ShanghaiTech University
School of Information Science and Technology

EE112 Lab Experiments

Experiment 3: Single Stage CE & CS Amplifier

Contents

1. Introduction

Common-Emitter (CE) and Common-Source (CS) are the two most widely used configurations for BJT and MOSFET amplifier design. In this pre-lab, you will explore the design of a single stage amplifier based on these two topologies to understand the trade-off between different specifications (gain, bandwidth and output swing). Initial design starts with hand calculation and finer tuning and verification will be carried out by Multisim simulation. You will use the device parameters you characterized in your Lab 2 in your design.

2. Design Specification

The BJT you will use is 2N4401 and the MOSFET you will use is BS170. The design specifications are given in the table below:

Table 1: Amplifier Specification

Middle Band Gain(Amid)	≥ 100
High Cutoff Frequency(f_H)	$\geq$20kHz
Output Swing(SW)	$\geq$2V (peak to peak)
Supply Voltage(V_{dd}/V_{ss})	+10V/-10V
Output load(C_{load})	1nF

3. Attenuation network for Input

Since the gain of the amplifier is large and the smallest magnitude of function generator is limited. You will need to attenuate the source signal before connecting to the input of your amplifier. The attenuation network is given as in Figure 1. Calculate the attenuation ratio between V_{source} and V_{in} and output impedance looking from Vin. Draw the Thevenin equivalent model of this network.
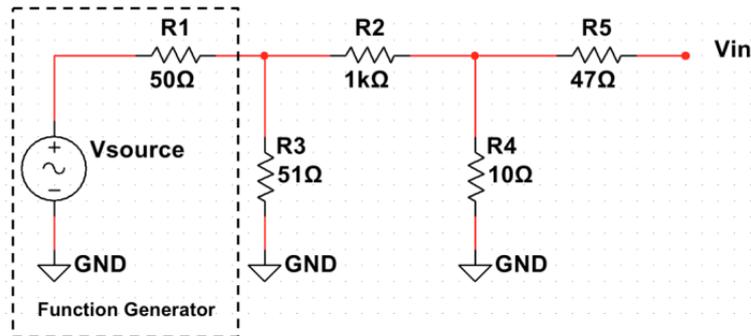

Figure 1: Attenuation Network

4. Single Stage Common-Emitter BJT Amplifier

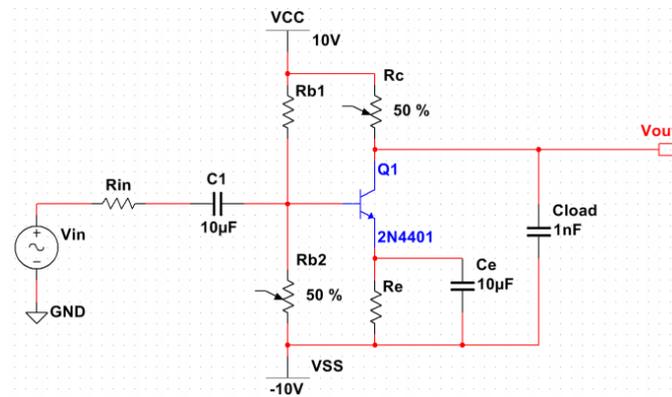The CE amplifier is given as in Figure 2.

Figure 2: Single Stage Common-Emitter Amplifier

4.1. Hand Calculation

Explain what is the function of R_e, draw small signal equivalent circuit. For hand calculation you could treat emitter as ac ground in your small signal circuit. Derive the expression for the middle band gain and high cutoff frequency (Hint: the high cutoff frequency is determined by C_{load} and small signal output impedance of the amplifier). Refer to your Lab 2 report for β and V_A. Use R_{in} from Thevenin model above. Pick reasonable resistor values to satisfy the design specifications. Since you cannot choose whatever resistor value you want, you need to pick R_{b1}, R_e according to the availability of the resistor values in our labs. Then design R_{b2} and R_c value accordingly. You will implement them as potential meter or a combination of resistor and potential meter if necessary in your real lab.

4.2. Multisim Simulation

Implement your design in Multisim and verify all the design specs in the simulation. Tune resistors value if necessary. Keep in mind how each resistor value affect the overall performance.

You need to include model file (npn 2N4401.mod) in your scripts and modify the BJT model by editing only B_f (β_F) and V_{af} (V_A) in that model file according to your extraction in your Lab 2.

Attach AC simulation results showing the gain and high cutoff frequency are satisfied. Plot gain in dB and frequency in log scale Attach transient simulation results with waveform of both V_{in} and V_{out} showing output swing. The way to measure output swing is as follows: Check the gain at middle band frequency while increasing the input magnitude. Notice the point when the gain starts to fall off middle band gain, which means the output has reached its swing limitation. Record the peak-to-peak value of output at that point as the output swing. Calculate the total power consumption. Measure the sum of the currents in R_{b1} and R_c, then time (V_{cc}-V_{ss}) to get the total estimation of power consumption.

5. Single Stage Common-Source MOSFET Amplifier

The CS amplifier is given as in Figure 3.
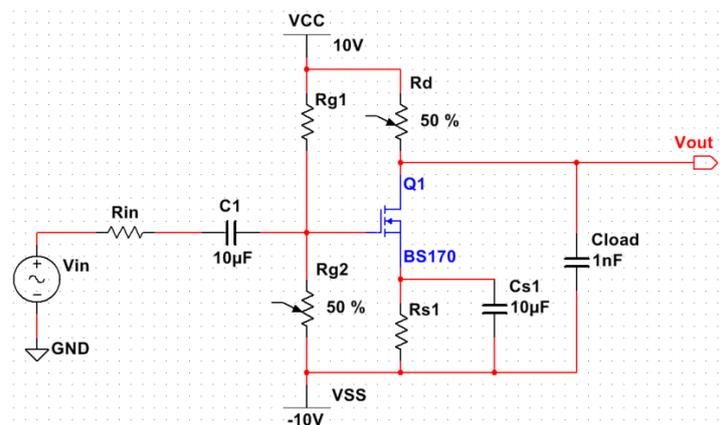

Figure 3: Single Stage Common-Source Amplifier

5.1. Hand Calculation

Explain what is the function of R_s. Draw small signal equivalent circuit. For hand calculation you could treat source as ac ground in your small signal circuit. Derive the expression for the middle band gain and high cutoff frequency (Hint: the high cutoff frequency is determined by C_{load} and the output impedance of the amplifier). Refer to your Lab 2 report for V_{th} and K_n. Use R_{in} from the Thevenin model above. Pick reasonable resistor values to satisfy the design specifications. Since you cannot choose whatever resistor value you want, you need to pick R_{g1}, R_s according to the availability of the resistor values in our labs. Then design R_{g2} and R_d value accordingly. You will implement them as potential meter or a combination of resistor and potential meter if necessary in your real lab.

5.2. Multisim Simulation

Implement your design in Multisim and verify all the design specs in simulation. Tune resistors value if necessary. Keep in mind how each resistor value affect the overall performance.

You need to include model file (mos BS140.mod) in your scripts and modify the model file by editing only V_{to} and K_p in that model file according to your extraction in your Lab 2.

Attach AC simulation results showing the gain and high cutoff frequency are satisfied. Plot gain in dB and frequency in log scale.

Attach transient simulation results with waveform of both V_{in} and V_{out} showing output swing. The way to measure output swing is as follows: Check the output magnitude at middle band frequency while increasing the input magnitude. Notice the point when the gain starts to fall off middle band gain, which means the output has reached its swing limitation. Record the peak-to-peak value of output at that point as the output swing.

Calculate the total power consumption. Measure the sum of the currents in R_{g1} and R_d, then time (V_{cc}-V_{ss}) to get the total estimation of power consumption.

Reference

[1] UNIVERSITY OF CALIFORNIA AT BERKELEY, College of Engineering Department of Electrical Engineering and Computer Sciences, EE105 Lab Experiments