Digital Dice Roller

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I. Introduction

A die roll is used to generate a random number, where the numbered face that lands uppermost determines the outcome. It is based on probability, with each die face having an equal opportunity or chance of landing in the uppermost position, creating a uniform distribution within the given range of face values. The standard six-sided die originated in ancient civilizations, and has many applications in modern games and simulations. The project aims to imitate the rolling of two standard six-sided dice using varying 555 timers and decade counters to light up an LED display.

II. Circuit Diagram

Figure 1 presented on the following page.

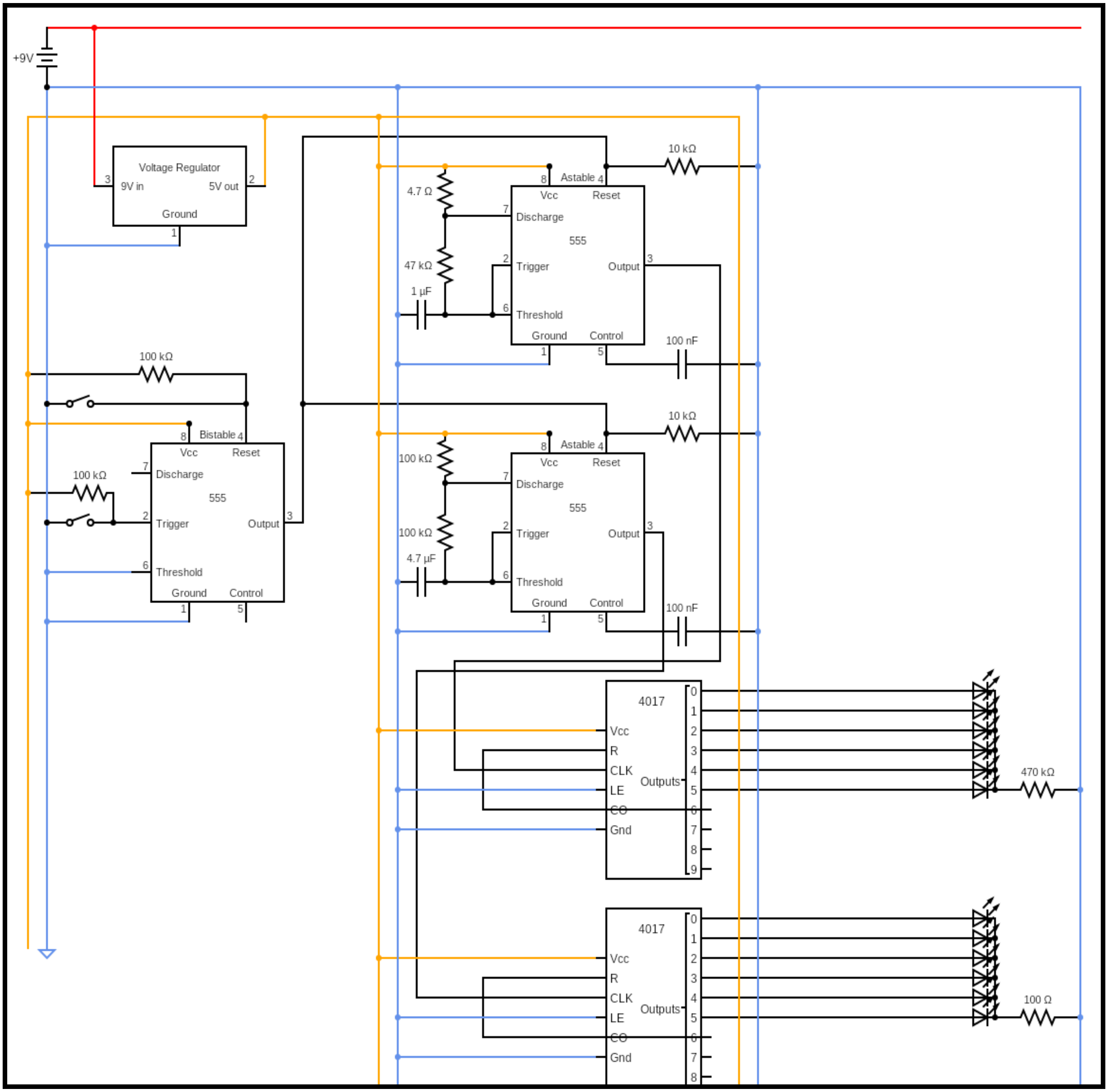

Figure 1. **Dice Roller Circuit Diagram**. Diagram was created using Circuit Diagram web editor, and features all the components in the layout of the breadboard. The outputs of the 4017 decade counters refers to the output numbers, not the pin numbers.

III. Components and Circuitry

A. Overall Operation

The top channel of the breadboard is powered by a 9-volt battery. Each vertical channel is grounded from this top channel, and the power of each channel is supplied from the output of a voltage regulator. These vertical channels power the remaining components of the circuit. A 555 timer in bistable mode is controlled using two buttons that connect the trigger and reset to ground. The output of this timer is sent to the reset of two 555 timers functioning as astable multivibrators with different RC values for differing oscillation frequencies. The outputs of these are sent to two 4017 decade counters resetting on their seventh output. The clock pulses from the two astable timers increment the counters, and the six possible outputs simulate the six sides of a die. These outputs light up LEDS, which allow the viewer to see which count the decade counter is currently on. When the bistable timer's trigger is connected to ground with a button, the astable timers will send clock pulses to the decade counter, and it will increment and simulate the dice rolling. Pressing the other button grounds the reset of the bistable timer, which switches the state of the internal SR flip-flop. The astable timers stop sending clock pulses to the decade counters, and they stop incrementing, stopping on outputs that represent the uppermost faces the dice landed on.

B. Logic Processes

a. 7805 Voltage Regulator

A voltage regulator is a component that outputs a stable voltage no matter the input voltage. The voltage regulator in this breadboard takes in 9 volts as input, and creates a stable 5 volt output that is used to power other components in the circuit. A transistor and bandgap reference work together to control the output voltage and keep it stable.

b. Bistable 555 Timer

A 555 timer in bistable mode is an SR flip-flop that has no timing. The two stable states are controlled directly by the trigger pin and reset pin. Pressing the button that connects the trigger pin to ground causes the positive side of the comparator receiving ⅓ Vcc to be greater than the negative side receiving the trigger pin input. This drives S high, and the Q output will be high. When the button connecting the trigger pin to ground is released, S will be driven low; however, now S and R will be low, and the state of the flip-flop will still be its previous state. It could change if the voltage from the threshold pin input is greater than the voltage at the negative side of the other comparator, which is ⅔ Vcc. Since the threshold pin is grounded, this will never happen. The only way for the flip-flop state to change is for the reset signal to go low, which would occur by pressing the button connecting the reset pin to ground. This allows the two buttons to control whether the timer is on or off, and the output is sent to the two astable timers. A diagram of the inside of a 555 timer is shown in Figure 2.

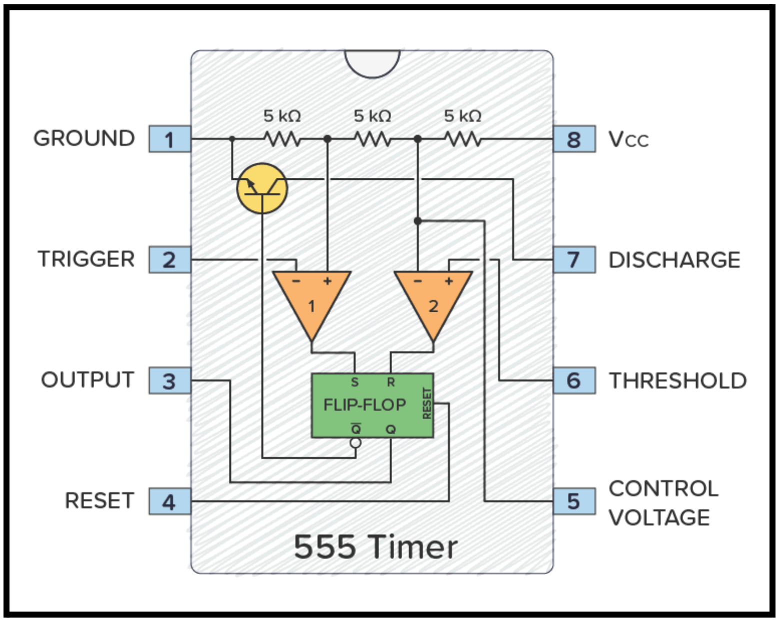

Figure 2. 555 Timer. Diagram shows the inside of a 555 timer.

c. Astable Multivibrator 555 Timer

A 555 timer in astable mode acts as a free running oscillator, with a frequency that can be adjusted by changing the values of the resistors and capacitors connected to the chip. This is achieved by continuously re-triggering the chip by connecting the trigger pin input and threshold pin input together, allowing the timer to switch between the two states without application of any external trigger. With the reset pin grounded, the timer will only activate with a high signal from the output of the bistable timer. A capacitor and two resistors connected through the threshold and discharge pins control the timing of the changing flip-flop states when the reset signal is high. The capacitor charges through the two resistors connected through Vcc. When the capacitor exceeds ⅔ Vcc, the threshold input will be greater than the negative input of the comparator, driving R high. Q will be low, but $\bar{Q}$ will be driven high, allowing the discharge pin transistor to activate. This pin will go low, and the capacitor will discharge through only one of the resistors. When it discharges past ⅓ Vcc, the trigger pin comparator will be driven high, setting Q to high and $\bar{Q}$ low again. The discharge transistor will deactivate, and the capacitor will start to charge again, repeating the process.

The voltage applied at the control pin will change the threshold voltage level, and is connected to ground via a capacitor to filter out external noise. The RC values chosen for the two astable timers determine the timing of the charging and discharging cycle, thus determining the frequency at which the SR flip-flop will oscillate. The goal is to generate pulses at a frequency that is too fast to observe, giving the illusion of random chance whenever you stop the dice from rolling. The two astable timers have differing RC values to differentiate their rolls from one another.

d. 4017 Decade Counter

The 4017 decade counter is an IC that counts to ten through ten outputs. The counter increases by one for every rising clock pulse it receives. The chip functions because of a cascading effect on the D flip-flops inside of it. The first D flip-flop is high, and it will output high to the first output. This high will be sent to the next D flip-flop, but it won't activate until the next rising edge clock pulse. Previous outputs will go low as the counter transitions to the next state. The seventh output will be sent to the reset pin, which will then be negated, driving all outputs low and resetting the counter. The outputs of the decade counters are connected to LEDs to display which die side landed uppermost. When the decade counter stops receiving clock pulses, the counter will not increment, and the LED it stopped on will remain lit. A diagram of the inside of a 4017 decade counter is shown in Figure 3.

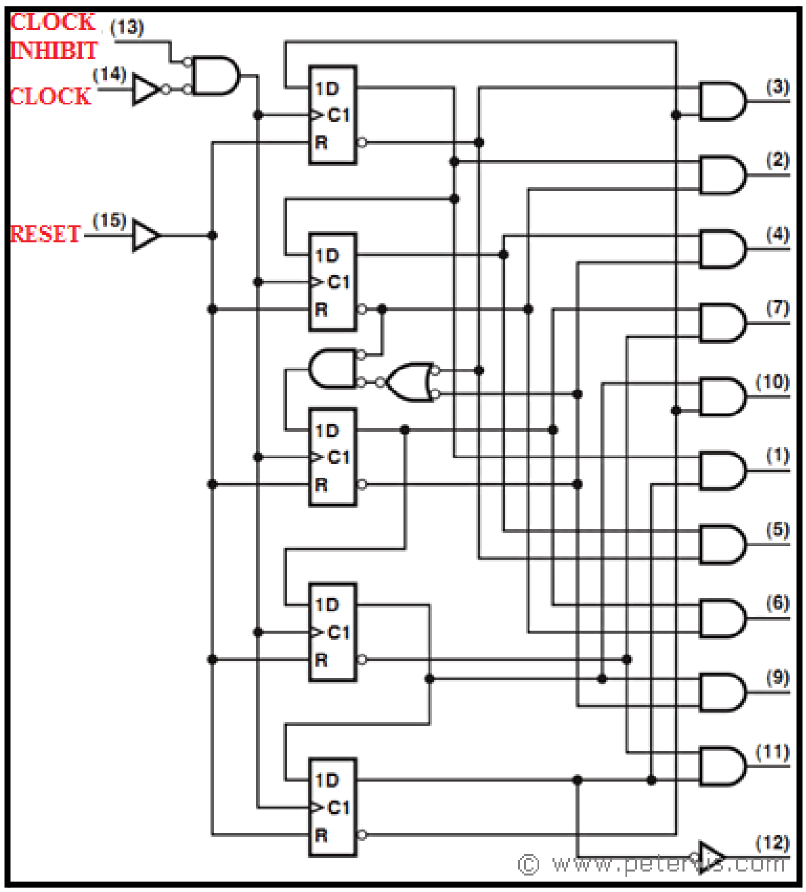

Figure 3. 4017 Decade Counter. Diagram shows the inside of a 4017 decade counter.

C. Non-IC Components

a. Push Buttons

Pushbutton switches are mechanical devices that connect or break an electrical connection. It will cause a temporary change in the state of an electrical circuit when the button is pressed or released. The push buttons in this circuit are used to control the SR flip-flop inside the bistable 555 timer. One button will ground the trigger pin, which will make the positive side of the comparator (⅓ Vcc) greater, driving S and Q high. With the threshold pin connected to ground, there is no way for the other comparator to go high, so the state of the flip-flop will stay even if S goes low again. The only way to change the flip-flop is for the reset signal to go low, which occurs with a press of the push button connected to the reset pin

b. LEDs

A light-emitting diode (LED) is a semiconductor device that emits light when current flows through it. In this circuit the LEDs are connected to the outputs of the 4017 decade counters, and then they are linked with a resistor to ground. An LED will only light if its connected output is high, which is only one at a time for a decade counter.

IV. Performance

The final product performs seemingly well. The voltage regulator correctly reduces the voltage from the 9-volt battery, the bistable 555 timer correctly responds to the push button external stimuli, the astable 555 timers send a steady stream of clock pulses to the 4017 decade counters, and the counters output to the LEDs consistently without error. I believe the decade counters are most likely still encountering noise, but it has not interfered with the working performance of the circuit.

V. Reflection

Overall, I greatly enjoyed my time working on this circuit, and I have learned a lot about the inner workings of the components that I did not fully understand before. I wish I would have either had more time to figure out the logic for a die display, or would have taken the time to research the binary counter featured in the dice project of Charles Platt's 3rd Edition of *Make: Electronics*. The logic for the die display with six inputs would be difficult for me to figure out, and the binary counter would be a new component for me to learn about with only three logic inputs for the die display, but it would then this project would have been taken directly from the course book. So, all in all, it is upsetting that I was not able to create a die display for the dice roller, but I am satisfied with my work and effort to create the circuit with different digital components.