RYERSON UNIVERSITY

Faculty of Engineering, Architecture and Science

Department of Electrical and Computer Engineering

Course Number	ELE504
Course Title	Electronic Circuits II
Semester/Year	Fall 2021

Instructor	Dr. Mike Kassam

ASSIGNMENT No.	**7**

Assignment Title	Linear Voltage-Controlled Function Generator (Milestone 4)

Submission Date	October 29, 2021
Due Date	October 29, 2021

Student Name	Reza Aablue
Student ID	500966944
Signature*	R.A.

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<u>Table of Contents</u>

1. Introduction

The report for Milestone 4 of the ELE504 major project, is presented herein. The lab session for this experiment took place on October 29th, 2021.

2. Objectives

The objective of this lab is to design, implement and test the waveform generator design of Milestone 3 with the additional user-controllable frequency range and gain control features. These features are integrated with the previous design to provide an output waveform of 4 volts peak and frequency ranges of 100 Hz to 3100 Hz (range #1) and 20 Hz to 620 Hz (range #2). The waveform generator is tested for verification, where theoretical and experimental results are compared for possible

discrepancies.

3. Prelab Assignment Summary

For the Prelab assignment and the lab, the following data were provided by Mr. Perczak (section 4 TA) for calculations and experimentation, as presented in **Table 3.1**. The following data was used in the Prelab assignment, and the experiment as well.

Table 3.1: Parameter set provided for the Major Project of the ELE504 course.

f_o = 3100 Hz

By observing the two frequency ranges at first, the values of the input resistance for the inverting integrator are calculated to be 706.18 Ω (range #1) and 3530.87 Ω (range #2). The idea, in this case, is to implement a switch to allow the user to alternate between the two frequency ranges. This process achieves the first requirement of Milestone 4.

Next, the values of the inverting bistable multivibrator's resistors are calculated based on the control and high threshold voltage values. Once that has been determined, the gain control requirement is taken into account for the overall design. Using a potentiometer in the gain control circuit, it is possible to control the feedback resistor's value to have a proper peak output voltage for the triangle and square waveforms. The gain control circuit consists of an LM318CN OP-AMP with a negative feedback network, which is directly connected to the integrator and the bistable multivibrator separately. It will control the peak output voltage for both triangular and square waveforms.

4. Experimental Results and Observations

All circuits from the lab manual are created and tested using the Multisim Software environment. The waveform generator design is completed with a switch that allows to alternate between frequency ranges, as the overall design contains 5 OP-AMPs (3 will be in cascading for range #1 and 4 will be in cascading for range #2). **Figures 4.1-4.2** demonstrate the overall circuit schematics for both frequency ranges. Two Multisim files have been used to accommodate for any necessary changes that need to be made when alternating from frequency range #1 to #2 or vice versa. **Figures 4.3-4.14** contain the square and triangular waveforms of the waveform generator (in both frequency ranges), outlining the effective frequency and peak output voltage for each test control voltage (control voltage ranges from 0.1 to 5 volts DC). **Table 4.1** will represent the expected and actual results of frequencies at each test control voltage value for both frequency range #1 and frequency range #2.

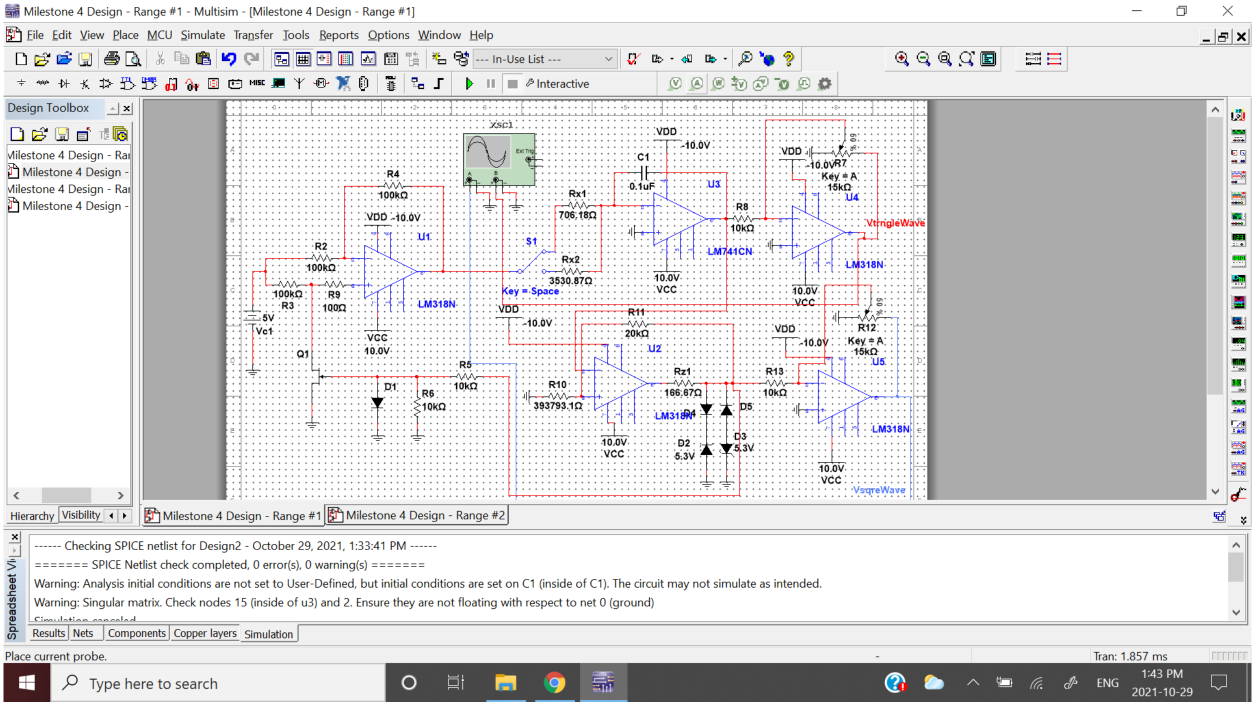

Figure 4.1: Multisim schematic of the waveform generator (frequency range #1).

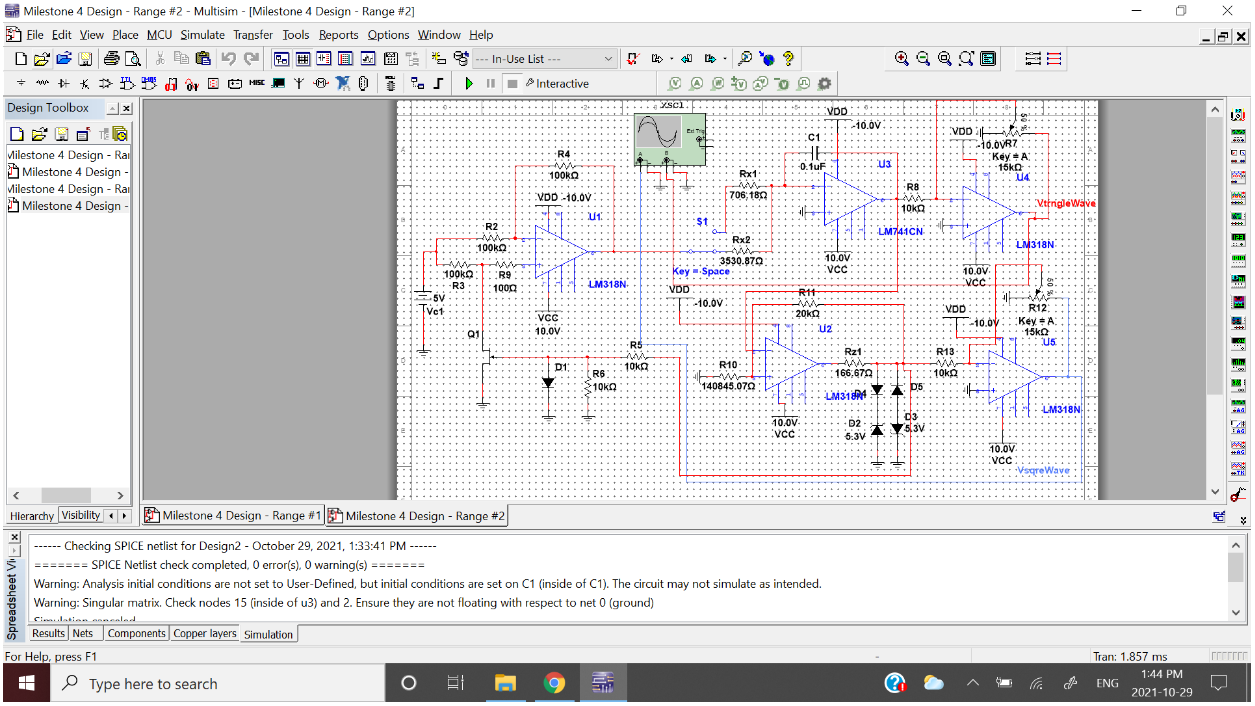

Figure 4.2: Multisim schematic of the waveform generator (frequency range #2).

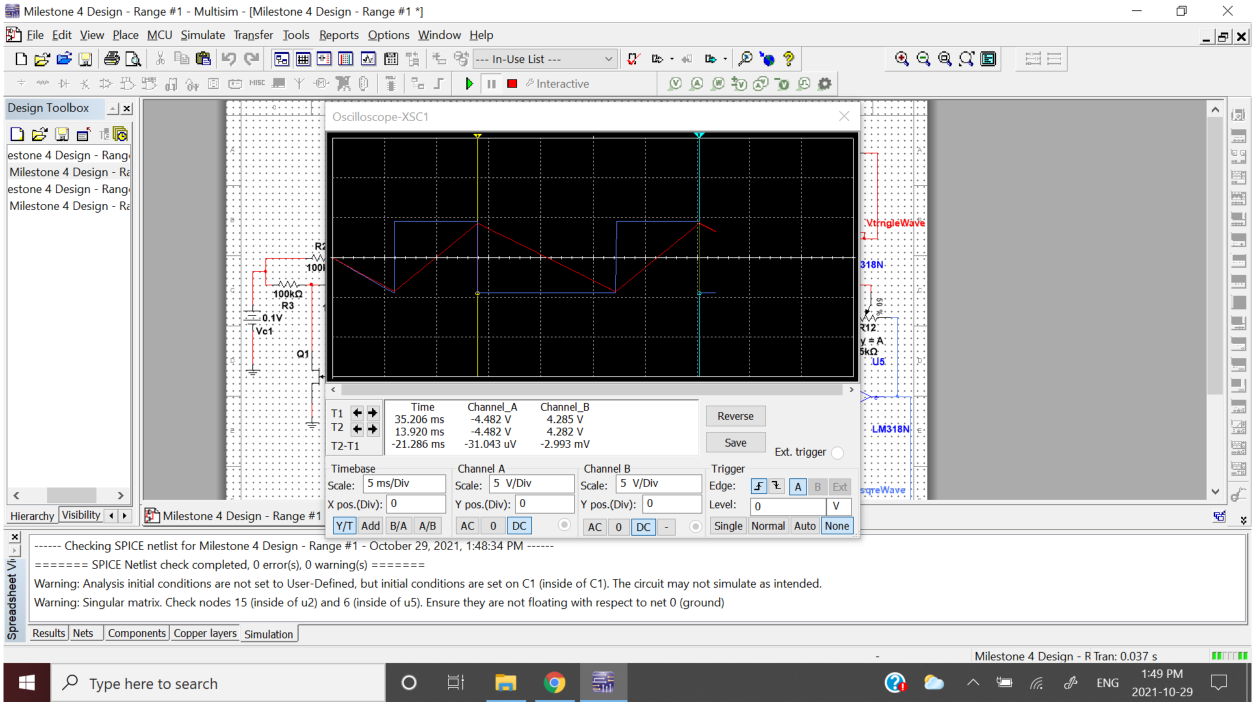

Figure 4.3: Multisim simulation of the waveform generator (testing at 0.1 V, frequency range #1).

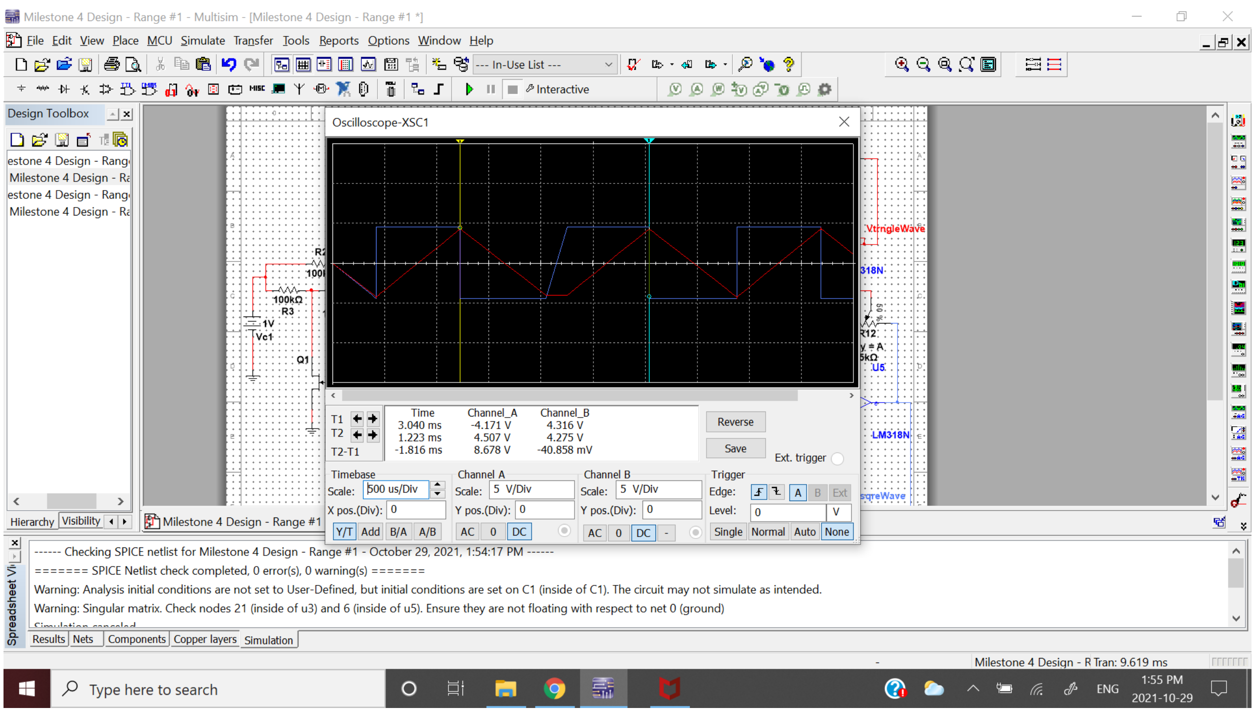

Figure 4.4: Multisim simulation of the waveform generator (testing at 1 V, frequency range #1).

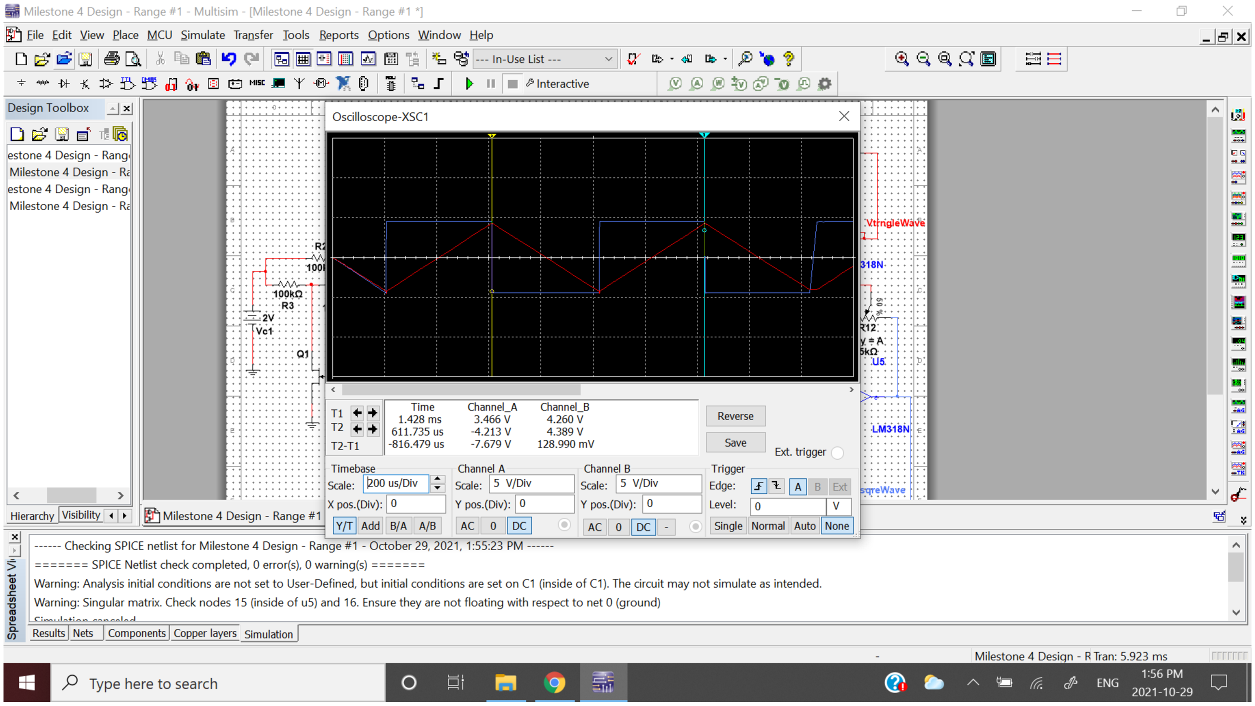

Figure 4.5: Multisim simulation of the waveform generator (testing at 2 V, frequency range #1).

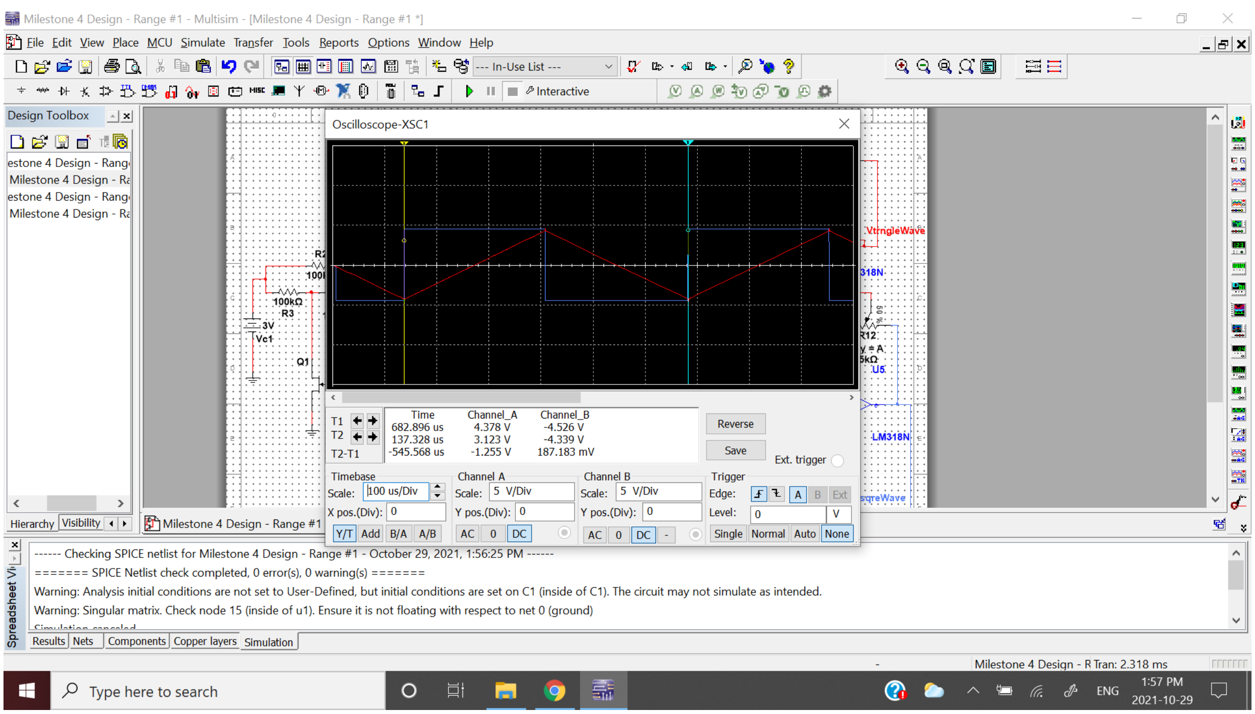

Figure 4.6: Multisim simulation of the waveform generator (testing at 3 V, frequency range #1).

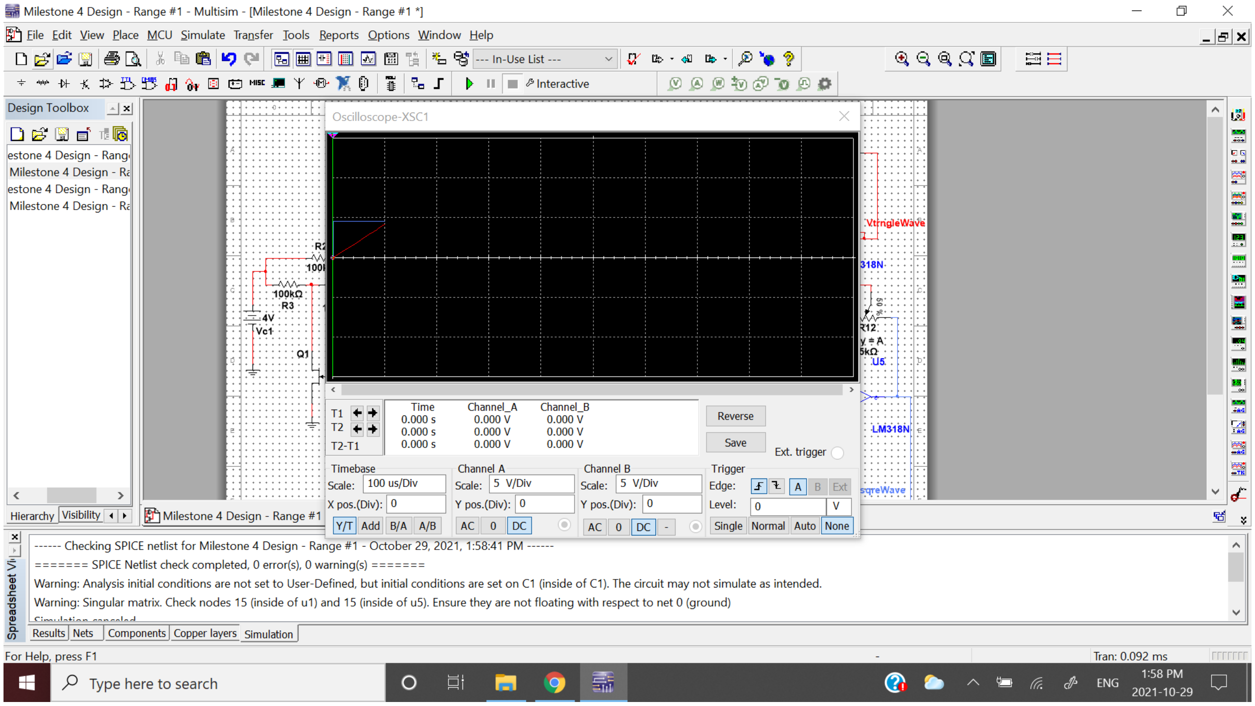

Figure 4.7: Multisim simulation of the waveform generator (testing at 4 V, frequency range #1).

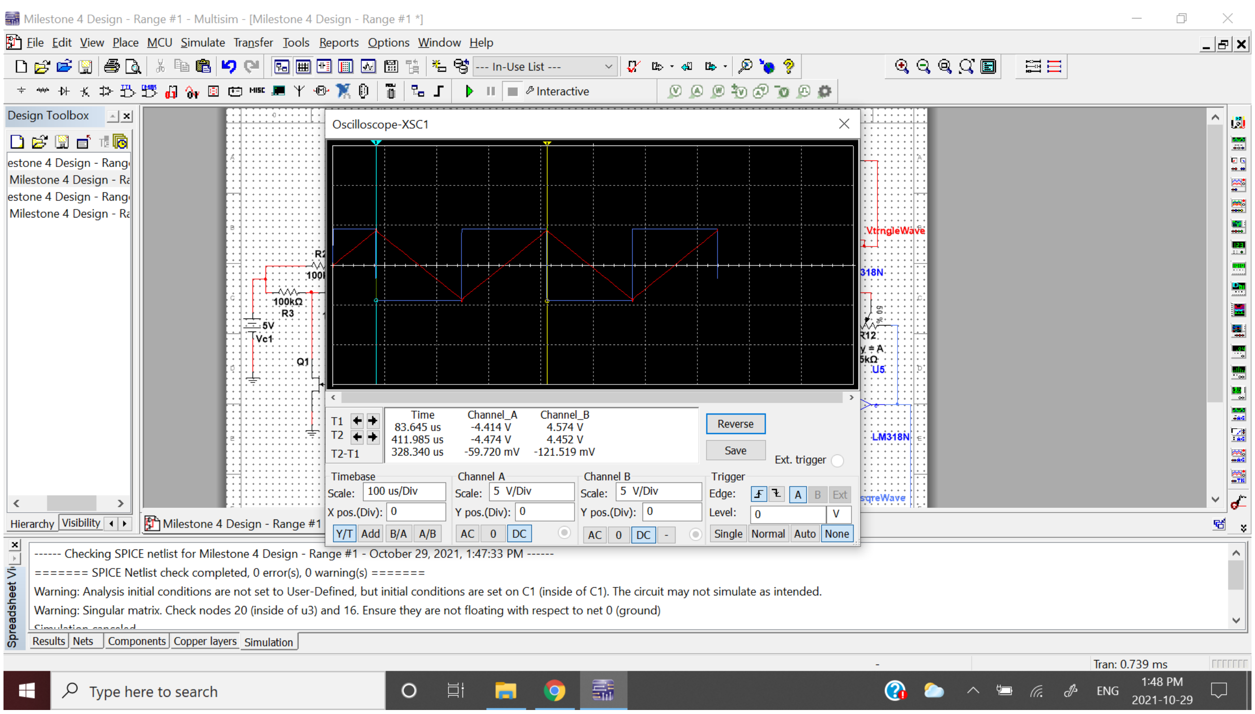

Figure 4.8: Multisim simulation of the waveform generator (testing at 5 V, frequency range #1).

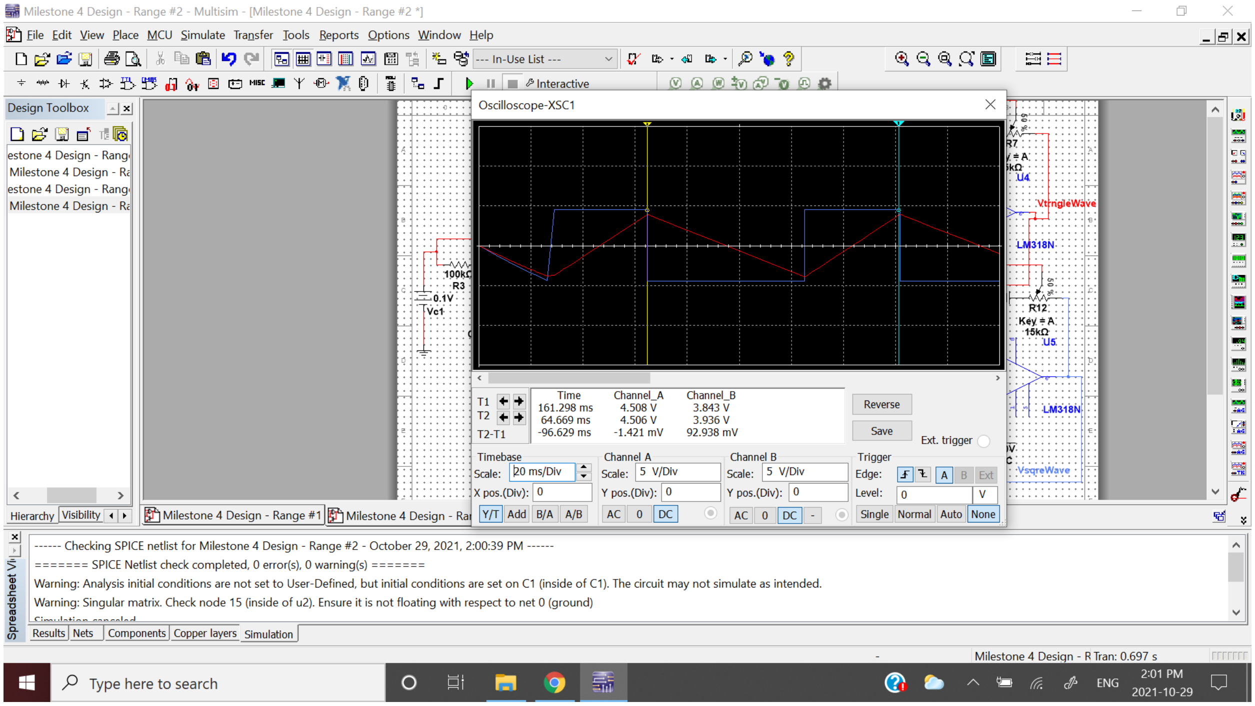

Figure 4.9: Multisim simulation of the waveform generator (testing at 0.1 V, frequency range #2).

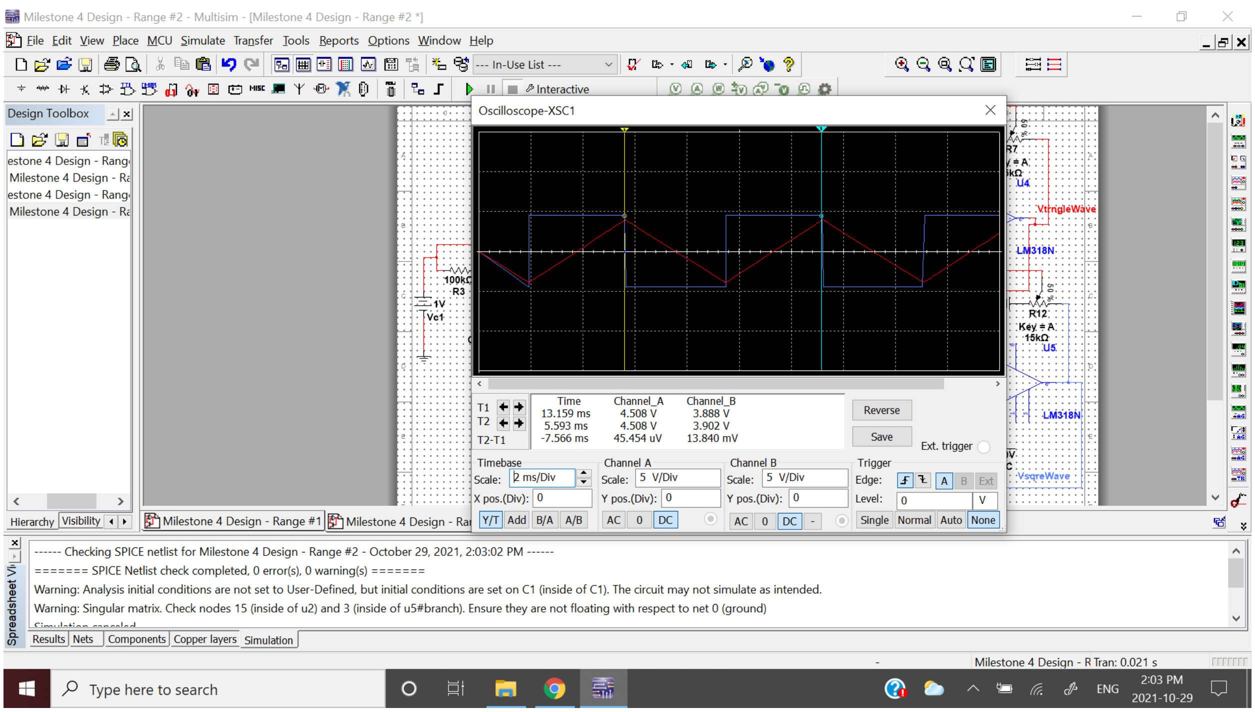

Figure 4.10: Multisim simulation of the waveform generator (testing at 1 V, frequency range #2).

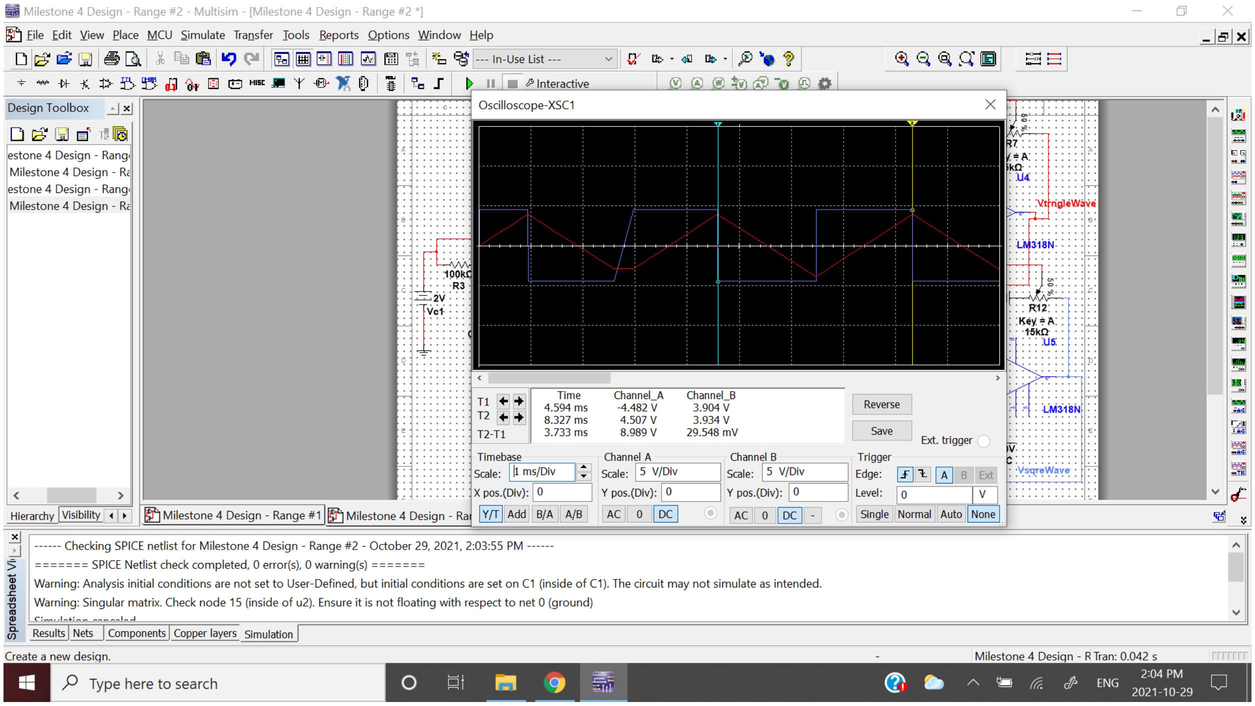

Figure 4.11: Multisim simulation of the waveform generator (testing at 2 V, frequency range #2).

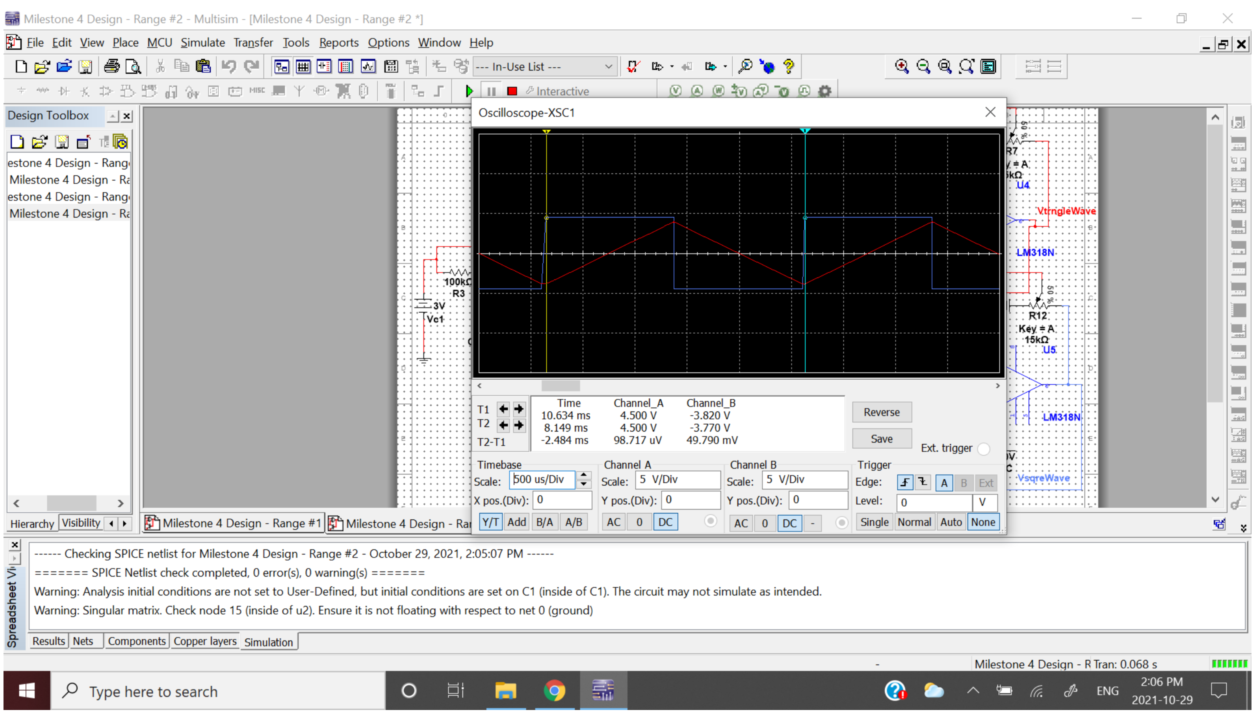

Figure 4.12: Multisim simulation of the waveform generator (testing at 3 V, frequency range #2).

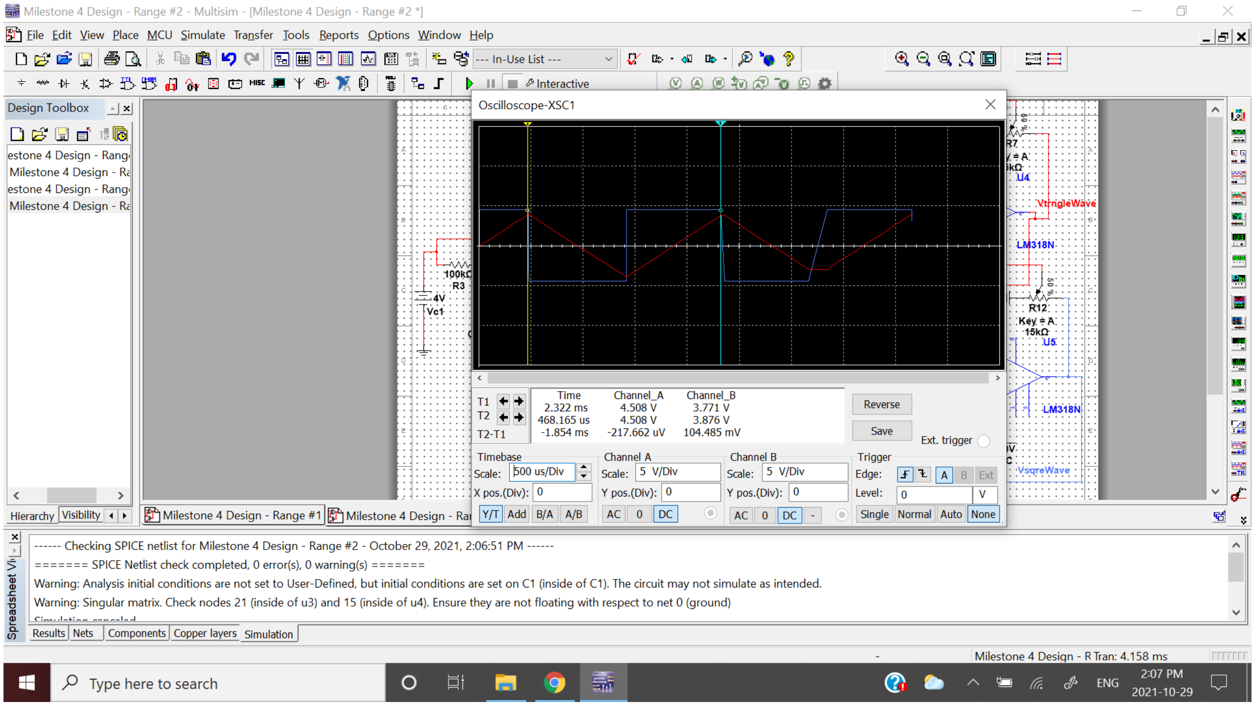

Figure 4.13: Multisim simulation of the waveform generator (testing at 4 V, frequency range #2).

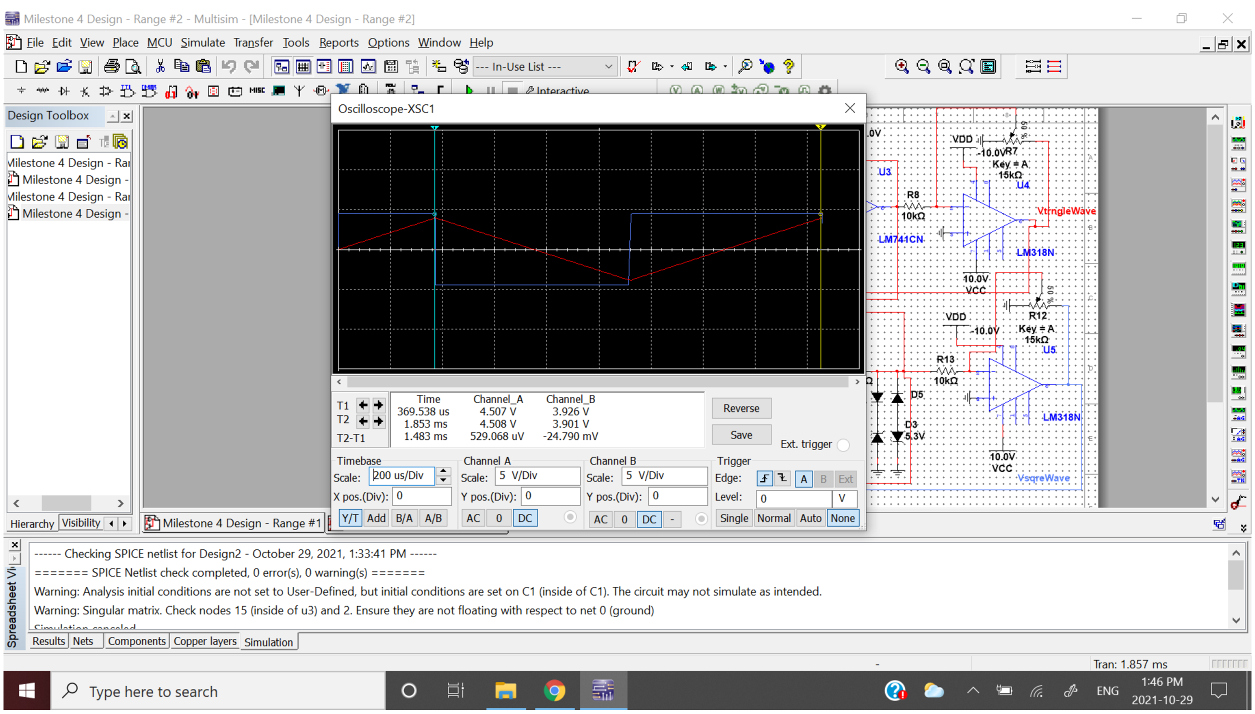

Figure 4.14: Multisim simulation of the waveform generator (testing at 5 V, frequency range #2).

Table 4.1: Expected and actual frequency for control voltage values of 0.1 volts to 5 volts (range #1 and range #2 under examination).

Control Voltage [V]	Expected Frequency (fx range) [Hz]	Actual Frequency (fx range) [Hz]	Expected Frequency (fx/5 range) [Hz]	Expected Frequency (fx/5 range) [Hz]
0.1	62	46.97	12.4	10.35
1	620	550.66	124	132.17
2	1240	1224.77	248	267.88
3	1860	1832.95	372	402.58
4	2480	N/A	496	539.37
5	3100	3045.60	620	672.95

5. Conclusions and Remarks

When comparing the theoretical (Prelab assignment) and the experimental (Multisim) results of this experiment, the design analysis's conclusions have translated to the simulation results in a consistent manner, with some minor discrepancies. There is a recurring issue from Milestone 3 that occurred again, where the waveform for 4 volts test voltage is not correct (despite the correct schematic, the output waveform fails to complete for at least 1 periodic cycle). This issue is not as damaging as before to the overall design, since it did not occur for frequency range #2. In frequency range #1, the actual frequency was slightly below the expected measurements by an average of 2% across all 6 cases, which is not so significant in this design. As for frequency range #2, the actual frequency was slightly above the expected values for each test voltage, by approximately 8% on average in the 6 cases. The peak voltage for square and triangular waveforms is at around 4.5 volts due to the circuit and OP-AMPs' imperfect nature, making it difficult to achieve ideal results. Therefore, through the validation process of this report, it has been decided that the final design for the linear voltage-controlled waveform generator is fairly consistent with the design analysis from the Prelab assignment.