Physics 117 Lab 9: Constructing a basic reaction timer

Ahmad Ali

UCLA Winter 2019

Partner: Alex Tolstov

---

1. The Circuit, its design, and its purpose

1.1. Part A

In this lab we are geared toward building a single circuit, its purpose to be a reaction timer that is controlled by two buttons, 1 to start the game and the other to stop it, we are able to record the time by using 3 LED 7-segment displays. Though to be concise and through I will provide a full run down of the circuit, based off the circuit diagram in figure 1, where instead of the normal DC supply and frequency generator we use a 555 timer chip, which is explained more below and the DC supply which is a battery pack rather than the normal DC supply voltage. We are asked to provide a through analysis of the circuit, I will provide pin numbering based off of figure 1 and explain the logic in a linear manner.

The first part of the circuit that I want to present is the buttons that are used for control throughout the circuit. We use 3 buttons in our circuit all supplied with 5 volts through a 10 kOHM resistors. The way the buttons work practically are as gates that separate the voltages they receive from one end to the other, and the pushing of the buttons close the gates. The first button is connected to the clock of the flip-flop chip, the second to the reset of the flip-flop chip, and the last to the reset of all the 10 counter chips, where they start, stop, and clear the circuit respectively, to see button 1 look at the second column of the circuit at pin 49 F to J and to see how it feeds the input of the Flip-flop, the second button is in the third column connected to pin 54 F tp J and the last button is connected at the first column going left to right; at pin 50 and then a wire in the second column connected to all the resets at pin 34 A to F second column is used.

The part of the circuit that provides the logic and control over the rest of the circuit resides with the D-type flip-flop chip (74HCT74), in the figure 1 it is the top right chip, the right of the chip pins along F to J and 11 to 17 on the right of the circuit board are set to ground as this part of the circuit is not used with the exception of pin 14 of the chip and 11 of the circuit since this is V_{cc} and needs 5 volts, pin 7 of the chip and 17 of A to E is ground and is fed into the ground of the busbar. Pin 1 of the chip which is in pin 11 of A to E on the right side of the circuit, is the reset of the circuit and receives the input from the second button of the circuit, the second button itself receives voltage from the bus bar and have a capacitor to make sure no stray is made; the reset of the circuit makes it lose its stored memory and have an low output until another input is made in the clock giving a rising edge and the data input is receiving voltage that can be stored for output reference. Pin 2 of the flip flop corresponding to pin 12 of A to E, is the data input and is constantly receiving a value of 5 V since this is what we want to store and we can control when it stores and to delete what it stores with the reset switch to clear inputs and the clock to allow for inputs to be recorded. The third pin of the flip flop chip was the clock, corresponding to pin 13 A to E, the clock controls if data is stored and is triggered when is struck with a voltage that has a rising edge, which occurs for us because we have a button that is connected to 5 volts so that is connected to the clock, so basically it is able to provide a rise from 0 to 5 volts that then allows for data to be stored, and since we constantly have 5 volts fed to the data input in our circuit it certainly means the flip-flop stores the data and has a high output whenever the first button is pressed and keeps it till the second button sending a voltage to reset is struck. Pin 4 is the asynchronous set-direct input, and basically makes our output change to stop this we have to supply a voltage into it as this causes it to not work. Pin 5 is our output of the chip on the left side of itself, this output is fed into the AND chip, and basically allows for the AND to give outputs since the other port has a 1 kHz square wave constantly held, and the 1kHZ controls the timing of the AND as it provides a high output every millisecond, Pin 6 is a complement output that we do not use. To summarize the D-type flip-flop chip, the right side of the chip was not used except for V_{cc} which was fed 5 volts, the left hand of the chip had the data input which was always held high, the reset and clock were controlled by buttons, which allowed them to control the reaction game, the output of the chip feeds the AND gate.

Discussion of the 555 chip would begin here but has been relegated below as it was its own question that was more fully answered, so assume a 1 kHz square wave from the function generator is fed into the AND chip which will be discussed more into. The AND chip (74LS08) is hooked up from pins 27 to 33 along in the middle of the 4th column looking left to right. The part of the chip along side F to J of the column were not used so all the inputs were set to ground except pin 14 of the chip which is at pin 27 F to J which is V_{cc} which has a 5 volts input. The left hand of the chip only 4 pins are used; the first three and then pin 7 of the chip (pin 33 4th column) which is ground which just goes to ground of a nearby bus bar, the other components also go to ground. Pin 1 is input for the AND gate, located at pin 27 A to E column 4, in our circuit, this is fed by the output of the flip-flop chip, which also has a diode light up when going through the AND gate; pin 2 the other input is the 1 kHz square wave, and this AND chip provides the logic necessary in coordination with the button switches to turn the AND gate on and off, where off occurs when the flip-flop is reset and on is when the flip-flop always yields a high output and the 1kHZ square wave provides a input every millisecond meaning the AND gate is only on once a millisecond, providing timing for our circuit that can be utilized with the 10 count chips. The output of the AND is located at pin 29 and connects to the first 10 count chips input at pin 10 D of Column 3. One last thing about the AND chip is that when the first button starting the game is pressed a diode located at pin 19 of column 4 lights up as it is connected to the flip flop output, indicating that the AND chip is receiving inputs.

The last parts that needs to be discussed are the 4026 chips and the 7 LED common cathodes. These components work in tandem, the 4026 receives an input in its pin 1, which for all the 4026 chips used occurs at the left side of row 10, and then the chips output whatever input they receive to a 7 part LED that lights up corresponding to a number. In our case because we are using the AND gate with the 1 kHz square wave the inputs received by all the divide by ten chips were divided by ten besides the one in column 3, meaning that the 4026 in column 3 receives millisecond impulses, it divides by 0 sends it along to the next chip where it receives inputs in centiseconds, and the last in deciseconds, which the LED's connected to the 4026 chips reciprocate and show in there LED's, allowing us to have a visual timer accurate to the millisecond. For the 4026 to work we go through the pins necessary, pin 1 is the clock which receives the inputs which it divides by 10 and displays on the LED display through its out ports of 6,7,9-13. The second pin located at row 11, is the clock inhibit which is set to ground so it does not inhibit the clock. We power up pin 3 which is enable input with 5 volts, we power up pin 4 which is enable output. We send the divide by ten counter from column 3 4026 chip to the column 2 and the column 2 divide by 10 output to column 1 4026 chip and the column 1 chip does not need to output a divide by 10 but would provide seconds if it did. Pin 8 located in row 17 is the ground of the circuit which was fed a ground of our bus bar along side of it. Pin 15 located at row 11 F to J is connected by a wire in all three 4026 chips to second column row 34 A to E, where another wire connects them to the third button that controls the resetting of the time to 0 for the game to work. Pin 16 located in row 10 F to J, is the V_{cc} of the circuit and needs to be powered up 5 volts in order for the circuit to work. The last thing the 4026 chip does is provides the inputs for the LED allowing them to display the time based on the frequency inputted into the circuit. To set up the LED to function this way we needed to just wire up the LED in a consistent manner with the 4026 chip and the actual logic is handled internally, the pinning of the chip went as thus. Pins 3 and 8 were connected to ground via a 270 Ohm resistor. Then the pin for A which is pin 10 for the 4026 and pin 7 for the LED are hooked up with a 270 Ohm resistor in between, this continues for pins 12 and 6; 13 and 4 ;9 and 2 ;11 and 1 ; 6 and 9 ; 7 and 10 for the 4026 and the 7LED display respectively, all with just a single 270 Ohm resistor in between.

The use of a battery pack that consisted of 4 1.5 Volts batteries that supplied 6 volts throughout the circuit was also used and powered and grounded the top bus bar which then supplied to the rest of the bus bars and ground. So to briefly summarize, the circuit has 3 buttons 1 to turn on the game by clocking the flip-flop which will automatically store a value and complete the AND gate as well as lighting a LED once the value is stored, this AND gate feeds a CD4026 chip which divides the signal by ten passing to another chip and that chip to another basically taking a 1 kHz square wave input to display milliseconds to deciseconds on the LED chips, the 1kHZ wave could be produced by a 555 chip or a frequency generator as well. To turn the game off we simply had a button connect to the reset of the flip flop, we clear the data and the AND chip stops outputting stopping the circuit, to reset the LED's to 0 we reset the CD4026 chips all at once by having a switch connect to all there resets. After all of these components we simply had a reaction tester game where we could click a button see the time go off and then click the other to stop it and then click one last more to make everything go back to start.

An important aspect of this lab had to do with the 555 timer chip, specifically it provides a 1 kHZ square wave to the AND gate which provides the timer for the rest of the circuit. You can see the output of the 555 timer chip in figure 2 and the circuit diagram for how we achieved a near 1kHz, at 994 Hz square wave in figure 3. In our particular case our square wave was slightly out of phase as its positive voltage was about 52 percent of the output wave though this was okay for consistency in the circuit. Also due to the 994 Hz rather than 1 kHz output our circuit was running slow, so the time is slightly delayed, because the ten count chips are basically dividing a smaller input. Though the inner mechanism of how this chip operates can be explained thusly, pin 1 is simply ground, pin 2 is the trigger responsible for set to reset, and the amplitude of the pulse applied effects the timer, and in our circuit a voltage that has went through two resistors and another 5 voltage that goes through a 10nF capacitor, this all feeds pin 2, pin 3 is the output of the circuit and feeds the AND gate that then feeds the 10 count chips, its hooked up between pins 54 and 28 for the 555 and the AND gate respectively. Pin 4 is the reset of the circuit and to make sure it doesn't trigger it is held as the same as V_{cc} which is 5v so simply wired to the bus bar of 5V. Pin 5 is the control voltage which controls the pulse width, it is received with a voltage that goes through a 10 nF capacitor so it can have a frequency base, pin 6 is the threshold and is responsible for the set state of the flip-flop of this circuit and for us it has no input, the next pin 7 is the Discharge, it discharges a capacitor and toggles the output from high to low when voltage reaches 2/3 voltage, for us the input is the 6.9 kOhm resistor that receives a 5 volt input through it to the $69kOHM$ M sistor, pin 8 is V_{cc} and receives an input of 5 volt from the bus bar. To calculate what the circuit would produce frequency wise we look at pin 2 and the relation between the resistors and capacitor vales uused in the circuit, the equation we used to find the near 1kHz voltage, is equation 1, theoretically our values of 6.9 and 69 kOHms respectively should yield 966 but because a simple thing the the nanoFarads being 9.9 nF rather than 10 makes the equation closer to 1 kHZ this eventually leads to a close value of 994 Hz. r

$$f = \frac{1.4}{(R1 + 2(R2)) * C} \qquad [1]$$

e

One of the last things we are asked is what is the average battery life of the circuit when using the battery pack as the source of power. In our particular circuit we observed the battery to be exerting 37 mA of current in its lowest end and 60 mA at its highest, as well as 75mA used when resetting the circuit. Consulting the data charts of the particular batteries we used which were Duracell Pro-cell batteries, we deduced that because the lower limit of True of a gate is around 3.3 Volts and the batteries continue to work till all have reached the .8V range, which occurs around 50 hours because the batteries are averaging about 50 mA and from Duracell's data sheets we can see the .8 Volt mark occurs around 50 hours.

The last thing we are asked to do is describe the reset switch that we construct for the circuit. In this lab we tried a variety of methods such as hooking up logic with an AND gate that feeds power when we click a switch , though the simplest way we were able to accomplish this was we simply had a button switch connected to power and all the reset switches of the counter connected to the other wire of the button switch, this allowed us to supply power to the reset switches at the will of a button, In figure 4 you can see a basic set up of how the reset switch works, it is connected to power via the left hand bus-bar where it can be placed any slot and then connected in series to a parallel point where a resistor and capacitor take in stray voltages, from bus bar 50 to 55, and 5 volts is sent through the other part of the circuit to 3 wires connected to the reset switches of the 10 count chips which resets there values to 0 essentially resetting our circuit, and are located at F11 for all three circuits.

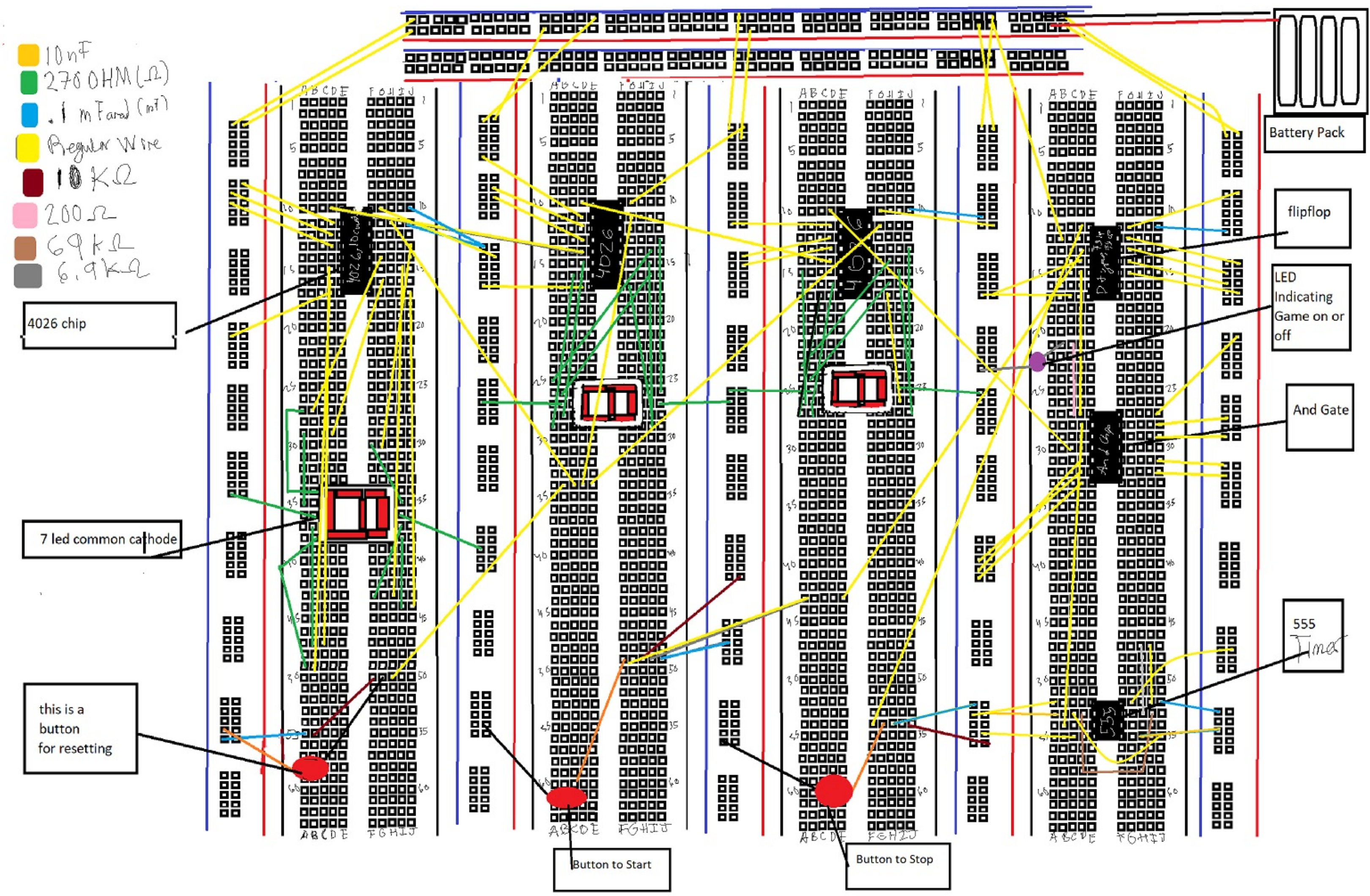

Figure 1: This schematic represents the circuit consisting of a total of 3 switches 3 Counters, 1 Flip flop, a And Chip and a 555 timer chip

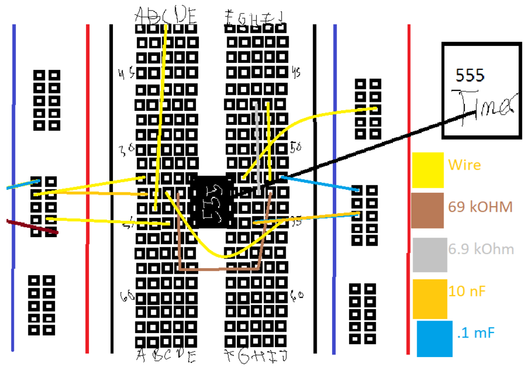

Figure 2: This shows the Circuit Diagram for the 555 timer chip

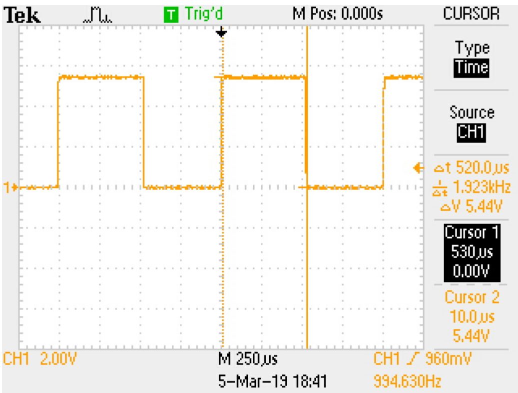

Figure 3: This shows oscillcope output for the 555 timer chip giving a 994 Hz output

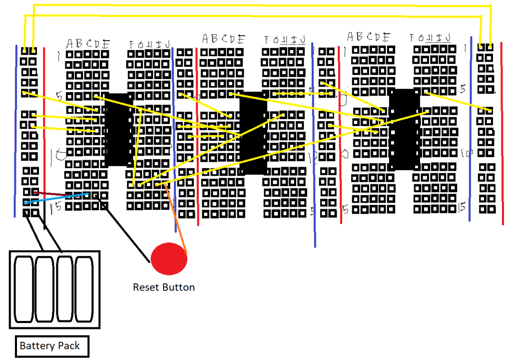

Figure 4: This shows the logic on how our reset switch worked, where a button hit the reset for all the ten counters at once