lab6

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Part I

Objective

This lab explores opamp non-idealities when designing microphone amplifiers.

Part II

Background

A condenser microphone operates on the principle of a variable capacitor ("condenser") where one plate is stationary and the other ("diaphram") is allowed to move in response to air pressure variations. A constant charge is applied to this capacitor and the diaphram movement changes the capacitance. A voltage results from these variations by:

$$Q = CV$$

or

$$V = Q/C$$

Electret condenser microphones do not require a DC polarization voltage, fed through a $10\,\mathrm{M\Omega} - \mathrm{G\Omega}$ resistance to maintian a constant charge. One of the plates is made of a dielectric material with charges embedded in it. Such materials remain effectively permenantly charged.

The voltage changes resulting from pressure variations ay be modelled as a Thevenin source with an output impedance consisting of the capacitance of the microphone capsule, shown in Figure 1. As this capacitance is small, on the order of pF, a very high load resistance is required to ensure the created high-pass filter's corner frequency reaches low enough for audio purposes. For example, a $1\,\mathrm{pF}$ capsule capacitance requires at least a $8\,\mathrm{G\Omega}$ load resistance to give a -3 dB frequency of $20\,\mathrm{Hz}$.

Due to this loading constraint, most electret microphones include a JFET amplifier in the capsule to buffer the signal. Figure 2 shows the standard configuration of a common-source amplifier. Also shown in the figure is the use of an external resistor (typically $0.5 - 5\,\mathrm{k\Omega}$) to provide drain current (around $0.5\,\mathrm{mA}$)

for the transistor and an impedance across which to develop the small-signal output voltage (as $v_{out} = g_m R_{bias} v_{mic}$).

The microphone + node has a superposition of DC voltage and AC signal due to this biasing arrangement. The DC component may be several volts, while the signal is only a few millivolts in magnitude. A coupling capacitor is placed in series in many circuits to block the DC bias value and pass only the small microphone signal. Figure 3 shows the Thevenin-equivalent circuit of a biased electret microphone signal. The output resistance of the circuit is the parallel combination of the JFET's r_o and R_{bias}, and is approximately equal to R_{bias} alone because r_o is much larger. When finding the frequency response of a circuit using this structure, the Thevenin-equivalent output impedance must be taken into account for the circuit's high-pass corner frequency.

Part III

Procedure

Design an amplifier system which increases the microphone's output signal by a factor of 500, has a high-pass corner frequency of no greater than $100\,\mathrm{Hz}$, and have a DC offset magnitude less than $100\,\mathrm{mV}$ at its output.

It will be necessary to deal with the amplifier's input bias current as a source of offset. See Figures 4, 5, 6, and 7 for partial circuit ideas on how to both achieve this large gain in multiple stages and to compensate for opamp offset.

Testing of gain and high-pass corner frequency is easiest accomplished by using a signal generator in place of the microphone, set to a similar amplitude. Write a **type-written** report detailing your design, design calculations, and measurements confirming proper amplifier system performance.