ELEC ENG 2CJ4 Circuits and Systems Lab 4

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Section L01

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Introduction

Oscillator circuits are essential components in analog electronics, widely used to generate periodic waveforms such as square, sine, and triangular signals. In this lab, we investigate the behavior of a relaxation oscillator using an operational amplifier (Op-Amp), resistors, and a capacitor. By analyzing the circuit in Fig. 9 from the Lab Manual, we aim to calculate the theoretical time period *T* and frequency *f* of oscillation and validate these values through experimental measurement using the AD3. The voltage across the capacitor and the output voltage will be observed and plotted over time. Furthermore, we explore the feasibility of generating a triangular waveform by modifying the circuit and incorporating an additional LM358P Op-Amp.

Question 1: Given the circuit in Fig. 9, calculate the period *T* and frequency *f* of the oscillator.

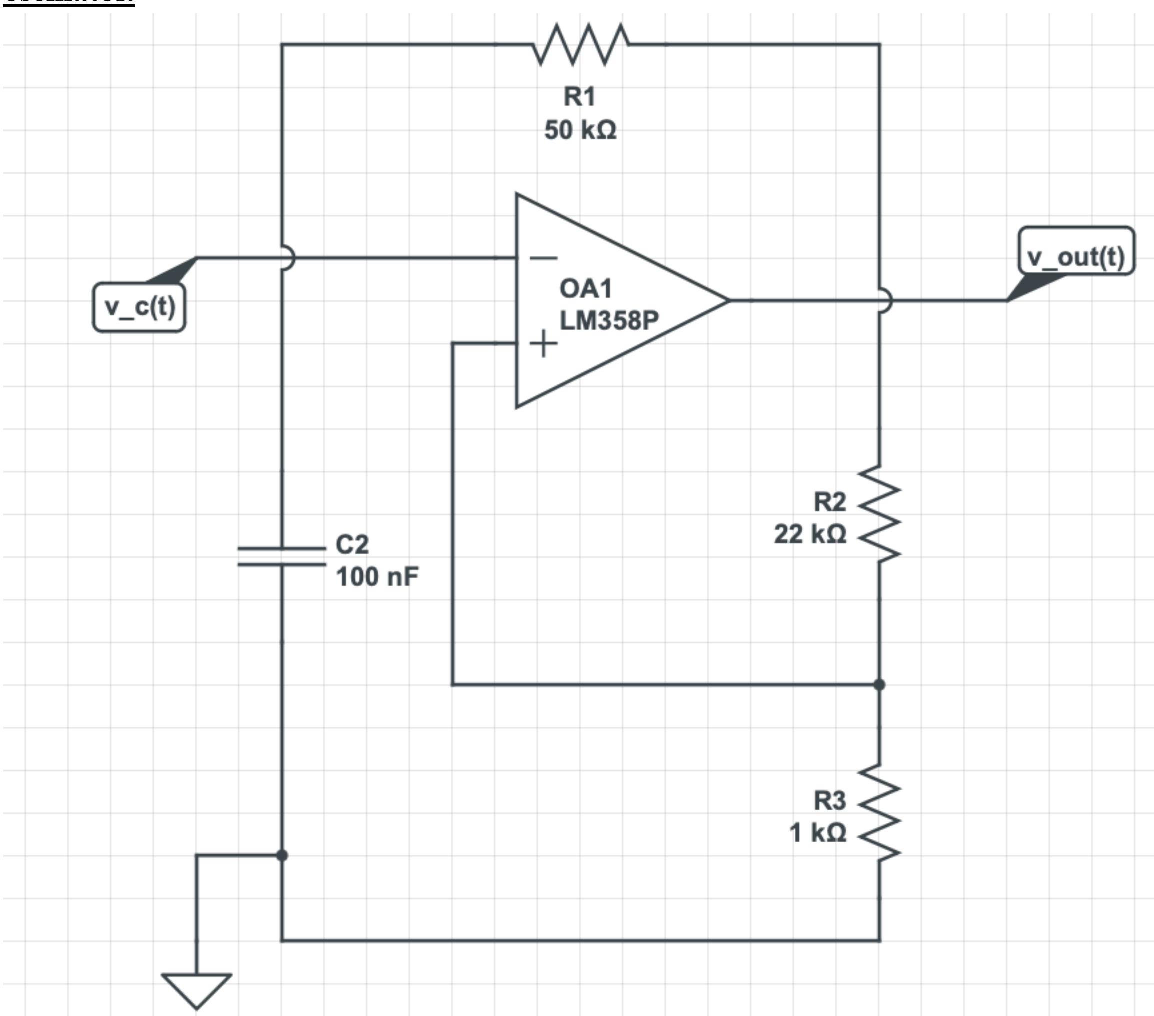

Figure 1: Circuit schematic

Calculate V_{th1} and V_{th2}

$$V_{th1} = \frac{R_1}{R_1+R_2} V_{sat+}$$

$$= \frac{1k}{1k+22k} \cdot 5$$

$$= 0.217V$$

$$V_{th2} = \frac{R_1}{R_1+R_2} V_{sat-}$$

$$= \frac{1k}{1k+22k} \cdot -5$$

$$= -0.217V$$

Calculate Time Period

$T_1 = C \cdot R \cdot ln(\frac{V_{sat+} - V_{th2}}{V_{sat+} - V_{th1}})$ where C = 100nF and R = 50kΩ

$$= (100n)(50k)ln\left(\frac{5-(-0.217)}{5-0.217}\right) = 4.34 \ \cdot 10^{-4}\ s$$

$T_1 = C \cdot R \cdot ln(\frac{V_{sat-} - V_{th1}}{V_{sat-} - V_{th2}})$ where C = 100nF and R = 50kΩ

$$= (100n)(50k)ln\left(\frac{-5-0.217}{-5-(-0.217)}\right) = 4.34 \ \cdot 10^{-4}\ s$$

$$T_{tot} = T_1 + T_2 = 4.34 \cdot 10^{-4} + 4.34 \cdot 10^{-4} = 0.868\ ms$$

Circuit Frequency

$$f = \frac{1}{T_{tot}} = \frac{1}{0.868m} = 1.152\ kHz$$

<u>Question 2: Build the circuit in Fig. 9 and plot the voltage of the capacitor and the output voltage with respect to time (assuming V_{sat}=±5V). Measure the time period *T* using the Analog Discovery 2 and compare it to the theoretical result.</u>

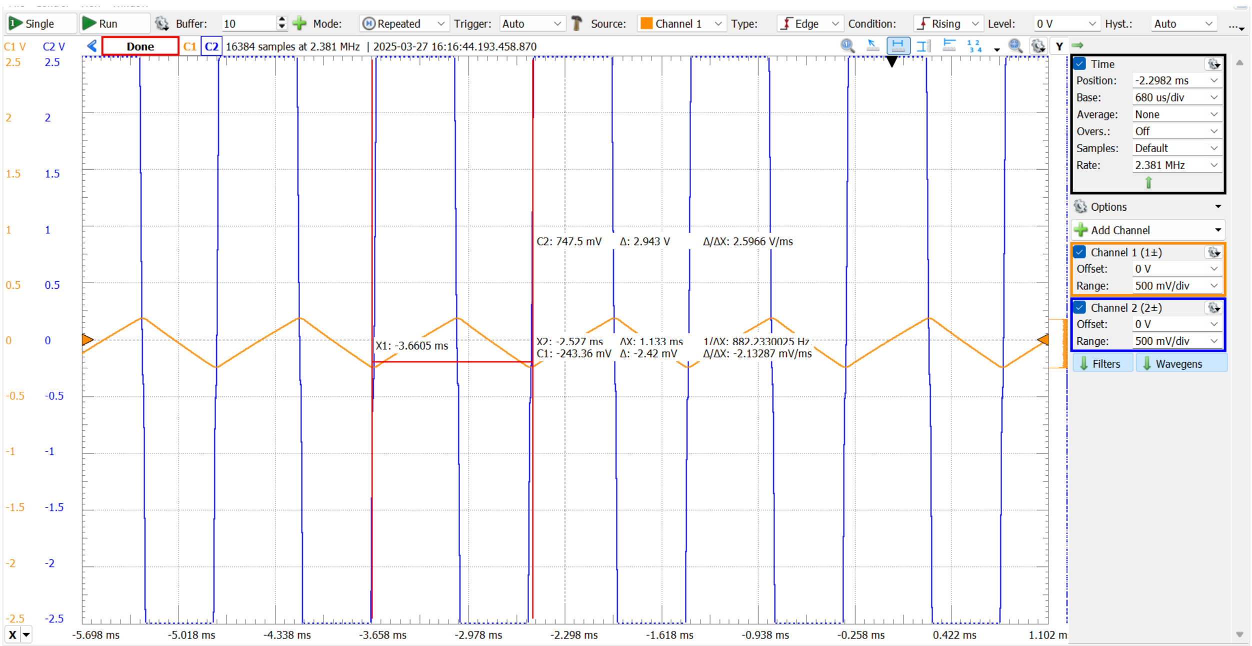

Figure 2: AD3 Waveform output

Looking at Figure 2, the measured time period, T, is 1.133 ms as seen by the ΔX value. The measured value is very similar to the calculated value of 0.868 ms with a percent error of 30.53% using the percent error formula in Figure 3. Reasoning for these discrepancies may be due to factors such as inaccurate measurements within the scope graph, which can be seen as the measured X values do not exactly align with the graph, internal resistance of components, fluctuations within op-amp values or resistor tolerances.

$$\boxed{Percent\ error = \frac{|Meaured - Actual|}{|Actual|} \cdot 100\%}$$

Figure 3: Percent error formula

Question 3: Can you build a circuit by using another Op-Amp LM358P to generate a triangular output? Explain.

Yes, you can build a circuit by using another Op-Amp LM358P to generate a triangular output, which would be a dual Op-Amp. This can be done by configuring one Op-Amp as a Schmitt Trigger and the other as an integrator. The Schmitt Trigger would produce a square wave output, which then serves as the input to the integrator. The integrator processes this square wave by generating a continuous ramp-up and ramp-down response due to the constant high and low states of the input signal. As a result, the output of the integrator forms a triangular waveform, combining two LM358P Op-Amps to create a triangular output.