| Class: | EE320L | | Semester: | Fall 2020 |
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| Instructor's comments: | | | | |

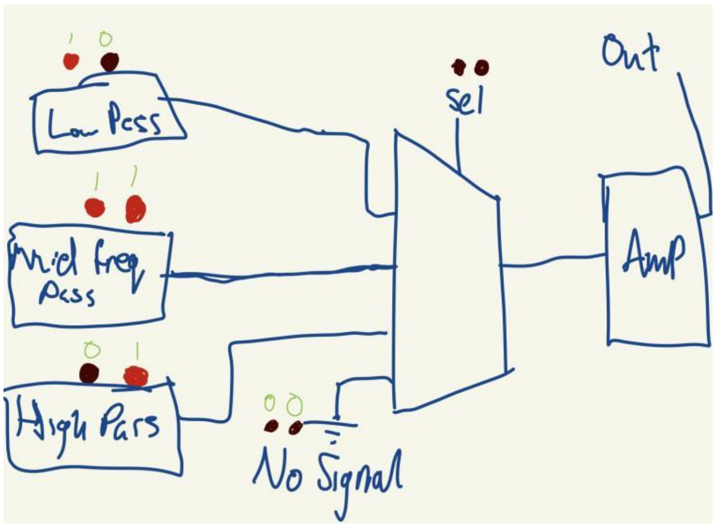
## 1. Introduction / Theory of Operation

This project is a digitally controlled audio filter and amplifier. The basic premise is that there is an audio input, as well as two selector inputs, and based on the selectors, the output will be an amplified, frequency filtered version of the audio input.

This functionality was achieved with CMOS logic gates and transistor amplifiers. The details of which will be explained in the report. The circuit was built in LTSpice but could be implemented on a physical circuit. In practice, the input could be a guitar signal, an MP3 player, or any sort of audio, and the output would go to a speaker.

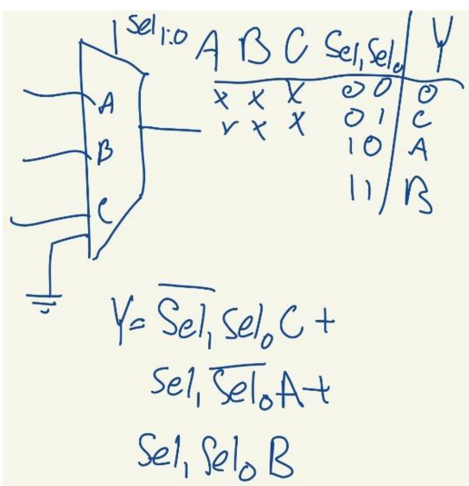
## 2. Project Documentation

The first step in the design process was having a rough idea of how I wanted the circuit to operate. This was achieved with a simple block diagram.



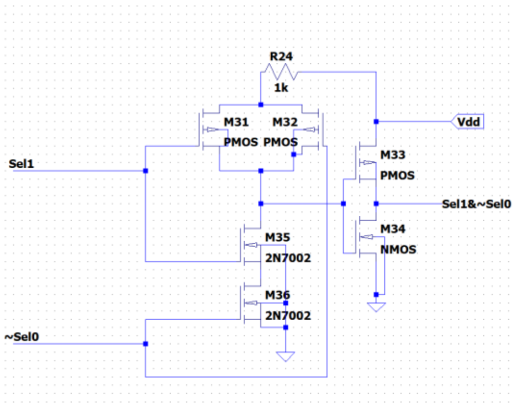

The lights signify the selector signals and each box on the left is an audio filter. The output of the multiplexer is then fed into an amplifier for the output.

The next step was writing equations for the logic of the multiplexer.



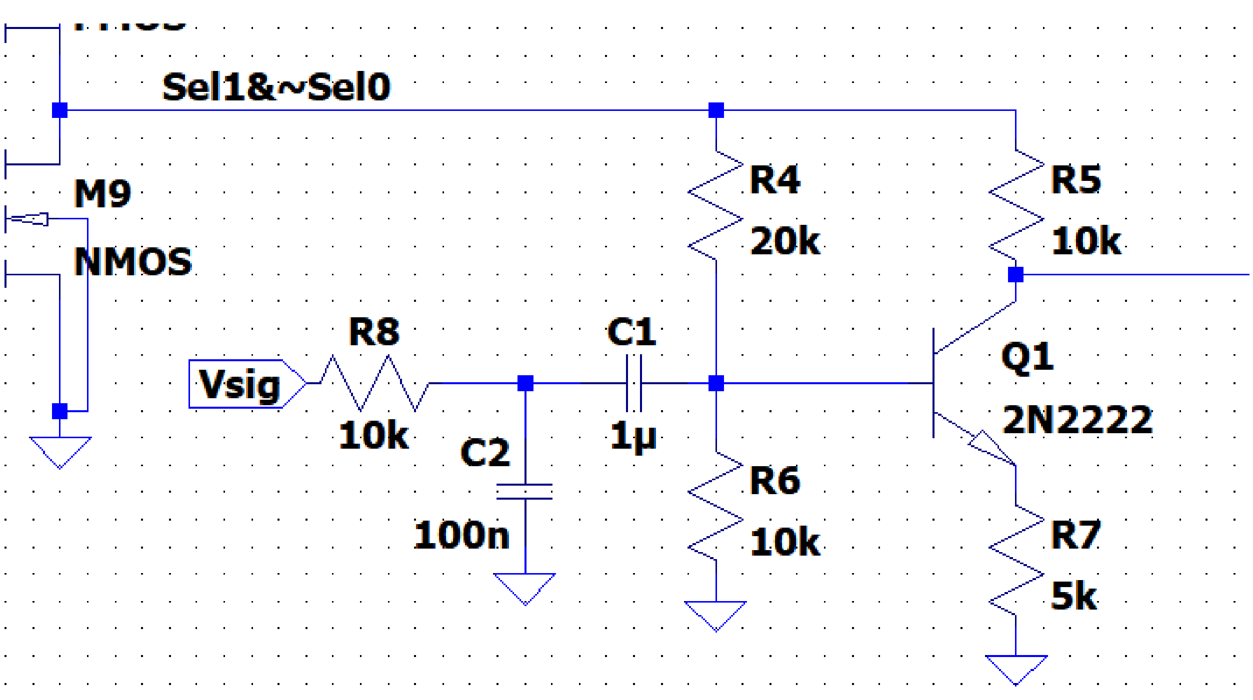

These equations made me realize that I did not need a whole multiplexer for the designed, and drastically simplified the circuit.

To implement the logic functions, CMOS technology was used for an AND-OR Network. I used three AND Gates and one 3-input OR gate to implement the equations.



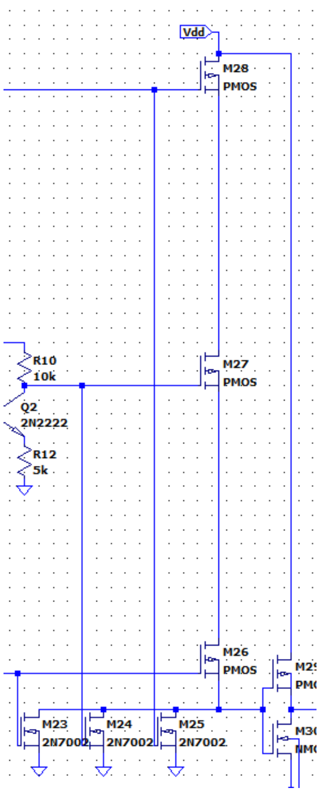

**Sample AND Gate**

The next problem was using mixed signals in the AND gate. I solved this issue by feeding the two selector signals into the AND gate and having the output of the initial AND Gate be the power supply (Vcc) of a Common-Emitter Amplifier. This effectively created a second stage AND gate because the amplifier would only be on if the corresponding selector signals were on.

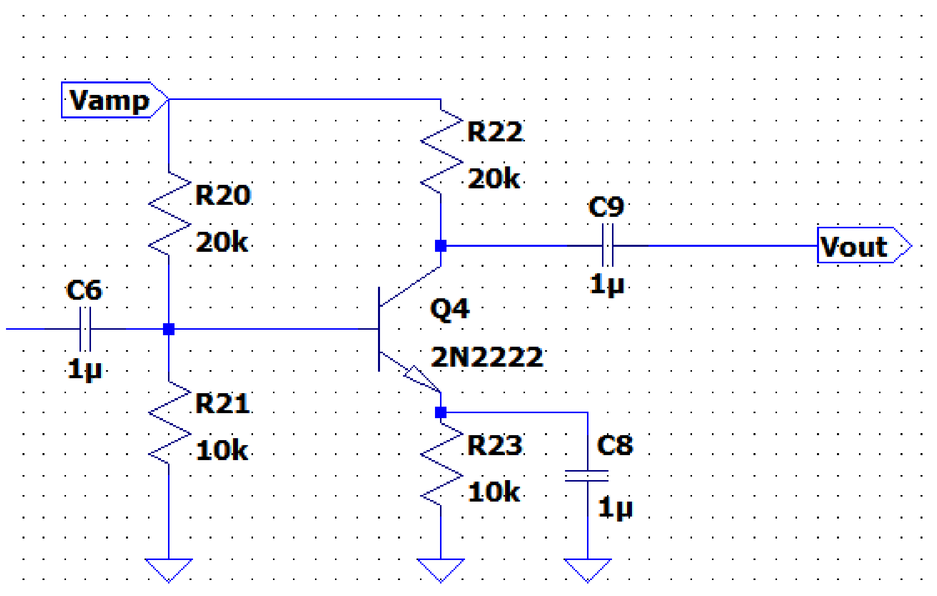



**Second Stage AND Gate as an Amplifier**

Now that the logic has been established, we now feed in the filtered audio as the input for the amplifier. The filter is implemented before the coupling capacitor of the amplifier. In the sample photo, this is the low-pass filter with a cutoff frequency of $\frac{1}{2*pi*RC}$, in this case approximately 200Hz, which is at the lower end of what human ears consider a low frequency. This filtered signal is then amplified and sent into a 3-input OR Gate for the next stage of the circuit.



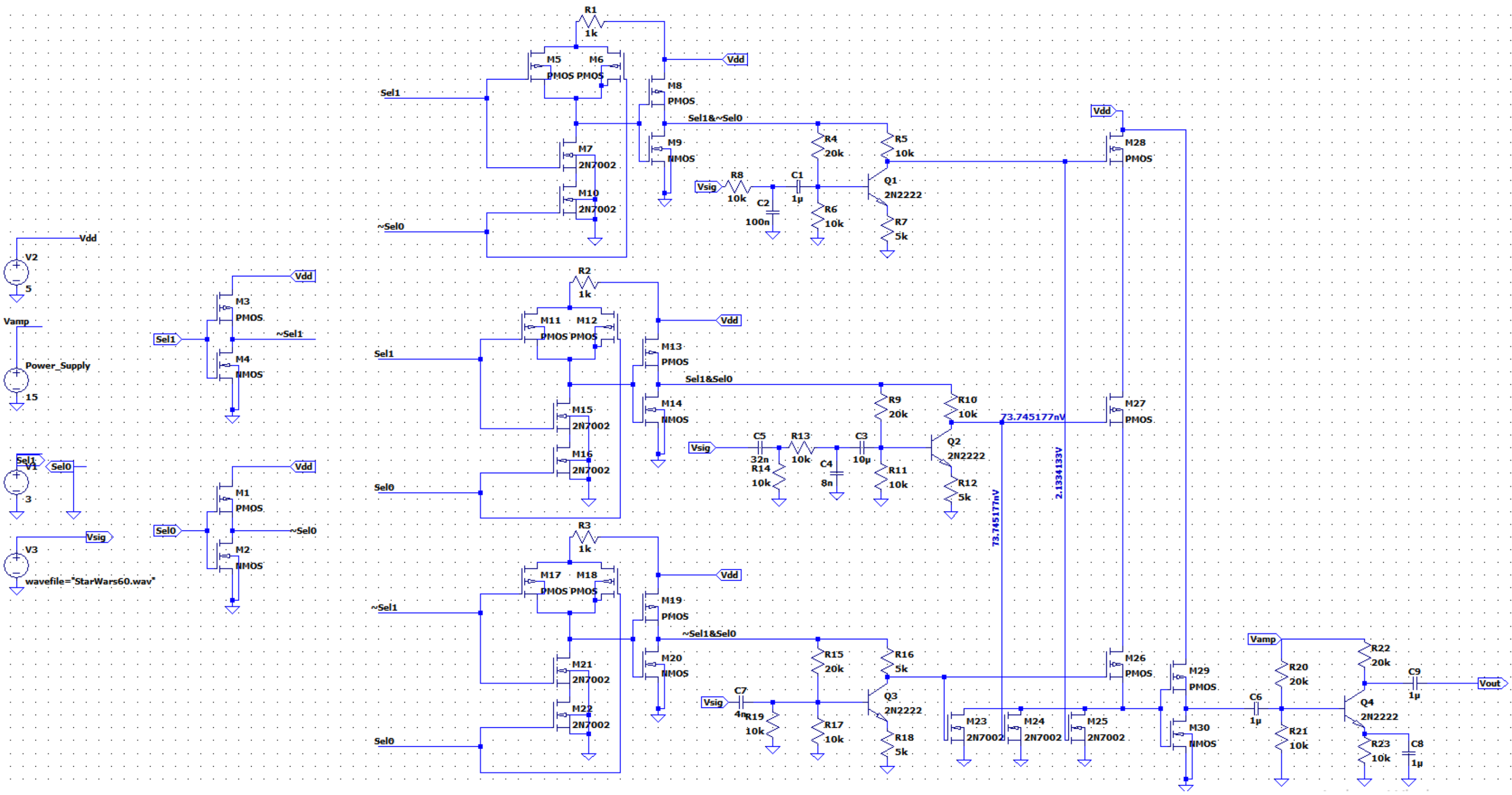

The OR gate takes in the 3 amplifier outputs and feeds it into the final stage strong amplifier.



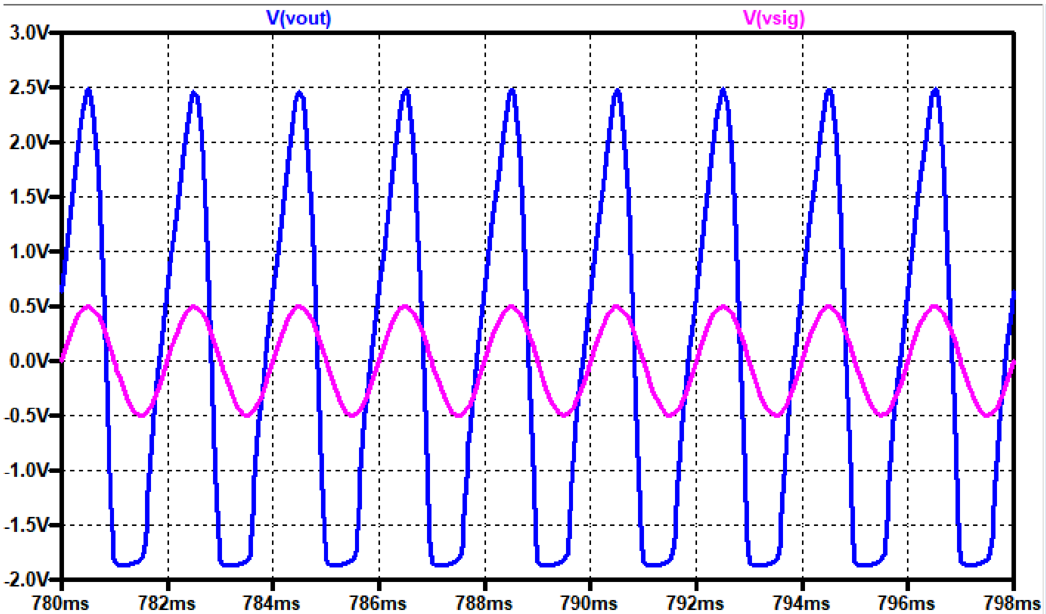

Final Stage Amplifier

The output was tested with both Sine Waves and an actual song in the form of a .wav file.

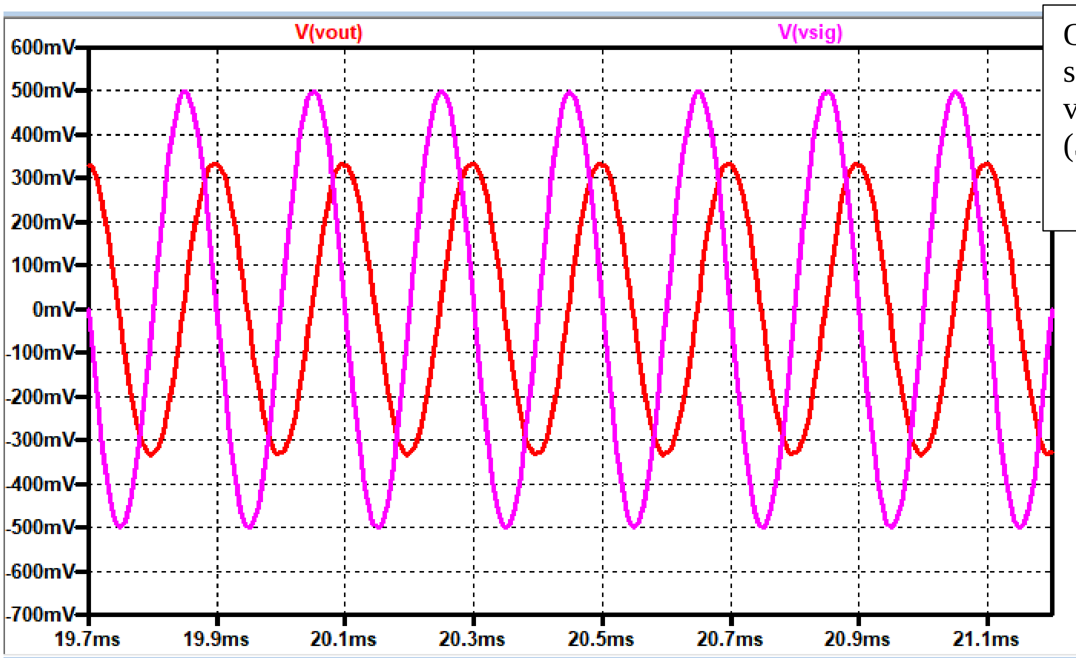
Full circuit with power supply voltages, selector inputs, and audio signal



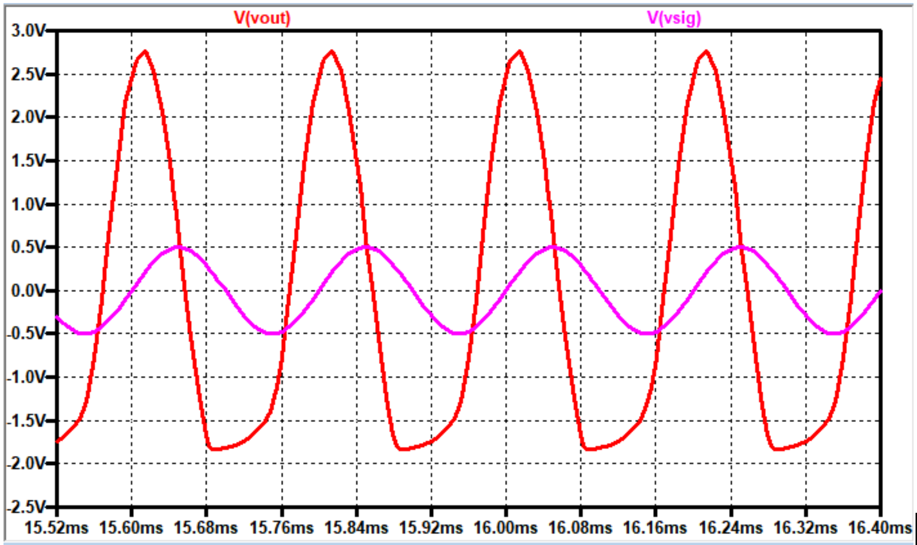
## 3. Results



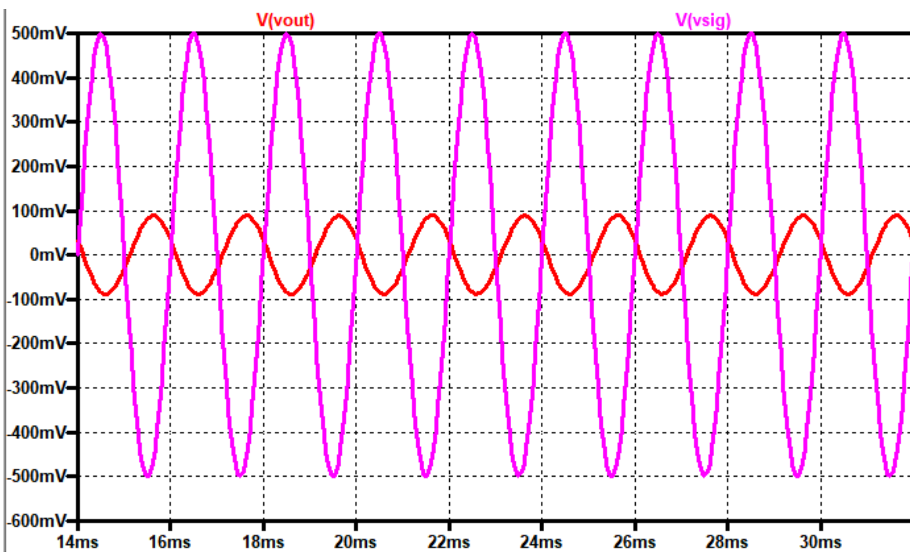

Output with lowpass mode selected. Vout is an amplified version of the input signal (500 Hz Sine wave)



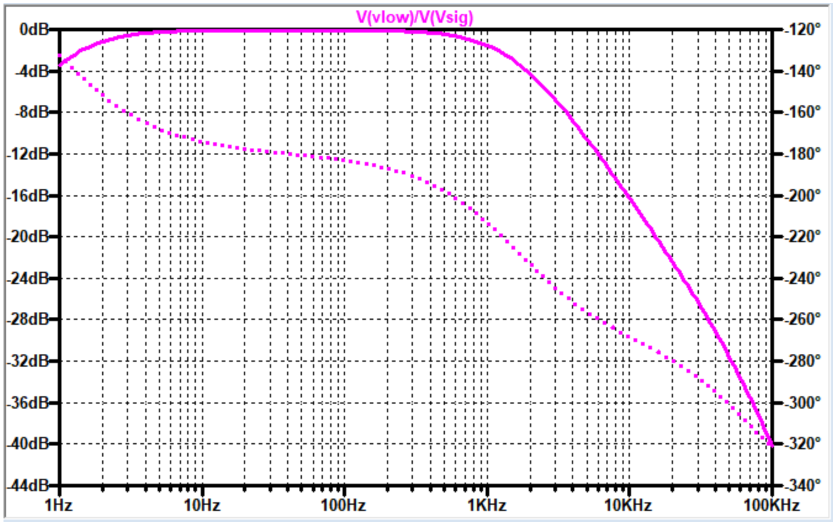

Output with lowpass mode selected. Vout is a smaller version of the input signal (5KHz Sine wave)

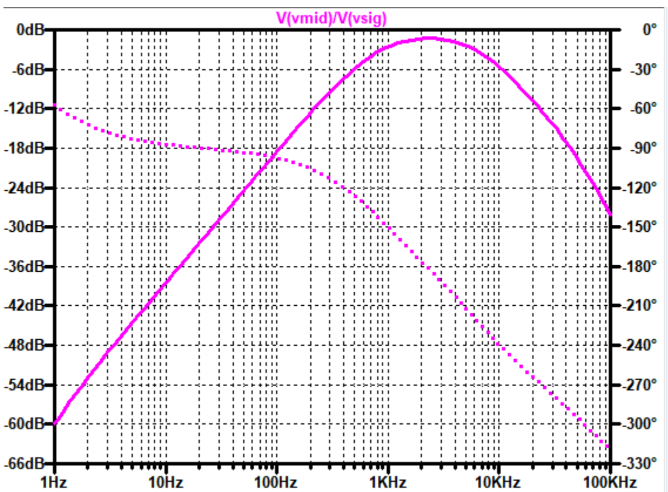



High pass mode selected, top photo is with input signal at 500Hz, Vout is amplified version of signal. Bottom photo, Vsig frequency is reduced to 500Hz and Vout becomes a smaller signal as expected.

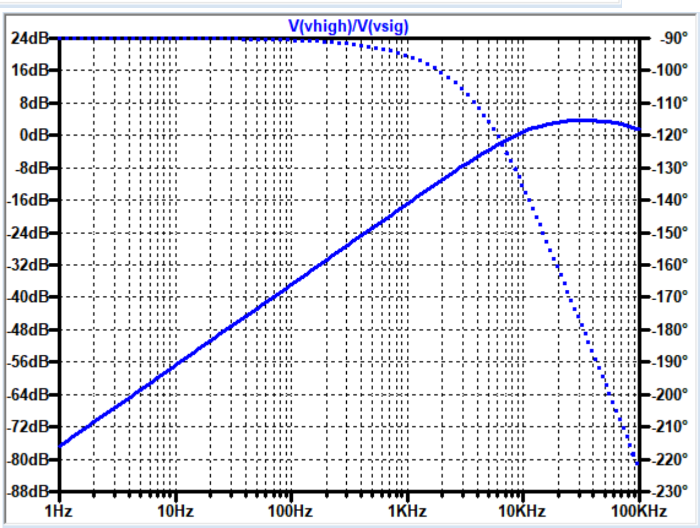


**Frequency Response**

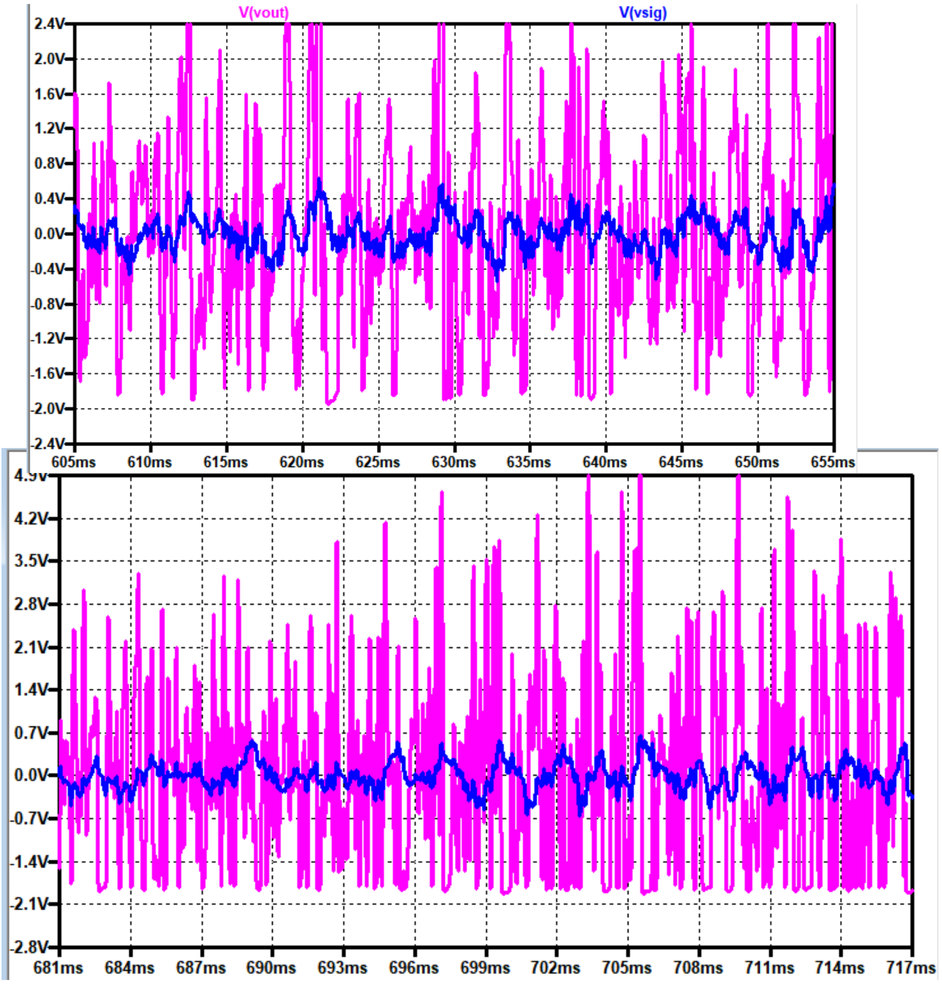


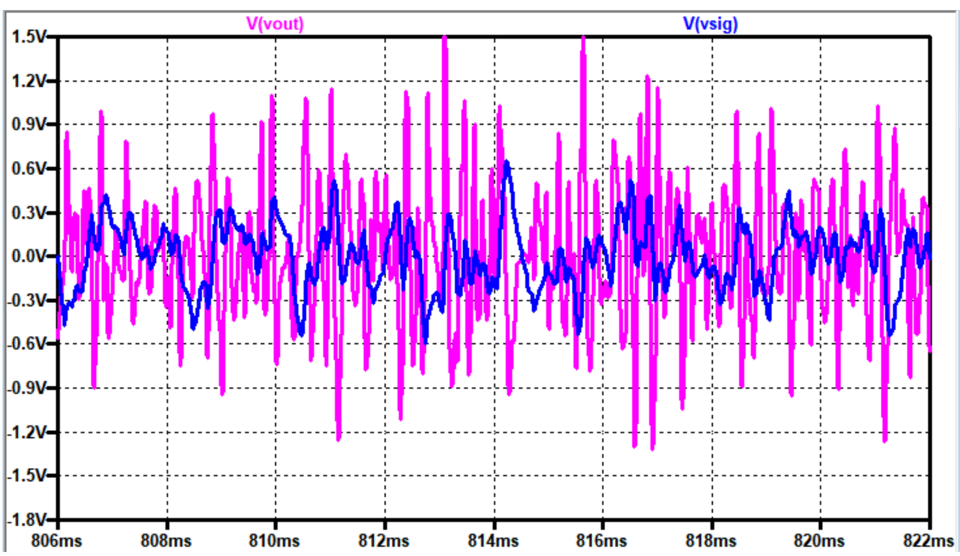




Frequency response where Vlow, Vmid, and Vhigh are the outputs of the first stage amplifier when their respective mode is selected.



## Output




Output when input is a .wav file and the respective modes are selected.
It is quite difficult to interpret the data here, but I imagine it would be very interesting to hear the result out of a speaker.

## 4. Conclusions

In conclusion, I learned a great deal about circuits during the process of building this circuit. I used almost every circuit element and concept I have learned thus far and then some. I used circuitry I never have before, and this was my first real circuit that I have designed. There are many improvements to be made.

I wish I could have built this circuit on a board and heard the output, maybe another semester. The circuit still requires more fine tuning to perfect the cutoff frequencies, something that would be easier if I could hear the output. Another improvement would be to add a transformer at the output so it can drive the low resistance speaker load. The filtering could be tuned better to prevent noise as well. I had many issues with biasing the transistors to act as amplifiers but they ended up working adequately. The high frequency filter produced a lower output than the others, something that could be fixed by selecting better capacitors.

In summary, I learned a lot and am proud of my circuit. I plan to make improvements to it in future semesters and hopefully build it in real life one day.