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2020-06676

Project #2
CS 20 M1

CS 20 Project 2: Stopwatch and Countdown timer

DOCUMENTATION

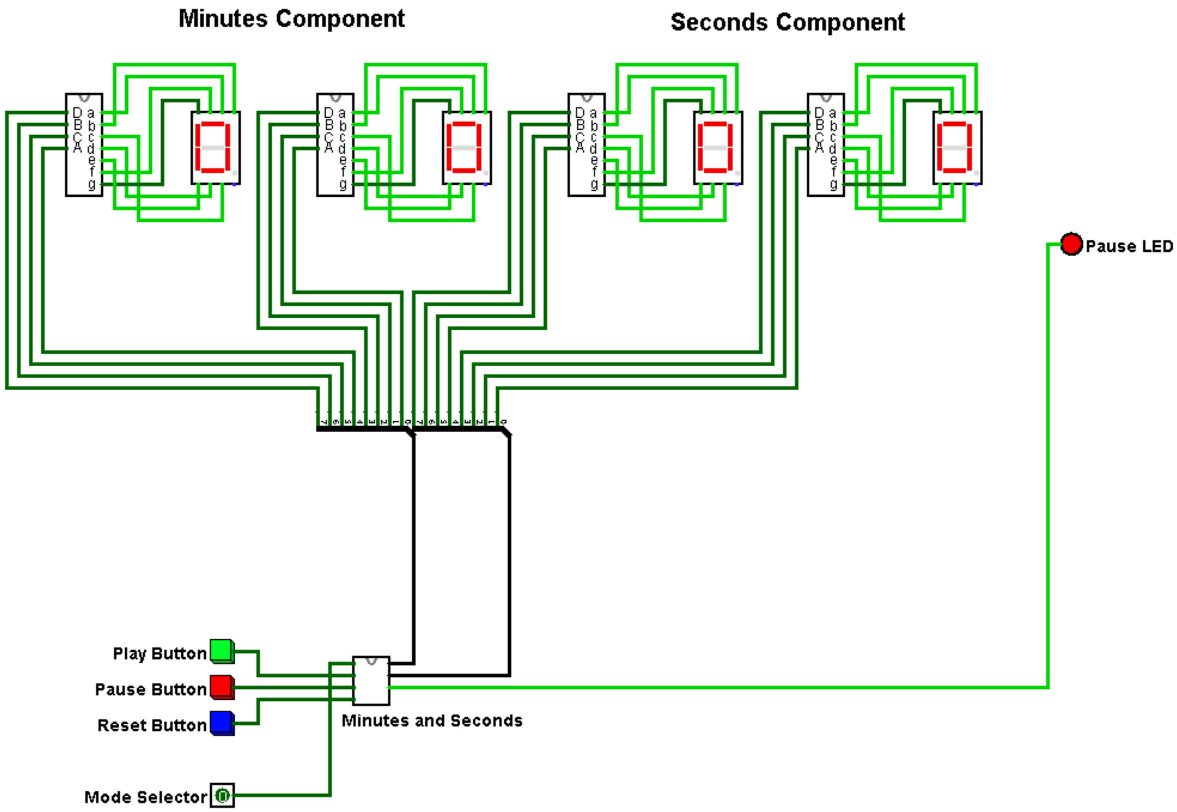

Fig 1. Schematic Diagram of the system

The system implemented is incomplete and only covers the stopwatch and countdown timer. Hence, there are only 3 buttons for the user input – play, pause, and reset buttons. There is also an input pin for the mode selector which depicts the mode that the system will implement. All these inputs are connected to the Minutes and Seconds Subcircuit which acts as the driving subcircuit of the system.

The main subcircuit has many components with the Counter Subcircuit as its base.

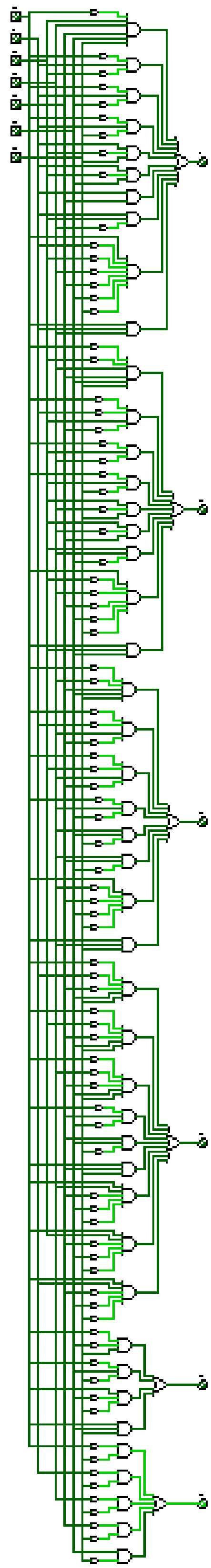

Fig 2. Schematic Diagram of the Counter Subcircuit

This subcircuit serves as the C1 for our stopwatch and countdown timer system. Since the minutes and seconds only go up to 59 (111011_2) which is made up of 6 bits, there would also be 6 D flip-flops that will act as input of C1 – denoted by q1, q2, q3, q4, q5, and q6. There is also an additional input m, which refers to the mode of the system. This subcircuit will be used for both minutes and seconds display.

The circuit is made using Logisim's combinational analysis function with the following truth table:

m	q1	q2	q3	q4	q5	q6	y1	y2	y3	y4	y5	y6
0	0	0	0	0	0	0	0	0	0	0	0	1
0	0	0	0	0	0	1	0	0	0	0	1	0
0	0	0	0	0	1	0	0	0	0	0	1	1
0	0	0	0	0	1	1	0	0	0	1	0	0
0	0	0	0	1	0	0	0	0	0	1	0	1
0	0	0	0	1	0	1	0	0	0	1	1	0
0	0	0	0	1	1	0	0	0	0	1	1	1
0	0	0	0	1	1	1	0	0	1	0	0	0
0	0	0	1	0	0	0	0	0	1	0	0	1
0	0	0	1	0	0	1	0	0	1	0	1	0
0	0	0	1	0	1	0	0	0	1	0	1	1
0	0	0	1	0	1	1	0	0	1	1	0	0
0	0	0	1	1	0	0	0	0	1	1	0	1
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0	0	1	0	0	1	1	0	1	0	1	0	0
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0	0	1	0	1	0	1	0	1	0	1	1	0
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0	0	1	0	1	1	1	0	1	1	0	0	0
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0	1	0	1	1	0	0	1	0	1	1	0	1
0	1	0	1	1	0	1	1	0	1	1	1	0

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1	1	1	1	1	0	0	x	x	x	x	x	x
1	1	1	1	1	0	1	x	x	x	x	x	x
1	1	1	1	1	1	0	x	x	x	x	x	x
1	1	1	1	1	1	1	x	x	x	x	x	x

Table 1. Truth Table of the Counter Subcircuit

From the 7 inputs, we denote the output for the flipflops as y1, y2, y3, y4, y5, and y6 – with y1 as the MSB and y6 as the LSB. Since D flipflops will be used, the next state of the circuit will also be the output. For the inputs with m as 0, the counter will count up to depict the stopwatch, so the next states will be the next number in binary form. Conversely, inputs with m as 1 will have the counter counting down to depict the countdown timer, so the next states will be the previous number in binary form. Don't care values are also placed for inputs with q1, q2, q3, q4, q5, q6 as 111100_2 (60) onwards because they are not part of the scope of the circuit.

Since there are 7 inputs, it would be difficult to create the k-maps but based on the combinational analysis of Logisim, the following are the SOPs of the outputs:

y1 = ~m q2 q3 q4 q5 q6 + ~m q1 ~q2 + ~m q1 ~q5 + ~m q1 ~q6 + q1 ~q2 q6 + q1 ~q2 q5 + q1 q4 + q1 q2 ~q3 + m ~q1 ~q2 ~q3 ~q4 ~q5 ~q6 + m q1 q3

y2 = ~m ~q2 q3 q4 q5 q6 + ~m ~q1 q2 ~q4 + ~m q2 ~q3 + ~m q2 ~q6 + q2 ~q3 q6 + q2 ~q3 q4 + q2 q3 ~q5 + m ~q2 ~q3 ~q4 ~q5 ~q6 + m q2 q5

y3 = ~m ~q3 q4 q5 q6 + ~m ~q1 q3 ~q4 + ~m ~q2 q3 ~q4 + ~m q3 ~q5 + q3 q5 ~q6 + q3 q4 ~q5 + m ~q3 ~q4 ~q5 ~q6 + m q3 q6

y4 = ~m ~q1 ~q4 q5 q6 + ~m ~q2 ~q4 q5 q6 + ~m ~q3 ~q4 q5 q6 + ~m q4 ~q5 + q4 q5 ~q6 + m q4 q6 + m q3 ~q4 ~q5 ~q6 + m q2 ~q4 ~q5 ~q6 + m q1 ~q4 ~q5 ~q6

y5 = ~m ~q5 q6 + ~m q5 ~q6 + m ~q5 ~q6 + m q5 q6

y6 = ~m ~q6 + ~q1 ~q6 + ~q3 ~q6 + ~q4 ~q6 + q5 ~q6

The counter (C1) will now be connected to the clock, flipflops, and actual outputs in the Clocked Counter Subcircuit.

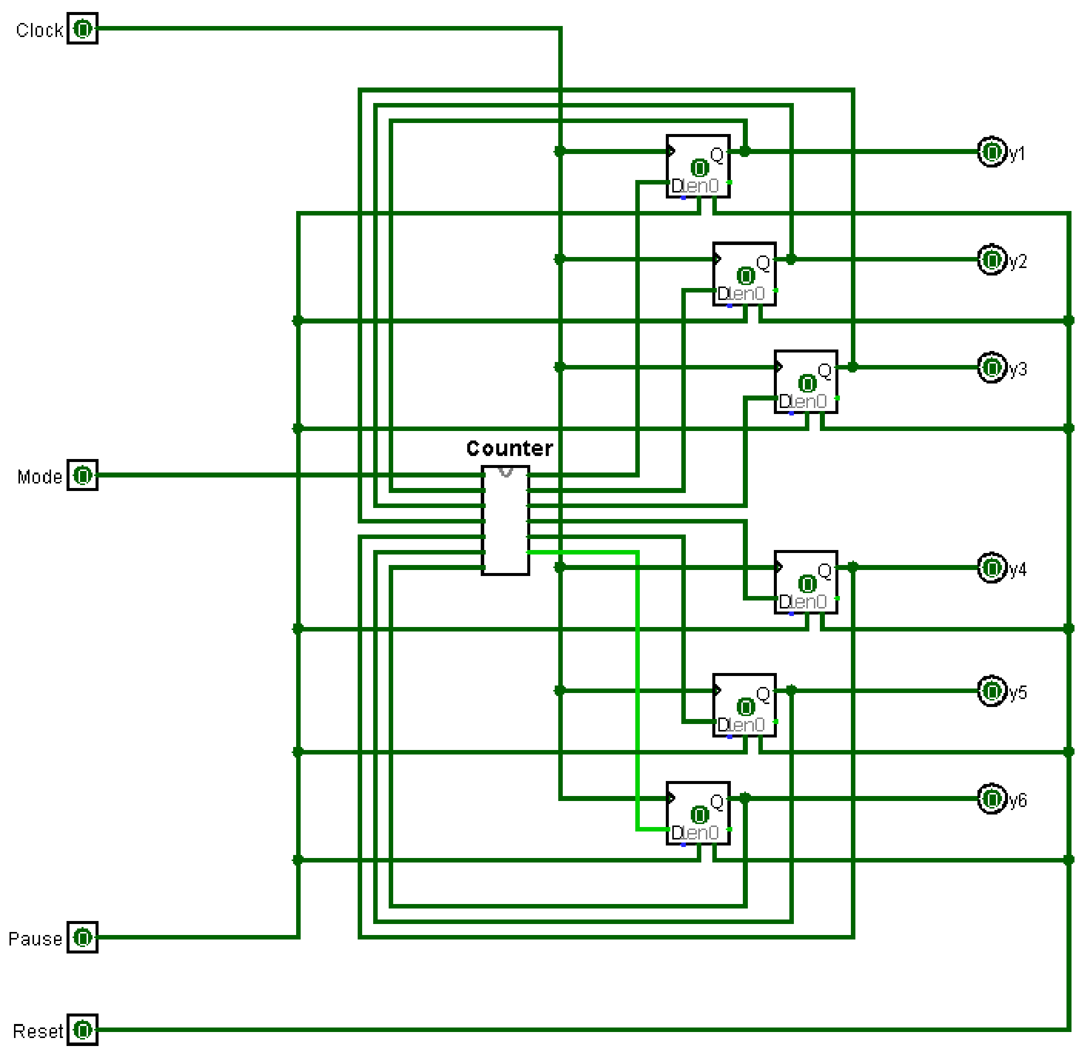

Fig 2. Schematic Diagram of the Clocked Counter Subcircuit

The mode input pin is connected to the m input of the Counter Subcircuit. Each q output of the D flipflops are connected to their respective input pins in the Counter Subcircuit. While the output of the Counter Subcircuit are connected to the respective D flipflops as well. Since the counter is synchronous, all flip-flops are connected to a single clock, enable, and clear pin denoted by clock, pause, and reset, respectively.

When the Pause pin is 0, the clock will be disabled in all flipflops, pausing the operation of the counter. On the other hand, when the Pause pin is 1, the clock resumes activity and continues the operation.

When the Reset pin is 0, it doesn't affect the counter. But when the Reset pin is 1, it sets all flipflops to 0.

The Clocked Counter Subcircuit will be used for both the minutes and seconds component. There will be a Minutes Clocked Counter and Seconds Clocked Counter that will be connected by a Connector Subcircuit.

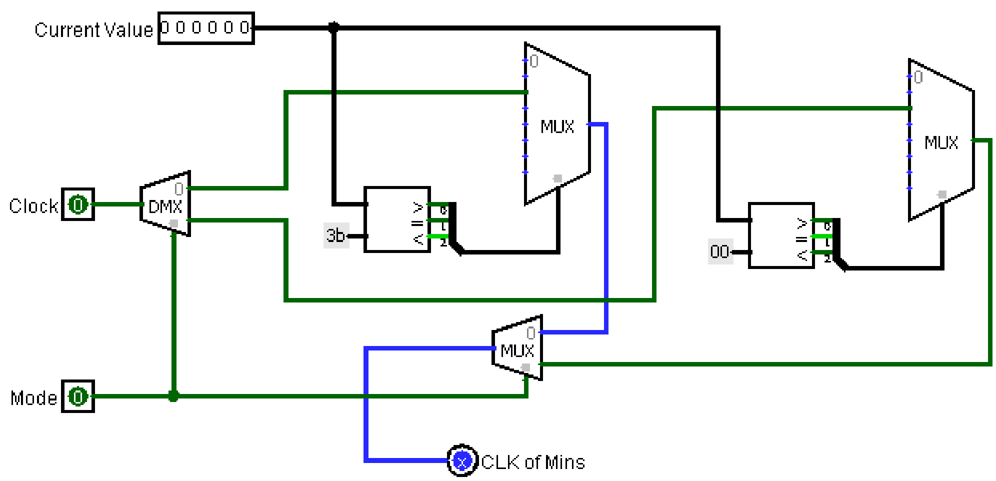

Fig 3. Schematic Diagram of the Connector Subcircuit

Since the Minutes Clocked Counter starts after the Seconds Clocked Counter, a connector subcircuit is made to control the Minutes Clocked Counter. The connector takes the current value and clock of the Seconds Clocked Counter. Since there are two modes, the Mode Selector Pin is also taken account for and acts as the destination address for a demultiplexer connected to the clock.

When the Mode pin is 0: Stopwatch

The clock will pass through input 2 of a multiplexer. Its source address is dependent on a comparator that takes in the current value and 0x3b (59). Since the clock is in input 2, it will only be passed if the address is 010_2 (2) or, in the case of the comparator, if the current value is equal to 0x3b (59). This means that for the Stopwatch function, the Connector Subcircuit will only output the clock and connect it to the Minutes Clocked Counter when the Seconds Clocked Counter has passed 59 (111011_2).

When the Mode pin is 1: Countdown Timer

The clock will also pass through input 2 of another multiplexer. This time, the source address is dependent on a comparator that takes in the current value and 0x0 (0). Since the clock is in input 2, it will only be passed if the address is 010_2 (2) or, in the case of the comparator, if the current value is equal to 0x0 (0). This means that for the Countdown Timer function, the Connector Subcircuit will only output the clock and connect it to the Minutes Clocked Counter when the Seconds Clocked Counter has passed 00 (000000_2).

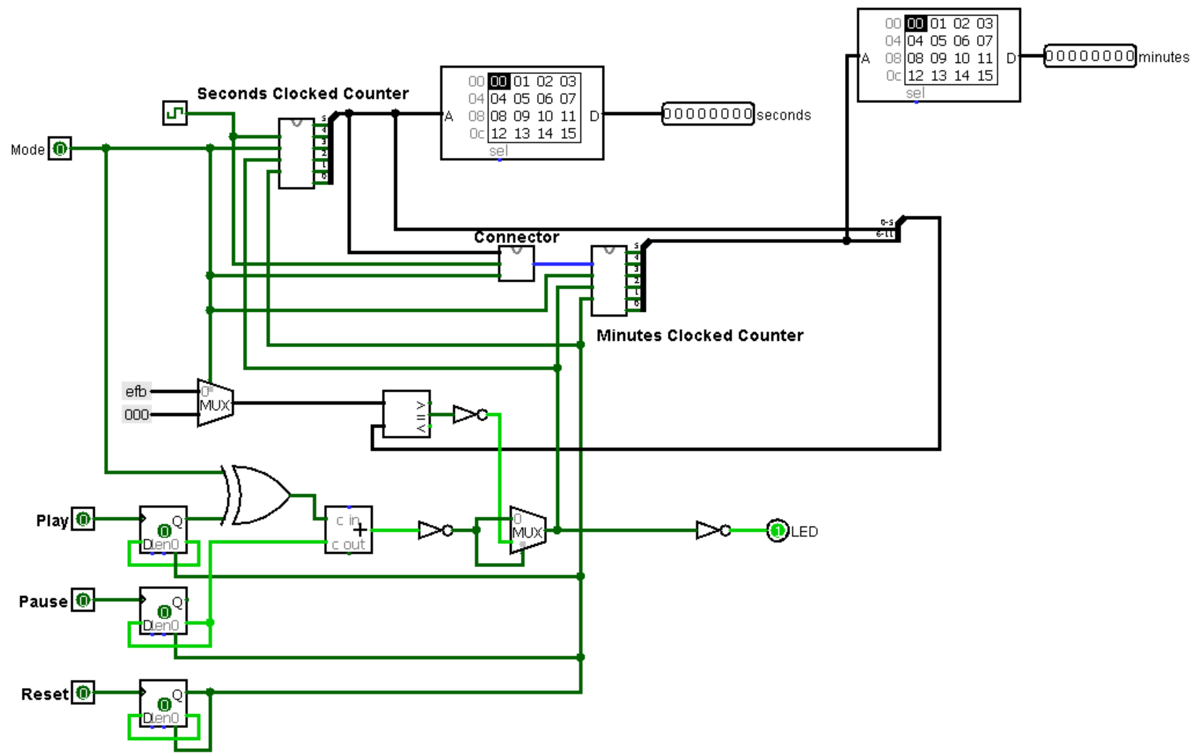

Fig 4. Schematic Diagram of the Minutes and Seconds Subcircuit

The main subcircuit is comprised of the Clocked Counter and Connector Subcircuits.

For the Seconds clocked counter, the main clock and mode selector pin is connected as its input together with Pause and Reset buttons. The output is connected to a splitter that inputs it to a 64 x 8 ROM where the address in binary corresponds to its decimal number in hexadecimal and outputs it as an 8-bit binary. For example, the address 010000_2 is 16 in decimal, so its value in the ROM is 0x16 which will be outputted as the binary 00010110_2. This will make it easy to convert in BCD because it is already in the form 0001 0110 which are the digits 1 and 6 in decimal. The 8-bit binary will be the output for the Seconds Component.

The same mechanism is applied to the Minutes Clocked Counter, except its clock is derived from the Connector Subcircuit which takes the main clock, mode selector pin, and current value of the Seconds Clocked Counter as input.

Since the buttons are instantaneous, there is a clock attached to the pins in order to store the value of a button press. Of the three buttons – play, pause, and reset – play and pause are opposites hence we can say that the play state is also the unpause state.

The circuit will pause if any of the following happens: the counter is 59 59 in stopwatch mode, the counter is 00 00 in countdown timer mode, the mode is shifted while playing, and the pause button is pressed. For the first two conditions, the limits of the counter, a multiplexer is connected to 0x000 and 0xefb ($111011\ 111011_2$ which is 59 59 if each 6-bit is converted to decimal) with source address depending on the Mode pin. The output of the multiplexer will be compared to the current value of both the Seconds and Minutes Clocked Counter which is joined by a splitter.

When the Mode pin is 0: Stopwatch

The source address of the multiplexer is 0 so 0xefb will be passed and compared to the current value. Since we will only take account the case where the counter is 59 59 or 0xefb, the output is only if the values are equal and is connected to a not gate and multiplexer to be compared to the other conditions of the pause state.

When the Mode pin is 1: Countdown Timer

Similar process to the Stopwatch mode. This time, the source address is now 1 so 0x000 will be passed and compared to the current value. The output accounted for is only when the current value is equal to 00 00 or 0x000.

As for the other conditions of the pause state, it depends on the Play and Pause buttons, as well as the Mode Selector Pin. Since the buttons are connected, and the pause function of the counter (the enable pin of the flipflops) is activated when input is 0, we will use the q' for Pause Button and q for Play Button. To account for the mode switching, there is also a XOR gate connecting the output of the Play Button and the Mode Selector pin. This is because changing the modes while playing should pause the circuit. To depict pause/unpause, the result of the XOR gate and the output of the Pause Button are inputted to a half adder.

Input		Output
Play	Pause	
0	1	1
0	0	0
1	1	0
1	0	1

Table 2. Truth Table of the Half Adder

Supposedly, when 1 is the output of the half adder, the state of the circuit should be paused however, the enable pin of the flipflops should be 0 to pause hence a not gate is attached.

Since the aforementioned conditions of the pause state are consolidated into 2 outputs, to depict which would be followed, both are connected to a multiplexer. Because the buttons can be inputted at any time, they take precedence over the condition of reaching the limits of the counter and will also be the source address of the multiplexer. If the result of the buttons is 0, that means either the user switched the mode while playing or pressed the pause button, so the demultiplexer will pass 0 to the pause pin of both Seconds and Minutes Clocked Counter. Otherwise, the multiplexer will pass the result of the comparator, which is defaulted to 1 unless the limits are reached. The result of the multiplexer is also connected to a not gate and the Pause LED so it will light up when the circuit is paused.

As for the Reset button, the clear pin of its clock is connected to its q output so it will not stay as reset the whole time. It is also connected to the clear pins of the clocks of the Pause and Play button so that when the clock is reset, it will automatically pause. This output is also connected to the reset pin of both Seconds and Minutes Clocked Counter.

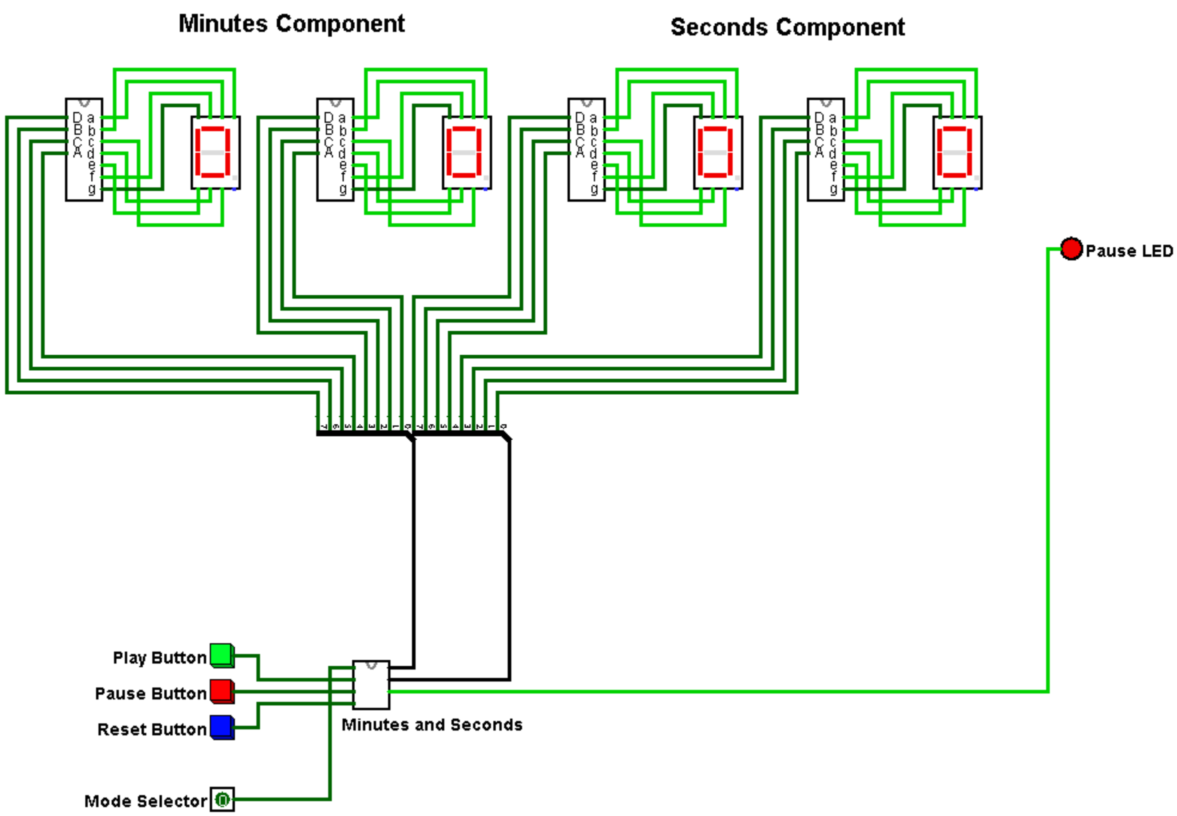

Fig 1. Schematic Diagram of the system

Hence, the output of the Minutes and Seconds Subcircuit is the 8-bit minutes component, 8-bit seconds component, and the result of the Pause LED. The first 4 bits of the Minutes Component from the MSB are attached to a 7-segment BCD decoder from the previous lab exercises to convert it to the 7-segment display as the first digit of the Minutes Component. The last 4 bits will then be accounted for the last digit of the Minutes Component. Similar process is done for the Seconds Component.

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LINK FOR THE DOCUMENTATION VIDEO:

https://drive.google.com/file/d/1U7-Q3sRWFSpmIT6OAEH_QPv8WcaDbdJH/view?usp=sharing