# ENR 157 Project Report

**Project Description:**

Design and simulate a consumer microwave oven control system that functions as an actual microwave controller, incorporating multiple sensors and components that function within the design restraints and requirements to simulate an actual microwave control system.

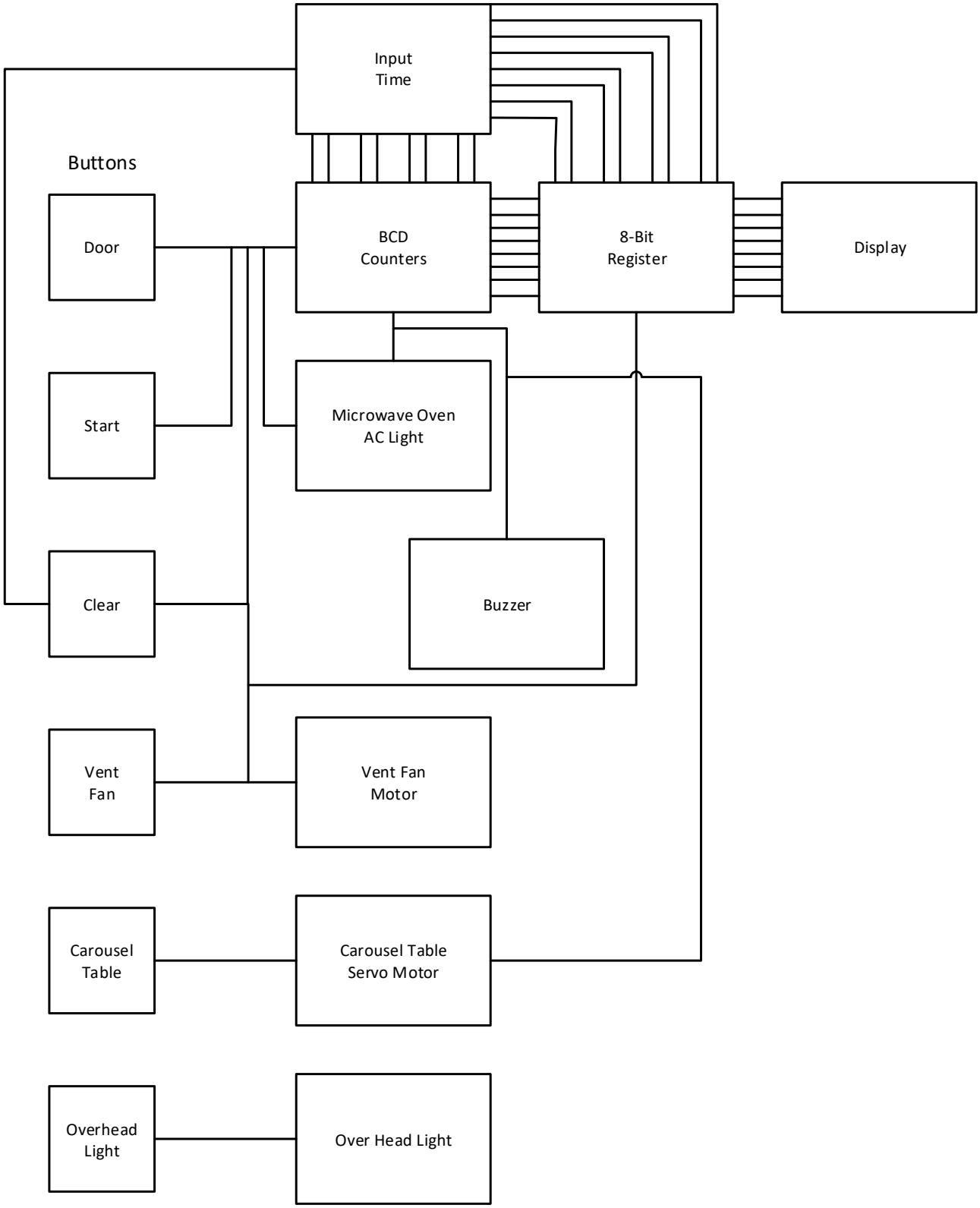
Sensors and Systems:

- Countdown Timer (set from 5 to 60 seconds in 5 second intervals)
- Microwave Generator (power adjustable motor from 10 to 100% in 10% increments)
- Carousel Table (servo motor, rotates fully back and forth)
- AC Oven Light
- Over the Counter Light (switch activated)
- Oven Door Sensor
- Buzzer/Tone
- Dual Speed Vent Fan (switch controlled motor)
- Set/Clear Switches

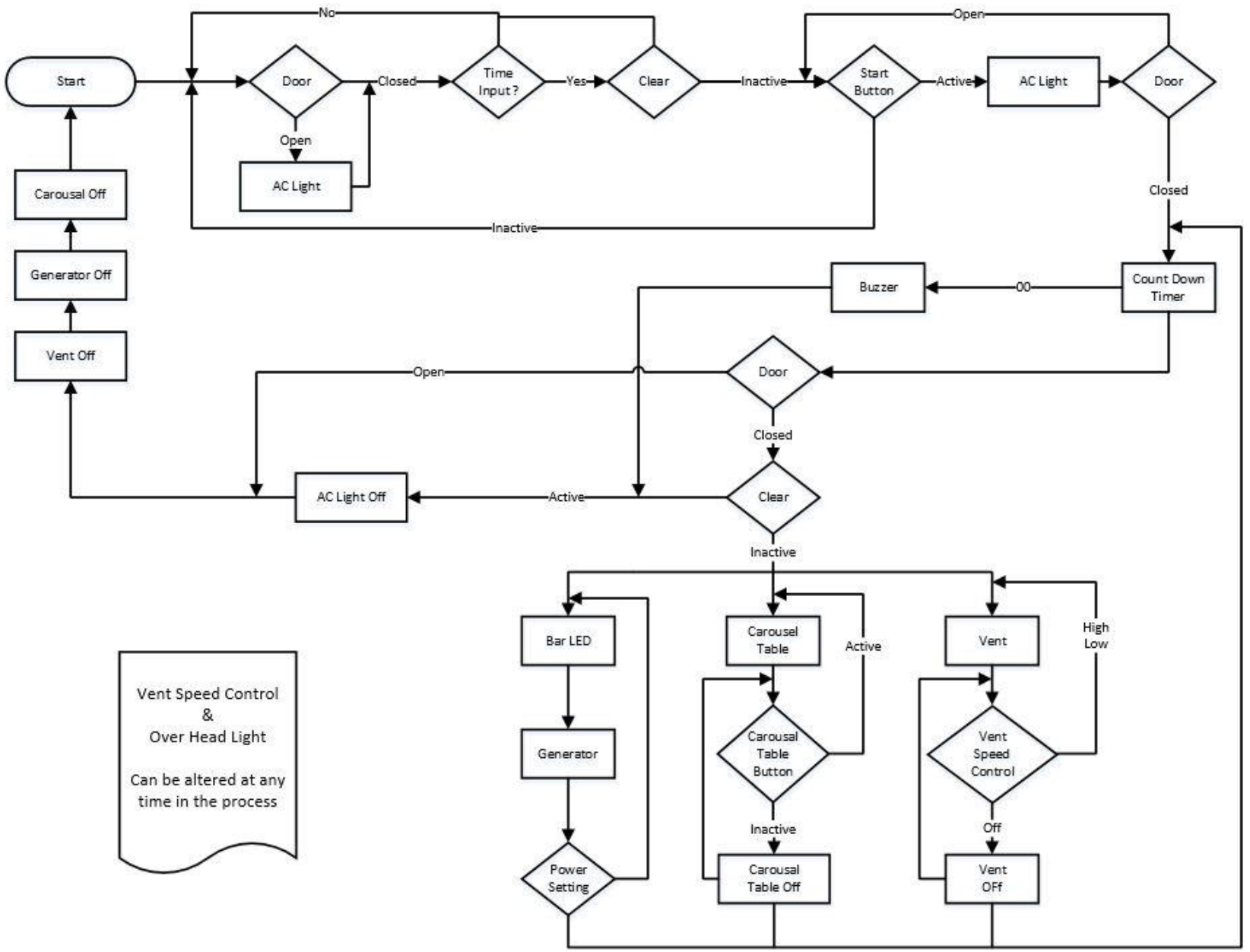
**Cost Analysis**

| Component | Cost($)/Unit | Gates/Chip | Components Used | Cost($)/ Component |
|---|---|---|---|---|
| 74LS04D | .37/ku | 4 | 4 | 0.00148 |
| 74LS08D | .34/ku | 4 | 3 | 0.00102 |
| 74LS32D | .31/ku | 4 | 3 | 0.00093 |
| 74LS83D | 2.19/ku | 2 | 2 | 0.00438 |
| 74LS107D | 1.40/u | 2 | 3 | 4.2 |
| 74LS112D | .45/ku | 2 | 2 | 0.0009 |
| 74LS192D | 3.49/u | 2 | 2 | 6.98 |
| 74LS363 | 3.02/u | 8 | 2 | 6.04 |
| 74LS395D | 1.26/u | 2 | 1 | 1.26 |
| EDR201A05 Relay | .01/u | -- | 5 | 0.05 |
| IRF530N Mosfet | 1.19/u | -- | 4 | 4.76 |
| IRF9530N Mosfet | 1.25/u | -- | 2 | 2.5 |
| 1N4001G Diode | .015/ku | -- | 8 | 0.00012 |
| Opto-Coupler | .12/u | -- | 4 | 0.48 |
| Motor | 3.50/u | -- | 3 | 10.5 |
| DCD Bargraph | 1.39/u | -- | 1 | 1.39 |
| Pushbutton Switch | .75/u | -- | 8 | 6 |
| SPDT Switch | .39/u | -- | 2 | 0.78 |
| 120V AC Light | 2.75/u | -- | 1 | 2.75 |
| | | Total | 60 | 47.70 |

**Block Diagram**



**System Flow Chart**

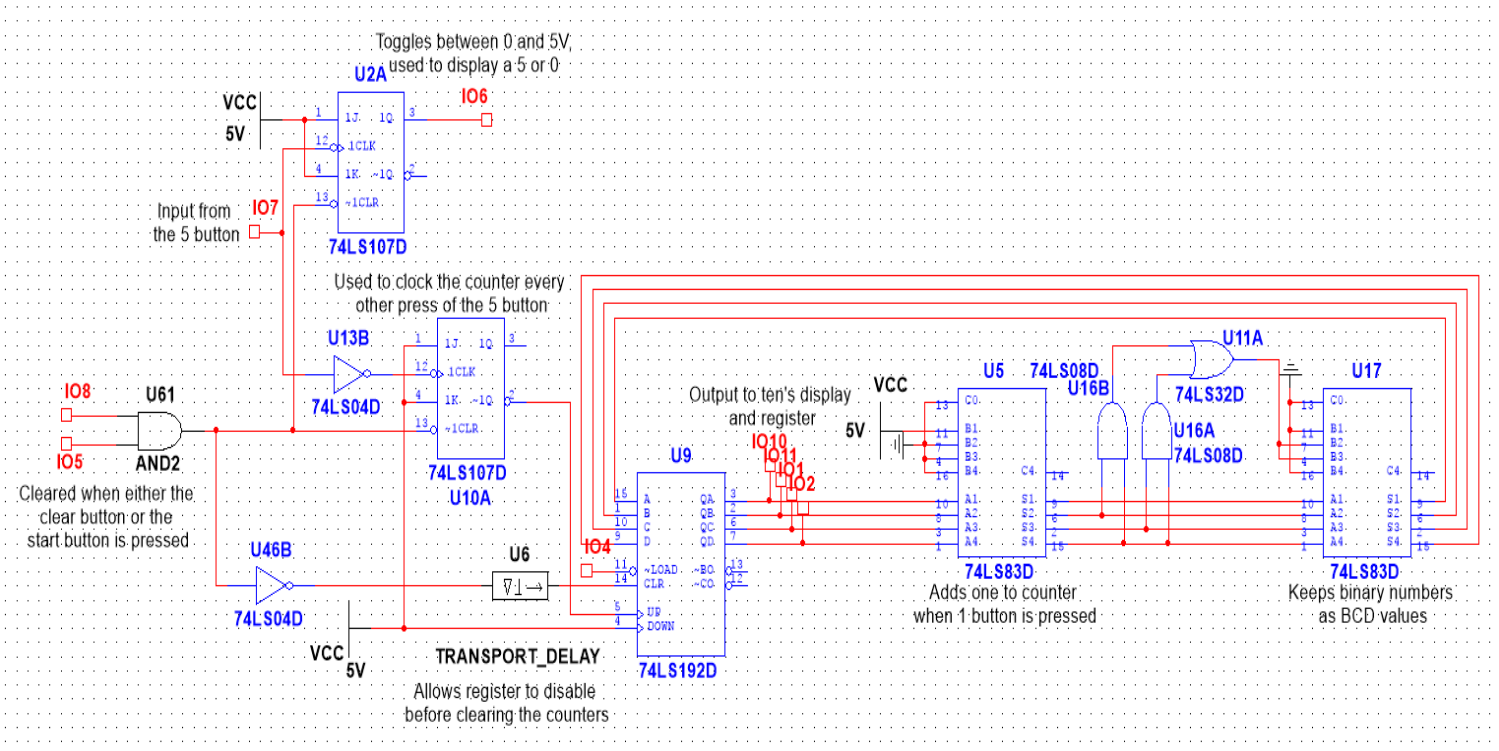


## Technical Discussion

### Sub-Systems

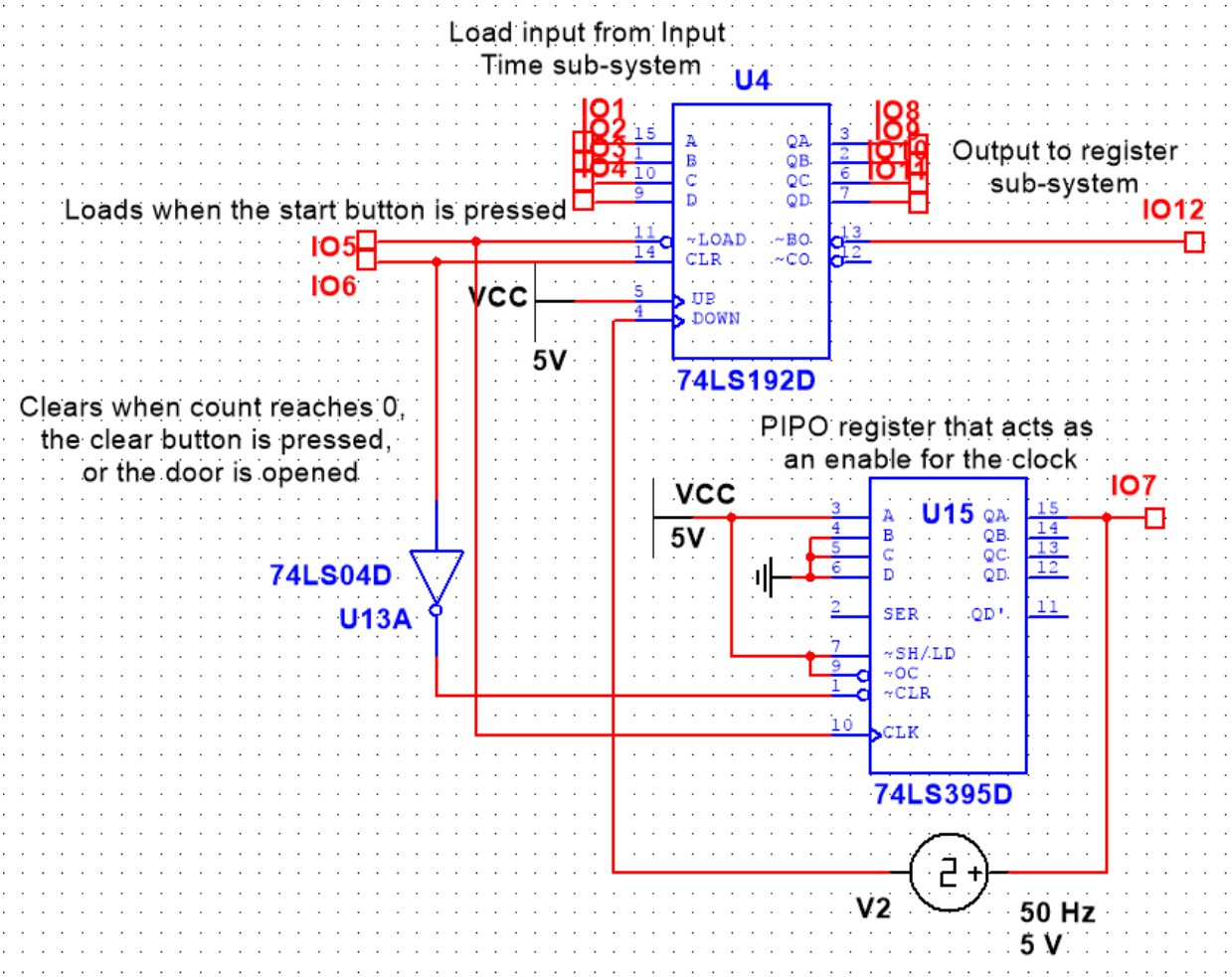
Input Time

| Component Functionality | System Function |
|---|---|
| **74LS83D**<br>The first full adder, going from left to right, adds 1 to the output of the counter and the second full adder adds 6 to any binary number greater than 9 from the output of the first counter (for BCD values). These two counters combined allow the inputs to the counter to always be 1 greater than its output and thus, every time the 1 button is pressed, it adds one to the output of the counter.<br>**74LS107D**<br>The first JK FF toggles output Q every time the 5 button is pressed. The output is then connected to the load inputs of the One's Counter sub-system. The second JK FF also toggles so that every other time the 5 button is pressed, it sends a PGT to the clock of the counter, adding one to its output.<br>**74LS192D**<br>This BCD counter receives its load inputs from the second full adder. When the 5 button is pressed twice, it counts up one and when the 1 button is pressed, it loads its inputs (adding one to its output). The outputs of this counter are the load inputs of the 10's Counter sub-system. | Takes the user's time input, any combination of the 5 and 1 buttons and outputs it to both the Hex displays on the user interface and the load inputs to the counter. The 5 button adds 5 to the One's Counter sub-circuit on every press and 1 to the Ten's Counter sub-circuit on every other press. The 1 button also adds 1 to it's the Ten's Counter sub-circuit on every press. The JK FFs were used because of their toggle function, the counter was used because of the need for two ways of adding 1 to its outputs; its load function and its up counter. The adders used in conjunction with the counter to add one to its load input on every change and the combinational logic was used to keep the numbers from the adders in BCD form. |



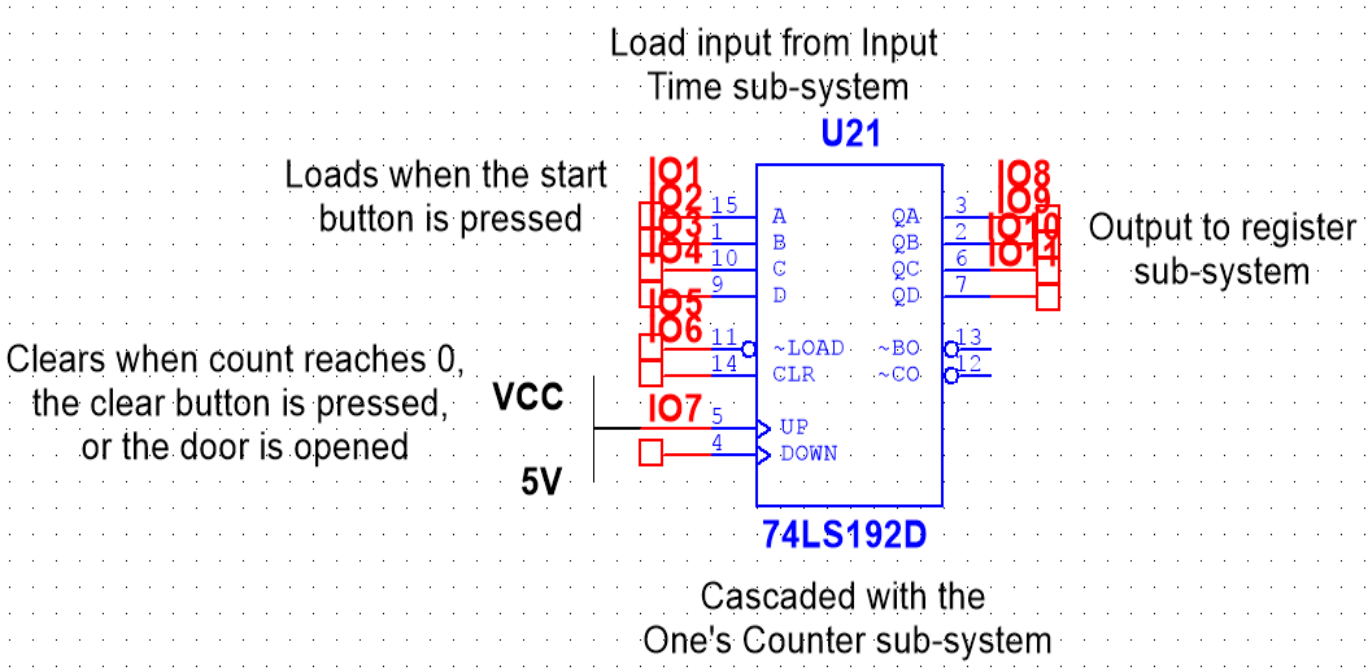
One's Place Counter

| Component Functionality | System Function |
|---|---|
| **74LS192D**<br>This BCD Counter receives a Load Input from the Input Time sub-system when the start button is pressed. It then starts counting down from that number because of the register and clock components. Its BO output goes to the down input of the ten's counter sub-system, to cascade the counters. This counter is also cleared whenever the count reaches 0, the clear button is pressed, or whenever the door is opened.<br>**74LS395D**<br>This register enables the clock when the start button is pressed because its clock is triggered by the start button, sending QA to 5 volts. The clock is then connected to the down counter of the 74LS192D, making it count down from its load input. | To receive the user inputted time from the Input Time sub-system and count down from that number when the start button is pressed. This system's outputs go into the register sub-system and is later used in the user interface display system. The logic and components used were derived from the need of a counter that could count down from 9-0 when its clock was enabled, a load option ability, a clear option, and it must have cascade ability. Thus the register acts as an enabler, and the 74LS192D was the perfect match for the required abilities. The inverter gate is used because both the counter and register need to be cleared by the same inputs, but one has an active high clear and the other, an active low clear. |



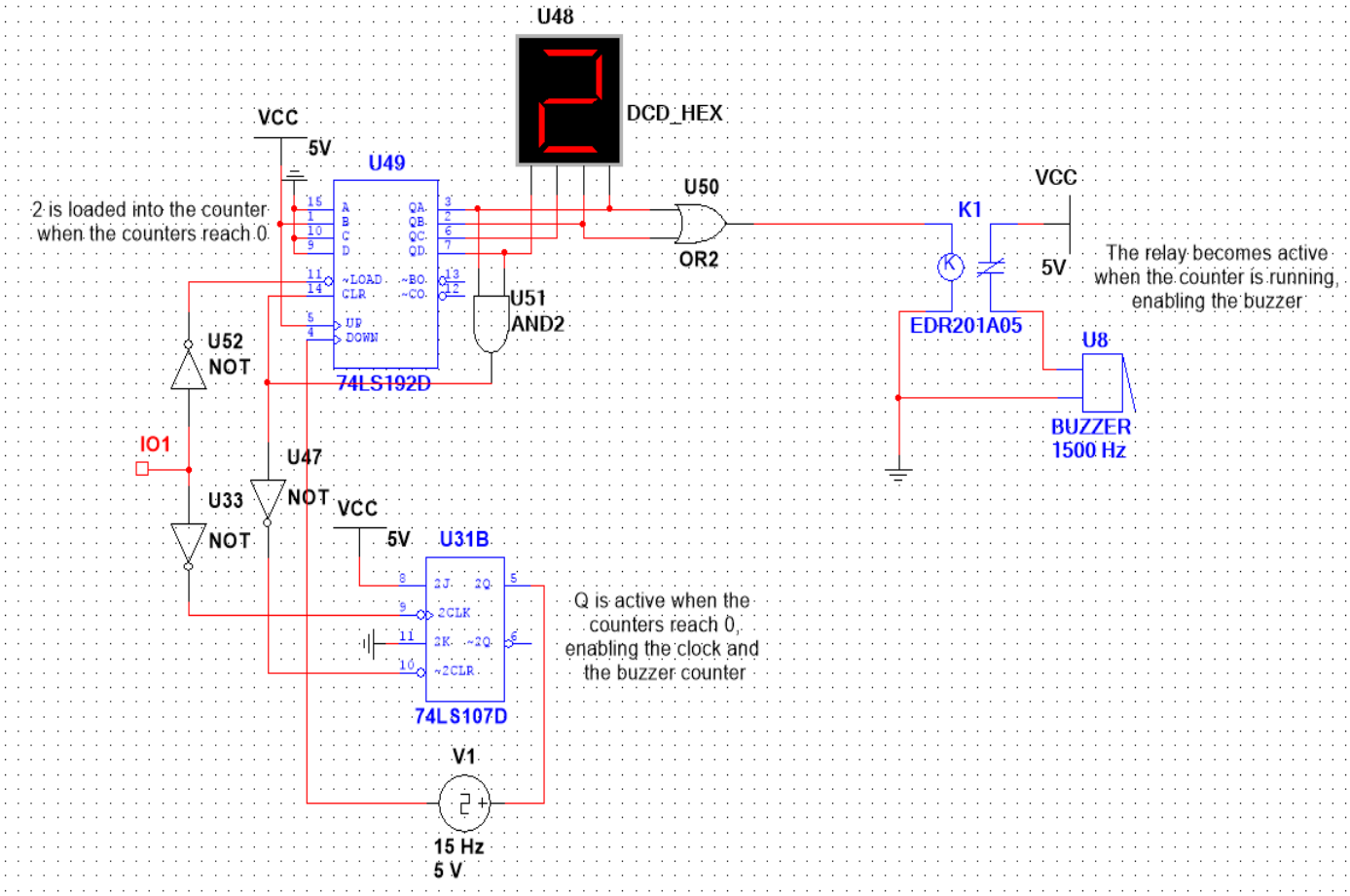
Ten's Place Counter:

| Component Functionality | System Function |
|---|---|
| **74LS192D**<br>This BCD Counter receives a Load Input from the Input Time sub-system when the start button is pressed. It then starts counting down from that number when the BO output of the ones counter pulses, cascading the counters. This counter is cleared whenever the count reaches 0, the clear button is pressed, or whenever the door is opened. | To receive the user inputted time from the Input Time sub-system and count down from that number when the start button is pressed. This system's outputs go into the register sub-system and is later used in the user interface display system. The logic and components used were derived from the need of a counter that could count down from 9-0, had a load option ability, a clear option, and a cascade ability. The 74LS192D was the perfect match for the required Counter. |



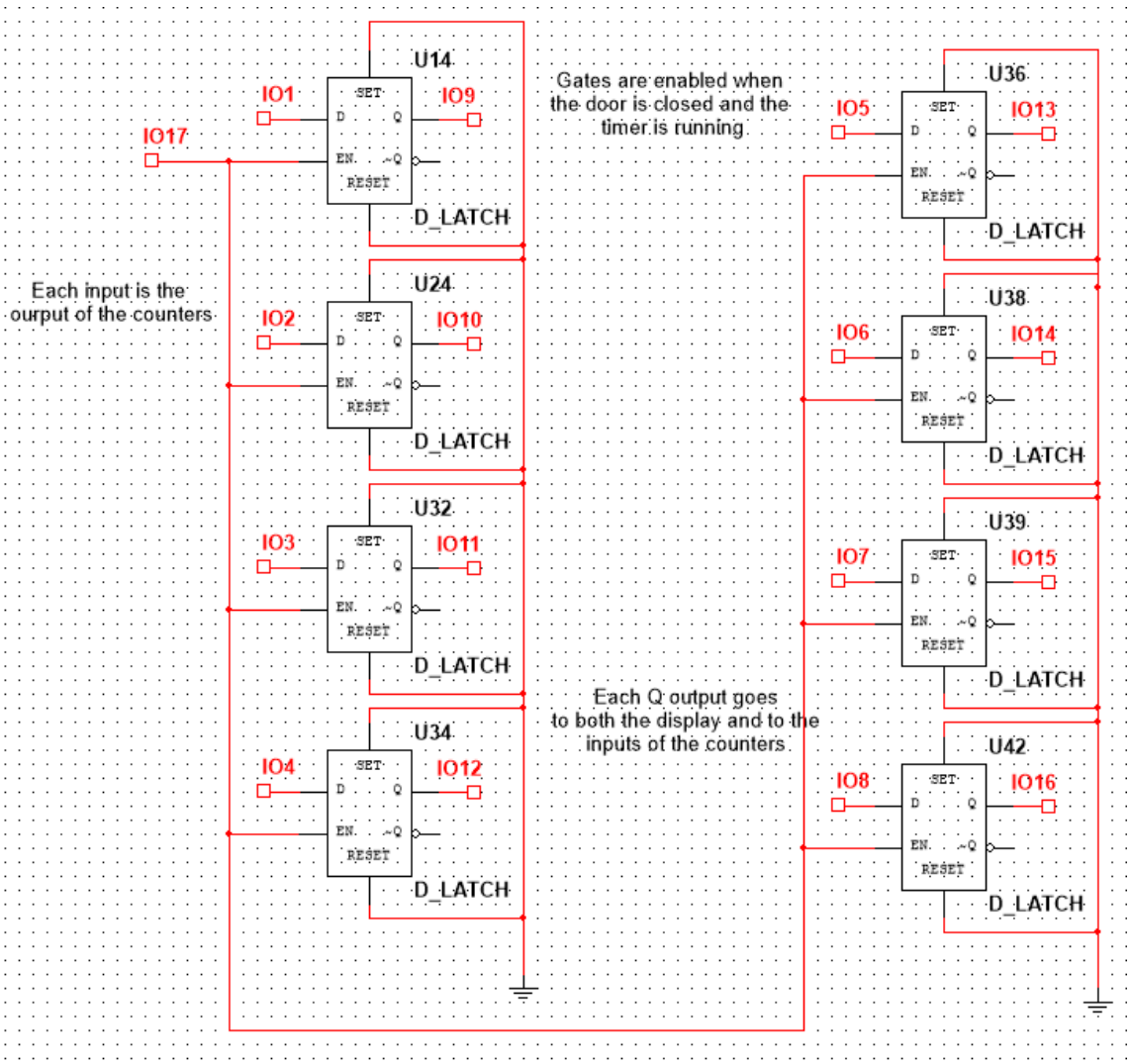
## Buzzer:

| Component Functionality | System Function |
|---|---|
| **74LS192D**<br>This BCD Counter receives a Load Input of 2 when the displays reach 0 when counting down. It then starts counting down from 2 to 0, enabling the buzzer for 2 seconds. The buzzer is disabled once this counter reaches 0.<br>**74LS395D**<br>This register enables the clock when the displays reach 0 when counting down. The output of the clock is the input to the counter allowing the buzzer to sound for 2 seconds.<br>**EDR201A05 Relay and Buzzer**<br>When the input to the relay is high, it connects the buzzer to 5V enabling it and since the relay is enabled by the counter, the buzzer is enabled for only 2 seconds. | The function of the Buzzer sub-circuit is to sound a tone for 2 seconds when the display and counters reach a time of 0. The logic and components used were derived from the need of a counter that could count down from 2-0 for the two second time span and the register was needed to enable the clock and down counter. The relay was needed to enable the buzzer when it was enabled by the counter, thus allowing the buzzer to sound for two seconds at the end of the timer countdown. |



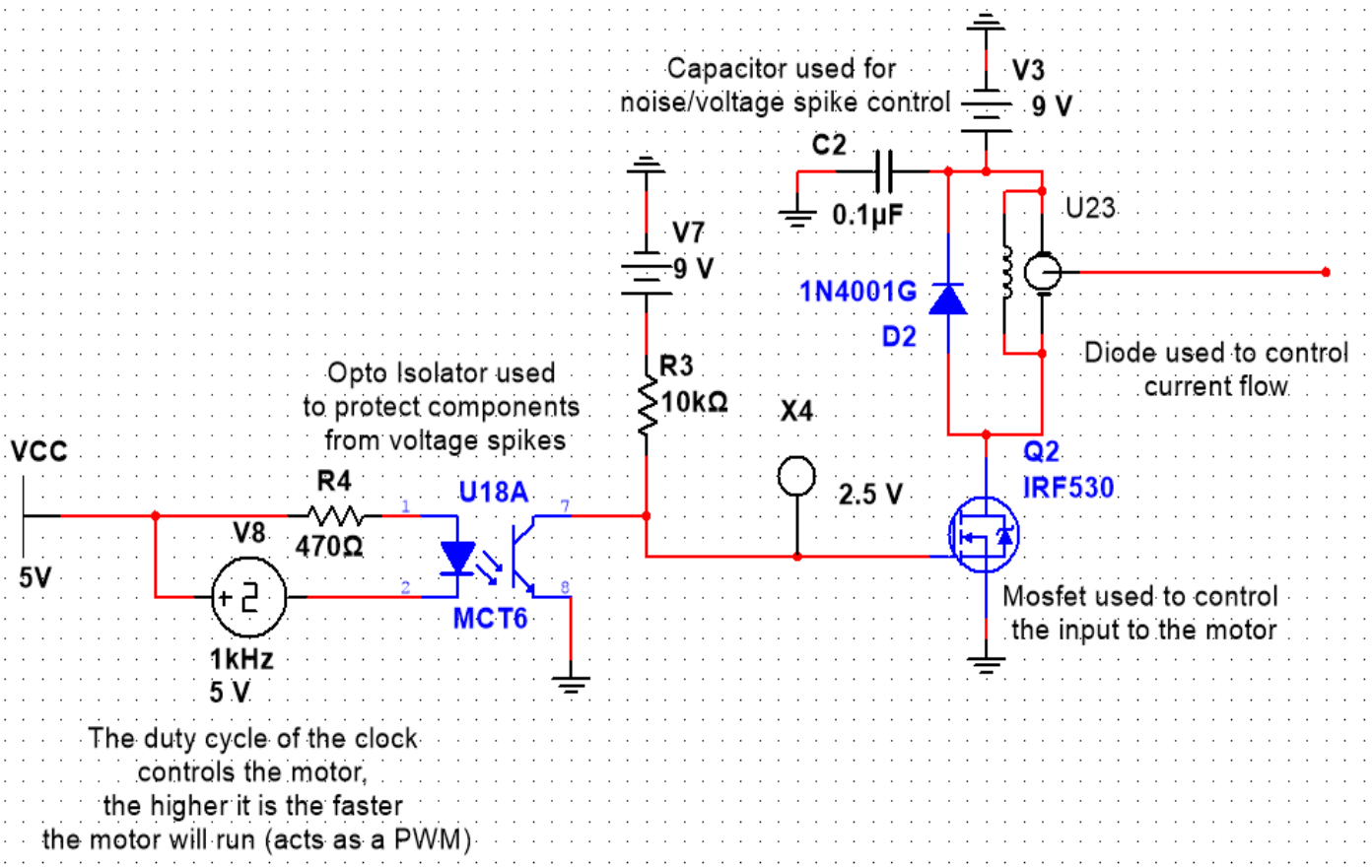
8-Bit Register:

| Component Functionality | System Function |
|---|---|
| **D-Latch**<br>Each d-latch is enabled when the door is closed and when the counters to the displays are enabled. Each D input is connected to the outputs of the 1's and 10's sub-circuits and the Q outputs are connected to the displays through or gates. | To "remember" the time of the displays once the door is opened. This sub-system allows the user to open the microwave door without changing the time displayed, giving the user the option of restarting the timer where it left off. Multiple d-latches were used because the delay of the octal d-type latches (the 74LS364D, 74LS363D, and the 74LS373DW) enable was greater than the time it took to clear the counters, making it clear the d-latches as well thus clearing the timer. |



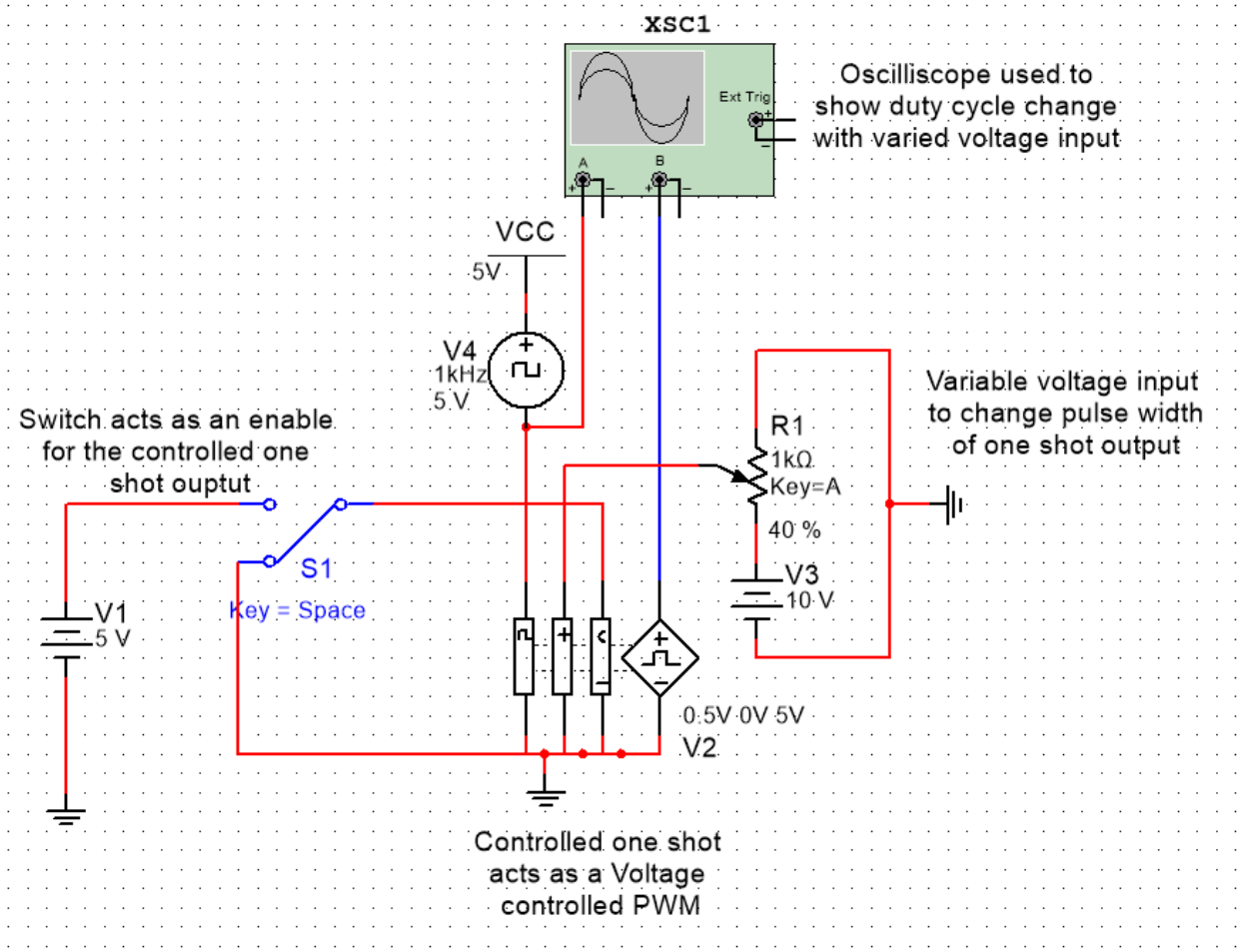
Motors:

| Component Functionality | System Function |
|---|---|
| **Opto-Coupler/Isolator**<br>Prevents damage to the basic stamp and other sensitive hardware.<br>**1N4001G Diode**<br>Prevents stray current from flowing into the mosfet<br>**IRF530 Mosfet**<br>Electronically controlled switch to control the motor with Pulse Width modulation (PWM).<br>**Motor**<br>Controlled by the Mosfet in conjunction with PWM from the controlled one shot. | There are 3 uses of this general system; the microwave generator, the dual speed vent fan and the carousel table. The microwave generator can be adjusted from 10 to 100% power in 10% increments, the vent fan has 2 speeds and can be turned off, and the carousel table can rotate fully back and forth. The optocoupler was used to protect the hardware, the Diode was used to prevent stray current flow and the Mosfet was used in order to control the fast changing input to the motors with PWM. The motor is just a representation of the various components that were needed like a generator or servo motor. |



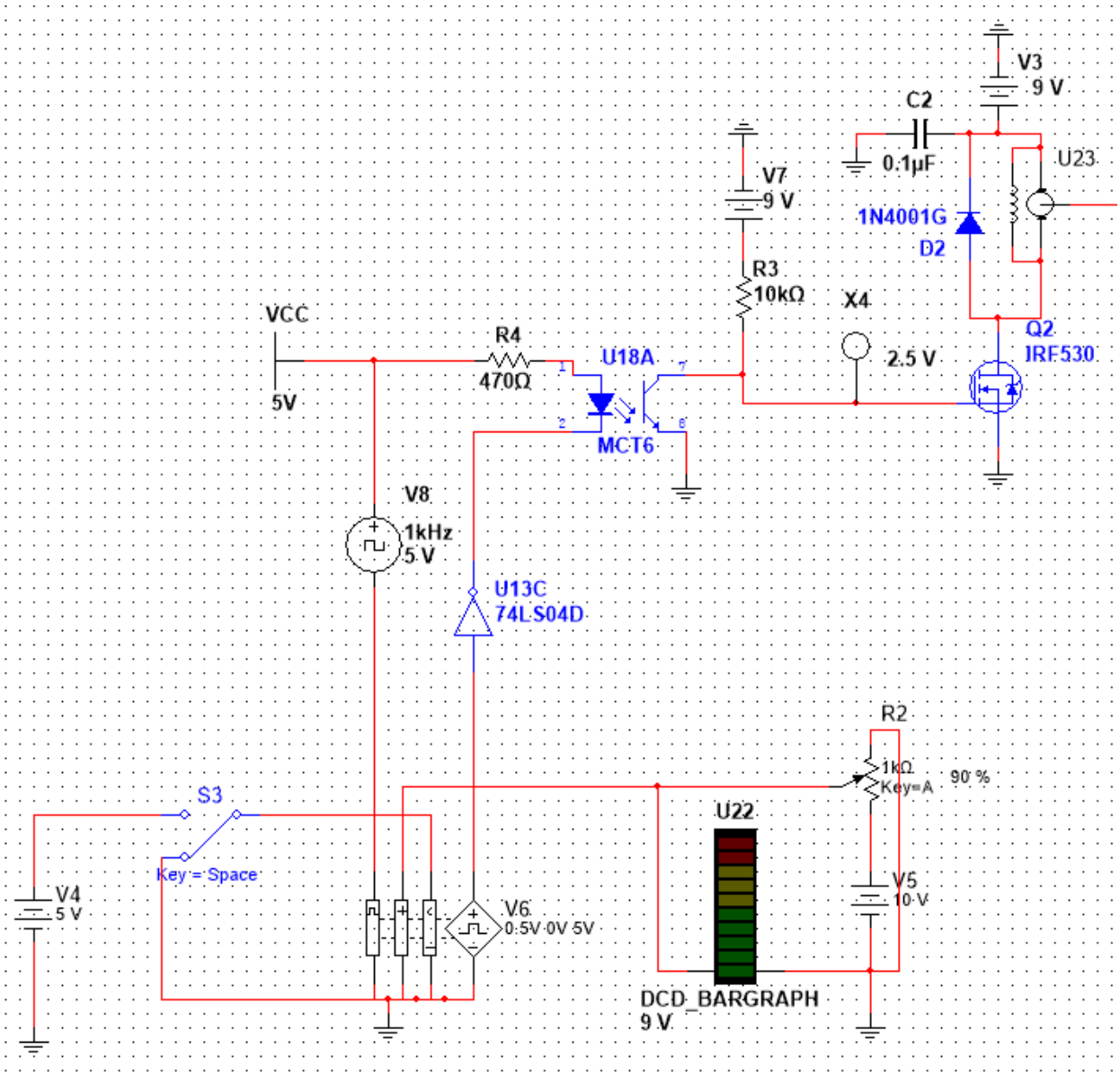
Voltage Controlled PWM

| Component Functionality | System Function |
|---|---|
| **Controlled One Shot**<br>Voltage controlled PWM with an enable feature provided with the switch.<br>**1KΩ Potentiometer**<br>Controls the voltage input to the controlled one shot for a variable duty cycle, its range being 0 to 10 V. Can also be controlled in incremental values.<br>**Bargraph**<br>Used to represent the motor speed in 10% increments with 100% being full motoer speed. Could be easily changed to 50% increments to represent two speeds with the potentiometer increment at 50% | Used in combination with the motors to create a control system for the motors through the change of input voltage with a potentiometer. The controlled one shot was needed to control the motors with a PWM, the potentiometer was used to change the pulse width of the controlled one shot and the bar graph was to be a user interface to represent the power/speed of the motor. |



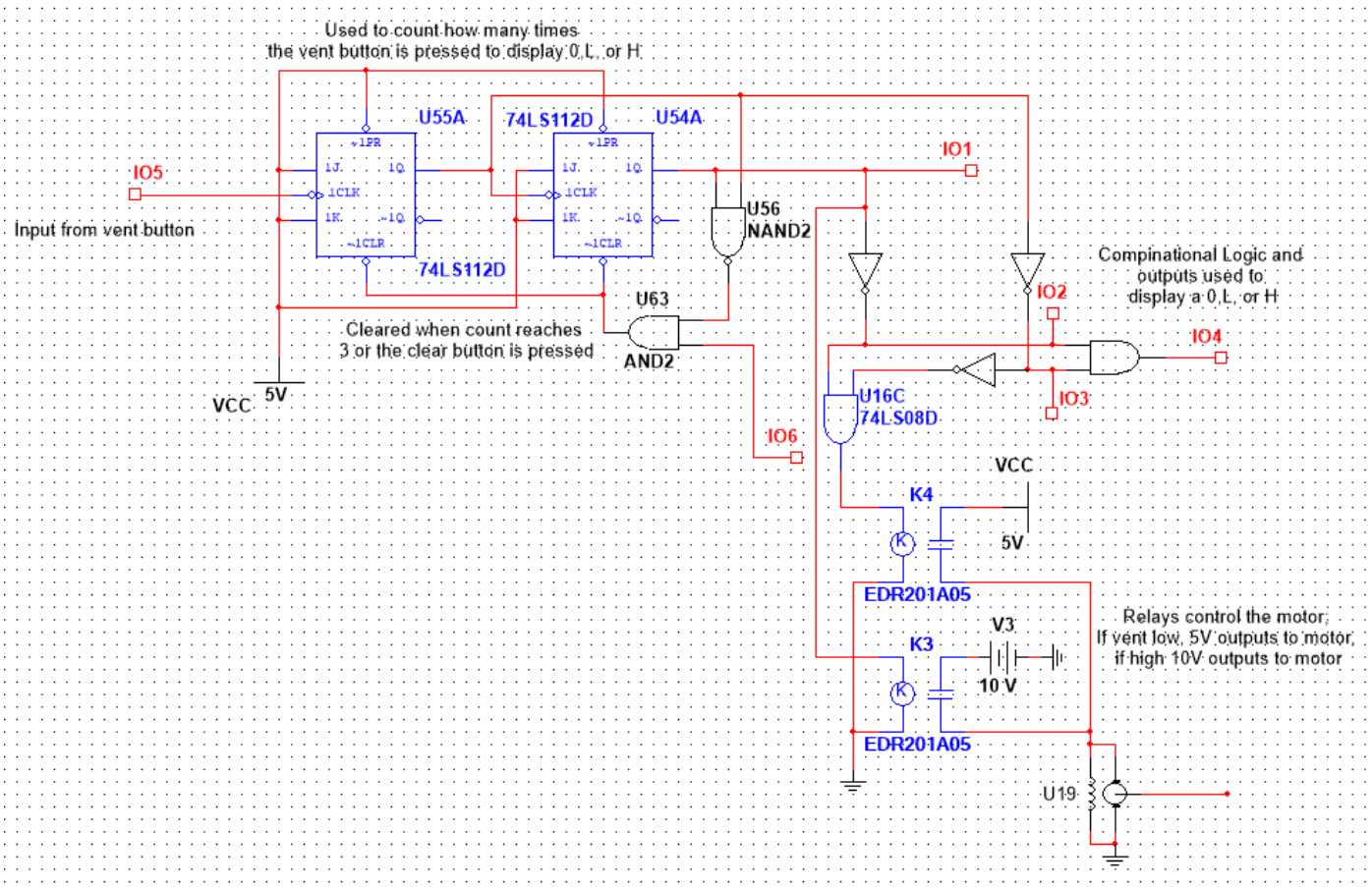
# Motor Control

To control motor speed and power, the duty cycle inputted to the mosfet from the opto-coupler must be altered. For easy alteration, the voltage controlled PWM system was coupled with the motor to create a control system. This control system was not used in the overall microwave system, however is the system that would be used to control the generator and vent fan. In replace of the system, a visual aspect was added to the microwave for simulation purposes.



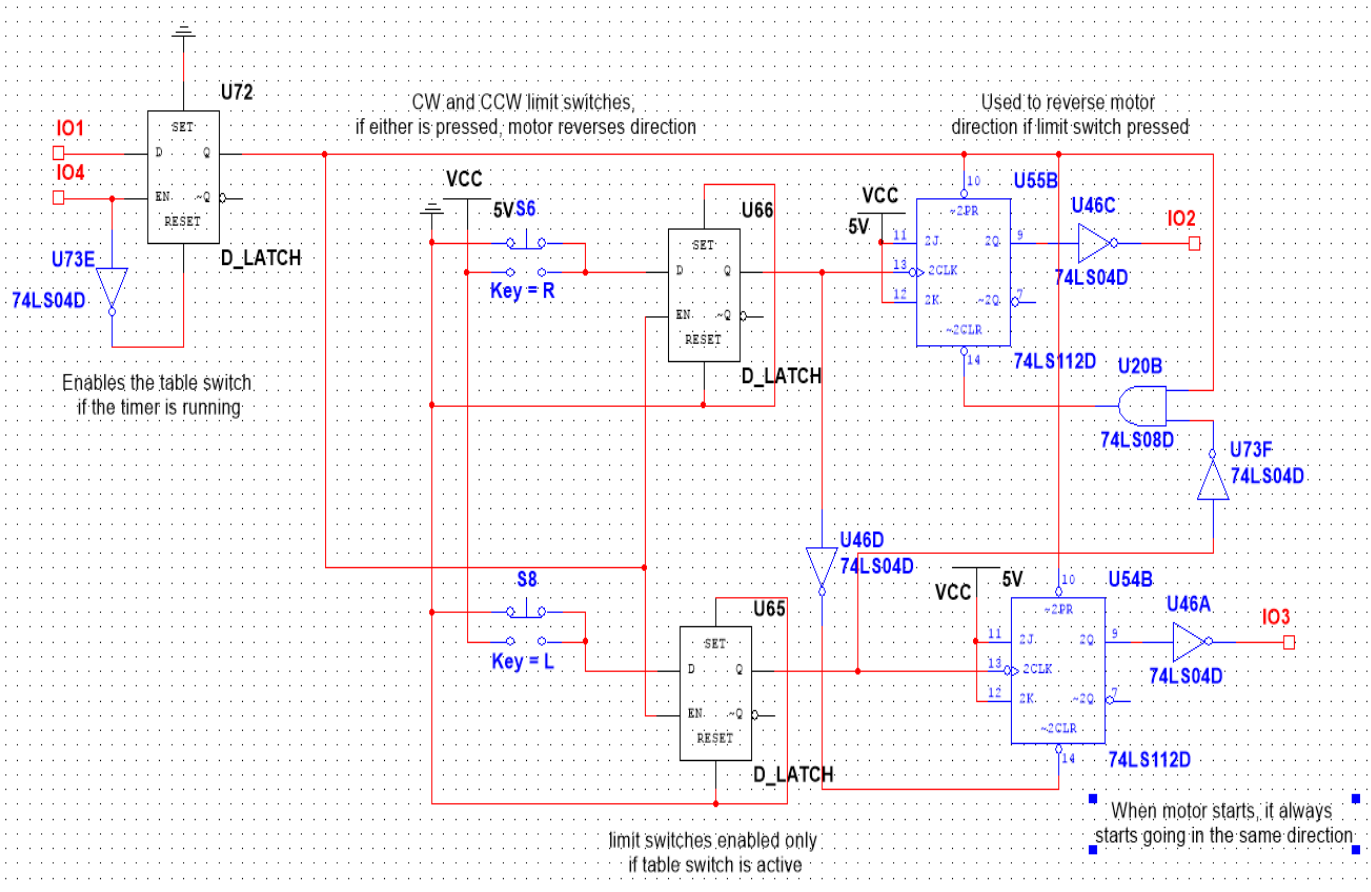
Vent Fan

| Component Functionality | System Function |
|---|---|
| **74LS112D**<br>Used for three unique states to represent the three different vent fan speeds. Cleared when the clear button is pressed or when the count reaches 3 to make three different states instead of four states.<br>**EDR201A05 Relays**<br>When vent fan speed is low, the input to the first relay is high which connects the motor to 5V and when the vent fan speed is high, the second relay connects the motor to 10V. | Used to control the three different states of the vent fan. If the vent button is pressed once, the motor speed is low and the display shows an L, if it's pressed twice, the motor speed is higher and the display shows an H. If the vent button is not pressed or pressed three times, the vent motor is off and the display shows a 0. These components were used because the JK FF are able to represent 3 states with the repetitive press of a button and the relays allow current to flow into the motors at each different state. |



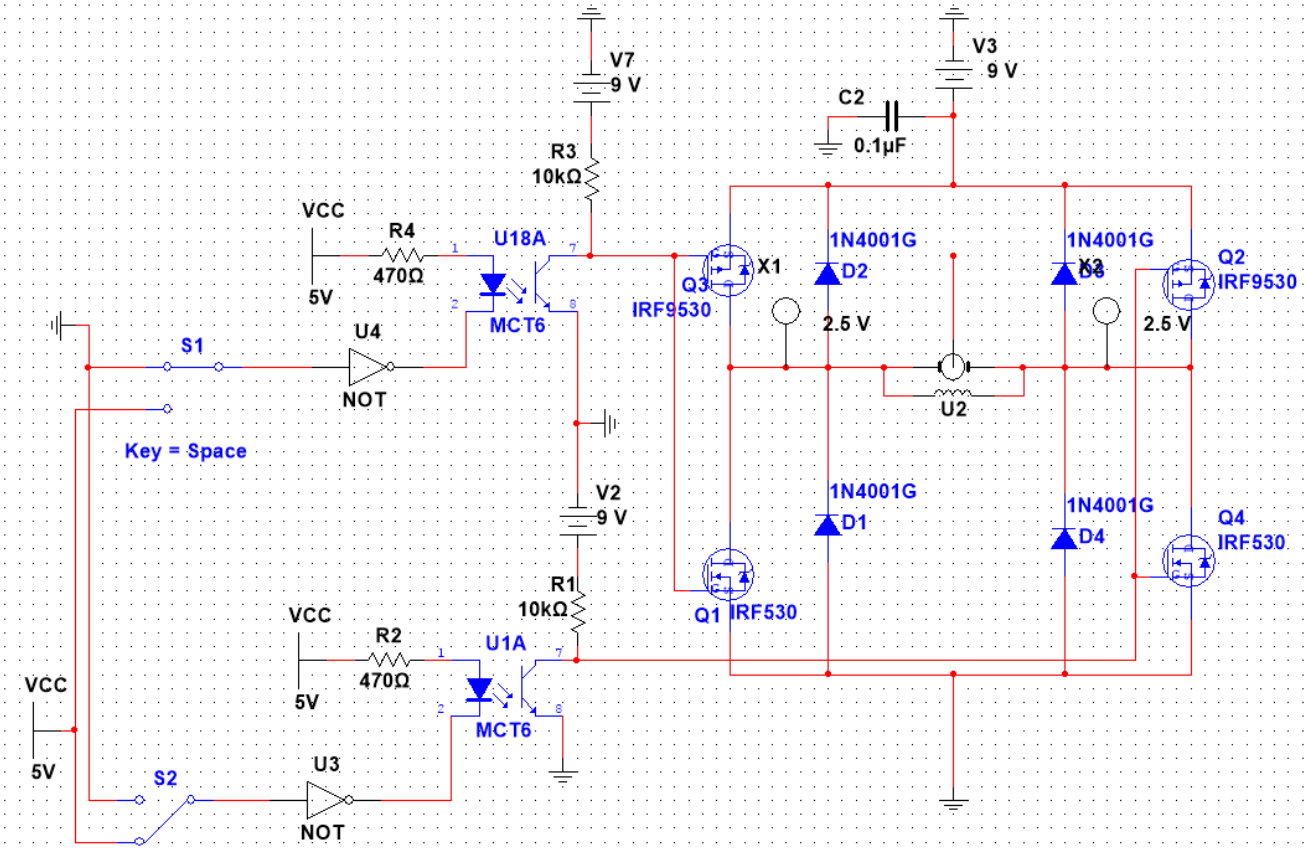
Carousel Table

| Component Functionality | System Function |
|---|---|
| **D-Latch**<br>The first one enables the carousel table switch when the timer is running and it clears when the timer is stopped. The other two latches enable the limit switches when the carousel table is enabled.<br>**74LS112D**<br>Allow the outputs to be the same when carousel table switch is inactive and different when it is active. The limit switches are used to control the direction of the motor by alternating the outputs of the JK FF when the carousel table is active. | Used to control the carousel table of the microwave system. The timer enables the carousel table switch which controls the motor state. If the switch is active, the outputs of the JK FF are opposite and when a limit switch is pressed, the outputs are reversed and because the motor will always start in the same direction, the R limit switch will be pressed before the L limit switch. These outputs would go to the motor directional control system to allow the carousel table button to control the motor. The d-latches were used because carousel table switch needed to be enabled only when the timer was running and the limit switches enabled when the carousel table was enabled. The JK FF were used to reverse the direction |



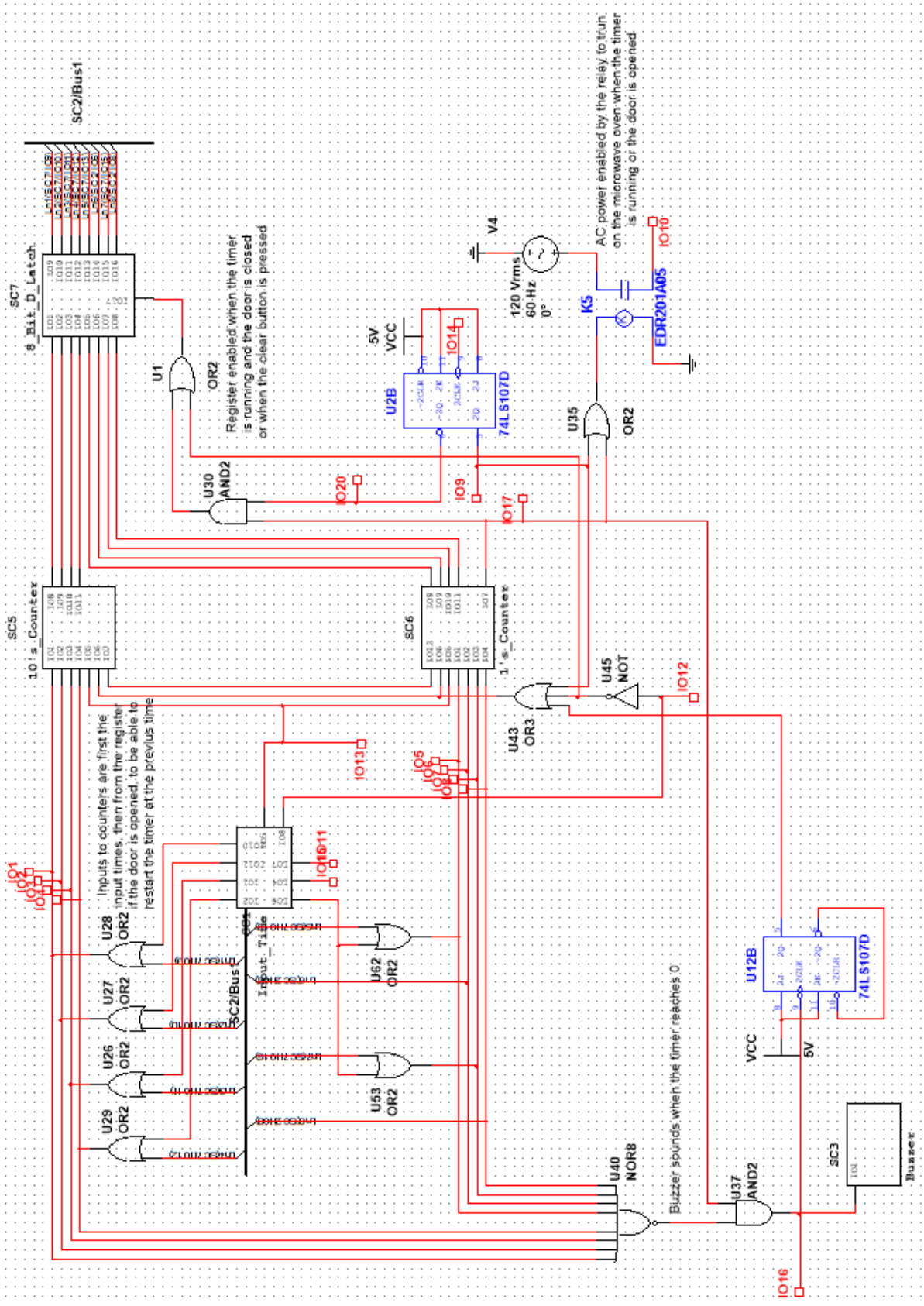
# Motor Directional Control

To change the direction of a motor, the voltage drop across the motor must be reversed. This system disables the motor if the input of both switches are the same and enables the motor if the inputs to the switches are opposite. When the inputs are opposite, the direction of the motor depends on which input is high; if the top input is high and the bottom one low, the motor will spin in the opposite direction than if the top input was low and the bottom input was high. This control system was not used in the overall microwave system, however this system would be used to control the carousel table. In place of the switches, the system's inputs would be the outputs of the two JK FF of the Carousel Table sub-system. All the components used are the same components used in the motor sub-system for the same reasons except for the additional mosfets required in this sub-circuit. There are two n-channel mosfets and two p-channel mosfets, used to control the input to the motor, thus controlling the direction of the motor through the change in direction of the voltage drop.

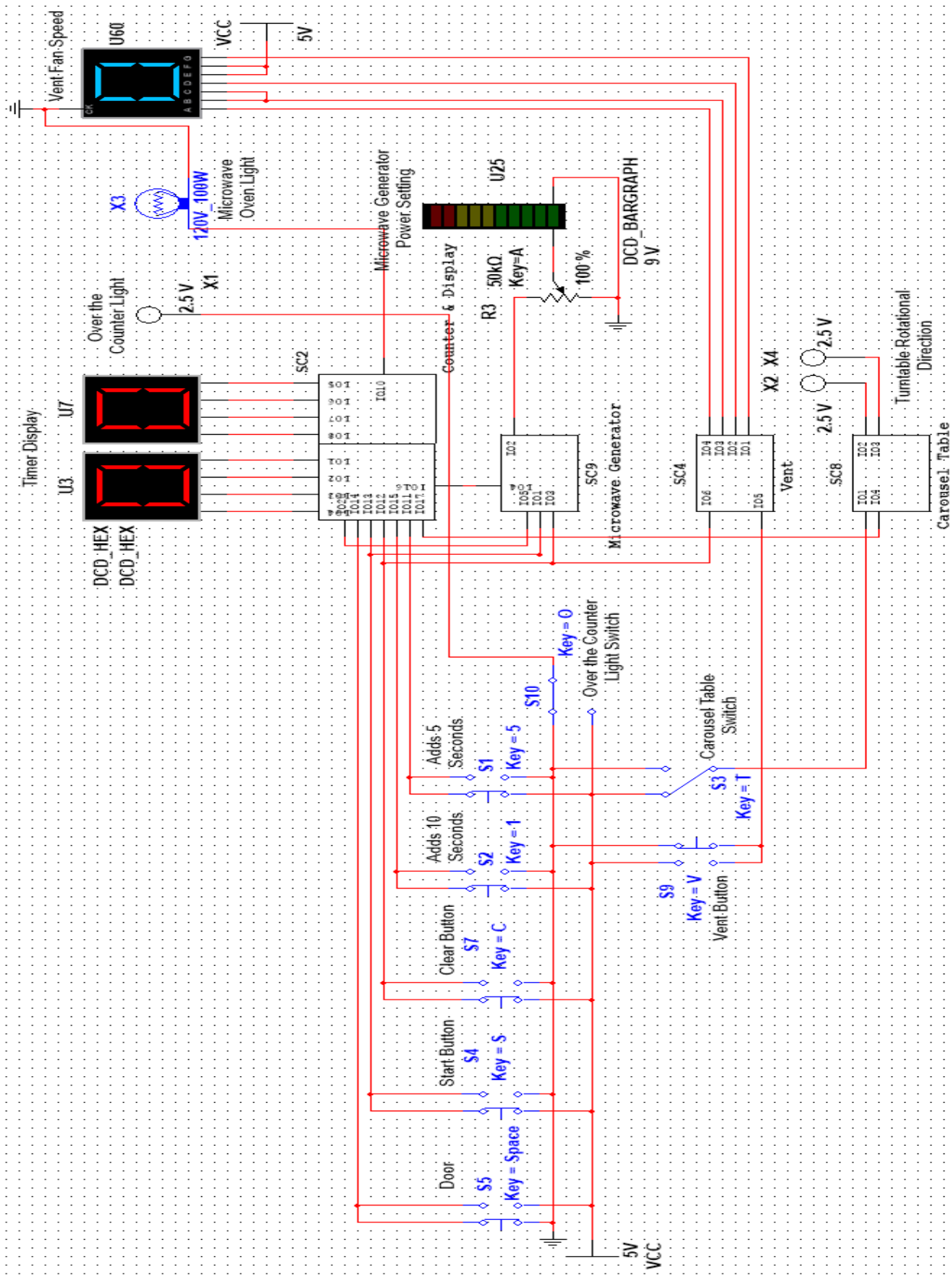


## Compilation of Minor Subsystems

The compilation of some of the sub-systems with miscellaneous combinational logic to control when each system is cleared and set.



# User Interface



**System Operation**

The program on button (F5) starts the program, from which you can consecutively add 5 or 10 seconds to the timer. The start button enables the count-down sequence from which there are two options; wait for the count to reach 0 or open the door. If the user opened the door, the timer stops as well as the generator. If the door is then closed, the user can either add more time or restart the timer by pressing start. If the countdown sequence reaches 0, a buzzer goes off and the timer stops. This process can be infinitely repeated and functions like the vent fan and over the counter light can be changed at any given time. The clear button can also be pressed at any time stopping all functions, but it doesn't and shouldn't close the door for you. The AC light is on whenever the door is opened or the timer is running and the carousel table is switch activated, but only turns when the timer is running. The carousel table also has limit switches to reverse the direction of the motor when either is pressed. The program can be turned off with the stop button next to the program start button. Refer to the flowchart for a visual representation of the system operation.

If any of these components were to fail; the AC light, the over the counter light or button, the carousel table switch or motor, the microwave generator, the vent fan or speed control switch, or the buzzer, there would be no adverse effects to the system, except for the fact that one of the components failed. If the clear switch fails, the user wouldn't be able to stop any functions. If any other component were to fail, like the start button, the counter components, or the door switch were to malfunction, then the whole system wouldn't function properly.

**Combinational Logic Derivation**

Most combinational logic was derived from the grammatical sense of the word. For every word or, and for every word and, a logic and/or gate was needed. For example, the start button enables the counters it is pressed and the door is closed. Another example, the counters need to be cleared whenever the clear button is pressed, or the door opens or the start button is pressed. Other combinational logic however, was derived from creating truth tables such as the inputs to the vent fan display. When the vent fan button is not pressed, the display shows a 0 for off, when it is pressed once, it shows an L for low speed, and when it is pressed twice, it shows an H for High speed. This cycle repeats because the JK FFs have 3 states, clearing on the fourth one. The inputs to the display are derived from this truth table. Thus the output G simplifies to simply Q2 the outputs E and F can be connected straight to VCC. All other combinational logic was derived in the same manner from necessity.

| **Inputs** | | **Outputs** | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Q1 | Q2 | A | B | C | D | E | F | G |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 |
| 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 |
| 1 | 1 | x | x | x | x | x | x | x |

**Components**

- Inverter Gates (74LS04D):
    - Takes an input and inverts it; A high input voltage is outputted low and a low input voltage is outputted high.
- And Gates (74LS08D):
    - Takes two input values and outputs a high voltage only when both inputs are high, if either are low its output is low.
- Or Gates (74LS32D):
    - Takes two input values and outputs a low only when both inputs are low, if either input is high, or if both inputs are high, its output is high.
- Full Adder (74LS83D):
    - The 74LS83D takes two 4-bit Binary numbers with a carry in (C0) input and sums them, outputting a 4-bit binary number with a carry out (C4) output.
- JK Flip Flop (74LS107D):
    - The 74LS107D has two active high synchronous inputs J and K as well as an active low (NGT) clock. It has an active low asynchronous clear and two outputs, Q and not Q. JK FF are used in a multitude of larger components and also have many uses on their own including counters, shift registers, data storage, etc.
- JK Flip Flop (74LS112D)
    - The 74LS112D has two active high synchronous inputs J and K as well as an active low (NGT) clock. It has an active low asynchronous clear and pre-set and two outputs, Q and not Q. JK FF are used in a multitude of larger components and also have many uses on their own including counters, shift registers, data storage, etc.
- BCD Counter (74LS192D):
    - The 74LS192D has the ability to count down from 9 to 0 or up from 0 to 9 and can also be cascaded with other counters with its BO and CO outputs. A 4-bit binary number can also be loaded into the counter with the active low load input, however when the load input is active the 74LS192D cannot count. This BCD counter is also equipped with an active high clear input that is used to clear the counter.
- 8-Bit D-latch (74LS363D):
    - Transfers the d-input to the output when the en input is active.
- Parallel In/Parallel Out (PIPO) Register (74LS395D):
    - The 74LS395D is a PIPO Register that transfers its inputs to its outputs on every PGT of a clock. This particular register also has the ability to be a Serial In/Parallel Out (SIPO) Register when its SH/LD input is active. The 74LS192D can be cleared

with its active low input CLR and has an active low enable input (OC) that allows the register to function when it is active.

- Relay
    - Works like a voltage controlled switch, when the input to the relay is high, it connects the other input to its output
- Transport Delay
    - Delays an input signal for a specified amount of time.
- IRF530N N-Channel Power Mosfet
    - Electronically controlled switch with fast switching speeds that can handle large amounts of current and voltage.
- IRF9530N P-Channel Power Mosfet
    - Transistor used for amplifying or switching electronic signals, allowing for the ability to control high power devices with low power control mechanisms.
- 1N4001G Diode
    - Allows current to flow in only one direction
- Optocoupler/Isolator
    - Prevents voltage spikes caused by the motor from damaging the basic stamp or other sensitive hardware.
- Motor
    - A machine that provides rotational energy to a system, often controlled by pulse width modulation.
- DCD Bargraph
    - 10 segment LED bar controlled by input voltage, each LED represents 10% of the maximum voltage input.