Electronic Devices & Circuits II - EE 3EJ4
Lab #3

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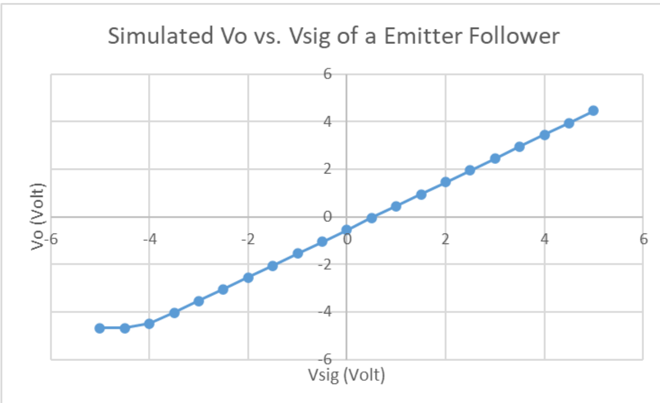
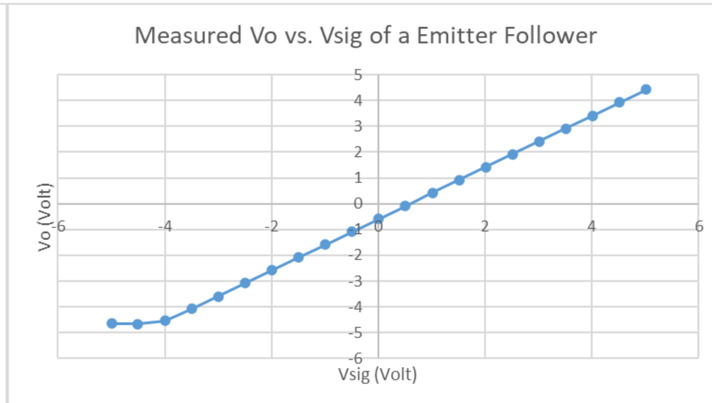
Questions for Part 1

Question 1

(1) Refer below for the simulated and measures plots of $V_0\ vs.\ V_{sig}$ …





As can be seen, the two graphs are both extremely similar in range of values and overall shape. Both graphs share a linear relationship with respect to $V_0\ vs.\ V_{sig}$ and have a range of values that will be discussed in part (2) of this question.

(2) From the graphs above, as well as the simulated data, the range for V_{sig} that allows the circuit to work as a Common Collector amplifier can be estimated as… $-\ 4.5V\ \le V_{sig} \le 5.0V$

The corresponding output range for V_0 can be estimated as…

$-\ 4.5V\ \le V_0 \le 4.5V$

(3) According to the simulated data, the V_{sig} value that corresponds to a simulated $V_0 \approx 0V$ is… $V_{sig} = 0.5V$, which achieves $V_{sig} = \ -\ 0.05265V$

Vsig	Vo	IE2
Volts	Volts	Amps
-5	-4.683472284	2.24E-09
-4.5	-4.683223268	-3.15E-08
-4	-4.478345149	-2.82E-05
-3.5	-4.024650412	-9.13E-05
-3	-3.545404771	-0.000154408
-2.5	-3.052495104	-0.000184748
-2	-2.552539257	-0.000184869
-1.5	-2.052561188	-0.00018499
-1	-1.552583106	-0.000184863
-0.5	-1.052605056	-0.000184736
0	-0.552626993	-0.000184876
0.5	-0.052648962	-0.000185017
1	0.44732908	-0.000184889
1.5	0.947307092	-0.000184762
2	1.447285114	-0.000184902
2.5	1.947263106	-0.000185043
3	2.447241108	-0.000184915
3.5	2.947219079	-0.000184788
4	3.447197061	-0.000184928
4.5	3.947175015	-0.000185069
5	4.447152936	-0.000184941

Question 2

Based on the simulation data in step 1.3, the intrinsic voltage gain has magnitude $0dB$

Based on the measured data in step 1.8, the intrinsic voltage gain has magnitude $0.8dB$

Both of these occur at a phase of about $-\ 8.84\ \times\ 10^{-5}$ degrees.

Questions for Part 2

Question 3

(1) Based on section 8.2.3 in the textbook, we can see that $\frac{I_o}{I_{ref}}$ is related to the area of the EBJ junctions of the transistors used. In our case, we are using the exact same transistors, so the area of the EBJ junctions will be the same. This means that we can say that $I_o = I_{ref}$

(2) From the simulation data in step 2.2, we find that when I_{REF} is $0.1mA$ we have a corresponding I_O of $0.104mA$. In other words, $I_O = 1.04I_{REF}$

IREF	Io
Amps	Amps
0.0001	0.000104

When I_{REF} is $1mA$ we have a corresponding I_O of $0.975mA$. In other words, $I_O = 0.975I_{REF}$

IREF	Io
0.001	0.000975

(3) We can generate the theoretical predictions by plugging the given values of I_{REF} into the equation that we developed in part (1)

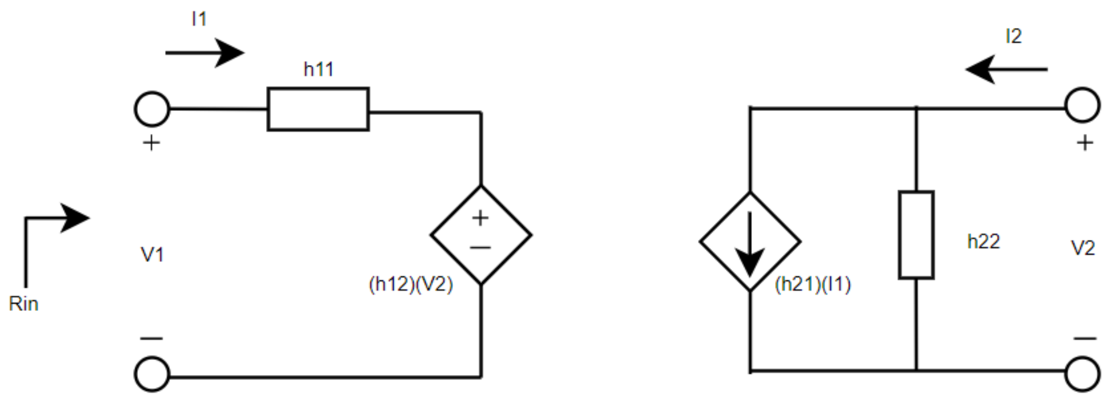
When $I_{REF} = 0.1mA\ldots\ I_O = 0.1mA$
When $I_{REF} = 1mA\ldots\ I_O = 1mA$
In both cases, the calculated values and measured values are relatively close.
When I_{REF} is $0.1mA$ we can predict that $I_O = 0.1mA$, which is relatively close to the actual value of $0.104mA$. Similarity, when I_{REF} is $1mA$, we would predict I_{REF} to also be $1mA$, which is relatively close to the actual value of $0.975mA$

Question 4

(1) We know that $h_{11} = R_{in}$ for unilateral amplifiers (as we have here). Based on the data obtained in step 2.5, $R_{in} = 389.12\Omega$
Similarly, we know that h_{21} represents the short-circuit current gain, A_i . Based on the data obtained in step 2.5, $A_i = 1.04\frac{A}{A}$

(2) We know that $R_o = \frac{1}{\left(h_{22} - \frac{1}{R_L}\right)}$. Based on the data obtained in step 2.6, $R_O = 1.58 \times 10^6\Omega$

(3) Using the above information, we obtain…



With the following parameters…

$h_{11} = 389.12\Omega$

$h_{22} = 1.01 \times 10^{-4}S$

$h_{21} = 1.04$

$h_{12} = 7.05\times10^{-7}@100Hz\ to\ 1.41\times10^{-6}@200Hz$

R11 = h11 = v1/i1@v2=0 (Ohm)	Ai = h21 = i2/i1@v2=0 (A/A)
Ohm	A/A
389.12	1.04
389.12	1.04
389.12	1.04
389.12	1.04
389.12	1.04
389.12	1.04
389.12	1.04
389.12	1.04
389.12	1.04
389.12	1.04
389.12	1.04

h12 = v1/v2@i1=0	h22 = i2/v2@i1=0
V/V	S
7.05E-07	1.01E-04
7.75E-07	1.01E-04
8.46E-07	1.01E-04
9.16E-07	1.01E-04
9.87E-07	1.01E-04
1.06E-06	1.01E-04
1.13E-06	1.01E-04
1.20E-06	1.01E-04
1.27E-06	1.01E-04
1.34E-06	1.01E-04
1.41E-06	1.01E-04

Questions for Part 3

Question 5

(1) Based on step 3.2, the voltage gain simulated was $70.07dB$

Frequency	M(V(Vo))	P(V(Vo))	Ad = 20*log(|Vo|/2mV)	GBW	GBW in Step 3.6, Lab 2
Hz	Volts	Degrees	dB	Hz	Hz
100	6.378607264	-0.518045119	70.07	3.57E+07	7.95E+07

(2) In step 3.6, the mismatch voltage calculated was $0.00525V = 5.25mV$ which was the offset voltage applied to V_2 in subsequent steps

VCC =VE3 = VE4	VC1 (= VC3 = VB3 = VB4)	Vo (= VC2 = VC4)	VEB3	VBC4	W2Offset
Volt	Volt	Volt	Volt	Volt	Volt
5.0	4.416	4.746	0.584	-0.33	5.25E-03
			Q3 is ON if VEB3 > 0.6	Q4 is in Active Region if VBC4 > -0.4 V	

(3) In step 3.8, the voltage gain from my simulation was $54dB$, which we can see is lower than the simulated value as discussed in part (1)

ΔC1 (V) = Vsig(Peak2Peak)	ΔC2 (V) = Vo(Peak2Peak)	Differential Voltage Gain Avd of a Single-Stage Differential Amplifier (dB)
1.2251E-03	1.2251	54.0

Question 6

To determine the value at which the upper 3-dB frequency occurs, we can find the point at which the amplitude becomes 0.707 of the low frequency value. At low frequency, we have magnitude of $6.3786V$, which means at the upper 3-dB frequency we should have magnitude of $0.707 \times 6.3786V = 4.5V$. From the data in step 3.2, we can determine that $f_{upper-3dB} \approx 11207Hz$

Frequency	M(V(Vo))
Hz	Volts
100	6.378607264

Frequency	M(V(Vo))
11207.40201	4.480927659

Question 7

In lab 2, it was found that the upper 3-dB frequency of the circuit was $8332821Hz$, which we can see is far greater than that one found in this lab. This can be easily explained if we consider the Miller Theorem. The miller theorem tells us that a higher voltage gain leads to a larger Miller capacitance, C_m, which in turn results in a lower 3dB frequency.

Question 8

In lab 2, it was found that with a resistive load the differential amplifier had a $GBW = 7.95 \times 10^7 Hz$

In this lab, we found that the current mirror loaded differential amplifier had $GBW = 3.57 \times 10^7 HZ$

GBW	GBW in Step 3.6, Lab 2
Hz	Hz
3.57E+07	7.95E+07