Signal Generator Project

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Contents

Design Specifications

The Signal generator should be able to provide a range of functionality that includes

- Producing Square, Triangle and Sinusoidal Wave
- Adjust Duty Cycle of Square and Triangle Wave
- Change frequency from a ”few Hz to 100KHz”
- Be able to amplify signal with a $\pm$ 20 dB range

From the given specifications, this product should not be used as a ”Student Signal Generator” for education purposes as the voltage it is designed to work with is dangerously high. This design could be used for Power Applications, Motors or for other instrumentation.

Circuit Design

After much research, it seems that using a Schmitt trigger and an integrator together in a circuit is the easiest to design and build (Astable Multivibrator + Integrator). However, instead of using the lab 3 circuit to build a Voltage Controlled Oscillator with the necessary adjustments to control duty cycle without frequency changing, I will use a Potentiometer at the positive terminal of the integrator to control the **duty cycle**. This is at the cost of frequency changing as the duty cycle changes. However, for the design specifications, it is not a concern.

I will provide a solution to control duty cycle with frequency unchanged as an alternative design decision so that the reader can use either circuit.

The Schmitt trigger will create a **Square Wave** and from the square wave the integrator will create a **Triangle Wave**. To create a **Sinusoidal wave**, the easiest option to design and build is a wien-bridge oscillator.

With a gain of 20 dB, the op amp chosen should be able to have a closed loop bandwidth close to 100,000 Hz to satisfy the design specifications.

For convenience purposes, I will be using an LM741 Op amp which has a GBP of about 1MHz which might not be able to quite reach 100KHz for my purposes however, it is the only Op amp that I have access to. Ideally, a CA3140 Wideband Op Amp would be good for this circuit as it has a 4.5 MHz GBP bandwidth.

Triangle & Square Waveform Generation

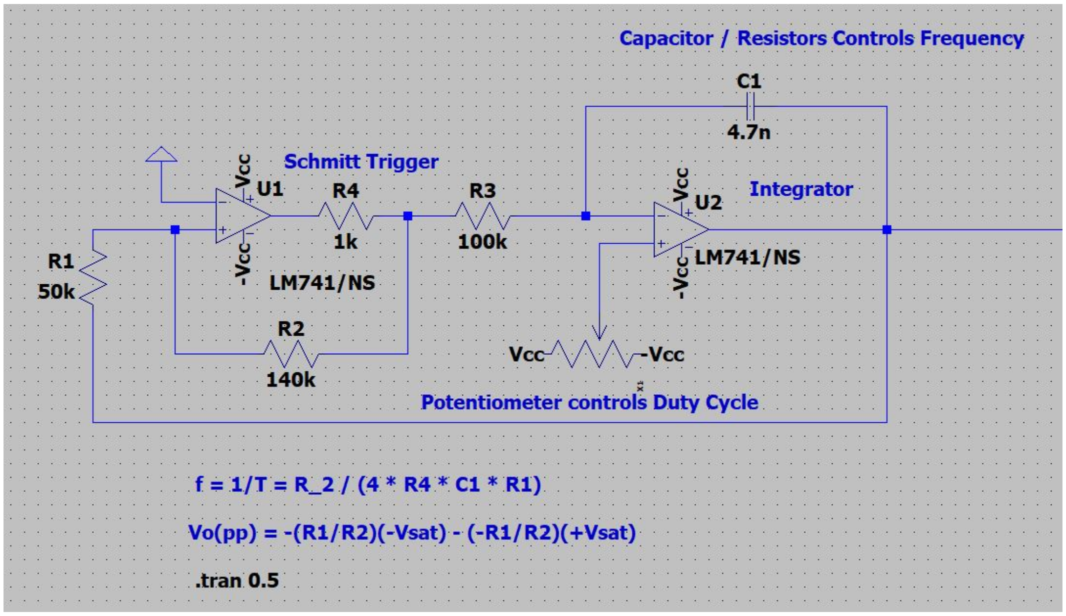


Figure 1: Triangle & Square Waveform Generator

The above circuit can be calculated using the given formulas. It is the same formulas as used in lab 3. I have chosen to implement 4 copies of the circuit to allow for different frequencies. The capacitor is the only component changed in each circuit to allow for different frequency ranges. I have decided to use a 470 nF Capacitor to achieve low frequencies in the 5-100 Hz Range. A 47 nF capacitor for 100-1000 Hz range, a 4.7 nF for 1000-10,000 Hz and a 1 nF Capacitor for 10,000 to approximately 100k.

Using R3 as a variable Resistor allows for frequency to be changed. Unfortunately, increasing the frequency will eventually cause a decay in gain. There are few ways to counteract this, ideally using the CA3140 would remove this problem for a 100KHz bandwidth as its 3dB bandwidth will be far greater than the LM741.

Sinusoidal Waveform Generation

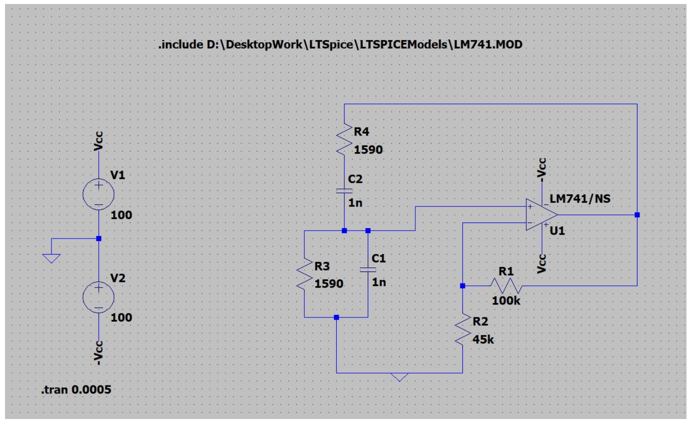
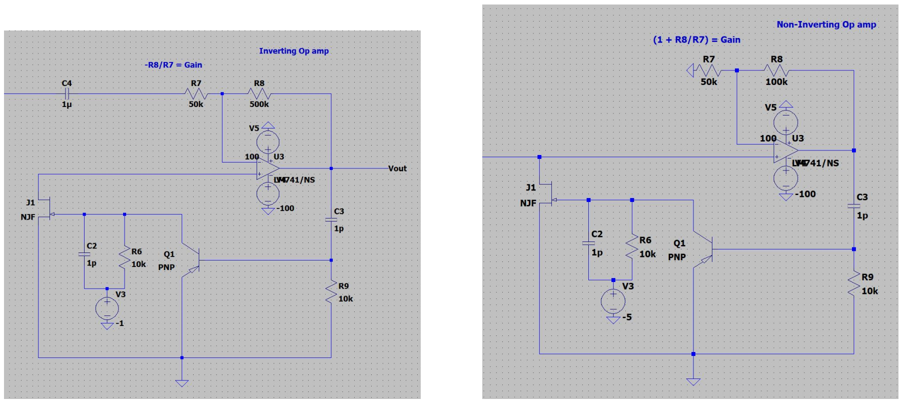


Figure 2: Wien Bridge Oscillator

The Wien Bridge Oscillator is used in this design to generate a sinusoidal wave. In the implementation, 4 Wien-Bridge Oscillators will be used to allow for different frequencies. R4 and R3 will both be variable resistors that will change frequency when its resistance is changed. Using the formula $f = \frac{1}{2\pi RC}$, where $R = R4 = R3$ and $C = C1 = C2$ in Figure 2, the desired frequency can be calculated.

For the 4 circuits, 1 μF capacitor will be used to reach ranges of 5-100 Hz, 100 nF capacitor will be used to reach up to 1000Hz, 10 nF capacitor will be used to reach 10KHz and 1 nF capacitor will be used to reach 100KHz. The variable resistor will be able to change from 1k to 20k ideally.

Automatic Gain Control Circuit



(a) Inverting AGC

(b) Non-Inverting AGC

Figure 3: Automatic Gain Control Circuit

To satisfy the -20dB and 20dB gain requirement of the specification, an Automatic Gain Control circuit is implemented to be able to amplify the output signal of the waveform to a desired level. The gain is easily controlled by varying R8 and R7 which can be replaced by a Potentiometer or by a variable resistor at R8 or R7. To provide versatility and a -20dB gain, there is an inverting and non-inverting AGC which can be toggled by a mechanical switch at the users choice. The inverting AGC carries the signal into the negative terminal of the op amp where the non-inverting carries the signal through the positive terminal of the op amp. An AC coupling capacitor is attached to the Inverting AGC to remove DC Offset and the DC Source of the transistor circuit is reduced to -1 Volt to remove excess DC Offset.

Complete Designed Circuit

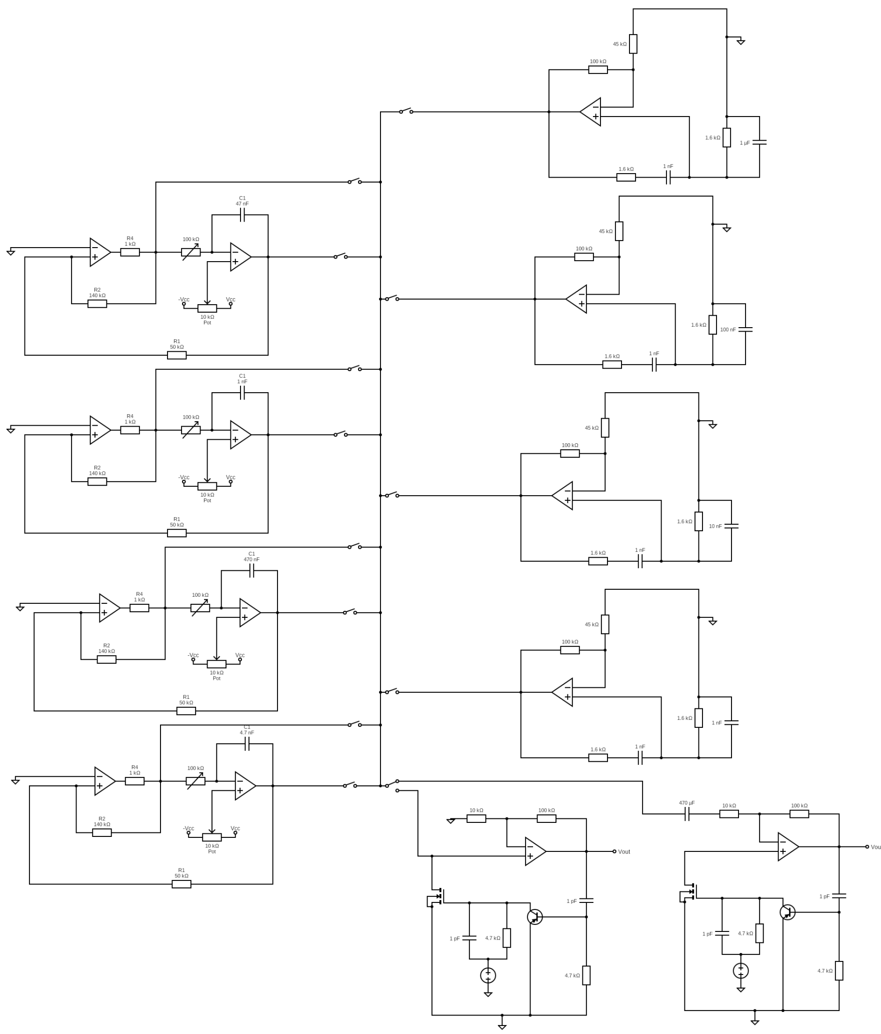


Figure 4: Full Designed Circuit

Note: The JFET in the LTSpice simulations is replaced by MOSFETS in Figure 4 but JFETs would be used in the real implementation, there were no JFET symbols available in the diagram software.

Simulations:

Triangle & Square Waveform + Non-inverting AGC

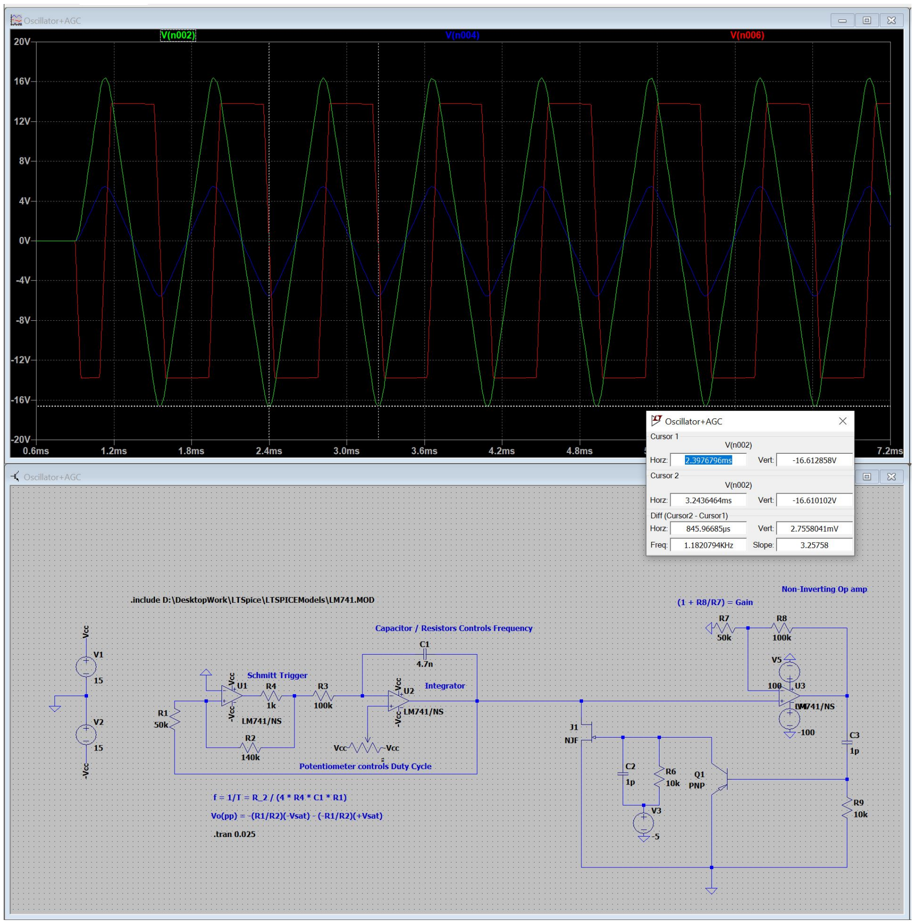


Figure 5: Triangle & Square Wave AGC

The Green waveform is the output of the AGC, the red is the square wave output and the blue is the triangle waveform output. The frequency of the wave forms are expected to be around the low KHz which corresponds to the simulations. The AGC is non-inverting and is almost 3x the amplitude of the triangular input waveform. This corresponds to the gain of $(1+\frac{R8}{R7}) = 3$.

Sinusoidal Waveform + Inverting AGC

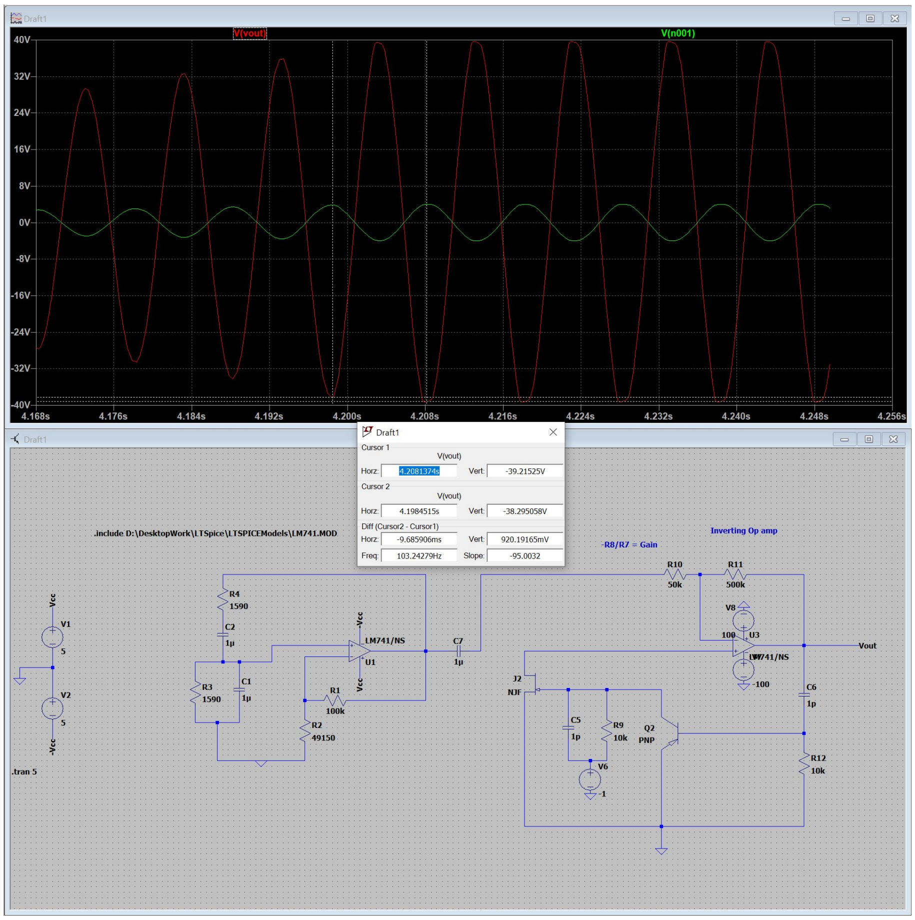
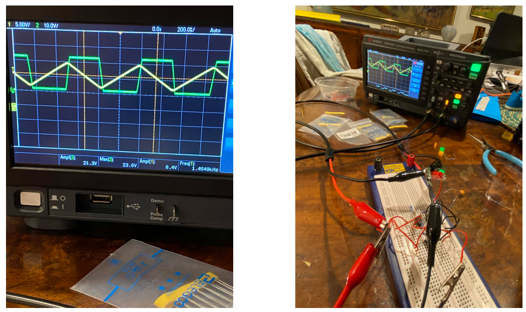


Figure 6: Sinusoidal waveform + Inverting AGC

The output of the Wien Bridge has a frequency of 103 Hz which is about the highest it can reach with a 1 μF capacitor. The output is then amplified by the AGC by a gain of about -10 which corresponds to the amplitudes of the green and red waveform. The gain is calculated using $-\frac{R8}{R7}$ which in this simulation is -10. The frequency would be controlled using the R3 and R4 resistors by varying their resistance.

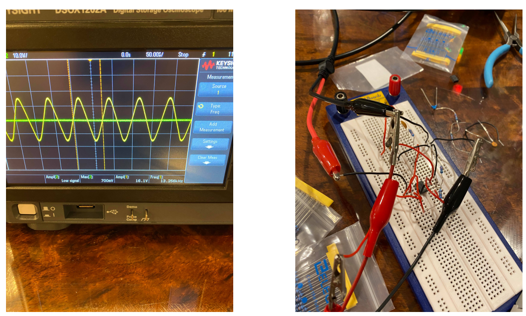
Real Life implementation



(a) Waveforms

(b) Circuit + Waveform

Figure 7: Triangle & Square Waveform



(a) Waveform

(b) Wien Bridge Oscillator

Figure 8: Wien Bridge Oscillator

Ultimately, the real-life implementation worked up until about 10-20KHz. I believe my design can not reach higher frequencies due to the bandwidth of the LM741. I believe the higher frequency it is outputting, the lower the gain and the frequency is ”capped” at a limit and cannot exceed any further.

Because the gain decreases as frequency increases, the capacitor charging time is dependant on the voltage (gain) and will therefore be limited to the bandwidth of the Op amp. I believe this is the case with both the Wien Bridge Oscillator and the Triangle & Waveform Generator. However, the Wien Bridge oscillator can reach higher frequencies due to the negative feedback extending the bandwidth albeit not close to 100KHz.

Conclusion

My circuit design could not satisfy the requirement of 100KHz due to the Op Amp chosen. However, I believe the project could be completed using the Wien Bridge sinusoidal wave as an input to the schmitt trigger and integrator circuit to achieve higher frequencies. This is a different configuration of the circuits and is depicted below.

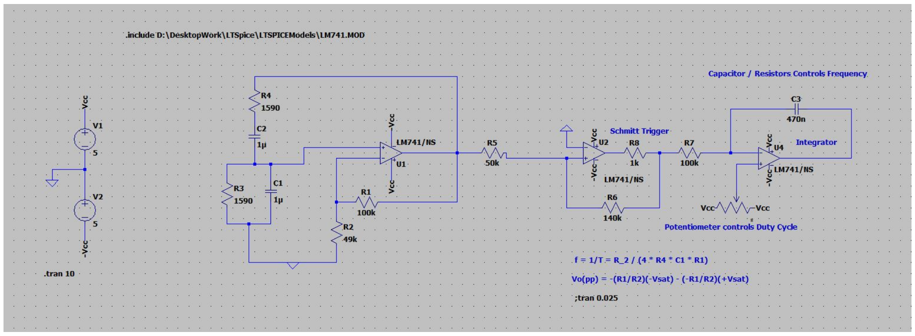


Figure 9: Untested New Waveform Generator

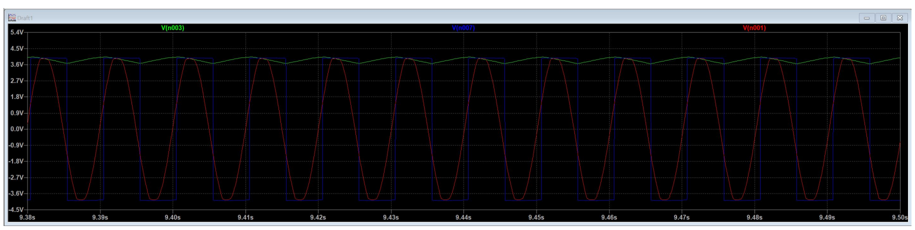


Figure 10: Simulating the waveform Generator

However, the potentiometer would no longer control the duty cycle and a new method would be required. A suggested solution that would need to be tested would be to introduce an asymmetric schmitt trigger to control the duty cycle of the Square wave and Triangle Wave. The AGC could still be included to amplify the waveforms and the frequency would be dependant on the RC equation in the Wien-Bridge Oscillator.

The simulations of the original circuit did show that the limit of the design was to be 20KHz however, I believed it to be LTSpice struggling to compute the circuit as I've experienced in the past.

Alternative Triangle & Square Waveform Generator

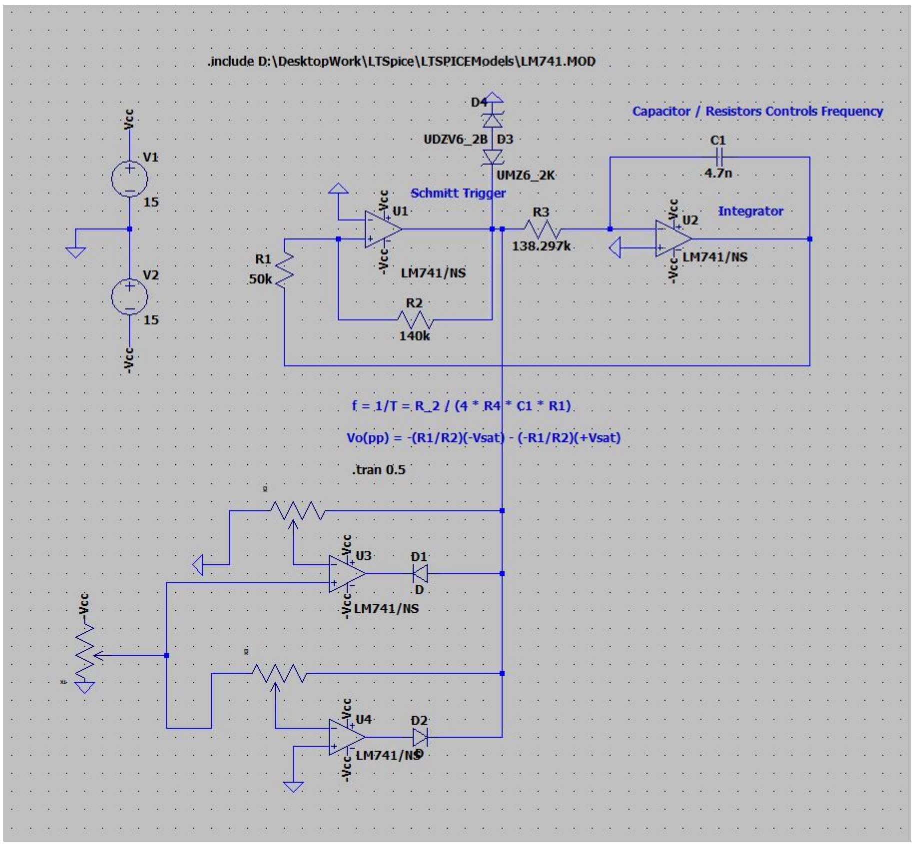


Figure 11: Sinusoidal waveform + Inverting AGC

The solution to adjust the duty cycle of the circuit is to implement two potentiometers at the bottom part of the circuit. A potentiometer should be attached to the inverting and non-inverting op amps. When adjusting one potentiometer, the other potentiometer should be inversely adjusted the same amount. This would solve the issue of frequency changing when adjusting duty cycle.

This circuit won't be able to produce a 100KHz frequency unless different Op Amps are used as discovered in the report.