Biasing and Testing of BJT Amplifiers

Electronics I for ECE Lab 5
March 23, 2007

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Table of Contents

List of Figures

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1 Introduction

Today we will begin with an inverting amplifier as presented in detail in the lecture on March 6. We look at the transistor, the amplifier requirements, and design a properly biased amplifier and test it.

We proceed with our term project, an audio speaker or headphone amplifier. We first analyze the bias model for the existing circuit and establish the parameters. Then we increase the supply voltage form 5 Volts to 12 Volts and re-examine the circuit voltages and bias. Finally we revise the biasing circuitry and test the new circuit.

2 The Inverting Amplifier

The circuit to be used is shown below as Figure 1. We have these requirements:

- The transistor to be used is the 2N3904[1].
- The power supply voltage V_{CC} is to be +12 Volts.
- The maximum power that the transistor may dissipate is 100 mW.
- The beta of the transistor is to be a factor of 120 nominally, but the circuit is to work well for a range of beta from 60 to 300.
- The output voltage swing of the circuit is to be maximized by the selection of the operating point.
- The voltage gain is to be 25.
- The Thévenin equivalent circuit is to have a current capacity of 10 times the maximum base current as designed for no load. That is, the voltage divider formed by R_{B1} and R_{B2} will have 10 times the maximum expected base current of the transistor.

Use the process defined in the posted lecture supplement for March 6 to design this circuit. Measure the voltages and verify that the circuit biasing is operating properly and measure the gain and the frequency response.

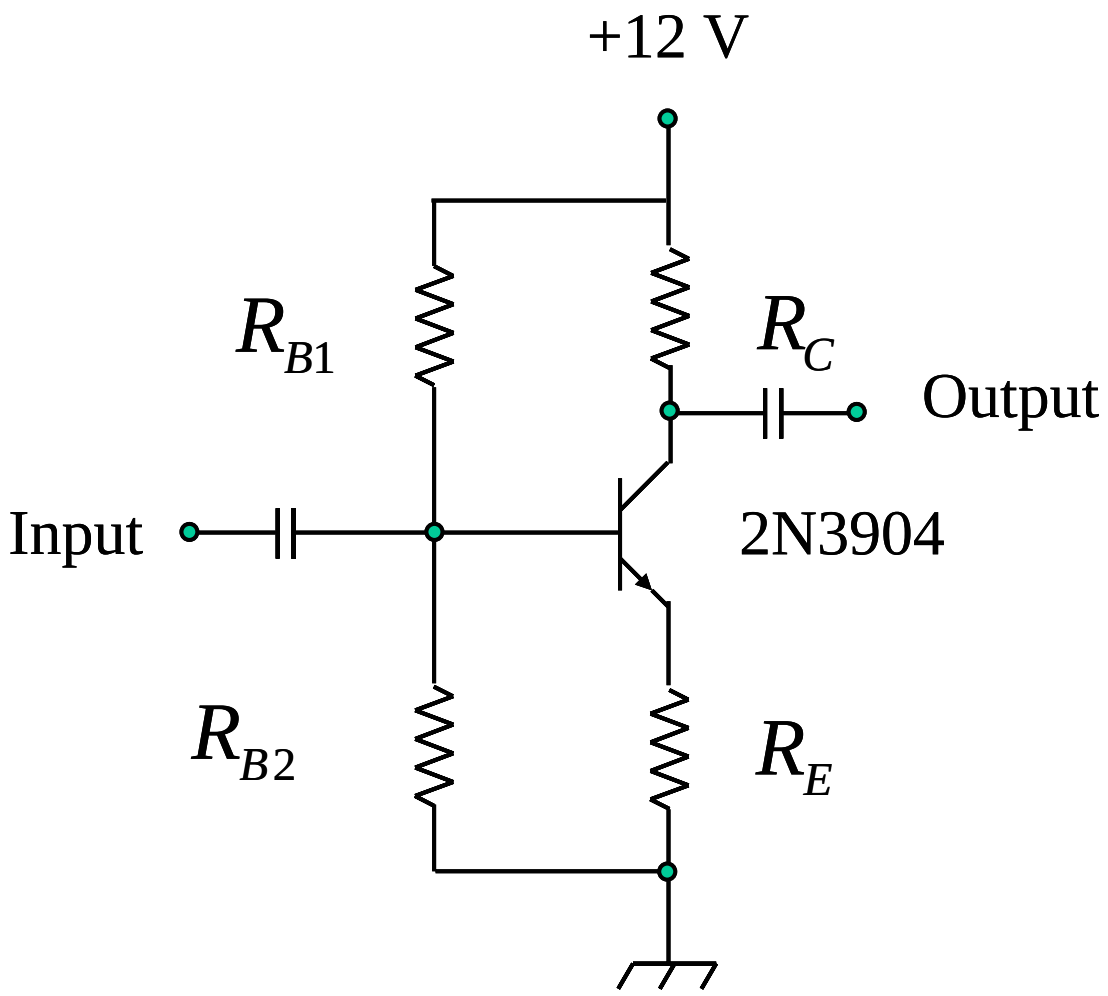

Figure 1. Inverting Amplifier using the 2N3904 Transistor and Feedback Biasing.

3 The Complementary BJT Follower

3.1 The Experiment

Begin with the original term project circuit shown below as Figure 2. Use a 220 microfarad capacitor and a 150 Ohm resistor in place of the 2200 microfarad capacitor and four ohm speaker in the figure. Make sure that the transistors are the 2N4401[2] and 2N4403[3], not a substitute that may have been used for an earlier laboratory. Note the frequency response limitation from the last laboratory and adjust R_2 and R_4 to give a high frequency 3 dB rolloff at 20 kHz for an op-amp gain-bandwidth product of 1 MHz, the nominal specification of our selected part.

Measure the voltages at the base terminals of both transistors, between the two bias circuit 1N4148/1N914[4] gold-doped diodes, and at the output between the two $5\,\Omega$ resistors. Note the expected base-emitter voltage drop for the 2N4401 and 2N4403, and for the 1N914/1N4148, and the typical beta for the selected transistors. Verify the proper operation of the bias circuit and record the values. Highlight the voltage drop across each

of the two bias circuit diodes. Observe the output waveform for an input sine wave of 1,000 Hz. If there is visible crossover distortion (any disturbance in the waveform as the sine wave goes through zero) work with the Instructor to adjust the bias circuit.

Increase the supply voltage from 5 Volts to 12 Volts and repeat the measurements. Adjust the $1\,k\Omega$ resistor in the bias circuit to provide just enough current to eliminate visible crossover distortion.

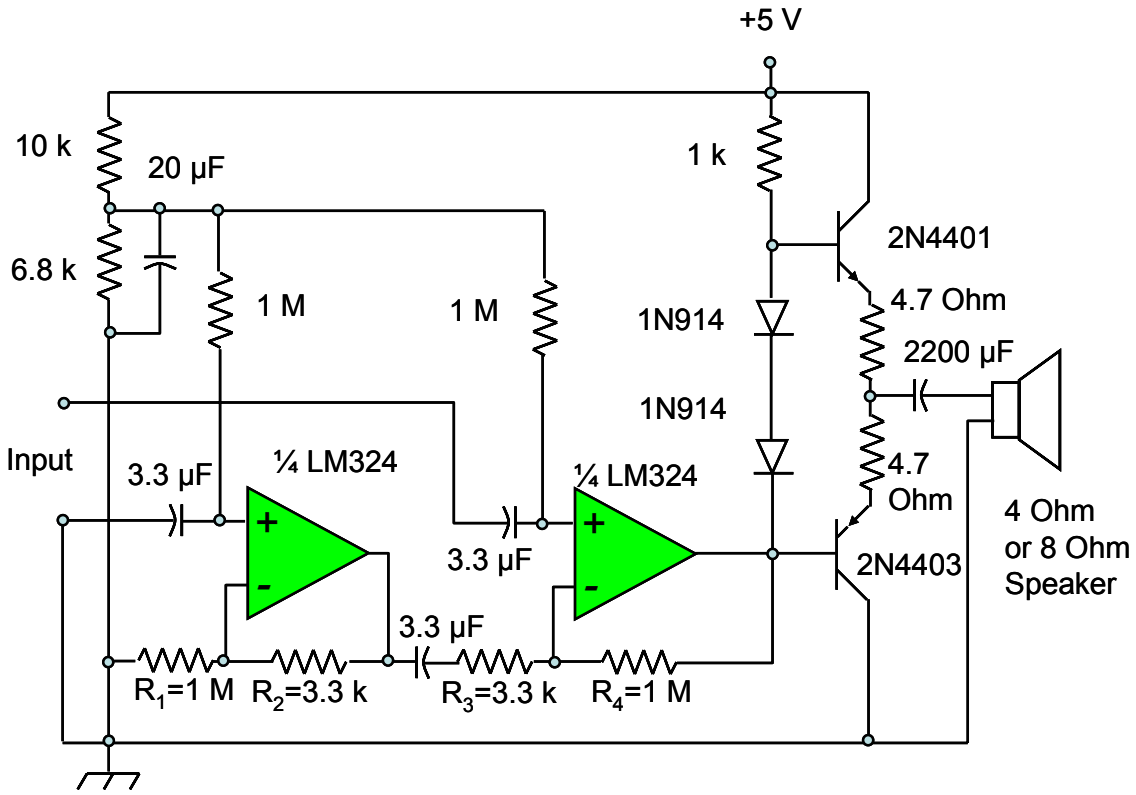

Figure 2. Original Headphone Amplifier with Differential Input.

Note that the voltage at the base of the 2N4403 is determined by the voltage divider represented in Figure 2 by a $10\,k\Omega$ resistor and a $6.8\,k\Omega$ resistor. Adjust this voltage divider as necessary to provide the best possible operating point for the output. Take into account the voltage swing of the LM324[5] op-amp as well as the saturation voltage drops of the transistors.

Measure the gain and frequency response of the completed circuit. Show the waveform of the output for a 1,000 Hz sine wave input at maximum voltage swing on output.

3.2 The Report

For the inverting amplifier, prepare a report due in one week as usual. Do not discuss the complementary amplifier follower.

For the term project, prepare a final report, due in four weeks. The scope of this report is all the experiments involving this circuit, beginning with the emitter follower and ending with today's experiment. Follow the report format given on the course web site for a full report. The format is similar to that of a lab report but the Introduction will be an Executive Summary as described in the instructions on the web site.

4 References

[1] Fairchild Semiconductor data sheet for the 2N3904/MMBT3904/PZT3904 Rev. A, dated 2001.
[2] Fairchild Semiconductor data sheet for the 2N4401/MMBT440 Rev. A, dated 2001.
[3] Fairchild Semiconductor data sheet for the 2N4403/MMBT4403 Rev. C, dated 2001.
[4] Fairchild Semiconductor data sheet for the 1N/FDLL 914/A/B / 916/A/B / 4148 / 4448 Rev. B2, dated 2007.
[5] National Semiconductor data sheet for the LM124/LM224/LM324/LM2902, document number DS009299, originally dated 2000 and current document copyright 2004.