Design Process for a COVID Circuit

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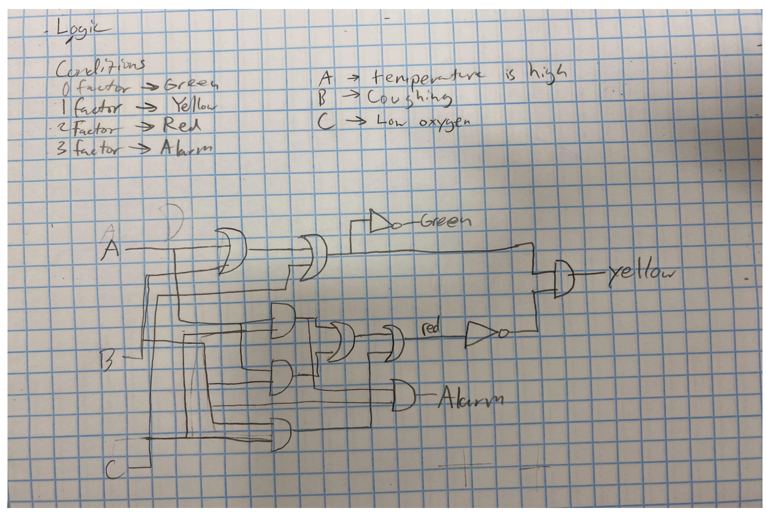
***Abstract*—COVID-19 was a global health problem that challenged health systems around the world. In order to mitigate some of this challenge, we attempted to build a system that detects coughing, low oxygen, and high temperature symptoms of the virus. The circuit uses the voltage logic produced by the symptom monitors to indicate the risk level of the patient. Based on the observed persisting symptoms of the patient, the different indicator lights show until the alarm is triggered, contacting healthcare providers. The system uses IC-555, Flip-Flop, and Logic chips to determine when the symptoms meet the risk thresholds, after which the indications and alarm go off accordingly. The circuit was split into multiple parts to be built, including the Logic Circuit, the Alarm Circuit, the Flip-Flop Circuit, and the Timer Circuit. The Flip-Flop and Logic Circuit were not completed. In order to complete the circuit and refine it in the future, the circuits themselves need to be more clear to avoid confusion, error, and malfunction.**

I. Introduction

The COVID-19 pandemic has presented unprecedented challenges to global health systems. Rapid and accurate detection of COVID-19 symptoms is crucial for controlling the spread of the virus and mitigating its impact. Traditional methods, such as PCR testing, although accurate, are time-consuming and resource-intensive. There is a demand for rapid symptom detection. The three main symptoms which are commonly detected are high temperature/fever, coughing and low oxygen **[1]** **[2]**.

This research paper explores the development of an electronic circuit designed to detect the Coronavirus depending on the symptoms displayed by the user. The two guidelines which we have set for the circuit is that it should have a fast response time and a good to high accuracy. A system/circuit like this will allow for better response times to this medical condition and will allow for the user and others to feel safe.



II. Theory

Digital Logic and Boolean Algebra

[3] Computers can only understand computer language. They can only read 0 and 1 or low voltage and high voltage. They need many easy logics to form a complex logic. The basic logic gates are And logic, Or logic and Not logic.

Figure 1. Logic circuit drawn using Boolean Algebra

A, B and C represent 3 symptoms of Covid.
Here are the logic equations.

Green: $\overline{((A + B) + C)}$
Red: A * B + A * C + B * C
Yellow: (A + B + C) * $\overline{(A * B + B * C + A * C)}$

Alarm: (A * B) * C
When A and B are 1 and C is also 1, the alarm will sound. When A and B are 1, or A and C are 1, or B and C are 1, the red light will be on. If none of A, B and C are 1 then the green light will be on. Conversely, if there is 1 and the red light is not on, the yellow light will turn on.
Here is the Truth Table

A	B	C	Green	Yellow	Red	Alarm
1	1	1	0	0	0	1
0	0	0	1	0	0	0
1	0	0	0	1	0	0
0	1	0	0	1	0	0
0	0	1	0	1	0	0
1	1	0	0	0	1	0
1	0	1	0	0	1	0
0	1	1	0	0	1	0

555 Chip

The 555 chip is a chip that can control the frequency of the output model through resistance. The calculation formula of these two resistors and the corresponding output frequency is $f = \frac{1}{ln(2) * C * (R1 + R2)}$

Flip-Flops

A flip-flop is a component used to store data in computer electronics. It stores binary data which are the numbers 0 and 1. A flip-flop does not instantly update user data input. It runs on a clock system which goes from low to high and high to low at regular intervals. The data is outputted whenever the clock goes from low to high; however, the input can occur at any time.

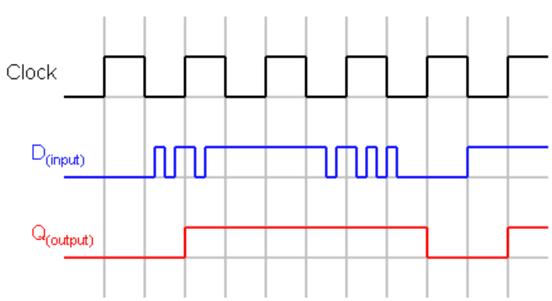


Figure 2. Basic structure of how a flip-flop's clock pulse allows for user inputs to be outputted at a certain point.

There are 4 different types of flip-flops which are SR (Set-Reset), JK, D (Data or Delay) and T (Toggle). However they are all based on one design which is the SR flip flop. The SR flip-flop is composed of a NOR and NAND logic gate. It's use is for basic memory storage where an invalid state can be avoided.

Truth Table

INPUT		OUTPUT
A	B	A NAND B
0	0	1
0	1	1
1	0	1
1	1	0

TRUTH TABLE

INPUT		OUTPUT
A	B	A NOR B
0	0	1
0	1	0
1	0	0
1	1	0

Figure 3. NAND and NOR dat tables

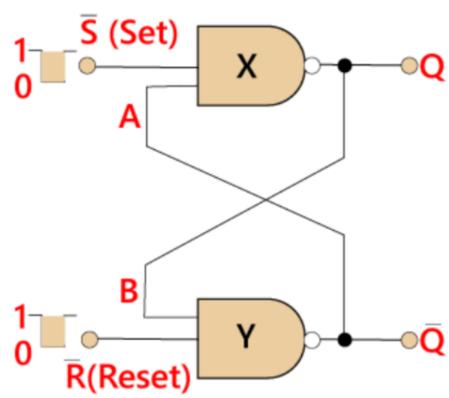


Figure 4. Structure of an SR flip-flop using logic gates.

A JK flip-flop is similar to an SR flip-flop however, it eliminates the invalid state. A D flip-flop allows for the input value to be outputted smoothly on the edge of the clock pulse. Finally, A T flip-flop is a simplified version of the JK flip-flop J and K inputs are tied together.

III. CIRCUIT DESIGN AND BUILDING

A) Circuits Broken Down

In order to build the patient monitor, we broke the circuit down into multiple different circuits: the Logic Circuit, the Timing Circuit, the Flip-Flop Circuit, and the Alarm Circuit.

B) Alarm Circuit

The alarm circuit used an IC-555 component to convert the signal to one that the buzzer could use **[4]**.

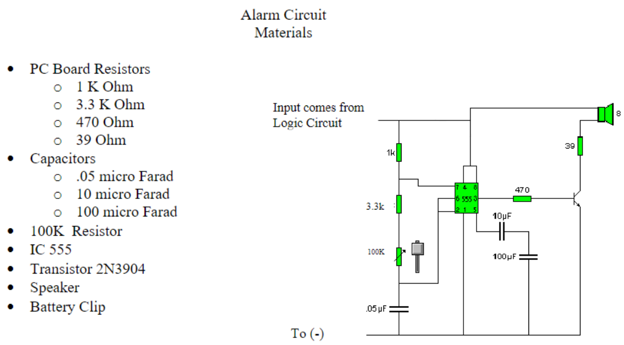


Figure 5. Alarm circuit diagram

The buzzer receives the output from the 555's astable pulses, creating the sound when the circuit is given flow.

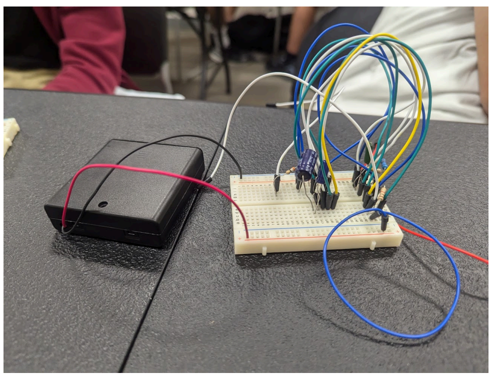


Figure 6. Alarm circuit on a breadboard

Our circuit used __ and __ ohm resistors, as well as __, __, and __ micro Farad capacitors to control and configure the 555 chip.

C) Timing Circuit **[4]**

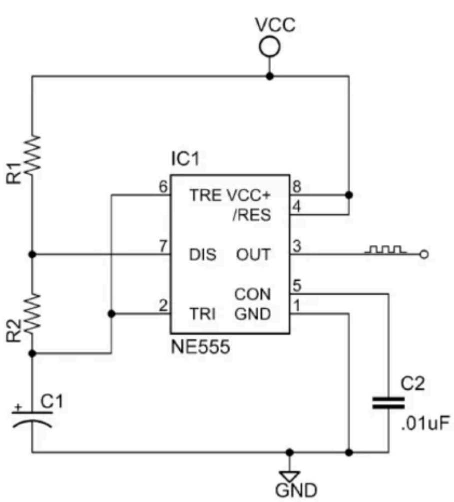


Figure 7. Timing circuit diagram

Reference **[5]** for schematic website

The timing circuit used another IC 555 in astable mode configured to pulse every 6-8 seconds. In order to target that time, it uses a 1 kilo ohm and 10 kilo ohm resistor, as well as a 0.1 microFarad and 100 microFarad capacitor. This allows it to pulse in a predictable timeframe. The output of the 555 connects to an led with a 1 kilo ohm resistor, displaying the state of the timer, switching from high to low with every pulse.

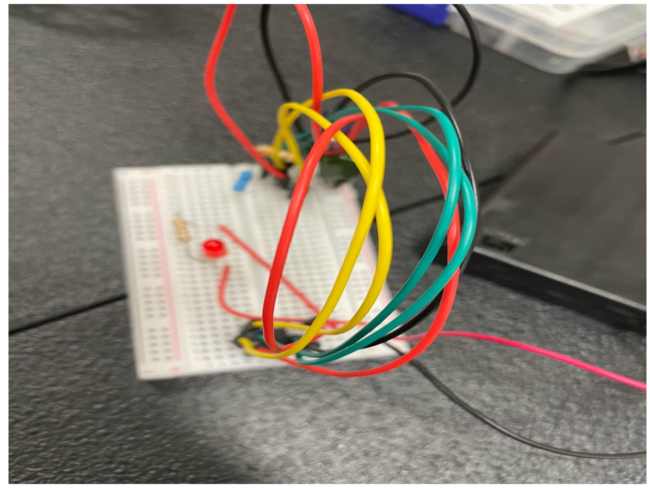


Figure 8. Timing circuit built on a breadboard

D) Logic Circuit **[3]**

The logic circuit is used to determine which LED light or alarm should be turned on. We first built the entire logic circuit for the red LED and green ELD on paper. Based on this, we built the logic circuit for the yellow LED. Finally, we used the red LED and a little extra logic circuit to complete the design of the entire circuit. Then we converted the logic circuit on paper into a real circuit in Tinkercad. During this process, we tested each LED circuit after we completed it. We encountered several problems during this process, which we solved by comparing the logic circuit diagram and inserting numerical tests.

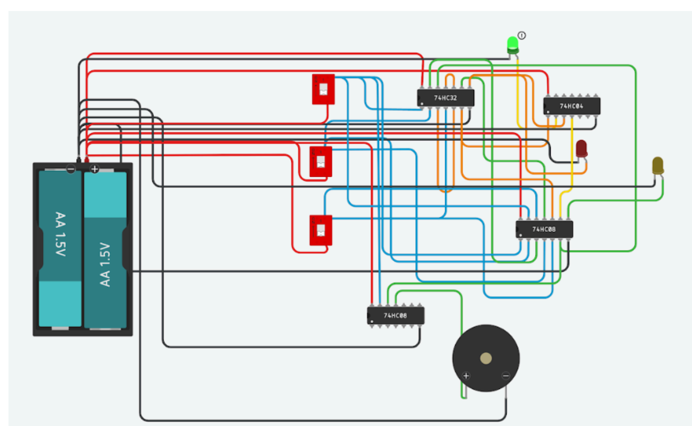


Figure 9. Image of TinkerCad logic circuit

Our circuit worked fine in Tinkercad, so we decided to build it. We ran into a few major challenges along the way. The first was too many wires. Initially, we used a lot of green wires because they were the longest. But as the number of wires increased, we couldn't tell which wires were connected. This caused us to start over several times. Later we changed our strategy and used different colors to distinguish the wires in different places. This puts our circuit in a much better place, but we still can't figure out how to get the red LED to light up. This puts our circuit in a much better place, but we still can't figure out how to get the red LED to light up. We chose to rebuild it several times but it didn't solve the problem. We then decided to just build the red LED to make sure it worked properly. Our red LED sometimes works fine. Then we chose to change players to change our thinking. Until the end we still didn't solve the problem of not being able to control the red LED.

E) Flip-Flop Circuit **[4]**

The Flip-Flop Circuit was intended to receive inputs from the logic circuit and turn on the display mechanisms of the monitor if the symptoms remained present. The flip-flops received input from the IC-555 of the timing circuit. The flip flop used the timer as a clock to indicate when to allow the inputs from the logic circuit to pass through to the outputs. This would allow the indicators to change based on symptoms being present for enough time, and prevents indicators going off for one-off symptoms.

In actuality, only the inputs of the flip flop circuit were completed, as the components used as outputs were being used to create the logic circuit. The inputs from the timer circuit were connected from the 555 to the flip-flop, but the inputs from the logic circuit were not attached due to the logic circuit being nonfunctional.

F) Assembly

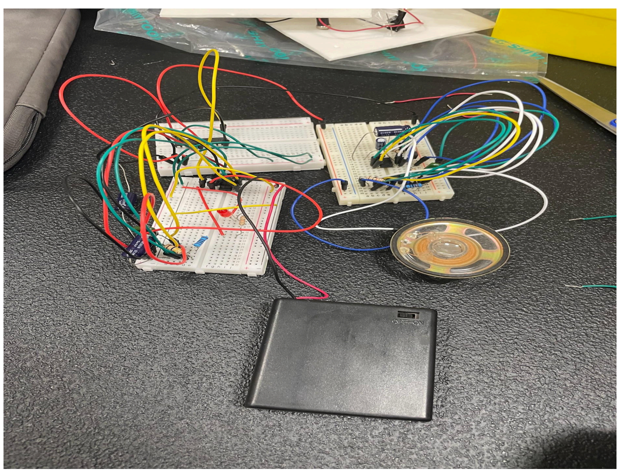


Figure 10. Timer circuit flip flop, and alarm circuit assembled together without the logic circuit inputs.

The circuit was meant to be assembled so that the flip-flop circuit would take input from the logic and timer circuits. It would then output to the different LED indicators, and eventually the alarm circuit. However, due to a failure to complete the circuit within the time frame, the circuit was assembled without the logic circuit, preventing it from being functional. In the assembly, the timing circuit is connected to the flip-flop through a wire from the output slot on the IC-555. The alarm circuit was also connected to the output of the flip-flop, allowing for any high signals passed through would activate the alarm.

IV. CONCLUSIONS

In other words, our project targeted the imminent need for a system to rapidly identify COVID-19 symptoms using a sophisticated electronic monitoring system. This is by leveraging principles of digital logic and timing circuits utilizing 555 chips, alongside flip-flops that ensure stability. We actually finished building all of the circuit boards and it worked, but we didn't have enough time to connect everything to see how it works.

It took meticulous design and testing phases to overcome many challenges typical in circuit implementation. Common challenges that we encountered included component functionality, missing/wrongly connected, or even color arrangement for wires. Normally, it took us more than half an hour to find out what the problems were. Also, we rebuilt the circuit several times. Later, we came up with different ways of debugging. We put a light bulb in there just to know if it is lighting, or we used a multimeter to check whether the current is flowing on the circuit. Refining each component's functionality was very important to ensure that it works reliably in this case. The fact that we moved logically from theoretical groundwork to practical implementation underlined our dedication to engineering excellence and innovation in health technology.

Unfortunately, we have all the circuit board working but didnt have a chance to connect all of it together and see how it works, however, through the satisfaction of having successfully carried out the circuit design, and troubleshooting finding out the problems, this cooperative effort helped not only in validating our approach but has also put an indispensable stamp on the fact that Interdisciplinary Teamwork and communication is an unavoidable component in the attainment of goals set. Moving further forward, lessons garnered from this project will catapult us into a cascade of processes for refinement, making sure that clarity of circuit lay-outs and rigorous testing protocols are adequate for the enhancement of system performance.

V. PROJECT EVALUATION

Our group approach to building the project involved distributing labor evenly among partners, prioritizing tasks that required more time or assistance, such as the FFs and timing circuits. By focusing on specific assignments, we aimed to enhance productivity and meet project deadlines effectively. Incorporating design strategies from chapters 21 and 22 of the textbook **[6]**, we emphasized qualities of a good designer, fostered teamwork without selfishness, and persistently debugged issues, illustrating our circuits for clarity and brainstorming. Each member had defined roles: Felipe and Xiaotong designed and built circuits, Pravir focused on logic gates, while Ray and Zhilin built circuits. Our successes included quickly constructing the alarm circuit and overcoming challenges in troubleshooting timing and flip-flop circuits. However, challenges like extensive troubleshooting time and logic circuit issues surfaced, resolved with TA assistance. To enhance future projects, we plan to implement clearer wire identification systems and regularly test circuits at each stage. Lessons learned emphasize better organization and continuous collective brainstorming from project outset, ensuring thorough understanding and minimized errors in future endeavors.

References

[1] "Coronavirus." *World Health Organization*, www.who.int/health-topics/coronavirus#tab=tab_3. Accessed 20 June 2024.

[2] "Symptoms of COVID-19." *Centers for Disease Control and Prevention*, 15 Mar. 2024, www.cdc.gov/coronavirus/2019-ncov/symptoms-testing/symptoms.html. Accessed 20 June 2024.

[3] Dr. Darin Gray, *"Binary number system and Digital Logic Design"*, Discover Engineering, 18 June 2024, USC Viterbi School of Engineering, https://drive.google.com/file/d/1OsBtVJsoWcqCbl6hlhJBNLjoIh2DEKFO/view?usp=sharing.

[4] Dr. Darin Gray, *"555 chips, timing circuits, and flip flops"*, Discover Engineering, 18 June 2024, USC Viterbi School of Engineering, https://drive.google.com/file/d/1whEN8ZR-5jhcxilVlsfpdu_63pnG21E7/view?usp=sharing.

[5] Kane, Philip. "555 Timer Tutorial - How to Configure a 555 Timer IC." *Jameco*, www.jameco.com/Jameco/workshop/TechTip/555-timer-tutorial.html. Accessed 23 June 2024.

[6] Kosky, Philip, et al. "Chapter 21: Introduction to Engineering Design, Chapter 22: Design Teams." *Exploring Engineering: AN INTRODUCTION TO ENGINEERING AND DESIGN*, Fifth Edition ed., Academic Press, Amsterdam , 2021, pp. 481–500.