Design Project—Fall 2004

Objective

The objective of this experiment is to evaluate a published low-noise design, to ascertain whether or not it can be used with a transformer coupled source, and to enhance the design if possible or necessary. The circuit is a low-noise microphone preamplifier circuit. The equivalent input noise of the amplifier is to be minimized.

Specifications

The published low-noise design is posted at the url:

http://sound.westhost.com/project66.htm

This circuit has a gain that is adjusted with a potentiometer. A fixed gain of $40u$ dB is specified for the design project.

The final preamplifier is to be designed for a source resistance of $600\,\Omega$ and a load resistance of $600\,\Omega$. The midband voltage gain is 40 dB. The input stage is to be transformer coupled to the microphone with a broad-band audio transformer having a $600\,\Omega$ to $4000\,\Omega$ impedance transformation ratio. Because transformers that are loaded into a high impedance exhibit high-frequency gain peaking, a series RC damping network is to be added in parallel with the transformer secondary to optimize the frequency response. This network must usually be designed by the seat of the pants. This can be done with either a swept-frequency sine-wave input signal or a fixed-frequency square-wave input signal. The square-wave is far easier and is recommended. The network should be adjusted to minimize and ringing on the square wave. Because this network is in parallel with the amplifier input, it is desirable for R to be as large as possible and C as small as possible for minimum effect on the noise.

Some additional specifications for the preamplifier are as follows:

- DC Power Supplies: either ± 15 V or ± 9 V (so that batteries may be used)
- Voltage Gain: 40 dB
- Maximum Input Voltage: 20 mV rms
- Lower -3 dB Frequency: 20 Hz or lower
- Upper -3 dB Frequency: 20 kHz or greater
- THD (total harmonic distortion): as low as possible at a frequency of 1 kHz with an input voltage equal to the maximum specified value.
- Source Resistance: $600\,\Omega$
- Load Resistance: $600\,\Omega$

- Stability: The preamplifier is to exhibit no continuous oscillations. With a square-wave input signal, the output is to exhibit no ringing. The peak overshoot is to not exceed 15% with a square wave.
- The noise is to be measured unweighted and A-weighted over the frequency range from 20 Hz to 20 kHz.

Experimental Measurements and Procedures

First, assemble the published circuit on a solderless breadboard with a 600 Ω load resistor and a 600 Ω source. Use 2N4401 for the NPN transistors and 2N4403 for the PNP. Use a linear 10 kΩ potentiometer to adjust the gain to 40 dB. Both the HP 34401A function generator and dynamic signal analyzer float so the output can be connected directly to the differential inputs of the diff amp. Do NOT connect either lead from the source to the circuit ground. Measure the noise parameters published for this circuit and compare with the published values. It is not necessary to duplicate the exact values of the large electrolytic capacitors.

Second, add the transformer between the source and the input to the diff amp. Adjust the pot so that the mid band gain is 40 dB. Repeat the above measurements. Modify the design if necessary to achieve the specifications. Specifically, try to minimize the noise. If necessary, the entire circuit could be rejected.

If the noise at the output of the TL071 op amp is too small to measure with the dynamic signal analyzer or the HP 3400 rms meter it will be necessary to use a gain stage. Use the fixed 40 dB gain available with the shielded boxes.

Once the design has been optimized, use the laboratory equipment to measure and record the circuit:

- mid-band voltage gain
- −3 dB frequencies
- positive and negative slew rates
- total harmonic distortion at $f = 1$ kHz
- quiescent or dc operating point
- percent overshoot with a square-wave input
- output dc offset with input grounded
- equivalent input noise voltage
- unweighted and A-weighted signal-to-noise ratio
- unweighted spot noise figure at $f = 1$ kHz and A-weighted noise figure over the audio band

The noise measurements should be made with the source replaced with a 600 Ω resistor. The other measurements should be made with the function generator as the source.

Simulation

Both circuits should be simulated with SPICE. The simulation should precede the circuit assembly.

The default values for `IS`, `BF`, `RB`, `VA`, `CJC`, `CJE`, and `TF` for the transistors are not to be used for the simulation. Instead, use the values obtained from curve tracer measurements or manufacturers' data sheets. The value of the base spreading resistance measured in a previous experiment is to be used as `RB`. (In determining the optimum collector current use an average or typical value that was measured for the transistor.)

A noise simulation of the circuit should be made which predicts the signal-to-noise ratio corresponding to an output signal level of 2 V rms.

The SPICE analyses should include `.OP` (to verify the biasing), `.AC` (to verify the frequency response specifications and stability specifications), `.TRAN` (to examine the clipping and slew rate performance), `.FOUR` (to verify the distortion specification), and `.NOISE` (to verify the noise specifications).

Laboratory Report

The laboratory report should simply, succinctly, and lucidly summarize the design philosophy, present the appropriate calculations, and compare the theoretical, simulation, and experimental results.

The design project will be weighted as three lab reports and will be graded somewhat more critically than the previous reports. Although the design project grade will in part depend on the write-up, the major criterion will be whether or not the circuit meets the design criteria.

Due Date

Monday December 6 at 8:00 p.m.