Aidan Carey
Aidan Chin
Lab 6

Introduce and define concepts (with citations)

Op-Amp circuit - An integrated circuit that amplifies the difference in voltage between two inputs.
Op Amp Source

Capacitor - An electrical component in a circuit that draws energy from a battery/source and stores it
Capacitor Source.

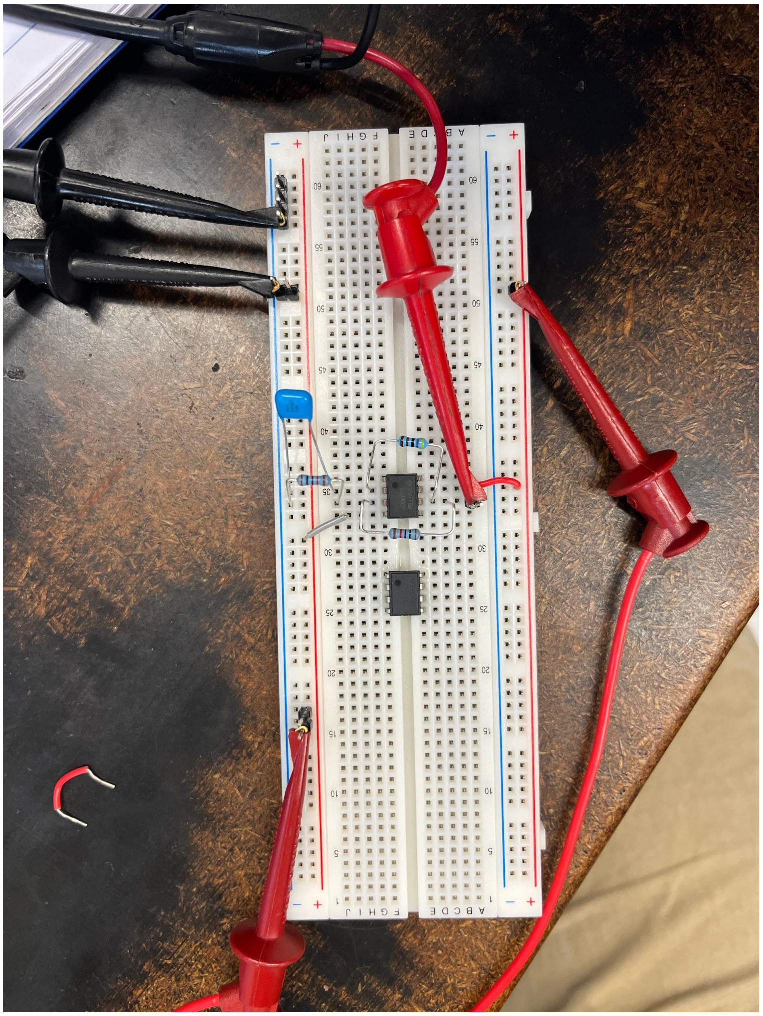
Integrator - An element of a circuit that outputs the integral of the input signal with respect to time
Integrator Source.

Low-pass filter - A circuit that only passes signals below its cutoff frequency, and disregards those above it
Low Pass Filter Source

Motivation for experiment

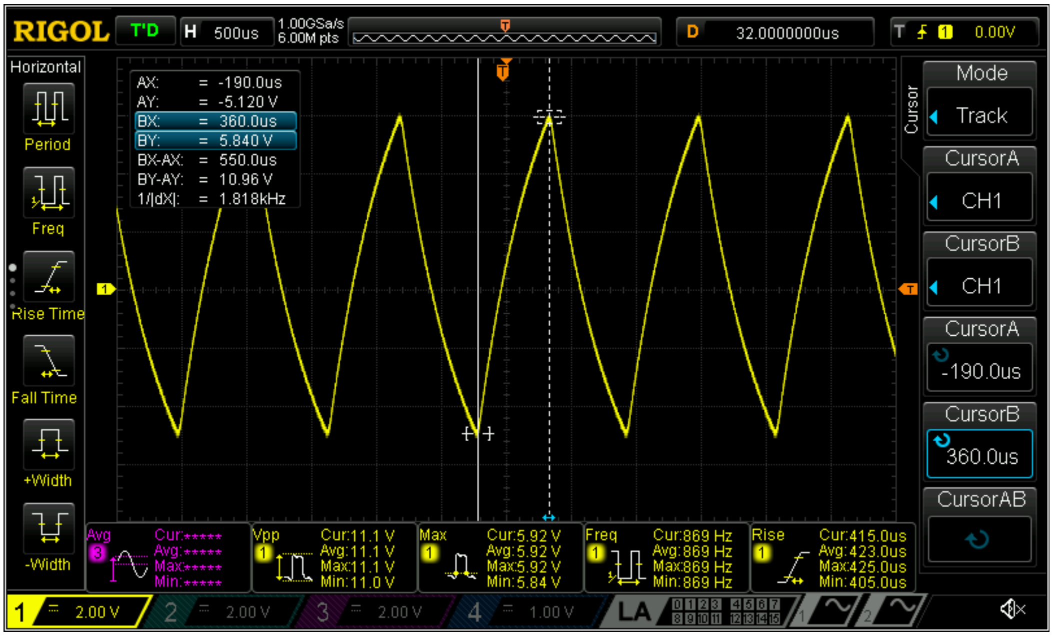
In this lab, we will be working with Op-Amp circuits combined with capacitors in order to produce specific wave forms. More specifically, we will be producing square waves, and evaluating their peak to peak voltage, frequency, and shape at their inputs and outputs. Next, we will use the output of the square wave as the new input, along with an integrator and capacitor, in order to generate a set of triangle waves. In the oscilloscope we will evaluate 2nd stage input and output, their Vpp, and their frequencies. Lastly, we will incorporate a low pass filter and use the triangle wave as an input to compute a sine wave as the output.

1) Experimental diagram

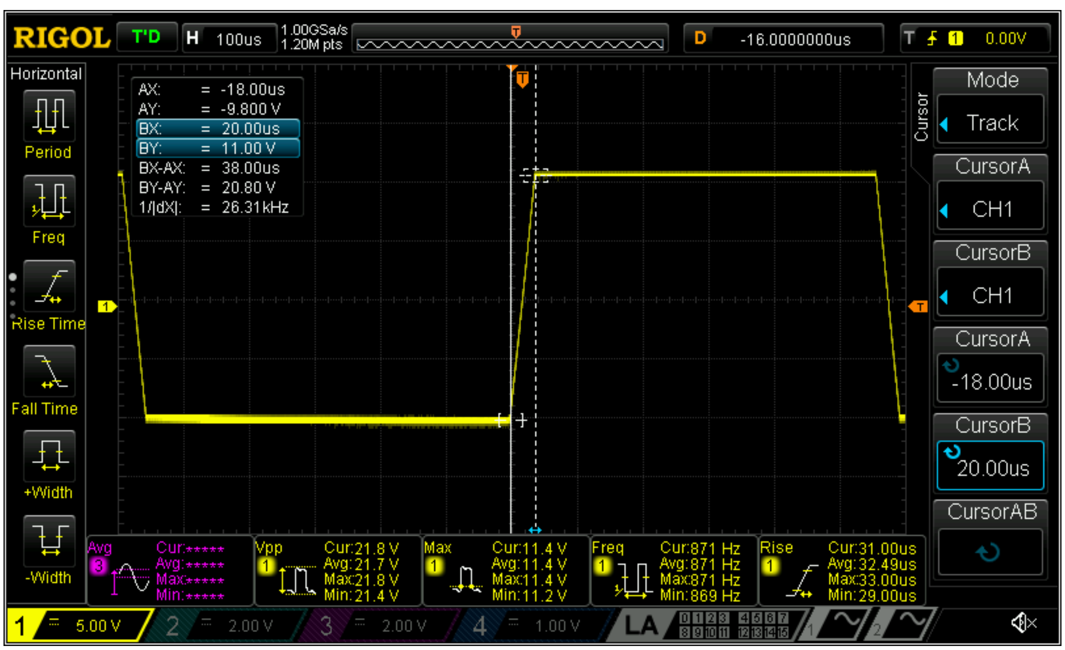


Plot - Output of Square Wave Circuit:

INPUT @ CAP



OUTPUT



Analysis

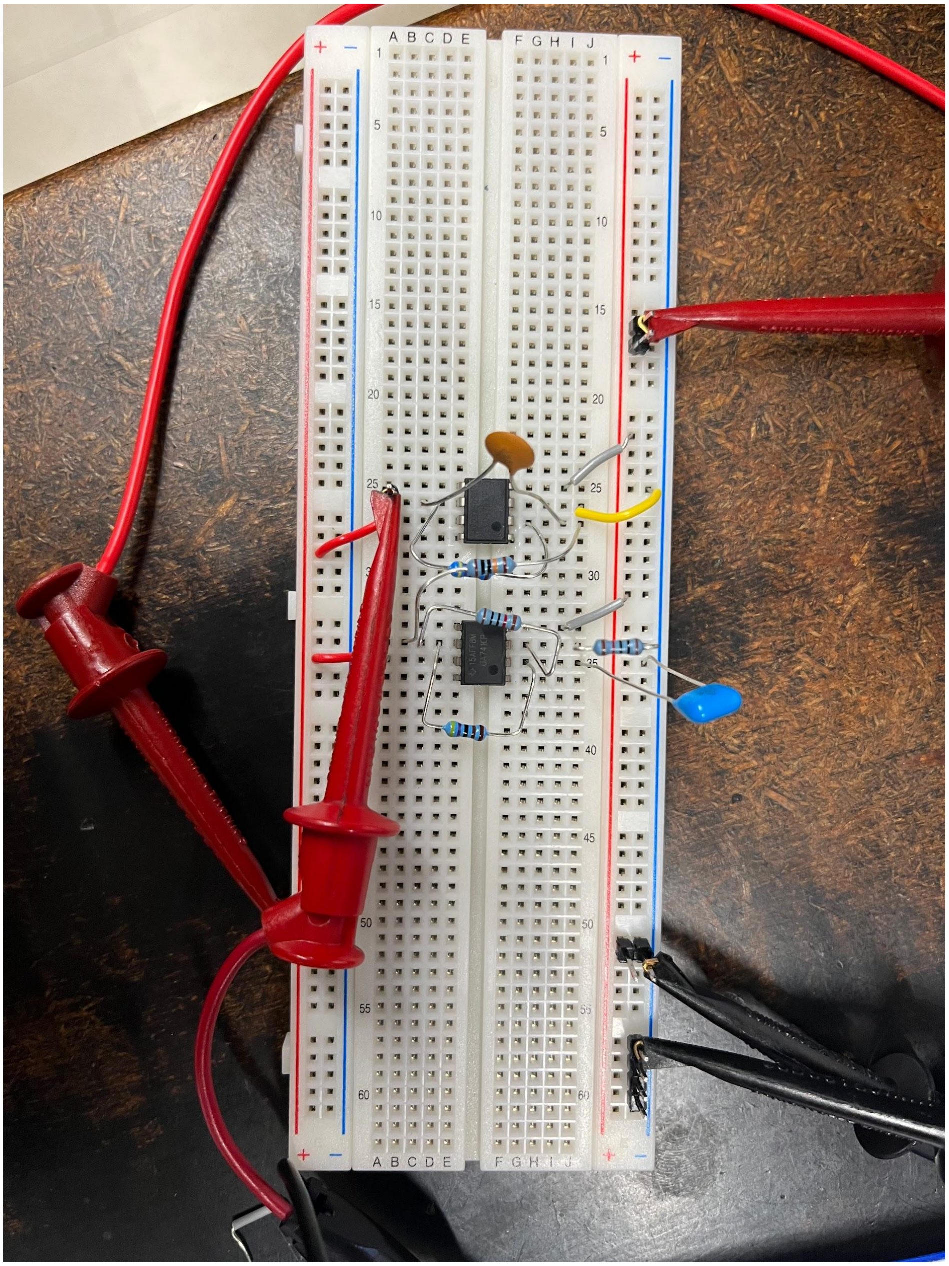
From observation, we can see the input of this circuit appears in sawtooth waves. (refer to plots above) This is because of the constant charging and discharging of the capacitor, thus making Vcap oscillate from < to > Vout/2. (creating the sawtooth wave) From the oscilloscope, we can determine that the peak to peak voltage is 11.1V, and its frequency is 869 Hz.

Jumping to the output, it appears to produce square waves, as expected. The oscilloscope reads a peak to peak voltage of 21.8V, and a frequency of 868 Hz.

The square wave constantly oscillates between positive and negative voltage. We calculated this small amount of time to be 38 microseconds.

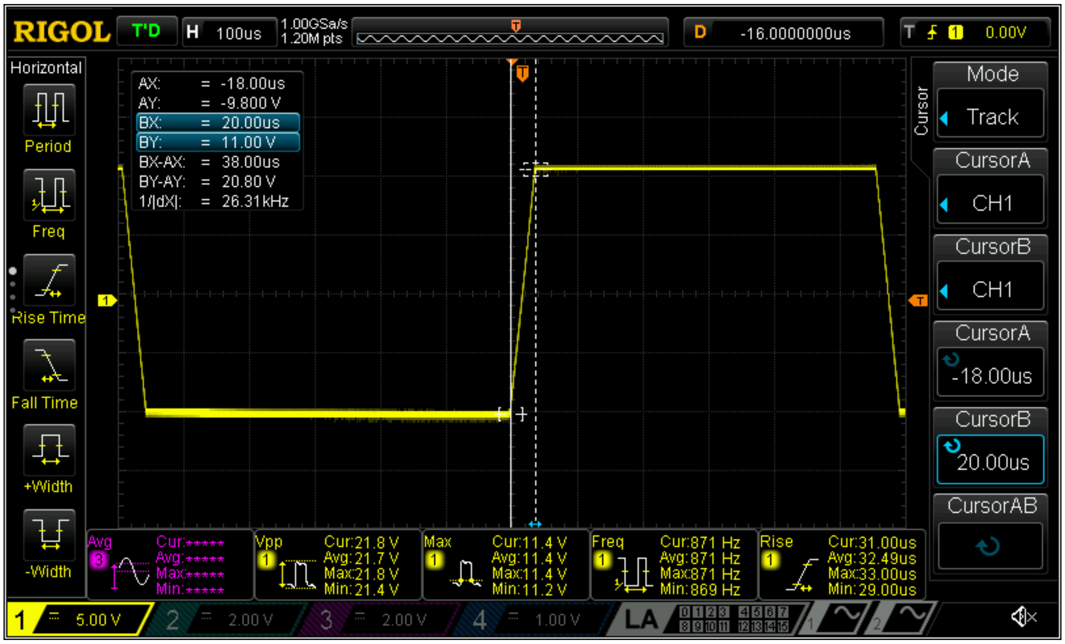
The rise time and fall time is determined by the amount of time it takes for the capacitor to charge and discharge, and that time is determined by the formula $\tau = RC$, plugging in the values, we get $\tau = 5e3 \; * \; 100e - 9 \; = \; 0.0005s$ or .5ms, this is very far off from our measured value, giving us a percent error of $\frac{3.8e-5 - 0.0005}{0.0005} * 100 \; = $ 92.4% error, in the lab we consulted the TAs and they were also unsure on why this is happening, and it reflected in other groups as well so I do not believe that this is an error on our part.

2) Experimental diagram

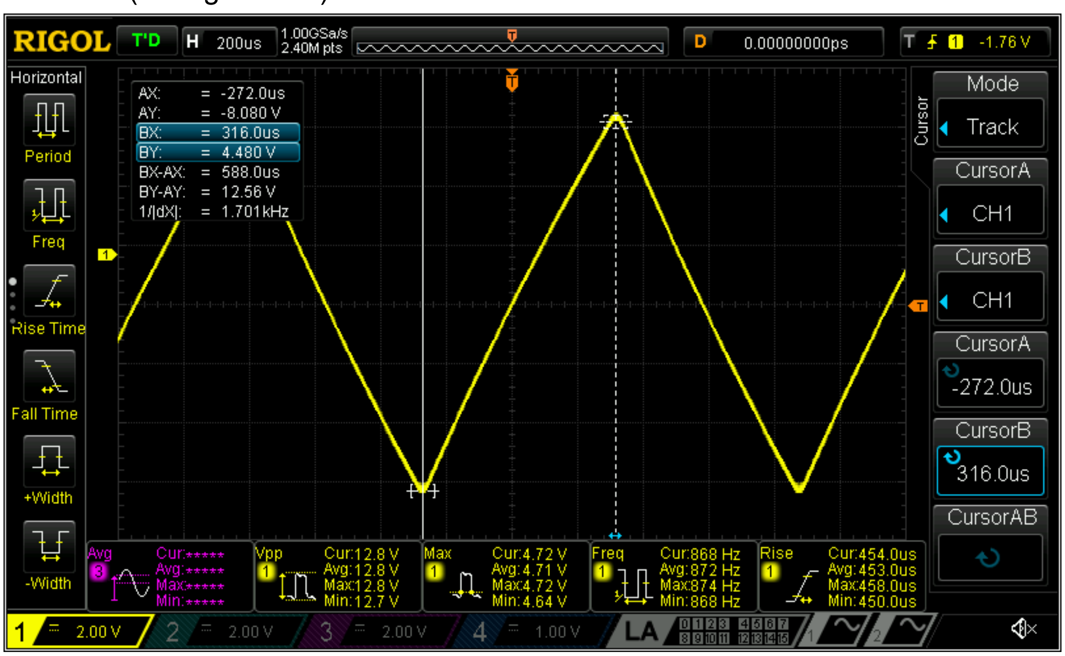


Plot - Output of Triangle Wave Circuit

INPUT (Output of Square wave generator)



OUTPUT (Triangle wave)



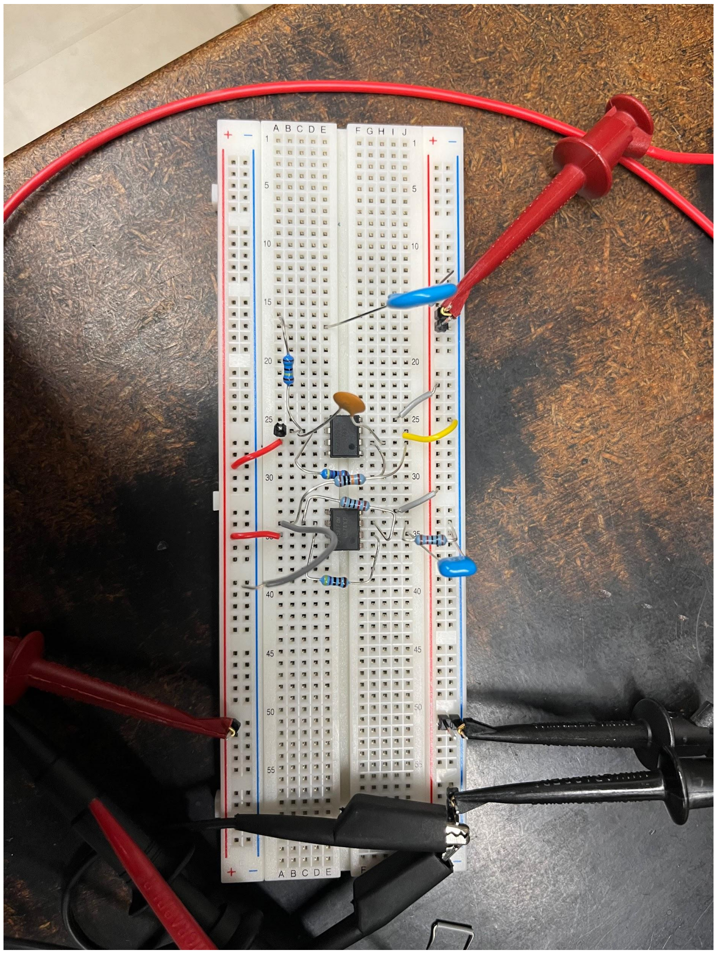
Analysis

It appears we successfully used an integrator by adding a 500k ohm resistor and a 4.7nF capacitor to convert the square waves to triangle waves. We expected the waves to be triangle, because the capacitor charges and discharges linearly when constant current is passing through, thus making it depend on the input resistor. This means the wave should oscillate linearly, in a triangle fashion.

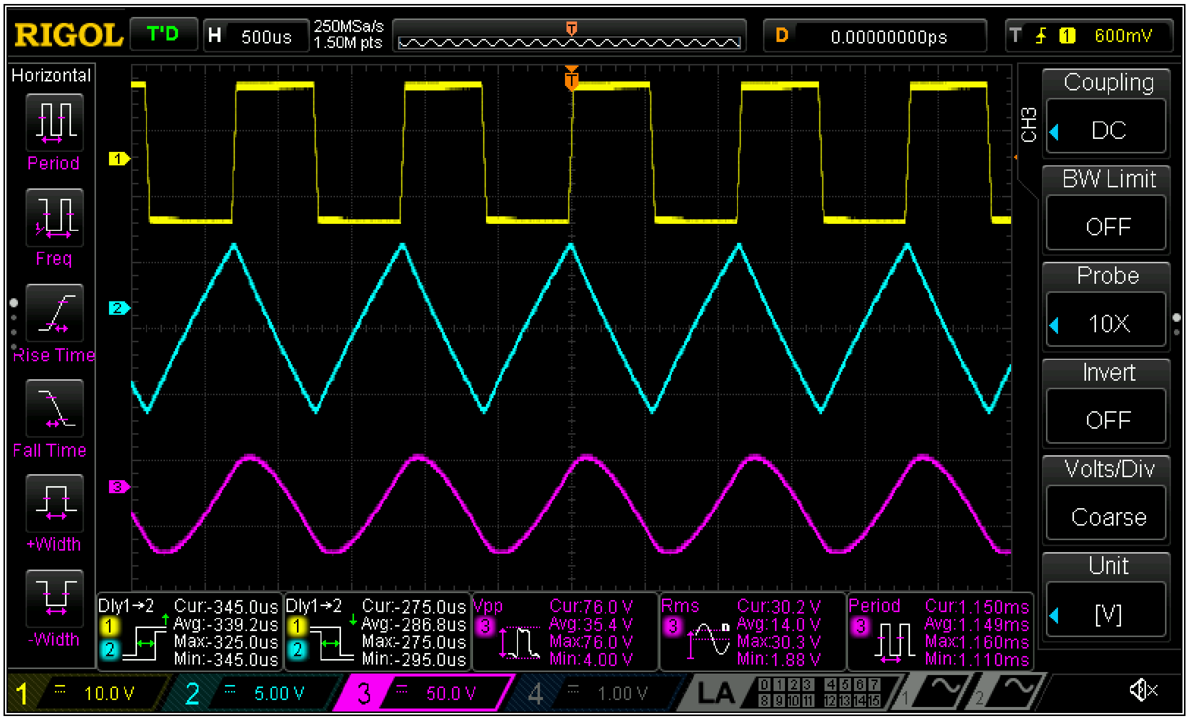
The input of this stage was 11.4V, and the Voutout (2nd stage output) read 4.6V by the oscilloscope. The frequency stayed the same at about 868 Hz.

Applying KCL a the inverting input in the integrator we use Kirchhoff's Current Law meaning that $\Sigma I = 0$ so all inputs at node for non-inverting terminal add up to zero, the I @ non-inverting = I @ inverting, and I @ inverting is 0 because it is grounded, so the only currents coming in are from the 2 resistors and capacitor $\frac{V_{sat}}{100k\Omega} + \frac{V_{out}}{.5M\Omega} + C\frac{dV_{out}}{dt} = 0$

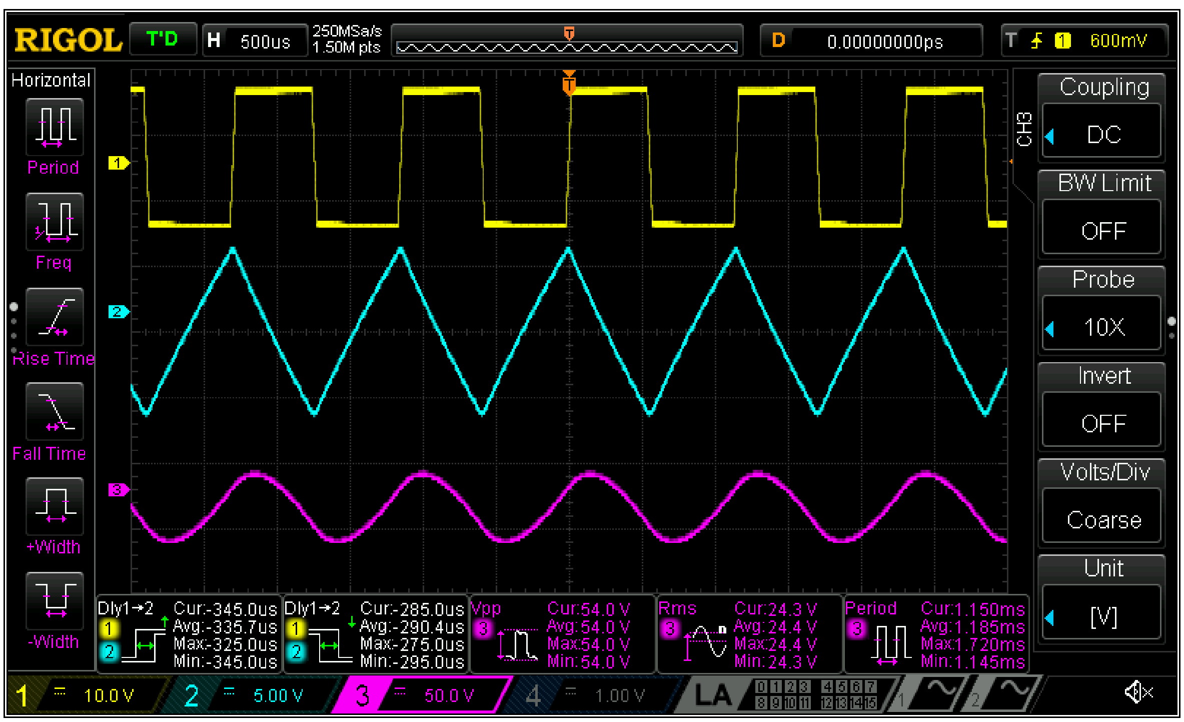
3) Experimental diagram



PLOT - Output from sine wave circuit from triangle wave



FOR 20k resistor, close to 18



FOR 33k Resistor

Analysis

In order to create a low pass filter, we needed to calculate the value of the resistor using the given low pass filter formula: $f_c = \frac{1}{2\pi RC}$, doing some moving around we can solve for $R = \frac{1}{2\pi f_c C}$, plugging in the values, $\frac{1}{2\pi*868*10e-9} = 18336\Omega$, in the lab, an 18k resistor is closest so we use that.
To make a low pass filter at half the frequency we use the same formula, except half the frequency, getting an resistance of 36671 Ohms, which is close to 33k resistor

What this does to alter the sinusoidal wave is change the Vpp, in the low pass filter for 868 Hz the Vpp is 22v higher than the low pass filter for 434Hz, the reason the Vpp changes is because a low pass filter cuts off higher frequencies, and at a lower frequency, it cuts off more voltage.

Conclusion

In this experiment, we worked with Op-Amp circuits, capacitors, integrators, and low-pass filters to manipulate waveforms to create the desired shapes. We created a square wave, triangle wave, and sine wave circuits.
In our square wave circuit we showed that the charging and discharging of a capacitor results in a sawtooth waveform, the observed Vpp was 11.1 V and the frequency was 869 Hz input, Our output successfully converted that sawtooth into a square wave, the Vpp of this wave was 21.8V and the frequency was 868 Hz. measuring the rise and fall time of the square wave the time was 38 microseconds, trying to confirm this value we calculated the rise and fall time, but got .5 ms, this value was far from expected and resulted in a percent error of 92.4%. We were not the only group to run into this and the TAs at the lab also were unsure why this was happening.
For the triangle wave, we input the square wave and transformed it into a triangle wave by using an integrating op amp, 500k Ohm resistor, and 4.7nF capacitor. The output was successful and the output voltage was measured at 4.6V, the output frequency was the same as the input at 868 Hz
Finally we created a sin wave using a low pass filter on the triangular wave. To create this we used an 18k resistor and 10nF resistor initially which output a Vpp of 76V. Next we used a 33k resistor to make a low pass filter for half the frequency and see the difference that makes. It turns out that the Vpp changes to 54V. This is expected because a low pass filter at a lower frequency filters out more, resulting in a lower Vpp
Overall, this lab provided practical experience with Op-amp circuits, capacitors, integrators and low pass filters in the use of manipulating a waveform, despite some measurements being off from what was expected, we were ultimately able to create the waveforms and successfully achieve the objectives laid out in the lab procedure.