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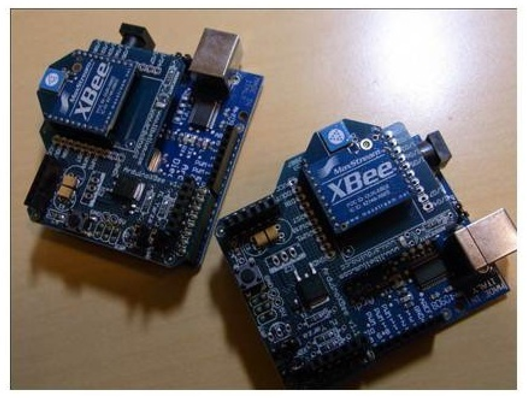
Enhanced Wireless Amplifier



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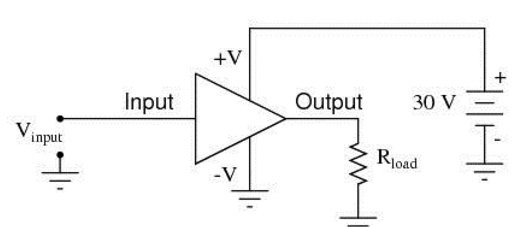
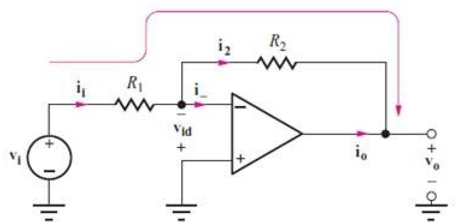
Abstract

Amplifiers are devices used to generate a greater output signal when compared to its input signal. In equation form: $V_o = AV_{in}$, where V_o is the output voltage, V_{in} is the input voltage and "A" is the gain. "A" is 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 can be used to amplify current. Amplifiers are used in countless circuits, but are well-known for being applied to the amplification of audio signals.

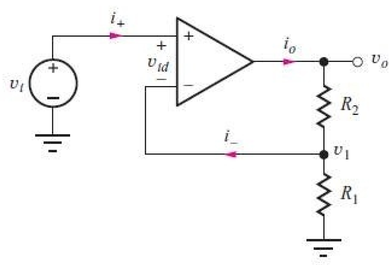
A typical configuration of an amplifier can be shown in the figure below:



In the figure, the amplifier is represented by the triangular object. The +V and -V terminals determine the maximum voltage swing that the amplifier can vary between when amplifying the input signal, meaning, the amplified output signal will clip off below -V or above +V. An input signal V_{input} is sent to the positive or negative input terminals and the output signal is seen across resistor R_{load}. The output signal will be some multiple of the input signal and can be either positive or negative.



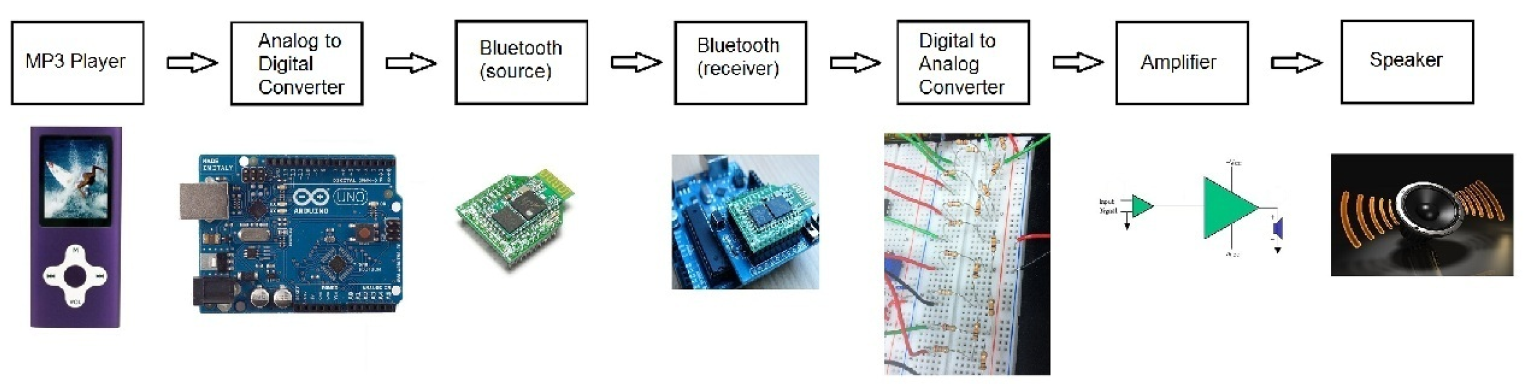
For most applications, the amplifier will be configured to operate in a inverting mode, which means V_{input} enters through the negative terminal after crossing a resistive component (R_1). The positive terminal is usually tied to ground. On the output line there is another wire leading back to the negative terminal that has a resistive component in (R_2). In this configuration, the gain of the amplifier ca be calculated to be $-(R_2/R_1)$, implying that not only is the output of the amplifier some multiple of the input, but that it is also negative, or phase-shifted 180^o.



In some cases, the amplifier may also be configured to act in a non-inverting mode. A similar setup applies as to the inverting mode, except the feedback loop and V_{input} reside on the positive terminal and the negative terminal is usually grounded. Taking the same notation as presented in the inverting mode, the gain of the non-inverting amplifier can be calculated to be $1+(R_2/R_1)$. The non-inverting region has its uses, but one must be careful with this configuration, as an uncontrolled output could cause the input to gradually increase, eventually clipping the output signal at the rail voltages.

Our design of a wireless amplifier was to take the idea behind an amplifier and give it wireless properties to send audio signals from a central base station to speakers around a room. We decided to use Bluetooth over Wi-Fi in this regard. Although Bluetooth suffers from lower bit rates than Wi-Fi, the amplifier configuration we designed solves this problem and the device pairing aspect of Bluetooth makes it a better choice for our application. Our setup has an audio player and a Bluetooth module on the source end, which transmits the audio signal to another Bluetooth module on the receiving end. The receiving end then passes the transmitted audio signal to an amplifier and then finally to a speaker. The amplifier is capable of making the sound louder, similar to volume control, by use of a 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.

Overall Design



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

1.) The MP3 Player

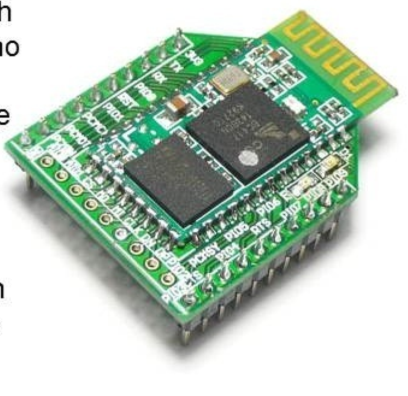
The MP3 player starts the process. It simply provides a song to the Arduino where it will soon be processed and transmitted via Bluetooth.

2.) The Transmission - Arduino Uno

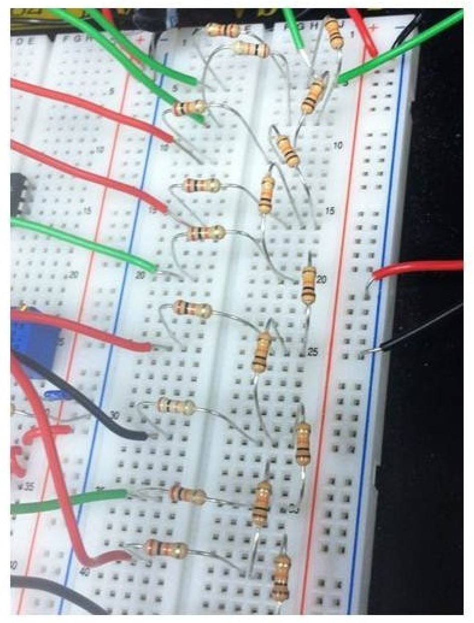
The Arduino Uno is a very versatile platform that is intuitive to code for. As such, it was a perfect platform for our design. We were going to need two of these boards: one for the processing and transmission of the audio file and one for the reception and playback of the audio file. For now, only the transmission board is of note. From the previous step, the Arduino Uno has an on-board Analog-to-Digital Converter (ADC) which takes the analog output from the MP3 player and then processes it through the Digital I/O pins of the Bluetooth Bee.

3.) The Bluetooth Bees

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 two 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.



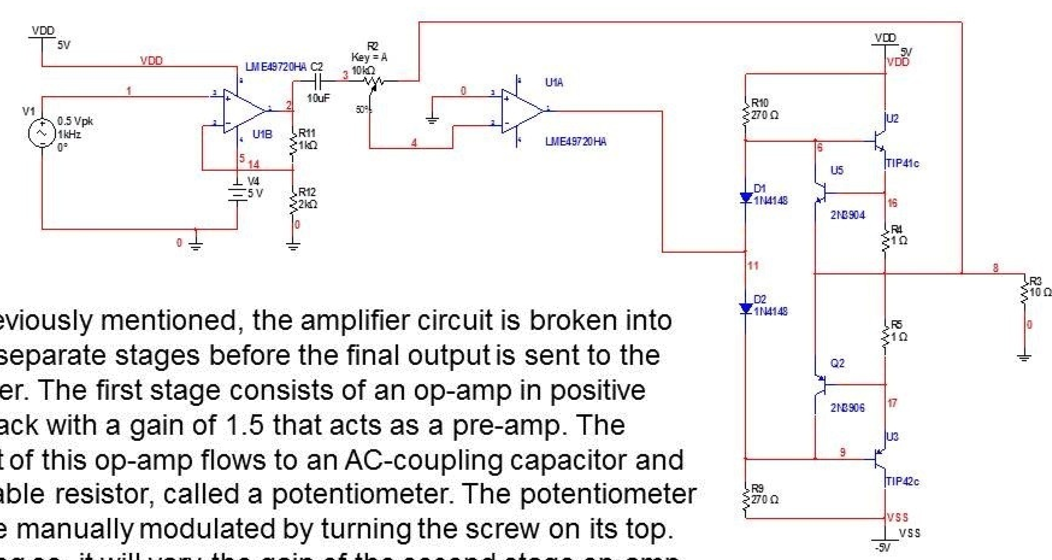
4.) The Off-Board Digital-to-Analog Converter
The receiving Arduino Uno takes in the output of the Bluetooth Bee and sends it to an off-board resistive ladder network (called an R-2R ladder). The song's bits are spread into a parallel arrangement and fed to the network from 10 of the Digital I/O pins on the Arduino board in the form of discrete HIGH (5V) and LOW (0V) voltage values. The HIGHs and LOWs generated at these pin sites are voltage divided within the resistive network and the analog signal is produced from variation in voltage divisions 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-amp) 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 Amplifer 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 adjusted to create about 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-TIP41 and the PNP-TIP42. 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 emitters of these transistors in the form of two very smaller resistors in parallel with two general purpose transistors: the NPN-2N23904 and the PNP-2N3906. 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 voltage to turn either of the general purpose transistors on. In doing so, they will steal 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