SIGNAL GENERATOR

ELEC2133 Practical Project

Riley Dean

Z5308666

Introduction

The design of a signal generator is useful electronics, where the production of a range of signals is useful in testing circuits under varying conditions. This report will cover the design and implementation of a signal generator that can produce square, triangle and sine waves, allowing for modification of features such as the amplitude, duty cycle, and frequency. Simulations and testing will be included in the appendices.

Square Wave Generation

The first stage in the signal generator is to generate a square wave. This can be done using a Schmitt trigger, which is created by using positive feedback on an operational amplifier. The positive feedback causes the amplifier to jump between positive and negative saturation voltages, upon reaching a threshold (Figure 1).

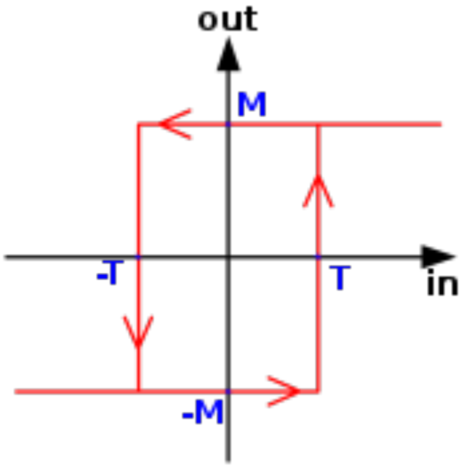

Figure 1: Hysteresis Conditions

To create a changing voltage, a capacitor is connected to the inverting terminal, which is also connected to the output through negative feedback. This means that a voltage is applied to the capacitor, causing it to charge. Once it charges past the threshold voltage, it will cause the output to saturate, resulting in the production of a square wave. The circuit is seen below. To alter the frequency of the circuit, the value of R1 can be modified, with the lower the resistance value, the higher the frequency.

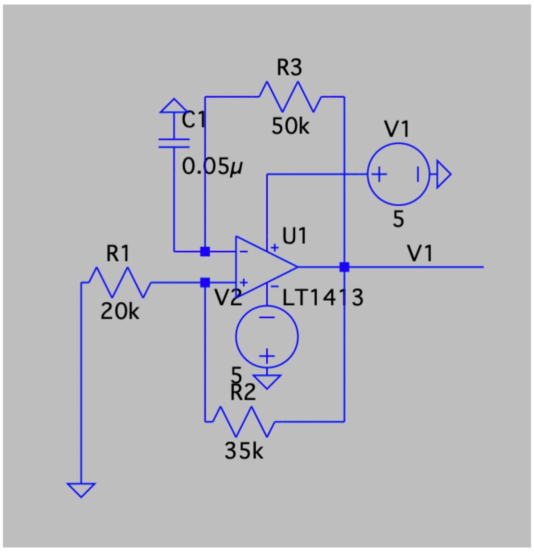

Figure 2: Simple Square Wave Generator

Triangle Wave Generation

To produce a triangle wave from a square wave, an operational amplifier configured as an integrator can be used. The output of this operational amplifier circuit is given by $V_{out} = -\frac{1}{RC}\int V_{in}dt$. A feedback resistor can be added to give further control over the gain. As seen in the circuit diagram below, there is feedback from the output of the triangular wave to the square wave, so as to ensure the signal is clean.

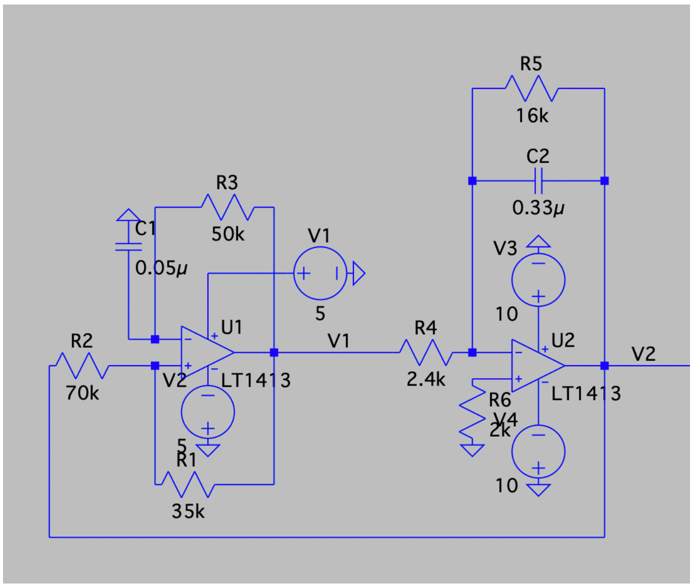

Figure 3: Triangle Wave Generator

Duty Cycle Modification

This simple circuit can be modified to alter the duty cycle, as seen below. By altering the value of R3, the duty cycle can be modified. As the value of R3 increases, the wave will stay at a HIGH state for longer in comparison to the LOW state, and vice versa, due to the linear equation $T_{high} = R_3C\ln(1+\frac{R_1}{R_2})$. This equation also gives explanation to the change in frequency by altering the resistance, as by modifying the value of R_1, the constant term for time taken at each level is altered. This would mean for the physical implementation; a log potentiometer could be used.

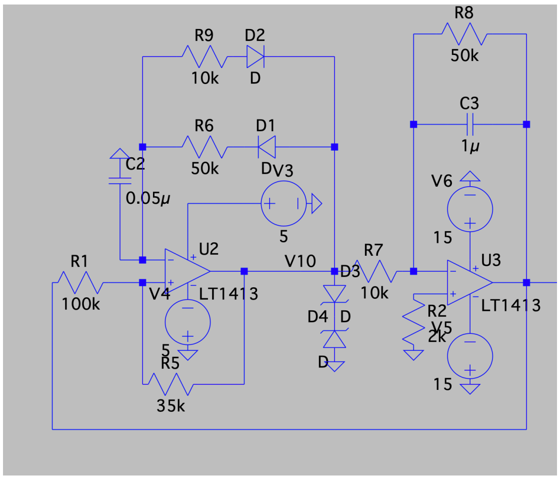

Figure 4: Wave Generator with Duty Cycle Modification

Another method of modifying the duty cycle is to introduce a comparator, and compare the triangular wave output with a DC signal. Then, once the wave has passed through this comparator, it can be integrated again to produce the triangular wave.

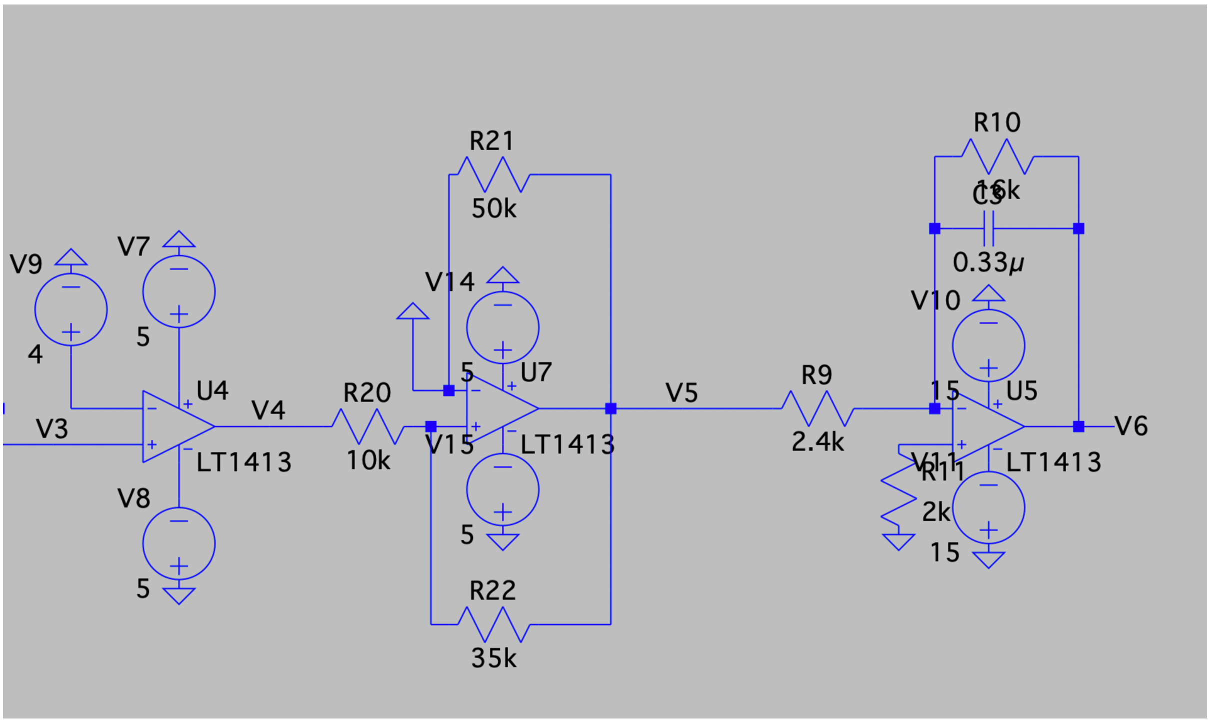

Figure 5: Comparator Duty Cycle Modification

Amplitude Modification

To change the amplitude, a simple inverting amplifier can be used, which has the output gain $A = \frac{-R_2}{R_1}$. Depending on the switch, it will either alter the amplitude of the triangular wave or the square wave. The maximum amplitude of the wave will be capped at the saturation voltage of the operational amplifier.

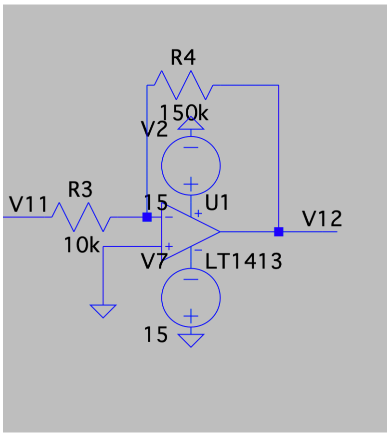

Figure 6: Inverting Amplifier with Gain -15

Sine Wave Generation

To generate a sine wave, multiple methods can be used. When given a square wave input, an RC circuit which filters out the harmonics of the square wave is the most feasible. This can be done using the circuit below, which creates a close approximation to a sine wave, by effectively creating a low pass filter, so that the only signal left is the lowest harmonic used to produce the sine wave. This is then amplified using the non-inverting amplifier seen above to produce higher amplitudes.

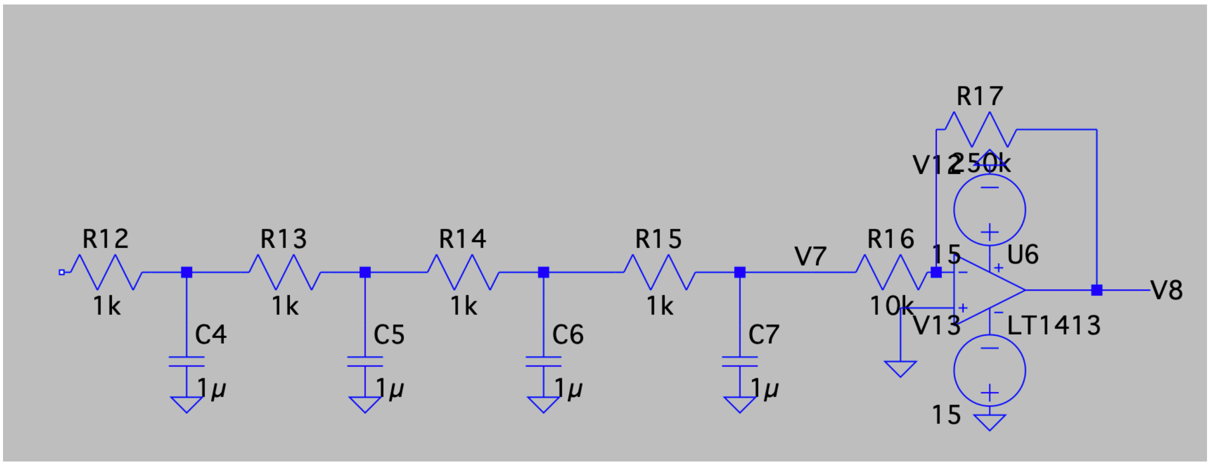

Figure 7: Sine Wave Generation by Filtering Harmonics

If no inputs were to be used however, a Wien Bridge Oscillator can be used. It uses a similar method of generation as the initial square wave generator, however it produces oscillations rather than a square wave, which used hysteresis to produce its output. First, the gain of the circuit can be calculated as a non-inverting amplifier, where $A = 1 + \frac{R_2}{R_1}$. Theoretically, this should be around equal to 3.1 to ensure oscillation. The resistances connected in series and parallel to the capacitors must remain equal, however as they change, it alters the frequency in an inverse proportional relationship.

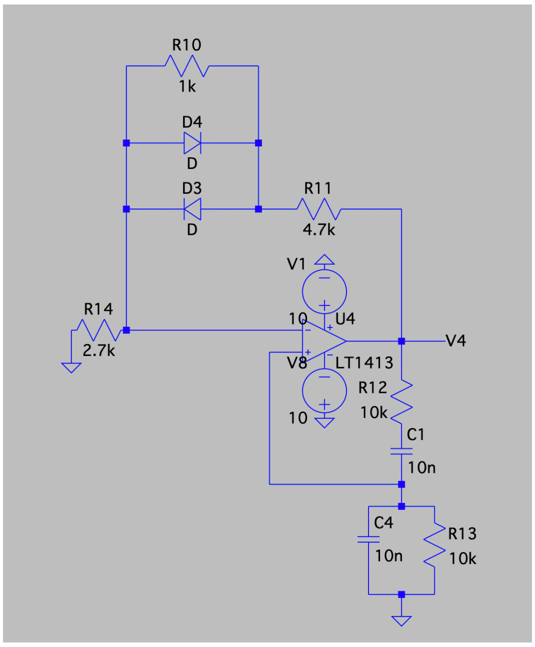

Figure 8: Wien Bridge Oscillator

Signal Generator Circuit

By combining all the elements mentioned above, it results in two possible methods for generating a variable duty cycle square and triangle wave, as seen below. The first factor to consider is cost. To determine cost, the most expensive parts to consider are operational amplifiers, and the first schematic uses 7, while the second only uses 4, along with having less parts in general. This means the second would be the cheaper option. Also, the other factor to be considered is complexity. Due to the sine wave generator being separate to the rest of the circuit for the second design, it prevents it from being altered by changes in the other circuit, in comparison to the first circuit, where almost all components affect the whole circuit. Overall, this has lead to the second circuit being chosen for use in the physical model.

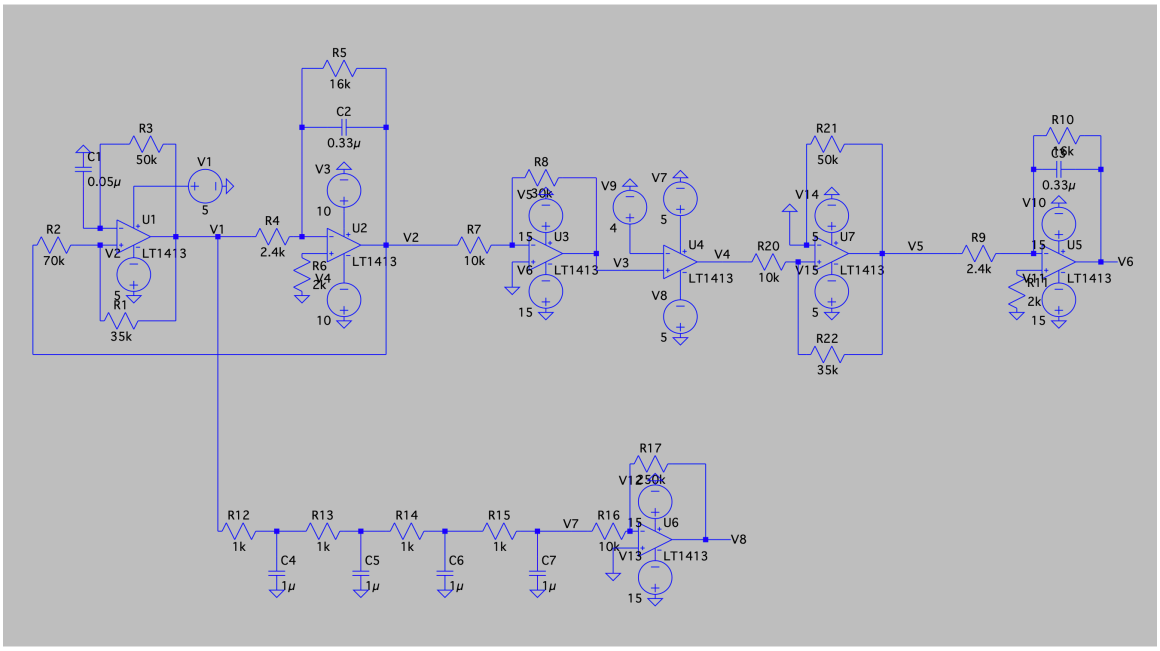
Figure 9: First Signal Generator

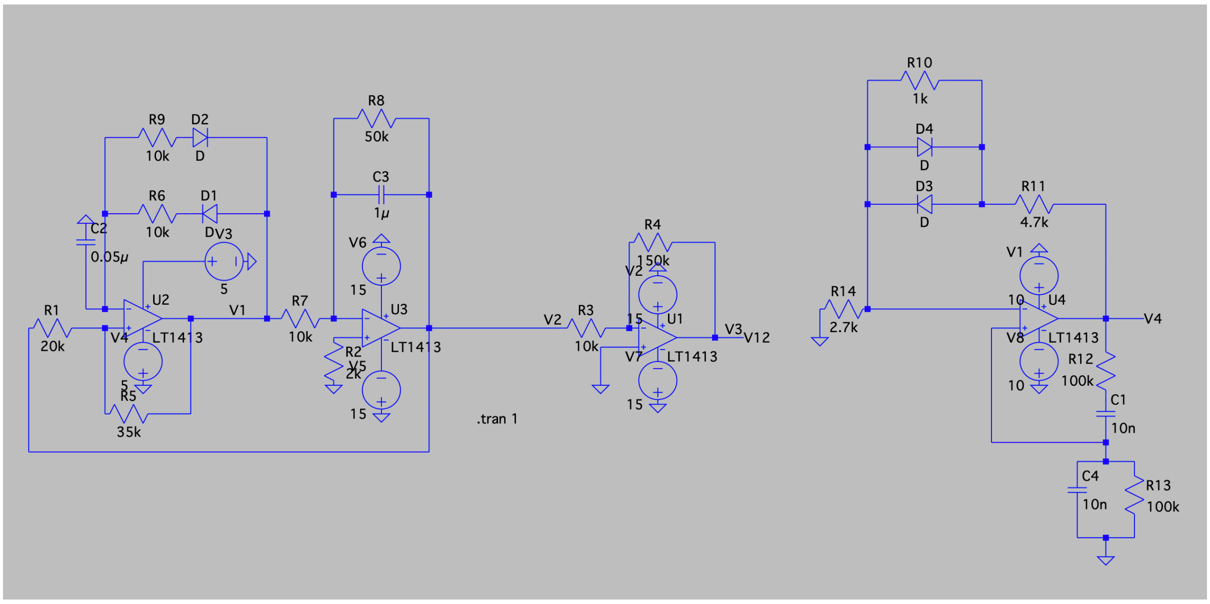

Figure 10: Second Signal Generator

Physical Implementation

When creating the physical implementation of the signal generator, the type of parts used had to be considered, to reduce cost and ensure that efficiency of the generator is possible. Firstly, in terms of the operational amplifier used, the LM348 quadruple operational amplifier was used, as this meant the whole generator could utilise just one chip, which would drastically reduce the cost of the project, as well as the footprint of the circuit. Secondly, for the diode, the general purpose 1n4004 was used. This has standard diode characteristics, and so will behave similar to the one in the simulation. In terms of resistors, Only three resistance values were used; 33k, 10k, and 1k Ohm, with other values created using parallel and series connections. In terms of switches, SPDT switches were used to split the circuit from producing square, triangle, and sinusoidal outputs. Potentiometers would be included, but cost restrictions prevented that in this iteration. As seen below, first this circuit was implemented with a breadboard to allow for testing. For testing, an LED was attached, and multimeter probes were used to ensure that it worked as specified in the schematic.

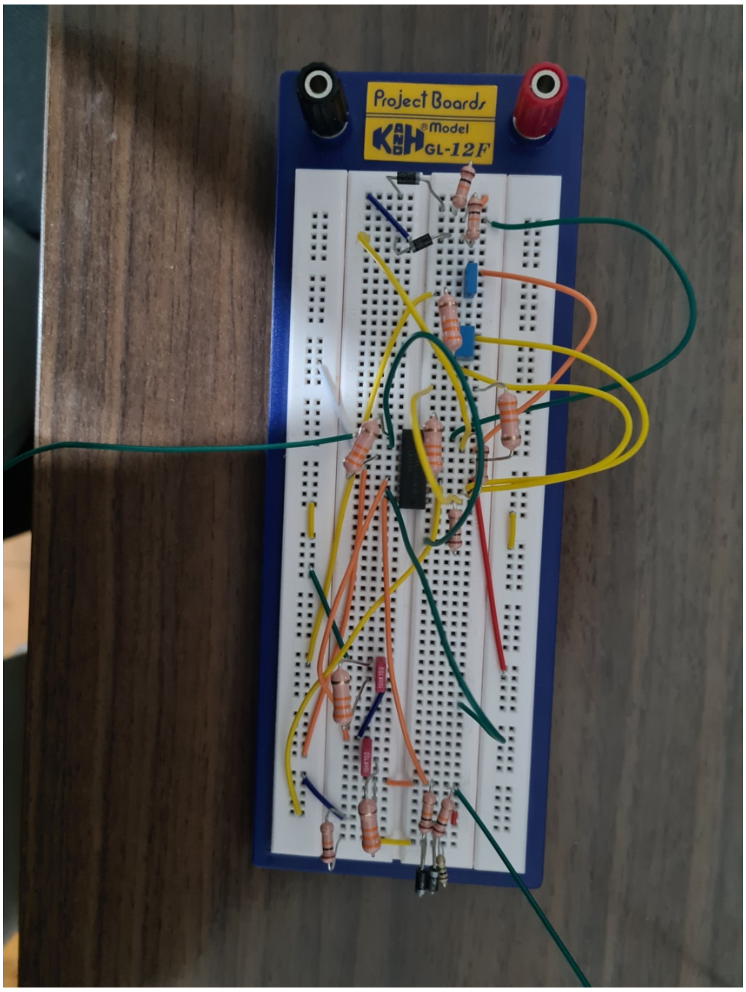

Figure 11: Breadboard Implementation

Testing to determine the nature of the waves in the circuit cannot be completed due to not having access to an oscilloscope, however the activation of the LED can provide evidence for the circuit working as intended when powered with a 9V battery.

Conclusion

Overall, through first calculation and then simulation of a signal generator circuit that implements a square, triangle, and sine wave with varying duty cycle, a physical circuit can then be designed, with this design process ensuring that the final product works as intended.

Appendix

Square Wave Generation

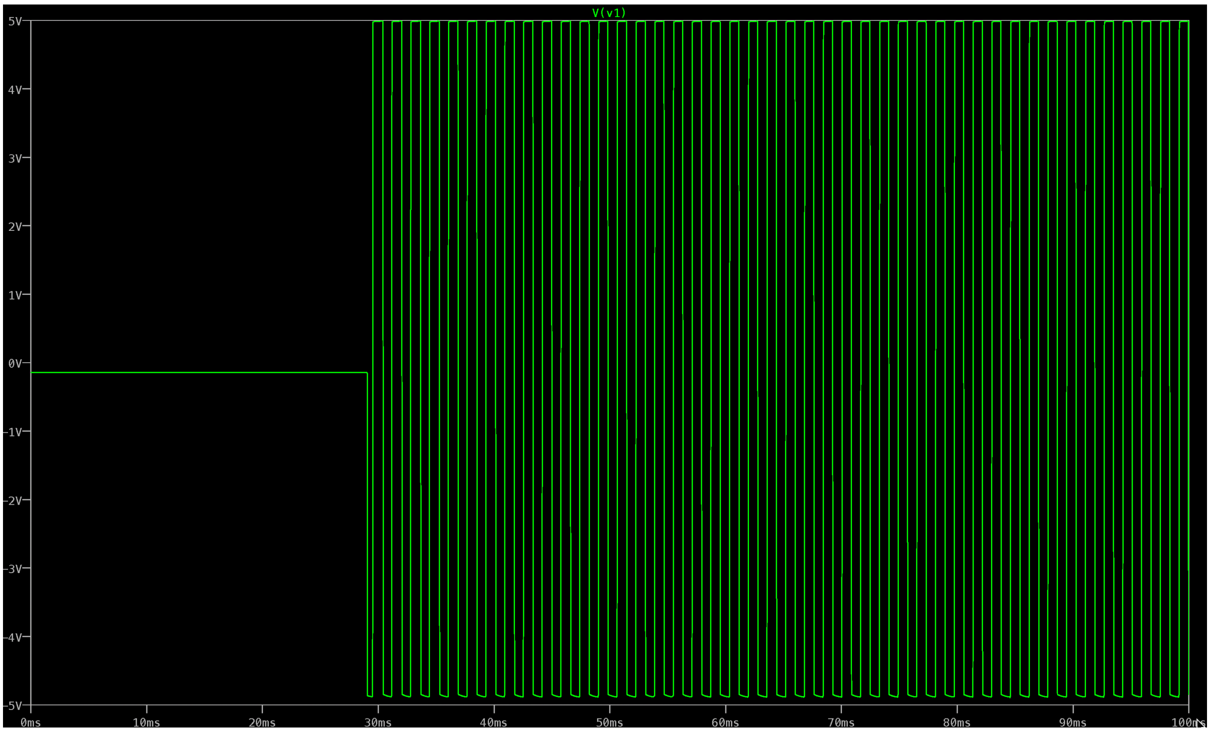

Figure 12: Simulation of Square Wave Generator with Duty Cycle 50%

Triangle Wave Generation

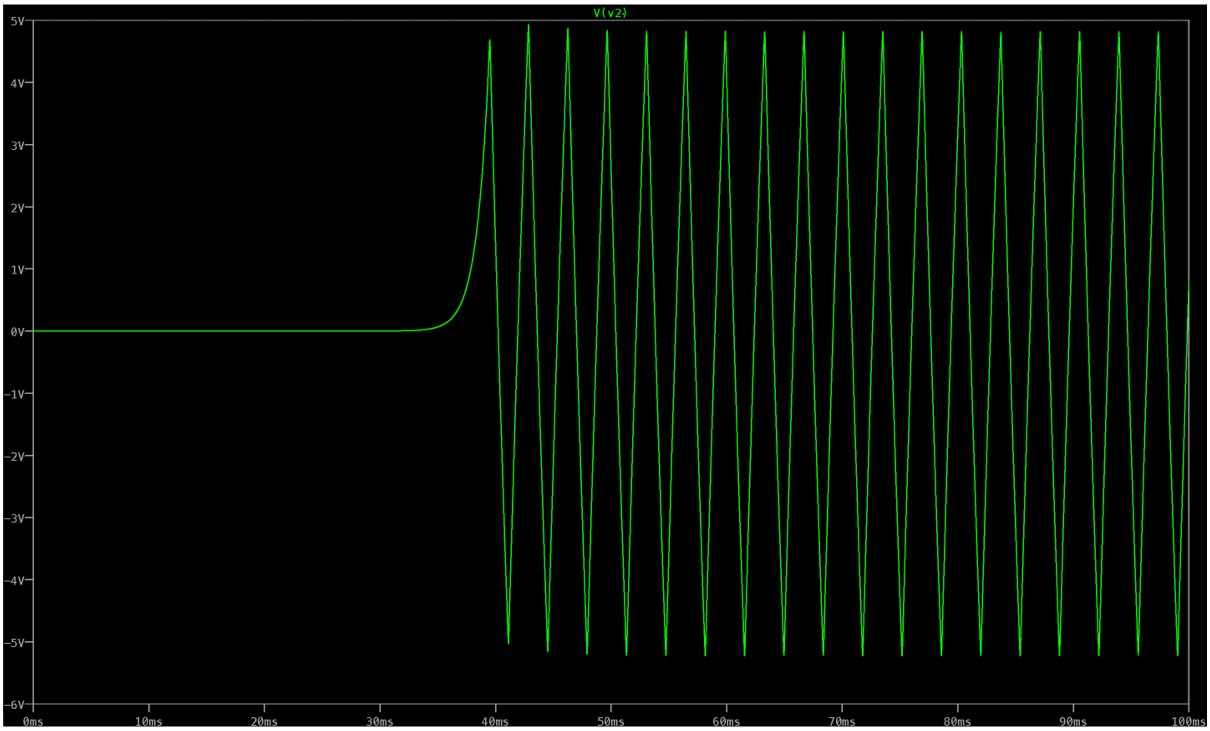

Figure 13: Triangle Wave with 50% Duty Cycle from Circuit 1

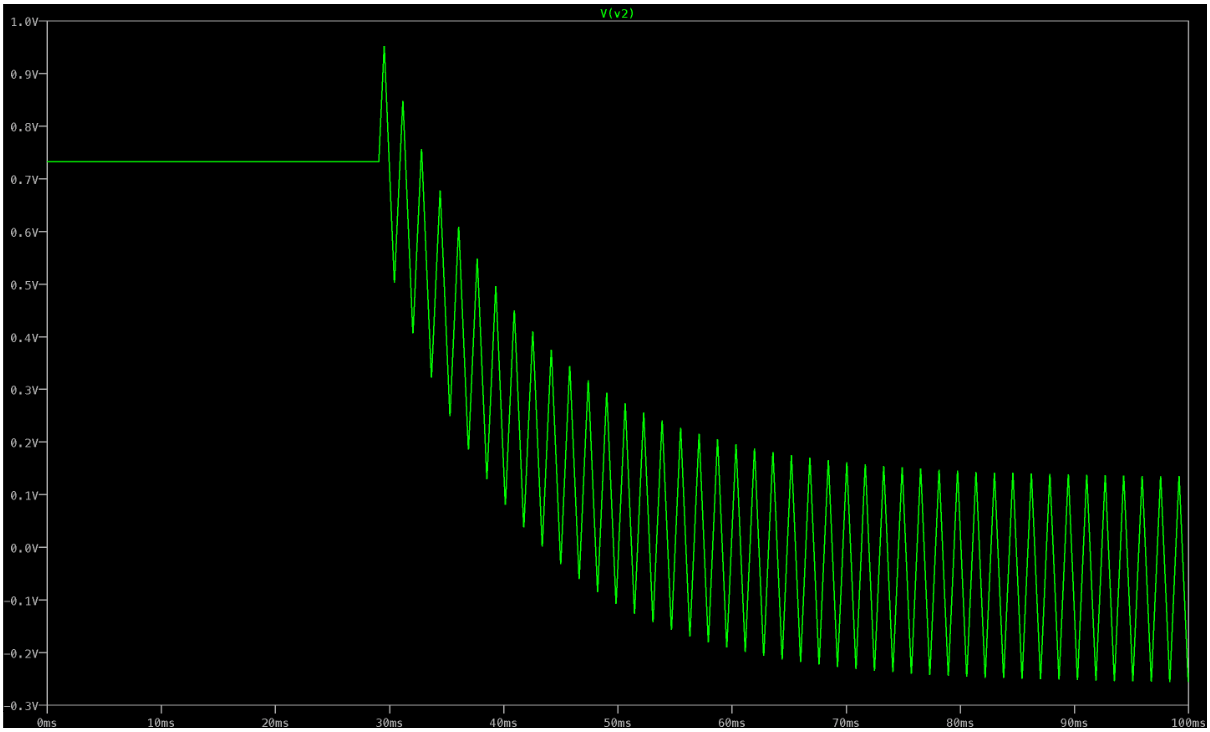

Figure 14: Triangle Wave with 50% Duty Cycle from Circuit 2

Duty Cycle Modification

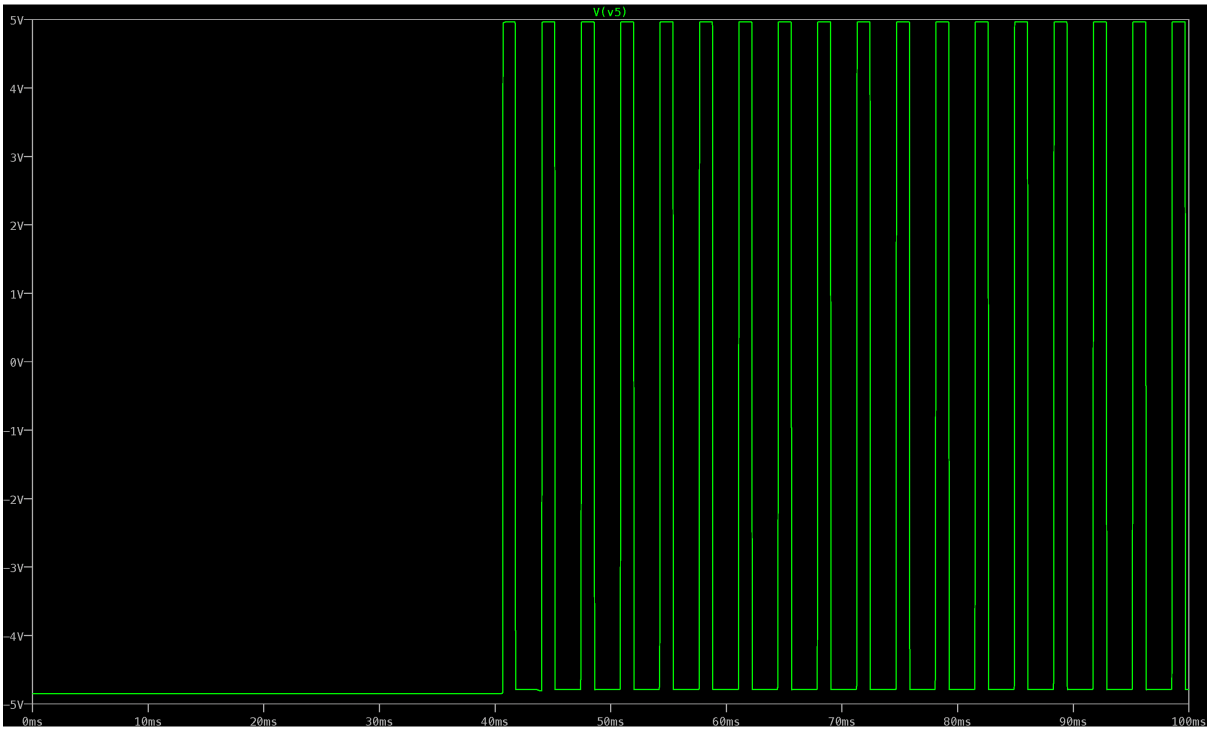

Figure 15: Modified Duty Cycle from Circuit 1

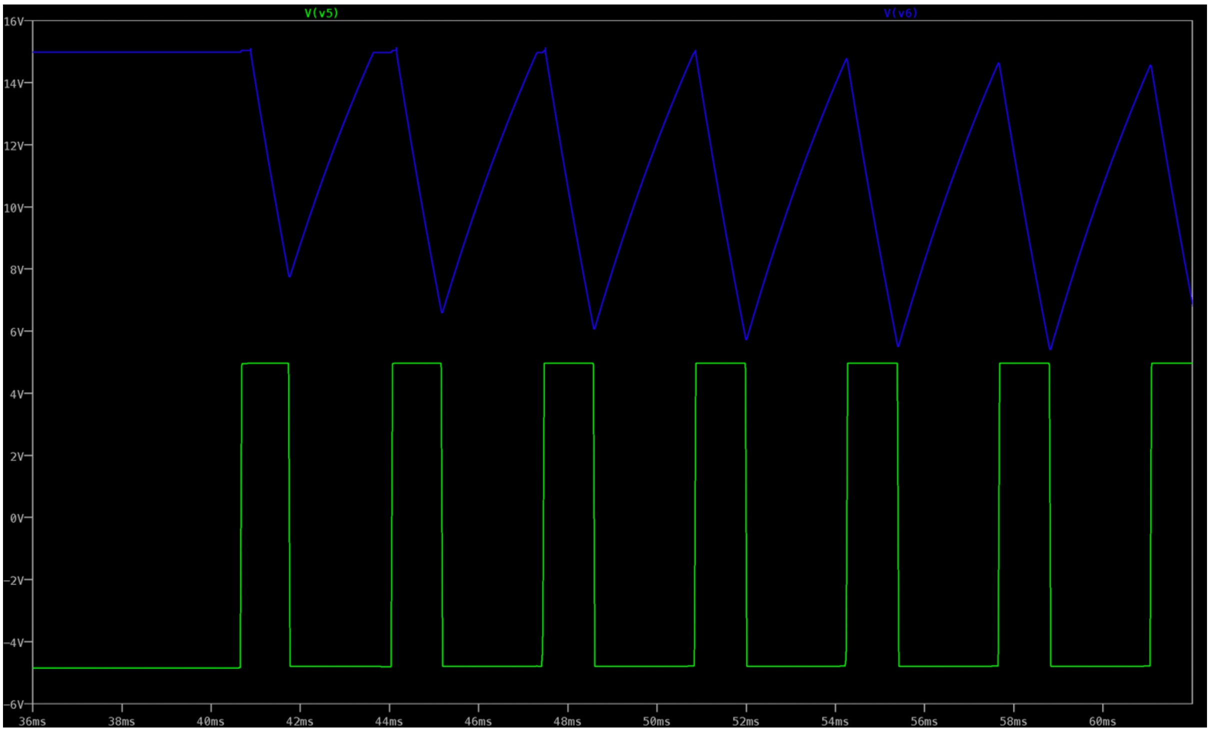

Figure 16: Triangular Wave with Modified Duty Cycle from Circuit 1 (Note error in output)

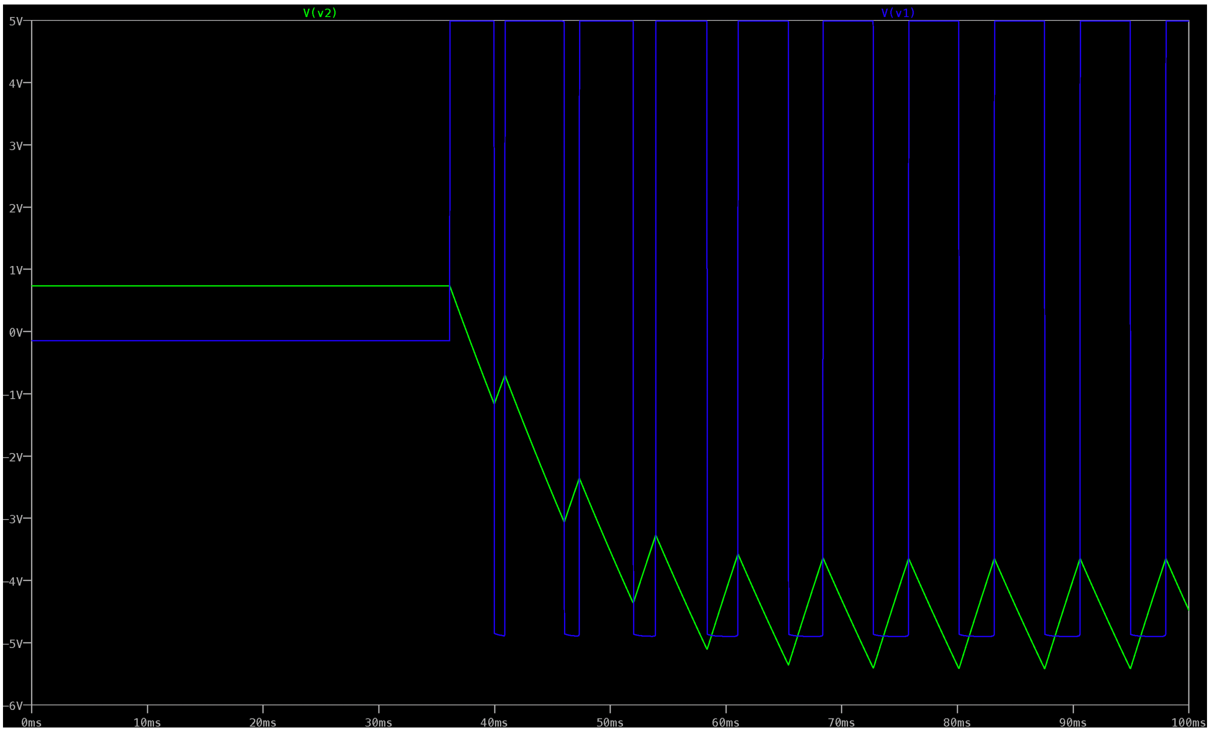

Figure 17: Modified Waves with Changed Duty Cycle from Circuit 2

Amplitude Modification

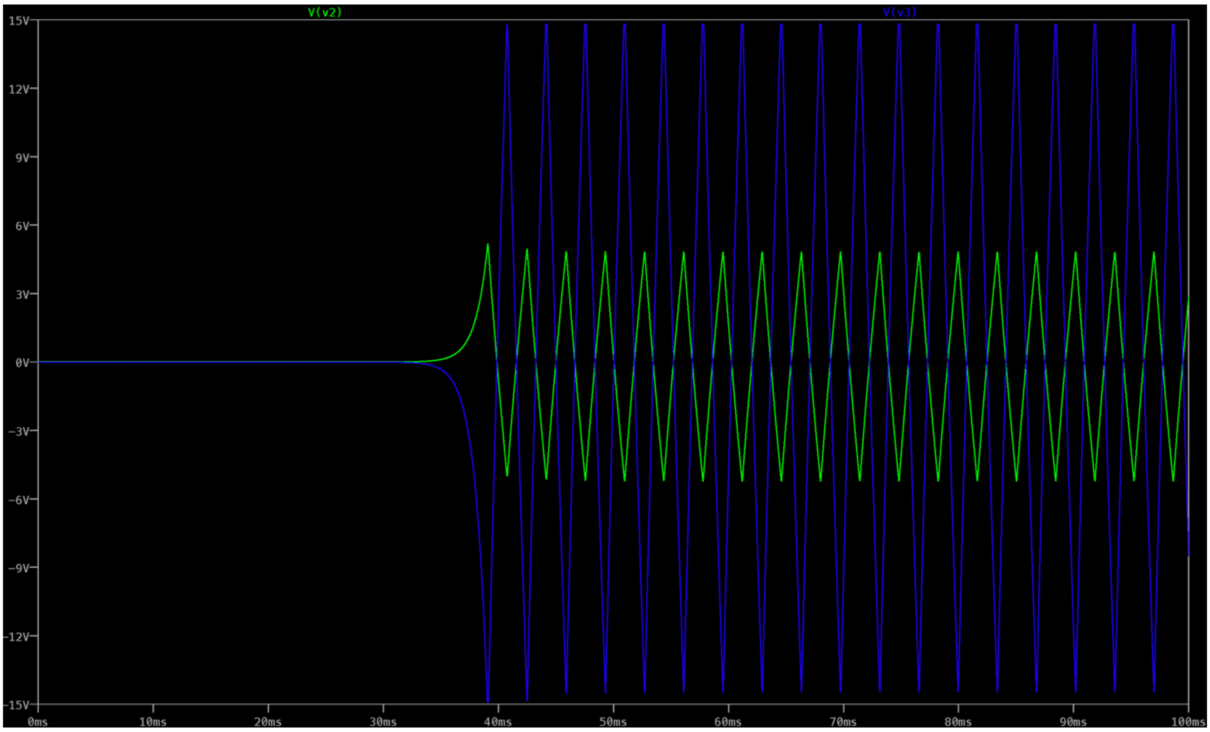

Figure 18: Amplitude Modification of Circuit 1

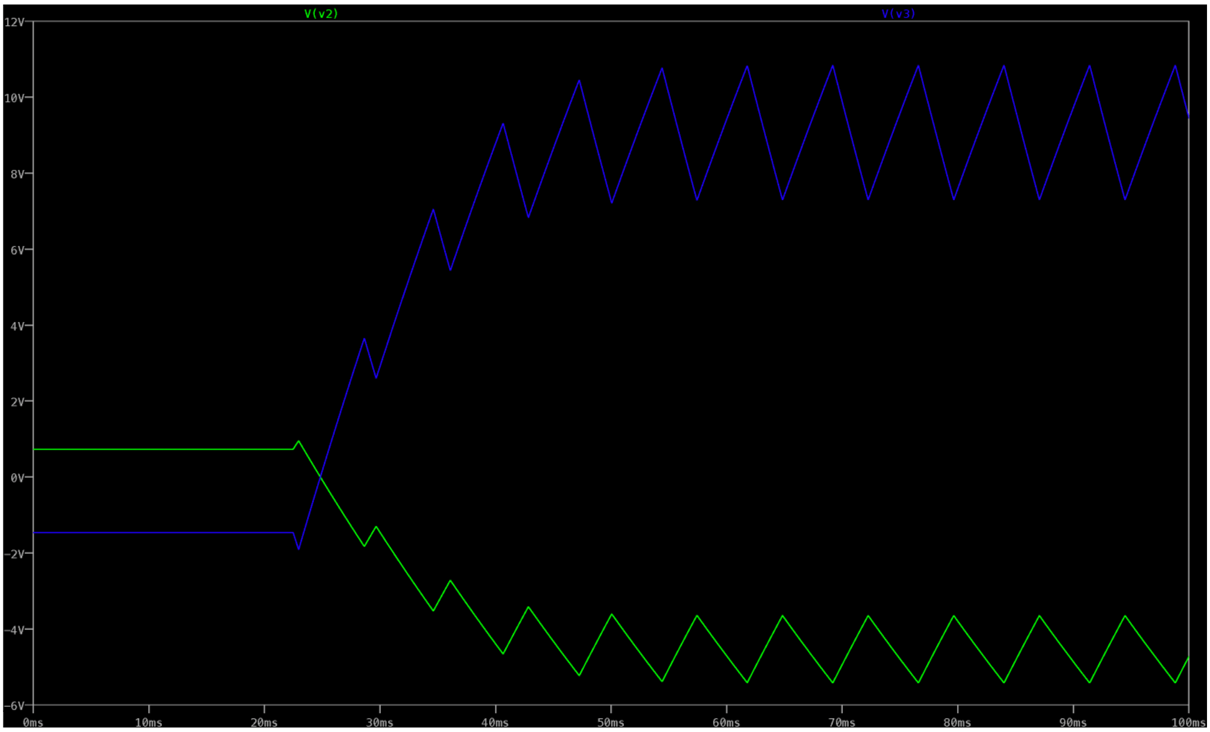

Figure 19: Amplitude Modification of Circuit 2

Sine Wave Generation

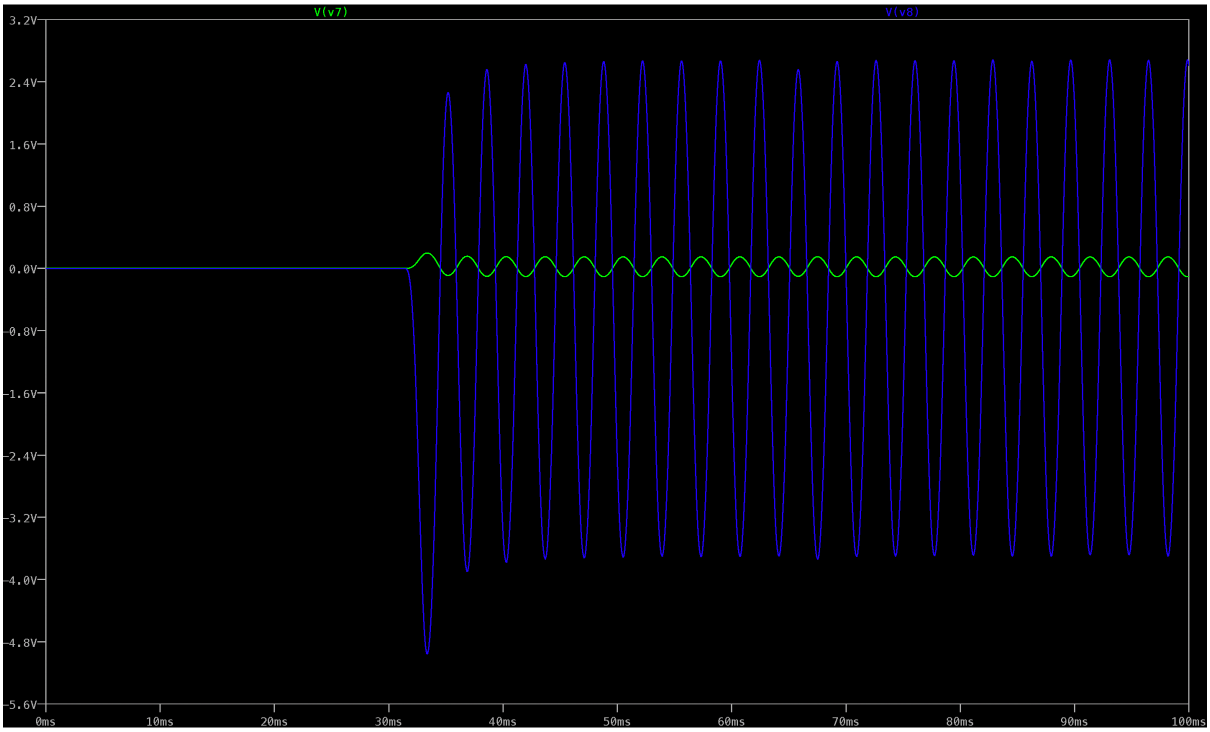

Figure 20: Sine Wave Production + Amplitude Modification Using Filtering

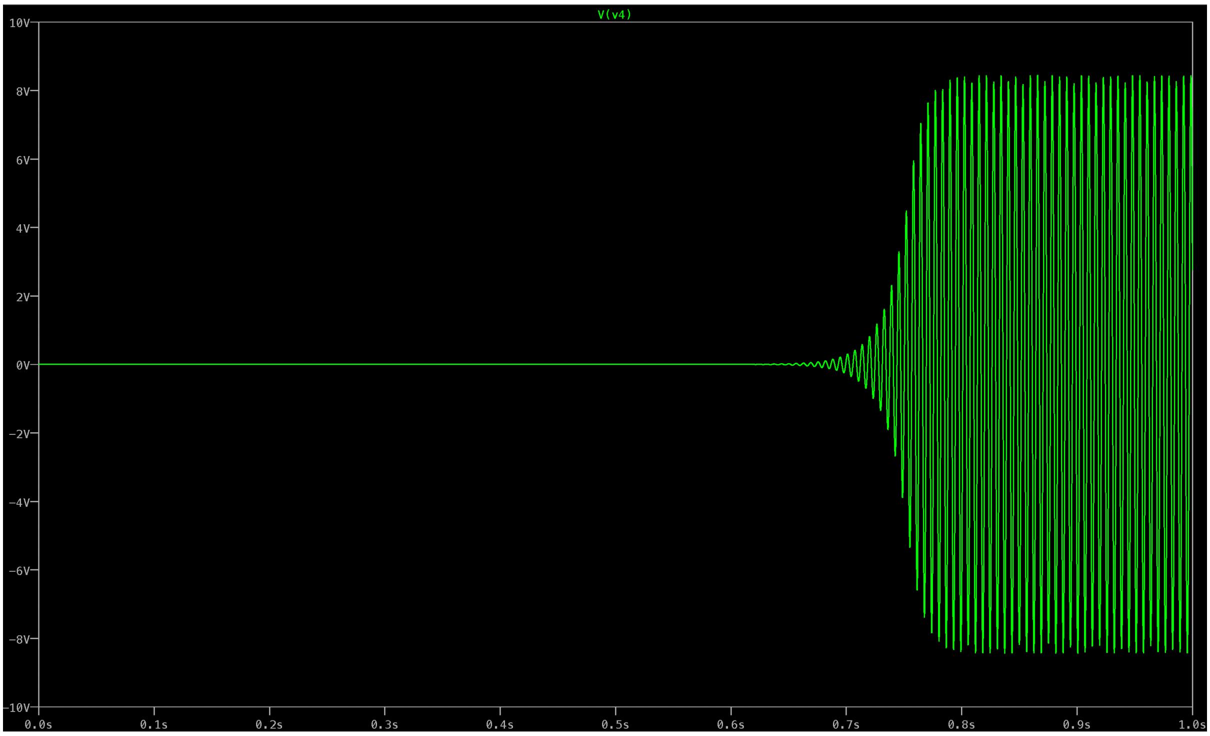

Figure 21: Sine Wave Generation Using Wien Bridge Oscillator

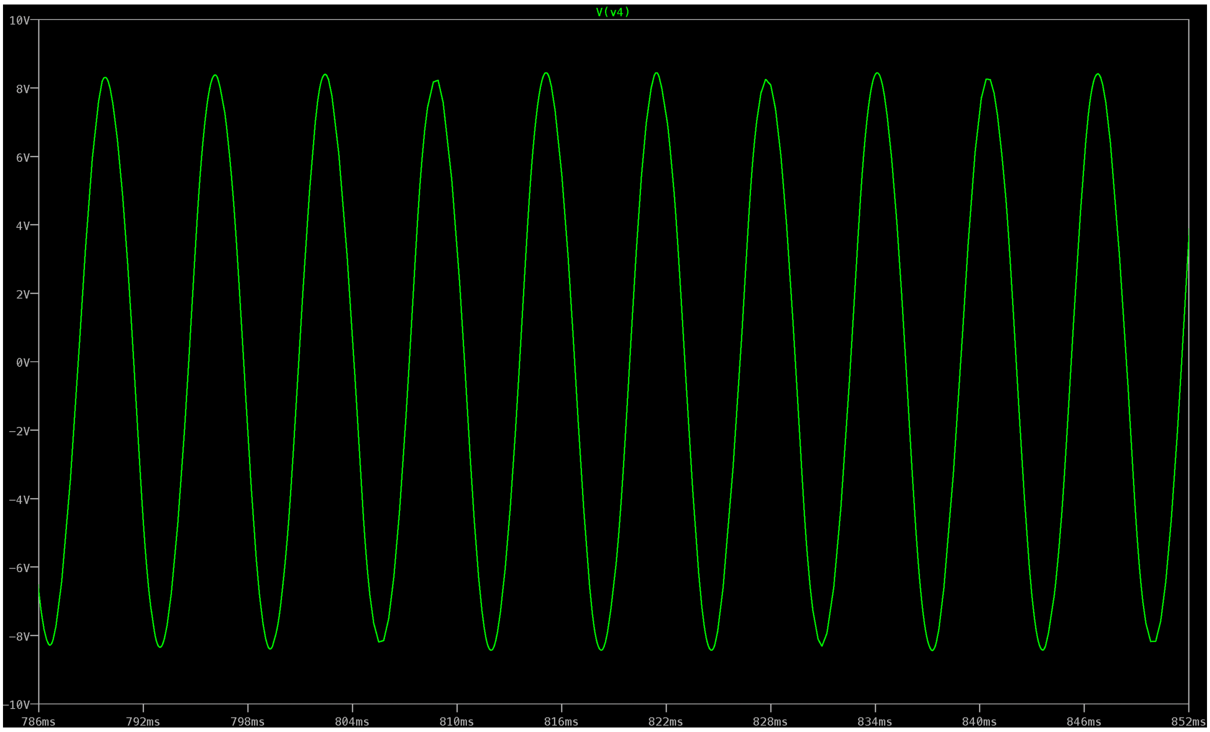

Figure 22: Zoom of Above Photo Showing High Accuracy Sinusoid