University of Portland
Donald P. Shiley School of Engineering

EE371
Electronics Laboratory

Lab #1
BJT Differential Amplifier

Assigned:	Jan 22, 2020
Checkoff Due:	Feb 12, 2020
Final Report Due:	Mon, Feb 17, 2020 (in EE352 class)

I. **Introduction:**

For this lab assignment, consider the following BJT Differential Amplifier circuit in Fig 1.

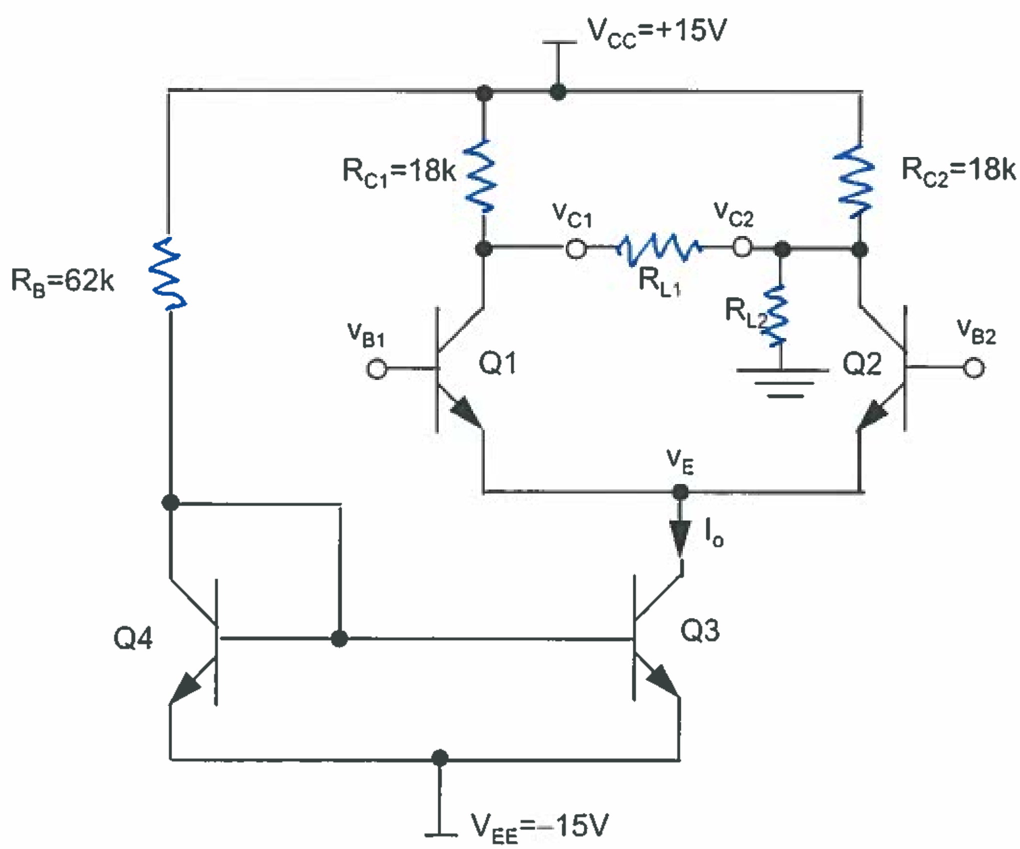


Fig. 1.

II. **Pre-Lab Exercises:**

1) Hand DC Analysis. Assume $R_{L1}=R_{L2}=\infty$ (i.e., opens), $V_{B1}=V_{B2}$=Ground, $\beta=100$, $V_A=100V$, $V_{BE\text{-}on}=0.7V$. Record all results in attached Summary Table.

   a) Calculate I_o
   b) Calculate V_E
   c) Calculate V_{C1}
   d) Calculate V_{C2}
   e) Calculate total DC Power, P_{DC}

2) Hand Midband AC Analysis in Differential-Output Mode (DOM). Assume: $v_{out}=v_{c1}-v_{c2}$, $R_{L1}=4.7k\Omega$, $R_{L2}=\infty$, $\beta=100$, $V_A=100V$, $V_{BE\text{-}on}=0.7V$. Record all results in attached Summary Table.

   a) Calculate A_d
   b) Calculate R_{id}
   c) Calculate R_{od}
   d) Calculate A_{cm}
   e) Calculate R_{icm}
   f) Calculate R_{ocm}
   g) Calculate CMRR

3) Hand Midband AC Analysis in Single-Ended-Output Mode (SEOM). Assume: $v_{out}=v_{c2}$, $R_{L1}=\infty$, $R_{L2}=470k\Omega$, $\beta=100$, $V_A=100V$. Record all results in attached Summary Table.

   a) Calculate A_d
   b) Calculate R_{id}
   c) Calculate R_{od}
   d) Calculate A_{cm}
   e) Calculate R_{icm}
   f) Calculate R_{ocm}
   g) Calculate CMRR

4) Re-do all above calculations in PSPICE (except for the R_{od}'s and R_{ocm}'s since PSPICE includes R_L in these calculations) using Transfer Function Analysis with Bias Point Details on (similar to how you did your Homework #1). Look at your xxx.out file for the answers. Record all results in attached Summary Table. For PSPICE, set VAF=100, BF=100.

III. **Laboratory Experimentation**

1) Measure and record all your resistor values before building your circuit.

2) Using your Lab Kit and components, build the BJT Differential Amplifier circuit in Fig. 1. Use an LM3046 Transistor Array component for the four matched NPN transistors. Match-up LM3046's Q1-Q4 just as they are called out in Fig. 1. (An LM3046 device spec is attached for your reference). **IMPORTANT:** Make sure Pin #13 is connected to VEE=−15V or else you'll *fry* the LM3046 chip.

3) DC Analysis: Ground both V_{B1} and V_{B2}. Set $R_{L1}=R_{L2}=\infty$ (i.e., opens) **Measure all DC node voltages and branch currents** as listed in Pre-Lab Exercise 1 above. (Note: when measuring branch currents, please do not use the DC Current option on your DMM due to its inherent unreliability. Instead, always measure the DC voltage across the series resistor using your DMM and then use Ohm's Law to get the current). Record all your results in the attached Summary Table.

4) Midband AC Analysis in Differential-Output Mode (DOM): Set R_{L1}=4.7kΩ and $R_{L2}=\infty$. (Note, $v_{out}=v_{C1}-v_{C2}$. Measure v_{out} *differentially* on the oscilloscope and use the Math mode).

   a) **Measure A_d:** Use the 10-to-1 source attenuator circuit shown in Fig. 2 to create v_{in} and connect to v_{B1}. Connect v_{B2} to GND. Set the frequency of v_s to approximately 10kHz. Monitor v_{out} while slowly increasing the v_s source until v_{out}=1V p-p approximately. Then, precisely measure v_{out} and v_{in} and calculate $A_d=v_{out}/v_{in}$.
   b) **Measure R_{id}:** Follow R_{in} procedure on attached sheet.
   c) **Measure R_{od}: Disconnect** R_{L1}. Follow R_{out} procedure on attached sheet.
   d) Record all your results in the attached Summary Table.

5) Midband AC Analysis in Single-Ended-Output Mode (SEOM): Set $R_{L1}=\infty$ and R_{L2}=470kΩ. (Note, $v_{out}=v_{C2}$. Measure v_{out} using simple *single-ended method* on the oscilloscope).

   a) **Measure A_d:** Use the 10-to-1 source attenuator circuit shown in Fig. 2 to create v_{in} and connect to v_{B1}. Connect v_{B2} to GND. Set the frequency of v_s to approximately 10kHz. Monitor v_{out} while slowly increasing the v_s source until v_{out}=1V p-p, approximately. Then precisely measure v_{out} and v_{in} and calculate $A_d=v_{out}/v_{in}$.
   b) **Measure R_{od}: Disconnect** R_{L2}. Follow R_{out} procedure on attached sheet.
   c) **Measure A_{cm}: Reconnect** R_{L2}. Disconnect v_{B2} from GND, connect v_{B1} and v_{B2} together and connect both directly to the function generator making $v_s=v_{in}$ (i.e., don't use the 10-to-1 attenuator circuit in Fig.2). Set $v_s=v_{in}$=2V p-p and 10kHz approximately. Then precisely measure v_{in} and v_{out} and calculate $A_{cm}=v_{out}/v_{in}$.
   d) **Calculate resulting CMRR.**
   e) Record all your results in the attached Summary Table.

6) **Lab Check-Off:** I must witness your Lab set-up and operation in order for you to receive your required Lab Check-Off.

IV. Lab Notebook:

Please record ALL your Pre-Lab Exercise calculations and lab data neatly, clearly and professionally in your Lab Notebook. Please follow the formal Lab Notebook format guidelines as explained in class.

V. Lab Report:

Please write-up and hand-in your Final Lab Report along with your Summary Table. Include your Pre-Lab Exercise calculations and your properly labeled PSPICE files. Compare and contrast your theoretical Pre-Lab calculations with your Lab measurements. Explain similarities and discrepancies. Your Formal Lab Report should be ***typed***, neat, professional, concise and clear. It should contain the following sections:

1) Title Page
2) Executive Summary (i.e., summarized purpose of lab experiment)
3) Lab Results Discussion
4) Conclusions
5) Summary Table (***typed***)
6) Attachment: Pre-Lab Hand calculations (brief)
7) Attachment: Pre-Lab PSPICE print-outs (5 annotated schematic files and 5 corresponding and annotated .out files)
8) Attachment: Xerox-copy of the "initialed and dated" page from your lab notebook certifying check-off of your lab 1 work

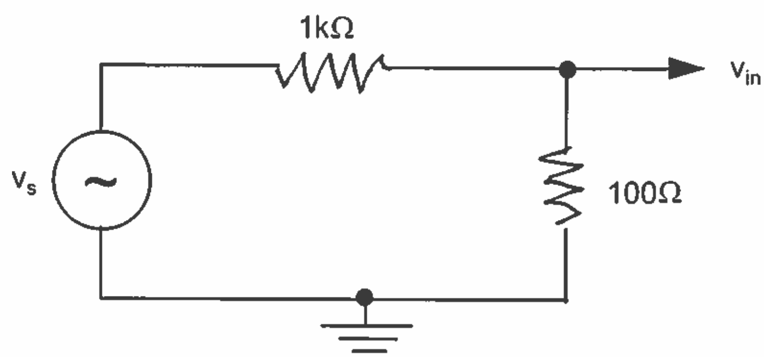
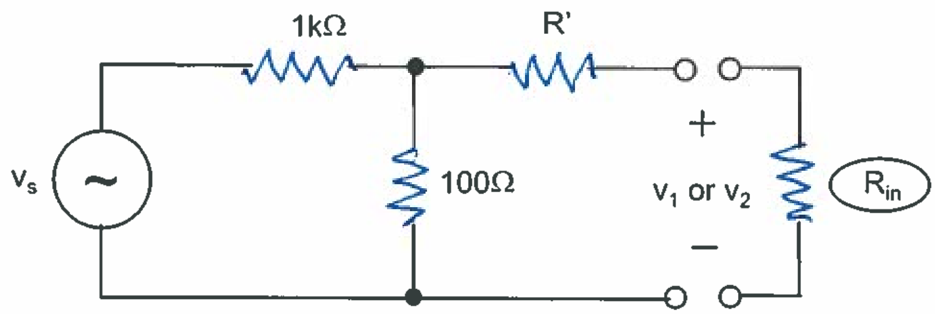


Fig. 2.

R_{in} and R_{out} Measurements

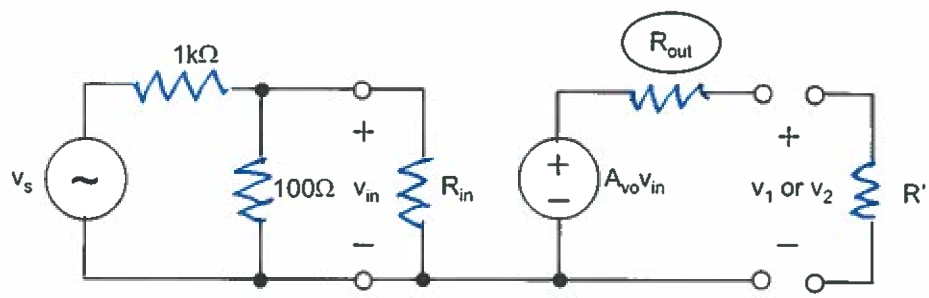
1) R_{in} Measurement:



a) Select $R' \approx R_{in}$ (expected).
b) With the input source circuit (including R') **connected** to R_{in} (i.e. v_{B1}) as shown above, set v_s such that $v_2 = v_{in} = v_{B1} \approx 50mV$ p-p and approximately 10kHz. Then, precisely measure v_2 and record.
c) Without disturbing the v_s setting, **disconnect** the entire input source circuit (including R') from R_{in} and then precisely measure the resulting open-circuit voltage of the input source circuit, v_1, and record.
d) Calculate R_{in} as follows:

$$R_{in} = R' \frac{v_2}{v_1 - v_2}$$

2) R_{out} Measurement:



a) Select $R' \approx R_{out}$ (expected).
b) With R_{L1} (or R_{L2}) removed, **connect** R' across the output. Set v_s such that $v_2 = v_{out} \approx 0.5V$ p-p with an approximate frequency of 10kHz. Then precisely measure $v_2 = v_{out}$ and record.
c) Without disturbing the v_s setting, **disconnect** R' and precisely measure the resulting open-circuit output voltage, $v_1 = v_{out}$, and record.
d) Calculate R_{out} as follows:

$$R_{out} = R' \frac{v_1 - v_2}{v_2}$$

Summary Table

Parameter	Hand Part II: 1), 2) and 3)	PSPICE Part II: 4)	Lab Part III: 3), 4) and 5)
DC:			
I_0			
V_E			
V_{C1}			
V_{C2}			
P_{DC}			
AC (DOM):			
A_d			
R_{id}			
R_{od}		N/A	
A_{cm}			N/A
R_{icm}			N/A
R_{ocm}		N/A	N/A
CMRR			N/A
AC (SEOM):			
A_d			
R_{id}			N/A
R_{od}		N/A	
A_{cm}			
R_{icm}			N/A
R_{ocm}		N/A	N/A
CMRR			

National Semiconductor

December 1994

LM3045/LM3046/LM3086 Transistor Arrays

General Description

The LM3045, LM3046 and LM3086 each consist of five general purpose silicon NPN transistors on a common monolithic substrate. Two of the transistors are internally connected to form a differentially-connected pair. The transistors are well suited to a wide variety of applications in low power system in the DC through VHF range. They may be used as discrete transistors in conventional circuits however, in addition, they provide the very significant inherent integrated circuit advantages of close electrical and thermal matching. The LM3045 is supplied in a 14-lead cavity dual-in-line package rated for operation over the full military temperature range. The LM3046 and LM3086 are electrically identical to the LM3045 but are supplied in a 14-lead molded dual-in-line package for applications requiring only a limited temperature range.

Features

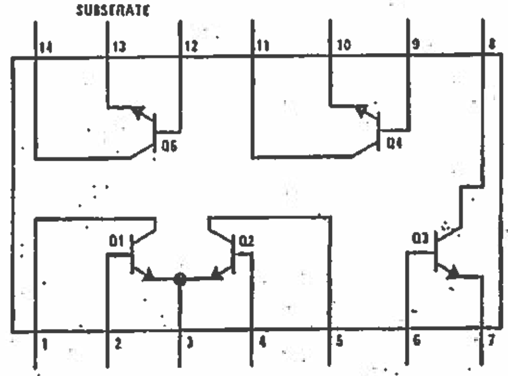
- Two matched pairs of transistors
  - V_{BE} matched ±5 mV
  - Input offset current 2 μA max at I_C = 1 mA
- Five general purpose monolithic transistors
- Operation from DC to 120 MHz
- Wide operating current range
- Low noise figure 3.2 dB typ at 1 kHz
- Full military temperature range (LM3045) −55°C to +125°C

Applications

- General use in all types of signal processing systems operating anywhere in the frequency range from DC to VHF
- Custom designed differential amplifiers
- Temperature compensated amplifiers

Schematic and Connection Diagram

Dual-In-Line and Small Outline Packages



TL/H/7950-1

Top View

Order Number LM3045J, LM3046M, LM3046N or LM3086N
See NS Package Number J14A, M14A or N14A

RRD-B30M115/Printed in U. S. A.

Name:____________________________

EE371 Lab 1 Final Report Grading Rubric

Item	Excellent	Acceptable	Incomplete or Missing
Title Page?			
Executive Summary (i.e., summarized purpose of lab experiment)?			
Discussion of Lab Results (with figures/schematics)?			
Conclusion			
Summary Table (type-written)?			
Attachment: Pre-Lab hand calculations			
Attachment: Pre-Lab PSPICE printouts (5 annotated schematic files and 5 corresponding/annotated .out files)			
Attachment: Copy of lab notebook "check-off" page			
Manhattan layout?			
Photograph of circuit is included?			
Report text is type-written?			
Section headers?			
Equations are type-written or neatly hand-written?			
Figures/schematics/attachments are neat, properly labeled, and properly referred to in text?			
Report is grammatically well-written, neat, clear, and concise?			

Comments:

Final Grade: _______