Analog Electronic Devices
(ESI038 / SE047)

Lab Experiment 4
Multi-Stage Amplifiers

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Objectives

The objectives of this lab experiment are:

a) to critically evaluate a previously designed multi-stage amplifier

b) to re-design a discrete multi-stage audio amplifier so that most of its performance parameters are improved

c) to simulate some of the most important features of a multi-stage amplifier using SPICE

d) to measure some of the most important features of a multi-stage amplifier using lab equipment

e) to contrast hand calculations, SPICE simulations and lab measurements for a multi-stage amplifier.

Components and Instrumentation

General purpose BJT (npn or pnp) and/or field-effect transistors (JFET or MOSFET, n or p channel) (2N3904, 2N2222, 2N5457, 2N5458, J201, CD4007, 2N7000, etc.)

A power transistor (BJT or MOSFET)

Several resistors, and capacitors, including some power resistors

An 8-Ω power resistor

An 8-Ω loudspeaker and a conventional microphone (optionally)

An adjustable DC power supply

A low frequency function generator

A digital multi-meter (DMM) with 2½ or more digits

An oscilloscope with x10 or x1 probes

A circuit simulation software: OrCad, WinSpice, Electronic Work Bench, or something similar.

Evaluating a 3-Stage Capacitively Coupled BJT Amplifier

1. Consider the 3-stage capacitively coupled BJT amplifier illustrated in Fig. 1. Component values are shown in Table I. This circuit was intended for the following design specifications:

    a. Magnitude of the voltage gain at middle frequencies of at least 1000 V/V

b. Magnitude of the input impedance at middle frequencies of at least 1KΩ

c. Magnitude of the output impedance at middle frequencies of 0.5Ω maximum

d. With a minimum output voltage swing of $6V_{p\text{-}p}$ (distortion limits greater than 3V)

e. Loaded with R_L = 8Ω.

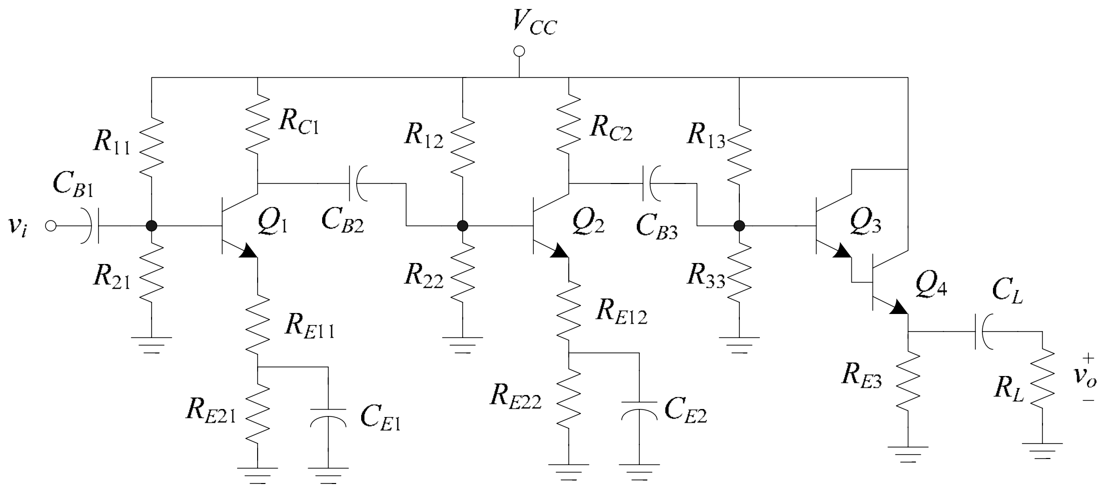

Fig. 1. A three-stage capacitively coupled BJT amplifier.

TABLE I
ELEMENT VALUES FOR THE PROPOSED 3-STAGE BJT AMPLIFIER

Component	Value	Component	Value
R_{11}	4.7KΩ	R_{C2}	6.8KΩ
R_{21}	2.2KΩ	R_L	8Ω
R_{12}	82KΩ	C_{B1}	47uF
R_{22}	22KΩ	C_{B2}	100uF
R_{13}	10KΩ	C_{B3}	220uF
R_{23}	56KΩ	C_{E1}	47uF
R_{E11}	75Ω	C_{E2}	100uF
R_{E21}	3.3KΩ	C_L	1000uF
R_{E12}	100Ω	$Q_1 - Q_3$	2N3904
R_{E22}	1.8KΩ	Q_4	2N3055
R_{E3}	12Ω	V_{CC}	15V
R_{C1}	5.6KΩ		

2. Simulate the previous circuit using SPICE. From the simulation results, fill out Table II, Table III and the second column of Table IV. Make an AC simulation to plot: a) the magnitude of the voltage gain of each stage and the overall gain; b) the magnitude of the input impedance of each stage; and c) the magnitude of the output impedance of each stage. Using transient simulations, plot a distorted output signal for each stage so that the corresponding distortion limits can be observed.
3. Implement in the lab the amplifier in Fig. 1. Make sure all the capacitors are correctly biased. Take into account that transistors in the output stage might need a heat sink. Measure the corresponding parameters to fill-out the third column of Table IV. Report the main problems you found for the amplifier as implemented in the laboratory.

TABLE II
BIAS POINT FOR EACH TRANSISTOR (SPICE RESULTS)

Parameter (DC)	Q1	Q2	Q3	Q4
V_B				
V_E				
V_C				
V_{CE}				
I_C				
P_Q				

TABLE III
AMPLIFICATION FEATURES OF EACH STAGE (SPICE RESULTS)

Parameter (at 1KHz)	Stage 1	Stage 2	Stage 3
$\|A_v\|$			
$\|Z_{in}\|$			
$\|Z_o\|$			
DL^+			
DL^-			

TABLE IV
GLOBAL CHARACTERISTICS OF THE FULL 3-STAGE AMPLIFIER

Parameter (at 1KHz)	SPICE Results	Lab Measurements
$\|A_v\|$		
$\|Z_{in}\|$		
$\|Z_o\|$		
DL^+		
DL^-		

Re-Designing the Amplifier

4. Taking into account the performance of the previous 3-stage amplifier, make all the necessary changes such that the original design specifications are fulfilled, subject to the following conditions: a) you can use a DC power supply of either 15V, or two symmetric DC voltages of ±6V; b) you can change the configuration of each amplification stage; c) you can change the kind of transistors used (other BJTs, JFETs, MOSFETs, etc.); d) you can change the kind of coupling used between stages (including direct coupling); and e) you can not use more than 3 amplification stages.
5. Once you have calculated all the component values of your amplifier, re-analyze it and summarize its main characteristics using tables.

Simulation and Lab Characterization of the Re-Designed Amplifier

6. Simulate your new three-stage voltage amplifier using SPICE. Obtain from the simulation all the necessary parameters to make a comparison with your analytical calculations.
7. Implement in the lab your new 3-stage amplifier. Measure the main DC voltages, the overall small signal voltage gain at 1KHz, the overall small signal input impedance at 1KHz, and the output distortion limits at 1KHz. Compare this measurement data with that one obtained from your analytical calculations and SPICE simulations.

Report

Write a report including all the theoretical, simulation and lab procedures as well as your conclusions. It is very important to justify all the critical decisions during the re-design process. The report must include the schematic of the complete final 3-stage amplifier.

Deadline and Assessment

The deadline for submitting the report is on Friday May 4, 2007. The report can be written either in English or in Spanish.

This lab experiment can be realized in teams of up to 4 students. The evaluation of the report will be as follows:

Quality of the report	30%
Accuracy of the theoretical analysis	30%
Lab measurements and procedures	40%

If the report is written in acceptable English, an extra 10% can be granted.