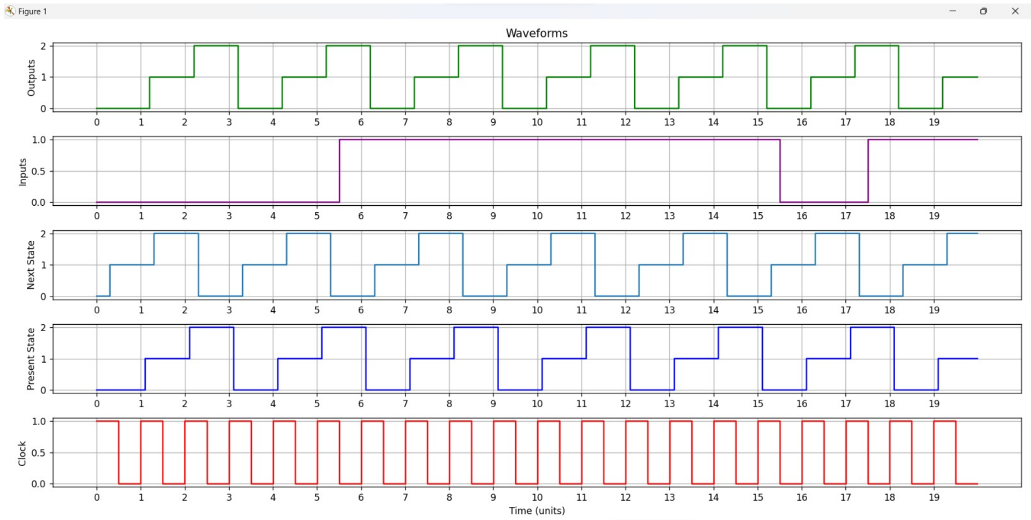


Figure 9: Waveforms

```
PS C:\Users\kavya\OneDrive\Desktop> python main.py
Time: 0.5, State: 000, Output: 000
Time: 1.5, State: 001, Output: 001
Time: 2.5, State: 010, Output: 010
Time: 3.5, State: 000, Output: 000
Time: 4.5, State: 001, Output: 001
Time: 5.5, State: 010, Output: 010
Time: 6.5, State: 000, Output: 000
Time: 7.5, State: 001, Output: 001
Time: 8.5, State: 010, Output: 010
Time: 9.5, State: 000, Output: 000
Time: 10.5, State: 001, Output: 001
Time: 11.5, State: 010, Output: 010
Time: 12.5, State: 000, Output: 000
Time: 13.5, State: 001, Output: 001
Time: 14.5, State: 010, Output: 010
Time: 15.5, State: 000, Output: 000
Time: 16.5, State: 001, Output: 001
Time: 17.5, State: 010, Output: 010
Time: 18.5, State: 000, Output: 000
Time: 19.5, State: 001, Output: 001
```

Figure 10: Output