Independent Design: Three in a Row

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I. INTRODUCTION

Electronic designs are very multifaceted and excel in the variety of problems they offer solutions to. The concept of bringing creative solutions to real problems is more relevant than ever right now as the populace finds itself amidst a pandemic and in need of solutions and distractions. Something that is equally important for the sake of progress in hard times is morale. So as people find themselves social isolating and quarantining, this electronic design offers friendly, energy efficient, and insightful challenge for those who are quarantining with a partner or their children. This familiar, classic game is Three in a Row.

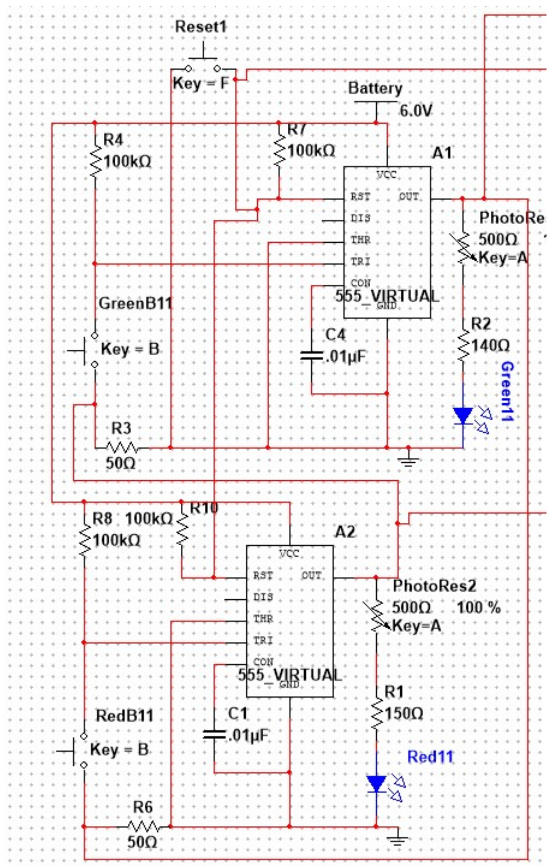
II. ABSTRACT

Three in a row contains a three by three matrix of LED’s consisting of two colors per space, one for player one and another for player two. Each space within the matrix will have two buttons, and each button pertains to a player’s color. The game will have an on switch which powers the board and a start switch to trigger one or more 555-timers. Once turned on, photoresistors will take in the lighting of the room to account for how brightly the LED’s should be lit when activated. Meaning if it’s a dark room then they will not be as bright. If the room is brightly lit then the LED’s will be too, so they are easier to see. Underneath the board of LED’s will be a complex underlay of logic pertaining to the specific buttons pushed. This will be done using MOSFET’s and will include AND, NAND, and XOR logic. This is in order to have a winner but also to avoid two players choosing the same space. The AND logic will account for the winner while also triggering a reset on the 555-timer that the system will depend on. Each row, column, and the two diagonals will have AND connections that will link them to the reset, so there would be 16 combinations of LED’s lighting up that would trigger the reset for the timer. If the game comes to a draw, then this will trigger the NAND gates for all combinations that will also reset the game. When there is a winner or a draw, the logic will also result in a temporary LED turning on that will represent the winning player’s color or the draw of the game before resetting. Overall, the game will include 555-timers, MOSFET’s, LED’s, photoresistors, and probably op-amps or more. The hope for the game is to find more opportunities in becoming more complex by possibly introducing sounds, trickier victory and draw results, or the ability to

let only one color go per turn and not just per space. Adding these complexities to the game make it a more interesting and enjoyable experience for players while also adding the creative challenge a project like this deserves. As many of opportunities for that as possible will be taken before the project is due, so let us play a game.

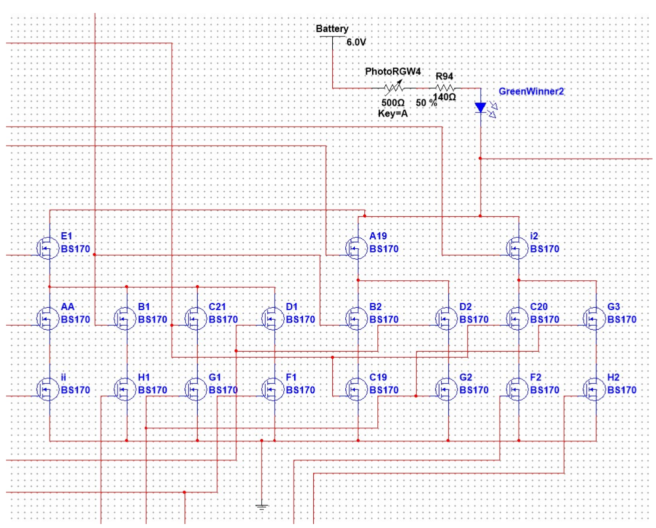
III. CIRCUIT DESIGN

The final design of the game consists of buttons, timers, photoresistors, LED's, and MOSFET's. The basis of the original design was purely logic behind the MOSFET's. They are still very relevant for the conclusive product, but because of the opportunity for limitless play it seemed more intuitive to add a global reset function to the game which also allows for buttons instead of just switches. In doing so, the design become comprised of a significant amount of 555-timers which also allowed constructive limitations for the gameplay while opening possibilities for simplification of the design. For example, row one column one of the three by three matrix is comprised of two buttons, two timers, two LED's, and resistors and photoresistors. The timers are in bistable mode so that they may output a consistent voltage to the LED selected by the player. Voltage is input into a timer by the batteries after the on switch is selected and then the system is essentially in standby while the players make their choices. Only when a button is pressed which drops the trigger to ground will the timer output voltage to the resistors and LED. This system also features the disabling of the other player's button once one is pressed so that only one LED is on at a time after a given turn. Disabling the button is done by sending the output voltage of an activated timer to the grounded side of the button for the other player. This does not create an error because a small resistor is in place between the button and ground so the button can still essentially



drive a trigger to ground yet can be deactivated between the button and resistor by another player. This is further discussed in the results and discussion portion as my initial design was more complex, but when telling others about my project Tim Weaver asked why I was not just deactivating the switch. It was a lightbulb moment.

The photo-resistors are in place from the output of the timers to the input of a second resistors which go to the LED's and ground. The photo-resistor measures the light in the room and given that the room is dimmer can save battery usage as it will draw less current and dim the LED's in accordance with the room the game is played. Each LED has both a photo-resistor and a regular resistor so that the brightness and battery usage may be limited, but if it is very bright then the second resistor ensures that the LED does not receive too much current. The second resistors differ in value because the green and red LED's have a different voltage drop, but their brightness level should be equal because of this. The literal placement of the photo-resistors in the fully built design would not be placed right next to the LED's to ensure they were not just reading the brightness of them. The processes are in place for every section of the matrix with two timers per column/row section totaling to nine sections full of this circuit design.

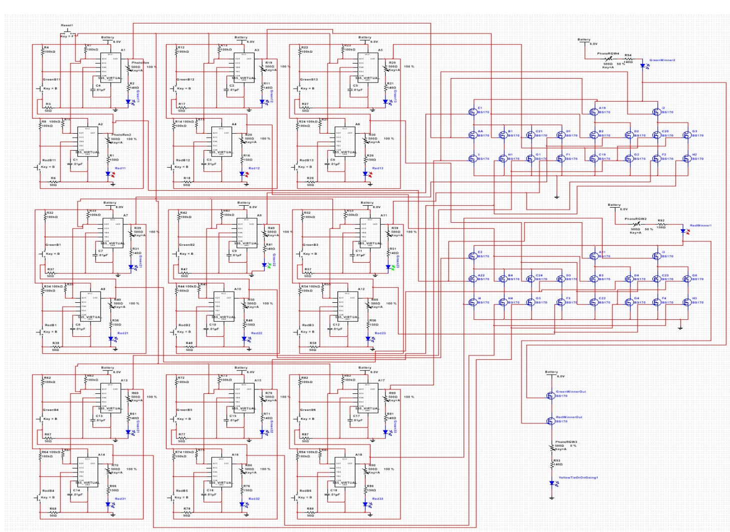


Each timer of the matrix also has output delivered to the system of MOSFET logic that determines a winner for each player or an ongoing/tied game. The simplification of the button deactivation removed the necessity for XOR logic, so the logic component of the overall system consists of AND, OR, and NOT logic. For every output of a timer is a corresponding npn transistor waiting to be activated in series of 3 waiting to deliver ground to an LED above the logic. There are eight combinations of logic per player that allow for a victory, so there are three columns of AND's and eight columns of OR's per player. With this grid system in mind, the logic was built:

A	B	C
D	E	F
G	H	I

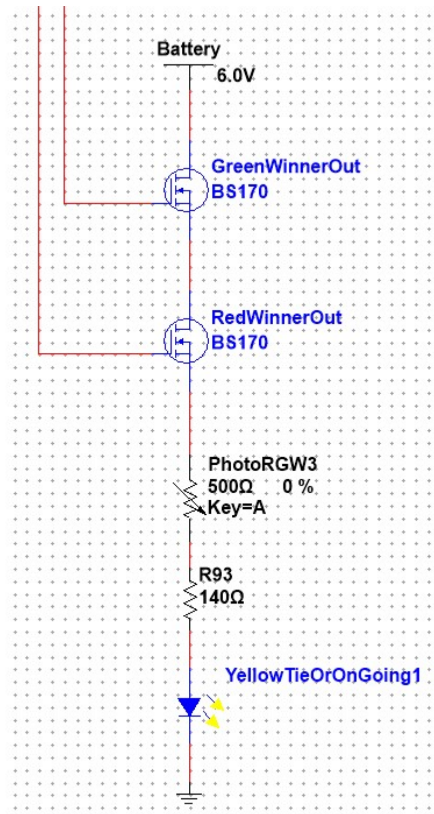
By totaling up the output combinations in the form of Boolean logic, it becomes clear that the space of E, or the row 2 column 2 of the matrix, appears in the most combinations. Because of little details like that less parts can be used, and the logic can be simplified by giving one MOSFET multiple outputs from the source to drains in other columns of logic. The schematic also features these letters on the given logic systems for both players so that it is clearer where to connect the gates of the MOSFETS to the timers.

Off to the side and underneath the logic systems for player victories is the logic for an ongoing game or tie. The logic here is simple as it is two npn transistors acting as not gates for the winning player sections. So, the gates of the transistors are connected to the cathodes of the winner LED's before the logic so that if any of the AND gates trigger a win, the yellow tie/ongoing game LED will be turned off. All LED's within the logic portion of the design also feature their own resistor and photo-resistor to ensure every LED is reactive to the lighting. The conclusion of all of this is the completion of the final design.



IV. DISCUSSION

Diving into the background of Computer Engineering, the border of Electrical Engineering and Computer Science, efficiency and dependency are critical for success. These are the driving factors behind the editing and simplification of the design. One such example is the fact that every LED has a photo-resistor instead of just having one photo-resistor attached after the battery. This is because though it would be simpler to just use one, if that one resistor malfunctions then the entire lighting system would be compromised. Another simplification of the design includes the transistors for the ongoing/tie LED. Initially, there were two op-amp comparators that were being used, but since there were already npn transistors being used it seemed like the right decision to be consistent. There was also a time where pnp transistors were being used but that was changed for the same reason. A similar situation was happening with the goal of limiting LED's being turned on by players before Tim's suggestion.



Previously, there was NOT, AND, and comparisons, but this was consistently resulting in the deactivation of both LED's even if one was already activated. One could deactivate the other regardless of whether someone had played, though it did do the trick by preventing the other player's LED from being on. Another error, though quite a bit simpler, was for a while if one button was pushed then multiple LED's would be activated, not just the one intended. Time was waisted and hair was lost, but in the end, it was as simple as multiple items in the simulation having the same name. For the logic portion of the design, MOSFETS that were connected to sections that appear more often than others in a resulting victory were given multiple outputs, not just the center section E but A and I as well. For added specificity, the reset button shares connections to all timers so that they are unified by wires and not just the letter key for the button press during the simulation. This is in contrast with the buttons for the players on the simulation which some may share a letter key to press, so they must be clicked individually. As for the difference between the simulation and reality, the only change may be capacitors in the rails.

V. RELIABILITY AND PARTS

This section will feature a summary of parts used and the 1-year circuit reliability calculation based on the ground fixed model. The parts included in this design are the following:

Part	Amount	λ_{GF}	π_Q	λ_p	Qty * λ_p
555 Timer	18	.024	10	0.24	4.32
Push-button (Player Buttons/Reset)	19	0.0030	20	0.060	1.14
Flip Switch (On/Off Switch)	1	0.0030	20	0.060	0.060
Yellow LED	1	0.0012	8	0.0096	0.0096
Green LED	10	0.0012	8	0.0096	0.096
Red LED	10	0.0012	8	0.0096	0.096
BS170	40	0.0011	8	0.0096	0.384
100 kilo-Ohm Resistor (Load/Pullup)	36	0.0022	10	0.022	0.792
140 Ohm Resistor (for Green/Yellow LED)	11	0.0022	10	0.022	0.242
150 Ohm Resistor (for Red LED)	10	0.0022	10	0.022	0.220
50 Ohm Resistor	18	0.0022	10	0.022	0.396
500 Ohm Photo-Resistor	21	0.029	8	0.232	4.872
0.01 micro-Farad Capacitor	18	0.0074	10	0.074	1.332

The sum of the failures every 10^6 hours comes out to be 13.9596. The reliability over the course of one year then becomes:

$$R = e^\wedge(-(13.9596E - 6) * 1\ year * 365.25\ days * 24\ hours)$$

$$R = 0.8848 = 88.5\%$$

VI. CONCLUSION

The circuit design has an overall reliability of 88.5% over the course of one year, so it should probably last through a few proper quarantines. The design is for a time when people could use some enjoyment, and when it comes down to it, the little things make bigger things seem better. The familiarity of the game makes it playable for a larger demographic while the battery saving opportunities makes it more reliable on top of the calculated reliability. This exemplifies the goals of computer engineers in that it has a purpose, is sophisticated yet simplified, and can help benefit people even in the little ways. What also makes it so relevant is the game is for two people; even at home with family people may be missing the significance of interactions with others. Overall, the design is for fun and the enjoyment of others, so let’s play a game.