ELEC3106 Configurable Amplifier Lab Report

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Introduction

This is a report for the ELEC3104 configurable amplifier project. This project aims to construct a circuit which has multiple gain and bandwidth settings which can be configured by two buttons which output a 2V logic level.

Simulation and Theory

Active Low Pass Filter

To control the BW and gain independently, we chose our design to be an active low pass filter (Figure 1); consisting of an RC circuit (BW control) and non-inverting amplifier (Gain control). We made this choice since it seemed to be the most effective design given that it is not too complicated. A power supply of $\pm$15V was used which we chose to align with the recommended operating conditions of the LM741 op amp. A 10nF decoupling capacitor is used to reduce the power supply variation. Controlling the gain and BW was implemented through parallel resistors. Gain is controlled by changing R_2 between 90kΩ and 25.7kΩ||90kΩ which changes the gain from 10 to 3 respectively according to $A = 1 + \frac{R_2}{R_1}$.
Similarly, the bandwidth is changed by changing R between 30kΩ and 30kΩ||15kΩ which changes the BW between 10kHz and 30kHz according to $BW = \frac{1}{2\pi RC}$. The switches that control the parallel resistor being connected/disconnected is obtained by using the DG442 switch IC. It takes an input (IN) that closes the switch (S-D) if IN>2.4V and opens the switch if IN<0.8V. The switch circuit will be discussed in more detail in the next section.

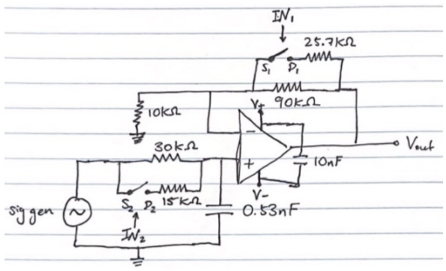

Figure 1: Active low pass filter circuit

Switch Circuit

The switch circuit (Figure 2) controls the parallel resistor being connected/disconnected (S-D connection). The voltage divider reduces the 15V power supply to 2V before entering the physical switch to satisfy the specifications of the project. Next, the signal is passed through a non-inverting amplifier with a gain of 2 to bump it to 4V (>2.4V) to satisfy the input criteria of the DG442 IC high state. Now when the physical switch is closed, IN=4V and S-D (parallel resistor) is connected. And when the physical switch is closed, IN=0V and S-D is disconnected. In our circuit, two of these switch circuits are used; one for each of the BW and gain controlling parallel resistor.

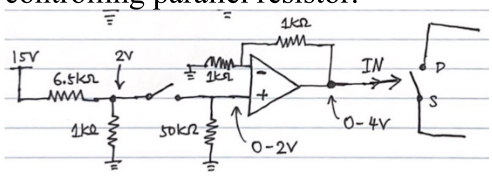

Figure 2: Switch circuit

Single Power Supply

To implement a single, one-sided power supply, we used a simple voltage divider with a 30V power supply to create a virtual GND. Each resistor used was 10kΩ which created a $\pm$15V node when we set the virtual GND to be the middle. These two nodes are then taken to be our V+ and V-.

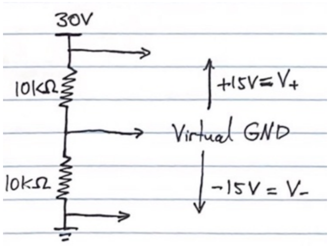

Figure 3: Virtual GND circuit

Simulations

Through the simulations of LTSpice, we were successfully able to obtain the desired function from our circuit before implementing it physically. The following gains and BW were obtained:
Gain = 2.977 and 9.998
BW = 10.078kHz and 30.27kHz.
Which align very closely to our desired values. Note that two other simulations were done to check Gain=3, BW=10kHz and Gain=10, BW=30kHz and the expected behaviour was obtained.

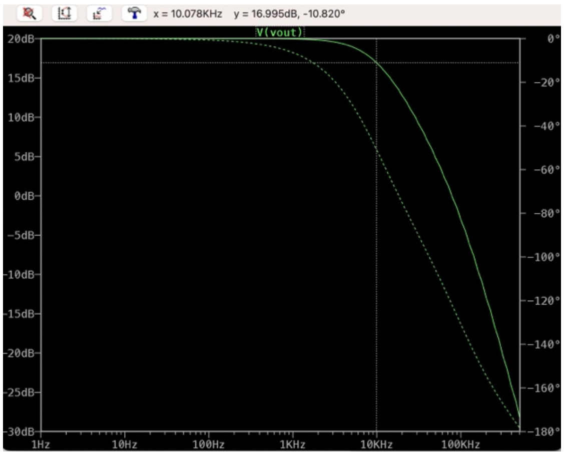

Figure 4: Gain = 10, BW = 10kHz

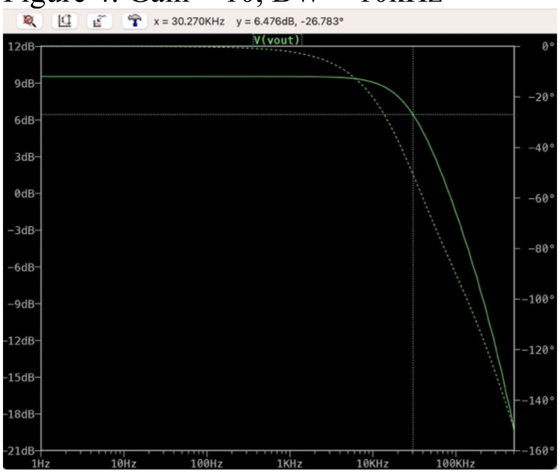

Figure 5: Gain = 3, BW = 30kHz

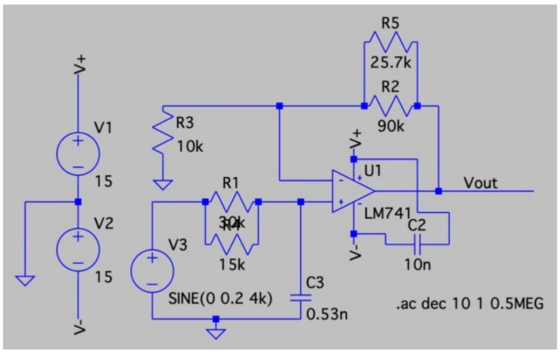

Figure 6: Simulation schematic

Real World Measurements

There are a total of four different settings for our circuit with two gain settings of approximately 3 and 10 alongside bandwidths of 10kHz and 30kHz

Gain and Bandwidth Measurements

The frequency was initially set to 200Hz to limit the effects of any bandwidth with peak-to-peak values of 608.87mV and 1.984V with a 198mV peak-to-peak sine wave input leading to gains of 3.075 and 10 which are close to the expected gain values. For the 10kHz bandwidth, the peak-to-peak output values at 10kHz were 412.58mV and 1.35V for gains of 3 and 10 respectively which were slightly lower than the expected values of 424.2 mV and 1.414V. For the 30kHz bandwidth the peak-to-peak output values at 30kHz were 419.44mV and 1.32V for gains of 3 and 10 respectively which were once again slightly slower than the expected values.

Points of difference between simulation

The output values for the bandwidth tests are less than 10% off the expected value and as such were treated as within reason. One way of reducing these differences in values would be to use smaller values of resistors in series to adjust the total resistance values to be more in line with those used in simulation since the resistors were tested to have significant but expected deviance from the expected values. Furthermore, the use of the DG441 switch may have induced an increased resistance in series with the resistors used in the circuit, affecting the gains and bandwidths.

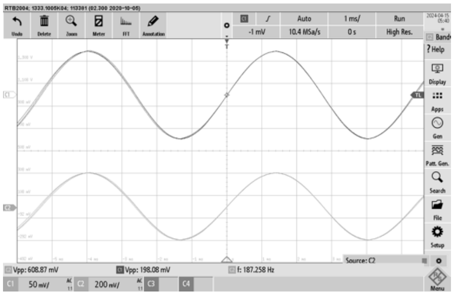

Figure 7: Gain 3 frequency 200Hz

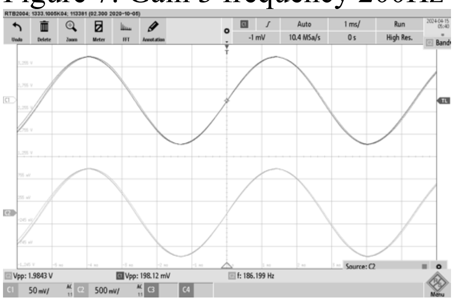

Figure 8: Gain 10 frequency 200Hz

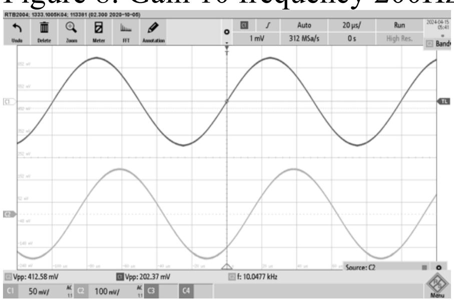

Figure 9: Gain 3 Bandwidth 10kHz

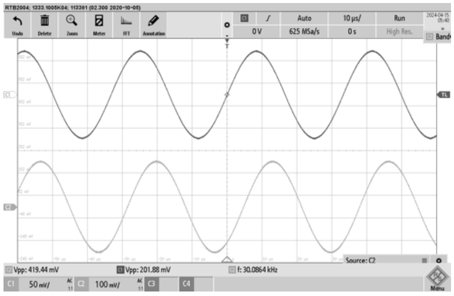

Figure 10: Gain 3 Bandwidth 30kHz

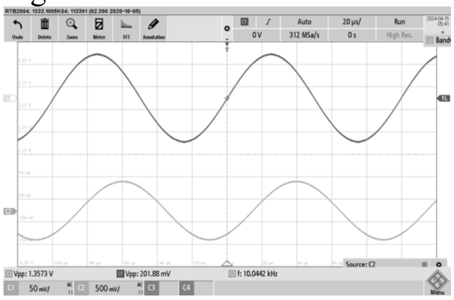

Figure 11: Gain 10 Bandwidth 10kHz

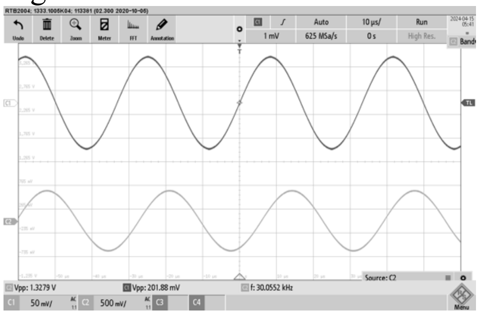

Figure 12. Gain 10 Bandwidth 30kHz

Logic and Distortion

Furthermore, the use of the 2V logic level dropped to 1.34V when connected due to the logic of the voltage input now becoming part of the circuit. Furthermore, as shown in figure 13, there was noticeable distortion that begun at around 27V. This distortion is likely due to the slew rate as evidenced by the increase being straighter than expected for an undistorted sine wave. The calculated slew rate is 0.53 V/µS which is similar to the typical value of 0.5 V/µS evidenced in the datasheet. There is also clipping at the bottom of the wave which is likely a result of the power supply limits as we were using +/- 15V as our upper and lower supply rails.

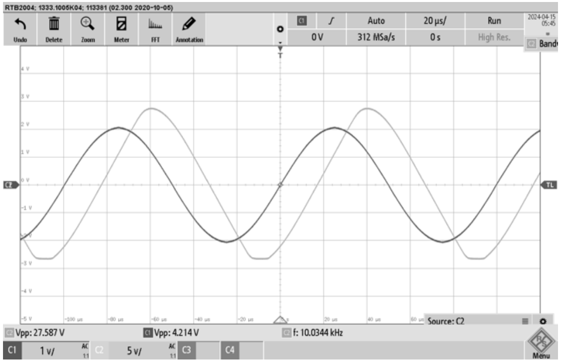

Figure 13: minimum voltage distortion

Power Consumption

Furthermore, the output power consumption of the system was calculated by measuring the currents present at the positive and negative power supply rails and subtracting them from each other to get the total power differential, resulting in the following:

Vee=-15.2V, Iee = 1.034mA

Vcc = 15.2V, Icc = 1.035mA

P = Vcc * Icc - Vee * Iee = 31.4mW

This value is quite a bit lower than the power draw of a single LM741 opamp. This may be due to the oscilloscope being the primary load and due to the large resistance, can be treated as an open circuit. This would in turn, reduce the total power draw of the circuit as a reasonable load was not connected to the output of the circuit.

Extension Improvements

Memory

Several improvements could be done to the circuit to improve the capabilities of the circuit. The implementation of multiple gain or bandwidth settings would require the use of memory within the circuit. This memory could be implemented with the use of a microcontroller or a logic circuit with D flip flops or SR latches which would then be used to change voltage levels on an edge trigger. This voltage could then be attached to the DG441 IC or another analogue switch IC to control the resistor and capacitor values in the circuit.

Increased Gain and Bandwidth

Furthermore, a high gain could be achieved by adjusting the resistors used in the non-inverting amplifier. For gains such as 300 and an input of 200mV would result in a 60V peak to peak voltage and thus would require an op amp with a supply limit of greater than +/- 30V such as the OPA445 high voltage FET-input which allows a max of a +/- 45V but costs considerably more than the LM741 which was used in this circuit. Furthermore, the bandwidth could also be changed with different values but would also require an op amp that allowed increased bandwidth as the LM741 would likely not have enough for any values about 1MHz. An IC such as the LTC6268-10 which has a typical gain bandwidth product of 4GHz could be used for this situation.

Conclusion

In conclusion, an active low pass filter alongside a 2V logic button connected to a set of analogue switches can be used as a configurable amplifier, giving values for gains and bandwidths within reasonable values and providing an output signal of sufficient amplitude and frequency without distortion.