Digital Design Assignment

Group 24: Digital Pipette

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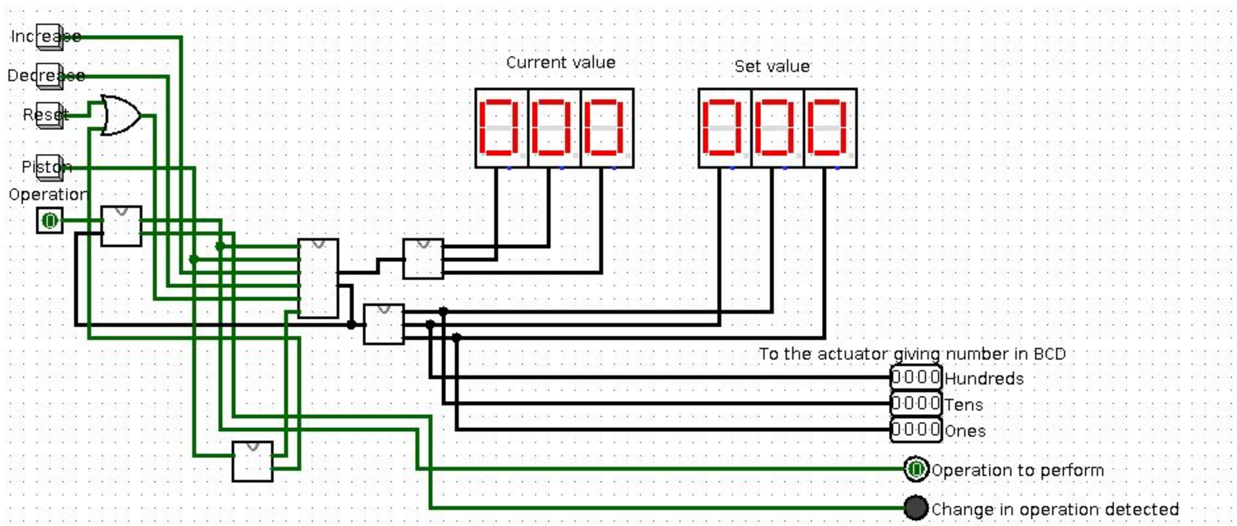
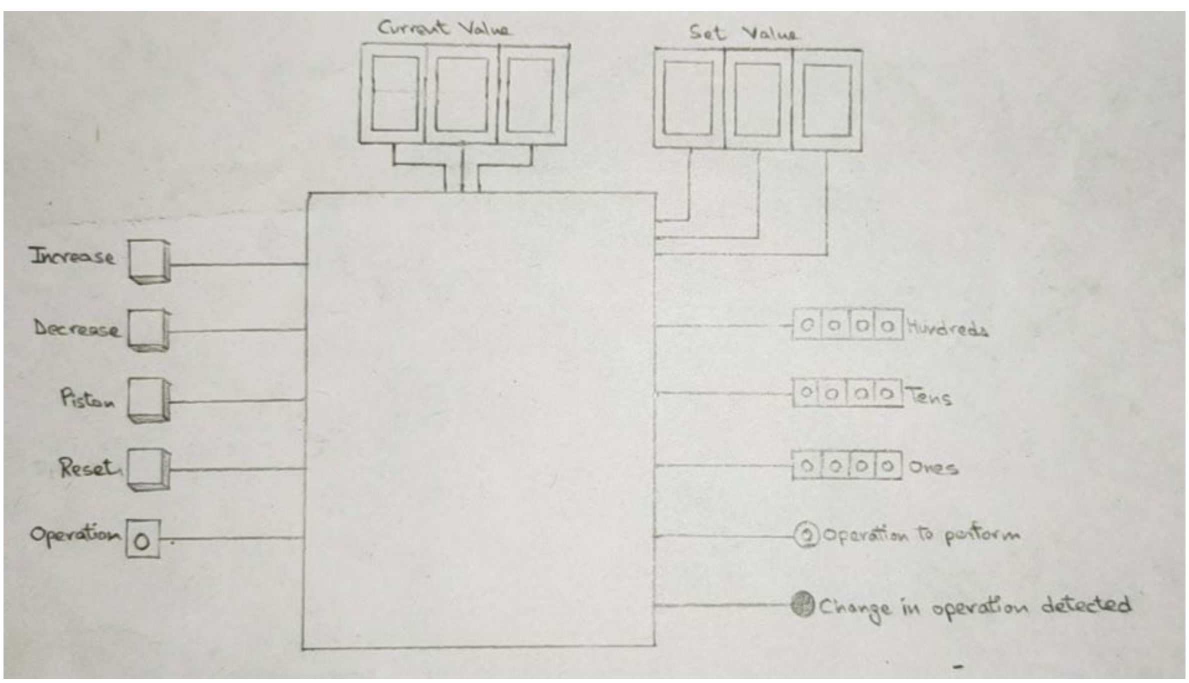
Problem statement

Design a digital pipette to precisely deliver a preset volume of liquid into a vial. Assume that the least count of pipette is 10ml. A digital pump is used to pull in or push out liquid in multiples of 10ml. The maximum volume of the pipette is 200ml.

Top level block diagram describing input and output signals

Image of the main circuit





Assumptions that we have made with respect to the design problem

The sensor inputs are:

1) Increase: This button increases the set value in multiples of 10.
2) Decrease: This button decreases the set value in multiples of 10.
3) Reset: This button resets the set value if the user wants.
4) Piston: This button signifies the piston of the pipette. The state of reset is treated as 0 and the state when pushed is treated as 1. When the transition from 0 to 1 takes place the set amount is pushed out of the pipette (if the operation says so) and when the transition 1 to 0 takes place the set amount is pulled in the pipette (if the operation says so). It is also used to update the value of the liquid inside the pipette.
5) Operation: As this pipette allows liquids to enter and exit the pipette multiple times using just the action of the piston is not enough hence another input to signify the operation is used. It is a normal input. 0 indicates pull in and 1 indicates push out.

All buttons must be held for approximately 0.25 seconds (as the clock frequency is 4 Hz).
The piston must be held for at least 0.5 seconds (as the flip flop is negative edge triggered and register is positive edge triggered).

Intermediate outputs:

1) Set value: It is the value the user wishes to set.
2) Current value: It is the current amount of liquid present inside the pipette.

The user outputs are:

1) Current value display: This displays the amount of liquid present in the pipette in milliliters.
2) Set value display: This displays the amount of liquid you wish to push-out or pull-in in milliliters.
3) Change in operation detected: This LED glows if the operation is changed after some value has been set.

The actuator outputs are:

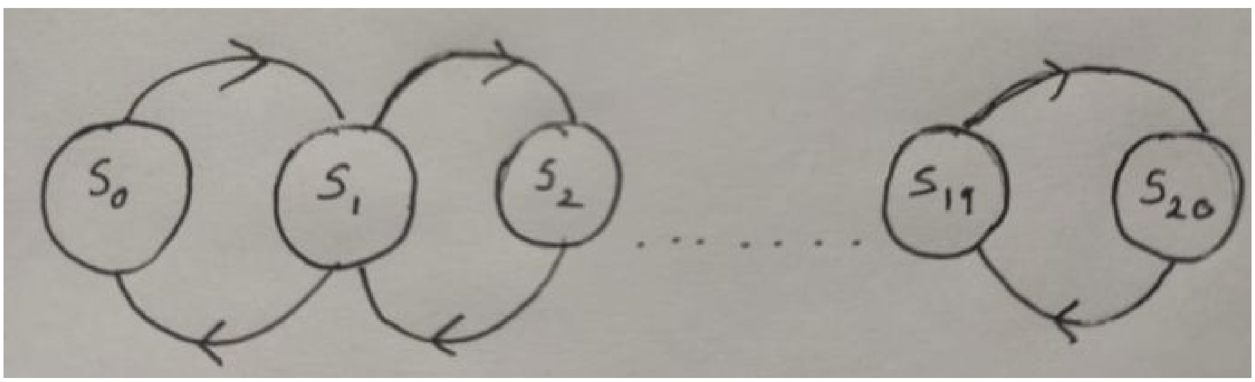
1) Hundreds: It signifies the hundreds position of the amount of liquid that must stay in the pipette.
2) Tens: It signifies the tens position of the amount of liquid that must stay in the pipette.
3) Ones: It signifies the ones position of the amount of liquid that must stay in the pipette.
4) Operation to perform: It signifies the operation the user wants to perform.

These outputs are provided to the actuator so that they can take care of the amount of liquid that must be retained inside the pipette when additional liquid is being taken in or to create a barrier so that only the set amount of liquid is passed.

State Diagram

State Diagrams:
The states of the 2 registers are thought of as 2 Moore machines.

Setter Register:
It stores the present value. It's summed with either +1 or -1 , which is the parallel input from the adder.
It has a load which is asserted when the piston is inactive when either one of increase or decrease is pressed but not both. In all other cases since the load is low, no state change occurs. Since all the transitions are determined by the increase or decrease button, they act as the only inputs.



Explanation:
- Each S_i denotes that the amount of liquid present in the pipette is (10*i)
- Valid increase: When the 'increase' button is pushed and the current state is S_i , $\forall i \in [0,19]$
- Valid decrease: When the 'decrease' button is pushed and the current state is S_i, $\forall i \in [1,20]$
- For any valid increase, the state of the pipette changes from S_i to S_{i+1}
- For any valid decrease, the state of the pipette changes from S_i to S_{i-1}
- The value does not increase after it has reached S_{20}.
- The value does not decrease after it has reached S_0.
- For any invalid increase/decrease, the state of the pipette remains the same.

Store Register :

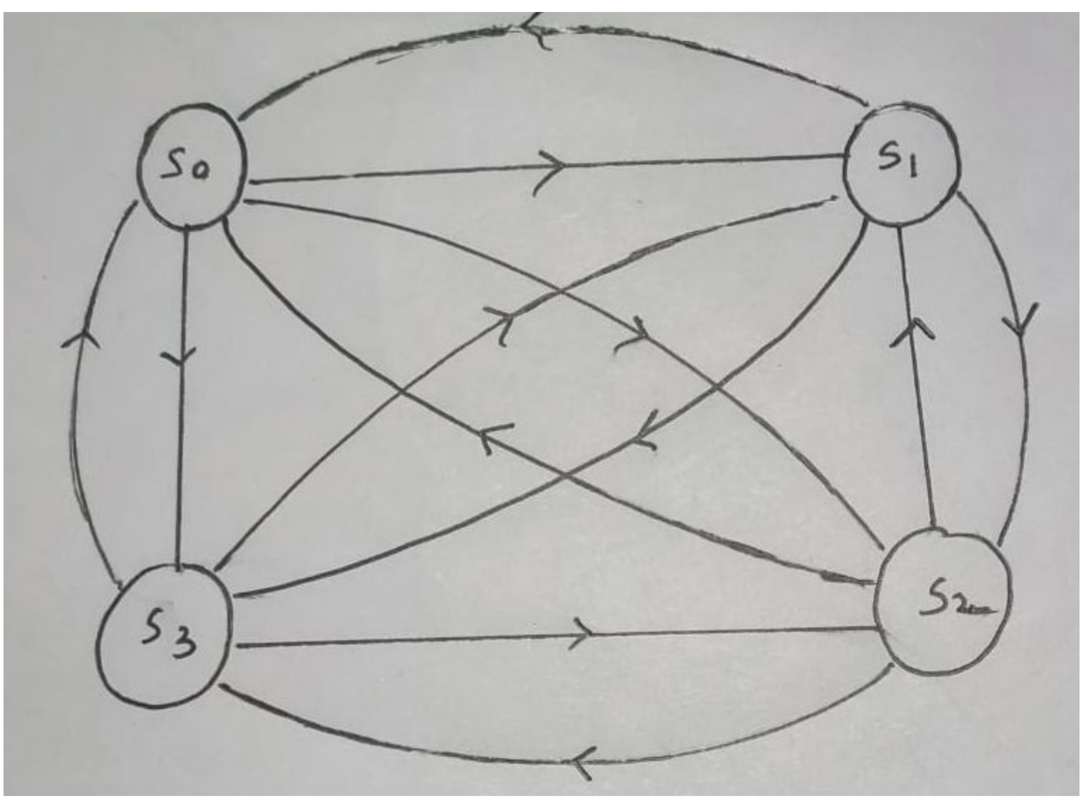
It stores the present state summed with the present state of the setter register . The sign of the present state register is determined by the operation to perform. Thus the state can transition from any state to any other state.
State varies from S_0 to S_{20}

Note :

- In the setter register , while changing its state the present state of the store register is used to determine whether such transitions can take place or not, thus ruling out undesirable cases.

- '0' in operations corresponds to pulling in and '1' corresponds to pushing out.

- Since the state diagram for S_0 to S_{20} would have been messy, a sub graph for S_0 to S_3 has been shown below



Explanation:

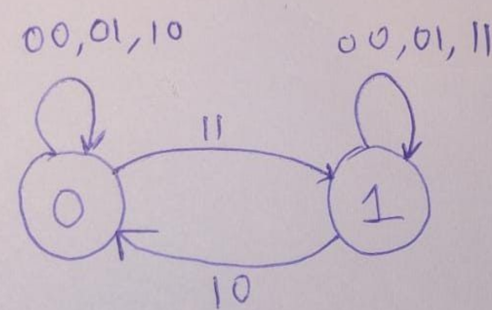
- Each S_i denotes that the amount of liquid present in the pipette is (10*i)
- Valid piston : When the 'piston' button is pushed and the current state is S_i , $\forall i \in [0,20]$
- For any valid increase, the state of the pipette changes from S_i to S_{i+k} o $\forall k \in [i+1,20]$
- For any valid decrease , the state of the pipette changes from S_i to S_{i-1} $\forall k \in [0,i-1]$
- The value does not increase after it has reached S_{20}.
- The value does not decrease after it has reached S_0.

Note the values of current value and set value are used to determine whether a particular operation is possible. The sum of both of these values must remain between 0 and 200.

Keep operation constant:

Let result from comparator be C.
Operation be O.
Real operation be RO

RO(t)	C	O	RO(t+1)
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	0
1	1	1	1



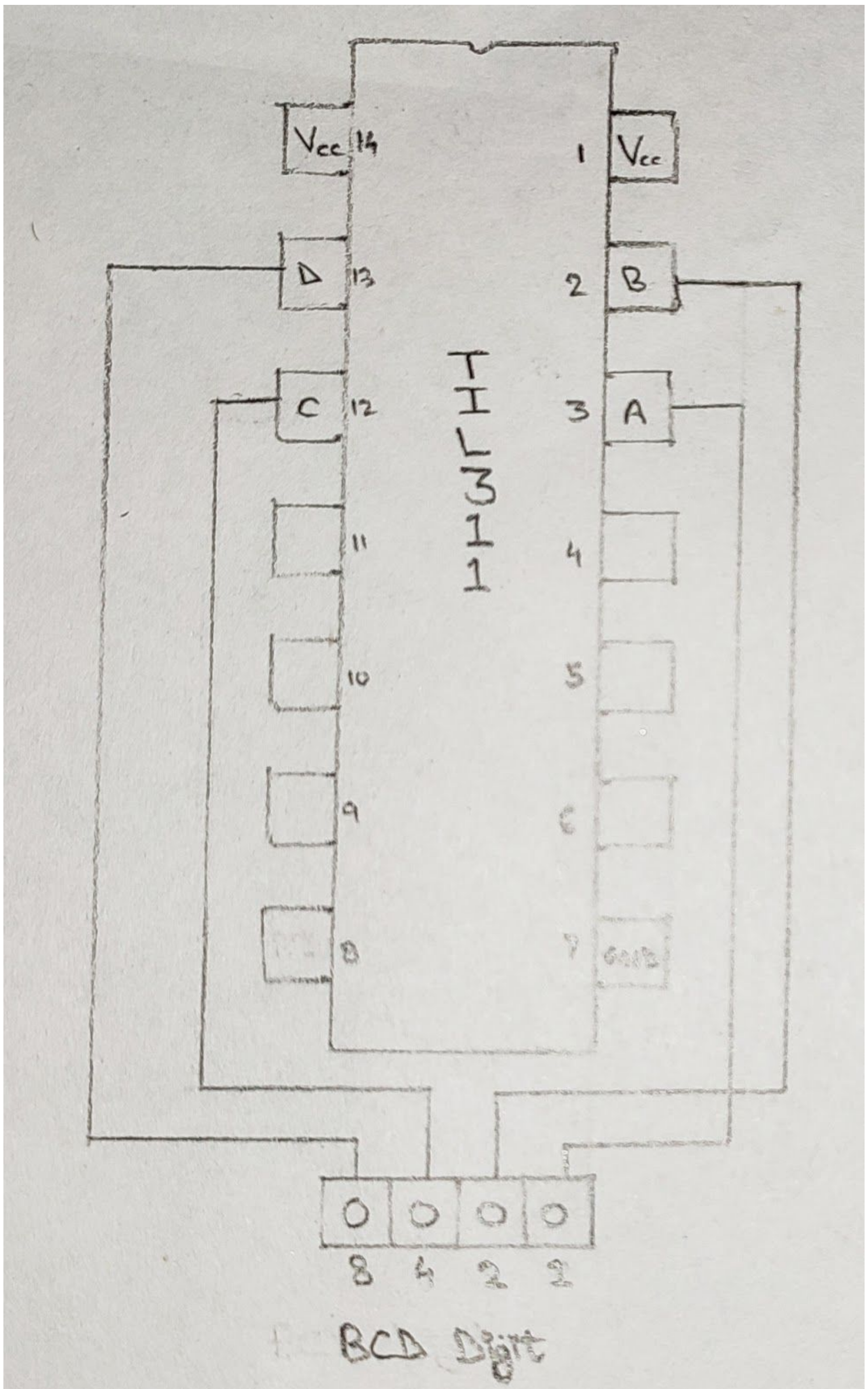
Explanation:

- The value of real operation can be changed only when the set value is 0.

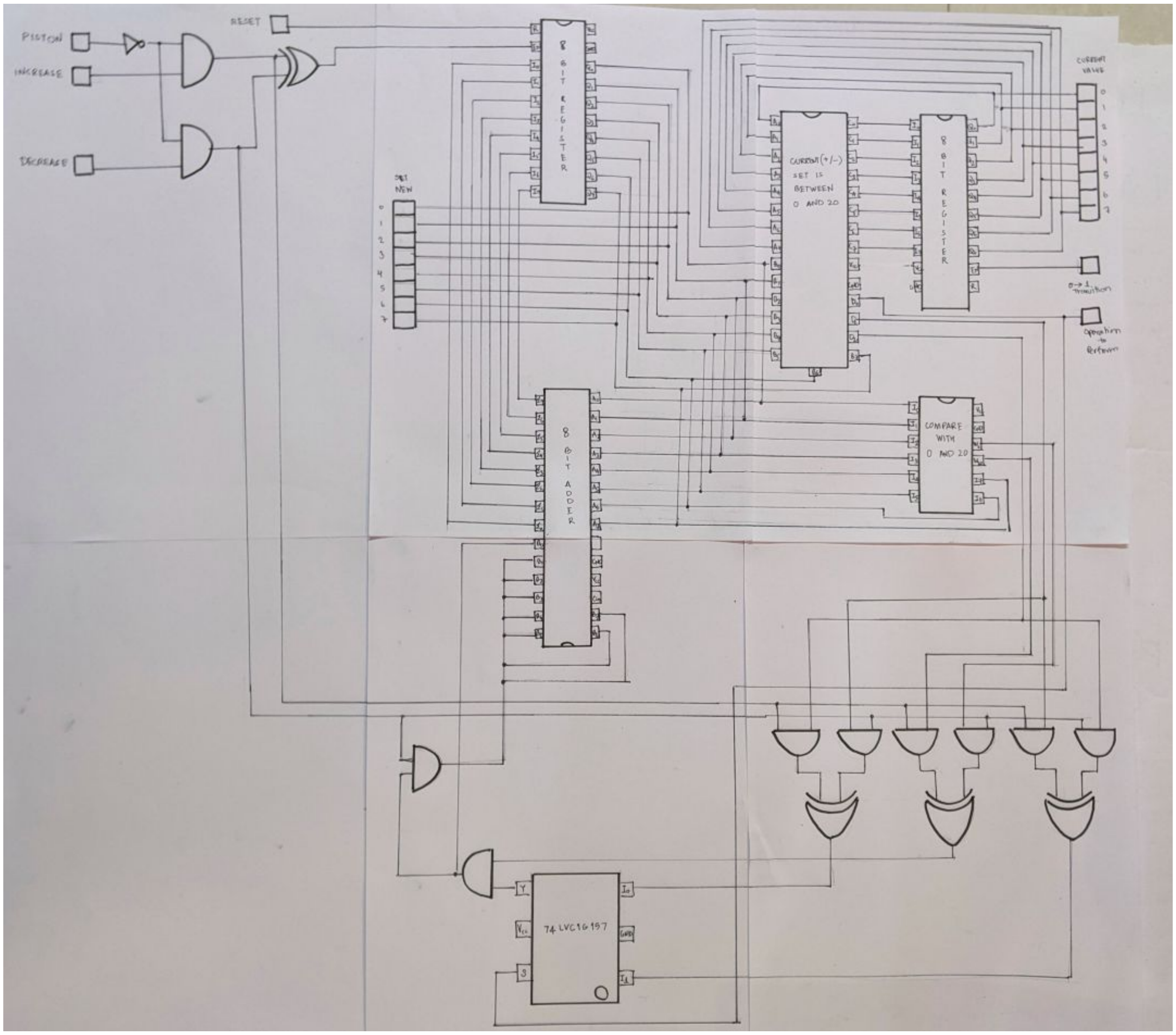
Pin out diagram

All have been added to the zip file as jpg files.
The pin out diagram doesn't show any wire to Vcc but it is connected to a power supply and the GND is also grounded.

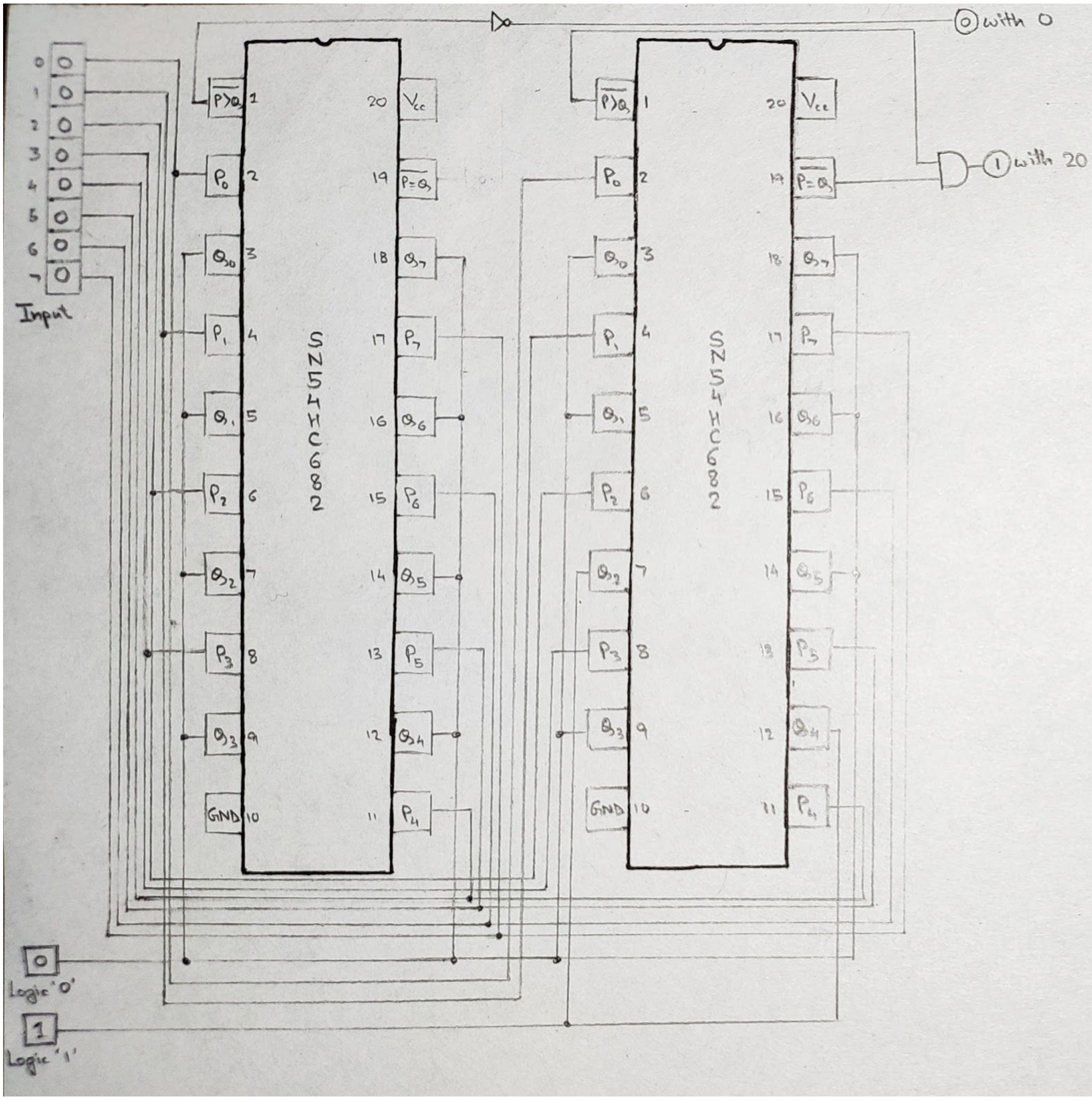
1. HEXADECIMAL DISPLAY



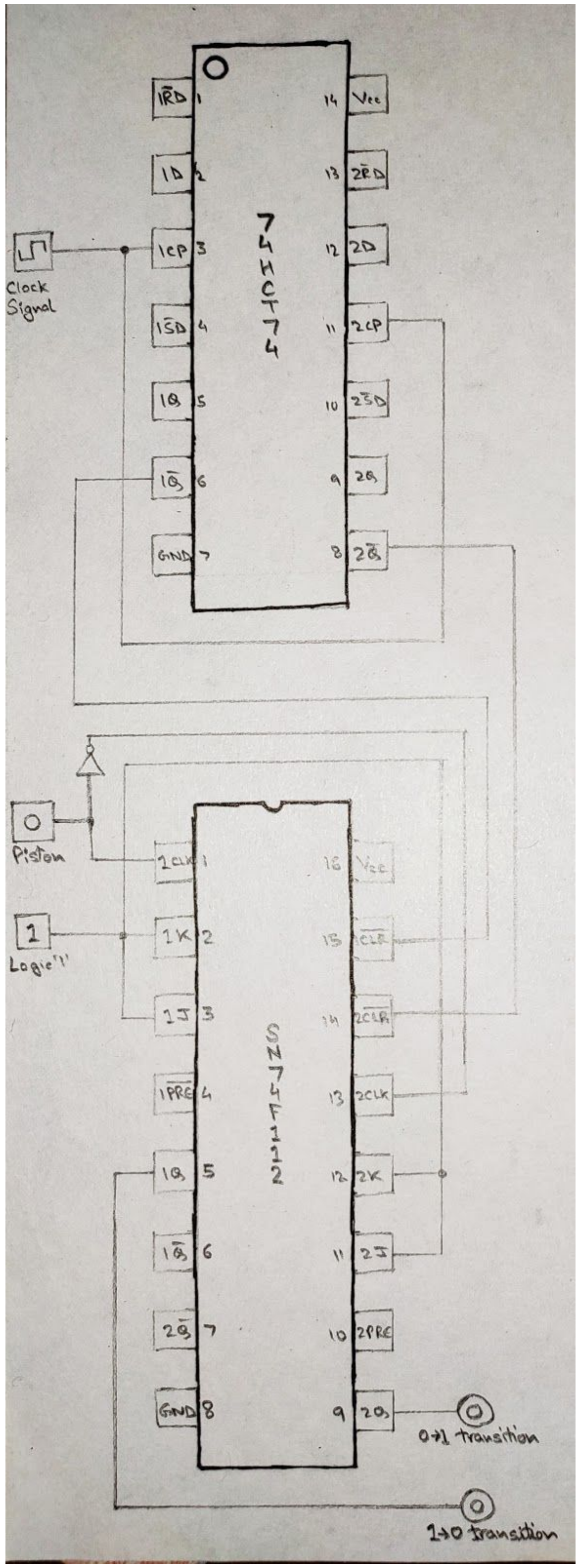
2.<u>COUNTING AND UPDATING</u>



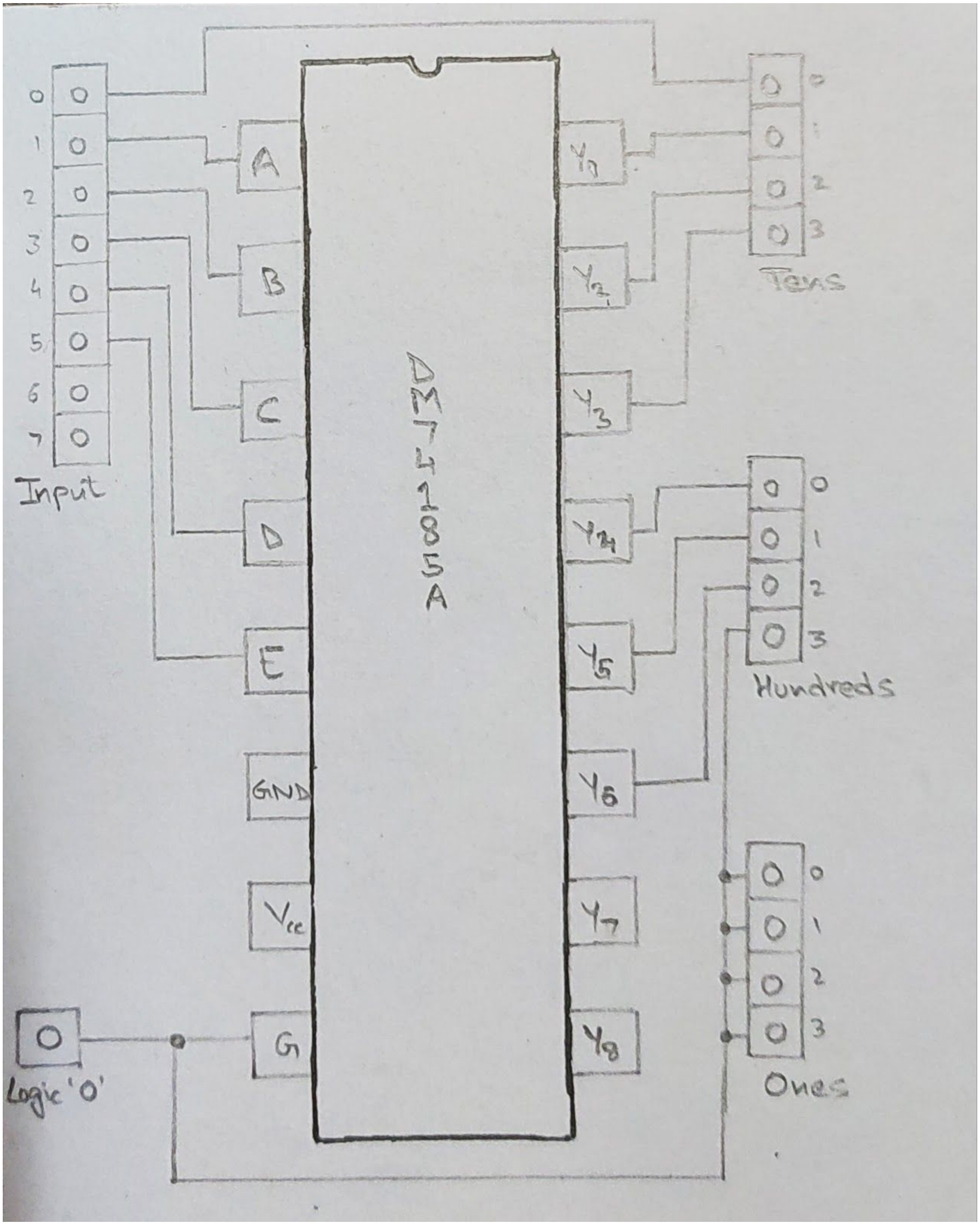
3. COMPARE WITH 0 AND 20



4. PULL IN AND PUSH OUT PULSE GENERATOR

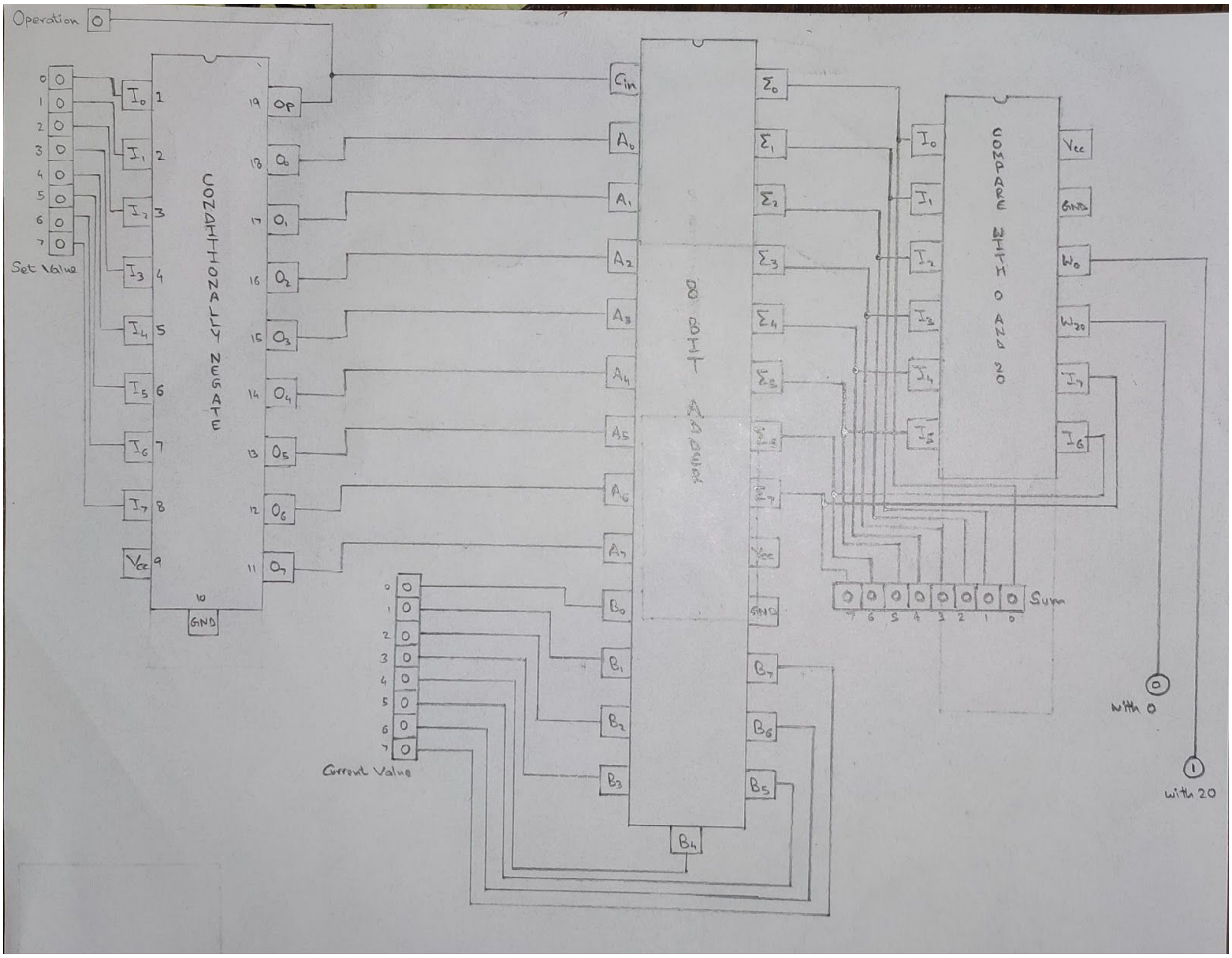


5. DISPLAY

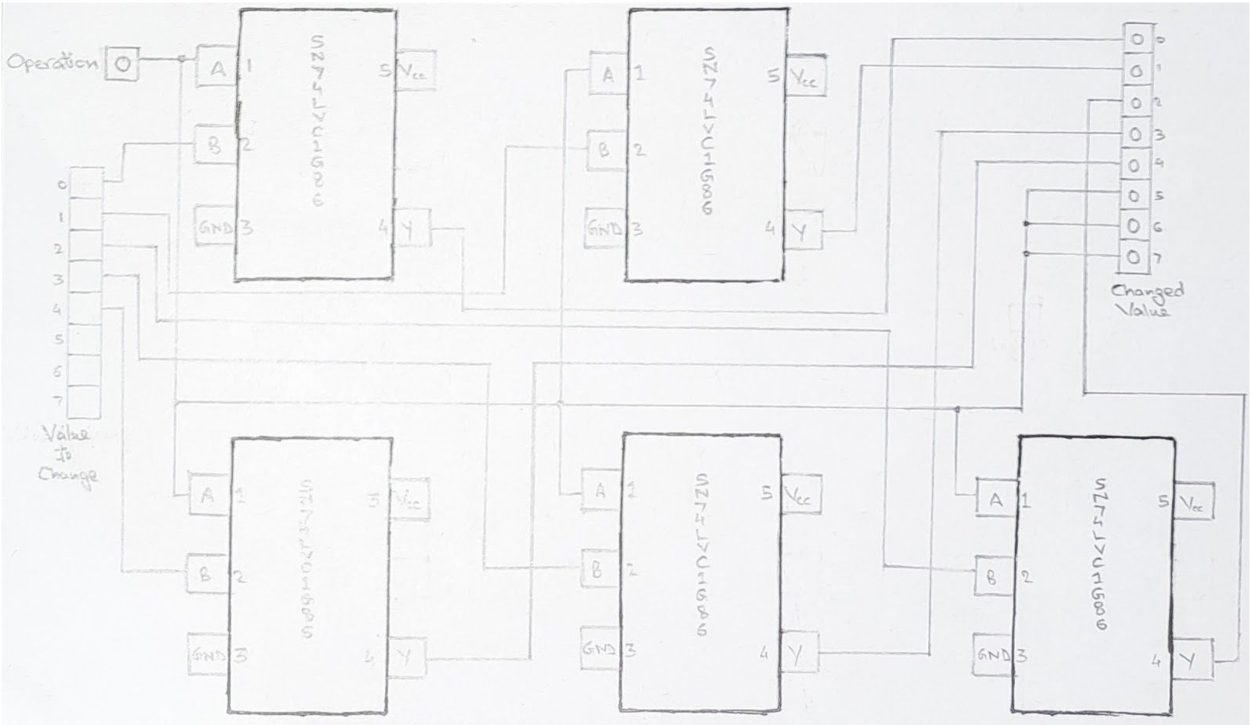


DM74185A
Input
0
1
2
3
4
5
6
7
A
B
C
D
E
GND
Vcc
G
Logic '0'
Y1
Y2
Y3
Y4
Y5
Y6
Y7
Y8
Tens
Hundreds
Ones

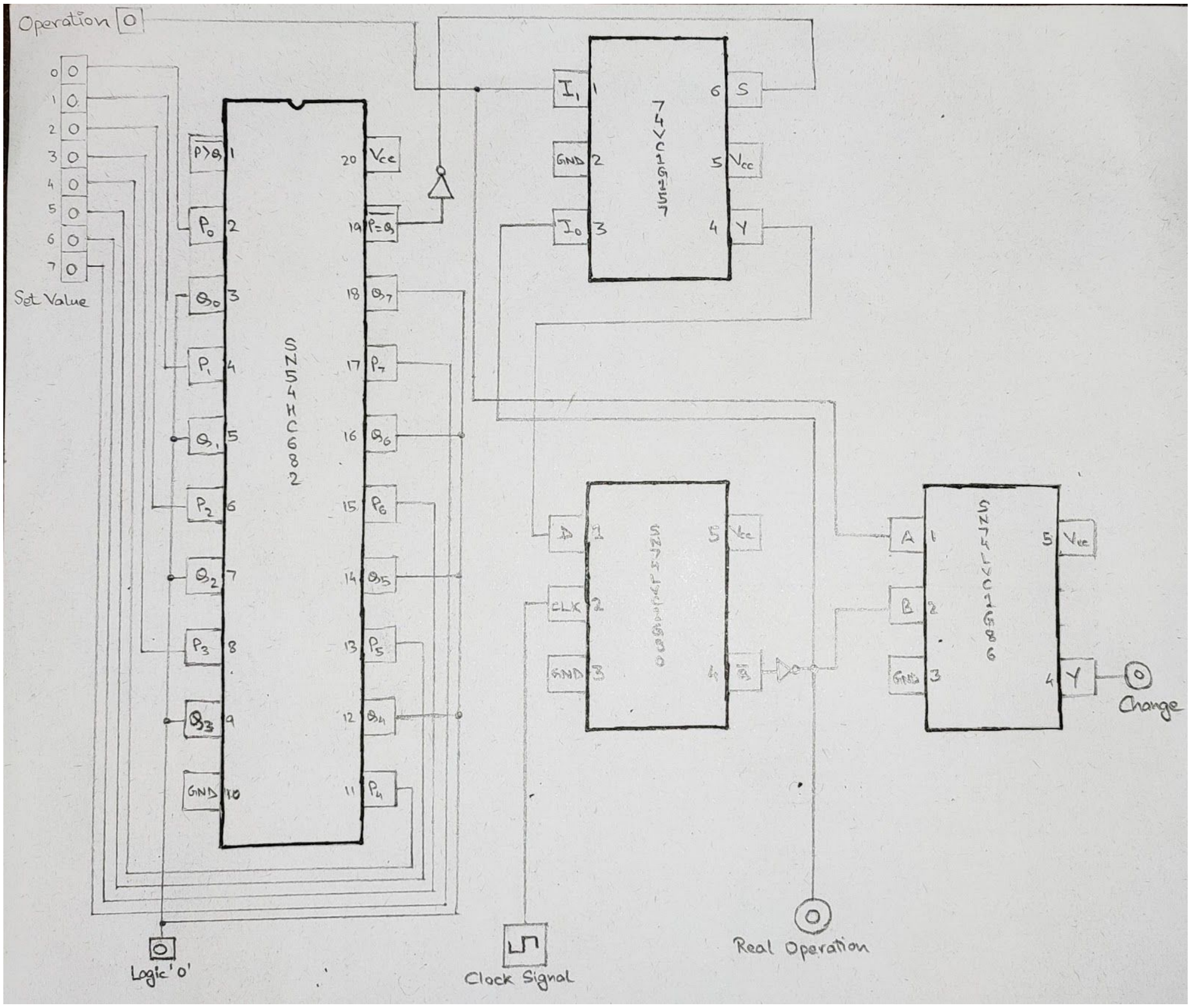
6. CURRENT (+ OR -) SET IS BETWEEN 0 AND 20



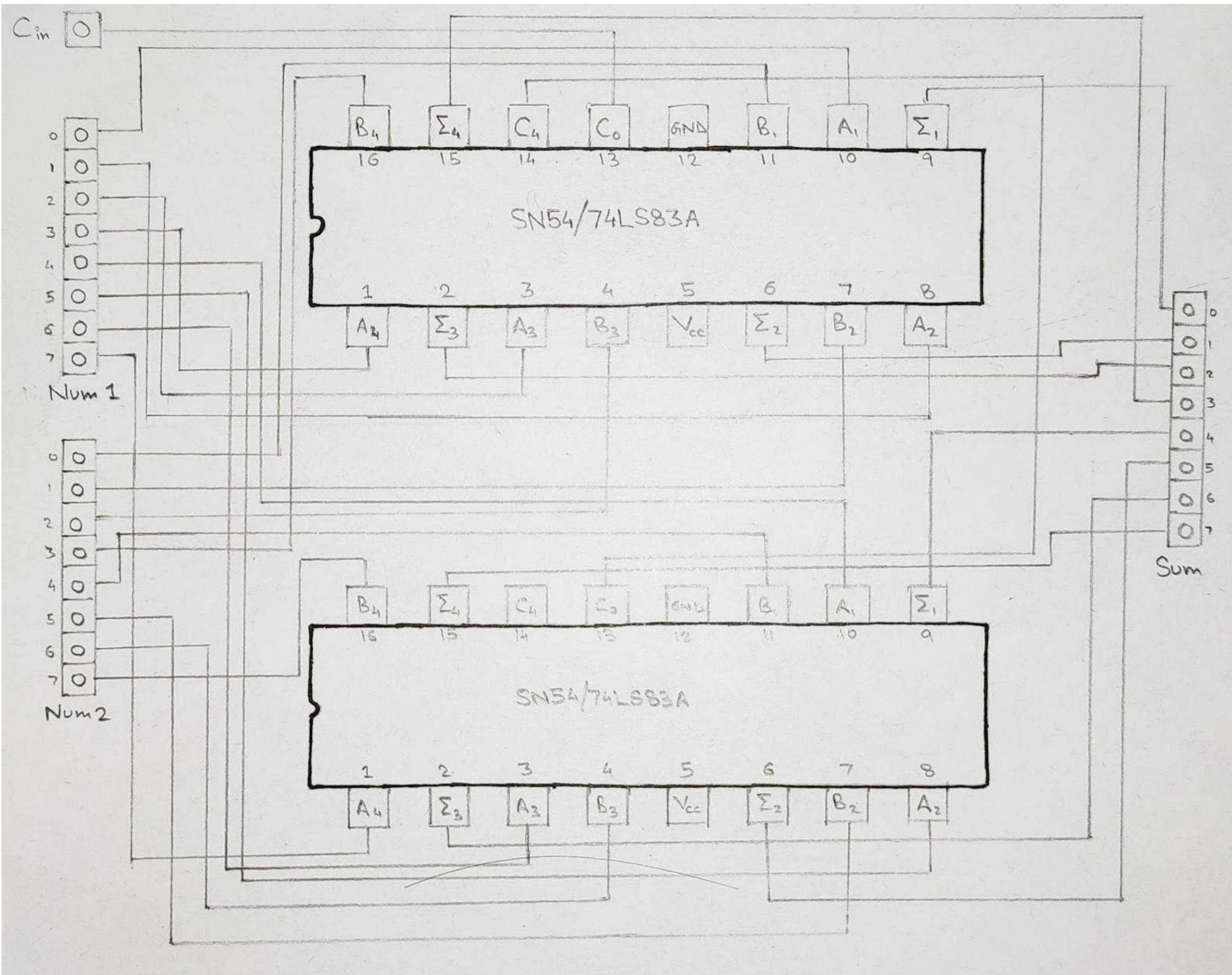
7. CONDITIONALLY NEGATE



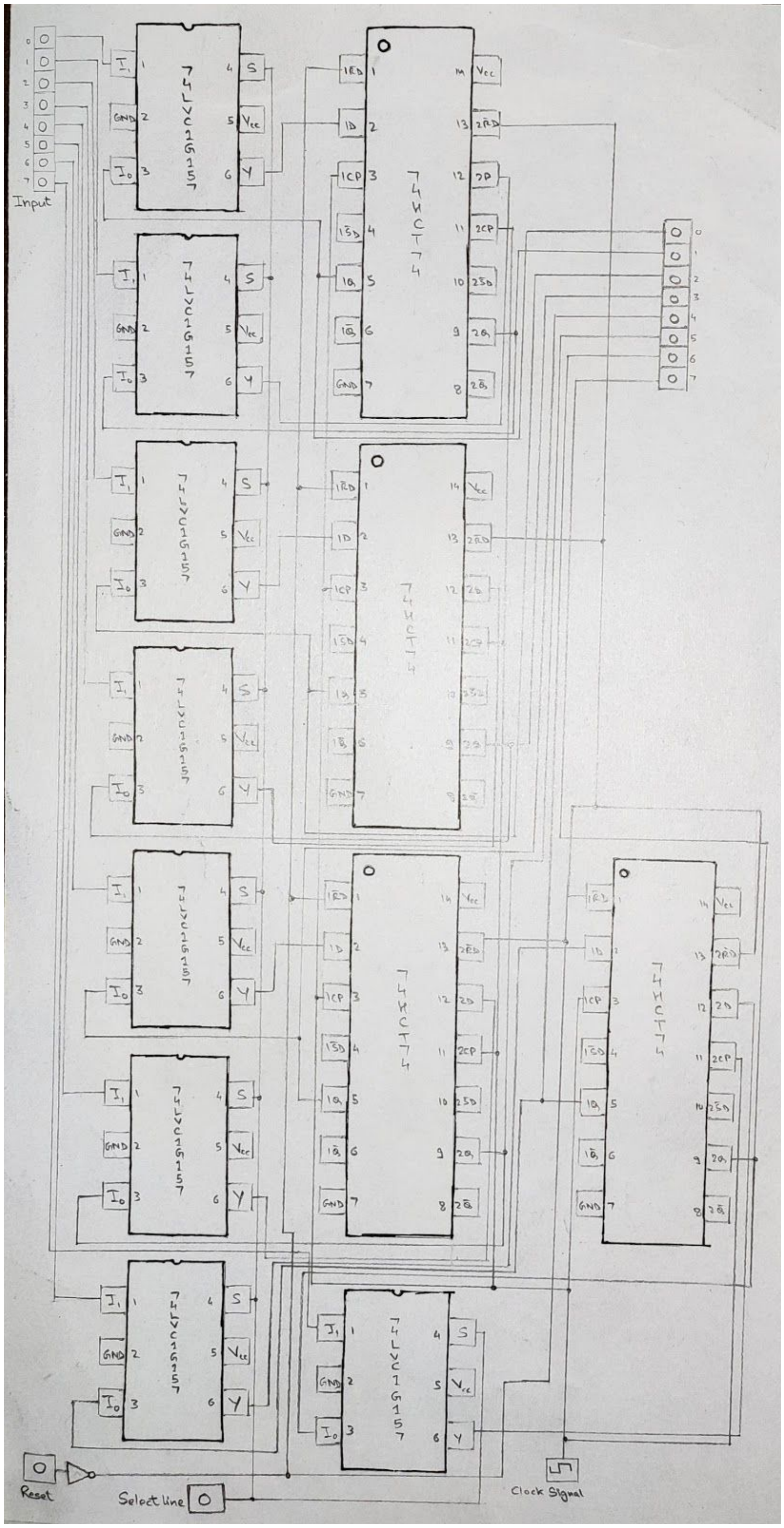
8. KEEP OPERATION CONSTANT



9. 8 BIT ADDER



10. 8 BIT REGISTER



One sample input/output combination that we have simulated

Perform the following operations:

1) Keep operation at 0 indicating you wish to pull in some amount of liquid.
2) Press the increase button till the set value reaches a 60ml.
3) Push the piston. The current value updates to 60ml.
4) Now release the piston the set value resets to 0.
5) Now try to pull another 110 ml by setting the set value to 110.
6) Push the piston. The current value updates to 170ml.
7) Now release the piston. The set value resets to 0.
8) Change the operation to 1 indicating you wish to push out some amount of liquid.
9) Press the increase button till the set value reaches 70ml.
10) Push the piston. The current value updates to 100ml.
11) Now release the piston. The set value resets to 0.
12) Press the increase button till the set value reaches 80ml.
13) Push the piston. The current value updates to 20ml.
14) Now release the piston. The set value resets to 0.

The respective images are in the file named “Images of input output.”

Additional functionalities and error reducing techniques.

1) The pipette allows for 3 operations increase, decrease and reset.
2) If both the increase and decrease button are pressed at the same time, the set value remains the same.
3) The set value cannot be changed once the piston is pushed thus making the actuators job a little simpler.
4) The numbers will always remain between 0 and 200 as a register is used instead of a counter. Thus escaping from taking care of unused states.
5) The pipette can be used to pull in liquid even when there is some liquid already present inside it.
6) The pipette can also be used to push only a set amount of liquid out keeping the remaining liquid inside.
7) The pushing and releasing of piston generates a pulse which is used to set the current value and resetting the set value respectively. Hence decreasing the possibility of error.
8) The pipette displays the set amount and the current amount of the pipette.
9) The operation can be changed only when the set amount is 0 thus ensuring the current value doesn’t go out of the 0 to 200 range.
10) If the user changes the value of the operation after setting a LED glows indicating the same.

Bill of materials

Component	Quantity	Datasheet
Button	4	
1-Bit Input Pin	1	
1-Bit Output Pin	1	
4-Bit Output Pin	3	
1-Bit Constant	8	
Clock Signal	4	
LED	1	
2-Input OR Gate	1	SN74LVC1G32-EP
8-Bit Magnitude Comparator (Unsigned)	6	SN54/74LS682
Dual JK Flip Flop (-ve edge)	1	SN74F112
D FF (+ve edge)	1	SN74LVC1G80
6-Bit Binary to BCD Convertor	2	DM74185A
2-Input AND Gate	10	SN74LVC1G08-Q1
2-Input XOR Gate	10	SN74LVC1G86
NOT Gate	2	SN74LVC1G04
Dual D FF (+ve edge)	9	74HCT74
4 Bit adder	4	SN54/74LS83A
2:1 Multiplexer	18	74LVC1G157
Hexadecimal Digit Display	6	TIL311

The inputs and outputs of only main are considered as the ones in the other components are intermediate inputs and outputs which are using inputs of main and are used to get outputs of main.

Datasheets

Component	Datasheet(link)
2-Input OR Gate	https://www.ti.com/lit/gpn/sn74lvc1g32-ep
8-Bit Magnitude Comparator (Unsigned)	https://www.ti.com/lit/ds/symlink/sn74hc682.pdf?ts=1605857954563
Dual JK Flip Flop (negative edge)	https://www.ti.com/lit/pdf/sdfs048
D Flip Flop (positive edge)	https://www.ti.com/lit/ds/symlink/sn74lvc1g80.pdf?ts=1605950701478&ref_url=https%253A%252F%252Fwww.google.com%252F
6-Bit Binary to BCD Convertor	http://susta.cz/fel/74/pdf/DM74184_74185.pdf
2-Input AND Gate	https://www.ti.com/lit/ds/symlink/sn74lvc1g08-q1.pdf?ts=1605839780454&ref_url=https%253A%252F%252Fwww.google.com%252F
2-Input XOR Gate	https://www.ti.com/lit/ds/symlink/sn74lvc1g86.pdf?ts=1605854636426&ref_url=https%253A%252F%252Fwww.google.com%252F
NOT Gate	https://www.ti.com/lit/gpn/sn74lvc1g04
Dual D Flip Flop (positive edge)	https://assets.nexperia.com/documents/data-sheet/74HC_HCT74.pdf
4 Bit Adder	http://www.ece.sunysb.edu/~dima/74ls83a.pdf
2:1 Multiplexer	https://assets.nexperia.com/documents/data-sheet/74LVC1G157.pdf
Hexadecimal Digit Display	https://www.jameco.com/Jameco/Products/ProdDS/32951.pdf