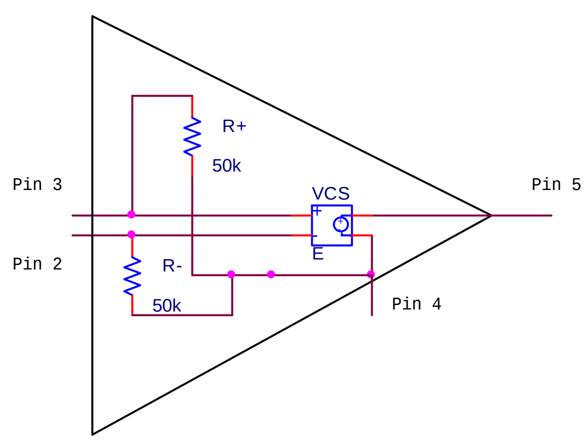
For Project 2 – A nearly complete simulation using PSpice

It is not possible to directly simulate the transmitter-receiver combination or to simulate all of the components with the student version of PSpice. The following shows one method for getting around these limitations.

A. Simulating the optical link and the audio amp.

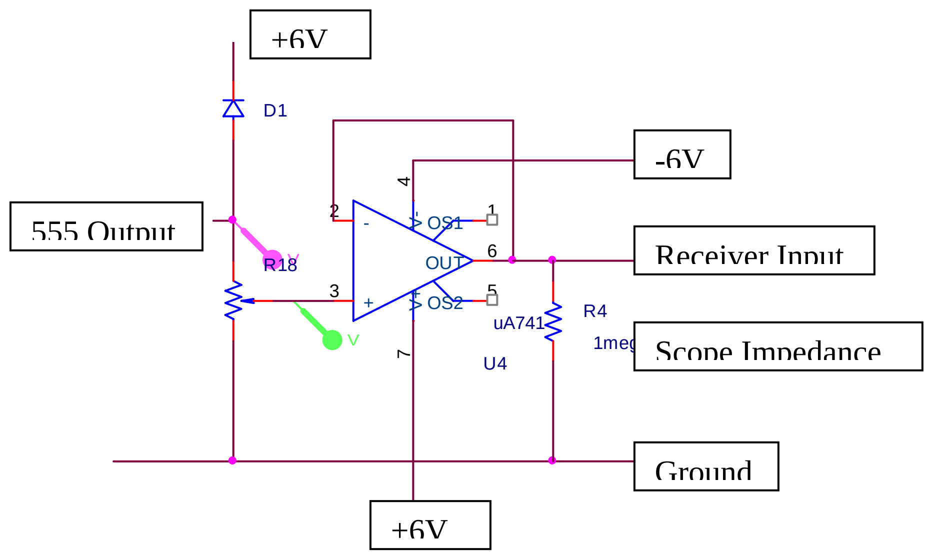
386 Audio Amplifier

There is no model for the 386 audio amp in the PSpice libraries. Thus, to complete your simulation, you should use the following (based on the internal workings of this device). Note that this model does not include the power connection (Pin 6) and the gain connections (Pins 1 and 8). The voltage controlled source (VCS) should be adjusted to have the overall gain set by what you connect to pins 1 and 8. The resistors in the model account for the input impedance. The VCS is called 'E' in PSpice. Remember that the gain available from the 386 amp is limited to a small number of options (full gain is 200).



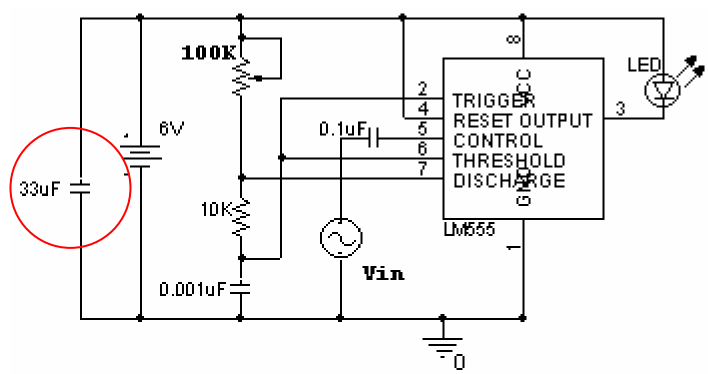
Connection Between the LED and the Photo Transistor

There is no simple way to show connection between an LED and a photo transistor. Instead, you can connect the output of the transmitter circuit to the input of the receiver circuit using a unity gain buffer circuit and a potentiometer to show the level of coupling. The buffer keeps the receiver from loading the transmitter (which it clearly cannot since they are not directly coupled in reality). The potentiometer should have a resistance of at least 10k. Also be careful specifying the set point. For the circuit shown, the set point was 0.9 to obtain 10% coupling. This is because the set point is measured from the top of the pot in this orientation. To keep the number of parts to a minimum in the simulation, it is not necessary to include the scope impedance. You will note that this has been removed in the full simulation described below. Note also that this set of components also shows the big advantage of optical links in measurement systems. While there is no direct connection and, thus, each section of a circuit is protected from problems created in other parts of the circuit, the signal still progresses through the system as it should.

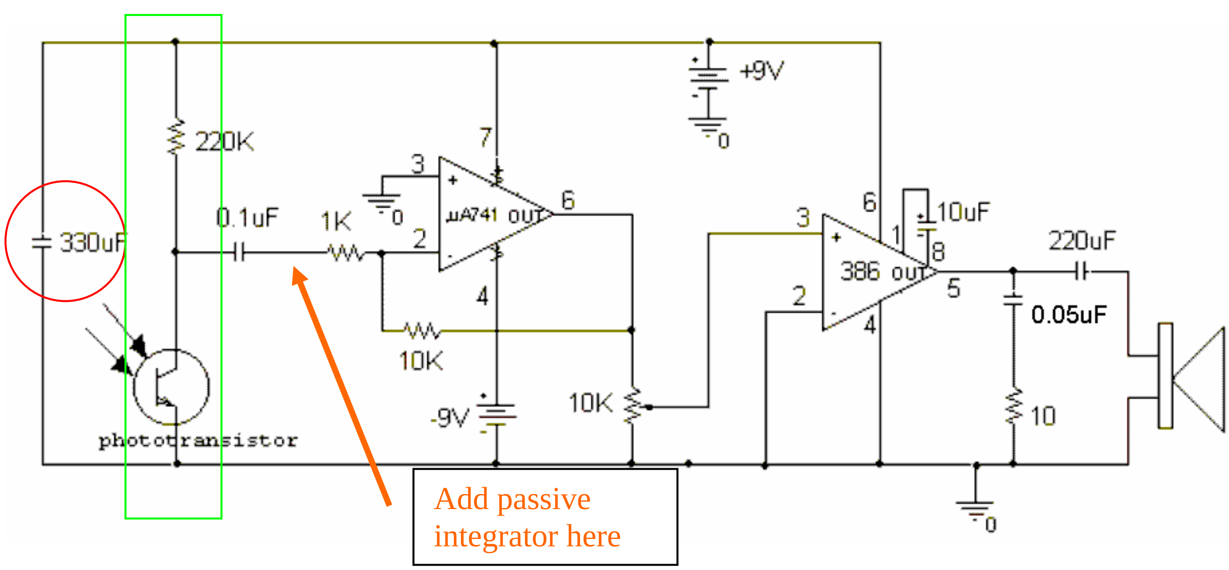


B. Project 2 Circuit Diagrams

The transmitter circuit is given in the project as:

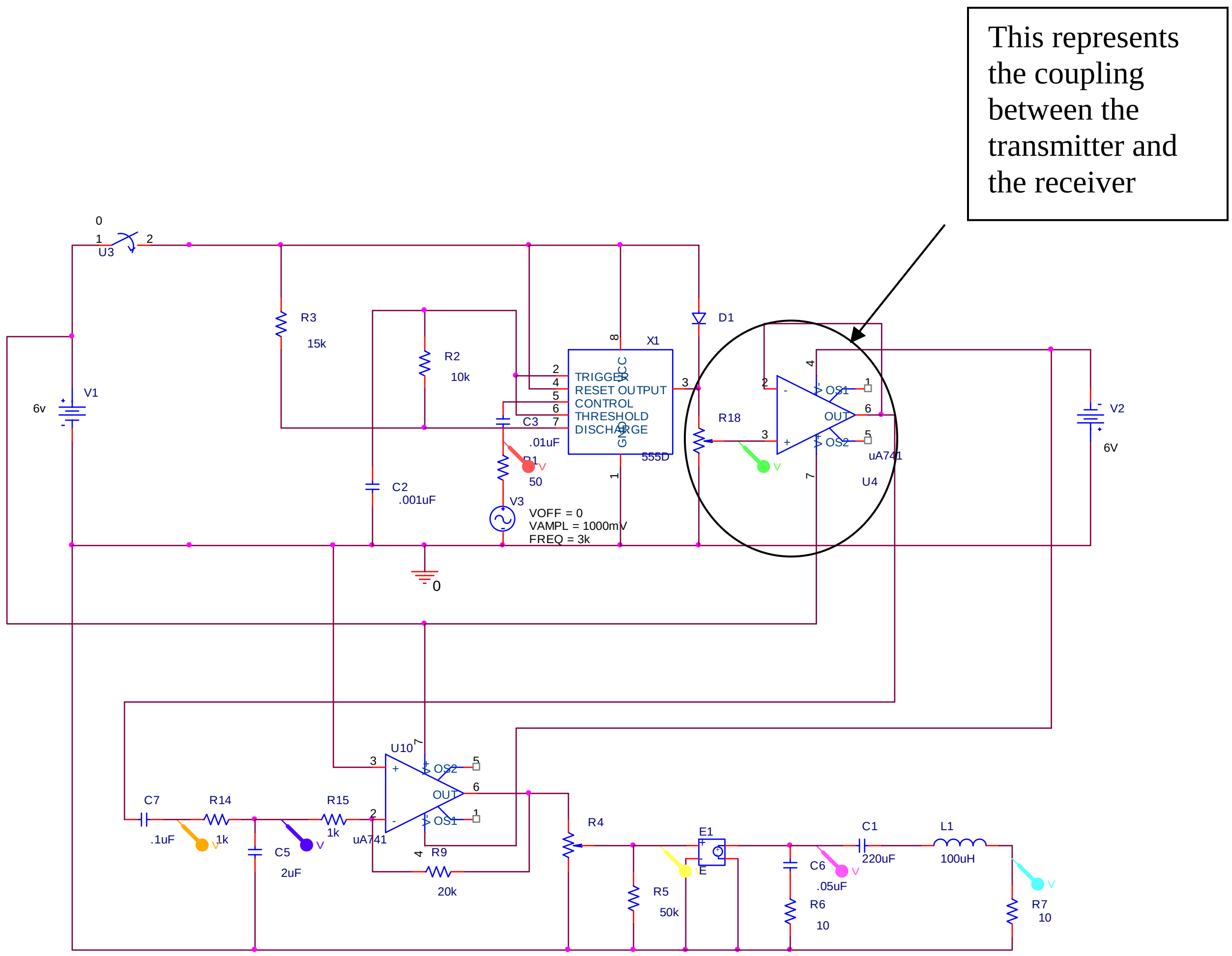


The receiver circuit looks like:

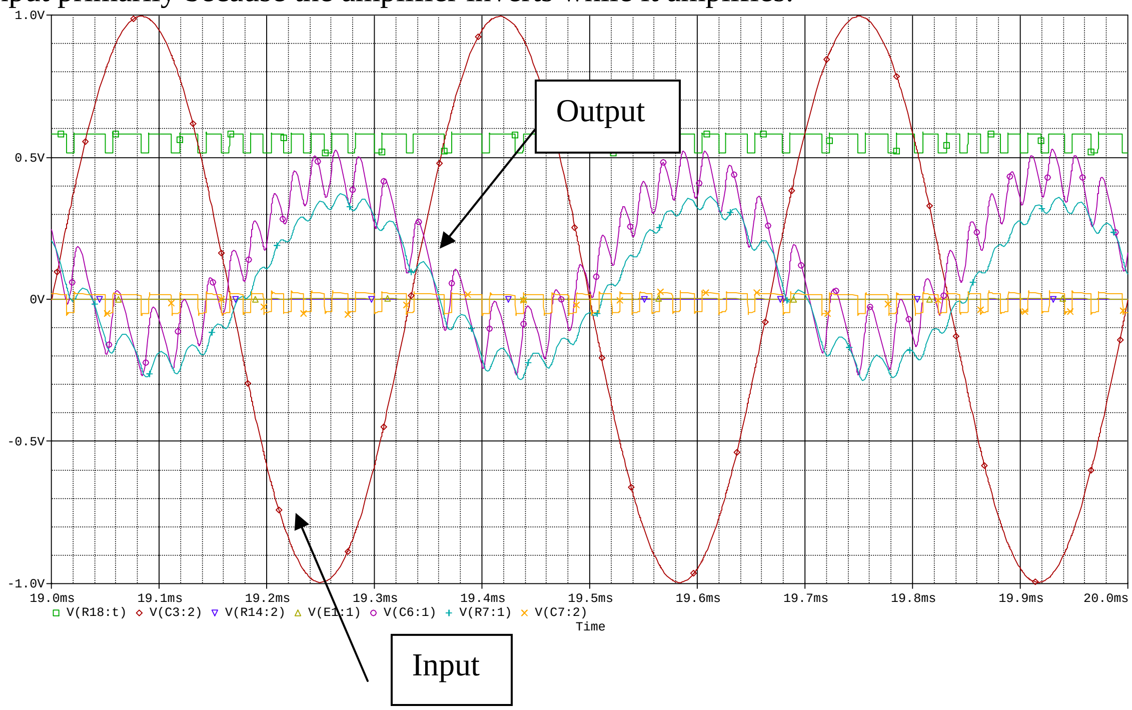


C. Simuation

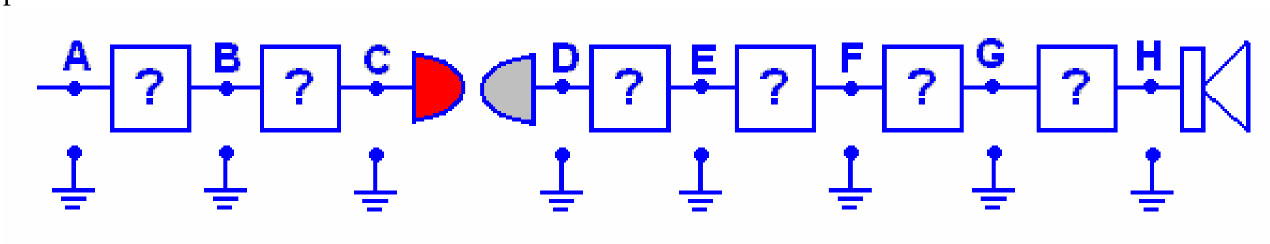
To simulate these circuits, it is not necessary to include the filter capacitors (circled in red) because there is no noise in the simulation. Also, the phototransistor and its bias resistor (in the green box) are replaced with the combination of potentiometer and buffer amplifier (described above). This does not do an exact replacement, since the properties of the transistor are not included. However, a qualitatively reasonable circuit will result that shows approximately what we should expect from the experiment. The 100k pot in the transmitter can be used as is or replaced with a fixed resistor. The latter choice is generally better since it is easier to tell what the actual value of the resistor is. The 386 audio amplifier is replaced with the simple model described above. Finally, we can add a passive integrator to the receiver circuit, between the 0.1uF capacitor and the 1k resistor. This significantly reduces the size of the high frequency pulses so it is easier to see the audio signal that eventually reaches the speaker.



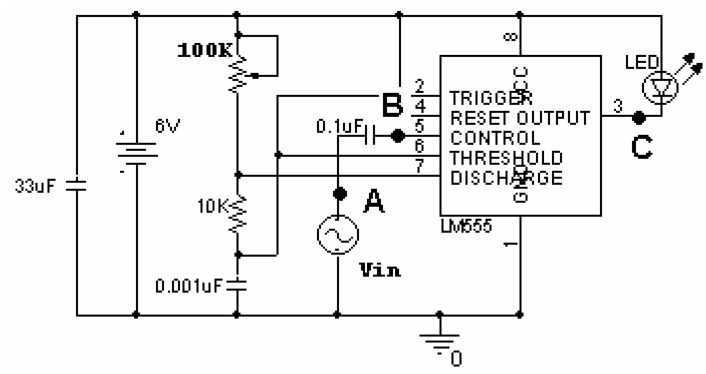
Because this is such a large circuit, with so many nodes, the student version of PSpice will not simulate enough time to show the circuit settling down to its steady-state values. However, one can see the trend clearly established. The input to the transmitter is a 3kHz sine wave. The output seen at the speaker should also be a 3kHz sine wave, with some additional noise on it from the modulation process. This is a residual signal due to the modulation, but it occurs at a high enough frequency that it is not possible for humans to hear it. The light blue signal is the voltage across the speaker. It is out of phase with the input primarily because the amplifier inverts while it amplifies.

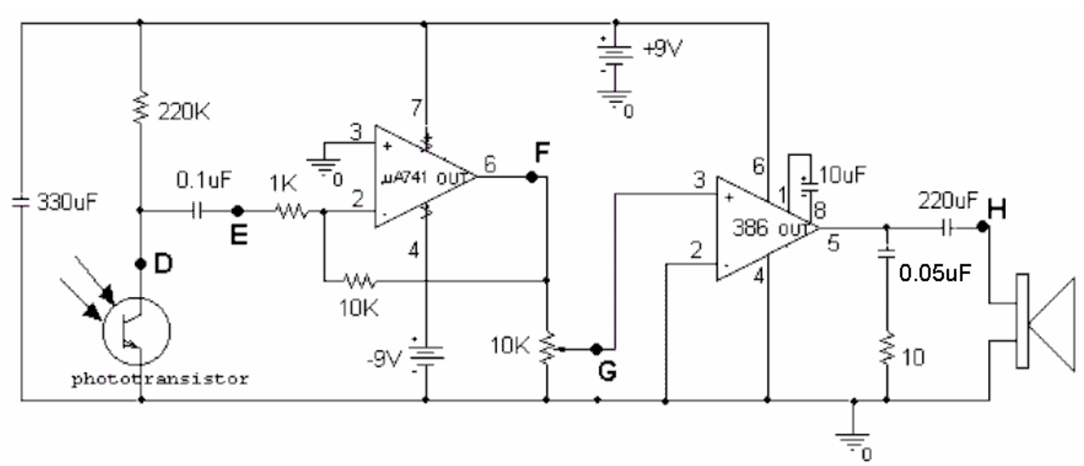


From the PowerPoint slides describing this project, we see that it is necessary to demonstrate that each of the functional blocks of the transmitter and receiver circuits works as it should. Thus, we should put voltage probes at each of the corresponding points in the simulation.

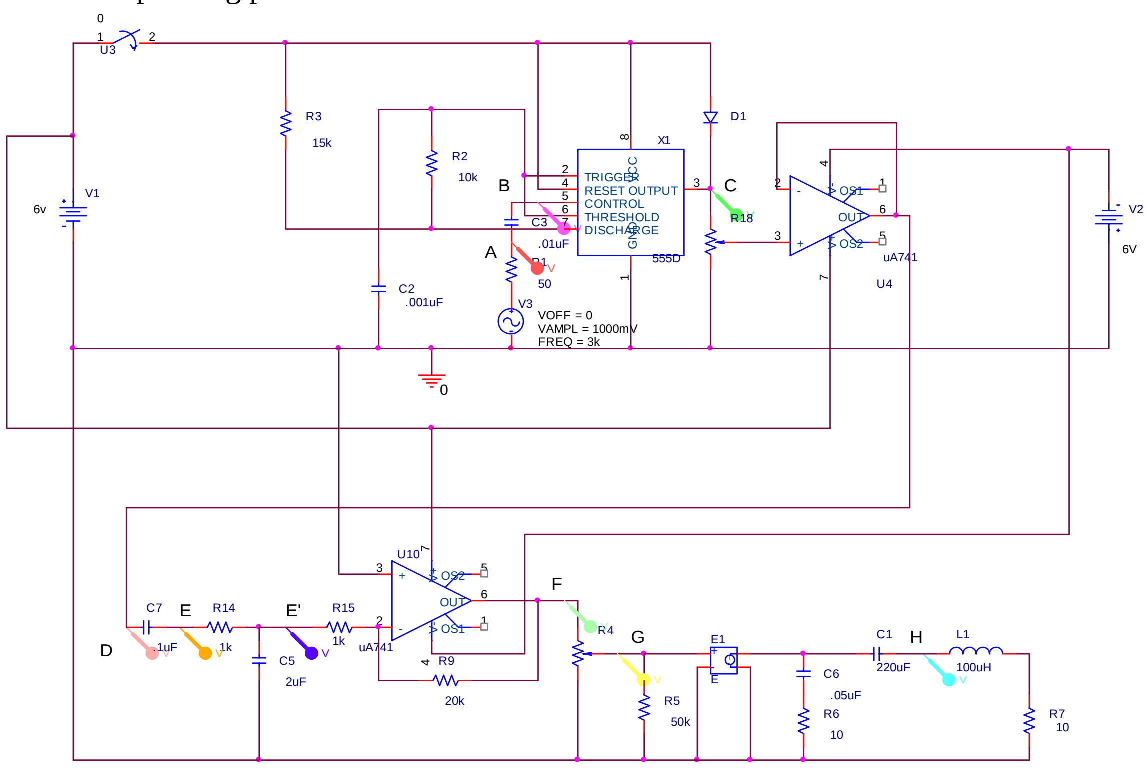


The specific points are shown in the project write up (reproduced below)

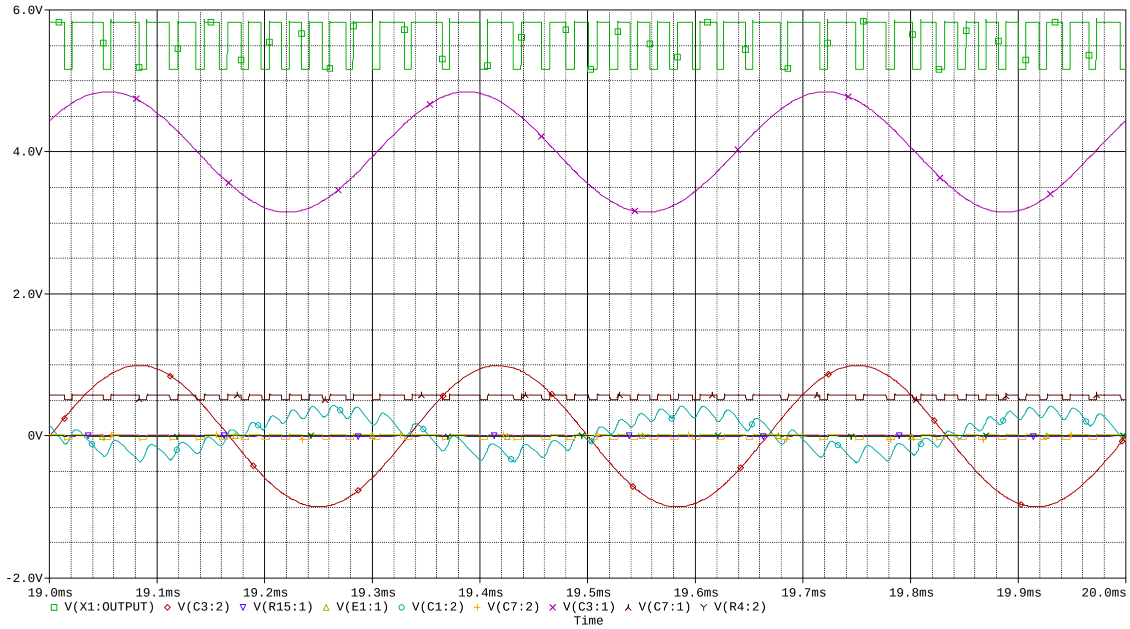




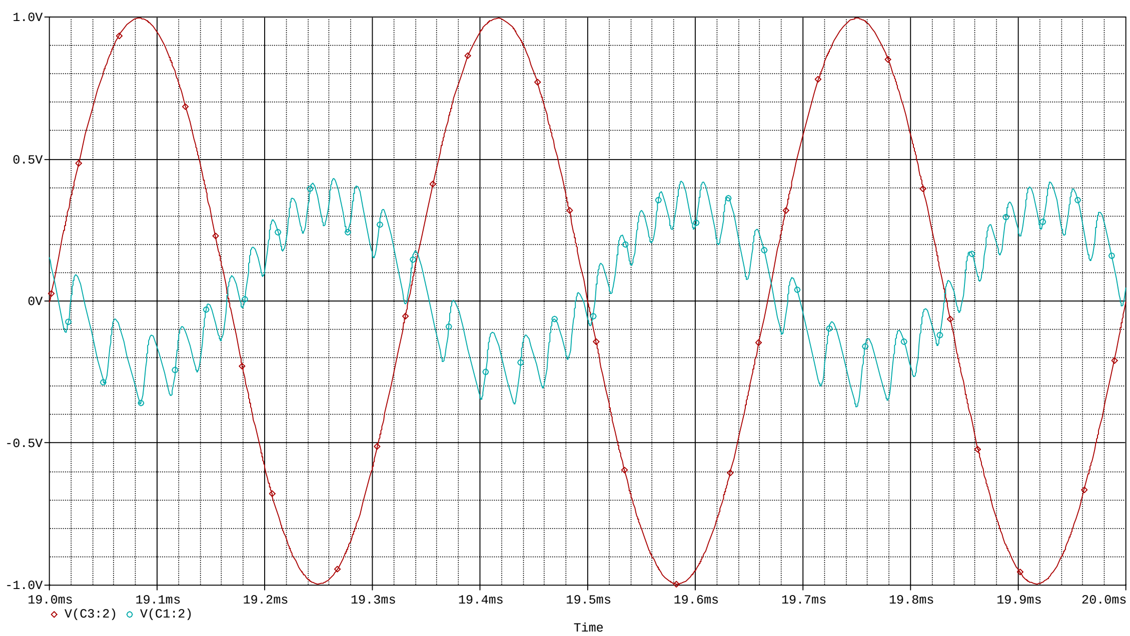
The corresponding points for the simulation are shown below:



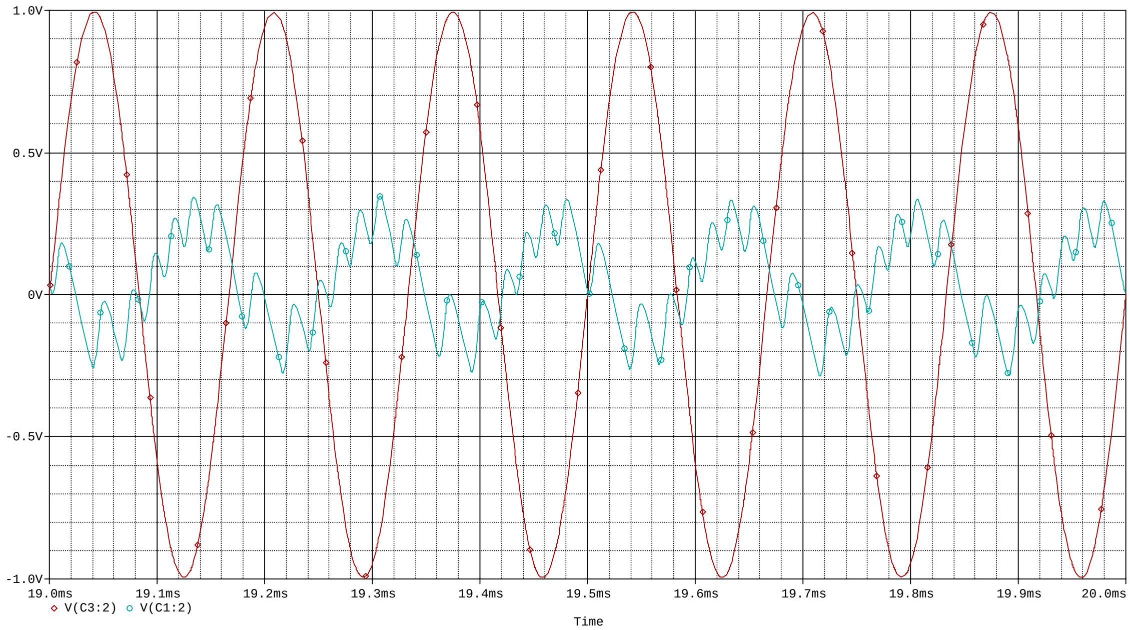
Note that two points are labeled E and E' since the original circuit does not have the passive integrator included. The signals from these points are shown below:



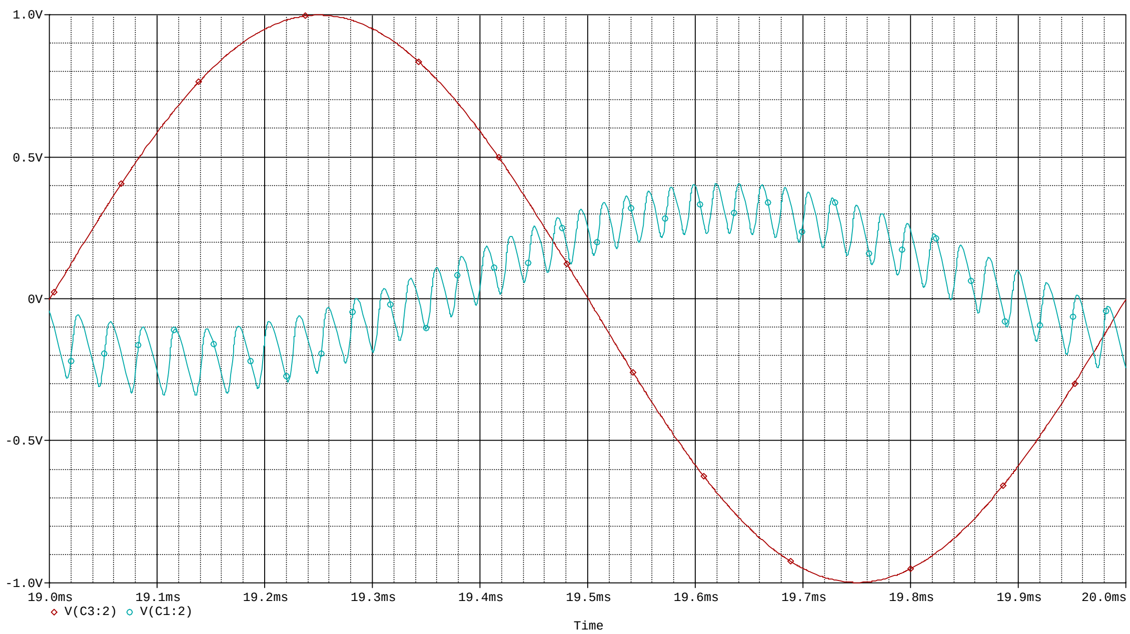
One can make the correspondence between the sinusoidal input and the output to the speaker more clear by only plotting these two functions. They are out of phase (one is positive while the other is negative) and the output has some residual high frequency components from the pulses, but they do look quite similar.



We can also try this with other frequencies. For an input signal at 6kHz, we have:



at 1kHz, we have:



Thus, we see that we can reproduce essentially any reasonable audio frequency.