ECE137a Lab project 3

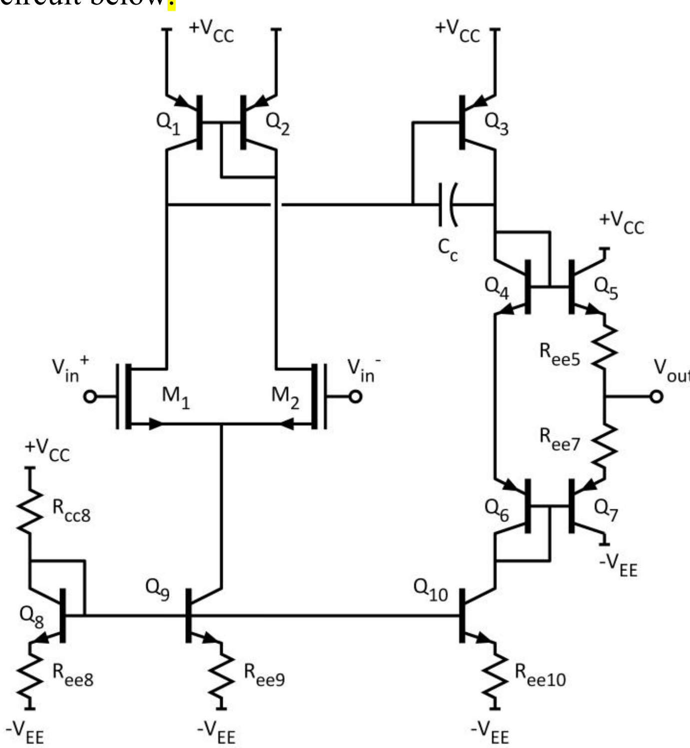
To save effort, this lab project will be assembled on a proto-board. Such assembly, if done sloppily, will result in major wiring parasitics and a circuit that does not operate properly. To operate correctly, all wiring must be kept **extremely short**. The whole circuit should be laid out in an area less than 2 inches by 2 inches. Cut off excess wire length of all resistors and capacitors. Proper supply bypassing, on the proto-board, is critical.

You will first design and build an op-amp. The op-amp will then be configured with frequency-dependent feedback to form an amplifier having frequency-dependent gain consistent with that specified by the NAB[1] for an old-fashioned reel-reel tape recorder in playback mode for playing music or sound recordings from magnetic tape .

Description

You must first design and construct an op-amp using a mixture of MOSFETs and bipolar transistors. The differential input stage CAN use MOSFETs or bipolar transistors. If you use MOSFETs, the ALD1101----ALD1107 series is recommended. You can use any circuit design you like, But we have relatively little time to complete this lab project, So it's perfectly fine to use exactly the circuit below.

Here is a suggested design. It has an input differential pair (M1, M2) with current-mirror loads, a high-gain common-emitter stage (Q3), and a push-pull output stage (Q5, Q7) with class-AB bias (Q4, Q6) with thermal stabilization resistors (Ree5, Ree7).



For stability once feedback is applied, the op-amp differential gain should vary as

$$A_d(j\omega) \triangleq V_{out}/(V_{in}^+ - V_{in}^-)$$
$$= A_{dc}(1 + j\omega/\omega_{pole})^{-1}$$

i.e. a single-pole rolloff with unity gain at $\omega_{unity} = 2\pi f_{unity} = A_{dc}\omega_{pole}$. The unity-gain frequency f_{unity} should be designed to be

The external load resistance (not shown, but you must have this present) is 600 Ω. This is a standard in

[1] National Association of Broadcasters; please see https://sound-au.com/project247.htm

between 1 to 2 MHz. sound recording studios.

One can show that $\omega_{unity} \cong 2(g_{m1}^{-1} + g_{m2}^{-1})^{-1}(C_c + C_{cb3})^{-1} A_{v5,7}$, where $A_{v5,7}$ is the voltage gain of the push-pull stage. Pick C_c to obtain the desired ω_{unity}.

It would be wise to pick the voltage drops across R_{EE8}, R_{EE9}, and R_{EE10} to be between 100mV and 150 mV.

The circuit is then to be connected with impedances Z2 and Z1, giving a frequency-dependent gain of

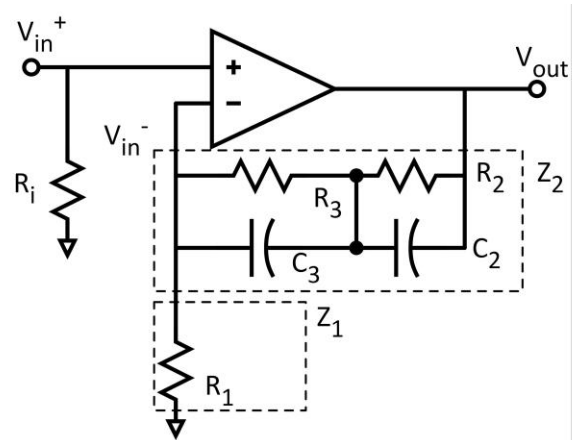
$$\frac{V_{out}}{V_{in}^{+}} = \frac{1}{\beta}\frac{T}{1+T} \text{ where } \beta = \frac{Z_1}{Z_1 + Z_2} \text{ and}$$

$T = A_d \beta$.

If and only if $T >> 1$, this becomes

$$\frac{V_{out}}{V_{in}^{+}} = \frac{1}{\beta} = \frac{Z_1 + Z_2}{Z_1}$$

Here R_i=47 kΩ



The target NAB transfer function is :

$$\frac{V_{out}}{V_{in}^{+}} = A_o \frac{(1 + jf / f_z)}{(1 + jf / f_p)}$$

where f_p=50 Hz and f_z=3.18 kHz.

We will design for $A_0 = 100$ (40 dB).

Starting with some assumed value of R1, you must calculate from this the values of R2, R3, C2, and C3. If you pick very small resistor values, then the required capacitors will be very big and expensive. Further the total load to the op amp is the 600 Ohm load in parallel with the impedance of the feedback network, So you don't want to pick too small a value of R1. If you pick a very big value of R1 the required values of capacitors may be comparable to the parasitic capacitances (~10 pF or so) associated with your circuit construction. (Also with big R1, the feedback network will then generate considerable noise voltage but that's beyond your present level of training in circuit design)

Specifications and testing

The op-amp is to be designed such at A_{DC} is greater than 10^3 at 1 Hz. Note that it will not be easy to measure this: you should include your calculation of this in your report, but you are not required to measure it on your prototype.

Power supplies= ±3.3 V

Must be able to drive 300 mV peak-peak into RL=600 Ohm at 1 kHz.

The circuit gain is to be measured at 20 Hz, 50 Hz, 3.18 kHz, and 20 kHz, its value should be within +/1.5 dB of the NAB transfer function given $A_0 = 100$.

The circuit output with a small-signal square-wave input should also be measured, photographed, and included in the report. Be sure when doing so to keep the signal adequately small to avoid overload effects. *You must explain in the report the resulting output waveform in terms of the specified NAB frequency response.*