LAB #2: AUDIO MONITOR

INTRODUCTION:

The last stage in many communications systems is an *audio amplifier* of some type. The audio amplifier provides both voltage and current gain for signals from the *detector* stage, so that a loudspeaker may be driven.

Before the advent of monolithic power ICs, designing even a simple audio power amplifier circuit involved a fair amount of labor. Today, ICs are available to deliver powers ranging from the sub-watt range (LM386), to more than 2000 watts.

In this experiment, the following will be accomplished:

1.) You will build an audio amplifier using the LM386 provided in the lab kit, and design input/output coupling networks to meet design specifications.

2.) You will measure the performance of the LM386, and learn how to measure audio power amplifier output characteristics.

3.) You will experiment with the addition of feedback networks to alter the frequency response of the LM386.

DESIGN INFORMATION:

Figure 1, below, is the basic circuit for the audio monitor; refer to the LM386 data sheet in appendix B for detailed information on the IC.

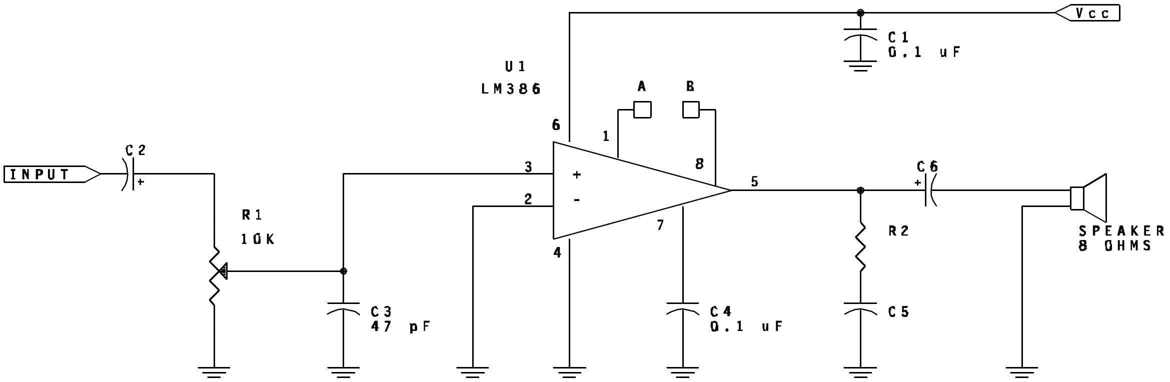

Figure 1 LM386 Audio Power Amplifier

DESIGN SPECIFICATIONS

These are the requirements for an *operational signoff.* The method for designing around these specifications will be discussed shortly.

1. The amplifier frequency response must be "flat" within +/- 3 dB from 100 Hz to 10,000 Hz. (You will plot the amplifier’s frequency response to demonstrate this).

2. The amplifier must provide at least 500 mW into an 8 Ohm load at any frequency between 100 Hz and 10,000 Hz *with no visible distortion on the amplifier output waveform*.

DESIGN STRATEGY FOR ENSURING FREQUENCY RESPONSE:

There are two primary factors that control the frequency response of an amplifier circuit; these are the choice of *active components* (such as transistors and ICs), and the design of *input and output coupling networks.*

The active components in a circuit tend to limit the *high frequency* response. The LM386 IC is capable of amplifying signals with frequencies well above 20 KHz; refer to the data sheet. Therefore, unless you were to deliberately limit the high frequency response of the circuit with a low-pass filter, the LM-386 would meet the high-end response specification as-is, and no designer effort is required to meet this specification.

The *low frequency* response is limited by the *coupling capacitors.* As frequency is reduced, capacitive reactance (Xc) increases; therefore, loads that are in series with capacitors receive less power at lower frequencies. In order to minimize this problem, capacitive coupling networks need to be designed for *firm coupling* at the *lowest frequency of interest*, which would be 100 Hz in this case.

When a capacitive coupling circuit is tightly coupled, it means that the capacitive reactance, Xc, is much smaller than the Thevenin resistance of the circuit; therefore, very little of the total voltage drops across the capacitor.

The design rule is:

$X_c <= R_{th} / 10$ (At the lowest frequency of interest; once Xc is found, find C).

For example, C6 is the output coupling capacitor. To the left of C6 is the IC chip output terminal. Because of negative feedback (internal to the IC), the output terminal has a resistance of about 0.1 Ohm. To the right of C6 is the 8 Ohm load. The equivalent Thevenin resistance is therefore 8.1 Ohms; for tight coupling, the reactance of C6 must be less than (8.1 / 10) Ohms at 100 Hz. Knowing this, we can solve for C6.

C2 is in a similar position; it sees a "perfect" source to the left (the circuit input), and to the right, it sees the volume control pot (10K) in parallel with the input impedance of the amplifier chip. By consulting the LM386 data sheet for the value of Z_{in}, it is possible to find a value for C2.

DESIGN STRATEGY FOR POWER OUTPUT:

The power output available from a direct-coupled, push-pull output amplifier like this one primarily depends on two factors. They are the power supply voltage, and the load resistance. The maximum undistorted RMS output voltage available from the amplifier circuit can be approximated by:

Vout = Vrail-rail / 4

Where *Vrail-rail* is the total power supply voltage for the push-pull output stage. In the LM386 (and other amplifiers), power output is limited by supply voltage, and available output current.

To control the maximum output power, you choose a value for Vcc. This value is calculated based on the power required, and the load resistance to be driven. In this circuit, no negative supply is used, so Vrail-rail = Vcc.

In your report, you should calculate the *minimum* Vcc required to obtain the specified output power, and how much undistorted power was actually available with the calculated value of Vcc applied.

OTHER CIRCUIT COMPONENTS

There are other passive components that are used in the circuit to either improve stability (prevent undesired oscillation), or prevent the amplification of unwanted signals. They are:

C3 : An RF bypass capacitor. C3 shorts RF signals to ground before they can be passed into the LM386, which might either amplify them, or worse, detect them, which would produce audible radio stations at the speaker!

C4 : A power supply bypass capacitor for the internal bias network of the LM386.

C1 : A bypass or filter capacitor for the MAIN power supply. Should be placed *very close* to the IC.

R2, C5 : An output "snubber" network. This network helps to prevent the LM386 from oscillating as a result of driving an inductive load (like a speaker). It is designed to be effective only above the audio range. For design purposes, R2 is usually set to R_L (8 Ohms) and C5 is set to 0.1 uF. The R2-C5 network is practically an open circuit below 10 KHz; above 10 KHz, where speaker inductance is rapidly rising, it begins to appear increasingly resistive, causing the amplifier to see a largely resistive load.

LABORATORY PROCEDURE

1. Design the audio monitor circuit. Show all calculations *clearly* in your "Design Method."

   NOTE: The A-B terminals in the circuit should be open circuited at this time. They will be used to apply feedback to the IC in steps 4 and 5.

2. Measure the maximum undistorted power output of the amplifier. To do this, apply a 1 KHz sine wave to the input of the unit, and increase the volume (or Wavetek output) until the speaker output waveform clips; then reduce until no clipping occurs.

3. Measure the frequency response of the amplifier. The basic procedure is as follows:

   a) Disconnect the speaker and connect an 8 Ohm non-inductive resistor. Combinations of small resistors will work. This prevents the inductive speaker from influencing your readings.

   b) Connect the Wavetek to the amplifier input, and the scope to both the input and output (use 10:1 probes).

   c) Measure the gain of the amplifier at each frequency of interest. *Your plots should start at 10 Hz and end at 100 KHz.* Use at least 10 readings in this range; a 1-2-5 sequence is suggested.

   Record the frequency response in a table, and plot it on semilog graph paper.

4. The LM386 has a feedback circuit accessable to designers; by inserting frequency-sensitive networks, we can alter its frequency response. Install the "1" feedback network from figure 2 below and measure the frequency response. Provide a table and graph as in step 3.

   NOTE: You may want to refer to the National databook for a detailed description of how the feedback in the '386 works.

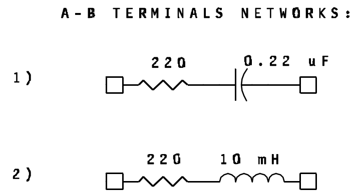

Figure 2 Feedback Networks

Laboratory Procedure - Continued:

5. Install the "B" feedback network and measure the frequency response. Provide a table and graph as in step 3.

WHEN YOU ARE DONE, SAVE YOUR CIRCUIT -- YOU’LL NEED IT FOR LATER EXPERIMENTS. (REMOVE THE ADDED FEEDBACK COMPONENTS WHEN YOU ARE FINISHED.)