RC Circuit Lab

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1 Abstract

This lab focused of the electrical response of an RC circuit to a button bounce. Circuit behavior was observed with an oscilloscope to measure the voltage across a capacitor through time.

Initially, the measured circuit was composed of a voltage source, a resistor and a button. When the button was pressed, the voltage changed sharply, and would have a bouncing effect that would cause the circuit to open and close rapidly before settling down. It was found that by adding a capacitor to the circuit, the voltage measured changed much more smoothly and importantly, without bounce.

2 Introduction

Picture yourself in an arcade. The lights are dim, the rows of machines echo beeps and buzzers, and you can't help but notice the carpet pattern that looks like a two-year-old took a large crayon to it. You approach your favorite game – Polybius. The glow of the CRT monitor gets brighter as you grab hold of the controls. Just when the game is getting intense, you tap the left button but it triggers twice and puts your character directly in the line of fire. That's it. Game over. But why?

As any well-seasoned gamer would say in such an event, ”This game's trash!” In this case, its true that it was not a lack of skill on your part that put an end to the game. It seems that you fell victim to the dreaded ”button bounce.”

Fortunately, however, button bounce is a common, yet easy-to-fix problem for electrical engineers the world over. The solution is a simple RC circuit.

3 Background

Before diving head first into the math, it is important to discuss what exactly an RC circuit is. Put simply, it is an electric circuit that consists of two components: a resistor and a capacitor.

One of the most intuitive ways to think of an RC circuit is through the *Hydraulic Analogy*. This analogy models electric circuits with pipes and water. An RC circuit would consist of a constricted pipe for the resistor and a rubber membrane as a capacitor. The restricted pipe makes pushing water more difficult, and the membrane acts as a break in the pipe that can store elastic potential energy. Additionally, hydraulic pumps act as batteries. Therefore, pumps can be used to stretch a rubber membrane over time, and rubber membranes can be used to push a limited amount of water through a closed loop for a limited time.

Bringing it back to the electrical world, capacitors can be charged by a voltage source and discharged through a closed circuit. It is also important to note that capacitors do not charge or discharge instantly. For this reason, capacitors are categorized as *reactive components*.

4 Procedure

The following steps were taken to create and measure the ”button debouncing” circuit.

4.1 The Circuit

First, use a breadboard to create recreate the circuit modeled by Figure 1.

4.2 Setting Up the Scope

Begin by configuring the scope. Start by pressing the **Default Setup** button, and confirm that the button is connected to channel 1. The scaling of the display can be altered by using the **Vertical Scaling** knob, which is portrayed by **Volts**/**Division**, and the horizontal knob which shows as **Seconds**/**Division**. Next, set up the scope's triggering. Select the **Trigger Type** of **Edge**, with **1 Source**, measuring a **Falling Slope**. Then for the **Trigger Mode**, one could either utilize the **Single Run** mode or **Trigger Mode: Normal** settings.

4.3 Capturing Bounce and Readjusting Scope

Next, capture the behavior of the button press. When pressed, the falling edge should be sharp. However, when the button is released, the rising edge will not be clean. Continue pressing the button until a bounce is recorded. Afterwards, alter the zoom

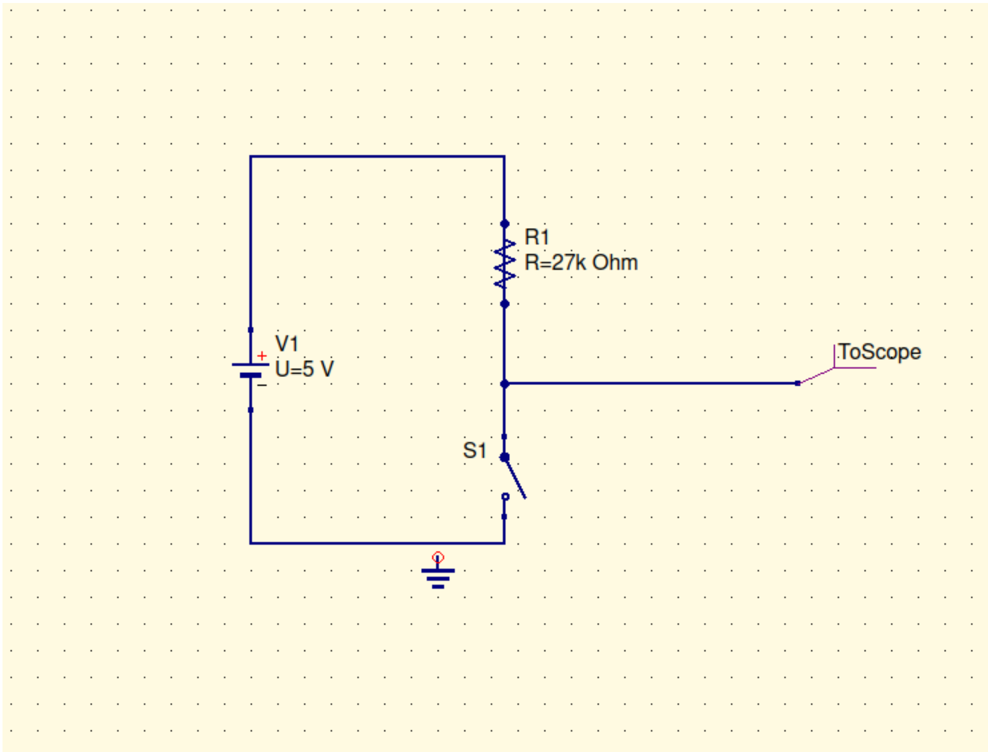

Figure 1: Circuit with button and resistor

using the **Horizontal Knob** and readjust the the Trigger by changing the slope to **Rising Edge** and the **Trigger Level** to 2.5V.

4.4 Measuring Waveforms

Now it is time to measure waveforms. This is the point when one realizes that they have never used this function of a scope before, and they need assistance. That is okay. If confident in abilities, one can start by pressing the **Cursors** button. The **Mode** should be set to **Manual**, there should be **1 Source**, and the X1 and X2 cursors should be enabled. Select X1 to control and use the **Cursors** knob to the beginning of a bounce. Place X2 on the other side of the bounce. The cursor panel will display the length of the bounce. Record this data.

4.5 Debouncing Circuit

Design a circuit that resembles Figure 2 by adding a capacitor in parallel with the resistor.

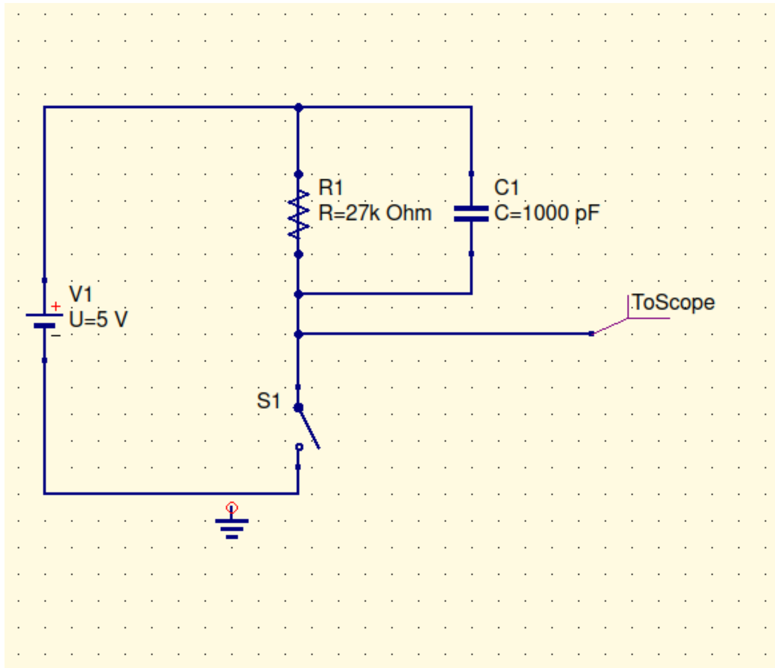

Figure 2: Circuit with button and resistor

4.6 Calculations

As stated earlier, capacitors are *reactive components*. In the case of RC circuits, the voltage across a capacitor is shown by Equation 1. Upon closer inspection, it becomes apparent that an ideal capacitor takes an infinite amount of time to fully charge. For this reason, it is often the case that the voltage is measured at 63% since this quantity closely approximates easy-to-calculate quantity shown by Equation 2.

$$V_{cap}(t) = V_{in}(1 - e^{-\,t/RC}) \tag{1}$$

$$(1 - e^{-\,RC/RC}) \approx 63\% \tag{2}$$

5 Evaluation and Results

The 27kΩ resistor was chosen because 27 is one of the lab partner's favorite numbers. A 220 pF capacitor was originally chosen for the debouncing circuit because it was a nice shade of blue, but it was too small to have a significant enough impact on the circuit. The bounce was still apparent. Therefore, it was swapped out for a 1000pF yellow capacitor instead (a much less visually attractive color). This neutralized the bounce, seen in Figure 3.

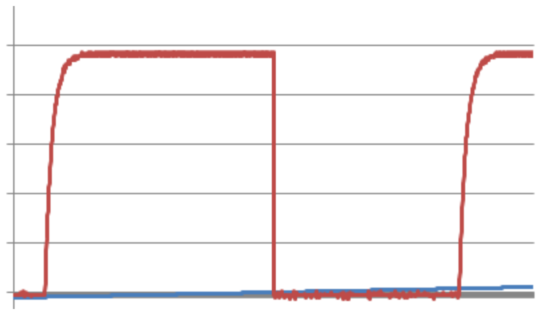

Figure 3: Smooth voltage changes from circuit with 1000pF capacitor.

5.1 Measurement Uncertainty

The resistors in the lab have a $\pm 5\%$ tolerance. While the resistor may have an approximate value of 27000Ω, this really can vary between 25650Ω-28350Ω. This impacts the circuit because the exact values of the debouncing circuit will be altered through propagation of error. The scope also has a degree of uncertainty. This means that the exact values measured on the scope may be just a little bit off. Additionally, all components utilized are impacted by their temperature.

6 Discussion/Conclusions

The ”debouncing” circuit was quite effective at smoothing voltage change over time. Additionally, since the circuit is both cheap and easy to construct, all electrical engineers should have this tool in their back pocket whenever working with buttons. There really is no excuse for unintentional button bounce.

At the end of the day, you might not ever get your money back from that sketchy arcade machine. However, the engineers behind it were obviously not competent, so you are probably better of staying away from that cabinet anyway.