Set 3 - Lab Report

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ELECENG 2CJ4 - Circuits and Systems

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Introduction

The purpose of this lab is to analyze integrator circuits and their behaviors with different waves. The integrator produces an output which integrates its input with respect to time. Triangular and sine waves with amplitudes of ±1V. The output is first calculated theoretically which is then compared using the Analog Discovery. Additionally, it aims to explore its behavior at lower frequencies.

Working Principle of the Circuit

The input voltage is applied through R_3, connected to the inverting terminal, the virtual ground. In an ideal integrator, the capacitor is placed in the feedback loop. R_4 is connected in parallel with the capacitor for stability. If R_4 is not included, the circuit would be insatiable due to high gain. The output voltage of the integrator circuit is given below.

$$V_o(t) = -\frac{1}{R_3 \times C_3}\int V_{in}(t)dt$$

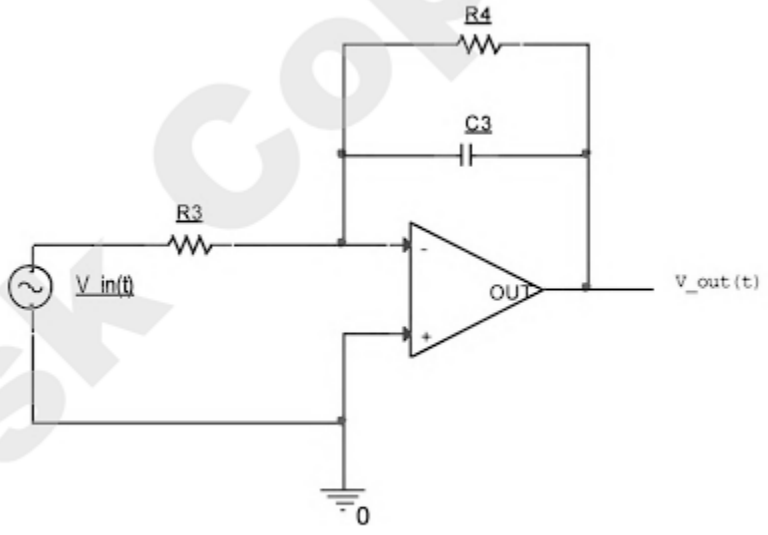

Figure 1: Integrator Circuit

Experiment

1. Given the circuit in Figure 4, assume R_3 = 10kΩ, R_4 = 2.2MΩ., C_3 = 100nF(104), V_{cc}^{+} = 5F, and V_{cc}^{-} = - 5V. Consider two types of inputs: 1) a square wave, 2) a sine wave (both with frequency of 1 KHz and peak-to-peak amplitude of 2V). Determine the output voltage and plot the relationship between the input voltage and the output voltage.

$$V_o = -\frac{1}{R_3 C}\int V_{in}\,dt$$

$$V_o = -\frac{1}{(10k)(100n)}\int V_{in}\,dt$$

$$V_o = -\,1000\int V_{in}\,dt$$

Square Wave (±1V)

$$V_o = -\,1000\int (1)\,dt \qquad V_o = -\,1000\int (-\,1)\,dt$$

$$V_o = -\,1000t \qquad V_o = \,1000t$$

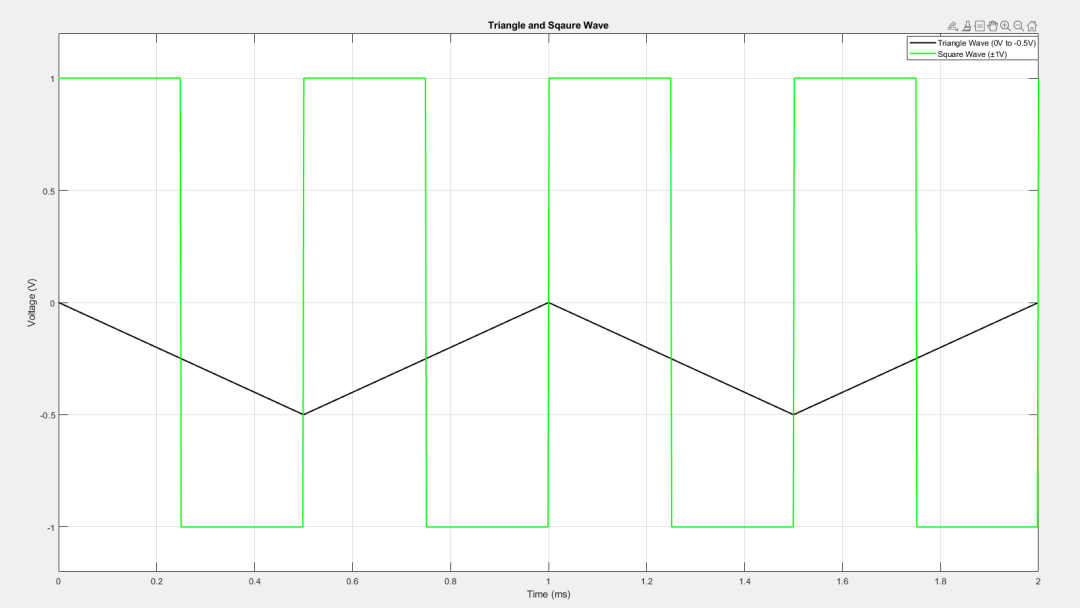

Figure 2: Triangle Wave From Square Wave

Sine Wave

$$V_o = -\ 1000 \int sin(2\pi(1k)t)dt$$

$$V_o = -\frac{1}{2\pi} cos(wt)$$

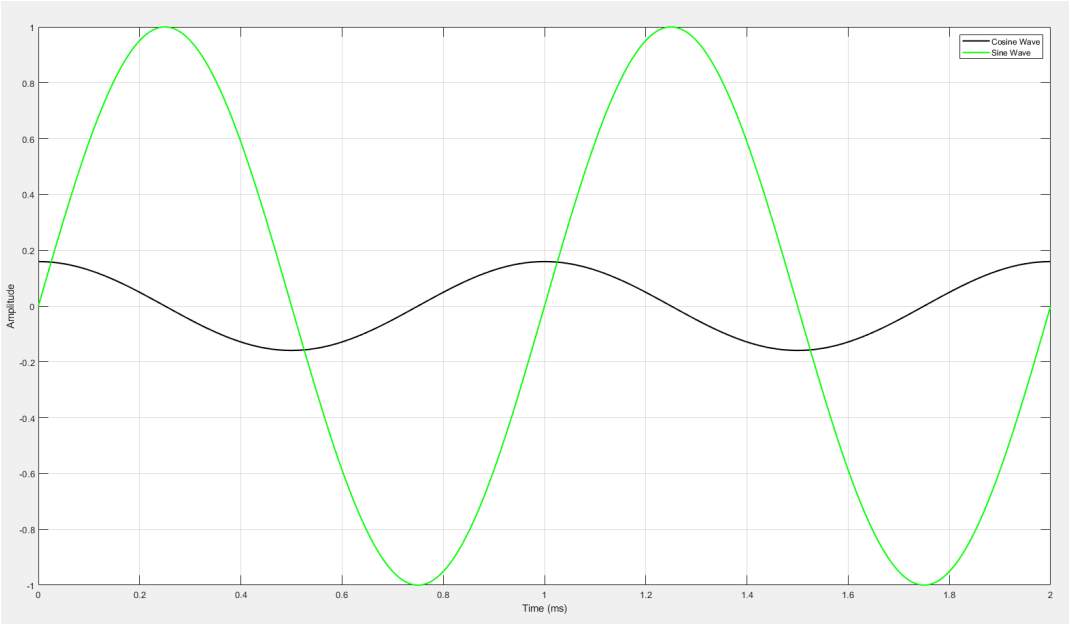

Figure 3: Cosine Wave from Sine Wave

2. Build the circuit in Figure 4 using the analog discovery 3 and measure the corresponding outputs. Compare your theoretical analysis with your measured responses.

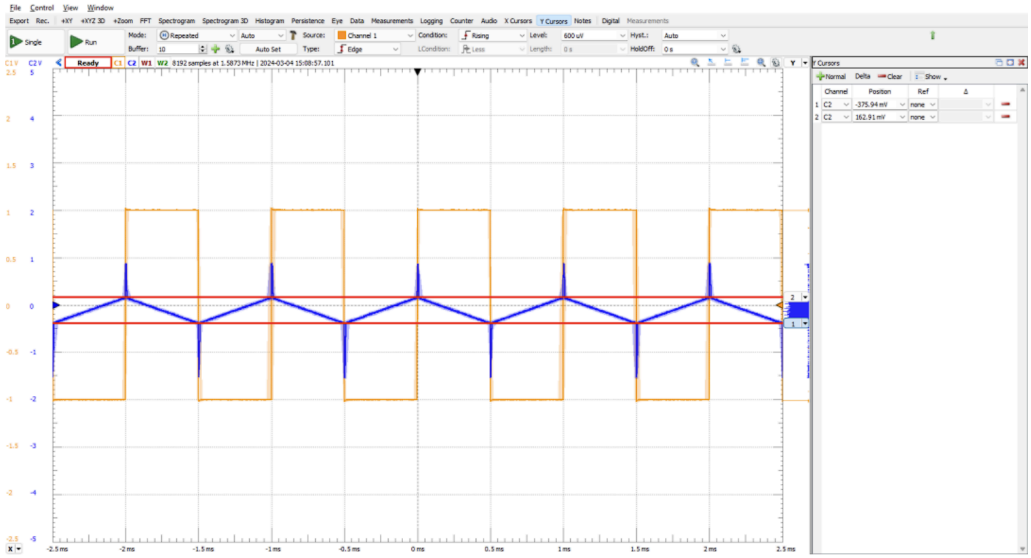

Figure 4: Square Wave Output

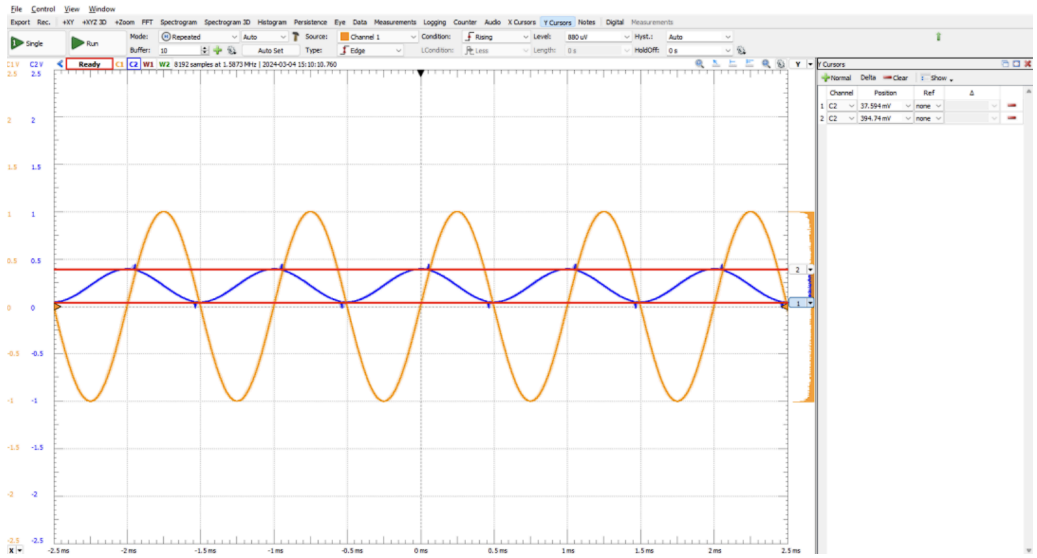

Figure 5: Sine Wave Output

As seen in the oscilloscope output in Figures 2 and 3, the outputs mostly align with the theoretical outputs. The amplitudes, phase, and periods are similar. The only issue is that the triangular wave is only supposed to be in the negative section, and the cosine wave should only be in both. However, this is not the case. The triangular wave bleeds through the negative y-axis and the sine wave only stays in the positive y-axis.

3. Set the frequency to 10 Hz or lower. Check whether the integrator functions properly and explain your findings.

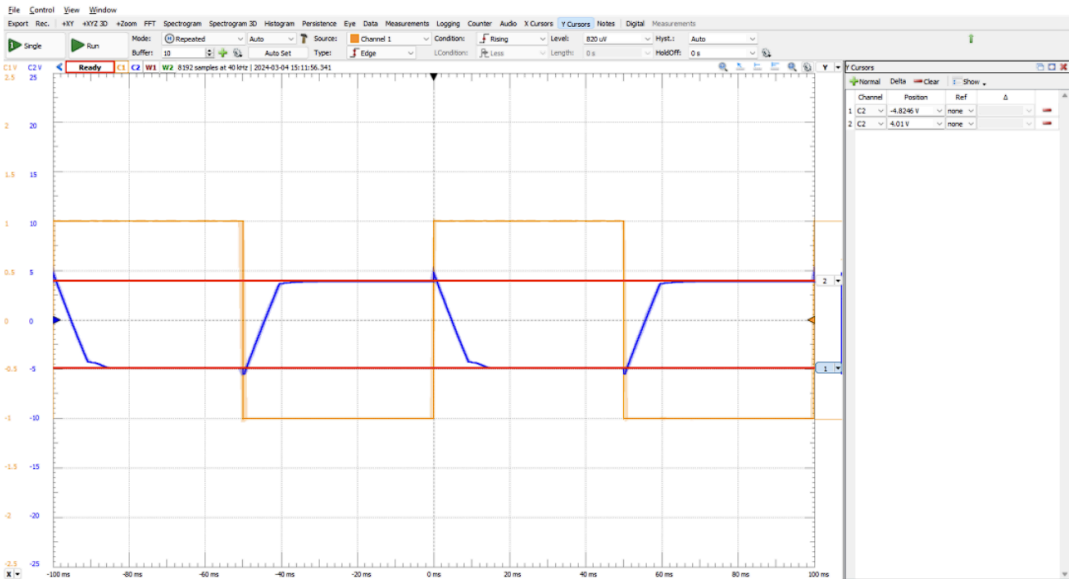

Figure 6: 10 Hz Square Wave

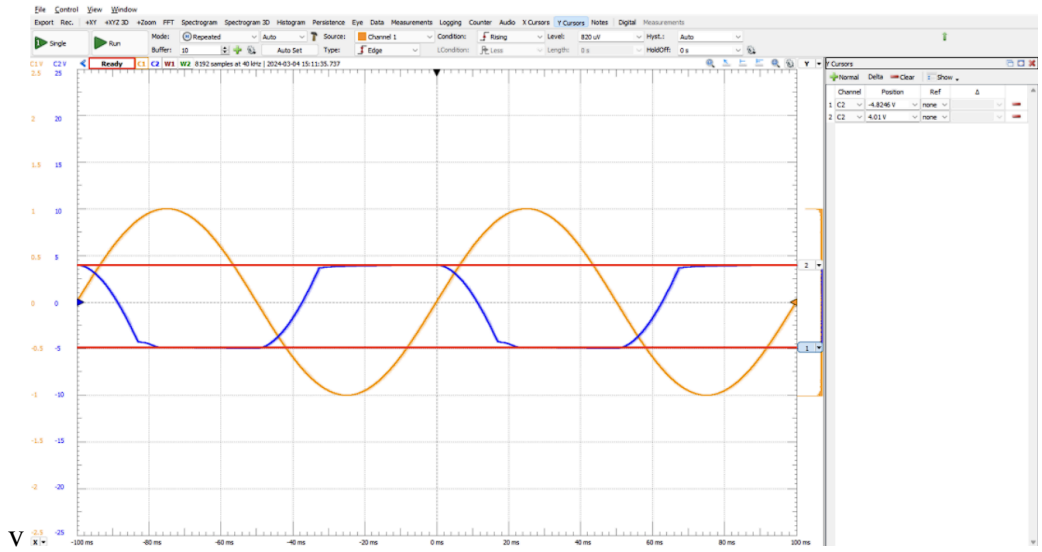

Figure 7: 10 Hz Sine Wave

Once the frequency is set to 10 Hz, both waves start to misbehave. This is as the output saturates the operational amplifier at V_{CC} and V_{EE} at ± 5V. Decreasing the frequency of the input signal increases the amplitude for the integrator circuit output increases, saturating the operational amplifier. The charge on the capacitor accumulates which prevents proper integration.

Discussion

The experimental results confirm that the integrator circuit behaves as expected. At 1kHz, a triangular wave is produced from a square wave while a cosine wave is produced from a sine wave. The shapes, magnitudes, and periods overall were similar except for some asymmetry and offset. However, at lower frequencies, such as 10hz, the output saturates to ±5V due to charge accumulation on the capacitor.