EE230 Analog Lab

Experiment - 4

Current Source, Current Mirror, and Differential Pair

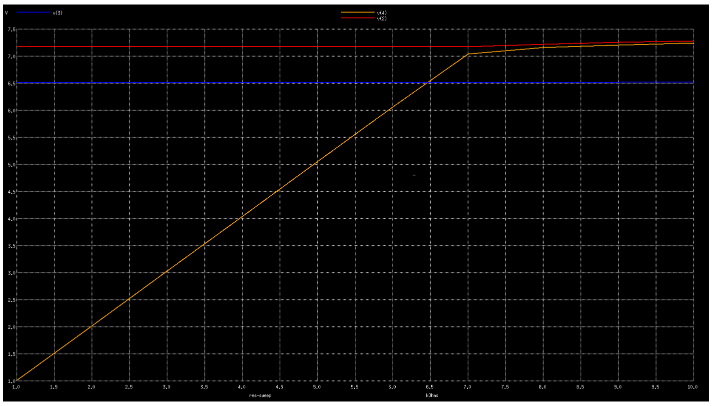
Report by Prasann Viswanathan - 190070047

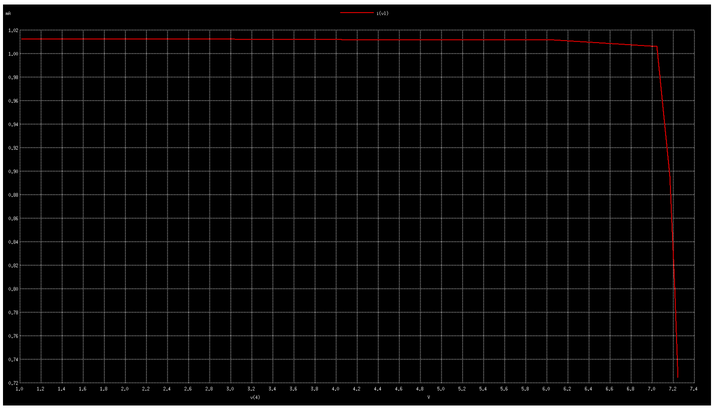
1. BJT Current Source

a. ngspice code:

```
Prasann Viswanathan 190070047 BJT Current Source Analysis

.include zener_B.txt
.model bc557a PNP IS=10f BF=100 ISE=10.3f IKF=50m NE=1.3
+ BR=9.5 VAF=80 IKR=12m ISC=47p NC=2 VAR=10 RB=280 RE=1 RC=40
+ tr=0.3u tf=0.5n cje=12p vje=0.48 mje=0.5 cjc=6p vjc=0.7 mjc=0.33 kf=2f

q1 4 3 2 bc557a
vcc 1 0 12
vl 5 0 0
xz 3 1 DI_1N4734A
re 1 2 4.7k
rb 3 0 2.2k
rl 4 5

*analysis commands
.dc rl 1k 10k 1k
.control
run

*display commands
plot i(vl)
plot v(2) v(3) v(4)
.endc
.end
```

b. Results





c. Learning Outcomes

I learnt how to do the DC analysis of a current source circuit (something which was new for us). I also saw that the values matched sufficiently with NGSPICE simulations as well. Finally I learnt that a practical current sources' current value decreases with increasing output voltage. (DC analysis below)

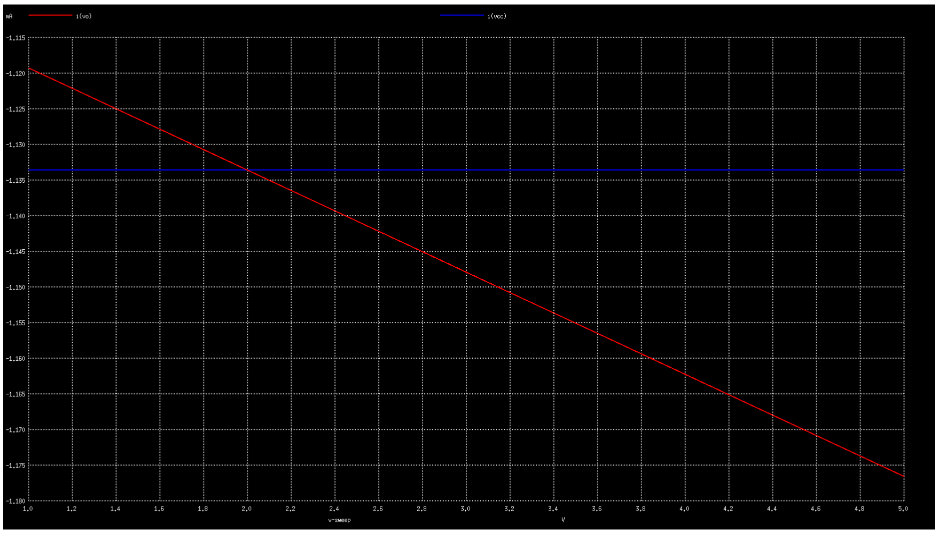
[i(vl) = 1.012823e-03 v(2) = 7.176963e+00 v(3) = 6.516322e+00 v(4) = 1.012823e+00]

2. BJT Current Mirror based Current Source

a. ngspice code:

```
Prasann Viswanathan 190070047 BJT Current Mirror

.model bc547a NPN IS=10f BF=200 ISE=10.3f IKF=50m NE=1.3
+ BR=9.5 VAF=80 IKR=12m ISC=47p NC=2 VAR=10 RB=280 RE=1 RC=40
+ tr=0.3u tf=0.5n cje=12p vje=0.48 mje=0.5 cjc=6p vjc=0.7 mjc=0.33 kf=2f

q1 2 2 0 bc547a
q2 3 2 0 bc547a
vcc 1 0 12
vo 3 0
r 1 2 10k

*analysis commands
.dc vo 1 5 0.5
.control
run

*display commands
plot i(vo) i(vcc)
.endc
.end
```

b. Results (plot is for Va = 80V case)



```
i(vcc) = -1.13359e-03
i(vo) = -1.11923e-03
v(2) = 6.641060e-01
```

c. Learning outcomes

For Q1, $V_{CE} = V_{BE} = 0.7V$. For $V_o = 1V, \beta = 100$, and $V_A = 80V$: $I_{ref} = (V_{CC} - V_{BE})/R = 1.13m$ A

$I_o = I_{ref}/(1+2/\beta) \cdot (1+ V_o - V_{BE}/V_A) = 1.167m$ A

For the values $V_o = 1V, \beta = 100$, and $V_A = 80V$, the value of Io obtained is 1.119mA which is reasonably close to the value of $I_o = 1.167m$ A calculated using analysis.

(Note that the currents in my analysis are negative as NGSPICE convention is to give negative sign to currents emanating from an Anode. Adding a dummy voltage source would lead to lengthy code)

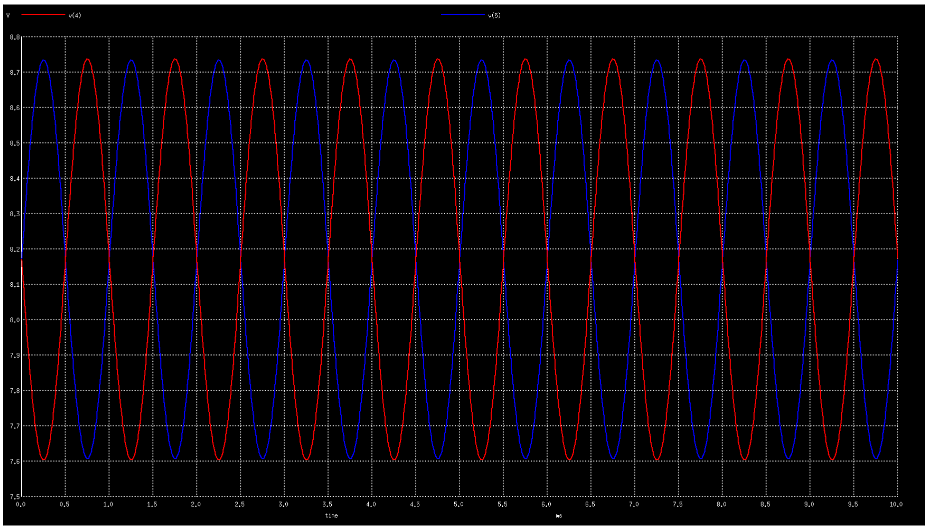
I learnt that the formulae is a very good approximation for actual simulated results and the effect of early voltage of the transistors is clearly seen in our plot as the magnitude rises when Vo is increased.

3. Differential Pair (Small Signal Analysis)

a. ngspice code:

```
Prasann Viswanathan 190070047 BJT Differential Amplifier

.model bc547a NPN IS=10f BF=200 ISE=10.3f IKF=50m NE=1.3
+ BR=9.5 VAF=80 IKR=12m ISC=47p NC=2 VAR=10 RB=280 RE=1 RC=40
+ tr=0.3u tf=0.5n cje=12p vje=0.48 mje=0.5 cjc=6p vjc=0.7 mjc=0.33 kf=2f

q1 4 6 8 bc547a
q2 5 7 8 bc547a
vcc 1 0 12
vin1 10 0 dc sin(0 10m 1k 0 0 0)
vin2 11 0 0
ve 9 0 -12
rc1 1 2 6.8k
rc2 1 3 6.8k
rb1 10 6 1k
rb2 11 7 1k
re 9 8 10k
vo1 2 4 0
vo2 3 5 0

*analysis commands
.tran 10u 10m
.control
run

*display commands
plot v(4) v(5)
.endc
.end
```

b. Results (Vo1 and Vo2 vs time)



```
i(vo1) = 5.630784e-04
i(vo2) = 5.630784e-04
i(ve) = 1.135396e-03
v(4) = 8.171067e+00
v(5) = 8.171067e+00
v(8) = -6.46041e-01
```

c. Learning outcomes

I learnt the gain expression for a single side is -gmRc/2 and this matches reasonably well with the experimental results as well. There is a phase shift of exactly pi between the two V_outputs, as explained in the lab lecture.

d. Doubts/Clarifications

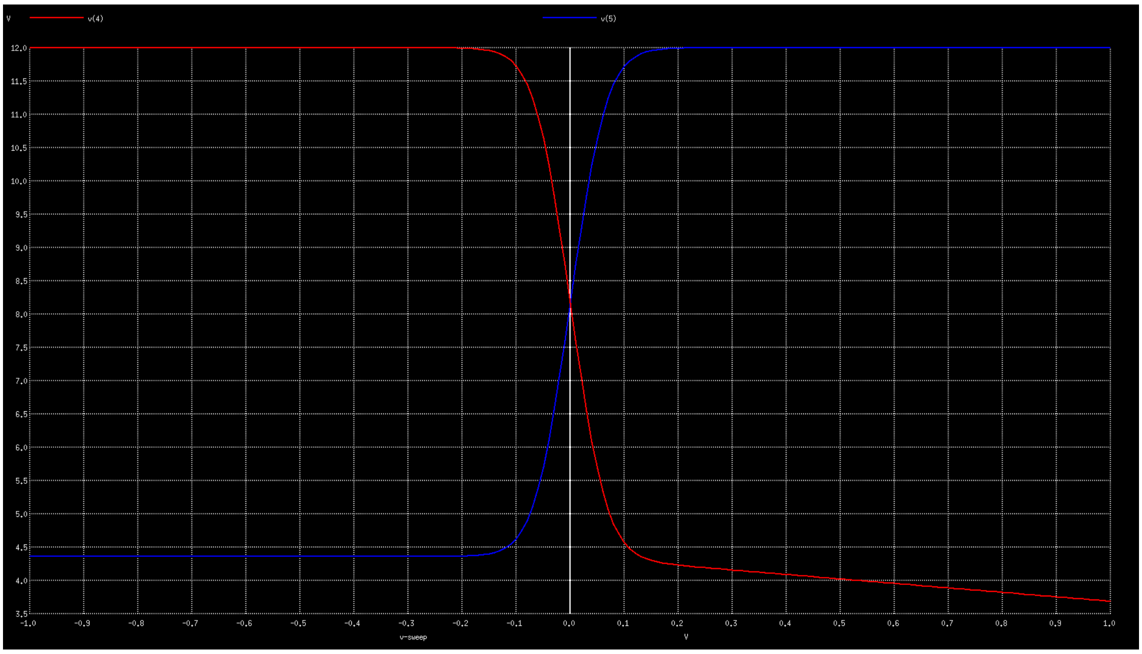
On doing small signal analysis, we get the gain expression (ignoring Rb) to be -gmRc/(1+2gmRe). Why?

4. Differential Pair (Large Signal Characteristics)

a. ngspice code:

```
Prasann Viswanathan 190070047 BJT Differential Amplifier

.model bc547a NPN IS=10f BF=200 ISE=10.3f IKF=50m NE=1.3
+ BR=9.5 VAF=80 IKR=12m ISC=47p NC=2 VAR=10 RB=280 RE=1 RC=40
+ tr=0.3u tf=0.5n cje=12p vje=0.48 mje=0.5 cjc=6p vjc=0.7 mjc=0.33 kf=2f

q1 4 6 8 bc547a
q2 5 7 8 bc547a
vcc 1 0 12
vin1 10 0 0
vin2 11 0 0
ve 9 0 -12
rc1 1 2 6.8k
rc2 1 3 6.8k
rb1 10 6 1k
rb2 11 7 1k
re 9 8 10k
vo1 2 4 0
vo2 3 5 0

*analysis commands
.dc vin1 -1 1 0.01
.control
run

*display commands
plot v(4) v(5)
.endc
.end
```

b. Results



c. Learning outcomes

When the value of Vin goes beyond the rough range (-0.1 to 0.1) then beyond that range, the values of Vo1 and Vo2 (Vc1 and Vc2) remain saturated. Also, there is asymmetry between values of Vc1 and Vc2 for Vin > 0.1, shown by the negative slope in the red graph.