Differential BJT amplifier

1. Introduction

The differential amplifier has two input signal sources. The ideal differential amplifier produces an output voltage that is the difference between the two input voltages. Vout = Avd(Vin1-Vin2) The differential amplifier has two single ended output voltages. Vout1 (inverting output) Vout2 (non-inverting output) or the differential out by taking the output across the two outputs.

The signal path for Vin1 to Vout1 is a CE (Q1) amplifier the signal path for Vin1 to Vout2 is a CC (Q1) followed by a CB (Q2)(common base) the CB has a voltage gain similar to CE but does not have inversion. The signal path for Vin2 is similar to Vin1 but from the other transistor (Q2).

For our project we will define the Vin1 as positive input and Vin2 as negative input. Vout2 as non-inverting output and Vout1 as inverting output

2. Components

Qty	Device
2	2N2222 NPN Transistors

4. Requirements

Rl1,Rl2 (R load)	10kΩ
Vout1, Vout2 (single ended measured to ground)	Greater than 0.5Vrms
F_L (low frequency cut off)	Between 20Hz and 200Hz
V+ positive supply	+9 Vdc
V- negative supply	0 Vdc (ground)
Beta Q1, Q2	150

5. Prelab design:

Draw schematic and label, Draw and label the AC model

Bipolar differential amplifier we use matched transistors Q1 and Q2 with a common emitter resistor Re, and we can design for a single power supply or two. We will use a transformer on the function generator isolate signal so we have a differential input signal. The Bode Box has a gain of Av = 0.1 and the impedance of about 10Ω. We will need to add in series Ri =180Ω, therefore Rs' = Ri + Box = 180 + 10 = 190Ω to keep Rs' about the same as other projects.

Design the differential (measured between Vout2 and Vout1) output voltage Voutdiff of 1Vrms at the midband frequency. The emitter resistor is used to the set the sum of the two emitter currents $I_{Re} = I_{E1} + I_{E2}$ that splits equally between the two transistors emitters (if the transistors are matched). We want the voltage Ve1 = Ve2 = Reb (Ie1 + Ie2) across Reb at about 3Vdc for negative feedback for temperature stability. We do not use a bypass capacitor on the Re because we need the signal to be passed to the other transistor. Recall as in the CE design, the select the collector resistors Rc1, and Rc2 by your required V_{CE1}, and V_{CE2} by knowing I_{C1}, and I_{C2}.

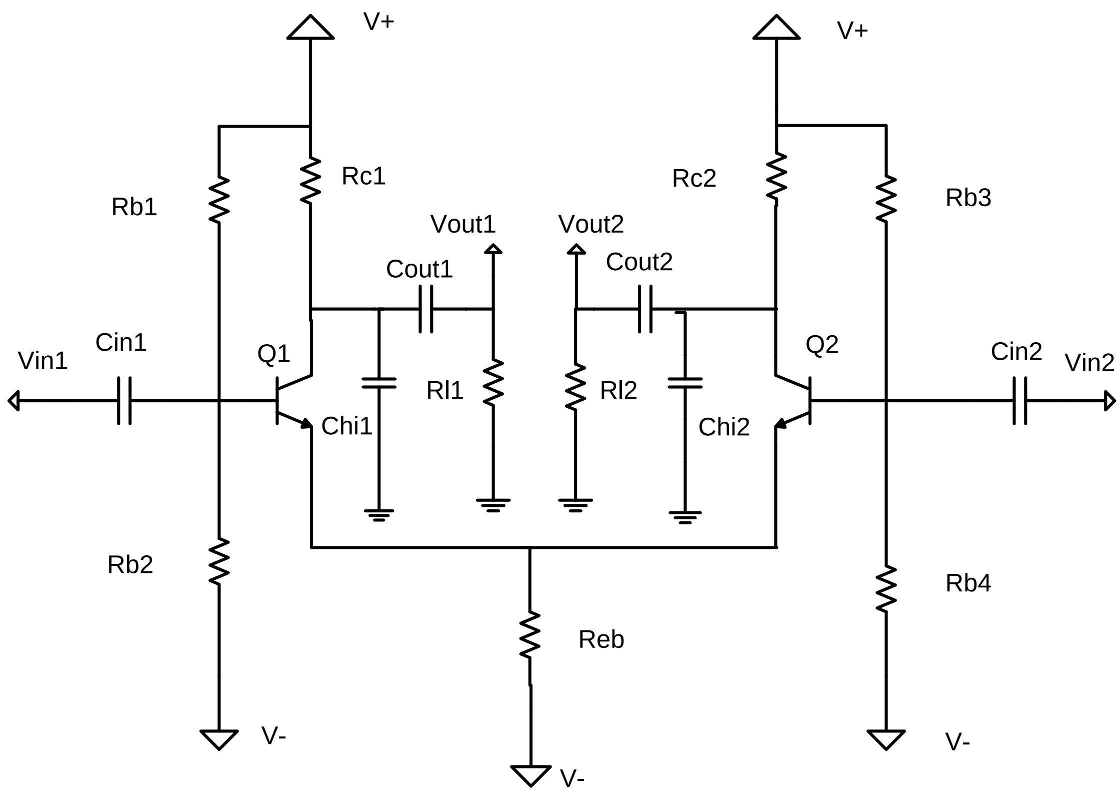
Run LTspice simulation of the differential amplifier, for both waveform, and frequency response. Include simulation schematics and plots.

5.1 Design requirements to insure that the differential amplifier is symmetric. Design one transistor and use the same values for the other transistor. Keep the base bias resistors below 35KΩ.

$I_{C1} = I_{C2}$; $V_{CE1} = V_{CE2}$; $R_{C1} = R_{C2}$; Rb1 = Rb3; Rb2 = Rb4; Cin1 = Cin2; Cout1 = Cout2

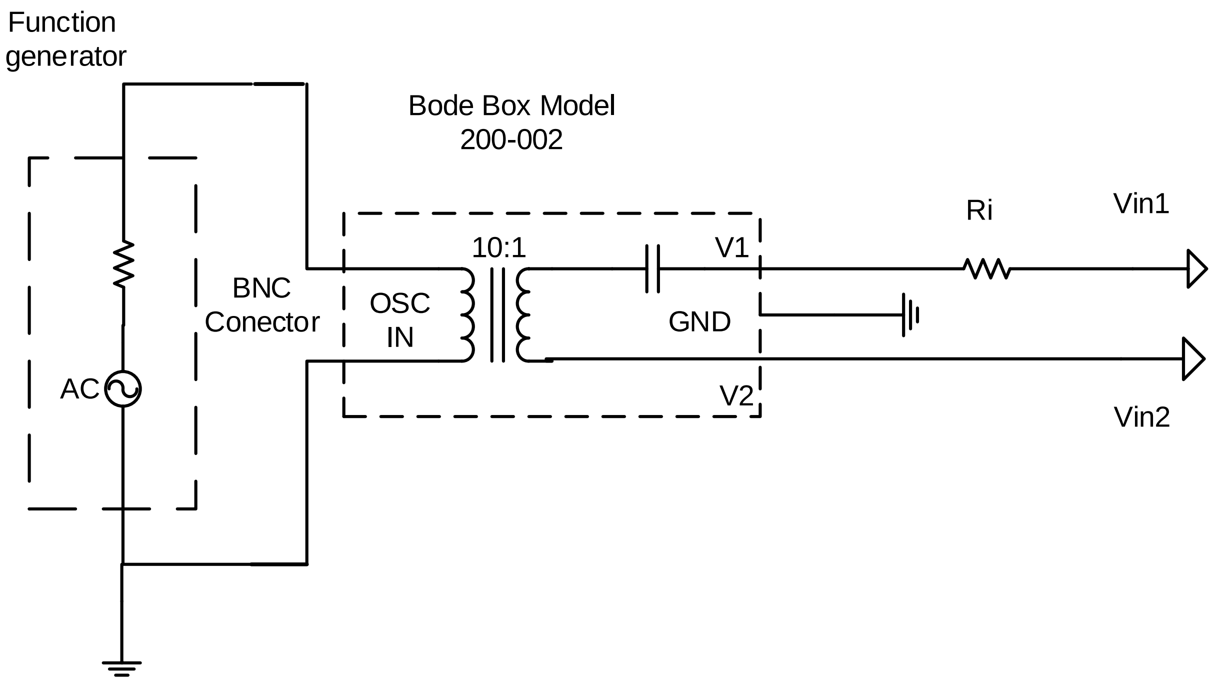
Ri	180Ω	Vbe	0.65
r_0 Q1,Q2	∞		
		I_{Re}	1ma
Rl1,Rl2	10kΩ	V_{Re}	3Vdc
Rs'	190Ω	Beta Q1,Q2	150
V+	9Vdc single supply	V-	0Vdc Ground

Table of given values



V- = Ground V+ = +9Vdc

Figure differential amplifier



Input circuit with bode box (blue box) for differential input. Ri = 180Ω

5.2 Design values for the differential amplifier. Design Q1 as a CE and duplicate for Q2.

Note: Reb will set the total bias current for the amplifier $I_{Reb} = I_E1 + I_E2$

Given: I_E1 = 0.5ma, I_E2=0.5ma, I_{Reb} =1.0ma, power supply V+=9.0Vdc, V- =0vdc (ground)

Cin1=Cin2=1uF, Cout1=Cout2=1uF, Chi1=Chi2=470pF

Keep the base bias resistors below 35KΩ.

Design the resistor bias (you may need to adjust **RB1, RB2** if the Low Frequency cutoff is below the minimum value) for Q1 then duplicate for Q2 include all equations calculated value and real components that you will use in lab circle answers. Include schematic drawing. Fill in design table data sheet to be turned in with design prelab. Prelab must be handwritten.

5.3 Bias voltages and Currents

Bias values from your design of Q1. Remember Reb common for both transistor. For Q2 duplicate the Q1 values.

Transfer you design values to the table bias design values for Q1 and Q2 design data sheet section.

5.4 AC characteristics values

Calculate Rout2 (single ended), and Av1-2 voltage gain from Vin1 to Vout2 with the load connected and Vin2 grounded.

Calculate Rout1 (single ended,) and Av2-1 voltage gain from Vin2 to Vout1 with the load connected and Vin1 grounded.

5.5 Over all AC characteristics.

Rindiff differential midband input resistance between the two inputs Vin1 and Vin2.

Routdiff differential midband output resistance is between the two outputs Vout1 and Vout2.

Avdiff differential gain Avd = Voutdiff / Vindiff is the voltage between (Vout2 –Vout1) / (Vin1 – Vin2).

Calculate the Low frequency cutoff of the single ended Vout1 by F_L = Fcin1 +Fcout1.

Calculate the High frequency cutoff for a single ended output F_H = Fchi.

5.6 Design tables data sheet to be include with your **prelab**.

Rl1,Rl2 (R load)	10kΩ
Vout1, Vout2 (single ended measured to ground)	Greater than 0.5Vrms
F_L (low frequency cut off) Adjust Rin	Between 20Hz and 200Hz
V+ positive supply	+9 Vdc
V- negative supply	0 Vdc (ground)

Table of requirements\

Name	Calculated value		Real value used
Rb1 below 35k			
Rb2 below 35k			
Rc1			
Reb			
Rb3 below 35k			
Rb4 below 35k			
Rc2			
Name	Real value used	Name	Real value used
Cin1	1uF	Cin2	1uF
Cout1	1uF	Cout2	1uf
Chi1	470pF	Chi2	470pF

Table of components design values

Dc bias values

V_{Re}		I_{Re}	
V_{E1}		I_{E1}	
V_{B1}		I_{B1}	
V_{C1}		I_{C1}	
V_{CE1}			

Table bias design values for Q1

V_{Re}		I_{Re}	
V_{E2}		I_{E2}	
V_{B2}		I_{B2}	
V_{C2}		I_{C2}	
V_{CE2}			

Table design bias values for Q2

AC characteristics design values (3 plots, Vout1, Vout2, and Vout Diff)

Rin1		Rload	
Rout1 (single ended)		Vout1 peak (single ended)	
Av Vin1 to Vout1 CE		I_{load} peak	

Table f Q1 AC characteristics

Rin2		Rload	
Rout2 (single ended)		Vout2 peak (single ended)	
Av Vin1 to Vout2 CB		I_{load} peak	

Table Q2 AC characteristics

Over all AC characteristics (1 plot)

Avdiff Differential gain		F_L Low cutoff	
Rindiff Differential input		F_H High cutoff	
Routdiff Differential output		BW bandwidth	

6.0 **Procedure**

Build the differential amplifier from your design, measure the performance, capture the plots.

6.1 Measure the DC bias point. Use the multimeter set on dc to measure the DC bias for both transistors. Fill in the table include the units. Calculate the current from the voltage across a resistor.

Q1:

Measure the DC bias point for Q1. Voltage measured to ground reference.

Q2:

Measure the DC bias point for Q2. Voltage measured to ground reference.

6.2 Measure the input and output impedance of both transistors set the differential input voltage such that the output is not clipping. Use the multimeter set to AC Voltage to measure input and output impedance needed values. Set the input signal source amplitude such that the output is not clipping verifier using the oscilloscope. Set the frequency to midband. Input current is calculated form measuring an AC voltage across the input shunt Ri.

Q1.

Ground the input (Vin2) to Q2 by grounding at the transformer leg connected to Q2 input (do not disconnect the transformer).

6.3 Differential gain.

Remove the ground on Vin1. Set the input differential voltage to 10mV RMS use the voltmeter measure the output differential voltage with the voltmeter.

6.4 Capture waveform on oscilloscope. (3 plots)

Adjust input so the differential output voltage to 1V RMS. Calculate the equivalent peak value.

Must use **10X scope probes** to avoid capacitive loading of the circuit. Connect channel 1 to Vout2 connect channel 2 Vout1. Add a math Step function to Basic Scope Capfor the differential output Voutdiff = Vout2 - Vout1

Save and print 3 plots Vout1, Vout2, and Voutdiff differential (Vout2 – Vout1)

6.5 Frequency response. (1 plot)

Use same input voltage as waveform capture (6.4) to sweep frequency from 10Hz to 300kHz.

Note: If high cutoff is above that range increase sweep range.

Save and print plot. Mark on plots cutoff points Include units

7.0 **Report data sheet** to be turn in at end of the lab.   Bench: _____   Date: _________

Name: ______________________Name: ________________________

Build the differential amplifier from your design, measure the performance, capture the plots.

V+ power supply		V- power supply	

Rb1		Rb3	
Rb2		Rb4	
Rc1		Rc2	
Reb		Rl1,Rl2	
Cin1	1uF	Cin2	1uF
Cout1	1uF	Cout2	1uF
Chi1	470pF	Chi2	470pF

7.1 Measure the DC bias point. Use the multimeter set on dc to measure the DC bias for both transistors. Fill in the table include the units. Calculate the current from the voltage across a resistor.

Q1:

Measure the **DC bias** point for Q1. Voltage measured to ground reference. Include units

V_{B1}			
V_{C1}		I_{C1} (calculate from R_{C1})	
V_{E1}			
V_{Reb} (across Reb)		I_{Reb} (calculate from Reb)	
V_{CE1} (across C-E)			

Q2:

Measure the DC bias point for Q2. Voltage measured to ground reference. Include units

V_{B2}			
V_{C2}		I_{C2} (calculate from R_{C1})	
V_{E2}			
V_{Reb} (across Reb)		I_{Reb} (calculate from Re)	
V_{CE2} (across C-E)			

7.2 Measure the input and output impedance of both transistors set the differential input voltage such that the output is not clipping. Use the multimeter set to AC Voltage to measure input and output impedance needed values. Set the input signal source amplitude such that the output is not clipping verifier using the oscilloscope. Set the frequency to midband (2kHz). Input current is calculated form measuring an AC voltage across the input shunt Ri.

Ground the input to Q2 by grounding at the transformer leg connected to Q2 input (do not disconnect the transformer).

Vin Diff (across Vin2 Vin1)		V_{load} (single ended)	
V_{Ri} (across Ri)		I_{load} (single ended)	
Iin (calculated)		V_{OC} (single ended)	
Rin Diff		Rout (single ended)	
		R_{OUT} Diff	

7.3 Differential gain.

Set the input differential voltage to 10mV RMS use the voltmeter measure the differential output with the voltmeter.

Vindiff differential		Voutdiff differential	
Avdiff differential			

7.4 Waveform capture. (3 plots)

Set the input voltage such that the differential output voltage (Voutdiff) is 1V RMS in the midband frequency. Use the math function of scope (Ch1 – Ch2) with Ch1 = Vout1 and Ch2 = Vout2.

Turn 3 plots. Vout1, Vout2, and Voutdiff.

7.5 Frequency response. (1 plot)

Use same input voltage as waveform capture (7.4) to sweep frequency from 10Hz to 300kHz.

Note: If high cutoff is above that range increase sweep range.

Save and print plot. Mark on plots cutoff points Include units

F_L low frequency cutoff	
F_H High frequency cutoff	
BW bandwidth	