Lab 10 RC Step Response

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Introduction

Understanding the step response of R-C circuits is crucial to understanding more complex circuits and gives insight into the physical properties of capacitors (i.e. what they actually *do* over time, and not just how they settle into steady-state configurations).

Capacitor and Resistor Calculations

To find a capacitor and resistor value, we start with the step response equation:

$$V(t) = V_{\text{inf}} + [V_0 - V_{\text{inf}}]e^{-\frac{t}{\tau}} \qquad \tau = RC$$

Assuming we start at 0 V and that the maximum voltage is 5 V:

$$V(t) = 5 + [0 - 5]e^{-\frac{t}{RC}}$$

Given the time to reach 50% of 5 V (2.5 V):

$$2.5 = 5 + -5e^{-\frac{10\times10^{-6}}{RC}} \implies 1 = 2e^{-\frac{10\times10^{-6}}{RC}}$$

$$\ln 1 = \ln\left(2e^{-\frac{10\times10^{-6}}{RC}}\right) \implies 0 = \ln 2 - \frac{10\times10^{-6}}{RC}$$

$$RC\ln 2 = 10\times10^{-6} \implies \boxed{RC = 14.427\,\mu\text{s}}$$

If the capacitor is set at **0.01 micro-Farads**, then it follows that the resistor must be **1442.7 ohms**.

Square Wave Calculations

Assuming a capacitor is "fully charged" at $t = 5\tau$ and that the square wave's period includes both a positive and negative section:

$$t = 5 \times 14.427\,\mu\text{s} = 72.135\,\mu\text{s}$$

$$T = 2 \times 72.135\,\mu\text{s} = 144.27\,\mu\text{s}$$

$$f = \frac{1}{T} \implies \boxed{f = 6.931\,\text{kHz}}$$

Results

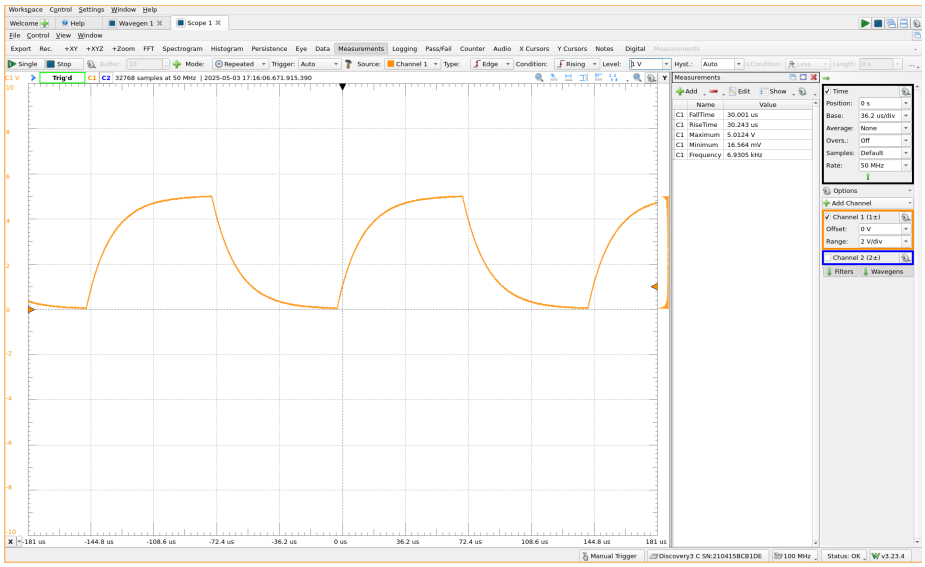

Figure 1: Oscilloscope View

Conclusion (Ceramic vs Electrolytic Capacitors)

Ceramic capacitors use ceramic as the dielectric between the conducting plates whereas electrolytic capacitors use a thin oxide layer on metal as the dielectric. The polarity determines which way the voltage drop/gain across a capacitor must face. For ceramic capacitors, this direction doesn't matter, and so they are said to be non-polarized. Electrolytic capacitors, on the other hand, do have a

polarity, and need to be placed in a circuit where the positive and negative (or smaller voltage) nodes match the capacitor.