EXPERIMENT #11: DESIGN OF SEQUENTIAL CIRCUITS

OBJECTIVES:

- Design and implement sequential circuits

Equipment and ICs:

- Mini-Lab ML-2001 lab station
- 2 - IC 7476 Dual J K-type flip-flops
- 2 - IC 7474 Dual D-type flip-flops
- 2 – IC 7400 Quad NAND gates

Introduction:

A sequential circuit is made up of flip-flops and combinational gates. The design of the circuit consists of choosing the flip-flops and then finding a combinational gate structure that, together with the flip-flops, produces a circuit that fulfills the stated specifications. The number of flip-flops is determined from the number of states needed in the circuit. The combinational circuit is derived from the state table by evaluating the flip-flop input equations and output equations.

The procedure for designing synchronous sequential circuits can be summarized by a list of recommended steps.

1. Derive a state diagram from given specifications.

2. Obtain a state table from given specifications or state diagram.

3. Reduce the number of states if necessary.

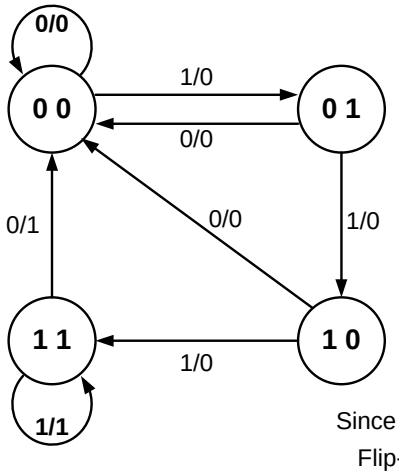
4. Choose the type of flip-flops to be used.

5. Derive the simplified flip-flop input equations and output equations.

6. Draw the logic diagram.

An example for implementing a sequential circuit whose state diagram is given is shown in the Figure 1 below.

Figure 1: Sequential circuit design



Present State		Input	Next State		Output	Flip-flop Inputs			
A	B	X	A	B	Y	JA	KA	JB	KB
0	0	0	0	0	0	0	x	0	x
0	0	1	0	1	0	0	x	1	x
0	1	0	0	0	0	0	x	x	1
0	1	1	1	0	0	1	x	x	1
1	0	0	0	0	0	x	1	0	x
1	0	1	1	1	0	x	0	1	x
1	1	0	0	0	1	x	1	x	1
1	1	1	1	1	1	x	0	x	0

Since there are 4 states, two FFs will be required to implement the circuit

Flip-flop inputs for a D FF are same as the Next State values

Flip-flop input equations for D FF

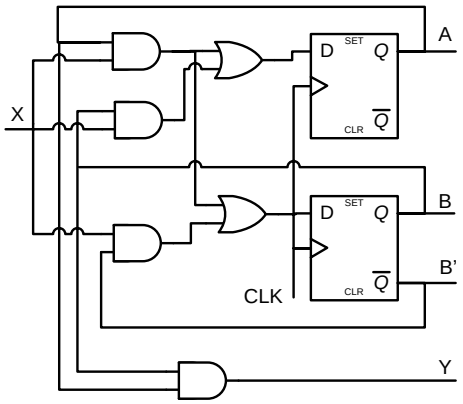
DA = Ax + Bx
DB = Ax + B'x

Output equation

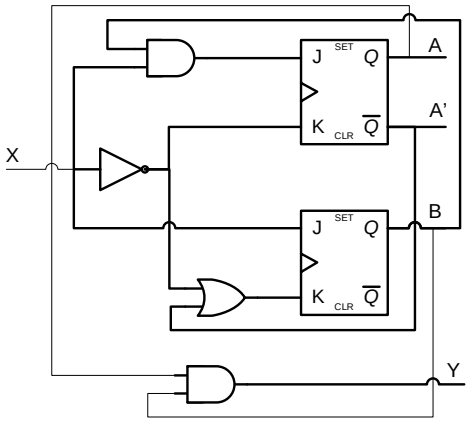
Y = AB

Flip-flop input equations for JK FF

JA = BX, KA = X'
JB = X, KB = A' + X'



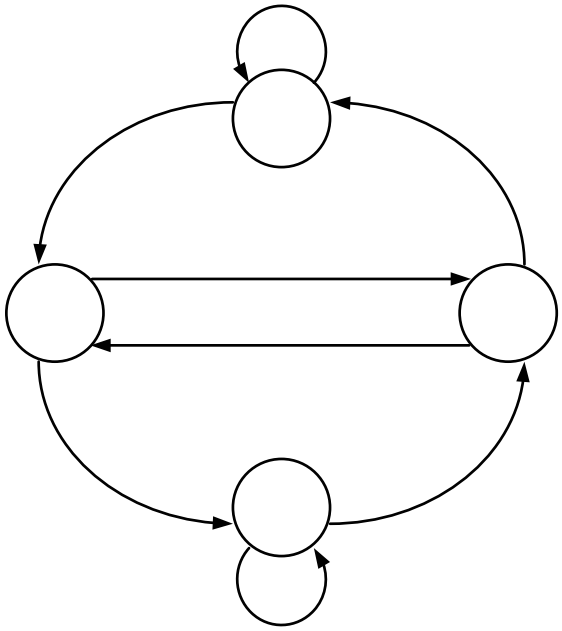
Implementation using D FFs



Implementation using JK FFs

Part 1:

Design a sequential circuit using JK flip-flops whose state diagram is shown in Figure 2 below. Designate the two flip-flops as A and B, the input as X, and the output as Y.



Pre-lab Work:

1. Obtain the state table from the state diagram.

2. Obtain simplified flip-flop input equations and output equation.

3. Draw the logic diagram of the circuit.

4. Draw and simulate your circuit in LogicWorks. Include your LogicWorks drawing in the pre-lab report.

Lab Work:

1. Implement the sequential circuit (you designed in the pre-lab) on the proto-board using IC 7476 which has two JK-type Flip-flops and any external gates required.
    a. Connect input X to a DIP switch.
    b. Connect PRESET and CLEAR inputs to logic-1.
    c. Connect CLK input to a pulser-button.
    d. Connect Q outputs of flip-flops A and B to two indicator lamps.

2. Apply clock pulses to the circuit by pushing the pulser-button and verify the state transition and output as shown in Figure 2 above.

3. Now connect the output of flip-flop B to the input X and observe the sequence of states and output that will occur with the application of clock pulses. Tabulate your observations in the form of a state table or draw a state diagram.

4. Record your results and observations for the lab report.

OBSERVATIONS:

Part 2: Counter Design

Design a counter that goes through the following sequence of binary states: 0, 1, 2, 3, 6, 7, 10, 11, 12, 13, 14, 15, and back to 0 to repeat. Note that binary states 4, 5, 8, and 9 are not used. The counter must be self-starting; that is, if the circuit starts from any one of the four invalid states, the count (clock) pulses must transfer the circuit to one of the valid states to continue to count correctly. Use JK flip-flops for your design.

Pre-lab Work:

1. Draw the state diagram for the counter.

2. Derive the state table from the state diagram.

3. Obtain simplified flip-flop input equations.

4. Draw the logic diagram for the counter circuit.

5. Draw and simulate your circuit in LogicWorks. Include your LogicWorks drawing in the pre-lab report.

Lab Work:

1. Implement the sequential circuit (you designed in the pre-lab) on the proto-board using IC 7476 which has two JK-type Flip-flops and any external gates required.
    a. Connect PRESET and CLEAR inputs to logic-1.
    b. Connect CLK input to a pulser-button.
    c. Connect Q outputs of all flip-flops to indicator lamps.

2. Apply clock pulses to the circuit by pushing the pulser-button and verify the required count sequence.

3. Verify that the circuit is self-starting by initializing the circuit to each unused state by means of the PRESET and CLEAR inputs and then applying pulses to see whether the counter reaches one of the valid states.

4. Record your results and observations for the lab report.

OBSERVATIONS: