3EJ4 Lab3

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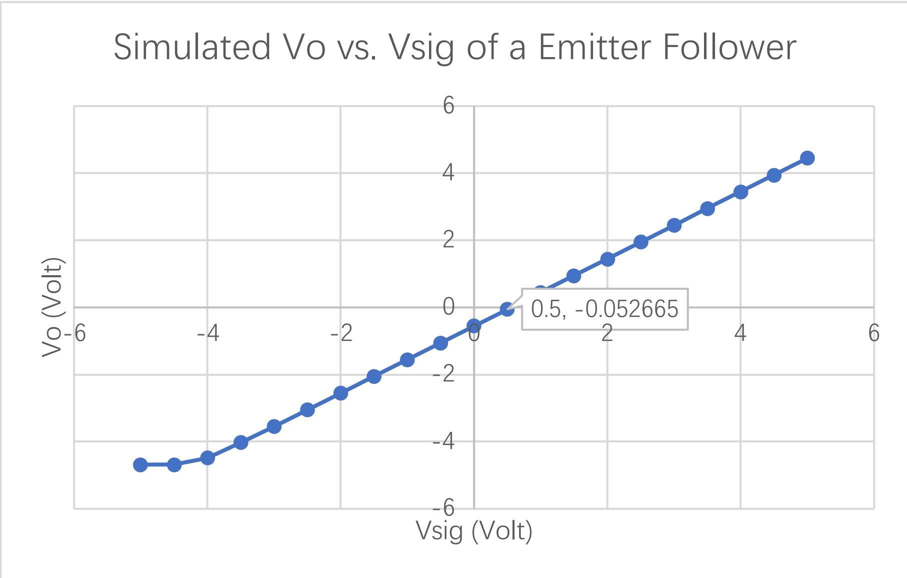
Part1:

Q1. (15 Points) Based on the simulation and measurement data obtained in Steps 1.2 and 1.6, (1) plot the simulated and measured V_o vs. V_{sig} characteristics and discuss/justify the characteristics. (2) To ensure the circuit work as a common-collector (CC) amplifier, find the DC input range for V_{sig} and the output voltage range for V_o. (3) Find the V_{sig} value that results in $V_o \approx 0$ V.

(1)



Discuss/Justify: As the graph shown above, Vsig is the input voltage range from -5V to 5V with a 0.5V step. In order to let the common-collector work as an amplifier, the output voltage Vo should have an increasing trend as shown above with the corresponding Vsig change. Therefore, the Vsig range to ensure the circuit work as a CC amplifier is -4.5V to 5.0V.

(2) To ensure the circuit work as a common-collector amplifier, Vsig should in the range of -4.5V to 5.0V and the output voltage Vo should be greater in the range of -4.683226V to 4.447137V.

(3) The Vsig values results in Vo = 0V is Vsig = 0.5V.

Q2. (10 Points) Based on the simulation and measurement data obtained in Steps 1.3 and 1.8, what are the simulated and measured intrinsic voltage gain A_{vo} at low frequency (i.e., 100 Hz) of this CC amplifier? Report its magnitude in dB and phase in degree.

The simulated intrinsic voltage gain A_{vo} at low frequency is 0dB with phase -8.47E-5deg.

The measured intrinsic voltage gain A_{vo} at low frequency is 0.8dB with phase 0deg.

Part2:

Q3. (15 Points) (1) Based on Section 8.2.3 in the textbook, derivate the relationship to express I_o as a function of I_{REF}. (2) Based on the simulation data obtained in Step 2.2, when I_{REF} is 0.1 mA, how is I_o compared with I_{ERF}? When I_{REF} is 1 mA, how is I_o compared with I_{ERF}? (3) Justify the observation between the theoretical prediction and the simulated result at I_{REF} is 0.1 mA and 1 mA, respectively.

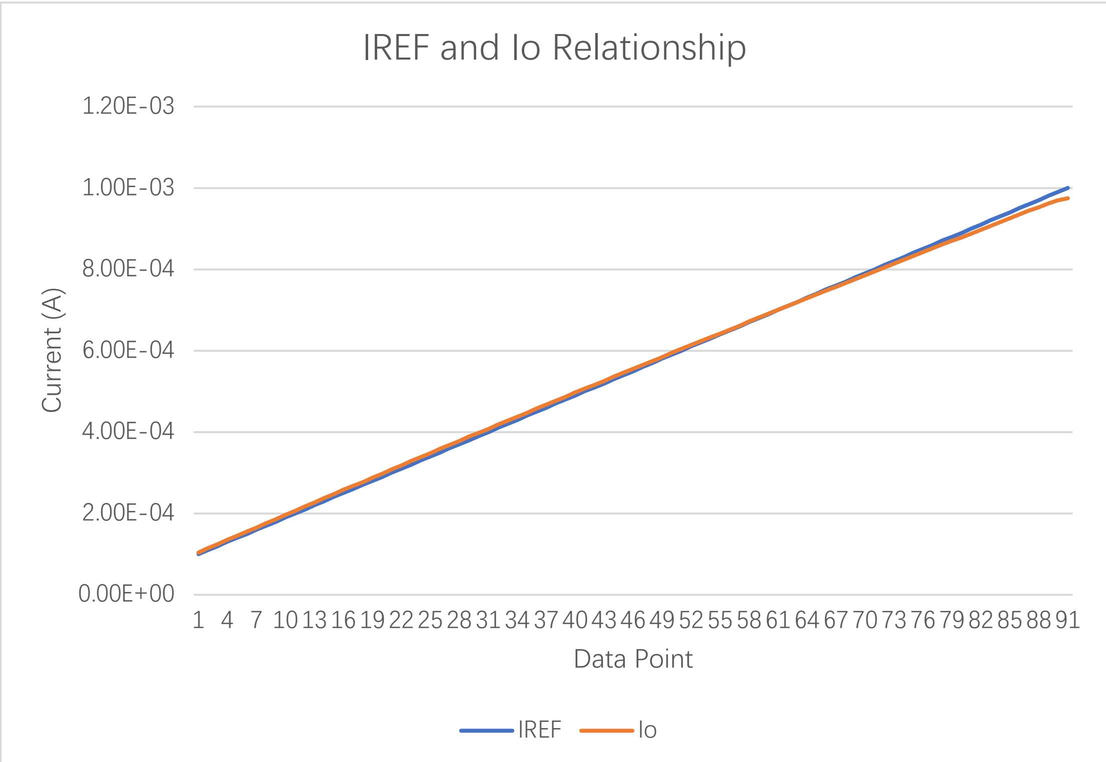
(1) According to the Section 8.2.3 in the textbook as shown below,

In general, the current transfer ratio is given by

$$\frac{I_O}{I_{REF}} = \frac{I_{S2}}{I_{S1}} = \frac{\text{Area of EBJ of } Q_2}{\text{Area of EBJ of } Q_1} \tag{8.17}$$

Since we are using the same two BJTs, the EBJ area of Q2 and Q1 should be the same. So, the relationship of Io and Iref is Io = Iref. Their ratio is equal to 1.

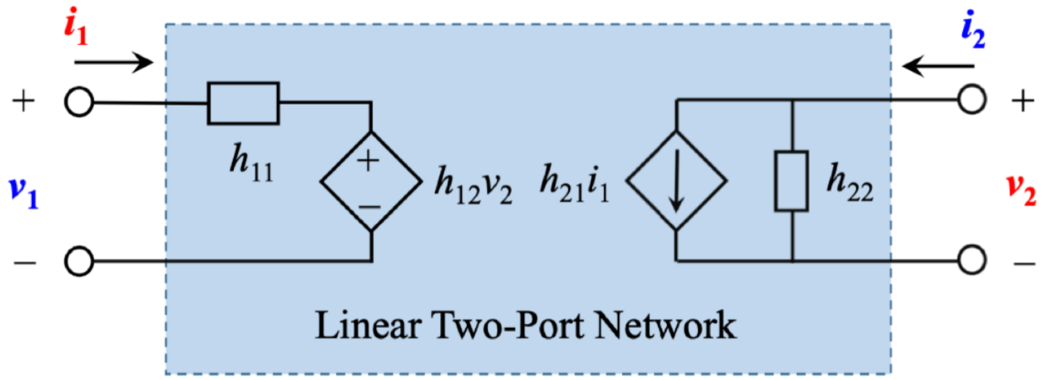
(2) As the below IRef and Io relationship graph shown below, the IREF and Io is nearly the same when they Iref is 0.1mA and 1mA.



(3) Based on the derivation formula that Iref=Io since they are using the same BJTs with equal EBJ area, the simulation result of IRef in the range from 0.1mA and 1mA proves the theoretical prediction which they are forming a current mirror with same current.

Q4. (15 Points) (1) Based on the simulation data obtained in Step 2.5, what is the input impedance R_{in} looking from V_{in} toward the collector of Q1? What is the current gain A_i of the current mirror? (2) Based on the simulation data obtained in 2.6, what is the output impedance R_o of the current mirror looking into the collector of Q2? (3) Based on the information obtained in (1) and (2), draw the linear two-port network for the current mirror using its h-parameters.

(1) Input impedance Rin = 389.12ohm. The current gain Ai = 1.048.
(2) Output impedance Ro = 1.58E+06ohm.
(3)



$h_{11} = 389.12\,\Omega$, $h_{21} = 1.048A$,
$h_{12} = 3.94E-10$, $h_{22} = 1.01E-4\ S$
$R_{in} = h_{11} = 389.12\,\Omega$
$R_o = 1/h_{22} = 1.58E+06$

Part3:

Q5. (15 Points) (1) Based on the simulation data obtained in Step 3.2, what is the voltage gain A_d in dB for the differential-mode signal? (2) Did you observe any mismatch in Step 3.6? If yes, how much offset voltage did you apply at V_2? (3) Compare your simulated result with the measured result obtained in Step 3.8.

(1) The voltage gain is 78.11dB.

Frequency	vm(vo)	ph(v(vo))	Ad = 20*log(|Vo|/2mV)	GBW	GBW in Step 3.6, Lab 2
Hz	Volts	deg	dB	Hz	Hz
1.00E+02	16.0942275	-5.18E-01	78.11	9.01E+07	1.07E+05

(2) Yes, the offset I applied at V2 is -0.00065V.

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Output

Offset voltage for Wavegen 1, Channel 2 = -0.0006500000000000001 V.
DC voltage at the collector of Q1 = 4.41 V.
DC voltage at the collector of Q2 = 4.415 V.
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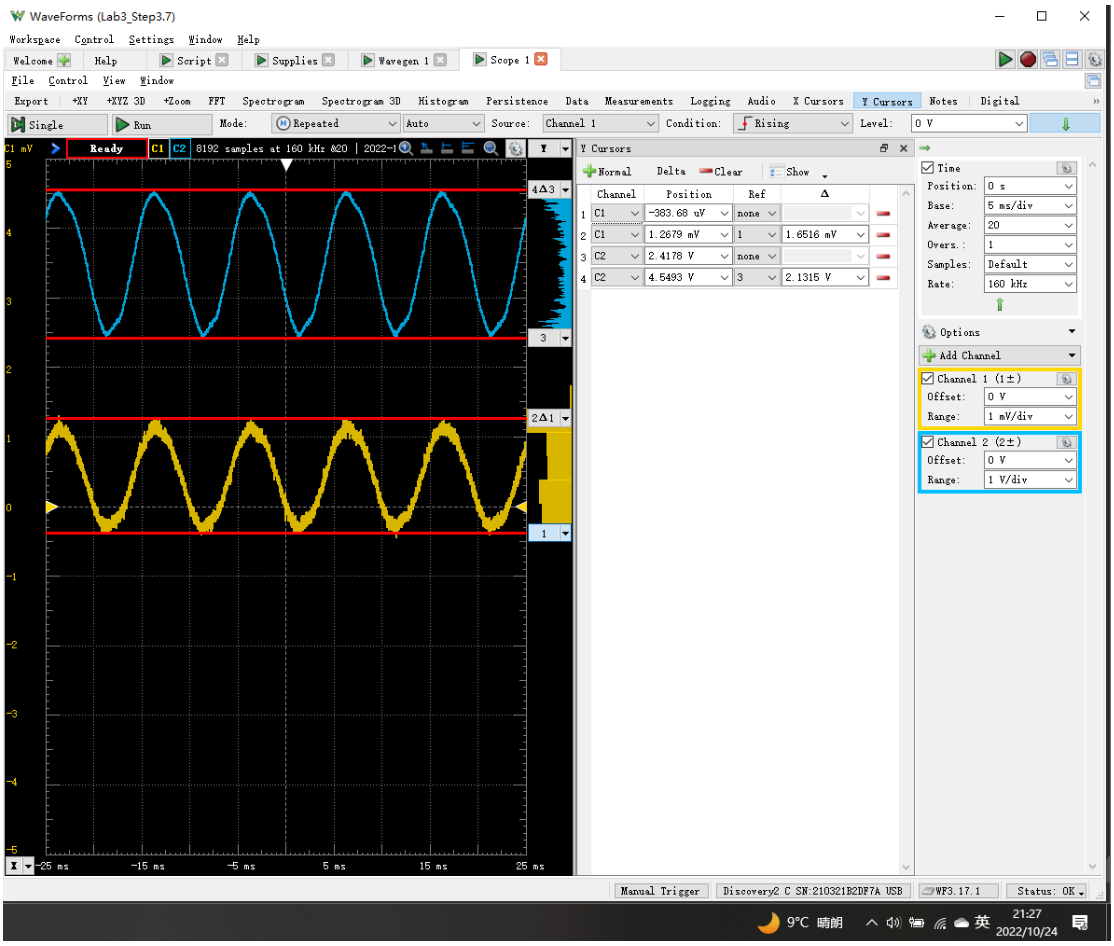
(3) The simulated result is 58.94dB and the measured result is 56.2dB which they are close enough.

ΔC1 (V) = Vsig(Peak2Peak)	ΔC2 (V) = Vo(Peak2Peak)	Differential Voltage Gain Avd of a Single-Stage Differential Amplifier (dB)
1.6516E-03	2.1315	56.2

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Output
Differential-mode voltage gain Avd = 58.93528405457579 dB.
Using the Y cursors in Scope 1 to confirm.
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Q6. (10 Points) Estimate its upper 3-dB frequency f_H (i.e., the frequency at which the amplitude becomes $1/\sqrt{2} = 0.707$ of its low-frequency value or the phase changes 45°).

The upper 3-dB frequency should around 1.54E+04 hz which will have the Vm(vo) amplitude close to 11.37861354V.

Frequency	vm(vo)	ph(v(vo))	Ad = 20*log(|Vo|/2mV)
1.54E+04	11.4058259	-5.44E+01	75.12

Q7. (10 Points) Compare the upper 3-dB frequency f_{3dB} of this differential amplifier with a current mirror load with that of the differential amplifier using resistive loads obtained in Q8 of Lab 2. Why the differential amplifier with the current mirror load has a smaller f_{3dB}?

The upper 3-dB frequency is 5655555.22514252Hz from question (8) of lab2 by using the differential amplifier. The upper 3-dB frequency from Q6 is around 15400Hz. The reason of the differential amplifier with the current mirror load has a smaller f3dB is because the differential amplifier using resistor loads has the gain Ad is 19.63dB and the differential amplifier using current mirror load has the gain Ad of 78.11dB. According to the Miller Theorem, the higher of the voltage gain gmRl', the larger of of τgd due to the Miller effect which results in the lower of the upper 3-dB frequency f3dB.

Q8. (10 Points) What are the gain-bandwidth products (GBW) in Hz of the two differential amplifiers with the current mirror load and the resistive load, respectively?

The GBW for the current mirror and resistive load is 9.01E+07 and 1.07E+05 separately as shown below. It is calculated by using the formula = (low frequency)Vm(Vo) / 0.002*11200.

Frequency	vm(vo)	ph(v(vo))	Ad = 20*log(|Vo|/2mV)	GBW	GBW in Step 3.6, Lab 2
Hz	Volts	deg	dB	Hz	Hz
1.00E+02	16.0942275	-5.18E-01	78.11	9.01E+07	1.07E+05