RYERSON UNIVERSITY

Faculty of Engineering, Architecture and Science

# Department of Electrical and Computer Engineering

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

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| Instructor | Dr. Mike Kassam |

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| **ASSIGNMENT No.** | **6** |

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| Assignment Title | Linear Voltage-Controlled Function Generator (Milestone 3) |

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| Submission Date | October 22, 2021 |
| Due Date | October 22, 2021 |

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| Student ID | 500966944 |
| Signature* | R.A. |

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**By: Reza Aablue**

**Date: 22/10/2021**

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## 1. Introduction

The report for Milestone 3 of the ELE504 major project, is presented herein. The lab session for this experiment took place on October 22nd, 2021.

## 2. Objectives

The objective of this lab was to design, implement and test the linear voltage-controlled waveform generator for triangular and square wave outputs. It is built by integrating the two separate components from milestone 2: the fixed-frequency waveform generator and the DC-to-$\pm$DC converter. The waveform generator and its converter component are both 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.**

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|---|
| $f_o$ = 3100 Hz |

When putting together the three components for the overall circuit, all components are used in their inverting configurations to keep the overall loop feedback of the circuit negative. The equation of the transfer function is now relying on the input voltage $V_C$, which is chosen as 5 volts DC. Through the equation, the new value of the inverting integrator's input resistance is calculated.

The Zener diodes' voltages and the resistance value before them are then calculated, using the same methodology as milestone 2. A voltage drop of 0.7 volts constant is assumed for $V_D$ when calculating the Zener diodes' voltages. The results for this section are unchanged.

When observing the DC-to-$\pm$DC converter, the resistance values are all calculated to be the same as for milestone 2, with the same assumptions. For these calculations, the results are again unchanged when compared to milestone 2.

## 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 designed using two LM318 OP-AMPs and one LM741CN OP-AMP. As for the Zener diodes, the 1N4734 model is used. **Figures 4.1-4.6** demonstrate the waveform generator's simulation results (tested at 3100 Hz frequency, from 0.1 to 5 volts control voltage). As for the DC-to-$\pm$DC converter, **Figures 4.7-4.13** demonstrate its simulation results, where the input voltage is incremented from 1 volt to 5 volts (1 volt at a time) to verify and validate its design (tested at 3100 Hz frequency). **Table 4.1** demonstrates the results of the output voltages for the integrator and the bistable, as well as the frequency of the circuit under each control voltage value, ranging from 0.1 to 5 volts.

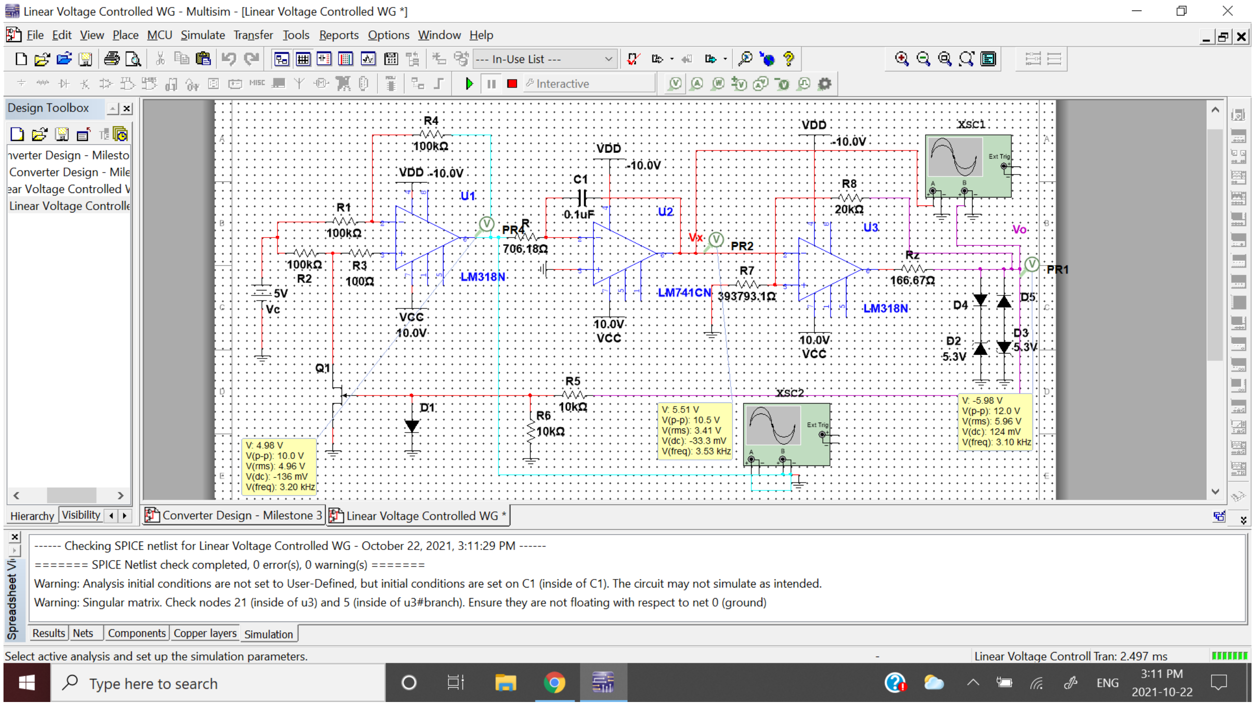


**Figure 4.1: Multisim schematic of linear voltage-controlled waveform generator.**

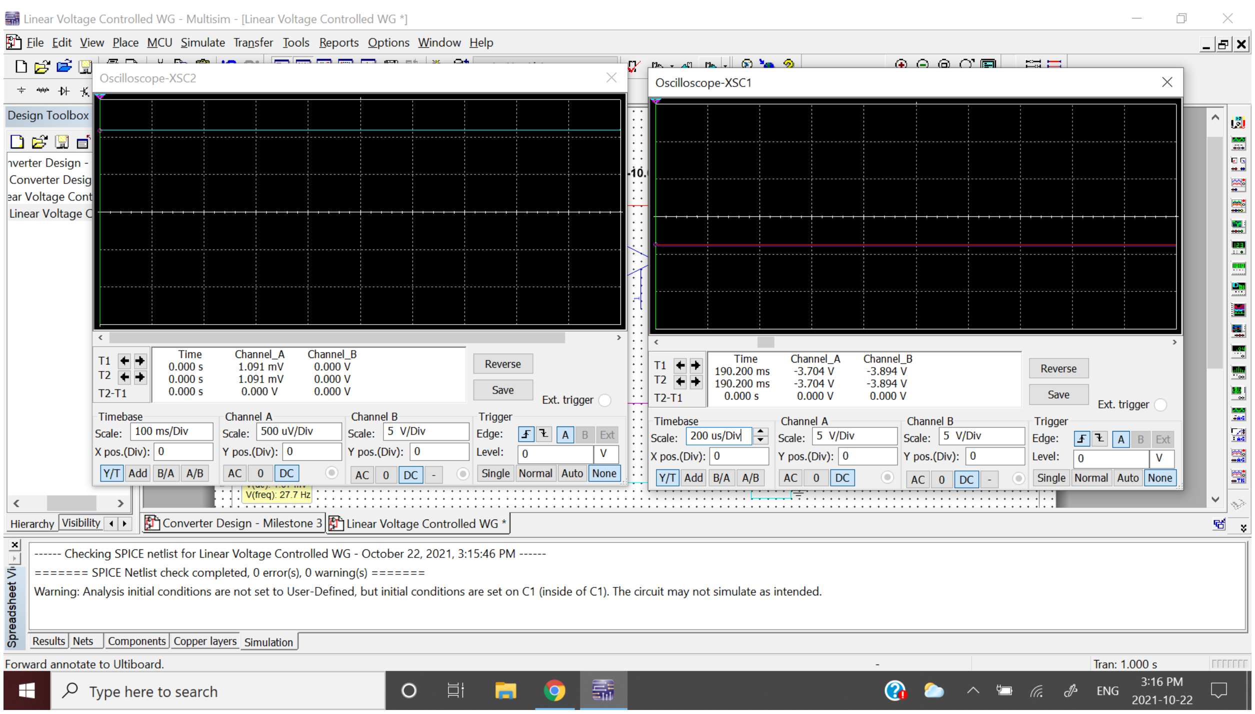


**Figure 4.2: Multisim simulation of linear voltage-controlled waveform generator (testing at 0.1 V).**

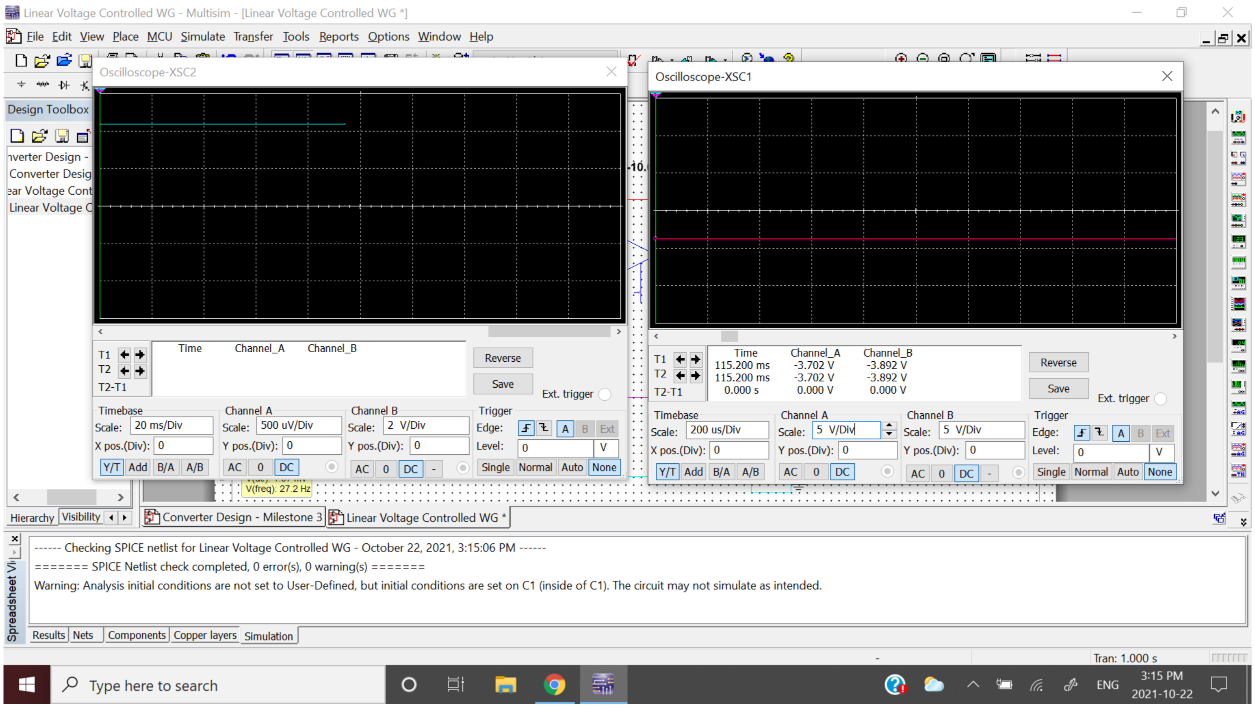


**Figure 4.3: Multisim simulation of linear voltage-controlled waveform generator (testing at 1 V).**

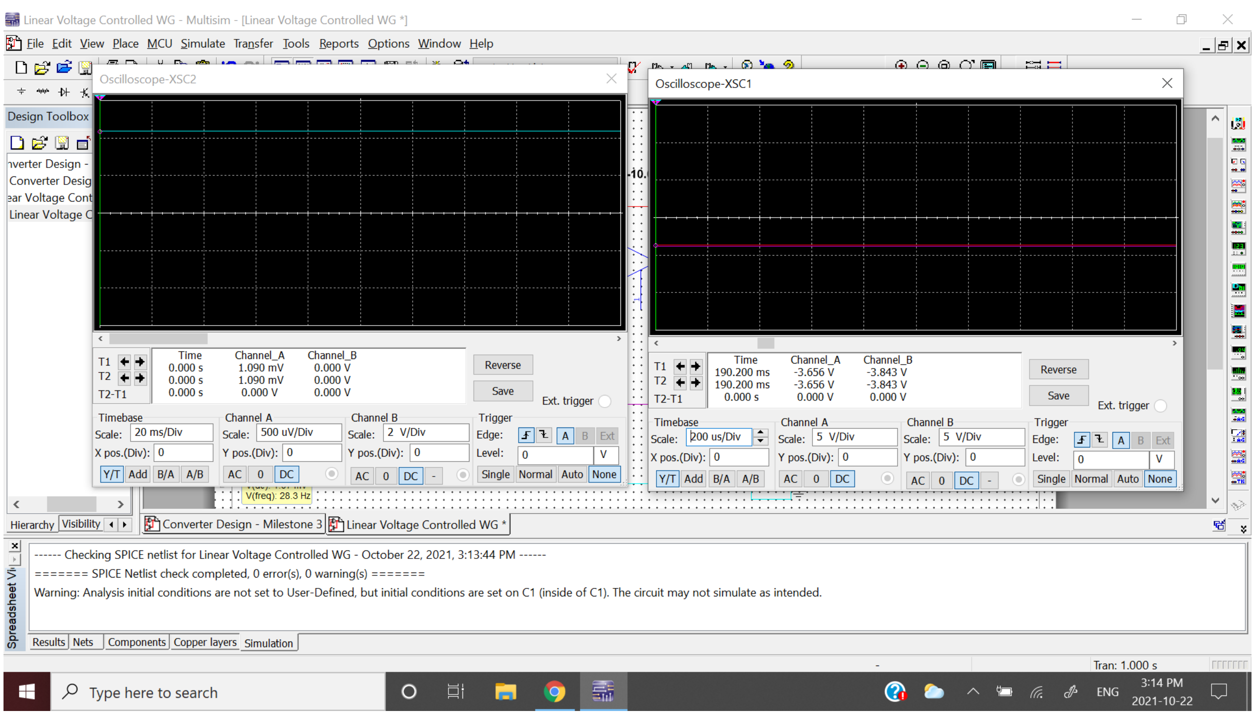


**Figure 4.4: Multisim simulation of linear voltage-controlled waveform generator (testing at 3 V).**

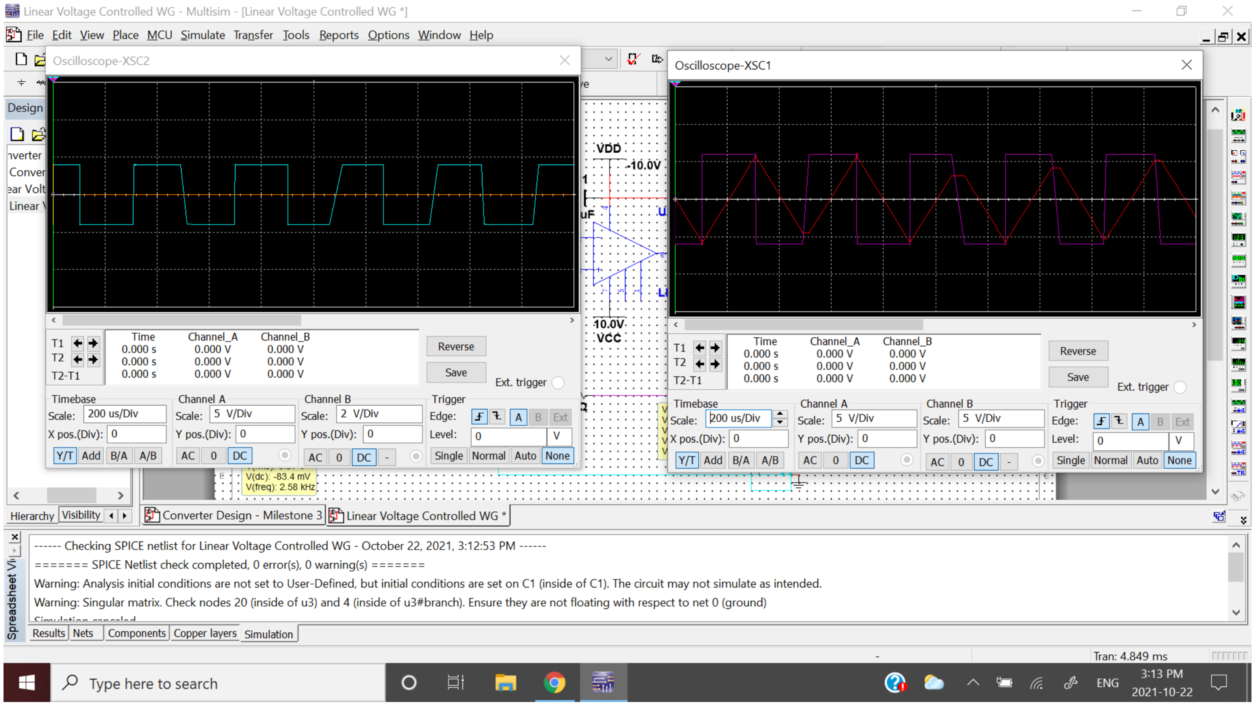


**Figure 4.5: Multisim simulation of linear voltage-controlled waveform generator (testing at 4 V).**

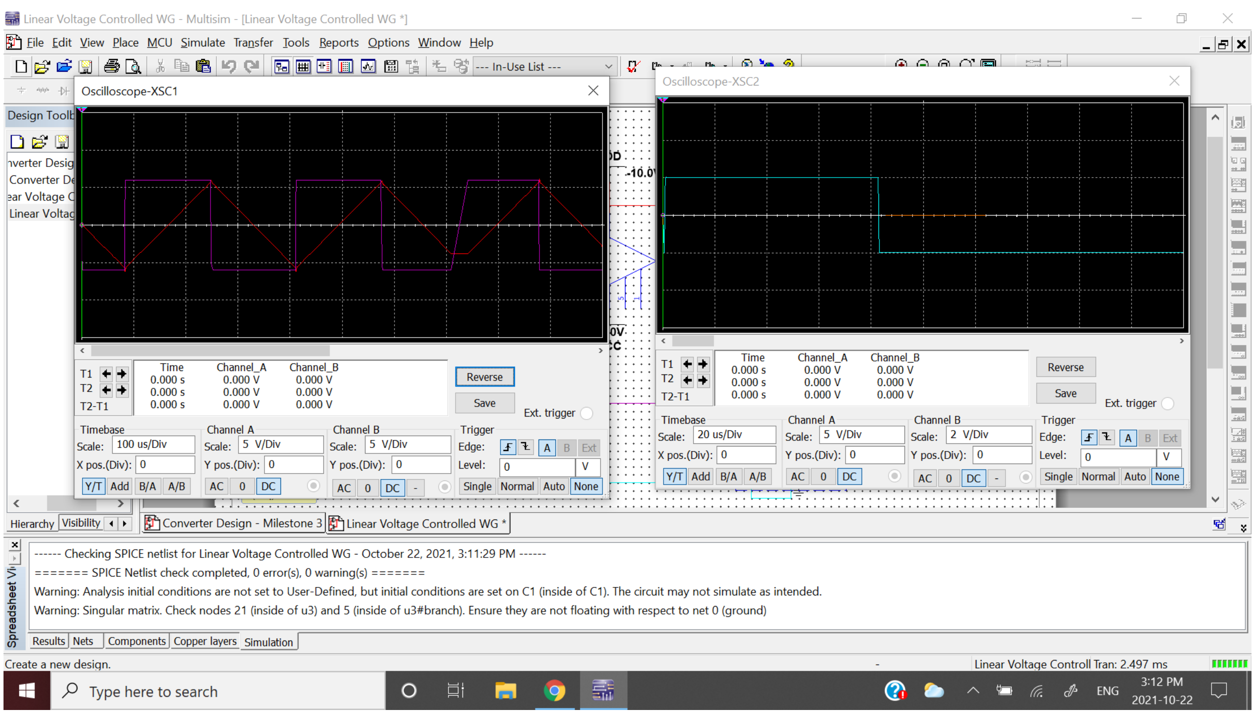


**Figure 4.6: Multisim simulation of linear voltage-controlled waveform generator (testing at 5 V).**

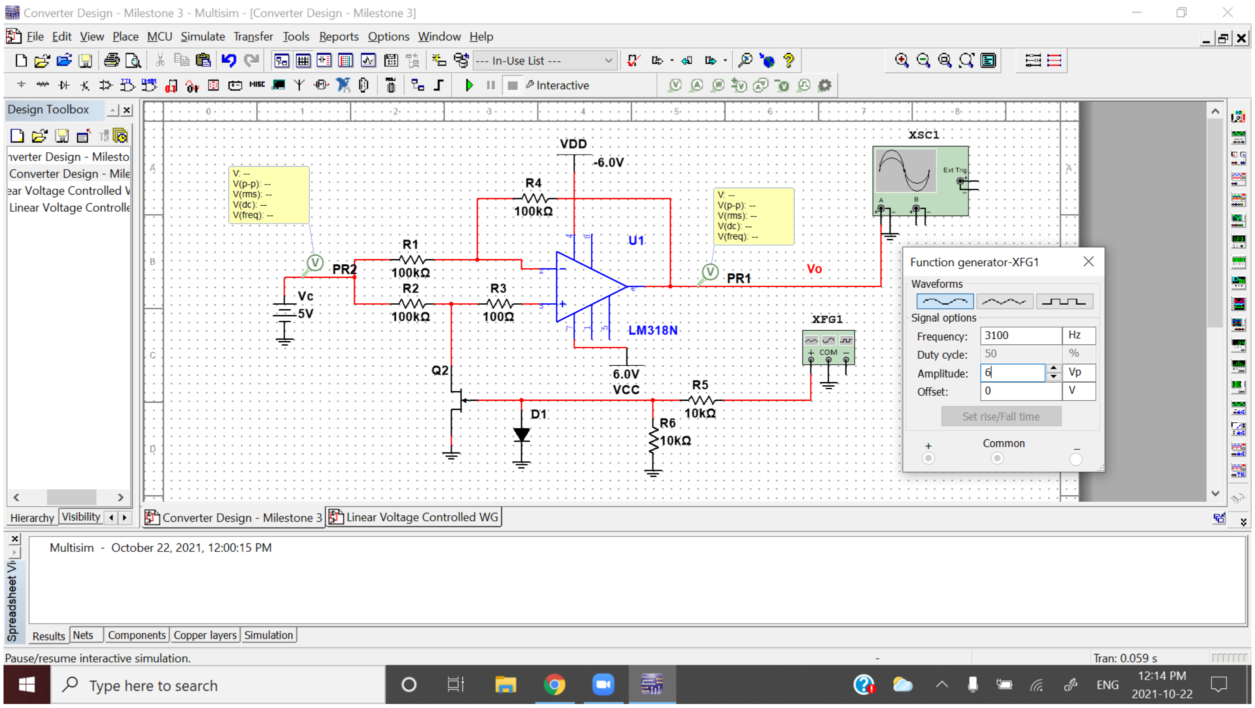

**Figure 4.7: Multisim schematic of DC-to-DC converter circuit.**

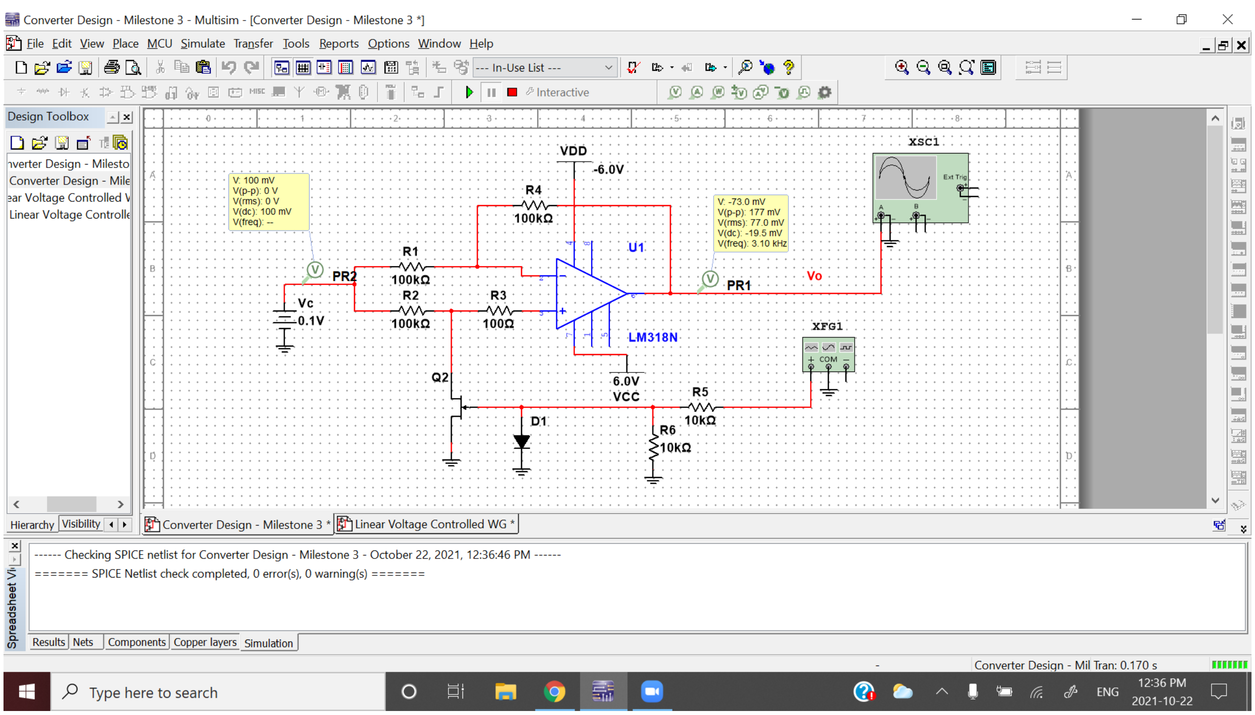

**Figure 4.8: Multisim schematic of DC-to-DC converter - part 1 (testing at 0.1 V, 3100 Hz).**

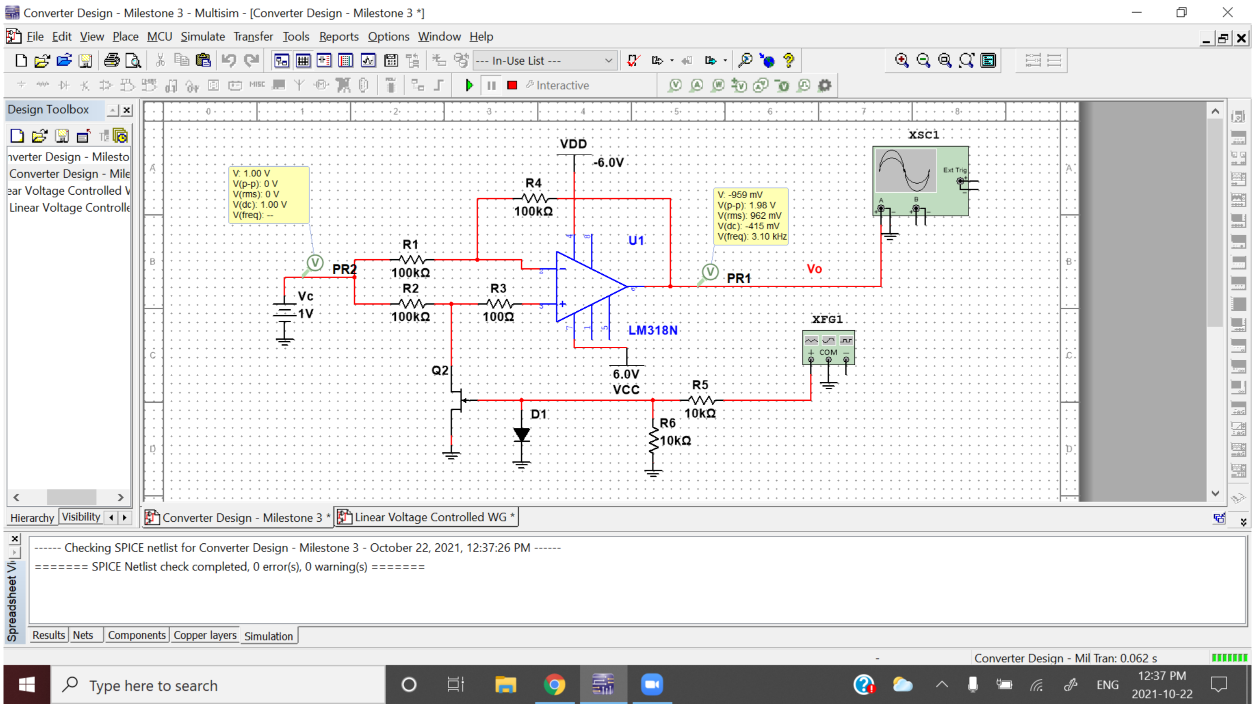


**Figure 4.9: Multisim schematic of DC-to-DC converter - part 2 (testing at 1 V, 3100 Hz).**

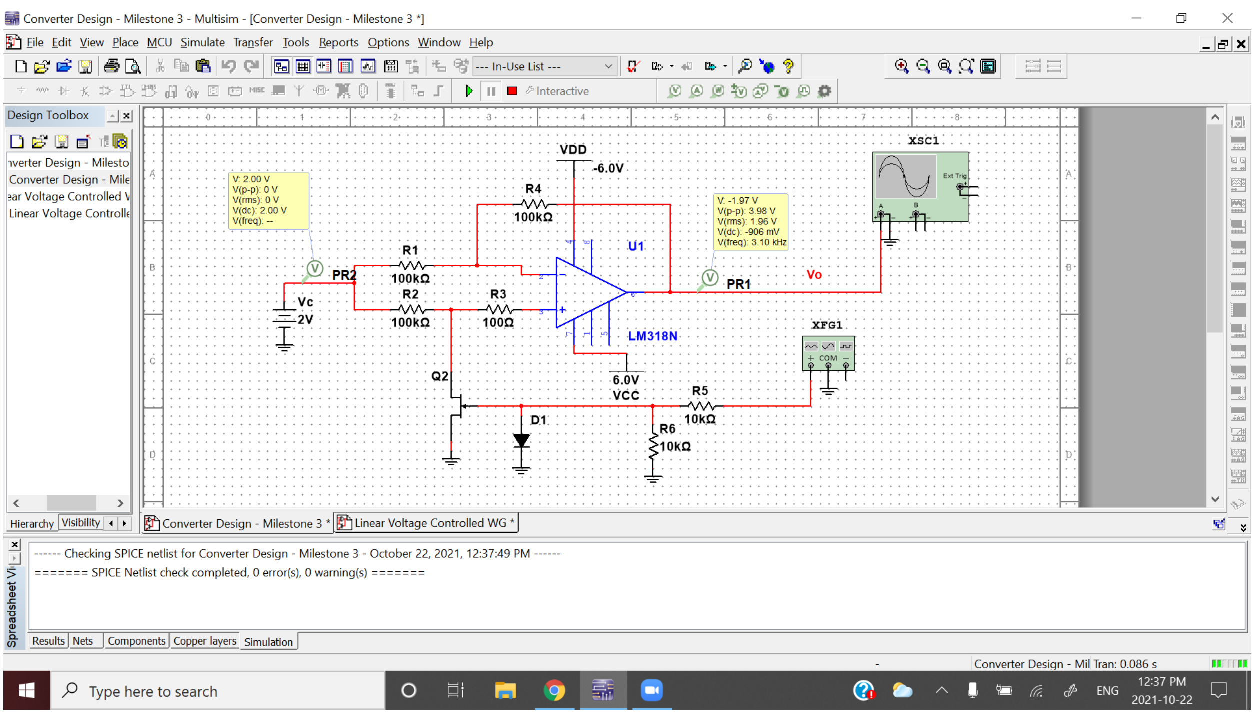


**Figure 4.10: Multisim schematic of DC-to-DC converter - part 3 (testing at 2 V, 3100 Hz).**

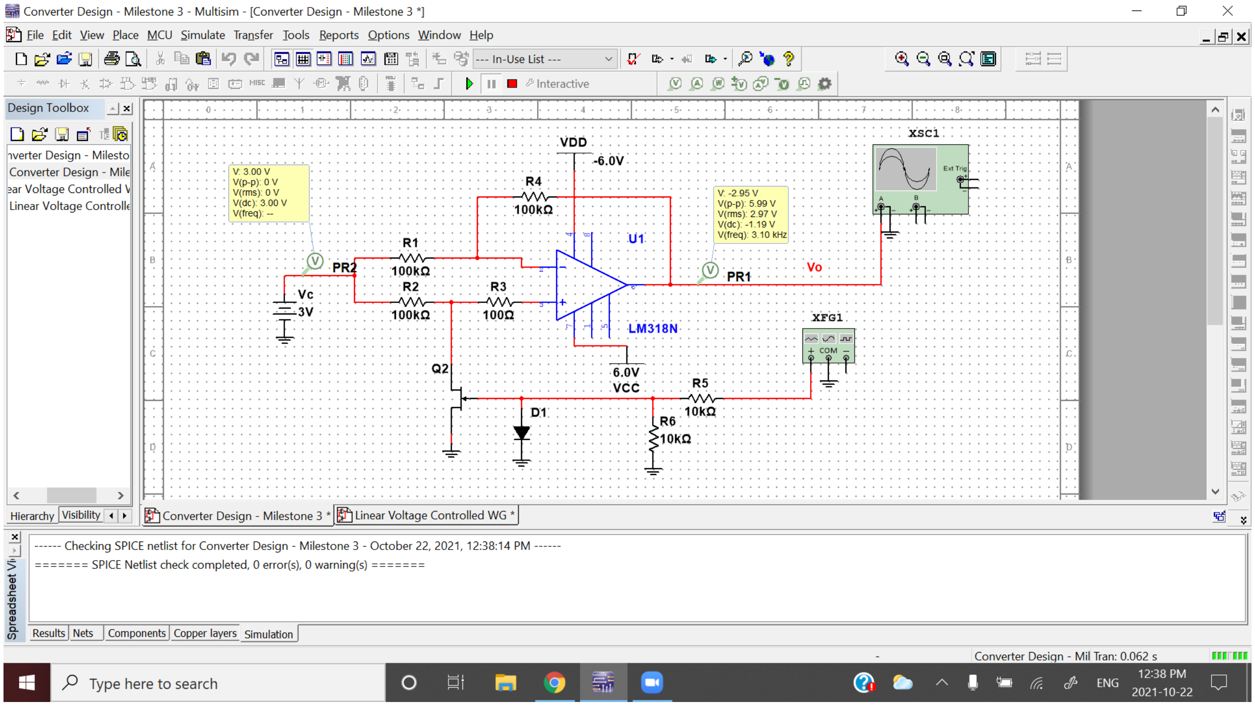

**Figure 4.11: Multisim schematic of DC-to-DC converter - part 4 (testing at 3 V, 3100 Hz).**

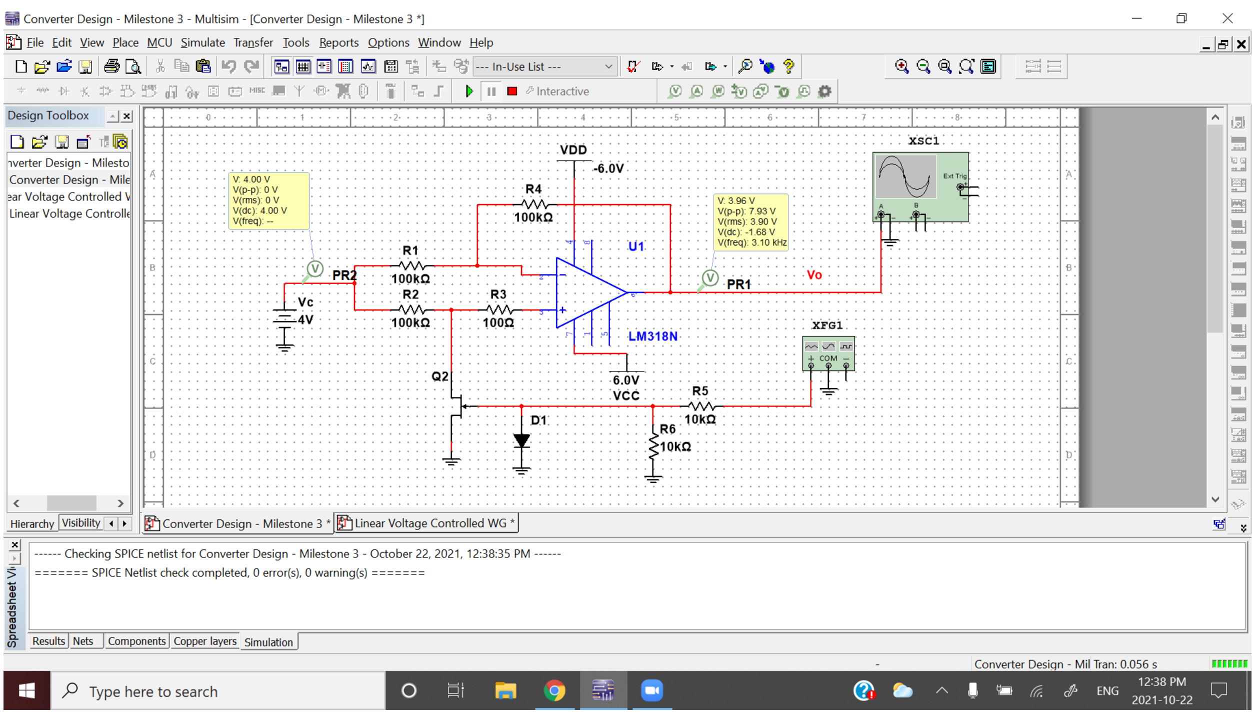

**Figure 4.12: Multisim schematic of DC-to-DC converter - part 5 (testing at 4 V, 3100 Hz).**

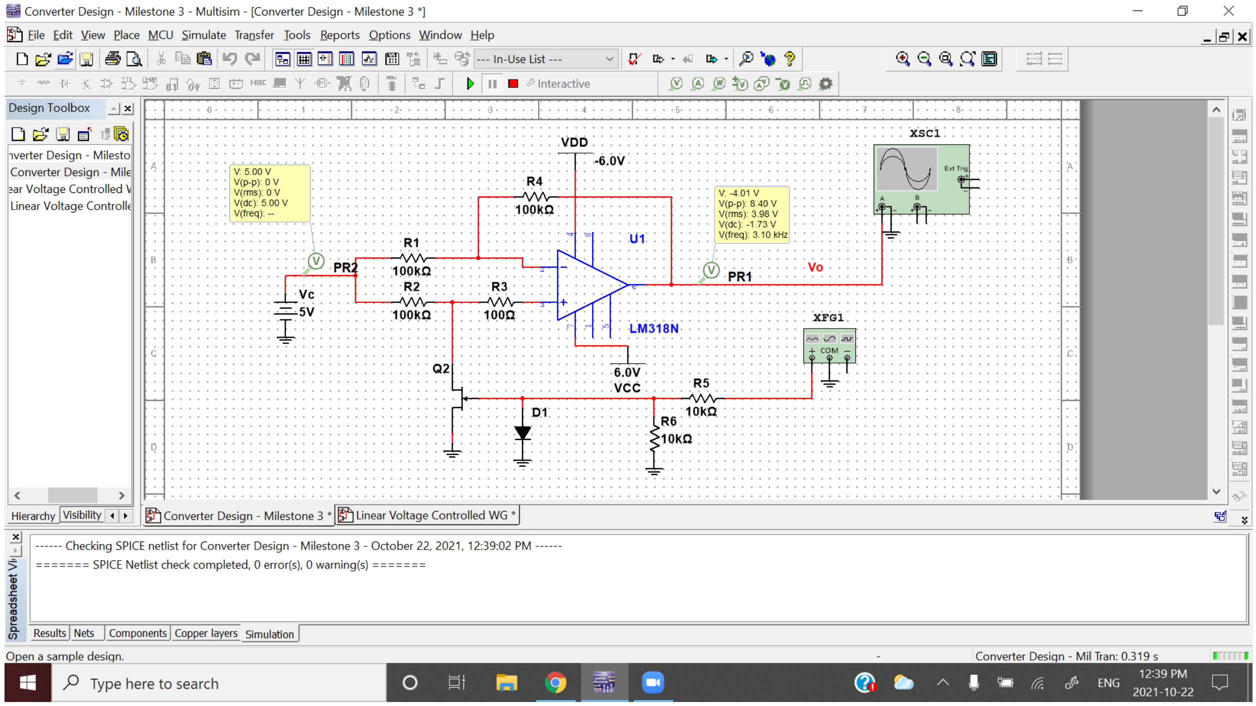


**Figure 4.13: Multisim schematic of DC-to-DC converter - part 5 (testing at 5 V, 3100 Hz).**

| Control Voltage [Volts] | Expected Frequency [Hz] | Actual Frequency [Hz] | DC-DC Output Peak Voltage [Volts] | Expected Integrator Output Peak Voltage [Volts] | Actual Integrator Output Peak Voltage [Volts] | Bistable Output Peak Voltage [Volts] |
|---|---|---|---|---|---|---|
| **0.1** | 62 | 50.9 | 5.996 | 5.71 | 5.75 | 7.6 |
| **1** | 620 | 604 | 5.996 | 5.71 | 5.9 | 7.7 |
| **2** | 1240 | N/A | N/A | 5.71 | N/A | N/A |
| **3** | 1860 | 1872 | 5.996 | 5.71 | 5.95 | 7.75 |
| **4** | 2480 | 2410 | 5.996 | 5.71 | 5.4 | 7.85 |
| **5** | 3100 | 3060 | 5.996 | 5.71 | 5.6 | 7.85 |

**Table 4.1: Outputs of the integrator and bistable for control voltage values of 0.1 volts to 5 volts.**

## 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. In the case of the linear voltage-controlled waveform generator, the frequency and output voltages of the integrator, converter and bistable are slightly different from the expected values in the Prelab assignment. There isn't a significant difference, but it is determined that this difference occurs due to the natural imperfections of the circuit. Another change that is noticeable is that the results for control voltage of 2 volts are not obtained as the simulation bizarrely fails to provide the outputs, even though the circuit is correctly built. The square and triangular waveforms look fairly similar, with the difference that the square wave is not exactly always straight due to the slew rate constraint. As for the converter circuit, the results appear to be fairly consistent with the experimental data. The output voltage in this case lies at 4.33 volts peak, which is relatively close to the desired 5 volts for the 5 volt control voltage. Therefore, through the validation process of this report, it has been decided that the final design for the linear voltage-controlled waveform generator and DC-to-$\pm$DC converter are consistent with the design analysis from the Prelab assignment.