# PreLab 4 – Differential Amplifier Design

## GOAL

The overall goal of Lab4 is to design, build, and test a differential amplifier.

## OBJECTIVES

To build, test, simulate, and understand the following:

1) BJT long-tail pair
2) Current source biasing to improve common-mode rejection ratio (CMRR)

## GENERAL GUIDELINES

1) Students are allowed (even encouraged) to work together. **However, you must turn in your own work!**
2) Prelabs count for 10% of the total lab grade.
3) Prelabs are graded using the following binary rubric: reasonable effort = 10 pts, poor effort = 0 pts.

## INTRODUCTION

The overall goal of Lab4 is to design, build, and test a differential amplifier. As an example application, your circuit will amplify the signal from an air pressure sensor. This sensor produces a differential output voltage, hence the need for a differential amplifier! How does the sensor work? In a nutshell, the sensor consists of a very thin silicon membrane with thin film resistors on each side. Air pressure causes the membrane to bend. This stretches resistors on one side but compresses resistors on the other side. These resistors form an electrical bridge network that produces a differential output voltage.

- The sensor properties are the following:
  - The output impedance is 3 kohm (worst case).
  - Responsivity = 0.8 mV/kPa.
  - Max pressure to be sensed is about 20 kPa.
  - Therefore, the max sensor voltage is $\Delta V_{SENSOR}$ = (0.8 mV/kPa) x (20 kPa) = 16 mV.

- Based on these sensor properties, your task is to design a BJT long-tail pair with the following properties:

  1) **Input impedance $R_{IN} \geq 60$ kohm**. This ensures that $V_{IN} \geq 0.95V_{SENSOR}$.
  2) **Differential gain $A_d \geq 100$**. This produces a max output voltage $\Delta V_{OUT} \geq 1.6$V, which is easily seen with a scope.

## AMPLIFIER DESIGN

Consider the differential amplifier shown in Fig. 1. The sensor requires a +10V supply, so your differential amplifier will be powered with $V_{CC}$ = +10V and $-V_{EE}$ = -10V. In the actual lab, you will use a LM3046 transistor array chip that contains a matched pair of npn transistors (nice!). The datasheet is on the course website. Although your bias current will be quite a bit lower than 1 mA, **the $\beta_{MIN}$ and $V_{BE}$ values at 1 mA should be adequate for your design calculations**.

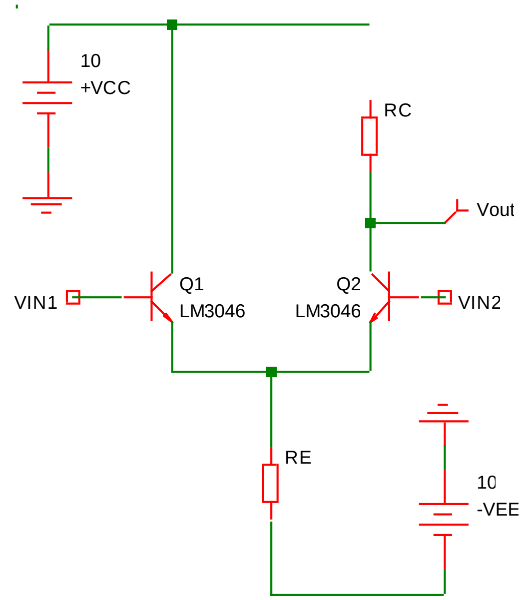


**Fig. 1: Differential amplifier using LM3046 transistor array.**

- Perform the following design calculations:
  - Maximum tail current $I_T$.
  - $R_E$: Choose the appropriate 5% resistor.
  - Compute your actual tail current and input impedance based on your choice of $R_E$.
  - $R_C$: Choose the appropriate 5% resistor.
  - Compute your actual $A_d$ based on your choice of $R_C$.
  - Quiescent collector voltage $V_{CQ}$.

- Simulate your circuit:
  - Use the 2N3904 transistor for Q1 and Q2. This is a reasonable substitute for the LM3046 transistors.
  - Let $V_{IN1}$ be a 10 $mV_P$ sine wave at 1 Hz.
  - Connect $V_{IN2}$ to ground.
  - Simulate over a 2 s interval (use a max time step of 2 ms).
  - Measure the peak-to-peak value of $V_{OUT}$.
  - Compute your differential gain $A_d$. How well does it agree with your calculated $A_d$?
  - Measure the peak-to-peak input current $I_{IN1}$ to Q1.
  - Compute the input impedance $R_{IN}$. How well does it agree with your calculated $R_{IN}$?
  - Measure the average value of $V_{OUT}$. Does it agree with your calculated $V_{CQ}$?
  - Provide the circuit schematic.
  - Provide the waveforms of $V_{IN}$ and $V_{OUT}$ with the peak-to-peak values on the graph.

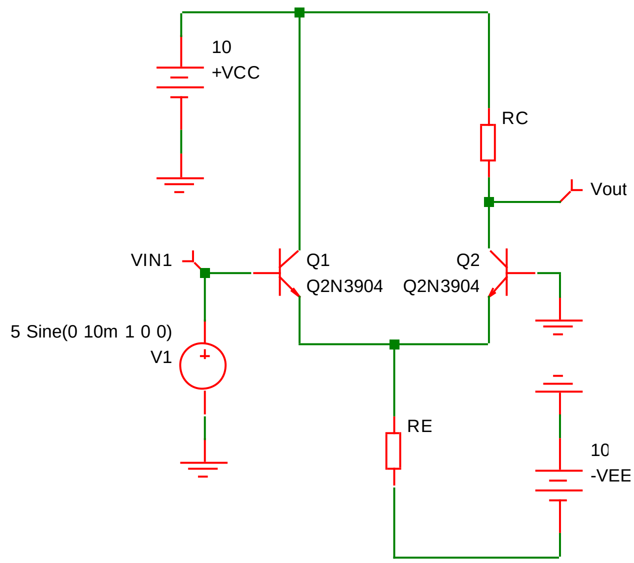


**Fig. 2: Differential amplifier simulation with 2N3904 transistors.**

(End of PreLab4)