Points to Remember

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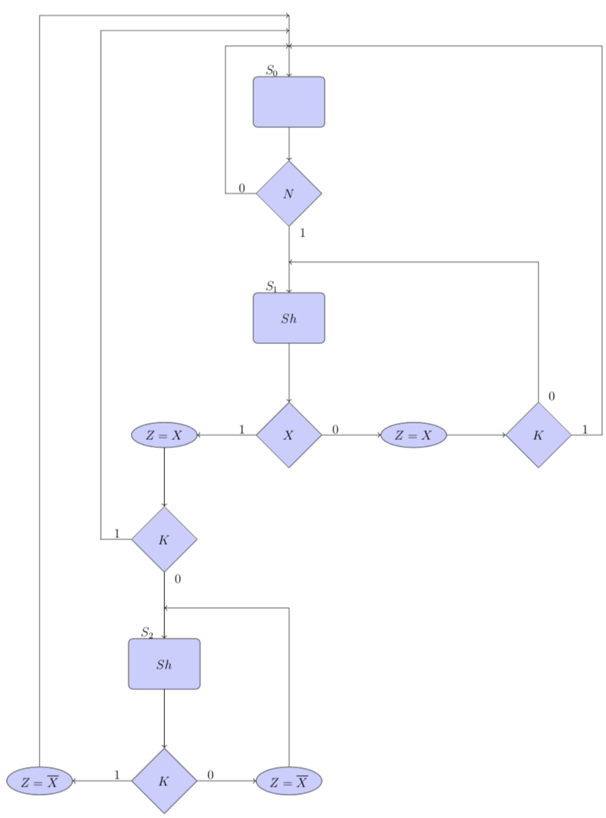
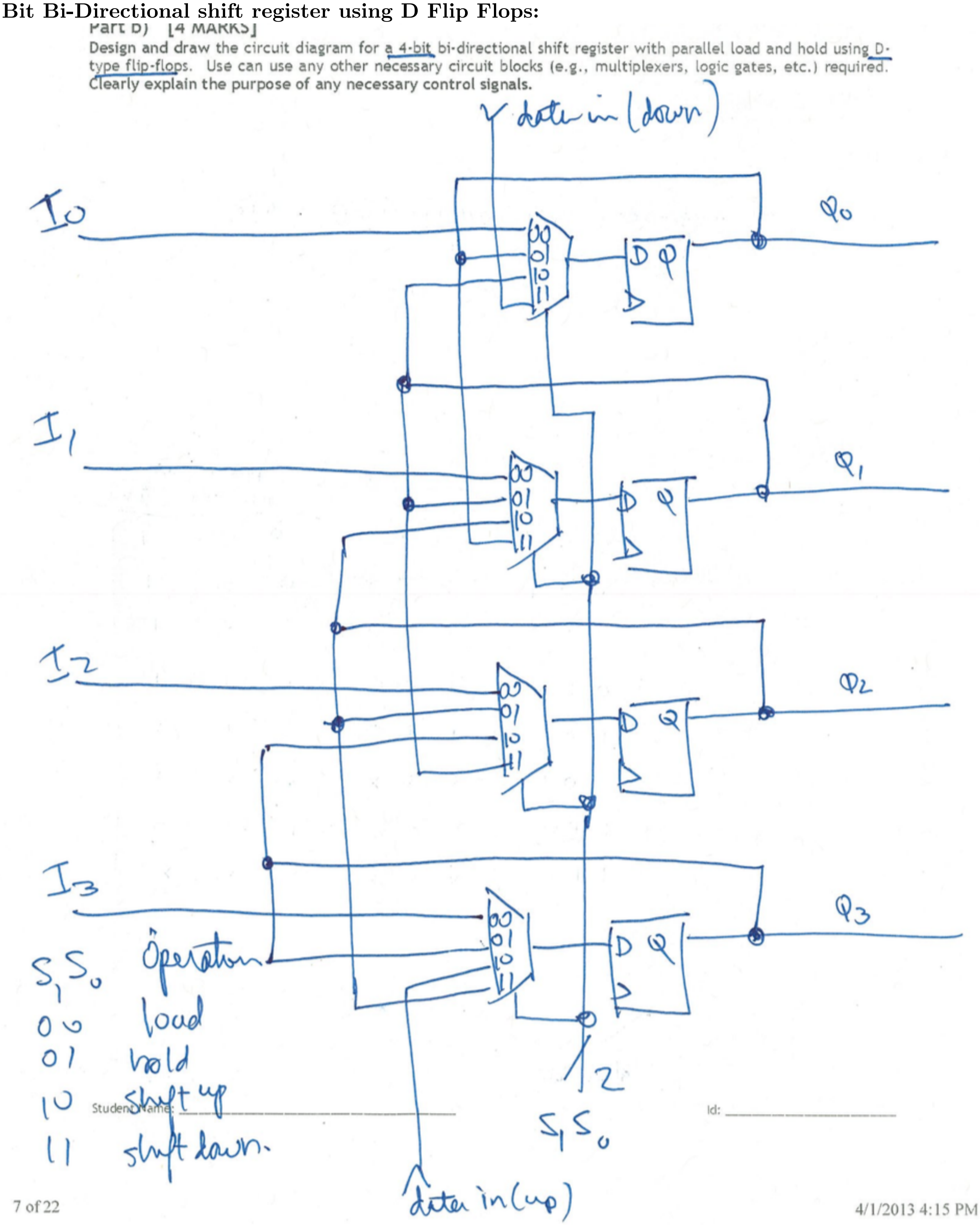
1. **For Asynchronous circuits:** The outputs are only to be written for the stable state condition while the other input conditions are all outputting don't cares i.e. X or $-$
2. **Fundamental mode:** The state diagram assuming fundamental mode operation (output is shown as a Moore output but it only assumes that value if the state is stable)
3. **State Reduction Table:** All states except first vertically down, all states except last horizontally right
4. **POS and SOP:** SOP $\rightarrow$ 1 and POS $\rightarrow$ 0 (to remember when writing equation from K-Map)
5. **Asynchronous circuit analysis:** Question 13 from Assignment 10 is so smart, so many little tricks combined
6. **Writing DFF equation:** The DFF equations can be written directly since the property $Q(t+1) = D$ is valid
7. **Mealy and Moore:** Mealy output on arrows, Moore output in state
8. **ASM:**



See the "Sh" shift signal for state dependent outputs

9. **4 Bit Bi-Directional shift register using D Flip Flops:**



10. **ASM:** ASM State changes are clocked by the edge

11. **f:** $T_{clock} + T_{setup} + T_{data} = T \Rightarrow f_{max} = \frac{1}{T}$

12. **State Machine Diagram to Timing Diagram:** Output follows in Mealy diagram

13. **DFF Equations:**

One hot encoding implies A is 0001, B is 0010, C is 0100 and D is 1000. This leads to the state table given by

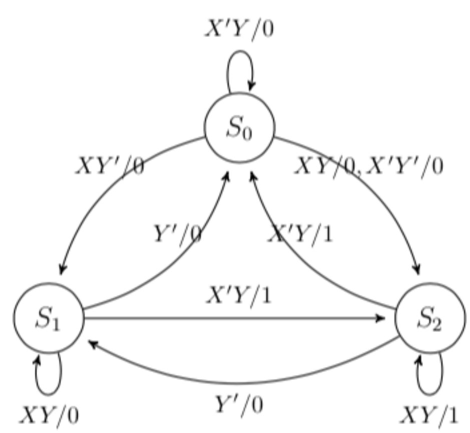
Current state	**Next state**		**Outputs**	
	$x=0$	$x=1$	$x=0$	$x=1$
$q_3q_2q_1q_0$	$q_3q_2q_1q_0$	$q_3q_2q_1q_0$	z	z
0001	0100	1000	0	0
0010	0010	0001	0	0
0100	1000	0001	0	0
1000	0100	0010	1	1

The DFF equations can be written down directly.

$$\begin{aligned} d_3 &= \overline{x}q_2 + xq_0 \\ d_2 &= \overline{x}q_3 + \overline{x}q_0 \\ d_1 &= \overline{x}q_1 + xq_3 \\ d_0 &= xq_2 + xq_1 \end{aligned}$$

The circuit output is given as

$$z = q_3$$



Solution:

Simply look at incoming edges for each state to get the flip flop input equations:

$$\begin{aligned} d_2 &= XYS_2 + X'YS_1 + X'Y'S_0 \\ d_1 &= XYS_1 + Y'S_2 + XY'S_0 \\ d_0 &= X'YS_0 + Y'S_1 + X'YS_2 \end{aligned}$$

The circuit output is a Mealy output given by

$$z = XYS_2 + X'YS_2 + X'YS_1$$

Note that I've written the flip flop inputs in terms of the symbolic state. You'd get the same thing if you did a state assignment; e.g., S_0 is 001, S_1 is 010, and S_2 is 100 and then called the flip flop outputs $q_2q_1q_0$ — the S_i would simply get replaced by q_i.