Digital Design
First Semester 2020-21
Tutorial : 09

Sequence Detector

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1. Design a 11011 sequence detector using JK flip-flops. Allow overlap.

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Step 1
We are designing a sequence detector for a 5-bit sequence, so we need 5 states. We label these states A, B, C, D, and E. State A is the initial state.

Step 2
Characterize Each State by What has been Input and What is Expected State

State	Has	Awaiting
A	--	11011
B	1	1011
C	11	011
D	110	11
E	1101	1

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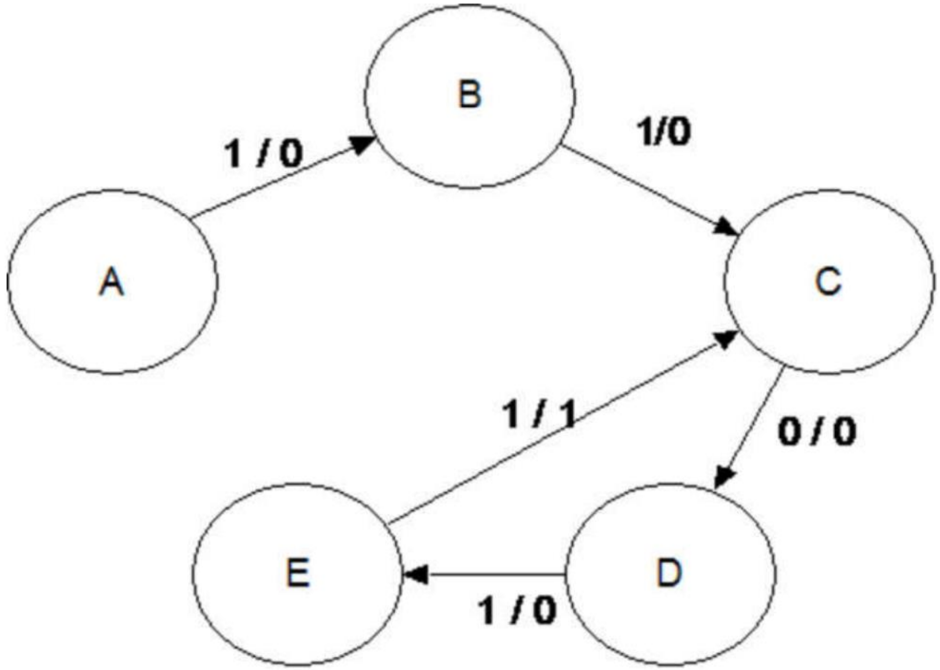
Step 3
Do the Transitions for the Expected Sequence



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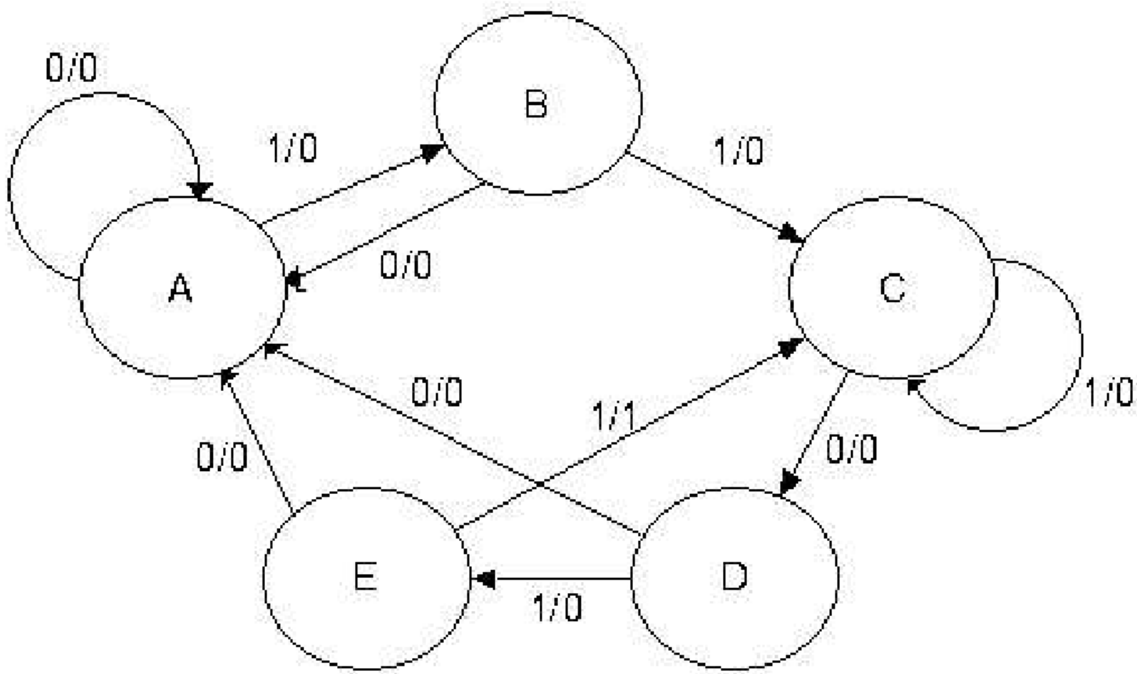
Step 4 Complete the State Diagram



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Step 5 Make State Table

Present State	Next State / Output	
	X = 0	X = 1
A	A / 0	B / 0
B	A / 0	C / 0
C	D / 0	C / 0
D	A / 0	E / 0
E	A / 0	C / 1

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Step 6 – Determine the Number of Flip-Flops Required
We have 5 states, so N = 5. We solve the equation 2P-1 < 5 £ 2P by inspection, noting that it is solved by P = 3. So we need three flip-flops.

Step 7 – Assign a unique P-bit binary number (state vector) to each state.
The simplest way is to make the following assignments

A = 000
B = 001
C = 011 Note that states 010, 110, and 111 are not used.
D = 100
E = 101

Occasionally, a better assignment can be detected by inspection of the next state table. I note that the next states in the table cluster into two disjoint sets for X = 0 and X = 1. For X = 0 the possible next states are A and D For X = 1 the possible next states are B, C, and E. For this reason, I elect to give even number assignments to states A and D, and to give odd number assignments to states B, C, and E.

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Step 8 – Generate the Transition Table With Output

Present State		Next State / Output	
		X = 0	X = 1
	$Y_2Y_1Y_0$	$Y_2Y_1Y_0$ / Z	$Y_2Y_1Y_0$ / Z
A	0 0 0	0 0 0 / 0	0 0 1 / 0
B	0 0 1	0 0 0 / 0	0 1 1 / 0
C	0 1 1	1 0 0 / 0	0 1 1 / 0
D	1 0 0	0 0 0 / 0	1 0 1 / 0
E	1 0 1	0 0 0 / 0	0 1 1 / 1

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Step 9 – Separate the Transition Table into Three Tables, One for Each Flip-Flop

Y2			Y1			Y0		
PS	Next State		PS	Next State		PS	Next State	
$Y_2Y_1Y_0$	X = 0	X = 1	$Y_2Y_1Y_0$	X = 0	X = 1	$Y_2Y_1Y_0$	X = 0	X = 1
0 0 0	0	0	0 0 0	0	0	0 0 0	0	1
0 0 1	0	0	0 0 1	0	1	0 0 1	0	1
0 1 1	1	0	0 1 1	0	1	0 1 1	0	1
1 0 0	0	1	1 0 0	0	0	1 0 0	0	1
1 0 1	0	0	1 0 1	0	1	1 0 1	0	1
Match	Y_1	$Y_2 \cdot Y_0'$		0	Y_0		0	1

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Step 10 – Separate the Transition Table into Three Tables, One for Each Flip-Flop

Y2			Y1			Y0		
PS	Next State		PS	Next State		PS	Next State	
$Y_2Y_1Y_0$	X = 0	X = 1	$Y_2Y_1Y_0$	X = 0	X = 1	$Y_2Y_1Y_0$	X = 0	X = 1
0 0 0	0	0	0 0 0	0	0	0 0 0	0	1
0 0 1	0	0	0 0 1	0	1	0 0 1	0	1
0 1 1	1	0	0 1 1	0	1	0 1 1	0	1
1 0 0	0	1	1 0 0	0	0	1 0 0	0	1
1 0 1	0	0	1 0 1	0	1	1 0 1	0	1
Match	Y_1	$Y_2 \cdot Y_0'$		0	Y_0		0	1

$D2 = X' \cdot Y1 + X \cdot Y2 \cdot Y0'$

$D1 = X \cdot Y0$

$D0 = X$

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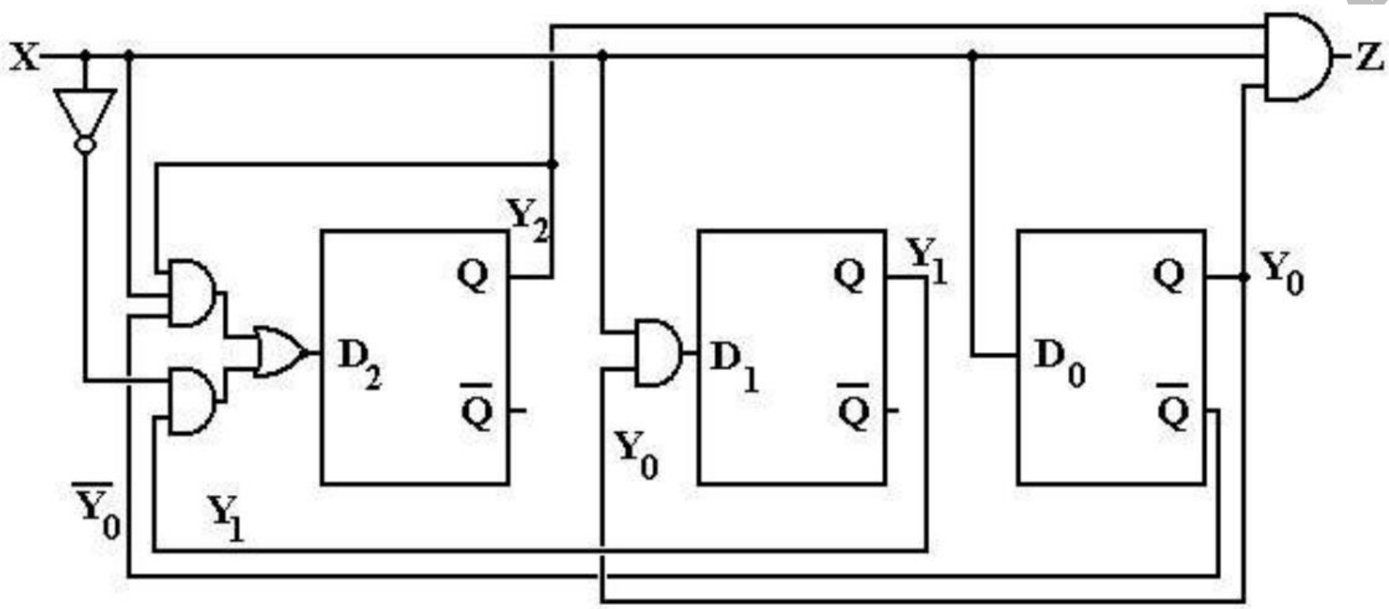
Step 11 – design implemented with D flip-flops



D2 = X’·Y1 + X·Y2·Y0’
D1 = X ·Y0
D0 = X

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Step 12 – Derive an Input Table for Each JK Flip-Flop using its Excitation Table And Produce the Input Equations for Each Flip-Flop

$Y_2Y_1Y_0$	X = 0			X = 1		
	Y_2	J_2	K_2	Y_2	J_2	K_2
0 0 0	0	0	d	0	0	d
0 0 1	0	0	d	0	0	d
0 1 1	1	1	d	0	0	d
1 0 0	0	d	1	1	d	0
1 0 1	0	d	1	0	d	1

X = 0	X = 1	
J2 = Y1	J2 = 0	thus, J2 = X’·Y1
K2 = 1	K2 = Y0	thus, K2 = X’ + X·Y0 = X’ + Y0.

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Step 13 – Derive an Input Table for Each JK Flip-Flop using its Excitation Table And Produce the Input Equations for Each Flip-Flop

$Y_2Y_1Y_0$	X = 0			X = 1		
	$\mathbf{Y_1}$	J_1	K_1	$\mathbf{Y_1}$	J_1	K_1
0 **0** 0	0	0	d	0	0	d
0 **0** 1	0	0	d	1	1	d
0 **1** 1	0	d	1	1	d	0
1 **0** 0	0	0	d	0	0	d
1 **0** 1	0	0	d	1	1	d

X = 0
J1 = 0
K1 = 1

X = 1
J1 = Y0
K1 = 0

thus J1 = X·Y0 and K1 = X'.

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Step 14 – Derive an Input Table for Each JK Flip-Flop using its Excitation Table And Produce the Input Equations for Each Flip-Flop

$Y_2Y_1Y_0$	X = 0			X = 1		
	Y_0	J_0	K_0	Y_0	J_0	K_0
0 0 **0**	0	0	d	1	1	d
0 0 **1**	0	d	1	1	d	0
0 1 **1**	0	d	1	1	d	0
1 0 **0**	0	0	d	1	1	d
1 0 **1**	0	d	1	1	d	0

X = 0
J0 = 0
K0 = 1

X = 1
J0 = 1
K0 = 0

thus J0 = X and K0 = X', as expected.

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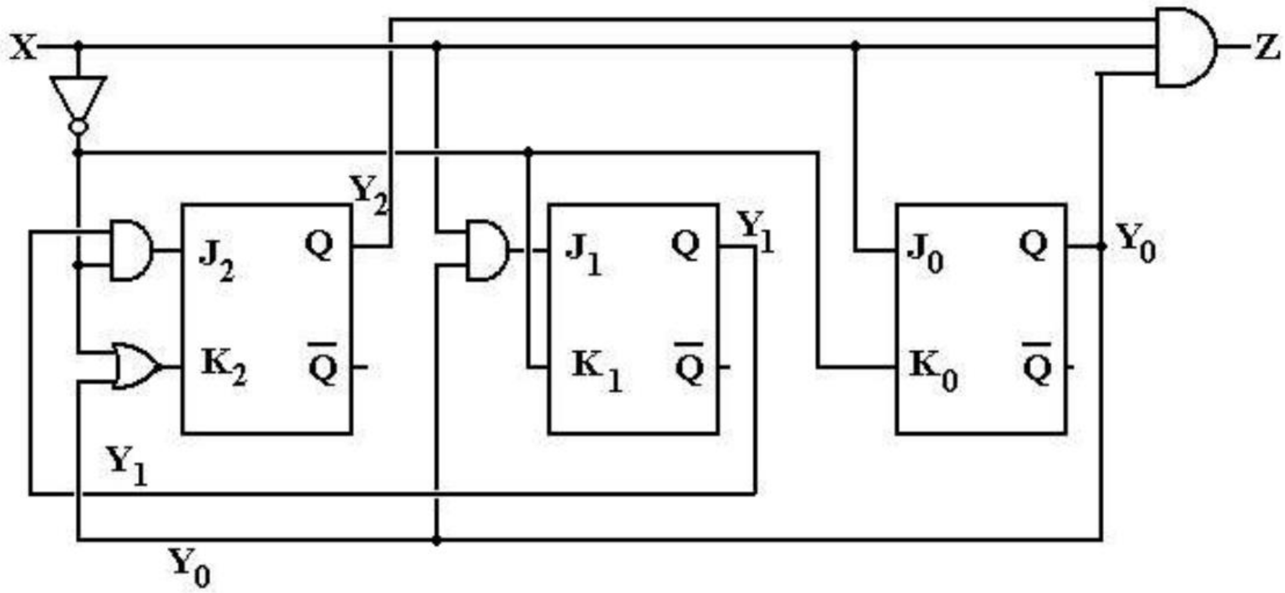
Step 15 – Draw Circuit



The equations implemented in this design are:

$$Z = X \cdot Y_2 \cdot Y_0$$

$J_2 = X' \cdot Y_1$ $\quad$ $K_2 = X' + Y_0$

$J_1 = X \cdot Y_0$ $\quad$ $K_1 = X'$

$J_0 = X$ $\quad$ $K_0 = X'$