EE3124 project 3 Jaeha Huh

1) Hand Calculation

A)

VCC	Rin*	Ai*
20V	4018.65Ω	200.54

B)

ICQ	VBEQ	VCEQ	PD
2.4mA	0.7V	17.5	42mW

C) Ips1 (project #1 and #2) = 186mA

Ips2 (Project #3) = 4.8mA

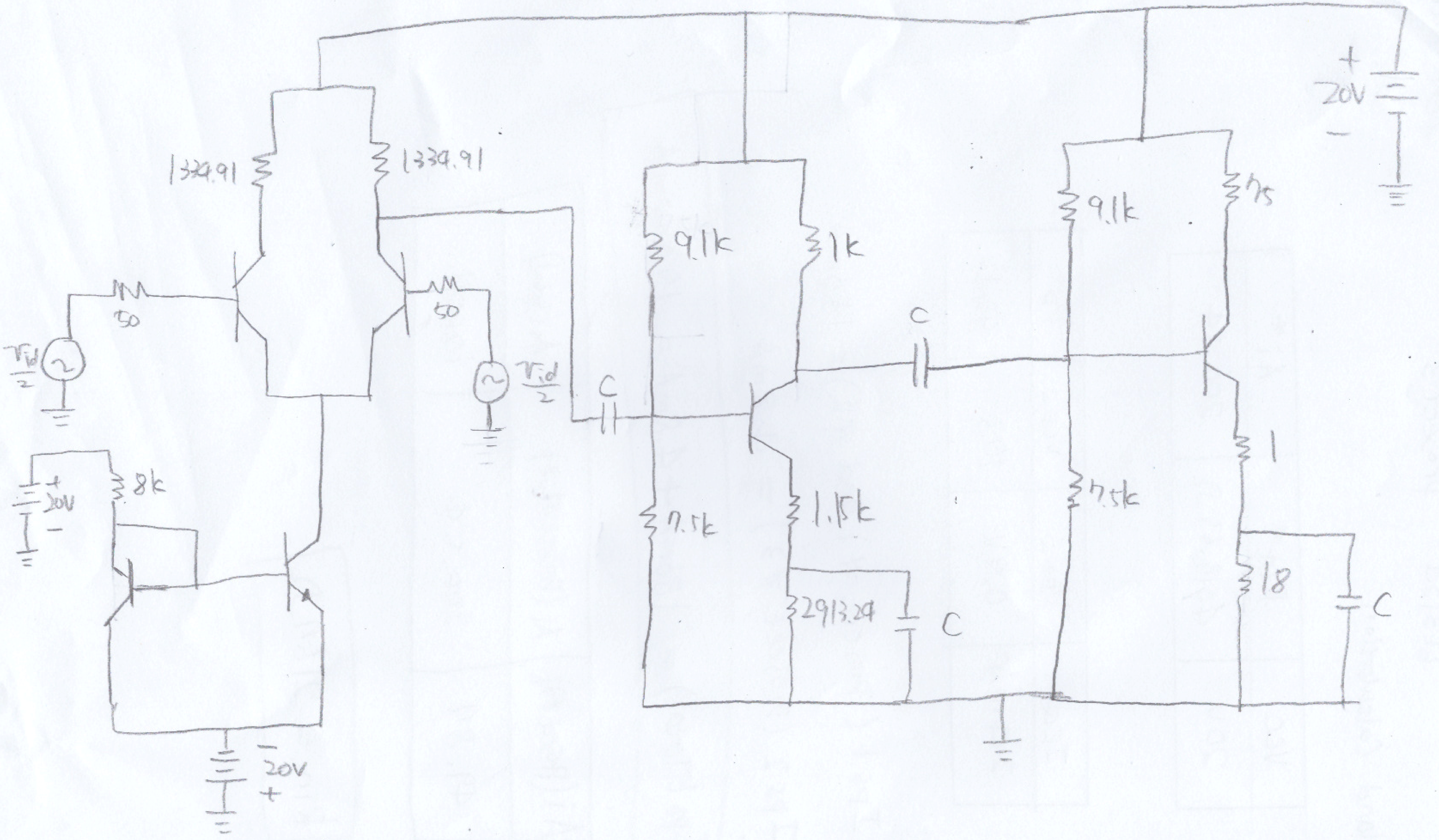
Ips (Total) = 186mA + 4.8mA = 190.8mA

D)

Ai (Project #3)	Ai (Project #1,2)	Ai (Total)
49.87	200.54	10001

E) Rin = 216MΩ

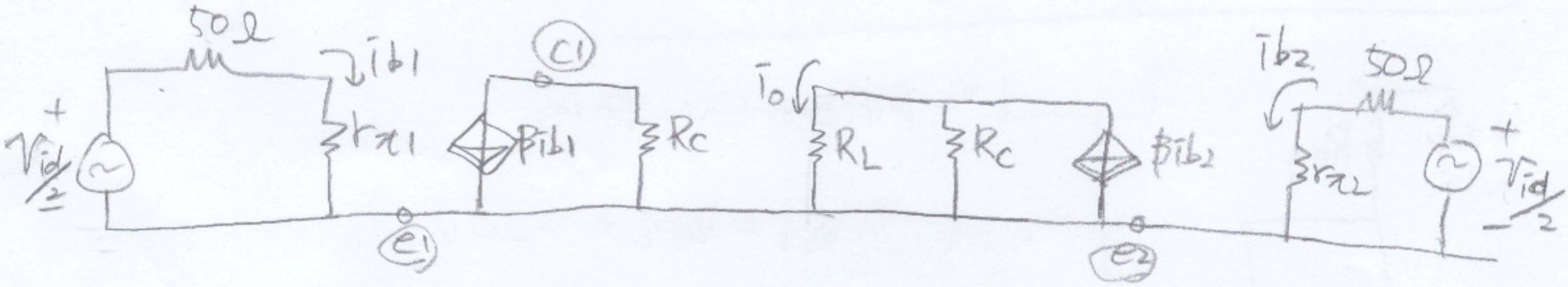
F)


1334.91
1334.91
50
50
Vid/2
Vid/2
C
9.1k
1k
C
9.1k
75
20V
8k
20V
7.5k
1.15k
7.5k
1
2913.24
C
18
C
20V

G) $A_i^* = 200.54$, $\beta = 200$

⇒ Current gain of Driver Amp = $10000/200.54 = \boxed{49.87}$

Differential-pair Small signal



① KVL @ e ($e_1 = e_2$)

$(1+\beta)\bar{i}_{b1} + (1+\beta)\bar{i}_{b2} = 0$

⇒ $\bar{i}_{b1} = -\bar{i}_{b2}$

$\bar{i}_{in} = \bar{i}_{b1}$, $\bar{i}_o = \beta \bar{i}_{b2}\left(\frac{R_C}{R_C+R_L}\right)$

⇒ $A_i = \frac{\bar{i}_o}{\bar{i}_{in}} = \frac{\beta \bar{i}_{b2}\left(\frac{R_C}{R_C+R_L}\right)}{\bar{i}_{b1}} = \frac{\beta \cancel{\bar{i}_{b2}}\left(\frac{R_C}{R_C+R_L}\right)}{-\cancel{\bar{i}_{b2}}} = -\beta\left(\frac{R_C}{R_C+R_L}\right) = 49.87$

⇒ $-200\left(\frac{R_C}{R_C+R_L}\right) = 49.87$

⇒ $\frac{R_C}{R_C+R_L} = |-0.2491| = 0.249$ $\quad R_L = R_{in}^* = 4018.65\,\Omega$

⇒ $\frac{R_C}{R_C+4018.65} = 0.249$ ⇒ $\boxed{R_C = 1334.91}$

DC Analysis (Differential-pair)

Q_1, Q_2 matched ⇒ $I_{S1} = I_{S2}$, $\beta_1 = \beta_2$

⇒ $i_{C1} = i_{C2}$ and $i_{E1} + i_{E2} = I_{DC}$

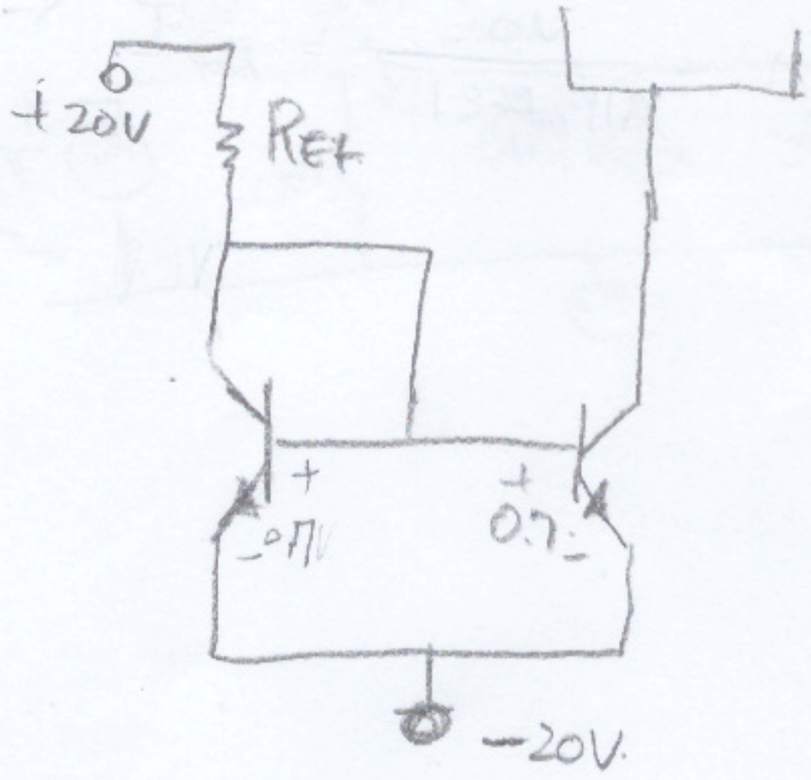
$V_{B1} = V_{B2} = \not{\phi} V$

$V_{E1} = V_{E2}$

$\Rightarrow V_{BE1} = V_{E2}$

$\Rightarrow I_{E1} = \frac{I_{C1}}{\alpha} = \frac{I_{C2}}{\alpha} = I_{E2} \Rightarrow I_{E1} = I_{E2} = \frac{I_{DC}}{2}$

Basic current Mirror (DC Analysis)



← Differential pair

$V_{E1} = V_{E2} = -20V$

$V_{BE1} = V_{BE2}$

$\frac{I_{DC}}{I_{REF}} = \frac{1}{(1 + 2/\beta)} = \frac{1}{1 + \frac{1}{50}} = \frac{1}{1.02}$

$I_{DC} = I_{REF}\left(\frac{1}{1.02}\right)$ $V_{CC} = 20V$, $V_{EE} = -20V$.

Let $R_{EF} = 8k\Omega$. $V_{BE} = 0.7V$.

$\Rightarrow \frac{20 - 0.7 - (-20)}{8k} = \frac{39.5V}{8000\Omega} = 0.004915 = 4.915mA.$

$\Rightarrow I_{DC} = 4.915\left(\frac{1}{1.02}\right) = 4.819mA.$

Differential pair (DC pair)

$I_{E1} = \frac{I_{DC}}{2} = \frac{4.819mA}{2} = 2.41mA = I_{E2}$

$I_{C1} = I_{C2} = \frac{\beta}{\beta+1} 2.41 = \frac{200}{201}(2.41) = \underline{2.4mA}$

$\Rightarrow I_{DS} = I_{C1} + I_{C2} = 4.8mA$

$V_{C1} = V_{C2} = V_{CC} - R_C I_{C1} = 20 - 1334.91\,(2.4mA)$

$= 16.8V$

$V_{E1} = V_{E2} = -0.7V$

$\Rightarrow V_{CE} = 16.8 - (-0.7V) = 17.5V$

$V_{CEQ} = 17.5V$
Forward Active

AC Analysis

$A_i = 49.87$ and $A_i^* = 200.54$ (project #1 and #2)

$\Rightarrow A_{i(total)} = (A_i)(A_i^*) = (49.87)(200.54) = 10001$

$A_i(total) = 10001$

$R_{in} = \frac{V_{in}}{I_{in}}$ $\quad I_{in} = i_{b1}$ $\quad i_{b1} = \frac{V_{in} - V_e}{50 + r_\pi} = \frac{V_{in}}{50 + r_\pi}$

$r_\pi = \frac{\beta V_t}{I_{CQ}} = \left(\frac{200(26mA)}{2.4mA}\right) = 2167\Omega$

$R_{in} = \frac{V_{in}}{\left(\frac{V_{in}}{2167\Omega}\right)} = 2167\Omega$

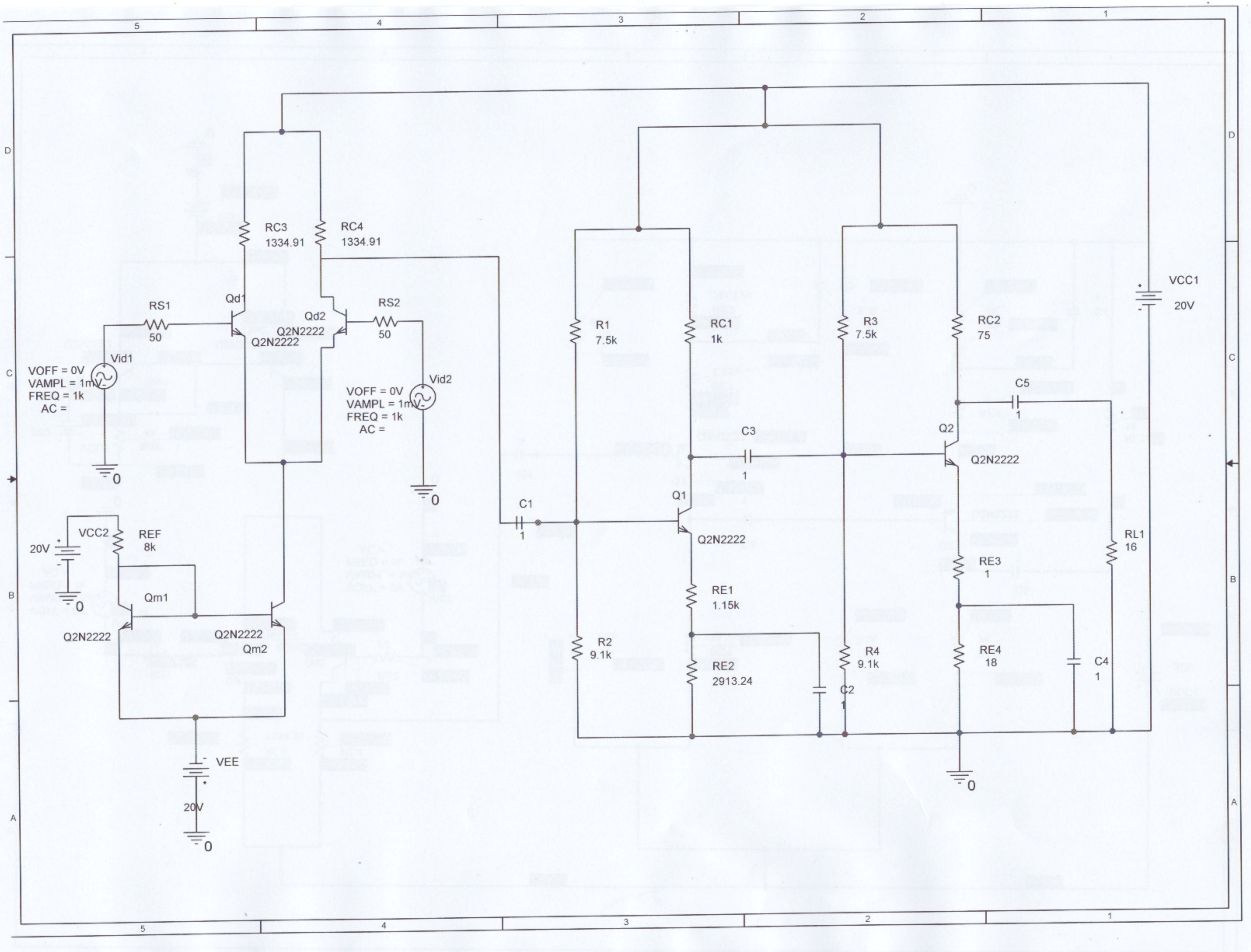
$R_{in} = 216\pi\,\Omega$

$$P_D = (V_{CEQ})(I_{CQ}) = (7.5V)(2.4mA) = 0.042$$

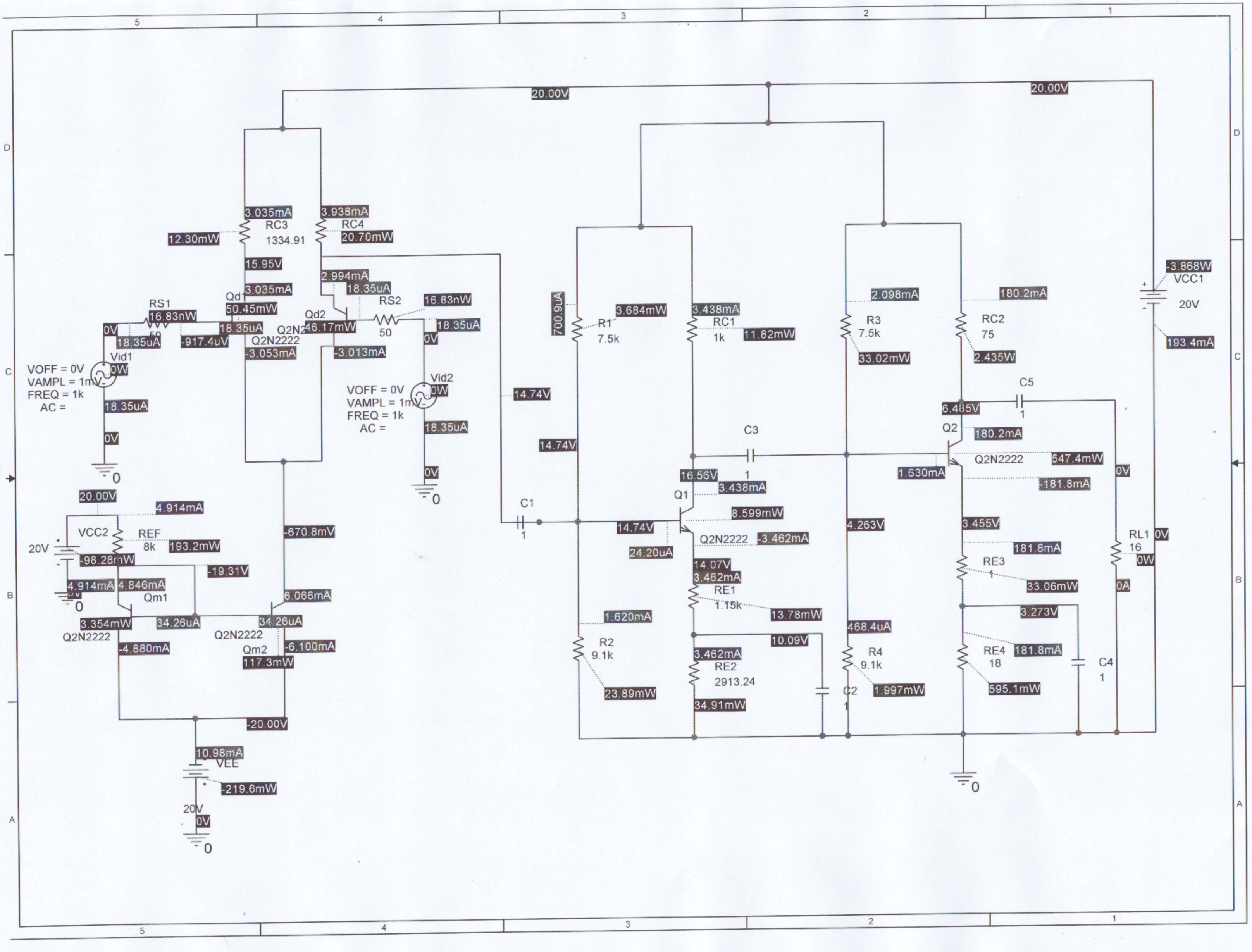
$$= 42mW$$

$$\therefore \boxed{P_D = 42mW}$$

A)


RC3
1334.91
RC4
1334.91
RS1
50
Qd1
Qd2
Q2N2222
Q2N2222
RS2
50
Vid1
VOFF = 0V
VAMPL = 1mV
FREQ = 1k
AC =
Vid2
VOFF = 0V
VAMPL = 1mV
FREQ = 1k
AC =
0
VCC2
20V
REF
8k
Qm1
Q2N2222
Q2N2222
Qm2
VEE
20V
C1
1
R1
7.5k
RC1
1k
Q1
Q2N2222
RE1
1.15k
R2
9.1k
RE2
2913.24
C3
1
R3
7.5k
RC2
75
Q2
Q2N2222
C5
1
RE3
1
RE4
18
C4
1
R4
9.1k
C2
1
VCC1
20V
RL1
16

A)


20.00V
20.00V
3.035mA
RC3
1334.91
12.30mW
3.938mA
RC4
20.70mW
15.95V
2.994mA
18.35uA
3.035mA
Qd1
50.45mW
RS1
16.83nW
50
18.35uA
-917.4uV
Q2N2222
-3.053mA
Qd2
46.17mW
RS2
16.83nW
50
18.35uA
0V
-3.013mA
Vid1
VOFF = 0V
VAMPL = 1mV
FREQ = 1k
AC =
0W
18.35uA
0V
0
Vid2
VOFF = 0V
VAMPL = 1mV
FREQ = 1k
AC =
0W
18.35uA
0V
0
14.74V
700.9uA
R1
7.5k
3.684mW
3.438mA
RC1
1k
11.82mW
2.098mA
R3
7.5k
33.02mW
180.2mA
RC2
75
2.435W
-3.868W
VCC1
20V
193.4mA
C5
1
6.485V
Q2
180.2mA
Q2N2222
547.4mW
1.630mA
-181.8mA
0V
C3
1
16.56V
3.438mA
Q1
8.599mW
14.74V
24.20uA
Q2N2222
-3.462mA
C1
1
14.74V
4.263V
3.455V
181.8mA
RE3
1
33.06mW
RL1
16
0V
0W
0A
14.07V
3.462mA
RE1
1.15k
13.78mW
3.273V
1.620mA
R2
9.1k
23.89mW
10.09V
3.462mA
RE2
2913.24
34.91mW
468.4uA
R4
9.1k
1.997mW
C2
1
RE4
18
181.8mA
595.1mW
C4
1
20.00V
4.914mA
VCC2
20V
REF
8k
193.2mW
-98.28mW
-19.31V
4.914mA
4.846mA
Qm1
0
6.066mA
3.354mW
34.26uA
34.26uA
Q2N2222
Q2N2222
Qm2
-4.880mA
-6.100mA
117.3mW
-670.8mV
-20.00V
10.98mA
VEE
-219.6mW
20V
0V
0

PSpice part

B) SIMLATED DC BIAS

(Project#1 and #2)

Simulated value (project # 1)	
ICQ	180.2mA
VCEQ	3.03V
VBEQ	0.808V
P_D,transistor	547.4mW
Simulated value (project #2)	
ICQ	3.438mA
VCEQ	2.49V
VBEQ	0.67V
P_D,transistor	8.599mW

Project#3

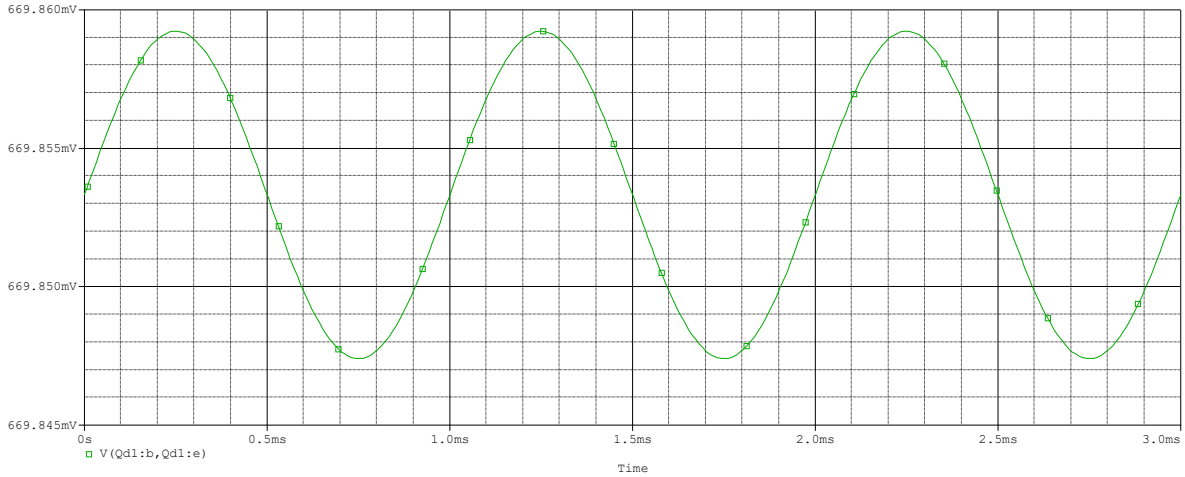
Simulated value		Hand-calculated value	
ICQ	3.035mA	ICQ	2.4mA
VCEQ	16.62V	VCEQ	17.5V
VBEQ	0.7V	VBEQ	0.7V
P_D,transistor	46.17mW	$P_D s$,transistor	42mW

C) SIMLATED POWER SUPPLY BIAS

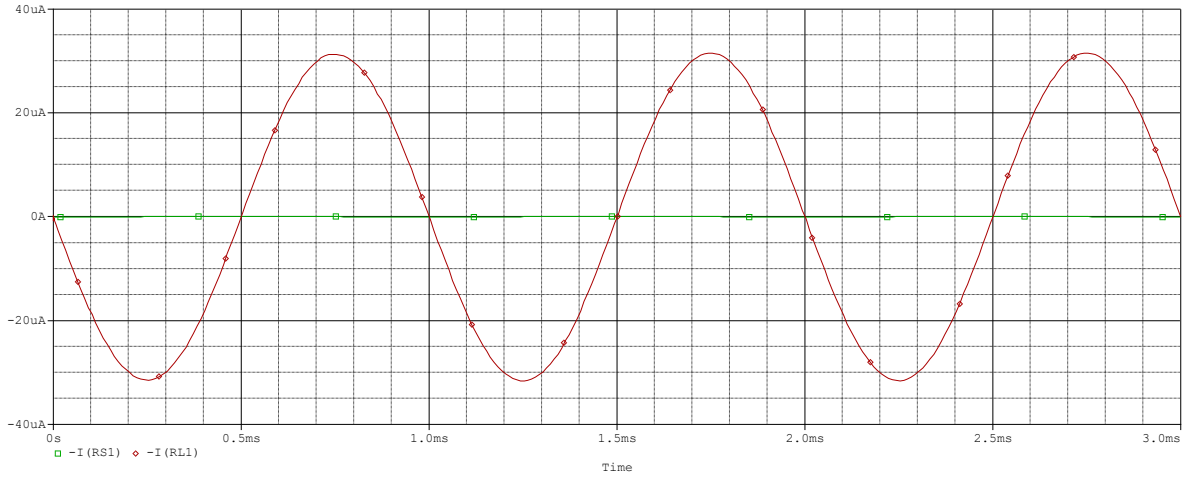
DC power Supply Current (Ips) = 193.4mA.

D) SIMULATED SMALL SIGNAL OPERATION

The amplitude value of the source voltage for small signal operation is 20mV for all transistors.



E) SIMULATED TWO-STAGE CURRENT GAIN (β=200)



$$\beta = 200, Ai = \frac{31.430uA}{2.84nA} = 11066.9$$

I almost achieve a current gain variation 10% about the nominal value of $\beta = 200$.

F) SIMULATED INPUT RESISTANCE

$$\beta = 200, Rin = \frac{10.908mV}{5.177uA} = 2017.01\Omega = 2\text{k}\Omega$$

The input resistance is not greater than $20k\Omega$.