National University of Sciences & Technology (NUST)
School of Electrical Engineering and Computer Science (SEECS)
Department of Electrical Engineering

Faculty Member: _____ **Dated:** _____

Semester:_____ **Section:** _____

EE313: ELECTRONIC CIRCUIT DESIGN

Lab10: Differential pair

(Mismatches and Offset Null adjustment)

S.no	Name	Reg. no.	Total/25
1			
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Objective

The input offset voltage of operational amplifiers (op amps) arises from unavoidable mismatches in the differential input stage of the op-amp circuit caused by mismatched transistor pairs, collector currents, current-gain betas (β), collector or emitter resistors, etc. This experiment deals with voltage offset due to collector resistance mismatch.

Materials

The items listed in table 1 will be needed. For this lab, assume all NPN transistors are identical 2N2222 BJTs.

CAUTION: Please DO NOT leave the circuit on for long periods since there is a risk of heating up of transistors.

Components	**Quantity**
Transistors:	2N2222 NPN x2
Resistors:	10k x 1 ,5.6k x 2, 1k variable resistor

Introduction

Consider the simplified input-stage circuit of the operational amplifier in Figure 1. The input offset voltage of the op amp results from mismatches in collector/emitter resistors and the transistor pair of the differential input. Each of these mismatches is examined separately below.

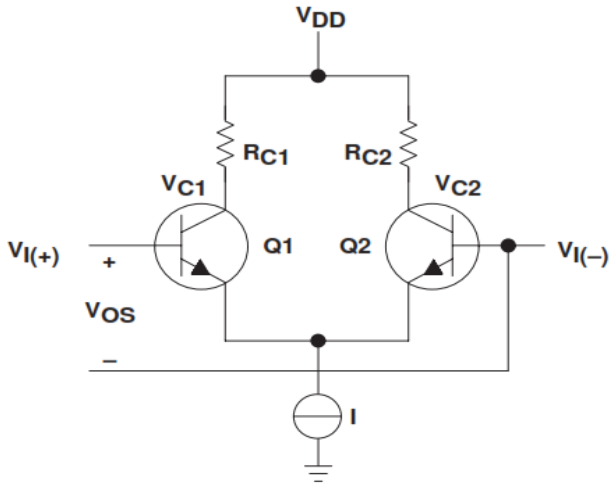

Figure 1. The Simplified Differential Input Circuit

Effect of Collector-Resistor (R_C) Mismatch on V_{os}

When the transistors Q_1 and Q_2 in Figure 1 are perfectly matched, the current, I, is divided equally between them.

Let $R_c = \frac{R_{c1} + R_{c2}}{2}$ and $\Delta R_c = R_{c1} - R_{c2}$

Then, $R_{c1} = R_c + \frac{\Delta R_c}{2}$ and $R_{c2} = R_c - \frac{\Delta R_c}{2}$

Thus, the output voltage, V_o, is [1a]:

$$V_o = V_{c2} - V_{c1} = \left(V_{DD} - \frac{\alpha I}{2} R_{c2}\right) - \left(V_{DD} - \frac{\alpha I}{2} R_{c1}\right) = \left[V_{DD} - \frac{\alpha I}{2}\left(R_c - \frac{\Delta R_c}{2}\right)\right]$$

$$- \left[V_{DD} - \left(\frac{\alpha I}{2}\right)\left(R_c + \frac{\Delta R_c}{2}\right)\right] = \Delta R_c \frac{\alpha I}{2}$$

The input offset voltage is $V_{os} = \frac{V_o}{A_d} = \frac{V_o}{g_m R_c} = \frac{\alpha\left(\Delta R_c\right)\left(\frac{I}{2}\right)}{\frac{\alpha I}{2} R_c} = V_T \frac{\Delta R_c}{R_c} = \frac{kT}{q} \frac{\Delta R_c}{R_c}$ (1)

where

$\alpha = \frac{\beta}{\beta + 1}$; differential gain : $A_d = g_m R_c$; $g_m = \frac{I_c}{V_T}$ and $V_T = \frac{kT}{q}$ is the thermal voltage.

Here k is Boltzmann's constant and q is the charge on the electron

Procedure

PART 1- CALCULATION

a) Consider the circuit shown in Figure 2 using 2N2222 transistors for the NPN BJTs.

Use R3 = 10 k Ω, R1 = R2 = 5.6 k Ω, VCC = 9 V and VEE= - 9V

b) Calculate the DC bias currents I_{C1} and I_{C2} and Voltages V_{C1} and V_{C2}.

I_{C1}:_____, I_{C2}:_____

V_{C1}:_____ V_{C2}:_____

c) Hence calculate the differential gain A_d for the give circuit.

A_d=_____

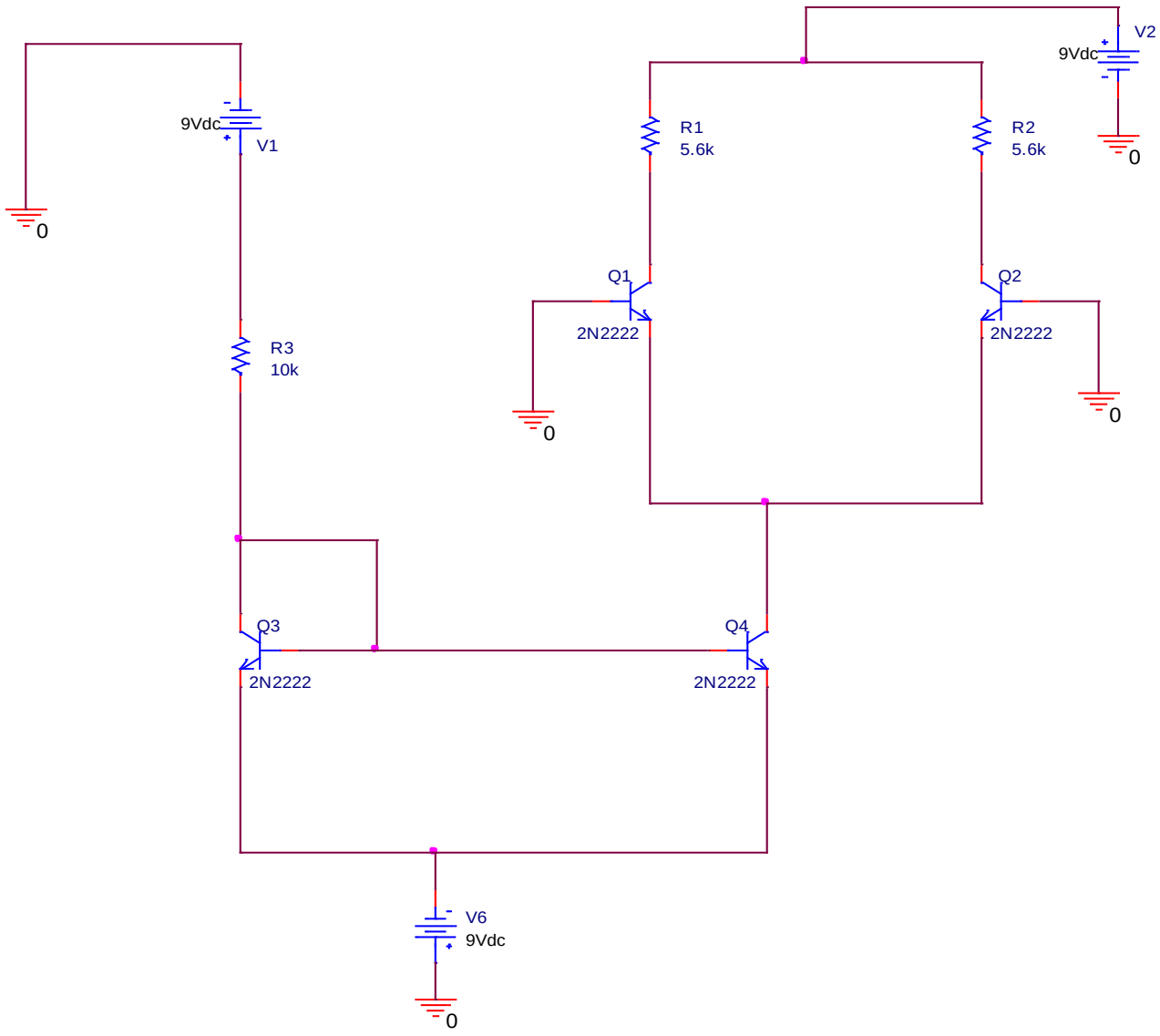

Figure 2. Differential Amplifier

d) Use a multimeter to measure the exact resistance of the 5.6k Ohms resistances. (Note: We shall use the higher resistance as R1 as shown in figure1.)

R1 (measured):_____ R2 (measured):_____

e) Using the values measured above calculate the mismatch.

$$\frac{\Delta Rc}{Rc} = \_\_\_\_\_$$

f) Using the measured values of resistance calculate the new collector voltages and hence the difference between the collector voltages

V_{C1}:_____ V_{C2}:_____

V_{C2}- V_{C1}:_____

d) Calculate the offset voltage using the formula given in introduction section.

V_{OS}=_____

PART 2- IMPLEMENTATION

a) On breadboard construct the circuit shown in Figure 2 using 2N2222 transistors for the NPN BJTs.

Use R3 = 10 k Ω, R1 = R2 = 5.6 k Ω, VCC = 9 V and VEE= - 9V

Note: Use the higher value resistance of the two 5.6kohm resistances as R1

b) Measure the DC bias currents I_{C1} and I_{C2} and Voltages V_{C1} and V_{C2}.

I_{C1}:_____, I_{C2}:_____

V_{C1}:_____ V_{C2}:_____ V_{C2}- V_{C1}:_____

c) Hence using the measured current, calculate the differential gain A_d for the give circuit.

A_d=_____

d) Using the measured values for V_{C2}- V_{C1} and A_d, Determine the offset voltage V_{OS}. Does it compare with the values calculated for PART 1?

V_{OS}=_____

e) Now add a variable resistor as shown in figure 3. Make sure that the resistance is equal on both sides.

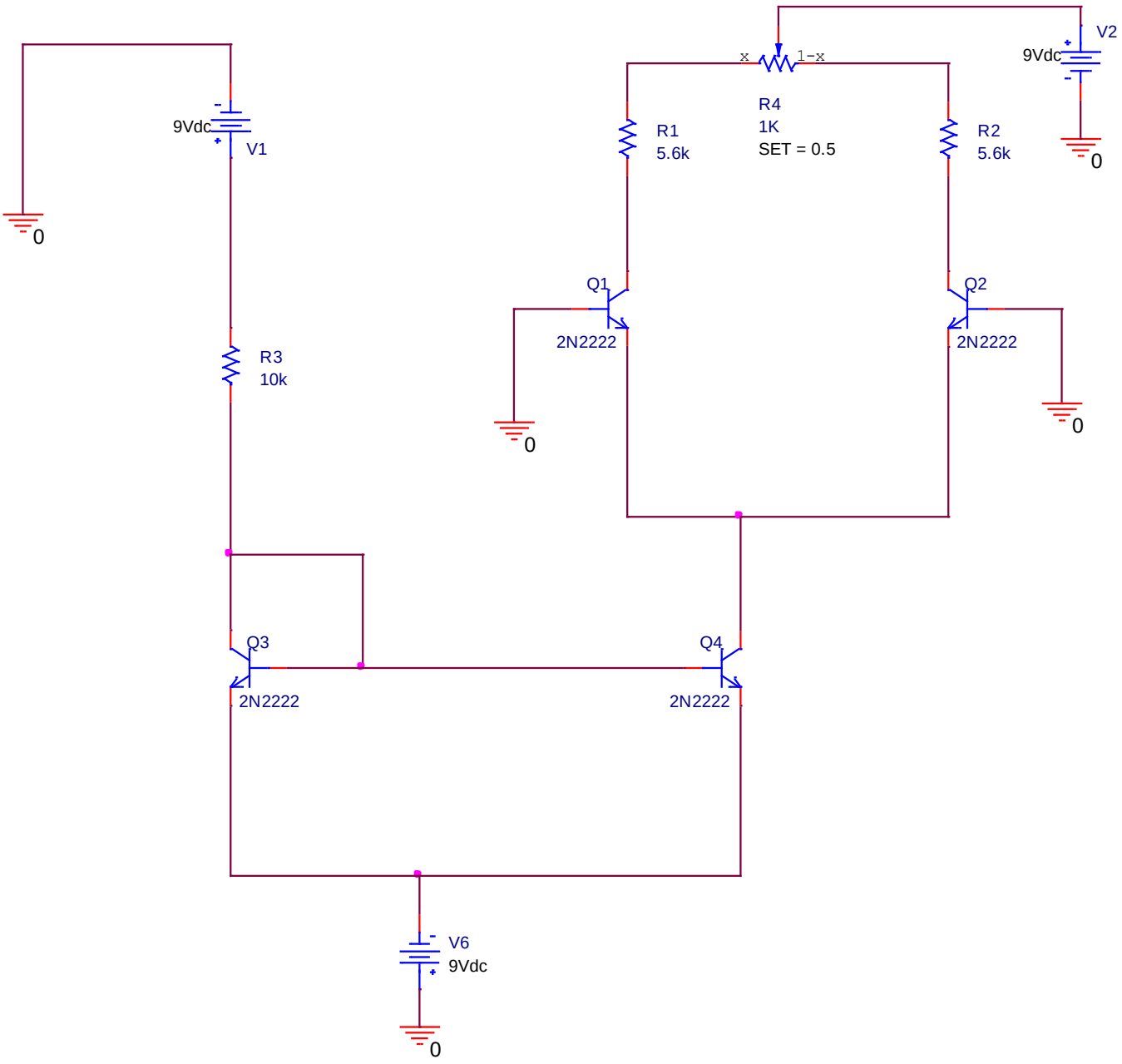

Figure 3. Differential Amplifier with potentiometer.

f) Adjust the potentiometer so that V_{C2}- V_{C1} becomes 0. Measure the resistances labeled **x** and **1-x** on figure3.

X: _____ **1-X: _____**

PART 3- SIMULATION

a) Simulate in PSpice the circuit shown in Figure 3 using 2N2222 transistors for the NPN BJTs. Use potentiometer(POT) from the breakout library in PSPICE

Use R3 = 10 k Ω, R1 = R2 = 5.6 k Ω, VCC = 9 V and VEE= - 9V

Note: Use the measured values for R1 and R2 and the higher value resistance of the two as R1

b) Use bias point analysis for DC bias currents I_{C1} and I_{C2} and Voltages V_{C1} and V_{C2}. When potentiometer is set at 0.5.

I_{C1}:_____, I_{C2}:_____

V_{C1}:_____ V_{C2}:_____ V_{C2}- V_{C1}:_____

c) Use the same values for X and 1-X measured for PART 2 and calculate the set point of potentiometer. Write down the

Note: Set: 0 means 1-x: 1kohms and set: 1 means x=1k ohms for the potentiometer

V_{C1}:_____ V_{C2}:_____ V_{C2}- V_{C1}:_____