Enhanced Wireless Amplifier

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Abstract

Amplifiers are devices used to generate a greater output signal when compared to its input signal. In equation form: \[ V_{out} = K \times V_{in} \] where \( V_{in} \) is the input voltage, \( V_{out} \) is the output voltage and \( K \) is the gain, a dimensionless and is a multiple of the input voltage and/or signal. While amplifiers are commonly linked to voltage gain, they are not limited to strictly voltage applications, as some amplifiers are linked to other parameters. Amplifiers are used in countless circuits, but are well-known for being applied to the amplification of audio signals.

A typical configuration of an amplifier can be shown in the figure below:

For most applications, the amplifier will be configured to operate in an inverting mode, which means \( V_{in} \) enters through the negative terminal after crossing a resistive component \((R_{in})\). The positive terminal is usually tied to ground. On the output line there is another wire leading back to the negative terminal that has a resistive component \((R_{out})\). In this configuration, the gain of the amplifier can be calculated to be \( \frac{R_{out}}{R_{in}} \), implying that not only is the output of the amplifier some multiple of the input, but that it is also negative, or phase-shifted by 180°.

In some cases, the amplifier may also be configured to act in a non-inverting mode. A similar setup applies to this inverting mode, except the feedback loop and \( R_{out} \) act on the positive terminal and not the negative terminal as was previously stated. The non-inverting terminal is usually grounded. Taking the same notation as previously presented, in the inverting mode, the non-inverting terminal will be set to \( \frac{R_{out}}{R_{in}} \). The non-inverting terminal has its own input mechanism and the output will be a multiple of the input signal and can be either positive or negative.

Overall Design

Our final design consists of about five distinct stages. A synopsis of these stages is presented below:

1.) The NRF Player

The NRF player starts the process. It simply provides a song to the Arduino where it will be processed and transmitted via Bluetooth.

2.) The Transmission - Arduino Uno

The Arduino Uno is a very versatile platform that is intuitive to code. As such, it was a perfect platform for our design. We were going to need two of these boards: one for the processing and transmission of the audio file and one for the reception and playback of the audio file. For now, only the transmission board is of note. The Arduino Uno has an on-board Analog-to-Digital Converter (ADC) which takes the analog output from the NRF player and then processes it through the Digital I/O pins of the Bluetooth Bee.

3.) The Bluetooth Bee

The Bluetooth Bee is a standard Bluetooth module that can be attached to the Arduino Uno. For our design, two Bluetooth Bees were necessary: one to send the audio file and one to receive the audio file for playback. The Bluetooth Bee acts as a slave device to the Arduino Uno. It is attached to: however, the Bees also exhibit a hierarchical relationship between each other, with the source Bee being the master device of that pair. The receiving Bluetooth Bee receives the data from the source Bluetooth Bee and sends it into a Digital I/O pin on the receiving Arduino Uno.

4.) The Off-Board Digital to Analog Converter

The receiving Arduino Uno takes the output of the Bluetooth Bee and sends it to an off-board resistive ladder network (called an R-2R ladder). The song’s bits are spread into a parallel arrangement and fed to the network from 10 of the Digital I/O pins on the Arduino Uno board in the form of discrete high (5V) and low (0V) voltage values. The HI pins and LOW pins generated at these pins are voltage divided within the resistive network and the analog signals produced through variation in voltage division as separate pins pulse HIGH or LOW. The output conversion is seen at the top of the ladder network and is then sent to the amplifying circuit.

5.) The Amplifier Circuit

The final step of our overall process is the amplifier circuit. It is composed of three distinct stages, which will be examined more thoroughly in the following sections. On a basic level, the amplifier acts to boost and modulate the gain of our audio file before it reaches the speaker through two separate operational amplifier (op-amps) stages and a buffer stage. While the op-amps control the gain, the buffer stage is needed to properly drive the speaker. The following sections will explain these stages in more detail.

The Amplifier Circuit

As previously mentioned, the amplifier circuit is broken into three separate stages before the final output is sent to the speaker. The first stage consists of an op-amp in positive feedback with a gain of 1.5 that acts as a pre-amp. The output of this op-amp flows to an AC coupling capacitor and a variable resistor, called a potentiometer. The potentiometer can be manually modulated by turning the screw on its top. In doing so, it will vary the gain of the second stage op-amp, which is in negative feedback connected to the output of the third stage with the potentiometer. The potentiometer can be used to create a gain of three on the second op-amp (75% turn) before clipping occurs on the output of the second stage. From the second stage, there is a final output stage using two high-powered BJTs. The NPN-2954 and the PNP-2954. Since the output from the second op-amp will be a varying sine wave, generally one of these transistors will be on at any given time, though a small crossover distortion where both are on also exists.

To reduce crossover distortion, two diodes were placed on the bases of each of these transistors to properly bias them. As a final measure, short circuit protection was also placed on the emitter ends of these transistors in the form of two very small resistor in parallel with each general purpose transistors, the NPN-295300 and the PNP-295300. If the current flowing through the TIP series BJTs becomes too great, the voltage drop across the resistors will be equal to or greater than the necessary value to turn either of the general purpose transistors on. In doing so, they will short current from the TIP series transistors to prevent them from burning out. Finally, the output signal will flow in feedback to the potentiometer and to the speaker itself, which will play the audio file.

Output

Our design of a wireless amplifier is built to work in areas behind an amplifier and give it wireless properties. Perhaps the most important from a central base station to speakers anywhere. Our setup uses Bluetooth over WiFi in this regard. Although inaudible from lower bit rates than WiFi, the amplifier configuration sends out digital WiFi packets and the device pairing aspect of Bluetooth is used for our application. Our setup has an audio player with a song on the source end, which transmits the audio signal over WiFi through the node on the receiving end. The receiving end then receives the audio signal to an amplifier and then finally to a speaker. To ensure the capability of making the sound louder, similar to volume control, we use a simple potentiometer. By creating this design, this would allow the user to place their speaker anywhere within a 10-meter radius of the base station without the hassle of wiring up the speaker to the base station.