EL 351 Linear Integrated Circuits Laboratory
BJT DIFFERENTIAL AMPLIFIER

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Equipment:

- Agilent 54622A Deep-Memory Oscilloscope
- Agilent E3631A Triple-Output DC power supply
- Agilent 33120A Function Generator
- Agilent 34401A Digital Multimeter

Introduction:

The differential amplifier is a basic circuit, used in all linear integrated circuits. It is also the basis for analog-to-digital and digital-to-analog converters. Understanding its operation, including DC bias operation, and its response to signal inputs, is important for further study of linear integrated circuits.

In this laboratory experiment you will construct and test two differential amplifiers, using BJTs. One will have a resistor in the long-tailed pair, the other will have a BJT "constant" current source (which you will design). The differential-mode gain ($A_{vdm)}$), the common-mode gain ($A_{vcm)}$), CMRR, waveforms of input and output voltages, and DC operating point voltages and currents will be measured and/or calculated.

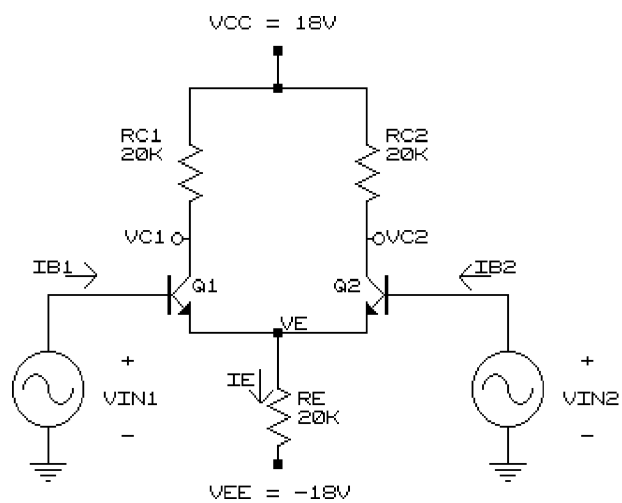
Circuit:

$Q_1 = Q_2$ = 2N1893 or 2N2222

(match β of Q_1 & Q_2 within 5%)

R_C = matched pair, 20K Ω1%

R_E = any old 20K Ω+/- 10%



Procedure:

Differential Amplifier, Long-Tail Pair Impedance is a Resistor

I.1. Find two matched transistors, and construct the circuit above. Of course, all resistances used should be measured and recorded before being used. Make the circuit quiescent (no signal applied) by connecting both bases to ground.

I.2. Measure DC values of V_{C1}, V_{C2}, V_E, I_{B1}, I_{B2} and I_E, <u>in a way that minimally disturbs the circuit!</u> Consider carefully the impedance of the measuring instruments; refer to impedance specifications in the manufacturers' manuals. Be sure to record which meter was used, and its range, for each measurement.

I.3. Measure the differential gain (only **one** input used), from **each** input, and the common-mode gain (both inputs connected to the same source), by applying 400 Hz sinusoidal input voltages as shown in Table I.

For each input condition (1st - diff. mode, 2nd - diff. mode, 3rd - common mode), measure the unknowns with **BOTH** the DVM and the oscilloscope, and **record all voltages in both RMS** (from DVM) **and peak-peak**, **with phase angle** (from oscilloscope). Always keep oscilloscope channel 1 on the input, and use it as the phase reference.

Sketch ALL waveforms (Vin1, Vin2, Ve, VC1 and VC2) for each input condition; be sure to include DC levels, peak-peak voltages, and **relative** phase information (show Vin1, Vin2, Ve, VC1 and VC2 one above the other).

TABLE I

Input Condition	Vin1	Vin2	Ve	Vc1	Vc2
First – Differential Mode	40 mVpp/ 0°	0 mVpp/ 0°	Vpp/____°	Vpp/____°	Vpp/____°
	Vrms	Vrms	Vrms	Vrms	Vrms
Second - Differential Mode	0 mVpp/ 0°	40 mVpp/ 0°	Vpp/____°	Vpp/____°	Vpp/____°
	Vrms	Vrms	Vrms	Vrms	Vrms
Third – Common Mode	40 mVpp/ 0°	40 mVpp/ 0°	Vpp/____°	Vpp/____°	Vpp/____°
	Vrms	Vrms	Vrms	Vrms	Vrms

I.4 Using the measured data in Table I, calculate A_{vcm}, A_{vdm} and CMRR. Express each in both numerical ratios (i.e. volts/volt) and in dB.

I.5 Using the approximate formulae for A_{vcm} and A_{vdm}, calculate, using parts values, both A_{vcm} and A_{vdm}. Compare these calculated gains with the measured gains from procedure I.4.

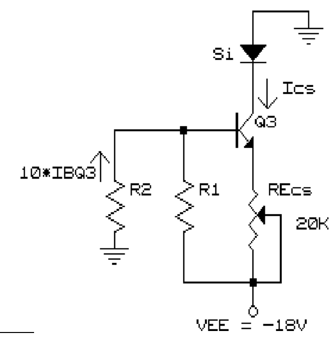
I.8. Have your data, up to this point, approved by instructor______________________

Procedure: Design and Test of Current Source by Itself

II.1. Using the measured data from I.2, design a “constant” current source, which WILL BE used later on to replace the fixed emitter resistor in the differential amplifier. The current source should make the differential amplifier operating point be identical to what it was with the fixed resistor in the LTP. Make $V_B = 0.5*V_{EE}$, and make $I_{R2} = 10*I_{BQ3}$.

Clearly show design procedures.

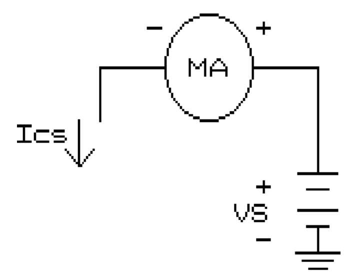
Note that the diode keeps the collector of Q3 at about 0.6 V below ground, just as it WILL BE later on when it is connected to the long-tailed pair of the differential amplifier.



II.2. Have your design approved by the instructor:__________________________

Then build the current source, but **do not connect it** to the Diff Amp. Use a 20K pot for R_E and adjust it to make the collector current of the current source to be the same as the long-tailed pair current (measured in I.2.), but DON’T connect it to the diff amp yet.

II.3. Measure all DC voltages and currents in the constant current source circuit <u>in a way that minimally disturbs the circuit!</u>



a. measure I_{cs0V} with $V_s = 0$ V.

b. measure I_{cs60V} with $V_s = 60$ V.

c. calculate $R_{apparent} = (60 - 0)V/(I_{cs60V} - I_{cs0V})A$

II.5. Now disconnect the test circuit, and connect the current source in place of the fixed emitter resistor in the differential amplifier (no Si diode is needed now). Verify that the Q point of the diff amp is essentially the same with the current source as it was with the fixed emitter resistor; if it isn’t, slightly adjust the 20KΩ trim pot to make it the same.

Procedure: Test of Differential Amplifier with Current Source

III.1. Repeat procedures I.3 (use Table II to record data), I.4, I.5 for the diff amp with current source. Be sure to sketch waveforms also. Note that a fourth input condition is needed, with a high common-mode input voltage (3 Vpp), since the common-mode gain is so small you won’t be able to see an output with only 40 mVpp as the common-mode input.

TABLE II

Input Condition	Vin1	Vin2	Ve	Vc1	Vc2
First –Differential Mode	40 mVpp/ 0°	0 mVpp/ 0°	Vpp/____°	Vpp/____°	Vpp/____°
	Vrms	Vrms	Vrms	Vrms	Vrms
Second - Differential Mode	0 mVpp/ 0°	40 mVpp/ 0°	Vpp/____°	Vpp/____°	Vpp/____°
	Vrms	Vrms	Vrms	Vrms	Vrms
Third –Common Mode (SMALL INPUT)	40 mVpp/ 0°	40 mVpp/ 0°	Vpp/____°	Vpp/____°	Vpp/____°
	Vrms	Vrms	Vrms	Vrms	Vrms
Fourth –Common Mode (VERY LARGE INPUT)	3000 mVpp/ 0°	3000 mVpp/ 0°	Vpp/____°	Vpp/____°	Vpp/____°
	Vrms	Vrms	Vrms	Vrms	Vrms

☞ **Be sure, in the Results part of your lab report, to compare and discuss the measured values of A_{vcm}, A_{vdm}, and CMRR for the two differential amplifier circuits.**