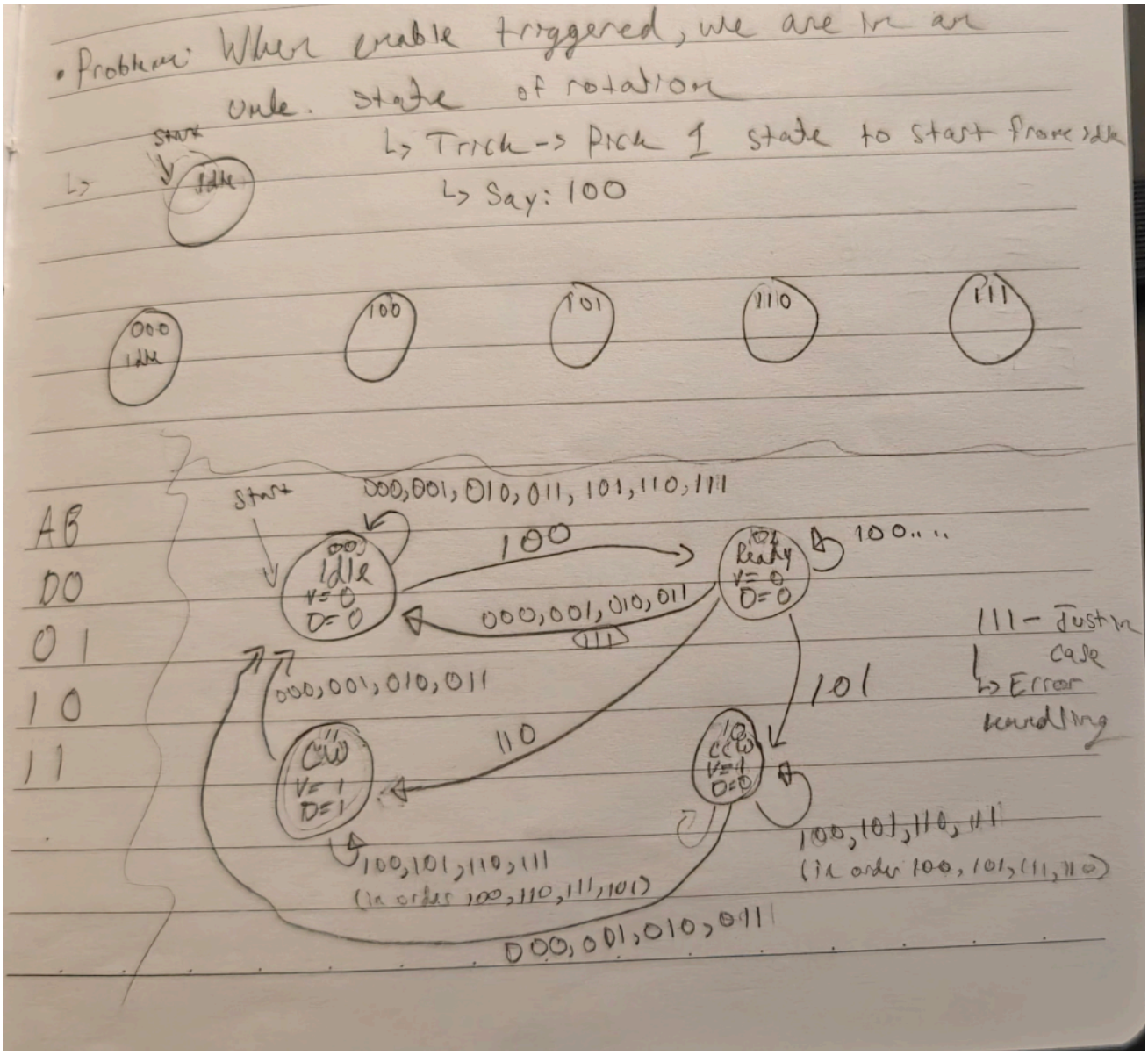
Lab 6 - Sequential Circuit Design

- Objective: Design a circuit that can determine the direction of a spinning disk given:
  - Two inputs that read disk position and are ON or OFF
  - One input for ENABLE, that turns ON when the disk is spinning at speed
  - Two outputs:
    - VALID: Switches HIGH when the disk direction has been determined
    - DIRECTION: Switches HIGH when the disk is rotating the the CLOCKWISE direction, will remain LOW when the disk is rotating COUNTER CLOCKWISE
  - Use two D Flip-Flop devices to determine states
- I/O Mapping and Logic
  - Inputs E | A | B
    - When the disk rotates and the ENABLE bit is HIGH the order of bits should be:
      - CCW: ... -> 100 -> 101 -> 111 -> 110 -> 100 -> 101 -> ...
      - CW: ... -> 100 -> 110 -> 111 -> 101 -> 100 -> 110 -> ...
- States:
  - This circuit will consist of 4 states:
    - 00 | *Idle* | VALID = Low, DIRECTION = Low
    - 01 | *Ready* | VALID = Low, DIRECTION = Low
    - 10 | *Counter Clockwise* | VALID = High, DIRECTION = Low
    - 11 | *Clockwise* | VALID = High, DIRECTION = High
  - Since this device will have 2-bits of state, it will require two D Flip-Flops
  - We will use the input EAB to determine which state the device will move to
    - The circuit will start at State 00 -> Idle and move to different states dependent on EAB input states
  - PROBLEM: Where to begin state changes given EAB inputs could be any combination during disk rotation
    - SOLUTION: Only begin disk direction state changes given the EAB value 100

- State Diagram:



  - Behavior:
    - The circuit will move from *Idle* to *Ready* only when the combination of inputs EAB are 100 -> ENABLE is High | A is Low | B is Low
    - The circuit will changes states in three different ways from *Ready*:
      - From *Ready* to *Idle* when the next combination of inputs EAB are 111 -> ENABLE is High | A is High | B is High
        - Reason: It is physically impossible for the device to receive a 111 computational input immediately after an input state of 100. This is only for error handling.
      - From *Ready* to *Counter Clockwise* when the next combination of inputs EAB is 101 -> ENABLE is High | A is Low | B is High
        - Reason: Following EAB combination 100, if the next combination of inputs is 101, then based on the location of the input devices, it can be determined that the disk is rotating CCW

        - From *Ready* to *Clockwise* when the next combination of inputs EAB is 110 -> ENABLE is High | A is High | B is High
            - Reason: Following EAB combination 100, if the next combination of inputs is 110, then based on the location of the input devices, it can be determined that the disk is rotating CW
- The circuit will change from any state to *Idle* if ENABLE is low:
    - EAB States to return circuit to *Idle*:
        - 000
        - 001
        - 010
        - 011
- When the circuit has changed to states 10 or 11 the circuit will remain in that state until the ENABLE bit has switched to low, and the circuit has been reset after a clock cycle

- Truth Table 1 to Determine Flip-Flop Behvaior:

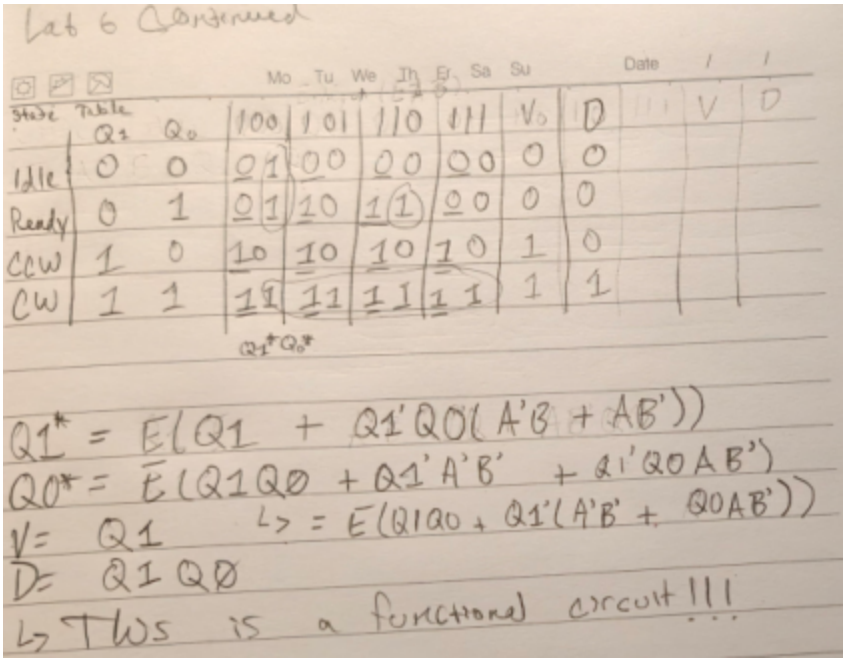
Current inputs			Current State		Future State	
E	A	B	Q1	Q0	Q1*	Q0*
0	0	0	0	0	0	0
0	0	0	0	1	0	0
0	0	0	1	0	0	0
0	0	0	1	1	0	0
0	0	1	0	0	0	0
0	0	1	0	1	0	0
0	0	1	1	0	0	0
0	0	1	1	1	0	0
0	1	0	0	0	0	0
0	1	0	0	1	0	0
0	1	0	1	0	0	0
0	1	0	1	1	0	0
0	1	1	0	0	0	0
0	1	1	0	1	0	0
0	1	1	1	0	0	0
0	1	1	1	1	0	0
1	0	0	0	0	0	1
1	0	0	0	1	0	1
1	0	0	1	0	1	0
1	0	0	1	1	1	1
1	0	1	0	0	0	0
1	0	1	0	1	1	0
1	0	1	1	0	1	0
1	0	1	1	1	1	1
1	1	0	0	0	0	0
1	1	0	0	1	1	1
1	1	0	1	0	1	0
1	1	0	1	1	1	1
1	1	1	0	0	0	0
1	1	1	0	1	0	0
1	1	1	1	0	1	0
1	1	1	1	1	1	1

  - Output VALID:
    - Triggered by Flip-Flop Q1
    - V = Q1
  - Output DIRECTION:
    - On if disk rotating in Clockwise direction
    - Triggered by combination of Flip-Flops Q1 & Q0
    - D = Q1Q0

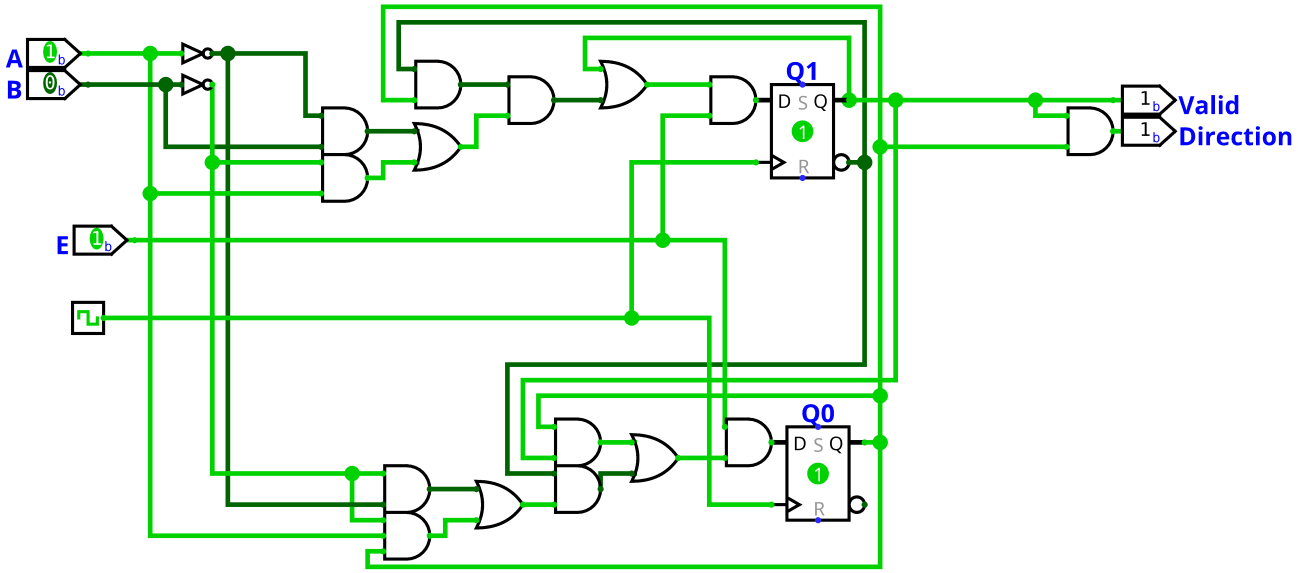
- State Table:

Status			Inputs: EAB | Q1*Q0*									
	Q1	Q0	000	001	010	011	100	101	110	111	V	D
Idle	0	0	00	00	00	00	01	00	00	00	0	0
Ready	0	1	00	00	00	00	01	10	11	00	0	0
CCW	1	0	00	00	00	00	10	10	10	10	1	0
CW	1	1	00	00	00	00	11	11	11	11	1	1

- Derived Equations from State Table:
  - Q1* = ENABLE•(Q1 + Q1'•Q0•(A'•B + A•B'))
  - Q0* = ENABLE•(Q1•Q0 + Q1'•(A'•B' + Q0•A•B'))
- Figure #2 Hand Notes:

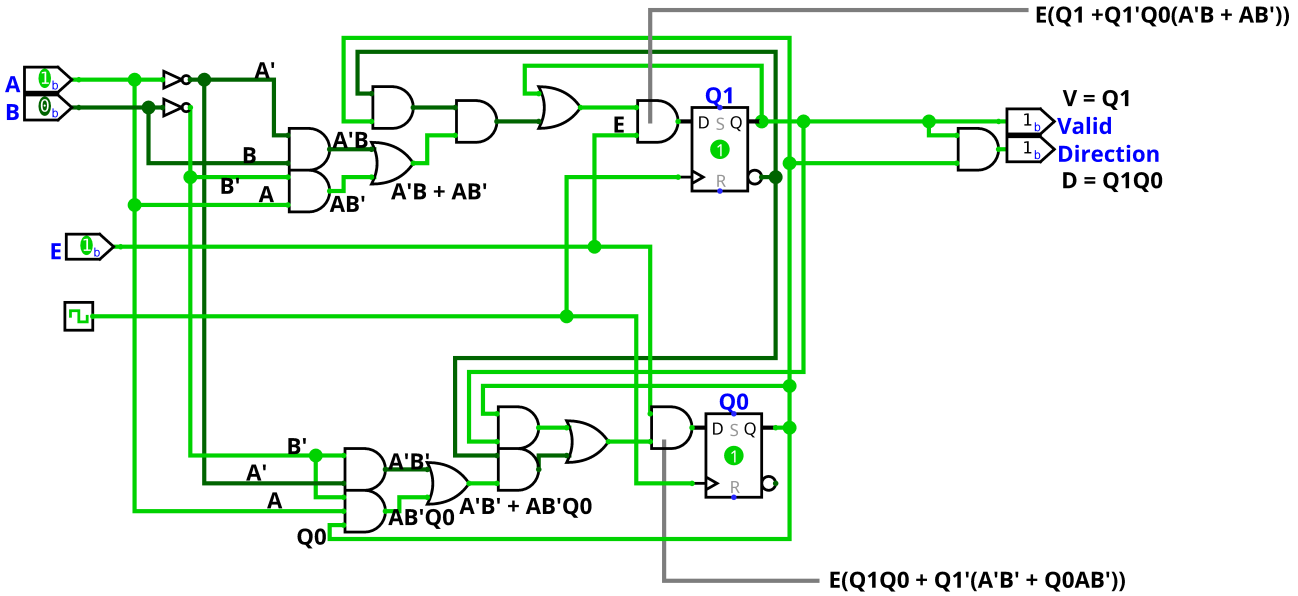


- Figure #3: Functional Circuit Diagram



Enable:
Asserted: When disk spinning at full speed
Held low when disk is stopped or changing direction

- Figure #4: Inclusive of Labels



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